INTERCHANGE REDESIGN:

MODERNIZING INFRASTRUCTURE IN STERLING, MA

SUBMITTED BY: SAM CALAMARI, BRAEDEN FRUCHTMAN, ABIGAIL PULLING, BRANDON TARANTO

ADVISED BY:SUZANNE LEPAGE

Abstract

This research examined the highway interchange connecting Interstate 190 and State Route 140 in Sterling, Massachusetts. Through a combination of on-site data collection and utilization of pre-existing data from MassDOT, the study pinpointed key problematic areas within the interchange. Subsequently, alternative designs were conceptualized tailored to the site's attributes, aligning with industry standards and employing advanced engineering software to analyze the system. Following the Intersection Control Evaluation (ICE) procedure, which considered factors such as safety, costs, and scalability for future capacity, a recommended redesign strategy emerged. This optimal strategy, a 2-lane roundabout for each I-190 ramp intersection was then visualized using Computer Aided Design (AutoCAD).

Executive Summary

The interchange of Route 140 and Interstate 190 is a primary access point for many people making their daily commutes. Interstate 190, a spur route of Interstate 90, spans 19 miles, connecting the City of Worcester, Massachusetts to the surrounding towns. Our project focused on the entire interchange, which comprises the I-190 Northbound and Southbound intersections, exploring new design options to accommodate the anticipated increase in traffic volumes in future years.

The Massachusetts Department of Transportation (MassDOT) determined this location for a potential redesign, as it has not been analyzed in over a decade. The goal for this Major Qualifying Project (MQP) was to carry out the Intersection Control Evaluation (ICE) process, which is a software utilized by MassDOT. This process analyzed the existing conditions of the site and output possible modern design alternatives for this interchange. The project team then devised potential designs for the intersection and carefully assessed them, considering aspects like cost, feasibility, and anticipated impacts on safety and efficiency. Ultimately, the design that comprehensively addressed all these transportation engineering elements was chosen and conceptualized utilizing modelling software (AutoCAD).

To accomplish the project goals, the following objectives were completed:

1. Understand best practices regarding interchange design.
2. Document existing conditions.
3. Formulate multiple control strategies.
4. Finalize a control strategy as an optimal redesign solution.
5. Develop the optimal strategy to a 10% design phase.

The ICE process conducted for this interchange allowed for a clear control strategy to be chosen. ICE Stage 1 looked at all possible control strategies and through initial intersection assessment, generated fewer possible control strategies. At the end of ICE Stage 2, which through MassDOT's ICE Tool software further analyzed the remaining control strategies, a single optimal control strategy was outputted. This single output was selected by having the highest benefit-cost ratio, as determined by evaluating traffic operations, safety considerations, and estimated costs associated with planning, design, construction, and maintenance, was determined. It was concluded that two multi-lane roundabouts located on Route 140 at the I-190 Northbound and Southbound interchanges would be the most efficient design for this project.

Final Control Strategy Resign on AutoCAD

Authorship
[1]

Section	Author	Editor
Abstract	Abigail	Braeden
Executive Summary	Brandon	Abigail
Acknowledgments	Abigail	Braeden
Capstone Design Statement	All	Braeden
Professional Licensure Statement	Braeden	Abigail
Introduction	Sam	Abigail
Background	Sam	Abigail
MassDOT Intersection Control Evaluation	Sam	Abigail
Interchange Design	Sam	Abigail
Diamond Interchanges	Abigail	Brandon
Route 12 and I-190	Abigail	Brandon
Roundabout Functionality	Abigail	Brandon & Sam
Benefits of a Roundabout	Abigail	Sam
Signalized Intersections	Abigail	Sam
Active Transport	Abigail & Braeden	Abigail
Transportation Engineering Elements	Brandon	Abigail
Overview of Methodology	Brandon & Sam	Abigail
Initial Analysis of Route 140 and I-190 Interchange	Abigail	Sam
Document Existing Conditions	Abigail	Sam
Vehicle Traffic Data	Abigail & Sam	Sam
Pedestrian and Cyclist Data	Abigail & Braeden	Sam
Crash Data	Abigail & Brandon	Sam
Preliminary Stages of the Intersection Control Evaluation	Sam	Braeden
ICE Stage 1	Sam	Braeden & Sam
SIDRA Analysis	Sam	Brandon & Sam
SYNCHRO Analysis	Sam	Brandon & Sam
Finalize an Optimal Control Strategy	Braeden & Sam	Sam
ICE Stage 2	Braeden	Sam
ICE Stage 3	Braeden	Abigail
Design to 10%	Sam	Sam
Limitations	Sam	Sam
Data Collection	Sam	Abigail
ICE Constraints	Braeden	Abigail
Recommendations and Conclusions	Abigail	Braeden
Roundabout and Signalized Control Strategy Combination	Abigail	Braeden
PTV Vissim	Abigail	Braeden
Summary	Braeden	Abigail

[1] AutoCAD Drafting was completed by Sam

Acknowledgments

We would like to thank the individuals and organization whose support and guidance made the successful completion of our project possible. Their collective efforts have been instrumental in guiding us through the challenges of our MQP. First and foremost, we would like to extend appreciation to Professor Lepage. Her insightful advice and continuous encouragement has pushed us to strive for greatness in this academic endeavor, and meet our expectations for the outcome of this project. Additionally, we express our sincere thanks to Joseph Frawley, Lisa Schletzbaum, and Theron Howe from MassDOT. Their generous assistance, guidance, and provision of resources have been indispensable throughout every stage of our project. Their combined efforts and expertise have significantly enriched our work and we are grateful for their contributions.

Capstone Design Statement

This project examined the existing interchange of Route 140 and Interstate 190 and resulted in a potential redesign option presented to MassDOT. To complete the Major Qualifying Project, Worcester Polytechnic Institute required the fulfillment of all the Accreditation Board for Engineering and Technology (ABET) capstone design elements. The following elements were addressed throughout the duration of our project:

Economic: This project will ultimately be completed with public funds. Our team has created a final design within the reasonable financial restraints set by MassDOT and analyzed financial principles to assess the feasibility, cost-effectiveness, and financial viability of the redesign construction project. This involved evaluating factors such as project costs. The cost of construction compared to the design's effectiveness was a crucial measure during final design selection.

Environmental: The potential expansion of the intersection increases local land degradation. While there were no protected areas within the area subject to development, the impact on the environment was considered when making a final design. Construction of roads and interchanges can harm local wildlife and disrupt natural drainage patterns, potentially causing flooding in some areas.

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

Health and Safety: The overall improvements made to the I-190 and Route 140 interchange were made to value the safety of people who use the corridor. Through turning movement counts, crash data, and traffic volume, effective analysis of safety was utilized to improve the interchange.

Constructability: Through possible intersection design strategies as outlined by MassDOT, the team not only looked at possible design strategies but also previous designs to select the best option with specific consideration of the cost and maintenance for the redesign. Specifically, local intersections, similar to the study location, were studied to see what design strategy was used by MassDOT and the effectiveness of it. This highlighted the longevity and functionality of the design and considered factors such as material selection, maintenance, and construction time.

Sustainability: The project aimed to address current needs, as well as prioritize any future needs to find a long-lasting solution as a redesign option for the interchange. The team optimized the intersection design best suited to minimize resource consumption and incorporate design aspects that promote efficiency to minimize the negative environmental, social, and economic impacts.

Professional Licensure Statement

Accredited professional engineers are individuals who have demonstrated both competence and accountability in their work. Upon licensure, they assume full responsibility for the projects they endorse and their impact on the public.

In the United States, the journey to engineering accreditation begins with passing the Fundamentals of Engineering (FE) exam, which serves as a foundational step, designating individuals as Engineering in Training (EIT). After at least four years under guidance of a Professional Engineer, they become eligible to pursue their Professional Engineering License. This licensure involves passing the Principles and Practice of Engineering (PE) exam, tailored to specific engineering disciplines such as Construction or Structural within Civil Engineering.

Once an individual has acquired their PE license, engineers gain the authority to prepare, endorse, and submit engineering plans. This elevated status brings forth increased responsibilities on projects, while simultaneously opening new career avenues. Despite the lengthy process involved in becoming a Professional Engineer, those who persevere emerge equipped with the necessary skills and ethical mindset to navigate projects responsibly and ethically.

Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

Interstate 190 is an auxiliary interstate highway which connects I-290 with Massachusetts Route 2. This auxiliary interstate highway is called a spur route, meaning it connects one main highway to another. The segment our team was focused on is at the interchange of I-190 and Route 140 located in Sterling, Massachusetts. The interchange is often busy during peak rush hours and has led to crashes due to the dangerous orientation of the intersections within the interchange. The section of road under the overpass on Route 140 was restriped in 2022 to include a bike lane and reduce the amount of vehicle lanes; however, even with the inclusion of a shared-use path, the general safety and efficiency of the road remains undetermined.

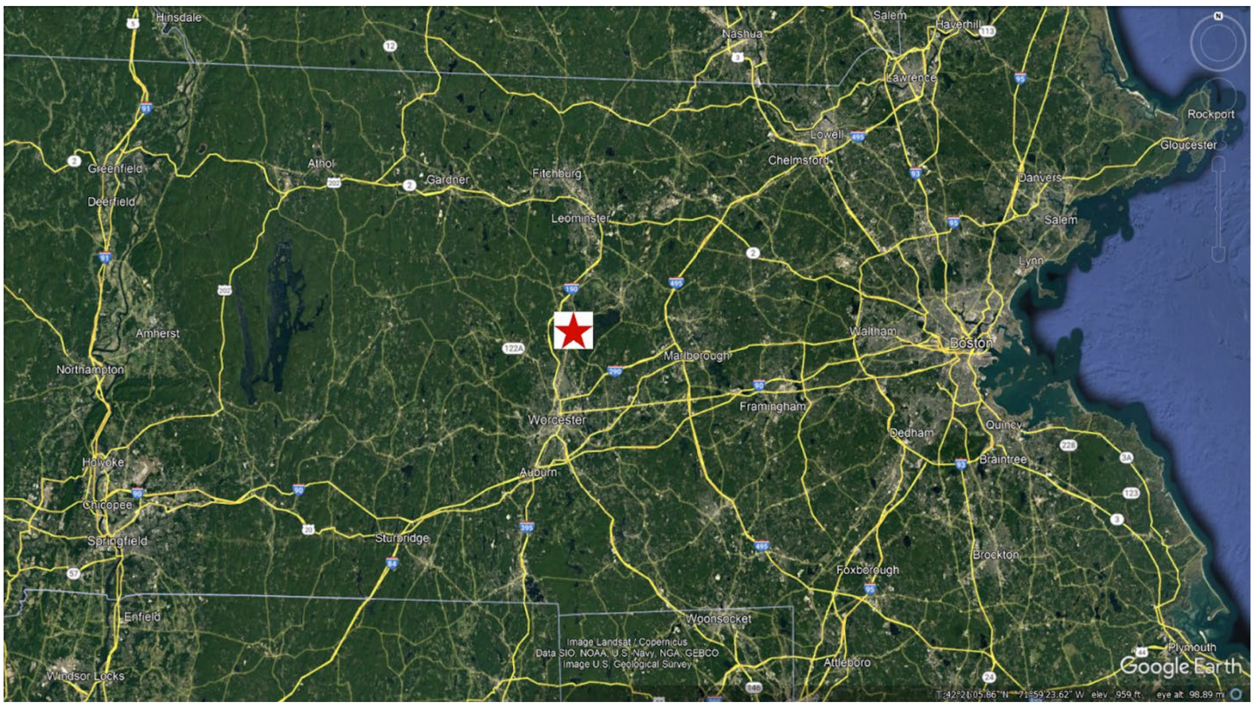


Figure 1: Location of Interchange (Google Earth, 2023)

In 2012, another WPI student team reviewed this same interchange and generated recommendations for design. Their process consisted of identifying current issues with the interchange, obtaining data from site visits and MassDOT, developing alternative designs, and eventually recommending a future design choice. At the conclusion of their project, the team suggested that the redesign be composed of a single-lane roundabout due to "safety, cost, and ability to meet future capacity demands." Although a concluding design was recommended, the development of this interchange never came to fruition.

This project aims to take a fresh look at the I-190 and Route 140 interchange with the end goal of improving functionality through a redesign process. This interchange falls under the jurisdiction of the MassDOT District 3 office in which they identified this site for study. Furthermore, our group has a particular interest in active transportation and has taken a closer look into how pedestrian and cyclist travel can be accommodated by the suggested redesign of the interchange.

To achieve a successful redesign of the interchange between Interstate 190 and Route 140, the team accomplished the following objectives:

1. Understand best practices regarding interchange design
2. Document existing conditions.
3. Formulate multiple control strategies.
4. Finalize a control strategy as an optimal redesign solution.
5. Develop the optimal strategy to 10% design phase.

2 Background

The interchange for this project is in Sterling, Massachusetts, and connects Interstate 190 to Route 140. Currently, the interchange is a diamond interchange, a common type of road junction where a controlled-access highway intersects with another road. At this location, this type of interchange creates two at-grade intersections with Route 140. The intersection shown in Figure 2 just north of the I-190 overpass services the I-190 Southbound ramps and is referred to as the "Southbound" intersection throughout this paper. Similarly, the ramp to the south of the overpass, servicing the I-190 Northbound ramps is called the "Northbound" intersection.

Figure 2: Bird's Eye View of Interchange (Google Maps, 2023)

The interchange consists of channelized off ramps from I-190 to Route 140, where vehicles cannot take a right turn immediately at the intersection, but instead yield to the oncoming traffic from Route 140. For left turns off the interchange, vehicles must cross over two lanes in order to continue in their desired direction. There is also a median separating the two directions of traffic. The section of Route 140 directly under I-190 was restriped in 2022 from three lanes of traffic to two. With the extra space, a substantial bike lane was created, leaving a buffer between vehicles and cyclists. There is an existing sidewalk between off-ramps on Route 140 going northbound. There is no crosswalk striping where the ramps meet the sidewalk, and there is also no signage for pedestrian or cyclist crossing.

Figure 3: View of Interchange Northbound

Although it has been re-striped to include fewer lanes of vehicle traffic, in its current state, the time it takes for a vehicle to take a left turn is not ideal, as two car lanes, one bike lane, and a wide concrete median must be crossed. Additionally, there is not an adequate direct line of sight for those turning left, as drivers edge into the bike line in order to have a full view of oncoming traffic in both directions. For drivers who exit I-190 traveling southbound and wish to turn left, there is visible vegetative overgrowth that also somewhat obstructs the view of traffic.

Currently, the area surrounding the interchange is overwhelmingly residential, with few commercial and recreational attractions. In both directions, the majority of the residences are single-family homes, however, there is a fairly new apartment complex about half a mile south of the interchange. Northbound on Route 140, there is a garden center and nursing home adjacent to the junction, and Wachusett Mountain is about a 12-mile distance from the interchange. Southbound on Route 140, the main attractions consist of a nursing home and Mass Central Rail Trail, which are at distances of 0.6 and 1 mile respectively.

2.1 MassDOT Intersection Control Evaluation

The prior 2012 MQP of this interchange was analyzed before the MassDOT Intersection Control Evaluation (ICE) was placed into effect. The purpose of the new ICE process is “to consider multiple context-sensitive control strategies consistently when planning a new intersection or modifying an existing intersection” (Plaza, n.d.). The goal of the process is to select a viable option that meets the project needs and fits well into the intersection’s location and existing conditions.

The ICE process is necessary for an intersection located on a state highway, requires the issuance of a Category II or III Access Permit, and receives MassDOT or Federal Highway Administration funding. Also, the general process is the same for new designs, redesigns, or any modifications of intersections. Forms for conducting an ICE can be found on the MassDOT website, with guiding information throughout the three stages of *Screening, Initial Assessment, and Detailed Assessment.* The first stage consists of considering a wide range of different intersection design strategies, the second stage includes traffic operations analysis, crash predictions, planning level opinions of probable design, right-of-way, and construction costs, and the third stage 3 involves detailed traffic operations analyses and preliminary geometric designs (MassDOT, 2021).

2.2 Interchange Design

Highway interchanges are specialized intersections that are designed to provide an efficient flow of traffic. By utilizing a system of interconnecting roadways and grade separations, they allow traffic to pass through an intersection without major interruptions. Interchanges are constructed to decrease congestion, improve safety, promote shared road space, and enable the smooth movement of vehicles and people from one road to another. While highway interchanges offer many transportation-related benefits, their effectiveness is dependent on proper planning, design, and maintenance.

A main pitfall of current interchange designs is that they are not created to accommodate the large flow of traffic, as traffic volume is continually increasing. Outdated interchanges may lack optimization and can be insufficient for pedestrian and cyclist safety. Therefore, it is essential to consider the specific needs of the area, compatibility with the surrounding land use, traffic patterns, and potential future growth when planning and constructing highway interchanges (Research on Common Problems and Countermeasures of Highway Interchange Design, 2022).

Improvements to interchange designs are made in areas with high traffic volume and dense land use. New improvements to interchanges referring to increased traffic flow result in creating more involved complex designs, and consideration of the local network system into the integration of design. Designers can consider the local road network by understanding the entire corridor instead of the individual interchange. Lastly, another modern approach to improving interchange performance specifically in terms of safety, is to “expand the knowledge of driver performance as a function of various design configurations” (FHWA, n.d.)

2.2.1 Diamond Interchanges

Diamond interchanges are commonly used in transportation engineering to connect two roads or highways. They are suitable and a prominent type of interchange for both rural and urban areas. This interchange variation involves two main roads, such as a highway or expressway, and a surface street. While a conventional at-grade intersection involves traffic crossing each other on the same level, a grade-separated interchange allows one of the roads to pass over the other using ramps and an overpass. Diamond grade-separated interchanges are designed to improve traffic flow, efficiency, and safety as they remove the need for vehicles on the surface street to cross over multiple lanes of high-speed traffic. They can become congested, especially when there is a high volume of left-turning movements on the crossroad (Missouri Department of Transportation, n.d.). To combat inefficiencies associated with traffic buildup, some diamond interchanges will include signalized ramp access, roundabouts, or other methods suited to improve the design at the specific site.

2.2.2 Route 12 and I-190

Approximately five miles north of our project site is a similarly designed diamond highway exchange that connects Route 12 and Interstate 190. This interchange was successfully redesigned in 2018 and was reconstructed to include a roundabout as shown in Figure 4 below.

Figure 4: Bird's Eye View of the MA-12 and I-190 Interchange (Google Earth, 2023)

Before reconstruction, vehicles turning left to travel northbound struggled to cross two lanes of oncoming traffic, as shown below in Figure 5. Especially when traveling at night, or during rush hour, identifying gaps in the flow was difficult, ultimately leading to safety concerns. This interchange was not efficient, and the wide cross-section made it a good candidate for improvement efforts.

Figure 5: Route MA-12 and Interstate 190 Street View 2011 (Google Earth, 2011)

Figure 6: Route MA-12 and Interstate 190 Street View 2023 (Google Earth, 2023)

Figure 6 reflects the current intersection conditions and shows how vehicles can now efficiently enter the roundabout. This is a single-lane roundabout that has bike lanes, pedestrian crossings, and sidewalks for active transporters.

2.3 Roundabout Functionality

A roundabout is a circular intersection that allows traffic to flow counterclockwise around a central island. The vehicles entering the circle must yield to those already inside, promoting a continuous stream of traffic. Roundabouts typically operate at slower speeds, which increases safety, and are more efficient than traditional intersections. Roundabouts contain the following elements, as shown in Figure 7.

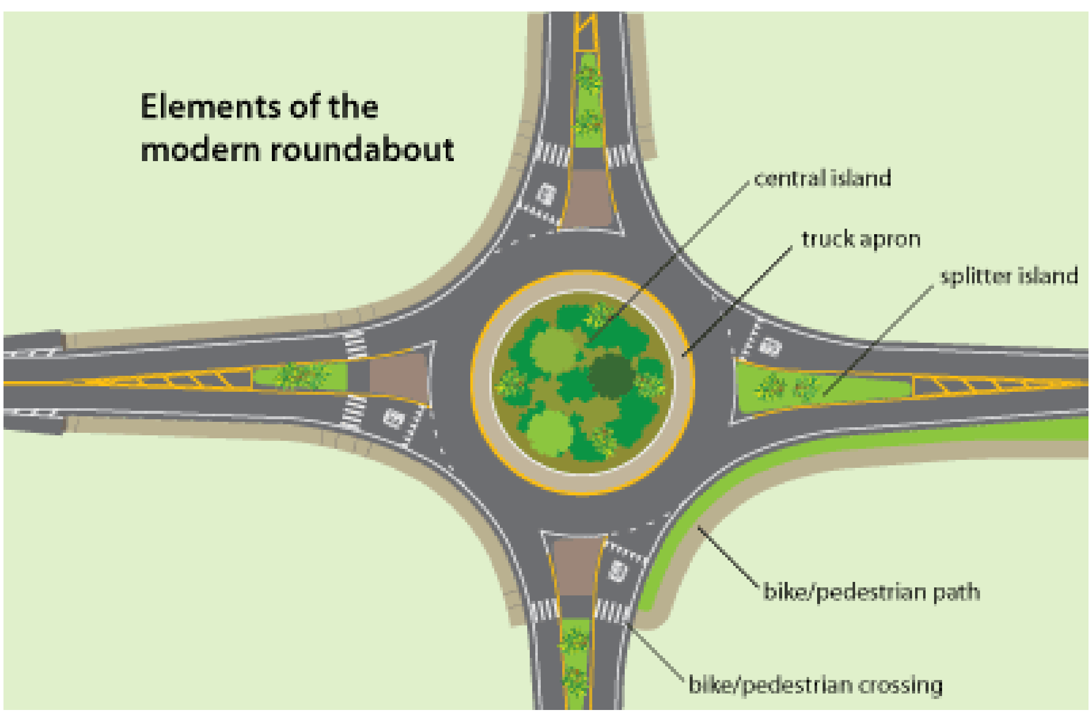
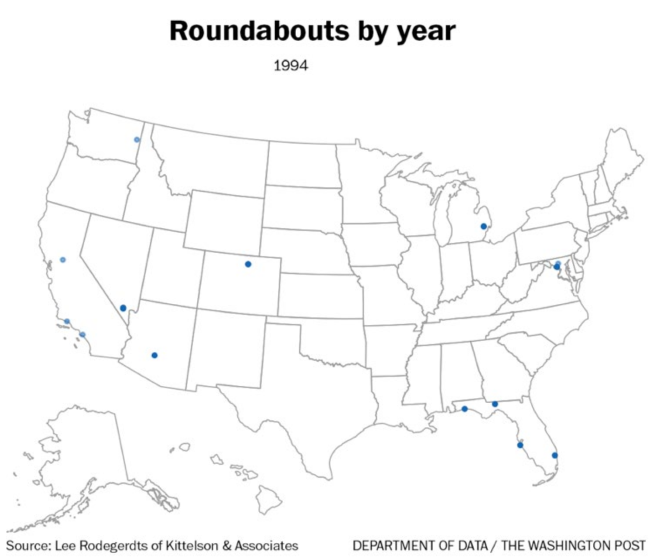
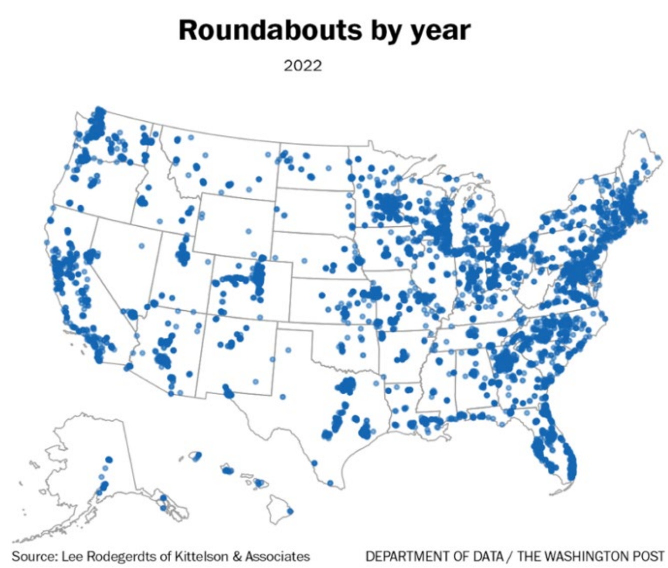


Figure 7: Elements of the Modern Roundabout (Roundabouts: An Informational Guide, n.d.)

The central island is typically landscaped, raised, and untraversable. This island allows the driver to see the intersection ahead and recognize the circular approach. Not all central islands are circular, but circular-shaped central islands promote continuous speeds as they have a constant radius. Oval or irregular shapes can increase difficulty while driving and decrease overall speeds. The truck apron, which surrounds the central island, primarily serves to accommodate the turning radius of larger vehicles, such as trucks, buses, and emergency vehicles, making it easier for them to navigate without encroaching onto the central island or curbing. The splitter islands, located at the four legs of the intersection, physically separate the entering and exiting traffic flows. They perform many beneficial functions and should be included in roundabout design. Splitter islands protect pedestrians, slow down approaching and departing traffic, and deter wrong-way movements (Roundabouts: An Informational Guide, n.d.). Providing safety for active transporters is important in all intersection designs. Bike and pedestrian paths are included in roundabouts and must balance convenience, safety, and operations.

Roundabouts have proven to be a modern approach to interchange design. The first presence of modern roundabouts in the United States was seen in the 1990s and resulted in a rise in roundabouts nationally and a decrease in older traffic circles and traditional signalized intersections (Analysis |The Rise of the Roundabout and Which State Has the Most, 2022). Figure 8 depicts this increase and allows for a visual representation of concentrated areas with the largest adoption of roundabouts.





Over the years, roundabouts have been redesigned to improve on earlier developments of the traffic circle. Early traffic circles were “nonconforming” in the sense that entering traffic would cut off circulating traffic. This lack of a clear yield and right-of-way was inefficient and led to a high frequency of collisions (Roundabouts: A Direct Way to Safer Highways | FHWA, n.d.). The modern roundabout has well-defined rules for entering and exiting and is currently the preferred design option.

2.3.1 Benefits of a Roundabout

Roundabouts, in many transportation projects, are considered superior to traditional intersections with stop signs or traffic signals. Benefits of roundabouts include simplification of traffic flow and improved safety. MassDOT further lists a variety of benefits when using a roundabout design in transportation engineering (What Are Roundabouts?, n.d.):

- Fewer conflict points between vehicles in an intersection.
- Reduction in property-damage-only crashes by 52% and fatal and injury crashes by 84%.
- Elimination of wasted time waiting at red lights at traffic signals during off-peak hours.
- Improved travel times for emergency vehicles responding to emergencies by eliminating unnecessary stops and delays.
- No maintenance requirement for traffic signals and can operate during power outages.
- Slower vehicle speeds are closer to the speeds of people biking, which increases their comfort.

2.4 Signalized Intersections

A signalized intersection, or traffic light-controlled intersection, regulates traffic flow by a system of red, yellow, and green lights that indicate a vehicle's right of way. Signalized intersections are a fundamental element of traffic control and are commonly used. Signalized intersections use signal timing, which is the length of each light cycle that is calculated from the estimated number of vehicles and pedestrians in the queue at a given time (FHWA, n.d.) This metric is used to help maximize the efficiency of the intersection for all users. By understanding the intersection or road capacity and crash data, signalized intersections can improve safety and decrease traffic buildup. Although signalized intersections increase the traffic handling ability and safety of pedestrians and vehicles, there are tradeoffs associated with the system. For example, signals can significantly increase the amount of rear-end collisions and can lead to the diversion of traffic to residential streets, especially in areas of high volume and congestion (FHWA, n.d.).

2.5 Active Transport

Active transportation encompasses transportation without the use of motorized vehicles, operated through human physical activity. This includes walking, biking, skateboarding, and many other forms of human-powered transportation. Active transportation has increased in the past 15 years due to an emphasis on physical activity and reducing carbon emissions. Between 2010 and 2019 bicycle trips within the 100 most populated cities in the United States increased from 320,000 to 136 million (Alternative Fuels Data Center: Active Transportation and Micromobility, n.d.). With this dramatic rise in active transportation, many towns including Sterling, MA, have created public bike paths to create a safe way for users to get physical activity as well as transport between places without the need for motorized vehicles. It is crucial to any roadway or intersection that active transport is accessible and safe.

Figure 9: Route 140 North Passing Under I-190 with a Bike Lane on the Right

The Massachusetts Department of Transportation published a guide on Separated Bike Lane Design and Planning which entails how a pedestrian bike lane should be constructed and the considerations that are to be made. Within the guide are recommendations for intersection design. Different types of intersections are listed along with the exposure pedestrians are likely to experience. These include conventional bike lanes (current intersection design), separated bike lanes, roundabouts, and protected intersections. In addition, the guide recommends raised bike lanes in many circumstances including crossing the interstate on ramps (*Intersection Design*).

In 2022 MassDOT updated their mapping of walkable trips. The segment of roadway on Route 140 is listed as having a low potential for walkable trips. This is likely due to a number of factors including safety and local infrastructure. Due to the limited infrastructure surrounding the interchange, which lacks essential amenities like shops, restaurants, or office buildings, it is improbable that the area would attract a substantial volume of active transport users. Without the convenient facilities nearby, the appeal for commuters to utilize alternative modes of transportation, such as walking or cycling, is significantly diminished.

2.6 Transportation Engineering Elements

Interchange data collection is a multifaceted process that utilizes a range of methods which include traffic counts, turning movement counts, and crash data.

Traffic counts aid in the data collection process on the volume and composition of traffic at a specific location. This information is critical for designing an interchange that can efficiently handle the current and future traffic demand. Additionally, traffic counts determine the number of lanes, lane configurations, and other design elements required to ensure safe and smooth traffic flow (MassDOT, 2020). Another outcome of this method is the calculation of Average Daily Traffic (ADT), which in turn can be used later to calculate the Average Annual Daily Traffic (AADT).

Turning movement counts are an important complement to traffic flow data and can provide reliable insights into traffic congestion. These counts provide valuable data about specific vehicle movements at interchanges, such as left turns, right turns, and through movements. This information is critical for assessing interchange safety by pinpointing potential conflict points prone to crashes so that safety can be enhanced in a targeted manner (MassDOT, 2020). Additionally, this data is essential for identifying capacity-related challenges and planning necessary improvements or expansions.

Highway and interchange design elements are highly interconnected to the safety of road users. Various factors including road geometry, lane width and configuration, and traffic control devices impact the frequency and severity of the collisions and the safety of active transporters. MassDOT collects and maintains data related to road safety to monitor and improve transportation safety.

Crash data is information collected by MassDOT, law enforcement, and the Registry of Motor Vehicles about collisions that occur on state roadways. These reports and databases contain information like the crash location, time of occurrence, vehicles involved (size, model), and other contributing factors such as the weather, driver behaviors, and road conditions. Crash data is critical for evaluating highway interchanges as it can pinpoint hazardous areas, such as merging lanes or exit ramps, and allows for targeted safety improvements.

Certain types of collisions are more common at interchanges, especially when lanes are merging or diverging. Some examples of collisions include rear-end, side-impact, and pedestrian and cyclist crashes (MassDOT, n.d.). Transportation engineering improvements have provided a variety of low-cost safety countermeasures that have been proven to decrease collision rates. For example, installing rumble strips which are an audible and physical feature that alerts drivers when they are drifting or approaching a hazard. To improve pedestrian and cyclist safety, slowing down vehicle speeds near crosswalks is a very low-cost solution, such as smaller scale roundabouts to encourage safe speeds (MassDOT, n.d.).

3 Overview of Methodology

To achieve the project objectives, the team initially established a comprehensive understanding of intersection design best practices. We relied on the Federal Highway Design Standards, overseen by the Federal Highway Administration (FHWA) under the U.S. Department of Transportation. These standards ensure consistency and safety across national highways and roads, outlining efficient and widely accepted methods for interchange design. Additionally, we consulted the guidelines provided by the American Association of State Highway and Transportation Officials (AASHTO), focusing on geometric design aspects, bicycle and pedestrian facility development, and operational planning. These guidelines are regularly updated to incorporate engineering advancements, safety enhancements, and evolving transportation demands. Drawing from our collective expertise at MassDOT, we adopted these federal standards as the foundation for our design criteria, customizing them to suit the unique needs of our project site. Moreover, we referred to MassDOT's Project Development and Design Guide (PDDG), which offers insights into developing context-sensitive and community-friendly road projects, ensuring adherence to industry best practices.

With this foundational knowledge in place, the team proceeded to implement the following methods, detailed in chronological order in Figure 10. Within the methods, the team utilized the Intersection Control Evaluation (ICE) procedures which incorporated many considerations for assessing intersection control strategies. Following the completion of ICE, the team completed the last method of a conceptual redesign using Computer Aided Design (CAD).

The remaining chapters in this study integrate the methods and results to provide a comprehensive understanding of the initial research process, from data collection to analysis and interpretation. By presenting the methodology alongside the results, it provides insight into how the project was conducted and how the findings were obtained or analyzed.

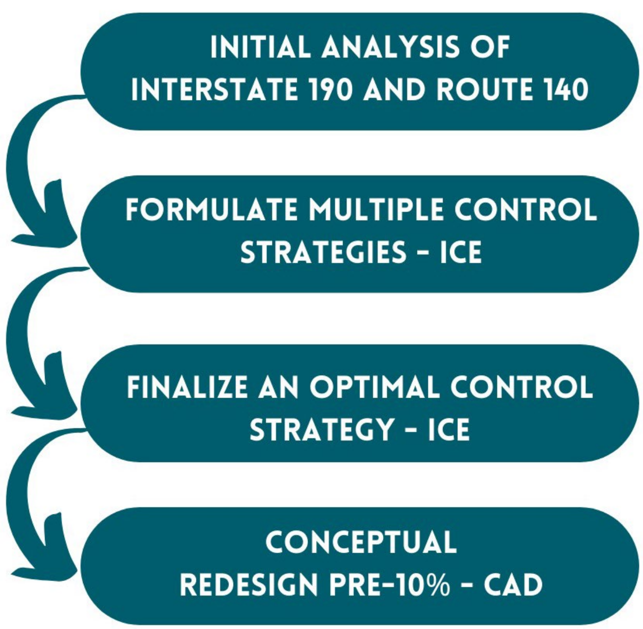


Figure 10: Chronological Overview of Methods

4 Initial Analysis of Route 140 and I-190 Interchange

The team's first objective in evaluating and redesigning the interchange was to conduct an initial analysis consisting of site visits, vehicle data collection, crash calculation, pedestrian and cyclist data, and turning movement counts. These activities provided valuable insights into the interchange's current conditions, including its layout, traffic patterns, and potential safety hazards. Understanding these aspects was crucial for identifying areas requiring improvement and prioritizing safety enhancements.

4.1 Document Existing Conditions

After developing an understanding of the best practices related to interchange design, the team documented and analyzed the existing conditions of the interchange. This was essential for gaining a comprehensive understanding of the current state of the intersections, and involved collecting data on traffic volume, user behavior, safety hazards, and local infrastructure. The collected information serves as a baseline assessment, helping the team to identify issues such as safety concerns. This documentation also aided in estimating project costs, considering factors such as new infrastructure requirements and potential modifications to the interchange. Overall, a detailed understanding of existing condition was fundamental for making an informed and effective intersection redesign plan that addressed the current challenges and overall functionality.

4.1.1 Site Visits

The team's site visits resulted in a better understanding of the interchange, local surroundings, and accessibility. After the series of site visits, the team determined that there are safety concerns with vehicles turning left approaching Route 140, as vehicles encroached into the bike lane and blocked pedestrian crossings. Additionally, the site visits served to examine the communities of Sterling and West Boylston to understand the infrastructure and developments nearby. The following is a timeline of completed site visits, and the various tasks and objectives associated with each visit:

9/12/2023 (17:30-1800) - **Initial Site Visit:** The team performed an initial evaluation of the site, and examined the safety conditions, for both pedestrians and drivers. The team determined that there were safety concerns with vehicles turning left on the off-ramp as vehicles encroached into the bike lane and blocked pedestrian crossings, as shown in Figure 11 below. Additionally, the team drove northbound and southbound on Route 140 to survey the towns of Sterling and West Boylston surrounding the interchange. By utilizing the interchange firsthand as pedestrians and drivers, we accurately documented concerns to be addressed in the redesign.

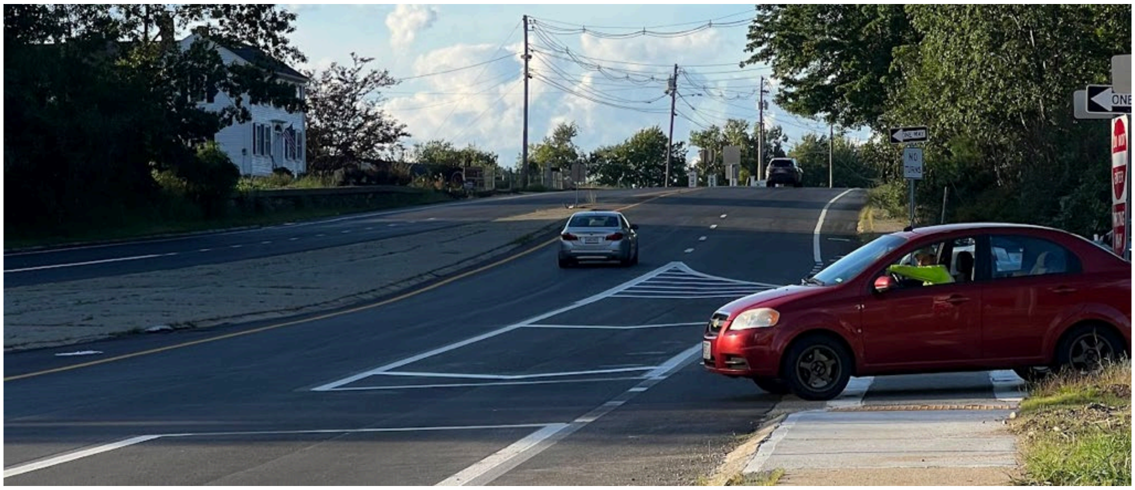


Figure 11: Vehicle in the Bike Lane and Crosswalk

10/4/2023 (10:00-10:30) - **Camera Location Determination**: The group scoped out the potential locations to position the camera at the interchange. This included looking at previous camera setup locations, and working with a MassDOT employee to determine which location would best capture the sidewalks and bike lane.

10/31/2023 (17:30-17:45) - **Camera Set-Up:** The group visited the site to set up the OWL camera. The goal of the camera was to collect the pedestrian and cyclist data at the interchange.

Figure 12: Camera Set-Up

11/2/2023 (16:00) - **Camera Pick-Up:** The group collected the traffic camera equipment and transferred the footage via USB to the computer to be analyzed.

4.1.2 Vehicle Traffic Data

After developing an understanding of the best practices of interchange design and conducting site visits, the team collected and reviewed existing interchange data provided by MassDOT. A detailed analysis of existing files, databases, dashboards, and interactive maps related to the Peak Hour Volumes, Turning Movement Counts, Annual Average Daily Traffic (AADT), and Average Daily Traffic (ADT), was conducted at our site.

MassDOT also provided the team with the updated turning movement counts starting the week of September 26th, 2023. To acquire the turning movement and traffic volume, MassDOT contacted Precision Data Industries L.L.C. as they had a traffic counter set up for the week of 9/26-9/29; the weekend was not counted. Additionally, there was a recount for the data collected on Route 140 in the northbound direction on 10/11/23. This data allowed the team to analyze the existing conditions for vehicle traffic and determine the peak hours.

The Route 140 and Interstate 190 interchange, depicted in Figure 13, has twelve data collection points. These stations correlate to the respective turning movement counts that were collected by MassDOT via the Precision Data Industries traffic counter.

Figure 13: Interchange Data Collection Stations

Average Daily Traffic Summaries

The average daily traffic is depicted below for stations 1, 6, 11, and 12. Stations 1 and 6 summaries are the Route 140 northbound and southbound counts, while stations 11 and 12 summaries display the Interstate 190 northbound and southbound daily travelers for the week of September 26th, 2023. The peak hours are displayed as both 0800 (8 AM) and 1700 (5 PM) for the described stations. In terms of volume, Interstate 190 receives heavier traffic flows, peaking at 797 vehicles in the morning and 829 vehicles in the afternoon. These peak hours, as shown in the Station 1 data, reflect a typical commuting pattern.

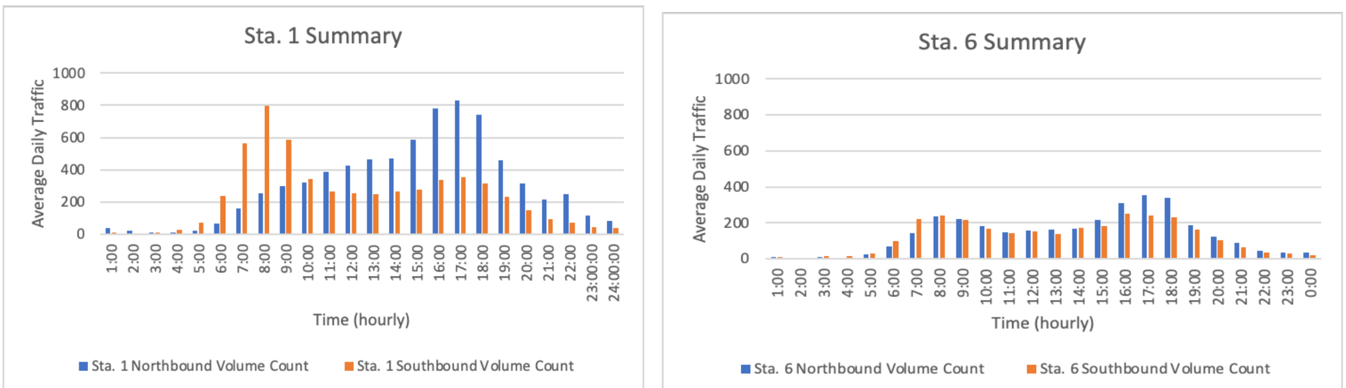


Figure 14: Station 1 and 6 Summaries Indicating AM and PM Peak Hours

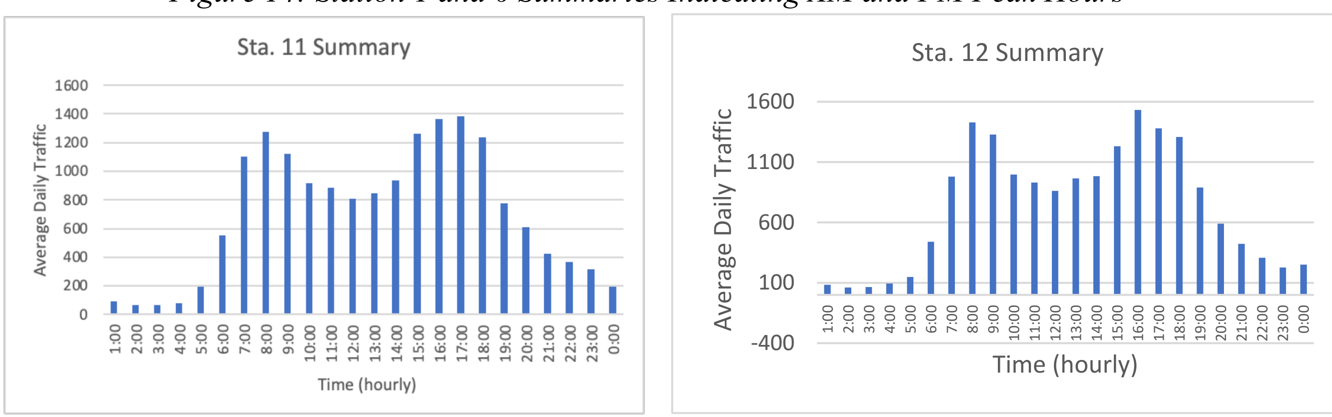


Figure 15: Station 11 and 12 Summaries Indicating AM and PM Peak Hours

Peak Hour Volumes

Peak hour volume refers to the highest level of hourly traffic flow on a roadway or transportation system. This is commonly associated with rush hours, which are times of the day when traffic congestion is at its peak due to a high volume of vehicles on the road. Peak hour volume traffic typically occurs during the morning and evening rush hours when people are commuting to and from work or school. The term is used to describe the maximum number of vehicles moving through a particular stretch of road or transportation network during these busy periods. Understanding peak hour volume is important for urban planning, traffic management, and transportation infrastructure development, as the data is used to analyze traffic control measures to optimize the flow of traffic and reduce congestion (Medina-Salgado et al).

To conduct an analysis of the different intersections, the interchange was split visually into two separate intersections as shown below in Figures 16, 17, 18, and 19. For the remainder of the report, these two intersections will be referred to as the I-190 Northbound and Southbound intersections. From there, the turning movement counts were evaluated for the peak hours, in the morning and evening, which were determined to be 0800 and 1700, respectively. These peak hours align with traditional commuting hours or “rush” hours.

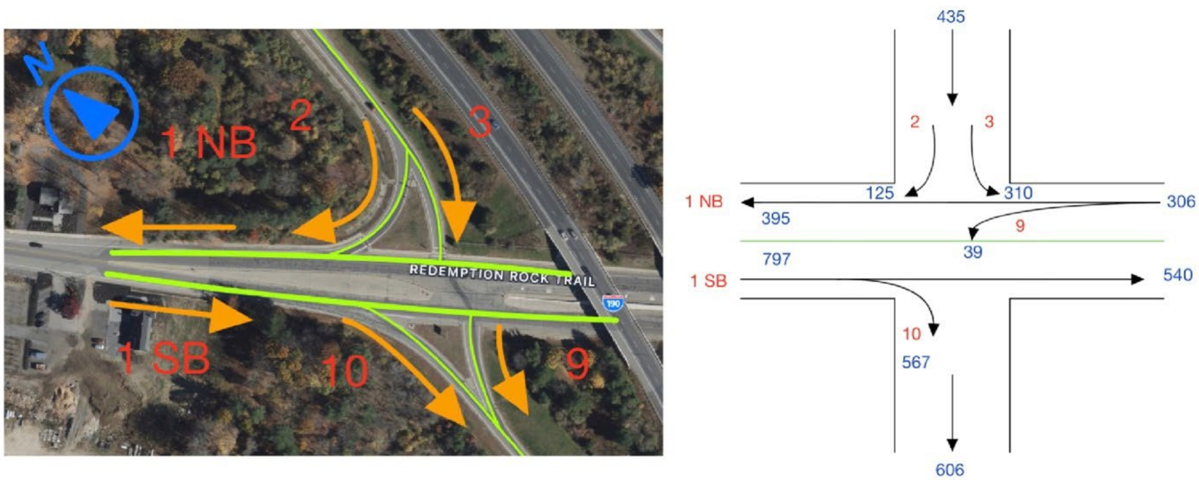


Figure 16: I-190 Southbound Intersection of Interchange at 8 AM (AM Peak Hour)

Figure 17: I-190 Northbound Intersection of Interchange at 8 AM (AM Peak Hour)

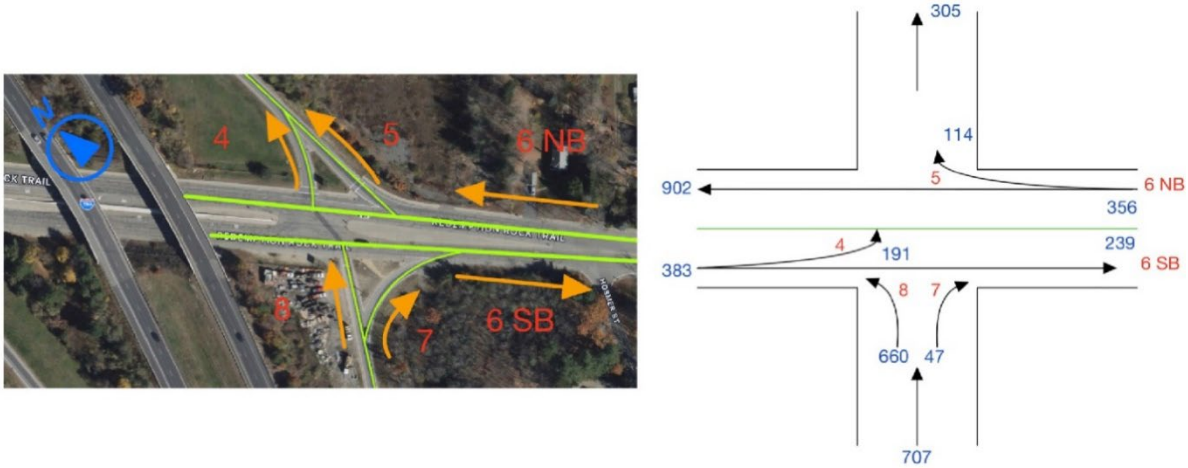


Figure 18: 1-190 Northbound Intersection of Interchange at 5PM (PM Peak Hour)

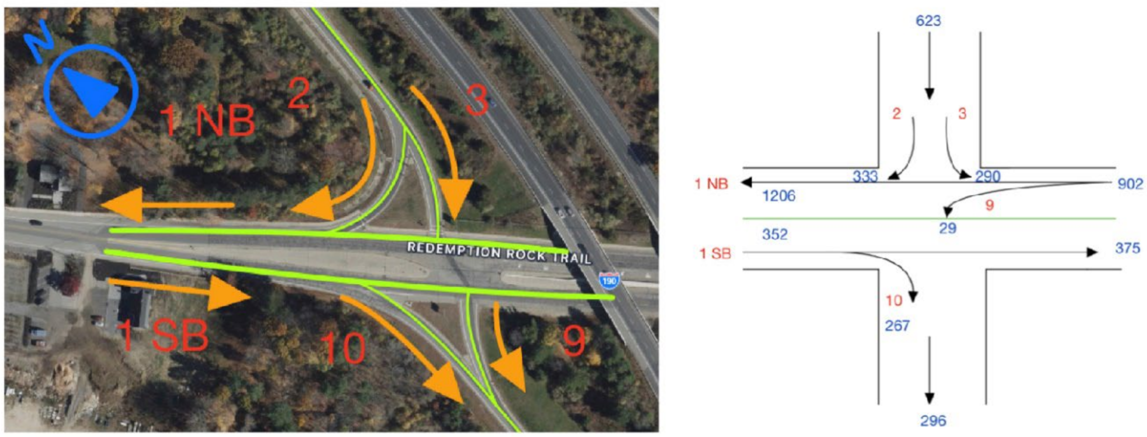


Figure 19: 1-190 Southbound Intersection of Interchange at 5 PM (PM Peak Hour)

4.1.3 Pedestrian and Cyclist Data

Utilizing a traffic camera placed strategically at the south intersection of I-190 and Route 140 facing traffic going northbound, a count was collected of all pedestrians and cyclists using the sidewalk and bike lane. This camera recorded 36 hours of footage between 17:30, October 31, and 15:30, November 1. This duration includes both peak times in the morning and afternoon. Using the OWL video software, the footage was significantly sped up to count the active transporters in a time efficient manner. From approximately 5:30 PM to 6:30 AM, the video footage goes dark. This prevented the team from counting the total number of active transporters during those times.

Figure 20:Traffic Camera was Placed at the South Intersection Pointing North

During this observation period, no pedestrians or cyclists were recorded. Due to a lack of streetlights, a conclusion can be made that no pedestrians used either the bike lane or sidewalk after sunset, however, as mentioned, the footage was too dark to know with certainty. Due to several factors including high traffic speeds, lack of local infrastructure, and obstructed turning views for drivers, such as large signs and overgrown vegetation, this is not a safe or desirable walkway and bikeway for most active transporters. If these factors were to be resolved the sidewalk and bike lane would potentially be more inviting for general usage. An additional factor impacting active transport volumes is the time of year and weather related to the time of data collection. The cold days and lack of sunlight are a plausible explanation for zero individuals counted.

4.1.4 Crash Data

The crash data for the interchange was collected through the MassDOT Online Crash Data Portal. The data was obtained from the years 2017-2022, indicating the crash type and severity. As the project has developed, it became evident that the crash data should be analyzed separately for the northbound and southbound intersection of the interchange, not as one system, as the crashes located on the interstate were not relevant to the project. Figure 21 below displays the portal dashboard with indicators of where the crash occurred. These crashes are then categorized by their severity and type at the given intersections.

Figure 21: Query & Visualization Tool via Crash Data Portal (MassDOT)

The crash severity refers to the categories of fatal, injury, property damage only, and unknown. Fatal crashes are the most severe and result in the loss of human life. Injury crashes involve varying degrees of harm to individuals, ranging from minor injuries to severe and life-altering conditions. Property damage-only crashes do not cause physical harm to individuals but result in damage to vehicles or other property. While less severe in terms of human impact, property damage-only crashes still contribute to economic costs, and the overall safety considerations of road transportation. Several factors contribute to crash severity, including the speed of the vehicles involved, the angle and point of impact, the size and type of vehicles, and the use of safety features. High-speed collisions or those involving vulnerable road users like pedestrians or cyclists tend to have a higher likelihood of causing severe injuries or fatalities. According to Federal Highway Administration Roadway Safety Information Analysis, knowledge of the severity of crashes in a jurisdiction can is crucial for determining safety needs of an intersection.

Tables 1 and 2 depict the crash severity for the I-190 Northbound and Southbound intersections with property damage only crashes being the most common. The interchange was split into two intersections, I-190 Northbound and I-190 Southbound for analysis. The absence of fatal crashes suggests that the design of the interchange, along with factors such as signage, visibility, and traffic control measures, may be effective in ensuring safe traffic flow and minimizing the risk of crashes resulting in fatalities. It could also indicate that drivers are adhering to traffic laws and regulations, driving responsibly, and that any potential hazards have been adequately mitigated. Given the rural surroundings and lack of infrastructure distractions, drivers may be more attentive.

Table 1: Crash Severity – I-190 Southbound Intersection

Year	FATAL	INJURY	PROPERTY DAMAGE ONLY	UNKNOWN	TOTAL
2017	0	0	0	0	0
2018	0	1	1	0	2
2019	0	0	1	0	1
2020	0	0	1	0	1
2021	0	0	0	0	0
2022	0	0	1	0	1

Table 2: Crash Severity – I-190 Northbound Intersection

Year	FATAL	INJURY	PROPERTY DAMAGE ONLY	UNKNOWN	TOTAL
2017	0	0	4	0	4
2018	0	1	1	0	2
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	1	0	1
2022	0	0	0	0	0

Crash types refer to the various ways in which vehicle collisions occur, each characterized by distinct patterns of impact and contributing factors. Single vehicle crashes involve only one vehicle and can result from factors like loss of control, adverse weather, or road obstacles. Sideswipe collisions occur when the sides of two vehicles make contact, typically during parallel movements. Angle collisions involve vehicles colliding at an angle, frequently occurring at intersections, and influenced by factors like red-light running. Rear-end collisions happen when one vehicle strikes the back of another, often in heavy traffic or sudden stops. Left-turn collisions occur when a vehicle making a left turn at an intersection collides with an oncoming vehicle. Table 3 and 4 display the crash types for the I-190 Southbound and Northbound Intersections. Understanding these crash types is important when implementing targeted safety measures and improving road design to reduce the occurrence and severity of accidents *(Federal Highway Administration, Crash Types and Causes*).

Table 3: Crash Type – I-190 Southbound Intersection

YEAR	SINGLE VEHICLE	SIDESWIP E	ANGLE	REAR-END	LEFT TURN
2017	0	0	0	0	0
2018	0	0	1	1	0
2019	0	0	0	1	0
2020	0	0	1	0	0
2021	0	0	0	0	0
2022	0	0	0	1	0

Table 4: Crash Type – I-190 Northbound Intersection

YEAR	SINGLE VEHICLE	SIDESWIPE	ANGLE	REAR-END	LEFT TURN
2017	1	0	1	2	0
2018	0	0	0	2	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	0	0	0	1	0
2022	0	0	0	0	0

The MassDOT Intersection Crash Rate Worksheet, in Appendix K, was used to calculate the crash rate of the interchange. The crash rate was then calculated to be 0.11 for southbound and 0.16 for northbound, as shown below. For further analysis, this crash rate was compared to the MassDOT District 3 average crash rate for unsignalized intersections, which is 0.61 (MassDOT 2018). The worksheet requires the approach/total peak hour volumes, the "k" factor, the total number of crashes per year (A) at the location, which was .83 in Southbound and 1.16 in Northbound, and the ADT (V) of the interchange. The "k" factor is not to be utilized in this equation since there is 24 hours' worth of entering volume. The average number of crashes per year (A) was obtained from the crash data. The formula for calculating the crash rate for an intersection is presented below. The “Rate” (R) is expressed in crashes per **M**illion **E**ntering **V**ehicles (MEV), which is standard to the Traffic Engineering profession.

$$R = \frac{A \text{ X } 1{,}000{,}000}{V * 365}$$

Where:

A = Average number of crashes at the study location per year
V = Intersection ADT (total daily approach volume)

Figure 22: Crash Rate Equation (MassDOT Crash Rate Analysis Worksheet)

At the I-190 and Route 140 interchange the following variables and factors were applied:

A= .83 for southbound traffic, 1.16 for northbound traffic
V= 20,248 for southbound intersection, 19,999 for southbound intersection

$$\boldsymbol{Southbound\ Rate = \frac{(0.83*1{,}000{,}000)}{(20{,}248*365)}} = \textbf{0.11 crashes per MEV}$$

$$\boldsymbol{Northbound\ Rate = \frac{(1.16*1{,}000{,}000)}{(19{,}999)*365}} = \textbf{0.16 crashes per MEV}$$

Given that the MassDOT District 3 average is 0.61, the crash rates for the Northbound and Southbound intersections are low. Additionally, with the supporting factor of an absence of fatal crashes, a deduction is made that there are no major safety concerns with either intersection.

5 Preliminary Stages of the Intersection Control Evaluation

Following the initial collection and analysis of existing data regarding the current state of the interchange, the team used the MassDOT Intersection Control Evaluation (ICE) to formulate a list of multiple control strategies that would be viable options for redesign. Initially, the team started the ICE process by analyzing the interchange as a whole and discussed the possibility of a large control strategy to satisfy the entire system. However, following the collection of volume counts at each intersection, it was clear that the two at-grade intersections, having different traffic patterns for different times of day, required separate analyses. The team also decided that a single solution for the entire interchange would require extensive construction and change to existing geometry and would overall be an overdesign.

5.1 ICE Stage 1

ICE is broken down into three stages: screening, initial assessment, and detailed assessment. Stage 1 encompasses a general look at various intersection designs to note if those intersections could potentially act as a solution for a redesign. Through an initial understanding of the intersection rather than data-driven figures, a list of viable options is generated. From a large list of potential control strategies, the team determined which were viable in terms of questions like, "does the intersection improve traffic operations?", or "does the intersection appear viable given the site constraints & location context?" The team then gave each question a simple yes or no answer and an overall yes or no to whether the strategy is viable in general in terms of the intersection.

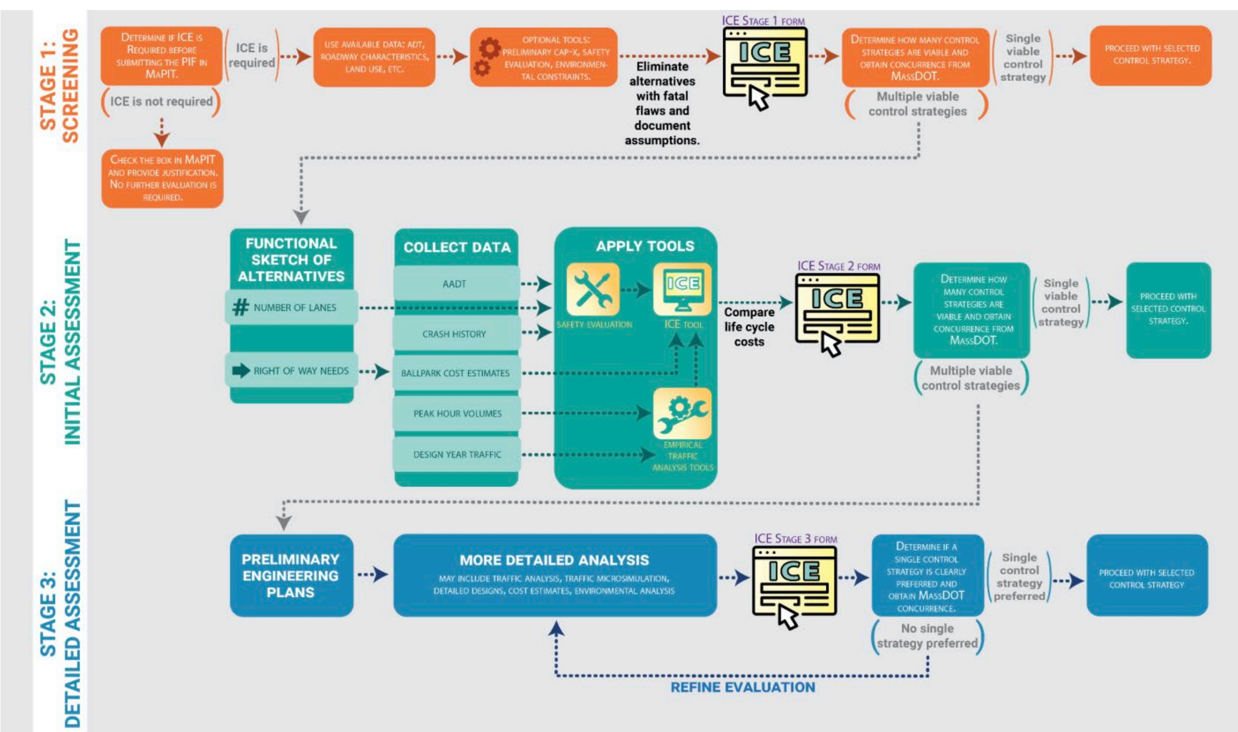


Figure 23: Illustration of the Three Stages of the ICE Process (Kristiansen, n.d.)

Following the first stage of ICE, the team narrowed viable control strategies to three: two-way stop control (the current state of the interchange), signalized stop control, and roundabout. Most of the non-chosen design options were ruled out mainly due to the strategy not fitting the context or site constraints of the existing interchange, those options would be an overdesign, or generally, the non-chosen strategies would not improve the operation of the interchange system. Examples of these types of solutions included jug handle, median U-turn, and an all-way stop control.

The team looked extensively into keeping the current diamond design. Initially, the assumption was that there needed to be a general design change. However, since the current design does work within the constraints of the existing conditions, the team discussed potentially changing lane geometry or width to improve the performance of the interchange system instead of starting over entirely.

In preparation for the second stage of ICE, the team further analyzed the volume counts by calculating growth projections for the years 2030 (opening year projection) and 2043 (10-year projection). A growth factor of 1% was applied to turning movement volumes for both the AM and PM peak hours, then those values were added to the recorded values from 2023 to project values for 2024. This process was repeated for each year until 2043. An example calculation is shown below, and the table of volume projections is available in Appendix D and Appendix E. The calculation was used for each station collecting volumes and was repeated for AM and PM peak hour volumes.

$$Volume\ for\ nth\ year\ since\ 2023 = 1.01^{n} * 2023\ Volume$$

The volume projections allowed the team to estimate traffic flow volumes for future years and predict operations for the future. By increasing the turning volumes, it was clear that the current conditions of the interchange would not meet the demands of future growth. In its current state, the left turns at both intersections create issues for drivers, as they need to cross two lanes of traffic and a large median to continue their journey. Since the left turn requires a longer clearance time to complete the turn, there is often a higher delay time associated with these movements. Maintaining the same infrastructure would only exacerbate these backups and delay periods, therefore the current geometry is not an optimal strategy for the long-term success at this interchange.

5.2 SIDRA Analysis

The projected traffic volumes were also important for conceptualizing projections for redesign strategies like roundabouts or signals. For roundabout analysis, the team utilized SIDRA software provided by MassDOT. Within this software, two roundabouts replaced the current two existing intersections. Initially, both intersections consisted of a one-lane roundabout, with three entry points and three exit points. The turning volumes from the existing southbound system were then input into the corresponding movement on the roundabout. This process was repeated six times– twice for the current year (2023), opening year (2030), and 10-year projection (2043). For each year, the two analyses were comprised of the AM and PM peak hour volumes. This process generated estimations of delay time and level of service (LOS) for the performance of the roundabout at current and future volumes. This process was replicated for the northbound at-grade intersection.

Despite the redesign, both one-lane roundabouts on the north and south intersections still underperformed in future years, resulting in a low LOS of F. To accommodate for the high delay times driving the poor LOS, the team changed the roundabout geometry to include two lanes where traffic volumes were generally high. The southbound roundabout was revised to include two lanes for the right turn onto I-190 and two lanes for the off-ramp right turn from I-190 onto Route 140. The northbound roundabout was revised to virtually change to the two-lane roundabout except for the right turn entry from Route 140 into the intersection.

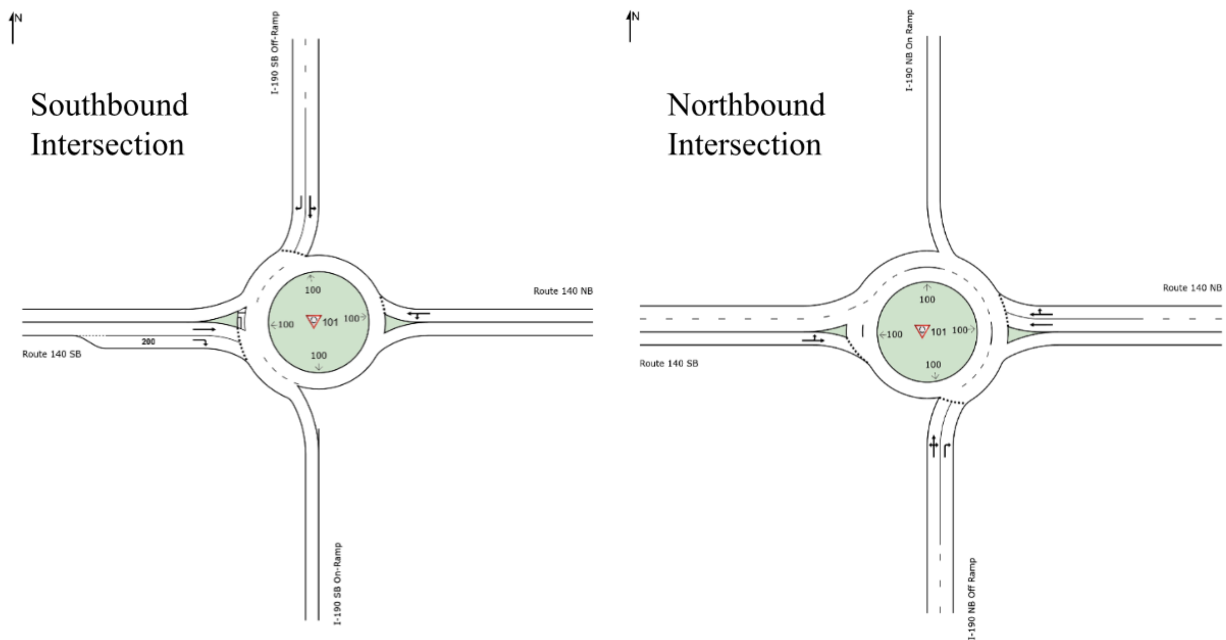


Figure 24: Southbound and Northbound SIDRA Roundabout Geometry

With the implementation of the revisions, generally, the LOSs for the three critical years for AM and PM peak hours resulted in a B or above for both intersections. The exception to this pertained to the southbound intersection, where the 2030 PM LOS was denoted as C, and the 2043 PM LOS was D. Despite the substandard results for the evening peak hour, the general operation of the roundabout was successful, and only during the 5 PM rush would there be significant delay times. Additionally, the team decided that the implementation of another lane for the right entry turn from Route 140 as well as the traveling lane within the roundabout, would improve the LOS for the evening. Most of the traffic around 5 PM consists of drivers exiting I-190 northbound, then turning left onto Route 140 northbound. Therefore, including another lane at that junction would allow more cars to travel through and experience fewer delay times. Complete reports of the SIDRA analyses can be found in Appendix F and G.

5.3 SYNCHRO Analysis

The team also conducted similar rounds of analyses for the intersections if they were to be signalized using SYNCHRO. SYNCHRO is a traffic signal timing software that transportation planners use to model and optimize signals and like SIDRA; SYNCHRO provides estimations on delay time and LOS. The two intersections were modeled similarly to the existing geometry, except for the exit ramp from I-190 northbound, which was modeled to have two lanes for a protected left turn and a dedicated right turn. This additional lane was to accommodate the evening traffic build-up for the left turn.

The signalized intersections did not perform well holistically in terms of delay and LOS. The intersections performed well for the AM peak hour, with both intersections in 2030 and

Figure 25: SYNCHRO Signalized Intersections Geometry

2043 having a LOS of B or A. The intersections during the PM peak hour however did not perform as well, with the highest LOS recorded being C. This is mainly due to the sheer number of vehicles entering the intersection in the evening compared to the morning. Additionally, signalized intersections lend themselves to having longer delay times compared to roundabouts, because the vehicles must come to complete stops for a specific amount of time, whereas a roundabout involves a steady, constant flow of traffic.

Overall, the results from SIDRA and SYNCHRO allowed the team to visualize and simulate redesign options with existing and future levels of traffic. The analysis presented that the roundabout option for the two intersections had a higher level of service and lower delay time than a signalized system and the current system. Despite the outputs from the software, the team further analyzed the system, reviewing options that included a roundabout and a signal as opposed to employing just one design strategy. This was because, despite the high level of service for the northbound intersection roundabout, the roundabout was drawn to be two lanes, which would require significant changes to existing geometry. Additionally, the main concern for the I-190 southbound intersection is the left turn onto Route 140 in the evening which is experiencing significant delays. Therefore, the team considered implementing a signal at that intersection, and a roundabout at the southbound intersection to avoid an overdesign of the southbound side.

6 Finalize an Optimal Control Strategy

With several options after the completion of ICE Stage 1, the next method was to finalize an optimal strategy. To complete this, the team utilized ICE Stage 2 as well as the ICE Stage 2 Tool. With these outputs, the team made an informed decision as to which design strategy was best for the interchange redesign.

6.1 ICE Stage 2

Following ICE Stage 1, the team next had to complete ICE Stage 2. This stage of the ICE process requires the implementation of data to generate a series of benefit-cost ratios that would provide the team with qualitative data for intersection selection.

To complete ICE Stage 2, MassDOT has provided a 'tool' that allowed the team to input data collected in the initial analysis of the interchange, as well as the performances of the roundabout and signalized option to compare the two viable options. The tool was a crucial component needed to complete the Stage 2 form. The Stage 2 tool is an Excel spreadsheet that includes sections regarding cost parameters, delay periods, and the generated outputs displayed as benefit-cost ratios. Like the SIDRA and SYNCHRO analysis, the at-grade intersections were analyzed separately, therefore two tools were completed.

In the Cost Parameter tab, the total construction and planning expenses for both the signal and roundabout options were estimated using data from previous MassDOT construction projects and the Construction Cost Estimator developed by the MassDOT Highway Division. Utilizing this software, an initial estimate was generated by referencing the state database of recent bid data. The breakdown of this estimate into various categories was facilitated by the ICE Stage 2 tool, as illustrated in Figure 26. For the roundabout option, costs were determined by consulting the MassDOT HWY Nomenclature document, which provided relevant cost information based on the associated Item Number (#). These item numbers were cross-referenced with the Construction Cost Estimator to ascertain the average costs over recent years. It's noteworthy that the general costs for both intersection options were found to be similar.

Planning & construction costs	Units
Total	Dollars
Survey	Dollars
Right of way	Dollars
Equipment, signs	Dollars
Utilities	Dollars
Construction	Dollars
Landscaping	Dollars
Labor	Dollars
Contigency	Dollars
Operating & maintenance costs	**Units**
Power	Dollars
Inspection	Dollars
Repaving	Dollars
Signing, striping	Dollars

Figure 26: ICE Stage 2 Tool Cost Estimate Breakdown

Additionally, crash data was input within the cost parameter section. The safety information section requires the implementation of the projected number of crashes for the opening year (2030) and the design year (2043) for each control strategy option. Within the tool, crashes were separated by the years (2030 and 2043) as well as fatal and injury crashes and total crashes. Similar to the calculations for the volume counts, a factor of 1% was applied to the number of crashes. Then, for roundabouts, a Crash Modification Factor (CMF) of 0.48 was applied to the grown crash rates and for signals, a CMF of 0.57 was applied. The CMFs were provided via MassDOT. An example calculation is shown below.

$$Number\ of\ Total\ Crashes\ for\ nth\ Year\ Since\ 2023\ for\ Roundabouts = (1.01^n * Number\ of\ Total\ Crashes\ in\ 2023)(0.48)$$

The next section of the tool requires projected delay times for the AM and PM peak hours for both the signal and roundabout for the opening and design years. These values were computed from the SIDRA and SYNCHRO analysis.

Finally, the last tab provided the team with benefit-cost ratios for the general expenses, the delay times, and safety. For all three categories, and for both intersections, the roundabout outperformed the signal. Following these outputs, the team used the results of the stage 2 tool to complete the stage 2 form.

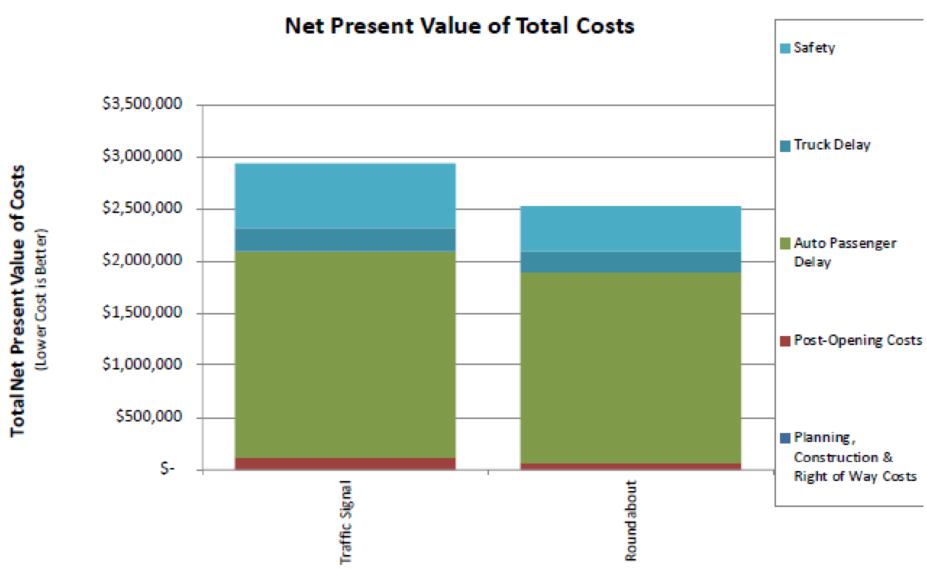


Figure 27: Southbound Intersection Outputs on ICE Stage 2 Tool

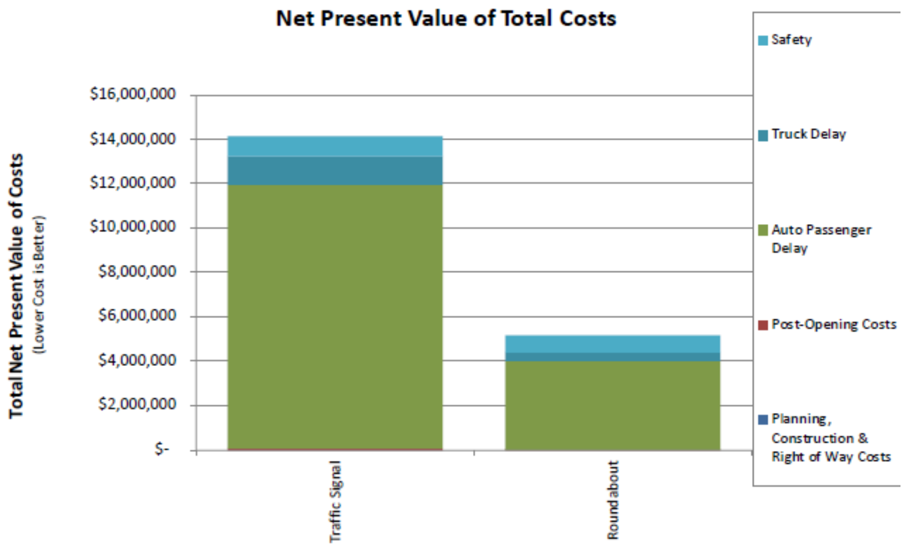


Figure 28: Northbound Intersection Outputs on ICE Stage 2 Tool

6.2 ICE Stage 3

The culmination of the Intersection Control Evaluation (ICE) process is ICE Stage 3. This final stage includes an in-depth analysis of any remaining control strategies through design and simulation methodologies. However, the necessity of Stage 3 only arises when multiple control strategies persist post the completion of Stage 2. Given that the team had already pinpointed an optimal control strategy following Stage 2, the completion of Stage 3 was deemed unnecessary. This highlights the efficiency and effectiveness of the ICE process, as it streamlined the decision-making by eliminating the need for further analysis when a clear and optimal control strategy had been identified.

7 10% Design Phase

As a final completion step to approach the end of a 10% design phase, the team created a conceptual design of the interchange. Broadly, this entailed drafting two roundabouts for both the I-190 southbound and I-190 northbound intersections. The drafting process began with a survey of the existing conditions of the interchange provided by MassDOT. The pavement lines from the survey served as a foundation for the roundabouts to be drawn, as the team attempted to stick as closely as possible to the existing geometry of the current intersections. As noted in prior chapters, the intersections are referenced based on the I-190 direction both with on and off ramps.

The northbound intersection was drafted first. To deflect the traffic speed to match these standards, the inscribed circle diameter was designed to be 120 ft. From there, the outer circles were offset by 16 ft (pavement width) twice to mimic a two-circulating lane roundabout. The exit lanes onto Route 140 were drawn first with radii of 300 ft. The exit lanes were then offset onto the entry lanes from Route 140 into the roundabout, to have a base to have the optimal radius for speed deflection. Joining arcs with radii of 75 ft connected the entry lanes from Route 140 southbound to the roundabout and joining arcs with radii of 175 ft connected the entry lanes from Route 140 northbound to the roundabout. The entry and exit lanes onto and from I-190 required a different approach because the on and off ramps are not perpendicular to the roundabout. Therefore, the existing on and off-ramps were extended to meet the outer circle of the roundabout, and that served as a base to draw an arc connecting the straight lines to make the curve match the roundabout geometry. The exit curves onto I-190 still used a radius of 300 ft, and the entry curves off of I-190 into the roundabout used a radius of 100 ft. For each exit and entrance, small arcs of 50 ft were added to create a more organic curve onto and from the main section of the roundabout. Once the northbound roundabout was drawn, it was copied and rotated to match the geometry of the southbound intersection. All radii for the northbound intersection mimicked the southbound intersection, except for the entry radius from Route 140 northbound into the roundabout, which had a radius of 75 ft. After the base roundabouts were drafted and placed, the number of exiting and entering lanes were drawn to match the SIDRA analysis, with the exception of the entering lane from Route 140 south into the southbound roundabout, as discussed in chapter 5. All pavement linings were denoted in the drawing as solid red lines.

The speed deflection of the circulating and entry movements within the roundabout were checked in order to make certain that the dimensions of the roundabout would be adequate safety-wise. The deflection speeds were determined by the graph in Figure 29.

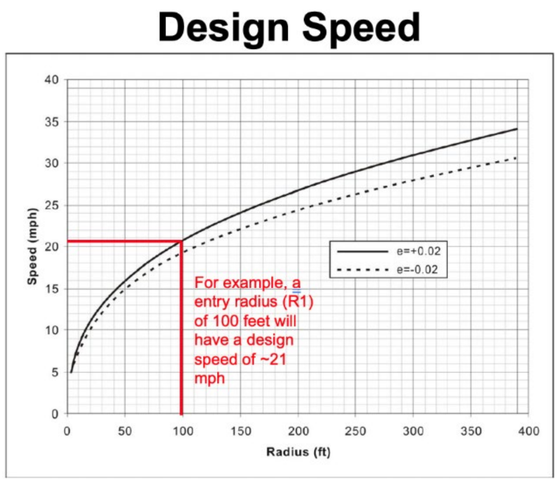


Figure 29: Graph to Determine Design Speed (MassDOT, 2022)

By Federal Highway Design Standards, ideally, the entering and circulating speeds are within 6 mph of each other, and the circulating speeds would be less than 30 mph. The inscribed circle diameter is 120 ft, meaning that the traveling speed would roughly be 22 mph and the second driving lane with a diameter of 136 ft would have a traveling speed of 23 mph. The entering radius for both roundabouts was 100 ft, meaning the entering speed would be 21 mph.

Similarly, the team also assessed the fastest path of both intersections to assess the geometry of the roundabouts. The fast path assessment offers a method for examining roundabout configurations and evaluating the anticipated speeds and speed correlations between consecutive maneuvers within the roundabout.

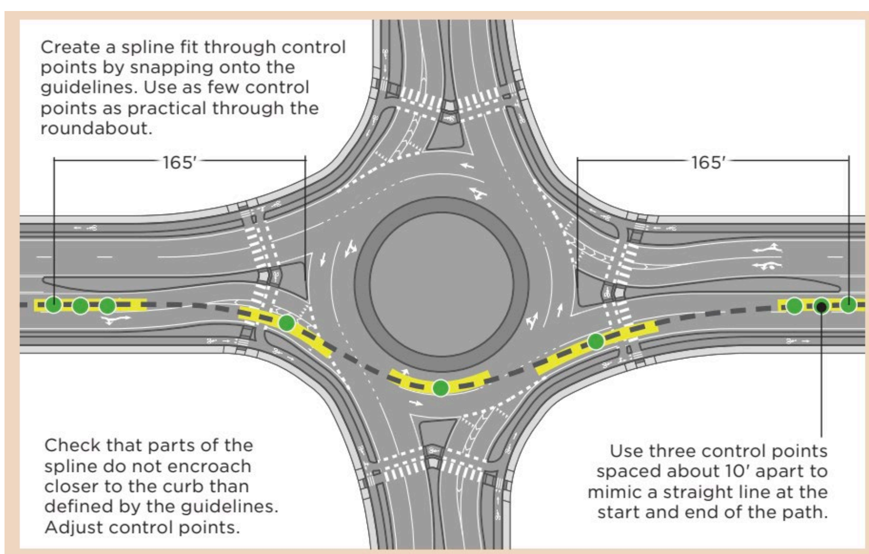


Figure 30: Fastest Path Analysis (MassDOT, 2022)

The process above was replicated for the right turn from Route 140, through the roundabout, and then exiting the roundabout to continue straight onto Route 140 southbound for both northbound and southbound intersections. Three arcs of best fit were drawn along the path, and then were connected using the spline tool on AutoCAD to simulate the trajectory of a vehicle taking the fastest path. The arcs were placed no closer than 5 ft from any curb lines, and similarly, the spline was not to encroach close curb lines as well.

After the design and measurements of the intersections were analyzed by checking speed deflection and the fastest paths, the bike and pedestrian paths were drafted. This entailed offsetting the curb line 15ft to accommodate for 6 ft of sidewalk, 4 ft of bike path, and a 5 ft buffer between bike and car traffic. The sidewalk was denoted in the drawing as dark blue with the concrete hatch, the bike path was denoted as cyan dashed lines, and the buffer was denoted as red with a diagonal hatch. At the sidewalk and on/off ramp intersections, the sidewalk was displaced 20 ft behind the outer curb line. Additionally, pavement stripping was implemented; this was lane designations in the form of white solid lines, and the center line for two-lane roadways was designated as a white dashed line.

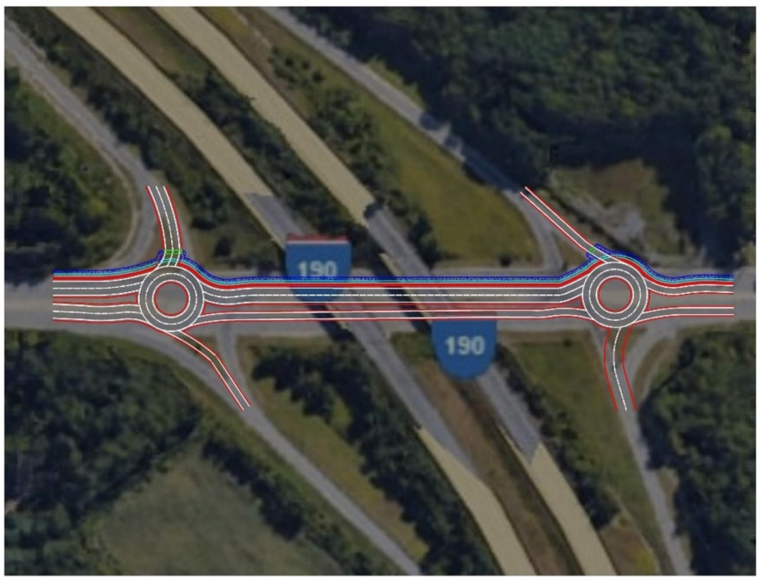


Figure 31: AutoCAD Design

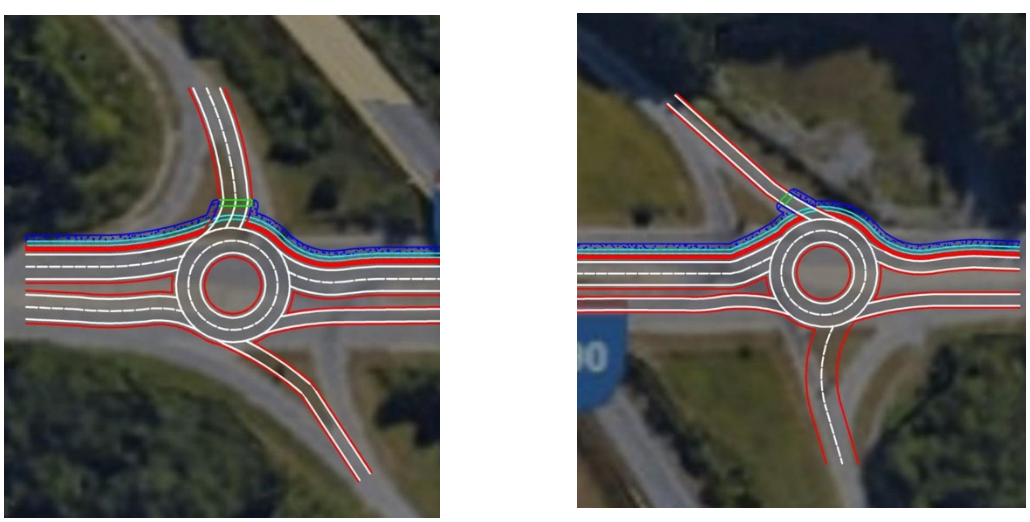


Figure 32: Cropped Image of Both Intersections in AutoCAD

8 Limitations

Through the completion of the stated objectives and methods, the team experienced limitations related to the data collection and utilization of the ICE procedures. These limitations ultimately had little effect on the outcome of the project but are still documented to understand the scope and enable a more realistic expectation of the result.

8.1 Data Collection

One of the initial challenges that the team faced was within the initial analysis of the existing conditions. The collection of turning volume counts took place over the course of several days, recording values from 12 PM until 12 AM on Tuesday, all 24 hours Wednesday and Thursday, and from 12 AM to 12 PM on Friday. However, station 1 counting for the northbound direction recorded zeros, requiring a recount to take place. The recount took place 15 days later, and recorded values the entire week all 24 hours, except for Wednesday which recorded values from 12 PM until 12 AM. Therefore, the recount volume averages included more data values, and values from different times of day that may have affected the peak hour averages for that one station. This also impacted balancing the volume counts for the southbound side of the interchange system, as the counts were not taken on the same day.

8.2 ICE Constraints

While the ICE tool provided a platform for analyzing intersections, the team encountered several limitations both with the tool itself and the overall procedure. The primary challenge arose from the tool treating intersections as a single continuous system rather than distinct entities. While interconnected, each intersection needed an individual investigation for a comprehensive analysis. Consequently, the team had to run the tool twice, once for each intersection, which halted progress within the project.

Stage 2 presented the team with many issues, ranging from locked pages to frustrating output errors. The primary culprit in this turned out to be the Stage 2 Tool itself. Numerous instances occurred where the program outputted values that were alarmingly higher than the eventual correct figures. Between meeting with MassDOT and troubleshooting as a team, it was uncovered that the use of Google Sheets, rather than Excel, lay at the heart of these discrepancies. These issues were a large setback for the team and required meeting with MassDOT multiple times to help determine the cause and solution.

Moreover, the tool's reliance on estimated data posed another limitation. Crash data, crucial for safety assessments, was largely extrapolated from online resources, offering only a rough estimate of past and potential future incidents. Similarly, cost estimation relied on comparisons with similar intersections, introducing uncertainties regarding the accuracy of the projected costs for the analyzed intersections. These limitations highlighted the need for more precise and reliable data sources to ensure the accuracy and validity of the analysis results.

9 Recommendations and Conclusions

Upon accomplishing the project's objectives, the team offers suggestions for future considerations as the project advances with MassDOT. These recommendations are intended to address the limitations previously identified and if given a greater timeline, the team would have pursued further. These suggestions encompass strategies to address any lingering challenges, optimize efficiency, and enhance the overall effectiveness of the project.

9.1 Roundabout and Signal Combination

Implementing a signal at the northbound intersection and a roundabout at the southbound intersection is a recommended control strategy for the interchange as it would be a strategic decision based on the analysis of vehicle traffic data. By adopting these two different control strategies, the aim is to prevent overdesigning the northbound side while effectively managing traffic flow in both directions along Route 140. As depicted in the vehicle traffic data, Figure 16, the northbound intersection of interchange at 5 PM, the PM peak hour, experiences a high number of left turns (660 vehicles). With that, the team recommends that the interchange is analyzed with a signal containing a protected left turn at this location. Due to the constraints of ICE, this was not able to be holistically reviewed, and therefore, additional software capable of analyzing the signal timing with the flow of a roundabout could be utilized.

9.2 PTV Vissim

Given the constraints of the MassDOT (ICE) procedure, the team inquired about a potential software that would better visualize and analyze the interchange as a system with two separate intersection control strategies. MassDOT provided that the German software, Planning Transport Traffic (PTV Vissim), would best accomplish this type of analysis.

PTV Vissim specializes in analyzing and simulating multimodal traffic interchanges featuring both signals and roundabouts. The software's microscopic simulation accurately models vehicle interactions, including drivers' responses to signals and navigation of roundabouts. This allows for a more precise evaluation of traffic flow, congestion, and safety within the interchange. With customizable features, the user can adjust signal timings, lane configurations, and roundabout geometry to investigate various design options and operational strategies. Detailed performance metrics enable the quantitative assessment of interchange efficiency, aiding in decision-making for optimization. The software's visualization tools, and reporting capabilities would further enhance analysis and communication of results, making PTV Vissim a recommended tool for optimizing a control strategy utilizing different types of design options within a system (PTV Group).

Figure 33: PTV Vissim Simulation of Signalized Intersection

After discussing the project further, the team proposed using PTV Vissim to enhance the design of the interchange intersections, tailoring control strategies to accommodate varying traffic volumes effectively. However, MassDOT informed the team that the software is outsourced due to its complexity and is not managed internally. Therefore, the team recommends that this interchange, specifically with the potential southbound roundabout and northbound signal, is evaluated using PTV Vissim software to better explore the combinations of control strategies in the system to prevent overdesign.

9.3 Summary

In summary, our team has developed a comprehensive understanding of intersection design best practices, analyzed vehicle traffic data provided by MassDOT, collected additional necessary information, such as pedestrian and cyclist counts, and evaluated multiple design options using the Intersection Control Evaluation (ICE) process. Following our analysis, the team's recommendation to MassDOT is a two-lane roundabout for both the Northbound and Southbound intersections on I-190. While this was the optimal control strategy output by the ICE Stage 2 Tool, it's important to acknowledge that there were limitations associated with this process and therefore, the final recommendation. To address the limitations, the team recommends the utilization of advanced software tools such as PTV VISSIM to facilitate in-depth analysis of multiple control strategies with regards to the system.

10 References

ASCE. (2021). *Modern roundabouts boost traffic safety and efficiency*. https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/issues/magazine-issue/article/2021/03/modern-roundabouts-boost-traffic-safety-and-efficiency

Federal Highway Association. (2023, July 21). *Reduce Crash Severity*. https://highways.dot.gov/safety/rwd/reduce-crash-severity

FHWA. (1995). *Roundabouts: A Direct Way to Safer Highways | FHWA*. https://highways.dot.gov/public-roads/autumn-1995/roundabouts-direct-way-safer-highways

FHWA. (2009). *Designing Complex Interchanges*. https://highways.dot.gov/public-roads/novdec-2009/designing-complex-interchanges#

FHWA. (2021). *Signalized Intersections | Intersection Safety - Safety | Federal Highway Administration*. https://safety.fhwa.dot.gov/intersection/signal/

Liu, H. (2022). Research on Common Problems and Countermeasures of Highway Interchange Design. *International Journal of Frontiers in Engineering Technology*, *4*(4). https://doi.org/10.25236/IJFET.2022.040413

MassDOT. (n.d.-a). *MassDOT Separated Bike Lane Planning & Design Guide*.

MassDOT. (n.d.-b). *Safe Speeds: Roadway Treatment Technical Toolkit*. Retrieved February 23, 2024, from https://www.mass.gov/info-details/safe-speeds-roadway-treatment-technical-toolkit#horizontal-countermeasures-.

MassDOT. (n.d.-c). *What are roundabouts? | Mass.gov*. Retrieved October 5, 2023, from https://www.mass.gov/info-details/what-are-roundabouts

MassDOT. (2020). *Guidance on Traffic Count Data*.

MassDOT. (2018, June 26). *Intersection and roadway crash rate data for analysis*. https://www.mass.gov/info-details/intersection-and-roadway-crash-rate-data-for-analysis#intersection-crash-rates-

MassDOT. (2022). *GUIDELINES FOR THE PLANNING AND DESIGN OF ROUNDABOUTS*. https://www.mass.gov/doc/massdot-guidelines-for-the-planning-and-design-of-roundabouts

Missouri Department of Transportation. (n.d.). *Diamond-Type Interchanges | Missouri Department of Transportation*. Retrieved October 5, 2023, from https://www.modot.org/diamond-type-interchanges

U.S. Department of Energy. (n.d.). *Alternative Fuels Data Center: Active Transportation and Micromobility*. Retrieved October 9, 2023, from https://afdc.energy.gov/conserve/active_transportation.html#:~:text=According%20to%20the%20National%20Association,year%20from%202018%20to%202019.

U.S. Department of Transportation. (n.d.). *Roundabouts: An Informational Guide*.

Van Dam. (2022, November 25). *Analysis | The rise of the roundabout and which state has the most*. Washington Post. https://www.washingtonpost.com/business/2022/11/25/roundabout-revolution-traffic-circles/

11 Appendix

I-190 AND ROUTE 140 INTERCHANGE REDESIGN IN STERLING, MA

A proposal submitted to the faculty of Worcester Polytechnic Institute and MassDOT in partial fulfillment of the requirements for the Bachelor of Science and Arts degree

WPI

massDOT
Massachusetts Department of Transportation

Written By: Sam Calamari, Braeden Frutchman, Abigail Pulling, Brandon Taranto

Advised By: Suzanne LePage

Table of Contents

List of Figures

List of Tables

Capstone Design Statement

This project will examine the existing interchange of Route 140 and Interstate 190. Upon completion, the project will result in a potential redesign option presented to MassDOT. To complete the Major Qualifying Project, Worcester Polytechnic Institute requires the fulfillment of all of the Accreditation Board for Engineering and Technology (ABET) capstone design elements. The following elements will be addressed throughout the duration of our project:

Economic: This project will ultimately be completed with public funds. Our team will create a final design that is within the reasonable financial restraints set by MassDOT, and analyze financial principles to assess the feasibility, cost-effectiveness, and financial viability of the redesign construction project. This will involve evaluating factors such as project costs and resource allocation.

Environmental: The construction of roads and interchanges has the potential to harm local wildlife and disrupt natural drainage patterns, potentially causing flooding in some areas. Our team will take these factors into account and will minimize environmental risks and degradation to the best ability.

Political and Social: The team will conduct this project in collaboration with MassDOT, and through them, local stakeholders like the residents of Sterling, MA, and those who will be utilizing the interchange. The needs and concerns of each stakeholder will be greatly taken into consideration and any concern raised by the residents that has been expressed to MassDOT will be factored into the design process. Additionally, the project will analyze any historical land use constraints and continue the project in accordance with local ordinances.

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 the ASCE Code of Ethics.

Health and Safety: The overall improvements made to the I-190 and Route 140 interchange will be made to value the safety of people who use the corridor. Collecting data through turning movement counts, crash data, and traffic volume will be used to improve the navigability and safety of the interchange.

Constructability: The team will look at design strategies and previous designs in order to select the best option with specific consideration of the cost and maintenance for the redesign. This will highlight the longevity and functionality of the design, and take into account factors such as material selection, maintenance, and construction time.

Sustainability: The project will aim to address current needs, as well as prioritize any future needs to find a long-lasting solution as a redesign option for the interchange. The team will optimize the roadway design best suited to minimize resource consumption and incorporate design aspects that promote efficiency to minimize the negative environmental, social, and economic impacts.

1.0 Introduction

Interstate 190 is an auxiliary interstate highway which connects I-290 with Massachusetts Route 2. This auxiliary interstate highway is referred to as a spur route meaning it connects one main highway to another. The segment our team will be focusing on is at the interchange of I-190 and Route 140 located in Sterling, Massachusetts. The interchange is often busy during peak rush hours and has led to crashes due to the dangerous orientation of the interchanges. The section of road under the overpass on Route 140 has recently been restriped to include a bike lane and reduce the amount of vehicle lanes; however, even with the inclusion of a shared-use path, the general safety and efficiency of the road remains undetermined.

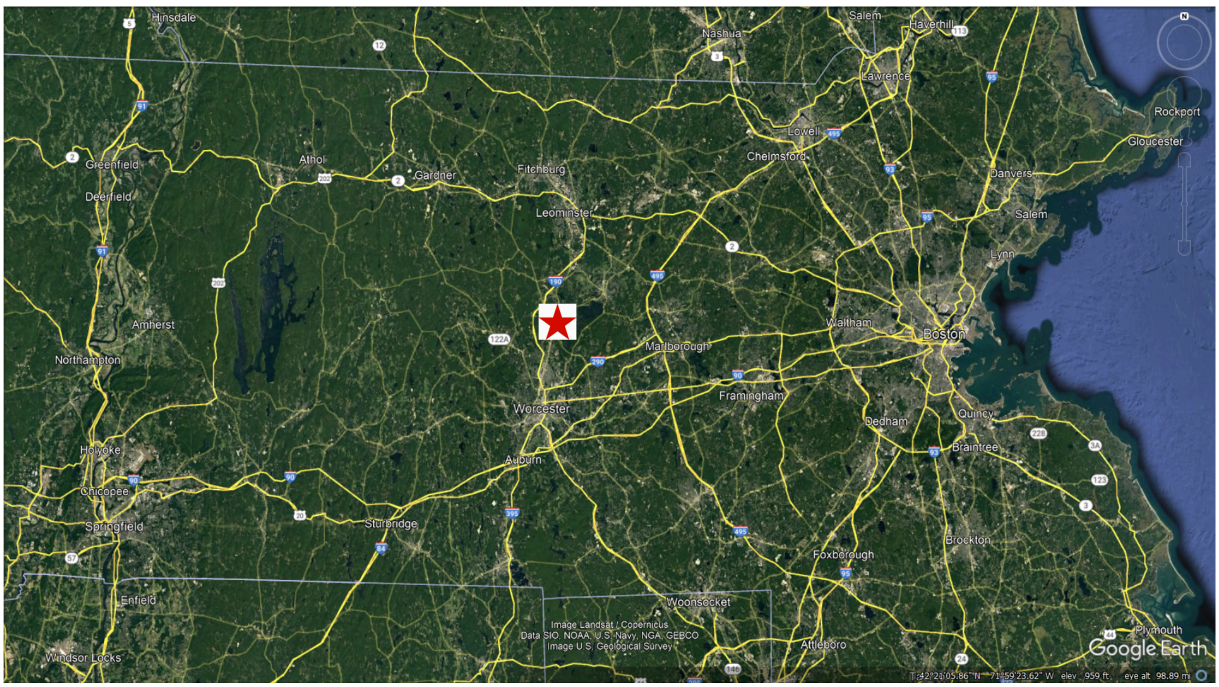


Figure 1: Location of Interchange (Google Earth, 2023)

In 2012, another WPI student team reviewed this same interchange and generated recommendations for design. Their process consisted of identifying current issues with the interchange, obtaining data from site visits and MassDOT, developing alternative designs, and eventually recommending a future design choice. At the conclusion of their project, the team suggested that the redesign be composed of a single-lane roundabout due to "safety, cost, and ability to meet future capacity demands." Although a concluding design was recommended, the development of this interchange never came to fruition.

This project aims to take a fresh look at the I-190 and Route 140 interchange with the end goal of improving functionality through a redesign process. Additionally, our group has a particular interest in active transportation and will take a closer look into how pedestrian and cyclist travel can be accommodated by the suggested redesign of the interchange.

In order to achieve a successful redesign of the interchange between Interstate 190 and Route 140, the team will pursue the following objectives:

1. Understand best practices regarding interchange design
2. Document existing conditions
3. Formulate multiple control strategies
4. Finalize a control strategy as an optimal redesign solution
5. Develop the optimal strategy to a 10% design phase

2.0 Background

The interchange for this project is located in Sterling, Massachusetts, and connects Interstate 190 to Route 140. Currently, the interchange is a diamond interchange, a common type of road junction where a controlled-access highway intersects with another road.

Figure 2: Bird's Eye View of Interchange (Google Maps, 2023)

The interchange consists of channelized off ramps from I-190 to Route 140, where vehicles cannot take a right turn immediately at the intersection, but instead yield to the oncoming traffic from Route 140. For left turns off the interchange, vehicles must cross over two lanes in order to continue in their desired direction. There is also a median separating the two directions of traffic. The section of Route 140 directly under I-190 was recently restriped from three lanes of traffic to two. With the extra space, a substantial bike lane was striped, as well as a concrete divider between bike and car traffic. There is an existing sidewalk between offramps on Route 140 going northbound. There is no crosswalk striping where the ramps meet the sidewalk, and there is also no signage for pedestrian or cyclist crossing.

Figure 3: View of Interchange Northbound

Although it has been re-striped to include fewer lanes of vehicle traffic, in its current state, the time it takes for a vehicle to take a left turn is not ideal, as two car lanes, one bike lane, and a wide concrete median must be crossed. Additionally, there is not an adequate direct line of sight for those turning left, as drivers edge into the bike line in order to have a full view of oncoming traffic in both directions. For drivers who exit I-190 traveling southbound and wish to turn left, there is visible vegetative overgrowth that also somewhat obstructs the view of traffic.

Currently, the area surrounding the interchange is overwhelmingly residential, with few commercial and recreational attractions. In both directions, the majority of the residences are single-family homes, however, there is a fairly new apartment complex about half a mile south of the interchange. Northbound on Route 140, there is a garden center and nursing home adjacent to the junction, and Wachusett Mountain is about a 12-mile distance from the interchange. Southbound on Route 140, the main attractions consist of a nursing home and Mass Central Rail Trail, which are at distances of 0.6 and 1 mile respectively.

2.1 MassDOT Intersection Control Evaluation

The prior 2012 MQP of this interchange was analyzed before the MassDOT Intersection Control Evaluation (ICE) was placed into effect. The purpose of the new ICE process is "to consider multiple context-sensitive control strategies consistently when planning a new intersection or modifying an existing intersection" (Plaza, n.d.). The general goal of the process is to select a viable option that meets the project needs and also fits well into the intersection's location and existing conditions.

The ICE process is necessary for an intersection located on a state highway, requires the issuance of a Category II or III Access Permit, and receives MassDOT or Federal Highway Administration funding. Also, the general process is the same for new designs, redesigns, or any modifications of intersections. Forms for conducting an ICE can be found on the MassDOT website, with guiding information throughout the three stages of *Screening, Initial Assessment, and Detailed Assessment.* The first stage consists of considering a wide range of different intersection design strategies, the second stage includes traffic operations analysis, crash predictions, planning level opinions of probable design, right-of-way, and construction costs, and the third stage 3 involves detailed traffic operations analyses and preliminary geometric designs (MassDOT, 2021).

2.2 Interchange Design

Highway interchanges are specialized intersections that are designed to provide an efficient flow of traffic. By utilizing a system of interconnecting roadways and grade separations, they allow traffic to pass through an intersection without major interruptions. Interchanges are constructed to decrease congestion, improve safety, promote shared road space, and enable the smooth movement of vehicles and people from one road to another. While highway interchanges offer many transportation-related benefits, their effectiveness is dependent on proper planning, design, and maintenance.

A main pitfall of current interchange designs is that they are not created to accommodate the large flow of traffic, as traffic volume is continually increasing. Outdated interchanges may lack optimization and can be insufficient for pedestrian and cyclist safety. Therefore, it is essential to consider the specific needs of the area, compatibility with the surrounding land use, traffic patterns, and potential future growth when planning and constructing highway interchanges (Research on Common Problems and Countermeasures of Highway Interchange Design, 2022).

Improvements to interchange designs are made in areas with high traffic volume and dense land use. New improvements to interchanges referring to increased traffic flow result in creating more involved complex designs, and consideration of the local network-system into the integration of design. Designers can consider the local road network by understanding the entire corridor instead of the individual interchange. Lastly, another modern approach to improving interchange performance specifically in terms of safety, is to “expand the knowledge of driver performance as a function of various design configurations” (FHWA, n.d.)

2.2.1 Diamond Interchanges

Diamond interchanges are commonly used in transportation engineering to connect two roads or highways. They are suitable and a prominent type of interchange for both rural and urban areas. This interchange variation involves two main roads, such as a highway or expressway, and a surface street. While a conventional at-grade intersection involves traffic crossing each other on the same level, a grade-separated interchange allows one of the roads to pass over the other using ramps and an overpass. Diamond grade-separated interchanges are designed to improve traffic flow, efficiency, and safety as they remove the need for vehicles on the surface street to cross over multiple lanes of high-speed traffic. They can become congested, especially when there is a high volume of left-turning movements on the crossroad (Missouri Department of Transportation, n.d.). To combat inefficiencies associated with traffic buildup, some diamond interchanges will include signalized ramp access, roundabouts, or other methods suited to improve the design at the specific site.

2.2.2 Route 12 and I-190

Approximately five miles north of our project site is a similarly designed diamond highway exchange that connects Route 12 and Interstate 190. This interchange was successfully redesigned in 2018 and was reconstructed to include a roundabout as shown in Figure 2 below.

Figure 4: Bird's Eye View of the Improved MA-12 and I-190 Interchange (Google Earth, 2023)

Before reconstruction, vehicles turning left to travel northbound struggled to cross two lanes of oncoming traffic, as shown below in Figure 3. Especially when traveling at night, or during rush hour, identifying gaps in the flow was difficult, ultimately leading to safety concerns. This interchange was not efficient and the wide cross-section made it a good candidate for improvement efforts.

Figure 5: Route MA-12 and Interstate 190 Street View 2011 (Google Earth, 2011)

Figure 6: Route MA-12 and Interstate 190 Street View 2023 (Google Earth, 2023)

Figure 4 reflects the current conditions of the intersection and illustrates how vehicles can now efficiently enter into the roundabout. This is a single-lane roundabout that has bike lanes, pedestrian crossings, and sidewalks for active transporters.

2.3 Roundabout Functionality

A roundabout is a circular intersection that allows traffic to flow counterclockwise around a central island. The vehicles entering the circle must yield to those already inside, promoting a continuous stream of traffic. Roundabouts typically operate at slower speeds, which increases safety, and are more efficient than traditional intersections. Roundabouts contain the following elements, as shown in Figure 5.

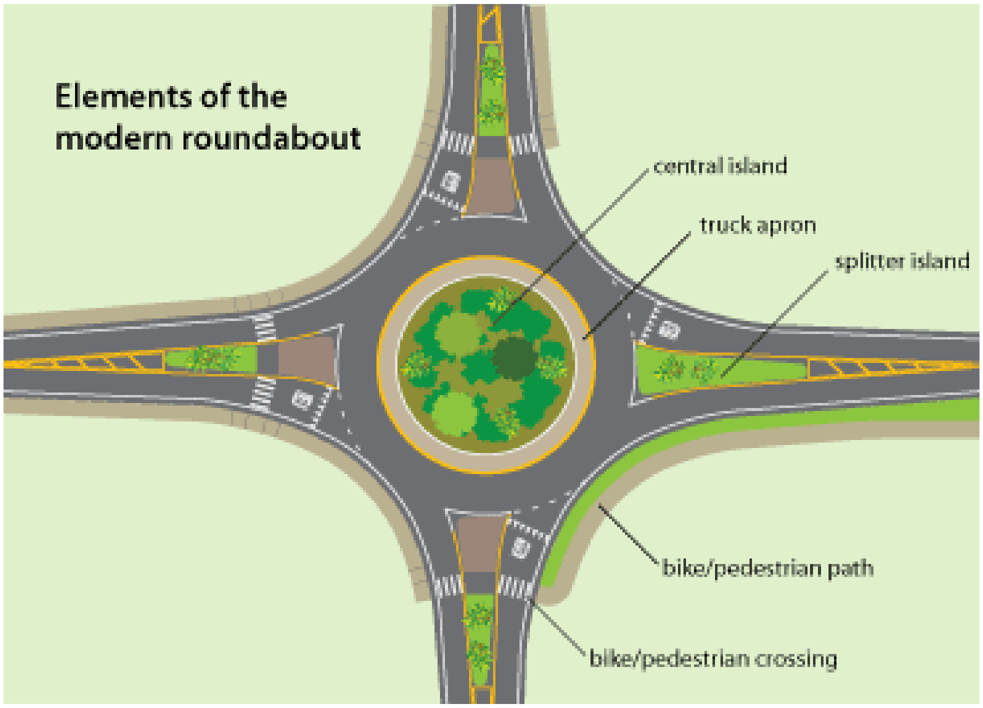


Figure 7: Elements of the Modern Roundabout (Roundabouts: An Informational Guide, n.d.)

The central island is typically landscaped, raised, and untraversable. This island allows the driver to see the intersection ahead and recognize the circular approach. Not all central islands are circular, but circular-shaped central islands promote continuous speeds as they have a constant radius. Oval or irregular shapes can increase difficulty while driving and decrease overall speeds. The truck apron, which surrounds the central island, primarily serves to accommodate the turning radius of larger vehicles, such as trucks, buses, and emergency vehicles, making it easier for them to navigate without encroaching onto the central island or curbing. The splitter islands, located at the four legs of the intersection, physically separate the entering and exiting traffic flows. They perform many beneficial functions and should be included in roundabout design. Splitter islands protect pedestrians, slow down approaching and departing traffic, and deter wrong-way movements (*Roundabouts: An Informational Guide*, n.d.). Providing safety for active transporters is important in all intersection designs. Bike and pedestrian paths are included in roundabouts and must balance convenience, safety, and operations.

Roundabouts have proven to be a modern approach to interchange design. The first presence of modern roundabouts in the United States was seen in the 1990s and resulted in a rise in roundabouts nationally and a decrease in older traffic circles and traditional signalized intersections (*Analysis | The Rise of the Roundabout and Which State Has the Most*, 2022). Figure 6 depicts this increase and allows for a visual representation of concentrated areas with the largest adoption of roundabouts.

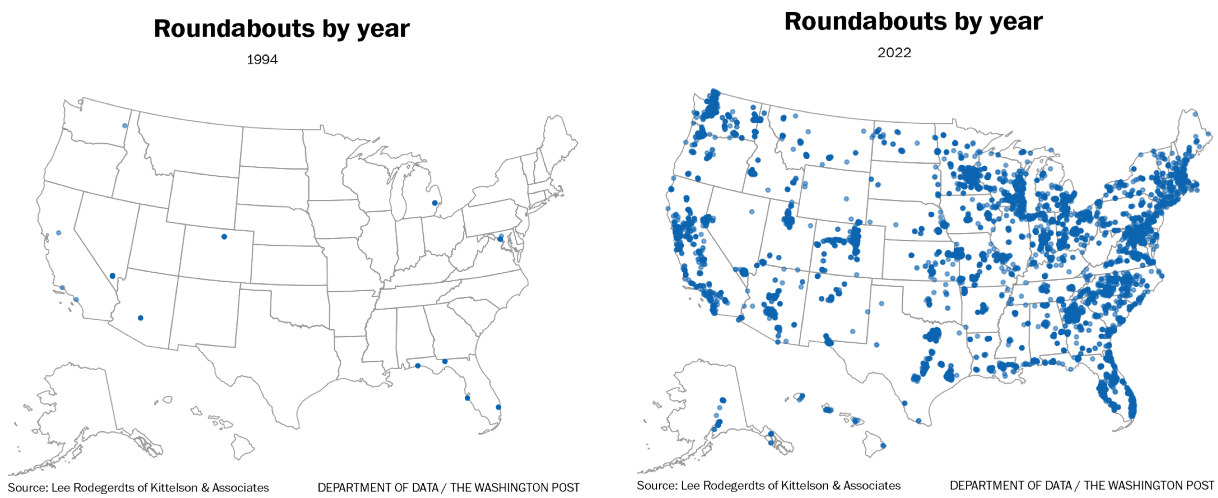


Figure 8: Comparison of Frequency Roundabouts in the United States by Year (1994 vs. 2022) (Van Dam, 2022)

Over the years, roundabouts have been redesigned to improve on earlier developments of the traffic circle. Early traffic circles were "nonconforming" in the sense that entering traffic would cut off circulating traffic. This lack of a clear yield and right-of-way was inefficient and led to a high frequency of collisions (*Roundabouts: A Direct Way to Safer Highways | FHWA*, n.d.). The modern roundabout has well-defined rules for entering and exiting and is currently the preferred design option.

2.3.1 Benefits of Roundabouts

Roundabouts, in many transportation projects, are considered superior to traditional intersections with stop signs or traffic signals. Benefits of roundabouts include simplification of traffic flow and improved safety. MassDOT further lists a variety of benefits when using a roundabout design in transportation engineering (*What Are Roundabouts?*, n.d.):

- ➔ Fewer conflict points between vehicles in an intersection
- ➔ Reduction in property-damage-only crashes by 52% and fatal and injury crashes by 84%
- ➔ Elimination of wasted time waiting at red lights at traffic signals during off-peak hours
- ➔ Improved travel times for emergency vehicles responding to emergencies by eliminating unnecessary stops and delays
- ➔ No maintenance requirement for traffic signals and can operate during power outages
- ➔ Slower vehicle speeds are closer to the speeds of people biking, which increases their comfort

2.4 Signalized Intersections

A signalized intersection, or traffic light-controlled intersection, regulates traffic flow by a system of red, yellow, and green lights that indicate a vehicle's right of way. Signalized intersections are a fundamental element of traffic control and are commonly used. To maximize efficiency for all users, signal timing is the length of each light cycle that is calculated from the estimated number of vehicles and pedestrians in the queue at a given time (FHWA, n.d.). By understanding the intersection or road capacity and crash data, signalized intersections can improve safety and decrease traffic buildup. Although signalized intersections increase the traffic handling ability and safety of pedestrians and vehicles, there are tradeoffs associated with the system. For example, signals can significantly increase the amount of rear-end collisions and can lead to the diversion of traffic to residential streets, especially in areas of high volume and congestion (FHWA, n.d.).

2.5 Active Transportation

Active transportation encompasses transportation without the use of motorized vehicles, operated through human physical activity. This includes walking, biking, skateboarding, and many other forms of human-powered transportation. Active transportation has increased in the past 15 years due to an emphasis on physical activity and reducing carbon emissions. Between 2010 and 2019 bicycle trips within the 100 most populated cities in the United States increased from 320,000 to 136 million (*Alternative Fuels Data Center: Active Transportation and Micromobility*). With this dramatic rise in active transportation, many cities including Sterling, MA, have created public bike paths to create a safe way for users to get physical activity as well as transport places without the need for motorized vehicles. Accessible means to safe active transportation is an important piece of city design and a crucial element to any roadway and intersection or interchange.

Figure 9: Route 140 North Passing Under I-190 with a Bike Lane on the Right

The Massachusetts Department of Transportation published a guide on Separated Bike Lane Design and Planning which entails how a pedestrian bike lane should be constructed and the considerations that are to be made. Within the guide are recommendations for intersection design. Different types of intersections are listed along with the exposure pedestrians are likely to experience. These include conventional bike lanes (current intersection design), separated bike lanes, roundabouts, and protected intersections. In addition, the guide recommends raised bike lanes in many circumstances including crossing the interstate on ramps (*Intersection Design*).

In 2022 MassDOT updated their mapping of walkable trips. The segment of roadway on Route 140 is listed as having a low potential for walkable trips. This is likely due to a number of factors including safety and local infrastructure. As the interchange does not include much infrastructure nearby, such as shops or restaurants, the area is not likely to boast large numbers of active transport users.

2.6 Transportation Engineering Elements

Interchange data collection is a multifaceted process that utilizes a range of methods which include Traffic Counts, Turning Movement Counts, and Crash Data.

Traffic counts aid in the data collection process on the volume and composition of traffic at a specific location. This information is critical for designing an interchange that can efficiently handle the current and future traffic demand. Engineers use traffic counts to determine the number of lanes, lane configurations, and other design elements required to ensure safe and smooth traffic flow (MassDOT, 2020). Another outcome of this method is the calculation of

ADT (Average Daily Traffic), which in turn can be used later on to calculate the AADT (Average Annual Daily Traffic).

Turning Movement Counts are an important complement to traffic flow data and can provide reliable insights into traffic congestion. These counts provide valuable data about specific vehicle movements at interchanges, such as left turns, right turns, and through movements. This information is critical for assessing interchange safety by pinpointing potential conflict points prone to crashes so that safety can be enhanced in a targeted manner (MassDOT, 2020). In addition, turning motion counts help transportation experts evaluate transfer capabilities. By gauging the volume of vehicles making different maneuvers, they can determine operational efficiency and congestion issues. This data is essential for identifying capacity-related challenges and planning necessary improvements or expansions.

Highway and interchange design elements are highly interconnected to the safety of road users. Various factors including road geometry, lane width and configuration, and traffic control devices impact the frequency and severity of the collisions and the safety of active transporters. MassDOT collects and maintains data related to road safety to monitor and improve transportation safety.

Crash data is information collected by MassDOT, law enforcement, and the Registry of Motor Vehicles about collisions that occur on state roadways. These reports and databases contain information such as the location of the crash, time of occurrence, vehicles involved (size, model), and other contributing factors such as the weather, driver behaviors, and road conditions. Crash data is critical for evaluating highway interchanges as it can pinpoint hazardous areas, such as merging lanes or exit ramps, and allow for targeted safety improvements.

Certain types of collisions are more common at interchanges, especially when lanes are merging or diverging. Some examples of collisions include rear-end, side-impact, and pedestrian and cyclist crashes. Collisions occur more frequently when weather factors impact road conditions and driver visibility, which emphasizes the need for proper signage and infrastructure. Transportation engineering improvements have provided a variety of low-cost safety countermeasures that are proven to decrease collision rates. For example, installing rumble strips which are an audible and physical feature that alert drivers when they are drifting or approaching a hazard. To improve pedestrian and cyclist safety, slowing down vehicle speeds near crosswalks is a very low-cost solution. Additionally, providing cyclists and pedestrians with protections, such as a cub or buffer space are easy fixes to help prevent crashes. While the precautionary measures, adaptations, and type of infrastructure vary depending on the location, safety remains a top priority in transportation engineering.

3.0 Methodology

In order to complete the end goal of taking a fresh look at the I-190 and Route 140 interchange to improve functionality through a redesign process, the team will pursue the following objectives:

1. Understand best practices regarding interchange design
2. Document existing conditions
3. Formulate multiple control strategies
4. Finalize a control strategy as an optimal redesign solution
5. Develop the optimal strategy to a 10% design phase

The Gantt chart below, Figure 10, depicts the project timeline and notable milestones the team will accomplish.

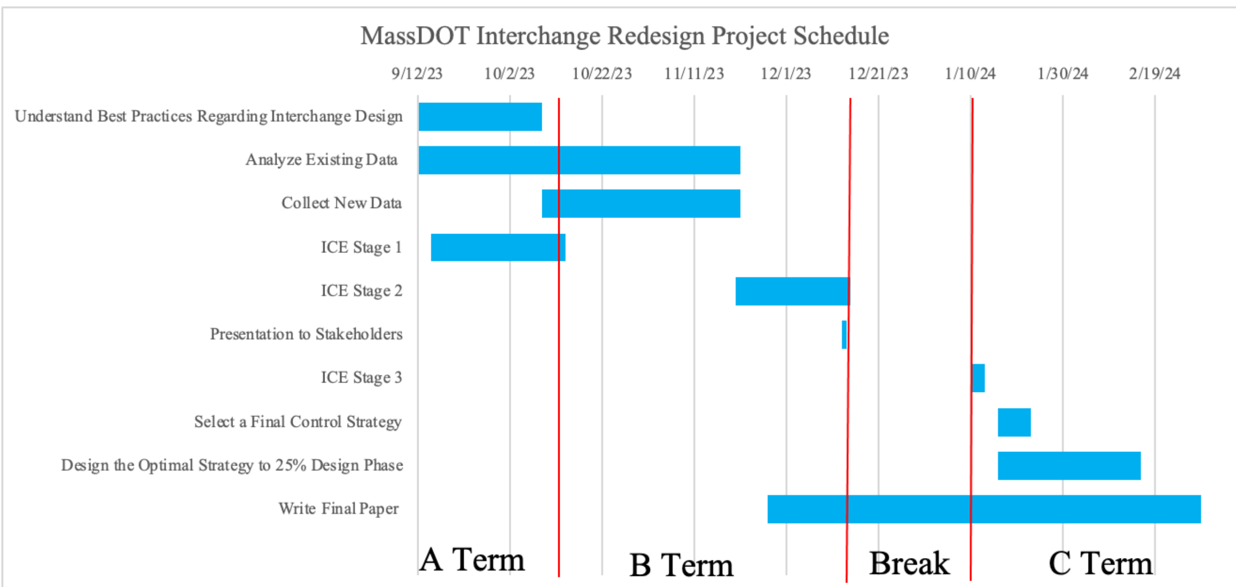


Figure 10: Project Schedule

3.1 Understand Best Practices Regarding Interchange Design

The team will develop an overarching understanding of best practices for intersection design. We will utilize the Federal Highway Design Standards which are established and maintained by the Federal Highway Administration (FHWA), and fall under the jurisdiction of the U.S. Department of Transportation. These standards ensure the uniformity and safety of highways and roadways across the country and will highlight the most efficient and generally accepted methods for interchange design. The team will also review the specific guidelines written by the American Association of State Highway and Transportation Officials (AASHTO) that pertain to geometric design aspects, the development of bicycle facilities, and the planning, design, and operations of pedestrian facilities. These standards are continuously updated and revised to reflect advances in engineering practices, safety considerations, and evolving transportation needs. Our team, with combined knowledge from MassDOT, will adopt these federal standards as a basis for our design criteria and tailor them to the specific requirements of our project site. Furthermore, MassDOT publishes the Project Development and Design Guide (PDDG) which serves as a guide for developing context-sensitive and community-friendly road projects. Our team will reference this document to ensure best practices are being met.

In addition to understanding the Federal Highway Design and MassDOT Standards, our team will utilize the Route 12 and 1-190 interchange that was redesigned in 2018. Given that this site has similar qualities to our project site, the team will learn how best practices were used in its development. This interchange will serve as a case study in which we will analyze the desired aspects and compare them to the specific goals of our project.

3.2 Document Existing Conditions

After developing an understanding of the best practices related to interchange design, the team will proceed with existing data provided by MassDOT. We will conduct a detailed analysis of existing files, databases, dashboards and interactive maps that relate to the Peak Hour Volumes, Turning Movement Counts, Annual Average Daily Traffic (AADT), Average Daily Traffic (ADT), and crash rates at our site, as shown in Figure 11 below. This data will be examined to determine if it meets the requirements for accuracy and if it is up to date. With this information, the team will create relevant analyses such as crash diagrams and traffic flow diagrams. This data will be a large input to the ICE process so it will be crucial for the team to analyze it thoroughly.

Table 1: Data Necessary for Analysis and Resources for Collection

Data	**Resources for Collection**
AADT/ADT	Traffic Volumes MassDOT / Precision Data Industries (LLC)
Turning Movements	Turning Movements MassDOT
Crash	MassDOT: Crash Data Portal (state.ma.us) $crash\ rate = \frac{crashes\ per\ year * 1{,}000{,}000}{average\ daily\ traffic * 365}$
Pedestrian & Cyclist Counts	Team will collect using the camera set up on-site

Once existing data has been found and analyzed, the team will collect supplemental data including turning counts and pedestrian counts to help better understand potential flaws in the current design. While much of the data that is needed for site analysis has already been conducted by MassDOT or other agencies, for proper site analysis, additional data is needed. The team will collaborate with MassDOT to help install cameras at the site which will allow for the team to track and update the data needed. During and following this data collection, the team will analyze this data and utilize it during the ICE process stage 2.

3.3 Formulate Multiple Control Strategies

ICE or Intersection Control Evaluation will be utilized to select multiple control strategies that would fit the demands of the intersection. ICE is broken down into 3 stages: screening, initial assessment, and detailed assessment.

Stage 1 encompasses a general look at various intersection designs to note if those intersections could potentially act as a solution for a redesign. These intersections are not specific to any single intersection and do not take site constraints into account. This stage is used to find which intersections could work for the redesign, it uses yes/no questions such as, “does the intersection improve traffic operations?”

During stage 2 data is collected and analyzed through constraints such as cost analysis, safety, and public input. This stage uses the chosen intersections from Stage 1 to see which of those fits the site constraints most efficiently. If a single intersection type has been selected following stage 2, stage 3 does not need to occur.

Stage 3 is utilized to further analyze the remaining strategies. This step includes environmental analysis, and historical analysis, in addition to any constraints not analyzed during stages 1 and 2. Stage 3 also includes preliminary design plans, to aid in visualization of size constraints.

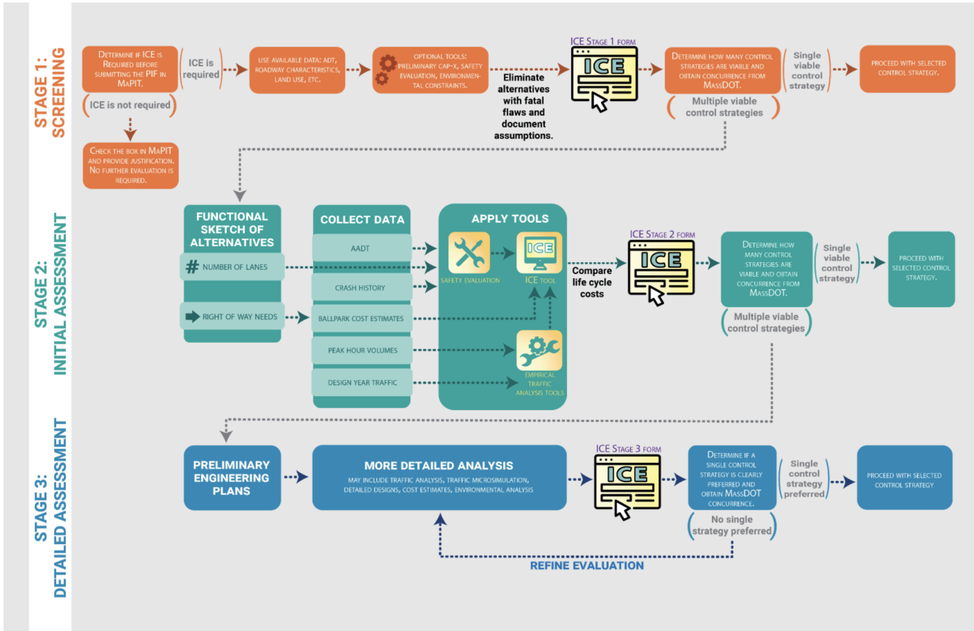


Figure 12: Illustration of the Three Stages of the ICE Process (Kristiansen, n.d.)

3.4 Finalize a Control Strategy as an Optimal Redesign Solution

After the conclusion of the ICE process, the team will assess further, by analyzing the constraints of the site that are not mentioned within the three stages of ICE. Specific physical constraints include the feasibility of certain designs given the amount of space of the current interchange, as well as any sensitive environmental zones that may be impacted by new development. The team will also take into consideration social constraints like potential historical significance that is present around the area, and if/how the redesign may impede historical preservation. In addition to existing constraints, in this stage, the team will also consider modes of active transport and how well the proposed design incorporates them. The team will examine the placement and feasibility of newly designed bike lanes and sidewalks, and then decide if the current solution is sufficient to accommodate these additions.

Following the analysis of factors separate from the ICE process, the team will be able to successfully finalize and continue with a redesign strategy for the interchange of I-190 and Route 140.

3.5 Develop the Optimal Strategy to 10% Design Phase

After the preferred redesign solution is finalized, the last step of the process is to compose a model of the interchange to a 10% design phase. The new design will take into consideration any site constraints, including environmental, historical, or others that may arise.

The main component of the 10% design phase is to form a drawing of the horizontal geometry of the new interchange. This would include curb lines, pavement striping, and impacted utilities that would need to be updated. The design will be modeled by using Automatic Computer-Aided Design 2023 (AutoCAD). The design will be overlaid on the existing AutoCAD survey of the interchange provided to the team by MassDOT, and the survey will include existing utilities, topography, and property lines. Once a design is reached, the team will compile the overall model, as well as detail sheets of the sidewalks, bike lanes, pavement striping, and signage locations to MassDOT.

Bibliography

ASCE. (2021). *Modern roundabouts boost traffic safety and efficiency*. https://www.asce.org/publications-and-news/civil-engineering-source/civil-engineering-magazine/issues/magazine-issue/article/2021/03/modern-roundabouts-boost-traffic-safety-and-efficiency

FHWA. (1995). *Roundabouts: A Direct Way to Safer Highways | FHWA*. https://highways.dot.gov/public-roads/autumn-1995/roundabouts-direct-way-safer-highways

FHWA. (2009). *Designing Complex Interchanges*. https://highways.dot.gov/public-roads/novdec-2009/designing-complex-interchanges#

FHWA. (2021). *Signalized Intersections | Intersection Safety - Safety | Federal Highway Administration*. https://safety.fhwa.dot.gov/intersection/signal/

Kristiansen, A. (n.d.). ICE Procedure Overview: Intersection Control Evaluation

Procedure. 16.

Liu, H. (2022). Research on Common Problems and Countermeasures of Highway Interchange Design. *International Journal of Frontiers in Engineering Technology*, *4*(4). https://doi.org/10.25236/IJFET.2022.040413

MassDOT. (n.d.-a). *MassDOT Separated Bike Lane Planning & Design Guide*.

MassDOT. (n.d.-b). *What are roundabouts? | Mass.gov*. Retrieved October 5, 2023, from https://www.mass.gov/info-details/what-are-roundabouts

MassDOT. (2020). *Guidance on Traffic Count Data*.

Missouri Department of Transportation. (n.d.). *Diamond-Type Interchanges | Missouri Department of Transportation*. Retrieved October 5, 2023, from https://www.modot.org/diamond-type-interchanges

U.S. Department of Energy. (n.d.). *Alternative Fuels Data Center: Active Transportation and Micromobility*. Retrieved October 9, 2023, from https://afdc.energy.gov/conserve/active_transportation.html#:~:text=According%20to%20the%20National%20Association,year%20from%202018%20to%202019.

U.S. Department of Transportation. (n.d.). *Roundabouts: An Informational Guide*.

Van Dam. (2022, November 25). *Analysis | The rise of the roundabout and which state has the most*. Washington Post. https://www.washingtonpost.com/business/2022/11/25/roundabout-revolution-traffic-circles/

Recount

Appendix B: AADT Recount (No Build)

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1
Starting: 10/11/2023

Page: 1

STA. 1 NB

Station #: 230240000080
Site ID: 000000010101
Location: Route 140 NB, north of I-190
Direction: NORTH

File: D1011001.prn
City: Sterling
County:

TIME	MON 16	TUE 17	WED 11	THU 12	FRI 13	WKDAY AVG	SAT 14	SUN 15	WEEK AVG	TOTAL
01:00	31	33		25	32	30	64	51	39	236
02:00	12	20		19	18	17	31	43	24	143
03:00	5	7		7	12	8	18	9	10	58
04:00	18	15		12	13	14	12	9	13	79
05:00	35	22		23	21	25	24	13	23	138
06:00	97	95		85	77	88	39	20	69	413
07:00	196	200		196	213	201	92	49	158	946
08:00	284	323		316	273	299	188	132	253	1516
09:00	314	313		364	305	324	267	217	297	1780
10:00	271	298	293	300	340	300	394	362	323	2258
11:00	322	339	328	344	327	332	586	456	386	2702
12:00	315	351	302	363	362	339	655	633	426	2981
13:00	371	340	352	358	429	370	720	681	464	3251
14:00	406	382	401	414	507	422	592	591	470	3293
15:00	553	620	570	576	655	595	563	564	586	4101
16:00	793	838	877	923	968	880	563	487	778	5449
17:00	943	942	987	998	1017	977	430	486	829	5803
18:00	816	940	881	865	875	875	410	392	740	5179
19:00	438	566	511	488	603	521	298	307	459	3211
20:00	308	340	336	362	343	338	290	241	317	2220
21:00	180	251	238	243	247	232	180	176	216	1515
22:00	108	128	171	178	191	155	193	83	150	1052
23:00	83	78	118	135	151	113	171	75	116	811
24:00	79	67	76	78	109	82	121	54	83	584
TOTALS	6978	7508	6441	7672	8088	7537	6901	6131	7229	49719
% AVG WKDY	92.6	99.6	85.5	101.8	107.3		91.6	81.3		
% AVG WEEK	96.5	103.9	89.1	106.1	111.9		95.5	84.8		
AM Times	11:00	12:00	11:00	09:00	12:00	12:00	12:00	12:00	12:00	
AM Peaks	322	351	328	364	362	339	655	633	426	
PM Times	17:00	17:00	17:00	17:00	17:00	17:00	13:00	13:00	17:00	
PM Peaks	943	942	987	998	1017	977	720	681	829	

Appendix C: AADT Counts for Interchange (No Build)

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1
Starting: 9/26/2023

STA. 1 NB

Station #: 230420000061
Site ID: 000000000101
Location: Route 140 NB, north of I-190
Direction: NORTH

File: D0926001.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			0	0	0	0			0	0
02:00			0	0	0	0			0	0
03:00			0	0	0	0			0	0
04:00			0	0	0	0			0	0
05:00			0	0	0	0			0	0
06:00			0	0	0	0			0	0
07:00			0	0	0	0			0	0
08:00			0	0	0	0			0	0
09:00			0	0	0	0			0	0
10:00			0	0	0	0			0	0
11:00			0	0	4	1			1	4
12:00		3	0	0	3	2			2	6
13:00		0	0	0	0	0			0	0
14:00		0	0	0		0			0	0
15:00		0	0	0		0			0	0
16:00		0	0	0		0			0	0
17:00		0	0	0		0			0	0
18:00		0	0	0		0			0	0
19:00		0	0	0		0			0	0
20:00		0	0	0		0			0	0
21:00		0	0	0		0			0	0
22:00		0	0	0		0			0	0
23:00		0	0	0		0			0	0
24:00		0	0	0		0			0	0
TOTALS		3	0	0	7	3			3	10
% AVG WKDY		100.0	0.0	0.0	233.3					
% AVG WEEK		100.0	0.0	0.0	233.3					
AM Times		12:00			11:00	12:00			12:00	
AM Peaks		3			4	2			2	
PM Times										
PM Peaks										

RECOUNT

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1
Starting: 9/26/2023

Station #: 230420000039
Site ID: 000000000102
Location: Route 140 SB, north of I-190
Direction: SOUTH

STA 1SB

File: D0926002.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			11	5	14	10			10	30
02:00			9	6	6	7			7	21
03:00			10	9	14	11			11	33
04:00			27	25	27	26			26	79
05:00			74	72	68	71			71	214
06:00			263	236	212	237			237	711
07:00			627	548	513	563			563	1688
08:00			931	800	660	797			797	2391
09:00			631	597	533	587			587	1761
10:00			341	347	340	343			343	1028
11:00			269	259		264			264	528
12:00		277	230	250		252			252	757
13:00		251	262	234		249			249	747
14:00		254	274	267		265			265	795
15:00		258	293	282		278			278	833
16:00		338	337	342		339			339	1017
17:00		291	317	447		352			352	1055
18:00		259	303	391		318			318	953
19:00		235	223	237		232			232	695
20:00		111	173	165		150			150	449
21:00		104	90	96		97			97	290
22:00		71	76	75		74			74	222
23:00		44	40	45		43			43	129
24:00		32	40	41		38			38	113
TOTALS		2525	5851	5776	2387	5603			5603	16539
% AVG WKDY		45.1	104.4	103.1	42.6					
% AVG WEEK		45.1	104.4	103.1	42.6					
AM Times		12:00	08:00	08:00	08:00	08:00			08:00	
AM Peaks		277	931	800	660	797			797	
PM Times		16:00	16:00	17:00		17:00			17:00	
PM Peaks		338	337	447		352			352	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1

Starting: 9/26/2023

Station #: 230420000097 STA .2SB File: D0926003.prn

Site ID: 000000000202 City: Sterling

Location: Off-ramp from I-190 SB to Route 140 NB County:

Direction: SOUTH

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			11	16	17	15			15	44
02:00			5	7	7	6			6	19
03:00			3	4	6	4			4	13
04:00			3	3	0	2			2	6
05:00			7	4	3	5			5	14
06:00			17	20	16	18			18	53
07:00			82	71	61	71			71	214
08:00			157	113	104	125			125	374
09:00			104	128	92	108			108	324
10:00			126	84	106	105			105	316
11:00			125	108		116			116	233
12:00		129	110	133		124			124	372
13:00		122	141	129		131			131	392
14:00		177	150	120		149			149	447
15:00		261	209	228		233			233	698
16:00		333	318	322		324			324	973
17:00		328	331	341		333			333	1000
18:00		340	314	294		316			316	948
19:00		224	187	209		207			207	620
20:00		131	127	120		126			126	378
21:00		90	96	137		108			108	323
22:00		47	71	75		64			64	193
23:00		36	36	39		37			37	111
24:00		33	36	41		37			37	110
TOTALS		2251	2766	2746	412	2764			2764	8175
% AVG WKDY		81.4	100.1	99.3	14.9					
% AVG WEEK		81.4	100.1	99.3	14.9					
AM Times		12:00	08:00	12:00	10:00	08:00			08:00	
AM Peaks		129	157	133	106	125			125	
PM Times		18:00	17:00	17:00		17:00			17:00	
PM Peaks		340	331	341		333			333	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1 Page: 1
Starting: 9/26/2023

Station #: 230400000119 STA. 35B File: D0926004.prn
Site ID: 000000000302 City: Sterling
Location: Off-ramp from I-190 SB to Route 140 SB County:
Direction: SOUTH

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			15	27	7	16			16	49
02:00			24	19	7	17			17	50
03:00			18	20	32	23			23	70
04:00			14	10	15	13			13	39
05:00			31	17	22	23			23	70
06:00			80	76	68	75			75	224
07:00			132	178	136	149			149	446
08:00			270	190	201	220			220	661
09:00			222	190	183	198			198	595
10:00			143	173	188	168			168	504
11:00			128	165		146			146	293
12:00		215	149	202		189			189	566
13:00		193	143	177		171			171	513
14:00		227	236	158		207			207	621
15:00		254	250	292		265			265	796
16:00		380	308	299		329			329	987
17:00		303	279	288		290			290	870
18:00		332	308	359		333			333	999
19:00		233	277	254		255			255	764
20:00		167	143	148		153			153	458
21:00		78	109	118		102			102	305
22:00		62	59	44		55			55	165
23:00		29	42	19		30			30	90
24:00		24	16	25		22			22	65
TOTALS		2497	3396	3448	859	3449			3449	10200
% AVG WKDY		72.4	98.5	100.0	24.9					
% AVG WEEK		72.4	98.5	100.0	24.9					
AM Times		12:00	08:00	12:00	08:00	08:00			08:00	
AM Peaks		215	270	202	201	220			220	
PM Times		16:00	16:00	18:00		18:00			18:00	
PM Peaks		380	308	359		333			333	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1
Starting: 9/26/2023

STA. 4 NB

Station #: 230420000143
Site ID: 000000000401
Location: On-ramp from Route 140 SB to I-190 NB
Direction: NORTH

File: D0926005.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			5	8	7	7			7	20
02:00			5	10	4	6			6	19
03:00			2	10	11	8			8	23
04:00			17	16	19	17			17	52
05:00			55	64	51	57			57	170
06:00			141	141	153	145			145	435
07:00			254	248	214	239			239	716
08:00			370	358	270	333			333	998
09:00			258	290	234	261			261	782
10:00			202	180	184	189			189	566
11:00			140	176		158			158	316
12:00		157	154	136		149			149	447
13:00		170	152	132		151			151	454
14:00		134	169	137		147			147	440
15:00		156	165	182		168			168	503
16:00		191	183	174		183			183	548
17:00		177	181	214		191			191	572
18:00		132	177	152		154			154	461
19:00		118	112	118		116			116	348
20:00		63	72	96		77			77	231
21:00		44	45	57		49			49	146
22:00		34	22	20		25			25	76
23:00		25	24	24		24			24	73
24:00		14	22	19		18			18	55
TOTALS		1415	2927	2962	1147	2872			2872	8451
% AVG WKDY		49.3	101.9	103.1	39.9					
% AVG WEEK		49.3	101.9	103.1	39.9					
AM Times		12:00	08:00	08:00	08:00	08:00			08:00	
AM Peaks		157	370	358	270	333			333	
PM Times		16:00	16:00	17:00		17:00			17:00	
PM Peaks		191	183	214		191			191	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1
Starting: 9/26/2023

STA. 5NB

Station #: 230420000036
Site ID: 000000000501
Location: On-ramp from Route 140 NB to I-190 NB
Direction: NORTH

File: D0926006.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			6	6	3	5			5	15
02:00			3	1	5	3			3	9
03:00			1	5	3	3			3	9
04:00			6	2	5	4			4	13
05:00			14	19	16	16			16	49
06:00			42	40	48	43			43	130
07:00			90	84	81	85			85	255
08:00			137	142	130	136			136	409
09:00			102	128	121	117			117	351
10:00			81	111	94	95			95	286
11:00			77	69		73			73	146
12:00		73	61	71		68			68	205
13:00		71	78	80		76			76	229
14:00		68	84	70		74			74	222
15:00		95	114	95		101			101	304
16:00		110	109	114		111			111	333
17:00		109	120	114		114			114	343
18:00		103	119	116		113			113	338
19:00		60	69	88		72			72	217
20:00		42	36	55		44			44	133
21:00		35	23	44		34			34	102
22:00		15	17	19		17			17	51
23:00		10	17	14		14			14	41
24:00		12	5	16		11			11	33
TOTALS		803	1411	1503	506	1429			1429	4223
% AVG WKDY		56.2	98.7	105.2	35.4					
% AVG WEEK		56.2	98.7	105.2	35.4					
AM Times		12:00	08:00	08:00	08:00	08:00			08:00	
AM Peaks		73	137	142	130	136			136	
PM Times		16:00	17:00	18:00		17:00			17:00	
PM Peaks		110	120	116		114			114	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1 Starting: 9/26/2023

Station #: 230420000126
Site ID: 000000000601
Location: Route 140 NB, south of I-190
Direction: NORTH

STA. 6NB

File: D0926007.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			8	11	7	9			9	26
02:00			9	3	9	7			7	21
03:00			2	13	13	9			9	28
04:00			8	5	8	7			7	21
05:00			23	29	20	24			24	72
06:00			67	69	74	70			70	210
07:00			161	141	128	143			143	430
08:00			249	243	221	238			238	713
09:00			206	230	221	219			219	657
10:00			161	184	194	180			180	539
11:00			150	145		148			148	295
12:00		166	152	152		157			157	470
13:00		153	144	187		161			161	484
14:00		152	189	155		165			165	496
15:00		199	217	229		215			215	645
16:00		277	309	339		308			308	925
17:00		350	357	361		356			356	1068
18:00		329	343	352		341			341	1024
19:00		171	188	208		189			189	567
20:00		121	109	137		122			122	367
21:00		82	80	100		87			87	262
22:00		41	45	50		45			45	136
23:00		31	35	33		33			33	99
24:00		37	27	37		34			34	101
TOTALS		2109	3239	3413	895	3267			3267	9656
% AVG WKDY		64.6	99.1	104.5	27.4					
% AVG WEEK		64.6	99.1	104.5	27.4					
AM Times		12:00	08:00	08:00	08:00	08:00			08:00	
AM Peaks		166	249	243	221	238			238	
PM Times		17:00	17:00	17:00		17:00			17:00	
PM Peaks		350	357	361		356			356	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1
Starting: 9/26/2023

STA. 6 SB

Station #: 230420000037
Site ID: 000000000602
Location: Route 140 SB, south of I-190
Direction: SOUTH

File: D0926008.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			8	10	10	9			9	28
02:00			6	4	2	4			4	12
03:00			9	21	19	16			16	49
04:00			12	13	13	13			13	38
05:00			30	26	27	28			28	83
06:00			101	110	89	100			100	300
07:00			240	230	187	219			219	657
08:00			277	243	204	241			241	724
09:00			232	224	196	217			217	652
10:00			152	170	174	165			165	496
11:00			151	135		143			143	286
12:00		171	137	158		155			155	466
13:00		136	134	146		139			139	416
14:00		159	186	164		170			170	509
15:00		179	174	194		182			182	547
16:00		260	252	247		253			253	759
17:00		236	229	253		239			239	718
18:00		225	223	244		231			231	692
19:00		145	174	163		161			161	482
20:00		104	104	104		104			104	312
21:00		60	68	70		66			66	198
22:00		32	35	33		33			33	100
23:00		31	29	25		28			28	85
24:00		18	18	21		19			19	57
TOTALS		1756	2981	3008	921	2935			2935	8666
% AVG WKDY		59.8	101.6	102.5	31.4					
% AVG WEEK		59.8	101.6	102.5	31.4					
AM Times		12:00	08:00	08:00	08:00	08:00			08:00	
AM Peaks		171	277	243	204	241			241	
PM Times		16:00	16:00	17:00		16:00			16:00	
PM Peaks		260	252	253		253			253	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1

Starting: 9/26/2023

STA. 7 SB

Station #: 230240000113
Site ID: 000000000702
Location: Off-ramp from I-190 NB to Route 140 SB
Direction:

File: D0926009.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			0	4	4	3			3	8
02:00			0	0	0	0			0	0
03:00			0	1	2	1			1	3
04:00			0	0	1	0			0	1
05:00			0	0	0	0			0	0
06:00			1	0	1	1			1	2
07:00			25	18	15	19			19	58
08:00			11	14	13	13			13	38
09:00			18	19	13	17			17	50
10:00			21	26	35	27			27	82
11:00			14	17		16			16	31
12:00		32	29	25		29			29	86
13:00		20	28	28		25			25	76
14:00		31	29	30		30			30	90
15:00		30	34	44		36			36	108
16:00		51	40	38		43			43	129
17:00		41	55	46		47			47	142
18:00		56	55	45		52			52	156
19:00		28	32	24		28			28	84
20:00		13	21	25		20			20	59
21:00		16	14	18		16			16	48
22:00		7	8	6		7			7	21
23:00		13	6	7		9			9	26
24:00		4	6	7		6			6	17
TOTALS		342	447	442	84	445			445	1315
% AVG WKDY		76.9	100.4	99.3	18.9					
% AVG WEEK		76.9	100.4	99.3	18.9					
AM Times		12:00	12:00	10:00	10:00	12:00			12:00	
AM Peaks		32	29	26	35	29			29	
PM Times		18:00	17:00	17:00		18:00			18:00	
PM Peaks		56	55	46		52			52	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1

Starting: 9/26/2023

Page: 1

STA 85B

Station #: 230420000044
Site ID: 000000000802
Location: Off-ramp from I-190 NB to Route 140 NB
Direction:

File: D0926010.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			37	19	27	28			28	83
02:00			12	7	11	10			10	30
03:00			14	5	5	8			8	24
04:00			6	13	11	10			10	30
05:00			42	38	14	31			31	94
06:00			70	40	52	54			54	162
07:00			229	154	106	163			163	489
08:00			271	226	115	204			204	612
09:00			297	217	109	208			208	623
10:00			315	190	135	213			213	640
11:00			285	209		247			247	494
12:00		378	346	234		319			319	958
13:00		345	354	270		323			323	969
14:00		392	321	262		325			325	975
15:00		579	550	444		524			524	1573
16:00		743	700	493		645			645	1936
17:00		816	699	465		660			660	1980
18:00		716	605	367		563			563	1688
19:00		409	314	230		318			318	953
20:00		334	251	180		255			255	765
21:00		214	183	92		163			163	489
22:00		136	94	65		98			98	295
23:00		95	80	65		80			80	240
24:00		55	52	37		48			48	144
TOTALS		5212	6127	4322	585	5497			5497	16246
% AVG WKDY		94.8	111.5	78.6	10.6					
% AVG WEEK		94.8	111.5	78.6	10.6					
AM Times		12:00	12:00	12:00	10:00	12:00			12:00	
AM Peaks		378	346	234	135	319			319	
PM Times		17:00	16:00	16:00		17:00			17:00	
PM Peaks		816	700	493		660			660	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1
Starting: 9/26/2023

Station #: 230420000064
Site ID: 000000000901
Location: On-ramp from Route 140 NB to I-190 SB
Direction:

STA. 9 NB

File: D0926014.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			2	3	1	2			2	6
02:00			1	0	1	1			1	2
03:00			0	0	1	0			0	1
04:00			0	0	0	0			0	0
05:00			5	1	1	2			2	7
06:00			7	6	11	8			8	24
07:00			19	16	18	18			18	53
08:00			45	39	33	39			39	117
09:00			42	31	38	37			37	111
10:00			28	27	35	30			30	90
11:00			25	19	23	22			22	67
12:00		37	39	21		32			32	97
13:00		16	30	17		21			21	63
14:00		32	32	27		30			30	91
15:00		29	27	41		32			32	97
16:00		34	31	30		32			32	95
17:00		31	27	30		29			29	88
18:00		25	35	27		29			29	87
19:00		11	20	21		17			17	52
20:00		12	10	15		12			12	37
21:00		13	8	11		11			11	32
22:00		3	7	4		5			5	14
23:00		4	6	4		5			5	14
24:00		12	7	10		10			10	29
TOTALS		259	453	400	162	424			424	1274
% AVG WKDY		61.1	106.8	94.3	38.2					
% AVG WEEK		61.1	106.8	94.3	38.2					
AM Times		12:00	08:00	08:00	09:00	08:00			08:00	
AM Peaks		37	45	39	38	39			39	
PM Times		16:00	18:00	15:00		15:00			15:00	
PM Peaks		34	35	41		32			32	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1

Starting: 9/26/2023

STA. 10 NB

Station #: 230420000150
Site ID: 000000001001
Location: On-ramp from Route 140 SB to I-190 SB
Direction:

File: D0926011.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			4	4	9	6			6	17
02:00			8	4	4	5			5	16
03:00			8	8	11	9			9	27
04:00			13	14	20	16			16	47
05:00			47	41	41	43			43	129
06:00			145	154	135	145			145	434
07:00			384	361	334	360			360	1079
08:00			622	577	503	567			567	1702
09:00			445	447	381	424			424	1273
10:00			222	246	219	229			229	687
11:00			195	201		198			198	396
12:00		172	159	188		173			173	519
13:00		178	210	198		195			195	586
14:00		204	207	217		209			209	628
15:00		210	232	213		218			218	655
16:00		260	243	274		259			259	777
17:00		204	240	356		267			267	800
18:00		202	218	313		244			244	733
19:00		171	156	169		165			165	496
20:00		74	128	123		108			108	325
21:00		78	63	69		70			70	210
22:00		45	63	56		55			55	164
23:00		35	28	29		31			31	92
24:00		22	28	36		29			29	86
TOTALS		1855	4068	4298	1657	4025			4025	11878
% AVG WKDY		46.1	101.1	106.8	41.2					
% AVG WEEK		46.1	101.1	106.8	41.2					
AM Times		12:00	08:00	08:00	08:00	08:00			08:00	
AM Peaks		172	622	577	503	567			567	
PM Times		16:00	16:00	17:00		17:00			17:00	
PM Peaks		260	243	356		267			267	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1
Starting: 9/26/2023

Station #: 230420000080
Site ID: 000000001101
Location: I-190 NB, over Route 140
Direction: NORTH

STA. 11 NB

File: D0926012.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			74	83	127	95			95	284
02:00			57	50	86	64			64	193
03:00			52	64	92	69			69	208
04:00			79	76	72	76			76	227
05:00			188	213	191	197			197	592
06:00			586	582	484	551			551	1652
07:00			1127	1117	1065	1103			1103	3309
08:00			1308	1352	1174	1278			1278	3834
09:00			1157	1175	1039	1124			1124	3371
10:00			895	941		918			918	1836
11:00		892	858	906		885			885	2656
12:00		794	799	840		811			811	2433
13:00		794	849	895		846			846	2538
14:00		892	904	1005		934			934	2801
15:00		1280	1279	1236		1265			1265	3795
16:00		1302	1408	1391		1367			1367	4101
17:00		1406	1417	1335		1386			1386	4158
18:00		1227	1284	1193		1235			1235	3704
19:00		788	801	734		774			774	2323
20:00		561	612	647		607			607	1820
21:00		395	419	457		424			424	1271
22:00		371	362	365		366			366	1098
23:00		272	295	378		315			315	945
24:00		155	188	241		195			195	584
TOTALS		11129	16998	17276	4330	16885			16885	49733
% AVG WKDY		65.9	100.7	102.3	25.6					
% AVG WEEK		65.9	100.7	102.3	25.6					
AM Times		11:00	08:00	08:00	08:00	08:00			08:00	
AM Peaks		892	1308	1352	1174	1278			1278	
PM Times		17:00	17:00	16:00		17:00			17:00	
PM Peaks		1406	1417	1391		1386			1386	

Mass Highway Department

WEEKLY SUMMARY FOR LANE 1

Starting: 9/26/2023

Station #: 230420000118
Site ID: 000000001202
Location: I-190 SB, over Route 140
Direction: SOUTH

STA. 12 SB

File: D0926013.prn
City: Sterling
County:

TIME	MON	TUE 26	WED 27	THU 28	FRI 29	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00			78	81	94	84			84	253
02:00			56	56	72	61			61	184
03:00			77	52	67	65			65	196
04:00			87	96	99	94			94	282
05:00			147	156	144	149			149	447
06:00			444	457	418	440			440	1319
07:00			975	1049	913	979			979	2937
08:00			1510	1502	1276	1429			1429	4288
09:00			1406	1329	1249	1328			1328	3984
10:00			995	1034	961	997			997	2990
11:00		939	935	915		930			930	2789
12:00		798	867	919		861			861	2584
13:00		887	971	1037		965			965	2895
14:00		1011	942	1000		984			984	2953
15:00		1146	1193	1357		1232			1232	3696
16:00		1448	1437	1715		1533			1533	4600
17:00		1322	1319	1498		1380			1380	4139
18:00		1200	1224	1499		1308			1308	3923
19:00		841	837	992		890			890	2670
20:00		562	586	623		590			590	1771
21:00		390	459	420		423			423	1269
22:00		280	282	360		307			307	922
23:00		211	214	257		227			227	682
24:00		246	245	262		251			251	753
TOTALS		11281	17286	18666	5293	17507			17507	52526
% AVG WKDY		64.4	98.7	106.6	30.2					
% AVG WEEK		64.4	98.7	106.6	30.2					
AM Times		11:00	08:00	08:00	08:00	08:00			08:00	
AM Peaks		939	1510	1502	1276	1429			1429	
PM Times		16:00	16:00	16:00		16:00			16:00	
PM Peaks		1448	1437	1715		1533			1533	

Appendix D: Projected Traffic Values Northbound

	Northbound Interchange AM						Northbound Interchange PM						
Year	Sta. 6 NB	Sta. 6 SB	Sta. 7	Sta. 8	Sta. 4	Sta. 5	Sta. 6 NB	Sta. 6 SB	Sta. 7	Sta. 8	Sta. 4	Sta. 5	
0	238	241	13	204	333	136	356	239	47	660	191	114	2023
1	240.38	243.41	13.13	206.04	336.33	137.36	359.56	241.39	47.47	666.6	192.91	115.14	
2	242.7838	245.8441	13.2613	208.1004	339.6933	138.7336	363.1556	243.8039	47.9447	673.266	194.8391	116.2914	
3	245.211638	248.302541	13.393913	210.181404	343.090233	140.120936	366.787156	246.241939	48.424147	679.99866	196.787491	117.454314	
4	247.6637544	250.7855664	13.52785213	212.283218	346.5211353	141.5221454	370.4550276	248.7043584	48.90838847	686.7986466	198.7553659	118.6288571	
5	250.1403919	253.2934221	13.66313065	214.4060502	349.9863467	142.9373668	374.1595778	251.191402	49.39747235	693.6666331	200.7429196	119.8151457	
6	252.6417958	255.8263563	13.79976196	216.5501107	353.4862102	144.3667405	377.9011736	253.703316	49.89144708	700.6032994	202.7503488	121.0132972	
7	255.1682138	258.3846199	13.93775958	218.7156118	357.0210723	145.8104079	381.6801854	256.2403492	50.39036155	707.6093324	204.7778523	122.2234301	Opening Year
8	257.7198959	260.9684661	14.07713717	220.9027679	360.591283	147.268512	385.4969872	258.8027526	50.89426516	714.6854257	206.8256308	123.4456644	
9	260.2970949	263.5781507	14.21790854	223.1117956	364.1971958	148.7411971	389.3519571	261.3907802	51.40320782	721.83228	208.8938871	124.6801211	
10	262.9000658	266.2139322	14.36008763	225.3429136	367.8391678	150.2286091	393.2454766	264.004688	51.91723989	729.0506028	210.982826	125.9269223	
11	265.5290665	268.8760715	14.50368851	227.5963427	371.5175594	151.7308951	397.1779314	266.6447349	52.43641229	736.3411088	213.0926542	127.1861915	
12	268.1843572	271.5648323	14.64872539	229.8723061	375.232735	153.2482041	401.1497107	269.3111822	52.96077642	743.7045199	215.2235808	128.4580534	
13	270.8662007	274.2804806	14.79521265	232.1710292	378.9850624	154.7806861	405.1612078	272.004294	53.49038418	751.1415651	217.3758166	129.742634	
14	273.5748628	277.0232854	14.94316477	234.4927395	382.774913	156.328493	409.2128199	274.724337	54.02528802	758.6529807	219.5495747	131.0400603	
15	276.3106114	279.7935182	15.09259642	236.8376669	386.6026621	157.8917779	413.3049481	277.4715803	54.5655409	766.2395105	221.7450705	132.3504609	
16	279.0737175	282.5914534	15.24352238	239.2060436	390.4686888	159.4706957	417.4379976	280.2462961	55.11119631	773.9019056	223.9625212	133.6739655	
17	281.8644547	285.417368	15.39595761	241.598104	394.3733756	161.0654027	421.6123776	283.0487591	55.66230827	781.6409247	226.2021464	135.0107052	2040
18	284.6830992	288.2715416	15.54991718	244.014085	398.3171094	162.6760567	425.8285013	285.8792467	56.21893136	789.457334	228.4641679	136.3608122	
19	287.5299302	291.1542571	15.70541636	246.4542259	402.3002805	164.3028173	430.0867864	288.7380392	56.78112067	797.3519073	230.7488095	137.7244204	
20	290.4052295	294.0657996	15.86247052	248.9187681	406.3232833	165.9458454	434.3876542	291.6254195	57.34893188	805.3254264	233.0562976	139.1016646	2043
21	293.3092818	297.0064576	16.02109522	251.4079558	410.3865161	167.6053039	438.7315308	294.5416737	57.9224212	813.3786806	235.3868606	140.4926812	
22	296.2423746	299.9765222	16.18130618	253.9220354	414.4903813	169.2813569	443.1188461	297.4870905	58.50164541	821.5124674	237.7407292	141.897608	
23	299.2047984	302.9762874	16.34311924	256.4612557	418.6352851	170.9741705	447.5500345	300.4619614	59.08666186	829.7275921	240.1181365	143.3165841	
24	302.1968464	306.0060503	16.50655043	259.0258683	422.821638	172.6839122	452.0255349	303.466581	59.67752848	838.024868	242.5193179	144.7497499	
25	305.2188148	309.0661108	16.67161594	261.616127	427.0498543	174.4107513	456.5457902	306.5012468	60.27430377	846.4051167	244.944511	146.1972474	
26	308.271003	312.1567719	16.83833209	264.2322883	431.3203529	176.1548588	461.1112481	309.5662593	60.8770468	854.8691679	247.3939562	147.6592199	
27	311.353713	315.2783396	17.00671542	266.8746111	435.6335564	177.9164074	465.7223606	312.6619219	61.48581727	863.4178596	249.8678957	149.1358121	
28	314.4672501	318.431123	17.17678257	269.5433572	439.989892	179.6955715	470.3795842	315.7885411	62.10067544	872.0520382	252.3665747	150.6271702	
29	317.6119226	321.6154343	17.3485504	272.2387908	444.3897909	181.4925272	475.0833801	318.9464265	62.7216822	880.7725585	254.8902404	152.1334419	
30	320.7880418	324.8315886	17.5220359	274.9611787	448.8336888	183.3074525	479.8342139	322.1358908	63.34889902	889.5802841	257.4391428	153.6547763	
31	323.9959223	328.0799045	17.69725626	277.7107905	453.3220257	185.140527	484.632556	325.3572497	63.98238801	898.476087	260.0135343	155.1913241	
32	327.2358815	331.3607035	17.87422882	280.4878984	457.855246	186.9919323	489.4788816	328.6108222	64.62221189	907.4608478	262.6136696	156.7432374	
33	330.5082403	334.6743106	18.05297111	283.2927774	462.4337984	188.8618516	494.3736704	331.8969304	65.26843401	916.5354563	265.2398063	158.3106697	
34	333.8133227	338.0210537	18.23350082	286.1257052	467.0581364	190.7504701	499.3174071	335.2158997	65.92111835	925.7008109	267.8922044	159.8937764	
35	337.1514559	341.4012642	18.41583583	288.9869622	471.7287178	192.6579748	504.3105811	338.5680587	66.58032953	934.957819	270.5711264	161.4927142	
36	340.5229705	344.8152768	18.59999419	291.8768319	476.4460049	194.5845546	509.353687	341.9537393	67.24613283	944.3073972	273.2768377	163.1076413	
37	343.9282002	348.2634296	18.78599413	294.7956002	481.210465	196.5304001	514.4472238	345.3732767	67.91859416	953.7504711	276.009606	164.7387177	
38	347.3674822	351.7460639	18.97385407	297.7435562	486.0225696	198.4957041	519.5916961	348.8270094	68.5977801	963.2879759	278.7697021	166.3861049	
39	350.841157	355.2635245	19.16359261	300.7209917	490.8827953	200.4806612	524.787613	352.3152795	69.2837579	972.9208556	281.5573991	168.049966	
40	354.3495686	358.8161598	19.35522854	303.7282017	495.7916233	202.4854678	530.0354892	355.8384323	69.97659548	982.6500642	284.3729731	169.7304656	
41	357.8930643	362.4043214	19.54878082	306.7654837	500.7495395	204.5103224	535.335844	359.3968167	70.67636143	992.4765648	287.2167028	171.4277703	
42	361.4719949	366.0283646	19.74426863	309.8331385	505.7570349	206.5554257	540.6892025	362.9907848	71.38312505	1002.40133	290.0888699	173.142048	
43	365.0867149	369.6886483	19.94171132	312.9314699	510.8146053	208.6209799	546.0960945	366.6206927	72.0969563	1012.425344	292.9897586	174.8734685	
44	368.737582	373.3855347	20.14112843	316.0607846	515.9227513	210.7071897	551.5570555	370.2868996	72.81792586	1022.549597	295.9196562	176.6222032	
45	372.4249578	377.1193901	20.34253971	319.2213924	521.0819788	212.8142616	557.072626	373.9897686	73.54610512	1032.775093	298.8788527	178.3884252	
46	376.1492074	380.890584	20.54596511	322.4136064	526.2927986	214.9424042	562.6433523	377.7296663	74.28156617	1043.102844	301.8676412	180.1723094	
47	379.9106995	384.6994898	20.75142476	325.6377424	531.5557266	217.0918283	568.2697858	381.5069629	75.02438183	1053.533873	304.8863177	181.9740325	
48	383.7098065	388.5464847	20.95893901	328.8941198	536.8712839	219.2627466	573.9524837	385.3220326	75.77462565	1064.069211	307.9351808	183.7937729	

Appendix E: Projected Traffic Values Southbound

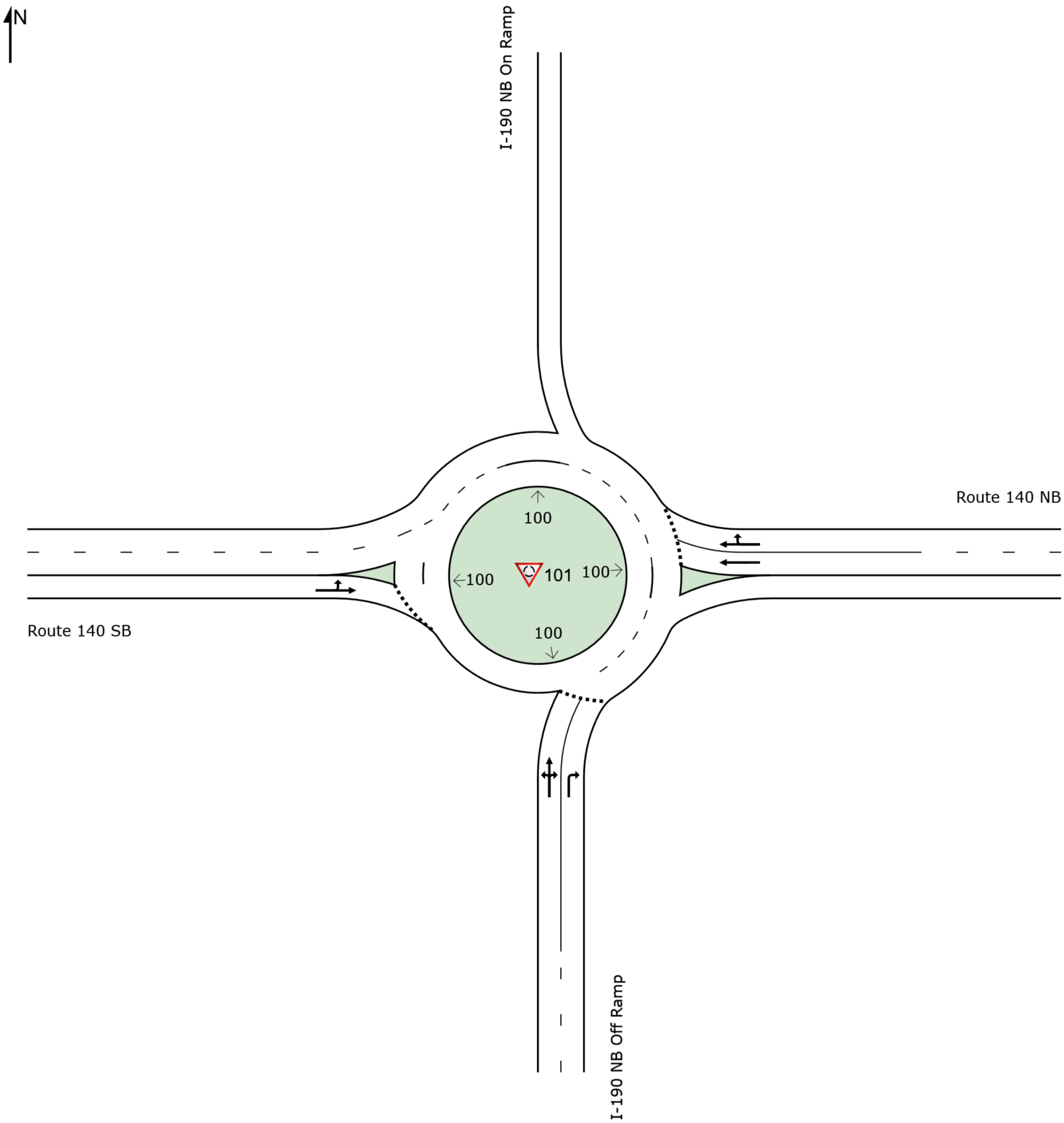
	Southbound Interchange AM						Southbound Interchange PM						
Year	Sta. 1 NB	Sta. 1SB	Sta. 2	Sta. 3	Sta. 10	Sta. 9	Sta. 1 NB	Sta. 1SB	Sta. 2	Sta. 3	Sta. 10	Sta. 9	
0	395	797	125	310	567	39	1206	352	333	290	267	29	2023
1	398.95	804.97	126.25	313.1	572.67	39.39	1218.06	355.52	336.33	292.9	269.67	29.29	
2	402.9395	813.0197	127.5125	316.231	578.3967	39.7839	1230.2406	359.0752	339.6933	295.829	272.3667	29.5829	
3	406.968895	821.149897	128.787625	319.39331	584.180667	40.181739	1242.543006	362.665952	343.090233	298.78729	275.090367	29.878729	
4	411.038584	829.361396	130.0755013	322.5872431	590.0224737	40.58355639	1254.968436	366.2926115	346.5211353	301.7751629	277.8412707	30.17751629	
5	415.1489698	837.6550099	131.3762563	325.8131155	595.9226984	40.98939195	1267.51812	369.9555376	349.9863467	304.7929145	280.6196834	30.47929145	
6	419.3004595	846.03156	132.6900188	329.0712467	601.8819254	41.39928587	1280.193302	373.655093	353.4862102	307.8408437	283.4258802	30.78408437	
7	423.4934641	854.4918756	134.016919	332.3619592	607.9007446	41.81327873	1292.995235	377.3916439	357.0210723	310.9192521	286.260139	31.09192521	Opening Year
8	427.7283987	863.0367944	135.3570882	335.6855787	613.9797521	42.23141152	1305.925187	381.1655604	360.591283	314.0284446	289.1227404	31.40284446	
9	432.0056827	871.6671623	136.7106591	339.0424345	620.1195496	42.65372563	1318.984439	384.977216	364.1971958	317.1687291	292.0139678	31.71687291	
10	436.3257395	880.383834	138.0777657	342.4328589	626.3207451	43.08026289	1332.174283	388.8269881	367.8391678	320.3404164	294.9341075	32.03404164	
11	440.6889969	889.1876723	139.4585433	345.8571875	632.5839526	43.51106552	1345.496026	392.715258	371.5175594	323.5438205	297.8834486	32.35438205	
12	445.0958869	898.079549	140.8531288	349.3157593	638.9097921	43.94617618	1358.950986	396.6424106	375.232735	326.7792587	300.862283	32.67792587	
13	449.5468458	907.0603445	142.2616601	352.8089169	645.29889	44.38563794	1372.540496	400.6088347	378.9850624	330.0470513	303.8709059	33.00470513	
14	454.0423142	916.130948	143.6842767	356.3370061	651.7518789	44.82949432	1386.265901	404.6149231	382.774913	333.3475218	306.9096149	33.33475218	
15	458.5827374	925.2922574	145.1211194	359.9003762	658.2693977	45.27778926	1400.12856	408.6610723	386.6026621	336.6809971	309.9787111	33.66809971	
16	463.1685647	934.54518	146.5723306	363.4993799	664.8520917	45.73056715	1414.129846	412.747683	390.4686888	340.047807	313.0784982	34.0047807	
17	467.8002504	943.8906318	148.0380539	367.1343737	671.5006126	46.18787282	1428.271144	416.8751598	394.3733756	343.4482851	316.2092832	34.34482851	2040
18	472.4782529	953.3295381	149.5184345	370.8057175	678.2156187	46.64975155	1442.553856	421.0439114	398.3171094	346.8827679	319.371376	34.68827679	
19	477.2030354	962.8628335	151.0136188	374.5137746	684.9977749	47.11624907	1456.979394	425.2543506	402.3002805	350.3515956	322.5650898	35.03515956	
20	481.9750658	972.4914618	152.523755	378.2589124	691.8477527	47.58741156	1471.549188	429.5068941	406.3232833	353.8551116	325.7907407	35.38551116	2043
21	486.7948164	982.2163765	154.0489925	382.0415015	698.7662302	48.06328567	1486.26468	433.801963	410.3865161	357.3936627	329.0486481	35.73936627	
22	491.6627646	992.0385402	155.5894825	385.8619165	705.7538925	48.54391853	1501.127327	438.1399826	414.4903813	360.9675993	332.3391346	36.09675993	
23	496.5793922	1001.958926	157.1453773	389.7205357	712.8114314	49.02935772	1516.1386	442.5213825	418.6352851	364.5772753	335.6625259	36.45772753	
24	501.5451862	1011.978515	158.7168311	393.617741	719.9395457	49.51965129	1531.299986	446.9465963	422.821638	368.2230481	339.0191512	36.82230481	
25	506.560638	1022.0983	160.3039994	397.5539185	727.1389412	50.01484781	1546.612986	451.4160622	427.0498543	371.9052786	342.4093427	37.19052786	
26	511.6262444	1032.319283	161.9070394	401.5294576	734.4103306	50.51499628	1562.079116	455.9302229	431.3203529	375.6243313	345.8334361	37.56243313	
27	516.7425069	1042.642476	163.5261098	405.5447522	741.7544339	51.02014625	1577.699907	460.4895251	435.6335564	379.3805747	349.2917705	37.93805747	
28	521.9099319	1053.068901	165.1613709	409.6001997	749.1719782	51.53034771	1593.476906	465.0944203	439.989892	383.1743804	352.7846882	38.31743804	
29	527.1290312	1063.59959	166.8129846	413.6962017	756.663698	52.04565119	1609.411675	469.7453646	444.3897909	387.0061242	356.312535	38.70061242	
30	532.4003216	1074.235586	168.4811144	417.8331638	764.230335	52.5661077	1625.505792	474.4428182	448.8336888	390.8761854	359.8756604	39.08761854	
31	537.7243248	1084.977941	170.1659256	422.0114954	771.8726383	53.09176877	1641.76085	479.1872464	453.3220257	394.7849473	363.474417	39.47849473	
32	543.101568	1095.827721	171.8675848	426.2316103	779.5913647	53.62268646	1658.178458	483.9791188	457.855246	398.7327968	367.1091612	39.87327968	
33	548.5325837	1106.785998	173.5862607	430.4939264	787.3872784	54.15891333	1674.760243	488.81891	462.4337984	402.7201247	370.7802528	40.27201247	
34	554.0179095	1117.853858	175.3221233	434.7988657	795.2611512	54.70050246	1691.507845	493.7070991	467.0581364	406.747326	374.4880553	40.6747326	
35	559.5580886	1129.032397	177.0753445	439.1468544	803.2137627	55.24750749	1708.422924	498.6441701	471.7287178	410.8147992	378.2329359	41.08147992	
36	565.1536695	1140.322721	178.8460979	443.5383229	811.2459003	55.79998256	1725.507153	503.6306118	476.4460049	414.9229472	382.0152652	41.49229472	
37	570.8052062	1151.725948	180.6345589	447.9737061	819.3583593	56.35798239	1742.762225	508.6669179	481.210465	419.0721767	385.8354179	41.90721767	
38	576.5132583	1163.243207	182.4409045	452.4534432	827.5519429	56.92156221	1760.189847	513.7535871	486.0225696	423.2628985	389.693772	42.32628985	
39	582.2783909	1174.875639	184.2653136	456.9779776	835.8274623	57.49077783	1777.791745	518.891123	490.8827953	427.4955275	393.5907098	42.74955275	
40	588.1011748	1186.624396	186.1079667	461.5477574	844.1857369	58.06568561	1795.569663	524.0800342	495.7916233	431.7704827	397.5266169	43.17704827	
41	593.9821865	1198.49064	187.9690464	466.163235	852.6275943	58.64634247	1813.525359	529.3208346	500.7495395	436.0881876	401.501883	43.60881876	
42	599.9220084	1210.475546	189.8487368	470.8248673	861.1538703	59.23280589	1831.660613	534.6140429	505.7570349	440.4490694	405.5169019	44.04490694	
43	605.9212285	1222.580301	191.7472242	475.533116	869.765409	59.82513395	1849.977219	539.9601833	510.8146053	444.8535601	409.5720709	44.48535601	
44	611.9804407	1234.806104	193.6646964	480.2884472	878.463063	60.42338529	1868.476991	545.3597852	515.9227513	449.3020957	413.6677916	44.93020957	
45	618.1002452	1247.154166	195.6013434	485.0913316	887.2476937	61.02761914	1887.161761	550.813383	521.0819788	453.7951167	417.8044695	45.37951167	
46	624.2812476	1259.625707	197.5573568	489.942245	896.1201706	61.63789533	1906.033379	556.3215169	526.2927986	458.3330679	421.9825142	45.83330679	
47	630.5240601	1272.221964	199.5329304	494.8416674	905.0813723	62.25427429	1925.093713	561.884732	531.5557266	462.9163985	426.2023393	46.29163985	
48	636.8293007	1284.944184	201.5282597	499.7900841	914.132186	62.87681703	1944.34465	567.5035793	536.8712839	467.5455625	430.4643627	46.75455625	

SITE LAYOUT

Site: 101 [I-190 NB Ramps at Route 140 - 2023 AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

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



MOVEMENT SUMMARY

Site: 101 [I-190 NB Ramps at Route 140 - 2023 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: I-190 NB Off Ramp														
3	L2	204	3.0	222	3.0	0.290	8.0	LOS A	1.2	30.6	0.61	0.61	0.61	31.2
8	T1	1	3.0	1	3.0	0.290	8.0	LOS A	1.2	30.6	0.61	0.61	0.61	31.1
18	R2	13	3.0	14	3.0	0.018	4.9	LOS A	0.1	1.7	0.52	0.40	0.52	34.0
Approach		218	3.0	237	3.0	0.290	7.9	LOS A	1.2	30.6	0.60	0.60	0.60	31.3
East: Route 140 NB														
6	T1	102	3.0	111	3.0	0.147	6.3	LOS A	0.5	13.9	0.54	0.51	0.54	34.5
16	R2	136	3.0	148	3.0	0.179	6.2	LOS A	0.7	16.9	0.53	0.51	0.53	33.3
Approach		238	3.0	259	3.0	0.179	6.3	LOS A	0.7	16.9	0.54	0.51	0.54	33.8
West: Route 140 SB														
5	L2	333	3.0	362	3.0	0.453	7.0	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
2	T1	241	3.0	262	3.0	0.453	7.0	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
Approach		574	3.0	624	3.0	0.453	7.0	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
All Vehicles		1030	3.0	1120	3.0	0.453	7.0	LOS A	1.2	30.6	0.25	0.24	0.25	34.5

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.

MOVEMENT SUMMARY

Site: 101 [I-190 NB Ramps at Route 140 - 2030 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: I-190 NB Off Ramp														
3	L2	219	3.0	238	3.0	0.173	6.8	LOS A	0.7	16.8	0.58	0.58	0.58	31.9
8	T1	1	3.0	1	3.0	0.173	6.8	LOS A	0.7	16.8	0.58	0.58	0.58	32.0
18	R2	14	3.0	15	3.0	0.173	6.8	LOS A	0.7	16.8	0.58	0.58	0.58	31.1
Approach		234	3.0	254	3.0	0.173	6.8	LOS A	0.7	16.8	0.58	0.58	0.58	31.8
East: Route 140 NB														
6	T1	109	3.0	118	3.0	0.164	6.8	LOS A	0.6	15.4	0.56	0.55	0.56	34.3
16	R2	146	3.0	159	3.0	0.199	6.6	LOS A	0.7	19.0	0.55	0.54	0.55	33.1
Approach		255	3.0	277	3.0	0.199	6.7	LOS A	0.7	19.0	0.56	0.55	0.56	33.6
West: Route 140 SB														
5	L2	357	3.0	388	3.0	0.485	7.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
2	T1	258	3.0	280	3.0	0.485	7.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
Approach		615	3.0	668	3.0	0.485	7.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
All Vehicles		1104	3.0	1200	3.0	0.485	7.1	LOS A	0.7	19.0	0.25	0.25	0.25	34.6

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.

MOVEMENT SUMMARY

Site: 101 [I-190 NB Ramps at Route 140 - 2043 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: I-190 NB Off Ramp														
3	L2	249	3.0	271	3.0	0.214	7.8	LOS A	0.8	20.8	0.62	0.62	0.62	31.4
8	T1	1	3.0	1	3.0	0.214	7.8	LOS A	0.8	20.8	0.62	0.62	0.62	31.5
18	R2	16	3.0	17	3.0	0.214	7.8	LOS A	0.8	20.8	0.62	0.62	0.62	30.6
Approach		266	3.0	289	3.0	0.214	7.8	LOS A	0.8	20.8	0.62	0.62	0.62	31.3
East: Route 140 NB														
6	T1	124	3.0	135	3.0	0.202	7.8	LOS A	0.7	19.1	0.60	0.60	0.60	33.8
16	R2	166	3.0	180	3.0	0.244	7.7	LOS A	0.9	23.4	0.59	0.59	0.59	32.6
Approach		290	3.0	315	3.0	0.244	7.7	LOS A	0.9	23.4	0.59	0.59	0.59	33.1
West: Route 140 SB														
5	L2	406	3.0	441	3.0	0.552	8.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
2	T1	294	3.0	320	3.0	0.552	8.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
Approach		700	3.0	761	3.0	0.552	8.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.2
All Vehicles		1256	3.0	1365	3.0	0.552	8.2	LOS A	0.9	23.4	0.27	0.27	0.27	34.3

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.

MOVEMENT SUMMARY

Site: 101 [I-190 NB Ramps at Route 140 - 2023 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: I-190 NB Off Ramp														
3	L2	660	3.0	717	3.0	0.433	9.3	LOS A	2.4	62.0	0.62	0.64	0.73	30.8
8	T1	1	3.0	1	3.0	0.433	9.3	LOS A	2.4	62.0	0.62	0.64	0.73	30.9
18	R2	47	3.0	51	3.0	0.433	9.3	LOS A	2.4	62.0	0.62	0.64	0.73	30.1
Approach		708	3.0	770	3.0	0.433	9.3	LOS A	2.4	62.0	0.62	0.64	0.73	30.8
East: Route 140 NB														
6	T1	242	3.0	263	3.0	0.334	11.2	LOS B	1.4	35.0	0.68	0.72	0.81	32.1
16	R2	114	3.0	124	3.0	0.334	10.5	LOS B	1.4	34.9	0.67	0.71	0.79	31.4
Approach		356	3.0	387	3.0	0.334	11.0	LOS B	1.4	35.0	0.67	0.71	0.81	31.9
West: Route 140 SB														
5	L2	191	3.0	208	3.0	0.339	5.6	LOS A	0.0	0.0	0.00	0.00	0.00	36.7
2	T1	239	3.0	260	3.0	0.339	5.6	LOS A	0.0	0.0	0.00	0.00	0.00	36.6
Approach		430	3.0	467	3.0	0.339	5.6	LOS A	0.0	0.0	0.00	0.00	0.00	36.7
All Vehicles		1494	3.0	1624	3.0	0.433	8.6	LOS A	2.4	62.0	0.46	0.47	0.54	32.5

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.

MOVEMENT SUMMARY

Site: 101 [I-190 NB Ramps at Route 140 - 2030 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: I-190 NB Off Ramp														
3	L2	708	3.0	770	3.0	0.479	10.3	LOS B	3.1	78.4	0.66	0.74	0.88	30.4
8	T1	1	3.0	1	3.0	0.479	10.3	LOS B	3.1	78.4	0.66	0.74	0.88	30.5
18	R2	50	3.0	54	3.0	0.479	10.3	LOS B	3.1	78.4	0.66	0.74	0.88	29.6
Approach		759	3.0	825	3.0	0.479	10.3	LOS B	3.1	78.4	0.66	0.74	0.88	30.3
East: Route 140 NB														
6	T1	260	3.0	283	3.0	0.381	12.8	LOS B	1.7	42.3	0.71	0.77	0.94	31.4
16	R2	122	3.0	133	3.0	0.381	11.9	LOS B	1.7	42.3	0.69	0.76	0.92	30.8
Approach		382	3.0	415	3.0	0.381	12.5	LOS B	1.7	42.3	0.70	0.77	0.93	31.2
West: Route 140 SB														
5	L2	205	3.0	223	3.0	0.363	5.9	LOS A	0.0	0.0	0.00	0.00	0.00	36.7
2	T1	256	3.0	278	3.0	0.363	5.9	LOS A	0.0	0.0	0.00	0.00	0.00	36.6
Approach		461	3.0	501	3.0	0.363	5.9	LOS A	0.0	0.0	0.00	0.00	0.00	36.7
All Vehicles		1602	3.0	1741	3.0	0.479	9.6	LOS A	3.1	78.4	0.48	0.53	0.64	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.

MOVEMENT SUMMARY

Site: 101 [I-190 NB Ramps at Route 140 - 2043 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: I-190 NB Off Ramp														
3	L2	805	3.0	875	3.0	0.581	13.3	LOS B	4.6	118.7	0.74	0.91	1.21	29.2
8	T1	1	3.0	1	3.0	0.581	13.3	LOS B	4.6	118.7	0.74	0.91	1.21	29.3
18	R2	57	3.0	62	3.0	0.581	13.3	LOS B	4.6	118.7	0.74	0.91	1.21	28.5
Approach		863	3.0	938	3.0	0.581	13.3	LOS B	4.6	118.7	0.74	0.91	1.21	29.2
East: Route 140 NB														
6	T1	295	3.0	321	3.0	0.490	17.3	LOS C	2.4	60.5	0.78	0.90	1.21	29.5
16	R2	139	3.0	151	3.0	0.490	16.0	LOS C	2.4	60.5	0.76	0.88	1.19	29.1
Approach		434	3.0	472	3.0	0.490	16.9	LOS C	2.4	60.5	0.77	0.90	1.20	29.4
West: Route 140 SB														
5	L2	233	3.0	253	3.0	0.414	6.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.7
2	T1	292	3.0	317	3.0	0.414	6.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.6
Approach		525	3.0	571	3.0	0.414	6.5	LOS A	0.0	0.0	0.00	0.00	0.00	36.7
All Vehicles		1822	3.0	1980	3.0	0.581	12.2	LOS B	4.6	118.7	0.53	0.64	0.86	31.1

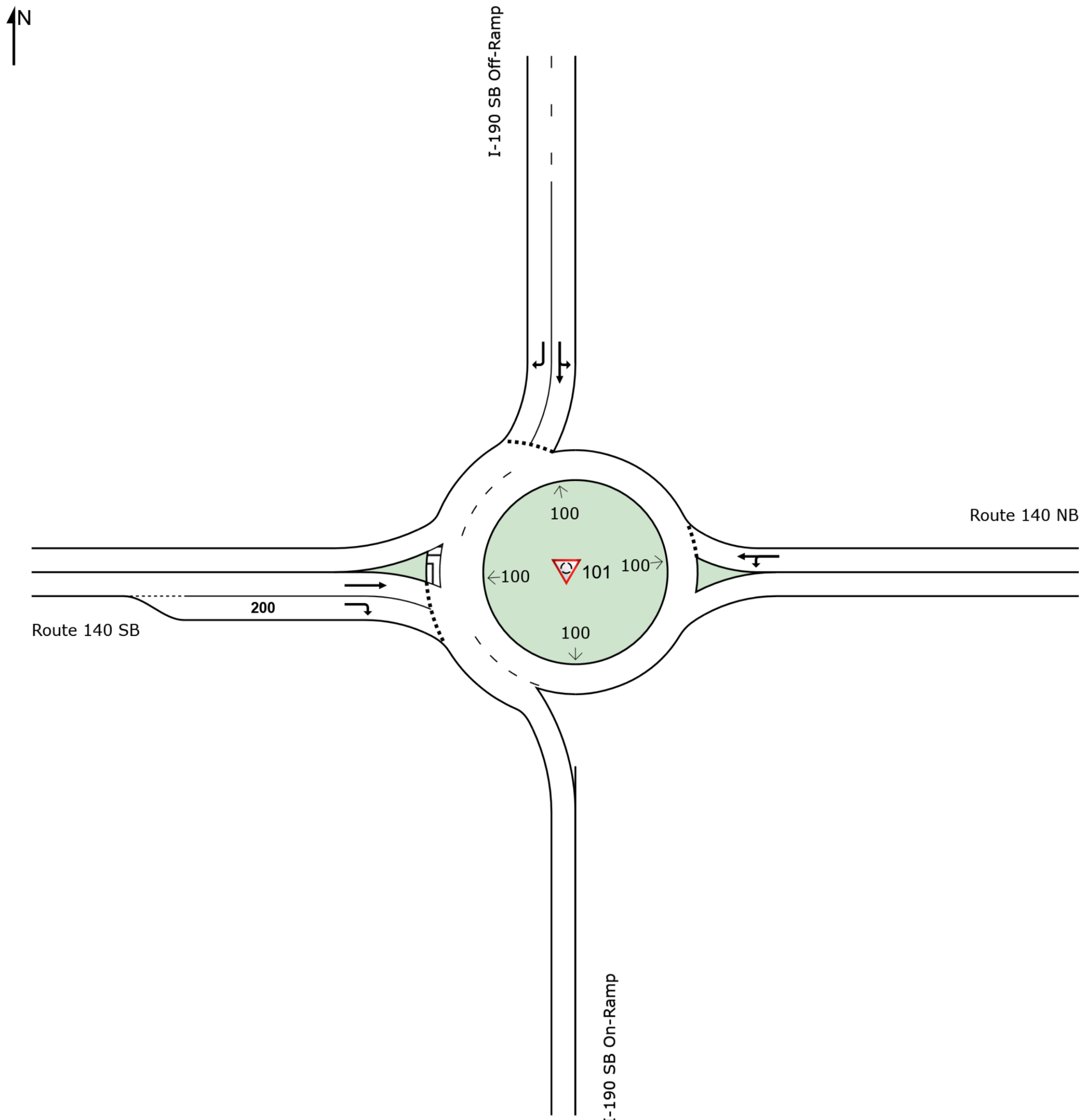
Site Level of Service (LOS) Method: Delay & v/c (HCM 6). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: Same as Sign Control.
Vehicle movement LOS values are based on average delay and v/c ratio (degree of saturation) per movement.
LOS F will result if 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.

SITE LAYOUT

Site: 101 [I-190 SB Ramps at Route 140 - 2023 AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

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



MOVEMENT SUMMARY

Site: 101 [I-190 SB Ramps at Route 140 - 2023 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
East: Route 140 NB														
1	L2	39	3.0	42	3.0	0.248	4.8	LOS A	0.0	0.0	0.00	0.00	0.00	37.8
6	T1	267	3.0	290	3.0	0.248	4.8	LOS A	0.0	0.0	0.00	0.00	0.00	37.7
Approach		306	3.0	333	3.0	0.248	4.8	LOS A	0.0	0.0	0.00	0.00	0.00	37.8
North: I-190 SB Off-Ramp														
7	L2	310	3.0	337	3.0	0.335	7.0	LOS A	1.6	40.5	0.51	0.42	0.51	31.6
4	T1	1	3.0	1	3.0	0.335	7.0	LOS A	1.6	40.5	0.51	0.42	0.51	31.6
14	R2	125	3.0	136	3.0	0.135	4.8	LOS A	0.5	13.7	0.43	0.33	0.43	34.0
Approach		436	3.0	474	3.0	0.335	6.4	LOS A	1.6	40.5	0.48	0.39	0.48	32.2
West: Route 140 SB														
2	T1	230	3.0	250	3.0	0.259	6.3	LOS A	1.1	28.8	0.50	0.43	0.50	34.5
12	R2	567	3.0	616	3.0	0.639	13.3	LOS B	7.1	181.0	0.73	0.87	1.20	30.1
Approach		797	3.0	866	3.0	0.639	11.3	LOS B	7.1	181.0	0.66	0.74	1.00	31.3
All Vehicles		1539	3.0	1673	3.0	0.639	8.6	LOS A	7.1	181.0	0.48	0.50	0.65	32.7

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.

MOVEMENT SUMMARY

Site: 101 [I-190 SB Ramps at Route 140 - 2030 AM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

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
Vehicle Movement Performance														
East: Route 140 NB														
1	L2	41	3.0	45	3.0	0.265	5.0	LOS A	0.0	0.0	0.00	0.00	0.00	37.8
6	T1	286	3.0	311	3.0	0.265	5.0	LOS A	0.0	0.0	0.00	0.00	0.00	37.8
Approach		327	3.0	355	3.0	0.265	5.0	LOS A	0.0	0.0	0.00	0.00	0.00	37.8
North: I-190 SB Off-Ramp														
7	L2	332	3.0	361	3.0	0.366	7.6	LOS A	1.8	45.2	0.54	0.46	0.54	31.4
4	T1	1	3.0	1	3.0	0.366	7.6	LOS A	1.8	45.2	0.54	0.46	0.54	31.3
14	R2	134	3.0	146	3.0	0.147	5.0	LOS A	0.6	15.1	0.44	0.35	0.44	33.9
Approach		467	3.0	508	3.0	0.366	6.8	LOS A	1.8	45.2	0.51	0.43	0.51	32.0
West: Route 140 SB														
2	T1	247	3.0	268	3.0	0.285	6.8	LOS A	1.3	32.1	0.52	0.46	0.52	34.3
12	R2	608	3.0	661	3.0	0.702	15.8	LOS C	9.3	237.9	0.80	1.04	1.47	29.1
Approach		855	3.0	929	3.0	0.702	13.2	LOS B	9.3	237.9	0.72	0.87	1.20	30.5
All Vehicles		1649	3.0	1792	3.0	0.702	9.8	LOS A	9.3	237.9	0.52	0.57	0.77	32.2

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.

MOVEMENT SUMMARY

Site: 101 [I-190 SB Ramps at Route 140 - 2043 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
East: Route 140 NB														
1	L2	48	3.0	52	3.0	0.303	5.4	LOS A	0.0	0.0	0.00	0.00	0.00	37.8
6	T1	326	3.0	354	3.0	0.303	5.4	LOS A	0.0	0.0	0.00	0.00	0.00	37.7
Approach		374	3.0	407	3.0	0.303	5.4	LOS A	0.0	0.0	0.00	0.00	0.00	37.8
North: I-190 SB Off-Ramp														
7	L2	378	3.0	411	3.0	0.437	8.9	LOS A	2.4	62.0	0.60	0.58	0.66	30.8
4	T1	1	3.0	1	3.0	0.437	8.9	LOS A	2.4	62.0	0.60	0.58	0.66	30.8
14	R2	152	3.0	165	3.0	0.175	5.5	LOS A	0.7	18.1	0.48	0.40	0.48	33.6
Approach		531	3.0	577	3.0	0.437	8.0	LOS A	2.4	62.0	0.57	0.53	0.61	31.5
West: Route 140 SB														
2	T1	281	3.0	305	3.0	0.342	7.8	LOS A	1.5	39.6	0.58	0.54	0.58	33.8
12	R2	692	3.0	752	3.0	0.843	25.6	LOS D	16.8	430.5	0.96	1.51	2.38	25.8
Approach		973	3.0	1058	3.0	0.843	20.5	LOS C	16.8	430.5	0.85	1.23	1.86	27.7
All Vehicles		1878	3.0	2041	3.0	0.843	13.9	LOS B	16.8	430.5	0.60	0.79	1.13	30.4

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.

MOVEMENT SUMMARY

Site: 101 [I-190 SB Ramps at Route 140 - 2023 PM (Site Folder: General)]

New Site
Site Category: (None)
Roundabout

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	INPUT VOLUMES HV] %	DEMAND FLOWS [Total veh/h	DEMAND FLOWS HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	95% BACK OF QUEUE Dist] ft	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed mph
East: Route 140 NB														
1	L2	29	3.0	32	3.0	0.732	13.3	LOS B	0.0	0.0	0.00	0.00	0.00	38.2
6	T1	873	3.0	949	3.0	0.732	13.3	LOS B	0.0	0.0	0.00	0.00	0.00	38.1
Approach		902	3.0	980	3.0	0.732	13.3	LOS B	0.0	0.0	0.00	0.00	0.00	38.1
North: I-190 SB Off-Ramp														
7	L2	290	3.0	315	3.0	0.575	17.9	LOS C	3.4	87.6	0.78	0.95	1.35	27.6
4	T1	1	3.0	1	3.0	0.575	17.9	LOS C	3.4	87.6	0.78	0.95	1.35	27.5
14	R2	333	3.0	362	3.0	0.658	21.5	LOS C	4.5	115.7	0.81	1.04	1.58	27.1
Approach		624	3.0	678	3.0	0.658	19.8	LOS C	4.5	115.7	0.80	1.00	1.47	27.3
West: Route 140 SB														
2	T1	85	3.0	92	3.0	0.093	4.5	LOS A	0.4	9.1	0.42	0.31	0.42	35.6
12	R2	267	3.0	290	3.0	0.292	6.6	LOS A	1.3	33.7	0.50	0.41	0.50	33.1
Approach		352	3.0	383	3.0	0.292	6.0	LOS A	1.3	33.7	0.48	0.39	0.48	33.7
All Vehicles		1878	3.0	2041	3.0	0.732	14.1	LOS B	4.5	115.7	0.36	0.41	0.58	33.0

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.

MOVEMENT SUMMARY

Site: 101 [I-190 SB Ramps at Route 140 - 2030 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
East: Route 140 NB														
1	L2	31	3.0	34	3.0	0.785	15.6	LOS C	0.0	0.0	0.00	0.00	0.00	38.2
6	T1	937	3.0	1018	3.0	0.785	15.6	LOS C	0.0	0.0	0.00	0.00	0.00	38.1
Approach		968	3.0	1052	3.0	0.785	15.6	LOS C	0.0	0.0	0.00	0.00	0.00	38.1
North: I-190 SB Off-Ramp														
7	L2	311	3.0	338	3.0	0.660	22.8	LOS C	4.3	110.8	0.82	1.05	1.60	26.1
4	T1	1	3.0	1	3.0	0.660	22.8	LOS C	4.3	110.8	0.82	1.05	1.60	26.0
14	R2	357	3.0	388	3.0	0.755	29.2	LOS D	6.0	153.5	0.86	1.19	1.97	24.7
Approach		669	3.0	727	3.0	0.755	26.2	LOS D	6.0	153.5	0.84	1.12	1.80	25.4
West: Route 140 SB														
2	T1	91	3.0	99	3.0	0.102	4.6	LOS A	0.4	10.0	0.44	0.34	0.44	35.5
12	R2	286	3.0	311	3.0	0.320	7.0	LOS A	1.5	37.6	0.52	0.45	0.52	32.9
Approach		377	3.0	410	3.0	0.320	6.5	LOS A	1.5	37.6	0.50	0.42	0.50	33.5
All Vehicles		2014	3.0	2189	3.0	0.785	17.4	LOS C	6.0	153.5	0.37	0.45	0.69	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.

MOVEMENT SUMMARY

Site: 101 [I-190 SB Ramps at Route 140 - 2043 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
East: Route 140 NB														
1	L2	35	3.0	38	3.0	0.892	23.7	LOS C	0.0	0.0	0.00	0.00	0.00	38.2
6	T1	1065	3.0	1158	3.0	0.892	23.7	LOS C	0.0	0.0	0.00	0.00	0.00	38.1
Approach		1100	3.0	1196	3.0	0.892	23.7	LOS C	0.0	0.0	0.00	0.00	0.00	38.1
North: I-190 SB Off-Ramp														
7	L2	354	3.0	385	3.0	0.858	44.5	LOS E	8.1	206.5	0.93	1.41	2.66	21.0
4	T1	1	3.0	1	3.0	0.858	44.5	LOS E	8.1	206.5	0.93	1.41	2.66	21.0
14	R2	406	3.0	441	3.0	0.982	68.4	LOS F	14.8	378.5	0.98	1.86	4.12	17.2
Approach		761	3.0	827	3.0	0.982	57.3	LOS F	14.8	378.5	0.95	1.65	3.44	18.8
West: Route 140 SB														
2	T1	104	3.0	113	3.0	0.122	5.0	LOS A	0.5	12.1	0.47	0.39	0.47	35.2
12	R2	326	3.0	354	3.0	0.382	8.2	LOS A	1.8	46.5	0.58	0.53	0.58	32.3
Approach		430	3.0	467	3.0	0.382	7.4	LOS A	1.8	46.5	0.55	0.50	0.55	33.0
All Vehicles		2291	3.0	2490	3.0	0.982	31.8	LOS D	14.8	378.5	0.42	0.64	1.25	27.8

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.

Intersection	
Int Delay, s/veh	8.4

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	230	567	39	267	0	0	0	0	310	0	125
Future Vol, veh/h	0	230	567	39	267	0	0	0	0	310	0	125
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	Yield	-	-	None	-	-	None	-	-	Yield
Storage Length	-	-	0	250	-	-	-	-	-	-	-	150
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	250	616	42	290	0	0	0	0	337	0	136

Major/Minor	Major1			Major2						Minor2		
Conflicting Flow All	-	0	0	250	0	0				624	624	290
Stage 1	-	-	-	-	-	-				374	374	-
Stage 2	-	-	-	-	-	-				250	250	-
Critical Hdwy	-	-	-	4.12	-	-				6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-				5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-				5.42	5.52	-
Follow-up Hdwy	-	-	-	2.218	-	-				3.518	4.018	3.318
Pot Cap-1 Maneuver	0	-	-	1316	-	0				449	402	749
Stage 1	0	-	-	-	-	0				696	618	-
Stage 2	0	-	-	-	-	0				792	700	-
Platoon blocked, %		-	-		-							
Mov Cap-1 Maneuver	-	-	-	1316	-	-				435	0	749
Mov Cap-2 Maneuver	-	-	-	-	-	-				435	0	-
Stage 1	-	-	-	-	-	-				696	0	-
Stage 2	-	-	-	-	-	-				767	0	-

Approach	EB	WB	SB
HCM Control Delay, s	0	1	29.1
HCM LOS			D

Minor Lane/Major Mvmt	EBT	EBR	WBL	WBT	SBLn1	SBLn2
Capacity (veh/h)	-	-	1316	-	435	749
HCM Lane V/C Ratio	-	-	0.032	-	0.775	0.181
HCM Control Delay (s)	-	-	7.8	-	36.4	10.9
HCM Lane LOS	-	-	A	-	E	B
HCM 95th %tile Q(veh)	-	-	0.1	-	6.7	0.7

Intersection	
Int Delay, s/veh	42.6

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	333	241	0	0	102	136	204	0	13	0	0	0
Future Vol, veh/h	333	241	0	0	102	136	204	0	13	0	0	0
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	Yield	-	-	Yield	-	-	None
Storage Length	270	-	-	-	-	0	-	-	150	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	362	262	0	0	111	148	222	0	14	0	0	0

Major/Minor	Major1			Major2			Minor1		
Conflicting Flow All	111	0	-	-	-	0	1097	1097	262
Stage 1	-	-	-	-	-	-	986	986	-
Stage 2	-	-	-	-	-	-	111	111	-
Critical Hdwy	4.12	-	-	-	-	-	6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-	5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-	5.42	5.52	-
Follow-up Hdwy	2.218	-	-	-	-	-	3.518	4.018	3.318
Pot Cap-1 Maneuver	1479	-	0	0	-	-	236	213	777
Stage 1	-	-	0	0	-	-	361	326	-
Stage 2	-	-	0	0	-	-	914	804	-
Platoon blocked, %		-			-	-			
Mov Cap-1 Maneuver	1479	-	-	-	-	-	~ 178	0	777
Mov Cap-2 Maneuver	-	-	-	-	-	-	~ 178	0	-
Stage 1	-	-	-	-	-	-	273	0	-
Stage 2	-	-	-	-	-	-	914	0	-

Approach	EB	WB	NB
HCM Control Delay, s	4.8	0	189.1
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBL	EBT	WBT	WBR
Capacity (veh/h)	178	777	1479	-	-	-
HCM Lane V/C Ratio	1.246	0.018	0.245	-	-	-
HCM Control Delay (s)	200.5	9.7	8.2	-	-	-
HCM Lane LOS	F	A	A	-	-	-
HCM 95th %tile Q(veh)	12.3	0.1	1	-	-	-

Notes			
~: Volume exceeds capacity	$: Delay exceeds 300s	+: Computation Not Defined	*: All major volume in platoon

Intersection												
Int Delay, s/veh	8.4											

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	230	567	39	267	0	0	0	0	310	0	125
Future Vol, veh/h	0	230	567	39	267	0	0	0	0	310	0	125
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	Yield	-	-	None	-	-	None	-	-	Yield
Storage Length	-	-	0	250	-	-	-	-	-	-	-	150
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	250	616	42	290	0	0	0	0	337	0	136

Major/Minor	Major1			Major2						Minor2		
Conflicting Flow All	-	0	0	250	0	0				624	624	290
Stage 1	-	-	-	-	-	-				374	374	-
Stage 2	-	-	-	-	-	-				250	250	-
Critical Hdwy	-	-	-	4.12	-	-				6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-				5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-				5.42	5.52	-
Follow-up Hdwy	-	-	-	2.218	-	-				3.518	4.018	3.318
Pot Cap-1 Maneuver	0	-	-	1316	-	0				449	402	749
Stage 1	0	-	-	-	-	0				696	618	-
Stage 2	0	-	-	-	-	0				792	700	-
Platoon blocked, %		-	-		-							
Mov Cap-1 Maneuver	-	-	-	1316	-	-				435	0	749
Mov Cap-2 Maneuver	-	-	-	-	-	-				435	0	-
Stage 1	-	-	-	-	-	-				696	0	-
Stage 2	-	-	-	-	-	-				767	0	-

Approach	EB			WB						SB		
HCM Control Delay, s	0			1						29.1		
HCM LOS										D		

Minor Lane/Major Mvmt	EBT	EBR	WBL	WBT	SBLn1	SBLn2
Capacity (veh/h)	-	-	1316	-	435	749
HCM Lane V/C Ratio	-	-	0.032	-	0.775	0.181
HCM Control Delay (s)	-	-	7.8	-	36.4	10.9
HCM Lane LOS	-	-	A	-	E	B
HCM 95th %tile Q(veh)	-	-	0.1	-	6.7	0.7

Intersection	
Int Delay, s/veh	4.2

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	241	0	0	102	136	204	0	13	0	0	0
Future Vol, veh/h	0	241	0	0	102	136	204	0	13	0	0	0
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	Yield	-	-	Yield	-	-	None
Storage Length	270	-	-	-	-	0	-	-	150	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	262	0	0	111	148	222	0	14	0	0	0

Major/Minor	Major1			Major2			Minor1		
Conflicting Flow All	111	0	-	-	-	0	373	373	262
Stage 1	-	-	-	-	-	-	262	262	-
Stage 2	-	-	-	-	-	-	111	111	-
Critical Hdwy	4.12	-	-	-	-	-	6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-	5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-	5.42	5.52	-
Follow-up Hdwy	2.218	-	-	-	-	-	3.518	4.018	3.318
Pot Cap-1 Maneuver	1479	-	0	0	-	-	628	557	777
Stage 1	-	-	0	0	-	-	782	691	-
Stage 2	-	-	0	0	-	-	914	804	-
Platoon blocked, %		-			-	-			
Mov Cap-1 Maneuver	1479	-	-	-	-	-	628	0	777
Mov Cap-2 Maneuver	-	-	-	-	-	-	628	0	-
Stage 1	-	-	-	-	-	-	782	0	-
Stage 2	-	-	-	-	-	-	914	0	-

Approach	EB	WB	NB
HCM Control Delay, s	0	0	13.6
HCM LOS			B

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBL	EBT	WBT	WBR
Capacity (veh/h)	628	777	1479	-	-	-
HCM Lane V/C Ratio	0.353	0.018	-	-	-	-
HCM Control Delay (s)	13.8	9.7	0	-	-	-
HCM Lane LOS	B	A	A	-	-	-
HCM 95th %tile Q(veh)	1.6	0.1	0	-	-	-

Intersection	
Int Delay, s/veh	11.8

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑	↱	↰	↑						↰	↱
Traffic Vol, veh/h	0	247	608	42	286	0	0	0	0	332	0	134
Future Vol, veh/h	0	247	608	42	286	0	0	0	0	332	0	134
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	Yield	-	-	None	-	-	None	-	-	Yield
Storage Length	-	-	0	250	-	-	-	-	-	-	-	150
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	268	661	46	311	0	0	0	0	361	0	146

Major/Minor	Major1			Major2						Minor2		
Conflicting Flow All	-	0	0	268	0	0				671	671	311
Stage 1	-	-	-	-	-	-				403	403	-
Stage 2	-	-	-	-	-	-				268	268	-
Critical Hdwy	-	-	-	4.12	-	-				6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-				5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-				5.42	5.52	-
Follow-up Hdwy	-	-	-	2.218	-	-				3.518	4.018	3.318
Pot Cap-1 Maneuver	0	-	-	1296	-	0				422	378	729
Stage 1	0	-	-	-	-	0				675	600	-
Stage 2	0	-	-	-	-	0				777	687	-
Platoon blocked, %		-	-		-							
Mov Cap-1 Maneuver	-	-	-	1296	-	-				407	0	729
Mov Cap-2 Maneuver	-	-	-	-	-	-				407	0	-
Stage 1	-	-	-	-	-	-				675	0	-
Stage 2	-	-	-	-	-	-				750	0	-

Approach	EB	WB	SB
HCM Control Delay, s	0	1	41
HCM LOS			E

Minor Lane/Major Mvmt	EBT	EBR	WBL	WBT	SBLn1	SBLn2
Capacity (veh/h)	-	-	1296	-	407	729
HCM Lane V/C Ratio	-	-	0.035	-	0.887	0.2
HCM Control Delay (s)	-	-	7.9	-	53	11.2
HCM Lane LOS	-	-	A	-	F	B
HCM 95th %tile Q(veh)	-	-	0.1	-	9.1	0.7

Intersection	
Int Delay, s/veh	66.2

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	357	258	0	0	109	146	219	0	14	0	0	0
Future Vol, veh/h	357	258	0	0	109	146	219	0	14	0	0	0
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	Yield	-	-	Yield	-	-	None
Storage Length	270	-	-	-	-	0	-	-	150	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	388	280	0	0	118	159	238	0	15	0	0	0

Major/Minor	Major1			Major2			Minor1		
Conflicting Flow All	118	0	-	-	-	0	1174	1174	280
Stage 1	-	-	-	-	-	-	1056	1056	-
Stage 2	-	-	-	-	-	-	118	118	-
Critical Hdwy	4.12	-	-	-	-	-	6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-	5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-	5.42	5.52	-
Follow-up Hdwy	2.218	-	-	-	-	-	3.518	4.018	3.318
Pot Cap-1 Maneuver	1470	-	0	0	-	-	~ 212	192	759
Stage 1	-	-	0	0	-	-	335	302	-
Stage 2	-	-	0	0	-	-	907	798	-
Platoon blocked, %		-			-	-			
Mov Cap-1 Maneuver	1470	-	-	-	-	-	~ 156	0	759
Mov Cap-2 Maneuver	-	-	-	-	-	-	~ 156	0	-
Stage 1	-	-	-	-	-	-	247	0	-
Stage 2	-	-	-	-	-	-	907	0	-

Approach	EB	WB	NB
HCM Control Delay, s	4.8	0	$ 300.6
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBL	EBT	WBT	WBR
Capacity (veh/h)	156	759	1470	-	-	-
HCM Lane V/C Ratio	1.526	0.02	0.264	-	-	-
HCM Control Delay (s)	$ 319.2	9.8	8.3	-	-	-
HCM Lane LOS	F	A	A	-	-	-
HCM 95th %tile Q(veh)	15.9	0.1	1.1	-	-	-

Notes

~: Volume exceeds capacity $: Delay exceeds 300s +: Computation Not Defined *: All major volume in platoon

Intersection	
Int Delay, s/veh	93.1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	91	286	31	937	0	0	0	0	311	0	357
Future Vol, veh/h	0	91	286	31	937	0	0	0	0	311	0	357
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	Yield	-	-	None	-	-	None	-	-	Yield
Storage Length	-	-	0	250	-	-	-	-	-	-	-	150
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	99	311	34	1018	0	0	0	0	338	0	388

Major/Minor	Major1			Major2				Minor2		
Conflicting Flow All	-	0	0	99	0	0		1185	1185	1018
Stage 1	-	-	-	-	-	-		1086	1086	-
Stage 2	-	-	-	-	-	-		99	99	-
Critical Hdwy	-	-	-	4.12	-	-		6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-		5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-		5.42	5.52	-
Follow-up Hdwy	-	-	-	2.218	-	-		3.518	4.018	3.318
Pot Cap-1 Maneuver	0	-	-	1494	-	0		~ 209	189	~ 288
Stage 1	0	-	-	-	-	0		~ 324	292	-
Stage 2	0	-	-	-	-	0		925	813	-
Platoon blocked, %		-	-		-					
Mov Cap-1 Maneuver	-	-	-	1494	-	-		~ 204	0	~ 288
Mov Cap-2 Maneuver	-	-	-	-	-	-		~ 204	0	-
Stage 1	-	-	-	-	-	-		~ 324	0	-
Stage 2	-	-	-	-	-	-		904	0	-

Approach	EB	WB	SB
HCM Control Delay, s	0	0.2	280.2
HCM LOS			F

Minor Lane/Major Mvmt	EBT	EBR	WBL	WBT	SBLn1	SBLn2
Capacity (veh/h)	-	-	1494	-	204	288
HCM Lane V/C Ratio	-	-	0.023	-	1.657	1.347
HCM Control Delay (s)	-	-	7.5	-	$ 357.6	212.7
HCM Lane LOS	-	-	A	-	F	F
HCM 95th %tile Q(veh)	-	-	0.1	-	22.4	19.8

Notes			
~: Volume exceeds capacity	$: Delay exceeds 300s	+: Computation Not Defined	*: All major volume in platoon

Intersection	
Int Delay, s/veh	1672.8

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	205	256	0	0	968	122	708	0	50	0	0	0
Future Vol, veh/h	205	256	0	0	968	122	708	0	50	0	0	0
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	Yield	-	-	Yield	-	-	None
Storage Length	270	-	-	-	-	0	-	-	150	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	223	278	0	0	1052	133	770	0	54	0	0	0

Major/Minor	Major1			Major2			Minor1		
Conflicting Flow All	1052	0	-	-	-	0	1776	1776	278
Stage 1	-	-	-	-	-	-	724	724	-
Stage 2	-	-	-	-	-	-	1052	1052	-
Critical Hdwy	4.12	-	-	-	-	-	6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-	5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-	5.42	5.52	-
Follow-up Hdwy	2.218	-	-	-	-	-	3.518	4.018	3.318
Pot Cap-1 Maneuver	662	-	0	0	-	-	~ 91	83	761
Stage 1	-	-	0	0	-	-	~ 480	430	-
Stage 2	-	-	0	0	-	-	~ 336	303	-
Platoon blocked, %		-			-	-			
Mov Cap-1 Maneuver	662	-	-	-	-	-	~ 60	0	761
Mov Cap-2 Maneuver	-	-	-	-	-	-	~ 60	0	-
Stage 1	-	-	-	-	-	-	~ 318	0	-
Stage 2	-	-	-	-	-	-	~ 336	0	-

Approach	EB	WB	NB
HCM Control Delay, s	5.9	0	$ 5092.1
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBL	EBT	WBT	WBR
Capacity (veh/h)	60	761	662	-	-	-
HCM Lane V/C Ratio	12.826	0.071	0.337	-	-	-
HCM Control Delay (s)	$ 5451	10.1	13.2	-	-	-
HCM Lane LOS	F	B	B	-	-	-
HCM 95th %tile Q(veh)	91.8	0.2	1.5	-	-	-

Notes

~: Volume exceeds capacity $: Delay exceeds 300s +: Computation Not Defined *: All major volume in platoon

Intersection	
Int Delay, s/veh	27.1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	281	692	48	327	0	0	0	0	378	0	153
Future Vol, veh/h	0	281	692	48	327	0	0	0	0	378	0	153
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	Yield	-	-	None	-	-	None	-	-	Yield
Storage Length	-	-	0	250	-	-	-	-	-	-	-	150
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	305	752	52	355	0	0	0	0	411	0	166

Major/Minor	Major1			Major2						Minor2		
Conflicting Flow All	-	0	0	305	0	0				764	764	355
Stage 1	-	-	-	-	-	-				459	459	-
Stage 2	-	-	-	-	-	-				305	305	-
Critical Hdwy	-	-	-	4.12	-	-				6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-				5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-				5.42	5.52	-
Follow-up Hdwy	-	-	-	2.218	-	-				3.518	4.018	3.318
Pot Cap-1 Maneuver	0	-	-	1256	-	0				~ 372	334	689
Stage 1	0	-	-	-	-	0				636	566	-
Stage 2	0	-	-	-	-	0				748	662	-
Platoon blocked, %		-	-		-							
Mov Cap-1 Maneuver	-	-	-	1256	-	-				~ 357	0	689
Mov Cap-2 Maneuver	-	-	-	-	-	-				~ 357	0	-
Stage 1	-	-	-	-	-	-				636	0	-
Stage 2	-	-	-	-	-	-				717	0	-

Approach	EB	WB	SB
HCM Control Delay, s	0	1	95.2
HCM LOS			F

Minor Lane/Major Mvmt	EBT	EBR	WBL	WBT	SBLn1	SBLn2
Capacity (veh/h)	-	-	1256	-	357	689
HCM Lane V/C Ratio	-	-	0.042	-	1.151	0.241
HCM Control Delay (s)	-	-	8	-	128.9	11.9
HCM Lane LOS	-	-	A	-	F	B
HCM 95th %tile Q(veh)	-	-	0.1	-	16.2	0.9

Notes

~: Volume exceeds capacity $: Delay exceeds 300s +: Computation Not Defined *: All major volume in platoon

Intersection												
Int Delay, s/veh	137.1											

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	406	294	0	0	125	166	249	0	16	0	0	0
Future Vol, veh/h	406	294	0	0	125	166	249	0	16	0	0	0
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	Yield	-	-	Yield	-	-	None
Storage Length	270	-	-	-	-	0	-	-	150	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	441	320	0	0	136	180	271	0	17	0	0	0

Major/Minor	Major1			Major2			Minor1		
Conflicting Flow All	136	0	-	-	-	0	1338	1338	320
Stage 1	-	-	-	-	-	-	1202	1202	-
Stage 2	-	-	-	-	-	-	136	136	-
Critical Hdwy	4.12	-	-	-	-	-	6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-	5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-	5.42	5.52	-
Follow-up Hdwy	2.218	-	-	-	-	-	3.518	4.018	3.318
Pot Cap-1 Maneuver	1448	-	0	0	-	-	~ 169	153	721
Stage 1	-	-	0	0	-	-	285	258	-
Stage 2	-	-	0	0	-	-	890	784	-
Platoon blocked, %		-			-	-			
Mov Cap-1 Maneuver	1448	-	-	-	-	-	~ 117	0	721
Mov Cap-2 Maneuver	-	-	-	-	-	-	~ 117	0	-
Stage 1	-	-	-	-	-	-	~ 198	0	-
Stage 2	-	-	-	-	-	-	890	0	-

Approach	EB	WB	NB
HCM Control Delay, s	5	0	$ 636.5
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBL	EBT	WBT	WBR
Capacity (veh/h)	117	721	1448	-	-	-
HCM Lane V/C Ratio	2.313	0.024	0.305	-	-	-
HCM Control Delay (s)	$ 676.7	10.1	8.6	-	-	-
HCM Lane LOS	F	B	A	-	-	-
HCM 95th %tile Q(veh)	23.5	0.1	1.3	-	-	-

Notes			
~: Volume exceeds capacity	$: Delay exceeds 300s	+: Computation Not Defined	*: All major volume in platoon

Intersection	
Int Delay, s/veh	182

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	105	326	35	1065	0	0	0	0	354	0	406
Future Vol, veh/h	0	105	326	35	1065	0	0	0	0	354	0	406
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	Yield	-	-	None	-	-	None	-	-	Yield
Storage Length	-	-	0	250	-	-	-	-	-	-	-	150
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	114	354	38	1158	0	0	0	0	385	0	441

Major/Minor	Major1			Major2						Minor2		
Conflicting Flow All	-	0	0	114	0	0				1348	1348	1158
Stage 1	-	-	-	-	-	-				1234	1234	-
Stage 2	-	-	-	-	-	-				114	114	-
Critical Hdwy	-	-	-	4.12	-	-				6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-				5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-				5.42	5.52	-
Follow-up Hdwy	-	-	-	2.218	-	-				3.518	4.018	3.318
Pot Cap-1 Maneuver	0	-	-	1475	-	0				~ 166	151	~ 239
Stage 1	0	-	-	-	-	0				~ 275	249	-
Stage 2	0	-	-	-	-	0				911	801	-
Platoon blocked, %		-	-		-							
Mov Cap-1 Maneuver	-	-	-	1475	-	-				~ 162	0	~ 239
Mov Cap-2 Maneuver	-	-	-	-	-	-				~ 162	0	-
Stage 1	-	-	-	-	-	-				~ 275	0	-
Stage 2	-	-	-	-	-	-				887	0	-

Approach	EB	WB	SB
HCM Control Delay, s	0	0.2	$ 548.3
HCM LOS			F

Minor Lane/Major Mvmt	EBT	EBR	WBL	WBT	SBLn1	SBLn2
Capacity (veh/h)	-	-	1475	-	162	239
HCM Lane V/C Ratio	-	-	0.026	-	2.375	1.846
HCM Control Delay (s)	-	-	7.5	-	$ 682.3	$ 431.4
HCM Lane LOS	-	-	A	-	F	F
HCM 95th %tile Q(veh)	-	-	0.1	-	32.3	30.7

Notes

~: Volume exceeds capacity $: Delay exceeds 300s +: Computation Not Defined *: All major volume in platoon

Intersection	
Int Delay, s/veh	3280.4

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	233	292	0	0	1100	139	805	0	57	0	0	0
Future Vol, veh/h	233	292	0	0	1100	139	805	0	57	0	0	0
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Free	Free	Stop	Stop	Stop	Stop	Stop	Stop
RT Channelized	-	-	None	-	-	Yield	-	-	Yield	-	-	None
Storage Length	270	-	-	-	-	0	-	-	150	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	253	317	0	0	1196	151	875	0	62	0	0	0

Major/Minor	Major1			Major2			Minor1		
Conflicting Flow All	1196	0	-	-	-	0	2019	2019	317
Stage 1	-	-	-	-	-	-	823	823	-
Stage 2	-	-	-	-	-	-	1196	1196	-
Critical Hdwy	4.12	-	-	-	-	-	6.42	6.52	6.22
Critical Hdwy Stg 1	-	-	-	-	-	-	5.42	5.52	-
Critical Hdwy Stg 2	-	-	-	-	-	-	5.42	5.52	-
Follow-up Hdwy	2.218	-	-	-	-	-	3.518	4.018	3.318
Pot Cap-1 Maneuver	584	-	0	0	-	-	~ 64	58	724
Stage 1	-	-	0	0	-	-	~ 431	388	-
Stage 2	-	-	0	0	-	-	~ 287	259	-
Platoon blocked, %		-			-	-			
Mov Cap-1 Maneuver	584	-	-	-	-	-	~ 36	0	724
Mov Cap-2 Maneuver	-	-	-	-	-	-	~ 36	0	-
Stage 1	-	-	-	-	-	-	~ 244	0	-
Stage 2	-	-	-	-	-	-	~ 287	0	-

Approach	EB	WB	NB
HCM Control Delay, s	7	0	$ 9989.2
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBL	EBT	WBT	WBR
Capacity (veh/h)	36	724	584	-	-	-
HCM Lane V/C Ratio	24.306	0.086	0.434	-	-	-
HCM Control Delay (s)	$ 10695.8	10.4	15.8	-	-	-
HCM Lane LOS	F	B	C	-	-	-
HCM 95th %tile Q(veh)	107.9	0.3	2.2	-	-	-

Notes			
~: Volume exceeds capacity	$: Delay exceeds 300s	+: Computation Not Defined	*: All major volume in platoon

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑	↱	↰	↑						↰	↱
Traffic Volume (vph)	0	247	608	42	286	0	0	0	0	332	0	134
Future Volume (vph)	0	247	608	42	286	0	0	0	0	332	0	134
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	0		0	250		0	0		0	0		150
Storage Lanes	0		1	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Lane Util. 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
Frt			0.850									0.850
Flt Protected				0.950							0.950	
Satd. Flow (prot)	0	1863	1583	1770	1863	0	0	0	0	0	1770	1583
Flt Permitted				0.585							0.950	
Satd. Flow (perm)	0	1863	1583	1090	1863	0	0	0	0	0	1770	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			661									146
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		1258			657			1167			1188	
Travel Time (s)		28.6			14.9			26.5			27.0	
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	268	661	46	311	0	0	0	0	361	0	146
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	268	661	46	311	0	0	0	0	0	361	146
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			0			0	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9
Number of Detectors		2	1	1	2					1	2	1
Detector Template		Thru	Right	Left	Thru					Left	Thru	Right
Leading Detector (ft)		100	20	20	100					20	100	20
Trailing Detector (ft)		0	0	0	0					0	0	0
Detector 1 Position(ft)		0	0	0	0					0	0	0
Detector 1 Size(ft)		6	20	20	6					20	6	20
Detector 1 Type		Cl+Ex	Cl+Ex	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	0.0	0.0
Detector 1 Queue (s)		0.0	0.0	0.0	0.0					0.0	0.0	0.0
Detector 1 Delay (s)		0.0	0.0	0.0	0.0					0.0	0.0	0.0
Detector 2 Position(ft)		94			94						94	
Detector 2 Size(ft)		6			6						6	
Detector 2 Type		Cl+Ex			Cl+Ex						Cl+Ex	
Detector 2 Channel												
Detector 2 Extend (s)		0.0			0.0						0.0	
Turn Type		NA	Perm	Perm	NA					Perm	NA	Perm
Protected Phases		2			6						4	
Permitted Phases			2	6						4		4

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Detector Phase		2	2	6	6					4	4	4
Switch Phase												
Minimum Initial (s)		5.0	5.0	5.0	5.0					5.0	5.0	5.0
Minimum Split (s)		23.0	23.0	23.0	23.0					23.0	23.0	23.0
Total Split (s)		34.0	34.0	34.0	34.0					26.0	26.0	26.0
Total Split (%)		56.7%	56.7%	56.7%	56.7%					43.3%	43.3%	43.3%
Maximum Green (s)		29.0	29.0	29.0	29.0					21.0	21.0	21.0
Yellow Time (s)		4.0	4.0	4.0	4.0					4.0	4.0	4.0
All-Red Time (s)		1.0	1.0	1.0	1.0					1.0	1.0	1.0
Lost Time Adjust (s)		0.0	0.0	0.0	0.0						0.0	0.0
Total Lost Time (s)		5.0	5.0	5.0	5.0						5.0	5.0
Lead/Lag												
Lead-Lag Optimize?												
Vehicle Extension (s)		3.0	3.0	3.0	3.0					3.0	3.0	3.0
Recall Mode		C-Max	C-Max	C-Max	C-Max					Max	Max	Max
Walk Time (s)		7.0	7.0	7.0	7.0					7.0	7.0	7.0
Flash Dont Walk (s)		11.0	11.0	11.0	11.0					11.0	11.0	11.0
Pedestrian Calls (#/hr)		0	0	0	0					0	0	0
Act Effct Green (s)		29.0	29.0	29.0	29.0						21.0	21.0
Actuated g/C Ratio		0.48	0.48	0.48	0.48						0.35	0.35
v/c Ratio		0.30	0.60	0.09	0.35						0.58	0.23
Control Delay		10.5	3.5	6.7	10.1						20.6	4.0
Queue Delay		0.0	0.0	0.0	0.0						0.0	0.0
Total Delay		10.5	3.5	6.7	10.1						20.6	4.0
LOS		B	A	A	B						C	A
Approach Delay		5.5			9.6						15.8	
Approach LOS		A			A						B	
Queue Length 50th (ft)		54	0	12	88						104	0
Queue Length 95th (ft)		97	47	31	135						180	31
Internal Link Dist (ft)		1178			577			1087			1108	
Turn Bay Length (ft)				250								150
Base Capacity (vph)		900	1106	526	900						619	648
Starvation Cap Reductn		0	0	0	0						0	0
Spillback Cap Reductn		0	0	0	0						0	0
Storage Cap Reductn		0	0	0	0						0	0
Reduced v/c Ratio		0.30	0.60	0.09	0.35						0.58	0.23

Intersection Summary

Area Type: Other

Cycle Length: 60

Actuated Cycle Length: 60

Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBTL, Start of Yellow, Master Intersection

Natural Cycle: 50

Control Type: Actuated-Coordinated

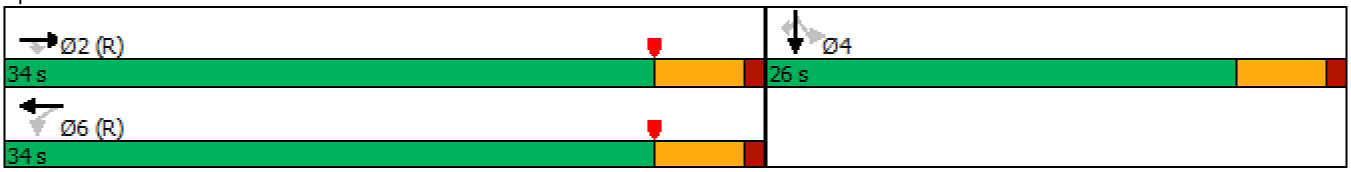
Maximum v/c Ratio: 0.60

Intersection Signal Delay: 9.2 — Intersection LOS: A

Intersection Capacity Utilization 72.7% — ICU Level of Service C

Analysis Period (min) 15

Splits and Phases: 1:



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	357	258	0	0	109	146	219	0	14	0	0	0
Future Volume (vph)	357	258	0	0	109	146	219	0	14	0	0	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	270		0	0		0	0		150	0		0
Storage Lanes	1		0	0		1	1		1	0		0
Taper Length (ft)	25			25			25			25		
Lane Util. Factor	1.00	1.00	1.00	1.00	0.95	1.00	0.95	0.95	1.00	1.00	1.00	1.00
Frt						0.850			0.850			
Flt Protected	0.950						0.950	0.950				
Satd. Flow (prot)	1770	1863	0	0	3539	1583	1681	1681	1583	0	0	0
Flt Permitted	0.677						0.950	0.950				
Satd. Flow (perm)	1261	1863	0	0	3539	1583	1681	1681	1583	0	0	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)						159			127			
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		657			774			1320			1412	
Travel Time (s)		14.9			17.6			30.0			32.1	
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)	388	280	0	0	118	159	238	0	15	0	0	0
Shared Lane Traffic (%)							50%					
Lane Group Flow (vph)	388	280	0	0	118	159	119	119	15	0	0	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)		12			12			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
Number of Detectors	1	2			2	1	1	2	1			
Detector Template	Left	Thru			Thru	Right	Left	Thru	Right			
Leading Detector (ft)	20	100			100	20	20	100	20			
Trailing Detector (ft)	0	0			0	0	0	0	0			
Detector 1 Position(ft)	0	0			0	0	0	0	0			
Detector 1 Size(ft)	20	6			6	20	20	6	20			
Detector 1 Type	Cl+Ex	Cl+Ex			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	0.0	0.0			
Detector 1 Queue (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Detector 1 Delay (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Detector 2 Position(ft)		94			94			94				
Detector 2 Size(ft)		6			6			6				
Detector 2 Type		Cl+Ex			Cl+Ex			Cl+Ex				
Detector 2 Channel												
Detector 2 Extend (s)		0.0			0.0			0.0				
Turn Type	pm+pt	NA			NA	Perm	Perm	NA	Perm			
Protected Phases	5	2			6			8				
Permitted Phases	2					6	8		8			

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Detector Phase	5	2			6	6	8	8	8			
Switch Phase												
Minimum Initial (s)	5.0	5.0			5.0	5.0	5.0	5.0	5.0			
Minimum Split (s)	10.0	23.0			23.0	23.0	23.0	23.0	23.0			
Total Split (s)	14.0	37.0			23.0	23.0	23.0	23.0	23.0			
Total Split (%)	23.3%	61.7%			38.3%	38.3%	38.3%	38.3%	38.3%			
Maximum Green (s)	9.0	32.0			18.0	18.0	18.0	18.0	18.0			
Yellow Time (s)	4.0	4.0			4.0	4.0	4.0	4.0	4.0			
All-Red Time (s)	1.0	1.0			1.0	1.0	1.0	1.0	1.0			
Lost Time Adjust (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Total Lost Time (s)	5.0	5.0			5.0	5.0	5.0	5.0	5.0			
Lead/Lag	Lag				Lead	Lead						
Lead-Lag Optimize?	Yes				Yes	Yes						
Vehicle Extension (s)	3.0	3.0			3.0	3.0	3.0	3.0	3.0			
Recall Mode	None	C-Max			C-Max	C-Max	None	None	None			
Walk Time (s)		7.0			7.0	7.0	7.0	7.0	7.0			
Flash Dont Walk (s)		11.0			11.0	11.0	11.0	11.0	11.0			
Pedestrian Calls (#/hr)		0			0	0	0	0	0			
Act Effct Green (s)	42.5	43.5			28.5	28.5	9.7	9.7	9.7			
Actuated g/C Ratio	0.71	0.72			0.48	0.48	0.16	0.16	0.16			
v/c Ratio	0.40	0.21			0.07	0.19	0.44	0.44	0.04			
Control Delay	4.1	2.2			11.0	3.3	26.8	26.8	0.2			
Queue Delay	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Total Delay	4.1	2.2			11.0	3.3	26.8	26.8	0.2			
LOS	A	A			B	A	C	C	A			
Approach Delay		3.3			6.6			25.3				
Approach LOS		A			A			C				
Queue Length 50th (ft)	19	13			12	0	42	42	0			
Queue Length 95th (ft)	38	22			28	31	78	78	0			
Internal Link Dist (ft)		577			694			1240			1332	
Turn Bay Length (ft)	270								150			
Base Capacity (vph)	968	1349			1678	834	504	504	563			
Starvation Cap Reductn	0	0			0	0	0	0	0			
Spillback Cap Reductn	0	0			0	0	0	0	0			
Storage Cap Reductn	0	0			0	0	0	0	0			
Reduced v/c Ratio	0.40	0.21			0.07	0.19	0.24	0.24	0.03			

Intersection Summary

Area Type: Other

Cycle Length: 60

Actuated Cycle Length: 60

Offset: 28 (47%), Referenced to phase 2:EBTL and 6:WBT, Start of Green

Natural Cycle: 60

Control Type: Actuated-Coordinated

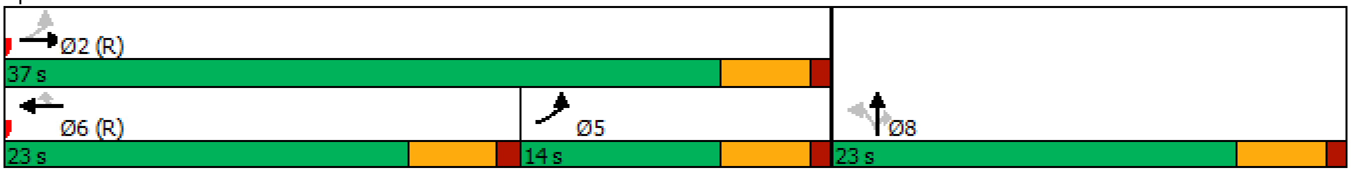
Maximum v/c Ratio: 0.44

Intersection Signal Delay: 8.7 | Intersection LOS: A

Intersection Capacity Utilization 72.7% | ICU Level of Service C

Analysis Period (min) 15

Splits and Phases: 2:

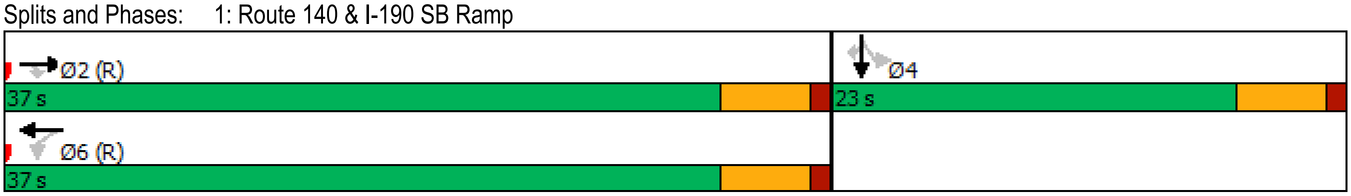


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑	↱	↰	↑						↰	↱
Traffic Volume (vph)	0	91	286	31	937	0	0	0	0	311	0	357
Future Volume (vph)	0	91	286	31	937	0	0	0	0	311	0	357
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	0		0	250		0	0		0	0		150
Storage Lanes	0		1	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Lane Util. 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
Frt			0.850									0.850
Flt Protected				0.950							0.950	
Satd. Flow (prot)	0	1863	1583	1770	1863	0	0	0	0	0	1770	1583
Flt Permitted				0.693							0.950	
Satd. Flow (perm)	0	1863	1583	1291	1863	0	0	0	0	0	1770	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			311									86
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		1258			657			1167			1188	
Travel Time (s)		28.6			14.9			26.5			27.0	
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	99	311	34	1018	0	0	0	0	338	0	388
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	99	311	34	1018	0	0	0	0	0	338	388
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			0			0	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9
Number of Detectors		2	1	1	2					1	2	1
Detector Template		Thru	Right	Left	Thru					Left	Thru	Right
Leading Detector (ft)		100	20	20	100					20	100	20
Trailing Detector (ft)		0	0	0	0					0	0	0
Detector 1 Position(ft)		0	0	0	0					0	0	0
Detector 1 Size(ft)		6	20	20	6					20	6	20
Detector 1 Type		Cl+Ex	Cl+Ex	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	0.0	0.0
Detector 1 Queue (s)		0.0	0.0	0.0	0.0					0.0	0.0	0.0
Detector 1 Delay (s)		0.0	0.0	0.0	0.0					0.0	0.0	0.0
Detector 2 Position(ft)		94			94						94	
Detector 2 Size(ft)		6			6						6	
Detector 2 Type		Cl+Ex			Cl+Ex						Cl+Ex	
Detector 2 Channel												
Detector 2 Extend (s)		0.0			0.0						0.0	
Turn Type		NA	Perm	Perm	NA					Perm	NA	Perm
Protected Phases		2			6						4	
Permitted Phases			2	6						4		4

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Detector Phase		2	2	6	6					4	4	4
Switch Phase												
Minimum Initial (s)		5.0	5.0	5.0	5.0					5.0	5.0	5.0
Minimum Split (s)		23.0	23.0	23.0	23.0					23.0	23.0	23.0
Total Split (s)		37.0	37.0	37.0	37.0					23.0	23.0	23.0
Total Split (%)		61.7%	61.7%	61.7%	61.7%					38.3%	38.3%	38.3%
Maximum Green (s)		32.0	32.0	32.0	32.0					18.0	18.0	18.0
Yellow Time (s)		4.0	4.0	4.0	4.0					4.0	4.0	4.0
All-Red Time (s)		1.0	1.0	1.0	1.0					1.0	1.0	1.0
Lost Time Adjust (s)		0.0	0.0	0.0	0.0						0.0	0.0
Total Lost Time (s)		5.0	5.0	5.0	5.0						5.0	5.0
Lead/Lag												
Lead-Lag Optimize?												
Vehicle Extension (s)		3.0	3.0	3.0	3.0					3.0	3.0	3.0
Recall Mode		C-Max	C-Max	C-Max	C-Max					None	None	None
Walk Time (s)		7.0	7.0	7.0	7.0					7.0	7.0	7.0
Flash Dont Walk (s)		11.0	11.0	11.0	11.0					11.0	11.0	11.0
Pedestrian Calls (#/hr)		0	0	0	0					0	0	0
Act Effct Green (s)		34.0	34.0	34.0	34.0						16.0	16.0
Actuated g/C Ratio		0.57	0.57	0.57	0.57						0.27	0.27
v/c Ratio		0.09	0.30	0.05	0.96						0.72	0.80
Control Delay		7.1	1.9	6.9	37.1						28.9	29.7
Queue Delay		0.0	0.0	0.0	0.0						0.0	0.0
Total Delay		7.1	1.9	6.9	37.1						28.9	29.7
LOS		A	A	A	D						C	C
Approach Delay		3.2			36.1						29.3	
Approach LOS		A			D						C	

Intersection Summary	
Area Type:	Other
Cycle Length: 60	
Actuated Cycle Length: 60	
Offset: 8 (13%), Referenced to phase 2:EBT and 6:WBTL, Start of Green	
Natural Cycle: 70	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.96	
Intersection Signal Delay: 27.7	Intersection LOS: C
Intersection Capacity Utilization 79.1%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 1: Route 140 & I-190 SB Ramp



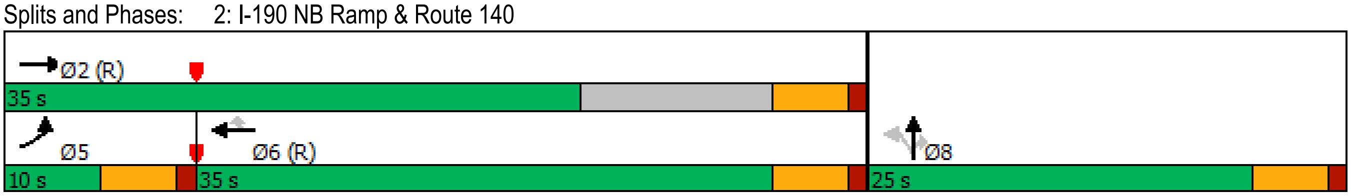
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	205	256	0	0	968	122	708	0	50	0	0	0
Future Volume (vph)	205	256	0	0	968	122	708	0	50	0	0	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	270		0	0		0	0		150	0		0
Storage Lanes	1		0	0		1	1		1	0		0
Taper Length (ft)	25			25			25			25		
Lane Util. Factor	1.00	1.00	1.00	1.00	0.95	1.00	0.95	0.95	1.00	1.00	1.00	1.00
Frt						0.850			0.850			
Flt Protected	0.950						0.950	0.950				
Satd. Flow (prot)	1770	1863	0	0	3539	1583	1681	1681	1583	0	0	0
Flt Permitted	0.950						0.950	0.950				
Satd. Flow (perm)	1770	1863	0	0	3539	1583	1681	1681	1583	0	0	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)						133			109			
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		657			774			1320			1412	
Travel Time (s)		14.9			17.6			30.0			32.1	
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)	223	278	0	0	1052	133	770	0	54	0	0	0
Shared Lane Traffic (%)							50%					
Lane Group Flow (vph)	223	278	0	0	1052	133	385	385	54	0	0	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)		12			12			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
Number of Detectors	1	2			2	1	1	2	1			
Detector Template	Left	Thru			Thru	Right	Left	Thru	Right			
Leading Detector (ft)	20	100			100	20	20	100	20			
Trailing Detector (ft)	0	0			0	0	0	0	0			
Detector 1 Position(ft)	0	0			0	0	0	0	0			
Detector 1 Size(ft)	20	6			6	20	20	6	20			
Detector 1 Type	Cl+Ex	Cl+Ex			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	0.0	0.0			
Detector 1 Queue (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Detector 1 Delay (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Detector 2 Position(ft)		94			94			94				
Detector 2 Size(ft)		6			6			6				
Detector 2 Type		Cl+Ex			Cl+Ex			Cl+Ex				
Detector 2 Channel												
Detector 2 Extend (s)		0.0			0.0			0.0				
Turn Type	Prot	NA			NA	Perm	Perm	NA	Perm			
Protected Phases	5	2			6			8				
Permitted Phases						6	8		8			

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Detector Phase	5	2			6	6	8	8	8			
Switch Phase												
Minimum Initial (s)	5.0	5.0			5.0	5.0	5.0	5.0	5.0			
Minimum Split (s)	10.0	23.0			23.0	23.0	23.0	23.0	23.0			
Total Split (s)	10.0	35.0			35.0	35.0	25.0	25.0	25.0			
Total Split (%)	14.3%	50.0%			50.0%	50.0%	35.7%	35.7%	35.7%			
Maximum Green (s)	5.0	30.0			30.0	30.0	20.0	20.0	20.0			
Yellow Time (s)	4.0	4.0			4.0	4.0	4.0	4.0	4.0			
All-Red Time (s)	1.0	1.0			1.0	1.0	1.0	1.0	1.0			
Lost Time Adjust (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Total Lost Time (s)	5.0	5.0			5.0	5.0	5.0	5.0	5.0			
Lead/Lag	Lead				Lag	Lag						
Lead-Lag Optimize?	Yes				Yes	Yes						
Vehicle Extension (s)	3.0	3.0			3.0	3.0	3.0	3.0	3.0			
Recall Mode	None	C-Max			C-Max	C-Max	None	None	None			
Walk Time (s)		7.0			7.0	7.0	7.0	7.0	7.0			
Flash Dont Walk (s)		11.0			11.0	11.0	11.0	11.0	11.0			
Pedestrian Calls (#/hr)		0			0	0	0	0	0			
Act Effct Green (s)	6.1	41.1			30.0	30.0	18.9	18.9	18.9			
Actuated g/C Ratio	0.09	0.59			0.43	0.43	0.27	0.27	0.27			
v/c Ratio	1.46	0.25			0.69	0.18	0.85	0.85	0.11			
Control Delay	268.3	8.1			19.3	3.2	43.1	43.1	1.2			
Queue Delay	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Total Delay	268.3	8.1			19.3	3.2	43.1	43.1	1.2			
LOS	F	A			B	A	D	D	A			
Approach Delay		123.9			17.5			40.4				
Approach LOS		F			B			D				

Intersection Summary

Area Type: Other
Cycle Length: 70
Actuated Cycle Length: 70
Offset: 56 (80%), Referenced to phase 2:EBT and 6:WBT, Start of Green
Natural Cycle: 60
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 1.46
Intersection Signal Delay: 46.2 Intersection LOS: D
Intersection Capacity Utilization 79.1% ICU Level of Service D
Analysis Period (min) 15

Splits and Phases: 2: I-190 NB Ramp & Route 140



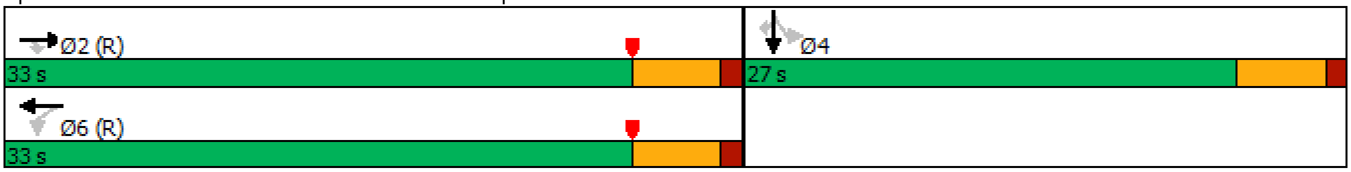
Lanes, Volumes, Timings | 2043 AM - Signal
1: Route 140 & I-190 SB Ramp | 12/12/2023

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	0	281	692	48	327	0	0	0	0	378	0	153
Future Volume (vph)	0	281	692	48	327	0	0	0	0	378	0	153
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	0		0	250		0	0		0	0		150
Storage Lanes	0		1	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Lane Util. 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
Frt			0.850									0.850
Flt Protected				0.950							0.950	
Satd. Flow (prot)	0	1863	1583	1770	1863	0	0	0	0	0	1770	1583
Flt Permitted				0.560							0.950	
Satd. Flow (perm)	0	1863	1583	1043	1863	0	0	0	0	0	1770	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			752									166
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		1258			657			1167			1188	
Travel Time (s)		28.6			14.9			26.5			27.0	
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	305	752	52	355	0	0	0	0	411	0	166
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	305	752	52	355	0	0	0	0	0	411	166
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			0			0	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9
Number of Detectors		2	1	1	2					1	2	1
Detector Template		Thru	Right	Left	Thru					Left	Thru	Right
Leading Detector (ft)		100	20	20	100					20	100	20
Trailing Detector (ft)		0	0	0	0					0	0	0
Detector 1 Position(ft)		0	0	0	0					0	0	0
Detector 1 Size(ft)		6	20	20	6					20	6	20
Detector 1 Type		Cl+Ex	Cl+Ex	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	0.0	0.0
Detector 1 Queue (s)		0.0	0.0	0.0	0.0					0.0	0.0	0.0
Detector 1 Delay (s)		0.0	0.0	0.0	0.0					0.0	0.0	0.0
Detector 2 Position(ft)		94			94						94	
Detector 2 Size(ft)		6			6						6	
Detector 2 Type		Cl+Ex			Cl+Ex						Cl+Ex	
Detector 2 Channel												
Detector 2 Extend (s)		0.0			0.0						0.0	
Turn Type		NA	Perm	Perm	NA					Perm	NA	Perm
Protected Phases		2			6						4	
Permitted Phases			2	6						4		4

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Detector Phase		2	2	6	6					4	4	4
Switch Phase												
Minimum Initial (s)		5.0	5.0	5.0	5.0					5.0	5.0	5.0
Minimum Split (s)		23.0	23.0	23.0	23.0					23.0	23.0	23.0
Total Split (s)		33.0	33.0	33.0	33.0					27.0	27.0	27.0
Total Split (%)		55.0%	55.0%	55.0%	55.0%					45.0%	45.0%	45.0%
Maximum Green (s)		28.0	28.0	28.0	28.0					22.0	22.0	22.0
Yellow Time (s)		4.0	4.0	4.0	4.0					4.0	4.0	4.0
All-Red Time (s)		1.0	1.0	1.0	1.0					1.0	1.0	1.0
Lost Time Adjust (s)		0.0	0.0	0.0	0.0						0.0	0.0
Total Lost Time (s)		5.0	5.0	5.0	5.0						5.0	5.0
Lead/Lag												
Lead-Lag Optimize?												
Vehicle Extension (s)		3.0	3.0	3.0	3.0					3.0	3.0	3.0
Recall Mode		C-Max	C-Max	C-Max	C-Max					None	None	None
Walk Time (s)		7.0	7.0	7.0	7.0					7.0	7.0	7.0
Flash Dont Walk (s)		11.0	11.0	11.0	11.0					11.0	11.0	11.0
Pedestrian Calls (#/hr)		0	0	0	0					0	0	0
Act Effct Green (s)		31.5	31.5	31.5	31.5						18.5	18.5
Actuated g/C Ratio		0.52	0.52	0.52	0.52						0.31	0.31
v/c Ratio		0.31	0.63	0.10	0.36						0.75	0.28
Control Delay		10.2	3.8	5.7	8.1						27.6	3.9
Queue Delay		0.0	0.0	0.0	0.0						0.0	0.0
Total Delay		10.2	3.8	5.7	8.1						27.6	3.9
LOS		B	A	A	A						C	A
Approach Delay		5.6			7.8						20.8	
Approach LOS		A			A						C	
Queue Length 50th (ft)		60	0	10	100						127	0
Queue Length 95th (ft)		115	51	33	153						203	32
Internal Link Dist (ft)		1178			577			1087			1108	
Turn Bay Length (ft)				250								150
Base Capacity (vph)		978	1188	547	978						649	685
Starvation Cap Reductn		0	0	0	0						0	0
Spillback Cap Reductn		0	0	0	0						0	0
Storage Cap Reductn		0	0	0	0						0	0
Reduced v/c Ratio		0.31	0.63	0.10	0.36						0.63	0.24

Intersection Summary	
Area Type: Other	
Cycle Length: 60	
Actuated Cycle Length: 60	
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBTL, Start of Yellow, Master Intersection	
Natural Cycle: 50	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.75	
Intersection Signal Delay: 10.4	Intersection LOS: B
Intersection Capacity Utilization 80.5%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 1: Route 140 & I-190 SB Ramp

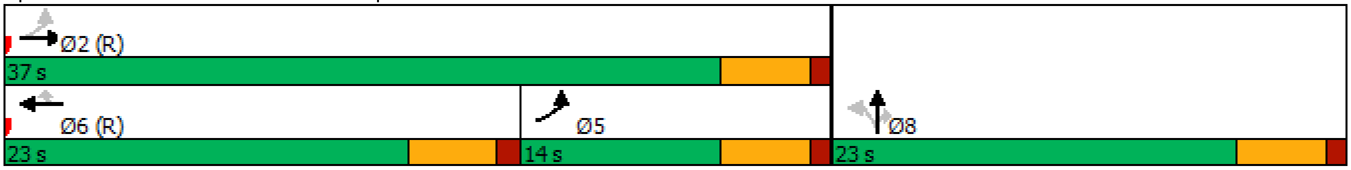


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	406	294	0	0	125	166	249	0	16	0	0	0
Future Volume (vph)	406	294	0	0	125	166	249	0	16	0	0	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	270		0	0		0	0		150	0		0
Storage Lanes	1		0	0		1	1		1	0		0
Taper Length (ft)	25			25			25			25		
Lane Util. Factor	1.00	1.00	1.00	1.00	0.95	1.00	0.95	0.95	1.00	1.00	1.00	1.00
Frt						0.850			0.850			
Flt Protected	0.950						0.950	0.950				
Satd. Flow (prot)	1770	1863	0	0	3539	1583	1681	1681	1583	0	0	0
Flt Permitted	0.666						0.950	0.950				
Satd. Flow (perm)	1241	1863	0	0	3539	1583	1681	1681	1583	0	0	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)						180			127			
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		657			774			1320			1412	
Travel Time (s)		14.9			17.6			30.0			32.1	
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)	441	320	0	0	136	180	271	0	17	0	0	0
Shared Lane Traffic (%)							50%					
Lane Group Flow (vph)	441	320	0	0	136	180	135	136	17	0	0	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)		12			12			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
Number of Detectors	1	2			2	1	1	2	1			
Detector Template	Left	Thru			Thru	Right	Left	Thru	Right			
Leading Detector (ft)	20	100			100	20	20	100	20			
Trailing Detector (ft)	0	0			0	0	0	0	0			
Detector 1 Position(ft)	0	0			0	0	0	0	0			
Detector 1 Size(ft)	20	6			6	20	20	6	20			
Detector 1 Type	Cl+Ex	Cl+Ex			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	0.0	0.0			
Detector 1 Queue (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Detector 1 Delay (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Detector 2 Position(ft)		94			94			94				
Detector 2 Size(ft)		6			6			6				
Detector 2 Type		Cl+Ex			Cl+Ex			Cl+Ex				
Detector 2 Channel												
Detector 2 Extend (s)		0.0			0.0			0.0				
Turn Type	pm+pt	NA			NA	Perm	Perm	NA	Perm			
Protected Phases	5	2			6			8				
Permitted Phases	2					6	8		8			

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Detector Phase	5	2			6	6	8	8	8			
Switch Phase												
Minimum Initial (s)	5.0	5.0			5.0	5.0	5.0	5.0	5.0			
Minimum Split (s)	10.0	23.0			23.0	23.0	23.0	23.0	23.0			
Total Split (s)	14.0	37.0			23.0	23.0	23.0	23.0	23.0			
Total Split (%)	23.3%	61.7%			38.3%	38.3%	38.3%	38.3%	38.3%			
Maximum Green (s)	9.0	32.0			18.0	18.0	18.0	18.0	18.0			
Yellow Time (s)	4.0	4.0			4.0	4.0	4.0	4.0	4.0			
All-Red Time (s)	1.0	1.0			1.0	1.0	1.0	1.0	1.0			
Lost Time Adjust (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Total Lost Time (s)	5.0	5.0			5.0	5.0	5.0	5.0	5.0			
Lead/Lag	Lag				Lead	Lead						
Lead-Lag Optimize?	Yes				Yes	Yes						
Vehicle Extension (s)	3.0	3.0			3.0	3.0	3.0	3.0	3.0			
Recall Mode	None	C-Max			C-Max	C-Max	None	None	None			
Walk Time (s)		7.0			7.0	7.0	7.0	7.0	7.0			
Flash Dont Walk (s)		11.0			11.0	11.0	11.0	11.0	11.0			
Pedestrian Calls (#/hr)		0			0	0	0	0	0			
Act Effct Green (s)	41.9	42.9			27.9	27.9	10.3	10.3	10.3			
Actuated g/C Ratio	0.70	0.72			0.46	0.46	0.17	0.17	0.17			
v/c Ratio	0.47	0.24			0.08	0.22	0.47	0.47	0.05			
Control Delay	5.6	2.7			11.4	3.3	26.9	27.0	0.2			
Queue Delay	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Total Delay	5.6	2.7			11.4	3.3	26.9	27.0	0.2			
LOS	A	A			B	A	C	C	A			
Approach Delay		4.4			6.8			25.4				
Approach LOS		A			A			C				
Queue Length 50th (ft)	19	14			14	0	47	47	0			
Queue Length 95th (ft)	85	47			33	34	86	86	0			
Internal Link Dist (ft)		577			694			1240			1332	
Turn Bay Length (ft)	270								150			
Base Capacity (vph)	946	1333			1648	833	504	504	563			
Starvation Cap Reductn	0	0			0	0	0	0	0			
Spillback Cap Reductn	0	0			0	0	0	0	0			
Storage Cap Reductn	0	0			0	0	0	0	0			
Reduced v/c Ratio	0.47	0.24			0.08	0.22	0.27	0.27	0.03			

Intersection Summary	
Area Type: Other	
Cycle Length: 60	
Actuated Cycle Length: 60	
Offset: 30 (50%), Referenced to phase 2:EBTL and 6:WBT, Start of Green	
Natural Cycle: 60	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.47	
Intersection Signal Delay: 9.4	Intersection LOS: A
Intersection Capacity Utilization 80.5%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 2: I-190 NB Ramp & Route 140



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	0	105	326	35	1065	0	0	0	0	354	0	406
Future Volume (vph)	0	105	326	35	1065	0	0	0	0	354	0	406
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	0		0	250		0	0		0	0		150
Storage Lanes	0		1	1		0	0		0	0		1
Taper Length (ft)	25			25			25			25		
Lane Util. 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
Frt			0.850									0.850
Flt Protected				0.950							0.950	
Satd. Flow (prot)	0	1863	1583	1770	1863	0	0	0	0	0	1770	1583
Flt Permitted				0.684							0.950	
Satd. Flow (perm)	0	1863	1583	1274	1863	0	0	0	0	0	1770	1583
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			354									107
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		1258			657			1167			1188	
Travel Time (s)		28.6			14.9			26.5			27.0	
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	114	354	38	1158	0	0	0	0	385	0	441
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	114	354	38	1158	0	0	0	0	0	385	441
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			0			0	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		16			16			16			16	
Two way Left Turn Lane												
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15		9	15		9	15		9	15		9
Number of Detectors		2	1	1	2					1	2	1
Detector Template		Thru	Right	Left	Thru					Left	Thru	Right
Leading Detector (ft)		100	20	20	100					20	100	20
Trailing Detector (ft)		0	0	0	0					0	0	0
Detector 1 Position(ft)		0	0	0	0					0	0	0
Detector 1 Size(ft)		6	20	20	6					20	6	20
Detector 1 Type		Cl+Ex	Cl+Ex	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	0.0	0.0
Detector 1 Queue (s)		0.0	0.0	0.0	0.0					0.0	0.0	0.0
Detector 1 Delay (s)		0.0	0.0	0.0	0.0					0.0	0.0	0.0
Detector 2 Position(ft)		94			94						94	
Detector 2 Size(ft)		6			6						6	
Detector 2 Type		Cl+Ex			Cl+Ex						Cl+Ex	
Detector 2 Channel												
Detector 2 Extend (s)		0.0			0.0						0.0	
Turn Type		NA	Perm	Perm	NA					Perm	NA	Perm
Protected Phases		2			6						4	
Permitted Phases			2	6						4		4

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Detector Phase		2	2	6	6					4	4	4
Switch Phase												
Minimum Initial (s)		5.0	5.0	5.0	5.0					5.0	5.0	5.0
Minimum Split (s)		23.0	23.0	23.0	23.0					23.0	23.0	23.0
Total Split (s)		71.0	71.0	71.0	71.0					29.0	29.0	29.0
Total Split (%)		71.0%	71.0%	71.0%	71.0%					29.0%	29.0%	29.0%
Maximum Green (s)		66.0	66.0	66.0	66.0					24.0	24.0	24.0
Yellow Time (s)		4.0	4.0	4.0	4.0					4.0	4.0	4.0
All-Red Time (s)		1.0	1.0	1.0	1.0					1.0	1.0	1.0
Lost Time Adjust (s)		0.0	0.0	0.0	0.0						0.0	0.0
Total Lost Time (s)		5.0	5.0	5.0	5.0						5.0	5.0
Lead/Lag												
Lead-Lag Optimize?												
Vehicle Extension (s)		3.0	3.0	3.0	3.0					3.0	3.0	3.0
Recall Mode		C-Max	C-Max	C-Max	C-Max					None	None	None
Walk Time (s)		7.0	7.0	7.0	7.0					7.0	7.0	7.0
Flash Dont Walk (s)		11.0	11.0	11.0	11.0					11.0	11.0	11.0
Pedestrian Calls (#/hr)		0	0	0	0					0	0	0
Act Effct Green (s)		66.1	66.1	66.1	66.1						23.9	23.9
Actuated g/C Ratio		0.66	0.66	0.66	0.66						0.24	0.24
v/c Ratio		0.09	0.30	0.05	0.94						0.91	0.96
Control Delay		6.4	1.4	1.5	15.8						64.9	63.0
Queue Delay		0.0	0.0	0.0	0.9						0.0	0.0
Total Delay		6.4	1.4	1.5	16.6						64.9	63.0
LOS		A	A	A	B						E	E
Approach Delay		2.6			16.2						63.9	
Approach LOS		A			B						E	
Queue Length 50th (ft)		24	0	0	449						239	219
Queue Length 95th (ft)		43	28	m2	m#958						#412	#417
Internal Link Dist (ft)		1178			577			1087			1108	
Turn Bay Length (ft)				250								150
Base Capacity (vph)		1231	1166	842	1231						424	461
Starvation Cap Reductn		0	0	0	13						0	0
Spillback Cap Reductn		0	0	0	0						0	0
Storage Cap Reductn		0	0	0	0						0	0
Reduced v/c Ratio		0.09	0.30	0.05	0.95						0.91	0.96

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 42 (42%), Referenced to phase 2:EBT and 6:WBTL, Start of Green

Natural Cycle: 90

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.96

Intersection Signal Delay: 29.5 Intersection LOS: C

Intersection Capacity Utilization 89.9% ICU Level of Service E

Analysis Period (min) 15

\# 95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 1: Route 140 & I-190 SB Ramp

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	233	292	0	0	1100	139	805	0	57	0	0	0
Future Volume (vph)	233	292	0	0	1100	139	805	0	57	0	0	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Storage Length (ft)	270		0	0		0	0		150	0		0
Storage Lanes	1		0	0		1	1		1	0		0
Taper Length (ft)	25			25			25			25		
Lane Util. Factor	1.00	1.00	1.00	1.00	0.95	1.00	0.95	0.95	1.00	1.00	1.00	1.00
Frt						0.850			0.850			
Flt Protected	0.950						0.950	0.950				
Satd. Flow (prot)	1770	1863	0	0	3539	1583	1681	1681	1583	0	0	0
Flt Permitted	0.950						0.950	0.950				
Satd. Flow (perm)	1770	1863	0	0	3539	1583	1681	1681	1583	0	0	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)						151			76			
Link Speed (mph)		30			30			30			30	
Link Distance (ft)		657			774			1320			1412	
Travel Time (s)		14.9			17.6			30.0			32.1	
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)	253	317	0	0	1196	151	875	0	62	0	0	0
Shared Lane Traffic (%)							50%					
Lane Group Flow (vph)	253	317	0	0	1196	151	437	438	62	0	0	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)		12			12			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
Number of Detectors	1	2			2	1	1	2	1			
Detector Template	Left	Thru			Thru	Right	Left	Thru	Right			
Leading Detector (ft)	20	100			100	20	20	100	20			
Trailing Detector (ft)	0	0			0	0	0	0	0			
Detector 1 Position(ft)	0	0			0	0	0	0	0			
Detector 1 Size(ft)	20	6			6	20	20	6	20			
Detector 1 Type	Cl+Ex	Cl+Ex			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	0.0	0.0			
Detector 1 Queue (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Detector 1 Delay (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Detector 2 Position(ft)		94			94			94				
Detector 2 Size(ft)		6			6			6				
Detector 2 Type		Cl+Ex			Cl+Ex			Cl+Ex				
Detector 2 Channel												
Detector 2 Extend (s)		0.0			0.0			0.0				
Turn Type	Prot	NA			NA	Perm	Perm	NA	Perm			
Protected Phases	5	2			6			8				
Permitted Phases						6	8		8			

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Detector Phase	5	2			6	6	8	8	8			
Switch Phase												
Minimum Initial (s)	5.0	5.0			5.0	5.0	5.0	5.0	5.0			
Minimum Split (s)	10.0	23.0			23.0	23.0	23.0	23.0	23.0			
Total Split (s)	22.0	65.0			43.0	43.0	35.0	35.0	35.0			
Total Split (%)	22.0%	65.0%			43.0%	43.0%	35.0%	35.0%	35.0%			
Maximum Green (s)	17.0	60.0			38.0	38.0	30.0	30.0	30.0			
Yellow Time (s)	4.0	4.0			4.0	4.0	4.0	4.0	4.0			
All-Red Time (s)	1.0	1.0			1.0	1.0	1.0	1.0	1.0			
Lost Time Adjust (s)	0.0	0.0			0.0	0.0	0.0	0.0	0.0			
Total Lost Time (s)	5.0	5.0			5.0	5.0	5.0	5.0	5.0			
Lead/Lag	Lead				Lag	Lag						
Lead-Lag Optimize?	Yes				Yes	Yes						
Vehicle Extension (s)	3.0	3.0			3.0	3.0	3.0	3.0	3.0			
Recall Mode	None	C-Max			C-Max	C-Max	None	None	None			
Walk Time (s)		7.0			7.0	7.0	7.0	7.0	7.0			
Flash Dont Walk (s)		11.0			11.0	11.0	11.0	11.0	11.0			
Pedestrian Calls (#/hr)		0			0	0	0	0	0			
Act Effct Green (s)	16.4	61.1			39.7	39.7	28.9	28.9	28.9			
Actuated g/C Ratio	0.16	0.61			0.40	0.40	0.29	0.29	0.29			
v/c Ratio	0.87	0.28			0.85	0.21	0.90	0.90	0.12			
Control Delay	82.7	3.2			35.3	4.3	57.4	57.7	5.2			
Queue Delay	0.0	0.0			0.5	0.0	3.1	3.2	0.0			
Total Delay	82.7	3.2			35.8	4.3	60.5	60.9	5.2			
LOS	F	A			D	A	E	E	A			
Approach Delay		38.5			32.3			57.0				
Approach LOS		D			C			E				
Queue Length 50th (ft)	171	26			370	0	275	276	0			
Queue Length 95th (ft)	m#216	m31			#498	39	#458	#462	23			
Internal Link Dist (ft)		577			694			1240			1332	
Turn Bay Length (ft)	270								150			
Base Capacity (vph)	300	1138			1404	719	504	504	528			
Starvation Cap Reductn	0	0			0	0	0	0	0			
Spillback Cap Reductn	0	0			37	0	25	25	0			
Storage Cap Reductn	0	0			0	0	0	0	0			
Reduced v/c Ratio	0.84	0.28			0.87	0.21	0.91	0.91	0.12			

Intersection Summary

Area Type: Other

Cycle Length: 100

Actuated Cycle Length: 100

Offset: 24 (24%), Referenced to phase 2:EBT and 6:WBT, Start of Green

Natural Cycle: 90

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.90

Intersection Signal Delay: 41.6 Intersection LOS: D

Intersection Capacity Utilization 89.9% ICU Level of Service E

Analysis Period (min) 15

95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.
m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 2: I-190 NB Ramp & Route 140

Moving Massachusetts Forward. massDOT Highway

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : ______________________ COUNT DATE : ____________

DISTRICT : ________ UNSIGNALIZED : [ ] SIGNALIZED : [ ]

~ INTERSECTION DATA ~

MAJOR STREET : ______________________

MINOR STREET(S) : ______________________

INTERSECTION DIAGRAM (Label Approaches)

North

PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						

" K " FACTOR : [ ] INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : [ ]

TOTAL # OF CRASHES : [ ] # OF YEARS : [ ] AVERAGE # OF CRASHES PER YEAR (**A**) : [ ]

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

Comments : ______________________

Project Title & Date: ______________________

Appendix L: ICE Tool Northbound - Volume Counts

At-Grade Intersections List

This sheet is used to manage the at-grade intersections list. After entering all inputs, use the "Setup Worksheets" button at the bottom of the tab before proceeding with the ICE analysis.

	Open Year	Design Year
Operating Cycle	2030	2043
Peak Hour Start	**From**	**To**
AM peak	8:00 AM	9:00 AM
PM peak	5:00 PM	6:00 PM
Weekend peak		

Enter peak period begin and end times:

Demand forecasts for the opening year *must* be provided below, and travel time/delay forecasts must be given in the Delay worksheet.

Select Analysis Basis:	Specific Day/Month
Select facility type:	Rural Interstate

Weekday Count:	Tuesday, September 26, 2023
Weekend Count:	

Enter dates as "mm/dd/yyyy"

Enter dates as "mm/dd/yyyy"

At intersections of varying facilities select the roadway that will be more representative of the volume, or interpolate between values.

Specify total volumes or turning counts?	Total Volumes	(If At-Grade, Select from drop-down menu)

Enter the total entering volume (i.e. sum of turning movement counts) for the peak hours. If data is not available for the weekend peak hour please leave blank.

	Units	Year	
		Opening	**Design**
		2030	**2043**
		Intersection 1	
AM peak hour volume	veh/hr	1,649	1,876
PM peak hour volume	veh/hr	2,012	2,290
Weekend peak hour volume:	veh/hr		
Average annual auto occupancy	Passengers per vehicle	1.0	1.0
Average annual % trucks	Average %	2.0%	2.0%

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	No	TWSC	Two-Way Stop Control	
2	No	AllStop	All Way Stop	
3	Yes	TrafficSignal	Traffic Signal	
4	No	TrafficSignalAlt	Traffic Signal (Alt.)	
5	Yes	Roundabout	Roundabout	
6	No	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

Press the "Setup Worksheets" button to create hidden worksheets that compute performance measures for each selected control strategy.

Appendix M: ICE Tool Northbound - Cost Parameters

Cost Parameters

This sheet defines the basic cost parameters used in the benefit-cost analysis. You may either use the default values or override th
dollars, preferably in base year dollars. Consult the Bureau of Labor Statistics web site for latest information on the consumer p

Type	Category	Unit valuation	Default value	Override value	Use value	Override date	
Existing (Base) year for discounting	N/A	N/A	N/A	2030	2030		All costs will be dis
Opening Year	N/A	N/A	N/A	2030	2030		
Design Year	N/A	N/A	N/A	2043	2043		
Discount rate	N/A	Percent	0.04		0.04		OMB Circular A-4 r
Value of time	Person (weekday)	$ per person hour	$ 17.67		$ 17.67		
	Person (weekend)	$ per person hour	$ 17.67		$ 17.67		2015 TTI Urban Mo
	Trucks	$ per truck hour	$ 94.04		$ 94.04		
Crashes	Fatal & Injury Crashes	$ per crash	$ 441,000		$ 441,000		MassDOT Safety - / https://www.mass
	Property damage only crashes	$ per crash	$ 16,700		$ 16,700		*Fatal & Injury (KAI

Planning & construction costs	Units	Minor Road Stop	All Way Stop	Traffic Signal	Roundabout	Displaced Left Turn (DLT)	Median U-Turn (MUT)
Total	Dollars	$ -	$ -	$ 500,000	$ 1,140,855		$ -
Survey	Dollars	$ -	$ -	$ -	$ 400		$ -
Right of way	Dollars	$ -	$ -	$ -	$ -	$ -	$ -
Equipment, signs	Dollars	$ -	$ -	$ -	$ 6,096	$ -	$ -
Utilities	Dollars	$ -	$ -	$ -	$ 22,234	$ -	$ -
Construction	Dollars	$ -	$ -	$ -	$ 877,977	$ -	$ -
Landscaping	Dollars	$ -	$ -	$ -	$ 10,480	$ -	$ -
(Other planning & construction costs)	Dollars				$ 119,954		
(Other planning & construction costs)	Dollars				$ 103,714		
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						

Appendix N: ICE Tool Northbound - Delay

Delay Information	Use this sheet to enter the delay information for each of the included control strategies.								
				Opening Year			Design Year		
At-Grade Intersections				Average vehicle delay			Average vehicle delay		
Control Strategy		Delay Type	Units	AM peak	PM peak	Weekend peak	AM peak	PM peak	Weekend peak
Traffic Signal	Single Input	Single Input	sec/veh	9.2	27.7		10.4	29.5	
Roundabout	Single Input	Single Input	sec/veh	9.8	17.4		13.9	31.0	
Other 2									

Appendix O: ICE Tool Northbound - Outputs

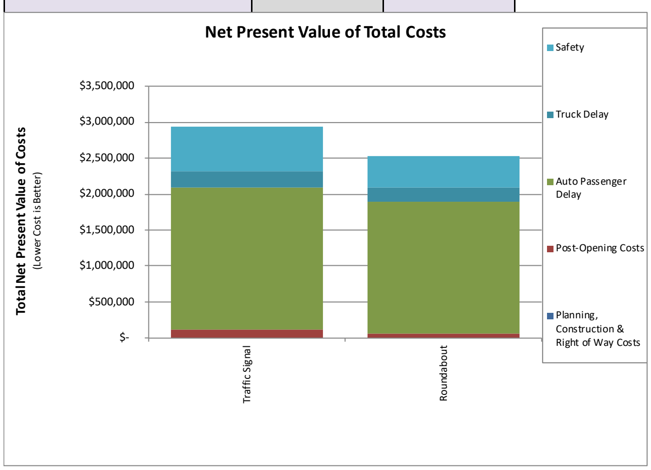
Outputs	This sheet compiles the data from summary tables in individual alternatives sheets. To populate the output sheet press the "Setup
Agency:	MassDOT
Project Name:	WPI MQP 2023
Project Reference:	12345
Intersection:	Route 140 and I-190 Interchange
City:	Sterling
State:	Massachusetts
Performing Department or Organization:	Transportation Department
Date:	12/11/23
Analyst:	WPI MQP 2023
Analysis Type	At-Grade Intersection

Analysis Summary

Cost Categories	Net Present Value of Costs	
	Traffic Signal	Roundabout
Planning, Construction & Right of Way Costs	$ -	$ -
Post-Opening Costs	$ 124,528	$ 56,631
Auto Passenger Delay	$ 1,974,018	$ 1,835,702
Truck Delay	$ 214,403	$ 199,380
Safety	$ 629,142	$ 444,049
Total cost	**$2,942,091**	**$2,535,762**

To exclude cost categories from the comparison clear all values in the row.

Select Base Case for Benefit-Cost Comparison: (Choose from list)		
Traffic Signal	**Net Present Value of Benefits Relative to Base Case**	
	Traffic Signal	**Roundabout**
Auto Passenger Delay		$ 138,316
Truck Delay		$ 15,023
Safety		$ 185,093
Net Present Value of Benefits		**$ 338,432**
Net Present Value of Costs		**$ (67,897)**
Net Present Value of Improvement		**$ 406,329**
Benefit-Cost (B/C) Ratio		**Control strategy preferred. Benefits are greater than base case and cost is less than base case.**
Delay B/C		**Control strategy preferred. Benefits are greater than base case and cost is less than base case.**
Safety B/C		**Control strategy preferred. Benefits are greater than base case and cost is less than base case.**



Warnings and Error Log

[Not used]

Appendix P: ICE Tool Southbound - Volume Counts

At-Grade Intersections List

This sheet is used to manage the at-grade intersections list. After entering all inputs, use the "Setup Worksheets" button at the bottom of the tab before proceeding with the ICE analysis.

	Open Year	Design Year
Operating Cycle	2030	2043
Peak Hour Start	**From**	**To**
AM peak	8:00 AM	9:00 AM
PM peak	5:00 PM	6:00 PM
Weekend peak		

Enter peak period begin and end times:

Demand forecasts for the opening year *must* be provided below, and travel time/delay forecasts must be given in the Delay worksheet.

Select Analysis Basis:	Specific Day/Month
Select facility type:	Rural Interstate

Weekday Count:	Tuesday, September 26, 2023	Enter dates as "mm/dd/yyyy"
Weekend Count:		Enter dates as "mm/dd/yyyy"

At intersections of varying facilities select the roadway that will be more representative of the volume, or interpolate between values.

Specify total volumes or turning counts?	Total Volumes	(If At-Grade, Select from drop-down menu)

Enter the total entering volume (i.e. sum of turning movement counts) for the peak hours. If data is not available for the weekend peak hour please leave blank.

	Units	Year	
		Opening	Design
		2030	2043
		Intersection 1	
AM peak hour volume	veh/hr	1,652	1,880
PM peak hour volume	veh/hr	2,012	2,290
Weekend peak hour volume:	veh/hr		
Average annual auto occupancy	Passengers per vehicle	1.0	1.0
Average annual % trucks	Average %	2.0%	2.0%

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	No	TWSC	Two-Way Stop Control	
2	No	AllStop	All Way Stop	
3	Yes	TrafficSignal	Traffic Signal	
4	No	TrafficSignalAlt	Traffic Signal (Alt.)	
5	Yes	Roundabout	Roundabout	
6	No	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

Press the "Setup Worksheets" button to create hidden worksheets that compute performance measures for each selected control strategy.

Appendix Q: ICE Tool Southbound - Cost Parameters

Cost Parameters

This sheet defines the basic cost parameters used in the benefit-cost analysis. You may either use the default values or override th
dollars, preferably in base year dollars. Consult the Bureau of Labor Statistics web site for latest information on the consumer p

Type	Category	Unit valuation	Default value	Override value	Use value	Override date	
Existing (Base) year for discounting	N/A	N/A	N/A	2030	2030		All costs will be dis
Opening Year	N/A	N/A	N/A	2030	2030		
Design Year	N/A	N/A	N/A	2043	2043		
Discount rate	N/A	Percent	0.04		0.04		OMB Circular A-4 r

Value of time	Person (weekday)
	Person (weekend)
	Trucks
		$ per person hour
		$ per person hour
		$ per truck hour
			$ 17.67
			$ 17.67
			$ 94.04
					$ 17.67
					$ 17.67
					$ 94.04
							2015 TTI Urban Mo

Crashes	Fatal & Injury Crashes	$ per crash	$ 441,000		$ 441,000		MassDOT Safety - / https://www.mass
	Property damage only crashes	$ per crash	$ 16,700		$ 16,700		*Fatal & Injury (KAI

Planning & construction costs	Units	Minor Road Stop	All Way Stop	Traffic Signal	Roundabout	Displaced Left Turn (DLT)	Median U-Turn (MUT)
Total	Dollars	$ -	$ -	$ 500,000	$ 1,140,855		$ -
Survey	Dollars	$ -	$ -	$ -	$ 400		$ -
Right of way	Dollars	$ -	$ -	$ -	$ -	$ -	$ -
Equipment, signs	Dollars	$ -	$ -	$ -	$ 6,096	$ -	$ -
Utilities	Dollars	$ -	$ -	$ -	$ 22,234	$ -	$ -
Construction	Dollars	$ -	$ -	$ -	$ 877,977	$ -	$ -
Landscaping	Dollars	$ -	$ -	$ -	$ 10,480	$ -	$ -
(Other planning & construction costs)	Dollars				$ 119,954		
(Other planning & construction costs)	Dollars				$ 103,714		
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						
(Other planning & construction costs)	Dollars						

Appendix R: ICE Tool Southbound - Delay

Delay Information		Use this sheet to enter the delay information for each of the included control strategies.																	
				Opening Year								Design Year							
At-Grade Intersections				Average vehicle delay			Standard deviation of vehicle travel time or delay			Average bicycle delay	Average pedestrian delay	Average vehicle delay			Standard deviation of vehicle travel time or delay			Average bicycle delay	Average pedestrian delay
Control Strategy		Delay Type	Units	AM peak	PM peak	Weekend peak	AM peak	PM peak	Weekend peak	All time periods	All time periods	AM peak	PM peak	Weekend peak	AM peak	PM peak	Weekend peak	All time periods	All time periods
Traffic Signal	Single Input	Single Input	sec/veh	8.7	46.2							9.4	41.6						
Roundabout	Single Input	Single Input	sec/veh	7.1	9.6							8.2	12.2						
Other 2																			

Appendix S: ICE Tool Southbound - Outputs

Outputs	This sheet compiles the data from summary tables in individual alternatives sheets. To populate the output sheet press the "Setup
Agency:	MassDOT
Project Name:	WPI MQP 2023
Project Reference:	12345
Intersection:	Route 140 and I-190 Interchange
City:	Sterling
State:	Massachusetts
Performing Department or Organization:	Transportation Department
Date:	12/11/23
Analyst:	WPI MQP 2023
Analysis Type	At-Grade Intersection

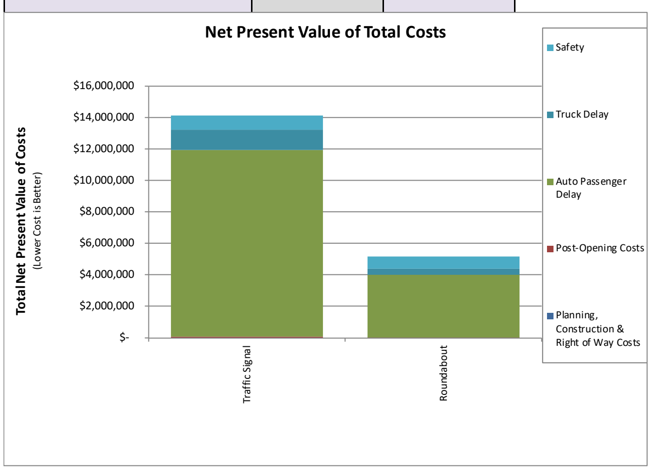
Analysis Summary

Cost Categories	Net Present Value of Costs	
	Traffic Signal	Roundabout
Planning, Construction & Right of Way Costs	$ -	$ -
Post-Opening Costs	$ 124,528	$ 56,631
Auto Passenger Delay	$ 11,839,310	$ 3,939,920
Truck Delay	$ 1,285,898	$ 427,925
Safety	$ 917,302	$ 733,841
Total cost	**$14,167,037**	**$5,158,317**

To exclude cost categories from the comparison clear all values in the row.

Select Base Case for Benefit-Cost Comparison: (Choose from list)

Traffic Signal	Net Present Value of Benefits Relative to Base Case	
	Traffic Signal	Roundabout
Auto Passenger Delay		$ 7,899,390
Truck Delay		$ 857,973
Safety		$ 183,460
Net Present Value of Benefits		**$ 8,940,823**
Net Present Value of Costs		**$ (67,897)**
Net Present Value of Improvement		**$ 9,008,720**
Benefit-Cost (B/C) Ratio		**Control strategy preferred. Benefits are greater than base case and cost is less than base case.**
Delay B/C		**Control strategy preferred. Benefits are greater than base case and cost is less than base case.**
Safety B/C		**Control strategy preferred. Benefits are greater than base case and cost is less than base case.**



Warnings and Error Log

[Not used]

Appendix T: ICE Stage 1

MassDOT Intersection Control Evaluation (ICE) Stage 1: Screening

massDOT
Massachusetts Department of Transportation

Project Name	
MassDOT District	District 3
City/Town	Sterling, MA
Major Street	Route 140
Minor Street	I-190
Existing Control Type	Other
Submitted By	WPI MQP Group
Agency/Company	Worcester Polytechnic Institute
Email	gr-massdotmqp-23@wpi.edu
Date	10/30/23
Latitude	**42.172564**
Longitude	**-72.030892**

Project Setting *(Describe the area surrounding the intersection)*

The Route 140 and Interstate 190 interchnage is located in Sterling, MA in a mostly rural residential area.

Project Need/Opportunity *(What is the catalyst for this project and intended outcomes?)*

The interchange has not been re-evaluated in ten years, this project aims to apply modern design practices to the interchange and improve safety from active transporters.

Multimodal Context *(Describe pedestrian, bicycle, and transit activity in the area)*

There is little active transport in the area. This is primarliy due to the lack of shops, resturants, and overall small population in the area.

Link to intersection location

Export to ICE Calcs

Export to CAP-X

COULD THE CONTROL STRATEGY:

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 viable given the site constraints & location context (e.g., ROW, cultural impacts)?	... appear viable with respect to other project factors (e.g., environmental, utility impacts)?	**VIABLE CONTROL STRATEGY?**	Decision Justification	sDOT Comments
Two-Way Stop Control (TWSC)	Yes	No	Yes	No	Yes	Yes	**Yes**	The TWSC strategy is a viable control strategy for the interchange as it logistically makes sense when the signage is located where the	
All-Way Stop Control (AWSC)	No	Yes	No	No	No	Yes	**No**	The AWSC strategy would not be an effective method for this interchanage and would likely result in an increase of congestion.	
Signalized Control	Yes	Yes	Yes	No	Yes	Yes	**Yes**	Signalizing the interchange in general is a potential control stratey that would improve overall safety of pedestrians (signalized	
Roundabout	Yes	Yes	Yes	Yes	Yes	Yes	**Yes**	A Roundabout is a viable control strategy for this intersection because it addresses and meets all screening questions. A	
Median U-Turn (MUT)	No	Yes	No	No	No	Yes	**No**	A Median U-Turn (MUT) intersection would not be a viable control strategy mainly because its does not fit well within the existing	
Partial Median U-Turn (PMUT)	No	Yes	No	No	No	Yes	**No**	Similar to the MUT, and Partial Median U-Turn (PMUT) also is not compatible with the size restrictions of the site, and a PMUT would	
Restricted Crossing U-Turn (RCUT) Signalized	No	Yes	Yes	Yes	No	Yes	**No**	A Restricted Crossing U-Turn (RCUT) Signalized Intersection will not be compatible with the site due to the size and environmental	
Restricted Crossing U-Turn (RCUT) Unsignalized	No	Yes	No	No	No	Yes	**No**	A Restricted Crossing U-Turn (RCUT) Unsignalized intersection will not be compatible with the site due to the conditions listed above.	
Jughandle	No	No	No	No	No	No	**No**	A Jughandle interchange will not be compatible with the site due to conditions listed above. The size restrictions of the site limit this	
Displaced Left-Turn (DLT)	No	No	No	No	No	No	**No**	Displaced Left-Turn (DLT) is not an effective design for this interchange. In a displaced Left-Turn interchange, left lanes cross	
Continuous Green Tee	No	No	No	No	No	No	**No**	Continuous green tee is not a viable interchange design for the interchanges being looked redesigned largely due to the form of	
Quadrant Roadway	No	No	No	No	No	No	**No**	Quadrant Roadway is not an effective interchange design for the interchanges being studied. This is due to the space needed for such	
Other									

Appendix U: ICE Stage 2 - Northbound

MassDOT ICE Stage 2: Initial Control Strategy Assessment

massDOT Massachusetts Department of Transportation

Import ICE Tool Safety and Delay Data

Reset Delay Default Values

Reset Safety Default Values

Project Name	Route 140 and I-190 Interchange Stering	Project File No.				Date	02/28/24
Submitted By	WPI MassDOT MQP	Agency/Company	Worcester Polytechnic Institute	Email	MassDotMQP-23@wpi.edu		

List all viable intersection control strategies identified in Stage 1 (Screening):

Signalized Control (Alt.)	Signalized Control	Roundabout

Existing Major Street Information

Exisiting Control Type	Other
Study Period #1 Traffic Volumes	Study Period #2 Traffic Volumes
Weekday AM Peak	Weekday PM Peak

Operational Analyses

Opening Year: 2030 — CAP-X Completed? Yes

Control Strategy	Weekday AM Peak		Weekday PM Peak		CAP-X	
	Delay (sec.)	All queues accommodated?	Delay (sec.)	All queues accommodated?	V/C	Rank
Signalized Control	9.2	Yes	28	Yes		
Roundabout	9.8	Yes	17	Yes		

DesignYear: 2043 — CAP-X Completed? Yes

Control Strategy	Weekday AM Peak		Weekday PM Peak		CAP-X	
	Delay (sec.)	All queues accommodated?	Delay (sec.)	All queues accommodated?	V/C	Rank
Signalized Control	10.4	Yes	29	Yes		
Roundabout	13.9	Yes	31	Yes		

Provide any additional discussion necessary regarding the results of the operational analysis:

Safety Performance

Summarize the five (5) most recent years of crash data available at the intersection (if existing).

Crash Type	Year					Total	
	2017	2018	2019	2021	2022		
PDO	0	1	1	0	1	3	
Injury	0	1	0	0	0	1	
Fatal	0	0	0	0	0	0	
Total	0	2	1	0	1	4	2020 is neglected due to COVID-19 travel patterns

Apply the MassDOT Safety Alternatives Analysis Guide to model to model anticaipted safety performance of each control strategy and qualitatively discuss its impact.

Control Strategy	Anticipated Impact on Safety Performance	Opening Year		Design Year	
		Predicted Total Crashes	Predicted Fatal+Injury Crashes	Predicted Total Crashes	Predicted Fatal+Injury Crashes
Signalized Control	Signalized has a CMF of 0.57	3.06	3.06	3.48	3.48
Roundabout	Roundabout has a CMF of 0.48	2.57	2.57	2.93	2.93

Costs

Remaining cognizant of the current level of detail of each control strategy's conceptual design, provide a cost estimate for each. Apply the MassDOT ICE Tool and provide the "Operations & Maintenance" and "Benefit-Cost Ratio" from the "Output" Tab for each control strategy.

Control Strategy	Costs ($)	Estimate Includes	Operations & Maintenance	Benefit-Cost Ratio
Signalized Control	$500,000	PE, ROW, Construction, Contingency	80000.00	
Roundabout	$1,140,855	PE, ROW, Construction, Contingency	0.00	

Multimodal Accomodations

Route # or Name:			Route # or Name:			Route # or Name:		
Direction			Direction			Direction		
Sidewalks along			Sidewalks along			Sidewalks along		
Crosswalk on Approach?			Crosswalk on Approach?			Crosswalk on Approach?		
On-Street Bike Facilities?			On-Street Bike Facilities?			On-Street Bike Facilities?		
Multi-Use Path?			Multi-Use Path?			Multi-Use Path?		
Schedule Bus Service?			Schedule Bus Service?			Schedule Bus Service?		
Bus Stop on Approach?			Bus Stop on Approach?			Bus Stop on Approach?		

Note the existing level of pedestrian/bicyclist activity at the study intersection during the evaluated peak hours.	Weekday AM Peak		Weekday PM Peak	
	Major Street	Minor Street	Major Street	Minor Street
# of ped. crossings (both approaches, if app.):	0	0	0	0

# of cyclists (both approaches, if app.):	0	0	0	0	

Summarize the ability of each viable control strategy to accommodate the existing/anticipated level of:

Control Strategy	Pedestrians and Bicyclists	Transit Services	Freight Needs
Signalized Control	Will include bike lane and crosswalk for safe travel		
Roundabout	Will include crosswalk for safe travel		

Environmental, Utility, and Right-of-Way Impacts

Summarize any issues related to environmental, utility, or right-of-way (including relocation) impacts specific to each control strategy:

Signalized Control	
Roundabout	A roundabout will create a demand for increased land, disturbing the environment

Public Input/Feedback

Summarize public input received or any stakeholder considerations regarding the control strategies.

Control Strategy Evaluation

Provide a brief justification as to why each of the following is either viable or not viable. If a single control strategy is recommended, select it as the only strategy to be advanced.

Control Strategy	Strategy Viable?	Justification	Strategy to be Advanced?
Signalized Control	No	The build cost along with delay cost create a cost benefit with a significantly higher cost than benefit	No
Roundabout	Yes	Between the delay cost and build cost, the beneifts are greater than the base case	Yes

Appendix V: ICE Stage 2 - Southbound

MassDOT ICE Stage 2: Initial Control Strategy Assessment

massDOT Massachusetts Department of Transportation

Import ICE Tool Safety and Delay Data

Reset Delay Default Values

Reset Safety Default Values

Project Name	Route 140 and I-190 Interchange Stering	Project File No.		Date	02/15/02
Submitted By	WPI MassDOT MQP	Agency/Company	Worcester Polytechnic Institute	Email	MassDotMQP-23@wpi.edu

List all viable intersection control strategies identified in Stage 1 (Screening):

Signalized Control (Alt.)	Signalized Control	Roundabout

Existing Major Street Information

Exisiting Control Type	Other
Study Period #1 Traffic Volumes	Study Period #2 Traffic Volumes
Weekday AM Peak	Weekday PM Peak

Operational Analyses

Opening Year: 2030 — CAP-X Completed? Yes

Control Strategy	Weekday AM Peak Delay (sec.)	Weekday AM Peak All queues accommodated?	Weekday PM Peak Delay (sec.)	Weekday PM Peak All queues accommodated?	CAP-X V/C	CAP-X Rank
Signalized Control	8.7	Yes	46	Yes		
Roundabout	7.1	Yes	10	Yes		

DesignYear: 2043 — CAP-X Completed? Yes

Control Strategy	Weekday AM Peak Delay (sec.)	Weekday AM Peak All queues accommodated?	Weekday PM Peak Delay (sec.)	Weekday PM Peak All queues accommodated?	CAP-X V/C	CAP-X Rank
Signalized Control	9.4	Yes	42	Yes		
Roundabout	8.2	Yes	12	Yes		

Provide any additional discussion necessary regarding the results of the operational analysis:

Safety Performance

Summarize the five (5) most recent years of crash data available at the intersection (if existing).

Crash Type	2017	2018	2019	2021	2022	Total
PDO	4	1	0	1	0	6
Injury	0	1	0	0	0	1
Fatal	0	0	0	0	0	0
Total	4	2	0	1	0	7

2020 is neglected due to COVID-19 travel patterns

Apply the MassDOT Safety Alternatives Analysis Guide to model to model anticaipted safety performance of each control strategy and qualitatively discuss its impact.

Control Strategy	Anticipated Impact on Safety Performance	Opening Year Predicted Total Crashes	Opening Year Predicted Fatal+Injury Crashes	Design Year Predicted Total Crashes	Design Year Predicted Fatal+Injury Crashes
Signalized Control	Signalized has a CMF of 0.57	4.28	4.28	4.87	4.87
Roundabout	Roundabout has a CMF of 0.48	3.60	3.60	4.10	4.10

Costs

Remaining cognizant of the current level of detail of each control strategy's conceptual design, provide a cost estimate for each. Apply the MassDOT ICE Tool and provide the "Operations & Maintenance" and "Benefit-Cost Ratio" from the "Output" Tab for each control strategy.

Control Strategy	Costs ($)	Estimate Includes	Operations & Maintenance	Benefit-Cost Ratio
Signalized Control	$500,000	PE, ROW, Construction, Contingency	80000.00	
Roundabout	$1,140,855	PE, ROW, Construction, Contingency	0.00	

Multimodal Accomodations

Route # or Name:			Route # or Name:			Route # or Name:		
Direction			Direction			Direction		
Sidewalks along			Sidewalks along			Sidewalks along		
Crosswalk on Approach?			Crosswalk on Approach?			Crosswalk on Approach?		
On-Street Bike Facilities?			On-Street Bike Facilities?			On-Street Bike Facilities?		
Multi-Use Path?			Multi-Use Path?			Multi-Use Path?		
Schedule Bus Service?			Schedule Bus Service?			Schedule Bus Service?		
Bus Stop on Approach?			Bus Stop on Approach?			Bus Stop on Approach?		

Note the existing level of pedestrian/bicyclist activity at the study intersection during the evaluated peak hours.	Weekday AM Peak Major Street	Weekday AM Peak Minor Street	Weekday PM Peak Major Street	Weekday PM Peak Minor Street
# of ped. crossings (both approaches, if app.):	0	0	0	0

# of cyclists (both approaches, if app.):	0	0	0	0	

Summarize the ability of each viable control strategy to accommodate the existing/anticipated level of:

Control Strategy	Pedestrians and Bicyclists	Transit Services	Freight Needs
Signalized Control	Will include bike lane and crosswalk for safe travel		
Roundabout	Will include crosswalk for safe travel		

Environmental, Utility, and Right-of-Way Impacts

Summarize any issues related to environmental, utility, or right-of-way (including relocation) impacts specific to each control strategy:

Signalized Control	
Roundabout	A roundabout will create a demand for increased land, disturbing the environment

Public Input/Feedback

Summarize public input received or any stakeholder considerations regarding the control strategies.

Control Strategy Evaluation

Provide a brief justification as to why each of the following is either viable or not viable. If a single control strategy is recommended, select it as the only strategy to be advanced.

Control Strategy	Strategy Viable?	Justification	Strategy to be Advanced?
Signalized Control	No	The build cost along with delay cost create a cost benefit with a significantly higher cost than benefit	No
Roundabout	Yes	Between the delay cost and build cost, the beneifts are greater than the base case	Yes

Strengthening Communities: A Holistic Approach to Enhancing Environmental and Social Sustainability through Asset-Based Development

Abigail Pulling - Environmental & Sustainability Studies '24
Advisor: Professor Robert Krueger

This report fulfills the additional ⅓ credit required for the dual degree program at Worcester Polytechnic Institute and is an appendix of the larger civil engineering component.

1.0 Introduction

The transportation engineering side of this project aimed to take a fresh look at the I-190 and Route 140 interchange with the end goal of improving functionality through a redesign process. With a particular interest in active transportation, the team focused on how pedestrian and cyclist travel can be accommodated through the suggested redesign of the interchange.

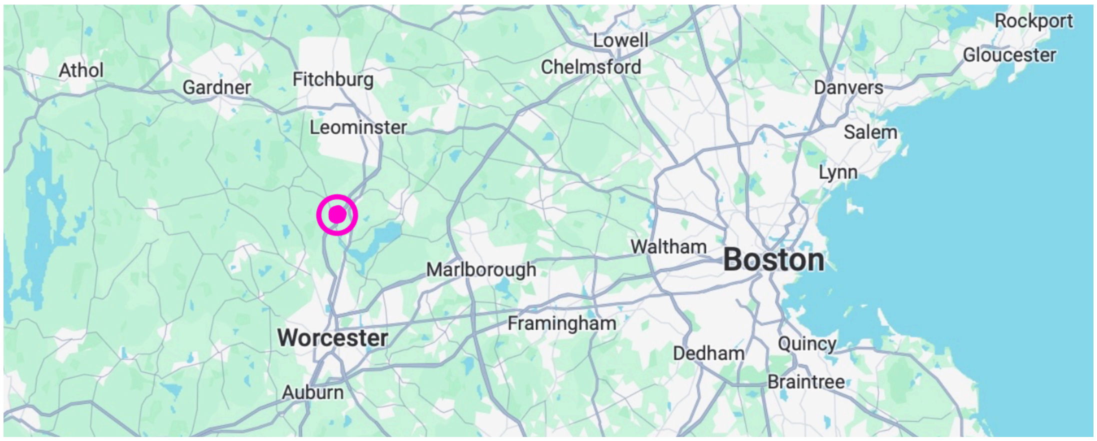


Figure 1: Interchange Location (circled in pink)

Recognizing the growing importance of non-motorized modes of travel for both recreational and commuting purposes, the project's focus extended beyond vehicular traffic to ensure the safety, accessibility, and convenience of pedestrians and cyclists using the interchange. The redesign plan incorporated dedicated crosswalks and protected lanes specifically designed for pedestrians and cyclists to enhance safety and encourage more people to choose active transportation options. These sidewalks and pathways aim to connect key destinations such as residential areas and recreational facilities, specifically the Massachusetts Central Rail Trail which has a trailhead less than a mile from the interchange.

This element of the project adopts an additional environmental and sustainability perspective to examine the community's existing assets, emphasizing strengths, resources, and capabilities. Through this lens, the research aims to identify areas for improvement, particularly focusing on development, accessibility, and enhancing social sustainability measures. This asset-mapping process results in recommendations that the towns can utilize to enhance their current communities and promote connectedness.

2.0 Background

The town of Sterling consists primarily of residential neighborhoods and rural areas with a lesser balance of small businesses and light industrial zones. Its location has made it a convenient commuter town for residents working in cities such as Worcester and Boston. Sterling offers some cultural attractions such as the Sterling Farmland and outdoor recreational locations at the Wachusett Reservoir and Wachusett Mountain State Reservation. West Boylston, Massachusetts, shares a similar historical background with Sterling. Over time, the town's economy has diversified, allowing for commercial developments while preserving its natural and historical landmarks (*Central Massachusetts Regional Planning Committee, 2021*). West Boylston is home to attractions such as the Old Stone Church, and the Mass Central Rail Trail, which offers biking and hiking routes. The town's proximity to outdoor recreational areas, combined with its local businesses and community attractions, creates a community for both residents and visitors. These community characteristics are important because they possess potential to create a more vibrant, sustainable, and well-rounded community.

2.1 Documented Community Limitations

Although the two communities have unique features, there is a substantial lack of infrastructure and public amenities surrounding the interchange and throughout the towns, especially being within a 20-minute drive of Worcester (10 miles), where there is a large-scale and wide range of attractions and work opportunities.

2.1.2 Active Transporters

During the data collection period of this project, the team performed an initial evaluation of the site, and examined the safety conditions, for both active transporters and drivers. The team found that there were safety concerns with vehicles encroaching into the bike lane and blocking pedestrian crossings.

Figure 2: Left turning vehicle encroaching the bike lane and crosswalk

To gauge how many active transporters actually utilized this interchange, a traffic camera was placed at the south intersection of I-190 and Route 140 facing traffic going northbound, and a count was collected of all pedestrians and cyclists using the sidewalk and bike lane. This camera recorded 36 hours of footage between 17:30, October 31, and 15:30, November 1. At night, the video footage goes dark, preventing the team from counting the total number of active transporters for the entire 24 hours. However, during the hours of daylight, there were no recorded active transporters.

In 2022 MassDOT updated their mapping of walkable trips. The segment of roadway on Route 140 is listed as having a low potential for walkable trips. This is due to a number of factors including safety and local infrastructure. Due to the limited infrastructure surrounding the interchange, which lacks essential amenities like shops, restaurants, or office buildings, it is improbable that the area would attract a substantial volume of active transport users. Without the convenient facilities nearby, the appeal for commuters to utilize alternative modes of transportation, such as walking or cycling, is significantly diminished.

Outside of this general area, the towns of Sterling and W. Boylston both lack adequate infrastructure for cyclists and pedestrians. The main documented issue in Sterling was the presence of fragmented bike lanes and sidewalks, as shown in Figure 3. Discontinued bike lanes and sidewalks present numerous challenges for cyclists, pedestrians, and communities. These disjointed pathways compromise safety by forcing cyclists or walkers to navigate mixed traffic, leading to increased risks of accidents and injuries. Additionally, they disrupt the flow of cycling traffic, discourage cycling participation, and promote a perception of inadequacy in infrastructure. The lack of continuous bike lanes and pedestrian crossings can also impact communities with limited access to transportation alternatives, and result in inefficient resource allocation.

Figure 3: Example of fragmented infrastructure near the interchange

Figure 3 displays how quickly pedestrian and cyclist infrastructure begins and ends, raising the question of how effective and safe the existing paths really are. According to a walking and biking case study conducted by the United States Department of Transportation Federal Highway Division, removing perceptions of danger and lack of good routes is "fundamental to tapping the existing potential" of bicycling. If bicycling facilities are designed to reduce safety concerns and are linked in such a way that access matches the access motorists have come to expect, then utilitarian bicycling will increase (*U.S. FWD*). Key findings from this study also included:

Cycling is primarily motivated by exercise and enjoyment, although environmental concerns also play a role. Concerns over traffic safety, lack of routes, and adverse weather conditions act as significant deterrents to bicycling. However, when considering bicycle commuting specifically, distance to the workplace, safety, and the absence of shower and parking facilities are the main obstacles.

Walking is more common than bicycling for both recreational and utilitarian purposes, although research on walking is limited compared to biking. Walkers, like bicyclists, are motivated by exercise and enjoyment. Utilitarian walking is often driven by convenience, especially for short errands in higher-density areas. Distance is the primary reason cited for not walking more often, along with concerns about carrying items, time constraints, and fear of crime. However, traffic safety is not as significant a deterrent to walking as it is to biking. Inadequate facilities are not commonly cited as a reason for not walking more often, evidence suggested that improving walking facilities and "creating more attractive walking spaces" could encourage more walking (*U.S. FWD*). Walking levels vary between urban and suburban areas, with urban residents in high-density districts walking more frequently, particularly for short trips. Suburbs and outlying areas often lack sidewalks, as seen in parts of Sterling and W. Boylston, which may impact walking rates.

In terms of this project, this research supports the need for proper active transport infrastructure in both Sterling and W. Boyslton, with both towns lacking adequate sidewalks and bike lanes in terms of safety and connectedness.

2.1.3 Public Transportation

Besides from a limited 2-van system for senior citizens, Sterling does not have any forms of public transportation. West Boylston has one bus stop that is a part of the Worcester Regional Transit Authority (WRTA), located at the Walmart. The map in Figure 4, shows the WRTA system, including the proximity of its northernmost stop to the location of the 1-190 and Route 140 interchange.

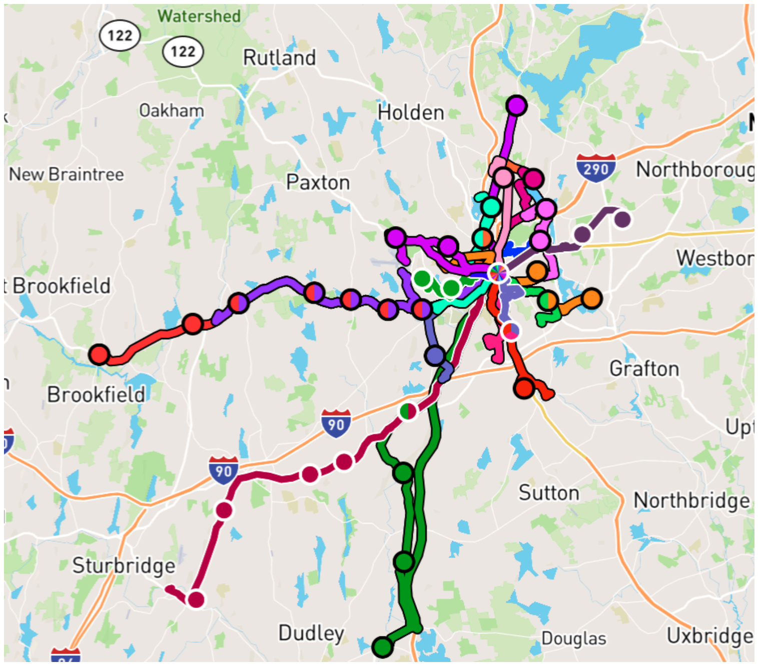


Figure 4: Worcester Regional Transit Authority System (Routes - WRTA)

Regional transit agencies (RTAs), such as the WRTA, are very important to the communities they serve, contributing significantly to housing, economic development, health, and climate objectives. However, to meet their full potential, substantial investments in transportation infrastructure are very important. Despite their importance, they often encounter constraints in terms of service hours and routes, with fares creating accessibility issues. Notably, the WRTA has operated fare-free for nearly four years. This strategy has yielded positive results, with WRTA ridership bouncing back quicker post-pandemic compared to other RTAs and the MBTA (Shei, 2024). This underscores the efficacy of fare-free policies amid rapidly increasing living expenses and emphasizes the necessity of preserving this public service. Although the towns of Sterling and W. Boylston are located beyond the closest systems of WRTA and MART (Montachusett Regional Transit Authority), the communities would benefit greatly from a route expansion.

2.2 Popular Community Attractions

The towns of Sterling and W. Bolyston mainly attract visitors for their natural and recreational assets, specifically the Mass Central Rail Trail and Wachusett Mountain.

2.2.1 Mass Central Rail Trail

The Mass Central Rail Trail follows the former route of the Central Massachusetts Railroad, which was established in the 19th century to connect Boston with cities and towns in central Massachusetts. In the late 20th and early 21st centuries, efforts began to repurpose these abandoned rail lines into recreational trails. Various organizations, municipalities, and volunteers have been involved in the planning, development, and maintenance of the trail, with Wachusett Greenways and the Department of Conservation and Recreation being the primary caretakers in the Sterling and West Boylston Sections.

The trail surface varies along its length, with some sections consisting of paved or crushed stone surfaces, while others are more natural and suitable for hiking or mountain biking. Most of the trail is relatively flat, following the gentle grade of the former railroad bed, making it accessible to a wide range of users. The Mass Central Rail Trail is divided into multiple segments, each with its unique character and points of interest. Trailheads and access points are located in various communities along the route, providing convenient entry and exit points for trail users. The West Boylston Section has a parking lot located less than a mile from the studied interchange in Sterling, also very close (0.5 miles) to the new apartment complex "92 on North Main" which will house many new community members.

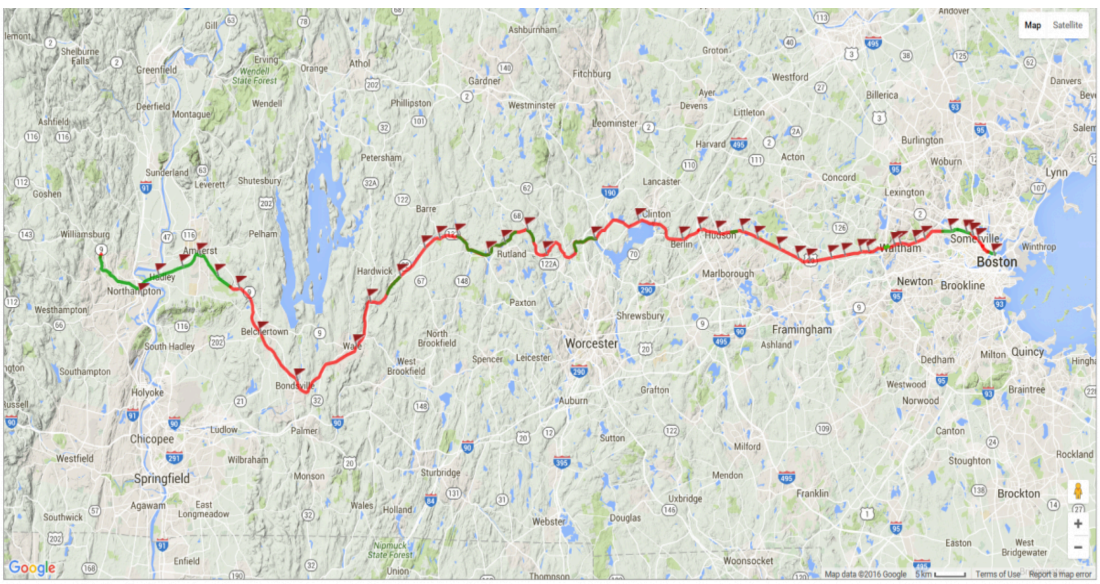


Figure 5: Full Mass Central Rail Trail

The trail passes through landscapes such as wooded areas, wetlands, farmland, and suburban neighborhoods creating opportunities for nature observation. The trail also provides access to several parks, conservation areas, and historic sites. The Mass Central Rail Trail creates a recreational and transportation resource for the communities it passes through, providing residents and visitors with opportunities for outdoor recreation, exercise, and commuting opportunities. This trail increases connections between communities, promoting regional cooperation and collaboration. Efforts are ongoing to expand and improve the Mass Central Rail Trail, including filling gaps in the trail network, upgrading trail amenities, and promoting public awareness and usage.

With that, a study conducted by the Norwottuck Network, a non-profit corporation that supports the build-out and operation of the Mass Central Rail Trail, assessed the potential benefits of completing the 104-mile multi-use trail system. The study predicted significant improvements in health, increased trail usage, economic growth, and job creation. Completion of the trail could also lead to annual economic benefits ranging from $87 to $182 million, with up to four to five million people using the trail annually (*Norwottuck Network, Inc*). The Norwottuck Network has been urging the state Department of Transportation to evaluate construction costs and create a completion timeline. This completed trail would connect to 18 other rail trails, forming a 273-mile network across Massachusetts, ultimately increasing the amount of overnight visitors greatly – further proving economic benefits. The study highlights the positive impact on Gateway Communities - such as Sterling and West Boylston, and notes similarities to successful trails elsewhere like in Cape Cod and Upstate NY. Additionally, current trail users expressed a strong interest in increased trail usage if it were completed. Overall, the study suggested substantial economic, health, and recreational benefits associated with completing the MCRT, and aims to get support from state and organizational entities.

2.2.2 Wachusett Mountain and Reservoir

Wachusett Mountain, located primarily in Princeton, MA, is a popular recreational destination. It is part of the Wachusett Mountain State Reservation, which encompasses over 3,000 acres of protected land, including trails that connect to the town of Sterling. The mountain offers a range of outdoor activities throughout the year, including hiking, skiing, snowboarding, and mountain biking. Additionally, the mountain is home to diverse ecosystems, making it an important ecological and recreational resource for the region. Wachusett Mountain's proximity to major cities like Boston and Worcester further contributes to its popularity among outdoor enthusiasts. The Wachusett Reservoir, in W. Boylston also attracts visitors with a variety of walk trails and bike routes.

2.1 Zoning

Zoning plays an important role in shaping the physical and functional aspects of communities. Zoning aims to balance competing interests, foster economic development, preserve natural resources, and maintain a cohesive and livable built environment for residents and businesses alike (*APA Policy Guide on Smart Growth*, n.d.). Zoning laws and ordinances regulate land use in jurisdictions. They originally aimed to separate incompatible land uses and ensure public health and safety. However, over time, zoning policies have expanded to regulate detailed aspects, like housing types. Massachusetts is a “home-rule state” (Chapter 43B) meaning that the individual cities and towns create their zoning laws, dividing land into districts outlined in zoning bylaws or ordinances (*Massachusetts Municipal Association*, 2021). These laws determine what can be built "as of right" or "by right" and outline dimensional requirements.

Zoning maps indicate the zoning districts for specific sites and are used to guide development decisions. Figures 6 and 7 display the zoning maps for Sterling and West Boylston, respectively. As outlined in the key, the majority of these two towns are rural, single residence, residential, or neighborhood.

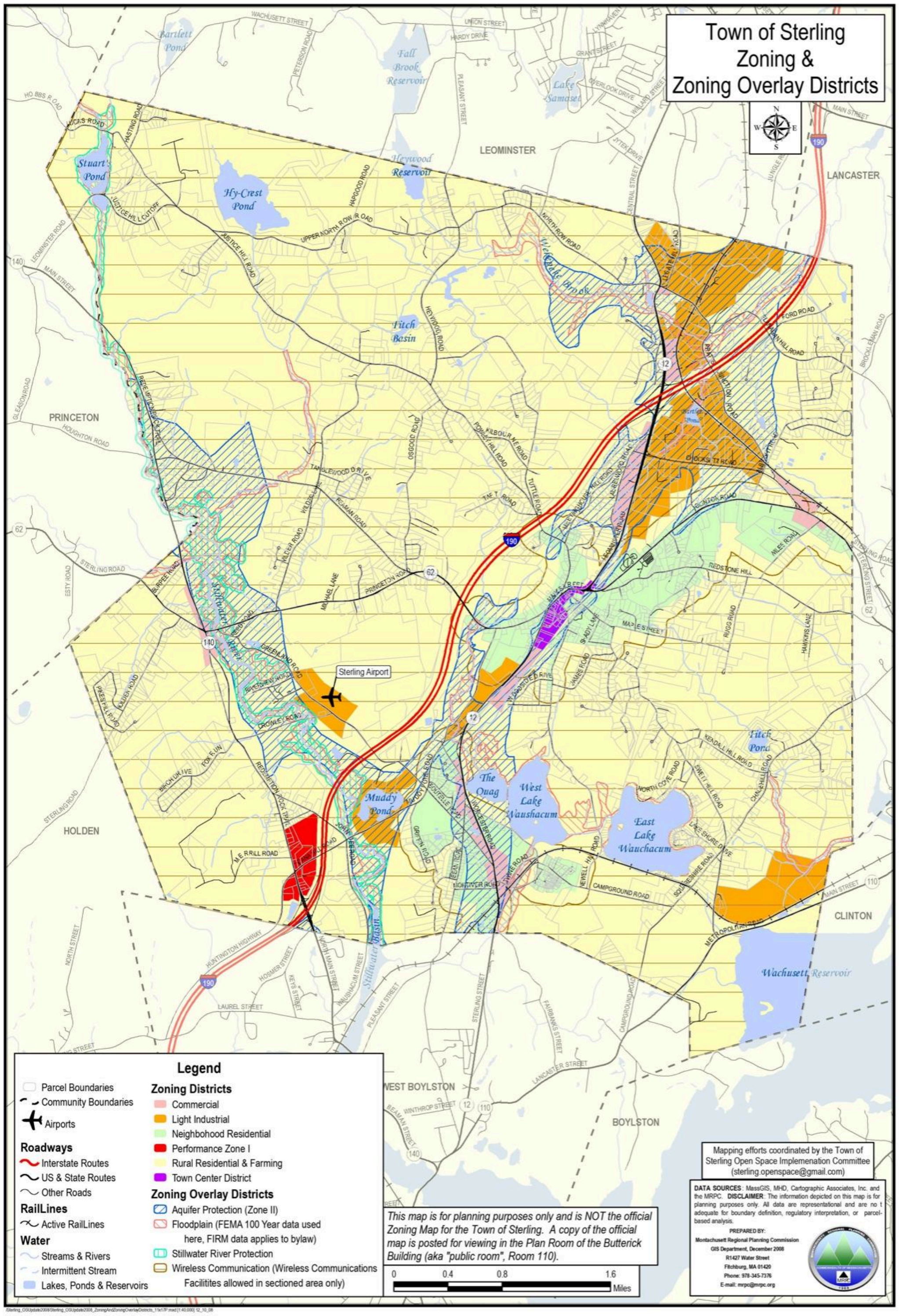


Figure 6: Sterling Zoning Map

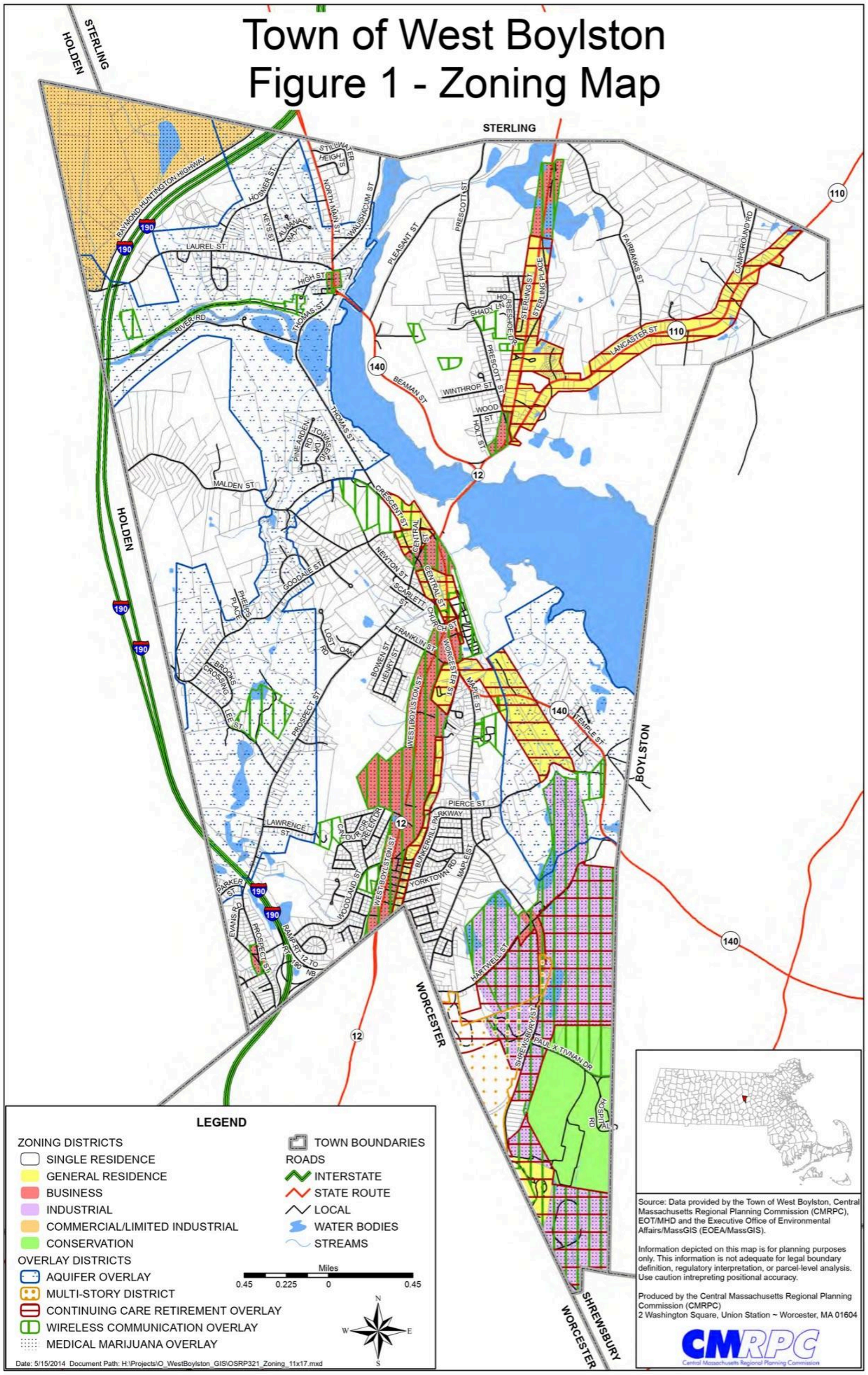


Figure 7: West Boylston Zoning Map

While zoning can be useful in planning, there are flaws inherent in relying solely on it for comprehensive development decisions. One of the main flaws is the rigidness of land use categories defined by zoning regulations. With strict categorical distinctions, they can prevent the development of mixed-use spaces that would otherwise promote vibrant, walkable communities and overall reduce local dependence on cars. This can result in segregated neighborhoods that have limited access to amenities and unequal economic opportunities for different groups.

Another flaw lies in zoning's ability to perpetuate social and economic disparities. By concentrating certain land uses in specific areas while excluding them from others, zoning can contribute to inequitable access to resources and services, such as affordable housing. This has the ability to contribute to socio-economic divisions which impacts the overall community well-being and cohesion. In terms of walkability, zoning laws tend to prioritize car-centric development through minimum parking requirements and zoning codes that favor road networks.

While zoning regulations can be made flexible, through zoning variances and special permits, these deviations are typically subject to review by zoning boards, planning commissions, or zoning departments. This slow and long process of amending zoning codes also poses challenges. The lack of flexibility in adapting to changing urban dynamics, technological advancements, and community needs can stifle innovation and hinder efforts to address pressing issues such as climate change and affordable housing shortages (*Nolan, 2023*).

Addressing these flaws requires comprehensive zoning reforms that promote flexible land use regulations, encourage sustainable and inclusive development practices, prioritize equity considerations, and integrate environmental resilience into planning. Zoning is currently impacting the towns of W. Boyslton and Sterling as the “rural” and single family “residential” are preventing the potential for sustainable and community growth, primarily surrounding existing assets.

3.0 Asset Mapping

Asset mapping is a process used to identify and inventory the strengths, resources, and capacities within a community. It involves systematically identifying and documenting the "tangible and intangible" assets that can be mobilized to address current challenges and achieve common goals (*Luo et al., 2023*). Asset mapping is applied in many contexts, including community development, organizational planning, and program evaluation.

3.1 Key Steps in Asset Mapping

The following steps outline the process of asset mapping and how it promotes a strength based approach to community development, emphasizing the utilization of existing assets and resources to promote resilience, innovation, and sustainable outcomes.

1. Identifying Assets: Identifying resources related to community planning involves assessing physical (infrastructure, built environment, natural resources), human, social (community organizations, networks, partnerships), cultural (institutions, traditions), and economic (local businesses, tourism) assets.

2. Mapping Assets: Assets are often mapped geographically to visualize their distribution and relationships. Mapping helps identify clusters of assets, gaps in resources, and opportunities for collaboration.

3. Building Connections: Asset mapping brings people together with displaying shared interests, potential collaborations, and complementary resources.

4. Strategic Planning: Organizations and communities can prioritize resources based on a comprehensive understanding of available assets and strengths.

5. Monitoring and Evaluation: An ongoing process that involves monitoring changes in assets over time and evaluating the effectiveness of asset utilization strategies. This iterative approach supports continuous improvement and adaptation.

Figure 8: Example Schematic of Community Asset Mapping Components

4.0 Method of Asset Mapping of Sterling and W. Boylston

Following the steps outlined above, an asset map was created of Sterling and West Boylston. This was done using Google Earth Pro as well as the ESRI Shapefile provided by the Mass Central Rail Trail website. The scope of this map was determined to be a 5 mile radius stemming from the Route 140 and I-190 Interchange located in proximity to the town border. This encompasses approximately eighty square miles.

4.1 Identifying Assets

Given the hypothesized strengths and weaknesses of the communities, the following categories of assets were determined. Additionally, the categories were color coordinated visually on the map in the shape of pushpins:

- Environmental - Green
- Historical - Yellow
- Recreational - Red
- Commerce - Blue
- Cultural/Religious - Orange
- Food/Drink - Purple

Figure 9: List of Mapped Community Assets

These destinations and community assets were chosen based on popular attractions, highly rated spots, and unique town features. Additionally, the locations were selected as they bring value to the community under each of their respective categories. This process not only took into account the highly rated spots and locations on the open web and on the town websites, but also found by driving through the communities and documenting destinations.

4.2 Mapping the Assets

Utilizing the Google Earth Pro tools, the assets were mapped and displayed in Figure 10. Outlined in white is the Mass Central Rail Trail.

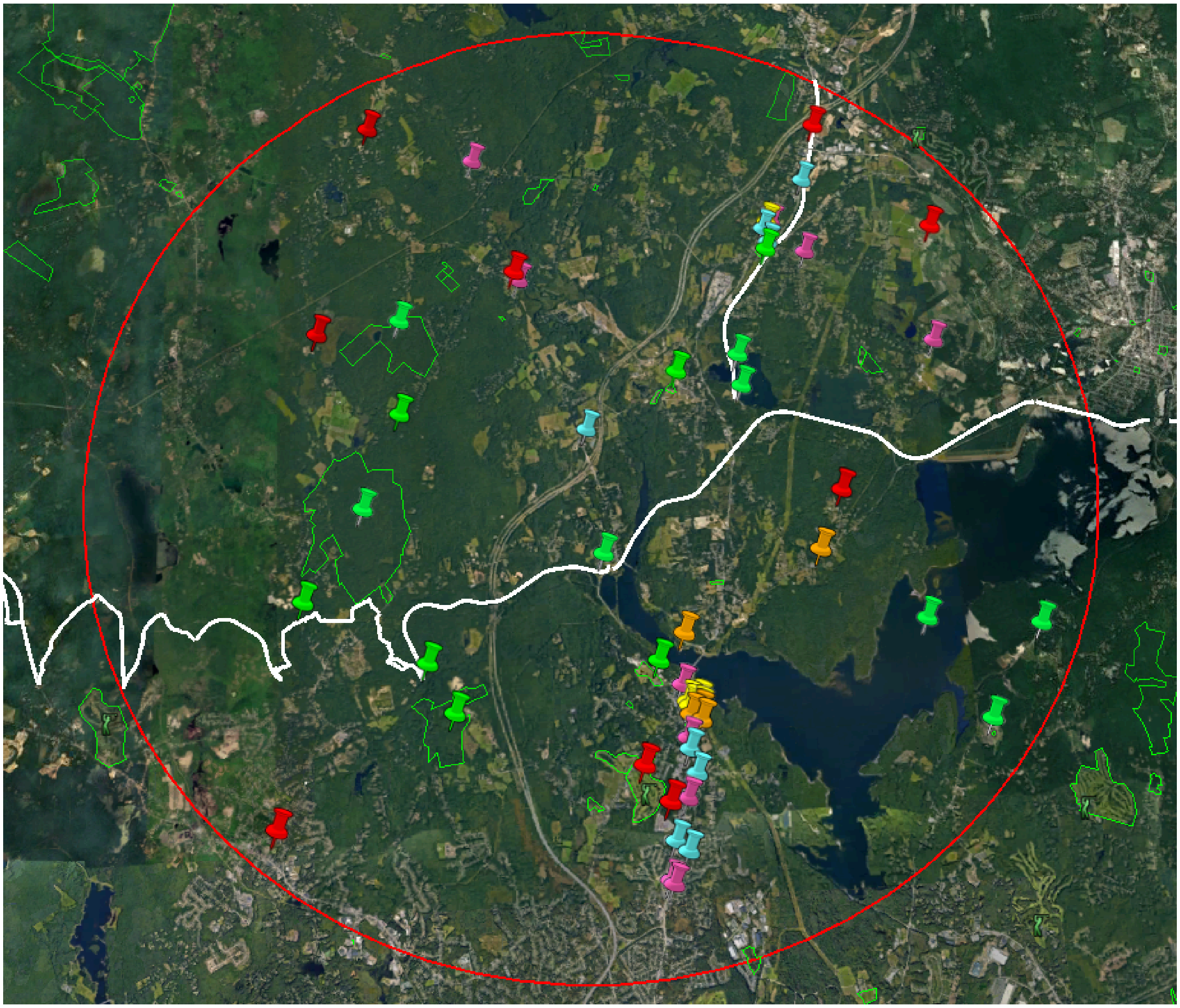


Figure 10: Map of Community Assets

4.3 Building Connections and Strategic Planning

As depicted in Figure 10, the rail trail is relatively separated from main spots of gathering, commerce, and recreation. Given that building connections is a key step in effectively asset mapping a community for holistic development, it is important to visually see where different types of assets are located and how they can be brought together. Additionally, the visual mapping of assets exposes where there are gaps in a community and how changes can create a sense of connectedness. For instance, Figure 10 highlights a significant number of mixed-categorical assets south of the rail tail and Wachusetts Reservoir, with the western side having relatively none. With this in mind, community planners can look to utilize improved active transport infrastructure to better connect the assets and also reassess the zoning regulations along the rail trail to promote economic and sustainable growth..

The Cape Cod Rail Trail is an excellent case study to see the concepts of strategic planning and community development connectedness in play. In April 2018, the Massachusetts DCR initiated plans for a 2-mile extension of the Cape Cod Rail Trail, stretching to Wellfleet Center. This extension, following the former railway grade, aimed to enhance accessibility and recreational opportunities for residents and visitors. As part of this project, the state acquired and renovated a former campground, resulting in the opening of the Wellfleet Hollow Campground in May 2019. Additionally, a 2019 study conducted for MassTrails estimated the Cape Cod Rail Trail contributed $9.2 million in economic activity and generated $1.5 million in state and local tax revenue in just a four-month period. The trail also contributed to 4,000 fewer vehicle trips during the four-month study period, leading to $2.2 million in savings from reductions in the social costs of greenhouse gas and other emissions (*MA Department of Conservation and Recreation, 2018*). This success is primarily a result of the key communities connected to the rail trail providing incentives and activities for users to benefit from. For example, many of the towns offer local cuisine, such as fish and chips, drinks, and quaint shops that are not a drive away from the trail as we see in Sterling and W. Boylston. Additionally, there are places of worship, historic sites, and conservation areas that are all conveniently located.

Some segments of the Mass Central Rail Trail have similar success stories, driven by a connected community and strategic development, however the towns of Sterling and W. Boyslton are still lacking. The following recommendations outline a few key planning changes that would better promote holistic development and connect main assets within the communities, allowing the communities to be more inviting, benefiting greatly in the categories of economics, environmental sustainability, and social well-being.

5.0 Recommendations and Conclusions:

After analysis of the community assets, primarily directly surrounding the Route 140 and I-190 interchange, it is clear that there are limitations to the infrastructure and attractions. These generally pertain to the lack of public transit, safety and accessibility for active transporters, current zoning, and public recognition of existing assets. As mentioned, by systematically documenting existing assets, the community's potential can be better understood. This process allows for a targeted, impactful, and holistic approach to community planning that is based on the inherent strengths and assets of the area.

5.1 Public Transit

While extending the entirety of WRTA or MART over a significant distance would not be feasible, especially given the relatively low populations of Sterling and W. Boylston, the addition of a stop or two would be beneficial. Adding a stop connecting people from Worcester to Wachusett Mountain, and stopping once along the way at the Mass Central Rail Trail entrance, would be valuable. Firstly, it would significantly increase the accessibility to the mountain and trails for recreational activities such as hiking and skiing. Thousands of students in the greater Worcester area regularly travel to Wachusett Mountain, especially in the winter, with many WPI clubs making trips up every weekend due to the low-cost student ski passes. Additionally, with a regular and consistent bus schedule, it could alleviate traffic congestion and parking issues, especially during the peak seasons, providing an alternative mode of travel. As documented in the transportation engineering side of this project, the Route 140 and I-190 interchange – the exit for Wachusett Mountain, is often subjected to high delay times and traffic due to the influx of cars at certain times of day. Finally, this relatively small addition to the Worcester Regional Transit Authority also has the potential to stimulate local economic development by attracting tourists and facilitating the growth of businesses in the local and surrounding areas, and increasing ridership.

5.2 Zoning Flexibility

Zoning flexibility along the Central Mass Rail Trail specifically would allow for the establishment of mixed-use developments along the trail. Mixed use zoning refers to the planning approach that allows for a variety of complementary land uses within the same area, such as recreational, residential, and commercial. This strategy encourages the development of walbale, and lively communities, reducing the need for long car travels. In Massachusetts, mixed-use zoning can be facilitated by local municipalities adopting ordinances that designate specific areas, such as those along the trail in Sterling and W. Boylston, as mixed-use districts, as opposed to their current "residential" and "rural." These ordinances may include provisions to parking requirements or building designs that would ensure the new development is compatible with the surrounding environment and contribute positively to the community. By permitting such spaces, established such as coffee shops, or restaurants create inviting spaces for those utilizing the trail and surrounding attractions, fostering a sense of community. The mixed-use development would also contribute to the economic vitality by attracting foot traffic supporting local business. Additionally, it would complement the recreational opportunities provided by the rail trail, encouraging active lifestyles and social interactions. While this zoning flexibility would primarily be beneficial around the rail trail, where most of the town's visitors are, it is important the environment and conservation practices are also preserved. Therefore, the towns should work to leverage and modernize run-down areas and spaces where community members are not disrupted or inconvenienced. This would require a citizen participation approach where the needs of the community members are embraced and listened to.

5.3 Active Transport Improvements

Improving the connectivity of bike lanes and sidewalks along the "hub" or main roads in Sterling and W. Boystol is essential for improving accessibility to shops, amenities, and the natural environment. As documented, the towns both have fragmented active transport infrastructure, significantly reducing the safety and appeal of utilizing these modes of travel. Currently, the fragmented nature is limiting opportunities for residents and visitors. By strategically planning a cohesive network of bike lanes and sidewalks, mainly connecting back to the rail trail and main town centers, the community will become more inviting to active transporters. Collaborative efforts between government agencies, like MassDOT, and community stakeholders will progress the integration of bike lanes and sidewalks to the existing infrastructure and will promote visitation to community assets, especially the points that are closely connected to one another.

5.4 Increased Awareness of Assets

In relatively smaller towns like Sterling and W. Boyslton, especially with rich historic charm and unique environmental assets, advertising and prominently displaying the community destinations can play a large role in fostering a strong sense of community and enhancing the overall appeal. By showcasing historic landmarks, quaint main roads with little shops and restaurants, and natural attractions through targeted advertisements, signage, and online platforms, the towns can highlight their distinct identity and heritage. This will also promote visitors to the area, especially given that the recreational, historical, and local restaurants are only a short distance from Worcester, where people enjoy a break from. Overall, the Mass Central Rail Trail is not very well known, especially among younger generations and students who may not be from the area. With an increased awareness of these community assets, more visitors will make the short trip to visit the area.

Additionally, with the proposed new expansions to the trail, making it a combined 104 miles, this area has the capability to be a hot spot for the influx of visitors across New England. In reference to the Norrotuck Network's work and research, it is crucial that information like this is shared throughout the communities. With growing support and momentum, the trail has the ability to transform the towns and promote a sense of connectedness, both locally and regionally.

The recommendations and conclusions drawn from the analysis of community assets around the Route 140 and I-190 interchange highlight several key areas for improvement including the need for enhanced public transit, zoning flexibility to encourage mixed-use development along the Central Mass Rail Trail, improvements in active transport infrastructure, and increased awareness of local attractions. With these enhancements, there is potential to attract more visitors to the area and foster a stronger sense of community identity, especially with the expansion of the Mass Central Rail Trail. Collaboration between government agencies and community stakeholders is emphasized to achieve these goals effectively, ultimately providing a holistic approach to the town's enhancement of environmental and social sustainability through asset-based development.

Works Cited

Cape Cod Rail Trail | Mass.gov. (n.d.). Retrieved from https://www.mass.gov/locations/cape-cod-rail-trail

Community Asset Mapping with NCFH (National Center for Farmworker Health)—YouTube. (n.d.). Retrieved from https://www.youtube.com/watch?v=FBCH7MEGH6E

Dining Options Along the Cape Cod Rail Trail | Vacation Cape Cod. (2018, September 10). https://www.vacationcapecod.com/dining-options-along-the-cape-cod-rail-trail/

Luo, Y., Ruggiano, N., Bolt, D., Witt, J.-P., Anderson, M., Gray, J., & Jiang, Z. (2023). Community Asset Mapping in Public Health: A Review of Applications and Approaches. *Social Work in Public Health*, *38*(3), 171–181. https://doi.org/10.1080/19371918.2022.2114568

Massachusetts Municipal Association (MMA). (n.d.). Massachusetts Municipal Association (MMA). Retrieved April 25, 2024, from https://www.mma.org/

Municipal managers discuss home rule in Massachusetts. (2021, September 17). *Massachusetts Municipal Association (MMA)*. https://www.mma.org/municipal-managers-discuss-home-rule-in-massachusetts/

Nolan, G. (2023, November 10). *The Case for Abolishing Zoning*. Strong Towns. https://www.strongtowns.org/journal/2022/6/30/the-case-for-abolishing-zoning

Planning & Community Design | Cape Cod Commission. (n.d.) 2024, from https://www.capecodcommission.org/our-work/topic/planning-and-community-design/

Rethinking Zoning to Increase Affordable Housing. (n.d.). The National Association of Housing and Redevelopment Officials (NAHRO). Retrieved from https://www.nahro.org/journal_article/rethinking-zoning-to-increase-affordable-housing

Roadway Safety Information Analysis—Safety | Federal Highway Administration. (n.d.). Retrieve from https://safety.fhwa.dot.gov/local_rural/training/fhwasa1210/s3.cfm

Shared use path study confirms importance of rail trails | Cape Cod Commission. (n.d.). Retrieved from https://www.capecodcommission.org/about-us/newsroom/shared-use-path-study-confirms-importance-of-rail-trails

Shei, A. (2024, February 16). *As we invest in the T, don't ignore vital role of regional transportation authorities*. CommonWealth Beacon. http://commonwealthbeacon.org/opinion/as-we-invest-in-the-t-regional-transportation-authorities-desperately-need-support-too/

The Report | Mass Central Rail Trail. (n.d.). Norwottuck Network from https://www.nnnetwork.net/the-report

Zoning Regulations. (n.d.). FasterCapital from https://fastercapital.com/startup-topic/Zoning-Regulations.html