

**APPLYING INTEGRATED ITS TECHNOLOGIES TO
PARKING MANAGEMENT SYSTEMS: A TRANSIT-
BASED CASE STUDY IN THE SAN FRANCISCO BAY
AREA**

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APPLYING INTEGRATED ITS TECHNOLOGIES TO PARKING MANAGEMENT SYSTEMS: A TRANSIT-BASED CASE STUDY IN THE SAN FRANCISCO BAY AREA

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SUMMARY

California Partners for Advanced Transit and Highways has teamed with the California Department of Transportation, the Bay Area Rapid Transit (BART) District, ParkingCarma™, and Quixote Corporation to launch a smart parking research demonstration at the Rockridge BART station in the East San Francisco Bay Area (California, USA). The results of an extensive literature review demonstrate that different smart parking applications implemented worldwide can ease traveler delays, increase transit ridership, and reduce operator costs. Observational analyses at the station indicated that existing parking supply exceeded demand and thus smart parking technologies could be applied to optimize capacity and potentially increase ridership. Focus groups and surveys were conducted to gauge interest in and the design of smart parking services. Key results included: (1) significant commuter frustration with parking shortages and interest in smart parking services; (2) the importance of accurate parking counts and parking enforcement to ensure system reliability; and (3) the potential for greater transit use among users of smart parking services. The field test technology includes traffic sensors that count vehicles in and out of the parking lot; a central computer that calculates space availability; an advanced and en-route reservation system accessed via cell phone, telephone, PDA, and Internet; and real-time parking information displayed on changeable message signs located on an highway adjacent to the station.

INTRODUCTION

In almost every major city in the U.S. and internationally, parking problems are ubiquitous. It is well known that the limited availability of parking contributes to roadway congestion, air pollution, and driver frustration and that the cost of expanding traditional parking capacity is frequently prohibitive. In the San Francisco Bay Area, parking has recently been at or near capacity at many of the 31 Bay Area Rapid Transit (BART) stations with parking facilities. Smart parking management technologies may provide a cost-effective tool to address near term parking constraints at BART transit stations.

This paper presents early findings from an application of advanced parking technologies to increase parking capacity at a transit station during the first half of 2004 in the San Francisco Bay Area, California (USA). Project partners include California Partners for Advanced Transit and Highways (PATH), the California Department of Transportation (Caltrans), the BART District, ParkingCarma™, and the Quixote Corporation.

Preliminary analyses indicated that the Rockridge BART District station in Oakland could benefit from smart parking management. Parking demand at the station is very high. Observational analyses indicated that regular unpaid parking typically filled around 7:30 am and that each morning, more than 30 cars cycled through the lot for parking and ultimately left. Monthly reserved paid parking was fully subscribed, with a substantial waitlist; however, many of the monthly reserved paid parking spaces were not occupied on every weekday. In addition, the Rockridge station is adjacent to Highway 24, an important commute corridor from the East Bay to downtown Oakland and San Francisco. Researchers, thus, saw an opportunity to apply smart parking technologies with the goal of expanding effective parking capacity, transit ridership, and revenues.

The system developed includes traffic sensors that count the number of vehicles entering and exiting the monthly reserved paid lot at the Rockridge BART station. This information is relayed to a central reservation system, which keeps a master tally of available station parking. The computer then relays this real-time information to the changeable message signs (CMS) on a highway adjacent to the station to alert drivers to the availability of parking spaces. The smart parking reservation system allows travelers to check availability and reserve spaces by Internet, phone, cell phone, and PDA, up to two weeks in advance of a trip. Before and after surveys and focus groups will be used to evaluate the travel effects, economic potential, and system technology of the field test.

This paper includes three sections. First, the authors present the results of a review of smart parking management systems and related literature to inform the design and implementation of the smart parking field test. Second, the major findings of a feasibility analysis, including the results of focus groups, technology testing, and exploratory surveys, are presented. The paper concludes with a summary of the project design and a discussion of the technology used in its implementation.

LITERATURE REVIEW

An extensive review of the literature related to smart parking management systems was conducted from the summer of 2002 to the winter of 2003. The review seeks to survey available smart parking management systems and to understand their potential effect on travel behavior and air quality. The types of technologies included in the review are parking guidance information (PGI), transit-based information, smart payment systems, and e-parking. This section documents the major finding of the literature review.

Early examples of smart parking management were Parking Guidance Information (PGI) systems that attempt to minimize parking search traffic in large parking facilities and central cities by dynamically monitoring available parking, and directing motorists with CMS. The first PGI systems were installed in Aachen, Germany, in the early 1970s. It is now estimated that more than 100 parking guidance information systems have been installed in cities throughout the world with the greatest concentration in Europe and Japan (1). In the U.S., city center PGI systems exist in St. Paul, Minnesota, and Pittsburgh, Pennsylvania. Large airport parking garage PGI systems have been installed in: Baltimore, Maryland; Houston, Texas; Orlando, Florida; and Minneapolis/St. Paul, Minnesota. Empirical and simulation studies of selected systems indicate that awareness and understanding of PGI signs can be relatively high, but in order to be effective, messages must display accurate information that meets travelers' needs (2, 3). Interestingly, visitors are more likely than resident commuters to use city center PGI systems (3). PGI systems were found to reduce parking facility queue lengths; however, system-wide reductions in travel time and vehicle travel, and economic benefits may be relatively small (4).

Building upon the objectives of PGI systems, transit-based smart parking systems seek to increase transit use and revenues, reduce vehicle travel, lower fuel use, and reduce air pollution. These systems provide motorists with information via CMS about spaces in park and ride lots, transit schedules and downstream traffic conditions. The literature suggests that parking shortages at suburban rail stations may significantly constrain transit ridership, thus more effective use of station parking may increase transit use and revenues (5, 6). In addition, motorists may respond to pre-trip and en-route information on parking availability at transit stations by increasing their use of transit (7). Finally, regular commuters are more responsive to information about parking in conjunction with transit than more basic PGI systems, because this information may be essential to catching a train during peak hours (8). Transit-based systems are concentrated in Europe and Japan; however, at least two have been initiated in the U.S.—in conjunction with Chicago's Metra System and San Jose's Valley Transit Authority.

Smart parking systems can also take advantage of innovative technologies to improve the ease and convenience of paying for parking. Smart cards can minimize transaction time by allowing a user to simply wave their card in front of a reader, and contactless cards with wireless communication capabilities can further reduce delays. Mobile communication devices can also be used in smart payment transactions. Smart parking payment systems are now being developed and implemented worldwide by cell phone developers, credit card companies, and other technology and service providers. Smart payment systems were found to reduce operation, maintenance and enforcement costs as well as improve collection rates (9, 10). When transit agencies attempt to induce drivers off of highways to take transit into a city center, time saving

technologies may mean the difference between a decision to park and ride transit or drive the remainder of a trip. Smart payment systems have been implemented in: Groningen, The Netherlands; Oulu, Finland; Hull, UK; and Dublin, Ireland; and Visa and Nokia have a pilot program in Finland and Sweden with customers of MeritaNordbanken. In the U.S., smart payment systems have been installed in: Berkeley and Monterey, California; Lansing, Michigan; the University of Maryland College; and in Orlando, Florida.

Combining some of the best concepts of its forerunners, e-parking is an innovative business platform that would allow drivers to inquire about parking availability, reserve a space, and even pay for parking upon departure—all from inside their cars (11, 12). E-parking is currently being tested in Brussels, Belgium and other demonstrations are under consideration.

Finally, the parking pricing and cash-out literature indicates that charging for parking—whereby revealing its true cost to motorists—can result in significant decreases in single-occupant vehicle travel (13, 14). However, many are hesitant to implement these innovative solutions for fear of charging for a historically free resource. Smart parking may provide a means to implement some of the powerful market-based solutions to the problems of traditional parking practices in the U.S. Smart parking technology could also facilitate the charging of market rates for parking depending on time of day. People may be more amenable to paying for parking if they feel they are getting an advanced benefit from it—which guaranteed parking reservations can provide.

In an increasingly digital and wireless age, parking managers can take advantage of available technology to reduce operation, maintenance, and enforcement costs as well as to improve ease and convenience for motorists. When transit agencies attempt to induce drivers off of highways to take transit into a city center, time saving technologies may mean the difference between a decision to park and ride transit or drive the remainder of a trip. Smart parking can make efficient use of existing parking spaces and to make reserving and paying for parking, fast, convenient, and reliable.

FEASIBILITY ANALYSIS

Researchers conducted a three-phased feasibility analysis during 2003 to guide the development of the field test project design. First, focus groups with BART and non-BART commuters were conducted to explore attitudes toward commute modes, parking, and smart parking design concepts. Second, the accuracy of vehicle sensor technology was tested. Finally, a survey of commuters who parked at the Rockridge BART station was conducted to identify traveler information needs and assess potential travel effects. What follows is a summary of the results of each phase of the feasibility analysis.

FOCUS GROUPS

To explore the parking information needs of BART riders (current and potential) and to refine smart parking design concepts for the project, two focus groups were conducted in late May 2003. One focus group was composed of 12 commuters who used BART as their primary

commute mode. The other focus group was composed of 7 commuters who drove to work but could ride BART. These focus groups yielded a number of important conclusions about the demand for smart parking services and insights into the design of the service:

- The most popular BART attributes were avoiding roadway traffic and the opportunities to sit and relax on the train.
- The biggest complaint about BART parking was that it filled up too early in the morning.
- Interest was expressed in using pre-trip and en-route parking information (free and daily paid) to reserved BART parking.
- Concern was expressed about the ability of the system to prevent someone from taking a reserved spot.
- Many volunteered that space-specific guidance information would be a valuable improvement to the proposed smart parking system.

The focus groups suggest a frustration with the lack of available parking and receptivity to a system that permits advanced parking reservations. The interest in en-route and pre-trip information suggests that some commuters may be amenable to altering their existing commute mode if provided with a more convenient option. To address commuter's concerns about guaranteeing reserved spots, project managers will ensure that traffic sensors transmit data frequently, and that BART police verify that vehicles in the smart parking lot all carry the proper parking reservation identification. Researchers were interested in feedback regarding space-specific guidance information because this improvement is contemplated in future phases of the project.

TECHNOLOGY TESTING

At a minimum, smart parking management systems must provide accurate parking information to travelers. Thus, an understanding of the potential accuracy of the vehicle counting technology (sensors) under different parking lot conditions is essential. To evaluate sensor accuracy, researchers compared vehicle counts from temporary wireless sensors with observed counts. From July 22 to August 22, 2003, researchers manually retrieved vehicle count data from the installed sensors. During this same period, researchers made weekly counts of the number of vehicles at each entrance and exit sensor location in the morning peak hours. A number of conclusions were drawn from this comparison:

- Sensor accuracy is good (typically, 3 percent or less) when the design of the entrance or exit driveway is narrow enough to ensure that a vehicle cannot avoid passing over the sensor's sensing radius (3 feet).
- Traffic cones can effectively guide drivers over sensors when entrance and exit driveways are joined and/or wide.
- When there is significant through or circulating traffic in a parking facility, sensors must transmit data frequently to the central computer to eliminate such traffic from the calculation of parking lot occupancy.

COMMUTER PROFILE

The final step in the feasibility analysis was the implementation of travel behavior surveys at the Rockridge BART station. The survey was developed with the results of the focus groups to better understand the travel patterns, demographic attributes, and attitudes of BART riders at this station. The results of this survey would be used to tailor the smart parking services and information to best suit the needs of Rockridge BART station riders and to achieve one of the project's key goals: increased BART ridership.

Two travel behavior surveys, one for commuters who did and one for commuters who did not use monthly reserved paid parking, were administered in person by University of California Berkeley student researchers at the Rockridge BART station from the hours of 5:30 to 7:30 pm Monday to Thursday during the month of November, 2003. One hundred and fifty eight surveys were completed for BART commuters who did not use monthly reserved paid parking. Sixty surveys were completed for BART commuters who did use monthly reserved paid parking. This constituted about 25 percent of the monthly reserved paid parkers.

More than three-fourths of the commuters surveyed at the Rockridge BART station are headed for work locations in downtown San Francisco. Congestion on freeways in the corridor from Rockridge to San Francisco is severe and the cost of parking in the downtown is very high. As a result, many commuters find BART travel, even with the additional cost of monthly reserved paid parking, to be overall less expensive and more convenient than auto travel. On the other hand, many commuters at this station do not use BART everyday to commute to work; instead, they regularly travel to work by car because of its greater flexibility with respect to running errands before, during, and after work.

The results of the demographic profiles suggest that those riders who use monthly reserved paid parking and those who do not differ most significantly with respect to income, auto availability, and fixed work schedule. Relatively high income (100,000 U.S. dollars and over) and an available auto are necessary conditions to subscribe to monthly reserved paid parking and the constraint of a relatively fixed 9 am to 5 pm, 5-day a work schedule makes the monthly service particularly attractive to these riders. These results suggest a potential market for a daily paid parking service among other riders and new riders with relatively high incomes, high auto availability, and more variable work schedules.

The survey results do suggest that limited parking at the Rockridge station may be a significant barrier to BART commuting. In fact, nine percent of riders without monthly reserved paid parking indicated that this was the case. Many of these riders also stated that they dislike searching for parking (31 percent) and the lack of available parking (28 percent). The primary reasons that riders do not purchase monthly parking are the high cost (62 percent) and the lack of monthly need (22 percent). When these riders were asked if they would use a paid daily parking service at the station, 15 percent said they would and 28 percent of those said that as a result they might use BART more often.

Based on the results of the feasibility analysis, researchers designed the Rockridge BART station field test. Below is a summary of the project.

PROJECT AND TECHNOLOGY SUMMARY

In the field test, commuters will be able to make advanced (up to two weeks), or same day reservations for parking spaces located in the monthly reserved lot. BART has initially agreed to permit the field test project to dynamically manage 53 parking spaces that are currently used for after 10:00 am parking. In the first phase of the field test, half of these spaces will be available for advanced reservations and half will be available for same day reservations. This ratio may change in response to demand, but not all the available spaces will be advertised on the CMS to ensure that there are enough spaces to meet demand. Each motorist is limited to three reservations over a two-week period to ensure that the project is attracting many new riders rather than several repeat riders. BART has also authorized the use of printed permits, which smart parking participants will receive electronically and display on their dashboards. For same day reservations, BART police will receive real-time messages via PDA informing them that these commuters have a legitimate reservation. To participate in the field test and reserve a daily parking space, BART patrons are required to join ParkingCarma™, use BART at least one to three times a week, and use the Internet, phone, or PDA to make a reservation.

The smart parking field test at the Rockridge BART station involves two real-time user interfaces: a CMS that will display parking availability information to motorists on Highway 24, and a centralized reservation system that permits commuters to check parking availability and reserve a space via telephone, cell phone, Internet, or PDA. Researchers have installed six wireless sensors at entrance and exits in the Rockridge paid parking lot. Traffic cones were installed to guide cars directly over sensors. The sensors send parking count data to two Local Base Units (LBUs)—solar-powered computerized data relay points. These LBUs relay the data to a Master Base Unit (MBU)—a computer transceiver that has wireless Internet capability. Together, these nine components act as a wireless counting system, transmitting data through local DSL to computer servers. The smart parking system integrates the traffic count data with the reservation system to provide accurate up-to-the-minute estimates of parking availability. If a motorist confronts congestion on Highway 24, he can check parking availability on the CMS, and instantly phone the reservation system to “lock-in” a space before exiting the freeway. The CMS will inform users how to reserve a space, and the reservation system will provide directions to the BART station. These signs can be accessed remotely to change messages, or to turn them off.

CONCLUSION

The Smart Parking Project is a two-year field test that employs advanced communication technologies to manage existing parking spaces at a BART station to increase effective capacity and transit access.

The literature review and feasibility analysis suggest a promising context for a smart parking management field test project at the Rockridge BART station. Smart parking systems implemented worldwide have been found to reduce delays and improve convenience of parking (15). Commuters are particularly receptive to smart parking systems in conjunction with transit, where real-time information may be critical to catching a train. While the impacts of parking

shortages on congestion, pollution and driver frustration are well-understood, less research has addressed the impact of parking shortages on transit ridership. The literature review suggests that increases in transit use and revenues resulting from more effective use of existing parking could be significant. Smart payment systems may improve driver satisfaction and cut costs, while reducing overall delays. Finally, smart parking may facilitate the expansion of parking pricing and thus reductions in vehicle travel and air pollution; drivers may be more willing to pay for the luxury of knowing that a parking space will be waiting for them at their final destination.

Focus group feedback suggests that BART commuters are frustrated with parking shortages and thus may be receptive to a system that permits pre-trip or en-route BART parking reservations. Project managers will ensure frequent transmission of sensor data and enforcement of parking restrictions to guarantee reserved parking spaces. Extensive technology testing gives the project managers a high degree of confidence in sensor accuracy. When placed properly, and combined with traffic cones, sensors are accurate to within one percent. Commuter interest in space-specific guidance information supports a second research phase that could employ more advanced parking management communication technology.

Survey feedback suggests that BART Rockridge commuters may be receptive to a smart parking system. Due to severe freeway congestion en-route to San Francisco, many commuters find BART travel, even with the additional cost of monthly reserved paid parking, to be less expensive and more convenient than auto travel. Survey analysis indicates a potential market for a daily paid parking service among new riders with relatively high incomes, high auto availability, and variable work schedules. Nine percent said that parking shortages at the Rockridge station limit their transit use, fifteen percent of respondents were interested in daily paid parking, and 28 percent said they would use BART more often as a result.

Smart parking technology that enables efficient use of parking will be increasingly important as a burgeoning population places ever-growing demands on existing transportation infrastructure. While the problems of parking shortages are well recognized, the cost of providing additional capacity is frequently prohibitive. Smart parking may provide a sensible means to effectively increase parking capacity, while simultaneously reducing demand by enabling parking service operators to charge market rates depending on time of day. The potential benefits of smart parking, including reduced traveler delay and increased transit use, make it an attractive land use management option for urban areas that face parking shortages.

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