Concept of Operations
Pedestrian Safety in Detroit, Michigan

Prepared for the NOCoE Transportation Technology Tournament

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Description of Problem

Scope of the Site

The City of Detroit has one of the highest fatal crash rates in the country, possibly resulting from overbuilt streets promoting speeding and the inability to enforce red-light and speed violations. In addition, Detroit has a challenging landscape, aging infrastructure, and neighborhoods that need reinvestment. The proposed project will take place in four neighborhoods: Southwest Detroit, the Riverfront, Corktown, and Livernois-McNichols.

Southwest Detroit

Figure 1 shows the Southwest Detroit corridor. Southwest Detroit has a growing neighborhood population and relatively high population density for the City. There are 14 traffic signals along the target corridor of this neighborhood that currently have no communication capabilities. Signals are not coordinated and the City relies on public reporting of issues such as signal outages.

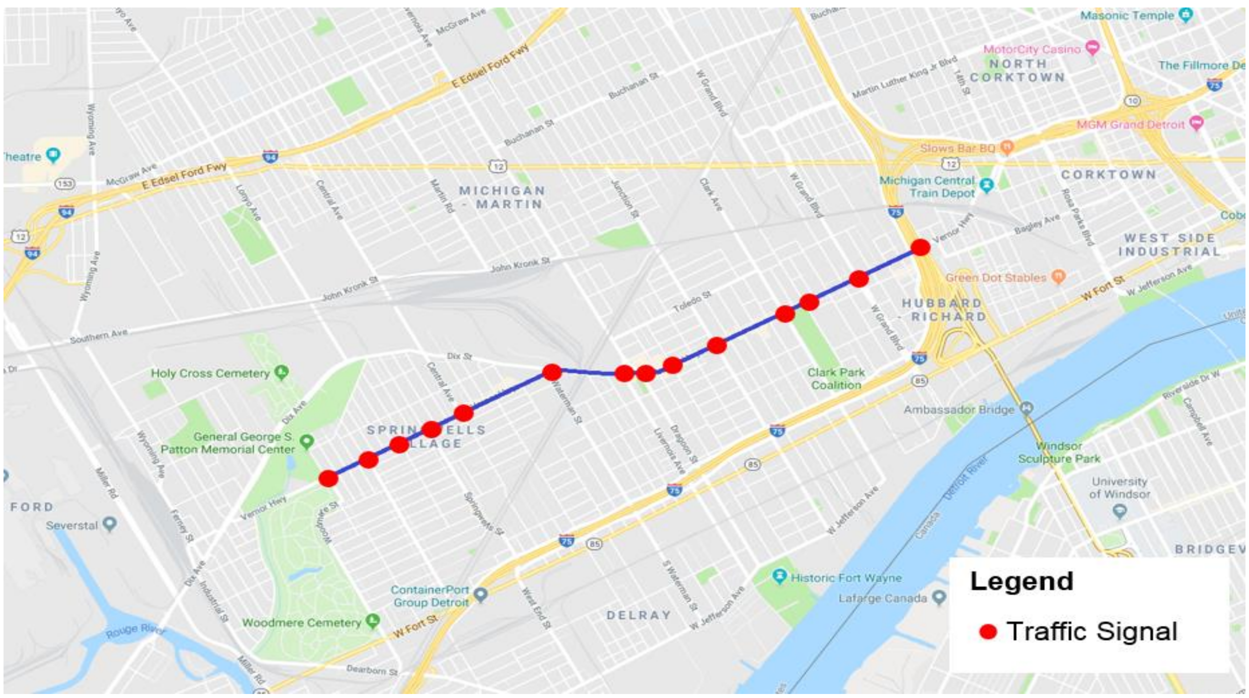

Figure 1: Southwest Detroit

East Riverfront

Figure 2 shows the East Riverfront corridor. Similar to Southwest Detroit, the 28 signals along the target corridor in East Riverfront currently have no communications capability. There is also no automated pedestrian crossing, and pedestrian crossing relies on push button technology which may malfunction and require public reporting for the City to become aware of repair needs. East Riverfront is the major commuter arterial route from Downtown to Grosse Pointe and currently has up to 9 lanes of traffic.

Figure 2: East Riverfront

Corktown

Figure 3 shows the Corktown corridor. The target corridor in the Corktown area is a state-owned road, with 3 signals that again, have no communication capabilities. Development of businesses and restaurants in recent years has increased pedestrian traffic and risk of conflict. This corridor features protected bike lanes, and parking is allowed on both sides of the street.

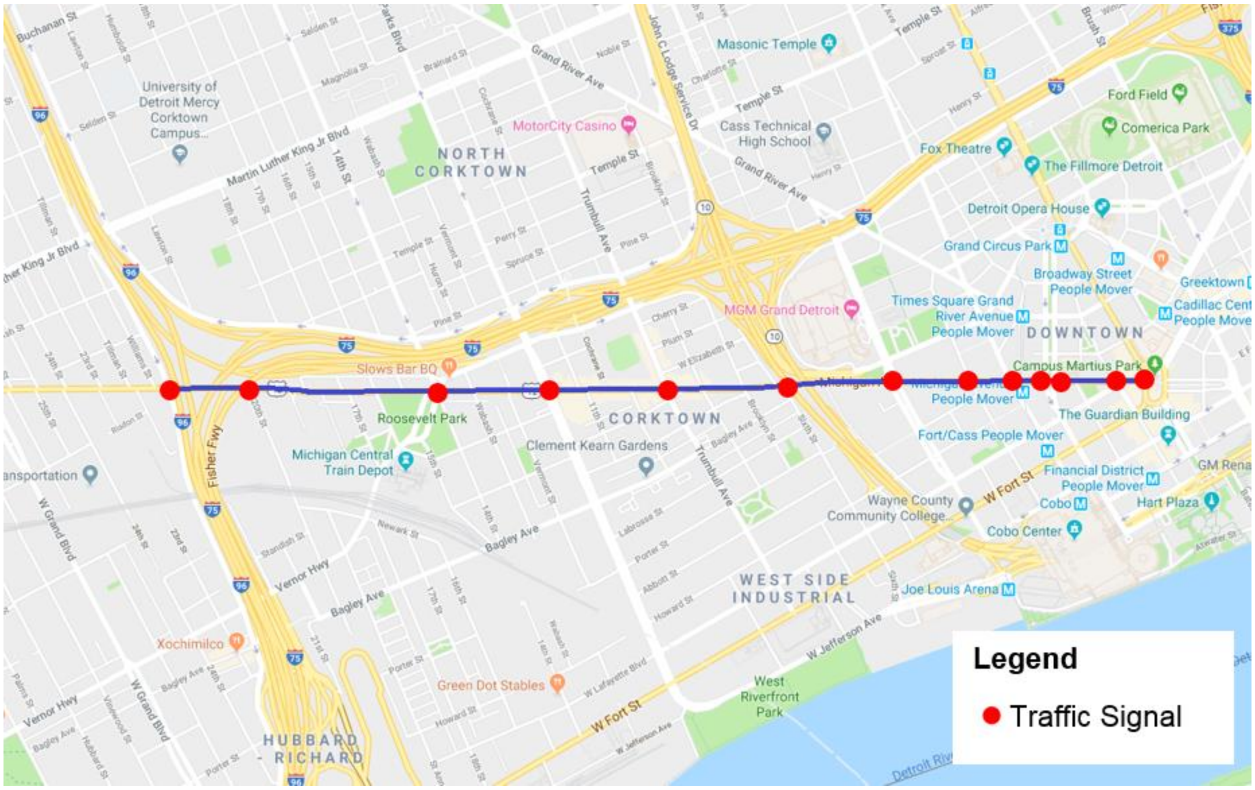

Figure 3: Corktown

Livernois-McNichols

Figure 4 shows the Livernois-McNichols corridor. Livernois-McNichols provides multi-modal commuter connection to the surrounding cities and suburbs of Detroit. This corridor also crosses multiple freeways and a railway, and passes between two academic institutions. There are 11 traffic signals and 2 pedestrian hybrid beacons along this corridor, with one parking lane in each direction of traffic and a 22’ median.

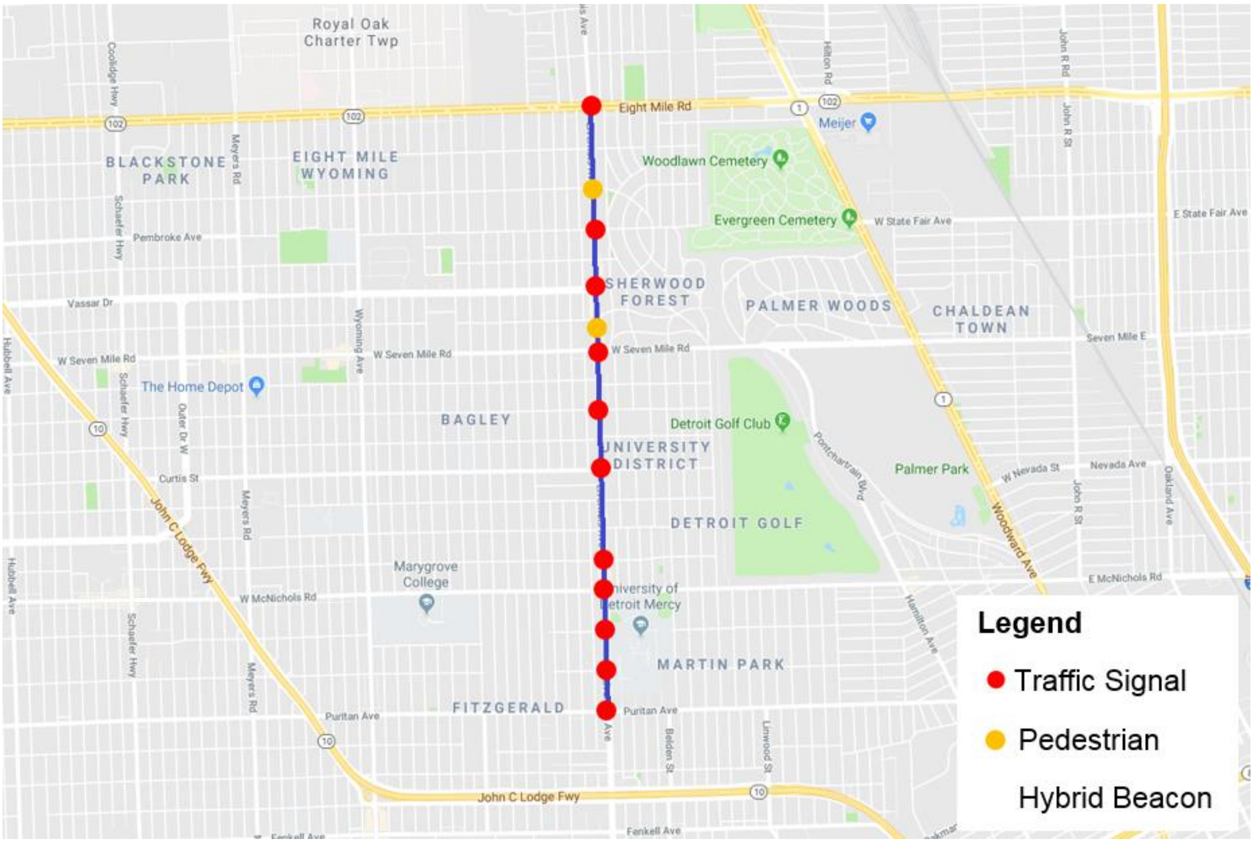

Figure 4: Livernois-McNichols

Requirements for the Solution

The solution to Detroit's pedestrian safety problems should improve safety, efficiency, and the environment.

Safety Requirements

- Reduce intersection crashes by 20%
- Reduce emergency response time by 1-2 minutes

Efficiency Requirements

- Reduce congestion and intersection delay by 30%
- Improve traffic operations maintenance efficiency by 40%

Environment Requirements

- Reduce greenhouse gas emissions by 3-5%

Additional Requirements

- The solution should be equitable, serving a broad range of demographics and mobility conditions in Detroit.
- The solution should use technology-compatible equipment that can be integrated with Detroit's legacy controllers and equipment.

Stakeholders

City of Detroit

Multiple departments in the City of Detroit are responsible for improving mobility. These departments include the Office of Mobility Innovation, the Department of Public Works, the Department of Planning and Development, the Department of Innovation and Technology, and the Department of Transportation (public transit). The Office of Mobility Innovation will be the lead department for the City of Detroit.

Partner Agencies

In addition, there are several partner agencies. The Michigan Department of Transportation and the Southeast Michigan Council of Governments (Detroit's metropolitan planning organization), will work with the City of Detroit to implement ITS solutions.

The City of Detroit can partner with the Argonne National Laboratory to expand the pilot deployment of the Array of Things to the four neighborhoods proposed for this project. The Argonne National Laboratory is a multidisciplinary science and engineering research center managed by UChicago Argonne, LLC, for the US Department of Energy's Office of Science [1].

Private sector partners can assist the City of Detroit with providing the technology to implement ITS solutions. These partners include traffic equipment vendors, autonomous and connected vehicle companies, and communications companies.

Description of Solution

We propose a suite of intelligent transportation systems that perform together to improve pedestrian safety in Detroit, while also providing a backbone for future ITS projects. These technologies include using dedicated short range communications, intelligent roadside units with processing centers, high-resolution video cameras, Array of Things sensors, and in-vehicle sensors and other communication devices. Pedestrian safety will improve if these technologies work together to detect pedestrians, cyclists, and other vulnerable road users, and communicate this information to connected vehicles.

DSRC and Cell Communications

Dedicated Short Range Communications (DSRC) is a two-way short- to medium-range wireless communications capability that permits very high data transmission critical in communications-based active safety applications [2]. The City of Detroit is planning to install DSRC at 66 intersections, which will serve as a communications backbone along the four corridors.

With DSRC, information from video cameras, traffic signals, cars, buses, freight trucks, emergency vehicles, and personal mobile devices can connect information via a roadside unit processing center. This increases safety for all road users, as information such as basic safety messages, Signal Phasing and Timing, and custom safety, weather, environment, and efficiency messages can be relayed to users.

In the aggregate, with these alerts, people can drive more cautiously, increasing pedestrian safety. For example, if emergency vehicles responding to an incident can send an alert to signals and connected vehicles en-route to the incident, drivers can quickly and safely move out of the way of approaching emergency vehicles, and emergency response times can decrease. All road users will be safer: pedestrians who are waiting to cross the street, emergency vehicle drivers, other drivers, and the people who need assistance.

Implementing DSRC will primarily be the City of Detroit's responsibility. However, construction on road segments under the jurisdiction of the State of Michigan will require coordination with the Michigan Department of Transportation.

High-resolution Video Cameras

High-resolution video cameras will provide a range of functions, from basic surveillance capabilities to more sophisticated functions such as detection and analysis. Surveillance and detection will allow the City of Detroit to optimize the network and implement more complicated traffic signal measures such as traffic counts, incident detection, and intersection control. A network of video cameras throughout the City can replace other detection technologies such as inductive loops and radar. The video cameras will need to be able to withstand the range of weather conditions in Detroit, from intense heat to snowstorms. They will also need to be high-sensitivity, so they can detect vehicles and pedestrians accurately at night and in all weather conditions.

From the video cameras, the City of Detroit can develop applications to detect different types of pedestrians and vehicles, their position and status, and use measures to prevent collisions based on certain cases. One such application is cameras communicating a walk time extension request to the signals when cameras or other sensors detect vulnerable pedestrians and other road users who might need more time to cross the street. If the extension is granted, connected vehicles may receive a message indicating that the walk time has been extended and their red light has been extended. This safety application can also apply in inclement weather conditions such as an icy road that warrants extra time for pedestrians to safely cross the street. This safety application can be extended to help visually-impaired people cross the street safely through audio cues from their mobile device. Detection of pedestrians, cyclists, and other road users in a crosswalk, during a walk signal and non-walk signal, will automatically trigger a notification to connected vehicles, warning drivers of a potential collision. Depending on the autonomous technology, vehicles may automatically brake after the reception of this message.

Another application from the video cameras is the enhancement of pedestrian safety at pedestrian hybrid beacons. At the two pedestrian hybrid beacons located on the Livernois Avenue corridor, video cameras can automatically detect pedestrians that need to cross the street at a beacon. The cameras relay a message to vehicles approaching the crosswalk to stop for a pedestrian. The drivers can also receive a message that informs them when they can proceed through the intersection, as some drivers are unfamiliar with the operation of pedestrian hybrid beacons.

Implementing video cameras will primarily be the City of Detroit’s responsibility. However, installing video cameras on road segments under the jurisdiction of the State of Michigan will require coordination with the Michigan Department of Transportation.

Array of Things Sensors

The City of Detroit is working with the Argonne National Laboratory to deploy Array of Things sensors on the four corridors. Array of Things sensors work like “Fitbits” for the city—instruments that collect real-time data to monitor the city’s environment, infrastructure, and activity to address challenges from air quality to transportation safety. The sensors can supplement the video cameras’ detection capabilities, as they can also detect vehicle and pedestrian traffic.

The sensors can detect the level of lighting on a road segment. If the sensors detect a streetlight outage, this information is communicated to the City of Detroit Traffic Management Center, which can send a maintenance team to repair the light. Street lighting increases pedestrians’ visibility and safety when walking at night.

If transportation data collected by the city is available to the public and an Application Program Interface (API) is provided, the city, its citizens, and developers can build software applications that can increase pedestrian safety using data from the Array of Things and their detection ability.

Implementing the Array of Things will primarily be the City of Detroit’s responsibility. However, if they are placed on state-owned poles or buildings, the City of Detroit will need to coordinate with the Michigan Department of Transportation. The Argonne National Laboratory will assist with the deployment of the sensors and will lead the work involving video analytics.

In-Vehicle Sensors and Communication Devices

Collision avoidance systems use in-vehicle sensors and communication devices. Vehicles with onboard sensors can detect pedestrians and warn drivers to brake to avoid contacting a pedestrian. Depending on the level of automation, braking may also be done automatically. This application can benefit the East Riverfront corridor since it currently has no automated pedestrian crossing allocation and has high car speeds. This application benefits Corktown, as many new businesses and restaurants that draw pedestrians have opened in recent years along the corridor. The Livernois McNichols corridor is located near two academic institutions; systems that warn drivers of pedestrians, especially at night, are important since there is special events traffic and significant student traffic.

Vehicles equipped with communications devices can receive messages about upcoming traffic, construction, and signal phase and timing. Although the timeframe for private vehicles adopting these technologies is uncertain, the City of Detroit can implement these technologies on public vehicles such as transit, emergency, and city maintenance vehicles equipped with in-vehicle. Pedestrian safety will increase if more drivers receive safety messages that encourage them to drive more cautiously.

The implementation of in-vehicle sensors and communication devices is dependent on vehicle manufacturers. However, the City of Detroit can pilot these technologies on city-owned vehicles. The communications infrastructure that vehicles need to communicate and receive messages with the infrastructure depends on the DSRC that is the City of Detroit’s responsibility.

Con-Ops for Solution

High-level Physical Architecture

The physical architecture of the system will leverage the installation of several technologies at intersections, including high-resolution video cameras, sensors, and DSRC-enabled roadside units with processing centers. These technologies will send and receive information with connected vehicles to create a safer environment for pedestrians. The hub of the automatic processes is the DSRC-enabled roadside units with processing centers, which enable the automatic processes to occur. Figure 5 shows the high-level physical architecture for the system.

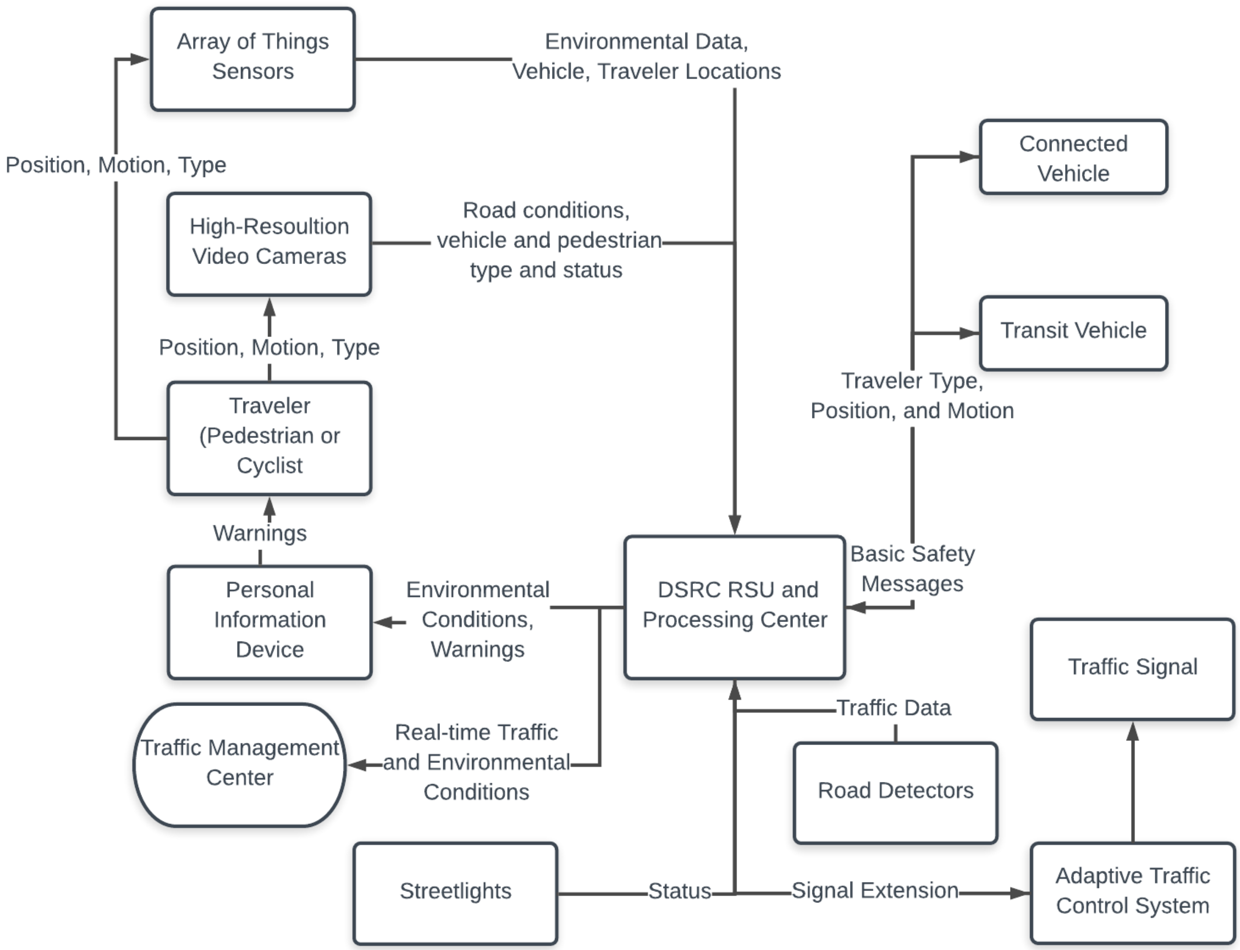

Figure 5: High-level Physical Architecture

High-level Functional Architecture

The functional architecture for the solution brings together several different functional objects from the National ITS Reference Architecture [3]. Functions include sending data from sensors to connected vehicles, collecting environmental data, and triggering walk extensions for vulnerable pedestrians. Table 1 shows the high-level functional architecture for the system.

Table 1: High-Level Functional Architecture

Physical Object	National ITS Reference Architecture Functional Object	Description
ITS DSRC Roadside Equipment	RSE Traveler Information Communications	Distributes information to travelers on road or traffic conditions, environmental hazards
ITS DSRC Roadside Equipment	Roadway Mixed Use Crossing Safety	Detections of cyclists, pedestrians, and other vulnerable road users will be sent to drivers when crosswalks are occupied or a potential conflict will occur
ITS DSRC Roadside Equipment	RSE Traffic Monitoring	Monitors basic safety messages for potential pedestrian conflicts or vehicle collisions
ITS DSRC Roadside Equipment	RSE Intersection Safety	Communicates to approaching vehicles of red lights or pedestrian crossing conflicts
ITS DSRC Roadside Equipment	Personal Traveler Information Reception	Provides environmental warnings to travelers
Traffic Management Center	TMC Data Collection	All system data is collected, sent to the TMC, and stored and analyzed
Vehicle OBE	Vehicle Basic Safety Communication	Sends details of vehicle location and motion to DSRC units
Vehicle OBE	Vehicle Intersection Warning	Vehicle may receive collision warning from DSRC-enable ITS infrastructure related to pedestrian conflicts
Vehicle OBE	Intersection Safety Warning and Collision Avoidance	Receives information from DSRC RSU of vehicle positions and potentially provides warnings
Streetlights	Roadway Lighting System Control	Streetlights automatically alert processing units when streetlights are non-functional
Array of Sensors	TMC Environmental Monitoring	Array of Sensors is able to dedect environmental data inclduing pollution and other hazards and send this back for analysis to the TMC
Array of Sensors	RSE Situation Monitoring	Collects traffic, environmental, and emissions data from passing vehicles
High-Resolution Video Cameras	Roadway Basic Surveillance	Monitors basic traffic conditions
High-Resolution Video Cameras	TMC Basic Surveillance	Sends video data to TMC for analysis
High-Resolution Video Cameras	Personal Intersection Safety	Detects pedestrian and cyclist locations and sends to DSRC RSE
Traffic Signal	RSE Signal Control	Receives walk-signal extension for vulnerable pedestrian
Personal Information Device	Personal Traveler Information Reception	Device receives environmental hazard and traffic data

High-level Enterprise Architecture

The enterprise architecture breaks the system down into the owners of each physical object. The objects are divided into jurisdictions controlled by DOTs, the Traveler, Connected Vehicles, and Transit Vehicle. Figure 6 shows the high-level enterprise architecture of the system.

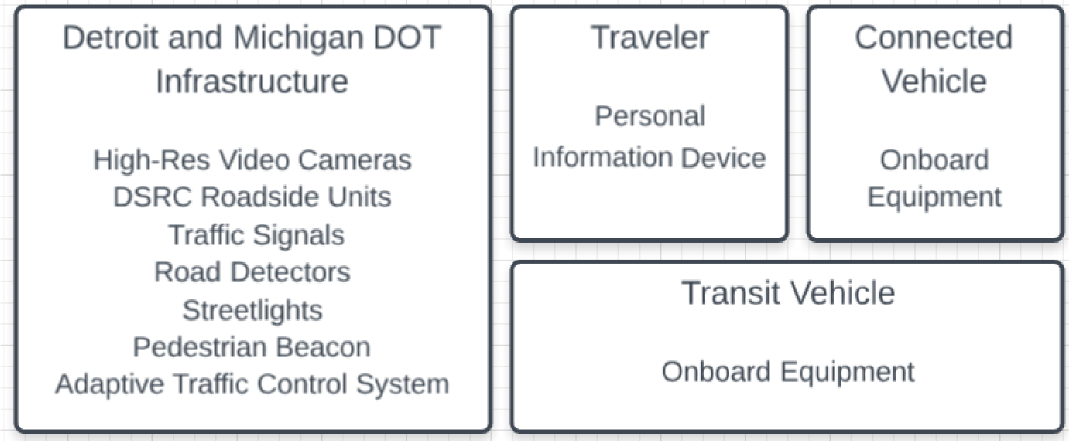

Figure 6: High-Level Enterprise Architecture Diagram

Work Estimate

Cost breakdown

Table 2 is a cost estimate of our solutions. The costs are based on the ITS Costs Database [4].

Table 2: Cost Estimate

	Description	Qty	Unit Price	Subtotal
1	Video Detection	66	$ 87,000.00	$ 5,742,000.00
2	Array of Things Sensor	66	$ 6,200.00	$ 409,200.00
3	Actuated Signal System	66	$ 65,000.00	$ 4,290,000.00
4	DSRC	66	$ 17,600.00	$ 1,161,600.00
			Total	$ 11,602,800.00

Timeline

Year 1
- Traffic signal equipment installation
- Installation of DSRC and processing unit cabinets
- Video-detection equipment installation
- Array of Things Sensors installation

Year 2
- Development of video-based analytics
- Development of safety analytics
- Testing with pedestrians and vulnerable road users

Year 3
- Testing with autonomous vehicles

- Development of safety analytics
- Development of predictive analytics

Anticipated Impacts

Operational benefits

A range of operational benefits result from the proposed ITS solutions. Array of Things sensors, video cameras, and analyzers can help with monitoring and providing the City with information regarding existing infrastructure conditions. This allows the City to be less dependent on public reporting to be become aware of malfunctioning infrastructure. An increase in data will enable the City to perform analysis regarding transportation issues. In-vehicle sensors and communication devices allow the City to more easily disseminate information to users.

Safety benefits

There are many safety benefits from our solutions. DRSC roadside units connect video cameras, lights, and personal mobile devices to information about traffic signals and weather or road detection with vehicles, making streets safer. Video detection will enable incident detection and the development of future applications to detect different types of pedestrians and vehicles to build analytic cases around safety issues beyond reported incidents. Advanced video detection and analytics and the development of V2I applications focused on safety can reduce pedestrian collisions. V2I software will communicate basic safety messages, construction warnings, and Signal Phasing and Timing, enabling drivers and pedestrians to be more aware of their surroundings.

Mobility benefits

Video cameras and analyzers at intersections can reduce traffic congestion and improve mobility, by providing more efficient transportation systems, enabling intersection control, and allowing traffic counts and classification studies to be completed quickly. DRSC and cell communications can collect, disseminate, and use real-time transportation information to reduce congestion and allow users to use the fastest route for their trip. A DRSC mesh network allows for signal communication and coordination amongst signals, decreasing unnecessary delays and unpredictability for pedestrians and bicyclists.

Environmental benefits

By reducing congestion and crashes, this project will reduce emissions, having a considerable impact on the air quality and environment in Detroit. Array of Things sensors can collect data on public health issues, such as asthma, and warn people of poor air quality. City departments could use data on heavy truck traffic and air quality to make decisions about commercial routing that preserve clean air and safe roads in residential neighborhoods.

Other benefits

The chosen corridors are in tipping point neighborhoods, with relatively stable populations and conditions that are positive for economic growth and resident attraction. Deploying mobility solutions in these areas presents the best opportunity for success. The effect of well-lit streets on crime rate varies between different cities, but crime rates can potentially decrease if streets are well-lit [5]. Furthermore, if the project is implemented, Detroit can serve as an example to cities in the Rustbelt and Sunbelt like Atlanta, Orlando, and Memphis. These cities each have dispersed, impoverished, and auto-reliant populations in need of enhanced mobility.

Sources

[1] “Argonne National Laboratory.” (n.d.). *History | Argonne National Laboratory*, <http://www.anl.gov/about-argonne> (May 31, 2018).

[2] “Intelligent Transportation Systems - DSRC: The Future of Safer Driving.” (n.d.). *Intelligent Transportation Systems - Accelerating Deployment*, <https://www.its.dot.gov/factsheets/dsrc_factsheet.htm> (May 31, 2018).

[3] “Architecture Reference for Cooperative and Intelligent Transportation.” (n.d.). *Connected Vehicle Reference Implementation Architecture*, <https://local.iteris.com/arc-it/index.html> (May 31, 2018).

[4] “Knowledge Resources.” (n.d.). *RITA | ITS | Costs: Unit Cost Components for Fiber Optic Cable Installation*, <https://www.itscosts.its.dot.gov/its/benecost.nsf/CostHome> (May 31, 2018).

[5] “Detroit Lights Up Darkened Streets, as Crime Rate Drops.” (2017). *Forensic Magazine*, <https://www.forensicmag.com/news/2017/01/detroit-lights-darkened-streets-crime-rate-drops> (May 31, 2018).