Transit Vehicle-to-Infrastructure (V2I) Applications: Near Term Research and Development

Transit Vehicle and Center Data Exchange: Operational Concept

www.its.dot.gov/index.htm
Final Report — March 2015
Publication Number: FHWA-JPO-14-196

U.S. Department of Transportation

Produced by Transit Vehicle-to-Infrastructure (V2I) Assessment Research
U.S. Department of Transportation
ITS Joint Program Office
Federal Transit Administration

Notice

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-14-196		
4. Title and Subtitle Transit Vehicle-to-Infrastructure (V2I) Applications: Near Term Research and Development Transit Vehicle and Center Data Exchange Application: Operational Concept		5. Report Date March 2015 6. Performing Organization Code
7. Author(s) Gabriel Lopez-Bernal, Amy Jacobi and John L. Craig		8. Performing Organization Report No.
9. Performing Organization Name And Address Noblis 600 Maryland Ave., SW, Suite 755 Washington, DC 20024		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-11-D-00018
12. Sponsoring Agency Name and Address ITS-Joint Program Office 1200 New Jersey Avenue, S.E. Washington, DC 20590		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code **HOIT-1**
15. Supplementary Notes		

16. Abstract

This document serves as an Operational Concept for the Transit Vehicle and Center Data Exchange application. The purpose of this document is to provide an operational description of "how" the Transit Vehicle and Center Data Exchange application may operate.

The Transit Vehicle and Center Data Exchange application will allow for advanced communications and data transfer between a transit vehicle and centers (e.g., Transit Management Center, Traffic Management Center [TMC], and Emergency Management Center [EMC]). These communications will allow authorized personnel to access Transit Vehicles as remote, mobile infrastructure, capable of gathering and transmitting data regarding the vehicle and its surroundings to the data center and other connected vehicles. The Operational Concept discusses the following scenarios:

Scenario 1: Transit Vehicle Transmits Data to Support Mobility Applications and Real-Time Trip Planning

Scenario 2: Transit Vehicle Approaching Non-recurring Congestion due to an Incident or Crash

Scenario 3: Emergency Situation aboard or Within Vicinity of Transit Vehicle

This document is intended to convey at a high-level how the application may work, so others may design and implement systems in the future. As such, the Transit V2I Operational Concept documents are "generalized" and not specific to a geographic area, an operating entity (e.g., transit agency), existing systems that may be in place for a region, agency operating procedures, nor political environment.

17. Key Words	18. Distribution Statement
Connected Vehicles, Safety, Transit, Vehicle-to-Infrastructure, Transit Center, Data Exchange	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	47	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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1 Introduction

This document serves as an Operational Concept for the Transit Vehicle and Center Data Exchange application. The purpose of this document is to provide an operational description of “how” the Transit Vehicle and Center Data Exchange application may operate. Within this document, three potential scenarios that will be addressed by this application will be presented.

The Transit Vehicle and Center Data Exchange application will allow for advanced communications and data transfer between a transit vehicle and centers (e.g., Transit Management Center, Traffic Management Center [TMC], and Emergency Management Center [EMC]). These communications will allow authorized personnel to access Transit Vehicles as remote, mobile infrastructure, capable of gathering and transmitting data regarding the vehicle and its surroundings to the data center and other connected vehicles. Communication between the various management centers and the Transit Vehicle occurs via periodic wireless communication with Roadside Unit (RSU) infrastructure. Further, the TMC, EMC, or other authorized center could “ping” infrastructure to request that the next transit vehicle passing the RSU provide a snapshot of the requested information.

The application also seeks to facilitate the communication necessary to support previously defined transit mobility applications, particularly those defined by the Integrated Dynamic Transit Operations (IDTO) bundle of applications. IDTO calls for advanced communications between the transit vehicles and Transit Management Centers. The data collected by the Transit Management Center would be collected, processed, and disseminated to travelers through the Transportation Information Center (TIC) applications. This application is designed to account for multiple Transit Vehicle and Center Data Exchange scenarios. The Operational Concept discusses the following three scenarios:

- **Scenario 1: Transit Vehicle Transmits Data to Support Mobility Applications and Real-Time Trip Planning.** This scenario describes the transfer of real-time transit data to the Transit Management Center, TMC, and EMC to support the deployment of other mobility applications and with trip planning. Through connected infrastructure, this information would be transmitted to Transit Management Centers and disseminated to travelers through the TIC applications.
- **Scenario 2: Transit Vehicle Approaches Non-recurring Congestion due to an Incident or Crash.** This scenario describes how a Transit Vehicle may serve as a mobile data collection unit for the Transit Management Center, TMC, and EMC. The TMC would be notified via dedicated short range communication (DSRC) to RSU infrastructure that an incident or crash has occurred on a corridor. Using the BSM transmitted by the Connected Vehicle, the TMC would also be notified that an equipped Transit Vehicle is in the vicinity of the incident and equipped with an on-board external surveillance system. The TMC, through the RSU, may engage the transit vehicle’s on-board external surveillance system to obtain a real-time assessment of the incident or emergency situation. The real-time view of the event would allow the TMC to respond accordingly to alleviate the impact on transportation within the corridor and will allow the EMC to better assess the threat to respond accordingly.
- **Scenario 3: Emergency Situation aboard or within Vicinity of Transit Vehicle.** This scenario describes how a Transit Vehicle may serve as a mobile data collection unit for the TMC or EMC. For example, if an emergency situation aboard or within the immediate vicinity of the transit vehicle prompts the driver to engage the emergency covert alarm, the TMC would be notified through DSRC communications that an emergency response has been triggered by the driver of that transit vehicle. The vehicle location would be provided to the TMC and appropriate escalation procedures would be followed.

The scenarios were developed to account primarily for their effect on mobility. Readers might come to find that for this particular application, corollary benefits might also include safety gleaned from enhanced communication and coordination between transit service providers and TMCs and EMCs.

This Operational Concept describes how the application applies to all modes of transit, including motor buses, bus rapid transit (BRT), light rail, heavy rail and commuter rail.

1.1 Goals

The Transit Vehicle and Center Data Exchange application is expected to meet the following goals:

- **Goal 1: Utilize and Transmit Transit Vehicle Data to Improve Service Delivery and Mobility through Enhanced Coordination and Communication.** This application will focus on utilizing the data generated from existing transit Intelligent Transportation Systems (ITS) to improve transit operations and the information made available to the public. The TIC will serve as the central repository for multi-modal data, including Transit. Through enhanced coordination between Transit Management Centers and TMCs and EMCs, access to onboard systems will prove invaluable in addressing non-recurring events such as in emergency situations or crashes.
- **Goal 2: Leverage existing and emerging applications and tools in an integrated approach which benefits travelers and agencies.** This integrated application provides benefits greater than the sum of the leveraged applications when used independently.
- **Goal 3: Research and Develop Innovative Technologies.** This application is expected to research, develop, and integrate mobility-oriented technologies and applications enabled and/or supported by the connected vehicle environment.

1.2 Connected Vehicle Research

Connected vehicle research is both a concept and a program of services that can transform travel as we know it. Connected vehicle research combines leading edge technologies – advanced wireless communications, on-board computer processing, advanced vehicle-sensors, Global Positioning System (GPS) navigation, smart infrastructure, and others – to provide the capability for vehicles to identify threats, hazards, and delays on the roadway and to communicate this information over wireless networks to provide drivers with alerts, warnings, and real time road network information. At its foundation is a communications network that supports vehicle-to-vehicle (V2V) two-way communications, V2I one- and two-way communications, and vehicle or infrastructure-to-device (X2D) one- and two-way communications to support cooperative system capability. In this context, the term “device” refers only to devices that are “carry-in” devices (i.e., devices that can be temporarily installed in vehicles and are not connected to in-vehicle information systems). These devices include ones (e.g., cell phones) that could also be carried by pedestrians or other users of the roadways (e.g., cyclists). Connected vehicles enable a surface transportation system in which vehicles are less likely to crash and roadway operators and travelers have the information they need about travel conditions to operate more effectively. Connected vehicle research will establish an information backbone for the surface transportation system that will support applications to enhance safety and mobility and, ultimately, enable an information-rich surface transportation system. Connected vehicle research also supports applications to enhance livable communities, environmental stewardship, and traveler convenience and choices.

The ability to identify, collect, process, exchange, and transmit real-time data provides drivers with an opportunity for greater situational awareness of the events, potential threats, and imminent hazards within the vehicle’s environment. When combined with technologies that intuitively and clearly present alerts, advice, and warnings, drivers can make better and safer decisions while driving. Additionally, when further combined with automated vehicle-safety applications, connected vehicle technology provides the vehicle with the ability to respond and react in a timely fashion when the driver either cannot or does not react quickly enough. Vehicle safety systems, because of the need for frequently broadcasted, real-time data, are expected to use dedicated short range communications (DSRC) technology for active safety applications. Many of the other envisioned applications could use other technologies, such as third generation (3G) or fourth generation (4G) cellular or other Wireless Fidelity (Wi-Fi) communications, as well as DSRC. The rapid pace of technological evolution provides tremendous opportunities for connected vehicles, and the program is positioned to capitalize upon these advances as they happen.

The U.S. Department of Transportation (USDOT) currently has a very active set of research programs that are focused on the development of crash avoidance systems based on both V2V and V2I (meaning both I2V and V2I) DSRC technology. In addition, the USDOT is actively researching ways to improve mobility and reduce environmental impacts of transportation, using wireless communications (not necessarily based on DSRC technology). The expectation is that, in the future, in-vehicle systems will run a combination of safety, mobility, and environmental applications that communicate using the most effective wireless technologies available.

1.3 The Transit V2I Research Program

The Intelligent Transportation Systems (ITS) Joint Program Office (JPO) is charged with planning and execution the ITS Program as authorized by Congress. The ITS JPO is under the Office of the Assistant Secretary for Research and Technology. This program encompasses a broad range of technologies applied to the surface transportation system. Under collaborative and transparent governance structure established for ITS JPO projects, the ITS JPO coordinates with and executes the program jointly in cooperation with all of the surface transportation modal administrations within the DOT to ensure full coordination of activities and leveraging of research efforts.

The USDOT is engaged in assessing applications that realize the full potential of connected vehicles, travelers, and infrastructure to enhance current operational practices and transform future surface transportation systems management. This effort is a collaborative initiative spanning the ITS JPO, Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Traffic Safety Administration (NHTSA).

One foundational element of the Connected Vehicle research efforts is the Transit V2I research area. The vision and objectives of the Transit V2I Program include:

Vision: Utilize Vehicle-to-Infrastructure communications to achieve safer, and more efficient, comfortable, reliable, and eco-friendly public transportation services that benefit all road users in general, and transit riders in particular.

Objectives: Use V2I technology:

- To prevent, reduce personal injury and loss of property resulting from transit vehicle collisions
- To optimize the effectiveness and efficiency of public transportation operations
- To improve traveler decision-making and access to transportation information
- To reduce transportation environmental impacts and maximize the benefits
- To quantify the transportation environmental impacts and benefits

A successful Transit V2I Program will lead to the more rapid and cost-effective deployment of interoperable technologies and applications that improve transit safety and enhance mobility for transit vehicles. The Transit

V2I Program will act to promote the highest levels of collaboration and cooperation in the research and development of V2I applications for connected vehicles. The Transit V2I Program positions the federal government to take on an appropriate and influential role as a technology steward for a continually evolving integrated transportation system.

1.4 Document Overview

The purpose of this document is to communicate user needs and desired capabilities for and expectations of the Transit Vehicle and Center Data Exchange application. This document also serves to build consensus among transit user groups and stakeholders concerning these needs and expectations. It is expected that users will read this document to determine whether their needs and desires have been correctly captured. Potential system developers and integrators will use this document as a basis for understanding the purpose and scope of the application for future system development. Finally, the document should act as a guideline moving forward with research and development of any part of the Transit V2I Program.

As shown in Figure 1-1, the Operational Concept provides a means for describing operational needs of a system without becoming overly detailed about technical issues that will be defined later in the process. Its purpose is to clearly convey a high-level view of the system to be developed that each stakeholder can understand. In doing so, the following questions are answered:

- **Who** – Who are the stakeholders/actors involved with the system?
- **What** – What are the elements and the high-level capabilities of the system?
- **Where** – What is the geographic and physical extent of the system?
- **When** – What is the sequence of activities that will be performed?
- **Why** – What is the problem or opportunity addressed by the system?

This document is intended to convey at a high-level how the application may work, so others may design and implement systems in the future. As such, this document and its complimentary Transit V2I Operational Concept documents are “generalized” and not specific to a geographic area, an operating entity (e.g., transit agency or TMC), existing systems that may be in place for a region, agency operating procedures, nor political environment.

This document is an interim document to a Concept of Operations that will be developed at a later date for specific prototypes and testing. Those Concept of Operations documents should use components of this document and present the materials in a format consistent with *IEEE Std. 1362-1998 IEEE Guide for Information Technology—System Definition—Concept of Operations (ConOps) Document*.

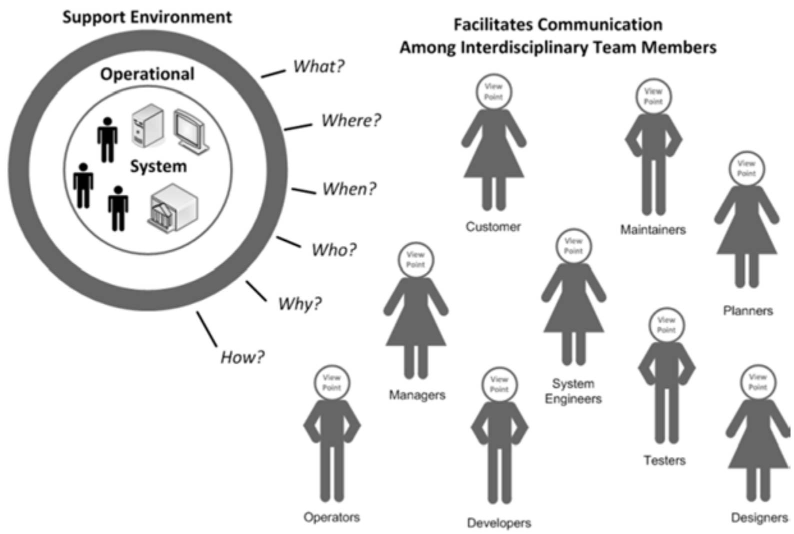

Figure 1-1: Conceptual Representation of the Operational Concept Document (*Source: USDOT, adapted from ANSI/AIAA's "Guide for the Preparation of Operational Concept Documents" ANSI/AIAA G-043-1992)*

This document includes the following chapters:

- **Chapter 1** provides the scope, introduction to the Transit V2I Program, and an overview of the document.
- **Chapter 2** includes an overview of the real-time data capture and management program and the role of the Transit V2I Program to develop applications which leverage real-time data to improve mobility. This chapter also includes an overview of near term Transit V2I applications being investigated by the USDOT.
- **Chapter 3** provides a description of the current situation and is intended to help stakeholders better understand the reasons the application is desired. Included is a discussion of existing ITS technologies that facilitate the communication and data exchange between transit vehicles and central transit dispatch centers.
- **Chapter 4** describes the shortcomings of current systems, situations, or applications that motivate research and development of the prototype application. This chapter provides a transition from Chapter 3 of the Operational Concept, which describes the current situation, to Chapter 5, which describes the proposed prototype concept.
- **Chapter 5** describes the Transit Vehicle and Center Data Exchange application from a systems engineering perspective.
- **Chapter 6** provides scenarios which help the readers of the document understand how application may be implemented to provide mobility (and safety) benefits. The scenarios are described in a manner that allows readers to walk through them and gain an understanding of how all the various parts of the application will function and interact.
- **Chapter 7** provides references used in the Operational Concept document.
- **Appendix A** provides a list of acronyms used in the report.

2 Overview of Transit Vehicle Communications and Real-Time Data Exchange and Management of the Transit V2I Program

One of the main focuses of the USDOT's Connected Vehicle Research program is to use connected vehicle technology to improve mobility. Connected vehicle mobility applications provide a connected, data-rich travel environment. The network captures real-time data from equipment located on-board vehicles (automobiles, trucks, and buses) and within the infrastructure. The data are transmitted wirelessly and are used by transportation managers in a wide range of dynamic, multi-modal applications to manage the transportation system for optimum performance.

With regards to mobility, there are two significant research programs oriented to the collection and development of applications which improve the safety and operational efficiency of transportation resources:

- Real-time Data Capture and Management (DCM) program; and
- Dynamic Mobility Applications (DMA) program.

2.1 Real-Time Data Capture and Management

The objective of the Real-Time Data Capture and Management (DCM) research program is to enable the development of environments that support the collection, management, integration, and application of real-time transportation data or data sets.

Real-time data applications offer an ability to increase safety and operational efficiency nationwide. Not only will this data allow travelers to make better informed travel decisions, but public- and private-sector data on all modes and roads can be used to transform transportation management. Real-time data also have the potential to support a range of multi-modal mobility applications. Real-time information on parking availability and transit schedules can enable more informed mode choice decisions and efficiencies for travelers. Updated freight movement data assists commercial freight operators with optimizing operations. Overall, the information developed from the DCM research program will reveal opportunities for achieving greater efficiencies within transportation systems.

Some types of data that can be captured and managed include: situational safety, environmental conditions, congestion data, and cost information derived from both traditional (traffic management centers, automated vehicle location systems) and non-traditional (Personal Information Devices, connected vehicle equipment) sources. Data can also be collected from sources that generate data on elements of the transportation system such as toll facilities, parking facilities, transit stations and transit stops.

The DCM Program plays a key role in supporting other initiatives identified in strategic plans, in the areas of safety, mobility, and environment. Many of these initiatives will require systematic capture and management of data over time to realize their objectives. The cross-cutting DCM Program is chartered to coordinate across these initiatives to identify comprehensive data needs.

The goals of the Real-Time DCM research program are to:

- Systematically capture real-time, multi-modal data from connected vehicles, devices, and infrastructure.
- Develop data environments that enable integration of high-quality data from multiple sources for transportation management and performance measures.

The Research Data Exchange (RDE) is a web-based data resource provided by the USDOT ITS JPO's DCM program. It collects, manages, and provides archived and real-time multi-source and multi-modal data to support the development and testing of ITS applications.

2.2 Dynamic Mobility Applications

The Dynamic Mobility Applications (DMA) program seeks to create applications that fully leverage frequently collected and rapidly disseminated multi-source data gathered from connected travelers, vehicles and infrastructure, and that increase efficiency and improve individual mobility while reducing negative environmental impacts and safety risks.

The USDOT has identified a portfolio of six high-priority mobility application bundles, including a common bundle collectively identified as Integrated Dynamic Transit Operations (IDTO), as part of the DMA program. The three applications under the IDTO bundle (Connection Protection, Dynamic Transit Operations and Dynamic Ridesharing) will ultimately enable transit systems to provide better information to travelers and increase the quality of service that they are able to provide. Being able to improve the transit experience will increase the use of public transit, allowing the program to meet its goals of improving the environment and increasing mobility.

In selecting these applications, the USDOT sought applications that had the potential to be transformative (i.e., they significantly alter existing transit services and result in substantial mobility improvements), are achievable in the near-term, and leverage the opportunities provided through connected entities. In the transit domain, this led to the selection of applications that already exist in some fashion today. These are applications that can be evolved from their current state leveraging Connected Vehicle technology to offer significant transformative impacts while minimizing a number of the risks and delays inherent in developing entirely new concepts.

2.2.1 Integrated Dynamic Transit Operations (IDTO)

The USDOT has identified a portfolio of ten high-priority mobility applications, including a common bundle collectively identified as Integrated Dynamic Transit Operations (IDTO), as part of the DMA program. The three applications under the IDTO bundle (Connection Protection, Dynamic Transit Operations and Dynamic Ridesharing) will ultimately enable transit systems to provide better information to travelers and increase the quality of service that they are able to provide. Being able to improve the transit experience will increase the use of public transit, allowing the program to meet its goals of improving the environment and increasing mobility.

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2.2.1.1 T-CONNECT

The goal of T-CONNECT is to improve rider satisfaction and reduce expected trip time for multimodal travelers by increasing the probability of automatic or intra-modal connections. T-CONNECT will protect transfers between both transit (e.g., bus, subway and commuter rail) and non-transit (e.g., shared ride modes) modes, and will facilitate coordination between multiple agencies to accomplish the tasks. In certain situations, integration with other IDTO bundle applications (T-DISP and D-RIDE) may be required to coordinate connections between transit and non-transit modes.

2.2.1.2 T-DISP

T-DISP seeks to expand transportation options by leveraging available services from multiple modes of transportation. Travelers would be able to request a trip via a handheld mobile device (or phone or personal computer) and have itineraries containing multiple transportation services (public transportation modes, private transportation services, shared-ride, walking and biking) sent to them via the same handheld device. T-DISP builds on existing technology systems such as computer-aided dispatch/automated vehicle location (CAD/AVL) systems and automated scheduling software. These systems will have to be expanded to incorporate business and organizational structures that aim to better coordinate transportation services in a region. A physical or virtual central system, such as a travel management coordination center (TMCC) would dynamically schedule and dispatch trips. T-DISP enhances communications with travelers to enable them to be presented with the broadest range of travel options when making a trip.

2.2.1.3 D-RIDE

The Dynamic Ridesharing (D-RIDE) application is an approach to carpooling in which drivers and riders arrange trips within a relatively short time in advance of departure. Through the D-RIDE application, a person could arrange daily transportation to reach a variety of destinations, including those that are not serviced by transit. D-RIDE serves as a complement subsystem within the IDTO bundle by providing an alternative to transit when it is not a feasible mode of transport or unavailable within a certain geographic area. The D-RIDE system would usually be used on a one-time, trip-by-trip basis, and would provide drivers and riders with the flexibility of making real-time transportation decisions. The two main goals for the D-RIDE application are to increase the use of non-transit ride-sharing options including carpooling and vanpooling, and to improve the accuracy of vehicle capacity detection for occupancy enforcement and revenue collection on managed lanes. By accomplishing these two goals, transit systems could also benefit from D-RIDE by reducing excess demand during peak periods, resulting in improved customer satisfaction and more appropriately and affordably scaled system designs.

2.2.1.4 Transportation Information Center and Advanced Traveler Information Systems Applications

The Transportation Information Center (TIC) collects, processes, stores, and disseminates transportation information to system operators and the traveling public. The TIC can play several different roles in an integrated ITS. In one role, the TIC provides a data collection, fusing, and repackaging function, collecting information from transportation system operators and redistributing this information to other system operators in the region and other TICs. In this information redistribution role, the TIC provides a bridge between the various transportation systems that produce the information and the other TICs and their subscribers that use the information. The second role of a TIC is focused on delivery of traveler information to subscribers and the public at large. Information provided includes basic advisories, traffic and road conditions, transit schedule information, yellow pages information, ridematching information, and parking information. The TIC is commonly implemented as a website or a web-based application service, but it represents any traveler information distribution service including systems that broadcast digital transportation data (e.g., satellite radio networks) and systems that support distribution through a connected vehicle network.

2.2.2 DMA Advanced Traveler Information Systems (ATIS) Bundle Applications

The ATIS applications provide for the collection, aggregation, and dissemination of a wide range of transportation information. The collection of information includes traffic, transit, road weather, work zone, and connected vehicle related data. All the sources of data are aggregated into data environments that can be used to drive data portals allowing dissemination of the entire spectrum of transportation information to travelers via mobile devices, in-vehicle displays, web portals, 511 systems, and roadside signage. Information that is collected, processed and disseminated by an ATIS has the potential to:

- Improve end user decision-making, both by individual travelers making independent travel choices, as well as by groups of travelers acting in a more coordinated fashion, such as a fleet of commercial vehicles under centralized dispatching or the participants in a Transportation Management Association (TMA);
- Improve transportation systems management and operations including freeways, arterials, managed lanes, tollways, and transit systems. Traveler information can assist in integrated corridor management by improving the coordination and synergy between transportation system components; and
- Provide valuable data on travel patterns and traveler characteristics to third parties such as planners or marketing groups.

In the context of ATIS, the term “information” is used to cover descriptive, predictive, and prescriptive information sought by travelers and system operators to assist in pre-trip and en-route decision making and roadway system management. The first two categories focus on the current and anticipated conditions in the transportation network; the latter is focused on the traveler’s activity or trip.

ATIS is an essential tool for the public sector to support transportation systems management and operations (TSM&O). Providing travelers with access to accurate, reliable, and easy to understand pre-trip and en-route traveler information can influence travel choice behavior demand and improve system performance.

2.3 Transit V2I Program Near-Term Applications

The Transit V2I Program identified twelve near term candidate applications that have the potential to maximize safety, mobility, and environmental benefits. The applications are depicted in Figure 2-1 and summarized below. Red icons indicate applications with the potential to impact safety, blue icons are related to mobility and the environment, and orange icons are crosscutting applications.

- **Red Light Violation Warning (Angle Crashes at Signalized Intersections).** The Red Light Violation Warning application includes a cooperative vehicle and infrastructure system that assists drivers in avoiding crashes at intersections by warning the vehicle driver that a signal violation is predicted to occur. An equipped vehicle approaching an equipped intersection receives messages about the intersection geometry, signal phase and timing (SPaT) information, and if necessary, position correction information. The driver is issued an alert if the vehicle processing platform determines that, given current operating conditions, the driver is predicted to violate the signal such that the vehicle enters the intersection during the red phase.

- **Stop Sign Violation Warning (Angle Crashes at Non-Signalized Intersections).** The Stop Sign Violation Warning application includes a cooperative vehicle and infrastructure system that assists drivers in avoiding crashes at intersections by alerting the vehicle driver that a stop sign violation is predicted to occur. An equipped vehicle approaching an equipped intersection receives messages about the intersection geometry and if necessary, position correction information. The driver is issued an alert if the vehicle processing platform determines that, given current operating conditions, the driver is predicted to violate the stop sign.
- **Left-Turn Assist (Left-turn Head-on Crashes at Intersections with Permissive Left-turn Phase.** The Left Turn Assist (LTA) application provides information to drivers performing unprotected left turns to judge the gaps in oncoming traffic and to warn them when it is unsafe to perform a left turn on a permissive green light. While this application may be supported using V2V communications where vehicles exchange information about their location, speed, trajectories, and other vehicles at the intersection, it may also leverage V2I communications such as SPaT, intersection map data, and infrastructure based vehicle and pedestrian detectors. The purpose of the application is to provide information to support the driver's decision making process regarding when it is unsafe to make a left turn at an intersection (i.e., gap rejection), but not make the decision for the driver. In other words, the LTA application does not tell the driver when it is safe to proceed, but assists with rejecting gaps that are unsafe.
- **Stop Sign Gap Assist.** The Stop Sign Gap Assist (SSGA) application provides the vehicle operator with timely, relevant information regarding unsafe conditions at a stop-controlled intersection. The SSGA safety application is intended to improve safety at two-way stop controlled intersections where only the minor road has posted stop signs. This application includes both onboard (for equipped vehicles) and roadside signage warning systems (for non-equipped vehicles). The purpose of the application is to provide information to support the driver's decision making process regarding when it is unsafe to proceed through the intersection (i.e., gap rejection), but not make the decision for the driver. In other words, the SSGA application does not tell the driver when it is safe to proceed, but assists with rejecting gaps that are unsafe.
- **Spot Weather Information Warning.** The Spot Weather Information Warning (SWIW) application is intended to improve safety in areas subject to repeated and localized adverse or inclement weather events, which may include relatively high-elevation or low-elevation areas that are more prone to reduced visibility, adverse surface conditions due to rain, snow, ice, and/or flooding, and high winds. This will be achieved through the integration of both vehicle-based and infrastructure-based technologies as well as backhaul networks to weather and TMCs, including onboard and roadside signage warning systems, to make drivers approaching an area with adverse weather conditions aware of the need to reduce speed or divert to safely navigate through or avoid the adverse weather impact area. This is not an application that is intended to provide the driver with weather information at every geographic location, but rather provide real time weather information at areas that are prone to adverse weather events, such as low-lying flood zones and bridges with high winds which may impose restrictions on high-profile vehicles. In this way, the SWIW application will help to increase driver awareness of the severity of hazardous weather conditions, reducing the risk potential for conflicts and crashes.
- **Transit Bus-Pedestrian/Cyclist Crossing Warning.** This application provides alerts to transit bus drivers of a pedestrian's or cyclist's presence while they are crossing the roadway at intersections and midblock crossings, using V2I wireless communications. When a pedestrian or cyclist is detected via the infrastructure, an RSU would send a message to nearby buses that a pedestrian or

cyclist is in or may be entering the roadway. The application would provide alerts to bus drivers for all bus movements (left, right, and straight) at infrastructure-equipped signalized and non-signalized intersections and at midblock crossings when imminent conflicts with pedestrians and bicyclists are possible.

Figure 2-1: Transit V2I Applications *(Source: USDOT, 2014)*.

- **3D Intersection Mapping for Collision Avoidance and Situational Awareness.** This 3D Mapping application enables RSU to rapidly recognize/update intersection configurations in 3D (latitude, longitude and elevation), including fixed objects such as signal cabinets and light poles. This 3D intersection configuration information embedded in the RSU will support V2I safety applications to mitigate single vehicle crashes.
- **Transit Bus Stop Pedestrian Safety.** The application, using V2I wireless communications, would provide alerts to pedestrians, via infrastructure (e.g., electronic signage with audible warnings), at major bus stops (e.g., those equipped with bus shelters serving multiple bus routes) indicating a transit bus' intention of pulling into or out of a bus stop. In certain situations and locations, the application may also alert pedestrians of motor vehicles in the vicinity of the bus stop, specifically alerting passengers alighting buses at the stop to address potential collisions of pedestrians with motor vehicles, whose sight are blocked by the bus.

- **Reduced Speed Zone Warning.** The Reduced Speed Zone Warning (RSZW) safety application features the concept of reduced speed zone where a reduction in transit approaching speed is required and/or advised, such as entrance to work zones, school zones, and roadway configuration alteration (e.g., lane closures, lane shifts). This will be achieved through the integration of both vehicle-based and infrastructure-based technologies, including onboard and roadside signage warning systems.
- **Transit Vehicle and Center Data Exchange.** Modern transit buses are equipped to collect/process data on transit vehicles (such as engine health monitoring) as well as the surrounding environment such as external facing digital cameras. This Transit Vehicle and Center Data Exchange application allows the authorized entities (such as traffic management centers, fire and emergency medical services (EMS), and transit dispatch centers) see what is happening at a location such as non-recurring congestion due to a crash or disabled vehicle by pinging an infrastructure point to request the next transit vehicle or vehicles passing the point to provide a snapshot of requested information, such as a short video. The bus could then capture a geo-referenced visual and upload at the next access point.
- **Transit Traveler Information Infrastructure.** The Traveler-Oriented Integrated Infrastructure Information application allows transit vehicles and travelers to be connected to nearby infrastructure, such as a smart intersection, smart bus stop, and smart parking. For example, transit vehicles would communicate with transit stops to provide travelers information on approaching vehicles, such as passenger loads, available disability seating, bicycle rack availability, fare information, etc. The application would support dynamic trip planning at transit stops.
- **Portable Infrastructure.** This transit V2I application features the concept of portable infrastructures such as portable RSUs and signage which may be used to handle special events (i.e., surging demand) at strategic locations, such as bus depots and light rail platforms to perform dynamic information collection/dissemination such as added buses or routes or assist transit vehicle maneuvers and detours.

Through a prioritization process that included both stakeholder input and USDOT strategic goals, two safety applications are being moved forward: Transit Bus-Pedestrian/Cyclist Crossing Safety Warning and Transit Bus Stop Pedestrian Safety. As the Crash Analysis showed, collisions with pedestrians and cyclists account for 14 percent of all motor bus collisions. The three costliest types of collisions (by average cost per collision) are all collisions with pedestrians, making it a high priority for USDOT and transit agencies alike.

Two potential mobility applications are also being investigated further: Transit Vehicle and Center Data Exchange; and Transit Traveler Information Infrastructure. These two applications show potential for leveraging existing ITS technologies in a connected vehicle environment to improve mobility for all modes.

3 Description of the Current Situation

This chapter provides a description of the current situation and is intended to help stakeholders better understand the reasons the application is desired. Included is a discussion of current transit technologies and communications between transit vehicles and dispatch centers. This chapter also describes existing technologies and systems, including on-board surveillance systems that have been implemented to improve safety aboard transit vehicles.

3.1 Transit Vehicle and Transit Center Communications

Transit communication technologies depend on the infrastructure and devices that are used to transmit voice and data. The infrastructure is critical to the integration and implementation of specific transit technology applications, such as AVL and traveler information systems. These communication systems provide critical links among drivers, dispatchers, emergency response, customers, and other personnel involved in transit. The technology can range from voice radio to more comprehensive systems that combine various technologies to allow interaction among a wide range of communication and data transfer. Voice, text, and data are transmitted over radio, cellular, or other wireless networks. More advanced communication systems are used to transmit text, data, and video. Wireless communication systems provide the operational backbone for many technologies and include the following:

- **Wide area wireless (WAW)**—communications networks based on radio frequency broadcasting. These networks can be generic or proprietary.
- **Wireless local area networks (WLANs)**—data communication systems (analogous to a wireless internet connection) that allow transit vehicles to communicate with a base station or vice versa. WLANs are used to upload or download data over the air, eliminating the need to use wired communications. In the transit industry, WLANs are commonly used in garages allowing transit vehicles, as they enter the garage, to transmit data such as passenger counts, as well as to receive on-board data updates (such as for an automated annunciation system).
- **Short-range communications**—a beacon/tag combination used in transit signal priority (TSP) systems and toll collection on bridges, tunnels, turnpikes, and parking facilities. The electronic tag, or transponder, contains a small radio transmitter that is used to emit a short-range radio signal that a beacon, or tag reader, receives. The beacon then transmits the data to the necessary computer hardware and software via radio frequency. The short-range radio signals are transmitted at a special frequency designated by the Federal Communications Commission (FCC) for these short-range communication needs. The tags can be either active or passive.
- **Land line and cellular telephone networks; and Internet and intranet**—provide the ability to transmit data from dispatch centers to remote infrastructure, dispatch centers to vehicles, and between dispatch centers, maintenance facilities, and other infrastructure. For wireless communications, commercial 3G or 4G/LTE (Long Term Evolution) are used provide voice and mobile broadband Internet access to transit vehicles equipped with wireless modems.

Without the ability to transmit data from a vehicle to dispatch or from one system to another, individual transit technology capabilities are diminished or not functional.

The majority of benefits of communication technologies improve reliability and on-time performance that can lead to increased customer satisfaction. Also, communications systems enhance the safety and security of vehicle operators and travelers through decreased emergency response time and increased visibility into incidents.

3.2 Existing ITS Solutions

The following are examples of technologies that have been implemented aboard transit vehicles to communicate and transfer data from a transit vehicle to a dispatch center and/or TMC. Some of these technologies have been implemented to support safety objectives, while others are aimed at improving service coordination and thus the mobility requirements of constituents. The technologies most applicable to this application are included.

3.2.1 Computer-aided Dispatch/Automatic Vehicle Location (CAD/AVL)

An Automatic Vehicle Location (AVL) system is defined as the central software used by dispatchers for operations management that periodically receives real-time updates on fleet vehicle locations. In most modern AVL systems this involves an onboard computer with an integrated Global Positioning System (GPS) receiver and mobile data communications capability. AVL systems allow transit managers to monitor the actual or approximate location of transit vehicles in their fleet at any given time. AVL, GPS, and dispatching software are independent technologies, not all one and the same. Essential to an AVL system is the on-board computer, the mobile data terminal (MDT) and the means to transmit the data back to a central dispatch location via a communication system for processing, interpretation, and response.

Computer-aided dispatch (CAD) software provides decision-support tools used by transit dispatchers and supervisors to monitor operations in real-time, allowing them to manage the operations proactively (handling delays, disruptions in service, and incidents as they occur). By having the CAD system notify operations staff of problems by exception, it allows staff to focus on areas of concern without the need to personally monitor operations to identify issues. Further, CAD can facilitate the adjustment of vehicle headways, dispatching replacement or additional vehicles, or reporting incidences.

A CAD/AVL system typically provides dispatchers with at least two displays: one that shows the locations of vehicles on a map (from the AVL system) and one that shows a queue of incidents or calls from vehicle operators (from the CAD system). Using these screens together, dispatchers can identify and respond to problems on their routes. When a vehicle operator calls, the dispatcher sees a message showing the vehicle number on the CAD screen (which prioritizes the operator calls). The dispatcher selects the vehicle calling from the incident list and refers to their Automatic Vehicle Location screen for its location. The CAD/AVL system helps dispatchers track route performance by notifying them of early, late, or off-route buses. Using the communication system, dispatchers or supervisors can communicate with vehicles individually, in a specific group, or with all vehicles.

On board the vehicle, the MDT is constantly checking the actual location of the vehicle vs. where the vehicle should be (based on the vehicle's schedule), resulting in the determination of schedule adherence. When the schedule adherence is outside a specific tolerance (set by the transit agency), this exception condition is reported to a dispatcher. Also, the schedule adherence is displayed for the vehicle operator on a MDT, and AVL data is constantly displayed on the dispatcher's workstation.

3.2.2 Mobile (On Board and Exterior) Video Surveillance

One of the two most common safety and security systems among transit agencies are on-board (interior) and exterior cameras for video surveillance. Cameras are a form of crime deterrence and are also used to review incidents that may have taken place on board a vehicle in the past. In addition, cameras are also playing a role in traffic enforcement on board buses. Today cameras are routinely being used to review driver's traffic violations such as running a red light and not stopping at a stop sign, as well as to review the last few seconds preceding a collision to determine fault. On-board and exterior video surveillance can be used for the following purposes:

- Review recorded images
- Potential crime prevention
- Identify criminal activity and perpetrator(s)
- Identify improper driver behavior
- Incident/insurance investigation

Some digital video systems allow authorized users to access the systems via wireless communications. This allows these users, such as police or transit supervisors, to view what is occurring inside the vehicle by accessing audio/video recorded from cameras during an incident.

Additionally, as a safety feature, some agencies are placing a “left-hand turn camera” on their commuter buses. This setup has a video screen connected to a camera that shows the left-hand view when the left indicator is activated. The external rear-view mirrors on the coaches are very large and cause a blind spot. However, the left-hand turn camera is independent of the closed-circuit television (CCTV) system. It uses an infrared camera so the time of day has no effect on the ability to "see" the blind spot.

3.2.3 Covert Live Audio

Covert microphones and other security technologies are typically deployed along with new CAD/AVL systems. The purpose of a covert microphone is to allow the transit dispatchers to listen in on what is going on inside the vehicle while an incident is taking place. Generally, covert microphones provide one-way communication in order not to alert the person responsible for the incident that the dispatcher and/or police are listening in. In some systems, when a driver in distress presses a covert switch that activates the covert microphone, the monitor in the dispatcher's office automatically displays the information for that vehicle and the map display highlights the vehicle in distress; all other screens on the dispatcher's computer will not be accessible until the driver cancels the alarm.

As stated in Transit Cooperative Research Program (TCRP) Synthesis 93, Practices to Protect Bus Operators from Passenger Assault, there are many implementations of covert alarms in transit. For example, the following agencies have deployed covert alarm systems:

- Greater Cleveland Regional Transportation Authority, Cleveland, OH
- Metro Transit, Madison, WI
- Pinellas Suncoast Transit Authority, St. Petersburg, FL
- VIA Metropolitan Transit, San Antonio, TX

Coordination between transit management centers and EMCs or TMCs is generally ad-hoc. That is, a transit agency dispatcher receives the emergency alarm and determines the correct course of action before communicating with EMC personnel. The literature review did not immediately identify instance where TMC or EMC centers would be notified automatically when a transit vehicle's covert alarm is activated.

3.2.4 Automatic Passenger Counters (APCs)

Automatic passenger counters (APCs) refer to technologies that are used to count the number of passengers boarding and alighting a transit vehicle. A microprocessor monitors the passenger activity and uses an algorithm to determine when a passenger has entered or exited a vehicle. Data can either be stored for downloading/uploading or be transmitted via radio. Downloading/uploading can be done by one of several methods, including infrared transfer over an agency's WLAN in or near an agency garage. Some APC systems monitor odometer readings and door switch signals to identify when a bus stop occurs.

There are several types of APC technology; the two most common ones are treadle mats and infrared technology. The latter method uses infrared beams to make the passenger counts. Infrared devices can be mounted either overhead or on the side of the door.

One important feature of APCs is the ability to accurately "stamp" the data with the exact bus stop location and time of day, most commonly done by integrating the APC with the AVL system. Also, another key component is an on-board microprocessor that can store the data for downloading or preprocessing it for immediate transmission to a central location. And real-time information from APC systems can be used for conditional TSP based on the number passengers on board at a given time.

APC systems are often implemented to reduce the cost of manual data collection and National Transit Database reporting requirements. The data can also be used for route scheduling by, for example, identifying the maximum load point, loading profiles, and optimizing locations for short-turn patterns. Transit operators typically deploy APC equipment on 12 to 25 percent of their vehicles and then rotate the vehicles on different routes as needed.

3.2.5 Integrated Corridor Management Transit Vehicle Real-Time Data Demonstration

As part of the U.S. Department of Transportation's Integrated Corridor Management (ICM) Initiative, Dallas Area Rapid Transit (DART) purchased new automatic passenger counter (APC) technology for their Red and Orange line light rail vehicles to provide real-time passenger counts to their train control center and to provide data to the ICM decision support system. By gaining access to real-time passenger counts, DART hopes to respond more effectively to unplanned incidents on the rail network by enabling more responsive service adjustments.

This combination of APC, improved communication technologies, and pre-existing AVL information allows DART to track passenger loads in real-time within the network. These data are used by the Dallas ICM Decision Support System to recommend transit strategies and at the train control center (TCC) to allow controllers better insight into passenger loads on trains and situations involving overcrowding. It was envisioned that the APC/AVL technology, combined with closer inter-agency coordination, would result in a change in incident management, possibly with better transit load balancing or mode shift recommendations.

Following the demonstration, it was clear that DART controllers had revised the incident management approach by specifically targeting improving the customer experience. However, the *Integrated Corridor Management Transit Vehicle Real-Time Data Demonstration: Dallas Case Study* (2014) notes that benefits could not be maximized due to various infrastructure and policy constraints and limitations.

Generally, new technologies such as real-time APC may allow transit agencies to be more flexible in how they respond to unplanned incidents by better understanding passenger load and demand across the network. Agencies can use this information to enact new strategies that were previously unavailable, impractical, or unreliable. In order to obtain and use real-time information, agencies may need to invest significant resources in updating equipment and software as well as training employees in the new equipment.

While ICM and APCs have eased one major constraint, the ability to obtain real-time passenger load data, it has not eased other constraints such as network capacity and organizational policy. DART along with other agencies around the country face issues such as platform length restrictions, headway limitations, and consist availability that all impact their ability to respond to passenger demand issues in real-time. Additionally, agencies may need to examine their own internal policies to understand how much impact ICM and APC technology could have on their operations. For instance while ICM and APC units might provide incentives to use operational strategies such as deadheading and expressing, if institutional policies prevent this, agencies may not be able to use this technology to its full potential.

3.2.6 Service Coordination Facilitated by Technology: Mobility Services for All Americans (MSAA) Initiative

The use of technology to facilitate the coordination of transportation services has been the focus of the Mobility Services for All Americans (MSAA) initiative, which was initiated in 2006 by the ITS JPO and FTA. This program, which has just completed its third phase, has funded the demonstration of this concept by several transit agencies/organizations. The first phase was conducting the foundation research that identified the most appropriate technology to facilitate the development of transportation management coordination centers (TMCCs) and developed a concept of operations. The second phase funded the definition of TMCCs by eight grantees. These grantees were required to use a systems engineering approach to define the TMCCs. Finally, the third phase funded the actual deployment of TMCCs by three transportation agencies.

The ITS JPO and FTA are in the process of producing a report that describes the results of the MSAA initiative. The following summary and description of one of the three MSAA TMCC sites comes directly from *Providing Guidance for the Design and Implementation of Travel Management Coordination Centers (TMCC)* (Hemily 2012):

> United We Ride is a Federal interagency initiative intended to simplify customer access to transportation, reduce duplication of transportation services, streamline Federal rules and regulations that may impede the coordinated delivery of services, and improve the efficiency of services using existing resources. The goal of the Mobility Services for All Americans (MSAA) initiative is to improve transportation services and simplify access to activities by means of advanced technologies and through extending transportation service partnerships with consumers and human service providers at the Federal, State, and local levels.
>
> The Paducah Area Transit System (PATS) provides coordinated human service and public transportation services for the Jackson Purchase region (8 counties) of Western Kentucky. The four primary transportation providers – Paducah Area Transit (PATS), Fulton County Transit (FCTA), Murray-Calloway County Transit (MCTA), and Easter Seals West Kentucky (ESWKY) provide a total of 700,487 coordinated public and human service trips annually.
>
> In March 2010, the Purchase Area Regional Transit Travel Management Coordination Center opened, providing transportation, human service information, and referral services to facilitate greater mobility. Utilizing the latest in hi-tech equipment, passengers are able to reserve, manage and track their transportation with Paducah Area Transit System, Easter Seals West Kentucky, Fulton County Transit Authority and Murray-Calloway Transit Authority. All four transportation providers came together to

form Purchase Area Regional Transit (PART) and are partners in the groundbreaking US Department of Transportation initiative.

Customers are able to access the center by phone or internet to make or alter travel plans, then track the vehicles in which they'll be riding utilizing GPS technologies on each vehicle. All four PART members are connected through the latest computer dispatching software, which communicates with every individual vehicle by on-board computers. Callers to the center are also able to receive information on health and human services and general governmental and educational information. "One call gets it all in Western Kentucky."

The center's establishment grows out of Paducah Area Transit System's participation in the U.S. Department of Transportation (USDOT) and Federal Transit Administration's (FTA) Mobility Services for All Americans research initiative. The goal of the research grant is developing a regional call center utilizing the latest technologies, or Intelligent Transportation Systems, which other transportation agencies across the nation could use as a blueprint to make transportation more cost efficient for providers and passengers alike, especially passengers facing special challenges, including disabilities, age or rural barriers.

3.2.7 Select Bus Service Video Bus Lane Enforcement

Supported jointly by MTA New York City Transit, the New York City Department of Transportation (NYCDOT) and the New York City Police Department (NYPD), Select Bus Service (SBS) is New York City's version of Bus Rapid Transit (BRT) --- an increased-speed, high-performance bus system incorporating off-board fare collection, fewer stops, low-floor hybrid-electric buses, and a branded, easily identifiable service. BRT combines the speed, reliability and amenities of rail-based rapid transit systems with the flexibility of buses.

A key element of SBS is its use of dedicated bus lanes. The New York State Legislature authorized use of camera enforcement for all vehicles in 2010. New York City Transit and NYCDOT work closely with the NYPD on bus lane enforcement. New York City Transit currently has cameras on board buses as part of a pilot for bus lane enforcement. Vehicles may enter a bus lane only to make the next available right turn, or to quickly drop off or pick up passengers. Violating bus lane rules results in a fine.

The on-board cameras work in much the same way as red light or speed cameras; violations trigger a digital photo of the license plate, which is stored and sent to a processing center. The City sends a $110 fine to the violator’s home address. The program pays for itself and it is estimated that it saves commuters using SBS an average of 10 minutes in travel time. The improved service makes transit service reliable and timely – leading to increased mobility and transit use.

The automatic triggering of a camera based on external input, in this case, a sensor, instead of requiring a driver to respond to a request for information from a TMC either through voice description or pushing a button for the photo.

4 Limitations of Existing Systems and Justification for Change

Chapter 3 provided an overview of existing technologies and systems to enhance communication between a Transit Vehicle and Transit Management Centers and TMCs. The Chapter also provided an overview of relevant projects which are leveraging onboard technologies to improve mobility, safety, and coordination among various transportation providers. While these systems have shown promise in improving safety and mobility, it is envisioned that connected vehicle technologies have the potential to provide additional benefits above current systems. This chapter discusses the limitations of existing systems and provides justification for connected vehicle applications.

This analysis was conducted to provide an assessment as rapidly as possible, based on very preliminary and incomplete definitions of the application. The findings will undoubtedly change to some extent as the concepts of operation and the requirements for the application are developed.

4.1 Limitations of Existing Systems

Traditional ITS technologies described in Chapter 3 have proven to be effective for accomplishing their stated objectives, such as improving service reliability with the SBS automated enforcement cameras or improving customer satisfaction through the ICM APC deployment. However, the technologies either do not transmit in real-time or cannot be activated or controlled by TMC operators, as would be necessary for mobility benefits desired by this application.

The connected vehicle environment will be a very data-rich environment where TMCs can dynamically respond to travel conditions as they change. However, most data captured by ITS technologies currently in place are trapped in institutional silos. For instance, AVL data is transmitted to the transit agency to report location and determine schedule adherence, but the TMC does not have access to that same data feed, which could be used for traffic signal adjustments or using the transit vehicle as a probe vehicle.

4.2 Connected Vehicle Technologies

Connected vehicle technologies offer tremendous promise for mobility improvements. Connected vehicle technologies function using a V2V and V2I data communications platform that, like the Internet, supports numerous applications, both public and private. This wireless communications platform provides the foundation to integrate data from the infrastructure (e.g., traffic signals) with data from the vehicle (e.g., position, speed, brake status).

Figure 4-1: A Connected Transit Vehicle *(Source: USDOT, 2014)*

Connected vehicle V2I data communications will enable vehicles to communicate with infrastructure located on the roadway. V2I safety applications utilize Dedicated Short Range Communications (DSRC) and other low latency communications, which are needed for crash imminent situations. V2I safety applications heavily rely on the basic safety message (BSM), Signal Phasing and Timing (SPaT) and Traveler Information Message (TIM) which are key message sets defined in the Society of Automotive Engineers (SAE) Standard J2735, DSRC Message Set Dictionary (November 2009). The development of the J2735 is ongoing and evolving. For instance, at the time of writing, the BSM consists of two parts, with the following characteristics:

- BSM Part 1 contains core data elements, including vehicle position, heading, speed, acceleration, steering wheel angle, and vehicle size. It is transmitted at a rate of about 10 times per second.
- BSM Part 2 contains a variable set of data elements drawn from an extensive list of optional elements. They are selected based on event triggers (such as when the antilock braking system [ABS] is activated). BSM Part 2 data elements are added to Part 1 and sent as part of the BSM message but are transmitted less frequently to conserve data communications bandwidth.

It is important to note that even if a data element is defined in BSM Part 2 of the SAE J2735 standard, it does not necessarily mean that vehicle manufacturers will provide it. Most of the Part 2 data elements are defined as optional information in the standard. Some of the Part 2 data elements are currently available on the internal data bus of some vehicles; others are not.

Connected vehicle technologies, as they relate to the Transit Vehicle and Center Data Exchange application, are discussed in more detail in Sections 5 and 6.

4.3 Description of Desired Changes

One objective of the Transit V2I Program is to provide mobility benefits for road users of all modes in a connected vehicle environment. The focus of the changes to existing systems involves both the mechanism and nature of the information being provided to the Transit Vehicle from infrastructure and information being provided to infrastructure by the Transit Vehicle. In short, the desire is to test the feasibility of using connected vehicle technologies to provide mobility enhancements through better data acquisition and dissemination. A key priority will be to integrate the connected vehicle technologies onto an existing transit vehicle and allow the TMC to communicate with and obtain information about the transit vehicle and its surroundings in real time.

A fundamental limitation that must be considered in order to facilitate the transmission of mobility data is the standard message that will be used. As indicated in Section 4.2, BSM Part 1 and 2 does not account for the transmission of mobility data (e.g. passenger count aboard transit vehicles, transit vehicle-captured sensory data, etc.) As such, this operational concept suggests the formation of a new message that would serve as the standard communications protocol for transit mobility-oriented data may need to be created.

5 Transit Vehicle and Center Data Exchange Mobility Application

5.1 Application Overview

The Transit Vehicle and Center Data Exchange application is intended to provide real-time data to Transit Management Centers, TMCs, and EMCs with which to improve the mobility and safety of Travelers. Modern transit vehicles are equipped with onboard technologies with which to collect, process, and transmit data. The Transit Vehicle and Center Data Exchange application allows authorized entities, such as the Transit Management Center, TMC, and EMC to access these onboard technologies and retrieve real-time updates from various onboard systems. This functionality may include remotely accessing a Transit Vehicle's onboard surveillance system to see what is happening at a location (e.g., non-recurring congestion due to a crash or disabled vehicle). This communication would occur between Connected Vehicles and management centers via connected infrastructure. The infrastructure communicates wirelessly with the Transit Vehicle and requests access to the required information. Using existing on-board technologies, the bus could capture a geo-referenced visual and transmit the data at the next access point.

Throughout this chapter, the general term Traveler will be used to encompass both the individuals aboard transit vehicles and those consulting trip planning tools and applications to determine the best mode for their trip needs. The Operational Concept discusses the following three scenarios:

- **Scenario 1: Transit Vehicle Transmits Data to Support Mobility Applications and Real-Time Trip Planning.** This scenario describes the transfer of real-time transit data to the Transit Management Center, TMC, and EMC to support the deployment of other mobility applications and with trip planning. Through connected infrastructure, this information would be transmitted to Transit Management Centers and disseminated to travelers through the TIC applications.
- **Scenario 2: Transit Vehicle Approaches Non-recurring Congestion due to an Incident or Crash.** This scenario describes how a Transit Vehicle may serve as a mobile data collection unit for the Transit Management Center, TMC, and EMC. The TMC would be notified via DSRC communication to RSU infrastructure that an incident or crash has occurred on a corridor. Using the BSM transmitted by the Connected Vehicle, the TMC would also be notified that an equipped Transit Vehicle is in the vicinity of the incident and equipped with an on-board external surveillance system. The TMC, through the RSU, may engage the transit vehicle's on-board external surveillance system to obtain a real-time assessment of the incident or emergency situation. The real-time view of the event would allow the TMC to respond accordingly to alleviate the impact on transportation within the corridor and will allow the EMC to better assess the threat to respond accordingly.
- **Scenario 3: Emergency Situation aboard or within Vicinity of Transit Vehicle.** This scenario describes how a Transit Vehicle may serve as a mobile data collection unit for the TMC or EMC. For example, if an emergency situation aboard or within the immediate vicinity of the transit vehicle prompts the driver to engage the emergency covert alarm, the TMC would be notified through DSRC communications that an emergency response has been triggered by the driver of that transit vehicle. The vehicle location would be provided to the TMC and appropriate escalation procedures would be followed.

Figure 5-1 depicts the high-level system architecture for the Transit Vehicle and Center Data Exchange application. Included are the following actors:

- **Traffic Management Center (TMC).** The TMC monitors and controls traffic and the road network. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. It communicates with ITS Roadway Equipment and Connected Vehicle RSU to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status. It manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters.
- **Transit Management Center.** The Transit Management Center manages transit vehicle fleets and coordinates with other modes and transportation services. It provides operations, maintenance, customer information, planning, and management functions for the transit property. It spans distinct central dispatch and garage management systems and supports the spectrum of fixed route, flexible route, paratransit services, transit rail, and bus rapid transit (BRT) service. With respect to the Transit Bus and Center Data Exchange application, the Transit Management Center is responsible for the delivery of transit services, the collection and dissemination of transit data (e.g. transit schedule, fares, and real-time departure information), and the maintenance of transit stop facilities and associated infrastructure (e.g. RSU, message signs, and kiosks). The Transit Management Center interfaces allow for communication between transit departments and with other operating entities such as emergency response services and traffic management systems, among others.
- **Emergency Management Center (EMC).** The EMC represents public safety, emergency management, and other allied agency systems that support incident management, disaster response and evacuation, security monitoring, and other security and public safety-oriented ITS applications. It includes the functions associated with fixed and mobile public safety communications centers including public safety call taker and dispatch centers operated by police (including transit police), fire, and emergency medical services. It includes the functions associated with Emergency Operations Centers that are activated at local, regional, state, and federal levels for emergencies and the portable and transportable systems that support Incident Command System operations at an incident.

  Interface with the Transit Management Center allows coordinated use of transit vehicles to facilitate response to major emergencies and to support evacuation efforts. The EMC also provides a focal point for coordination of the emergency and evacuation information that is provided to the traveling public, including wide-area alerts when immediate public notification is warranted. It tracks and manages emergency vehicle fleets using real-time road network status and routing information from the other centers to aide in selecting the emergency vehicle(s) and routes that will provide the most timely response.

  Interface with the TMC allows strategic coordination in tailoring traffic control to support emergency vehicle ingress and egress, implementation of special traffic restrictions and closures, evacuation traffic control plans, and other special strategies that adapt the transportation system to better meet the unique demands of an emergency.
- **Transportation Information Center (TIC).** The TIC collects transportation-related data from other centers, performs data quality checks on the collected data and then consolidates, verifies, and refines the data and makes it available in a consistent format to applications. The TIC supports operational data sharing between centers and delivers traveler information to end-users. The TIC provides a bridge between the various transportation systems that produce the information and the other TICs and their subscribers that use the information. The TIC delivers traveler information to subscribers and the public at large. Information provided includes basic advisories, traffic and road

conditions, transit schedule information, ridematching information, and parking information. The TIC is commonly implemented as a website or a web-based application service, but it represents any traveler information distribution service including systems that broadcast digital transportation data (e.g., satellite radio networks) and systems that support distribution through a connected vehicle network. The TIC can be accessed at transit stations through a dedicated kiosk, web-portal, or personal information device.

- **Roadside Unit (RSU).** The RSU actor includes devices that are capable of both transmitting and receiving data using DSRC radios, using the 5.9 GHz band approved for DSRC use by the FCC. For this application, RSUs will be deployed at selected intersection and roadside locations and at designated transit stop locations. These RSUs will provide necessary infrastructure information (e.g., SPaT, TIM, MAP, etc.) to the Transit Vehicle Actor for processing and triggering alerts to the Transit Vehicle Driver actor as appropriate. The RSU may interface with traffic signal controller where appropriate and to the backhaul communications network necessary to support the applications and support such functions as data security, encryption, buffering and messaged processing. Within this actor is the following subsystem:
    - **Communication Radio (DSRC).** The Communications Radio (DSRC) Subsystem within the Roadside Unit actor provides the capability for the RSU to disseminate and receive messages using DSRC.
- **Transit Vehicle.** This actor is a vehicle that provides the sensory, processing, storage, and communications functions necessary to support safe operations. DSRC radio communications allow the Transit Vehicle actor to disseminate information about its status (i.e., current speed, acceleration, braking, and average emissions) and receive information and/or commands from the TMC, EMC, and transit dispatch center (e.g., engage on-board surveillance to monitor an incident) through the Roadside Unit actor or via existing cellular communications. It collects accurate ridership levels and supports electronic fare collection. It supports a traffic signal prioritization function that communicates with the roadside physical object to improve on-schedule performance. It also furnishes travelers with real-time travel information, continuously updated schedules, transfer options, routes, and fares. Included are the following subsystems:
    - **Driver-Vehicle Interface.** The Driver-Vehicle Interface (DVI) Subsystem provides the means by which the user (e.g., transit vehicle driver) and a computer system interact. The types of interface may incorporate any combinations of audible and visual feedback for drivers.
    - **Communication Radio (DSRC).** The Communications Radio (DSRC) Subsystem within the Transit Vehicle actor provides the capability for the transit vehicle to disseminate and receive messages using DSRC communications. This capability allows the transit vehicle to communicate wirelessly with infrastructure, and vice versa. The Transit Vehicle may have other wireless communications mechanisms, including cellular, 800 MHz data radio, or Wi-Fi. DSRC will be used primarily for this application.
    - **Vehicle Diagnostics System.** The Vehicle Diagnostics Subsystem collects diagnostics data from on-board systems located on the transit vehicle. Data includes the vehicle's location, speed, acceleration, trajectory, braking status, and other data elements included in SAE J2735 BSM. The source for much of the data would be the controller area network (CAN) bus.
    - **Global Positioning System (GPS).** The Global Positioning System (GPS) Subsystem includes a GPS antenna and receiver that allows the Transit Vehicle to provide lane level accuracy of the transit vehicle's position.

  - **Computer-aided Dispatch/Automatic Vehicle Location (CAD/AVL).** The AVL system is defined as the central software used by dispatchers for operations management that periodically receives real-time updates on fleet vehicle locations. In most modern AVL systems this involves an onboard computer with an integrated GPS receiver and mobile data communications capability. Computer-aided dispatch (CAD) software provides decision-support tools used by transit dispatchers and supervisors to monitor operations in real-time, allowing them to manage the operations proactively (handling delays, disruptions in service, and incidents as they occur).
  - **Automatic Passenger Counters (APCs).** APCs are sensors that are used to count the number of passengers boarding and alighting a transit vehicle. A microprocessor monitors the passenger activity and uses an algorithm to determine when a passenger has entered or exited a vehicle.
  - **Onboard Audio/Video Surveillance and Safety Systems.** Safety and security technologies include video surveillance cameras, silent alarms and covert microphones on vehicles, and "smart" cards for driver identification.
- **Traveler.** The Traveler represents any individual who uses transportation services. The interfaces to the traveler provide general pre-trip and en-route information supporting trip planning, personal guidance, and requests for assistance in an emergency that are relevant to all transportation system users. It also represents users of a public transportation system and refers to interfaces these users have within a Transit Vehicle or at transit facilities such as transit stops and centers.
- **Transit Vehicle Driver.** The Transit Vehicle Driver actor represents the human entity that operates a licensed transit vehicle on the roadway. For the purposes of this document, the driver operates a Transit Vehicle. This actor originates driver requests (e.g. emergency alarm) and receives driver information that reflects the interactions which might be useful to transit vehicle.

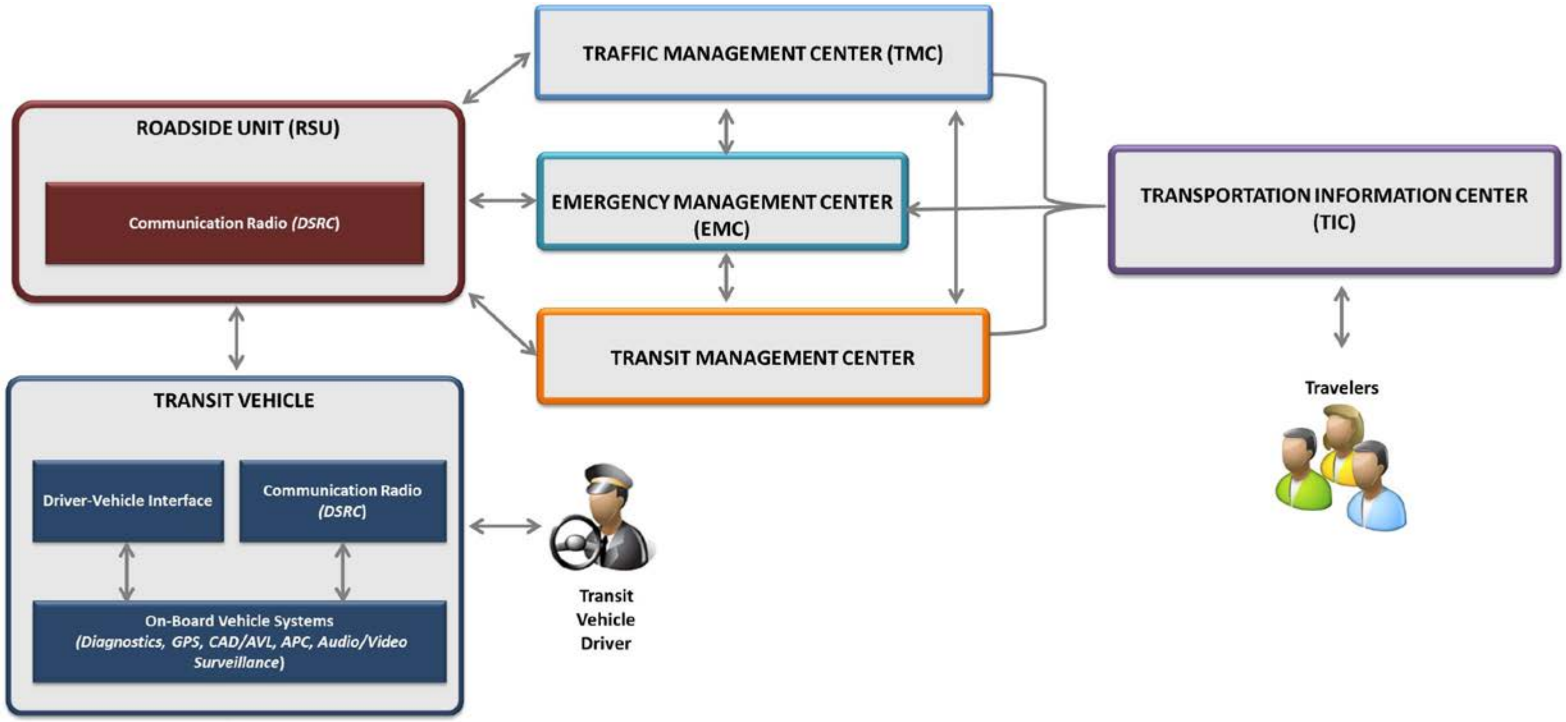

Figure 5-1: Transit Vehicle and Center Data Exchange Application *(Source: USDOT, 2014)*

5.2 Assumptions

One significant assumption is that connected vehicle technology for the Transit Vehicle and Center Data Exchange application is available on the transit vehicles, and in appropriately spaced RSUs to ensure coverage across the transit service area. During the design of this application, careful consideration should be given to the types of communication needed for this application. During the design of the application careful consideration should be given to the type of communication required for this application. DSRC offer low latency communication whereas other forms of wireless communication may have higher latency that may not meet the application requirements. This Operational Concept document is technology agnostic, instead assuming that radio communication is available and being used by all vehicles and infrastructure and possibly travelers.

A second assumption is that there will be a standardized message for DSRC transmission of mobility data, such as passenger load.

The final assumption is that the TMC has access to transit vehicle data through agreements with local transit agencies.

6 Scenarios

This chapter describes the scenarios for the Transit Vehicle and Center Data Exchange application. A scenario is a step-by-step description of how the proposed systems should operate, with actor interactions and external interfaces described under a given set of circumstances. Scenarios help the readers of the document to understand how all the pieces interact to provide operational capabilities. Scenarios are described in a manner that allows the reader to walk through them and gain an understanding of how all the various parts of the Operations Concept will function and interact. Each scenario includes events, actions, stimuli, information, and interactions as appropriate to provide a comprehensive understanding of the operational aspects of the proposed systems. These scenarios provide readers with operational details for the proposed systems; this enables them to understand the actors' roles, how the systems should operate, and the various operation features to be provided.

The Operational Concept discusses the following scenarios:

- **Scenario 1: Transit Vehicle Transmits Data to Support Mobility Applications and Real-Time Trip Planning.** This scenario describes the transfer of real-time transit data to the Transit Management Center, TMC, and EMC to support the deployment of other mobility applications and with trip planning. Through connected infrastructure, this information would be transmitted to Transit Management Centers and disseminated to travelers through the TIC applications.
- **Scenario 2: Transit Vehicle Approaches Non-recurring Congestion due to an Incident or Crash.** This scenario describes how a Transit Vehicle may serve as a mobile data collection unit for the Transit Management Center, TMC, and EMC. The TMC would be notified via DSRC communication to RSU infrastructure that an incident or crash has occurred on a corridor. Using the BSM transmitted by the Connected Vehicle, the TMC would also be notified that an equipped Transit Vehicle is in the vicinity of the incident and equipped with an on-board external surveillance system. The TMC, through the RSU, may engage the transit vehicle's on-board external surveillance system to obtain a real-time assessment of the incident or emergency situation. The real-time view of the event would allow the TMC to respond accordingly to alleviate the impact on transportation within the corridor and will allow the EMC to better assess the threat to respond accordingly.
- **Scenario 3: Emergency Situation aboard or within Vicinity of Transit Vehicle.** This scenario describes how a Transit Vehicle may serve as a mobile data collection unit for the TMC or EMC. For example, if an emergency situation aboard or within the immediate vicinity of the transit vehicle prompts the driver to engage the emergency covert alarm, the TMC would be notified through DSRC communications that an emergency response has been triggered by the driver of that transit vehicle. The vehicle location would be provided to the TMC and appropriate escalation procedures would be followed.

All of the scenarios assume that the Transit Vehicle is equipped with the necessary on-board technology to collect and disseminate the required data. The scenarios also assume that the bus is equipped with on-board video/audio surveillance systems and that this data can be transmitted to the transit management center, TMC, and EMC.

6.1 Scenario 1: Transit Vehicle Transmits Data to Support Mobility Applications and Real-Time Trip Planning

Description. This scenario describes the collection and transfer of real-time transit data to the Transit Management Center and TMC. This data is collected, processed, stored, and disseminated by the TIC to system operators and the traveling public. The TIC will also support the deployment of mobility applications (e.g., IDTO) and with multi-modal trip planning. The IDTO defined three mobility applications that are of high priority research for the FTA. For all three IDTO applications to function, a physical or virtual central system, such as the TIC would dynamically schedule and dispatch trips. Further, the DMA ATIS applications will provide for the collection, aggregation, and dissemination of a wide range of transportation information including traffic, transit, road weather, work zone, and connected vehicle related data. Thus, it is envisioned that this Transit Vehicle and Center Data Exchange application would enhance the data available to Travelers and enable them to be presented with the broadest range of travel options when planning a trip.

Modern transit vehicles feature an array of on-board technologies which collect information, including: vehicle location, speed, heading, passenger loads, and engine health, among other data. DSRC V2I communications between the Transit Vehicle and RSU could be used to periodically transmit this data to the Transit Management Center and ultimately to the TMC. The Transit Management Center will receive and process the message, incorporating relevant information for trip planning requests and routing. This information will be made available to the TIC for trip planning purposes and in support of mobility applications. Sensory based technologies, such as external video detection systems, could also be used to collect and transmit data regarding the operating conditions surrounding the transit vehicle. This real-time view of the corridors on which transit operates could allow the TMC and Travelers to gain a better understanding of the current traffic conditions.

Actors. Transit Management Center; TIC; RSU; Transit Vehicle; and Travelers.

Constraints and Assumptions. The following constraints apply to this scenario:

- Transit Vehicles are equipped with communication radios to transmit messages or receive messages from infrastructure. In this scenario, messages are transmitted and received using DSRC.
- The Transit Vehicle's onboard equipment (OBE) meets minimum performance requirements (e.g., SAE J2945) as needed.
- CAN bus information can be obtained from the Transit Vehicle as needed by the application (e.g., SAE J1939); any missing data needed for the application may be obtained by other means.
- Positioning data is accurate to provide lane level position of the Transit Vehicle using global positioning (GPS) technology.
- The Transit Vehicle is equipped with a DVI to communicate transfer requests, schedule adherence, and other service-oriented information to the vehicle operator.
- A Channel Plan is in place to allow the RSU to transmit and receive BSMs and other messages.
- A Security Credential Management System is in place to allow RSUs to check BSMs and other messages.
- RSUs are equipped with communication radios to transmit messages or receive messages from infrastructure and vehicle. In this scenario, messages are transmitted and received using DSRC.

- The TIC is equipped to handle trip planning, dynamic ridesharing, dynamic transit operations, and traveler information distribution, among other core connected vehicle functions. The TIC is equipped to communicate trip planning and trip requests to the Transit Management Center for overall demand responsive transit schedules and deployment.
- The Transit Vehicle is equipped with OBE including but not limited to: an Automatic Passenger Count system, an Automatic Fare Collection System, Surveillance System, Interior/Exterior Dynamic Message Signs, Automatic Voice Announcement, and a Cellular Based Communications System.

Preconditions. The following preconditions apply to this scenario:

- The Transit Vehicle is performing scheduled, fixed-route service along an established route on a corridor that has been equipped with RSU.
- A combination of or all of the following transit services are available at the transit stop and within the geographic area of the scenario: fixed-route transit, dynamic ridesharing, demand-response transportation, and dynamic transit services.

Flow of Events. The flow of events is included below:

1) The Transit Vehicle is operating under normal conditions. As it approaches an RSU, a message is transmitted via DSRC containing vehicle location, passenger count, and other relevant data necessary to facilitate IDTO and other mobility applications.

2) The RSU receives the message data and transmits it to the Transit Management Center.

3) The application continually transmits mobility information to the TIC to facilitate trip planning.

4) Travelers access TIC applications to facilitate trip planning.

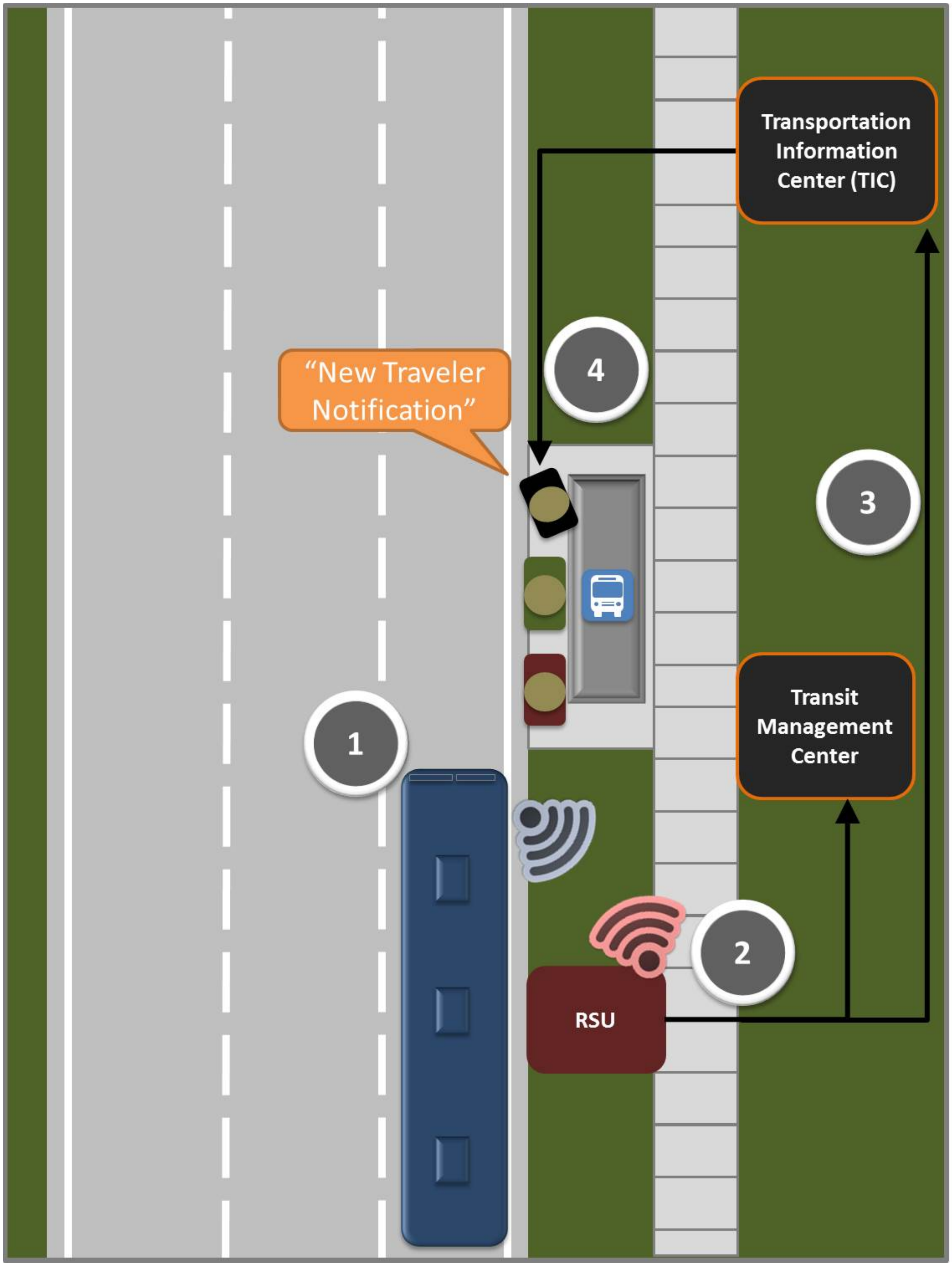

Figure 6-1: Transit Vehicle Transmits Data to Support Mobility Applications and Real-Time Trip Planning *(Source: USDOT, 2015)*

6.2 Scenario 2: Transit Vehicle Approaching Non-recurring Congestion due to an Incident or Crash

Description: This scenario describes how a Transit Vehicle may serve as a mobile data collection unit for the Transit Management Center, TMC, and EMC. The TMC is notified through DSRC communication to the RSU infrastructure that an incident or crash has occurred on corridor (alternatively, the Transit Vehicle, acting as a mobile RSU, could detect the crash and initiate communication with the TMC). The TMC Incident Dispatch Coordination/Communication application is tasked with formulating and managing the incident response. Using the location information transmitted via the BSM, the TMC is notified that an equipped Transit Vehicle is in the vicinity of the incident and equipped with an on-board exterior surveillance system. The TMC Traffic Surveillance application, which monitors and controls traffic sensors and surveillance (e.g., CCTV) equipment, activates the Transit Vehicle's on-board surveillance system via DSRC communication from the RSU. The TMC would retain access, control, and a real-time audio/video feed from the vehicle's external surveillance system. The audio/video is broadcasted to the Transit Management Center, TMC, and EMC to provide a real-time feed of the incident. Further, in the event of an emergency, the Emergency Incident Command application would provide tactical decision support, resource coordination, and communications integration for Incident Commands that are established by first responders at or near the incident scene to support local management of an incident.

Based on the severity of the incident, the TMC may issue a travel advisory and could coordinate the appropriate response. If necessary and possible, transit services along the corridor may be rerouted along parallel corridors through the TMC Multi-Modal Coordination application. In the event that transit is rerouted dynamically, the Transit Traveler Information Infrastructure application would update Travelers of the service changes and real-time arrival status of the vehicle. Further, the TIC would update accordingly to reflect the real-time travel conditions and times – passengers using the trip planner are directed onto alternative services until the non-recurring event has abated. Passengers downstream of the event are notified of the delays affecting transit services and are directed to alternatives, if available.

Actors. Transit Vehicle; RSU; Transit Management Center; TMC; EMC, and TIC.

Constraints and Assumptions. The following constraints apply to this scenario:

- Transit Vehicles are equipped with communication radios to transmit messages or receive messages from infrastructure. In this scenario, messages are transmitted and received using DSRC and cellular/wireless communications.
- The Transit Vehicle's onboard system meets minimum performance requirements (e.g., SAE J2945) as needed.
- CAN bus information can be obtained from the Transit Vehicle as needed by the application (e.g., SAE J1939); any missing data needed for the application may be obtained by other means.
- Positioning data is accurate to provide lane level position of the Transit Vehicle using global positioning (GPS) technology.
- A Channel Plan is in place to allow the RSU to transmit and receive BSMs and other messages.
- A Security Credential Management System is in place to allow RSUs to check BSMs and other messages.
- RSUs are equipped with communication radios to transmit messages or receive messages from infrastructure and vehicle. In this scenario, messages are transmitted and received using DSRC.
- The TIC is equipped to handle trip planning, dynamic ridesharing, dynamic transit operations, and traveler information distribution, among other core connected vehicle functions. The TIC is

equipped to communicate trip planning and trip requests to the Transit Management Center for overall demand responsive transit schedules and deployment.

- The Transit Vehicle is equipped with OBE including but not limited to: Surveillance System, Interior/Exterior Dynamic Message Signs, and a Cellular Based Communications System.

Preconditions. The following preconditions apply to this scenario:

- The Transit Vehicle is performing scheduled, fixed-route service along an established route on a corridor that has been equipped with RSU.
- A combination of or all of the following transit services are available at the transit stop and within the geographic area of the scenario: fixed-route transit, dynamic ridesharing, demand-response transportation, and dynamic transit services.

Flow of Events. The flow of events is included below:

1) The Transit Vehicle is operating under normal conditions. BSMs from vehicles in the vicinity of a non-recurring event (e.g. collision or other emergency response incident) indicate that an incident has occurred along the corridor. BSMs are transmitted to a TMC via the RSU.

2) The TMC is notified of the incident. The TMC coordinates with the Transit Management Center and is automatically notified of the nearest Transit Vehicle's position. The Transit Management Center provides the TMC permission to "ping" the RSU nearest the Transit Vehicle to engage the vehicle to gather and transmit data to the TMC.

3) The Transit Vehicle is "pinged" by the RSU to engage on-board systems with which to collect and transmit data (e.g. audio/video) to the TMC. External cameras are engaged and begin transmitting audio/video data to the TMC via wireless communications. The Transit Vehicle's digital video recorder (DVR) automatically stores a backup of the live feed.

4) TMC staff view the live broadcast and determine appropriate response (e.g. request EMS, fire, or police) and issue a travel advisory for the corridor. Transit Riders awaiting service downstream of the crash/incident are notified of delays in service via the Transit Traveler Information Infrastructure application.

5) The travel advisory is used to temporarily augment transit services by rerouting vehicles along parallel routes around the incident, if available. The data is incorporated into real-time trip planning requests to the TIC. Alternate routes are provided to individuals engaging the TIC's trip planning service.

6) The D-RIDE application is updated to prioritize service downstream and around the incident. The T-connect application updates connection protection requests due to the predicted arrival time of passengers requesting connections.

7) The incident/event is resolved and travel is restored along the arterial. The TMC and transit services resume normal operation.

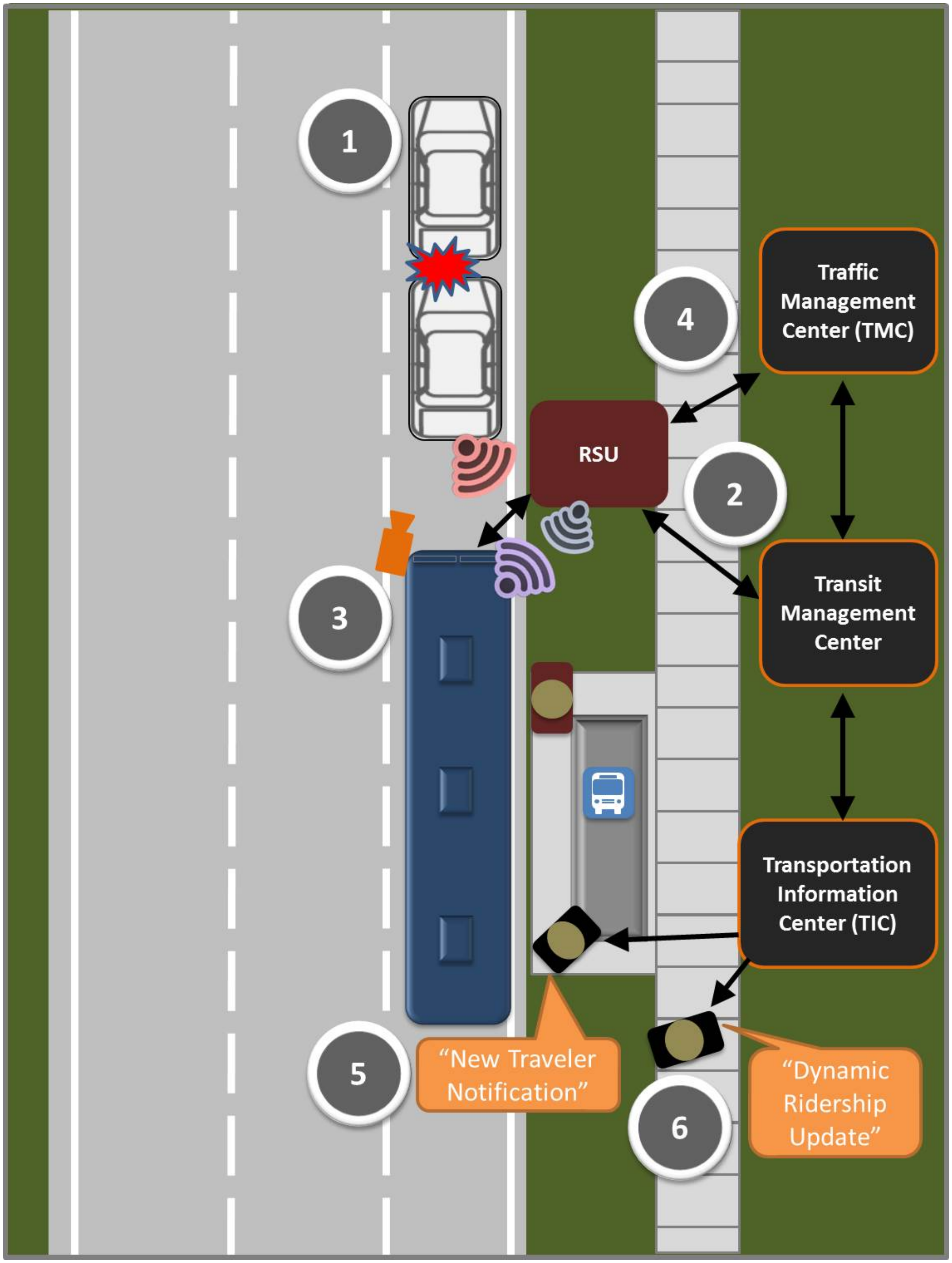

Figure 6-2: Transit Vehicle Approaching Non-recurring Congestion due to an Incident or Crash *(Source: USDOT, 2015)*

6.3 Scenario 3: Emergency Situation aboard or Within Vicinity of Transit Vehicle

Description: This scenario describes how a Transit Vehicle may serve as a mobile data collection unit for the Transit Management Center, TMC, and EMC. An emergency situation aboard or within the vicinity of the Transit Vehicle has prompted the driver to engage the emergency covert alarm. The Transit Management Center is notified through DSRC communication to RSU infrastructure that an emergency response has been triggered by the driver of a transit vehicle. In the event that the vehicle is not within range of an RSU, an alternative wireless communication (e.g., cellular) is engaged. Using the location information transmitted by the Transit Vehicle's AVL, the Transit Management Center is also notified that the vehicle is equipped with an on-board surveillance system. The Transit Vehicle's on-board surveillance system is "pinged" by the RSU using DSRC to provide a live audio/video feed. The video feed is broadcasted to the Transit Management Center. Based on the severity of the event, the TMC can coordinate an appropriate response from the EMC. Passengers downstream of the event are notified of the delays affecting transit services and are directed to other alternatives, if possible.

Actors. Transit Vehicle; TMC; Transit Management Center; Vehicle Driver; TIC; and EMC

Constraints and Assumptions. The following constraints apply to this scenario:

- Transit Vehicles are equipped with communication radios to transmit messages or receive messages from infrastructure. In this scenario, messages are transmitted and received using DSRC and cellular/wireless communications.
- The Transit Vehicle's onboard system meets minimum performance requirements (e.g., SAE J2945) as needed.
- CAN bus information can be obtained from the Transit Vehicle as needed by the application (e.g., SAE J1939); any missing data needed for the application may be obtained by other means.
- Positioning data is accurate to provide lane level position of the Transit Vehicle using global positioning (GPS) technology.
- A Channel Plan is in place to allow the RSU to transmit and receive BSMs and other messages.
- A Security Credential Management System is in place to allow RSUs to check BSMs and other messages.
- RSUs are equipped with communication radios to transmit messages or receive messages from infrastructure and vehicle. In this scenario, messages are transmitted and received using DSRC.
- The TIC is equipped to handle trip planning, dynamic ridesharing, dynamic transit operations, and traveler information distribution, among other core connected vehicle functions. The TIC is equipped to communicate trip planning and trip requests to the Transit Management Center for overall demand responsive transit schedules and deployment.
- The Transit Vehicle is equipped with OBE including but not limited to: Surveillance System, Interior/Exterior Dynamic Message Signs, and a Cellular Based Communications System.

Preconditions. The following preconditions apply to this scenario:

- The Transit Vehicle is performing scheduled, fixed-route service along an established route on a corridor that has been equipped with RSU.

- A combination of or all of the following transit services are available at the transit stop and within the geographic area of the scenario: fixed-route transit, dynamic ridesharing, demand-response transportation, and dynamic transit services.

Flow of Events. The flow of events is included below:

1) The Transit Vehicle is operating under normal conditions. An emergency event occurs aboard or within the vicinity of the Transit Vehicle that prompts the Vehicle Driver to engage the covert alarm.

2) A broadcast from the transit vehicle to the RSU indicates that an emergency event has occurred aboard the vehicle which requires a transit agency, EMS, and/or TMC response.

3) The Transit Management Center is notified of the incident. The Transit Management Center dispatch staff is automatically notified of the Transit Vehicle's position. The Transit Management Center "pings" the RSU nearest the motor bus to engage the vehicle to gather and transmit data to the TMC.

4) The Transit Vehicle is "pinged" by the RSU to engage on-board systems with which to collect and transmit data (e.g. audio/video) to the Transit Management Center. Internal and external cameras are engaged and begin transmitting audio/video data to the Transit Management Center via cellular/wireless communications. The Transit Vehicle's DVR automatically stores a backup of the live feed.

5) The Transit Management Center and EMC Personnel view the live broadcast and determine appropriate response (e.g. dispatch EMS, fire, or police to the site).

6) The incident/event is resolved and the TMC and transit services resume normal operation.

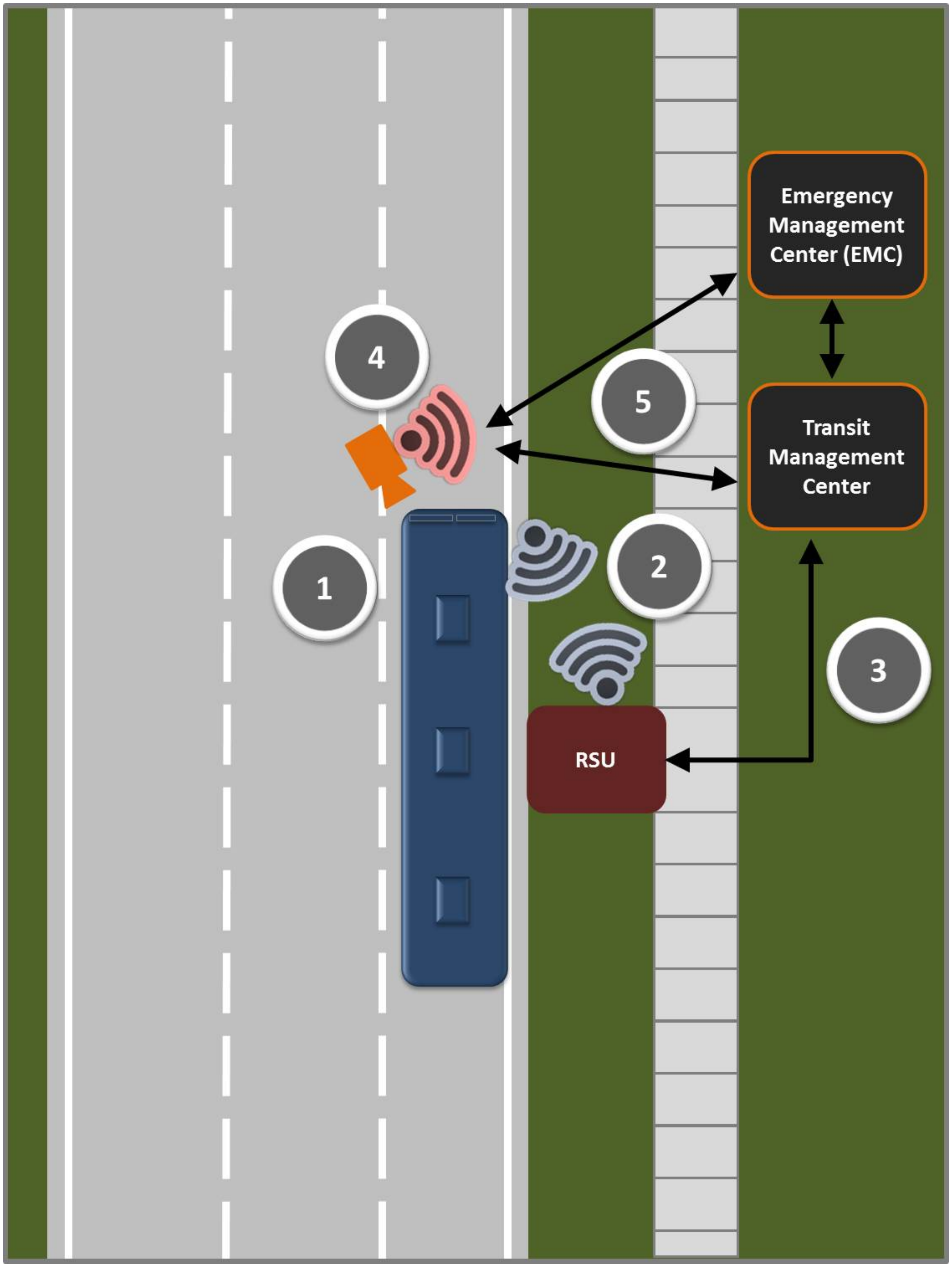

Figure 6-3: Emergency Situation aboard or Within Vicinity of Transit Vehicle *(Source: USDOT, 2015)*

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APPENDIX A. List of Acronyms

Acronym	Meaning
ABS	Antilock Braking System
APC	Automatic Passenger Counters
ATIS	Advanced Traveler Information Systems
AVL	Automatic Vehicle Location
BRT	Bus Rapid Transit
BSM	Basic Safety Message
CAD	Computer Aided Dispatch
CAN	Controller Area Network
CCTV	Closed Circuit Television
DART	Dallas Area Rapid Transit
DCM	Data Capture and Management
DMA	Dynamic Mobility Applications
DOT	Department of Transportation
D-RIDE	Dynamic Ridesharing
DSRC	Dedicated Short Range Communications
DVI	Driver-Vehicle Interface
DVR	Digital Video Recorder
EMC	Emergency Management Center
EMS	Emergency Medical Services
ESWKY	Easter Seals West Kentucky
FCC	Federal Communications Commission
FCTA	Fulton County Transit Authority
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FTA	Federal Transit Administration
GPS	Global Positioning System
I2V	Infrastructure-to-Vehicle
ICM	Integrated Corridor Management
IDTO	Integrated Dynamic Transit Operations
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LTA	Left Turn Assist
LTE	Long Term Evolution
MAP	Metropolitan Atlanta Performance
MCTA	Murray-Calloway County Transit Authority
MDT	Mobile Data Terminal
MSAA	Mobility Services for All Americans
MTA	Metropolitan Transit Authority
NEMA	National Electrical Manufacturers Association
NHTSA	National Highway Traffic Safety Administration
NYCDOT	New York City Department of Transportation
NYPD	New York Police Department

Acronym	Meaning
OBE	On-Board Equipment
PATS	Paducah Area Transit System
RDE	Research Data Exchange
RSU	Roadside Unit
RSZW	Reduced Speed Zone Warning
SAE	Society of Automotive Engineers
SBS	Select Bus Service
SSGA	Stop Sign Gap Assist
SWIW	Spot Weather Information Warning
TCC	Train Control Center
T-CONNECT	Connection Protection
TCRP	Transit Cooperative Research Program
T-DISP	Dynamic Transit Operations
TIC	Transportation Information Center
TIM	Traveler Information Message
TMA	Transportation Management Association
TMC	Transportation Management Center
TMCC	Travel Management Coordination Center
TSM&O	Transportation Systems Management and Operations
TSP	Transit Signal Priority
USDOT	U.S. Department of Transportation
UTC	Coordinated Universal Time
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WAW	Wide Area Wireless
WLAN	Wireless Local Area Network
X2D	Vehicle or Infrastructure-to-Device

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