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Bridge and Intersection Design at Louisiana State University

Anna R. Gore

Worcester Polytechnic Institute

Megan Anna Hanshaw

Worcester Polytechnic Institute

Taylor Venter

Worcester Polytechnic Institute

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Bridge and Intersection Design at Louisiana State University

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

Anna Gore
Megan Hanshaw
Taylor Venter

March 14, 2018

Advisors:
Leonard Albano
Suzanne LePage



Abstract

The purpose of this project was to provide an intersection design and a structural bridge design for Louisiana State University to achieve the mobility goals of the LSU Master Plan. The team determined technical bridge and intersection design components and created three preliminary intersection and bridge designs. The final recommendation was to build a Warren Truss bridge and an intersection that encourages walking and biking with design features including a shared space for pedestrians and cyclists, bike crossings, and crosswalks.

Executive Summary

In an effort to develop and modernize the entire campus, Louisiana State University has developed a Master Plan. One of the goals outlined in this plan is to increase the mobility on campus in order to improve safety on campus, reduce conflicts between cars, bikes, and pedestrians, and define a mode of transportation hierarchy. This hierarchy will be comprised of a pedestrian core, two transit spines, a bike and pedestrian spine connecting the core of campus to the periphery, and parking pushed from the core of campus to the perimeter. One of the areas LSU aims to redevelop is the eastern edge of campus adjacent to the Corporation Canal. This area will have residential halls, a new athletic center, and a parking garage built in the future. To increase the mobility within this area of campus, a new bridge will be built for transit and a new road will be made, creating an intersection.

The goal of this Major Qualifying Project (MQP) was to work in conjunction with Stantec Consulting Services Ltd to provide LSU with a preliminary structural design for a bridge and adjoining intersection to support LSU's campus transportation improvements. The existing bridge crosses over Corporation Canal from South Campus Drive. The proposed intersection would be an extension of South Campus Drive west that connects to West Lakeshore Drive and a new road extending north called Veterans Drive.



Proposed East side of LSU campus and Corporation Canal

To achieve the project goal, the following objectives were defined:

1. Determined technical components, government standards, and industry regulations involved in bridge and intersection design
2. Document existing and proposed conditions
3. Evaluate obtained information versus industry standards and regulations
4. Using guidelines, produce multiple design options
5. Refine the preliminary designs into a final design
6. Assess final design based on project goals to show successes and areas for improvement of the design
7. Present recommendations to Stantec

To understand the technical components involved in bridge and intersection design, the team gathered information using sources such as the *Manual on Uniform Traffic Control Devices*, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the National Association of City Transportation Officials. Next, the team documented the existing conditions of the site using the LSU Master Plan and images obtained on the internet. The proposed conditions were documented using the LSU Master Plan and AutoCAD drawings provided by the sponsor. During the evaluation stage, the team evaluated the preliminary designs for compliance with applicable regulations and industry standards. The team was able to use the guidelines to produce three preliminary design options. After a meeting with the sponsor, the team received feedback from Stantec professionals about the functionality, intuitiveness, efficiency, and other assets of the designs. The project team then synthesized the three design options and sponsor feedback into a fourth and final design.

The final intersection design included a multi-use cyclist and pedestrian space in the east-west direction as well as a two-way stop on one approach as traffic control, four-way pedestrian crossing, designated bike crossings, and a buffer between the transit route and the pedestrian and

cyclist multi-use space. This project concluded that a Warren Truss bridge design best satisfied the project requirements.

To evaluate the final design, the project team used eight project goals: economic; environmental; sustainability; efficiency; intuitiveness; ethics; social and political; and health and safety. After evaluating the final design to show the successes and areas of improvement for the design, the team determined that it completely met five of the goals, partially met two of the goals, and did not meet one of the goals. The team recommended Stantec and Louisiana State University create a weighted matrix, so LSU can adjust the design to best align with their needs at the point of construction and their current progress in executing the Master Plan.

Acknowledgements

The completion of this project would not have been possible without the help of the following people. We first want to thank Worcester Polytechnic Institute for the opportunity to experience working in the professional world as students. We would like to thank Stantec Consulting Services, Ltd. for the resources, time, and workspace they gave to us to help us complete our project. Specifically, we would like to thank our sponsor Tom Yardley, along with Betsy Kirtland, Ryan Marshall, and Jason Schreiber for their help in the areas of planning, transportation design, and structural design, which was vital to the development of the final project. Additionally, we especially would like to thank our advisors Leonard Albano and Suzanne LePage for their guidance, support, and feedback throughout the entire MQP process.

Authorship

The project team worked as a unit to complete the MQP report. Project team member Anna Gore primarily wrote the structural bridge sections including the background, methodology, and results as her concentration is structural engineering. Project team members Taylor Venter and Megan Hanshaw primarily wrote the intersection design sections as well as the intersection background, methodology and results. The team worked together to write and edit the rest of the report.

Capstone Design Statement

The Civil and Environmental Engineering program at WPI requires all Major Qualifying Projects (MQPs) to include a Capstone Design Experience to meet Accreditation Board for Engineering and Technology (ABET) objectives. Through the MQP students demonstrate their engineering design knowledge. To meet this requirement, this MQP proposed an intersection design and new bridge design located at Louisiana State University. Due to the fact that the project team was unable to visit the project site, the team relied on the project sponsor to supply the necessary data and observations. The project team determined design criteria and developed several preliminary designs for the intersection and bridge before selecting a final design. All designs followed state and federal transportation standards and complied with all state and national bridge structural codes. In this report, calculations were shown including loads for the bridge, turning radii for the intersection, and the necessary intersection type based on traffic volume and flow. This Major Qualifying Project is intended to satisfy the ABET requirements as it is a culmination of earlier course work and incorporates engineering standards with realistic constraints in the design. The constraints imposed on this alternative design considered construction economics, environmental factors, sustainability, constructability, social, political, ethical, and safety factors. The final design was selected based on these constraints and using the knowledge the team garnered at WPI.

Economic

Since this is a small portion of the larger Master Plan for the redesign of LSU's campus transportation, economic factors must be considered when developing the design to account for the allocated budget. The project team conducted cost analyses for the principle members of each bridge design, and evaluated the cost of each intersection relative to other designs as opposed to

assigning each a numeric value. The budget for this portion of Master Plan was not available. Therefore, the team gave a recommendation for Stantec and LSU to further examine the costs of the intersection and bridge designs.

Environmental

One of the goals of the Master Plan is “to promote environmental stewardship”, primarily through encouraging more students, faculty, and staff to walk and use public transportation instead of driving through campus and parking in the campus core.¹ The design of this bridge and intersection supported that vision by ensuring the ease of cyclists, pedestrians, and public transportation when navigating through the intersection and over the bridge.

Sustainability

This bridge and intersection design are part of a larger plan for transportation improvements that rely on transit and vehicle passage through this area, which will not be possible if the designs do not have a sustained design life. The bridge and intersection were designed with the consideration that the design could be implemented in many locations throughout campus to increase continuity. Both designs were created with the intent that they would withstand a long design life and be adaptable to other changes that may happen on campus in the future.

Constructability

The constructability of the bridge and intersection were considered when creating the designs. The bridge was determined to be of appropriate construction type for the given site conditions. The bridge designs relied on the use of structural steel members. Due to the fact that the intersection is of new construction and not currently a major route, the intersection

¹ *Comprehensive and Strategic Campus Master Plan, 4*

construction would have little impact on campus life and alternative routes to cross Corporation Canal into the center of campus exist.

Ethical

There are many ethical factors that were taken into consideration when developing the design for the bridge and intersection. The work was completed according to the American Society of Civil Engineers (ASCE) Code of Ethics. Most relevant from the Code of Ethics, the design placed the health, safety, and welfare of the users of this infrastructure as the top priority. The safety of motorists, cyclists and pedestrians guided aspects of the intersection design such as intersection type, pedestrian amenities, and striping configuration. The bridge design accounted for worst-case scenario loading to ensure there is no bridge failure that may endanger anyone who crosses the bridge. Additionally, this design process upheld professional honor, treated others fairly by allowing safe crossing for all, and provided true and competent designs.²

Social and Political

In terms of political and social considerations for the design, the focus fell on the users of the proposed infrastructure as well as compliance with the new LSU vision. The new vision of a car-free campus core and promotion of remote parking affects many students, faculty, and staff who live and work on LSU's campus. The proposed bridge and intersection as a part of the transportation system re-development supports the users of the new parking garage on the east side of campus, and the movement of people over Corporation Canal and into the campus core.

Some stakeholders may be concerned about the negative impacts the proposed transportation changes may have on campus. This design for a new bridge and intersection

²Code of Ethics. ASCE

considered the social implications of the project and how the design may enhance or hinder the experience of users moving through the campus based on the new transportation system.

The team included intuitiveness in the political and social constraint, and defined intuitiveness as how easy and user-friendly the intersection would be for new pedestrians, drivers, and cyclists trying to navigate through the intersection. The intersections and bridge designs are unique on the campus, but with proper signage and pavement markings will be user-friendly for new users of the intersection after construction and in the future.

Health and Safety

The health and safety of users of the bridge and intersection were major components in the design. The design ensures that the bridge does not fail during its design life. AASHTO Design Specifications for Highway Bridges are calculated to ensure newly constructed bridges meet a specified level of reliability.³ This includes design for vehicles, pedestrians, and public transit buses due to the fact that the traffic volume of this bridge will increase as it becomes part of the newly designated LSU East-West Transit Spine. The intersection design also ensures that motorists, cyclists, or pedestrians are at the lowest possible risk when navigating through the intersection, and that the design minimizes potential conflicts between cars and pedestrians or cyclists.

Included in the evaluation of an intersection is the efficiency of the flow for pedestrians, cyclists, private vehicles, and transit movement through it. In the interest of the health and safety of all users of the intersection, some level of efficiency was compromised to allow pedestrians and cyclists to cross where appropriate.

³ Design Specifications for Highway Bridges, AASHTO

Professional Licensure Statement

The National Council of Examiners for Engineering and Surveying (NCEES) provides professional licensing to engineers to certify that only qualified individuals practice engineering.⁴ This ensure the safety of the public by holding all engineers to the same standard of education and experience.

It has become increasingly important to be certified as a Professional Engineer (PE) as it is a legal requirement that PEs prepare and sign final engineering work and plans for projects.

In order to become a licensed Professional Engineer, the following requirements must be satisfied:

- Earn a four-year degree in engineering from an accredited engineering program
- Pass the Fundamentals of Engineering (FE) exam
- Complete four years of progressive engineering experience under a PE
- Pass the Principles and Practices of Engineering (PE) exam

Additional requirements may be listed by state, and each state approves certifications individually. More information on exams, state requirements, and other criteria can be found on the National Council of Examiners for Engineering and Surveying (NCEES) website.

Professional Engineers did not participate in the pre-design and planning of this project. Once the project is past preliminary stages a Professional Engineer will sign the plans and engineering work.

⁴ NCEES website

Table of Contents

Abstract	ii
Executive Summary	iii
Acknowledgements	vi
Authorship	vii
Capstone Design Statement	viii
Professional Licensure Statement	xii
Table of Contents	xiii
List of Tables	xv
List of Figures	xvi
1.0 Introduction	1
2.0 Background	3
2.1 LSU’s Vision for the Area	3
2.2 Bridge Design	5
2.2.1 Bridge Type Selection Study	6
2.2.2 Design Method	7
2.2.3 CSI Bridge Software	7
2.3 Intersection Design	8
2.3.1 Crosswalks and Crossings	8
2.3.2 Corner Radii and Size	11
2.3.3 Visibility and Sight Distance	12
2.3.4 Traffic Controls	13
2.3.5 Lanes	17
2.3.6 Striping of Intersections	20
2.3.7 ADA Compliance	20
3.0 Methodology	22
3.1 Determined Technical Components and Industry Regulations	22
3.1.1 Determine technical components involved in design	22
3.1.2 Research Industry Regulations	23
3.2 Document Existing and Proposed Conditions	24
3.3 Evaluate Obtained Information versus Industry Standards and other Regulations	26
3.4 Use Guidelines to Produce Design Options	27

3.5 Refine the Preliminary Designs into a Final Design	28
3.6 Assess Final Design based on Project Goals to show Successes of the Design	28
3.7 Present Our Recommendations to Stantec	28
4.0 Results	29
4.1 Technical Components and Industry Regulations	30
4.2 Document existing and proposed conditions	31
4.3 Evaluate Obtained Information versus Industry Regulations and Calculations	33
4.4 Use Guidelines to Produce Design Options	37
4.5 Refine the Preliminary Designs into a Final Design	45
4.6 Evaluate Final Design based on Project Goals	47
4.7 Present our Recommendations to Stantec	49
5.0 Conclusion and Final Recommendations	50
5.1 Intersection Design	50
5.2 Structural Bridge Design	50
5.3 Final Recommendations	51
6.0 References	52
7.0 Appendix	54
Appendix A: Project Proposal	54
Appendix B: Traffic Signal Warrants	80
Appendix C: Stop Sign Warrants	81
Appendix D: Left Turn Lane Warrants	82
Appendix E: Final Design with Dimensions	83
Appendix F: Bridge Type Selection Study	84

List of Tables

Table 1: Recommendations for installing marked crosswalks and other pedestrian amenities....	10
Table 2: Minimum Required Stopping Sight Distances	12
Table 3: Factors that Warrant Traffic Control Signals	14
Table 4: Criteria for Installation of Multi-Way Stop	17
Table 5: Left Turn Lane Criteria.....	18
Table 6: Characteristics of an Accessible Curb Ramp.....	21
Table 7: Information Matrix for Intersection Design Specification Input	24
Table 8: Data Obtained from Stantec.....	25
Table 9: Components of Intersection Design.....	30
Table 10: Components of Bridge Design.....	31
Table 11: Documentation of Intersection Conditions	32
Table 12: Documentation of Bridge Conditions	33
Table 13: Bridge Types versus Industry Standards	37
Table 14: Sponsor Feedback and Design Changes	45
Table 15: Design Scores Based on Project Goals	48

List of Figures

Figure 1: East Side of LSU Campus and Corporation Canal.....	1
Figure 2: Concept Design of Student Life Spine	4
Figure 3: Colored proposed transit spines-- East/West Transit Spine in Orange	5
Figure 4: Approach Sight Triangles.....	13
Figure 5: Channelized Right Turn Lane from A Policy of Geometric Design of Highways and Streets.....	19
Figure 6: AASHTO H93 Design Live Loading	26
Figure 7: Design 1- Safest but least transit friendly	38
Figure 8: Design 2- Most Economic Option.....	39
Figure 9: Design 3- Best Compromise.....	40
Figure 10: Design 1- Steel Girder Bridge	43
Figure 11: Design 2- Pratt Truss	43
Figure 12: Design 3- Warren Truss	44
Figure 13: Final Intersection Design.....	46

1.0 Introduction

Louisiana State University (LSU) has created a Master Plan for the next 20-30 years to develop and modernize the entire campus. A large part of this redevelopment aims to increase the mobility on campus by addressing different factors including the street network, circulation, and transportation options through campus. The proposed changes to LSU’s campus will improve safety on campus, reduce conflicts between cars, bikes, and people on foot, and define a mode of transportation hierarchy. This hierarchy will be comprised of a pedestrian core, two transit spines, a bike and pedestrian spine connecting the core of campus to the periphery, and parking pushed from the core of campus to the perimeter.⁵ In an effort to improve the circulation on campus, LSU determined priority projects to increase the campus mobility by decreasing usage of private vehicles and increasing walkers, cyclists, and transit usage.⁶ One of the areas in need of development is situated on the east side of LSU’s campus around Corporation Canal.



Figure 1: East Side of LSU Campus and Corporation Canal⁷

⁵ *Comprehensive and Strategic Campus Master Plan*, 57

⁶ *Comprehensive and Strategic Campus Master Plan*, 57

⁷ *Comprehensive and Strategic Campus Master Plan*, 81

A bridge and proposed intersection will become an integral part of the proposed transit spine that spans east to west across the campus. The existing bridge is used by private vehicles, university transit, pedestrians, and cyclists. The goal of this Major Qualifying Project is to develop a design for a new bridge and adjacent intersection where South Campus Drive crosses Corporation Canal to accommodate the newly proposed traffic patterns. The proposed changes will help this section of the LSU campus to achieve the Master Plan's goals of incentivizing the use of remote parking options, providing dedicated transit roadways into the campus core, and removing private vehicles and the associated parking needed in the campus core.

2.0 Background

This chapter provides an overview of the characteristics of the vision Louisiana State University has for this area of campus. This bridge and intersection design are part of a larger development plan called the Student Life Spine, aiming to redevelop the area around Corporation Canal.⁸ The processes described in the sections below encompass how to design both a bridge and intersection, which are components necessary to complete this project.

2.1 LSU's Vision for the Area

The vision for the area of campus near the Corporation Canal area of campus comes directly from the Louisiana State University's Master Plan. The goal of the Student Life Spine is to create a new, open-space corridor connecting students to residential areas and the core of campus.⁹ In conjunction with the overarching goals of the Master Plan, this section of the plan eliminates surface parking lots around this part of campus and enhances connections between the two parts of campus on either side of Corporation Canal. A concept design of the Student Life Spine can be found in Figure 2.

⁸ *Comprehensive and Strategic Campus Master Plan*, 82

⁹ *Comprehensive and Strategic Campus Master Plan*, 82



Figure 2: Concept Design of Student Life Spine¹⁰

The specific bridge and intersection included in this project are located along South Campus Drive. The bridge over Corporation Canal will be part of the East-West Transit Spine, another proposed improvement to the LSU campus transportation program. The East-West Transit Spine is a public transit route proposed to connect the parking on the east side of campus to the campus core, and then to the parking on the west side of campus. Figure 3 below shows the proposed transit spines.

¹⁰ *Comprehensive and Strategic Campus Master Plan, 83*



Figure 3: Colored proposed transit spines-- East/West Transit Spine in Orange¹¹

The East-West Transit Spine route aims to entice more students, faculty, and staff to park in the remote parking on the eastern and western edges of the campus. The need for parking in central campus will be eliminated if more people utilize public transportation. As part of the development near the Student Life Spine, a new parking garage is proposed adjacent to the Alumni Center. This will eliminate additional parking spaces in the campus core and further align with the goals of the Master Plan.

2.2 Bridge Design

Bridges provide transportation over water, roadways, and other obstacles. In order for an engineer to safely design a bridge, all users of the bridge must be taken into account, the loads

¹¹ *Comprehensive and Strategic Campus Master Plan, 99*

must be accurately determined, and the materials must be carefully chosen. In general, bridges may be rehabilitated due to load changes or deterioration or designed from scratch.

There are many different bridge types including beam, truss and arch. The first step in determining the bridge type is to develop either single or multiple potential span arrangements. If applicable, bridge geometrics such as clearance height and width should be taken into consideration during the preliminary bridge design stage.

The desired specifications of a bridge are crucial to its design and efficiency. Before any design begins, these specifications must be determined, including load capacity and bridge type. Next, results from surveying are used to determine the span and abutment type. From there, the columns, beams, and slabs will be designed followed by the deck. The designs for all bridge components are governed by the regulations set by each state. In Louisiana, the standards are set by the LADOTD Bridge Design and Evaluation Manual (BDEM)¹².

2.2.1 Bridge Type Selection Study

A Bridge Type Selection Study is a method used to determine which bridge types are appropriate for a particular area. The study begins with a thorough explanation of the existing conditions of the site including the bridge structure, roadway type, utilities, etc. Additionally, the study includes the project parameters for the new design such as proposed traffic, clearances, and necessary roadway features. Using the previous data, appropriate bridge types are determined and described, and then inappropriate bridge types are discarded. Calculations are then performed on the appropriate bridge types to determine principal member sizing and a brief cost estimate.

¹² *LADOT Bridge Design and Evaluation Manual 2016*

2.2.2 Design Method

This most important indicator for the design of a bridge includes the anticipated dead and live loads. Dead load is defined as the intrinsic weight that makes up the materials of a structure. Live loads encompass everything else, such as passengers or weather loads. According to the Louisiana Department of Transportation and Development (LaDOTD), dead loads shall be distributed equally across the entire bridge. Live loads are determined based on the method used for design.¹³

For the design of truss bridges, preliminary member sizes can be determined using the method of joints. This design method utilizes the fact that the net force on all joints should be equal to zero in order to determine the individual forces in each member.

For the design of a steel girder bridge, the Load and Resistance Factor Design (LRFD) Method and American Association of State Highway and Transportation Officials (AASHTO) Design Specifications for Highway Bridges are used to determine the percentage of the load that will be placed on each girder using the moment distribution factor. The maximum moments are found this way and used to decide principal member sizing.

2.2.3 CSI Bridge Software

CSI Bridge is a structural analysis software used specifically for the design of bridges. To analyze the members of a bridge, it is first drawn in either 2D or 3D. The members are analyzed based on the loads inputted into the system, and the program generates moment and shear diagrams. Another feature of the software includes the ability to optimize the members in the

¹³Bridge Load Ratings Guidelines, In *LRFD Bridge Manual*

case that the member sizes chosen can handle much more load than necessary. This software is usually used to double check hand calculations.

2.3 Intersection Design

Intersections are a critical aspect of street design to ensure safety for all vehicles, cyclists, and pedestrians. Intersection designs must address mobility and safety goals. Similarly, a redesign of an intersection should enhance the public realm.¹⁴ Intersection design must take into account crosswalks, crossings, corner radii, visibility and sight distance, street striping, number of lanes, Americans with Disabilities Act (ADA) compliance, traffic signals, and other alternative signaling such as stop signs.

2.3.1 Crosswalks and Crossings

To install a crosswalk, an engineering study must be done to analyze three factors: the behavior of pedestrians, the traffic flow, and the history and future usage of the intersection.¹⁵ The *Manual on Uniform Traffic Control Devices (MUTCD)* does not specify specific guidance relative to the site conditions, such as traffic and pedestrian volume, presence of medians, or number of lanes. However, analyzing the behavior of pedestrians, the traffic flow, and history and future the intersection can aid the decision process of adding a crosswalk.¹⁶

Crosswalks are critical to pedestrians to ensure their safety. The *MUTCD* provides guidance on marked crosswalks specifying that they should not be less than six feet wide. Additionally, crosswalk lines should extend the full width of the pavement. Crosswalks should

¹⁴ Intersection Design Elements- NACTO.

¹⁵ *Manual on uniform traffic control devices for streets and highways (MUTCD)*

¹⁶ *Manual on uniform traffic control devices for streets and highways (MUTCD)*

be marked at all intersections that have a potential for conflict between vehicular and pedestrian movements. On streets with low volumes of less than 3000 average daily traffic (ADT), low speeds of less than 20 mph, or few lanes (1-2), marked crosswalks are not always necessary. However, areas such as schools, transit stops, hospitals, campuses, and other areas frequently used by pedestrians can benefit from crosswalks regardless of the traffic flow, speed, and volume.¹⁷

Additional crosswalk installation determination depends on multiple factors including land use; present and future demand; pedestrian compliance; and history of speed, safety, and crashes. Minimum spacing criteria of crosswalks is generally 300 feet; however, this may not be adequate for all cases. The street network must be evaluated prior to making decisions as to where crosswalks should be located. It is unsafe to discourage pedestrian crossings by leaving popular crossing points unmarked. This does not deter crossing at that point, and instead it encourages unsafe behavior and discourages walking. Popular unmarked crossings can be made marked crossings if possible or practical. Additionally, efforts can be made to highlight existing crossings by raising the crossings, adding other safety measures, installing flash beacons, or other safety countermeasures that are less expensive than full signalization.¹⁸

On multilane roads, marked crosswalks have significantly lower pedestrian crash rates than unmarked crosswalks.¹⁹ On two-lane roads and lower volume multilane roads with ADTs less than 12,000, marked crosswalks were not found to have any positive or negative impact on pedestrian crash rates.²⁰ A benefit of marked crosswalks is that a marked crossing encourages pedestrians to cross the street safely. However, crosswalks without other crossing enhancements

¹⁷ Intersection Design Elements- NACTO

¹⁸ Intersection Design Elements- NACTO

¹⁹ Safety Effects of Marked Versus Unmarked Crosswalks

²⁰ Safety Effects of Marked Versus Unmarked Crosswalks

should not be installed at locations that may pose safety risks to pedestrians, such as intersections with limited sight distance, complex designs, or other dangers. Recommendations for installing marked crosswalks and other needed pedestrian improvements depend on the vehicle ADT, roadway type, and speed limit. Table 1 below from the Federal Highway Administration shows recommendations for pedestrian amenities at varying types of intersections.

Table 1: Recommendations for installing marked crosswalks and other pedestrian amenities²¹

Roadway Type	Vehicle ADT < 9,000			Vehicle ADT >9,000 to 12,000			Vehicle ADT >12,000 to 15,000			Vehicle ADT >15,000		
	Speed Limit											
	<30 mph	35 mph	40 mph	<30 mph	35 mph	40 mph	<30 mph	35 mph	40 mph	<30 mph	35 mph	40 mph
Two Lanes	C	C	P	C	C	P	C	C	N	C	P	N
Three Lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multilane with raise median	C	C	P	C	N	N	P	P	N	N	N	N
Multilane without raised median	C	P	N	P	N	N	P	N	N	N	N	N

- “C” as a candidate for marked crosswalks
- “P” as there would be a possible increase in pedestrian crash risk if crosswalks are added without other pedestrian facility enhancements
- “N” as marked crosswalks alone are insufficient and there needs to be other treatments such as traffic-calming or signals.

²¹ Safety Effects of Marked Versus Unmarked Crosswalks

A critical crossing point occurs at signalized intersections. All legs of signalized intersections must have marked crosswalks unless pedestrians are prohibited from the section of the roadway, or there is no pedestrian access on either corner. According to the FHWA, crosswalks may be used to indicate pedestrian paths across roadways under specific conditions, including at locations with stop signs so motorists are aware of the pedestrian path, in designated school zones, and at locations where engineering judgement finds crosswalks desirable.²²

2.3.2 Corner Radii and Size

Corner radii of an intersection are designed to facilitate turning of design vehicles. The design vehicle is selected based on the largest vehicle type that regularly uses the intersection. The design vehicle appropriate for most types of transit service is the “City-BUS” as defined by AASHTO. This vehicle is 40 feet long, 8 feet wide, and has outer and inner turning wheel paths of 42.0 feet and 24.5 feet respectively.²³ Other factors that influence the definition of appropriate corner radii include the angle of the intersection, usage of pedestrians and cyclists, and geometric constraints. Large skew angles make maneuvers more difficult for vehicles like buses or trucks. Additionally, if the intersection size needs to be increased to account for larger vehicles, drainage can become more difficult and signal clearance must be longer to clear the intersection. In areas with high crossings of pedestrians and cyclists, smaller radii are used to reduce turning speeds and also to decrease the distance for pedestrians and cyclists to cross. Lastly, constraints such as curves, offsets, or elevations can impact the turn path of the vehicle and reduce the required right-of-way.²⁴

²²*A Policy on Geometric Design of Highways and Streets, AASHTO*

²³*A Policy on Geometric Design of Highways and Streets, AASHTO*

²⁴ Signalized Intersections: Informational Guide

2.3.3 Visibility and Sight Distance

Sight distance is the length of the roadway that is visible to a driver. It must be sufficient to allow motorists to see approaching vehicles and pedestrians in order to slow down or stop when necessary.²⁵ Intersection alignment controls the location of all intersection elements including edge of pavement, pavement elevation, and curb elevation. The horizontal alignment can affect the visibility of motorists. Intersections should intersect as close to right angles as possible, rather than skewed angles.²⁶ Visibility is also impacted by the operating speed of the roadway. Table 2 from AASHTO below shows the minimum required sight distances for vehicles to be able to stop based on the speed.

Table 2: Minimum Required Stopping Sight Distances²⁷

Vehicles Speed (mph)	Reaction Distance (feet)	Braking Distance (feet)	Summed Distance (feet)	Stopping Sight Distance(feet)
15	55.1	21.6	76.7	80
20	73.5	38.4	111.9	115
25	91.9	60.0	151.9	155
30	110.3	86.0	196.7	200
35	128.6	117.6	246.2	250

Sightlines are typically based on the 85th percentile speed; however, this is not sufficient in all cases. Designers need to proactively lower speeds near conflict points like intersections before taking measures such as widening the intersection or removing sightline obstacles.

²⁵ NACTO- Sight Distance Study

²⁶ Chapter 6: Intersection Design. In *Project Development and Design Guide*

²⁷ AASHTO

A motorist approaching an intersection should have an unobstructed view of the intersection including traffic control devices. The unobstructed views form sight triangles. In a four quadrant intersection, sight triangles are the areas along the approach of the intersection to the corners across (Figure 4). The triangular areas must be large enough that the motorists can see approaching vehicles and pedestrians to slow down or stop when necessary.

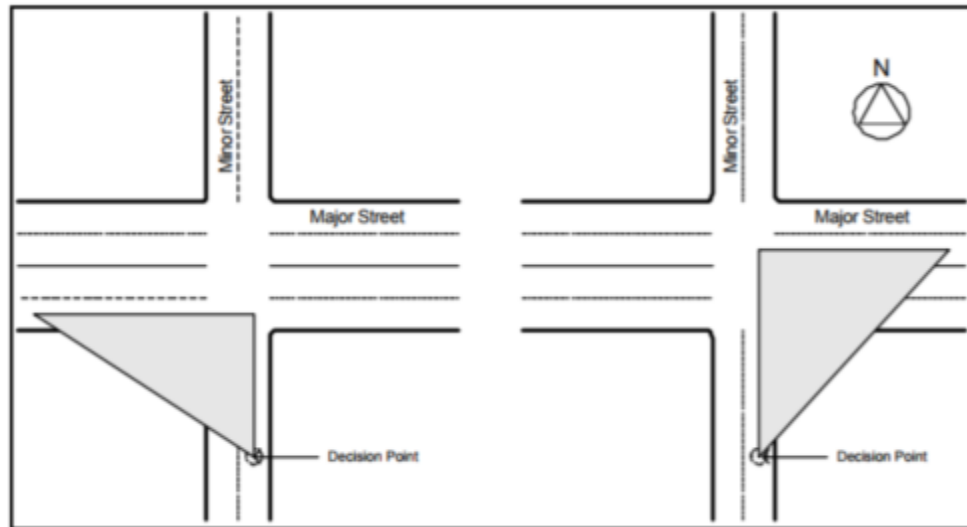


Figure 4: Approach Sight Triangles²⁸

2.3.4 Traffic Controls

An engineering study of traffic conditions, pedestrian and bicyclist characteristics, and physical characteristics of the site must be done to determine if a traffic control signal is justified at the location. There are nine factors that must be analyzed; however, engineering judgement is the deciding factor if an intersection requires the installation of a traffic control system.²⁹ The warrants are listed in Table 3 which is adapted from the MUTCD.

²⁸ NACTO- Sight Distance Study

²⁹ Manual on uniform traffic control devices for streets and highways (MUTCD)

Table 3: Factors that Warrant Traffic Control Signals

Warrant 1	Eight-Hour Vehicular Volume
Warrant 2	Four-Hour Vehicular Volume
Warrant 3	Peak Hour
Warrant 4	Pedestrian Volume
Warrant 5	School Crossing
Warrant 6	Coordinated Signal System
Warrant 7	Crash Experience
Warrant 8	Roadway Network
Warrant 9	Intersection Near a Grade Crossing

At a location that is under development or construction, it may not be possible to obtain a traffic count that will represent future traffic conditions. In this case, hourly volumes should be estimated in an engineering study to determine the traffic signal warrants using TripGenerator, a process used to forecast projected traffic patterns³⁰. Detailed information on the warrants can be found in the *Manual on Uniform Traffic Control Devices (MUTCD)*, a governing document that has specifications for traffic control.³¹

Alternatives to signalized intersections are uncontrolled intersections, yields, stop sign controlled intersections with minor-road-only stop control, or with multi-way stop control.³² In uncontrolled intersections the entrance from any of the approaches is not regulated by a stop sign, yield sign, or traffic signal. This functions under Per §11-401 of the Uniform Vehicle Code set by the National Committee on Uniform Traffic Laws and Ordinances: "*when two vehicles approach or enter an intersection from different highways at approximately the same time, the*

³⁰ Intersection Design- ConnDOT

³¹ *Manual on uniform traffic control devices for streets and highways (MUTCD)*

³² *Types of Unsignalized Intersections*

driver of the vehicle on the left shall yield the right-of-way to the vehicle on the right.” The driver must also yield to vehicles in the intersection and pedestrians on marked or unmarked crosswalks. Uncontrolled intersections are generally limited to very low-volume roads in residential or rural areas.

Yield sign-controlled intersections are another form of unsignalized intersections, where the entrance into the intersection of one or more approaches is controlled by a yield sign. Drivers approaching a yield must reduce their speed and concede to the right-of-way vehicles and pedestrians in the intersection. Adequate sight distance is very important to give the driver enough time to stop. Yield signs can be installed when any of the following conditions apply:

- If approaches to a street or highway do not warrant a full stop
- If the median at the intersection is 30 feet or greater
- If the median at the intersection is at an entrance from a channelized turn lane
- If the median at an intersection has a special problem that a yield sign would correct
- If the entering roadway would allow a merge-type movement.

Another type of intersection is a stop sign-controlled intersection. With a stop sign, drivers are required to come to a complete stop. There are two types of stop-controlled intersections. The first is a minor-road only stop control. This intersection typically has a stop sign for the minor road approach and no control for the major road approach. The other type is a multi-way stop control where all approaches are required to come to a complete stop. If two vehicles arrive at the same time, the vehicle on the right has the right-of-way.³³ Minor-road only stop control can be used if one or more of the following conditions exist: (1) an intersection of a

³³ *Types of Unsignalized Intersections*

minor road to major road, (2) a street entering a designated through highway or street, or (3) an unsignalized intersection in a signalized area.

Additionally, stop or yield signs should be considered if the following conditions apply:

- At the intersection of two minor streets
- On local roads where an intersection has more than three approaches
- If combined pedestrian, vehicular, and bicycle volume from all approaches averages more than 2,000 units per day
- If there is limited visibility, or if crash records show that five or more crashes that involve failure to yield at the intersection have been reported in a 3-year period
- If there were three or more crashes in a two-year period.³⁴

For a multi-way stop, the criteria in Table 4 should be used to consider the installation of a multi-way stop.

³⁴*A Policy on Geometric Design of Highways and Streets, FHWA*

Table 4: Criteria for Installation of Multi-Way Stop³⁵

Criteria 1	Multiway stop is an interim measure if traffic control signals are justified
Criteria 2	Five or more reported crashes in a 12-month period that can be corrected by a multi-way stop installation.
Criteria 3	Vehicular volume entering the intersection from the major street approaches averages at least 300 vehicles per hour for any eight hours on an average day
Criteria 4	Combined vehicular, pedestrian, and bicycle volume entering the intersection from the minor street approaches averages at least 200 units per hour for the same eight hours as Criteria 3, with an average delay to minor street traffic of at least 30 seconds during the highest hour
Criteria 5	85th percentile approach speed of the major traffic exceeds 40 mph and the minimum warrants are 70 percent of the above values
Criteria 6	If Criteria 2 and 3 are all satisfied to 80 percent of the minimum values

2.3.5 Lanes

Intersections can be designed with single lanes, designated left-turn or right-turn lanes, or multiple lanes. Lanes are added to address safety and operational concerns. Left-turn vehicles often encounter conflicts with pedestrians, cyclists, opposing traffic, crossing traffic, and through traffic in the same direction. The demand for left-turns at some intersections also affects the amount of green time on a signal that is allocated to other traffic movements.³⁶ A single left-turn lane is the most common approach to improve safety and reduce delay with left turns. This lane provides left-turning vehicles space to safely decelerate away from the traffic. It also gives through traffic space to safely pass the vehicles turning left. Left turn lanes can improve a signal's efficiency by improving the flow rate through the signal for the left-turn vehicles and

³⁵A Policy on Geometric Design of Highways and Streets, FHWA

³⁶ Signalized Intersections- Individual Movements

through traffic. Different signal phasing options can be adjusted to accommodate heavy flow rates at peak hours. Left turns are warranted under the conditions in Table 5.³⁷

Table 5: Left Turn Lane Criteria

Criteria 1	Significant intersections with high approach speeds and traffic volumes
Criteria 2	Increasing approach speeds
Criteria 3	Higher volumes of vehicles turning left than continuing right or through
Criteria 4	High volumes of opposing vehicles
Criteria 5	To improve sight distance
Criteria 6	Depending on crash history of turning vehicles

A high volume of right-turn movements can significantly impact the safety and operations of a signalized intersection. Right-turn lanes can provide benefits for approaching vehicles, reduce vehicular delay, and increase intersection capacity. Key design criteria for right-turn lanes are entering taper, deceleration length, storage length, lane width, corner radius, and sight distance. Further information can be found in *A Policy on Geometric Design for Highways and Streets*.³⁸ Channelized islands that physically separate through and right turning movements can provide larger turning radii to accommodate larger vehicles and allow for higher turning speeds. These factors help increase the efficiency of the right-turning vehicles, and allows some queuing of through traffic (Figure 5). If this measure is adopted, raised islands should be provided for pedestrian refuge.³⁹

³⁷ Signalized Intersections- Individual Movements

³⁸ *A Policy on Geometric Design of Highways and Streets, FHWA*

³⁹ Signalized Intersections- Individual Movements

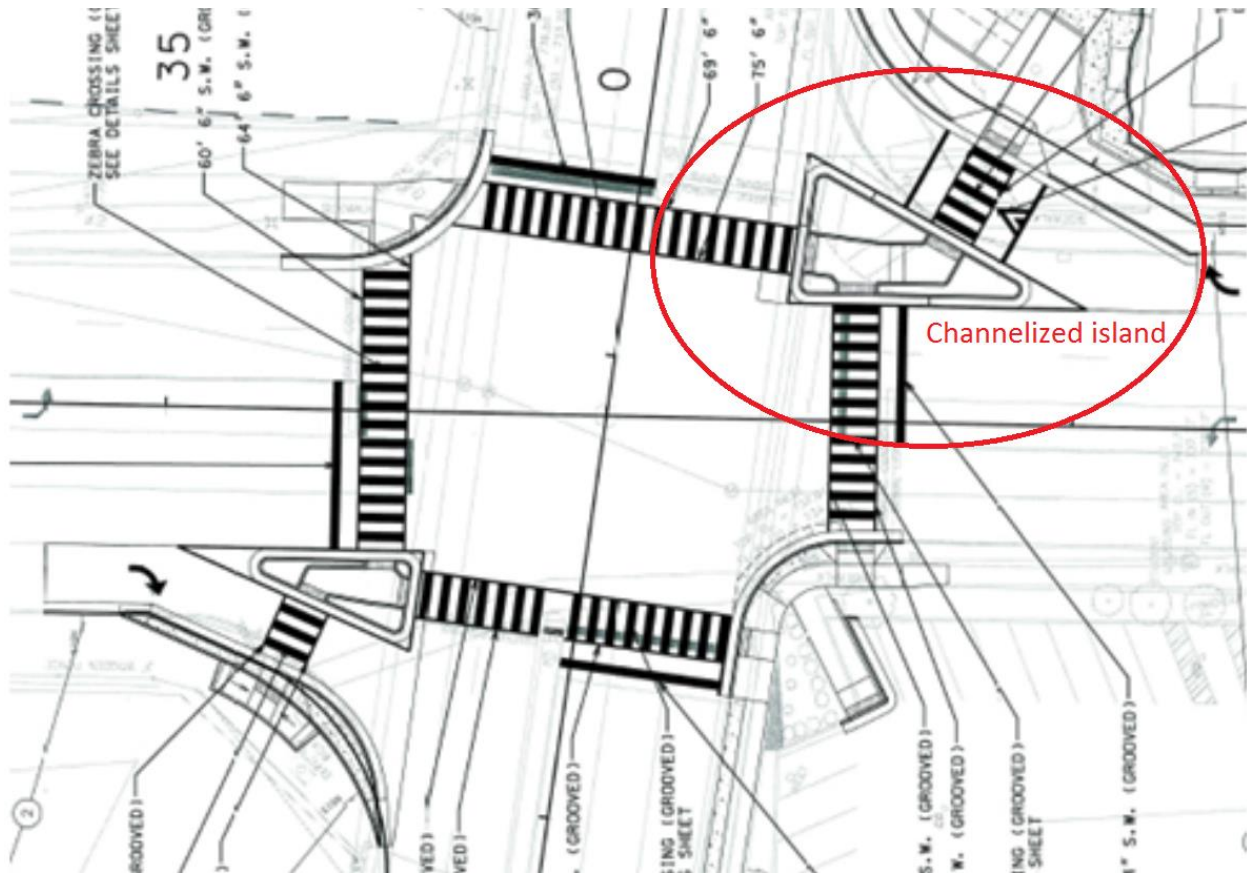


Figure 5: Channelized Right Turn Lane from *A Policy of Geometric Design of Highways and Streets*⁴⁰

When a street is expanded to accommodate a left turn lane or an additional through lane, it is called a flared intersection. This design is effective in increasing capacity when widening the lanes beyond the intersection is not needed to achieve the desired level-of-service, not feasible due to constraints nearby, or not desirable within the project context.⁴¹ Intersection approaches can also be flared without adding an additional lane. This can help ease the vehicle turning movement and benefits traffic flow. However, flared intersections increase the pedestrian crossing time due to the fact that the pedestrians have a longer distance to traverse. Thus, the signalization must account for a longer pedestrian crossing signal.⁴²

⁴⁰ Signalized Intersections- Individual Movements

⁴¹Intersection Design- ConnDOT

⁴²*A Policy on Geometric Design of Highways and Streets, FHWA*

2.3.6 Striping of Intersections

The *MUTCD* does not require stop lines (stop bars). However, many intersections use stop bars to indicate the point where vehicles should stop in compliance with a stop sign or red light. Typically, stop bars are 12 inches wide and are placed at the desired stopping point. In intersections with crosswalks, the stop line is placed four feet in advance of it.⁴³

2.3.7 ADA Compliance

Curb ramps must be compliant with Title II of the Americans with Disabilities Act (ADA) standards. Sidewalks must give pedestrians a designated safe place to travel and, whenever possible, be free of obstructions in order to eliminate tripping hazards. In order to meet ADA compliance, sidewalks must consist of a paved area that is at minimum four feet wide, with a running slope of either less than 5%, or at the same grade as the roadway. The sidewalk does not have to be marked.⁴⁴ An accessible curb ramp must follow specific characteristics, outlined in the table below. This table was adapted from the *MUTCD*.

⁴³ *Manual on uniform traffic control devices for streets and highways (MUTCD)*

⁴⁴ Sidewalk Ramp and Curb Ramp Design Criteria - FHWA

Table 6: Characteristics of an Accessible Curb Ramp

Characteristic 1	The ramp run must have the least running slope possible. Running slope is defined as the slope in the direction of pedestrian travel.
Characteristic 2	Curb ramps constructed after January 26, 1992 must have a slope of 8.33 percent (1:12) or less.
Characteristic 3	The cross slope of the ramp run itself may not exceed 2 percent (1:50). The cross slope is defined as the slope perpendicular to the direction of pedestrian travel.
Characteristic 4	The ramp or ramp run must be at least 36 inches wide, not including the flared sides.
Characteristic 5	The ramp run must have detectable warnings, i.e. dome-shaped bumps, that extend the full width and depth of the ramp
Characteristic 5	Transitions from the ramp to the walkway, gutter, and street must be flush and free of abrupt level change

3.0 Methodology

The goal of this project was to design a bridge and intersection to support LSU's campus transportation improvements. The existing bridge crosses over Corporation Canal from South Campus Drive. The proposed intersection would be an extension of South Campus Drive that connects to West Lakeshore Drive and a new road extending north called Veterans Drive. This chapter contains the objectives and steps to complete the final design recommendations for Stantec. The team pursued these seven objectives to achieve the project goal:

1. Determined technical components, government standards, and industry regulations involved in bridge and intersection design
2. Documented existing and proposed conditions
3. Evaluated obtained information versus industry standards and other regulations
4. Used guidelines to produce multiple design options
5. Refined the preliminary designs into a final design
6. Assessed final design based on project goals to show successes of the design
7. Presented our recommendations to Stantec

3.1 Determined Technical Components and Industry Regulations

The project team first determined the technical components involved in both intersection design and bridge design. After researching the components, the team researched into state and federal regulations and regulatory documents. The team later used this information to determine guidelines for the bridge and intersection designs.

3.1.1 Determine technical components involved in design

Intersection

Based on background research and guidance from Stantec, the project team determined the six main components of intersection design. We considered different modes of transportation

including pedestrians, cyclists, private vehicles, and public vehicles. By determining the components of intersection design, the project team was prepared to conduct calculations and gather data from the sponsor. Then, the team could compare the data to the industry regulations to produce design options.

Bridge

Based on background research and guidance from Stantec, the project team determined the five main components of bridge design necessary for structural integrity. By determining the components of bridge design, the project team was prepared to gather data from the sponsor and from research to perform the necessary calculations based on industry regulations to design the bridge.

3.1.2 Research Industry Regulations

As this project takes place in Louisiana, the project team researched the state and federal regulations and regulatory documents. We found the federal and local industry codes based on the components of intersection and bridge design researched in the background from accepted sources such as the Federal Highway Administration and the American Association of State Highway and Transportation Officials. We used traffic industry regulations and bridge codes to compile a list of potential options for each component. The regulations determined which option would be incorporated into the design. Regulations are discussed further in Section 4.



3.2 Document Existing and Proposed Conditions

Intersection

From the technical components and industry regulations, we determined the information required to complete an intersection design. This information is outlined in the matrix shown in Table 7. An X indicates that the information required corresponds with the design parameter.

Table 7: Information Matrix for Intersection Design Specification Input

DESIGN PARAMETER	<u>Crosswalks</u>	<u>Type of Intersection</u>	<u>Sight Distance</u>	<u>Turning Radius</u>	<u>Number of Lanes</u>	<u>Striping of Intersection</u>
INFORMATION REQUIRED						
<u>Speed</u>	X	X	X			X
<u>Pedestrian Usage</u>	X	X	X	X	X	
<u>Bike Usage</u>	X	X	X	X	X	
<u>Vehicles (ADT)</u>	X	X			X	X
<u>Type of Traffic</u>				X		X
<u>History of Crashes</u>	X				X	
<u>Available Space</u>				X	X	
<u>Type of Site</u>	X					X
<u>Number of Lanes</u>						X
<u>Angle of Intersection</u>			X	X		
<u>Sight Distance</u>		X			X	X
<u>Type of Intersection</u>					X	X

The project team obtained data of the existing and proposed conditions from Stantec. The data obtained included the transit schedule, CAD files, and quantitative data. The data is outlined in Table 8 below.

Table 8: Data Obtained from Stantec

Summary	Explanation
Transit schedule	Stantec provided the team with the transit schedule for the North-South Transit Spine which was used to estimate the traffic flow.
CAD files	Stantec gave the project team detailed CAD files to calculate the available space for the intersection.
Crash history	The crash history of South Campus Drive is not available since this intersection does not currently exist.
Condition Data	Stantec provided the team with information on the existing and proposed conditions that the team interpreted facts from. This information can be found in Table 11 in Chapter 4.

The project team made observations using satellite images, CAD files, and by understanding the goals for the area. The maps and files along with calculations allowed the team to determine the geometric requirements for the intersection including number of lanes, angle of intersection, sight distance, and type of intersection. Additionally, by analyzing the goals of the LSU Master Plan, the team was able to estimate the pedestrian and bike usage as well as the design the school would want for the intersection.

Bridge

From the technical components and industry regulations, we determined the information required to complete a bridge design. This information is outlined in the Bridge Type Selection Study located in Appendix F.

The required data presented in the study was obtained through Stantec as well as observations provided by research. The physical properties of the area were determined from AutoCAD files from Stantec. Pedestrian usage and traffic flow, which were used to partially

determine the live load, were obtained through predictive studies given to us by Stantec and LSU's vision to increase alternative modes of transportation. Specifically, Stantec determined the design vehicle loading to mimic the H93 truck provided by AASHTO as shown in Figure 6 below.

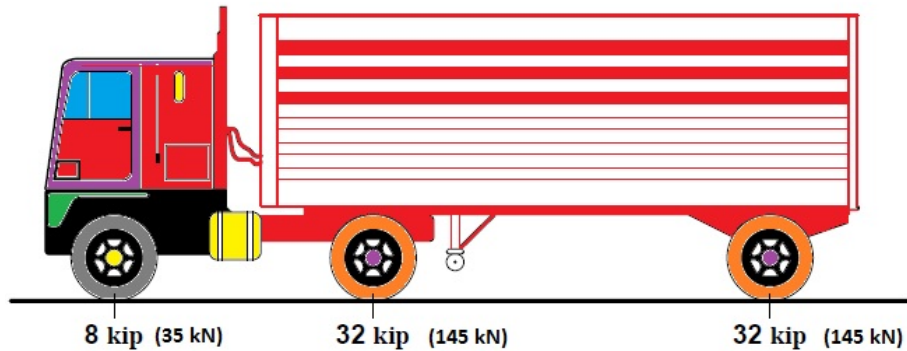


Figure 6: AASHTO H93 Design Live Loading⁴⁵

Other factors considered in calculating the live loads include wind, snow, and seismic activity, which were determined through research. The dead load was determined based on the specifications of the bridge and the materials used. Overall, many of the bridge's characteristics were designed with the discretion of the project team.

3.3 Evaluate Obtained Information versus Industry Standards and other Regulations

For each component of the intersection and bridge design, the information gathered was compared to the industry regulations and warrants. The warrants included signal warrants as well as turning lane warrants. The project team read literature published by the Federal Highway

⁴⁵ AASHTO

Administration (FHWA), the National Association of City Transportation Officials (NACTO), the American Association of State and Highway Transportation Officials (AASHTO), and the Louisiana Department of Transportation and Development (LADOTD).

Each regulation was organized in a table with the regulation and how it applies to our specific project. The team was able to determine the design options for each component from the regulations and used them as guidelines to guide the design process.

3.4 Use Guidelines to Produce Design Options

Each component had a different set of guidelines depending on if the regulation had leniency or not. There was a variety of regulations including ranges the information needed to fall between, to specific numbers based on calculations. Other regulations left the design up to the discretion of the engineer using engineering judgement. Additionally, the project team used the best practice design solutions suggested by the National Association of City Transportation Officials (NACTO).

The team organized a list of the requirements for the intersection and bridge design. After having a full understanding of the required components, LSU's aesthetic vision could be incorporated. LSU's design regulations were researched to ensure the intersection and bridge design coincides with the rest of the campus.

The team used AutoCAD and CSIBridge to create both technical and visual representations of the three different designs. The team used a method of cost analysis to determine which bridge would be most budget-friendly for LSU. First, the total pounds of steel necessary for each design was determined and then multiplied by the cost of steel per pound.⁴⁶

⁴⁶ *Midwest Steel Supply*

The costs presented in this report are only representative of the materials necessary for the principal member sizes shown in the designs.

3.5 Refine the Preliminary Designs into a Final Design

After a meeting with the sponsor, the team received feedback from Stantec professionals about the functionality, intuitiveness, efficiency, and other assets of the designs. The project team then synthesized the three design options and sponsor feedback into a fourth and final design.

3.6 Assess Final Design based on Project Goals to show Successes of the Design

The team used a variety of project goals to evaluate the final design and highlight the design's successes and areas for improvement. The project goals included the following constraints: economic; environmental and sustainability; constructability; ethical; social and political; and health and safety. Based on advice from the sponsor, the team rated each goal of the design with a full circle, half circle, or no circle. The full circle represented that the project goal is met completely, a half circle that it was partially met, and no circle that it was not met. The team decided not to use a numeric score or a weighted score because the priorities of LSU for this particular project are not yet set.

3.7 Present Our Recommendations to Stantec

The team presented the final recommendation to Stantec. The design details were presented with graphics, tables, and explanations in an oral presentation as well as in the form of

a final MQP report. The team incorporated comments from Stantec to refine the final design and ensure it met all goals of both LSU and Stantec.

4.0 Results

This chapter discusses the results of each objective the project team completed.

4.1 Technical Components and Industry Regulations

Intersection

Based on our research, we developed various options for the intersection design including crosswalks, type of intersection, sight distance, turning radii, lanes, and the striping of an intersection. For each component there are multiple options for the intersection design, shown in Table 9. This table lists all the options for each design component that were considered when creating the designs. The options were later evaluated and will be discussed in Section 4.3.

Table 9: Components of Intersection Design

<u>Crosswalks</u>	<u>Type of Intersection</u>	<u>Sight Distance</u>	<u>Turning Radius</u>	<u>Lanes</u>	<u>Striping, Signing, and Pavement Markings</u>
-No crosswalk -1 crosswalk -2 crosswalks -3 crosswalks -4 crosswalks -marked crosswalks -raised crosswalks -signalized	-Signalized -Uncontrolled -2 -way stop -4-way stop	-skew angles -right angles	-calculated based on the design vehicle, City-bus	-One lane -Left turn lane -Right turn lane -Multi-lane -Bike Lanes -Sidewalk	-Lanes -Stop bars -Crosswalks -Dotted tracks -Bike lane

Bridge

Based on research, six structural components of the bridge were determined. These components include bridge type, span type, abutment type, foundation type, pier type, and deck type. For each component there are multiple options for design as shown in Table 10.

Table 10: Components of Bridge Design

<u>Type of Bridge</u>	<u>Span Type</u>	<u>Abutment type</u>	<u>Foundation Type</u>	<u>Deck Type</u>	<u>Pier Type</u>
-Beam -Cantilever -Arch -Suspension -Truss	-Simple -Continuous -Cantilever -Suspended	-Counterfort -Open	-Pile footing -Pedestal Pier -Drilled Pile -Driven Pile -Spread footing	-Beam -Slab -Box Girder	-Solid Wall -Hammerhead -Rigid Frame

The Bridge Type column is highlighted because that is the component that was selected for further design based on available skills and time. In addition, the substructure costs would be similar for different types of bridges, which allowed the team to focus on the varying types of superstructures.

4.2 Document Existing and Proposed Conditions

The project team conducted research into the local area regulations and into the LSU Master Plan and performed calculations in order to obtain the information needed to document the conditions. The conditions the team used to design the intersections are documented in the table below.

Intersection

Table 11: Documentation of Intersection Conditions

INFORMATION REQUIRED	
<u>Speed</u>	The speed is left to the discretion of the engineers but is within the range of 10-30 mph. It will be set after other information is found and a preliminary design is made. Appropriate speeds range from 10 mph to 30 mph based on nearby roadways on the campus. There are golf carts that frequently drive on this road, so the speed must be low enough to protect this form of transit.
<u>Pedestrian Usage</u>	LSU's vision is for heavy pedestrian foot traffic across the campus on this spine. The intersection will need to account for many pedestrians crossing each day.
<u>Bike Usage</u>	The South Campus Drive is one of two roads that run North to South. The goal for this new spine is to have heavy bike traffic rather than private vehicles driving back and forth.
<u>Vehicles (ADT)</u>	The average daily traffic on the South Campus Drive is expected to be low, and almost completely consist of three transit vehicles on a loop. The average daily traffic on Veterans Drive is projected from another east-west road on campus and will be less than 9,000 vehicles per day.
<u>Type of Traffic</u>	The spine will be primarily used by transit vehicles, bicycles, and pedestrians. There will also be deliveries to the residence halls by large delivery trucks. Private vehicles will not be permitted on the transit spine, but will cross the Veterans Drive in the East-West direction.
<u>History of Crashes</u>	N/A
<u>Available Space</u>	The space measurements were taken from the AutoCAD file provided by Stantec to give guidelines for the width of the bridge/roads and the surrounding space available for sidewalks and bike paths.
<u>Type of Site</u>	The design will take into consideration the location of the project. The primary users of this area are college students.
<u>Number of Lanes</u>	The number of lanes will be determined by the ADT, history of crashes, pedestrian and bike usage, speed, type of traffic, and available space. In future objectives the number of lanes will be determined based on the above information and industry regulations.
<u>Angle of Intersection</u>	N/A
<u>Sight Distance</u>	The sight distance will be measured and will be used to take into account things surrounding the intersection.
<u>Type of Intersection</u>	The type of intersection will be determined by the ADT, history of crashes, pedestrian and bike usage, speed, type of traffic, and available space. In future objectives the number of lanes will be determined based on the above information and industry regulations.

Bridge

The Bridge Type Selection Study located in Appendix F explains all the existing and proposed conditions given to us by Stantec and determined through observation, research and calculations. Some of the important information shown in the study is highlighted in Table 12 below.

Table 12: Documentation of Bridge Conditions

INFORMATION REQUIRED	
<u>Loads</u>	Live load: The live load was determined by the predicted traffic flow given by Stantec as well as research on weather patterns Dead load: The dead load was determined through the weight of materials specified by LSU
<u>Pedestrian Usage</u>	LSU's vision is for heavy pedestrian foot traffic across the campus on this spine. The bridge will need to account for many pedestrians crossing each day.
<u>Clearance</u>	Minimum 12 ft underpass for trails and bikeways is necessary as specified in Section 2.3.3 of the LADOTD Bridge Design and Evaluation Manual
<u>Ground Conditions</u>	The ground conditions were determined through measurements found on CAD files provided by Stantec.
<u>Owner Requests</u>	Specific aesthetic and physical requirements were determined by LSU and found in the Master Plan.

4.3 Evaluate Obtained Information versus Industry Regulations and Calculations

The following section outlines the intersection components, the regulations and their source, the specifics to LSU, and the decision made for this project.

The first component was crosswalks. The FHWA states that for a two-lane road, with a vehicle ADT of less than 9000 and a speed of less than 30 mph, a marked crosswalk could be installed. The project site at LSU will have an ADT of less than 9000, and the two lane road will

have a speed of no greater than 25 mph. Thus, the intersection is a candidate for a marked crosswalk.

The next component was the type of intersection. The MUTCD and the FHWA says that warrants for installation of a traffic signal involve hourly vehicular traffic, number of lanes, pedestrian volume, crash history. More details of warrants can be found in Appendix B. None of the warrants are met for a signalized intersection. The regulation for a two-way stop says that it can be used if a minor road is intersecting a major road, entering a designated through street, or is unsignalized in a signalized area. Veterans Drive is a minor road intersecting South Campus Drive, which is to become a major transit and pedestrian-cyclist spine. The regulation for a multi-way stop says that it can be used if the intersection meets any of the six criteria listed in Appendix C. For this intersection, South Campus Drive and Veterans Drive do not meet any criteria. Engineering judgement can be used to determine if a minor intersection with a low ADT can be uncontrolled or yield controlled. Due to the predicted pedestrian and cyclist usage and the college campus setting, the intersection should be controlled. Based on all the types of intersections and warrants, South Campus Drive should be a two-way stop for vehicles approaching on Veterans Drive.

The next component was site distance. The Policy on Geometric Design of Highways and Streets from AASHTO says that stopping sight distance is based on the vehicle speed, which gives a reaction distance, braking distance, and total distance. The vehicle speed for the project site is 25 mph, therefore the stopping sight distance should be 155 feet.

The next component was the turning radius. The Policy on Geometric Design of Highways and Streets from AASHTO says that the size of the intersection and turning radius are influenced by the largest design vehicle. The City-Bus is defined as 40 feet long and 8 feet wide.

This intersection will be a part of the East-West spine and use the City-Bus as the design vehicle. The turning radius would be 42.0 ft for the minimum design turning radius and 37.8 ft for the centerline turning radius.

The next component was the lanes. The AASHTO policy on left turn lanes says that left turn lanes can increase flow and safety of traffic in signalized intersections. Detailed criteria can be found in Appendix D. Right turn lanes can increase efficiency of traffic flow and can be added to design based on engineering judgement. Veterans Drive will be used mostly as a through road for all types of vehicles, and South Campus Drive will be used primarily as a through transit route for campus buses. Due to the fact that both approaches will be mostly through traffic with limited turning movement, there is no need for turn lanes on any approach.

The next component was the striping, signing, and pavement markings. The regulation comes from the FHWA and the MUTCD. Yellow centerlines are used to mark the separation of traffic lanes with opposite directions of travel. No passing is allowed over yellow centerlines. Sight distance on each approach to the intersection would not allow for a passing zone. Therefore, there will be a yellow centerline on both South Campus Drive and Veterans Drive to prevent passing. Stop lines should be used to indicate the point a vehicle should stop at a traffic control signal or crosswalk. Stop lines should be 12 to 24 inches wide. This area has high predicted pedestrian and bike usage, therefore stop lines will be used to protect the pedestrians and cyclists. Chapter 9A of the MUTCD describes all of the required signs and pavement markings to indicate to motorists the use of a bike lane in the area. Chapter 3B-18 of the MUTCD describes all of the required signs and pavement markings to indicate to motorist pedestrian crossing in the area. This area has a high predicted pedestrian and cyclist usage. LSU hopes this route will become a way for people to get from remote parking to the campus core.

The pavement markings and signage should enhance the safety and intuitiveness of the intersection. Therefore, all of the bike lanes in each design will be striped and signed according to MUTCD regulations.

The next component is ADA Compliance. Title II of the Americans with Disabilities Act says that curb ramps must be compliant with Title II of the ADA regulations. This area has high predicted pedestrian usage. All the curb ramps and sidewalks will comply with ADA regulations to make the intersection and pathway accessible to all.

Based on the comparison and regulations, each intersection design option is required to have the following characteristics:

- Marked crosswalks
- Two-way stop on the Veterans Drive approaches
- Turning radius of minimum 42 ft
- Single lane from all approaches, and no turn lanes
- Striping in accordance with MUTCD regulations for lanes
- Signage and pavement markings indicating a bike lane in accordance with MUTCD regulations
- Sidewalks and crosswalk access compliance with Title II ADA regulations

Bridge

As seen in Table 13 below, bridge types were considered for further review if its typical span length fell within the industry regulation for that specific type of bridge. The types of bridges chosen for further review include a Truss, Girder, and Arch.

Table 13: Bridge Types versus Industry Standards

Type of Bridge	Necessary Length given by LSU	Suggested Length (Industry Standards)	Further Consideration?
Truss	80'	Up to 300'	Yes
Girder	80'	Up to 100'	Yes
Arch	80'	Up to 800'	Yes
Suspension	80'	2,000-7,000'	No
Cable-Stayed	80'	200-3,000'	No

4.4 Use Guidelines to Produce Design Options

This section describes each of the preliminary intersection and bridge design options the team compiled.

Intersection

Each design was based on the required characteristics determined in Section 4.3, and then the team incorporated other aspects of intersection design for function, safety, and aesthetic considerations. Each design included the characteristics outlined above. Additionally, each of the three preliminary designs include varied position of design features including pedestrian walkways and bike lanes.

Design 1: Safest but least transit friendly

The first design was called “Safest but least transit friendly” as it focused on putting safety as the number one priority, with downfalls to efficiency of vehicle movement. Design 1 can be seen in Figure 7 below.

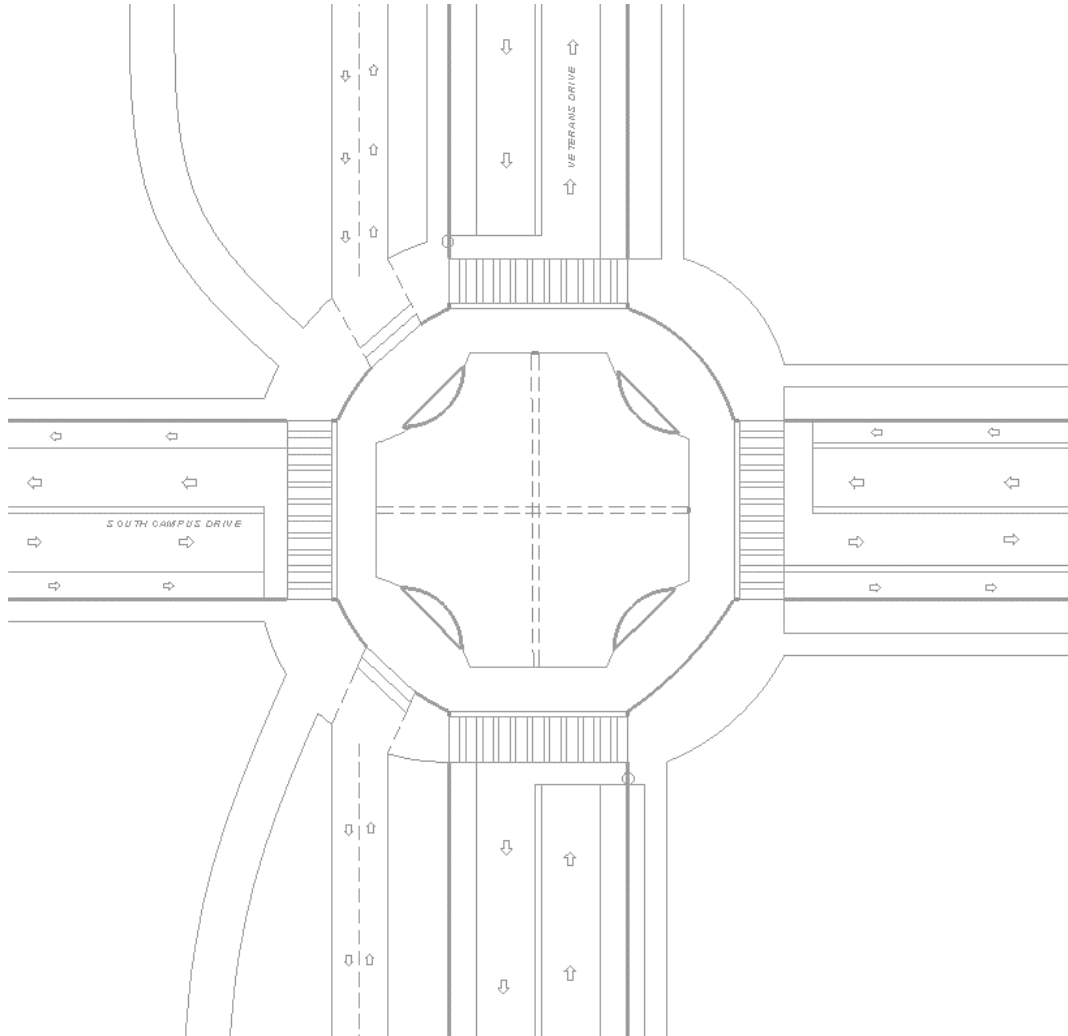


Figure 7: Design 1- Safest but least transit friendly

The project team focused on adding design features that would give additional protection to pedestrians and cyclists. Every pedestrian crosswalk is raised and flush with the sidewalk level. This gives added protection to pedestrians crossing the street. Additionally, there are buffers protecting turning cyclists from turning vehicles.

In the North-South Spine there is a separated bike path. In the East-West Spine there are buffered bike lanes on either side of the road. There are pedestrian sidewalks on each side of every approach of the intersection. The downside to this design feature is the transit vehicle must

pass over the raised crosswalks a total of four times every loop it makes.

Intersection Design 2: Most Economic Option

The second design was called “the Most Economic Option” as it focused on ensuring the transit has the most efficiency and convenience, while still ensuring safety for pedestrians and cyclists. Design 2 can be seen in Figure 8 below.

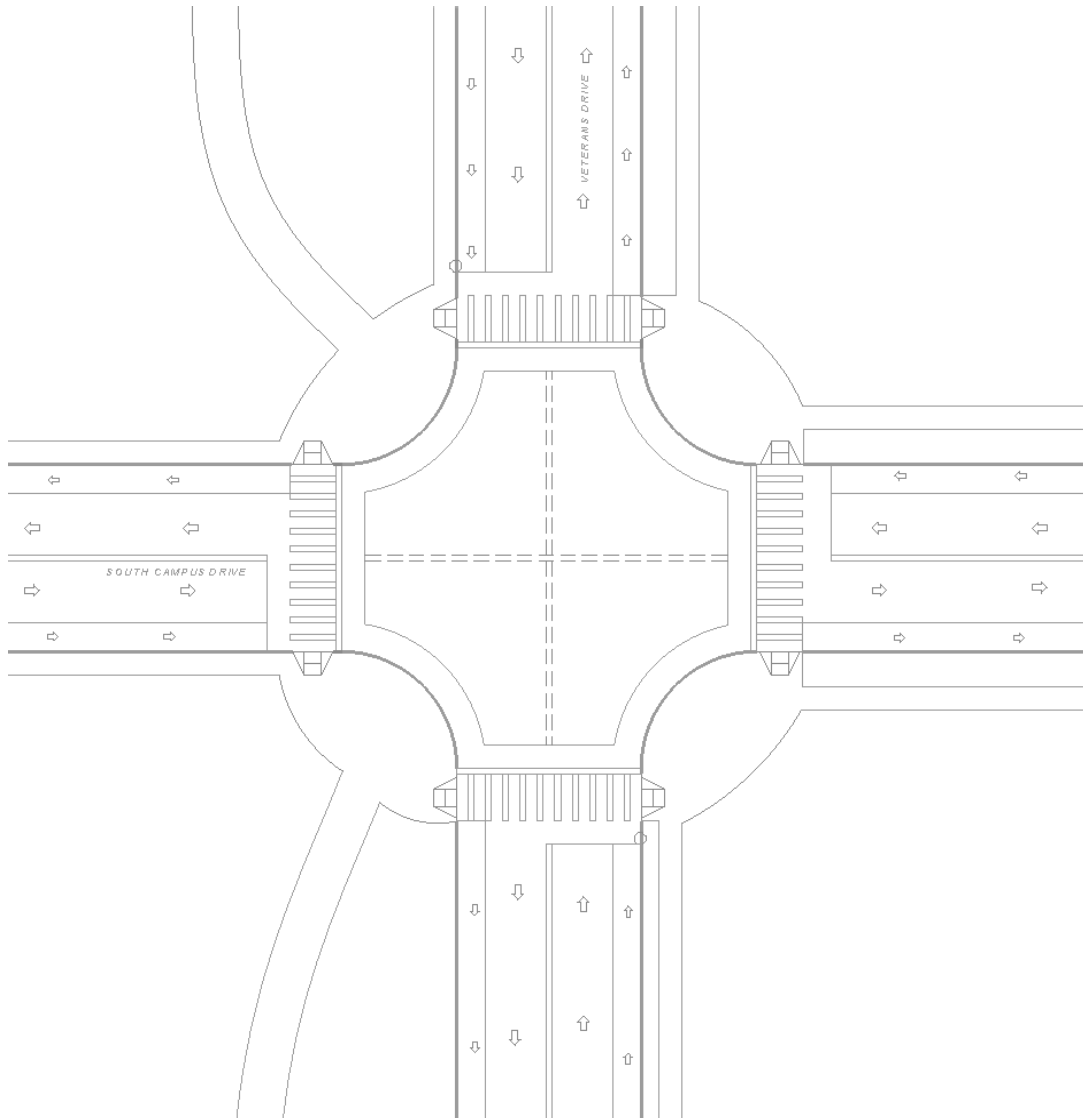


Figure 8: Design 2- Most Economic Option

The project team focused on the flow of traffic. There are bike lanes alongside the road with every approach, the most predictable design for drivers. This design allows drivers to have

an immediate understanding of where cyclists will be and how they will be crossing. The pedestrian sidewalks are flush with the pavement surface, minimizing the effect of the crosswalks for the vehicles. The downside to this design feature is the cyclists are not protected from traffic other than with pavement markings.

Design 3: Best Compromise

The third design was called “Best Compromise” as it focused on both ensuring the transit has efficiency and convenience, while equally ensuring safety for pedestrians and cyclists.

Design 3 can be seen in Figure 9 on the next page.

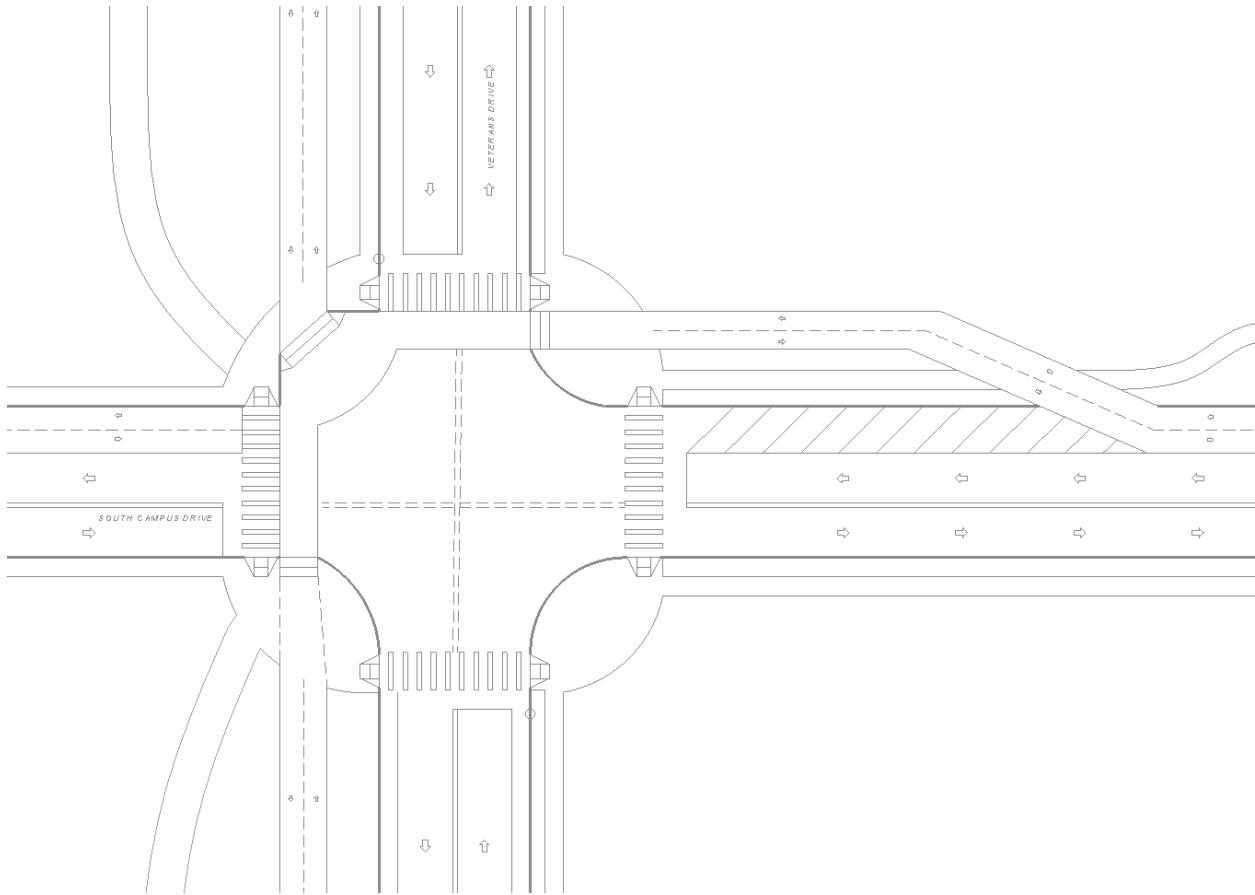


Figure 9: Design 3- Best Compromise

Similar to other designs, pedestrian walkways exist on each side of all the approaches. In the North-South direction there is a bi-directional bike path separate from the road. In the East-West spine there is a bi-directional bike lane on the street level. Cyclists can only turn at the north-west corner of the intersection. This minimizes potential conflicts between vehicles and cyclists. Additionally, since South Campus Drive (East-West direction) is transit only, private vehicles cannot make turns from Veterans Drive onto South Campus Drive. Therefore, the cyclists crossing or waiting to cross at the intersection will be at little risk of turning vehicles.

At the north-east corner of the intersection, there is a bump out of the bike lane. This is designed to minimize conflicts cyclists may have with other cyclists, pedestrians, and motorists as they navigate through the intersection. The space left along the street from this bump out is

striped with diagonal lines to ensure cars do not park in the area if private vehicles are allowed on South Campus Drive.

The downside to this design is that the bike lanes are not where drivers, pedestrians, or cyclists may expect which may cause additional conflicts. This design does not reflect actual user behavior and could put all who navigate through the intersection at risk.

Bridge

Of the three bridges that passed the industry standards for appropriate span length, the truss and girder bridge were chosen because of ease of implementation and transferability to other locations on campus. Two types of trusses, the Pratt and Warren, were developed to ensure multiple design options.

Design 1: Steel Girder Bridge

The first design is a steel girder bridge which consists of four W40X278 steel beams spaced at 11 feet apart. The cost of the materials for these principal members is \$94,000. Compared to the following designs, this option is more expensive and would require a lot more earthwork due to the vertical height of the members. Additionally, this design is more traditional and doesn't fit with LSU's aesthetics. LSU hopes to make additions to the campus that agree with its vision which would include an aesthetically designed bridge, meaning that this design is not necessarily the best option.

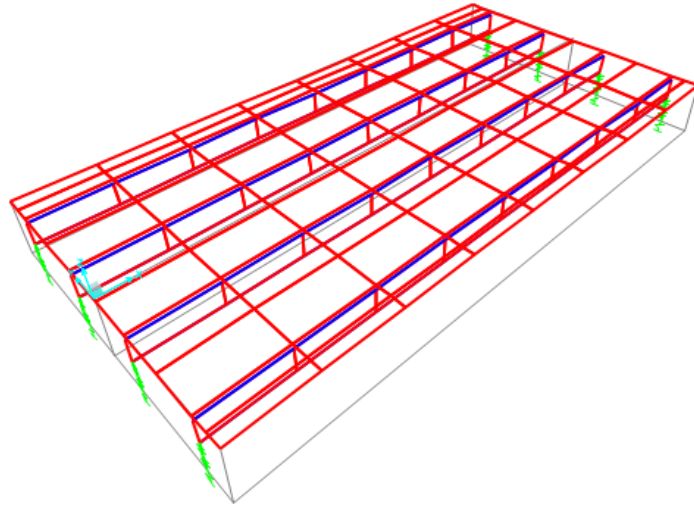


Figure 10: Design 1- Steel Girder Bridge

Design 2: Pratt Truss

The second design is a Pratt Truss which consists of 4" diameter A36 steel throughout. The cost of the materials for these principal members is \$32,000. This is a good option for LSU because it fits in with LSU's vision of updating the campus while preserving its historical attractions. In terms of budgeting, this is a more expensive truss type, which could be designed more efficiently to lower the cost.

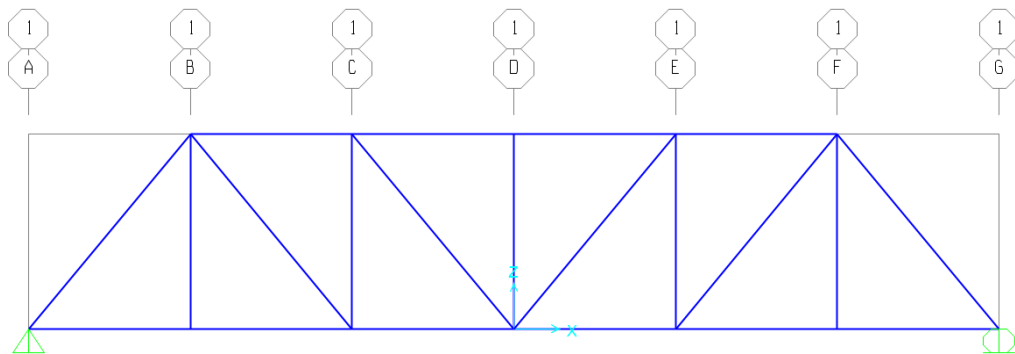


Figure 11: Design 2- Pratt Truss

Design 3: Warren Truss

The third design is a Warren Truss consisting of 3" diameter A36 steel members. The cost of these members totals \$15,500. The principal cost savings of this truss compared to the Pratt include less length of the members and a smaller necessary diameter. In addition to the low cost, this bridge also fits LSU's vision. This is why it was chosen as the final design for the bridge over Corporation Canal.

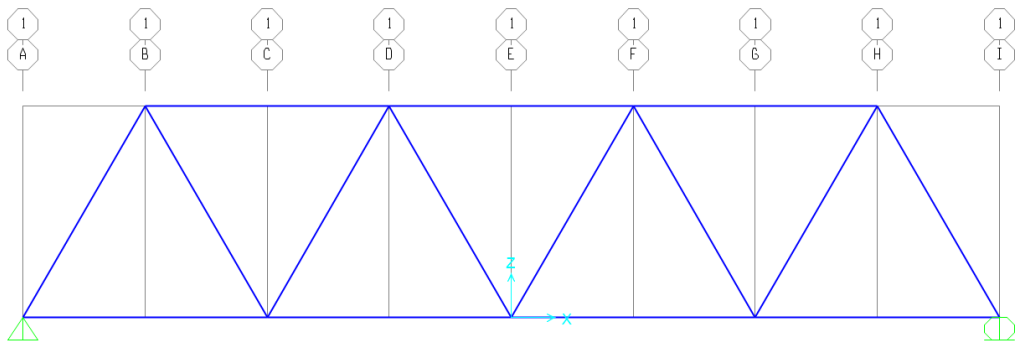


Figure 12: Design 3- Warren Truss

4.5 Refine the Preliminary Designs into a Final Design

Refining the Designs

The project team used the feedback from the sponsor to redesign the intersection. The new design included both features from the preliminary designs and also new design features based on the feedback. This new design is a new, fourth option. The following table explains the sponsor feedback, their reasoning, and the changes the team made.

Table 14: Sponsor Feedback and Design Changes

Feedback	Reasoning	Changes
The sponsor preferred bi-directional bike lanes or paths in both directions	cyclists are more likely to want to cycle to campus if they are protected from traffic	The team determined both directions would have bi-directional bike paths
Turning areas for cyclists do not match biker behavior.	Cyclists are unlikely to follow the marked bike paths through the intersection, and rather continue along a path they were already traveling in.	The team changed the cyclist crossings to be in line with the bike paths entering and exiting the intersection.
Crosswalk locations do not match pedestrian behavior.	The crosswalks on each approach in the preliminary designs were offset from the intersection. Based on behavior of pedestrians, they are not likely to change their path to cross on the marked crosswalk.	The team tightened the intersection for the final design. This also reduced the standing area space to be a more realistic size.
Together, the sponsor and the team determined that creating a pedestrian and cyclist spine would best encourage students who are accustomed to driving on the East-West Spine to walk or bike.	This will complement the green spine and best encourage cyclists and pedestrians to not drive to campus.	The team created a pedestrian and cyclist spine in the East-West direction.

Final Intersection Design

The final design focused on efficiency for pedestrians, cyclists, and vehicles, ensuring safety for all who navigate the intersection, and encouraging students to want to walk or ride bikes. Section 4.3 outlines the design features the final intersection included. The final design can be seen in Figure 13 below.

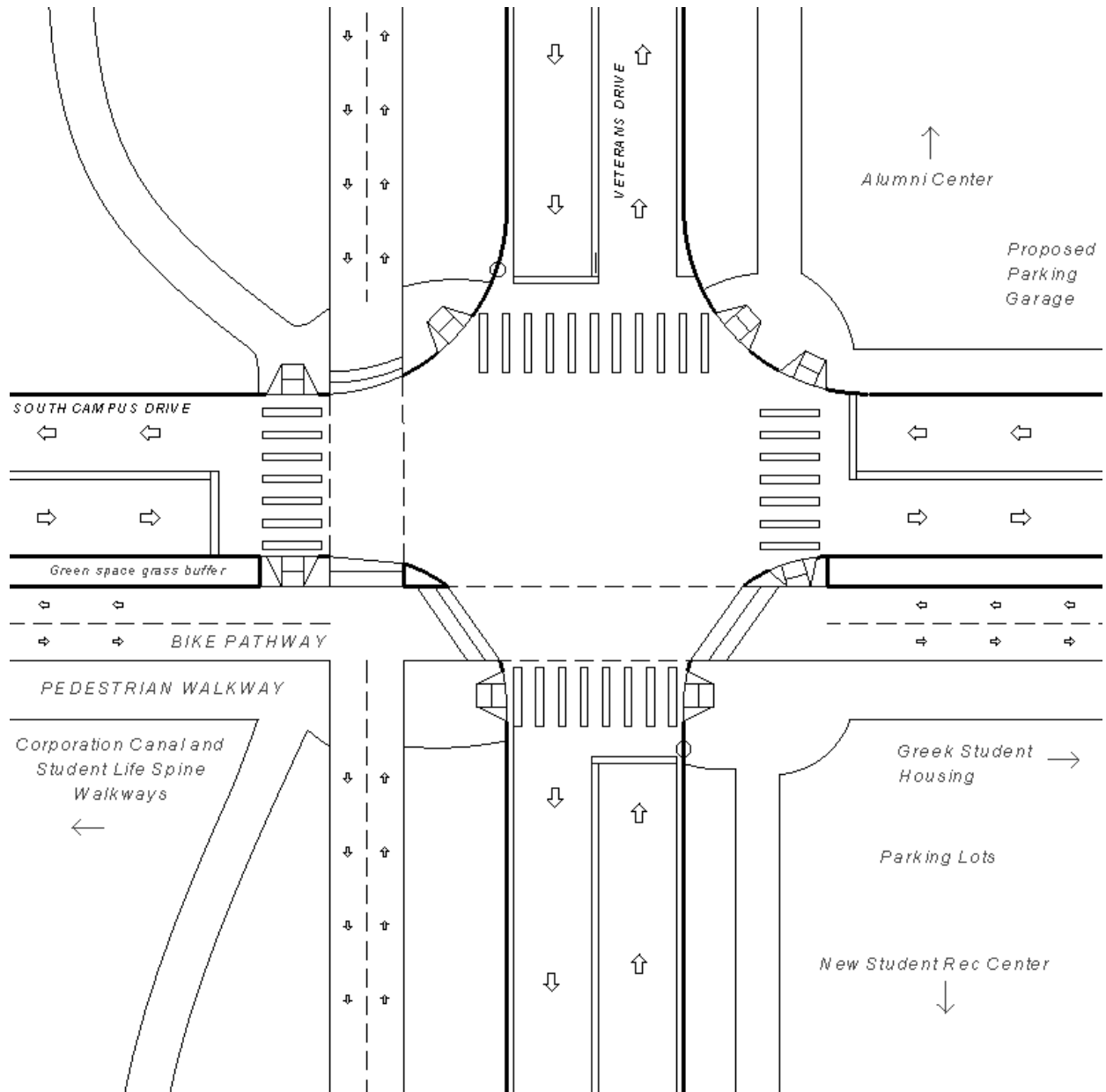


Figure 13: Final Intersection Design

4.6 Evaluate Final Design based on Project Goals

The team used the following project goals to evaluate the final design: economic; environmental; transferability; efficiency; intuitiveness; ethical; social and political; and health and safety. The project goals were derived from the Capstone Constraints that outline all aspects that should be considered in engineering design projects. The following table is a breakdown of the scores for the final design. Based on advice from the sponsor, the team rated the final design for each goal with a full circle, half circle, or no circle. The full circle (O) represented that the goal is met completely, a half circle (C) that it was partially met, and no circle that it was not met.

Table 15: Design Scores Based on Project Goals

Constraint	Final Design	Explanation
Economic	C	The economic goal was partially met. The flashers for crossing, green space buffer, and larger lanes all increase the cost.
Environmental	O	The environmental goal is met completely. This design will encourage students to walk and ride bikes as opposed to drive into the center of campus.
Transferability	O	The transferability goal of the design is met completely. LSU could implement an East-West pedestrian and bike spine across the entire campus and at many other locations.
Efficiency	C	The efficiency goal of this intersection is partially met. The turning of the transit vehicles may be slower due to the design, as will speeds due to narrow lanes. However, the cyclists and pedestrians will cross most efficiently.
Intuitiveness		The intuitiveness goal of the intersection received no circle. For new visitors at this intersection, it could be confusing to know where the pedestrians and cyclists are in reference to the vehicles, as it is a unique design on this campus.
Ethical	O	This design meets the ethical criteria completely, as it complies with all codes and regulations.
Social and Political	O	The social and political goals are completely met. The intersection completely aligns with the goals of the LSU Master Plan.
Health and Safety	O	The health and safety criteria were completely met. This intersection protects cyclists, pedestrians, and vehicular traffic and minimizes potential conflicts.

4.7 Present our Recommendations to Stantec

The project team presented the final design to Stantec including the project background, methods, and results. The team also made a poster presentation for WPI.

5.0 Conclusion and Final Recommendations

In this project, the team developed a preliminary bridge design and an intersection design for Louisiana State University to satisfy the goals of the LSU Master Plan. The design complied with LADOTD, FHWA, and AASHTO requirements. To design the bridge, the team used the AASHTO LRFD design approach and CSIBridge to determine the necessary materials for different bridge types. The team used AutoCAD to design the intersection. The project team evaluated the final design using a series of project goals including economic, environmental, transferability, efficiency, intuitiveness, ethical, social, political, and health and safety goals. After an analysis of the final bridge and intersection designs, the team has the following recommendations for Stantec in regard to the design of this project.

5.1 Intersection Design

The team developed three preliminary intersection designs and a final design for the new intersection at the crossing of Veterans Drive and South Campus Drive. The design has a two-way stop on Veterans Drive, and a four-way pedestrian crossing with flashers to ensure safety when crossing. The design also includes marked cyclist crossings. In the North-South direction there is a bi-directional bike path that is separated from traffic with a green buffer. In the East-West direction there is a pedestrian and cyclist spine separated from vehicular traffic. The pedestrian and cyclist spine will encourage students to walk or bike to class rather than drive. This intersection design best fits the mobility goals of the LSU Master Plan.

5.2 Structural Bridge Design

The team developed three design options for the bridge over Corporation Canal. The final design was chosen based on cost and compliance with LSU's Master Plan. This design features a

Warren truss whose principal member sizes include 3” diameter A36 steel. The cost of the material for these principal members totals \$15,500.

5.3 Final Recommendations

Regardless of the bridge that Stantec chooses to pursue, the team recommends further analysis and investigation on a more detailed structural design. For the intersection, a drainage analysis and plan would have to be completed before construction. Additionally, the team recommends an analysis of costs to ensure the design fits with the economic goals of the LSU Master Plan and the funds are available. When LSU has made more progress with accomplishing the goals of the Master Plan, we recommend evaluating the design using a weighted matrix in addition to the evaluation done by the project team. This will allow LSU to choose the best design features for them based on their priorities for the project.

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7.0 Appendix

Appendix A: Project Proposal

Bridge and Intersection Design at Louisiana State University

A Major Qualifying Project Proposal Submitted to the Faculty

Of

Worcester Polytechnic Institute

In Partial Fulfillment of the requirements for the Bachelor of Science Degree

By

Anna Gore

Megan Hanshaw

Taylor Venter

December 21, 2017

Advisors:

Leonard Albano

Suzanne LePage



Capstone Design Statement

The Civil and Environmental Engineering program at WPI requires to have all Major Qualifying Projects (MQPs) include a Capstone Design Experience to meet educational ABET objectives. Through this exercise students demonstrate their engineering design knowledge. In order to meet this requirement, this MQP proposes an intersection design and new bridge design located at the Louisiana State University. Due to the fact that the project team will be unable to visit the project site, the team will rely on the project sponsor to supply the necessary data and observations. The project engineers will determine design criteria and develop several designs for the intersection and bridge. All designs will follow State and Federal Transportation Standards and comply with all State and National Building Codes. In this report, calculations will be shown concerning loads for the bridge, turning radii for the intersection, and the necessary intersection type based on traffic volume and flow. This portion of this Major Qualifying Project is intended to satisfy the ABET requirements as it is a culmination of earlier course work and incorporates engineering standards with realistic constraints in the design. The constraints imposed on this alternative design consider construction economics, environmental factors, sustainability, constructability, social and political, ethical, and safety factors. The final design will be selected based on these constraints and using the knowledge we have garnered at WPI.

Economic

The design will be based on the budget allowed for the development of this bridge and intersection. Since this is a small portion of the larger master plan for the redesign of LSU's campus transportation, economic factors must be considered when developing the design to account for the allocated budget. Discussions with our sponsor and LSU will be necessary to determine if there is a set budget for this project.

Environmental and Sustainability

The design of the bridge and intersection will need to be environmentally friendly and sustainable so that it aligns with LSU's vision set in the Master Plan. One of the goals of the Master Plan is "to promote environmental stewardship", primarily through encouraging more students, faculty, and staff to walk and use public transportation instead of driving through campus and parking in the campus core. The design of this bridge and intersection must support that vision by ensuring the ease of cyclists, pedestrians, and public transportation when navigating through the intersection and over the bridge.

In addition to environmental sustainability, this bridge and intersection must be sustainable for the campus for long-term use. This bridge and intersection design are part of a larger plan for transportation improvements that rely on transit and vehicle passage through this area, which will not be possible if the designs do not have a sustained design life. For example, if the bridge over the canal is not updated then it will not be able to support the weight of the transit vehicles passing over it.

Constructability

The designs for the proposed bridge and intersection will be analyzed to ensure both can be constructed adequately and used safely. Standards for constructability will be based on Stantec's best

practices and those set by the Louisiana State Department of Transportation and Development (LaDOTD).

Ethical

There are many ethical factors that should be taken into consideration when developing the design for the bridge and intersection. This design will be developed according to the American Society of Civil Engineers (ASCE) Code of Ethics. Most relevant from the Code of Ethics, this design must prioritize the health, safety, and welfare of the users of this infrastructure as the top priority. The safety of motorists, cyclists and pedestrians will guide aspects of the intersection design such as intersection type, pedestrian amenities, and striping configuration. The bridge design will account for worst-case scenario loading to ensure there is no bridge failure that may endanger anyone who crosses the bridge. Additionally, this design process must uphold professional honor, treat others fairly, and provide true and competent designs.

Social and Political

In terms of political and social considerations for the design, the focus falls on the users of the proposed infrastructure as well as compliance with the new LSU vision. The new vision of a car-free campus core and promotion of remote parking affects many students, faculty, and staff that live and work on LSU's campus. The proposed bridge and intersection as a part of the transportation system re-development must support the users of the new parking garage on the east side of campus, and the movement of people over Corporation Canal and into the campus core.

Some people may be in favor of or against the proposed transportation changes and the negative effects it may have on campus. This design for a new bridge and intersection must consider the social

implications of the project and how the design could enhance or hinder the experience of users moving through the campus based on the new transportation system.

Health and Safety

The health and safety of users of the bridge and intersection will be major components in the design. The design must ensure that the bridge does not fail during its design life. AASHTO bridge design guidelines are calculated to ensure newly constructed bridges meet a specified level of reliability. This includes design for vehicles, pedestrians, and public transit buses due to the fact that the traffic volume of this bridge will increase as it becomes part of the newly designated LSU East-West Transit Spine. The intersection must not put motorists, cyclists or pedestrians at risk of being injured while navigating through the intersection.

Table of Contents

Capstone Design Statement 2

1.0 Introduction 6

2.0 Background 7

2.1 LSU's Vision for Area 7

2.2 Bridge Design 8

2.2.1 Bridge Rehabilitation 9

2.2.2 Bridge Design 9

2.2.2.1 Bridge Ratings and Load Design 9

2.2.2.2 Bridge Type 10

2.2.2.3 General Design Requirements 10

2.3 Intersection Design 11

2.3.1 Crosswalks and Crossings 11

2.3.2 Corner Radii and Size 11

2.3.3 Visibility and Sight Distance 12

2.3.4 Traffic Controls 13

2.3.5 Lanes 14

2.3.6 Striping of Intersections 14

3.0 Methodology 15

3.1 Document Conditions 15

3.1.1 Traffic 16

3.1.2 Aesthetic Design 16

3.1.3 Pedestrian Usage 17

3.1.4 Other Site Observations 17

3.2 Determine Design Criteria 17

3.2.1 Intersection Design 18

3.2.1.1 Determination of Type of Intersection 18

3.2.1.2 Determination of Geometric Specifications 19

3.2.1.3 Determination of Crosswalks 19

3.2.2 Structural Design 20

3.3 Develop Design Options 20

3.4 Evaluate the Bridge and Intersection Designs and Select a Design 21

4.0 References 22

1.0 Introduction

Louisiana State University (LSU) has created a Master Plan for the next 20-30 years to develop and modernize the entire campus. A large part of this redevelopment aims to increase the mobility on campus by addressing different factors including the street network, circulation, and transportation options through campus. The proposed changes to LSU’s campus will improve safety on campus, reduce conflicts between cars, bikes, and people on foot, and define hierarchy of modes of transportation. This hierarchy will be comprised of a pedestrian core, two transit spines, a bike and pedestrian spine connecting the core of campus to the periphery, and parking pushed from the core of campus to the perimeter. In efforts to improve the circulation on campus, LSU determined priority projects to increase the campus mobility by decreasing usage of private vehicles and increasing walkers, cyclists, and transit usage. One of the areas in need of development is situated on the east side of LSU’s campus around Corporation Canal.



Figure 1: East Side of LSU Campus and Corporation Canal

One of the areas in need of development is situated on the east side of LSU's campus around Corporation Canal. A bridge and proposed intersection will become an integral part of the proposed transit spine that spans east to west across the campus. This bridge is currently used by private vehicles, university transit, pedestrians, and cyclists. The goal of this Major Qualifying Project is to develop a design for a new bridge and adjacent intersection where South Campus Drive crosses Corporation Canal to accommodate the newly proposed traffic patterns. The proposed changes will help this section of the LSU campus to achieve the Master Plan's goals of incentivizing the use of remote parking options, providing dedicated transit roadways into the campus core, and removing private vehicles and the associated parking needed in the campus core.

2.0 Background

This chapter provides an overview of the characteristics of the vision Louisiana State University has for this area of campus. This bridge and intersection design are part of a larger development plan called the Student Life Spine, aiming to redevelop the area around Corporation Canal. The processes described in the sections below encompass how to design both a bridge and intersection, which are components necessary to complete this project.

2.1 LSU's Vision for Area

The vision for this area of campus comes directly from the Louisiana State University's Master Plan. The goal of the Student Life Spine is to create a new open space corridor connecting students to residential areas and the core of campus. In conjunction with the overarching goals of the Master Plan, this section of the plan eliminates surface parking lots around this part of campus and enhances connections between the two parts of campus on either side of Corporation Canal. A concept design of the Student Life Spine can be found in Figure 2.

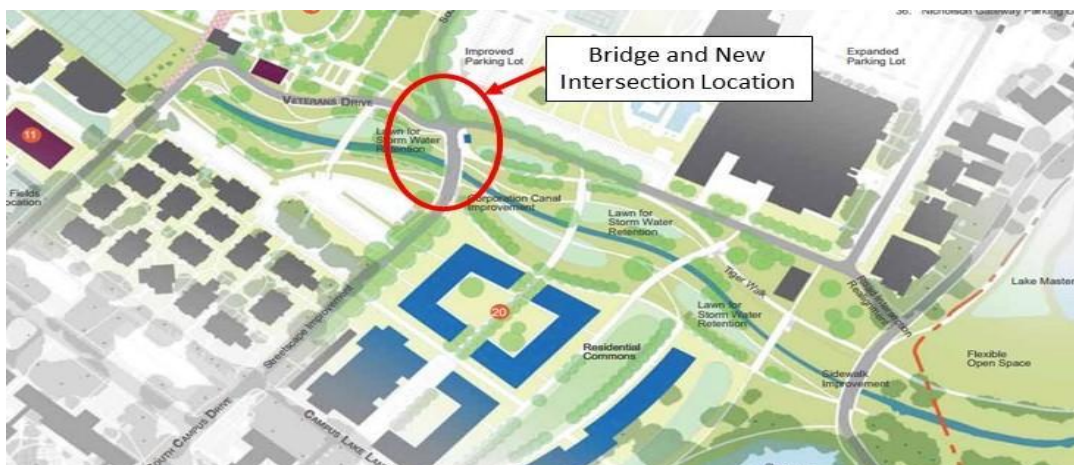


Figure 2: Concept Design of Student Life Spine

The specific bridge and intersection included in this project are located along South Campus Drive. The bridge over Corporation Canal will be part of the East-West Transit Spine, another proposed improvement to the LSU campus transportation program. The East-West Transit Spine is a public transit route proposed to connect the parking on the east side of campus to the campus core, and then to the parking on the west side of campus. Figure 3 below shows the proposed transit spines.



Figure 3: Colored routes showing the proposed transit spines-- East-West Transit Spine in Orange

The East-West Transit Spine route aims to entice more students, faculty, and staff to park in the remote parking on the eastern and western edges of the campus. By riding public transit into the core of campus, the need for parking in central campus is eliminated. As part of the development near the Student Life Spine, a new parking garage is proposed near the Alumni

Center, eliminating more parking spaces in the campus core and further aligning with the goals of the Master Plan.

2.2 Bridge Design

Bridges are necessary for transportation over water, roadways, or other obstacles. In order to safely design a bridge, all users must be taken into account, the loads must be accurately determined, and the materials must be carefully chosen. In general, bridges can be rehabilitated due to load changes or deterioration, or designed from scratch.

2.2.1 Bridge Rehabilitation

There are many causes for bridge rehabilitation including service failures or to serve an alternative purpose. The most common types of bridge redesign include bridge deck widening or replacement and expansion. When redesigning or rehabilitating an existing bridge, the original construction plans are used to verify dimensions and details. Next, the needs of the new bridge must be considered. If the purpose has deviated from the original, then a new purpose and design specifications must be set. Design specifications include all the requirements necessary for the proposed traffic patterns (i.e. width, loads, types of travel). Once the requirements are determined, specific parts of the bridge can be designed, such as the foundation, superstructure, and deck.

2.2.2 Bridge Design

The desired specifications of a bridge are crucial to its design and efficiency. Before any design begins, these specifications must be determined, including load capacity and bridge type. Next, results from surveying will help determine the span and abutment type. From there, the

columns, beams, and slabs will be designed followed by the deck. The designs for all bridge components are governed by the regulations set by each state,. This project will use the LADOTD Bridge Design and Evaluation Manual (BDEM), which sets the standards in Louisiana.

2.2.2.1 Bridge Ratings and Load Design

Dead load is defined as the intrinsic weight that makes up the materials of a structure.

Live loads encompass everything else, for example passengers and weather loads. According to the Louisiana Department of Transportation and Development (LaDOTD), dead loads shall be distributed equally across the entire bridge. Live loads are determined based on the method used for design.

Bridge Ratings are a method of evaluating existing bridges. The four different factors that contribute to the overall sufficiency of a bridge are defined by the National Bridge Institute (NBI) and include structural evaluation of deck, superstructure, substructure, and culvert.

Ratings are given on a scale of 0-9 with 0 meaning the bridge must be closed and 9 meaning the bridge is superior to necessary criteria. Loads are rated based on two different categories,

Inventory Rating and Operating Rating, both defined by the AASHTO *Manual for Bridge*

Evaluation. Inventory rating is the load that can safely and indefinitely utilize the bridge, and

Operating Rating is the maximum permissible live load that can be placed on the bridge.

2.2.2.2 Bridge Type

Bridges come in many different types including beam, truss and arch. The first step in determining the bridge type is to develop potential span arrangements, either single or multiple

spans. Bridge geometrics such as clearance height and width, if applicable, should be taken into consideration during the preliminary bridge design stage. Next the foundation and substructure of the bridge must be designed to adhere to the geometrics previously set.

2.2.2.3 General Design Requirements

The two main parts of the bridge, superstructure and substructure, are designed using the service load design method and the strength design method, respectively. The steel reinforcement and thickness of the deck slabs are determined using Section 3 of the AASHTO Specifications. Footings are also designed using these specifications.

2.3 Intersection Design

Intersections are a critical aspect of a street design to ensure safety for all vehicles, cyclists, and pedestrians. Intersection designs must address mobility and safety goals, and a redesign of an intersection should enhance the public realm.

2.3.1 Crosswalks and Crossings

To install a crosswalk, an engineering study must be done to analyze the behavior of pedestrians, the traffic flow, and the history and future usage of the intersection. Additional crosswalk installation determination depends on multiple factors including land use, present and future demand, pedestrian compliance, and history of speed, safety, and crashes. All legs of signalized intersections must have marked crosswalks unless pedestrians are prohibited from the section of the roadway, or there is no pedestrian access on either corner. According to the FHWA, unsignalized intersections may be used to indicate pedestrian paths across roadways under specific conditions, including at locations with stop signs so motorists are aware of the

pedestrian path, in designated school zones, and at locations where engineering judgement finds crosswalks desirable.

2.3.2 Corner Radii and Size

Corner radii of an intersection are designed to facilitate turning of design vehicles. The design vehicle is selected based on the largest vehicle type that regularly uses the intersection. The design vehicle appropriate for most types of transit service is the “City-BUS” as defined by AASHTO. Other factors that influence the creation of appropriate corner radii include the angle of the intersection, usage of pedestrians and cyclists, and geometric constraints. Large skew angles make maneuvers more difficult for vehicles like buses or trucks. In areas with high crossings of pedestrians and cyclists, smaller radii are used to reduce turning speeds and also to decrease the distance for pedestrians and cyclists to cross. Lastly, constraints such as curves, offsets, or elevations can impact the turn path of the vehicle and reduce the required right-of-way.

2.3.3 Visibility and Sight Distance

Sight distance is the length of the roadway that is visible to a driver, and must be sufficient to allow motorists to see approaching vehicles and pedestrians in order to slow down or stop when necessary. Intersection alignment controls the location of all intersection elements including edge of pavement, pavement elevation, and curb elevation. The horizontal alignment can affect the visibility of motorists. Intersections should intersect as close to right angles as possible, rather than skewed angles. Visibility is also impacted by the operating speed of the roadway.

Sightlines are typically based on the 85th percentile speed; however, this is not sufficient in all cases. Designers need to proactively lower speeds near conflict points like intersections before taking measures like widening the intersection or removing sightline obstacles.

2.3.4 Traffic Controls

An engineering study of traffic conditions, pedestrian and biker characteristics, and physical characteristics of the site must be done to determine if a traffic control signal is justified at the location. There are nine factors that must be analyzed; however, engineering judgement is the deciding factor if an intersection requires the installation of a traffic control system.

Table 2: Factors that Warrant Traffic Control Signal

Warrant 1	Eight-Hour Vehicular Volume
Warrant 2	Four-Hour Vehicular Volume
Warrant 3	Peak Hour
Warrant 4	Pedestrian Volume
Warrant 5	School Crossing
Warrant 6	Coordinated Signal System
Warrant 7	Crash Experience
Warrant 8	Roadway Network
Warrant 9	Intersection Near a Grade Crossing

At a location that is under development or construction, it may not be possible to obtain a traffic count that will represent future traffic conditions. In this case, hourly volumes should be estimated in an engineering study to determine the traffic signal warrants. Detailed information on the warrants and how

to calculate them can be found in the *Manual on Uniform Traffic Control Devices (MUTCD)*, a governing document that has specifications for traffic control. Alternatives to signalized

intersections are uncontrolled intersections, yields, stop sign controlled intersections with minor-road-only stop control, or with multi-way stop control.

2.3.5 Lanes

Intersections can be designed with single lanes, designated left-turn or right-turn lanes, or multiple lanes. Lanes are added to address safety and operational concerns. Left-turn vehicles often encounter conflicts with pedestrians, cyclists, opposing traffic, crossing traffic, and through traffic in the same direction. The demand for left-turns at some intersections also affects the amount of green time on a signal that is allocated to other traffic movements. Left turns are warranted under six different conditions including speed, volume, and sight distance. A high volume of right-turn movements can significantly impact the safety and operations of a signalized intersection. Right-turn lanes can provide benefits for approaching vehicles, reduce vehicular delay, and increase intersection capacity. Key design criteria for right-turn lanes are entering taper, deceleration length, storage length, lane width, corner radius, and sight distance. Further information can be found in *A Policy on Geometric Design for Highways and Streets*.

Flared intersections can also accommodate right turning vehicles and allow for more traffic flow.

2.3.6 Striping of Intersections

The *MUTCD* does not require stop lines (stop bars). However, many intersections use stop bars to indicate the point where vehicles should stop in compliance with a stop sign or red light. Typically, stop bars are 12 inches wide and are placed at the desired stopping point. In intersections with crosswalks, the stop line is placed four feet in advance of it.

3.0 Methodology

The goal of this project is to design a bridge and intersection to support LSU’s campus transportation improvements. The existing bridge crosses over Corporation Canal from South Campus Drive. The proposed intersection would be an extension of South Campus Drive that connects to West Lakeshore Drive and a new road extending north called Veterans Drive. This chapter contains the objectives and steps to complete the final design recommendations for Stantec. The team will pursue these four objectives to achieve the project goal:

- Document existing and proposed conditions
- Determine design criteria
- Develop design options
- Evaluate the bridge and intersection designs and select and refine final design

These objectives and their associated tasks are outlined below in the proposed Project Timeline.

		Document existing and proposed conditions			Determine Design Criteria			Develop Design Options				Evaluate Designs and Select one to Present Recommendations		
		Gather Traffic and Ped. Usage data	Site Observations and Design Aesthetics	Review LSU's plan	Research Louisiana standards	Conduct calculations - structural, traffic flow, EIS	Model the designs using CAD or software	Constructability, Safety, Construction Management	Economic	Environmental, Sustainability	Social, Ethical, Political	Compare benefits and drawbacks of design alternatives	Prepare final report	Prepare presentation
January 10-12	Week 1													
January 15-19	Week 2													
January 22-26	Week 3													
January 29-February 2	Week 4													
February 5- 9	Week 5													
February 12-16	Week 6													
February 19-23	Week 7													
February 26-March 2	Week 8													

Figure 4: Proposed Project Timeline

3.1 Document Conditions

The MQP team will take an inventory of the existing and proposed conditions that will affect how the bridge and intersection designs will be developed. As the project team will not be visiting the project site, collaboration with Stantec and Louisiana State University will be vital to

ensuring there is enough information to successfully meet the project goal. Observations may include raw data, images and videos, preliminary designs, concept art, and verbal communication.

3.1.1 Traffic

The type and volume of traffic traveling in the area is a significant consideration in the design of a bridge and an intersection. Since two of the roads will be new, the expected volume of traffic through the intersection will need to be estimated based on the recorded values for nearby roads. Hourly volumes should be estimated in an engineering study to determine the traffic volumes. Detailed information on how to calculate this can be found in transportation engineering literature such as the MUTCD or the Trip Generation Manual. Information on the current traffic volumes and types on South Campus Drive will be collected to predict the volume of traffic on the new Veterans Drive and South Campus Drive extension. Additionally, research on intersection and traffic standards specific to Louisiana will be conducted. Information on the projected bus route and schedule that will use the bridge and intersection will be collected to determine frequency of transit traffic through this area.

3.1.2 Aesthetic Design

The existing bridge and roadway, as well as surrounding areas, will be observed based on prior design and aesthetics, in order to improve their visual aspects. These observations will take place in the form of images, videos, and collaboration with both Stantec and Louisiana State University. The LSU Master Plan shows an increase in beautification and development in the

area around Corporation Canal and the Student Life Spine. These other concept designs will be acquired to ensure the team has an understanding of the whole vision LSU has for the area.

3.1.3 Pedestrian Usage

The current bridge and standing roadway will be evaluated for the frequency of current foot traffic. The team will take an inventory of the pedestrian amenities in the area, including sidewalks and crosswalks. The LSU Master Plan indicated that the campus hopes to increase its walkability to encourage less parking in the campus core. The plan includes a proposed parking garage on the east side of campus and developmental improvements to the Student Life Spine. The team will gather information on how LSU's proposed changes to the area as a whole will impact pedestrian usage and accessibility to the bridge and intersection.

3.1.4 Other Site Observations

Other observations will be taken about the existing bridge and roadways to ensure future design is possible and adequate in the area. Since the team will not be present in Louisiana to make observations, the team will rely on information provided by Stantec, the campus, and LSU's Master Plan regarding the existing roadway geometry, proposed intersection angles, surrounding roadways and available space on location

3.2 Determine Design Criteria

The design criteria for the proposed new construction of the bridge and intersection will be based off the vision LSU has for the area and the calculated needs for the campus transportation. Designs will take into consideration the aesthetics of the surrounding area to ensure that the proposed bridge and intersection fit into the campus surroundings. This section

describes how the team will take standards and criteria from accepted design practices and compare them to existing and proposed conditions to determine our design specifications.

3.2.1 Intersection Design

The characteristics of the proposed intersection will be determined by many variables and the accepted design standards for each characteristic. Each of the characteristics and the required information can be found in the information matrix found in Table 5.

3.2.1.1 Determination of Type of Intersection

To determine the type of intersection, the existing and proposed conditions for the area will be evaluated according to the criteria listed that warrant each type of intersection. The team will evaluate if the intersection warrants a full signal, stop sign controls, or no controls at the intersection. The warrants and standards for establishing a type of intersection can be found in the *MUTCD*. The parameters considered when making this determination can be found in Table 5.

Table 5: Information Matrix for Intersection Design Specification Input

DESIGN PARAMETER	<u>Crosswalks</u>	<u>Type of Intersection</u>	<u>Sight Distance</u>	<u>Turning Radius</u>	<u>Number of Lanes</u>	<u>Striping of Intersection</u>
INFORMATION REQUIRED						
<u>Speed</u>	X	X	X			X
<u>Pedestrian Usage</u>	X	X	X	X	X	
<u>Bike Usage</u>	X	X	X	X	X	

<u>Vehicles (ADT)</u>	X	X			X	X
<u>Type of Traffic</u>				X		X
<u>History of Crashes</u>	X				X	
<u>Available Space</u>				X	X	
<u>Type of Site</u>	X					X
<u>Number of Lanes</u>						X
<u>Angle of Intersection</u>			X	X		
<u>Sight Distance</u>		X			X	X
<u>Type of Intersection</u>						X

3.2.1.2 Determination of Geometric Specifications

To determine the geometric specification of the proposed intersection, including turning radius, sight distance, and number of lanes, existing and proposed conditions will be evaluated based on the standards for those parameters. The intersection could be designed in many ways depending on the input variables and standards established by AASHTO, FHWA, and local standards that the project team will research.

3.2.1.3 Determination of Crosswalks

To determine if a crosswalk or multiple crosswalks are warranted at this intersection, the existing and proposed conditions will be compared to the standard values established by the *MUTCD* and FHWA. Each of these criteria will be evaluated based on the values gathered about the proposed conditions of the intersection to inform the design. The criteria required to indicate

whether or not a crosswalk(s) should be included in the design can be found in the information matrix in Table 5.

3.2.2 Structural Design

To determine the structural components of the bridge design, existing and proposed conditions will be considered in order to determine the span type, length, and load. The team will design the superstructure and substructure based on the standards set by AASHTO and the aforementioned specifications. The following parameters will also guide the team’s bridge design.

Table 6: Information Matrix for Bridge Design Specification Input

DESIGN PARAMETER	<u>Abutment</u>	<u>Deck</u>	<u>Piers</u>	<u>Beams</u>	<u>Footin g</u>	<u>Railings/ Sidewalks</u>
INFORMATION REQUIRED						
<u>Loads</u>	X	X	X	X	X	
<u>Pedestrian Usage</u>		X				X
<u>Span Type</u>	X	X		X		

3.3 Develop Design Options

The team will use the input characteristics, defined specifications, and constraint considerations to design several options for the new bridge and intersection. The designs will then be evaluated to meet standards set for intersection and bridge design best practices and

address all identified constraints. The designs will be drawn using AutoCAD and the intersection designs will be tested using software available from Stantec.

3.4 Evaluate the Bridge and Intersection Designs and Select a Design

At this point, the project team will have identified and determined the information required for each design parameter and will have developed several design options. Each design parameter will then be classified under the factors outlined by the Capstone Design Statement including economic, environmental and sustainability, constructability, ethical, social and political, and health and safety. We will develop a rating scale to classify each factor in order to determine which design to select. The final bridge and intersection design will be presented to Stantec in the form of a final report and presentation. We will also present AutoCAD drawings and concept art.

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Appendix B: Traffic Signal Warrants

Criteria		Application at S Campus Drive and Veterans Drive
Warrant 1	Eight-hour vehicle volume must exceed 500 vehicles in an eight-hour period from both major approaches and 150 vehicles in an eight-hour period from one minor approach.	It is not predicted that the vehicular traffic will exceed these numbers in any timeframe from any approach
Warrant 2	<i>Based on chart in MUTCD</i>	ADT below the threshold, so does not warrant a signal
Warrant 3	<i>Based on chart in MUTCD</i>	ADT below the threshold, so does not warrant a signal
Warrant 4	<i>Based on chart in MUTCD</i>	ADT below the threshold, so does not warrant a signal
Warrant 5	School crossing where children frequently cross the major street; decisions made using engineering judgement.	While these will not be school children, the intersection is on a college campus and students may frequently be crossing Veterans Drive to walk along S Campus Drive.
Warrant 6	A signal is needed to control flow of traffic and platooning of vehicles in areas where multiple other coordinated signals exist.	Other intersections along both roads may be signalized but these signals should not interfere with the flow of traffic at this intersection
Warrant 7	If there is a history of crashes involving this intersection, and engineering study could show that a signalized intersection would increase safety.	No crash data for a non-existent intersection
Warrant 8	If an engineering study finds the intersection to be an important part of the surrounding roadway network, a signal can be installed to ensure organized traffic flow.	Although this is part of a campus roadway network, the flow does not need to be dictated by a signal.
Warrant 9	Based on vehicle ADT and railroad crossing	N/A-- no railroad crossing

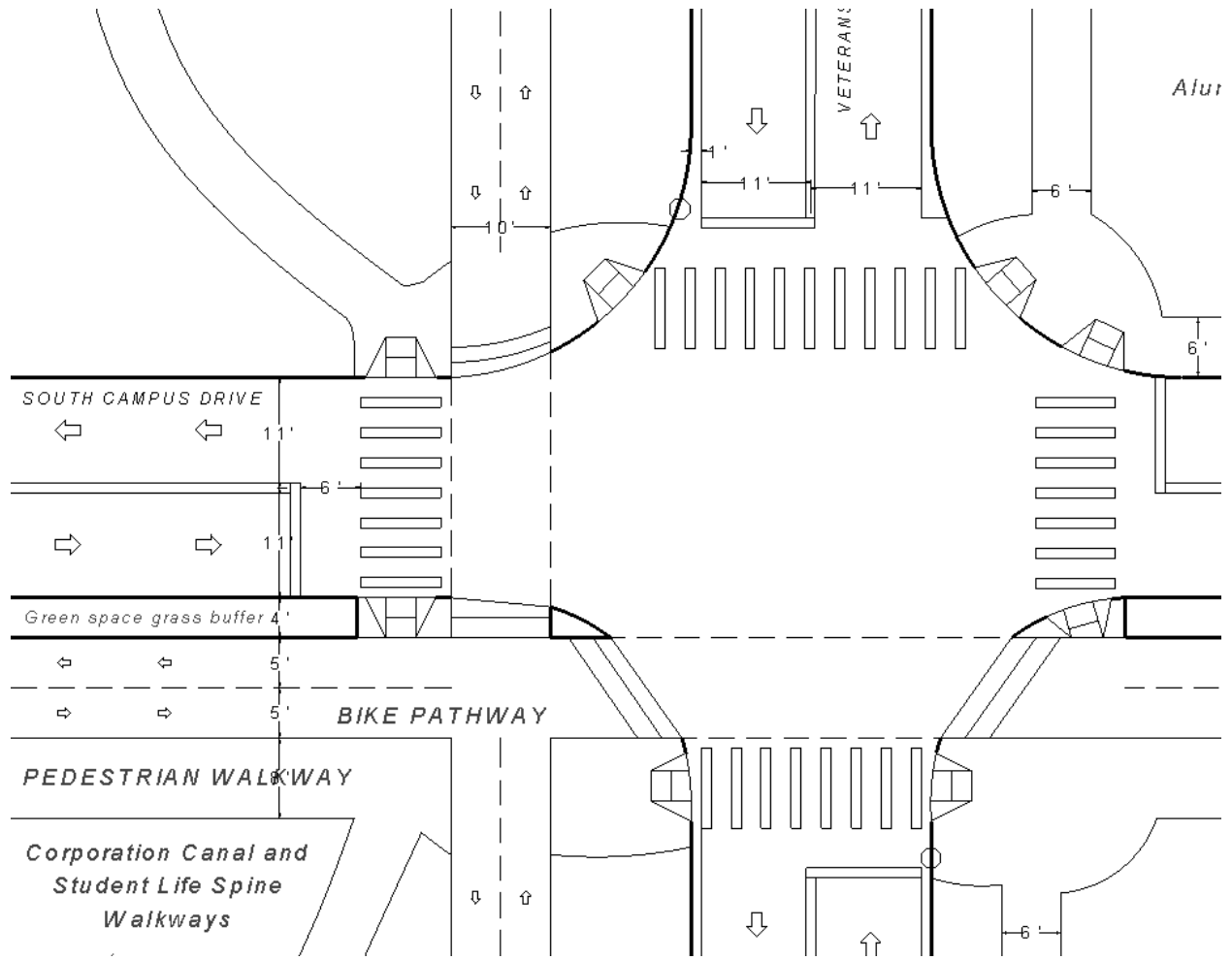
Appendix C: Stop Sign Warrants

Criteria		Application to S Campus Drive and Veterans Drive
Criteria 1	Multiway stop is an interim measure if traffic control signals are justified	N/A
Criteria 2	Five or more reported crashes in a 12-month period that can be corrected by a multi-way stop installation.	No crash data for a non-existent intersection
Criteria 3	Vehicular volume entering the intersection from the major street approaches averages at least 300 vehicles per hour for any eight hours on an average day	At peak times, the buses will be will be running on a 5-7 minute scheduled service, extending to an 8-10 minute service throughout the rest of the day.
Criteria 4	Combined vehicular, pedestrian, and bicycle volume entering the intersection from the minor street approaches averages at least 200 units per hour for the same eight hours as Criteria 3, with an average delay to minor street traffic of at least 30 seconds during the highest hour	There is not an expected delay of more than 30 seconds on any approach at any time.
Criteria 5	85th percentile approach speed of the major traffic exceeds 40 mph and the minimum warrants are 70 percent of the above values	Speed: 25 mph
Criteria 6	If Criteria 2 and 3 are all satisfied to 80 percent of the minimum values	N/A

Appendix D: Left Turn Lane Warrants

Criteria		Application to S Campus Drive and Veterans Drive
Criteria 1	Significant intersections with high approach speeds and traffic volumes	Posted speed will be 25 mph, and projected vehicle ADT through the intersection will be low, so here a left turn lane is not warranted.
Criteria 2	Increasing approach speeds	For Veterans Drive, vehicles will be approaching a stop sign, and transit vehicles on the S Campus Drive approaching should be within the posted speed of 25 mph.
Criteria 3	Higher volumes of vehicles turning left than continuing right or through	Since most of the traffic is through traffic, this is not applicable.
Criteria 4	High volumes of opposing vehicles	Veterans Drive will have more through traffic, but campus buses on the transit spine through S Campus Drive are the priority so this should not cause a conflict.
Criteria 5	To improve sight distance	N/A-- Sight distance not a concern
Criteria 6	Depending on crash history of turning vehicles	N/A—No crash data for a non-existent intersection

Appendix E: Final Design with Dimensions



Appendix F: Bridge Type Selection Study

1.0 Project Location

- 1.1 City: Baton Rouge
- 1.2 District: N/A
- 1.3 Bridge Number: N/A
- 1.4 BIN: to be assigned
- 1.5 Structure Number: to be assigned
- 1.6 Roadway on Bridge: South Campus Drive
- 1.7 Featured intersection: South Campus Drive and Veterans Drive

2.0 Description of Existing Site Conditions

2.1 Description of Existing Bridge Structure:

The site features a small roadway, South Campus Drive, over the Corporation Canal. The road currently has a weight limit of 5 tons. The existing bridge is a

2.2 Description of Existing Roadway:

The existing roadway approaching the bridge include a two way road, South Campus Drive. The new road structure will introduce an intersection to the west of the bridge, which will cross South Campus Drive with Veterans Drive.

2.3 Description of Feature Under the Bridge Structure:

This bridge will span over the Corporation Canal, a small stormwater drainage canal with low water levels.

2.4 Description of Existing Hydraulics at the Bridge Site:

The existing bridge crosses over the corporation canal. The new bridge is not expected to interfere with the current flow of the Corporation Canal. The span and ground conditions are expected to change but this will not affect the overall hydraulics.

2.5 Description of All Utilities Within the Bridge Site:

There are currently two street lights located on either side of the bridge.

2.6 Description of Environmentally Sensitive or Cultural Resource Areas Affecting the Bridge Site:

2.6.1 Environmentally Sensitive Areas

There are currently many species of fowl surrounding the Corporation Canal that must be considered during the construction phase. However, the updates should not affect the wildlife because LSU aims to make the space more sustainable and environmentally friendly.

2.6.2 Cultural Resource Areas

The Bridge will follow the historical and aesthetic principles set forth in the LSU Master Plan to update the campus as well and preserve it.

2.7 Hazardous Materials

No data is available for the water quality of the Corporation Canal, however it can be assumed that the water in the canal is strictly runoff and therefore not hazardous.

3.0 Description of Project Parameters and Constraints

3.1 Description of Proposed Roadway Cross Section:

The proposed roadway is designed to be used as part of a public transit spine, which contains city buses, bikes, and pedestrians. Geometrics include:

3.2 Proposed Traffic Management:

Coordination during construction with Louisiana State University is necessary to minimize impacts. Considering this road is transitioning into a public transit vehicle only road, only that vehicular traffic will need to be considered in the rerouting of the surrounding roadways. As for pedestrian and bike traffic, there is a foot bridge approximately 200 ft from the existing bridge that can be utilized. For rerouting of the public transit, South Campus drive loops around approximately 1000 feet to the South, allowing for an alternative crossing point over Corporation Canal.

3.3 Proposed Clearances

Proposed clearances for a new structure include the following:

- Minimum 12 ft underpass for trails and bikeways as specified in Section 2.3.3 of the LADOTD Bridge Design and Evaluation Manual

3.4 Hydraulic Data

The proposed bridge spans over the Corporation Canal. Because the proposed bridge foundation system will be far from the canal itself, the hydraulic area will not be affected and a hydraulic study is not necessary.

3.5 Preliminary Geotechnical Data

Never received this information from Stantec

3.6 Constraints Imposed by Approaching Roadway Features

The roadway over the bridge will continue into an intersection within 100 ft of the end of the bridge. The bridge must take into account the possibility for standing traffic on the roadway.

3.7 Constraints Imposed by Feature Crossed

It is necessary to maintain adequate hydraulic opening for the Corporation Canal including vertical and horizontal clearances over the proposed walkways. The river bed will be widened to accommodate for the proposed walkways and new vision for the canal.

3.8 Constraints Imposed by Utilities

Consideration is needed for lighting over the bridge for pedestrian, bike, and vehicular traffic.

3.9 Constraints Imposed by Environmentally Sensitive Areas

Consideration is needed for the current wildlife living in and near the canal as well as the current littering situation.

3.10 Constraints Imposed by Cultural Resource Areas

Louisiana State University has a vision to preserve the history and culture of their campus while making updates to enhance the learning environment. Consideration of these two areas is needed for the design of the bridge.

3.11 Hazardous Materials Disposition:

No data is available for the water quality of the Corporation Canal, however it can be assumed that the water in the canal is strictly runoff and therefore not hazardous.

3.12 Other Project Constraints

In the CAD files provided, the bridge is shown to have a slight horizontal curve. If this curve is determined to be important to LSU, then the design chosen must account for this.

4.0 Appropriate Bridge Structure Types

Geometries considered for design development are:

Geometry Option 1: The bridge crosses straight over the Corporation Canal.

Geometry Option 2(not further considered): The bridge crosses over the Corporation Canal with a bend.

Structural bridges types not considered for design development include:

- **Suspension Bridge**
Typical span lengths for a suspension bridge range from 2,000 to 7,000 feet and are very expensive to construct. Given only a span of 80 feet, this type of bridge does not make sense.
- **Cable-Stayed Bridge**
Typical span lengths for a Cable-Stayed bridge range from 200 to 3,000 feet and are usually expensive to construct. Given only a span of 80 feet, this type of bridge does not make sense.

For a straight geometry (option 1) the following three types of bridges are considered for further evaluation:

- Through truss
- Steel Girder Beam
- Tied Arch

For a curved geometry (option 2) one alternative bridge type is considered:

- Box Girder Beam

4.1 Prefabricated Through-Truss

This approach provides a fairly economical option that is also aesthetically pleasing and has been applied to many similar situations in the past. Either a Warren or Pratt shape could be used depending on the vision LSU has for this bridge, which would improve its appearance. A composite concrete deck will be used with this design.

This bridge type would work with both geometries, but is suggested for the straight geometry bridge.

Preliminary Calculations suggest that the Pratt truss would include 4" diameter A36 steel while the Warren truss would only need a 3" diameter.

Advantages to this type of bridge include less excavation and fill needed to get the necessary clearance for the walkways.

4.2 Steel Girder Beam Bridge

This approach provides an economical solution to the need for a new bridge. The girders can be used for the entire span, however for shipping purposes the girders must be cut and spliced together in the field.

According to preliminary calculations, 4 W40X278 rolled beams should be used to span a distance of 80 feet.

A disadvantage to this type of bridge is the profile must be raised to provide adequate vertical clearance for the walkways below due to the support being under the deck. The increase in approach fill sections as well as the concrete in the wing walls will be costly.

4.3 Tied Arch Bridge

This bridge type was not further developed because it would be difficult to transfer this design to other areas on campus.

This approach provides an extremely aesthetically pleasing bridge to incorporate into LSU vision to enhance their campus. There will be one arch on either side of the bridge which will be anchored to piers near the underpass. The deck will be held up by cables attached to the arches.

This option has the shallowest structure so although it may be more costly to construct the actual bridge, costs can be cut in approach fill and concrete retaining walls.

4.4 Concrete Box Girder

This Bridge type was no longer considered due to the recommendation by Stantec to make the bridge straight.

This approach will allow LSU to create the horizontal curve if they believe that to be an important aspect. The box shape will resist the torsion created from the curve. This design is both aesthetically pleasing and economical.

Disadvantages to this design include the complexity and extra materials necessary to add a horizontal curve which will increase the overall length. Other disadvantages to this type of bridge is the profile must be raised to provide adequate vertical clearance for the walkways below due to the support being under the deck. The increase in approach fill sections as well as the concrete in the wing walls will be costly.