EVALUATION OF INNOVATIVE ROADWAY TECHNOLOGY APPLICATIONS

TECHNICAL MEMORANDUM

WAR-63 PRIORITY PROJECT
WARREN COUNTY, OHIO

Warren County Transportation Improvement District
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PURPOSE OF EVALUATION

This technical memorandum was prepared to identify and evaluate innovative roadway technology applicable to the Warren County AR 63 Priority Project.

RL RECORD LLC conducted a literature search that identified applications of both mature and emerging technologies and concepts in roadway management including traffic, safety, and operations. The scan was limited to technologies and applications relevant to intersections or roadway segments of 3 miles or less.

PART I identifies and describes how innovative roadway technologies could be used to extend the service life of the SR63 priority segment roadway investment, support roadway operations, or improve the safety of the facility.

PART II provides a description of the underlying enabling technologies used to accomplish the operations described in PART I.

PART III provides a screening of the current state of these enabling technologies based on the following criteria:

1. Performance;
2. Life cycle[1];
3. Cross-application potential;
4. Summary of findings.

PART IV evaluates the functional application of these technologies to the Warren County SR 63 Priority Project based on the following criteria:

1. Purpose;
2. Benefits;
3. Enabling technologies;
4. External concerns and requirements;
5. Applicability to the project;
6. Cross-application potential;
7. Timing considerations;
8. Summary of findings.

These documents were reviewed by the Warren County TID, and the Ohio DOT, and were included in stakeholder and public outreach efforts.

The recommendations section contains the distillation of this process and provides the reasoning supporting the selected applications.

[1] Life cycle refers to state of current usage, shelf-life, trend line and trajectory of the technology.

This is followed by a discussion regarding procurement and maintenance considerations for the recommended applications.

PART I

IDENTIFICATION AND DESCRIPTION OF RELEVANT APPLICATIONS OF INNOVATIVE ROADWAY TECHNOLOGIES

The following uses of innovative technologies could extend the service life of the **SR63 priority segment roadway investments**, support roadway operations, or improve the safety of the facility.

1. Variable speed limits
   Variable speed limits are used to adjust legal speed according to weather or congestion conditions in order to improve the safety of the roadway.

2. Smart roadway lighting[2]
   Streetlights, or highway lighting using LED technology can, due to its efficiency and small size, accommodate other sensors or cameras in the pole. These sensors and cameras can be used for a number of data collection and enforcement purposes. Importantly they can be used to adjust the ambient lighting level based on traffic volumes.

3. Smart intersections[3]
   Initially piloted in Detroit during its 2013 bankruptcy to maintain the lights and signals at intersections. Instead of relying on citizen complaints remote monitoring is used to alert the City to maintenance needs. The camera and sensor technology used to remotely monitor faulty equipment offered an enormous number of additional benefits including, smart monitoring of cyclists; fast sophisticated data gathering; sending alerts to connected cars and Waze users that jaywalkers are ahead; and providing priority access for emergency and freight vehicles.

   It is an open architecture-based system so new software applications can be added easily to the existing hardware, enabling constant innovation and improvement of services.

   In Detroit, emergency vehicle response times have improved by 20%, and travel times by 30%.

   System technology includes a-360-degree fisheye camera, smart sensors, and an Internet of Things (IoT) connected hub coupled with video analytics to accurately monitor intersections and analyze data.

[2] Traffic Technology International, January, 2018, Lighting the way, page 053
[3] Traffic Technology International, October/November 2018, Intersection of ideas, page 020

These intersection technologies allow the department to collect crash data in real time to identify problems more quickly. It also allows the City to analyze near misses. As a result, Detroit's pedestrian fatality rate, once the worst in the nation, has decreased by detecting such things as worn pavement markings, malfunctioning traffic signals, jaywalking, and cars making dangerous movements.

Vulnerable road users, cyclists using bike lanes on the road, and the elderly using pedestrian walkways, often move more slowly than the timed signals allow for, benefit because Detroit's system monitors the dilemma zone and can send real time signals to the controller to hold green time, allowing safe passage.

Detroit's system provides real-time tracking of freight vehicles. When loaded with cargo, they get green light priority at certain times of the day, resulting in a roughly 25% reduction in fuel use for heavy trucks.

4. Connected Traffic Signals (CTS)[4]
   CTS provide connected drivers with real-time information about the status of signals they are approaching. The driver is informed about the duration of a red light, and five seconds before it turns green, an alert sounds so the driver can redirect his or her attention from texting to driving. The system tells the driver whether he or she is going to make the light, discouraging the driver from speeding to catch the green and then slamming on his or her breaks. This information enables drivers to become more fuel-efficient and keeps them safer while reducing congestion.

   Super sourcing[5] allows the application to extract signal phase and timing data without a direct feed.

5. Automated traffic signal analysis[6]
   Automated traffic signal analysis relies on a signal control algorithm that allows for vehicle paths and signal control to be jointly optimized based on advanced communication technology between approaching vehicles and the signal controller, with changes made in real-time to intersection function.

6. Smart traffic signals[7]
   Connected vehicles with on-board navigation or a smartphone can be connected to an intelligent traffic light controller, providing the traveler information about signal timing while using the information collected from the vehicles to adjust signal timing and phasing.

7. Automated incident detection (AID)

[4] Traffic Technology International, February/March 2018, Mystery tech makes Manhattan signal data public, page 008
[5] Super sourcing refers to using crowd-sourced data including on-board, blue-tooth, 4G and 5G signals as well as external CCTV feeds.
[6] Signal control optimization in for automated vehicles at isolated signalized intersections, Zhuofei Li, LilyElfteriadou, Sanjay Ranka
[7] Traffic Technology International, February/March 2018, Optimal traffic flow with smart traffic signal, page 074

Automated incident detection is the ability to capture, analyze and report traffic incidents or near misses in real time. Incidents can include such things as a stopped vehicle, queuing, or a person or object in the roadway so that appropriate action might be taken. If combined with communication software, it can communicate this in real time to connected vehicles using OBUs or cellphone applications like WAZE.

One example of the use of AID is to warn connected vehicles of wildlife in, or close to. the roadway.

8. Real-time accident identification and incident management[8]
Real-time accident identification uses AID to notify first-responders when a crash occurs.

9. On-demand hard shoulder running (HSR)[9]
HSR is an active travel demand management strategy that allows traffic to run on shoulders or narrowed lanes during peak periods. It can be combined with variable speed limits. Generally, the speeds are lowered, but the throughput capacity of the facility is increased due to the availability of an additional lane. The shoulders can also be used as transit lanes, freight lanes or HOV/HOT lanes with some design modifications beyond traditional shoulder design.

10. Speed enforcement[10]
Uniform enforcement of speed limits using cameras and Automated License Plate Recognition systems has been shown to substantially reduce crashes, virtually eliminating fatalities connected with speeding. Additionally, uniform speeds increase capacity on the roadway.

11. Traffic data mining and modeling[11]
Traffic data mining allows for the analysis of speed, delay, level of service, volumes, travel time, travel time distribution, mode, and trip types, to create customized models of travel networks that are predictive.

12. Weather conditions monitoring[12]
Weather conditions monitoring involves the use of remote sensors including temperature sensors that measure pavement temperature, air temperature, and humidity, (to determine visibility), and surface state sensors that relay the presence of water, spray, slush, and ice crystals. The surface state sensors measure the level of grip on the road's surface which helps determine at what speed a vehicle may slide

[8] Traffic Technology International, June/July 2018, Real-time information and incident management – a seamless solution, page 065
[9] Federal Highway Administration, Performance Based Practical Design for Operations, Use of Narrow Lanes and Narrow Shoulders on Freeways: A Primer on Experiences, Current Practice and Implementation Considerations, July 2016
[10] Traffic Technology International, August/September 2018, Wee-deployed speed enforcement can help achieve vision zero
[11] Traffic Technology International, February/March 2018, Tailor-made models, page 040
[12] Traffic Technology International, January 2018, Remove winter hazards, page 037

out and thereby safe speeds during inclement weather. This can be used to set Variable Speed Limits, communicate with motorists, and alert maintenance crews.

13. Pavement (roadway) condition monitoring
    Pavement condition monitoring, using sensors or cameras, allows the maintenance agency to remotely monitor pavement conditions for faults such as potholes or guardrail damage and respond pro-actively.

14. Pavement composition
    Use of open-graded bituminous asphalt pavement can allow water to run through the pavement, reducing pooling and increasing motorist safety. It also has the benefit of improving drainage and reducing stormwater runoff.

15. Pavement markings[13]
    Providing lighting from below and beside the motorist instead of using overhead lighting can improve both the motorist experience, and the quality of life in non-urban settings. Advanced glass-bead retro-reflectivity can accomplish this is some applications.

16. Vulnerable road user protection
    Vulnerable road users include slower moving vehicles (electronic scooters), human powered modes of transportation (cyclists, pedestrians, in-line skaters), and at-risk populations (elderly, hearing impaired, vision impaired, smart phone addicts) that are unprotected in a conflict with a vehicle.

    A number of strategies can be applied to protect VRUs including, interactive road surfaces, detection systems, traffic calming methods and enforcement.

17. Three revolutions in transportation (3R) support[14]
    There can (theoretically), be an 80% cut in CO_2 emissions if cities embrace 3 revolutions (3R) in vehicle technology: automation, electrification, and, most importantly, ride sharing**:**

    a. Business-as-usual (BAU) scenario—Through 2050, we continue to use vehicles with internal combustion engines at an increased rate, and use transit and shared vehicles at the current rate, as population and income grow over time. (Estimate 2.1 Billion Vehicles and 4,600 megatons of CO_2 emissions)

    b. 2 Revolutions (2R) scenario—We embrace more technology. Electric vehicles become common by 2030, and automated electric vehicles become dominant by 2040. But we continue to embrace of single-occupancy vehicles, with even more car travel than in the BAU. scenario (Estimate 2.1 Billion Vehicles and 1,700 megatons of CO_2 emissions)

[13] Traffic Technology International, January 2018, Safely guiding drivers at night, page 064
[14] Institute for Transportation and Development Policy, 3 Revolutions in Urban Transportation, May 3, 2017

c. 3 Revolutions (3R) scenario—We embrace of technology in the 2R scenario and then maximize the use of shared vehicle trips. By 2050, cities have ubiquitous private car sharing, increased transit performance—with on-demand availability—and strengthened infrastructure for walking and cycling, allowing maximum shared trip efficiency. (Estimate .5 Billion Vehicles and 700 megatons of CO2 emissions)

18. Transportation (Mobility) as a service (MaaS)[15]

Mobility as a Service refers to the overall integration of all mobility and ancillary digital services. Seven levels of MaaS are recognized:

0. Baseline – There are account-based systems in place – individual modes of transportation already have a digital interface and the traveler has information available on-line or with an app.

1. One-to-one integration between **private services** – Services start to develop joint offerings. For example, private car and ferry, and park-and-ride bus services,

2. Integrated payment and ticketing across modes involving limited public and private modes of transportation – greater integration of services occurs, but now between **privately operated and public transportation services**.

3. Unified interface for a **single account used across multiple modes of transportation services** – instead of having multiple channels, a unified interface across modes, providers, and services, allows the traveler to plan and pay for their journeys.

4. **All modes are integrated, both public and private, including routing, ticketing, and payment** – open data and standards are commonly defined and used.

5. Active artificial intelligence choices are made based on travel preferences and real-time data for ad-hoc changes – based on traveler-specific behavior and profiling, minimal intervention is needed by the traveler for **end-to-end journey decisions**.

6. MaaS **connects beyond mobility,** interfacing with the Internet of Things (IoT), smart buildings, smart roads, and smart cities – Level 6 is the overall integration of all mobility and other digital services. For example, the travelers' smart home recognizes their departure and shuts off lights, locks doors, activates security services, and sets heating and cooling levels. Deliveries of food, groceries, and shopping are coordinated, and tickets for

[15] Traffic Technology International, April/May 2018, Defining Levels of MaaS, page 070

entertainment activities and reservations for sports, dinning, and other entertainment are made and ticketed.

19. Autonomous shuttle service[16]
In June of 2018, Detroit became the first urban center in the US to deploy a permanent, self-driving shuttle route on public streets alongside cars, cyclists, and pedestrians. This allowed a fleet of three-dozen private gasoline powered shuttle buses used to deliver workforce to Quicken Loan's various locations to be replaced by electric autonomous vehicles that operate on a mapped, closed-loop system, relying on lidar (a remote sensing method that uses light in the form of a pulsed laser to measure ranges), radar, camera sensors and radio frequency signals implanted in signs and streetlights along the route.

[16] Traffic Technology International, October/November 2018, AV uptake to Quicken, page 023

PART II

DESCRIPTIONS OF ENABLING TECHNOLOGIES

This section provides a description of the underlying enabling technologies used to accomplish the functions described in PART I.

1. 4G – refers to the fourth-generation broadband cellular network technology. A 4G system must provide capabilities defined by the International Telecommunications Union. Applications include mobile web access, voice over IP, gaming services, HDTV, video conferencing, and 3D television.

2. 5G – refers to fifth generation broadband service. 5G networks achieve much higher data rates than previous cellular networks, up to 10 Gigabytes/second; which is faster than current cable internet, and 100 times faster than the previous cellular technology (4G LTE). Another advantage is lower network latency (faster response time), below 1 millisecond, compared with 30 - 70 milliseconds for 4G. Because of the higher data rates, 5G networks will serve not just cellphones but are also envisioned as a general home and office networking provider, competing with wired internet providers like cable. Previous cellular networks provided low data rate internet access suitable for cellphones, but a cell tower could not economically provide enough bandwidth to serve as a general internet provider for home computers or commercial applications.

   Initial deployment is scheduled for April 2019.

3. Agnostic IT, also open-sourced – In an information technology (IT) context, agnostic refers to something that it is interoperable among various systems. The term can refer not only to software and hardware, but also to business processes or practices, eliminating proprietary systems.

4. Artificial intelligence (AI) – a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation. The goals of AI research include reasoning, knowledge, representation, planning, learning, natural language processing, perception, and the ability to move and manipulate objects.

5. Automated License Plate Recognition (ALPR), also Automated Number Plate Recognition (ANPR) – a technology that uses optical character recognition (OCR) on camera-generated images (CCTV) to read vehicle registration plates and create vehicle location data. ALPR is used by law enforcement around the world for speed and road rule enforcement purposes, vehicle location, and determining if a vehicle is registered or licensed. It is also used for electronic toll collection on pay-

per-use roads and by highway agencies as a method of cataloguing the movements of traffic.

6. Blockchain technology (BC) – is a way for one internet user to transfer a unique piece of digital property to another internet user, such that the transfer is guaranteed to be safe and secure, everyone knows that the transfer has taken place, and nobody can challenge the legitimacy of the transfer.

7. Bluetooth technology (BT) – is a short-range wireless communications technology used to replace the cables connecting electronic devices, allowing a person to have a phone conversation via a headset, use a wireless mouse and synchronize information from a mobile phone to a PC.

8. Closed-circuit television (CCTV), also video surveillance – is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. It differs from broadcast television in that the signal is not openly transmitted, though it may employ point to point (P2P), point to multipoint (P2MP), or mesh (distributed and dynamically configuring) wired or wireless links.

9. Cloud computing – is the on-demand delivery of computing power, database storage, applications, and other IT resources with pay-as-you-go pricing. Cloud computing has three main types that are commonly referred to as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

   Infrastructure as a Service contains the basic building blocks for cloud IT and typically provides access to networking features, computers (virtual or on dedicated hardware), and data storage space.

   Platforms as a service remove the need for organizations to manage the underlying infrastructure (usually hardware and operating systems).

   Software as a Service provides the user with a completed product that is run and managed by the service provider. In most cases, people referring to Software as a Service are referring to end-user applications.

10. Dedicated short-range communication (DSRC) – is an open-source protocol for wireless communication, similar in some respects to Wi-Fi. While Wi-Fi is used mainly for wireless Local Area Networks, DSRC is intended for highly secure, high-speed wireless communication between vehicles and infrastructure. It is the technology upon which autonomous and connected vehicles is based.

11. "Escher" crossings – use of special *trompe l'oiel* artwork to create crosswalks and speed bumps that look three dimensional. Drivers see a three-dimensional crosswalk that appears to float above the surface of the road. Pedestrians look like they are stepping on a series of rocks across a small stream. When viewed from above, the crosswalk looks like a collection of vertical walls.

12. Fiber-optic cable – optical fibers are long, thin strands of very pure glass about the diameter of a human hair. They are arranged in bundles called optical cables and used to transmit light signals over long distances. They are the current day equivalent of an underground "land line" and provide secure communications during most emergency situations.

13. Gateway treatments – Many rural communities have developed around highways or major county roads; as a result, the main street through small rural communities (like the City of Lebanon) is often part of a high-speed rural highway. Highways and county roads are characterized by high speeds outside the city limits; they then transition into a reduced speed section through the rural community. Consequently, drivers passing through the community often enter at high speeds and maintain those speeds as they travel through the community.

    Traffic calming measures include: Bulb-Outs, Neckdowns, Chokers, or Mid-Block Crossings, Transverse Rumble Strips, Chicanes. Landscaping, Center Islands, Community Gateways, Transverse Lane Markings, Surface Treatments, Raised Intersections, Dynamic Speed Displays and Vehicle Actuated Signs, Enforcement, Four to Three-Lane Conversion, Shoulder Widening to Narrow Travel Lanes, Pavement Marking Legends, Roundabouts, Speed Humps and Tables, and Mini-Roundabouts

14. Global positioning system (GPS) – is a global navigation satellite system that provides location and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

15. Infrared wireless technology (IR) – is the use of wireless technology in devices or systems that convey data through infrared (IR) radiation. Infrared is electromagnetic energy at wavelengths somewhat longer than those of red light. The shortest-wavelength IR borders visible red in the electromagnetic radiation spectrum; the longest-wavelength IR borders radio waves.

    Some engineers consider IR technology to be a sub-specialty of optical technology. The hardware is similar, and the two forms of energy behave in much the same way. But strictly speaking, "optical" refers to *visible* electromagnetic radiation, while "infrared" is *invisible* to the unaided eye. To compound the confusion, IR is sometimes called "infrared light."

    IR wireless is used for short- and medium-range communications and control. Some systems operate in *line-of-sight mode*; this means that there must be a visually unobstructed straight line through space between the transmitter (source) and receiver (destination). Other systems operate in *diffuse mode*, also called *scatter mode*. This type of system can function when the source and destination are proximate, but not directly visible to each other.

IR wireless technology is used in intrusion detectors; home-entertainment control units; robot control systems; medium-range, line-of-sight laser communications; cordless microphones, headsets, modems, and printers and other peripherals. Unlike radio-frequency (RF) wireless links, IR wireless cannot pass through walls. Therefore, IR communications or control is generally not possible between different rooms in a house, or between different houses in a neighborhood (unless they have facing windows). This might seem like a disadvantage, but IR wireless is more private than RF wireless. Some IR wireless schemes offer a level of security comparable to that of hard-wired systems. It is difficult, for example, to eavesdrop on a well-engineered, line-of-sight, IR laser communications link.

16. Light Emitting Diode (LED) Lighting

Lifespan – the average LED lasts 50,000 operating hours to 100,000 operating hours or more. That is 2-4 times as long as most fluorescent, metal halide, and even sodium vapor lights, and is more than 40 times as long as the average incandescent bulb. Less frequent replacement means lower maintenance costs in terms of labor and replacement parts.

Energy efficiency – LEDs consume low amounts of power in comparison to other lighting solutions.

Improved safety – LEDs emit almost no forward heat while incandescent bulbs convert greater than 90% of the total energy used directly into heat. Because LEDs consume less power they can operate effectively on low-voltage electrical systems making them a safer option.

Small size – LEDs are adaptable to a wide variety of applications and provide design flexibility. They can be used in isolation or combined in bunches.

Color Rendering Index (CRI) – LEDs have a high CRI, a measurement of a light's ability to reveal the actual color of objects as compared with natural light. This improves contrast, and roadway safety.

Directional Emissions – LED technology emits light for only 180 degrees compared to every other type of lighting which emit light for 360 degrees around the source. This reduces the negative impacts of ambient roadway lighting while increasing efficiency.

Solid State – glass is entirely unnecessary

Dimming Capability – LEDs can operate at a virtually any percentage of their rated power (0 to 100%), are easily dimmed, and they get more efficient as the power is reduced.

LEDs turn on and off instantaneously – frequent switching does not cause degradation in the device.

Environmental Safety – LEDs do not have the environmental issues common to traditional lighting solutions and thus do not require special handling at the end of the product's useful lifespan.

Public Safety – LEDs emit most of their energy in the visible spectrum, a small amount in the infrared spectrum, and virtually none in the ultraviolet portion of the spectrum.

Operating Conditions – LEDs operate on very low voltage making them suitable for use in outdoor lighting applications, and they work well in a wide range of operating temperatures without significant degradation.

Correlated Color Temperature (CCT) – LEDs are available in a wide range of correlated color temperature (CCT) values. They can be purchased with a "warm," yellowish glow, as a "cool," white light and a variety of other options.

17. <u>Live traffic data (LTD)</u> – Equips controllers to provide real-time data that can facilitate:
    - Mapping and navigation to reduce travel times and optimize routing, and provide more accurate ETA information;
    - Speed advisory information to catch the green wave;
    - Countdown to the next traffic signal phase;
    - Stop/start engine synchronized with traffic signal phases (for hybrid and electric vehicles);
    - Optimization of ride-share routes;
    - Optimization of delivery times through efficient routes;
    - Increased ROI of deployed vehicles by reducing labor, fuel consumption and carbon footprint;
    - Usage based insurance to reduce losses from red light running accidents;
    - Determination driver behavior at signalized intersections;
    - Accident reconstruction.

18. <u>Maintenance information system</u> – a GIS based asset management system that tracks road conditions and maintenance needs in real time from sensors and probe inputs.

19. <u>On-board unit (OBU)</u> – signal sending and receiving technology traditionally used in tolling applications (*E-ZPASS*) is increasingly being used in V2V, V2I, and V2X applications and to support autonomous vehicles.

20. <u>Open-graded bituminous asphalt</u> – is a porous asphalt mix formulated to provide large voids (in excess of 20 per cent) to allow surface water to drain through the pavement, increasing safety for the motorist, and improving stormwater management. It reduces

tire splash/spray in wet weather. The high air voids trap tire road noise, reducing it by up to 50-percent (10 dB A).[17]

21. Optical character recognition (OCR) – the identification of printed characters using photoelectric devices and computer software, an early AI application.

22. Pavement loops - Vehicle detection loops, also called *inductive-loop traffic detectors*, can detect vehicles passing or arriving at a certain point, for instance approaching a traffic light or in roadway traffic. An insulated, electrically conducting loop is installed in the pavement. When a vehicle passes over the loop or is stopped within the loop, the vehicle induces eddy currents in the wire loop, which decrease its inductance. The decreased inductance actuates an electronics unit output relay or solid-state optically isolated output, which sends a pulse to the traffic signal controller signifying the passage or presence of a vehicle.

    The relatively crude nature of the loop's structure means that only metal masses above a certain size can trigger the relay. This is good in that the loop does not thus produce very many "false positive" triggers (say, for example, by a pedestrian crossing the loop with a pocket full of loose metal change) but it also means that sometimes bicycles, scooters, and motorcycles may not be detected.

    Inductance loops can also be used to classify vehicle type.

23. Radar – is used to measure vehicle velocity. Additionally, it is used to control traffic light systems, and not just when red lights are run. The traffic light systems can be triggered depending on the measured volume of traffic, including temporary deactivation of the traffic lights when roads are quiet.

    Other radar technologies include vehicle distance measuring systems that display vehicle speeds on mobile signs ("You are driving" signs for example) in traffic-calming zones.

    Radar preserves anonymity, it does not deliver high-resolution pictures of persons & vehicle registration numbers, it provides information on speed and distance, and the detection technology is independent of lighting and weather conditions.

24. Real-time traffic control (RTTC) – uses data collected by field sensors as input to algorithms that uses AI to reprogram controllers in real time.

25. Refuge Island – a section of sidewalk where pedestrians can stop while crossing a road; typically used when a street is very wide, and the pedestrian crossing is too long for some individuals to cross during one traffic light cycle. A refuge island may also be used on roads with higher speed limits.

[17] National Asphalt Pavement Association (NAPA) (1995), *Thin Hot Mix Asphalt Surfacings*, National Asphalt Pavement Association, Lanham, MD.

26. Remote sensors – in remote sensing, a detector is located at a significant distance from a target. The sensor can be part of a radar or satellite system used for surveillance of meteorological and oceanographic conditions. Images and observations from remote sensors are used for weather monitoring and forecasting from local to global scales. Remote sensing is used for quantitatively measuring atmospheric temperature and wind patterns, monitoring advancing fronts and storms (e.g., hurricanes, blizzards), imaging of water (i.e., oceans, lakes, rivers, soil moisture, vapor in the air, clouds, snow cover), as well as estimating runoff and flood potential from thawing.

27. Retro-reflectivity – is an optical phenomenon in which reflected rays of light are preferentially returned in directions close to the opposite of the direction from which the rays came. Increased safety in night driving is achieved using glass beads embedded in paint used for pavement markings. "Next Generation" paint provides increased contrast and "wet reflectivity" during inclement weather.

28. Self-generating pavement studs – solar powered raised pavement markings.

29. Separate facilities – are multi-use paths that separate slower moving and active transportation from the roadway to avoid conflicts and improve safety.

30. Surface state sensors - an in-road sensor that monitors real-time road/pavement surface conditions, detecting temperature, and dry, wet, and ice conditions.

31. Traffic probes – use of mobile phones and on-board units to gather traffic data.

32. Variable message sign (VMS), also changeable (CMS), electronic, or dynamic (DMS) message sign – are electronic traffic signs used on roadways to give travelers information about special events, warn of traffic congestion, crashes, incidents such as terrorist attacks, Alerts, and work zones on a specific highway segment.

    In urban areas, VMS are used as part of parking guidance information systems to direct drivers to available car parking spaces.

33. Variable speed limit signs (VSL) – are legally enforceable traffic signs. Sensors along the roadway detect when congestion or weather conditions exceed specified thresholds and automatically reduce the speed limit (in 5 mph increments) to slow traffic and postpone the onset of congestion.

34. Vehicle to everything (V2X) - Vehicle-to-everything communication is the passing of information from a vehicle to any entity that may affect the vehicle, and vice versa. It is a vehicular communication system that incorporates other more specific types of communication as V2I (infrastructure), V2N (network), V2V (vehicle), V2P (pedestrian), V2D (device) and V2G (grid).

35. Vehicle to infrastructure (V2I) – Vehicle-to-Infrastructure (V2I) is the next generation of Intelligent Transportation Systems (ITS). V2I technologies capture vehicle-generated traffic data, wirelessly providing information such as advisories from the infrastructure to the vehicle that inform the driver of safety, mobility, or environment-related conditions.

36. Vehicle to vehicle (V2V) – is a communication technology designed to allow vehicles to "talk" to each other. The systems will use a region of the 5.9 GHz band set aside by the United States Congress in 1999, the unlicensed frequency also used by Wi-Fi.

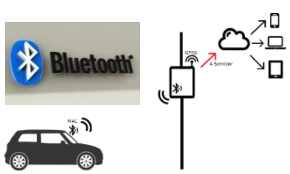
37. Video image processing (VIP) – a method of performing operations on an image, in order to enhance it or to extract useful information from it (Photoshop for example). Digital image processing algorithms can be used to:
    - Convert signals from a camera into digital images;
    - Improve clarity, and remove noise and other artifacts;
    - Extract the size, scale, or number of objects in a scene;
    - Enhance facial recognition;
    - Prepare images for display or printing;
    - Compress images for communication across a network.

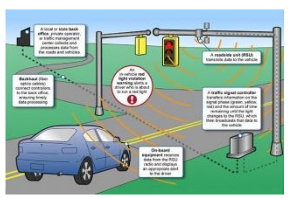
38. Weather stations, also Road Weather Information Stations (RWIS) – are Environmental Sensor Stations (ESS) that collect real-time field including atmospheric parameters, pavement conditions, water level conditions, and visibility. Employing a communication system for data transfer, and central systems to process data, multiple RWIS can be linked.

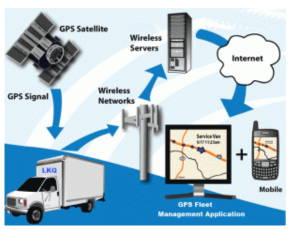
PART III
SCREENING OF ENABLING TECHNOLOGIES FOR APPLICATION IN THE WAR-63 PRIORITY PROJECT

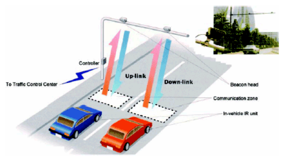
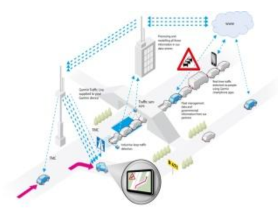
Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
4G Network		Satisfactory – some limitations and outages	Mature – current platform for OBUs and apps	Communications ✓ Efficiency ✓ Safety ✓ Value	Acceptable for implementation today
5G Network		Unknown – initial deployment scheduled for April 2019	Incipient technology but expected to be successful based on previous generations of technology	Communications ✓ Efficiency ✓ Safety ✓ Value	Implement when supporting infrastructure becomes available
Agnostic IT platforms, systems, hardware, software		Depends on the software/app/hardware developer	Constantly evolving – an open sourced system development environment which supports adding functionality to existing technology investment (see Detroit's experience with Smart Intersections)	All IT based applications ✓ Efficiency ✓ Safety ✓ Value	Specification should include open-sourced agnostic development environment

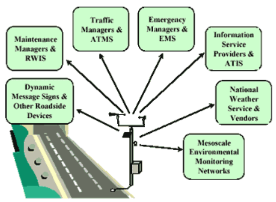
[18] Life-cycle status refers to the current state of adoption (usage), shelf-life, trend-line, and trajectory of the technology

Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
Artificial intelligence (AI)		Not fool-proof	Evolving technology	Accident identification Real time traffic management Traffic signal optimization ✓ Efficiency ✓ Safety ✓ Value	Consider for future implementation
Automated license plate recognition (ALPR)		Dramatically improved	Used primarily in toll collection and enforcement applications	OCR Automated enforcement activities ✓ Safety ✓ Value	Consider for future implementation if conditions warrant
Blockchain technology (BC)		Demonstrated success (digital currency and reservations; coming fast in trucking and multimodal logistics)	Just beginning in transportation currently, but vital to MaaS (Mobility as a Service)	Mobility as a Service 3R enabler ✓ Efficiency ✓ Value	Fit with logistics parts of Corridor economic development; consider for future implementation
Bluetooth technology (BT)		Demonstrated success, but privacy issues (individuals' mobile identifiers) and does not provide accurate location information	Mature technology – evolving technologies could replace	Communications ✓ Efficiency ✓ Safety ✓ Value	Implement if there is clear pathway to migration to more comprehensive system

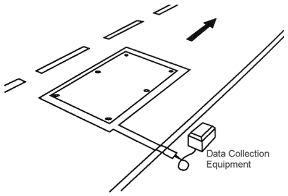
Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
Closed-circuit television (CCTV)		Dramatically improved demonstrated success. Intelligent image interrogation algorithm can effectively identify VRUs. Detection area is highly configurable.	Performance is continually improving	Data capture Vulnerable Roadway User (VRU) protection ✓ Efficiency ✓ Safety ✓ Value	Acceptable for implementation today
Cloud computing in Intelligent Transportation Systems (CCITS)		Demonstrated success	Mature technology that is constantly improving; has magnified efficiency, reach and benefits of ITS frameworks	Storage and handling of big data/ high volume computations ✓ Efficiency ✓ Safety ✓ Value	Acceptable for implementation today
Dedicated short-range communication (DSRC)		Secure alternative or supplement to Wi-Fi; Roadside Units (RSU) key link	Developing and expanding technology; DOT push	V2V, V2X ✓ Efficiency ✓ Safety ✓ Value	Plan for; implement if forward compatible in timing of technology
Escher/3D zebra pedestrian crossings		Low-cost, low-tech, easily installed and removed	Not widely implemented	VRU safety ✓ Safety ✓ Value	Consider pilot implementation on access point roadways at WAR-63 mainline

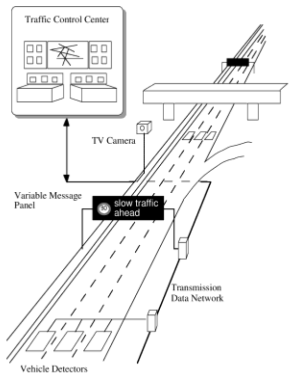
Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
Fiber-optic cable		Demonstrated excellence as communication backbone	Provides more secure service with fewer maintenance problems than cellular based options	Communications; wide variety of data flow applications; Economic Development ✓ Efficiency ✓ Safety ✓ Value	Consider for implementation; investigate shared resources with fiber-optic provider
Gateway treatments		Proven "visual signal" safety improvement; does not have to utilize overhead gantry beam; may be pillars or other visual registration points	Low-tech, high return	Vulnerable road user protection, and highlight roadway function change to users ✓ Safety ✓ Value	Incorporate in final design for select access points as developed, and possibly mainline east of SR 741 approaching Lebanon
Global positioning systems (GPS)		WAR-63 corridor is conducive to GPS use	In-place, in use, and effective	Automated incident detection, enforcement Roadway conditions monitoring Fleet tracking ✓ Efficiency ✓ Safety ✓ Value	Available for use with other technologies

Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
Infrared wireless (IR)		Significant limitations as a communications technology, but has important benefits as a sensor technology.	IR sensors are in use and offer advantages to temperature sensors in monitoring pavement conditions	Weather conditions monitoring (pavement); parking; V2V and V2X Vulnerable Road User Protection ✓ Efficiency ✓ Safety ✓ Value	Incorporate technology as appropriate
Light-emitting diode (LED) lighting		Excellent performance in terms of lumens per net unit of energy input and lamp life, but spectrum considerations	Upward adoption trajectory, becoming common	Significant environmental benefits (energy), but correct spectrum considerations ✓ Efficiency ✓ Safety ✓ Value	Appropriate for implementation today, with conditions
Live traffic data (LTD)		Depends on software and application	Upward adoption trajectory	Mapping and navigation Traffic signal and phasing information for motorist Optimize delivery times and increase ROI on commercial vehicles Optimization of intersection function and automated	Can be incorporated as part of a Smart intersection program over time

Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
				controller programming ✓ Efficiency ✓ Safety ✓ Value	
Maintenance information system		Successfully deployed by transportation authorities	Increased deployment and development of systems	Weather conditions monitoring Variable speed limits ✓ Efficiency ✓ Safety ✓ Value	Prepare for future implementation
On-board unit (OBU)		OEM are including in all currently manufactured vehicles	Upward trajectory with more vehicles in service	V2V, V2X Live traffic data Real-time traffic control ✓ Efficiency ✓ Safety ✓ Value	Applications incorporating this technology are viable
Open-graded bituminous asphalt		Demonstrated performance in spray and hydroplane control, noise control, and in cold climates and areas with freeze-thaw cycles[19]	Mature technology with continuous development and testing to improve product	Stormwater management and other environmental benefits (tire noise) ✓ Efficiency ✓ Safety	Incorporate into design specification

[19] https://www.dot.state.mn.us/research/TS/2012/2012-12.pdf, http://www.apa-mi.org/docs/PorousAsphaltCont..pdf

Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
				✓ Value	
Optical character recognition (OCR)		Improving Performance	Upward trajectory	ALPR, AI, Automated Enforcement ✓ Efficiency ✓ Safety ✓ Value	Prepare for future implementation
Pavement loops		Reliable count data	Mature technology, may be supplanted by CCTV and OCR	Data collection ✓ Efficiency	Investigate emerging technologies that may yield the same information
Radar		Provides detection for large areas and moving objects, but not good for small or stationary objects, can be slow	Mature technology	Vulnerable Road User Safety ✓ Efficiency ✓ Safety	Consider other technologies first

Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
Real-time traffic control (RTTC)		Pilot projects have demonstrated success	Developing technology	Cost savings Safety ✓ Efficiency ✓ Safety ✓ Value	Prepare for future implementation
Refuge island		Low-cost, low tech solution to pedestrian safety	Demonstrated success	Vulnerable road user protection ✓ Safety ✓ Value	Appropriate for implementation today, consider in project design
Remote sensors for weather response		GPS network is in place. Initial success with applications	Developing software algorithms to analyze data and predict conditions	Weather conditions monitoring ✓ Efficiency ✓ Safety ✓ Value	Provide flexibility for future implementation

Technology		**Performance**	**Life Cycle Status**[18]	**Cross-application in efficiency, safety, value**	**Findings for WAR-63**
Retro-reflectivity (next generation materials)		Next – generation paint (proprietary from 3M is anticipated to be introduced to market shortly)	Current technology requires maintenance and is not as bright	Lighting Safety ✓ Efficiency ✓ Safety ✓ Value	Implement current technology and anticipate use of improved product in future.
Self-generating (solar) pavement studs		Newer versions include wake up and sleep functions, automatic brightness control and darkness detection, indicators to assess problems with the stud, and remote programming capability. They are designed to be effective in areas with low-sun exposure	Product is continually being improved	Lighting Safety ✓ Efficiency ✓ Safety ✓ Value	Consider for current implementation
Separate facilities		Separates Vulnerable Road Users from vehicular traffic	Demonstrated success	3R enabling technology ✓ Efficiency ✓ Safety ✓ Value	Plan for implementation; community plans call for such a facility linked to a network of paths in development

Technology		**Performance**	**Life Cycle Status[18]**	**Cross-application in efficiency, safety, value**	**Findings for WAR-63**
Surface state sensors		Demonstrated reliability	Products are continually being improved	Weather conditions monitoring Safety ✓ Efficiency ✓ Safety	Prepare for future implementation
Traffic probes (data)		OBUs and smart phone technologies exist today	Applications are being developed continually	Data gathering V2V, V2X ✓ Efficiency ✓ Safety	Applications using this technology are viable
Variable message sign (VMS)		Technology has become more reliable in field application over time	Mature technology	Variable speed limits Hard Running Shoulder ✓ Efficiency ✓ Safety ✓ Value	Consider implementing with HRS and VSL
Variable speed limit sign (VSL)		Reliable technology	Number of installations is increasing	Variable operating conditions Weather and incident management Hard Running Shoulder ✓ Efficiency ✓ Safety ✓ Value	Consider implementation, ODOT has the infrastructure in place to support

Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
Vehicle to everything (V2X)		Parts of the concept are already in practice	Incipient technology	Communication and data gathering Operations and optimization ✓ Efficiency ✓ Safety	Provide flexibility such as open-sourced systems for future implementation
Vehicle to infrastructure (V2I)		Parts of the concept are already in practice	Incipient technology	Communication and data gathering Operations and optimization ✓ Efficiency ✓ Safety	Provide flexibility such as open-sourced systems for future implementation
Vehicle to vehicle (V2V)		Parts of the concept are already in practice	Incipient technology	Communication and data gathering Operations and optimization ✓ Efficiency ✓ Safety	Provide flexibility such as open-sourced systems for future implementation
Video image processing (VIP)		Extension of OCR and other	Improving technology; may be superseded	Data gathering and operations ✓ Efficiency ✓ Safety	Provide flexibility such as open-sourced systems for future implementation

Technology		Performance	Life Cycle Status[18]	Cross-application in efficiency, safety, value	Findings for WAR-63
Weather Stations (RWIS)		Generally reliable in application	Constantly improving technology	Weather condition monitoring ✓ Efficiency ✓ Safety	Provide flexibility such as open-sourced systems for future implementation

PART IV

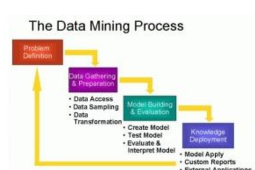
EVALUATION OF INNOVATIVE ROADWAY TECHNOLOGY APPLICATIONS
RELEVANT TO WAR-63 PRIORITY PROJECT

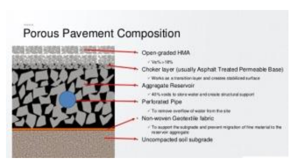
Application		Purpose	Benefits	Enabling Technologies	External Concerns & Requirements	Applicability to SR 63 Priority Segment	Cross Application Potential	Timing Considerations	Findings and Recommendations for Project Integration
Variable speed limits		Safety	• Modal and weather accommodation	• Variable message signs (VMS) • Variable speed limit signs (VSL) • Fiber optic cable • 4G	Coordination with Ohio DOT traffic management	Allows for special purpose use of shoulders	Combined with HSR	Current implementation/ Prepare for future implementation	Consider in design Possible ATC
		Capacity	• Extracts best traffic flow for available roadway in varying conditions						
		Incident management	• Safest roadway management response to crashes and events						
Smart roadway lighting		Environmental stewardship	• Energy savings • Sensors measure air pollution levels	• Self-generating pavement studs • CCTV (deployed on any lamppost or controller) • LED lighting (easily dimmed)	Public safety (disabled vehicle, changing a tire) Cyber-security (hacking)	Addresses resident concerns about ambient lighting east of SR 741	• Pavement markings	Current implementation	Use LED lighting where warranted Use enhanced retro-reflective pavement markings and self-generating pavement studs
		Quality of life	• Adjusts brightness and focal area of lighting according to conditions • Can achieve community dark sky and safety goals						
		Data collection	• Accurate traffic counts • Vehicle classification • Vehicle speed						
		Operations	• Traffic signal timing						
		Safety	• Manage safe						

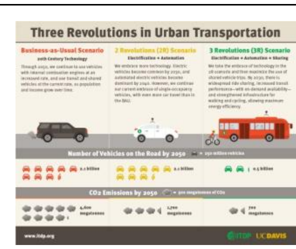
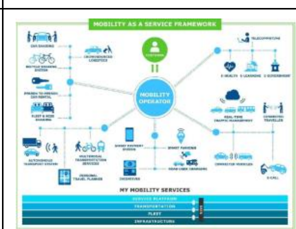
Application		Purpose	Benefits	Enabling Technologies	External Concerns & Requirements	Applicability to SR 63 Priority Segment	Cross Application Potential	Timing Considerations	Findings and Recommendations for Project Integration
			pedestrian movements						
Smart Intersections		Operations and maintenance	• Intersection monitoring • Identification of maintenance problems (signage, pavement markings, potholes) • Congestion reduction (travel times improved)	• CCTV cameras • Radar • Optical character reading (OCR) • Traffic probes (on-board car cameras) • Traffic probes (cell phone apps: WAZE/OnStar) • Camera and vendor agnostic software • 5G • Distributed short-range communication (DSRC)		High - SR 63/SR 741 intersection is expected to under increasing pressure with planned development	• Connected traffic signals • Automated traffic signal analysis • Smart traffic signals • Automated incident detection • Real-time accident identification and incident management	Current implementation	Explore value-based options under ATCs in Project Design-Build package
		Capacity	• Automated license plate reader (ALPR)						
		Data collection	• Smart monitoring of cyclists (holding green zone for slower vehicles)						
		Traffic enforcement	• Pedestrian monitoring						
		Modal management	• Freight vehicle priority • School bus priority • Services for vulnerable road users (elderly, visually or audibly impaired)						
		Environmental stewardship	• Freight vehicle priority – reduction in fuel usage						
		Safety	• Incident detection • Alerts to connected cars (WAZE)						

Application		Purpose	Benefits	Enabling Technologies	External Concerns & Requirements	Applicability to SR 63 Priority Segment	Cross Application Potential	Timing Considerations	Findings and Recommendations for Project Integration
			• Emergency vehicle signal priority (response time reduction) • Analyze near-misses						
Connected Traffic Signals (CTS)		Safety	• Predictable for users • Lessens user impertinence • Reduced crash rates	• OBUs • 3G • 4G		Primarily east of SR 741	In conjunction with Smart Intersections	Prepare for implementation with Phase 2	Explore costs, cost-effectiveness and value as an ATC Phase 2
		Capacity	• Platoon capacity boost • Lessens trucks adverse effects						
		Environmental stewardship	• Increased fuel efficiency • Lessens accel/decal noise						
Automated traffic signal analysis	ATSPM Automated Traffic Signal Performance Measures	Operations and maintenance	• Signal timing based on live traffic data • Life-cycle cost savings – retiming of signals • Improves throughput	• Signal timing based on live traffic data (LTD) • Cloud • Agnostic software		SR 63/SR741 intersection optimization	In conjunction with both Smart Intersections and Connected Traffic Signals (CTS)	Prepare for future implementation	Open-sourced/ Agnostic development environment
		Capacity	• Signal status • Traffic volume • Daily and weekly flow rates • Arrival on green • Overall delay time • Queue length						
		Data collection	• Travel time • Vehicle trajectories • Space and time diagrams						

Application		Purpose	Benefits	Enabling Technologies	External Concerns & Requirements	Applicability to SR 63 Priority Segment	Cross Application Potential	Timing Considerations	Findings and Recommendations for Project Integration
		Operations	• Supports performance-based evaluation						
Smart traffic signals		Mobility	• Links traffic signals to road users • Links smart products and applications • Informs mobile apps	• Fiber optics • On-board units (OBUs) • DSRC		Future applicability	• Smart intersections	• Prepare for future implementation	Open-sourced/ Agnostic development environment
		Capacity	• Optimize traffic flow						
Automated incident detection (AID)		Safety	• Analyze near-misses •	• Artificial intelligence (AI) • CCTV cameras	Coordination with first responders	Future applicability	• Smart intersections	• Prepare for future implementation	Open-sourced/ Agnostic development environment
		Incident management	• Quick clear						
		Capacity	• Quick clear • Reduced congestion						
		Operations and maintenance	Quick clear						
Real-time accident identification and incident management		Capacity	•	• Vehicle to everything (V2X) • Real-time traffic control (RTTC) • On-board units (OBUs)	Coordination with incident responders	Future applicability	• Smart intersections	• Prepare for future implementation	Open-sourced/ Agnostic development environment
		Incident management							
		Safety (crash avoidance)	• Reduces secondary crashes						

Application		Purpose	Benefits	Enabling Technologies	External Concerns & Requirements	Applicability to SR 63 Priority Segment	Cross Application Potential	Timing Considerations	Findings and Recommendations for Project Integration
On-demand hard shoulder running (HSR)		Capacity	• Extend functional life of facility	• Pavement loops • Radar • CCTV • VMS • VSL	Coordination with ODOT ITS	High – addresses mixed mode concerns and extends functional life of baseline build	Motorist information	• Current implementation	• Design for hard-running • Consider ATC
Speed enforcement		Safety	•	• Cameras • Cloud-based monitoring • ALPR	Coordination with law-enforcement required in OH	Moderate	Real-time accident information and incident management	Prepare for future implementation	Open-sourced/ Agnostic development environment
		Capacity	• Reduces speed differentials						
		Enforcement	• Limits platooning (improves throughput)						
Traffic data mining and modeling		Data Collection	• Predictive modeling	• CCTV • Agnostic software • Apps		Low – primarily benefits a roadway network		Flexibility to include concept down the road	Open-sourced/ Agnostic development environment
		Planning							
Weather conditions monitoring		Safety		• Weather stations • Remote sensors • Surface state sensors • CCTV cameras • GPS • Maintenance information system (MIS) • DSRC • Traffic probes	Flexibility to include concept down the road	Moderate	Pavement (roadway) condition monitoring	Flexibility to include concept down the road	
		Operations and maintenance							
		Environmental stewardship	• Reduce chloride levels						

Application		Purpose	Benefits	Enabling Technologies	External Concerns & Requirements	Applicability to SR 63 Priority Segment	Cross Application Potential	Timing Considerations	Findings and Recommendations for Project Integration
Pavement (roadway) condition monitoring		Operations and maintenance		• Remote sensors • Surface state sensors • CCTV cameras	Flexibility to include concept down the road	Moderate	Weather conditions monitoring	Flexibility to include concept down the road	
		Asset management	•						
		Safety	•						
Pavement composition		Safety		• Open graded bituminous asphalt	Coordination with Ohio DOT regarding asset management	High – stormwater drainage and water quality concerns		Current implementation	Include in performance specifications
		Environmental Stewardship	•						
Pavement markings		Safety	• Improved inclement weather route markings •	• Retro-reflectivity – next generation glass beads providing visibility under wet conditions • Self-generating pavement studs		High		Current implementation	Include in performance specifications
		Quality of life	• Lighting from below – less ambient lighting •						
		Environmental stewardship	• Increased durability •						

Application		Purpose	Benefits	Enabling Technologies	External Concerns & Requirements	Applicability to SR 63 Priority Segment	Cross Application Potential	Timing Considerations	Findings and Recommendations for Project Integration
		Life-cycle cost savings	• Increased durability						
Vulnerable road user protection		Safety	• Protect at-risk populations (elderly) • Protect pedestrians, bicyclist, and other human powered modes of transportation (walking, skateboarding and in-line skating) • Protect alternative transportation choices (scooters, golf carts) • Promote active transportation alternatives	• CCTV • Video image processing (VIP) • Radar • Infrared (IR) • Bluetooth (BT) • LED surface lighting • "Escher" crossings • Separate facilities (multi-purpose lanes for low-speed and human-powered transportation)		High - % of vulnerable road users including elderly	Coordination with Smart Intersections	Current implementation	Consider in post-construction
		Capacity	• Minimize modal conflicts and delays to road users						
Three revolutions in transportation (3R) support		Integration of technologies, shared mobility, and automation	• Transportation choices •	• Detection (VIP) • Lighting improvements • Refuge islands • Gateway treatments • Separate facilities (multi-purpose lanes)	Support and funding for multi-use path	High – in multiple planning documents	MaaS	Concurrent development	ATC
		Environmental Stewardship	• Pollutant reduction						
Transportation (Mobility) as a service (MaaS)		Reliability	• Reserve time on facility • Guaranteed arrival times	• Blockchain technology (BC) • On-board units (OBUs)	Value at network level	3R	3R	Future implementation	Open-sourced/ Agnostic development environment

Application		Purpose	Benefits	Enabling Technologies	External Concerns & Requirements	Applicability to SR 63 Priority Segment	Cross Application Potential	Timing Considerations	Findings and Recommendations for Project Integration
Autonomous shuttle service		Mobility	• Alternative Mode	• V2V • V2X	Current state of technology		3R MaaS	Future implementation	Open-sourced/ Agnostic development environment Incorporate in design planning for future accomodation

RECOMMENDATIONS

The following uses of innovative technology have a high level of applicability to the SR 63 corridor project.

1. An initial investment in Smart Intersection camera and sensor technology at the SR 63/SR741 intersection could provide immediate benefits in terms of remote monitoring of maintenance needs, and smart monitoring of vulnerable road users. In this corridor with an extremely high percentage of truck traffic it could also provide real-time tracking and green-light priority for cargo-loaded freight vehicles.

   Using an open-sourced, hardware agnostic, development environment this investment could be scaled-up over time to include connected traffic signals, smart traffic signals, and automated traffic signal analysis where real-time changes are made to the controller in response to intersection function.

   Real time accident identification and incident management and response could be added as conditions warrant.

2. Design that incorporates a full in-board or out-board shoulder for on-demand hard shoulder running has the potential to extend the functional service life of the facility. The shoulder could also be used as special purpose transit or freight lanes with some design modifications. This technology could be used in conjunction with variable speed limits.

3. Use of LED lighting where necessary, that incorporates sensors that can adjust the ambient lighting level based on traffic volumes, combined with use of retro-reflective pavement markings and self-generating pavement studs to provide lighting from below and beside the motorist has the potential to help retain the rural character of the existing roadway.

4. Use of open-graded bituminous asphalt pavement that can allow water to run through the pavement, reducing pooling and increasing motorist safety. It has the benefit of improving drainage and reducing stormwater runoff while improving stormwater quality. It is also a quieter pavement, providing a quality of life benefit in this historically rural corridor.

PROCUREMENT AND MAINTENANCE CONSIDERATIONS

As a general policy, it is advantageous to write performance-based specifications, and let the market determine the enabling technology for the application. Being too prescriptive limits innovation and results in a less desirable solution. This is especially true if the contractor is expected to maintain the installation (DBM). Design-Build-Maintain is an attractive option where the owner does not have the in-house technical capability to service the technology (hardware and/or software)

One exception to this however is in the choice of the communication backbone. Fiber-optic cable has some significant advantages over other wireless options. It is less vulnerable to natural disasters (storms, ice, tornadoes), and to cyber-security threats (hacking). It has the additional benefit of supporting the type of economic development desired along the corridor.

When soliciting an Alternative Technical Proposal or a Design-Build proposal with innovative technology elements, it is important to gauge the capability of suppliers, and the breadth of market interest. A pre-solicitation supplier engagement event will help advertise the project to the market and measure supplier interest, resulting in more competitive ideas and bids.

Finally, Carlos Braceras, executive director at Utah DOT, chair of the ITS America board, and President of AASHTO, who was instrumental in Utah making the decision to install fiber-optics on every project since the early 1990s states: *"Personally I believe in the idea of safety sooner,"*[20]

[20] *Traffic Technology International*, June/July 2018 Interview, Carlos Braceras, Page 012