World’s Premiere Roadway Detector Evaluation Facility “Open for Business”

Fred Yazdan, Caltrans

Tens of thousands of roadway detectors throughout California provide the “infostructure” on which Intelligent Transportation Systems (ITS) services are based. The resolution, accuracy, and cost effectiveness of these detectors are critical to Caltrans and other transportation service providers. To meet the need for data of known quality, and to evaluate the increasing number of available roadway detector technologies, California PATH researchers at UC Irvine, working with Caltrans’ Division of Research and Innovation, Inductive Signature Technologies, Inc., and Loragen Corporation, have developed and deployed a detector evaluation facility that can quickly and automatically determine the operational accuracy of traffic detectors with unprecedented statistical accuracy.

The Traffic Detector and Surveillance Sub-Testbed (TDS²) consists of two contiguous sites on the seven-lane Interstate 405, south of Irvine. TDS² overhead cameras automatically take a picture of every passing vehicle at both the upstream and downstream sites. Detection modules use the video data to generate a numeric Video Signature Vector (VSV) for each vehicle, and transmit these to a central Internet-connected computer via a low-power wireless network. The correlation computer matches the VSVs and re-identifies the vehicles. This not only provides an absolute ground truth to which other detectors can be compared, but also allows the same detector to be set up at each site to evaluate reproducibility as a function of speed, lane, headway, vehicle type, lighting, or other types of environmental or traffic conditions that may effect detection accuracy. This capability not only determines which detector works best overall, but also determines the specific conditions that cause a particular type of detector to misread.

The overall purpose of the TDS² is to provide a real-world laboratory for the development and evaluation of emerging traffic
detection and surveillance technologies relative to: appropriateness for ITS operations and performance measurement, data quality and consistency, ease of use, ease of installation, and overall cost. The growing popularity of the PeMS (Performance Measurement System), traveler information systems, and other ITS functions have placed an increased emphasis on data validity and the detection systems upon which this “intelligence” is based.

The TDS² has been specifically optimized to assess the accuracy of all types of non-intrusive overhead and side-fire roadway detectors, and compare them with conventional form factor rectangular loops. Although the facility can evaluate any type of detector, it is optimized to evaluate the types of high fidelity detection systems needed for ITS. Travel time is becoming a very useful parameter for PeMS, Advanced Transportation Management and Information Systems (ATMIS), incident detection, congestion routing and other functions, and the true travel time estimation requires vehicle characteristics to be re-identified between detection sites. Likewise, Origin/Destination (O/D) data is an essential input for traffic models to make future predictions, and this site can directly assess the applicability of detectors for these types of functions.

The TDS² has a number of unique capabilities optimized for detector evaluation, which in aggregate are not duplicated anywhere else in the nation. These high-tech capabilities include:

- The video “ground truth” system, developed by PATH researcher and Cal Poly San Luis Obispo Professor Art MacCarley, and deployed by Loragen Corporation, which takes a picture of each vehicle and automatically re-identifies it downstream independent of its lane or speed.
- Inductive Signature loops that output the unique waveform or “signature” of each vehicle and then use this information to re-identify each vehicle downstream. This provides independent automatic confirmation of the video re-ID system above. These loop detectors, from Inductive Signature Technologies, Inc. (www.ist-traffic.com) can also output the more conventional bivalent data compatible with 170 and 2070 controllers, but with much greater accuracy than is produced by loops at other freeway sites.
- Three streaming Pan-Tilt-Zoom (PTZ) video cameras that can be accessed and controlled through any web browser connected to the Internet. This is the closed-circuit television (CCTV) camera system of the future.
- Wireless broadband communication that allows all types of information to be available real time across the Internet. The data passes through UC Irvine, City of Irvine, and Caltrans communication hardware on its way to the Web, in a remarkable institutional synergy of interagency cooperation.

The TDS² also has two overcrossings with overhead mounting and wiring systems, which allow detectors to be installed over traffic lanes without shutting down lanes. This capability is not available anywhere else in California. Moreover, the
TDS\textsuperscript{2} is equipped with poles pre-wired for installation of side-fire detectors on the outside shoulder of both sites. One site also has a pole and wiring on the inside shoulder, to evaluate HOV detectors, dual side-fire detectors, or both. Finally, the facility includes a completely instrumented freeway offramp. This offramp, in conjunction with an instrumented freeway interchange just upstream of the facility, ensures a high degree of accuracy in detecting traffic weaving, which has traditionally been very difficult for detectors to detect, but very important for traffic engineers to understand.

The TDS\textsuperscript{2} is on its way to becoming the premier detector evaluation site in the nation. This evaluation facility will help engineers meet the data needs of ITS well into the future. It will provide valuable service to Caltrans Traffic Operations, university researchers, and the detector development community in the 21st century.

“The overall purpose of the TDS\textsuperscript{2} is to provide a real-world laboratory for the development and evaluation of emerging traffic detection and surveillance technologies.”
Understanding how people will respond to new technologies and concepts is not an exact science. Yet this is exactly the information that transportation innovators and entrepreneurs need to bring new ideas to commercialization. Obtaining such information is a key objective of the California PATH Program’s latest initiative: the Innovative Mobility Research (IMR) program. IMR researchers collect and analyze before-and-after data to provide industry, innovators, and policymakers with critical information about transportation projects’ societal impacts.

**IMR and PATH**

PATH’s Advanced Transportation Management and Information Systems (ATMIS) group, under the new leadership of PATH Deputy Director Hamed Benouar, is reorganizing its research efforts into several new program areas based on clusters of expertise. The goal of this new program approach is to provide more modal choice and improve the transportation system’s overall efficiency, safety, and security. This new approach will better address the mission and goals of PATH’s main partner and sponsor, the California Department of Transportation (Caltrans—www.dot.ca.gov).

The new program areas being developed will be managed by PATH lead researchers, in close collaboration with faculty and students across the State, government, and industry. The new research areas include: Innovative Mobility, Traffic Management, Public Transit, and Systems Management (which incorporates benefit and cost analysis, planning, and ITS decision support). The Innovative Mobility program area, led by Dr. Susan Shaheen, is the first to reach final shape. It will serve as a model for the other new program areas.

**Premise**

Innovative Mobility is based on the premise that transportation systems can facilitate mobility by providing a variety of modes that people can choose from when making trips, modes that can be competitive with the private automobile. Innovative Mobility services enable users to evaluate costs, convenience, and impacts before making a modal choice.

PATH’s Innovative Mobility Research program (IMR) conducts research into advanced technologies and mobility solutions that could create more transportation options and improve connectivity among different transportation modes, while minimizing transportation systems’ negative societal and environmental impacts.

Research conducted at IMR evaluates the options that consumers might choose for transportation...
and offers impartial information for policymaking decisions and the commercialization of mobility services and technologies.

**Goal**

The goal of this research is to help industrial leaders, policy makers, and innovators to gain crucial early information about new technologies and ideas. IMR specializes in designing custom programs to test emerging mobility technologies and concepts, and in executing comprehensive, state-of-the-art evaluations to understand these technologies and concepts, their societal impacts, user interfaces, and business models.

Based at PATH’s Center for Commercialization of Intelligent Transportation System Technologies (CCIT) in Berkeley, IMR has grown from four to twelve research team members (including numerous UC students) and has established several new promising industry partnerships. Hamed Benouar, who also serves as the Executive Director of CCIT, is pleased that CCIT has been able to provide an arena for new private members of CCIT, such as Parking Carma and Segway LLC, to collaborate with IMR on research projects and to access Center benefits.

**Research Projects**

IMR is committed to facilitating the development, deployment, and adoption by consumers of innovative mobility services. Researchers design projects and conduct evaluations, principally in California, but nationally and internationally as well. Each effort focuses on understanding user behavior, developing new business models, and testing advanced technologies. IMR’s current research areas are: shared-use vehicle systems (carsharing, station cars, shared bikes, and Segway Human Transporters), innovative mobility and smart growth, and smart parking management. IMR’s current projects are described below.

**CarLink (www.gocarlink.com)**

The CarLink II project, building on experience from CarLink I (see below), deployed a fleet of twenty Honda Civics at the California Avenue Caltrain Station in Palo Alto that were shared by commuters. The pilot ran from August 2001 until June 2002, and has been successfully transitioned to a third party operator. Final analysis of the pilot will be completed in early 2004.

**Project Partners:** California PATH Program, Caltrans, American Honda, ITS-Davis, Caltrain, and Stanford Business Park.

CarLink I was a commuter-based carsharing pilot that ran between 1999 and 2000 at the Bay Area Rapid Transit (BART) District Dublin-Pleasanton Station, employing a fleet of twelve natural gas Honda Civics and smart carsharing technologies.

**Project Partners:** ITS-Davis, Caltrans, American Honda, California PATH Program, Bay Area Rapid Transit (BART) District, and Lawrence Livermore National Laboratory.

**Smart Mobility Model Initiative**

Smart growth, including access to transit with safe pedestrian and bicycle facilities, has been shown to reduce automobile use. IMR is evaluating the links among smart growth; urban design based on compact, multi-use, people-friendly communities; and innovative mobility in the Sacramento-Davis region. The first phase of this research is well underway (transportation modeling, expert interviews, and focus groups).

**Project Partners:** California PATH Program, UC Davis campus, Caltrans, and ITS-Davis.

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Early in 2002, the Riverside Transit Agency (RTA) approached UC Berkeley Institute of Transportation Studies Director Martin Wachs for assistance in assessing the potential of a Bus Rapid Transit (BRT) demonstration project in Western Riverside County.

BRT can be seen as a “rapid” transit system that combines buses, stations, services, running way, and Intelligent Transportation System (ITS) elements into a fully integrated system with a unique identity. BRT combines flexible service with advanced technologies to improve system reliability and customer convenience, shorten travel time and delay, and lower the operating, maintenance and capital cost of buses.

Professor Wachs assembled a team of ITS faculty from several UC campuses, as well as PATH staff, post-doctoral researchers, and graduate students to conduct a focused and critical analysis of travel demand by mode in Western Riverside County. The team included Professors Cervero, Deakin, Skabardonis, and GSR Ying-Hsiu Jill Liu from Berkeley; researchers Mike Mauch, Mark Miller, Wei-Bin Zhang, and Jim Misener from PATH; Professor Matt Barth from Riverside; and Professor Brian Taylor from UCLA. The analysis required constructing planning level models, evaluating existing demand for modes of travel, and reviewing worldwide BRT systems and practices with an eye to which of these would be most applicable to Western Riverside County.

**Riverside Study**

The Riverside studies focused on land-use patterns (i.e., land-use density plots) along subregional areas and along corridors to gain insight into the potential transit demand, given enhancement of transit services between subregional areas or corridors with relatively high travel demand.

The interim conclusion was straightforward: even with the explosive growth of population in Western Riverside County, near-term implementation of BRT would probably not attract significant ridership. However, a longer-term deployment of technologies that lead to BRT—technologies that will enhance the quality of rider service not just in terms of reducing travel time—may be a successful precursor to BRT. This was persuasively presented to RTA, and our effort has shifted toward a 4–5 year deployment horizon for BRT, with precursor technologies happening on a much shorter term.

Within this deployment horizon, the three most promising potential BRT route alternatives (from the demand side) are likely to be:

1) Parallel to SR-91 from the north Corona area, through the city of Riverside and then to Moreno Valley.

2) From the downtown Riverside area to Loma Linda and/or downtown San Bernardino, running mainly on SR-91 and I-215 with a small number of stops at each end.

3) From the Temecula area to the north Corona area, mainly along I-15, with a small number of stops at each end.

Even at this early stage of design, Alternative 1 (which would run mainly on arterial streets with regular stops along much of the route) would look much different from Alternative 2 or Alternative 3, which would serve more as point-to-point service, with much of the line-haul distance on freeways possibly without intermediate stops.
Worldwide Review of BRT Systems and Practices

Ying-Hsiu Jill Liu’s review of BRT systems and practices screened a large number of projects and selected sixteen with special relevance to Riverside. However, the insights gleaned from these projects offer more general relevance, since the selected BRT projects are marked by elements that have been uniquely successful or unsuccessful. They offer insights into the process that was used to plan these BRT projects, how BRT services were financed and priced, the physical designs of BRT routes, and the use or rejection of technological innovations in particular settings. Also of general interest are: how these BRT services are operated, how services have been maintained or changed over time, and how the systems are managed.

The review also sought information about broader planning issues that can influence the success or failure of BRT programs, including land use policies (densities, locations, and mixes of land uses), the provision and pricing of parking, and the existence or absence of feeder services and park-and-ride facilities.

The screening process looked for BRT projects that: serve low-density, high-growth, suburban communities with multiple city centers; are integrated with an existing network of local bus services and include connections to regional commuter rail or long distance commuter bus services; and are attentive to the need for effective feeder service.

Typically, however, a BRT system contains these elements:

**Exclusivity:** Most BRT systems are operated on bus-only lanes or busways, but a few operate in mixed traffic on ordinary streets in systems that also use other BRT features.

**Improved Fleet Management Technology:** Fleet management combines infrastructure with ITS technology to improve travel time and reliability of bus service, as well as traffic flow for other vehicles. Strategies include: bus turnouts or curb realignments, automatic vehicle location (AVL) systems, and preferential signal treatment for buses.

**Advanced Bus Technology:** This includes clean fuel propulsion systems, low-floor configurations, advanced communication systems, improved access, maneuverability, improved operating efficiency, reduced emissions, and lower bus weights.

**Distinctive Aesthetics or Amenities:** These include enhanced stops or stations, passenger information systems including schedules, brochures, and real-time information, and distinctive aesthetics to provide more friendly facilities and amenities.

**Faster Fare Collection and Boarding:** This is achieved through the application of prepayment methods (e.g. Smart Cards) and reconfigured platform design for easier and faster access.

Think rail, use buses

Because the high costs of such capital-intensive modes as light and heavy rail have limited their applications to a few select cities and densely populated corridors, transportation officials have increasingly seen BRT as a cost-effective way to improve transit services in a larger variety of settings. Successful BRT projects, for example, Pittsburgh, Los Angeles, Honolulu, Curitiba, and Adelaide, have shown promise in using lower cost strategies to make bus transit attractive and competitive.

BRT systems are designed to be appropriate to the market they serve and their physical surroundings. They can be incrementally implemented in a variety of environments, from exclusive rights-of-way, high occupancy vehicle (HOV) lanes, and expressways, to sharing the roads with other traffic modes.

In concept, Bus Rapid Transit combines the speed, comfort, and environmental efficiency of light rail with the flexibility, convenience, and relatively low cost of buses.
Integrated transit development with land-use policy: Such integration builds a market for transit services and reinforces Transit-Oriented Development (TOD) in areas or corridors with building site and street designs favoring transit and pedestrian usage.

**Innovative Project Delivery Methods:** New approaches for procuring, designing, constructing, operating, maintaining, and financing transit systems.

**Benefits of BRT**

BRT improves mobility by addressing roadway congestion to reduce travel time and increase reliability. Deployment can be done in phases to get rapid transit operating as soon as possible while preserving options for later expansion and upgrading.

BRT costs substantially less than rail transit. BRT can offer a level of service similar to rail transit's with respect to reliability and frequency, with the added flexibility of operating outside a fixed corridor to provide almost door-to-door service. BRT does not require a fully dedicated right-of-way over the entire length of a busy corridor, nor sophisticated single-purpose signaling or power supply systems, nor extra construction of bus operating and maintenance facilities.

BRT has been successful in attracting new ridership to public transportation. Transit ridership in Miami-Dade's South US-1 Corridor has increased 49 percent on weekdays and more than 70 percent on weekends. Finally, land use changes due to integrated Transit-Oriented Development (TOD) policy can increase the share of regional jobs located near transit stations and create investment opportunities in the vicinity of the corridor. TOD also helps to create more pedestrian- and less auto-oriented communities.

**Overview of Selected BRT Systems**

Eight of the cases selected are in the United States: Eugene, Oregon; Santa Clara County and Los Angeles, California; Hartford, Connecticut; Pittsburgh, Pennsylvania; Charlotte, North Carolina; and Orlando and Miami, Florida. Eight cases are outside the US: Quebec, Montreal, and Ottawa, Canada; Adelaide and Brisbane, Australia; Bogotá, Columbia; Curitiba, Brazil; and Nagoya, Japan.

Four Federal Transit Administration (FTA) BRT demonstration projects—Eugene, Hartford, Santa Clara, and Charlotte—were included in our review because of their general similarity to Western Riverside County, in that they to some extent serve suburban neighborhoods or low-density development.

Several successful urban BRT systems were assessed to provide a better understanding of the characteristics and benefits of BRT systems.

The other US BRT cases are Los Angeles' MetroRapid project; Orlando's downtown “Lymmo” free loop circulator service, which incorporates outstanding marketing strategies to attract riders and serves a market area comparable to downtown Riverside; an industrial city, Pittsburgh; and a tourist destination, Miami.

<table>
<thead>
<tr>
<th>Location</th>
<th>Canada</th>
<th>Australia</th>
<th>Brazil</th>
<th>Columbia</th>
<th>Japan</th>
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<tbody>
<tr>
<td>City/ Country</td>
<td>Montreal, Canada</td>
<td>Ottawa, Canada</td>
<td>Quebec, Canada</td>
<td>Adelaide, Australia</td>
<td>Brisbane, Australia</td>
</tr>
<tr>
<td>Agency</td>
<td>STM</td>
<td>OC Transpo</td>
<td>SCTR</td>
<td>Adelaide Metro</td>
<td>Queensland Transport</td>
</tr>
<tr>
<td>Corridor</td>
<td>Boulevard Pie-X</td>
<td>Downtown Grade-Separated Right-of-way</td>
<td>Rapid Metrobuses Routes 800 and 801</td>
<td>O-Bahn</td>
<td>Southeast Busway</td>
</tr>
<tr>
<td>Market</td>
<td>Montreal City</td>
<td>Compact Center and Spread-out Suburbs</td>
<td>Provincial Capital</td>
<td>North-Eastern suburbs to Central Business District (CBD)</td>
<td>Suburban Corridor</td>
</tr>
<tr>
<td>Length</td>
<td>8.6 km (5.3 miles)</td>
<td>16 km (10 miles)</td>
<td>31 km (19.3 miles)</td>
<td>12 km (7.5 miles)</td>
<td>16.5 km (10.3 miles)</td>
</tr>
<tr>
<td>Operational Settings</td>
<td>Reserved</td>
<td>Dedicated</td>
<td>Transitways (Graded Separated Lanes)</td>
<td>Dedicated Lanes on both sides of Surface Streets</td>
<td>Mainly Guided Busway</td>
</tr>
<tr>
<td>Mixed Traffic</td>
<td>no</td>
<td>yes (2.1 miles)</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

Table 1a Foreign Cases
which were selected because of their integrated feeder networks, financial sustainability, technology innovation, and supportive land-use policies.

Ottawa, Quebec, and Montreal have innovative operational settings, fleet management, traffic signal systems, impressive schedule adherence and reliability, a transit-first policy that requires planners to give precedence to public transit over all forms of road construction, and integrated Transit-Oriented Development (TOD). Adelaide and Brisbane serve suburban corridors. With their distinctive vehicle design, enhanced stations, high operating speeds or limited stops, and increased land values along the corridors, these Australian cities resemble many BRT systems in European countries, especially France and Germany. The urban BRT systems of Curitiba, Bogotá, and Nagoya show that BRT can achieve service levels and ridership similar to rail transit. Their systems, integrated with other transit modes or feeder networks, offer customers seamless transfers and reduced travel time while generating high system productivity and efficiency.

**BRT Technology**

Different BRT cases use a variety of technologies, as appropriate for their specific transit corridors, traffic problems, and local environments. Table 2 summarizes the basic technology elements used in the sixteen cases.

<table>
<thead>
<tr>
<th>Location</th>
<th>Current</th>
<th>Planned</th>
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<tbody>
<tr>
<td>City/ Country</td>
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<tr>
<td>City/ Agency</td>
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<tr>
<td>Corridor</td>
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<td>Market</td>
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<td>Length</td>
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<td>Start-up Date</td>
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<tr>
<td>Operational Setting</td>
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<tr>
<td>Mixed Traffic</td>
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Guided busways, a subset of dedicated busways, achieve operating speeds of up to 100 km per hour (60 mph) in Adelaide and Nagoya without competing with other traffic. Guided busway technology combines the flexibility of bus transit with the permanence of rail transit at a much lower cost than rail.

BRT integrated into typical Bus/HOV systems can be found in Charlotte and Quebec. Integrating the systems is advantageous: when BRT vehicles can share the roadway with other high-occupancy vehicles while achieving the same service standards as BRT vehicles operated on exclusive lanes, the result is a higher utilization rate of infrastructure.

Former railroad rights-of-way provided Hartford and Miami with space for their busways. In Hartford's planned busway system, traffic control will be required for busway vehicle entry and exit at a number of at-grade roadway intersections and some intermediate access points.

<table>
<thead>
<tr>
<th>Table 1b United States Cases</th>
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<tbody>
<tr>
<td><strong>City/ Agency</strong></td>
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<tr>
<td><strong>Corridor</strong></td>
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<td><strong>Market</strong></td>
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<td><strong>Length</strong></td>
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<td><strong>Start-up Date</strong></td>
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<tr>
<td><strong>Operational Setting</strong></td>
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<tr>
<td><strong>Mixed Traffic</strong></td>
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</table>
Fleet management and other technology options

Fleet management consists of various strategies and technologies incorporated into the BRT system for better schedule adherence, service reliability, and reduced delay and travel time. These include preferential signal treatment at intersections, infrastructure reconfigurations, and some ITS technologies, including automatic vehicle location (AVL), electronic payment, real-time transit information, and station/facility reconfiguration.

Signal priority involves detecting the presence of a bus, predicting its arrival time at the intersection, and giving the transit vehicle special treatment. Twelve of the sixteen BRT cases adopt it, the exceptions being Charlotte, Adelaide, Bogotá, and Nagoya.

Queue-jump lanes, also called “by-pass lanes,” are short stretches of bus lane combined with special bus-only early green signal priority. They can be installed in right-turn only lanes or between straight-through and right-turn lanes, permitting straight-through movements for buses only.

Bus bulbs are sections of sidewalk extending into the curb lane at a bus stop, so that buses do not have to pull over to pick up or drop off passengers. Bus bulbs provide larger passenger waiting areas, minimize bus delay, and shorten passenger walking distance. However, they may cause traffic congestion behind a stopped bus, and they cost more than conventional curbside stops. Bus bulbs are used in Santa Clara County and Quebec.

Automatic Vehicle Location (AVL) systems, used in twelve of our sixteen cases, track bus movements and offer real-time “next bus” information for display at bus stops, on kiosks, or transmission over information networks.

Enhanced bus stop and station design lets buses pick up and drop off passengers in more effective

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**Table 2. Technologies Employed in BRT Systems Worldwide**

<table>
<thead>
<tr>
<th>Operational Setting</th>
<th>Fleet Management and other Technology Options</th>
<th>Bus Stations</th>
<th>Advanced Bus Technology</th>
<th>Fare Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Signal Priority/Preemption</td>
<td>Priority Merge</td>
<td>AVL</td>
<td>Other Technology</td>
</tr>
<tr>
<td>U.S. BRT cases: 4 planned cases; 4 current cases</td>
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<tr>
<td>Charlotte, NC (planned)</td>
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<td>Eugene, OR (planned)</td>
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<td>Hartford, CT (planned)</td>
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<td>Santa Clara, CA (planned)</td>
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<td>Orlando, FL</td>
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<tr>
<td>Miami, FL</td>
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<td>Los Angeles, CA</td>
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<td>Pittsburgh, PA</td>
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<td>Overseas BRT cases: Canada (3), Australia (2), Brazil (1), Columbia (1), Japan (1)</td>
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<td>Montreal, QC, Canada</td>
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<td>Ottawa, ON, Canada</td>
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<td>Quebec City, Canada</td>
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<td>Adelaide, Australia</td>
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<td>Brisbane, Australia</td>
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<td>Curitiba, Brazil</td>
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<td>Bogotá, Columbia</td>
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<td>Nagoya, Japan</td>
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</table>

| Total Number Utilizing Technologies | 8 | 2 | 11 | 2 | 7 | 3 | 2 | 12 | 10 | 1 | 6 | 5 | 15 | 5 | 3 | 7 | 2 | 2 | 6 | 3 | 2 | 2 |
and efficient ways, reduces delay, and provides friendly facilities integrated into the local environment. Issues include bus stop spacing, bus stop location, and shelter design.

Five US BRT systems and three overseas have increased the distance between bus stops, to permit higher vehicle speeds and thus save travel time. The average spacing between stops is about 500-800 meters, and can be as great as 3-6 kilometers (2-3.5 miles), especially in Australia. Another strategy is to offer limited-stop service combined with regular local services in high-demand bus corridors. For example, the Los Angeles Metro Rapid lines, with stops about 1.3 km (0.8 miles) apart, operate on the same streets as slower local bus lines that stop more frequently.

Bus stops can be located at the near side of an intersection, the far side, or mid block. Far side stops are preferable if signal priority systems and queue jumper lanes are used. Near side stops may have a greater impact on other traffic modes because of interference to discharging flow from intersections. It’s also hard for buses to merge into the traffic stream from near side stops.

Stops and stations can be designed to convey a “brand” identity while harmonizing with the local environment by incorporating aesthetic elements, high-tech materials, or historical references. A well-designed station should include efficient landscaping, visibility, easy access with mobility aids, protection from the weather, and security enhancement.

**Advanced Bus Technology**
Advanced Bus Technology speeds up the process by which passengers board and leave the bus, thus reducing the time buses spend stopped, and also reducing passenger travel time.

**Low-floor buses** use an on-vehicle ramp to fill the gap between the step and the curb. The alternative is a raised platform on the same level as the top of the bus steps.

**Multiple-Door or Wide-Door Design** facilitates passengers’ rapid entry and exit. A multiple-and-wide door bus in Bogotá can discharge twelve people per second and reduce bus-stopping time from ten seconds to two seconds.

**Low-Emission and Low-Noise Vehicles** powered by compressed natural gas (CNG) and hybrid electric-diesel can give BRT vehicles a clean and green image (Eugene, Hartford, Los Angeles, Orlando, etc.). Generally speaking, low-emission buses cost about $1 million each; low-floor, articulated, compressed natural gas-hybrid electric buses cost $1.5 million each. Implementation of BRT, however, is certainly possible using lower-cost rolling stock.

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Smart Parking Management (with ParkingCarma)

Parking is a 26 billion dollar industry in the United States. Parking availability influences how individuals commute, impacting transit use, single occupancy vehicle driving, and traffic congestion. Smart parking approaches range from dynamic displays on roadway signs telling drivers about parking lot location and capacity, to the use of the Internet and cell phones to provide information about space availability, location, and pricing.

IMR’s Smart Parking Project is a pilot program that taps into communication technologies to help manage existing parking spaces at and around a BART station to increase space availability and transit access. IMR will evaluate smart parking management technologies and services to assess their potential to improve parking access (especially at transit stations), optimize parking space, and reduce congestion.

**Project Partners**: California PATH Program, Caltrans, BART, and ParkingCarma.

Enhancing BART Connectivity with the Segway Human Transporter

IMR is researching the use of the Segway Human Transporter (HT) as a device to improve connectivity to transit and for short trips (serving as an alternative to the private automobile). Institutional issues under investigation include use of the Segway HT on sidewalks. Central to this examination are safety issues associated with the introduction of the Segway HT on sidewalks for surrounding pedestrians and users. Other research areas include regulatory analysis of national, state, and local ordinances governing the introduction and use of the Segway HT on sidewalks, a shared-use business model, and training/deployment. This project also examines other low-impact modes and pedestrian interactions, such as wheelchairs, bicycles, scooters, and in-line skates.

**Project Partners**: California PATH Program, Caltrans, BART, Segway LLC, and DeweySquare.

Innovative Mobility Research

We invite you to meet the IMR team and learn more about the projects at [www.innovativemobility.org](http://www.innovativemobility.org). Additionally, you can learn more about CCIT at [www.calccit.org](http://www.calccit.org).
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