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Smart Parking Pilot on the Coaster Commuter Rail Line in San Diego, California

Caroline Rodier, Susan A. Shaheen, Tagan Blake

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

California Partners for Advanced Transit (PATH) Task Order 6115

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

Tagan Blake
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

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ABSTRACT

Public transit authorities increasingly 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 report describes 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 report begins with a discussion of the relevant background of the pilot. What follows is a feasibility analysis that includes a literature review of parking management and pricing strategies, a parking problem assessment at each of six northern COASTER stations based on ridership trends, observed station parking demand, and focus groups with COASTER commuters. Finally, alternative and implemented smart parking management programs are described. Key recommendations drawn from the pilot research and implementation process are then presented.

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

EXECUTIVE SUMMARY

Public transit authorities are increasingly 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 long-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 (Shaheen and Kemmerer 2008; Rodier and Shaheen 2007; Shaheen et al. 2005), public and private partners, which include 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,™ embarked 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 current project, funded by Caltrans, was originally conceived as the next phase of this research: a smart parking pilot on a suburban commuter corridor (stations on the COASTER commuter line) in San Diego. At that time, parking at most of the stations on this corridor filled well before the final commute train departed, and ridership was clearly limited by station parking capacity. SANDAG approached researchers and Caltrans requesting that the project be located in San Diego on the COASTER line, and it appeared that there was strong institutional support for testing and evaluating smart parking pilot. The larger scale of the project would also help researchers better understand the scale of economies necessary to operate elements of the smart parking program. Subsequently, SANDAG was awarded VPPP funds to expand the initial Caltrans funded pilot at the COASTER station.

Soon after the project began in the fall of 2006, researchers met with project partners and stakeholders to begin the design and implementation of the pilot and research plans. After these initial meetings, it became clear that a significant effort would be required to obtain the necessary approvals from the NCTD Board of Directors to operate the pilot because of concerns about initiating parking charges at COASTER stations. In the summer of 2007 the NCTD staff granted the pilot partners approval to proceed with the smart parking project in a feasibility analysis phase, which included a literature review of parking management and pricing alternatives relevant to the pilot design and an analysis of the general and station-specific parking problems along the northern COASTER line.

The literature review for the San Diego smart parking pilot shows that public transit agencies have been slow to adopt 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 of 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 for allocating 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 easier for customers, gather useful data for improving parking management, and improve enforcement efficiency.

The parking problem analysis identified several major issues that a COASTER parking management plan should address to help alleviate parking shortages and promote ridership in the short term. Three stations had short-term capacity problems, and all stations had long-term capacity problems. Long-term and non-public transit users occupied from 5% to 20% of parking capacity at the five COASTER stations during the morning commute. At two stations, other transit users competed for parking in COASTER-designated parking. Poor signage was a major contributor. Because of increasing demand, focus group participants who used the three most crowded COASTER stations revealed that they parked earlier, switched to a less crowded station, or drove to work more often.

The problem identification analysis and proposed near-term parking management strategies to address those problems were presented to the NCTD staff and their Board in September of 2008. Proposed alternatives for the near term included strategies to (1) free up more space for COASTER riders by restricting non-COASTER and overnight parking or allowing non-COASTER and overnight parking through fee payments; (2) generate more COASTER riders per parking space by encouraging carpooling and vanpooling and by providing preferential parking for those commuters adjacent to the platforms; and (3) attract new or more frequent daily COASTER riders through the provision of reserved paid parking, which would also be located in a preferential location, and by providing information on the real-time availability of general free parking at the COASTER stations via the ParkingCarma™ reservation website.

The NCTD Board conditionally approved the near-term strategies in September 2008 and project partners began working to implement the pilot project. Partners worked with NCTD staff and the NCTD Planning Committee on details of the pilot implementation. However, by this time it had become apparent that the U.S. was plunging into the deepest economic downturn since the 1930s: the San Diego region would soon be hit harder by the recession than the nation as a whole; the COASTER line faced serious fiscal deficits and was forced to raise COASTER fares; and COASTER ridership had declined significantly.

Project partners began working with the NCTD staff and Board to develop a plan that took advantage of existing resources available for research and planning during the economic downturn. The objective was to lay the foundation for future expansion of the smart parking program once the economy turned around and greater demand for service returned. During this period NCTD staff and the Planning Committee also expressed concerns that COASTER riders would find it onerous to place on their cars the proof of ridership that was necessary for enforcement. As a result, the plan that was ultimately implemented did not enforce restricted parking nor implement paid parking for non-transit or overnight uses. However, the plan did include preferential carpool and vanpool parking, reserved paid parking services, and provision of real-time parking availability information via the ParkingCarma™ reservation website. The pilot plan received final board approval in May of 2009 and was implemented in August of 2009 at the Carlsbad Village, Poinsettia and Encinitas stations. Researchers will return to the NCTD Board after three to six months to report on findings and, if appropriate, recommend expansion to three more stations. Parking information will soon be posted on the ParkingCarma™ website.

The current economic downturn and declining ridership provides a window of opportunity for pilot partners and NCTD to lay a solid foundation for future expansion of parking management programs by carefully evaluating the following issues:

1. Basic comparisons of the relative revenue projections generated from fare increases and from parking pricing management plans including their operation, maintenance, and capital costs. The next phase of the research will also address these issues.

2. A proof of ridership system that allows for cost-effective enforcement without inconveniencing riders; such a system would likely include recommendations for changes to the parking enforcement codes that disallow parking tickets and fines for parking in COASTER stations and only allows for towing.

3. Legal barriers to implementing alternative parking management plans on COASTER station parking lots (e.g., prior “equal access” agreements) and needed resolutions to these barriers.

4. Posting changeable message sign (CMS) messages on I-5 along the northern COASTER line informing drivers of transit departure times, station parking availability, and any downstream congestion delays. Fixed CMS have now been installed on this section on I-5.

5. An expanded integration of smart parking information and reservations with San Diego’s new 511 system, which provides real time information via phone and Web services on traffic conditions, incidents and driving times, and transit schedule, route and fares.

6. Increased demand for COASTER parking, as the economy improves, and demand responsive adjustments (i.e., by time of day, day of week, and season) of reserved paid parking spaces and fee rates. The collection of demand and response data would assist in the evaluation of revenue streams for alternative parking management plans.

7. Monthly reserved paid parking that meets the needs of commuters who have a monthly pass, but would like the convenience of arriving at the parking lot whenever they want.

8. The cost-effectiveness of implementing valet parking to expand lot capacity.

The next phase of the project involves expanded data collection to conduct a broader regional analysis of the cost-effectiveness of alternative parking management plans.

1.0 Introduction

Increasingly, public transit authorities are harnessing advances in sensor, payment, and enforcement technologies to enhance customer parking experiences, to gather detailed parking data, and to 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 long 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 (Shaheen and Kemmerer 2008; Rodier and Shaheen 2007; Shaheen et al. 2005*)*, public and private partners, which include the San Diego Association of Governments (SANDAG), North County Transit District (NCTD), the California Department of Transportation (Caltrans), the University of California, Berkeley (UC Berkeley), and ParkingCarma,™ embarked 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).

This report presents the San Diego COASTER Smart Parking Pilot project and the effort to measure and evaluate riders' response to some recent innovations in smart parking technology and management. The report begins with a discussion of the relevant background of the pilot. What follows is a feasibility analysis incorporating a literature review of parking management and pricing strategies as well as a parking problem assessment at each of six northern COASTER stations based on ridership trends, observed station parking demand, and focus groups with COASTER commuters. Finally, alternative and implemented smart parking management programs are described. Key recommendations drawn from the pilot research and implementation process are then presented.

The scalability of the proposed smart parking system for San Diego was analyzed by the California Center for Innovative Transportation (CCIT) as part of the study (Appendix A). That report outlines the factors influencing scalability of the Smart Parking system, leading to full-scale deployment. The specific scenarios developed by NCTD are not addressed; rather, the emphasis is on larger design through a discussion of smart parking technologies, general strategies, and identification of key decision points for stakeholder consideration. This report provides an initial framework for developing a more comprehensive systems engineering approach to smart parking design and implementation.

2.0 Background

The current project builds on the results of the smart parking field test conducted between 2004 and 2006 at the Rockridge BART station in Oakland, California. BART provided 50 spaces to be used for peak period commuter parking that had previously been reserved exclusively for off-peak parking (i.e., after 10 am). The field test involved two real-time user interfaces: (1) two changeable message signs (CMSs) that displayed parking availability information to motorists on an adjacent commute corridor into downtown Oakland and San Francisco (Highway 24), and (2) a centralized intelligent reservation system that permitted commuters to check parking availability at the 50 designated spaces and reserve a space via telephone, mobile phone, Internet, or personal digital assistant (PDA). Those who used the system for en-route reservations called in their license plate number via mobile phone when they parked in the smart parking lot. BART enforcement personnel ensured that those parking in the smart parking lot either had: (1) an advanced reservation parking permit or (2) a license plate number, which matched one of the numbers provided real-time to enforcement personnel via PDA for en-route reservations.

The smart parking system integrated 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. Smart parking facilitated pre-trip planning by permitting users to reserve a space up to two weeks in advance, but it also enabled en-route decision making, providing real-time parking availability information to encourage motorists to use transit. If a motorist confronted congestion on Highway 24, he/she could check parking availability on the CMS, exit the freeway, and park in the smart parking area at the Rockridge BART station. Reservations were initially free of charge. A pricing structure was introduced for both types of parking reservations in October 2005. Users who made en-route reservations were charged $1.00 for this service, while those making pre-trip reservations were charged $4.50. BART has since implemented daily and overnight reserved paid parking, preferential free carpool parking, and valet parking in addition to monthly reserved parking throughout the BART system.

The results of the field test suggested that such applications may be an effective way to expand transit ridership and reduce vehicle miles traveled (VMT). However, the capital, operation, and maintenance costs of the system indicated that it had to operate at a scale that is significantly larger than the field test (50 spaces at one station) to recover system costs. Expanding smart parking to more stations would also have the added benefit of reducing the VMT generated by those riders who might be inclined to drive farther from the station closest to their home without smart parking to access the service at another station.

The current project, funded by Caltrans, was originally conceived as the next phase of this research: a smart parking pilot on a suburban commuter corridor (stations on the COASTER commuter line) in the San Diego area. At that time most of the stations on this corridor filled well before the final commute train departed, and ridership was clearly limited by station parking capacity. SANDAG approached researchers and Caltrans requesting that the project be located in San Diego on the COASTER line. It appeared that there existed strong institutional support for testing and evaluating a smart parking pilot. The larger scale of the project would also help researchers better understand the scale of economies necessary to operate elements of the smart parking program. Subsequently, SANDAG was awarded Value Pricing Pilot Project funds to expand the initial Caltrans funded pilot at the COASTER station.

Soon after the project officially began in the fall of 2006, researchers met with project partners and stakeholders to begin the design and implementation of the pilot and research plans. Key pilot project partners and stakeholders and their respective roles, objectives, constraints, and contributions are described in Table 2.1. After these initial meetings, it became clear that a significant effort would be required to obtain the necessary approvals from the NCTD Board of Directors to operate the pilot in the transit stations and to initiate parking pricing. General concerns were expressed about initiating parking charges at COASTER stations.

UC Berkeley researchers and SANDAG staff worked closely with NCTD staff to develop a proposal to take to the NCTD Board of Directors. In the summer of 2007 NCTD staff granted the research team approval to proceed with the smart parking project in a feasibility analysis phase, which included a literature review of parking management and pricing alternatives relevant to the pilot design (see 3.0 below), as well as an analysis of the general and station specific parking problems along the northern COASTER line (see 4.0 below). The staff also approved the installation of parking sensors at the six stations that would likely become part of the implemented pilot.

The SANDAG marketing staff developed a marketing and outreach campaign for the pilot in coordination with project partners, which was ultimately called QuickPark.

Table 2.1 Partners' and Stakeholders' Roles, Objectives, Constraints, and Contributions with Respect to the Smart Parking Pilot Project.

Partners & Stakeholders	**SANDAG**	**NCTD Staff & Board of Directors**	**Public or System Users**	**ParkingCarma™**	**Caltrans Headquarters & District 11**
Role(s)	Regional transportation planning organization.	NCTD operates the COASTER line. The Board of Directors includes representatives (e.g., mayors & council members) from jurisdictions along the COASTER line.	Customers.	Smart parking system operator.	Project funder & control over freeway right-of-way & CMS signs
Objective(s)	Improve the regional transportation system; Evaluating potential of local funding mechanisms for transportation projects; Local geography limits freeway growth; & Transit expansion key to meeting future regional travel demand.	Provide high quality transit service, increase ridership & control user costs.	Parking available when they want it at no cost.	Develop a viable business by establishing a foothold in transit & then expanding to other parking facilities.	Reduce highway congestion; efficient & safe operation of the transportation system.
Constraint(s)	Did not have direct control over NCTD parking facilities.	The Board of Directors must be responsive to local constituents who generally oppose fare increases & parking fees; & limited funding & resources.	COASTER costs are already high; auto dominant access mode to the COASTER stations & few feasible alternatives; & high cost of living in region.	Business model requires larger transaction volumes; typically start up operations without diversified funding streams & limited resources.	
Contribution(s)	Regional leader with strong institutional relationships; some influence over the funding of local transportation projects; expended significant resources to secure project approval; & marketing resources & expertise.	Approval by the Board of Directors necessary to operate pilot in station lots & to charge fees; staff assisted in the installation of the sensing network, access to wireless network points, and pilot signage.	If the supply of available station parking is limited, they may see value in the information services & be willing to pay for guaranteed parking spaces.	Typically able to get donations & significant in-kind project contributions.	State leader with strong local institutional relationships & some funding influence.

3.0 Literature Review

3.1 Parking Management Strategies

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 parking management strategies in downtowns, urban centers, retail, and employee parking lots. 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 (Shoup 2005). 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 (Merriman 1998).

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 (Merriman 1998). 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 (Ferguson 2000). 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 (Foote 2000; Turnbull et al. 2004). 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 (EPA 2006; Shoup 2005).

Typically, public transit agencies make parking investments according to simplified decision-making processes. The Washington Metropolitan Area Transit Authority (WMATA) in Washington, DC and the State of New York's Metropolitan Transit Authority in New York City have measured parking demand by projecting ridership and assuming a constant modal access share for drivers (WMATA 2008; MTA Metro-North Railroad 2005; Marchwinski et al. 2003). Often, transit agencies simply direct their investments to the stations with the most overcrowding (SANDAG 2002) or those stations where they wish to induce demand (New York MTA 2008). 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 (SEPTA 2007).

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 (Shoup 2005). 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 negatively affects 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 (Shoup 2004).

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 (Mass Transportation Commission of the Commonwealth of Massachusetts 1964). 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 (Marchwinski 2003).

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 (Decker 2007). 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 (Frank-Keyes 2007).

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 (Teodorovic and Lucic 2006).

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 (Nexus Properties 2008). 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 (MBTA 2008). BART's most recent pricing strategy offers separate options for carpools, long-term users, reservations, and valet services (BART 2008). Advanced parking management technology innovations could accelerate the further adoption of advanced pricing and management strategies by public transit authorities.

3.2 Advanced Parking Management Systems

Advanced parking management systems are technology and software tools that can be used to improve integration of separate parking operation elements and increase parking facility efficiency. Smart parking is the application of advanced parking management systems with a focus on the customer interface and service, for example, to help users with the location of parking, advance information on parking conditions, parking space reservations, and easy electronic payment options. The context of smart parking applications continues to broaden and now includes private parking facilities, central business district parking information systems, airport parking, street parking, and transit parking.

Advanced parking management systems allow for a more efficient parking experience for drivers as well as owner-operators of parking facilities with respect to enforcement, revenue management, and management data. Parking facilities that use advanced parking management systems can collect real-time parking space inventories which help the facility managers track the demand for parking (Federal Transit Administration 2007). Improved demand data allow parking managers to set more effective pricing policies, increase enforcement efficiency, and develop improved business strategies. Smart parking benefits drivers by saving search time, reducing parking uncertainty, improving parking decisions, saving money, preventing parking violations, and, in general, decreasing parking frustrations.

3.2.1 Advanced Payment Systems

Advanced payment systems are an important component of smart parking and can be central to quality customer service and experience. In this section, pay-by-phone, Smart Cards and Radio Frequency Identification (RFID), and In-Vehicle Meters are reviewed.

Pay-by-phone systems use automated answering machines or short messaging service (SMS) to allow prepayment of parking. Drivers use their mobile phones to wirelessly deposit money towards time in a parking space, and most systems can give users updates about remaining or expired time via SMS messages. Drivers usually must register their license plate and credit card information to use the wireless metering (Smith et al. 2003). Pay-by-phone systems have been widely implemented for paid street parking or surface lots because they require minimal up-front costs – mainly signage, advertising, and handheld devices for parking enforcement officers. The pay-by-cell method works within multiple parking zones, rates, and tariffs (Laufer 2007). Handheld devices give enforcement officers a list of license numbers that are paid within a given area. The officer then checks the plate of a vehicle against his list and writes citations for vehicles not on it (Parking Today 2005).

In West Palm Beach, launching pay-by-phone was a cost-effective alternative to replacing old street parking meters with expensive kiosks to offer users cashless payment options. Users dial the local number on the meter and enter the meter's identification number. When leaving, users merely dial the same number and press "one" to confirm their departure. Business owners supported this more flexible and convenient parking system that would not deter customers. The system allows the city to monitor individual space occupancy and revenue generation, to track users, and to check citation appeals against digital records. Users have signed up at rates well above initial projections (Olley 2007).

In Vancouver, Canada, and Seattle, Washington, Verrus Mobile Technologies Inc. provides pay-by-cell parking options. Adoption rates of the payment system is very high in both cities, with average utilization running at more than three sessions per week per customer (Podmore 2002). Vancouver integrated the system with its enforcement database that allows officers to check a vehicle's payment status, permits, and past citations, and to ticket or dispatch towing from a single device. The city records as many as 1,500 transactions a day with 20% of drivers using the pay-by-cell option. The system is already showing higher compliance rates and increased revenue (Yong 2007). Two London neighborhoods have fully replaced street meters with pay-by-cell technology to reduce collection overhead and combat theft of meters (Decker 2007).

Newer systems have improved performance and continue to introduce new features. Users can be notified if their parking request violates any parking restrictions, preventing unnecessary tickets and towings (Podmore 2005); they can also review their usage via online statements (Yong 2007). Because of improved communication with the customer, parking managers can more easily change pricing schemes, adjust parking zones, and manage permit parking. Pay-by-cell is ideal for open parking lots because there are no lines drivers must wait in to pay or receive a ticket; the transaction can be done while they are walking to their destinations. However, not everyone owns or will have a cell phone with them at the time they are parking. A phone might need to be placed in the parking lot for this option to be viable.

Smart cards allow drivers to electronically "load" money onto a card with an integrated circuit chip and then have the money debited with each use of the card. Smart card technology is highly secure and relatively inexpensive (Laufer 2007). Fee calculations are performed simply by reading and writing to data files on smart media with the smart card. This leads to large reductions in ticket consumption costs, major improvements in equipment and system reliability, significant decreases in field maintenance costs, as well as decreases in transaction times.

As part of the June 2004 launch of the SmarTrip card, Washington Metropolitan Area Transit Authority (WMATA) instituted cashless parking at all forty-two Metro stations with parking, and required every driver to purchase the five-dollar smart card. Every rail station is equipped with at least one smart card dispenser, but drivers can also buy smart cards online and in select stores. During the summer it was found that up to 50% of smart cards purchased for parking are bought by one-time users who must still pay the five-dollar surcharge to cover new cards' cost and handling. Many WMATA parking facilities have spare capacity on most days, and the smart card system deters low frequency users (Ashok 2006). Parking facilities at six pilot stations now accept credit cards in an attempt to accommodate these users (WMATA 2008).

RFID tags are another wireless payment technology that can be installed in a smart card, cell phone or in a vehicle, and typically serve as account numbers from a third party system responsible for billing and history (Dekozan 2007). There are two types of RFIDs, short-range and long-range wireless communication systems. Long-range RFID technology uses higher frequency radio signals and is more appropriate for long distance communication and for applications with high-speed transportation. The most promising form of long-range RFID is cellular-based parking technology like the Triffiq unit used in some Dutch cities. Upon parking, the driver turns on an in-vehicle device which communicates with the company's central system through the cellular network and with the enforcement officer's handheld device. The device offers the convenience of pay-by-cell with simpler enforcement (Mouskos et al. 2007).

Short-range wireless communication systems send the information from a transponder installed in the vehicle to an antenna reader – usually within 100 feet – to a data processing center. This type of system is being implemented as a parking payment system by the Port Authority of New York and New Jersey at Kennedy, Newark, and LaGuardia airports (Mouskos, Boile, & Parker 2007). Short-range wireless communication systems are most effective in parking facilities with a gated entrance, which typically ensures vehicles are within the radius of the antenna reader. The advantages of using RFID are that they are low cost and low maintenance and have simple operation. Radio signals assure no contact and can penetrate opaque structures.

The E-ZPass toll collection system has been installed at toll facilities throughout the Northeast U.S. and allows on-the-fly toll payment at freeway speeds. The system can also control access and payment at parking facilities and be used estimate a facility's occupancy without tracking every vehicle entering and exiting. An antenna reader must be installed at each entrance and exit, and the parking facility must have a server, landline or wireless communication, and a data processing center to use the E-ZPass system (Mouskos et al. 2007). Because each unit costs $25 to purchase and to open an account, the inconvenience and cost may preclude some drivers from participating, especially infrequent users. Both smart cards and RFID streamline transactions and save users time, while gathering valuable data. However, the two options require more investment, and can be impractical for open parking facilities requiring a more complex installation.

In-vehicle meters are typically an extension of smart card or pay-by-phone systems. When drivers pull into a parking spot they either use a smart card or mobile phone to pay for their parking. The in-vehicle meter communicates wirelessly with a centralized management system and allows for easy, visual parking enforcement similar to pay and display meter receipts ("Pay by Cell" 2008). Typically, the user must purchase the in-vehicle meter, which can be expensive even if subsidized. The higher user cost discourages adoption of the technology and is not practical for low frequency users, so the technology is more often implemented for commuter parking (Bergstrom 2005; "Pay by Cell" 2008).

The University of Wisconsin in Milwaukee launched a program that offers in-car meters to employees. This program gives employees the option to pay as they park in lieu of purchasing an expensive annual permit. Users lease the in-vehicle meters through the university, paying a $20 administrative charge and a $25 deposit. Drivers turn on the meter when they park and use a smart card to pay for the desired amount of time at rates between $0.40 and $0.50 per hour, about half the typical daily rate. The university created a new fine for users who fail to turn on their meters. Soon after the implementation of the program, it became apparent that the in-vehicle meters were more labor intensive for the office staff than annual parking permits. However, the program did successfully reduce parking lot overcrowding and improve the efficiency of parking usage (Bergstrom 2005; UW Milwaukee 2008).

In-vehicle meters allow price discrimination among user groups and promote more efficient use of parking resources through pay-as-you-go parking pricing. However, the technology is not cost effective for serving low frequency users. In vehicle meters can reduce enforcement costs, but the necessity of installing a redundant payment system for other users can easily offset the technology's benefits.

E-parking is an advanced parking management concept for off-street parking which brings together **parking reservation and payment systems**. The e-parking system relies on an electronic parking brokerage for parking providers. Drivers use their cellular phones, PDAs, or the internet to access the portal site and view available spaces and prices and then reserve a parking space based on their preferred location. The system confirms the reservation with the parking provider and provides the user with an access code. The car enters and exits the parking facilities using Bluetooth to open the barrier. Once the car exits the car park, electronic payments are made and the whole operation is registered on the brokerage site. (Hodel and Cong 2003)

The e-parking concept would benefit high-demand destinations with a fractured parking market with many suppliers. Centralized reservation systems promote more efficient use of parking resources. 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 (Shaheen et al. 2005). However, the system breaks down in markets like airports where the dominant parking supplier has little incentive to use the system. At overcrowded transit stations, e-parking could be an effective solution to encourage additional private parking supply by allowing private businesses and organizations to monetize their parking resources when they are not in use by patrons.

Parking information systems allows a driver to receive information on the availability of parking from the internet, mobile phone, PDA, or variable message signs on the road. Sensors or gates monitor the parking facility's occupancy, so parking space availability or forecast information can be updated regularly (Bannert 2002; US Dept. of Transportation 2007). Many parking information systems are integrated with reservation and payment systems for parking facilities. Information on parking locations, costs, space reservations, and restrictions helps users improve their travel decision-making and promotes more efficient use of transportation systems (Smith et al. 2003).

Cologne, Germany has one of the world's most advanced parking guidance systems. Stadtinfo (what is this?) monitors thirty-seven parking facilities with a totally capacity of about 17,000 spaces. The system gathers data from parking facilities and street meters and disseminates timely parking and other travel information to drivers via variable message signs, videotext, TV, and radio, allowing them to better plan their trips and to make better travel decisions. The system is integrated with a parking reservation system that allows users to book spaces in advance in garages around the city (Stadtinfo Cologne 2007). Parking information systems are an important component of any smart parking system communicating up-to-date system information to the public.

Many **parking companies** are deploying components of advanced parking management systems or comprehensive programs. Until recently, Europe and Japan have lead implementation of advanced parking management systems, but adoption of advanced parking management technology and practicing is accelerating in the U.S. Companies like mPARK, Verrus Mobile, New Parking and ParkMagic are spreading their pay-by-cell technology throughout the U.S. All of these companies use similar technology: the driver calls in, uses a credit card to pay for parking time, and then the information is forwarded to parking enforcement officers via their handheld devices (Olley 2007; The Space Race 2007; "Pay by Cell" 2008; Podmore 2005).

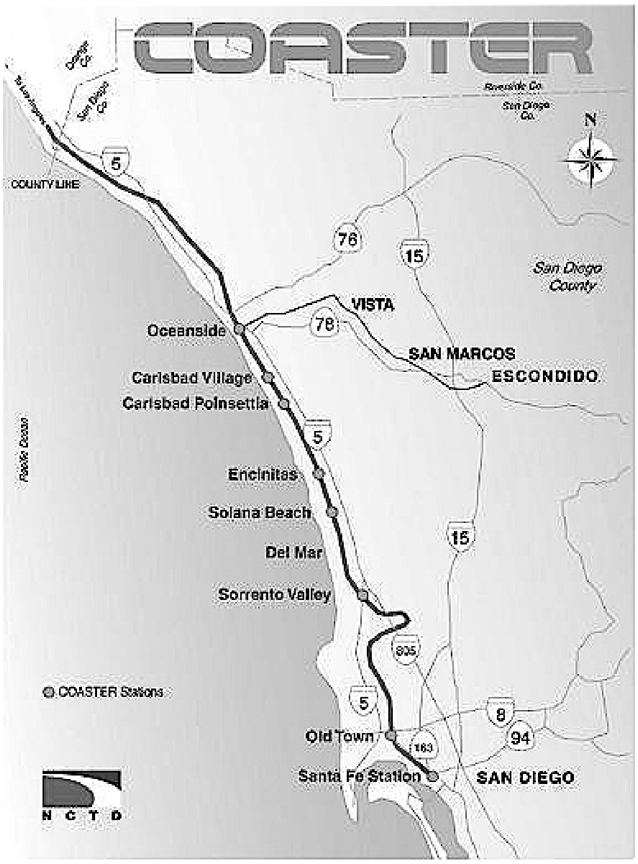
ParkMagic and Ganis Systems both manage in-vehicle meters. Ganis Systems' users pay with a smart card, and ParkMagic uses the pay-by-cell method. Neither system requires additional equipment for enforcement officers, and both claim to be low cost for the owner/operator of a parking facility (Pay by Cell 2008; Bergstrom 2005).

Streetline is partnering with the City of San Francisco to use sensor technology to update information on the availability of street parking spaces at a data center (Parking Management 2006). SIPARK is also using a similar technology concept to inform drivers of park facilities with empty parking spaces (Bannert 2002). MobileParking provides drivers both availability information and a parking reservation service (US Dept. of Transportation 2007). Pay-by-phone is the most common medium for transactions for all these services. With cellular phones nearly ubiquitous, drivers can use the same interface to receive parking information and to complete payment. Pay-by-phone systems save parking managers expensive infrastructure investments, allow managers to track individuals' behavior, and make use of a technology with which most drivers are already familiar and comfortable.

4.0 Problem Identification

An initial step in the development of the smart parking pilot along the COASTER line (shown in Figure 4.1) was a careful analysis of the parking at each of the six North County COASTER stations. These stations lie in various suburban contexts, sharing some common characteristics but diverging in many respects. Figure 4.2 provides a qualitative comparison of the station attributes.

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 (SANDAG 2002), 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, which were conducted in March 2008, contributed information about commuter perceptions about parking conditions at the four most crowded stations.



Source: NCTD

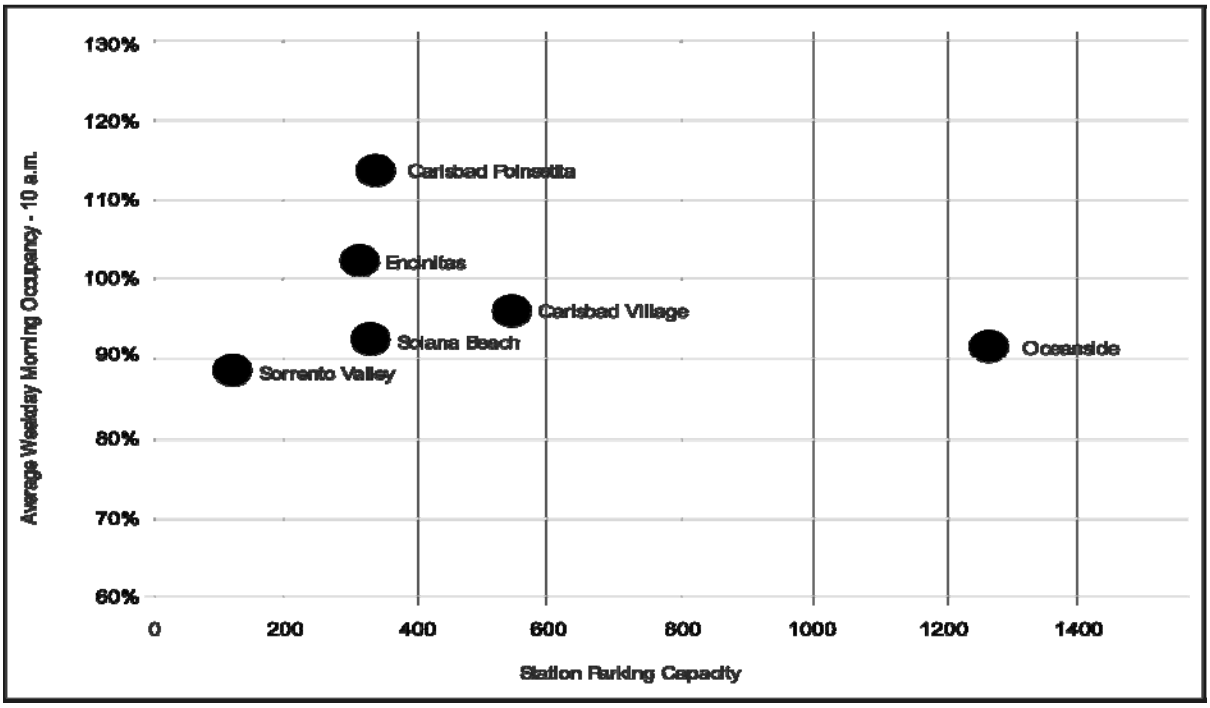
Figure 4.1 COASTER system map.

	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 4.2 Qualitative station characteristics.

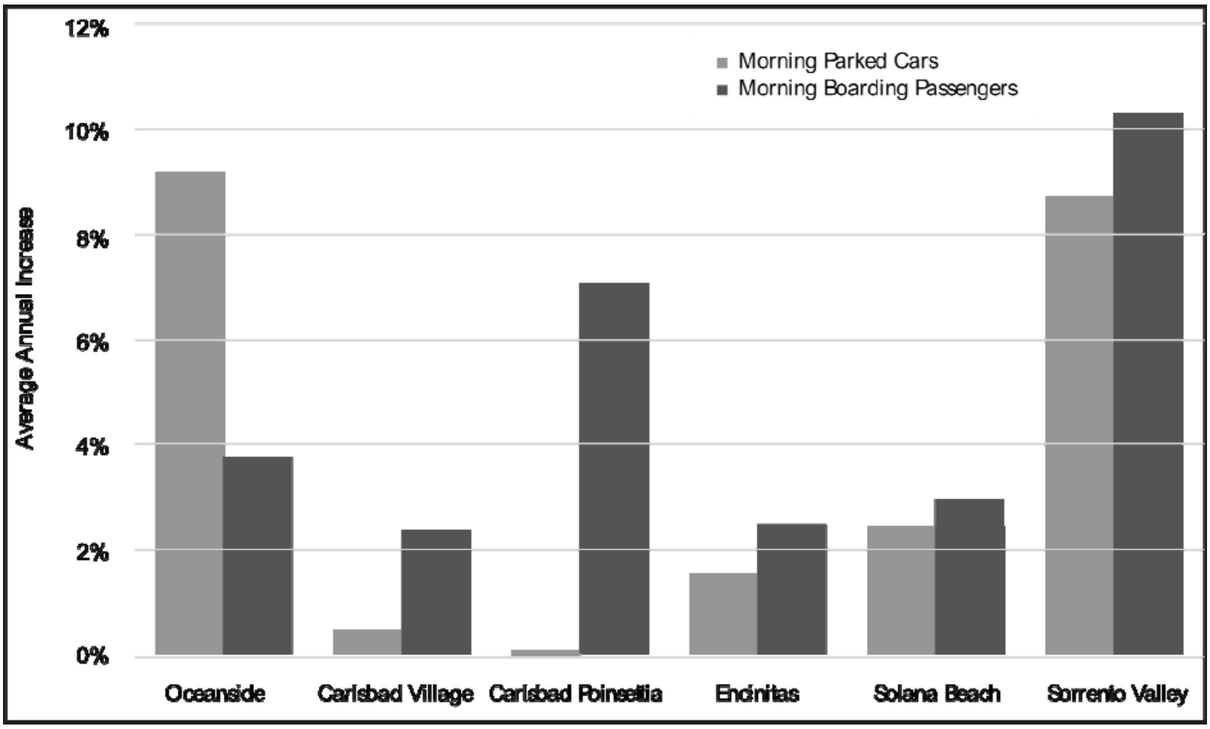
NCTD and SANDAG's parking and passenger data suggest that the system could benefit substantially from a parking management program: NCTD's and SANDAG's parking and ridership data show healthy average annual passenger growth of 4.7% since 2002, but overall only 1.1 morning passengers are generated per parked vehicle. This figure includes riders who use alternate access modes, and indicates that COASTER parking could be used more efficiently. Figure 4.3 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 4.3 Average weekday morning parking occupancy (June 2008).

As indicated in Figure 4.4, 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 4.3): 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 4.4 Growth in morning parking and passengers (2003 to 2008).

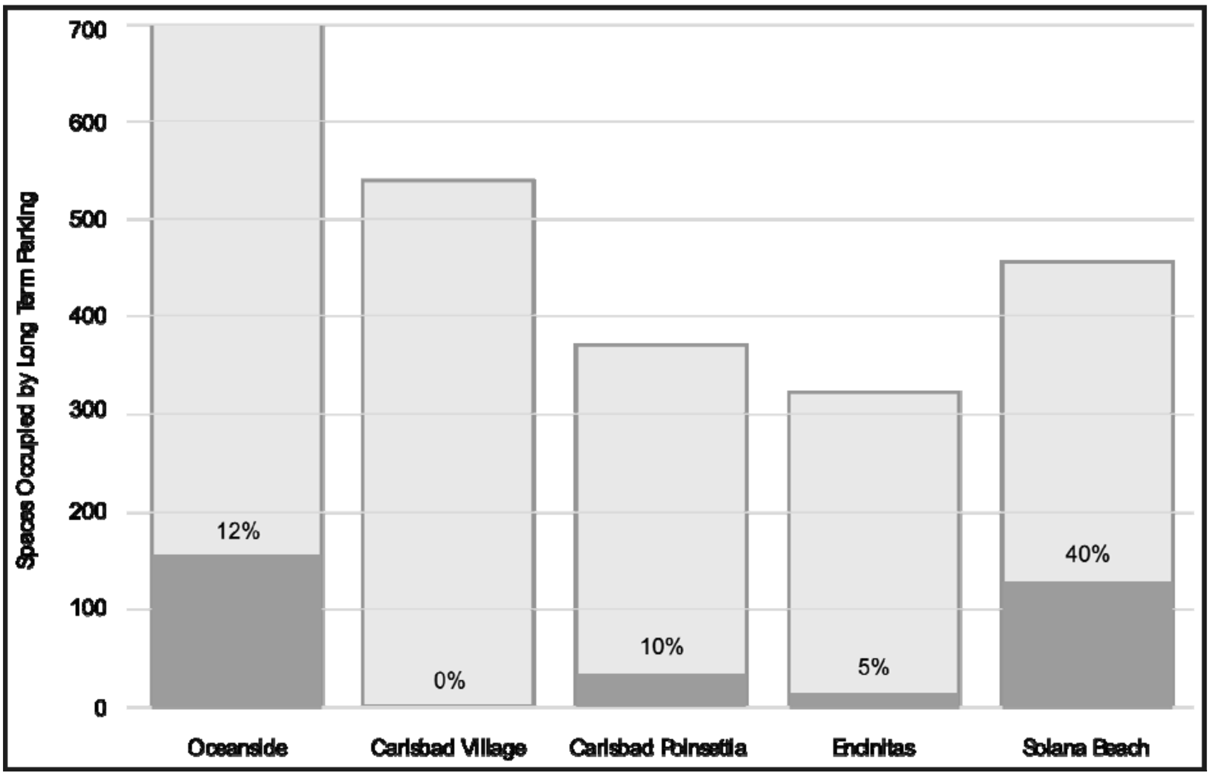
Currently, all COASTER parking is free and unmanaged with minimal signage. Observational analysis shows that long-term and non-transit users occupy from 5% to 60% of parking during commute hours. These are the primary user groups displacing daily COASTER commuters from overcrowded NCTD lots. When excess 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.

4.1 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 (Metrolink 2007), 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 (Caltrans 2007). Supplemental field observations showed large numbers of Amtrak and MetroLink riders use 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 (Wilson & Company 2006).

4.2 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 4.5 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 (SANDAG 2002) 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 affected 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 4.5 Long-term and non-public transit parking.

4.3 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 (Wilson & Company 2006). 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.

4.4 Parking Facility 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 (SANDAG 2002). 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 two 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 appeared to affect 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.

4.5 Sensor Performance

The data collected from parking sensors installed in entrance and exit lanes at the COASTER stations were compared to parking observations. A typical result is provided in Figure 4.6. At the time, it was determined that the sensor technologies installed in the COASTER parking lots could be used to indicate that the lots were full, had good space availability, and were filling up (e.g., red, green, and yellow indicators).

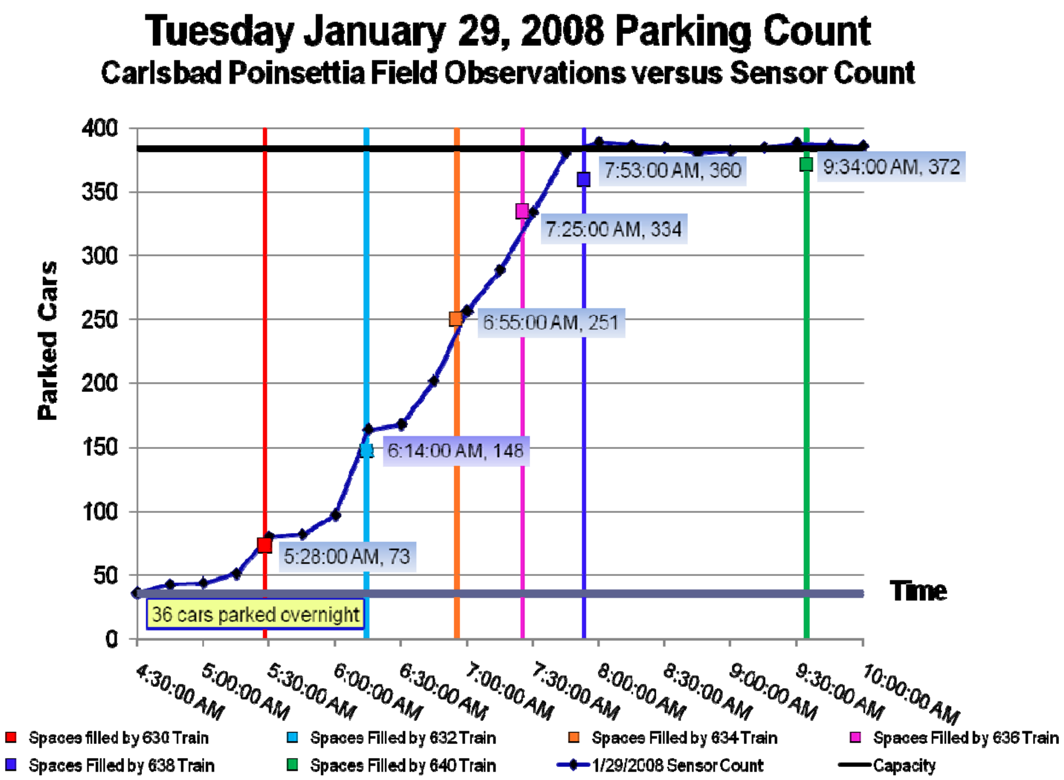


Figure 4.6 Example of Sensor Performance.

5.0 Proposed and Implemented Alternatives

The problem identification analysis and near-term parking management strategies to address those problems were presented to the NCTD staff and their Board in September of 2008. Table 5.1 provides a summary of the parking problems (by station) that were presented to staff and the Board. These problems included significant non-COASTER parking and overnight parking, which limited parking for COASTER riders in stations that were already filling prior to the departure of the last COASTER train. In some instances, COASTER riders were parking in unauthorized neighborhood spaces outside of the station lots. Table 5.2 summarizes the parking management strategies presented to NCTD as near-term alternatives and associated implementation issues. The near-term alternatives included strategies to (1) free up more space for COASTER riders by restricting non-COASTER and overnight parking, or to allow non-COASTER and overnight parking through fee payments; (2) generate more COASTER riders per parking space to encourage carpooling and vanpooling by providing preferential parking adjacent to the platforms; (3) attract new or more frequent daily COASTER riders by providing reserved paid parking, which would also be located in a preferential locations, and by providing information on the real-time availability of general free parking at the COASTER stations via the ParkingCarma™ reservation website.

These strategies would first be tested at the Carlsbad Village, Carlsbad Poinsettia, and Encinitas stations and then expanded to the remaining six stations. Enforcement of parking restrictions and parking fees would be provided as part of the pilot project at participating stations. Coaster riders parking in the lot would have to display a printed receipt or validation on their dashboards. Signs would be installed to increase awareness about parking restrictions in each lot prior to enforcement and charging for non-transit and overnight parking. Non-public transit users could use the general station parking during the day or at night for a higher daily fee. Those parking overnight would also pay a daily fee. Parking violators would receive written notices and repeat violators would be towed. See Appendix B for common definitions of smart parking; different operational concepts; and a map of the system's main functions for future reference and to establish requirements.

The NCTD Board conditionally approved the near-term strategies in September 2008, and project partners began working to implement the project. Partners worked with NCTD staff and the planning committee on details of pilot implementation.

Table 5.1 Summary of Station Specific Parking Problems.

	Non-COASTER Parking	Overnight Parking	Over-Capacity	Neighborhood Spillover	Lack of Enforcement
Oceanside	X	X			X
Carlsbad Village	X	X	X	X	X
Carlsbad Poinsettia	X	X	X	X	X
Encinitas	X	X	X	X	X
Solana Beach	X	X	X		X
Sorrento Valley	X	X	X		X

TABLE 5.2 Smart Parking Strategies and Associated Considerations.

	Community Spillover	Signage Required	3rd Party Enforcement Required	Leverages Parking Services	Compass Integration	Grant Funding Applicability*
Restricted Parking:						
Non-COASTER	X	X	X		X	
Overnight	X	X	X		X	
Restricted but Paid:						
Non-COASTER	X	X	X	X	X	X
Overnight	X	X	X	X	X	X
Enhanced Services:						
Carpool/Vanpool		X	X	X	X	X
Reserved Solo Spaces		X	X	X	X	X

*Eligible for funding under Caltrans and VPPP grants.

However, by this time it had become apparent that the U.S. was plunging into the deepest economic downturn since the 1930s: the San Diego region would soon be hit harder by the recession than the nation as a whole; the COASTER line faced serious fiscal deficits and was forced to raise COASTER fares; and COASTER ridership had declined significantly.

As a result, project partners began working with the NCTD staff and Board to develop a plan to take advantage of existing resources available for research and planning during the economic downturn to lay the foundation for future expansion once the economy turned around and demand for service returned to normal. During this period NCTD staff and the Planning Committee expressed concerns that COASTER riders would find it onerous to display proof of ridership, which was necessary for enforcement. Other issues were also raised about "equal" access agreements that the transit agency originally entered into with jurisdictions when they constructed the parking facilities. Station parking overcrowding also began to diminish. As a result, the implemented plan did not enforce restricted parking or implement paid parking for non-transit or overnight uses. However, the plan did include preferential carpool and vanpool parking, reserved paid parking services, and provision of parking availability information via the ParkingCarma™ reservation website. The pilot plan received final board approval in May of 2009 and was implemented in August of 2009 at the Carlsbad Village, Poinsettia and Encinitas stations. Researchers will return to the NCTD Board after three to six months to report on findings and, if appropriate, recommend expansion to three more stations. Parking availability information will soon be posted on the ParkingCarma™ website. See appendix B for a more detailed description of the implemented QuickPark pilot project.

6.0 Conclusion

The literature review for the San Diego smart parking pilot shows that public transit agencies are slow to adopt 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 of 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 current economic downturn and declining ridership provides a window of opportunity for pilot partners and NCTD to lay a solid foundation for future expansion of parking management programs by carefully evaluating the following issues:

1. Basic comparisons of the relative revenue projections generated from fare increases and from parking pricing management plans including their operation, maintenance, and capital costs. The next phase of the research will also address these issues.

2. A proof of ridership system that allows for cost-effective enforcement without inconveniencing riders; such a system would likely include recommendations for changes to the parking enforcement codes that disallow parking tickets and fines for parking in COASTER stations and only allows for towing.

3. Legal barriers to implementing alternative parking management plans on COASTER station parking lots (e.g., prior "equal access" agreements) and needed resolutions to these barriers.

4. Posting CMS messages on I-5 along the northern COASTER line informing drivers of transit departure times, station parking availability, and any downstream congestion delays. Fixed CMS are now installed on this section of I-5.

5. An expanded integration of smart parking information and reservations with San Diego's new 511 system, which provides real time information via phone and Web services on traffic conditions, incidents and driving times, and transit schedule, route and fare information.

6. Increased demand for COASTER parking, as the economy improves, and demand responsive adjustments (i.e., by time of day, day of week, and season) of reserved paid parking spaces and fee rates. The collection of this data would assist in evaluating revenue streams for alternative parking management plans.

7. Monthly reserved paid parking that meets the needs of commuters who have a monthly pass, but would like the convenience of arriving at the parking lot whenever they want.

8. The cost-effectiveness of implementing valet parking to expand lot capacity.

The next phase of the project involves expanded data collection to conduct a broader regional analysis of the cost-effectiveness of alternative parking management plans.

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Appendix A: Smart Parking System Analysis

California Center for Innovative Transportation

CCIT Task Order 1013: Transportation Deployment

Smart Parking System Analysis

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Prepared by:

Olga Amuzinskaya
Graduate Student Researcher, CCIT

JD Margulici
Senior Development Engineer, CCIT

For:

California Department of Transportation

Division of Research and Innovation

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

Contents

1 Introduction

1.1 Background

"Smart Parking" at rail transit stations designates a parking inventory management system that disseminates real-time parking availability information to the public and features a reservation system. It uses information technology to maximize existing parking capacity at and nearby transit stations, reduce trip uncertainty, and enable informed decisions by commuters. As such, Smart Parking leads to better land utilization and can potentially increase transit ridership along congested corridors.

Innovative Mobility Research (IMR), a group at the California Partners for Advanced Transit and Highways (PATH), started developing the Smart Parking concept in 2002, as part of PATH Task Order 5101. The IMR research encompasses an overall assessment of the concept in a transit environment, initial system architecture and design, and a Field Operational Test (FOT), the main focus being on commuters' response. The FOT was a limited implementation (50 spaces) of a Smart Parking system at the Rockridge BART station in Berkeley. It was operated for over a year starting in December of 2004, through a partnership between PATH, Caltrans, BART and private companies, including Acme Innovation as the system provider. The IMR research concluded that the Smart Parking technology was well received by commuters and that certain population segments were ready to pay for the added convenience offered by the service. The research also suggested that the technology had brought new riders to BART.

In the fall of 2004, the California Center for Innovative Transportation (CCIT) contracted with Acme Innovation as part of CCIT Task Order 5 to evaluate the scalability of the FOT architecture and identify design elements that may limit a full-scale deployment. This resulted in a report that outlines the factors influencing scalability of the Smart Parking system. The findings of this report will be directly applicable to a larger-scale deployment.

The next step in the Smart Parking program is likely to be a scaled pilot deployment to address the following matters:

- Validate the operational parameters of Smart Parking and define the functional and performance requirements;
- Determine technology elements for a scalable design;
- Assess the overall costs and benefits of deploying Smart Parking;
- Evaluate the public's response to the system on a larger scale than during the FOT;
- Overall, assess the marketability and feasibility of Smart Parking and derive lessons learned and best practices for future widespread deployment.

Deploying Smart Parking on a larger scale will answer pending research questions about system acceptance and actual costs and benefits. It will also constitute a significant showcase for further expansion and to encourage transit operators to follow suit. Specifically, the scaled pilot project findings will be documented to assist transit operators with deployment of their own Smart Parking solution. We presume that the main obstacles to deployment are: 1) uncertainty about the actual benefits, 2) complexity of the procurement process, and 3) reluctance to explore uncharted territories with regards to public acceptance and institutional partnerships. Following the scaled pilot, a deployment package, intended as a design and implementation handbook, would be produced to help public agencies overcome these obstacles.

Ultimately, Smart Parking is about better use of existing resources, and therefore benefits every actor in transportation. It can mean time savings and reduced stress for commuters, increased revenues and better management tools for transit operators, and reduced congestion on busy freeway corridors. By moving Smart Parking towards statewide deployment, Caltrans would be accomplishing two sets of goals. First, in its role as a statewide planning and regulatory agency, Caltrans would enable commuter choices and better land utilization. Second, as a freeway operator, Caltrans will be adding an additional demand management piece to its toolbox.

While there is a number of design solutions and technologies available for building a Smart Parking system, a general concept of operations needs to be established before the project's implementation can be discussed with main stakeholders. This report constitutes a system analysis of the Smart Parking model. Its focus is on defining general concepts of operations for a parking information and management system, and identifying high-level functional areas. As such, it targets both the scaled pilot deployment project and subsequent implementations. The system analysis presented in this report would become part of the Smart Parking deployment package.

The report utilizes the previous research in technology, institutional environment, and trends in transportation, demographics, and public demand for additional parking services in highly populated urban areas of California, such as the San Francisco Bay Area and North San Diego County. It also utilizes the expertise and knowledge that were generated by the Smart Parking FOT.

1.2 Report's Objectives

The goal of the Smart Parking system analysis is to provide a definition of Smart Parking, identify operational parameters and the corresponding usage scenarios, and decompose the system into a set of high-level functions.

In that, the Smart Parking system analysis:

- Provides a definition of Smart Parking that can serve as a common ground for dialogue among various stakeholders;
- Explores different operational concepts that have to be considered by the stakeholders;
- Offers a mapping of the system's main functions for future reference and to establish requirements;
- Identifies the key decision points that have to be factored into the system requirements before the design and implementation stage.

1.3 Definitions, Acronyms, and Abbreviations

CMS – Changeable Message Sign. These are either portable or permanent roadway luminous panels whose display can be updated remotely.

Detectors or **car sensors** designate any mechanical devices capable of detecting cars that pass at a given location. The sensors are either inserted in pavement or mounted off-pavement.

Gates refer to systems that prevent drivers from entering or exiting a parking lot. We distinguish between two options:

- A **Physical Gate** is a barrier that physically prevents motorists from entering or exiting the parking lot, usually until they provide either payment or a form of identification.
- A **Virtual gate** is a warning sign installed at the entrance of the parking lot. The sign can display the availability of parking spaces, or specifically warn that drivers should not enter.

The **Parking Inventory** is the collection of all parking spots in a parking facility or set of facilities.

A **Parking Lot** or **Parking Area** is a continuous array of parking spots, with defined entrances and exits.

A **Parking Spot** or **Space** is a marked location where a single car can park.

Segregated or **Divided Lots** are lots that can be adjacent to each other but are distinctly separate and have their own entrances and exits.

A **Sprinkled Parking Lot** is a lot that mixes parking spaces where different rules apply. Different types of parking spaces are usually distinguished by visual clues and signage.

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2 System Description

2.1 Definition of Smart Parking

For the sake of this analysis, Smart Parking is defined as a parking management system that provides real-time information to the public about the availability of parking spaces at designated lots. Information is disseminated through the internet, an IVR phone server, and Changeable Message Signs (CMS) on nearby roadways. Smart Parking offers membership for repeat users. An option for advanced reservation is a preferred feature, although we did not make it mandatory.

The context of the analysis is parking at transit stations. In this context, Smart Parking carries a strong inter-modal component, attempting to lure drivers away from their cars and towards transit.

The system relies on traffic sensors to detect cars that enter and exit the parking lot areas. In some cases, sensors could be installed into individual parking spaces, but the current costs make this solution prohibitive for parking lots that are not highly profitable and do not have a very high customer turnover rate.

Smart Parking is particularly intended to work with personal mobile devices. The system then allows users to find available parking, make reservations, and execute payment transactions “on the go”. Technologies such as RFID and smart cards can also be used to make the users’ interactions with the system even more convenient, fast, and cost-efficient.

In addition to providing services to the public, Smart Parking has the potential to significantly improve parking lot operations. The operator can enjoy real-time occupancy information, streamlined enforcement, customer relationship management, and detailed reporting. Conceivably, Smart Parking may be combined with value pricing and yield management, taking into account such dimensions as customer segment, car occupancy, and current parking demand.

2.2 System’s Stakeholders

The system has several distinct classes of stakeholders:

- **Users** are the parking customers, who are ideally looking for a guaranteed parking space when they arrive at a lot. The Rockridge BART FOT has identified the following dominant characteristics for Smart Parking users:
  - Busy professionals
  - Highly educated
  - Usually have families
  - Often have children
  - In their mid-20’s and up
- The **Parking Lot Owner** owns the land where parking is located.
- **Parking Lot Operator and Employees**
  - The **Operators** is the organization that operates and maintains the parking facilities

and the parking management system.

  - **Attendants** are employees of the parking lot operator who are responsible for the day-to-day management of the parking lots, including parking inventory monitoring, space allocation and fee collection.
  - **Enforcement Personnel** have the specific duty to issue warnings or citations to motorists who violate parking rules.
- The **Transit Operator** is a provider of public transit, such as a commuter rail.
- **Neighbors** are residents, property owners, and businesses in the areas surrounding the Smart Parking lots.
- The **Metropolitan Planning Organization** (MPO) is the regional transportation planning and coordination authority, such as MTC in the San Francisco Bay Area and SANDAG in the San Diego region.
- The **Roadway Operators** usually own the right of way needed for CMS. They may be State DOT such as Caltrans, counties or cities.
- **Caltrans** is also the research sponsor and the California state DOT. Caltrans has an interest in encouraging transit development and modal shift.
- **Enforcement and Judicial Organizations** such as Police Department and Courts may be impacted by the Smart Parking system in so far as it modifies the parking rules and their enforcement.

Although those roles are logically distinct, one organization or individual may assume several of them.

2.3 Stakeholders Benefits

This section describes the potential benefits to the stakeholders. Although the Rockridge BART FOT established some benefits from empirical data, this section only looks at the benefits from a conceptual angle and does not rely on hard evidence.

- **Users** will receive new services in the form of parking availability information and an opportunity to reserve a guaranteed parking space "on the go." From their standpoint, the primary benefit of Smart Parking will be reduced uncertainty and time savings. On the con side, a new parking management model may require users to adjust, which will inconvenience some of them. The implementation of a new system may also be accompanied by increased parking fees, although this is, strictly speaking, independent from the system itself.
- The **Parking Lot Owner** may be able to realize cost savings on operating expenses and boost revenue by increasing parking lots' utilization.
- **Parking Lot Operators and Employees**
  - The **Operator** may, like the lot owner, benefit from reduced cost and increased revenues.
  - **Attendants** may be able to monitor availability and better serve users. On the other hand, their job would likely be eliminated as a result of parking management

automation.

- **Enforcement Personnel** would probably see significant changes in how they carry out their work. Depending on the operational scenario that is selected, their workload may vary.

- The **Transit Operator** may be able to increase ridership by attracting new customers and augmenting loyalty. Parking availability information and the convenience of advanced reservation would raise the overall level of service. An added benefit may be in the revenues generated by the Smart Parking fee-based services.
- **Neighbors** of the Smart Parking lots:
  - **Residential neighborhoods** that are some distance from the train stations may benefit from the improved public transportation parking services. On the other hand, the neighborhoods that are directly adjacent to the parking lots might be concerned about the increase of automotive traffic if the parking usage intensifies.
  - **Businesses** surrounding the parking lots and the train stations may benefit from the inflow of park-and-ride commuters into the area.
- The local **Metropolitan Planning Organization** will benefit from modified commuting patterns consistent with their objectives to reduce road congestion and encourage transit ridership.
- The **Roadway Operators** will benefit from reduced road traffic. On the other hand, they may incur added responsibility from managing roadway signs to inform motorists.
- **Caltrans** will benefit by fulfilling its policy objectives. The organization bears part of the R&D costs but is ultimately benefiting from the knowledge gained through research and the implementation of the concepts in various localities.
- **Enforcement and Judicial organizations** may see a shift in their workload resulting from different behaviors and violations, although it is hard to predict how that would play quantitatively.

The benefits come at the cost of implementing, advertising and operating the system. Moreover, each Smart Parking project runs a risk to be rejected by one of more groups, in which case the project would backfire and the benefits would not be realized. Proper execution and outreach are key mitigating factors.

2.4 Technologies

The technologies involved in Smart Parking implementation include the following categories and items:

- Vehicle sensors: Vehicle detection devices are placed at each entrance and exit of the equipped parking lots. The sensors count vehicles in and out of the lot to keep track of current utilization.
- Dynamic signage: Dynamic signage is a key feature of Smart Parking, enabling real-time information dissemination to nearby roadways. Such signs can be posted on freeways and arterials. Changeable signs may also be employed in the parking lots to display current availability, and potentially guide drivers to open spaces.

- Identification and transaction technologies: One of the convenient features of Smart Parking is the possibility to setup an account and to use personal mobile devices to initiate transactions. While most operators will elect to keep a cash payment option on the premises, there is a wide array of technological options to choose from for premium users. These include mobile phones, RFID tags in the vehicle or as a key fob, smart cards, etc. Ideally, Smart Parking can make use of existing electronic payments such as FasTrak or TransLink in the Bay Area, or the Compass card in the San Diego area.
- Enforcement tools: Real-time parking information can profoundly modify enforcement methods. Certain lots may be restricted to registered users only, with access being controlled by either a physical gate or a non-intrusive identification system such as an RFID tag reader or a license plate recognition camera. Enforcement officers may be able to use the information to patrol more effectively, targeting only those spaces where no valid transaction has been recorded. Personal Digital Assistants (PDAs) may be loaded with software that provide real-time information to enforcement officers.

These technologies are linked together by Smart Parking management software and appropriate communication interfaces.

2.5 Existing Implementations

This section provides some examples of how technological tools are currently used to in parking management and information systems solutions. The list presented here is not comprehensive of all systems currently deployed in the parking industry. The examples were chosen because they showcase the use of technology to create innovative parking services.

Acme Innovations: ParkingCarma

ParkingCarma is the brand name of the Smart Parking system designed by Acme Innovation. This technology was used for the Rockridge BART FOT. It utilizes sensors to monitor and manage the inventory of available parking spots in each covered parking area. The company offers services through its web site and voice IVR system, but the services can also be ported to a third-party web site. The current implementation relies on cell phones as the primary transaction medium. Acme's strength is to provide customer-friendly interfaces to motorists to reserve and pay for parking, while also taking care of the back-end for system operators.

Park-by-Phone

Similar to ParkingCarma, the company provides both parking reservations and payment services for registered users via cell phones (but does not seem to rely on voice processing). Once they find a parking space, customers are required to call the system via their cell phones and provide their stall number and user id. This debits an account that gets invoiced monthly. Park-by-Phone is promoted by Clancy, who also manages parking reservations for BART.

BART Advanced Parking Reservation System

The advanced reservation system allows users to make reservations at some of the BART's parking lots. Three different programs are implemented: monthly reservations, daily reservations, and long-term parking at the San Francisco airport. The daily reservations program is the most recently implemented feature and is essentially an off-shoot of the Smart Parking FOT. The transaction is conducted online and generates a confirmation permit page that customers print and display on their front windshield. Reserved parking is contained to specific marked areas in the lots.

VehicleSense Inc.

The company developed parking management software that allows lot operators to monitor the availability of parking spaces. The system is integrated with wireless magnetic sensors and parking meters to detect vehicles and relay the data in real-time. The current system addresses street parking management but the company is also developing the SmartLot parking system for use in parking lots.

Spark Parking

Spark Parking is a newly formed start-up company that uses wireless sensors for individual parking spots or in small sub-sections of a parking lot to track utilization and direct drivers to empty spaces. Parking payment transactions are handled by their mobile phone payment service.

3 Operational Concept and Parameters

3.1 Introduction

In this chapter, we describe the fundamental operational concept underlying Smart Parking. The operational concept consists essentially in the interactions between the users and the system. How other stakeholders operate the system is, for the most part, a consequence of the end-user model.

Beyond the basic premise to provide real-time parking availability, there are a number of operational parameters that will affect the user's experience. In order to describe Smart Parking operational concepts and their consequences for the users and operators, we need to identify the distinguishing characteristics that make one high-level system design solution different from another. Those characteristics, and how they can be adjusted to modify Smart Parking operations, are presented in this chapter.

In general, operational parameters are mutually interdependent. For instance, if specific spaces are allocated for reserved users, the inventory is not managed in the same way as if all spaces are shared among users. This, in turn, would affect how users complete parking transactions. After examining the core concept and reviewing the operational parameters, we present four high-level Smart Parking scenarios based on select combinations of the operational parameters. The resulting versions of the Smart Parking operational concept can be used by stakeholders during the planning and design stages.

3.2 Core Concept

The specific context of the Smart Parking concept is parking at rail transit stations. In the absence of information, commuters may make one of two sub-optimal trip decisions:

1. They may drive to work rather than ride public transit and get to their destination cheaper and faster. This may be because they simply never consider transit as an option. Or they may fear that parking will not be available, either by lack of knowledge or because of past experience.
2. They may drive to a public transit station only to find that no parking is available. This means wasted time, efforts and gasoline getting off their commute route and looking for parking, with the result of having to drive anyway.

Clearly, the second event feeds into the first one. Commuters who have unsuccessfully looked for parking more than a few times may simply never try again.

Smart Parking uses ITS technology to provide real time parking availability information. The information is broadcast through the internet, a phone system and roadway signage. Moreover, Smart Parking lets customers create on-line accounts that they can use to simplify parking transactions. Such accounts can be made even more convenient by associating them with technologies such as smart cards or RFID tags that streamline the check-in process.

The real time information addresses both sub-optimal trip decisions described above. Parking availability will attract drivers that either did not know much about their transit option, or drive by fear of not finding parking. Likewise, commuters exposed to the system will no longer waste time driving to lots that are already full.

A major feature of Smart Parking is reservations, although it seems to us that it is not strictly part of the core concept (an agency may decide to provide real time information without offering a reservation option). With reservations made up to a few days in advance, commuters may experience an even more convenient and reassuring trip.

Based on these premises, we can derive the following underlying assumptions:

(A) Categories of users

We can distinguish between the following types of parking users:

- Non-registered users are casual, anonymous users who do not have an account.
- Registered or premium users have a Smart Parking account. Consequently, they may also use an advanced identification technology such as a smart card or RFID tag.
- Reserved users are registered users who have reserved a parking space on the day where the show up at the lot.
- By comparison, both registered and non-registered users that have not reserved are referred to as drive-in users.

These categories of users may come in addition to other categories depending on local parking rules. At BART stations, for instance, users may be entitled to permanent reservations.

(B) Car counting

The use of traffic sensors at the entrances and exits of each lot is assumed in all the operational scenarios in this analysis. The use of RFID tags may make sensors unnecessary in some implementations, but this is a marginal case. Some parking management systems rely on sensors that monitor individual parking spaces. However, this is a much more expensive proposition, and is therefore not considered.

The core interactions between the users and the system are as follows:

(1) The user gets information about parking availability.

The user's interactions with the system begin when they either request or receive information about parking at a train station. For example, a user can request this information from the transit agency website. The parking availability information can also be delivered to drivers struggling with traffic via a CMS or a text message.

(1bis) The user may make a reservation.

If the system provides parking reservations, a user can reserve a spot either on-line or on the phone. The Smart Parking either grants a parking permit or denies the reservation if no space is available for a particular time. If the reservation is denied, the system can provide information about alternative parking spaces in adjacent train stations' parking lots. Unless the reservation is free, the user is then requested to pay a fee. The reservation is then associated with a unique identifier: this can be a reservation number, a personal cell phone number, a smart card, an RFID tag, etc.

(2) The user drives to the parking lot. Their vehicle is detected by a traffic sensor as they enter the lot.

The traffic sensor simply records passing vehicles entering the lot. The detection event is sent to the parking management system, which updates the inventory of available spaces accordingly. Note that we are not making any assumption about whether access to the lot is regulated or not, an operational parameter that is presented later in this chapter.

(3) The user locates an empty parking space in the lot and parks.

Here, we do not assume anything about the parking rules, or whether spaces are differentiated are not. Similarly, we do not distinguish between a reserved or non-reserved user. Such specific rules are part of the operational parameters discussed later in this chapter. The assumption here is that the user finds an available space based on prior knowledge about availability.

(4) The user validates their transaction.

Registered users who have set up an account may identify themselves with the means provided by the system, such as:

- Using their cell phone to confirm that they have parked, by either calling or sending a text message.
- Scanning their Smart Card or RFID key fob at a kiosk.
- Scanning their RFID tag at the parking entrance (in this case, the transaction is chronologically concurrent with step 2).

Unregistered users can make a transaction in one of the following ways, depending on how the system is set up:

- Using their cell phone and credit card, or send a paid SMS.
- Use a cash machine or kiosk in the parking lot or in the transit station.
- Pay at the entrance of the lot, if access is controlled (in this case, the transaction is chronologically concurrent with step 2).

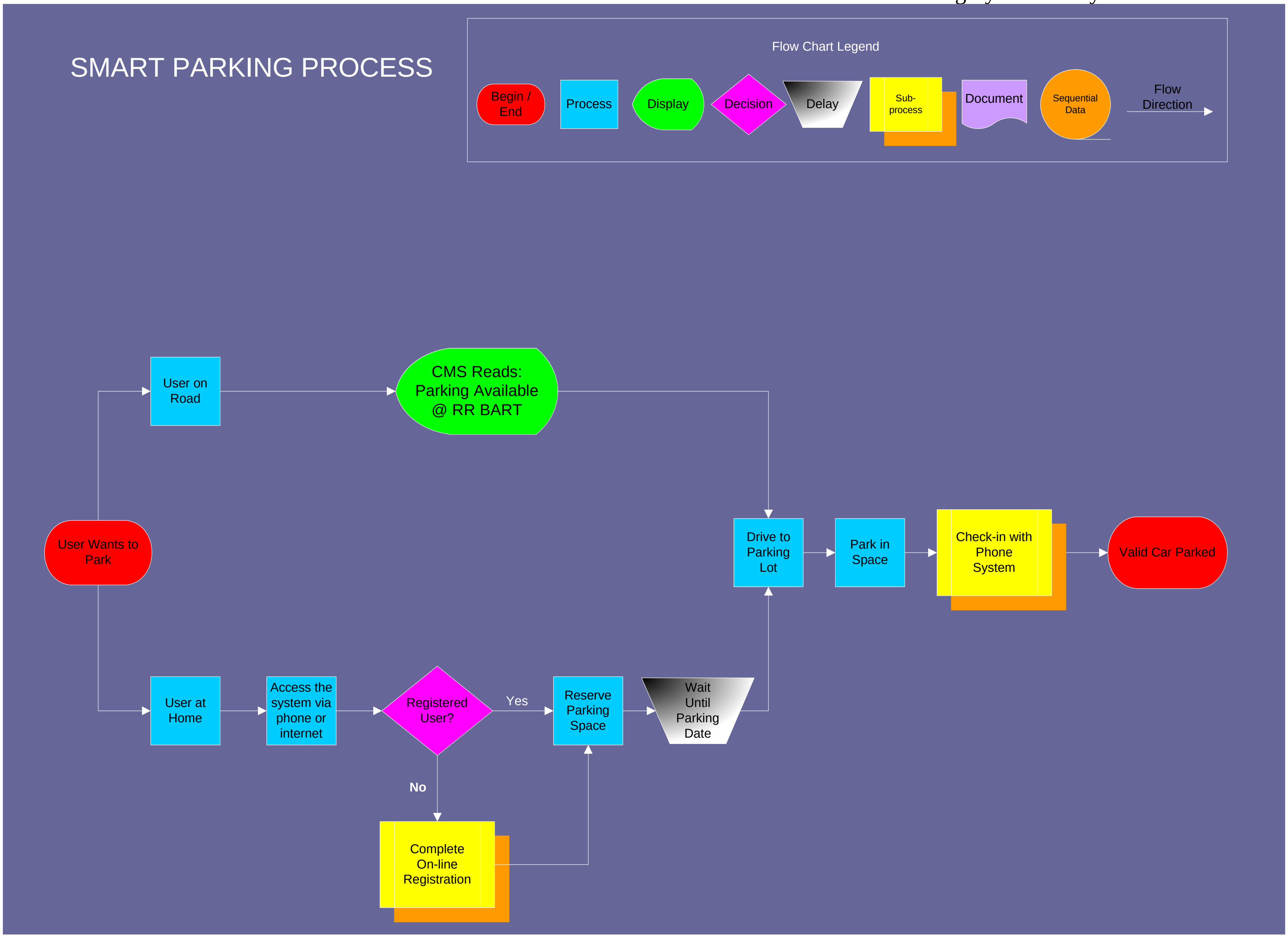
The various options outlined above are a mix of different operational concepts and technology choices. These options are sorted out in the section describing operational parameters.

(5) The user proceeds to their transit trip. Upon their return, they go back to their car and drive out of the lot. A traffic sensor detects the car as they leave the lot.

The detection event is transmitted to the parking management system and used to update the inventory of available spaces.

Figure 1 is summarizes these interactions in a concise flow chart. It is based on the Rockridge BART implementation but focuses on the core process described above.

Smart Parking System Analysis



3.3 Operational Parameters

Following the description of the core concept, we now delve into some of the specific parameters that affect user interactions and overall system management. As can be seen from the following list, some of the parameters can result from deliberate choices by the system stakeholders, while others (e.g. the layout of the lots) will probably be existing conditions.

For each parameter that was identified, we attempt to provide a definition, a list of alternative options, and suggest the operational consequences of these options.

1. **Reservations**: In so far as the possibility to reserve a parking space in advance is considered an optional feature of Smart Parking, whether or not to offer it has important implications for both the user experience and the system management.
2. **Parking hours and regulations**: In general, hours of operations and local parking rules, whether inherited from the past or entirely new, will affect the design of the system. Key questions include:
    a. <u>Hours of operations</u>: The Smart Parking management system has to consider whether lots are open 24/7 or only at certain hours. Overnight or multiple-day parking options have to be factored in.
    b. <u>Usage</u>: Specific rules may apply to determine who can park and under what conditions. Transit agencies may want to insure that only transit patrons use the lot. Yet, such rules may be dependent on the day of the week or time of the day. Also, there may be legacy users to take into account. At BART, for instance, there is a monthly reservation program in place.
    c. <u>Fees</u>: Whether or not fees are collected is obviously a key decision. If that is the case, rules may vary widely. Fees may be collected on a daily or hourly basis. In the latter case, it implies that the duration of stay is tracked for each user, which may severely complicate the transaction process. In addition, only certain hours of the day may be paid while others are free. The current rule at certain BART lots, for instance, is to charge a flat daily fee which is waived for arrivals later than 3pm.
    d. <u>Reservation rules</u>: Reservations give users the possibility to adjust their arrival time without having to worry about space availability. However, reservations result in a number of "no-shows". From a parking revenue standpoint, this is mitigated by the fact that fees are collected ahead of time. But for the transit agency, a space that remains empty is a lost customer. A possible measure is to overbook, as is done in the airline industry. Alternatively, or in addition, the parking operator may also open unclaimed spaces after a set grace delay. This implies that specific rules need to be developed to that end. Such rules have to be considered in conjunction with other lots regulations, and parameters such as space differentiation and lot layout described below.
3. **Parking Spaces Differentiation** and **Lot Layout**: Spaces differentiation and lot layout are among the most important operational factors with regards to parking rules and their implementation. Spaces differentiation refers to the physical allocation of parking spaces according to types of users. Differentiation can be implemented with markings of different colors or signage for different types of spaces. In some cases, lot operators may even resort to segregated lots. Lot layout precisely refers to the physical and logical organization of parking spaces when differentiation is employed.

Spaces differentiation is most critical when it comes to holding reservations. If a specific set of marked spaces is kept for reservations, the reservable inventory is fixed. The system becomes less flexible: if the inventory is too high, some spaces will go unreserved and cannot be used by drive-in users; if on the other hand the inventory is too low, the reservation feature is not exploited to its full benefits. The other possibility is to not differentiate. If that is the case, other mechanisms have to be placed to hold reservations, such as using stall numbers. This approach can be hard to implement and less readable for users. Yet, the advantage is the possibility to dynamically allocate reserved spaces, thus not constraining the supply.

In the end, there are five options available to stakeholders. The first option is common use spaces. A single category of spaces is employed. Reservations are managed dynamically.

The four other options basically combine two differentiation schemes and two possible layouts. The differentiation can be either:

a. Two categories: in this scheme, we distinguish between drive-in spaces and reserved spaces.

b. Three categories: three different types of spaces are allocated for non-registered users, premium users and reserved users.

And the layout possibilities are:

a. Segregated lots: two or more completely separate parking areas with independent entrances are allocated to different users.

b. Sprinkled lot: a single lot with one common entrance and differentiated spaces that are distinctly marked.

4. **Access Control**: Access control refers to the mechanisms regulating access to and exit from the parking lots. Access control may be used as a way of enforcing payment, as is the case of most gated lots. But besides, it is usually desirable to discourage drivers from entering a lot if no spaces are available. This will enhance the user experience while limiting undue traffic in the lot. Overall, up to four options can be outlined:

    a. Open lot. There is no access control in this case. This was the option used for the BART Rockridge FOT.

    b. Entrance gate. The gate prevents free access to the lot. Premium or reserved users may enter by using a smart tag or a registration code. For non-registered users, this option is equivalent to a conventional gated lot. They may have to get a ticket or pay at the gate. This presents some clear disadvantages because it can slow down access considerably. Moreover, gates are easily vandalized.

    c. Virtual gate. A virtual gate is basically a mechanism to bar access to the lot without a physical implement. A virtual gate may be implemented by requiring payment upon entrance of the lot. In this scheme, premium users may be able to dash through if they are equipped with a Smart Tag, while non-registered users may still have the option of a cash or credit card machine. Another implementation of a virtual gate may be to display counts of empty drive-in spaces on dynamic signs, with the understanding that access may only be allowed if spaces are available. This will divert most drivers and spare them the time and emotional distress of having to look for an empty space.

d. Exit gate. An exit gate is needed to enforce payment when parking fees are charged by the hour. In the majority of parking lots at commuter train stations, users are expected to leave their cars for the whole day and are charged a daily rate. It is unlikely that Smart Parking scenarios would require exit gates, but this is dependent upon parking rules and policies.

5. **Transaction Methods**: Whether the parking lot has fees or not, parking transactions need to be actuated each time a space is occupied. Transactions can be recorded by different methods as outlined below. Where and when the transaction takes place is determined, to a large degree, by the physical lot layout and access control decisions.

   a. No transactions. The system may rely solely on sensors to keep track of parking utilization. This method does not allow either fee payments or reservation tracking, although fees may be collected separately from the Smart Parking management system.

   b. Cell phones: With cell phone transactions, users call a designated number to inform the system that they are parked. For premium users, the call charges a registered account. For non-registered users, payment may be processed with a credit card.

   c. Premium SMS: This method is gaining traction, especially in Europe, for small payment transactions. The user sends an SMS from their cell phone, and their cell carrier account is charged accordingly. The carrier then transfers the money back to the parking operator.

   d. Smart card: Smart cards can be conveniently used to pay for small amounts against a set account. In the context of Smart Parking, smart cards are ideally shared for both parking and public transit transactions. Payment can be collected at a kiosk or a pole installed at the parking entrance.

   e. RFID Tags: Similar in concept to a smart card (which can in fact be using RFID technology), an RFID tag may be conveniently used by premium users. The RFID tag may be an in-vehicle device such as a toll tag reader, or a more personal device, such as a key fob.

   f. Home-based transactions: Reserved users will usually pay directly from their home, using the internet or a phone system. However, this method may also be implemented for premium users that are granted unlimited access for a set period of time.

   g. Payment machines / kiosks: Traditional payment machines accepting cash and/or credit cards will most probably be needed to guarantee continuity of service to non-registered users or low-tech citizens.

6. **Enforcement Methods**: The mechanisms set to enforce the parking rules will depend in large part on the access control and transaction methods. Technology may bring significant changes in how enforcement is conducted. For instance, depending on the transaction methods employed, the system may have information on each space supposed to be occupied at a given time. If that is the case, enforcement officers may limit their inspection to those spaces that should not be occupied. Different parameters may be listed as follows:

   a. Cross-referencing: Cross-referencing refers to verifying the association between a vehicle and a parking space as a legitimate transaction. This implies that vehicles can be identified. Identification may be enabled by a permit as described below, or by the vehicle's license plate. The operational question is whether transactions have to be associated with a specific stall number for enforcement purposes. If that is the case, the Smart Parking system can consequently track utilization of individual spaces, which will facilitate enforcement. However, this places an additional constraint on users who need to declare their space number and it complicates system management to a certain extent.

b. Permits: Reserved users, premium users, and even non-registered but valid users may identify themselves by displaying a permit on their dashboard. This provides an easy visual check for enforcement purposes. However, this may not be needed if 1) access to the lot is only granted to valid users or 2) the system keeps track of space utilization in real time. In the latter case, the system may still not be able to pinpoint latecomers who park in a previously occupied space.

   Premium users may be given a somewhat permanent permit. Reserved users can print out a permit from their home computer, the method currently employed at BART. Non-registered users could be delivered a permit when they actuate their parking transaction. This necessarily means that kiosks have to be installed.

c. Personal Digital Assistants: PDAs may be given to enforcement officers in some cases so that they can benefit from the real-time information that the Smart Parking system provides. Officers in the field may then be able to cross-reference occupied spaces with users in real-time, without having to resort to cumbersome print-outs.

3.4 User's Interactions with the Field Operational Test

The Rockridge BART FOT serves as an illustration of the operational parameters described in the previous section. The experimental system was provided and operated by Acme Innovation under the brand ParkingCarma. It implemented the core concept of Smart Parking, with sensors tracking vehicles in and out the lot. Two Changeable Message Signs were placed along California State Route 24 to display real time parking availability. Acme Innovation set up a web site and an IVR phone server, and ran customer service. The experimental nature of the FOT was evidenced by the fact that only 50 spaces were included in the management system. Those 50 spaces were restricted to an area inside the larger lot reserved for monthly parking permit holders.

The BART FOT had the following characteristics with regards to the operational parameters:

1. **Reservations**: Daily reservations were enabled through the ParkingCarma web site. The inventory of spaces available for reservation represented about a third of the lot.

2. **Parking hours and regulations**: Except for first-time use, only registered users were allowed to park in the Smart Parking lot. The Smart Parking regulations applied every day until 10am, after which access to the lot became unregulated. This is consistent with rules in the larger monthly-reserved lot. Registered users received a windshield sticker to identify themselves.

   Daily reservations were available to registered users, with a limit of 3 reservations per 2-week period.

   In the first months of the FOT, both reservations and drive-in parking were free. Starting in the summer, BART started charging a $1 premium for Smart Parking daily reservations. Soon after, however, this became the rule for the whole parking lot at the Rockridge BART station.

3. **Space Differentiation** and **Lot Layout**: Within the Smart Parking lot, spaces were not differentiated between drive-in use and daily reservations. In theory, nothing prohibited drive-in users to fill the lot before all reserved users have arrived. This rarely happened in practice, and the real-time updates on the freeway CMS prevented that to some extent. In the few occurrences when the situation did arise, holders of daily reservations were allowed to park in the monthly-reserved section.
4. **Access Control**: The Smart Parking lot was marked but physically unrestricted. Unauthorized use was prevented by displaying ParkingCarma signs along with the lot regulations. As mentioned in the Space Differentiation item, no mechanism deterred registered users to start filling spaces held for reservations.
5. **Transaction methods**: The primary transaction method was the use of cell phones. Both drive-in parkers and daily reservation holders signaled their arrivals by calling the IVR phone system and spelling their license plate and their stall number. Registrations and reservations were processed on the ParkingCarma web site. Users printed a reservation permit delivered by the web site on their home computer.
6. **Enforcement methods**: Enforcement was conducted by BART parking enforcement officers as part of their routine control of the Rockridge monthly-reserved lot. All registered users carried a ParkingCarma windshield sticker to facilitate enforcement. Enforcement officers wrote down license plates of first-time users and violators, which could be differentiated by the Smart Parking management system.

3.5 Proposed Scenarios

Off the six categories of operational parameters laid out in section 3.3, **Lot Layout** and **Access Control**, along with the **Reservations** option, were determined to have the most conceptual significance. By contrast, the **Parking Hours and Regulations** are a more detailed feature, and the **Transaction** and **Enforcement Methods** are more technology-driven. As a result, we complete the analysis by further describing four scenarios that mix different settings of those parameters. Scenarios 1 through 4 are laid out along the Lot Layout and Access Controls dimensions in Figure 2.

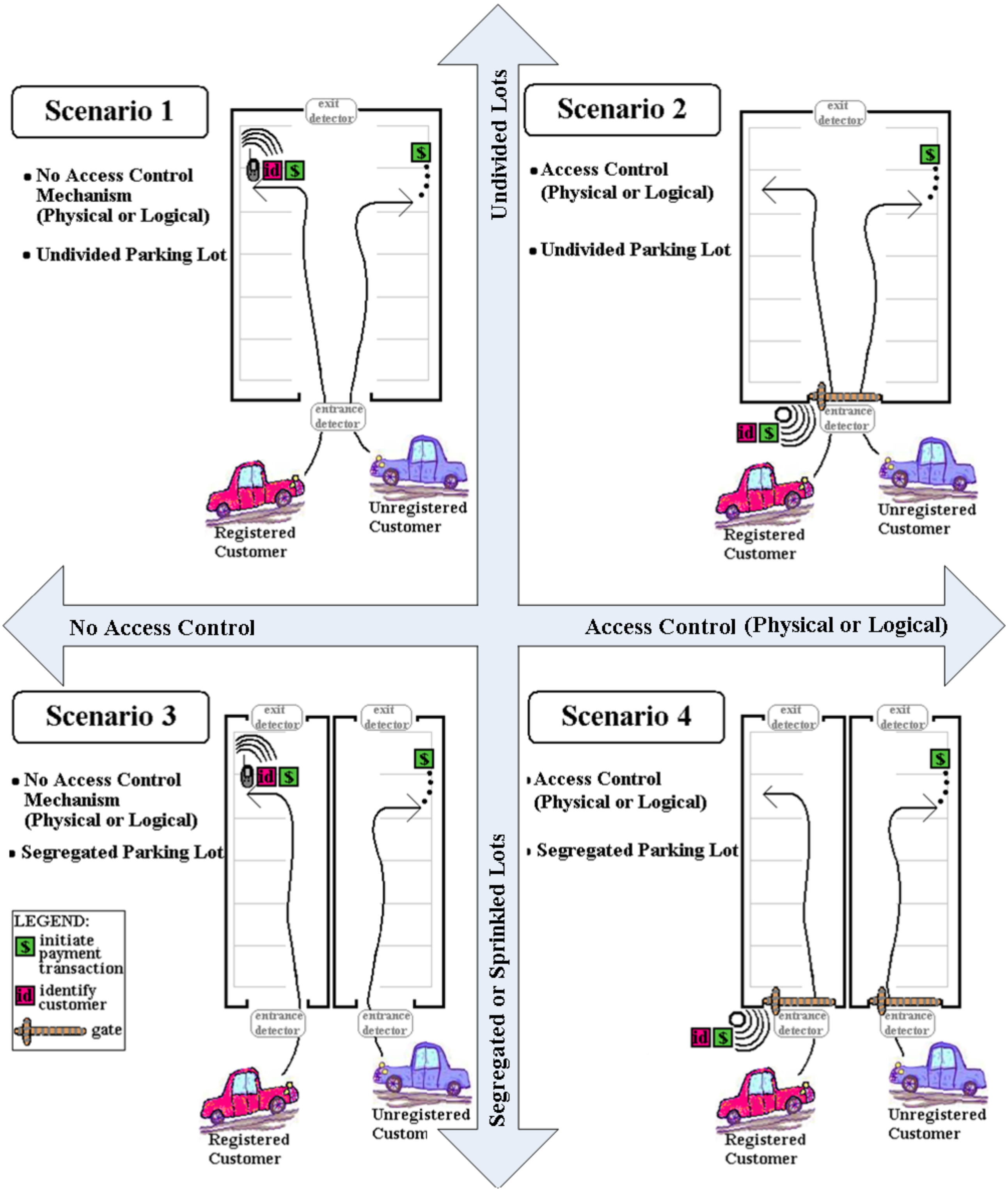
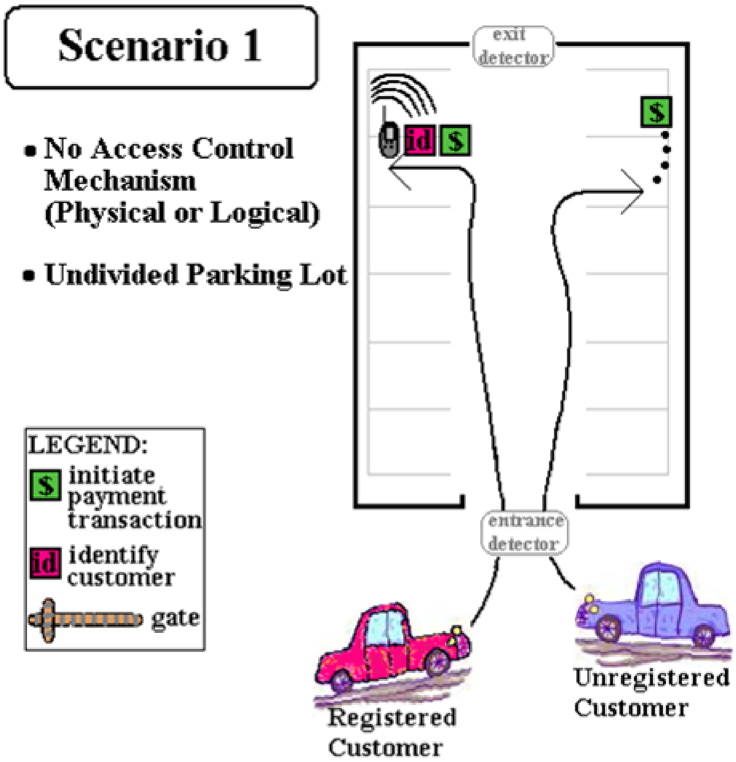


Figure 2 - Selected Smart Parking Scenarios

Two versions exist for each of the scenarios 2, 3, and 4, based on whether they feature **Reservations**. The reservations are not provided in scenario 1 because proper implementation of the reservation service should rely on some form of control to preserve empty spots for reserved users.

Each scenario is a base upon which further variations can be constructed based on the choice of **Transaction Methods** and other parameters. Flowcharts of the user interaction model for each scenario are presented in Appendix A.

Scenario 1: Undivided Lot, No Access Control



Scenario 1 - Schematic

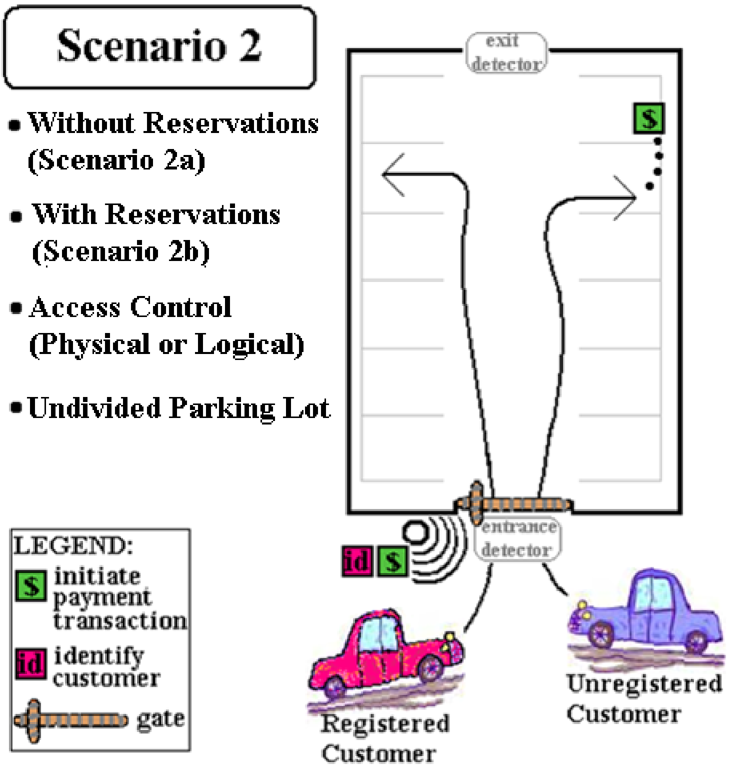
Scenario 1 - Operational Parameters

1.	**Reservations**	Not possible.
2.	**Parking Rules**	Undetermined.
3.	**Lot Layout**	Undivided, undifferentiated.
4.	**Access Control**	None other than parking rules.
5.	**Transactions**	See below.
6.	**Enforcement**	Undetermined.

Scenario 1 - Transaction Methods

Registered Users	**Unregistered Users**
• Mobile device • RFID / Smart Card • Online transaction with printout	• Payment machine in the lot

Scenario 2: Undivided Lot, Access Control



Scenario 2 - Schematic

Scenario 2 - Operational Parameters

1.	**Reservations**	Optional. Scenario 2a features no reservations. Scenario 2b features reservations.
2.	**Parking Rules**	Undetermined.
3.	**Lot Layout**	Undivided. Reserved spaces can be sprinkled or differentiated, with varying consequences on access control and transactions management. For example, if the lot is undifferentiated, a warning sign at the entrance can display: "No spaces remain for drive-in users" as soon as the only empty spots left are for reserved users. The payment machines can be configured to deny transactions drive-in users at that point.
4.	**Access Control**	Yes, physical or virtual gate.
5.	**Transactions**	See below.
6.	**Enforcement**	• Physical gates prevent unauthorized access. • Virtual gates can be combined with payment machines that are configured no to sell tickets to unauthorized users. • Parking enforcement personnel.

Scenario 2 - Transaction Methods

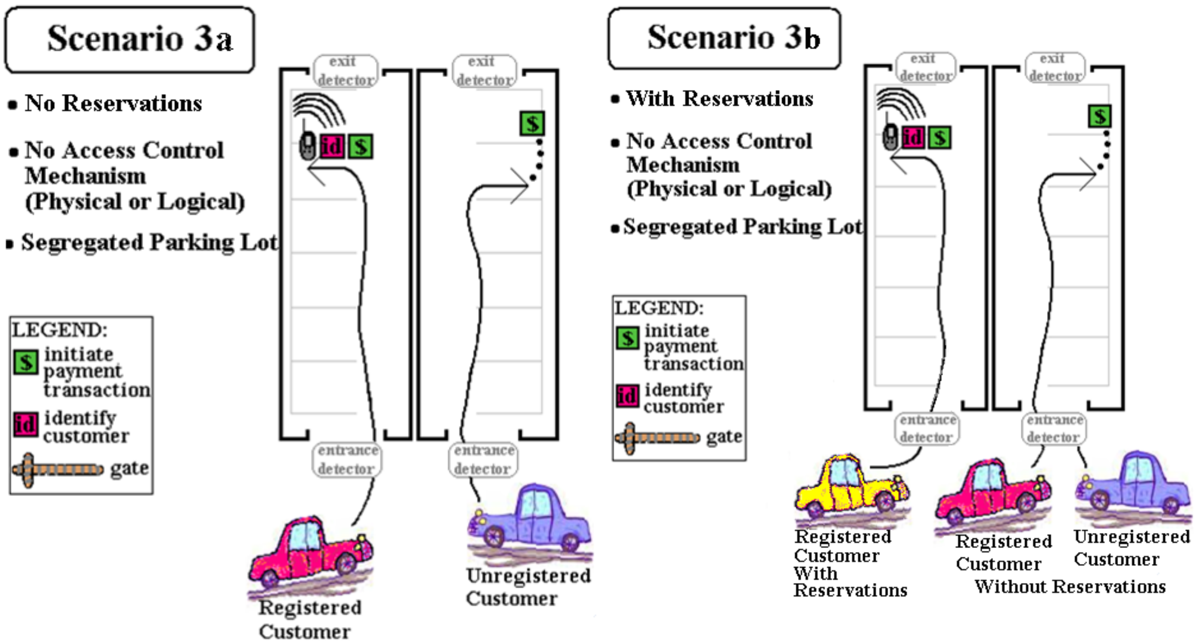
Registered Users	Unregistered Users
• RFID / Smart Card • Mobile device • Dialed code	• Payment machine at the entrance • Payment machine in the lot

If **physical gates** are used to control the access to the parking lot, RFID/smart card technology is recommended for registered users identification and transaction over the use of personal mobile devices. They provide a convenient medium for granting access to the lot.

The use of the warning signs at the entrance is recommended in combination with the physical gate, to prevent motorists from attempting to enter the lot when there are no spaces left.

If **virtual gates** (i.e. warning signs at the entrances) are used to control the entrance access to the lot, then personal mobile devices and RFID technology can be considered as equally convenient.

Scenario 3: Divided Lot, No Access Control



Scenario 3 – Schematic

Scenario 3 - Operational Parameters

1.	**Reservations**	Optional. Scenario 3a features reservations. Scenario 3b features no reservations.

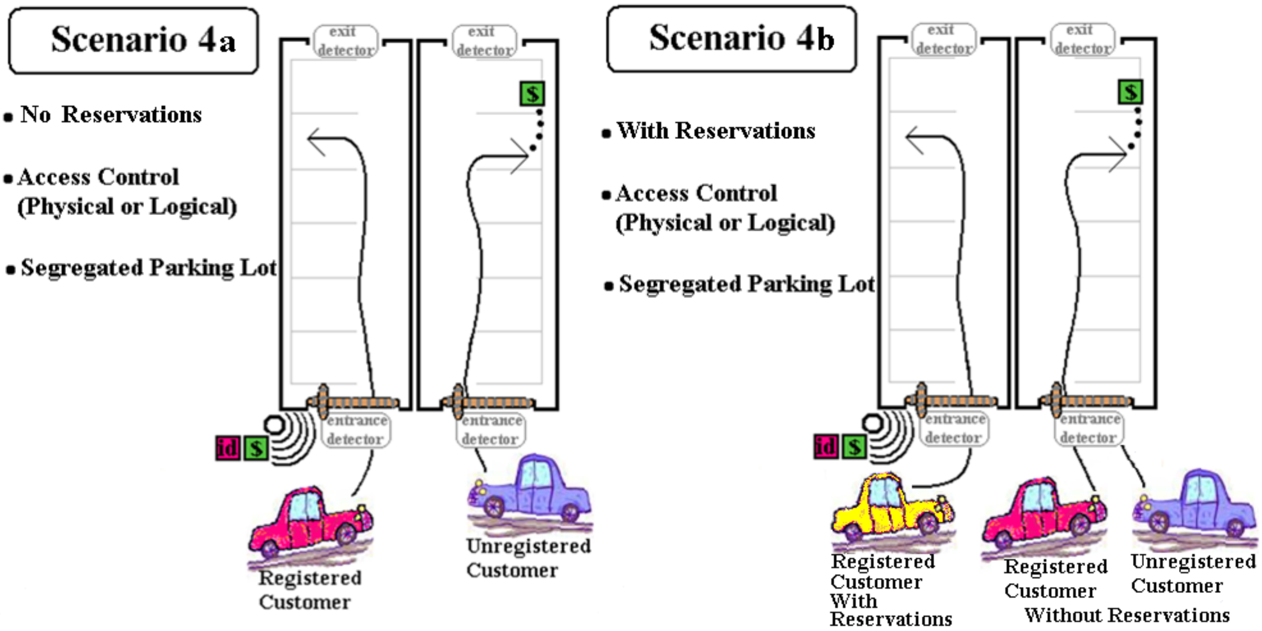
2.	**Parking Rules**	Undetermined.
3.	**Lot Layout**	Divided lot: • In Scenario 3a (without reservations), the lot is segregated into two areas for registered and unregistered users. • In scenario 3b (with reservations), a lot can be segregated into two areas like in scenario 3a, or into two areas for reserved and non-reserved users.
4.	**Access Control**	Parking rules only.
5.	**Transactions**	See below.
6.	**Enforcement**	Undertermined.

Scenario 3 - Transaction Methods

Registered Users	**Unregistered Users**
• Mobile device • RFID / Smart Card • Online transaction with printout	• Payment machine at the entrance • Payment machine in the lot

The model of user's interactions with the Smart Parking system for this scenario is mostly similar to the core concept. In the case of a sprinkled parking lot, users are required to park in the appropriately marked spaces.

Scenario 4: Divided Lot, Access Control



Scenario 4 – Schematic

Scenario 4 - Operational Parameters

1.	**Reservations**	Optional. Scenario 4a features reservations. Scenario 4b features no reservations.
2.	**Parking Rules**	Undetermined.
3.	**Lot Layout**	Divided lot: • In Scenario 4a (without reservations), the lot is segregated into two areas for registered and unregistered users. • In scenario 4b (with reservations), a lot can be segregated into two areas like in scenario 3a, or into two areas for reserved and non-reserved users.
4.	**Access Control**	Yes, physical or virtual gate.
5.	**Transactions**	See below.
6.	**Enforcement**	• Physical gates prevent unauthorized access. • Virtual gates can be combined with payment machines that are configured no to sell tickets to unauthorized users. • Parking enforcement personnel.

Scenario 4 - Transaction Methods

Registered Users	**Unregistered Users**

• RFID / Smart Card • Mobile device • Dialed code	• Payment machine at the entrance • Payment machine in the lot

The model of user interactions with the Smart Parking system for this scenario is generally similar to the core concept. This scenario combines elements of both Scenarios 2 and 3. In the case of a sprinkled parking lot, users are required to park in the appropriately marked spaces.

If **physical gates** are used to control the access to the parking lot, RFID/smart card technology is recommended for registered users identification and transaction over the use of personal mobile devices. They provide a convenient medium for granting access to the lot.

The use of the warning signs at the entrance is recommended in combination with the physical gate, to prevent motorists from attempting to enter the lot when there are no spaces left.

If **virtual gates** (i.e. warning signs at the entrances) are used to control the entrance access to the lot, then personal mobile devices and RFID technology can be considered as equally convenient.

4 System Functions

The previous chapter dealt with the operational concept of Smart Parking and the interactions between the system and its users. This chapter delves into a description of the system itself as a set of interconnected functional modules. There are many design solutions and various technologies, both time-proofed and recently emerging, that can be used to implement a Smart Parking system. Yet, the fundamental functions of the system are invariant and each Smart Parking solution must include at least some of the following functional modules presented on Figure 4.

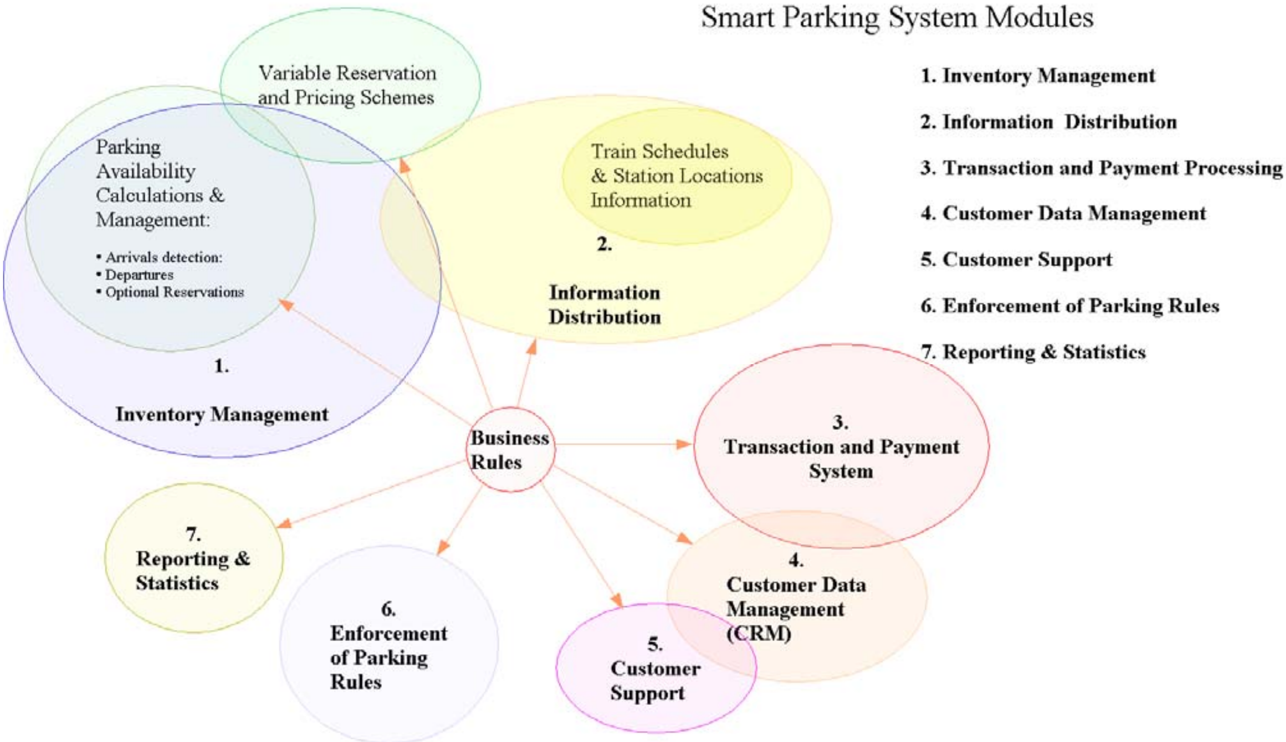


Figure 3 - Smart Parking Functions

As shown on Figure 4, the relationships between the functional modules are driven by the system's business rules, which originate from the operational parameters of the Smart Parking implementation. The following sections describe the functional roles of each module of the system.

4.1 Inventory Management and Inventory Pricing

The role of the Inventory Management module is to keep track of the number of parking spaces that are **available**, **occupied** or **reserved**. The Inventory Management module turns detection events and transactions into real-time information regarding parking availability, possibly using prediction algorithms.

Optionally, this same module can implement variable pricing based on business rules and dynamic information regarding parking facilities, time of day, parking duration, type of parker or parking space, etc…

4.2 Information Distribution

The Information Distribution module is responsible for information delivery to users through a variety of channels. Information may include:

- Real-time parking availability;
- Parking pricing and programs information;
- Stations and parking lots information;
- Train schedules and trip planning tools.

As described in the previous chapter, distribution channels may include internet web sites, SMS- and Web-enabled hand-held devices such as cell phones and PDAs, highway signage, satellite radio, and automotive navigational displays (such as GPS). Ideally, Smart Parking information system should be tightly integrated with existing transportation information systems, such as regional 511, trip planners and highway CMS.

4.3 Transaction and Payment

This module encompasses the transaction and payment methods as well as their processing. Transaction processing should provide for accounting and distribution of fees through a linkage to financial institutions.

From a system integration standpoint, the transaction and payment module may often be the most difficult piece to implement. Revenue generated from parking fees may be shared between the lot operator, the lot owner, the transit agency and the Smart Parking system provider. The core concept does not prescribe how such revenues should be split and who should collect the fees. Legacy system and existing regional payment initiatives such as FasTrak and TransLink in the Bay Area present both opportunities and risks: while they may provide a readily-available transaction infrastructure, they will impose their own set of constraints.

4.4 Customer Management

At a minimum, this module holds a user database that stores and maintains data about the system's users. In addition, the Customer Management module can manage user accounts, keep track of user transactions, and implement Customer Relationship Management (CRM) functions, such as communications and direct marketing.

4.5 Customer Support

The Customer Support module is a set of services providing assistance to Smart Parking users. Assistance may be needed with parking operations and with information systems (e.g. web interfaces). The Customer Support module should be primarily comprised of online assistance and a phone hot line, which can be partially automated through a voice IVR system. Operators are needed for assistance that cannot be automated and to resolve conflicts. These days, customer support can be outsourced rather than setup from scratch.

4.6 Enforcement

The Enforcement piece of Smart Parking is enacted by supplementing the enforcement officers with tools and information available from the system. Enforcement is responsible for monitoring the parking rules and regulations and issuing tickets when these rules are violated. Enforcement also requires setting a mechanism to let users contest tickets, and legal recourses against violators who do not pay tickets.

4.7 Data Gathering and Reporting

The Reporting module is responsible for gathering business intelligence data about the system. Such data is essential to parking lot owners and operators to keep track of operations. The implications are financial, operational and commercial. Proper reporting should therefore be available to the relevant authorities. More elaborate systems may enable user-input queries and custom reporting.

5 Parking Management

5.1 General Objectives

5.1.1 Meeting the growth in the nation's transportation demand

With the continuous growth in population, demand for transportation increases. Transportation systems are expected to provide services that meet the growth in demand.

5.1.2 Expanding Service area and service frequency

Both service area and frequency require expansion for larger-scope service. However, more does not always mean better; hence, careful management and an optimized use of resources are of primary importance.

5.1.3 Upgrading current transportation systems

From all aspects (cost, land use, environment…), building new facilities has progressively become a non-popular resort in the world of planning. A more desirable approach consists of upgrading the already-existing transportation systems, so that they are managed and controlled in a way that would enhance their services both in quantitative and qualitative terms.

5.2 **Parking Pricing and Fees**

While considering any instauration or even alteration of parking pricing and fees, it is of utmost importance to take into account the traveler response to changes in level, structure or method of application of parking fees. In fact, elasticity of demand with respect to pricing is a crucial parameter to be accounted for. In other terms, the travelers' willingness to pay for parking services or even he segmentation of the different travelers according to many sub-categories would all be ways to evaluate and sort of qualitatively predict the reactions vis-à-vis parking pricing and fees. The benefits that would be collected from the fees should *not* be counter-balanced by decrease in parking demand (if the fees go beyond the travelers' willingness to pay for parking for example).

There are Actions that can change the costs to users or parking even without fee changes. Among those actions, we cite the following:

- Elimination of Employer parking Subsidies
- Fee structures that differentiate by modes of parking (short vs. long term parking)
- Differentiation by modes of travel (drive-alone vs. ride sharing)

On another hand, the Effects of Parking pricing are linked to the effects of parking supply. Also, parking pricing is frequently accompanied by other strategies.
The Effects of parking pricing are felt and identified in traveler responses reported for multimodal strategies, transit strategies and land use alternatives.

The concept of elasticity of demand with respect to pricing and fees is of key importance:

- How travelers respond to both the introduction of parking pricing and fees?
- How do travelers respond to changes in the level and structure or method of application of parking fees?

5.2.1 Purposes of Parking Pricing and Fees

- Parking facility owners/operators: to cover costs and earn a reasonable return on investment. This should be balanced with the desire to attract shoppers and employees.
- Prices are influenced by competition in the private market based on the law of supply and demand
- Prices may also be manipulated by public agencies in order to realize public policy objectives.

5.2.2 Alteration of the level/distribution of parking prices: several objectives

- Passing along the actual [market] cost of parking from provider to user
- Differentiating prices among different users to achieve economical, strategic and/or policy objectives
- Reducing the incidence of private vehicle trips, VMT, and the need for parking spaces associated with private vehicle travel
- Price of parking may be used to influence travel choice by altering the cost of private vehicle travel; its attractiveness relative to travel alternatives including transit.

5.3 Policy objectives

In line with policy objectives (i.e. the objectives set by the planners), Effective implementation of parking pricing is required. For example, one policy objective may be to reduce the number of vehicle-miles traveled (VMT). Another policy goal can be Promoting Transit Use.

Therefore, depending on the goals set before the deployment of any system or any alteration/change in the current configuration of a given system, the implementation of the project, or in other terms the managing direction of the system, should put into perspective the general goals and main aims of the policy planners.

A pricing scheme that would favor a reduction in VMT would be one that gives advantage to HOV vs. SOV for example.
On another hand, a management pattern that would help in promoting transit use should make the park-and-ride facilities much more efficient, and thus much more "attractive" for the travelers.

5.4 Perspective: Economists

The optimum parking fee per unit time should be equal to the Marginal Cost of providing a parking space (parking cost and availability are closely tied to vehicle usage and roadway congestion)
Parking fees have been suggested as an alternative to roadway pricing
Parking fees can be an effective instrument to influence commute travel, but parking may have limited/perverse effects on congestion

5.5 Concern: Economical Dislocation

When setting parking fees for policy purposes, there is a potential to trigger shifts in the locations of trips themselves and with them the economical opportunity that trips represent, leading to economical dislocation.

5.6 Types of Parking Pricing Strategies

- Fee Increases and Decreases (overall rates in area changed from pre-existing level for all users)

- Short vs. Long-term fee differentials: fee structure typically shaped to favor long term vs. short term use, to eliminate discount rates which attract commuters, and preserve parking capacity for shoppers/ other non-commuter purposes

- Elimination of Employer Parking Subsidy

- Employee SOV vs. Rideshare differential (SOV vs HOV; reward rideshare)

Output data (typical), communications

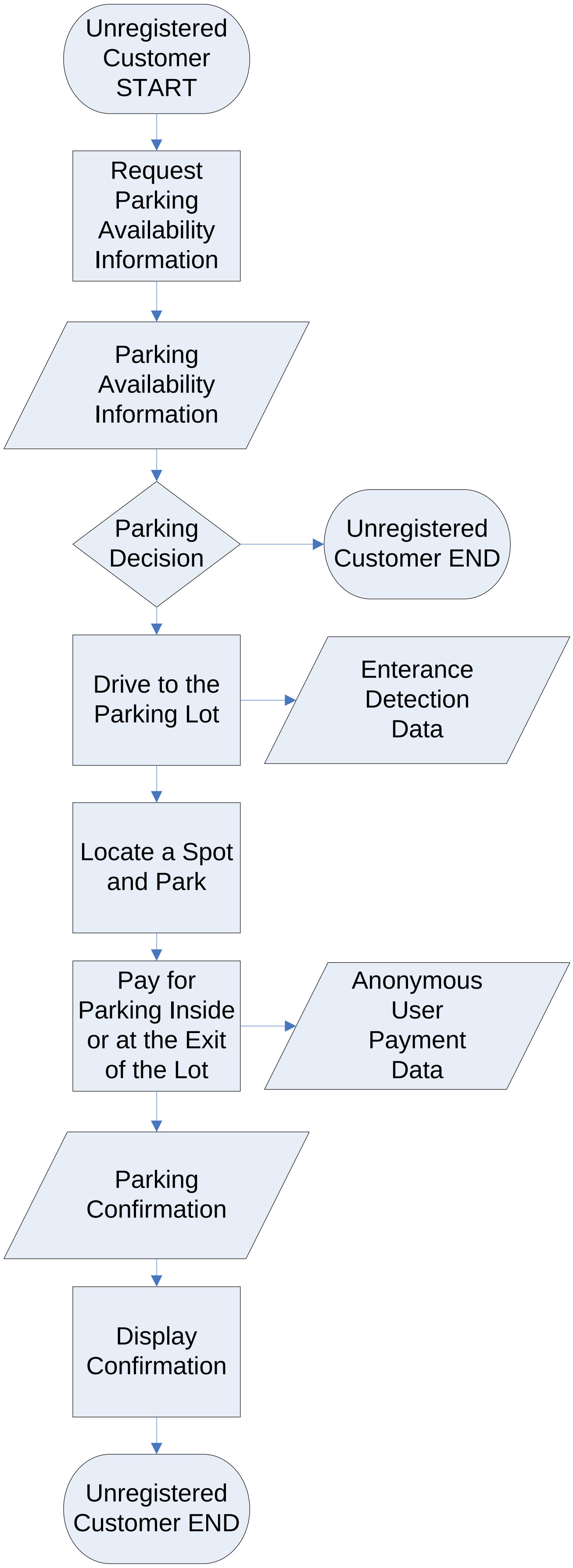
Sensor Technology	Count	Presence	Speed	Output Data Occupancy	Classification	Multiple Lane, Multiple Detection Zone Data	Communication Bandwidth	Sensor Purchase (each in 1999 US
Inductive Loop	✓	✓	✓[illegible]	✓	✓[illegible]		Low to moderate	Low[illegible] ($500 - $80
Magnetometer (two axis fluxgate)	✓	✓	✓[illegible]	✓			Low	Moderate ($900 - $6,3
Magnetic Induction Coil	✓	✓[illegible]	✓[illegible]	✓			Low	Low to mode ($385-$2,0
Microwave Radar	✓	✓[illegible]	✓	✓[illegible]	✓[illegible]	✓[illegible]	Moderate	Low to mode ($700-$2,0
Active Infrared	✓	✓	✓[illegible]	✓	✓	✓	Low to moderate	Moderate to ($6,500-$3,3
Passive Infrared	✓	✓	✓[illegible]	✓			Low to moderate	Low to mode ($700-$1,2
Ultrasonic	✓	✓		✓			Low	Low to mode (Pulse model:
Acoustic Array	✓	✓	✓	✓		✓[illegible]	Low to moderate	Moderate ($3,100-$8,1
Video Image Processor	✓	✓	✓	✓	✓	✓	Low to high[illegible]	Moderate to ($5,000-$26,

Appendix A: User Interactions Flowcharts

This appendix presents flowcharts of the system-user interactions for scenarios 1 through 3 and their respective variations presented in section 3.5.

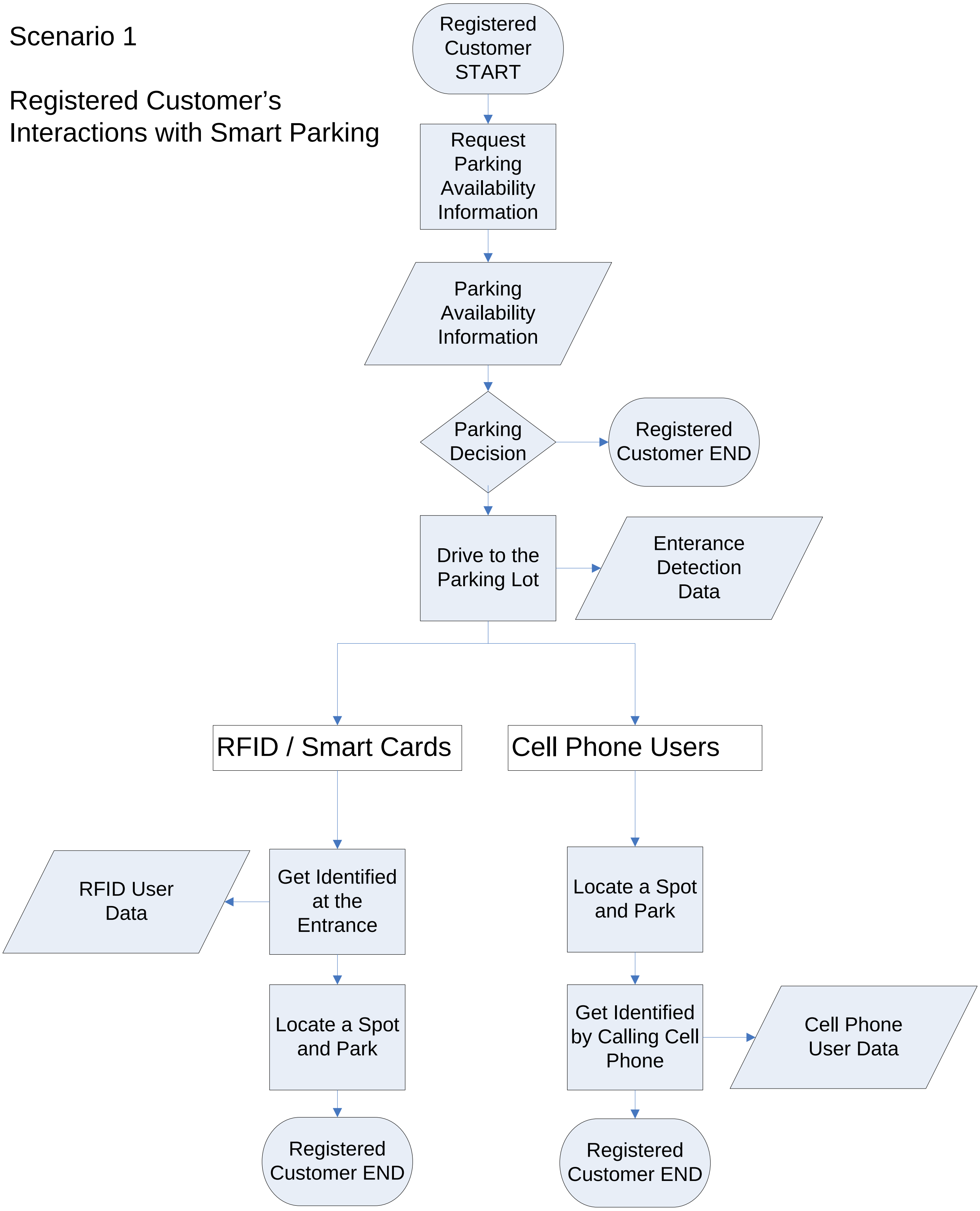
Scenario 1

Unregistered Customer's Interactions with Smart Parking



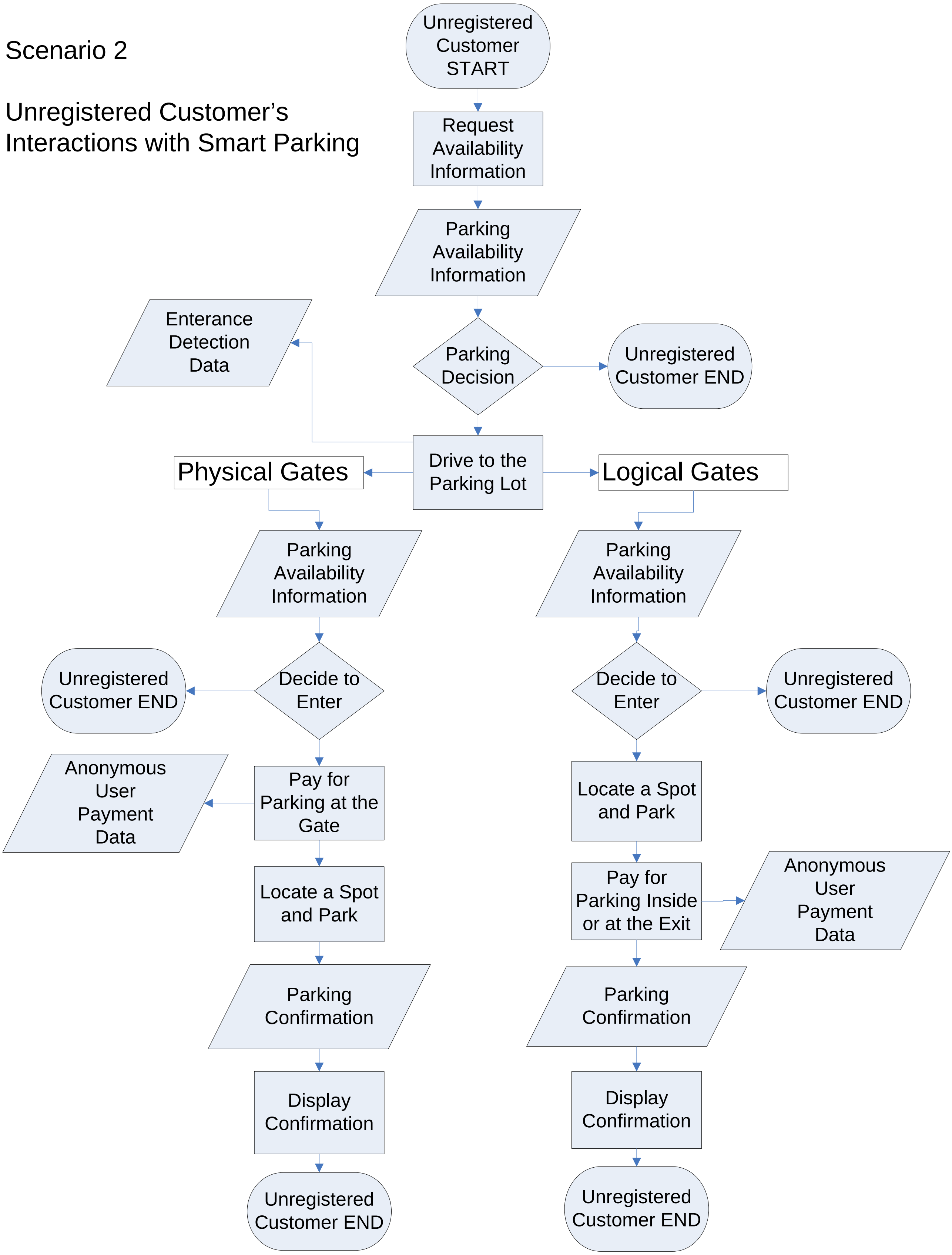
Scenario 1

Registered Customer's Interactions with Smart Parking



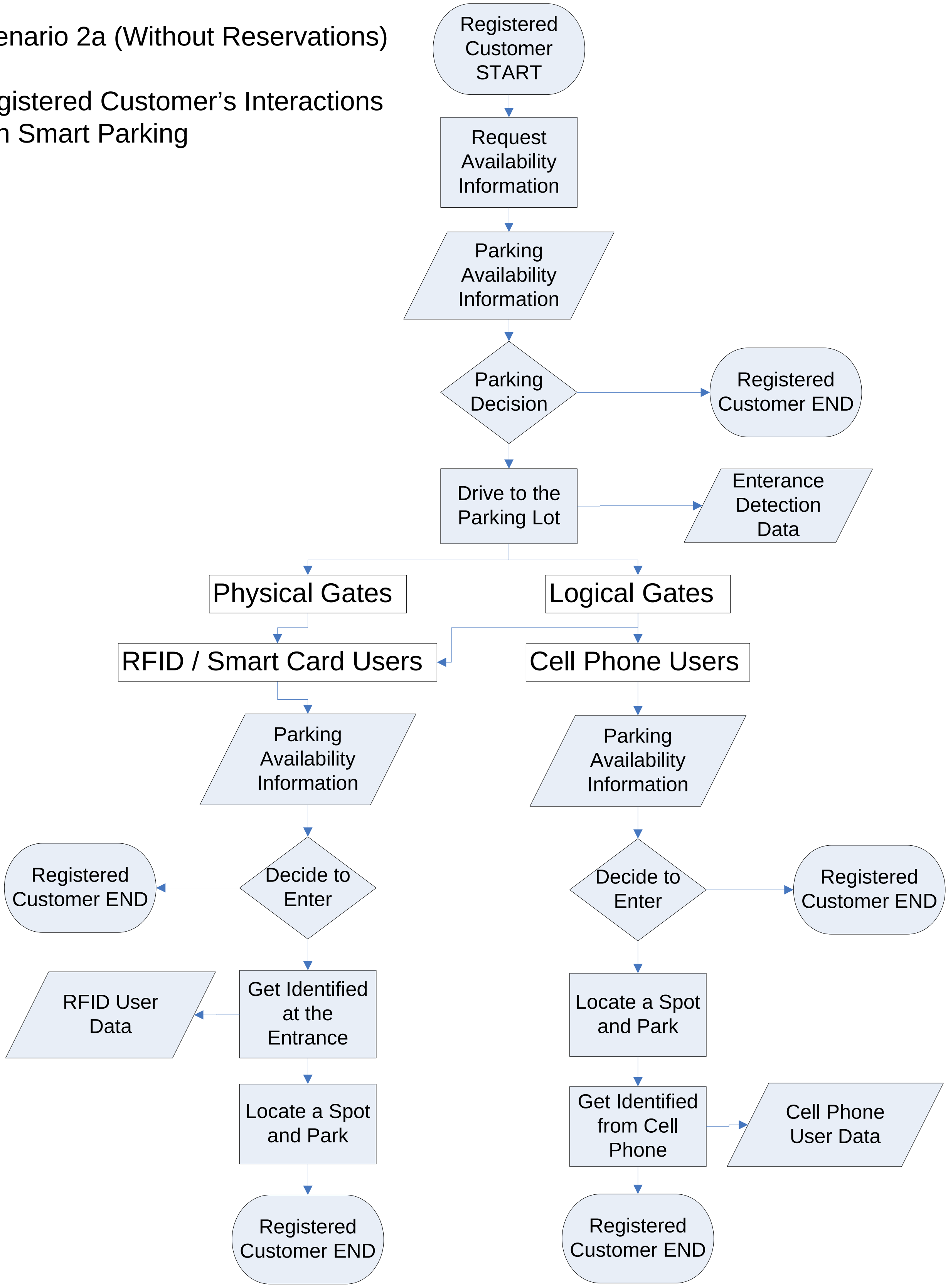
Scenario 2

Unregistered Customer's Interactions with Smart Parking



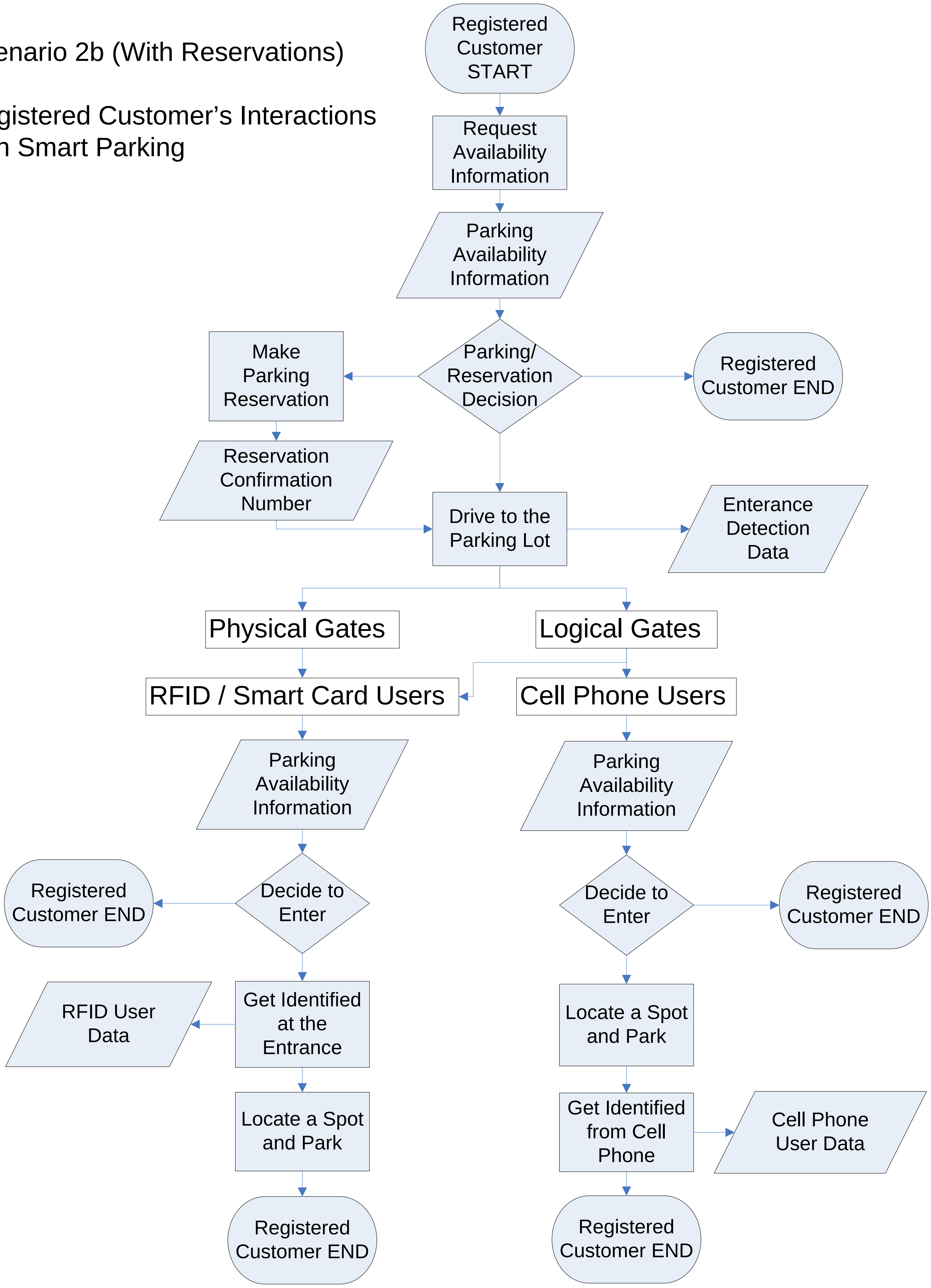
Scenario 2a (Without Reservations)

Registered Customer's Interactions with Smart Parking



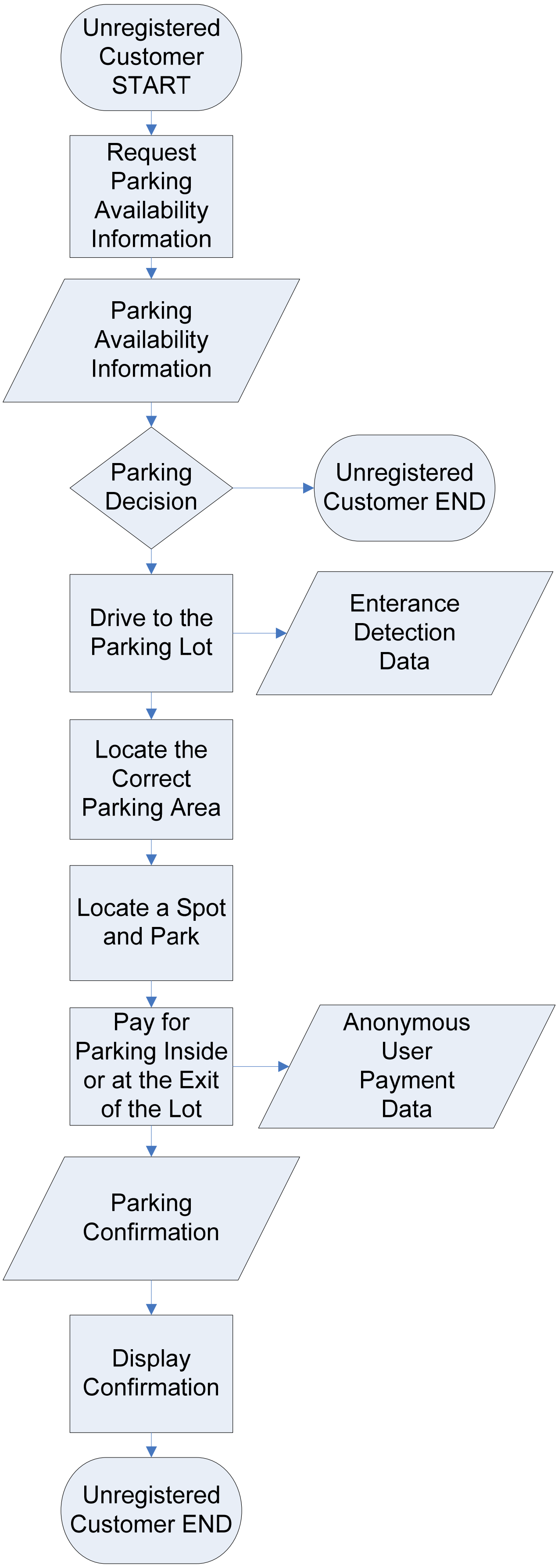
Scenario 2b (With Reservations)

Registered Customer's Interactions with Smart Parking



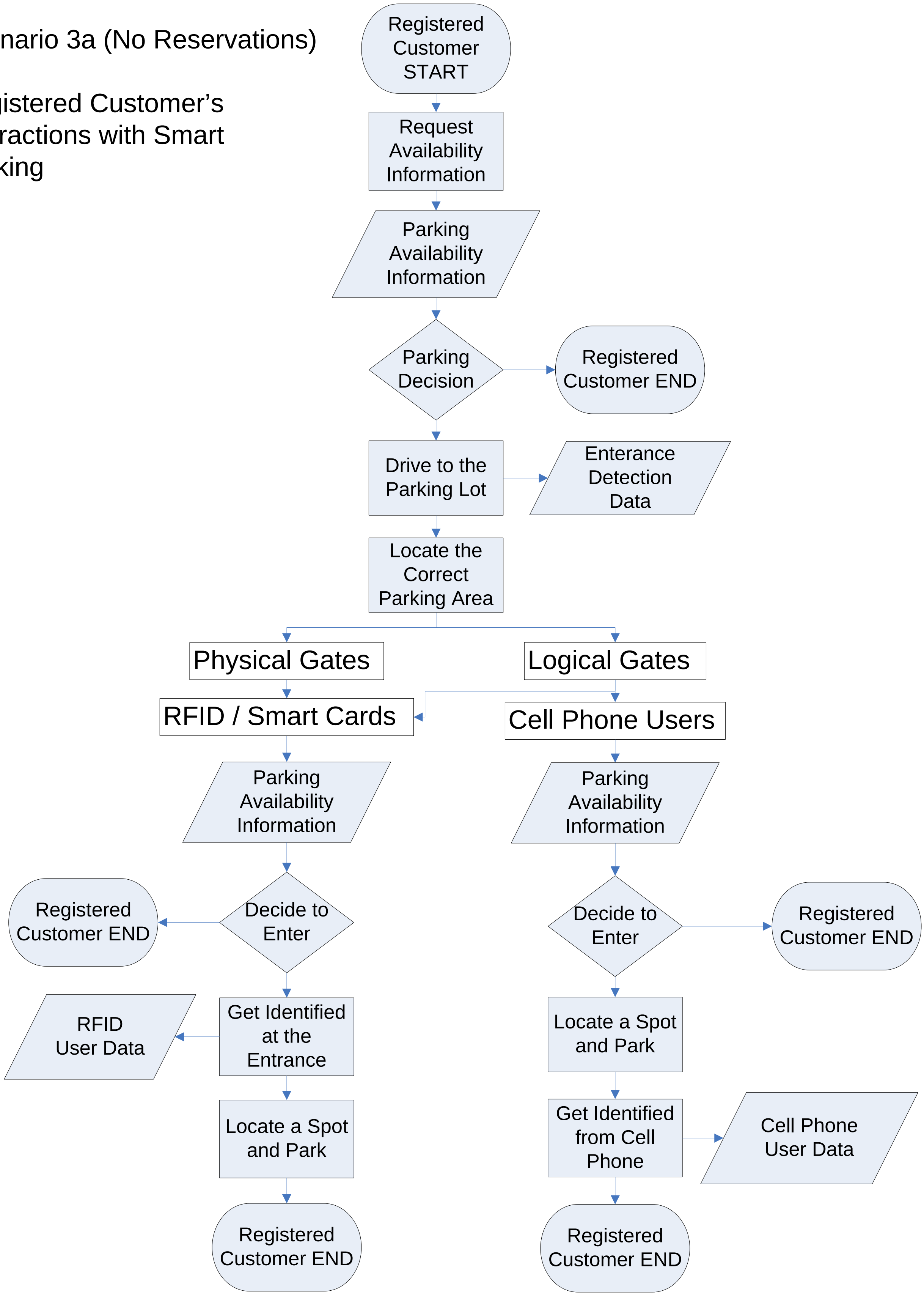
Scenario 3

Unregistered Customer's Interactions with Smart Parking



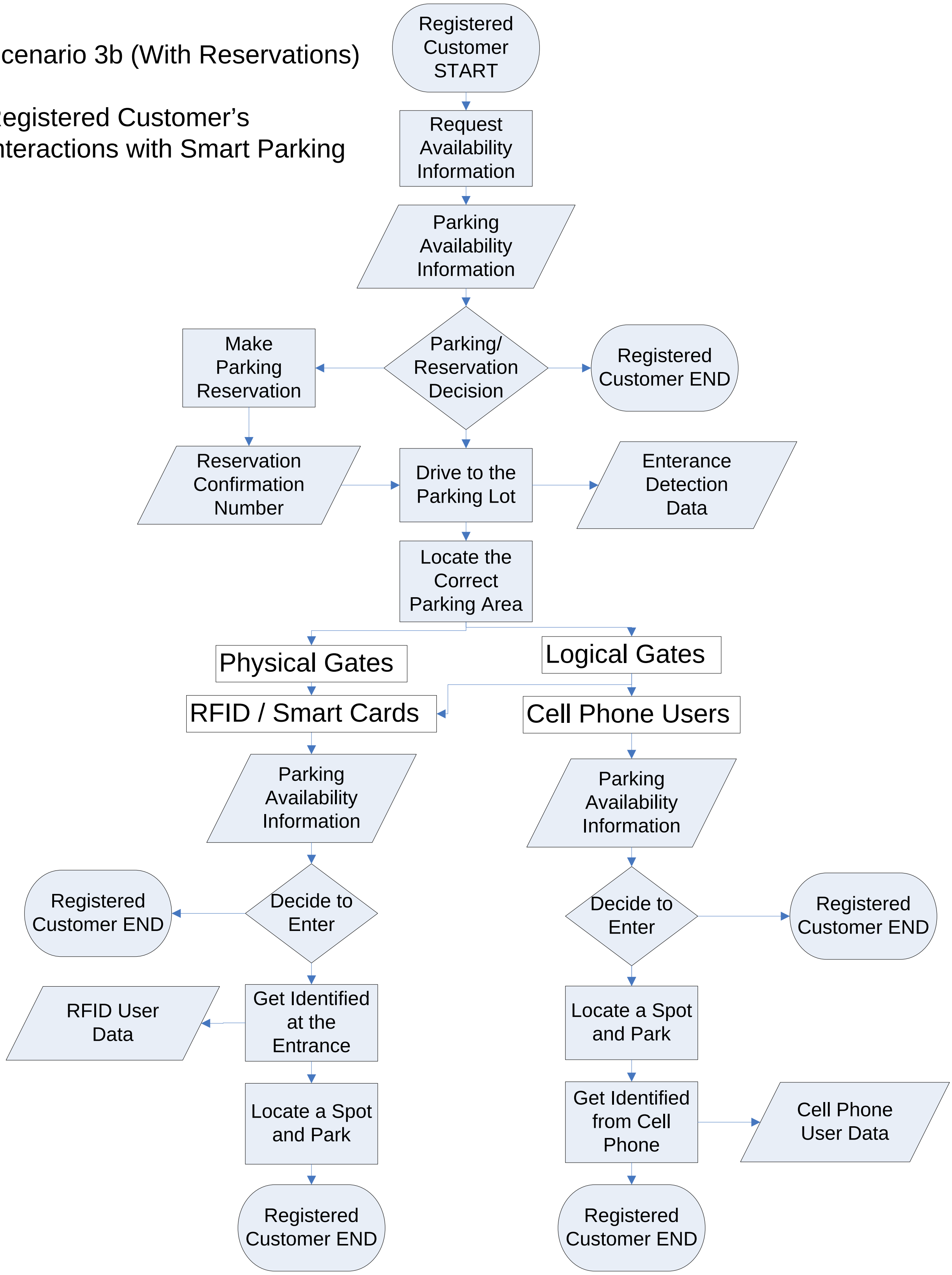
Scenario 3a (No Reservations)

Registered Customer's Interactions with Smart Parking



Scenario 3b (With Reservations)

Registered Customer's Interactions with Smart Parking



Appendix B: Description of the Implemented Smart Parking Research Pilot

I. Smart Parking Research Pilot at COASTER Stations

The research implementation will be located at six (6) COASTER stations: Oceanside, Carlsbad Village, Carlsbad Poinsettia, Encinitas, Sorrento Valley and Solana Beach. The first phase will begin at the Carlsbad Village, Poinsettia and Encinitas stations.

The research pilot will investigate a smart parking system for the COASTER stations including disincentives for non-COASTER parking, providing preferential parking for COASTER riders, and providing information about parking availability. The evaluation will include value pricing scenarios and patron feedback about the system.

II. Research Pilot at Carlsbad Village, Poinsettia and Encinitas

The Carlsbad Village, Poinsettia and Encinitas are the most impacted stations on the COASTER route. These stations will be in the first phase of the research pilot smart parking program. The initial design will target non-COASTER riders and provide services to COASTER riders. This phase will begin in mid-June, with expansion to the other three stations after a report back to the NCTD Board.

Scenarios

Carpool/Vanpool

Free for COASTER riders – COASTER riders only
3-6 spaces at each lot.
Spaces nearest to the platform
Go to 511SD and link to ParkingCarma
Register as a carpool/vanpool member
Choose days that carpooling will occur
Print daily Dash Passes (each carpool member)
Display all carpool passes on windshield

Advanced Reservations COASTER Riders

$2/day for COASTER riders – COASTER riders only
10 spaces per lot (This can change if fills, or not)
Spaces nearest to the platform
Go to 511SD and link to ParkingCarma website
Pay for number of days (maximum 2 week timeframe)
Print Dash Passes for chosen days
Display Dash Pass each day on windshield

III. User Interface

The user interface is designed to be conducted primarily through the website, with a phone option for more immediate access or for those who are not connected.

Users can call ParkingCarma during morning commute hours to reserve a space on the spot, or leave a message.

- Website: 511SD and ParkingCarma
- Phone interface: 511SD connected to ParkingCarma

IV. Enforcement and Outreach Procedures

The enforcement will be conducted by a third party vendor, Sunset Parking. There is no mechanism at NCTD for issuing tickets, so towing is the only enforcement option. Sunset parking will use communication with patrons and warnings to avoid towing vehicles.

Enforcement Process

- Visual inspection of cars in lots between (7:30 – 9:30)
- Rotate lots on a daily basis for first few weeks, then a weekly basis
- Report any issues with designated spaces
- Feedback on project design and operation
- Only Tow after three warnings.

V. Outreach and Signage

A primary component of this program is pre-implementation outreach to municipalities and commuters to inform them of the program.

UC Researcher worked closely with SANDAG Planners and Marketing Team to design and place signage at each station. They also provided outreach personnel through the Stimulus Project to inform patrons about the program.

- **Banner at each station announcing the program**
- **NCTD Rider Alert announcing the program**
- **Flyers distributed to each patron the week before, and 2 weeks after program launch**
- **Signage at each area delineating range of spaces for Carpool and Solo Reserved spaces**
- **Stencil on each space for "QuickPark Reserved" par**