Preliminary Investigation
Caltrans Division of Research, Innovation and System Information (DRISI)
Produced by: Ms. Lee Provost, P.E., M.S., DRISI

Demand Responsive Travel Operation Based on Dynamic Passenger Information (Dynamic Ride Share by Smartphone request)

Requested by: Bradley Mizuno, Transportation Engineer, Electrical, P.E. Caltrans DRISI
Date: April 16, 2014

The Caltrans Division of Research, Innovation and System Information (DRISI) receives and evaluates numerous research problem statements for funding every year. DRISI conducts Preliminary Investigations on these problem statements to better scope and prioritize the proposed research in light of existing credible work on the topics nationally and internationally. Online and prints sources for Preliminary Investigations may include the National Cooperative Highway Research Program (NCHRP) and other Transportation Research Board (TRB) programs, the American Association of State Highway and Transportation Officials (AASHTO), the research and practices of other transportation agencies, and related academic and industry research. The views and conclusions in cited works, while generally peer reviewed or published by authoritative sources, may not be accepted without qualifications by all experts in the field.

Contents

Executive Summary 2
- Background 2
- Summary of Findings 2
- Gaps in Findings 3
- Next Steps 3
- Contacts 3
- Body of Preliminary Investigation 3
  - National Guidance 3
  - Current Caltrans Practices 6
  - State DOT Manuals, Guidance, or Practices 7
  - Industry Resources and Other Organizations 7
  - Related Research 9
  - Legal Issues 9
  - Key Websites 10
  - Survey responses 10
- Appendix 11

Executive Summary

Background

Currently, there is real-time information available to transit operations and travelers via the internet that can be accessed on a laptop, Smartphone (android cell phone) or similar. This technology provides notifications of travel delays, arrivals, alternatives and other travel information, which can be helpful in making travel decisions for fixed routes and times. In contrast, what if a traveler put in a request via their Smartphone or laptop to have transit fit their schedule? GPS tracking is already in use for buses and Smartphones, but the idea is to have a demand-type ride based on a cell phone request. This preliminary investigation (PI) research request is for Dynamic Ride Share(D Ride), allowing the location, messaging and computing capabilities of Smartphones to share information between drivers and riders in real time, in order to make transit more convenient toward an individual traveler's schedule. This PI will determine if there anyone in the United States (U.S.) putting these D Ride concepts to use or testing a prototype.

Summary of Findings

Today, app-based transportation alternatives such as car and ride share programs thrive in Sacramento, Ca. "UBER" offers a low cost ride share service, "Zipcar" offers a fleet of local small car rentals and "Lyft" offer community members an option for ride-sharing alternative taxi cab. ("Car and Ride Share Programs in Sacramento" *Capitol Public Radio November 7, 2013*.)

The core of this PI is more than just a singular taxi-cab transportation alternative. This PI research is geared toward a more transit-orientated D Ride, to make transit more convenient toward a particular individual traveler's schedule that is Smartphone based.

This PI discovered that there *is* a prototype being developed and tested for Integrated Dynamic Transit Operations (IDTO) by the U.S. Department of Transportation (DOT), Federal Transit Administration (FTA). The lead researcher is Ronald Boenau, Office of Research Management in Washington, DC. The prototypes are being tested in Orlando, Florida and Columbus, Ohio this year (2014). The full report is listed in the appendix of this document. However, there is no current use of this type of IDTO being used in the U.S.

Topics may include:

- National Guidance
- Current Caltrans Practices
- State DOT Policies and Practice
- Industry Resources and Other Organizations
- Related Research
- Legal Issues
- Web Resources
- Research in Progress

Gaps in Findings

None

Next Steps

A research project may be requested to fit California's transit needs and a follow up to see the US DOT FTA's project findings at the end of this year (2014).

Contacts

Ronald E. Boenau, P.E., Senior Transportation Systems Manager, Special Operations. Office of Research Management, TRI-30. Federal Transit Administration, U.S. DOT, 1200 New Jersey Avenue, S.E. Washington, DC. 20590. (202) 366-0195 Ronald.Boenau@dot.gov. Please refer to the research survey responses found below in this PI.

Body of Preliminary Investigation

National Guidance

Integrated Dynamic Transit Operations (IDTO) Prototype Development
Ronald E.Boenau, P.E, Federal Transit Administration (FTA), Philadelphia, PA. September 2013
Power point for the USDOT Connected Vehicle Research project, ITE Mid-Atlantic Section
http://www.masite.org/PDF/Past/2013_09_20_02G_Boenau.pdf

Prototypes are being tested in Orlando, Florida and Columbus, Ohio in Winter and Spring 2014, with results expected by Fall 2014.

Connection Protection: to increase likelihood of making successful transfers, particularly multi-modal or multi-agency.
Dynamic Transit Operations: –Traveler - accesses real-time information on travel options, costs and arrival times. *Agency* - extends demand / response services to support dynamic routing and scheduling and add/remove vehicles from service based on traffic conditions, vehicle capacity, ridership, origin-destination, etc.
Dynamic Ridesharing: leverages the positioning, messaging, and computing capabilities of Smartphones to allow drivers and riders exchange information in real time.

An email was sent on 4-15-14 to Mr. Ronald Boenau, FTA to ask if he was aware of anyone else in the U.S. who is putting his concepts or testing the technology now. Ronald.Boenau@dot.gov

RITA: Assessment of Relevant Prior and Ongoing Research for the Concept Development and Needs Identification for Integrated Dynamic Transit Operations November 2011
http://www.its.dot.gov/ FHWA-JPO-12-082

3-IDTO Assessment of Ongoing Research

Entire report is available. Click on the icon.

This report was a response e mail from Mr. Ronald Boenau, FTA on 4-16-14. He said he's not aware of anyone else conducting testing like he's doing in IDTO, but he cc'd his contractor Tom Timcho of Battelle, who might have additional insights. He attached the above initial research report.

Report 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. There are three Integrated Dynamic Transit Operations (IDTO) applications: Connection Protection (T-CONNECT); Dynamic Transit Operations (T-DISP); and Dynamic Ridesharing (D-RIDE). The T-CONNECT application will provide transit users and riders the means to ensure successful transit transfers. T-DISP will allow travelers to make real-time trip requests through personal mobile devices. D-RIDE will identify and accept potential ridesharing opportunities along a given travel route.
This report provides a review of relevant past and ongoing research and also provides a definition and vision for the IDTO applications, currently available technologies, methodologies, and existing practices. Also described is a summary and synthesis of findings, potential impacts of IDTO implementation from an institutional, operational and technical perspective, and next steps. This research forms the basis for the current state definition within the Concept of Operations (ConOps).

Real Time Bus Arrival Info Systems TCRP Synthesis 48
http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_syn_48.pdf

This synthesis report will be of interest to transit staff concerned with implementing real-time bus arrival information systems at their agencies. Information on relevant technical capabilities, agency experience, cost, and bus rider reactions to these information systems was documented. The report describes the state of the practice, including both U.S. and international experience. It documents survey information, a review of the relevant literature, as well as interviews with key personnel at agencies that have, or are in the process of, implementing these systems.

Transit Connected Vehicle Research Program- Enhances Mobility Choices
Intelligent Transportation Systems Joint Program Office
RITA US DOT Research Innovative Technology Administrations
http://www.its.dot.gov/factsheets/transit_connectedvehicle.htm

The overarching goal of the Transit Connected Vehicle for Mobility program is to improve public transportation by increasing transit productivity, efficiency, and accessibility; mitigating congestion in an integrated transportation environment; and providing travelers with better transportation information and transit services. Transit-oriented connected vehicle mobility applications support dynamic system operations and management, enable a convenient and quality travel experience, and provide an information-rich environment to meet the needs of travelers and system operators across all modes.
The following three mobility applications have been selected as high-priority applications and are collectively identified as the *Integrated Dynamic Transit Operations* (IDTO) "bundle":

Connection Protection (T-CONNECT): Enables public transportation providers and travelers to communicate to improve the probability of successful transit transfers.
Dynamic Transit Operations (T-DISP): Advances 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 when requesting transit service.
*Dynamic Ridesharing (D-RIDE)**:*** Makes use of in-vehicle and hand-held devices to allow dynamic ride-matching, thereby reducing congestion, pollution, and travel costs to the individual with a low initial investment.
A description of all the high-priority Connected Vehicle for Mobility applications and the process through which they were selected and grouped can be found at: www.its.dot.gov/press/2011/mobility_app.htm.

Connected Vehicle Reference Implementation Architecture (CVIRA)
RITA US Dept of Transportation, Research & Innovation Technology Administration
Draft 2-17-14
http://www.iteris.com/cvria/html/applications/app77.html

The Dynamic Transit Operations application allows travelers to request trips and obtain itineraries using a handheld mobile device (or personal computer). The trips and itineraries would cover multiple transportation services (public transportation modes, private transportation services, shared-ride, walking and biking). This application builds on existing technology systems such as computer-aided dispatch/ automated vehicle location (CAD/AVL) systems and automated scheduling software, providing a coordination function within and between transit providers that would dynamically schedule and dispatch or modify the route of an in-service vehicle by matching compatible trips together. – Related resources: Integrated Dynamic Transit Operations (IDTO) ConOps Draft 5/11/12

Active Transportation and Demand Management (ATDM) Program Brief
http://ops.fhwa.dot.gov/publications/fhwahop13002/fhwahop13002.pdf

ATDM is the dynamic management, control, and influence of travel demand and traffic flow on transportation facilities. Through the use of available tools and assets, traffic flow is managed and traveler behavior is influenced in real-time to achieve operational objectives, such as preventing or delaying breakdown conditions, improving safety, promoting sustainable travel modes, reducing emissions, or maximizing system efficiency. Using archived data and or/predictive methods, agencies continuously monitor the transportation system and perform in real-time to achieve or maintain system performance.
Active management of transportation and demand can include multiple approaches spanning demand management, traffic management, parking management, and efficient utilization of other transportation modes and assets. An agency can deploy a single ATDM approach in order to capitalize on a specific benefit or can deploy multiple active strategies to gain additional benefits across the entire transportation system. Some example approaches are included in the table. This brief focuses on the active demand management (ADM) component of ATDM.

This ATDM report has several ADM strategies listed in a table, such as Dynamic ridesharing, lane pricing, parking pricing or predictive traveler information. There was only one ADM test

study for On-Demand Transit (ODT) in Cork, Ireland. No U.S. studies for ODT have been tested. Four people working for US DOT were listed for more information:
Robert.Sheehan@dot.gov (202) 366-6817 Jim.Hunt@dot.gov (717) 221-4422
James.Colyar@dot.gov (360) 753-9408 GregM.Jones@dot.gov (404) 562-3906

TRID: BELLEVUE SMART TRAVELER: DESIGN, DEMONSTRATION, AND ASSESSMENT. FINAL TECHNICAL REPORT October 2013
http://trid.trb.org/view/448206
http://www.wsdot.wa.gov/research/reports/fullreports/376.1.pdf

New approaches must be taken to make high occupancy vehicle (HOV) commuting more attractive. One approach is to use innovative communication technology to provide commuters with the means to easily and flexibly arrange for HOV commuting to and from their downtown office buildings. The project team accomplished this goal by developing, implementing, demonstrating, and testing a traveler information center (TIC) prototype in downtown Bellevue, Washington.
The TIC integrated phone and paging technology to deliver three types of personal commuter information: (1) dynamic ride matching information, (2) current traffic congestion information, and (3) transit information. The usage patterns and various surveys that were conducted suggested that participants liked the idea of dynamic ridesharing, liked the presentation of the information, liked the technology, were willing to offer rides, and used BST to receive other forms of information. However, for various reasons they were either unable or unwilling to form ride matches.

TRID: Fill Those Empty Seats!- Dynamic Ridesharing October 2013
https://www.fhwa.dot.gov/publications/publicroads/13sepoct/03.cfm

Dynamic ridesharing is more flexible than traditional carpooling. Drivers and passengers meet at designated or unofficial locations near transit routes, such as along highways with high-occupancy vehicle (HOV) lanes, often using Smartphone apps that help users find rides.

Current Caltrans Practices

Spatially Focused Travel Data and Analysis, Caltrans DRISI, Task 2243
UC Irvine, Institute of Travel Studies July 2013 Project Manager: B. Justice
The final report is not out yet. It is a travel behavior study based within the Southern California Association of Governments (SCAG) region. The benefit of this study is that improved information enhances travel demand modeling and transportation.

Task 2243 Research Results.docx

Click on this icon to view this draft document.

Caltrans Mobile Survey, DRISI, Office Travel and Forecasting and Analysis Oct 2012
http://dot.ca.gov/hq/tsip/otfa/tab/mobile_survey.html Project Manager: M. Assadi

Mobile Survey is a comprehensive system, designed for conducting automated travel surveys. It takes advantage of capabilities and growing use of smart phones by the general public, and will provide a low-cost, efficient and highly scalable method of conducting travel and transportation surveys by utilizing Smartphone apps and automation algorithms. The main apps will cover all major Smartphone platforms and will be used for a continuous travel survey. The continuous survey collects core data elements for a typical travel survey. Most detailed activity information can be detected by the system through automation algorithms and geocoding. Main applications may be used for household travel surveys and most other travel surveys regardless of size and complexity. The main apps may need to be modified for some specialized surveys. The system is being considered for development at Caltrans. Contact: mohammad.assadi@dot.ca.gov

The Connected Traveler Project: a Component of the SafeTrip-21 Initiative
Caltrans Technical Report CA12-1935 May 2012 Author: G. Larsen
http://www.dot.ca.gov/newtech/researchreports/reports/2012/safe_trip-21/safe_trip-21_report.pdf

This report describes the Connected Traveler Project, research performed under the SafeTrip-21 Initiative, which was part of the Vehicle-Infrastructure Integration Program administered by the US Department of Transportation's Research and Innovative Technology Administration. The purpose of the SafeTrip-21 Initiative was to build upon current and prior research into the use of sophisticated information, navigation, and communications technologies to further national transportation goals in safety and mobility. The Connected Traveler Project provided a Field Test Site with Intelligent Transportation Systems (ITS) applications, and was comprised of the Connected Traveler Test Bed, with the appropriate hardware, software, and architecture to field test a broad range of ITS applications, together with intermodal ITS applications covering the mobility, safety, and e-payment areas.

State DOT Manuals, Guidance, or Practices

None. Please refer to next section which has transit agencies listed.

Industry Resources and Other Organizations

Transit Agencies

There were several metropolitan transit agencies that offer real time information sent to traveler's cell phone via the internet, such as for a bus schedule. However, there wasn't anything found on transit travel demand, where a commuter would enter in his/her schedule. For now, there are only fixed schedules, say for a commuter bus and the traveler could get information if the bus is late or where to catch another bus. Below is just a small list of transit agencies found on the website that offers this "connection" information daily.

Smart Ride: Mobility Authority for Regional Transportation (SMART), SE Michigan
http://www.smartbus.org/Pages/default.aspx

SMART: The Suburban Mobility Authority for Regional Transportation (SMART) is Southeast Michigan's only regional bus system. *SMART offers the latest in trip planning technology.* SMART Trip Planner powered by Google™ provides our customers point to point routing to any destination within our service area. SMART also makes Google Translate™ available to our customers, enabling you to interpret our website into more than 20 different languages. MyConnector is an automated phone and internet system that allows you to create an account to

access your personal Connector information every day, any time! It's a quick and easy way to book*, confirm and cancel rides on SMART Connector.

Massachusetts Bay Transportation Authority
http://www.mbta.com/rider_tools/apps/Default.asp

Website: Subway, Bus, Commuter Rail and Boats Trip Planner and Service Updates.

Tri Delta Transit, Antioch, CA
http://www.trideltatransit.com/

Email/Text Alerts: Tri Delta Transit provides our customers with up-to-date information with an Email/Text Alert System. Be the first to know about any detours or changes to your preferred bus routes including out of service bus stops. Sign up for EMAIL/TEXT ALERTS! It's free and takes about a minute. Email/text alerts will send you an email and/or text message when something changes to your route. It will also keep you informed about schedule and service changes so you're always prepared. Their bus stop real time and bus route maps can be downloaded on a mobile device by installing Microsoft's "Silverlight" application for real time arrival. It doesn't have *demand type* of rides based on a cell phone.

MITTENS- Travel Times on Changeable Message Signs for Caltrans-San Francisco Bay Area, CA. California Center for Innovation Transportation (CCIT), UC Berkeley
http://www.calccit.org/projects_id=29.html

Predictive Traveler Information: Real-time highway and scheduled transit travel time displayed to induce in-route mode shift.
California Center for Innovative Transportation (CCIT) has implemented a system that provides travelers with travel time messages on Changeable Message Signs (CMS). This system is able to calculate real-time highway driving time as well as train trip time for pre-defined trip itineraries and displays related messages on a network of signs.
Real-time traveler information on Changeable Message Signs (CMS) has gained popularity in urban areas. CCIT is upgrading MITTENS to allow deployment in other Caltrans districts, including District 3, District 5, and District 10.

Predict a Trip- San Francisco, CA. Bay Area Traveler Information http://traffic.511.org/

Predictive Traveler Information: Predictive travel times using historical data to inform pre-trip travel decisions.
511 is managed by a partnership of public agencies led by the Metropolitan Transportation Commission, the California Highway Patrol, and the California Department of Transportation.
511 was developed with the mission to provide comprehensive, accurate, reliable and useful multimodal travel information to meet the needs of Bay Area travelers.
511 Traffic is the free, comprehensive traffic information source for the San Francisco Bay Area. Use the interactive Traffic Map to calculate driving times for your trip, see incidents and construction details, check congestion levels, and view live traffic cameras. If you're planning a future trip, use can estimate your driving time or check predicted traffic conditions for a specific

time and day so you know when to leave. 511 Traffic also provides a quick view of your three most recent trips and the latest news affecting drivers in the Bay Area.
If you're heading out the door or already on your way, you can access traffic information on your phone by dialing 511, or on your mobile device at m.511.org. 511 reminds you to take precautions to stay safe on your driving trip – use the 511 phone service or 511 Mobile before you're on the road or have a passenger check current conditions for you.
The 511 Traffic page is part of the SF Bay Area's 511 Traveler Information Service. For more information about all of 511's offerings, including transit, rideshare, and bicycling features, click here.

Related Research

Sacramento's App-Based Transportation Alternative Portfolio

App- based transportation program	lyft	UBER	zipcar
Driver	Community members with cars and cell phones.	Commercially licensed driver partners, for UBERx the divers are private individuals	The member (Zipster), basically you drive yourself.
Cost	Suggested donation based on time spent in car and distance driven.	Three different price levels UBERx, UBERblack and UBERsuv.	$60 a year membership and rentals between $8.50 to $14 an hour.
The Cars	Individually owned, newer than 2000	Commercially licensed and individually owned cars of varying makes and models	A variety of models from the expansive Zipcar fleet
In Sacramento since...	Launching Friday, November 8th, at 4 p.m.	January 2013	2011, expanding their fleet this week with three new locations and new models
Creative marketing tactics	Pink mustaches on cars	Temporary ice cream delivery service, one-day kitten delivery in three cities and free UBERx rides Nov 8th - 10th	The low-car diet, getting people to keep their cars parked and use alternatives to get around
Tagline	Your friend with a car	Everyone's Private Driver	Wheels when you want them

Legal Issues

Legal issues were not researched. However, the US DOT FTA IDTO study does follow the US DOT's Intelligent Transportation Systems'(ITS) Mobility Program research.

Key Websites

Key Words: Dynamic Rideshare (D-Ride)/Transit Operations, Smartphone Transit Operations/Traveler Demand, Smartphone Dynamic Transportation
Key Websites: TRID, Google

Survey responses

This is an e mail response from Ms. Lee Provost of DRISI to Mr. Ronald Boenau of US DOT FTA under the guidance of Mr. B Mizuno of DRISI. Please note the original question is shown below the more recent response shown on top:

Response
From: Ronald.Boenau@dot.gov [mailto:Ronald.Boenau@dot.gov]
Sent: Wednesday, April 16, 2014 12:22 PM
To: Provost, Lee K@DOT
Cc: Mizuno, Bradley Y@DOT; timchot@battelle.org
Subject: RE: Question on your research

Greetings Lee,
Per your inquiry, I am not aware of anyone else conducting testing as we are doing in IDTO, but I will copy our contractor, Tom Timcho of Battelle, who might have additional insights.

Before we started the prototype development, we conducted an initial research effort and I will attach that report for your information.

I hope this helps.
Ron

Ronald E. Boenau, P.E.
Senior Transportation Systems Manager – Special Operations
Office of Research Management, TRI-30
Federal Transit Administration, U.S. DOT
1200 New Jersey Avenue, S.E.
Washington, DC 20590
(202) 366-0195 [phone]
Ronald.Boenau@dot.gov

Original Question
From: Provost, Lee K@DOT [mailto:lee.provost@dot.ca.gov]
Sent: Tuesday, April 15, 2014 5:38 PM
To: Boenau, Ronald (FTA)
Cc: Mizuno, Bradley Y@DOT
Subject: Question on your research

Hello. I'm doing a very rough draft of a research preliminary investigation on demand transit using a smart phone. I'm working with Brad Mizuno of Caltrans Research.
I found your power point presentation on line today for the Integrated Dynamic Transit Operations (IDTO) Prototype**,** USDOT Connected Vehicle Research project, ITE Mid-Atlantic Section. It mentioned the Prototypes are being tested in Orlando, Florida and Columbus, Ohio in 2014.

Are you aware of anyone else in the U.S. putting these concepts to use now or anyone else who is testing this technology now?
In simplistic terms, for someone who is taking transit to use their smart phone (or similar) to make transit fit/meet their own schedule, instead of adjusting their individual work time around a fixed bus schedule, for example. Thank you for your assistance.

Leanne "Lee" Provost, PE, MS
Senior Transportation Engineer
Project Management, Research Preliminary Investigations
Office of Policy, Planning & Innovation
Caltrans Division of Research, Innovation & System Information
1227 O. St, Sacramento, CA 95814 MS#83
916-654-8183

Appendix

The full report from Mr. Ronald Boenau is included in the above research section entitled Body of Preliminary Investigation, National Guidance. The entire report is attached.

Assessment of Relevant Prior and Ongoing Research for the Concept Development and Needs Identification for Integrated Dynamic Transit Operations

www.its.dot.gov

Final Report — November 7, 2011
FHWA-JPO-12-082

U.S. Department of Transportation

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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. There are three Integrated Dynamic Transit Operations (IDTO) applications: Connection Protection (T-CONNECT); Dynamic Transit Operations (T-DISP); and Dynamic Ridesharing (D-RIDE). The T-CONNECT application will provide transit users and riders the means to ensure successful transit transfers. T-DISP will allow travelers to make real-time trip requests through personal mobile devices. D-RIDE will identify and accept potential ridesharing opportunities along a given travel route.

This report provides a review of relevant past and ongoing research and also provides a definition and vision for the IDTO applications, currently available technologies, methodologies, and existing practices. Also described is a summary and synthesis of findings, potential impacts of IDTO implementation from an institutional, operational and technical perspective, and next steps. This research forms the basis for the current state definition within the Concept of Operations (ConOps).

17. Key Words	18. Distribution Statement
Integrated Dynamic Transit Operations, IDTO, Assessment of Research, ConOps, T-CONNECT, T-DISP, D-RIDE, Dynamic Mobility Applications, DMA, Intelligent Transportation Systems, ITS.	No restrictions.

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Unclassified	Unclassified	61	N/A

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Table of Contents

Chapter 1. Integrated Dynamic Transit Operations Assessment of Relevant Prior and Ongoing Research 1

1.1 PURPOSE OF THE DOCUMENT 1

1.2 DOCUMENT OVERVIEW 1

1.3 REFERENCES 1

Chapter 2. Introduction and Background 5

2.1 INTRODUCTION 5

2.2 INTEGRATED DYNAMIC TRANSIT OPERATIONS OVERVIEW 6

2.2.1 T-CONNECT Definition and Overview 6

2.2.2 T-DISP Definition and Overview 6

2.2.3 D-RIDE Definition and Overview 7

2.3 RELATIONSHIP WITH OTHER DYNAMIC MOBILITY APPLICATIONS AND CONNECTED VEHICLE ACTIVITIES 9

Chapter 3. Scan of Relevant Prior and Ongoing Research 11

3.1 T-CONNECT RESEARCH 11

3.2 T-DISP RESEARCH 12

3.2.1 Coordination 13

3.2.2 Technology 18

3.3 D-RIDE RESEARCH 21

3.4 IDTO THEORY OF OPERATION 25

3.4.1 T-CONNECT Theory of Operation 25

3.4.2 T-DISP Theory of Operation 27

3.4.3 D-RIDE Theory of Operation 28

3.5 IDTO CAPABILITIES 30

3.5.1 T-CONNECT Capabilities 30

3.5.2 T-DISP Capabilities 30

3.5.3 D-RIDE Capabilities 32

Chapter 4. Scan of Current Practice 34

4.1 T-CONNECT CURRENT PRACTICE 34

4.2 T-DISP CURRENT PRACTICE 35

4.2.1 USDOT's UWR/MSAA Initiative 35

4.2.2 FlexBus in Orlando, Florida 37

4.2.3 North and East Brainerd Dial-A-ride Routes in Chattanooga, Tennessee 38

4.2.4 Belbus in Belgium and Flexlinje in Gothenburg, Sweden 39

4.3 D-RIDE CURRENT PRACTICE 40

Chapter 5. Summary of Results and Synthesis of Findings 44

5.1 GENERAL FINDINGS 44

5.2 BENEFITS AND IMPACTS 45

5.3 PERFORMANCE MEASURES 46

5.4 ISSUES 47

5.5 LESSONS LEARNED 47

Chapter 6. Concept Development 49

6.1 PROPOSED IDTO IMPLEMENTATION 49

6.2 IMPACT OF THE PROPOSED IDTO IMPLEMENTATION 50

6.2.1 Institutional Impact 50

6.2.2 Operational Impact 51

6.2.3 Technical Impact 52

Chapter 7. Next Steps 53

Appendix A: List of Abbreviations/ Acronyms 54

List of Tables

Table 4-1. Current State of T-CONNECT Implementation by Mode 34

List of Figures

Figure 2-1. D-RIDE scenario where Driver (Person A) uses a D-RIDE application to pick up two passengers along their usual route to work... 8

Figure 2-2. Dynamic Mobility Applications (DMA) Program Bundles..... 10

Figure 3-1. D-RIDE application information exchange and communication network..... 29

Figure 3-2. Potential T-DISP Operation 31

Figure 4-1. Overview of the Operational Process 40

Figure 4-2. Screenshot of match information details on Avego's iPhone application. 42

Chapter 1. Integrated Dynamic Transit Operations Assessment of Relevant Prior and Ongoing Research

1.1 Purpose of the Document

The purpose of the Assessment of Relevant Prior and Ongoing Research is to provide a clear understanding of relevant research in the area of Integrated Dynamic Transit Operations (IDTO) that might impact the development and eventual deployment of an IDTO system.

Relevant research identified in this Assessment will form the basis for the current state definition within the Concept of Operations (ConOps).

1.2 Document Overview

This document is organized as follows:

- The background against which the study is being performed;
- A definition and vision for the IDTO applications;
- Currently available technologies and methodologies;
- A scan of the existing practice; and
- A summary of results and synthesis of findings
- The proposed concept development.

1.3 References

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Chapter 2. Introduction and Background

2.1 Introduction

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. Under this program, the USDOT has identified a portfolio of ten high-priority mobility applications, including a common bundle collectively identified as Integrated Dynamic Transit Operations, or IDTO. The three applications under the IDTO bundle 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 improve adoption allowing the program to meet its goals of improving the environment and increasing mobility.

These applications are:

- Connection Protection (T-CONNECT);
- Dynamic Transit Operations (T-DISP); and
- Dynamic Ridesharing (D-RIDE).

In selecting these applications, the USDOT sought applications that had the potential to be transformative (i.e., that they significantly alter existing transit services and result in substantial mobility improvements), that are achievable in the near-term, and that 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 project is to facilitate concept development and needs refinement for the IDTO applications and assess readiness for development and testing. The research identified in this Assessment will form the basis for the current state definition of the concept development.

The sections below reflect the results of the literature review that was initiated of current and historical studies, programs, and field tests that have a direct or indirect link to the transit industry as it pertains to the three IDTO applications: T-CONNECT, T-DISP, and D-RIDE.

2.2 Integrated Dynamic Transit Operations Overview

2.2.1 T-CONNECT Definition and Overview

Many public transportation trips require multiple transfers. These transfers may be between different transit modes, such as buses, subways, and commuter trains, and are sometimes across multiple transit agencies. Any segment of a trip can be delayed by traffic congestion or other causes, such as extra time needed for boarding and alighting passengers, and equipment failures. A potential consequence can be that passengers wishing to transfer to a particular bus, for example, may miss their connection. This often leads to cascading delays, and causes a substantial increase in travel time and decrease in travel time reliability. Travelers are often uncertain about whether they will actually make the planned connection due to lack of information and means of communication. As a result, the overall quality of public transportation service is compromised.

T-CONNECT is a concept that is intended to improve the probability of automatic intermodal transfer connections for travelers who utilize more than one mode for their trips. Travelers will have 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.

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 continue to monitor the situation and provide connection protection status updates to 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.

2.2.2 T-DISP Definition and Overview

T-DISP links available transportation service resources with travelers through dynamic transit vehicle scheduling, dispatching and routing capabilities. Also, T-DISP enables travelers to make real-time trip requests through personal mobile devices. A more detailed description of the T-DISP theory of operations and capabilities is provided in Section 3.5.

T-DISP explores the concept of personal mobility management within the passenger transportation industry. It offers a set of solutions that would address the challenges faced by traditional fixed-route and fixed schedule transit service in meeting the travel needs of people travelling in low density and

dispersed origin/destination environments. Generally, these operational characteristics are inherently inefficient in cost to deliver service, generate low ridership and productivity, and create lengthy travel times for the travelers. The challenge is in matching persons with transportation options and information dynamically, in near real-time, and to do so conveniently for both travelers and transportation providers.

The current options available for travelers to explore and assess different travel options through transit, paratransit, taxi, human service agency and other transportation providers are fragmented. Some communities have expanded options through websites and call centers, especially through '511' or other transit agency efforts. However, these efforts are typically for information and referral type services, i.e., providing information to a traveler, who would in turn contact a specific transportation provider to obtain information about the service they need. The ability for transportation providers to communicate with each other is also fragmented, often within the same agency. Fixed-route bus or fixed rail may be operated by a different transportation provider or agency than demand response, which could mean that there are different communications and technology systems. Private transportation providers, such as taxi services, typically have their own means of communication. Thus transportation providers cannot easily communicate with each other and are not able to leverage their services through dynamic routing, dispatching and scheduling based on real-time conditions. As described in Section 3.2, there are elements of T-DISP that are in operation or being explored throughout the US, but there are no examples that function exactly as T-DISP has been defined.

2.2.3 D-RIDE Definition and Overview

Dynamic Ridesharing (D-RIDE) is an approach to carpooling in which drivers and riders arrange trips within a relatively short time in advance of departure. In the dynamic ridesharing model, drivers and passengers arrange one-way transportation between an origin and a destination at a mutually convenient time. In traditional carpools, drivers and riders are bound to a specific meeting time and location, which is not amendable to last-minute changes in schedule.[1] Through the D-RIDE model, a person could arrange daily transportation to reach a variety of destinations, including those that are not serviced by transit.

Target markets for D-RIDE include:

- Carpool riders who find carpools inconvenient in the event of an emergency or when working later than a scheduled carpool pickup;
- Transit commuters whose typical transit route is delayed due to congestion or involves indirect routes and transfers that create longer commute times; and/or
- Drive-alone commuters who would like to save money on gas or decrease travel time spent in congestion by using a high-occupancy vehicle (HOV) lane occasionally, but have the flexibility of not dedicating daily commutes to full-time carpooling.

By contrast, D-RIDE arrangements are usually made on a one-time, trip-by-trip basis, and they provide drivers and riders with the flexibility of making real-time transportation decisions. D-RIDE

[1] Amey, Andrew M. "Real-Time Ridesharing: Exploring the Opportunities and Challenges of Designing a Technology-based Rideshare Trial for the MIT Community." (June 2010), http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/AMEY_Thesis_Final.pdf

technology, which can include phone- or internet-based systems, mobile device applications, and/or voice-activated on-board equipment, matches riders and drivers along their route.[2]

D-RIDE technology relies on location specific data to match drivers with non-driving commuters. For example, a driver either enters their starting location, or it is determined by GPS-enabled technology. The driver then enters their destination/route. A potential rider, whose current location is also entered manually or detected via GPS, enters a preferred destination. D-RIDE software then matches drivers with riders who are seeking destinations along the driver's route.[3] It can provide a location at which the driver can pick up the rider as well as real-time information on the driver's current location and expected arrival time. Figure 2-1 provides an example scenario of how D-RIDE technology can work.

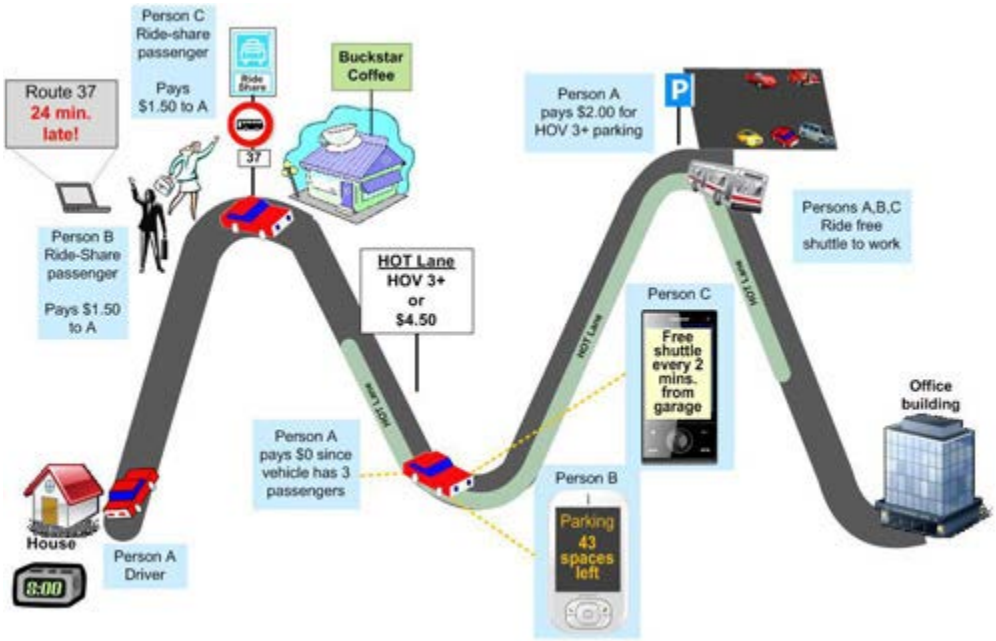

Figure 2-1. D-RIDE scenario where Driver (Person A) uses a D-RIDE application to pick up two passengers along their usual route to work.

Source: FHWA Road Pricing Resources Website (http://www.fhwa.dot.gov/ipd/revenue/road_pricing/resources/webinars/webinar_072811.htm)

D-RIDE specifically benefits locations with heavy traffic congestion, such as cities and their surrounding metropolitan areas. During the morning "rush hour" period, from around 6am to 9am in most major cities, thousands of travelers drive towards a single concentrated area, providing ample opportunity for ridesharing. However, most vehicles on the road during the heaviest traffic hours

[2] Spencer, Jeffrey L. "Priority Connected Vehicle Application for Bus and Paratransit." USDOT's Connected Vehicle Program. (24 May 2001), Slide 18 http://www.apta.com/mc/bus/previous/2011/Presentations/USDOT-J-Spencer.pdf

[3] Concept of Development and Needs Identification for Integrated Dynamic Transit Operations (IDTO). Kick-Off Meeting. (16 August 2011), Slides 11-12.

contain only one occupant. If roadways contained more vehicles with higher occupancy, traffic congestion could decrease, further reducing travel times for individual commuters.[4]

The benefits of D-RIDE can affect multiple aspects of society, including the environment. By increasing the flexibility of ridesharing, D-RIDE can create enough of a mode shift to reduce vehicle load on the roadway, mitigating traffic congestion, and subsequently lowering emissions and energy consumption. Research has shown that enhancing policies to increase carpooling is the most effective strategy to reduce energy consumption aside from prohibiting driving.[5]

Additionally, D-RIDE is capable of improving network efficiency by allowing transportation infrastructure to be used more effectively by focusing on "person throughput versus vehicle throughput," minimizing the frequency of repair and construction costs to government agencies. Additionally, D-RIDE programs can provide socially-necessary transportation alternatives to certain groups who may not have easy access to public transportation, such as senior citizens and college students (Webinar, Oliphant).

Thirdly, participants in carpool arrangements save money due to shared travel costs, and time due to the availability of HOV Lanes. Their employers benefit from the reduced demand for parking infrastructure.[6]

2.3 Relationship with other Dynamic Mobility Applications and Connected Vehicle Activities

The IDTO bundle of applications bears similarities to the ENABLE ATIS bundle due to the fact that each deals with the core issue of how to effectively present information to travelers. However, as depicted in Figure 2-2, IDTO is distinctive among the bundles in its emphasis on ways travelers can communicate with each other and with the transit system, outside the vehicle-to-vehicle or vehicle-to-infrastructure communications paradigm.

Additionally, IDTO applications are not constrained by the data latency requirements of some of the other bundles (such as INFLO, for example, which cannot function without very high-speed/low latency dedicated short-range communications [DSRC] technologies). IDTO, therefore, can utilize a wider variety of communication means, including standard cellular technology and even social media, to achieve its goals.

[4] Swisher, Myron. USDOT Resources: Overcoming the Challenges of Congestion Pricing 2011 FHWA Webinar Series. Session 6: Dynamic Ridesharing and Congestion Pricing (Webinar Transcript). (28 July 2011). http://www.fhwa.dot.gov/ipd/revenue/road_pricing/resources/webinars/transcript_072811.htm

[5] Noland, et al., as cited in Chan, Nelson. "Ridesharing in North America: Past, Present, and Future" (1 August 2010). http://emergingridesharingsolutions.wikispaces.com/file/view/TRB11-3038.pdf

[6] Chan, Nelson. "Ridesharing in North America: Past, Present, and Future" (1 August 2010). http://emergingridesharingsolutions.wikispaces.com/file/view/TRB11-3038.pdf

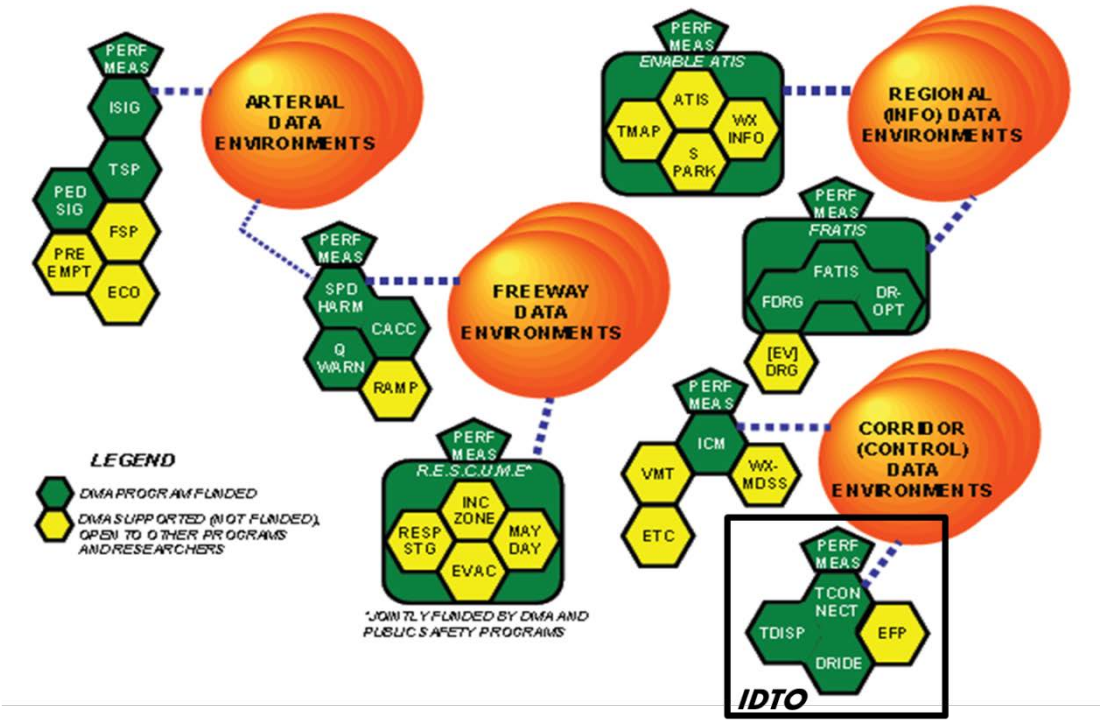

Figure 2-2. Dynamic Mobility Applications (DMA) Program Bundles

Chapter 3. Scan of Relevant Prior and Ongoing Research

3.1 T-CONNECT Research

A review of the available literature was conducted to discover past and ongoing studies relevant to the T-CONNECT concept. Based on this review, we determined that the current state of implementation of this concept is very limited due to the level of coordination required between modes in terms of underlying technologies, policies and inter-agency or inter-service coordination activities (discussed further later in this section and in Section 3.4.1).

The literature available on T-CONNECT-type systems is limited. The most relevant information is available from the evaluation of the Utah Transit Authority's (UTA's) implementation of the T-CONNECT concept as discussed below. Further, research was conducted by the Regional Transportation Authority (RTA) in Chicago[7] to explore the potential of implementing transfer connection protection (TCP) for the three service boards in the Chicago region (Chicago Transit Authority, Pace and Metra). The TCP strategy discussed in the report was not implemented by the RTA. The key issues identified in this study that are pertinent to the T-CONNECT concept are discussed later in this section.

In 2003 and 2004, the USDOT ITS program partnered with the Utah Transit Authority and successfully launched a connection protection service in Salt Lake City for transfers from the higher frequency light rail TRAX trains to the lower frequency bus services. The evaluation of the program[8] revealed that the TCP service has been well regarded by the stakeholders, especially travelers. The evaluation revealed that almost 86% riders (out of a total of 522 survey respondents) were satisfied with their connection experiences. The overall feedback from the TRAX-to-bus TCP implementation was positive. However, the evaluation noted that the operators' opinion of TCP implementation was largely mixed. This was mainly due to a high number of unnecessary TCP messages received by bus operators. Also, a majority of operators surveyed (70%) thought that it would be easier for them to wait if their routes were not tightly scheduled. Also, the evaluation found that downstream bus-to-bus connections were found to be jeopardized due to late departures at TRAX stations due to operator's wait as per "hold until"[9] instructions. The evaluation concluded that TCP can be a useful tool to meet the needs of customers. However, operators' judgments regarding wait times as per the "hold until" TCP message at transfer points (e.g., based on bus schedules, current schedule adherence status and expected arrival of the "incoming"[10] vehicle) are "key ingredients" to successful TCP implementations.

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[7] Wilson Consulting, "Regional Transportation Authority Transfer Connection Protection (TCP) Project," prepared for Regional Transportation Authority (Chicago), October 25, 1999.

[8] Battelle Memorial Institute, *Evaluation of Utah Transit Authority's Connection Protection System*, prepared for U.S. Department of Transportation, ITS Joint Program Office, HOIT-1, Final Project Report, Contract Number: DTFH61-96-C-00077, Task Number: BA7745, May 12, 2004.

[9] The amount of time an "outgoing" or "to" vehicle should be held

[10] "Incoming" vehicle in the context of TCP refers to the vehicle from which a TCP is requested

Another study related to T-CONNECT was conducted by Eui-Hwan Chung and Amer Shalaby,[11] to measure the rider experience with commuter rail-to-fixed-route bus connections in Brampton, Ontario, Canada. This study modeled passenger waiting time using a simulation model. The waiting time included "transfer passenger waiting time (from incoming vehicle)," "in-vehicle passenger waiting time (for the outgoing[12] vehicle)" and "downstream passenger waiting time (for outgoing vehicle)." The study mainly focused on operational strategies and did not address the underlying technologies. However, their findings can be useful in developing the algorithms that may be used by a T-CONNECT system to determine appropriate "hold-until" times. The "hold-until" time was found to be a result of a trade-off between various passenger waiting times in order to ensure the efficiency of transfers. One of the key findings of the research was that the outgoing transit vehicle should be held if the incoming vehicle is experiencing "moderate" (to be defined by agencies based on headways) delays. However, in the event of "long" (to be defined by agencies based on headways) delays with the incoming vehicle, the outgoing vehicle should operate according to its schedule.

The study conducted by the RTA identified several key issues that should be addressed by T-CONNECT-type systems, as follows:

- Electronic information exchange is necessary but it is also important to ensure the consistency of coordination on business processes related to transfers (e.g., determination and approval of "hold-until" time by dispatchers in a multi-modal/multi-agency environment, and operator's response to "hold-until" instructions);
- After-the-fact review of transfer trips, especially where inter-agency transfers are involved, should be conducted;
- A "maximum allowed" waiting-time should be defined;
- The definition of TCP should be by route and not by vehicle;
- Manual intervention by a dispatcher should be allowed by automated TCP systems; and
- The accuracy of real-time locations of transit vehicles involved in transfers should be ensured.

Our field experience with TCP to date reflects the above findings. In our experience, fixed-route to fixed-route TCP is the only T-CONNECT-type implementation that exists today in the United States. The primary reason for this deployment limitation stems from the complexity involved in the exchange of intermodal real-time operational data (e.g., between fixed-route and paratransit) and the determination of "hold-until" time, particularly when multiple agencies/modes are involved. Also, other factors relevant to the underlying technologies include inaccurate location and schedule adherence information available from vehicles (e.g., rail vehicles for which locations are refreshed at infrequent intervals), variability in predicted arrival times (e.g., due to the variability in travel times), and delays in the delivery of operator messages due to communication network limitations.

3.2 T-DISP Research

T-DISP as defined includes four significant components that, based on the current state-of-the-practice, must become more dynamic and integrated. These components are as follows:

[11] Eui-Hwan Chung and Amer Shalaby, "Development of a Control Strategy for Intermodal Connection Protection of Timed-Transfer Transit Routes" for the Transportation Research Board, 2007

[12] "Outgoing" vehicle in the context of TCP refers to the vehicle to which riders will transfer

1. Transportation Operations – including public transportation (fixed route, heavy rail, light rail, commuter rail, demand response, paratransit and flexibly-routed services); and private transportation services;
2. Travelers/Users – including existing and potential transit riders;
3. Coordination – including the need for coordination among agencies and providers (partnerships) and integration among systems (such as providing real-time information for multiple services operated by different entities);
4. Technology – the systems (e.g., software and hardware) that provide the necessary solutions for T-DISP and the real-time and static information that covers the full spectrum of data that assists in travel-making decisions.

Of these four components, the research regarding travelers and transportation providers is significant and covers a wide array of topics, not all of which are pertinent to T-DISP. For the purposes of this particular research effort, general research on transportation operations and travelers/users has not been examined because of the project approach that will directly engage these stakeholder groups and provide feedback specific to T-DISP. The majority of the research related to T-DISP has examined the coordination of public transportation services. Also, there is significant research available on the technology and systems that would support T-DISP operations. However, there is little research on the utilization of these two concepts together. The following subsections describe research relevant to T-DISP coordination and technology.

3.2.1 Coordination

Coordination of transportation services has been discussed and promoted for decades. It is a challenging concept and involves local, state and federal government, multiple funding programs, and multiple agencies. It seeks to encourage public and private entities to work together. The challenges to successful coordination are significant, but the potential benefits are significant also, so efforts for improved coordination continue. A recent coordination effort had a formal foundation in the 2004 Presidential Executive Order regarding Human Services Transportation Coordination. It stated that "federally assisted community transportation services should be seamless, comprehensive, and accessible to those who rely on them for their lives and livelihoods." Also, it states that "persons with mobility limitations related to advanced age, persons with disabilities, and persons struggling for self-sufficiency, transportation within and between our communities should be as available and affordable as possible." This order and related funding programs in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) directed local agencies to devise methods to coordinate public transportation and human services transportation. Since some private transportation entities provide supplemented service for both public and human service transportation, these entities were included in local efforts.

Further supporting the push toward better coordination was the Mobility Services for All Americans (MSAA) initiative, which is one of the USDOT's ITS Joint Program's initiatives. The goal of the MSAA initiative is to provide enhanced mobility and accessibility to all Americans through the use of technology integration, service coordination and the efficient use of resources. The foundation of the MSAA initiative is built around the notions of service coordination and technology integration. The MSAA program is closely coordinated with the United We Ride (UWR) program, which is a federal interagency initiative aimed at improving the availability, quality, and efficient delivery of transportation services for older adults, people with disabilities, and individuals with lower incomes. Currently, limited resources and lack of coordination challenge the effective and efficient delivery of human services transportation; resulting in service area gaps, limited services and/or confusing, low quality customer service.

The USDOT, through the MSAA initiative, is engaged in an effort to create an approach to the application of technological solutions to the barriers to accessibility and mobility. Ultimately, MSAA seeks to: "Establish replicable and scalable models of traveler management coordination centers (TMCC) that provide one-stop, unified customer-based travel information and trip planning services, and supports coordinated human services transportation operations." The MSAA program provides insight into the combination of technology and coordination of transportation services. Projects in a variety of service operations have been conducted as part of MSAA: from small, rural environments to larger, metropolitan areas. The phases of the MSAA program are as follows:

- Phase 1: Coalition Building
- Phase 2: Foundation Research
- Phase 3: Technology Integration Field Operational Tests and Evaluations
- Phase 4: Traveler Management Coordination Center Model Deployment
- Phase 5: Technology Transfer and Outreach

Efforts are now focused on the Phase 4, which includes three deployment sites: Paducah, Kentucky, Aiken, South Carolina, and Camden County, New Jersey. These three sites were selected from eight sites that participated in Phase 3 to plan and design a TMCC (additional information about this program is included in Section 4.2). This initiative provides the most significant results from the combination of coordination and technology specific to transit services. The deployment sites are in the process of evaluating and implementing a range of technology projects, including advanced scheduling software packages, computer-aided dispatch (CAD/AVL) and passenger information systems. The deployment sites have varied their approaches from decentralized operations and technology to a centralized approach. The results of the evaluation of the MSAA deployments will provide guidance to the development of the T-DISP concept of operations.

The second phase of the MSAA initiative was Foundation Research[13] and explored the gaps, barriers, past and current innovations, and emerging opportunities for coordination. It established a baseline for future performance measurement. It developed an inventory of information and body of knowledge for future TMCC projects. Also, it identified related activities underway in the public sector. The results from the Foundation Research and the deployment projects described in Section 4.2 will provide input to the formulation of the T-DISP concept of operations since the MSAA initiative is similar in concept as T-DISP. The MSAA initiative will be completing Phase 5 in the upcoming year, with an expected closing date of December 2012. This final phase will include the completion of the evaluations on the sites and continued information sharing and lessons learned. The efforts in the final phase may also help inform the development of the concept of operations for the IDTO bundle.

In addition to the body of knowledge provided by the MSAA program, there have been other research efforts and reports related to coordination. The *Regional Transit Coordination Guidebook*[14] prepared for the Center for Transportation Training and Research and the Texas Transportation Institute provides a concise overview of coordination efforts and reports on considerations for technological solutions. This guidebook examined efforts in the State of Texas and other locations. It includes guidance on strategies and methods of organization, methods of providing transit information, explanations on specialized transportation, and estimation methods for regional intercity travel demand.

[13] United We Ride website http://www.its.dot.gov/msaa/

[14] Lewis, et al. "Regional Transit Coordination Guidebook." September 2006. http://tti.tamu.edu/documents/0-5345-P1.pdf

The guidebook reports the following as considerations when selecting and implementing transit technology packages:

- Consider how the technology will work with current transit business practices
- Consider the costs associated with the technology
- Consider future expansion
- Introduce new technologies gradually
- Promote and market the regional information system
- Evaluate the system

The report includes a briefing on information sources for transit travelers. It included a summation of regional transit directories. These transit directories provide riders with a single source of transit services in an area, but do not provide customized travel information (like trip planning or real-time information). Also, it examined regional trip planners, including Transtar in Los Angeles; San Francisco's 511 system, Find-a- Ride in the Puget Sound area in Washington state and the Google Trip Planner. Further, the guidebook looked at on-line reservations systems for demand-response trips, including examples from the Suburban Mobility Authority for Regional Transportation (SMART) in suburban Detroit and Rider's Choice in Cumberland County, Maine.

This compilation of regional transit directories, trip planners, and on-line reservations systems are examples of attempts to coordinate transportation services by mode and service provider. The report did not indicate the degree of success or use of these information sources. A topic of future research, which could provide significant input to IDTO implementation, could be to examine how these information sources were used (or not used) by travelers, which could provide best practices for information dissemination related to T-DISP.

Another report that looked at coordination was a study similar to the Texas Guidebook in its approach and results. Clemson University's *Barriers and Catalysts for Statewide Coordination of Transportation Services,*[15] which was prepared for the South Carolina Department of Transportation. The report explored coordination at the national and regional level, specifically transportation operations in South Carolina. The report included perspectives from stakeholder groups including: regional transit providers; elderly communities and aging populations; people with disabilities and special needs; Head Start programs and transportation for children; and tribal involvement and interest.

The report provided guidance and considerations for regional transit coordination. This guidance included strategies to consider for promoting regional coordination, including the following:

- Use of communications, technology and data
- Performance monitoring
- Funding and resource sharing
- Institutional arrangements and consolidation
- Maintaining identity and local pride
- Migrating demand-response riders to fixed-route services
- Land use coordination with local planning agencies

[15] Dunning, et al. "Barriers and Catalysts for Statewide Coordination of Transportation Services." June 2007. http://www.clemson.edu/transportation/sctransit/

- Volunteer and volunteer networking

Some of the key findings from the report that relate directly to the coordination aspect of T-DISP include the following:

- Identify coordination motivators such as jobs, congestion, or scarcity of resources that encourage transit providers, local leaders, business leaders, and the general public to support coordination efforts.
- Look to sister regions with similar characteristics that have had rewarding coordination programs. Ambassadors from such regions who can vouch for the processes and benefits can build local confidence in coordination efforts.
- Use a few immediate partnerships as demonstration examples for other transportation providers.
- Make the process of using transportation services seamless and pleasant for consumers.
- Display the success and financial savings to the public to promote political motivation towards supporting more new coordination strategies.
- Work to overcome territorialism by bringing all issues to the discussion table and remaining respectful to all concerns.
- Do not expect immediate success in all coordination attempts. Some benefits take time to manifest.
- Determine and identify potential negative consequences at an early stage, create a solution or mitigation plan, and calibrate the expectations of all stakeholders in advance.
- Identify creative solutions that incorporate non-traditional stakeholders who might be specific to a particular region.
- Take small initiatives and grow them into bigger projects. Small demonstrations of success can inspire large-scale commitments and contributions as perception of risk decreases and perception of benefits to the community rise.

Another report that examined coordination, but focused on rural transportation, is *TCRP Report 101: Toolkit for Rural Community Coordinated Transportation Services.*[16] This report, although somewhat dated now, provides a national perspective on coordination and identifies ways to improve ongoing coordination efforts. It documented the critical factors that help determine the success or failure in establishing sustainable rural public transportation services. Special attention is given to successful strategies used to obtain the necessary ongoing operational funding for the transportation services.

One section focused on the use of technology and recommended the following systems as yielding the most benefit:

- Fleet Management, including
  - Communications systems,
  - Geographic information systems (GIS),
  - Automatic vehicle location (AVL) systems, and
  - Operations software;
- Systems Management, including financial management and accounting software;

[16] Burkhardt et al. Transit Cooperative Research Program, Report 101. "Toolkit for Rural Community Coordinated Transportation Services." 2004.

- Traveler Information, including
  - Pre-trip information systems,
  - In-terminal/wayside information systems,
  - In-vehicle information systems,
  - Multimodal traveler information systems,
  - Electronic fare payment, and
  - Other technologies, such as automated service coordination.

The focus of the report was on rural transit service provision and profiled the following agencies for their efforts in coordination and technology:

- *Rural Nevada* - Division of Aging Services (DAS) provided a grant to the Northern Nevada Transit Coalition (NNTC) to develop and implement the use of magnetic swipe cards in several transit operations that serve senior citizens.
- *Sweetwater, Wyoming* - Sweetwater County Transit Authority (STAR), in cooperation with local human service and coordinating agencies, installed a semi-automated dispatching system to assist with the operation of their paratransit service. The dispatching system uses color-coded computer-based maps to identify origins and destinations and route the particular bus. STAR has chosen to disable the fully automated driver notification features and route the buses via voice instructions.
- *Arrowhead, Minnesota* - The Arrowhead region of Minnesota is a rural area that covers 18,000 square miles in the northeastern area of the state. The ARCTIC (Advanced Rural Transit Information and Coordination) system has coordinated communication between transit vehicles and the central dispatch facility. Automatic vehicle locator (AVL) systems allow the central facility to track the exact location of transit vehicles. In addition, the automated scheduling system handles reservations and routing for the region's fixed-route, paratransit, and subscription services.
- *Cape Cod, Massachusetts* – implemented a CAD/AVL solution with on-board vehicle technology
- *Montgomery County, Maryland* – implemented a CAD/AVL solution with on-board vehicle technology
- *Florida Commission of the Transportation Disadvantaged* – planning efforts for a CAD/AVL solution

While several of these systems have changed since this report was published, there are valuable lessons learned from each of these systems that directly relate to T-DISP.

In summary, these reports on coordination consider a number of factors that directly relate to T-DISP. The first is that attempts for coordination of services are not without challenges, and these challenges are complex. Second, technology has assisted in overcoming the coordination barriers, but technology alone will not overcome all the barriers. The third is that the application of technology and coordination together has been successfully demonstrated in a limited way in a variety of operating scenarios and environments (urban, suburban and rural). Finally, travelers and their needs represent a critical part of the T-DISP concept, particularly in the information they are provided about transportation services and how they access this information.

3.2.2 Technology

There is a significant amount of research on transit ITS, and the systems and technology that would support T-DISP operations. The research efforts and reports include feedback on and analysis of programs and projects that have been designed and deployed. However this research does not focus specifically on the combination of technology and coordination that would be pertinent to T-DISP. Also, some of the available reports and publications include projects and findings that have since become outdated, due to advancements in software functionality and the capabilities of data storage and data communication. The current state-of-the-art of transit ITS systems are based on concepts and designs that were not possible before. In addition to the research, there are countless examples of transit ITS deployments that have not been evaluated, but are in operation and provide insight into the possibilities for T-DISP. While each agency or transportation provider has unique operating characteristics and systems that have been customized for them, there are some common items that are relevant to T-DISP operations:

- **Systems that Reserve and/or Track Passenger Requests for Travel:**
  - Booking and reservations systems
  - Trip Planners
  - Phone systems and Call Centers
  - Websites and information sites
- **Systems that Automate Scheduling and Create Trips:**
  - Paratransit
  - Flexible
  - Fixed Route Scheduling
- **Systems that Track Vehicles and Support Operations:**
  - Computer Aided Dispatch / Automatic Vehicle Location (CAD/AVL)
  - Voice and Data Communications Systems
- **Systems that Provide Information to Customers:**
  - Real Time information Systems
  - Website Integrations
  - Phone System Integrations
  - Variable or Dynamic Messaging Signs

A critical element for T-DISP is that the ability to provide relevant information to customers is highly dependent on the underlying systems, since these systems generate and/or manage the data that forms the traveler information needed by a traveler. For example, real-time information can be calculated using a predictive algorithm that uses vehicle locations (from a CAD/AVL system) together with information on schedule adherence (also from a CAD/AVL system) to disseminate information to a variety of media (e.g., phone, Internet, dynamic message sign).

The underlying systems that generate and synthesize operational data have been implemented in many transit agencies, having been provided by vendors or system integrators. The systems range from proprietary (most common) to open solutions. Customization is necessary in some cases, but many products, especially software for fixed-route and paratransit scheduling, have been deployed in transit agencies of varying sizes. Currently, most of the customization and innovation is on the customer information side.

Another element for consideration regarding these systems is the communication systems that move and manage the data. Countless transit providers have used a voice radio system for decades as their primary method of communicating with vehicle operators. The deployment of transit ITS and the advent of new communications technologies (e.g., voice over IP) has resulted in numerous data communication solutions. Based on field experience, cellular communication is growing as the most common solution for data communication. The cost of cellular communication has decreased in recent years, which has made it a favorable solution for many transportation providers. The benefits and costs for one particular communication solution over other potential solutions are dependent on the needs and constraints of the transit provider(s) and must be considered as agencies move forward with transit ITS deployment.

While there are many agencies that have deployed transit ITS that would be required to support T-DISP, there are agencies that have not. For example, FTA's *Real-Time Transit Information Assessment*[17] identified the following reasons why transit providers have not deployed real-time transit information systems:

- Costs of infrastructure investments;
- Institutional issues; and
- Liability and the loss of integrity associated with providing inaccurate or unreliable information.

Another key element of technology relevant to T-DISP includes the coordination and dissemination of information to existing and potential travelers. These travelers have a range of information needs; starting with a potential traveler, who is interested in using public transportation but has little knowledge or understanding of their travel options; including an occasional traveler who may use public transportation a few times a month; and the daily commuter who rides public transportation at least five days a week. This range of existing and potential customers requires a variety of information on transportation services. Some information sources could be as basic as a telephone book or printed schedules, and some as advanced as mobile applications developed for use on a smartphone. Not only are these sources of information disparate, but so are the travelers and potential travelers who would access the information. A challenge for the implementation of T-DISP will be the ability to provide useful, relevant, timely, reliable and concise information to the users. Specifically in T-DISP, real time transit information will be likely the most critical information needed by travelers. However, consideration should be given to the complete range of traveler's information needs.

An exceptional example of formalized traveler information sources is 511, which was designated in the year 2000 as the three digit number to access traveler information. *TCRP Report 134: Transit, Call Centers, and 511: A Guide for Decision Makers*[18] describes the status of how 511 is used around the US. Since 511's designation, many, but not all states have adopted and promoted its use. Many states provide real time highway and roadway conditions, and offer this information via voice telephone, website, and mobile devices. Some, but not all states have included transit information in 511. A few states have included more robust traveler information, including real time transit information. Some of the findings from this TCRP report are that there are few states that include transit information on 511; there are very few adverse impacts from including transit information; and that even modest benefits for including transit information in 511 justify the costs. The report indicates

[17] Cham, et al. "Real-time Bus Arrival Information Systems Return-on-Investment Study" 2006. http://www.fta.dot.gov/documents/Final_Report_-_Real-Time_Systems_ROI_Study.doc
[18] Battelle, et al. TCRP Report 134, "Transit, Call Centers,a nd 511: A Guide for Decision Makers." 2009.

that benefits increase in regions where there are multiple transit providers and a significant number of travelers who decide on mode choice based on daily traffic and transit conditions.

One particular case study in the use of 511 comes from the Center for Urban Transportation Research's report *Dynamic Travel Information Personalized and Delivered to Your Cell Phone.*[19] The 511 system in Florida has the ability to deliver traveler alerts via emails and text messages as part of traffic alert subscriptions. These advanced 511 "push" systems can provide the user a method of reducing the scope of alerts to specific pre-scheduled times and roads (i.e. the information most relevant to my particular commute). Communicating information to travelers includes the provision of information (either static or dynamic) at a location that travelers can access, such as a phone system or website. The report focused on a project developed in Florida using 511, cell phones and TRAC-IT, a software architecture supporting simultaneous travel behavior data collection for all modes of transportation and real-time location-based services for GPS-enabled mobile phones. The TRAC-IT system features a mobile phone application that can capture real-time user positions as frequently as once per second on any mode of transportation (e.g., car, public transportation, biking, walking) for opt-in travel behavior surveys and archive this data for later analysis. Since travel behavior data is collected in real-time, TRAC-IT has the potential to provide real-time location-based services, such as travel information or traffic alerts, to the user in order to give them an incentive for participating in a survey.

Another source of coordinated travel information comes from the private sector from 1-800-TAXICAB, Inc. Founded in 1999, this company maintains a comprehensive national referral network of independently owned and operated taxi companies. Passengers call the toll-free number and will be connected to a local taxi company. The idea is to have a "One Number Nationwide"® for local taxi service. The company provides information on other transportation services including airport shuttles, limousines, and paratransit service. The company's mission is "to provide the most comprehensive, accurate directory of licensed ground transportation services." The website does indicate that there is not a guarantee regarding the accuracy of the telephonic referral services or any of the online directories, the licensing status of the listed companies, or that all cities are listed. This notation indicates one of the challenges of information coordination, managing the accuracy and relevance of information.

Another element to consider regarding information about transportation services is the wide variation in media preference and use by the travelers wishing to obtain information. These considerations include people with disabilities, but also travelers without access to mobile devices. Additionally, there are a number of reports and publications detailing specific components of real time transit information, which include the following:

- FTA Guidance on Real-time Transit Information Systems
- FTA Advanced Traveler Information Systems (ATIS) Human Factors Assessment
- Transit Cooperative Research Program (TCRP) Synthesis 48 – Real-Time Bus Arrival Information Systems
- TCRP Report 92 – Strategies for Improved Traveler Information
- TCRP Synthesis 68 - Methods of Rider Communication
- TCRP Synthesis SA-25 - Use of Mobile Device Technology for Real-Time Transit Information (publication expected April 2011)

[19] Barbeau et al. " Dynamic Travel Information Personalized and Delivered to Your Cell Phone." March 2011 http://www.nctr.usf.edu/wp-content/uploads/2011/03/77804.pdf

- TCRP Report 84, Volume 8 - Improving Public Transportation Technology Implementations and Anticipating Emerging Technologies.

3.3 D-RIDE Research

Dynamic Ridesharing evolved from the concept of carpooling, which increased in the 1970s in response to the high gasoline prices of the energy crisis. To incentivize drivers to carpool and reduce energy consumption, states began implementing HOV lanes. This traditional ridesharing saved users time and money, but it was static and could not be arranged on a need-basis.[20]

In the 1990s, casual carpooling began to develop in the San Francisco Bay Area, and "slugging" in the Washington, DC Area – both organically. These are informal ridesharing arrangements, not pre-established or scheduled. Potential riders meet in designated locations (i.e., at major office building, train station, etc.), and drivers with similar travel destinations pick them up; riders wait in a line for drivers and vice versa. Riders and drivers usually do not know each other during these informal exchanges, which is a cause for concern by many commuters.[21] Most travelers use these ridesharing methods to save money on toll roads and time by driving on HOV lanes, specifically HOV-3+ lanes, since carpools with three or more passengers are particularly difficult to form and maintain.[22]

The natural development of casual carpooling/slugging reflects travelers' desire to participate in ridesharing on a flexible, nonrecurring basis. Therefore, in the mid-1990s, Federal and State transportation agencies began investing in research projects to develop formal technologies and systems that could help users access and employ informal ridesharing. The following ridesharing projects employed a range of technologies, from cell phones and pagers, to information kiosks, to the internet and smart phones.

- The **Bellevue Smart Traveler (BST)** was one of the first dynamic ridesharing projects, which took place in downtown Bellevue, Washington, east of Seattle, from November 1993 to April 1994, with a second phase in 1995. This project investigated the impact cellular phones could have on carpooling. The project team, funded by the Federal Highway Administration (FHWA) and Washington State DOT, set up a computer-based phone service "traveler information center." Test participants subscribed to the information center, which provided voice-activated current traffic information, transit information, and ride-matching lists. Although participants responded positively to the concept of the system, they were largely unwilling to arrange carpools with their matches for several reasons. Participants responded that it was difficult to find and confirm matches, which researchers attributed to having too small of a participant pool for the pilot. Secondly, participants said they felt uncomfortable carpooling with strangers. Researchers concluded that adding security features to the system or refocusing the pilot on specific business clusters to establish social/traveling networks were both possible solutions to this problem. Lastly, participants indicated that more

[20] Swisher, Myron. USDOT Resources: Overcoming the Challenges of Congestion Pricing 2011 FHWA Webinar Series. Session 6: Dynamic Ridesharing and Congestion Pricing (Webinar Transcript). (28 July 2011). http://www.fhwa.dot.gov/ipd/revenue/road_pricing/resources/webinars/transcript_072811.htm

[21] Heinrich, Susan. "Implementing Real-time Ridesharing in the San Francisco Bay Area." (June 2010). http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/Implementing_Real-Time_Ridesharing_Heinrich.pdf

[22] Swisher, Myron. USDOT Resources: Overcoming the Challenges of Congestion Pricing 2011 FHWA Webinar Series. Session 6: Dynamic Ridesharing and Congestion Pricing (Webinar Transcript). (28 July 2011). http://www.fhwa.dot.gov/ipd/revenue/road_pricing/resources/webinars/transcript_072811.htm

incentives, particularly financial incentives, would have made more willing to take an active part in the pilot.[23]

- The ***Coachella Valley TransAction Network*** project took place in Riverside County, California, in 1994. Automated phone system and computer technologies were established at four travel kiosks to provide users with traffic information, transit information, and ride match lists for one-time ridesharers. The project found that the kiosks were rarely used for ridesharing, and the system was not the most effective way to promote carpooling in the area.[24]
- In 1996, the ***Seattle Smart Traveler (SST)*** system was implemented at the University of Washington. This program, which used Internet and email technology, was conducted by the University, Washington State DOT, King County Metro, and five private sector partners, and was funded by the FHWA. Potential participants used the SST website by logging in with their University identification numbers and completing an application form. They could then choose a pre-set pickup location and enter destination location, preferred day of week, and arrival/departure times, and the program would find potential matches for regular commute trips, regular additional trips, and/or occasional trips. Users could then send pre-formatted emails to their matches requesting or offering rides. After the program was heavily marketed, there was a "considerable increase" in usage, leading the project team to conclude that there was a demand for a dynamic ridesharing program.[25]
- The ***Germany "M21" Mobility Services Trial*** was designed as package of six interconnected services, which included a pre-planned carpool service, a car-sharing service, and a real-time carpool service. The pre-planned carpool service was designed to operate in a single-employer environment. Employees were encouraged to log their ride offers and requests through the company's internal computer system or through a phone system. Every afternoon, the service would match participants notify them of their matches via text or email. Through the car sharing service, employees could drive company-provided vehicles. Those using shared cars were expected to give rides to fellow employees who needed to make real-time rideshare arrangements along a similar route.[26]
- More recently, the ***RideNow*** project was tested by several public and private agencies in Dublin and Pleasanton, California, in 2006. This program implemented a phone system to arrange matches for one-time ridesharers to/from one BART train station in the San Francisco Bay Area. Users were given incentives, such as a guaranteed ride home (by taxi, if necessary), free BART tickets for registering and for making matches, and orientations on how to use the program. Results showed that though users enjoyed the incentives program,

[23] "Ridesharing." Victoria Transport Policy Institute TDM Encyclopedia. (15 December 2010). http://www.vtpi.org/tdm/tdm34.htm

[24] Heinrich, Susan. "Implementing Real-time Ridesharing in the San Francisco Bay Area." (June 2010). http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/Implementing_Real-Time_Ridesharing_Heinrich.pdf

[25] Ibid.

[26] Amey, Andrew M. "Real-Time Ridesharing: Exploring the Opportunities and Challenges of Designing a Technology-based Rideshare Trial for the MIT Community." (June 2010), http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/AMEY_Thesis_Final.pdf

the system was not convenient overall. Participants found the phone system confusing, and they reported that the 15 minute notification timeframe for ride matches was too short.[27]

- The Centers for Disease Control (CDC) in Atlanta began testing **RideCell**, a real-time, internet-based ridesharing application for its 3,500 employees, in 2010. In the pilot phase, potential drivers and riders set up a profile and enter their trip information, selecting if they want to carpool on a regular or one-time basis, as well as their match preferences (smoking/nonsmoking, gender, etc.). Users can choose to be dropped off at home or another location, and the system provides well-known pick-up locations so rideshare matches can easily find each other. The system, which is also available as an application on iPhone and Blackberry, then sends text-messages and emails to participants when they have matches. So far, RideCell has struggled to find participants. Researchers conclude that either CDC employees already participate in carpool arrangements or services and do not need or want to join another, or those that have signed up have done so for the traffic information component of RideCell rather than for ridesharing.[28]

Current research projects and D-RIDE products, including the following, are evolving to be more mobile and internet-based.

- **2009 to Present.** The University College Cork (UCC) in Ireland started testing the ***Avego*** real-time ride-sharing technology in 2009 by having actual drivers post for non-existent "ghost" riders. The original pilots focused on usability testing and understanding consumer attitudes toward ridesharing. In February 2011, Avego launched another three-month pilot program, which focused on building a "critical mass" of drivers and riders at UCC. Avego provided free iPhones and subsidized phone contracts to the first 20 participants, who would use the Avego application at least 20 times a month to offer rides. This demonstration tests the technology more than demand for the technology. More information on the Avego technology can be found under Section 4.3, D-Ride Current Practice.[29]
- **2010 to Present.** Ecology and Environment (E&E) developed the ***QuickFlow*** system for the New York State Department of Transportation (NYSDOT) and New York State Department of Energy (NYSDOE). E&E is a consulting firm that offers a range of services, including a ride-matching system called GreenRide, of which QuickFlow is an add-on application. Users can make traditional ridesharing arrangements or real-time, one-time matches. QuickFlow sends users their matches via phone, text message, email, cell phones, and/or the internet, and it is available on the iPhone, Blackberry and Palm.[30]
- **2010 to 2011.** ***The European Commission OPTI-TRANS Trial*** is a project made up of five partners from four EU countries. The project includes a personal traveler navigation system accessible through a mobile device. This system uses the Global Navigation Satellite System to provide users with travel information based on their current location. It integrates multiple sources on public and private travel into one system in order to recommend to users the most suitable mode of travel (i.e., walking, taxi, rideshare, bus) based on type of traveler

[27] Heinrich, Susan. "Implementing Real-time Ridesharing in the San Francisco Bay Area." (June 2010). http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/Implementing_Real-Time_Ridesharing_Heinrich.pdf

[28] Ibid.

[29] Ibid.

[30] Ibid.

(commuter, tourist, etc.) and traveler needs (fastest trip, cheapest trip, fewest transfers, etc). It also allows users to choose their desired mode of contact, such as email, texting, or phone call. There have been three OPTI-TRANS trials: two in Madrid (January-March 2010 and January-March 2011), and one in Athens (January to March 2011). Final reports on the trials are in production.[31]

Several conclusions and recommendations can be formulated based on ridesharing technology projects conducted in recent decades, including but not exclusive to those listed above:

- Findings showed that a fear of strangers was often cited as a reason for not sharing rides, highlighting the need to allow potential carpoolers to target others who are part of their social networks. Therefore, D-RIDE programs targeted towards specific institutions or companies, as in the Seattle Smart Traveler and the Germany M21 programs, can make participants feel more comfortable making travel arrangements with would-be strangers.[32]
- Providing familiar, commonly-known meeting points and drop-off locations in additions to users' homes is another way to make users feel more comfortable using a rideshare service.[33]
- Marketing is necessary to draw an initial crowd to a D-RIDE system, and incentives (e.g., iPhones offered by Avego or free BART tickets offered by RideNow) can draw more users.[34]
- D-RIDE systems that incorporate accurate GPS technology mitigate several concerns of potential users. First, GPS enhances ridesharing services utility by providing directions and convenient meeting locations. In one survey, 90% of responders said rideshare systems should provide driving directions so that the driver can easily find and pick up the passenger.[35] Secondly, GPS can save users' time by automatically detecting their starting locations. Lastly, GPS can enhance security for passengers by allowing them to track their route and confirm that the driver is not going off-course.[36]
- Applications that run on smart phones and other mobile devices fulfill users' desires for easily accessible, convenient rideshare services. In several projects (Bellevue Smart Traveler, TransAction Network), participants found rideshare systems overly complicated and the matching process too long. With mobile devices, users can establish rideshare arrangements

[31] Amey, Andrew M. "Real-Time Ridesharing: Exploring the Opportunities and Challenges of Designing a Technology-based Rideshare Trial for the MIT Community." (June 2010), http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/AMEY_Thesis_Final.pdf

[32] Heinrich, Susan. "Implementing Real-time Ridesharing in the San Francisco Bay Area." (June 2010). http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/Implementing_Real-Time_Ridesharing_Heinrich.pdf

[33] Ibid.

[34] Amey, Andrew M. "Real-Time Ridesharing: Exploring the Opportunities and Challenges of Designing a Technology-based Rideshare Trial for the MIT Community." (June 2010), http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/AMEY_Thesis_Final.pdf

[35] Heinrich, Susan. "Implementing Real-time Ridesharing in the San Francisco Bay Area." (June 2010). http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/Implementing_Real-Time_Ridesharing_Heinrich.pdf

[36] Amey, Andrew M. "Real-Time Ridesharing: Exploring the Opportunities and Challenges of Designing a Technology-based Rideshare Trial for the MIT Community." (June 2010), http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/AMEY_Thesis_Final.pdf

on-the-go and can take their ride-match contact and trip information with them when they go to meet drivers/riders and throughout the trip.[37]

3.4 IDTO Theory of Operation

3.4.1 T-CONNECT Theory of Operation

Most of the current vendors'/system integrators' TCP functionality for fixed-route vehicle to fixed-route vehicle (the most prevalent is between buses) works in the following way:

- Mobile data terminals (MDTs) are mounted on transit vehicles. The MDTs typically contain a GPS receiver that provides vehicle location information to an operations control center;
- When a passenger is interested in a transfer, the driver of the vehicle that the passenger boarded enters the transfer information into the MDT. This information is relayed to the TCP subsystem (within a computer-aided dispatch (CAD)/automatic vehicle location (AVL) system) at the central dispatch site/operations control center, and it automatically calculates which vehicle will be impacted by the requested transfer;
- Immediately, the TCP system determines if the vehicle that the passenger is transferring to should be held (protecting the connection) and how long this vehicle should wait without serious impact to the schedule; and
- An automated message is sent to the operator of the vehicle that the passenger is transferring to, instructing him/her to wait a specific amount of time for the arriving vehicle.

The TCP concept implemented by UTA follows a slightly different approach to enable intermodal transfers. The TCP system monitors the current light rail vehicle location and based on its estimated arrival time at a train station, it determines the impact on pre-determined transfers to local fixed-route buses that may be in jeopardy. The system automatically notifies operators on those buses about the "hold-until" time.

However, the approaches described above are not sufficient to enable and protect multi-modal transfers. Based on our field experience of TCP implementations, the following factors are critical in order to implement a fully-functional multi-modal T-CONNECT concept.

3.4.1.1 Technology Factors

Data Communication: As stated earlier, data communication is necessary for the timely transport of information between vehicles and central dispatch/operations control. If the communication system experiences any problems that result in the inability to send critical information, this will impact the TCP subsystem's ability to timely determine the most appropriate "hold-until" time and inform operators in a timely manner. The limitation of data communication systems will be more significant in larger transit agencies if they rely on traditional data radio networks, which typically have limited bandwidth. Another factor is the rate at which vehicles are polled for their location (e.g., 1-2 minutes intervals). Thus, data messages critical to a TCP algorithm (discussed below) may not be delivered when needed.

[37] Heinrich, Susan. "Implementing Real-time Ridesharing in the San Francisco Bay Area." (June 2010). http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/Implementing_Real-Time_Ridesharing_Heinrich.pdf

Automatic Vehicle Location (AVL): Real-time vehicle location is key to a successful T-CONNECT-type system. T-CONNECT algorithms determine whether or not a vehicle should be held based on the last known location of incoming and outgoing vehicles. If vehicle locations are outdated, inappropriate decisions will be made and drivers will be notified with potentially incorrect "hold-until" messages.

Route and Schedule Adherence (RSA): Similar to AVL information, RSA is critical to determining TCP accuracy. TCP decisions are made based on the estimated time of arrival of the "incoming" vehicle as discussed below, which will rely on accurate RSA information.

Arrival Prediction: In order to successfully determine whether or not a transfer is in jeopardy, an automated T-CONNECT system should have access to the most accurate predicted arrival time information. Predicted arrival times are dependent not only on AVL and RSA information discussed above, but also on several other operational factors such as travel time variability.

3.4.1.2 Operational Factors

Data Sharing and Service Coordination for Interagency and Intermodal Transfers: In order to enable real-time data exchange, a transit agency should have data sharing arrangements in place, especially in the event that manual intervention is required from dispatch in a multi-modal/ multi-agency environment. Ideally, a T-CONNECT system should have access to real-time information for connecting vehicles from a common operational database for multiple agencies or modes to avoid message processing delays due to data exchange between transit management systems for individual modes/agencies, and inherent data communication network latency issues. In order to minimize delays with real-time data exchange between various systems involved in T-CONNECT implementations, standards addressing this type of exchange (e.g., Service Interface for Real-time Information (SIRI)) should be considered.

Also, policies and procedures need to be in place where manual intervention is required. For example, sometimes, transfers may be denied by the automated T-CONNECT system due to the anticipated downstream impact on service performance or predefined transfers for the route for which a TCP message was issued. However, dispatchers may be in a position to issue a "hold-until" message based on their previous experience with the routes, vehicles and operators involved in such situations. Thus, policies should be developed, especially in a multi-modal and multi-agency environment, describing those scenarios under which a dispatcher can intervene. Also, procedures that should be followed in these situations (e.g., seeking approval from supervisors or transportation managers, coordination with control centers at other agencies, if applicable) should be developed as well. Policies and procedures should be updated on a regular basis (e.g., every sixth months) based on field data collected on transfer requests (e.g., number of automatic approvals/denials and corresponding scenarios, number of manual approvals/denials and corresponding procedures followed by dispatchers).

Agency Policy for "Holding" Vehicles: Agencies should establish a policy for determining the amount of time a vehicle should be held. Various factors that should be considered in determining the "hold-until" time are as follows:

- Consider the trade-off between "hold-until" times and the maximum allowable threshold for schedule deviations;
- Consider travel time variability based on historic travel time and/or current traffic conditions;
- Consider service anomalies and disruptions;

- Account for “on-time” and other service standards for different agencies or modes to determine the impact on schedules when vehicles from different agencies and modes are involved in a transfer;
- Determine an acceptable waiting time for passengers based on the following: transfer waiting time, in-vehicle waiting time and downstream waiting time;
- Consider the impact of dwell time for the “outgoing vehicle” when determining the impact on downstream stops. Particularly, elements such as wheelchair boarding time should be considered; and
- Capacity of the “outgoing” vehicle should be considered by the T-CONNECT vehicle algorithm.

3.4.2 T-DISP Theory of Operation

The theory of operations for T-DISP is the connection of public and private transportation services and real-time information allowing travelers to be aware of the transportation options and to make decisions on the most appropriate mode(s). In theory, T-DISP would include:

- All transportation modes, including fixed, flexible and demand response transit services, taxi and other private transportation providers
- The coordination of transit operations across transit agencies, systems and jurisdictions
- Travelers being able to make trip request on demand without advanced booking requirements
- Travelers being provided desired destination & departure time tagged with their current location through personal mobile devices
- Travelers being able to access information on multiple transit options through a single consolidated source of information
- The integration with transit connection protection (T-CONNECT) capabilities
- Accessibility to people with special needs

T-DISP would include a dynamic scheduling and dispatching system, which would route vehicles by matching compatible trips. These trips would be constructed from traveler requests that contain origin, destination and departure or arrival time from a variety of devices. The destination would be matched with various modal options, including fixed, flexible or demand response transit services, and private services. As these trips are scheduled and routed, the system would consider real-time traffic conditions and vehicle capacity.

Inherently, the intent of T-DISP is to better match requests for service, or unmet travel needs, with a more appropriate and cost effective service type. As an example, a fixed-route bus provides service to an office park for 15 hours per day. However, people traveling to this office park only work specific shifts, which would warrant service at three specific times during the day. T-DISP would provide another method for transporting those travelers to that job site by dynamically scheduling trips at the times when they are needed.

There are a number of issues for consideration in the theory of operation. A principal consideration is coordination. The concept of coordination as it pertains to T-DISP includes the following:

- Coordination of transportation services between modes, and between public and private transportation providers;

- Coordination of technology systems that are used to manage and operate the transportation providers; and
- Coordination of information generated from the underlying technology systems and disseminating it to travelers.

As described in Section 3.2, there are a number of barriers to coordination. Institutional practices, funding, inter-agency conflicts, and intra-agency departmental silos are significant. Breaking these barriers down requires a thoughtful and measured approach to be successful. Another barrier is the significant (perceived or actual) financial reasons that inhibit coordination of services. These financial reasons include the complexity of funding programs, and the requirements for receiving and using certain types of funds for certain purposes. It also includes individual agency financial considerations, which may involve viewing that, unless there is a larger amount of funding available for transportation services, the concept of coordination of services may mean that some transportation providers provide less service, thereby receiving less funding. Another complication is that even within a particular transit agency, there may be departmental silos. These silos could be caused by management and labor union differences, simply interpersonal/ personality issues between staff members or simply a lack of leadership to advance coordination efforts.

3.4.3 D-RIDE Theory of Operation

Figure 3-1 describes the flow of communications during a typical D-RIDE ridematching information exchange.

Interfaces
Drivers and passengers typically interface with a web-based platform to input their needs for a rideshare match. This is done through the internet with a variety of technologies/devices, including computers, GPS-devices, smart phones, or social networking sites. These devices connect to a centralized D-RIDE data center which both takes in information from user devices and relays information back to their device once a rideshare match is made.

User Guidelines
Persons interested in using a D-RIDE application need to have access to an internet-equipped device to enable the entering of rideshare information prior to their trip. In many cases, D-RIDE applications may be proprietary in nature and require subscription and additional security features (i.e., PIN numbers) to use the service. In some D-RIDE applications, users can opt to allow GPS to locate the traveler's starting point to facilitate faster and real-time location information.

Inputs
The passenger interested in ridesharing uses an Internet-equipped device to enter their trip information (also known as a trip plan request) into a web-based portal, or D-RIDE application. A user must enter origin (or allow GPS to determine origin location) and destination of the proposed trip, any routing constraints, preferences specified by the traveler, compatibility of this rideshare with rideshares confirmed by other travelers, and the requesting traveler's eligibility data. In some D-RIDE applications, traffic data is sent along with the trip plan to the D-RIDE data center for accurate routing and travel time information.[38]

[38] Ibid.

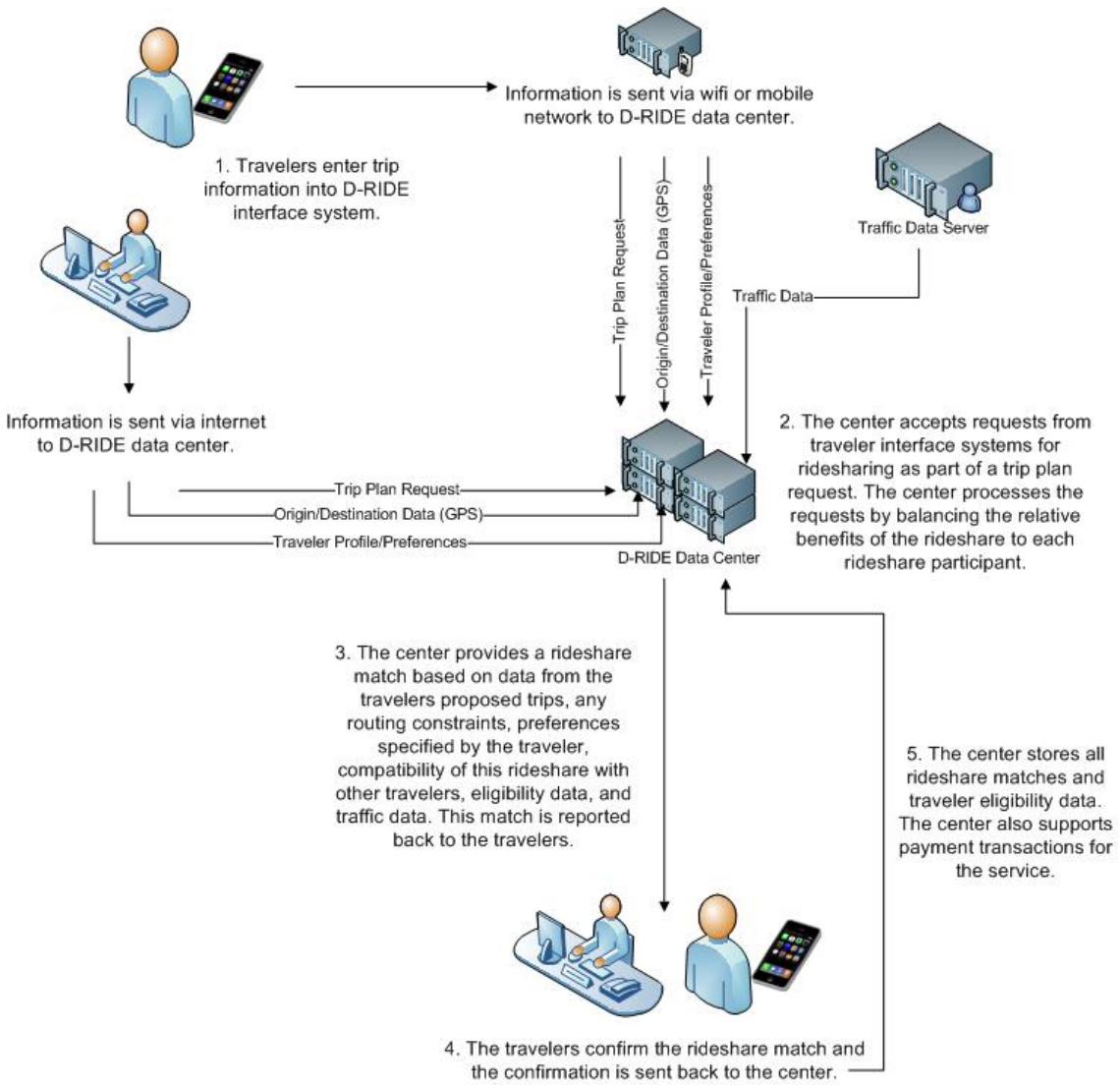

Figure 3-1. D-RIDE application information exchange and communication network.[39]

Processing

The D-RIDE application sends the trip plan and other information (e.g., traveler profile, traveler preferences, location data, and traffic data) to a D-RIDE data center which processes rideshare requests using an algorithm to optimally match passengers to drivers and then sends the information to each rideshare participant. The D-RIDE data center for some D-RIDE applications can also arrange other trip-planning information (e.g., transit connections) for multi-segment trips using additional algorithms and available trip planning data. The D-RIDE data center can also process payment when rideshare matches are accepted by users.[40]

[39] USDOT National ITS Architecture Version 6.1 - Infrastructure Provided Dynamic Ridesharing. http://www.iteris.com/itsarch/html/ep/ep25.htm
[40] Ibid.

Outputs
The D-RIDE data center then provides a confirmation of the rideshare match and corresponding route, pickup time, travel time, and other trip information to both the traveler and the driver. Upon confirmation and acceptance of the rideshare match, a message is sent from the interface application to the data center for payment processing, if applicable. The D-RIDE data center stores all positive rideshare matches and traveler eligibility data in order to draw upon these matches for future trips.

3.5 IDTO Capabilities

3.5.1 T-CONNECT Capabilities

T-CONNECT will provide the capability to protect transfer requests between multiple transit modes even when those modes are operated by different agencies. Thus, T-CONNECT will significantly improve the current state of T-CONNECT technology in which the implementation is primarily limited to fixed-route systems (light rail and fixed-route buses). Since T-CONNECT can be applied to paratransit, demand response and flexibly-routed systems, it has the capability to enhance the mobility of riders who are primarily dependent on paratransit vehicles due their inability to use fixed-route services. T-CONNECT can accomplish this by providing intermodal transfer capability as discussed below in T-CONNECT's relation to the T-DISP concept. Such a capability will not only improve the rider's experience but also enable agencies to provide services in an efficient manner through service consolidation and partnerships with regional transit and other transportation and human service agencies. Further, T-CONNECT has the ability to bridge the gap between transit and non-transit modes as discussed below regarding the relationship between T-CONNECT and D-RIDE concepts.

A multi-modal/multi-agency T-CONNECT has the capability to assist with the implementation of T-DISP and D-RIDE as follows:

- *TCONNECT and T-DISP:* T-CONNECT technologies can be highly useful in the implementation of the T-DISP concept. In order to support intermodal connectivity for T-DISP, the T-connect concept should be implemented to ensure intermodal transfers so that the riders have seamless experience when transferring from one mode to the other for the trips booked by the T-DISP system.
- *T-CONNECT and D-RIDE:* A truly multimodal T-CONNECT implementation can assist a D-RIDE system in determining the time a rideshare vehicle should be held for an incoming passenger from a personal vehicle or from a pedestrian. However, this implementation will require access to various external data sources such as current/historic traffic conditions to determine estimated time of arrival for incoming passengers. T-CONNECT to D-RIDE interface will also be complex since the TCP algorithm will need to be customized to address riders' personal travel preferences (e.g., type of vehicle and number of existing on-board passengers on rideshare vehicles).

3.5.2 T-DISP Capabilities

T-DISP will advance the concept of demand-responsive transportation services utilizing advanced transit ITS systems, such as CAD/AVL, real-time information and 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 TMCC, or decentralized system would dynamically schedule and dispatch or modify the route of an in-service vehicle by matching compatible trips together. This application may consider both public and private (e.g., taxi) transportation providers and may include paratransit,

flexible and fixed -route bus services and rail transit services. For example, if a paratransit vehicle is not available, a traveler would be given information on the closest fixed-route or private service to where they are located.

The proposed application may consider a common platform that allows people to effectively communicate and access shared transportation resources more readily than the current state-of-the-practice suggests. 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 significant 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 midday fixed-route services. Figure 3-2 provides an illustration of how T-DISP could work.

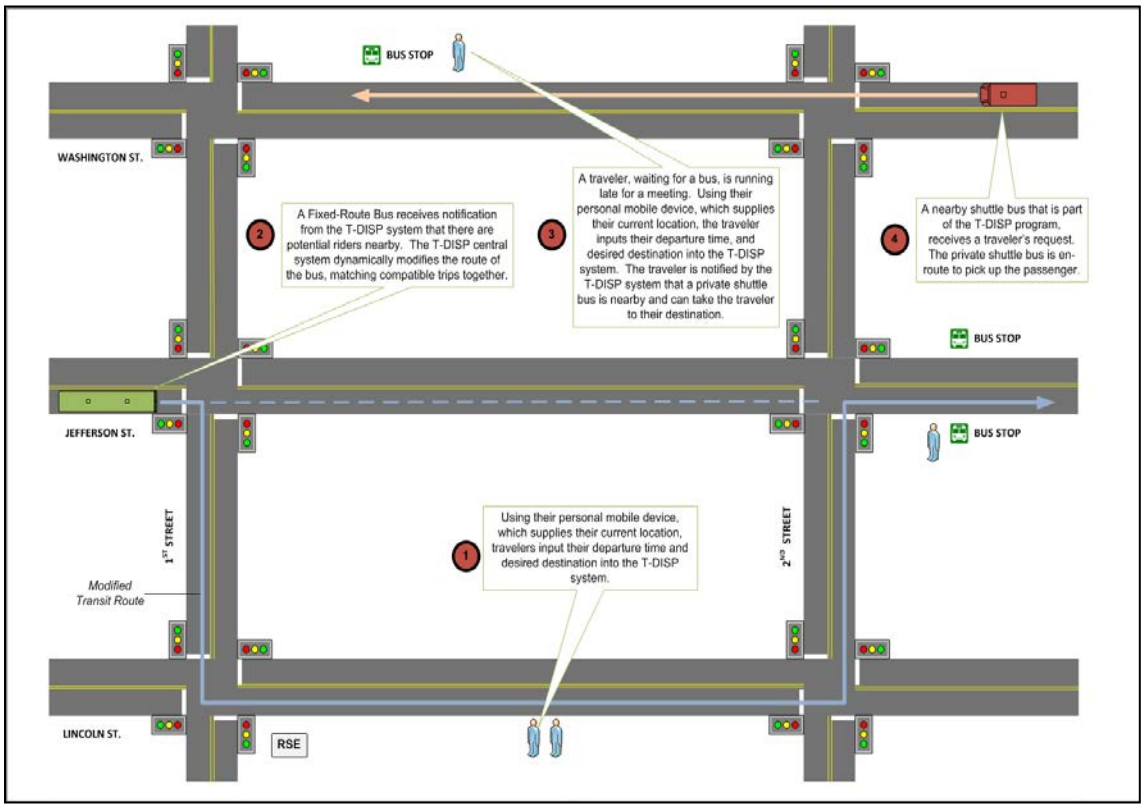

Figure 3-2. Potential T-DISP Operation

The following anticipated capabilities would impact the components of T-DISP:

- Travelers/Users are impacted by the availability of additional trips or more effective trips (e.g., shorter travel times). Also, they are impacted by changing the way their trips are planned or scheduled (i.e., using a phone or the Internet to schedule a trip, as opposed to reading and interpreting a bus schedule). The change in how their trips or service is scheduled may not

be desirable to some customers or some travelers may not have access to the types of devices that are envisioned.

- Transportation providers are impacted by having to provide more service so that the traveler has more options. There may be strong institutional barriers that preclude additional service from being provided, unless costs can be minimized. For example, an agency may not have the necessary resources (staff, vehicles, funding) to modify services in such a way that meets T-DISP requirements. Also, there may not be an incentive to change business practices to provide more service because it means that roles and responsibilities may change for staff members or there may be a change in workload (either increase or decrease).
- Technology is also impacted, specifically scheduling and reservations software to flexibly route service, and/or for scheduling service between fixed-route and demand response modes. Based on field experience, the actual use of flexibly-routed scheduling software is limited. There is room for improvement beyond the current state-of-the-art especially if the flexibly-routed service needs to become more dynamic (e.g., scheduling pick-ups within 15 minutes of the customer's trip request). For the other systems (CAD/AVL and real-time information systems), the back-end and central systems exist. However, not every agency or transportation provider has deployed the underlying systems that would be necessary to implement T-DISP. Additional transit ITS deployments throughout the US would be necessary. And as these systems are deployed, they would need to be integrated between modes and providers.

3.5.3 D-RIDE Capabilities

D-RIDE technologies offer many capabilities and features that make real-time ridesharing more accessible, convenient, and socially acceptable:[41]

- **Mobile-Equipped:** Rideshare service providers have begun to develop platforms that can be used on smart phones, such as the Apple iPhone and Google Android, as well as Blackberry and other mobile devices. This allows users to access rideshare software on-the-go and allows them to make and accept ride offers and requests on short-term notice.
- **GPS-Enabled:** Many rideshare providers have incorporated the Global Positioning System (GPS) into their applications to make them "location aware." This means that users do not need to manually enter their current locations as they are already detected via GPS. GPS also allows drivers and passengers using rideshare applications on mobile devices to receive directions to pick up locations and to track their progress along their destination route.
- **Social Networks:** Many prospective users of D-RIDE software may be wary of making travel arrangements with strangers. Therefore, many rideshare providers have linked their systems with online sites like Facebook so that users will only be matched for rides with individuals within their social network. In addition, some providers, such as RideCell, offer rideshare services to a particular company or institution so that users are matched with members of the same organization.
- **Participant Evaluation:** Other rideshare software companies provide users with the opportunity to rank their experiences with particular drivers or riders. This allows users to

[41] Amey, Andrew M. "Real-Time Ridesharing: Exploring the Opportunities and Challenges of Designing a Technology-based Rideshare Trial for the MIT Community." (June 2010), http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/AMEY_Thesis_Final.pdf

avoid repeating unsatisfactory carpool experiences, and it allows future users to make more informed decisions when they accept or reject drivers or riders.

- **User Profiles:** Most D-RIDE systems allows users to create and save profiles containing information such as name, home and work locations, common routes, and even a photo. Some contain a photo of the driver's vehicle and license number. These profiles allow users to feel like they know more about a potential rider and driver before deciding to share a trip with them.
- **Automated Financial Transactions:** Because many individuals use carpooling as a way to save money, several D-RIDE services allow for drivers and riders to automatically calculate the costs of travel. Some allow users to set their own prices so that ride matches can either be accepted or rejected based on the acceptability of the costs. Others recommend values based on standard IRS vehicle costs or other calculations, such as a pre-fixed cost per mile. Furthermore, some providers use online payment systems like PayPal so that users can make automatic transactions, while others provide a suggested cost so that users can personally work out and agree on a price from there.
- **Incentives/Loyalty Rewards:** D-RIDE providers can offer incentives or loyalty rewards programs by offering points based on a user's frequency of participation. For example, those who use the software more could receive gas cards, free tolls, etc.
- **Transit Information:** Some rideshare services can incorporate information on other modes of transportation, such as shuttle and bus information, so that users can decide if ridesharing really is their best travel option. Also, in the event that a user does not find a ride match, they still information on back-up transportation.
- **User Preferences:** Many rideshare services allow users set their travel preferences. For example, they can choose smoking/nonsmoking, preferred gender of riders/drivers, preferred seat, etc., so that their rideshare experience is more enjoyable and comfortable.
- **Audio Notifications:** Drivers using rideshare applications on a mobile device can receive audio notifications when a match is made or when a rider pick-up stop is approaching so they do not have to interact with their phone while operating a vehicle.

Chapter 4. Scan of Current Practice

4.1 T-CONNECT Current Practice

The major fixed-route CAD/AVL vendors have offered TCP functionality within their products for several years. Agencies where this technology was initially implemented include:

- Ann Arbor Transit Authority (AATA) in Ann Arbor MI, and Fresno Area Express (FAX) in Fresno CA using the Rockwell (now Trapeze) CAD/AVL system; and
- Chicago Transit Authority (CTA) using an Orbital (now ACS/Xerox) CAD/AVL system.

Even though the reliability of TCP functionality has improved since its inception, the way this functionality has been implemented by vendors works in a somewhat cumbersome manner as discussed in Section 3.4.1. Also, it is not convenient for transit customers – they must request a transfer verbally when they board a transit vehicle and may not be informed about whether or not they can actually make the transfer. Further, even though studies have been done describing how multi-agency TCP could be deployed (e.g., the RTA study referred to earlier), it has never been widely implemented in the US. Currently, all instances of TCP have only been deployed within one agency. Our team has been involved in recent field deployments of fixed-route only TCP systems at the following agencies:

- Capital Metro Transportation Authority (a.k.a. CapMetro) in Austin, TX
- York County Transportation Authority (a.k.a rabbittransit) in York, PA
- Wichita Transit in Wichita, KS
- Worcester Regional Transit Authority (WRTA) in Worcester, MA.

Table 4-1shows the current status (Y=implemented, N=not implemented or no evidence available) of mode-to-mode implementation of the T-CONNECT concept in the U.S. As stated earlier, most of the current implementations in the U.S. are for fixed-route to fixed-route bus transfers only.

Table 4-1. Current State of T-CONNECT Implementation by Mode

	FR Bus*	Flex/DR/ Para Bus	Light/Heavy Rail	Commuter Rail	Ferry
Fixed-route Bus	Y	N	N	N	N
Flexible/Demand Response/Paratransit Bus	N	N	N	N	N
Light/Heavy Rail	Y**	N	N	N	N
Commuter Rail	Y†	N	N	Y‡	N
Ferry	N	N	N	N	N

* There are several examples available of fixed route implementations. This technology is becoming commonplace with most fixed-route bus operators equipped with a CAD/AVL system as an add-on technology

** For example, UTA's implementation of TCP to enable transfers between TRAX light rail vehicles and connecting fixed-route buses

	FR Bus*	Flex/DR/ Para Bus	Light/Heavy Rail	Commuter Rail	Ferry

† For example, commuter rail to local fixed-route bus route in Brampton, Ontario, Canada

‡ There is no evidence of the direct implementation of the T-CONNECT concept, but commuter rail systems traditionally provide "unconditional" transfers between systems. For example, transfers are protected between Metropolitan Transportation Authority Metro North and Long Island Railroad in New York City, NY (page 220, "APTS State of the Art Update," US Department of Transportation, March 30, 2006)

4.2 T-DISP Current Practice

The application of T-DISP has been somewhat limited in the US transit industry to date. There are a number of agencies that provide flexibly-routed services and use some degree of technology, but overall the use of flexibly routed service with a technology component is somewhat limited in the US. As discussed in Section 3.2, the move toward coordination of transportation of services has been explored and there are successful projects. Regarding the overall use of transit ITS, based on the *2010 Deployment of ITS: A Summary of the 2010 National Survey Results* from the ITS JPO, approximately 85% of demand response vehicles and 65% of fixed-route vehicles are equipped with CAD/AVL systems. Eighteen agencies reported operating a TMCC. Also, there are several real-time transit information systems, including agency-developed applications such as Transit Tracker in Tri-Met (Portland, OR), vendor-developed applications such as NextBus andr RouteShout, and applications developed by third-parties using open data. Google Transit is another notable information application because it utilizes a de-facto standard called the General Transit Feed Specification (GTFS). Similar standardization has been deployed for real-time information such as the European standard called Service Interface for Real Time Information (SIRI).

So, in summary, there are examples of sites that have made progress regarding coordination of transportation services. There are sites that have implement transit ITS. There are sites that use transit ITS to provide information to customers. There are locations that operate a TMCC. But one complete system or site that has fully-functional T-DISP capabilities does not currently exist. The challenge to developing the Concept of Operations for T-DISP will be to synthesize the lessons learned and practical knowledge gained from the partial application of T-DISP capabilities around the U.S.

There are four existing programs that can provide relevant information in developing the T-DISP concept:

- USDOT's UWR/MSAA initiative;
- FlexBus in Orlando, FL;
- North and East Brainerd Dial-A-Ride routes in Chattanooga, Tennessee; and
- Belbus in Belgium and Flex Sweden

The following subsections highlight the elements of these projects that will provide insight to T-DISP.

4.2.1 USDOT's UWR/MSAA Initiative

The USDOT's UWR/MSAA initiative has demonstrated the planning, design and deployment of technology to facilitate service coordination. In addition to the practical details and lessons learned from these projects, the overall approach is worth noting as a way to move the IDTO bundle forward following the Concept of Operations phase. After the foundation research phase, eight sites were

chosen for grant awards for the planning and designing TMCCs. The following includes brief descriptions of several of sites' TMCC designs.

- *Aiken, SC* – planning and design of an expanded human service transportation network to include more human service transportation providers and vehicle tracking abilities (e.g., GPS), and enable customers to receive information and manage their own trips through a toll-free number and web-based applications.
- *Camden County, NJ* - planning and design of a transportation brokerage system supported by a comprehensive set of transportation modes, and promotion of fixed-route public transportation usage for human service clients through accessibility improvement.
- *Fitchburg, MA* – planning and design of an enhanced communication system that allows a collection of devices to access real-time traveler information and support, such as a telephone, the Internet, wireless personal digital assistants (PDA), or a self-served kiosk or ticket booth at a train station.
- *Kent, OH* – planning and design of a human service transportation network that involves a call center to support trip planning/management and real-time traveler information using ITS (such as interactive voice response (IVR) and web-based applications). This project also incorporates emergency evacuation as a service scenario.
- *Louisville, KY* – planning and design a customer-based traveler information center that not only provides one-stop travel support for all consumers, but also functions as the broker for transportation providers to enable resources sharing and operational coordination. The proposed center aims to incorporate a comprehensive set of transportation services to meet the mobility needs of all area residents.
- *Orlando, FL* – integration with existing ITS deployments to promote multi-jurisdictional coordination, and introduce a universal cashless fare payment system and automated billing functions to enhance human service transportation operations.
- *Paducah, KY* – expansion of an existing call center to cover a larger geographic area and provide around-the-clock access to traveler support. The strengthened call center will add customer-oriented features, such as automated telephone and Internet-based trip reservations and management.

The next phase of MSAA provided grant funds to three of the eight sites to deploy the systems that they had planned and designed. The sites chosen for deployment were Aiken, SC; Paducah, KY and Camden County, NJ. Four of the remaining sites were awarded some continuing funds to implement portions of their conceptual designs.

The Paducah site held a grand opening for the Purchase Area TMCC in March 2010. Paducah's TMCC integrates dispatching and scheduling information from four transportation providers: Paducah Area Transit System, Murray Calloway Transit, Fulton County Transit and Easter Seals West Kentucky. These four transit agencies have come together to form a new entity – the Purchase Area Regional Transit System (PART) that will operate the TMCC. In addition to the coordination of transportation services, travelers will be able to access a searchable database of human service resources, government and educational institutional information.

In August 2010, the Aiken site had a grand opening for their expansion of a $2.9 million transportation resource center that is providing enhanced, coordinated, accessible and cost-effective transportation choices for older adults, people with disabilities and low-income populations in a six-county region. The Aiken site leveraged funds from the American Recovery and Reinvestment Act grant and the

MSAA initiative to deploy the TMCC. The Lower Savannah Council of Governments Aging, Disability & Transportation Resource Center (ADTRC) is providing accessible customer-based travel information and trip planning services to a 4,000 square-mile rural area with a population of 300,000 people. The enhanced call center has added automated telephone and Internet-based trip reservations and management. The center, through coordination of services, has expanded to provide service to four counties that previously had no access to transportation services.

The third site to receive funds to deploy their system is in Camden County, NJ. Their project includes the coordination of faith-based entities who provide transportation (e.g., church vans) and the local Workforce Investment Board. Their plans include implementing automated scheduling software, setting up a call center to reserve rides, providing customer information over the phone and a website, and installing on-board technology. The deployment is currently underway.

4.2.2 FlexBus in Orlando, Florida

Lynx, the public transit agency in Orlando, FL, developed a concept of operations, functional requirements, and implementation and business plans for FlexBus service. The project is expected to enter a demonstration phase in late 2011/early 2012. The proposed FlexBus service consists of operating a station-to-station transit service that utilizes certain roadway improvements and ITS applications to improve mobility in the Altamonte Springs area, a major activity center in the northern part of the Orlando metropolitan area. The service will operate between designated locations such as Altamonte Mall, Florida Hospital and the future commuter rail station. The FlexBus concept of operations is to serve stations at designated locations according to the user's request rather than by a fixed schedule. The FlexBus service will be integrated with the proposed commuter rail service, and the existing and future bus networks. The intent of the FlexBus system is to achieve greater operational effectiveness, cost efficiencies, travel speeds and customer responsiveness than traditional transit services.

The FlexBus system will include targeted infrastructure improvements such as short segments of bus-only lanes; attractive and comfortable shelters; and kiosks offering customer information. The FlexBus service will employ transit ITS applications to facilitate vehicle location, scheduling, dispatching, routing, trip assignment and manifesting capabilities, and to utilize customer user interface devices to allow customers to request service in real-time or in advance. Briefly, FlexBus will operate as follows. A passenger can access the service at FlexBus stations in designated locations. Requests for service will be made either in real-time or up to 24 hours in advance via the following:

- Kiosks at a station (addressed as station kiosks in this document) or kiosks located adjacent to a building or remote to a station (addressed as remote kiosks in this document);
- The FlexBus website; or
- An interactive voice response (IVR) phone system.

The trip requests made via the website and IVR phone system will be available only to registered users of the FlexBus service. The FlexBus vehicles in service will continuously receive work assignments through mobile data communication from the control center. These work assignments will be generated through an optimized scheduling, assignment and electronic manifesting process. The FlexBus operation will be dependent on various ITS technologies that will be installed and deployed:

- Automated scheduling and dispatch software;
- CAD/AVL;
- Automated Annunciation System (AAS);

- On-board Surveillance System;
- On-board Validation of fare payments for the trip[42];
- Kiosks;
- DMS at Stations;
- IVR Enhancement;
- FlexBus website enhancement;
- Maintenance Software Integration; and
- Data Management System.

4.2.3 North and East Brainerd Dial-A-ride Routes in Chattanooga, Tennessee

The Chattanooga Area Regional Transportation Authority (CARTA) has undertaken a phased ITS implementation program that includes fixed-route, demand response and flexibly-routed service. The transit ITS components for their operation include:

- Automated scheduling (all three modes);
- CAD/AVL;
- AAS;
- DMS;
- Real time information systems;
- On-board surveillance;
- Public Wi-fi on-board vehicles;
- Automated fare collection; and
- Vehicle component monitoring.

The flexibly-routed service was in operation prior to the transit ITS implementation. The service operates between three designated points (Eastgate Town Center, Eastwood Manor, and Fox Plaza, which are retail centers) throughout a neighborhood and can deviate on request from a passenger. Passengers may wait at the connection points, call for a pick up along the way (in a designated zone from the main pick up point) or wait at a designated bus stop along the way. The use of transit ITS will automate the manual process of having customer service representatives contact operators over the radio to determine location and verify if they are able for a pick up. The use of on-board mobile data terminals and automated scheduling programs allows trips to be slotted into the next available time and customer service representatives can let the caller know right away when the bus can pick them up, and if their trip can be completed as requested. The overall ITS project is in the final stages of system acceptance as of fall 2011. The basic functionality of the flexibly-routed service has been demonstrated but data communication issues (cellular) which were discovered in the pilot testing phase are being addressed as of October 2011.

[42] Fare payment for FlexBus trips will be completed at a kiosk, on the phone or on the FlexBus website (described in Sections 8 and 9), and validated on-board FlexBus vehicles. Fare payment for FlexBus trips will be processed by the LYNX financial clearinghouse (back office).

4.2.4 Belbus in Belgium and Flexlinje in Gothenburg, Sweden

Outside the US, two examples of flexibly-routed service using technology in Europe share operational characteristics and provide insight to T-DISP. The Belgian city of Hasselt with a population of 150,000 implemented a flexibly-routed service called Belbus. The service was implemented to replace earlier fixed route service and functioned similarly to demand-response service. Customers call one hour before they need to be picked up. They walk to a designated stop to be picked up. Drivers receive manifests on-board the vehicle's mobile data computer as each trip is scheduled. Belbus uses in-house software called RING for scheduling, dispatching and automatic vehicle location. Their communications systems include Mobitex (analogous to text messaging service for cellular service) and a radio. Figure 4-1 provides an overview of the Belbus operational processes. Belbus service was replicated throughout several rural areas throughout Belgium.

Another example of flexibly-routed service using technology is in Gothenburg, Sweden, which has a population of 500,000. Looking to reduce costs for the Special Transport Services (demand response service), a flexibly-routed service called Flexlinje was implemented. The service operates with two fixed end points between which vehicles depart every 30 or 60 minutes. The vehicles operate to "meeting points" between the two points – only points for which a reservation was made are served. These "meeting points" are no further than 150 meters from a customer's origin (typically their home). The service uses PLANET reservations, scheduling and dispatching software. Passengers make a reservation using interactive voice response (IVR) system and receive an automated trip notification 15 minutes prior to their pick up. The use of a magnetic card (swipe card) allows passengers to book their return trip within 15 minutes of departure.

Both the Belbus and Flexlinje examples indicate that there are solutions to providing transit services in lower density environments with dispersed origins and destinations. The system's technology is similar to that deployed in the US. Similar to that reported in the US for flexible services, passengers of these systems report increased mobility and access to services, especially for medical trips. Finally, not everyone in these areas has access to a mobile device or a computer, especially elderly or people with disabilities.

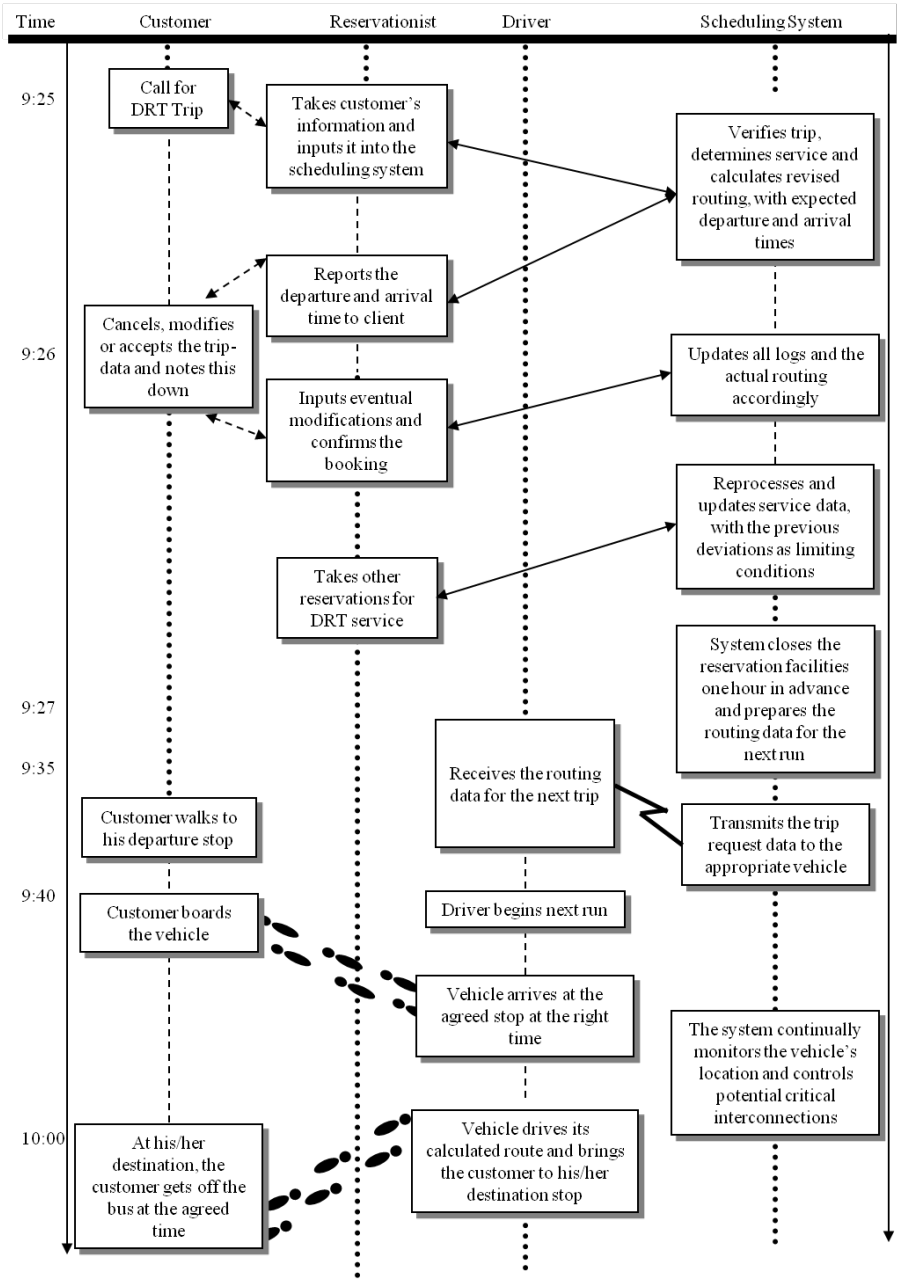

Figure 4-1. Overview of the Operational Process

4.3 D-RIDE Current Practice

Many business entities, both privately and publicly-funded, are currently conducting further research on D-RIDE technologies, or are testing and implementing these technologies. This section summarizes recent or ongoing federally- or state-funded D-RIDE projects as well as companies currently offering new D-RIDE technologies.

Federally-Funded Projects:
The Santa Barbara County Association of Governments (SBCAG) was awarded a 2010 Federal High Administration (FHWA) **Value Pricing Pilot Program (VPPP)** grant to pilot a D-RIDE project in two corridors of Highway 101 in Santa Barbara County. The purpose of the pilot is to:

1. Test the performance of D-RIDE as a tool to reduce traffic congestion;
2. Test D-RIDE in the specific markets of commuters and college students;
3. Test how cash rideshare incentives and automated cost sharing systems affect travel behavior;
4. Determine the number of participants needed to support a D-RIDE system; and
5. Collect information on the type of trips most conducive to D-RIDE.

SBCAG has not yet awarded a contract to a D-RIDE provider, so results have not yet been published on the details of the technology or its operation.[43,44]

The FHWA is also sponsoring a scan study of the casual carpooling/slugging phenomenon through the **Exploratory Advanced Research (EAR)** Program. Experts looked at organic, non-technology driven ridesharing along the I-95 corridor in Virginia, in Houston, Texas, and in the San Francisco Bay Area (webinar). The Houston scan concluded that casual carpooling is concentrated in the morning hours, between 6 and 9 am, during HOV 3+ periods. In the Northern Virginia DC area, a significant HOV lane area, the scan showed that more than 10,000 people slug to work every day.[45]

A 2011 **Small Business Innovation Research (SBIR)** grant was awarded to a D-RIDE project in San Diego that will investigate ways to sync D-RIDE software with an in-vehicle computer. The project will also explore in-vehicle technology that can calculate how many passengers are in a car traveling in a HOV lane, either with hardware such as seat sensors, or with software applications.[46]

In 2009, the Washington State Legislature directed the **Washington State Department of Transportation (WSDOT)** to conduct a rideshare pilot project along the SR 520 corridor. The purpose of the project was to determine whether D-RIDE could help mitigate traffic congestion and to provide a detailed cost-benefits analysis of D-RIDE technology. The rideshare system was provided by Avego and consisted of an application for GPS-enabled iPhones that:

- Provided ride verification;
- Captured trip travel time, location and distance; and
- Allowed for micro-payment capabilities between drivers and riders, based on miles traveled.

The program also included security features, such as a pre-screening process for participants, and a user evaluation system. The pilot occurred from January through May 2011, and included 962 participants, including 842 regular SR 520 commuters. WSDOT is working to produce a final report on the project results.[47,48]

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[43] SBCAG Request for Proposals: Santa Barbara Dynamic Ridesharing Pilot Project. http://www.trafficsolutions.info/PDFs/SB_Dynamic_Ridesharing_RFP.pdf

[44] Oliphant, Marc. USDOT Resources: Overcoming the Challenges of Congestion Pricing 2011 FHWA Webinar Series. Session 6: Dynamic Ridesharing and Congestion Pricing (Webinar Transcript). (28 July 2011). http://www.fhwa.dot.gov/ipd/revenue/road_pricing/resources/webinars/transcript_072811.htm

[45] Ibid.

[46] Ibid.

[47] "Carpool Pilot Project." Washington State Department of Transportation. http://www.wsdot.wa.gov/Transit/Rideshare/carpoolpilot.htm

Other Companies and Programs:

Avego is a real-time ride-matching system that utilizes the internet and offers an iPhone application. Up to 30 minutes in advance of travel time, drivers with GPS-enabled iPhones enter their destination to offer rides; riders enter their desired location to find drivers on the same route. Avego allows drivers and riders to automatically exchange money based on the length of the trip, and provides a user-rating system. It also establishes a convenient pick-up point along the driver's route and within easy walking distance for the rider. Participants much register before using Avego, and, as a security measure, users receive PINs when matched for a ride, which they must share with the driver/rider they are paired with.[49]

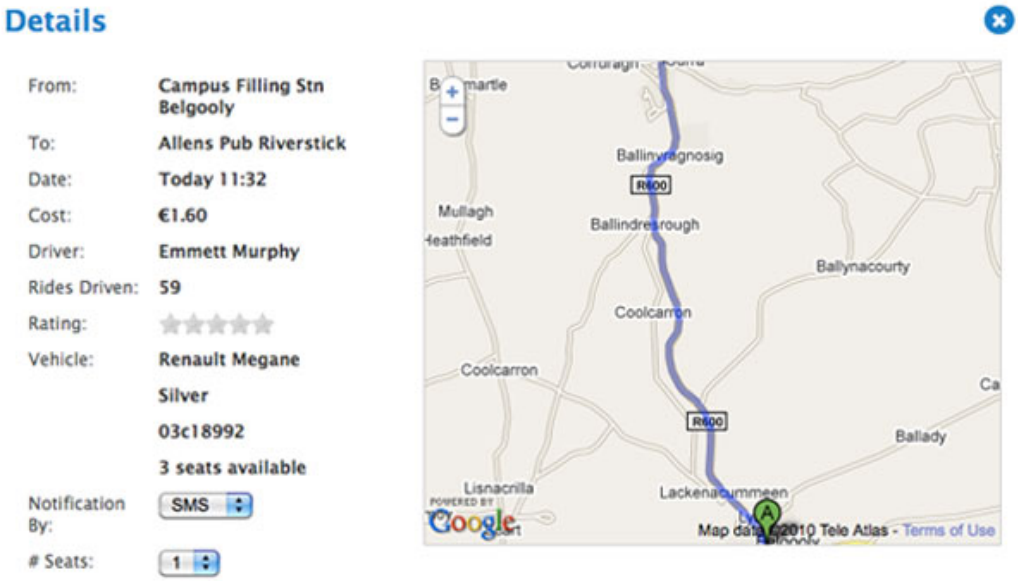

Figure 4-2. Screenshot of match information details on Avego's iPhone application.
Source: Avego Website (http://www.avego.com/st/index.php)

RideAmigos began as a taxi-sharing network in New York City. It has developed into a website for travelers to make consistent carpool arrangements. Users enter their desired commutes, and can then either contact a matching "amigo" or post a commute if no match is found. Once matched, it is up to the user to arrange meeting times and locations with their matches. RideAmigos also provides ridesharing arrangements for major events, such as the Grammy Awards.[50]

Participate is a real-time ridesharing application for the iPhone. It is a free application, available to the public, world-wide. The Participate system identifies the user's location using the phone's GPS

[48] Misek, Shamus. USDOT Resources: Overcoming the Challenges of Congestion Pricing 2011 FHWA Webinar Series. Session 6: Dynamic Ridesharing and Congestion Pricing (Webinar Transcript). (28 July 2011). http://www.fhwa.dot.gov/ipd/revenue/road_pricing/resources/webinars/transcript_072811.htm

[49] Heinrich, Susan. "Implementing Real-time Ridesharing in the San Francisco Bay Area." (June 2010). http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/Implementing_Real-Time_Ridesharing_Heinrich.pdf

[50] Ride Amigos Website. "About Us." http://rideamigos.com/about

capabilities. The user enters his or her start and end locations and arrival times to search for real-time or scheduled rides with other users who are seeking riders or drivers at the same time. As of May 2010, Participate has 2,944 registered users, and the application has been downloaded 30,000 times.[51]

Trip Convergence, Ltd., based in Auckland, New Zealand, encourages ridesharing in part by providing "flexible carpooling" technology through an operational website. Members walk, ride or drive to meeting places to form fuller cars in order of arrival, traveling to pre-established destinations. Flexible carpooling includes a ride credits system that entitles you to a ride for every ride you give, as well as a guaranteed ride home system that offers free taxis to users with no other available transportation.[52]

TerpRiders is a carpool program at the University of Maryland intended to reduce the number of single occupancy vehicles on campus. Utilizing an online social-networking application (Facebook), interested riders can post messages and exchange information regarding both regularly scheduled, temporary, and/or ad-hoc carpooling opportunities with other TerpRiders. Students and faculty can arrange carpools and receive a TerpRider permit when they turn in two regular parking permits. TerpRider permits save users 50% off the cost of their parking registration, and they are eligible for priority parking in convenient locations on campus.[53]

[51] Heinrich, Susan. "Implementing Real-time Ridesharing in the San Francisco Bay Area." (June 2010). http://ridesharechoices.scripts.mit.edu/home/wp-content/papers/Implementing_Real-Time_Ridesharing_Heinrich.pdf

[52] "Introducing Trip Convergence Ltd from Auckland, New Zealand." http://www.tripconvergence.co.nz/solutions.pdf

[53] "Share the Ride." University of Maryland Department of Transportation Services. http://www.transportation.umd.edu/share.html

Chapter 5. Summary of Results and Synthesis of Findings

This section is a summary of the various findings, impacts, performance measures, and lessons learned gleaned from the research information presented in the previous sections.

5.1 General Findings

T-CONNECT

- Literature available on T-CONNECT-type systems is limited, but there is some.
- Evaluation of the UTS TCP program revealed that the TCP service has been well regarded by the stakeholders, especially travelers.
- Fixed-route to fixed-route TCP is the only T-CONNECT-type implementation that exists today in the United States.

T-DISP

- Reports that addressed T-DISP coordination consider a number of factors that directly relate to T-DISP.
    - The first is that attempts for coordination of services are not without challenges, and these challenges are complex.
    - Second, technology has assisted in overcoming the coordination barriers, but technology alone will not overcome all the barriers.
    - The third is that the application of technology and coordination together has been successfully demonstrated in a limited way in a variety of operating scenarios and environments (urban, suburban and rural).
    - Finally, travelers and their needs represent a critical part of the T-DISP concept, particularly in the information they are provided about transportation services and how they access this information.
- TCRP reports indicate that there are few states that include transit information on 511; there are very few adverse impacts from including transit information; and that even modest benefits for including transit information in 511 justify the costs.

D-RIDE

- Ridesharing projects have employed a range of technologies, from cell phones and pagers, to information kiosks, to the internet and smart phones. Current D-RIDE projects are evolving to a more mobile and internet-based technologies.
- Findings showed that a fear of strangers was often cited as a reason for not sharing rides, highlighting the need to allow potential carpoolers to target others who are part of their social networks. Therefore, D-RIDE programs targeted towards specific institutions or companies, as in the Seattle Smart Traveler and the Germany M21 programs, can make participants feel more comfortable making travel arrangements with would-be strangers.

- Providing familiar, commonly-known meeting points and drop-off locations in additions to users' homes is another way to make users feel more comfortable using a rideshare service.
- Marketing is necessary to draw an initial crowd to a D-RIDE system, and incentives (e.g., iPhones offered by Avego or free BART tickets offered by RideNow) can draw more users.

5.2 Benefits and Impacts

A summary of the benefits and impacts of these applications is listed below.

T-CONNECT

A well implemented T-CONNECT system offers the following potential benefits:

- Reduced frequency of missed connections for transit users
- Fewer cascading delays
- Decrease in expected travel time
- Increase in travel time reliability
- More reliable, more accessible, and a greater amount of information available to transit users regarding connections
- Decreased uncertainty among transit users regarding missed connections

While the literature available on T-CONNECT-type systems is limited, research indicates some positive reviews of T-CONNECT implementations:

- In the UTA TCP study, evaluation revealed that almost 86% riders (out of a total of 522 survey respondents) were satisfied with their connection experiences

T-DISP

A well implemented T-DISP system offers the following potential benefits:

- Synthesized travel options made available to travelers
- Improved understanding of travel options to transit users
- Decreased uncertainty among transit users regarding public transportation trips
- Decreased travel time for transit users
- Increased system capacity and efficiency

Literature review has indicated the following benefits and impacts:

- TCRP reports indicate that benefits for including transit information on 511 increases in regions where there are multiple transit providers and a significant number of travelers who decide on mode choice based on daily traffic and transit conditions.
- There are significant impacts to the public and private transportation providers. The impacts include changing business practices, purchase and incorporation of new technology, and possible loss or gain of revenue.

D-RIDE

- D-RIDE specifically benefits locations with heavy traffic congestion, such as cities and their surrounding metropolitan areas. During the morning "rush hour" period, from around 6am to 9am in most major cities, thousands of travelers drive towards a single concentrated area, providing ample opportunity for ridesharing.

- The benefits of D-RIDE can affect multiple aspects of society, including the environment. By increasing the flexibility of ridesharing, D-RIDE can create enough of a mode shift to reduce vehicle load on the roadway, mitigating traffic congestion, and subsequently lowering emissions and energy consumption. Research has shown that enhancing policies to increase carpooling is the most effective strategy to reduce energy consumption aside from prohibiting driving.
- D-RIDE is capable of improving network efficiency by allowing transportation infrastructure to be used more effectively by focusing on “person throughput versus vehicle throughput,” minimizing the frequency of repair and construction costs to government agencies.
- D-RIDE programs can provide socially-necessary transportation alternatives to certain groups who may not have easy access to public transportation, such as senior citizens and college students
- Participants in carpool arrangements save money due to shared travel costs, and time due to the availability of HOV Lanes. Their employers benefit from the reduced demand for parking infrastructure.

5.3 Performance Measures

T-CONNECT

- Transfer passenger waiting time (from incoming vehicle).
- In-vehicle passenger waiting time (for the outgoing vehicle).
- Downstream passenger waiting time (for outgoing vehicle).
- Rate of downstream transit missed connections.
    - T-CONNECT has the potential to increase downstream missed connections due to the increased variability of transit schedule deviations upstream.
    - Any future T-CONNECT implementation should carefully monitor downstream effects in the development and refinement of TCP algorithms.

T-DISP

- Customers served per revenue hour (expected to increase due to improved service).
- Average passenger travel time (expected to decrease due to shorter waits and more direct routes).

D-RIDE

- Person throughput (as opposed to vehicle throughput), especially during peak period travel times and on high demand road facilities (such as bridges and tunnels).
    - As a key measure of network efficiency of transportation infrastructure, person throughput would be expected to increase under the D-RIDE scenario, given that the program incentivizes and enables increased carpooling.
- Transportation accessibility (among typically low transit-accessible groups, such as senior citizens and college students).
- Parking infrastructure demand (expected to be reduced).

5.4 Issues

T-CONNECT

The RTA Study revealed that several key issues must be addressed by a T-CONNECT-type system:

- Electronic information exchange is necessary but it is also important to ensure the consistency of coordination on business processes related to transfers (e.g., determination and approval of "hold-until" time by dispatchers in a multi-modal/multi-agency environment, and operator's response to "hold-until" instructions);
- After-the-fact review of transfer trips, especially where inter-agency transfers are involved, should be conducted;
- A "maximum allowed" waiting-time should be defined;
- The definition of TCP should be by route and not by vehicle;
- Manual intervention by a dispatcher should be allowed by automated TCP systems; and
- The accuracy of real-time locations of transit vehicles involved in transfers should be ensured

T-DISP

T-DISP research has revealed several issues that have limited the success of T-DISP-like systems and will pose challenges to future T-DISP implementations:

- Difficulty in coordinating among multiple transit agencies, funding programs, and local, state, federal entities
- Lack of effective coordination structures has contributed to
  - Service area gaps
  - Limited services
  - Confusing and low quality customer service
- Limited deployment of real-time transit information systems (due to cost concerns, institutional issues, and liability concerns regarding providing inaccurate information)

D-RIDE

The following issues must be addressed for future D-RIDE implementations to be successful:

- Implementing controls to minimize safety concerns regarding sharing a vehicle with a stranger
- Lack of established ride share infrastructure (meeting points and drop-off locations)

5.5 Lessons Learned

T-CONNECT

- In UTA, a majority of operators surveyed (70%) thought that it would be easier for them to wait if their routes were not tightly scheduled.
- The UTA evaluation found that downstream bus-to-bus connections were found to be jeopardized due to late departures at TRAX stations due to operator's wait as per "hold until" instructions.

- One of the key findings of the Brampton, Ontario research was that the outgoing transit vehicle should be held if the incoming vehicle is experiencing “moderate” (to be defined by agencies based on headways) delays. However, in the event of “long” (to be defined by agencies based on headways) delays with the incoming vehicle, the outgoing vehicle should operate according to its schedule.
- In order to enable real-time data exchange, a transit agency should have data sharing arrangements in place, especially in the event that manual intervention is required from dispatch in a multi-modal/ multi-agency environment
- Agencies must establish a policy for how long vehicles should be held.
- Accurate real-time vehicle location is the key to a successful T-Connect system

T-DISP

- A critical element for T-DISP is that the ability to provide relevant information to customers is highly dependent on the underlying systems, since these systems generate and/or manage the data that forms the traveler information needed by a traveler. For example, real-time information can be calculated using a predictive algorithm that uses vehicle locations (from a CAD/AVL system) together with information on schedule adherence (also from a CAD/AVL system) to disseminate information to a variety of media (e.g., phone, Internet, dynamic message sign).

D-RIDE

- D-RIDE systems that incorporate accurate GPS technology mitigate several concerns of potential users. First, GPS enhances ridesharing services utility by providing directions and convenient meeting locations. In one survey, 90% of responders said rideshare systems should provide driving directions so that the driver can easily find and pick up the passenger. Secondly, GPS can save users’ time by automatically detecting their starting locations. Lastly, GPS can enhance security for passengers by allowing them to track their route and confirm that the driver is not going off-course.
- Applications that run on smart phones and other mobile devices fulfill users’ desires for easily accessible, convenient rideshare services. In several projects (Bellevue Smart Traveler, TransAction Network), participants found rideshare systems overly complicated and the matching process too long. With mobile devices, users can establish rideshare arrangements on-the-go and can take their ride-match contact and trip information with them when they go to meet drivers/riders and throughout the trip.

Chapter 6. Concept Development

By definition, concept development is a process driven by a set of customer needs and target requirements (and eventually, specifications), which are then converted into a conceptual design(s) and potential technological solution(s). The customer needs will be identified during Subtask 2.2 when we solicit stakeholder input on transformative goals, performance measures and user needs. The final concept of operations document, which will be developed in Subtask 2.3, will be a guideline for the implementation of the IDTO bundle.

However, given the current state-of-the-practice with T-CONNECT, T-DISP and D-RIDE, and the SAIC Team's hands-on experience with the implementation of current technologies that reflect these concepts, we can begin to define the proposed implementation of these technologies. Further, we can describe the potential impacts of IDTO implementation from an institutional, operational and technical perspective. The following subsections cover initial thoughts about the implementation of the IDTO bundle and the impacts resulting from the implementation.

6.1 Proposed IDTO Implementation

Given the research described in this report and the upcoming tasks, this subsection covers the process that we propose to USDOT for the eventual implementation of the IDTO bundle. The first step in this process is gathering stakeholder input on the needs associated with the three mobility applications. The purpose of this step is "to solicit stakeholder input in identifying transformative benefits or goals for [each] application, corresponding performance measures, and user needs for [each] application, which shall be used in the development of the IDTO Concept of Operations and functional requirements."[54] This step will include conducting a webinar and face-to-face meeting to obtain this stakeholder input. The input will consist of the stakeholders' view of the transformative benefits or goals for each application, performance measures and user needs.

The second step leading to implementation is the development of the Concept of Operations. This step will incorporate the findings from assessment of relevant prior and ongoing research described in this report and the stakeholder input received in the previous step. The final Concept of Operations document will be a guideline for the implementation of the IDTO bundle. It will identify connections and attributes of the three applications, and the interfacing entities and systems. The Concept will include operational scenarios for the three applications. Stakeholders may use these scenarios as they consider those scenarios they would like to include in the final Concept of Operations.

The third step is the development of the functional requirements, qualitative and quantitative performance targets for each functional requirement that must be accomplished in achieving the transformative goals identified in the prior step, and high-level data and communication needs. System Requirements serve as the foundation for developing an effective solution. In order to ensure successful implementation, system requirements must be correct, compatible, complete, clear, feasible, verifiable, traceable, and modifiable. This assessment report will enable the project team to address the needs, interface and capability requirements identified during the research. The Team will

[54] Statement of Work, *Concept Development and Needs Identification for Integrated Dynamic Transit Operations (IDTO)*

convert these items into a set of requirements in a matrix format that ties each requirement back to the original driver. The team will address all required aspects of the development to support defining the functional and performance requirements including the software application, hardware components, network protocols, data needs, and interfaces that the applications will need to support. This will help ensure that the applications support the range of capabilities desired by USDOT including interfacing with the Connected Vehicle system and other identified systems.

The third step includes the identification of high-level data and communications needs based on the Concept of Operations, and Functional and Performance Requirements.

The final step prior to deciding whether or not IDTO applications should be demonstrated is determining how realistic it will be to begin further development. This requires an understanding of the criteria for testing the applications. The purpose of this task will be to assess the technical and non-technical issues related to the field testing of the IDTO System

6.2 Impact of the Proposed IDTO Implementation

As described throughout this report, there are numerous impacts resulting from the implementation of the IDTO applications as they are currently defined. While the user needs, Concept of Operations and requirements will be developed after the submission of this report, the potential impacts of IDTO implementation are not completely known at this time. However, we are aware of potential impacts based on our field experience and the current state-of-the-practice of the three applications. The following subsections briefly describe the potential impacts in three categories: institutional, operational and technical.

6.2.1 Institutional Impact

The implementation of the IDTO bundle could have several impacts in institutional and organizational areas. First, the existing institutional environment in the location or region where the implementations will take place will be a key factor in the success of the deployment. If the institutions involved have not worked together or coordinated before, there could be a significant effort needed to bring the stakeholders together. This institutional issue also extends to application vendors, who traditionally provide proprietary solutions and do not share information with their competitors. And there may be changes necessary within the organizations participating in the implementation. For example, staff may need to be reassigned to focus on the IDTO implementation.

Second, the implementation may require that the participating organizations conduct business in a different way, as was mentioned earlier in the discussion of T-DISP. This may lead to reorganization or at least a change in the way that service is operated and dispatched, and the way that customer service is structured. Further, if the IDTO implementation provides new tools for operations and customer service staff, their individual roles and responsibilities may change.

Finally, from a traveler perspective (although they are not technically part of an institution or organization), there will be significant impacts resulting from the implementation. Travelers will have access to more information with which they can make more informed choices about trips from several perspectives. More accurate, timely and consistent information will facilitate travelers' decisions regarding mode(s), routes and timing. Further, having access to complete and consistent information about all transportation services in a region regardless of the service operator/provider will help travelers make trips that they may not have made on transit.

Other potential institutional impacts include:

- Changes required to the existing institutional environment in the location(s)/region(s) being considered for deployment;
- Financing necessary for technology procurement, implementation, and on-going operations and maintenance;
- Coordination with other providers and agencies in order to jointly procure systems and/or exchange data and information;
- Lacking ITS technical experience - this can relate to either human or computer resources;
- Changes needed in the technology vendor community to successfully develop and implement new systems to accomplish the goals of the three IDTO technologies and
- Changes needed to ensure that technology vendors are familiar with or have experience with coordinated operations and transportation services.

6.2.2 Operational Impact

From an operational perspective, significant impacts are expected after the IDTO applications are implemented. Currently, many transit agencies operate independently and, as mentioned earlier in this report, do not coordinate their services with any other agencies. While coordination results in a more efficient and effective mechanism to provide transit services, it does cause changes in the way agencies schedule and operate their services. Since the IDTO applications require varying levels of agency coordination, we can expect these changes.

According to a California Partners for Advanced Transit and Highways (PATH) report[55], "If accepted by transit operators, they will change their operating processes and maybe even corporate cultures accordingly to satisfy customers' needs. The challenge for transit operators is to provide transit services under an array of policies and objectives from different governmental and regulatory agencies and satisfy the needs of the traveling public simultaneously."

In anticipating operational impacts, our team will examine the results of the Integrated Corridor Management (ICM) projects in Dallas and San Diego. We anticipate that there will be lessons learned from an operational perspective - the Federal evaluation being conducted by the Volpe National Transportation Systems Center is looking at this in addition to examining other impacts.

The implementation sites which are selected eventually will affect the specific operational impacts. However, several preliminary operational impacts could include:

- Nature of the existing operations among transportation providers (e.g., modes and services);
- Nature of the interface(s) among existing and proposed technology systems required for IDTO. For example, systems may operate via central, physical centers, virtual centers with centralized hardware and databases, or virtually with no centralized hardware or database support.
- Role of each agency and their operations in both the entire transportation system and in the proposed IDTO operation.
- Nature of the proposed changes caused by the deployment of the IDTO applications in the transportation system.

[55] Amy Lam and Mark A. Miller, "Investigating Institutional Aspects of Multi-Agency Transit Operations-Review of the Literature," California Partners for Advanced Transit and Highways (PATH) Working Paper UCB-ITS-PWP-2002-3, Institute of Transportation Studies, UC Berkeley, May 1, 2002, http://escholarship.org/uc/item/5d14h128#page-1.

6.2.3 Technical Impact

Technical impacts from IDTO implementation are expected, particularly given the current Connected Vehicle initiative and the trend toward increasing ownership of “smart” mobile devices. One impact is based on the fact that there will likely still be old (and perhaps unintelligent) infrastructure in the location/region where IDTO is deployed, so technically, there will have to be a way of incorporating this old infrastructure into the physical and logical architecture for the IDTO applications. As was mentioned earlier, while current TCP technology exists in a limited way, the future T-CONNECT systems will still need to incorporate “manual” processes for a number of reasons. For example, if the technology should fail, there should still be a way to manually perform transfer connection protection functions.

Further, there will be travelers who do not have a mobile device capable of functions needed to interact with T-CONNECT, T-DISP and D-RIDE applications. Agencies will have to account for these individuals and ensure “information equity,” which is defined as providing information via at least two dissemination media, and in both audio and visual formats.

Other technical impacts may include the following:

- The automation of functions. In some cases, automation can alienate agency staff as well as customers, thus the benefit of technology may not be realized;
- The nature of the existing ITS/technologies and the ability to use these or integrate these with new technologies in the agencies/region being considered for the deployment;
- A lack of technical guidance and information for agency staff who will be directly involved in the IDTO implementation; and
- A lack of ITS infrastructure (alluded to earlier), especially in rural areas.

Chapter 7. Next Steps

This document was intended to present a comprehensive assessment of relevant research related to Integrated Dynamic Transit Operations (IDTO) that might impact the development and eventual deployment of an IDTO system.

Findings from this task, in particular the institutional, operational, and technical impacts identified in Section 6, shall be used to inform stakeholder discussions on transformative goals, performance measures, and user needs (Task 2.2) and ultimately direct the development of the current state definition for the Concept of Operations (Task 2.3). The Concept of Operations document will be a guideline for the implementation of the IDTO bundle and will identify connections and attributes of the three applications as well as the interfacing entities and systems.

It is anticipated that this Assessment will be a "living document," such that any new research or findings that the team encounters relevant to IDTO will be integrated into future versions of the document.

Appendix A: List of Abbreviations/ Acronyms

The following is a list of the acronyms described in this document:

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
D-RIDE	Dynamic Ridesharing IDTO application
FHWA	Federal Highway Administration
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
IDTO	Integrated Dynamic Transit Operations
ITS	Intelligent Transportation Systems
MDT	Mobile Data Terminal
PDT	Project Development Team
PMP	Project Management Plan
SRS	System Requirements Specifications
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Process
SOW	Statement of Work
T-CONNECT	Transfer Connection IDTO application
TCP	Transfer Connection Protection
T-DISP	Transit Dispatch IDTO application
TMO	Transportation Management Organization
TRB	Transportation Research Board
USDOT	United States Department of Transportation

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