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LIVE zone
Logistics Innovation and
Vehicle Electrification Zone

Technology Readiness Assessment

Prepared For:

EASTGATE
Regional Council of Governments

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Version History

Version #	Date	Author(s)	Reviewer(s)	Summary of Changes
1.0	6/29/22	Alex Thomas	Jim Katsafanas	First draft
1.1	8/2/22	Alex Thomas	Jim Katsafanas	Final

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List of Acronyms

Acronym/Abbreviation	Definition
AI	Artificial Intelligence
CNG	Compressed Natural Gas
Eastgate	Eastgate Regional Council of Governments
FHWA	Federal Highway Administration
FSP	Freight Signal Priority
IoT	Internet of Things
MAASHTO	Mid-America Association of State Highway Transportation Officials
NASA	National Aeronautics and Space Administration
OBU	On-board Unit
ODD	Operational Design Domain
RSU	Roadside Unit
SPaT	Signal Phasing and Timing
TRA	Technology Readiness Assessment
TPIMS	Truck Parking Information Management System
TRL	Technology Readiness Level
UPS	United Parcel Service

1 Introduction

This Technology Readiness Assessment (TRA) is a formal evaluation of the maturity of technology identified for deployment in the Logistic Innovation and Vehicle Electrification (LIVE) Zone. It will systematically assess the technology and determine the critical enabling technology required to develop a system that meets the vision of the Eastgate Regional Council of Governments (Eastgate).

1.1 Project Background

Located in Trumbull County, Ohio, Lordstown is a rural village northwest of Youngstown. The transportation features of this community include access to major links such as Norfolk Southern and CSX rail lines, Interstate 80, and Interstate 76. A vehicle manufacturing plant previously owned by General Motors in Lordstown was a large generator of jobs for the surrounding areas. Since the plant's closure, Lordstown Motors has now entered the space and is creating new manufacturing opportunities by producing electric pickup trucks. The project limits also extend into Jackson Township, Mahoning County, which features many of the same characteristics as Lordstown. It is mostly rural interspersed with manufacturing and logistics/warehousing

The LIVE Zone is a strategic infrastructure and logistics initiative endorsed by Eastgate. Lordstown and Jackson Township, located at the convergence of multiple transportation modes, poises them uniquely to serve as premier regional warehousing, manufacturing, and distribution hub. Investments in logistics technology such as a Long Combination Breakdown Lot, solar-powered electric vehicle charging, and Smart Corridor solutions will allow the region to better serve as the confluence of the major transportation modes it already contains and bolster supply chain resiliency.

1.2 Goals and Objectives

Readiness is assessed through a Technology Readiness Level (TRL) scale ranging from concept to real-world proven operations. The Technology Readiness Assessment (TRA) will distinguish off-the-shelf solutions that can be put into practice now from those still in development. A range of potential technologies have been identified for implementation into the LIVE Zone and examined if feasible for deployment.

Innovative technology, automation, hardware, software, communications, systems, or services selected were identified, researched, described, and evaluated during this process. This TRA will also highlight enabling technology that will be most critical to the success of LIVE Zone. This assessment will be used to support the vision for the system and subsequently the design and development of the LIVE Zone.

This assessment does not evaluate risks in technology development or how this technology may advance to subsequent levels of readiness and the challenges associated. It does not identify the potential impacts or benefits of the technology or market demand.

1.3 References and Applicable Documents

Technology Readiness Guidebook, FHWA, 2017
https://www.fhwa.dot.gov/publications/research/ear/17047/17047.pdf

ITS4US Task 7 Training: Enabling Technology Readiness Assessment, 2021
https://its.dot.gov/its4us/pdf/ITS4US_ETRA_Training.pdf

2 Identify Enabling Technologies

2.1 Technology Readiness Framework

Technology Readiness Assessments were originally developed by the National Aeronautics and Space Administration as a tool to manage complex systems and technology development. This concept was later adopted by the US Department of Defense and Federal Highway Administration (FHWA). Each agency developed its framework and guidance for TRAs tailored to their needs.

The technology framework chosen for this application was that of the FHWA, Report No. FHWA-HRT-17-047 Technology Readiness Guidebook (2017), chosen for its relevance to transportation. It is noted that the framework is principally intended to facilitate discussions or funding between technology developers/researchers and investors/stakeholders. The framework will be used here to assess the proposed technology for its current viability in this project.

The technology is evaluated through research of available internet literature on the subjects and from the Teams' own experience with these technologies. Knowledge gaps may be present as the Team is not directly involved with the development of these technologies; however, this will serve as the basis from which to refine as the project progresses.

2.2 Enabling Technologies Inventory

The following lists and describes the technologies considered, their manufacturers, and the current state of technology. Their intended application is detailed further in the Implementation Plan.

2.2.1 Smart Yard

The Smart Yard of the eastern interchange will offer a staging area and recharging/alternative fuel refilling for trucks destined to or from the LIVE Zone. This yard will house the transfer of freight between business partners and long-haul trucks and rail through autonomous yard jockeys. The following elements are anticipated for this area.

1. Automated Trailer Breakdown/Container Lifter

   The automated truck breakdown area will house operations regarding shipping container movement between trucks and the autonomous yard jockeys. To accommodate the various types of freight form factors anticipated, several technologies will be deployed.

   A. Freight Container Transfer

      An automated machine will transfer shipping containers between trucks and autonomous yard jockeys. In the event direct transfer between trucks and autonomous yard jockeys is not available, given both parties may not be available at the same time, the machine will move the shipping container to an intermediate staging area. Shipping containers are universal in their handling but may vary in size.

Machines for this purpose vary in form from overhead gantries to wheeled loaders to trailer-mounted cranes.

B. Automated Container Loading

Automated container loaders perform the task of moving raw materials or finished products into a shipping container. The container loader is an open platform where goods can be stowed prior to the arrival of a truck or shipping container. The platform then shifts the goods into the shipping container, eliminating potential damage to goods and reducing load time. This technology is currently commercially available and operating in relevant outdoor environments.

C. Automated Trailer Coupling/Decoupling

Trailers of various sizes may be delivered to the Smart Yard as an intermediate before final delivery to the consignee. The trailers will be decoupled automatically and transferred to the consignee by autonomous yard jockeys. Autonomous yard jockeys already have the capacity to couple and decouple trailers automatically.

D. Pallet and Other Non-conforming Loads

Product shipments are typically transported on pallet-type load units. Other shipments may require chains or straps, and some may require clamps. These different load types can be accommodated with different attachments to a forklift. Depending on the application, there are autonomous solutions available for moving pallet loads. These are used in warehouse settings and may require additional engineering to operate in an open environment.

2. Opportunity Charging

Opportunity charging for the autonomous machines of the LIVE Zone is the charging that can be done in between missions via an inductive plate. These plates can be located at optimal positions to quickly charge before moving on to the next mission. Multiple charging locations in key areas provide greater efficiency and less downtime. This technology is commercially available by companies such as Delta Group and Wiferion. Opportunity charging is typically used for smaller EVs like pallet jacks or forklifts within a warehouse. Warehouse management would coordinate with vendors on the most ideal places to locate charging stations.

3. EV Truck Charging

Electric vehicle truck charging will deploy truck charging stations within the interchange yards. This charging is done by direct hookup. Several companies currently offer these products commercially such as ChargePoint and Blink Charging. Power for charging stations will come from either the grid or from solar arrays installed as part of this project and discussed in Section 2.2.4.

4. Rail Intermodal at the Norfolk Southern Goodman Yard

An autonomous side loader can be deployed to transfer containers between rail cars, autonomous yard jockeys, and trucks. The side loader will be positioned as the Norfolk

Southern Goodman Yard, where autonomous yard jockeys will transfer freight to the Smart Yard for staging or to the consignee.

2.2.2 Truck Parking and Long Combination Breakdown Lot

The west interchange will feature a triple trailer breakdown area in a key location near the Ohio Turnpike and the Pennsylvania border allowing trucks to uncouple the third trailer to continue into Pennsylvania or other Ohio highways, which have different restrictions on combination loads.

1. EV Truck Charging

This is the same technology described in Section **2.2.2**.

2. Alternative Fueling – CNG

Various alternative fuels are available for trucks such as compressed natural gas (CNG). This fuel type is commercially available with widespread stations for refueling, according to the US Department of Energy. Alternative fueling will be deployed to be available for trucks using the LIVE Zone or pass-by trips.

3. Truck Parking Information System

Safe truck parking is a ubiquitous concern for truckers nationwide. Finding that parking presents a compounding challenge. Efforts to address those issues are being taken by both state agencies and private companies. The Mid America Association of State Transportation Officials collaborated with the FHWA to develop the Truck Parking Information Management System (TPIMS) in eight states including Ohio. Private companies such as Truck Specialized Parking Service and netPark offer software-based parking management services.

2.2.3 Smart Corridor

The following elements are considered for the Smart Corridor. These elements will connect manufacturing and distribution centers and intermodal facilities in the LIVE Zone, providing the network needed for advanced technologies.

1. Over-the-Road Automated Freight (autonomous yard jockeys)

Autonomous freight vehicles are anticipated to traverse the public right of way and not be relegated to private yards. This can be accomplished using dedicated lanes for autonomous vehicles or by mixing with public traffic on existing right of way. This concept can be used to ferry loads between the proposed truck yards, businesses, and intermodal rail lines.

Currently, autonomous terminal trucks, or yard jockeys, are presently deployed in several locations by Outrider Technologies, Inc. and by United Parcel Service (UPS). A potential challenge of deploying this technology in this project is that research indicates that these vehicles have been confined to private yards and do not traverse public right of way. By controlling their environment, these vehicles are specially tailored to that environment. Progressing to roadway operations is an entirely new challenge that these vehicles may not support. However, a partnership here could provide an opportunity for the development of these capabilities.

2. Freight Signal Priority (V2X Communication)

Freight signal priority (FSP) is a traffic signal modification that extends the green time to allow an oncoming truck to proceed through the intersection. This prevents running red lights due to limited deceleration and avoids lost time with slowly accelerating trucks on start-up. FSP can use vehicle-to-infrastructure communications, leveraging onboard units (OBUs) and roadside units (RSUs), to coordinate the priority needs.

This application is currently in operations in Atlanta, Georgia with more planned. The implementation may require the replacement of existing traffic signal controllers with ones that are interoperable with RSUs. FSP is most useful in areas where trucks make up a high percentage of traffic, like in and around the LIVE Zone manufacturing and distribution areas. With existing projects utilizing FSP, it is expected that to be able to be deployable with no modifications necessary.

3. Intersection Situational Awareness

This technology concept is not specifically defined, however, it references the ability to use artificial intelligence to gather information about the situation at an intersection, whether it be vehicles, pedestrians, or bicycles, and develop a digital twin of the objects. The gathering of data is usually completed using camera detection with analytics to identify and classify an object and assign its location, speed, and heading of the object. Some are testing this technology using 5G telematics inside OEM vehicles instead of cameras. The infrastructure-based system uses the digital twin objects method to perform edge computing, generating messages about the objects that aid in safety and mobility. The system may be capable of using predictive analytics to predict the future path of objects as well, as a means to reduce the likelihood of near-miss collisions.

4. In-Road Inductive Charging

In-road inductive charging is the dynamic charging of electric vehicles as they move along the roadway. This allows for greater traveled distances and a reduced need for stationary charging. This technology is currently state-of-the-art with limited testing applications. It has been tested in several real-world environments in foreign countries, while the first in the US is expected in Michigan in 2023. The Indiana Department of Transportation is partnering with German startup Magment GmbH. The LIVE Zone is an opportunity for the first deployment of in-road dynamic charging in the state of Ohio.

2.2.4 Power and Electrification

Electrification needs and power generation are addressed by this concept. Increased power consumption and anticipated electrification of vehicles are anticipated needs of the LIVE Zone.

1. Solar Fields/Farm/Storage

Available space in the ramp infield areas and adjacent to interchanges can house additional solar arrays to meet the electrical demands of the proposed east and west yards and support electric vehicle charging. Solar power generation technology is widely available with established consultants, suppliers, and contractors to design and construct these facilities. A vanadium redox flow battery storage system is anticipated to be used to store electrical power. This technology has already been used in various solar power projects.

2. Private EV Charging

As the nationwide vehicle market continues to electrify, more demand is placed on charging solutions. Charging provided at the workplace while vehicles are parked provides a solution as well as makes the company attractive to employees and supports retention. Charging products are currently available to deploy at employers' parking lots from ChargePoint and Blink Charging, among others. Coupled with the proposed solar arrays, this can provide 100% “green” power generation for vehicles.

2.2.5 Distribution Prioritization and Mission Control System

A fundamental element of the LIVE Zone is the definition of prioritization protocols, or critical operating rules, to be built into the fleet management software system to identify and optimize the distribution network priorities. The critical missions or “reservations” that are assigned to freight movement within the LIVE Zone would be coordinated through a central control system that will prioritize, schedule, and track the missions within the entire transportation network.

The logic framework contained in the central control system would be designed to manage the freight movement across the full spectrum of transfer points, from non-automated modes to the autonomous environment, and integrated with the larger distribution network within the Lordstown region.

This concept to build out over time is to create the scaffolding in which future technologies can be integrated into the proposed LIVE Zone system.

2.2.6 Data Communications

Communications are a requirement for advanced systems. The LIVE Zone will require various forms of communications and infrastructure between truck yards, vehicles, charging stations, management systems, and other key network nodes of the system. Housed within a single unit are communications for IoT (LoRa), WiFi, and 5G, these totems can be installed in warehouses, manufacturing buildings, at truck or rail yards, and roadside. This provides an extensive platform for various applications as needed at each location. It provides the hub with a centralized communication network over a broad area.

2.2.7 Transit

Moving people and freight is the foundation of the economy. From home to work, to shopping, and recreation, transit provides a solution to efficiently move people. Advances in transit are now expanding their services to serve more people in new capacities. Transit is considered for its ability to transport people to their place of work at the LIVE Zone.

1. Automated Transit for First/Last Mile to Employment

Automated transit are small vehicles capable of operating without a driver. These vehicles have been deployed all over the world in various capacities, though typically in slow-speed operations. Though these deployments are numerous, many of them are still characterized as pilots rather than long-term operations and maintenance. Several manufacturers provide automated transit including Navya, Easy Mile, and May Mobility. There are also operators in this space such as Beep. There is a shift from the automated transit to a more purposeful, higher speed transit vehicle, that support the same function, which should be federal safety standard approved. Generally, the automated shuttles do not have steering wheels and other controls that do not allow them to meet Federal Motor Vehicle Safety Standards (FMVSS), therefore these vehicles receive waivers from the National Highway Traffic Safety Administration (NHTSA) to operate under lower speed conditions (less than 25 mph). They higher speed AV transit designed from traditional vehicles will follow state laws to operate as long as they are FMVSS compliant.

2. Long-Haul Automated Bus

The long-haul automated bus is a vehicle that capable of regular bus routes and eventually long-haul routes to more distant regions. As Society of Automotive Engineers Level 4, the bus is capable of fully autonomous driving with no driver at the wheel, however, a driver may be present in initial phases of the deployment. New Flyer is currently developing a battery-powered bus for service in North America. Testing of this bus is anticipated in 2022.

2.2.8 Regional Transportation Network Improvements

Several transportation improvements are proposed consisting of traditional civil engineering practices. In addition, new traffic signal controller communications are becoming available for connected and autonomous vehicle applications.

1. Traffic Signal Enhancements

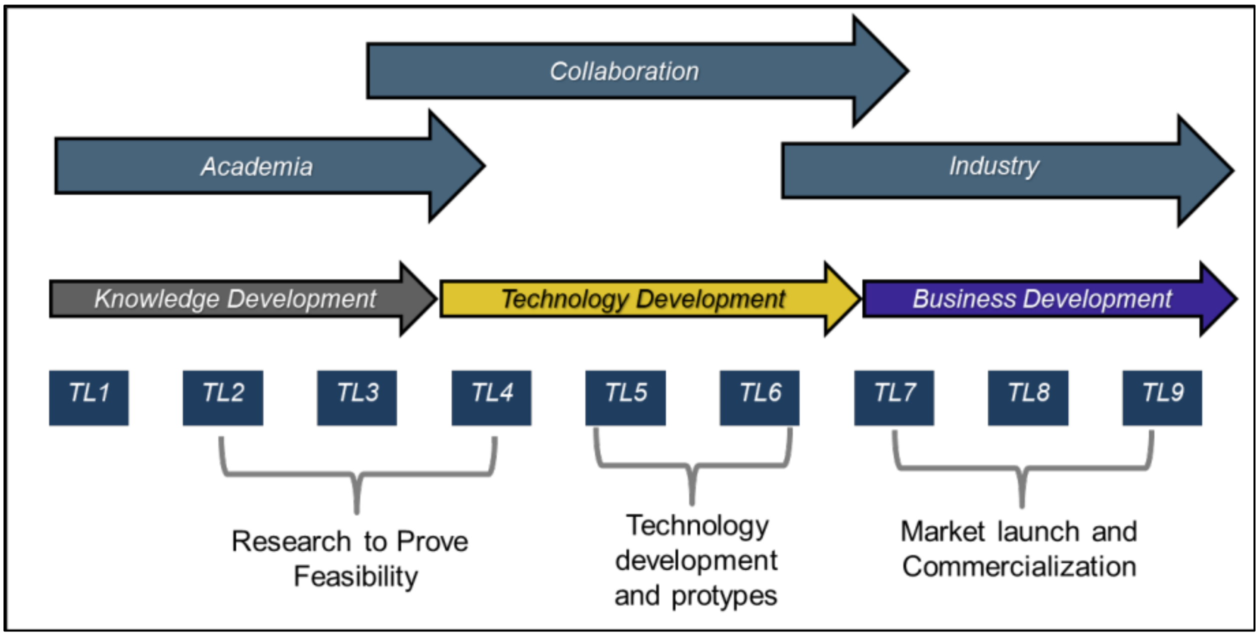
Traffic signal CAV applications are making their way into the industry with applications such as signal phasing and timing SPaT, MAP messages, basic safety messages, as well as transit and freight priority. RSUs at the intersection transmit messages from connected vehicles to the controller and vice versa. RSUs may be augmented to existing signal controllers if compatible or the controller will need to be upgraded if not. Roadside units are critical to the operation of applications such as freight signal priority.

3 Technology Readiness Level

3.1 TRL Assessment Process

Assessing the readiness of technology is done by comparing the current development stage of the technology against the TRL scale. The TRL scale contains nine ranks of maturity from level 1 (basic research) to level 9 (implementation), each with its testing requirements and milestones. The scale also considers two aspects of the completed test: how complete was the technology when it was tested, and how representative was the test environment. The diagram on the following page illustrates the development process from levels 1 to 9.

Figure 1. TRL Progression



Source: ITS4US Task 7 Training: Enabling Technology Readiness Assessment

The TRL scale's testing requirements for each level are shown on the following page in **Table 1**. These testing requirements are used to assign a TRL level to each technology.

Table 1. TRL Descriptions and Requirements

TRL	Description	Requirements
1	Basic principles and research	• Do basic scientific principles support the concept? • Has the technology development methodology or approach been developed?
2	Application formulated	• Are potential system applications identified? • Are system components and the user interface at least partly described? • Do preliminary analyses or experiments confirm that the application might meet the user's needs?
3	Proof of concept	• Are system performance metrics established? • Is system feasibility fully established? • Do experiments or modeling and simulation validate performance predictions of system capability? • Does the technology address a need or introduce an innovation in the field of transportation?
4	Components validated in a laboratory environment	• Are end-user requirements documented? • Does a plausible draft integration plan exist, and is component compatibility demonstrated? • Were individual components successfully tested in a laboratory environment (a fully controlled test environment where a limited number of critical functions are tested)?
5	Integrated components demonstrated in a laboratory environment	• Are external and internal system interfaces documented? • Are target and minimum operational requirements developed? • Is component integration demonstrated in a laboratory environment (i.e., a fully controlled setting)?
6	The prototype demonstrated in a relevant environment	• Is the operational environment (i.e., user community, physical environment, and input data characteristics, as appropriate) fully known? • Was the prototype tested in a realistic and relevant environment outside the laboratory? • Does the prototype satisfy all operational requirements when confronted with realistic problems?
7	The prototype demonstrated in an operational environment	• Are available components representative of production components? • Is the fully integrated prototype demonstrated in an operational environment (i.e., real-world conditions, including the user community)? • Are all interfaces tested individually under stressed and anomalous conditions?
8	Technology is proven in an operational environment	• Are all system components form-, fit-, and function-compatible with each other and with the operational environment? • Is the technology proven in an operational environment (i.e., meets target performance measures)? • Was a rigorous test and evaluation process completed successfully? • Does the technology meet its stated purpose and functionality as designed?
9	Technology refined and adopted	• Is the technology deployed in its intended operational environment? • Is information about the technology disseminated to the user community? • Is the technology adopted by the user community?

Source: FHWA Technology Readiness Level Guidebook 2017

3.2 TRL Scale for each ET

A matrix showing the TRL scale of each technology scale is provided on the following page in Table 2.

Table 2. TRL Matrix

Concept	Technology	Operational Description/Domain	TRL	Deployable Now	Readiness Notes
Smart Yard	Automated Trailer Breakdown and Container Lifter System	Freight container transfer from truck trailer to autonomous yard jockey trailer	8	Yes	Side loader machines mounted on trailer currently available and are remote controlled.
		Automated Container Loader	9	Yes	Automated Container Loaders in production and commercial use in relevant environments by companies like SmartTEH
		Automated trailer decoupling and positioning	8	Yes	Autonomous yard jockey or terminal trucks with management software currently available. Have proven to work within a defined ODD such as a yard.
		Pallet or other non-conforming form factor freight transfer from truck trailer to yard jockey trailer	9	Yes	Depending on the application of forklift/pallet jack, there are autonomous solutions available for moving pallet load or other loads. These are typically operated by private companies to move material as needed. Autonomous solutions are available, but used within the warehouse setting on smooth finished concrete.
	Opportunity Charging	Charging in between assignments	9	Yes	Several commercial scale manufacturer's currently offering inductive charging equipment for industrial machines. Within a defined ODD, the opportunity charging is monitored and managed by the backend operating system.
	EV Truck Charging	Smart Yard electric truck charging stations	9	Yes	Long-haul trucking is not yet a strong market sector as there are limitations with battery technology and charging infrastructure to support long-haul operations of EV trucks. However, shorter, regional and local operations can and do exist. Truck charging solutions commercially available but limited market penetration. First electric truck charging station being built now in Bakersfield Cal, however, charging infrastructure is similar to traditional passenger vehicle charging infrastructure.
	Rail Intermodal @ Norfolk Southern Goodman Yard	Intermodal yard with rail siding freight container transfer between train, truck, and autonomous yard jockeys	9	Yes	Wheeled side loaders commercially available.
Truck Parking and Long Combination Breakdown Lot	EV Truck Charging	Truck Parking and Long Combination Breakdown Lot electric truck charging stations	9	Yes	See above Smart Yard - EV Truck Charging
	Alternative Fueling Stations	Truck Parking and Long Combination Breakdown Lot CNG fueling stations	9	Yes	CNG stations currently deployed across nation and some in Canada; LNG stations sparsely available; Propane stations widely available; Hydrogen stations limited to California; Biodiesel stations spread out across nation, though only three stations offer in Ohio
	Truck Parking Information System	Third-party applications, broadcast to DMS, and MAASTO TPIMS	9	Yes	Applications currently available that offer truck parking information using various technologies to determine and disseminate available spaces.
Smart Corridor	Over-the-Road Automated Freight (autonomous yard jockey)	Dedicated travel lanes	8	Yes	Automated yard jockey or terminal trucks with management software currently available. Have proven to work within a defined ODD such as a yard and show potential viability of being able to replicate successful function in a modified environment such as dedicated lanes. A mixed traffic ODD likely would be more challenging at this point of technology maturity. Use or need for a driver as a fail safe will likely be dictated based on local and state requirements.
		Mixed traffic environment	6	No	
	Freight Signal Priority (V2X communication)	Traffic signals	9	Yes	Freight Signal Priority (FSP) utilizes signal request message set similar to transit signal priority within the connected vehicle SAE message set. The demonstration and implementation of FSP has been performed by outfitting demonstration vehicles with on-board equipment. Active deployment in Atlanta Transit Signal Priority Pilot: Midtown Atlanta with State Rail and Tollway Authority (SRTA) and Cisco/MARTA In Operation as of March 2021
	Intersection Situational Awareness	Traffic signals	8	No	Situational awareness devices have been deployed by third party solution providers and tech companies such as Honda, Bosch, Derq, Cisco, and Verizon. These devices have been deployed in limited pilot test locations within very specific operational environments.
	In-Road Dynamic Inductive Charging	Over-the-road dedicated or mixed traffic	7	No	The technology has been demonstrated in real-world environment with limited exposure. Tests have been conducted on short road segments in Israel, Sweden, and Germany. Bid for first dynamic road charging in US for Michigan to be operational in 2023.
Power and Electrification	Solar Field/Farm/Storage	Dedicated solar farm field with vanadium redox storage	9	Yes	Solar power generation and storage infrastructure widely available. Vanadium Redox storage systems currently in use in San Dirgo and Australia.
	Private EV charging	Private business partner property and parking lot.	9	Yes	EV charging infrastructure available for workplace charging
Distribution Prioritization and Mission Control System	Centralized Control System to Prioritize, Schedule and Track Critical Missions in the Transportation Network	Automated environment within the Zone	8	Yes	The fleet management systems require AI and critical operating rules to identify and optimize the distribution network priorities. Several companies offer AI in specific areas of logistical needs. UPS has ORION to determine fastest and most cost effective route for vehicles dynamically in route. Lineage uses AI to manage warehouses and product storage.
		Non-automated modes within the larger distribution network (Warren, Youngstown, YNG)	9	Yes	To integrate external systems, a software "airgap" / integration point would be required between the systems with an enterprise service bus. This type of application would allow integration of an existing order management system from an airport, logistics hub, private sector partner, and transportation system to all be queued into one fleet manager and order system. There are several suitable options for this integration.
Data Communications	Private Network Interface - IoT network (LoRa) - Wi-Fi - 5G with edge computing	Interior located and exterior totems that house a full spectrum of wireless communications	9	Yes	These technologies are all proven communication mediums that have been applied in various operating environments.
Transit	Automated Transit for First/Last mile to Employment	Dedicated travel lanes or mixed traffic	8	Yes	Deployments of low speed automated transit increasing around world, though many still characterized as pilot deployments. Deployments in US includes Columbus, OH; University of Michigan; Dallas Fort Worth; Utah Transit Authority, Jacksonville Florida; Contra Costa County, CA; Arlington, Virginia. Most operate in a controlled ODD and are operating in limited mixed environments. Use or need for a driver as a failsafe will likely be dictated based on local and state requirements. Development of approved transit vehicles that comply with federal safety standards (operate over 25 mph) is evolving with the first deployments expected in 2022.
	Long-Haul Automated Bus	Open road/mixed traffic	6	No	Automated bus has been developed and constructed by New Flyer but yet to demonstrated in an operational environment. SAE Level 4 transit vehicles are not yet available on the market. The timeframe estimated is to be 2024-25. Use or need for a driver as a fail safe will likely be dictated based on local and state requirements.
Regional Transportation Network Improvements	Traffic Signal Enhancements	n/a	9	Yes	Existing traffic signal technology for advanced systems - SPaT, MAP, BSM, as well as Transit and Freight priority are prevalent throughout the United States. Deployments of newer C-V2X technology is limited but known.

4 Risk Assessment

Risk is determined for all known and anticipated risks that may affect deployment. Those identified are specific regarding deployment and not related to technological maturity. The risks are evaluated in the following matrix and on a low, medium, and high scale.

Table 3. Risk Matrix

Concept	Technology	Risk Assessment	Risk Level
Smart Yard	Freight Container Transfer	Solutions exist for wheeled machines to transfer between trucks and autonomous yard jockeys or staging areas, though they may be manned or remote controlled. Autonomous solutions may not be available.	Med
	Automated Container Loading	Solutions currently exist in production and commercial adoption in a relevant operating environment.	Low
	Automated Trailer Coupling/Decoupling	Automated yard jockeys can currently couple and decouple trailers.	Low
	Pallet and Other Non-conforming Loads	Automated pallet transfer machines and forklifts currently available, though are only seen in warehouse environments.	Med
	Opportunity charging	While technology readily available, other requirements for charging include the design of the facilities and power supply to those facilities. If solar arrays cannot meet energy demands of LSLH, then a grid connection will be required to span that gap.	Low
	EV truck charging	Long haul etrucks have yet to become prevalent in the market. Since these trucks don't yet exist in numbers, it is high risk to build charging infrastructure with no demand. While EV truck charging technology is available, R&D is still being done for high-powered fast charging for trucks. Electric truck charging in its current state is relegated to facilities that operate on return-to-base types where trucks can be charged overnight at the owners stations.	High
	Rail Intermodal at the Norfolk Southern Goodman Yard	Side loaders for transfer of freight from rail cars commercially available, though automated solutions may not be available.	Med
Truck Parking and Long Combination Breakdown Lot	EV truck charging	See above	High
	Alternative Fueling – CNG	Alternative fuels are widely available with a range of vehicles that use them. Some fuels have enough market penetration to make them viable for deployment like CNG.	Low
	Truck Parking Information System	Integration into existing truck parking information systems easily attained. Requires coordination with MAASHTO and private companies.	Low
Smart Corridor	Over-the-Road Automated Freight (autonomous yard jockeys)	While proven in the operational domain of warehouse yards, the autonomous yard trucks have not been deployed on public right of way. Doing so may require additional programming or design for the new environment.	Med
	Freight priority (V2X communication)	Freight signal priority has been deployed at several locations. Since this is a connected vehicle application, coding and system architecture is available through the ITS JPO. This application can be easily added to intersection RSUs during construction and deployment.	Low
	Intersection Situational Awareness	This technology has been deployed in various projects, though the programming required to detect, analyze, and flag moving objects is notoriously difficult.	Med
	In-road inductive charging (P3)	This technology is still being developed and tested in small deployments. Currently there are no deployments in the United States. Standards are yet to be developed and performance data is not readily available.	High
Power/ Electrification	Solar Fields/Farm/Storage	Design and contruction of solar arrays to be done by licensed professional. Solar arrays may or may not generate enough energy to meet demand of LSLH. An interoperable system with grid connection would be required if not. Vanadium redox flow battery storage is considered to be safer than lithium-ion batteries, however the market price of vandium is highly volatile.	Low
	Private EV charging	Commercial units available for purchase. Estimations of demand for shifting workforce or shifts in market for Evs may results in supply/demand imbalance, however installing additional units after would be quick and efficient with existing connections to power supply.	Low
Distribution Prioritization and Mission Control System	Artificial intelligence	Artifical intelligence offered in off the shelf solutions. These would require the relevant interface and network connections as required by the application. It is likely that some programming for site specific conditions are also needed.	Med
	Freight movement by "missions"	See artificial intelligence above	Med
	Build out automation over time	Building out automation requires developing a system that is easily adjusted or modified to implement new technologies in the future, there should redundancy in system design to allow for network capacity of communications and power infrastructure. Additional physical components can be installed as needed per the manufacturer but it is not anticipated that additional network will need to be added.	Low
Data Communications	Communications totem	Communications totesm will require power and physical components installed. Design of the system will likely require coordination with the system designer and manufacturer during system design.	Low
Transit	Automated Transit for First/Last Mile to Employment	Automated transit has been in use but limited to pilot type deployments. No standard operating automated transit vehicles are in employ.	Med
	Long-Haul Automated Bus	Long haul automated buses still in develop and yet to be tested in operational environment. Testing could be done here, but being rural there is less demand for transit.	High
Regional Transportation Network	Traffic signal enhancements	Intersection RSUs can be augmented to existing controllers if compatible. If not, the controllers will need upgraded to ones that can, increasing system costs. No other traffic signal hardware is anticipated to need replaced or modified.	Low