November 28th, 2018

Anthony Ingle, PE
Department of Civil and Environmental Engineering
Michigan State University
3577 Engineering Building
East Lansing, MI 48823

Subject: <u>Bogue Street Redesign</u>

Dear Sir,

Respectively, we the undergraduate Engineering students of Michigan State University have reported on the "Redesign of the intersection of Bogue Street at Grand River Avenue on the Michigan State University Campus" through the course CE 341 Transportation Engineering.

In accordance with the class guidelines, we are required to provide you with a Final report. This report has been prepared in conformance with CE 341 "Final Project" grading rubric. This report includes information on how to improve the intersection at Grand River Ave. and Bogue Street. Due to a foreseen influx of pedestrian and automobiles around this intersection from the construction of The Hub, data was collected in order to create potential design improvements. The recommendation is to make Bogue is single lane road with various turn lanes at Auditorium and Waters Edge intersection to allow for the highest flow rate in those areas. That is based on those changes additionally allowing for a bike lane to be added and a wider sidewalk along Bogue for the pedestrian and cyclist traffic as well these changes minorly decreasing the level of service in two locations.

Sincerely,

Group 3: Peter Baker, Garrett Preston, Devin Powers, Michael Licata, and Jordan Buck

Bogue Street Redesign

CE 341 Transportation Engineering

To: Anthony Ingle, PE

From: Group 3: Peter Baker, Garrett Preston, Devin Powers, Michael Licata, and Jordan Buck

Table of Contents

Bogue Street Redesign

Executive Summary:

Group 3 was employed to study the traffic operations down Bogue Street in East Lansing, Michigan. The intersections down Bogue Street including Grand River, Waters Edge, and Auditorium were included in the study. The team was able to design a new roadway that includes single lanes with turn lanes, wider sidewalks, and a new bike lane. The purpose of the study was to determine what is wrong with the current roadway and use the data collected to determine if the Level of Service is operating at an adequate level. The study is important to improve both the traffic operations and safety of pedestrians on Bogue street for the future demands it will require when the construction of a new apartment complex called The Hub is completed and opened in the Fall of 2019.

The data collection of all three intersections were counted by monitoring the traffic flow in 15-minute intervals in the morning, midday, and afternoon. The collected data was used to calculate each of the Level of Service of the three intersections during the observed time periods. The different time periods allowed for the team to collect data at peak moments when traffic on Michigan State University campus is at its busiest. The results from the traffic study found that peak traffic hours on Bogue Street occur between the times of 9:30 AM-10:30 AM, 11:45 AM-12:45 PM, and from 5:15 PM to 6:15 PM. The data was collected by the traffic counter, uploaded in Microsoft Excel and analyzed with the traffic counting software Synchro 5. Additional data collected was the dimensions of the roadway of Bogue and the three intersections of interest, which was “plotted” in Autocad. Assumptions made include a predicted increased level of service of 10% with the construction of the apartment complex The Hub.

The following report shows a detailed interpretation of the purpose, procedures, the processes of conducting a traffic study, and the suggestion of a new design.

Introduction:

After the confirmation and approval of the traffic study project on Bogue Street by Professor, Anthony Ingle, Group 3 was able to investigate and address the problems of the existing intersection of Bogue Street at Grand River Avenue (including Bogue Street from Grand River Ave to East Shaw Lane). Opening in the fall of 2019 at the corner of Bogue and Grand River, directly across from the campus of Michigan State, is a new 10 story high-rise called The Hub. The large apartment complex will add 158 parking spots and provide housing for 585 residences(Lansing State Journal). The new apartment complex will add more traffic to the outdated intersections, roadway, and sidewalks on Bogue Street. The teams in CE 341 used a traffic counter to perform a volume count on the intersections along Bogue Street at Grand River Avenue, Waters Edge Drive, and at Auditorium Road. The intersections of interests are circled in Figure 1.

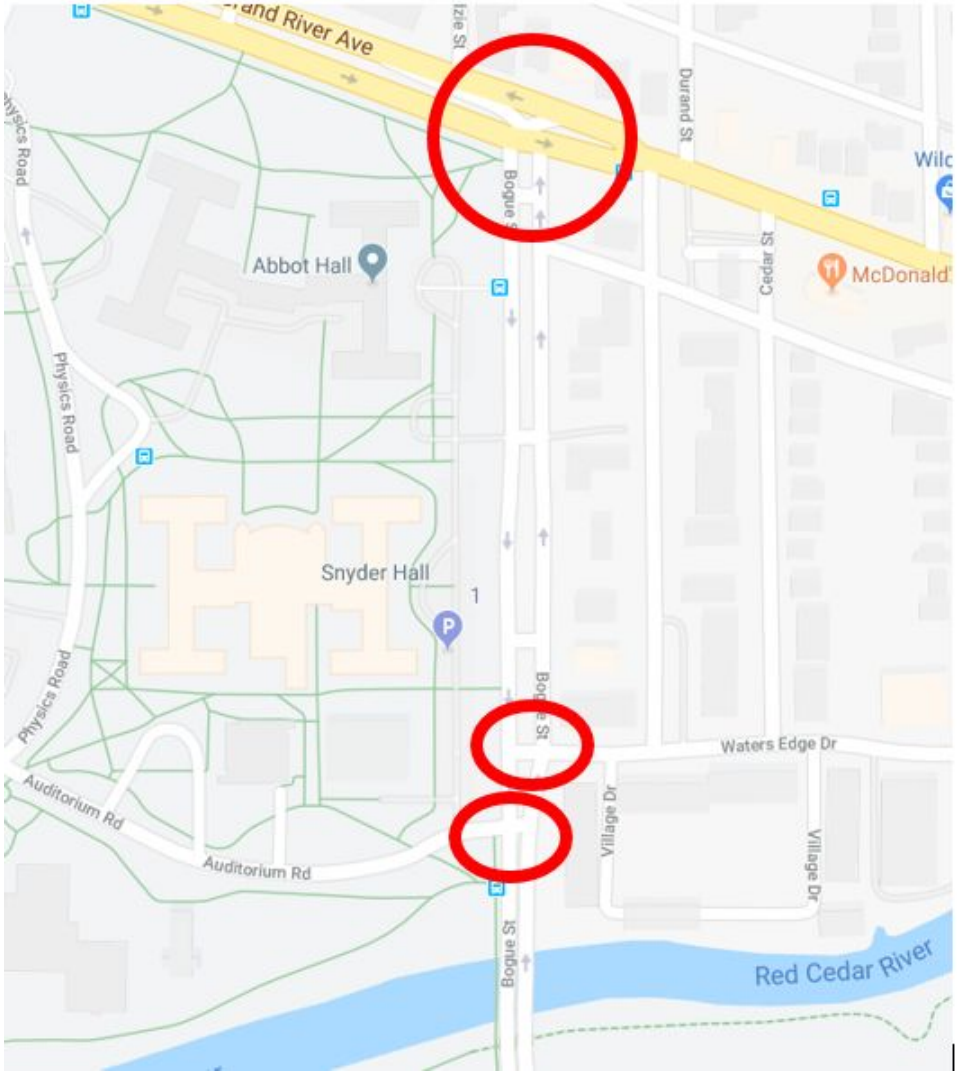

Figure 1. Site Locations of Intersections (from Google maps)

The data from the traffic counts at the intersections were used to determine the level of service at the AM, mid-day, and PM peak periods. Group 3 determined from both the level of service data and visual observations, that the roadway down Bogue Street was not efficient for vehicles, pedestrians, and bicyclists. The traffic was determined to be both congested and slow while from the visual observations the group noticed narrow sidewalks for bicyclists and pedestrians to share.

Group 3 designed a new single lane road down Bogue Street with turn lanes, wider sidewalks, and an added bike lane on Bogue Street. The new design was constructed in AutoCAD and the data was tested using both Synchro 5 and Simtraffic software. The design of the project was to increase the efficiency of traffic flow for both cars and pedestrians. The downside to the updated design the team created, was the removal of green spaces and the decrease in the level of service of eastbound travel at the Bouge Street and Auditorium intersection, in which the level of service went from an "E" to "F" during the afternoon hours.

The final report includes the finding of the research which includes the data collection, analyzation the data, and the interpretation to design with the purpose of improving traffic operations.

Data Collection Methods and Interpretation:

The Data from traffic survey was collected by all groups in CE 341 using an intersection counter shown in Figure 2.

Figure 2: Intersection Counter

The team performed the traffic survey, that record a traffic volume count, which included both vehicles and pedestrian traffic (Bicyclist included). The data from the volume count included all vehicle, pedestrians, and bicyclist traffic that interacted with the intersection. The volume count used to determine the peak hours.

The intersection counter was able to record and count the directions that the vehicles went in 15-minute intervals. The 15-minute intervals were an important aspect that the group considered because it allowed for the traffic flow to be consistent throughout the hour. The peak hour factor was determined by dividing the peak hour volume by four times the peak 15-minute volume. The counter was also used to collect the direction of both pedestrians and bicyclist using the buttons labeled 1,5,9, and 13 in figure 2. Pedestrians and Bicyclists who crossed roads without crosswalks were not included in the study.

The team was able to use the traffic volume data to run a simulation of Bogue Street and the three intersections using the Synchro 5 and Traffic-sim programs. Level of service is used to analyze roadways and intersections by categorizing traffic flow and assigning quality levels of traffic based on performance measures such as vehicle speed, density, and congestion. A graph of the level of service is shown below in figure 3.

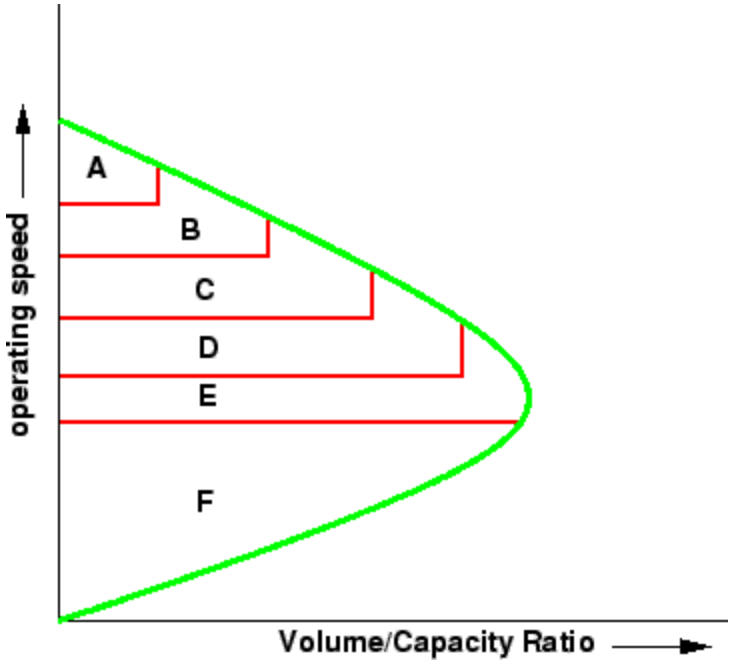

Figure 3: Level of Service related to Operating Speed and Volume/Capacity Ratio

In figure 3, the level of service is shown from A to F. The level of service A represents the zone of free flow, where traffic volume will be at the lowest. In which allows drivers to have complete freedom to choose their preferred speed. At a level of service of F, traffic is at a region of forced flow were drivers are at a low speed.

Synchro Analysis:

The group used, Synchro software to set up a traffic diagram of Bogue Street with the 3 intersections of interest. The group's Synchro diagram is shown in Figure 4. The Synchro software allows for programmers to design a simulation of the road(s) of interest.

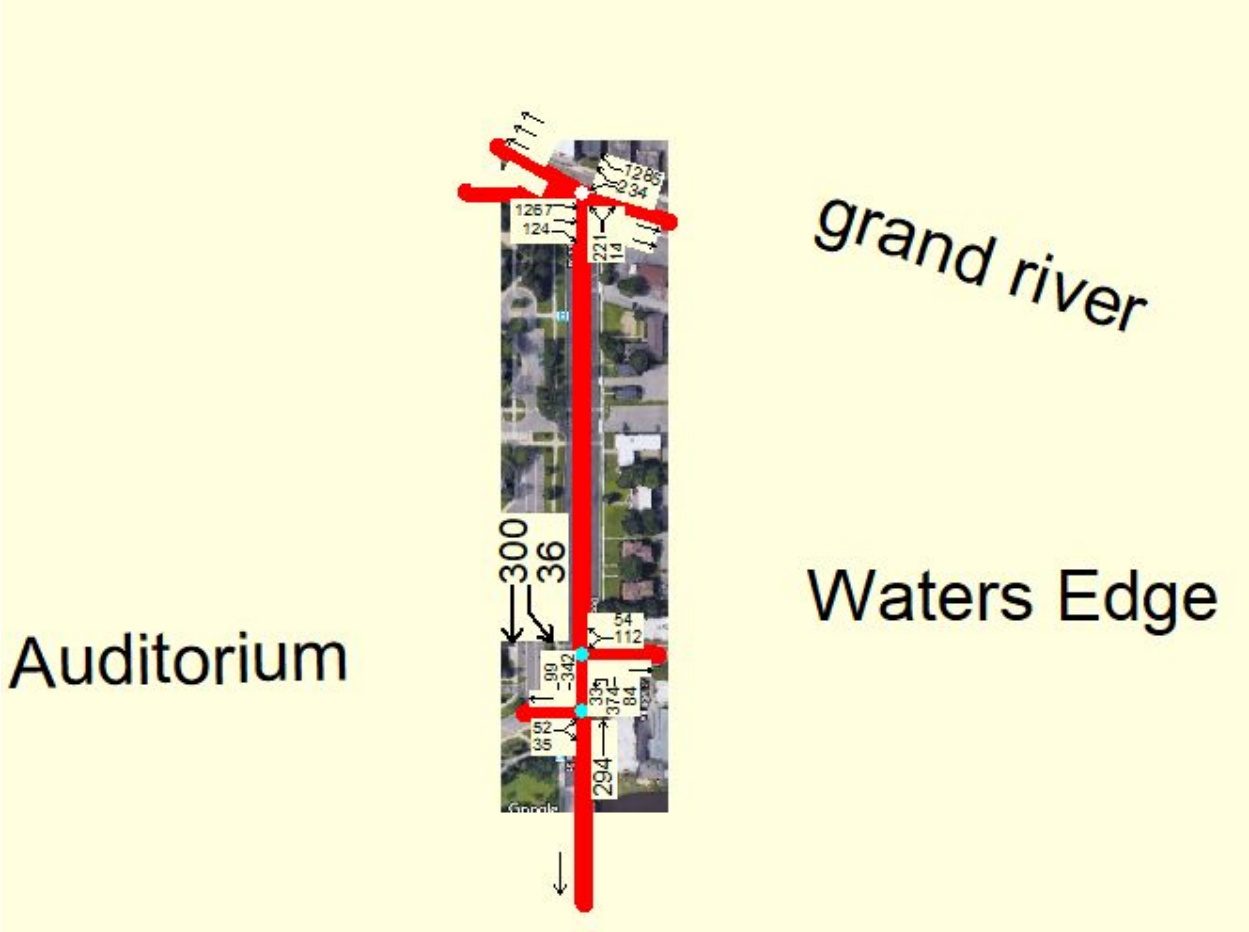

Figure 4: Model of Bogue Street and Key Intersections in Synchro 5

After the roads, intersections, turn lanes, and volume of traffic was imported and created in Synchro, traffic sim was used to create a visual simulation of Bogue Street during the 3 different time periods. The traffic sim that group 3 created for existing conditions of Bogue Street is shown in figure 5. No outputs are directly received from the traffic sim program, but it allows for the inputs and road design to be visually checked to ensure it is accurately representing the conditions. The outputs from the Synchro 5 program are the delays at signalized intersections, level of service of signalized intersections, and approach level of service at an intersection. The approach level of services is reported in table 4 through table 7 for the three intersections throughout the day. The approach level of service was chosen to be reported because there is not an intersection level of service given at Waters Edge and Bogue Street as well as Auditorium and Bogue Street because those are not signalized.

Figure 5: Model of the Existing Conditions of Bogue Street in Traffic Sim

Results:

Using all traffic count data from other groups, a master sheet of all traffic data was created and the peak traffic hours were determined from that. The peak traffic hours of Bogue Street are 9:30 AM to 10:30 AM, 11:45 AM to 12:45 PM, and 5:15 PM to 6:15 PM. Using those hours, the peak hour factors for each intersection were found. In Table 1 below, it shows the values that were put into the Synchro 5 program to obtain the level of service at the intersection of Waters Edge and Bogue Street. The traffic count numbers were adjusted to created equilibrium on roads between intersections.

Table 1. Peak Hour Traffic Volume and Peak Hour Factor for Waters Edge

Waters Edge												
	Southbound				Westbound				Northbound			
	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds
9:30 AM	0	366	28	55	30	0	75	33	40	140	46	82
PHF		0.90	0.58		0.58		0.78		0.58	0.80	0.78	
11:45 AM	0	312	33	152	47	0	95	46	70	270	40	207
PHF		0.57	0.63		0.78		0.48		0.67	0.81	0.78	
5:15 AM	0	300	36	84	54	0	112	70	84	374	33	133
PHF		0.83	0.75		0.71		0.80		0.68	0.78	0.69	

Table 2 shows the values used for inputs into the Synchro 5 program to obtain the level of service for the intersection of Auditorium Street and Bogue Street. The traffic count numbers were also adjusted for equilibrium.

Table 2. Peak Hour Traffic Volume and Peak Hour Factor for Auditorium

Auditorium												
	Southbound				Northbound				East Bound			
	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds
9:30 AM	124	363	0	11	0	191	0	51	30	0	35	349
PHF	0.77	0.82				0.74			0.82		0.75	
11:45 AM	161	471	0	14	0	248	0	66	39	0	46	453
PHF	0.77	0.82				0.74			0.82		0.75	
5:15 AM	99	342	0	10	0	294	0	45	35	0	52	351
PHF	0.78	0.93				0.75			0.73		0.68	

Table 3 shows the values used for inputs for the Synchro 5 program to get the level of service for the intersection of Grand River Avenue and Bogue Street. Additionally, the traffic count numbers were adjusted for equilibrium.

Table 3. Peak Hour Traffic Volume and Peak Hour Factor for Grand River

Grand River												
	Westbound				Northbound				East Bound			
	Right	Thru	Left	Peds	Right	Thru	Left	Peds	Right	Thru	Left	Peds
9:30 AM	0	735	208	193	63	0	95	249	158	699	0	0
PHF		0.91	0.61		0.74		0.71		0.67	0.89		
11:45 AM	0	989	196	185	132	0	135	253	205	920	0	0
PHF		0.71	0.53		0.89		0.75		0.48	0.91		
5:15 AM	0	1285	234	69	146	0	221	147	124	1267	0	0
PHF		0.90	0.74		0.52		0.91		0.74	0.85		

Tables 4 through 7 display the level of service of the approaches of the three intersections, Bogue Street and Auditorium Street, Bogue Street and Waters Edge, and Bogue Street and Grand River Avenue, at different conditions. Table 4 and 6 are the current conditions of the three intersections and are used as a control to judge the redesigned conditions.

Table 4. Existing Level of Service based on Current Conditions

Level of Service of Exisiting Conditions									
Time	Bogue and Auditorium			Bogue and Waters Edge			Bouge and Grand River		
	NB	EB	SB	NB	SB	WB	NB	EB	WB
9:30	A	D	A	A	C	A	B	B	B
11:45	A	F	A	A	F	A	B	B	B
5:15	A	E	A	A	F	A	B	C	B

The current traffic count data was run on a redesigned Bogue Street, featuring a single travel lane and various turn storage lanes at intersections, the outputs from this created table 5. From table 5 it is then determined that new design would decrease the level of service of eastbound travel at the Bogue Street and Auditorium intersection from E to an F during the afternoon hours and would not affect the remainder of the network.

Table 5. Predicted Level of Service based on Current Conditions with New design

Level of Service of New Conditions									
Time	Bogue and Auditorium			Bogue and Waters Edge			Bouge and Grand River		
	NB	EB	SB	NB	SB	WB	NB	EB	WB
9:30	A	D	A	A	C	A	B	B	B
11:45	A	F	A	A	F	A	B	B	B
5:15	A	F	A	A	F	A	B	C	B

Following the current conditions being modeled, the predicted level of service with the 10% growth added from the construction of The Hub for both the current design and the new

design is found by adding network growth rate in the Synchro 5 program. The predicted level of service is displayed in table 6 and 7 for both the current and the new design respectively. Due to the 10% growth, there is a predicted fall in the level of service at eastbound Bogue Street and Auditorium from a D to an E in the morning hours and at eastbound Bogue Street and Grand River Avenue from a B to a C in the morning hours.

Table 6. Predicted Level of Service based on Current Conditions and Growth

Level of Service of Exisiting Conditions with 10% Growth									
Time	Bogue and Auditorium			Bogue and Waters Edge			Bouge and Grand River		
	NB	EB	SB	NB	SB	WB	NB	EB	WB
9:30	A	E	A	A	A	C	B	C	B
11:45	A	F	A	A	A	F	B	B	B
5:15	A	E	A	A	A	F	B	C	B

Now, comparing table 6 to table 7 the new conditions would only cause an additional drop in the level of service at eastbound Bogue Street and Grand River from a B to a C during the mid-day hours.

Table 7. Predicted Level of Service based on Current Conditions with New Design and Growth

Level of Service of New Conditions with 10% Growth									
Time	Bogue and Auditorium			Bogue and Waters Edge			Bouge and Grand River		
	NB	EB	SB	NB	SB	WB	NB	EB	WB
9:30	A	E	A	A	C	A	B	C	B
11:45	A	F	A	A	F	A	B	C	B
5:15	A	E	A	A	F	A	B	C	B

While the new design of Bogue Street may create additional decreases in the level of service, using only one 12 foot lane for traffic instead of two 12-14 foot lanes greatly increases the amount of space for the predicted increased pedestrian traffic due to The Hub.

Discussion:

The values of the peak hour volumes and peak hour factors are based on the original traffic count data but include multiple assumptions because for example there was no data count conducted at Auditorium Street during the mid-day hours. The assumptions for the AM peak hour volume data was that growth displayed from 8:30-9:30 am peak volume to 9:30-10:30 am peak volume at Grand River Avenue and Bogue Street is the same as Bogue Street intersections with Auditorium and Waters Edge since there was no data for 9:30-10:30 am at those intersections. The peak hour factor at 9:30-10:30 am for Bogue Street intersections with Auditorium and Waters Edge is assumed to be the same as the peak hour factor for 8:30-9:30 am. Otherwise, the peak hour volume and peak hour factor calculations were based on the traffic count.

During the mid-day hours, as stated before, there was no traffic count data for Auditorium and Bogue Street intersection. So, the traffic growth from 8:30-9:30 am to 11:45 am-12:45 pm at Water's Edge and Bogue Street is assumed to be the same as Auditorium growth for that same time period as well as the peak hour factor for 11:45 am-12:45 pm is assumed to be the same as the peak hour factor from 9:30-10:30 am at Auditorium and Bogue Street. Otherwise, no other assumptions were made for the mid-day hours and the original count data was used.

During the PM hours, Auditorium data was not collected during the peak hours at Grand River completely and was partially assumed for the missing 15-minute intervals. The Auditorium count numbers were then based on growth at Water's Edge to create peak hour volume for 5:15-6:15 pm. The peak hour factor for Auditorium was assumed to be that same as the peak hour factor during 5:30-6:30 pm. Otherwise, no other assumptions were made for the PM hours and the original count data was used. The Waters Edge growth was used to create and assume data for Auditorium due to the two roads being geographically close to each other and having similar peak traffic volumes and peak hour factor throughout the day.

Reviewing all the data, two possible solutions were generated to solve the predicted vehicle and pedestrian traffic volume issue from the construction of The Hub. One possible solution was to not change any of Bogue Street. The second solution was to change Bogue Street down to a single lane road with 100-foot turn lanes at important turns. More specifically at the Grand River intersection, a right turn lane was added for northbound traffic, Grand River Avenue was not changed for this proposal. At the intersection with Auditorium, southbound traffic has a right turn lane added. At the intersection with Waters Edge, a left turn lane would be added to the northbound through-lane and the through-lane can additionally make right turns onto Waters Edge. Additionally, with the space created from changing to a single lane on Bogue Street, a bike lane would be added on both northbound and southbound lanes as well as the sidewalk along the east side of Bogue Street would be widened to accommodate the increased cyclist traffic volume and pedestrian traffic volume from The Hub. The added biked lane would additionally increase the safety of the cyclist using the road.

From observing the small decrease of the level of service of a B to a C for eastbound traffic at the Grand River Intersection for the predicted conditions, the second solution to redesign Bogue Street was ultimately chosen due to the increased accommodation for the current issue of pedestrian and cyclist traffic along Bogue Street and the plan's small impact on the level of service of Bogue Street. Figure 6 shows a model of the redesigned road in the Traffic Sim program to clearly show the location of the added turn lanes, however, the model does not show the median between northbound and southbound, but it would remain there.

Figure 6. Model of the Redesigned Intersection in the Traffic Sim Program

Webster's Formula:

$$C_o = \frac{1.5L+5}{1-\Sigma(V/s)}$$

Equation 1: Webster Formula

Where,
Co= Optimum cycle length
L= total lost time per cycle (sec)
V/s= Maximum value of the ratios of approach flows to saturation flows for all lane groups (critical sum)

Webster's Formula is used to optimize the cycle length at an intersection and aims to minimize the delay experienced by the drivers at a given intersection. Webster's Formula was applied to the signalized intersection of Grand River Avenue and Bogue Street in the Synchro 5. The program was used to optimize the cycle and assign the timing of lights for the various phases shown in figure 7 below.

Figure 7. Optimized phases at the intersection of Grand River and Bogue Street in Synchro

Warrants Considered:

Before final design alterations on Bogue Street were considered, Group 3 addressed warrants from the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD defines the standards used by road managers nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public travel (MUTCD). The 9 different warrants listed by the MUTCD are listed below.

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

The warrants are considered for Auditorium and Waters Edge because Grand River already has a signalized intersection. Warrants 1 and 2 were not considered as traffic data was not collected for eight or four consecutive hours. Warrant 3 was considered, however, the three conditions were not met for the warrant. Warrant 4 was not considered due to insufficient data. Warrant 5 was not considered as well because there is not a school on Bogue Street. Warrants 6 and 7 were also not considered because there is not a signal system present and crash data was not collected. Warrant 8 and 9 were both considered, however, the conditions were not met. Overall, none of the considered warrant conditions were met and those intersections will remain as stop-controlled in the redesigned plan.

Conclusion:

In conclusion, the Team was able to make several changes to the benefit of the public regarding the entirety of Bogue Street and it's varying intersections. One assumption made included a predicted increase level of service of 10% due to the construction of the new apartment complex on the corner of Bogue and Grand River. Several changes were applied to Bogue Street by the Team in order to handle the new influx of traffic. These changes include; single lanes with turn lanes, wider sidewalks, and a new bike lane. The purpose of transforming Bogue Street to have single lanes with turn lanes was to account for the heavy amount of pedestrian traffic stemming from the new apartment complex. The single lane with turning lanes would increase automobile traffic slightly on Bogue Street but will greatly decrease the traffic pedestrians would have experienced. Shortening the lanes on Bogue Street down to one lane will then allow the Team to expand the sidewalks along Bogue to accommodate more pedestrian traffic and add a bike lane along Bogue Street to encourage more bikers to ride in the roadway instead of sidewalks. The expanded sidewalks and additional bike lane will promote the safety for all current and future users of Bogue Street.

References:

Hansen, H. (2018). East Lansing City Council approves 10-story student apartment for downtown. Retrieved from https://www.lansingstatejournal.com/story/news/2017/12/15/east-lansing-city-council-approves-10-story-student-apartment-downtown/955827001/

Manual on Uniform Traffic Control Devices (MUTCD) - FHWA. (2018). Retrieved from https://mutcd.fhwa.dot.gov/

Appendix:

TIMING WINDOW	EBL	EBT	EBR	WBL	WBT	WBR	NBL2	NBL	NBR	SEL	SER	SER2	PED	HOLD
Lanes and Sharing (#RL)													—	—
Traffic Volume (vph)	0	699	158	208	0	735	0	95	63	0	0	0	—	—
Turn Type	—	—	Perm	Prot	—	—	—	—	Perm	—	—	—	—	—
Protected Phases	—	4		3	—	7	—	2		—	—	—		
Permitted Phases	—		4		—	8 7	—		2	—	—	—	—	—
Detector Phases	—	4	4	3	—	7	—	2	2	—	—	—	—	—
Minimum Initial (s)	—	4.0	4.0	4.0	—	4.0	—	4.0	4.0	—	—	—	—	—
Minimum Split (s)	—	20.0	20.0	8.0	—	8.0	—	20.0	20.0	—	—	—	—	—
Total Split (s)	—	20.0	20.0	19.0	—	17.0	—	21.0	21.0	—	—	—	—	—
Yellow Time (s)	—	3.5	3.5	3.5	—	3.5	—	3.5	3.5	—	—	—	—	—
All-Red Time (s)	—	0.5	0.5	0.5	—	0.5	—	0.5	0.5	—	—	—	—	—
Lead/Lag	—	Lag	Lag	Lead	—	Lead	—	—	—	—	—	—	—	—
Allow Lead/Lag Optimize?	—	Yes	Yes	Yes	—	Yes	—	—	—	—	—	—	—	—
Recall Mode	—	Max	Max	Max	—	Max	—	Max	Max	—	—	—	—	—
Actuated Effct. Green (s)	—	16.0	16.0	15.0	—	35.0	—	17.0	17.0	—	—	—	—	—
Actuated g/C Ratio	—	0.27	0.27	0.25	—	0.58	—	0.28	0.28	—	—	—	—	—
Volume to Capacity Ratio	—	0.83	0.50	0.77	—	0.48	—	0.27	0.21	—	—	—	—	—
Control Delay (s)	—	24.8	3.4	27.6	—	5.7	—	17.2	4.9	—	—	—	—	—
Level of Service	—	C	A	C	—	A	—	B	A	—	—	—	—	—
Approach Delay (s)	—	19.9	—	—	12.2	—	—	12.4	—	0.0	—	—	—	—
Approach LOS	—	B	—	—	B	—	—	B	—	A	—	—	—	—
Queue Length 50th (ft)	—	140	0	115	—	61	—	37	0	—	—	—	—	—
Queue Length 95th (ft)	—	#223	15	119	—	100	—	58	17	—	—	—	—	—
Queuing Penalty	—	0	0	0	—	0	—	0	0	—	—	—	—	—
Stops (vph)	—	633	26	190	—	304	—	71	14	—	—	—	—	—
Fuel Used (g/hr)	—	8	1	3	—	4	—	1	1	—	—	—	—	—
Dilemma Vehicles (#/hr)	—	0	0	0	—	0	—	0	0	—	—	—	—	—

Figure 6. Intersection Screen from Synchro 5 for Grand River and Bogue Street for 9:30am