ADVANCED PUBLIC TRANSPORTATION SYSTEMS: DEPLOYMENT AND BENEFITS

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Introduction

Intelligent Transportation Systems can be defined as the "*integrated application of advanced sensor, computer, electronics, and communications technologies and management strategies – in an integrated manner – providing traveler information to increase the safety and efficiency of surface transportation systems*" (FHWA, 2006). In USA, the Federal Highway Administration (FHWA) has arranged all of the applications of intelligent transportation systems into 8 categories: Traveler Information, Traffic Management, Public Transport, Electronic Payment, Commercial Vehicle Operations, Emergency Management, Vehicle Safety and Control Systems, and Information Warehousing.

Any system that has been deployed in the Transportation field implies a cost, but at the same time these systems were developed to provide different kinds of benefits. According to the Apogee Report on Global ITS Benefits, the projected benefits of ITS systems that are expected in the USA in the period 1996-2015 are: 44% in accident cost savings, 41% in time savings, 6% in emissions and fuel savings, 5% in operating cost savings, 4% in agency cost savings and 1% in additional savings.

The purpose of this paper is to make an overview of the deployment and main benefits of the Intelligent Transportation Systems applied to Public Transportation. The acronym commonly used by the FHWA is APTS, which stands for Advanced Public Transportation Systems.

Advanced Public Transportation Systems (APTS)

The application of technology in public transportation started many decades ago, especially when the number of vehicles began to increase leading to high congestion in the cities, time delays, high costs for all users, pollution increase, among others. The purpose of these new technologies is to enhance the mobility in the cities and achieve benefits for both, the transit operator and the users of the system (Dailey and Haselkorn, 1994).

In the case of the transit operator, one of the benefits is to have access to real time information, which will allow planners to use this information for positioning stops, planning routes, evaluate the accuracy of the system and to develop long-term plans in terms of capacity and system enhancement. As for the users of the public transportation system, some general benefits include: increased productivity, reduced stress, increased public safety, increased ridership and mode change, and environmental pollution.

The Department of Transportation of the United States created the Research and Innovative Technology Administration or RITA, which coordinates the research programs and deployment of the intelligent transportation systems along the country. The website includes the updated information for all the sub-categories of ITS systems. In the case of Advances Public Transportation Systems, there are 3 main components, which are: Transit Management Systems, Traveler Information Systems, and Electronic Fare Payment Systems. For the purpose of the RITA website on ITS systems, APTS covers the following aspects: Operations and Fleet Management, Information Dissemination, Transportation Demand Management, and Safety and Security.

Operations and Fleet Management have several applications, but the most important ones in terms of deployment and benefits are the Automated Vehicle Location or AVL, and the Computer Aided Dispatch or CAD. Several benefits will be discussed later on, including important reductions in passenger wait times due to updated information for people working at the management centers. Transit

Signal Priority has also achieved important benefits in the system's performance, as it uses sensors to alter signal timings when detecting transit vehicles approaching to a particular intersection. This has been especially useful in cities where capacity has reached high levels of congestion, which might cause high delays in transit. Maintenance refers to the vehicle maintenance information which is monitored in real time. All the information that the management centers receive is very useful for planning new services, modifications or adjustments to existing services, as well as to manage particular problems in a specific route or line. Finally, the service coordination which integrates the communication and flow of information of transit systems.

Information dissemination has several benefits, especially to users. These technologies allow them to confirm scheduling information, coordinate transfers between lines or routes, or even transfers between different transit services, and all this reduces wait times. There are 3 main ways in which this information is given to the user: in-vehicle, in-terminal or wayside, and internet and phone. One of the main challenges is to coordinate with regional or multimodal traveler information, to increase the system performance.

Transportation Demand Management refers mainly to services as ride sharing or matching, and dynamic routing or scheduling. This is mainly applicable in places where the coverage is limited. Some of these services use also automatic vehicle location, combined with dispatching and reservation technologies for users' flexibility.

Safety and security are very important in users' choice between particular vehicles or the use of transit. Technology plays a clue role in this type of applications, providing advanced software and communications between the management centers and the transit vehicles. For instance in vehicle surveillance; video cameras monitor the interior of buses, as well as audio surveillance through microphones and transmitters. Silent alarm features are also available to enhance safety. Video and audio facility surveillance is also available for security in terminals, stations and stops. Employee credentialing refers to identification and access control systems to maintain the security of the system, as well as remote disabling systems which can remotely shutdown transit vehicles from the dispatch centers.

Benefits of APTS Systems

All kinds of technologies are available, but the benefits are critical factors in determining if it is actually worthwhile to install them, and most important, to get approval and funding for them. The main benefits of the Intelligent Transportation Systems as defined by the FHWA are safety, delay, cost, effective capacity, customer service and energy and environment.

It has been identified by the USDOT that Operations and Fleet Management has substantial positive benefits in mobility, productivity and customer satisfaction. Positive benefits include efficiency, energy and environment. Regarding Information Dissemination, benefits generally are notorious in customer satisfaction. In the case of Transportation Demand Management, positive benefits in customer satisfaction have been achieved and substantial positive impacts in productivity. Finally, technology applied to Safety and Security has been another positive impact, especially for customers (Maccubbin et al. - RITA, 2008).

Several studies have analyzed the costs and benefits or expected benefits of ITS applications. Benefits will be described both qualitative as well as quantitative by given some examples, especially within Canada and the USA. Benefits will follow the 3 main components of the APTS systems: Transit Management Systems or Operations and Fleet Management, Traveler Information Systems or Information Dissemination, and Electronic Fare Payment Systems or Fare Collection.

1. Operations and Fleet Management Benefits

The benefits of the Operations and fleet management include the technologies shown in Table 1.

Table 1. Benefits of operations and fleet management.

Technology	Description	Benefits
Automatic Passenger Counter (APC)	Records automatically number of passengers, time and location of each stop: generally infrared beams.	Transit planners can modify routes and/or schedules for better service quality, and helps in long-term planning in existing routes or additional ones.
Automatic Vehicle Location (AVL)	One of the most common and useful systems. Satellite geo-positioning technology tracking vehicles.	For agencies: optimization of service with available fleet, reroute buses, reduce fleet. For costumers: accuracy in planning an itinerary or avoiding time wasting Overall benefits: for emergencies and for safety purposes
Geographical Information Systems (GIS)	Collects, stores, analyzes and displays data by location.	Provides agencies with information regarding mobility problems, planning new routes or improving existing ones according to land use: residential areas, hospitals, commercial areas, industry.
Scheduling and Dispatch (S&D), or Computer Aided Dispatch (CAD)	Software used to aid in designing and modifying transit routes. Generally combined with GIS and AVL.	Increase the efficiency of transit operations, enhance safety, improve service and reduce costs. Schedule adherence was also improved.
Traffic Signal Priority (TS)	Technology for holding a traffic light green, or to turn it green as needed by a particular bus, especially buses behind schedule.	Keeps transit public vehicles on schedule, improves on-time performance, customer service satisfaction, fewer vehicles for a route (cost savings).

(Source: the author, based on information by Hough et al., 2002)

Automatic Vehicle Location is one of the most important and common applications. Generally the cost is high, but benefits are achieved. AVL integrates information on vehicle performance and location, and it allows planners to use the information on vehicle position, as well as operational status. More benefits were described by Gillen et al.: increased dispatching and operating efficiency, more reliable service increases ridership, quicker response to service disruptions, increased driver and passenger safety and security, effective response to mechanical failures, improved data collection at a lower cost, better quality and more quantity.

2. Information Dissemination Benefits

Table 2 shows the benefits of information dissemination especially with the use of the four more common and successful technologies.

Table 2. Benefits of information dissemination of some technologies.

Technology	Description	Benefits
Automated Trip Itineraries	Developed for traveler trip planning, including: modes of travel, travel time, fares, transfers, schedules, tourist information, weather.	They provide accurate and timely information for customers through a variety of means, providing high service quality and traveler satisfaction. Reduces caller waiting time, as more people will use internet instead.
In-Vehicle Announcers	Generally are on-board audio and visual systems to provide passengers with next stop information, and other kinds of messages as well.	Very useful especially for people unfamiliar with a route or a system, as well as for impaired users. In San Francisco, the effectiveness of this system was tested with visually impaired subjects.
Interactive Kiosks	Found in hotels, malls, transit centers, stations, terminals. They provide the customer with information as routes, schedules, delays, congestion, weather, etc.	Customer satisfaction and increased ridership, hence potential increased revenues.
Variable Message Signs and Monitors	Information regarding arrival and departure times.	Reduce customer anxiety and stress Enables dispatchers and planners to make changes in the schedule

(Source: the author, based on information by Hough et al., 2002)

3. Fare Collection Benefits

Fare collection or Electronic Fare Payment has shown significant benefits which justify their implementation (FHWA, 1999). The main benefits of fare public transportation collection are shown in Table 3.

Table 3. Benefits of fare collection.

<table>
<tr><th>Description</th><th>Benefits</th></tr>
<tr><td rowspan="4">▪ System in which cards are used in place of coins or tokens to pay for transit rides.
▪ Most commonly: magnetic stripe cards, credit cards, or smart cards that can be contact or contactless.</td><td>Reduce the expense of handling and protecting transit revenues.</td></tr>
<tr><td>Customer convenience.</td></tr>
<tr><td>More secure fare collection system.</td></tr>
<tr><td>Potential for additional transit revenue due to an increase in marketing strategies, such as transaction fees.</td></tr>
</table>

(Source: the author, based on information by Hough et al., 2002)

Integrating APTS Technologies

Regarding the technologies of Operations and Fleet Management, the units are generally provided with adaptive signal timing and communication control, route destination display, AVL technology, driver information display, automated fare collection and passenger counting, and smart card reader. In terms of information dissemination, travelers must be able to access updated information through several means, including cellular phones, the internet, calling the transit information center, at information kiosks, and even on-board information. Main applications of the Smart Cards are also detailed, which have been integrated among different public means of transportation to improve service and user comfort. This system might include buses, toll plazas, parking, tramways, metro systems, railroad and special transportation for disabled people or with reduced mobility, depending on the city.

More benefits can be achieved with these technologies if they are integrated and coordinated. The flow of information and communication is vital for the success of a system. As it can be seen in Figure 1, all must work in an integrated way: vehicle diagnostics, dispatch information center including the AVL systems, smart buses with trip recorder, automated fare collection, automated passenger counting, automated location annunciator, transit priority system, real-time transit information, silent alarm and communications.

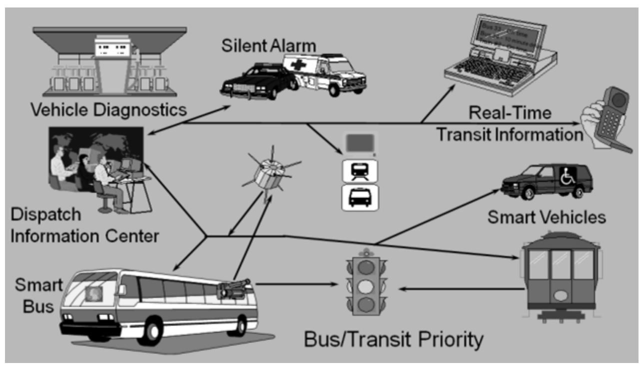

Figure 1. Integration of technologies. (FHWA, 1999)

Quantitative Benefits of APTS Technologies

According to 1996 data, U.S. had predicted benefits between $3.8 billion and $7.4 billion due to APTS technologies over the following years. Of that amount, the following breakdown was expected:

- 44% due to operations and fleet management
- 34% due to electronic fare collection
- 21% due to information dissemination
- 1% due to the Computer-aided Dispatch system

In the case of Canada, by 1999 five Canadian operators were using AVL on fleets, with a total of 3,700 buses. The biggest fleet is in Toronto, with 2,300 buses at that time.

Table 4 shows some quantitative benefits of different APTS technologies mainly in the United States.

Table 4. Quantitative benefits of different APTS technologies.

City/Agency	Technology	Quantitative Benefits
Winston-Salem, North Carolina	CAD System Scheduling System 17 bus fleet	▪ Users: from 1,000 to 2,000 in 6 months ▪ Vehicle miles per passenger-trip grew 5% ▪ Operating expenses dropped 2% per passenger trip ▪ Decrease in passenger wait time: 50%
Kansas City, Missouri	AVL and CAD Systems	▪ Savings in operating and capital expense ▪ City recovered AVL investment in 2 years ▪ Reductions in fleet size: 4% to 9% ▪ Improved on-time performance: 12%
Portland, OR	AVL System (15 transit systems)	9-23% improvement in schedule adherence
Milwaukee, WI		
Baltimore, MD		
London Transport	ROUTES: Rail, Omnibus, Underground Travel Enquiry System (Computerized route planning system)	▪ 80% of callers make the journey according to the given information ▪ 38% of callers changed route based on information received ▪ 13% changed to transit for certain trips ▪ £1.3 million of revenue for bus companies ▪ £1.2 million for underground ▪ £1.0 million for railways
Boston	SmartTraveler	Estimation of 33% in reduction of CO pollutant from travelers changing travel plans
Manchester, UK	Electronic Fare Payment	Estimated $1.5 million reductions in data collection
Phoenix	Electronic Fare Payment since 1991 Bus Card Plus System	90% of fares paid by bus pass cards VISA and MasterCard accepted since 1995
New Jersey Transit	Electronic Fare Payment	Savings of $2.7 million due to a reduction in the costs of handling and processing cash

(Source: the author, based on data from Maccubbin et al. - RITA, 2008)

Table 4. Quantitative benefits of different APTS technologies. *(cont.)*

City/Agency	Technology	Quantitative Benefits
Ventura, California	Electronic Fare Payment	▪ Savings of $990,000 in reduced handling costs ▪ Improved data accuracy
Seattle	Electronic Fare Payment	One fare card for 6 different systems
New York City Transit	Electronic Fare Payment	▪ More than $40 million savings with magnetic cards, due to greater security measures and less fare evasion ▪ Increased ridership: $49 million (estimate)
Atlanta, Georgia	Electronic Fare Payment	Estimation of $2 million in savings

(Source: the author, based on data from Maccubbin et al. - RITA, 2008)

Canadian Study Case: Vancouver's 98 B Line BRT

Vancouver developed a 16 km Bus Rapid Transit system connecting Richmond City Hall, the Airport Station and Downtown Vancouver. This project was implemented in stages, starting back in November 2000 and the service was opened to users in summer 2001. The 98-B Line was the first to include ITS technologies. One of the most important features was to provide a line that runs within arterial roads with traffic signal improvements in order to compete with the passenger vehicle travel (IBI Group and Translink, 2003).

The following objectives and benefits were achieved:

- improve mobility and transportation efficiency, productivity, safety and security for passengers and freight;
- improve intermodal connections, electronic commerce implementation, data exchange at transfer and entry points;
- increase operational and regulatory efficiencies for system;
- reduce environmental impacts including air emissions and increase the use of alternative transportation modes; and
- improve traveler information and data collection for more effective policy planning and operational management.

Some of the main ITS systems that were used include:

- Automated Vehicle Location (AVL) with Differential Global Positioning System (DGPS) technology, which includes in-vehicle and central equipment for transit management.
- Transit Signal Priority (TSP) in 59 of the 68 intersections of this 98-B Line. Nine of them were not provided with this technology due to hign traffic volumes and/or high pedestrian volumes. This included bus detection, transponders to communicate with traffic signals, traffic signal controller interface. TSP works either with green extension, or red truncation, also called early green.
- Real-time passenger information, both on-board and at-station. Dynamic Message Signs (DMS) work in coordination with AVL system.

The benefits of this line were classified in user benefits and owner/operator benefits. In the case of user benefits, evaluations were made based on travel times, reliability of service and customer satisfaction (Transport Canada, 2003). More specifically:

- Travel time savings for users of approximate 20% reduction in time compared to previous services.
- On-time performance improved significantly over all sections of the system due to the real-time vehicle location tracking system and the traffic signal priority measures.
- Changeable message signs in the stations inform riders of the arrival time of the next bus. On-board audio and video displays announce next stops.
- Surveys indicated that approximately 23% of the users of the 98 B-Line were former car drivers or car passengers who have changed mode to ride transit.
- An additional benefit of a shift in mode from auto mode to transit mode is reduced vehicle emissions.
- Based on a preliminary analysis of average vehicle trip lengths and occupancies, the shift from auto to transit associated with the 98 B-Line represents a reduction of 8 million vehicle kilometres per year by private automobile.

In the case of owner/operator benefits, the reduction in travel time and improvement in on-time performance results in reduced numbers of vehicles, reduced vehicle hours of operations and reduced capital and operating costs, all of which are benefits to TransLink. It is estimated that these improvements result in a reduction of vehicles and vehicle hours of operation of approximately 25%. Including user travel time benefits and capital and operating cost savings to TransLink, the benefits are estimated to be 30% higher than the costs, expressed on an annualized basis, for a benefit/cost ratio of 1.3.

The overall conclusion for this 98 B-Line is that the system provides benefits in all the areas, especially for users and owner/operators. These benefits are greater with the use of ITS technologies, increasing safety in the system, reliability and ridership. This particular study accomplished the additional objective of providing feedback and supporting information for other places within Canada where these Bus Rapid Transit systems might also be successful.

Discussion and Conclusions

A literature review was undertaken in order to find sources of benefit-cost studies of different advanced public transportation technologies in different parts of the world. A significant amount of documents and references were reviewed, but the results were not as expected. Among studies of different European countries, no specific benefit-cost analyses were found in terms of ITS technologies applied to public transportation. Generally the studies justify the overall investment in public transportation systems and the benefits and costs are explained in detail, but not isolating or quantifying benefits of specific ITS applications. The same was found in Latin American transit systems. For example, the case of the Bus Rapid Transit system in Bogotá, Colombia named Transmilenio: this system uses AVL technology as well as smart cards for users, among other ITS applications, but they were considered since the planning stages of the project, so isolate benefits of these technologies are not easy to quantify.

Canada has a great potential for improving the transit system with ITS technologies, especially in big and medium cities. One case study in this paper was the Vancouver 98 B-Line bus rapid transit, which shows a good benefit-cost ratio. In the ITS Canada website several documents show benefits and costs of new technologies. However, as it is stated by several studies, the greatest benefits are for the users due to travel time savings. Other important benefits are collision reductions, reduced emissions and reduced fuel consumption.

One of the last Canadian reports shows an evaluation methodology to provide a framework to promote the consistency of results and benefit-cost studies across the country and across different ITS technologies. The framework is basically based on 4 evaluation steps: evaluation planning, data collection, data analysis, and recommendations and reporting. Two examples were analyzed in depth: New Brunswick's Weigh-in-Motion (WIM) system for commercial vehicle enforcement; and Vancouver's 98 B-Line Bus Rapid Transit System (Bruzon and Mudge, 2007).

The United States is probably the leader worldwide speaking of Intelligent Transportation Systems, including the development of new technologies, deployment, integration and coordination among systems, evaluation and continuous enhancement. They have invested millions of dollars just to improve the transit systems, especially in the main metropolitan areas. One of the problems they face is that they still have not been able to significantly increase transit ridership due to their high dependence on private vehicles.

Both qualitative and quantitative benefits were found among US cities, and since several years ago they have been investing in RITA, or Research and Innovative Technology Administration, which is in charge of the ITS systems along the country. They are constantly improving their databases in order to keep track of benefits and costs of the systems currently in operation, including information on deployment and lessons learned for future projects.

In the case of operations and fleet management, the main benefits identified are automatic passenger counter, automatic vehicle location

(AVL), geographical information systems (GIS), computer aided dispatch (CAD) and traffic signal priority (TSP). Regarding information dissemination, the main benefits are automated trip itineraries, in-vehicle announcers, interactive kiosks and variable message signs and monitors. Finally, the benefits associated with fare collection are: reduction of the expense of handling and protecting transit revenues, customer convenience, more secure fare collection systems and an increase in ridership.

Public transportation has a very high economical impact, especially in big cities. The challenge is bigger for developing countries with limited budgets to build more roads for vehicles, and where congestion and environmental problems increase daily. APTS applications have been designed to improve transit systems while saving costs, but at the same time they imply a big initial investment that some agencies cannot afford. Assigning a monetary value to benefits so they can be comparable with the costs is not an easy task and many studies show different methodologies to approach this problem, but most benefits are for users.

According to the references found, it seems that there are still not enough arguments for developing countries to rely on in terms of quantitative ITS benefits for transit systems from the agency perspective in order to invest in new technologies. Finally, there is a common reality in ITS implementation: “the beneficiaries may not always shoulder the implementation cost” (Parviainen et al., 1997). It is strongly recommended that agencies investing in APTS technologies quantify their benefits, using good models and methodologies in order to generate reliable benefit-cost databases that can be useful for new future systems.

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