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TRANSIT-BASED SMART PARKING: EARLY FIELD TEST RESULTS

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ABSTRACT

Smart parking management technologies may provide a cost-effective tool to address near-term parking constraints at transit stations. Smart parking management systems have been implemented in numerous European, British, and Japanese cities to more efficiently use parking capacity at transit stations by providing real-time information via variable message signs to motorists about available parking spaces in park-and-ride lots. This paper describes the results of initial focus groups and surveys of participants in a smart parking field operational test, which was launched at a San Francisco Bay Area Rapid Transit (BART) District station in Oakland, California on December 8, 2004. Insights into the project's travel effects are gained from an analysis of participant travel behavior before they started using the service. The results indicate that the project is attracting new (14 percent) and infrequent BART commuters (25 percent). While some participants may drive further (two miles on average) to access the Rockridge BART station, where the field test is based, the magnitude of this increase is unlikely to off-set total auto travel reductions (an average of 18 miles) due to shifts from auto to BART for commute trips. Thus, it appears that the smart parking project is getting cars off the road during peak periods and onto transit.

KEY WORDS: Parking management, travel behavior, intelligent transportation systems

INTRODUCTION

In suburban areas, quick convenient auto access to park-and-ride lots can be essential to making transit competitive with the auto. Most people will only walk about one quarter of a mile to transit stations or stops, and fixed route bus or shuttle feeder services can be expensive and less convenient than the auto. In the San Francisco Bay Area, peak hour parking at most of the 31 suburban Bay Area Rapid Transit (BART) District stations has recently been at or near capacity.

Smart parking management technologies may provide a cost-effective tool to address near-term parking constraints at BART transit stations. Smart parking can be defined broadly as the use of advanced technologies to help motorists locate, reserve, and pay for parking. Smart parking management systems have been implemented in numerous European, British, and Japanese cities to more efficiently use parking capacity at transit stations. These smart parking systems typically provide real-time information via Variable Message Signs (VMS) to motorists about the number of available parking spaces in park-and-ride lots, departure time of the next train, and downstream roadway traffic conditions (e.g., accidents and delays).

To evaluate the feasibility of the smart parking concept in a transit context, public and private partners jointly launched a smart parking field operational test at the Rockridge BART station in Oakland, California on December 8, 2004. In this paper, the results of focus groups and an initial survey of smart parking participants are evaluated to understand participant: (1) demographic attributes, (2) commute needs and constraints, and (3) commute travel behavior. Importantly, an analysis of participant travel behavior before joining the smart parking project provides insight into the potential magnitude of increased transit ridership and auto access to transit, and the overall change in auto travel among participants. This paper begins with a literature review on the travel effects of smart parking related systems, next the smart parking field operational test is described, then early results from the user focus groups and surveys are discussed, and finally some conclusions are drawn from the initial user evaluation.

LITERATURE REVIEW

There appears to be only one published (English language) study that systematically evaluates the effectiveness of smart parking systems with respect to increasing park-and-ride lot use. Khattak and Polak (*1*) evaluate a real-time parking information system in Nottingham, England in which "real-time information was disseminated through the radio, while historical information regarding parking lots was disseminated though newspaper advertisements and leaflets" (*1,* p. 373). The results indicate that "drivers were more inclined to use the relatively under-utilized park-and-ride facilities instead of the city center car parks, if they received parking information from newspaper advertisements and leaflets" (*1,* p. 373). This study shows the importance of pre-trip information with respect to parking choice and increased transit use.

Another study that suggests the potential significance of pre-trip traffic information with respect to mode change was conducted by Conquest et al. (*2*). In this study, on-road survey data was collected (3,893 motorists) and evaluated to examine the effect of traffic information on driver behavior. The study found that 23.4 percent of respondents would not change their mode, route, or departure time, but 50 percent were receptive to pre-trip information and as a result might alter their mode, route, or departure time (*2*).

Opinion surveys of the Frottmaning, Germany and Toyota, Japan smart parking systems are generally described in the literature. Cervero (*3*) reports that German Ministry of the Interior

surveys cited the highway park-and-ride displays in the Frottmaning system as the main reason many motorists have shifted from driving to taking the train to work. A survey about the Toyota system indicated that after six months of operation: (1) 95 percent of respondents were aware of the signs; (2) 71 percent made use of the information; (3) 87 percent thought the system was helpful; and (4) 32 percent of those who used the system lived outside the city (*4*).

There is also limited evidence on the effect of parking capacity at transit stations on transit demand (*5*). One empirical study of parking-constrained commuter stations in the Chicago area (Metra) suggests that each additional parking space may generate between 0.6 to 2.2 additional transit users (*5*). The author notes "on the margin, new riders may use parking spaces a bit more intensively than the average (e.g., carpools may be more common), but it seems unlikely that an additional parking space could attract as many as two new riders" (*5,* p. 575). In a separate study, Ferguson reports that "a market research study undertaken by Metra in 1985 identified a lack of parking at surburban rail stations as the single largest factor contributing to the observed ridership losses" (*6,* p. 108). Moreover, a more recent survey conducted for a Metra smart parking management project indicates that parking availability affects transit ridership (*7*). The survey found that "although about 58 percent of all riders surveyed stated that they would simply park farther from the station if the parking lot nearest to the station was full, 18 percent of the riders stated that they would drive to their destination if their only choice was to travel to the next station downstream" (*7*, p. 2).

FIELD TEST

The smart parking field test at the Rockridge BART station involves two real-time user interfaces: two VMSs that display parking availability information to motorists on an adjacent commute corridor into downtown Oakland and San Francisco (Highway 24), and a centralized intelligent reservation system that permits commuters to check parking availability and reserve a space via telephone, cell phone, Internet, or personal digital assistant (PDA). The system integrates traffic count data from entrance and exit sensors at the BART station parking lot with an intelligent reservation system to provide accurate up-to-the-minute counts of parking availability. BART provided 50 spaces to be used in the smart parking field test, which were previously reserved by BART for use after 10:00 am only and are now available prior to 10:00 am. Initially, 15 of these spaces are available for advanced reservations, and the remainder (less a buffer of five spaces) is available for same day, en-route reservations. In addition, one user is allowed only three parking reservations during a two-week period. Those who use the system for en-route reservations call in their license plate number via cell phone when they park in the smart parking lot. BART enforcement personnel ensure that those parking in the smart parking lot either have the advanced reservation parking permits, or license plate numbers that match the numbers provided to the enforcement personnel in real-time via PDA for en-route reservations. Currently, the smart parking service is free, but BART will begin charging in August 2005.

FIGURE 1 Images of smart parking field operational test.

EARLY RESULTS

In this section, the authors provide early findings from the smart parking field test, including focus group and survey results.

Focus Groups

To understand the initial travel effects, parking preferences, and system technology of the smart parking field, two focus groups were conducted in May 2005 in Oakland, California. Participants involved in the Rockridge BART smart parking field test were asked about the effect of the program on their commute and level of satisfaction with system features and design. In total, 13 women and ten men participated in the two focus groups; 18 of the 23 participants commute regularly into downtown San Francisco.

Questionnaires were administered before the start of each focus group, and the results indicated that participants in this focus groups were most likely to have been between the ages of 24 and 59, with an average age of 43 years; live with a spouse and a child or children; have two commuters in their household; have a Bachelor's degree or a graduate/professional degree; use Internet and cellular phones regularly, with half also owning a PDA; and have a yearly household income of $175,000.

In the focus group discussions, participants commented on their travel and system preferences. Most participants used BART as their primary commute mode and had positive experiences with it; those who drove alone or took the bus were frustrated and did not like what they thought was a lack of reasonable commute alternatives. A majority of participants drove and parked at Rockridge BART as their primary access mode. Before smart parking, their concerns included uncertainty about finding a guaranteed spot, inconvenience at having to wake up early, and concerns about safety on side streets where they parked. Because of the smart parking field test, more people did take BART for their primary mode more frequently. However, several people drove further to park at the Rockridge station (and access the smart parking system), and one person changed her access mode from bus to car. Participants offered four main suggestions to improve the program: (1) use a transponder or FasTrak™ device for payment; (2) expand smart parking to all BART stations; (3) change use restrictions; and (4) convert existing monthly reserved paid parking (where many spots were observed to be empty) to smart parking.

Survey Results

The final evaluation of the smart parking field test at the Rockridge BART station will include "before" and "after" user surveys, focus groups, and in-person interviews. The analysis presented here is based on 285 "before" surveys completed by participants before the end of June 2005. Because this is a research project, all users are required to complete a questionnaire when they initially join the smart parking project to continue using the service. Analysis of survey results provides insight into the demographic attributes; commute travel needs and constraints; and commute travel patterns of participants.

Demographic Attributes

A number of demographic trends are suggested by the early survey responses (see Table 1, below). More women than men have participated in the program (60 percent). The most common age range of respondents is between 41 and 60 years old (47.5 percent) and 24 to 40 (42.5 percent). Generally, participants are highly educated (51.2 percent have a graduate degree or higher) and have a relatively high income level (52.4 percent have a household income of more than $110,000 per year). Eighty-eight percent of respondents regularly use a cell phone; over 80 percent regularly use the Internet at work, and about 40 percent regularly use a PDA. The most common household type is comprised of one or two adults with a child or children (40.7 percent).

TABLE 1 Demographic attributes of survey respondents.

Gender (N=285)	**Percent**
Female	60.0
Male	40.0
Age (N=280)	**Percent**
0 – 23	5.3
24 – 40	42.5
41 – 60	47.5
61 – or older	4.7
Household Structure (N=285)	**Percent**
Self only	20.7
Self with spouse/partner only	32.6
Self with/out spouse/partner and child(ren)	40.7
Self with roommate(s) or other	6.0
Education (N=285)	**Percent**
Graduate/Professional	51.2
College	42.8
Grade, High, and Trade School	6.0
Job Type (N=285)	**Percent**
Professional/technical	57.2
Manager/administrator	22.8
Homemaker or other	20.0
Income (N=254)	**Percent**
Under $49,999	10.3
$50,000 - $79,999	18.5
$80,000 - $109,999	18.9
$110,000 or more	52.4
Technology Use (N=285)	**Percent**
Mobile Phone	88.1
Internet at Work	81.4
Internet at Home	84.6
PDA	38.9

Income total sums to 100.1% rather than 100.0% because of rounding error.

Commute Needs and Constraints

Most respondents use the smart parking system and BART to commute from the East Bay to downtown San Francisco (83.7 percent). Congestion on freeways in this corridor is severe, and the cost of parking in downtown San Francisco is high. Seventy percent of respondents report that they pay for workplace parking at a modal monthly cost of $325.00, a daily cost of $12.00, and an hourly cost of $3.00. Moreover, some respondents spend a considerable amount of time searching for a parking space (i.e., 11 minutes or more according to ten percent of respondents) and then walking to their place of work (i.e., 11 minutes or more for eight percent of respondents). Approximately 40 percent report parking at their place of work on a regular monthly or weekly basis.

Almost 81 percent of respondents report that they work full time; 74 percent state that they work five days a week, 52 percent work 41 or more hours a week, and 29 percent work 31 to 40 hours a week. Among those who work five or more days a week, about 17 percent must commute from home directly to a different work location one or more days a week, and 25 percent do so one to two days a month, as indicated in Table 2 below.

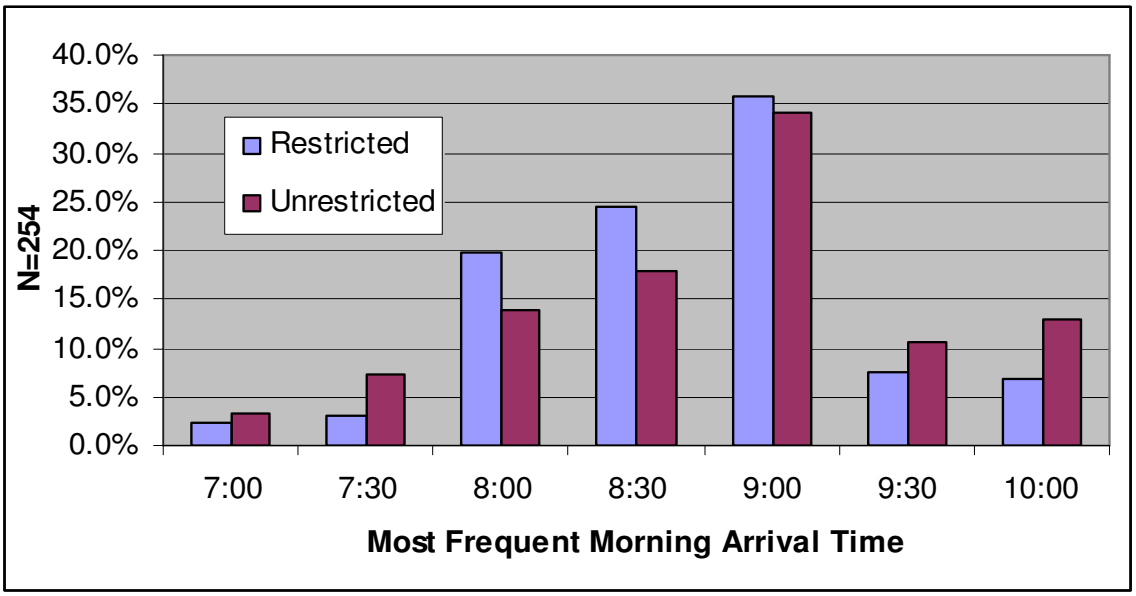
TABLE 2 Frequency of working five or more days a week and commuting from home to a different location (n=232).

Frequency	Percent Commuting from Home to Different Work Location
Less than 1 day per month	58.2%
1 - 2 days per month	24.9%
1 - 3 days per week	11.6%
4 - 5 days per week	4.7%
> 5 days per week	0.4%

Total sums to 99.8% rather than 100.0% because of rounding error.

Just over half of the respondents indicate that they may arrive at work on their own schedule, but all respondent share a modal arrival time of approximately 9:00 am, as depicted in Figure 2 below. Moreover, all respondents are most likely to arrive at work between 7:30 and 9:00 am; however, those without requirements are somewhat more likely to arrive before 7:30 am and after 9:00 am than those with requirements. Respondents also indicate that they are slightly more likely to drive alone than take BART, if they arrive between 7:30 and 8:30 am in the morning.

FIGURE 2 Most frequent morning arrival times by respondents with restricted and unrestricted work schedules.



In-person interviews with participants suggest that one reason for the 9:00 am arrival time preference is that women and men with children under the age of 16 (28.8 percent of respondents) have to drop their children at school or daycare between 7:30 and 8:30 am, and thus smart parking provides them the option to take BART by making an advanced reservation. Previously, their only choice was to drive to work because unpaid parking at the Rockridge station typically fills by 7:30 am. The drive-alone and carpool primary mode share for these families is higher than their BART mode share by 8.1 and 10.2 percentage points, respectively.

Commute Travel Patterns

It appears that the smart parking program is attracting new BART commuters; approximately 14 percent of respondents had not used BART to commute prior to joining the smart parking project. In addition, as indicated in Table 3 (below), a sizable number of current BART users could use BART more frequently for both primary and secondary commute travel (25 and 64 percent, respectively). New or more frequent BART commuters may increase their use of transit for non-work travel; a significant correlation among survey respondents was found between frequency of BART commute use and frequency of transit use for non-work travel (Chi-Square Likelihood Ratio at the 0.07 significance level).

TABLE 3 Primary and secondary long-haul commute mode by frequency.

Primary (N=266)	**BART**	**Drive Alone**	**Carpool**	**Bus**	**Total**
< 1 day per week	4.0%	13.2%	0%	0%	4.9%
1-2 days per week	10.6%	7.9%	0%	14.3%	9.4%
3-4 days per week	36.4%	34.2%	62.5%	57.1%	39.1%
≥ 5 days per week	49.0%	44.7%	37.5%	28.6%	46.6%
Total	74.4%	14.3%	6.0%	2.6%	100.0%
Secondary (N=154)	**BART**	**Drive Alone**	**Carpool**	**Bus**	**Total**
< 1 day per month	7.3%	24.1%	23.8%	25.0%	17.0%
1-3 days per month	52.7%	39.7%	0%	33.3%	45.1%
1 day per week	25.5%	22.4%	19.0%	8.3%	19.6%
2 days per week	12.7%	6.9%	4.8%	16.7%	11.8%
≥ 3 days per week	1.8%	6.9%	13.7%	16.7%	6.5%
Total	35.9%	37.9%	32.7%	7.8%	100.0%

Note that total mode share does not sum to one hundred because some modes were omitted from this table.

Prior to joining smart parking, the largest primary long-haul commute mode share among respondents was for BART (74.4 percent), followed by drive-alone (14.3 percent), carpool (6.0 percent), and then bus (2.6 percent), as depicted in Table 3. For the secondary long-haul commute mode, drive-alone has the largest share (37.9 percent), followed by BART (35.9 percent), carpooling (13.7 percent), and then bus (7.8 percent). Secondary commute BART use is approximately half of the mode share of primary commute BART use. Forty-seven percent of respondents use their primary mode five or more days a week, and 93 percent of respondents who use a secondary mode do so three or fewer days per week. For primary commute travel, respondents use BART and drive-alone most commonly five or more days a week, and most use carpool and bus drive-alone three to four days a week. For secondary commute travel, most respondents use BART three days per week to one day per month, and those who use drive-alone, carpool, and bus do so most frequently three or less days a month.

The results presented in Table 3 also suggest that the secondary commute mode is associated with a higher drive-alone mode share. If the auto is used for secondary commute travel because it is needed to conduct personal business before or after work and this activity may be conducted with an auto parked at a home-end BART station, then it is possible that the smart parking service may allow some respondents to take BART instead of driving. Moreover, the drive alone mode is used relatively frequently for the secondary commute (62 percent), and thus shifts to BART may produce noticeable reductions in auto travel. Table 2 (above) suggests that a sizeable number of these secondary commute auto trips may be used to commute directly from home to an alternate commute location; 40.8 percent of respondents do so with somewhat regular frequency.

Most project participants already drive and park or are dropped off at BART (87 percent); 13 percent report using carpool, bus, walk, bike, and other modes to access BART with some frequency as depicted in Table 4 below. The Rockridge BART station is downstream for approximately 23 percent of respondents' most frequently used station, and thus some of these respondents may be driving more to access parking at the Rockridge station. However, the difference between the mean distance from home for respondents, whose most frequently used

home-end BART station is not the Rockridge station, is only two miles. Moreover, 14.3 percent of respondents drive-alone with regular frequency for their primary commute mode, and 37.9 percent for their secondary commute mode; the average vehicle miles traveled for both of these commutes is 18 miles as depicted in Table 5 below. These results suggest that while there may be some increase in auto access mode share and auto travel distance to the BART station among participants, the magnitude of this increase is not likely to completely off-set the total reduction in auto travel resulting from a shift to long-haul BART trips.

TABLE 4 BART access mode share by frequency.

Frequency (N=246)	Drive & Park	Dropped Off	Carpool	Bus	Walk, Bike & Other	Total
Only occasionally	6.3%	14.3%	25.0%	0%	0%	6.1%
1-3 days per month	14.5%	14.3%	0.0%	25.0%	4.2%	13.4%
1-3 days per week	19.3%	0.0%	25.0%	25.0%	29.2%	19.9%
4-5 days per week	55.1%	71.4%	50.0%	50.0%	62.5%	56.1%
> 5 days per week	4.8%	0.0%	0.0%	0.0%	4.2%	4.5%
Total	84.1%	2.8%	1.6%	1.6%	9.7%	100%

Total sums to 99.8% rather than 100.0% because of rounding error.

TABLE 5 Average minutes and miles for long-haul primary and secondary commute mode by frequency of use.

Frequency	Average	
Primary (N=266)	**Minutes**	**Miles**
< 1 day per week	31	26
1-2 days per week	32	19
3-4 days per week	32	18
≥ 5 days per week	33	16
Total (standard deviation)	32 (15)	18 (11)
Secondary (N=154)	**Minutes**	**Miles**
< 1 day per month	36	16
1-3 days per month	40	18
1 day per week	48	19
2 days per week	31	13
≥ 5 days per week	25	18
Total (standard deviation)	39 (18)	18 (9)

CONCLUSIONS

A number of key findings can be drawn from this analysis of smart parking field test focus groups and surveys regarding participants' demographic attributes and commute needs and constraints. The typical smart parking participant is a woman between the ages of 41 and 60, with one or more children and a high level of education, income, and technology use. Most

participants need to commute from the East San Francisco Bay to the downtown where parking is scare and costly. Many participants are also required to commute on a regular basis to an alternate work location directly from home. The typical work arrival time for participants is between 8:00 and 9:00 am; however, those who can arrive at work on their own schedule are more likely than those who have fixed arrival times to arrive before 7:30 am and after 9:00 am to avoid peak traffic. It also appears that parents may be using the smart parking service because it allows them to meet their morning childcare schedules; this may suggest that parking pricing may be more equitable than free parking for this population segment because of constraints that make it impossible for them to pay for parking with time rather than money.

A number of interesting insights into the potential travel effects of the smart parking project are garnered from the analysis of participant travel behavior before they started using the service. The project appears to be attracting new BART commuters; approximately 14 percent of respondents had not used BART to commute prior to joining the project. Moreover, at least 25 percent of those who commuted by BART could use it more frequently. New or more frequent BART commuters may increase their use of transit for non-work travel; a significant correlation was found between frequency of BART commute use and transit use for non-work travel. Finally, the results also suggest that while there may be some increase in auto access mode and travel distance to the BART station among participants, the magnitude of this increase is not likely to off-set the reduction in total auto travel resulting from modal shifts from drive-alone to BART. Thus, it appears that the smart parking project is getting cars off the road during peak periods and onto transit.

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