Module 5: Personal Transportation

Authored by **Alex Skabardonis**, Research Engineer, Kittelson & Associates, Inc., Oakland, CA, USA/Professor, University of California, Berkeley, Berkeley, CA, USA

Purpose

Personal transportation is concerned with the trips individuals make across all travel modes and the purpose of the trips. Intelligent Transportation Systems (ITS) technologies offer an array of applications and enhancements for personal transportation, from real-time information to safety systems and driver conveniences.

The purpose of this module is to describe current and emerging ITS technologies that enhance driver experience in terms of convenience, safety, and security.

Objectives

This module has the following objectives:

- Learn of the capabilities, features and limitations of ITS technologies for personal transportation.
- Understand how ITS personal transportation applications impact the user and the transportation system in terms of mobility and accessibility.
- Understand deployment opportunities and constraints for ITS technologies for personal transportation.
- Understand emerging and future trends in ITS technologies for personal transportation.

Introduction

This module describes real-time travel information systems for both auto and transit users for all trip stages. Driver assistance systems to improve safety are presented with ITS applications to enhance traveler convenience. This module also discusses alternative energy portions for private vehicles and alternative concepts for mass transit, and outlines emerging ITS technologies for personal transportation.

Real Time Travel Information

Traveler information is one of the core concepts of ITS. Travelers value high-quality information in terms of expected travel times, reliability of travel times, and easy and timely access to that information with a high-quality user interface and preferably at a low cost preferably free. Consumer demand for traveler information is a function of the characteristics and the amount of congestion on the transportation network, of the availability of alternative routes and modes for individual trips, and the traveler information characteristics in terms of information quality and user interface.

ITS applications that provide traveler information can assist travelers prior to their trip or en route, to help users make more informed decisions for trip departure, route choice, and mode of travel. Pretrip information consists of traffic, weather, transit, incidents, and work zone information posted on Internet websites, television, radio, cellular phones or kiosks. En-route information available via roadside or in-terminal message signs, in vehicle devices, wireless devices, and telephone services allows users to make informed decisions regarding alternate routes and expected arrival times.

Before the 1990s, traveler information dissemination was typically limited to existing media outlets, such as television, radio, and newspapers; and field devices, such as changeable message signs (CMS), message boards, and highway advisory radio (HAR). Although early attempts to communicate with travelers proved successful, (e.g. the experimental route guidance system in Washington, DC, in the late 1960s and the Pathfinder experiment in Los Angeles, CA , in mid 1980s) off-the-shelf products or systems were limited. In Europe and Japan route guidance and information systems were also tested with real-time information displays on in-vehicle devices. Similar technologies were tested in the United States and proved to be effective; however, commercial products never reached the market. An assortment of telephone systems existed to provide regional or local travel information. Although the capabilities existed to disseminate travel information using telephone systems, wide-scale branding of a common phone number was lacking, and only a limited set of the population knew about the systems.

The introduction of the Internet World Wide Web to the general population in the early-to mid-1990s allowed public agencies to create websites to disseminate real-time travel speeds on the network links and surveillance camera images from critical transportation network locations to anyone with Internet access. The Web also allowed private sector information service providers to create local, regional, or nationwide traveler information systems.

The Federal Communications Commission (FCC) designation of the three-digit dialing code, 5-1-1, as the national traveler information phone number, and the financial support by the USDOT to states in launching 511 phone systems across the country, has been successful. 5-1-1 based travel information systems are now available to half of the population in the United States.

Operations of these traveler information dissemination systems may be performed by either public or private agencies. Currently, travelers have a variety of sources from which they can receive traveler information, including the following:[1,2,3,4]

- Public-operated 5-1-1 phone systems are available free of charge to anyone with access to a telephone; currently there are 5-1-1 phone systems in 41 States offering coverage to 128 million Americans (47% of the population).
- Public-operated traveler information websites are available free of charge to users. Each of the 50 States offers some form of traveler information website.
- Field devices such as Changeable Message Signs (CMS) provide information to drivers on expected travel times for certain destinations, and alerts on incidents,

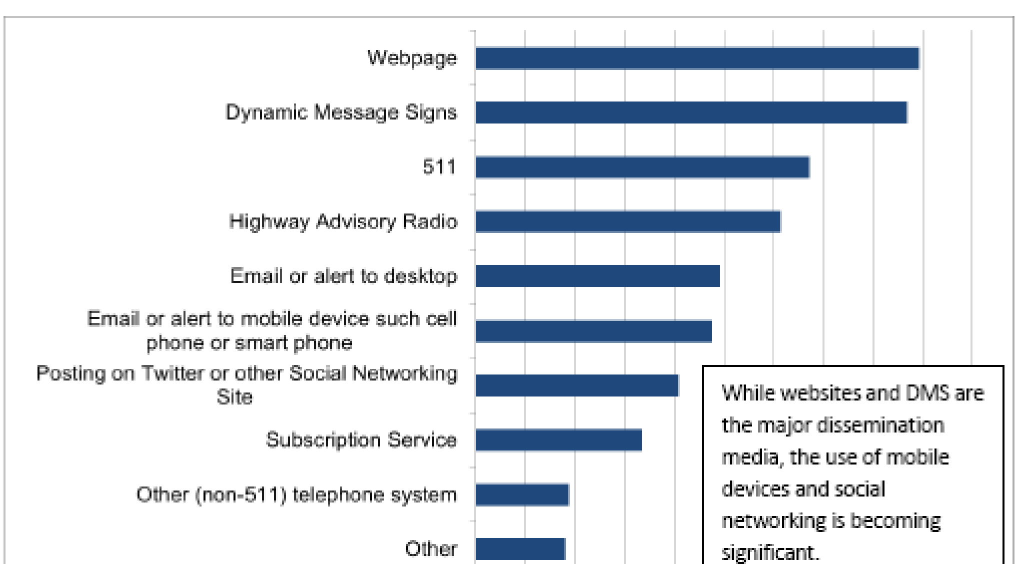
inclement weather and other events. CMS are typically installed on freeway typically near major interchanges that provide opportunities for selecting alternate routes. Portable CMS also are used to provide information about major incidents, work zone, or special events.
The following video link illustrates how the West Michigan Traffic Operations Center (WMTOC) uses real-time traffic flow data to display real-time travel times on CMS throughout the Michigan Department of Transportation (MDOT) Grand Region, and on the Mi Drive website. See [www.youtube.com/watch?v=tUNgPSx0rxk.](www.youtube.com/watch?v=tUNgPSx0rxk)
CMS are also utilized to display messages related to emergencies. Examples include AMBER (America's Missing: Broadcast Emergency Response) alerts, which are issued to notify drivers about abductions of children; LEO (Law Enforcement Officer) alerts, which are issued to notify drivers who may have valuable information concerning an injured police officer; and SILVER alerts[5], which can be used to assist law enforcement in the rescue of cognitively impaired individuals who become lost while thriving a vehicle or on foot.

- HAR units allow travelers to hear reports on traffic conditions in the vicinity of HAR from their standard AM or FM radios.
- Private sector traveler information providers offer web, phone, or special devices (e.g., in-vehicle navigation system or handheld devices) primarily in metropolitan areas; some products are now expanded to include rural areas.
- Private-operated news and media outlets disseminate traffic, weather, and event information over radio and television broadcasts with the majority of traffic and event information describing metropolitan areas.

Dissemination

Recent Deployment Tracking Survey data (Figure 1) indicates that the Internet is the most common medium for traveler information dissemination and is used by almost 89 percent of freeway management agencies, 40 percent of arterial agencies, and 85 percent of transit agencies. Email and text messaging also are common methods of distributing both pre-trip information (alerts to desktop and subscription services) and en route information (alerts to mobile devices). The next most widely adopted traveler information technology includes 5-1-1 systems and HAR units which are used by approximately 60 percent of the agencies. Slightly over 40 percent of the agencies reported using social media and networking sites such as Twitter to distribute traveler information.

Figure 1. Methods of Traveler Information Dissemination



Source: USDOT, *ITS Benefits, Cost Deployment and Lessons Learned Desk Reference, 2011 Update*

There are several differences regarding email and text messages. Text messages are generally short (some carriers limit this to 160 characters) whereas e-mail messages have no practical limit on length. Text messages are plain text and do not include support for graphics, attachments, or text formatting, whereas e-mail messages can be formatted as rich text and include support for different fonts, styles, sizes, as well as embedded images. In regard to user costs, text messages are often subject to fees from cellular providers at a typical rate of 5 or 10 cents per message, with volume discounts and unlimited text message plans usually available. Email messages are lumped together with all other general Internet data usage, and are only indirectly charged for through the customer's data plan fees. In terms of support and availability, text messages are supported by almost all devices currently offered by cell phone companies, and sent on a separate type of connection specifically for them. But email messages can only be checked on smartphones and other Internet-enabled phones with data plans because e-mail messages are transmitted over the Internet connection to the phone. Additionally, with respect to delivery times, text messages typically operate on a "push" system wherein the message gets delivered to the user as soon as possible after it is sent (subject to the recipient's phone having cellular service); whereas, email messages are more often delivered on a "pull" system where the phone follows a user-defined "check-in" schedule and only checks for new messages according to this schedule (which is typically once every 2 to10 minutes).

Increased connectivity through social media, email, and texting is considered one of the main reasons younger people are delaying getting their drivers' license, according to recent studies by the University of Michigan Transportation Research Institute, University of Michigan, and other organizations. Most are using public transit, biking, or walking to travel to work, and there is less need for social trips because of the virtual social interaction[6].

A recent study[7] also reported that social networking sites such as *WAZE,* a route-planning mobile application for drivers enriches the travel experience. Drivers share their experience as they travel on traffic routes; when there's congestion the application re-computes alternative routes, based on the shared information, and informs the drivers, i.e., connecting people by shared traffic routes. Further information on *WAZE* and related community driven applications is presented in Module 14 ("ITS Emerging Opportunities and Challenges").

An important consideration in providing en-route information to drivers is the possibility of driver distraction. Distracted drivers cause up to 30 percent of the 6 million automotive crashes in the United States[8]. As more complex controls, displays, communications devices, and entertainment systems appear in cars, the level of driver distraction is expected to increase.   Real-time information provided en-route in the form of text messages or in-vehicle navigation systems may further increase driver distraction and information overload.

Ongoing research and development efforts focus on systems that integrate data from in-vehicle technologies and control the information flow to the driver through an adaptive driver-vehicle interface. The objective is to lower the frequency with which drivers multitask, reduce their exposure to risk, reduce the complexity of distracting tasks, and manage the multitasking options that drivers can make to avoid information overload.

Data Sources

Data sources for traveler information systems include:

- Fixed sensors: typically loop detectors installed along each travel lane at approximately 0.5-mile intervals. These sensors provide traffic volume and speed data every 30 seconds. The data are sent to the transportation management centers (TMCs) where they are checked and aggregated into typically 5-minute values. They are used to produce color-coded speed maps and estimate travel times for certain origins and destinations.
  Fixed sensors are either embedded in the pavement (loop detectors or magnetometers) or are nonintrusive and mounted overhead or on the side of the road. Examples include microwave radar detectors, and video, laser, and ultrasonic technology. Module 9, "Supporting ITS Technologies," provides detailed coverage on vehicle detection.
- Incident and other event information from police patrols and/or incident management teams. Incident information can be also obtained from closed-circuit television (CCTV) cameras, if available, and from cellular phone callers reporting events witnessed while traveling. Often CCTV cameras are the main source for incident detection and verification by TMC staff.
- Probe data can be obtained from toll tags (transponders) and cellular phones. Such data can be used to estimate travel times between various points in the network. Bluetooth readers can be also used to obtain travel times between fixed points, in addition to personal and commercial in-vehicle navigation systems (e.g., delivery trucks). The wide spread use of smartphones equipped with global positioning systems (GPS) has significantly increased the coverage and accuracy of data from mobile sources. An increased number of private vendors are working on data acquisition and marketing of data using mobile phones as probes.

Benefits

Evaluation of traveler information services show that these systems are well received by those that use them. Benefits are found in the form of improved on-time reliability, better trip planning, and reduced early and late arrivals. The overall number of people who use traveler information on a daily basis represents a relatively small portion of travelers in a region; however, demand can be extremely high during periods of severe weather, emergencies, or special events. Traveler information systems during these periods have recorded extremely high usage. Recent studies indicate that traveler information can be very effective during periods of non-recurring congestion caused by unexpected events such as incidents. Although the estimated impacts are lower for transit traveler information compared to highway traveler information, simulation models indicate that up to up to 4 percent of travelers will shift to transit when adequate information is available.

Data reliability, however, is critical. In order to gain and maintain public trust, traveler information must be accurate. The U.S. DOT FHWA has recommended that traveler information such as travel time data be at least 80 to 90 percent accurate.[8,9]

Figure 2 shows that traveler information systems have positive impacts mostly in the area of customer satisfaction, based on past evaluations. Travelers positively perceive the effectiveness of such systems in terms of mobility, efficiency and customer satisfaction even in cases where the absolute amount of travel time saved is small. New applications for delivering traveler information through the mobile internet and the effective integration of traveler information with network transportation management on freeways and arterial systems, will increase the benefits of timely and accurate travel information.

Figure 2. Benefits of Traveler Information Systems

Traveler Information Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Pre-Trip Information		◉	◉		◉	●
En-Route Information		◉		◉	◉	●
Tourism and Events						●

● – substantial positive impacts	◉ – positive impacts
○ – negligible impacts	⇅ – mixed results
✖ – negative impacts	(blank) – not enough data

Source: USDOT, *ITS Benefits, Cost Deployment and Lessons Learned Desk Reference, 2011 Update*

Transit

Transit-specific traveler information systems are operated by various public and private service providers. Transit traveler information systems range from human-operated phone systems to complex vehicle tracking systems tied to automated phone and Internet delivery systems.[11] The key elements of transit information systems technology and applications include information content (location of bus stops), information format (tables, maps or text) and delivery media (print, online, message boards and mobile devices). Table 1, adopted from a recent study by the Volpe transportation Center,[12] shows a summary of transit information systems, uses, strategies and levels of technology. Also shown the trip stages for which each element is suitable, namely pre-trip (PT), en-route (ER), at the station/stop (AS) and all (ALL).

Table 1. Technology for Transit Information Systems

A. Information Delivery Media

Uses	Basic	State-Of-The-Practice	State-Of-The-Art
Signage	Signage – static fixed signage (ER, AS)	Signage – dynamic and mobile signage (ER, AS)	Remote Infrared Audible Signage (RIAS) (AS)
Public Announcement	Live voice (ER, AS)	Recorded voice (ER, AS)	Automated – text-to-speech (ER, AS)
Telephone	Landline to Customer Service Center (PT)	Cellular access to live and automated Customer Service Center (ALL)	Interactive Voice Response (IVR) (ALL)
Human Assistance	Human assistance (ER, AS)		
Personal Computer	Networked – stationary (PT)		Networked – mobile (ALL)
Mobile Device		Non-networked (ALL)	Networked – centralized (ALL) Quick Response (QR) codes (ER, AS) GPS (ER, AS)
Transit Television		Transit TV (ER, AS)	
Kiosk		Non-networked (AS)	Networked – interactive (AS)

B. Information Content

Uses	Basic	State-Of-The-Practice	State-Of-The-Art
Routes	Routes (ALL)	(PT)	Real-time route info (ALL)
Stations/Stops	Stations/stops (ALL)	Station access (ALL)	
Fare	Schedules (ALL)	Travel mode & route fare/cost options – Financial Comparisons (PT)	Financial Comparisons (PT)
Service Alerts	Elevator/escalator station access (ALL) Signage/oral instructions (AS)	Service alerts (ALL)	Customized service alerts (ALL)
Real-Time Location		Self (ER, AS)	Transit vehicles (ER, AS)
Destinations	Station/stop names (ALL)	Non-integrated Landmarks, Points of Interest (PT)	Integrated (ALL)
Passenger Load	Seasonal surveys (PT)	Using APC for planning (PT)	

C. Information Format

Uses	Basic	State-Of-The-Practice	State-Of-The-Art
Map	Hardcopy map (ALL)	Personalized: Web-based (PT)	Personalized: Mobile Device (ALL)
Table	Table (ALL)		Dynamic Table (ALL)
Text	Text (ALL)		Dynamic Text (ALL)
Audio	Customer Service Center (PT) Operator/Station public address (ER, AS)	508 Compliant website & reading software (PT) ADA-Required In-Vehicle/Station stop announcements (ER, AS)	Station direction from Remote Infrared Audible Signage (RIAS) (AS)
Website	Website – static information (PT)	Website – dynamic information (PT)	Website – frequent updates (ALL)
Trip Planner		Single mode – static and non real-time (PT)	Multimodal and/or real-time (ALL)
Electronic Message		E-mail (PT) Really Simple Syndication (RSS) (PT) SMS (ALL)	E-mail (ALL) Really Simple Syndication (RSS) (ALL)

Trip Stages: Pre-Trip (PT), En Route (ER), At-station/Stop (AS), All Trip Stages (ALL)

Source: USDOT, *Traveler Information Systems and Wayfinding Technologies in Transit Systems.*

One transit service example is the Tri-County Metropolitan Transportation District of Oregon (Tri-Met). Tri-Met operates a real-time traveler information system for transit riders. The Tri-Met system includes an online transit trip planner offering Statewide transit trip planning services. Tri-Met tracks transit vehicles using Automated Vehicle Location (AVL) and offers updated arrival and departure times on both the website and traveler information phone system. These updates allow riders to call a phone number or visit the website to view the real-time arrival of their bus. An example of a private-operated transit trip planning system is a system operated by Google. Google offers transit trip planning services in a large number of cities and metropolitan areas throughout the United States (e.g., the Portland, OR, metropolitan area..

The provision of easily accessible real time information to travelers for both automobile and transit services is key to making travelers aware of the options that they have for travel. Prior to 2006, most transit agencies implemented their own custom trip planner systems and web interface software. With the release of Google Transit, the General Transit Feed Specification (GTFS) for transit data, and other open source platforms such as OpenTripPlanner, there has been a major change in the level of effort and costs required to implement transit and multimodal trip planners by both large and small transit agencies. the Web-based Multi-Modal Trip Planning System (MMTPS) in North Eastern Illinois, which was sponsored by the Federal Transit Administration (FTA) and implemented from 2004 to 2010, demonstrates this change. The MMTPS aimed to integrate driving itineraries, transit trip planners, and real-time monitoring systems to provide side-by-side comparisons of trip itineraries using transit, driving, or any combination of non-motorized modes including biking and walking. The goal was to create a comprehensive decision support tool for choosing travel options that incorporates convenience, efficiency, and cost from the traveler's perspective. The cost of the MMTPS and its development of a custom application was just more than $4 million. Transit agencies now have the tools to provide many of the same features by converting schedule and route information to the GTFS feed and providing it to Internet service providers at a fraction of the cost of a custom system. The cost includes anywhere from 12 hours to two-person months of labor and about 2 hours per change of schedules.

Parking Information

Parking information traditionally consisted of maps of available parking facilities. Currently, most cities across the U.S. provide pre-trip parking information over the Internet.[14] Web pages provide maps with the location of the parking facilities and other information, i.e., the facility’s address, capacity, hours of operation, costs, and forms of payment accepted.

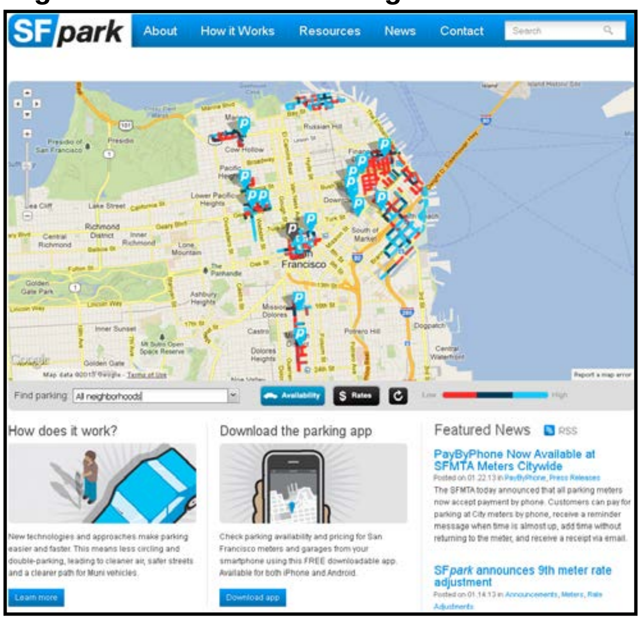
Parking lot-specific systems employ dynamic message signs to provide both and space availability information. More sophisticated parking information systems have signs on every floor of a garage, at the start of every aisle, and sometimes in front of every individual parking space.

The basic technologies employed consist of entry/exit counters and space occupancy sensors. Inductive loops, ultrasonic sensors and video are typical surveillance technologies. Communications is provided through fiber optic lines (for airport parking facilities) and radio frequency identification (RFID) on most parking facilities.

Currently a number of private service providers (e.g., Streetline, ParkMe, Park Assist ParkingCarma, ParkMobile, Parking Panda) have developed applications through the Web or in mobile devices to display parking availability in real-time, provide online reservations, and allow electronic payments. These providers obtain real-time information through parking occupancy sensors or, when such data is not available by predicting the parking facility's occupancy from past information.

An example of an advanced parking information and management system is SFpark implemented by the city of San Francisco, California. Parking availability is displayed on the web and on smartphones through custom mobile applications (Figure 3). Parking occupancy is obtained from wireless sensors at each parking location. Pricing on both street parking and garages varies by time of day and day of the week to maximize utilization. Essentially pricing is determined to maintain parking occupancy up to 85%.[15]

Figure 3. Real-Time Parking Information



The availability of real-time parking availability at transit stations and online reservation systems permits the linking of auto and transit trips that allows travelers to change travel modes en-route. CMS display information to motorists on roadway traffic conditions (e.g., accidents and delays), availability of parking in park-and-ride lots, and departure time of the next train. Drivers may decide to park and ride transit if the expected travel time to their destination is faster than the estimated driving time. A pilot test (smart parking) sponsored by the California Department of Transportation (Caltrans) in collaboration with the Bay Area Rapid Transit (BART) District demonstrated the feasibility of the system.

Researchers at the University of California, Berkeley conducted a pilot test sponsored by Caltrans to determine whether the roadside display of real-time trip times for highway and transit modes to the same destination in the Bay Area influenced commuters' mode choice. The pilot test consisted of three CMS deployed before exits to two major transit stations (Millbrae and Redwood City). The CMS displayed three items (Figure 4): highway travel time, train commute-hour express service travel time, and the next train departure time. The findings indicate that about 2 percent of motorists chose transit when travel time-savings was 15 minutes or less, and 8 percent choose transit when the time-savings was greater than 20 minutes.[16]

Figure 4. Display of MultiModal Travel Information on CMS

Source: Evaluation of Displaying Travel Information on CMS, UC Berkley Report CWP-2009-2.

Driver Assistance Systems

This section focuses on technologies and systems primarily designed to improve driver safety. ITS technologies for traveler comfort and convenience are described in the next section.

ITS technologies for improving driver safety include:

- Intersection collision warning systems (CWS) detect and warn drivers of approaching traffic and potential right-of-way violations at intersections.
- Obstacle detection systems, including side object detection systems use vehicle-mounted sensors to detect obstructions—such as other vehicles, road debris, or animals—in a vehicle's path or projected path and alert the driver.
- Blind-spot detection/information systems (BLIS), alert the drivers for presence of other vehicles in their blind spot.
- Lane change warning systems alert drivers of the presence of vehicles, or other obstructions, in adjacent lanes when the driver prepares to change lanes.
- Rollover warning systems notify drivers when they are traveling too fast for an approaching curve, given their vehicles operating characteristics.
- Road departure warning systems warn drivers that their vehicle is about to leave the roadway, whether they are approaching a curve too fast, or about to unintentionally drift off the travel lane.
- Forward collision warning (FCW) systems, also known as rear-end collision avoidance systems, warns drivers that they are in a conflict situation with a lead vehicle. These conflicts can arise when the lead vehicle is stopped, slowing, or traveling at a constant speed.

- Rear-impact warning systems warn the lead vehicle driver that they are in conflict with a following vehicle. The warning can be presented by the lead vehicle or transmitted from the following vehicle to an in-vehicle warning system in the leading vehicle.
- In-vehicle vision enhancement improves visibility for driving conditions involving reduced sight distance due to night driving, inadequate lighting, fog, drifting snow, or other inclement weather conditions.
- Drowsy driver warning systems alert the driver that he or she is fatigued which may lead to lane departure or road departure.

Most of the above described systems have been developed or tested under the USDOT Integrated Vehicle-Based Safety System (IVBSS) initiative, which focuses on improving safety for light vehicles and heavy trucks.[17]

The video on the link below shows an advanced driver assistance system developed at the California PATH, University of California Berkeley. This system integrates GPS, digital map, on-board sensors, and wireless communication to perform a variety of driver assistance functions, such as in-vehicle signage, speed warning, curve over-speed warning, lane-departure warning, and wrong-way warning.

The system provides access to real-time roadway information and map update via vehicle-infrastructure wireless communication, robust high-accuracy vehicle positioning through sensor fusion of GPS, DR sensors, and digital map data, and multiple warning means, such as audio, visual, and speech warnings, through selected driver machine interfaces (e.g.: a dashboard device or a bluetooth enabled cell phone).
Visit https://www.youtube.com/watch?v=5vuKvW_5QVM

Adaptive Cruise Control

Adaptive cruise control (ACC) systems currently available on most high-end automobiles consist of cruise control systems combined with radar sensors to measure the range to the vehicle in front and adjust the vehicle's speed to maintain a preset headway (minimum of 1 sec). Gap control, acceleration, and braking are tuned to give a natural feel similar to the driver's own driving. The behavior of an ACC equipped vehicle car in traffic is similar to a car under manual control, with a cautious driver. ACC equipped vehicles have negligible effects on highway lane capacities.

Cooperative ACC (CACC) systems consist of ACC systems and wireless data communications among vehicles. They permit adoption of shorter gaps by the following drivers and improved string stability. Field tests with subject drivers at the University of California PATH Program have shown that the mean following gap is about 1.5 seconds for ACC vehicles and 0.72 seconds for CACC vehicles. Simulation results indicate that penetration rates of 70 percent for CACC vehicles may increase lane capacities by about 5o0 percent (3,000 vphl); a penetration rate of 100 percent CACC may double the capacity of the travel lane.[18]

Precision Docking

Precision docking systems automate the positioning of vehicles at loading/unloading areas. The technology is particularly useful for transit busses because it permits fast loading and unloading of passengers with special needs at bus stops, thereby reducing waiting time and improving ease of access for all passengers. Precision docking and lane assist technologies for transit greatly contribute to the success of Bus Rapid Transit (BRT) systems that aim to provide rail transit comfort and reliability using conventional busses and can operate on narrow travel lanes.

Technologies for precision docking and lane assist include magnetic guidance systems consisting of magnets embedded in the center of the travel lane, GPS systems, and machine vision systems from video images. Precision docking of a 60 ft articulated bus was successfully demonstrated by the California PATH Program in real-world conditions in Oakland, CA.[19]
The following video link below shows the preparation for and the actual field test for precision docking and lane assist performed by the California PATH, University of California Berkeley in Oakland, CA.

Visit **http://www.youtube.com/watch?v=JvXLdifNfmg**

On-Board Monitoring

On-board monitoring applications track and report cargo conditions, safety and security, and the mechanical condition of vehicles equipped with in-vehicle diagnostics. In-vehicle data recorders (IVDR) collect data on driving behavior and provide feedback to drivers, either in real time or through a post trip report. In the event of a crash or near-crash, the IVDR can record vehicle performance data and other input from video cameras or radar sensors to improve postcrash data processing.

On-board monitoring systems are used to report mileage and other vehicle utilization patterns to the driver's insurance company in return for a discount on insurance premiums. Further information is provided on Module 14, "ITS Emerging Opportunities and Challenges". The interface of on-board monitoring units with GPS-equipped in-vehicle navigation systems permits the implementation of congestion pricing schemes by distance traveled, time of day, and location. Additional information is provided in Module 8 "Electronic Tolling and Pricing".

Most on-board safety monitoring systems focus on commercial vehicles.[20] The findings of several evaluation studies indicate that they are effective in reducing accidents or improve driver behavior as relates to safety. Reduction of more than 30 percent in safety-related events has been reported. However, other studies offer evidence that the effects of the intervention are not sustained indefinitely—the rates return to pretreatment levels after a period of time, ranging from 4 to 10 months in the reported studies.[21] Therefore, it has been suggested that strategies to promote continued engagement in the process should be part of any such implementation.

Traveler Comfort and Convenience

This section describes ITS technologies for improving the travel experience. For drivers, such technologies include navigation systems, electronic payment and parking assistance. For transit riders, the technological innovation is electronic payment systems.

In-vehicle navigation and route guidance systems with GPS technology provide turn-by-turn directions to drivers to reach their destinations, thereby reducing unnecessary distance traveled. Typically these systems include additional information for local businesses (electronic yellow pages), and parking availability. These systems may be autonomous or provided by auto manufacturers for a monthly subscription service (e.g., General Motor's OnStar® system).

Electronic toll collection (ETC) facilitates payment at toll facilities. Drivers pay the posted tolls through a supplied transponder in the vehicle without stopping at the toll plaza. ETC systems operate as either an integrated multistate system such as the E-ZPass system, or single-state or single toll authority systems such as the California FasTrack system. Module 8 "Electronic Tolling and Pricing," provides additional information on characteristics, types and benefits of ETC systems.

ETC improves toll lane capacities by up to four times and up to five times under open road tolling (ORT). Open road tolling does not utilize toll booths and drivers transverse toll plazas at highway speeds. Open-road ETC systems also can use license-plate recognition technology to bill drivers who don't have transponders. Because drivers do not have to stop at toll plazas, OTR can reduce fuel consumption and emissions at toll booths by minimizing delays, queuing, and idling time. ETC transponders may be also used to pay for parking at airports and other facilities.

ORT facilities have significant safety benefits. A recent study at the Garden Expressway in New Jersey shows that crashes at locations where ORT systems were deployed are decreased by about 24 percent after deployment of these systems.[22] Recent data from Florida's Turnpike Enterprise, Orlando-Orange County Expressway Authority and the Texas Turnpike Authority division of TxDOT show that conversion to ORT reduces tolling accidents by more than 60 percent.[23,24]

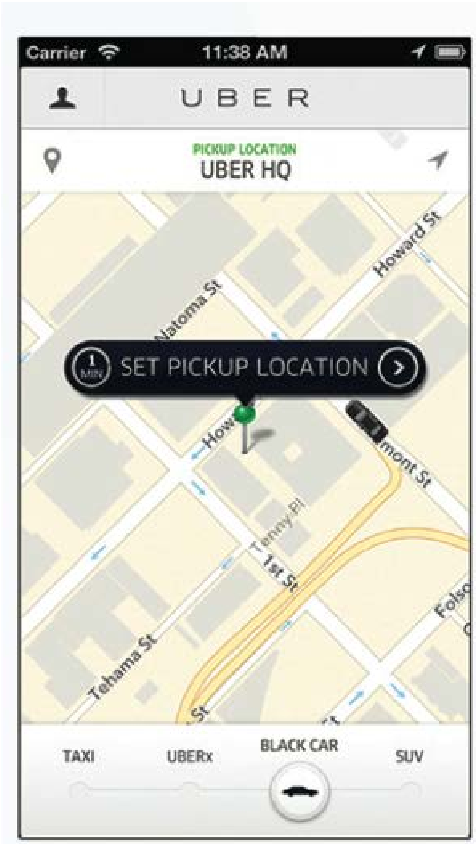
ETC technology is essential for the implementation of congestion pricing schemes that are increasingly been implemented on existing highway facilities, e.g., express lanes, and conversion of High Occupancy Vehicle (HOV) to High Occupancy Toll (HOT) lanes. Drivers must have ETC transponders to use these facilities. The ETC technology is generally different than the traditional toll collection since pricing varies by prevailing traffic conditions in order to maintain a predetermined level of service and passenger occupancy levels.

Electronic transit fare payment systems can provide increased convenience to customers and generate significant cost savings to transit agencies by reducing the costs involved in cash-handling transactions. Transit users may use magnetic stripe cards (read-only or read-write), smart cards with varying levels of memory and computing power, credit cards or mobile phones to pay for transportation services. Fare-transaction machines can read and write to multiple types of media and fare products, and regional processing centers can consolidate financial information and streamline fare transaction management for multiple transit agencies.

The widespread connectivity, available because of the smartphones and associated applications greatly enhances the traveler experience especially the hiring of taxis and the use car sharing systems especially in large metropolitan areas.

A number of smartphone based applications that utilize the phone's GPS signal to hire a taxi service. All of these services also allow passengers to link a credit card for payment to eliminate the problem of having cash or getting a receipt for reimbursement. Additionally, passengers are typically able to rate their drivers. An early market leader is the hailo application popular in London, England. Uber now operational in over 300 cities around the world allows the user to choose the type of service, private vehicle, taxi or shared ride (Figure 5). The Lyft application is currently focusing on shared-rides.

Figure 5. Uber Application



s://www.uber.com

Car sharing is a form of car rental for short time periods. Car sharing is designed for users who need occasional access to a private vehicle. Car sharing services are available to most metropolitan areas worldwide and provided by private companies (e.g., Zipcar and Citycarshare), traditional rental companies (e.g., Hertz on Demand), auto manufacturers (Daimler' car2go and BMW's Drivenow), and public agencies (city of Paris Autolib' electric car sharing service). Applications for mobile devices allow users to locate and reserve vehicles. Customers are also able to see the fuel or battery available for gasoline powered vehicles or battery charge for electric cars, and they also can reserve parking for their destination. Benefits of car sharing include reduction in auto ownership, increase in transit ridership reductions in fuel consumption and emissions.

As of January 2014, in the United States 1,228,573 members shared 17,179 vehicles among 24 operators... In addition to conventional car sharing usage, several agencies including car2go and DriveNow offer one-way (or point-to-point) car sharing, which allows members to pick-up a vehicle at one location and drop it off at another. [25]

Electrified Vehicles

Consumers are increasingly interested in electric vehicles (EVs) and most vehicle manufacturers are interested in increased availability of electric models. This interest is driven by concerns about the rising cost and availability of fossil fuels, the health of the environment, particularly noise and exhaust emissions, and recent developments in batteries and fuel cells. Electric vehicles employ various technologies for power sources include batteries only, hybrid, and plug-in hybrid electric vehicles.[26]

Battery-powered EVs use an electric motor for propulsion with batteries for electricity storage.
The energy in the batteries provides all motive and auxiliary power onboard the vehicle. Batteries are recharged from grid electricity and brake energy recuperation, and also potentially from non-grid sources, such as photovoltaic panels at recharging centers.

EVs offer the prospect of zero vehicle emissions of GHGs and air pollutants, as well as very low noise.

An important advantage of EVs over conventional internal combustion engine (ICE) vehicles is the very high efficiency and relatively low cost of the electric motor. The main drawback is their reliance on batteries that presently have very low energy and power densities compared to liquid fuels. Although there are very few electric automobiles for road use being produced today (probably only a few thousand units per year worldwide), many manufacturers have announced plans to begin serious production within the next 2 to 3 years.

Hybrid electric vehicles (HEVs) use both an engine and motor, with sufficient battery capacity (typically 1 kWh to 2 kWh) to both store electricity generated by the engine or by brake energy recuperation. The batteries power the motor when needed, to provide auxiliary motive power to the engine or even allow the engine to be turned off, such as at low speeds.[27] Over the past decade, over 1.5 million hybrid vehicles have been sold worldwide, and their market penetration is approaching 3 percent in the United States. [28] None of today's hybrid vehicles has sufficient energy storage to warrant recharging from grid electricity, nor does the powertrain architecture allow the vehicles to cover the full performance range by electric driving.

However, a new generation of plug-in hybrid vehicles (PHEVs) is designed to do both, primarily through the addition of significantly more energy storage to the hybrid system. PHEVs combine the vehicle efficiency advantages of hybridisation with the opportunity to travel part-time on electricity provided by the grid, rather than just through the vehicle's internal recharging system. PHEVs can run on electricity for a certain distance after each recharge, depending on their battery's energy storage capacity – expected to be typically between 13 to 50 miles. This means that a significant share of daily driving probably can be satisfied by PHEVs' all-electric range. For example, in Europe, 80 percent of the trips are less than 16 miles. In the United States, about 60 percent of vehicles are driven less than 30 miles with about 85 percent are driven less than 60 miles.[29] The market for PHEVs has grown rapidly in the last 2 years, reaching more than 300,000 unit sales worldwide in 2014.[30] Forecasts indicate that HEVs and PHEVs combined will represent 3.1% of worldwide auto sales and 5.1% of total U.S. vehicle sales by the year 2017.

Personal Rapid Transit (PRT)

PRT systems consist of small, driverless vehicles efficiently navigating a network of interconnecting tracks. Key operational characteristics include off-line stations, on-demand operation, point-to-point travel and 'taxi' style comfort and convenience. PRT systems can be used as feeders into existing transit systems or as a stand alone systems providing direct service within city centers, at airports, attractions, campuses, parks and hospitals.

The concept of PRT, originally developed in the late 1950s as an alternative public transport mode in areas where the population densities were too low to justify the construction of a conventional metro system. The automated guidance allows short vehicle headways in the order of a few seconds which increases the route capacity, allowing the vehicles to become much smaller while still carrying the same passenger load in a given time. Smaller vehicles in turn would require simpler fixed guideways and smaller stations that result in lower capital costs.

Numerous PRT systems were designed in the late 1960s and early 1970s; most of them were consisting of small four to six passenger vehicles, but most evolved to larger designs over time. However, none of these systems was implemented because of high capital costs and other factors. The only production PRT system installed is the Morgantown PRT system in Morgantown, WV (Figure 6), which connects the three Morgantown campuses of West Virginia University (WVU) and the downtown area, for a total track length of 8.65 miles and five stations. The system became operational in 1975 and has operated continually with 98.5 percent reliability for more than thirty years. The Morgantown PRT system includes 73 vehicles approximately 15 feet long, with a capacity of twenty passengers. The vehicles feature automatic doors on both sides that open to the platform, and are handicapped-accessible.

The Morgantown system uses automated control and operates in three modes, "demand", “schedule" and circulation". Demand mode operates during off-peak hours and reacts dynamically to rider requests who press a button to request service. A vehicle is activated to service the passenger call after a predetermined time limit (typically 5 minutes), even if no other passengers have requested the same destination. Also, if the number of passengers waiting to travel to the same destination exceeds a predetermined limit, usually 15 passengers, a vehicle is immediately dispatched.

Figure 6. The Morgantown PRT System

Source: WVU Photographic Services (http://trasportaion.wvu.edu/prt

During peak hours, the system switches to schedule mode, which operates the cars on fixed routes of known demand to reduce the waiting time for a car traveling to a given destination. During low-demand periods, the system switches to the circulation mode, operating a small number of vehicles that stop at every station, which reduces the total number of vehicles circulating on the network.

Review of the operational characteristics of existing and proposed PRT technologies indicate that vehicle capacity ranged from one to 15 people, with four being the average. Line speed ranged from 13 to 150 mpg, with an average speed of 30 mph. Only three systems claimed line speeds of 65 mph or higher, with the rest of the systems operating in a more conservative 13 to 38 mph range. Minimum headways ranged from 0.5 to 4 seconds. Short headways provide for higher throughput to accommodate high passenger demands. However, the minimum chosen headway must satisfy the requirement that the following vehicle must be able to stop without affecting an immediately upstream vehicle that comes to a sudden stop ("brick-wall" headway). The minimum headway varies with speed and system capabilities with typical values of 1.5 to 2 seconds.[32]

Urban Light Transit (ULTra) is a PRT system developed by ULTra PRT and is operational at London's Heathrow airport since May 2011 (Figure 7). It runs between the airport's Terminal 5 and its business parking lot, with 2.4 miles of track and 21 vehicles. Operational statistics in May 2012 show above 99% system reliability, and an average passenger wait time over the one year period of 10 seconds. The 2getthere system in the city of Masdar in Abu Dhabi consists of five stations over a 1.1 mile of truck with 13 vehicles, each carrying up to six passengers. The system is operational for over 5 years with 35,000 passengers/month.[33]

Figure 7. The ULTra PRT System

Source: Ultra Global PRT 2013 (www.ultraglobalprt.com)

The PRT system in Syncheon, South Korea became operational in April 2014. It consists of 3 miles of track and two stations connecting the downtown Syncheon to an exhibition center.[34]

Following the implementation of the ULTra system, several feasibility studies have been conducted for implementing PRT systems as a "last mile" solution, connecting low density traveler destinations (residences, places of employment) with conventional transit systems. Examples include transit oriented developments and business parks in Silicon Valley and Pleasanton in Northern California. [35]

Vehicles, Internet, Phone and the Future

Emerging vehicle technologies include cooperative vehicle infrastructure systems, and automated driving to improve safety, mobility and to reduce excess fuel consumption and emissions. Cooperative vehicle infrastructure systems or *connected vehicles (CV)* consist of vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and infrastructure to vehicle (I2V) communications. Module 13 focuses on the status and potential applications of CVs, and Module 14 discusses emerging trends on ITS applications.

According to US DOT, the V2V vision is that eventually, each vehicle on the roadway (inclusive of automobiles, trucks, buses, busses, and motorcycles) will be able to communicate with other vehicles.[36] The dynamic wireless exchange of data between nearby vehicles can be achieved though Dedicated Short-Range Communication (DSRC), and mobile devices, such as smartphones or laptop computers.

By exchanging anonymous, vehicle-based data regarding position, speed, and location (at a minimum), V2V communications enables a vehicle to sense threats and hazards with a 360- degree awareness of the position of other vehicles and the threat or hazard they present, calculate risk, issue driver advisories or warnings, or take pre-emptive actions to avoid and mitigate crashes. The basic application is the Here I Am data message, which can be derived using non-vehicle-based technologies such as GPS to identify location and speed of a vehicle, or vehicle-based sensor data wherein the location and speed data is derived from the vehicle's computer and is combined with other data such as latitude, longitude, or angle to produce a richer, more detailed situational awareness of the position of other vehicles. V2V communications will enable active safety systems that can assist drivers in preventing 76 percent of the crashes on the roadway.

V2I communications for safety is the wireless exchange of critical safety and operational data between vehicles and highway infrastructure, intended primarily to avoid or mitigate motor vehicle crashes but also to enable a wide range of other safety, mobility, and environmental applications. An example is the ability for existing traffic signal systems to communicate the signal phase and timing (SPaT) information to the vehicle in support of delivering active safety advisories and warnings to drivers, as illustrated in Figure 8. V2I communications could potentially address an additional 12 percent of crash types not addressed under V2V communications. [37,38]

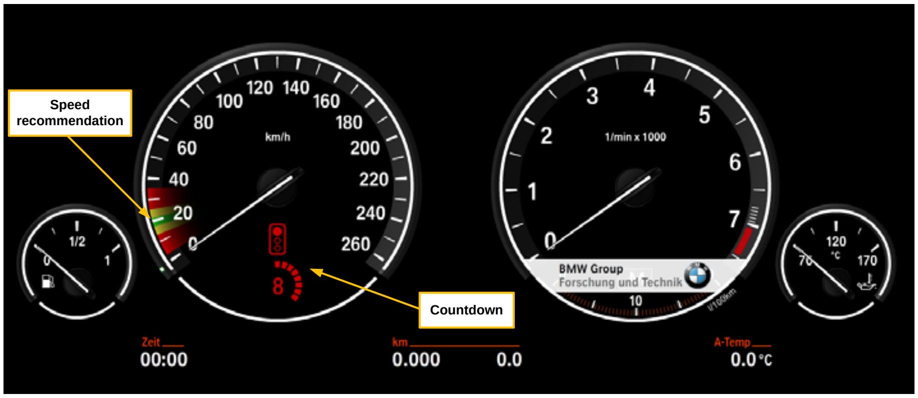
Figure 8. V2I Communication -- The SPaT Message

Source: www.its.dot.gov/strategic plan 2010 2014

The availability of connected vehicle data will provide the opportunity for a wide range *of* dynamic, multi-modal applications *to manage the transportation system for optimum performance.*[39] Examples *include adaptive* signal control, accurate and timely traveler information, strategies *to* mitigate incident impacts, and improve travel time reliability for transit and freight movements. The deployment of such strategies depends on the penetration rate of CV-equipped vehicles.

V2I connected vehicle data may also significantly reduce environmental impacts of each trip. Informed travelers may decide to take environmentally friendly routes to save both time and fuel cost. The availability of vehicle data (location, speed) and the SpaT information from the signal system is used to create driver speed advisories to minimize fuel consumption and emissions. An experimental system developed by BMW as part of a USDOT exploratory advanced research project provides in-vehicle, real-time speed advisory based on the SPaT information from traffic signals. The driver interface displays the recommended speed for minimum fuel use (Figure 10).[40]

Figure 9. BMW In-Vehicle Driver Speed Advisory



Source: BMW, Advanced Traffic Signal Control, prepared for FHWA Exploratory Advanced Research Project

References

1. FHWA, Real-Time Traveller Information Program, http://ops.fhwa.dot.gov/travelinfo/tinews.htm
2. FHWA, "*What Have We Learned about Intelligent Transportation Systems: Chapter 4: ATIS,"* Washington, DC, 2000.
3. USDOT RITA, "*Intelligent Transportation Systems Benefits, Costs, Deployment, and Lessons Learned Desk Reference: 2011 Update*," Final Report FHWA-JPO-11-140, September 2011.
4. USDOT RITA, "*Deployment of ITS: A Summary of the 2010 National Survey Results,"* Final Report, prepared by Oak Ridge National Laboratory, August 2011.
5. SILVER Alert: http://nationalsilveralert.org/silveralert.htm
6. Sivak, M. and B. Schottle, "*Recent Changes in the Age Composition of U.S. Drivers: Implications for the Extent, Safety and Environment Consequences of Personal Transportation*," Report UMTRI-2011-23, University of Michigan, June 2011.
7. New Cities Foundation, "*Connected Commuting: Research and Analysis on the New Cities Foundation Task Force in San Jose*", www.newcitiesfoundation.org/wp-content/uploads/ New-Cities-Foundation-Connected-Commuting-Full-Report.pdf, 2012.
8. GHSA, "*Distracted Driving: What Research Shows and What States Can Do*," Washington, DC, 2011.
9. Deeter, D., "*Real Time Traveler Information Systems*," NCHRP Synthesis Report 399, Transportation Research Board, Washington DC, 2009.

10. FHWA 2000.
11. Rahman, M., S. C. Wirasinghe, and L. Kattan, "Users' Views on Current and Future Real-Time Bus Information Systems, *Journal of Advanced Transportation*, 2012.
12. USDOT RITA, "*Traveler Information Systems and Wayfinding Technologies in Transit Systems,*" Report FTA-MA-26-7998-2011.1, May 2011.
13. Ibid.
14. FHWA, "*Advanced Parking Management Systems: A Cross-Cutting Study*," Report FHWA-JPO-07-011, January 2007.
15. Shoup, D., "*The High Cost of Free Parking*," Updated Edition, American Planning Association, Chicago, IL, 2011.
16. Mortazavi, A. et al., "*Evaluation of Displaying Transit Information on Changeable Message Signs*," Research Report UCB-ITS-CWP-2009-2, University of California Berkeley, September 2009.
17. ITS JPO Integrated Vehicle-Based Safety Systems www.its.dot.gov/ivbss

18. Nowakowski, C., et al., "*Cooperative Adaptive Cruise Control: Testing Drivers' Choices of Following Distance,"* California PATH Research Report UCB-ITS-PRR-2010-39, UC Berkeley, November 2010.
19. Tan H-S, et al, "*Field Demonstration and Tests of Lane Assist/Guidance and Precision Docking Technology*," California PATH Research Report UCB-ITS-PRR-2009-12, January 2009.
20. Misener, J. A., et al.," *Onboard Monitoring and Reporting for Commercial Motor Vehicle Safety*," Report No.FMCSA-RRT-07-030, Federal Motor Carrier Safety Administration, Washington, DC, 2007.
21. Horrey, W. J., et al., "On-Board Safety Monitoring Systems for Driving: Review, Knowledge Gaps, and Framework, "*Journal of Safety Research*, Volume 43 (1), pp 49–58, February 2012.

22. Yang, H., K. Ozbay, and B. Bartin, "*Effects of Open Road Tolling on Safety Performance on Freeway Mainline Toll Plazas*," 91st TRB Annual Meeting, Washington, DC, January 2012.
23. Gordin, E., J. Klodzinski, and C. Dos Santos, "Safety Benefits from Deployment of Open Road Tolling for Main-Line Toll Plazas in Florida," *Transportation Research Record, Journal of the Transportation Research Board, No. 2229,* Washington, DC, 2011.
24. PBS&J, "Removing Tollbooths Produces Major Safety Improvements," *AASHTO Journal*, December 2009 www.aashtojournal.org/Pages/121109ortsafety.aspx
25. Shaheen 2012.
26. Shaheen, S. and A. Cohen, "*Innovative Mobility Carsharing Outlook Carsharing Market Overview, Analysis, and Trends*," Transportation Sustainability Research Center, University Of California, Berkeley, 2012.
27. Larminie, J. and J. Lowry, "*Electric Vehicle Technology Explained*," Wiley, 2003.
28. International Energy Agency, "*Technology Roadmap: Electric and plug-in hybrid electric vehicles,*" Organization for Economic Cooperation and Development, 2009.
29. International Energy Agency 2007.
30. International Energy Agency, http://www.iea.org/evi/Global-EV-Outlook-2015-Update_1page.pdf
31. Overview of PRT systems and links to PRT websites. Maintained by J. B. Schneider. http://faculty.washington.edu/jbs/itrans/prtquick.htm. Accessed December 2012.
32. Cottrell, W.D. and O. Mikosza, "New-Generation Personal Rapid Transit Technologies: Overview and Comparison," *Transportation Research Record, Journal of the Transportation Research Board, No. 2042,* Washington D.C., 2008, pp. 101–108.
33. Mazdar PRT system http://www.2getthere.eu/masdar-city-operations-extension/
34. Suncheon BRT system http://globalblog.posco.com/koreas-first-personal-rapid-transit-prt-skycube/
35. Raney, S., J. Paxson, and D. Maymudes, "Design of Personal Rapid Transit Circulator for Major Activity Center: Hacienda Business Park, Pleasanton, California," *Transportation Research Record, Journal of the Transportation Research Board, No. 2006,* Washington, DC, 2007.
36. ITS JPO, Connected Vehicles Basics http://www.its.dot.gov/cv_basics/
37.. Ibid
38. USDOT RITA, "*AASHTO Connected Vehicle Infrastructure Deployment Analysis*," Final Report FHWA-JPO-11-090, Washington, DC, June 2011.
39. California PATH, "*Investigating the Potential Benefits of Broadcasted Signal Phase and Timing (SPaT) Data under IntelliDrive*," Final Report, IntelliDrive Pooled Fund Study, University of Virginia, May 2011.
40. BMW of North America, "*Advanced Traffic Signal Control*," Final Report, prepared for the FHWA Exploratory Advanced Research Project, July 2012.

List of Acronyms

ACC	Adaptive Cruise Control
AMBER Alert	America's Missing: Broadcast Emergency Response Alert
AVL	Automatic Vehicle Location
APC	Automatic Passenger Counters
BLIS	Blind Spot Information System
BRT	Bus Rapid Transit
CACC	Cooperative Adaptive Cruise Control
CCTV	Closed Circuit Television
CMS	Changeable Message Sign
CV	Connected Vehicles
DMS	Dynamic Message Sign
DSRC	Dedicated Short Range Communications
ETC	Electronic Toll Collection
EV	Electric Vehicle
FCC	Federal Communications Commission
FTA	Federal Transit Administration
FMCSA	Federal Motor Carrier Safety Administration
GPS	Global Positioning System
HEVs	Hybrid Electric Vehicles
HOV	High Occupancy Vehicle (Lane)
HOT	High Occupancy Toll (Lane)
IVBSS	Integrated Vehicle-Based Safety System
MVDS	Microwave Vehicle Detection System
LEO Alert	Low Enforcement Officer Alert
ORT	Open Road Tolling
PHEVs	Plug-In Hybrid Electric Vehicles
PRT	Personal Rapid Transit
RFID	Radio Frequency Identification
SMS	Short Message Service
TMC	Transportation Management Center
VAA	Vehicle Assist and Automation
V2I	Vehicle to Infrastructure Communications
V2V	Vehicle to Vehicle Communications