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Implementing BRT Intelligent Transportation Systems

Abstract: This document establishes a recommended practice for incorporating intelligent transportation systems (ITS) into bus rapid transit (BRT) services and infrastructure.

Keywords: bus rapid transit (BRT), intelligent transportation systems (ITS)

Summary: ITS is an umbrella term used to describe a variety of technologies, treatments and strategies that allow improvements to the flow of transit systems. In many cases, insertion of ITS types of technologies provide transit travel improvements with a minimal of capital investment. In other words, these methods extract efficiencies from an existing system by adding refinements to the system and/or infrastructure rather than major rehabilitation.

Scope and purpose: This *Recommended Practice* is part of a series of APTA documents covering the key elements that may comprise a bus rapid transit (BRT) system. Each document is intended to guide an organization when implementing a specific BRT system element. The decision to implement any particular element will depend on the local environment. In the planning process, care should be taken to ensure that the chosen combination of elements will achieve the goal of providing high-quality rapid transit service for customers. This document provides guidance for transit agencies and their partners in incorporating ITS into their BRT service(s). It focuses on the integration of the ITS elements into the building, operating and maintaining of BRT services and infrastructure. The document reviews the types of ITS that can be considered for BRT and highlights best practices and examples.

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Contents

1. Integration of ITS for BRT

There are a wide variety of individual ITS elements that can be considered for inclusion with any BRT service or infrastructure. This section brings these elements together with BRT by providing two tools to assist agencies and practitioners that are considering BRT implementation.

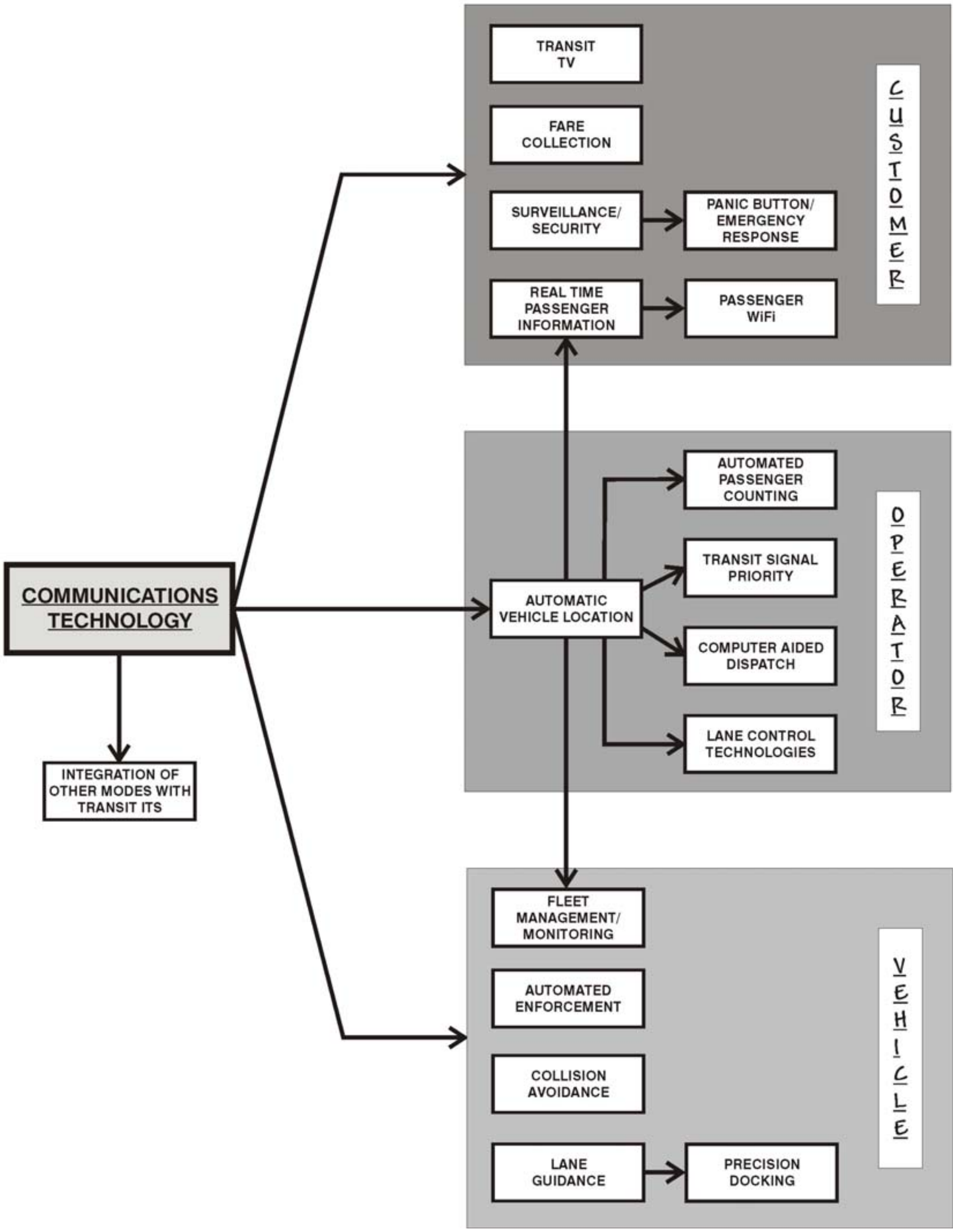
The first tool is provided in **Table 1**. It considers all the forms of ITS discussed in the remainder of this document and inserts them into sections that relate the component of BRT infrastructure with whether the ITS element is primarily for the customer for or the service provider/operator.

TABLE 1
BRT/ITS Integration Matrix

	Customer	**Operator**
Running way	• Precision docking	• Transit signal priority • Lane control technologies (intermittent bus lanes) • Lane guidance • Automated enforcement
Station	• Passenger information (on-board, at station, online) • Fare collection (at station, on-board) • Surveillance/CCTV/security systems • Precision docking • Passenger Wi-Fi • Commercial passenger information/advertising (i.e., Transit TV)	• Surveillance/CCTV/security systems • Lane guidance
Vehicle	• Passenger information (on-board, at station, online) • Fare collection (at station, on-board) • Surveillance/CCTV/security systems • Precision docking • Passenger Wi-Fi • Commercial passenger information/advertising (i.e., Transit TV)	• Transit signal priority • Lane control technologies (intermittent bus lanes) • Automatic passenger counters • Automatic vehicle location/control • Surveillance/CCTV/security systems • Panic button/emergency response • Computer-aided dispatching • Fleet management/monitoring • Collision avoidance systems • Automated enforcement
Off-corridor	• Real-time passenger information (on-board, at station, online)	• Transit signal priority • Automatic passenger counters • Automatic vehicle location/control • Fare collection (at station, on-board) • Surveillance/CCTV/security systems • Panic button/emergency response • Computer-aided dispatching • Fleet management/monitoring • Performance monitoring/archiving/data mining

The second tool is provided in **Figure 1**. This flowchart illustrates how the various ITS elements can work together in a BRT context and groups the elements into those for the customer, operator and vehicle.

FIGURE 1
Integration of ITS Elements



2. Communications technology: the core of transit ITS

Nearly all the transit ITS technologies listed in the previous section require some form of communications technology in order to function, provide data to other systems and receive instructions. The following sections examine the elements of communications technology, their benefits, their interdependence with other systems, references for additional information, and examples of where the technology has been applied in other jurisdictions.

2.1 What is it?

Communication technologies are widely used in ITS systems. Most buses now have at least one method of communicating to the outside world, be it by the driver's cell phone or via a WLAN antenna. Communications technologies are evolving rapidly, and it would be futile to list the best communication method for each application. The quantity of *all* data packets to be transferred and the amount of time in which the transfer must take place have to be considered when choosing a communication method.

Communication can be broken down into two categories: live and deferred. Until recently, voice and data also were processed separately. Recent advances in digital technology have transformed voice (analog) to another data transmission (digital).

2.1.1 Live data

Live data refers to data being sent during normal operations, when the bus is no longer in the confines of the garage. This includes the following:

- voice from and to the driver
- GPS coordinates (automatic vehicle location, or AVL)
- text messages from and to the driver
- emergency button events transmitted to the control center
- live video stream
- other information judged essential to bus operations

Live data is usually more expensive to transmit due to the required range. Data is therefore limited to light data transfers (3 to 5 MB per month per bus). Common methods of transmitting live data include the following:

- cell phone (voice and data)
- long-range radio system

2.1.2 Deferred data

Deferred data refers to data stored on the bus computer and downloaded once the bus is within the garage or at a scheduled time. Data may also originate from the garage to the bus. It includes the following:

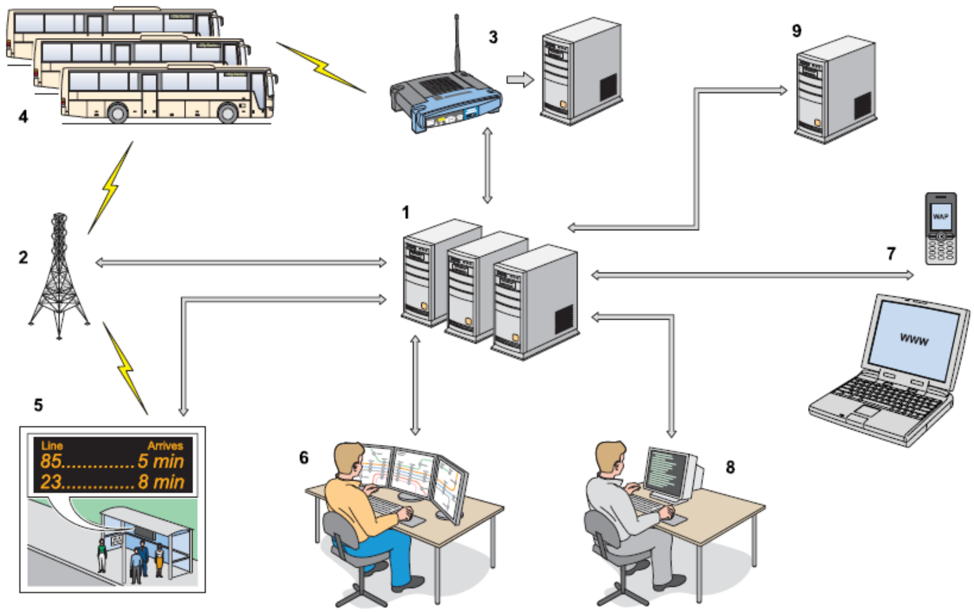
- passenger counts
- vehicle data (for example, fuel consumption)
- video surveillance segments
- update of route, announcements, and schedules
- update of destination sign program
- update of multiplex software
- update of onboard advertising

Deferred data is usually reserved for heavy data transfers. Transmitting large files on a cellular network could be cost prohibitive in terms of dollars per kilobyte. Common methods of transmitting deferred data include the following:

- WLAN
- infrared
- short-range radio system

Figure 2 illustrates a bus fleet that uses cellular technology for positioning and voice (it.2) and Wi-Fi for deferred (heavy downloads) data (it.3). Please note that street-side passenger information signs can also be updated using cellular technology, since the data stream is relatively low (it.5). Using cellular technology for the bus stop display requires power only to the bus stop.

FIGURE 2
Cellular Communications in a Bus Fleet



2.2 Overview of communications technologies

Private radio networks: Consists of a radio base, radio towers and transmitter/receivers in each bus. Enables long-distance exchange of live data. Since the packet sizes are limited, heavy downloads can be performed but may require a considerable amount of time.

Cellular: Each bus has a cell phone for voice and a cell modem for data (can also be combined). Enables long-distance exchange of live data. Fees are calculated on the quantity of bytes transmitted. This method should be limited to live data only or extremely small packets, such as vehicle information.

Wi-Fi: Consists of a garage or an area with wireless access points. Each bus has a Wi-Fi bridge that links the bus to the network. Limited area of coverage and encryption is required to prevent hacking.

Infrared: Consists of a receiver/transmitter in the garage and a receiver/transmitter in each bus. Bus needs to be aligned to the receiver/transmitter. Limited speed of transmission.

Emerging technologies: WiMAX, a third-generation cellular technology.

2.3 Other technologies used

RFID: Identifies the location of a vehicle at a particular point on the circuit. This information is then sent to the central system by another means of communication.

Inductive loops: Similar to RFID, confirms location of a vehicle at a particular point on the circuit. This information is then sent to the central system by another means of communication.

Street-side beacons: Bus triggers a street-side beacon by short wave or another means as it passes by. This information is then sent to the central system by another means of communication.

2.4 Benefits

Communications technologies are inherent to most ITS systems. Communication technologies are therefore a means of achieving benefits from ITS systems. Until recently, communications technologies were not reliable, available or well integrated. ITS systems therefore relied on manual intervention. For example, first generation automated passenger counters (APCs) required a manual intervention on the bus to retrieve the data. Communications technologies now allow this data to be transmitted remotely without having to locate and immobilize the bus. The data automatically retrieved can also be remotely processed, and actions such as sending an e-mail to a concerned party can be done automatically. One typical application of this is fleet management. If a fault code appears on the bus powertrain, this code can be sent to the garage maintenance crew automatically. The maintenance crew can act on the code by performing a road call or by planning maintenance when the bus comes back to the depot.

2.5 Integration/interdependence with other ITS systems

Most ITS systems use one form or another of communications technologies. The following are a few examples of integration with ITS systems. More information in integration is found in the individual sections of this document.

Traffic signal priority: Communications is used to trigger the change (for example, short-range radio from the bus to the signal controller). Communications is also used to detect the presence of the bus relative to an intersection.

APCs: Passengers counts can be transferred to a server remotely.

Passenger information: Communications is essential if real-time information is provided. Vehicle positioning is relayed back to a central console, which then estimates arrival time and transfers the ETA to the passenger information device.

Fare collection: Communications can be used to validate a transaction such as a smart card or credit card.

Surveillance systems: Communication can be used to transmit an image or a stream of images from the bus to the control center upon request or in an emergency situation. Communications can also be used to retrieve video footage from a bus remotely (i.e., upon entering the depot, all “events” are automatically and wirelessly transmitted to a server and saved for future reference).

Computer-aided dispatching: Communications is used to locate a vehicle that is required to provide demand responsive transit (DRT) services.

Panic button: Communication is used to track the vehicle position in real time. Communications can also be used to transmit audio and video data back to the control center.

Fleet management: Communications is used to download operational data once the bus returns to the depot. Real-time information (i.e., fault codes) can also be communicated to the maintenance crew.

Passenger Wi-Fi: Communications is used to provide passengers with Internet access on board. The vehicle can be equipped with a Wi-Fi router that has an external link such as GPRS.

2.6 References for more information

- *Transit Communications Interface Profiles (TCIP) Standard Development Program*, American Public Transportation Association, 2006. http://www.aptastandards.com/StandardsPrograms/ITStandardsProgram/TCIPProgram/tabid/113/Default.aspx
- *Communication Technologies Fact Sheet*, Federal Transit Administration. http://www.pcb.its.dot.gov/factsheets/comm/comFix_print.htm

2.7 Examples

- **BC Transit** uses a cellular connection to retrieve APC data and vehicle data remotely.
- **York Regional Transit** uses a cellular connection between the buses and the control center for its AVL system
- **Translink** uses a private radio network in its AVL/APC system.
- **Brampton Transit** buses will communicate via three different communication modes: Wi-Fi, two-way radio and cellular connections.

3. Transit ITS for the system operator

This section describes the types of transit ITS that are either controlled by or most benefit the transit service provider or operator. It describes what the technology is, the benefits of it and how it is integrated or interdependent with other transit ITS technologies. It also provides references and examples for more information.

3.1 Automatic vehicle location

3.1.1 What is it?

Automatic vehicle location (AVL) technology is applied to monitor the location of transit vehicles in real time through the use of GPS devices or other location-monitoring methods. Information about the vehicle location is transmitted to a centralized control center in either raw data format or as processed data.

As of 2006, based on data provided by FHWA, 69 percent of fixed-route transit vehicles (including BRT and non-BRT) in the 78 largest metro agencies in the United States use AVL systems. The capital cost associated with implementing AVL has ranged from $1,000 to $10,000 per vehicle.

3.1.2 Benefits

There are several benefits associated with application of an AVL system on BRT vehicles:

- **Improved system control.** The system can be calibrated with greater ease to distribute service times and coverage adequately through the application of signal priority and control centre and on-street supervision.
- **Improved bus safety.** In an emergency, the transit control center can relay vehicle location immediately to emergency response agencies.
- **Improved quality of service.** Passengers can be notified in real time of the location of the next bus and its expected arrival time.
- **Improved system integration.** Bus transfers can be better scheduled and controlled by knowing the location of each vehicle.
- **Reduced need for voice communication.** This can simplify vehicle operation for the bus operator.

- **Follow-up analysis.** Storing the AVL data collected over time can provide the opportunity to complete off-line analysis of service performance and comparison of scheduled with actual running times.

In addition to these points, some agencies have reported economic benefits from reductions in bus fleet size, increased ridership and lower operating costs associated with their AVL systems.

3.1.3 Integration/interdependence with other systems

An AVL system can be integrated with certain vehicle diagnostic systems and security features incorporated to provide enhanced vehicle monitoring. This results in quicker response to breakdowns and emergencies on vehicles.

AVL can be integrated with transit signal priority, as mentioned previously, to allow for TSP conditional priority. AVL also can be integrated with passenger information systems, both onboard stop annunciators and station passenger information systems, to provide real-time information on stop arrivals. AVL also can be integrated with APC systems to provide transit agencies with transit origin-destination data.

3.1.4 References for more information

- *Characteristics of Bus Rapid Transit for Decision Making*, FTA, 2004. http://144.171.11.107/Main/Public/Blurbs/Characteristics_of_Bus_Rapid_Transit_for_Decision_161288.aspx
- *TCRP Report 118: BRT Practitioner's Guide*, 2007. http://144.171.11.107/Main/Public/Blurbs/Bus_Rapid_Transit_Practitioners_Guide_158960.aspx
- *Automatic Vehicle Location Successful Transit Applications: A Cross-Cutting Study: Improving Service and Safety*, Joint Program Office for Intelligent Transportation Systems, FTA, July 2000. http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/11487.pdf

3.1.5 Examples

Agencies that operate BRT services and use AVL systems in North America include King County Metro in Seattle; Los Angeles MTA; Kansas City Area Transportation Authority; York Region, Ontario; and TransLink in Vancouver, British Columbia.

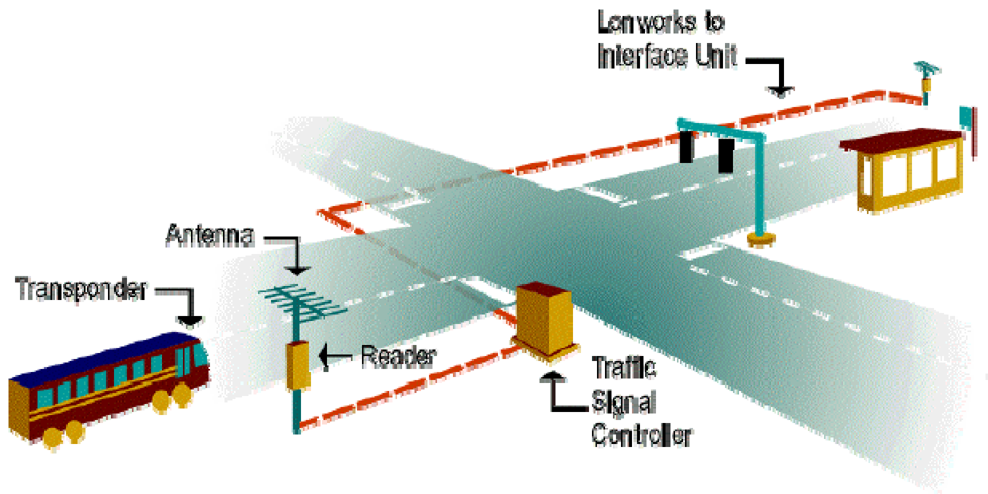
3.2 Transit signal priority

3.2.1 What is it?

Transit signal priority (TSP) is the process of altering traffic signal timing at intersections to give a priority to transit operations. TSP can be triggered by BRT vehicles operating in their own right-of-way or in mixed traffic along a street (known as "mainline" priority), or operating in an auxiliary lane at an intersection (known as a "queue jump"). With mainline TSP, the typical treatment is to extend the green signal or truncate the red signal to allow priority for BRT vehicles, thus reducing intersection delay. With a queue jump, the transit vehicle receives a separate green phase to go through the intersection before the adjacent through traffic. In either case, the signal timing is adjusted to preserve the signal cycle length and thus keep the signal system in coordination. TSP is different from signal pre-emption, which interrupts normal signal operation and changes the signal cycle length to accommodate special events, such as a train approaching a railroad grade crossing adjacent to a signal or an emergency vehicle responding to an emergency call. See **Figure 3**.

FIGURE 3

TSP Communications



TSP systems can be manually implemented by the transit operator or activated automatically using onboard technology. The latter is preferred because it eliminates requiring the operator to remember to activate the emitter or to deactivate the emitter when not required. Two types of priority can be implemented:

- **Unconditional priority,** where a BRT vehicle would always have priority at a particular intersection.
- **Conditional priority,** where the BRT vehicle would receive priority at an intersection only if certain transit or traffic operating conditions are met.

TSP is typically applied when there is significant traffic congestion and hence bus delays along a roadway. Studies have found that TSP is most effective at signalized intersections operating in congested conditions (in traffic engineering terms, this means under level of service F conditions with a volume to capacity ratio between 0.80 and 1.00). A basic guideline is to apply TSP when there is an estimated reduction in bus delay with negligible change in general traffic delay. Given this condition, the total person delay (on both buses and general traffic) should decrease with application of TSP at a particular intersection or along an extended corridor.

For mainline TSP to be most effective, bus stops should be located on the far side of signalized intersections so that a bus activates the priority call and travels through the intersection and then makes a stop. For queue jump treatments, it is preferable to have the transit stop on the near side of the intersection, where a bus serves the stop and then the operator triggers the queue jump call.

Costs for implementing TSP along a BRT corridor will vary based on the configuration of the existing signal system (with higher cost associated with signal upgrades), equipment/software for the intersection, vehicles, and the central management system. Costs are highly dependent on whether the TSP system will be localized to a corridor or centralized and integrated into a transit or regional traffic management center. These are the key cost elements to consider:

- need for replacement of any traffic signal controller equipment
- communications linkages
- on-bus or in-ground equipment requirements for detection

3.2.2 Benefits

Benefits from TSP to BRT operations can be found in three areas:

- **Reduced bus travel time:** Travel time savings associated with TSP in North America and Europe have ranged from 2 to 18 percent, depending on the length of corridor, particular traffic conditions, bus operations, and the TSP strategy implemented. The reduction in bus delay at signals has ranged from 6 to 80 percent, again variable based on particular local conditions and strategies.
- **Improved service reliability:** Schedule adherence as measured by the variability in BRT travel times and arrival times at stops can improve significantly with TSP application. In Seattle and Vancouver, bus travel time variability with TSP application was reduced by 35 to 40 percent. In Portland, Tri-Met avoided adding a bus to a corridor by using TSP and experienced up to 19 percent reduction in bus travel time variability.
- **Reduced bus operating costs:** By reducing bus travel time and delay and the variability in travel time and delay, transit agencies have experienced both capital cost savings (by saving one or more buses during the day on a route) and operating cost savings (due to more efficient bus operation). For the first two BRT corridors implemented in Los Angeles (along Wilshire/Whittier and Ventura boulevards), the transit agency realized an estimated cost savings of $110 per bus per day or $3.3 million per year.

3.2.3 Integration/interdependence with other systems

To implement TSP, there must be an emitter-type device to interact with a wayside reader or receiver at the intersection tied to the signal controller. Different TSP detection systems include optical, GPS, wayside reader, "smart" inductive loops and Wi-Fi. The signal controller must also have appropriate software to interpret and process a signal priority call, either at the controller cabinet or through communication back to centralized signal control. With automated TSP, in many cases it will be tied to an AVL and/or APC system so that only conditional priority can be implemented. In the case of integration with an AVL system, TSP would be activated only if the BRT vehicle is behind schedule, with the degree of lateness triggering priority to be programmed and possibly adjusted over time. If TSP is integrated with an APC system, then that would provide the capability of activating TSP at an intersection only if the BRT vehicle had a certain number of passengers on board, and again this could be adjusted over time.

3.2.4 References for more information

- *An Overview of Transit Signal Priority*, Intelligent Transportation Society of America, July 2002. http://www.itscosts.its.dot.gov/its/benecost.nsf/ID/478B21EDD18C9EAE85256DB100458929?OpenDocument&Query=CApp
- *Transit Signal Priority: A Planning and Implementation Handbook*, Intelligent Transportation Society of America, 2005. http://www.geodecisions.com/projectdetail.aspx?ProjectID=43441A
- TCRP Report 118: *BRT Practitioner's Guide*, 2007. http://144.171.11.107/Main/Public/Blurbs/Bus_Rapid_Transit_Practitioners_Guide_158960.aspx

3.2.5 Examples

As of 2005, more than 40 urban areas provided some form of TSP (for bus and/or rail) in North America. This included most BRT systems, including Los Angeles; Kansas City; Eugene, Ore.; San Jose; York Region, Ontario; and Vancouver, British Columbia.

3.3 Automatic passenger counting

3.3.1 What is it?

Automatic passenger counters (APCs) are devices onboard transit vehicles used to record boardings and alightings at each stop and keeping a running total of passengers onboard the vehicle. The APC units include sensors (typically infrared) at doorways to monitor passenger movements on and off a vehicle. An APC system creates an electronic record at each bus stop, typically including stop location, stop date and time, time of door opening and closing, and number of passengers boarding and alighting. APC data downloading options include manual downloading via a laptop computer, wireless data via a local area network, and real time reporting.

3.3.2 Benefits

A key benefit associated with an APC system is the ability to provide a continual record of ridership onboard a transit route, and the ability of quickly summarizing the data. Conducting ridership surveys historically has been labor extensive and has provided only a snapshot of ridership conditions to transit agencies, given that only a sampling of bus routes generally can be surveyed.

3.3.3 Integration/interdependence with other systems

APC units can be tied into an overall vehicle ITS monitoring system, including integration with the AVL and TSP systems. If integrated with TSP, conditional priority to buses is given based on a minimum number of passengers onboard a vehicle. In some cases, APC has been implemented as a standalone system with its own GPS separate from the AVL system, either because the APC preceded the AVL or because the APC was deployed after the AVL but with a different vendor. These situations have created incomplete and mismatched data and higher maintenance costs, with added post-data-collection processing needed to match the APC with AVL data.

3.3.4 References for more information

- TCRP Report 113, *Using Archived AVL-APC Data to Improve Transit Performance and Management*, Transit Cooperative Research Program, Washington, D.C., 2006. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_113.pdf
- Kimpel, Thomas, and James Strathman, *Automatic Passenger Counter Evaluation: Implications for National Transit Database Reporting*, Center for Urban Studies, Portland State University, April 2002. http://www.upa.pdx.edu/CUS/publications/docs/PR124.rtf
- TCRP Synthesis 29, *Passenger Counting Technologies and Procedures*, Transit Cooperative Research Program, Washington, D.C., 1998. http://144.171.11.107/Main/Public/Blurbs/153666.aspx

3.3.5 Examples

Of the existing BRT systems in North America, 10 (Albuquerque, Chicago, Las Vegas, Los Angeles, Oakland, Orlando, Ottawa, Sacramento, San Jose, and York Region) have APC systems on all or a portion of their BRT fleet. In general, typically transit agencies that have installed APC systems have been able to replicate existing ridership about 95 percent of the time based on field checks.

3.4 Computer-aided dispatch

3.4.1 What is it?

Computer-aided dispatch (CAD) is often used by operators of demand-responsive transit (DRT) services. DRT services are typically used to provide disabled passengers with a complimentary transit service that usually includes door-to-door services on an as-needed basis. DRT services are often provided by a combination of one or more type of vehicle: in-house transit vehicle, taxicab, or independent service contractor operating a small bus or a modified van or car.

3.4.2 Benefits

Because the demands on the service fluctuate greatly from day to day—and even from hour to hour—many transit agencies have acquired CAD software to improve the efficiency of their operations. The software can be used either to send messages to the transit vehicle or taxicab via a mobile data terminal and/or to store and retrieve data (radio logs, field interviews, client information, schedules, etc.). A dispatcher may announce the call details to field units over a two-way radio. Some systems communicate using a two-way radio system's selective calling features. CAD systems may send text messages with call-for-service details to alphanumeric pagers or wireless telephony text services. The central idea is that people in a dispatch center are able to easily view and understand the status of all units being dispatched. CAD provides displays and tools so that the dispatcher has an opportunity to handle calls for service as efficiently as possible.

CAD typically consists of a suite of software packages used to initiate public safety calls for service and dispatch, and to maintain the status of responding resources in the field. It is generally used by emergency communications dispatchers, call-takers and 911 operators in centralized, public-safety call centers, as well as by field personnel utilizing mobile data terminals (MDTs) or mobile data computers (MDCs).

CAD systems consist of several modules that provide services at multiple levels in a dispatch center and in the field of public safety. These services include call input, call dispatching, call status maintenance, event notes, field unit status and tracking, and call resolution and disposition. CAD systems also include interfaces that permit the software to provide services to dispatchers, call takers and field personnel with respect to control and use of analog radio and telephony equipment, as well as logger-recorder functions.

Computerized mapping, AVL, automatic number identification and caller identification technology are often used to enhance the service by pinpointing the locations of both the customer and the most suitable vehicle for serving the customer.

3.4.3 Integration/interdependence with other ITS systems

Some CAD systems allow several sources of information to be combined. For example, adding AVL and geographic information systems (GIS) could improve service by getting transit vehicles to a call location faster. Ideally, CAD is connected to monitor vehicle locations provided by an AVL system. This information is used to suggest the closest vehicle to a customer.

3.4.4 References for more information

- TCRP Synthesis 57: *Computer-Aided Scheduling and Dispatch in Demand-Responsive Transit Services*, Transportation Research Board, 2005. http://144.171.11.107/Main/Public/Blurbs/ComputerAided_Scheduling_and_Dispatch_in_DemandRes_155357.aspx

3.4.5 Examples

- **Charlotte Area Transit System:** Added CAD system to existing AVL system with mobile data terminals.
- **Santa Clara Valley Transit:** Introduced CAD along with GIS in order to simplify and improve communications between control center, passengers and management.

3.5 Lane control technologies

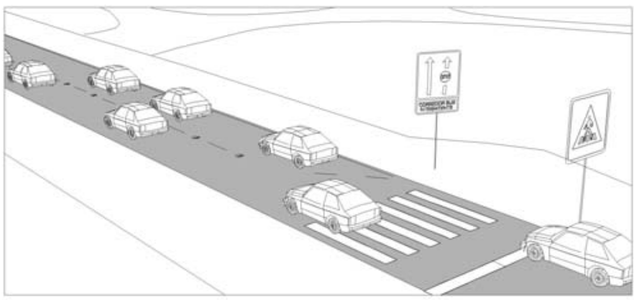
3.5.1 What is it?

An intermittent bus lane (IBL)—or moving bus lane (MBL)—is a restricted lane for the short time that the bus uses that particular lane. IBL can also be called a moving bus lane. This concept consists of using a general-purpose lane that can be changed to a bus-only lane just for the duration of time needed for the bus to pass. Afterward, the lane reverts back to a general-purpose lane until another approaching bus needs the lane for its movement.

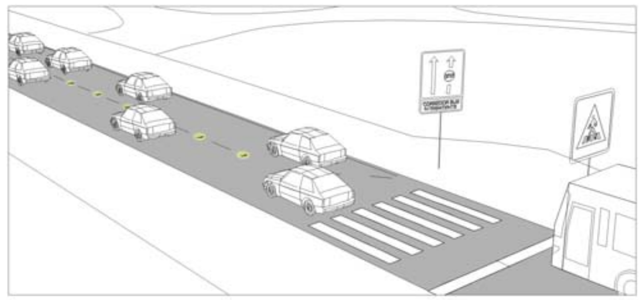
From an operational protocol standpoint, the IBL system is intended to be activated only when the flow of general traffic is operating below a speed that inhibits bus transit speeds. When that threshold is reached—as sensed by technologies that can provide knowledge of real-time traffic conditions—longitudinal flashing lights embedded in the roadway lane divider are activated to warn general-purpose drivers that they cannot enter that lane and that a bus is approaching. Vehicles already in the lane are allowed to continue on. This leaves a moving gap or a moving time window for the bus to travel through. This moving gap can be best described as a zone measured from the back of the bus bumper to a fixed distance ahead of the bus.

When traffic conditions are not expected to cause delays to the bus movement, the intermittent bus lanes should not be activated. **Figure 4** describes the IBL sequence.

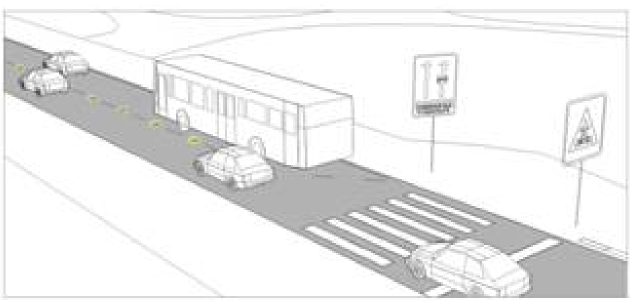
FIGURE 4
Intermittent Bus Lane



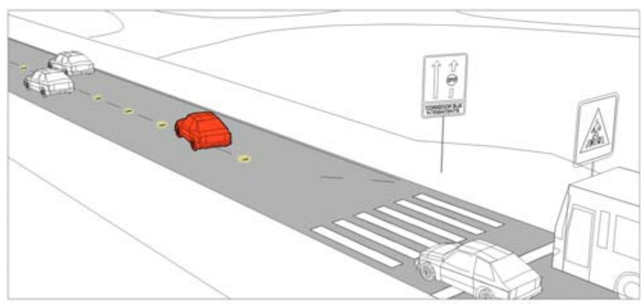
1. IBL in "off" status: LED signals are off, and any vehicle can enter
and use the rightmost lane.



2. Bus approaching the IBL: The LEDs are flashing, and general traffic vehicles are not allowed to enter the right-most lane.



3. Bus flowing in the IBL: The LEDs are flashing, and still no cars can enter the rightmost lane.



4. Car entering the IBL while the LED signals are flashing: Driver behavior is not allowed.

3.5.2 Benefits

Bus speeds and reliability are improved whenever the bus is able to flow independently from the general traffic, but it can be cost-prohibitive to build exclusive bus lanes for routes that are lower in frequency. IBL does not require expensive capital costs because it uses the existing roadway infrastructure and takes only the time it needs to move separately from general traffic. This allows the bus lane to be used for general traffic the majority of time.

It has low implementation costs and uses well known, widely used and proven traffic signal management technologies and products.

3.5.3 Integration/interdependence with other systems

An AVL system is required to establish the bus location. This system ties into variable message signs (VMS) to inform the drivers of lane restriction. This system also requires integration into real-time ITS traffic monitoring systems that record levels of congestion and compute the dynamic space and approach length required to activate on and off the longitudinal embedded flashers. This system is dependent on an interconnect and special software within the signal controller system of the existing roadway.

3.5.4 References for more information

- Viegas, J.M., et al., *The Intermittent Bus Lane System; Demonstration in Lisbon*, 86th Transportation Research Board Annual Meeting, Washington, D.C., 2007. http://pubsindex.trb.org/view.aspx?id=802041
- Currie, G., and H. Lai, *Intermittent and Dynamic Transit Lanes – The Melbourne Experience, Paper 08-0626 TRB*, 87th Transportation Research Board Annual Meeting, Washington, D.C., 2008. http://pubsindex.trb.org/view.aspx?id=847587

3.5.5 Examples

Feasibility is still a question for this treatment, as the two known IBL systems have varying degrees of success.

- **In Lisbon, Portugal,** a demonstration project of IBL was conducted by José Manuel Viegas in 2005-2006. Field data reported transit travel speed increases of 15 to 25 percent. This system was inserted into a two-lanes-each-way arterial street one-half mile miles long. The system works effectively when traffic congestion is moderate. In saturated flow conditions, the reduced road capacity—if even for a few seconds—can create significant backups in the general traffic. Driver compliance was good, as the drivers understood that the restriction would be for only a short time.
- **In Melbourne, Australia,** the Dynamic Fairway project started in 2001 on Toorak Road and continues today. This 1.3-mile stretch is a two-lanes-each-way urban street that utilizes VMS signing and embedded LED flashing lights similar to Lisbon. The transit mode is a TRAM operating in the center lanes as the restricted lane. Travel speed increases of 1 to 10 percent were reported. Melbourne is developing a study for the bus lines called the MBTL (Moving Bus/Tram Lane). This study also modeled simulations for the bus lanes and has yet to build a pilot project.

In general IBL/MBL systems can be promising for specific applications and circumstances.

- IBL applications do not work well in saturated traffic flow conditions at peak.
- IBL seems better suited for lower bus headways (three buses per hour).

4. Transit ITS for the customer

This section describes the types of transit ITS that most benefit the transit user. Each of the following sections describe what the technology is, the benefits of it, how it is integrated or interdependent with other transit ITS technologies, and provides references and examples for more information.

4.1 Real-time passenger information

4.1.1 What is it?

Passenger information (**Figure 5**), specifically information related to the transit service, takes many forms, including information needed before making a trip, during the trip and at the termination of a trip. The main sources of information need to be provided as follows:

- **Through appropriate media that can be accessed before making a trip.** These help with trip planning and the ultimate decision to use transit;

- **At stations or other points prior to boarding a transit vehicle.** Relating primarily to vehicle arrival, these help instill rider confidence and comfort and can contribute to overall travel time competitiveness (e.g., a rider can do a quick errand if a vehicle arrival is several minutes away).
- **On the vehicle itself.** Next-stop information, traffic updates and service disruption alerts can also instill confidence and comfort by helping passengers reach destinations and transfer connections most efficiently;
- **At a termination point.** Destination and transfer information can help manage rider expectations during and after the trip.

FIGURE 5
Real-time Passenger Information

Through ITS, the most valuable recent advance in quality transit service information has been real-time information, where pre-set and theoretical schedule times have been replaced by real time, which takes into account delays and other variations that affect the actual arrival and departure times. Real-time information is generated by algorithms that can accurately predict the time a transit vehicle will arrive at a specific location thanks to data from technologies such as satellite-based GPS or roadside sensors. This is then combined with automatic signage that transmits this information to users of the service.

Many BRT services, and transit systems in general, are now providing real-time transit service information through a fully integrated ITS system that brings together many or all of the elements described in this section. Passenger information services that are part of these systems include the following:

- **"Next-bus" arrival displays at stations:** These displays are provided trough variable message signs (VMS), either LED or similar, programmable for a single route or multiple routes (flashing or scrolling mode), with sign units mounted into the shelter or station infrastructure.
- **"Next-stop" displays and automatic stop annunciators (ASA) on vehicles:** This is also provided through VMS, typically mounted behind the driver, used in conjunction with the onboard audio system using automated voice generation (important for those who are visually impaired). An automated audio system ensures accuracy and sound clarity and removes the need for drivers to announce next stops.
- **Online information sources:** This including schedule pages on transit Web sites and personal communication devices.
- **Interactive voice response (IVR) system:** This interactive telephone service uses prompts to provide schedules and other information.
- **Interactive automated trip planners:** These can be accessible via online services, IVR, mobile devices and kiosks at stations.

4.1.2 Benefits

Good, accurate and easy-to-use transit service information is one of the most important factors in a potential transit rider's decision on whether or not to use transit. Being well informed goes a long way toward instilling a high level of confidence and comfort in using the system and being assured that the trip will be relatively stress-free and will take place as planned.

The advent of real-time information takes service information to a much higher level, in that delays and reliability issues are taken into account and the information is (or at least should be) very accurate. As a result, the comfort and confidence level of passengers is greatly enhanced, and more people will use the service and will be more likely to use it on a regular basis. This has been the case in many systems where, through surveys, passengers have identified real-time information, especially the variable-message arrival displays at stations, as one of the highest factors in their decision to use the service (e.g. Viva BRT service in York Region, Ontario).

4.1.3 Integration/interdependence with other ITS systems

Automated transit service information, especially real-time information, needs to be fully integrated with an overall ITS and communications system. Essential to this is AVL, the technology that uses GPS or other means to accurately determine the location of a specific vehicle and predict its arrival at a particular station. The AVL information, in addition to providing arrival information to passengers, also provides the means through (through CAD) for the transit operation to monitor and adjust the positions of vehicles, in order to maximize schedule reliability and consistency of service frequencies (avoid or minimize "bunching" of vehicles due to delays and traffic constraints).

4.1.4 References for more information

- *TCRP Synthesis 48: Real-Time Bus Arrival Information Systems,* Transportation Cooperative Research Program, 2003. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_syn_48.pdf
- *TCRP Research Results Digest 5: Electronic On-Vehicle Passenger Information Displays (Visual and Audible),* Transportation Cooperative Research Program, 1995. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rrd_05.pdf
- *TCRP Report 92: Strategies for Improved Traveler Information,* Transportation Cooperative Research Program, 2003. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_92.pdf
- *TCRP Report 90: Bus Rapid Transit Implementation Guidelines,* Transportation Cooperative Research Program, 2003. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_90v2.pdf
- *TCRP Report 118: BRT Practitioner's Guide,* Transportation Cooperative Research Program, 2007. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_118.pdf
- *Characteristics of Bus Rapid Transit for Decision Making,* Federal Transit Administration, 2004. http://www.nbrti.org/media/documents/Characteristics%20of%20Bus%20Rapid%20Transit%20for%20Decision-Making.pdf

4.1.5 Examples

BRT systems in North America that feature automated passenger information technologies include York Region "Viva" (Ontario), Los Angeles Metro Rapid, Las Vegas MAX, Boston Silver Line, and Cleveland Health Line.

4.2 Passenger Wi-Fi

4.2.1 What it is

Wi-Fi (see **Figure 6**) allows transit customers to connect to the Internet using enabled mobile devices, such as laptops, cell phones and PDAs. Public access is provided through hotspots provided either free of charge or for a fee (pay-per-use or subscriptions models are possible). These wireless hotspots can be located both onboard transit vehicles and at stations.

At stations, wireless service can be provided with off-the shelf routers and modems (cable or DSL). For on-board Wi-Fi, two options exist: installing routers on each vehicle connected to satellite networks, or creating a continuous wireless mesh along the corridor through a number of overlapping fixed access points.

FIGURE 6
Passenger Wi-Fi

4.2.2 Benefits

Wireless Internet provision is not a critical transit component; however it is a high-quality customer amenity. Wi-Fi is used with laptops and an increasing number of mobile devices to provide higher speed access to the Internet than is available through cellular networks.

One of the many potential benefits to customers is an increased enjoyment of transit. In particular, it can allow people to make use of their time in transit for entertainment or work, which could have the effect of decreasing their perceived transit travel times. This is especially the case for customers with long journeys. In addition, the availability of Wi-Fi can contribute to increased customer perception of “premium” levels of service. This may increase the appeal of transit to nontraditional market segments.

4.2.3 Integration/interdependence with other ITS systems

Strictly speaking, passenger Wi-Fi is independent from other ITS systems. In some instances, however, it may be able to piggyback on other operational systems that make use of data communications. All of the following ITS systems can be implemented with Wi-Fi technologies, which could also include a passenger Wi-Fi component:

- automated passenger counters
- onboard security cameras
- electronic fare collection/smart cards
- passenger information (stop announcements, displays and real-time information signs)
- transit signal priority
- fleet monitoring through various smart-bus system configurations or patches, and vehicle diagnostics

4.2.4 References for more information

- "Bay Area Demonstrates Successful Public Transit Wi-Fi," 2008. http://www.dslreports.com/shownews/Bay-Area-Demonstrates-Successful-Public-Transit-WiFi-91508
- Hengst, Amy, "AC Transit Offers Free Wifi for Bay Area Commuters," Daily Wireless, 2007. http://www.dailywireless.com/features/transit-offers-free-wifi-051707/
- Mass Transit Magazine, "Internal Wi-Fi: Piggybacking essential business applications on a rider-attracting Wi-Fi network," 2009. http://www.masstransitmag.com/print/Mass-Transit/Internal-Wi-Fi/1$5313

4.2.5 Examples

- Utah Transit Authority
- AC Transit, Alameda-Contra Costa, Calif. (currently the largest fleet in the nation offering Wi-Fi)
- Capital Metro Transit, Austin, Texas
- Orange County Transportation Authority (OCTA), Orange County, Calif.
- Charles River Transportation Management Association (CRTMA), Cambridge, Mass.

4.3 Fare collection

4.3.1 What Is It?

Fare collection is the manner in which passengers pay their fares, either on the bus, at the station, or in advance. Decisions about fare collection can be divided into decision about policy (e.g., What is the fare to be paid? What is the transfer policy?) and about technology (e.g., What is the fare media? How are tickets vended?). Although this section focuses only on the technology elements, it is important to recognize that technology and policy cannot be separated. For example, if a proof-of-payment policy is being adopted, this will clearly have implications on the technology required to implement it. Conversely, once a decision has been made about a specific technology, this may eliminate certain policy options (although this is becoming less of an issue as smart-card technology becomes more widely deployed, given its inherent flexibility). Implementation of BRT may also provide an opportunity to revamp fare collection for an entire system, by introducing new technologies that allow for a more customer-friendly experience.

As noted below in the references, there is a great deal of research and practical experience related to fare technology, so this document does not attempt to re-create all that information. However, some key technology areas to consider include the following:

- **Fare media:** What medium/media will be used to store fare information. Options include simple tickets, flash passes, magnetic stripe passes, magnetic stripe stored value cards, and smart cards (typically contactless). Each of these fare media has advantages and disadvantages, and the selection of a specific medium should take into account the fare policy that is being implemented.
- **Sales/vending technology:** Most rail-based transit systems employ some type of vending machine technology, but these are generally less common on bus systems, with agencies relying instead on cash fare and point-of-sale merchants to sell items such as monthly passes and multi-ride tickets. Given the higher-quality image and customer-friendly experience that is often one of the goals of BRT, introducing ticket vending machines at BRT stations may be very beneficial, even if these are not typically deployed at regular bus stops.
- **Communications:** Many state-of-the-art fare collection systems now require real-time communications for activities such as credit card verification and status monitoring. Particularly in an on-street environment, hard-wired communications may be expensive and difficult to maintain, so consideration should be given to developing a secure wireless communications network to support the fare collection system.

4.3.2 Benefits

The principal benefit of improving fare collection is to reduce dwell time at stations, thereby improving average travel speed and reliability. Fare collection technology can also support goals for providing a high-quality, customer-friendly experience, as well as projecting an overall high-technology image for the system.

4.3.3 Integration/interdependence with other ITS systems

- passenger information, particularly at the station
- automatic passenger counters, since fare boxes also collect boarding data
- communications technologies
- computer-aided dispatching and fleet management/monitoring, for central monitoring of fare equipment
- surveillance/CCTV/security systems, to provide security for equipment and customers paying fares

4.3.4 References for more information

- *TCRP Report 10: Fare Policies, Structures, and Technologies*, Transit Cooperative Research Program, 2002. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_94.pdf
- *TCRP Report 32: Multipurpose Transit Payment Media*, Transit Cooperative Research Program, 2009. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_32.pdf
- *TCRP Report 94: Fare Policies, Structures, and Technologies: Update*, Transit Cooperative Research Program, 2003, http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_94.pdf
- *TCRP Report 115: Smartcard Interoperability Issue for the Transit Industry*, Transit Cooperative Research Program, 2007, http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_115.pdf

4.3.5 Examples

York Region's VIVA system and the Las Vegas MAX systems both incorporate off-board fare collection opportunities on their BRT services.

4.4 Surveillance/CCTV/security systems

4.4.1 What is it?

Security systems include both surveillance CCTV as well as alarms, both of which can be located both onboard vehicles as well as off-board in stations or along guideways.

FIGURE 7
Surveillance/CCTV/Security Systems

Surveillance devices are principally made up of closed-circuit television (CCTV) cameras, occasionally equipped with microphones. These enable a central dispatch and/or control center to remotely monitor vehicles, stations and guideways. Increased resolution recording can be triggered by an operator onboard or remotely by central dispatch.

Alarms can include passenger-activated alarm strips or buttons on vehicles or in stations, and operator panic buttons including those found on mobile data terminals (MDTs) as part of real-time CAD/AVL communication systems.

There are two types of panic alarms: overt and covert. Once activated, overt alarms can be heard by all passengers. This type of alarm is preferred in emergencies to alert all passengers to take immediate action (i.e., evacuate the bus). In contrast, the activation of covert alarms is known only to the operator and central dispatch.

Integration to real-time CAD/AVL communications means that central dispatch is able to track the exact location and direction of travel of a bus requiring assistance and can identify what resources are accessible to the bus (law enforcement, emergency response, transit support staff, other buses, etc). Information can also be passed on to other agencies tied to 911 services for improved, integrated support.

4.4.2 Benefits

These systems provide the benefit of improved assistance and emergency response to both the operator and the public. Cameras and microphones can allow central dispatch to continually monitor and assess the onboard and off-board situation to determine appropriate help by transit security, law enforcement or other forms of emergency response (i.e., medical aid, Hazmat, terror threat).

An operator/agency benefit is increased surveillance of properties and vehicles, with limited staffing requirements and high-quality archival data. These systems provide strong evidence for criminal investigations, Motor Vehicle Administration (MVA) investigation/adjudication and related onboard incidents (fare evasion, physical assaults, etc.).

Such systems also are perceived to reduce vandalism and crime, including operator assaults. They may also contribute to increasing passengers' sense of safety, though they may also have the adverse effect of heightening anxiety if CCTV is viewed as an indicator of a high-risk environment.

4.4.3 Integration/interdependence with other ITS systems

- **Computer-aided dispatch and automatic vehicle location:** Locates vehicle(s) instantly on control center console, enabling dispatch to identify available nearby resources, communicate information to other agencies and coordinate response.
- **Panic button:** Activation by the operator onboard can trigger increased-resolution recording.
- **Communications technologies:** The transmission of high-resolution audio and video data to the control center relies on the capacity of the communications technologies.
- **Performance monitoring/archiving/data mining:** Security recordings (audio and video) will be archived to support agency investigations.

4.4.4 References for more information

- *TCRP Synthesis 38: Electronic Surveillance Technology on Transit Vehicles: A Synthesis of Transit Practice,* Transit Cooperative Research Program, 2001. http://onlinepubs.trb.org/onlinepubs/tcrp/tsyn38.pdf
- "Video Surveillance for Transit Buses: Keeping up with Technology," Mass Transit Magazine, 2006. http://www.masstransitmag.com/print/Mass-Transit/Video-Surveillance-for-Transit-Buses/1$1616
- "Better Service, Safer Service: Transit Management for Fixed-Route Systems," Intelligent Transportation Systems, U.S. Department of Transportation. http://www.fhwa.dot.gov/tfhrc/safety/pubs/its/pabroch/betterservice.pdf

4.4.5 Examples

- **Los Angeles (LACMTA):** 70 percent of 2,500-bus fleet equipped with CCTV
- **Chicago (CTA):** 70 percent of 1,890-bus fleet equipped with CCTV
- **NYC Transit:** 400 buses equipped with CCTV
- **San Diego Transit (NCTD):** 300 buses equipped with CCTV
- **New Jersey Transit:** 50 buses equipped with CCTV
- Many other agencies of all sizes pursuing installation of CCTV

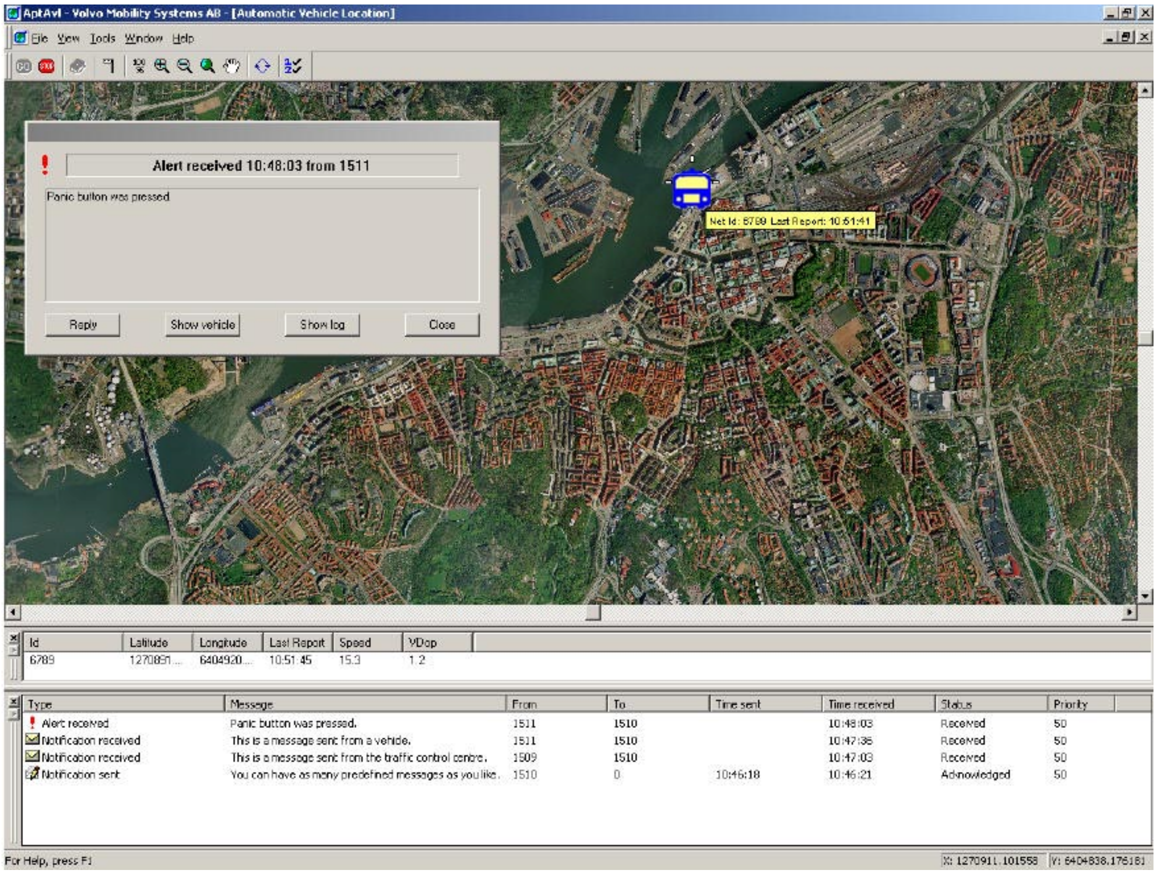
4.5 Panic button emergency response

4.5.1 What is it?

A panic button (**Figure 8**) is a device used by the operator in case of an emergency. This panic button may be hidden as to not draw attention to passengers on board. Current fleets use panic buttons to change the destinations signs to alert the public to call 911, activate a strobe light on top of the bus and/or open the radio channel so that the control center can listen to activities on the bus.

With the advent of ITS, the panic button capabilities are greatly enhanced. It can trigger an alarm on the control center AVL console so the bus continuously reports its position. The control center AVL console can then zoom in on the distressed vehicle and, using the AVL functions, locate the nearest supervisors' vehicle.

FIGURE 8
Panic Button Emergency Response



The control center operator is also able to contact local authorities and provide them with an accurate description of the situation. Some AVL systems with panic button functions will also automatically send a still image of the interior of the bus to the control center. A one way audio channel can also be initiated so that the control center is able "listen" to what is going on in the bus, some systems will automatically store this recording.

4.5.2 Benefits

Safety is the main benefit of the emergency button. Linking the emergency button to an AVL system and, if possible, a CCTV system increases onboard security and greatly reduces intervention time.

4.5.3 Integration/interdependence with other ITS systems

- **Automatic vehicle location/control:** Locates the vehicle instantly on the control center console.
- **Surveillance/CCTV/security systems:** Once the emergency button is pressed, this can create an "event" in the CCTV system for easy video footage retrieval. It can also send a still picture to the control center. If communications bandwidth allows it, a continuously streaming video also can be sent to the control center.
- **Fleet management and monitoring:** Similar to CCTV, once the emergency button is pressed, this is recorded as an event in the fleet management system. It is therefore possible to determine vehicle behavior at the time the button was pressed (speed, throttle position, brake pressure, doors open or closed, etc.)

- **Communications technologies:** The communication method used onboard may limit the amount of data transmitted during an emergency button event, (i.e., streaming video).

4.5.4 References for more information

- "ITS Technologies that Improve Human Services Transportation," U.S. DOT report, August 2006. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/14140_files/section_3.htm
- Lysecki, Sarah, "GO Transit deploys GPS/AVL," 2006. http://www.itbusiness.ca/it/client/en/home/News.asp?id=38844

4.5.5 Examples

Most transit authorities equipped with an AVL system use it to coordinate their emergency response. Many cities such as Houston, New York, Washington, D.C., and Toronto benefit from emergency alarms tied to their vehicles' AVL systems.

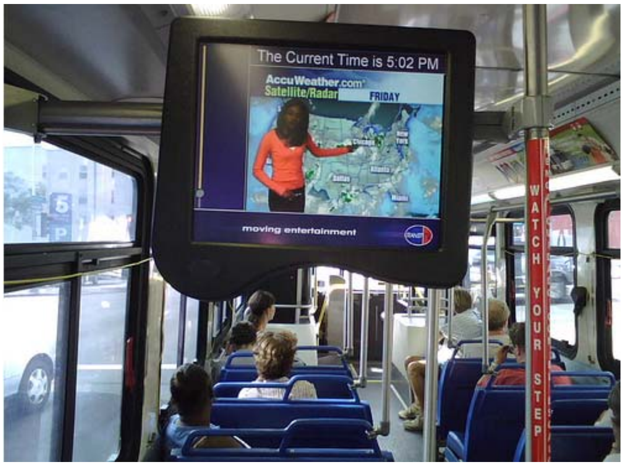
4.6 Commercial passenger information and advertising

4.6.1 What is it?

Commercial passenger information and advertising (aka Transit TV) consists of one or more LCD information panels at stations or onboard vehicles that display still images or videos. "Transit TV" also can offer audio-only programming content via FM radio and/or cell phones in parallel with the visual onscreen programming.

The system is a platform for either stored or dynamically updated digital media. In addition to display advertisements, it can provide news and weather, customer information and alerts, and real-time transit information.

FIGURE 9
Transit TV



4.6.2 Benefits

The primary customer benefit of Transit TV is improved customer information. Station and vehicle displays can provide customer information and alerts, and even be a platform for displaying real-time transit information such as next stop announcements, the vehicle's location on a map, and so on. It can also provide real-time news and weather content, which may be of value to customers. In some cases, a significant share of passengers has been found to use Transit TV as their primary sources of daily news and weather.

In these instances, Transit TV can provide increased enjoyment of transit and reduce the perceived travel times. It may also increase customer perception of a premium level of service, and thus appeal to new transit market segments.

Transit TV can also provide a way of focusing advertising in one location, and eliminating other forms of ads, which can reduce visual clutter. If it is a platform for dynamic and targeted ads, customers may find it preferable to traditional static billboards. However, Transit TV also carries a substantial risk of visual clutter that competes with branding, wayfinding and customer information. In addition, it is seen as highly intrusive by some passengers and could substantially degrade their perception of the transit service.

The primary agency benefit is through increased advertising revenue made possible by this attractive advertising platform. By enabling focused marketing for advertisers, it provides another option to static onboard billboards and bus-wrap ads. Transit TV has been found to have higher than average advertising recall rates.

A related agency benefit is that Transit TV can provide a means for providing infrastructure for other customer information at lower cost. As a result it is an effective means of dissemination of a variety of real-time information to customers.

4.6.3 Integration/interdependence with other ITS systems

- **Communications technologies:** Transit TV can be tied into communication systems (and AVL) to update content remotely and dynamically (for time-sensitive information). Dynamic updating of content requires greater bandwidth than once-daily uploading of content.
- **Automatic vehicle location:** AVL is necessary to update location-sensitive content (such as service alerts, traffic conditions, emergency alerts and vehicle location), or to enable location-specific advertising.
- **Passenger information:** Transit TV can be tied to, or can be a substitute for, passenger information systems, thereby providing an effective means of dissemination a variety of real-time information to customers

4.6.4 References for more information

- http://www.transitv.com/
- "Transit TV," Daily Wireless. http://www.dailywireless.org/2005/05/07/transit-tv/
- "High Recall Rates for Transit TV Advertising." http://www.marketingcharts.com/television/high-recall-rates-for-transit-tv-advertising-931/
- "Advertising on MARTA," http://www.itsmarta.com/advertising-on-marta.aspx?terms=Transit+TV

4.6.5 Examples

Transit TV is in use in the following systems:

- LACMTA (Los Angeles County)
- MARTA (Atlanta)
- Chicago PACE
- LYNX (Orlando)
- MCTS (Milwaukee)
- WMATA (Washington, D.C.) (in progress)

5. Transit ITS for the vehicle

This section describes the types of transit ITS that are most related to the transit vehicle. Each of the following sections describes what the technology is, the benefits of it, how it is integrated or interdependent with other transit ITS technologies, and provides references and examples for more information.

5.1 Fleet management/monitoring

5.1.1 What is it?

Fleet management provides the fleet manager a complete overview of all buses. A fleet management system records key performance indicators defined by the fleet manager. Some data can be stored in raw data form, while other data may be stored as average during a given period. For example, it may be worthwhile to know how many times the doors were opened (raw data = door opening count). On the other hand, fuel consumption can be reported as an average over the course of the day or route.

The data is stored on the vehicle computer and downloaded to a central system. Usually this data does not need to be live; the data can therefore be downloaded at the end of the day. Once the data is retrieved, it can be compared to other buses, other routes, and so on. Data analysis software can be used to correlate indicators. Most commercial fleet management software has pre-defined reports.

5.1.2 Benefits

Fleet management allows the fleet manager to answer questions such as the following:

- How much does a given route cost (i.e. fuel, time and distance driven)?
- Which drivers use the least amount of fuel per line or route?
- Which vehicle use the least fuel per line or route?
- Are there any fault codes on my buses?
- What is my overall fuel consumption?
- What is my overall idling time?

5.1.3 Integration/interdependence with other ITS systems

- **Automatic passenger counters:** It may be worthwhile to correlate passenger counts and fuel economy.
- **Automatic vehicle location/control:** Linking the route number to the fleet data can help in bus/route matching for optimal fuel economy.
- **Surveillance/CCTV/security systems:** Extraordinary events (engine overheating) can be stored as events in the CCTV system.
- **Panic button/emergency response:** Key information can be transmitted when the button is pressed (e.g., throttle position, doors opened or closed, brake pressure).
- **Communications technologies:** Since this data does not need to be live, a high-speed download can occur at the end of the day within the confines of a garage (wireless local area network, infrared).

5.1.4 References for more information

- "Development of Bus Maintenance Information Advisory System," 2001. http://www.utrc2.org/research/projects.php?viewid=5

5.1.5 Examples

Fleet management/monitoring is in use in the following systems:

- WMATA (Washington, D.C.): http://www.wmata.com/pdfs/planning/Metrobus_Network_Eval_ExecSummary%20final%20April%2018.pdf
- SEPTA (Philadelphia, Pa.): http://www.highbeam.com/doc/1G1-54822981.html

5.2 Collision avoidance systems

5.2.1 What is it?

Collision avoidance technologies can be divided into systems that are progressively more intrusive, starting with those that merely warn or advise the driver based on sensors inside or outside the vehicle. Next are those that take over partial control of the vehicle or make safety-enhancing adjustments such as tightening seatbelts, turning down the throttle, activating the brakes and changing the suspension, without the driver taking action. The third type takes over full control of the vehicle.

5.2.2 Benefits

Collision warning systems act on the principle that enabling drivers to accurately recognize their environment will enhance their safety. They prompt the driver with an alert when danger exists during a lane change or when the vehicle is having difficulties in lane-keeping.

Several types of collision avoidance systems (CAS) have been developed, tested and implemented to reduce the number and severity of collisions. Some of the vehicle-based technologies under development include the following:

- Forward collision warning systems or rear-end collision avoidance systems warn drivers that they are in a conflict situation with the vehicle in front of them. These conflicts may be due to the lead vehicle stopping, slowing or maintaining a constant speed relative to the approaching vehicle.
- Rear impact warning systems warn the lead vehicle driver that he or she is in conflict with the approaching vehicle. The warning can be given to the lead vehicle or the approaching vehicle.
- Intersection warning systems are designed to detect and warn drivers of approaching vehicles and potential right-of-way violations at intersections.
- Obstacle detection systems use vehicle-mounted sensors to detect and alert the driver to obstructions, such as other vehicles, debris or animals in the vehicle's path.
- Lane-change warning systems warn drivers that the vehicle is unintentionally drifting out of the lane.
- Rollover warning systems notify drivers that they are traveling too fast for an approaching curve, based on the vehicle's 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 drift off the road on a tangential section.

A key issue related to most CAS is the use of algorithms to accurately assess false alarms and to recognize actual dangers from trivial threats (i.e., a stopped car versus a roadside sign on a curved road).

Most of the above technologies are currently under development, but some have begun to be implemented on in-service transit vehicles. Due to the emergence of these CAS, there is limited data available to determine the actual benefits of these systems. The costs of the systems either are estimates or are based on early production costs. It has been noted that the infrequency and uncertainty of bus collisions makes it difficult to accurately assess the true benefits and costs associated with CAS.

5.2.3 Integration/interdependence with other ITS systems

Collision avoidance systems are usually independent of other ITS technologies, as they are typically sensors fitted to the transit vehicle. There is the potential for some overlap in technology with lane guidance systems and automated enforcement.

5.2.4 References for more information

- "3.1. Collision Avoidance Systems," Intelligent Transportation Systems, U.S. Department of Transportation. http://www.its.dot.gov/jpodocs/repts_te/14073_files/sec_3_1.htm
- Veermallu, Srinivasa Rao, "Collision Avoidance Systems," Center for Transportation Research and Education, Iowa State University, 2000. http://www.ctre.iastate.edu/mtc/papers/veer.pdf

5.2.5 Examples

One existing type of system is designed to be an extension of the driver's mirrors, providing blind-spot coverage. Ultrasonic sensors detect nonstationary objects within a defined perimeter. The sensors are installed at six locations on the vehicle—one sensor on each front corner and one sensor each fore and aft of each of the front wheels. Sensors may also be installed at the rear of the vehicle for backing functions. The sensors transmit a signal and detect objects based on a recognizable echo reflected from an object.

The Washington Metropolitan Area Transit Authority, Utah Transit Authority, and the Greater Cleveland Regional Transit Authority have all used this type of system.

5.2.6 What is it?

Automated enforcement provides a means of enforcing BRT-related regulations (particularly regulations prohibiting standing in bus stops and bus lanes, and driving in bus lanes) without requiring an ongoing presence by enforcement personnel. Enforcement cameras can also be used to enforce prohibitions against entering and/or crossing busways. Under such a system, cameras capture still pictures or videos of violations and automatically create an enforcement action against the violator (although some level of human review is usually required to ensure that proper procedures are followed and to reduce spurious violations).

Cameras can be mounted on buses, at the roadside, or in marked or unmarked enforcement vehicles parked to observe the bus lane or stop. Although automated enforcement is considered to be very effective, it often generates concerns related to civil liberties. In addition, because the technology has not fully matured, there are a limited number of examples of automated enforcement for bus lanes or bus stops, with the largest system having been installed in London.

Typically, two types of violations can be issued, one related to the vehicle license plate and the other related to the driver of the vehicle. In the first case, the camera simply records the vehicle license plate number, which is then referenced back to the owner of the car, who then receives some type of violation notice by mail. Because the violation is issued to the vehicle owner based on the vehicle registration, it is typically the equivalent of a parking ticket, with only a monetary fine. In the second case, the photographic evidence actually captures an image of the driver so that he or she can be positively identified. Based on this evidence, a moving violation is sent by mail to the driver, with the same penalties that would be imposed if the violation had been issued directly by a police officer.

Although the second approach generally has a higher impact (due to higher fines and penalties levied against the driver’s license), it is much more complicated to administer due to the need to positively identify the driver (which generally requires greater human involvement). In addition, the photo of the driver creates civil-liberties concerns that can generate additional opposition to implementing an automated enforcement system.

Other issues to take into consideration when developing an automated enforcement program include the legislative approvals that may be required, the chain of custody necessary to ensure that photo/video evidence is kept secure, and the system that will be used to adjudicate violations and appeals.

5.2.7 Benefits

The principal benefit resulting from automated enforcement is to improve the integrity of bus lanes and bus stops, thereby improving the speed and reliability of bus service and ensuring that bus stops are kept clear. Automated enforcement also can be used as a revenue-generation tool, although a program that generates a great deal of excess revenue (above installation and operating costs) can generate controversy as to whether the primary purpose of the program is enforcement or revenue generation.

5.2.8 Integration/interdependence with other ITS systems

- Automatic vehicle location/control, to verify the locations of videos/photos taken by bus-mounted cameras.
- Surveillance/CCTV/security systems, particularly if bus-mounted enforcement cameras can be combined with bus-mounted security cameras.

- Lane guidance and collision avoidance systems, if bus-mounted enforcement cameras can be used for either of these functions.

5.2.9 References for more information

- "Traffic Enforcement in the Digital Age." http://www.tfl.gov.uk/assets/downloads/corporate/TE-digital-age.pdf

5.2.10 Examples

- **SFMTA (San Francisco):** parking
- **Transport for London:** digital traffic enforcement system

5.3 Lane guidance

5.3.1 What is it?

Lane guidance, also called lane assist, is a system that provides feedback to the bus operator for more precise steering. These systems can also provide the ability for a bus to steer itself through computerized or mechanical means. The bus driver still operates the throttle and brake, much like the operator on a train, but is hands-free on the steering wheel except in emergency situations. It should be noted that newer computerized guidance systems have been implemented to various levels of success and should still be considered experimental, while there is a proven mechanical system that has been in service for a number of years. Types of technologies used to accomplish lane guidance are described below:

Mechanical guide wheel: A small 4½- to 6-inch diameter "guide" wheel mounted laterally near each front bus tire that makes contact with the vertical face of the platform curb. These guide wheels are connected directly to the vehicle's steering linkage. Guide wheels can additionally be mounted on the rear of the bus chassis. This type of guidance system is of modest cost

Optical guidance: In this vision-based technology, a camera is mounted on the vehicle that uses optics to "see" specific lane markings on the road ahead to determine the vehicle relation in the lane. A computer analyzes the image looking for special striping within the busway to steer the bus to follow.

Magnetic guidance: Magnets at 4-meter intervals are imbedded within the busway. A sensor on the vehicle detects the magnetic material, using it to determine the vehicle's lateral deviation from the magnet. This deviation is then relayed to an onboard computer to compute a steerage correction in order to guide the vehicle along a programmed path.

GPS guidance: A highly accurate constellation satellite network system and antenna mounted on the bus can triangulate the precise location of the bus, and with the addition of differential correction can to locate the bus to know its location to within 1 to 2 inches. This technology enables the bus to be guided by comparison to the real time GPS coordinate set of the moving bus to a predetermined alignment that has coordinates established along its route.

5.3.2 Benefits

Lane guidance or lane-assist technology allows for reduced lane width requirements, within the tolerances of the guidance system implemented, due to the precision and repeatability of the guidance system. The busway width can be reduced to a 10-foot (3-meter) wide lane from the standard 12-foot (3½- to 3¾-meter) lane. Mechanical guidance can reduce the lane to a width as little as 2 inches (50 millimeters) to either side of the vehicle guidance system. As a result of the reduced cross-section width, lane guidance systems can result in reduced right-of-way acquisition costs, together with the reduced facility construction costs.

Another benefit cited by vendors of lane guidance systems is such systems' ability to provide a high level of safety due to stress relief and to the fact that the system more reliably stays on track compared with the typical performance of a human operator. In the case of the mechanically guided system, the bus is confined to the guideway and unable to move laterally if the driver removes his or her hands from the steering wheel.

These systems do have some drawbacks. Careful study of the tracking of the vehicle is necessary in curvilinear sections of the alignment to make certain that adequate width for the vehicle dynamic envelope is provided. This is especially true with mechanical guidance where physical contact with guidance rails is necessary, but the curvature of such rails could pinch the trailing section of the vehicle. The turning radius of the vehicle is slightly larger with guidance systems.

The maximum speed for some optical guidance systems is 45 to 50 miles per hour (70 to 80 kilometers per hour).

Additionally, any implemented guidance system has to have the full confidence of the bus drivers to be effective. If the drivers do not have such confidence, they will often override the system and steer the vehicles themselves, potentially creating a hazardous condition if the lane widths are too narrow for the skill level of the driver.

5.3.3 Integration/interdependence with other ITS systems

Lane guidance is independent to other ITS systems, though it is complementary to precision docking, with an overlap of technologies.

5.3.4 References for more information

Mechanical wheel guidance:

- "Bus Priority Systems: Special Feature On Kerb Guided Buses (O-Bahn)." http://www.citytransport.info/OBahn.htm

Optical guidance:

- "Optiguide," Siemens Transportation Systems, SAS, Mobility Division. http://www.sfu.ca/person/dearmond/morph/3-7-Vincent-Pouyet-Siemens.pdf

Magnetic guidance:

- Bu, Fanping, et al., "Lane Assist Systems for Bus Rapid Transit, Volume III: Interface Requirements," Institute of Transportation Studies, University of California Berkeley, 2007. http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/2007/PRR-2007-23.pdf
- FROG Navigations Systems, Netherlands. http://www.frog.nl/index.php?newlang=en

GPS guidance:

- "Bus Rapid Transit Lane Assist Technology Systems," Volume I Technology Assessment, Federal Transit Administration, 2003. http://www.its.umn.edu/Research/FeaturedStudies/brt/laneassist/LAfinal1.pdf
- Bus Rapid Transit IVI Lane Assist Technology Requirement, Federal Transit Administration, 2004. http://rip.trb.org/browse/dproject.asp?n=9336

5.3.5 Examples

- **Mechanical guide wheel:** This type of guidance system, called the O-Bahn, originated in Essen, Germany, and has been applied successfully in Adelaide, Australia, and Leeds and Bradford, UK. It is planned to be used on the Cleveland, Ohio, Euclid Corridor BRT and the Cambridgeshire BRT in Cambridge, UK.

- **Optical guidance:** The Civis vehicle by Irisbus used in Las Vegas, Nevada, came installed with this type of system. It is also used in the TEOR System (Rouen, France) and in Clermont-Ferrand, France.
- **Magnetic guidance:** The Phileas vehicle by APTS used in Eindhoven, Netherlands, uses this system. (http://www.apts-phileas.com) Additionally, the ParkShuttle bus (Amsterdam Schipol Airport, Netherlands) uses magnetic guidance.
- **GPS guidance:** Minneapolis-St. Paul Metro Transit outfitted a bus with GPS receivers to drive on the "bus on shoulders" route.

5.4 Precision docking

5.4.1 What is it?

Precision docking is the ability for a bus to approach and depart a station platform through optical, mechanical or other guided means, in order to get as close to the platform as possible and to provide as small as gap as practical between the platform and the bus chassis/doors. This also involves the ability for the bus to dock in the same location reliably every time the bus vehicle services the station. Types of technologies used to accomplish precision docking are described below:

Kassel Kerb: A curb face with a sloped face or shape factor. Typically made out of smooth granite or dense concrete. The operator drives obliquely to the tangent and forces the edge wall of the bus tires to rub and establish the tire to a fixed constant location away from the platform edge. Testing has shown that the outer face of the curb can accelerate tire wear if the curb face is not smooth enough. Additionally, tires can "ride up" onto the shaped face of the curb if the curb face is not smooth. Kerb heights of 12 to 14 inches may interfere with the lugs nuts on the bus wheels.

Low-friction rub bar: Similar to the Kassel Kerb but uses a synthetic material with ultra-low frictional properties as the contact surface with the tire. The material typically used is ultra-high molecular weight polyethylene (UHMWPE). The UHMWPE is attached directly to the face of the curb as an aid in avoiding lug nut contact with the curb face.

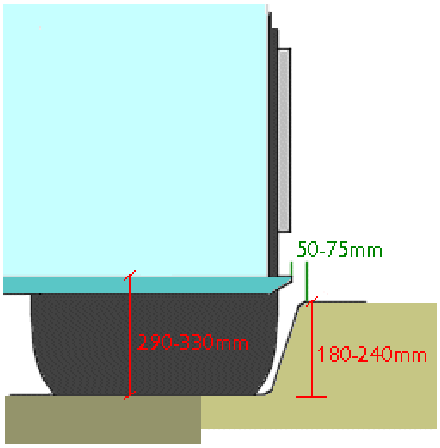
Mechanical guide wheel: A small 4½- to 6-inch diameter "guide" wheel mounted laterally onto near each front bus tire that makes contact with the vertical face of the platform curb. These guide wheels are connected directly to the vehicle's steering linkage. Guide wheels can additionally be mounted on the rear of the bus chassis. This type of guidance system is of modest cost.

Optical guidance: In this vision-based technology, a camera is mounted on the vehicle that uses optics to "see" specific lane markings on the road ahead to determine the vehicle relation in the lane. A computer analyzes the image, looking for special striping within bus way to steer the bus to follow.

Magnetic guidance: Magnets at 4-meter intervals are imbedded within the busway. A sensor on the vehicle detects the magnetic material, using it to determine the vehicle's lateral deviation from the magnet. This deviation is then relayed to an on-board computer to compute a steerage correction in order to guide the vehicle along a programmed path.

Figure 10 shows examples of these systems.

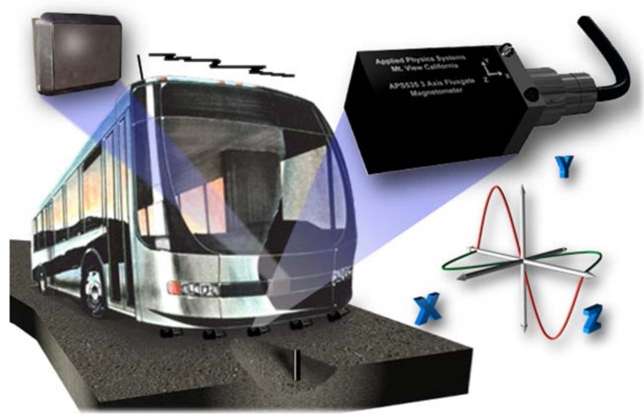
FIGURE 10
Some Precision Docking Systems



Kassel Kerb


Mechanical Guide Wheel


Optical Guidance



Magnetic Guidance

5.4.2 Benefits

Precision docking allows for faster and safer boarding and alighting. This benefit is realized by a reduction of the horizontal gap between the platform edge and the bus floor to less than 3 inches—the maximum ADA dimension allowed without necessitating the employment of a bridge plate. If this can be accomplished reliably, the boarding operation would no longer require a bridge plate, which adds dwell time due to the time it takes for extension and retraction. It is assumed that the bus floor is nearly level with the station platform.

Other benefits include a predictable and reliable docking location expectation of the patrons by removing variations due to differing levels of skill of the operators.

Precision docking provides the added safety benefit of a reduced gap that otherwise may become a hazard for patrons.

5.4.3 Integration/interdependence with other ITS systems

Precision docking is dependent on and needs to work in conjunction with the elevation or height of the platform to be level or nearly so with the bus floor. Per current ADA standards in the United States, the vertical differential should be no more than ¾ inch between the platform and the bus floor. In the event this height differential is exceeded, a bridge plate would then be required.

The approach and departure angle, the geometry of the station platform curb face, and configuration are all determinants in the success of precision docking.

5.4.4 References for more information

Kassel Kerb:

- "Testing the gap distance between Kassel Kerbs and Public Service Vehicle boarding steps," March 2001 field test. http://www.tbus.org.uk/kassel.htm
- Wood, Chris, "Bus Stop Innovation: A Comparison of UK Trials," CILT the Center for Independent Transport Research, 1998. http://www.cilt.dial.pipex.com/comparison.htm
- Brett. http://www.brett.co.uk/
- Lafarge Concrete Products, Leicestershire, UK. http://www.lafargenorthamerica.com/wps/portal/

Low-friction rub bar:

- Lane Transit District, EMX BRT Project; Eugene, Oregon. http://www.ltd.org/search/showresult.html?versionthread=d38519362672c662c61a9300c1dd78be

Mechanical guide wheel:

- "Bus Priority Systems: Special Feature On Kerb Guided Buses (O-Bahn)." http://www.citytransport.info/OBahn.htm

Optical guidance:

- "Optiguide," Siemens Transportation Systems, SAS, Mobility Division. http://www.sfu.ca/person/dearmond/morph/3-7-Vincent-Pouyet-Siemens.pdf

Magnetic guidance:

- Bu, Fanping, et al., "Lane Assist Systems for Bus Rapid Transit, Volume III: Interface Requirements," Institute of Transportation Studies, University of California Berkeley, 2007. http://www.path.berkeley.edu/PATH/Publications/PDF/PRR/2007/PRR-2007-23.pdf
- FROG Navigations Systems, Netherlands. http://www.frog.nl/index.php?newlang=en

5.4.5 Examples

- **Kassel Kerb:** Used in more than 140 cities in Europe, including Birmingham, UK, Line 33.
- **Low friction rub bar:** Used in Eugene, Oregon, Franklin Segment EMX BRT.
- **Mechanical guide wheel:** This type of guidance system, called the O-Bahn, originated in Essen, Germany, and has been applied successfully in Adelaide, Australia, and Leeds and Bradford, UK. It is planned to be used on the Cleveland, Ohio, Euclid Corridor BRT and the Cambridgeshire BRT in Cambridge, UK.
- **Optical guidance:** The Civis vehicle by Irisbus used in Las Vegas, Nevada, came installed with this type of system. It is also used in the TEOR System (Rouen, France) and in Clermont-Ferrand, France.
- **Magnetic guidance:** The Phileas vehicle by APTS used in Eindhoven, Netherlands, uses this system. Additionally, ParkShuttle bus, Amsterdam Schipol Airport, Netherlands.

Abbreviations and acronyms

APC	automated passenger counter
ASA	automatic stop annunciators
AVL	automatic vehicle location
BRT	bus rapid transit
CAD	computer-aided dispatch
CAS	collision avoidance system
CCTV	closed-circuit television
CRTMA	Charles River Transportation Management Association
CTA	Chicago Transit Authority
DOT	Department of Transportation
DRT	demand responsive transit
ETA	estimated time of arrival
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GIS	geographic information systems
GPRS	general packet radio service
GPS	Global Positioning System
IBL	intermittent bus lane
ITS	intelligent transportation systems
IVR	interactive voice response
LACMTA	Los Angeles County Metropolitan Transit Authority
LED	light-emitting diode
MB	megabytes
MBL	moving bus lane
MBTL	Moving Bus/Tram Lane (study)
MCTS	Milwaukee County Transit System
MDC	mobile data computer
MDT	mobile data terminal
MVA	Motor Vehicle Administration
NCTD	North County Transit District
OCTA	Orange County Transportation Authority
PDA	personal digital assistant
SEPTA	Southeastern Pennsylvania Transit Authority
TCRP	Transit Cooperative Research Program
TSP	transit signal priority
VMS	variable message signs
WMATA	Washington Metropolitan Area Transit Authority