SMART PARKING PILOT ON THE COASTER COMMMUTER RAIL LINE IN SAN DIEGO, CALIFORNIA

Tagan Blake (corresponding author)
Graduate Student Researcher, Transportation Sustainability Research Center
University of California, Berkeley
1301 S. 46th Street, Richmond Field Station (RFS), Bldg. 190, Richmond, CA 94804
(415) 283-6962; (510) 665-2183, taganb@gmail.com

Caroline Rodier, Ph.D.
Senior Researcher, Transportation Sustainability Research Center
University of California, Berkeley
1301 S. 46th Street, Richmond Field Station (RFS), Bldg. 190, Richmond, CA 94804
(510) 665-3524; (510) 665-2183, caroline@tsrc.berkeley.edu

Susan A. Shaheen, Ph.D.
Honda Distinguished Scholar, Institute of Transportation Studies, Davis &
Co-Director, Transportation Sustainability Research Center
University of California, Berkeley
1301 S. 46th Street, Richmond Field Station (RFS), Bldg. 190, Richmond, CA 94804
(510) 665-3483; (510) 665-2183, sashaheen@tsrc.berkeley.edu

November 15, 2008

Submitted to the 2009 Transportation Research Board's Annual Meeting

ABSTRACT
Increasingly, public transit authorities are harnessing advances in sensor, payment, and enforcement technologies to operate parking facilities more efficiently. In the short term, these innovations promise to enhance customer parking experiences, increase the effective supply of existing parking with minimal investment, and increase ridership and overall revenue. Over the longer term, these systems could further expand ridership by generating revenue to add parking capacity and improve access. This paper reports on the Smart Parking Pilot Project on the COASTER commuter rail line in San Diego (California, USA), which builds on the transit-based smart parking field test research conducted at the Rockridge San Francisco Bay Area Rapid Transit (BART) District station. The paper begins with a literature review of related parking technology, management and pricing strategies, and the optimization of parking resources at transit facilities. Next, the authors describe results of an initial pilot feasibility study. Finally, the phased smart parking implementation plan, carefully tailored to address key transit-related parking problems at the station and corridor levels, is described along with the pilot project's evaluation criteria.

Key Words: Parking pricing, value pricing, transit, parking management, parking technologies

INTRODUCTION
Increasingly, public transit authorities are harnessing advances in sensor, payment, and enforcement technologies to enhance customer parking experiences, gather detailed parking data, and operate parking facilities more efficiently. In the short term, these innovations promise to increase the effective supply of existing parking with minimal investment and thereby increase ridership and overall revenue. Over the longer term, these systems could be used to generate revenue to expand parking capacity, improve access, and further expand ridership.

Building on the smart parking field test research conducted at the Rockridge Bay Area Rapid Transit (BART) District station (*1,2,3)*, public and private partners, including the San Diego Association of Governments (SANDAG); North County Transit District (NCTD); the California Department of Transportation (Caltrans); the University of California, Berkeley; and ParkingCarma™ are embarking on a larger-scale pilot project involving six stations on the COASTER commuter rail line. The pilot is supported by Caltrans and by the Federal Highway Administration's Value Pricing Pilot Program (VPPP). The larger scale of the San Diego research effort will allow for improved evaluation of the cost effectiveness of smart parking for transit applications, including an analysis of commuters' willingness-to-pay for smart parking services. The suburban COASTER pilot project complements the urban smart parking project currently underway in San Francisco, which is supported by a federal Urban Partnership Agreement (UPA) grant and will be among the first to balance parking demand throughout a whole corridor (*4*).

This paper presents the San Diego COASTER Smart Parking Pilot project and the effort to measure and evaluate riders' response to some of the recent innovations in smart parking technology and management. It begins with a literature review of parking management and pricing strategies related to the optimization of parking resources at public transit facilities. Next, a project feasibility analysis is presented, which investigates the parking challenges faced at all six stations based on an evaluation of ridership trends, observed station parking demand, and focus groups with COASTER commuters. The paper examines the lessons learned about unmanaged transit parking and user behavior. Finally, the phased smart parking implementation plan, carefully tailored to address identified transit-

related parking problems, is described. Key conclusions drawn from the analysis are then presented.

LITERATURE REVIEW

New management systems enable the collection of detailed data on parking demand patterns and create new opportunities to optimize use of resources and increase cost effectiveness. Currently, the parking literature provides a good foundation for understanding the effects of parking pricing and other management strategies in downtowns, urban centers, retail, and employee parking. Although the same principles apply to transit station parking as to other parking contexts, transit parking facilities often face additional complexities and unique practical management issues.

Because riders dislike uncertainty and inconvenience in finding parking, public transit officials often maintain spare parking capacity, relative to average occupancy, to accommodate fluctuations in stochastic demand, with an 85% average occupancy being the rule of thumb (*5*). To mitigate the effects of excess demand, the transit agency can either implement more advanced management strategies, including pricing, parking restrictions, and technology solutions, or it can expand parking supply (*6*).

Investment decisions at overcrowded transit parking facilities are complex. Adding parking usually has diminishing marginal returns. Riders may stop carpooling, move from alternate parking locations, or switch from a nearby station, so an additional space may serve well under one additional rider per day (*6*). A study of parking conditions at stations in the Metra commuter rail system in Chicago (Illinois, USA) showed that passengers using overflow parking on the street or elsewhere tended to move into the Metra lots where parking was more convenient, so additional parking spaces did not create a proportional increase in ridership. However, adding additional parking did not appear to induce users employing alternative access modes to start driving (*7*). Park-and-ride users tend to switch from driving alone at higher rates than from bus or other public transit modes, but transit parking's effectiveness at diverting trips off of the highway depends on factors including the level of transit service, the fare and parking prices, the availability of other public transportation, roadway congestion levels, and many structural factors (*8,9*). Generally, if the marginal expected revenue of the net new spaces is greater than the marginal cost, the proposed new spaces should be added. The expected revenue from supplying additional parking to transit stations comes mostly from a greater number of ticket sales due to increased ridership and also from parking fee revenue. Shoup (2005) provides a useful discussion of the costs of supplying additional parking and the opportunity cost of investments. When the cost per additional space is sufficiently high because of land values or the type of construction necessary, real estate development may bring more benefit in revenue and ridership than investing in parking (*10,5*).

Typically, public transit agencies make parking investments according to simplified decision-making processes. The Washington Metropolitan Area Transit Authority (WMATA) in Washington, DC (USA) and the State of New York's Metropolitan Transit Authority in New York City (New York, USA) have measured parking demand by projecting ridership and assuming a constant modal access share for drivers (*11,12,13*). Often, transit agencies simply direct their investments to the stations with the most overcrowding (*14*) or those stations where they wish to induce demand (*15*). One reason many transit agencies do not use comprehensive decision models is that they do not fully internalize the cost of building a new lot or garage. Much of the funding for these projects can come from the federal, state, or local government in the form of grants or bonds (*16*).

A central lesson of the recent parking literature is that parking managers ought to rationalize pricing. Shoup (2005) argues that providing free transit parking is often an inefficient subsidy that is unfair to riders arriving by alternate modes since they do not receive any benefits from the parking and forego funding invested in parking. When transit parking is underused, parking costs per ride generated are even higher, and the public transit authority ought to find more beneficial uses for its real estate, such as transit-oriented development. Cash-out programs have demonstrated that many commuters adjust their habits significantly when presented with the true cost of their parking, and pricing is a strong tool to influence drivers' behavior (*5*). Studies of downtown parking reveal that when surplus-parking demand exists, search and congestion costs diminish the consumer surplus created by discounted parking prices. Lack of space turnover reduces accessibility and impacts businesses. An optimal management plan will not necessarily generate the most revenue, but rather it will maximize overall benefit. Reinvesting surplus parking revenue into the community can magnify the benefits of parking pricing and win over political support (*17*).

Studies suggest that the same principles can apply to transit parking facilities. In one of the earliest studies of the effects of park-and-ride pricing on public transit ridership, the Massachusetts Bay Transit Authority (MBTA) reduced parking fees at underused stations and found that revenue from the increased number of cars more than compensated for the lower price charged. The difference in the cost of parking at adjacent stations caused a shift of parkers from the more expensive lot to the cheaper lot, resulting in a redistribution of available spaces (*18*). A study of the Liberty State Park intermodal public transit facility in New Jersey showed free parking was an effective tool to induce demand at the parking lot because most parking lots nearby were overcrowded and required payment. Parking use and ridership continued to increase even after New Jersey Transit reinstated parking charges at the park-and-ride facility (*13*).

Airport operators' parking facilities provide an instructive example for transit park-and-ride since they face similar modal competition and stochastic demand. In response to competition, airport operators have led innovation in parking management, going beyond flat fees and creating sophisticated parking pricing strategies. At Minnesota-St. Paul International Airport, parking generates a third of the airport operator's revenue. The airport's parking competes successfully with alternate access modes and maintains a very high occupancy rate. The airport attributes a large share of its success to augmenting superior convenience and focusing on customer needs: minimizing transit time from cars to the terminal. Real-time monitoring allows prices to be adjusted for entering passengers at specific lots based on current and forecasted demand (*19*). At the British airport operator BAA's airports, a sophisticated yield management system lets managers closely watch demand forecasts and adjust pricing regularly in response to the market (*20*).

Parking has key attributes that make yield management a valuable tool. Parking spaces are perishable goods: any instance when they go unused is lost value. It is important to maintain occupancy levels and maximize usage levels. New technologies are continually improving the ease of reserving spaces and gathering information about customers and parking use. Teodorovic and Lucic (2006) view variable pricing as an important tool to regulate demand and to equitably raise tax revenue; they apply yield management principles to create a generalized program to optimize revenue for a parking structure or neighborhood with excess parking demand. They also observe that technology allows easy market segmentation, which can be used to benefit vulnerable groups and promote more efficient use of spaces while raising additional revenue (*21*).

Public transit agencies may not seek to only maximize revenue; nevertheless, they can benefit from the airport parking example. A private transit park-and-ride facility in New Jersey offers a range of parking options including a daily commuter rate, monthly reserved

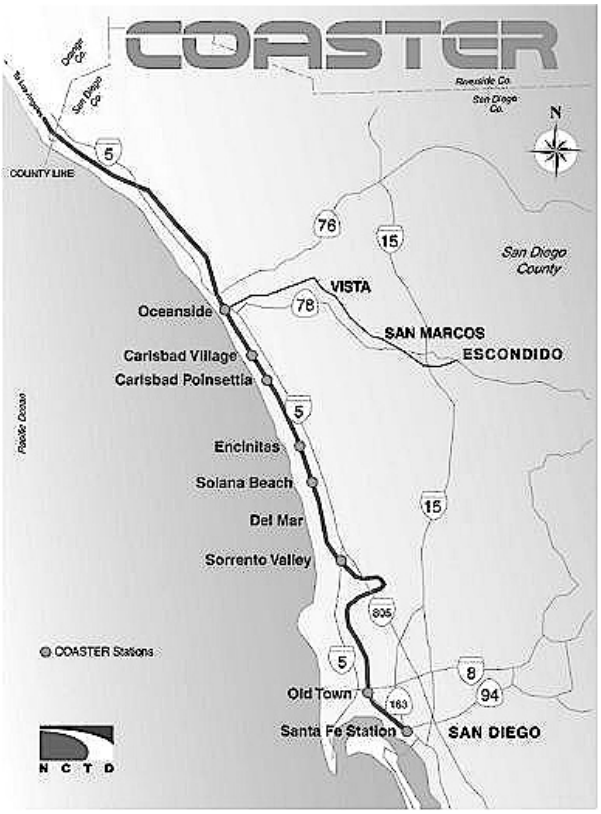
and non-reserved passes, a monthly commuter pass, and regular charge by time. The pricing system segments the market based on parking purpose, convenience, and length of stay (*22*). A station with the MBTA employs an hourly rate, but during special events, it uses a flat rate, which is equivalent to at least five hours of parking (*23*). BART's most recent pricing strategy offers separate options for carpools, long-term users, reservations, and valet services (*24*). Advanced parking management technology innovations could accelerate the further adoption of advanced pricing and management strategies by public transit authorities.

Advanced parking management systems are technology and software tools that can be used to improve and integrate parking operational elements, such as payment systems and data collection. Smart parking uses advanced parking management systems to improve customer interfaces and service, for example, help users with parking location, advance information on parking conditions, parking space reservations, and easy electronic payment options (*1*). Facilities that use advanced parking management systems can collect real-time parking space inventories that help managers track demand (*25*). Improved operations data allow parking managers to set more effective pricing policies, increase enforcement efficiency, and develop improved business strategies. Smart parking can minimize driver search time, reduce the uncertainty of finding a space, improve travel decisions, save money, prevent parking violations, and decrease parking frustration (*3*).

Information on parking locations, costs, space reservations, and restrictions helps users improve their travel decision-making and promotes more efficient transportation system use (*26*). Parking information systems allow drivers to receive parking information from the Internet, mobile phone, PDA, or variable message signs on the road. Sensors or gates monitor the parking facility's occupancy and update parking space availability or forecast information regularly (*27*,*25*).

Increasing numbers of parking payment systems and information systems offer parking space reservation services. Reservations are typically made by phone or Internet using automated systems (*28*). Drivers can benefit from reduced uncertainty and more competition among suppliers, saving users both time and money. Parking managers can learn more about overall demand and improve their pricing and revenue management (*3*). The Rockridge smart parking pilot project successfully included a reservation system (*1*), and Stadtinfo has integrated a reservation service into its transportation information system (*29*).

The current literature provides an important theoretical framework for improving public transit parking performance. Improved data collection, payment, and enforcement systems allow transit agencies to better analyze and forecast parking demand and to offer more advanced parking services to allocate their parking resources more efficiently. New technologies vary in cost to implement and maintain, and different technologies are suitable only for specific contexts. The focus of the San Diego COASTER Smart Parking Pilot will be on testing the effectiveness of specific technologies to implement advanced parking management principles.



Source: NCTD

FIGURE 1 COASTER system map.

PROBLEM IDENTIFICATION

NCTD operates the COASTER and owns and manages the six COASTER stations lying north of the City of San Diego (shown in Figure 1) and their parking lots. NCTD only shares parking at Oceanside. The agency's full control over the COASTER facilities made permission and access for the installation of equipment and field observations relatively simple and easy. The six North County COASTER stations lie in various suburban contexts, sharing some common characteristics but diverging in many respects. Figure 2 provides a qualitative comparison of the station attributes.

	Oceanside	Carlsbad Village	Carls Bad Poinsettia	Encinitas	Solana Beach	Sorrento Valley
Adjacent to downtown	Yes	Yes	No	Yes	Yes	No
Residential density within 1 mile	Medium	Medium	Low-Medium	Medium-High	Low-Medium	Very Low
Employment density within 1 mile	Medium	Medium	Low	Medium	Low	Low
Pedestrian Accessibility	Moderate	High	Poor	High	Moderate	Poor
Connectivity to other transit	Very High	Moderate	Low	Moderate	High	Moderate
Other transit available	Amtrak, MetroLink, BREEZE, Greyhound, Orange County Commuter Buses	BREEZE	BREEZE, COASTER Connection	BREEZE	Amtrak, BREEZE	BREEZE, COASTER Connection, MTS Buses,

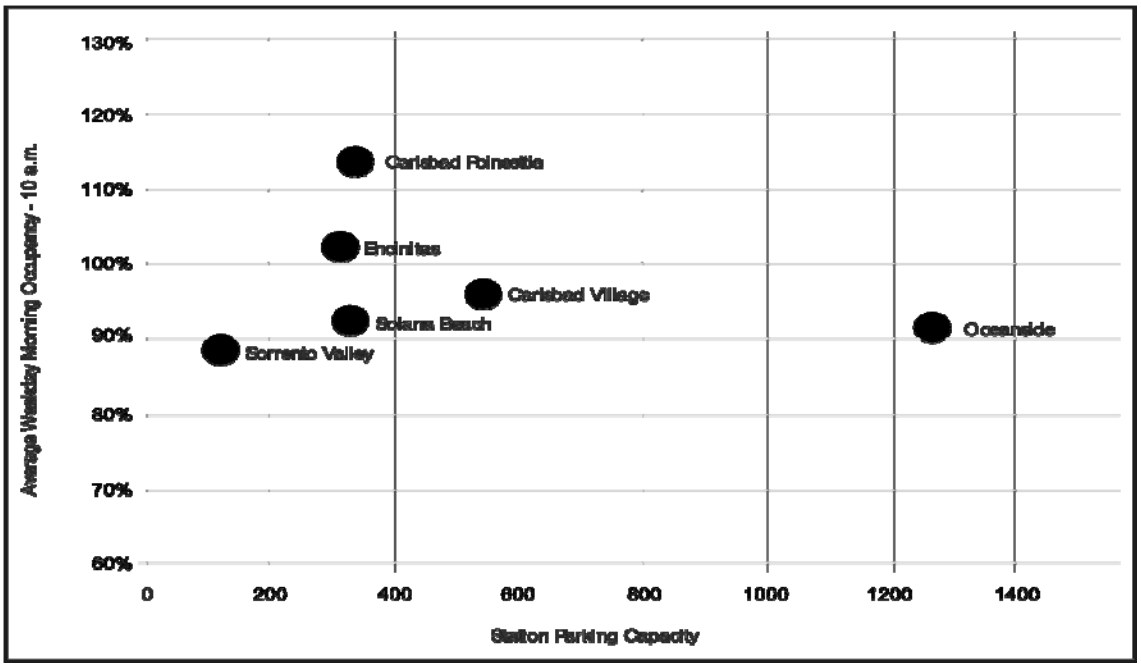
Source: field observations; SANDAG maps

FIGURE 2 Qualitative station characteristics.

A number of sources provided the basis for the analysis of current parking conditions and behavior at all six North County COASTER stations. The analysis builds on a previous parking study conducted by SANDAG in 2001 (*14*), by analyzing updated parking counts, ridership, and passenger data provided by SANDAG and NCTD. Parking occupancy was also monitored by sensor arrays installed at the COASTER stations by ParkingCarma^{TM} in November 2007. In addition, observational analyses of morning commute parking were conducted at each station for five weekdays in January 2008. The observations were augmented, as necessary, by subsequent supplemental field observations in Spring and Summer 2008. Finally, two focus groups conducted in March 2008 contributed information about commuter perceptions about parking conditions at the four most crowded stations.

Analysis

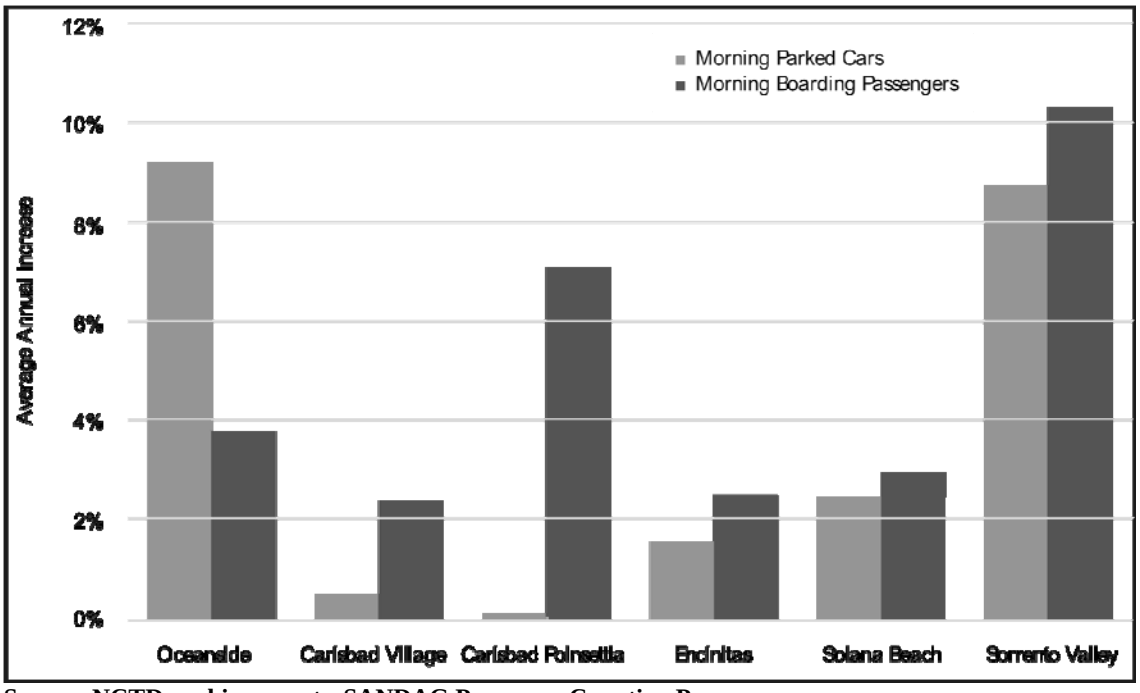
NCTD and SANDAG's parking and passenger data suggest that the system could benefit substantially from a parking management program: NCTD's and SANDAG's parking and ridership data show healthy average annual passenger growth of 4.7% since 2002, but overall only 1.1 morning passengers are generated per parked vehicle. This figure includes riders who uses alternate access modes and indicates that COASTER parking could be used more efficiently. Figure 3 shows that most North County stations have high parking occupancy and limited parking capacity. Occupancy at several stations exceeds 100% because drivers regularly park in unmarked spaces. When 130 spaces added 35% more capacity to the Carlsbad Village station in June 2008, occupancy quickly rebounded to 96% of capacity by August, 2008—a 20% annual increase in parked vehicles.



Source: NCTD parking counts

FIGURE 3 Average weekday morning parking occupancy (June 2008).

As indicated in Figure 4, a comparison of historical annual ridership and morning parking growth rates indicates that annual ridership growth is still strong (ranging from 2% to 7%) at stations with parking constraints (as illustrated in Figure 3): Carlsbad Village, Carlsbad Poinsettia, Encinitas, and Solana Beach. At these stations, growth in annual ridership surpasses growth in annual morning parking. High demand at these stations continues to drive passenger growth. This suggests that better management of existing parking capacity could grow COASTER ridership even faster. The stations where parking occupancy growth nearly matches or even exceeds passenger growth are experiencing competition from non-COASTER users. Competition for parking spaces is highest at Oceanside where the station serves many other public transit services and is adjacent to the popular downtown.



Source: NCTD parking counts, SANDAG Passenger Counting Program

FIGURE 4 Growth in morning parking and passengers (2003 to 2008).

Currently, all COASTER parking is free and unmanaged with minimal signage. Observational analysis shows that long-term and non-transit users occupy from 5 to 60% of parking during commute hours. These are the primary user groups displacing daily COASTER commuters from overcrowded NCTD lots. When excess parking demand exists, long-term parking generates fewer trips in a given period and thus has a lower benefit to NCTD than daily transit rider parking. Non-COASTER parking brings NCTD no direct benefit at all. When excess parking demand exists, both user groups cost NCTD by occupying spaces that would otherwise have generated more riders and revenue.

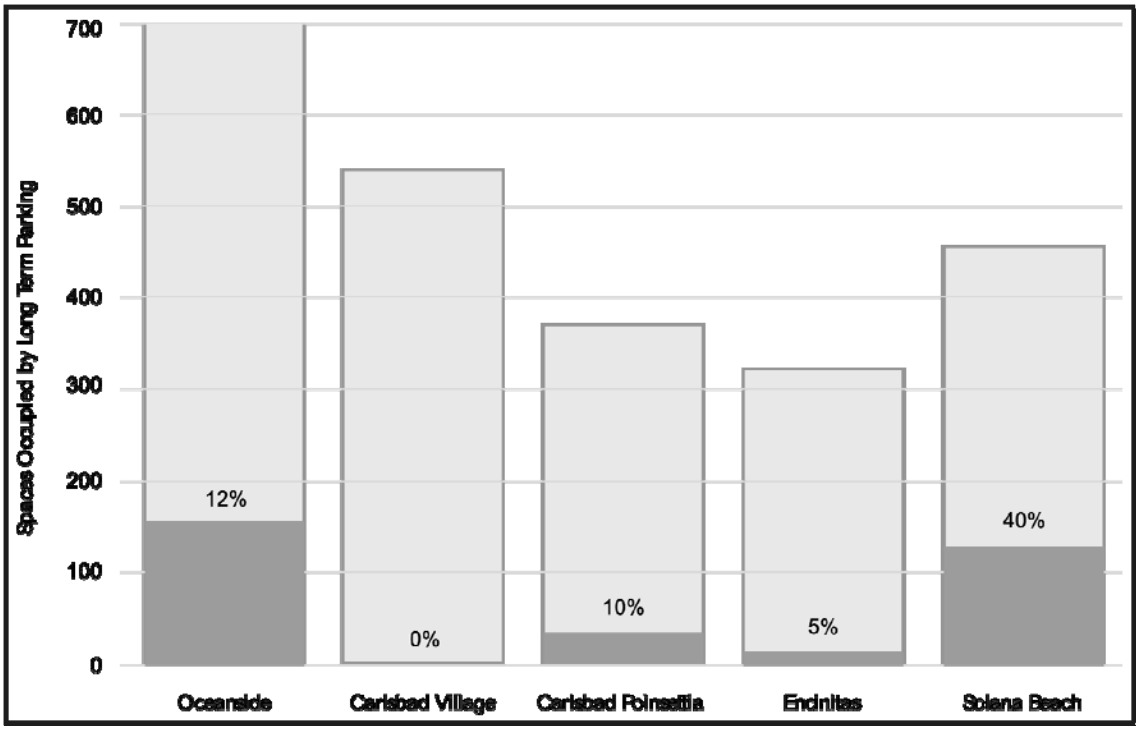
Non-COASTER Transit

At Oceanside and Solana Beach, Amtrak and MetroLink riders are the most numerous non-COASTER users of COASTER parking. Most Amtrak trips from Solana Beach and MetroLink trips from Oceanside are daily commuter trips. NCTD supplies parking for the majority of MetroLink and Amtrak riders without receiving a concomitant benefit. MetroLink and Amtrak boardings outnumber the COASTER's: a March 2007 passenger count at Oceanside recorded 452 riders board MetroLink trains before 8:30 AM (*30*), and Caltrans data from fiscal year 2005 show an average of 836 Amtrak riders originating from Oceanside each day and 1,132 riders from Solana Beach (*31*). Supplemental field observations showed large numbers of Amtrak and MetroLink riders using the Oceanside and Solana Beach COASTER parking, and many of these passengers park for multiple days. A 2006 study determined 48% of those parking at Solana Beach station were taking Amtrak—more than double the number parking for the COASTER (*32*).

Long-Term Parking

Overnight parking is not technically permitted at COASTER stations, but poor signage and lack of enforcement means most users are not aware of this. Station cars—vehicles that riders use to get from their end station to their destination—and the cars of local residents are

usually only parked overnight and generally have less impact on ridership. However, Amtrak riders, airport passengers, and others often park for multiple days. These vehicles incur additional security costs to NCTD. Figure 5 shows observational analysis results that indicate that long-term and overnight parkers are a problem at all stations except Carlsbad Village. Overall, they occupy 15% of available COASTER parking: approximately 440 spaces. A comparison of the observational analysis to data on long-term parking collected in 2001 (*14*) reveals that overnight parking has increased at every station except Carlsbad Village. Amtrak and MetroLink riders are responsible for most long-term parking, which explains why Oceanside and Solana Beach are the most impacted by long-term parking. Field observations indicate that at Oceanside and Solana Beach most long-term parking is for Amtrak use. Field observations also revealed significant airport use, especially from Oceanside and Carlsbad Poinsettia.



Source: observational analysis, January 28, 2008 to February 1, 2008

FIGURE 5 Long-term and non-public transit parking.

Non-Public Transit Users

When parking at COASTER stations, the lack of enforcement along with crowded and restricted street parking can encourage non-COASTER parking. Four COASTER stations are adjacent to downtowns, and all have local employees and shoppers parking in their lots regularly. Five of six stations lie within a quarter mile of the beach and are subject to parking by recreational users. Field observations showed non-public transit parking to be a significant issue at only three stations. Two of these, Oceanside and Solana Beach, usually have excess parking capacity regardless but are fast approaching capacity. A 2006 parking study at Solana Beach found 11% of people parking in the lot on a weekday were not using public transit (*32*). Non-transit parking is most severe at the Encinitas COASTER station. While the observational analysis recorded an average of only 11 people using the parking lot for non-COASTER uses each weekday, supplemental field observations revealed substantially higher numbers, counting between 15 and 20 people parking for a non-transit destination during the

peak morning commute in March and May 2008. Overall, field observations suggest that non-public transit users with local destinations take up at least 5%, and possibly more than 10%, of the lot's capacity on a typical weekday.

Every COASTER station lies within half a mile of Interstate-5, and non-transit commuter vanpools contribute to overcrowding of COASTER parking. Commuters park at COASTER stations in the morning and carpool or vanpool to work. Multiple non-public transit vanpools make pickups at Carlsbad Poinsettia, Encinitas, and Solana Beach. Oceanside has at least six vanpools. Most of the vanpool passengers leave their vehicle in the COASTER parking lot.

Park-and-Ride Overcrowding

Available parking is a major factor in COASTER ridership. Most riders prefer to drive alone to the station. According to SANDAG's 2002 COASTER parking and access survey, 68% of North County COASTER riders typically drove alone to the station (*14*). On average after the morning commute, occupancy is 96% for the six North County stations. In the most crowded lots, users park in undesignated spaces, often illegally, to take advantage of any extra space in the lots. According to the observational analysis, the parking lots at Carlsbad Poinsettia and Encinitas typically fill well before the last morning commute train leaves. Using NCTD's parking count data, Carlsbad Village and Solana Beach are projected to begin filling regularly within the next year and Oceanside within two years.

Surveys and focus groups provide useful information about the effects of overcrowded parking on individuals. SANDAG's 2002 COASTER station parking and access study revealed more riders use alternate access modes at stations with overcrowded parking. Survey respondents cited lack of parking as an important reason for accessing the station by an alternate mode. Riders who do not drive alone to the station tend to arrive later, which may reflect: 1) greater uncertainty about finding parking spaces for later trains and 2) a general user preference for departing later during commute hours.

UC researchers conducted 2 focus groups with 28 total participants in March 2008. The results provided valuable qualitative insights into current riders' responses to parking conditions at the four most overcrowded stations. The focus group participants from Carlsbad Village, Carlsbad Poinsettia, Encinitas, and Solana Beach regularly experienced parking difficulties when taking later trains. Many participants cited parking difficulties as one of the most negative aspects of riding the COASTER. Long-time riders noted that parking difficulties are steadily increasing over time. Parking problems were least severe at the Solana Beach station where most participants said they could find a spot for any train most of the time. At all stations, some reported parking on the street due to lack of lot space. To compensate for increased parking demand, some Carlsbad Village, Carlsbad Poinsettia, and Encinitas participants arrived earlier for their trains, and several reported switching to an earlier train or the next station to avoid parking problems. Parking shortages appear to impact the majority of participants, but only a minority stated any willingness-to-pay for more convenient parking. Those that expressed interest in paying for a guaranteed space wanted the flexibility to park to take a later train.

Focus group participants were all regular commuters and nearly all bought monthly passes, so they tended to express the most interest in the monthly reserved parking alternative rather than paid preferential parking. Many also expressed interested in valet parking but had feasibility concerns. Few were interested in daily reserved parking, as daily COASTER commuters would only expect to use it occasionally. A majority of participants supported reserved carpool spaces, viewing it as a fair way to improve the efficient use of the parking lots.

The majority of focus group participants supported parking enforcement of non-COASTER uses. Many thought this ought to precede any paid-parking scheme, while others were concerned that enforcement costs would fall on them. A small proportion of participants opposed enforcement for equity reasons, believing other users had as much right to park there as COASTER and other public transit users. Focus group participant observations and opinions added depth to the data analysis and helped to anticipate COASTER rider needs and response to a new COASTER parking management program.

MANAGEMENT MEASURES AND IMPLEMENTATION

The data collection phase identified two main challenges that any comprehensive parking management plan must address to bring NCTD's parking facilities closer to optimal use. The first challenge is to address non-COASTER use of the lots, which is of two types: 1) non-public transit users and 2) Amtrak and MetroLink riders. NCTD could either prohibit these users from parking or should recover the costs incurred from transit ridership loss. The pilot project's second challenge is to increase the efficiency of COASTER rider use of its parking facilities. One important goal is to increase the usage intensity of each lot by discouraging long-term parking, which generates relatively few trips per space per day and encouraging carpooling, which generates relatively high ridership per parking space. Another goal is to reduce parking uncertainty and thereby reduce the unused parking capacity during COASTER commute hours. This project investigates management strategies that can generate revenue to recover parking operational costs and prevent these costs from falling on COASTER riders using alternate access modes. In the future, excess revenue could potentially go towards expanding parking capacity or improving non-driving COASTER access.

The phased implementation of the parking management plan addresses parking issues systematically according to magnitude and management complexity. The goal is to make an early positive impact and continue with minimal disruption for COASTER riders. An incremental approach improves the project partners' ability to measure the effects of each management strategy and to provide useful feedback to the NCTD board of directors as the project progresses.

The first phase of the Smart Parking Pilot implementation plan lasts approximately three months and initially focuses primarily on the Carlsbad Village, Carlsbad Poinsettia, and Encinitas stations. These stations have the highest demand and exclusively serve the COASTER. NCTD's near-term goal is to discourage non-public transit parking in the COASTER lots. The installation of more signage will increase awareness about parking restrictions in each lot. COASTER riders at the Carlsbad and Encinitas stations must post proof of ridership to park. For parking violators, a notification of the new pilot project measures precedes warning notices and then towing for repeated violations. After three months, the pilot partners will evaluate and update the enforcement plan and launch the parking management plan at the remaining stations. The Compass Card—San Diego County's integrated transit smart card—provides a useful way to distinguish between COASTER and non-COASTER riders. ParkingCarma™ will use the Compass Card system in conjunction with their website to validate parking permits.

The first phase also introduces preferential carpool parking adjacent to the platforms at the three stations to encourage more transit trips per parking space. Carpools spaces are free and available on a first come first serve basis for NCTD riders who display proper validation from ParkingCarma™'s website. Participants are required to present a printed receipt or validation for each rider on their dashboard. The new parking management program also subjects overnight parking at Carlsbad Village, Carlsbad Poinsettia, and

Encinitas to a daily fee based on a daily rate. Non-public transit users may use the general station parking during the day or at night for a higher daily fee. At Oceanside and Solana Beach stations Amtrak and MetroLink riders parking in NCTD's parking lots will pay non-COASTER parking fees for daily parking.

The first phase also involves launching paid reserved parking options at the three Carlsbad and Encinitas stations. The reserved parking includes a number of preferential spaces convenient to the station platform available for daily reservations by COASTER riders. Enforcement follows a program similar to general parking and carpool parking enforcement systems. The pilot's second phase will examine a monthly reserve parking option for monthly pass holders at select stations. Monthly and daily reserved spaces can provide options for COASTER riders to decrease parking uncertainty. The pilot project is continuing to test and develop an information system to provide up-to-date online information on parking availability to reduce uncertainty and allow users to better plan their trips.

The second phase expands existing management measures to more stations. Riders will be able to take advantage of paid preferential parking at the Oceanside, Solana Beach, and Sorrento Valley stations. Paid parking and enforcement for overnight parking are included at these stations. The expansion of the smart parking pilot to all stations also provides an opportunity to evaluate the enforcement program and ParkingCarma^{TM}'s user interface.

The second phase focuses greater attention to the paid preferential parking options and to technologies that improve information for COASTER riders. In a preliminary step towards value pricing, the second phase will re-examine pricing at each station and expand programs based on pilot usage levels and data collected. Prices and levels of reserved parking may be adjusted to balance demand levels among the stations and to promote efficient use of parking resources at each station. The project will also examine additional value pricing mechanisms, such as charging based on daily demand, time of day, and season to take advantage of off-peak and variable un-used parking capacity.

ParkingCarma^{TM}'s web portal for COASTER parking information provides additional opportunities for conveying information to riders. Additional services could include displaying availability at neighboring stations, improved outreach and distribution of parking information, the use of Bayesian logic to better estimate and predict demand, and the provision of user information and reservations via mobile phone.

The second phase also explores the integration of ParkingCarma^{TM}'s platform with San Diego's 511 system, which is a general portal for commuter information. Making COASTER parking information more accessible and robust will help reduce parking uncertainty further, while promoting COASTER awareness and use among the broader population.

The third phase will investigate the pilot project's transfer to NCTD for ongoing operations. This step will help to ensure the program's sustainability and allow NCTD to assess its continued cost effectiveness. Key elements in this transfer include a more advanced enforcement program, parking fees for Amtrak and MetroLink riders, and advanced value pricing mechanisms.

CONCLUSION

The literature review for the San Diego smart parking pilot shows that public transit agencies lag in their adoption of advanced parking management technologies and strategies. However, in the context of public transit, the benefits and impacts of these new technologies and practices have yet to be fully tested. More research is needed to understand the effects transit

parking management strategies on public transit ridership, especially at the corridor level. Nevertheless, the literature indicates that transit agencies should improve their decision analysis regarding parking investments and examine the tradeoffs of expansion, advanced parking management systems, and real estate development. At overcrowded parking facilities, pricing is a strong tool to allocate demand efficiently. Recovering the operational costs of parking is fairer to users who use alternate access modes. Customers are more likely to pay for street parking and parking in open facilities when convenient cashless payment options are available. Advanced parking management systems should make transactions more convenient for customers, gather useful data for improving parking management, and improve enforcement efficiency.

The pilot project's initial study phase identified several main issues that a COASTER parking management plan should address to help alleviate parking shortages and promote ridership in the short term. Three stations have short-term capacity problems, and all stations have long-term problems. Long-term and non-public transit users occupy from 5 to 20% of parking capacity at COASTER stations during the morning commute. At two stations, other transit users compete for parking in COASTER-designated parking. Poor signage is a major contributor. Because of increasing demand over the last two years, many focus group participants using the three most crowded COASTER stations revealed that they now park earlier, have switched to a less crowded station, or drive to work more often.

To address station overcrowding and improve riders' parking experience, the COASTER smart parking pilot project will institute an enforcement program to deter non-public transit use of COASTER parking facilities. The initial pilot phase includes the installation of clearer signage and warning notices and towing enforcement for non-transit users of COASTER parking, as well as towing enforcement for repeat violations. To reduce parking uncertainty for peak commute trains and provide revenue generating value-added parking options, the pilot project is implementing paid preferential parking programs with reservations and permits. The smart parking system will also offer parking availability estimates through the Internet to improve traveler information for all COASTER riders.

The study is continuing to examine the impacts of parking management strategies on individual stations and on the entire North County COASTER system. The pilot project is also investigating drivers' willingness-to-pay for COASTER parking and factors that can make paid preferential parking more attractive. Data will help evaluate the benefits of advanced parking management strategies in a variety of suburban contexts.

ACKNOWLEDGEMENTS

The authors would like to thank the California Department of Transportation (Caltrans), California Partners for Advanced Transit and Highways (PATH), and the Federal Highway Administration Value Pricing Pilot Program for funding this research. In particular, we would like to thank Caltrans staff: Gale Ogawa, Nancy Chinlund, Nicole Longoria, Bob Justice; SANDAG staff: Samuel Johnson and Alex Estrella; the North County Transit District; ParkingCarma™ staff: Rick Warner and Chris Paul; and Allen Greenberg of FHWA. Without their assistance and contributions, this research would not have been possible. Linda Novick, Caitlin Dahl, Tony Yang, and Nathan McKenzie of the Transportation Sustainability Research Center and the Innovative Mobility Research group at the University of California, Berkeley also are acknowledged for their contributions to this project. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein.

REFERENCES

(1) Shaheen, S. A. and C. Kemmerer (2008). “Smart Parking Linked to Transit: Lessons Learned from the San Francisco Bay Area Field Test,” *Transportation Research Record*, Publication Forthcoming.
(2) Rodier, C.J., and S.A. Shaheen. Transit-Based Smart Parking: An Evaluation of the San Francisco Bay Area Field Test. *Transportation Research Part C*, 2007, Publication Forthcoming.
(3) Shaheen, S. A., C.J. Rodier, and A.M. Eaken. *Smart Parking Management Field Test: A Bay Area Rapid Transit (BART) District Parking Demonstration – Interim Final Report*. UCB-ITS-PRR-2005-5. Institute of Transportation Studies, University of California, Berkeley, 2005.
(4) SFCTA. "Doyle Drive Value Pricing Program." *San Francisco County Transit Authority.* 2007. http://www.sfcta.org/content/category/4/86/293/ (accessed June 14, 2008).
(5) Shoup, D. *The High Cost of Free Parking.* Chicago: American Planning Association, 2005.
(6) David Merriman. "How Many Parking Spaces Does It Take to Create One Additional Transit Passenger?" *Regional Science and Urban Economics*, no. 28 (1998): pp. 565-584.
(7) Ferguson, E. "Parking Management and Commuter Rail: The Case of Northeastern Illinois." *Journal of Public Transportation* Vol 3, no. 2 (2000): pp. 99-121.
(8) Foote, P. J. "Chicago Transit Authority Weekday Park-and-Ride Users: Choice Market with Ridership Growth Potential." *Transportation Research Record*, no. 1735 (2000).
(9) Turnbull, K. F., R. H. Pratt, J. E. Evans, IV, and H. S. Levinson. “Traveler Response to Transportation System Changes, Chapter 3—Park-and-Ride/Pool,” *TCRP Report 95*. Washington, DC: Transportation Research Board, 2004.
(10) EPA, 2006
(11) WMATA. "Parking at Metrorail Stations." *Washington Metropolitan Area Transit Authority.* 2008. http://www.wmata.com/metrorail/daily-parking.cfm (accessed July 12, 2008).
(12) MTA Metro-North Railroad. "North White Plains Station EIS for Improved Station Access and Additional Parking." *New York Metropolitan Transit Authority Metro-North Railroad.* June 2005. http://www.mta.info/mta/planning/nwp/ (accessed July 16, 2008).
(13) Marchwinski, Thomas, Gregory Spitz, and Thomas Adler. "Planning and Forecasting for Light Rail Transit: How the Introduction of the HBLRT Changed the Demand for the Liberty State Park Park-and-Ride Facility." *Transportation Research Board - 9th Annual Light Rail Conference E-Circular.* November 2003.
(14) SANDAG. "North County COASTER Station Access Study Part I." San Diego Association of Governments, 2002.
Merriman 1998, op. cit.
(15) MTA. "Beacon Celebrates Train Station Improvements." *Metropolitan Transportation Authority, State of New York: The MTA Newsroom.* 2008.
http://www.mta.info/mta/news/newsroom/beacon.htm (accessed July 21, 2008).
Marchwinski, Thomas, Gregory Spitz, and Thomas Adler. "Planning and Forecasting for Light Rail Transit: How the Introduction of the HBLRT Changed the Demand for the Liberty State Park Park-and-Ride Facility." *Transportation Research Board) 9th Annual Light Rail Conference E-Circular*. November 2003.
(16) SEPTA. "Fiscal Year 2008 Capital Budget, Fiscal Years 2008-2019 Capital Program and Comprehensive Plan." *Southeastern Pennsylvania Transit Authority*. May 24, 2007.
http://www.septa.com/inside/reports/CB08_BudgetApproved.pdf (accessed July 18, 2008).

(17) Shoup, D. "The Ideal Source of Local Public Revenue." *Regional Science and Urban Economics*, no. 34 (2004): pp. 753-784.
(18) Mass Transportation Commission of the Commonwealth of Massachusetts; McKinsey & Co.; Systems Analysis & Research Corp.; Joseph Napolitan & Assoc. *Mass Transportation in Massachusetts.* Washington, DC: US Housing and Home Finance Agency, 1964.
(19) Decker, R. "At MSP - Innovation, Thy Name is Parking." *Parking Today*, July 21, 2007: pp. 24-26.
(20) *The Airport Operator.* "Airport Parking - the Great Debate." July 23, 2007. http://www.aoa.org.uk/publications/Airportoperator_news_items.asp?nid=250 (accessed July 16, 2008).
(21) Teodorovic, D., and P. Lucic. "Intelligent Parking Systems." *European Journal of Operational Research*, 2006: 1666-1681.
(22) "Trenton Park-and-Ride." *Nexus Properties.* 2008. http://www.trentongarage.com/trenton_park.html (accessed April 8, 2008).
(23) MBTA. "Riding the T: Parking." *Massachusetts Bay Transportation Authority.* 2008. http://www.mbta.com/riding_the_t/parking/ (accessed July 22, 2008).
(24) BART. "Parking." *Bay Area Rapid Transit.* 2008. http://www.bart.gov/guide/parking/ (accessed July 18, 2008).
(25) Federal Highway Administration. "Advanced Parking Management Systems: A Cross-Cutting Study." *Intelligent Transportation Systems, U.S. Department of Transportation.* January 2007.
(26) Smith, L., H. Roth, and M. Benko. *Services and Technology.* 2003. www.calccit.org/itsdecision/serv_and_tech/Parking_Systems_Technologies/parking_systems_tech_report.htm (accessed June 15, 2008).
(27) Bannert, P. "At Your Convenience." *Traffic Technology International*, 2002: 68-70.
(28) Mouskos, K. C., M. Boile, and N. Parker. *Technical Solutions to Overcrowded Park and Ride Facilities.* Federal Highway Administration, May 2007.
(29) Stadtinfo Cologne. "Stadtinfo Cologne Traffic and Parking Data System, Germany." *Road Traffic Technology.* 2007. www.roadtraffic-technology.com/projects/stadinfo/ (accessed March 5, 2007).
(30) MetroLink. "Orange County Line 2007 Weekday Fact Sheet." *Southern California Regional Rail Authority, MetroLink Trains.* 2007. http://www.metrolinktrains.com/about/?id=6 (accessed March 12, 2008).
(31) Caltrans. "Pacific Surfliner Route FFY 2007-2008 Business Plan." *California Department of Transportation, Division of Rail.* June 2007.
(32) Wilson & Company, Inc. "Solana Beach Joint Development Project: Train Station Parking Demand Analysis." Appendix H: Cedros Crossing Draft Environmental Impact Report, 2006.