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Civil Engineering Senior Design Project: Traffic Signal Phasing and Analysis

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Civil Engineering Senior Design Project: Traffic Signal Phasing and Analysis

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Project Abstract

The growth in population in West Huntsville has led to the development of houses and businesses throughout the area. This rise in population and development has led to a need for emergency services to help serve the community in need of emergencies. This has led to the development of Huntsville Fire and Rescue 20 to help serve the growing West Huntsville area and its design is the focus for the senior design project for Civil Engineering. However, the goal of this project is to go further in determining how emergency services stationed in the future Huntsville Fire and Rescue 20 development can reach the core of the community, using traffic software and signal timing on an important intersection nearby the future development and show the importance of signal timing and traffic volume on a growing population.

Chapter 1: Introduction

One of the most important attributes of transportation and traffic design is to create effective roadways and signals for vehicles. However, there are times where signals will need to be adjusted for the presence of emergency vehicles to allow for clearance on the roadways and to accommodate travel for the emergency vehicles. Therefore, the traffic timing and operation must be efficient for emergency vehicles to get through intersections and to allow them to arrive quickly at their destination. This project is an addition toward the transportation section of the Civil Engineering Senior Design project of the design of Huntsville Fire and Rescue 20 for the City of Huntsville, located at 13175 Burgreen Road, Huntsville, Alabama. The location of the fire station shown in Figure 1, is shown in proximity toward US Route 72.

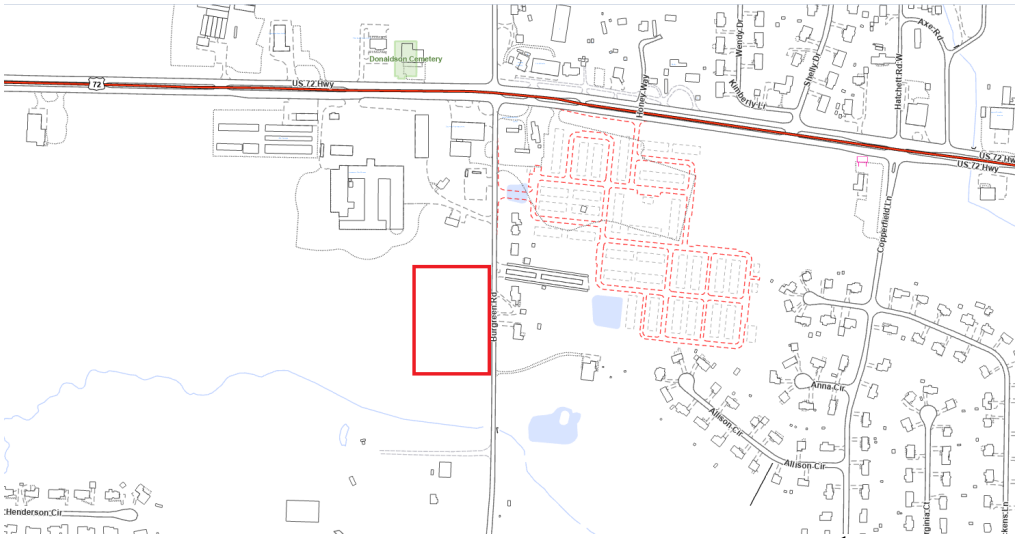

Figure 1: Location of Huntsville Fire and Rescue 20[1]

For this project, the intersection of US Route 72 and Burgreen Road is studied to determine the most ideal time for emergency vehicles arriving at the intersection using traffic

[1] "City of Huntsville GIS", *City of Huntsville*, https://maps.huntsvilleal.gov/public/

counts and software. This analysis can obtain an understanding of how fast emergency vehicles can enter major roadway intersections from the Fire and Rescue building and how traffic software can help determine the signal timing needed to efficiently move emergency vehicles toward the main roadways. This is an important aspect for the city of Huntsville, as the location of Huntsville Fire and Rescue 20 is in one of the fastest growing populations of both Madison and Limestone Counties and determining an ideal signal timing for the nearest intersection towards the new site will help give an accurate representation on how quick and efficiently emergency vehicles can be used to help reach incidents and situations throughout the West Huntsville area.

Figure 2: Intersection of US Route 72 and Burgreen Road

Chapter 2: Data Collection and Traffic Design

Chapter 2.1: Data Collection

The process began by obtaining traffic counts for the intersections on US Route 72 and Burgreen Road. The data collected from the Alabama Department of Transportation's (ALDOT) Traffic Data[2] website helps obtain an accurate understanding of the amount of traffic that occurs throughout the intersection in all directions during their peak times of the traffic count. Peak times were chosen instead of the highest traffic counts at separate times to give a more realistic count of travel during the periods of high level of traffic from both directions.

Road	Direction	Traffic Count
US Route 72	East[3]	1211
US Route 72	West	1375
Burgreen Road	North[4]	169
Dupree Worthy Road	South	157

Table 1: Traffic Count Data at Intersection (ALDOT Traffic Data)

The collection of the data infers that most of the traffic occurs on US Route 72, while the lower traffic count numbers attribute to both roadways on the north and southbound side being two lanes and located in both rural areas. The traffic count also determined that the amount of traffic entering in the intersection from Burgreen Road, has a low traffic count, which positively

[2] "ALDOT Traffic Data Manager Public Interface", *Alabama Department of Transportation*, https://aldotgis.dot.state.al.us/TDMPublic/

[3] East and Westbound Data Collected on 12-8-2020.

[4] North and Southbound Data Collected on 1-20-2021.

affect the amount of time needed to travel from the Fire and Rescue Building towards the intersection with US Route 72.

Chapter 2.2: Traffic Design and Results

The next step in the process was to use the data used in the process to design the intersection to determine the traffic timings and the level of service. The system used to create the traffic diagram is called Synchro[5]. Synchro is a signal timing software that helps assist traffic engineers in determining signal timing and signal operations, with access to simulating traffic intersections. The focus of using Synchro is to help calculate the accurate traffic flow rate at the intersection and to help determine a viable traffic timing for the emergency vehicles. See Appendix A for the full Synchro results.

Information	Results
Total Signal Cycle Length	62 seconds
Green Time (North/South)	30 seconds
Green Time (East/West)	22.5 seconds
Yellow and All-Red Time	4.5 seconds
Maximum Volume to Capacity Ratio	0.96
Intersection Delay	32.5 seconds
Level of Service	Level C

[5] "Synchro Studio 11 User Guide", *Cubic Transportation Systems* https://cubicits.freshdesk.com/support/solutions/articles/69000541835-synchro-studio-11-user-guide

Table 2: Intersection Results from Synchro Software

From Synchro, it is determined that the intersection for US Route 72 and Burgreen Road is determined to have a cycle length of just over a minute for the entire cycle, with an ideal maximum volume to capacity ratio of 0.96. The importance of the volume to capacity ratio determines if the light timings can handle the overall volume of vehicles placed on the roadways and their respective intersections. If the volume to capacity ratio is placed to be above a total of one, then the capacity of the intersection cannot handle the volume of vehicles that enter the intersection, which automatically gives the intersection and grade of an F and must be fixed to give a volume to capacity ratio of less than one, before proceeding. After determining the volume to capacity ratio, the intersection delay is calculated, and the level of service is determined, as the lower the intersection delay, the higher grade for level of service is given. The level of service of C is ideal as most of the traffic signaling design is designed to support a level service of C on the roadways, which states that the flow at the intersection is a stable flow. The following result from the timings allows for an accurate timing on determining how fast an emergency vehicle can reach the designated intersection from Huntsville Fire and Rescue 20.

Chapter 2.3: Traffic and Distance Analysis

The following process can be determined using speed and distance formulas to form the results of the signal timings of the intersection. The ISO Fire Suppression Rating Schedule (FSRS) determines the evaluated resources that a community has by using a performative evaluation of travel time using computer aided software, to maintain that the fire departments will meet time constraints in accordance with the NFPA 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments* (ISO Section 560). The ISO manual uses

the RAND Institute to determine the average speed of a fire engine, in terms of time T in seconds, producing this equation 2.1[6].

$$T = 0.65 + KD$$

Equation 2.1

The following equation determines that K is the constant by speed determined by the RAND studies at different rate of speeds, D determines the distance between Huntsville Fire and Rescue 20 and the intersection of US Route 72 and Burgreen Road, listed in miles. 0.65 is a solved acceleration constant for travel time. The calculations were solved to determine the speeds of 35 mph, the listed mile posted roadway on Burgreen Road, and 45 mph, for the potential of an urgent and serious scenario for the fire engine to arrive at the intersection at an allotted time.

Miles Per Hour	Distance (D)	Constant (K)	Results
35 mph	0.18 miles	1.7	57.5 seconds
45 mph	0.18 miles	1.3	53 seconds

Table 3: Results of Distance Equation 2.1

The results show that the emergency vehicles can ideally reach the intersection in less than a minute, due to the proximity of Huntsville Fire and Rescue 20 towards the intersection. With a placed emergency signal located at the station, the traffic flow on Burgreen will be

[6] "Estimating the Travel Time of Fire Apparatus" *Municipal Technical Advisory Service (University of Tennessee),* https://www.mtas.tennessee.edu/reference/estimating-travel-time-fire-apparatus

stopped, and will allow for emergency response vehicles to reach the intersection at a viable time, however, the calculation must be determined to allow for cross traffic flow at the US Route 72 intersection to immediately shut down all flows of traffic and allow emergency vehicles to enter through the northbound side, meaning that all lights at the intersection would have to automatically go through the process of going towards a yellow and all-red time, in order to allow the northbound and southbound directions on Burgreen Road and Dupree Worthy Road to begin their green timings, to allow for free flowing traffic for the emergency vehicles, noted in equation 2.2:

$$t_{total} = t_{veh} + t_{yellow} + t_{all-red}$$

Equation 2.2

Miles Per Hour	Time to Intersection	Yellow and All Red Time	Total Time Needed
35 mph	57.5 seconds	4.5 seconds	62 seconds
45 mph	53 seconds	4.5 seconds	57.5 seconds

Table 4: Results of Time Needed for Emergency Vehicles

Chapter 3: Discussions and Results

From the calculations, it is determined that the time needed for the emergency vehicles will need 62 seconds from the parameters of the designed traffic signal from Synchro and the time from Huntsville Fire and Rescue 20 and the intersection. This project heavily relied on obtaining the traffic data from the Alabama Department of Transportation and their various traffic counts from across the state. The traffic counts can give a general basis on the effective traffic volume count throughout the entire intersection. The use of the traffic counts can also obtain information on future predictions for if an intersection needs to be improved or a traffic signal needs to be adjusted towards a longer cycle timing, up until the capacity can no longer support the volume of traffic that travels throughout the intersection. This can have a major effect on the roadways and with emergency vehicles, as the more volume of vehicles exist throughout the roadways, then the larger chance that the capacity built for the vehicles will not be able to sustain the volume that comes in. This can lead toward higher delay times which cannot support the volume of vehicles, even with a traffic signal working as efficiently as possible. With this, the rise in delay causes an effect on the response times for emergency vehicles and leading toward a waste of crucial seconds needed in important situations. Therefore, it is important in design situations, to account for how effective your traffic signals and your roadways can be.

The use of Synchro is one of the many tools used in traffic signaling and traffic analysis to help develop cities and urban areas. The use of Synchro helped elevate the senior design project as it helped focus more on just the given design of Huntsville Fire and Rescue 20. The original transportation section of the senior design focused on the creation of the parking area around the structure. However, the use of Synchro and determining the time needed for

emergency vehicles has allowed for more of a scope of using traffic software can help determine the effects of signal timing on both the public and on emergency vehicles.

Chapter 4: Conclusion and Self-Assessment

The location of Huntsville Fire and Rescue 20 is an important emergency service for the growing area of West Huntsville. The use of traffic data counts and traffic design software such as Synchro has led to determining a suggested time that is ideal toward the general public and a low emergency response time from Huntsville Fire and Rescue 20 towards the main intersection of US Route 72 and Burgreen Road. There is a confidence in the goals completed in this project as the data and results were in reason with the location of the station and with the level of service in other differing locations throughout the city. The project relied heavily on information from the ALDOT traffic data service and the use of Synchro through ALDOT, allowing for this project to be studied and completed.

Appendix

Appendix A: Synchro Results

SIMULATION SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	73	1100	138	96	1179	100	60	49	60	50	57	50
Future Volume (vph)	73	1100	138	96	1179	100	60	49	60	50	57	50
Storage Length (ft)	105	—	0	240	—	0	0	—	0	0	—	0
Storage Lanes (#)	1	—	—	1	—	—	—	—	—	—	—	—
Taper Length (ft)	135	—	—	115	—	—	—	—	—	—	—	—
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Lane Width (ft)	12	12	12	12	12	12	12	12	12	12	12	12
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Median Width (ft)	—	12	—	—	18	—	—	0	—	—	0	—
Link Offset (ft)	—	0	—	—	0	—	—	0	—	—	0	—
Crosswalk Width (ft)	—	16	—	—	16	—	—	16	—	—	16	—
TWLTL Median	—	☐	—	—	☐	—	—	☐	—	—	☐	—
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Turning Speed (mph)	15	—	9	15	—	9	15	—	9	15	—	9
Mandatory Distance (ft)	—	258	—	—	258	—	—	258	—	—	258	—
Positioning Distance (ft)	—	1320	—	—	1320	—	—	1320	—	—	1320	—
Mandatory Distance 2 (ft)	—	880	—	—	880	—	—	880	—	—	880	—
Positioning Distance 2 (ft)	—	1760	—	—	1760	—	—	1760	—	—	1760	—

Data and Road Setup for the US Route 72 and Burgreen Road Intersection (Collected from ALDOT)

PHASING SETTINGS	2-NBTL	3-WBL	4-EBT	6-SBTL	7-EBL	8-WBT
Minimum Initial (s)	5.0	5.0	5.0	5.0	5.0	5.0
Minimum Split (s)	22.5	9.5	30.0	22.5	9.5	30.0
Maximum Split (s)	22.5	9.5	30.0	22.5	9.5	30.0
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0
Lagging Phase?	—	☐	☑	—	☐	☑
Allow Lead/Lag Optimize?	—	☑	☑	—	☑	☑
Optimize Phs Weights - Delays	1.0	1.0	1.0	1.0	1.0	1.0
Vehicle Extension (s)	3.0	3.0	3.0	3.0	3.0	3.0
Minimum Gap (s)	3.0	3.0	3.0	3.0	3.0	3.0
Time Before Reduce (s)	0.0	0.0	0.0	0.0	0.0	0.0
Time To Reduce (s)	0.0	0.0	0.0	0.0	0.0	0.0
Recall Mode	Max	Max	Max	Max	Max	Max
Pedestrian Phase	☐	☐	☐	☐	☐	☐
Walk Time (s)	—	—	—	—	—	—
Flash Dont Walk (s)	—	—	—		—	—
Pedestrian Calls (#/hr)	—	—	—	—	—	—
Dual Entry?	☑	☐	☑	☑	☐	☑
Fixed Force Off?	☑	☑	☑	☑	☑	☑
90th %ile Green Time (s)	18 cd	5 mr	26 mr	18 cd	5 mr	26 mr
70th %ile Green Time (s)	18 cd	5 mr	26 mr	18 cd	5 mr	26 mr
50th %ile Green Time (s)	18 cd	5 mr	26 mr	18 cd	5 mr	26 mr
30th %ile Green Time (s)	18 cd	5 mr	26 mr	18 cd	5 mr	26 mr
10th %ile Green Time (s)	18 cd	5 mr	26 mr	18 cd	5 mr	26 mr

Traffic Signal Timing for US Route 72 and Burgreen Road

US Route 72 and Burgreen Road Intersection Setup from Synchro

NODE SETTINGS	
Node #	3
ATMS.now Controller ID	0
Import from ATMS.now:	Import
Export to ATMS.now:	Export
Zone:	
X East (ft):	9836
Y North (ft):	21656
Z Elevation (ft):	0
Description	
Control Type	Pretimed
Cycle Length (s):	62.0
Lock Timings:	☐
Optimize Cycle Length:	Optimize
Optimize Splits:	Optimize
Actuated Cycle(s):	62.0
Natural Cycle(s):	65.0
Max v/c Ratio:	0.96
Intersection Delay (s):	32.5
Intersection LOS:	C
ICU:	0.65
ICU LOS:	C
Offset (s) :	22.5
Referenced to:	Begin of Green
Reference Phase:	2+6 - NBTL SBTL
Coordination Mode:	Fixed
Master Intersection:	☐
Yield Point:	Single
Mandatory Stop On Yellow:	☐

Data for the US Route 72 and Burgreen Road Intersection

TIMING SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR	PED	HOLD
Lanes and Sharing (#RL)													—	—
Traffic Volume (vph)	73	1100	138	96	1179	100	60	49	60	50	57	50	—	—
Future Volume (vph)	73	1100	138	96	1179	100	60	49	60	50	57	50	—	—
Turn Type	Prot	—	—	Prot	—	—	Perm	—	—	Perm	—	—	—	—
Protected Phases	7	4	—	3	8	—		2	—		6	—		
Permitted Phases			—			—	2		—	6		—	—	—
Permitted Flashing Yellow	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Detector Phases	7	4	—	3	8	—	2	2	—	6	6	—	—	—
Switch Phase	0	0	—	0	0	—	0	0	—	0	0	—	—	—
Leading Detector (ft)	20	100	—	20	100	—	—	100	—	—	100	—	—	—
Trailing Detector (ft)	0	0	—	0	0	—	—	0	—	—	0	—	—	—
Minimum Initial (s)	5.0	5.0	—	5.0	5.0	—	5.0	5.0	—	5.0	5.0	—	—	—
Minimum Split (s)	9.5	30.0	—	9.5	30.0	—	22.5	22.5	—	22.5	22.5	—	—	—
Total Split (s)	9.5	30.0	—	9.5	30.0	—	22.5	22.5	—	22.5	22.5	—	—	—
Yellow Time (s)	3.5	3.5	—	3.5	3.5	—	3.5	3.5	—	3.5	3.5	—	—	—
All-Red Time (s)	1.0	1.0	—	1.0	1.0	—	1.0	1.0	—	1.0	1.0	—	—	—
Lost Time Adjust (s)	0.0	0.0	—	0.0	0.0	—	—	0.0	—	—	0.0	—	—	—
Lagging Phase?	☐	☑	—	☐	☑	—	—	—	—	—	—	—	—	—
Allow Lead/Lag Optimize?	☑	☑	—	☑	☑	—	—	—	—	—	—	—	—	—
Recall Mode	Max	Max	—	Max	Max	—	Max	Max	—	Max	Max	—	—	—
Speed limit (mph)	—	30	—	—	30	—	—	30	—	—	30	—	—	—
Actuated Effct. Green (s)	5.0	25.5	—	5.0	25.5	—	—	18.0	—	—	18.0	—	—	—
Actuated g/C Ratio	0.08	0.41	—	0.08	0.41	—	—	0.29	—	—	0.29	—	—	—
Volume to Capacity Ratio	0.56	0.93	—	0.73	0.96	—	—	0.39	—	—	0.36	—	—	—
Control Delay (s)	44.6	30.8	—	60.2	35.5	—	—	16.0	—	—	16.0	—	—	—
Queue Delay (s)	0.0	0.0	—	0.0	0.0	—	—	0.0	—	—	0.0	—	—	—
Total Delay (s)	44.6	30.8	—	60.2	35.5	—	—	16.0	—	—	16.0	—	—	—
Level of Service	D	C	—	E	D	—	—	B	—	—	B	—	—	—
Approach Delay (s)	—	31.6	—	—	37.2	—	—	16.0	—	—	16.0	—	—	—
Approach LOS	—	C	—	—	D	—	—	B	—	—	B	—	—	—
Queue Length 50th (ft)	29	238	—	39	254	—	—	40	—	—	38	—	—	—
Queue Length 95th (ft)	#80	#381	—	#111	#403	—	—	89	—	—	84	—	—	—
Stops (vph)	66	1020	—	80	1061	—	—	99	—	—	93	—	—	—
Fuel Used (g/hr)	1	20	—	3	38	—	—	2	—	—	2	—	—	—

Full Data from the US Route 72 and Burgreen Road Intersection in all Directions