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ENTERPRISE

Defining and Advancing Roadway Digital Infrastructure (RDI)

ENTERPRISE TRANSPORTATION POOLED FUND STUDY TPF-5(490)

FINAL REPORT

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16. Abstract

Roadway Digital Infrastructure (RDI) is a term that has been increasingly used in the context of roadway operations to describe the non-physical aspects that supplement the physical infrastructure in the support of operations. The collection, movement, and use of data is the most widespread example of digital infrastructure. This document describes collaborative and coordinated national-level RDI activities being conducted. In addition to researching and documenting national RDI activities, this ENTERPRISE project conducted engagement and discussions among members around conceptual or actual examples of RDI deployments in their agencies. Key takeaway and themes from these discussion include: transportation agency procurement of RDI systems and support is still evolving, transportation agency integration of RDI into existing systems is challenging, the Department of Transportation (DOT) role in RDI is still evolving with unanswered questions, there is some confusion about the term RDI and the justification for investments in it, and RDI data presents new opportunities and challenges for DOTs.

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The cover page image is provided courtesy of Joe from Pixabay.

Project Champion

Charles Tapp from the Texas Department of Transportation was the ENTERPRISE Project Champion for this effort. The Project Champion served as the overall lead for the project.

ENTERPRISE Members

The ENTERPRISE Board consists of a representative from each of the following member entities.

- Illinois Department of Transportation
- Iowa Department of Transportation
- Kansas Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Ontario Ministry of Transportation
- Texas Department of Transportation
- Wisconsin Department of Transportation

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List of Abbreviations

AI	Artificial Intelligence
ATMS	Advanced Transportation Management Systems
CCTV	Closed-circuit television
CSW	Curve Speed Warnings
CV	Connected Vehicle
CVRIA	Connected Vehicle Reference Implementation Architecture
DMS	Dynamic Message Signs
DOT	Department of Transportation
ENTERPRISE	Evaluating New Technologies for Roads Program Initiatives in Safety and Efficiency
FHWA	Federal Highway Administration
IDOT	Illinois DOT
I&IT	Information and Information Technology
IT	Information Technology
ITS	Intelligent Transportation System
KDOT	Kansas DOT
MDOT	Michigan DOT
MnDOT	Minnesota DOT
MTO	Ontario Ministry of Transportation
NOCoE	National Operations Center of Excellence
PFS	Pooled Fund Study
PS&E	Plans Specifications and Engineering
RDI	Roadway Digital Infrastructure
RWIS	Road Weather Information Systems
SaaS	System as a Service

SDX	Situational Data Exchange
SWRI	Southwest Research Institute
TMC	Transportation Management Center
TRB	Transportation Research Board
TxDOT	Texas DOT
V2X	Vehicle to Everything
VRU	Vulnerable Road Users
WisDOT	Wisconsin DOT
WWD	Wrong-Way Driving

Executive Summary

Roadway Digital Infrastructure (RDI) is a term that has been increasingly used in the context of roadway operations to describe the non-physical aspects that supplement the physical infrastructure in the support of operations. The collection, movement, and use of data is the most widespread example of digital infrastructure.

This document describes collaborative and coordinated national-level RDI activities being conducted by three different but overlapping groups:

- The National Strategy for RDI being led by the Federal Highway Administration (FHWA).
- The Digital Infrastructure Strategy by ITS America.
- A Collaborative Agenda for RDI Research, Development and Deployment by a volunteer RDI Working Group.

In particular, the top 10 critical areas of collaboration for research, development, and deployment, identified in A Collaborative Agenda for RDI Research, Development and Deployment are presented in the table below.

Table E-1 Top 10 Critical Areas of Collaboration for RDI Research, Development, and Deployment [1]

Category	Critical Area
Organizational	Data governance and Enterprise Data Management
	Business models, public/private partnership
	Agency workforce practices around digital infrastructure
Technical	Data quality, trustworthiness
	Cross-map referencing, location integrity
	Interoperability and standards
	Security, resilience, risk
Scaling	Geographic scaling approaches
	Priority use cases
	Incentivizing deployment and commercialization

In addition to researching and documenting national RDI activities, this ENTERPRISE project conducted engagement and discussions among members around conceptual or actual examples of RDI deployments in their agencies. High-level takeaways and themes from these discussions with ENTERPRISE member agencies include:

[1] RDI Working Group. A Collaborative Agenda for RDI Research, Development and Deployment. August 2025.

- **Transportation agency procurement of RDI systems and support is still evolving.** Experiences shared by member agencies suggest that the costs for RDI products are generally higher than expected. However, procurement for RDI solutions is similar to Intelligent Transportation System (ITS) projects (e.g., procuring a service from a consultant, vendor, or supplier), such that the agency can start small and expand if performance is satisfactory. Agencies may also be able to benefit from private sector RDI products without a need to own the assets to collect the RDI in-house.
- **Transportation agency integration of RDI into existing systems is challenging.** Integration of RDI solutions with legacy systems (e.g., Advanced Transportation Management Systems (ATMS)) may require modernization of existing systems to benefit from the RDI solutions. Additionally, it is challenging to think of integrating individual systems into an overarching RDI, and the roles of ATMS and Transportation Management Centers (TMCs) need to be defined in relation to RDI.
- **The Department of Transportation (DOT) role in RDI is still evolving with unanswered questions.** For example:
    - Are data scientists needed at the DOT, and if so, what role(s) would they play regarding RDI?
    - How much data/information should the DOT store and/or buy?
    - Is it in a DOTs best interest to prepare for massive data given unknown costs and benefits?
- **There is some confusion about the term RDI and the justification for investments in it.** Agency executives are asking why the DOT should focus on DOT systems (e.g., traveler information systems) that utilize RDI if the information can be provided by others (e.g., Google Maps or Apple Maps), either now or in the future. Additionally, there are risks of relying on private RDI solutions as fundamental components of an overall system if the vendor stops providing the solution or costs increase substantially. However, systems engineering and corridor assessments should answer RDI questions and assist in determining where to focus RDI efforts.
- **RDI data presents new opportunities and challenges for DOTs.** For example, many typical roles that DOTs performed with agency-owned data collection, processing, and dissemination systems are now possible with primarily private sector data and infrastructure. In addition, many states have challenges with Information Technology (IT) and ITS coordinating (e.g., new devices come with new software). Finally, many states are not ready for the massive data that is possible in RDI as resources are already a challenge and RDI data would require additional and possibly new resources.

Chapter 1: Introduction

The physical infrastructure of the road includes physical structures that support movement of people and goods such as pavement, bridges, signs, lighting, and conduit. Examples of Intelligent Transportation Systems (ITS) physical infrastructure include Dynamic Message Signs (DMS), Road Weather Information Systems (RWIS), ramp meters, Closed-circuit television (CCTV), loop detectors, and other non-intrusive detection systems.

Roadway Digital Infrastructure (RDI) is a term that has been increasingly used in the context of roadway operations to describe the non-physical aspects that supplement the physical roadway infrastructure in the support of operations. The collection, movement, and use of data is the most widespread example of digital infrastructure.

> What is RDI?
>
> RDI describes the non-physical aspects that supplement the physical roadway infrastructure in the support of operations.

A working definition of RDI is included in the National Operations Center of Excellence (NOCoE) website as "the collective public and private technology assets that create, exchange, or use data or information to improve national transportation system outcomes by optimizing the provision of existing and new transportation services." [2]

Is RDI New?

While RDI is a relatively new term with expanded use in the industry, the digital infrastructure described by it has existed for years. For example, as early as 1999 state DOTs provided travel times on DMS for selected corridors in and around metropolitan areas. The typical approach was that loop detector data was collected in the field and communicated to a Transportation Management Center (TMC) to calculate average vehicle speeds over segments of roadway. The speed data was converted to travel times. DMS messages were created in the Advanced Transportation Management Systems (ATMS) and sent to the DMS to display the travel times. This collection of data, communication, and processing of the data to create content to deliver travel times to the public was RDI by today's definition. RDI described in this was typically entirely owned and operated by the public sector Department of Transportation (DOT) in 1999.

How has RDI Evolved?

Expanding upon the DOT example above, in 2025, travelers can still view travel times computed by the DOT and displayed on DMS. However, in 2025, DOTs have more sources of data than they did in 1999, and these sources often include the use of private sector data that enable additional coverage areas beyond those areas equipped with DOT-owned data sources (e.g., detectors). Similarly, a traveler using a private sector 3rd Party application, such as Google Maps or Apple Maps, can view travel times for any

[2] National Operations Center of Excellence: Digital Infrastructure Activities. Accessed October 2025: https://transportationops.org/roadway-digital-infrastructure-activities.

route selected, regardless of whether the travel is on the DOT roads equipped for travel time displays. Therefore, a primary way that RDI has evolved over the past 25 years is the transition towards more private RDI data sources and solutions and the combination of public and private sources and services.

Parallels Between Physical Infrastructure and RDI Evolution

As noted above, RDI was traditionally primarily DOT owned (e.g., loop detectors, fiber communications, roadside DMS) and has transitioned to be increasingly privately owned and operated. There is an interesting parallel to the physical infrastructure being a combination of public and private infrastructure. For example, the most thought of physical infrastructure of the transportation network are the pavement, bridges, signs, etc. But, in addition to these public examples of physical infrastructure, there are privately owned and operated elements, such as gas stations, restaurants, and cell phone towers that make local and long-distance travel convenient.

Project Purpose

The term RDI may be newer to some in the transportation industry, and there are multiple definitions of digital infrastructure from different perspectives. Therefore, ENTERPRISE Pooled Fund Study (PFS) Members expressed interest in clarifying definitions and understanding early activities they could perform related to RDI. As with many technology-related research efforts, this project, *Defining and Advancing RDI*, provides a snapshot in time of RDI knowing it may become outdated soon after the publishing date.

Project Purpose

To clarify RDI definitions and understand early activities ENTERPRISE members could perform related to RDI.

1.1 Project Objectives

There were four (4) overall objectives for this project.

- To allow ENTERPRISE members to come to a common definition of RDI.
- To engage members to step through and interpret the national definition and strategy for RDI as it evolved through national efforts.
- To research supported dialogue and member discussions about their potential or actual use cases for RDI.
- To identify near-term considerations for members to help them as they advance RDI within their agencies and determine if any near-term actions would benefit from future ENTERPRISE projects.

1.2 Project Approach

To accomplish the project objectives, the draft content developed to support national definition and strategy development for RDI was reviewed and documented as well as engagement with FHWA. In addition, each ENTERPRISE member state presented RDI-related topics or projects within their agency to support dialogue and discussion of RDI.

The core deliverables of the project were a series of webinars with ENTERPRISE members to discuss each members' perspectives on examples of RDI within their organization.

1.3 Report Organization

This report includes the following sections.

- Chapter 2: National RDI Activities includes definitions of RDI and describes national activities and documentation available.
- Chapter 3: Member States RDI Perspective summarizes conceptual or actual examples of ENTERPRISE members RDI deployments in their agencies and notes key high-level takeaway and themes.
- Chapter 4: Summary and Implementation Plan provides an overall project summary and documents a suggested implementation plan.

Chapter 2: National RDI Activities

This chapter describes collaborative and coordinated national-level RDI activities being conducted by three different but overlapping groups:

- The National Strategy for RDI being led by the Federal Highway Administration (FHWA).
- The Digital Infrastructure Strategy by ITS America.
- A Collaborative Agenda for RDI Research, Development and Deployment by a volunteer RDI Working Group.

2.1 National Strategy for RDI

FHWA has been working collaboratively with public and private stakeholders to champion the development of a national strategy for RDI. This national strategy "seeks to align and accelerate realization of a multi-stakeholder digital infrastructure framework that advances current and future national transportation goals."[3] [2]

A series of workshops have been conducted at the Transportation Research Board (TRB) annual meetings in 2023, 2024, and 2025 around the discussion and concept of a national collaborative RDI strategy. During these workshops, the working definition presented was:

> "RDI is the collective public and private technology assets or network of networks that create, exchange, or use data or information to improve the transportation system by the provision of existing and new services for travelers, businesses, and agencies. RDI is more than the data it generates and supports, it includes all the assets that generate, move, process, and display data and information; and those assets that support end user usage of the generated information."

Through discussions and presentations during these workshops, three primary goals for RDI that were identified and discussed were to:

- Modernize systems;
- Streamline exchanges; and
- Integrate insights.

[3] National Operations Center of Excellence: Digital Infrastructure Activities. Accessed October 2025: https://transportationops.org/roadway-digital-infrastructure-activities.

2.2 ITS America Digital Infrastructure Strategy

ITS America completed a report in September 2023 titled the Digital Infrastructure Strategy Report.[4] The report outlines real-world use cases for digital infrastructure deployment and provides a roadmap for successful implementation by U.S. DOT. The digital infrastructure definition provided in this report is:

> "Digital infrastructure is the public and private technology assets that create, exchange or use data to provide information and insights to advance transportation safety, sustainability, equity, access and opportunity. Digital infrastructure is the data, communications systems, servers, routers, hardware, sensors, software applications, and computing to share information through data exchanges and platforms. Digital infrastructure includes the transfer, storage and processing of digital information shared through communications networks across users, companies, devices and public agencies."

2.3 Collaborative Agenda for RDI Research, Development and Deployment

In August 2025, a discussion paper entitled "A Collaborative Agenda for RDI Research, Development and Deployment" was circulated that resulted from contributions of a collaborative team that included participants in the RDI Working Group and those that participated in charettes at the TRB Annual Meeting in 2025, including acknowledgements to 60 individuals.[5]

This document included a definition of RDI that is consistent with earlier activities (e.g., the TRB workshops described in section 2.1) and based on a definition of digital infrastructure provided by RAND:

> "a network of networks consisting of hardware and software elements that digitally process, store, and transmit data that is shared across many domains such as finance, telecommunications, energy, information technology, public health security, and transportation, among others." [6]

RDI Working Group Membership
Participation in the RDI Working Group is voluntary and coordinated through a LinkedIn Group. Individuals may join at: https://www.linkedin.com/groups/14612189/

The document then provides a more specific definition, which precedes the definition presented at the TRB workshops described in section 2.1 above:

[4] ITS America. Digital Infrastructure Strategy Report. September 2023. Accessed Oct 2025: https://itsa.org/advocacy-material/digital-infrastructure-strategy-report.

[5] RDI Working Group. A Collaborative Agenda for RDI Research, Development and Deployment. August 2025.

[6] Brackup, Julia, Sarah Harting, and Daniel Gonzales. Digital Infrastructure and Digital Presence: A Framework for Assessing the Impact on Future Military Competition and Conflict. Santa Monica, CA: RAND Corporation, 2022.

> "Roadway Digital Infrastructure (RDI) describes the unique aspects of the broader digital infrastructure that are used in the transportation domain and highlights the opportunity for the necessary modernization and evolution of those aspects."

The document notes "RDI focuses on the 'how,' looking at the underlying data/information, electronic, and communications capabilities, public-private partnerships, and integration with broader technology domains."

In this document, the collaborative research agenda for RDI is identified through:

- The definition of principles of RDI research.
- The top 10 critical areas for collaboration on RDI research, development, and deployment.
- The priority research needs.

Most relevant to this document and the ENTERPRISE PFS are the top 10 critical areas of collaboration for research, development, and deployment, summarized below, as included in the document. See Table 2-1.

Table 2-1. Top 10 Critical Areas of Collaboration for RDI Research, Development, and Deployment

Category	Critical Area
Organizational	Data governance and Enterprise Data Management
	Business models, public/private partnership
	Agency workforce practices around digital infrastructure
Technical	Data quality, trustworthiness
	Cross-map referencing, location integrity
	Interoperability and standards
	Security, resilience, risk
Scaling	Geographic scaling approaches
	Priority use cases
	Incentivizing deployment and commercialization

Chapter 3: Member States RDI Perspective

The primary activity in this ENTERPRISE project was engagement and discussions among members around conceptual or actual examples of RDI deployments in their agencies. To accomplish this, the ENTERPRISE group conducted a series of project-specific webinars to discuss such examples, and they engaged in dialogue to advance the understanding of RDI. This engagement was productive and insightful. In total, four webinars were conducted on various RDI topics. See Table 3-1.

Table 3-1. ENTERPRISE Members RDI Webinar Topic(s)

Date	Agency	RDI Topic(s)
Webinar #1 1.28.25	Minnesota DOT (MnDOT)	• Truck Parking Information
	Iowa DOT	
Webinar #2 2.25.25	Illinois DOT (IDOT)	• ITS Security Audits • Shift from Centralized Vehicle Detection to Edge Computing • Reversible Lane Control Upgrades Coordinated with Bridge Joint Repair and Resurfacing
	Michigan DOT (MDOT)	• Edge Analytics Supporting Vulnerable Road User Detection and Wrong-Way Driving (WWD) Detection
Webinar #3 3.25.25	Kansas DOT (KDOT)	• A Concept for RDI Supporting Incident Detection
	Texas DOT (TxDOT)	• A Comparison of Project Development for Physical Infrastructure, ITS, and RDI • An RDI Concept for Curve Speed Warnings
Webinar #4 5.27.25	Wisconsin (WisDOT)	• ITS Systems, Traffic Data & Integration of Projects
	Ontario Ministry of Transportation (MTO)	

Overall, RDI is a difficult concept to grasp when thinking of it in general. Instead, smaller and more tangible "bites" can help agencies identify candidate activities. ENTERPRISE member agencies are purchasing several turnkey products and shared a number of examples of RDI solutions, as presented in Table 3-2. In particular, ENTERPRISE member agencies are improving safety and mobility by:

- Utilizing RDI services from private companies (consuming and using data).
- Benefiting from RDI products that assist other technical solutions.
- Contributing to the RDI through data sharing (potential for considerably more in future years).

Additionally, travelers in ENTERPRISE states also benefit from all private RDI solutions (e.g., 3rd party navigation).

Table 3-2. Sample RDI Solutions

Solution	Description	Example
All Private	RDI solutions that will be **entirely private, do not rely on DOTs**	• Examples of private vehicles that slow in advance of curves (as shared by Iowa DOT). • Examples of products such as Google Maps that are self-sufficient (as shared by Iowa DOT).
Services	RDI solutions that are **turnkey products/ services to DOTs**	• The concept of purchasing crash data from one or more vendors (as shared by KDOT). • The concept of procuring truck parking space availability data (as shared by MnDOT, Iowa DOT). • The concept of procuring private sector traffic/vehicle data (as shared by MTO and WisDOT).
Assist	RDI solutions to **support/assist DOT functions or systems**	• The concept of edge analytics that are integrated with Vulnerable Road Users (VRUs) and WWD systems (as shared by MDOT). • Edge computing for vehicle detection when merged with legacy loops (as shared by IDOT). • The concept of creating an environment to house/ manage/quality control the data that results from RDI (as shared by MTO).
DOT Provided	RDI solutions where **DOT content may be offered to "the cloud"**	• The concept of curve speed warnings defined by "geofencing" for 3rd parties to use (as shared by TxDOT). • The concept of state DOT event data feeds (as operational in multiple ENTERPRISE member states, e.g., Work Zone, Incidents, Driving Conditions).

Some high-level takeaways and themes from these discussions with ENTERPRISE member agencies include:

- **Transportation agency procurement of RDI systems and support is still evolving.**
    - As the industry transitions to the availability of increased RDI capabilities through private sources, agencies may be able to benefit from cutting edge technology and investments of private sector RDI products without a need to own the assets to collect the RDI in-house.
    - Input from ENTERPRISE members indicates that costs for RDI products are generally higher than expected and desired. If an agency is not dependent on the RDI product (e.g., if they have existing infrastructure to support the data needs) then buying it is an option. But, as existing infrastructures are reduced, there will be increased reliance on private RDI solutions.

  - Procurement for RDI solutions is similar to ITS projects (e.g., buying a service), such that the agency can start small and expand if performance is satisfactory. Performance will likely depend on the percentage of connectivity (e.g., vehicles, parking spaces).
  - Many systems for ITS devices and the supporting network were developed slowly, step-by-step with pilots that expanded and became permanent. If a system for ITS devices and the supporting network were to be built from scratch now, the system would be completely different.
- **Transportation agency integration of RDI into existing systems is challenging.**
  - Integration of RDI solutions with legacy systems (e.g., ATMS) may require modernization of existing systems to benefit from the RDI solutions.
  - It is challenging to think of integrating individual systems into an overarching RDI.
  - The roles of ATMS and TMCs need to be defined in relation to RDI:
    - TMCs are being asked to monitor and do more with new systems.
    - TMCs do not want to embed new systems into the ATMS.
    - ATMS were not initially designed for all the systems they are being asked to integrate and monitor.
  - Crash reports could be enhanced by overlaying outside conditions (e.g., RWIS data, congestion data, work zone data) but it is difficult with many systems.
- **The DOT role in RDI is continuing to evolve with still unanswered questions including.**
  - Are data scientists needed at the DOT to best understand and utilize the data available through RDI?
  - How much data/information should the DOT store?
  - How much data/information should the DOT buy?
  - Should the DOT modernize its systems?
  - How much of data analytics, storage, and access will be private-led and not "touch" the DOT (e.g., Google Maps is used for millions of trips daily)?
  - Is it in a DOT's best interest to prepare for massive data given unknown costs and benefits, including what data would be used, ingested, and turned into useful information for customers and/or improved safety?
- **There is some confusion about the term RDI and the justification for investments in it.**
  - Executives in agencies are asking why the DOT should focus on DOT systems that utilize RDI if the information can be provided by others (e.g., 3rd party traveler information services now deliver travel times), either now or in the future.
  - Vehicle built-in navigation may automatically slow the vehicle around a curve through adaptive speed control, for example; however, this option could be turned off by the user or the car company may decide, based on feedback, to discontinue this feature. As such, DOTs should still consider providing curve speed warnings.
  - Members identified the potential risks of reliance on private RDI solutions as fundamental components of an overall system if the vendor stops providing the solution or costs increase substantially.

  - Systems engineering should answer RDI questions and not be an afterthought with projects.
  - Corridor assessments during planning stages should consider connectivity assessments (e.g., how ubiquitous is connectivity on the corridor, the percentage of drivers operating with connected devices, etc.) to assist in determining where to focus RDI efforts.
- **RDI data presents new opportunities and challenges for DOTs.**
  - Many typical roles that DOTs performed with agency-owned data collection, processing, and dissemination systems are now possible with primarily private sector data and infrastructure.
  - Many states have challenges with Information Technology (IT) and ITS coordinating (e.g., new devices come with new software).
  - Data consistency within an agency and among states is a challenge, so consider a case study for one system. Data in one state may not be of interest to another state, but it should be standardized (e.g., does truck parking or driving conditions mean the same in one state as another).
  - Some DOTs have expressed that they are not ready for the massive data that is possible in RDI.
  - Resources (e.g., time and funding) are already a challenge and RDI data would require additional and possibly new resources.

The subsections below highlight aspects of the dialogue in each ENTERPRISE member RDI discussion webinar.

3.1 Minnesota DOT and Iowa DOT RDI Discussion

MnDOT and Iowa DOT shared their perspectives on RDI in relation to truck parking information. The discussion involved the context of private services delivering truck parking information as an illustration of the transition from public owned infrastructure, such as pavement sensors to detect the presence of vehicles in parking spaces to a private service of processing camera images (or other sources to determine parking availability). Themes of the discussion included the following:

> MnDOT and Iowa DOT Takeaways
>
> Early stages of RDI deployments may replicate the early stages of ITS.

- Ownership of private services that may be offered to support truck parking is not as easily understood as ownership of physical infrastructure and ITS components that are typically procured, installed, and operated by the DOTs.
- DOTs do not always have clarity on how much they are willing to spend, what the quantified benefits are, or what the end user expectations are for the private services. Whereas, when DOTs take a more traditional approach by deploying physical devices to collect data, this enables more accurate predictions of the costs of equipment and maintenance through the use of established contracting mechanisms.

- It is expected that involving private "RDI providers" would introduce data and information that extends beyond what DOTs reasonably capture through physical equipment sources, but DOTs recognize that there are likely additional costs that would be included in procuring these private sources. The procurement of probe data by multiple DOTs is an example of RDI providers delivering data.
- Entirely private RDI solutions already exist and are expected to continue to emerge (e.g., private app with truck parking, truckers sharing over radio, private business advertising parking spaces) where DOT involvement is limited or non-existent.
- As privately owned RDI continues to emerge and offer solutions, DOTs may limit initial uses while they test the new information. Test runs of cost and user demand are still driving factors in what services will be continued.

Finally, both states agreed that if RDI is approached like ITS is approached (i.e., on a project-by-project basis, using professional services contracts as the DOT gains more insight and experiences, then transitions to larger more complex build/buy contracts if successful), this may allow incremental additions of RDI vs. wholesale changes within the DOT. Additionally, the concept that if new resources are needed in the DOT (e.g., data scientists) to fully utilize RDI potential, university or consultant support may aid during the transition and while new systems are in the early stages of assessment, with DOTs considering adding these staffing capabilities later.

3.2 Michigan DOT RDI Discussion

MDOT shared experiences with RDI in the context of two deployments:

- VRU detection to identify possible conflicts with transit buses and deliver alerts of these conflicts.
- WWD detection systems to warn the wrong-way driving vehicle and other vehicles.

A commonality to both MDOT deployments was the use of System as a Service (SaaS), a private sector edge analytics service solution to support deployment decisions. In the VRU detection, the role of edge analytics was to process data in real-time and provide information on conflicts, near misses, and driver behavior. In the wrong-way driving detection the role of the edge analytics was to analyze the raw video and metadata to identify near-miss conditions and specific driving behaviors of wrong-way drivers. MDOT cited several questions that surfaced in these deployments that collectively help describe aspects of RDI. These are summarized as:

> **MDOT Takeaways**
>
> - Security
> - Understanding performance measures
> - Documenting approaches

- The need for security precautions that may result from reliance on these external SaaS solutions, recognizing that security issues are likely minimal in these demonstration projects but may expand if the locations of the deployments expand.
- The contracting approaches for SaaS may need to evolve as agencies learn more and expand their experiences, especially about understanding performance measures to assess the provider(s).

- There are concerns that the details of the external SaaS solutions may be unknown to the agencies operating them, perhaps somewhat of a 'black box' environment where the process for performing analyses is unknown. To this regard, if the outcomes are being used to achieve system optimization, how will agencies be able to cite how the optimizations were determined if there are no defined algorithms.

Concluding thoughts expressed that edge analytics, as one example of a privately delivered RDI solution, are recognized as beneficial, but agencies should consider possible unexpected costs and challenges.

3.3 Illinois DOT RDI Discussion

IDOT shared examples of activities that involve RDI and physical infrastructures. One example was the approach of collecting data through loop detectors and communicating the data to central locations for processing and analyses. In contrast, IDOT is considering approaches of edge computing where more processing and analyses on the data would occur decentralized.

A second example was the upgrades to reversible lane controls in conjunction with physical infrastructure changes. The fact that the combination of physical and digital infrastructure modifications were occurring on portions of the system, as compared to an entire redesign and overhaul, led to increased complexities.

IDOT shared the perspective that integrating new technology with legacy infrastructure tends to lead to opting for vendors delivering SaaS as it is often easier for an external system to deliver the service. However, SaaS introduces challenges to the roles that IT and security groups must address, and there may be preferences towards keeping these services and solutions internal for security purposes.

3.4 Texas DOT RDI Discussion

TxDOT shared thoughts on a likely transition to RDI through three different perspectives:

Perspective #1: Traditional Approach to Physical Infrastructure

Traditional physical infrastructure deployments involved the major high-level stages: project initiation, planning, plans specifications and engineering (PS&E), construction, and maintenance and operations. Additional perspectives included:

- Planning typically involved travel demand forecasts, capacity analyses, and origin-destination models to understand when capacity increases are needed and justified.
- PS&E involves traditional steps such as feasibility studies, environmental (and other) impact analyses, structural analyses (as needed), and preliminary and final designs.
- Construction typically involves the selection of a contracting approach, contracting, design, and finally the building of the infrastructure.
- Operations and maintenance is typically DOT or contractor provided and includes preventive maintenance, real-time operations, and responsive maintenance.

Perspective #2: ITS Components

The introduction of ITS components to the traditional approach involves physical devices and infrastructure working together with technology and technology systems with additional perspectives of:

- Planning is similar to that of traditional physical infrastructure with security being a larger concern. There is also the increased need to understand when and where technologies are needed.
- PS&E includes additional aspects such as the systems engineering process and use of the ITS Architecture (e.g., understanding the service packages and interfaces between systems).
- Construction typically is a less traditional letting process and more of a combination of professional services contracts and vendor procurements. Security is a key aspect to the installation of ITS systems and often requires more input from IT as a result of increased risks.
- The operation and maintenance of ITS are typically less DOT operations and more software and hardware support services contracts with supporting warranties for systems. With ITS systems, outages are often very visible outages (e.g., websites with cameras not available) and generate considerable public feedback.

TxDOT Takeaways

RDI has potential for significant benefits with limited costs, but individual states will not achieve this. There is a need for a national strategy.

Perspective #3: Digital Infrastructure Supporting ITS & Physical Infrastructure

RDI has the potential to influence (and already is influencing) considerable aspects of both ITS and physical infrastructure. Examples discussed in the webinar include:

- Individual vehicle connectivity to both send and receive data to increase the data available to DOTs as well as the options for disseminating information.
- 3rd Party Systems and services exist and are expanding, with examples that include Google Maps, Apple Maps, and Waze. The traveling public has considerable resources available and state and local DOTs can deliver information to these 3rd Party systems.
- Automobile manufacturer’s telematics systems (e.g., Ford ProTM , Nissan Connect, OnStar, etc.) that are utilizing data to inform drivers.
- Public and private data exchanges that include examples such as RITIS, Situational Data Exchange (SDX), and Southwest Research Institute (SWRI) Data Exchange called ActiveDXTM.
- Private data providers such as Reko, INRIX, Geotab, HERE, and TomTom.

As a result of these examples of RDI, considerations regarding planning for RDI include:

- Security is an even bigger concern (e.g., vehicle and movement data is a privacy concern);
- There are more options for acquiring data/information – more product sales solicitations.
- Connectivity Growth - percentage of vehicles in an area/corridor that are connected now? In 5 years?

    - What services can we offer these 'connected vehicles?' What can we expect from these 'connected vehicles?'
- Data availability - percentage of vehicles in an area/corridor reporting speed/harsh braking/etc. now? In 5 years?
- Vehicle turnover and evolution to connectivity and on-board devices must be considered.
- Analogous to sidewalks – cannot have breaks in the connectivity or coverage.

Regarding engineering, the Connected Vehicle Reference Implementation Architecture (CVRIA) has the functional, physical, and communications views to support the integration of RDI. As the role of RDI evolves, transportation agencies may need to address new questions, such as the following:

- Are data scientists needed?
- How much data/information to store?
- How much data/information to buy?
- How much will be private led and not "touch" the DOT (e.g., Google Maps is used for millions of trips daily)?

Example RDI Deployment

TxDOT shared a conceptual example in the approach to performing Curve Speed Warnings (CSW).

- The ITS approach to CSW is monitoring pavement conditions in selected curves, possible coupled with vehicle speed and/or height detection. As conditions meriting an alert are detected, an upstream sign can be activated to warn vehicles as they approach the curve. This is an effective approach to reaching all vehicles approaching the curve but requires the infrastructure at each curve to support the warnings.
- The connected vehicle (CV) approach to this is to broadcast CSW messages from roadside units upstream of the curve. This requires the detection infrastructure at each curve as well as the CV infrastructure to broadcast Vehicle to Everything (V2X) messages to vehicles using either V2X Direct or V2X Network and for the vehicles to have the capability to either receive V2X Direct broadcasts or Network V2X message communications.
- A potential RDI approach to CSW could involve the following:
    - A geofenced area being defined around a curve.
    - The ingest of pavement and weather data from nearby weather stations and possibly from public and private vehicle probes in the area.
    - The determination of alerts based on conditions, and the distribution of virtual alerts through network communications that enable existing applications such as Google Maps, Apple Maps, or Waze to receive alerts and notify drivers.

  The RDI approach involves much heavier involvement from private sector entities, and therefore there is less ownership and control by public sectors but also fewer costs that would need to be borne by public agencies.

Concluding thoughts from TxDOT were the following:

- There are potentially substantial benefits with minimal investments using RDI.
- However, RDI approaches would be more difficult to accomplish as an individual state conducting a “one off” deployment (e.g., a single state creating virtual curve warnings would be of less interest to national 3rd Party providers).
- Therefore, there is a need for a national strategy and combined approach that all states can support and move towards while sending common messages to 3rd Party providers.

TxDOT shared the perspective that the addition of RDI expands the need for Systems Engineering and adds a further element of data management to projects. As a result of this, future considerations may need to consider the anticipated growth rate of connectivity along primary corridors (e.g., what percentage of the vehicles may be reporting data and consuming data for analyses and presentation to drivers).

3.5 Kansas DOT RDI Discussion

KDOT shared the perspective that RDI could be a tool that helps reduce the time to notify vehicle incidents. This could result through vehicles self-reporting incidents and RDI enabling this communication to transportation agencies. Benefits of RDI performing this role would include the following:

- The use of RDI may decrease time to detect incidents and initiate a response.
- The use of RDI may avoid heavy deployment of physical infrastructure for detection.

However, KDOT recognizes that the implementation of RDI in this role may introduce new challenges, such as:

- How to select the services procured?
- How to define performance measures and how to monitor if vendor delivers on them?
- Will the vendor/services exist over the long term? Is the business model sustainable?

KDOT shared the following illustrative example:

If a DOT procured incident detection services from data vendors, it is possible that this could be a provided data service that enables individual vehicles to self-report incidents. The process of vehicles reporting incidents and the data reaching the DOT to initiate the response would be a form of RDI. In this scenario, the DOTs role could be to receive the reports and to then move the data to emergency responders and data disseminators that (through RDI) might be able to reach vehicles upstream of the incidents.

KDOT Takeaways

RDI has potential for increased data sources but is likely to introduce new challenges that must be addressed.

The following illustration was shared to further explain this potential scenario.

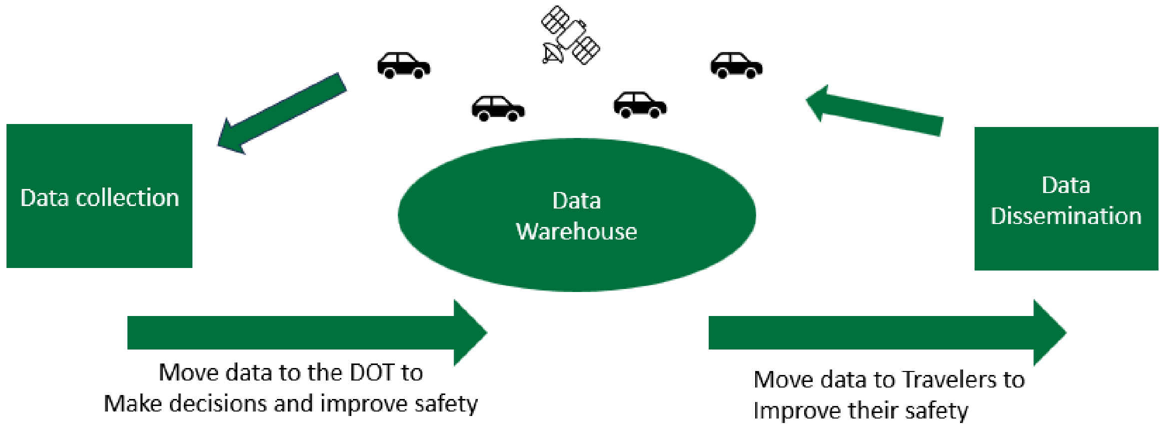

Figure 3-1. RDI Scenario - Vehicles Reporting Incidents and the Data Reaching the DOT to Initiate Response

3.6 Wisconsin DOT and Ministry of Transport Ontario RDI Discussion

WisDOT and MTO presented their insights together and shared many similar perspectives. Both agencies shared the following insights:

Integration of systems into an RDI. Both sites noted that it is challenging to think of integrating individual systems into an RDI. Both agencies operate a large number of ITS systems that were developed slowly over time, step by step. Often, these initiatives started as pilots and expanded into full operations and are now permanent. The agencies expressed that if they were to start over and approach all these systems in the context of contributing to and consuming from a universal RDI, it would be straightforward, but incrementally adapting each system to better utilize and contribute to RDI would be a challenge.

Both sites also expressed that, in an ideal world, all systems would be integrated. But, with proprietary software and hardware solutions, the concept of full integration is more difficult to achieve.

Benefiting from ubiquitous data. Both sites were asked whether they think state DOTs are ready for the massive amount of data that is available through RDI, with the answer being "no" in both cases. They further noted additional questions they feel should be asked as part of RDI considerations, including:

- Will the benefits of RDI justify the costs and complexities added?
- What are the benefits? Are they truly understood?
- Specifically, what data would we use? What would we ingest and turn into useful information for customers and/or improved safety?
- Will the benefits surpass the resources (time and funding) that will be required, recognizing that time and funding are already a challenge and RDI integration will require additional and possibly new resources?

Beyond these commonalities, WisDOT and MTO each shared their perspectives on possible solutions to consider as RDI advances.

WisDOT offered the following examples of possible solutions:

- ***Continue the needs-based approaches.*** ITS and Traffic Operations that have been deploying ITS for decades understand what they need, and through exchanges they can understand how other areas can benefit from their systems.
- **Ask whether there are established mechanisms for awareness or to share data statewide**. The challenge of tracking data availability across program areas within a DOT was described. Before pursuing extensive RDI efforts, agencies should define how they will organize data and make it available to others who need it.
- ***It may be more difficult to realize the potential benefits of data sharing than anticipated.*** While the concept of ubiquitous data sharing is hard to argue against, there are many logistical challenges (e.g., identifying stakeholders, appropriate overseers, territorial barriers, individual program needs, etc.), and it is easy for the benefits and use cases to get lost in the big picture logistics of accomplishing data sharing.

> WisDOT Takeaways
>
> Implementing RDI into existing ITS solutions introduces challenges that would have been avoided if this was the initial approach.

In addition to the expressions shared above, MTO offered the following examples of possible solutions as RDI moves forward:

- ***Conduct planning and preparations for centralized data storage, governance, and access.*** MDOT described internal efforts by the Information and Information Technology (I&IT) office to design and establish a platform to house data, with concepts that include:
  - Artificial intelligences (AI) built in for analyses.
  - Cybersecurity data rules that will make the data safe for sharing and consuming.
  - Metadata describing the data that not only describes it but also includes an assessment of "how good is the data."
  - Increasing staff resources to include Data Scientists on-board to support this (e.g., topics such as data conflation).

> MTO Takeaways
>
> There is a massive amount of data available, we need to understand if we are ready for it and how much of it do we want to acquire, store, use, etc.

Chapter 4: Summary and Implementation Plan

This section summarizes overall project key findings and provides a suggested implementation plan.

4.1 Summary

There are collaborative and coordinated national-level RDI activities being conducted by three different but overlapping groups:

- The National Strategy for RDI being led by the Federal Highway Administration (FHWA).
- The Digital Infrastructure Strategy by ITS America.
- A Collaborative Agenda for RDI Research, Development and Deployment by a volunteer RDI Working Group.

In particular, the top 10 critical areas of collaboration for research, development, and deployment, identified in A Collaborative Agenda for RDI Research document were presented in Table 2-1 above.

In addition to researching and documenting national RDI activities, this ENTERPRISE project conducted engagement and discussions among members around conceptual or actual examples of RDI deployments in their agencies. High-level takeaways and themes from these discussions with ENTERPRISE member agencies include:

- Transportation agency procurement of RDI systems and support is still evolving.
- Transportation agency integration of RDI into existing systems is challenging.
- The DOT role in RDI is still evolving with unanswered questions.
- There is some confusion about the term RDI and the justification for investments in it.
- RDI data presents new opportunities and challenges for DOTs.

4.2 Implementation

The research resulted in findings that ENTERPRISE member agencies can use to help make decisions about procuring RDI solutions. This primarily includes definitions for RDI and information about national RDI activities (Chapter 2) and findings from different ENTERPRISE member discussions (Chapter 3) about agency perspectives that may help to better understand how other agencies make decisions about procuring and using RDI.

Transportation agencies can implement the results of this research in several ways. Recommended implementation steps could include the following actions:

1. Distribute the report to agency staff, including operations and maintenance staff and decision makers, at ENTERPRISE agencies.

2. Learn from other agency experiences documented in these research findings and consider procuring RDI solutions on a small-scale to understand potential benefits.

3. Engage with national RDI activities, such as the RDI Working Group, which is voluntary and coordinated through a LinkedIn Group. Individuals may join at: https://www.linkedin.com/groups/14612189/

Overall, the research conducted for this project can support ENTERPRISE member agencies' decisions and practices to consider and use RDI.