Advanced Parking Management Systems:

A Cross-Cutting Study

Taking the Stress Out of Parking

January 2007

Dear Reader,

We have scanned the country to bring together the collective wisdom and expertise of transportation professionals implementing Intelligent Transportation Systems (ITS) projects across the United States. This information will prove helpful as you set out to plan, design, and deploy ITS in your communities.

This document is one in a series of products designed to help you provide ITS solutions that meet your local and regional transportation needs. We have developed a variety of formats to communicate with people at various levels within your organization and among your community stakeholders:

- **Benefits Brochur**es let experienced community leaders explain in their own words how specific ITS technologies have benefited their areas.
- **Cross-Cutting Studi**es examine various ITS approaches that can be used to meet your community's goals.
- **Case Studi**es provide in-depth coverage of specific approaches being taken in communities across the United States.
- **Implementation Guid**es serve as "how to" manuals to assist your project staff in the technical details of implementing ITS.

ITS has matured to the point that you are not alone as you move toward deployment. We have gained experience and are committed to providing our state and local partners with the knowledge they need to lead their communities into the future.

The inside back cover contains details on the documents in this series, as well as sources to obtain additional information. We hope you find these documents useful tools for making important transportation investment decisions.

Sincerely,

Jeffrey F. Paniati
Associate Administrator for Operations
Federal Highway Administration

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Executive Summary

Many metropolitan areas have seen explosive growth in the number of visitors and patrons due to urban revitalization, extension of transit services into suburban areas, and the general trend toward increased mobility of our society. As a result, frustration with parking is becoming a major concern. Parking patrons often do not know where the best parking locations are, what the facility operating hours are, what the expected costs are, and, most importantly, whether a parking place will be available when they arrive.

Advanced parking management systems (APMS) help people find parking spots quickly, thereby reducing frustration and enhancing the visitor's experience. Advanced parking management systems include elements from traditional traveler information systems, as well as specialized parking management applications. The applied traveler information concepts cover a wide range of applications, from pre-trip Web-based information systems to navigation systems that provide turn-by-turn directions all the way to an individual parking space.

This study examines advanced parking management systems in three venues: airports, central business districts, and transit park-and-ride locations. Specifically, the systems examined in this study provide directional and space availability information to patrons as they proceed to the parking facility.

This study presents findings from current advanced parking management literature and visits to APMS project sites. Lessons collected from six sites are presented and three sites are profiled in depth. Interviews with planners, deployers, and operators provide insight into the benefits, costs, and issues from differing venues located in different regions of the country.

The study discusses various types of benefits that have been attributed to APMS including the following:

- At Baltimore-Washington International (BWI) Airport, nearly 13,000 hourly and daily parking spaces are served by an advanced parking management system. During an initial test period, the system increased customer satisfaction and improved traffic flow in the hourly facilities. The stakeholders' praise for the system is evident. Says Harry Zeigler, Assistant Manager for the Maryland Department of Transportation's Office of Transportation and Terminal Services at BWI Airport, "The impact of SmartPark at BWI has been tremendous—it has not only made parking easier and faster, but it has improved customer satisfaction and reduced illegal parking."

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–Harry Zeigler, Assistant Manager, Maryland Department of Transportation, Office of Transportation and Terminal Services, BWI Airport

For the traveler, a survey conducted for this study indicated that over 2/3 of the airport patrons felt that parking at BWI was quicker and easier than comparable parking at other major airports in the region.

For the airport authority, the system has reduced illegal parking and recirculation which block fire lanes and increase congestion in and around parking facilities.

- In San Francisco, advanced parking management increased the probability that commuters would leave their personal automobile and switch to transit.

- In downtown St. Paul, an advanced parking management system demonstrated positive impacts for patrons looking for special event parking and reduced congestion at a key intersection during the period immediately preceding special events. In the time period preceding a major special event, the estimated vehicle delay at the intersection of West 7th Street & Kellogg Boulevard decreased by 10 percent, while the total intersection volume increased by 15 percent.

This study also identifies major lessons learned to help guide others in achieving similar benefits. The following list highlights some of these elements critical to successful APMS deployment.

- **It is important to involve all stakeholders in a formal and collaborative manner to ensure that the needs of all stakeholders are met.** Advanced parking management systems can benefit many stakeholders including travelers, parking operators, attraction operators, nearby neighborhoods, and the local jurisdiction itself.

- **There must be a champion and a formalized stakeholder group.** Because APMS deployments are often integrated into urban or neighborhood environments, they take time and involve a very diverse group of stakeholders. Therefore, it is important to maintain the leadership role of a champion and to ensure that the stakeholder group works from a formal charter that binds the member organizations to the effort.

- **APMS sign structure and locations require continuity of effort.** Coordinating sign appearance and locations with historical preservation organizations, commercial property owners, and local jurisdictions requires continuity of effort over several years. In two of the three sites visited, changes to signage in the latter part of the deployment introduced significant costs and delays.

- **Coordination with the regional ITS architecture helps ensure interoperability and helps leverages resources.** Stakeholders should consider APMS as part of a developing local ITS architecture. In doing so, it may be possible to leverage funding for the system by sharing costs with other ITS-based traveler information systems, congestion management efforts, and clean air attainment programs. Broader stakeholder support and a wider range of funding options increase the potential for successful deployment.

- **System accuracy is a critical factor.** System error characteristics can cause the inventory count to be in error in a positive or a negative direction. Under-counting available spaces means a lost opportunity for a patron and lost revenue for the operator. Over-counting available spaces results in extremely frustrated patrons and potential loss of future credibility and revenue for the operator.

- **It is important to identify the roles and responsibilities of each agency for system operations and maintenance.** It is critical to identify these responsibilities early in the planning process. At one of the sites visited, the effort was delayed for nearly a year as the stakeholder group resolved the funding responsibilities for the operations and maintenance costs. Failure to maintain the systems will reduce credibility and public acceptance will be negatively impacted.

The purpose of this study is to enable those considering advanced parking management systems to benefit from the experience of others in their planning, design, operation, and maintenance.

Introduction

Many areas have seen explosive growth in the number of visitors and patrons as the result of urban revitalization, suburban development, and the general trend of ever-increasing mobility. Parking is increasingly becoming an important aspect of transportation planning.

As stakeholders set out to address parking management issues, they often consider Intelligent Transportation Systems. ITS applications involving APMS have been employed in Europe and Japan for several years and are beginning to be deployed in the U.S. Advanced parking management systems maintain real-time parking space inventories across a set of participating facilities. These data are used to generate parking availability messages that are distributed to travelers through several different means. Such data also help facility owners track demand. In some cases, the information is provided for pre-trip use to travelers seeking information on the Internet. In other cases, it is provided to motorists on roadways by dynamic message signs (DMS) located at key decision points along routes to a desired destination.

Advanced parking management systems help travelers find parking spots quickly, thereby reducing frustration and enhancing a visitor's overall experience. Advanced parking management systems include elements from traditional traveler information systems, as well as specialized parking management applications. Advanced parking management systems offer a wide range of applications, from pre-trip Web-based information systems to navigation systems that provide turn-by-turn directions all the way to an individual parking space.

A topic of growing interest in the U.S. is the use of ITS for finding safe and legal parking for commercial vehicles, especially large trucks. Hours-of-service regulations require that commercial vehicle drivers rest after driving for certain periods of time. In order to rest, drivers need to find a place to park their trucks. In cases where truck parking is not available, drivers are forced to choose between equally bad options, such as going over their legal hours of service or parking in undesirable—or even dangerous—locations. A 2005 white paper[1] noted that, while the number of available truck parking spaces equals demand when averaged nationwide, there are regional shortages, especially in the Northeast, the Northwest, and southern California. ITS technologies are seen as a cost-effective way to help drivers plan where they will stop when their hours-of-service for the day have expired. In 2007, the Federal Motor Carrier Safety Administration (FMCSA) will announce the selection of one or more vendors for implementation of a project called

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[1] Volpe National Transportation Systems Center (2005). *Intelligent Transportation Systems and Truck Parking.*
http://www.fmcsa.dot.gov/facts-research/research-technology/report/
intelligent-transportation-truckparking.htm.

SmartPark to demonstrate the use of ITS technologies for truck parking. The cross-cutting study provided in this report, however, will only address the use of ITS for parking as it applies to automobiles, not commercial vehicles.

Among advanced parking management systems currently deployed or being considered, there are common elements that can be identified. This study discusses common parking problems, defines the stakeholders and their interests, and examines the range of APMS technologies in use within the U.S. today. In addition, this study provides summaries of three case studies and concludes with findings and lessons learned that may help accelerate APMS solutions.

The Parking Challenge

National Trends

Parking is an ever-growing challenge in cities and towns across the U.S. Increasingly, availability of parking is one of the more significant issues that town and city staffs face.

- In some communities, ample public parking is available, but travelers are unaware of where the parking facilities are, the hours the facilities are open, or the costs of these facilities.

- In others, public parking is in short supply, and privately owned parking is available and underutilized.

- In others, there is a shortage of parking facilities, and travelers are unaware of this fact until they arrive at their destination.

In all three cases, travelers lack credible, timely information. The absence of information causes travelers to make bad decisions, including not making the trip, exhibiting poor driving habits due to frustration in not locating a parking place, missing the beginning of an event, and parking illegally.

Site-Specific Challenges

Parking demand is routinely high at airports, in downtown areas, and around transit park-and-ride facilities due to several factors, including record level air travel, large interest in attending downtown events, and the desire for commuters to avoid delays by switching to transit at opportune points along their route during the trip. While serving different traveler needs, each situation has one thing in common - people in a hurry want to know the answers to three main questions: "Where are parking facilities close to my destination?", "Is there an open spot in the facility I choose?", and "How much is this going to cost me in time and parking fees?"

Airports

At airports, the challenge is to provide an efficient transition for the traveler from the roadway transportation system to the airport transportation system. Many travelers run on tight agendas and are under pressure to make a scheduled flight. These travelers do not have time to search for parking. Because many BWI passengers are not frequent air travelers, they are unfamiliar with the airport parking facilities. As a result, they often depart their homes or workplaces excessively early rather than risk missing check-in times. As they circle from floor to floor in a parking garage looking for an empty space, frustration begins to mount. In desperation, some travelers are tempted to park illegally in fire lanes or other restricted areas.

Central Business Districts

In central business districts (CBDs), visitors may not be familiar with the downtown street layout and get lost as they search for difficult-to-find parking facilities. Excessive circulation results in more traffic congestion on the street system, which overwhelms the traffic signals in the vicinity of the downtown attractions. Traffic congestion can become gridlock, leading to drivers' heightened frustration levels. In Seattle, traffic

congestion is so bad near the Seattle Center that locals have nicknamed it, the "Mercer Mess," as shown in Figure 1.

Park-and-Ride Lots

At transit park-and-ride facilities, the problem is three-fold:

- Frustration associated with a commuter hunting for a parking spot while trying to meet a train or bus departure schedule may result in the vehicle being parked in nearby neighborhoods.

- A commuter who cannot find a parking spot and does not elect to abandon his or her vehicle in a neighborhood due to tight ticketing or towing policies will return to the freeway or arterial roadway, having lost valuable time.

- Commuters who habitually have problems finding parking at the park-and-ride facility ultimately may elect not to ride transit. As a consequence, these additional vehicles contribute to already excessive freeway and arterial roadway congestion and traffic-related emissions.

Public Sentiment

The risks of traveling in areas with inadequate parking information vary with the type of trip. For those going to the airport, difficulty finding a parking spot can lead to a missed flight. For travelers going to a central business district, the risk is evident in a late arrival at a show or sporting event for which expensive tickets were purchased. For commuters seeking to transfer to transit, the risk is a missed transit departure.

Figure 1. The "Mercer Mess" in Downtown Seattle

Following is a sampling of public sentiment regarding the risks of traveling in areas with inadequate parking:

- A 2003 intercept survey of off-airport parking users at Detroit's Wayne County International Airport indicated that many travelers opted for off-airport parking because of the level of confidence they had in the time it would take to find a parking space and to take a shuttle to the terminal. Over 50 percent felt that the lack of parking availability signage on the freeways approaching the airport was a significant factor in their decision.[2]

- A 2002 Metropolitan Planning Organization survey of the Seattle-Tacoma region found that a majority of respondents said that they plan to travel to the downtown area at least eight times in a given year. These people also indicated that parking in the downtown Seattle area is a major problem. In a separate 2003 survey developed to gain specific insight into perceptions of Seattle Center parking, visitors to the center on a major event evening were asked about their satisfaction with the parking situation: 37 percent of the respondents indicated they were "Dissatisfied" or "Very Dissatisfied" with the parking situation.[3]

- A Chicago Metra transit rider survey conducted in 2000 measured the parking needs of the customers and their preferences regarding parking information. Over 300 commuters were interviewed at various Metra rail stations during and immediately following the morning rush hour. At least 62 percent of total transit riders believed that parking signage indicating where to park could be improved. The survey found that 80 percent of the Metra riders who felt signage around stations could be improved were regular rush hour travelers.[4]

These statistics indicate that the ease of finding a parking space can influence the decisions people make about traveling. Better information reduces the uncertainty that leads to early departures, recirculation trips, and late arrivals resulting in missed connections or missed events.

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[2] A survey of travelers that chose off-airport parking was conducted at Detroit's Wayne County International Airport twice in the fall of 2003. The first survey was conducted in mid-October on a Wednesday, during which 34 travelers were surveyed during the AM peak departure period. The second survey was conducted on the Wednesday before Thanksgiving, during which 40 travelers were surveyed during the peak AM departure period.

[3] In addition, a survey of over 200 Seattle Center patrons attending simultaneous evening events in three different venues was conducted in November 2003 in support of this study. Visitors were surveyed as they made their way from the parking facility to the event itself.

[4] Wilbur Smith Associates (1999). *Parking Management Systems: Needs Assessment Report.*

APMS—What are They?

There are several different types of advanced parking management systems currently in use in the U.S. today.

Pre-trip parking information systems can be as low-tech as publishing a map of available parking facilities. For more high-tech systems, several cities across the U.S. provide pre-trip parking information over the Internet. These Web pages provide a map of where the parking facilities are relative to major access routes and attractions. These Web pages also provide other information to help the traveler make a parking plan, i.e., the facility's address, capacity, hours of operation, costs, and forms of payment accepted. One such website in Milwaukee, Wisconsin (http://www.parkmilwaukee.com), as shown in Figure 2, operates independent of any real-time parking information being collected at the individual garages. Often, this approach is the first step in moving towards a more sophisticated APMS solution.

Pre-Trip Parking Information Systems

Figure 2. Parking Destination Information Available at ParkMilwaukee.com[5]

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[5] ParkMilwaukee.com Website (2006). *ParkMilwaukee.com—Your Downtown Parking Resource.* http://www.parkmilwaukee.com.

Lot-Specific Parking Information Systems

Lot-specific systems provide parking information using signs that typically have both passive and active components. The passive component provides simple directions to parking facilities, such as with an arrow. The active component supplements the passive component to advise the traveler of the availability of spaces at the facility. The Chicago Metra Park-and-Ride and the Seattle Center advanced parking management systems profiled in this report both use signs to provide lot-specific information. Figure 3 shows one of the signs used by Metra.

Figure 3. A Chicago Metra Sign Providing Lot-Specific Parking Information

Floor-, Aisle-, and Space-Specific Parking Information Systems

In addition to providing information about which lots are full and how many spaces are available at remaining lots, more complex advanced parking information systems have signs on every floor of a garage, at the start of every aisle, and sometimes in front of every individual parking space. The BWI Airport advanced parking management system profiled in this report is an example of a system that provides information on the availability of parking spaces at the floor, aisle, and parking space level of specificity. Figure 4 is an artist's rendering of the system used at BWI airport with signs showing the number of spaces available per aisle.
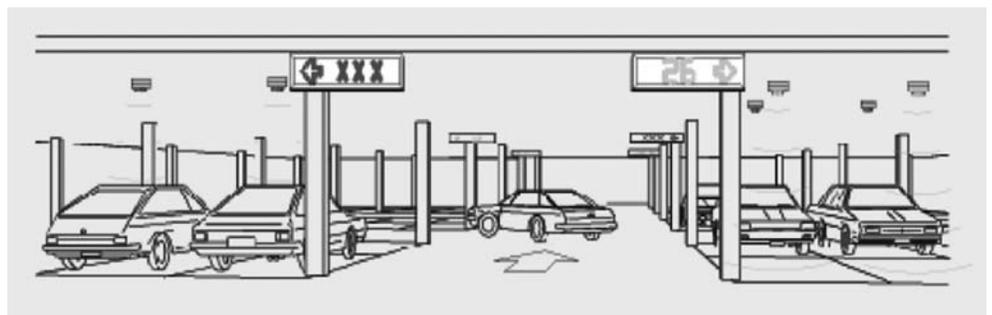
Figure 4. Illustration of Availability by Aisle at BWI Airport

Some advanced parking management systems allow the traveler to reserve and pay for a parking space using the telephone, Internet or wireless handheld devices. The system used by Bay Area Rapid Transit at a park-and-ride facility in Millbrae, California, and the services offered by private companies such as MobileParking LLC and SpotScout™, all of which are profiled in this report, are examples of reservation systems. (See Other APMS Applications, page 9-1.)

The most sophisticated type of advanced parking management system under development is one that guides the traveler to an open spot. A prototype of such a system was demonstrated by XM Satellite Radio in 2005. (See Other APMS Applications, page 9-1.)

Parking Reservation Systems

Parking Navigation Systems

APMS—Who is Using Them?

Advanced parking management systems have been operational in Europe and Japan since the early 1970s to reduce the congestion, environmental impact, and driver frustration associated with trying to find parking in city center areas. In the U.S., however, the use of ITS technologies to distribute parking information to travelers is still in its infancy. A 2004 survey of state transportation agencies shows that only four states (Arizona, Maine, Texas, and Virginia) distribute some sort of advanced parking information.[6] More detail about this statistic, as well as others relating to advanced parking management systems, is available on the U.S. DOT's ITS Deployment Statistics website http://www.itsdeployment.its.dot.gov.

Several advanced parking management systems are operational in the U.S. and others are in the design or installation phase. In each of these applications, parking information for drivers is displayed on specially designed dynamic message signs that provide both directional information as well as space availability information. The information helps drivers plan and execute a parking search strategy more efficiently, since valuable information is made available at key decision points along the selected travel route.

In the U.S., advanced parking management systems have seen the widest application in airports including Baltimore-Washington International Airport, Orlando International Airport, and Detroit's Wayne County International Airport. More limited CBD applications include systems in St. Paul, Minnesota; Seattle, Washington; and Norfolk, Virginia. In 2005, transit park-and-ride applications were initiated in Chicago, Illinois; and San Francisco, California.

The primary reason that APMS applications in the U.S. have been limited to airports, CBDs, and park-and-ride facilities is the level of infrastructure required to make the systems work. Many advanced parking management systems in the U.S. rely on fixed-location, dedicated components that include vehicle detection, space inventory management, and communication equipment.

However, although the majority of advanced parking management systems in the U.S. invest in such an extensive level of infrastructure, such a level of investment is actually not required. In fact, other systems use a combination of dynamic and static message signs or other low-cost options. Other potential venues that would benefit from APMS include special event facilities, such as festival locations and sports arenas. In Lincoln, Nebraska, for example, an online system allows University of Nebraska football fans to reserve their downtown parking spaces in advance.

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[6] U.S. DOT (2006). *ITS Deployment Statistics Database.*
http://www.itsdeployment.its.dot.gov.

APMS—What are the Technology Options?

When planning advanced parking management systems, two main decisions need to be considered: "What type of system will count the number of vehicles in the facility?" and "How will the various components of the system communicate with each other?"

There are two types of counting systems: entry/exit counters and space occupancy detectors.

Entry/exit counters can use one of several technologies currently available. Traditional induction loop counters can be employed where surfaces and anticipated weather treatments support their application. In cases where loop detectors are not feasible, video detection technologies similar to those used in actuated traffic signal control may be considered. Another alternative, shown in Figure 5, is the use of small ultrasonic counting devices installed in the surface of the roadway. These devices can be powered by long-life batteries and can communicate using a radio frequency (RF) transmitter.

Space occupancy detectors are manufactured for installation in the ground under the vehicle, on a post in front of the space, or over the space on garage ceilings. Most occupancy detectors use ultrasonic sensors or induction loops. Each approach has unique power and communication requirements.

Traditionally, APMS applications have focused on solutions that employ closed systems that use dedicated resources to generate and display parking space availability in real-time. These closed systems—such as Chicago Metra and BWI Airport—use signs, space occupancy detectors, and a dedicated central computer. These systems typically use dedicated fiber optic lines to communicate between nodes. Though these systems provide real-time, high-quality information, they are expensive and
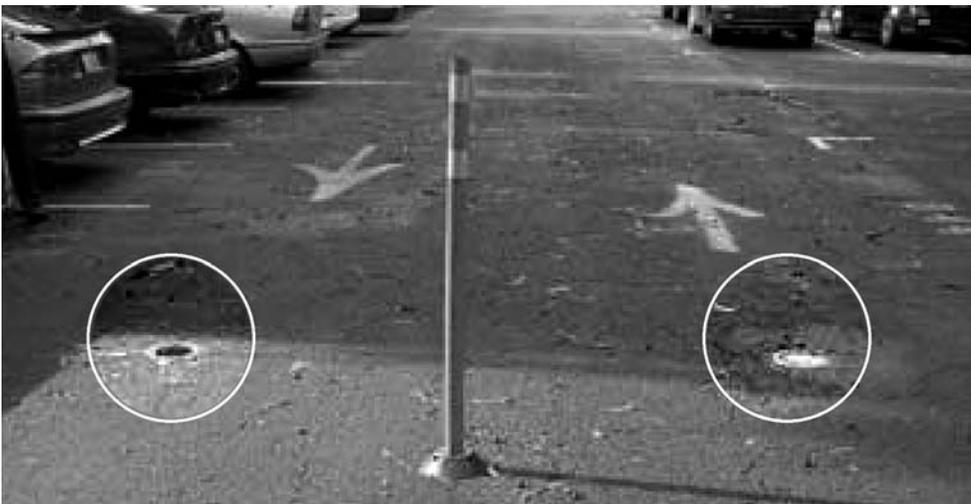
Counting Systems

 Entry/Exit Counters

Space Occupancy Detectors

Communication Systems

Figure 5. Entry/Exit Counter (Highlighted in Pavement) with Traffic Delineation Guide

usually require that the communications infrastructure be included in the facility construction. These systems may also require purchase or lease of dedicated fiber optic communications capacity to serve the APMS sign system.

Because not all APMS projects involve new construction, fiber optic communications are not always practical. Space occupancy sensors that use RF communications are a good choice when existing facilities are retrofitted with an advanced parking management system. These RF transmitters communicate between individual parking spaces and a local hub. The local hubs collect and forward that information using wireline or wireless media to the central computer.

Communications with APMS signs can also be accomplished wirelessly using owned or leased microwave systems that operate under Federal Communications Commission (FCC) guidelines. Cellular telephones are generally not practical as a communications medium, due to the frequent communication required to update the information that is necessary to maintain an accurate count of available spaces.

When choosing a technology option, decision-makers need to consider whether the facility is new construction or a retrofit, whether the facility is subject to periodic repaving, and whether or not the parking configuration will change over the long term. Whether new construction or a retrofit, stakeholders should expect some challenges in dealing with dynamic field conditions.

Barry Resnick, Planner for the Department of Planning and Real Estate Development at Metra, said, "Uniquely uncommon causes [for power and communications obstacles] are not always considered or investigated during the design engineering phases prior to such demonstrations or deployments." Metra was proactive in addressing any potential issues by calling for a radio frequency field study as part of the construction bid.

Each ITS-based parking management solution is different, requiring a carefully chosen architecture that meets the needs of the various stakeholders. Factors that should be considered when deciding among these options include:

- Availability of mounting space for detectors
- Operational environment in which the components will be used
- Communication channels
- Electrical power supplies.

Factors to Consider When Choosing Counting and Communication Systems

"Uniquely uncommon causes [for power and communications obstacles] are not always considered or investigated during the design engineering phases prior to such demonstrations or deployments."

–Barry Resnick, Planner, Department of Planning and Real Estate Development, Metra

APMS—Who Should be Involved?

In ITS projects, the stakeholder groups and their interests must be identified early in the process. In the case of parking management, this notion holds especially true as there are many direct stakeholders who would not necessarily be included in deployments of other types of ITS technologies.

In parking management applications, project planners must consider the point of view of each stakeholder group, including private sector concerns and neighborhood issues. In most advanced parking management systems, there will be many stakeholder groups, such as attraction operators, parking operators (public and private), parking patrons, departments of transportation (city, county, state, and Federal), Councils of Government, utility providers, historical preservation groups, and neighborhood boards.

Typical interests of the first three stakeholder groups—attraction operators, parking operators, and parking patrons—are outlined below within the context of CBD, airport, and transit park-and-ride applications.

- **Attraction operators** are interested in providing safe and efficient access to their patrons. Downtown shop owners are interested in customer access to parking near shopping districts, while airport authorities are interested in the orderly flow of traffic to, from, and through the terminal area and into the parking area. Transit operators are interested in providing timely transfer opportunities for park-and-ride patrons.

- **Parking operators** are interested in maximizing the utilization of their facilities and minimizing the cost of providing parking services. Operators in business districts want to ensure that visitors are aware of availability of parking facilities. Those operating airport facilities want to ensure that patrons are aware of available spaces at the various facilities that support short- and long-term parking on the airport grounds. Airport parking operators also want to ensure that patron frustration with recirculation does not lead to parking in fire lanes or other illegal locations. Park-and-ride operators want to ensure that patrons view the transfer from the freeway or arterial roadway to transit vehicle as quick, safe, and frustration-free.

- **Parking patrons** are interested in minimizing the time spent looking for a parking spot and in minimizing the distance from the parking spot to the attraction. In airport parking environments, patrons are interested in saving time and in having adequate information to allow them to select the level of service that corresponds with their preference for high-, moderate-, or low-cost parking. In park-and-ride situations, patrons are especially interested in knowing whether space is available before they leave the freeway or arterial street as

they want to reduce the chance that they will have to return after wasting time in a fruitless search. Transit parking patrons want to eliminate the need to search for a parking space, in an effort to minimize the time to transfer from the private to the transit vehicle.

Forming the Stakeholder Group

Most localities and regions actively address parking issues within their cooperative governmental structures ranging from neighborhood participation in city-run parking forums to jurisdiction representation in Councils of Government (COGs). COGs often form special committees that address parking issues. These committees define parking problems, investigate parking management solutions, and estimate parking management benefits and costs. Within these governmental groups are many stakeholders, including those who represent public agencies, components of the private business sector, and citizens of the community or region. Parking is becoming an increasingly important aspect of transportation planning.

Stakeholder group membership depends on the individual jurisdiction—its governmental organization, the division of responsibilities for parking operations and maintenance, jurisdiction membership in regional COGs, and participation of Citizen Action Committees (CACs). Table 1 lists the agencies and groups that may be included in an APMS project and identifies the roles each may have in the planning, installation, operations, and maintenance of advanced parking management systems.

Stakeholder	Responsibility
State Department of Transportation	• Integrate APMS project into regional initiatives and larger statewide ITS architectures
City or County Planning Departments	• Seek Federal and state Congestion Management and Air Quality (CMAQ) funds • Coordinate growth and development plans
City or County Transportation or Public Works Department	• Champion the project • Coordinate with local transportation planning efforts including transit development • Seek Federal and state transportation and transit improvement funds
City or County Police Departments	• Support the APMS project, seeking reduction in uniformed police services to enforce illegal parking and/or control intersections in close proximity to major attractions
Councils of Government	• Coordinate with other jurisdictions within the participating region identifying interoperability issues and resource sharing opportunities
Citizen Action Committees	• Support the APMS project, seeking improved neighborhood environments • Help promote public awareness
City or County Architectural Control Boards	• Review signage plans to ensure consistency and fit within the architectural and visual environment
Utility Companies	• Provide information on the availability of power sources and advise on restrictions to power access
Communications Companies	• Provide information on the availability of fiber optic, T-1, and twisted copper wire communications media • Advise on restrictions to communications access
Privately Owned Parking Vendors	• Provide the information and linkages required to develop large-scale public and private facility networks

Table 1. Potential Stakeholders and Roles

Study Site Descriptions

Site Selection

Three sites—Baltimore-Washington International Airport near Baltimore, Maryland; Seattle Center in Seattle, Washington; and the Chicago Metra park-and-ride facilities near Chicago, Illinois—are featured in this section. These APMS sites represent a range of system maturity, stakeholder relationships, and APMS technical approaches.

BWI has equipped over 13,000 spaces in its parking garages with APMS technology in an effort to improve service for the airport's travelers. Seattle Center has equipped publicly owned parking facilities with APMS technology to improve the downtown sports arena and cultural center visit experience. The Chicago Metra commuter rail system has installed APMS technology at two park-and-ride locations. Table 2 provides a summary of key characteristics of each site.

Site Characteristic	Seattle Center	Chicago Metra Park-and-Ride	BWI Airport
Setting	Central business district	Suburban freeway	Airport property
Attraction(s) Served	Cultural and sports attractions	Commuter rail station	Airport
Number of Signs Deployed	2	8	**Hourly Garage** • 10 (one per level and one at each up/down ramp) • 32 aisle signs[7] Approximately 4,800 LED indicators (one above each space) **Daily Garage A** • 17 (one per level, one at each up/down ramp, entrance) • 135 aisle signs Approximately 7,100 LED indicators (one above each space)

Table 2. APMS Site Overview *(continued on next page)*

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[7] Aisle signs in the Hourly Garage and Daily Garage A convey the number of spaces available per row.

Site Characteristic	Seattle Center	Chicago Metra Park-and-Ride	BWI Airport
Distance of Signs from the Facility	Approximately 1 mile	Between 1/4 and 3 miles away from both stations	All signs and LED indicators are located at the entrance to, or within, the Daily and Hourly Garages.[8]
Facility Type	Multi-level garages and surface lots	Surface lots	Multi-level garage
Counter Type	Entry/Exit	Entry/Exit	Individual space
Communication Backbone	Wireline/ Wireless	Wireline/ Wireless	Wireline
Integration with Regional ITS	Yes	Yes	No

Table 2. APMS Site Overview *(continued from previous page)*

The following sections present each site's APMS deployment and operations experience in terms of the history of the deployment, planning considerations, operational environment, and operations and maintenance of the facility.

Seattle Center

Seattle Center, located in the downtown area of Seattle, Washington, is an example of an APMS deployment in a CBD environment. The Seattle Center site was developed for the 1962 World's Fair. It is a 74-acre urban park that serves as a center of the cultural, festival and sports interests of the Puget Sound region which has a population of 3.5 million people. Surveys of Seattle metropolitan area residents conducted by the Puget Sound Regional Council (PSRC) indicate that members of the average household will frequent Seattle Center approximately eight times per year, attending events at a variety of venues including museums, concert halls, convention facilities, and sports arenas. Often, many events run concurrently, creating a surge in travelers on the downtown streets as ticket holders strive to arrive in time for the opening curtain or tip-off. To meet the parking demand, Seattle Center operates several parking facilities, providing a total of 3,535 parking spaces located around the park complex. Figure 6 shows a map of Seattle Center parking facilities.

The problem faced by Seattle Center patrons is that on nights when multiple events take place, there are significant delays encountered on

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[8] Signs located on the roadway approaching BWI are maintained by the Maryland Aviation Administration and inform travelers of availability and the cost per hour of each parking facility at the airport.
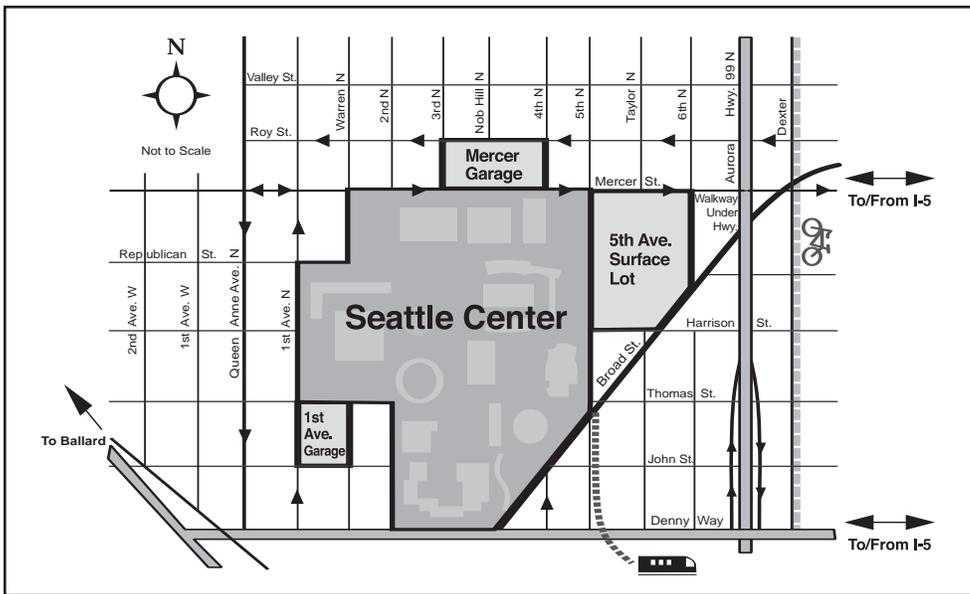
Figure 6. Map of Seattle Center Parking

the streets that access Seattle Center parking facilities from nearby Interstate-5 (I-5). Traffic occasionally backs up to the freeway exit ramp as patrons queue up to approach the first of the several facilities operated in support of Seattle Center events. Events at the Seattle Center contribute to heavy traffic between Mercer Avenue and I-5, which must follow a complex path of one-way streets. Locals call traffic backups that result the "Mercer Mess."

To address these problems, Seattle Center and the Washington Department of Transportation (WSDOT) began the deployment of an advanced parking management system in 2003. The system includes signs with both active and passive components. As of 2006, only the passive pieces of the signs were being used. At the time of this study's publication, the local stakeholders were continuing to work towards implementing a stable, functioning system that includes both passive and active components. If both components operate as designed, the Seattle Center advanced parking management system will become part of the Puget Sound region's SmarTrek traveler information system.

As designed, the system consists of remote sensors, a central computer, strategically located dynamic message signs, a website interface, a SmarTrek data systems interface, and the associated communications and power infrastructure. The APMS signs are configured so that they may contain both active and passive message components. Figure 7 shows a sign with both active and passive components, although the active component is not operational in this photograph. The active component can provide space availability at the various facilities. The passive component points to nearby garages. If both pieces were operational, these two elements would provide the traveler with the

Figure 7. Seattle Center Sign Illustrating Active and Passive Components

information required to make the best choice on whether to wait in the entry queue or whether to divert to another facility.

Should the active sign components become operational, the garage facilities will use an entry/exit counting system to track the number of spaces available. The number of spaces available would then be forwarded to a central computer and used in generating displays on the active components of the APMS signs. The use of entry/exit counters, while not as accurate as individual space sensors, can overcome the difficulty of installing in-surface space sensors in pre-existing garage facilities, which are not equipped with the conduit required to support a space-by-space counting system.

The surface lot also uses in-surface sensors, such as the one shown in Figure 8, that communicate wirelessly with an inventory management system that provides count information to the central computer. The systems selected do not require in-surface wiring and can be removed to facilitate periodic resurfacing of the asphalt surface.

A centralized system can monitor the number of vehicles in each facility and then generate the messages to be displayed on the active piece of the sign and the Seattle Center website. Two dynamic message signs, located along adjacent roadways, have been installed to present real-time parking availability information, should the active piece become operational. Figure 9 illustrates the system's architecture. As currently deployed, various elements on the passive sign direct traffic to nearby parking facilities.

Figure 8. Seattle Center In-surface, Wireless Vehicle Detector
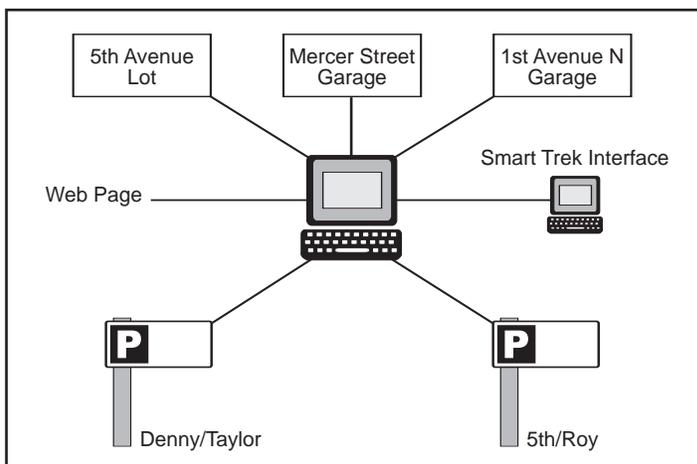
Figure 9. Seattle Center APMS System Architecture

The system was funded primarily by WSDOT. Seattle Center, which is a separate government entity, is responsible for the maintenance of the system. The system is designed to provide parking availability for the First Avenue North Garage, the Mercer Garage, and the Fifth Avenue Parking Garage. The system has not yet operated as designed due to various issues. Many of these issues are directly related to the system's central computer. For example, security upgrades within the central computer have affected the communication with the dynamic message signs.

The Fifth Avenue garage has also experienced problems with the wireless communications between the detectors and the central computer. While some of the dynamic message signs have the option of being operated manually, this has never been done. The technical challenges encountered have caused the project to be delayed many times. This has led to waning interest among participants and lowered the priority of the project. Additionally, many of the agencies involved have experienced staff changes in key positions since the project began, resulting in the need to continually seek buy in, as new staff members become involved.

Chicago Metra Park-and-Ride

As part of an integrated corridor management plan, the Chicago Metra commuter railroad is deploying an advanced parking management system to guide commuters from the freeway to park-and-ride lots with open parking spaces. As of the date of this study's publication, all the equipment had been deployed and operational testing was underway.

The system was installed on the Rock Island Line, which is one of 12 lines operated by Metra that run from downtown Chicago to the outlying suburbs. Figure 10 shows a map of the Metra system with the Rock Island Line highlighted. The two stations where the system is installed are the Hickory Creek/Mokena station and the Tinley Park/80th Avenue station. Both stations are located a short distance from Interstate-80 (I-80). As with many commuter railroads, park-and-ride facilities are an integral part of the service Metra provides.
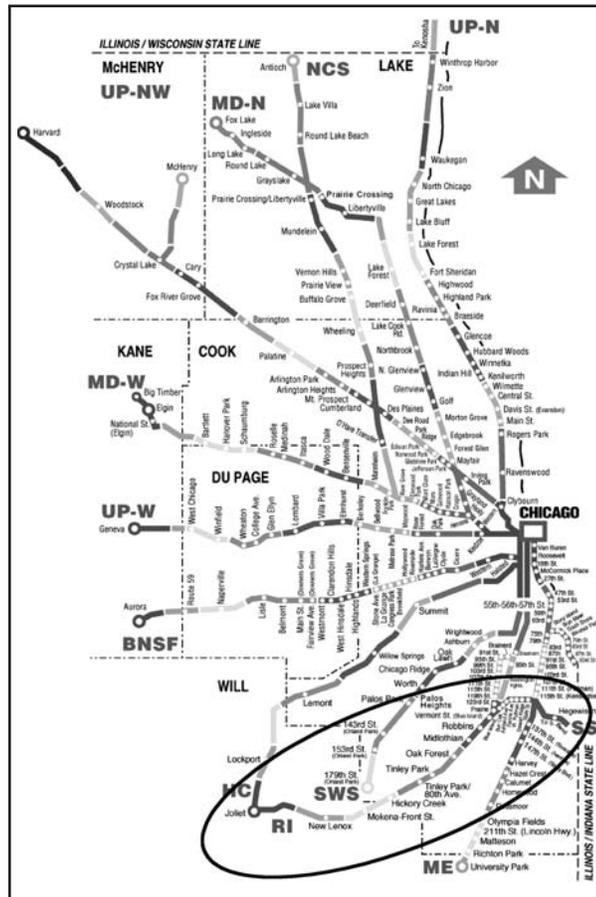

Figure 10. Map of the Chicago Metra System with the Rock Island Line Highlighted[9]

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[9] Northeast Illinois Regional Commuter Railroad Corporation (2006). *Metra System Map.* http://metrarail.com/System_map/index.html.

Metra implemented the system with the hope that the park-and-ride APMS application would increase the number of monthly pass holders on the line. Approximately 60 percent of riders from the two Rock Island Line stations use monthly passes. The remainder use 10-trip or single ride passes. One of Metra's goals for the system is to convert occasional riders to monthly pass holders, securing a more stable ridership base and associated revenue streams. Additionally, the system is expected to reduce the number of times commuters return to the roadway or park in a nearby neighborhood as a result of not finding parking.

The State of Illinois received Federal funding for the advanced parking management system in 2000. The project, overseen by the Regional Transit Authority (RTA), involves design, deployment, testing, and evaluation of a prototype system at two Metra park-and-ride facilities. The system will collect information on parking availability at select park-and-ride lots, and will provide this information to travelers through dynamic message signs located on the freeways and arterial streets along the commuter corridor. Signs will provide travelers with "road-to-parking lot" guidance, as well as "lot-to-lot" guidance within parking facilities or between nearby parking facilities where appropriate.

Functional system design was guided by information collected from transit rider surveys conducted during a needs assessment. Metra conducted surveys of commuters at various rail stations during and immediately following the morning rush hour. The survey consisted of 11 questions on station parking, station signage, and types of information that riders would like posted on dynamic message signs. The survey found that a majority (62 percent) of all transit riders felt that signage around transit stations could be improved. The survey found that over 3/4 of regular transit riders felt that inadequate parking guidance information was a significant issue.[10]

The first station served by the system is the Tinely Park/80th Avenue station. Tinley Park is considered a high-growth area. The station has approximately 2,000 surface spots and 40 handicapped spots situated in two parking lots. These lots are nearly 100 percent utilized on weekdays. This station has an approximate daily ridership of 2,297. The second station, the Hickory Creek/Mokena Station, is located south of the 80th Avenue/Tinley Park Station off of I-80. This station has roughly 2000 available spaces in one parking lot, which are 70 to 80 percent utilized each weekday. The Hickory Creek Station has a daily ridership of 1,135.

Metra hopes to create an inter-station group that will allow riders to park at either facility, since the two stations are located close to each other. As such, the system provides parking availability information on all lots that would be of interest based on the DMS location. The dynamic message signs provide the available number of spaces at each lot and static directional arrows to direct the drivers to these lots.

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[10] Wilbur Smith Associates (1999). *Parking Management Systems: Needs Assessment Report.*

Metra's system uses entry/exit detectors at all lots, with a field processor that communicates the availability information to eight dynamic message signs at various locations. Communication between the lots and the field processor and between the field processor and the DMS devices is wireless. The system employs one microwave tower that serves the entire network. The signs, located on the nearby freeways and arterial streets, operate within a carefully planned information network. Figure 11 shows a schematic map of the system. Metra expects the system to become operational in 2006.
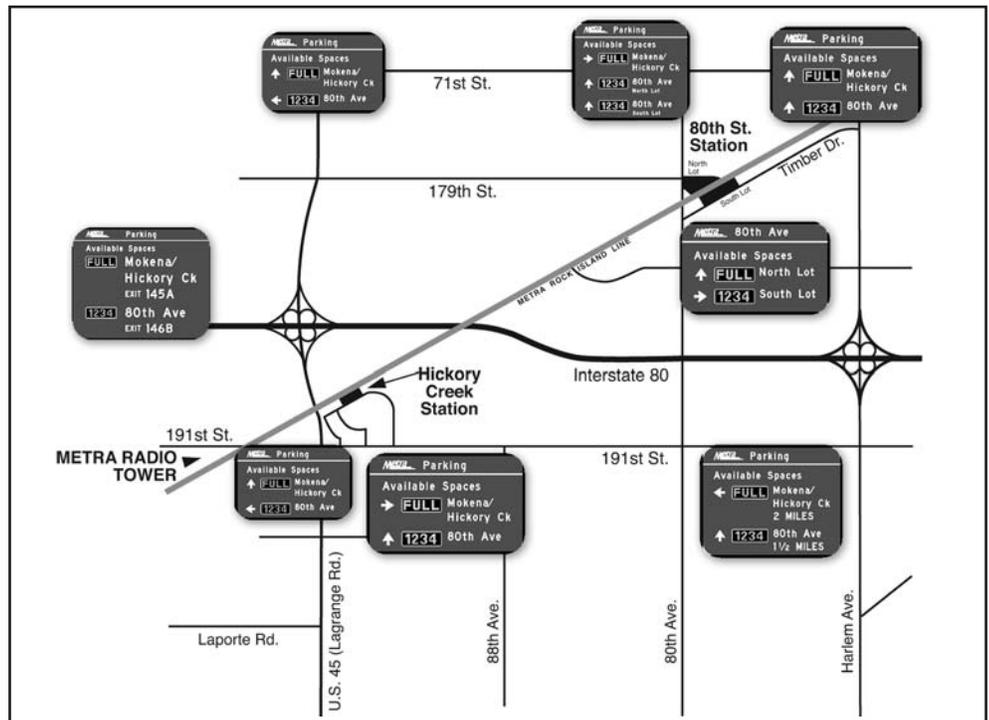
Figure 11. Chicago Metra's APMS System Illustrating the Parking Information Network

Baltimore-Washington International Airport

Baltimore-Washington International Airport near Baltimore, Maryland has been a leader in APMS applications at U.S. airports. The site has the largest airport ITS parking system in the country. The system determines garage space availability in real time and guides travelers to the available parking spaces. BWI deployed the system to improve the traveler's experience as part of the airport's aggressive growth strategy.

In April 2001, an advanced parking management system was installed on Level 2 of the hourly garage (approximately 1,100 spaces) as an operational test of the system. The purpose of the limited installation was to test the effectiveness of the parking system prior to making a large capital investment. During the operational test, the Maryland Aviation Administration (MAA) received an overwhelmingly positive response through surveys and e-mail comments. In addition to the positive feedback, the parking operators found a reduction in the

number of cars parked illegally in fire lanes and other no-parking areas. Based on the positive operational test results, the MAA expanded the system to the other four levels of the Hourly Garage. In addition, installation of APMS technology was included in the construction of a new garage–Daily Garage A. This expansion was completed in early 2004. Daily Garage A offers 7,100 spaces on eight levels, bringing the total number of spaces served to over 13,000. Total cost of the BWI system is estimated at $6 million.

The BWI system uses ultrasonic sensors positioned over each parking space to monitor the availability of the space. Information is collected for each aisle, floor, and facility. The information is processed in a central computer. General parking guidance information is provided to travelers on a dynamic message sign on the airport access road. This sign indicates the "Open" or "Full" status of each facility. As the traveler drives through an APMS-equipped facility, billboard signs at the entry to each level indicate the number of spaces available on that floor. There are also signs on the up and down ramps within the garage that indicate the number of spaces on floors above and below. Daily Garage A also has a sign at the main entrance listing the number of spaces available on all floors, as shown in Figure 12.

Figure 12. BWI Daily Garage Entrance Sign Providing Availability by Floor[11]

Once on the aisle, the traveler sees space availability on a light-emitting diode (LED) sign over each space. The LED system displays the space status based on the ultrasonic detector located in the detector/display assembly. The LED displays green for "available" and red for "unavailable." Those spaces reserved for handicapped-accessible parking spaces are equipped with a blue LED display.

[11] Schick Electronic, SA Website (2006). *Signal-Park.* http://www.signal-park.com.

New advanced parking management systems go beyond providing information to the traveler on the availability of parking spaces. Some APMS applications take reservations for parking spaces and some even guide travelers, with turn-by-turn directions, all the way to the available parking space.

The California Department of Transportation (Caltrans) is sponsoring the development and testing of a parking management system with reservation capabilities. Caltrans is partnering with the University of California at Berkeley, Bay Area Rapid Transit (BART), ParkingCarma™, and Quixote Corporation to test the system at the BART park-and-ride lot in Millbrae, California.The project began in September 2004, following two years of research and development. Electronic sensors in the east lot of the Rockbridge BART park-and-ride facility communicate space availability to commuters on the freeway using two temporary dynamic message signs. Figure 13 shows a schematic map of the Millbrae BART parking facility with the two lots that operate the ParkingCarma™ system highlighted.

Facility-Based Reservation Systems
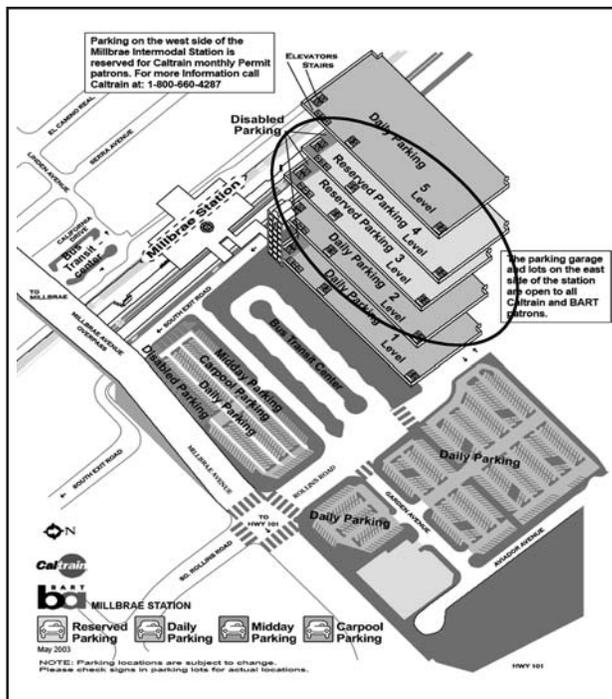
Figure 13. BART Park-and-Ride Facility in Millbrae, California[12]

BART riders may reserve any of these 50 spaces over the Internet, personal digital assistant (PDA) or telephone. Daily or monthly reservations are available up to two weeks in advance. It costs a commuter $4.50 to reserve a spot in advance through ParkingCarma™, compared to the daily rate of $1.00 for those who drive into the lot and find a space.

[12] Bay Area Rapid Transit (2006). *Millbrae Station Parking Map.* http://www.bart.gov/docs/permit/pk_millbrae.pdf.

Utilization of the reserved parking spaces has increased from 10 percent before the test to 75 percent after the test.[13] Over 1,000 users have registered to participate in the reservation program. Stakeholders believe that the system also has improved difficult-to-quantify measures such as customer satisfaction. One commuter said that without the ParkingCarma™ service, "I would probably not take BART."[14]

Online Reservation Systems

The latest trend in parking management is online reservation services. Two companies—including MobileParking LLC and SpotScout™—allow drivers to check parking availability for select cities using their radio, cellular telephone or computer. MobileParking LLC currently covers 400 parking facilities in 50 cities across the U.S. MobileParking's service allows drivers to call a toll-free number from their cellular telephones to check parking availability in their city. After the driver provides the operator with his or her final destination, the operator directs the driver to the closest available space. The first reservation is free. Additional reservations cost $1.75 each. At some of MobileParking's partner garages, in addition to paying MobileParking for the reservation, customers can also pay the parking fee itself through MobileParking, eliminating the need to make a separate payment to the garage operator.

SpotScout™ launched in 2004 and began taking parking reservations in New York and Boston beginning in 2006. The SpotScout™ service allows drivers to reserve and pay for parking spots either online or through Web-enabled cellular telephones. Once a driver has reserved a spot and paid for it, a text message is sent to the driver's cell phone with a confirmation code and directions to the facility.

In addition, SpotScout™ allows users to sell their personal parking spaces to other motorists for short-term use. These users are called "SpotCasters." SpotScout™ allows users to "set the price and time parameters within which they wish to make their space(s) available."[15]

In the future, SpotScout™ hopes to include on-street spaces in its network of parking spaces. Since the SpotScout™ service allows the parking facilities to update the number of available spots online, no sensor infrastructure is required.

[13] Botkin, Donald (2005). *ParkingCarma's Innovative Smart Parking System Featured this Week at ITS World Congress in San Francisco.*
http://www.parkingcarma.com/ITSPR.aspx.

[14] Saranow, Jennifer (2006). "Your Space is Waiting: Reserving a Parking Spot." *The Wall Street Journal.*
http://www.post-gazette.com/pg/06088/677762-96.stm.

[15] SpotScout™ Website (2006). *SpotScout™: Parking the Mobile Generation.*
http://www.spotscout.com.

In 2005, XM Satellite Radio, which already provides real-time traffic information to in-vehicle navigation devices, demonstrated a potential service called "Dynamic Parking Information." The service provides XM Radio users with the number of available parking spaces at specific lots.

The system relies on sensors within the parking lots to transmit the availability information to the vehicle's navigation system. (Parking lots in San Francisco, Los Angeles and Detroit provided data for the demonstration.) The in-vehicle display uses color-coded icons to reflect the percentage of unoccupied spaces.

XM Radio has plans to take the service nationwide. At the time of the demonstration, company officials announced that it was in negotiation with major parking providers about participating in the service.

Parking Navigation Systems

This section presents the benefits, costs and lessons learned findings from the three sites visited. These findings, as well as additional benefits, costs, lessons learned, and extent of deployment of advanced parking management systems are available on the ITS Applications Overview website http://www.itsoverview.its.dot.gov and search for "parking management."

The benefits of APMS are specific to the stakeholders involved:

- **Travelers**: easier access, reduced time spent looking for parking, and reduced frustration

- **Venue operators**: increase in accessibility and associated increase in patronage and customer satisfaction

- **Parking operators**: increased space occupancy and associated increase in revenue

- **The jurisdiction and nearby neighborhoods**: reduction in the number of patrons circulating through the street network looking for a parking space and fewer vehicles parked illegally on local streets.

Specific benefits found in visits to APMS sites are cited below.

An October 2003 survey of BWI travelers found that most have a positive impression of parking at BWI Airport. Of the 63 travelers surveyed, 81 percent answered that they "strongly agree" or "agree" that parking is easier at BWI than at the other airports they frequented. Similarly, 68 percent responded that they "strongly agree" or "agree" that parking is faster at BWI than at the other airports they frequented. Figure 14 shows a graph of the survey results.

Benefits

Ease of Access

"Customer satisfaction became the major factor in the decision to expand from a test of several thousand spaces to deployment across all hourly and daily garage facilities at BWI."

–Harry Zeigler, Assistant Manager, Maryland Department of Transportation, Office of Transportation and Terminal Services, BWI Airport
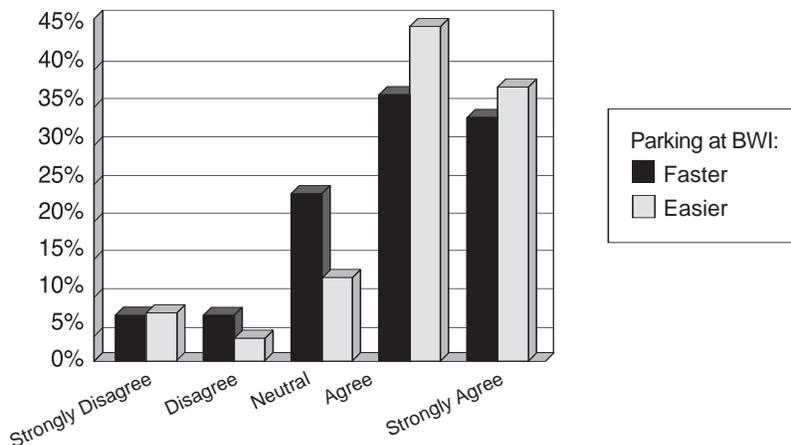
Figure 14. Customer Satisfaction Survey Responses at BWI

Reduced Frustration

Direct BWI customer feedback gathered by the Maryland Aviation Authority indicates that customers felt the system "saved them aggravation" leading to very high levels of customer satisfaction with the BWI parking experience. Harry Zeigler, Assistant Manager for the Maryland Department of Transportation's Office of Transportation and Terminal Services at BWI Airport, stated: "Customer satisfaction became the major factor in the decision to expand from a test of several thousand spaces to deployment across all hourly and daily garage facilities at BWI."

Increased Venue Accessibility

In Milwaukee, Wisconsin, several business improvement districts have embarked on an ambitious plan to improve parking in the downtown area, and survey results indicate that the city's efforts have been successful. In recent years, the city has installed better signage at parking facilities and launched a Web-based pre-trip parking information service. A survey conducted in 2003 of metropolitan area residents found that there was a 10 percent decrease (as compared with the previous year) in the number of respondents who felt that parking availability prevented them from visiting downtown Milwaukee.[16] The same survey revealed that a larger portion of citizens (68 percent in 2003 compared with 54 percent in 2002) felt that the Milwaukee downtown area is improving as a place to visit.

Increased Facility Occupancy

In February 2004, a downtown St. Paul, Minnesota parking survey was conducted to determine the city's ability to accommodate Winter Carnival visitors. The survey district included an area served by 42 parking facilities—17 of which are participants in the downtown St. Paul advanced parking management system. The vacancy rate at the facilities participating in the system was much lower—17 percent versus 38 percent.[17]

Improved Traffic Flow

The system in St. Paul connects 10 parking facilities in the downtown area. Fifty-six (56) signs provide information on parking availability: 10 of these are dynamic message signs providing parking availability, while 46 are static signs which guide drivers to facilities.

A study of the traffic flow impacts of the APMS was conducted in St. Paul as part of the system's 1997 field operational test. The impacts on travel time and intersection performance were measured in the vicinity of the West 7th Street and Kellogg Boulevard. Travel time on a street in the CBD area was measured before and after activation of the system during periods of equivalent demand. Over the measured course, travel

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[16] Milwaukee Downtown (2003). *Status of the Downtown Milwaukee Brand in Southeastern Wisconsin.* http://www.milwaukeedowntown.com/pdf/whitepaper.pdf.

[17] St. Paul Transportation Management Organization (2004). *Event Parking Empty Space Report.*

times were reduced by 9 percent and the stopped time delay over the course decreased by 4 percent. At the signalized intersection itself, individual vehicle delay was reduced by 10 percent even as intersection volume increased by 15 percent.

Advanced parking management systems can range widely in cost, depending on several factors including the following:

- Type and level of accuracy of the information provided

- Degree of complexity in installation of the sensors

- Availability of communications channels

- Availability of power supplies for remote components

- Signage required to convey the information at appropriate decision points.

This study has found that advanced parking management systems cost between $250 and $800 per space, depending on the factors listed above.

At BWI, the unit cost of the equipment was approximately $450 per parking space. BWI stakeholders estimate that the system would have been more expensive if an existing garage had been retrofitted with the system's equipment. The advanced parking management system was estimated to cost between 2 and 5 percent of the overall construction cost of the new parking structure, excluding land costs.

In the case of Seattle Center, the cost per space varied widely based on the facility type (garage or surface). The overall cost was driven to a significant degree by the cost of getting the signs installed and linked to the central computer and to local power supplies.

For the Chicago Metra project, Metra will have a two-year warranty period that will begin when the system becomes operational. During that time, Metra will document operational costs such as staff time and materials. Metra expects the electrical costs to be approximately $20 per month for each electrical sign. There are seven electrical signs in the Metra system; an eighth sign is solar-powered. Metra expects the annual electrical costs to be $1,680. The cities in which the project is taking place have offered to pay these electrical costs, and Metra expects to take them up on their offer.

Costs

The costs for an advanced parking management system are typically split between the parking facility operators and the local jurisdictions. These life cycle costs cover all of the system's functional requirements. These costs can be divided into several categories: system design, equipment, installation, communications, operations, and maintenance.

System design, equipment, installation, communications, operations, and maintenance costs can themselves be divided into categories:

- Sensors
- Integration and operating software
- Display systems
- Electronic payment systems
- Power supplies.

Communications costs can be divided into the following categories:

- System interface terminals
- Line charges for twisted wire, fiber optic, T-1, or wireless services, depending on the configuration of the system
- Web-based services.

Lessons Learned

This section summarizes specific lessons reported by the sites visited. The lessons were common across all three sites, and are presented in terms of policy and planning, design and deployment, and management and operations.

Policy and Planning

- **Involve all appropriate stakeholders in a formal and collaborative manner throughout the planning, deployment, and operations phases.** Advanced parking management systems will impact many stakeholders, both public and private, including travelers, parking operators, venue operators, nearby neighborhoods, and the local jurisdiction itself. To be successful, the needs and concerns of all stakeholder groups must be addressed. For those APMS projects that involve very diverse groups, including those located in CBDs and transit park-and-ride facilities, stakeholders need to consider forming a formal organization and writing a memorandum of understanding that outlines the short- and long-term roles of each member.

  Barry Resnick, Planner for the Department of Planning and Real Estate Development at Metra, cites government coordination as a key aspect of the deployment's success: "Positive aspects of coordination among the various levels of government helped stave off unnecessary future costs and potential relocation of systems."

- Ensure that the stakeholder group works from a formal charter that binds the member organizations to the effort, provides a forum for resolution of issues, and ensures a consistent advocacy message. APMS deployments, with the exception of airports, are often integrated into urban or neighborhood environments and, as such, take time and involve a very diverse group of stakeholders. Late-breaking or unresolved stakeholder concerns can stall the effort indefinitely. To prevent stalling, the stakeholder group should obtain formal endorsement from the leadership of the jurisdiction involved. The mayor or county executive should seek city or county council endorsement and should designate a staff member or a specific public agency as "champion" of the system. The champion should exercise executive leadership within the stakeholder group and represent the project in public policy discussions and funding requests.

  As Eldon Jacobson, Advanced Technology Engineer for the Washington Department of Transportation, noted regarding the challenges encountered during the Seattle Center APMS deployment, "One lesson that can be learned is to never start a project like this unless there is a signed public agency agreement outlining roles and responsibilities that is approved at the highest levels within a city."

- Integrate the APMS project into a larger regional ITS architecture. An important consideration in the design phase is to link the APMS project to a regional ITS architecture. In doing so, it may be possible to leverage existing resources, such as communications channels and traveler information media, that are funded under larger regional efforts. Several of the APMS projects examined during the course of this study suffered delays and cost overruns because of uncertainties with stand-alone communications, power, and design and placement of the signs. Linking with a regional ITS architecture reduces the potential for these technical surprises that delay implementation and increase costs. In addition, connection to a regional ITS architecture provides opportunities to seek Federal and state funding associated with ITS-based traveler information systems, congestion management, and clean air attainment programs.

- For systems that use entry/exit counting systems, consider the sensor's detection zone in design of entrance or exit driveways. Wide driveways and narrow detection zones can lead to missed counts. In addition, when there is significant transient traffic that shares the entrance with the parking facility, (e.g., vehicles going to "kiss and ride" drop-off zones) the system count refresh rate needs to by fairly high to ensure that transient or circulatory traffic is not counted against the number of spaces available.

"One lesson that can be learned is to never start a project like this unless there is a signed public agency agreement outlining roles and responsibilities that is approved at the highest levels within a city."

–Eldon Jacobson, Advanced Technology Engineer, Washington Department of Transportation

Design and Deployment

- **Research the availability of communications lines and power supplies thoroughly and get the permit process going early; check availability in the field before committing to a design.** APMS devices, although small and mostly self-sufficient, require access to communications channels and power supplies. Solving connectivity issues is a major activity with in the system design and installation process.

- **Involve those that have authority and influence in the approval of sign appearance and location early in the design process.** Throughout the design process, records of approvals and changes should be kept. A final sign design must be formally agreed upon. Sign appearance and locations can become a significant source of delay and increased costs, as they must often be approved by architectural control boards and historical preservation organizations. In addition, APMS signs may conflict with local commercial property signs that are planned or already in place. Late changes in sign appearance and location can be catastrophic to progress, as they often require redesign and re-permitting for new communications infrastructure and power access. In two of the three sites visited, changes to signage in the latter part of the deployment introduced significant costs and delays.

Management and Operations

- **For systems that use space occupancy counting systems, confirm detector operation periodically.** In the case of the LED light system employed at BWI, attendants conduct periodic drive-through inspections to ensure all the detectors accurately reflect the space status.

- **Identify the roles and responsibilities of each agency for system operations and maintenance early in the planning process.** Failure to maintain the systems will reduce credibility and public acceptance will be negatively impacted. At one of the sites visited, the effort was delayed for nearly a year as the stakeholder group resolved the debate over who would pay for operations and maintenance.

Conclusion

Parking is and will remain an issue that affects everyone in the community, from traffic management and law enforcement to attraction owners to residents of nearby neighborhoods. All types of systems will be needed to address the parking challenge, from systems that provide parking availability at the regional and lot-, floor-, aisle- or space-specific level to high-tech parking reservation and navigation systems.

This study has found that facilities, venues, and communities that have deployed APMS have experienced a wide range of benefits, from increased customer satisfaction to higher patronage and revenues. These benefits are the result of collaboration among diverse stakeholders, as advanced parking management systems take the stress out of parking.

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http://www.fmcsa.dot.gov/facts-research/research-technology/report/intelligent-transportation-truckparking.htm.

Wilbur Smith Associates (1999). *Parking Management Systems: Needs Assessment Report.*

Smith, Lauren and Hans Roth (2003). *Parking Systems Technologies.*
http://www.calccit.org/itsdecision/serv_and_tech/
Parking_Systems_Technologies/parking_systems_tech_report.htm.

> This website provides basic overviews of advanced parking systems, parking guidance systems, parking information services, automated parking systems, advanced payment systems, and advanced parking meters. This site also provides brief descriptions of various deployments of these systems throughout the U.S., Europe and Asia.

Pati, Bikash Ron (1998). "Using ITS Technology to Manage Congestion at Parking Facilities." *Network.*
http://www.pbworld.com/news_events/publications/
network/Issue_43/43_30_PatiB_ITSTechnologyManage.asp.

> This article provides a high-level overview of both parking guidance systems and parking management systems. The article also lists the common components that make up the system, a general description of system operations, per space system cost estimates, and the benefits the project stakeholders can expect after deploying either type of system.

ITS Applications Overview Website (2006).
http://www.itsoverview.its.dot.gov, search for "parking management."

This Web page provides "one-stop shopping" for information on the benefits, costs, lessons learned, extent of deployment and other information about advanced parking management systems. This page allows "one click" access to the parking management sections of the ITS Benefits Database, the ITS Costs Database, the ITS Lessons Learned Knowledge Resource, and the ITS Deployment Statistics Database.

Spillar, Ron (1998). "Smart Parks: The Next Generation in Park-and-Ride Facilities." *Network.*
http://www.pbworld.com/news_events/publications/
network/Issue_42/42_10_SpillarR_SmartParksNextGen.asp.

> This article discusses the Santa Clara Valley Transit Authority's Smart Park deployment in San Jose, California, which is unique in that it ties parking management information with traveler information. The article provides an overview of the deployment, which provides riders with trip planning and vehicle location information in addition to alerting them to parking availability through DMS and LED indicators.

Overview of APMS

APMS Case Studies

Shaheen, Susan A and Caroline J. Rodier (2004). *Applying Integrated ITS Technologies to Parking Management Systems: A Transit-Based Case Study in the San Francisco Bay Area.* http://www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-04-18.pdf.

This report presents the background research that was conducted as part of Caltrans' test deployment at the Rockbridge BART station. The report provides the results of an extensive literature review of various smart parking applications worldwide. Also described is the field test technology that was used in the deployment. The document includes the results of focus groups and surveys that were conducted pre-deployment to gauge consumer interest in smart parking services.

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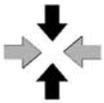Additional Transportation Stakeholders

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