SMART PARKING LINKED TO TRANSIT: LESSONS LEARNED FROM THE SAN FRANCISCO BAY AREA FIELD TEST

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ABSTRACT

Rising demand for parking at suburban transit stations, such as the Bay Area Rapid Transit (BART) District in California, necessitates strategies to manage traveler demand. To better manage parking supply, researchers implemented a smart parking field test at the Rockridge BART station from 2004 to 2006 to evaluate the effects of smart parking technologies (changeable message signs (CMSs), Internet reservations and billing, mobile phone and personal digital assistant communications, and a wireless parking lot counting system) on transit ridership and response to service pricing. Researchers employed expert interviews, Internet surveys, focus groups, and parking reservation data to conduct this analysis. Survey data indicated that the field test increased BART trips and resulted in 9.7 fewer miles per participant per month on average. Key lessons learned include that it would have been beneficial to anticipate additional time for project scoping and permitting, and fixed wayfinding signs were beneficial in both directing vehicles from the highway to the smart parking lot and addressing resident concerns about increased traffic. Additionally, the majority of participants continued to use the service when fees were implemented. However, the CMSs were not widely employed in users' decision-making processes in this application. Finally, the wireless counting system worked well, with the exception of the in-ground sensors, which were prone to miscounts. This paper provides an overview of the project and key literature, behavioral effects of the field test, and lessons learned.

Key Words: Smart parking, parking management, field test, institutional and behavioral understanding, and lessons learned

INTRODUCTION

The San Francisco Bay Area has a higher share of transit commuters than the U.S. national average of 4.7%. In 2005, both San Francisco (32.7% of commuters 16 years of age or older) and Oakland (16.5%) ranked high in transit ridership in a U.S. Census Bureau survey of commute modes (*1*). The Bay Area Rapid Transit (BART) District is a rail agency serving this area, with 43 stations and approximately 46,000 parking spaces at 31 of the stations (Linton Johnson, unpublished data). Many of these stations have a parking shortage, especially during peak commute hours, and it is often difficult to secure land and funding for additional spaces (*2*).

The Rockridge, Oakland BART station in the East Bay has a high demand for parking and 862 total spaces. BART launched reserved parking in 2002 to guarantee commuters a space during peak hours at stations with high parking demand. At popular stations, there can be a substantial waitlist for monthly spots. Furthermore, if monthly subscribers do not take transit every day, there can be under use of reserved spaces (even with a 10% over subscription rate). Thus, a daily smart parking service (peak period) might complement a monthly reserved program by providing daily flexibility during the AM commute to those who do not use transit every day.

Maximizing parking efficiency has additional benefits; searching for parking has negative effects on the environment through wasted fuel and increased air pollution. Shoup (2005) found that motorists within a 15-block commercial district in Los Angeles wasted an average of 945,000 miles, 100,000 hours, and 47,000 gallons of gasoline annually searching for curb parking (*3*).

The term "smart parking" is broadly defined as the integration of technologies to streamline the parking process—from dynamic space availability information to simplified payment methods. To test a daily smart parking concept during peak commute times, researchers helped to implement a smart parking field test at the Rockridge BART station from December 2004 to April 2006. Researchers evaluated the behavioral impacts of the smart parking system on transit ridership and participant response to pricing when fees were implemented in October 2005. The project integrated several advanced technologies to maximize parking efficiency and traveler convenience. The service included changeable message signs (CMSs), located on the highway, that displayed dynamically updated parking availability information for motorists; a wireless counting system in the BART parking lot to provide data for these updates; and parking reservations facilitated through the Internet and an interactive voice response (IVR) system. This paper examines the institutional, travel behavior impacts, user perspective, and operational lessons learned from the smart parking field test. The authors first provide an overview of the smart parking field test model and research methodology. Next, a review of past and current projects using smart parking technologies is presented. Third, institutional lessons learned from the field test are examined. Next, travel behavior impacts, user, and operational lessons learned are discussed. Finally, the authors summarize key findings.

SMART PARKING FIELD TEST AND RESEARCH OVERVIEW

The smart parking field test was a partnership among the California Department of Transportation (Caltrans); California Partners for Advanced Transit and Highways (PATH) of the Institute of Transportation Studies at the University of California, Berkeley; the BART District; ParkingCarma, Inc.; and Quixote Corporation, with technology donations from Microsoft and Intel Corporations. Researchers evaluated the following project elements: 1) effectiveness of an advanced smart parking system in managing a parking resource, 2) impacts of smart parking management on transit ridership, 3) behavioral response to parking information and reservations, and 4) lessons learned from the smart parking field test.

Brief Overview of Smart Parking Model Tested

To study the daily smart parking service, BART provided 50 of the 862 total parking spaces at the Rockridge station for the smart parking field test—35 for drive-in reservations and 15 for advanced reservations, with a five-space buffer. Before the smart parking field test, these spaces were reserved for use after 10:00 AM. The service operated during the peak commute hours of 7:30 to 10:00 AM, Monday through Friday. Advanced reservations could be made from two weeks up to the same day (if available); researchers limited the number of advanced reservations to a maximum of three every two weeks to encourage new users. BART security personnel received a daily log of vehicle license plate numbers registered to use the service each day, and they ticketed vehicles without reservations. Officers also used PDAs, beginning in January 2006, to access the license plate numbers of vehicles with reservations. The project involved three key technologies: 1) in-ground sensors, located at the BART station parking lot, to count the number of vehicles entering and exiting the smart parking lot; 2) a computer reservation system that facilitated a real-time online user interface and telephone IVR service; and 3) two solar-powered CMSs, located on Highway 24 near the exit for the Rockridge BART station. The CMSs provided motorists with real-time space availability information. Fees were introduced ten months after the field test launch to evaluate the effects of pricing on user behavior.

The smart parking wireless counting system was comprised of six in-ground sensors; two local base units (LBUs); and a master base unit (MBU) installed in the Rockridge BART station smart parking lot; and a computer server situated at ParkingCarma, Inc. Sensors were located at each entrance and exit of the smart parking lot to track vehicle entrance and egress. They wirelessly communicated parking count information to the solar-powered LBUs, which transmitted data to the MBU. From there, data were transmitted to the ParkingCarma, Inc. central computer through the Internet. Once data reached the central computer, parking availability information was updated on the three user interfaces (CMSs, IVR system, and the reservation website) (*4*).

Methodology

Researchers evaluated the smart parking field test using results from two focus groups, a before and after Internet-based user survey, reservations data from the ParkingCarma, Inc. central computer, and expert interviews with project partners and the smart parking field test manager. The two focus groups were held in May 2005 and included a combined total of 23 participants. Over 400 responses were collected during the initial field test survey in December 2004, and there were 177 responses for the final survey in early 2006. Reservations data were collected by ParkingCarma, Inc. and included all parking reservations made during the field test. Expert interviews with project partners were held in early- to mid-2007. A literature review presenting past and current smart parking projects is provided in the following section.

BACKGROUND

The last decade has seen an increase in the prevalence and variety of parking information and payment services available to travelers searching for parking. CMSs can be used to inform travelers of available parking and provide directions to the closest parking lot with vacancies. Mobile phone and Internet services can be employed to provide parking availability information and facilitate parking payment. CMS, mobile phone, and Internet technologies have been integrated to enable smart parking in areas with high parking demand.

CMSs can be used to display a range of parking information for travelers. In Edinburgh, Scotland, for example, CMSs formerly displayed messages indicating if car parks were “full,” “nearly full,” or available with “spaces” (*5*). Twenty radio-controlled CMSs now installed throughout the city are planned to display the exact number of available parking spaces for city parking garages (*6*; Michael Gallagher, unpublished data). In Cologne, Germany, the city uses CMSs at 90 locations to display dynamically updated parking information (*7*). Some signs at the city boundary indicate the parking availability rate for the downtown area (e.g., 70% full). At more than 90% capacity, the signs recommend travelers use nearby park-and-ride lots. Other signs closer to the city center display the number of remaining spaces in a group of parking garages or even the closest approaching garage (Hartmut Sorich, unpublished data). Leicester, England employs over 30 CMSs to display city parking space information using color classifications (*8*).

To encourage transit ridership, CMSs also have been used to display information for park-and-ride lots. The Chicago Metra line, for example, provides parking availability information for two station park-and-ride lots using eight CMSs placed on highways and arterial streets as part of a two-year demonstration project launched in Summer 2006 (Patrick Waldron, unpublished data). Detectors at the parking lot entrances and exits communicate vacancy information to the CMSs, which provide dynamic information (i.e., the number of available parking spaces) and static directions to the parking lots (*9*). The Washington Metropolitan Area Transit Authority (WMATA) launched a pilot project in early 2007 to notify travelers about the number of available spaces at the Vienna/Fairfax-George Mason University station parking lot in Fairfax, Virginia using two CMSs. The agency has future plans to display a message directing travelers to another station parking lot in the event that it reaches capacity (Patrick Smith, unpublished data). In York, England, CMSs display parking availability and transit schedule information for park-and-ride lots in the city (*10*).

Parking information also is accessible through mobile phones, PDAs, and the Internet; parking payment can be facilitated through these interfaces as an added convenience for travelers. Drivers in Vienna, Austria, can register with a private parking service, mParking, and send a text message from their mobile phone to pay for parking using either a registered credit card or pre-paid account. Customers of mParking are automatically sent a text message before their parking session expires (*11*). mParking is also available in over 15 cities in Ireland, Australia, the United Kingdom, Germany, and the United States (known also as “mPARK”) (*12)*. Another parking system, RingGo, allows travelers in the United Kingdom to pay for parking at First Great Western railway stations using a mobile phone. Travelers also receive a text message reminder ten minutes before their parking reservation expires (*13*). A field test in Brussels, Belgium, called e-Parking, provides travelers parking availability information and enables users to make reservations and payments through a parking space optimization service (PSOS), accessible by mobile phone, the Internet, or PDA. Travelers gain access to parking entrances and exits through Bluetooth technology in their mobile phones, and the PSOS enables users to automatically pay for parking through a registered credit card when exiting the lot (*14*).

The research project Stadtinfo Köln (means “City Info Cologne”) incorporated CMSs, mobile phones, PDAs, the Internet, and in-vehicle navigation interfaces to provide traveler information—from transit schedules to parking availability information and forecasts—to participants in Cologne, Germany. Tested between 1998 and 2002, Stadtinfo Köln provided parking information on 37 parking lots (approximately 17,000 spaces) and 1,000 metered spaces via 19 CMSs. Parking spaces also could be reserved using a license plate number or separate unique identification number (*15*). Finally, a project in Toyota City, Japan provided parking availability information to travelers through telephone, CMSs, and radio. An interim survey of system users revealed that 95% of respondents saw the CMSs, and 71% used the information in their decision-making process about what parking lot to use (*16*). Interestingly, during the BART-based smart parking field test, the CMSs were not found to be as effective due to uncertainty about count accuracy, message clarity, and the potential need for more signage on additional highway routes traveled by participants.

Advanced parking management systems have been used to successfully inform travelers of available parking across the globe. The majority of the experience in smart parking involves CMSs, and activity has been most common in Europe. More recently, smart parking has integrated mobile phones, PDAs, and Internet communication and reservations. The institutional lessons learned from the Rockridge BART smart parking field test are discussed in the next section.

INSTITUTIONAL UNDERSTANDING

The smart parking field test provided a unique opportunity to document the institutional success factors and lessons learned from a real-world smart parking field test. Institutional lessons address the following areas: the public-private partnership, site selection, smart parking signage, operating and encroachment permits, and enforcement.

Public-Private Partnership

A key success factor of the smart parking field test was the strength of the public-private partnership. A collection of interagency agreements and contracts outlined specific roles and responsibilities for each partner, which facilitated the use of private resources to implement smart parking at a transit station. Furthermore, the project agreements documented that the partners were willing to work together to implement and launch the field test at the Rockridge BART station.

The strength of the public-private partnership resulted from the set of skills and resources that each partner applied to the field test, such as Caltrans' development of the smart parking design and funding commitment, PATH's research expertise, ParkingCarma, Inc.'s technical knowledge and equipment access, and BART's parking facility and enforcement personnel. Primary partners and subcontractors were identified while the project proposal was developed. Periodic meetings and weekly updates helped to maintain these relationships throughout the project. Researchers learned that it is helpful to anticipate project delays, such as refining the project scope, coordinating numerous agencies, and addressing additional project variables (e.g., parking payment policies). Approximately six months were allocated for the field test project scoping phase. In the future, an additional three months is advised for this step.

Site Selection

The criteria for selecting the smart parking transit site were as follows: 1) the field test should be located at a station at or near maximum parking capacity; 2) the location should be near a major freeway or arterial; 3) there should be structured access (entrances and exits) to the parking lot for placement of vehicle sensor technology to ensure accurate parking counts; and 4) agreement among the BART District and other partners on the selected site.

Initially, the field test was envisioned to incorporate an overflow parking strategy for the Dublin/Pleasanton BART station in Pleasanton, California. However, an economic downturn in the Bay Area lessened the parking demand at the station before the project began. Thus, a new site was selected. This was an early lesson learned: changes in the economy can impact congestion and affect parking demand and ultimately site selection.

Three additional stations were then considered based on the site selection criteria: 1) El Cerrito Del Norte in the City of El Cerrito, 2) downtown Walnut Creek, and 3) Rockridge in the City of Oakland. The Walnut Creek BART station was excluded based on city zoning laws that prevented CMS use on roadways. An analysis of 1998 BART passenger survey data demonstrated that of all the stations considered, the Rockridge station was among the least likely to be accessed by auto. Researchers hypothesized that this might be the result of high parking demand. Observational analyses conducted by researchers in April 2003 found that parking demand was the highest at the Rockridge station (between the El Cerrito Del Norte and Rockridge stations). Thus, it was selected as the smart parking test site (*4*).

Smart Parking Signage

The smart parking CMSs were placed on Highway 24 before and after a heavily traveled three-bore tunnel in the East Bay. Researchers examined the effects of the CMSs on travel times to determine whether the signs impeded traffic by recording driving times at three checkpoints before and after the CMSs were deployed in November 2004 and again in April 2005 (*17*). Driving times varied due to different drivers, whether there was an unrelated traffic accident, and changes in traffic flow. The limited analysis did not indicate sign-related traffic impediments. A limitation of this evaluation, however, was that variables other than the CMSs could have affected the observed traffic flow including: weather, driving behavior, and traffic conditions. In addition, travel times on the highway were recorded to the nearest minute, and actual times could have differed by as much as 30 seconds (*17*). A lesson learned is to plan and budget for a CMS impact evaluation, if CMSs are to be used in future projects.

Fixed station and wayfinding signs for the smart parking service were installed on local streets leading up to and at the smart parking site. Wayfinding signs directed vehicles from Highway 24 to the Rockridge BART station and helped to address community concerns that vehicles searching for the smart parking lot would create more traffic. This also provided BART with additional advertising. Fixed signs located at the Rockridge BART station designated smart parking spots and hours of operation. While the signs were a success factor of the field test, focus group participants and final survey respondents indicated that better fixed signage would have been beneficial to designate the smart parking spaces at the station. Existing artwork (a large-scale mural), however, made it difficult to install additional signs at the lot. The smart parking project manager also suggested that better project branding (i.e., a project name and logo) and additional monthly reserved parking signs may have helped to distinguish the smart parking spaces. Finally, fixed signage in Spanish may prove beneficial in areas with diverse populations.

Operating and Encroachment Permits

Both BART and the local Caltrans district require permits for installing and operating equipment on their rights-of-way. The smart parking field test secured a construction (permit to enter) and an operation (concession) permit from BART for the wireless sensors and associated parking lot technology. An encroachment permit from Caltrans was required for the CMSs on Highway 24. These permits addressed local site conditions, insurance, and the amount of time the project was permitted to operate. The field test did not have a separate budget for permitting; however, time to obtain the permits was built into the implementation project phase. Two months were allocated for permitting; however, this actually took between six to seven months. A lesson learned is that more time should be designated for the permitting process (at least six months), and a budget should be prepared for this project stage, including permit funds, review, and safety fees. The cost to obtain the permits and safety inspection from BART was approximately $2,000 US. Caltrans did not charge for the permit because they were the research-funding agency for this project and exempt all public agencies from such fees. Caltrans typically charges $328 US to review encroachment permit applications, and agency inspectors charge $82 US per hour to inspect equipment installation. One Caltrans permitting engineer estimated that it would require four hours of inspection time to install two CMSs at a cost of $328, plus the application fee for a total of $656 US.

Enforcement

Enforcement personnel, comprised of BART police officers and paid community service assistants, used two methods to enforce parking reservations during the field test. First, a list of license plate numbers for vehicles with reservations was faxed to Rockridge BART enforcement officers at both 9:30 and 10:05 AM by ParkingCarma, Inc. Second, in January 2006, ParkingCarma, Inc. decided to test PDAs as an enforcement tool. Two PDAs were assigned to enforcement personnel to access registered smart parking user license plate information, which enabled them to identify vehicles that did not have a valid reservation. ParkingCarma, Inc. provided the necessary personnel training for accessing the registered vehicle data. One ParkingCarma, Inc. staff member noted that the field test did not employ enough PDAs for every enforcement officer to use because the initial budget did not include them. Due to enforcement staff rotations, it was not possible to consistently implement this method of enforcement during the research project. If vehicles parked in a smart parking space were not in the database, they were issued a ticket. If they were in the database but did not have a reservation, their account was charged. As part of the registration process, users entered a credit card that was charged a flat fee of $30 US. Reservation fees were deducted from their account balance. An additional $30 US was added automatically, as needed. Later, as the field test approached its end, users were charged on a per-transaction basis.

Since free parking was offered at the Rockridge BART station at 10 AM, this made it difficult to determine if an unreserved vehicle had parked legally (after 10 AM) using the faxed list of confirmed reservations alone. One officer used chalk to mark tires at 9:30 AM and issued a ticket if the vehicle did not have a reservation by 10:05 AM. One ParkingCarma, Inc. staff member indicated that it was helpful to have a live operator available to assist users when parking tickets were issued in error; an employee of ParkingCarma, Inc. assisted users as requests came in. The provision of a live operator introduces additional costs of approximately $26,775, over 18 months for a full-time employee (estimating 40 hours per week and 255 days per year) to the service (*17*). In the following section, the authors discuss travel behavior impacts.

SMART PARKING TRAVEL BEHAVIOR IMPACTS

Travel behavior effects of the smart parking field test were evaluated through a before and after Internet-based user survey. More than 30% of respondents indicated that smart parking encouraged them to use BART instead of driving alone to their typical place of work or on-site work location, and 55.9% stated the same for commutes to an off-site work location (e.g., to attend meetings) (*18*).

Furthermore, the program attracted a new user population to BART. Forty-nine percent of respondents did not use BART to commute to work before smart parking and were encouraged to use BART more because they could drive to the station. In addition, smart parking resulted in sizable increases in BART modal share. On average, BART use per participant increased by 5.5 trips per month for on-site work commutes and by four trips per month for off-site commutes. Finally, the program reduced overall vehicle miles traveled by 9.7 fewer miles per participant per month on average and decreased the average commute time by 2.6 minutes (*18*). For more information on the program's effects on travel behavior see Shaheen et al., 2006 (*17*). In the next section, the authors provide an overview of lessons learned from the user perspective from the project.

USER PERSPECTIVE

At the conclusion of the field test in 2006, there were over 13,000 successful smart parking events from 1,245 unique users (*19*). Space utilization increased from 5 to 75% (i.e., 38 of 50 spaces filled) during the first three months of operation and was sustained at that level for the remainder of the project. Users provided feedback on the: online reservation system, telephone reservations, CMSs, and pricing.

Online Reservation System

More than 4,000 smart parking reservations were made through the online reservation system. The ParkingCarma, Inc. website enabled users to register for the service and reserve parking spaces up to two weeks in advance. Users also had access to account services (e.g., billing information), directions to the smart parking site, and pricing information once fees were introduced. Through focus groups and a final survey, users expressed greater satisfaction with reserving spaces online in contrast to the telephone-based IVR system. Furthermore, users indicated that they wanted to make more advanced reservations than the limit allowed (i.e., three reservations every two weeks).

Participants noted that the online reservation system could be improved and indicated the following concerns:

- It was not user-friendly (e.g., one participant said she had to re-teach herself how to use the reservation system every time she visited the website).
- Parking spaces could only be reserved before 10:00 AM, and some wanted the time extended later in the day.
- It was difficult to change the primary car listing (e.g., if a user purchased a new vehicle).

Survey respondents also indicated that they had difficulty creating an online account. One ParkingCarma Inc. staff member noted that the website wizard—a tool created to help first-time users—was underused.

Participants generally liked that they could access their reservation history and the printout feature for advanced reservations. A few survey respondents noted that they did not like having to print the advanced reservation receipt to post in their windshield, and one suggested using a decal sticker instead. Another recommended a reminder of their parking reservation via PDA. Overall, 75% of survey respondents indicated that their reserved space always had been available when they arrived at the smart parking lot.

Telephone Reservations

Telephone reservations, facilitated through a customized IVR system, accounted for approximately 9,000 reservations during the smart parking field test. Users dialed a ParkingCarma, Inc. telephone number—displayed on the smart parking fixed signage in the BART station lot—to make reservations. If they had previously registered with the service, they provided their user ID and PIN. If it was an individual’s first time as a user, she entered her license plate number to reserve a space. The user was then provided with a space number—a unique number painted on the smart parking space—to indicate where her vehicle was parked.

Participants indicated that they liked the ability to call in reservations real time. The majority of concerns with the reservation process involved the IVR system. They include:

- The IVR system voice, known as “Kate,” did not repeat nor confirm information stated by the user, and it did not decipher verbal commands consistently.
- Participants indicated that it was easier to make drive-in reservations than advanced reservations via the IVR system.
- Survey respondents reported that the system had an introductory message that was too long for repeat users, and no by-pass option was available.
- Other respondents were concerned about using the IVR in a transit environment that was often noisy and had poor mobile phone reception.
- Respondents also indicated that the IVR space count was unreliable.

Respondents suggested that the system have a numerical keypad option, in addition to the IVR, to address the concern that verbal commands were not well understood. Furthermore, a Spanish language option might be helpful.

Finally, participants did not like that there was not an easily accessible phone nor kiosk near the smart parking lot, making it difficult for users without mobile phones to make drive-in reservations. It was suggested that a courtesy phone be placed closer to the smart parking area to make it more convenient for users without mobile phones.

Changeable Message Signs (CMSs)

CMSs located on Highway 24 in Oakland displayed real-time parking availability information for morning commuters from 7:30 to 9:40 AM, Monday through Friday. The signs displayed two alternating messages: 1) the number of available smart parking spaces at the Rockridge BART station, which was continuously updated by the wireless counting system, and 2) static directions to the smart parking site from the highway (i.e., “Exit College Ave.”). An expert interview with the smart parking project manager indicated that the CMSs were beneficial because they provided general project awareness and, after seeing the parking availability every day at the same time, some travelers were encouraged to participate in the field test. CMS placement is important, and the location should be on users’ commute routes.

Results from the focus groups and final survey indicate, however, that the signs were underused. Only 39% of users reported seeing the CMSs on Highway 24. Of survey respondents, 58% reported that they had never used the signs in their decision-making process; among focus group participants, this number was as high as 87%. Survey results also indicated that 35% had found the information on the CMSs to be accurate, compared to 54% who were “unsure,” and 11% who did not. Focus group participants generally expressed one of two concerns: 1) the CMSs were not located on their commute route, and 2) the information on the signs was not descriptive enough. Some participants indicated that travelers might not be sure if the spaces would be available when they pulled off the highway, particularly as the number of available parking spaces displayed on the signs did not change frequently. One suggestion from the focus groups is that more public outreach could be developed to help motorists better understand the purpose of the information displayed on the CMSs. Finally, participants indicated that they were confused about what information the signs were trying to convey; in addition, some felt that only project users would understand what the messages meant.

Pricing

The smart parking field test began charging users in October 2005, ten months after the initial launch. This provided researchers with an opportunity to test the effects of pricing on smart parking behavior. Users were charged $1.00 US per day for drive-in reservations and $4.50 US per day for advanced reservations, as determined by BART managers. BART currently charges vehicles $1 a day for unreserved, first-come, first-served spaces, which went into effect in January 2006.

After fees were implemented, reservation data from ParkingCarma, Inc.’s central computer revealed that drive-in reservations increased while advanced reservations decreased. From January to March 2005, before charges began, “drive-ins” averaged 57% of total reservations. For the same time period in 2006, after users were charged to park, drive-in reservations averaged 80% of total reservations, an increase of 23 percentage points.

Sixty-four percent of survey respondents reported that they continued smart parking use when fees were introduced; however, nearly 75% of respondents noted that they would stop using the service, if daily parking fees equaled or exceeded $5.00 US per day. Furthermore, 43% answered “yes” when asked if they made fewer advanced versus drive-in reservations when parking fees were implemented, while 46% answered “no” and 11% were “unsure.”

Focus group participants agreed overall that they would be willing to pay for smart parking, but that it should not be more expensive than monthly reserved parking—$84 US per month at the Rockridge BART station parking lot (equivalent to $4.00 US per workday). Others suggested that it should not cost more than nearby commercial parking. Commercial parking lots within a three-mile radius of the Rockridge BART station have average parking rates as follows: $3.00 US hourly, $13 US daily, and $158 US monthly.

Respondents indicated that their greatest concern with smart parking pricing was that the cost of parking combined with BART fares was too expensive. Roundtrip BART fares average $6 to $8 US, depending on the user’s end station (*18*). Using the smart parking service every workday, in addition to the cost of a roundtrip BART ticket, would range $147 to $189 US monthly for drive-in reservations and $220.50 to $262.50 US monthly for advanced reservations, assuming 21 workdays per month.

Others indicated that the smart parking fees were too expensive, particularly those for advanced reservations, and they did not like the price discrepancy between the advanced and drive-in reservations. Some suggested not charging for the service. There also were concerns about charging flat increments of $30 US into a ParkingCarma electronic account to reserve a space; some preferred a per transaction charge. For instance, one respondent noted that she had borrowed a vehicle for a short period and would not use her entire balance since she did not own a car. At the end of the field test, participants who had balances received refunds. A discussion of the operational lessons learned is provided in the following section.

OPERATIONAL PERSPECTIVE

Smart parking relied on the successful installation and operation of an integrated network of technologies. Since a majority of the hardware was off-the-shelf, there were numerous challenges in customizing the equipment. Operational lessons learned were garnered from the user interfaces and parking lot technology.

User Interfaces

Both the telephone and website reservation systems operated well and without significant problems. Substantial testing of the user interfaces (e.g., research staff testing phone and Internet reservations) in late 2004 before the field test launched enabled researchers to have a high degree of confidence that the system could perform accurately during peak periods (*4*). Since first-time, drive-in callers made smart parking reservations by providing their license plate numbers, technical experts at ParkingCarma, Inc. programmed the IVR system with California specific Department of Motor Vehicle license plate regulations (e.g., California license plates do not start with the number ‘5,’ so the system would not recognize this as a first number), which successfully conserved computer data space. The longest caller wait time was two seconds, with peak load time occurring at 8:30 AM. According to one ParkingCarma, Inc. staff member, it was sometimes difficult for the IVR system to identify users’ accents, and for some users, English was not their first language. Staff further indicated that it was helpful to have a live operator available, especially during peak periods, to answer questions about the service.

Overall, the smart parking website performed well. One ParkingCarma, Inc. employee suggested that less screens on the website would make it easier for users to navigate.

The project team encountered difficulties with the CMSs as both had intermittent, unreliable operations due to electronic and communication problems. One CMS in particular had trouble with mobile phone communication, which was the result of a defective modem and an improperly configured sign controller that was later repaired by the vendor (*17*). Another concern was that the CMSs were expensive to operate due to frequent real-time updates of smart parking space availability. As a result, ParkingCarma, Inc. technical staff switched the mobile phone standard used for the signs to the global system for mobile communications (GSM) at the same time that Quixote replaced the signs, which resulted in airtime data charge savings of approximately 10 to 30%. One Quixote employee indicated that as the signs age (the first two CMSs used for the field test had been in storage for one year), repairs and firmware upgrades make replacement more cost effective.

Parking Sensor System

Expert interviews revealed that the most difficulty arose from the in-ground sensors. Prior to this project, the sensors had been used on highways and streets with traffic in one direction only. Project partners modified the firmware to detect two-way vehicle movements, and testing at an off-site location indicated that they worked well. At the BART station, however, the sensors were unpredictable in their ability to accurately count vehicles moving at parking lot speeds. As a result, the hardware vendors determined that changes were necessary for the counter software (*17*). Technicians and senior partner officials tried to fix the sensors and performed a number of investigations, but they continued to miscount vehicles. Project partners noted that this problem may have resulted from the magnetic field at the BART station, since the sensors perform by detecting the changing magnetic fields from vehicles passing over the sensors. Also, sensors had difficulty accounting for atypical vehicle movements, such as cars driving into or out of the lot the wrong way. Researchers tried to minimize such movements through the use of temporary barriers. The sensors were eventually replaced during the field test with ones that were situated aboveground, which were more effective and less expensive. The integration of the new sensors with the wireless counting system resulted in communication protocol problems that were resolved by ParkingCarma, Inc. technicians. Researchers ultimately maintained count accuracy by using a proprietary algorithm developed by ParkingCarma, Inc. that corrected the sensor problems and accounted for instances when vehicles queued above the sensors. See Table 1 below, which summarizes key institutional, user perspective, and operational success factors and lessons learned.

TABLE 1 Lessons Learned from the Smart Parking Field Test

	Success Factors	Lessons Learned
Public-Private Partnership	The partnership was a success due to the resources and expertise of each partner.	Three additional months (nine months total) should be allocated for the project scoping phase to account for unexpected delays.
Site Selection	Identifying a site that reflects project criteria (e.g., high parking demand, potential to more efficiently manage parking) is critical to project success.	Local economic conditions can change and affect parking demand and subsequently site selection.
Smart Parking Signage	Wayfinding signs directing vehicles to the smart parking site can alleviate concerns that the project may create additional traffic on local roadways.	- Budget for a CMS impact evaluation. - Additional fixed signage and project branding could help drivers locate spaces better in the future.
Operating and Encroachment Permits	Obtaining operating and encroachment permits from governmental agencies allowed equipment installation and operation.	A minimum of six months should be allocated and budgeted for the permitting process.
Enforcement	A live operator helped assist users when parking tickets were issued in error.	Increased investment in enforcement technology (e.g., handheld PDAs) may be beneficial in the future.
Online Reservation System	- Users liked the ability to make online reservations, and it was a popular feature of the smart parking service. - The reservation history and print-out feature for advanced reservations were generally liked.	- Websites should be user friendly, and the process for creating an account should be simple. - A parking reservation reminder via PDA would be helpful. - Consider another method for verifying reservations, such as decals.
Telephone Reservations	The telephone reservation system enabled users to make en-route and on-site parking reservations.	- A successful IVR system should repeat and confirm information. Additionally, it should understand verbal commands in noisy environments, such as transit stations. A touchtone option may be used as an alternative for users having difficulty with the system. - Introductory messages should be informative but concise. A bypass option should be provided. - A courtesy phone or kiosk could enable travelers without mobile phones access to the service.
Changeable Message Signs	After seeing the CMSs every day on their commute route, some travelers were encouraged to try the service.	- CMS placement is important, and the location should be on users' commute routes. - Enhanced project publicity may increase confidence in the CMS messages. - Further study of message wording is necessary to ensure travelers understand sign communications.
Pricing	The majority of users continued using the service after fees were implemented.	Fees could be charged per transaction for users who want to use the service only in the short term.
User Interface Operations	- Substantial testing before the field test began ensured the technology worked well. - IVR system data space was conserved by programming California specific license plate rules. - A live operator helped answer questions users had about making reservations.	- An IVR system that recognizes accents and is available in Spanish could be beneficial. - Changing the mobile phone standard used for the CMSs saved money.
Parking Sensor System Operations	- The local base units, master base unit, and computer server operated well. - Temporary barriers can help direct vehicles over parking lot sensors.	Above-ground sensors that can identify vehicles moving at parking lot speeds and can account for atypical vehicle movements (e.g., wide turns) should be used.

CONCLUSION

It is important to review the success factors and lessons learned from the smart parking field test so that they can be used as a guide for planners and practitioners interested in implementing smart parking projects in the future. The BART smart parking field test was the first of its kind in the U.S., which was preceded by a handful of international projects in Germany and Japan. Over the last decade, the majority of past smart parking projects have focused on CMSs, particularly in Europe. Parking payment via mobile phone has developed more recently. The Rockridge field test is notable for its integration of numerous smart parking technologies, including Internet reservations and billing and mobile phone and PDA communications.

The smart parking field test successfully increased BART use by 5.5 trips per month for on-site work commutes and by four trips per month for off-site commutes. Participants reduced vehicle miles traveled by 9.7 miles per month on average and decreased their average commute time by 2.6 minutes (*18*).

A review of the institutional issues associated with the smart parking field test indicated some key success factors including the strength of the public-private partnership and the use of static wayfinding signs to direct travelers to the BART station smart parking lot. Lessons learned include the following:

- Allocating additional time for the project scoping phase and permitting process;
- Anticipating and budgeting for an impact evaluation on traffic flow due to the CMSs;
- Project branding for additional publicity and user understanding; and
- Increased investment in enforcement technology.

Users noted a preference for the online reservation system over the telephone IVR system, despite more reservations having been made via IVR throughout the field test due to the project parameters. The majority also continued to use the service once fees were implemented, but indicated that the service should not cost more than nearby commercial parking or monthly reserved parking at the BART station. Lessons learned include:

- Making the website more user friendly;
- Improving IVR system communications (e.g., ensuring it can repeat and confirm information);
- Installing a courtesy phone or kiosk in the parking lot for users to make reservations;
- Increased lot signage, including signs in Spanish, to help travelers find smart parking spaces;
- Charging parking reservation fees on a per-transaction basis instead of carrying a balance; and
- Installing CMSs on all nearby, popular commute routes with access to the transit station.

From an operational perspective, initial testing of the user interface technology ensured that the systems worked well prior to the project launch. The wireless counting system, with the exception of problems associated with the in-ground sensors, also performed well during the field test, and temporary barriers helped direct vehicles over the sensors. Lessons learned include:

- Using an IVR system that is better able to understand all users (e.g., those with accents and who speak Spanish);
- Selecting a mobile service standard that will keep the costs associated with the CMSs low; and
- Employing sensors that can account for a range of parking lot vehicle movements.

As smart parking for transit projects move beyond the testing phase to pilot programs—including an upcoming California PATH and Federal Highway Administration Value Pricing Pilot Program initiative at five stations in conjunction with the San Diego Coast Express Rail (COASTER) to launch in 2008—careful consideration of success factors and lessons learned from the Rockridge field test should be factored into the design. In addition, ongoing documentation of lessons learned, behavioral impacts, and cost effectiveness should be continued to further advance the knowledge of this promising parking service.

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