SR260/SR89A Intersection Analysis

Final Proposal

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List of Abbreviations

AASHTO...................... American Association of State Highway and Transportation Officials
ADOT...Arizona Department of Transportation
E...Project Engineer
EB..Eastbound
FHWA... Federal Highway Administration
GC.. Clayey gravel soil under USCS
GI.. Grading instructor
GIS...Geographic Information System
HCM..Highway Capacity Manual
LOS.. Level of Service
OH...Overhead
MOE..Measure of Effectiveness
MUTCD.. Manual on Uniform Traffic Control Devices
NAU...Northern Arizona University
NB..Northbound
NEMA... National Electrical Manufacturing Association
PM...Project Manager
SB.. Southbound
SE..Senior Engineer
SR...State Route
TA..Technical advisor
USCS... Unified Soil Classification System
USDA...United States Department of Agriculture
USDOT...United States Department of Transportation
V/C ratio... Volume-to-Capacity Ratio
WB...Westbound

0 Foreword

The intersection of State Route 260 and State Route 89A in Cottonwood, Arizona connects various highly trafficked tourist destinations in the state, namely the cities of Sedona and Jerome. Currently there are various users to this intersection including commercial, local, and tourist populations. Recent upticks in traffic along SR260 and SR 89A have caused the level of service for both highways to deteriorate and the frequency of accidents to increase.

Traffic-related accidents and deaths are considered as a public health problem by the World Health Organization (WHO) [1]. Regularly assessing roads is critical in mitigating traffic injuries and deaths to promote road and public safety. This project recognizes the role of reviewing and implementing new traffic designs especially for roads and intersections. Implementing new traffic designs (i.e. bikeways, traffic signals, trails, and pedestrian lines) can have a lasting impact on overall traffic operations.

The accurate prediction of how these changes influence traffic can be challenging to understand. Traffic engineers recognize these complex issues surrounding traffic components including the intersection. Over the years, good intersection designs play vital roles in improving traffic systems. Features such as pedestrian signal phasing strategies, signal controller, signage, bicycle lanes, and others contributed to making intersections more comfortable and safer for the public.

1 Project Understanding

1.1 Project purpose

The purpose of this project is to analyze the intersection of SR 260 and SR 89A, in Cottonwood, Arizona, for operational deficiencies and to evaluate the feasibility of redesigning the intersection to correct any such operational deficiencies, as well as to make a design that would quantifiably improve the performance and safety of the intersection.

Assessing the intersection will help develop new interventions that will mitigate traffic and road accidents. This report will rely on industry standard models to accurately predict the impact of the intersection's current design to traffic and how to optimize strategies that will protect the public from traffic-related safety hazards.

1.2 Project background

The Arizona Department of Transportation (ADOT) initiated a traffic study in 2015 along the SR260/SR89A/SR179 corridor [2], which identified the intersection of SR260 and SR 89A in Cottonwood as a problem area in terms of traffic flow and safety. The 4-mile segment of SR260 and SR89A surrounding the intersection was identified by Kimley-Horn in a March 2018 study [2] as having a high need for safety improvements as well as freight mobility improvements.

One of the busiest intersections in Cottonwood [3], this intersection directly serves all traffic traveling between the Cottonwood/Clarkdale area and Camp Verde, as well as between Jerome and Sedona, two popular tourist destinations in northern Arizona. In the immediate vicinity of the intersection, there are two big-box stores (Fry's and Home Depot), a few hotels, and multiple restaurants. The site is near the Verde River, a major river in Arizona.

According to the Kimley-Horn study, the segment surrounding the intersection has a Mobility Index of 0.77 and a projected daily volume-to-capacity (V/C) ratio of 0.90, a bicycle accommodation of only 29% [2], and a Freight Index of 0.14 [2], which are all categorized as "poor." In addition, the Safety Index, which relates to fatal and incapacitating crashes, for this segment is 2.22, and the westbound segment has a directional Safety Index of 4.24, which is almost four times the threshold for a "Below Average" rating of 1.20 [2]. Seventeen crashes occurred at this intersection in 2016, making it the 3rd most dangerous intersection in Verde Valley that year [3].

The intersection currently operates at Level of Service (LOS) C or D and is projected to operate at LOS E or F if no mobility improvements are made [2]. LOS C is currently the minimum acceptable LOS, and LOS D, E, and F are considered unacceptable. Table 1-1 below, from the Highway Capacity Manual [4], defines the level of service criteria for this project:

Table 1-1: Definitions of the chosen LOS (level of service)

Level of Service (LOS)	**Definition**
C	A flow that is at a stable condition and remains that way and this is only with having significant interactions depending on the traffic flow. can also be not convenient for some users as the inconvenience level can increase at this point
D	A flow that has a high volume of traffic, where speed decreases and delay can be performed leading to increase in the level of inconvenience and comfort although the traffic is at a stable condition
E	The flow here is unstable, and users are packed close to each other leading to discomfort of the users and a major breakdown
F	The flow here is stated as a forced flow meaning that the roadway has more users leading to a breakdown in the traffic flow and all of this is because it exceeded the amount that is usually served. Thus, users here would have to stop and go several times leading to discomfort and inconvenience for the users

According to the USDA Web Soil Survey, the intersection rests on Mingus and Tapco soil [5]. The top layer of soil is classified as GC, defined as “extremely gravelly clay loam” under USCS [6], and A-2-7 under AASHTO [7]. A-2-7 is stated as a slightly plastic sandy loam or clayey gravel (sl pl SL); this type of soil is mostly gravel and contains 10 to 30 percent clay [5]. A-2-7 is one of the most common types of soil and is highly suitable for use as a road subgrade [7].

According to StreamStats, nearby streams have a catchment area of 0.32 mi^2 (approximately 205 acres). The 100-year peak flood in the area has a volume of 456 cubic feet per second (cfs) [8]. Existing drainage at the site conforms to all applicable standards.

Figure 1-1 below presents the location of Cottonwood within Arizona relative to Phoenix and Flagstaff.

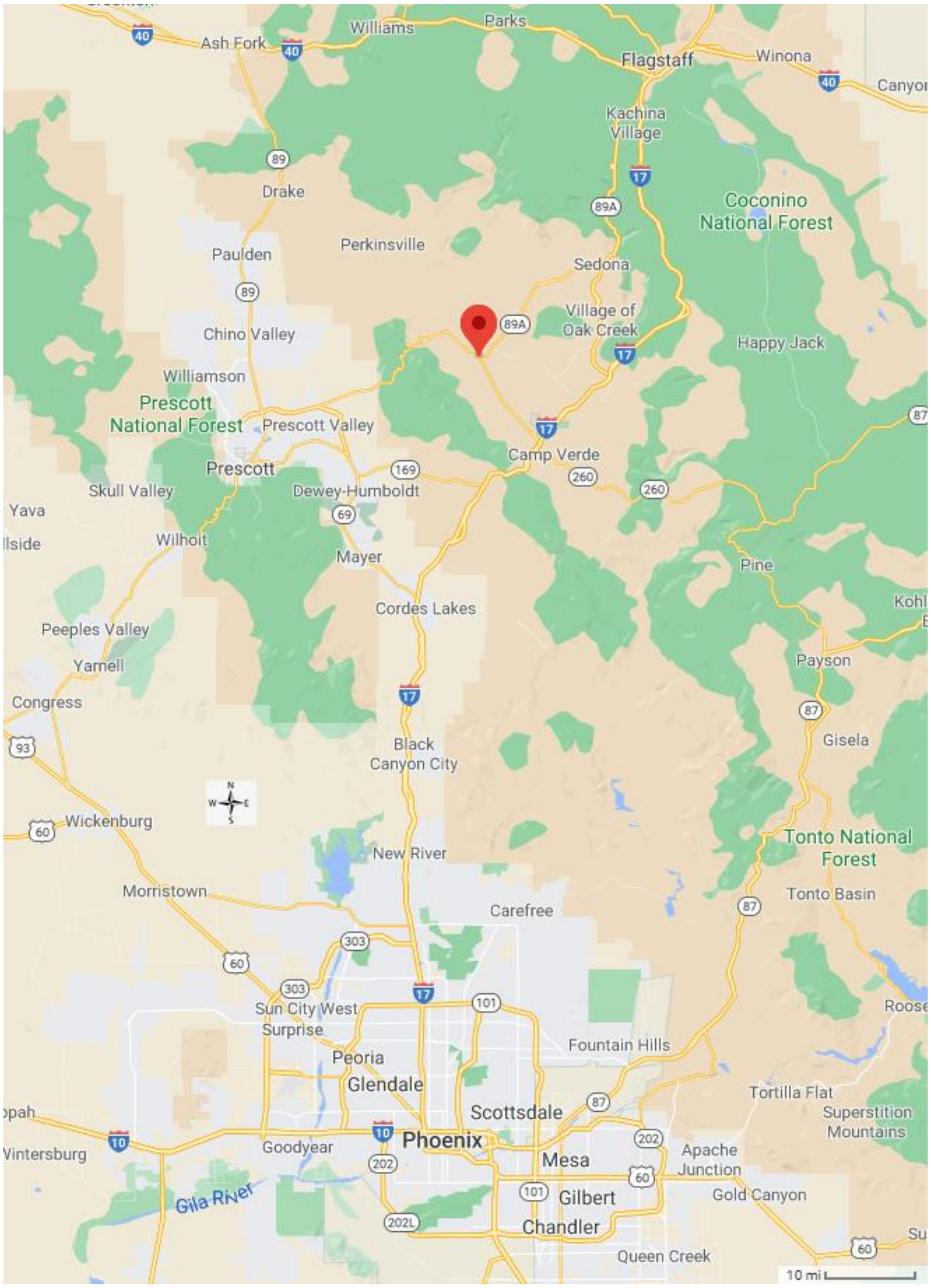

Figure 1-1: Location of Cottonwood within Arizona. Image credit Google Maps

Figure 1-2 shows the signalized intersections in the vicinity of the site, denoted by traffic signal symbols. The site is circled in red.

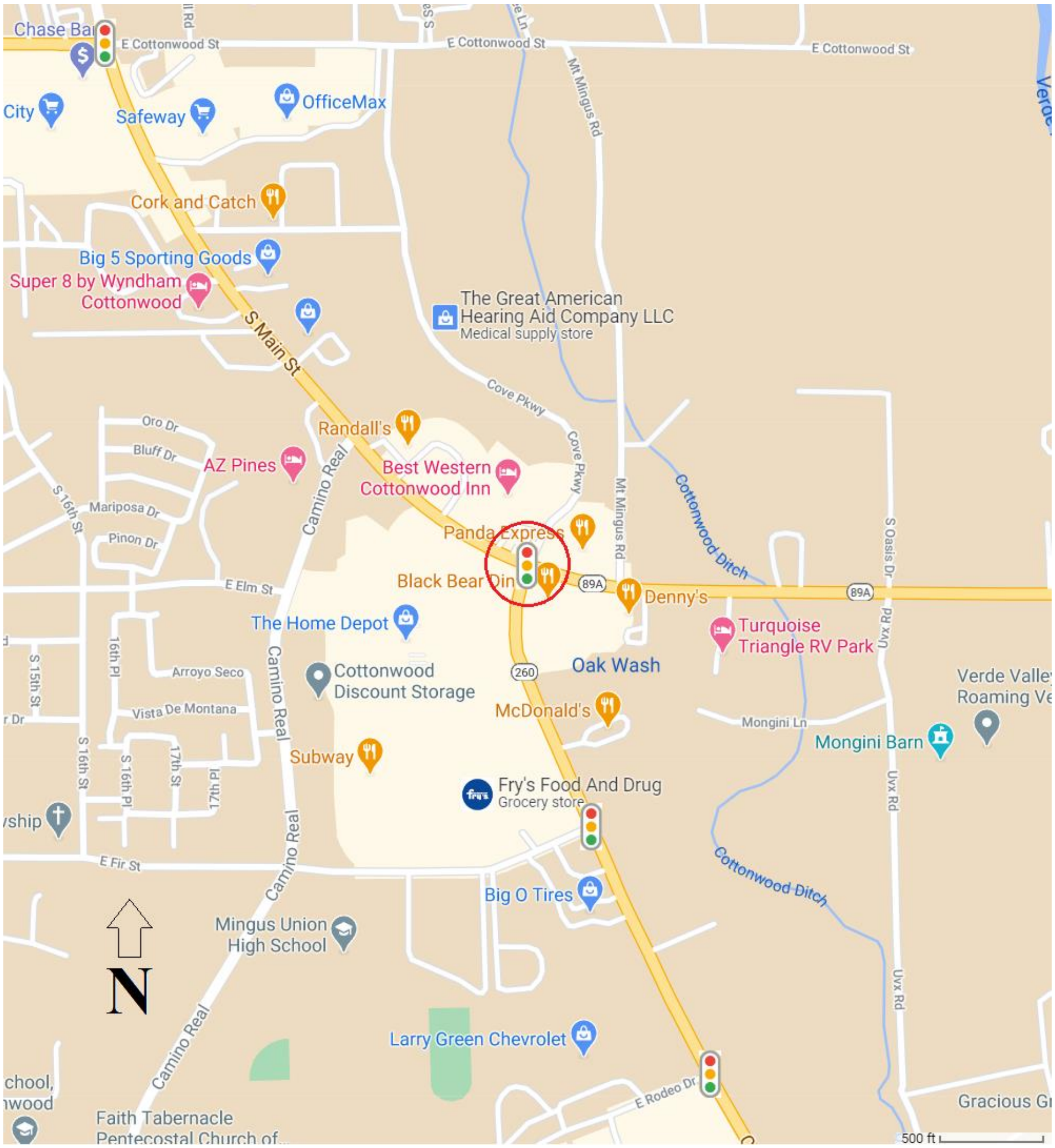

Figure 1-2: Location of the project within Cottonwood. Image credit Google Maps

The northbound (NB), eastbound (EB), and westbound (WB) approaches all have four lanes, with at least two being turn-only lanes. The southbound (SB) approach (Cove Pkwy) has two lanes, which serve primarily local business traffic. Crosswalks are present at all approaches. The signal at the intersection is actuated and uses radar and inductive loops for detection. All left turns are protected-only.

The two left lanes on the NB approach (SR 260 WB) are left-turn only lanes, the center right lane is a through lane, and the far-right lane is a right-turn only lane. The four lanes on the EB approach (SR 89A NB) are left-turn only, through only, through or right-turn, and right-turn only. The two left lanes on the WB approach (SR 89A SB) are left-turn only lanes and the two right lanes are through lanes, with the far-right lane also allowing right-turns. The left lane on the SB approach (Cove Pkwy SB) is a left-turn only lane and the right lane is a through or right-turn lane. Due to the local alignment of the state highways, the signed directions are rotated 90 degrees counterclockwise relative to the actual direction of travel (i.e. NB approach is 260 WB, EB approach is 89A NB). An aerial view of the intersection is presented in Figure 1-3. Note that S Main St is both SR 260 and SR 89A, going south and west from the intersection, respectively.

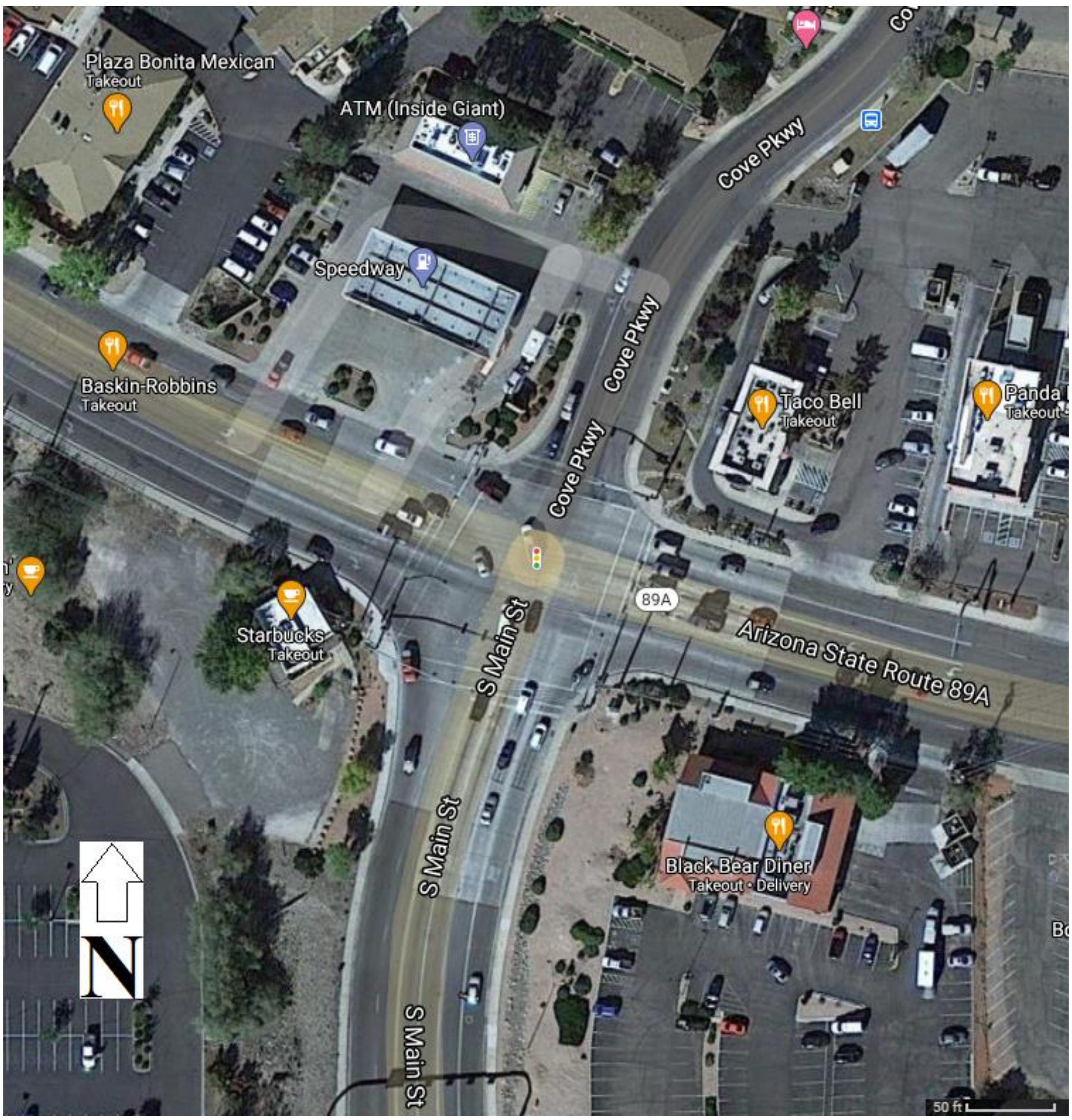

Figure 1-3: Aerial view of the study intersection. Image credit Google Maps

1.3 Technical considerations

This project will involve an in-depth traffic analysis, along with considerations in land surveying, geotechnical engineering, hydraulics, hydrology, and environmental regulations.

A topographic survey will be needed to create a topographic map of the project area, which can later be used to generate the final design including drainage work. A soil report will be needed to evaluate relevant soil properties, such as consolidation, bearing capacity, and shear strength.

Vehicular, pedestrian, and bicycle volumes will be analyzed along with delays per lane group and crash data. The timing, phasing, and configuration of the intersection will need to be evaluated for mobility and safety flaws, and several design changes will be considered with all aforementioned factors in mind.

The following constraints have been identified for this project:

- Meet all applicable local, state, and federal standards, including:
  - Manual on Uniform Traffic Control Devices (MUTCD) [9]
    - ADOT supplement [10]
  - Highway Capacity Manual (HCM) [4]
  - AASHTO Green Book [11]
  - ADOT Roadway Design Guidelines [12]
- Conform to local, county, and state drainage standards
- Meet objectives specified in the Arizona Strategic Traffic Safety Plan [13]
- Be on level terrain
- Improve vehicle, pedestrian, and cyclist safety by reducing the likelihood and frequency of crashes over the existing design
- Improve traffic mobility and efficiency over the existing design, such that the intersection operates at LOS C or above during peak-hour conditions
- Use the most cost-effective materials and building methods currently available

1.4 Potential challenges

The following potential challenges have been identified for this project:

- The intersection is constrained to the SW, NW, and NE by Starbucks, Speedway, and Taco Bell, respectively. There is, however, approximately 50 feet of space on the southeast corner between the right-of-way and Black Bear Diner. It is therefore important to select a final design that creates minimal disruption to existing businesses.

- Unpredictable or extreme weather conditions may adversely affect the timely delivery of this project.

1.5 Stakeholders

The following parties have been identified as stakeholders in this project:

- United States Department of Transportation (USDOT), who may provide federal grants
- Federal Highway Administration (FHWA), a subsidiary of USDOT
- Arizona Department of Transportation (ADOT), the primary benefactor and client for this project
- City of Cottonwood, the municipality in which the project is located, and will benefit from:
    - Safety improvements, as less spending is required on response to accidents and subsequent litigation, and
    - Increase in capacity, as more travelers will result in more spending, translating to an increase in tax revenue for the City.
- Residents, visitors, and through travelers, all of whom will benefit from any mobility and safety improvements made to this intersection

2 Scope of Services

2.1 Task 1.0: Research and Regulatory Considerations

In this task, past solutions and current regulations will be reviewed that will help guide the design of any proposed changes to the intersection. These include:

2.1.1 Task 1.1: Review Past Solutions

Past similar projects will be researched and evaluated to look at possible solutions for this project.

2.1.2 Task 1.2: Regulatory Considerations

There are regulations and requirements that impact the final design that are to be thoroughly reviewed for compliance with federal, state, and local requirements.

2.1.2.1 Task 1.2.1: Federal Highway Administration (FHWA)

The FHWA allocates funds for projects related to the National Highway system which includes both SR 260 and SR 89A. The following federal regulations will be considered:

- MUTCD: Standards for signal, geometry, and sign setback
- Highway Capacity Manual: Contains information used in analyzing a highway's quality of service.

2.1.2.2 Task 1.2.2 ADOT Roadway Design Guidelines

The state highway design manual will be used to create models for the traffic analysis. Recommended alternative will follow these regulations in addition to the federal regulations listed above.

2.2 Task 2.0: Site Investigation

This task is aimed at assessing the current conditions of the site by reviewing existing data including current traffic data, surveying data, and the current design of the existing intersection. These data will be used in the design of the intersection.

2.2.1 Task 2.1: Surveying and Soil Data

Soil data will be researched using the USDA Web Soil Survey to ascertain the suitability of the soil as road subgrade.

2.2.2 Task 2.2: Existing Geometry

Existing geometry, roadway alignments, and radii of curvature for turns will be determined and measured using satellite imagery and/or existing plan sets from

ADOT. This geometry will be used to create and calibrate a software model to be used in the analysis.

2.2.3 Task 2.3: Identify Contributing Intersections

The first two preceding intersections with traffic signals will be identified, if applicable. The distance between these intersections will be measured along the centerline from stop-line to stop-line which will be inputted into the VISSIM model.

2.2.4 Task 2.4: Lane Configurations

The linework of the road will be examined using satellite imagery to determine the number, grouping, width, and length of all lanes on each approach.

2.2.5 Task 2.5: Site Restrictions

The site will be investigated for any possible restrictions that may interfere with the proposed design. The boundaries between the ADOT right-of-way and private properties will be determined using existing GIS data or ADOT plan sets. This task will also involve locating utility easements.

2.2.6 Task 2.6: Investigate Proposed Developments

To project future growth, proposed developments in the area, if any, will be investigated to estimate future traffic growth. This will be done by researching ongoing or proposed housing developments and by reviewing city council meetings for granted rezoning applications and building permits. Then, the demand these development(s) will add to the SR260/89A intersection will be estimated and considered for the traffic analysis.

2.3 Task 3.0: Collection of Traffic Data from ADOT

The following data are related to the traffic analysis but will be obtained from ADOT (rather than being collected by the team at the site). This data will be obtained after the kickoff meeting with the client.

2.3.1 Task 3.1: Existing Plan Set

The most up-to-date plan set of the intersection will be obtained from ADOT to assist in determining the geometry of the intersection.

2.3.2 Task 3.2: Classification of Vehicles

The percentage of large trucks or recreational vehicles using the intersection will be determined, as it is necessary to determine the design vehicle per AASHTO Green Book guidelines [11].

2.3.3 Task 3.3: Five-Year Crash Data

A qualitative analysis of the last 5 complete years of crash history will be performed to identify patterns and trends as well as any potential design-related causes of crashes.

2.3.4 Task 3.4: Signal Timing and Phasing

The current timing and NEMA phasing of the signal will be obtained in the form of a ring-barrier diagram to be used in the analysis.

2.4 Task 4.0: Traffic Counts

A peak-hour traffic count will be required to count different paths users take at the intersection. This is currently planned to take place at the site, pending the status of the COVID-19 pandemic and any associated restrictions imposed by NAU.

2.4.1 Task 4.1: Field Safety Plan

An OSHA-compliant field safety plan will be developed for any field work that needs to be done.

2.4.2 Task 4.2: Peak Hour Volumes

Traffic counts will be performed at the peak hour using JAMAR boards. The peak hours have been identified as Wednesday from 7:30-8:30 am, 12:00pm-1:00pm and from 3:00-4:00pm [14].

2.4.3 Task 4.3: Upload Data

Data will be reduced into PetraPro software, then exported into an Excel file for use in the analysis. The output from PetraPro will be included as an appendix in the final report.

2.5 Task 5.0: Traffic Analysis

The team will use computer software to observe both the current traffic data and projected traffic data. This will be done for base conditions and all hypothetical designs created.

2.5.1 Task 5.1: Base Model Creation and Calibration

A base model will be created in VISSIM showing the intersection in its existing lane configuration and traffic volumes. Road geometry and lane configurations will be recreated to create an accurate model. The VISSIM model created in Task 5.1 will be calibrated to ensure accuracy with real-world conditions. Several client meetings will take place during this Sub-Task to ensure the model is accurate.

2.5.2 Task 5.2: VISSIM Analysis of Base Conditions

Traffic conditions at the intersection will be simulated in VISSIM to evaluate for level of service, approaches and lane groups most prone to congestion, and possible treatments for any sources of congestion. Several key parameters will be analyzed, including, but not limited to:

- Generators of traffic
- Volume-to-capacity (VC) ratio
- Density/Level of Service (LOS)
- Delay (control, uniform, and incremental)
- Phasing
- Coordination with other signals in the vicinity

2.5.3 Task 5.3: 20-Year Projection

In reference to the VISSIM analysis described above, the base traffic volumes collected in Task 4 will be increased by increments of 2 percent per year, up to 20-40 percent. An increase of 20 percent will serve as the design volume, and an increase of 40 will serve as the "check" volume.

The breakdown in level of service and other measures of effectiveness (MOEs) with increasing volumes will be documented to determine how much longer the intersection can maintain acceptable MOEs without improvements. This will serve as the no-build alternative, which will be compared to other design alternatives developed in Task 6.2.

2.6 Task 6.0: Alternatives and Evaluation of Impacts

This task involves the drafting, comparison, and analysis of the alternatives resulting from the traffic analysis in Task 5. Each alternative will be scored, with the highest scoring one being selected as the final recommendation.

2.6.1 Task 6.1: Scoring System

A weighted scoring system will be established based on the critical design constraints of this project. Each criterion below will be assigned a weight according to importance to the overall project.

2.6.1.1 Task 6.1.1: Design Criteria

Design criteria governing the functionality of the intersection will be integrated into the scoring system and assigned a weight, including improvements to:

- Level of service
- Delay

- Queue length
- Travel time variance [15]
- Safety

2.6.1.2 Task 6.1.2: Construction Considerations

In addition to functionality, an appropriate scoring weight will be assigned to the approximate:

- Cost of construction
- Timeframe of construction

2.6.1.3 Task 6.1.3: Evaluation of Impacts

In addition, the degree to which each alternative impacts the following items listed below will be evaluated:

- Social
- Environmental
- Economic
- Right-of-way expansion/possibility of eminent domain

2.6.2 Task 6.2: Generate and Analyze Alternatives

Design alternatives will be developed based on the critical design constraints established in the project understanding, and then analyzed under future conditions as described in Task 5.3. This task will largely overlap with Task 5.3. Different configurations will be analyzed, which include changing the:

- Number of lanes
- Signal timing/phasing
- Intersection geometry

As with Task 5.3, a 20 percent increase will serve as the design volume, which will be checked with a 40 percent increase in volume for this analysis. In addition, the maximum volume each alternative can handle while maintaining acceptable LOS and other MOEs will be determined

Alternatives deemed unfeasible will be eliminated from further consideration. Three to five final alternatives will be considered for further analysis in the steps outlined below.

2.6.3 Task 6.3: Scoring, Selection of Final Alternative

Based on the weighted scoring system established in Task 6.1, each alternative will be evaluated and scored. This will involve a combination of quantitative factors, such as level of service and construction cost, and qualitative factors, such as safety and impacts.

Then, the highest-scoring alternative will be selected as the final recommendation. Additional justification will be given as to why that alternative was selected over the others.

2.6.4 Task 6.4: Preliminary and Final Design Plan Sets

A preliminary sketch of the final design will be drafted and forwarded to the client for review. This sketch will include the lane configurations, detailed geometry, a signal timing plan, topographic contours, the location of storm drains, property and right-of-way boundaries, and any other information deemed necessary by the client. Once reviewed by the client, revisions will be made until the final plan set is approved.

2.7 Task 7.0: Project Deliverables

The following deliverables associated with the project will be completed and submitted before their respective deadlines:

2.7.1 Task 7.1: 30% Report and Presentation

The following tasks will be completed and included in the 30% report:

- Task 1: Research and Regulatory Considerations
- Task 2: Site Investigation
- Task 3: Collection of Traffic Data from ADOT

The following tasks will be in progress by the 30% mark:

- Task 4: Traffic Counts

2.7.2 Task 7.2: 60% Report and Presentation

Along with the items identified in Task 7.1, the following tasks will be completed and included in the 60% report:

- Task 4: Traffic Counts
- Task 5.1: Base Model Creation and Calibration

The following tasks will be in progress by the 60% mark:

- Task 5: Traffic Analysis
    - Task 5.2: VISSIM Analysis of Base Conditions
    - Task 5.3: 20-Year Projection
- Task 6: Alternatives and Evaluation of Impacts

2.7.3 Task 7.3: 90% Report

A draft final report will be compiled based on the findings of the traffic analysis and submitted to the grading instructor for feedback. Along with the items identified in Tasks 7.1 and 7.2, the following tasks will be completed and included in the 90% report:

- Task 5: Traffic Analysis
- Task 6: Alternatives and Evaluation of Impacts

2.7.4 Task 7.4: Final Submittal

All tasks, as well as the final project report, will be completed. In addition, the findings of this analysis will be presented at NAU's Undergraduate Symposium (UGRADS).

2.7.4.1 Task 7.4.1: Final Report

A final report will be complied detailing the methodology and findings of the analysis, as well as the final alternative and plan set.

2.7.4.2 Task 7.4.2: UGRADS Presentation

The team will present their findings at NAU's Undergraduate Symposium (UGRADS).

2.7.5 Task 7.5: Website

A website will be created to showcase all work completed throughout the project.

2.7.5.1 Task 7.5.1: 90% Website

A rough draft of the website will be created and submitted to the grading instructor for review.

2.7.5.2 Task 7.5.2: Final Website

The draft website will be revised according to feedback from the grading instructor. The final website will then be published in the NAU senior capstone archive.

2.8 Task 8.0: Project Management

Project management consists of the following subtasks:

2.8.1 Task 8.1: Resource Management

Resources will be used and managed in a manner that maximizes efficiency and performance. Staffing and work will be tracked via a spreadsheet to ensure the project stays on schedule.

2.8.2 Task 8.2: Client and TA Meetings

Meeting with both the client and the technical advisor will happen regularly throughout the project. An agenda will be created and forwarded to the client or TA at least 24 hours prior to each meeting. Meeting minutes will be generated after each meeting and provided in the Meeting Memo Binder.

2.8.3 Task 8.3: GI Meetings

Meetings with the grading instructor will happen regularly throughout the course of this project. An agenda will be created and forwarded to the GI at least 24 hours prior to each meeting. Meeting minutes will be generated after each meeting and detailed in the Meeting Memo Binder.

2.8.4 Task 8.4: Team Meetings

The team will meet regularly to ensure that work is performed in a timely manner, deadlines are met, and all team members agree on the manner in which tasks identified in this Scope are carried out. An agenda will be created at least 24 hours prior to each meeting. Meeting minutes will be generated after each meeting and detailed in the Meeting Memo Binder

2.8.5 Task 8.5: Schedule Management

Schedule briefings will take place regularly to ensure adherence to the project schedule. An official Gantt chart will be maintained and updated after the completion of each task.

2.9 Exclusions

The following items are excluded from this Scope with supporting justification:

2.9.1 Construction

The scope of this project does not include construction of the final design due to the time constraints associated with this project. This exclusion extends to the production of a plan set as well as the creation of a temporary traffic control (TTC) plan

2.9.2 Drainage analysis/design

Drainage work will not be required as this is strictly a traffic analysis and alternative recommendation. Drainage work will likely be done by ADOT themselves.

2.9.3 Soil samples

Geotechnical data will be provided by ADOT or the USGS Web Soil Survey [5], so it is not included in this project.

2.9.4 Topographic survey

Since survey data will be provided by ADOT, it is not necessary to perform a topographic survey as part of this project.

2.9.5 Pavement design

Pavement design requires geotechnical work which falls outside the scope of a traffic analysis. Pavement design will likely be performed by ADOT.

2.9.6 Public outreach

Engineers are typically not involved in public communication. This will be handled by ADOT and the City of Cottonwood.

3 Schedule

This project is estimated to last from January 13 to April 29, 2021, for a total of 74 working days. The full project Gantt chart may be seen in Appendix A.

Task 1: Research and Regulatory Considerations, Task 2: Site Investigation, and Task 3: Collection of Traffic Data from ADOT, which primarily concern background information about the site, are all scheduled to start within the first five working days of the start of the project. These tasks are all scheduled to last 10 to 17 working days, with Task 2.0: Site Investigation, taking the longest. Following Task 3 is Task 4: Traffic Counts, which is scheduled for just seven working days. This is relatively short compared to the first three tasks, but traffic counts only need to be collected over the span of two days, shortening the overall task.

After the traffic counts, the longest major tasks begin, which are Task 5: Traffic Analysis, followed by Task 6: Alternatives and Evaluation of Impacts, which are scheduled for 20 and 27 working days, respectively. These tasks constitute the lion’s share of the work in this project and are thus given the most time to complete.

The critical path is comprised of the tasks that all must be completed on time to prevent overall project delays, which are highlighted in red on the Gantt chart shown in Appendix A. Many tasks on the critical path are prerequisites to the tasks that follow, necessitating the timely completion of each task on the critical path. Most of Tasks 2 through 6 are on the critical path, with one notable exception being Task 4: Traffic Counts. This gap in the critical path serves as float in the project schedule, allowing for delays due to weather or any COVID-related restrictions in traveling to the site.

The site investigation (Task 1), collection of field data (Tasks 2 and 3), and traffic counts (Task 4) are all crucial required to perform the traffic analysis (Task 5), which is the primary and longest task in this project. The traffic analysis must be completed before an alternative can be recommended (in Task 6), so this task must be completed on time so that all deadlines can be met.

The timing of items on the critical path will be maintained by starting and completing each task as early as possible. If predecessor tasks are completed early, then tasks following those may be started early.

4 Staffing Plan

4.1 Billing Rates

The following positions have been identified as necessary to complete the project:

Table 4-1: Summary of positions

Position	Code
Senior Engineer	SE
Engineer	E
Project Manager	PM
Drafter	DR

Table 4-2 below presents the total billing rate and multiplier for each position associated with this project:

Table 4-2: Summary of billing rates by position

Position	Code	Billing rate ($/hr)	Multiplier
Senior Engineer	SE	$152.59	2.36
Engineer	E	$105.98	1.97
Project Manager	PM	$89.62	2.08
Drafter	DR	$56.32	1.74

4.2 Qualifications for Each Position

Below are the qualifications required for each position associated with this project:

4.2.1 Senior Engineer (SE)

A Senior Engineer is responsible for being the bridge of communication between the client and the team and overseeing projects with the key characteristics of having organizational and managerial skills. This position requires a master's degree or doctorate in an engineering discipline with background in business administration.

This role is best suited for engineers who have 8+ years of experience in other engineering positions, and licensure (PE) is required. A senior engineer's roles are to allocate resources, supervise multidisciplinary construction teams, sign/seal final designs, and inspect completed projects. Specific project tasks primarily for the senior engineer are Task 7: Project Deliverables and Task 8: Project Management, which consist of inspecting reports, drawings, and software before approving for final submittals. In addition, the senior engineer will review work and place their stamp of approval on all other tasks.

4.2.2 Engineer (E)

The Engineer is responsible for heading the site investigation, making critical analysis and design decisions, monitoring the progress made in each project, and checking the work done by the drafter. They are also responsible for creating cost estimates for each phase of the project. This position requires a bachelor's degree in a related field in addition to 5 years of project experience. PE licensure is required. The primary tasks allocated to the engineer are Tasks 5 and 6, where they are responsible for making critical analysis and design decisions. The engineer will also be heavily involved in Tasks 1 through 4.

4.2.3 Project Manager (PM)

Project managers are responsible for the planning and oversight of a project, determining project responsibilities by splitting the project into various phases, and managing and allocating resources. This position requires a bachelor's degree, PE licensure, and 5+ years of experience in an engineering management-related role, along with excellent skills in management, communication, critical thinking, and adaptability. The primary tasks allocated to the project manager are Task 8: Project Management as well as supervisory roles in every task from Task 1 through Task 6. The project manager may also assist the project engineer in the analysis and design in Tasks 5 and 6.

The project manager differs from the engineer in that the project manager oversees day-to-day operations of the project and the engineer is responsible for making the final analysis and design decisions.

4.2.4 Drafter (DR)

The drafter is responsible for drafting the final design plan set. Drafters are typically proficient in AutoCAD and Civil 3D, in addition to other computer software programs. Drafters typically have fewer than five years' experience in engineering work, holding a bachelor's degree in an engineering field, and have passed the Fundamentals of Engineering (FE) exam, certifying them as engineers in training (EIT). This position is best suited for recent graduates who are technologically and creatively adept. The primary tasks allocated to the drafter are finishing drawings.

The drafter will primarily be used in Task 6, specifically Task 6.4: Preliminary and Final Design Plan Sets. The drafter also plays a significant role in Task 5: Traffic Analysis as well as Tasks 2.2 and 2.4, which concern the roadway geometry and lane configurations of each approach leading up to the intersection, which are important for the drafter to know before starting work on the plan sets.

4.3 Qualifications of Team Personnel

4.3.1 Ahmad Alrajhi

Senior student at NAU majoring in civil engineering. Completed:

- Geotechnical I & II
- Land Surveying, learned how to use most of the surveying equipment such as total station, collecting data and importing them into Civil 3D to create a topographic map and calculating the area surrounding
- Traffic Analysis
- Experienced in both Civil 3D- AutoCAD (4+ years)
- Water Resources I & II
- Worked as a site manager
- Good in time management
- Have a good understanding of site field testing before starting the project and analyzing the area
- Worked at a construction company in Kuwait as an EIT
- Built a construction company and a partner in it since 2018 as a freelancer and EIT in Kuwait

4.3.2 Jessica Coolidge

Senior civil engineer student at NAU with previous work and academic experience in the following:

- Traffic and signal studies and highway design. Utilizing highway traffic analysis and highway design.

- AutoCAD 2016-2020 edition, Civil 3D, Carlson mining with AutoCAD edition.
- ArcGIS software, ESRI, and Garmin navigation technology.
- Water Resources 1 and 2 with laboratory. Which demonstrates characteristics of hydrology and delineation of a watershed.
- Surveying showed the uses of total station and robotic GIS capabilities of getting data for software manipulation. Using Trimble equipment and stalking.
- Geotechnical engineering identifying the soil properties and usability for construction.
- Working experience gained from working at companies:
    - Project Management
    - Administration work
    - Time management
    - Reliable
    - Gained software knowledge

4.3.3 Daniel Navarro

Daniel Navarro is a senior civil engineering student with previous experience in the following:

- Traffic and signal study
- Computer aided design
- Intersection analysis
- Traffic counting
- Water resources and hydrology
- Geotechnical analysis
- GIS
- Surveying analysis
- Municipal Engineering

4.3.4 Kent Roeckner

Kent Roeckner is a senior civil engineering student with previous experience in the following classes:

- Kent Roeckner is a senior civil engineering student with previous experience in the following classes:
- Traffic Study and Signal
    - Learned critical aspects of traffic studies
    - Performed traffic counts with JAMAR boards
- Highway Engineering

    - Calculated Level of Service (LOS) and other highway performance metrics
    - Learned crucial elements of road geometry, including horizontal and vertical curvature
- Engineering Design: The Process
    - Redesigned the intersection at Butler Ave and Fourth Street
- Computer Aided Drafting
    - Gained proficiency in AutoCAD and Civil 3D
- Geotechnical Engineering
- Water Resources I and II
- Municipal Engineering/Water Resources II Lab
    - Gained proficiency in Microsoft Excel
- Surveying

4.4 Staffing Matrix

Table 4-3 on the next page summarizes the total number of personnel-hours for each position by major task.

Table 4-3: Summary of hours by position and major task

Task	SE	E	PM	DR	Total
Task 1.0: Research and Regulatory Considerations	**10**	**14**	**16**	**12**	**52**
Task 1.1: Review Past Solutions	5	6	8	4	23
Task 1.2: Regulatory Considerations Task 1.2.1: Federal Highway Administration (FHWA) Task 1.2.2 ADOT Roadway Design Guidelines	5	8	8	8	29
Task 2.0: Site Investigation	**7**	**13**	**22**	**31**	**73**
Task 2.1: Surveying and Soil Data	1	2	2	4	9
Task 2.2: Existing Geometry	2	4	4	8	18
Task 2.3: Identify Contributing Intersections	1	3	2	3	9
Task 2.4: Lane Configurations	0	0	2	4	6
Task 2.5: Site Restrictions	2	2	6	6	16
Task 2.6: Investigate Proposed Developments	1	2	6	6	15
Task 3.0: Collection of Traffic Data from ADOT	**8**	**19**	**25**	**18**	**70**
Task 3.1: Existing Plan Set	3	6	12	12	33
Task 3.2: Classification of Vehicles	2	4	4	2	12
Task 3.3: Five-Year Crash Data	1	4	4	0	9
Task 3.4: Signal Timing and Phasing	2	5	5	4	16
Task 4.0: Traffic Counts	**0.5**	**13**	**13**	**10**	**36.5**
Task 4.1: Field Safety Plan	0	4	4	4	12
Task 4.2: Peak Hour Volumes	0	6	6	6	18
Task 4.3: Upload Data	0.5	3	3	0	6.5
Task 5.0: Traffic Analysis	**23.5**	**47.5**	**47.5**	**47.5**	**166**
Task 5.1: Base Model Creation and Calibration	14	28	28	28	98
Task 5.2: VISSIM Analysis of Base Conditions	5	10.5	10.5	10.5	36.5
Task 5.3: 20-Year Projection	4.5	9	9	9	31.5
Task 6.0: Alternatives and Evaluation of Impacts	**41**	**66**	**55**	**71**	**233**
Task 6.1: Scoring System Task 6.1.1: Design Criteria Task 6.1.2: Construction Considerations Task 6.1.3: Evaluation of Impacts	8	16	12	12	48
Task 6.2: Generate and Analyze Alternatives	15	20	15	15	65
Task 6.3: Scoring, Selection of Final Alternative	2	6	4	4	16
Task 6.4: Preliminary and Final Design Plan Sets	16	24	24	40	104
Task 7.0: Project Deliverables	**19**	**34**	**34**	**34**	**121**
Task 7.1: 30% Report and Presentation	3	6	6	6	21
Task 7.2: 60% Report and Presentation	3	6	6	6	21
Task 7.3: 90% Report	3	6	6	6	21
Task 7.4: Final Report and Presentation	--	--	--	--	--
Task 7.4.1: Final Report	3	6	6	6	21
Task 7.4.2: UGRADS Presentation	4	4	4	4	16
Task 7.5: Website	--	--	--	--	--
Task 7.5.1: 90% Website	2	4	4	4	14
Task 7.5.2: Final Website	1	2	2	2	7
Task 8.0: Project Management	**34**	**34**	**44**	**24**	**136**
Task 8.1: Resource Management	5	5	10	0	20
Task 8.2: Client and TA Meetings	8	8	8	8	32
Task 8.3: GI Meetings	8	8	8	8	32
Task 8.4: Team Meetings	8	8	8	8	32
Task 8.5: Schedule Management	5	5	10	0	20
Total of All Tasks	**143**	**240.5**	**256.5**	**247.5**	**887.5**

In total, this project is estimated to take 887.5 personnel-hours to complete. These hours are estimated based on the length of each task according to the project schedule (see Appendix A). The high number of hours is a conservative estimate to account for any project delays that may arise, particularly due to the COVID-19 pandemic.

The task with the most hours is Task 6.0: Alternatives and Evaluation of Impacts, followed by Task 5.0: Traffic Analysis, at 233 and 166 personnel-hours, respectively. These tasks constitute the lion's share of the work in this project, and as such they received the highest number of hours. The task with the lowest hours is Task 4.0: Traffic Counts, due to the brief window to collect relevant traffic data.

5 Cost of Engineering Services

Table 5-1 below presents the cost of engineering services for this project. The items are separated into three categories: personnel, travel, and supplies.

Table 5-1: Breakdown of cost of engineering services

	Classification	Rate per Hour	Quantity	Cost
	Senior Engineer (SE)	$152.59	143	$21,820
	Engineer (E)	$105.98	240.5	$25,488
	Project Manager (PM)	$89.62	256.5	$22,988
1.0 Personnel	Drafter (DR)	$56.32	247.5	$13,939
	Total personnel			**$84,235**
	Classification	**Rate per Mile**	**Miles**	**Cost**
	Travel to site			
	3 vehicles, 2 round trips, 130 miles roundtrip, @ $0.445/mile	$0.45	780	$347
2.0 Travel	**Total travel**			**$347**
	Classification	**Rate per Day**	**Days**	**Cost**
	Traffic Lab access			
3.0 Supplies	20 days @ $100/day	$100.00	20	$2,000
	Total supplies			**$2,000**
4.0 Total Cost of Engineering Services				**$86,582**

Based on the cost of personnel, travel, and supplies, the total estimated cost of engineering services was determined to be $86,582. The highest cost by far is personnel, at $84,235, constituting over 97 percent of the total cost. More details on this may be seen in the staffing matrix.

Following personnel, the mileage rates for travel costs were estimated using the State of Arizona Accounting Manual, produced by the General Accounting Office (GAO) [16]. The GAO reimbursement rate is currently $0.445/mile [16]. The reimbursement amount was determined by assuming two round trips to the site (one for the initial site investigation and one to collect data) in three personal vehicles, for the approximate roundtrip distance between NAU and Cottonwood of 130 miles. The total mileage incurred by all personnel on these trips was calculated to be 780 miles, bringing the reimbursement amount to approximately $347.

The second-largest expense was supplies, which consist purely of the expense of renting the traffic lab at the prevailing rate of $100/day. Since the lab will only be used during Task 5: Traffic Analysis, which is currently scheduled to last 20 working days, the total cost of renting the lab was determined to be $2,000.

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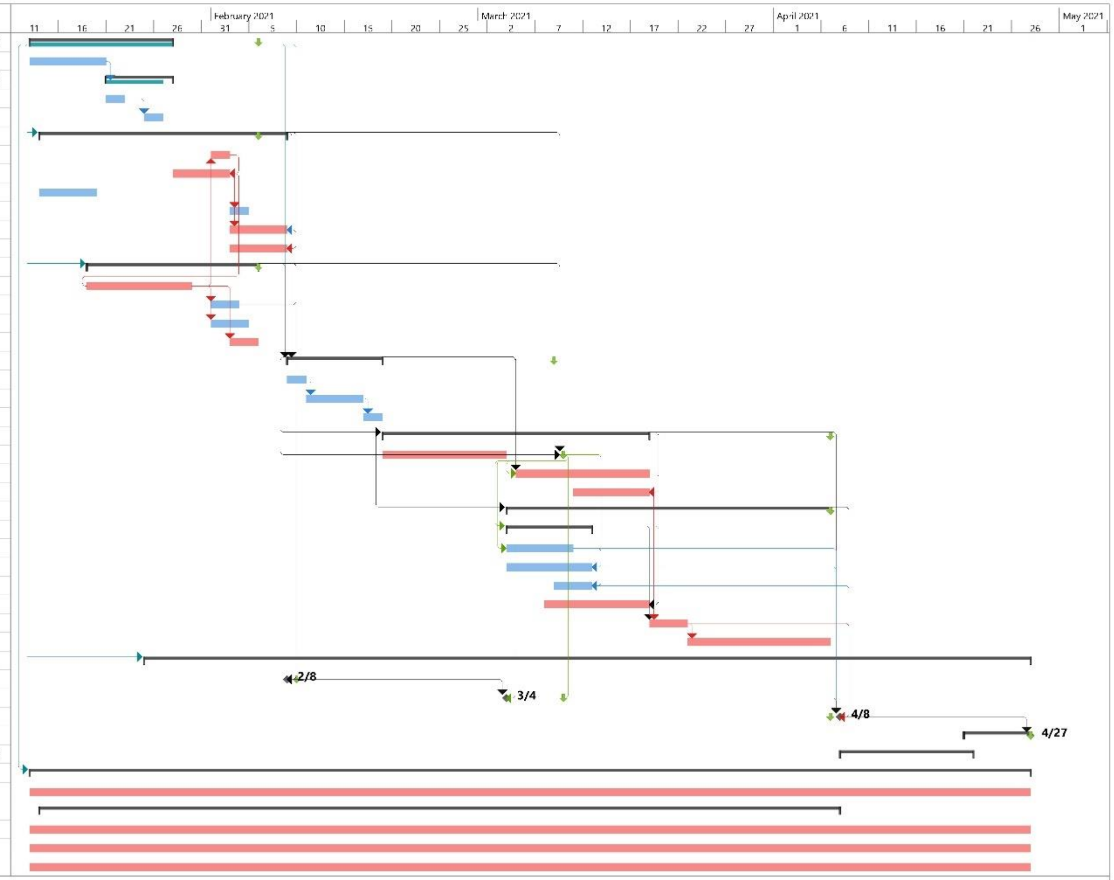
Appendices

Appendix A: Project Schedule

ID	Task Name	Duration	Start	Finish
1	**Task 1.0: Research and Regulatory Considerations**	**10 days**	**Wed 1/13/21**	**Wed 1/27/21**
2	Task 1.1: Review Past Solutions	5 days	Wed 1/13/21	Wed 1/20/21
3	**Task 1.2: Regulatory Considerations**	**5 days**	**Thu 1/21/21**	**Wed 1/27/21**
4	Task 1.2.1: FHWA	2 days	Thu 1/21/21	Fri 1/22/21
5	Task 1.2.2: ADOT	2 days	Mon 1/25/21	Tue 1/26/21
6	**Task 2.0: Site Investigation**	**17 days**	**Thu 1/14/21**	**Mon 2/8/21**
7	Task 2.1: Surveying and Soil Data	2 days	Mon 2/1/21	Tue 2/2/21
8	Task 2.2: Existing Geometry	4 days	Thu 1/28/21	Tue 2/2/21
9	Task 2.3: Identify Contributing Intersections	3 days	Thu 1/14/21	Tue 1/19/21
10	Task 2.4: Lane Configurations	2 days	Wed 2/3/21	Thu 2/4/21
11	Task 2.5: Site Restrictions	4 days	Wed 2/3/21	Mon 2/8/21
12	Task 2.6: Investigate Proposed Developments	4 days	Wed 2/3/21	Mon 2/8/21
13	**Task 3.0: Collection of Traffic Data from ADOT**	**14 days**	**Tue 1/19/21**	**Fri 2/5/21**
14	Task 3.1: Existing Plan Set	9 days	Tue 1/19/21	Fri 1/29/21
15	Task 3.2: Classification of Vehicles	3 days	Mon 2/1/21	Wed 2/3/21
16	Task 3.3: Five-Year Crash Data	4 days	Mon 2/1/21	Thu 2/4/21
17	Task 3.4: Signal Timing and Phasing	3 days	Wed 2/3/21	Fri 2/5/21
18	**Task 4.0: Traffic Counts**	**8 days**	**Tue 2/9/21**	**Thu 2/18/21**
19	Task 4.1: Field Safety Plan	2 days	Tue 2/9/21	Wed 2/10/21
20	Task 4.2: Peak Hour Volumes	4 days	Thu 2/11/21	Tue 2/16/21
21	Task 4.3: Upload Data	2 days	Wed 2/17/21	Thu 2/18/21
22	**Task 5.0: Traffic Analysis**	**20 days**	**Fri 2/19/21**	**Thu 3/18/21**
23	Task 5.1: Base Model Creation and Calibration	9 days	Fri 2/19/21	Thu 3/4/21
24	Task 5.2: VISSIM Analysis of Base Conditions	10 days	Fri 3/5/21	Thu 3/18/21
25	Task 5.3: 20-Year Projection	6 days	Thu 3/11/21	Thu 3/18/21
26	**Task 6.0: Alternatives and Evaluation of Impacts**	**24 days**	**Thu 3/4/21**	**Tue 4/6/21**
27	**Task 6.1: Scoring System**	**7 days**	**Thu 3/4/21**	**Fri 3/12/21**
28	Task 6.1.1: Design Criteria	5 days	Thu 3/4/21	Wed 3/10/21
29	Task 6.1.2: Construction Considerations	7 days	Thu 3/4/21	Fri 3/12/21
30	Task 6.1.3: Evaluation of Impacts	4 days	Tue 3/9/21	Fri 3/12/21
31	Task 6.2: Generate and Analyze Alternatives	9 days	Mon 3/8/21	Thu 3/18/21
32	Task 6.3: Scoring, Selection of Final Alternative	2 days	Fri 3/19/21	Mon 3/22/21
33	Task 6.4: Preliminary and Final Design Plan Sets	11 days	Tue 3/23/21	Tue 4/6/21
34	**Task 7.0: Project Deliverables**	**67 days**	**Mon 1/25/21**	**Tue 4/27/21**
35	Task 7.1: 30% Report and Presentation	11 days	Mon 1/25/21	Mon 2/8/21
36	Task 7.2: 60% Report and Presentation	11 days	Wed 2/17/21	Thu 3/4/21
37	Task 7.3: 90% Report	11 days	Wed 3/24/21	Thu 4/8/21
38	**Task 7.4: Final Report and Presentation**	**5 days**	**Wed 4/21/21**	**Tue 4/27/21**
41	**Task 7.5: Website**	**10 days**	**Thu 4/8/21**	**Wed 4/21/21**
44	**Task 8.0: Project Management**	**74 days**	**Wed 1/13/21**	**Tue 4/27/21**
45	Task 8.1: Resource Management	74 days	Wed 1/13/21	Tue 4/27/21
46	**Task 8.2: Client and TA Meetings**	**59 days**	**Thu 1/14/21**	**Thu 4/8/21**
54	Task 8.3: GI Meetings	74 days	Wed 1/13/21	Tue 4/27/21
55	Task 8.4: Team Meetings	74 days	Wed 1/13/21	Tue 4/27/21
56	Task 8.5: Schedule Management	74 days	Wed 1/13/21	Tue 4/27/21



Project: CENE 476 Schedule
Date: Fri 11/20/20

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Critical | Critical Split | Progress | Manual Progress