Concept of Operations for An Interactive Transit Station Information System (ITSIS) Using Connected Vehicle Technologies

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1.0 Introduction

This study aims to develop and test an innovative Interactive Transit Station Information System (ITSIS) that uses Connected Vehicle technologies to enable the real-time interaction between passengers and transit systems at bus stations. The objective of ITSIS is to better inform transit travelers during their trips and to enable dynamic transit operations to better serve travelers. The ultimate goal is to make transit more friendly and attractive to the traveling population such that transit will become a viable choice for travel and an integrated part of the solution for congestion relief. The findings from this study will provide valuable stepping stones to incorporate and deploy broader interactive information into our transit ITS systems and operations.

1.1 Statement of Problem

Although public transit is an important means of transportation for many American travelers, it is still largely underutilized. Encouraging greater transit use is seen as part of the integrated solution to the congestion problem in metropolitan areas and has been a major objective for transportation innovations such as Integrated Corridor Management (ICM). The real-time transit traveler information system has been one of the key innovations to enhance the user experience and to encourage mode shifts. Effective TTIS solutions have already been implemented worldwide and are providing essential core travel information to users, empowering them to make better transportation choices. While this information is typically still provided to travelers using dynamic messaging signs (DMS) at fixed locations, recently, it is becoming more common for it to be made available through the internet (website) and personal mobile devices (e.g., smart phones) with enhanced connectivity applications installed on them (FTA, 2011). In some cases, real-time information is simply “pushed” to interested individual users without the need for significant user input. However, there have been significant efforts in developing interactive information system for transit stations in the United States. As we look at moving to a more robust interactive system, there exist several technical gaps in the current implementation of TTIS that must be overcome. These can generally be grouped into three major categories.

Limited coverage

The use of Computer Aided Dispatching (CAD) and GPS-based Advanced Vehicle Location (AVL) systems is now well-established in transit bus and light rail networks. By 2010, 60.1% of buses and 55.3% of light rail vehicles were implemented with CAD/AVL systems (APTA, 2011). However, only about half of these installations have been used to provide transit traveler information (RITA, 2010).

Low update rate

Real-time information collected by CAD/AVL systems is of particular relevance to TTIS. For the state-of-the-art CAD/AVL systems, the polling interval to get a transit vehicle’s location update is generally between 60 and 120 seconds (TRB, 2008). This long polling interval makes it difficult to generate accurate vehicle arrival predictions when transit stations/stops are closely located, as is the case in most metropolitan transit systems. It also makes it difficult to provide timely departure information. The built-in delay in transmission of information packets clearly impacts the accuracy of information presented to travelers in metropolitan areas.

Lack of "personalized" information

The information displayed on a Dynamic Message Sign located at a transit station or stop typically shows the predicted arrival(s) (or countdown) of the next transit vehicle(s). Although this type of information has proven to produce significant passenger benefits in generating higher passenger satisfaction levels (Dziekan & Kottenhoff, 2007), it does not include other valuable information for passengers, such as the transfer and connection information (40% of transit trips involve at least one transfer between transit vehicles (APTA, 2007)).

Connected Vehicle technologies can potentially offer solutions to fill these gaps.

1.2 Overview of this Research Project on ITSIS

This project is to develop and field test a prototype ITSIS using Connected Vehicle technologies to research three important questions:

- Can the Connected Vehicle and Infrastructure technologies envisaged by the USDOT enable more timely and accurate passenger information, and an interactive transit station information process?
- Can ITSIS benefit passengers by allowing them to interact with transit systems for obtaining 'personalized' information?
- Can ITSIS enable more efficient operation of transit?

In this project, we will stress using a combination of innovative real-time data capture and data management methodologies to enable improved dynamic mobility for transit and intermodal applications. ITSIS provides for the next jump in improved level of service to passengers and supports future enhanced transit operations by enabling travelers to *interact* with transit systems on their current trip plans and real-time needs. This results in better passenger information service for passengers and better origin-destination (O-D) data collection for transportation providers. The addition of real-time interactive sessions with travelers will expand the horizon for public transit management, offering them the opportunity to both improve service level and facilitate better operational and planning decisions.

The ITSIS system will be field tested at the California Connected Vehicle test bed in Palo Alto, California. This Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) test bed, implemented by Caltrans and California PATH, is comprised of 11 signalized intersections two-miles in length along State Highway 82 (also known as El Camino Real). Roadside units (RSU) units have been installed on the test bed with up-to-date software and hardware packages that meet the Connected Vehicle standards. A backhaul network will also be installed to transport data to/from RSUs and centralized systems.

The Santa Clara Valley Transportation Authority (VTA) is a perfect partner in this project since they operate in the California Connected Vehicle test bed area. VTA operates two bus routes that travel along the El Camino Real test bed, the conventional bus service Route 22 and a bus rapid transit service Route 522. Appendix A provides route maps for these two bus routes. Route 22 makes 88 trips every weekday in both northbound and southbound directions, and Rapid 522 operates at 15-minute headways in both directions. Twenty-eight bus-stops on Route 22 and four on Rapid 522 are within the coverage of Dedicated Short-Range Communication (DSRC) to a nearby RSU. In addition, VTA has deployed the Computer-Aided Dispatch (CAD) and Global Positioning System (GPS)-based Automatic Vehicle Location (AVL) system on its bus fleets. A selected bus station along VTA Route 22 within the Connected Vehicle testbed will be selected as an ITSIS case study test site.

The California test bed and the VTA's bus system provide a real-world and operational environment for the development and testing of this proposed research. The closely spaced transit stops and frequent transit services of Route 22 and Rapid 522 present an optimal situation for testing ITSIS applications. The development and testing of effective mobility and convenience transportation applications that make the use of available V2V/V2I test beds are among the core focus areas of Connected Vehicle research. The findings from this project will provide valuable stepping stones to incorporate and deploy this technology into our transportation system.

1.3 Document Overview

This report describes the Concept of Operation (ConOps) for an innovative Interactive Transit Station Information System. The ConOps describes the goals, functions, key concepts, architecture, operational scenarios, operational policies, and impacts of interactive transit station information systems. A summary of benefits and costs follows the ConOps description. This document follows the outline provided by IEEE Standard 1362-1998, with small variations to reflect the nature of the specific system under study.

The ConOps will be a basis for the research, development and field testing of ITSIS. It is expected that this ConOps will be updated at the end of the research project. The updated ConOps will serve as a tool for transit technology developers to develop ITSIS related technologies and for transit agencies to implement ITSIS.

This document is organized as follows:

Section 1.0, Introduction provides the context for developing a concept of operations for ITSIS.

Section 2.0 Reference provides acronyms and cited references.

Section 3.0, Current Situation reviews state-of- the- practice of bus stop operations and existing deployments of traveler information systems.

Section 4.0, Motivation for ITSIS describes the needs for ITSIS and how ITSIS addresses these needs.

Section 5.0, Concept of Proposed ITSIS summarizes the goals, functionalities and the key concepts of ITSIS and provides a proposed system architecture.

Section 6.0, Operational Scenarios summarizes the operational scenarios, information needs, and functionality associated with the ITSIS.

Section 7.0, Summary of Impacts analyzes the operational policies, the operational and organizational impacts, and benefits and costs of the ITSIS.

Section 8.0, Analysis of the Proposed ITSIS provides a summary of ITSIS and disadvantages/limitations of this system.

2. References

2.1 Acronyms and Definitions

APTA	American Public Transportation Association
AVL	Automatic Vehicle Location
BSM	Basic Safety Message
CAD	Computer Aided Dispatch
CONOPS	Concept of Operations
DMS	Dynamic Messaging Sign
DPI	Dynamic Passenger Information
DRI	Caltrans Division of Research and Innovation
DSRC	Dedicated Short-Range Communication
DVI	Driver Vehicle Interface
FTA	Federal Transit Administration
FAVL	Fused Automatic Vehicle Location
GPS	Global Positioning System
GUI	Graphical User Interface
I2S	Infrastructure to Station
ICM	Integrated Corridor Management
ITS	Intelligent Transportation System
ITSIS	Interactive Transit Station Information System
JPO	Joint Program Office
NT-T/SP	Networked Traveler – Transit and Smart Parking
OBE	On Board Equipment
O-D	Origin-Destination
PATH	California Partners for Advanced Transportation Technology
PFT	Prototype Field Test
RFS	Richmond Field Station (PATH Headquarters)
RSU	Roadside Unit
SIH	Station Interactive Hub
TSP	Transit Signal Priority

TRB	Transportation Research Board
USDOT	United States Department of Transportation
VRM	Vehicle Revenue Miles
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle

2.2 References

[1] "IEEE Guide for Information Technology --- System Definition --- Concept of Operations (ConOps) Document," IEEE Standard 1362-1998.

[2] Joy Dahlgren and Betsy Morris, Advanced Bus Stops for Bus Rapid Transit, California PATH Research Report UCB-ITS-PRR-2005-6

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3.0 Current Situation

A comprehensive study on Advanced Bus Stops for Bus Rapid Transit (Dehlgren 2002) provides insights of the current situation for bus stops. Importantly, it investigated, from the perspectives of travelers and operators, the information needs and status at bus stops. While the study was conducted 10 years ago, the characteristics of bus stop operations remain the same and the technological status has not advanced substantially. This report adopts the findings from the PATH project report on Advanced Bus Stops for Bus Rapid Transit. Relevant sections from the Advanced Bus Stops for Bus Rapid Transit PATH report are included in the ITSIS Concept of Operations (this document) verbatim in italics.

3.1 Overview of Bus Stop Operation

The bus stop operation was studied extensively under this PATH study (Dehlgren 2002). Literature on bus stop amenities and technologies that could be employed at bus stops were reviewed. Field surveys of bus stops along VTA Route 22, field observations of bus operations (including 300 stop operations), and observations of passenger activities at bus stops were conducted. An on-board survey of 300 passengers on Route 22 was carried out. Key VTA staff involved in BRT plans and bus stop facilities, VTA trainers and supervisors were interviewed. Bus stop information and products were reviewed.

3.1.1 What Passengers Do at Bus Stops

Passengers waiting for buses were observed at the most highly used bus stop in downtown San Jose during the late morning and early afternoon on 4 weekdays and a Saturday in January 2001. This stop is served by 3 routes, with headways of 10, 15, and 30 minutes. The stop is in front of the VTA customer service center, which has an overhanging roof that shelters those waiting. There are four benches that can each accommodate three to four people. One schedule is posted. On the days of the observations, a security officer who was stationed inside the VTA office came outside periodically to patrol the area. Of the 876 people observed, 68% were male, 6% appeared to be high-school age, 10% college age, 18% over 60, and 66% between college and retirement age. Only 1% had children with them. There were always 2 or 3 people who did not get on any bus and appeared to be homeless. Over 90% of the passengers arrived at the bus stop on foot, 4% transferred from another bus, 3% rode bicycles or skate boards.

Most people just stand and wait for the bus. They may be reluctant to read or leave the stop because they do not know when their bus will arrive. Although the average time between buses matched the scheduled frequency, the buses often bunched leaving unpredictable intervals between buses.

3.1.2 2002 Route 22 Bus Passenger Survey

Passengers on twenty-four Route 22 runs and twelve Route 300 (a limited stop version of Route 22) runs were surveyed in May and June of 2002. The runs were at all times of day on weekdays and weekends in both directions. Thus the responses were more representative of Route 22 and 300 passengers than the bus stop observations. Questionnaires were offered in either English or Spanish as passengers sat down on the bus and collected as they left. A fair number of passengers did not appear to speak or read either of these languages. Sixty percent of the 958 completed surveys were in English and 40% in Spanish. The age, gender, trip frequency proportions of survey respondents were similar to those found in bus passenger surveys that VTA had conducted in previous years.

Passengers were asked where they boarded the bus, how useful they found various types of information, if they felt safe at the bus stop, what would make them feel safer, what they liked to do while waiting for the bus, if various types of bus stop amenities would make waiting more pleasant, and if they would take more bus trips if the stop had more information, was safer, or was more pleasant. They were also asked if they owned a cell phone, pager or personal digital assistant or if they had access to the internet at work or at home. Over 50% of people responding to the question regarding electronic devices had one or more. Sixty-three percent of people responding to the internet question had access to the internet, 40% at home, 32% at work, and 17% at other locations. Many had access at more than one location. The percentages were much lower among Spanish speakers than among English speakers.

Even though 78% of those surveyed rode the bus four or more days a week, they still found many types of information useful, as shown in Table 1. Schedule information was by far the most useful; 62% found it very useful and almost 80% found it very or somewhat useful. Next most useful was the time when the next bus will arrive. Route maps, connecting routes and transfer points, and the current time of day were judged very useful by over 40% of riders and very or somewhat useful by about 60%. Less useful, but still somewhat useful for a majority of riders, were service updates, fares, and the customer service telephone number. The survey asked if people were interested in a map of activities close to the bus stop. About half felt this would be very or somewhat useful. More people were interested in information about health services, businesses, and parks and recreation, less in movies and entertainment, family activities and government services. People were also asked "What other information would you like to have at this bus stop?" The most common response was schedule information, indicating some lack of understanding of the survey, but also reinforcing the importance of schedules to bus patrons.

These findings are consistent with studies elsewhere. *Bus stop real-time information systems appear to be very popular with riders. A survey of London bus passengers six months after the Countdown signs were installed found that they were reliable and accurate and that 90% of riders looked at them at least once during their wait for the bus. Over 2/3 of passengers felt that they waited for a shorter time (perceived wait time dropped from 11.9 to 8.6 minutes) and that service reliability had improved since Countdown was implemented even though reliability had actually declined. Passengers valued Countdown at an average of more than 31 cents (Schweiger, 2003). The bus arrival time display, if visible to passersby, serves the added function of informing people who do not use transit about the frequency of the bus service.*

3.1.3 How Useful Is Bus Stop Information?

Of 761 responses, 78% said they would take more bus trips if the bus stops had more information. The percentage was the same regardless of whether the stop at which passengers boarded had a shelter or not or whether it was a heavily used stop. Fifty-five percent of 762 respondents said they would take more bus trips if bus stops had information in another language beside English. Of the 217 people who named another language, 84% named Spanish, 3% Chinese, 2% Tagalog, 1% Vietnamese, 1% Japanese, and less than 1% named each of 10 other South Asian, European, and African languages.

Table 1 ***Information useful to Travelers*** **(Dehlgren 2002)**

Information type	Very useful to me		Very or somewhat useful to me	
	Number	Percent of all surveyed	Number	Percent of all surveyed
Schedule	598	62%	753	79%
Time when the next bus will arrive	474	49%	646	67%
Route maps	402	42%	605	63%
Connecting routes and transfer points	392	41%	574	60%
Current time of day	379	40%	558	58%
Updates on bus services	326	34%	545	57%
Fares	325	34%	496	52%
Customer service phone number	310	32%	500	52%
Map of activities close to the bus stop	277	29%	468	49%
• Medical and health services	360	38%	551	58%
• Shops and businesses	330	34%	492	51%
• Parks and recreation	309	32%	488	51%
• Movies and entertainment	256	27%	445	46%
• Activities for children and families	248	26%	443	46%
• Government services	243	25%	422	44%
Information about other transit agencies	265	28%	477	50%
Bus web address	211	22%	406	42%

3.2 Overview of State-of-the-Art Bus Stop Information Systems

Real-time information system systems have been employed throughout Europe. London's Countdown system began operation in the early 1990s. In Lyon, France, 500 bus stops are equipped with LCD displays for displaying estimated waiting times. Such systems in the United States began to be deployed in the 2000s. The early deployment includes real-time information systems at Los Angeles Metro Rapid transit bus stops, at bus stops in Portland, at stops on San Francisco's Muni first and then other Bay Area transit systems, and at bus stops on other smaller systems, such as San Luis Obispo.

The arrival information is generally displayed on LED dynamic message signs. They display the route and either the number of minutes until the next bus or the arrival time of the next bus. The method by which expected arrival time is estimated varies depending on the communications and vehicle tracking equipment available and the nature of the bus operations. Some systems, such as those used in Seattle and Portland, have been developed by the transit agencies. Other agencies use proprietary systems, such as NextBus.

Elsewhere, interactive bus stop information has been explored. *The Kowloon Motor Bus Company (KMB) in Hong Kong has developed a Cyber Bus Stop equipped with a touch screen linked to a microcomputer that is linked to the KMB homepage. Passengers can use KMB's point-to–point route search and other information on the KMB website. A web-camera at the bus stop allows management to monitor the bus stop remotely.*

While real-time bus arrival information have become available on the Internet and through mobile applications, the arrival information at bus stops provides additional benefits, including improved customer service, increased customer satisfaction and convenience, and improved visibility of transit in the community.

4.0 Motivation for ITSIS

The proposed ITSIS is motivated by a number of key factors, including: (1) bus stops have largely remained the same as their initial forms despite the fact that substantial technological changes have been made in the transportation industry during the past 20+ years; (2) although the 'nextbus' information becomes available at some BRT bus stops, the accurate prediction of transit arrival has been challenging because of the low sampling rate; and (3) there is little effort in developing interactive bus stop information products and services.

4.1 Stakeholder Needs

The PATH study on advanced bus stops concluded that among the technological products and services offered for bus stops, real-time bus arrival information systems were rated highest, followed by electronic fare cards, interactive information displays, solar powered lights, beacons and information panels. Other studies of bus stop behaviors indicated that passengers perceive waiting times to be greater than actual waiting times at a bus stop and real-time passenger information systems can reduce the perceived waiting time for buses when providing accurate information. Interactive and personalized transit information provided by ITSIS can further alter their concept of transit routes, travel times, waiting times, and service reliability.

Transit agencies such as VTA have found that passengers care more about frequency and reliability of service than about bus stops themselves. While it is critical for transit agencies to focus on providing more frequent, reliable and direct service, how much improvement can be done is constrained by the available resources. VTA and other transit agencies have learned from recent experience that real-time information can reduce perceived waiting times and compensate for some of the service uncertainties and deficiencies. This change of perceptions could potentially be translated into reduced operating costs (e.g., through efficiency of on-demand service) or increased passenger satisfaction and, ultimately, into increased ridership for public transit. Transit agencies are interested in exploring further applications of real-time information including ITSIS.

4.2 How ITSIS Addresses the Stakeholders' Needs

ITSIS offers a combination of innovative real-time data capture and data management methodologies to enable improved dynamic mobility for transit and intermodal applications. ITSIS provides for the next jump in improved level of service to passengers and supports future enhanced transit operations by enabling travelers to *interact* with transit systems on their current trip plans and real-time needs. This results in better passenger information service for passengers and better origin-destination (O-D) data collection for transportation providers. The addition of real-time interactive sessions with travelers will expand the horizon for public transit management, offering the opportunity to both improve service level and facilitate better operational and planning decisions.

Specifically, VTA is interested in this study to examine: (1) how advanced communication means such as DSRC can improve the quality of real-time data and the application and services powered by real-time data (e.g., improved resolution and information accuracy); (2) how ITSIS can provide additional information such as bike loading condition on upcoming buses, service breakdown, etc. that will affect passengers trip decisions; and (3) how interactive traveler information can further help passengers travel by transit and improve users appreciation of reasonableness of transit services, (4) how ITSIS can enable real-time dynamic transit operations.

4.3 Assumptions and Constraints

Our hypothesis is that some of the technical gaps for implementation of ITSIS can be effectively overcome by using Connected Vehicle technologies and the innovative information gathering and dissemination methodologies envisioned by the Connected Vehicle environment.

Our assumptions are that (1) RSUs are installed at a sequence of signalized intersections and are connected to the communication backhaul, (2) on-board equipment (OBE) is instrumented on selected transit vehicles that travel through RSU-equipped intersections, (3) ITSIS is installed at selected transit stations/stops which are within the DSRC communication range of one of the RSUs, (4) communications between RSUs and bus OBE, and between bus OBE are based on SAE J2735 standard, and (5) RSUs may have more than one communication channels, to include not only DSRC, but also Bluetooth or WiFi capabilities.

4.4 Description of Desired Bus Station Operation

A desirable transit real-time information system at a bus stop provides not only real-time 'next arrival' information but also in interactively determining the best possible use of the transit network for travelers. This is focused on finding the "best" travel itinerary from the current station/stop to the final destination station/stop using the most up-to-date transit network status information, including detailed connectivity information about transfer points, out-of-vehicle travel instructions and total trip duration. The system also provides customers with information about real-time vehicle load factors (i.e., the ratio of actual passengers to capacity), the availability of bike racks or wheelchair spaces of the upcoming bus, bus service disruptions along the trip route, and other information that allows them to make their trip in a timely, comfortable and easy manner.

5.0 Concept of the Proposed System

5.1 ITSIS Goals

The goal of the Connected Vehicle technologies based ITSIS is to support a new passenger experience and improve transit service. More specifically, ITSIS will:

- Enable more timely and accurate passenger information: A typical transit management system has a 60 sec to 120 sec pooling cycle, which often creates errors for bus arrival prediction. ITSIS bus-to-station communication will facilitate buses to provide accurate arrival and departure information to correct the prediction error by the transit management system. This will eliminate the possibility for inaccurate information that informs passengers bus arrival when no bus is visible or a bus has already left the station.
- Benefit passengers by enabling them to interact with transit systems through 'personalized' information: ITSIS will provide certainties to all transit passengers and assist passengers who are unfamiliar with the transit system to navigate to their destination.
- Enable more efficient operation of transit. This passenger waiting information will help bus operators to prepare for the next stop and potentially enables on-demand transit service to reduce costly, unnecessary stops thereby speeding up transit operations and enhancing transit rider satisfaction levels.

5.2 Functions of ITSIS

It is envisioned that ITSIS will have the following primary functions:

- Enables passengers waiting near transit stations to receive "personalized" real-time trip information about transit vehicle arrivals at their current stop locations and at future stations (i.e., "downstream" stations) on their planned travel route. The improved vehicle's arrival prediction accuracy is enabled by the DSRC V2I communication between arriving bus and the station ITSIS.
- Provide real-time information regarding the current status of transit vehicles, including service disruption notice, bike rack availability on the upcoming bus, etc.
- Provide trip specific modal and intermodal connectivity options to passengers "on-demand" and before passengers reach their transfer stations and stops.
- Communicate passenger waiting and trip data to the transit operation center to enable

transit dynamic operation.

- Collect passenger O-D data to provide transit agencies an opportunity to improve transit operations and planning.

5.3 Key Concepts

When OBE-equipped transit vehicles travel through RSU-equipped intersections, the real-time information about departure time, location and speed of transit vehicles is transmitted to downstream RSUs and to the passenger information server. DSRC provides a reliable way to quickly update the status of transit vehicles as they progress towards the downstream stations. Its high update rate makes it possible to more accurately predict a transit vehicle's arrival at stations near RSUs and to even extend that accuracy to stations much farther downstream than is possible with the update methods currently utilized in CAD/AVL systems.

At transit stations near RSUs, the ITSIS that facilitates DSRC communication allows customers to query real-time transit information, plan a transit trip, and transmit O-D data to the dispatch center for cost-effective dynamic transit operations.

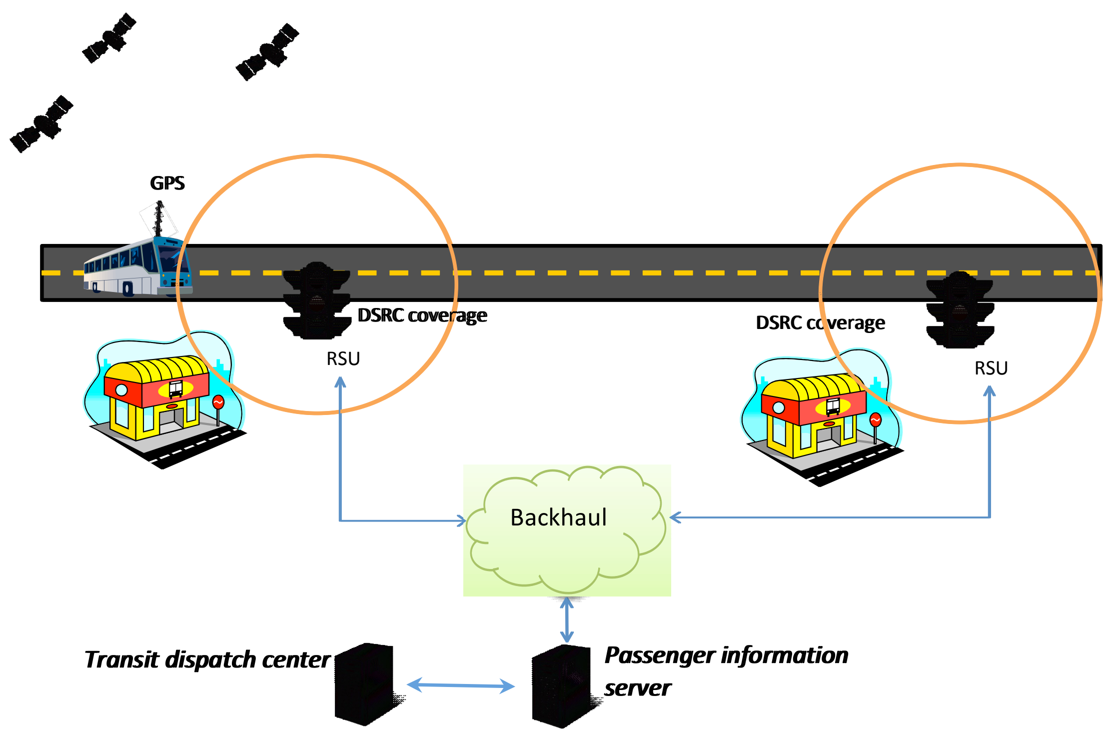


Figure 1 DSRC Link and AVL

5.4 Proposed Architecture

California PATH has developed a system architectural framework for an integrated transit information/management system. This open architecture includes the basic functions for the proposed ITSIS.

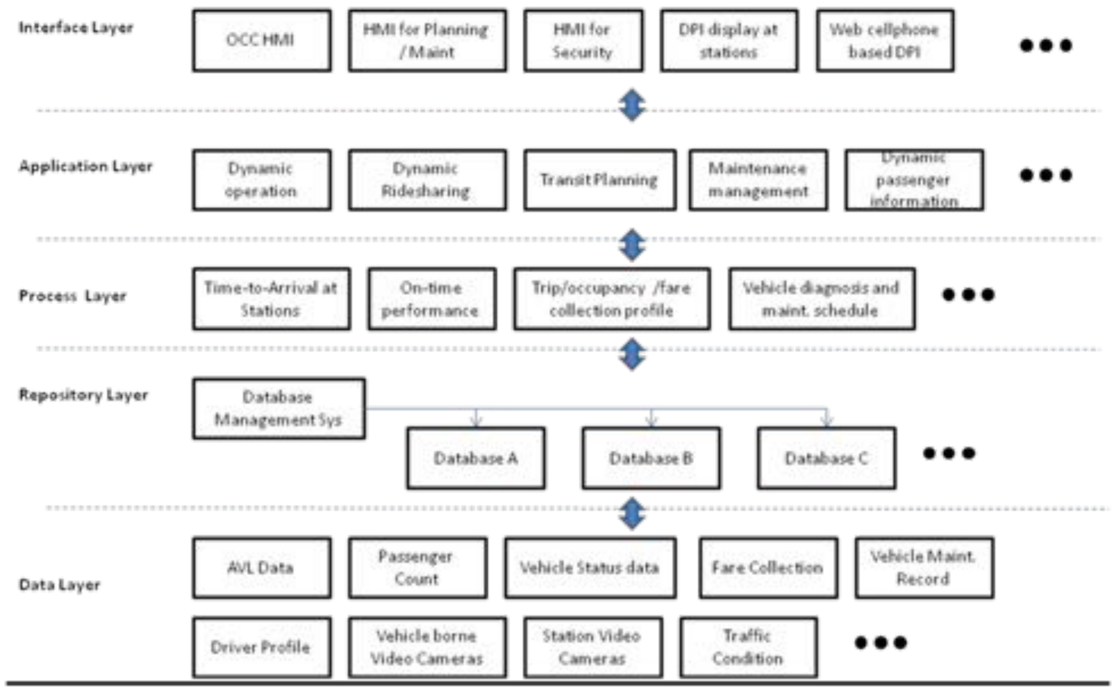


Figure 2 Integrated Transit Information/Management Architecture

Using this architecture as a base, an experimental architecture for the ITSIS will be developed sufficiently to support the prototype testing. The architecture will address two major aspects of ITSIS: (1) bus infrastructure integration and (2) the integration of interactive passenger information with transit operations.

There are several viable approaches for the integration of the bus and transit dispatch center with the passenger information center. With the existing transit CAD/AVL system built upon dedicated transit radio channels, transit vehicles send AVL and service data such as occupancy and bus conditions to the dispatch center and receive operational data back from the dispatch center at intervals of 60 to 120 seconds. Under the Connected Vehicle environment, the bus OBE broadcasts the Basic Safety Message (BSM) at high frequency to the RSU and receives messages from the RSU containing the interactive passenger inputs. It is envisioned that the DSRC link between the bus OBE and RSU can be utilized for communicating the transit vehicle's location and speed data at a higher frequency to achieve higher resolution and more accurate transit information, and to enable interactive traveler input data for 'personalized' passenger information and dynamic transit operation (see Figure 3). ITSIS will contain a Station Interactive Hub (SIH) to enable passengers to acquire transit information through a graphical user interface (GUI). Mobile devices, via cellular network, will be also considered as an interactive device within this system architecture that serves as an outlet interface of real-time passenger information.

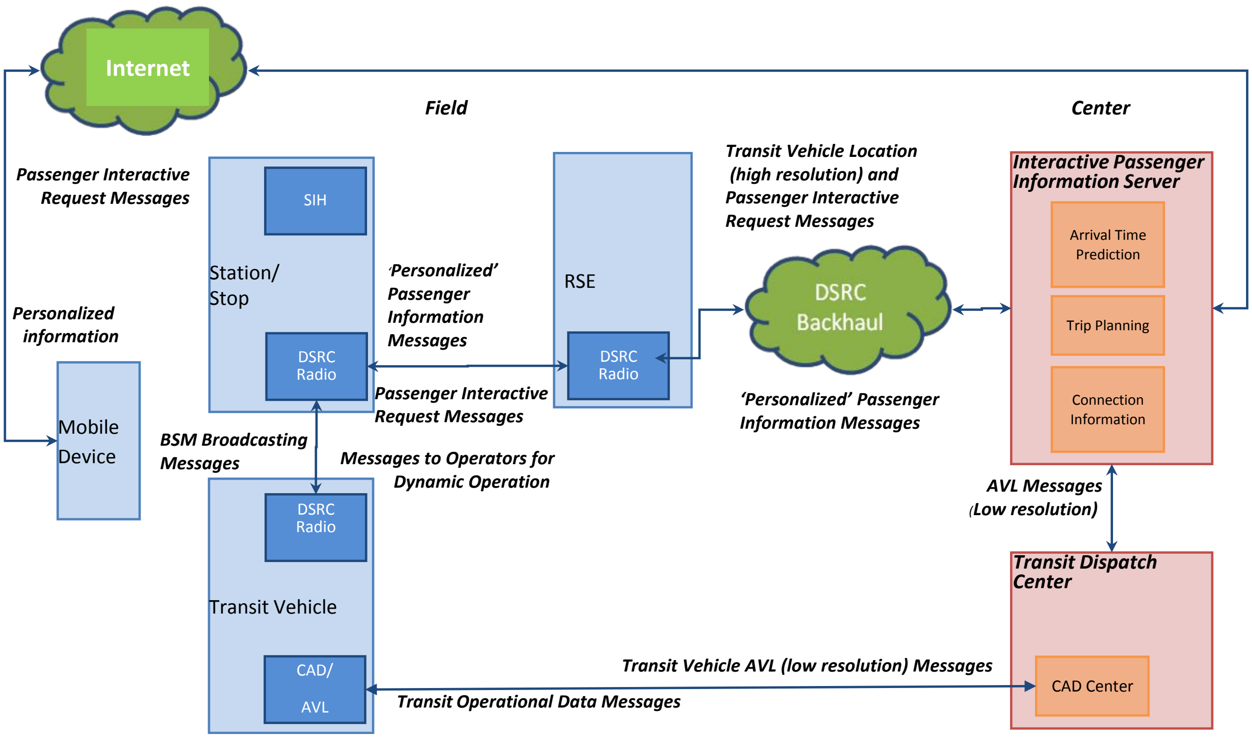


Figure 3 ITSIS Physical Architecture and Data Flow

We will explore different approaches and identify the most cost-effective method for the development and testing of the proposed ITSIS applications. The considerations will include the communication needs of ITSIS, the specific conditions of the California Connected Vehicle Test Bed, the in-place transit communication technology and operation characteristics, and the testing facility and environment available at Richmond Field Station (RFS). The design of the prototype ITSIS will be based on the existing technologies and test bed environment. The initial design will be completed in the early stage of this research effort and presented to the Caltrans Division of Research and Innovation (DRI) and the Federal Transit Administration (FTA) for concurrence prior to proceeding to final prototype design.

6.0 Operational Scenarios

This section provides scenarios that show how ITSIS could help transit passengers on their trip decision and trip making and facilitate dynamic operations by transit operators. Each scenario may include a number of use cases.

6.1 Scenario 1: Acquiring Transit Service Information

ITSIS provides transit service information, helping passengers to glance at service options before making their trip decisions.

1) Passengers use the SIH to inquire about route maps, schedules, real-time next bus arrival information, estimated arrival time at future (downstream) transit stations, available seating and available bike rack space information.
2) The query of real-time transit information is transmitted to the passenger information server via the combination of DSRC and its backhaul.
3) The information returned by the server is presented to the customer via SIH

6.2 Scenario 2: Acquiring Transit Trip Information

ITSIS assists travelers by interactively providing trip information at the station through the SIH or when approaching a station through mobile devices.

(a) Passengers acquire trip information at the station through the SIH

1) Passengers provide their destinations by either selecting a transit station/stop or inputting a street address using the SIH interactive interface.
2) The destination information is transmitted to the passenger information server where a transit trip itinerary is generated using the most up-to-date transit network status information;
3) The trip itinerary is returned and presented to passengers. The returned information includes the route, transit vehicle's ID, its arrival time at the current station and predicted arrival time at the destination or transfer station, if any, the connection information at transfer point(s) (e.g., transit vehicle route, transit vehicle's ID, arrival time of the connecting vehicle, walking distance between transfer stations/stops), the arrival time at the final destination station/stop, transit vehicle seating availability / passenger load information, and bike rack availability information.
4) Passengers can confirm the planned trip using the interactive interface, and the confirmation is communicated to the passenger information server through the nearby RSU.

(b) Passengers acquire trip information through a designated application

1) Passengers plan trip or activate a pre-stored trip plan prior to the trip through a web or mobile application that is linked with the passenger information server where a transit trip itinerary is generated using the most up-to-date transit network status information.
2) Passengers are provided trip information similar to scenario 2(a) with additional information about the trip segment between the origin and the first transit station. This transit data will be updated.

6.3 Scenario 3: On-Demand Transit Station Operation (Technology Feasibility Demonstration only)

While scenarios 1 and 2 focus on the dissemination of transit traveler information to passengers, scenario 3 aims to enhance transit operations by providing bus operators with real-time ‘passenger waiting’ information. The information enables the bus operators to prepare for picking up passengers at stations. This function is particularly useful at night and when visibility is poor. The passenger waiting call is also critical for dynamic transit operation. When passengers are familiar with the passenger waiting call function, the same way they are used to pedestrian request button at signalized intersections, transit operators can achieve dynamic operation by determining which stop to serve based on the station passenger waiting call information.

(a) Passenger request transit service using the SIH

1) Passengers use the SIH to request transit service at the current station either by pushing a ‘waiting for route X’ button on the interactive interface or by confirming a planned trip.
2) The ‘passengers waiting’ information is communicated with the OBE on transit vehicles and presented to the bus operator via an on-board driver vehicle interface (DVI).
3) The bus operator makes an early lane change, if not already in the curb lane, to prepare for a stop, or deviates from the route for flex-route operations.

(b) Request transit service through a mobile device

1) When approaching a station, the mobile device carried by a passenger automatically communicates ‘passenger waiting’ and pre-selected destination information to transit vehicles through wireless means via Interactive Passenger Information Server.
2) The passenger waiting information is presented to the bus operator via a DVI. Similar to scenario 3(a), this information calls the bus but without passengers’ interaction with any SIH.

7.0 Summary of Impacts

7.1 Operational Policies

Real-time transit information is the enabler for the ITSIS. Most of the transit agencies in the United States have developed real-time transit information systems for their fleet and have begun to make it available to travel information providers.

The ITSIS services can be provided by transit agencies or by private service providers. In the case where transit agencies are responsible for the development and service of ITSIS, dedicated budget and technical staff are needed. ITSIS service may also be provided by private entities, either paid for by transit agencies or through revenue generating advertisements using the SIH at stations.

Dedicated budget for supporting on-going ITSIS services can be a roadblock for a decision for implementing ITSIS. The fare box return rate for all transit agencies in the United States is very low (ranging 30-50 percent on average). Transit agencies are therefore very sensitive to operational costs. It is very difficult for transit agencies to expand non-essential services such as ITSIS unless large benefits can be justified.

A new business model for financing and operated by private service providers could make the deployment of ITSIS more viable. This of course will depend on the business viability judged by the private service providers. Some transit agencies have strict requirements on advertising policy at transit stations and these requirements may need to be relaxed in order for this new business model.

Dynamic transit operation using inputs from ITSIS is new and will require change of variation of the existing transit operation policy and practices.

The above and additional issues on operation policies will be analyzed throughout the project and the results will be included in the final project report.

7.2 Impacts

Operational and organizational impacts will be analyzed during the project and the results will be included in the updated ConOps and final project report.

7.3 Benefits and Costs

The benefits and costs analysis below are preliminary information collected at the start of the project. Further analysis will be conducted on benefits and costs through customer surveys and discussion with transit stakeholders. The findings from this in-depth analysis will be included in the final project report.

7.3.1 Benefits

Providing real-time transit information at stations will significantly improve the trip experience for transit passengers and assist travelers who do not regularly take transit or are not familiar with transit systems in the region to gain confidence of the transit service. Ultimately, it can potentially be an ITS transit solution for attracting more transit riders, with an ultimate goal of making transit as a portion of the solutions for congestion relief.

Cost-effectiveness is another important benefit of ITSIS. Compared with the traditional CAD/AVL system-based passenger information systems, the ITSIS uses the DSRC infrastructure to provide reliable and high quality passenger information, reducing the need for dedicated communication link at the station This way, the cost needed to deploy and maintain the passenger information system can be significantly reduced.

7.3.2 Costs

A PATH study revealed the costs of the existing bus stop real-time passenger information systems (Dahlgren 2002). The study revealed that the capital costs for station signs in the US range from $3,500 to $10,000 per unit. Costs for arrival time prediction system range from $300,000 to $500,000. As an example, the NextBus system costs are on the order of $7,000 per bus and $4,000 per stop for installation and service for 5 years. The PATH study also investigated the costs of Interactive information kiosks used in rail transit stations and airports for some time (Dahlgren 2002), revealing that the cost of these systems range from $5,000 to $30,000 per unit. If the station information system costs are of the same magnitude, they are not affordable for large numbers of bus stops. . While this study is more than ten years old, there hasn't been any low-cost interactive station information systems reported. With dramatic cost reduction of computers and interactive LED displays, we expect that the cost of ITSIS station display will be within $1000. However, the costs for developing housing and brackets are unknown at this stage of the project. This information will be updated after the design is developed and approved by transit stakeholders.

8.0 Analysis of the Proposed ITSIS

An in-depth analysis to include customer surveys and discussion with transit stakeholders will be conducted to evaluate the improvements that ITSIS provides, and disadvantages and limitations. The findings from this in-depth analysis will be included in the final project report.

8.1 Summary of Improvement

ITSIS will improve the transit ITS system by connecting the information flow among transit stations, transit operation management center and the transit vehicles. Real-time transit information is provided to travelers while the information about passengers waiting at a transit station/stop is provided to a bus operator. Consequently, ITSIS can improve the customer experience and transit operations.

We will conduct further study through field testing, customer surveys, interaction with stakeholders and additional analysis to address improvements of ITSIS to the transit operation, customer experience and possibly the condition of the overall transportation system.

8.2 Disadvantages and limitations

Important feedback from transit stakeholders so far is the fact that station amenities are often subject to vandalism. SIHs at transit stations may become targets of vandalism. SIH may be installed at stations where security measures such as surveillance or regular security patrol are available. This will limit the locations where SIH can be made available. The mobile app can become a supplement tool for ITSIS, which however, is also limited to those who has mobile devices and are interested in using the ITSIS apps.

This study will analyze the disadvantages and limitations of the proposed system during the project and explore the possible means to overcome these disadvantages and limitations.

Regarding the project scope, some of functionalities identified in this ConOps document are new and beyond the initial scope of development (e.g., on-bus bike detection); we will explore the possibility of including these additional functionalities. However, we may choose not to implement these additional functionalities if the development is not supported by the available resources.

9.0 Next Steps

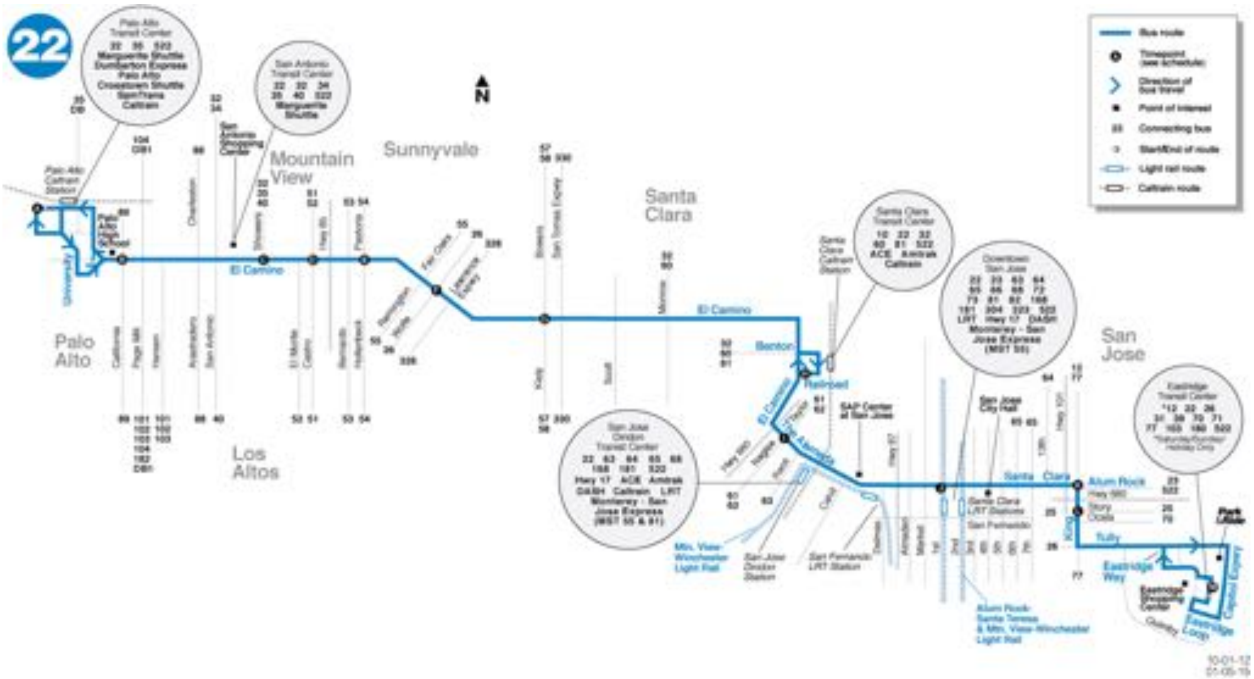
We will carry out this project to achieve the following objectives: (1) to identify issues and gaps of the existing real-time traveler information communication systems, (2) to develop issue-resolving concepts and approaches for a DSRC-based Connected Vehicles ITSIS and (3) to conduct testing of a prototype ITSIS application. To accomplish this the project will utilize the system developed for the Networked Traveler – Transit and Smart Parking (NT-T/SP) project under the SafeTrip-21 initiative as the starting point, which includes some of the core elements for development the ITSIS (i.e., system architecture, transit trip planner and arrival time prediction), and the California Connected Vehicle Test Bed for the prototype testing.

The ITSIS concept will be improved throughout of the project, we will follow the tasks in the proposal to investigate innovative approaches (including messages and protocols for ITSIS and associated transit and modal applications) for implementing ITSIS and to develop a prototype ITSIS system. The prototype field test (PFT) and a concluding live demonstration are planned to use the California Connected Vehicle Test Bed. We plan to conduct the prototype field test (PFT) of scenarios 1 and 2 with in-revenue service buses and scenario 3 with PATH test vehicles. Scenarios 1 and 2 do not require any involvement of bus operators. Testing with in-revenue service buses for these two scenarios allows the best use of the test bed and existing transit environment, and enables the passengers to experience the ITSIS technology under real-world conditions. Scenario 3 requires the operator of the bus/vehicle to react to the 'passenger waiting' information delivered in real-time via the on-board DVI. Conducting scenario 3 tests under a controllable environment with PATH test vehicles makes it possible for the research team to focus on the technology side while eliminating the institutional issues related with transit operation.

At the conclusion of the research effort, a final report will document the study results of the ITSIS concept, the communication needs and requirements, the development of the prototype ITSIS and report on the PFT test results. If deemed appropriate, a recommendation will be provided, identifying potential next steps needed to move forward with the development of these initial findings and suggesting a reasonable path forward and ending with a workable and deployable product.

Appendix A Route Maps for VTA 22 and 522

Route Map for VTA Route 22 (http://www.vta.org/routes/rt22)



Route Map for VTA Route 522 (http://www.vta.org/routes/rt522)