# ROUTE 122 - AIRPORT ROTARY INTERSECTION REDESIGN IN WORCESTER

A MAJOR QUALIFYING PROJECT SUBMITTED TO THE FACULTY OF WORCESTER POLYTECHNIC INSTITUTE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE BACHELOR OF SCIENCE DEGREE


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**Abstract**

Route 122 Airport Rotary, an intersection in Worcester, Massachusetts has experienced congestion, and with higher traffic volumes in the future, this congestion will only worsen. To address the current and foreseeable issues, a redesign of this rotary was provided to Massachusetts Department of Transportation (MassDOT). A roundabout intersection was chosen as the recommended design after evaluating collected data and using the Intersection Control Evaluation (ICE) procedure established by MassDOT. Cost estimates and manual turning movement counts were conducted. Using Synchro and Sidra software, a level-of-service analysis was performed for each potential intersection that was screened. A roundabout design offers the greatest benefit-cost when compared to other alternatives assessed.

**Executive Summary**

State highway Route 122, named Pleasant Street for the section of Route 122 from the Paxton town line and Tatnuck Square in Worcester, Massachusetts, is a primary artery for traffic coming into the city from the north and south. This project focused on a corridor of Pleasant Street, from Tatnuck Square to the Paxton town line, as one needing improvement due to its high travel speed, unsafe conditions for pedestrians, and the Airport Rotary. The Airport Rotary, an intersection along Pleasant Street connecting to the Worcester Airport, has been previously investigated by Massachusetts Department of Transportation (MassDOT), and subsequent contracted engineering companies for redesign. The goal for this Major Qualifying Project (MQP) was to complete an intersection control evaluation (ICE) on the existing intersection and analyze proposed alternative control strategies that would best meet the needs of this intersection. To successfully meet the project goal, the following objectives were met:

1. Understand Best Practices Regarding Intersection Design
2. Analyze the Existing Conditions at the Intersection
3. Formulate Multiple Control Strategy Options using ICE
4. Select a Final Control Strategy as the Optimal Redesign Solution

The team was able to conduct an ICE on the intersection. Out of the three stages that the intersection evaluation contains, stages one and two were conducted in this report which included conceptual designs for the suggested alternatives, will allow MassDOT to advance the selected alternative to the 25% design stage. Originally the team considered 12 potential control strategies, but through a comparative analysis the team ultimately chose a singular option as the best fit. The procedure began with Stage 1 where an initial screening of the process was conducted. Roundabout and signalized control were the two primary control strategies identified

at the end of Stage 1. Two signalized control alternatives and one roundabout alternative were developed from the ICE Stage 1 results. Stage 2 consisted of collecting different forms of data and then analyzing this data through the ICE tool to find the best alternative option, defined here as the alternative that has the highest benefit-cost ratio based on an analysis of traffic operations, safety, and estimated planning, design, construction, and maintenance costs. The final design recommendation was to implement the Alternative 3 single-lane roundabout at the intersection. Figure 1 below presents the configuration of Alternative 3. The team noted the possibility of the preferred alternative changing if more detailed analysis is conducted, since the current alternative was finalized using preliminary cost data.

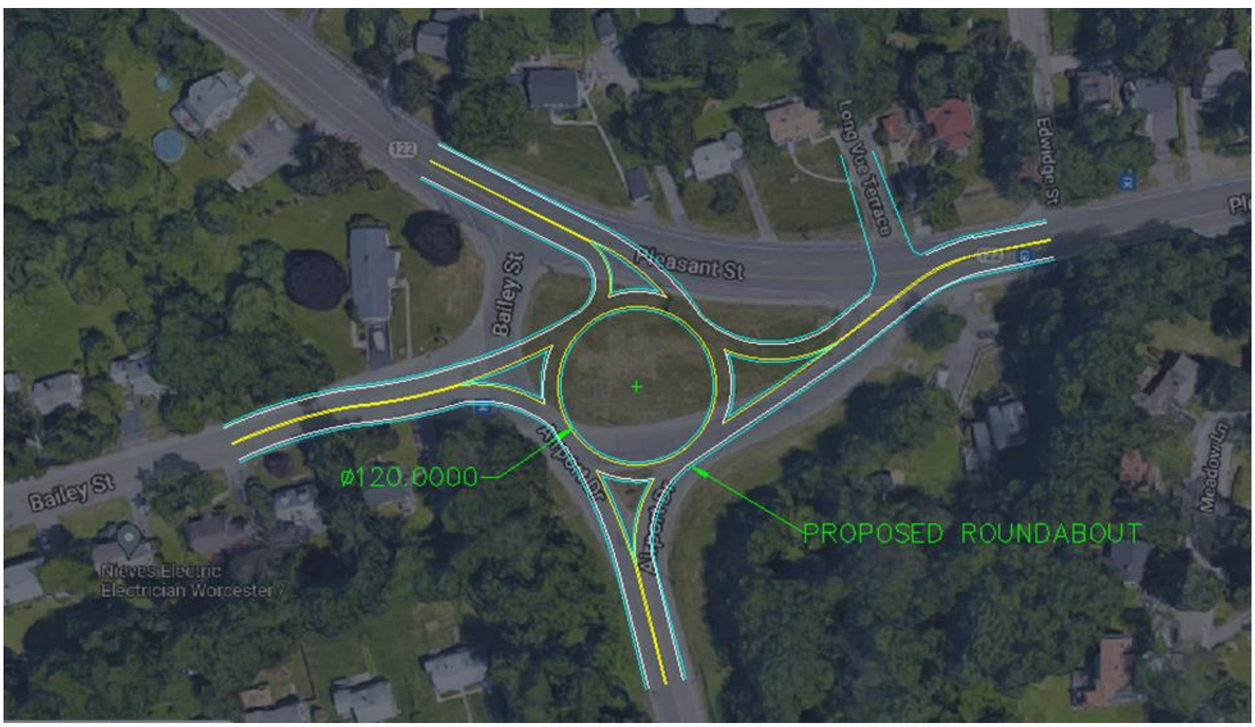


Figure 1: Finalized Alternative 3 single-lane roundabout design

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| 4.4 - Select a Final Alternative as the Optimal Redesign Solution | Ritesh Prasannakumar | All Team Members |
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**Capstone Design Statement**

This project involved analyzing the existing corridor of Route 122/Pleasant Street and examining its intersection with Bailey Street and Airport Drive. Worcester Polytechnic Institute Engineering Programs require that said projects fulfill all of the Accreditation Board for Engineering and Technology (ABET) capstone design elements. For this project, the elements recommended by ABET were taken into account in order to fulfill the Capstone Design requirement. These aspects that were addressed in this project include the following:

*Constructability*: The team looked at previous and possible designs for the Route 122 - Airport Drive intersections and corridor redesigns and aimed to select the best one with consideration to constructability such as cost, maintenance, time to complete, and compatibility with existing utilities.

*Economic*: For this project, preliminary construction cost analysis was conducted in order to gauge the economic feasibility of the redesign. Cost effectiveness assisted in the decision-making process for which redesigns make the most efficient improvements for the evaluated cost. The relative cost of production compared to the benefits added was fundamental in selecting a final design as overly expensive projects with little added benefit were not deemed as suitable as a less expensive one with similar benefits.

*Environmental*: Any changes or improvements that were made through the intersection and corridor were considered with preserving and maintaining the local environment. Special consideration was given to the local forest and water streams that run throughout and around Route 122.

*Ethical*: The design project and design project team worked to not diminish the reputation of WPI and the Massachusetts Department of Transportation and all decision-making and project elements were made in compliance with three ASCE Code of Ethics.

*Health and Safety*: The overall improvements made to Route 122 and the Airport Drive intersection were made to value the safety of people who use the corridor. An easier to understand intersection and improvements made to the usability of the route for non-motorists were prioritized to reduce crash rates and severity on the route.

*Political*: The team collaborated with MassDOT and, through them, local residents, commuters, and the City of Worcester to present design improvements that worked to better the state highway and the city as a whole. The needs of each of these stakeholders was highly considered when identifying a final redesign.

*Social*: This project has a primary concern to improve the safety and usability of Route 122 for regional commuters, local residents, and any others who would travel along this stretch of the state highway. Their concerns, through previously held public meetings attended by MassDOT, was factored into the final design decision and the suggested improvements prioritized benefiting the residents.

*Sustainability*: The team worked to identify a redesign that prioritizes present and future needs with consideration to expected growth in the area that affects the intersection and corridor. Long-lasting sustainability in the area is a goal that was prioritized through redesigns that consider the area's future.

**Professional Licensure Statement**

Professional engineers are accredited individuals who have obtained marks of competency and are held responsible for their work and the lives impacted by what they produce. In the United States, these engineers must obtain licenses unique to each state and district that allow them to prepare, sign and seal, and submit engineering plans and function as a professional engineer (PE).

To become a professional engineer, individuals must ensure that they have completed a four-year degree in engineering from an accredited program, pass the Fundamentals of Engineering (FE) exam, complete four years of progressive engineering experience under a PE, and then successfully pass the Principles and Practice of Engineering (PE) exam (National Society of Professional Engineers 2022).

After successfully passing the PE exam and becoming a licensed professional engineer, said individual is able to expand the opportunities available for their career and they become much more responsible for the health, safety, and ethical integrity of their work and the work they stamp and approve. Obtaining this license is a lengthy process that ensures that those who receive it and become accredited have the necessary experience and standards to ensure a higher quality of work. This license also ensures that professional engineers have the necessary legal requirements to operate their work or practice and are held accountable for what they produce for the public.

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## 1.0 Introduction

As the second largest city in the New England region, Worcester has a large number of commuters coming into the city due to its size and location. Its roadways, throughout the city, should allow for a balance of use and accessibility for all users, whether they are motorists, pedestrians, or cyclists. A major throughput for Worcester is Route 122, the study area for this project, also known as Pleasant Street. The part of this state highway that is subject to possible improvements and redesigns is the intersection of Route 122 and Airport Drive near the Paxton town line that connects the suburban town to the Worcester Regional Airport and the more urban environments of the city.

This intersection and the corridor on which it is located has been identified by local residents, motorists, commuters, and the Massachusetts Department of Transportation (MassDOT) as a location needing improvement due to being relatively unsafe for pedestrians and cyclists as well as having a confusing intersection off of a state highway that could be made more efficient and safe. Currently, the corridor provides little safety to pedestrians despite having a sizable housing community along the highway and nearby side streets. The road is designed for much higher speeds than the posted speed limit of 30 mph would indicate. The intersection that leads to the airport and the Webster Square area is a popular cut-through, yet the intersection gives full right-of-way to Pleasant Street while using a semi-roundabout design for the rest of the intersection that has much room for improvement in safety, traffic capacity, and ease of use and understanding.

MassDOT has already commenced with a redesign project concerning this intersection and corridor and, throughout this MQP project, a final design recommendation was presented for the Worcester Airport Rotary Intersection.

## 2.0 Background

A major corridor going through Worcester is the state highway, Route 122, starting in Blackstone, MA until it ends in Orange, MA. In Worcester specifically, the route cuts through the city from Grafton in the south to Paxton in the north (Figure 2).

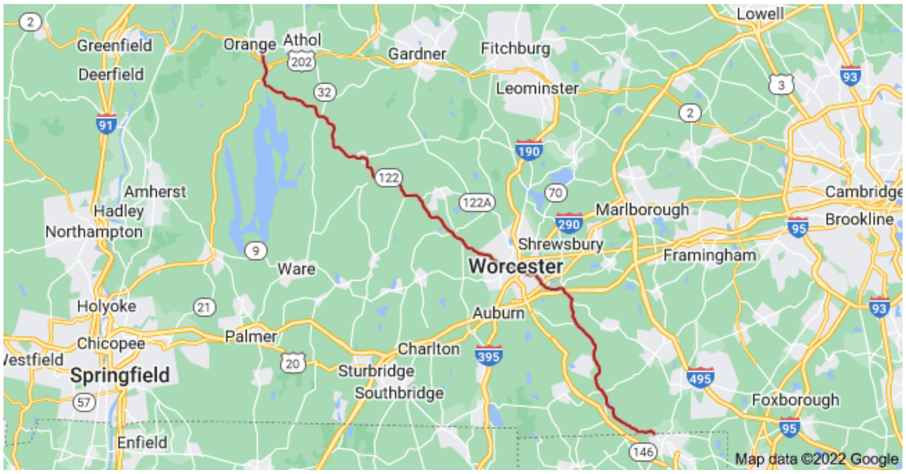



Figure 2: Map detailing the bounds of Route 122 throughout Massachusetts (Google Maps, 2022)

The location examined for the project is the state-owned section from Tatnuck Square to the Paxton Town line. The intersection located between Bailey Street, Airport Drive, and Pleasant Street (Route 122) has been identified as a problematic area that needs some level of redesign. Specifically, there are a number of issues known to the city government, locals, and the state transportation department including high traffic speeds based on the design of the road, a lack of pedestrian safety with few total crosswalks along the route and no sidewalks on the northbound side of the road, and an intersection that does not have the design capabilities to support a safe and constant flow of traffic.


Figure 3: Map detailing the stretch of Route 122 in Worcester that this project is examining (Google Maps, 2022)

The intersection itself is the focus of a redesign project initiated by MassDOT in 2019, first focusing on pedestrian safety on the state highway before transitioning to examining the rotary. Throughout a standard weekday, the intersection can reach an Average Daily Traffic (ADT) of 14,864 and 15,770 vehicles at its busiest locations (points C and F in Figure 4), with peak hours being from 7:15 - 8:15 AM in the morning, 1:45 - 2:45 PM in the midday, and 4:45 - 5:45 PM in the evening (*Worcester (TMCs & ATRs) Memo)*. Site visits to the area reveal what has been mentioned from locals and transportation officials where the area around the intersection is generally unsafe with only two painted crosswalks along Pleasant Street; the only way to cross Pleasant Street is near Mower Street or down by Baxter Street. High speeds through the rotary and a lack of adequate safety for pedestrians is of primary concern. Turning movement counts conducted by MassDOT indicate high levels of usage through the intersection. A redesign of this rotary into a safer alternative for pedestrians and one that is easier to drive through and understand for motorists is a primary goal.

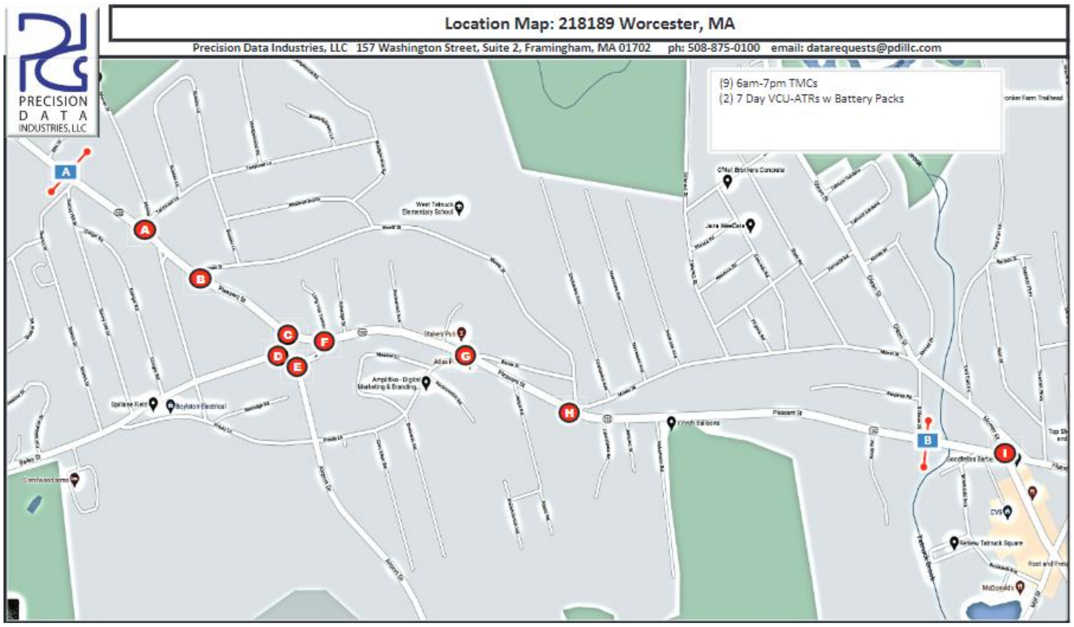



Figure 4: Locations along Pleasant Street in Worcester where turning movement counts were conducted (*Worcester (TMCs & ATRs) Memo)*

MassDOT has already identified this intersection as in need of a redesign. In order to produce a coherent design, MassDOT has a consistent and objective procedure based on certain performance criteria to compare several intersection control strategies, called Intersection Control Evaluation (ICE). With this evaluation procedure in mind, both current and future alternatives can be critically examined to see if they are the best fit for this intersection. As this project is located on a State Highway, an ICE is required for the final product, but it can still be applied to any number of possible submittals. An ICE consists of 3 primary stages involving a screening, initial assessment, and a detailed assessment stage. Any fatally flawed alternative is identified in Stage 1 and removed. In order to move forward with a redesign past Stage 1, a Project Initiation Form is submitted to MassDOT that requires the department's approval. This form consists of the project's location, purpose and description, costs and responsibilities, and general information. If no single control strategy emerges from Stage 1, a Stage 2 assessment would be submitted afterwards with the pre-25% design package. If no single control strategy emerges from Stage 2, a Stage 3 assessment would be completed prior to the 25% design submission. The amount of data and analysis done in each stage allows the design to be as comprehensive as possible, incorporating crash predictions, planning level opinions of probable design, right-of-way, construction costs, traffic operation analyses, and geometric designs, all of which are done throughout the process, especially in Stages 2 and 3, to evaluate the intersection as thoroughly as possible.

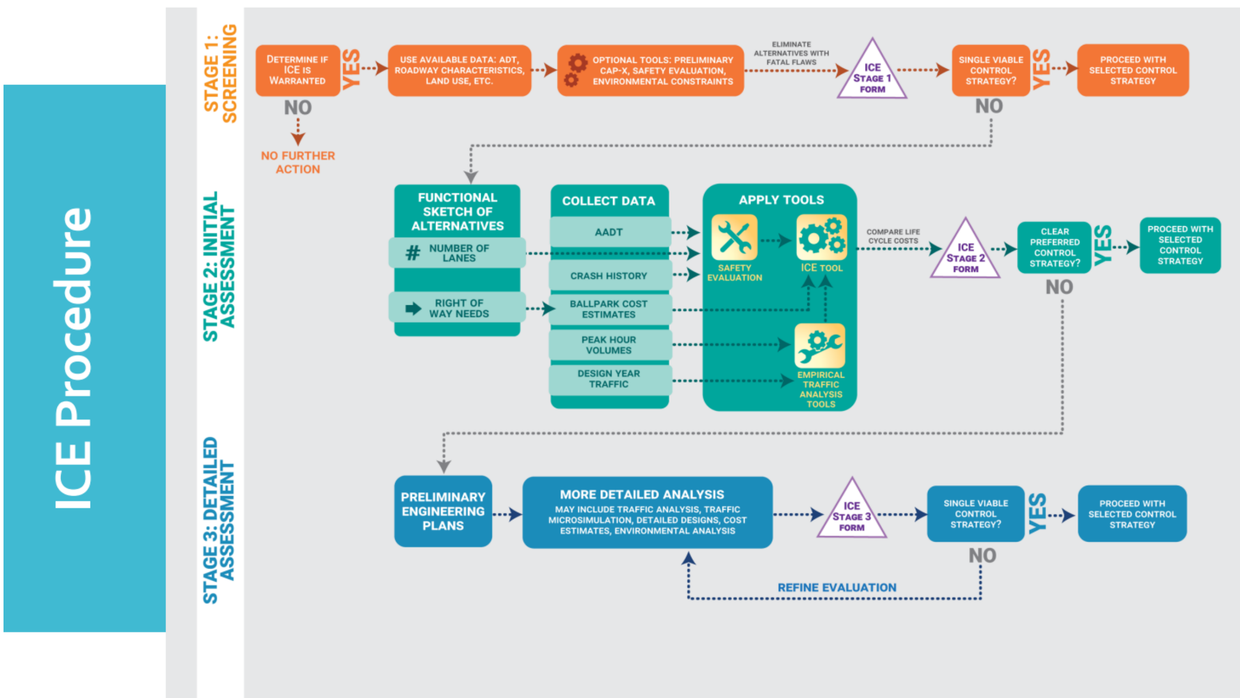



Figure 5: Flow chart depicting the ICE procedure through all 3 stages

## 3.0 - Methodology

The goal of this MQP was to create a new design of the intersection of Route 122, Airport Drive, and Bailey Street that is safer and better utilized by the community. To satisfy the project goal, certain objectives were developed, and the methods required by these objectives are detailed in this section. The aforementioned objectives are:

1. Understand Best Practices Regarding Intersection Design
2. Analyze the Existing Conditions at the Intersection
3. Formulate Multiple Control Strategy Options using ICE
4. Select a Final Control Strategy as the Optimal Redesign Solution

### 3.1 - Understand Best Practices Regarding Intersection Design

The team gained an understanding of best practices regarding intersection design. The potential different designs of intersections were studied, including the general benefits associated with roundabouts and signalized intersections. Studying the general benefits helped the team better understand complex intersections that make use of roundabouts and signals. In order to design these complex intersections, the team familiarized themselves with the Intersection Control Evaluation (ICE) method employed by MassDOT. ICE is a three-stage approach to develop traffic control alternatives for intersections (MassDOT 2021).

### 3.2 - Analyze the Existing Conditions at the Intersection

Once the team familiarized itself with the best practices regarding intersection design, the existing conditions at the intersection were analyzed. Peak Hour Volumes from previous studies conducted at the intersection on May 13, 2021, and November 4, 2021 were provided by MassDOT and analyzed by the group. These Peak Hour Volumes were used to verify the accuracy of the values through comparison to the actual study Peak Hour Volumes collected by the group.

### 3.2.1 - Collection and Analysis of Turning Movement Counts

The team conducted traffic counts as a collective group during the first week of November 2022, on the days of 11/1 and 11/2. After working with MassDOT to secure an access permit for the installation of the traffic camera, the group attached the Owl Camera at the Airport Rotary as shown in Figure 6.

Figure 6: Owl Camera facing Airport Rotary on Route 122

After the two day span the team took down the traffic camera and obtained the video file. The team proceeded to complete a standard turning movement study with a TDC Ultra traffic data collection tool. The team decided on how each of the turning movements of the intersection would be recorded on the tool. The team then proceeded to take turning movement counts from 6-10 AM for 11/1 and 11/2. In addition to this, the team also recorded counts for 2-6 PM for 11/1 and 11/2. Once the turning movement counts were recorded with the TDC Ultra traffic data collection tool, the data was then uploaded to PetraPro software where the data was displayed in an easy-to-read tabular format with 15-minute intervals.

After the video data was collected, the TMCs from the intersection were analyzed. Since the turning counts for the AM and PM periods of two days were acquired, the counts were averaged to produce one AM and PM period. The averaged counts were deemed to be a better representation of the actual volumes passing through the intersection. The averaged AM and PM counts were then used to find the AM/PM peak hour. These peak hours were defined as the four consecutive 15-minute intervals where the entering volumes were the highest. Once the AM/PM peak hours were found, the total AM/PM peak hour volumes along with the AM/PM peak hour volumes for each approach and movement were calculation.

The peak hour volumes were used to find the Existing and Design Average Daily Traffic (AADT). Before the Study AADT was identified, the Average Daily Traffic (ADT) was found for each approach. The approach ADT was calculated by dividing the AM peak hourly volume for each approach by the k-factor. The k-factor is the standard used by MassDOT, and a default k-factor value of 0.09 can be assumed for insufficient ATR data (Intersection and Roadway Crash Rate Data for Analysis , n.d.). The k-factor value of 0.09 essentially means that a typical peak hour represents 9% of ADT. The 9% of ADT is between the typical range for urban facilities of 7% to 12% (FHWA, 2018). Each approach ADT was then summed to find the Intersection ADT (V). Each of the approach ADTs were then multiplied by the Monthly Expansion Factor (MEF) given in the 2019 MassDOT weekday seasonal and axle correction factors document to find the Study AADT. The Monthly Expansion Factor (MEF) changes depending on the month and the factor group of the type of road. The factor group of each road was determined using MassDOT’s Road Inventory GIS.

The study AADT derived from the standard turning movement study was adjusted for the year 2042 (Design AADT) using the growth factors for the respective streets acquired from the Central Massachusetts Regional Planning Commission (CMRPC). The current and design AADT were utilized to carry out a crash analysis.

### 3.2.2 - Synchro Analysis of Existing Rotary

After the peak hour data was collected, the group determined the measures of effectiveness of the Airport Rotary. MassDOT provided the MQP group with Synchro software, a traffic signal timing software that transportation planners use to model and optimize signalized and unsignalized intersections (including roundabouts). Software analysis incorporated specifics about the number of lanes, percent of heavy vehicles, controls, and approach grades.

The team first represented the existing intersection in Synchro by modeling the intersection with links and nodes. The team then entered the corresponding averaged peak hour volumes for the left, thru, and right turning movements for each approach of the intersection. The team repeated this process for both AM and PM peak hour volumes. The program displayed data on the level of service (LOS), volume to capacity ratio, and intersection delay times for each time period. This process was repeated for 2042 expected traffic volumes by adjusting the volumes with growth rate factors obtained from CMRPC for Airport Drive and Pleasant Street.

### 3.2.3 - Collection and Analysis of Crash Data

Existing crash data at the Airport Rotary was collected by using the MassDOT Online Crash Data Portal. The number and types of crashes between 2017 - 2021 was collected, since five years of crash data is the standard used by MassDOT for analysis. The crashes were tabulated and organized by the crash types and crash severities.

#### 3.2.3a - Crash Rate and Crash Diagram

The MassDOT Intersection Crash Rate Worksheet was used to calculate the crash rate. The sheet requires inputs for the approach/total peak hour volumes, the "k" factor, the average number of crashes per year (A), and the intersection ADT (V). The approach/total peak hour volumes and the "k" factor are not needed for the calculation of the crash rate if the intersection ADT (V) variable is already known. The intersection ADT (V) variable was derived from the standard turning movement count study using the approach stated in Section 3.2.1, while the average number of crashes per year (A) variable was acquired from the collected crash data. The crash rate equation (Figure 7) was then used to find the crash rate. The calculated intersection crash rate was then compared to see if the value exceeds the average crash rate for the District and the State for unsignalized intersections. A crash diagram was also made in order to visualize the safety conditions of the intersection.

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(V * 365)}$$

Figure 7: Crash Rate Equation

**3.2.3b - Safety Analysis using MassDOT's Safety Alternatives Analysis Guide Spreadsheet Tool for No Build Conditions**

The various values for the estimated crashes during the design year for no-build conditions ( $N_{estimated.design.nobuild}$) were found using the general guidance provided by the MassDOT Safety Alternatives Analysis Guide. This guide lays out three different methods depending on the conditions of the intersection being analyzed.

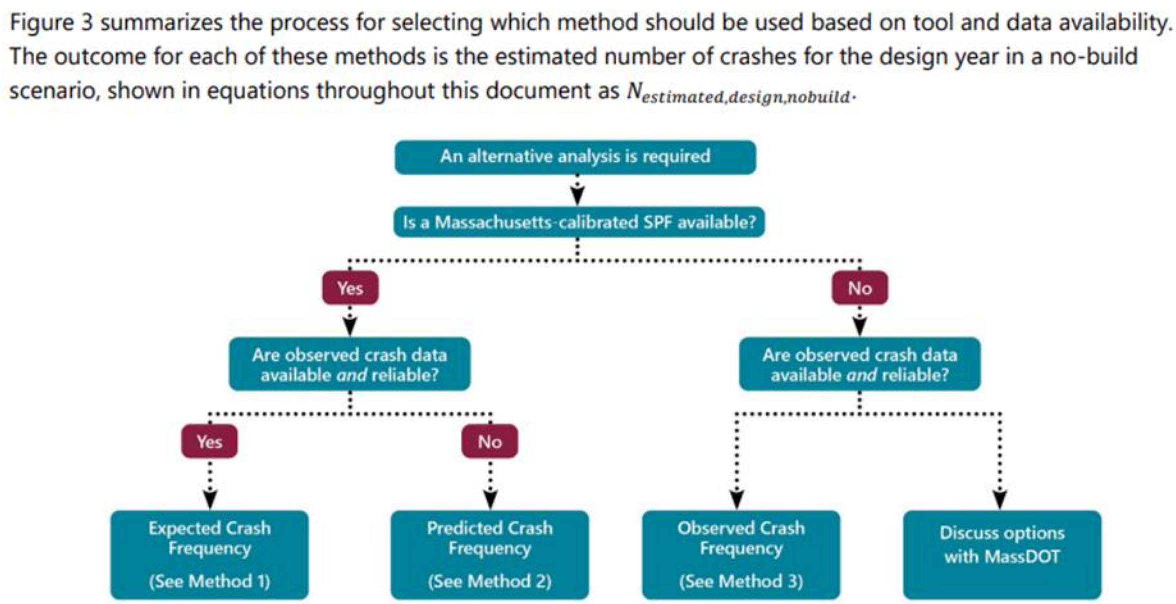



Figure 8: Flowchart for safety analysis method (MassDOT, 2021)

The unique configuration of the Airport Rotary intersection meant that a Massachusetts-calibrated SPF was not available although observed crash data was reliable. This meant that Method 3 of the MassDOT Safety Alternatives Analysis Guide would need to be used.

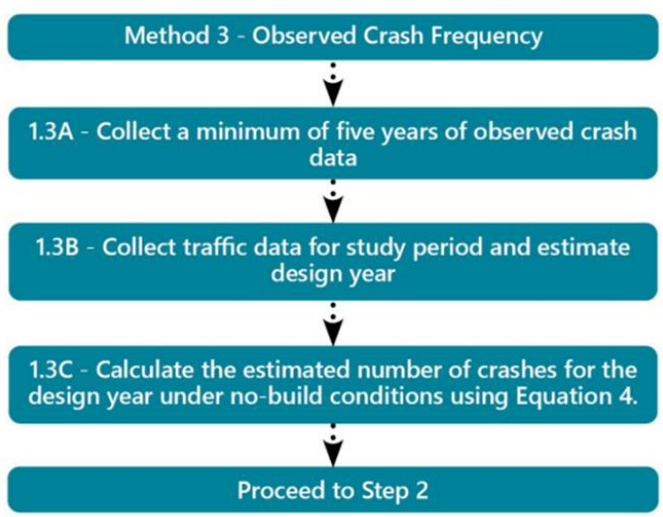



Figure 9: Flowchart for safety analysis method 3 (MassDOT, 2021)

Step 1 of Method 3 would start by organizing the types of crashes collected from the MassDOT Online Crash Data Portal by the crash type followed by severity. The possible crash types included single-vehicle crashes (SV), multi-vehicle crashes (MV), pedestrian crashes (Ped), and bike crashes (Bike). The severity for each crash type was classified as property damage only (PDO), fatal and injury (FI), or all severity (ALL). The equation present in Figure 10 associated with Method 3 was used with the Study and Design AADT variables calculated in Section 3.2.1 along with the number of crashes for each crash type and severity. These values can be utilized to find the $N_{estimated.design.nobuild}$ values for SV, FI crashes, MV, FI crashes, SV, ALL crashes, and MV, ALL crashes.

$$N_{estimated,design,nobuild,MV,FI} = N_{obs,design} = \frac{N_{obs,study}}{AADT_{study} * Y_{years,study}} * AADT_{Design}$$
$$= \frac{21\ MV, FI\ Crashes}{13{,}450\ vpd * 6\ years} * 15{,}450\ vpd = 4.02$$

Figure 10: Equation and example calculation of estimated number of multi-vehicle FI crashes for the design year under no-build conditions using Method 3 (MassDOT, 2021)

### 3.3 - Formulate Multiple Control Strategy Options using ICE

After the team analyzed the existing conditions at the intersection the ICE procedure was started. ICE was started with Stage 1 and a few alternatives were selected for further analysis. In order to further analyze these alternatives data was collected. Once the data was collected it was analyzed in the ICE tool and the team was able to select a final control strategy in Stage 2.

### 3.3.1 - ICE Stage 1

The team started ICE procedure at Stage 1 with the preselected list of 12 control strategies shown in Figure 11 below to find 2 or 3 viable control strategies.

Select intersection types from the following table to include in the ICE analysis. To include an intersection, select "Yes" in the include column, and to exclude an intersection, select "No" in the include column.

**At-Grade Control Strategies**

| Control # | Include | Short Name | Description | Notes |
|---|---|---|---|---|
| 1 | Yes | TWSC | Two-Way Stop Control | |
| 2 | Yes | AllStop | All Way Stop | |
| 3 | Yes | TrafficSignal | Traffic Signal | |
| 4 | Yes | TrafficSignalAlt | Traffic Signal (Alt.) | |
| 5 | Yes | Roundabout | Roundabout | |
| 6 | Yes | DLT | Displaced Left Turn (DLT) | |
| 7 | No | MUT | Median U-Turn (MUT) | |
| 8 | No | SignalRCUT | Signalized Restricted Crossing U-Turn (RCUT) | |
| 9 | No | UnsignalRCUT | Unsignalized Restricted Crossing U-Turn (RCUT) | |
| 10 | No | GreenT | Continuous Green-T Intersection | |
| 11 | No | Jughandle | Jughandle | |
| 12 | No | Quadrant Itx | Quadrant Roadway Intersection | Note that no safety information is available |

Figure 11: Twelve control strategies evaluated in ICE tool (MassDOT, 2021)

The viability of each of the control strategies was measured through yes/no answers to a series of six questions located on the ICE form. These questions were answered by deriving information from the FHWA manual for each control strategy and comparing with the needs, purposes, and limits of the project. If all six questions were justified with a “yes”, then the control strategy was moved to Stage 2 for further analysis.

ICE STAGE 1 QUESTIONS

1. Does the control strategy address the project need in a balanced manner and in scale with the project?
2. Does the control strategy improve safety performance in terms of reducing severe crashes?
3. Does the control strategy improve safety, convenience and accessibility for pedestrians and cyclists?
4. Does the control strategy improve traffic operations (congestion, delay, reliability, etc.)?
5. Does the control strategy appear feasible given the site constraints & location context (e.g., ROW, cultural impacts)?
6. Does the control strategy appear feasible with respect to other project factors (e.g., environmental, utility impacts)?

Figure 12: The six questions used in ICE Stage 1 to narrow control strategies (MassDOT, 2021)

### 3.3.2 - ICE Stage 2

After Stage 1 was completed, the lack of a singular control strategy prompted the use of Stage 2. Stage 2 includes a basic analysis of each viable control strategy from Stage 1. Stage 2 required three inputs: empirical traffic analysis, safety analysis, and design and construction cost estimates.

### 3.3.2a - Empirical Analysis

The first step of the empirical analysis was to develop one or two alternatives for each viable control strategy that emerged from ICE Stage 1. The associated functional sketches included the number of lanes and right of way needs along with the AM/PM peak hour volumes collected in Section 3.2.1 for each approach of the intersection. These functional sketches were used to draw the alternatives in Synchro. Once the alternatives were drawn in Synchro, the LOS, volume to capacity ratio, and intersection delay times were found for each time period using the software. The intersection delay times were used as the major inputs for the empirical analysis in ICE Stage 2.

In order to create a roundabout alternative, the team used Sidra, an intersection evaluation program that, in comparison to Synchro, is able to more accurately model roundabouts. This program produces comprehensive tables detailing an intersection's level of service, average delay, demand flow, and volume/capacity ratio. Using this software package, a comprehensive analysis of how efficient a roundabout intersection could be using the traffic data collected in Section 3.2.1 was constructed. The program is less geographically based compared to Synchro, but due to the consistency of roundabout designs, the data that was collected from this program is accurate and applicable to deciding which alternative would be used. The delay data provided by the program were used as the major empirical inputs in the ICE Tool.

#### 3.3.2b - Safety Analysis using MassDOT's Safety Alternatives Analysis Guide Spreadsheet Tool for Alternatives

For the safety analysis needed for ICE Stage 2, the team started with the$N_{estimated.design.nobuild}$ values for SV, FI crashes, MV, FI crashes, SV, ALL crashes, and MV, ALL crashes calculated with the method in Section 3.2.2. Crash modification factors (CMFs) for the alternatives analyzed in ICE Stage 2 were acquired from the MassDOT State-Preferred CMF List, available in the Massachusetts Safety Analysis Tools. This list has various CMFs associated with SV and MV crashes for the ALL and FI severity levels. The respective CMFs can be multiplied by the respective $N_{estimated.design.nobuild}$ values to find the respective values for the estimated crashes during the design year for the alternative ($N_{estimated.design.alternative}$). The $N_{estimated.design.alternative}$ values for the SV, ALL crashes and the MV, ALL crashes were summed together to find the total amount of ALL crashes for the design year (Total, ALL). The $N_{estimated.design.alternative}$ values for the SV, FI crashes and the MV, FI crashes were then summed together to find the total amount of FI crashes for the design year (Total, FI). The Total, FI and Total, ALL values were used as the major safety inputs in the ICE Tool.

#### 3.3.2c - Cost Analysis

A cost analysis was performed for the three alternatives; the analysis included the design, construction, and right-of-way costs for each control strategy. The team determined probable construction costs for each item based on the unit costs presented in the MassDOT online weighted bid price application. The most recent costs were downloaded for the time period from November 2021 to November 2022. For the traffic signal items that were not in the weighted bid price application the team referenced a contract bid estimate in 2022, for a traffic signal repair project provided by MassDOT.

After setting up a calculation book in Excel, a rough estimated total cost for each control strategy was determined. The total cost was determined by multiplying the unit cost of each item by its respective quantity and then summing each cost per item. The quantities for each item were measured with a tool in Google Earth, with each measured quantity varying for each alternative. Some of the measurements were linear foot, square yards, and cubic yards. A 10% contingency and a 5% for traffic police was assumed for this project. The ROW costs for each alternative design were determined to be zero as there will be no expected changes to the existing bounds. The engineering costs were determined to be 10% of the construction cost. The design, construction, and engineering cost were entered into the ICE tool for the three alternatives.

**3.3.2d - ICE Tool and ICE Form**

The team inputted all the required data gathered in the objectives above into the ICE tool. This data included the total AM/PM peak hour volumes collected in Section 3.2.1 along with the advanced control strategies from Stage 1, which were put into the “Alternatives_MasterList” tab of the sheet. The cost and safety analysis inputs were inserted into the “CostParameters” tab. Finally, the intersection delay times were input into the “Delay” tab. The ICE tool was then run using the “Setup Worksheets” function on the “Alternatives_MasterList” tab. The “Outputs” tab included the Net Present Value (NPV) of Total Costs and the benefit-cost comparison for each control strategy.

### 3.4 - Select a Final Control Strategy as the Optimal Redesign Solution

The B/C ratios calculated in the benefit-cost comparison were one of the factors used to select an alternative as the final design for the Worcester Airport Rotary intersection. Alternatives with higher B/C ratios were preferred. The overall positive effects on safety, pedestrian access, traffic throughput, construction cost, and ease of use was also examined for each alternative. The most balanced design in these areas was chosen to be the final recommended design that the team moved forward with.

The team did not move on to Stage 3 of ICE as the alternative selected in Stage 2 was definitive and time constraints prevented further analysis. A more detailed analysis might require revising the Stage 2 analysis or proceeding to Stage 3. The recommendation given to MassDOT was considered to help with future analysis and move the project from a 25% design to a 75% design phase.

## 4.0 - Results

The methods explained in Section 3 were utilized by the team to construct an overall recommendation on what the intersection redesign should be. These methods produced comprehensive results that allowed a specific alternative to be recommended primarily using the ICE tools provided by MassDOT with consideration to their redesign process.

### 4.1 - Understand Best Practices Regarding Intersection Design

Using the ICE tool and examining functional design reports allowed the team to get a better understanding of some of the tactics MassDOT uses when redesigning intersections. The number of possible alternatives was reduced from any initial brainstorming phase as constraints from the existing conditions analyzed in Section 3.2 and the intersections present in the ICE tool gave a clearer picture on what could be done at the Airport Rotary.

Roundabouts are an efficient type of intersection because they do not have stop-and-go conditions as traditional intersections, which reduces congestion. An advantage of a roundabout design is that they do not include traffic signals, so they are not susceptible to power outages. Roundabouts make sure that traffic does not maintain high speeds, this reduces the severity and frequencies of crashes compared to signalized intersections. Some of the most severe types of vehicle crashes are eliminated with this design, such as T-bone, left turn, and head-on collisions. Another safety feature of roundabouts is that they reduce the number of conflict points between people biking and vehicles. Compared to other control strategies a roundabout has a 90% reduction in fatalities, 76% reduction in injuries, and 35% reduction in all crashes (FHWA, 2022).

A signalized control strategy is a viable design because it addresses the project need in a balanced manner while being in scale with the project. Signals can help better optimize traffic flow by making sure all directions are able to clear the intersection in an efficient manner. Signals are also in scale with the project, as they can be implemented to the existing intersection with relative ease, although a different configuration of the intersection might be more optimal for signalization. Signalized Control improves safety performance in terms of reducing severe crashes. This is because signalization will make cars on Pleasant Street slow down to a stop while allowing for cars to turn in a dedicated phase. Pedestrians and cyclists were able to achieve safer travel since the signals will provide an opportunity to provide a phase for pedestrian crossings. This control strategy provides a signal phase for every turning movement, which can potentially allow for less delay and more efficient travel.

**4.2 - Analyze the Existing Conditions at the Intersection**

MassDOT provided the Peak Hour Volumes from previous studies conducted at the intersection on May 13, 2021, and November 4, 2021, with this data being presented in Figure 13 below. The data in Figure 13 was compared to the Peak Hour Volumes collected by the group presented in Table 1.

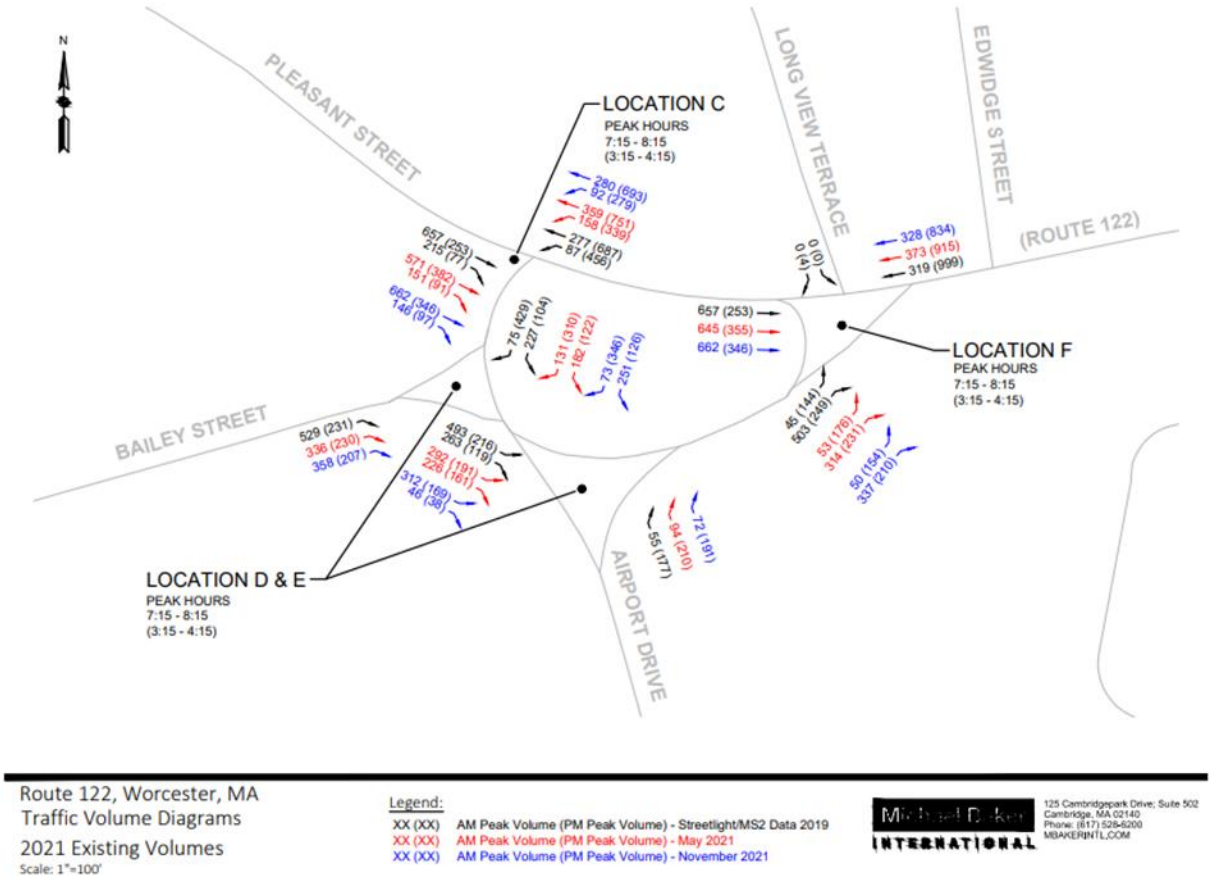


Figure 13: The TMC data from previous studies conducted at the intersection on May 13, 2021, and November 4, 2021 (MassDOT, 2021)

### 4.2.1 - Collection and Analysis of Turning Movement Counts

After collecting the traffic volumes on November 1st and 2nd, 2022, the peak hours for the existing operations were determined to be 7:15 AM to 8:15 AM and 3:00 PM to 4:00 PM. The peak hour volume for each approach is presented in Table 1 and the corresponding turning movements for each approach is in Figure 14.

Table 1: Peak hour volumes for each approach in the existing intersection with predicted amounts for 2042

| Peak Hour Volumes | Pleasant Street Southbound | | | | Pleasant Street Northbound | | | |
|---|---|---|---|---|---|---|---|---|
| 2022 | Towards Bailey | Towards Airport | Thru | Total | Thru | Towards Bailey | Towards Airport | Total |
| AM | 12 | 146 | 647 | 805 | 240 | 35 | 41 | 316 |
| PM | 38 | 73 | 318 | 429 | 513 | 134 | 27 | 674 |
| 2042 | | | | | | | | |
| AM | 14 | 166 | 736 | 916 | 273 | 40 | 47 | 360 |
| PM | 44 | 84 | 365 | 493 | 589 | 154 | 31 | 774 |

| Bailey Street | | | | Airport Drive | | | | |
|---|---|---|---|---|---|---|---|---|
| Towards Airport | Towards SB | Towards NB | Total | Towards NB | Towards SB | Towards Bailey | Total | |
| 16 | 317 | 18 | 351 | 28 | 20 | 3 | 51 | AM |
| 11 | 120 | 19 | 150 | 59 | 106 | 0 | 165 | PM |
| | | | | | | | | |
| 18 | 363 | 21 | 402 | 32 | 23 | 3 | 58 | AM |
| 12 | 136 | 22 | 170 | 67 | 120 | 0 | 187 | PM |

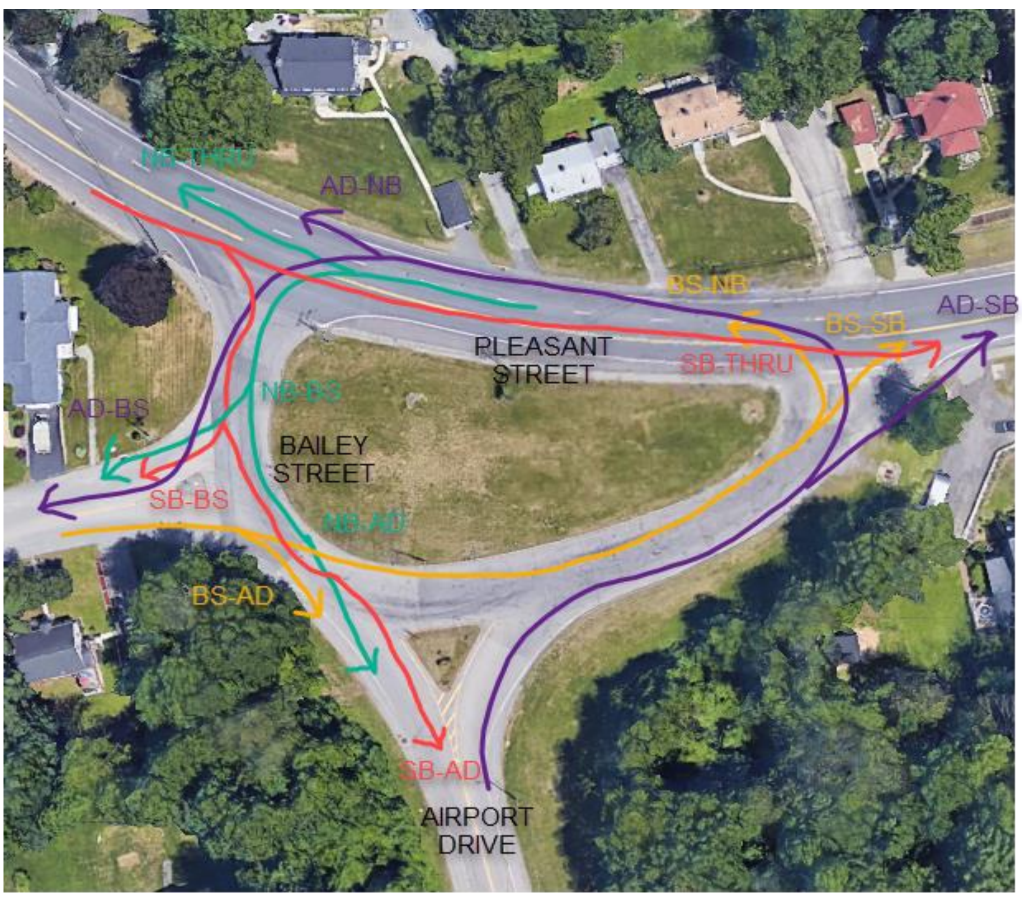



Figure 14: Turning movements for each approach at Airport Rotary

In addition to collecting traffic volumes from the intersection, it was also required to plan for the future and calculate how said traffic would grow in 20 years. A growth factor was provided to the team through the Central Massachusetts Regional Planning Commission that was applied to the traffic counts previously found. According to the CMRPC, the growth factors were 15.3% in the AM and 12.7% in the PM. These values were given to the team through correspondence with the CMRPC's individual responsible for the regional travel demand forecasting model. These were applied to the counted volumes to get predicted volumes for 2042 as seen in Table 2.

Table 2: Total peak hour volumes for the intersection for the AM/PM peaks in 2022 and 2042

| Total Peak Hour Volumes | | |
|---|---|---|
| **Year** | **2022** | **2042** |
| AM | 1523 | 1736 |
| PM | 1418 | 1624 |

The peak hour volumes of each approach given in Table 1 were summed to find the total peak hour volumes for the intersection as presented in Table 2. It was found that the AM peak hour had the higher total peak hour volume and was thus used for further analysis.

The approach AM peak hour volumes from Table 1 were utilized to find the Exisitng and Design AADT using the methods from Section 3.2.1. A k-factor of 0.09 was utilized. Pleasant Street was classified as being in the U3 factor group, having a MEF of 0.97 for November. Bailey Street and Airport Drive were classified as being in the U4-U7 factor group, having a MEF of 0.99 for November. Table 3 below shows the various factors and values used to calculate the Study and Design AADT.

Table 3: The factors and values used to calculate the Study and Design AADT

| AADT Calc | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Approach | Peak Hour Volume | "k" factor | ADT (V) | MEF for NOV | Approach AADT | Study AADT |
| | Pleasant Street | 1121 | 0.09 | 12456 | 0.99 | 12331 | |
| | Airport Drive | 51 | 0.09 | 567 | 0.97 | 550 | |
| 2022 AM Peak Hour | Bailey Street | 351 | 0.09 | 3900 | 0.97 | 3783 | 16664 |
| | | | | | | | Design AADT |
| | Pleasant Street | 1266 | 0.09 | 14071 | 0.99 | 13931 | |
| | Airport Drive | 187 | 0.09 | 2078 | 0.97 | 2016 | |
| 2042 AM Peak Hour | Bailey Street | 170 | 0.09 | 1889 | 0.97 | 1833 | 17779 |

### 4.2.2 - Synchro for Existing Rotary

To evaluate the existing traffic conditions, an intersection capacity utilization (ICU) was performed to determine the LOS for the intersection. An ICU is the sum of the ratios of approach volume divided by approach capacity for each leg of intersection which controls overall traffic signal timing plus an allowance for clearance times. The ICU is used for existing conditions because it can determine the capacity utilization if the intersection were to be signalized, the output from ICU is similar to the intersection volume to capacity ratio. The LOS results for AM/PM peak hour traffic volumes were evaluated for both 2022 and 2042, these volumes can be found in Table 4 and Appendix B. The ICU level of service was performed on the rotary by splitting it up into four different intersections. The intersections and their corresponding traffic movements and volumes can be found in Figure 15.

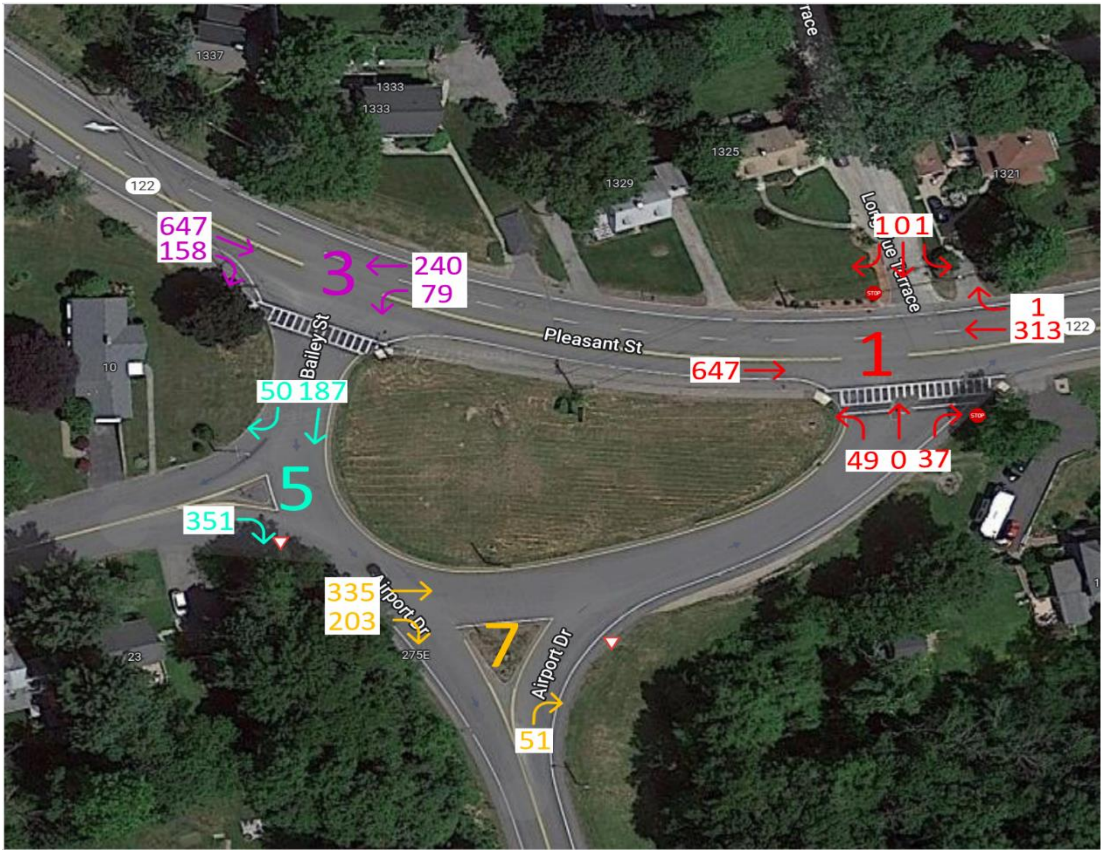



Figure 15: Four different intersections and corresponding volumes at existing rotary

Table 4: ICU LOS for each intersection of the existing rotary

| ICU LOS Analysis | | | | |
|---|---|---|---|---|
| | 1 | 3 | 5 | 7 |
| AM 2022 | H (Err%) | B (59.2%) | A (25.1%) | A (25.8%) |
| AM 2042 | H (Err%) | C (67.1%) | A (28.5%) | A (28.6%) |
| PM 2022 | H (Err%) | A (49.0%) | A (21.5%) | A (24.3%) |
| PM 2042 | H (Err%) | A (54.5%) | A (24.2%) | A (26.9%) |

Table 4 above presents the LOS and percent capacity of the intersection for the 2022 and 2042 AM/PM peak hours. A worsened LOS level and a higher percent capacity are predicted for the 2042 AM/PM peaks, suggesting that the intersection will experience more congestion in the future. A LOS of H indicates that a portion of this intersection is 9% or greater over capacity, thus the percent capacity for this intersection is represented as an error. Most industry standards require the ICU LOS to be E or better. To achieve this, a change to the rotary design may be required.

### 4.2.3 - Crash Data

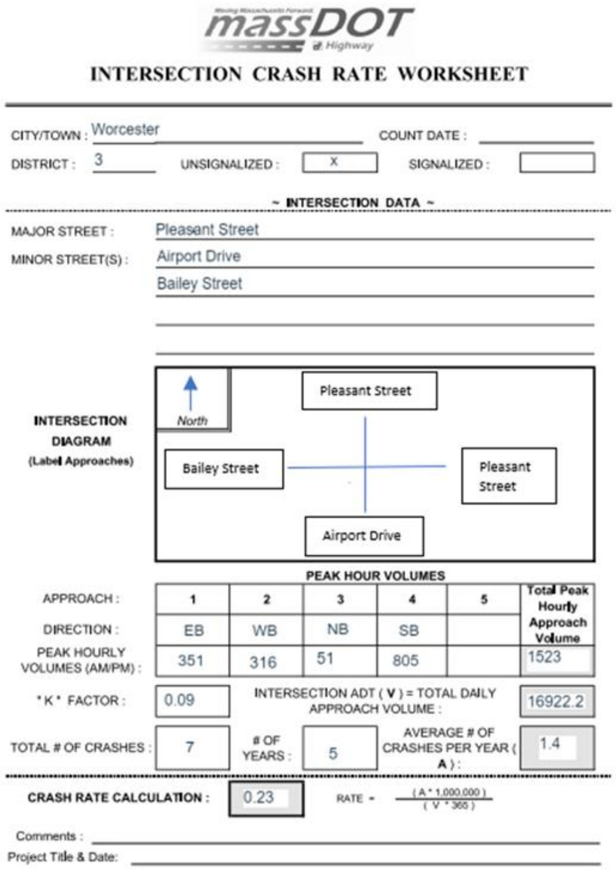
The relevant crash data was acquired from the MassDOT Online Crash Data Portal for the years 2017-2021 and tabulated in Table 5. A total of 7 crashes happened over the 5-year period, with the average number of crashes per year (A) being 1.4 crashes per year.

Table 5: Intersection crash data received from the MassDOT Online Crash Data Portal

| Crash Type, Severity | Total | Average per Year | Year 1 (2017) | Year 2 (2018) | Year 3 (2019) | Year 4 (2020) | Year 5 (2021) |
|---|---|---|---|---|---|---|---|
| MV, FI | 1 | 0.20 | 0 | 0 | 0 | 0 | 1 |
| MV, PDO | 3 | 0.60 | 1 | 0 | 1 | 0 | 1 |
| SV, FI | 1 | 0.20 | 0 | 0 | 0 | 1 | 0 |
| SV, PDO | 2 | 0.40 | 0 | 1 | 0 | 1 | 0 |
| Ped, FI | 0 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| Ped, PDO | 0 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| Bike, FI | 0 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| Bike, PDO | 0 | 0.00 | 0 | 0 | 0 | 0 | 0 |

### 4.2.3a - Crash Rate and Diagram

The MassDOT Intersection Crash Rate Worksheet, shown in Figure 16, was completed using the Intersection ADT (V) of 16922.2 from Table 1 in Section 4.2.1 and the average number of crashes per year (A) of 1.4 crashes per year.



massDOT

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Worcester | COUNT DATE :

DISTRICT : 3 | UNSIGNALIZED : X | SIGNALIZED :

~ INTERSECTION DATA ~

MAJOR STREET : Pleasant Street

MINOR STREET(S) : Airport Drive

Bailey Street

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

| APPROACH : | 1 | 2 | 3 | 4 | 5 | Total Peak Hourly Approach Volume |
|---|---|---|---|---|---|---|
| DIRECTION : | EB | WB | NB | SB | | |
| PEAK HOURLY VOLUMES (AM/PM) : | 351 | 316 | 51 | 805 | | 1523 |

"K" FACTOR : 0.09 | INTERSECTION ADT ( V ) = TOTAL DAILY APPROACH VOLUME : 16922.2

TOTAL # OF CRASHES : 7 | # OF YEARS : 5 | AVERAGE # OF CRASHES PER YEAR ( A ) : 1.4

CRASH RATE CALCULATION : 0.23 | RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments :

Project Title & Date:

Figure 16: MassDOT Intersection Crash Rate Worksheet

Using the Crash Rate Equation in Figure 7, the intersection crash rate was calculated to be 0.23. Table 6 below compares the intersection crash rate to the average statewide and District 3 crash rates.

Table 6: Intersection crash data compared to statewide and district crash rate

| Intersection Name | # of Crashes (2017-2021) | Intersection Crash Rate | Avg. Crash Rate (Statewide) | Avg. Crash Rate (District 3) |
|---|---|---|---|---|
| **Airport Rotary** | 7 | 0.23 | 0.57 | 0.61 |

The crash data did not reveal any overwhelming safety concerns, as the intersection was below the average statewide and District 3 crash rates.

The team created crash diagrams to further identify the issues and trends that contribute to the crashes by organizing the crash data by type and specific location in the intersection. The crash diagram was constructed using the 2017-2021 data from the MassDOT Crash Data portal. There was a total of seven crashes with no fatal injuries reported on the Airport Rotary in that interval of time. Different types of crashes with their location on the map were constructed on the crash diagram using PowerPoint software. There was a total of four angle collisions, one sideswipe, and two rear-end collisions. The crash diagram includes a description box at the bottom which displays symbols for each type of crash. The majority of the crashes happened on Pleasant Street and Bailey Street. The crash diagram is presented below as Figure 17.

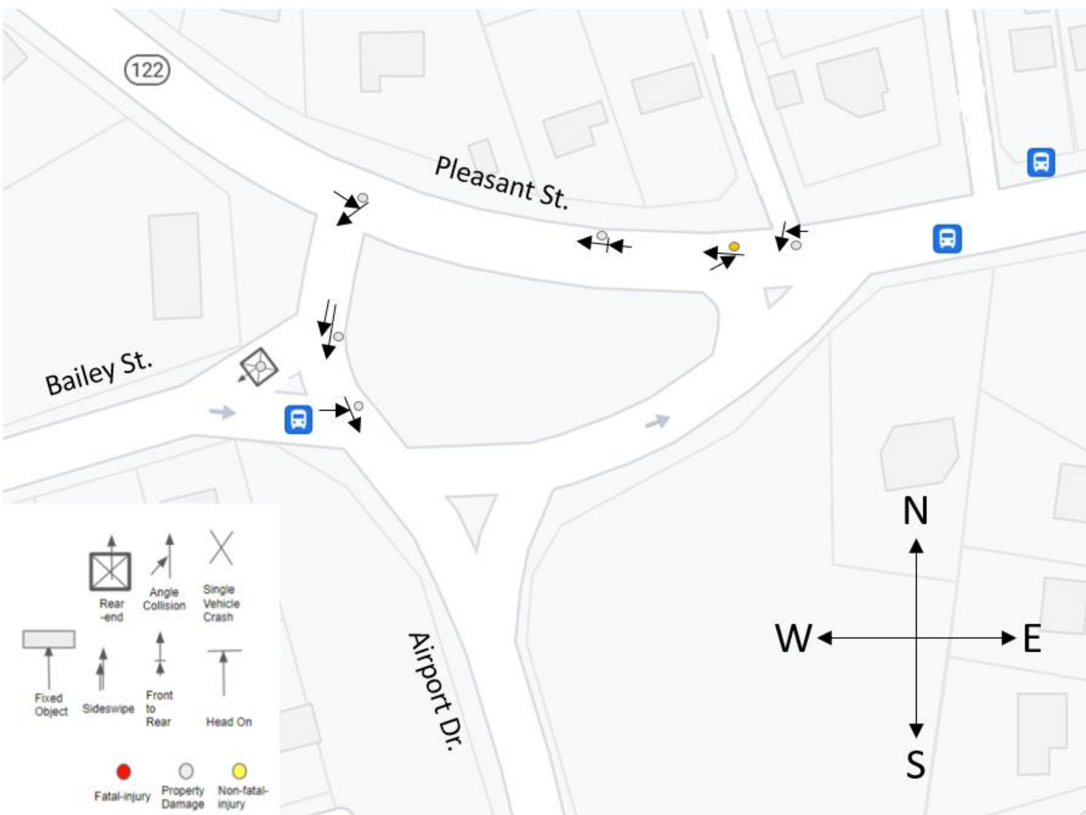



Figure 17: Crash Diagram of the Airport Rotary

### 4.2.3b - Safety Analysis using MassDOT's Safety Alternatives Analysis Guide

The safety analysis done with the MassDOT's Safety Alternatives Analysis Guide Spreadsheet Tool involved the use of Equation 4 of Method 3 (Figure 10) from the document to find the $N_{estimated.design.nobuild}$ value. Equation 4 used the values from Table 5 for the total number of crashes depending on crash type and crash severity. The Study AADT value of 16664 and the Design AADT value of 17779 from Table 3 were also utilized. Table 7 below presents the results of the safety analysis for the design year and the final $N_{estimated.design.nobuild}$ values derived from Equation 4.

Table 7: Safety Analysis for the Design Year using Method 3 of the MassDOT Safety Alternatives Analysis Guide for Existing Conditions

**Existing Conditions**

| Crash Type, Severity | # of Crashes | Study AADT (2022) | Design AADT (2042) | Estimated Crashes During the Design Year using Method 3, No-Build |
|---|---|---|---|---|
| MV, ALL | 4 | 16664 | 17779 | 0.85 |
| MV, FI | 1 | | | 0.21 |
| MV, PDO | 3 | | | 0.64 |
| SV, ALL | 3 | | | 0.64 |
| SV, FI | 1 | | | 0.21 |
| SV, PDO | 2 | | | 0.43 |
| Total (FI) | | | | 0.43 |
| Total (PDO) | | | | 1.07 |
| Total (ALL) | | | | 1.49 |

### 4.3 - Formulate Multiple Control Strategy Options using ICE

Once the existing conditions had been analyzed, the ICE process could be initiated in order to develop viable alternatives.

### 4.3.1 - ICE Stage 1

**MassDOT Intersection Control Evaluation (ICE) Stage 1: Screening** massDOT Massachusetts Department of Transportation

| | | |
|---|---|---|
| Project Name | Worcester Airport Rotary | Project Setting *(Describe the area surrounding the intersection)* |
| MassDOT District | District 3 | Residential Neighborhood |
| City/Town | Worcester | |
| Major Street | Route 122/ Pleasant Street | Project Need/Opportunity *(What is the catalyst for this project and intended outcomes?)* |
| Minor Street | Bailey Street/Airport Drive | Traffic Improvements |
| Existing Control T | Two-way Stop-Control | |
| Submitted By | TH,MD,AM,RP | Multimodal Context *(Describe pedestrian, bicycle, and transit activity in the area)* |
| Agency/Company | WPI | Pedestrian and bicyclist activity is low |
| Email | | |
| Date | 12/01/22 | |

Does the control strategy:

| Control Strategy | VIABLE CONTROL STRATEGY? | ...address the project need in a balanced manner and in scale with the project? | ...improve safety performance in terms of reducing severe crashes? | ...incorporate safety, convenience, and accessibility for pedestrians and/or cyclists? | ...improve (or preserve) traffic operations (congestion, delay, reliability, etc.)? | ...appear feasible given the site constraints & location context (e.g., ROW, cultural impacts)? | ...appear feasible with respect to other project factors (e.g., environmental, utility impacts)? | |
|---|---|---|---|---|---|---|---|---|
| Two-Way Stop-Controlled | No | | | | | | | |
| All-Way Stop-Controlled | No | | | | | | | |
| Signalized Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes | |
| Roundabout | Yes | Yes | Yes | Yes | Yes | Yes | Yes | |
| Median U-Turn | No | | | | | | | |
| Restricted Crossing U-Turn (RCUT) Signaliz | No | | | | | | | |
| Restricted Crossing U-Turn (RCUT) Unignali | No | | | | | | | |
| Jughandle | No | | | | | | | |
| Displaced Left-Turn | No | | | | | | | |
| Continuous Green Tee | No | | | | | | | |
| Quadrant Roadway | No | | | | | | | |
| Other | No | | | | | | | |

Figure 18: Overview of Stage 1 ICE Tool used to determine which control strategies were the most viable

Stage 1 of the ICE tool provides 12 different control strategies that MassDOT considers, mainly present due to their frequent occurrence in intersection design. As a part of the team's first step towards selecting an alternative, all of these strategies had to be considered and either deemed as a viable or non-viable alternative. The primary ones selected and considered were the signalized and roundabout intersections due to their ability to improve traffic throughput and pedestrian and cyclist safety as well as being able to be built within the geography of the preexisting intersection. Many of these control strategies were deemed as non-viable due to this geographic restriction as large-scale expansion was not feasible with on-street residential buildings. Among these were the median u-turn, quadrant roadway, jughandle, restricted crossing u-turn (RCUT) signalized, RCUT unsignalized, and displaced left-turn strategies, with these strategies being immediately eliminated. The continuous green tee control strategy could be feasible with the geographic bounds; however, current MassDOT projects include changes to the Pleasant Street corridor that would make this intersection type incompatible. The current rotary is already a two-way stop-controlled intersection and so could be implemented physically, but the team discarded it because of its already existing presence and changing the stop locations along the rotary would not sufficiently improve traffic. The last strategy somewhat considered was the all-way stop controlled alternative, however, this did not advance to Stage 2 of ICE as it did not appear to improve the traffic operations of an intersection. This assessment was made based on the limits of an all-way stop controlled intersection where approaching vehicles all need to slow down and stop. While useful for roads with less traffic, continuing on Pleasant Street is the most common turning movement vehicles undergo and so having them always come to a complete stop would slow down traffic in a much less efficient way than what the timing and delays on a signalized intersection would provide. The final control strategy MassDOT considers are ones that do not fall within these previous 11 and no alternatives were constructed that could not be reasonably associated with one of the pre-established ones.

### 4.3.2 - ICE Stage 2

Roundabout and signalized control were the control strategies that were finalized in ICE Stage 1, and these strategies were further analyzed in ICE Stage 2.

#### 4.3.2a - Empirical Analysis of Alternatives

The team created three alternatives based on the control strategies that were advanced to Stage 2. Alternative 1 proposes a signalized control intersection where Pleasant Street and the rotary intersect. It also proposes a stop control for traffic exiting Airport Drive onto the Rotary as seen in Figure 19.

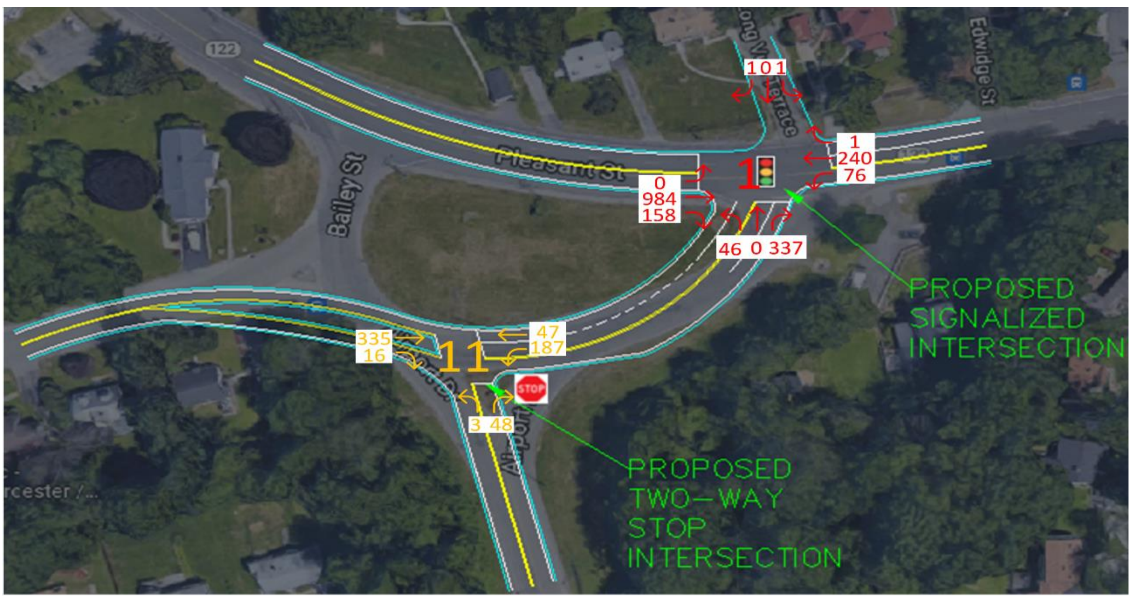



Figure 19: Alternative 1

The signal delay and LOS values were acquired for intersections “1” and “11” in Alternative 1 from Appendix E and are presented in Table 8.

Table 8: Alternative 1 LOS and Delay

| Alternative 1 | | | |
|---|---|---|---|
| | 1 | | 11 |
| | Signal Delay (sec/veh) | LOS | ICU LOS |
| AM 2022 | 19.5 | B | A (42.3%) |
| AM 2042 | 10.4 | B | A (37.3%) |
| PM 2022 | 9.8 | A | A (33.7%) |
| PM 2042 | 10.4 | B | A (37.3%) |

Alternative 2 is a 4-leg signalized control intersection. Alternative 2 includes a dedicated thru lane for northbound traffic on Pleasant Street. Bailey Street has a left turn lane to northbound Pleasant Street and a straight and right turn lane. The LOS for Alternative 2 is in Table 9.

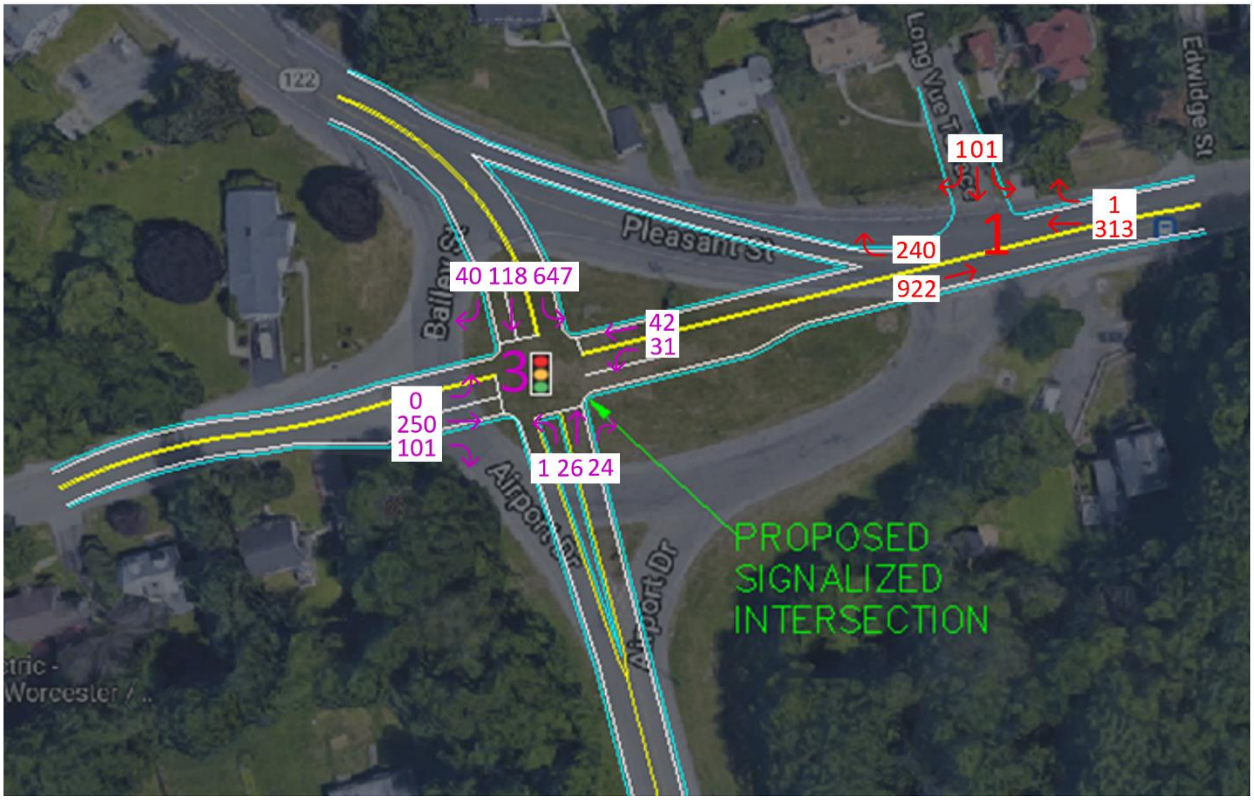



Figure 20: Alternative 2

The signal delay and LOS values were acquired for Alternative 2 from Appendix G and are presented in Table 9.

Table 9: Alternative 2 LOS and Delay

| Alternative 2 | | |
|---|---|---|
| | Signal Delay (sec/veh) | LOS |
| AM 2022 | 19.2 | B |
| AM 2042 | 26.9 | C |
| PM 2022 | 11.9 | B |
| PM 2042 | 13.0 | B |

Alternative 3 is a single-lane roundabout as presented in Figure 21. The roundabout utilized an Inscribed Circle Diameter (ICD) of 152 feet and an interior diameter of 120 feet. Using the traffic counts collected in 4.2.1, all the required data was received from the Sidra program when the roundabout alternative was constructed. This roundabout alternative had six different files produced, all representing different times the intersection would be used. These included versions in 2022, the opening year of the intersection positioned to be in 2026, and the design year in 2042 all with two files - one with the peak AM volumes and one with the peak PM volumes. These volumes were calculated using a predicted growth factor provided to the team through the Central Massachusetts Regional Planning Commission mentioned in Section 4.2.1.

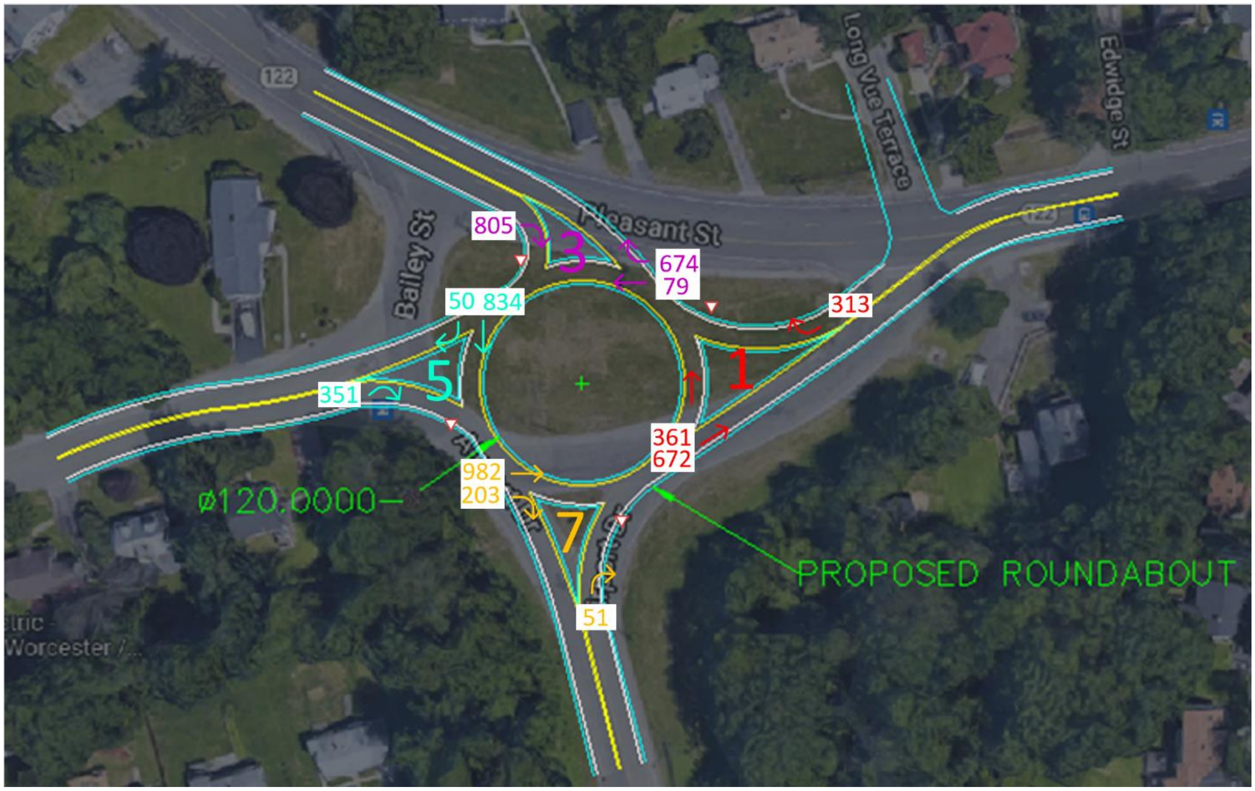



Figure 21: Alternative 3 roundabout design

Important data that was collected from the reports constructed by Sidra included the level of service, volume/capacity ratio, and average delay for each approach and an average for the intersection as a whole. The AM/PM peak hours volumes are included in Appendix H for this alternative. The signal delay and LOS were found for Alternative 3 and presented in Table 10.

The volume/capacity ratio for this alternative was better during the afternoon hours and all versions of the alternative had under a 1.0 volume/capacity ratio, indicating that the intersection could adequately support the amount of traffic that is predicted to move through the roundabout. The ratio increased during the later design years and reached a peak of 0.933 and 0.723 in 2024 AM and PM respectively. This alternative was predicted to work well enough that a two-lane roundabout design was deemed not necessary and would be more confusing for motorists to navigate, less safe for pedestrians and cyclists to cross through, and too expensive to make for the unneeded gain in reducing delay.

Table 10: Alternative 3 LOS and Delay

| Alternative 3 | | | |
|---|---|---|---|
| | Average Delay (sec/veh) | LOS | Volume/Capacity |
| AM 2022 | 14.1 | B | 0.710 |
| AM 2042 | 24.2 | C | 0.933 |
| PM 2022 | 9.0 | A | 0.624 |
| PM 2042 | 11.1 | B | 0.723 |

A summary of the delay information for each alternative sketch is presented in Table 11. The delay values below were used as the major empirical inputs for the alternatives in the ICE Tool.

Table 11: Delay information for alternative sketches

| Delay | | 2022 | | 2042 | |
|---|---|---|---|---|---|
| | Units | AM peak | PM peak | AM peak | PM peak |
| Alternative 1 | sec/veh | 19.5 | 9.8 | 30.0 | 10.4 |
| Alternative 2 | sec/veh | 19.2 | 11.9 | 26.9 | 13.0 |
| Alternative 3 | sec/veh | 14.1 | 9.0 | 24.2 | 11.1 |

**4.3.2b - Safety Analysis using MassDOT's Safety Alternatives Analysis Guide Spreadsheet Tool for Alternatives**

For the safety analysis needed for the alternatives, the values of $N_{estimated.design.nobuild}$ from Table 6 were utilized. From the Massachusetts State-Preferred CMF List, it was found that the CMFs for a Signalized Intersection Improvement was 1 for SV FI, 0.46 for MV FI, 1 for SV ALL, and 0.57 for MV ALL crashes. These CMF values were applied to the "Estimated Crashes During the Design Year using Method 3" column in Table 12, to estimate the $N_{estimated.design.alternative}$ for Alternatives 1 and 2. Table 12 below presents the Safety Analysis for the design year for a Signalized Intersection Improvement. The two $N_{estimated.design.alternative}$ values highlighted in red were used as the major safety inputs for the Traffic Signal alternative in the ICE Tool.

Table 12: Safety Analysis for the Design Year using Method 3 of the MassDOT Safety Alternatives Analysis Guide for a Signalized Intersection Improvement

| Alternatives 1 & 2 | | | | |
|---|---|---|---|---|
| Countermeasure 1 | Signalized Intersection | | | |
| Crash Type, Severity | Estimated Crashes During the Design Year using Method 3, No-Build | CMF 1 | Estimated Crashes During the Design Year using for Alternatives 1 and 2 | Reduced Crashes for Alternatives 1 and 2 |
| MV, ALL | 0.85 | 0.57 | 0.49 | 0.37 |
| MV, FI | 0.21 | 0.46 | 0.10 | 0.12 |
| MV, PDO | 0.64 | | 0.39 | 0.25 |
| SV, ALL | 0.64 | 1 | 0.64 | 0.00 |
| SV, FI | 0.21 | 1 | 0.21 | 0.00 |
| SV, PDO | 0.43 | | 0.43 | 0.00 |
| Total (FI) | 0.43 | | 0.31 | |
| Total (PDO) | 1.07 | | 0.82 | |
| Total (ALL) | 1.49 | | 1.13 | |

The CMFs for a Roundabout Improvement were 1 for SV FI, 0.16 for MV FI, 1 for SV ALL, and 0.48 for MV ALL crashes. Table 13 below presents the Safety Analysis for the design year for a Roundabout Improvement. The two $N_{estimated.design.alternative}$ values highlighted in red were used as the major safety inputs for the Roundabout alternative in the ICE Tool.

Table 13: Safety Analysis for the Design Year using Method 3 of the MassDOT Safety Alternatives Analysis Guide for a Roundabout Improvement

| Alternative 3 | | | | |
|---|---|---|---|---|
| Countermeasure 1 | Roundabout | | | |
| Crash Type, Severity | Estimated Crashes During the Design Year using Method 3, No-Build | CMF 1 | Estimated Crashes During the Design Year using for Alternative 3 | Reduced Crashes for Alternative 3 |
| MV, ALL | 0.85 | 0.48 | 0.41 | 0.44 |
| MV, FI | 0.21 | 0.16 | 0.03 | 0.18 |
| MV, PDO | 0.64 | | 0.38 | 0.26 |
| SV, ALL | 0.64 | 1 | 0.64 | 0.00 |
| SV, FI | 0.21 | 1 | 0.21 | 0.00 |
| SV, PDO | 0.43 | | 0.43 | 0.00 |
| Total (FI) | 0.43 | | 0.25 | |
| Total (PDO) | 1.07 | | 0.80 | |
| Total (ALL) | 1.49 | | 1.05 | |

**4.3.2c - Cost Estimates**

Table 14: Cost Estimate for each Alternative Design

| Cost Estimate | | | |
|---|---|---|---|
| Control Strategy | Total Construction | Total Design | Total Project Cost |
| Alternative 1 | $1,262,514 | $126,251 | $1,388,765 |
| Alternative 2 | $1,206,467 | $120,646 | $1,327,113 |
| Alternative 3 | $1,137,453 | $113,745 | $1,251,198 |

The total construction and design cost estimates can be found in Table 14 above. The most expensive design option is Alternative 1 while Alternative 3 is the most inexpensive option. Alternative 3 did not include any traffic signal items, so the cost is lower because of this. Alternative 2 is a slightly less costly option than Alternative 1 because the milling and paving quantity is a smaller amount. The total design costs were calculated to be 10% of the total construction costs. The ROW cost for each alternative is zero because there will be no anticipated change to the bounds of the project. It should be noted that this estimate does not include inflation to a future construction year. The preliminary estimate is included in Appendix I.

### 4.3.2d - ICE Tool and ICE Form

The required delay, cost, and safety values were input into the ICE tool, with the resulting data represented in the "Outputs" tab. Table 15 and Figure 22 present the NPV of Total Costs calculated by the ICE tool.

Table 15: Table with the NPV of Total Costs for the three alternatives

| Cost Categories | Net Present Value of Costs | | |
|---|---|---|---|
| | Traffic Signal Alt 1 | Traffic Signal Alt 2 | Roundabout |
| Planning, Construction & Right of Way Costs | $ 1,388,765 | $ 1,327,113 | $ 1,251,199 |
| Post-Opening Costs | $ 164,060 | $ 164,060 | $ 75,213 |
| Auto Passenger Delay | $ 3,916,552 | $ 4,628,007 | $ 3,594,960 |
| Truck Delay | $ 425,387 | $ 502,660 | $ 390,458 |
| Safety | $ 156,034 | $ 156,034 | $ 131,120 |
| **Total cost** | **$6,050,798** | **$6,777,874** | **$5,442,950** |

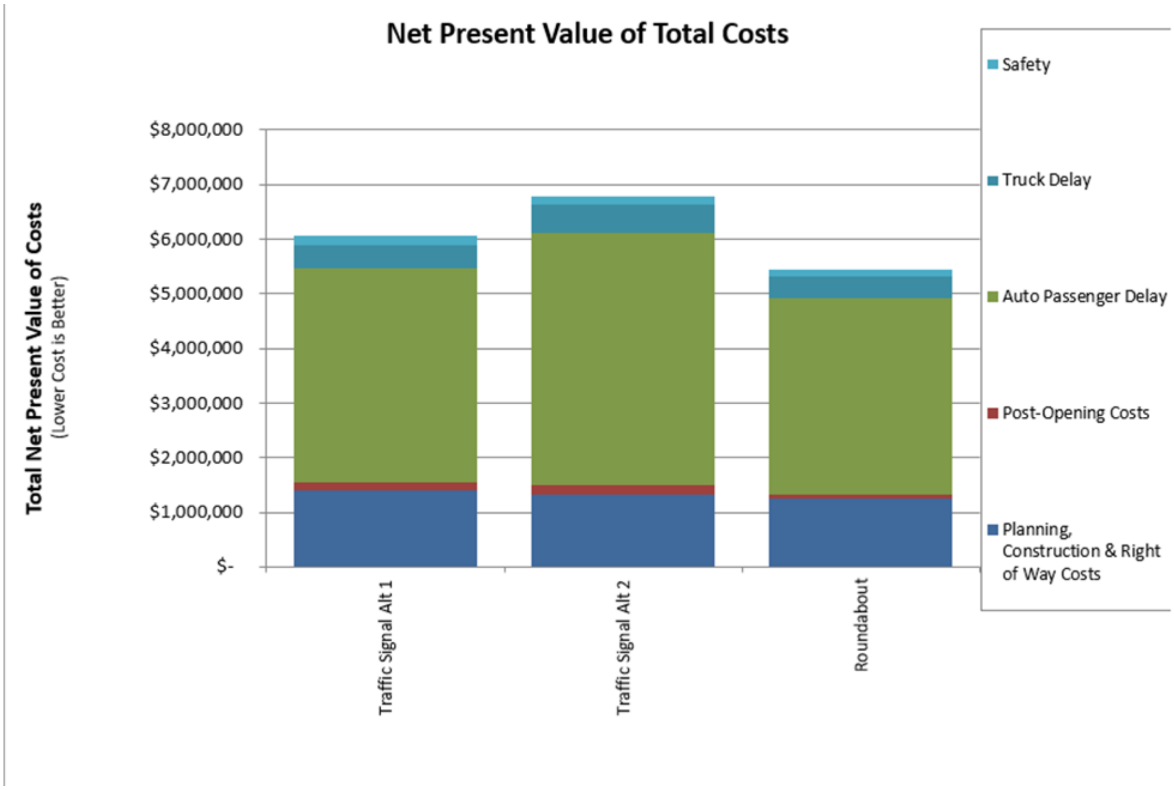



Figure 22: Graph with the NPV of Total Costs for the three alternatives

The benefit-cost comparison conducted by the tool required a base case for comparison. The base case was required to not be the existing condition; thus "Traffic Signal Alt 2" (Alternative 2) was used as the base case since it represented the highest NPV. Alternatives with lower NPV's were preferred, so the using Alternative 2 as the base condition allowed the alternatives with lower NPV's to be compared. Table 16 presents the benefit-cost comparison for the three alternatives with Alternative 2 being the base case.

Table 16: Benefit-cost comparison for the three alternatives

| Select Base Case for Benefit-Cost Comparison: (Choose from list) | | | |
|---|---|---|---|
| **Traffic Signal Alt 2** | **Net Present Value of Benefits Relative to Base Case** | | |
| | **Traffic Signal Alt 1** | **Traffic Signal Alt 2** | **Roundabout** |
| Auto Passenger Delay | $ 711,456 | | $ 1,033,047 |
| Truck Delay | $ 77,273 | | $ 112,202 |
| Safety | $ - | | $ 24,914 |
| **Net Present Value of Benefits** | **$ 788,729** | | **$ 1,170,163** |
| **Net Present Value of Costs** | **$ 61,652** | | **$ (164,761)** |
| **Net Present Value of Improvement** | **$ 727,077** | | **$ 1,334,924** |
| **Benefit-Cost (B/C) Ratio** | **12.79** | | **preferred. Benefits are greater than base case and cost is less than** |
| **Delay B/C** | **12.79** | | **preferred. Benefits are greater than base case and cost is less than** |
| **Safety B/C** | **0.00** | | **preferred. Benefits are greater than base case and cost is less than** |

### 4.4 - Select a Final Alternative as the Optimal Redesign Solution

Based on the benefit-cost comparison done with the ICE tool, one of the alternatives can be finalized. The benefit-cost comparison provided B/C ratios for "Traffic Signal Alt 1" (Alternative 1). For the "Roundabout" (Alternative 3), the analysis provided the following text output; "Control strategy preferred. Benefits are greater than base case and cost is less than base case". Alternative 3 did not yield a B/C ratio since the associated calculations involved dividing a positive (+) net present value (NPV) benefit by a negative (-) NPV cost. NPV is predominately used in economics to predict the future value of a business or company with all of the present cash flows. For this cost analysis, NPV is being used to predict the value of an alternative using benefits as a positive "revenue" and other costs and improvements that do not directly result in a benefit as "investments". There are essentially no NPV costs associated with Alternative 3 while there are NPV costs associated with Alternative 1, indicating that Alternative 3 is more cost effective and still retains positive benefits. Roundabouts are excellent for safety, pedestrian access, and traffic throughput as established in Section 4.1. Therefore, the Alternative 3 Roundabout was recommended by the team to be the optimal redesign solution for Worcester Airport Rotary intersection.

**5.0 - Conclusion and Recommendations**

In conclusion, the team gained an understanding of the best practices regarding intersection design, analyzed existing data provided by MassDOT, collected necessary data, and analyzed multiple potential options using the ICE process. Based on the analysis, the final design recommended by the team to MassDOT was the Alternative 3 Roundabout. Although this design has been recommended by the team, there are a few associated limitations which must be addressed. It is worth noting that the team only completed the ICE process up to Stage 2, meaning there is ample opportunity for MassDOT to conduct further analysis of the alternatives using Stage 3 of the ICE process. Further analysis is certainly recommended by the team, as the cost values used in Stage 2 are only rough estimates. It is more than likely that more detailed analysis will modify the costs of certain alternatives, and this may prompt the reevaluation of which control strategy is preferred.

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**Appendix A: Project Proposal**

# Route 122 - Airport Rotary Intersection Redesign in Worcester

*A Major Qualifying Project Proposal Submitted to the Faculty of Worcester Polytechnic Institute in Partial Fulfillment of the requirements for the Bachelor of Science Degree*


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10/23/2022

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| Project Design Statement | Theron Howe | Mitchell Decelles |
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| 3. Methodology | Ritesh Prasannakumar | All Team Members |
| 3.1 Objective 1 | Ritesh Prasannakumar | All Team Members |
| 3.2 Objective 2 | Ritesh Prasannakumar | Azat Mukhametkulov |
| 3.3 Objective 3 | Azat Mukhametkulov | Ritesh Prasannakumar |
| 3.4 Objective 4 | Mitchell Decelles | Theron Howe |
| 3.5 Objective 5 | Mitchell Decelles | Theron Howe |
| Team Gantt Chart | Theron Howe | All Team Members |
| 4. Conclusion | Mitchell Decelles | All Team Members |

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## Contents

**Capstone Design Statement**

This project will involve analyzing the existing corridor of Route 122/Pleasant Street and examining its intersection with Bailey Street and Airport Drive. Worcester Polytechnic Institute, for all of its Major Qualifying Projects, requires that said projects fulfill all of the Accreditation Board for Engineering and Technology (ABET) capstone design elements. For this project, the elements recommended by ABET will be taken into account in order to fulfill the Capstone Design requirement. These aspects that will be addressed in this project include the following:

*Constructability*: The team will look at previous and possible designs for the Route 122 - Airport Drive intersections and corridor redesigns and aim to select the best one with consideration to constructability such as cost, maintenance, time to complete, and compatibility with existing utilities.

*Economic*: For this project, preliminary construction cost analysis will be conducted in order to gauge the economic feasibility of the redesign. Cost effectiveness will assist in the decision making process for which redesigns make the most efficient improvements for the evaluated cost. The relative cost of production compared to the benefits added will be fundamental in selecting a final design as overly expensive projects with little added benefit will not be deemed as suitable as a less expensive one with similar benefits.

*Environmental*: Any changes or improvements that will be made through the intersection and corridor will be designed with preserving and maintaining the local environment with special consideration given to the local forest and water streams that run throughout and around Route 122.

*Ethical*: The design project and design project team will work to not diminish the reputation of WPI and the Massachusetts Department of Transportation and all decision-making and project elements will be made in compliance with three ASCE Code of Ethics.

*Health and Safety*: The design projects and overall improvements made to Route 122 and the Airport Drive intersection will be made to value the overall safety and well-being of all who use the road. An easier to navigate intersection and improvements made to the usability of the route for non-motorists will be made with a goal to reduce the amount and severity of crashes on the roadway.

*Political*: The team will collaborate with MassDOT and, through them, local residents, commuters, and the City of Worcester to present design improvements that will work to better the state highway and the city as a whole. The needs of each of these stakeholders will be highly considered when identifying a final redesign.

*Social*: This project has a primary concern to improve the safety and usability of Route 122 for regional commuters, local residents, and any others who would travel along this stretch of the state highway. Their concerns, through previously held MassDOT town meetings, will be factored into the final design decision and the suggested improvements will prioritize benefiting the residents.

*Sustainability*: The team will work to identify a redesign that prioritizes present and future needs with consideration to expected growth in the area that will affect the intersection and corridor. Long-lasting sustainability in the area is a goal that will be prioritized through redesigns that consider the area's future.

## Introduction

As the second largest city in the New England area, Worcester has a large number of commuters coming into the city due to its size and location. Its roadways, throughout the city, should allow for a balance of use and accessibility for all users, whether they are motorists, pedestrians, or cyclists. A major throughput lane for Worcester is Route 122, also known as Pleasant Street for the part of Worcester that is being examined in this project. The part of this state highway that is subject to possible improvements and redesigns is the intersection of Route 122 and Airport Drive near the Paxton town line that connects the suburban town to the Worcester Regional Airport and the more urban environments of the city.

This intersection and the corridor on which it is located has been identified by local residents, motorists, commuters, and the Massachusetts Department of Transportation (MassDOT) as a location needing improvement due to being relatively unsafe for pedestrians and cyclists as well as having a confusing intersection off of a state highway that could be upgraded for throughput to be more efficient and safe. Currently, the corridor provides little safety to pedestrians despite having a sizable housing community along the highway and nearby side streets. The road is designed for much higher speeds than the posted speed limit of 30 mph would indicate. The intersection that leads to the airport and the Webster Square area is a popular cut-through, yet the intersection gives full right-of-way to Pleasant Street while using a semi-roundabout design for the rest of the intersection that has much room for improvement in safety, traffic capacity, and ease of use and understanding.

MassDOT has already commenced with a redesign project concerning this intersection and corridor and, throughout this MQP project proposal, recommendations will be made on which redesigns are the most effective.

## Background

A major throughput lane going through Worcester is the state highway, Route 122, starting in Blackstone, MA until it ends in Orange, MA. In Worcester specifically, the route cuts through the city from Grafton in the south to Paxton in the north (Figure 1).

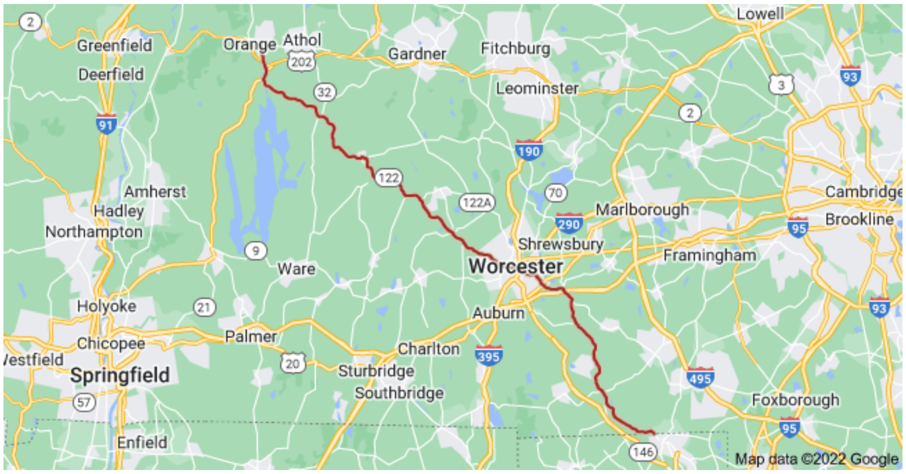



Figure 1: Map detailing the bounds of Route 122 throughout Massachusetts (Google Maps, 2022).

The location examined for the project is the state-owned section from Tatnuck Square to the Paxton Town line. The intersection located between Bailey Street, Airport Drive, and Pleasant Street (Route 122) has been identified as a problematic area that needs some level of redesign. Specifically, there are a number of issues known to the city government, locals, and the state transportation department including high traffic speeds based on the design of the road, a lack of pedestrian safety with few total crosswalks along the route and no sidewalks on the northbound side of the road, and an intersection that does not have the design capabilities to support a safe and constant flow of traffic.


Figure 2: Map detailing the stretch of Route 122 in Worcester that this project is examining (Google Maps, 2022).

The intersection itself is the focus of a redesign project initiated by MassDOT in 2019, first focusing on pedestrian safety on the state highway before transitioning to examining the rotary. Throughout a standard weekday, the intersection can reach an Average Daily Traffic (ADT) of 14,864 and 15,770 vehicles at its busiest locations (points C and F in Figure 3), with peak hours being from 7:15 - 8:15 AM in the morning, 1:45 - 2:45 PM in the midday, and 4:45 - 5:45 PM in the evening (*Worcester (TMCs & ATRs) Memo)*. Site visits to the area reveal what has been mentioned from locals and transportation officials where the area around the intersection is generally unsafe with only two painted crosswalks along Pleasant Street; the only way to cross Pleasant Street is near Mower Street or down by Baxter Street. High speeds through the rotary and a lack of adequate safety for pedestrians is of primary concern. Turning movement counts conducted by MassDOT indicate high levels of usage through the intersection. A redesign of this rotary into a safer alternative for pedestrians and one that is easier to drive through and understand for motorists is a primary goal.

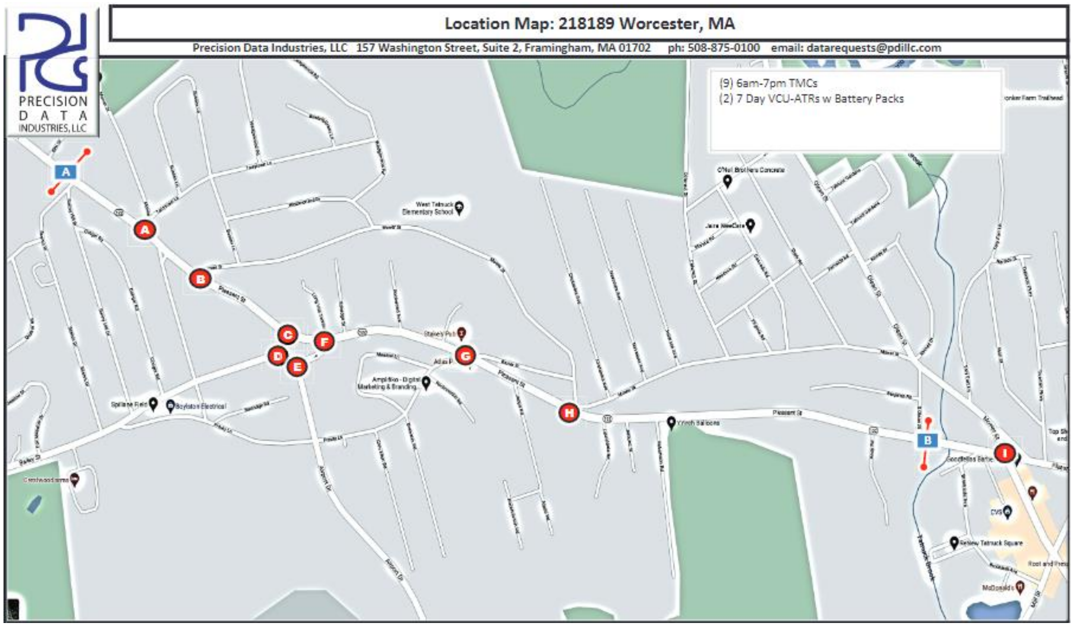



Figure 3: Locations along Pleasant Street in Worcester where turning movement counts were conducted (*Worcester (TMCs & ATRs) Memo).*

MassDOT has already identified this intersection as in need of a redesign. In order to produce a coherent design, MassDOT has a consistent and objective procedure based on certain performance criteria to compare several intersection control strategies, called Intersection Control Evaluation (ICE). With this evaluation procedure in mind, both current and future alternatives can be critically examined to see if they are the best fit for this intersection. As this project is located on a State Highway, an ICE is required for the final product, but it can still be applied to any number of possible submittals. An ICE consists of 3 primary stages involving a screening, initial assessment, and a detailed assessment stage. The intricacy and number of control strategies and variables that are considered expand throughout the stages. Any fatally flawed alternative is identified in stage 1 and removed. In order to move forward with a redesign past stage 1, a Project Initiation Form is submitted to MassDOT that requires the department's approval. This form consists of the project's location, purpose and description, costs and responsibilities, and general information. If no single control strategy emerges from stage 1, a stage 2 assessment would be submitted afterwards with the pre-25% design package. If no single control strategy emerges from stage 2, a stage 3 assessment would be completed prior to the 25% design submission. The amount of data and analysis done in each stage allows the design to be as comprehensive as possible, incorporating crash predictions, planning level opinions of probable design, right-of-way, construction costs, traffic operation analyses, and geometric designs, all of which are done throughout the process, especially in stages 2 and 3, to evaluate the intersection as thoroughly as possible.

## Methodology

The goal for this MQP is to create a new design of the intersection of Route 122, Airport Drive, and Bailey Street that will be safer and better utilized by the community.

### Objective 1: Understanding best practices regarding intersection design

The team will gain an understanding of best practices regarding intersection design. The potential different designs of intersections will be studied, including the general benefits associated with roundabouts and signalized intersections. Studying the general benefits will help the team better understand complex intersections that make use of roundabouts and signals. In order to design these complex intersections, the team will familiarize themselves with the Intersection Control Evaluation (ICE) method employed by MassDOT. ICE is a three-stage approach to develop traffic control alternatives for intersections (MassDOT 2021). The team will familiarize itself with this process by inputting data from a sample project and taking it through the three steps of ICE. Two sample projects that will be used in order to develop include the Lynnfield Street (Route 129) Roadway Reconstruction Project and Corridor Improvements on Centre Street/ Brockton Avenue (Route 123), Brockton and Abington, MA Project. Once these sample projects have been taken through the process, the results will be compared with the actual work done by MassDOT to ensure that the ICE procedure is being accurately followed. Practice with the ICE Method will help the team in analyzing the proposed configurations that MassDOT has come up with for the Airport Rotary.

### Objective 2: Analyze existing data provided by MassDOT

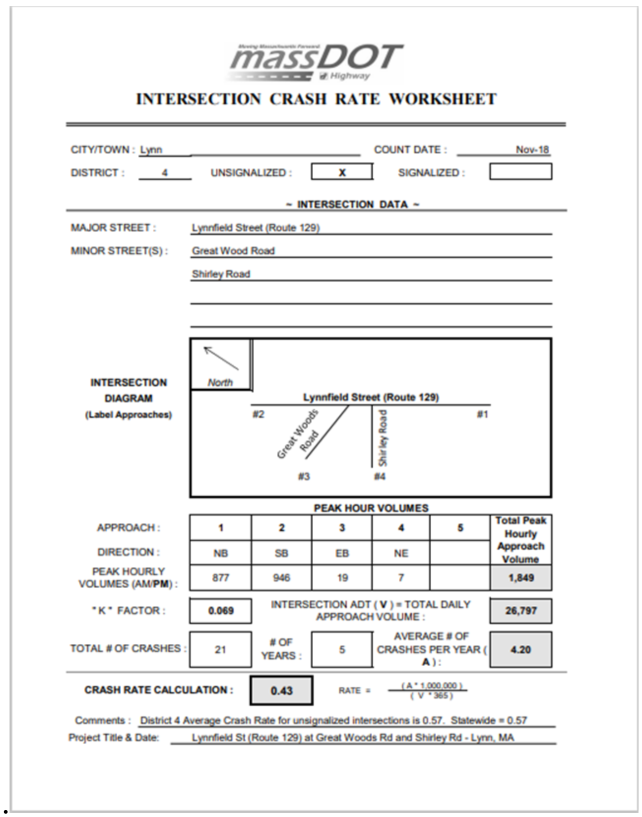
Once the team has familiarized itself with the best practices regarding intersection design, the existing data provided by MassDOT will be analyzed. This data will be closely looked at to ensure that any information utilized is not outdated. If information is found to be outdated, the group will rectify the situation by either consulting a different source or collecting the data themselves. Missing information not provided elsewhere in the existing data will also need to be collected by the group. The team will specifically analyze existing Synchro files while also taking a look at the listening sessions and meetings providing direct feedback from the community. The team will try to derive accurate values for Peak Hour Volumes, Turning Movement Counts, Annual Average Daily Traffic (AADT), and Average Daily Traffic (ADT) from the given data. The frequency of certain types of crashes and the crash rates can also be derived from the existing data, with these values being a major input in the ICE process.

**Objective 3: Collecting necessary data**

Based on the analysis of traffic counts and crash data documents from MassDOT, the team will collect and analyze additional data as necessary from the airport rotary. The team will conduct traffic counts as a collective group in October 2022. With the help from WPI and MassDOT, the group will attach the Owl Camera at the airport rotary. In conjunction with the TDC Ultra traffic data collection tool, the team will use the video recordings from the Owl Camera to derive comprehensive data that will include AADT (Averaged Annualized Daily Traffic) data from each leg of the intersection considering time and day of the week. The video system will allow the group to collect 24-hour counts for one week. The group will then be able to derive peak hours from those recordings. This data will indicate the flow of the traffic and provide the group with potential problematic issues that may occur through visual observations.

After the data collection, the group will determine the measures of effectiveness of the airport intersection. Software tools that will be provided by MassDOT and WPI include Synchro and Sidra softwares. They will be used to determine intersection and network capacity. Software analysis will incorporate specifics about the number of lanes, percent of heavy vehicles, controls, and approach grades.

Existing crash data at Route 122 will be collected by using the MassDOT Online Crash Data Portal. The number and types of crashes will be analyzed from 2017 - 2021. Once the total number of crashes and other variables are determined, the MassDOT Intersection Crash Rate Worksheet will be used to calculate the crash rate. The crash rate will be used to determine if the average rate of crashes exceeds the "average" for the District and the State for unsignalized intersections. The team will then create crash diagrams to further identify the issues and trends that contribute to the crashes by organizing the crash data by type and specific location in the intersection.


INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Lynn COUNT DATE : Nov-18

DISTRICT : 4 UNSIGNALIZED : X SIGNALIZED :

~ INTERSECTION DATA ~

MAJOR STREET : Lynnfield Street (Route 129)

MINOR STREET(S) : Great Wood Road

Shirley Road

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

| | | | | | | |
|---|---|---|---|---|---|---|
| APPROACH : | 1 | 2 | 3 | 4 | 5 | Total Peak Hourly Approach Volume |
| DIRECTION : | NB | SB | EB | NE | | |
| PEAK HOURLY VOLUMES (AM/**PM**) : | 877 | 946 | 19 | 7 | | 1,849 |

"K" FACTOR : 0.069 INTERSECTION ADT ( **V** ) = TOTAL DAILY APPROACH VOLUME : 26,797

TOTAL # OF CRASHES : 21 # OF YEARS : 5 AVERAGE # OF CRASHES PER YEAR ( **A** ) : 4.20

**CRASH RATE CALCULATION :** 0.43 RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : District 4 Average Crash Rate for unsignalized intersections is 0.57. Statewide = 0.57

Project Title & Date: Lynnfield St (Route 129) at Great Woods Rd and Shirley Rd - Lynn, MA

Figure 4: MassDOT Intersection Crash Rate Worksheet for the Lynnfield Street (Route 129) Roadway Reconstruction Project used as sample (MassDOT, 2021).

## Objective 4: Formulating multiple potential options using ICE.

The team will use ICE procedure as seen below in the flowchart (Figure 5).

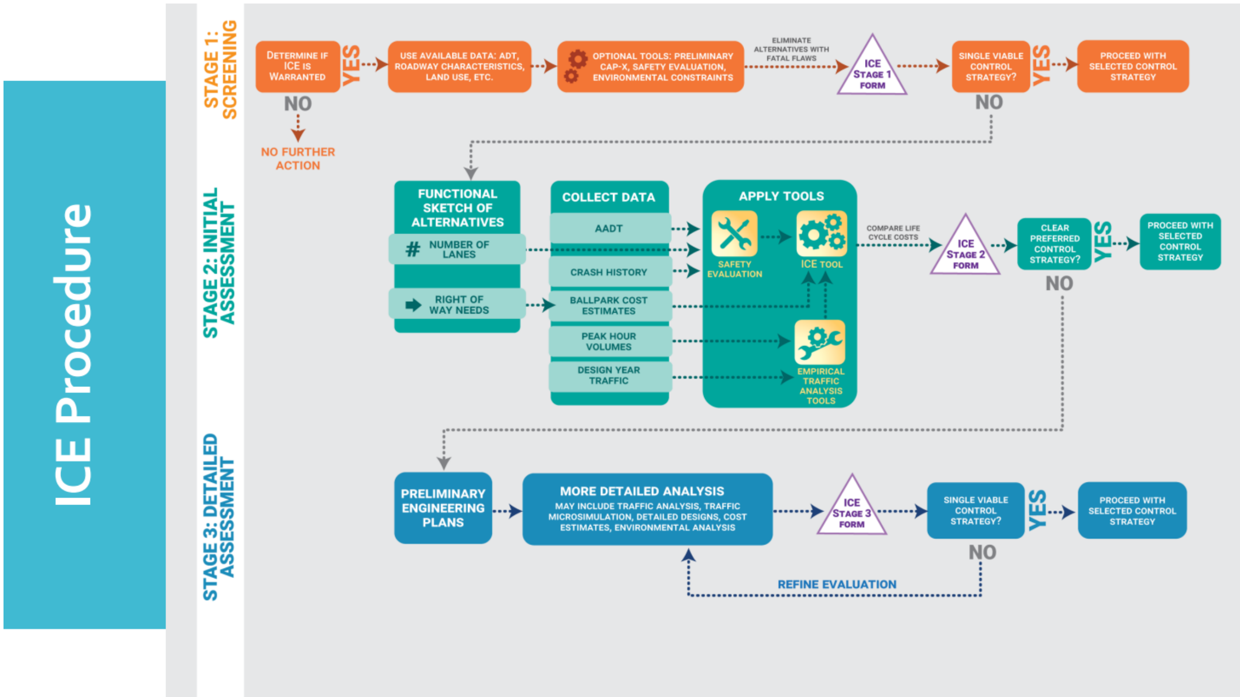



Figure 5: Flowchart of ICE Procedure (Kristiansen, n.d.)

The team will start ICE procedure at stage 1, which is a high-level screening analysis that uses the ICE form to document the viability of 12 control strategies (Figure 6).

Select intersection types from the following table to include in the ICE analysis. To include an intersection, select "Yes" in the include column, and to exclude an intersection, select "No" in the include column.

At-Grade Control Strategies

| Control # | Include | Short Name | Description | Notes |
|---|---|---|---|---|
| 1 | Yes | TWSC | Two-Way Stop Control | |
| 2 | Yes | AllStop | All Way Stop | |
| 3 | Yes | TrafficSignal | Traffic Signal | |
| 4 | Yes | TrafficSignalAlt | Traffic Signal (Alt.) | |
| 5 | Yes | Roundabout | Roundabout | |
| 6 | Yes | DLT | Displaced Left Turn (DLT) | |
| 7 | No | MUT | Median U-Turn (MUT) | |
| 8 | No | SignalRCUT | Signalized Restricted Crossing U-Turn (RCUT) | |
| 9 | No | UnsignalRCUT | Unsignalized Restricted Crossing U-Turn (RCUT) | |
| 10 | No | GreenT | Continuous Green-T Intersection | |
| 11 | No | Jughandle | Jughandle | |
| 12 | No | Quadrant Itx | Quadrant Roadway Intersection | Note that no safety information is available |
| 13 | No | Other1 | Other 1 | Safety information must be provided |
| 14 | No | Other2 | Other 2 | Safety information must be provided |

Figure 6: 12 control strategies evaluated in ICE tool (MassDOT, 2021)

The team will then consider 12 control strategies that MassDOT has preselected based on previous research that was conducted on increasing the safety and mobility of intersections

(FHWA, 2009). A rapid comparative analysis for all control strategies that are proposed will be completed and a single alternative may be selected at this stage. The comparative analysis will include a safety analysis using the MassDOT Safety Alternatives Guide. This procedure should take around 8 hours according to MassDOT. The team will first complete stage 1 of the analysis where the team will complete and submit the document to employees at MassDOT for review.

If a control strategy does not immediately emerge after stage 1 is completed then stage 2 will need to be conducted. Stage 2 includes a basic analysis of each viable control strategy from stage 1. The team will then use the ICE Tool to determine the lifecycle cost and a benefit-cost ratio for each control strategy. The ICE will require three inputs: empirical traffic analysis, safety analysis, and design and construction cost estimates. The empirical analysis will include data collected in objective 2, like turning movement counts and lane configurations. The team will then enter the data into Synchro to determine intersection delay. The intersection delay for the AM and PM peak hours for the opening and design year will be entered into the ICE tool. For the safety analysis, the team will use MassDOT Safety Alternatives Analysis Guide to predict the total and fatal injury crashes for each control strategy. The team will then enter the number of crashes into the ICE tool. A cost analysis will be performed and the parameters to be considered include the redesign, construction, right-of-way, and maintenance costs for each control strategy. The design, construction, and maintenance cost will be plugged into the ICE tool.

The team will document additional information on the intersection and record the multi-modal accommodations, the right-of-way, utility, and environmental impacts, and any public feedback of each control strategy. The ICE tool will then calculate the life cycle for each control strategy. Based on the lifecycle cost, the team will decide on one preferred control strategy. The results from the analyses will be documented in the ICE form, if there are still more than one control strategy the team will move on to step 3. If there is only one control strategy at this stage then the team will not continue with ICE and will submit this document along with the pre-25% design package to MassDOT traffic section.

If required, the team will move on to stage 3, which is a deeper analysis of each control strategy that emerges from stage 2. The traffic operations, project costs, safety, multi-modal accommodations, the right-of-way, utility, and environmental impacts, and public input are further refined. The team will document all findings in the ICE form.

**Objective 5: Selecting a final control strategy as the optimal redesign solution.**

The team will then select one control strategy as the final alternative design for the Worcester Airport Road intersection based on the ICE procedure. The team will emphasize how this intersection is safer, more balanced, and a more cost-effective solution based on objective performance metrics.

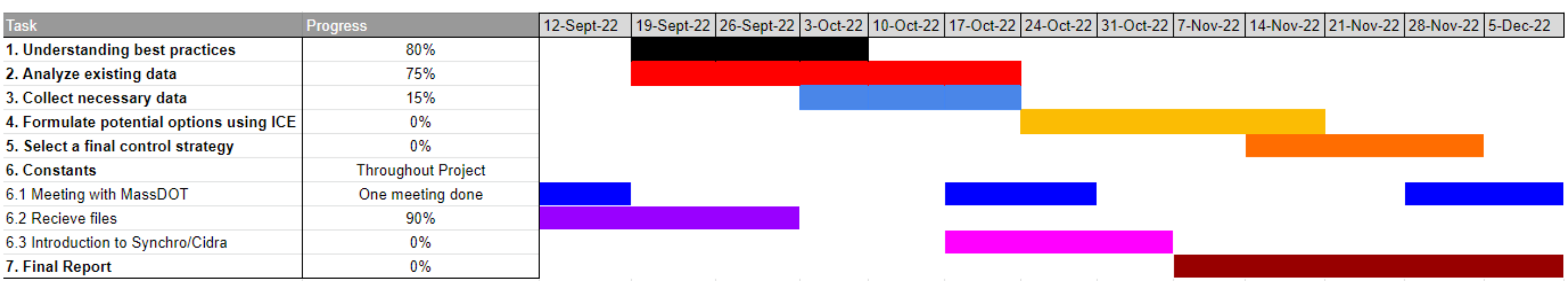



Figure 7: Team Gantt Chart used for scheduling tasks and objectives throughout the project.

In order to timely act upon each of these methods along with broader tasks including data collection and analysis and interaction and correspondence with MassDOT, the team will use the Gantt Chart (Figure 7) as a way to schedule work and progress. Each task is mapped on the Gantt

Chart and will accordingly be worked on within each designated period with some time allowed in case more is needed. Some tasks are consistent throughout the project and the dates are estimates of when the team anticipates work will be done. The schedule is flexible and allows for changes if events happen at a different pace than anticipated.

## Conclusion

In conclusion the team will gain an understanding of the best practices regarding intersection design, analyze existing data provided by MassDOT, collect necessary data, and formulate multiple potential options and then select one control strategy over the others for Worcester Route 122 Airport Intersection. The team will make a recommendation regarding a new design of the intersection and submit it to MassDOT.

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# Appendix B: Existing Conditions Analysis

Existing Conditions AM 2022

Lanes, Volumes, Timings
1: 11/22/2022

| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Traffic Volume (vph) | 0 | 647 | 0 | 0 | 313 | 1 | 49 | 0 | 337 | 1 | 0 | 1 |
| Future Volume (vph) | 0 | 647 | 0 | 0 | 313 | 1 | 49 | 0 | 337 | 1 | 0 | 1 |
| 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 | 0.95 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | | | | | | | 0.850 | | | 0.932 | |
| Flt Protected | | | | | | | 0.950 | | | | 0.976 | |
| Satd. Flow (prot) | 0 | 0 | 0 | 0 | 3539 | 0 | 1770 | 1583 | 0 | 0 | 1694 | 0 |
| Flt Permitted | | | | | | | 0.950 | | | | 0.976 | |
| Satd. Flow (perm) | 0 | 0 | 0 | 0 | 3539 | 0 | 1770 | 1583 | 0 | 0 | 1694 | 0 |
| Link Speed (mph) | | 30 | | | 30 | | | 30 | | | 30 | |
| Link Distance (ft) | | 318 | | | 307 | | | 288 | | | 180 | |
| Travel Time (s) | | 7.2 | | | 7.0 | | | 6.5 | | | 4.1 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 0 | 703 | 0 | 0 | 340 | 1 | 53 | 0 | 366 | 1 | 0 | 1 |
| Shared Lane Traffic (%) | | | | | | | | | | | | |
| Lane Group Flow (vph) | 0 | 703 | 0 | 0 | 341 | 0 | 53 | 366 | 0 | 0 | 2 | 0 |
| 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) | | 0 | | | 0 | | | 12 | | | 12 | |
| 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 |
| Sign Control | | Free | | | Free | | | Stop | | | Stop | |

Intersection Summary

Area Type: Other

Control Type: Unsignalized

Intersection Capacity Utilization Err% ICU Level of Service H

Analysis Period (min) 15

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 647 | 158 | 79 | 240 | 0 | 0 |
| Future Volume (vph) | 647 | 158 | 79 | 240 | 0 | 0 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 0.95 | 0.95 | 1.00 | 1.00 |
| Frt | 0.973 | | | | | |
| Flt Protected | | | | 0.988 | | |
| Satd. Flow (prot) | 1812 | 0 | 0 | 3497 | 0 | 0 |
| Flt Permitted | | | | 0.988 | | |
| Satd. Flow (perm) | 1812 | 0 | 0 | 3497 | 0 | 0 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 301 | | | 318 | 98 | |
| Travel Time (s) | 6.8 | | | 7.2 | 2.2 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 703 | 172 | 86 | 261 | 0 | 0 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 875 | 0 | 0 | 347 | 0 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 0 | | | 0 | 0 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Free | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 59.2% | ICU Level of Service B |
| Analysis Period (min) 15 | |

| Lane Group | EBL | EBR | SBL | SBR | NWL | NWR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 0 | 351 | 187 | 50 | 0 | 0 |
| Future Volume (vph) | 0 | 351 | 187 | 50 | 0 | 0 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | 0.865 | 0.972 | | | |
| Flt Protected | | | 0.962 | | | |
| Satd. Flow (prot) | 0 | 1611 | 1742 | 0 | 0 | 0 |
| Flt Permitted | | | 0.962 | | | |
| Satd. Flow (perm) | 0 | 1611 | 1742 | 0 | 0 | 0 |
| Link Speed (mph) | 30 | | 30 | | 30 | |
| Link Distance (ft) | 270 | | 98 | | 162 | |
| Travel Time (s) | 6.1 | | 2.2 | | 3.7 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 0 | 382 | 203 | 54 | 0 | 0 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 0 | 382 | 257 | 0 | 0 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Right | Left | Right |
| Median Width(ft) | 0 | | 12 | | 0 | |
| Link Offset(ft) | 0 | | 0 | | 0 | |
| Crosswalk Width(ft) | 16 | | 16 | | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | 15 | 9 | 15 | 9 | 15 | 9 |
| Sign Control | Yield | | Free | | Stop | |

Intersection Summary

Area Type: Other

Control Type: Unsignalized

Intersection Capacity Utilization 25.1% ICU Level of Service A

Analysis Period (min) 15

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 335 | 203 | 0 | 0 | 0 | 51 |
| Future Volume (vph) | 335 | 203 | 0 | 0 | 0 | 51 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 0.95 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.943 | | | | | 0.865 |
| Flt Protected | | | | | | |
| Satd. Flow (prot) | 3337 | 0 | 0 | 0 | 0 | 1611 |
| Flt Permitted | | | | | | |
| Satd. Flow (perm) | 3337 | 0 | 0 | 0 | 0 | 1611 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 162 | | | 288 | 201 | |
| Travel Time (s) | 3.7 | | | 6.5 | 4.6 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 364 | 221 | 0 | 0 | 0 | 55 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 585 | 0 | 0 | 0 | 0 | 55 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 0 | | | 0 | 0 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Stop | Yield | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 25.8% | ICU Level of Service A |
| Analysis Period (min) 15 | |

Existing Conditions AM 2042



| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Traffic Volume (vph) | 0 | 647 | 0 | 0 | 313 | 1 | 49 | 0 | 337 | 1 | 0 | 1 |
| Future Volume (vph) | 0 | 647 | 0 | 0 | 313 | 1 | 49 | 0 | 337 | 1 | 0 | 1 |
| 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 | 0.95 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | | | | | | | 0.850 | | | 0.932 | |
| Flt Protected | | | | | | | 0.950 | | | | 0.976 | |
| Satd. Flow (prot) | 0 | 0 | 0 | 0 | 3539 | 0 | 1770 | 1583 | 0 | 0 | 1694 | 0 |
| Flt Permitted | | | | | | | 0.950 | | | | 0.976 | |
| Satd. Flow (perm) | 0 | 0 | 0 | 0 | 3539 | 0 | 1770 | 1583 | 0 | 0 | 1694 | 0 |
| Link Speed (mph) | | 30 | | | 30 | | | 30 | | | 30 | |
| Link Distance (ft) | | 318 | | | 307 | | | 288 | | | 180 | |
| Travel Time (s) | | 7.2 | | | 7.0 | | | 6.5 | | | 4.1 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 100% | 115% | 100% | 115% | 115% | 115% | 116% | 116% | 116% | 100% | 100% | 100% |
| Adj. Flow (vph) | 0 | 809 | 0 | 0 | 391 | 1 | 62 | 0 | 425 | 1 | 0 | 1 |
| Shared Lane Traffic (%) | | | | | | | | | | | | |
| Lane Group Flow (vph) | 0 | 809 | 0 | 0 | 392 | 0 | 62 | 425 | 0 | 0 | 2 | 0 |
| 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) | | 0 | | | 0 | | | 12 | | | 12 | |
| 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 |
| Sign Control | | Free | | | Free | | | Stop | | | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: | Other |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization Err% | ICU Level of Service H |
| Analysis Period (min) 15 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 647 | 158 | 79 | 240 | 0 | 0 |
| Future Volume (vph) | 647 | 158 | 79 | 240 | 0 | 0 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 0.95 | 0.95 | 1.00 | 1.00 |
| Frt | 0.973 | | | | | |
| Flt Protected | | | | 0.988 | | |
| Satd. Flow (prot) | 1812 | 0 | 0 | 3497 | 0 | 0 |
| Flt Permitted | | | | 0.988 | | |
| Satd. Flow (perm) | 1812 | 0 | 0 | 3497 | 0 | 0 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 301 | | | 318 | 98 | |
| Travel Time (s) | 6.8 | | | 7.2 | 2.2 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 115% | 115% | 115% | 115% | 100% | 100% |
| Adj. Flow (vph) | 809 | 198 | 99 | 300 | 0 | 0 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 1007 | 0 | 0 | 399 | 0 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 0 | | | 0 | 0 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Free | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 67.1% | ICU Level of Service C |
| Analysis Period (min) 15 | |

| Lane Group | EBL | EBR | SBL | SBR | NWL | NWR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 0 | 351 | 187 | 50 | 0 | 0 |
| Future Volume (vph) | 0 | 351 | 187 | 50 | 0 | 0 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | 0.865 | 0.972 | | | |
| Flt Protected | | | 0.962 | | | |
| Satd. Flow (prot) | 0 | 1611 | 1742 | 0 | 0 | 0 |
| Flt Permitted | | | 0.962 | | | |
| Satd. Flow (perm) | 0 | 1611 | 1742 | 0 | 0 | 0 |
| Link Speed (mph) | 30 | | 30 | | 30 | |
| Link Distance (ft) | 270 | | 98 | | 162 | |
| Travel Time (s) | 6.1 | | 2.2 | | 3.7 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 100% | 116% | 116% | 116% | 100% | 100% |
| Adj. Flow (vph) | 0 | 443 | 236 | 63 | 0 | 0 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 0 | 443 | 299 | 0 | 0 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Right | Left | Right |
| Median Width(ft) | 0 | | 12 | | 0 | |
| Link Offset(ft) | 0 | | 0 | | 0 | |
| Crosswalk Width(ft) | 16 | | 16 | | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | 15 | 9 | 15 | 9 | 15 | 9 |
| Sign Control | Yield | | Free | | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 28.5% | ICU Level of Service A |
| Analysis Period (min) 15 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 335 | 203 | 0 | 0 | 0 | 51 |
| Future Volume (vph) | 335 | 203 | 0 | 0 | 0 | 51 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 0.95 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.943 | | | | | 0.865 |
| Flt Protected | | | | | | |
| Satd. Flow (prot) | 3337 | 0 | 0 | 0 | 0 | 1611 |
| Flt Permitted | | | | | | |
| Satd. Flow (perm) | 3337 | 0 | 0 | 0 | 0 | 1611 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 162 | | | 288 | 201 | |
| Travel Time (s) | 3.7 | | | 6.5 | 4.6 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 116% | 116% | 100% | 100% | 100% | 116% |
| Adj. Flow (vph) | 422 | 256 | 0 | 0 | 0 | 64 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 678 | 0 | 0 | 0 | 0 | 64 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 0 | | | 0 | 0 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Stop | Yield | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 28.6% | ICU Level of Service A |
| Analysis Period (min) 15 | |

## Lanes, Volumes, Timings
1: 11/22/2022

| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Traffic Volume (vph) | 0 | 647 | 0 | 0 | 313 | 1 | 49 | 0 | 337 | 1 | 0 | 1 |
| Future Volume (vph) | 0 | 647 | 0 | 0 | 313 | 1 | 49 | 0 | 337 | 1 | 0 | 1 |
| 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 | 0.95 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | | | | | | | 0.850 | | | 0.932 | |
| Flt Protected | | | | | | | 0.950 | | | | 0.976 | |
| Satd. Flow (prot) | 0 | 0 | 0 | 0 | 3539 | 0 | 1770 | 1583 | 0 | 0 | 1694 | 0 |
| Flt Permitted | | | | | | | 0.950 | | | | 0.976 | |
| Satd. Flow (perm) | 0 | 0 | 0 | 0 | 3539 | 0 | 1770 | 1583 | 0 | 0 | 1694 | 0 |
| Link Speed (mph) | | 30 | | | 30 | | | 30 | | | 30 | |
| Link Distance (ft) | | 318 | | | 307 | | | 288 | | | 180 | |
| Travel Time (s) | | 7.2 | | | 7.0 | | | 6.5 | | | 4.1 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 0 | 703 | 0 | 0 | 340 | 1 | 53 | 0 | 366 | 1 | 0 | 1 |
| Shared Lane Traffic (%) | | | | | | | | | | | | |
| Lane Group Flow (vph) | 0 | 703 | 0 | 0 | 341 | 0 | 53 | 366 | 0 | 0 | 2 | 0 |
| 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) | | 0 | | | 0 | | | 12 | | | 12 | |
| 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 |
| Sign Control | | Free | | | Free | | | Stop | | | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization Err% | ICU Level of Service H |
| Analysis Period (min) 15 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 318 | 111 | 161 | 513 | 0 | 0 |
| Future Volume (vph) | 318 | 111 | 161 | 513 | 0 | 0 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 0.95 | 0.95 | 1.00 | 1.00 |
| Frt | 0.965 | | | | | |
| Flt Protected | | | | 0.988 | | |
| Satd. Flow (prot) | 1798 | 0 | 0 | 3497 | 0 | 0 |
| Flt Permitted | | | | 0.988 | | |
| Satd. Flow (perm) | 1798 | 0 | 0 | 3497 | 0 | 0 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 301 | | | 318 | 98 | |
| Travel Time (s) | 6.8 | | | 7.2 | 2.2 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 346 | 121 | 175 | 558 | 0 | 0 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 467 | 0 | 0 | 733 | 0 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 0 | | | 0 | 0 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Free | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: | Other |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 49.0% | ICU Level of Service A |
| Analysis Period (min) 15 | |

| Lane Group | EBL | EBR | SBL | SBR | NWL | NWR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 0 | 150 | 272 | 50 | 0 | 0 |
| Future Volume (vph) | 0 | 150 | 272 | 50 | 0 | 0 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | 0.865 | 0.979 | | | |
| Flt Protected | | | 0.959 | | | |
| Satd. Flow (prot) | 0 | 1611 | 1749 | 0 | 0 | 0 |
| Flt Permitted | | | 0.959 | | | |
| Satd. Flow (perm) | 0 | 1611 | 1749 | 0 | 0 | 0 |
| Link Speed (mph) | 30 | | 30 | | 30 | |
| Link Distance (ft) | 270 | | 98 | | 162 | |
| Travel Time (s) | 6.1 | | 2.2 | | 3.7 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 0 | 163 | 296 | 54 | 0 | 0 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 0 | 163 | 350 | 0 | 0 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Right | Left | Right |
| Median Width(ft) | 0 | | 12 | | 0 | |
| Link Offset(ft) | 0 | | 0 | | 0 | |
| Crosswalk Width(ft) | 16 | | 16 | | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | 15 | 9 | 15 | 9 | 15 | 9 |
| Sign Control | Yield | | Free | | Stop | |

Intersection Summary

Area Type: Other

Control Type: Unsignalized

Intersection Capacity Utilization 21.5% ICU Level of Service A

Analysis Period (min) 15

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 335 | 203 | 0 | 0 | 0 | 51 |
| Future Volume (vph) | 335 | 203 | 0 | 0 | 0 | 51 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 0.95 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.943 | | | | | 0.865 |
| Flt Protected | | | | | | |
| Satd. Flow (prot) | 3337 | 0 | 0 | 0 | 0 | 1611 |
| Flt Permitted | | | | | | |
| Satd. Flow (perm) | 3337 | 0 | 0 | 0 | 0 | 1611 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 162 | | | 288 | 201 | |
| Travel Time (s) | 3.7 | | | 6.5 | 4.6 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 364 | 221 | 0 | 0 | 0 | 55 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 585 | 0 | 0 | 0 | 0 | 55 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 0 | | | 0 | 0 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Stop | Yield | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 25.8% | ICU Level of Service A |
| Analysis Period (min) 15 | |

Existing Conditions PM 2042



| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Traffic Volume (vph) | 0 | 318 | 0 | 0 | 674 | 1 | 70 | 0 | 226 | 1 | 0 | 1 |
| Future Volume (vph) | 0 | 318 | 0 | 0 | 674 | 1 | 70 | 0 | 226 | 1 | 0 | 1 |
| 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 | 0.95 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | | | | | | | 0.850 | | | 0.932 | |
| Flt Protected | | | | | | | 0.950 | | | | 0.976 | |
| Satd. Flow (prot) | 0 | 0 | 0 | 0 | 3539 | 0 | 1770 | 1583 | 0 | 0 | 1694 | 0 |
| Flt Permitted | | | | | | | 0.950 | | | | 0.976 | |
| Satd. Flow (perm) | 0 | 0 | 0 | 0 | 3539 | 0 | 1770 | 1583 | 0 | 0 | 1694 | 0 |
| Link Speed (mph) | | 30 | | | 30 | | | 30 | | | 30 | |
| Link Distance (ft) | | 318 | | | 307 | | | 288 | | | 180 | |
| Travel Time (s) | | 7.2 | | | 7.0 | | | 6.5 | | | 4.1 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 100% | 113% | 100% | 100% | 113% | 100% | 115% | 115% | 115% | 100% | 100% | 100% |
| Adj. Flow (vph) | 0 | 391 | 0 | 0 | 828 | 1 | 88 | 0 | 283 | 1 | 0 | 1 |
| Shared Lane Traffic (%) | | | | | | | | | | | | |
| Lane Group Flow (vph) | 0 | 391 | 0 | 0 | 829 | 0 | 88 | 283 | 0 | 0 | 2 | 0 |
| 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) | | 0 | | | 0 | | | 12 | | | 12 | |
| 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 |
| Sign Control | | Free | | | Free | | | Stop | | | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: | Other |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization Err% | ICU Level of Service H |
| Analysis Period (min) 15 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 318 | 111 | 161 | 513 | 0 | 0 |
| Future Volume (vph) | 318 | 111 | 161 | 513 | 0 | 0 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 0.95 | 0.95 | 1.00 | 1.00 |
| Frt | 0.965 | | | | | |
| Flt Protected | | | | 0.988 | | |
| Satd. Flow (prot) | 1798 | 0 | 0 | 3497 | 0 | 0 |
| Flt Permitted | | | | 0.988 | | |
| Satd. Flow (perm) | 1798 | 0 | 0 | 3497 | 0 | 0 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 301 | | | 318 | 98 | |
| Travel Time (s) | 6.8 | | | 7.2 | 2.2 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 113% | 113% | 113% | 113% | 100% | 100% |
| Adj. Flow (vph) | 391 | 136 | 198 | 630 | 0 | 0 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 527 | 0 | 0 | 828 | 0 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 0 | | | 0 | 0 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Free | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 54.5% | ICU Level of Service A |
| Analysis Period (min) 15 | |

| Lane Group | EBL | EBR | SBL | SBR | NWL | NWR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 0 | 150 | 272 | 50 | 0 | 0 |
| Future Volume (vph) | 0 | 150 | 272 | 50 | 0 | 0 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | 0.865 | 0.979 | | | |
| Flt Protected | | | 0.960 | | | |
| Satd. Flow (prot) | 0 | 1611 | 1751 | 0 | 0 | 0 |
| Flt Permitted | | | 0.960 | | | |
| Satd. Flow (perm) | 0 | 1611 | 1751 | 0 | 0 | 0 |
| Link Speed (mph) | 30 | | 30 | | 30 | |
| Link Distance (ft) | 270 | | 98 | | 162 | |
| Travel Time (s) | 6.1 | | 2.2 | | 3.7 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 115% | 115% | 115% | 115% | 100% | 100% |
| Adj. Flow (vph) | 0 | 188 | 340 | 63 | 0 | 0 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 0 | 188 | 403 | 0 | 0 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Right | Left | Right |
| Median Width(ft) | 0 | | 12 | | 0 | |
| Link Offset(ft) | 0 | | 0 | | 0 | |
| Crosswalk Width(ft) | 16 | | 16 | | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | 15 | 9 | 15 | 9 | 15 | 9 |
| Sign Control | Yield | | Free | | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 24.2% | ICU Level of Service A |
| Analysis Period (min) 15 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | ↑↱ | | | | | ↱ |
| Traffic Volume (vph) | 139 | 111 | 0 | 0 | 0 | 165 |
| Future Volume (vph) | 139 | 111 | 0 | 0 | 0 | 165 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 0.95 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.933 | | | | | 0.865 |
| Flt Protected | | | | | | |
| Satd. Flow (prot) | 3302 | 0 | 0 | 0 | 0 | 1611 |
| Flt Permitted | | | | | | |
| Satd. Flow (perm) | 3302 | 0 | 0 | 0 | 0 | 1611 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 162 | | | 288 | 201 | |
| Travel Time (s) | 3.7 | | | 6.5 | 4.6 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 115% | 115% | 100% | 100% | 115% | 115% |
| Adj. Flow (vph) | 174 | 139 | 0 | 0 | 0 | 206 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 313 | 0 | 0 | 0 | 0 | 206 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 0 | | | 0 | 0 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Stop | Yield | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 26.9% | ICU Level of Service A |
| Analysis Period (min) 15 | |

**Appendix C: Existing Conditions**


Existing Conditions AM 2022


Existing Conditions AM 2042


Existing Conditions PM 2022


Existing Conditions PM 2042

**Appendix D: Alternative 1 Drawings**


Alternative 1 AM 2022


Alternative 1 AM 2042


Alternative 1 PM 2022


Alternative 1 PM 2042

# Appendix E: Alternative 1 Analysis

Alt 1 AM 2022

Lanes, Volumes, Timings
1: 11/22/2022

| Lane Group | EBL | EBT | WBT | WBR | SBL | SBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 0 | 984 | 316 | 1 | 1 | 1 |
| Future Volume (vph) | 0 | 984 | 316 | 1 | 1 | 1 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | | | | 0.925 | |
| Flt Protected | | | | | 0.976 | |
| Satd. Flow (prot) | 0 | 1863 | 1863 | 0 | 0 | 0 |
| Flt Permitted | | | | | 0.976 | |
| Satd. Flow (perm) | 0 | 1863 | 1863 | 0 | 0 | 0 |
| Link Speed (mph) | | 30 | 30 | | 30 | |
| Link Distance (ft) | | 195 | 307 | | 180 | |
| Travel Time (s) | | 4.4 | 7.0 | | 4.1 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 0 | 1070 | 343 | 1 | 1 | 1 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 0 | 1070 | 344 | 0 | 2 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Left | Left | Right | Left | Right |
| Median Width(ft) | | 0 | 0 | | 0 | |
| Link Offset(ft) | | 0 | 0 | | 0 | |
| Crosswalk Width(ft) | | 16 | 16 | | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | 15 | | | 9 | 15 | 9 |
| Sign Control | | Free | Free | | Stop | |

Intersection Summary

Area Type: Other

Control Type: Unsignalized

Intersection Capacity Utilization Err% ICU Level of Service H

Analysis Period (min) 15

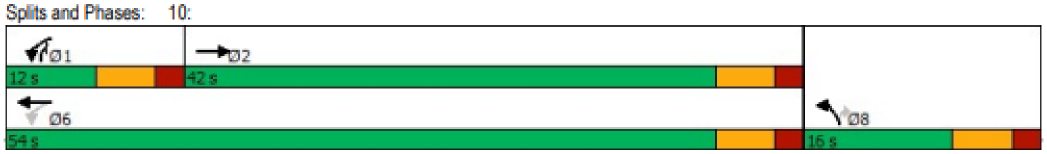
| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 647 | 158 | 76 | 240 | 46 | 337 |
| Future Volume (vph) | 647 | 158 | 76 | 240 | 46 | 337 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.973 | | | | | 0.850 |
| Flt Protected | | | 0.950 | | 0.950 | |
| Satd. Flow (prot) | 1812 | 0 | 1770 | 1863 | 1770 | 1583 |
| Flt Permitted | | | 0.105 | | 0.950 | |
| Satd. Flow (perm) | 1812 | 0 | 196 | 1863 | 1770 | 1583 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 26 | | | | | 181 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 123 | | | 195 | 102 | |
| Travel Time (s) | 2.8 | | | 4.4 | 2.3 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 703 | 172 | 83 | 261 | 50 | 366 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 875 | 0 | 83 | 261 | 50 | 366 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 12 | | | 12 | 12 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Number of Detectors | 2 | | 1 | 2 | 1 | 1 |
| Detector Template | Thru | | Left | Thru | Left | Right |
| Leading Detector (ft) | 100 | | 20 | 100 | 20 | 20 |
| Trailing Detector (ft) | 0 | | 0 | 0 | 0 | 0 |
| Detector 1 Position(ft) | 0 | | 0 | 0 | 0 | 0 |
| Detector 1 Size(ft) | 6 | | 20 | 6 | 20 | 20 |
| Detector 1 Type | Cl+Ex | | Cl+Ex | Cl+Ex | Cl+Ex | Cl+Ex |
| Detector 1 Channel | | | | | | |
| Detector 1 Extend (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 1 Queue (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 1 Delay (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 2 Position(ft) | 94 | | | 94 | | |
| Detector 2 Size(ft) | 6 | | | 6 | | |
| Detector 2 Type | Cl+Ex | | | Cl+Ex | | |
| Detector 2 Channel | | | | | | |
| Detector 2 Extend (s) | 0.0 | | | 0.0 | | |
| Turn Type | NA | | pm+pt | NA | Prot | pm+ov |
| Protected Phases | 2 | | 1 | 6 | 8 | 1 |
| Permitted Phases | | | 6 | | | 8 |
| Detector Phase | 2 | | 1 | 6 | 8 | 1 |
| Switch Phase | | | | | | |
| Minimum Initial (s) | 5.0 | | 5.0 | 5.0 | 5.0 | 5.0 |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Minimum Split (s) | 24.0 | | 11.0 | 24.0 | 16.0 | 11.0 |
| Total Split (s) | 42.0 | | 12.0 | 54.0 | 16.0 | 12.0 |
| Total Split (%) | 60.0% | | 17.1% | 77.1% | 22.9% | 17.1% |
| Maximum Green (s) | 36.0 | | 6.0 | 48.0 | 10.0 | 6.0 |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | 4.0 |
| All-Red Time (s) | 2.0 | | 2.0 | 2.0 | 2.0 | 2.0 |
| Lost Time Adjust (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | | 6.0 | 6.0 | 6.0 | 6.0 |
| Lead/Lag | Lag | | Lead | | | Lead |
| Lead-Lag Optimize? | Yes | | Yes | | | Yes |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | 3.0 |
| Recall Mode | None | | None | None | None | None |
| Act Effct Green (s) | 31.7 | | 44.3 | 47.6 | 7.5 | 13.6 |
| Actuated g/C Ratio | 0.55 | | 0.76 | 0.82 | 0.13 | 0.23 |
| v/c Ratio | 0.88 | | 0.26 | 0.17 | 0.22 | 0.72 |
| Control Delay | 25.3 | | 5.1 | 3.3 | 29.1 | 19.1 |
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Delay | 25.3 | | 5.1 | 3.3 | 29.1 | 19.1 |
| LOS | C | | A | A | C | B |
| Approach Delay | 25.3 | | | 3.7 | 20.3 | |
| Approach LOS | C | | | A | C | |
| Queue Length 50th (ft) | 287 | | 8 | 28 | 19 | 61 |
| Queue Length 95th (ft) | #573 | | 21 | 57 | 49 | 143 |
| Internal Link Dist (ft) | 43 | | | 115 | 22 | |
| Turn Bay Length (ft) | | | | | | |
| Base Capacity (vph) | 1201 | | 322 | 1529 | 323 | 512 |
| Starvation Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Spillback Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Storage Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Reduced v/c Ratio | 0.73 | | 0.26 | 0.17 | 0.15 | 0.71 |

**Intersection Summary**

Area Type: Other
Cycle Length: 70
Actuated Cycle Length: 58
Natural Cycle: 70
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.88
Intersection Signal Delay: 19.5 Intersection LOS: B
Intersection Capacity Utilization 74.5% ICU Level of Service D
Analysis Period (min) 15
# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 10:



| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 335 | 16 | 187 | 47 | 3 | 48 |
| Future Volume (vph) | 335 | 16 | 187 | 47 | 3 | 48 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.994 | | | | 0.872 | |
| Flt Protected | | | 0.950 | | 0.997 | |
| Satd. Flow (prot) | 1852 | 0 | 1770 | 1863 | 1619 | 0 |
| Flt Permitted | | | 0.950 | | 0.997 | |
| Satd. Flow (perm) | 1852 | 0 | 1770 | 1863 | 1619 | 0 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 247 | | | 102 | 187 | |
| Travel Time (s) | 5.6 | | | 2.3 | 4.3 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 364 | 17 | 203 | 51 | 3 | 52 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 381 | 0 | 203 | 51 | 55 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 12 | | | 12 | 12 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Free | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 42.3% | ICU Level of Service A |
| Analysis Period (min) 15 | |

Alternative 1 AM 2042



| Lane Group | EBL | EBT | WBT | WBR | SBL | SBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 0 | 318 | 674 | 1 | 1 | 1 |
| Future Volume (vph) | 0 | 318 | 674 | 1 | 1 | 1 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | | | | 0.925 | |
| Flt Protected | | | | | 0.976 | |
| Satd. Flow (prot) | 0 | 1863 | 1863 | 0 | 0 | 0 |
| Flt Permitted | | | | | 0.976 | |
| Satd. Flow (perm) | 0 | 1863 | 1863 | 0 | 0 | 0 |
| Link Speed (mph) | | 30 | 30 | | 30 | |
| Link Distance (ft) | | 195 | 307 | | 180 | |
| Travel Time (s) | | 4.4 | 7.0 | | 4.1 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 113% | 113% | 113% | 113% | 100% | 100% |
| Adj. Flow (vph) | 0 | 391 | 828 | 1 | 1 | 1 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 0 | 391 | 829 | 0 | 2 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Left | Left | Right | Left | Right |
| Median Width(ft) | | 0 | 0 | | 0 | |
| Link Offset(ft) | | 0 | 0 | | 0 | |
| Crosswalk Width(ft) | | 16 | 16 | | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | 15 | | | 9 | 15 | 9 |
| Sign Control | | Free | Free | | Stop | |

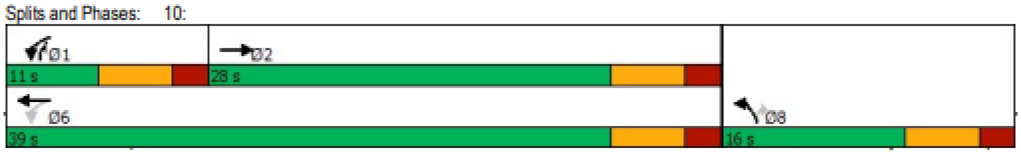
| Intersection Summary | | |
|---|---|---|
| Area Type: Other | | |
| Control Type: Unsignalized | | |
| Intersection Capacity Utilization Err% | | ICU Level of Service H |
| Analysis Period (min) 15 | | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 318 | 111 | 161 | 513 | 78 | 226 |
| Future Volume (vph) | 318 | 111 | 161 | 513 | 78 | 226 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.965 | | | | | 0.850 |
| Flt Protected | | | 0.950 | | 0.950 | |
| Satd. Flow (prot) | 1798 | 0 | 1770 | 1863 | 1770 | 1583 |
| Flt Permitted | | | 0.243 | | 0.950 | |
| Satd. Flow (perm) | 1798 | 0 | 453 | 1863 | 1770 | 1583 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 38 | | | | | 283 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 123 | | | 195 | 102 | |
| Travel Time (s) | 2.8 | | | 4.4 | 2.3 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 113% | 113% | 113% | 113% | 115% | 115% |
| Adj. Flow (vph) | 391 | 136 | 198 | 630 | 98 | 283 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 527 | 0 | 198 | 630 | 98 | 283 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 12 | | | 12 | 12 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Number of Detectors | 2 | | 1 | 2 | 1 | 1 |
| Detector Template | Thru | | Left | Thru | Left | Right |
| Leading Detector (ft) | 100 | | 20 | 100 | 20 | 20 |
| Trailing Detector (ft) | 0 | | 0 | 0 | 0 | 0 |
| Detector 1 Position(ft) | 0 | | 0 | 0 | 0 | 0 |
| Detector 1 Size(ft) | 6 | | 20 | 6 | 20 | 20 |
| Detector 1 Type | Cl+Ex | | Cl+Ex | Cl+Ex | Cl+Ex | Cl+Ex |
| Detector 1 Channel | | | | | | |
| Detector 1 Extend (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 1 Queue (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 1 Delay (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 2 Position(ft) | 94 | | | 94 | | |
| Detector 2 Size(ft) | 6 | | | 6 | | |
| Detector 2 Type | Cl+Ex | | | Cl+Ex | | |
| Detector 2 Channel | | | | | | |
| Detector 2 Extend (s) | 0.0 | | | 0.0 | | |
| Turn Type | NA | | pm+pt | NA | Prot | pm+ov |
| Protected Phases | 2 | | 1 | 6 | 8 | 1 |
| Permitted Phases | | | 6 | | | 8 |
| Detector Phase | 2 | | 1 | 6 | 8 | 1 |
| Switch Phase | | | | | | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Minimum Initial (s) | 5.0 | | 5.0 | 5.0 | 5.0 | 5.0 |
| Minimum Split (s) | 24.0 | | 11.0 | 24.0 | 16.0 | 11.0 |
| Total Split (s) | 28.0 | | 11.0 | 39.0 | 16.0 | 11.0 |
| Total Split (%) | 50.9% | | 20.0% | 70.9% | 29.1% | 20.0% |
| Maximum Green (s) | 22.0 | | 5.0 | 33.0 | 10.0 | 5.0 |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | 4.0 |
| All-Red Time (s) | 2.0 | | 2.0 | 2.0 | 2.0 | 2.0 |
| Lost Time Adjust (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | | 6.0 | 6.0 | 6.0 | 6.0 |
| Lead/Lag | Lag | | Lead | | | Lead |
| Lead-Lag Optimize? | Yes | | Yes | | | Yes |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | 3.0 |
| Recall Mode | None | | None | None | None | None |
| Act Effct Green (s) | 17.5 | | 29.6 | 33.2 | 8.2 | 12.9 |
| Actuated g/C Ratio | 0.40 | | 0.68 | 0.76 | 0.19 | 0.30 |
| v/c Ratio | 0.71 | | 0.42 | 0.44 | 0.30 | 0.42 |
| Control Delay | 17.9 | | 7.1 | 6.3 | 21.4 | 4.1 |
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Delay | 17.9 | | 7.1 | 6.3 | 21.4 | 4.1 |
| LOS | B | | A | A | C | A |
| Approach Delay | 17.9 | | | 6.5 | 8.5 | |
| Approach LOS | B | | | A | A | |
| Queue Length 50th (ft) | 118 | | 22 | 93 | 27 | 0 |
| Queue Length 95th (ft) | #232 | | 48 | 181 | 64 | 38 |
| Internal Link Dist (ft) | 43 | | | 115 | 22 | |
| Turn Bay Length (ft) | | | | | | |
| Base Capacity (vph) | 1014 | | 473 | 1436 | 446 | 668 |
| Starvation Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Spillback Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Storage Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Reduced v/c Ratio | 0.52 | | 0.42 | 0.44 | 0.22 | 0.42 |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Cycle Length: 55 | |
| Actuated Cycle Length: 43.6 | |
| Natural Cycle: 60 | |
| Control Type: Actuated-Uncoordinated | |
| Maximum v/c Ratio: 0.71 | |
| Intersection Signal Delay: 10.4 | Intersection LOS: B |
| Intersection Capacity Utilization 56.6% | ICU Level of Service B |
| Analysis Period (min) 15 | |
| # 95th percentile volume exceeds capacity, queue may be longer. Queue shown is maximum after two cycles. | |

Splits and Phases: 10:



| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 139 | 11 | 100 | 172 | 0 | 165 |
| Future Volume (vph) | 139 | 11 | 100 | 172 | 0 | 165 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.990 | | | | 0.865 | |
| Flt Protected | | | 0.950 | | | |
| Satd. Flow (prot) | 1844 | 0 | 1770 | 1863 | 1611 | 0 |
| Flt Permitted | | | 0.950 | | | |
| Satd. Flow (perm) | 1844 | 0 | 1770 | 1863 | 1611 | 0 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 247 | | | 102 | 187 | |
| Travel Time (s) | 5.6 | | | 2.3 | 4.3 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 115% | 115% | 115% | 115% | 115% | 115% |
| Adj. Flow (vph) | 174 | 14 | 125 | 215 | 0 | 206 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 188 | 0 | 125 | 215 | 206 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 12 | | | 12 | 12 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Free | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 37.3% | ICU Level of Service A |
| Analysis Period (min) 15 | |

Alternative 1 PM 2022



| Lane Group | EBL | EBT | WBT | WBR | SBL | SBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 0 | 318 | 674 | 1 | 1 | 1 |
| Future Volume (vph) | 0 | 318 | 674 | 1 | 1 | 1 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | | | | 0.925 | |
| Flt Protected | | | | | 0.976 | |
| Satd. Flow (prot) | 0 | 1863 | 1863 | 0 | 0 | 0 |
| Flt Permitted | | | | | 0.976 | |
| Satd. Flow (perm) | 0 | 1863 | 1863 | 0 | 0 | 0 |
| Link Speed (mph) | | 30 | 30 | | 30 | |
| Link Distance (ft) | | 195 | 307 | | 180 | |
| Travel Time (s) | | 4.4 | 7.0 | | 4.1 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 0 | 346 | 733 | 1 | 1 | 1 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 0 | 346 | 734 | 0 | 2 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Left | Left | Right | Left | Right |
| Median Width(ft) | | 0 | 0 | | 0 | |
| Link Offset(ft) | | 0 | 0 | | 0 | |
| Crosswalk Width(ft) | | 16 | 16 | | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | 15 | | | 9 | 15 | 9 |
| Sign Control | | Free | Free | | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization Err% | ICU Level of Service H |
| Analysis Period (min) 15 | |

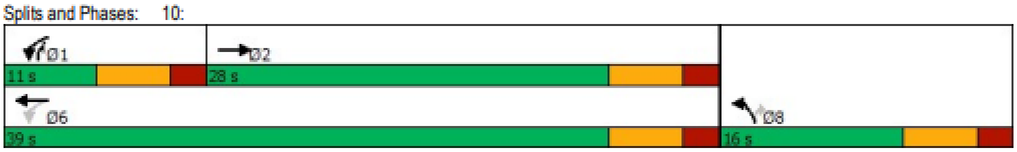
| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 318 | 111 | 161 | 513 | 78 | 226 |
| Future Volume (vph) | 318 | 111 | 161 | 513 | 78 | 226 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.965 | | | | | 0.850 |
| Flt Protected | | | 0.950 | | 0.950 | |
| Satd. Flow (prot) | 1798 | 0 | 1770 | 1863 | 1770 | 1583 |
| Flt Permitted | | | 0.274 | | 0.950 | |
| Satd. Flow (perm) | 1798 | 0 | 510 | 1863 | 1770 | 1583 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 38 | | | | | 246 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 123 | | | 195 | 102 | |
| Travel Time (s) | 2.8 | | | 4.4 | 2.3 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 346 | 121 | 175 | 558 | 85 | 246 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 467 | 0 | 175 | 558 | 85 | 246 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 12 | | | 12 | 12 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Number of Detectors | 2 | | 1 | 2 | 1 | 1 |
| Detector Template | Thru | | Left | Thru | Left | Right |
| Leading Detector (ft) | 100 | | 20 | 100 | 20 | 20 |
| Trailing Detector (ft) | 0 | | 0 | 0 | 0 | 0 |
| Detector 1 Position(ft) | 0 | | 0 | 0 | 0 | 0 |
| Detector 1 Size(ft) | 6 | | 20 | 6 | 20 | 20 |
| Detector 1 Type | Cl+Ex | | Cl+Ex | Cl+Ex | Cl+Ex | Cl+Ex |
| Detector 1 Channel | | | | | | |
| Detector 1 Extend (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 1 Queue (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 1 Delay (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 2 Position(ft) | 94 | | | 94 | | |
| Detector 2 Size(ft) | 6 | | | 6 | | |
| Detector 2 Type | Cl+Ex | | | Cl+Ex | | |
| Detector 2 Channel | | | | | | |
| Detector 2 Extend (s) | 0.0 | | | 0.0 | | |
| Turn Type | NA | | pm+pt | NA | Prot | pm+ov |
| Protected Phases | 2 | | 1 | 6 | 8 | 1 |
| Permitted Phases | | | 6 | | | 8 |
| Detector Phase | 2 | | 1 | 6 | 8 | 1 |
| Switch Phase | | | | | | |
| Minimum Initial (s) | 5.0 | | 5.0 | 5.0 | 5.0 | 5.0 |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Minimum Split (s) | 24.0 | | 11.0 | 24.0 | 16.0 | 11.0 |
| Total Split (s) | 28.0 | | 11.0 | 39.0 | 16.0 | 11.0 |
| Total Split (%) | 50.9% | | 20.0% | 70.9% | 29.1% | 20.0% |
| Maximum Green (s) | 22.0 | | 5.0 | 33.0 | 10.0 | 5.0 |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | 4.0 |
| All-Red Time (s) | 2.0 | | 2.0 | 2.0 | 2.0 | 2.0 |
| Lost Time Adjust (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | | 6.0 | 6.0 | 6.0 | 6.0 |
| Lead/Lag | Lag | | Lead | | | Lead |
| Lead-Lag Optimize? | Yes | | Yes | | | Yes |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | 3.0 |
| Recall Mode | None | | None | None | None | None |
| Act Effct Green (s) | 15.2 | | 27.5 | 31.3 | 8.0 | 12.8 |
| Actuated g/C Ratio | 0.37 | | 0.66 | 0.76 | 0.19 | 0.31 |
| v/c Ratio | 0.68 | | 0.34 | 0.40 | 0.25 | 0.37 |
| Control Delay | 17.0 | | 6.2 | 5.9 | 20.2 | 3.9 |
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Delay | 17.0 | | 6.2 | 5.9 | 20.2 | 3.9 |
| LOS | B | | A | A | C | A |
| Approach Delay | 17.0 | | | 5.9 | 8.1 | |
| Approach LOS | B | | | A | A | |
| Queue Length 50th (ft) | 97 | | 18 | 75 | 21 | 0 |
| Queue Length 95th (ft) | 191 | | 43 | 151 | 57 | 36 |
| Internal Link Dist (ft) | 43 | | | 115 | 22 | |
| Turn Bay Length (ft) | | | | | | |
| Base Capacity (vph) | 1085 | | 509 | 1463 | 479 | 658 |
| Starvation Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Spillback Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Storage Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Reduced v/c Ratio | 0.43 | | 0.34 | 0.38 | 0.18 | 0.37 |

Intersection Summary

Area Type: Other
Cycle Length: 55
Actuated Cycle Length: 41.4
Natural Cycle: 55
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.68
Intersection Signal Delay: 9.8 Intersection LOS: A
Intersection Capacity Utilization 51.7% ICU Level of Service A
Analysis Period (min) 15

Splits and Phases: 10:



| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 139 | 11 | 100 | 172 | 0 | 165 |
| Future Volume (vph) | 139 | 11 | 100 | 172 | 0 | 165 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.990 | | | | 0.865 | |
| Flt Protected | | | 0.950 | | | |
| Satd. Flow (prot) | 1844 | 0 | 1770 | 1863 | 1611 | 0 |
| Flt Permitted | | | 0.950 | | | |
| Satd. Flow (perm) | 1844 | 0 | 1770 | 1863 | 1611 | 0 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 247 | | | 102 | 187 | |
| Travel Time (s) | 5.6 | | | 2.3 | 4.3 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Adj. Flow (vph) | 151 | 12 | 109 | 187 | 0 | 179 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 163 | 0 | 109 | 187 | 179 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 12 | | | 12 | 12 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Free | Stop | |

Intersection Summary

Area Type: Other

Control Type: Unsignalized

Intersection Capacity Utilization 33.7% ICU Level of Service A

Analysis Period (min) 15

Alternative 1 PM 2042

Lanes, Volumes, Timings
1: 11/22/2022

| Lane Group | EBL | EBT | WBT | WBR | SBL | SBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 0 | 318 | 674 | 1 | 1 | 1 |
| Future Volume (vph) | 0 | 318 | 674 | 1 | 1 | 1 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | | | | | 0.925 | |
| Flt Protected | | | | | 0.976 | |
| Satd. Flow (prot) | 0 | 1863 | 1863 | 0 | 0 | 0 |
| Flt Permitted | | | | | 0.976 | |
| Satd. Flow (perm) | 0 | 1863 | 1863 | 0 | 0 | 0 |
| Link Speed (mph) | | 30 | 30 | | 30 | |
| Link Distance (ft) | | 195 | 307 | | 180 | |
| Travel Time (s) | | 4.4 | 7.0 | | 4.1 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 113% | 113% | 113% | 113% | 100% | 100% |
| Adj. Flow (vph) | 0 | 391 | 828 | 1 | 1 | 1 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 0 | 391 | 829 | 0 | 2 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Left | Left | Right | Left | Right |
| Median Width(ft) | | 0 | 0 | | 0 | |
| Link Offset(ft) | | 0 | 0 | | 0 | |
| Crosswalk Width(ft) | | 16 | 16 | | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | 15 | | | 9 | 15 | 9 |
| Sign Control | | Free | Free | | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization Err% | ICU Level of Service H |
| Analysis Period (min) 15 | |

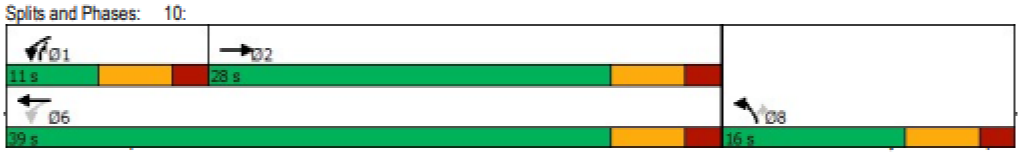
| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 318 | 111 | 161 | 513 | 78 | 226 |
| Future Volume (vph) | 318 | 111 | 161 | 513 | 78 | 226 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.965 | | | | | 0.850 |
| Flt Protected | | | 0.950 | | 0.950 | |
| Satd. Flow (prot) | 1798 | 0 | 1770 | 1863 | 1770 | 1583 |
| Flt Permitted | | | 0.243 | | 0.950 | |
| Satd. Flow (perm) | 1798 | 0 | 453 | 1863 | 1770 | 1583 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 38 | | | | | 283 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 123 | | | 195 | 102 | |
| Travel Time (s) | 2.8 | | | 4.4 | 2.3 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 113% | 113% | 113% | 113% | 115% | 115% |
| Adj. Flow (vph) | 391 | 136 | 198 | 630 | 98 | 283 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 527 | 0 | 198 | 630 | 98 | 283 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 12 | | | 12 | 12 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Number of Detectors | 2 | | 1 | 2 | 1 | 1 |
| Detector Template | Thru | | Left | Thru | Left | Right |
| Leading Detector (ft) | 100 | | 20 | 100 | 20 | 20 |
| Trailing Detector (ft) | 0 | | 0 | 0 | 0 | 0 |
| Detector 1 Position(ft) | 0 | | 0 | 0 | 0 | 0 |
| Detector 1 Size(ft) | 6 | | 20 | 6 | 20 | 20 |
| Detector 1 Type | Cl+Ex | | Cl+Ex | Cl+Ex | Cl+Ex | Cl+Ex |
| Detector 1 Channel | | | | | | |
| Detector 1 Extend (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 1 Queue (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 1 Delay (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Detector 2 Position(ft) | 94 | | | 94 | | |
| Detector 2 Size(ft) | 6 | | | 6 | | |
| Detector 2 Type | Cl+Ex | | | Cl+Ex | | |
| Detector 2 Channel | | | | | | |
| Detector 2 Extend (s) | 0.0 | | | 0.0 | | |
| Turn Type | NA | | pm+pt | NA | Prot | pm+ov |
| Protected Phases | 2 | | 1 | 6 | 8 | 1 |
| Permitted Phases | | | 6 | | | 8 |
| Detector Phase | 2 | | 1 | 6 | 8 | 1 |
| Switch Phase | | | | | | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Minimum Initial (s) | 5.0 | | 5.0 | 5.0 | 5.0 | 5.0 |
| Minimum Split (s) | 24.0 | | 11.0 | 24.0 | 16.0 | 11.0 |
| Total Split (s) | 28.0 | | 11.0 | 39.0 | 16.0 | 11.0 |
| Total Split (%) | 50.9% | | 20.0% | 70.9% | 29.1% | 20.0% |
| Maximum Green (s) | 22.0 | | 5.0 | 33.0 | 10.0 | 5.0 |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | 4.0 |
| All-Red Time (s) | 2.0 | | 2.0 | 2.0 | 2.0 | 2.0 |
| Lost Time Adjust (s) | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Lost Time (s) | 6.0 | | 6.0 | 6.0 | 6.0 | 6.0 |
| Lead/Lag | Lag | | Lead | | | Lead |
| Lead-Lag Optimize? | Yes | | Yes | | | Yes |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | 3.0 |
| Recall Mode | None | | None | None | None | None |
| Act Effct Green (s) | 17.5 | | 29.6 | 33.2 | 8.2 | 12.9 |
| Actuated g/C Ratio | 0.40 | | 0.68 | 0.76 | 0.19 | 0.30 |
| v/c Ratio | 0.71 | | 0.42 | 0.44 | 0.30 | 0.42 |
| Control Delay | 17.9 | | 7.1 | 6.3 | 21.4 | 4.1 |
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Delay | 17.9 | | 7.1 | 6.3 | 21.4 | 4.1 |
| LOS | B | | A | A | C | A |
| Approach Delay | 17.9 | | | 6.5 | 8.5 | |
| Approach LOS | B | | | A | A | |
| Queue Length 50th (ft) | 118 | | 22 | 93 | 27 | 0 |
| Queue Length 95th (ft) | #232 | | 48 | 181 | 64 | 38 |
| Internal Link Dist (ft) | 43 | | | 115 | 22 | |
| Turn Bay Length (ft) | | | | | | |
| Base Capacity (vph) | 1014 | | 473 | 1436 | 446 | 668 |
| Starvation Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Spillback Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Storage Cap Reductn | 0 | | 0 | 0 | 0 | 0 |
| Reduced v/c Ratio | 0.52 | | 0.42 | 0.44 | 0.22 | 0.42 |

Intersection Summary

Area Type: Other
Cycle Length: 55
Actuated Cycle Length: 43.6
Natural Cycle: 60
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.71
Intersection Signal Delay: 10.4 Intersection LOS: B
Intersection Capacity Utilization 56.6% ICU Level of Service B
Analysis Period (min) 15
\# 95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 10:



| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Traffic Volume (vph) | 139 | 11 | 100 | 172 | 0 | 165 |
| Future Volume (vph) | 139 | 11 | 100 | 172 | 0 | 165 |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Lane Util. Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Frt | 0.990 | | | | 0.865 | |
| Flt Protected | | | 0.950 | | | |
| Satd. Flow (prot) | 1844 | 0 | 1770 | 1863 | 1611 | 0 |
| Flt Permitted | | | 0.950 | | | |
| Satd. Flow (perm) | 1844 | 0 | 1770 | 1863 | 1611 | 0 |
| Link Speed (mph) | 30 | | | 30 | 30 | |
| Link Distance (ft) | 247 | | | 102 | 187 | |
| Travel Time (s) | 5.6 | | | 2.3 | 4.3 | |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Growth Factor | 115% | 115% | 115% | 115% | 115% | 115% |
| Adj. Flow (vph) | 174 | 14 | 125 | 215 | 0 | 206 |
| Shared Lane Traffic (%) | | | | | | |
| Lane Group Flow (vph) | 188 | 0 | 125 | 215 | 206 | 0 |
| Enter Blocked Intersection | No | No | No | No | No | No |
| Lane Alignment | Left | Right | Left | Left | Left | Right |
| Median Width(ft) | 12 | | | 12 | 12 | |
| Link Offset(ft) | 0 | | | 0 | 0 | |
| Crosswalk Width(ft) | 16 | | | 16 | 16 | |
| Two way Left Turn Lane | | | | | | |
| Headway Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Turning Speed (mph) | | 9 | 15 | | 15 | 9 |
| Sign Control | Free | | | Free | Stop | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Control Type: Unsignalized | |
| Intersection Capacity Utilization 37.3% | ICU Level of Service A |
| Analysis Period (min) 15 | |

**Appendix F: Alternative 2 Drawings**


Alternative 2 AM 2022


Alternative 2 AM 2042


Alternative 2 PM 2022


Alternative PM 2042

# Appendix G: Alternative 2 Analysis

HCM 6th Signalized Intersection Summary

11: 11/22/2022

| Movement | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Traffic Volume (veh/h) | 18 | 317 | 16 | 41 | 35 | 240 | 3 | 28 | 20 | 647 | 146 | 12 |
| Future Volume (veh/h) | 18 | 317 | 16 | 41 | 35 | 240 | 3 | 28 | 20 | 647 | 146 | 12 |
| Initial Q (Qb), veh | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped-Bike Adj(A_pbT) | 1.00 | | 1.00 | 1.00 | | 1.00 | 1.00 | | 1.00 | 1.00 | | 1.00 |
| Parking Bus, Adj | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Work Zone On Approach | | No | | | No | | | No | | | No | |
| Adj Sat Flow, veh/h/ln | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 |
| Adj Flow Rate, veh/h | 20 | 345 | 17 | 45 | 38 | 0 | 3 | 30 | 22 | 703 | 159 | 13 |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Percent Heavy Veh, % | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Cap, veh/h | 381 | 412 | 20 | 126 | 80 | | 68 | 185 | 127 | 988 | 967 | 79 |
| Arrive On Green | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.00 | 0.18 | 0.18 | 0.18 | 0.31 | 0.57 | 0.57 |
| Sat Flow, veh/h | 1370 | 1768 | 87 | 142 | 344 | 1585 | 28 | 1010 | 692 | 1781 | 1706 | 139 |
| Grp Volume(v), veh/h | 20 | 0 | 362 | 83 | 0 | 0 | 55 | 0 | 0 | 703 | 0 | 172 |
| Grp Sat Flow(s),veh/h/ln | 1370 | 0 | 1855 | 486 | 0 | 1585 | 1730 | 0 | 0 | 1781 | 0 | 1845 |
| Q Serve(g_s), s | 0.0 | 0.0 | 11.2 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 18.5 | 0.0 | 2.7 |
| Cycle Q Clear(g_c), s | 0.9 | 0.0 | 11.2 | 12.5 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 18.5 | 0.0 | 2.7 |
| Prop In Lane | 1.00 | | 0.05 | 0.54 | | 1.00 | 0.05 | | 0.40 | 1.00 | | 0.08 |
| Lane Grp Cap(c), veh/h | 381 | 0 | 433 | 206 | 0 | | 381 | 0 | 0 | 988 | 0 | 1046 |
| V/C Ratio(X) | 0.05 | 0.00 | 0.84 | 0.40 | 0.00 | | 0.14 | 0.00 | 0.00 | 0.71 | 0.00 | 0.16 |
| Avail Cap(c_a), veh/h | 381 | 0 | 433 | 206 | 0 | | 381 | 0 | 0 | 988 | 0 | 1046 |
| HCM Platoon Ratio | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Upstream Filter(I) | 1.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 |
| Uniform Delay (d), s/veh | 18.0 | 0.0 | 21.9 | 20.9 | 0.0 | 0.0 | 20.7 | 0.0 | 0.0 | 11.2 | 0.0 | 6.2 |
| Incr Delay (d2), s/veh | 0.1 | 0.0 | 13.4 | 1.3 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 2.4 | 0.0 | 0.3 |
| Initial Q Delay(d3),s/veh | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| %ile BackOfQ(50%),veh/ln | 0.2 | 0.0 | 6.1 | 0.9 | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 6.5 | 0.0 | 0.9 |
| Unsig. Movement Delay, s/veh | | | | | | | | | | | | |
| LnGrp Delay(d),s/veh | 18.0 | 0.0 | 35.3 | 22.2 | 0.0 | 0.0 | 21.5 | 0.0 | 0.0 | 13.6 | 0.0 | 6.6 |
| LnGrp LOS | B | A | D | C | A | | C | A | A | B | A | A |
| Approach Vol, veh/h | | 382 | | | 83 | A | | 55 | | | 875 | |
| Approach Delay, s/veh | | 34.4 | | | 22.2 | | | 21.5 | | | 12.2 | |
| Approach LOS | | C | | | C | | | C | | | B | |
| Timer - Assigned Phs | 1 | 2 | | 4 | | 6 | | 8 | | | | |
| Phs Duration (G+Y+Rc), s | 23.0 | 17.0 | | 20.0 | | 40.0 | | 20.0 | | | | |
| Change Period (Y+Rc), s | 4.5 | 6.0 | | 6.0 | | 6.0 | | 6.0 | | | | |
| Max Green Setting (Gmax), s | 18.5 | 11.0 | | 14.0 | | 34.0 | | 14.0 | | | | |
| Max Q Clear Time (g_c+I1), s | 20.5 | 3.6 | | 13.2 | | 4.7 | | 14.5 | | | | |
| Green Ext Time (p_c), s | 0.0 | 0.1 | | 0.2 | | 1.0 | | 0.0 | | | | |
| Intersection Summary | | | | | | | | | | | | |
| HCM 6th Ctrl Delay | | | 19.2 | | | | | | | | | |
| HCM 6th LOS | | | B | | | | | | | | | |

Notes

Unsignalized Delay for [WBR] is excluded from calculations of the approach delay and intersection delay.

Scenario 1 2:15 pm 11/04/2022 Baseline

Synchro 11 Report
Page 1

Alternative 2 AM 2022

| Movement | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Traffic Volume (veh/h) | 18 | 317 | 16 | 41 | 35 | 240 | 3 | 28 | 20 | 647 | 146 | 12 |
| Future Volume (veh/h) | 18 | 317 | 16 | 41 | 35 | 240 | 3 | 28 | 20 | 647 | 146 | 12 |
| Initial Q (Qb), veh | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped-Bike Adj(A_pbT) | 1.00 | | 1.00 | 1.00 | | 1.00 | 1.00 | | 1.00 | 1.00 | | 1.00 |
| Parking Bus, Adj | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Work Zone On Approach | | No | | | No | | | No | | | No | |
| Adj Sat Flow, veh/h/ln | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 |
| Adj Flow Rate, veh/h | 23 | 400 | 20 | 51 | 44 | 0 | 4 | 35 | 25 | 809 | 182 | 15 |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Percent Heavy Veh, % | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Cap, veh/h | 345 | 442 | 22 | 89 | 58 | | 53 | 159 | 105 | 1032 | 1023 | 84 |
| Arrive On Green | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.00 | 0.16 | 0.16 | 0.16 | 0.39 | 0.60 | 0.60 |
| Sat Flow, veh/h | 1362 | 1766 | 88 | 81 | 231 | 1585 | 35 | 1018 | 675 | 1781 | 1705 | 140 |
| Grp Volume(v), veh/h | 23 | 0 | 420 | 95 | 0 | 0 | 64 | 0 | 0 | 809 | 0 | 197 |
| Grp Sat Flow(s),veh/h/ln | 1362 | 0 | 1854 | 313 | 0 | 1585 | 1729 | 0 | 0 | 1781 | 0 | 1845 |
| Q Serve(g_s), s | 0.0 | 0.0 | 17.6 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.7 | 0.0 | 3.8 |
| Cycle Q Clear(g_c), s | 1.4 | 0.0 | 17.6 | 20.0 | 0.0 | 0.0 | 2.6 | 0.0 | 0.0 | 28.7 | 0.0 | 3.8 |
| Prop In Lane | 1.00 | | 0.05 | 0.54 | | 1.00 | 0.06 | | 0.39 | 1.00 | | 0.08 |
| Lane Grp Cap(c), veh/h | 345 | 0 | 464 | 147 | 0 | | 317 | 0 | 0 | 1032 | 0 | 1107 |
| V/C Ratio(X) | 0.07 | 0.00 | 0.91 | 0.64 | 0.00 | | 0.20 | 0.00 | 0.00 | 0.78 | 0.00 | 0.18 |
| Avail Cap(c_a), veh/h | 345 | 0 | 464 | 147 | 0 | | 317 | 0 | 0 | 1043 | 0 | 1107 |
| HCM Platoon Ratio | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Upstream Filter(I) | 1.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 |
| Uniform Delay (d), s/veh | 23.0 | 0.0 | 29.1 | 31.4 | 0.0 | 0.0 | 29.6 | 0.0 | 0.0 | 13.6 | 0.0 | 7.2 |
| Incr Delay (d2), s/veh | 0.1 | 0.0 | 21.2 | 9.3 | 0.0 | 0.0 | 1.4 | 0.0 | 0.0 | 3.9 | 0.0 | 0.4 |
| Initial Q Delay(d3),s/veh | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| %ile BackOfQ(50%),veh/ln | 0.3 | 0.0 | 10.2 | 2.2 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 11.0 | 0.0 | 1.4 |
| Unsig. Movement Delay, s/veh | | | | | | | | | | | | |
| LnGrp Delay(d),s/veh | 23.1 | 0.0 | 50.3 | 40.7 | 0.0 | 0.0 | 31.0 | 0.0 | 0.0 | 17.6 | 0.0 | 7.5 |
| LnGrp LOS | C | A | D | D | A | | C | A | A | B | A | A |
| Approach Vol, veh/h | | 443 | | | 95 | A | | 64 | | | 1006 | |
| Approach Delay, s/veh | | 48.9 | | | 40.7 | | | 31.0 | | | 15.6 | |
| Approach LOS | | D | | | D | | | C | | | B | |
| Timer - Assigned Phs | 1 | 2 | | 4 | | 6 | | 8 | | | | |
| Phs Duration (G+Y+Rc), s | 35.5 | 18.5 | | 26.0 | | 54.0 | | 26.0 | | | | |
| Change Period (Y+Rc), s | 4.5 | 6.0 | | 6.0 | | 6.0 | | 6.0 | | | | |
| Max Green Setting (Gmax), s | 31.5 | 12.0 | | 20.0 | | 48.0 | | 20.0 | | | | |
| Max Q Clear Time (g_c+I1), s | 30.7 | 4.6 | | 19.6 | | 5.8 | | 22.0 | | | | |
| Green Ext Time (p_c), s | 0.3 | 0.1 | | 0.1 | | 1.2 | | 0.0 | | | | |

| Intersection Summary | | |
|---|---|---|
| HCM 6th Ctrl Delay | | 26.9 |
| HCM 6th LOS | | C |

Notes

Unsignalized Delay for [WBR] is excluded from calculations of the approach delay and intersection delay.



Alternative 2 AM 2042

## HCM 6th Signalized Intersection Summary
11:

11/22/2022

| Movement | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Traffic Volume (veh/h) | 19 | 120 | 11 | 27 | 134 | 513 | 0 | 59 | 106 | 318 | 73 | 38 |
| Future Volume (veh/h) | 19 | 120 | 11 | 27 | 134 | 513 | 0 | 59 | 106 | 318 | 73 | 38 |
| Initial Q (Qb), veh | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped-Bike Adj(A_pbT) | 1.00 | | 1.00 | 1.00 | | 1.00 | 1.00 | | 1.00 | 1.00 | | 1.00 |
| Parking Bus, Adj | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Work Zone On Approach | | No | | | No | | | No | | | No | |
| Adj Sat Flow, veh/h/ln | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 |
| Adj Flow Rate, veh/h | 21 | 130 | 12 | 29 | 146 | 0 | 0 | 64 | 115 | 346 | 79 | 41 |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Percent Heavy Veh, % | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Cap, veh/h | 398 | 267 | 25 | 123 | 236 | | 0 | 173 | 310 | 712 | 651 | 338 |
| Arrive On Green | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.00 | 0.00 | 0.29 | 0.29 | 0.17 | 0.56 | 0.56 |
| Sat Flow, veh/h | 1242 | 1687 | 156 | 159 | 1490 | 1585 | 0 | 599 | 1077 | 1781 | 1160 | 602 |
| Grp Volume(v), veh/h | 21 | 0 | 142 | 175 | 0 | 0 | 0 | 0 | 179 | 346 | 0 | 120 |
| Grp Sat Flow(s),veh/h/ln | 1242 | 0 | 1842 | 1649 | 0 | 1585 | 0 | 0 | 1676 | 1781 | 0 | 1762 |
| Q Serve(g_s), s | 0.0 | 0.0 | 3.0 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 | 5.1 | 0.0 | 1.4 |
| Cycle Q Clear(g_c), s | 0.5 | 0.0 | 3.0 | 4.4 | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 | 5.1 | 0.0 | 1.4 |
| Prop In Lane | 1.00 | | 0.08 | 0.17 | | 1.00 | 0.00 | | 0.64 | 1.00 | | 0.34 |
| Lane Grp Cap(c), veh/h | 398 | 0 | 292 | 359 | 0 | | 0 | 0 | 483 | 712 | 0 | 989 |
| V/C Ratio(X) | 0.05 | 0.00 | 0.49 | 0.49 | 0.00 | | 0.00 | 0.00 | 0.37 | 0.49 | 0.00 | 0.12 |
| Avail Cap(c_a), veh/h | 608 | 0 | 603 | 651 | 0 | | 0 | 0 | 483 | 767 | 0 | 989 |
| HCM Platoon Ratio | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Upstream Filter(I) | 1.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 1.00 |
| Uniform Delay (d), s/veh | 15.4 | 0.0 | 16.4 | 16.9 | 0.0 | 0.0 | 0.0 | 0.0 | 12.1 | 7.1 | 0.0 | 4.4 |
| Incr Delay (d2), s/veh | 0.1 | 0.0 | 1.3 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | 0.5 | 0.0 | 0.3 |
| Initial Q Delay(d3),s/veh | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| %ile BackOfQ(50%),veh/ln | 0.2 | 0.0 | 1.2 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | 1.4 | 0.0 | 0.4 |
| Unsig. Movement Delay, s/veh | | | | | | | | | | | | |
| LnGrp Delay(d),s/veh | 15.4 | 0.0 | 17.7 | 17.9 | 0.0 | 0.0 | 0.0 | 0.0 | 14.3 | 7.6 | 0.0 | 4.7 |
| LnGrp LOS | B | A | B | B | A | | A | A | B | A | A | A |
| Approach Vol, veh/h | | 163 | | | 175 | A | | 179 | | | 466 | |
| Approach Delay, s/veh | | 17.4 | | | 17.9 | | | 14.3 | | | 6.8 | |
| Approach LOS | | B | | | B | | | B | | | A | |
| Timer - Assigned Phs | 1 | 2 | | 4 | | 6 | | 8 | | | | |
| Phs Duration (G+Y+Rc), s | 11.7 | 18.3 | | 12.8 | | 30.0 | | 12.8 | | | | |
| Change Period (Y+Rc), s | 4.5 | 6.0 | | 6.0 | | 6.0 | | 6.0 | | | | |
| Max Green Setting (Gmax), s | 8.5 | 11.0 | | 14.0 | | 24.0 | | 14.0 | | | | |
| Max Q Clear Time (g_c+I1), s | 7.1 | 5.6 | | 5.0 | | 3.4 | | 6.4 | | | | |
| Green Ext Time (p_c), s | 0.2 | 0.4 | | 0.5 | | 0.6 | | 0.5 | | | | |
| Intersection Summary | | | | | | | | | | | | |
| HCM 6th Ctrl Delay | | | 11.9 | | | | | | | | | |
| HCM 6th LOS | | | B | | | | | | | | | |

**Notes**

Unsignalized Delay for [WBR] is excluded from calculations of the approach delay and intersection delay.

Scenario 1 2:15 pm 11/04/2022 Baseline

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Alternative 2 PM 2022

| Movement | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | ↰ | ↱ | | | ↰ | ↱ | | ✣ | | ↰ | ↱ | |
| Traffic Volume (veh/h) | 19 | 120 | 11 | 27 | 134 | 513 | 0 | 59 | 106 | 318 | 73 | 38 |
| Future Volume (veh/h) | 19 | 120 | 11 | 27 | 134 | 513 | 0 | 59 | 106 | 318 | 73 | 38 |
| Initial Q (Qb), veh | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ped-Bike Adj(A_pbT) | 1.00 | | 1.00 | 1.00 | | 1.00 | 1.00 | | 1.00 | 1.00 | | 1.00 |
| Parking Bus, Adj | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Work Zone On Approach | | No | | | No | | | No | | | No | |
| Adj Sat Flow, veh/h/ln | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 | 1870 |
| Adj Flow Rate, veh/h | 24 | 150 | 14 | 33 | 165 | 0 | 0 | 74 | 132 | 391 | 90 | 47 |
| Peak Hour Factor | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 | 0.92 |
| Percent Heavy Veh, % | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Cap, veh/h | 379 | 295 | 28 | 118 | 258 | | 0 | 169 | 301 | 699 | 653 | 341 |
| Arrive On Green | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.00 | 0.00 | 0.28 | 0.28 | 0.19 | 0.56 | 0.56 |
| Sat Flow, veh/h | 1221 | 1685 | 157 | 155 | 1472 | 1585 | 0 | 602 | 1075 | 1781 | 1157 | 604 |
| Grp Volume(v), veh/h | 24 | 0 | 164 | 198 | 0 | 0 | 0 | 0 | 206 | 391 | 0 | 137 |
| Grp Sat Flow(s),veh/h/ln | 1221 | 0 | 1842 | 1627 | 0 | 1585 | 0 | 0 | 1677 | 1781 | 0 | 1762 |
| Q Serve(g_s), s | 0.0 | 0.0 | 3.7 | 1.7 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | 6.3 | 0.0 | 1.7 |
| Cycle Q Clear(g_c), s | 0.7 | 0.0 | 3.7 | 5.4 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | 6.3 | 0.0 | 1.7 |
| Prop In Lane | 1.00 | | 0.09 | 0.17 | | 1.00 | 0.00 | | 0.64 | 1.00 | | 0.34 |
| Lane Grp Cap(c), veh/h | 379 | 0 | 323 | 376 | 0 | | 0 | 0 | 470 | 699 | 0 | 994 |
| V/C Ratio(X) | 0.06 | 0.00 | 0.51 | 0.53 | 0.00 | | 0.00 | 0.00 | 0.44 | 0.56 | 0.00 | 0.14 |
| Avail Cap(c_a), veh/h | 616 | 0 | 680 | 709 | 0 | | 0 | 0 | 470 | 773 | 0 | 994 |
| HCM Platoon Ratio | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Upstream Filter(I) | 1.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 1.00 |
| Uniform Delay (d), s/veh | 16.0 | 0.0 | 17.2 | 17.8 | 0.0 | 0.0 | 0.0 | 0.0 | 13.6 | 7.8 | 0.0 | 4.7 |
| Incr Delay (d2), s/veh | 0.1 | 0.0 | 1.2 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.7 | 0.0 | 0.3 |
| Initial Q Delay(d3),s/veh | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| %ile BackOfQ(50%),veh/ln | 0.2 | 0.0 | 1.5 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 1.8 | 0.0 | 0.5 |
| Unsig. Movement Delay, s/veh | | | | | | | | | | | | |
| LnGrp Delay(d),s/veh | 16.0 | 0.0 | 18.4 | 18.9 | 0.0 | 0.0 | 0.0 | 0.0 | 16.6 | 8.5 | 0.0 | 5.0 |
| LnGrp LOS | B | A | B | B | A | | A | A | B | A | A | A |
| Approach Vol, veh/h | | 188 | | | 198 | A | | 206 | | | 528 | |
| Approach Delay, s/veh | | 18.1 | | | 18.9 | | | 16.6 | | | 7.6 | |
| Approach LOS | | B | | | B | | | B | | | A | |
| Timer - Assigned Phs | 1 | 2 | | 4 | | 6 | | 8 | | | | |
| Phs Duration (G+Y+Rc), s | 13.1 | 18.9 | | 14.1 | | 32.0 | | 14.1 | | | | |
| Change Period (Y+Rc), s | 4.5 | 6.0 | | 6.0 | | 6.0 | | 6.0 | | | | |
| Max Green Setting (Gmax), s | 10.5 | 11.0 | | 17.0 | | 26.0 | | 17.0 | | | | |
| Max Q Clear Time (g_c+I1), s | 8.3 | 6.6 | | 5.7 | | 3.7 | | 7.4 | | | | |
| Green Ext Time (p_c), s | 0.3 | 0.4 | | 0.7 | | 0.7 | | 0.7 | | | | |
| Intersection Summary | | | | | | | | | | | | |
| HCM 6th Ctrl Delay | | | 13.0 | | | | | | | | | |
| HCM 6th LOS | | | B | | | | | | | | | |

Notes

Unsignalized Delay for [WBR] is excluded from calculations of the approach delay and intersection delay.



Alternative 2 PM 2042

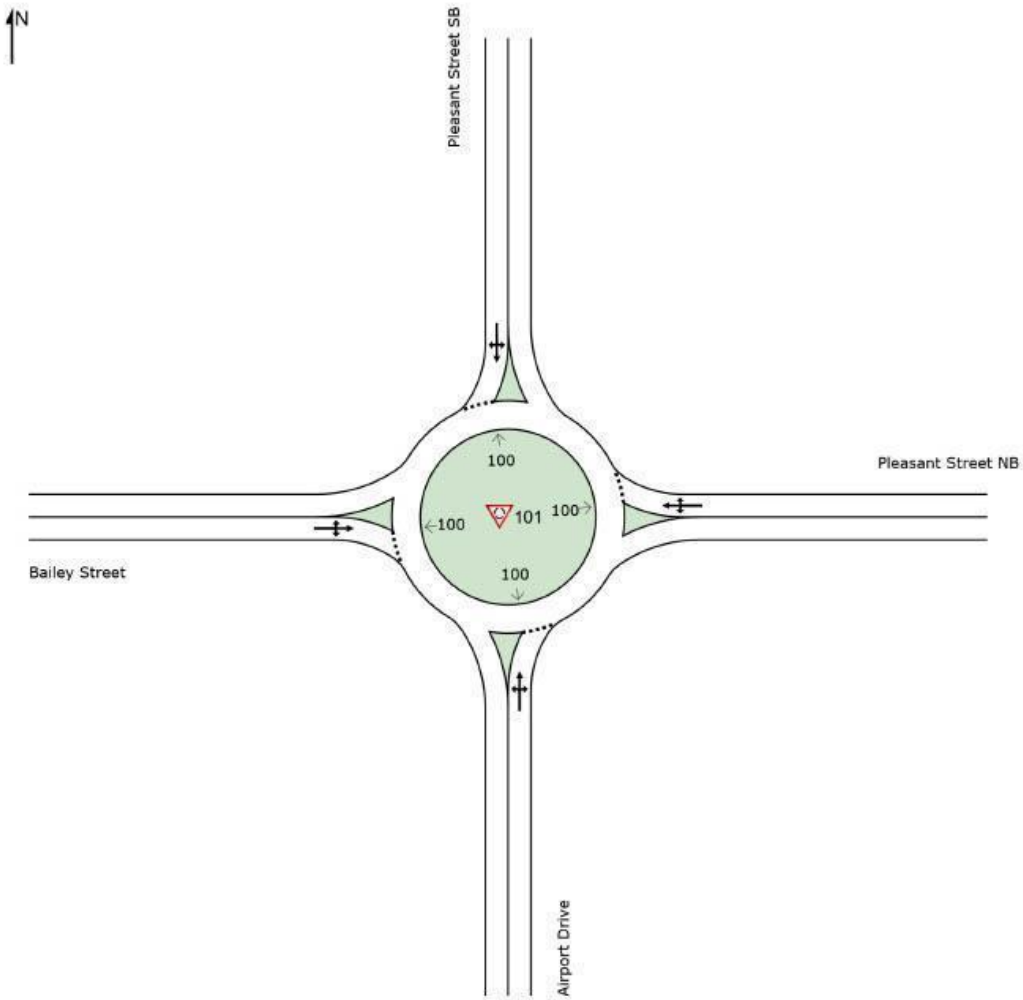
## Appendix H: Alternative 3 Sidra Analysis

### SITE LAYOUT

**Site: 101 [Worcester - Airport Rotary 2022 AM (Site Folder: General)]**

New Site
Site Category: (None)
Roundabout

Layout pictures are schematic functional drawings reflecting input data. They are not design drawings.

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Project: S:\D3\Projects\Traffic\Joe\Worcester\WPI MQP - Worcester Pleasant Street Files\Roundabout Analysis file.sip9

# MOVEMENT SUMMARY

**Site: 101 [Worcester - Airport Rotary 2022 AM (Site Folder: General)]**

New Site
Site Category: (None)
Roundabout

**Vehicle Movement Performance**

| Mov ID | Turn | INPUT VOLUMES [ Total veh/h | HV ] % | DEMAND FLOWS [ Total veh/h | HV ] % | Deg. Satn v/c | Aver. Delay sec | Level of Service | 95% BACK OF QUEUE [ Veh. veh | Dist ] ft | Prop. Que | Effective Stop Rate | Aver. No. Cycles | Aver. Speed mph |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South: Airport Drive | | | | | | | | | | | | | | |
| 3 | L2 | 3 | 0.0 | 3 | 0.0 | 0.123 | 9.6 | LOS A | 0.4 | 11.3 | 0.70 | 0.70 | 0.70 | 32.7 |
| 8 | T1 | 20 | 2.0 | 22 | 2.0 | 0.123 | 9.8 | LOS A | 0.4 | 11.3 | 0.70 | 0.70 | 0.70 | 32.6 |
| 18 | R2 | 28 | 2.0 | 30 | 2.0 | 0.123 | 9.8 | LOS A | 0.4 | 11.3 | 0.70 | 0.70 | 0.70 | 31.7 |
| Approach | | 51 | 1.9 | 55 | 1.9 | 0.123 | 9.7 | LOS A | 0.4 | 11.3 | 0.70 | 0.70 | 0.70 | 32.1 |
| East: Pleasant Street NB | | | | | | | | | | | | | | |
| 1 | L2 | 41 | 2.0 | 45 | 2.0 | 0.266 | 5.1 | LOS A | 1.4 | 36.7 | 0.18 | 0.07 | 0.18 | 34.8 |
| 6 | T1 | 35 | 2.0 | 38 | 2.0 | 0.266 | 5.1 | LOS A | 1.4 | 36.7 | 0.18 | 0.07 | 0.18 | 34.7 |
| 16 | R2 | 240 | 2.0 | 261 | 2.0 | 0.266 | 5.1 | LOS A | 1.4 | 36.7 | 0.18 | 0.07 | 0.18 | 33.7 |
| Approach | | 316 | 2.0 | 343 | 2.0 | 0.266 | 5.1 | LOS A | 1.4 | 36.7 | 0.18 | 0.07 | 0.18 | 33.9 |
| North: Pleasant Street SB | | | | | | | | | | | | | | |
| 7 | L2 | 647 | 2.0 | 703 | 2.0 | 0.707 | 13.1 | LOS B | 7.8 | 199.4 | 0.56 | 0.30 | 0.56 | 29.6 |
| 4 | T1 | 146 | 2.0 | 159 | 2.0 | 0.707 | 13.1 | LOS B | 7.8 | 199.4 | 0.56 | 0.30 | 0.56 | 29.6 |
| 14 | R2 | 12 | 2.0 | 13 | 2.0 | 0.707 | 13.1 | LOS B | 7.8 | 199.4 | 0.56 | 0.30 | 0.56 | 28.8 |
| Approach | | 805 | 2.0 | 875 | 2.0 | 0.707 | 13.1 | LOS B | 7.8 | 199.4 | 0.56 | 0.30 | 0.56 | 29.6 |
| West: Bailey Street | | | | | | | | | | | | | | |
| 5 | L2 | 18 | 0.0 | 20 | 0.0 | 0.710 | 25.0 | LOS C | 5.8 | 145.3 | 0.87 | 1.13 | 1.75 | 26.9 |
| 2 | T1 | 317 | 0.0 | 345 | 0.0 | 0.710 | 25.0 | LOS C | 5.8 | 145.3 | 0.87 | 1.13 | 1.75 | 26.9 |
| 12 | R2 | 16 | 0.0 | 17 | 0.0 | 0.710 | 25.0 | LOS C | 5.8 | 145.3 | 0.87 | 1.13 | 1.75 | 26.3 |
| Approach | | 351 | 0.0 | 382 | 0.0 | 0.710 | 25.0 | LOS C | 5.8 | 145.3 | 0.87 | 1.13 | 1.75 | 26.8 |
| All Vehicles | | 1523 | 1.5 | 1655 | 1.5 | 0.710 | 14.1 | LOS B | 7.8 | 199.4 | 0.56 | 0.46 | 0.76 | 29.7 |

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

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# MOVEMENT SUMMARY

## Site: 101 [Worcester - Airport Rotary 2022 PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

**Vehicle Movement Performance**

| Mov ID | Turn | INPUT VOLUMES [ Total veh/h | HV ] % | DEMAND FLOWS [ Total veh/h | HV ] % | Deg. Satn v/c | Aver. Delay sec | Level of Service | 95% BACK OF QUEUE [ Veh. veh | Dist ] ft | Prop. Que | Effective Stop Rate | Aver. No. Cycles | Aver. Speed mph |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South: Airport Drive | | | | | | | | | | | | | | |
| 3 | L2 | 1 | 0.0 | 1 | 0.0 | 0.223 | 6.7 | LOS A | 1.0 | 24.8 | 0.58 | 0.53 | 0.58 | 34.4 |
| 8 | T1 | 106 | 2.0 | 115 | 2.0 | 0.223 | 6.8 | LOS A | 1.0 | 24.8 | 0.58 | 0.53 | 0.58 | 34.2 |
| 18 | R2 | 59 | 2.0 | 64 | 2.0 | 0.223 | 6.8 | LOS A | 1.0 | 24.8 | 0.58 | 0.53 | 0.58 | 33.2 |
| Approach | | 166 | 2.0 | 180 | 2.0 | 0.223 | 6.8 | LOS A | 1.0 | 24.8 | 0.58 | 0.53 | 0.58 | 33.9 |
| East: Pleasant Street NB | | | | | | | | | | | | | | |
| 1 | L2 | 27 | 2.0 | 29 | 2.0 | 0.624 | 11.1 | LOS B | 5.4 | 136.2 | 0.56 | 0.36 | 0.56 | 32.0 |
| 6 | T1 | 134 | 2.0 | 146 | 2.0 | 0.624 | 11.1 | LOS B | 5.4 | 136.2 | 0.56 | 0.36 | 0.56 | 32.0 |
| 16 | R2 | 513 | 2.0 | 558 | 2.0 | 0.624 | 11.1 | LOS B | 5.4 | 136.2 | 0.56 | 0.36 | 0.56 | 31.1 |
| Approach | | 674 | 2.0 | 733 | 2.0 | 0.624 | 11.1 | LOS B | 5.4 | 136.2 | 0.56 | 0.36 | 0.56 | 31.3 |
| North: Pleasant Street SB | | | | | | | | | | | | | | |
| 7 | L2 | 318 | 2.0 | 346 | 2.0 | 0.414 | 7.5 | LOS A | 2.5 | 63.6 | 0.46 | 0.31 | 0.46 | 32.0 |
| 4 | T1 | 73 | 2.0 | 79 | 2.0 | 0.414 | 7.5 | LOS A | 2.5 | 63.6 | 0.46 | 0.31 | 0.46 | 32.0 |
| 14 | R2 | 38 | 2.0 | 41 | 2.0 | 0.414 | 7.5 | LOS A | 2.5 | 63.6 | 0.46 | 0.31 | 0.46 | 31.1 |
| Approach | | 429 | 2.0 | 466 | 2.0 | 0.414 | 7.5 | LOS A | 2.5 | 63.6 | 0.46 | 0.31 | 0.46 | 32.0 |
| West: Bailey Street | | | | | | | | | | | | | | |
| 5 | L2 | 19 | 0.0 | 21 | 0.0 | 0.190 | 6.1 | LOS A | 0.8 | 21.0 | 0.55 | 0.49 | 0.55 | 34.4 |
| 2 | T1 | 120 | 0.0 | 130 | 0.0 | 0.190 | 6.1 | LOS A | 0.8 | 21.0 | 0.55 | 0.49 | 0.55 | 34.3 |
| 12 | R2 | 11 | 0.0 | 12 | 0.0 | 0.190 | 6.1 | LOS A | 0.8 | 21.0 | 0.55 | 0.49 | 0.55 | 33.4 |
| Approach | | 150 | 0.0 | 163 | 0.0 | 0.190 | 6.1 | LOS A | 0.8 | 21.0 | 0.55 | 0.49 | 0.55 | 34.3 |
| All Vehicles | | 1419 | 1.8 | 1542 | 1.8 | 0.624 | 9.0 | LOS A | 5.4 | 136.2 | 0.53 | 0.38 | 0.53 | 32.1 |

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

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## MOVEMENT SUMMARY

### Site: 101 [Worcester - Airport Rotary 2026 AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

**Vehicle Movement Performance**

| Mov ID | Turn | INPUT VOLUMES [ Total veh/h | HV ] % | DEMAND FLOWS [ Total veh/h | HV ] % | Deg. Satn v/c | Aver. Delay sec | Level of Service | 95% BACK OF QUEUE [ Veh. veh | Dist ] ft | Prop. Que | Effective Stop Rate | Aver. No. Cycles | Aver. Speed mph |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South: Airport Drive | | | | | | | | | | | | | | |
| 3 | L2 | 3 | 0.0 | 3 | 0.0 | 0.133 | 10.1 | LOS B | 0.5 | 12.1 | 0.71 | 0.71 | 0.71 | 32.5 |
| 8 | T1 | 21 | 2.0 | 23 | 2.0 | 0.133 | 10.2 | LOS B | 0.5 | 12.1 | 0.71 | 0.71 | 0.71 | 32.4 |
| 18 | R2 | 29 | 2.0 | 32 | 2.0 | 0.133 | 10.2 | LOS B | 0.5 | 12.1 | 0.71 | 0.71 | 0.71 | 31.5 |
| Approach | | 53 | 1.9 | 58 | 1.9 | 0.133 | 10.2 | LOS B | 0.5 | 12.1 | 0.71 | 0.71 | 0.71 | 31.9 |
| East: Pleasant Street NB | | | | | | | | | | | | | | |
| 1 | L2 | 42 | 2.0 | 46 | 2.0 | 0.274 | 5.2 | LOS A | 1.5 | 38.2 | 0.19 | 0.07 | 0.19 | 34.7 |
| 6 | T1 | 36 | 2.0 | 39 | 2.0 | 0.274 | 5.2 | LOS A | 1.5 | 38.2 | 0.19 | 0.07 | 0.19 | 34.7 |
| 16 | R2 | 247 | 2.0 | 268 | 2.0 | 0.274 | 5.2 | LOS A | 1.5 | 38.2 | 0.19 | 0.07 | 0.19 | 33.6 |
| Approach | | 325 | 2.0 | 353 | 2.0 | 0.274 | 5.2 | LOS A | 1.5 | 38.2 | 0.19 | 0.07 | 0.19 | 33.9 |
| North: Pleasant Street SB | | | | | | | | | | | | | | |
| 7 | L2 | 666 | 2.0 | 724 | 2.0 | 0.729 | 14.0 | LOS B | 8.5 | 216.2 | 0.59 | 0.33 | 0.59 | 29.3 |
| 4 | T1 | 150 | 2.0 | 163 | 2.0 | 0.729 | 14.0 | LOS B | 8.5 | 216.2 | 0.59 | 0.33 | 0.59 | 29.3 |
| 14 | R2 | 12 | 2.0 | 13 | 2.0 | 0.729 | 14.0 | LOS B | 8.5 | 216.2 | 0.59 | 0.33 | 0.59 | 28.5 |
| Approach | | 828 | 2.0 | 900 | 2.0 | 0.729 | 14.0 | LOS B | 8.5 | 216.2 | 0.59 | 0.33 | 0.59 | 29.3 |
| West: Bailey Street | | | | | | | | | | | | | | |
| 5 | L2 | 19 | 0.0 | 21 | 0.0 | 0.752 | 28.7 | LOS D | 6.6 | 165.1 | 0.89 | 1.20 | 1.93 | 25.8 |
| 2 | T1 | 327 | 0.0 | 355 | 0.0 | 0.752 | 28.7 | LOS D | 6.6 | 165.1 | 0.89 | 1.20 | 1.93 | 25.7 |
| 12 | R2 | 16 | 0.0 | 17 | 0.0 | 0.752 | 28.7 | LOS D | 6.6 | 165.1 | 0.89 | 1.20 | 1.93 | 25.2 |
| Approach | | 362 | 0.0 | 393 | 0.0 | 0.752 | 28.7 | LOS D | 6.6 | 165.1 | 0.89 | 1.20 | 1.93 | 25.7 |
| All Vehicles | | 1568 | 1.5 | 1704 | 1.5 | 0.752 | 15.4 | LOS C | 8.5 | 216.2 | 0.58 | 0.49 | 0.82 | 29.2 |

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

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## MOVEMENT SUMMARY

### Site: 101 [Worcester - Airport Rotary 2026 PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

**Vehicle Movement Performance**

| Mov ID | Turn | INPUT VOLUMES [ Total veh/h | HV ] % | DEMAND FLOWS [ Total veh/h | HV ] % | Deg. Satn v/c | Aver. Delay sec | Level of Service | 95% BACK OF QUEUE [ Veh. veh | Dist ] ft | Prop. Que | Effective Stop Rate | Aver. No. Cycles | Aver. Speed mph |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South: Airport Drive | | | | | | | | | | | | | | |
| 3 | L2 | 1 | 0.0 | 1 | 0.0 | 0.231 | 6.9 | LOS A | 1.0 | 25.7 | 0.58 | 0.55 | 0.58 | 34.3 |
| 8 | T1 | 109 | 2.0 | 118 | 2.0 | 0.231 | 7.0 | LOS A | 1.0 | 25.7 | 0.58 | 0.55 | 0.58 | 34.1 |
| 18 | R2 | 60 | 2.0 | 65 | 2.0 | 0.231 | 7.0 | LOS A | 1.0 | 25.7 | 0.58 | 0.55 | 0.58 | 33.2 |
| Approach | | 170 | 2.0 | 185 | 2.0 | 0.231 | 7.0 | LOS A | 1.0 | 25.7 | 0.58 | 0.55 | 0.58 | 33.8 |
| East: Pleasant Street NB | | | | | | | | | | | | | | |
| 1 | L2 | 28 | 2.0 | 30 | 2.0 | 0.642 | 11.6 | LOS B | 5.7 | 144.2 | 0.59 | 0.38 | 0.59 | 31.8 |
| 6 | T1 | 137 | 2.0 | 149 | 2.0 | 0.642 | 11.6 | LOS B | 5.7 | 144.2 | 0.59 | 0.38 | 0.59 | 31.8 |
| 16 | R2 | 526 | 2.0 | 572 | 2.0 | 0.642 | 11.6 | LOS B | 5.7 | 144.2 | 0.59 | 0.38 | 0.59 | 30.9 |
| Approach | | 691 | 2.0 | 751 | 2.0 | 0.642 | 11.6 | LOS B | 5.7 | 144.2 | 0.59 | 0.38 | 0.59 | 31.1 |
| North: Pleasant Street SB | | | | | | | | | | | | | | |
| 7 | L2 | 326 | 2.0 | 354 | 2.0 | 0.426 | 7.7 | LOS A | 2.6 | 66.4 | 0.47 | 0.32 | 0.47 | 32.0 |
| 4 | T1 | 75 | 2.0 | 82 | 2.0 | 0.426 | 7.7 | LOS A | 2.6 | 66.4 | 0.47 | 0.32 | 0.47 | 31.9 |
| 14 | R2 | 39 | 2.0 | 42 | 2.0 | 0.426 | 7.7 | LOS A | 2.6 | 66.4 | 0.47 | 0.32 | 0.47 | 31.1 |
| Approach | | 440 | 2.0 | 478 | 2.0 | 0.426 | 7.7 | LOS A | 2.6 | 66.4 | 0.47 | 0.32 | 0.47 | 31.9 |
| West: Bailey Street | | | | | | | | | | | | | | |
| 5 | L2 | 19 | 0.0 | 21 | 0.0 | 0.196 | 6.2 | LOS A | 0.9 | 21.7 | 0.56 | 0.50 | 0.56 | 34.4 |
| 2 | T1 | 123 | 0.0 | 134 | 0.0 | 0.196 | 6.2 | LOS A | 0.9 | 21.7 | 0.56 | 0.50 | 0.56 | 34.3 |
| 12 | R2 | 11 | 0.0 | 12 | 0.0 | 0.196 | 6.2 | LOS A | 0.9 | 21.7 | 0.56 | 0.50 | 0.56 | 33.3 |
| Approach | | 153 | 0.0 | 166 | 0.0 | 0.196 | 6.2 | LOS A | 0.9 | 21.7 | 0.56 | 0.50 | 0.56 | 34.2 |
| All Vehicles | | 1454 | 1.8 | 1580 | 1.8 | 0.642 | 9.3 | LOS A | 5.7 | 144.2 | 0.55 | 0.40 | 0.55 | 31.9 |

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

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## MOVEMENT SUMMARY

### Site: 101 [Worcester - Airport Rotary 2042 AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

**Vehicle Movement Performance**

| Mov ID | Turn | INPUT VOLUMES [ Total veh/h | HV ] % | DEMAND FLOWS [ Total veh/h | HV ] % | Deg. Satn v/c | Aver. Delay sec | Level of Service | 95% BACK OF QUEUE [ Veh. veh | Dist ] ft | Prop. Que | Effective Stop Rate | Aver. No. Cycles | Aver. Speed mph |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South: Airport Drive | | | | | | | | | | | | | | |
| 3 | L2 | 3 | 0.0 | 3 | 0.0 | 0.164 | 11.9 | LOS B | 0.6 | 14.8 | 0.75 | 0.75 | 0.75 | 31.7 |
| 8 | T1 | 23 | 2.0 | 25 | 2.0 | 0.164 | 12.1 | LOS B | 0.6 | 14.8 | 0.75 | 0.75 | 0.75 | 31.6 |
| 18 | R2 | 32 | 2.0 | 35 | 2.0 | 0.164 | 12.1 | LOS B | 0.6 | 14.8 | 0.75 | 0.75 | 0.75 | 30.7 |
| Approach | | 58 | 1.9 | 63 | 1.9 | 0.164 | 12.0 | LOS B | 0.6 | 14.8 | 0.75 | 0.75 | 0.75 | 31.1 |
| East: Pleasant Street NB | | | | | | | | | | | | | | |
| 1 | L2 | 47 | 2.0 | 51 | 2.0 | 0.305 | 5.6 | LOS A | 1.7 | 44.1 | 0.21 | 0.09 | 0.21 | 34.6 |
| 6 | T1 | 40 | 2.0 | 43 | 2.0 | 0.305 | 5.6 | LOS A | 1.7 | 44.1 | 0.21 | 0.09 | 0.21 | 34.5 |
| 16 | R2 | 273 | 2.0 | 297 | 2.0 | 0.305 | 5.6 | LOS A | 1.7 | 44.1 | 0.21 | 0.09 | 0.21 | 33.5 |
| Approach | | 360 | 2.0 | 391 | 2.0 | 0.305 | 5.6 | LOS A | 1.7 | 44.1 | 0.21 | 0.09 | 0.21 | 33.7 |
| North: Pleasant Street SB | | | | | | | | | | | | | | |
| 7 | L2 | 736 | 2.0 | 800 | 2.0 | 0.815 | 18.4 | LOS C | 11.9 | 301.3 | 0.79 | 0.46 | 0.79 | 27.7 |
| 4 | T1 | 166 | 2.0 | 180 | 2.0 | 0.815 | 18.4 | LOS C | 11.9 | 301.3 | 0.79 | 0.46 | 0.79 | 27.7 |
| 14 | R2 | 14 | 2.0 | 15 | 2.0 | 0.815 | 18.4 | LOS C | 11.9 | 301.3 | 0.79 | 0.46 | 0.79 | 27.1 |
| Approach | | 916 | 2.0 | 996 | 2.0 | 0.815 | 18.4 | LOS C | 11.9 | 301.3 | 0.79 | 0.46 | 0.79 | 27.7 |
| West: Bailey Street | | | | | | | | | | | | | | |
| 5 | L2 | 21 | 0.0 | 23 | 0.0 | 0.933 | 55.8 | LOS F | 12.9 | 322.4 | 0.97 | 1.65 | 3.32 | 19.7 |
| 2 | T1 | 366 | 0.0 | 398 | 0.0 | 0.933 | 55.8 | LOS F | 12.9 | 322.4 | 0.97 | 1.65 | 3.32 | 19.7 |
| 12 | R2 | 18 | 0.0 | 20 | 0.0 | 0.933 | 55.8 | LOS F | 12.9 | 322.4 | 0.97 | 1.65 | 3.32 | 19.4 |
| Approach | | 405 | 0.0 | 440 | 0.0 | 0.933 | 55.8 | LOS F | 12.9 | 322.4 | 0.97 | 1.65 | 3.32 | 19.7 |
| All Vehicles | | 1739 | 1.5 | 1890 | 1.5 | 0.933 | 24.2 | LOS C | 12.9 | 322.4 | 0.71 | 0.67 | 1.26 | 26.3 |

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

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## MOVEMENT SUMMARY

**Site: 101 [Worcester - Airport Rotary 2042 PM (Site Folder: General)]**

New Site
Site Category: (None)
Roundabout

**Vehicle Movement Performance**

| Mov ID | Turn | INPUT VOLUMES [ Total veh/h | HV ] % | DEMAND FLOWS [ Total veh/h | HV ] % | Deg. Satn v/c | Aver. Delay sec | Level of Service | 95% BACK OF QUEUE [ Veh. veh | Dist ] ft | Prop. Que | Effective Stop Rate | Aver. No. Cycles | Aver. Speed mph |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South: Airport Drive | | | | | | | | | | | | | | |
| 3 | L2 | 1 | 0.0 | 1 | 0.0 | 0.269 | 7.7 | LOS A | 1.2 | 30.2 | 0.62 | 0.60 | 0.62 | 33.9 |
| 8 | T1 | 120 | 2.0 | 130 | 2.0 | 0.269 | 7.8 | LOS A | 1.2 | 30.2 | 0.62 | 0.60 | 0.62 | 33.7 |
| 18 | R2 | 67 | 2.0 | 73 | 2.0 | 0.269 | 7.8 | LOS A | 1.2 | 30.2 | 0.62 | 0.60 | 0.62 | 32.8 |
| Approach | | 188 | 2.0 | 204 | 2.0 | 0.269 | 7.8 | LOS A | 1.2 | 30.2 | 0.62 | 0.60 | 0.62 | 33.4 |
| East: Pleasant Street NB | | | | | | | | | | | | | | |
| 1 | L2 | 31 | 2.0 | 34 | 2.0 | 0.723 | 14.3 | LOS B | 8.3 | 209.9 | 0.70 | 0.48 | 0.73 | 30.7 |
| 6 | T1 | 154 | 2.0 | 167 | 2.0 | 0.723 | 14.3 | LOS B | 8.3 | 209.9 | 0.70 | 0.48 | 0.73 | 30.6 |
| 16 | R2 | 589 | 2.0 | 640 | 2.0 | 0.723 | 14.3 | LOS B | 8.3 | 209.9 | 0.70 | 0.48 | 0.73 | 29.8 |
| Approach | | 774 | 2.0 | 841 | 2.0 | 0.723 | 14.3 | LOS B | 8.3 | 209.9 | 0.70 | 0.48 | 0.73 | 30.0 |
| North: Pleasant Street SB | | | | | | | | | | | | | | |
| 7 | L2 | 365 | 2.0 | 397 | 2.0 | 0.489 | 8.8 | LOS A | 3.2 | 81.0 | 0.53 | 0.39 | 0.53 | 31.5 |
| 4 | T1 | 84 | 2.0 | 91 | 2.0 | 0.489 | 8.8 | LOS A | 3.2 | 81.0 | 0.53 | 0.39 | 0.53 | 31.4 |
| 14 | R2 | 44 | 2.0 | 48 | 2.0 | 0.489 | 8.8 | LOS A | 3.2 | 81.0 | 0.53 | 0.39 | 0.53 | 30.6 |
| Approach | | 493 | 2.0 | 536 | 2.0 | 0.489 | 8.8 | LOS A | 3.2 | 81.0 | 0.53 | 0.39 | 0.53 | 31.4 |
| West: Bailey Street | | | | | | | | | | | | | | |
| 5 | L2 | 12 | 0.0 | 13 | 0.0 | 0.228 | 6.9 | LOS A | 1.0 | 25.4 | 0.59 | 0.56 | 0.59 | 34.2 |
| 2 | T1 | 135 | 0.0 | 147 | 0.0 | 0.228 | 6.9 | LOS A | 1.0 | 25.4 | 0.59 | 0.56 | 0.59 | 34.0 |
| 12 | R2 | 21 | 0.0 | 23 | 0.0 | 0.228 | 6.9 | LOS A | 1.0 | 25.4 | 0.59 | 0.56 | 0.59 | 33.1 |
| Approach | | 168 | 0.0 | 183 | 0.0 | 0.228 | 6.9 | LOS A | 1.0 | 25.4 | 0.59 | 0.56 | 0.59 | 33.9 |
| All Vehicles | | 1623 | 1.8 | 1764 | 1.8 | 0.723 | 11.1 | LOS B | 8.3 | 209.9 | 0.63 | 0.48 | 0.64 | 31.2 |

Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if v/c > 1 irrespective of movement delay value (does not apply for approaches and intersection).
Intersection and Approach LOS values are based on average delay for all movements (v/c not used as specified in HCM 6).
Roundabout Capacity Model: US HCM 6.
Delay Model: HCM Delay Formula (Geometric Delay is not included).
Queue Model: HCM Queue Formula.
Gap-Acceptance Capacity: Traditional M1.
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

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Project: S:\D3\Projects\Traffic\Joe\Worcester\WPI MQP - Worcester Pleasant Street Files\Roundabout Analysis file.sip9

## Appendix I: Cost Estimates

| | ALTERNATIVE 1 | | | | |
|---|---|---|---|---|---|
| ITEM # | ITEM DESCRIPTION | UNITS | UNIT COST | QUANTITY | COST |
| 100.0 | SCHEDULE OF OPERATIONS-FIXED PRICE $ | LS | $70,500.00 | 1 | $70,500.00 |
| 101 | CLEARING AND GRUBBING | A | $32,800.00 | 10 | $328,000.00 |
| 120 | EARTH EXCAVATION | CY | $60.00 | 1600 | $96,000.00 |
| 120.1 | UNCLASSIFIED EXCAVATION | CY | $38.50 | 1200 | $46,200.00 |
| 141.1 | TEST PIT FOR EXPLORATION | CY | $103.31 | 10 | $1,033.10 |
| 151 | GRAVEL BORROW | CY | $20.00 | 1200 | $24,000.00 |
| 170 | FINE GRADING AND COMPACTING-SUBGRADE AREA | SY | $8.50 | 8000 | $68,000.00 |
| 201 | CATCH BASIN | EA | $4,500.00 | 2 | $9,000.00 |
| 202 | MANHOLE | EA | $3,495.99 | 2 | $6,991.98 |
| 220 | DRAINAGE STRUCTURE ADJUSTED | EA | $400.00 | 6 | $2,400.00 |
| 220.7 | SANITARY STRUCTURE ADJUSTED | EA | $331.21 | 11 | $3,643.31 |
| 415.2 | PAVEMENT FINE MILLING | SY | $8.75 | 8000 | $70,000.00 |
| 450.23 | SUPERPAVE SURFACE COURSE-9.5 (SSC-12.5) | TON | $130.00 | 120 | $15,600.00 |
| 450.32 | SUPERPAVE INTERMEDIATE COURSE-12.5(SIC-12.5) | TON | $98.42 | 120 | $11,810.40 |
| 451 | HMA FOR PATCHING | TON | $160.84 | 10 | $1,608.40 |
| 505 | GRANITE CURB TYPE VA5-STRAIGHT | FT | $48.25 | 550 | $26,537.50 |
| 505.1 | GRANITE CURB TYPE VA5-CURVED | FT | $48.25 | 350 | $16,887.50 |
| 510 | GRANITE EDGING TYPE SA | FT | $48.25 | 200 | $9,650.00 |
| 514 | GRANITE CURB INLET-STRAIGHT | FT | $430.00 | 6 | $2,580.00 |
| 701 | CEMENT CONCRETE SIDEWALK | SY | $125.00 | 160 | $20,000.00 |
| 701.2 | CEMENT CONCRETE PEDESTRIAN CURB RAMP | SY | $122.50 | 20 | $2,450.00 |
| 734 | SIGN REMOVED AND RESET | EA | $162.50 | 10 | $1,625.00 |
| 740 | ENGINEERS FIELD OFFICE AND EQUIPMENT (TYPE A) | MO | $3,000.00 | 1 | $3,000.00 |
| 748 | MOBILIZATION | LS | $204,000.00 | 1 | $204,000.00 |
| 751 | LOAM FOR ROADSIDES | CY | $50.00 | 200 | $10,000.00 |
| 765 | SEEDING | SY | $2.40 | 200 | $480.00 |
| 767.121 | SEDIMENT CONTROL BARRIER | FT | $6.00 | 300 | $1,800.00 |
| 811.35 | PULL BOX ADJUSTED | EA | $200.00 | 1 | $200.00 |
| 812.3 | STANDARD SIGNAL POST FOUNDATION SD3.030 | EA | $550.00 | 1 | $550.00 |
| 812.41 | MAST ARM FOUNDATION, 42-INCH DIAMETER (7 FT-6 IN. TO 17 FT-0 IN. EMBEDMENT DEPTH) | EA | $3,500.00 | 1 | $3,500.00 |
| 815.513 | TRAFFIC SIGNAL CONTROLLER & CABINET ASSEMBLY, NEMA SIZE 5, TS2 TYPE 1, CONFIGURATION 3 | EA | $16,760.00 | 1 | $16,760.00 |
| 817.602 | STEEL MAST ARM, 40-FOOT TO 60-FOOT SPAN | EA | $6,400.00 | 1 | $6,400.00 |
| 818.003 | SIGNAL HEAD, THREE SECTION | EA | $700.00 | 8 | $5,600.00 |
| 818.42 | PEDESTRIAN SIGNAL HEAD | EA | $650.00 | 4 | $2,600.00 |
| 819.85 | PEDESTRIAN PUSH BUTTON | EA | $65.00 | 4 | $260.00 |
| 851.1 | TRAFFIC CONES FOR TRAFFIC MANAGEMENT | DAY | $1.00 | 50 | $50.00 |
| 860.106 | 6 INCH REFLECTORIZED WHITE LINE (PAINTED) | FT | $1.25 | 2400 | $3,000.00 |
| 860.112 | 12 INCH REFLECTORIZED WHITE LINE (PAINTED) | FT | $2.50 | 480 | $1,200.00 |
| 861.106 | 6 INCH REFLECTORIZED YELLOW LINE (PAINTED) | FT | $1.25 | 2000 | $2,500.00 |
| 861.112 | 12 INCH REFLECTORIZED YELLOW LINE (PAINTED) | FT | $2.50 | 0 | $0.00 |
| 874.2 | TRAFFIC SIGN REMOVED AND RESET | EA | $118.44 | 12 | $1,421.28 |
| | TOTAL | | | | $1,097,838.47 |
| | POLICE (5%) | | | | $54,891.92 |
| | CONTINGENCY (10%) | | | | $109,783.85 |
| | GRAND TOTAL | | | | $1,262,514.24 |

| ALTERNATIVE 2 | | | | | |
|---|---|---|---|---|---|
| ITEM # | ITEM DESCRIPTION | UNITS | UNIT COST | QUANTITY | COST |
| 100.0 | SCHEDULE OF OPERATIONS-FIXED PRICE $ | LS | $70,500.00 | 1 | $70,500.00 |
| 101 | CLEARING AND GRUBBING | A | $32,800.00 | 10 | $328,000.00 |
| 120 | EARTH EXCAVATION | CY | $60.00 | 1484 | $89,040.00 |
| 120.1 | UNCLASSIFIED EXCAVATION | CY | $38.50 | 1037 | $39,924.50 |
| 141.1 | TEST PIT FOR EXPLORATION | CY | $103.31 | 10 | $1,033.10 |
| 151 | GRAVEL BORROW | CY | $20.00 | 1000 | $20,000.00 |
| 170 | FINE GRADING AND COMPACTING-SUBGRADE AREA | SY | $8.50 | 7000 | $59,500.00 |
| 201 | CATCH BASIN | EA | $4,500.00 | 2 | $9,000.00 |
| 202 | MANHOLE | EA | $3,495.99 | 2 | $6,991.98 |
| 220 | DRAINAGE STRUCTURE ADJUSTED | EA | $400.00 | 6 | $2,400.00 |
| 220.7 | SANITARY STRUCTURE ADJUSTED | EA | $331.21 | 11 | $3,643.31 |
| 415.2 | PAVEMENT FINE MILLING | SY | $8.75 | 6500 | $56,875.00 |
| 450.23 | SUPERPAVE SURFACE COURSE-9.5 (SSC-12.5) | TON | $130.00 | 100 | $13,000.00 |
| 450.32 | SUPERPAVE INTERMEDIATE COURSE-12.5(SIC-12.5) | TON | $98.42 | 100 | $9,842.00 |
| 451 | HMA FOR PATCHING | TON | $160.84 | 10 | $1,608.40 |
| 505 | GRANITE CURB TYPE VA5-STRAIGHT | FT | $48.25 | 500 | $24,125.00 |
| 505.1 | GRANITE CURB TYPE VA5-CURVED | FT | $48.25 | 340 | $16,405.00 |
| 510 | GRANITE EDGING TYPE SA | FT | $48.25 | 150 | $7,237.50 |
| 514 | GRANITE CURB INLET-STRAIGHT | FT | $430.00 | 6 | $2,580.00 |
| 701 | CEMENT CONCRETE SIDEWALK | SY | $125.00 | 160 | $20,000.00 |
| 701.2 | CEMENT CONCRETE PEDESTRIAN CURB RAMP | SY | $122.50 | 20 | $2,450.00 |
| 734 | SIGN REMOVED AND RESET | EA | $162.50 | 10 | $1,625.00 |
| 740 | ENGINEERS FIELD OFFICE AND EQUIPMENT (TYPE A) | MO | $3,000.00 | 1 | $3,000.00 |
| 748 | MOBILIZATION | LS | $204,000.00 | 1 | $204,000.00 |
| 751 | LOAM FOR ROADSIDES | CY | $50.00 | 200 | $10,000.00 |
| 765 | SEEDING | SY | $2.40 | 200 | $480.00 |
| 767.121 | SEDIMENT CONTROL BARRIER | FT | $6.00 | 300 | $1,800.00 |
| 811.35 | PULL BOX ADJUSTED | EA | $200.00 | 1 | $200.00 |
| 812.3 | STANDARD SIGNAL POST FOUNDATION SD3.030 | EA | $550.00 | 1 | $550.00 |
| 812.41 | MAST ARM FOUNDATION, 42-INCH DIAMETER (7 FT-6 IN. TO 17 FT-0 IN. EMBEDMENT DEPTH) | EA | $3,500.00 | 1 | $3,500.00 |
| 815.513 | TRAFFIC SIGNAL CONTROLLER & CABINET ASSEMBLY, NEMA SIZE 5, TS2 TYPE 1, CONFIGURATION 3 | EA | $16,760.00 | 1 | $16,760.00 |
| 817.602 | STEEL MAST ARM, 40-FOOT TO 60-FOOT SPAN | EA | $6,400.00 | 1 | $6,400.00 |
| 818.003 | SIGNAL HEAD, THREE SECTION | EA | $700.00 | 8 | $5,600.00 |
| 818.42 | PEDESTRIAN SIGNAL HEAD | EA | $650.00 | 4 | $2,600.00 |
| 819.85 | PEDESTRIAN PUSH BUTTON | EA | $65.00 | 4 | $260.00 |
| 851.1 | TRAFFIC CONES FOR TRAFFIC MANAGEMENT | DAY | $1.00 | 50 | $50.00 |
| 860.106 | 6 INCH REFLECTORIZED WHITE LINE (PAINTED) | FT | $1.25 | 2400 | $3,000.00 |
| 860.112 | 12 INCH REFLECTORIZED WHITE LINE (PAINTED) | FT | $2.50 | 480 | $1,200.00 |
| 861.106 | 6 INCH REFLECTORIZED YELLOW LINE (PAINTED) | FT | $1.25 | 2000 | $2,500.00 |
| 861.112 | 12 INCH REFLECTORIZED YELLOW LINE (PAINTED) | FT | $2.50 | 0 | $0.00 |
| 874.2 | TRAFFIC SIGN REMOVED AND RESET | EA | $118.44 | 12 | $1,421.28 |
| | TOTAL | | | | $1,049,102.07 |
| | POLICE (5%) | | | | $52,455.10 |
| | CONTINGENCY (10%) | | | | $104,910.21 |
| | GRAND TOTAL | | | | $1,206,467.38 |

| ALTERNATIVE 3 | | | | | |
|---|---|---|---|---|---|
| **ITEM #** | **ITEM DESCRIPTION** | **UNITS** | **UNIT COST** | **QUANTITY** | **COST** |
| 100.0 | SCHEDULE OF OPERATIONS-FIXED PRICE $ | LS | $70,500.00 | 1 | $70,500.00 |
| 101 | CLEARING AND GRUBBING | A | $32,800.00 | 10 | $328,000.00 |
| 120 | EARTH EXCAVATION | CY | $60.00 | 1000 | $60,000.00 |
| 120.1 | UNCLASSIFIED EXCAVATION | CY | $38.50 | 1000 | $38,500.00 |
| 141.1 | TEST PIT FOR EXPLORATION | CY | $103.31 | 10 | $1,033.10 |
| 151 | GRAVEL BORROW | CY | $20.00 | 1000 | $20,000.00 |
| 170 | FINE GRADING AND COMPACTING-SUBGRADE AREA | SY | $8.50 | 4000 | $34,000.00 |
| 201 | CATCH BASIN | EA | $4,500.00 | 2 | $9,000.00 |
| 202 | MANHOLE | EA | $3,495.99 | 2 | $6,991.98 |
| 220 | DRAINAGE STRUCTURE ADJUSTED | EA | $400.00 | 6 | $2,400.00 |
| 220.7 | SANITARY STRUCTURE ADJUSTED | EA | $331.21 | 11 | $3,643.31 |
| 415.2 | PAVEMENT FINE MILLING | SY | $8.75 | 9000 | $78,750.00 |
| 450.23 | SUPERPAVE SURFACE COURSE-9.5 (SSC-12.5) | TON | $130.00 | 130 | $16,900.00 |
| 450.32 | SUPERPAVE INTERMEDIATE COURSE-12.5(SIC-12.5) | TON | $98.42 | 130 | $12,794.60 |
| 451 | HMA FOR PATCHING | TON | $160.84 | 10 | $1,608.40 |
| 505 | GRANITE CURB TYPE VA5-STRAIGHT | FT | $48.25 | 250 | $12,062.50 |
| 505.1 | GRANITE CURB TYPE VA5-CURVED | FT | $48.25 | 500 | $24,125.00 |
| 510 | GRANITE EDGING TYPE SA | FT | $48.25 | 300 | $14,475.00 |
| 514 | GRANITE CURB INLET-STRAIGHT | FT | $430.00 | 6 | $2,580.00 |
| 701 | CEMENT CONCRETE SIDEWALK | SY | $125.00 | 160 | $20,000.00 |
| 701.2 | CEMENT CONCRETE PEDESTRIAN CURB RAMP | SY | $122.50 | 20 | $2,450.00 |
| 734 | SIGN REMOVED AND RESET | EA | $162.50 | 10 | $1,625.00 |
| 740 | ENGINEERS FIELD OFFICE AND EQUIPMENT (TYPE A) | MO | $3,000.00 | 1 | $3,000.00 |
| 748 | MOBILIZATION | LS | $204,000.00 | 1 | $204,000.00 |
| 751 | LOAM FOR ROADSIDES | CY | $50.00 | 200 | $10,000.00 |
| 765 | SEEDING | SY | $2.40 | 200 | $480.00 |
| 767.121 | SEDIMENT CONTROL BARRIER | FT | $6.00 | 300 | $1,800.00 |
| 811.35 | PULL BOX ADJUSTED | EA | $200.00 | 1 | $200.00 |
| 851.1 | TRAFFIC CONES FOR TRAFFIC MANAGEMENT | DAY | $1.00 | 50 | $50.00 |
| 860.106 | 6 INCH REFLECTORIZED WHITE LINE (PAINTED) | FT | $1.25 | 2400 | $3,000.00 |
| 860.112 | 12 INCH REFLECTORIZED WHITE LINE (PAINTED) | FT | $2.50 | 480 | $1,200.00 |
| 861.106 | 6 INCH REFLECTORIZED YELLOW LINE (PAINTED) | FT | $1.25 | 2000 | $2,500.00 |
| 861.112 | 12 INCH REFLECTORIZED YELLOW LINE (PAINTED) | FT | $2.50 | 0 | $0.00 |
| 874.2 | TRAFFIC SIGN REMOVED AND RESET | EA | $118.44 | 12 | $1,421.28 |
| | TOTAL | | | | $989,090.17 |
| | POLICE (5%) | | | | $49,454.51 |
| | CONTINGENCY (10%) | | | | $98,909.02 |
| | GRAND TOTAL | | | | $1,137,453.70 |