Transport Policy 44 (2015) 89–95

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Optimizing the use of public garages: Pricing parking by demand

Gregory Pierce [a,*], Hank Willson [b], Donald Shoup [c]

[a] Luskin Center for Social Innovation, UCLA Luskin School of Public Affairs, 3250 Public Affairs Building, Los Angeles, CA 90095-1656, USA
[b] Sustainable Streets Division, San Francisco Municipal Transportation Agency, USA
[c] Department of Urban Planning, UCLA Luskin School of Public Affairs, 3250 Public Affairs Building, Los Angeles, CA 90095-1656, USA

ARTICLE INFO

Article history:
Received 9 March 2015
Received in revised form
16 June 2015
Accepted 11 July 2015
Available online 28 July 2015

Keywords:
Parking garage
Public asset management
Performance pricing
SF*park*

ABSTRACT

Many cities build public garages at great cost but with scant public scrutiny or economic analysis. Other than aiming to recover the cost of debt service and operations, cities appear to have few clear policy aims in managing these garages. In this paper, we outline how U.S. cities currently manage off-street parking structures under their control. We argue that this management largely ignores the logic of both economics and public benefits. We also make the conceptual case for how cities should manage their parking assets to maximize public benefits. Finally, we examine the most promising example of off-street parking public management, using data from 14 garages included in San Francisco's SF*park* program. We find that SF*park* increased the public use of garages by more than a third, reduced the average price for drivers, and maintained a stable revenue stream for the city.

1. Introduction

In 2011, San Francisco adopted the biggest price reform for public parking since the invention of the parking meter in 1935. San Francisco's parking prices for portions of both its public on-street and off-street supply now vary by time of day and by location. The goal for on-street parking is to charge the lowest possible prices that will leave between 20 percent and 40 percent of curb spaces open on every block at any time. The program attempts to achieve this aim by adjusting prices approximately every eight weeks. The goal for off-street parking is to leave some – but not too many – open spaces available in public garages at all times.

SF*park*, San Francisco's dynamic pricing program, aims to solve the problems created by charging too much or too little for public parking. If parking prices are too high and many spaces remain open, nearby stores lose potential customers, employees lose jobs, and governments lose tax revenue. If prices are too low and no spaces are open, drivers cruising to find an open space waste time and fuel, congest traffic, and pollute the air.

On-street parking spaces are part of the city's street system and have few ongoing maintenance costs after they are paved and marked. Nevertheless, cities that offer free or under-priced on-street parking to drivers incur a high cost for this mismanagement. Accordingly, a wave of recent research has demonstrated how cities can more effectively price on-street parking. The SF*park* program in particular has received much publicity for adjusting the prices at 7000 parking meters to achieve a target occupancy rate for on-street parking spaces (Chatman and Manville, 2014; Millard-Ball et al., 2014; Pierce and Shoup, 2013).

On the other hand, cities routinely build off-street parking spaces at great cost to the public, but with scant public scrutiny or scholarly analysis. Other than aiming to recover the cost of debt service and operations for the garages, cities appear to have few clear management goals. In the same SF*park* program that has made demand-responsive adjustments to on-street prices, San Francisco experimentally adjusted the prices of 11,500 off-street parking spaces in 14 city-owned parking garages. While the proportion of public off-street spaces subject to the experimental treatment is higher than for on-street spaces, no one has yet analyzed the off-street component of SF*park*.

In this paper, we first outline how U.S. cities currently manage off-street parking assets. We argue that the status quo of public management of these assets largely ignores economic logic. We next make the conceptual case for how cities should manage their parking assets to maximize public benefits. Finally, we compare the status quo to the most promising example of off-street parking public management using data from the 14 garages included in the SF*park* program. SF*park* represents a great improvement over the previous management regime. We find that SF*park* increased the public use of garages by more than one-third while marginally lowering the average price for drivers and maintaining a stable revenue stream for the city.

* Corresponding author.
E-mail addresses: gspierce@ucla.edu (G. Pierce), Hank.Willson@sfmta.com (H. Willson), shoup@ucla.edu (D. Shoup).

http://dx.doi.org/10.1016/j.tranpol.2015.07.003
0967-070X/

Both our conceptual model for optimal off-street parking policy and the findings from SF*park* suggest practical steps that cities can take to improve outcomes for both municipalities and residents. These steps are cheap and logistically simple compared to on-street reforms. The principles of demand-sensitive parking management can also be easily extended to non-city off-street spaces. Despite their importance, analyses of public off-street management are scant compared to the literature assessing public on-street parking. We conclude this paper by outlining a future research agenda for off-street studies, including making use of more detailed occupancy data than are available in the on-street context.

2. Optimal pricing policy for public garages

Whether on-street or off-street, managing parking well presents a challenge because parking space is a perishable good. Perishable goods have fixed, sunk costs and their value cannot be stored. Perishable goods thus require careful management to ensure their efficient use (Kimes, 1989; Weatherford and Bodily, 1992). Other prominent examples of perishable goods include airline seats, hotel rooms, and advertising time on television.

Effective management for perishable goods has three essential components. First, the good must be sold within a limited time period. Seats on airplanes or rooms in a hotel, for example, are either used by a fixed deadline or wasted; these assets cannot be resold later. The use of parking space is similar. Second, perishable goods have a fixed number of units. Regardless of demand, new parking spaces cannot be manufactured quickly or cheaply. Finally, perishable goods are optimally managed either by charging different prices for the same product at different times, or for different people at the same time. This strategy of price differentiation is already common practice in the parking industry, as evidenced by the lower rates often offered to early birds or to nearby shop customers through validated parking. Yet the techniques employed by managers of public parking garages have lagged significantly behind the more sophisticated private parking operators (Akhavan-Tabatabaei et al., 2014; Guadix et al., 2009). Private operators set prices for perishable goods to yield the maximum revenue, which is why the science of pricing perishable goods has come to be called yield management. A city's goal, however, should be different. A city should try to optimize the use of public garages, rather than to maximize the revenue.

Cities typically follow one of three approaches to set the prices for parking: they (1) price at the marginal cost, regardless of the market rate, (2) price at the market rate, regardless of the cost, or (3) price to reach a revenue goal.[1] The policy of providing free on-street parking represents the first approach. For decades, planners naively assumed that there was no cost to recoup from the use of on-street space. Demand-responsive pricing exemplifies the second approach. Market-priced curb parking can generate considerable revenue for a city if the price exceeds the collection and maintenance costs. SF*park* explicitly targets optimal occupancy—not maximum revenue—when setting prices, yet the program's revenue has remained almost unchanged even as prices varied to optimize occupancy.

For off-street parking spaces, cities commonly set revenue goals. This strategy may seem appropriate because cities incur high costs to build and operate garages. A recent study in 12 American cities found that public garage construction costs averaged $24,000 per space for aboveground structures and $34,000 per space for underground garages (Shoup, 2011). Parking prices high enough to recoup these construction costs can leave substantial vacancies. Private garages can maximize profits despite substantial vacancy rates when they face inelastic demand. While not all private firms maximize profits in practice, their primary incentive is certainly to earn profit. [2] If the capital and operating costs of a parking lot are fixed, the owner can maximize revenue and profits at the occupancy rate where reducing the price to attract additional customers produces no additional revenue, even if many spaces remain vacant.

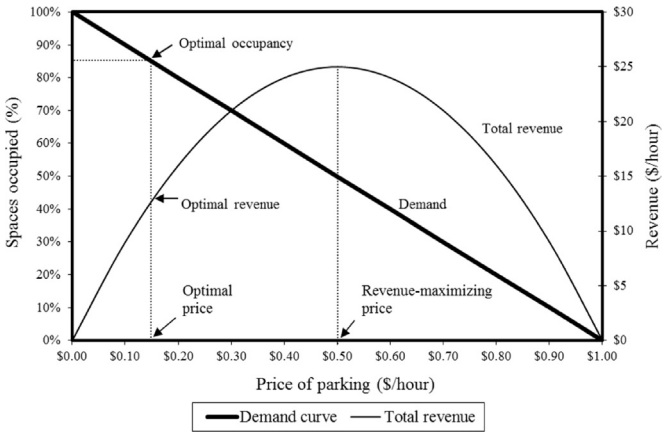

Fig. 1. Parking prices, occupancy, and revenue.

Fig. 1 illustrates how a 100-space garage can maximize revenue with only a 50 percent occupancy rate (adapted from Shoup, 2011). Price is on the *X*-axis, and the demand curve slopes downward. The garage is full when the price is zero, and has zero occupancy when the price is $1 an hour. Maximum revenue, $25 an hour, occurs at a price of $0.50 an hour ($0.50 × 50 occupied spaces = $25). But leaving half the parking spaces vacant is not optimal for a public garage. A parking system operates most efficiently at an occupancy rate between 85 and 95 percent of capacity, so entering cars don't have to circle through the entire garage to find a vacant space. If a city aims for an 85 percent occupancy rate to manage the parking supply efficiently, the garage would price parking at 15¢ an hour, yielding a total revenue of $12.75 an hour ($0.15 × 85 occupied spaces = $12.75). Therefore, pricing parking to achieve efficient occupancy generates only about half the maximum total possible revenue.[3]

[1] Kenneth Button (1977, p. 43) says, "In practice, two quite distinct types of charging policy for parking spaces may be discerned: There is an administrative approach and an economic one. The former is concerned with cost recovery and is closely entwined with the highway engineer approach to urban traffic problem. The economic way is to regulate charges in sympathy with the prevailing state of demand in the say way that other commodity prices vary. Charges are therefore based on the 'willingness to pay' principle." In addition to these two approaches, some cities have a revenue goal to cover the debt service and operating costs of public garages.

[2] Epstein (2001, p. 25) states that "Presumably, the ideal system [of charging for curb parking] is one in which the City maximized its revenue from use." Unfortunately, this confuses a city's goals with those of commercial parking operators, which theory suggests will aim to maximize profits, not social benefits. If the goal of pricing curb parking is to achieve a 15 percent vacancy rate, higher prices and a lower occupancy rate can increase revenue but leave too many spaces empty.

Commercial parking operators have downward-sloping demand curves because they are in "monopolistic competition." If all costs are fixed regardless of the occupancy rate, the owner will maximize revenue and profits at the price where demand is unit elastic. If demand is inelastic (less than unity), raising prices will increase revenue and profits. If demand is elastic (greater than unity), reducing prices will increase revenue and profits. If costs are fixed, maximum profits will accrue only at the price where the elasticity of demand is unity. At times when the maximum revenue is less than the operating cost, the parking lot will close.

[3] A 2003 survey of parking in downtown Los Angeles found that the occupancy rates of off-street parking lots and garages was only 38 percent on Saturday afternoon, and only 10 percent on weekday evenings (Kimley-Horn and Associates, 2003). A parking survey in Tempe, Arizona, found that only 52 percent of spaces were occupied on a Friday evening when on-street parking was hard to find (Minett 1994).

Full occupancy denies service to new customers, while low occupancy limits the number of potential visitors to adjacent businesses, schools, and other amenities. Unlike private sector operators, a city must balance the competing goals of reliable availability and high occupancy. The greater the variation in demand during a time period, the greater the conflict between the two goals. A driver's probability of finding an open space upon arrival is therefore a key measure in setting prices.

Given the random nature of arrivals and departures, a city should have three goals when setting garage occupancy targets:

1. **Ready availability**. Availability is the share of an hour in which spaces are available. Ready availability means that drivers can easily find a convenient open space.
2. **High occupancy**. Occupancy is the average share of spaces that are occupied during the hour. High occupancy means that the parking spaces are well-used and serve many customers.
3. **Revenue**. Revenue depends on both the price and the occupancy rate. While cities should not maximize revenue as a primary goal, they should prioritize recovering revenue at least equal to the marginal cost of operations.

No evidence suggests a uniform weight that cities should assign to each of these goals, and we do not advocate such a rule. Appropriate trade-offs between revenue, occupancy and availability are likely to vary by locality. Rather, we argue that individual cities should manage parking garages based on explicit concern for each of these goals. Many cities do not attempt this complex task, but instead rely on a simple unitary goal such as a cost-recovery revenue target.

3. The status quo in urban off-street parking policy

Many cities also employ faulty logic in making decisions regarding building more off-street parking space. In dense urban areas, private investors rarely build stand-alone parking garages because the high upfront construction costs and low returns prove less attractive an investment compared to residential or commercial buildings. Additionally, the public sector makes private parking investments less appealing by under-pricing curb parking and requiring ample off-street parking. By contrast, public parking agencies typically build garages because they believe that this infrastructure maintains or increases local economic competitiveness (for instance, see City of Los Angeles, 2010). Public garages are often built not to serve existing demand, but rather to accommodate a perceived latent demand. Cities attempt to provide parking for customers and workers who they think would shop or work in the area if cheap, plentiful parking were available.

In other words, public sector agencies build parking garages to induce driving to an area. Bawolek (2004) states that while public garages nearly always lose money and deter private construction, they remain necessary to enhance urban growth. Bawolek's statement represents the conventional wisdom on public garages: they drain public coffers but promote other desired economic outcomes.[4] Cities also build off-street parking to satisfy particular merchants or to make redevelopment plans more palatable to nearby residents. In some cases, like the Japan Center in San Francisco, merchants conduct business above or in the same structure as a public garage. Similarly, the City of Seattle paid $61,000 per space to construct a 1200-space garage beneath the privately-owned Pacific Place shopping center (Shoup 2011, 190). In other cases, garages are seen as community assets. Some garages in San Francisco have been built by non-profit corporations whose board members are local neighborhood leaders.

A 1965 article by George Berkley on public parking supply in Boston provides the only detailed, scholarly account of how cities justify building off-street parking. The city of Boston constructed public garages based on "the bolstering effect they would produce on the city's economy" by attracting shoppers (Berkley, 1965, p. 220). The city's department of transportation was so convinced of the economic boon that it constructed the garages even "when no interest was evinced from the private sector" (Berkley, 1965: 214). Even using the most favorable estimate of possible retail activity generated by the city's off-street spaces, Boston still lost $184,000 annually on garage operations in 1965 (Berkley, 1965). This cost equates to more than $1.3 million in 2015 U.S. dollars (Bureau of Labor Statistics, 2015). Because of the cost, Berkley advised the city to build no additional garages in the future, but rather to charge a higher price for existing off-street parking (Berkley, 1965). Despite this recommendation, nearly half a century later Boston continues to construct and subsidize off-street parking. Today it owns and operates more than 30 garages (Boston Transportation Department, 2001).

While mass media observers have recognized the folly of fiscally-drained cities providing off-street parking at a loss (see Yglesias, 2011), scholars have largely ignored this issue even though charging the right price is much easier for off-street parking than for on-street parking. In particular, drivers with disabled placards, many of whom abuse the privilege, usually cannot park for free in garages, and thus do not skew parking demand (Manville and Williams, 2012). Moreover, construction, temporary-no park zones, and other on-street obstacles do not affect garage occupancy. Data for off-street parking are also more precise and cheaply collected than on-street data. Nevertheless, the vast majority of off-street parking studies focus on garages' physical designs and traffic flows. Few researchers have examined the process by which private or public sector actors decide to build and operate off-street spaces.

Arnott analyzed downtown parking garages in Boston and estimated that an equivalent amount of on-street parking would consume over two-fifths of the downtown land area (Arnott, 2006, p. 3). By building garages, the city subsidizes drivers—to the detriment of non-drivers—and reduces residents' incentive to use existing public transit. In short, building garages increased public spending in Boston and likely encouraged automobile use. Parking garages can also crowd out higher-value land uses (Manville, 2013). More efficient use of existing parking space can substitute for construction of new garages on valuable land.

In the only existing review of off-street parking policies in the scholarly literature, Barter (2010) finds that space in public parking garages rarely recovers the costs of construction and ongoing operations. Barter consequently categorizes public parking garages as stranded public assets. Given the gaps in previous research, in this study we provide both the conceptual case for and empirical evidence of the outcome when public garage prices respond to demand.

4. Recent parking strategy considerations: Chicago, Los Angeles, and San Francisco

The Great Recession and resulting fiscal austerity have compelled public managers to make better use of scarce public resources. Three cities in the U.S. have recently re-considered the management of their parking assets: Chicago, Los Angeles and San Francisco.[5] The

[4] During the Cold War, public agencies also built underground garages for physical security in the case of an emergency. The national government subsidized some cities for up to 50 percent of garage construction costs (Toledo Blade, 1951; National Public Radio, 2009).

[5] On average, European cities have reformed garage management practices more quickly than in the U.S. (Kondransky and Hermann, 2011). Asian

disparate paths they chose reveal the lack of consensus in urban off-street parking policy.

In 2008, Chicago captured national attention when it leased all of the city's on-street parking spaces to a private investor for 75 years. As is often the case, the privatization of public assets created great controversy. In this instance, the public outcry was largely merited. The length and terms of the contract mortgaged the future of Chicago's public space for a short-term gain—a case of burning all the furniture to stay warm on a cold night. In a much less publicized transaction in 2006, however, Chicago also leased 9,178 public spaces in four off-street garages near the city's downtown loop to a private consortium. Chicago Loop Parking LLC assumed control of the city's garages for 99 years in exchange for $563 million (Ashton et al., 2012).

Several aspects of the off-street deal were objectionable. First, as with the on-street parking management deal, the length of the off-street lease suggested that the city prioritized meeting short-term budget needs. The contract also allowed the consortium lessee to dictate parking prices without any constraints. This price-setting authority was problematic because the city had also granted the consortium a local monopoly—exclusive garage operating rights within the downtown loop. Within seven years of the nearly century-long contract, contentions arose around the city's off-street parking decision. Soon after signing the lease, Chicago violated the exclusive operating agreement when it granted permission to another private firm to construct a garage within the downtown loop. In response, the consortium sued and reaped more than $57 million from Chicago (Fusco and Mihalopoulos, 2013). In addition, a citizens' taxpayer movement challenged the original lease in court (Harris, 2013). Despite the seemingly advantageous terms of the deal, by 2013 the consortium defaulted on the agreement due to lower than expected economic returns (Ori, 2013).

In the face of a similar fiscal crisis in 2008, Los Angeles also reconsidered whether to lease its off-street parking assets, including 10 multi-level structures and 58 metered lots. In a publicly available document, the city weighed three options: privatizing its parking assets over a 50-year term; reforming its internal management system; or maintaining the status quo. With its decision, the city hoped to maintain current service levels to residents while ensuring a stable revenue stream. Ironically, Los Angeles weighed leasing its existing off-street assets due to fiscal problems stemming from ongoing operations *at the same time* as it continued to build new garages (City of Los Angeles, 2010).

Los Angeles' off-street parking management was highly inefficient. Among its garages, occupancy peaked at 46 percent on weekend nights, and was lowest (22 percent) on weekday mornings. The city's financial advisor expressed little confidence that off-street garage management would improve in the future, despite identifying the reasons for past technical and fiscal mismanagement. While the city recognized that it could increase revenue by adjusting price based on demand for off-street parking, it did not institute this policy. Ultimately, Los Angeles settled on a new management program called *ExpressPark*, which implemented performance pricing for on-street parking much like San Francisco's SF*park*. However, *ExpressPark* left the city's garage management strategy unchanged except for an attempt to better publicize available garage spaces via digital technology. In other words, Los Angeles opted to maintain the status quo in off-street asset management despite revolutionizing its on-street space methods.

(*footnote continued*)
municipalities tend to follow U.S. garage parking policy more closely, with a few progessive exceptions in wealthier East Asia (Barter, 2011).

5. San Francisco before SF*park*

By 2008, San Francisco had also recognized the need to reconsider its parking strategy. Unlike most other cities, San Francisco controls a substantial portion of its off-street parking supply. City-managed garages account for as much as 60 percent of the publicly available off-street parking spaces in some neighborhoods. The San Francisco Municipal Transportation Authority (SFMTA) manages both parking and extensive non-automobile travel systems—bus, light rail, streetcar and cable car—in the city. Traditionally, the agency has set parking prices to achieve a revenue goal rather than to manage occupancy. To achieve this goal, San Francisco charged drivers more to park in off-street parking facilities than at on-street meters. This pricing system encouraged drivers to cruise the streets hoping to find a free or cheap on-street parking space, while commuters and long-term parkers used higher-priced garages as all-day car storage. As a result of the price difference, on-street metered parking spaces were usually scarce while garages had many available spaces on most days and at most times.

For years, short-term visitors to the city—those patronizing downtown and commercial corridor businesses—saw garages a last resort for parking. A driver would park in a garage only after unsuccessfully trying to find free or cheap on-street parking. *SFWeekly*, a newspaper focused on civic issues in San Francisco, described the average driver's thought process when parking in the city:

> "There are a few accepted theories on how long you should search for parking before settling for a garage. There is the single loop around the block, the zigzags through adjacent streets, the stalking of people exiting restaurants. What does not vary is the feeling of defeat you get when rolling toward the yellow gate [in a parking garage] and pushing the button for a ticket." (SFWeekly, 2012).

Facing the reality of its unattractive off-street supply, San Francisco took a different course from either Chicago or Los Angeles. The city commenced an ambitious reform pilot program for parking called SF*park*. SFMTA launched the SF*park* pilot in April 2011 to overhaul both on-street and off-street public parking management.

6. The innovations of SF*park* in off-street space management

As detailed in the SFMTA's evaluation of the pilot program, SF*park* adjusts hourly parking rates every three months based on the parking demand at each garage during five different time intervals during the day: midnight–9 AM, 9 AM–noon, noon–3 PM, 3 PM–6 PM and 6 PM–midnight (SFpark, 2014). The city aims for each garage to have an average occupancy no lower than 40 percent and no higher than 80 percent at all times. By maintaining such a wide target range, the city hopes to avoid peak occupancies that exceed 95 percent.[6] The city measures average occupancy for each time band and adjusts prices four times a year. If expected garage occupancy exceeds 80 percent for a particular time period in a quarter, the hourly rate for that time period is raised by $0.50. If expected garage occupancy is below 40 percent for a quarter, the hourly rate is lowered by $0.50. SF*park's* rate-setting policies for both on- and off-street parking have brought garage hourly rates

[6] Targeting peak occupancy above 95 percent may result in parking shortages, long search times, and entry/exit queues. Internally, SFpark uses a "parking reliability" measure for evaluation which captures the percent of time that a given garage is below 95 percent occupied. Los Angeles also considers peak occupancy to be the most useful metric for comparing the performance of garages (City of Los Angeles, 2010).

equal to—and in many cases below—nearby parking meter rates, giving drivers a financial incentive to go straight to the garages rather than circle looking for on-street parking. Thus dynamic pricing in garages can reduce congestion and make the streets safer and clearer for public transit vehicles, pedestrians, cyclists, and other drivers.

In addition to varying hourly prices based on demand, SF*park* garage policy addresses non-price factors. For instance, rush-hour garage queues cause drivers to lose time. In response, the program adjusted early bird parker time requirements and added off-peak discounts to lessen the peak congestion in and near garages at rush hour. (This policy contrasts with the common practice of offering early bird discounts which encourage commuting at peak hours). As a result, most garages saw far fewer cars entering at the morning rush and exiting during the evening rush (SFpark, 2014). This non-price adjustment can reduce local traffic congestion.

SF*park* has not, however, dramatically simplified the schedule of parking prices potentially paid by a driver; the program continues the tradition of price discrimination for off-street space. SF*park*'s demand-responsive time-of-day pricing has actually made hourly rates more complicated than they once were: a driver's hourly rate, and thus total parking charge, depends on when she parks, not just how long. As Table 1 shows, the program also maintains several additional rate schedules that are not subject to demand-based adjustments. Each of the other rates is also less expensive on an hourly basis compared to demand-responsive pricing. Drivers may also pay on multiple rate bases depending on when they park. For instance, a driver might pay a daytime hourly rate for the first portion of a parking session, and a lower evening rate for the remainder of the stay.

Consider the variety of price options, shown in Table 1, available to a driver who wants to park in a garage. The complicated rates and discounts, combined with payment at exit rather than in advance (as at meters), mean that a driver does not need to calculate how much parking costs until leaving the garage. The varied parking rates, alongside price maximums, discounts and validations, make calculating drivers' responses to price changes—demand elasticity—difficult because parkers each pay different rates and no one rate fully describes how much any particular driver might pay.

We can, however, evaluate how changes in the hourly price of parking affected occupancy in the SF*park* garages. We also present evidence, however, on changes in total revenue, which accounts for the both hourly and special parking rates. We obtained SF*park* data, disaggregated by type of rate and garage, for the time period between October 2011, when the first demand-responsive price changes were made, and October 2013. Data included 560 potential changes in hourly price, based on occupancy in the previous period (560 potential price changes = 14 garages × 5 intraday time periods × 4 times a year × 2 years). We present evidence of the program's effect on hourly price, hourly occupancy and total revenue in its first two years of operation.

Table 1
Off-street parking rate variations in a typical parking garage under SF*park*.

Hourly rates based on demand vary over five time periods: midnight–9 AM, 9 AM–noon, noon–3 PM, 3 PM–6 PM, 6 PM–midnight
Early bird specials for commuters who arrive before 8:30AM charged as flat rates that significantly discount the cost of all-day parking
Off-peak discounts for drivers who enter the garage before the morning rush hour (7 AM) or leave after the evening rush hour (7 PM)
Monthly rates that vary depending on whether a space is reserved or used for carpooling
Daily maximum rates charged for 24 h of parking
Merchant validations that reduce or entirely cover a driver's parking cost

7. SF*park* results: price, occupancy and revenue

Similar to findings regarding on-street parking under SF*park* (Pierce and Shoup, 2013), occupancy changes showed a wide variance in response to price changes. The degree and direction of occupancy changes resulting from price changes suggests that planners will never be able to accurately predict the prices needed to achieve the target occupancy for every garage at every time period. Instead, the best way to achieve a target occupancy goal is to do what SF*park* does: adjust prices in response to the observed occupancy based on trial and error. Because most garages initially had many available spaces on most days and at most times, the average hourly price of parking across all garages fell by 20 percent during the program's first year. During the program's second year, the average daytime hourly rate at SF*park* garages rose, but still remained lower than the average price of hourly parking before the program started (SFpark, 2014, p. 126).

At the same time as prices fell modestly, average weekday occupancy for hourly parkers rose by 38 percent in the first two years of the program. As Fig. 2 shows, this positive trend remained remarkably consistent across time bands during normal working hours, with more erratic responses during the early morning and late evening periods. Total revenue across garages first dipped, but recovered to surpass pre-program revenue by the end of fiscal year 2013 (SFpark, 2014). By comparison, revenue from non-experimental garages remained consistent throughout the period.

Initiating the SF*park* program represented a large revenue risk for SFMTA. This risk, however, clearly paid off. After SFMTA's first two years of dynamic pricing, drivers pay similar or lower hourly prices. Not surprisingly, drivers facing lower prices are more eager to park in garages, leading to higher garage occupancy. Moreover, San Francisco has marginally increased its revenue yield from the garages which are subject to demand-responsive pricing. In other words, everyone wins under SF*park*. Falling prices, rising occupancy, and higher revenues benefit drivers, neighborhoods, and the city.

SF*park*'s positive effects are best illustrated by looking more closely at the Performing Arts garage, which is located near the civic center neighborhood in downtown San Francisco. Before the SF*park* program, garage daytime rates were set uniformly at $2.50 per hour, and peak weekday hourly occupancy averaged only about 25 percent. Under SF*park*, low occupancy rates resulted in repeated hourly price reductions every three months. By January 2013, hourly rates for the Performing Arts garage had dropped to the statutory minimum of $1 per hour. Simultaneously, the garage's peak weekday occupancy rose to about 85 percent and total revenue increased more than 10 percent.

8. Improving SF*park*'s off-street program

Despite vast improvements already made by SF*park* in off-

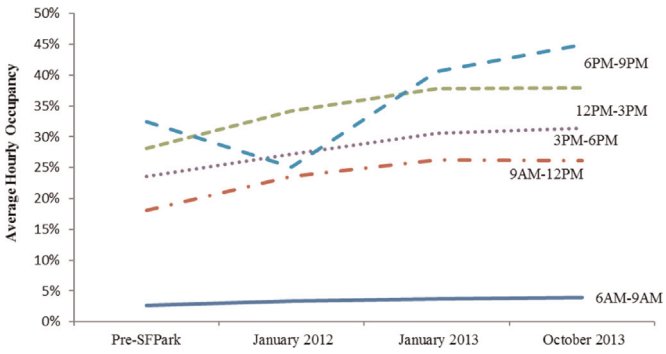

Fig. 2. Average hourly occupancy in SF*park* garages.

street parking management, the program can make three easy improvements. First, the program can set narrower target occupancy bands; second, it can vary prices more transparently; and finally, SF*park* can base monthly and early bird rates on segmented rather than total garage occupancy estimates.

SF*park* established its target on-street occupancy range as between 60 and 80 percent. However, the current target occupancy for off-street parking is much wider. Garage prices are not reduced unless occupancy is below 40 percent and are not increased unless occupancy is above 80 percent. SFMTA reasons that a wider range will help to avoid peak occupancy above 95 percent. However, since peak occupancy rarely, if ever, exceeds 95 percent in any garage, the lower-bound 40 percent occupancy target appears too low to keep prices unchanged. SF*park* could raise its lower-bound target to at least 60 percent occupancy to ensure that public parking assets are better used, even if this policy leads to revenue loss. A higher minimum occupancy goal will enable the city to increase usage while still rarely inviting excess occupancy (above 95 percent) which denies drivers a place to park.

Price changes can also be more transparent. Although SF*park* maintains explicit criteria for adjusting price based on occupancy, in practice SFMTA does not always change prices uniformly when occupancy dictates. Refraining from rule-based price changes creates distortions in the market for off-street parking and also invites speculation as to the reasons for deviation from publicized criteria. SFMTA should, at a minimum, publicly explain its rationale if it sets prices to achieve alternative objectives.

Finally, SFMTA can improve garage management by basing prices on the demand for special types of parking rather than on total demand. Currently, all garage early bird and monthly price changes are dictated by total garage occupancy, which is largely a function of the demand for hourly parking. Employing a single pricing policy for very different kinds of parking (particularly hourly, early bird, monthly) is illogical. For instance, in the Japan Center garage, the high demand for monthly parking pushes up overall occupancy, which has raised mid-day hourly rates, even though mid-day hourly demand has not increased.

The principles of performance-based pricing for off-street spaces can also be applied to parking assets managed by other public entities. For instance, universities located in dense urban areas often maintain parking lots and garages on their campuses, but these spaces are occupied during the day primarily by those with permits, and many spaces remain vacant in the evening. A campus can seem quite dead in the evening despite the numerous plays, concerts, and other cultural events that take place on the campus. Reducing the price of parking in the evening to increase occupancy of the garages can increase the attendance at cultural events, improve the sense of community, and even improve safety via more eyes on the street, and relieve the burden on nearby residential parking (Sherman, 2010; Shoup, 2008).

9. Conclusion

We argue that cities can more effectively manage their parking assets to maximize public benefits by setting occupancy rather than revenue targets. We support our argument with evidence from the most promising practical example of off-street parking public management, San Francisco's SF*park* program. This program decreased parking prices and increased garage occupancy while maintaining revenue for the city. While the program can be improved by establishing narrower occupancy targets and achieving greater price transparency, its early successes demonstrate the ease with which public management practices can be improved by simple changes to parking policy.

Acknowledgments

This research was generously funded by the University of California Office of the President's Multi-campus Research Program Initiative as part of a larger research project, “Congestion-priced Parking in California: Equity, Efficiency and Implementation”.

References

Akhavan-Tabatabaei, R., Bolívar, M.A., Hincapie, J.A., Medaglia, A.L., 2014. On the optimal parking lot subscription policy problem: a hybrid simulation-optimization approach. Ann. Oper. Res. 222, 29–44.
Arnott, R., 2006. Spatial competition between parking garages and downtown parking policy. Transp. Policy 13 (6), 458–469.
Ashton, P., Doussard, M., Weber, R., 2012. The financial engineering of infrastructure privatization. J. Am. Plan. Assoc. 78 (3).
Barter, P.A., 2010. Off-street parking policy without parking requirements: a need for market fostering and regulation. Transp. Rev. 30 (5), 571–588.
Barter, P.A., 2011. Parking Policy in Asian Cities. Asian Development Bank, Phillippines.
Bawolek, K., 2004. What Drives Parking Investments? Commer. Invest. Real Estate 23 (2), 36.
Berkley, G., 1965. Municipal garages in Boston: a cost-benefit analysis. Traffic Q. 19, 3.
Boston Transportation Department, 2001. Access Boston, 2000–2010: Boston's Citywide Transportation Plan.
Bureau of Labor Statistics, 2015. CPI Inflation Calculator. See ⟨http://www.bls.gov/data/inflation_calculator.htm⟩ (accessed 24.02.2015).
Button, K., 1977. The Economics of Urban Transport. Westmead, England.
Chatman, D.G., Manville, M., 2014. Theory versus implementation in congestion-priced parking: an evaluation of SFpark, 2011–2012. Res. Transp. Econ. 44, 52–60.
City of Los Angeles, 2010. Proposed Public-Private Partnership for Parking Assets Options. (January 28, 2010). See http://clkrep.lacity.org/onlinedocs/2010/10-0139-s1_RPT_CAO_01-28-2010.pdf.
Epstein, R., 2001. The allocation of the commons: parking and stopping on the commons. John M. Olin Program in Law and Economics Working. 134.
Fusco, C., Mihalopoulos, D., 2013. City of Chicago hit with $57.8 million tab in parking garage snafu. Chicago Sun Times. (March 20, 2013). See ⟨http://www.suntimes.com/news/metro/18993800-418/city-of-chicago-hit-with-57-million-tab-over-parking-garage-snafu.html#.U2pwWCgyaEo⟩.
Guadix, J., Cortés, P., Muñuzuri, J., Onieva, L., 2009. Parking revenue management. J. Revenue Pricing Manag. 8 (4), 343–356.
Harris, A., 2013. Chicago' 99-Year Parking Garage Lease Draws Taxpayer Suit Bloomberg News. February 13.
Kimes, S.E., 1989. Yield management: a tool for capacity-considered service firms. J. Operat. Manag. 8 (4), 348–363.
Kimley Horn and Associates, 2003. Downtown Los Angeles parking study for portions of the historic core and adjacent areas. Prepared for the Community Redevelopment Agency of the City of Los Angeles.
Kondransky, M., Hermann, G., 2011. Europe's parking u-turn: from accomodation to regulation. The Institute for Transportation and Development Policy.
Manville, M., 2013. Parking requirements and housing development: regulation and reform in Los Angeles. J. Am. Plan. Assoc. 79 (1), 49–66.
Manville, M., Williams, J.A., 2012. The price doesn’t matter if you don’t have to pay: legal exemptions and market-priced parking. J. Plan. Educ. Res. 32 (3), 289–304.
Millard-Ball, A., Weinberger, R.R., Hampshire, R.C., 2014. Is the curb 80 percent full or 20 percent empty? Assessing the impacts of San Francisco’s parking pricing experiment. Transp. Res. A: Policy Pract. 63, 76–92.
Minett, J., 1994. Parking in Downtown Tempe. Interim Report to the Parking Task Force of Downtown Tempe Community, Inc.
National Public Radio, 2009. Parking Garages: A Multilevel History. (November 18, 2009). See ⟨http://www.wbur.org/npr/120545290/parking-garages-a-multi level-history⟩.
Ori, R., 2013. Investor group prepares to hand city parking garages back to lender. *Chicago Business*. (September 12, 2013). See ⟨http://www.chicagobusiness.com/realestate/20130912/CRED03/130919936/investor-group-prepares-to-hand-city-parking-garages-back-to-lender⟩.
Pierce, G., Shoup, D., 2013. Getting the prices right: an evaluation of pricing parking by demand in San Francisco. Journal of the American Planning Association 79 (1), 67–81.
Sherman, A., 2010. The Effects of Residential Off-Street Parking Availability on Travel Behavior in San Francisco (Master Thesis in Urban Planning). San Jose State University, San Francisco.
Shoup, D., 2008. The politics and economics of parking on campus. In: Ison, Stephen, Rye, Tom (Eds.), Transport Demand Management Measures: An International Perspective,
pp. 121–149 ⟨http://shoup.bol.ucla.edu/PoliticsAndEconomicsOfCampusParking.pdf⟩.
Shoup, D., 2011. The High Cost of Free Parking. Planners Press, Chicago, IL.
SFpark, 2014. (June 2014). Pilot Project Evaluation: The SFMTA's evaluation of the

benefits of the SFpark pilot project. (June 2014).
SFWeekly, 2012. Best Parking Garage For The Price Of A Meter. ⟨http://digitalissue.sfweekly.com/article/Best_Parking_Garage_For_The_Price_Of_A_Meter/1062536/111524/article.html⟩. (accessed 05.01.2014).
Toledo Blade, 1951. Garage-Shelter Fund Aid Hinted. (January 20, 1951).
Weatherford, L.R., Bodily, S.E., 1992. A taxonomy and research overview of perishable-asset revenue management: yield management, overbooking, and pricing. Oper. Res. 40 (5), 831–844.
Yglesias, M., 2011. The Folly of City-Owned Parking Garages. The Atlantic Cities. October 17.