NORTHERN ARIZONA UNIVERSITY

Traffic Signal Redesign 50% Design Report

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CENE 486 Capstone

J3Z Engineering

March 10th, 2016

NORTHERN ARIZONA UNIVERSITY

Table of Contents

1.0 Project Description 1

1.1 Project Purpose 1

1.2 Project Location 1

2.0 Technical Sections 2

2.1 Traffic Studies 2

2.1.1 Volume/Speed/Classification Study 2

2.1.2 Turning Movement Counts 4

2.1.3 Stop Sign Delay Study 5

2.1.4 Sight Distance Study 5

2.2 Analysis 6

2.2.1 Peak Hour Analysis 6

2.2.2 Existing Level of Service 6

2.2.3 Right-of-Way 7

2.2.4 Existing VISSIM Model 8

2.2.5 Existing Synchro Model 8

2.3 Warranting 8

2.3.1 Warrant 1: Eight-Hour Vehicular Volume 9

2.3.2 Warrant 2: Four-Hour Vehicular Volume 9

2.3.3 Warrant 7: Crash Experience 10

3.0 Appendices 11

Appendix A: Vehicle Classification Sheet 12

Appendix B: Synchro Output Map 13

Appendix C: HCS Output Sheet 14

Appendix D: Warrant 3-6 and 8-9 Information / Charts 15

List of Figures and Tables

Figure 1: Broad Location of Project Site Location [1] 1

Figure 2: Project Site Location in relation to the Purina Dog Food Tower [1] 2

Figure 3: Count Locations, Average Daily Traffic, and Speeds [1] 3

Figure 4: Percentage of Classified Vehicles 4

Figure 5: Sight Distances measured using GPS [1] 5

Figure 6: Examples of LOS A and LOS F respectively [4], [5] 7

Figure 7: Project Location Property Lines [6] 7

Figure 8: Tables showing conditions A and B for warrant 1 in the MUTCD [8] 9

Figure 9: Major and Minor street volume chart from the MUTCD [8] 10

Table 1: Turning movement counts for all approaches of the intersection 4

Table 2: Synchro Peak Hour Volumes 6

Table 3: Synchro Delays 8

Acknowledgements

A special thanks to Stephanie Sarty the Project Manager for the City of Flagstaff and Dr. Edward Smaglik for his guidance and recommendations over the course of this project.

1.0 Project Description

The intersection of N. Country Club Dr. and E. Old Walnut Rd. has been determined to be a hazardous intersection by the City of Flagstaff. The two-way road Country Club Drive is an uncontrolled (free-flow) multi-lane road with a large average daily traffic (ADT). Old Walnut Canyon Road is a two-way road with stop-control for all movements (left, right and through) at the intersection. The City of Flagstaff has identified the intersection of N. Country Club Dr. and E. Old Walnut Canyon Rd. as an intersection that requires re-evaluation because of its volume and poor safety record. The City of Flagstaff has requested that the intersection be re-evaluated for use of a traffic signal. The intersection re-design must meet industry standards and the standards set by the City of Flagstaff and Arizona Department of Transportation (ADOT).

1.1 Project Purpose

The purpose behind the intersection redesign of N. Country Club Dr. and E. Old Walnut Canyon Rd. is to improve the safety and efficiency of the intersection. Currently the intersection has safety concerns due to sight distances and Right-of-Way, among other criteria. These concerns will be mitigated by the implementation of a traditional traffic signal.

1.2 Project Location

The project site is located on the East side of Flagstaff, AZ at N. Country Club Dr. And E. Old Walnut Canyon Rd. The project site location in relation to Flagstaff, AZ is shown in Figure 1.

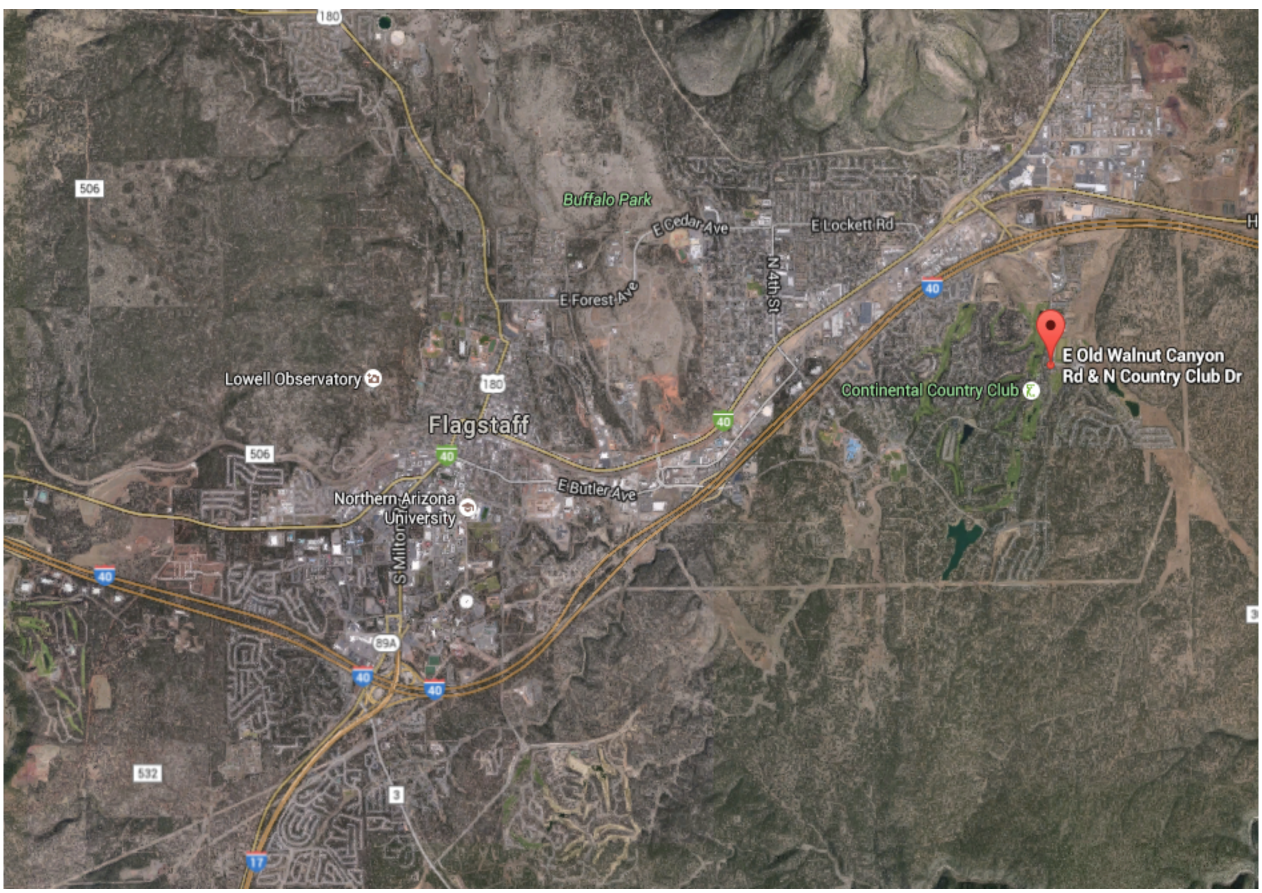


Figure 1: Broad Location of Project Site Location [1]

For additional reference, the project site is located South of the Flagstaff city mall and the Purina dog food tower. The project location in relation to the Purina dog food tower is shown in Figure 2.

Figure 2: Project Site Location in relation to the Purina Dog Food Tower [1]

2.0 Technical Sections
The following section outlines the various studies completed according to the agreed scope of work. All studies were completed per applicable ADOT and MUTCD standards.

2.1 Traffic Studies
In order to determine the current performance and level of service of the intersection, various traffic studies were conducted. The traffic studies consisted of a volume/speed/classification study, 12 hour turning movement count, stop sign delay study, and a sight distance study. Analysis and warranting of the intersection were done based upon these studies.

2.1.1 Volume/Speed/Classification Study
Vehicle volumes, speeds, and classifications were collected using JAMAR Technologies TRAX pneumatic counters. These counters use two rubber hoses that span the width of the road and are a set a specified distance apart from each other. Connected to the end of the hoses is a data recorder that measures the speed, volume and classification of vehicles as they roll over them by calculating the axle distance as a function of time [2]. The tubes were placed on each of the four legs of the intersection. This study was performed in October to avoid winter driving conditions that affect the performance of the counters. The counts were taken Tuesday through Thursday to capture peak driving conditions. Figure 3 shows the location of

the counters, the average daily traffic (ADT) and the 85% speeds. The 85th percentile is the speed at, or below, which 85 percent of vehicles travel.

Figure 3: Count Locations, Average Daily Traffic, and Speeds [1]

Vehicle classification is an important set of data that shows what kind of vehicles are moving through the intersection. The layout of the redesigned intersection will primarily depend on what types of vehicles will use it. The TRAX counters give an accurate classification of what vehicles pass over the tubes based on the distance between the axles. The graph in Figure 4 shows the vehicle classifications based on percentages. Class 2 represents passenger cars. Class 3 represents pickups, vans and other two-axle, four-tire single unit vehicles. Class 5 represents two-axle, six-tire single unit trucks. Class 14 represents unclassified vehicles, which are vehicles that do not fall into the other thirteen classes [3]. As a rule, a high percentage of vehicles in class 14 can indicate faulty equipment of setup. In the case of this particular intersection, golf carts travel from the driving range on the Northeast corner of the intersection to the Country Club Golf Course on the West side, over the installed TRAX counters and account for the class 14 volumes as golf carts do not fall into a traditionally vehicle category. A full description of each class of vehicle is provided in Appendix A.

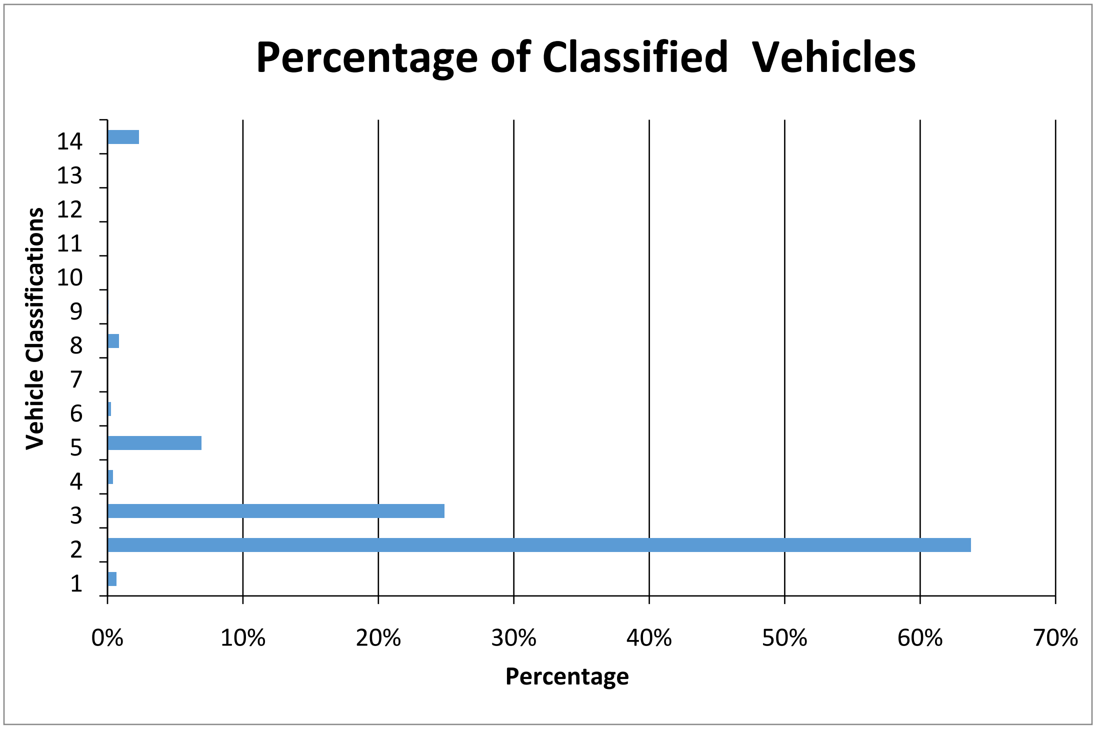


Figure 4: Percentage of Classified Vehicles

2.1.2 Turning Movement Counts

Vehicle turning movement counts were collected using a JAMAR Technologies board. These boards are used by utilizing the North arrow on each board in order to align the lanes with their respective lanes on the JAMAR Technologies board. For this study, vehicles that turn left, right, and go straight were recorded on the JAMAR Technologies board in order to determine the flow of traffic as it is occurring. For this study, a 12 hour turning movement count was conducted in order to determine movements for a normal day. This study took place on October 14th, 2015. This date for the turning movement counts was used in order to avoid winter driving conditions. Furthermore, this date fell on a Wednesday which is optimal because traffic engineering studies dictate that the studies must fall on or between a Tuesday and Thursday because all other days are considered to have abnormal driving patterns. Table 1 shows the turning movement counts the intersection encountered during the 12 hour turning movement count.

Table 1: Turning movement counts for all approaches of the intersection

SB				WB			
RT	THR	LT	PED	RT	THR	LT	PED
683	897	1355	4	1412	147	130	6
NB				EB			
RT	THR	LT	PED	RT	THR	LT	PED
193	1067	76	1	39	143	633	1

A turning movement count is an important study to complete to determine the flow of traffic for each approach of the intersection. Furthermore, this study can be used for programs such as Synchro and VISSIM which are both microscopic vehicle simulation software, and Highway Capacity System (HCS) software which is based off design standards for the Highway Capacity Manual to create level of service simulations and three dimensional driver simulations.

2.1.3 Stop Sign Delay Study

A stop sign delay study was conducted to measure the amount of delay vehicles were experiencing on the eastbound and westbound legs. This study took place on a Wednesday during the PM peak hour from 5:00-6:00. Delays were minimal with occasional delays with eastbound and westbound traffic making a through and left turn movement. Delays can also be found using the VISSIM and Synchro software.

2.1.4 Sight Distance Study

A sight distance study was performed in order to determine the length of roadway users have when they see another vehicle about to make a turning movement. This study was conducted for vehicles travelling on N. Country Club Dr. for when they can see a vehicle making a turning movement on E. Old Walnut Canyon Rd. To complete this study, neon orange cones were placed where vehicles stop on E. Old Walnut Canyon Rd. when making a turning movement and then an individual drove along N. Country Club Dr. and marked along the roadway where they were able to see the neon orange cone, using GPS. Figure 5 shows the sight distances that were calculated using a GPS system.

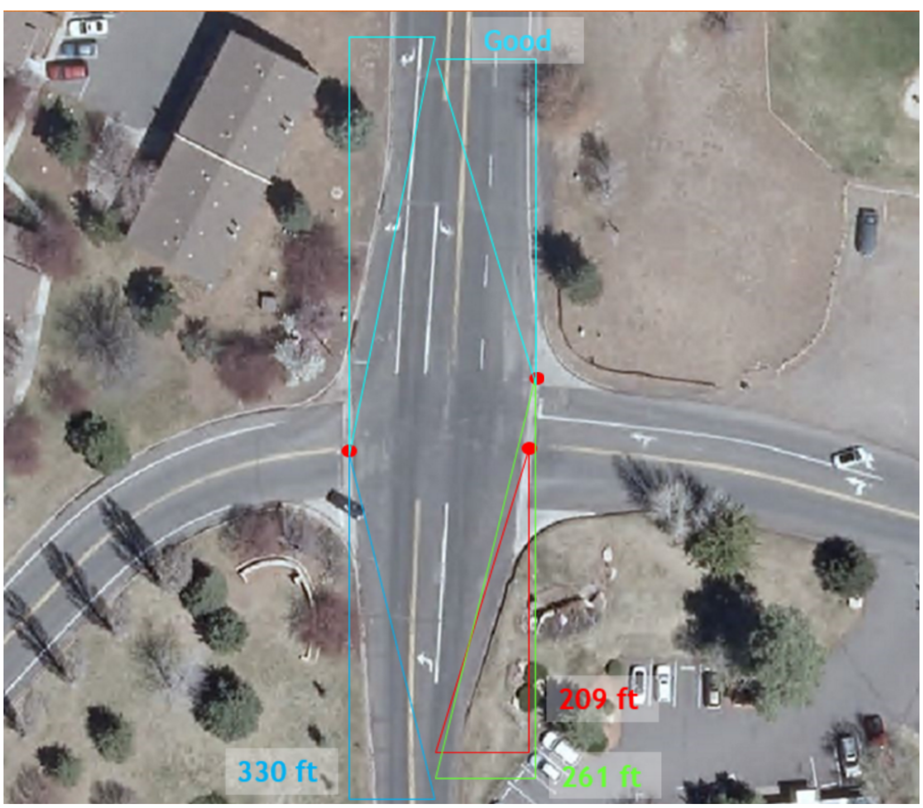


Figure 5: Sight Distances measured using GPS [1]

It is important to perform a sight distance study to calculate sight triangles of the current intersection layout. In the case of large obstructions or sudden changes in grade due to vertical curves, grade changes may be recommended to increase the safety and visibility for drivers using the intersection. It was determined that the current sight triangles are not up to standards. For the NB approach on N. Country Club Dr., the WB left turning lane represented in red on Figure 5 should have a sight distance of 390 ft., the WB right turning lane represented in green on Figure 5 should have a sight distance of 335 ft., and the EB right turning lane represented in blue should be 330 ft.

2.2 Analysis

The following sections outline the types of analysis used in determining the current operational conditions of the intersection.

2.2.1 Peak Hour Analysis

The amount of users travelling through the intersection N. Country Club Dr. and E. Old Walnut Canyon fluctuates due to weather conditions, business hours, residential events, etc. Peak hours are determined when user volumes at the intersection are the highest. To complete this study, the volume study data was utilized to determine what hours on a normal day have the highest volumes. Table 2 shows the AM and PM peak hours on each approach for the intersection.

Table 2: Synchro Peak Hour Volumes

Peak Hour Volume				
Leg of Intersection	**AM Peak Hour**	**AM Volume**	**PM Peak Hour**	**PM Volume**
NB Country Club	8:00-9:00	228	4:30-5:30	263
SB Country Club	7:15-8:15	540	5:00-6:00	687
EB Oakmont	11:00-12:00	142	3:00-4:00	174
WB Old Walnut Canyon	8:00-9:00	284	5:00-6:00	399

It is important to determine peak hours of the intersection for the warranting process. Warrant's 1, 2, and 3 utilize peak hours when determining if a traffic signal is warranted at the intersection.

2.2.2 Existing Level of Service

The Level of Service (LOS) is used to determine how well the intersection N. Country Club Dr. and E. Old Walnut Canyon is functioning. LOS values that can be assigned consist of: A, B, C, D, E, and F. LOS A pertains to a roadway that is functioning at its optimal abilities, meaning there are short wait times or low volumes of vehicles travelling at free flow speed. LOS F pertains to a roadway that is functioning poorly and is experiencing large amounts of delay or high volumes of vehicles with slow travel speeds. The existing LOS was determined using two different software programs, Synchro and HCS. The output data sheets from both these Synchro and HCS are shown in appendices B and C respectively. Figure 6 shows the difference between a roadway with a LOS A and a roadway with a LOS F. LOS is important to determine because it is used to measure the amount of delay that the intersection is experiencing due to users

Figure 6: Examples of LOS A and LOS F respectively [4], [5]

2.2.3 Right-of-Way

The Right-of-Way (ROW) is the land that is owned by the City of Flagstaff. The ROW shown in Figure 7 was determined using an ArcMap provided by the City of Flagstaff.

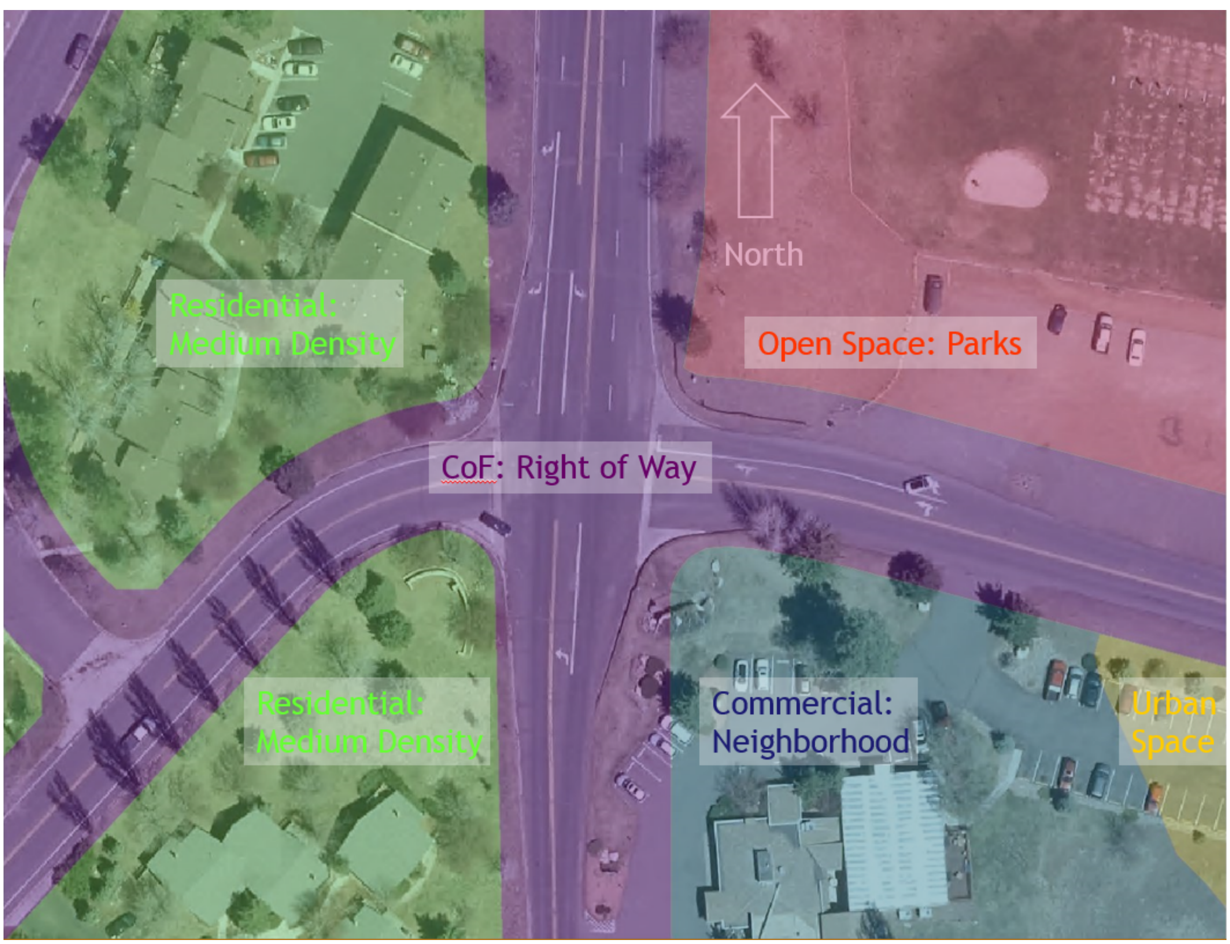


Figure 7: Project Location Property Lines [6]

As seen in Figure 7, the City of Flagstaff owns land on either side of the paved road. This extra land is used for things such as public sidewalks, streetlights, utilities, street parking, and control devices. Also, for widening or altering the roadway in the future. Based on the ROW owned by the City of Flagstaff, the intersection of N. Country Club Dr. and E. Walnut Canyon Rd. will be able to be redesigned without acquiring more ROW.

2.2.4 Existing VISSIM Model

VISSIM is three dimensional optimization software for roadways. In addition to its ability to model virtual vehicles based on real-world traffic volumes, it can also simulate free flow, stop controlled and signalized intersections. VISSIM produces a real-time model of how traffic will flow during different times of the day, allowing the designer to optimize the signal timing plan and placement to a high degree.

2.2.5 Existing Synchro Model

Synchro is an analysis and optimization software application. Synchro supports the Highway Capacity Manual's methodology (2000 & 2010 methods) for signalized intersections [7]. Synchro uses the turning movement count data as well as the geometry of the intersection. Upon analyzation of the input data, Synchro outputs important information such as delay times and LOS. Table 3 shows the delay time for each leg of the intersection. These numbers reflect the peak hour volumes. Due to uncontrolled traffic flows moving north and south, the eastbound and westbound left and through traffic movements experience moderate delays. In particular the eastbound has the highest delay due to traffic being restricted to only one lane for all three movements. From the Table 3, the eastbound route experiences the most delay per vehicle followed by the westbound.

Table 3: Synchro Delays

Direction	EB	WB	NB	SB	All
Volume (vph)	108	236	169	411	924
Control Delay / Veh (s/v)	47	12	1	4	11
Queue Delay / Veh (s/v)	0	0	0	0	0
Total Delay / Veh (s/v)	47	12	1	4	11
Total Delay (hr)	1	1	0	0	3
Stops / Veh	1.00	1.00	0.11	0.82	0.76

Synchro determined the LOS of the intersection at a LOS of B. All legs of the intersection scored adequate LOS except for the eastbound movement which scored and LOS of E. This again is due to traffic being restricted to only one lane for all three movements.

2.3 Warranting

Warranting is what traffic engineers use when determining what type of traffic control device will be needed for the intersection in question. For the intersection of N. Country Club Dr. and E. Old Walnut Canyon Rd., the intersection warrants were determined for a traffic control signal. The Manual of Uniform Traffic Control Devices (MUTCD) outlines the different types of Warrants there are along with how the Warrants should be interpreted and used. This is an important technical aspect for the Traffic Analysis Capstone Project to ensure a traffic control signal is the optimal design for the intersection along with determining how the intersection will primarily function. For the intersection N. Country Club Dr. and E Old Walnut Canyon Rd., warrants 1, 2, and 7 met out of all 9 warrants. See Appendix D for a list of warrants 1 through 9.

2.3.1 Warrant 1: Eight-Hour Vehicular Volume

Warrant 1consists of compiling volume counts for both the minor and major streets and comparing the peak hours of each of any eight hours of an average day [8]. The MUTCD has two conditions (A and B) that if either is met, a signal may be warranted. The eight-hour vehicle warrant was conducted by analyzing the eight highest vehicle volumes. Figure 8 shows conditions A and B for Warrant 1: Eight-Hour Vehicular Volume.

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume

Condition A—Minimum Vehicular Volume									
Number of lanes for moving traffic on each approach		**Vehicles per hour on major street (total of both approaches)**				**Vehicles per hour on higher-volume minor-street approach (one direction only)**			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	500	400	350	280	150	120	105	84
2 or more	1	600	480	420	336	150	120	105	84
2 or more	2 or more	600	480	420	336	200	160	140	112
1	2 or more	500	400	350	280	200	160	140	112
Condition B—Interruption of Continuous Traffic									
Number of lanes for moving traffic on each approach		**Vehicles per hour on major street (total of both approaches)**				**Vehicles per hour on higher-volume minor-street approach (one direction only)**			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	750	600	525	420	75	60	53	42
2 or more	1	900	720	630	504	75	60	53	42
2 or more	2 or more	900	720	630	504	100	80	70	56
1	2 or more	750	600	525	420	100	80	70	56

Figure 8: Tables showing conditions A and B for warrant 1 in the MUTCD [8]

2.3.2 Warrant 2: Four-Hour Vehicular Volume

The four-hour vehicle volume warrant consists of compiling volume counts for both the major and minor streets and comparing the peak hours for each of any four hours of an average day to determine if the volume of intersecting traffic is high enough to warrant a signal [8]. The four-hour vehicle warrant will be conducted once volumes are counted and analyzed. The four-hour vehicle warrant was conducted by analyzing the four highest vehicle volumes. Figure 9 shows the chart used when warranting warrant 2.

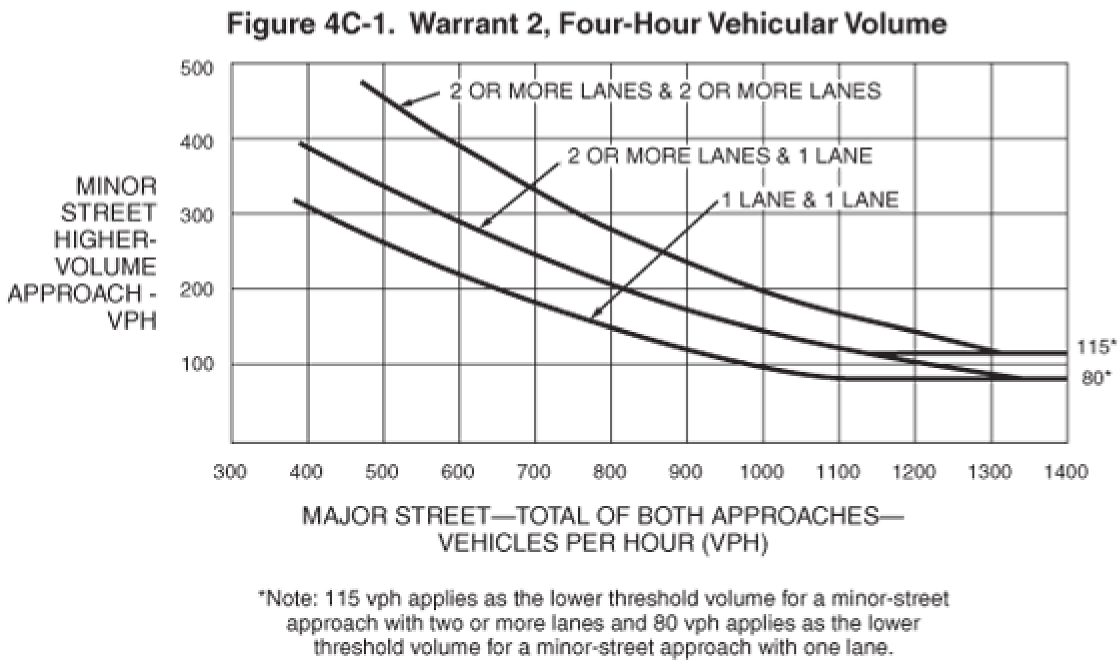


Figure 9: Major and Minor street volume chart from the MUTCD [8]

2.3.3 Warrant 7: Crash Experience

Crash data was obtained and analyzed to determine if the intersection warrants a signal due to crash experience. According to the MUTCD an intersection may warrant a signal if alternate methods do not reduce the crash rate, and if five or more crashes occur in any twelve month period [8]. The volume of both the major and minor streets must also be high enough to where it meets the 80 percent columns of condition A and B from the eight-hour vehicle volume warrant [8].

References

[1] Google, "Google Maps," [Online]. [Accessed 20 January 2016].

[2] *HCM 2000,* Transportaion Research Board of the National Acadamies.

[3] "Vehicle Classification Support," JAMAR Technologies, Inc., [Online]. Available: http://www.jamartech.com/S04008.html. [Accessed 3 2 2016].

[4] J. Deshaies, "THE I-81 CHALLENGE," [Online]. Available: http://thei81challengeblog.org/archive/learning-center-what-is-level-of-service-los/. [Accessed 08 March 2016].

[5] "How We Drive," [Online]. Available: http://www.howwedrive.com/2009/03/03/los-rip/. [Accessed 08 March 2016].

[6] C. o. Flastaff, "City of Flagstaff-Map-ArcReader," City of Flagstaff, Flagstaff, 2014.

[7] Trafficware, "Planning & Analysis Software," [Online]. Available: http://www.trafficware.com/synchro-studio.html. [Accessed 9 3 2016].

[8] FHWA, "2009 Edition Chapter 4C. Traffic Control Signal Needs Studies," MUTCD, 2009. [Online]. Available: http://mutcd.fhwa.dot.gov/htm/2009/part4/part4c.htm. [Accessed 08 March 2016].

3.0 Appendices

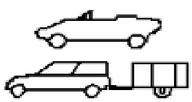
Appendix A: Vehicle Classification Sheet
Appendix B: Synchro Output Map
Appendix C: HCS Output Sheet
Appendix D: Information for Warrants 3-6 and 7-9

Appendix A: Vehicle Classification Sheet

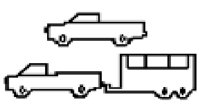
In traffic terms, a vehicle's 'classification' is the category it is sorted into based on its physical characteristics.

Most classification studies are done use the Federal Highway Administration's Scheme F as a basis.
This scheme contains 13 separate classes of vehicles, described below:

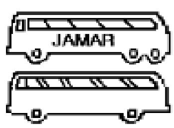
Class 1 - Motorcycles
This class includes all two- or three-wheeled motorized vehicles. These vehicles typically have a saddle-type of seat and are steered by handlebars rather than a steering wheel. This includes motorcycles, motor scooters, mopeds, motor-powered bicycles and three-wheel motorcycles.



Class 2 - Passenger cars
This class includes all sedans, coupes and station wagons manufactured primarily for the purpose of carrying passengers, including those pulling recreational or other light trailers.

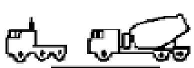


Class 3 - Pickups, Vans and other 2-axle, 4-tire single unit vehicles
This class includes all two-axle, four tire vehicles other than passenger cars, which includes pickups, vans, campers, small motor homes, ambulances, minibuses and carryalls. These types of vehicles which are pulling recreational or other light trailers are included.

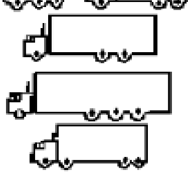


Class 4 - Buses
This class includes all vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This includes only traditional buses, including school and transit buses, functioning as passenger-carrying vehicles. All two-axle, four tire minibuses should be classified as Class 3. Modified buses should be considered to be trucks and classified appropriately.

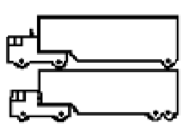
Class 5 - Two-Axle, Six-Tire Single Unit Trucks
This class includes all vehicles on a single frame which have two axles and dual rear tires. This includes trucks, camping and recreation vehicles, motor homes, etc.



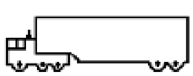
Class 6 - Three-Axle Single Unit Trucks
This class includes all vehicles on a single frame which have three axles. This includes trucks, camping and recreation vehicles, motor homes, etc.



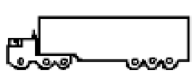
Class 7 - Four or More Axle Single Unit Trucks
This class includes all vehicles on a single frame with four or more axles.



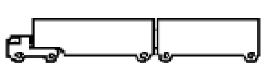
Class 8 - Four or Less Axle Single Trailer Trucks
This class includes all vehicles with four or less axles consisting of two units, in which the pulling unit is a tractor or single unit truck.



Class 9 - Five-Axle Single Trailer Trucks
This class includes all five-axle vehicles consisting of two units in which the pulling unit is a tractor or single unit truck.

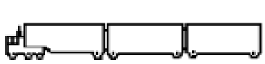


Class 10 - Six or More Axle Single Trailer Trucks
This class includes all vehicles with six or more axles consisting of two units in which the pulling unit is a tractor or single unit truck.



Class 11 - Five or Less Axle Multi-Trailer Trucks
This class includes all vehicles with five or less axles consisting of three or more units in which the pulling unit is a tractor or single unit truck.

Class 12 - Six-Axle Multi-Trailer Trucks
This class includes all six-axle vehicles consisting of three or more units in which the pulling unit is a tractor or single unit truck.



Class 13 - Seven or More Axle Multi-Trailer Trucks
This class includes all vehicles with seven or more axles consisting of three or more units in which the pulling unit is a tractor or single unit truck.

What are unclassified vehicles?
Most class studies also contain data for **Class 14 - Unclassified Vehicles**. This class includes all vehicles which could not process into one of the existing 13 classes. This data can be retained in your reports, or it can be redistributed by the software into the existing 13 classes based on the percentages in each of those classes.

Appendix B: Synchro Output Map

Appendix C: HCS Output Sheet

Vehicle Volumes and Adjustments																
Approach	Eastbound				Westbound				Northbound				Southbound			
Movement	U	L	T	R	U	L	T	R	U	L	T	R	U	L	T	R
Priority		10	11	12		7	8	9	1U	1	2	3	4U	4	5	6
Number of Lanes		0	1	0		0	1	1	0	1	1	0	0	1	1	1
Configuration			LTR			LT		R		L		TR		L	T	R
Volume (veh/h)		4	12	53		118	13	11		16	89	7		57	75	113
Percent Heavy Vehicles		9	9	9		17	17	17		9				14		
Proportion Time Blocked																
Right Turn Channelized	No				Yes				No				Yes			
Median Type	Undivided															
Median Storage																
Delay, Queue Length, and Level of Service																
Flow Rate (veh/h)			75			142		12		17				62		
Capacity			815			524		918		1473				1412		
v/c Ratio			0.09			0.27		0.01		0.01				0.04		
95% Queue Length			0.3			1.1		0.0		0.0				0.1		
Control Delay (s/veh)			9.9			14.4		9.0		7.5				7.7		
Level of Service (LOS)			A			B		A		A				A		
Approach Delay (s/veh)	9.9				13.7				1.0				1.8			
Approach LOS	A				B				A				A			

Appendix D: Warrant 3-6 and 8-9 Information / Charts

Appendix D-1: Warrant 3: Peak Hour [8]

Standard:

02 **This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.**

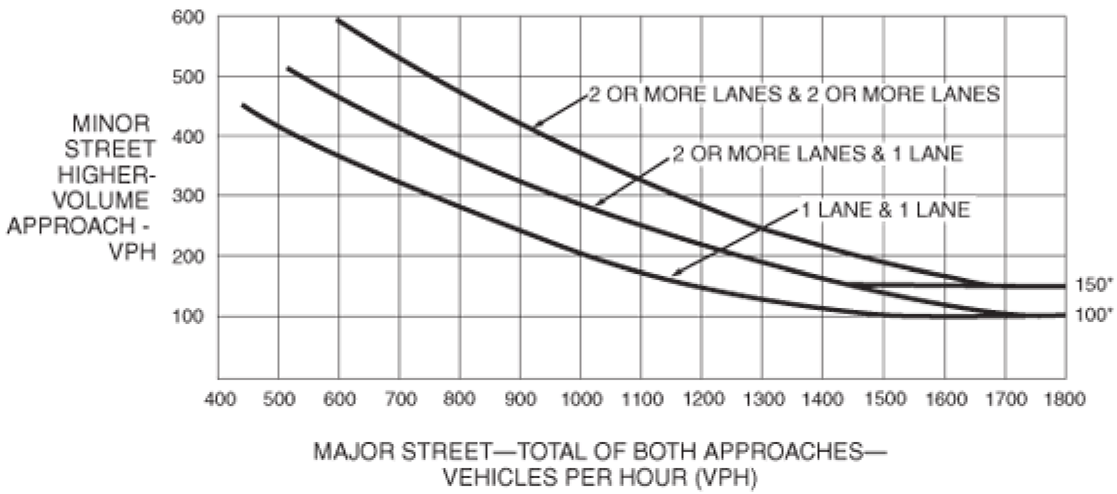
03 **The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:**

A. If all three of the following conditions exist for the same 1 hour (any four consecutive 15-minute periods) of an average day:

1. **The total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach or 5 vehicle-hours for a two-lane approach; and**
2. **The volume on the same minor-street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes; and**
3. **The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.**

B. The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4C-3 for the existing combination of approach lanes.

Figure 4C-3. Warrant 3, Peak Hour



*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

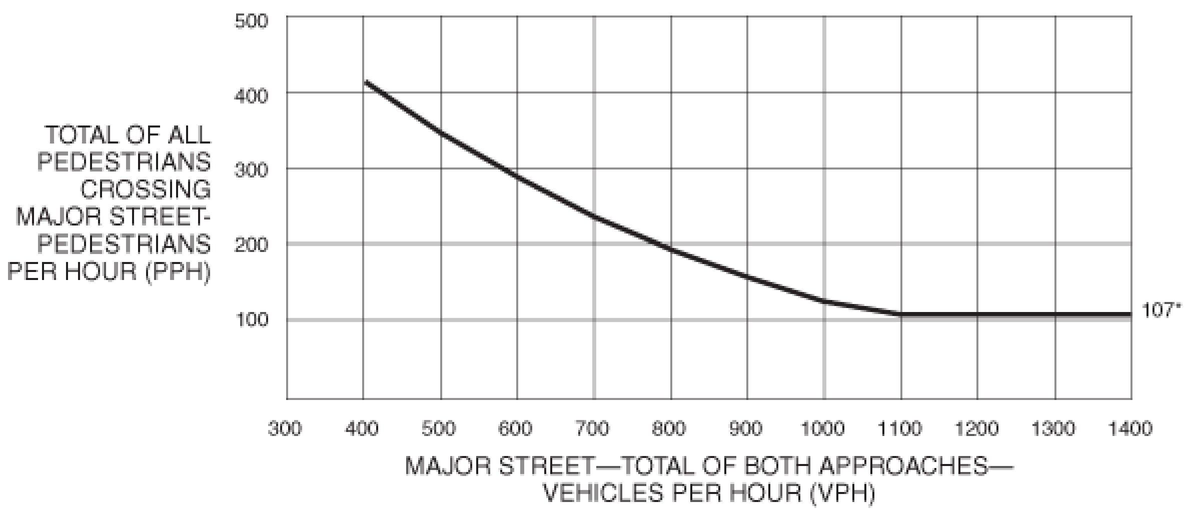
Appendix D-2 Warrant 4: Pedestrian Volume [8]

Standard:
02 **The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that one of the following criteria is met:**

A. For each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) all fall above the curve in Figure 4C-5; or

B. For 1 hour (any four consecutive 15-minute periods) of an average day, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) falls above the curve in Figure 4C-7.

Figure 4C-5. Warrant 4, Pedestrian Four-Hour Volume



*Note: 107 pph applies as the lower threshold volume.

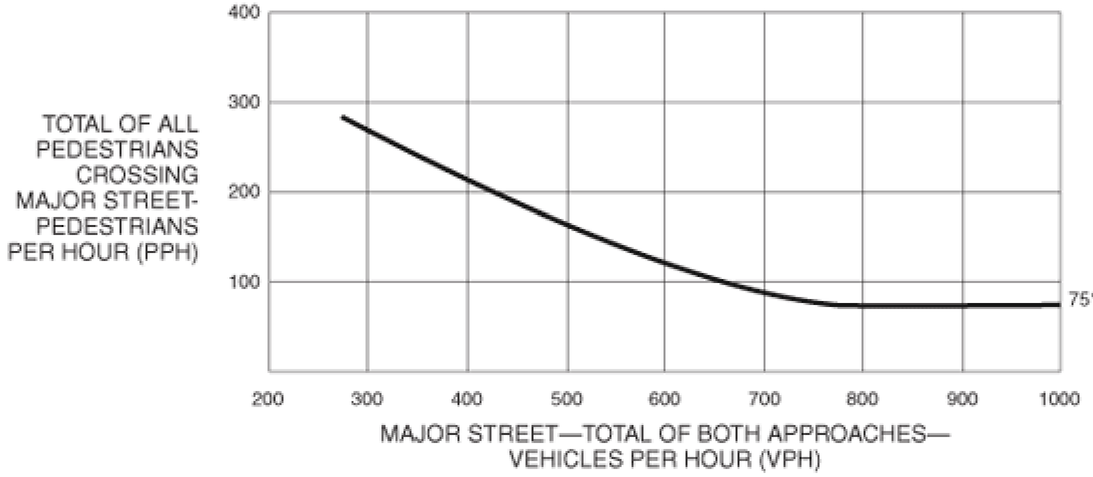
Appendix D-3 Warrant 5: School Crossing [8]

Standard:
02 **The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that one of the following criteria is met:**

A. For each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) all fall above the curve in Figure 4C-5; or

B. For 1 hour (any four consecutive 15-minute periods) of an average day, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) falls above the curve in Figure 4C-7.

Figure 4C-6. Warrant 4, Pedestrian Four-Hour Volume (70% Factor)



Appendix D-4 Warrant 6: Coordinated Signal System [8]

Section 4C.07 Warrant 6, Coordinated Signal System

Support:

01 Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:**

A. On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.

B. On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.

Appendix D-5 Warrant 8: Roadway Network [8]

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:**

A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or

B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday).

03 **A major route as used in this signal warrant shall have at least one of the following characteristics:**

A. It is part of the street or highway system that serves as the principal roadway network for through traffic flow.

B. It includes rural or suburban highways outside, entering, or traversing a city.

C. It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.

Appendix D-6 Warrant 9: Intersection near a Grade Crossing [8]

Standard:

03 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following criteria are met:**

A. A grade crossing exists on an approach controlled by a STOP or YIELD sign and the center of the track nearest to the intersection is within 140 feet of the stop line or yield line on the approach; and

B. During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the minor-street approach that crosses the track (one direction only, approaching the intersection) falls above the applicable curve in Figure 4C-9 or 4C-10 for the existing combination of approach lanes over the track and the distance D, which is the clear storage distance as defined in Section 1A.13.