Advising the CTDOT on Accessibility Compliance, Safety, and Stormwater Management in Bridgeport, CT

Major Qualifying Project Proposal

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Abstract

The purpose of this Major Qualifying Project was to redesign an intersection to assist the CTDOT with their goal of improving ADA accessibility while addressing flooding risks and safety for all users. A five-way signalized intersection was selected that has traffic concerns in addition to having non-compliant curb ramps and crossings. The team conducted a site visit to inspect curb ramps and collect data on the existing conditions. The short-term solutions address the non-compliant ramps, pedestrian safety, and traffic flow. The long-term design of the intersection involves the creation of a roundabout in AutoCAD, the relocation of pedestrian crossings, and the inclusion of new stormwater BMPs based on a Civil 3D water drop analysis.

Acknowledgements

We would like to acknowledge and thank our advisor, Professor Suzanne LePage for guiding us throughout this process. We greatly appreciate her vast knowledge, thoughtfulness, and mentorship which helped us create a well-rounded learning experience and successful project.

We would like to thank Katherine Hedberg, ADA Coordinating and Transportation Engineer at CTDOT, for sponsoring our project. We appreciate the flexibility given to us in the scope of our work and the inclusion of our own personal interests. We are grateful for her guidance and insights into the real life applications of our work. We greatly appreciated being able to speak with an alumni about the industry and learning about the standard practices of the CTDOT.

Thank you to Scott Bushee, P.E., Nicholas Ivanoff, P.E., and Dominic Antonio, P.E., for taking time to meet with us to discuss and provide feedback on our designs. Their insights were very helpful in the formation of our final results and we appreciate them taking the time to meet with us.

Finally, we would like to thank each other for the effort put in over the course of the year. With a clear goal in mind and a deep commitment to creating a positive learning environment, the successful completion of our Major Qualifying Project is a testament to the teamwork we displayed as a group.

Capstone Design Statement

The Accreditation Board for Engineering and Technology (ABET) requires that graduating engineering students in an ABET accredited program complete a capstone design project. This capstone design work takes the form of a Major Qualifying Project (MQP) at WPI, where students display the skills they have developed in their undergraduate engineering studies in a real world application.

The purpose of this MQP was to redesign an intersection to assist the CTDOT with their goal of ADA compliance while addressing flooding risks and safety for all users. This project was assessed through the lens of different constraints to determine its ability to successfully solve the problem at hand.

Economic

This project's recommendations are cost effective for the CTDOT. The team considered the feasibility of the proposed design to ensure the CTDOT can adequately manage maintenance.

Environmental

This project was completed with consideration to various environmental factors, namely stormwater. Based on the analysis of the site, the team proposed a design that will improve stormwater management in the Bridgeport intersection. Additionally, the creation of the long-term design solution would create an overall reduction in vehicle emissions.

Social

The team assisted the CTDOT by recommending a design that addresses the stormwater management in the study intersection, while ensuring ADA compliance. By doing so, the team aimed to improve both the safety and public perception of the Bridgeport intersection.

Political

The team considered the political implications of this project, which includes the impact of site redesign on the city of Bridgeport and abutting property owners. Measures were taken throughout the project to ensure the design complied with the state's road design standards and met the needs of residents.

Ethical

This project adheres to the American Society of Civil Engineers (ASCE) Code of Ethics. The team made every effort to ensure ethical decision making throughout the project.

Health and Safety

This project addresses intersection safety for all users, meaning pedestrians, cyclists, and traffic moving through the study intersection. It also considers safety of the intersection for users with accessibility needs of any kind.

Manufacturability

This project considered the ability of the team's design to be executed in a real world application. As such, we considered next steps that would need to be executed in order to move forward with the construction of our recommendations, such as the town and public's desire for change in the study intersection.

Sustainability

The team considered sustainability in the design recommendations for the study intersection. The team also considered green infrastructure and low impact development practices that help improve overall sustainability.

Professional Licensure Statement

Achieving the status of a Professional Engineering license shows a high level of commitment to the practice of engineering and the upholding of its standards. The National Council of Examiners for Engineering and Surveying (NCEES) outlines the path to licensure for both engineers and surveyors on their website and acts as the organizing body that administers the exams for Fundamentals of Engineering (FE) and Principles and Practice of Engineering (PE).

The first step on the path to licensure is to obtain an ABET accredited degree in engineering. The next requirement is the successful passing of the FE exam, after which the Engineer in Training (EIT) certification will be achieved. After gaining 4 years of relevant work experience under the supervision of a Professional Engineer, an EIT can take the PE exam. If passed successfully, they will become a licensed Professional Engineer in the state where they take the exam (NCEES, 2024).

A licensed engineer is expected to uphold certain standards of practice in terms of education, ethics, professionalism, and care for the safety and wellbeing of the public good. Professional Engineers are held to a certain 'Standard of Care,' which requires that engineers use their knowledge and expertise in the same manner that a reasonable and cautious engineer would. Obtaining professional licensure is an important milestone in an engineer's career because it allows them to take on a wider range of responsibilities and establishes a credible reputation for the individual. These standards create value not only for the licensed individual, but also for society, which benefits from stricter engineering controls. Such standards protect the health, safety, and welfare of the public (NCEES, 2024).

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List of Acronyms

ABA – Architectural Barriers Act
ADAAG – Americans with Disabilities Act Accessibility Guidelines
ADA – Americans with Disabilities Act (of 1990)
BMP – Best Management Practice
CAD/AutoCAD – Computer Aided Design
CT – Connecticut
CTDOT – Connecticut Department Of Transportation
CSO – Combined Sewer Overflow
DWS – Detectable Warning Surface
EIT – Engineer in Training
FE – Fundamentals of Engineering
FEMA – Federal Emergency Management Agency
GIS – Geographic Information System
ICD – Inscribed Circle Diameter
IIJA – Infrastructure and Investment Jobs Act
LID – Low Impact Development
LiDAR – Light Detection and Ranging
MassDOT – Massachusetts Department of Transportation
MQP – Major Qualifying Project
MUTCD – Manual on Uniform Traffic Control Devices
NACTO – National Association of City Transportation Officials
NCEES – National Council of Examiners for Engineering and Surveying
NCHRP – National Cooperative Highway Research Program
NOAA – National Oceanic and Atmospheric Administration
P.E. – Professional Engineer
PROWAG – Public Right-of-Way Accessibility Guidelines
RRFB – Rectangular Rapid Flashing Beacon
SLOSH – Sea, Lake, and Overland Surge from Hurricanes
SS4A – IIJA's Safe Streets and Roads for All
TIN – Triangulated Irregular Network
UConn – University of Connecticut
VIP – Vendor-in-Place
WPI – Worcester Polytechnic Institute

Authorship and Contributions

While this report is representative of the combined efforts of our team, each member took additional responsibilities for completing different aspects of the project. Kendall completed the drainage models and stormwater analysis using Civil 3D, Maggie created the long-term design solution of the roundabout in AutoCAD and Civil 3D, and Bridget established accessibility components and curb ramp details associated with the short-term solutions. All team members equally edited the paper, and feel that the distribution of work throughout the project was equitable.

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Executive Summary

Achieving equity through accessibility has been a pressing issue in the United States since the Americans with Disabilities Act (ADA) was passed in 1990. To continue this work, the Connecticut Department of Transportation (CTDOT) is undertaking the task of accomplishing full ADA compliance at major intersections and state roads to establish accessibility for people with disabilities and to improve safety for all users. Provided with a comprehensive list of intersections in Connecticut that remained uninspected for ADA compliance, the team selected one that contained the greatest potential for improvement in terms of accessibility, traffic congestion, pedestrian safety, and drainage and future flooding concerns. The selected study intersection is located at the five-way signalized intersection at North Ave., Dewey St., Howard Ave., and Briarwood Ave. in Bridgeport, Connecticut.

This site was selected as an appropriate study intersection due to its unique geometry, proximity to the nearby Rooster River and the southern coast of Connecticut, lack of ADA compliance in a heavy foot traffic area, and traffic safety concerns as reported by the UConn Crash Data Repository. Upon further investigation, the team discovered that the site falls directly adjacent to areas of concern for Sea, Lake, and Overland Surge from Hurricanes (SLOSH) and in various Annual Chance Flood Hazards. These, and other site features, factored into the team's decision to pursue this site as the study intersection with special attention to stormwater management.

After site selection, the team set out to design a new intersection that would touch on improvements in each of the three main categories: ADA compliance, traffic conditions and pedestrian safety, and drainage considerations. The team conducted a site visit to collect relevant data relating to these three categories, such as existing curb ramp conditions,

observations of traffic and pedestrian flow, and catch basin locations. The team also collected conceptual data relating to congestion and the overall safety of the intersection.

To provide the CTDOT with a comprehensive report of the site's challenges and potential design solutions, the team split up feedback into two categories: short-term and long-term solutions. The short-term solution is mainly focused on bringing the intersection up to ADA compliance at crossings and curb ramps. It also aimed to improve signalized pedestrian infrastructure to help users with physical disabilities safely use the intersection. The long-term solution is characterized by the team's conceptual design of a roundabout as well as drainage features that prepare for increasing storm events due to climate change. Although the short-term solution is the most feasible option due to its comparative low cost and ability to meet the minimum responsibilities of the CTDOT for ADA compliance, the long-term solution addresses more concerns relating to the longevity of traffic flow throughout the site and the future effects of climate change on the city of Bridgeport.

Beyond the short and long-term solutions, the team recommends some practices in the future design phases of this project. Performing a comprehensive traffic study in the intersection will help to define the full scope of the problem at this intersection, and will assess the effectiveness of a roundabout in this area. Similarly, the team recommends another site visit be performed to collect stormwater samples to assess the current water quality situation and necessary level of Best Management Practices (BMPs) treatment. Lastly, the team recommends that the CTDOT and any future consultants on the project work closely with the City of Bridgeport to ensure a smooth planning process.

Chapter 1: Introduction

As part of Connecticut's efforts to reach full compliance with the Americans with Disabilities Act (ADA), the Connecticut Department of Transportation (CTDOT) is charged with assessing and upgrading the accessibility components of every intersection throughout the state. Full ADA compliance increases mobility and removes barriers for people with disabilities, which greatly improves the quality of life for many vulnerable groups. Universal access is especially important because it removes barriers for all users, without the need for accommodations or specialized design. Compliance is necessary in transportation infrastructure, like intersections, where safety for all users must be prioritized.

The goal of this MQP is to redesign an intersection to assist the CTDOT with their goal of ADA compliance while addressing flooding risks and safety of all users. The selected site (Figure 1) for this task is the intersection at North Ave., Dewey St., Howard Ave., and Briarwood Ave. in Bridgeport, Connecticut.

Figure 1. An aerial view of the intersection at U.S Route 1 (North Ave.), Dewey St,, Howard Ave. and Briarwood Ave. in Bridgeport, Connecticut (Google Maps).

This is a five-way signalized intersection with five pedestrian crosswalks which are connected by 10 curb ramps, none of which meet ADA compliance. An adjacent side street, Cartright St., is part of the same traffic signal and contains two additional curb ramps, for a total of 12 in the area. There is also a pedestrian crossing between the two curb ramps at Cartright St. The site falls directly adjacent to areas of concern for SLOSH and annual chance flood hazards. Additionally, the study intersection resides near the coastline of the state and Rooster River, which flows through the adjacent 125-Acre Mountain Grove Cemetery. This and other considerations relating to the hydrology of the area affected how the team approached stormwater management at the study intersection.

Chapter 2: Background

This section discusses necessary information for site redesign of the intersection North Ave., Dewey St., Howard Ave., and Briarwood Ave. in Bridgeport, Connecticut. First, the history of ADA compliance is discussed, along with the current standards and systems that CTDOT uses to check compliance of pedestrian facilities. Then, important elements for intersection redesign are considered, including stormwater management, green infrastructure, and traffic engineering. Lastly, the Bridgeport intersection site is discussed, highlighting the necessity for the redesign elements detailed earlier.

2.1: History of ADA Compliance

There are many legal protections in place to ensure accessibility in the built environment, so both public and private spaces can be freely used by all members of the public. The Architectural Barriers Act (ABA), signed in 1968, prevents discrimination against those with physical disabilities in all buildings that are federally financed or intended to be used by the general public (*Architectural Barriers Act (ABA)*, 1986). The Americans with Disabilities Act (ADA), signed into law in 1990, federally protects against discrimination of people with disabilities on a broader scale (*Introduction to the Americans with Disabilities Act*, 2023). Another important piece of legislation is Section 504 of the 1973 Rehabilitation Act, which legally protects Americans with disabilities from discrimination in programs and activities that receive federal funding in any capacity, and from services carried out by federal agencies (*Section 504, Rehabilitation Act of 1973*, n.d., p. 504). Both the ADA and Section 504 apply directly to work conducted by any state branch of the U.S. Department of Transportation in the maintenance and construction of any transportation system.

The ADA is a tiered system, separated into five titles which apply the law to different environments including Employment, State and Local Government Services, Businesses Open to the Public, Telecommunications, and Other Important Requirements. The process of updating existing or new intersections to be accessible falls under Title II, State and Local Government services. Title II specifically references all service programs, activities, and public transportation systems both nationally and regionally. The Public Right-of-Way Guidelines (PROWAG) provide more detailed guidelines that can be used to uphold the ADA in traffic and transportation settings (*U.S. Access Board - About PROWAG*, n.d.). The ADA Accessibility Guidelines (ADAAG), as enforced by the U.S. Department of Transportation and U.S. Department of Justice, are also used for cases of technical infeasibility where PROWAG cannot reasonably be used as the guideline for design. Together, these tools are used to update antiquated pedestrian control facilities in all intersections across the state. As such, any time a roadway or surface is altered, it is required to address ADA in these pedestrian settings in the form of legally compliant sidewalks and curb ramps.

The process of amending these intersections to be ADA compliant is documented in the CTDOT's Transition Plan, which is a living document that represents the department's progress statewide. It contains digital appendices, which are updated frequently and provide information through geographic information systems (GIS), dashboards, and other visuals for residents to understand the state of pedestrian accessibility in their communities (CTDOT, 2023).

2.2: Current ADA Standards and Compliance Procedure

The number of persons a public entity employs determines the degree of ADA compliance they are held to. Since the CTDOT passes the threshold of 50 or more employees, full compliance of Title II is required. Full compliance can be summarized into seven key steps:

general ADA compliance, designation of an ADA Coordinator, providing public notice, adopting a grievance procedure, conducting a self-evaluation, maintaining public documentation of the self-evaluations, and developing a transition plan. The CTDOT is in the process of completing these steps to reach full compliance.

As previously mentioned, the CTDOT's current Transition Plan is governed by the rules and regulations specified by PROWAG. More specifically, chapter three of PROWAG provides the technical requirements for intersection redesign compliance, including, but not limited to, minimum clear widths and grading at pedestrian access routes; sloping, grading, and transition requirements at curb ramps; specifications of detectable walking surfaces; and other key requirements that apply to intersections, such as accessible pedestrian signal walk indications, crosswalks, and transit stops and shelters (*U.S. Access Board - About PROWAG*, n.d.). Although this chapter encompasses a wide variety of requirements for the CTDOT to follow, the agency's main goal is to ensure all curb ramps are ADA compliant. To achieve this goal, the CTDOT follows a summarized list of PROWAG curb ramp requirements when working in the field (Figure 2). All other supplementary intersection redesign requirements and considerations must comply with the guidelines set forth by PROWAG.

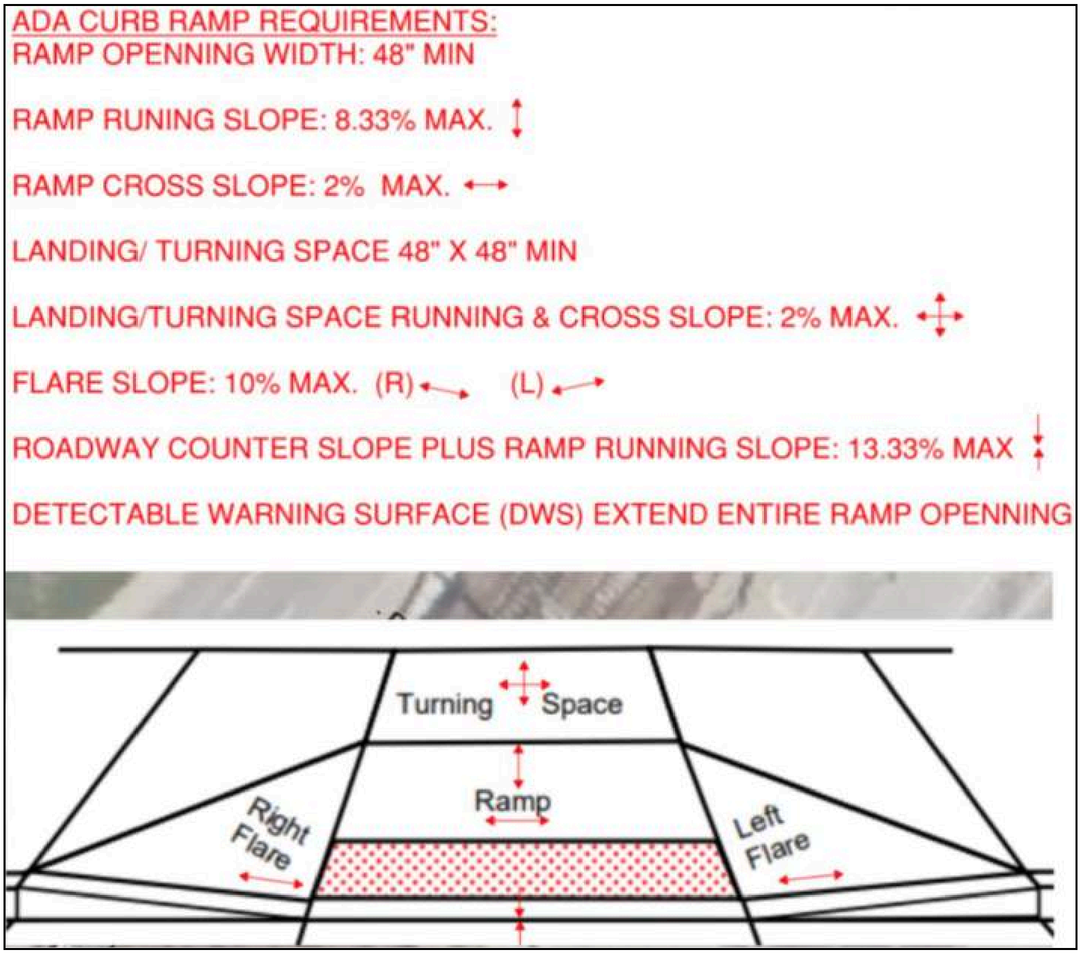

Figure 2. The CTDOT's Key Guidelines to ADA Compliance at Curb Ramps.

Although full compliance is the end goal, the CTDOT recognizes that bringing some sites up to the standard presents significant challenges that would be unnecessarily burdensome or unreasonable to pursue. Such challenges often include conflicts due to drainage, underground structures (like utilities), historic sites, and right-of-way availability (*TIF-Technical Infeasibility Form*, n.d.). The CTDOT therefore has a policy regarding such Technical Infeasibilities, where waivers may be granted for ADA compliance if the proper reasoning and proof of documentation is presented. Depending on the severity of the challenge, these waivers may be temporary or long-term. PROWAG recognizes these variances and allows for flexibility where existing conditions create undue challenges (*U.S. Access Board - About PROWAG*, n.d.).

2.3: Addressing Stormwater at Intersections

Stormwater management is an important consideration when redesigning an intersection. The impacts of climate change have been felt globally in recent years, with noticeable changes in regional weather patterns and a rising number of natural disasters. Recent research from the National Oceanic and Atmospheric Administration (NOAA) shows that over 1.3 million Americans across 20 counties in the U.S. are expected to experience a “1-in-100 year flood” every eight to ten years (Eby, 2023). The Northeast specifically has seen a 70 percent increase in precipitation from intense storm events from 1958 to 2016, resulting in an increase in flooding and erosion in coastal areas (*What Climate Change Means for Massachusetts*, 2016). Connecticut alone now sees a 38 percent increase in precipitation annually, according to the NOAA (Wescott, 2023).

Tools such as the Federal Emergency Management Agency (FEMA) Flood Hazard Layer and the Connecticut SLOSH Maps are useful in predicting which areas may be the hardest hit by flooding; however, these are traditionally based on historical weather patterns. As the weather patterns continue to change, these resources may become less accurate. While there are many people and agencies currently studying the impact of climate change on weather and flooding patterns, it will take time to fully establish the ways in which infrastructure will be impacted by these changes. This creates a need to increase design standards to protect against potential flooding in areas beyond what would normally be considered ‘at risk.’ The harmful impacts of flooding due to climate change need to be considered in an effort to limit the detrimental impacts on local communities.

The adverse effects of flooding are worsened in impervious areas, like roadways and intersections. Oftentimes, old existing stormwater systems were not designed to accommodate large volumes of stormwater runoff from high intensity precipitation events. When these systems are overwhelmed, there is a greater risk of roadways flooding, as well as an increase of harmful contaminants in the runoff. These pollutants can then enter surrounding waterways, contributing to poor water quality in local communities (*Climate Adaptation and Stormwater Runoff*, 2023). With this in mind, it is important for engineers to make thoughtful design choices about stormwater management and think about ways to improve existing systems.

The 2004 Connecticut Stormwater Quality Manual is the current planning and guidance tool used by regulatory agencies and communities in Connecticut when considering the design of stormwater management systems. The manual focuses heavily on practices to reduce the negative impacts of post-construction runoff. A new 2023 manual is being created to address changes in best practices and understanding of stormwater management over the last two decades (*EBC Connecticut Webinar*, 2023). The 2000 CTDOT Drainage Manual is also used to help provide guidelines and best practices for consideration of stormwater runoff during the design and construction of roadways.

Low Impact Development (LID) is an approach to land development that implements environmentally conscious design techniques, namely preserving the ability of a site to naturally manage rainfall. An additional mitigation technique for redirecting or absorbing stormwater is the use of green infrastructure. Green infrastructure is a broad term used to describe an urban planning method created to integrate more natural features into the built environment. These practices can improve stormwater runoff management, road user happiness, local ecosystem health, and excess traffic. Some pieces of technology used to achieve these improvements are rain gardens, bicycle corridors, widened sidewalks, bioswales, permeable pavement, and street trees, among others (*Green Infrastructure*, 2012). Some of these features are also known as Best Management Practices (BMPs), which aim to reduce the amount of pollution generated by non-point sources in stormwater (Hill, 2023). When an intersection is being redesigned for ADA accessibility, this provides a good opportunity to also include green infrastructure components to further improve the stormwater management and overall appeal of the area.

2.4: Traffic Engineering

Designing safe transportation infrastructure for all users is being incentivized more frequently as a direct result of recent legislation. One of the main goals of the Infrastructure and Investment Jobs Act (IIJA), passed by Congress in November 2021, is to upgrade aging and failing infrastructure through government funding (The White House, 2021). The IIJA's Safe Streets and Roads for All (SS4A) Grant Program specifically aims to address roadway and traffic safety concerns. Additionally, the State of Connecticut's "Vision Zero" Bill, passed by Congress in June 2023, aims to prevent roadway injuries and deaths. The bill requires the CTDOT to address and improve roadway safety for all users, which presents more opportunities for ADA compliance efforts (*CTDOT Statement on HB5917*, 2023).

The process of redesigning an intersection relies on the understanding of essential concepts of traffic engineering. This can include, but is not limited to, calculations related to volumes of cars and people, the shape of the intersection, line of sight, associated traffic laws and regulations, and the safety measures used to protect road users. This project will utilize part of the roadway design process, which mainly consists of three stages. The first is the conceptual design phase, which is used to establish the basic shape and road widths of the respective intersection. This stage relies on the existing layout information gathered through survey work or photographs (ITDP, n.d.). The designs that are created during this phase have the ability to show multiple different options for redesign while still fitting the available space and base traffic volume requirements of the area. The next two phases are preliminary design and detailed design, both of which build off the conceptual design established in the first phase. As the traffic design process progresses through each phase, more data is included for the purpose of addressing every possible component of the intersection. This data includes not only traffic design components but also surrounding urban design and stormwater design, among others. This project will utilize the conceptual design phase, which will assist in the redesign of the selected intersection to meet the previously mentioned goals.

When considering the redesign of an intersection, there is frequently an additional process of assessing the appropriateness or potential for a roundabout in place of the current design. This process includes considering the feasibility of using a roundabout to replace the study intersection given their benefits in the areas of both safety and traffic flow. The suggested material to be included in a feasibility analysis includes, but is not limited to: the reason for considering a roundabout, the current state of traffic flow in the area, a conceptual design considering factors such as number of lanes, potential benefits to the design, rudimentary cost analysis, and any potential challenges that would come from implementation (Rodegerdts et al., 2010).

2.5: Design Guides

In addition to the design requirements outlined in PROWAG and the stormwater and drainage manuals provided by CTDOT, there are other helpful design guides that the team considered during the redesign process. There are also past student projects at WPI and other universities that show different approaches to intersection redesign, which the team used to inform the design approach. These resources include:

- Connecticut Department of Transportation Highway Design Manual
- National Association of Transportation Officials (NACTO) Design Guides for Intersections and Urban Street Stormwater
- 2021 WPI Major Qualifying Project *Preparing for the Rise: A Study of Boston's Sea Level & Designs for Coastal Resiliency*
- 2018 WPI Major Qualifying Project *Intersection Redesign in Tewksbury, Massachusetts*
- 2011 WPI Major Qualifying Project *Stormwater Management Plan for the West Boylston Brook Subbasin*

Chapter 3: Methodology

3.1: Objective 1: Select intersection for redesign with consideration to ADA compliance, pedestrian mobility and crash reports, and stormwater drainage and potential for high risk flood events.

To select a site for redesign, the team first utilized a list of intersections provided by the CTDOT, which had been identified by the department as having ADA non-compliant accessibility features. These intersections were compared to several other resources, including the UConn Crash Data Repository, FEMA Flood Hazard Layers, and SLOSH Maps, as well as looking at each site on Google Maps.

Several resources were used to evaluate the current flooding risks associated with the locations. The SLOSH Maps were particularly relevant to this process. SLOSH Maps divide the state of Connecticut into regions and predict each area's potential of hurricane surges along the coast. In addition to the coastline, the state also has an extensive network of rivers and other freshwater sources that can become overwhelmed during large storms, causing flooding hazards in the roadway.

The FEMA's National Flood Hazard layer was also used to cross reference the location of the team's intersections. Many non-compliant intersections also existed in low lying areas, which were frequently identified as being part of either the 1-percent or 2-percent chance annual flood discharge zones. The National Flood Hazard information was overlaid with the previously mentioned SLOSH maps which allowed for the identification of intersections at higher risks for potential flooding or stormwater management issues.

The Connecticut Crash Data Repository organized by the University of Connecticut was used to help identify locations where traffic safety could be improved. This web tool compiles crash report data collected by state and local law enforcement officers and uses GIS to show the location of each incident. For the given list of intersections, the number of crashes that took place over the last three years was taken into consideration using the aforementioned resources.

Based on these criteria, three sites with the potential for improvement in the areas of accessibility, stormwater management, and safety of road users were selected. Each team member presented one of the three sites to the CTDOT for a redesign, and the team ultimately selected the final study area based on sponsor feedback. The first potential site was at the intersection of U.S. Route 1 (Post Rd. West) and U.S. Route 1 (Post Rd. East) at Route 33 (Riverside Ave. and Wilton Rd), in Westport. The team believed this intersection to be a promising option due to its close proximity to the Saugatuck River, and therefore may contain interesting drainage design challenges. However, the group was advised that the intersection's geometry would likely prove too challenging for any major redesign efforts.

The second option was the intersection of U.S. Route 1 (Kings Highway East) at Chambers St. and Private Dr., in Fairfield. The team flagged this intersection due to its high number of crash reports, as well as its location being in the SLOSH zone and at an elevated annual chance flood hazards percentage. However, this intersection was ruled out because it contained only one pedestrian crossing and was located in an area that would not likely see a high volume of foot traffic. The third site that the group studied, the intersection at North Ave., Dewey St., Howard Ave., and Briarwood Ave. in Bridgeport, was chosen as the final study area. The CTDOT's comments expressing that the geometry of this intersection presented a unique opportunity to explore how to design for both roundabout and drainage considerations led the team to choose this intersection as the final study area.

3.2: Objective 2: Document the existing conditions of the intersection through data collection.

The main methods of documenting existing conditions were taking photographs of the intersection, making written observations during the site visit, and reviewing existing data on the drainage network in the area. Taking many photographs of the study intersection allowed the team to recall physical conditions of the intersection without having to make rudimentary estimations using online tools like Google Maps, or even travel back to the site. The team took many photographs during the inspections of the two curb ramps on Cartright St. to ensure there was enough recordkeeping on the process of ADA compliance inspection. In order to conduct these curb ramp inspections, the team also used the CTDOT's curb ramp inspection form in the ArcGIS Field Maps App. This form had fields for measurements for features of the ramp, including Ramp Running Slope, Landing Turning Space Cross Slopes, Ramp Flare Slopes, and more, with areas to include pictures of the ramp and surrounding area. This information then enters a database that CTDOT employees can access for future reference to see the status of certain intersections and whether they have ADA compliant curb ramps.

The team also photographed all other aspects of the intersection, even those that may not have seemed relevant, in case they were important later. For example, the team documented the location of the intersection's utilities, in case the final design option would result in the relocation of utility poles or boxes. By walking through the intersection and surveying the state of the roads, crosswalks, traffic signal timing, and other conditions, the team was able to observe and document the existing conditions in a way that online tools had not allowed the team to.

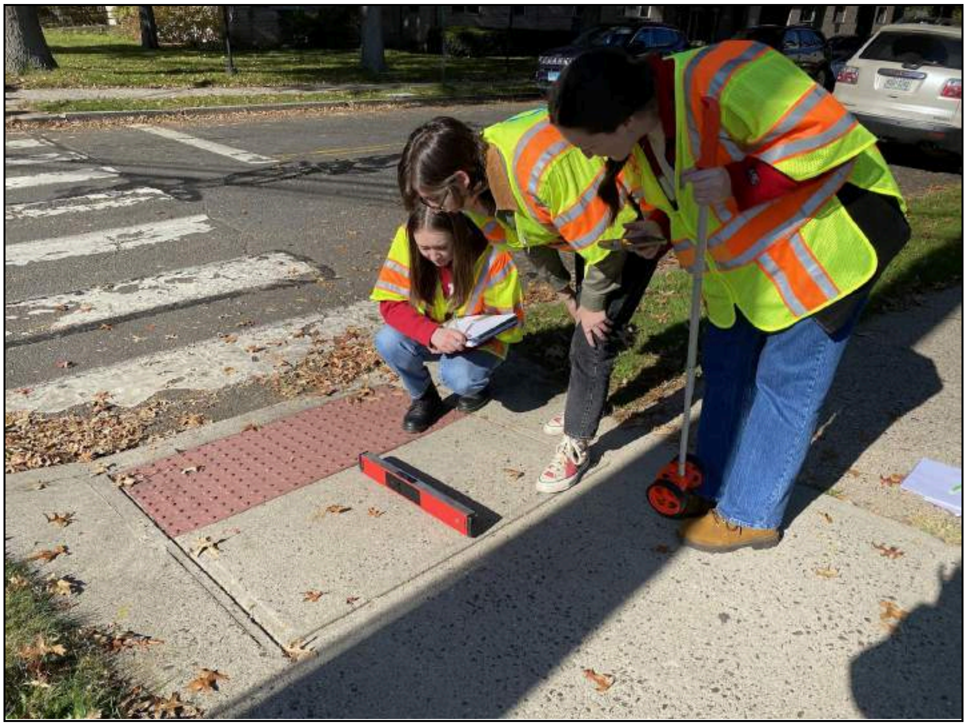

Figure 3. The team conducting a curb ramp inspection (#11 curb ramp) on Cartright St.

In order to consider the existing drainage conditions in the intersection, the team documented the locations of catch basins in the area during the site visit. The team also researched existing data regarding the drainage network, including the CTDOT Drainage Network Interactive Map, to get a sense of where stormwater was being directed or naturally traveling around the intersection. We also interviewed Dominic Antonio, P.E., Transportation Supervising Engineer for CTDOT's Hydraulics and Drainage Unit, and Nicholas A. Ivanoff, P.E., Project Manager in the CTDOT's State Highway Design Unit. With their design expertise, we were able to ask them questions about their process for considering drainage when looking at highway and intersection design. From their recommendations, we used 2016 Aerial and LiDAR data from the University of Connecticut to create a TIN surface in Civil 3D. Then, the TIN surface was used to perform a flow path analysis using the water drop tool. Because the area is one of potential flood risk, getting an idea of where the stormwater may be stagnant in the roadway would be helpful to justifying some of the team's long-term design choices.

3.3: Objective 3: Based on the areas of improvement identified through documentation of existing conditions in Objective 2, develop potential design solutions.

3.3.1 Short-Term Solutions

The short-term design solutions were developed considering the area of highest importance identified by our project sponsor, which is ADA compliance. In order to address these concerns at a minimum, the ADA non-compliant ramps would have to be made compliant. To determine what these improvements would look like, the team used the past curb ramp inspection data for the intersection from CTDOT to identify the types of curb ramps in the intersection. The 2023 Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) was also used to consider how the pedestrian crossings could be made compliant and safer in conjunction with the existing traffic signals.

3.3.2 Long-Term Solutions

The long-term design solution consists of the creation of a roundabout to replace the current intersection. This conclusion was reached after considering the overall shape of the intersection, its traffic pattern, the in-person observations of traffic jams and unsafe crossing situations, and the potential for reallocating existing impervious space to improve drainage.

The geometry of roundabouts causes motorized users to slow their speed both before and while traversing the intersection, which results in a reduction of crashes. In fact, the 2007 National Cooperative Highway Research Program (NCHRP) Report 572 found that roundabouts caused a 35% reduction in overall crashes, and a 75% reduction in injury crashes across the 55 sites studied in the U.S. (Rodegerdts, 2007). Additionally, the NCHRP highlights an additional advantage of roundabouts for non-motorized users, which is that pedestrians only have to consider one direction of traffic when deciding if it is safe to cross. Considering the high number of crashes over the past several years at the study intersection, as well as the unsafe crossing conditions observed at the site, the team decided that a roundabout would be an effective solution to improve the safety of all users in the intersection.

Additionally, roundabouts improve the overall traffic flow and efficiency of an intersection because there are less delays and stops from traffic signal cycles (Nevada Department of Transportation, 2024). This reduction in vehicle delays subsequently reduces emissions from stalling vehicles, fuel use, and associated noise, rendering roundabouts a more environmentally conscious alternative to a typical signalized intersection (Nevada Department of Transportation, 2024). Roundabouts increase the overall lifespan of an intersection and without traffic signals, municipalities benefit from lower maintenance fees and electrical costs. (Nevada Department of Transportation, 2024).

The roundabout design itself was created using AutoDesk AutoCAD software in combination with the design standards and resources identified during research. The basic geometric components of a roundabout consist of a circulatory roadway surrounding a central island. Entry and exit lanes are often divided by medians or splitter islands depending on the needs of road users in the area. Each key feature of the roundabout relies on the use of standard values for consistent design, shown in Figure 4 and include the various radii, diameters, and widths used to create the actual shape of the intersection.

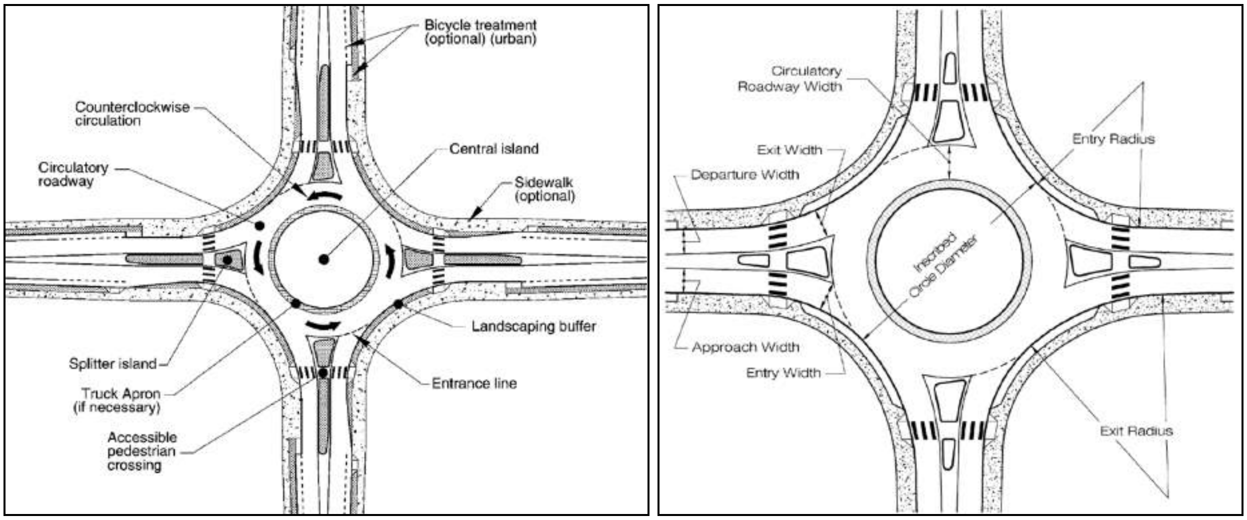

Figure 4. Key Roundabout Features and related measurements (Rodegerdts et al., 2010).

For single lane roundabouts, inscribed circle diameter (ICD) should fall in the range of 110 - 150 ft. The entry radius should range between 90-110 ft., and the exit radius should fall in the range of 400-800 ft. Truck aprons, which surround the center island and allow for 18-wheelers to travel safely through the intersection, should be at least 13 ft. in width according to CT state standards. Depending on the jurisdiction in which a roundabout is being designed, there may be different sets of values for each of these components that are considered "standard." For the purposes of this project, we utilized the MassDOT Introduction to Roundabout Design presentation, the Connecticut Highway Design Manual, and the NCHRP Report 672 "Roundabouts: An Informational Guide." The team also met with Scott Bushee, P.E., who is a Principal Engineer in CTDOT's State Highway Design Unit and chairman of the CTDOT Roundabout Committee. His insight and feedback helped the team consider the steps CTDOT takes when conducting their own roundabout designs.

When creating a roundabout in a real life application, performance checks are conducted to determine the fastest potential speed that a car could travel while in the intersection. These checks are included as a built-in feature of AutoCAD Civil 3D. The intersection was regenerated using the ‘Create Roundabout’ tool and then the performance checks were calculated using the respective radii of the intersection.

To improve the stormwater drainage in the long-term, the team also considered the relocation of catch basins and implementation of green infrastructure and BMPs in the area. By changing the geometry of the intersection, the path of stormwater moving through the intersection also changed. This created an opportunity to redirect and retain stormwater through the use of new drainage features. Additionally, the change in impervious area from the existing conditions to the proposed recommendations was determined.

Chapter 4: Results

Using the methodology described in the previous chapter, this section presents the team's findings, analysis and recommendations for improvements to the chosen intersection in the areas of ADA compliance, safety of all users, and stormwater management.

4.1: Objective 1: Select intersection for redesign with consideration to ADA compliance, pedestrian mobility and crash reports, and stormwater drainage and potential for high risk flood events.

To address accessibility, the team utilized a list of intersections provided by the CTDOT that were considered 'non-compliant' for the ADA. ADA compliance involves factors related to ramp slopes, the inclusion of detectable warning strips (DWS) or lack thereof, and the shape of the crossing, among other components which are specified in PROWAG. The locations were then considered for flood mitigation and safety improvements using the resources previously laid out in the methods section (3.1).

The culmination of these criteria led the team to select the intersection of Briarwood Ave., Dewey St., Howard Ave., and North Ave. (Rt. 1). This signal controlled five-way intersection sits along the U.S. Route 1 in the easternmost part of the city. The side street leading up to the intersection, Cartright St., is also controlled by the same signal. The study intersection has five pedestrian crossings, along with one additional pedestrian crossing at the entrance of Cartright St. Only two of the main five crossings are signalized. Abutting properties include a gas station, a local business, residential buildings, and a large, 125-acre cemetery. Foot traffic in the neighborhood is supported by the sidewalks that connect each of the roads in the intersection.

This intersection had been identified by CTDOT as a site with pedestrian accessibility issues. According to their inspection, all of the curb ramps in the intersection are non-compliant with PROWAG. The two curb ramps at the entrance of Cartright St. are also non-compliant with PROWAG. Additionally, data from the UConn Crash Data Repository shows there have been 30 reported crashes in the intersection over the past three years, 13 of which were injury crashes, and one of which involved a pedestrian (*Connecticut Crash Data Repository*, 2023). These factors point to mobility and safety concerns in this intersection for all users.

This specific intersection in Bridgeport lies near Rooster River, which flows into the larger reservoir Ash Creek and is eventually released into the Long Island Sound. Due to its proximity to these water bodies, the area is at a higher risk for flooding. Rooster River falls within both FEMA 0.2% and 1% annual chance flood hazard zones, as shown in Figure 5. Additionally, FEMA predicted sea level rise data shows that by 2050, the area will be subject to 0.8 to 1.5 ft. of sea level rise, leading to increased coastal flood elevations and the expansion of these 0.2 percent and 1 percent annual chance floods (*FEMA Flood Hazard and Risk Data Viewer*, 2021).

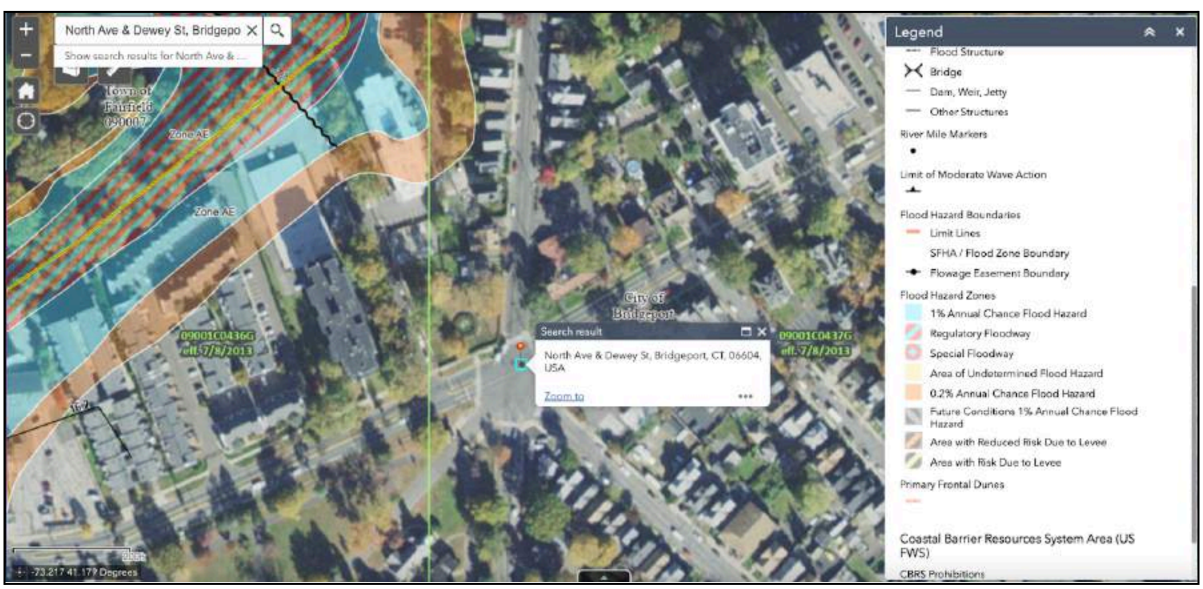

Figure 5. FEMA National Flood Hazard Layer over the selected site in Bridgeport, CT.

The city of Bridgeport is located on the southernmost border of the state and contains part of Connecticut's coastline. In the scenario of 10 ft. of water elevation above the local high tide line, there would be additional flooding risks to the intersection. This case is depicted in Figure 6 below, compiled by the Surging Seas Risk Finder created by Climate Central (*Surging Seas*, n.d.).

Figure 6. Areas of flooding risk given 10 ft. water level above local high tide line. The study intersection is circled in red. Green areas indicate below water level but isolated, blue areas indicate below water level.

An alternative comparison can be made based on predicted temperature increase as depicted in Figure 7. Generated using Climate Central's interactive coastal risk screening tool, long-term sea level outcomes can be compared at different temperatures. For example, the different changes in the height of the tideline can be seen in the figure below. The blue areas of the map represent the tideline at a 3.4° F increase and the red areas represent the tideline at a 6.4° F increase in overall global temperatures.

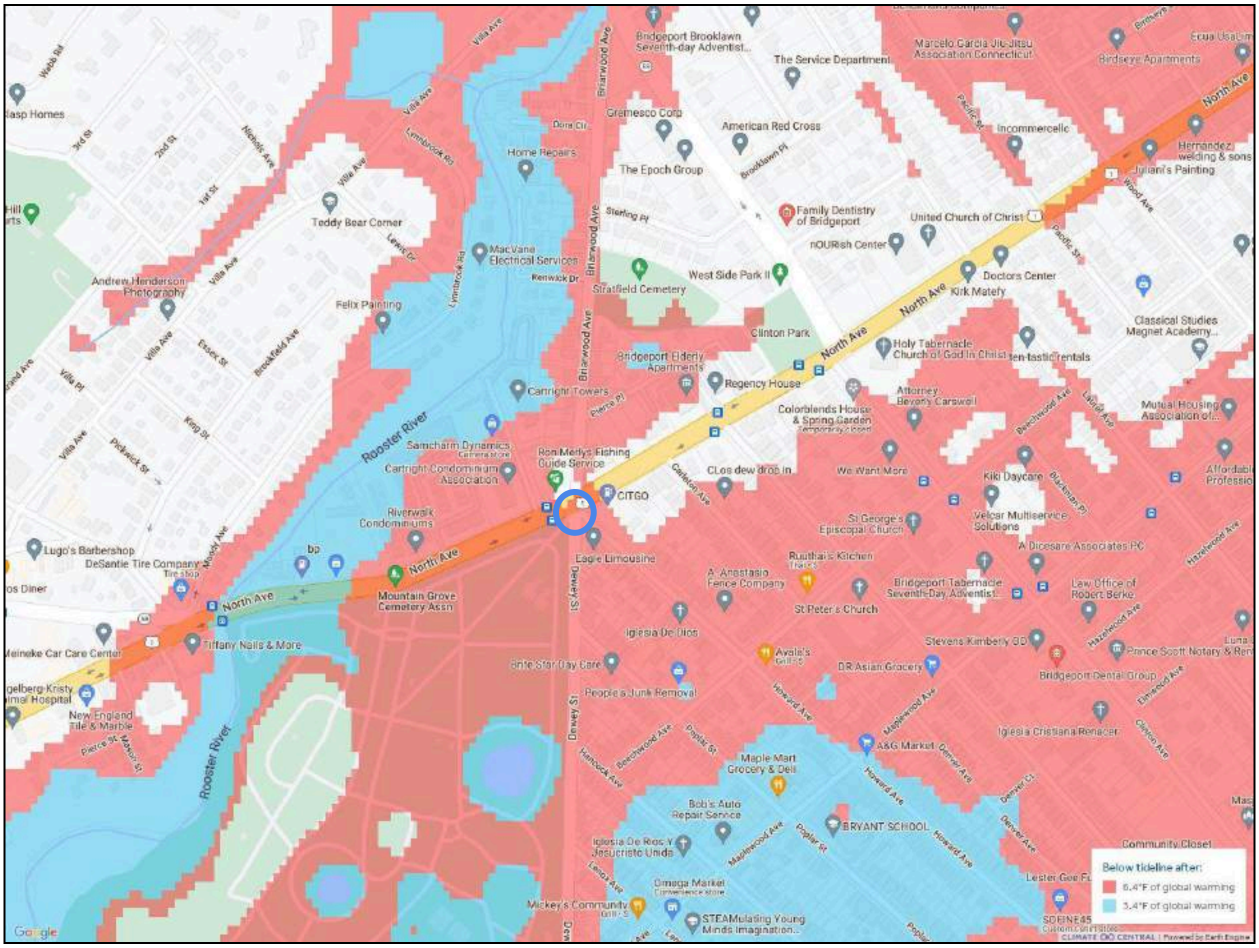

Figure 7. Map depicting areas below the tideline given 3.4° F (blue) and 6.4° F (red) increase in temperature. Intersection circled in blue.

Furthermore, SLOSH data from the US Army Corps of Engineers (Figure 8) shows the location is surrounded by Category 3 and 4 SLOSH zones, due to the proximity of the Rooster River on the western side of the intersection and other surrounding features (*Coastal Inundation and SLOSH MAPS*, 2012). While the study intersection itself does not fall into these areas, its proximity to water features and potential flood zones would suggest that in time and with the unpredictable nature of climate change, the intersection is soon to be impacted by higher risks of flooding.

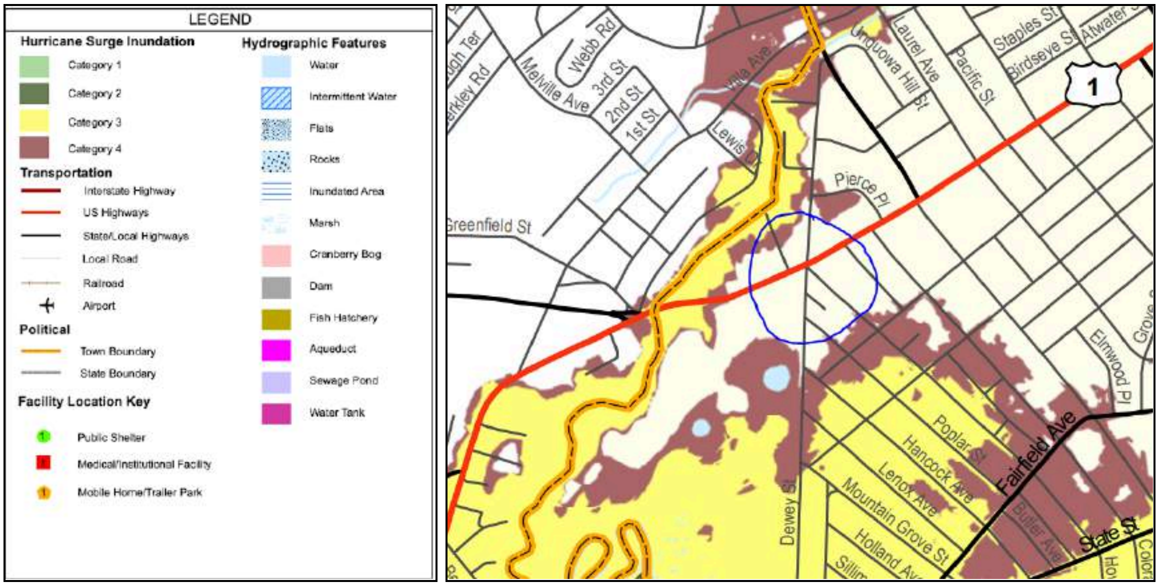

Figure 8. Sea, Lake, and Overland Surge from Hurricane (SLOSH) as created by the Connecticut Division of Emergency Management and Homeland Security, intersection circled in blue.

As mentioned in the background (2.3), many existing drainage systems cannot accommodate large volumes of stormwater runoff from high intensity precipitation events. Combined sewers are a prime example of this, and often exist in older communities in the U.S. with aging infrastructure. Combined sewers collect water from stormwater events, domestic sewage, and industrial applications all in the same pipes, and distribute this water to plants for treatment. Although this system streamlines the collection for wastewater treatment plants, the large volume of water collected can quickly overwhelm piping systems and overflow during extreme weather events, which are increasing due to climate change. Raw sewage is often discharged into nearby bodies of water when Combined Sewer Overflows (CSO) occur and can pose potential health and environmental risks from the contamination (Tibbetts, 2005). The study area contains both combined and separated sewers (Figure 9). While complete treatment does not occur during CSO events in Bridgeport, excess flow does receive primary treatment and disinfection (*Section 2 Basic Planning Criteria*, 2021). This policy is an improvement over discharging raw sewage directly into the ocean. CSO events can cause excess flooding in roadways and spread contaminants this way as well.

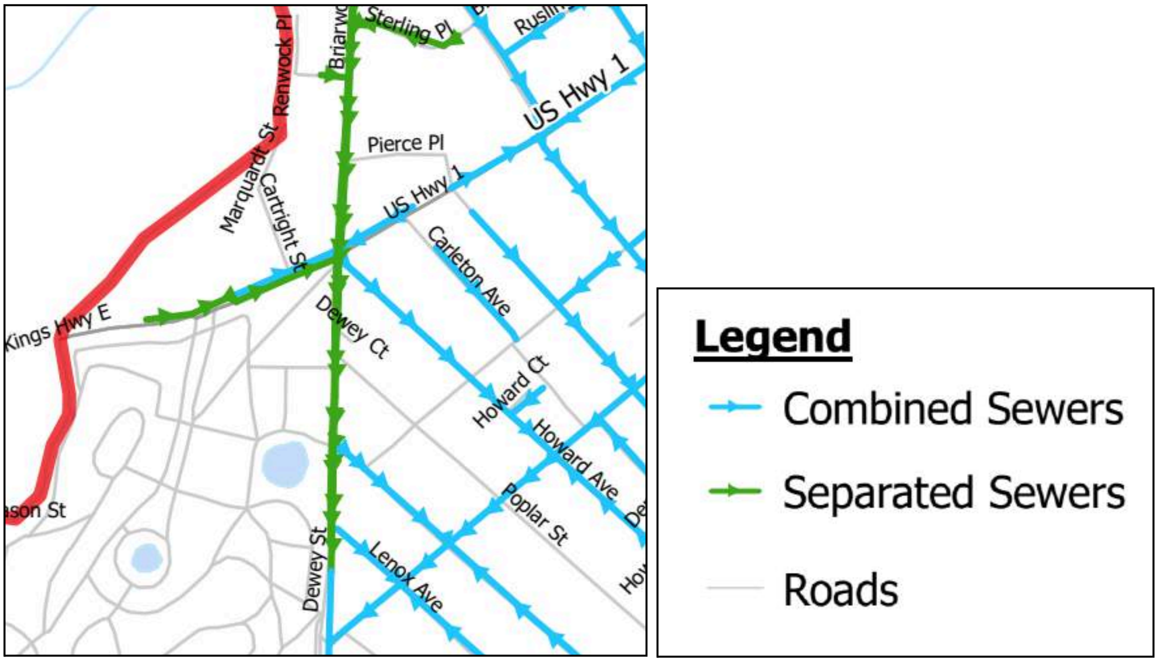

Figure 9. Sewer Service Collection System Map City of Bridgeport, CT (Section 2 Basic Planning Criteria, 2021).

4.2: Objective 2: Document the existing conditions of the intersection through data collection.

4.2.1 Traffic Conditions

While the junction of North Ave. (Rt. 1), Dewey St., Howard Ave., and Briarwood Ave. form the intersection, the signal timing for the intersection also considers Cartright St. which ends roughly 100 ft. to the west of the main intersection. There is also a private drive, which is positioned in between North Ave. and Dewey St, marking the entrance to the Mountain Grove Cemetery. For the purposes of this project, both the private drive and Cartright St. will be considered in the redesign of the intersection.

During in person observation, the direction of vehicles moving through the study intersection was often unclear. It was also unclear what traffic signals corresponded to specific turning lanes as there are ten traffic signals. Despite all vehicles in the intersection having no turn on red rules, there were many vehicles that made illegal turns and caused honking and other driving conflicts (Figure 10). Figure 11 shows an image of the intersection taken from the perspective of Dewey St. and angled to include North Ave, Briarwood, and Howard Ave.

Figure 10. Backup of traffic on North Ave. (westbound).

Figure 11. Photograph of intersection directed at North Ave. (eastbound).

4.2.2 Pedestrian Crossings

Poor pedestrian crossing conditions were also observed during the site visit. There are a total of six crosswalks in and surrounding the intersection, all in varying degrees of substandard conditions. One such condition was the deteriorating paint on the crosswalks (Figure 12). Notably, there was no painted crosswalk joining the sidewalks that frame the main entrance of Mountain Grove Cemetery. Although the private road at the cemetery's entrance does not experience high traffic volume, the vehicles that use this road have no signal to follow. These circumstances make traversing the road especially risky for pedestrians, who must cross while cars may be looking elsewhere for their chance to enter or exit the road. Similar issues with traffic signal sightlines contributed to unsafe pedestrian conditions throughout the intersection. At most crosswalks, pedestrians cannot see whether oncoming cars have a green or red light.

This poor orientation of traffic signals relative to the crosswalks further contributes to the overall sense that pedestrian safety has not been prioritized in the design of this intersection (Figure 13).

Figure 12. Deteriorating Crosswalk Paint.

Figure 13. Poor sightlines to traffic signals for pedestrians.

Of the six total crosswalks, only two were signalized. Those two crosswalks spanned across North Ave. These signalized intersections were not accessible, most notably because they did not contain auditory tones, speech messages, and/or vibrating surfaces at pedestrian signal detectors (Federal Highway Division, 2023). The signals themselves resemble miniature versions of stop lights, simply indicating whether or not it is safe to cross (Figure 14). During the site visit, this resemblance to traffic signals created confusion among team members as to whether this signal was meant for pedestrians or for cars. The existing devices are in stark contrast to an accessible walk signal (Figure 14) that contains a pedestrian signal head device (the walking person symbol), pedestrian change interval (the flashing upraised hand symbol), pedestrian clearance time, and other key features (Federal Highway Division, 2023).

Figure 14. Pedestrian Signal from intersection (left) compared to standard pedestrian signal (right, Photo by https://en.wikipedia.org/wiki/User:Coolcaesar).

The observed pedestrian clearance time in the two signalized crosswalks was especially poor, as the green and yellow lights did not shine for a long enough period to reasonably leave the curb, traverse the road, and safely reach the opposite curb. Additionally, the traffic signal timing was in direct conflict with the pedestrian signal timing. During the site visit, the team frequently had the green or yellow light to traverse the crosswalk, but could not proceed because cars also had a green light and were oncoming (Figure 15). Similar to the poor sightlines that pedestrians experience with traffic signals, vehicles experience poor visibility to the pedestrian signals. This combination may increase the likelihood of vehicle crashes with pedestrians.

Figure 15. Oncoming Car during Yellow Pedestrian Signal.

The team observed a steady volume of pedestrians using the intersection, likely due to the high number of bus stops along North Ave. and nearby residential facilities, one of which is an elderly facility. Throughout the two-hour period during the site visit, the team observed a myriad of pedestrian experiences in this intersection. Frustrated with the complicated geometry and overall confusion of the crosswalks, the group observed some pedestrians forgoing all crosswalks, waiting for a lull of traffic volume, and finally running across the entire intersection. The team also observed multiple pedestrians who were wheelchair users, one of which expressed their frustration with the unevenness of the curb ramps and sidewalks. Indeed, sidewalks were often patched with little consideration to levelness or were simply obstructed (Figure 16). In one instance, a fire hydrant obstructed a sidewalk, making it difficult for all users to travel around the area without having to traverse into the road (Figure 17).

Figure 16. Unlevel Sidewalk Patching Conditions.

Figure 17. Fire Hydrant Obstructing Sidewalk on Briarwood St.

As for the team's curb inspections, neither of the two inspected ramps were ADA compliant. Curb ramp #11 exceeded the maximum tolerances for Ramp and Landing Running Slope values and curb ramp #12 contained considerate cracking in the concrete which rendered it non-compliant. A summary of the collected data can be found in Table 1 in Chapter 4.3, with an accompanying key in Figure 18. Additional data for the other ten curb ramps in the intersection from the CTDOT's previous inspections can also be seen in Table 1, alongside the data the team collected. Due to the lack of pavement and curb cuts leading to the bus stop, individuals who use wheelchairs or other mobility aids could not access the bus from the sidewalk, and would have to compromise their safety by traveling into the road to get on the bus (Figure 19). With such a high traffic volume on North Ave., pedestrians waiting by the bus stop were forced to stand farther away from the road, sometimes obstructing the sidewalk for other users. The team's overall experience as pedestrians was negative, even feeling unsafe at times, due to the sidewalk and crosswalk design accommodating cars, instead of people.

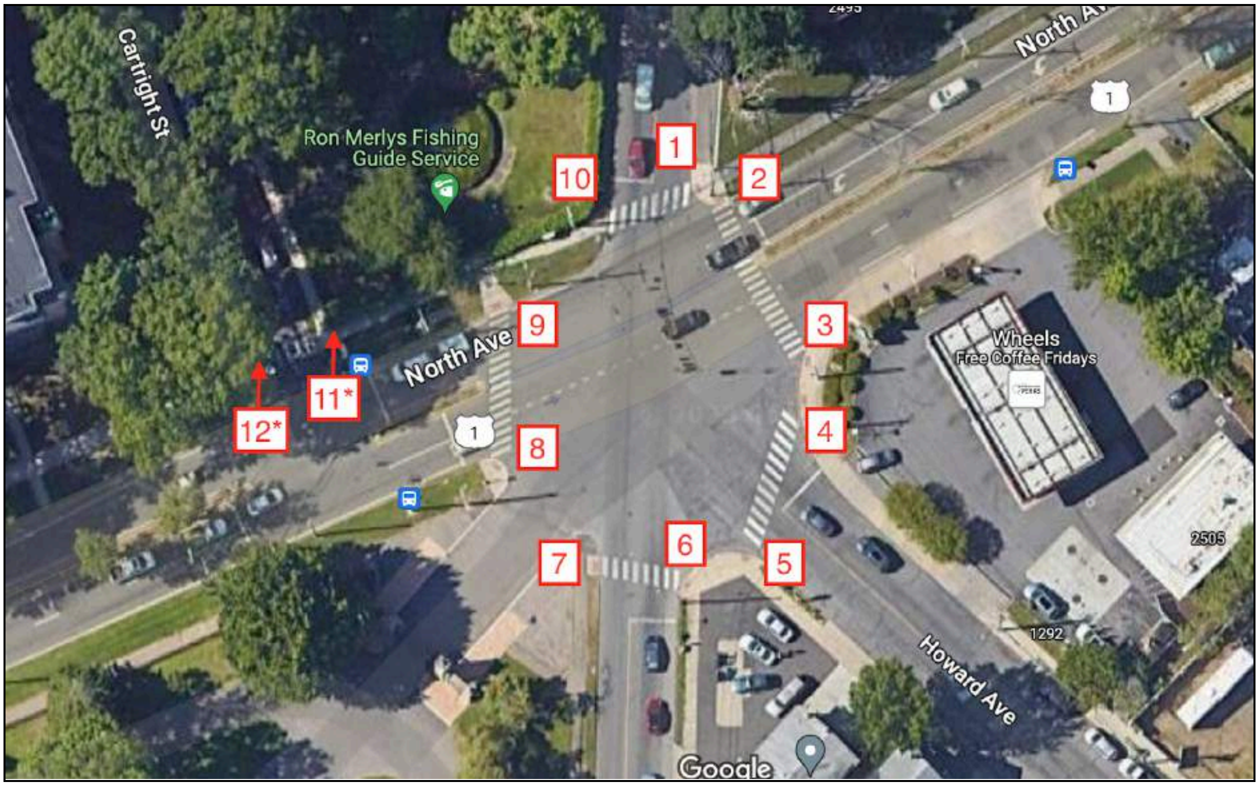

Figure 18. Aerial view of the intersection with each curb ramp identified and numbered.

Figure 19. Inaccessible Bus Stop Access Route.

4.2.3 Drainage Considerations

The existing conditions of the intersection include four catch basins in the immediate area, for which the coordinate data was marked on Google Maps as shown in Figure 20. The two closest to the intersection are on opposite sides of North Ave., while the other catch basins are farther west along the same road. The conditions of the catch basins can be seen in Figure 21. There are also catch basins at the exit of the gas station at the corner of the intersection, which are on the gas station property to control their private stormwater runoff.

The sloping of the area is also generally flat. North Ave. has a slight high point in the center of the roadway and slopes down on both sides towards the curb, which can be beneficial to drainage by directing runoff away from the center of the intersection. Additionally, during the site visit, the team noticed many utility markups around the intersection that seemed new (Figure 22). There was also an Aquarion Water Company truck parked by the cemetery during the site visit. This could signal a city water project in the area and possible future work done in the intersection. Overall, for an intersection of this size, there seems to be a very small drainage system in place, especially considering its vulnerability to flooding.

Figure 20. Coordinate Locations of Catch Basins surrounding the intersection, labeled 1-4 (Google Maps).

Figure 21. Conditions of the four catch basins in the vicinity of the intersection as labeled in Figure 20.

Figure 22. Utility Markups along North Ave.

After visiting the site in person, the team searched for available data on the existing drainage near the intersection. One map, the CTDOT Drainage Network Interactive Map, provided some general data on the drainage in the intersection. As shown in Figure 23, the map shows the locations of several inlets and manholes, and the pipe network seems to move water along North Ave. and down Howard Ave. However, the available data in this area is incomplete. Several attempts to contact the city of Bridgeport's Public Facilities Team and the city engineer regarding additional drainage data for this area were unsuccessful.

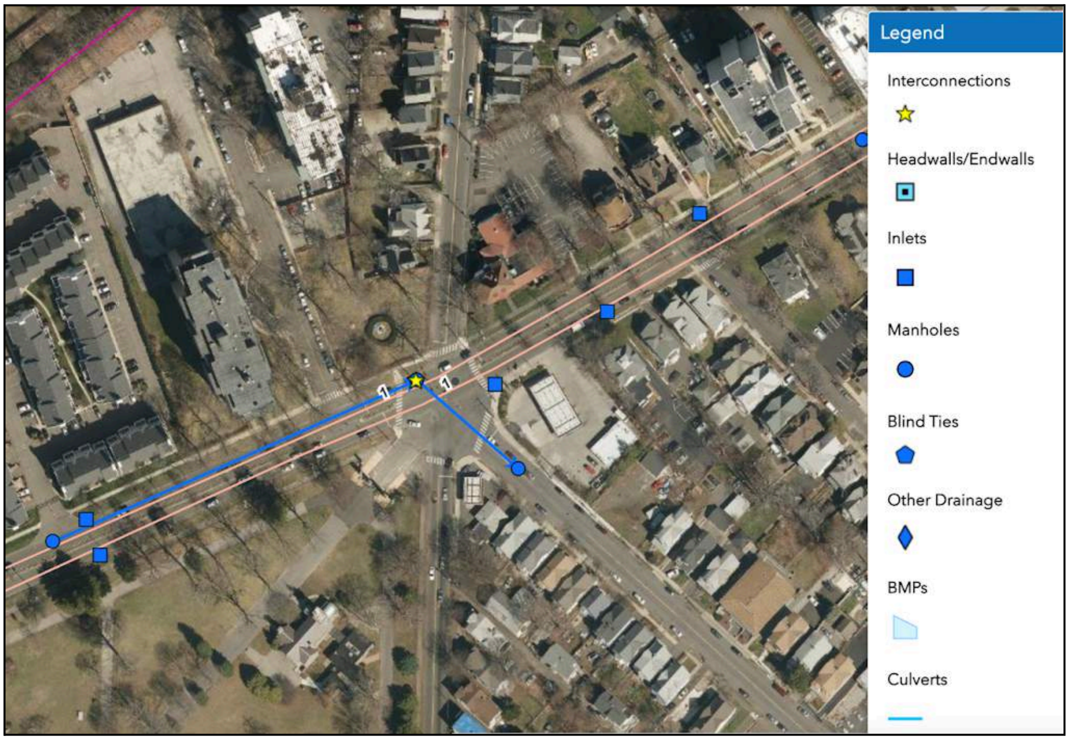

Figure 23. CTDOT Drainage Network Interactive Map showing available drainage data at North Ave. & Dewey St. (CTDOT).

After speaking with Nicholas Ivanoff, P.E. and Dominic Antonio, P.E. from CTDOT, they advised us that without any survey data, and extremely minimal data on the drainage network in the area, the best method for analyzing drainage was creating a surface using Aerial and LiDAR imagery in Civil 3D. Once the surface was created and the aerial image was aligned underneath, the water drop tool was used. The water drop flow path tool simulates the longest flow path that a drop of water could take from a point of interest. The points of interest, or the initial locations of the water drops, are represented by the dark blue squares shown in the schematic (Figure 24).

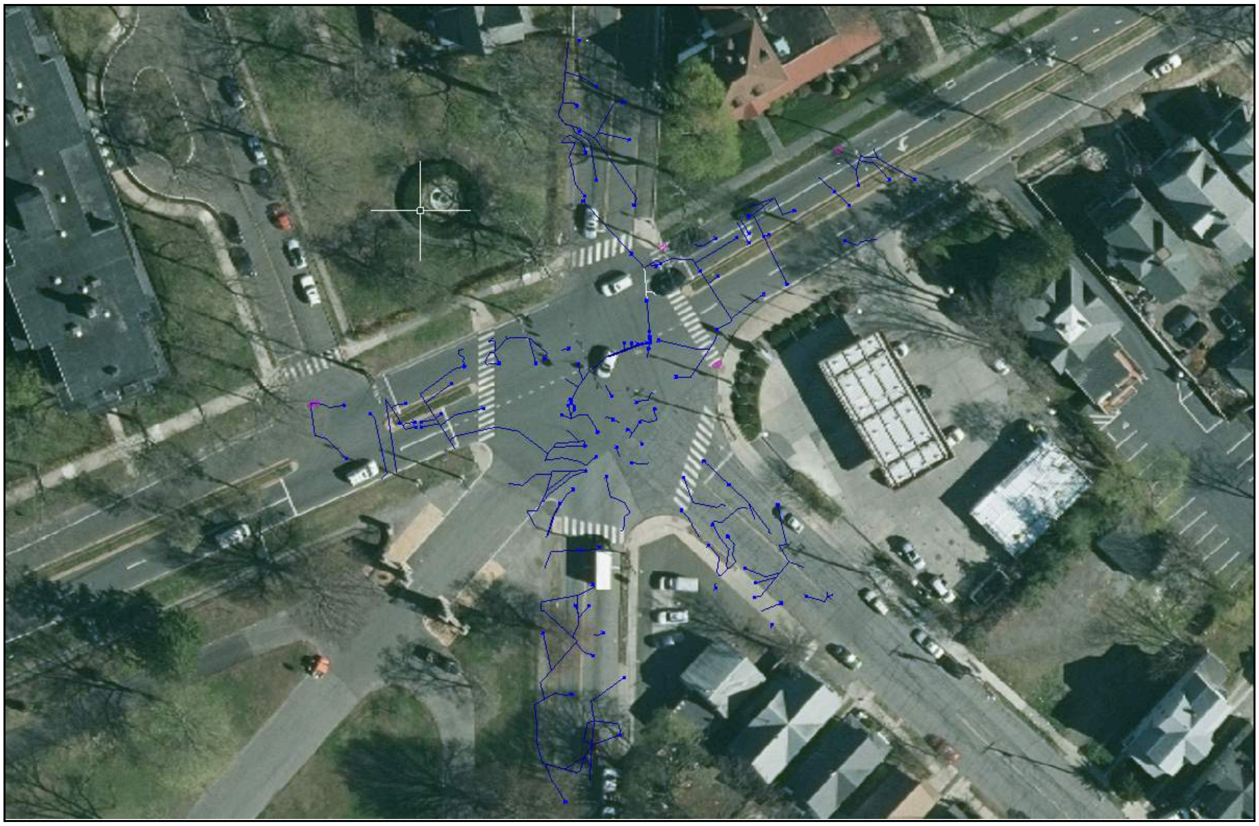

Figure 24. Drainage Schematic of North Ave. and Dewey St., rendered using Civil 3D.

By examining several points in and around the intersection, it was evident that on all of the surrounding streets, the water was directed out of the roadway, towards both shoulders of the road. However, in the center of the intersection, the water drops displayed very short flow paths. This shows that this area of the intersection could be susceptible to stormwater pooling and accumulating, without being able to drain. If this area of the intersection were made pervious, this would help improve the intersection compared to its current conditions.

4.3: Objective 3: Based on the areas of improvement identified through documentation of existing conditions in Objective 2, develop potential design solutions.

As previously mentioned, the potential design solutions for addressing the accessibility of the intersection can be divided into two categories: short-term and long-term solutions.

4.3.1 Short-term Solutions

The short-term solutions involve prioritizing the immediate safety and accessibility concerns in the intersection. Notably, this involves addressing ADA non-compliant ramps and crossings, in addition to some limited sidewalk and curb repairs. The repairs and maintenance of these features would limit disturbance to the traffic flow of the intersection and would minimize costs, while addressing the main problem.

To ensure ADA compliance of accessibility features in the intersection, construction of new curb ramps and repairs to sidewalks are necessary. Sidewalk maintenance and repair falls to the local municipality per state statute. Therefore, it falls to Bridgeport to conduct necessary accessibility improvements related to sidewalks and curb ramps. The CTDOT has an annual Vendor-in-Place (VIP) Paving Program, which involves the resurfacing of 200 two lane miles every year. In 2013, a joint technical assistance was issued by the DOT on Title II of the Americans With Disabilities Act to include the construction of curb ramps as a requirement with resurfacing (*Connecticut Department of Transportation Americans With Disabilities Act ADA/504 Transition Plan*, 2018). This could be an opportunity for Bridgeport to have repairs made to sidewalks and curb ramps if repaving is needed in this area in the future.

The existing conditions of the 12 curb ramps are documented in Figure 25, with details about their ADA non-compliance in Table 1. Table 1 also outlines proposed modifications to each of the 12 curb ramps as a short-term solution. According to the CTDOT's previous inspections of each of the ten curb ramps, as well as for the two curb ramp inspections conducted by the team, all of the curb ramps were identified as perpendicular. The proposed modifications to the 12 curb ramps will follow the ADA specifications for a Perpendicular Curb Ramp with 48 in. By-Pass, also identified as Type 8 by CTDOT. A basic image showing the design of a perpendicular curb ramp can be seen in Figure 26.

Figure 25. Existing Curb Ramp Conditions from CTDOT curb ramp inspection report data (1-10), as well as the team's curb ramp inspections from the site visit (11 & 12).

Table 1. Record of Existing ADA Curb Compliance throughout the Intersection and Proposed Improvements.

Curb Ramp Number	**Is it ADA Compliant?**	**Reason for Non-Compliance**	**Proposed Improvements**
1	No	Ramp Running Slope > 8.33% Landing Running Slope > 2%	Replace existing curb ramp with perpendicular curb ramp, type 8.
2	No	Ramp Running Slope > 8.33% Ramp Cross Slope > 2% Landing Running Slope > 2% Ramp to Gutter Transition > 0.5”	Replace existing curb ramp with perpendicular curb ramp, type 8. There is also a utility pole directly next to the curb ramp that would have to be relocated in order to make these improvements if it is within 28” from the ramp flare.

3	No	Ramp to Gutter Transition > 0.5” Detectable Walking Strip not Flush with Ramp	Replace existing curb ramp with perpendicular curb ramp, type 8. This would also replace the detectable warning surface, which is currency not flush with the ramp.
4	No	Ramp Running Slope > 8.33% Landing Running Slope > 2% Accessible Pedestrian Signal inside Turning Space	Replace existing curb ramp with perpendicular curb ramp, type 8.
5	No	Ramp Running Slope > 8.33% Landing Running Slope > 2% Ramp to Gutter Transition > 0.5”	Replace existing curb ramp with perpendicular curb ramp, type 8.
6	No	Landing Running Slope > 2%	Replace existing curb ramp with perpendicular curb ramp, type 8.
7	No	Ramp to Gutter Transition > 0.5”	Pave and make flush so that Gutter Transition =< 0.5”
8	No	Ramp Running Slope > 8.33% Ramp Cross Slope > 2%	Replace existing curb ramp with perpendicular curb ramp, type 8.
9	No	Ramp Running Slope > 8.33% Ramp Cross Slope > 2% Ramp to Gutter Transition > 0.5”	Replace existing curb ramp with perpendicular curb ramp, type 8. Relocation of the accessible pedestrian signal out of the turning space here is necessary to meet ADA compliance. This kind of improvement would be more complex, somewhere in the range of medium to long-term improvements. It could be possible to, while repainting crosswalks, angle the crossing farther to the left and shift the curb ramp over as well. However, that positions the crosswalk even further in the roadway, which could be a safety concern.
10	No	Ramp Running Slope > 8.33%	Replace existing curb ramp with perpendicular curb ramp, type 8.
11*	No	Ramp Running Slope > 8.33% Landing Running Slope > 2% Crack exceeds ¼” vertical gap	Replace existing curb ramp with perpendicular curb ramp, type 8.
12*	No	Crack exceeds ¼” vertical gap	Replace existing curb ramp with perpendicular curb ramp, type 8 which includes patching of concrete.

*Curb Ramps that were inspected by the team during the 10/24 site visit

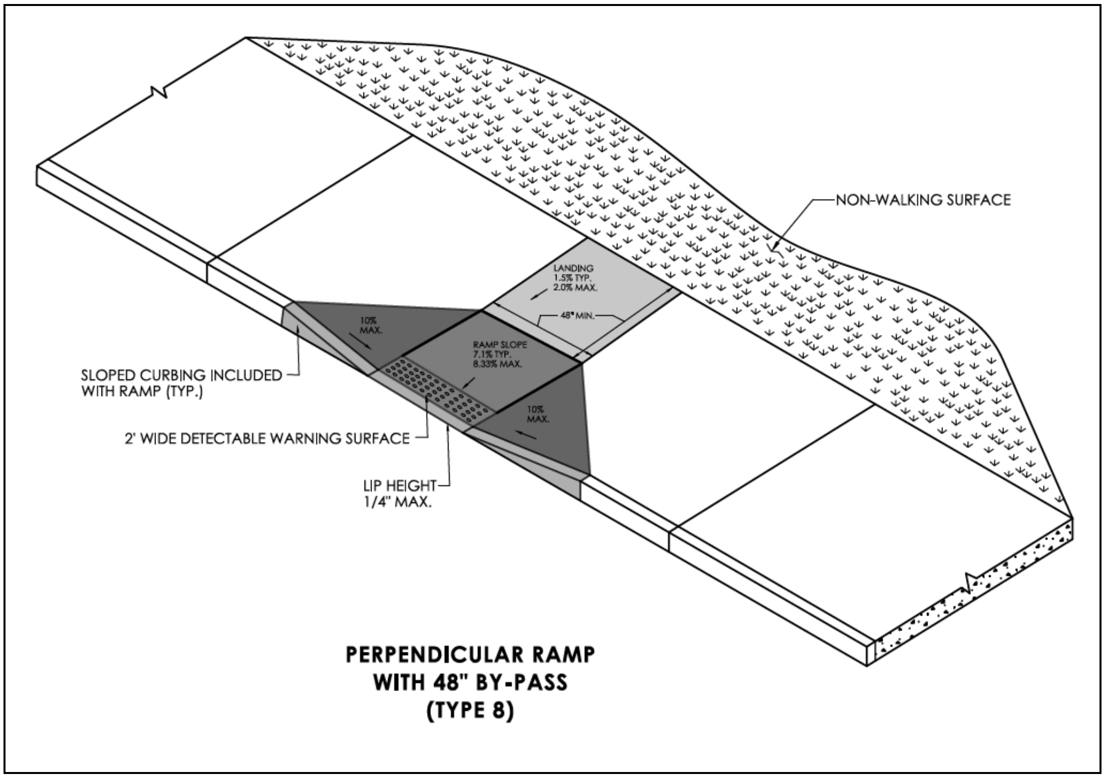

Figure 26. CTDOT Guidesheet for a Perpendicular Ramp with a 48" By-Pass, Type 8 (CTDOT Highway Standard Drawings, 2022).

Other improvements include the repair of several curbs along North Ave. that are broken off and pose safety concerns. In order to improve pedestrian safety as well, the sidewalk along North Ave. between Cartright St. and Briarwood Ave. also must be repaved, as it was improperly patched previously making it difficult to navigate. There is also a fire hydrant obstructing the sidewalk along the west side of Briarwood Ave, which would need to be relocated in order to provide effective pedestrian access to the sidewalk.

In addition to curb ramp, sidewalk and curb repairs, short-term solutions include improvements to the pedestrian crossings at the site. Currently, the two pedestrian crossing signals present in the intersection are not compliant with ADA or the 2023 MUTCD. To make the intersection safer for pedestrians to navigate in the short-term, the existing signals should be replaced with updated pedestrian signal heads and push button detectors, and additional signals should be added for the three other pedestrian crossings in the intersection.

Considering the fact that there are pedestrian crossings already in the intersection, it could be assumed that the volume of pedestrian traffic justifies the use of signals at these crossings. The MUTCD states that pedestrian signal heads "should be installed for each marked crosswalk at a location controlled by a traffic control signal" (Federal Highway Division, 2023). Additionally, as is standard with the MUTCD, a traffic engineering study should be conducted to justify the use of pedestrian crossing signal heads and to coordinate the pedestrian and traffic signal timing, which describes the situation observed at this intersection. Typical pedestrian signal indications can be seen in Figure 27 .

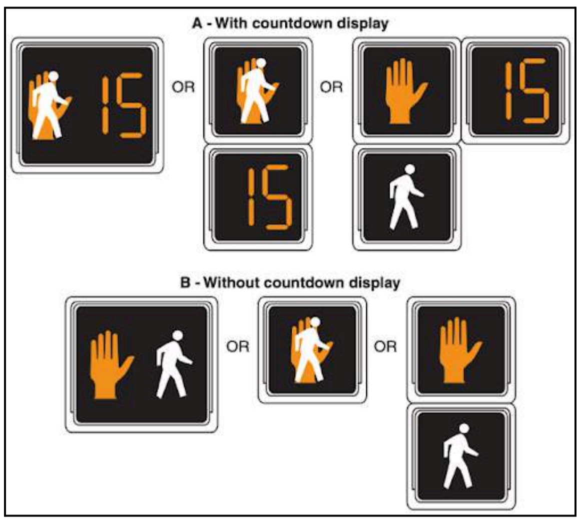

Figure 27. Typical Pedestrian Signal Indications, from Figure 4I-1 from 2023 MUTCD (Federal Highway Division, 2023).

4.3.2 Long-term Solutions

The long-term design solution is the creation of a roundabout in place of the existing intersection. The goal of the roundabout is to reduce the number of crashes in the area and safely direct the flow of traffic from the five intersecting roads, which in turn, should allow for greater pedestrian safety. The conceptual design of this roundabout is pictured in Figure 28, and was designed using AutoCAD 2D modeling software.

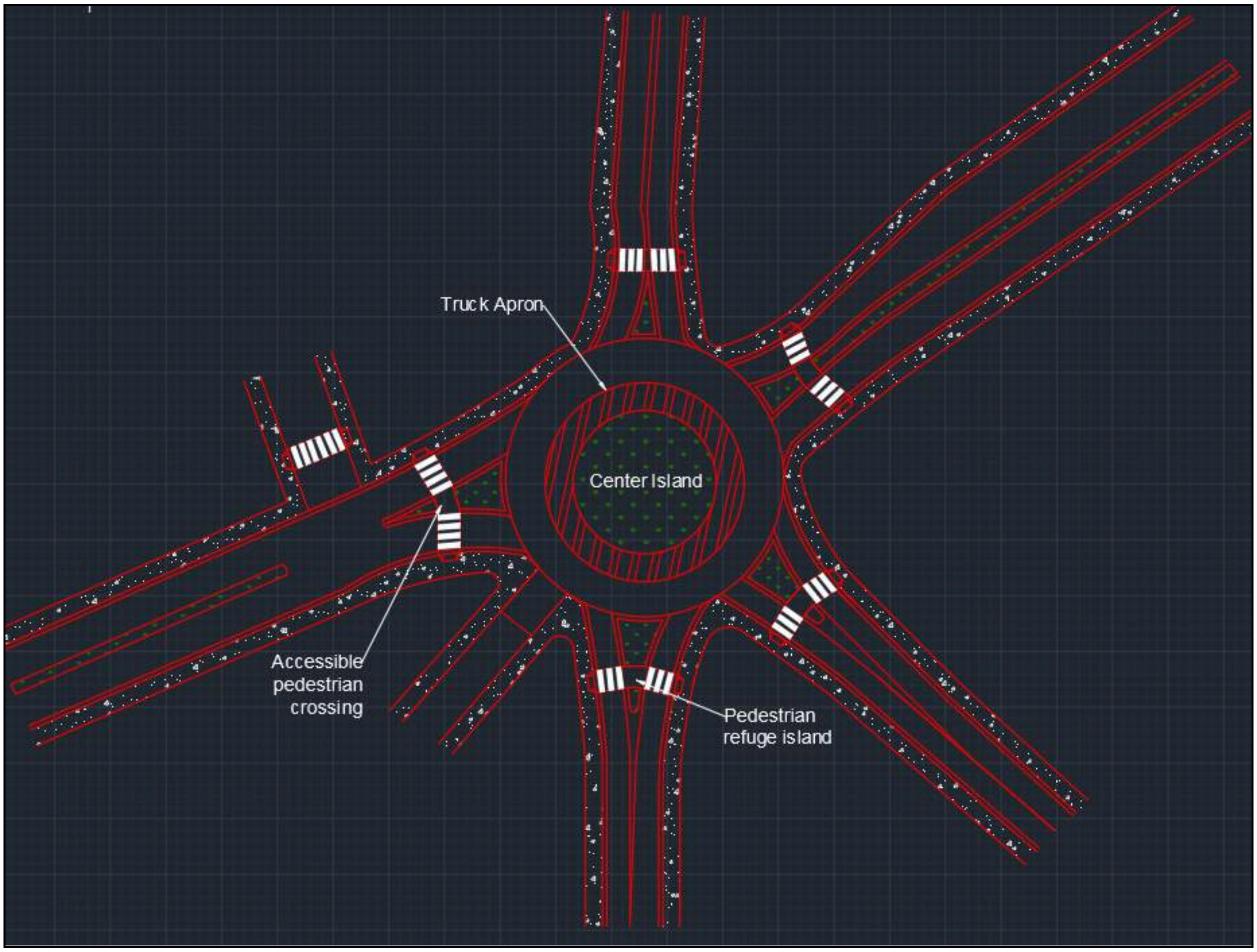

Figure 28. Conceptual Design of Roundabout for Intersection.

This long-term intersection redesign would remove existing signals and relocate all pedestrian crossings, curb ramps, and bus stops. Additionally, to create an appropriate amount of deflection, the approach angle and location of some of the side roads were altered. Splitter islands were added to four of the five approaches to the intersection, with crossings at each island for pedestrian refuge. The location of the crossings themselves were pushed back from their original locations to be at least 20 ft. away from the edge of the new roundabout. The change in location in addition to the pedestrian refuge island will make crossings much safer overall, as pedestrians will only have to worry about one direction of oncoming traffic at a time. They will also have space on the splitter islands to wait for cars to stop, allowing them to walk across in sections instead of all at once. Crossings will also include flashing signs with auditory signals to increase pedestrian safety. The most common example of this technology is a Rectangular Rapid Flashing Beacon (RRFB), which has been shown to reduce crashes by up to 47% (US DOT, n.d.). An example of a RRFB can be seen in Figure 29.

Figure 29. Example of RRFBs at crosswalks in a roundabout in Oakland County, Michigan (Schroeder et al., 2017).

Because the intersection would be entirely reconstructed, all existing curb ramps would need to be demolished, and new ADA compliant ramps would be constructed at each appropriate junction. Figure 30 below shows the type of ramp that could exist at each crossing, from CTDOT's Highway Standard Design Guide Sheets. The appropriate curb ramp type for the splitter island would be the Type 22 Cut-through pedestrian refuge island crossings. However, this would need to be evaluated pre-construction of the roundabout to adapt to the existing conditions.

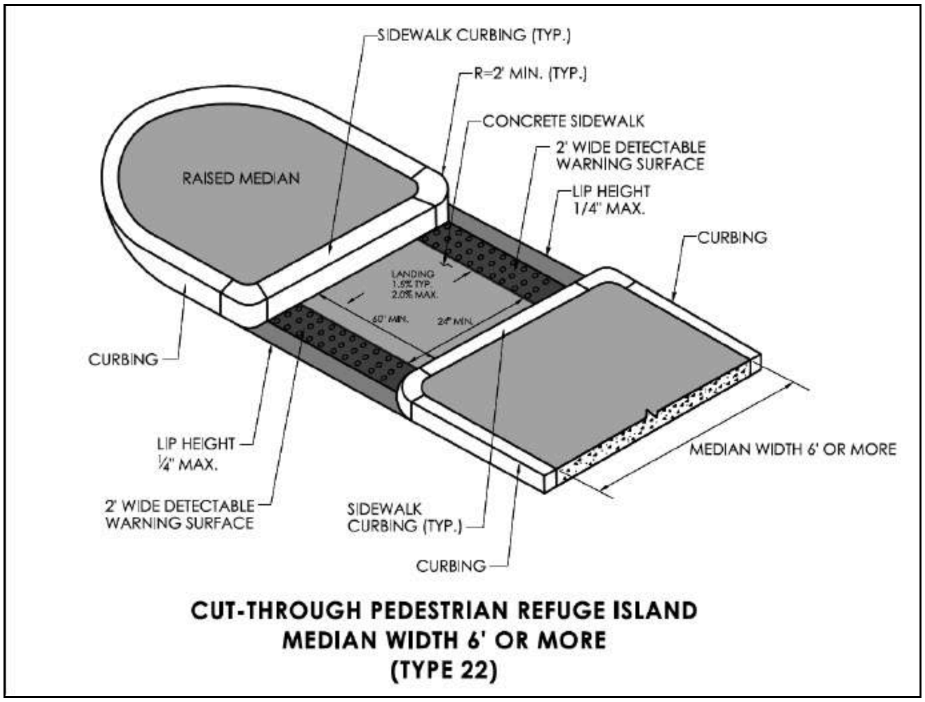

Figure 30. CTDOT Guidesheet for Type 22 Cut-Through Pedestrian Refuge Island crossings, with curb ramps and DWSs. (CTDOT Highway Standard Drawings, 2022).

The values used for the actual conceptual design of the roundabout were taken from the MassDOT roundabout presentation as previously mentioned, as well as the meeting the team had with Scott Bushee, P.E., Chairman of the Roundabout Committee for CTDOT. The single lane roundabout was selected because of the original size of the intersection. However, a traffic study including vehicle counts would need to be conducted in the future to determine whether there is enough traffic to warrant a two lane roundabout. The lane widths for smaller roads such as Dewey, Howard, and Briarwood were made to be 12 ft. with 2 ft. shoulders. The higher volume North Ave. was left to be wider at 16 ft. The entry radii as the streets connect to the intersection are approximately 100 ft., while the exit radii are approximately 600 ft. The total inscribed circle diameter is 130 ft., which is surrounded by a 13 ft. truck apron. Each of the crossings that contain splitter islands were measured to be at least 6 ft. wide to provide appropriate pedestrian refuge, while all the crosswalks themselves are 10 ft. wide. The cross slopes of the pedestrian crossings themselves would not exceed the street grade. This can be seen in Figure 31 below, which shows how the crosswalk cuts through a break in the splitter island, indicating a flat continuous surface. The final roundabout design overlaid with an aerial map image can be seen in Figure 32 below.

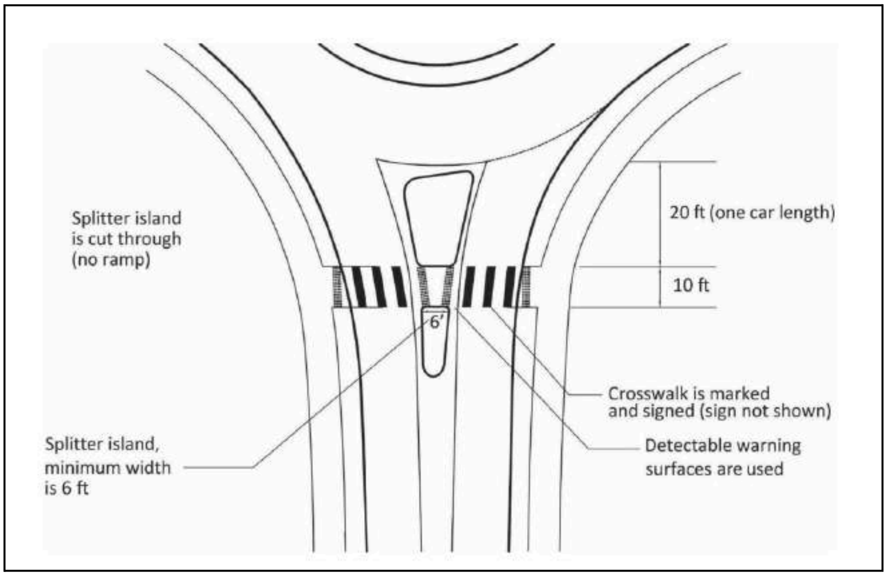

Figure 31. Typical crosswalk dimensions and features of a single-lane roundabout, Figure 4-1 from NCHRP Research Report 834 (Schroeder et al., 2017).

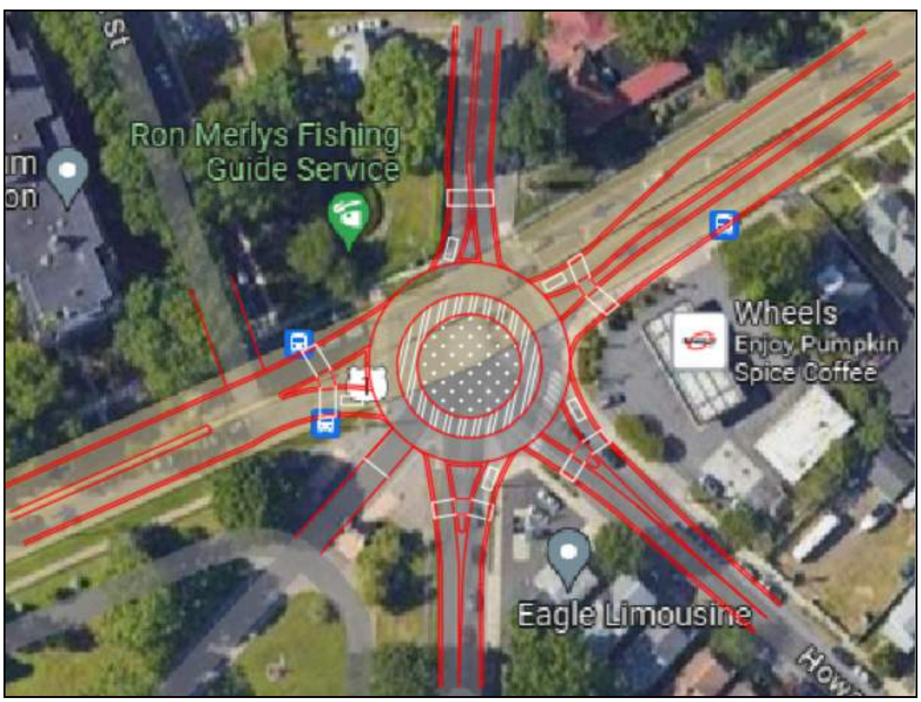

Figure 32. Conceptual Design of Roundabout for Intersection overlaid with aerial map.

To adapt the existing roads to the new roundabout design, there were several adjustments made to the lane width and locations. To allow for more space between respective entry and exit lanes, the road width for Briarwood was angled westward. Similarly, the entrance of North Ave. (westbound) was angled southward to provide extra space for entering vehicles.

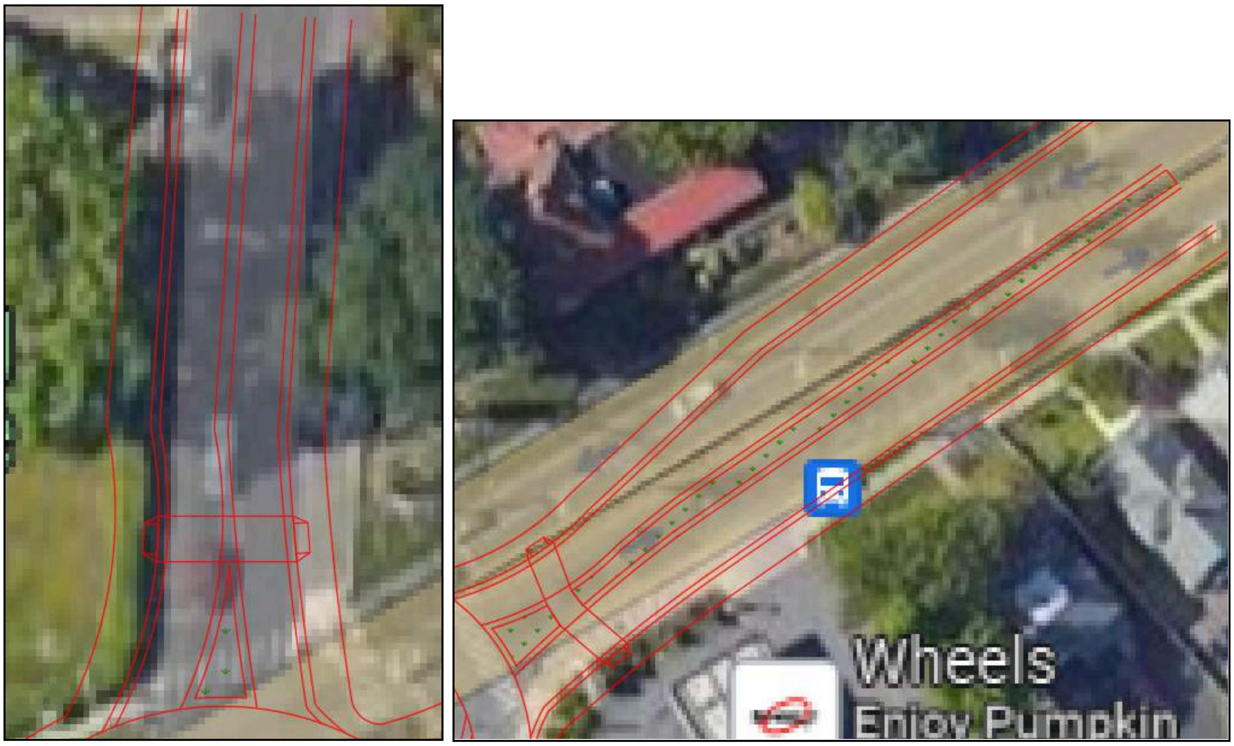

Figure 33. Images highlighting the adjustment of existing road locations, Briarwood Ave. on the left and North Ave. on the right.

While not connected to the roundabout, Cartright St. needs to be considered in the overall design. As it exists currently, there is a secondary traffic signal at Cartright and North Ave. that causes significant backup into the intersection. For the long-term design solution, one option is to prohibit left turns from Cartright St. onto North Ave., while traffic from North Ave. (eastbound) would still be allowed to turn left into Cartright. Vehicles who wish to leave Cartright and head east will now have to take a right and use the newly created left turn storage lane to make a U-turn approximately 500 ft. west of the existing break in the median (Figure 34).

Figure 34. Images of potential left turn storage lane adjustment to existing median on North Ave. westbound.

Although this change may seem inconvenient for those drivers on Cartright who want to take an immediate left turn, the lack of frequent traffic light changes will reduce traffic jams and allow cars to flow more efficiently through the intersection. To address the private road that acts as the entrance to the cemetery, the new design assumes this entrance will be a one way street – enter only. Since there are multiple exit routes within the cemetery, this will likely not disrupt traffic flow on the grounds, and will create less confusion than a two-way street would at the roundabout. It should be noted that with the increased deflection from the roundabout, vehicles may need to circumnavigate the intersection one additional time to allow for an easier turning radius into the cemetery.

To confirm the roundabout design that was created by the team, the 'create roundabout' built-in feature of AutoCAD Civil 3D was used. In a similar method to the previous design, an aerial image was used to determine the size and center of the intersection and the roundabout was designed on top. In Civil 3D, the software is designed to create the entire intersection based on inputs from the drafter. For example, certain components such as the ICD are given to the computer but it makes its own conclusions about the associated size of the radii based on the given values. Because of this, it allows for the creation of the intersection in a mere fraction of the time it took to create the design ‘by hand.’

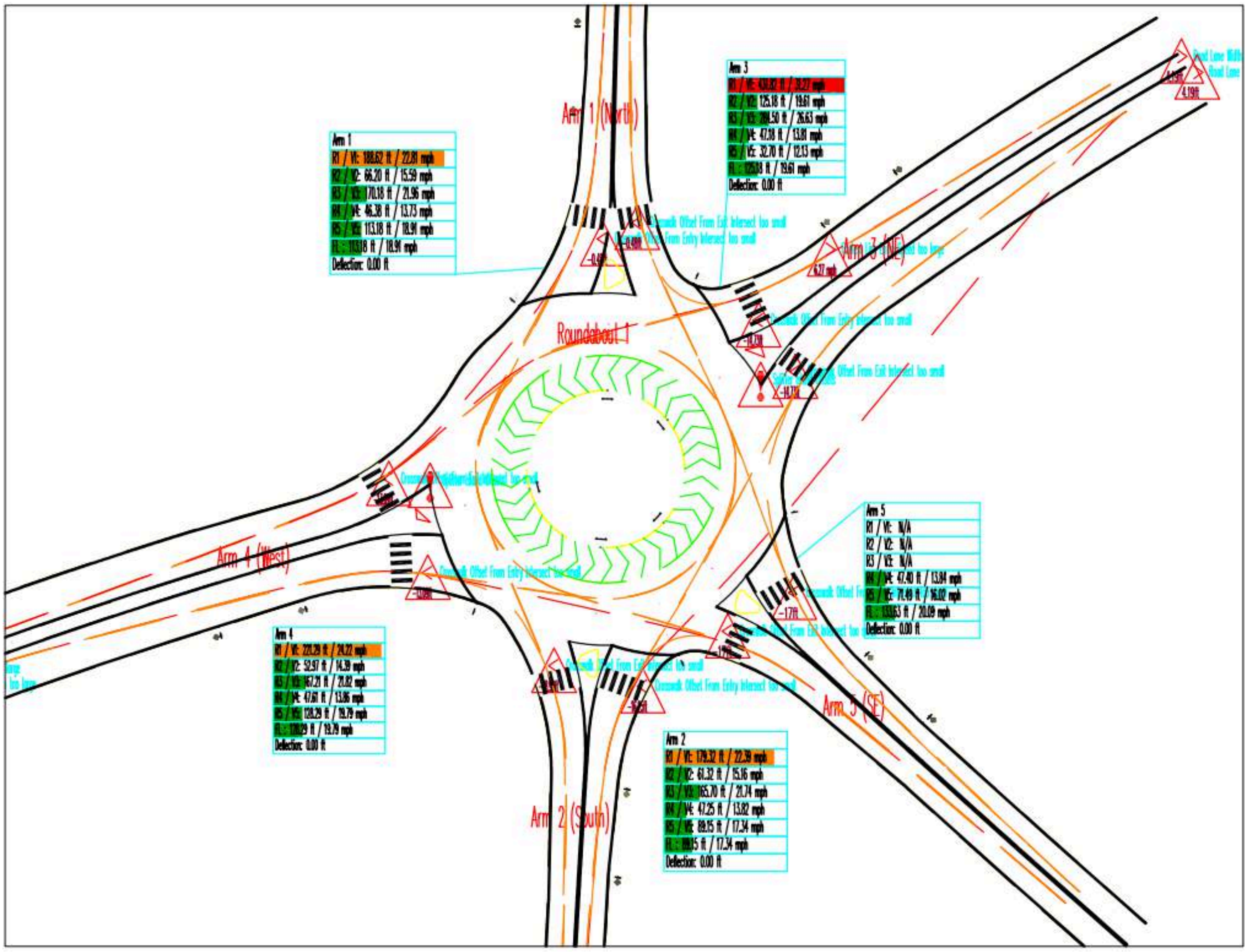

Figure 35. Image of roundabout created using Civil 3D ‘Create Roundabout’ feature including associated performance checks.

As previously mentioned, performance checks are an important step of the design process and are used to determine the fastest potential speed that a car could travel while in the roundabout. After generating the intersection and adding all appropriate approaches, these checks were completed automatically using the geometry and respective radii for each arm using Civil 3D software. All but one arm would have fastest path speeds of under 25 mph, which is the target speed for vehicle safety. As seen in Figure 35, this roundabout, while similar to the original conceptual design presented in Figure 28, varies slightly in the angle and width of the roads and their respective deflections. Because the 'Create Roundabout' feature operates using a design formula, some of the features would need to be adjusted using hand drafting or different design software to further account for the unique geometry of the intersection.

Improvements to the drainage system were also made, to properly redirect the stormwater given the new geometry of the intersection. This process involved the relocation of existing drainage and implementation of stormwater BMPs surrounding the intersection. A schematic showing these BMP recommendations can be seen in Figure 36. The two existing catch basins located outside of Cartright St. and westbound on North Ave., labeled as basins one and four in Chapter 4.2, would be kept at their existing locations, since they would likely remain unchanged by the roundabout construction. However, catch basins two and three would need to be relocated to accommodate the new geometry of the intersection. Based on the direction of stormwater flow identified in the water drop analysis, the team recommends relocating them to Howard Ave. and Dewey St., as shown by the blue dots in the schematic.

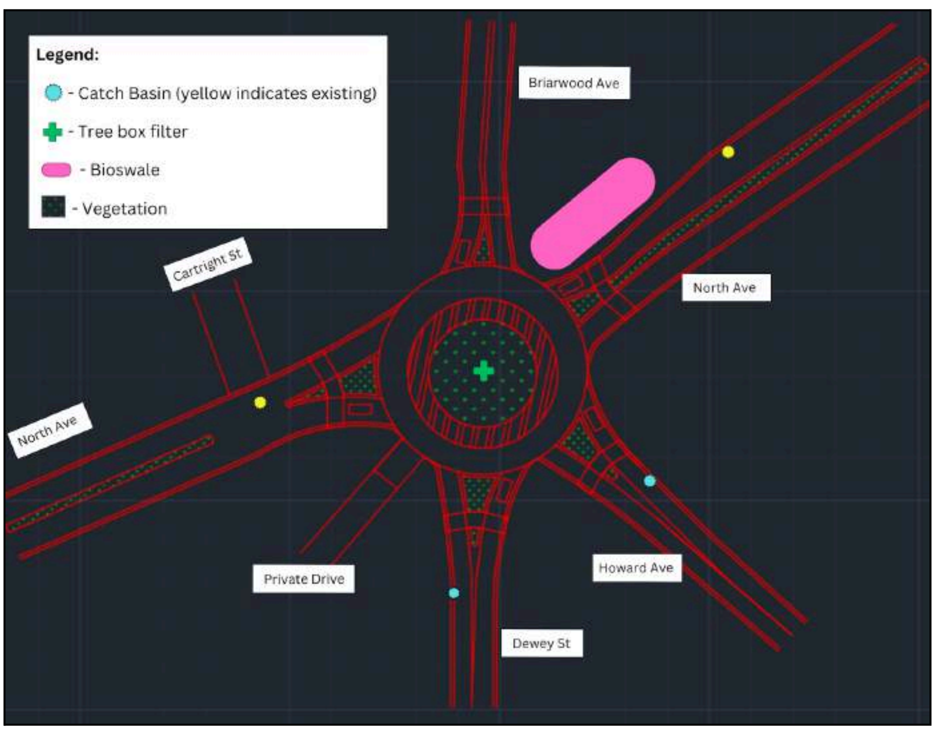

Figure 36. Diagram of recommended BMPs for the intersection.

Additional BMPs included in the recommendation are a tree box filter with vegetation in the center island, and a bioswale along the westbound side of North Ave. A tree box filter is useful for the center island because it creates lower visibility across the center of the roundabout, causing vehicles to slow down when entering and traversing. The vegetation and tree trench also allows for infiltration of stormwater. The bioswale achieves very similar stormwater management. Having a bioswale along North Ave. makes use of the additional space created by changing the geometry of the intersection for low-maintenance drainage implementation. The chosen BMPs in combination with the overall impervious surface reduction created by the center island of the roundabout and splitter islands would contribute to better runoff management. In fact, with the recommendations proposed by the team, the impervious area would be reduced from the current conditions by 18%, around 5,000 sqft.

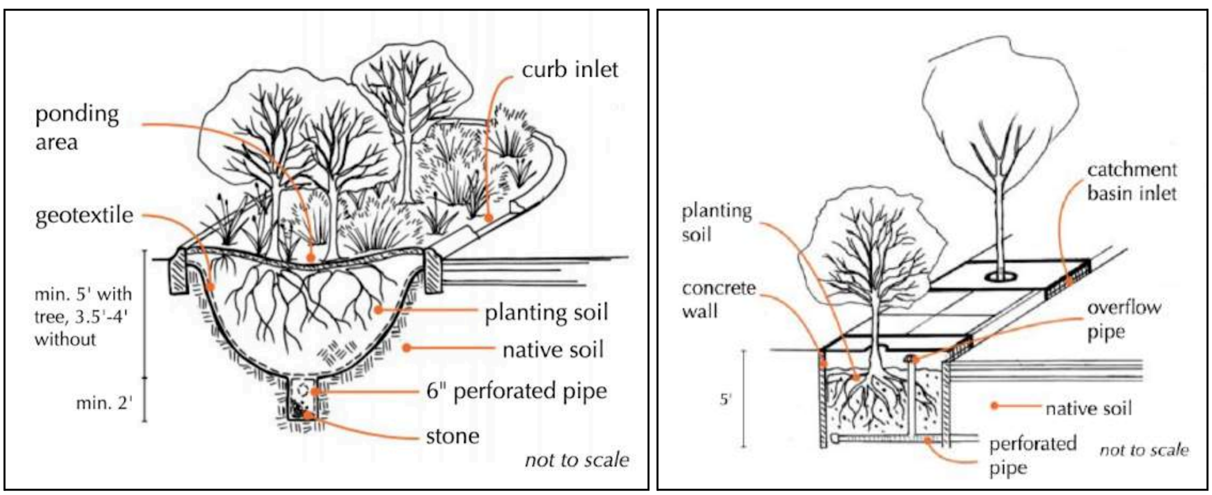

Figure 37. BMP Diagrams including a Bioswale (left) and Tree Box (right) (The Conway School, 2014).

The use of green infrastructure and LID techniques in Bridgeport will also help mitigate the urban heat island effect. Urban heat islands are formed when green spaces are replaced by urban development, like buildings and pavement which retain heat (*Reduce Urban Heat Island Effect*, 2024). This contributes to uncomfortable seasonal heat waves in urban environments, which is exacerbated by rising global temperatures caused by climate change. Additional green space creates cooler and more comfortable conditions for pedestrians and those waiting at bus stops (*Reduce Urban Heat Island Effect*, 2024).

Chapter 5: Conclusion and Recommendations

5.1: Short-term Solutions

In order to meet CTDOT's immediate goals, the curb ramps and pedestrian crossings in the intersection must be made ADA compliant. Next steps in the design process would be to create AutoCAD drawings for the 12 curb ramps in and around the intersection, correcting their geometry from their existing conditions. In order to implement safer pedestrian crossings, a traffic study would also need to be conducted. This would not only help justify the need for signalized pedestrian crossings as recommended by MUTCD, but would also be necessary to coordinate signal timing between vehicle and pedestrian traffic. It would also be beneficial to make improvements to sidewalk and curb conditions during the construction of new curb ramps in order to prioritize the safety of all users. With the VIP Paving Program, the city of Bridgeport could utilize CTDOT's resources to repair curb ramps and sidewalks while doing future roadway resurfacing work.

5.2: Long-term Solutions

Although the CTDOT's main focus is to bring crossings and other pedestrian related infrastructure in the study intersection up to ADA compliance, further research into the future of the study intersection would greatly benefit the public's best interest. The first step to accomplishing this research would be completing a comprehensive traffic study, performed to collect basic data such as vehicle volume, turning movement counts, and pedestrian foot traffic, as well as project future traffic patterns and growth. Special attention should be given to the signal at Cartright St. during the traffic study. With this data, a design team could provide an evidence-based solution to the left turn signal conflict in a roundabout design. As is, the study intersection is congested and functioning poorly for pedestrians, and a traffic study is necessary to justify any design choices that may remedy this dysfunction.

To improve the efficiency of transportation and ensure the safety of all users, the team recommends that the city of Bridgeport implement a roundabout in the study intersection using the team's conceptual design as a guide. This conceptual design also includes drainage features that plan for increasing storm events due to climate change, which is of growing importance in the coastal city.

To improve this conceptual roundabout design, the team recommends further investigation into the orientation of approaching roads to increase the deflection in the roundabout. Implementing an iterative design process that is guided by performance checks would reduce speed and increase safety for all users. In addition to a traffic study, our team also recommends a site visit be performed to collect stormwater quality data. Although a team would have to wait for significant rainfall to collect samples, the data would confirm the selected BMPs are appropriate for the site, and help to identify any other drainage issues that had not been considered in the scope of this project.

The team recommends that CTDOT and the city of Bridgeport work closely together to coordinate future planning efforts to ensure smooth operation. One challenge the team faced while designing the roundabout was limited space. Any future roundabout design efforts must be made in cooperation with nearby landowners and the city of Bridgeport, who ultimately have authority over the city's urban planning efforts. Additionally, a traffic plan that diverts and manages traffic during construction will also be necessary to mitigate congestion. The team also recommends performing a comprehensive cost estimate of the project's design and construction to determine the feasibility of a roundabout in the study intersection.

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Appendices

Appendix A: Proposal

Working with the CTDOT to address Accessibility Compliance and Stormwater Management in Bridgeport, CT

Major Qualifying Project Proposal
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Worcester Polytechnic Institute
Advisor: Suzanne LePage
Date: 13 October 2023

Capstone Design Statement

The purpose of this MQP is to redesign an intersection to assist the CTDOT with their goal of ADA compliance while addressing flooding risks and safety of all users. This project will be assessed through the lens of different constraints to determine its ability to successfully solve the problem at hand.

Economic

This project's recommendations will be cost effective for the CTDOT. The team will conduct calculations to determine the cost effectiveness of the proposed design and to ensure the CTDOT can adequately finance any associated maintenance.

Environmental

This project will be completed with consideration to various environmental factors, namely stormwater. Based on the analysis of the site, the team will propose a design that will improve stormwater management in the Bridgeport intersection.

Social

The team will assist the CTDOT by recommending a design that addresses the stormwater management in the intersection, while ensuring ADA compliance. By doing so, the team will improve the public's perception of and safety within the Bridgeport intersection.

Political

The team will consider the political implications of this project, which includes the impact of site redesign on the city of Bridgeport. Measures will be taken throughout the project to ensure the design complies with Bridgeport's municipal entities and meets the needs of residents. The site redesign, if implemented in the future, would also have to comply with town zoning and bylaws, as well as be approved by the city's planning board.

Ethical

This project will adhere to the American Society of Civil Engineers (ASCE) Code of Ethics. The team will make every effort to ensure ethical decision making throughout the project.

Health and Safety

This project addresses intersection safety for all users, meaning pedestrians, cyclists, and traffic moving through the intersection. It also considers safety of the intersection for users with accessibility needs of any kind.

Manufacturability

This project will take into consideration the capability of our design to be executed in a real world application. As such, we will consider factors such as cost, timeline of construction, and the town and public's desire for change in the intersection.

Sustainability

This project will consider sustainability in our design through the consideration of the stormwater management of the intersection. It will also consider some green engineering practices that also help improve overall sustainability

Table of Contents

Chapter 1: Introduction

As part of the State of Connecticut's efforts to reach full compliance with the Americans with Disabilities Act (ADA), the Connecticut Department of Transportation (CTDOT) is charged with assessing and upgrading the accessibility components of every intersection throughout the state. Despite this task being a large undertaking for the agency, it is ultimately in the public's best interest. Full ADA compliance increases mobility and removes barriers for disabled users, which greatly improves the quality of life for many vulnerable groups. Compliance is especially important in transportation infrastructure, like intersections, where safety for all users must be prioritized.

The goal of this MQP is to redesign an intersection to assist the CTDOT with their goal of ADA compliance while addressing flooding risks and safety of all users. The selected site (Figure 1 below) for this task is the intersection at North Ave., Dewey Street, Howard Ave., and Briarwood Ave. in Bridgeport, Connecticut.

Figure 1. An aerial view of the intersection at U.S Route 1 (North Ave.), Dewey Street, Howard Ave and Briarwood Ave, in Bridgeport, Connecticut (Google Maps).

This is a 5-way signalized intersection with five pedestrian crosswalks which are connected by 10 curb ramps, the majority of which do not meet ADA compliance. An adjacent side street, Cartright Street, is part of the same traffic signal and contains 2 additional curb ramps, with another pedestrian crossing connecting the two. The site falls directly adjacent to areas of concern for Sea, Lake, and Overland Surge from Hurricanes (SLOSH) and for various Annual Change Flood Hazards. Additionally, the intersection resides near the coastline of the state and Rooster River, which flows through the adjacent 125-Acre Mountain Grove Cemetery. This and other considerations relating to the hydrology of the area will affect how the team approaches stormwater management at the intersection.

Chapter 2: Background

2.0 Background

This section discusses necessary information for site redesign of the intersection North Ave., Dewey Street, Howard Ave., and Briarwood Ave. in Bridgeport, Connecticut. First, the history of ADA compliance will be discussed, along with current standards and systems that CTDOT uses to check compliance of pedestrian facilities. Then, important elements for intersection redesign will be considered, including stormwater management, green infrastructure, and traffic engineering. Lastly, the Bridgeport intersection site will be discussed, highlighting the necessity for the redesign elements detailed earlier.

2.1 History of ADA Compliance

There are many legal protections in place to ensure accessibility in the built environment, so both public and private spaces can be freely used by all members of the public. The Architectural Barriers Act (ABA), signed in 1968, prevents discrimination against those with physical disabilities in all buildings that are federally financed or intended to be used by the general public (*Architectural Barriers Act (ABA)*, 1986). The Americans with Disabilities Act (ADA), signed into law in 1990, federally protects against discrimination of people with disabilities on a broader scale (*Introduction to the Americans with Disabilities Act*, 2023). Another important piece of legislation is Section 504 of the 1973 Rehabilitation Act, which legally protects against discrimination to Americans with disabilities from programs and activities that receive federal funding in any capacity, and from services carried out by federal agencies (*Section 504, Rehabilitation Act of 1973*, n.d.). Both ADA and Section 504 apply directly to work conducted by any state branch of the U.S, Department of Transportation in the maintenance and construction of any transportation system.

The ADA is a tiered system, separated into 5 titles which apply the law to different environments including Employment, State and Local Government Services, Businesses Open to the Public, Telecommunications, and Other Important Requirements. The process of updating existing or new intersections to be accessible falls under Title II, State and Local Government services. Title II specifically references all service programs and activities and public transportation systems, both nationally and regionally. The Public Right-of-Way Guidelines (PROWAG) provide more detailed guidelines that can be used to uphold ADA in traffic and transportation settings (*U.S. Access Board - About PROWAG*, n.d.). The ADA Accessibility Guidelines (ADAAG), as enforced by the Department of Transportation and Department of Justice, is also used for cases of technical infeasibility where PROWAG cannot reasonably be used as the guideline for design. These tools are utilized in combination for the updating of antiquated pedestrian control facilities in all intersections across the state. As such, any time a roadway or surface is altered to achieve this goal, it is required to address ADA in these pedestrian settings in the form of legally compliant sidewalks and curb ramps. The process of amending these intersections to be ADA compliant is documented in the CTDOT’s Transition plan, which is a living document that represents the department's progress statewide. It also contains digital appendices, which are updated frequently and provide information through geographic information systems (GIS), dashboards, and other visuals for residents to understand the state of pedestrian accessibility in their communities (CTDOT, 2023).

2.2 Current ADA Standards and Compliance Procedure

The number of persons a public entity employs determines the degree of ADA compliance they are held to. Since the CTDOT passes the threshold of 50 or more employees, full compliance of Title II is required. Full compliance can be summarized into seven key steps:

general ADA compliance, designation of an ADA Coordinator, providing public notice, adopting a grievance procedure, conducting a self-evaluation, maintaining public documentation of the self-evaluations, and developing a transition plan. The CTDOT is in the process of completing these steps to reach full compliance.

As previously mentioned, the CTDOT's current Transition plan, which includes bringing the State of Connecticut's intersections up to ADA code compliance, is governed by the rules and regulations as specified by PROWAG. More specifically, chapter three of PROWAG provides the technical requirements for intersection redesign compliance, including, but not limited to, minimum clear widths and grading at pedestrian access routes, sloping, grading, and transition requirements at curb ramps, specifications of detectable walking surfaces, and other key requirements that apply to intersections, such as accessible pedestrian signal walk indications, crosswalks, and transit stops and shelters (*U.S. Access Board - About PROWAG*, n.d.). Although this chapter encompasses a wide variety of requirements for the CTDOT to follow, the agency's main goal for this project is to ensure all curb ramps are ADA compliant. To achieve this goal, the CTDOT follows a summarized list of PROWAG curb ramp requirements when working in the field (Figure 2). All other supplementary intersection redesign requirements and considerations must comply with the guidelines set forth by PROWAG.

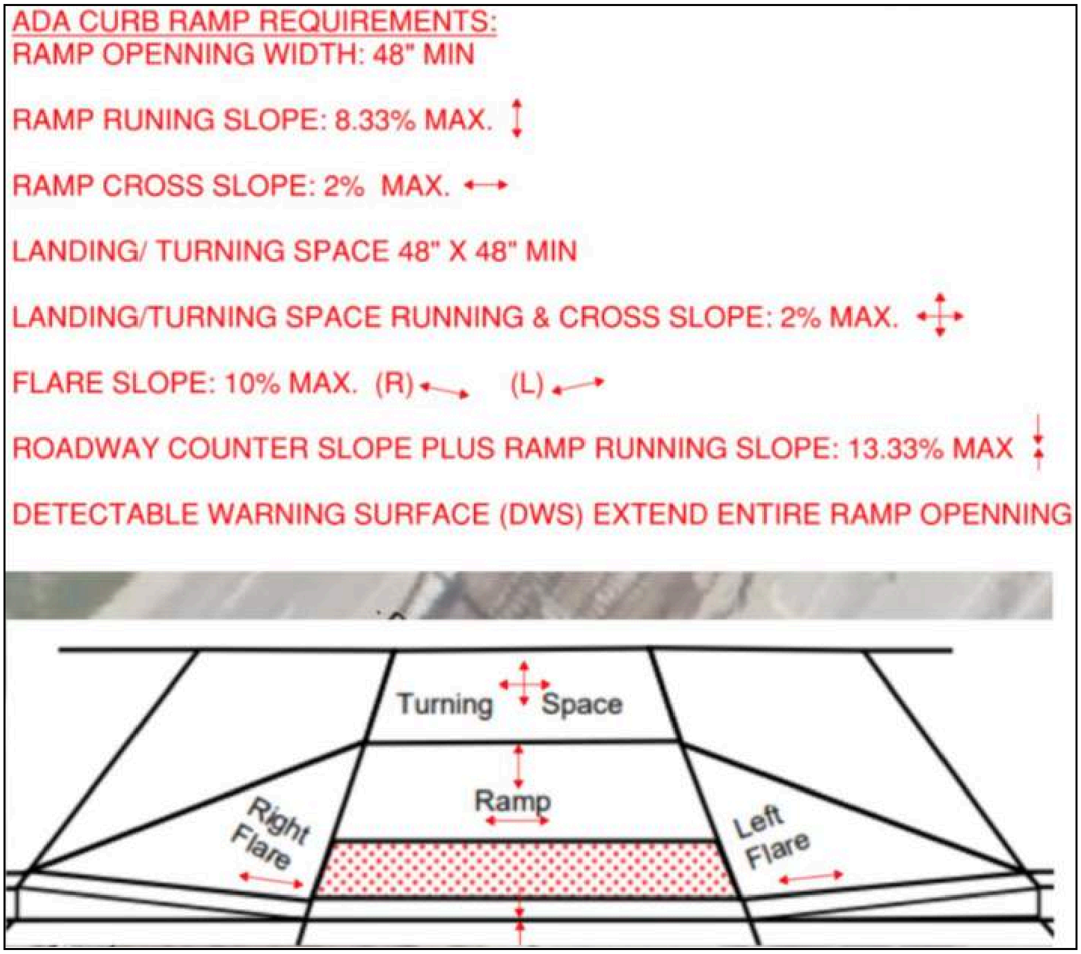

Figure 2. The CTDOT's Key Guidelines to ADA Compliance at Curb Ramps.

Although full compliance is the end goal, the CTDOT recognizes that bringing some sites up to the standard presents significant challenges that would be unnecessarily burdensome or unreasonable to pursue. Such challenges often include conflicts due to drainage, underground structures (like utilities), historic sites, and right-of-way availability (*TIFTechnicalInfeasibilityFormREV0920.Pdf*, n.d.). The CTDOT therefore has a policy regarding such Technical Infeasibilities, where waivers may be granted for ADA compliance if the proper reasoning and proof of documentation is presented. Depending on the severity of the challenge, these waivers may be temporary or long term. PROWAG recognizes these variances and allows for flexibility where existing conditions create undue challenges (*U.S. Access Board - About PROWAG*, n.d.).

2.3 Addressing Stormwater at Intersections

Stormwater management is an important consideration when redesigning an intersection. The impacts of climate change have been felt globally in recent years, with noticeable changes in regional weather patterns and a rising number of natural disasters. The Northeast specifically has seen a 70 percent increase in precipitation from intense storm events from 1958 to 2016, resulting in an increase in flooding and erosion of coastal areas (*What Climate Change Means for Massachusetts*, 2016). Connecticut alone now sees a 38% increase in precipitation annually, according to the NOAA (Wescott, 2023). Tools such as the Federal Emergency Management Agency (FEMA) Flood Hazard Layer and the Connecticut Sea, Land, and Overland Surge from Hurricane (SLOSH) Maps are useful in predicting which areas may be the hardest hit by flooding; however, these are traditionally based on historical weather patterns. As the weather patterns continue to change, these resources may become less accurate. While there are many people and agencies currently studying the impact of climate change on weather and flooding patterns, it will take time to fully establish the ways in which infrastructure will be impacted by these increases. This creates a need to increase design standards to protect against potential flooding in areas beyond what would normally be considered at risk. The harmful impacts of flooding due to climate change need to be considered in an effort to limit the detrimental impacts on local communities.

The adverse effects of flooding are worsened in impervious areas, like roadways and intersections. Oftentimes, old existing stormwater systems were not designed to accommodate large volumes of stormwater runoff from high intensity precipitation events. When these systems are overwhelmed, there is a greater risk of roadways flooding, as well as an increase of harmful contaminants in the runoff. These pollutants can then enter surrounding waterways, contributing to poor water quality in local communities (*Climate Adaptation and Stormwater Runoff*, 2023). With this in mind, it is important for engineers to make thoughtful design choices about stormwater management, and think about ways to improve existing systems.

The 2004 Connecticut Stormwater Quality Manual is the current planning and guidance tool used by regulatory agencies and communities in Connecticut when considering the design of stormwater management systems. The manual focuses heavily on practices to reduce the negative impacts of post-construction runoff. A new 2023 manual is being created to address changes in best practices and understanding of stormwater management over the last two decades (*EBC Connecticut Webinar*, 2023). CTDOT also has a 2000 Drainage Manual, used to help provide guidelines and best practices for consideration of stormwater runoff during the design and construction of roadways.

One mitigation technique for redirecting or absorbing stormwater is green infrastructure. Green infrastructure is a broad term used to describe an urban planning method created to integrate more natural features into the built environment. These practices can improve stormwater runoff management, road user happiness, local ecosystem health, and help manage excess traffic. Some of the pieces of technology used to achieve these improvements are rain gardens, bicycle corridors, widened sidewalks, bioswales, permeable pavement, and street trees among others (*Green Infrastructure*, 2012). When an intersection is being redesigned for ADA accessibility, this provides a good opportunity to also include some green infrastructure components to further improve the stormwater management and overall appeal of the area.

2.4 Traffic Engineering

Designing safe transportation infrastructure for all users is being incentivized more frequently as a direct result of recent legislation. One of the main goals of the Infrastructure and Investment Jobs Act (IIJA), passed by Congress in November 2021, is to upgrade aging and failing infrastructure through government funding (The White House, 2021). The IIJA's Safe Streets and Roads for All (SS4A) Grant Program specifically aims to address roadway and traffic safety concerns. Additionally, the State of Connecticut's "Vision Zero" Bill, passed by Congress in June 2023, aims to prevent roadway injuries and deaths. The bill requires the CTDOT to address and improve roadway safety for all users, which presents more opportunity for ADA compliance efforts (CTDOT Statement on HB5917, 2023).

The process of redesigning an intersection relies on the understanding of essential concepts of traffic engineering. This can include but is not limited to calculations related to volumes of cars and people, the shape of the intersection, line of sight, associated traffic laws and regulations, and the safety measures used to protect road users. This project will utilize part of the roadway design process, which mainly consists of three stages. The first is the conceptual design phase, which is used to establish the basic shape and road widths of the respective intersection. This relies on the existing layout information gathered through survey work or photographs (ITDP, n.d.). The designs that are created during this phase have the ability to show multiple different options for redesign while still fitting the available space and base traffic volume requirements of the area. The next two phases are preliminary design and detailed design, both of which build off the conceptual design established in the first phase. As the traffic design process progresses through each phase, more data is included for the purpose of addressing every possible component of the intersection. This includes not only traffic design components but also surrounding urban design and stormwater design, among others. This project will utilize the conceptual design phase, which will assist in the redesign of the selected intersection to meet the previously mentioned goals.

2.5 Design Guides

In addition to design requirements outlined in PROWAG and the stormwater and drainage manuals provided by CTDOT, there are other helpful design guides that the team intends to consider during the redesign process. There are also past student projects at WPI and other universities that show different approaches to intersection redesign, which we can use to inform our design approach. These resources include:

- Connecticut Department of Transportation Highway Design Manual
- National Association of Transportation Officials (NACTO) Design Guides for Intersections and Urban Street Stormwater
- 2016 University of British Columbia Design Report *NW Marine Drive/Chancellor Boulevard/East Mall Intersection Redesign*
- 2021 WPI Major Qualifying Project *Preparing for the Rise: A Study of Boston's Sea Level & Designs for Coastal Resiliency*
- 2018 WPI Major Qualifying Project *Intersection Redesign in Tewksbury, Massachusetts*

2.6 Site Specific Details

The site chosen for redesign is at the intersection of North Ave., Dewey Street, Howard Ave and Briarwood Ave, in Bridgeport, Connecticut. This signal controlled 5-way intersection sits along U.S. Route 1 in the easternmost part of the city. Figure 1 shows an aerial view of the site using Google Maps. The side street leading up to the intersection, Cartright Street, is also controlled by the same signal. It has five pedestrian crossings, two of which are signalized. There is also a pedestrian crossing at the entrance of Cartright Street. Abutting properties include a gas station, local businesses, residential buildings, and a large cemetery. Each of the intersecting roads also has sidewalks on both sides, signifying a potential for these neighborhoods to be high foot traffic areas.

This intersection had been identified by CTDOT as a site with pedestrian accessibility issues. According to their inspection, 9 out of 10 of the curb ramps in the intersection are non-compliant with PROWAG. The two curb ramps at the entrance of Cartright Street are compliant with PROWAG. Additionally, data from the UConn Crash Data Repository shows there have been 30 reported crashes in the intersection over the past 3 years (*Connecticut Crash Data Repository*, 2023). These factors point to mobility and safety concerns in this intersection for all users.

Bridgeport is a large city on the southeast coast of Connecticut. This specific intersection in Bridgeport lies near Rooster River, which flows into the larger reservoir Ash Creek and is eventually released into the Long Island Sound. Due to its proximity to these water bodies, the area is at a higher risk for flooding. FEMA National Flood Hazard Data shows the area is near 0.2 percent and 1 percent annual chance flooding zones, as shown in Figure 3 (*FEMA National Flood Hazard Layer*, 2021). Additionally, FEMA predicted sea level rise data shows that by 2050, the area will be subject to 0.8 to 1.5 feet of sea level rise, leading to increased coastal flood elevations and the expansion of these 0.2 percent and 1 percent annual chance floods (*FEMA Flood Hazard and Risk Data Viewer*, 2021). Sea, Lake, and Overland Surge from Hurricane (SLOSH) data from the US Army Corps of Engineers (Figure 4) shows the area is at high risk of inundation from hurricanes, as it lies adjacent to high risk zones (*Coastal Inundation and SLOSH*

MAPS, 2012). The effects of the changing climate on sea level rise and intense precipitation leaves this area vulnerable to hazardous flooding in the future.

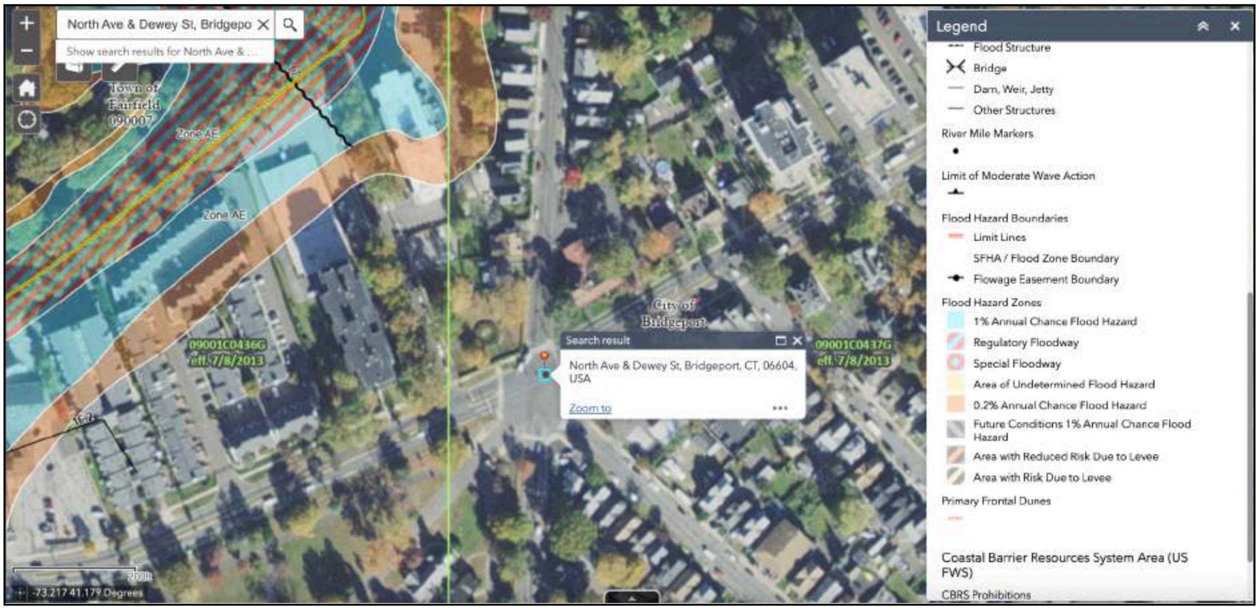

Figure 3. FEMA National Flood Hazard Layer over the selected site in Bridgeport, CT.

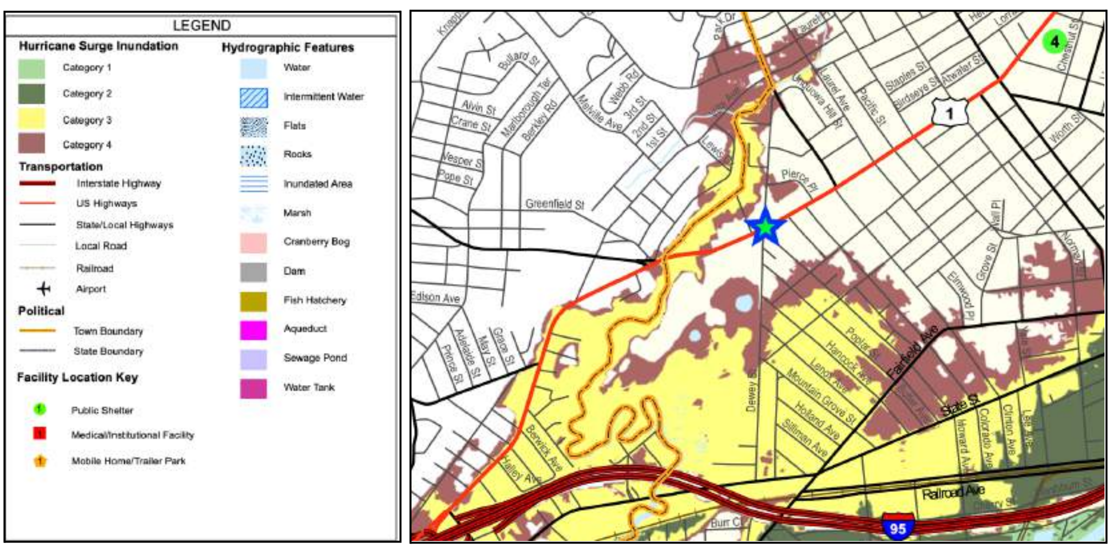

Figure 4. SLOSH Map of Bridgeport, CT. showing the selected intersection. The North Ave and Dewey Street intersection is designated by the blue star.

Chapter 3: Methods

The purpose of this MQP is to redesign an intersection to assist the CTDOT with their goal of ADA compliance while addressing flooding risks and safety of all users. We have outlined five objectives that will help us achieve our project goal. These objectives can be seen in the methods flowchart below (Figure 5).

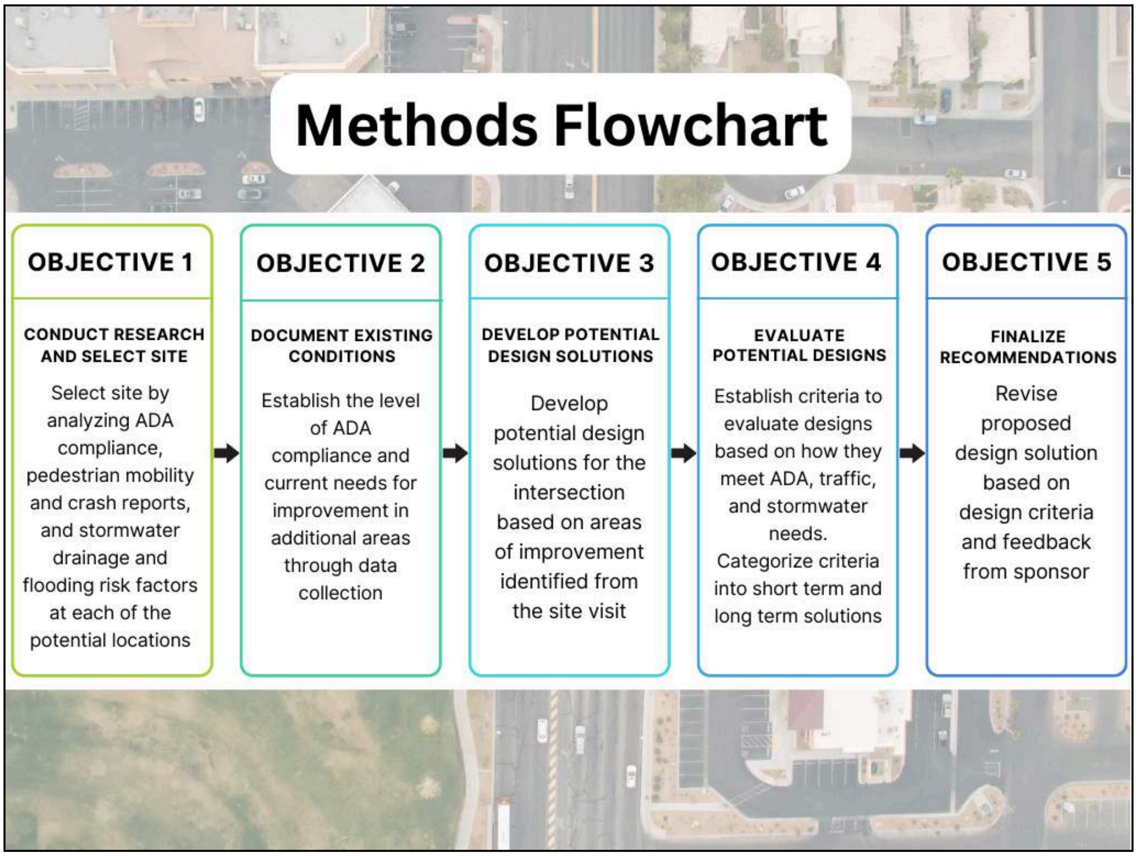

Figure 5. Flowchart of the five objectives outlined in Chapter 3 to help achieve our project goal.

A Gantt chart (Figure 6 below) was also created to apply a more specific timeline to our methods flowchart. The chart features major project milestones in addition to the objectives described in the following section.

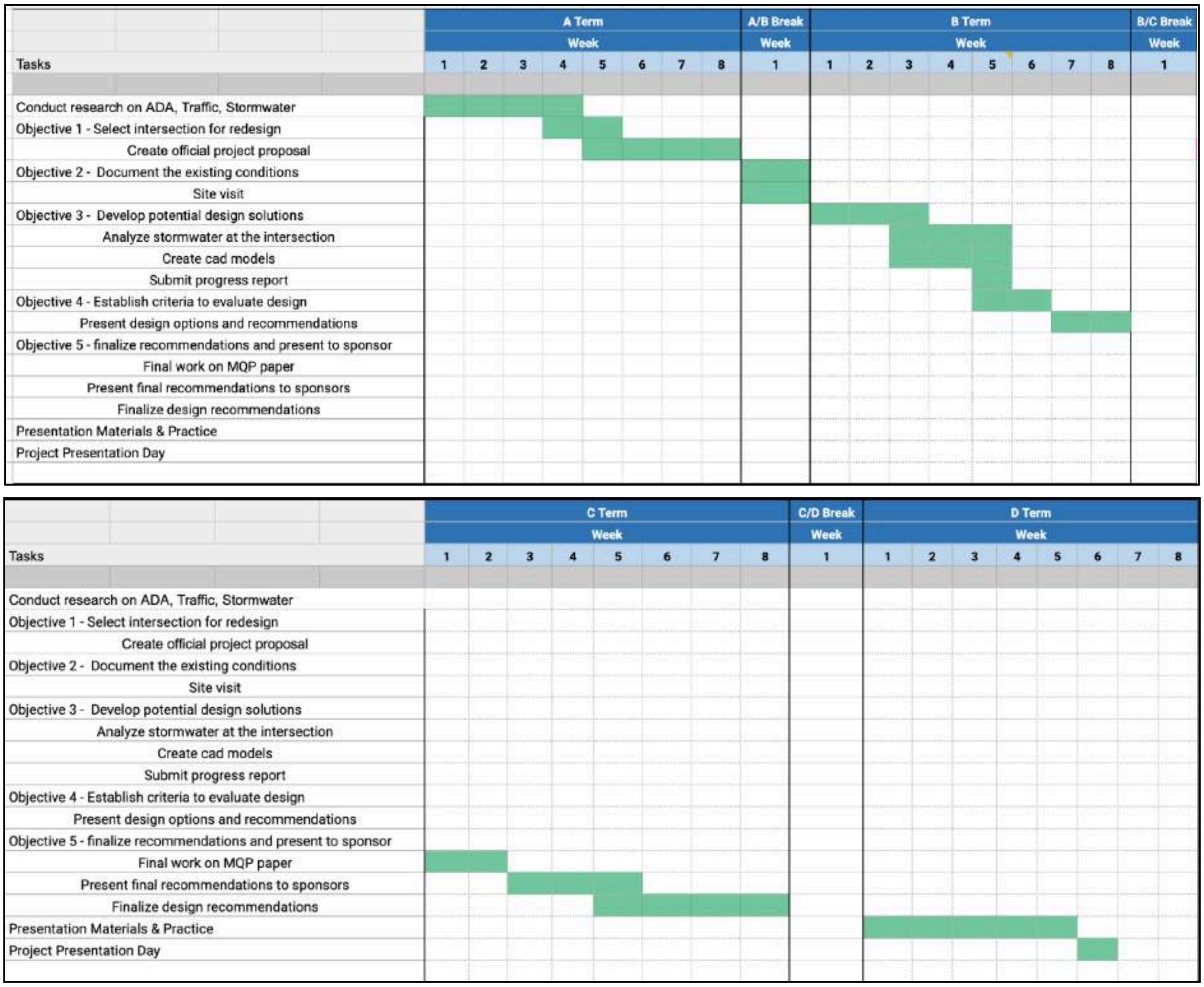

Figure 6. Gantt Chart reflecting current project timeline and major milestones.

Objective 1: Select intersection for redesign with consideration to ADA compliance, pedestrian mobility and crash reports, and stormwater drainage and potential for high risk flood events.

To address accessibility, the team utilized a list of intersections provided by the CTDOT that are considered ‘non compliant’ for the ADA. This could involve many factors related to ramp slopes, the inclusion of detectable warning strips (DWS) or lack thereof, the shape of the crossing, among other components which are specified in PROWAG.

Using a table of non-compliant intersections provided by the sponsor, the locations were considered for other improvements including flooding mitigation and safety. As such, it was crucial that the site selected also contained the potential for improvement in the areas of stormwater management and safety of road users.

To evaluate the potential for flooding, several resources were used to estimate the current risks associated with the location. One that was particularly relevant was the state Connecticut's Division of Emergency Management and Homeland Security and their Coastal Inundation and SLOSH Maps. Sea, Lake, and Overland Surge from Hurricane (SLOSH) Maps are divided into regions and used in planning to predict the potential of hurricane surges in CT. In addition to the coastline, the state also has an extensive network of rivers and other freshwater sources that can become hazardous during large storms.

The Federal Emergency Management Agency's National Flood Hazard layer was also used to cross reference the location of our intersections. Many non-compliant intersections also existed in low lying areas, which were frequently identified as being part of either the 1-percent or 2-percent chance annual flood discharge zones. The National Flood Hazard information was overlaid with the previously mentioned SLOSH maps which allowed for the identification of intersections at higher risks for potential flooding or stormwater management issues.

The Connecticut Crash Data Repository organized by the University of Connecticut was used to help identify locations where traffic safety could be improved. This web tool compiles crash data collected by state and local law enforcement officers and uses GIS to show the location of each incident. For the noncompliant intersections, the number of crashes that took place over the last 3 years was taken into consideration.

Objective 2: Document the existing conditions of the intersection through data collection.

Once we have chosen the intersection that will serve as the case study for this project, the next step is to document the existing conditions of the intersection through data collection. Since the intersection selection was in part aided by Google Maps, which may contain outdated data, the group must conduct a site visit to document the current conditions. ADA compliance is the most pressing condition of concern in the site, and data collection to assess compliance may include measuring sloping, grading, and clear width space, observing transitions at curb ramps, and assessing detectable walking surfaces. The site visit will also address the current needs for improvement in other areas of the intersection. Documenting the current conditions on site is especially important when considering that technology like Google Maps and GIS layers cannot provide all relevant data on such areas of improvement, such as utility locations, traffic signal timing, pedestrian mobility, catch basins specifications, and more.

Our group plans to document these conditions in our lab notebooks and by taking photographs of the intersection to observe how vehicles, pedestrians, and all users move through it. It should be noted that the chosen intersection may have site specific challenges that can only be observed in certain conditions, such as during inclement weather like rain or during high peak volume of vehicles. One or more site visits to the selected intersection will help to define the scope of our project and ensure that we are made aware of any site specific challenges.

Objective 3: Based on the areas of improvement identified through documentation of existing conditions in Objective 2, develop potential design solutions.

The goal of objective three is to use the information gathered during the second objective to inform the creation of several potential design solutions. As previously mentioned, the second objective focuses on data collection at the chosen site, looking primarily at the areas of ADA compliance, traffic and pedestrian mobility, and stormwater management. The team will first analyze the information we collect by identifying what needs improvement in these areas. In order to analyze the stormwater needs of the intersection, the team will model the drainage in the area using HydroCAD. The team will use precipitation data and the Natural Resources Conservation Service (NRCS) method to analyze storm size and determine the volume requirements of the drainage system in the area. These calculations and models will inform our design choices in order to improve drainage in the intersection.

We also plan to use state guidelines and existing design guides to inform our approach. A list of potential guides can be found in Section 2.5 of Background Chapter 2. We plan to incorporate 2D typical standard designs of roadway cross sections from CTDOT to help model and plan the intersection. Several designs will be created to make sure that different options and problems are being considered fully.

Objective 4: Establish criteria to evaluate design solutions and identify the most potentially effective option.

Once several design options have been created, the next step will be evaluating our options. In order to evaluate our solutions, the team will identify criteria that are important to the project's success. This could include how well the design meets ADA compliance, how it addresses flooding and traffic safety risks, and potentially considering cost or challenge of implementation as well. We will also consider the short term and long term solutions for each area of concern. We plan to use a criteria matrix, like the example shown in Table 1, to rate the solutions on a weighted scale. The best score would represent the most well rounded design solution. This evaluation, along with feedback from our sponsors, will help narrow down the best solution for our site, so that we can finalize our recommendations.

Table 1. Sample Criteria Matrix for Evaluation of our Design Solutions.

Criteria	Weight	Option 1	Option 2

ADA compliance	5		
Flood Risks	4		
Safety	3		
Cost	3		

Objective 5: Finalize recommendations based on sponsor feedback and propose a final solution.

Once our designs have been evaluated in objective four, the next step will be to choose the most effective solution and finalize our recommendations. We plan to take into account sponsor feedback and make any necessary changes to improve the design. Once the design has reached completion, the team will present the final recommendations to our sponsor, accompanied by a comprehensive written design report. Future steps taken with this project could include consideration for implementation by CTDOT.

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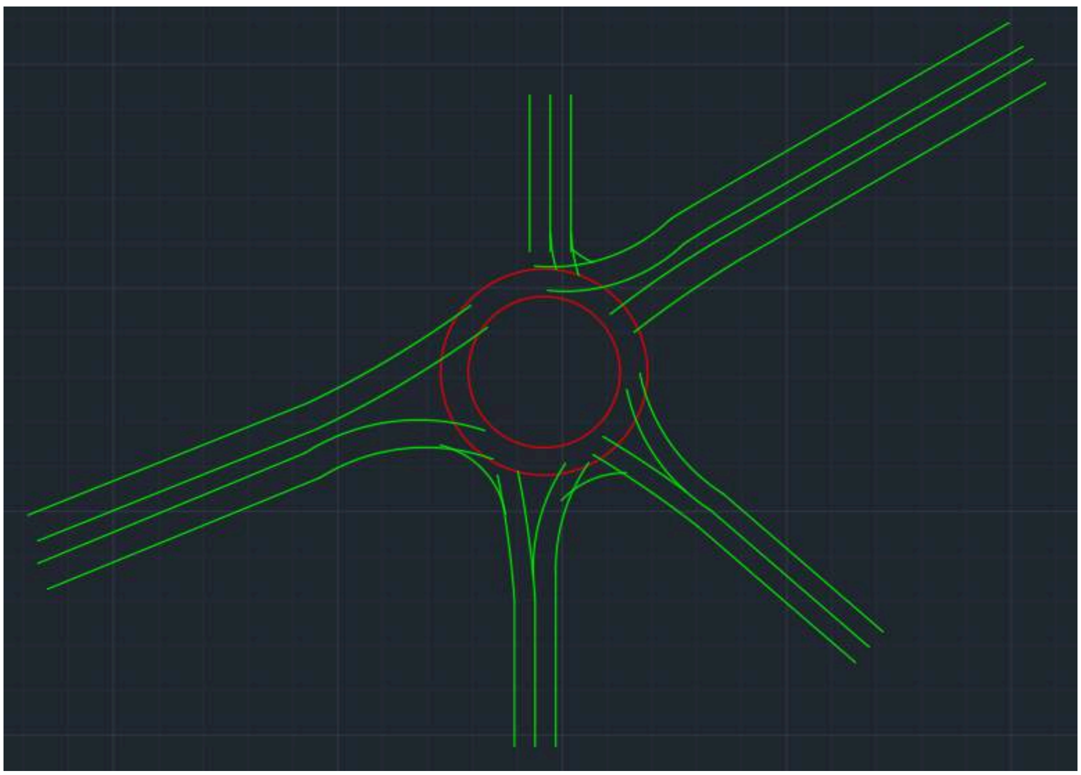
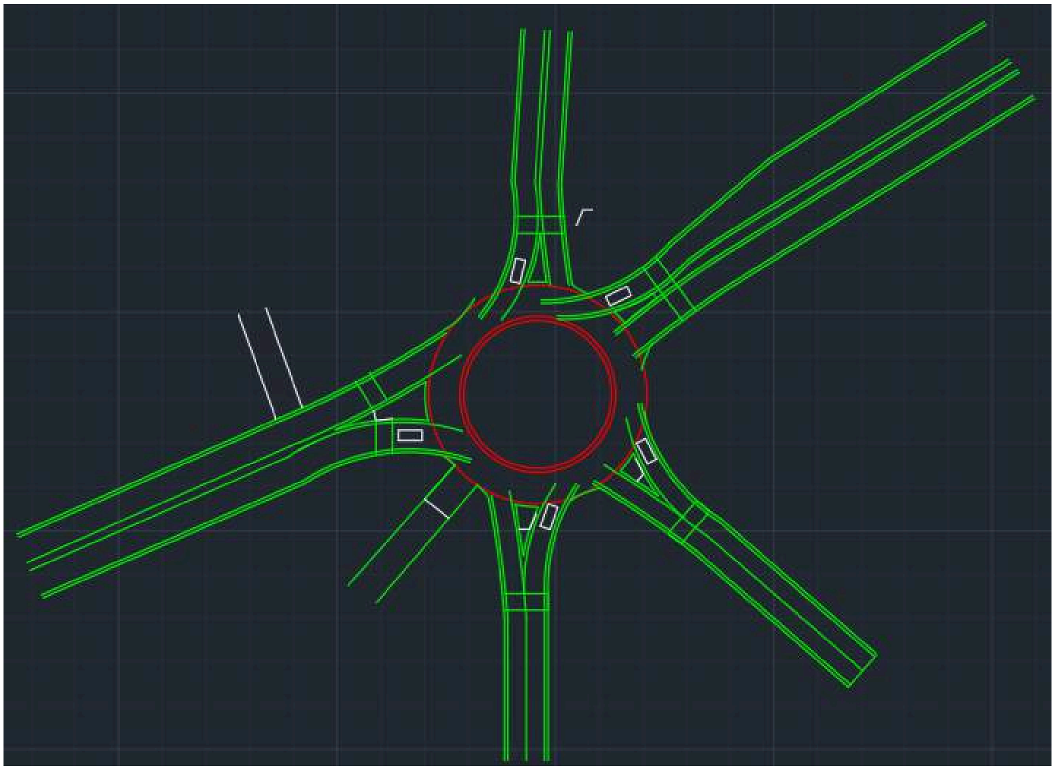
Appendix B: Roundabout Design Process

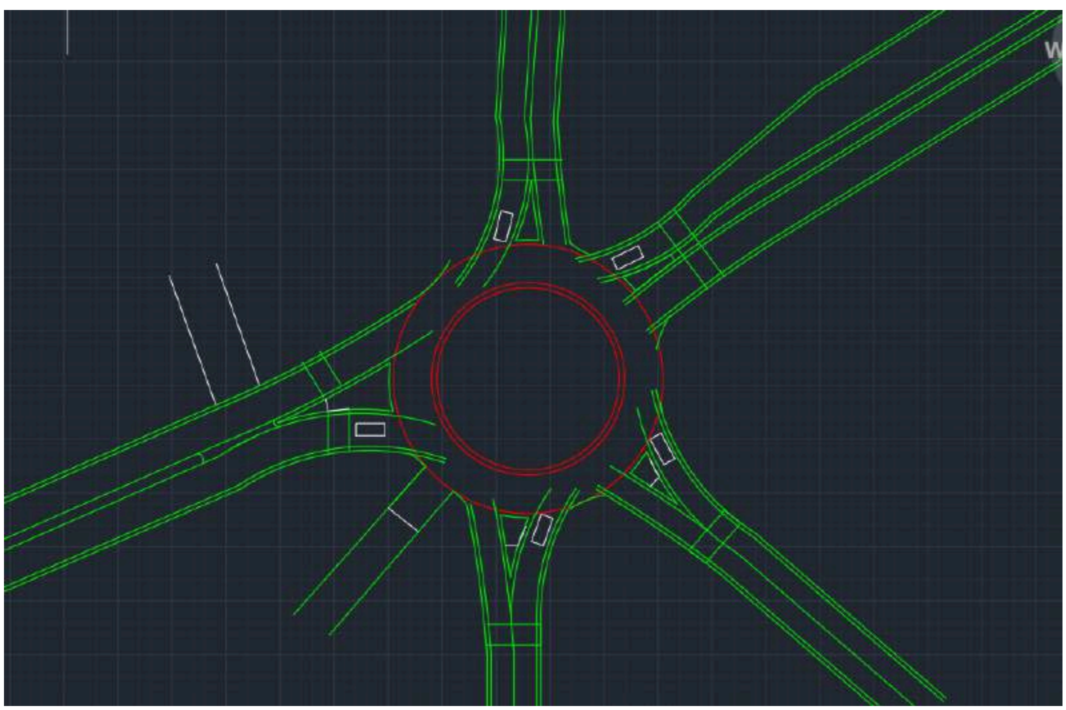
The creation of the conceptual roundabout followed a standardized design process. The images below show the progress of the intersection as it evolved over the course of three months. The design was created using the resources identified in *Section 2.5: Design Guides* on page 11. Additionally, the design was adjusted based on feedback from Scott Bushee, P.E., Principal Engineer of CTDOT's State Highway Design Unit.



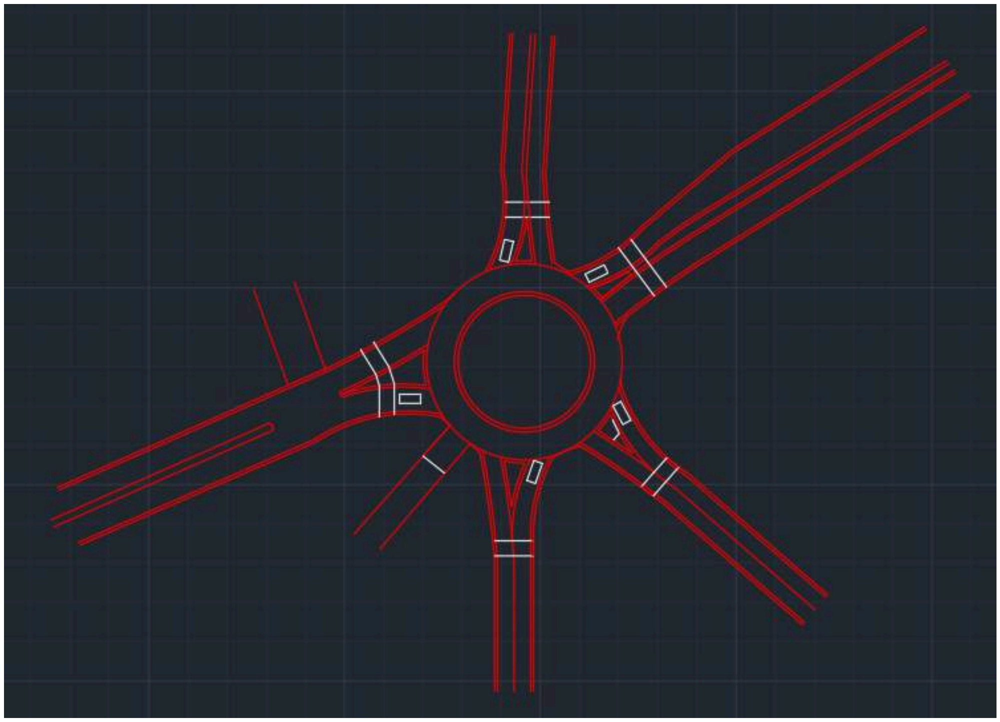
Initial sketch of the roundabout based on existing road locations.



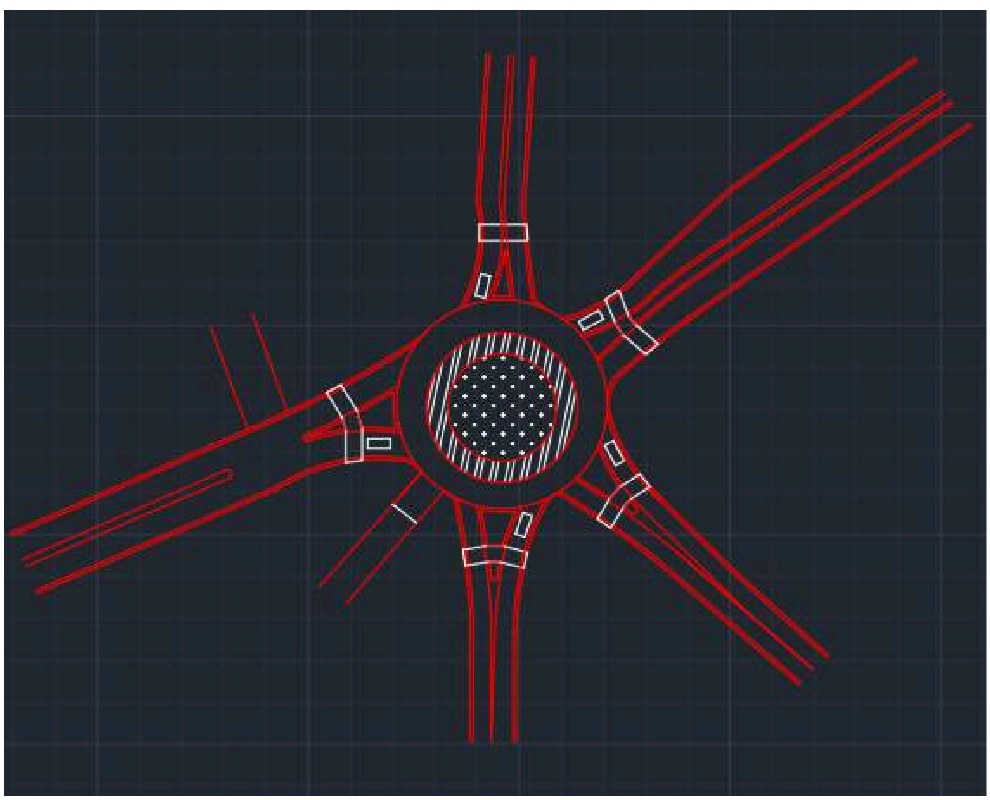
Inclusion of multiple lanes with entry and exit radii.



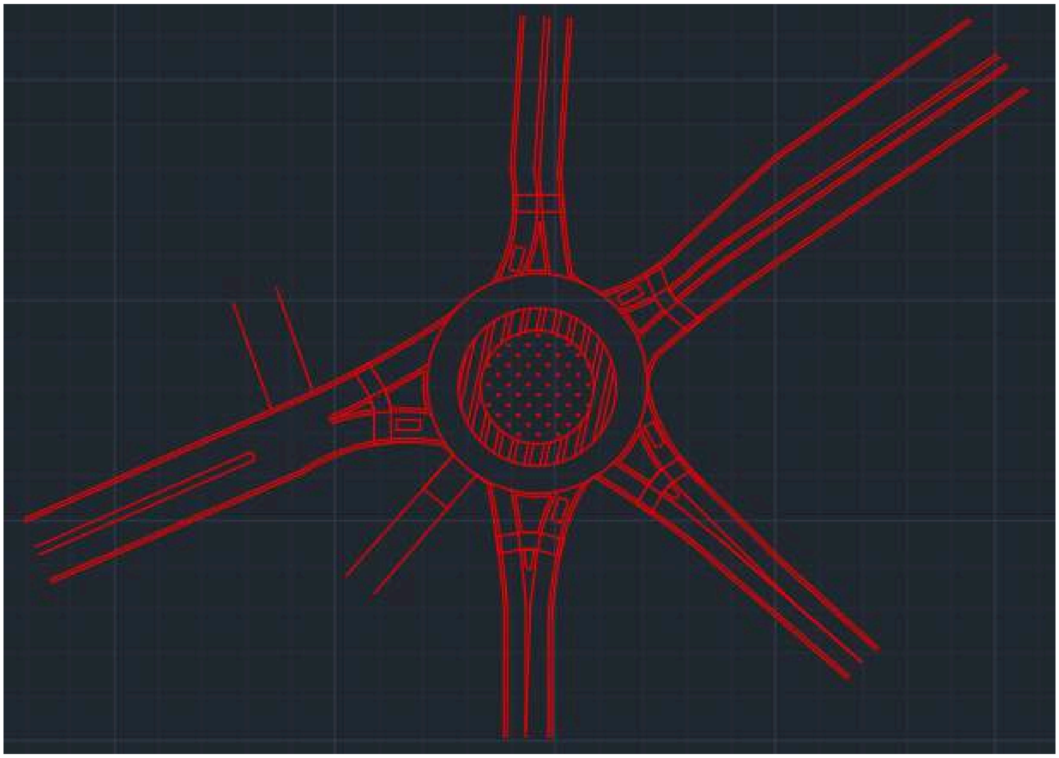
Adjustment of the deflection along North Ave.



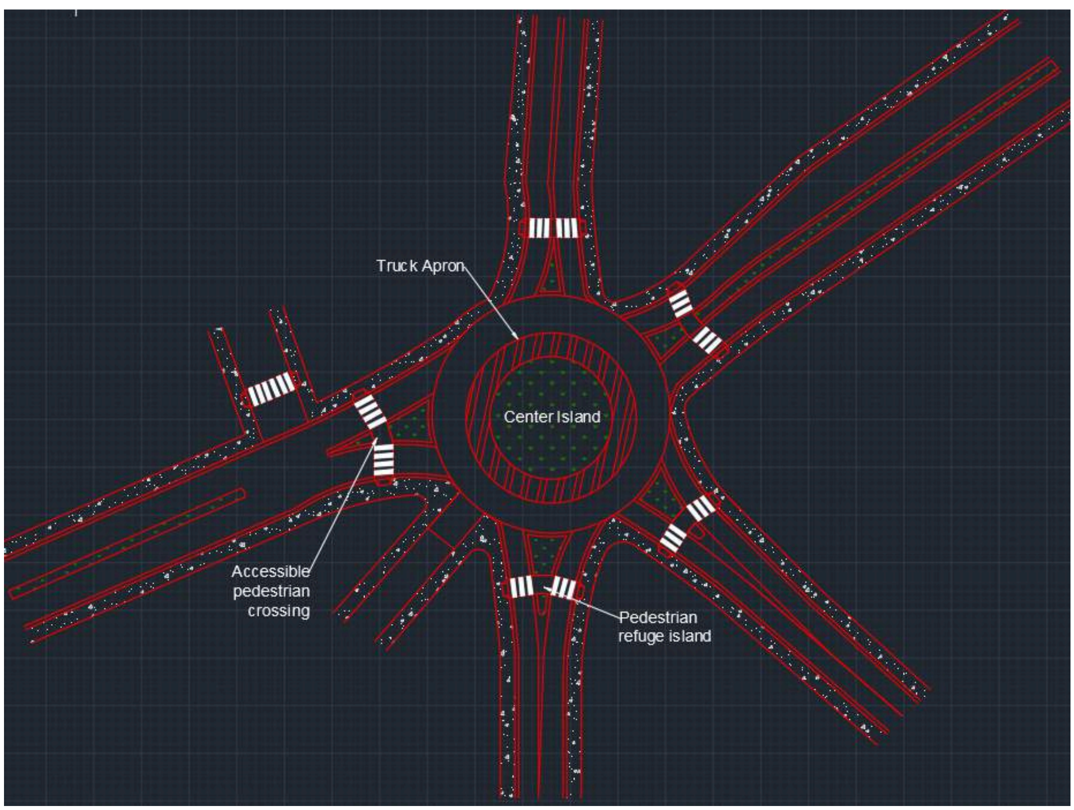
Simplification of linework to connect approach roads with intersection and updated crossings.



Expansion of the width of the truck apron to the state standard of 13 ft. and inclusion of the center island hatching.



Further simplification of the linework and splitter island design.



Final roundabout design with the addition of crossings, appropriate hatching denoting the center island and location of sidewalks, and labels.