SR-795 Smart Corridor

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1 Disclaimer

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2 Problem Statement

The section of State Route 795 between Interstate 75 and Interstate 280 that is being focused on for our project is a major arterial road that travels through and connects Perrysburg, Moline, and Millbury. The State Route also connects several commercial, industrial, and residential properties. Developments on the route have been causing increased traffic volume which in turn, has been having quite the impact on the effectiveness and safety of the route. Newly introduced industrial and distribution properties (e.g., Amazon Fulfillment Center), residential properties (e.g., Gulfstream Development), and high traffic volume interstates (e.g., I-75, I-280, I-80/I-90) have increased truck, civilian, and school traffic. State Route 795 was not initially designed to carry the amount of traffic that has been recently introduced to it, and as a result, several adverse effects have come to fruition. Sections of the corridor have seen slowdowns because of heavy traffic, dipping below the posted speed limits. Vehicle collisions have also been noticed to be an increasing issue, especially at major intersections. To counteract these effects, it has come to the attention that something needs to be done to the corridor to handle these changes.

3 Objectives

We, the UT senior design team, worked alongside the Wood County Port Authority (WCPA) to conduct a smart corridor project on State Route 795. This smart corridor design project aims to make SR-795 more intelligent, mobile, and safer to serve the roads surrounding commercial, industrial, and residential properties. We created several alternatives that would help maximize the existing transportation network's efficiency, smooth traffic flow, and improve safety to meet anticipated growth needs. This might be divided into several phases due to some constraints. In this report, however, we will be discussing what we suggest as a phase 1 option.

4 Constraints

Our client, The Wood County Port Authority, did not have many constraints for this project. The UT team was not provided a maximum budget because it is unknown where this smart corridor project might be headed. Depending on the solution that is chosen by The Wood County Port Authority will also determine how much money is needed and proposed to stakeholders invested in the project. The Wood County Port Authority will also have to determine both short and long term goals for the SR-795 Smart Corridor project that the UT team will help provide. The performance requirements for the Smart Corridor are based on decreasing travel time on SR-795 as well as accounting for an increased traffic capacity of the major arterial road (SR-795). The existing condition of the selected corridor of SR-795 bound between I-75 and I-280 is a 2 lane road with an added turn lane at major intersections in both the eastbound and westbound directions. A sample of the existing conditions for SR-795 is depicted in Figure 1 on the next page. The corridor is bound on the north and south by privately owned land that would raise the project cost due to right of way purchasing.

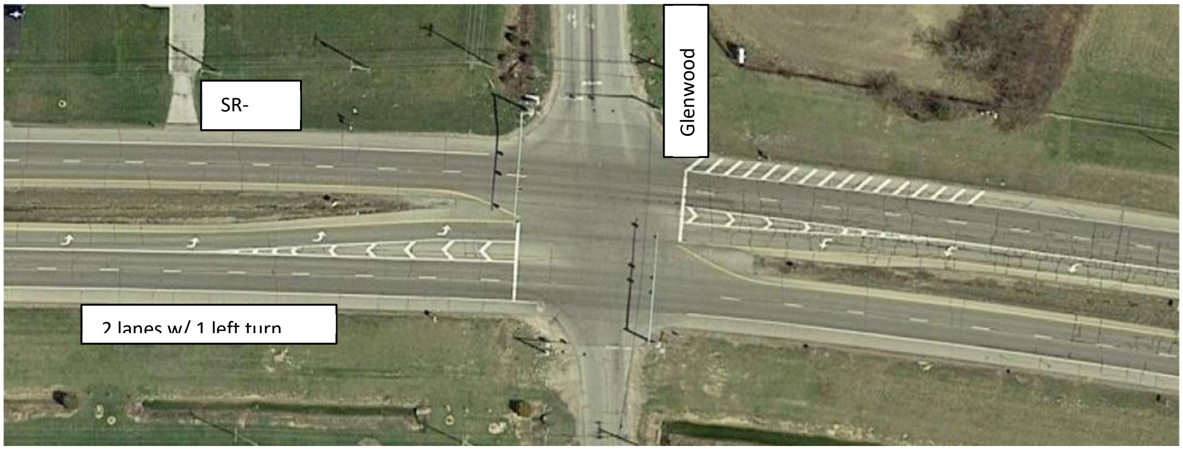

Figure 1: Existing SR-795 Corridor

5 Alternatives

5.1 Introduction

There are several options to go about handling the increased traffic volume occurring on SR-795. We have looked into multiple alternatives and will ultimately end up suggesting to the Wood County Port Authority what we believe is the best method to help handle the increased traffic volume. In the following sections, we will discuss the alternatives that have potential to work in this corridor for the heavy traffic volumes and loads.

5.2 Smartboards and Digital Signposts with Artificial Intelligence (AI) Cameras

The first alternative we are considering is the integration of smart boards and digital signpost. This option would make use of light emitting diodes (LEDs) and digital sign boards in conjunction with wireless digital traffic signposts and AI cameras. An example of a digital smartboard is seen in Figure 2 on the next page.

Figure 2: Digital Smartboards

(http://www.photonplayinc.com)

For intelligent roads of the future, we would need traffic signs to be wireless and traffic information and data to be sent wirelessly. An example can be seen in Figure 3 on the next page. This alternative will involve using hardware that is programmable. The wireless hardware will be able to transmit digital signs and traffic information onto oncoming vehicles on a road. These wireless smartboards and digital signposts will transmit signals from the road to the Heads-up-Displays (HUDs) of cars, dashboards of cars and even smartphones present in the car. The AI cameras will monitor various variables on the road such as density of the road, speed of cars on the road and location of cars on the road to transmit information to the smartboards for dissemination.

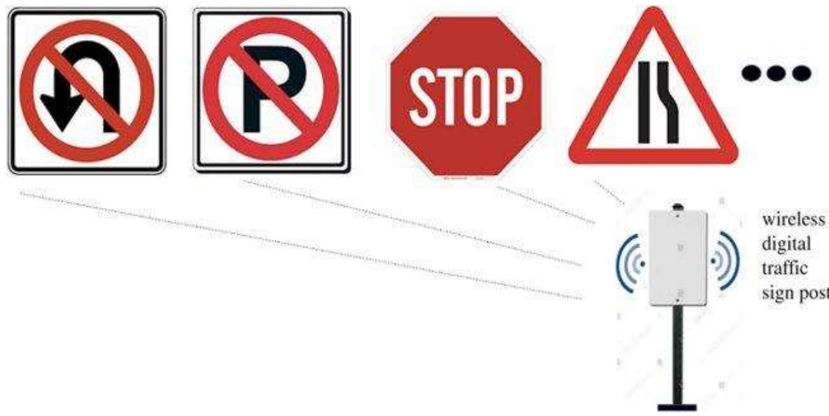

Figure 3: Digital Signposts Showing Traffic Signs

(https://royalsocietypublishing.org)

5.3 Vehicle-to-Infrastructure (V2I) Technology

As smartboards and digital signposts progress, it is possible to start looking at Vehicle-to-Infrastructure (V2I) technology. This type of technology will make traffic signals smarter as it is the next generation of intelligent transportation systems (ITS). V2I technology is capable of capturing traffic data generated by the vehicles or roadside infrastructure and wirelessly providing information back to the vehicle, to alert the driver of safety, mobility, or environmental-related conditions. We can see an example of this in Figure 4 on the next page. State and local agencies may install or integrate V2I infrastructure alongside existing ITS facilities. This is the next wave of the future of transportation where traffic lights and vehicles will be able to talk with one another to determine when a vehicle is able to go or when it must stop for traffic.

Figure 4: V2I technology on an Urban Road

(https://www.its.dot.gov/v2i/)

5.4 Fiber Optic Lines and Sensors

Another alternative option to consider is running fiber optics on SR-795. With this method, roughly 432 strands of high-speed data fiber optic line would be installed along the roadway. Along with the fiber optic line, embedded wireless sensors would also be installed along the east and west bound sides of SR-795. An example of this has been done on the road between, East Liberty, OH and Dublin, OH shown in Figure 5 on the next page. This alternative option will prepare better for the future when autonomous and connected vehicles become more relevant. The autonomous vehicles will be able to read the sensors along the road and the fiber optics line will allow communication to take place between the vehicle and any objects the fiber optic line is fed to. It will also allow for more frequent and accurate traffic counts which is some of the information our client is asking to receive. Not only this, but this solution will provide weather and surface condition monitoring along with incident management improvements.

Figure 5: The 33 Smart Mobility Corridor

5.5 Addition of Lanes

The last option to withstand the increase in traffic is to expand the state route and add more lanes to both the east and west bound routes. This option would effectively handle a larger volume of vehicles and the traffic will have more lanes to be able to spread out. Since there are warehouses and schools on this corridor, different types of vehicles such as passenger cars, pickup trucks, semi-trucks, and busses are all occurring more and in much higher volumes. This option would account for the diversity in traffic and the additional volume that comes with it.

When looking at adding additional traffic lanes, turning lanes will also help take care of the larger traffic volume. With the increase in freight vehicle traffic, it is possible that more road accidents will occur and the safety with pedestrians could be at stake. Turn lanes will help mandate traffic and keep pedestrians safe. When adding turn lanes, it will require the area near the intersection to be expanded. One of the intersections to consider is that of Oregon Rd and

Avenue rd. seen in Figure 6 below. In order to design reasonable lane widths and lengths, traffic flow studies would need to be analyzed from the previous 20 years as well as forecasting what the traffic flow may be like in the next 20 years. Adding lanes and expanding intersections to account for more turn lanes will help handle the increase in traffic volumes.

Figure 6: Overview of the intersection of Oregon Rd and Avenue Rd on SR-795

6 Evaluation of Alternatives

6.1 Smartboards and Digital Signposts with Artificial Intelligence (AI) Cameras

To handle the congestion on a road, we cannot just build our way out of congestion, rather we should design for a system which is efficient, effective, and reliable. One of such systems would be implementing the digital signposts and smartboards with AI cameras on SR-795. The greatest benefit of smart boards and digital signposts with AI cameras is the on-demand customizability they have. The messages can wirelessly be custom made by the governing bodies for the current conditions of the road and allow for the most beneficial information for drivers to take priority without delays. These signs are also lit-up with an LED display, allowing for easy visibility for drivers viewing them.

Traffic crashes arising from misinterpreting signs or signs not being visible as a result of poor weather conditions can be avoided. Various digital signposts with AI cameras and smart boards can be present on the SR-795 to enhance direct connectivity to the oncoming vehicles. This can be seen in Figure 7 below. The signs can be customized to present the same information to widen the availability of the message, or work in tandem with each other to maximize traffic efficiency. This is very similar to the location information which is already present in the majority of cars today such as GPS. This alternative is future proof for smart cities of the future as it considers the wireless transmissions that will occur between the road and the car.

Figure 7: Digital signposts transmitting information to driver.

(https://ietresearch.onlinelibrary.wiley.com)

Some challenges will arise in implementing the traffic signposts with AI cameras and smartboards. One of such challenges will be powering the technology. The wireless technology will need to be powered 24 hours a day, seven days a week for 365 days a year. The technology can be powered by solar generated power and batteries charged by wind turbines. It can still be connected to the main power grid as a contingency plan. This is a method currently used to power traffic lights so extending it to signposts and smart boards would not be too difficult, as most current power grids of cities are more than capable of handling the power they will require. Another challenge will be the security of the technology. As a result of this system being wireless, it will be susceptible to hacking. Therefore, the signals disseminated from the signposts and smart boards need to be authenticated and verified before transmitting to the oncoming vehicle on the road. Currently, there are no laws governing digital signals, but this will likely occur in the near future to ensure safety of motorists. A last challenge will be regulation of hardware and frequency. Future cars will need to have pre-approved electronic units which will reflect digital signals from signposts and smartboards onto their navigation alert system. Also, there needs to be recommendations from the Federal Communications Commission (FCC) on what frequencies the signals from this technology should be and who can transmit on these frequencies.

6.2 Vehicle to Infrastructure (V2I) Technology

Vehicle-to-Infrastructure (V2I) technology is being developed as the next generation of intelligent transportation systems. At this stage of the program, V2I technology is still in the trial and evaluation phase. About 20 percent of intersections are expected to be installed in the next five years, according to the U.S. Department of Transportation (U.S. DOT). As a future national transportation strategy, the DOT is working with the automotive manufacturers, academic institutions, technology companies, and state and local agencies to develop vehicle-to-infrastructure technology that enables vehicles to communicate with road infrastructure, such as traffic signals, via wireless data exchange. These include warning drivers of upcoming road conditions, such as construction zones, or that they are approaching a curve at an unsafe speed;

Adjust traffic lights to give priority to emergency vehicles or solve traffic congestion problems; Inform drivers of upcoming traffic and alternative routes; and offer driving advice to reduce stop-and-go driving.

In terms of traffic safety and automobile crash rates, V2I technology may significantly reduce the number of accidents. The Roadside V2I Unit provides real-time speed advice for drivers, as well as a variety of potential hazards around the road, in order to guide the driver to make the correct driving judgment. For example, if a car runs a red light or fails to brake at a yellow light, the V2I sensor will detect the unsafe factors and transmit real-time warnings and countermeasures to the driver. Simultaneously, other vehicles will also receive warnings to slow down and alert them to possible dangers. An example of this can be seen in Figure 8 below.

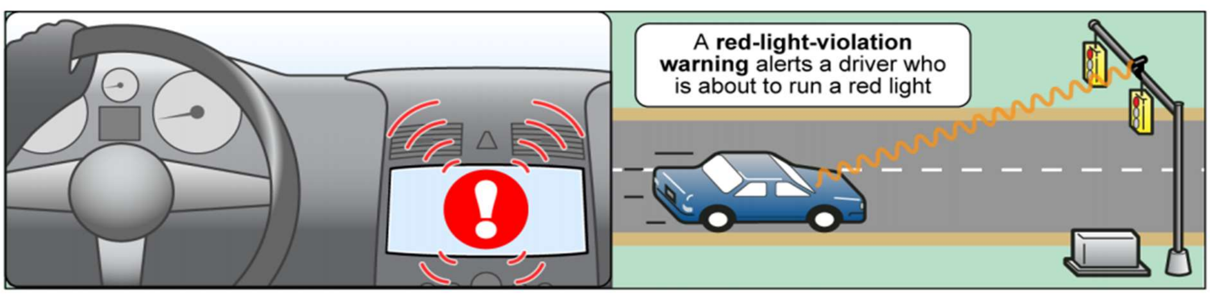

Figure 8: V2I Detecting Red-Light Violation

The V2I technology presents potential challenges in development and management evaluation. A common standard and interoperable technology need to be agreed upon among the various automakers. Automakers need to evaluate the suitability and value of the technology in the vehicle. V2I is undoubtedly a trend that will be necessary for the future, but it will be a worry for automakers, at least in the next few years. At the same time, V2I technology also put forward higher requirements for managers. Who will run and maintain it? This will either be the local traffic management department of a small city if it has sufficient capacity to carry out systematic management in a problem that needs to be considered. The cost of running and maintaining this can be significant.

Cost in development and management is certainly not to be ignored. As of now, the costs are unknown, but they will undoubtedly be huge. The U.S. Department of Transportation has invested more than 100 million dollars in research and development over the past five years. In the following pilot operation, the financial support for various coordination is also tremendous. Of course, this is not a consideration for our clients. Only in terms of installation, maintenance, management, our customers may not be able to operate. It is going to be deployed by the Ohio Department of Transportation.

6.3 Fiber Optic Lines and Sensors

Time and money will be big factors that need to be accounted for with this option. Running the fiber optic line and installing the sensors on a 10-mile stretch of road will not be a cheap option. To compare, a similar project has taken place on U.S. Route 33 in Columbus, Ohio. The fiber optic on this road will span a total of 35 miles and the budget built in for this installment is $15 million. It will also take a lot of time to install the fiber optic line along this 10 miles of roadway. The client may not be willing to take this time and want results quicker. This option is also assuming that autonomous vehicles will communicate with objects that have sensors on them and have fiber optic lines run to said objects. It is entirely possible that autonomous vehicles may communicate with each other and its surroundings by satellite. This would completely outdate this option and have innovation go in a completely different route. All of these points must be considered with this alternative option.

6.4 Addition of Lanes

When looking to add additional lanes and widen intersections, three important factors must be considered. The first thing to consider is funds. Both the east and west bound routes between I-75 and I-280 span roughly 10 miles. Not only this, but all of the intersections on this route must be considered when thinking about adding more turning lanes. The result of adding multiple lanes to both the east and west bound routes, as well as adding more turn lanes, would surely be a large amount of money that would need to be funded in order to complete the project.

Another important factor to consider is time. It would take a lot of time to add multiple lanes to both the east and west bound lanes for a 10-mile stretch and expand intersections. The actions that would need to be taken to complete this consist of developing, calculating, designing, permitting, and constructing. From start to finish, this project could take up to 15 years to complete and the increased volume of traffic is occurring now. Not only this but, the increase in traffic is only continuing to grow as more warehouses continue to be constructed on SR-795.

The third thing that will need to be considered is preparing for the future. Each day that goes by is another day closer to having autonomous vehicles on the road. Our client has asked us to consider the near future of autonomous vehicles becoming relevant as the basic means for travel. Therefore, the client would like to make SR-795 a “Smart Corridor” so that it is ready for autonomous vehicles. Adding more lanes to both the east and west bound lanes does not necessarily help prepare for autonomous vehicles of the future.

7 Proposed Solution

7.1 Introduction

After carefully looking over and evaluating all of our potential solutions, we recommend that the Wood County Port Authority implement the smart boards with AI cameras solution to make SR-795 a smart corridor. Installing smart boards along the SR-795 will aid in our problem of congestion on the road. In the following sections, our group will be discussing our proposed solution.

7.2 Smart Board

Our main solution to the problem along State Route 795 is the addition of smart boards at several locations along the corridor. Based on the load able to be supported by the tubular overhead sign foundation the smart boards that have been chosen to have a length of 23 feet and a width of 9 feet. These smart boards are going to be able to display messages to drivers in real time, so that drivers will be able to react to crashes ahead and re-route if necessary or be able to account for estimated travel time between connected cities.

7.3 Smartboard Overhead Sign Foundation

The next component of our proposed solution is the structure for our smartboards. The structure that is being proposed is a tubular overhead sign foundation. The tubular foundation has a frame span of 48 feet which will be able to span 2 lanes of road. The height of the smartboard was determined by the ODOT requirements of 18 feet 6 inches underneath overhead signs. Based on this, the overhead sign has a height of 23 feet. The foundation is able to account for 3,000 pounds.

7.4 Artificial Intelligence Cameras

The smart boards are to be used in conjunction with artificial intelligence (AI) cameras. The AI cameras are placed along the corridor by the smartboards in order for the smartboards and AI cameras to work in conjunction with each other. These locations have considered the speed of cars on the road, the distance between the drivers and the smartboards, as well as the cameras and how big the words on the sign would be for the drivers to see the information disseminated. The AI cameras will run 24/7 and will help in identifying the number of cars on the road, the speed those cars are driving, and where each car is in relation to one another.

8 Design

We used AutoCAD for our designs. We designed smartboards for dynamic messaging and have a tubular foundation. Our design included a smartboard location sheet, a tubular foundation sheet for the smartboards, and a general notes sheet for our design. For our design of the smartboards, we have to consider our stopping-sight-distance (SSD). This is the minimum distance available for a driver to stop when traveling at a design speed to prevent collision and/or obstruction. The stopping-sight-distance we calculated produced a value of 476 ft. This means that the smart boards need to be placed a minimum of 476 feet away from the eight major intersections on SR-795. These eight major intersections are the main points of concern for traffic crashes and traffic build-ups.

Our next variable to consider is reaction time. This is the time it takes for a driver of a vehicle to respond to an information from a sign while on the road. Our reaction time was calculated to be 14 seconds. This reaction time was used to calculate the area of the sign which was 1130 square feet. A note of this should be taken since every space of the smartboard was used. ODOT recommends a maximum of 3 lines of text containing 17 letters each. The reaction time was also used to calculate the reaction distance. This is the distance that the driver will use to react to the information provided by the smartboard. Depending on the size, speed, and type of road, letter heights and width is important so the driver can adequately react to the displayed message and act appropriately and safely. These letter dimensions were calculated using the reaction distance, and we calculated this to be about 38 inches in height and 25 inches in width. Using the Ohio Department of Transportation (ODOT) standards of 3 lines containing 17 characters, it was calculated that our total message area would be 316.71 square feet.

While the above design calculations are appropriate and meet the necessary criteria to be good examples of dimensions that would be adequate for the job, existing ODOT standards can be used, and should be used, in the design of the smart boards, or Dynamic Message Signs (DMS). Using ODOT's Supplemental Specification 909 Intelligent Transportation Systems (ITS) Devices and Components, section 909.05.1 and 909.05.2a, dimensions of the lettering, the message enclosure, and the mount can be found. According to the specification, the text should be 18 inches in height. The message board should also not exceed 8.5 feet high by 26 feet 1 inch wide, and not exceed 3 feet 11 inches in depth at its widest point. The maximum weight of the smart board is given, which should not exceed 4300 pounds.

As it can be seen, the calculated values using the USSC standards gave excessive values when compared to the ODOT standardized specification values. It is recommended that if smart boards are implemented on SR-795, the ODOT specification's standardized values be used when considering the dimensions of the smart boards.

9 Multimedia Video

YouTube Video Link: https://youtu.be/j-Ow9S-OgDc

OneDrive .mp4 Link: https://1drv.ms/u/s!Aj_y0W51dFt7ajU0KLc57Mskm1E?e=ikzzjP

10 Cost Estimate Analysis

10.1 Introduction

A cost estimate analysis is conducted to examine the costs of the digital smart boards and artificial intelligence cameras. This analysis evaluated the construction costs, operation costs, maintenance costs and utility costs. The cost data used in this analysis was obtained from the Ohio Department of Transportation bid histories from 2016-2020 as this was the most recent to get accurate price data. The total cost that was calculated for this project was $1,494,214.16.

10.2 Construction Costs

The construction costs included various activities that would occur while the construction process is being executed. The primary items involved in this alternative are dynamic message boards and artificial intelligence cameras. A single camera would cost $13,900. For this project, a total of sixteen cameras would be needed. That would lead to a total of $222,400 to be spent on the cameras. The dynamic message boards would cost $24,125 apiece. There will be sixteen smart boards installed on SR-795. This leads us to a total of $386,000 for the smart boards to be installed on this project. For the installation of these two primary items, other items to consider for this project are, the signal controller interface which cost $800 for a single interface; and for sixteen interfaces will cost $12,800. The high speed ethernet radio repeater would also be needed, and it costs $2,529.38 for a single repeater; and for sixteen repeaters will cost $40,470.08 and a housing assembly with controller which cost $983.84 for a single and will cost $15,741.44 for sixteen housing assemblies.

To mount the smart board on the road, we will need a sign attachment assembly and a sign hanger assembly. For a sign attachment assembly, it costs $4.54 for a single and for sixteen dynamic boards we would need 64 sign attachment assemblies which equals to a total of $290.56. For a sign hanger assembly, it costs $75 for a single and it would cost $1200 for sixteen of these assemblies. The back-up power of these smart boards will be generated from a generator power panel and a ground mounted power service. A generator power panel cost $410 which totals to $6,560 for sixteen power panels. A ground mounted power service will cost $2,091.25 for one and will cost $33,460 for sixteen. These units and total calculations are shown in Table 1.1 on the next page.

	Construction Costs	Units	Quantity	$/unit	Total
	Rigid overhead sign support foundation	each	16	$ 2,277.50	$ 36,440.00
	Signal contoller interface	each	16	$ 800.00	$ 12,800.00
	Sign attachment assembly	each	64	$ 4.54	$ 290.56
	Sign hangar assembly, mast arm	each	16	$ 75.00	$ 1,200.00
	Housing assembly with controller	each	16	$ 983.84	$ 15,741.44
	Ground mounted power service	each	16	$ 2,091.25	$ 33,460.00
	Generator power panel	each	16	$ 410.00	$ 6,560.00
	High speed ethernet radio repeater	each	16	$ 2,529.38	$ 40,470.08
	Dynamic message sign- full color walk-in	each	16	$ 24,125.00	$ 386,000.00
	Artificial Intelligence cameras	each	16	$ 13,900.00	$ 222,400.00
	Inspectors	hours	240	$ 40.00	$ 9,600.00
	Professional engineer	hours	240	$ 60.00	$ 14,400.00
					$ 779,362.08
	Administrative Costs				
	Operation costs				$ 18,750.00
	Utility costs	month	12	$ 105.34	$ 1,264.08
	Planning estimates				$ 100,000.00
	Legal estimates				$ 100,000.00
	Contigency costs				$ 100,000.00
	Cost of inspection				$ 100,000.00
	Design costs				$ 120,000.00
					$ 540,014.08
	An average inflation of 2.72% and cumulative inflation of 17.48%				$ 174,838.00
				Total Cost	**$ 1,494,214.16**

Table 1.1: Cost Estimate Analysis of Smart Boards and Artificial Intelligence Cameras

10.3 Administrative Costs

After construction of the dynamic message boards and artificial cameras have been executed, the operation costs of these components have been considered. It has been calculated from ODOT bid histories to cost $18,750 for the operation costs. The planning estimates and legal estimates are about $100,000 each. The utility costs have also been considered and this is mainly electric power to the smart boards and the artificial cameras. A cost of $105.34 per month would be adequate to power the combination of the two and for twelve months, it is calculated to cost $1,264.08. The contingency costs and cost of inspection is about $100,000 each. The design costs are about 8% of the project which is about $120,000. Inflation was also calculated for the project. The average inflation of 2.72% and cumulative inflation of 17.48% was used to calculate $174,838. These units and total calculations are shown in Table 1.1 on the previous page.

11 Environmental Analysis

11.1 Introduction

With the increasing number of private cars, school buses, especially trucks based on logistics transportation. The traffic pressure of SR-795 exceeds its design capacity. In the analysis of the environmental impact of the SR-795 smart upgrade, we could focus on air quality, noise pollution, and other aspects along the road.

Smart upgrade design to relieve the SR-795's traffic pressure can minimize construction costs and environmental impact as much as possible than road widening. We have decided to use the smart board as our essential design solution in this smart design project. In the assessment of the environmental impact of the smart board, the smart board itself is an environmentally friendly decision in terms of installation and construction, as well as the impact on road traffic after installation. Smart boards in the installation and construction process do not need a lot of mechanical operations and do not need to occupy additional land resources.

11.2 Air Quality

Air quality along the roadside is mainly determined by traffic congestion and the number of large transport trucks. Since the number of large transport trucks is not something we can decide, our design purpose is to release traffic pressure to satisfy more transport trucks. The mobility of road traffic mainly determines road air quality. Traffic congestion is the leading cause of poor air quality around roads because vehicles may drive only at low speeds. Also, frequent stop-and-go traffic increases the energy consumption of vehicles and increases exhaust emissions. After installing the smart board, the driver can make effective judgments based on the smart board's real-time information prompts. Simultaneously, combined with the artificial intelligence camera, the smart information board can prompt the driver to a reasonable driving speed to avoid the stop-and-go driving mode.

11.3 Noise Pollution

Noise pollution often occurs in the road construction process and the high-speed traffic. The noise generated by the smart board's installation process can be ignored because mechanical operations such as installation and hoisting can be completed in a short time. The smart board generates no noise during use. Assuming that the application of smart boards improves the mobility and carrying more capacity of the SR-795, it is possible that high speed, high flow road conditions will cause noise pollution to surround facilities. This pollution mainly affects schools and the residential zone along the road. The specific extent of the impact depends on public reactions and field experimental results. If the noise pollution is caused by the extent of the impact, the sound barriers should be considered in the necessary traffic sections.

11.4 Natural Environment

Considering that there is no wild park, forest, and other natural environment along the road of SR-795, it is not necessary to consider protecting terrestrial wild animals along the SR-795. But it is worth noting that two creeks (Cedar Creek and Dry Creek) cross SR-795. Both streams are mussel habitats and under protected in the State of Ohio (Section 1533.324 of the

Ohio Revised Code). According to the Ohio Mussel Survey Protocol in April 2020, Cedar Creek and Dry Creek are classified as Group 1: Small to mid-sized streams, FLS not expected. During the smart upgrade process, there is no effect on the stream ecosystem because the streams are located underneath bridges that are not located within our construction limits.

12 Social/Economic Analysis

12.1 Introduction

Based on our corridor and the solution that our team is proposing, we wanted to highlight some of the social and economic impacts. Our team is focusing on the economic growth of the corridor, emergency response times, and the business/school traffic. In the following sections our team will expand on these impacts and how they affect drivers, residential areas, businesses, and schools.

12.2 Economic Growth

After the installation of our proposed solution, the supply chain is expected to become more efficient because the corridor will have less congestion. With the supply chain running more efficiently, the businesses along the corridor will be making a larger profit.

12.3 Emergency Vehicles

A benefit to the timeline of our project not being significantly long is that emergency vehicles will not have to re-route for long. Emergency vehicles are an important part to road construction. During construction they have to account for detours and traffic slowdowns in construction zones. After construction has concluded, response time along the corridor should decrease, allowing emergency vehicles to decrease their overall response time.

12.4 School and Business Traffic

Just like emergency vehicles, it is expected that school and business traffic will need to be rerouted during the construction phase of the project. Luckily, the construction phase of smart boards and AI cameras should not take long, so the school and business traffic will not need to be rerouted for long. The traffic flow on SR-795 should see an increase after project completion since there should be less traffic flow on the surrounding local roads. Unfortunately, there is the potential that businesses located near the smart board placement locations may experience temporary loss in sales. These businesses may see a decline since the areas around the smart boards will be temporarily closed off. Again, the construction phase should not last long, so the businesses should only see a minor decrease in sales for a short period of time. Once the smart boards and AI cameras are installed, it is expected that the school and business traffic will be able to go back to normal and the traveling time should be quicker since the smart boards and AI cameras will help reduce traffic congestion.

13 Rating Systems and Awards

To further emphasize the advantages of smart board implementation on roads while also possibly gaining widespread recognition for Wood County's engineering efforts, applying for various awards and ratings could be very beneficial. While researching possible opportunities for the smart board implementation on SR-795 to be eligible for ratings and rewards, a particular system was found that could apply to this kind of project. The *2021 National Roadway Safety Awards* sponsored by the Federal Highway Administration (FHWA) and the Roadway Safety Foundation (RSF) is a biennial awards program that recognizes roadway safety achievements that move towards making the roads of the nation safer for drivers and pedestrians.

There are two categories of awards that can be given, *Infrastructure and Operational Improvements* and also *Program Planning, Development, and Evaluation*, with the category *Infrastructure and Operational Improvements* applying to the SR-795 smart board implementation. The award criteria for which the submission will be graded upon are based on three criteria: *Effectiveness*, *Innovation*, and *Efficient Use of Resources*. First, smart boards will have to be implemented and observed over a stretch of time to see its effectiveness in reducing crashes, which is one of its main focuses. Their messages can also be used to distribute safety promoting information that will help educate the public and possibly yield a positive change in transportation safety culture.

Next, smart boards should be considered innovative based on their creative approach to improving roadway safety, while also being a new technology that has not been widely used to improve road safety. To further improve standings in this category, the actual implementation of the smart boards should strive to be innovative as well. It would also be beneficial to gain the support of the public and/or stakeholders, to be more monetarily efficient and gain a larger audience's approval.

Lastly, to make the smart board project efficient, several factors should be considered. The land-use footprint used for placement of the boards should be kept to a minimum, to lessen the impact on the existing environment and reduce the amount of used land. The cost of implementing the boards themselves on SR-795 should also be minimized to emphasize the monetary efficiency of them, which would promote interest potential in future roadway safety improvement projects. Lastly, the required electricity to run the smart board infrastructure should be kept to a minimum, to keep them as energy efficient as possible and reduce the amount of energy consumption.

If these three criteria were emphasized when implementing the smart board technology on SR-795, and also proves to be effective at improving roadway safety, it is possible that the award could be given to the SR-795 Smart Corridor project. Included in the reward is national recognition through national and local media support, appearances on several websites operated by the FHWA and RSF, and appearances on various publications of national safety and transportation organizations. Lastly, Wood County would be invited to an award ceremony in Washington, DC to receive an engraved plaque and be exposed to possible opportunities to network with key transportation officials.

To sum things up, if Wood County were to apply for the *2021 National Roadway Safety Awards* and win the award, it could lead to more widespread adoption and recognition for smart board technology, which could then lead to smart board technology improvements and improved overall safety of the nation’s roads. It would also give Wood County more recognition as a county that prioritizes safety of its citizens and strives to improve safety on its roads. Overall, it is an excellent opportunity that should be looked into by the county to maximize the benefits of the smart board implementation smart corridor project.

14 Conclusion

Many options were considered when looking to improve the increasing traffic volume concerns on State Route 795 between I-75 and I-280. This major arterial roadway was not originally designed to handle the traffic diversity and traffic volume that it experiences today with the two school buildings, Amazon warehouse building, and First Solar Energy building. The school bus and semi-truck traffic has increased and only continues to grow as more warehouse buildings continue to be constructed on this State Route.

The solution we believe that will ultimately help improve the safety of the corridor and help limit traffic slowdowns is to implement sixteen total smart boards expanding across the roadway (eight over the eastbound lanes and eight over the westbound lanes). Along with installing the smartboards, sixteen AI cameras should also be installed to help aid in determining where traffic congestion points are, and what can be done by drivers to help reduce traffic slowdowns. This solution will make the corridor “smart”, and it is a cost effective solution compared to the other alternative solutions we have considered.

When considering the actual design of the proposed smartboards, it would be best to place each of the smartboards 476 feet away from the eight major intersections. We determined that the smart boards should be placed 476 feet away from each of the eight major intersections since this is where we determined the main points of concerns are for traffic crashes and traffic build-ups. We also were able to determine that the reaction time drivers need to have to process what is on the smartboard is 14 seconds. From this calculated reaction time, we determined the area of the sign needs to be 1130 square feet. Additionally, we were able to determine that the letter height needs to be 38 inches and the letter width needs to be 25 inches on the smartboard. It was determined that we would use the Ohio Department of Transportation standard for smartboards which is 3 lines with 17 characters. From the information determined about the needed letter height, width, lines, and characters, the smart boards will need to have a total message area of 34 feet by 24 feet.

Once our design and calculations were completed, we looked at the cost analysis of our proposed solution. When looking to determine a total cost value, it was essential that we looked at construction costs, operation costs, maintenance costs, and utility costs. From each of these sectors, we could determine a total cost to install and run each of our proposed smart boards as well as AI cameras. We were able to determine that the construction cost would total to roughly $780,000. We also were able to determine that the operation cost would be roughly $19,000 per year. And the utility costs would total to be $1,500 per year. This meant that to install all sixteen smart boards and all sixteen AI cameras along with the first year operation and utility costs, the total cost would come out to be roughly $1,500,000.

We evaluated the environmental analysis of our proposed solution. We were able to determine that air quality and noise pollution along the corridor would be minimal compared to the other alternative options we considered. Smartboards require relatively small amounts of construction when compared to adding additional lanes or introducing fiber optic lines. Since smart boards require little construction, the smartboard solution helps limit noise pollution put out by heavy machinery as well as limit air pollution put out by the same heavy machinery. High concentrations of air pollution will only be a concern where vehicles are stagnant, but the information displayed by the smartboards should help drivers limit congestion and keep traffic flowing. The one other environmental aspect that needs to be considered is that the corridor comes into contact with two streams. Mussel habitats are held within these streams and they are protected by the State of Ohio. The construction of smart boards will not affect these mussel habitats.

We also made it a point to evaluate the social and economic analysis of our proposed solution. When looking at the overall supply chain, it is expected that the smart boards and AI cameras will help the economy experience growth. Economic growth is expected since the supply chain will be running more efficiently with less traffic congestion. This will ultimately lead to larger profit margins for companies along SR-795. When looking at emergency vehicles on SR-795, it is expected that emergency vehicle response time will increase during the construction phase of the smartboards and AI cameras. Luckily, this is a short construction process, so once the construction phase is done it is expected that response times of emergency vehicles will decrease. Just like emergency vehicles, school and business traffic will need to be rerouted for a short time. Once the construction of the smartboards and AI cameras is completed, school and business traffic will be able to go back to its normal routes. It is expected that traffic congestion will reduce and travel time on SR-795 should become more efficient.

After the smartboard implementation is officially completed, it is possible that Wood County could apply for the *2021 National Roadway Safety Awards*. If Wood County were to win the award, then smart board technology may receive more recognition for its ability to help reduce congestion and protect society. Not only this, but Wood County would be recognized for their achievement to help keep the general population safe with its dedication to making their roads smarter with smart boards. All in all, this would be a major achievement for Ohio and an even bigger achievement for Wood County specifically.

15 Next Steps

There are several options that the Wood County Port Authority may consider when looking to the next steps of SR-795 after the smart boards are implemented. Wood County will want to continue keeping SR-795 a smart corridor and will need to keep up with ever improving ideas on how to make roads smarter and safer for everyone. This is why our team believes that rather than implementing smart boards and considering the project done, the Wood County Port Authority should consider introducing phases to the SR-795 project. Multiple phases could be used to keep improving the corridor and prepare for the changes in types of vehicles in the near future. It is believed that the future will have a main focus on vehicles being electric, connected, and autonomous.

Since there will be a focus on electric vehicles in the near future, the Wood County Port Authority should consider adapting an electrified charging lane in roughly four to six years. Electrified charging lanes are still currently in the research and development phase, but the idea is gaining popularity as car manufacturers plan to produce just electric vehicles in roughly ten years. Prototypes of electrified charging lanes are being used, but they still need work to make them more efficient and easier for everyone to use. Currently, prototype electric charging lanes use embedded rails in the center of public roads where a moveable arm attached to a vehicle transfers energy from the two tracks in the road to the vehicle. If a vehicle were to stop while driving on this lane, the current between the road and the vehicle is disconnected which helps limit each vehicle's energy consumption. All of the electricity that is produced by these rails is roughly six centimeters below the surface of the road, so the electricity will not cause danger to the drivers on the road. Other possible charging ideas are being researched as well. An idea that may develop is having structures with magnets fastened to them create electrical currents as vehicles with magnets under their hoods pass under the structures. If this idea were to develop, it would complement our smart board solution nicely as the magnets could be fastened to the existing structures that support the smart boards.

Our team also believes that previously mentioned vehicle-to-infrastructure (V2I) technology could become more relevant in eight to ten years. The idea of adding smart infrastructure could be used on SR-795 as another phase following the successful completion of electrified charging lanes. Once the attention draws away from electric vehicles, it is believed that connected vehicles will become the main focus for vehicle manufacturers. Although it may be too early and too expensive to implement V2I technology on SR-795 now, it could become a strong solution in the future to keep making the corridor smarter. This will allow drivers to let their vehicles make more decisions for them while driving and help reduce accidents. The connected vehicles will be able to interact with the infrastructure and other vehicles around it to make smarter decisions that will ultimately become safer for the public. This solution is still strongly being researched and developed and may not become a popular idea to construct for many years to come. There will come a time, however, where the focus will shift to making vehicles connected and autonomous. This is when V2I technology will gain popularity and be a viable constructing phase to SR-795.

16 Appendix

16.1 Appendix A: Contacts

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16.2 Appendix B: Statement of Qualifications

Jessica Wilson

Civil Engineering Student

EDUCATION

- Bachelor of Science in Civil Engineering, University of Toledo, August 2021

PROFESSIONAL AFFILIATION & REGISTRATION

- Student Member, American Society of Civil Engineers

PROFESSIONAL BACKGROUND

Ms. Wilson co-oped with the Ohio Department of Transportation: District 2 and DGL Consulting Engineers. Her background is primarily focused on Roadway Design and Traffic/Planning Projects in Ohio. Ms. Wilson is experienced with the following design software; MicroStation, GEOPAK, and AutoCAD. While at ODOT, she completed over 50 crash diagrams as part of safety studies. She also performed multiple traffic counts and traffic control signal studies. During her time working in roadway design, she was a part of several ODOT projects. Ms. Wilson worked on all aspects of design projects including stage 1, stage 2, stage 3, and final design primarily for road resurfacing and bridge replacements. During her time as a traffic Co-Op at DGL Consulting Engineers, Ms. Wilson assisted with the State Signal Timing for FY20 using Visio to create system layouts and existing phase diagrams. She also has experience using Synchro 9 creating traffic simulation models for various projects. In addition, Ms. Wilson prepared traffic control sheets and traffic control cost estimates for several projects.

RELEVANT PROJECT EXPERIENCE

Traffic/Planning Projects:

- Wood County US-6 Safety Corridor
- City of Maumee Safety Study
- SR-53 Safety Study
- Ohio State Signal Timing

Mitchell Huffman

Civil Engineering Student

EDUCATION

- Associates of Science in Pre-Engineering, Monroe County Community College, December 2018
- Bachelor of Science in Civil Engineering, University of Toledo, May 2021

PROFESSIONAL AFFILIATION & REGISTRATION

- Former Social Media Chair Member (2019), American Society of Civil Engineers
- Student Member, American Society of Civil Engineers

PROFESSIONAL BACKGROUND

Mitch Huffman has co-op experience at Mannik & Smith Group and Rudolph Libbe Group. Two co-op rotations were spent at Mannik & Smith Group and one co-op rotation at Rudolph Libbe Group. During his first rotation at Mannik & Smith Group, Mr. Huffman worked on an MDOT local agency project. This project was applying healer sealer on 12 different bridge decks throughout Monroe County. Some of his responsibilities included keeping track of materials used, taking progress photos, and writing daily reports on the work completed. During the second rotation at Mannik & Smith Group, Mitch worked on another MDOT project in which an Oakland County bicycle bridge was replaced over Paint Creek. This project also included keeping track of materials, taking progress photos, and writing daily reports. When working on all MDOT projects, Mitch would use Fieldbook to write the daily reports and to keep track of materials. During this same co-op rotation, Mitch also worked on a couple of Monroe County Drain Commission projects where existing subdivisions were expanding. He documented as-built invert elevations for water main, sanitary, and storm piping. During his co-op rotation at Rudolph Libbe Group, Mr. Huffman attended weekly meetings for an office renovation project at Master Fluids. During this co-op, he would take progress photos, complete safety audits, write contracts, subcontracts, change orders, and purchase orders. He also received a little experience in TakeOff for additional projects.

RELEVANT PROJECT EXPERIENCE

- MDOT local agency bridge deck enhancement in Monroe County
- MDOT bike trail bridge replacement in Oakland County over Paint Creek
- Various Monroe County Drain Commission projects
- Master Fluids office renovation

Nate Franz

Civil Engineering Student

EDUCATION

- Bachelor of Science in Civil Engineering, University of Toledo, May 2021

PROFESSIONAL AFFILIATION & REGISTRATION

- Student Member, American Society of Civil Engineers

PROFESSIONAL BACKGROUND

Nate Franz has gone on co-ops with the Ohio Department of Transportation District 4, The Port Authority of Allegheny County, and with Lucas County Engineer's Office. During his time at ODOT, he assisted in the calculations and supervision of a state park bridge construction, while spending most of his time in the field working alongside a project supervisor. While at the Port Authority of Allegheny County, various tasks were completed such as park-and-ride inspection, project cost estimations, and creating an HVAC inventory system for PA owned buildings. Lastly, during his yearlong stay with the LCEO, he completed several in the field survey projects for structures such as roads, buildings, bridges, ditches, and roundabouts, while also mastering survey equipment such as the Trimble SX10, TSC7 and the associated Trimble Access Software, and the R10 VRS GPS. He then worked alongside the chief surveyor of LCEO and inspected the in-field data on software such as Civil-3D and Trimble Business Center.

RELEVANT PROJECT EXPERIENCE

- Extensive work on features of road design during LCEO survey experience
- Practice in cost estimation for project completion during Port Authority experience
- On-site road construction experience during ODOT and Port Authority experience

Zhenguo Liu

Civil Engineering Student

EDUCATION

- Bachelor of Science in Civil Engineering, University of Toledo, May 2021

PROFESSIONAL BACKGROUND

Zhenguo Liu has one co-op experience with the China Railway Construction Company (CRCC), and two research experience in the field of transportation and geotechnical engineering. During his professional work at CRCC, he assisted in project construction surveying and performed the test on concrete and soil on the construction site. While in his research activity on the transportation aspect for the ODOT project, he studied and learned with Dr. Eddie Chou to use AI machine learning models to process highway traffic data. He is responsible for classifying vehicles on highways by using the Computer Vision Annotation Tool (CVAT), so can be analyzed by deep learning software. In his geotechnical engineering research project about solid-fluid interaction models, Liu researched the formation, internal principle, and prevention of sinkhole.

RELEVANT PROJECT EXPERIENCE

- Heavy duty railway construction technology, and in-site surveying experience
- CVAT for image annotation in the application of traffic engineering
- Research on Solid-Fluid interaction and sinkhole scenario

Arua Udensi

Civil Engineering Student

EDUCATION

- Associate of Science, Jackson College, May 2018
- Bachelor of Science in Civil Engineering, University of Toledo, May 2021

PROFESSIONAL AFFILIATION & REGISTRATION

- Student member, National Society of Black Engineers

PROFESSIONAL BACKGROUND

Arua Udensi has co-oped with Corna Kokosing, Kalkreuth Roofing and Sheet Metal and Tyme Consulting Engineering. During his time at Corna Kokosing, he assisted project engineers and project managers in operations. This involved creating submittal logs of projects, providing closeouts, and creating a cost book for budget of projects. At Kalkreuth Roofing and Sheet metal, he processed architectural metal orders. He also created a safety process for the fabrication shop and updated its inventory logs. At Tyme Consulting Engineering, he inspected and performed bridge scoping of several bridges in the Wayne county area. He was also involved in the concrete patching and asphalt pavement of M-150 in Rochester, MI. Arua Udensi is experienced with the following software programs: Bluebeam, AutoCAD, ProjectWise.

RELEVANT PROJECT EXPERIENCE

- I-696 & I-75 bridge scoping
- M-150 concrete patching and asphalt pavement
- I-275 fiber optics inspection

16.3 Appendix C: Design Calculations

A. Smart Board Location

To adequately design for the proper location and dimensions of the smart boards, the calculations for several different values need to be found. The calculations that would be required for the smart board alternative include the location limits of the sign and the various appropriate dimensions of the smart board.

To find an appropriate location of the sign, we should find the Safe Stopping Distance (SSD) so that the sign can adequately prepare the driver for a given message and avoid an incident.

<u>Formula</u>: $SSD = 1.47vt + \frac{v^2}{30(\frac{a}{g} \pm G)}$

- Speed (v): 55mph
- Average perception reaction time (t): 2.5 seconds
- Deceleration rate on pavement (a): 11.2 ft/sec^2
- Deceleration rate due to gravity (g): 32.2 ft/sec^2
- Grade of road (G): 0% (assuming flat surface, no grade)

Then: $SSD = 1.47(55)(2.5) + \frac{55^2}{30(\frac{11.2}{32.2} \pm 0)}$ = ***476 feet***

Since the intersections have the largest concentration of accidents and traffic build-up, then the signs should be placed at least 476 ft away from the intersection entrances so that drivers have the adequate distance to see, recognize, and adequately and safely prepare themselves for any possible incidences at the intersections.

B. Smart Board Size

Next, we need to find the proper dimensions of the smart boards themselves. The smart boards dimensions should directly correlate with the characteristics of the road. Using the *United States Sign Committee's* (USSC) *On-Premise Sign Standards*, we can find the required dimensions of the smart board to coincide with the SR-795 locations characteristics.

To find the total area of the sign in square feet, we use the following equation from USSC:

Formula: $A_{sign} = \frac{3n}{80}[\frac{(VRT)(MPH)}{LI}]^2$

- *n*: Number of letters
- *VRT*: Vehicle Reaction Time
- *MPH*: Speed of road in miles per hour
- *LI*: Legibility index

To find the necessary variables to calculate the total area of the smart board sign, we first can find the vehicle reaction time. Using Table 2 on the *USSC On-Premise Sign Standards*, we can find the appropriate values for SR-795. Since the SR-795 can be classified as an urban, commercial multi-laned road with a speed over 35 mph, we can use the Multi Lane variables given in Table 2 to calculate Viewer Reaction Time. The design should account for a maximum message allowed by ODOT's standards of a maximum amount of 3 rows, 17 letters each (51 total available letters), to allow for a possible full message to be communicated.

Formula: VRT(*seconds*): Detection + Message Scan + Reorientation Scan + Maneuver

VRT(*seconds*): 1 + 0.1(51) + 0.04(51) + 6 = ***14.14 seconds***

Using the found Viewer Reaction Time, we now need the Legibility Index, which can be found using Table 4 in the *USSC On-Premise Sign Standards*, which is **32** if we use white neon Helvetica lettering in all caps with a black background. So, 32 for *LI* can be substituted into the area of the sign equation.

With all the information we have, we can now find the total sign area using the following.

$$A_{sign} = \frac{3(51)}{80}\left[\frac{(14.14)(55)}{32}\right]^2 = \textbf{\textit{1130 square feet}}$$

(area of the sign if the maximum number of letters is used on the board is used, 51 spaces)

C. Smart Board Lettering Size

Now that we have found the total surface area of the smart board using the previous formulas, we can now find the required lettering size of the smart board sign. First, we need to find the Viewer Reaction Distance (VRD) using the speed of the road, which is 55 mph, and the calculated viewer reaction time which was found to be 14.14 seconds.

<u>Formula</u>: VRD = speed (*in feet per second*) * VRT

Speed (*in feet per second)* = 1.47 * Speed *(in miles per hour)*

Speed (in feet per second) = 1.47 * 55 = 80.85 fps

VRD = 80.85 * 14.14 = ***1143.22 feet***

Using the found Viewer Reaction Distance, the letter height can be calculated while also using the legibility index found on Table 4 in the *USSC On-Premise Sign Standards*. In this case, the white neon Helvetica on a black background with all caps will be used, which has a Legibility Index of ***32***:

Formula: Letter Height (*inches*) = $\frac{Viewer\ Reaction\ Distance}{Legibility\ \ Index}$

Letter Height (*inches*) = $\frac{1143.22}{32}$ = ***35.73 inches***

The width of the letters works on a 0.7:1 ratio with the height, so:

Formula: Letter Width (*inches*) = Letter height * 0.7

Letter Width (*inches*) = 35.73 in. * 0.7 = ***25.01 inches***

So, the dimensions of the letters are approximately **35.73 inches by 25.01 inches**. To find the area of each letter, the width and height can be multiplied together. We can also then convert the area to square feet:

Formula: Single Letter Area (*in square inches*) = letter height * letter width

Single Letter Area = 35.73 in. * 25.01 in. = ***893.61 square inches***

Single Letter Area (*in square feet*) = 893.61 sq.in./144 sq.in. per sq.ft.

= **6.21 square feet**

D. Copy Area and Negative Space

Now, going off ODOT's standards of a maximum of 3 lines, 17 characters each, a maximum usage total of 51 characters is found. We can now find the total copy (message) area by multiplying the 51 total letters by their respective found square footage, which was calculated to be 6.21 square feet:

Formula: Copy Area = 51 * 6.21 = ***316.71 square feet***

Now we need to find the negative space where there is not going to be any messaging such as between the message lines or around the messages themselves. Negative space accounts for 60 percent of the total sign and runs on a 60:40 ratio with the copy area. So, we can multiply the previously calculated total copy area by 1.5 to meet the 60:40 ratio rule:

Formula: Negative Space = 316.71 * 1.5 = ***475.07 square feet***

Now we can add the 316.71 square foot Copy Area with the 475.07 square foot Negative Space to find the total required area of the smart board sign (*if every space in the 3 row, 17 letters each, is used*).:

Formula: A_{sign}= 316.71 + 475.07 = ***791.78 square feet***

E. Sign Dimensions

To calculate the dimensions of the sign's length and height in feet, we can use the same 0.7:1 ratio that was used to find the dimensions of the letters. The following equation can be used to find the dimensions:

Formula: Area (*square feet*) = 0.7X * X

0.7X = the height of the smart board message area

X = the length of the smart board message area

Using the area of the sign calculated in part B, 1130 square feet, it can be used to find the length of sign value X, which can be converted to find the height of sign value 0.7X :

$$1130 \text{ square feet} = 0.7X^2 \rightarrow X = \textbf{\textit{40.18 feet}} \text{ (length)}$$

$$40.18*0.7 = 0.7X = \textbf{\textit{28.13 feet}} \text{ (height)}$$

So, if the 0.7:1 ratio of height to width is followed, the sign would have dimensions of **40 ft length by 28 feet width.**

The above calculations were all found using formulas found in the USSC Handbook. While these values could be used in the design of the smart board, using the Ohio Department of Transportation’s Supplemental Specification 909: Intelligent Transportation System (ITS) Devices and Components dimensional values should be used to meet ODOT standard.

16.4 Appendix D: Design Drawings

X/XX	WOO-795 SMART CORRIDOR	Smart Board Locations (2 of 2)	JEW

2/28	WOO-795-3.24 SMART CORRIDOR	TUBULAR SIGN FOUNDATION	JEW

The link posted is to the PDF versions for the State Route 795 Smart Corridor proposed design drawings: **https://1drv.ms/b/s!Aj_y0W51dFt7cv_prkwpPKQzDs4?e=DqJOa8**

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