Report on Functional and Performance Requirements and High-Level Data and Communication Needs for Integrated Dynamic Transit Operations (IDTO)

www.its.dot.gov

Final Report — August 13, 2012
FHWA-JPO-12-085

U.S. Department of Transportation

Produced under the “Technical Support and Assistance for the Federal Highway Administration’s Office of Operations” contract
U.S. Department of Transportation
Research and Innovative Technology Administration
Federal Highway Administration

Cover photo credits, Carol Schweiger.

NOTICE

Technical Report Documentation Page

1. Report No. FHWA-JPO-12-085	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Report on Functional and Performance Requirements, and High-Level Data and Communication Needs for Integrated Dynamic Transit Operations (IDTO)		5. Report Date August 13, 2012	
		6. Performing Organization Code	
7. Authors Santosh Mishra, Carol Schweiger, Ayeshah Abuelhiga, Carrie Butler, Kari Beasley, Robert Sanchez		8. Performing Organization Report No.	
9. Performing Organization Name and Address Science Applications International Corporation (SAIC) 8301 Greensboro Drive, Mailstop E-12-3 Mclean, VA 22102		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. DTFH61-06-D-00005, Task No. T-11-018	
12. Sponsoring Agency Name and Address United States Department of Transportation ITS Joint Program Office Research And Innovative Technology Administration (RITA) 1200 New Jersey Avenue, SE Washington, DC 20590		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code HOIT-1	
15. Supplementary Notes Mr. Ron Boenau, COTM			

16. Abstract

In support of USDOT's Intelligent Transportation Systems' (ITS) Mobility Program, 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 to increase efficiency and improve individual mobility while reducing negative environmental impacts and safety risks. The Integrated Dynamic Transit Operations (IDTO) applications, which are the subject of this document, will provide transit users and riders the means to ensure successful transit transfers (T-CONNECT), to make real-time trip requests through personal mobile devices (T-DISP), and to identify and accept potential ridesharing opportunities along a given travel route (D-RIDE).

This document identifies the functional requirements (with corresponding operational mode); qualitative and quantitative performance targets for each functional requirement that must be accomplished in achieving the transformative goals identified in the Concept of Operations (ConOps); and high-level data and communication needs, for the IDTO bundle of applications. In addition, this document also describes the verification methods for each requirement and the traceability matrices showing the linkage between requirements to user needs.

17. Key Words Integrated Dynamic Transit Operations, IDTO, Functional Requirements, Performance Requirements, T-CONNECT, T-DISP, D-RIDE, Dynamic Mobility Applications, DMA, Intelligent Transportation Systems, ITS.		18. Distribution Statement No restrictions.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No of Pages 66	22. Price N/A

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

Preface

In support of USDOT's Intelligent Transportation Systems' (ITS) Mobility Program, several of the Department's agencies are fully engaged in exploiting active interaction between fixed and mobile transportation system entities both in the way new forms of data are being exchanged and in the opportunities that are afforded to extend the geographic scope, precision and control of our Nation's surface transportation system. An important initiative within the framework of this strategic effort is the Dynamic Mobility Applications (DMA) program which, in part, 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.

To that end, the Integrated Dynamic Transit Operations (IDTO) applications, which are the subject of this document, will provide transit users and riders the means to ensure successful transit transfers (T-CONNECT), to make real-time trip requests through personal mobile devices (T-DISP), and to identify and accept potential ridesharing opportunities along a given travel route (D-RIDE). The purpose of this report is to identify the functional requirements; qualitative and quantitative performance targets for each functional requirement that must be accomplished in achieving the transformative goals identified in the Concept of Operations (ConOps); and high-level data and communication needs, for the IDTO bundle of applications. The requirements, like the ConOps, explicitly reflect updated USDOT guidance on standards as well as institutional, policy and legal issues.

Table of Contents

List of Tables

List of Figures

Chapter 1. Scope of System

1.1 Identification of System

This document contains the Functional and Performance Requirements, and High-Level Data and Communication Needs for the Integrated Dynamic Transit Operations (IDTO) bundle within the Dynamic Mobility Applications portion of the Connected Vehicle Applications element of the Connected Vehicle Program.

1.2 Document Overview

The USDOT initiated this Systems Engineering (SE) project to define the Concept of Operations (ConOps), requirements and readiness of the IDTO bundle. The ConOps is a prerequisite to this document and is recommended reading prior to reading this document. The ConOps describes the characteristics of the three applications within the IDTO bundle from the system user's viewpoints. The requirements build upon those concepts, particularly the User Needs, to document the required functionality, performance, interfaces, and other required characteristics for the IDTO applications.

The structure of this document is based on Institute of Electrical and Electronics Engineers (IEEE) Standard 1233-1998 IEEE Guide for Developing System Requirements Specifications and Federal Highway Administration's (FHWA) System Engineering Guidebook (SEGB) that adapted IEEE-1233.

This document consists of the following sections:

- Section 1 provides an overview of IDTO and an introduction to this document.
- Section 2 lists the documents used as background information and the sources of requirements.
- Section 3 provides the requirements for the three IDTO applications.
- Section 4 lists the Verification Method for each requirement from Section 3.
- Section 5 provides the Traceability Matrices tracing each requirement to the User Needs and vice versa.
- Section 6 contains a glossary of terms, and a list of abbreviations and acronyms.
- Appendix A contains a list of stakeholders.

The intended audience for this document includes:

- US Department of Transportation (DOT)
- Transit agency and transportation organization managers
- Device manufacturers and software developers
- Information service providers
- Application developers

1.3 System Overview

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 Dynamic Mobility Applications (DMA) program (see Figure 1-1 below).

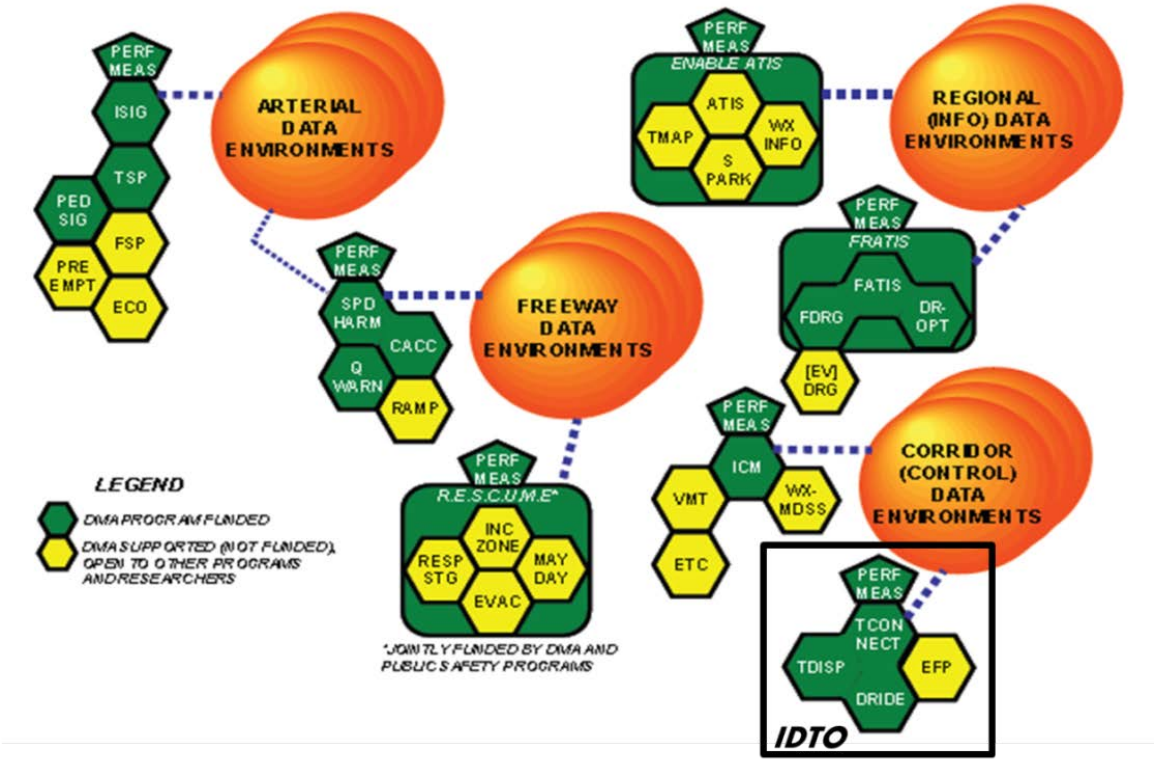

Figure 1-1. Dynamic Mobility Applications (DMA) Program Bundles

The 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 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.

This philosophy of identifying applications that can be deployed in the near-term is in keeping with the USDOT's goals of quickly moving these applications from the research stage to adoption in the field.

Other considerations that will promote this wide-spread implementation include carefully considering user needs and requirements, ensuring the availability of required data sources, identifying potential barriers to implementation, and (wherever possible) using non-proprietary and/or open source approaches that can readily be adopted by a wide variety of potential end users in both the public and private sector.

The purpose of the IDTO ConOps is to describe system concepts, operational scenarios and the rationale for key concept decisions that reflect the transformative goals (with respect to mobility, environment and safety impacts) that might be realized with the deployment of the IDTO bundle of applications. The IDTO ConOps was used to develop the functional and performance requirements, and high-level data and communication needs for IDTO. Further, the ConOps facilitated the identification and assessment of key technical and non-technical issues related to field-testing the IDTO bundle and its individual component applications.

The following subsections present a brief overview of the three applications that comprise the IDTO bundle: Connection Protection (T-CONNECT), Dynamic Transit Operations (T-DISP) and Dynamic Ridesharing (D-RIDE).

1.3.1 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 intermodal 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.

1.3.2 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.

1.3.3 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. As a result of accomplishing these two goals, a myriad of other benefits could exist that benefit transit systems including that D-RIDE could help reduce peak demand for public transit so the public transit system can be designed more affordably and can have greater customer satisfaction during spikes in ridership.

1.4 Project Stakeholders, Acquirer, Users and Support Agencies

The following stakeholders have been identified for participation in the development of requirements for the IDTO bundle. These stakeholder groups represent a range of interests and will be able to provide input on the requirements identified in this report. A list of stakeholder contact information is included in Appendix A.

- Connected Vehicle Subject Matter Experts (SMEs) – who provide an understanding of the state of the program and the future vision for how transit applications will be integrated into the whole.
- Transit System Operators – who provide service and would ultimately deploy and maintain technology related to IDTO. Representatives from all transit modes (bus, bus rapid transit, light rail, heavy rail [subway], commuter rail, ferry, demand-response, ridesharing) should be included.
- Transit System Managers – who make or guide decisions about how transit service is operated.
- Transit System Riders – the users of the transit service, and eventually who will directly benefit from aspects of the IDTO bundle, e.g., rider advocacy groups or professional facilitated focus groups.
- Travelers who regularly share rides with others – another user group who will benefit from aspects of the IDTO bundle.
- Metropolitan/regional/rural planning organizations – groups that ensure that existing and future expenditures of governmental funds for transportation projects and programs are based on a continuing, cooperative, and comprehensive planning process.
- ITS Transit and Intermodal Travel Information System Experts – who will provide insight into existing systems.
- Transit Vehicle Original Equipment Manufacturers – who will inform and guide how software and hardware could be deployed on vehicles.
- Transit and/or Transportation Software Application Developers – who will provide insight into the existing systems, especially those already in use that provide data and information about travel.
- Private System Vendors and Consultants – who can contribute their knowledge of existing systems similar to the IDTO bundle of applications.
- Transportation (non-transit) providers/organizations – users of the transportation network such as package delivery companies (e.g., Federal Express), transportation management associations (TMAs) and airport ground transportation (e.g., terminal shuttle buses).

- Transportation association representatives – For example. Transportation Research Board (TRB), American Association of State Highway and Transportation Officials (AASHTO), American Public Transportation Association (APTA), Community Transportation Association of America (CTAA), Institute of Transportation Engineers (ITE) and ITS America – who can speak to the larger, industry-wide issues relative to the IDTO bundle.

Chapter 2. Supporting Documentation

This section provides information that may add to the understanding of the Requirements without going elsewhere. This section contains the description of the proposed applications within the IDTO bundle.

2.1 T-CONNECT

T-CONNECT will provide travelers the ability to request a transfer using their personal devices or on-board transit vehicles (with assistance from drivers or using agency-equipped on-board interactive devices). Based on the system configuration (system schedule, schedule adherence status and delay thresholds, and service variability), connection protection rules and traveler requests, the system will automatically determine the feasibility of a requested transfer. When a transfer request can be met, the system will automatically notify the traveler and the driver of the vehicle to which the traveler intended to transfer. T-CONNECT will be designed to work in both single agency and multi-agency environments across single or multiple modes of transportation.

While making decision on a transfer request, the T-CONNECT system is expected to take into account the overall state of the transportation system, including connection protection requests made by other travelers as well as real-time and historical travel conditions for the services affected, and pre-determined connection protection rules agreed upon by the participating agencies and transit modes, as indicated earlier. The system will also take into account the preferences and priorities about connection protection for those travelers who choose to provide that information to the T-CONNECT system.

Also, T-CONNECT will be integrated with the two other IDTO applications: T-DISP and D-RIDE to:

- Provide trip alternatives to travelers for whom a connection cannot be protected; and
- Provide connection opportunities to the users of T-DISP and D-RIDE.

The system will also continue to monitor the situation and provide connection protection status to notify agency dispatchers and travelers regarding any updates to the connection protection requests. While agency dispatchers may view status in real-time directly on the T-CONNECT system, the T-CONNECT system will notify travelers as appropriate on their personal devices. In addition, travelers onboard affected (e.g., delayed) transit vehicles (such as buses waiting at a commuter rail station for a delayed train) may also receive information through onboard devices, such as dynamic message signs (DMS), indicating the vehicle is waiting for other travelers.

An overview of the activities involved in completing a transfer connection protection request as part of the T-CONNECT application is provided in Figure 2-1.

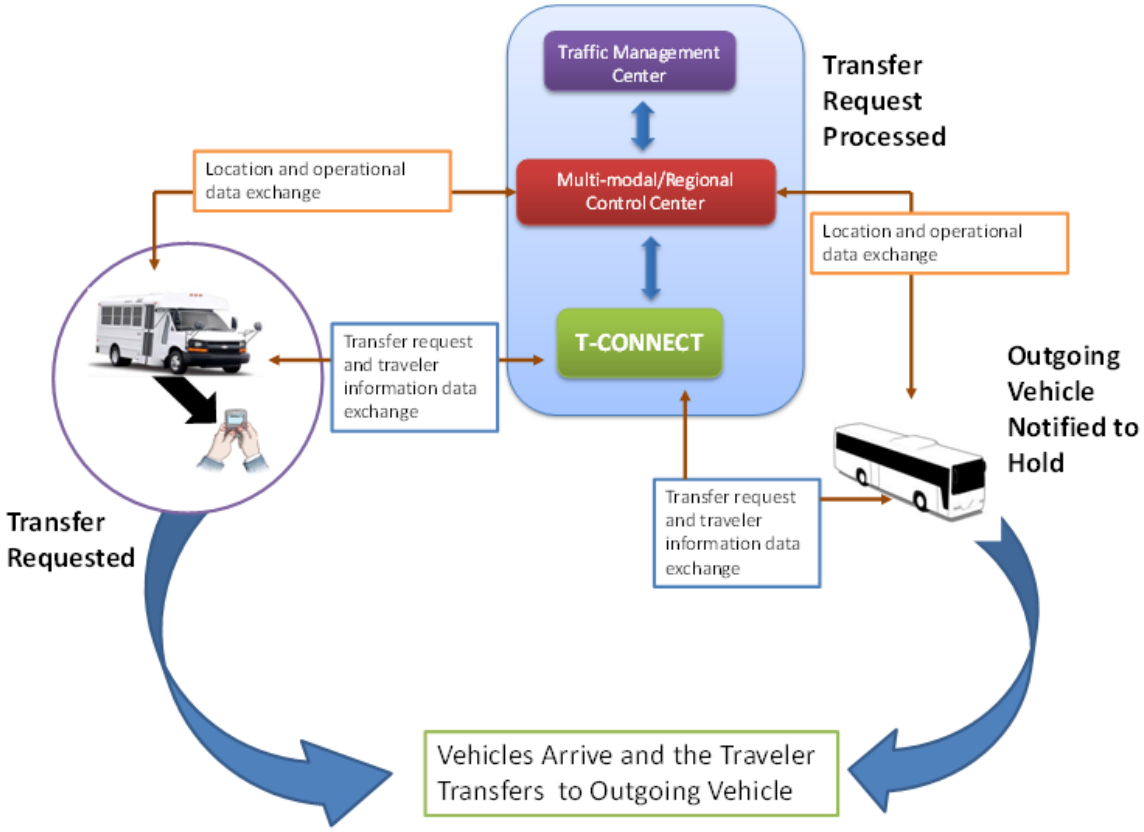

Figure 2-1. T-CONNECT Concept Overview

2.2 T-DISP

The T-DISP application will advance the concept of demand-responsive transportation services utilizing the global positioning system (GPS) and mapping capabilities of personal mobile devices to enable a traveler to input a desired destination and time of departure tagged with their current location. A central system, such as a Travel Management Coordination Center (TMCC) or decentralized system, would dynamically schedule and dispatch or modify the route of an in-service vehicle by matching compatible trips together. The application may consider both public and private (e.g., taxi) transportation providers and may include paratransit, fixed -route bus, flex-route bus, and rail transit services. For example, if a paratransit vehicle is not available, a traveler would be given information on fixed-route service or connected to a private service.

The proposed application may consider a common platform that allows people to effectively communicate and access shared transportation resources more readily than currently occurs. The platform would provide a transit exchange that allows prospective travelers and vehicle operators to trade in a transparent market on demand for optimal mobility solutions without advanced notice.

The application may consider real-time traffic conditions to dynamically route vehicles as necessary (i.e., to select the optimum route), and real-time vehicle capacity to dynamically assign or remove vehicles from service as necessary. It would accommodate dispersed origin-destination trips and trips in low density, low ridership areas, and may replace some late night or mid-day fixed-route service.

T-DISP is envisioned to consist of the high-level components and features shown in Figure 2-2.

Figure 2-2. T-DISP Concept Overview

The following systems will be included in the T-DISP application:

- Voice radio communications to facilitate interactions between drivers and dispatchers, and to serve as a back-up if data communication fails;
- Data communication to exchange data and trip information between the Control Center and vehicles
- Computer aided dispatch/automatic vehicle location (CAD/AVL) systems to track vehicle locations and assist in messaging between drivers and dispatchers;
- A common interface between CAD/AVL and messaging systems, especially in the case of a multiple agency/multiple transportation provider environment;
- A common network interface that extracts information from both legacy and new technology systems, facilitates communication among such systems, and provides outputs to end users and external systems;
- A multi-modal scheduling system that can dynamically schedule service based on traveler preferences and requests, and match them to available vehicles. This system would enhance the basic functionality that exists within existing demand-response scheduling software to include a series of business rules and scheduling parameters that allow dynamic scheduling and dispatching; and
- A customer messaging and information system to serve as the traveler interface for service requests, especially for travelers with disabilities, or special needs.

The following entities will be included in T-DISP:

- Public transit agencies;
- Private transportation providers;
- Traffic management center; and
- Coordination center, either as part of an existing entity or a new entity.

In its simplest form, T-DISP seeks to match travelers' requests for trips with available transportation providers' services. This matching occurs within a Control Center and by the use of systems that communicate with customers and vehicles, and schedule trips for customers.

2.3 D-RIDE

At the highest level, D-RIDE is an approach to carpooling in which drivers and riders can arrange trips in real time. Current systems do not have the functionality to dynamically match passengers to drivers

no matter their location and usually require preplanning of carpool trips. The D-RIDE application allows travelers to arrange carpool trips through a stand-alone personal device with a wireless connection and/or an automated ridematching system (e.g., call center or web-based application loaded on a personal computer or kiosk at a transit facility).

The D-RIDE application follows the process flow shown below in Figure 2-4. As you go through the application, inputs are needed from both passengers and drivers pre-trip (blue), during the trip (green), and post-trip (purple). These inputs are then translated into “optimal” pairings between passengers and drivers to provide both with a convenient route between their two origin and destination locations. After the trip, information is provided back to the application to improve the user’s experience for future trips and monitor use of high-occupancy lanes.

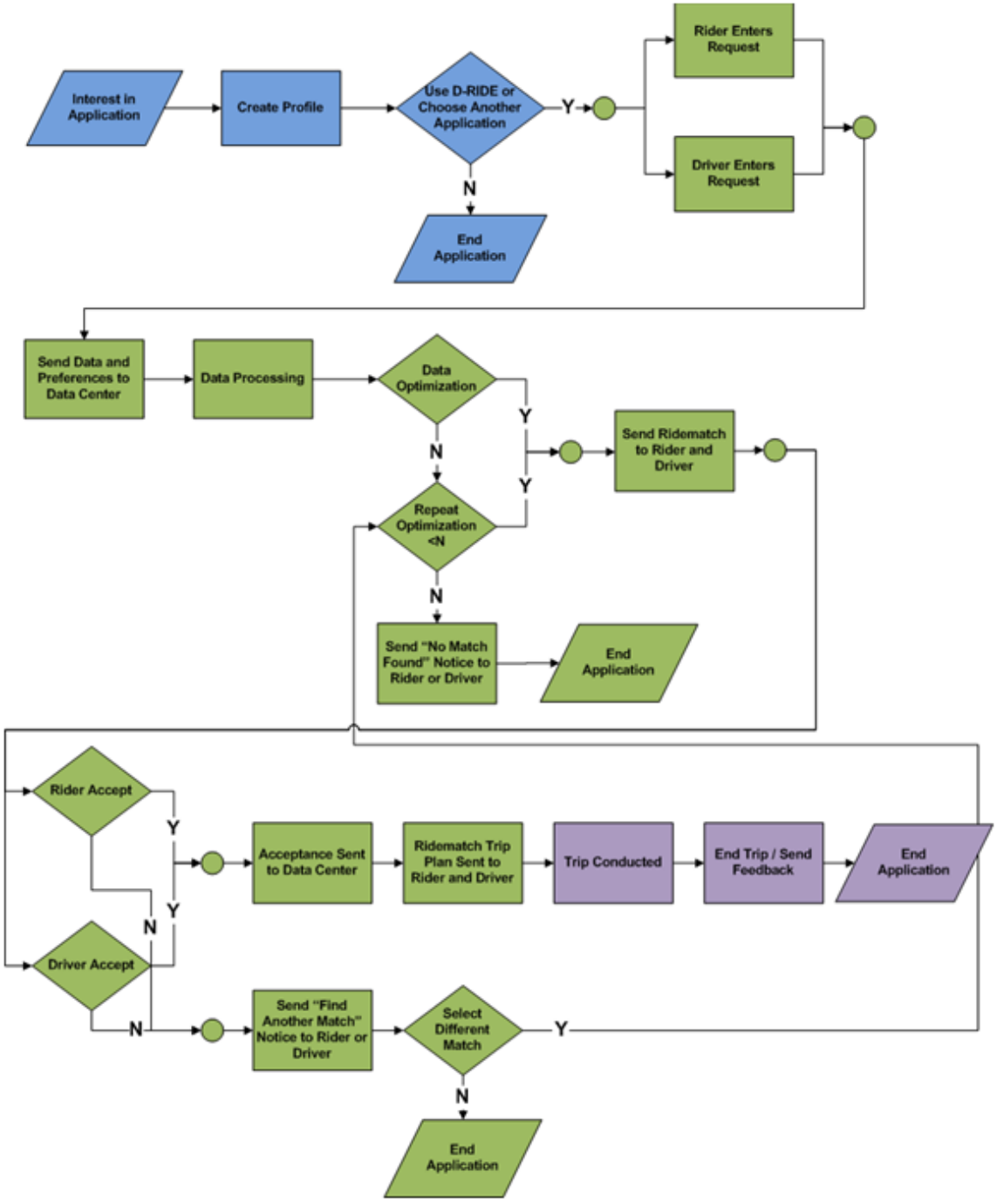

Figure 2-3. D-RIDE Concept Overview

Chapter 3. Referenced Documents

This section lists the documents referenced in this Requirements Report including title, revision, and report date.

The project process leading up to the development of the requirements identified in this report included the development of the following documents:

- Project Management Plan (PMP)
- Systems Engineering Management Plan (SEMP)
- Report on Assessment of Relevant Prior and Ongoing Research
- Report on Stakeholder Input on Transformative Goals, Performance Measures and User Needs
- Concept of Operations (ConOps) for IDTO

The documents used in the development of the IDTO requirements are shown in Table 3-1.

Table 3-1. Documents Used in the Development of Requirements

Title	Revision	Date
Systems Engineering Guidebook for Intelligent Transportation Systems	3.0	November 21, 2009
IEEE Standard 1362-1998, *IEEE Guide for Information Technology – System Definition – Concept of Operations (ConOps) Document*		
IEEE Standard 1233-1998, *IEEE Guide for Developing System Requirements Specifications*		
Project Management Plan for the Concept Development and Needs Identification for Integrated Dynamic Transit Operations	2.0	September 28, 2011
Systems Engineering Management Plan for the Concept Development and Needs Identification for Integrated Dynamic Transit Operations	2.0	September 28, 2011
Report on Assessment of Relevant Prior and Ongoing Research for the Concept Development and Needs Identification for Integrated Dynamic Transit Operations	0.4	November 2, 2011
Integrated Dynamic Transit Operations (IDTO) Workbook	1.0	January 27, 2012
Report on Stakeholder Input on Transformational Goals, Performance Measures and User Needs for Integrated Dynamic Transit Operations	3.2	February 17, 2012
Integrated Dynamic Transit Operations (IDTO) Concept of Operations	3.0	May 11, 2012

Chapter 4. Stakeholder Needs

This section contains tables that show stakeholder needs, which were derived initially from the ***Report on Stakeholder Input on Transformational Goals, Performance Measures and User Needs for Integrated Dynamic Transit Operations.*** Then, these needs were refined during the development of the ***IDTO Concept of Operations***. The final set of user needs was developed and finalized just prior to the development of the requirements.

4.1 T-CONNECT Stakeholder Needs

Table 4-1 provides a list of user needs that were used to determine the requirements for the T-CONNECT application.

Table 4-1. T-CONNECT Stakeholder Needs

ID	T-CONNECT Stakeholder Needs
TC-1	Vehicles should be wirelessly connected using "Connected Vehicle" or conventional wireless technologies (e.g., private radio, cellular data).
TC-2	Drivers should be able to access the interface using a mobile data terminal (MDT) or a similar interface to intake request for transfers from customers. The application should approve or deny a request. If the request is approved, the application should continuously monitor and provide a status to interested parties. Drivers on outgoing vehicles should be able to indicate the completion of a transfer request once the customer requesting that transfer is on-board and paid for the trip, as necessary.
TC-3	Agencies/service operators need to have access to the transfer requests and relevant analytical tools for operational monitoring (e.g., to view real-time status, calculate ETA, determine need for an additional bus etc.)
TC-4	A request broker should be implemented to obtain and process transfer request from a variety of sources for public or private transit modes. The request broker should determine feasibilities of transfers based on pre-configured policies and procedures pertinent to the parties involved in the transfers. The request broker may use the capabilities of T-DISP and D-RIDE to complete a transfer request when needed.
TC-5	Agencies/service operators need to have real-time access to information on vehicle location, RSA and other event-based data (e.g., incident/accident) for all vehicles involved with a transfer request
TC-6	Agencies/service operators need to have the ability to manually override the decision made by the T-CONNECT system in the event decision is going to have an impact on the operations due to real-time events not known to the automated system

ID	T-CONNECT Stakeholder Needs
TC-7	Agencies/service operators need to have the ability to configure agency-specific fare policies in the system. The application should use this information to determine any fare to be collected from customers.
TC-8	Customers need to be able to use a connected personal device to request transfer to a particular route and subsequently monitor the status of their requests.
TC-9	The customer should be able to receive real-time information and alerts as per their preferences (e.g., emails, text messages) when a transfer is approved or denied, and if status has changed for a pre-approved request. When an outgoing vehicle is waiting for customers, on-board riders should be notified about the hold time. Also, when customers are waiting at a stop, ETA for the outgoing vehicle should be provided using appropriate media.
TC-10	Customers should be able to register with the T-CONNECT application to store their profile and personal preferences for transfer connections. Also, the application should allow registered customers to pay for trip using a web-based interface.
TC-11	Two-way communication gateway and infrastructure as needed should be established so that connected vehicles can communicate with control center(s) and the T-CONNECT applications
TC-12	Two-way communication gateway and infrastructure as needed should be established between regional agencies so that control centers and operational tools/applications hosted by those centers can communicate in real-time when needed
TC-13	Two-way communication with regional traffic management centers should be established so that estimated time of arrival of vehicles can be corrected based on real-time or historic traffic information when available

4.2 T-DISP Stakeholder Needs

Table 4-2 provides a list of user needs that were used to determine the requirements for the T-DISP application.

Table 4-2. T-DISP Stakeholder Needs

ID	T-DISP Stakeholder Needs
TD-1	Travelers/public transit customers need to be able to request trips and use public and private transportation services.
TD-2	Travelers with special needs/ paratransit customers need to be able to request trips based on their individual accessibility needs as well as use public and paratransit services.
TD-3	Multimodal transportation planners need to be able to analyze and review the performance of the T-DISP application in order to make any needed adjustments or changes to how service could be deployed.

ID	T-DISP Stakeholder Needs
TD-4	Bicycle and pedestrian planners need to be able to provide bicycle and pedestrian network information to the multi-modal scheduling system.
TD-5	TMCC has access to real-time data (from multiple modes and jurisdictions) and access to network configuration data from one or more sources.
TD-6	TMCC needs to be able to send trip options/description characteristics back to travelers.
TD-7	TMCC needs to be able to have and understand the business rules to guide decisions about how trips are distributed to transportation providers.
TD-8	Public and private transportation providers need to be able to generate and provide vehicle availability and location information to a TMCC.
TD-9	Public and private transportation providers have business rules to guide decisions about how trips are distributed to transportation providers
TD-10	ITS/IT managers need to develop ITS-specific IT hardware and software standards, and deploy IT equipment and applications
TD-11	ITS, IT and maintenance staff need to operate and maintain equipment.
TD-12	Parking facility staff need to operate, monitor and maintain parking facilities including park and ride; and provide information to the TMCC about park and ride space availability.
TD-13	Shared-ride / Carpool / Vanpool entities need to provide information on available shared ride, carpool, vanpool services to the TMCC / Multi-modal scheduling system.
TD-14	Transit operations managers need to plan, manage, and dispatch transit operations throughout the transportation network.
TD-15	Transit supervisors and dispatchers need to maintain communications with transit operators and monitor transit vehicle schedule adherence, breakdowns, on-board incidents and safety issues.
TD-16	Transit operators need to operate vehicles in a safe and efficient manner.
TD-17	Private transportation providers plan, manage and dispatch transit operations throughout the transportation network.
TD-18	Private transportation providers operate vehicles in a safe and efficient manner.
TD-19	Transit maintenance needs to monitor status of onboard equipment.
TD-20	Transit customer service centers need to interface with the transit users, providing assistance and answering questions.
TD-21	Transit customer service centers need to be able to receive calls for trip requests and input the requests into the Multi-modal Scheduling System.

4.3 D-RIDE Stakeholder Needs

Table 4-3 provides a list of user needs that were used to determine the requirements for the D-RIDE application.

Table 4-3. D-RIDE Stakeholder Needs

ID	D-RIDE Stakeholder Needs
DR-1	Users need to be able to enter personal information into the application interface.
DR-2	Users need to be able to transmit personal information to the application data center.
DR-3	Users need to be able to enter geographic information about the user's destination.
DR-4	Users need to be able to enter information into the application interface securely.
DR-5	Users need to be able to access the application interface using multiple media (e.g., web-based, call-center-based, or via a smart-phone interface).
DR-6	Users need a safe (e.g., limited distraction) method for accessing the application interface while driving.
DR-7	Users need to be able to enter payment information into the application interface.
DR-8	Users need to be able to transmit payment information to the application data center.
DR-9	Users need to be able to accept/decline ridematches using the application interface.
DR-10	Users need to be able to enter preferred routings into the application interface.
DR-11	Support agencies need to be able to view reports of application usage and performance.
DR-12	Users need to be able to provide feedback on ridematches after completion via the application interface.

Chapter 5. Requirements, Verification Methods and Traceability

Functional requirements for the three IDTO applications were derived from the Concept of Operations. These high-level requirements are technology-agnostic, as the specific implementation of each application may vary widely from agency to agency and jurisdiction to jurisdiction based on their specific needs. Performance requirements for the three IDTO applications were derived from conversations held with stakeholders in January and April 2012, as well as from the ***Report on Stakeholder Input on Transformational Goals, Performance Measures and User Needs for Integrated Dynamic Transit Operations***. The performance requirements may need to be reevaluated for specific implementations to balance scope, schedule and cost, but should serve as a baseline for specifications development as this project moves into design and implementation.

Along with the functional and performance requirements, we have indicated the verification method for each requirement. For each requirement, one of the following methods of verification is indicated:

- **Demonstrate:** verification through demonstration of features, without any need for an external test requirement
- **Test:** verification through use of an external piece of test equipment.
- **Analyze:** verification through a logical conclusion or mathematical analysis of a result.
- **Inspect:** verification through a visual comparison.

Further, each requirement is traced back to the stakeholder needs (shown in Section 4). The relationship of each requirement to the user needs is shown in each application's requirements table in the User Need ID column.

5.1 T-CONNECT

Table 5-1 provides a list of T-CONNECT functional requirements. These requirements are grouped in the following categories (please refer to the "Section" column):

- **In-vehicle System**: refers to the features that will be used by drivers to input transfer requests on customers' behalf, review the list of transfers and obtain the real-time status of a transfer request.
- **Central System**: refers to various systems, subsystems and interfaces that will be installed at control centers and data centers. The central system primarily refers to a transfer request brokerage and processing subsystem, a dynamic transfer request manager and a real-time traveler information subsystem. Further, the central system will be integrated with the following external systems:
  - CAD/AVL system
  - APC system
  - Fare payment system

- Customer information system
- T-DISP
- D-RIDE
- Vehicle arrival prediction system
- Traffic management center system

The T-CONNECT integrator will facilitate communication between these external systems and internal T-CONNECT systems/subsystem components.

- **Customer-end system**: refers to a list of systems and subsystems that will enable customers to submit transfer requests and monitor the status of their requests.

Figure 5-1 provides an overview of the system configuration for T-CONNECT.

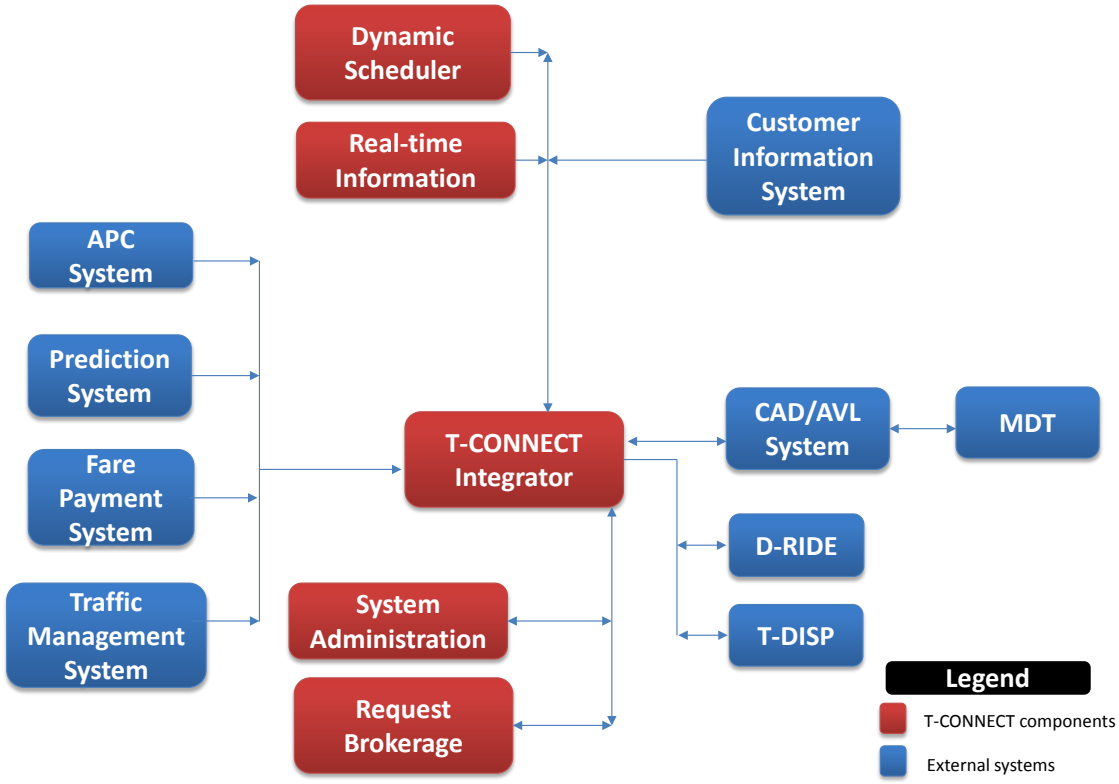

Figure 5-1. T-CONNECT System Overview Diagram

Each requirement in Table 5-1 is assigned a unique identification number. Further, the following modes of operation are identified for each requirement:

- Normal Mode [N]
- Overloaded Mode [O]
- Premium Mode [P]
- Failure Mode [F]
- Test/Training [T]

These modes of operation were defined in the Concept of Operations document as follows:

- **Normal Mode**: T-CONNECT applications will be designed to perform normally in most situations per the pre-determined standard operating procedures. In normal operational mode, T-CONNECT will receive and process transfer requests and notify users about the real-time status of the requests when appropriate. Please note that the standard operating procedures required for the normal mode of T-CONNECT operations will be agency-specific and will be developed by individual agencies deploying T-CONNECT.
- **Overloaded Mode:** The system may not be able to complete transfer requests entirely based on user preferences, due to the number of such requests from travelers, or due to system constraints (e.g., issues with individual system components within T-CONNECT or operational/service constraints). In these situations, T-CONNECT may operate with limited functionality and may offer connections to only vehicles associated with a limited numbers of agencies and transportation modes.
- **Premium Mode:** As recommended by the Stakeholders, T-CONNECT could consider offering guaranteed connections for a premium price according to traveler preferences (e.g., preferred transit mode). Innovative policies and procedures may be required for the development of premium T-CONNECT features to avoid any inconvenience to other travelers. For example, premium features may be available for limited use only for travelers who are entitled to premium services (e.g., once every week during rush hour). As stated earlier, these business rules will be agency-specific and will be determined by individual agencies deploying T-CONNECT.
- **Failure Mode:** There may be situations when T-CONNECT is completely non-operational due to planned (e.g., preventive system maintenance) or unplanned events (e.g., system crash). When T-CONNECT is unavailable due to planned maintenance or other known reasons, system users must be notified ahead of time about any planned unavailability of the system. In these situations, the system users must be advised to use the fixed/fallback-schedule, as applicable.

  Further, there should be provisions in the system to account for accidental system crashes by deploying a redundant system environment to ensure the “continuity of business.” However, in extreme circumstances, the entire system may fail, in which case the system users must be notified to follow the fixed/fallback-schedule, as applicable.

  Also, if customers have subscribed to be notified about planned or unplanned unavailability of T-CONNECT, they must be notified per their subscription preferences (e.g., email or text alerts).
- **Test/Training Mode:** T-CONNECT should be configured with a test/training environment for system administrators and other relevant users. This configuration will ensure that the “live” system is not impacted due to inadvertent errors in configurations originally meant for testing or training modes of operations.

Table 5-1. T-CONNECT Functional and Performance Requirements, Verification Methods and Traceability

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
Functional Requirements					
	3.1.1.1	**In-Vehicle System**			
	3.1.1.1.1	**Incoming Vehicle**			
	3.1.1.1.1.1	**Transfer Request Issuance**			
RC-1		The application shall allow drivers to request transfers on customers' behalf using their mobile data terminals (MDTs).	N,O,P, T	Demonstrate	TC-2
RC-2		The application shall allow drivers to specify if the requesting passenger is using a mobility aid or requires special services.	N,O,P, T	Demonstrate	TC-2
RC-3		The application shall notify drivers about any required fare payment for customers requesting the transfer.	N,O,P, T	Test	TC-2, TC-7
RC-4		The application shall provide alternate provisions[1] to avoid manual input of transfer requests by drivers on MDTs or other in-vehicle equipment.	N, O, P	Test	TC-2
	3.1.1.1.1.2	**Transfer Request Status Monitoring**			
RC-5		The MDT shall retry the delivery of transfer requests for a configurable amount of time. The application shall notify drivers about the acceptance and failed delivery of transfer requests.	N,O,P,T	Demonstrate	TC-2
RC-6		Once the confirmation has been received and processed by the T-CONNECT Request Broker, the MDTs shall notify if the Transfer has been accepted or denied.	N,O,P,T	Demonstrate	TC-2, TC-4
RC-7		The central T-CONNECT subsystem shall continue to monitor the status of transfer requests and notify the driver if a requested transfer cannot be protected.	N,O,P,T	Demonstrate	TC-3, TC-4

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
	3.1.1.1.2	**Outgoing Vehicle**			
	3.1.1.1.2.1	**TCP Request and Monitoring**			
RC-8		The application shall notify drivers about an upcoming transfer on their MDTs.	N,O,P,T	Demonstrate	TC-2
RC-9		The drivers shall be able to view a list of the current list of transfer requests and any changes in the upcoming transfer requests for the outgoing vehicle.	N,O,P, T	Test	TC-2
RC-10		The application shall require that drivers confirm the completion of a transfer once the customer is on-board the outgoing vehicles.	N,O,P	Demonstrate	TC-2
	3.1.1.1.2.2	**Fare Payment**			
RC-11		The MDT shall display the driver the amount a transferring customer is required to pay.	N,O,P	Demonstrate	TC-2, TC-7
RC-12		The application shall allow customers to pay for the trip using approved fare media.	N,O,P	Demonstrate	TC-2
RC-13		The application shall validate the payment and notify the driver if the paid amount is not as expected or the payment is not successful.	N,O,P	Test	TC-2 TC-7
	3.1.1.2	**Central System**			
	3.1.1.2.1	**Transfer Request Brokerage and Processing**			
RC-14		T-CONNECT shall include a central transfer request brokerage subsystem capable of processing transfer requests from customers in a mixed-mode (e.g., fixed-route bus, demand response bus, and rail) environment to determine the feasibility of a connection protection request. The application shall automatically	N,O,P, T	Test	TC-3, TC-4

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
		group transfers when multiple customers are requesting for transfers at the same location for a route within a preconfigured timeframe (e.g., within 15 minutes).			
RC-15		The brokerage subsystem shall have the capability to process transfer requests involving modes owned and operated by multiple public transit agencies and private operators	N,O,P, T	Test	TC-3, TC-4
RC-16		Based on the availability of real-time coordination between various transportation management systems (e.g., ridesharing systems, taxi dispatch systems), the brokerage subsystem shall be able to determine (e.g., with the help of T-DISP and D-RIDE) non-transit connection alternatives when needed.	N, P	Test	TC-3, TC-4
RC-17		The brokerage subsystem shall determine the transfer feasibility based on preconfigured policies and procedures (e.g., maximum allowable hold time).	N,O,P	Test	TC-4
RC-18		The brokerage subsystem shall determine the feasibility of transfers based on customer preferences.	N,P	Test	TC-4
	3.1.1.2.2	**Dynamic Management of Transfer Requests**			
RC-19		The application shall be capable of creating and managing a dynamic list of feasible transfer requests for various modes in a single or multiple agency environments.	N,O,P	Demonstrate	TC-4

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
RC-20		For connections involving fixed-route modes, the application shall first determine the feasibility of a transfer based on fixed-schedule and then monitor the real-time status using input from the control center(s) for determine the updated feasibility of transfer requests.	N,O,P	Test	TC-2, TC-3, TC-4, TC-6, TC-9
		The application shall dynamically update the list of transfer requests based on the following information:			
RC-21		a.) Current location of incoming and outgoing vehicles.	N,O,P	Test	TC-3, TC-4
RC-22		b.) Route and schedule adherence (RSA) of incoming and outgoing vehicles.	N,O,P	Test	TC-3, TC-4
RC-23		c.) Predicted arrival of incoming and outgoing vehicles at transfer locations.	N,O,P	Test	TC-3, TC-4
RC-24		d.) Current passenger capacity of the outgoing vehicle for wheelchair and non-wheelchair passengers.	N,O,P	Test	TC-3, TC-4
RC-25		e.) Dynamic changes in operations to incorporate operational situations such as short-turn of buses and addition of runs/vehicles by agencies.	N,O,P	Test	TC-3, TC-4
RC-26		f) Impact of dwell time of outgoing vehicles at transfer points on schedule adherence at downstream stops.	N,O,P	Test	TC-3, TC-4
RC-27		g.) Preconfigured customer preference and agency policies and procedures.	N,P	Test	TC-3, TC-4
RC-28		h) Changes in transfer requests by customers.	N,P	Test	TC-3, TC-4

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
RC-29		In the event the system determines that a transfer is in jeopardy, the application shall notify the individuals as per system configurations. These configurations shall depend on an agency's standard operating procedures.	N,P	Test	TC-2, TC-9
RC-30		The application shall allow manual intervention of dispatchers and operational supervisors to override the system-determined feasibility of transfer requests.	N,O,P, T,F	Test	TC-3, TC-6
	3.1.1.2.3	**Real-time Traveler Information**			
RC-31		The application shall notify customers about the feasibility of requested transfers immediately when determined by the system. The application shall continuously monitor and provide customers updates on the current status of the feasibility as per their preferences.	N,O,P, T	Demonstrate	TC-2, TC-4, TC-6, TC-9
RC-32		The application shall provide real-time status of requested transfers to travelers via a variety of media (e.g., Dynamic Message Signs (DMS) at Transfer Points, text alerts, Internet, interactive voice response (IVR))	N,O,P, T	Demonstrate	TC-9
RC-33		If the system does not have the access to real-time data such as real-time vehicle location and RSA information, the application shall calculate transfer feasibility based on schedule data.	F	Demonstrate	TC-3, TC-4
RC-34		The system shall provide the capability to manually override the transfer alternatives suggested by the system.	N,O,P, T	Demonstrate	TC-3, TC-6

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
	3.1.1.2.4	**Interfaces (managed by T-CONNECT Integrator)**			
	3.1.1.2.4.1	**Data Communication System**			
RC-35		The T-CONNECT central servers shall be connected with relevant servers (e.g., computer aided dispatch/automatic vehicle location [CAD/AVL], Real-time Information) via local area network and wide area network connectivity for real-time data exchange.	N,O,P, T	Demonstrate	TC-3, TC-11, TC12
RC-36		The application shall be connected with vehicles via wireless data communication system directly or indirectly (e.g., via a CAD/AVL system) for real-time data exchange.	N,O,P, T	Demonstrate	TC-1
	3.1.1.2.4.2	**CAD/AVL System**			
RC-37		T-CONNECT shall be connected with the CAD/AVL system used for managing incoming and outgoing vehicles for obtaining information on the current locations of vehicles and the most recent route and schedule adherence information.	N,O,P, T	Demonstrate	TC-3, TC-4, TC-5, TC-12
RC-38		T-CONNECT shall have the capability to interface with and process information from multiple CAD/AVL systems, representing real-time operations management system for participating agencies and private operators.	N,O,P, T	Demonstrate	TC-3, TC-4, TC-5, TC-12
	3.1.1.2.4.3	**Automated Passenger Counting (APC)Systems**			
RC-39		The application shall obtain real-time passenger count information from outgoing vehicles to determine current	N,O,P, T	Demonstrate	TC-3, TC-4, TC-5, TC-12

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
		vehicle capacity.			
	3.1.1.2.4.4	**Vehicle Arrival Prediction System**			
RC-40		The application shall be interfaced with vehicle arrival prediction system(s) to obtain information on expected time of arrival (ETA) of incoming and outgoing vehicles at transfer points.	N,O,P, T	Demonstrate	TC-2, TC-3, TC-4, TC-5, TC-9, TC-12
RC-41		When vehicle arrival prediction information is not readily available, T-CONNECT shall be equipped to determine predicted arrival information based on current vehicle location, RSA information obtained from vehicles and predicted arrival of the passenger at the outgoing vehicle stop, including the walking time between the two stops.	N,O,P, T	Test	TC-2, TC-3, TC-4, TC-5, TC-9, TC-12
	3.1.1.2.4.5	**Fare Payment System**			
RC-42		The application shall be interfaced with the fare payment system to determine required amount of fare to be paid by the customers requesting for a transfer based on agency fare rules.	N,O,P, T	Demonstrate	TC-2, TC-7
RC-43		The application shall update the fare payment system with amount paid, date and time of fare transaction, and location of fare transaction based on information obtained from outgoing vehicles.	N,O,P, T	Demonstrate	TC-2, TC-7
	3.1.1.2.4.6	**Traffic Management Center**			
RC-44		The application shall be interfaced with the regional or local traffic management center to obtain information on	N,P	Test	TC-2, TC-3, TC-4, TC-9,

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
		current and prediction traffic conditions to update the vehicle arrival prediction information.			TC-12, TC-13
	3.1.1.2.4.7	**T-DISP Application**			
RC-45		The application shall be interfaced with T-DISP applications to provide other trip alternatives to customers when transfer requests cannot be completed using available operational resources.	P	Test	TC-4
	3.1.1.2.4.8	**D-RIDE Application**			
RC-46		The application shall be interfaced with D-RIDE applications to provide public or private shared ride trip alternatives to customers when transfer requests cannot be completed using available operational resources.	P	Test	TC-4
	3.1.1.2.5	**System Administration**			
RC-47		The application shall allow agencies to create and modify transfer points. These configurations shall be by mode (e.g., fixed-route and demand response), time of day (e.g., AM and PM peaks and mid-day) and type of operation (e.g., public or private).	N,O,P	Demonstrate	TC-4
RC-48		The application shall allow agencies to modify the following parameters:	N,O,P	Demonstrate	TC-4
RC-49		a.) Maximum hold-until time for outgoing vehicles	N,O,P	Demonstrate	TC-4
RC-50		b.) Maximum wait time for customers transferring from incoming to outgoing vehicles	N,O,P	Demonstrate	TC-4
RC-51		c.) Maximum number of transfers allowed to each customer for a defined time period (e.g., within a month)	N,O,P	Demonstrate	TC-4

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
RC-52		d.) Number of minutes prior to the connection when the system notifies the drivers of outgoing vehicles about the upcoming transfers	N,O,P	Demonstrate	TC-4
RC-53		e.) Whether or not to seek alternatives with the help of T-DISP and D-RIDE when requests cannot be completed.	N,P	Demonstrate	TC-4
	3.1.1.3	**Customer-end Systems**			
	3.1.1.3.1	**Profile Management**			
RC-54		The application shall provide a web-based interface to agency customers to create, modify and delete their profiles and enter preferences for travel and real-time information.	N,O,P, T	Demonstrate	TC-10
RC-55		The process of customer information intake, storage and retrieval must be compliant with Health Insurance Portability and Accountability Act (HIPAA) requirements.	N,O,P, T	Demonstrate	TC-10
RC-56		In the event customers have registered with the agency for other services (e.g., fare payment system), the application shall have the ability to link customer databases to avoid duplication of information and maintain data integrity.	N,O,P, T	Demonstrate	TC-8, TC-9, TC-10
	3.1.1.3.2	**Transfer Request Issuance**			
RC-57		The application shall provide customers a web-based interface for requesting transfers in advance or in real-time.	N,O,P, T	Demonstrate	TC-8, TC-9, TC-10
RC-58		The application shall allow customers to modify or cancel their requests in real-time.	N,O,P, T	Test	TC-8, TC-9, TC-10
	3.1.1.3.3	**Fare Payment System**			

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
RC-59		The application shall allow customers to pay for transfer trips using a web-based interface and provide an electronic or paper-based proof of payment.	N,O,P, T	Test	TC-8, TC-9, TC-10
	3.1.1.3.4	**Real-time Traveler Information**			
	3.1.1.3.4.1	**Transfer Location Signage**			
RC-60		The application shall notify customers about the predicted arrival of incoming vehicles at transfer locations using DMS installed at those transfer locations.	N,O,P, T	Test	TC-8, TC-9, TC-10
	3.1.1.3.4.2	**Web-enabled Devices**			
RC-61		The application shall notify customers about the status of their transfer requests via a web-based interface.	N,O,P, T	Test	TC-8, TC-9, TC-10
RC-62		The application shall notify customers about the predicted arrival time of incoming vehicles via a web-based interface.	N,O,P, T	Test	TC-8, TC-9, TC-10
	3.1.1.3.4.3	**Interactive Voice Response**			
RC-63		The application shall notify customers about the status of their transfer requests via an IVR-based interface.	N,O,P, T	Test	TC-8, TC-9, TC-10
RC-64		The application shall notify customers about the predicted arrival time of incoming vehicles via an IVR-based interface.	N,O,P, T	Test	TC-8, TC-9, TC-10
	3.1.1.3.4.4	**Alerts**			
RC-65		The application shall send alerts to customers based on their subscription preferences.	N,O,P, T	Demonstrate	TC-8, TC-9, TC-10
RC-66		The application shall allow customers to subscribe and unsubscribe to alerts via web and IVR-based interfaces.	N,O,P, T	Demonstrate	TC-8, TC-9, TC-10

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
RC-67		The application shall allow customers to provide preferences for alerts via a web-based interface. These preferences shall be stored in customer profiles.	N,O,P, T	Test	TC-8, TC-9, TC-10
Performance Requirements					
	3.2.1.1	**In-Vehicle System**			
	3.2.1.1.1	**Incoming Vehicle**			
	3.2.1.1.1.1	**Transfer Request Issuance**			
RC-68		The data entry interface shall allow drivers to complete the entry of transfer requests for each customer or a group of customers within a configurable number of seconds.	N,O,P	Demonstrate	TC-2
RC-69		The application shall immediately pre-process driver request to determine the feasibility of a transfer based on a preconfigured matrix of transfer points within MDTs (e.g., combination of fixed-routes) and notify the driver about any exceptions prior to sending the request to the T-CONNECT Request Broker.	N,O,P	Demonstrate	TC-2
	3.2.1.1.1.2	**Transfer Request Status Monitoring**			
RC-70		The application shall resend the transfer request to the T-CONNECT Request Broker unless the acknowledgement is received. The application shall try at least three (3) times prior to notifying the driver of the failed delivery of a transfer request.	N,O,P	Demonstrate	TC-2, TC-4

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
RC-71		The central application shall monitor the status of a transfer request for every configurable number of seconds to notify drivers of any changes in the status of the feasibility of the request, when the transfer is expected to occur within the next configurable number of minutes.	N,O,P	Demonstrate	TC-1, TC-2, TC-4, TC-11, TC-12
	3.2.1.1.2	**Outgoing Vehicle**			
	3.2.1.1.2.1	**TCP Request Receipt**			
RC-72		The outgoing vehicles shall receive the transfer request a configurable number of minutes prior to the expected time of arrival of those vehicles at transfer points. Once the transfer is a configurable number of minutes away, the application shall check the status of transfer feasibility every sixty (60) seconds.	N,P	Demonstrate	TC-1, TC-2, TC-11
RC-73		If the transfer requests are submitted after a configurable number of minutes, the application shall either deny the transfer request or suggest an alternative based on available resources.	N,P	Demonstrate	TC-1, TC-2, TC-11
	3.2.1.1.2.2	**Fare Payment**			
RC-74		In the event fare payment is required, the processing time shall be less than a configurable number of seconds per customer.	N,P	Demonstrate	TC-1, TC-7, TC-11
	3.2.1.2	**Central System**			
	3.2.1.2.1	**Transfer Request Brokerage and Processing**			
RC-75		The application shall obtain the transfer request from the vehicles within sixty (60) seconds from the time a request is entered on the MDT	N,O,P, T	Analyze	TC-1, TC-2, TC-11

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
		or other media.			
RC-76		The application shall receive AVL information every thirty (30) seconds.	N,P	Analyze	TC-1, TC-3, TC-4, TC-11, TC-12
RC-77		The application shall obtain RSA information at least at a time interval equivalent to 20% of the total trip length (e.g., every five minutes on a twenty minute trip).	N,O,P	Analyze	TC-1, TC-3, TC-4, TC-11, TC-12
RC-78		When more than one system (single or multiple agency environments) are involved in determining the transfer feasibility, required information shall be synchronized between systems every thirty (30) seconds.	N,P	Analyze	TC-3, TC-4, TC-12
RC-79		When determining the transfer feasibility, the application shall ensure that the average wait time for passengers waiting for the outgoing vehicles at transfers point is not more than a configurable number of minutes.	N,P	Analyze	TC-3, TC-4
	3.2.1.2.2	**Dynamic Management of Transfer Requests**			
RC-80		The application shall be able to determine the real-time feasibility of a transfer request at least five (5) minutes prior to the actual transfer.	N,O,P	Demonstrate	TC-3, TC-4
RC-81		The application shall automatically monitor the status of each transfer request every sixty (60) seconds when the transfer is due within the next five (5) minutes.	N,O,P	Demonstrate	TC-2, TC-3, TC-4, TC-9
RC-82		In the event a transfer is in jeopardy, the application shall notify the affected parties	N,O,P	Demonstrate	TC-2, TC-3, TC-4,

Rqmt No.	Section	T-CONNECT Requirements	Operational Mode	Verification Method	User Need ID
		within thirty (30) seconds.			TC-9
	3.2.1.3	**Customer-end Systems-Real-time Information**			
RC-83		The application shall provide real-time information on the status of transfer feasibility and the ETA of incoming and outgoing vehicles at a transfer point to customers with an accuracy of at least 95% when the transfer is due within five (5) minutes.	N,O,P	Analyze	TC-9

[1] Currently, drivers input transfer request manually on the MDTs which is time consuming and causes boarding delays for customers and increased dwell times at stops. Advanced technologies can be used to minimize manual entries and such delays. For example, drivers can obtain transfer requests by scanning a quick response (QR) code representing transfer request on a paper or on personal mobile devices carried by customers (e.g., QR code may say: request transfer from Route X to Route Y at stop ABC). Alternatively, transfer requests can be obtained on to the fare collection units or MDTs via near field communication (NFC) from an NFC-equipped smartphone.

5.2 T-DISP

Table 5-2 provides a list of T-DISP functional requirements. These requirements are grouped in the following categories (please refer to the "Section" column):

- **In-vehicle Integration**: refers to required integration with mobile data terminals (MDTs)
- **Central System**: T-DISP will consist of a multi-modal trip scheduling system. Further T-DISP will be connected with the following external systems:
  - CAD/AVL system
  - Customer information system
  - T-CONNECT
  - D-RIDE
  - Revenue management system
  - Vehicle arrival prediction system

  The T-DISP integrator will facilitate communication between these external systems and internal T-DISP systems/subsystem components.

- **Customer-end system**: refers to a list of subsystems that will enable customers to submit travel requests (via web-based or mobile self-service portals or through customer service representatives) and obtain real-time information on the status of their trips through integration with a Customer Information System.

Figure 5-2 provides an overview of the system configuration for T-DISP.

In the Concept of Operations, two modes of operations were defined for T-DISP. However, during the development of the requirements, it was determined that the following modes of operation were more appropriate:

- Normal Mode [N]
- Overloaded Mode [O]
- Premium Mode [P]
- Test/Training [T]

These modes of operation are defined in Section 5.1 in this report.

Each requirement in Table 5-2 is assigned a unique identification number.

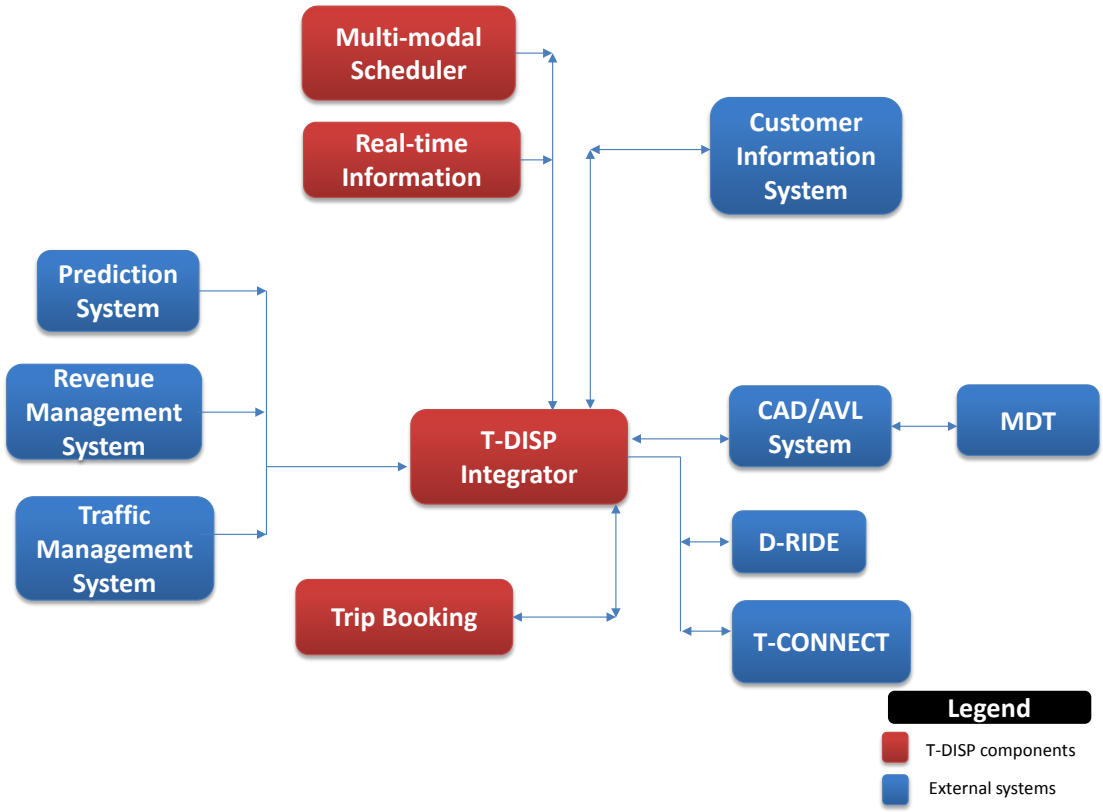

Figure 5-2. T-DISP System Overview Diagram

Table 5-2. T-DISP Functional and Performance Requirements, Verification Methods and Traceability

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
Functional Requirements					
	3.1.2.1	**In-Vehicle Integration with Mobile Data Terminals (MDTs)**			
RD-1		The T-DISP application shall utilize the capabilities of an existing MDT, integrated with central CAD/AVL software, to accomplish the following:	N, O, P, T	Inspect	TD-8, TD-10, TD-11, TD-19
RD-2		Automated vehicle location tracking	N, O, P, T	Demonstrate	TD-8
RD-3		Monitoring of route and schedule adherence	N, O, P, T	Demonstrate	TD-8
RD-4		Wireless voice and data communications between drivers and the dispatcher	N, O, P, T	Demonstrate	TD-15
RD-5		Management of manifest data	N, O, P, T	Demonstrate	TD-8, TD-9, TD-17
RD-6		Fare payment	N, O, P, T	Demonstrate	TD-8, TD-15
RD-7		Automated vehicle announcements	N, O, P, T	Demonstrate	TD-8, TD-15
	3.1.2.2	**Central System**			
	3.1.2.2.1	**Multi-Modal Scheduling System**			
RD-8		The application shall accept trip origin and destination requests from travelers.	N, O, P, T	Demonstrate	TD-5, TD-21
RD-9		The application shall schedule trip requests based on configurable settings for: - Traveler trip time and location request - Cost of trip to provider - Traveler presence - Vehicle characteristics	N, O, P, T	Analyze, Demonstrate	TD-5

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
RD-10		The application shall allow for trips to be scheduled based on configurable settings related to the cost of the mode of service[1].	N, O, P, T	Demonstrate	TD-5, TD-8
RD-11		The application shall provide alternative trip options[2] and parking availability.	N, O, P, T	Demonstrate	TD-3, TD-4, TD-12
RD-12		The application shall track all vehicles and their characteristics in the application.	N, O, P, T	Demonstrate	TD-5
RD-13		The application shall calculate time and distance between origins and destinations.	N, O, P, T	Analyze, Demonstrate	TD-5
RD-14		The application shall assign available vehicles based on how soon a vehicle can meet a trip origin request.	N, O, P, T	Demonstrate	TD-5
RD-15		The application shall calculate the earliest pick-up time availability.	N, O, P, T	Analyze, Demonstrate	TD-5
RD-16		The application shall track existing vehicle availability in real-time to determine solutions for each trip request.	N, O, P, T	Analyze, Demonstrate	TD-5
RD-17		The application shall track and confirm the status of trip requests (e.g., requests that are not completed, trips underway, and completed trips).	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-8
RD-18		The application shall dynamically reflect the changing availability of vehicles in terms of geographic and temporal location, and capacity.	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-8

[1] For example, the application shall assign a cost to each available mode or type of service in the system (e.g., fixed rail, route, paratransit)

[2] For example, over the telephone (landline or mobile) or the internet.

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
RD-19		The application shall automatically move trips to another manifest if a vehicle falls behind schedule. Additionally, the application shall allow the manual reassignments and adjustments of trips to manifests and vehicles in such situations.	N, O, P, T	Demonstrate	TD-5, TD-6, TD-8
RD-20		The application shall be capable of scheduling, in batch mode, all bookings for the next travel day, using parameters associated with street network segments as established in the GIS system (e.g., physical barriers, running speed by time of day, and appropriate dwell times for the boarding and alighting of passengers).	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-8
RD-21		The application shall calculate available trip options based on configurable settings, including: - Origin and destination times based on vehicle locations relative to pick-up and drop-off locations - Vehicle locations relative to pick-up and drop-off locations - Available modes of services (i.e., fixed-route bus, express bus, demand response)	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-8
RD-22		The application shall include a geographic information system (GIS) module to provide and display map data.	N, O, P, T	Inspect	TD-5, TD-6, TD-8
RD-23		The application shall be capable of processing trip origin and destination using latitude and longitude coordinates, in order to maximize the possible set of trip patterns.	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-8

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
RD-24		The application shall include a GIS module that will calculate travel times between origins and destinations.	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-8
RD-25		The application shall calculate the possible vehicle trip assignments for each request and searches for solutions based on predetermined weighted factors, including: travel time, distance, impact on other passengers, and impact on allowable maximum travel and wait times.	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-8
RD-26		The application shall produce a daily manifest for each driver/vehicle.	N, O, P, T	Demonstrate	TD-5, TD-6, TD-8
RD-27		The application shall be able to display all manifests generated for a given day. The application shall provide tools to allow manual adjustments to the run manifests, including manually moving trips between manifests.	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-8
RD-28		The application shall allow trips to be added to an existing manifest on the same day.	N, O, P, T	Demonstrate	TD-5, TD-6, TD-8
RD-29		The application shall identify a range of alternatives for assigning the trip to existing manifests for that day so as to best satisfy the requirements of the trip request while minimizing any impact on existing trips.	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-7, TD-8
RD-30		The application shall present these alternatives in rank order (or another scheme) with a numerical “score” to indicate the degree of difference between choices presented to a reservations agent.	N, O, P, T	Analyze, Demonstrate	TD-5, TD-6, TD-7, TD-8
	3.1.2.2.2	**Integration with External Systems**			

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
	3.1.2.2.2.1	**Computer-Aided Dispatch/Automatic Vehicle Location System**			
RD-31		The application shall be integrated with a CAD/AVL system (or multiple CAD/AVL systems in a multi-agency environment) to accomplish the following;.	N, O, P, T	Inspect	TD-5, TD-15, TD-16, TD-17, TD-18
RD-32		Obtain vehicle location information at every configurable number of seconds	N, O, P, T	Analyze, Demonstrate	TD-8
RD-33		Communicate with drivers wirelessly via canned messages, free-form text messages, and one-way or two-way voice calls.	N, O, P, T	Demonstrate	TD-15
RD-34		Electronically transmit and manage driver manifest data (e.g., pick-ups, drop-offs and no-shows).	N, O, P, T	Demonstrate	TD-5, TD-8, TD-9, TD-17
RD-35		Track on-board passenger counts	N, O, P, T	Demonstrate	TD-15
	3.1.2.2.2.2	**Customer Information System**			
RD-36		The application shall be integrated with a Customer Information System to obtain customer input and provide real-time information on the status of their trips.	N, O, P, T	Demonstrate	TD-1, TD-2, TD-5, TD-6, TD-20
	3.1.2.2.2.3	**T-CONNECT**			
RD-37		The application shall be integrated with T-CONNECT to determine transfer opportunities for multi-modal trips.	N, O, P, T	Demonstrate	TD-5
	3.1.2.2.2.4	**D-RIDE**			
RD-38		The application shall be integrated with D-RIDE to determine ridematch opportunities.	N, O, P, T	Demonstrate	TD-5, TD-13
	3.1.2.2.2.5	**Revenue Management System**			

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
RD-39		The application shall be integrated with a revenue management system to determine the fare paid by customers for trips scheduled by T-DISP.	N, O, P, T	Inspect	TD-8, TD-15
	3.1.2.2.2.6	**Vehicle Arrival Prediction System**			
RD-40		The application shall be interfaced with a vehicle arrival prediction system(s) to obtain information on the expected time of arrival (ETA) for vehicles conducting customer-requested pick-ups and drop-offs.	N, O, P, T	Analyze, Demonstrate	TD-5, TD-8
	3.1.2.2.2.7	**Traffic Management Center**			
RD-41		The application shall be interfaced with the regional or local traffic management center to obtain information on current and prediction traffic conditions to update the vehicle arrival prediction information	N, P	Inspect, Demonstrate	TD-5
	3.1.2.3	**Customer-end System**			
	3.1.2.3.1	**Customer Profile Management and Trip Booking**			
RD-42		The application shall enable requests for trips to be made via multiple media[3].	N, O, P, T	Test	TD-3, TD-21
RD-43		The application shall allow travelers to request trips including origin, destination, time and a return trip.	N, O, P, T	Demonstrate	TD-3, TD-20, TD-21

[3] For example, the following preference parameters: maximum transfer wait time; range of arrival time (i.e., +/- five minutes at destination); maximum walking or travel distance to pick-up and/or drop-off location based on actual walking paths (i.e., not as the crow flies) or buffers; mode preferences; willingness to pay for private service; customized traveler needs, particularly for those with disabilities (e.g., wheelchair, mobility device, service animal); assistance or special requests; and preferred method of contact

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
RD-44		The application shall allow automated trip reservations for preferred locations and/or common trips for customers.	N, O, P, T	Demonstrate	TD-1, TD-2
RD-45		The application shall include a user profile for all trip requests. The process of customer information intake, storage and retrieval must be compliant with Health Insurance Portability and Accountability Act (HIPAA) requirements.	N, O, P, T	Demonstrate	TD-1, TD-2
RD-46		The user profile shall include configurable traveler preferences and requirements for use during trip requests.[4]	N, O, P, T	Analyze, Demonstrate	TD-1, TD-2
RD-47		The application shall include in the user profile additional information necessary for the provision of Medicaid or ADA complementary paratransit service.	N, O, P, T	Demonstrate	TD-1, TD-2
RD-48		The application shall permit trip booking while the call taker is on the phone with the client.	N, O, P, T	Demonstrate	TD-1, TD-2, TD-7, TD-20, TD-21
RD-49		The application shall be capable of booking both subscription (standing-order) and demand response trips while the call taker is on the phone with the client.	N, O, P, T	Demonstrate	TD-2
RD-50		The application shall be capable of booking same day trips.	N, O, P, T	Demonstrate	TD-7
RD-51		The application shall have the ability to place the automated trip in a pending reservations list, until it is confirmed through the reservations software/staff.	N, O, P, T	Demonstrate	TD-7

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
RD-52		The application shall allow the caller to enter the origin and destination utilizing frequently used addresses available.	N, O, P, T	Demonstrate	TD-7
RD-53		The application shall be capable of accepting trip requests up to a configurable number of days in advance of the requested trip date.	N, O, P, T	Demonstrate	TD-7
RD-54		The application shall provide a confirmation or trip number for the traveler to have for reference.	N, O, P, T	Demonstrate	TD-7
RD-55		The application shall identify and automatically geocode the location associated with each entered address. If the automatic geocoding fails, the application shall provide alternative methods of establishing x- and y- map coordinates for the address. One of the alternative methods supported shall be clicking on a map location with the mouse.	N, O, P, T	Analyze, Demonstrate	TD-7
RD-56		The application shall transmit trip choices to the traveler.	N, O, P, T	Demonstrate	TD-7
RD-57		The application shall receive a trip confirmation back from the traveler.	N, O, P, T	Demonstrate	TD-7
RD-58	**3.1.2.3.2**	**Real-time Traveler Information**			
RD-59		The application shall send real-time service status to travelers per their request in real-time or per their subscription preferences (e.g., five minutes before vehicle arrival).	N, O, P, T	Demonstrate	TD-7
RD-60		The application shall provide trip details to the traveler when requested.	N, O, P, T	Demonstrate	TD-7
Performance Requirements					

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
	3.2.1	**Central System- Multi-Modal Scheduling System**			
RD-61		The application shall process trip origin and destination requests from travelers in less than two (2) minutes.	N,O, P	Analyze, Demonstrate	TD-1, TD-2, TD-6
RD-62		The application shall prompt the user to accept the suggested trip within 15 to 30 seconds.	N,O, P	Analyze, Demonstrate	TD-1, TD-2, TD-6
RD-63		The application shall display a timer and a warning of a 'system time out' when the suggested trips are within five (5) seconds of expiring.	N,O, P	Demonstrate	TD-1, TD-2, TD-6
RD-64		The application shall develop trip suggestions to keep traveler wait time at the boarding location under configurable number of minutes.	N,O, P	Demonstrate	TD-1, TD-2
RD-65		The application shall not allow trip additions to manifests that increase the time on-board for existing passengers to be more than a configurable number of minutes.	N,O, P	Analyze, Demonstrate	TD-7, TD-9, TD-14
RD-66		When more than one (1) system (single or multiple agency environments) is involved in determining trip feasibility, required information shall be synchronized between systems every thirty (30) seconds.	N,O, P	Analyze, Demonstrate	TD-7, TD-9
RD-67		The application shall post trips to the vehicle's electronic manifest on the vehicle MDT within 30 seconds of receiving a confirmed trip from the traveler.	N, O, P	Analyze, Demonstrate	TD-14
	3.2.2	**Customer-end System**			

Rqmt No.	Section	T-DISP Requirements	Operational Mode	Verification Method	User Need ID
RD-68		The application shall provide real-time information on the status of trip feasibility and the estimated time of arrival (ETA) of incoming and outgoing vehicles with an accuracy of at least 95% when the trip request is due within five (5) minutes.	N,O, P	Analyze, Demonstrate	TD-5, TD-15
RD-69		The application shall provide trip confirmation details to the traveler within a configurable number of seconds after the trip request submission.	N,O, P	Analyze, Demonstrate	TD-6

5.3 D-RIDE

Figure 5-2 provides an overview of the system configuration for T-DISP. Table 5-3 provides a list of D-RIDE functional requirements, which are divided into two categories: application user interface requirements and data (control) center requirements.

Each requirement in Table 5-3 is assigned a unique identification number. Further, the following modes of operation are identified for each D-RIDE requirement:

- Normal Mode [N]
- Overloaded Mode [O]
- Test/Training [T]

These modes of operation are defined as follows:

- **Normal Mode:** D-RIDE will be designed to perform normally in most situations per the pre-determined standard operating procedures. In normal operational mode, D-RIDE will receive and process ridesharing requests and notify users about the real-time status of the requests when appropriate.
- **Overloaded/Degraded Mode:** The application may not be able to complete ridesharing requests entirely based on user preferences, due to the number of such requests from travelers, or due to system constraints (e.g., issues with individual system components within D-RIDE or operational/service constraints). In these situations, D-RIDE may operate with limited functionality and may offer connections to only vehicles associated with a limited numbers of agencies and transportation modes.

  Test/Training Mode: D-RIDE should be configured with a test/training environment for system administrators and other relevant users. This configuration will ensure that the "live" application is not impacted due to inadvertent errors in configurations originally meant for testing or training modes of operations.

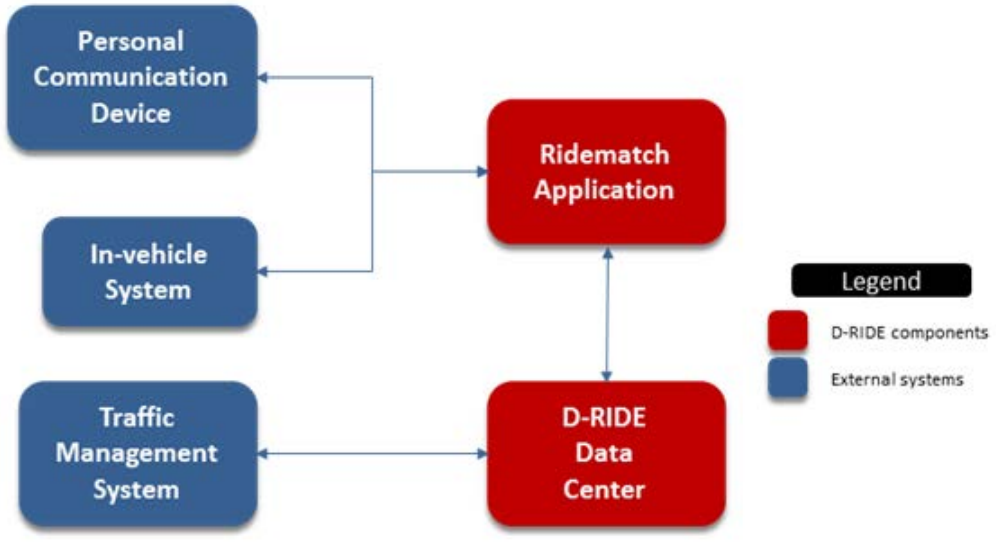

Figure 5-3. D-RIDE System Overview Diagram

Table 5-3. D-RIDE Functional and Performance Requirements, Verification Methods and Traceability

Rqmt No.	Section	D-RIDE Requirements	Operational Mode	Verification Method	User Need ID
Functional Requirements					
	3.1.3.1	**Application User Interface**			
RR-1		The application shall communicate potential trips with drivers/riders via multiple communication methods (e.g., WiFi, cellular, Ethernet, etc.).	N, O, T	Demonstrate	DR-4, DR-5, DR-6, DR-9
RR-2		The application shall identify current user location.	N, O, T	Test	DR-3, DR-4
RR-3		The application interface and data center shall communicate via a standard protocol relevant to the communication method used.	N, O, T	Inspect	DR-2, DR-4
RR-4		The application shall provide a user interface to obtain customizable profile information from customers.	N, O, T	Demonstrate	DR-1, DR-3, DR-4, DR-5, DR-6, DR-9, DR-10
RR-5		The application shall accept multiple forms of payment.	N, T	Demonstrate	DR-7
RR-6		The application shall provide a hands-free function-mode for use when driving.	N, O, T	Demonstrate	DR-6
RR-7		The application user interface shall track payment information with a payment system.	N, T	Analyze	DR-4, DR-7, DR-8
RR-8		The application shall accept routing preferences from users.	N, T	Demonstrate	DR-10
RR-9		The application shall provide an interface for rating ridematches after completion.	N, T	Demonstrate	DR-12
RR-10		The application shall provide the capability to push messages to both the rider and driver.	N,O,T	Demonstrate	DR-5
	3.1.3.2	**Data (Control) Center**			
RR-11		The application data center shall optimize stored	N, O, T	Analyze	DR-3

Rqmt No.	Section	D-RIDE Requirements	Operational Mode	Verification Method	User Need ID
		profile and geographic data to provide optimal ridematches for users.			
RR-12		The application data shall be integrated with a payment system.	N, T	Demonstrate	DR-4, DR-7, DR-8
RR-13		The application data center shall collect profile information from each traveler.	N, O, T	Demonstrate	DR-2, DR-4, DR-5
RR-14		The application data center shall store profile information from each traveler.	N, O, T	Analyze	DR-2
RR-15		The application data center shall collect preferred routings from each traveler (e.g., stop/start location, time of day, day of week).	N, T	Demonstrate	DR-2, DR-4
RR-16		The application data center shall store preferred routings from each traveler.	N, T	Analyze	DR-4
RR-17		The application data center shall communicate with support agencies (e.g., departments of transportation, transit agencies, etc.) to pull information from agencies (e.g., schedules, vehicle locations).	N, O, T	Demonstrate	DR-4
RR-18		The application data center shall have a back-end interface for viewing usage statistics for the application.	N, T	Demonstrate	DR-11
Performance Requirements					
	3.2.3.1	**Application User Interface**			
RR-19		The application shall transmit any traveler data to the data center from the application within one (1) minute of receiving the original request.	N, T	Analyze	DR-5
RR-20		The application shall determine a ridematch or lack thereof within five (5) minutes of the request being sent from the data center.	N, T	Analyze	DR-9

Rqmt No.	Section	D-RIDE Requirements	Operational Mode	Verification Method	User Need ID
	3.2.3.2	**Data (Control) Center**			
RR-21		The data center shall transmit ridematches to ensure that riders are picked-up within a user-identified timeframe for the driver/vehicle to arrive.	N, T	Analyze	DR-9
RR-22		The data center shall communicate the result of the ridematch search within five (5) minutes 99.5% of the time.	N, T	Analyze	DR-9

Chapter 6. Data and Communication Needs

The high-level data and communications needs identified in this section are based on the ConOps and requirements identified in Section 5.0.

6.1 T-CONNECT

Table 6-1 provides a list of data needs for T-CONNECT. Further, Table 6-1 lists originating and terminating ends for each data element, and identifies the potential data communication method for data exchange. Table 6-1 uses the following categories to identify data communication methods:

- **Land Mobile Radio (LMR)**: includes public safety/dispatch/private systems,
- **Commercial Mobile Radio Systems (CMRS)**: includes all cellular systems and subscription-based broadband wide area data systems,
- **Broadband Wireless LANs (Wi-Fi)**: includes Wi-Fi and its competitors,
- **Fixed Communications (Fixed)**: includes LAN/WAN or leased lines for things like center to center

Table 6-1. T-CONNECT Data and Communication Needs

ID	Data Element	Originating End	Terminating End	Communication Mode
DC-1	Transfer request (from drivers)	MDT (incoming vehicle) via CAD/AVL software	T-CONNECT Request Broker	LMR/CMRS
DC-2	Transfer request (from customer)	Customer devices[4]	T-CONNECT Request Broker	LMR/CMRS, Fixed
DC-3	Vehicle location	CAD/AVL Software	T-CONNECT Request Broker	Fixed
DC-4	RSA	CAD/AVL Software	T-CONNECT Request Broker	Fixed
DC-5	Transfer feasibility status	T-CONNECT Request Broker	MDT via CAD/AVL software	Fixed
DC-6	Transfer feasibility status	T-CONNECT Request Broker	Customer device	LMR/CMRS/Fixed

[4] Represent web-enabled devices that customers will use to request transfers

ID	Data Element	Originating End	Terminating End	Communication Mode
DC-7	ETA of outgoing vehicles	Vehicle Arrival Prediction System	Dissemination Media (e.g., dynamic message sign, mobile device, telephone)	LMR/CMRS/Fixed
DC-8	ETA of incoming vehicles	Vehicle Arrival Prediction System	Real-time Information Media	LMR/CMRS/Fixed
DC-9	ETA of outgoing vehicles	Vehicle Arrival Prediction System	T-CONNECT Request Broker	LMR/CMRS/Fixed
DC-10	ETA of incoming vehicles	Vehicle Arrival Prediction System	T-CONNECT Request Broker	LMR/CMRS/Fixed
DC-11	Real-time vehicle capacity	MDT	APC System (central end)	LMR/CMRS
DC-12	Real-time vehicle capacity	APC System (central end)	T-CONNECT Request Broker	Fixed
DC-13	Estimated hold-time for outgoing vehicles	T-CONNECT Request Broker	MDT(outgoing vehicle) via CAD/AVL software	LMR/CMRS
DC-14	Real-time traffic data	Traffic Management System	T-CONNECT Request Broker	Fixed
DC-15	Transfer points/ mode-to-mode transfer matrix	Wireless LAN Data Transfer System	MDT via CAD/AVL software	Wi-Fi

6.2 T-DISP

Table 6-2 provides a list of data needs for T-DISP. Further, Table 6-2 lists originating and terminating ends for each data element, and identifies the potential data communication method for data exchange. Table 6-2 uses the same communication mode categories as identified for T-CONNECT.

Table 6-2. T-DISP Data and Communication Needs

ID	Data Element	Originating End	Terminating End	Communication Mode
DD-1	Vehicle location (e.g. latitude and longitude, heading)	MDT via CAD/AVL software	Multi-modal scheduling system	Fixed
DD-2	Schedule adherence event (e.g. run number, vehicle number, operator	MDT via CAD/AVL software	Multi-modal scheduling system	Fixed

ID	Data Element	Originating End	Terminating End	Communication Mode
	number)			
DD-3	Traveler trip request (e.g. origin, destination, time)	Traveler	Customer Information System	LMR/CMRS, Fixed, web
DD-4	Trip request process	Customer Information System	Multi-modal scheduling system	Fixed
DD-5	Trip request process – GIS (e.g. historic travel time information, pick-up and drop-off dwell times, real-time traffic conditions, road segment travel speeds)	GIS	Multi-modal scheduling system	Fixed
DD-6	Manifest information (e.g. trip number, action required, action time, traveler information)	Multi-modal Scheduling System	MDT via CAD/AVL software	LMR/CMRS
DD-7	Operations data for storage	CAD/AVL Software	Data Storage	Fixed
DD-8	User Profile – General (e.g. Traveler Identification Number, Password, Home Address, City, State, Zip, Phone, Email, Traveler Preference, Emergency Contact Information)	Customer Information System	Multi-modal Scheduling System	Fixed
DD-9	User Profile – Medical/Paratransit (e.g. Medical Assistance Number, Date of Birth, Eligibility Certification / Expiration Date, Gender, Mobility Aid Use, Disability Code, Billing / Funding Code)	Customer Information System	Multi-modal Scheduling System	Fixed

6.3 D-RIDE

Table 6-3 provides a list of data needs for D-RIDE. Further, Table 6-3 lists originating and terminating ends for each data element, and identifies the potential data communication method for data exchange. Table 6-3 uses the same categories to identify data communication methods as were used for T-CONNECT and T-DISP.

Table 6-3. D-RIDE Data and Communications Needs

ID	Data Element	Originating End	Terminating End	Communication Mode
DR-1	Identification Elements (Name/Phone/Email/ Address/User ID/Password)	Application User Interface	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-2	Traveler Preferences (preferred routes, time of day, day of week)	Application User Interface	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-3	Device Characteristics (make/model/commu nications platform)	Application User Interface	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-4	Payment Transaction Elements (credit card number, expiration date)	Application User Interface	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-5	Origin	Application User Interface	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-6	Destination	Application User Interface	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-7	Travel Profile	Application User Interface	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-8	Number of Passengers with Rider	Application User Interface	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-9	Traffic Conditions	Local Agencies	Data (Control) Center	Fixed (may be pre-integrated with data center)
DR-10	HOV/HOT Lane Location/Configuratio n	Local Agencies	Data (Control) Center	Fixed (may be pre-integrated with data center)
DR-11	Ridematch Information (driver car make/model, contact phone number, time of match, confirmation number)	Data (Control) Center	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-12	Meeting Location	Data (Control) Center	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS
DR-13	Suggested Route	Data (Control) Center	Data (Control) Center	Wi-Fi/ Fixed/ LMR/CMRS

Chapter 7. Glossary and List of Abbreviations

ConOps: The Concept of Operations document results from a stakeholder view of the operations of the system being developed. This document will present each of the multiple views of the system corresponding to the various stakeholders. These stakeholders include operators, users, owners, developers, maintenance, and management. This document can be easily reviewed by the stakeholders to get their agreement on the system description. It also provides the basis for user requirements.

IDTO: A collection of high-priority transformative applications identified by the USDOT's Dynamic Mobility Program. The IDTO bundle of applications consists of the T-CONNECT, T-DISP and D-RIDE applications, as described below.

T-CONNECT: The transit multi-modal and multi-agency application will enable public transportation providers and travelers to communicate to improve the probability of successful transit transfers. Travelers can initiate a request for connection protection anytime during the trip using a personal mobile device, or potentially via transit vehicle or personal automobile onboard equipment / interface, and receive a confirmation based on a set of criteria indicating whether the request is accepted. The system will take into account the overall state of the system, including connection protection requests made by others as well as real-time and historical travel conditions for the services affected, and pre-determined connection protection rules agreed upon by participating agencies and transit modes. The system will then continue to monitor the situation and provide connection protection status updates to the travelers as appropriate.

In addition, travelers onboard of affected transit vehicles (such as buses waiting at a commuter rail station for a delayed train) may also receive information through onboard devices, such as dynamic message signs, indicating the vehicle is holding for an additional x minutes for other travelers.

T-DISP: The application will advance the concept of demand-responsive transportation services utilizing the global positioning system (GPS) and mapping capabilities of personal mobile devices to enable a traveler to input a desired destination and time of departure tagged with their current location. A central system, such as a Travel Management Coordination Center, or decentralized system would dynamically schedule and dispatch or modify the route of an in-service vehicle by matching compatible trips together. The application may consider both public and private (e.g., taxi) transportation providers and may include paratransit, fixed -route bus, flex-route bus, and rail transit services. For example, if a paratransit vehicle is not available, a traveler would be given information on fixed-route service or connected to a private service.

The application may consider a common platform that allows people to effectively communicate and access shared transportation resources more readily than currently occurs. The platform would provide a transit exchange that allows prospective travelers and vehicle operators to trade in a transparent market on demand for optimal mobility solutions without advanced notice.

The application may consider real-time traffic conditions to dynamically route vehicles as necessary (i.e., to select the optimum route), and real-time vehicle capacity to dynamically assign or remove

vehicles from service as necessary. It would accommodate dispersed origin-destination trips and trips in low density, low ridership areas, and may replace some late night or mid-day fixed-route service. The application would apply the best practices learned from the USDOT Mobility Services for All Americans (MSAA) initiative.

D-RIDE: This application will make use of in-vehicle and hand-held devices to allow ride-matching, thereby reducing congestion, pollution, and travel costs to the individual with a low initial investment. Dynamic ridematching technology already exists for hand-held mobile applications (iPhone, SMS text enabled phones, etc.) but that technology has yet to find widespread use. Using a hand-held device for communicating one's ridesharing needs is fine for passengers but is not ideal for drivers due to the devices' hands-on nature that can lead to distracted driving. By integrating carpooling functions into a vehicle computer, voice activated ridesharing technology can be built into the vehicle's interface enabling the driver to find and accept potential ridematches along his/her route without having to divert concentration from the roadway. By combining existing mobile ridesharing applications with in-vehicle and roadway based technology, a number of problems associated with carpooling can be solved.

Although vehicles can currently sense the weight of passengers so as to activate or deactivate air bags, it is difficult to accurately verify the true load of a vehicle. Variations of the proposed application can be used by HOV/HOT enforcement agencies to verify vehicle occupancy. Additionally, it may be possible to reduce a toll for each additional passenger in the vehicle instead of a single-preset discount whether the vehicle is carrying two, three, or four passengers.

List of Abbreviations and Acronyms

Acronym	Description
AVA	Automatic Vehicle Annunciation
AVL	Automatic Vehicle Location
CAD	Computer-Aided Dispatch
ConOps	Concept of Operations
COTM	Contracting Officer's Task Manager
DMA	Dynamic Mobility Applications
DMS	Dynamic Message Sign
DOT	Department of Transportation
D-RIDE	Dynamic Ridesharing IDTO application
FHWA	Federal Highway Administration
GPS	Global Positioning System
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
IEEE	Institute of Electrical and Electronics Engineers
IDTO	Integrated Dynamic Transit Operations
ITS	Intelligent Transportation Systems
MDT	Mobile Data Terminal
MPO	Metropolitan Planning Organization
PDT	Project Development Team
PMP	Project Management Plan
RSA	Route and Schedule Adherence
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Process
SIRI	Service Interface for Real-time Information
SOW	Statement of Work
SRS	System Requirements Specifications
T-CONNECT	Transfer Connection IDTO application
TCP	Transfer Connection Protection
T-DISP	Transit Dispatch IDTO application
TMO	Transportation Management Organization
TRB	Transportation Research Board
VPPP	Value Pricing Pilot Program

Acronym	Description
USDOT	United States Department of Transportation

Appendix A: List of Stakeholders

Last Name	First Name	Organization
Abegg	Michael	Minnesota Valley Transit Authority
Adair	Robin	TIP Global
Alden	Andrew	VA Tech
Allen	Todd	RouteMatch Software
Badini	Perrin	Alcalde & Fay
Baetzner	Arnd	Mobility Car Sharing Switzerland
Bata	Andrew	New York City Transit
Berg	Roger	DENSO International America, Inc.
Boenau	Ron	Federal Transit Administration, USDOT
Boston	Bill	Self Employed
Braband	John	Pace Suburban Bus
Brandauer	David	trapeze
Bregman	Susan	Oak Square Resources, LLC
Bryan	Rebecca	Independent
Canfield	John	www.NetworkCommuting.com
Caruso	Philip	ITE
Chamberlain	Chuck	Northrop Grumman IS
Clemons	Robert	Daimler Buses N.A.
Dalton	Ben	RideAmigos
DeBellotte	Yvonne	MARTA
Dion	Francois	University of California - Berkeley
DiPalma	Chris	FHWA
Dixon	Philip	Toggle Corporation
Dorsey	Dennis	Central Maryland Regional Transit Corporation
Dow	Kevin	APTA
Ed	Seymour	TTI
Edelen	Vas	EastBanc Technologies
Einsig	Barry	Harris Corporation
Fangnigbe	Leon	MLFSolutions
Finn	Brendan	ETTS Ltd.
Fok	Edward	USDOT/FHWA
Frumin	Michael	MTA
Goodine	Aletha	USDOT/FTA
Greene	Jessi	University of Michigan

Last Name	First Name	Organization
Griffith	Amanda	TrueFit
Gross	Yehuda	USDOT/RITA
Hallberg	Jan	Ann Arbor Transportation Authority
Harrington-Hughes	Kathryn	Harrington-Hughes & Associates
Harris	Mike	Kimley-Horn
Haynes	Michael	Chicago Transit Authority
Hemily	Brendon	ITS America
Hesse	Eric	TriMet
Hickman	Mark	University of Arizona
Hilliard	Michael	Oak Ridge National Laboratory
Hinebaugh	Dennis	Bational Bus Rapid Transit Institute
Jamison	Doug	LYNX
Kabatchnik	Edan	SQLstream
Kain	Carl	Noblis, Inc.
Kandarpa	Ram	Booz Allen Hamilton
Keane	David	Battelle
Keaveny	Ian	Trapeze
Koebel	Mike	Mentor Engineering Inc.
Krehnbrink	Dan	ViTae Systems
Krieger	Will	Repass & Partners
L	Sundar	Ideophone
Lance	Melissa	Virginia Department of Transportation
Li	Yanlin	Noblis
Lopez-Bernal	Gabriel	USDOT Volpe Center
Lyons	Rachel	McAndrew Company
Macri	Joseph	HP
Malone	Joseph	Techventus
Margulici	JD	Novavia Solutions
Messa	Tyler	ITSA
Miller	Mark	Self proprietor consultant
Misener	James	Booz Allen Hamilton
Moore	Charles	NYS Department of Transportation
Moore	Michael	System Ventures Inc
Mortensen	Steve	Federal Transit Administration
Ng	Henry	TransLink
Novosad	Stephen	Atkins
Olyai	Koorosh	DART

Last Name	First Name	Organization
Ozdemir	Hasan	Panasonic
Padbanaban	Sripathi	Guident
Partridge	Ellen	RITA
Patro	Sooraz	Hidalgo County MPO
Pickerall	Brian	Booz Allen Hamilton
Poe	Kelly	Pulsar Advertising
Quinn	Tim	RouteMatch Software
Ritter	Gary	USDOT RITA Volpe Center
Sah	Prakash	California Department of Transportation
Saleem	Faisal	Maricopa County DOT
Samuel	Aneil	Blacksburg Transit
Sanchez	Robert	SAIC
Schweiger	Carol	TranSystems Corporation
Schwetz	Tom	Lane Transit District
Seymour	Ed	TTI
Silver	Phil	LogicTree Corporation
Sloan	Suzanne	US DOT
Sorensen	Jon	Atkins North America
Spata	Steve	Mid-size Bus Manufacturers Association
Steinfeld	Aaron	Carnegie Mellon University
Stone	Jason	Volvo Trucks
Sundararajan	Ashok	Booz Allen Hamilton
Szudy	James	Bendix CVS
Tate	Bill	Battelle
Thomas	Edward L	200consult
Thompson	Kenneth	Easter Seals Project ACTION
Toone	John	King County Metro
Torng	Gwo-Wei	Noblis
Toups	Derek	Kimley-Horn and Associates, Inc.
Tufan	Hasan	Ministry of Transport Maritime Affairs and Communications Turkey
Wagle	Ram Krishna	ITS-Nepal
Weisenberger	Tim	John A. Volpe Center
Whitaker	Stuart	Whitaker Associates
Wilder	Ralph	StarMetro
Wilder	Charlene	FTA
Witten	Timothy	Blacksburg Transit

Last Name	First Name	Organization
Wong	James	Georgia Tech
Yazersky	Gail	GY Associates
Zhang	Wei-Bin	UC Berkeley, PATH
Zimmer	Rob	Battelle

U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free “Help Line” 866-367-7487
www.its.dot.gov

FHWA-JPO-12-085

U.S. Department of Transportation