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1.0 Executive Summary

The State of Iowa is taking a proactive approach to preparing for increasing levels of vehicle automation. This document sets out a comprehensive vision for the Iowa Department of Transportation’s (DOT) role in the future transportation environment, and a plan for accelerating progress towards that future. In particular, it covers:

- **Why?** The National Highway Traffic Safety Administration (NHTSA) has estimated that 94 percent of vehicle crashes are due in some measure to human error, and projects that some 80 percent of these could be mitigated or eliminated by the application of automation. Automated vehicles (AVs) are expected to operate most effectively if such vehicles have access to high quality, continuously updated driving environment information beyond that which can be directly captured by on-board sensors.

- **What?** Iowa DOT seeks “to deliver a safe, reliable, and efficient transportation system by developing an AV-ready driving environment.” To this end, Iowa DOT has set out goals (see Figure 1) which address both near term improvements in the availability of driving environment information for safer human driving, and longer term availability of data to support automated driving functions as they become commercially available.

- **How?** Iowa DOT has identified a set of key capabilities which support the above goals. The state is partnering with the private sector and academia to develop and execute a roadmap which lays out Iowa DOT’s priority use cases for deployment, the key enablers which may be required to support that deployment, and the research and development (R&D) program necessary to further explore and develop the enablers. The roadmap also includes an ongoing stakeholder outreach activity to ensure both awareness and engagement in key communities.

This Vision Document includes a set of industry timelines which reflect current understanding and projections, and which are used to inform timing and investment decisions in the roadmap. However, it is expected that both the timelines and the roadmap will continue to evolve over time; therefore this Vision Document will be maintained as a “living document” with regular updates to reflect ongoing change.

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1 This document assumes that vehicles will add increasing levels of automated functionality which can be applied in an increasingly broad variety of driving environments over time. The terms “automated vehicles” and “vehicle automation” are therefore used throughout to avoid confusion with the concept of “autonomous vehicles,” which are often considered to be fully automated vehicles which require no human participation in the driving task. For detailed definitions of the various levels of vehicle automation, see Appendix B.

2 [https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115](https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115)
2.0 Vision and Goals

This section describes Iowa DOT’s vision for the future vehicle automation system and its impact, including the specific high-level goals of the program.

Background

Vehicle automation is regarded by many as a key part of the solution to existing and upcoming transportation challenges. In particular, NHTSA has estimated that 94 percent of vehicle crashes are due in some measure to human error, and projects that some 80 percent of these could be mitigated or eliminated by the application of automation.³ Public, private and academic practitioners alike are investing heavily in developing all aspects of an overall transportation system which can significantly improve road safety and efficiency by removing error-prone human drivers from many driving situations for passenger, freight, and fleet vehicles.

For government, the key benefits of AV technology lie in its ability to enhance mobility, safety, and freight movement. For Iowa DOT, these key measurable benefits resonate across several key deployment themes:

- **Mobility** – Mobility in Iowa is largely influenced by the rural nature of the state and the severe weather conditions that can impact travelers at any time of the year. Establishment of a live integrated AV corridor between Cedar Rapids and Iowa City will focus AV solutions on the needs of Iowa’s travelers. AV technology will arguably be the single largest change in human mobility options since the advent of the automotive industry. Iowa’s vision is to establish an effective starting point that will help the state prepare to leverage the mobility benefits of AV technology. Beyond establishing a proving ground, Iowa DOT will be part of directing where AV technology is applied and how it can be harnessed to solve key mobility challenges of the future. With the AV corridor, Iowa DOT and the university community will be able to define and influence the future of travel in Iowa by exploring new ways to enhance mobility with communication between vehicles and infrastructure, by powering predictive models with real-time weather and traffic data, and by empowering travelers and vehicles with precise information on what lies ahead.

- **Roadway Safety** – The long term potential of AV to deliver a crash-free roadway system is perhaps one of the most compelling factors driving AV deployment. However, vehicle automation alone is not enough to achieve true network efficiencies and crash-free transportation. Beyond the vehicle, transportation networks must empower agencies and infrastructure to communicate with vehicles in real-time. Smart traffic controllers, lane closures, ice and snow mitigation, work zones, and speed advisories are examples of DOT functions that must be automated and closely monitored to enable safe automated vehicle operation. The vision of Iowa DOT is that most functions related to operating and maintaining roadway infrastructure would need to be automated to effectively communicate conditions in real-time with automated vehicles.

- **Freight Movement** – Freight movement lies at the core of Iowa’s agricultural based economy and is a key focal point for AV investments. Commercial drivers need better information on traffic, weather, road conditions, parking and services to plan routes and make more informed decisions about how fast to drive, what route to take, or where to stop for fuel or parking. Automated trucks will help avoid crashes, particularly those related to driver fatigue, and make

³ [https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115](https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115)
Iowa’s roads safer for everyone. This project will engage with the trucking community to set a foundation for a range of technologies designed to enhance freight movement and safety. Emphasis on freight movement will:

- Help move freight more efficiently and reliably.
- Help establish Iowa as a key intermodal freight mobility hub.
- Support Iowa’s key freight partnerships and bring these companies to the table for pilot projects.
- Drive towards measurable CV/AV freight efficiency benefits.
- Attract 3rd party investments in Iowa freight mobility and services.

The initial focus of automated vehicle development has largely been on vehicle-based solutions, i.e., the addition of sensors and software to vehicles so that those vehicles can either assist human drivers to better perform specific functions or directly perform those functions on behalf of the human driver.

However, while the sensors on the vehicle can help detect the driving environment around the vehicle, additional high quality driving environment data from external sources can add significant value by helping the vehicle understand and anticipate driving conditions. This external information allows vehicles to “see” further ahead in all conditions, and serves as an additional set of input data for automated vehicle control functions, adding to the safety and comfort of automated driving. Figure 2 shows a few examples of the questions which such data can help automated vehicles to answer.

![Figure 2 Example Information Needs for Vehicle Automation](image)

At this time, the full set of driving environment data of the coverage, quality, and standardization that would be necessary to add the greatest potential value to automated vehicle systems does not exist. This situation creates a unique opportunity for states and other public sector infrastructure owner operators to contribute to the development and eventual provision of this information by building on the transportation information data that they already provide to the traveling public. Iowa DOT
recognizes this opportunity and has made work in this area the centerpiece of its efforts to enable automated driving.

In particular, Iowa DOT envisions an automotive-grade\(^4\) information architecture, which can continuously provide an up-to-date view of driving conditions to enhance the vehicle’s decision making and control functions. This information architecture is shown in Figure 3.

Within this architecture, an array of information flows to and from vehicles, the infrastructure (e.g., roadside sensors) and devices (e.g., smartphones). This information is typically collected and managed by a variety of participants, such as DOTs, telecommunications companies (Telcos), and private sector data aggregators who combine information from multiple sources.

A key component of the architecture is a living map, a central function which synthesizes this wide array of data to provide a continuously-updated representation of the driving environment. This “map” combines content from the road infrastructure, vehicle sensors, and other mobile devices, with high-definition spatial data. An example of the kinds of information which may be included is shown in Figure 4.

Data from the living map may be distributed as a series of information streams which can be used by humans, vehicles, and infrastructure owner/operators to improve safety, mobility, and efficiency throughout the transportation network. These information streams may include specific types of data, or may be offered in the form of centrally-generated alerts, driving condition predictions, or other pre-

\(^4\) Automotive-grade: Meets automotive industry standards which include rigorous testing and validation for suitability and use in the automotive environment.
processed information. The development of such datafeeds is central to Iowa DOT’s AV program as is detailed in the Vision and Goals sections that follow.

Figure 4 Sample Driving Environment Data

Vision

Iowa DOT recognizes the value of automated driving and seeks to become a leader in enabling these new solutions. Simply put, Iowa DOT’s AV Vision is:

To deliver a safe, reliable, and efficient transportation system by developing an AV-ready driving environment.

This effort will include critical focus areas such as freight logistics, vehicle to vehicle/infrastructure (V2X) communications, advanced mobility applications, and the integrated flow of data and services.

Current work on vehicle automation has naturally focused on driving environments with reduced complexity, e.g., locations with consistently good weather, clear lane markings, etc. Iowa’s profile as a four-season state with significant truck traffic and a highly cooperative transportation community makes it an excellent facilitator for the next stage of development, offering a “real world” development environment which can help vehicle automation achieve its ultimate goal of operating in all conditions.

Goals

In support of this vision, Iowa DOT is investing in an Automated Vehicle Technologies Project. The goals for this project are designed to create an environment where automated driving and advanced transportation technologies can thrive in Iowa. The goals are:

- Build new capabilities that will assist people to drive more effectively and move freight more efficiently than today.
- Facilitate highly automated driving as it becomes available.
- Make Iowa a leader in offering an AV-Ready driving environment.
As part of this program, Iowa DOT intends to work with its partners to develop and deploy a set of Key Capabilities to the driving public. These capabilities center around providing automotive-grade information, including:

- **Advanced Predictive Travel Condition Datafeeds** for use by drivers and automated vehicles.
- **Real-time availability of core AV-Ready Datafeeds** for ingestion by automated vehicles. This includes High Definition (HD) Maps for key corridors.
- **Real-time Driving Environment Data** for use by the state traffic management center (TMC) and state fleets.

A core component of the AV project is the development of a vehicle *research platform* which will allow both testing and demonstration of new capabilities. Further information about the project is detailed in the sections below.

### 3.0 Getting There

#### Industry Timelines

The automated vehicle industry is evolving rapidly. Activities are underway worldwide to automate everything from passenger and agricultural vehicles to transit shuttles and long haul freight trucks. The pace of investment is being further accelerated by the large number of new business and transportation models which may be viable in the automated environment, including car-sharing, various forms of transit/individual vehicle integration, etc. For example, car-as-a-service (CaaS), in which travelers share vehicles rather than owning them, and mobility-as-a-service (MaaS), in which travelers access a combined set of public and private transportation services through a consolidated interface, may both benefit significantly from the availability of automated vehicles.

It is important for Iowa DOT to closely monitor this evolution and periodically refine the project to reflect the state of the industry. By understanding industry timelines, Iowa DOT can take a leadership role in defining what transportation agencies can provide to facilitate automated driving. At the same time, Iowa DOT can avoid making premature investments. A realistic view of the industry pace will keep Iowa DOT’s research, demonstration, and pilots in line with what can be most useful and deployable at scale.

This section summarizes Iowa DOT’s current perspective on this situation. To begin with, it is important to note a key assumption: vehicles will add new automated functionality progressively rather than changing directly from human to fully automated driving. This functionality will evolve to handle an increasingly broad variety of driving environments over time. The Society of Automotive Engineers
(SAE) has developed industry standard definitions of these levels of automation. These definitions have recently been adopted by NHTSA in the Federal Automated Vehicles Policy document⁵:

- Level 0: No Automation
- Level 1: Driver Assistance
- Level 2: Partial Automation
- Level 3: Conditional Automation
- Level 4: High Automation
- Level 5: Full Automation

Appendix B includes detailed definitions of each of these levels.

The development of automated vehicle functions, however, is not the only factor necessary to realize Iowa DOT’s vision. Other key factors include:

- **Driving Environment Coverage.** The current SAE standard describing levels of automation only addresses the automated functionality for levels 1-5. It does not consider whether this functionality will be available in all driving environments. Driving environments may vary by road type (controlled access, interchanges, arterials), location (urban, rural, mountainous), road surface condition, traffic congestion levels, construction activity, and weather. At this time, the primary focus of commercial development for automated vehicles has been on controlled access highway driving in relatively clear weather, on clear lanes (i.e., no construction), with clear road markings. It is difficult to project when these systems will become capable of handling automated driving on arterials and other more complex situations. With this in mind, Iowa DOT’s initial efforts will focus on Interstate highway scenarios that aim to test a specified set of complex conditions on Interstates.

- **External Data Integration.** In order for automated vehicles to benefit from real-time infrastructure data, automotive original equipment manufacturers (OEMs) and/or aftermarket suppliers will need to produce vehicles with connectivity, automation functions, and the ability to ingest and apply the infrastructure data to those vehicle control functions (sensor fusion using external data) as shown in Figure 5. Some Tier One automotive suppliers are developing systems which will provide this capability today, but automotive OEM production timeframes have not yet been announced. Based on what we know now, we expect that production will most likely begin to take place in the 3- to 5-year timeframe.

Figure 5 Key Factors in External Data Integration

- **Commercial Availability.** There have been many announcements about the upcoming availability of the technologies noted in the previous bullet for consumer, freight, and professional fleet AV use. However, these are highly complex systems and there are known issues to overcome as the industry works to make the technology truly ready for the road. Connectivity is the furthest along this path, with the majority of new cars sold expected to include some type of connectivity by 2020, but actual commercial availability of all the necessary components is still the subject of projections. Based on what we know now, we project that initial commercial availability of Level 3 automated vehicles, which can include infrastructure data in their decision-making, will occur in about 2020.

- **Market Adoption.** Once automated vehicles are available, it will take time for consumers and fleet owners to begin purchasing and using them. Consumer interest in this technology is particularly strong among both owners and passengers, but until those consumers have a chance to interact with and purchase such vehicles, it is difficult to project actual uptake rates reliably. Freight adoption may well occur sooner, as business owners seek to realize cost and safety benefits in a competitive marketplace.

The timeline in Figure 6 summarizes the Project Team’s current perspective on these factors, based on a wide variety of industry analyst reviews and direct conversations with the industry. It is a current best estimate based on those sources, and will be updated on a regular basis to reflect ongoing industry evolution. As shown in the table, it appears that the industry will be at the point where information infrastructure support for vehicle automation begins to be beneficial in about 2020. This timeframe is thus the correct target for early state AV-support readiness, and the roadmap for this project has been designed accordingly. (See Appendix C for roadmap details.)
Stakeholders, Roles and Partnering

The automated vehicle ecosystem is both complex and evolving. Daily news headlines announce new entrants, and re-combinations and partnerships among existing ones. For example, a high-level snapshot of current discussions reveals 16 different public and private categories of manufacturers, operators, integrators, and aggregators (Figure 7). And that snapshot does not take into account the finer-grained distinctions within each category or the extended circle of industries that will likely be significantly impacted by the advent of vehicle automation.

Adding to the complexity of this situation, traditional categories have begun to blur, as automotive OEMs invest in Mobility as a Service (MaaS) providers, and as technology firms who are not part of the traditional automotive community lay plans to build automobiles, or become automotive software component suppliers. This blurring reflects the fact that vehicle connectivity and automation have already moved transportation squarely into the realm of consumer Big Data and the Internet of Things. Transportation is no longer a silo, but is instead a part of a larger, highly integrated flow of information and services which impact every aspect of the consumer’s daily life.
Each of these stakeholders plays a role in the ecosystem. For example, public sector infrastructure owner operators manage the physical transportation network assets, such as roads and signals, and work to optimize travel within that network. These roles might lead to a collaboration like the one shown in Figure 8:

- **Automotive and Freight System Vendors** serve as sub-system integrators, combining hardware and software of their own manufacture and from other firms to provide functionality specified by the OEMs.

- **Component Suppliers** provide the sub-components used by the System Vendors and, in some cases, directly by the OEMs.

- **Telecommunication Companies** manage the wireless communications networks, such as cellular, which transport information to and from vehicles.

- **Infrastructure Owner Operators** manage the physical transportation network as noted above, including providing driving environment data to vehicles.

- **Data Aggregators** collect driving environment data from a variety of sources, process it to produce automotive-grade information, and provide it back to vehicles.
In this highly dynamic environment, Iowa DOT is carefully considering their role in key areas, such as:

- **Regulation, Policy and Public Acceptance.** The introduction of automated vehicles has the potential to drive major change in everything from mobility to social norms, tax and funding bases, and the structure of associated businesses such as insurance. Early, clear, and on-going interaction with policy-makers and the general public will be critical to ensuring that the benefits of vehicle automation are recognized and accepted as quickly and smoothly as possible.

- **Partnerships.** The automated vehicle space is inherently networked. A wide variety of participants is necessary to build such vehicles and provide them with the security, software, and data resources to operate effectively, as shown in Figures 7 and 8. State and local governments can foster progress in a variety of ways, including facilitation and support of key public/private R&D and deployment programs which address the needs of a wide variety of stakeholders. For this project, Iowa DOT has established partnerships with HERE, Iowa State University, and the University of Iowa (the current Project Team). Additional partners and stakeholders are expected to become part of the program over time. Further detail will be documented here and in the *Stakeholder Outreach* section as this effort evolves.

- **Technology Deployment.** The eventual architecture required to support automated driving is evolving daily, but it seems clear that both physical and virtual infrastructure will play a role. Iowa DOT is working towards meeting these future requirements, which will likely include connectivity, high quality real-time data, transport system integration, and many other related solutions.
Stakeholder outreach and engagement is critical to the success of all three of these areas. This project includes such outreach as one of the key components of its roadmap and expects to systematically and consistently address these interactions as part of the ongoing program. (See Appendix C for roadmap detail.)

**Enablers & Investments**

Deploying the key capabilities set out in the goals will require a complex, multi-year, multi-partner effort. This section provides a concise snapshot of the key enablers which may be required to implement the vision for automated driving, and the planned activities and timeline to further investigate and potentially deploy those enablers. This snapshot is summarized in the roadmap.

At the highest level, the project is made up of three components, as shown in Figure 9. The project will work to:

- Generate key automotive-grade info-streams. Establish sources for high quality driving environment data and process it into useful streams of information.
- Establish distribution infrastructure. Build the platforms necessary to intelligently send the right information at the right time to the right end users.
- Integrate with end client systems. Establish the interfaces and tools to provide information safely to:
  - Human drivers (e.g., through mobile devices and in-dash displays)
  - Automated vehicle systems
  - DOT transportation management systems

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6 An end client system in this case is any device which can receive and process driving environment data.
This approach allows Iowa DOT to build solutions which will support both humans and machines as automated driving becomes increasingly capable and prevalent. The safety and efficiency of human driving can be improved with more extensive and timely information and alerts about the driving environment in the near term, and the functionality of automated vehicles can be enhanced with information tailored for machine use in the longer term.

To translate these components into a roadmap, the Project Team considered four key building blocks, as shown in Figure 10:

- **Use Cases.** The Key Capabilities described in the Goals provide a high level view of the functionality Iowa DOT wishes to offer end users (e.g., real‐time V2X hazard alerting). Given this direction, it is then necessary to select a prioritized set of use cases, which provide a detailed description of more specific functionality to be tested and eventually deployed to the public (e.g., work zone, weather, and traffic jam alerts).

- **Enablers.** As the use cases are selected, the Team can then assess which physical and virtual infrastructure components (enablers) appear to be necessary to build a system to deliver such capabilities. Policy and standards enablers may also be required to ensure that the system can function as desired.

- **R&D.** The heart of the project is the research and development effort which will allow us to develop the enablers needed to realize the Key Capabilities. This is envisioned as an iterative effort in which various components and solutions will be designed, tested, and piloted.

- **Outreach.** As noted above, stakeholder outreach will be critical to promoting Iowa DOT’s activities to supporters and additional partners. This activity will be an ongoing effort throughout the program.
The full roadmap, including anticipated timelines for each of the building block activities, is shown in Appendix C, and should be regarded as a “living document.” It is expected that the roadmap will evolve as the Project Team learns from its work and the industry continues to progress.

The sections below provide more detail about each of the items in the roadmap.

Use Cases

This section addresses the key question: What functionality do we want to be able to offer end users and by when? The answer to this question falls into two categories which correspond to the goals of the overall project:

- **Build new capabilities that will assist people to drive more effectively and move freight more efficiently than today.**
- **Enable automated vehicle driving as it becomes available.**

As a first step the Project Team has identified pressing safety and mobility challenges for the state of Iowa such as winter weather events and special events like the State Fair, Iowa’s largest event, attracting approximately 1 million visitors from all over the Midwest. From these, the Project Team settled on an initial set of use cases related to hazard alerting for initial deployment (see Table 1). These use cases correspond to the V2X Hazard Alerting Key Capability, and address the nearer term need to improve information for human drivers.

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7 Iowa State Fair - Fair Dates and Attendance, available at: https://www.iowastatefair.org/about/fair-dates-attendance/ (accessed on December 7, 2016).
<table>
<thead>
<tr>
<th>Use Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash</td>
<td>When a crash is detected on the identified corridor, deliver safety messages to drivers as they approach the crash, alerting them to slow down, change lanes and/or exit, thereby alleviating a pinch point. Includes both crashes which are protected by first responders and those in which first responders have not yet secured the scene.</td>
</tr>
<tr>
<td>Weather</td>
<td>During events of extreme weather or hazardous road conditions, notify drivers to slow down or avoid the area or transmit other useful information. “Other information” is defined as more detailed information about the type of weather or road condition (e.g., “black ice on road” alert vs “adverse weather condition” alert) at this time.</td>
</tr>
<tr>
<td>Obstacle</td>
<td>When an obstacle is detected to be blocking one or more travel lanes on the identified corridor, notify travelers to slow down, change lanes and/or exit to alleviate congestion around a pinch point.</td>
</tr>
<tr>
<td>Work Zones</td>
<td>Provide notifications to drivers of the exact location and timing of active construction zones to prevent unsafe situations around work zones.</td>
</tr>
<tr>
<td>Wide Moving Jam</td>
<td>As traffic congestion builds, the tail-end of the congestion can move against the flow of traffic as cars are speeding up and slowing down. This situation is called a “tail-end queue,” “shockwave,” and “end of queue.” When this situation occurs, alert drivers to reduce speed and stay alert for oncoming traffic jam.</td>
</tr>
<tr>
<td>Event Congestion</td>
<td>During scheduled special events, notify drivers of real-time conditions and queues, allowing them to take alternate routes where possible.</td>
</tr>
</tbody>
</table>

The Team has chosen to start its work with a focus on three of these use cases: work zone, weather and wide moving jam.

For automated driving, the Iowa Project Team will identify an additional set of use cases to address the AV-ready Datafeeds Key Capability by providing information which will be directly ingested by automated vehicle functions and used to inform control decisions. A sample of potential AV functions that can be augmented with external driving environment data is shown in Figure 11. For example, a vehicle which has on-board equipment to handle blind spot detection might benefit by receiving data about the location of known obstacles and slow moving vehicles, both to confirm on-board sensor readings and to extend the range of those sensors around curves or other geographic limitations. Current functions which are under discussion for initial work include curve warning, adaptive cruise control (ACC), and speed advisory.
It also should be noted that it is expected that further use cases for deployment will be added as the project progresses.

**Enablers**

This section answers the key question: What enablers may need to be in place to allow us to deploy the identified use cases?

The Project Team has begun the process of identifying and developing the key enablers. The initial set of enablers under considerations is shown in Table 2.

![Table 2](Table2.png)
### Table 2  Key Enablers

<table>
<thead>
<tr>
<th>Policy/Standards</th>
<th>Quality and Data Exchange (QDE) Specification version 1</th>
<th>Specification for infrastructure datafeeds to ensure sufficient quality, accuracy, and operational consistency. Specification is expected to evolve during the course of the project and to be contributed as an open standard for national use.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Infrastructure</td>
<td>Connected traffic signal infrastructure</td>
<td>Traffic control infrastructure capable of sharing Signal Phase and Timing (SPaT) data in real-time.</td>
</tr>
<tr>
<td></td>
<td>DOT roadside and fleet-based sensor assets</td>
<td>Infrastructure and vehicle-based monitoring of the driving environment, e.g., construction/lane closure start and end sensors, snowplows capable of transmitting real-time location and road conditions, etc.</td>
</tr>
<tr>
<td>Virtual Infrastructure</td>
<td>Initial Infrastructure datafeeds per Specification</td>
<td>Incident, Congestion, Weather, Obstacle, and Work Zone datafeeds for proof of concept testing. Should meet or exceed Quality and Data Exchange Specification.</td>
</tr>
<tr>
<td></td>
<td>Initial Predictive Travel Model</td>
<td>Travel model which successfully provides high-accuracy predictive travel times using weather data. Final model can be applied globally.</td>
</tr>
<tr>
<td></td>
<td>HD Map for Selected Sections of Interstate Corridors</td>
<td>Highly accurate (10-20cm) mapping data. Provides a foundation for automated vehicle functions and all other real-time datafeeds, supporting vehicle positioning, localization, maneuver planning, etc.</td>
</tr>
<tr>
<td></td>
<td>Cloud Platform</td>
<td>Cloud data platform which ingests infrastructure and vehicle sensor data, and enables distribution of alerts.</td>
</tr>
<tr>
<td></td>
<td>Software for initial Use Cases</td>
<td>Application software which processes incoming data, generates appropriate alerts, transmits and displays them for human drivers and for vehicles. May include analytics, communications, and display tools.</td>
</tr>
</tbody>
</table>

These initial enablers are envisioned as building blocks for the overall system, as shown in Figure 12. In this figure, the green overlays show how several of the enablers listed in Table 2 fit into the basic information architecture which was described above in the Background section.
In future years, additional enablers are planned as shown in the roadmap (Appendix C). The detailed descriptions of these enablers will be developed as the project evolves, but the overall concept is to incrementally add capability to the overall system over time.

**Research & Development**
Substantial research and development is needed to explore, validate, and finally establish the key enablers which will be needed to support eventual deployment. This work will include:

- **Proof of Concept** – A limited test to prove that a function or set of functions works. Proof of concept testing may be conducted in the lab or in the field. Once system capability is sufficiently proven by proofs of concepts, functionality becomes eligible for more advanced testing in real-world Pilots. One example of a proof of concept might be: “prove that our basic V2X platform can successfully send messages to vehicles and that we can successfully use the necessary datafeeds to support weather and work zone alerts.”

- **Pilot** – A test of real-world operation of a package of functions. The purpose of a pilot is to get feedback from a limited number of users in a real-world setting for a period of time. Conducting a pilot involves recruiting pilot participants and coordinating feedback from the participants. The lessons learned from a pilot, and in particular the feedback obtained from pilot participants, can inform further testing and plans for later wide-scale deployment. One example of a pilot might be: “Outfit vehicles with hazard alerting devices which communicate with the V2X platform and trial them in the field.”

- **Demonstration** – A public presentation of a function or set of functions. Demonstrations (or demos), may serve one or more of the following end goals: educating and raising awareness among policy makers and the public, establishing advancement and leadership in the field, and attracting new partners and industry. It is important to note that demos are intended to give participants the “experience” of using the functions only, and may involve technical workarounds (such as the use of archived weather data for demos of winter hazard
warnings). One example of a demonstration might be: “Invite the public to see vehicles successfully receiving a set of hazard alerts under specific, predefined conditions.”

Once the research and development work has produced successful results, Iowa DOT will then be positioned for deployment, which is defined in this program as the real world operation of a package of functions. One example of a deployment might be: “Make hazard alerting data stream available to consumer and freight vehicles which choose to receive it.”

As shown in Figure 13, it is expected that development will be an iterative process, with multiple proofs of concept and pilots leading up to eventual deployments, and that the deployments themselves will address a specific geographic scope and scale in coverage over time. The actual program of proofs of concept, demonstrations, etc., is under development at this time.

The Team has organized the initial work in four areas, focused on development and testing of:

- **V2X Hazard Alerting.** This work will show that datafeeds can be successfully ingested by the Data Platform, and that appropriate hazard alerts can be generated by the platform, intelligently distributed to and received by test devices. Test devices will include both smartphones and an in-vehicle dashboard display.

- **Connected Traffic Signal Information.** This work will show that signal phase and timing (SPaT) data can be successfully ingested by the data platform, and that messages can be generated by the Platform, intelligently distributed to and received by test devices.

- **Predictive Travel Conditions Model.** This work will show a travel model which successfully provides high-accuracy predictive travel times using weather data. It is expected that the final model will be applicable in any geographic location where input data is available.

- **AV-Ready Datafeeds.** This work will show that specific automated vehicle functionality can successfully use incoming data to inform vehicle control.

It is expected that these efforts will result in three key activities during 2017:
• V2X Hazard Alerting to smartphones. A proof of concept will confirm that specific datafeeds from the DOT and HERE can successfully be processed through the cloud platform and provided to a smartphone. A pilot is also planned to collect feedback from a limited number of users in a real-world setting, to inform further testing and plans for later wide-scale deployment.

• V2X Hazard Alerting to an in-vehicle dashboard display. This proof of concept is planned to show that specific datafeeds from the DOT and HERE can successfully be processed through the cloud platform and provided to an in-vehicle display.

• V2X Hazard Alerting and AV-Ready Datafeeds to support partial automated vehicle control on predetermined routes. This proof of concept is planned to show that specific datafeeds can be ingested by a research vehicle and used as sensor inputs to the vehicle control system for specific automated driving functions.

Each of these activities will work with a subset of the overall driving environment data to explore how specific use cases might function (e.g., work zone data and HD map data). This work is in its early stages and may evolve as the Team learns from its efforts.

The plan is then to build on these activities with pilots of the initial set of V2X use cases in 2018, followed by deployment of those use cases in 2019. A similar progression is anticipated for the Predictive Travel Modeling work stream. The work on AV-ready datafeeds is dependent on the development and production availability of vehicle technologies outside the control of the current program partners. Activities in that area will be progressed as feasible, with an eye to the currently expected 2020 commercial deployment timeframe for automated vehicle functionality which can ingest and integrate externally provided datafeeds.

Stakeholder Outreach
The Project Team anticipates the need for ongoing outreach to a wide array of stakeholders. Planning and execution for this activity will be an ongoing effort. The first items in the program plan are:

• Five Year Vision Document. This document is being developed to articulate the core concepts and messaging about this project. It is expected that new revisions will be issued on an annual basis.

• Marketing Demonstrations. As described above in the discussion of 2017 activities, the Team plans to provide live demonstrations of how provision of high quality real-time data and alerts into a vehicle can enable safer driving by both humans and vehicle automation functions.

• Communications Highlights. Opportunities for further demonstrations and public outreach based on key project milestones and concepts will be identified and discussed with Iowa DOT’s Strategic Communications team. In 2017, this will likely include the release of this Vision document and the demonstrations.

Performance Measures
Iowa DOT intends that its support for automated driving development will result in both more rapid progression of industry capabilities and the eventual improvements in safety, mobility and resulting economics indicated in the overall vision and goals for this effort. Pre-deployment, the primary measure which can be used for performance, is the successful completion of key milestones in the roadmap. Iowa DOT and its partners are therefore targeting a steady progression, from R&D through proofs of concept, pilots, and eventual deployment, and will be reviewing this progress in a series of status updates. Additional performance measures will be developed and tracked post-deployment.
Adoption

A great deal of attention is focused on consumer adoption of automated vehicle systems, but the earliest adopters are much more likely to be in freight, transit, and professional fleets (e.g., taxis). In particular, transit buses traveling at low speeds on relatively short routes within controlled access facilities such as airports are very strong candidates for high levels of automation. Experiments in this area are underway in a number of locations around the globe.

Freight vehicles are also strong candidates, as relatively small benefits from automation can translate to very large economic benefits across an entire commercial operation. As Iowa currently moves 947 million tons of freight across the state annually, with a projected 75 percent growth by 2040⁸, this is a logical area of initial focus. As part of this project, Iowa DOT has already begun conversations with potential freight partners, and is proactively working to engage them in R&D activities which will help accelerate their adoption of vehicle automation.

Iowa DOT expects to expand their efforts to accelerate adoption to additional communities as industry progress dictates, and will develop detailed plans for those activities as appropriate.

4.0 Key Takeaways

Vehicle automation holds great promise to improve transportation mobility and safety. The Iowa DOT is proactively exploring how it can best advance this future. This Vision Document is one part of that effort, and includes the following key concepts:

- Additional high quality driving environment data from external sources can add significant value by helping the vehicle understand and anticipate driving conditions. Iowa DOT envisions an automotive-grade information architecture, which can continuously provide an up-to-date view of driving conditions to enhance the vehicle’s decision making. This external data would be combined with on-board vehicle sensor data within automated vehicles.

- It appears that the 2020 timeframe is the point where information infrastructure support for vehicle automation begins to be beneficial. Iowa DOT is therefore targeting this timeframe for its own AV-support readiness.

- As part of its work towards facilitating AV-readiness, Iowa DOT is working with partners to develop and eventually deploy a set of Key Capabilities. This includes Real-time V2X Hazard Alerting; Advanced Predictive Travel Condition Datafeeds, Real-time availability of core AV-Ready Datafeeds for ingestion by automated vehicles, and Real-time Driving Environment Data for use by the state traffic management center (TMC) and state fleets.

- Iowa DOT expects to share key outputs of these activities with the global automated vehicle community to help accelerate progress wherever possible.

The Iowa team will maintain this Vision Document as a ‘living document’ and will revise both the document and its overall program regularly in response to and in coordination with ongoing industry evolution.

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⁸ [http://www.iowadot.gov/systems_planning/freight/Iowa%20Freight%20Facts%20and%20Figures.pdf](http://www.iowadot.gov/systems_planning/freight/Iowa%20Freight%20Facts%20and%20Figures.pdf)
### Appendix A: Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregator</td>
<td>In this context, a Data Aggregator which collects driving environment data from a variety of sources, processes it to produce automotive-grade information, and provides it back to vehicles.</td>
</tr>
<tr>
<td>Automotive-grade</td>
<td>Meets automotive industry standards which include rigorous testing and validation for suitability and use in the automotive environment.</td>
</tr>
<tr>
<td>AV</td>
<td>Automated Vehicle. A vehicle that operates at Levels 1 and above on the SAE J3016 automation scale.</td>
</tr>
<tr>
<td>CaaS</td>
<td>Car as a Service. A transportation resource model in which travelers share vehicles rather than owning them.</td>
</tr>
<tr>
<td>CV</td>
<td>Connected Vehicle. A vehicle which has the ability to receive and/or send information to external sources via any wireless medium.</td>
</tr>
<tr>
<td>Demonstration</td>
<td>A public presentation of a function or set of functions.</td>
</tr>
<tr>
<td>DOT</td>
<td>Department of Transportation</td>
</tr>
<tr>
<td>ECU</td>
<td>Electronic Control Unit. Part of a vehicle which controls internal mechanical or electronic systems.</td>
</tr>
<tr>
<td>Enabler</td>
<td>In this context, a physical and virtual infrastructure component, or a policy or standard necessary to deliver an AV-ready driving environment</td>
</tr>
<tr>
<td>End Client System</td>
<td>In this case, any device which can receive and process driving environment data.</td>
</tr>
<tr>
<td>HAV</td>
<td>Highly Automated Vehicle. A vehicle that operates at Levels 3 and above and above on the SAE J3016 automation scale. These are systems that rely on the automation system (not on a human) to monitor the driving environment.</td>
</tr>
<tr>
<td>HD</td>
<td>High Definition</td>
</tr>
<tr>
<td>Living Map</td>
<td>A central function which synthesizes a wide array of data to provide a continuously-updated representation of the driving environment for use by humans, vehicles, and infrastructure owner/operators to improve safety, mobility, and efficiency.</td>
</tr>
<tr>
<td>MaaS</td>
<td>Mobility as a Service. A transportation resource model in which travelers access a combined set of public and private transportation services through a consolidated interface.</td>
</tr>
<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer. An individual or (more usually) a company that manufactures new motor vehicles or motor vehicle equipment.</td>
</tr>
</tbody>
</table>

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10 Ibid.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>A test of real-world operation of a package of functions.</td>
</tr>
<tr>
<td>PoC</td>
<td>Proof of Concept. A limited test to prove that a function or set of functions works.</td>
</tr>
<tr>
<td>QDE Spec</td>
<td>Quality and Data Exchange Specification. Draft specification for infrastructure datafeeds to ensure sufficient quality, accuracy, and operational consistency which is planned to evolve as part of the Iowa DOT AV Program. (See Enablers section for more detail.)</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>Roadmap</td>
<td>Snapshot of the key enablers required to implement the vision for automated driving, and the planned activities and timeline to investigate and deploy those enablers.</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineers (formally known as SAE International)</td>
</tr>
<tr>
<td>SPaT</td>
<td>Signal Phase and Timing</td>
</tr>
<tr>
<td>Telco</td>
<td>Telecommunications company</td>
</tr>
<tr>
<td>TMC</td>
<td>Traffic Management Center</td>
</tr>
<tr>
<td>Use Case</td>
<td>As defined by ISO, the description of the behavioral requirements of a system and its interaction with a user. A detailed description of specific functionality that Iowa DOT wishes to offer to the traveling public.</td>
</tr>
<tr>
<td>V2X</td>
<td>Vehicle to Vehicle / Vehicle to Infrastructure</td>
</tr>
</tbody>
</table>

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### Appendix B: Levels of Vehicle Automation

<table>
<thead>
<tr>
<th>SAE level</th>
<th>Name</th>
<th>Narrative Definition</th>
<th>Execution of Steering and Acceleration/Deceleration</th>
<th>Monitoring of Driving Environment</th>
<th>Fallback Performance of Dynamic Driving Task</th>
<th>System Capability (Driving Modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

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Appendix C: Roadmap

A detailed description of the components of this roadmap is provided in the *Enablers and Investments* section above.

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industry Timeline</strong></td>
<td>Levels 0-2</td>
<td>Levels 0-2</td>
<td>Levels 0-2</td>
<td>Level 3 + connectivity and invehicle data fusion</td>
</tr>
<tr>
<td><strong>Deployed Use Cases</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Enablers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Policy/ Standards</strong></td>
<td>Quality and Data Exchange (QDE) Spec rev 1</td>
<td>Quality and Data Exchange (QDE) Spec rev 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Physical Infrastructure</strong></td>
<td>Connected traffic signal infrastructure</td>
<td>DOT roadside and fleet-based sensor assets</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Virtual Infrastructure</strong></td>
<td>Initial Infrastructure datafeeds available per Spec</td>
<td>HD Map for Selected Corridors on Controlled Access Roads</td>
<td>Live Predictive Travel datafeeds available</td>
<td>Operational Infrastructure and Vehicle Sensor datafeeds available</td>
</tr>
<tr>
<td></td>
<td>Initial Predictive Travel Model</td>
<td>Cloud Platform A available</td>
<td>Initial Vehicle Sensor datafeeds available per Spec</td>
<td>Cloud Platform B available</td>
</tr>
<tr>
<td><strong>R&amp;D</strong></td>
<td>Successful test of Initial V2X Use Cases</td>
<td>Pilot, Initial V2X Use Cases</td>
<td>Pilot; Predictive Data Provision</td>
<td>Deployment; Initial V2X Use Cases</td>
</tr>
<tr>
<td><strong>Stakeholder Outreach</strong></td>
<td>Vision Document rev 1</td>
<td>Demo: Info for Humans &amp; Machines</td>
<td>Communications Highlights</td>
<td>Vision Document rev 2</td>
</tr>
<tr>
<td><strong>Performance Measures</strong></td>
<td>Successful Proof of Concepts</td>
<td>Successful Pilots</td>
<td>Successful Deployment</td>
<td>Vision Document rev 3</td>
</tr>
</tbody>
</table>

*Figure 14 Enabler Roadmap*