Traffic and Safety Improvement at a Busy T-Intersection

I. Project Description

Introduction

An unsignalized T-junction at one of the local county roads which has heavy vehicular traffic and poor sight distance was deemed to be a traffic and safety hazard for vehicles and pedestrians. The situation was exacerbated by a nearby hiking trail. The county approached our university's capstone program to develop a design that would improve public safety and traffic flow. The project was completed by a team of five civil engineering seniors under the supervision of two engineers from the county (one a PE and the other an EIT) and two civil engineering faculty members (one a PE-PLS and the other a PE).

Project Background and Deliverables

Figure 1 shows the aerial view of the project site. The east-west running "Side Street" meets the north-south running "Main Street" at a T-intersection with a single stop sign on Side Street. Main Street is a two-lane road with north and south bound lanes of 10.5ft and 11ft width, respectively. The Side Street is a two-lane road with east and west bound lane widths of 11.5ft and 10.5ft. The Main Street has shoulders 1.5 to 2 ft wide while the Side Street has 6 to 8 ft wide paved shoulders.

Figure 1. Aerial View of Project Site (source: Google Maps)

The area west of the Main Street has a steep slope with dense vegetation and utility poles. The sight distance for drivers entering Main Street from Side Street is impeded by thick vegetation at the southeast corner of the intersection. This problem is worsened by the lack of street lighting at the intersection.

A multi-use trail runs parallel to and 150 ft east of Main Street. The paved trail is 10 ft wide and is heavily used by hikers, bicyclists and horse riders. The proximity of the trail to the Main Street poses a safety hazard to the trail users, especially if the drivers turning from Main Street into Side Street do not slow down despite signages posted on Main Street.

The area between the Main Street and the trail is designated wetland and thus identified as critical area. The area south of the Side Street is privately owned.

Although the area surrounding the intersection is classified as rural and has a mix of commercial and residential property use, the Average Daily Traffic (ADT) has increased from 7,600 in 2016 to 10,040 in 2021 and is anticipated to grow to 15,600 by 2035.
The county requested the team to evaluate various design alternatives to improve safety at the intersection, select a preferred option and take it to 30% design.

In developing their design alternatives, the team addressed a variety of factors including trail safety hazards, overhead utility poles, underground utilities, sight distances, right of way acquisition, wetland mitigation, environmental impact and cost.

Design Alternatives Investigated

After some brainstorming sessions, the team decided to evaluate four alternatives of which the first three are presented in Figure 2:

a) **Single-Lane Roundabout** maintains continuous flow around a central island at the intersection.
b) **Three-way stop** reduces traffic congestion by adjusting the number of travel lanes and lane widths to accommodate through and turning traffic.
c) **Traffic Signal** incorporates traffic lights at the junction in addition to adjusting the number of travel lanes as described in b).
d) **No-build** leaves the intersection as-is; this option serves as a reference and helps compare how options a) through c) would improve the intersection.

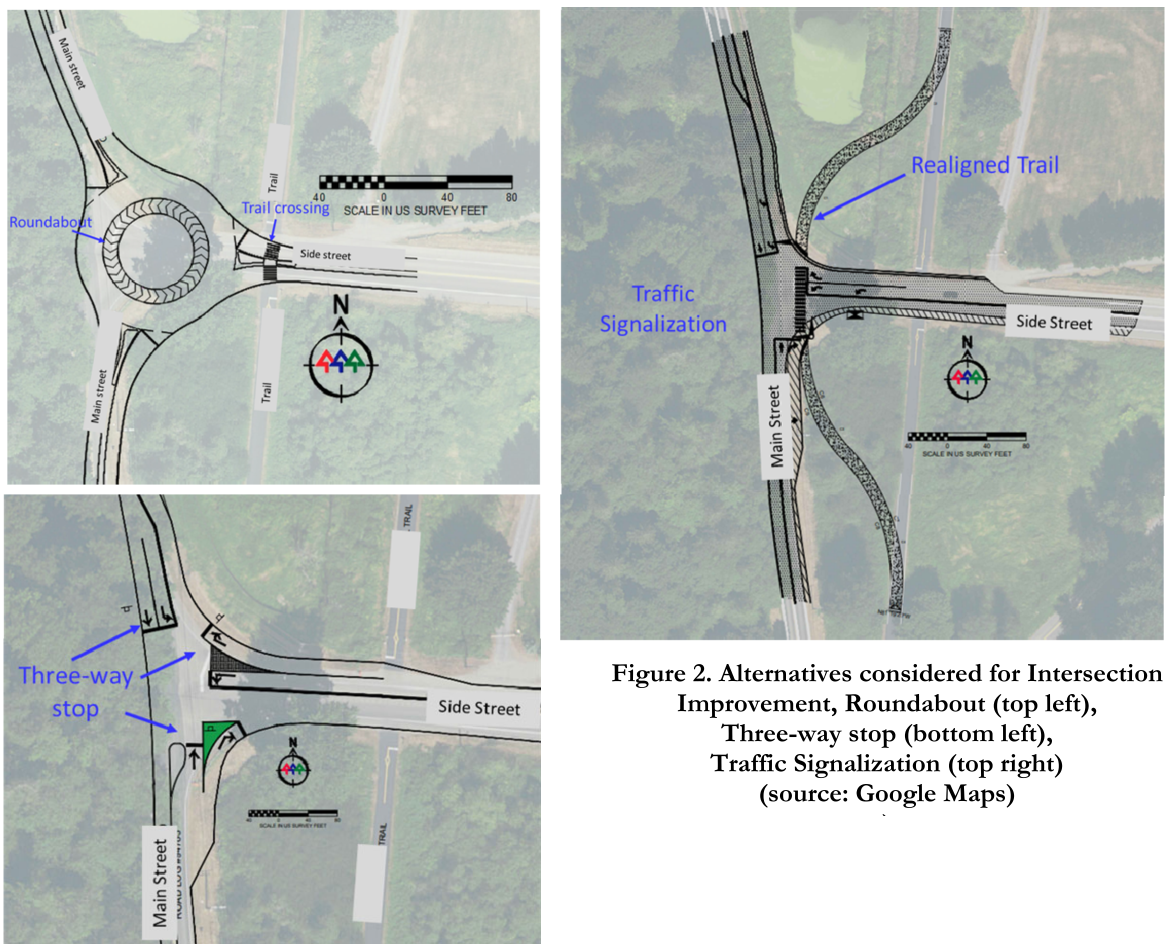

Figure 2. Alternatives considered for Intersection Improvement, Roundabout (top left), Three-way stop (bottom left), Traffic Signalization (top right) (source: Google Maps)

Evaluation of Alternatives

The team came up with a preliminary design for each alternative; then it evaluated the alternative for traffic collision reduction, non-motorized (pedestrian and bicyclists) improvement, traffic operations (evaluated through a level of service (LOS) analysis where LOS designation of A is the best traffic flow and LOS of F is the worst traffic), construction and maintenance costs, environmental impact (evaluated by its impacts on the surrounding wetland, amount of earthwork involved and impervious surface added) and right of way (ROW) acquisition. Each of the above seven factors was rated on a scale of 1 (worst) to 5 (best). This information was then compiled into a decision matrix to select the preferred alternative. These details are summarized below for each option.

Roundabout at the intersection is within an inscribed circle of 130 ft. The trail crossing is a 10 ft wide cross walk within the splitter island on Side Street as seen in Figure 2. Traffic analysis showed that this option resulted in a minimum Level of Service (LOS) of C. Although this option improves driver safety by eliminating collisions it does not improve non-motorized user safety. This option resulted in the highest cost of installation of $2.9 million of all options and the highest right of way (ROW) acquisition of 7,000 sq ft. This option impacts the adjacent wetland and involves the highest amount of earthwork and impervious surface area and thus has adverse environmental impact.

Three-way stop adds a left turn lane on southbound Main Street, a right turn lane on northbound Main Street and a right turn lane on westbound Side Street. It has a minimum LOS of C due to the stop-and-go nature of stop signs. Though this option improves driver safety, because the trail alignment is left unaltered, pedestrian safety is not improved. The three-way stop has a relatively low cost of installation of $655,000. This option does require 1000 sq. ft ROW acquisition. It does impact surrounding wetland and has lowest earthwork.

Traffic Signalization option consists of the three added turn lanes as described under three-way stop along with the combination of traffic signal lights. In addition, the trail is realigned such that it crosses the Side Street at the T-intersection (as shown in Fig 2) which greatly improves non-motorized user safety. For this option, the overall LOS was a B; traffic collision was reduced significantly. This option has the second highest cost of $2.1M. It has ROW acquisition of 5,000 sq. ft. and impacts the wetland and has moderate earthwork.

No-Build option was analyzed to compare the other three options to the existing condition. The LOS was similar to that of re-channelization. Driver and pedestrian safety were very low due to time taken for left-turn decision making. Traffic collision reduction was also low due to the number of conflict points in the case of drivers, and unsignalized crossing in the case of the pedestrians. There is no construction/maintenance cost, ROW acquisition or adverse environmental impact.

Table 1 presents the decision matrix for the four alternatives. The traffic signal option received the highest score and thus was chosen as the preferred alternative.

Table 1. Decision Matrix of the four alternatives*

Alternative	Roundabout	3-way stop	Traffic Signal	No build
Traffic collision reduction	5	4	5	1
Non-motorized improvement	1	1	5	1
Traffic Operations	4	1	3	1
Construction costs	1	4	3	5
Maintenance cost	3	4	2	5
Environmental Impacts	1	5	4	5
Right of Way impacts	1	5	4	5
Total	16	24	26	23

* Each factor ranked on a scale of 1(worst) to 5(best)

30% Design of Preferred Alternative of Traffic Signal

The 30% design consisted of signal warrant analysis, utility relocation, storm water control, best management practices, engineer's cost estimate and a complete engineering plan set.

The team carried out a signal warrant analysis and confirmed that a traffic signal was needed at the intersection. Based on the site survey and field observations the team identified that power, fiber optics and storm drainage as utilities that need be relocated and informed the county of its findings to coordinate with the utility companies prior to construction.

The team designed a storm water control and pollution prevention system as shown in Figure 3. Catch basins placed at 250 ft intervals on the west side of Main Street will route the storm water to the bio-retention swales placed along the perimeter on the east side of the Main Street and both sides of Side Street. Bio-retention swales enable pollution removal through infiltration through engineered media. The swales are connected by 12" polyethylene pipe to a stormwater detention pond located at the southeast corner of the intersection as shown in Figure 3. Water will discharge into the wetland (which is explained in the next paragraph) through a flow control structure.

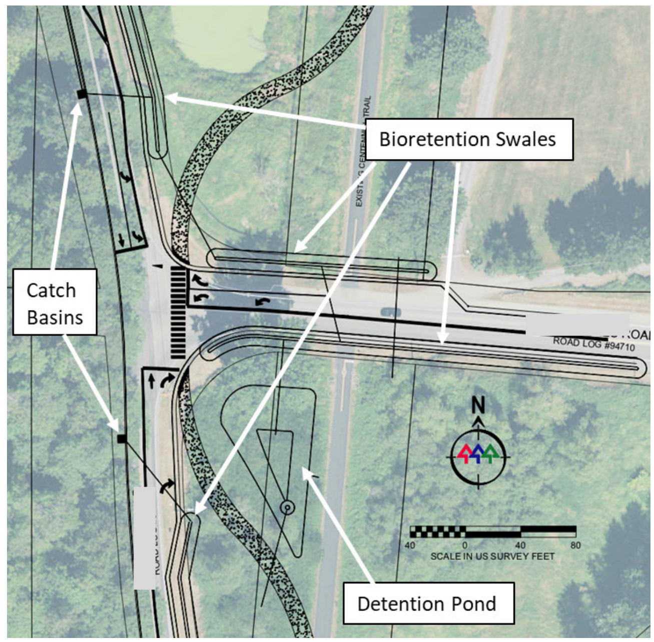

Figure 3. Stormwater and Pollution Control Plan for the Preferred Alternative

The proposed alternative was found to impact about 14,000 sq ft of the surrounding wetland. Therefore, the team came up with a wetland mitigation plan as shown in Figure 4. The area east of the trail and south of Side Street was dedicated to wetland mitigation. The plan included removal of invasive plants such as blackberry shrubs and planting native species such as salmon berry and thimble berry. In addition, adding willows and woody debris would encourage native, small animal species to return and increase the function of the wetland.

The team performed a preliminary engineering cost estimate for the project, the details of which are presented in the poster. Finally, the team prepared a set of professional quality engineering drawings showing the channelization (ie. the modified lane configuration), typical roadway cross sections, roadway paving plan, storm water drainage plans and traffic control plan to be used during construction. Excerpts of the engineering drawings are presented in the accompanying poster.

II. Collaboration of Faculty, Students and Licensed Professional Engineers

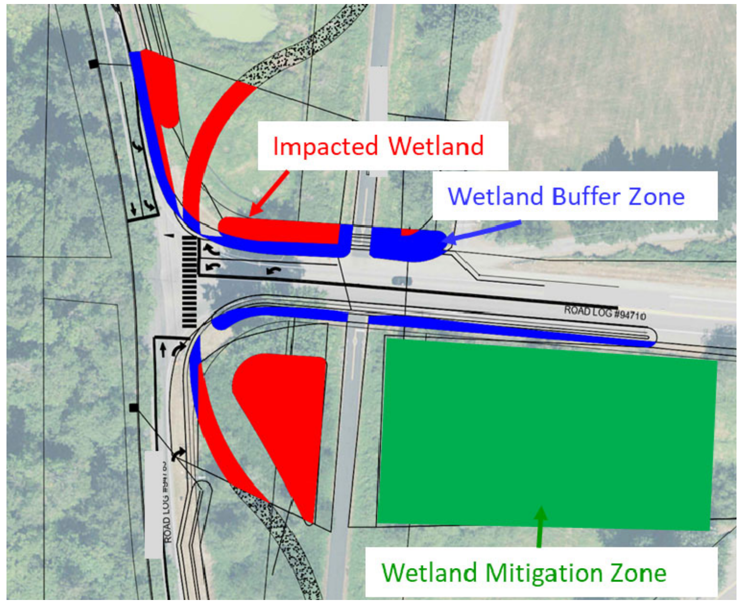

Figure 4. Wetland Mitigation Plan (Impacted wetland in red; wetland buffer zone in blue)

All engineering students in our institution complete a year-long capstone project for an external sponsor. A team of five students worked on this project under the supervision of two liaison engineers from the county (one a PE and the other an EIT) and a faculty member from the university who is a PE-PLS. In addition, the senior design course is taught by a faculty member who is a PE. The students met weekly with the faculty advisor and had weekly conference calls with the county liaisons. The faculty members and the liaisons provided feedback on the proposal, design and final report throughout the academic year.

Our department has an active advisory board consisting of eight licensed, local civil engineering practitioners and meets twice yearly to discuss industry-academic partnership related issues. The team made an oral presentation to the board early in the academic year describing their project scope and plan of action. The board members attended the project completion presentations at the end of the academic year.

The team participated in a presentation competition organized by a local professional society. The presentations were judged by a panel of five civil engineering PEs.

The team presented their work to the county twice – first to present the project understanding and approach in the early part of the academic year and next to present their completed work towards the end of school year. Diverse groups of professionals attended these presentations. The students found these presentations to be quite challenging due to the extensive knowledge and experience of the audience and the questions asked, but found it to be a great career growth experience.

III. Protection of Health, Safety and/or Welfare of the Public

The intersection is heavily used by semi-trucks; horizontal sight distance is a major issue for vehicles turning south from Side Street to Main Street; the nearby hiking trail poses a safety hazard to its users due to its proximity to the intersection. Therefore, the project impetus was pedestrian, driver and trail user safety and welfare.

Stormwater analysis, detention facility design and wetland mitigation issues gave the students an appreciation for public health and welfare issues in engineering projects.

IV. Multidiscipline and/or Allied Profession Participation

This project encompassed multiple disciplines within civil engineering: transportation for roadway design, environmental and water resources for storm water analyses, detention facility design and wetland mitigation. The team also carried out land surveying of the intersection to obtain any missing information of the site. Students also acquired knowledge in construction and cost estimating. Furthermore, the team needed strong drafting skills to produce professional quality engineering drawings. To facilitate this, the county provided training sessions to the team on Civil 3D drafting software.

V. Knowledge and/or Skills Gained

The project enabled the students to develop the following: technical skills, oral and written communication skills, project management and leadership skills, ability to work in a team setting and to interact with clients.

a) Technical skills

The project gave the students an opportunity to apply what they have learned from the various civil engineering sub-disciplines (transportation, water, environmental) in a real-life project. Along the way they acquired the skill to use the following tools:

- Federal and State Design Manuals, Standards, Specifications and Guidelines: Highway Capacity Manual, Federal Highway Administration Design Manual, State Department of Transportation design manual and Cost Estimating Manual.
- County Design Guidelines: Engineering Design and Development Standards, Drainage Manual.
- Computer aided drafting using AutoCAD and AutoDesk Civil 3D 2018.
- Design Software: Synchro® traffic planning and analysis software.

b) Communication skills

The students submitted a written proposal to the county early in the academic year outlining their understanding of the project, scope of work, plan of implementation, work breakdown structure and schedule. At the end of the academic year, they submitted a final report describing the work done, analysis, and engineering drawing.

Throughout the year the team worked in a hybrid environment with a mix of in-person and virtual meetings. The county office was located about 30 miles away from campus thus the virtual meetings cut down on the travel time for all project participants.

The students made oral presentations to their peers several times during the year. In addition, they presented their proposed work to the county early in the year and their final design recommendations at the end of the year. The academic year concluded with a mini-conference style event, where the team presented its work to the entire university community, sponsors of all senior capstone projects from all engineering disciplines, current and prospective sponsors, friends, family and alumni.

c) Project Management and Leadership skills

The student team met with the faculty advisor weekly and with the county engineers biweekly. Each student served as the project manager (PM) for part of the academic year. The PM responsibilities comprised of setting up the team meetings, developing meeting agendas, conducting the meetings, assigning tasks and following up on action items, and contacting the liaison and the faculty advisor in between team meetings, when needed.

VI. SUMMARY

A local county requested improvement to one of its T-intersections. A team of five civil engineering seniors worked under the supervision of two engineers (one a PE and the other an EIT) from the county and two licensed faculty members (a PE and a PE-PLS). The team evaluated four options (round about, three-way stop, traffic signalization and no build) for traffic collision reduction, non-motorized (pedestrian and bicyclists) improvements, traffic operations (level of service analysis), construction and maintenance costs, environmental impact, and right of way acquisition. Using the decision matrix and with the county's guidance, the team selected traffic signalized intersection as the preferred alternative. The students took the preferred alternative to 30% design which comprised of roadway and storm water design, wetland mitigation, preparation of engineering drawings, cost estimation, and traffic control plan during construction. This capstone experience gave the students an opportunity to acquire and apply technical skills to solve a real-world problem. It also demonstrated the relevance of health, safety, and welfare of the public in engineering projects. The students learned to use various design manuals, engineering software, and honed their written and oral presentation skills. The team developed project management, leadership, and communication skills through this project.