TMS Engineers, Inc.

Updated Purpose & Needs Study

City Wide Adaptive Signals
Hudson, Ohio

May 21, 2019

Prepared for:

City of Hudson
115 Executive Parkway
#400
Hudson, Ohio 44236

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1. INTRODUCTION

1.1 Purpose of Report

This Purpose & Need Study is an update to the report dated May 14, 2018 that evaluated the conditions of the existing twenty-one (21) traffic signals throughout the City and determine the potential of “Smart City” or “adaptive signal” improvements to increase the operational efficiency of those signals.

1.1.1 Review city wide fiber network information to determine the availability of additional infrastructure to provide interconnection the City's signal system to a central network. Determine fiber count and splice locations available to traffic signal use.

1.1.2. Update the estimate of probable construction costs using the City's fiber network for interconnection.

1.1.3. Compute the estimate of construction costs based upon a phased approach for implementation (i.e.; phase 1 - downtown & phase 2 - remainder of City). Research the scope of the size of the phases and separate out the costs.

1.1.4. Provide a discussion of a possible alternative route implementation to reduce congestion in the downtown area. Provide possible benefits and costs of implementation.

1.1.5. Provide a discussion on the future of adaptive signals and their relationship with autonomous vehicles. Discuss possible benefits and time frame for implementation.

1.1.6. Provide a discussion on the future of application based ride-hailing service and their effect on travel demand.

1.2 Background

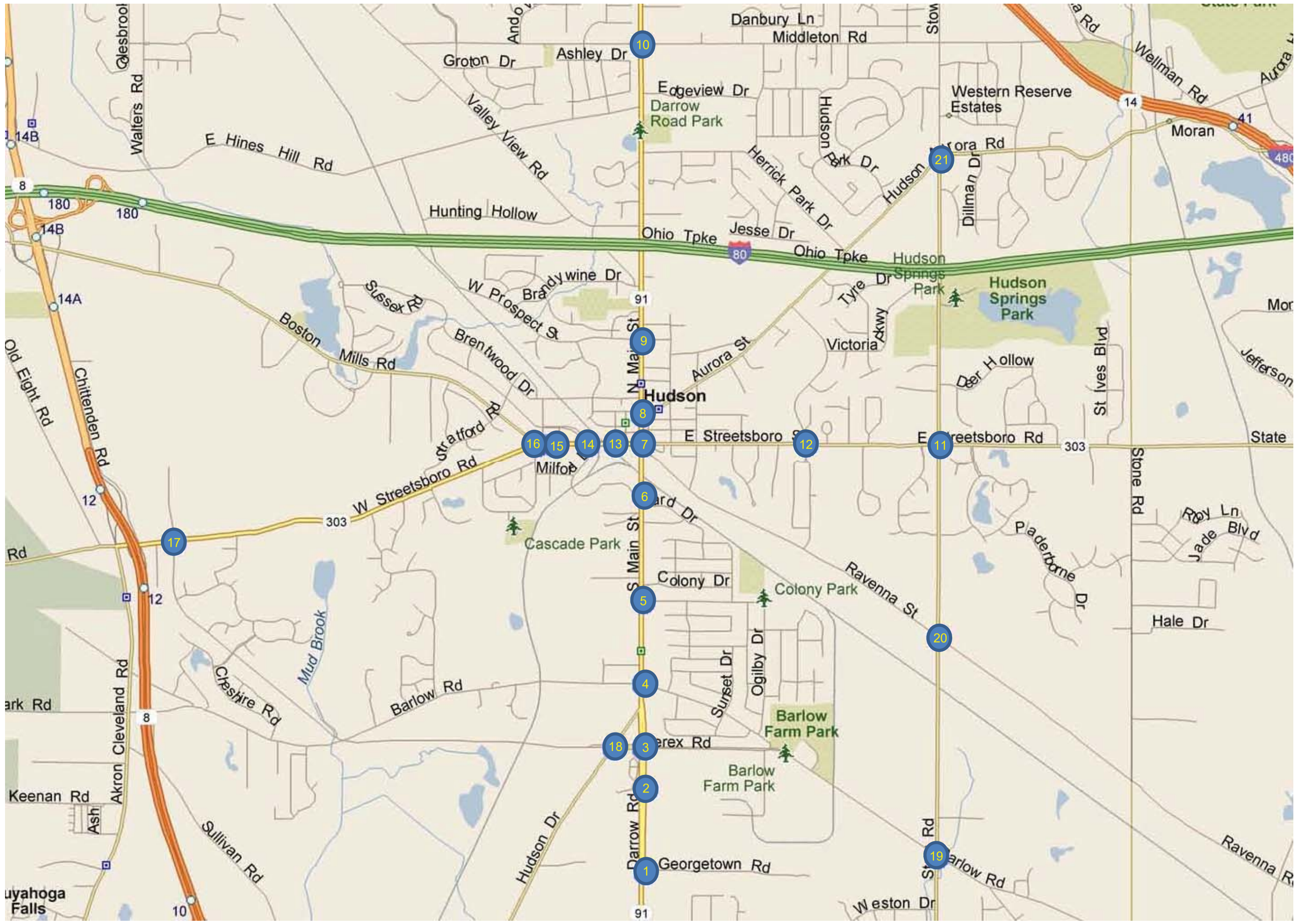
The City of Hudson is located in Summit County, Ohio and has a population of approximately 22,250 residents. The City has a total area of 25.9 square miles and is bordered by Twinsburg to the north, Streetsboro to the east, Stow to the south, and Boston Heights to the west. SR 303 is a major roadway within the City having an east-to-west orientation. Major roadways within the City having a north-to-south orientation include S. Main Street / Darrow Road (SR 91) and Stow Road.

1.3 Brief Overview of Existing Traffic Signals System

The City of Hudson has twenty-one (21) signalized intersections using traditional "closed loop" system control. These are grouped into four (4) subsystems or zones and an assortment of isolated intersections. Six (6) intersections are contained in Zone 1 which includes intersections on State Route 91 from Georgetown to Stoney Hill Drive and includes the intersection of Hudson Drive and Terex Road. Six (6) intersections are contained in Zone 2 which includes intersections surrounding downtown Hudson. Two (2) intersections comprise Zone 3 which are located at SR 303 / Plaza Drive and SR 303 / Boston Mills Road. The Zone 4 includes a single intersection within the City of Hudson (SR 303 / Terex Road) which is interconnected to two intersections within neighboring Boston Heights. The remaining six (6) signalized intersections are isolated and are operating without coordination with surrounding traffic signals. The signal systems are shown in **Figure 1, Page 3.**

NOT TO SCALE

1. SR 91 (Darrow Road) & Georgetown Road
2. SR 91 (Darrow Road) & Corporate Drive
3. SR 91 (Darrow Road) & Terex Road
4. SR 91 (Darrow Road) & Barlow Road
5. SR 91 (Darrow Road) & Stoney Hill Drive
6. SR 91 (S. Main Street) & Veterans Way
7. SR 91 (Main Street) & SR 303 (Streetsboro Street)
8. SR 91 (N. Main Street) & Aurora Street / Clinton Street
9. SR 91 (N. Main Street) & Prospect Street
10. SR 91 (Darrow Road) & Middleton Road
11. SR 303 (Streetsboro Street) & Stow Road
12. SR 303 (Streetsboro Street) & Hayden Parkway
13. SR 303 (Streetsboro Street) & Library Street
14. SR 303 (Streetsboro Street) & Atterbury Blvd / Veterans Way
15. SR 303 (Streetsboro Street) & Plaza / McDonald's
16. SR 303 (Streetsboro Street) & Boston Mills Road / Case Drive
17. SR 303 (Streetsboro Street) & Hudson Crossing / Terex Road
18. Terex Road & Hudson Drive
19. Stow Road & Barlow Road
20. Stow Road & Ravenna Street
21. Stow Road & Hudson Aurora Road



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Purpose & Need Study
Citywide Signal System
City of Hudson

Existing Signal Network

Figure 1

1.4 Previous Recommendations

The May 14, 2018 report identified needs that meet certain goals that include safety, efficiency, conservation as well as reducing liability, operation and maintenance costs. The following recommendations were made.

- Install an advanced adaptive central traffic control system in order to bring all existing signal controllers under a single operational system and prepare for future additions and expansions wherever they may be needed. This adaptive signal system will adhere to the "Smart City" principals in which technology and sensors will increase operational efficiency of a traffic signal and allow each signal to be constantly optimized to reduce delay and increase travel speeds throughout the entire City.

- In order for the adaptive signal system to operate, a total of approximately one hundred and ninety (190) detectors are needed to be installed at the coordinated signalized intersections. Each mainline travel lane will require a stop bar, a set back and a down stream detector.

- The traffic signal controllers at sixteen (16) intersections should be upgraded to NEMA TS-2 which are ATC compliant. All traffic signal controllers should be upgraded to include network addressable components to communicate with the system. All of the intersections which are currently using Econolite brand controllers, so it is recommended that a consistent controller type be used for all future improvements within the City.

- A system of CCTV cameras should be installed at SR 91 / SR 303 and SR 303 / Terex Road intersections near the SR 8 interchange. The cameras will allow quick detection and respond to incidents at these critical locations.

The May 14, 2018 report also indicated that if the City of Hudson desired to secure State or Federal funding, some aspects of their current signal system would need to be upgraded in order to be in compliance with the **Ohio Manual of Uniform Traffic Control Devices**, **Americans with Disabilities Act** and current design standards outlined in ODOT's **Traffic Engineering Manual**. These include:

- Mast arm signal supports installed at all four intersections that are currently using strain wire supports. This improvement is necessary for increased visibility of the signal heads on all approaches of the intersection and match the standard signal practices throughout the City.

- Curb ramps at fourteen intersections upgraded to ADA standards. It is estimated that thirty-eight curb ramps may need to be reconstructed or improved in order adhere to current ADA standards.

- Vehicle and pedestrian signals at eight signalized intersections retrofitted to LED technology. It is estimated that fifty-one red, yellow and green lenses will need to be reamed along with eleven green and yellow arrow lenses and ten walk and don't walk lenses. This improvement will reduce the energy consumption by approximately 88,248 kilowatts per year resulting in an annual savings of approximately $5,295 in energy costs.

- Uninterrupted power supplies should be installed at seventeen signalized intersections. These power supply backups will prevent the signal from going into unsafe "dark" mode during power outages.

- Pedestrian signal heads at all signalized intersections should be installed as or ungraded to countdown type as required by the **Ohio Manual of Uniform Traffic Control Devices**.

- It is recommended that pedestrian pushbuttons at all intersections should be installed with or ungraded to include indicator pilot lights.

The May 14, 2018 report recommended the replacement of the City's existing 6-pair copper cable and radio interconnect along the SR 91 and SR 303 corridors. It was recommended to be replaced with a fiber optic cable system. In addition, fiber optic cable was recommended to be installed to connect all signals back to a central location. It was since determined that the City of Hudson owns their own fiber optic cable system which would provide ample bandwidth for the signal system and any future devices or applications that the City wishes to add. The existing system is currently centered around the downtown district with some outlying areas of coverage. This report will take into consideration the use of this existing system and re-calculate the cost to upgrade the City’s signal system to adaptive control.

2. EXISTING TRAFFIC SYSTEM CONDITIONS

2.1 Introduction

The vehicular and pedestrian traffic volumes throughout the City of Hudson have created the need for signalization of many of the City's intersections. In order to improve the operation of these signalized intersections, many of the traffic signals have been grouped together into a coordinated subsystem to allow them to communicate with each other and provide progressive traffic flow along the main corridors with the City. However, the individual subsystems do not currently communicate with each other and there is no efficient means to visually monitor traffic issues within the city or to quickly modify traffic timings at the outlying isolated intersections.

2.2 System Description & History

The City of Hudson maintains twenty-one (21) traffic signals within the community. The signals utilize a traditional "closed loop" type design. Basically, a closed loop traffic signal system is one that physically connects, through some communications medium, such as copper cable pairs or radio, a series of traffic signals to a master controller, which is then monitored by the central monitoring system.

The signalized intersections are grouped into four (4) subsystem or zones that are connected to an on-street master controller. There is a fifth group, consisting of isolated intersections which are not connected through an on-street master. Six (6) intersections are contained in Zone 1 which includes intersections along State Route 91 from Georgetown to Stoney Hill Drive and the intersection of Hudson Drive / Terex Road. Six (6) intersections are contained in Zone 2 which includes intersections surrounding downtown Hudson. Two (2) intersections comprise Zone 3 which are located at SR 303 / McDondald's and SR 303 / Boston Mills Road. The Zone 4 includes a single intersection within the City of Hudson (SR 303 / Terex Road) which is interconnected to two intersections within neighboring Boston Heights. The remaining six (6) signalized intersections are isolated intersections and are operating without coordination to surrounding traffic signals.

The following signalized intersections compose the closed loop traffic signal systems and are numbered according to Figure 1 on page 4:

Zone 1 - Southern SR 91 and Hudson Drive (6 Signals)

4	SR 91 & Barlow Road
3	SR 91 & Terex Road
18	Terex Road & Hudson Drive
2	SR 91 & Corporate Drive
1	SR 91 & Georgetown Road
5	SR 91 & Stoney Hill Drive

Zone 2 - Downtown Hudson (6 Signals)

7	SR 91 & 303
8	SR 91 & Aurora Road/Clinton Street
9	SR 91 & Prospect Street
13	SR 303 & Library Street
14	SR 303 & Atterbury
6	SR 91 & Veterans Ways

Zone 3 - SR 303 & Boston Mills (2 Signals)

16	SR 303 & Boston Mills Road
15	SR 303 & Hudson Plaza Drive

Zone 4 - SR 303 & Terex Road (1 Signal)

17	SR 303 & Terex Road

Isolated Intersections (6 Signals)

10	SR 91 & Middleton Road
12	SR 303 & Hayden Parkway
11	SR 303 & Stow Road
21	Stow Road & Hudson Aurora Road
20	Stow Road & Ravenna Street

19 Stow Road & Barlow Road

The signals within the non-isolated zones operate under actuated-coordinated control which means that all signals are coordinated with each other and actuated as necessary with detectors at select approaches. The individual zone masters communicate with a central PC though a “dial-up” connection using a telephone line.

Existing condition diagrams for each of the signalized intersections are provided in **Appendix A**. These diagrams show the location of the existing signal equipment along with the current signal sequence / phasing for each of the intersections.

2.3 Local Intersection Equipment & Hardware

The City of Hudson utilizes a “closed loop” type system manufactured by the Econolite Corporation, Anaheim, California. The controllers at the signalized intersections include models ASC2, ASC3 and Cobalt. The ASC 2 and ASC3 models are no longer manufactured and the Cobalt model is the current production model. The ASC2 model is no longer supported since individual parts making up the assembly are not available. The ASC3 model is currently supported and repair parts are available, however, it is not know for how long that availability will continue. The City has the following numbers in service at this time:

ASC2 - 16
ASC3 - 2
Cobalt - 3

Cobalt controllers are currently installed at the following intersections:

8 SR 91 & Aurora Road/Clinton Street
9 SR 91 & Prospect Street
11 SR 303 & Stow Road

The May 14, 2018 report recommended that all of the outdated ASC 2 and ASC3 controllers be replaced with Cobalt controllers.

It was found that the traffic signals with the Cobalt controller also had a battery backup system to maintain power during outages. It was found that four signalized intersections have these battery backup systems. They are:

3	SR 91 & Terex Road
7	SR 91 & 303
8	SR 91 & Aurora Road/Clinton Street
9	SR 91 & Prospect Street

It was recommended that the other seventeen intersections be upgraded to have a battery backup system.

2.4 Vehicular & Pedestrian Traffic Signal Displays

The May 14, 2018 report identified vehicular traffic signal displays within the City to be powered by a mixture of incandescent and LED type lamps. Thirteen (13) intersections were fully illuminated using the LED type signal lamps and three (3) intersections have been partially upgraded to LED signal lamps. The remaining five (5) signalized intersections are currently powered by incandescent lamps. The following intersections utilize incandescent lamps in all of the vehicular signals:

4	SR 91 & Barlow Road
15	SR 303 & Hudson Plaza Drive
16	SR 303 & Boston Mills Road
17	SR 303 & Terex Road
18	Terex Road & Hudson Drive

The following intersections have a mixture of both incandescent and LED lamps in the vehicular signals:

10 SR 91 & Middleton Road
12 SR 303 & Hayden Parkway
20 Stow Road & Ravenna Street

Four (4) signalized intersections were found to have vehicular signals mounted on span wires suspended from strain poles. The remaining seventeen (17) intersection utilize mast-arm signal supports. The use of mast-arms is typically preferred since they provide additional signal head visibility to motorists on all approaches of an intersection. It was recommended that all intersections with strain pole supports be replaced with mast arm supports. The following intersections have span wire mounted vehicles signals recommended for replacement:

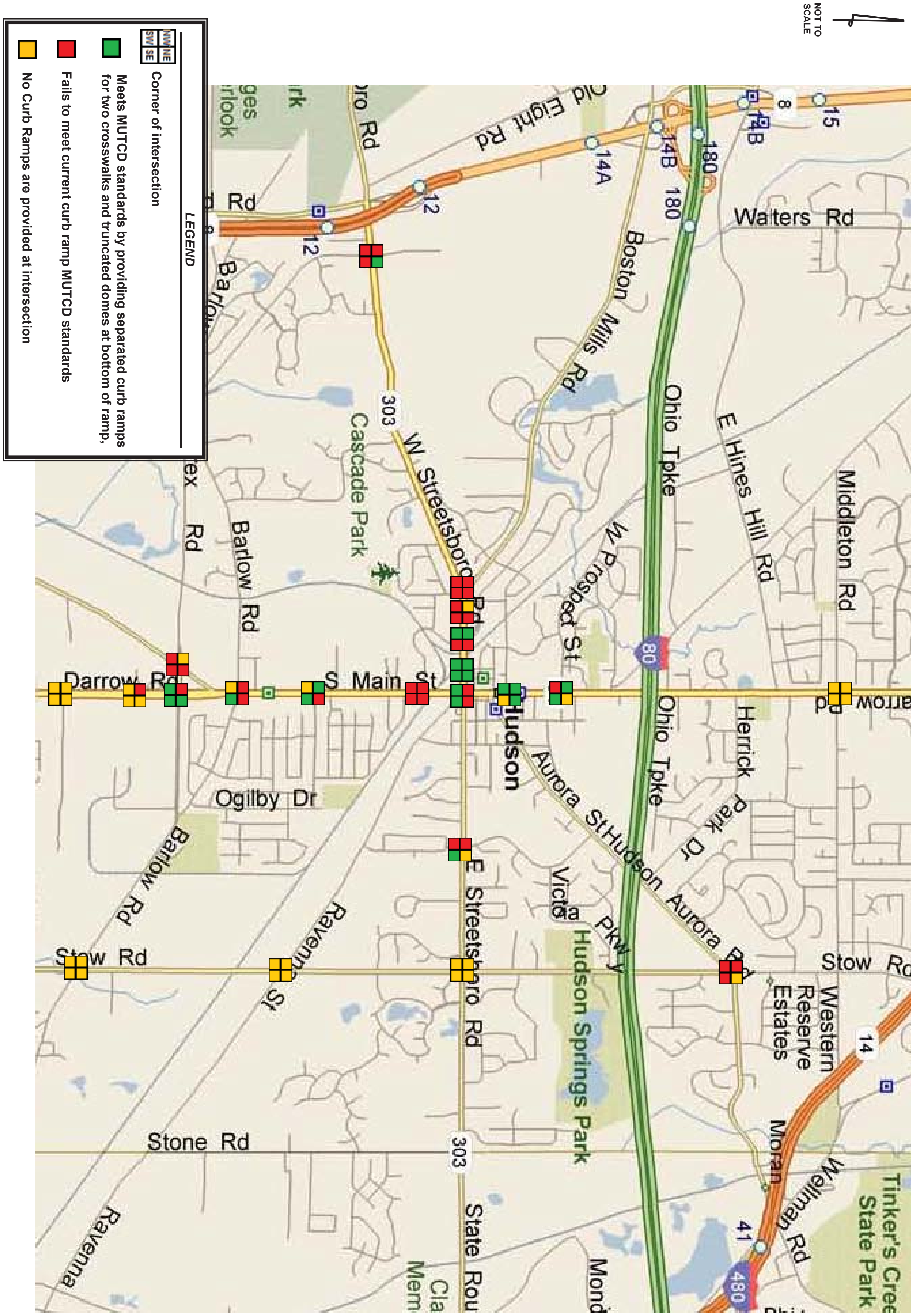
10 SR 91 & Middleton Road
18 Terex Road & Hudson Drive
20 Stow Road & Ravenna Street
21 Stow Road & Hudson Aurora Road

Pedestrian signals were found to be present at the majority of the signalized intersections throughout the City and were illuminated using either incandescent and LED lamps. These signals were typically pole mounted although several were observed on individual pedestals when signal poles were not present at the crosswalk location. It was recommended that all of the incandescent pedestrian signal displays be removed and replaced with LED lenses.

2.5 Curb Ramps

The City of Hudson has upgraded many intersections over the years to provide compliance with the **Americans with Disabilities Act (ADA)** standards for curb ramps and other pedestrian facilities. However, some locations were identified in the May 14, 2018 report that do not fully meet the ADA requirements or the requirements from the **Ohio Manual of Uniform Traffic Control Devices (OMUTCD)** by providing a single curb ramp for two crosswalks or no detectable warning devices.

A photographic log is provided in **Appendix B** showing the present conditions at each signalized intersection. **Figure 2, Page 13** graphically shows the condition of curb ramps at traffic signals in the City of Hudson.



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			Page 13

2.6 Emergency Vehicle Preemption

Currently all twenty-one traffic signals within the City of Hudson are outfitted with emergency vehicle preemption. The system is GPS based and responds to the detection of an approaching emergency vehicle. No improvements were found to be necessary to the emergency preemption systems throughout the City of Hudson.

2.7 Night Time Flashing Operation

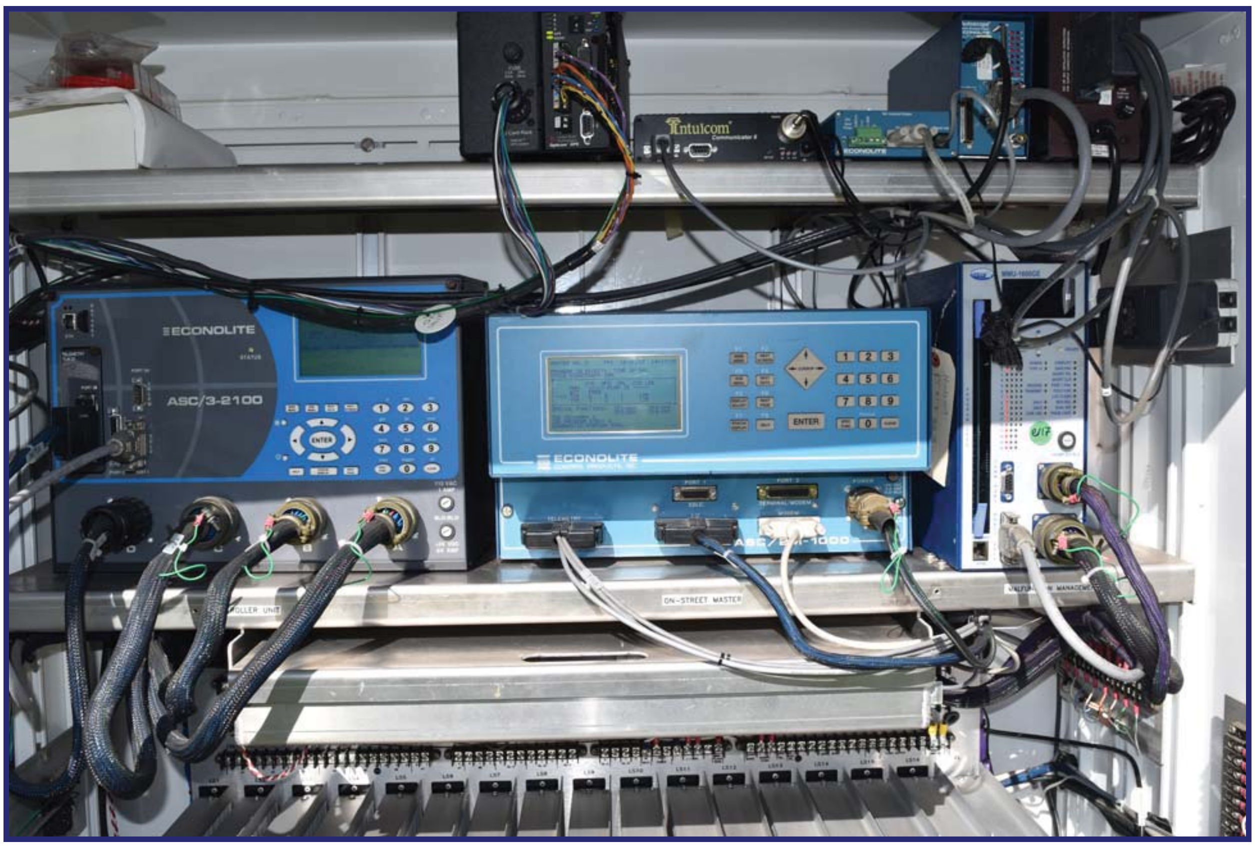
It was noted in the May 14, 2018 report that there are a number of signalized intersections operate in a flashing mode on a regularly scheduled basis. The flashing operation prevents the emergency vehicle preemption system from working and is a concern for safety forces during these time periods. If the City decides to implement a city wide upgrade to "adaptive control" technology, it would be recommended that the signals be operated in the full time "stop and go." Concerns for long wait times during late night hours can be abated by the placing the signals in "free" operation mode, proper design of the signal to use dilemma zone detection and the optimization of signal timing.

2.8 Signal Control System Configuration

Four signal sub-systems Hudson are connected using an Econolite brand ASC/2M Zone on-street master. The masters are located at the following intersections:

3	SR 91 & Terex Road - Zone 1
7	SR 91 & 303 - Zone 2
16	SR 303 & Boston Mills Road - Zone 3
--	SR 303 & SR 8 Northbound Ramp / Chittenden Road - Zone 4 (maintained by Village of Boston Heights)

The ASC/2M is an on-street arterial system master that has the ability to command up to twenty-four traffic controllers via telemetry interconnect. The master stores event, alarm, and diagnostic data from the attached controllers and can send their logs to a PC based work station. The master controllers have the ability to select traffic plans based on manual command, external input, time-of-day, or traffic responsive but is limited to the patterns which have been pre-programmed based on historical traffic counts which can be several years old. ASC/2M zone masters communicate with attached controllers at a rate of once per second. The photograph below shows a typical controller cabinet with an on-street master and other components.



It is recommended that the City of Hudson immediately take advantage of the current systems's capability of traffic responsive operation. This will improve the efficiency of the signal systems and reduce delay to motorists on the SR 91 and SR 303 corridors.

2.9 Communications System Configuration

Phone service is installed to the master controller locations noted above which provides remote monitoring and access of the systems. The SR 303 and SR 8 / Chittenden (Boston Heights) system did not have a working phone drop at the time of the writing of this report. Using the software program "Aries", each controller can be accessed remotely in order to perform observational troubleshooting by displaying real-time intersection graphics and controller programming. At this time, communication between the master and local controllers is through copper wire interconnect or radio interconnect. It is recommended that the City consider replacing the outdated "dial-up" system and install a modern central signal system control station (CSSCS).

3. EXISTING LOCAL INTERSECTION EQUIPMENT EVALUATION & NEEDS

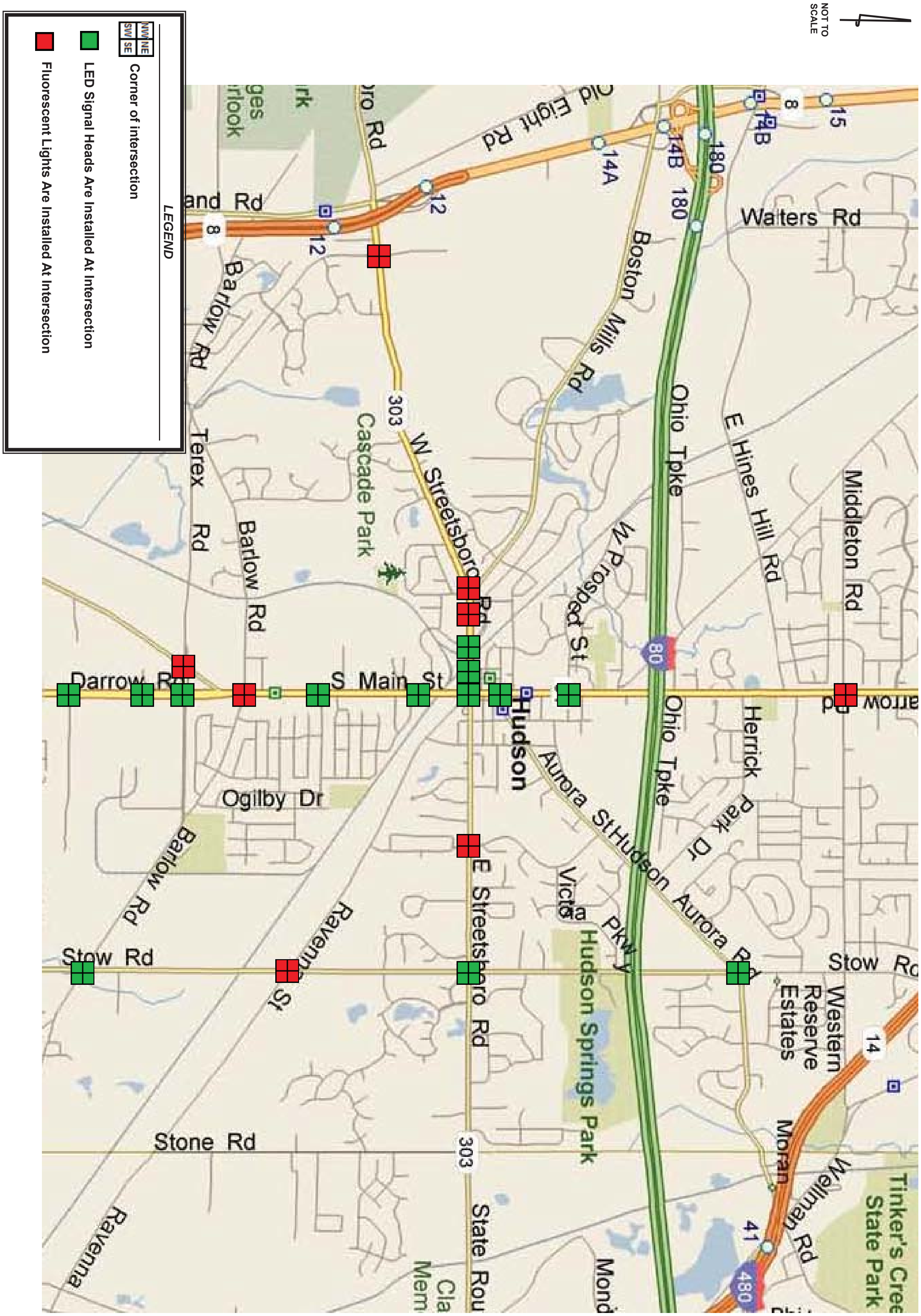
3.1 Introduction

The May 14, 2018 report found that some of the traffic signal equipment controlling the City of Hudson intersections has been in operation for an extended length of time beyond its design life and much of the equipment and hardware has been found to be outdated and no longer manufactured. Advances in technology now allow for improvements to the efficiency of these traffic signals in just about every aspect of operation. The following describes various technologies that are available that could improve the efficiency, operation and the environment.

3.2 Energy Consumption

As previously noted, some of the traffic and pedestrian signal displays are currently comprised of incandescent lamps which require high amounts of electricity for operation. Intersections generally have an average of eight signal heads and eight pedestrian heads that will each have at least one incandescent lamp on 24 hours a day.

An inventory of the twenty-one signalized intersections was provided in the May 14, 2018 report. It was determined where incandescent lamps are installed and where a certain intersections have been upgraded with the new light emitting diode technology. It was found that thirteen (13) of the twenty-one intersections are currently using this new technology. Five (5) signalized intersections have the traditional incandescent lamp type traffic signal heads and three (3) signals have a mixture of both LED signal heads and incandescent signal heads. **Figure 3 , Page 18** shows graphically where incandescent and LED lamps are inventoried.


NOT TO SCALE
LEGEND
NW NE
SW SE
Corner of intersection
LED Signal Heads Are Installed At Intersection
Fluorescent Lights Are Installed At Intersection
Old Eight Rd
Walters Rd
Boston Mills Rd
Ohio Tpke
E Hines Hill Rd
Middleton Rd
W Streetsboro Rd
Cascade Park
W Prospect St
Darrow Rd
S Main St
Hudson
Aurora St
Hudson Aurora Rd
Herrick Park Dr
Barlow Rd
Terex Rd
Ogilby Dr
Victoria Pkwy
Hudson Springs Park
Stow Rd
Ravenna St
E Streetsboro Rd
Western Reserve Estates
Stone Rd
State Route
Moran
Wellman Rd
Tinker's Creek State Park
Ravenna
8
12
14A
14B
15
180
303
80
14
41
480

Light Emitting Diode (LED) traffic signals have proven to be an effective alternative to the traditional incandescent lamps. The main advantage of LED signals is the low power consumption which ranges from 6 watts to 14 watts per light. This, compared to an incandescent lamp, which uses 135 to 150 watts, results in a significant reduction in energy consumption of up to 96%. For the signalized intersections in the City of Hudson, the installation of LED's at the eight (8) signals was found to reduce the energy consumption by approximately 88,248 kilowatts per year resulting in an annual savings of approximately $5,295 in energy costs. The installation of LED signal heads will have a payback in 2.26 years. The calculations are provided in the May 14, 2018 report.

3.3 Environmental Emissions

Another advantage to LED traffic signals is that the reduction in energy consumption will result in less greenhouse gas emissions as a direct result of a more efficient use of electricity. Switching to LED traffic signals at remainder of the City's signalized intersections will result in an annual reduction in over one hundred and forty-four thousand pounds of carbon dioxide. The reduction in emissions for the City of Hudson would be the equivalent of removing sixteen (16) vehicles annually from the cities roadways.

3.4 Maintenance Considerations

In addition to the cost savings from less energy consumption, LED traffic signals also require less maintenance. Incandescent lamps, particularly the red, green, walk and don't walk indications, typically burn out once a year and need to be replaced. LED's on the other hand, were found to last seven to ten years before needing to be replaced. Due to their low wattage, LED signals do not burn the lens cover that is typically found with incandescent bulbs. A burnt lens cover will reduce the brightness of the light after several years in operation and will need to be replaced at some point. Lastly, the lower wattage of LED's also allows them to draw less power which keeps the intersection wiring from deteriorating as fast as intersections with conventional incandescent lamps. A savings in maintenance costs was estimated at approximately $4,680 per year.

3.5 Side-Street Bicycle Detection

Detection of bicyclists at signalized intersections can decrease delay to bicyclists and discourage red light running by cyclists without causing increased delay to motorists. Bicycle detection at intersections is commonly accomplished using specially designed loop detectors. The standard loop detector is designed to detect the metal frame of a vehicle which takes up the entire lane width but this loop layout is inadequate to detect the small amount of metal on a typical bicycle. To provide adequate bicycle detection, the Powerhead configuration shown on Standard Construction Drawing TC-82.10 provides both bicycle and motorists detection with a single loop. It is recommended that all of the standard side-street loop detectors within the City of Hudson be replaced with Powerhead type detectors.

3.6 Safety Considerations

Signalized intersections that lose power create a dangerous situation for motorists on the road. An intersection experiencing a power failure, by the requirements in the **Ohio Motor Vehicle Code**, is to be treated as a four-way stop. Since some drivers do not adhere to this or do not see the unlit signal, the police department is oftentimes required to direct traffic.

Uninterrupted Power Supply

Due to the low power requirement of LED traffic signals, intersections can be outfitted with an uninterrupted power supply (UPS) battery backup device that will continue to power the intersection in the event of a local power outage. These devices can provide immediate power to the extent that no noticeable switch to battery backup is observed by motorists. This will eliminate the need to dispatch police resources to direct traffic and the need for stop signs at signalized intersections.

LED Signal Heads

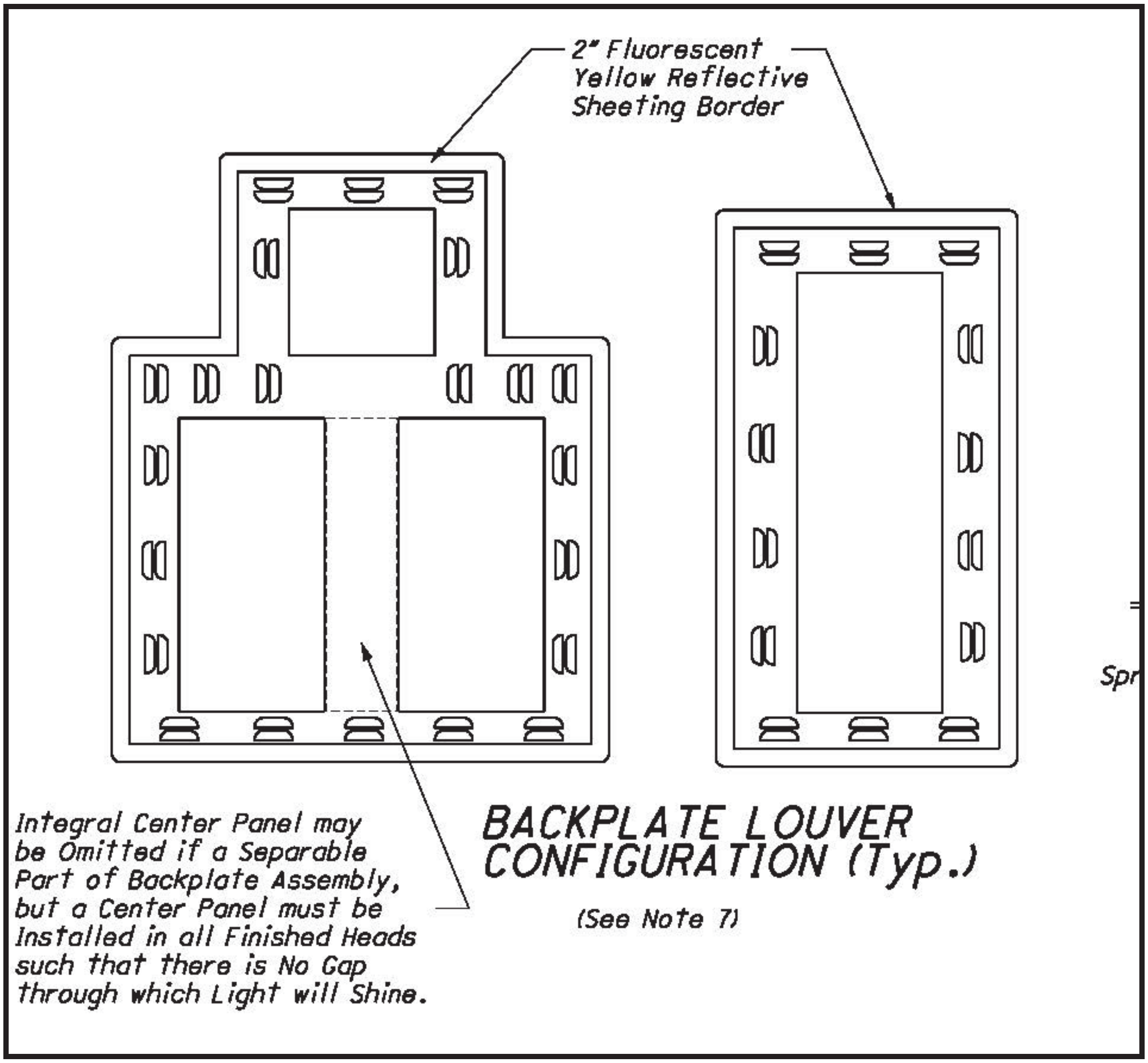
LED traffic signals also avoid immediate burnouts that incandescent bulbs are accustomed to. Since an LED signal is made up of a matrix of several dozens LED’s, the signal will continue to function even if several of the diodes stop working. The City of Hudson will have the ability to replaces the LED’s before the lamp stops working completely unlike a conventional bulb. LED signals also appear much brighter than incandescent bulbs which will improve intersection safety.

Backplates on Signal Heads

It is recommended by the OMUTCD in section 4D-11 that backplates should be installed on all signal faces to improve visibility of the traffic signal by making the signal head stand out from its surroundings and by helping to prevent confusion due to distracting features in the background. The use of backplates also enhances the contrast between traffic signal and their surroundings for both day and night conditions, which is helpful to elderly drivers.

It was stated in the May 14, 2018 report that ODOT is currently in the process of changing the signals within their jurisdiction to ones with backplates. Furthermore, the backplates are being fitted with retro-reflective sheeting. Since signal backplates are located overhead, they are disadvantaged with respect to vehicle headlights, aimed to illuminate the roadway directly in front of the driver and not overhead signs. Therefore, high intensity sheeting material is recommended for use as a border material on the backplates. The following pictures show backplates with retro-reflective tape during the daytime, providing evidence that the tape highlights the border of the backplate. The second photo shows that the tape provides a distinctive frame around the traffic signal display, allowing drivers to more readily locate the signal head among background lighting.

Backplates were recommended to have louvers within the plate and oriented to scoop air from the front side and oriented with the openings facing alternate directions by groups shown in the figure below. The retro-reflective tape should not be applied over the louvers. The louver area is recommended to be at least 8 percent of the total backplate area. 5-section backplates are recommended to have notched top corners. Louvers and notched top corners will reduce damage to the backplates caused by excessive wind conditions.



Backplate Detail From ODOT's Standard Construction Drawing TC-85.22

Pedestrian Safety

Pedestrian safety has proven to a high priority concern for the City of Hudson. One method of improving pedestrian safety is through the use of what is referred to as "Countdown Pedestrian Signals". A countdown signal displays the number of seconds left to finish the crossing. This device is intended to aid pedestrians in getting out of the street before they would be exposed to the danger of oncoming vehicular traffic. A pedestrian who just arrives in the queuing area can use this information to decide whether to start crossing. A person who is in the crosswalk when the flashing Don't Walk interval begins can see the number of seconds remaining before the cross traffic gets a green light. This will reduce the likelihood that a person is still in the intersection when the light changes.

It should be noted that countdown pedestrian signals are required by the OMUTCD for use in controlling crosswalks. FHWA set a compliance date that all pedestrian signals shall have the countdown feature by December 22, 2013.

An inspection of the City's existing pedestrian signals revealed that there are 64 signals that do not have the "countdown" feature. There is one intersection, State Route 91 and Corporate Drive, that no pedestrian signals are present but would benefit from installing signals at its location. It is estimated that to upgrade the existing 64 units and to install 8 more at the SR 91 and Corporate Drive intersection would cost approximately $50,000.

Pedestrian push buttons are utilized at all signalized intersections within the City of Hudson that have pedestrian signals. Typically they are designed utilizing a 2" "mushroom" type button for activation. This button is designed to be activated by the minimum force requirements from **ADA**. The **OMUTCD** allows the use of a pilot light or other means of indication installed with a pedestrian push button. This will inform the pedestrian that the button has been pressed and that their desire to cross has been communicated to the controller. This indicator will extinguish itself once the walk interval is displayed for the crosswalk. It is recommended that all of the pedestrian push buttons be replaced with ones that have pilot lights.

Inspection of field conditions indicated that approximately 72 pedestrian push buttons would need to be upgraded to the ADA standard and using an indicator pilot light. Cost to construct this improvement is estimated at $10,000.

Span Wire Installations

Seventeen (17) intersections within the City are currently using mast arm type supports. The remaining four (4) intersections were found to be using steel strain poles with span wire. Our field investigation from the May 14, 2018 report revealed that the span wire supporting hardware, the signal mounting hardware, and steel poles appear to be in good condition but exhibiting some signs of wear and aging. This condition were deteriorate over time. Mounting on span wire allows movement between poles, span wire and signals, causing the wear. Using mast arm support construction would allow signals to be fixed to prevent swinging and reduce wear. The estimated construction cost to upgrade the traffic signals using mast arm type supports at the four intersections is estimated at $700,000.

3.7 Recommendations

It was recommended that all signalized intersections within the City of Hudson be upgraded to include certain improvements. The savings achieved from less energy consumption and maintenance combined with the added safety and environmental emissions benefits make the investment an excellent opportunity to reduce future costs and improve the efficiency and safety of the Citywide system. The following improvements were recommended:

- Mast arm signal supports should be installed at four (4) intersections that are currently using strain wire supports:

  10 SR 91 & Middleton Road
  18 Terex Road & Hudson Drive
  20 Stow Road & Ravenna Street
  21 Stow Road & Hudson Aurora Road

Estimated construction cost is $700,000.

- Curb ramps at fourteen intersections should be upgraded to ADA standards. It is estimated that 38 curb ramps may need to be re-constructed or improved. See figure 2 on page 14 which the location of the needed improvements. Estimated construction cost is $38,000.

- Vehicle signal heads at eight (8) signalized intersections should be retro-fitted to LED technology. It is estimated that 51 red, yellow and green lenses will need to be re-lamped along with 11 green and yellow arrow lenses and 10 walk and don't walk lenses. Estimated construction cost is $50,000.

- Uninterrupted power supplies should be installed at seventeen (17) signalized intersections. Estimated construction cost is $85,000.

- Pedestrian signals heads at all signalized intersections should be installed as or up-graded to countdown type. Estimated construction cost is $50,000.

- All pedestrian pushbuttons should be up-graded to include indicator pilot lights. Estimated construction cost is $10,000.

It is also recommended that the City of Hudson consider the use of mast arm signal supports, LED vehicle and pedestrian signals, countdown type pedestrian signals and pedestrian push buttons with pilot lights on all future traffic signal installations. Curb ramps at any of these future locations should also be constructed to the current **ADA** and **OMUTCD** standards.

4. EXISTING SYSTEM EVALUATION & NEEDS

4.1 Introduction

The existing City of Hudson traffic corridors have twenty-one intersections that are controlled by traffic signals. Ten (10) of the traffic signals are along the Main Street / Darrow Road (SR 91) corridor and seven (7) are along the Streetsboro Road (SR 303) corridor. There are four (4) additional traffic signals in outlying areas. Fifteen signals are currently interconnected into four (4) sub-systems of a traditional "closed loop" system.

4.2 Types of Control

All four of the signal sub-systems are controlled using an Econolite ASC/2M Zone Masters. The ASC/2M is an on-street arterial system master that has the ability to command up to twenty-four traffic controllers via telemetry interconnect. This master will retrieve event, alarm, and diagnostic data from the attached controllers. It has the ability to select traffic plans based on manual command, external input, time-of-day, or traffic responsive. An ASC/2M zone master will communicate with attached controllers once per second. Closed-loop systems do create an issue in that they prohibit traffic signals that are not within the system from communicating with one another, even if they are in close proximity. As shown on **Figure 1**, the southern SR 91, SR 303 / Boston Mills Road and the downtown systems are all located close to each other and it appears beneficial for these three systems to be able to communicate with each other.

4.3 Traffic Control Configuration

As noted in section 4.1, "closed loop" systems have the ability to operate under traditional time-of-day schedule or plans selected with traffic responsive procedures. In general, traffic responsive mode will slightly lag that of a well timed time-of-day system because the traffic responsive system takes additional time to recognize changes in traffic flow and then transition to the appropriate control plan. However, traffic responsive mode performance will be significantly better than a TOD system if the traffic responsive mode is properly calibrated to respond to traffic demand that cannot be predicted by time-of-day. It is recommended that the City implement the traffic responsive mode of operation to take advantage of efficiencies can be attained.

The four closed-loop sub-systems are currently running in the time of day mode. There are some system sensors installed in each zone which potentially would allow each zone to run in the traffic responsive mode. This study determined that 16 system sensors should be installed on the SR 91 corridor and 8 system sensors should be installed on the SR 303 corridor in order to implement the traffic responsive mode of operation as an interim measure.

The four closed-loop sub-systems have the capability of being monitored using the proprietary software; “Aries Traffic Management System”. Using Aries, each controller can be accessed remotely in order to perform limited troubleshooting by displaying real-time intersection graphics and controller programming. Aries has been suitable for monitoring closed-loop systems such as the ones currently in the City of Hudson. However, many of the signalized intersections could work more efficiently if they had the ability to work together and automatically pulled apart to work in smaller groups of coordinated systems. Staff who monitor the operation of the traffic signal system efficiencies and equipment failures would benefit from a modern central signal system control station (CSSCS).

For the City of Hudson, which has a major east-to-west corridor that intersect with a major north-to-south corridor, a more advanced traffic management system may be more suitable for optimal operation. The central signal system control station will provide a centralized integrated platform for signal control, ITS field device monitoring and control, information management, and graphical data display. With a central signal system control station, all traffic controllers are tied directly to the main system and eliminate the need for closed-loop systems and zone master controllers. The central system can adjust signal timings and offsets based on real-time minute by minute traffic data. This type of central control adheres to the “Smart City” principals and should provide decreased travel times through the City to the benefit of all residents. An additional benefit of the central system is new traffic signal controllers, CCTV cameras, and other ITS devices can easily be added to the system once constructed.

A cental signal system control station, using “Smart City” technology, can increase the efficiency of each traffic signal. However, the ability for City personal to quickly assess any traffic issues and quickly respond is almost as important from a operations standpoint. Due to high volumes and increased congestion along the City’s traffic corridors, an incident management system consisting of CCTV cameras is recommended surrounding the SR 91 and SR 303 intersection and possibly at the SR 303 and Terex Road intersection. The use of CCTV cameras will allow City officials to observe traffic and signal conditions directly in order to more expeditiously address any potential problems.

4.4 Factors Justifying The Need For Traffic Control Signals

A properly placed traffic signal can improve the safety and efficiency of flow through an intersection. An unnecessary signal can be the source of danger and annoyance to all who use the intersection including pedestrians, bicyclists, and motorists. It can also increase air pollution and cause driver frustration if there is not much traffic on the major street. If changes in traffic patterns eliminate the need for a traffic control signal, consideration should be given to removing it and replacing it with appropriate alternative traffic control devices, if any are needed.

The next sections of this report will address the necessity of each of the traffic signals at the City’s twenty-one signalized intersections. If the City of Hudson desires to secure State of Federal funding for the upgrade of their traffic signal system, they will be required to show that conditions at their signalized intersection justify signal control. When determining whether or not a traffic signal is necessary at a specific location, an evaluation of the candidate location (called a signal warrant study) is conducted to determine the answers to the following questions:

1. How much traffic is there on the intersecting streets?
2. Are high levels of traffic consistent throughout the day or just during a few hours?
3. Is there a significant amount of pedestrian traffic?
4. Is the street a wide, high speed, and busy thoroughfare?
5. Are school children crossing the street?
6. Will a signal improve the flow of traffic or cause gridlock with other nearby signals?

The signal warrant study collects all of the relevant data at a location that is being considered for a traffic signal. Once the data is collected, it is compared to criteria that has been established by extensive research and experience and documented in the latest edition of the **Ohio Manual of Uniform Traffic Control Devices** (**OMUTCD**).

The **Ohio Revised Code** requires that an engineering signal warrant study must be performed to determine whether installation of a traffic signal is justified at a particular location. Meeting one of the warranting criteria is necessary for the planning of improvements funded by any Federal source. Therefore, it is important to have a record showing that a signal is justified by the **OMUTCD** criteria.

Satisfaction of the signal warrants do not necessarily justify installation of a traffic signal. Other, more appropriate solutions should be considered prior to considering installation of a traffic signal. Spacing between signals is always a major concern beyond the basic warranting analysis and should be carefully reviewed before deciding on installation of a new signal.

It should be noted that traffic signals do not prevent motor vehicle crashes. Engineering studies have shown that in many instances, total intersection crashes increase after a traffic signal is installed. Certain types of crashes are susceptible to correction by installation of traffic signals, however, overall the number of crashes generally increase.

4.5 Traffic Signal Warrant Criteria

The OMUTCD provides eight (8) sets of criteria, called warrants. The warrants are;

Warrant 1 - Eight Hour Vehicular Volume

This warrant has three conditions. The Minimum Vehicular Volume, Condition A, is intended for application where a large volume of intersecting traffic is the principal reason to consider installing a traffic signal. The Interruption of Continuous Traffic, Condition B, is intended for application where the traffic volume of a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street. The third condition is a combination of Condition A and Condition B in which 80% of each condition must be satisfied.

Warrant 2 - Four Hour Vehicular Volume

This warrant is addresses the need for signalization based on situations existing for less than eight hours and is based upon a sliding scale or combined volume. Fours hours of volume must be met.

Warrant 3 - Peak Hour Vehicular Volume

This warrant is intended for use at a location where traffic conditions are such for a minimum of one hour of an average day, the minor street suffers undue delay when entering or crossing the major street. This warrant is only applied in unusual cases. Such cases include, but are not limited to, office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.

Warrant 4 - Pedestrian Volume

This warrant is intended for applications where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

Warrant 5 - School Crossing

This warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic signal.

Warrant 6 - Coordinated Signal System

This warrant is used when progressive movement of traffic in a coordinated signal system sometimes necessitates installing a traffic signal at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Warrant 7 - Crash Experience

This warrant is intended for application where the severity and frequency of crashes are the principal reason to consider installing a traffic signal.

Warrant 8 - Roadway Network

This warrant is used at the intersection of two major routes where installing a traffic signal may encourage concentration and organization of traffic flow on a roadway network.

4.6 Traffic Volumes

Data collection was performed for the May 14, 2018 report which consisted of acquiring nine hour, weekday turning movement counts at all of the twenty-one signalized intersections within the City of Hudson. Copies of the intersection turn movement counts are included in **Appendix C** for each intersection.

4.7 Traffic Signal Warrant Analysis

All of the data collected for this study was analyzed and compared to the thresholds established by criteria from the **OMUTCD**. The warrant analysis worksheets for each intersection can be found in **Appendix D**. This is repeated for this report so the City of Hudson will have a convenient record for use in securing funding or providing justification for signal control at a particular intersection.

The table on the following page shows a summary of the results of the traffic signal warrant analysis.

	WARRANT #1A	WARRANT #1B	WARRANT #1A & B	WARRANT #2	WARRANT MET
SR 91 & Georgetown Road				X	YES
SR 91 & Corporate Drive		X	X	X	YES
SR 91 & Terex Road	X	X	X	X	YES
SR 91 & Barlow Road	X	X	X	X	YES
SR 91 & Stoney Hill Drive		X		X	YES
SR 91 & Veterans Way		X		X	YES
SR 91 & SR 303	X	X	X	X	YES
SR 91 & Aurora Street	X	X	X	X	YES
SR 91 & Prospect Street		X		X	YES
SR 91 & Middleton Road	X	X	X	X	YES
SR 303 & Stow Road	X		X	X	YES
SR 303 & Hayden Parkway				X	YES
SR 303 & Library Street		X		X	YES
SR 303 & Veterans Way				X	YES
SR 303 & McDonalds		X		X	YES
SR 303 & Boston Mills Road		X		X	YES
SR 303 & Terex Road	X	X	X	X	YES
Terex Road & Hudson Drive				X	YES
Stow Road & Barlow Road				X	YES
Stow Road & Ravenna Street		X		X	YES
Stow Road & Hudson Aurora Road				X	YES

The following sections explain the results of the analyses.

Warrant 1 consists of three conditions of which only one needs to be satisfied.

4.7.1 Warrant 1 - Condition A

Condition A is the minimum volume that must occur for any *eight* hours based upon the number of approach lanes at the intersection and the posted speed limit. If the speed limit is posted at 40 miles per hour or higher, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000 the minimum threshold may be reduced by 70%. Several of the study intersections were found to meet the 40 miles per hour or higher condition, therefore those intersections were reduced to the 70% level.

There were at least eight hours found to meet the minimum main street and side street volume thresholds at the following intersections:

3	SR 91 & Terex Road
4	SR 91 & Barlow Road
7	SR 91 & SR 303
8	SR 91 & Aurora Street
10	SR 91 & Middleton Road
11	SR 303 & Stow Road
17	SR 303 & Terex Road

4.7.2 Warrant 1 - Condition B

Condition B is the minimum volume that must occur for any *eight* hours based upon the number of approach lanes at the intersection and the posted speed limit. If the speed limit is posted at 40 miles per hour or higher, the minimum threshold may be reduced by 70%. None of the study intersections were found to meet the 40 miles per hour or higher condition, therefore the thresholds were not reduced to the 70% level.

There were at least 8 hours that were found that simultaneously met both the major street and minor street volume thresholds at the following intersections:

2	SR 91 & Corporate Drive
3	SR 91 & Terex Road

4 SR 91 & Barlow Road
5 SR 91 & Stoney Hill Drive
6 SR 91 & Veterans Ways
7 SR 91 & SR 303
8 SR 91 & Aurora Street
9 SR 91 & Prospect Street
10 SR 91 & Middleton Road
13 SR 303 & Library Street
15 SR 303 & Plaza Drive (McDonald's)
16 SR 303 & Boston Mills Road
17 SR 303 & Terex Road
20 Stow Road & Ravenna Street

4.7.3 Warrant 1 - Combination of Conditions A & B

Any eight hours are required to meet 80% of the minimum volume thresholds for both condition A and condition B. If the speed limit is posted at 40 miles per hour or higher the minimum threshold may be reduced by 70%. None of the study intersections were found to meet the 40 miles per hour or higher condition, therefore the thresholds were not reduced to the 70% level. There were at least 8 hours that were found that simultaneously met both the major street and minor street volume thresholds at the following intersections:

2 SR 91 & Corporate Drive
3 SR 91 & Terex Road
4 SR 91 & Barlow Road
7 SR 91 & SR 303
8 SR 91 & Aurora Street
10 SR 91 & Middleton Road
11 SR 303 & Stow Road
17 SR 303 & Terex Road

4.7.4 Warrant 2 - Four Hour Vehicular Volume

In order to meet warrant 2, the four highest hours of traffic volumes must be plotted on a graph from the **OMUTCD** and the resulting intersection of the main street volume (shown in dark blue) to side street volume must be greater than the thresholds (shown in light blue) established by the graph. The Warrant 2 graphs can be seen in **Appendix D**.

There were at least 4 hours that were found that simultaneously met both the major street and minor street volume thresholds at the following intersections:

1 SR 91 & Georgetown Road
2 SR 91 & Corporate Drive
3 SR 91 & Terex Road
4 SR 91 & Barlow Road
5 SR 91 & Stoney Hill Drive
6 SR 91 & Veterans Ways
7 SR 91 & SR 303
8 SR 91 & Aurora Street
9 SR 91 & Prospect Street
10 SR 91 & Middleton Road
11 SR 303 & Stow Road
12 SR 303 & Hayden Parkway
13 SR 303 & Library Street
14 SR 303 & Atterbury / Veteran's Way
15 SR 303 & Plaza Drive (McDonald's)
16 SR 303 & Boston Mills Road
17 SR 303 & Terex Road
18 Terex Road & Hudson Drive
19 Stow Road & Barlow Road
20 Stow Road & Ravenna Street
21 Stow Road & Hudson Aurora Road

Therefore Warrant 2 is satisfied for all twenty-one intersections in the City of Hudson.

4.8 Conclusion

All of the signalized intersections with the City of Hudson were found to meet at least one of the previously discussed signal warrants. No additional warrant analysis was carried out for warrants 3 - 9. All of the existing signals were found to meet at least one of the necessary signal warrants, therefore none of the signals should be considered for removal.

4.9 Alternate Route Implementation

A possible alternative route implementation to reduce congestion in the downtown area has been discussed as another aid in improving traffic flow in the City of Hudson. Several roadway alternatives were reviewed and it was determined that Stow Road is the only viable north-south roadway within the City of Hudson which could be used as an alternate route to reduce congestion on SR 91. The rerouting of traffic from SR 91 onto Stow Road could be accomplished by using changeable message signage which would alert motorists to congestion on SR 91 to prompt a diversion of vehicles. However, Stow Road is currently congested during peak hours and traffic may experience an increased travel time if they use Stow Road which would make it a non-ideal alternative route.

A series of travel runs were performed on SR 91 and Stow Road in order to determine the viability of Stow Road as an alternate route for SR 91 traffic. The travel route for a possible Stow Road alternate route was from SR 91 onto Middleton Road, south on Stow Road and then west on Barlow / Terex Road. This route was compared to the travel times of motorists who travel on SR 91 through the City between Terex Road and Middleton Road.

The travel runs on both routes were performed during the AM peak hours (7:00 - 8:30 AM) and during the PM peak hours (4:00 - 6:00). Three runs were performed during each peak hour and on both SR 91 and the Stow Road routes. The average of the three travel runs during each of the peak hours are shown in the following table.

Route	*AM Peak Northbound*	*AM Peak Southbound*	*PM Peak Northbound*	*PM Peak Northbound*
SR 91	13.5 minutes	9.3 minutes	13.1 minutes	12.5 minutes
Stow Road	16.4 minutes	16.3 minutes	15.1 minutes	16.9 minutes

The travel run analyses indicates that traffic that would utilize a possible Stow Road alternate route, would incur an average of 34% more travel time compared to continuing to utilize SR 91 to travel thru the City. This significant increase in travel time may make any alternative route signage non-beneficial since motorists may be unwilling to divert their route onto a roadway with higher travel times.

4.10 Corridor Improvement Summary

The recommended improvements to the City's signal system, which includes the use of central signal system control station with adaptive algorithms with full interconnection of all traffic signals was found to reduce congestion and delay. The reduction in delay and increase in speeds along the corridors will also reduce the amount of emissions being released into the atmosphere which will improve the air quality within the City of Hudson.

In order to quantify the improvements expected along the corridors, the Synchro computer program was used to model the signal systems. The PM peak hour traffic volumes were utilized in the modeling for this determination since this hour constitutes the worse case traffic conditions. The corridor measures of effectiveness for the existing conditions and the proposed conditions have been compared in a table which is shown in **Appendix E.**

The results of analyses show the corridors are expected to have a decrease in overall delay of approximately 39 hours once the signal system is upgraded. The signal upgrades were also shown to cause a decrease of 2,274 stops and a decrease of 39 hours in travel time. This decrease in delay and travel time was shown to reduce the CO emissions by 3,200 grams and Nox emissions by 620 grams.

4.11 Recommendations

While the existing intersections and closed-loop system has been suitable for operation, there are several limitations that will prohibit the introduction of advanced traffic control systems and future technology which is necessary for "Smart City" traffic optimization and monitoring. It is recommended that the City of Hudson install an central signal system control station in order to bring all existing signal controllers under a single operational system and prepare for future additions and expansions wherever they may be needed.

The traffic signal controllers should be upgraded with NTCIP communications protocol. This will allow the City to achieve maximum operational efficiency for the current traffic conditions and evolve with future changes to accommodate any issues they may face in the future. All traffic signal controllers should be upgraded to include network addressable components to communicate with the system. A system of CCTV cameras should be installed at the SR 91 and SR 303 intersection and possibly at the SR 303 and Terex Road intersection.

It is noted that the upgrade of the City's signal system may take time for implementation, especially if State or Federal funding is to be obtained. Therefore, it is also recommended that system downstream system detectors be installed for each of the closed loop sub-systems and to implement the traffic responsive mode of operation as an interim measure to improve traffic flows and reduce delays.

Cost to construct a central traffic control system is estimated to be approximately $175,000. The installation of system detection is estimated at $190,000. The construction cost for upgrading the traffic signal controllers to communicate with a central traffic control system is estimated at $255,000. The cost to install a system of CCTV cameras at the intersections of SR 91 / SR 303 and SR 303 / Terex is estimated to be approximately $30,000.

Cost to construct and implement traffic responsive operation in the existing closed loop systems is estimated at $75,000 for the construction and $25,000 for the programming and implementation.

5. COMMUNICATIONS EVALUATION & NEEDS

5.1 Introduction

The May 14, 2018 report recommended the functional aspects of a "Smart City" type communications system, reviewed the communications options available for application and outlined the trade-offs associated with each technology. The report assessed the type of communications suitable for the City of Hudson in which various factors were considered. These factors include existing communication system make-up, reliability, maintainability, expandability and adaptability. It was recommended that the existing wire conduit and radio interconnect along SR 91 and SR 303 be replaced with a fiber optic cable system. In addition, fiber optic cable should also be installed to connect the controllers back to a central location. The fiber optic cable system would provide ample bandwidth for any future devices or applications that the City wishes to add.

5.2 Composition

The City of Hudson currently posses four signal systems of which two use copper wire interconnect and two use radio interconnection. The City provide information on an existing fiber cable system installed for other uses where unlit fibers are available for traffic control purposes. It was determined that it could be utilized and would constitute a savings toward the signal improvement cost. This study now assume that the existing fiber cable system can be utilized for traffic purposes within the City of Hudson.

5.3 Recommendations

The communication system will be an important component of the traffic control system. It will be defined of by the number, types, and location of traffic controllers, the location of the central control system and other specific special capabilities discussed in the next section. The analysis indicated that a centralized control system with traffic responsive capabilities would be recommended. The analysis of the communications media previously presented, the type of system recommended, current industry trends, the status of the existing system and other considerations indicates the following needs:

1. It is recommended that the City of Hudson replace the existing copper wire interconnect and radio interconnect along SR 91 and SR 303 and utilize their existing fiber optic cable system where available. As the fiber system expands in the future, consideration should be given to interconnecting outlying signalized intersections. The fiber optic cable will be a critical component of the adaptive system and will quickly relay necessary information to the central computer.

6. SYSTEM FEATURES & ENHANCEMENTS

6.1 Introduction

In section 3, the traffic control system was recommended that will provide the greatest benefit to the citizens and motorists who use the City of Hudson's street system. This central signal system control station will adhere to the principals of a "Smart City" since it will allow the City to use information and communication technology to improve traffic services. Several features or enhancements can be added to not only enhance the benefits but also assist engineers and operators by adding increased functionality. This section presents features and technologies that should be considered for the system.

6.2 Adaptive Signal Control

Poor traffic signal timing contributes to traffic congestion and delay. Conventional signal systems use pre-programmed, daily signal timing schedules. Adaptive signal control technology adjusts the timing to accommodate changing traffic patterns and ease traffic congestion. The main benefits of adaptive signal control technology over conventional signal systems are that it can:

- Continuously distribute green light time equitably for all traffic movements
- Improve travel time reliability by progressively moving vehicles through green lights
- Reduce congestion by creating smoother flow
- Prolong the effectiveness of traffic signal timing

Adaptive Signal Control Technologies (ASCT), in conjunction with well engineered signal timing, can adjust to actual conditions. By receiving and processing data from strategically placed sensors, ASCT can determine which lights should be red and which should be green. ASCT has been found to improve the quality of service that travelers experience on local roads and highways.

The process is relatively simple. First, traffic sensors collect data. Next, traffic data is evaluated and signal timing improvements are developed. Finally, ASCT implements signal timing updates. The process is repeated every few minutes to keep traffic flowing smoothly. On average, ASCT has been found to improves travel time by more than 10 percent. In areas with particularly outdated signal timing, improvements can be 50 percent or more. It is our opinion that the City of Hudson could improve travel time by more than 15 percent using ASCT based upon a Synchro analysis performed for this project. The results of this analysis can be found in **Appendix E**.

The traditional signal timing process is time consuming and requires substantial amounts of manually collected traffic data. Traditional time-of-day signal timing plans do not accommodate variable and unpredictable traffic demands. This produces customer complaints, frustrated drivers, and degraded safety. In the absence of complaints, months or years might pass before inefficient traffic signal timing settings are updated. With ASCT, information is collected and signal timing is updated continually.

Special events, construction, or traffic incidents typically wreak havoc on traffic conditions. While large-scale construction projects and regular events can be anticipated, determining their impact on traffic conditions can be extremely difficult. Other disruptions, such as crashes, are impossible for time-of-day signal timing to accommodate.

Outdated traffic signal timing incurs substantial costs to businesses and consumers. It has been estimated that they account for more than 10 percent of all traffic delay and congestion on major routes alone. For consumers, this causes excess delays and fuel consumption. For businesses, it decreases productivity and increases labor costs.

According to the Texas Transportation Institute, the cost of traffic congestion is $87.2 billion in wasted fuel and lost productivity. That translates to $750 per traveler.

Outdated signals also affect costs. Personnel must respond to citizen complaints when traffic signals do not meet traveler needs. Personnel compile the data for transportation specialists or consultants who then analyze the data and develop updated signal timing using the traditional signal timing process before generating their recommendations. Because these specialists must balance the needs of one intersection against system requirements, this is time consuming as well as expensive.

With ASCT, the data collection and analysis are done automatically. More important for travelers, signal timing updates are made as situations occur—topping many complaints from ever happening.

Implementing ASCT can maximize the capacity of existing systems, ultimately reducing costs for both system users and operating agencies.

Many choices are available from many vendors, with more in development. Available adaptive signal control technologies include the Split Cycle Offset Optimization Technique (SCOOT), Sydney Coordinated Adaptive Traffic System (SCATS), Real Time Hierarchical Optimized Distributed Effective System (RHODES), and Optimized Policies for Adaptive Control (OPAC) "Virtual Fixed Cycle", ACS Lite and CENTRACS including Signal Performance Measures (SPM) with Background Plan Generator (BPG).

FHWA, in their 2007 Traffic Signal Report Card, released by the National Transportation Operations Coalition (NTOC), assigned an overall grade of "D" to traffic signal operations practices in the United States, indicating that "agency programs that support efficient maintenance and operations of traffic signals are not as effective as they could be."

It is estimated that, on average, travelers spend 36 hours per year in traffic tie-ups. For urbanites, the number is much higher. Collectively, Americans spend nearly 4.2 billion hours sitting in backups. Implementing ASCT can help improve customer satisfaction scores.

“Smart City” adaptive signal control technologies are also kinder to the environment. Using ASCT can reduce emissions of hydrocarbons and carbon monoxide due to improved traffic flow.

An example of adaptive signal control technology in Ohio can be seen working in the Cities of Brunswick, Westlake and Beachwood. In Brunswick, the system improved traffic flow conditions by reducing average delay by 47 seconds per vehicle, reducing stops by 0.75 stops per vehicle and by reducing travel time by 31 seconds per vehicle.

The City of Westlake found similar results on seven major corridors that have an average daily traffic volume that range from 14,000 to 29,000 vehicles per day. The City was being faced with traffic congestion conditions created by the newly constructed Crocker Park retail center, the influx of more employees to the relocated American Greetings business and the expansion of other businesses such as Hyland Software. Other traffic generating developments such as the new Cuyahoga County Community College was expected to increase traffic volumes in the City. These developments led to the City choosing a more robust traffic control system using ASCT to manage traffic conditions.

The City of Beachwood was able to obtain an average delay reduction of 18 seconds per vehicle, 0.3 stops per vehicle and travel time reduction of 30 seconds per vehicle on a portion of the Chagrin Boulevard corridor in the Village of Woodmere. This portion of Chagrin has an average daily traffic volume of approximately 30,000 vehicles per day and ASCT is being used as a "stop gap" measure until capacity widening can be constructed to alleviate traffic congestion in this community.

An estimate of expected improvements for the City of Hudson was determined from a Synchro analysis. The results are provided in **Appendix E**. The following benefits were estimated for the ASCT system:

MOE (Measures of Effectiveness)	***Existing Peak Hr***	***Expected Future Peak Hr***	***Improvement***
Total delay/vehicle (sec/veh)	26	18	-30.8%
Total delay (hrs)	196	137	-30.1%
Stops (#)	14,363	12,910	-10.1%
Average speed (mph)	16	19	18.8%
Fuel consumed (gal)	467	414	-11.3%
Fuel economy (mpg)	12.4	14	12.9%
CO emissions (kg)	32.7	28.9	-11.6%
NOx emissions (kg)	6.4	5.6	-12.5%
VOC emissions (kg)	7.6	6.7	-11.8%

6.3 Traffic Surveillance & Census

The automated collection, analysis and storage of traffic data can be one of the benefits of a centralized traffic control system. The installation of detectors can be used to provide full lane traffic counts. This would enable the collection of traffic data on all major routes throughout the City of Hudson for planning and operations. There are also opportunities to collect data on traffic entering and exiting the City by placing count stations on arterials at the Cities boundaries.

Finally, specialized traffic count data can be collected at intersections to determine operational capacity by measuring turning and through movements individually. All of this data can be used to evaluate the efficiency of the new control system.

6.4 Custom System Report

Reports are generated for most activities implemented by the system. It is possible and could be advantageous to be able to pick and choose data from different system reports to format and customize reports. It is recommended that reporting features for the system include structured query language (SQL). SQL is a relational database access language and is essentially a core group of standard commands to which product vendors add extensions. Customized reports can be used for many purposes such as intersection inventories, utility usage, timing plan development and presentations.

The Federal Highway Administration (FHWA) is promoting “automated traffic signal performance measures” (ATSPMs) as a means to improve on the traditional re-timing processes by providing continuous performance monitoring capability. Signal re-timing efforts can be based directly on actual performance without dependence on software modeling or expensive, manually collected data.

ATSPMs consist of a high-resolution data-logging capability added to existing traffic signal infrastructure and data analysis techniques. This provides agency professionals with the information needed to pro-actively identify and correct deficiencies. They can then manage traffic signal maintenance and operations in support of an agency's safety, livability and mobility goals.

The technology is cost effective, as ATSPMs can be applied to a wide range of signalized intersections and use existing infrastructure to the greatest extent possible. ATSPMs will also support the validation of other technologies and operational strategies, such as adaptive signal control and emerging connected vehicle applications.

The benefits are:

- **Increased Safety**. A shift to proactive operations and maintenance practices can improve safety by reducing the traffic congestion that results from poor and outdated signal timing.
- **Targeted Maintenance**. ATSPMs provide the actionable information needed to deliver high-quality service to the community, with significant cost savings to agencies.
- **Improved Operations**. Active monitoring of signalized intersection performance lets agencies address problems before they become complaints.

This "Smart City" technology is the outcome of a collaboration among FHWA, the American Association of State Highway and Transportation Officials (AASHTO), state departments of transportation (DOTs) and academic research efforts. Most recently, a study, "Traffic Signal Systems Operations and Management," led by the Indiana DOT with participation from the FHWA, 11 state DOTs, and the City of Chicago, produced an open source software option that provides a framework for continued innovation in data analysis techniques.

The traffic data and resulting charts from ATSPMs can be monitored by the City Traffic Engineer and it will indicate "hot spots" of congestion that should be looked at further. The program "transforms qualitative and quantitative data into actionable information". This program provides a definite step towards integrating continuous traffic data into quick changes to the traffic network which is integral to the "Smart City" concept. Currently Purdue University, is developing guidance on the Performance-Based Management of Traffic Signals, which will describe signal performance measures, how they are derived, and how they can be applied to improve the performance of signal systems. The guidebook, due to be completed in spring 2018, will outline for agencies and practitioners how to select, implement, and apply ATSPMs to a signal system – large or small.

The typical process consists of selecting a traffic signal location on a map, selecting an available metric from a list, selecting a time and date range and then creating a chart to review before and after conditions. As an a example, a complaint may have been received regarding a traffic signal with a long main street red condition at 2 AM. The chart may show the video detection not working in that time period. Maintenance can be sent to investigate and make repairs and a new metric chart can be created to show that the system is now operating. Another example may be a complaint of long queuing and short green time during the PM peak period. A metric chart created could show that an adjustment to a signal timing parameter could influence the signals ability to extend the green time more efficiently. A metric chart, prepared after the adjustment, will show the green time is being extended to reduce queuing effects. The metrics can also provide alerts on the health of the system such as identifying when data collection is not occurring, there are too many pedestrian activations at a location or a vehicle detector is stuck on.

6.5 Intelligent Transportation System Technologies

Intelligent transportation systems (ITS) provide a wide range of traffic based services through the use of advanced technologies. Three ITS technologies; closed circuit television surveillance, dynamic message sign display and environmental monitoring, may be appropriate for future application in the City of Hudson. Closed circuit surveillance cameras have been used primarily to monitor freeway conditions, however, as more cities become interested in achieving peak performance of their computerized traffic signal system, there is increasing interest in using wide area surveillance cameras to monitor traffic conditions on primary surface streets and diversion routes. Wide area surveillance can also be used to adjust signal timing to improve intersection capacity, identify and monitor incidents and to coordinate incident response activities. Twenty-four hour surveillance is not necessary for day-to-day operation.

ITS technologies can also be used for environmental monitoring. Monitoring weather conditions and air quality has become an important feature of traffic control systems. The detection of snow and ice for snow removal efforts is also becoming an increasingly efficient tool for maintenance staffs.

Another benefit of this feature is the ability to adjust signal timing plans based upon detected information. Some cities monitor vehicle emissions for use in evaluating the efficiency of the new control system.

The City of Hudson should strongly consider the use of CCTV cameras and other technologies in the new system so that they may be implemented in the future.

6.6 Autonomous Vehicle Considerations

Recent research on autonomous vehicles have suggested that self driving vehicles are expected to not be available until 2020 but it may not be until 2030 or 2040 before they are commonplace. The National Highway Traffic Safety Administration (NHTSA) has defined five layers of autonomous vehicles with each level providing less motorists control of the vehicle. The five layers which have been defined are as follows:

No Automation (Level 0)	All systems controlled by humans
Function-specific Automation (Level 1)	Certain systems, such as cruise control or braking, may be controlled by a car
Combined function Automation (Level 2)	The car can control two simultaneous functions, like acceleration and steering, but requires humans for safe operation
Limited Sel-Driving Automation (Level 3)	The car can manage all safety-critical functions, but the driver is expected to take over when alerted
Full Self-Driving Automation (Level 4)	The car is completely capable of self driving

Unfortunately, the higher the level of autonomy, the less trusting the American public is of the vehicle, especially after the recent fatalities which have been accredited to self-driving vehicles. If the integration projections are accurate, then it is feasible that the City of Hudson would not expect a large increase in the capacity on it's roadways until 2030 and probably no sooner. The autonomous vehicles will all travel through the city with very little head room between vehicles and will communicate with the adaptive signals in order to adjust travel speeds to insure less delay at upcoming signals. But this anticipated reduction in congestion will be contingent on a large number of self driving cars being purchased and the level or autonomy reaching level 3 or higher. It is currently unclear if this will occur in the very near future.

6.7 Ride Hailing Service Considerations

One promise of ride-hailing companies like Uber and Lyft was fewer cars creating congestion on city streets. However, current research suggest the opposite. Ride-hailing companies may be reducing bus ridership and reducing the number of bicycle trips. Recent reports are showing ride sharing is actually increasing congestion of roadways compared to the anticipated reduction which was expected. The study found that ride sharing companies are adding 2.8 miles for every 1 which is saved. This is primarily due to approximately 60% of ride sharing customers would have used public transportation, walked or bicycled if ride-hailing service was not available. The increase in congestion is also contributed to ride-hailing drivers having to drive around waiting for customers and the delay caused when they stop to pick up people. The creators of the ride sharing platforms are anticipating that people will in the future stop needing their own vehicle which will remove additional vehicles from roadways but the initial findings are not confirming these assertions. We do not anticipate the City of Hudson will see any improvements to travel times on the congested roadways due to ride-hailing services.

6.8 Recommendations

Based upon the review of the various technologies and the review of the existing traffic control infrastructure, it is recommended that a central signal control station with adaptive control and

ATSPM's be pursued, specified and implemented. Under a centralized adaptive system configuration, the central computer stores timing plans and based upon time of day schedules or traffic responsive parameters, will send plan information to the traffic signal controller. The traffic signal controller stores the cycle length, offset and split data for each timing plan and responds to commands from the central computer. The central computer monitors the operation and acknowledges malfunctions of the traffic signal controllers. Under traffic responsive control, the system collects and processes system detector data, identifies the correct timing plan to implement and transmits the proper command to implement the signal timing plan to each controller. On-street master units, such as the one employed by the existing systems on North Main Street (SR 91) and SR 303, will no longer be needed.

The centralized adaptive system will provide a level of control that meets the present and future control system needs. The flexibility of the recommended system provides the City's staff the ability to implement specific features such as upload/download capabilities while allowing future integration of other special features. In order to obtain adequate, up-to-date traffic data, it is recommended that stop bar, set back and down stream detectors be installed on each mainline travel lane of all coordinated intersections. It is estimated that 190 advanced detection zones will be necessary in order to initiate the features of an adaptive control algorithm.

The system should be outfitted with technologies to utilize CCTV cameras for area wide surveillance and monitoring at critical areas of high vehicular traffic. Finally, it should have the ability to monitor environmental conditions that affect traffic flow and efficiencies.

The system would be expected to reduce congestion and move traffic through the SR 91 and 303 corridors more efficiently. It is also expected that improvements in delay, travel time and stop reductions could be realized in a magnitude equal to those other communities discussed in section 6.2. Congestion reduction can be expected to result in an improvement in safety. It is expected that the number of yearly motor vehicle crashes will be reduced.

7. SUMMARY OF RECOMMENDATIONS & NEEDS

7.1 Introduction

The goal of this report is to make recommendations for the upgrade to City of Hudson's traffic control system which will provide safety, efficiency, conservation as well as reduce liability, operation and maintenance costs. These goals include;

7.1.1 Safe and reliable control and coordination of intersections

7.1.2 Efficient and economical equipment maintenance

7.1.3 Operations monitoring capability

7.1.4 Flexibility in providing and revising traffic signal timing

7.1.5 Economical system integration and expansion

This section summarizes the various recommendations made in this report and ties them into a system recommendation which should meet the City's goals. The recommendations include short term, low cost to long term, higher costs improvements.

7.2 Needs

This report has identified certain needs that meet the goals established above in section 7.1 The following recommendations were made.

7.2.1 Construct improvements and implement traffic responsive operation in the City's closed loop signal systems on State Route 91 and State Route 303 as a low cost immediate solution. The improvements will include the construction of approximately 16 downstream system detectors on State Route 91 and 8 downstream system sensors on State Route 303. A consultant proficient in programming and implementing traffic responsive operation should be retained to make the system operational and provide a report detailing the attained efficiencies of the implementation.

7.2.2 Install an advanced central signal system control station (CSSCS) in order to bring 14 existing signal controllers under a single operational system and prepare for future additions and expansions wherever they may be needed. Procure software for the CSSCS that will allow the system to run adaptive operational technologies. Install approximately 80 vehicle detectors on State Routes 91 and 303 in order to implement the adaptive algorythms. Each mainline travel lane will require a stop bar, set back and downstream detector. Connect the signalized intersections on State Route 91 from Prospect Street to Georgetown Road and on State Route 303 from Old Mill Road to State Route 91 to the CSSCS. Utilize the City's existing fiber optic cable system to provide the interconnection between the CSSCS and the signalized intersections. The traffic signal controllers should be upgraded with NEMA TS-2 which are ATC compliant. All traffic signal controllers should be upgraded to include network addressable components to communicate with the system. Install CCTV cameras at the SR 91 / SR 303 signalized intersection for traffic surveillance and traffic flow monitoring. This recommendation could be performed as an interim solution or as part of a City Wide project funded through State or Federal programs.

7.2.3 Upgrade all signalized intersections where there is non-compliance issues with the **Ohio Manual of Uniform Traffic Control Devices**, **Americans with Disabilities Act** and current traffic signal design standards. This would be a high cost, long term improvement or could be performed over several years in individual project but would include:

7.2.3.1 Mast arm signal supports should be installed at all intersections that are currently using strain wire supports (4 locations). Existing signalized intersections that already have mast arm signal supports should be evaluated for loading conditions to use back plates on vehicle signals. Mast arms that do not meet recommended design values for loading should be replaced. Defective or non-standard back plates should replaced with louvered and reflective units.

7.2.3.2 Curb ramps at fourteen of the twenty-one signalized intersections should be upgraded to ADA standards. It is estimated that 38 curb ramps may need to be re-constructed or improved.

7.2.3.3 Vehicle and pedestrian signals at eight signalized intersections should be retro-fitted or replaced to LED technology. It is estimated that 51 red, yellow and green lenses will need to be re-lamped along with 11 green and yellow arrow lenses and 10 walk and don't walk lenses.

7.2.3.4 Uninterrupted power supplies should be installed at seventeen signalized intersections.

7.2.3.5 Pedestrian signals at signalized intersections should be installed as or up-graded to countdown type.

7.2.3.6 All pedestrian pushbuttons at the signalized intersections should be installed with or up-graded to include indicator pilot lights.

7.2.4 Connect the remainder of the City signalized intersections; 7, to the CSSCS installed as part of item 7.2.2 as City's fiber network expands to area where the signals reside or as part of a State of Federally funded project to install additional fiber interconnect cabling. CCTV cameras should be installed at the SR 303 / Terex Road intersection near the SR 8 interchange.

7.3 Estimated Construction Costs

7.3.1 Low cost immediate improvements and implementation of traffic responsive operation in the City's closed loop signal systems on State Route 91 and State Route 303 (14 locations).

Install Downstream System Detection $40,000.00
Systems Analysis, Set-up & Programming $25,000.00

Total Construction Costs $65,000.00
Contingencies (20%) $13,000.00
Engineering Design. . . . . est $25,000.00

Total Project Cost $103,000.00

7.3.2 Medium cost, interim solution with local funding to install an advanced central signal system control station (CSSCS) at 14 existing signalized intersections using adaptive control.

Central Control System & Software $175,000.00
Advanced Detectors for Adaptive Control $190,000.00
Upgrade Traffic Signal Controllers (14 Locations) $210,000.00
Video Surveillance (1 Locations) $30,000.00
Interconnect Existing Signals for Coordination & Monitoring utilizing City's Fiber Network $50,000.00
Systems Analysis, Set-up & Programming $50,000.00

Total Construction Costs $705,000.00
Construction Engineering (10%) $70,500.00
Total Construction Costs & Construction Engineering $775,500.00
Contingencies (5%). $38,775.00

Total Project Construction Costs $814,275.00
Engineering Design. . . . . est $165,000.00

Total Project Cost $979,275.00

7.3.3 High cost, long term solution with State of Federal funding to upgrade the City's 21 signalized intersections, install additional fiber network to connect the remainder of the City traffic Signals to the City's central signal system control station (CSSCS).

Replace Traffic Signals Poles at Span Wire Locations (4 Locations) . . $800,000.00
Upgrade Curb Ramps (14 Locations) $38,000.00
Install New Cabinets & UPS (21 Locations) $380,000.00
Upgrade Pedestrian Signals to Count-Down & Vehicle Signals to LED
Lenses $100,000.00
Upgrade Pedestrian Push Buttons with Pilot Lights $10,000.00
Bicycle Detectors (20 detectors). $40,000.00
Upgrade Traffic Signal Controllers (7 Locations) $105,000.00
Video Surveillance (1 Locations) $30,000.00
Interconnect Existing Signals for Coordination & Monitoring with Expanded City's
Fiber Network. $300,000.00
Systems Analysis, Set-up & Programming $25,000.00

Total Construction Costs $1,828,000.00
Construction Engineering (10%) $182,800.00
Total Construction Costs & Construction Engineering $2,010,800.00
Contingencies (5%). $100,540.00

Total Project Construction Costs $2,111,340.00

Engineering Design. . . . . est $317,00.00

Eligible AMATS Federal Grant (80% of Total Construction)
If Approved $1,689,072.00
Current Local Construction Participation $422,268.00

It should be noted that right of way and environmental documentation costs are not known at this time. These would be evaluated in the engineering design stage of the project. If the project can be constructed within the existing right of way, these costs will be minimal. It should be noted that the medium cost and high cost projects could be combined into a single project for either total local or combined local / Federal funding.

7.4 Benefits and Costs

The Ohio Department of Transportation (ODOT) has developed a methodology to estimate the benefits which can be attributed to the signal improvements along a corridor. An analysis was preformed to determine the expected benefits from the recommended project. The results of the analysis for the recommended City of Hudson signal system and its benefits are shown in **Appendix F**.

The reduction of delay along the State Route 91 and 303 corridors is expected to save motorists a combined 18,633 hours of time sitting in traffic which is a savings of $364,326 annually, based on the calculations developed by ODOT. The 71,444 gallons of gas, which is saved by reducing stopped, idling time, is expected to be a savings of $135,744 per year based upon a $1.90 a gallon price of fuel. The reduced in congestion is expected to cause a savings of 5.3 kg of emissions which calculated to be an estimated savings of $7,159 per year.

It is estimated that the new signal system, when operating under “adaptive signal control technology, will result in a reduction in delay and congestion and may potentially eliminate 10 crashes along the corridor per year. This reduction in crashes was calculated to be a benefit of $172,613 per year.

The Hudson ASCT system could result in a combined savings of $679,842 per year. The savings for a ten (10) year design life of the system is calculated to be $6,798,420. The benefit to cost ratio was found to be 2 to 1. This is illustrated in **Appendix F**

7.5 Funding, Timetable & Delivery Strategy

Funding for these types of project, magnitude and scope is eligible for Federal participation through a grant from Akron Metropolitan Area Transportation Study (AMATS). The funding would be through the Congestion Mitigation Air Quality (CMAQ) program.

It is recommended that the City of Hudson pursue the funding by making application as soon as possible. Applications are due before June of each year. It is estimated that the process and design will take approximately 5 years before construction activities begin after approval of the funding by AMATS. A copy of AMATS application for this funding is provided in **Appendix G**.