Drivers Willingness to Pay Progressive Rate for Street Parking

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16. Abstract

This study finds willingness to pay and price elasticity for on-street parking demand using stated preference data obtained from 238 respondents. Descriptive, statistical and economic analyses including regression, generalized linear model, and factor analysis are performed on the data. The average willingness to pay for on-street parking among participants is found to be $2.65. The majority of respondents preferred to pay for street parking upon departure versus upon arrival, with a fixed-rate parking fee.

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Problem Statement

In most large cities, the currently underpriced on-street parking encourages drivers to cruise to find an available space. However, cruising causes traffic congestion, air pollution, and accidents. Most of the world's parking authorities use enforcement to increase turnover and decrease parking duration. Parking meter violations are not foreseen in travel demand models; thus, they counteract travel demand management strategies. The enforcement strategy is not based on market pricing and it costs some users a large amount of money because of parking time expiration, while others pay well below the market price for on-street parking. In 2011 in Baltimore city, nearly 130,000 tickets were issued for expired parking meters, grossing revenue of more than $3.5 million (data.baltimorecity.gov) for this city of around 621,000 residents (2010 Maryland Census). On the other hand, authorities pay to enforce parking and collect fines. Replacing enforcement policies with efficient pricing can address the cruising issue, increase turnover, and generate revenue for cities.

In a new plan for the collection of on-street parking fees proposed by Ardeshiri and Jeihani (in TRB 2013), automated parking meters can be changed with no additional cost to charge the users per exact usage time. The fee is calculated by applying a progressive hourly rate, and is debited from the account associated with the bank card that was swiped. The account remains open during the parking period and concludes by confirming an exit command, much like parking garages. Thus, drivers do not have to be concerned about their meter expiring. The key proposition of the plan is that the rate increases the longer the car is parked, which ensures that turnover is not compromised and spots are not occupied for too long. Furthermore, cruising problem and traffic congestion can be addressed by an efficient pricing policy.

What guarantees the success of the proposed plan as a substitute to citation revenue is the users' willingness to pay meter fees when the rate is designed to rise progressively. This is an important factor in parking demand analysis; however, it is quite unknown to researchers, since parking meter rates have been constantly static and the proposed plan has never been implemented. Therefore, stated preference would be the best suitable method to collect such data. This study conducts a stated preference survey to determine users' willingness to pay the increasing rate of meter fees. This information from users will help researchers develop a realistic plan for meter fee collection. The results will present an effective pricing scheme for possible courses of action.

The concept of progressive parking rates in this research is analogous to the progressive tax concept (i.e., an increase in the tax rate as the taxable amount increases) or various kinds of selective taxation, such as a high sales tax on luxury goods or the exemption of basic necessities. This concept has economic and psychological effects on consumers and is an attempt to address social inequality. Consumers' behavior in response to such public policies has been studied by researchers in social sciences. Mitra et al. (1998) found majority voting support of a marginal rate progressive tax over any marginal rate regressive type. Oishi et al. (2012) demonstrated that progressive taxation had a positive correlation with the subjective well-being of people. They also revealed that such a statistical relationship was mediated by people's satisfaction with public affairs, such as the public transportation system.

This research postulates that a progressive rate structure for on-street parking spaces would reduce inequality in the utilization of public parking spots. In the current system, the cost of parking tickets due to expired parking meters is far higher than what it would have cost to pay the meter. However, in many circumstances, the violator did not deliberately intend to break the rule and accidentally exceeded the duration that was initially presumed. A well-calculated parking rate that increases progressively assures that on the one hand, consumers will be charged reasonably and fairly, and on the other hand, parking spots are not being occupied excessively by users.

Emerging intelligent transportation systems (ITS) and innovations in the information and communication technologies (ICT) have affected people's choices on travel characteristics such as travel departure time and travel mode. Dominant usage of smartphone applications are now impacting parking, car sharing, and ride sharing activities. The rapid growth of innovative transportation service providers in this field, such as ZipCar, Uber, UberX, Lyft, Sidecar, Car2Go, and Enterprise CarShare implies that people demand a modern perspective from the transportation systems. Public transportation infrastructure is anticipated to adapt with the dynamically transforming travel patterns and habits. Street parking spots as one of the facilities open to the public should be able to present a more competitive payment structure. Several smartphone applications are now established to provide real time parking guidance to the users in some cities. Parker™ by Streetline offers the status and cost of every parking space, such as curbside. Grazioli et al. (2013) developed a modular, service-based smart parking application for parking users and operators. This system guided users to the available parking areas based on their destination and also allowed them to share their knowledge of parking occupancy with other potential users cruising for parking spaces.

Literature Review

The first parking meter was put into service in 1935 in Oklahoma City to increase traffic turnover in a dense business district. Parking meters traditionally have been operated by coins. Figure 1 shows the first type of parking meter, a typical coin meter still in use, and an automated meter.

Typically, local governments handle regulations of on-street parking. They set and enforce the rules by determining parking fees and length of stay restrictions and supervising space. On-street parking is a common choice among drivers because of its low prices. If a driver goes into the city, he/she will normally have the option to park in an off-street parking facility or cruise to find on-street parking. The lower the price of on-street parking, the greater the number of drivers who decide to cruise to find an available parking space on-street (Calthrop and Proost, 2005). Interestingly, on-street parking appears more attractive than off-street parking to many drivers even if the alternatives have an identical walking distance and parking fee. (Adiv and Wang, 1987). Simulation models have been applied to replicate parking choices and study the effects of the choices on traffic congestion (Gallo et al. 2011).

Figure 4: The First Parking Meter Ever Used (Top Left), A Similar One Still in Use (Top Right), and an Automated Parking Meter (Bottom)

Cruising creates a mobile queue of cars that are waiting for available on-street parking. Cruising is thought to be a main source of congestion, but it's hard to determine the cruising effect because it is invisible. When drivers cruise, they tend to flow with the cars that are going somewhere, making it hard for transportation planners to realize the source of congestion. Shoup (2006) stated that between 8 percent and 74 percent of traffic is cruising for parking and the average time for a driver to find an available on-street space is 3.5 to 14 minutes (Shoup, 2006). Arnott and Rowse (1999) reported that over half of the cars driving in downtown Boston (and other cities with major parking problems) are cruisers trying to find an available parking space. Ommeren et al. (2011) calculated the cost of cruising for residents in Amsterdam, Netherlands.

Although Amsterdam's parking tariffs are among the highest in the world, cruising for on-street parking is still an issue, especially in the evenings, because many residents have access to residential parking permits.

Underpriced on-street parking encourages cruising when looking for an available space. It's individually rational to cruise for on-street parking if it is cheaper. However, cruising congests traffic, causes accidents, wastes fuel, pollutes the air, and degrades the pedestrian environment. Shoup (2006) found that the price of curb parking, the price of off-street parking, parking duration, the price of fuel, the number of persons in the car, and the value of time are six factors that affect drivers' decision to cruise. For decades cities have been grappling with how to handle a lack of on-street parking and reduce cruising. Traditionally, cities enforced parking limits and priced parking to increase parking turnover.

Enforcing parking limits generates revenue for cities. In Baltimore city, more than one million tickets were issued totaling over $46 million during a one-year period in a city of 621,000 residents (Maryland census, 2010). The average amount for a fine was $44.86 and the average charge per capita was $74.81 annually. Almost 36 percent of the citations were parking-related violations (Jeihani and Ardeshiri, 2013). Table 1 presents the total amount of fines distributed in Baltimore City in a one-year period, March 2010 to the end of February 2011. Fines are mechanisms to ensure space is allocated on an economic basis. They also encourage people to use the space responsibly. The problem for most city officials is collecting the fines given to drivers (Lambe, 1988). In France in 1990, about two-thirds of road offenses were related to parking. In Lyon in 1993, vehicles with unpaid parking fees accounted for about 80 percent of the parking offenses. In Amsterdam, 50 percent of commuters regularly take the risk of not paying the parking fee, and drivers did not pay for 67 percent of the parked hours (Petiot, 2004). Different cities have been creating ways to improve the enforcement process for unpaid fines. With more than a million cases of non-payment per year in London alone, the United Kingdom in 1986 introduced a $6 additional penalty for those paying after 28 days if a court hearing is not initiated beforehand (Lambe, 1988).

Table 6: Baltimore City's Parking Citation Data for One Year (Ardeshiri and Jeihani, 2013)

Violation Code	Description	Frequency	Violation Fine ($)	Total Fines ($)
1	Abandoned Vehicle	1148	302	267,216
2	No Stopping or No Parking Pimlico Event	20	77 / 102	1,715
3	Obstruct/Impeding Flow of Traffic	4930	77 / 102	745,515
4	Snow Emergency Route Violation	7	52 / 77	464
5	Obstruct/Impeding Movement of Pedestrian	13,018	77	864,831
6	Fire Lane/Handicapped Violation	947	77	62,394
8	No Stopping/Standing Tow-Away Zone	37,381	52	1,768,272
9	Commercial Veh/Residence over 20,000 lbs	152	502	60,704
10	Commercial Veh/Residence under 20,000 lbs	917	252	174,234
11	Residential Parking Permit Only	33,689	52	1,602,138
12	No Stopping/Standing Not Tow-Away Zone	59,586	32	1,771,696
13	Blocking Garage or Driveway	417	32	12,309
15	No Stopping/Parking Stadium Event Camden	6181	102	542,837
16	In Transit Zone/Stop	9538	77	627,576
17	Less Than 15 feet from Fire Hydrant	4323	77	286,991
18	All Other Parking Meter Violations	128,584	32	3,575,444
19	Exceeding 48 Hours	2466	32	72,987
20	Passenger Loading Zone	7390	32	219,440
22	Expired Tags	31,126	20 / 32	927,605
23	In Taxicab Stand	49	27 / 32	1458
25	Less 30 ft from Intersection	397	32	11,874
26	No Stop/Park Handicap	1556	502	559,876
27	No Stop/Park Street Cleaning	48,995	52	2,315,490
28	No Stop/Stand/Park Cruising	143	52 / 77	8986
30	Red Light Violation	95,695	75	7,177,125
31	Right on Red	30,577	75	2,293,275
32	Fixed Speed Camera	406,308	40	16,252,320
33	Mobile Speed Camera	95,153	40	3,806,120
99	All Other Stopping or Parking Violations	14,946	32	446,645
Total		1,035,639	__	46,457,537

Petiot (2004) found that an increase in fines paradoxically increases car use and parking violations. Furthermore, enforcement procedures for payment of fines are costly. To mail a notice for payment, an address must be found and an envelope prepared. Sometimes the authorities or a summons server may need to make a trip to a person's residence to inform them that they must make an appearance at the Court registry. Courts employ judges, clerks, and administrators as well as gathering witnesses. Cost is involved in transferring funds, particularly if the fine is paid in installments and the person becomes delinquent in payment. If the address of a vehicle is not available and /or the person lives out of state there is cost. A court case can be lost if a witness is absent or more time has passed than the statute of limitation permits. Many drivers can also be acquitted because of defects in the legal requirements of the enforcement system, such as flaws in the construction of the Bylaw or inappropriate wording on the citation statement given to the motorist (Lambe, 1988).

Parking Pricing

On-street parking is currently regulated by price ceilings and rationing, which results in a shortage of supply, queues, unnecessary cruising, and favoritism and corruption. Albany Parking Authority (APA) used market pricing and dynamic pricing concepts for its on-street parking to improve congested traffic, reduce fuel consumption, reduce air pollution, and save people time and money (Klein, 2006). Market prices are more efficient than price ceilings and rationing because price is determined by supply and demand. APA aimed to remove overtime tickets, especially for visitors. They removed the previous limit of two hours on on-street parking and increased the hourly cost by $.25 per hour for stays longer than the two hours. The focus addressed customer service needs using a cost/benefit approach. A driver has the option to pay $21.50 to park all day or take a break halfway through the day and re-feed the same meter (without moving their car) for a total cost of $15.50 (two five-hour purchases of $7.75 each). They also have the option to go to their car every two hours and pay $12.50 (five two-hour purchases of $2.50). Figure 2 presents APA's rate structure.

Figure 5: On-Street Parking Rate Structure in Albany (Klein, 2006)

In a new plan for street parking fees collection proposed by Ardeshiri and Jeihani (2013), with a slight change in the current automated parking meters, the meters would be able to measure the fee based on an exact parking period. The process differs from the current system, which charges for an estimated time at the beginning of the parking period in time-restricted zones. In their proposed method, the fee is calculated by applying a progressive hourly rate, and is debited from the account associated with the bank card that was swiped. The account remains open during the parking period and concludes by confirming an exit command, much like parking garages. The fee is fair, based on the exact amount of time a driver utilizes the facility. There are no concerns about the parking expiration time. The key proposition of the plan is that the rate increases by parking time, which ensures that the turnover is not compromised and spots are not long occupied. The longer the vehicle is parked in a high-demand area, the higher the hourly rate will be for the later times. The pricing scheme depends on the demand pattern, time of day, and also special events. If the rate is $2/hr in an existing 2-hr limited zone, $3/hr (for instance) can be set for the second 2-hour period, and so on for the next hours. A fee catalog for the upcoming hours may become available to users on the meter’s screen. This approach dismisses the current parking time restrictions. Demand for parking, turnover, and parking duration is controlled by efficient pricing rather than by enforcement because it would be very costly for consumers to stay in a parking spot for a long time. It is also subsidy-free pricing because a group of users – the ones who are ticketed – do not pay for all other users, and each user pays a fair amount of parking fees. The progressive pricing scheme can substitute for parking tickets to recoup lost citation revenue. It may be argued that a city’s revenue decreases because of the loss of fees from citations; however, the city can benefit from the proposed escalating rates if they are properly set. Furthermore, cities would not have to spend money and time collecting the fines for parking expiration tickets.

PayBySky is another solution to the problems of cruising, regulating on-street parking, and reducing congestion and enforcement costs that has been available to different cities. It proposes a volunteer program that installs sensors inside of individual vehicles as opposed to in the infrastructure. It automatically detects when a vehicle is parked in a controlled spot (time rationed and/or payable). When a driver parks in any spot that is part of the PayBySky network, his/her account is automatically billed without any interaction. The built-in wireless technology and geographical parking maps are used to automatically determine when a vehicle is parked, what fee is due, and how long parking is permitted. PayBySky prevents users from making any errors and cheating because it will determine the correct charge itself, every time in any type of parking facility. It also provides users with traffic and parking spot data, and gives customers views of traffic congestion and parking spot availability (PayBySky (Applied Telemetrics, Inc.), 2014). Congestion can be reduced and revenue increased because PayBySky enables a city to manage parking demand, using pricing rather than time rationing. The ability to do progressive pricing – increasing the price as the vehicle stays – can regulate on-street parking and enforce average turnover, reduce enforcement costs and increase revenue. PayBySky also has the ability to reduce enforcement costs.

Economic Analysis

One of the important factors in parking demand analysis is travelers' willingness to pay parking fees, which depends on their demographics, income level, and trip purposes. Barata et al. (2011) applied a logistic regression model to determine the relationship between travelers' attributes and their willingness to pay for reserved parking space. Ommeren et al. (2011) calculated and analyzed Amsterdam residents' willingness to pay street parking and the private cost of cruising.

Shoup (2006) calculated the elasticity of the maximum time a driver is willing to cruise with respect to different variables and found the following. The elasticity of search time to the price of on-street parking depends only on the on-street and off-street parking. The demand for on-street parking is inelastic when its rate is well below off-street parking. It can become elastic when its prices approach off-street parking rate. When curb parking is free, reducing the price of off-street parking by 10 percent reduces willingness to cruise by 10 percent. The longer parking duration causes a longer cruising. The elasticity of cruising time with respect to fuel depends on the relative values of fuel, vehicle occupancy, and the value of their time. If the fuel cost is much less than the value of time, an increase in fuel cost has little effect on willingness to cruise. The elasticity of cruising time with respect to vehicle occupancy is the same as the one with respect to the value of their time.

Pratt (1999) calculated the elasticity of parking to be between -0.1 and -0.3, depending on socio-economic characteristics, location, travel choice, and trip characteristics.

To mitigate parking shortages and utilize the parking supply system more efficiently, Bagloee et al. (2012) proposed a pragmatic methodology to model drivers' parking choices. A logit model was calibrated to evaluate the effect of factors such as parking price, parking lots security, and the availability of underground parking facilities. The study developed a new parking pricing policy to change drivers' parking behaviors.

Research Approach and Methodology

To evaluate the general response of drivers to the proposed street parking fee collection system, the research team designed a stated preference survey. The team prepared a survey questionnaire, received IRB approval for human subject research, and distributed the questionnaire among peers as a pilot. After revising the questionnaire, an online version was provided. The research team distributed the survey questionnaire among faculty, staff, and students at Morgan State University and Virginia Tech. The survey was also randomly distributed in the following cities and areas: Baltimore, MD; Northern Virginia, Washington D.C., New York City and Albany, NY; San Francisco, San Diego, and Los Angeles in CA; Phoenix, AZ, and Blacksburg, VA.

The questionnaire asks participants about their socio-economic information, choices of parking garage versus on-street parking, attitude toward the current parking provisions and prices, and willingness to pay on-street parking. Participants' choices between flat rate and dynamic rate were also asked in different pricing schemes.

The survey concentrated on evaluating the response of drivers to a dynamic parking rate where the rate was designed to grow progressively. Before the presentation of various pricing scenarios, the survey inquired about drivers' maximum willingness to pay street parking fees for different hours of usage.

The research team formed a database from the collected data and performed descriptive, statistical, and economical analysis.

Economic Model

Since on-street parking is managed and operated by monopolistic municipalities, the demand and marginal revenue are as in Figure 3. If parking were operated by a private party, the chosen price and quantity would be P* and Q^*_m to maximize the firm's profit. As shown in Figure 4 (left), the pricing is inefficient and there is a dead-weight loss due to monopoly pricing. However, since the on-street parking is operated by governments, efficient pricing can be chosen as presented in Figure 4 (right). Efficient pricing happens when marginal cost and demand are equal. In this case, there is no dead-weight loss (DWL) and society's welfare and consumer surplus is higher than that in monopoly pricing, while producer surplus is lower. Furthermore, parking prices are lower and parking supplies are higher than that of the monopoly case. DWL is the societal loss in welfare and measures the inefficiency of monopoly.

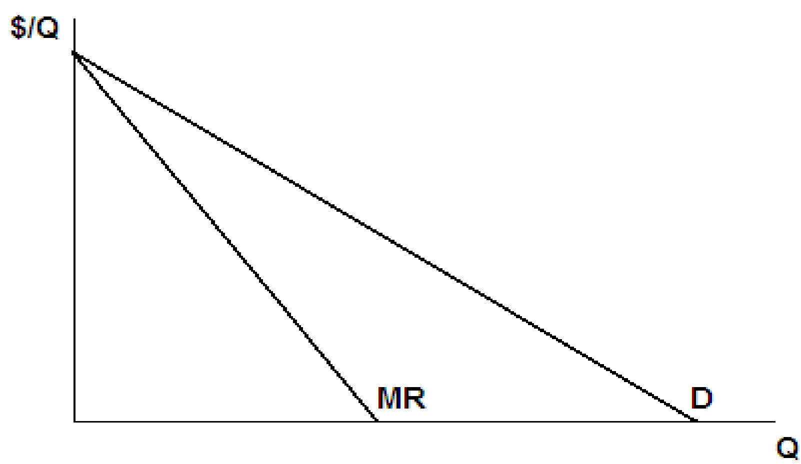


Figure 6: Demand, Marginal Revenue, and Short-run Marginal Cost in Monopoly

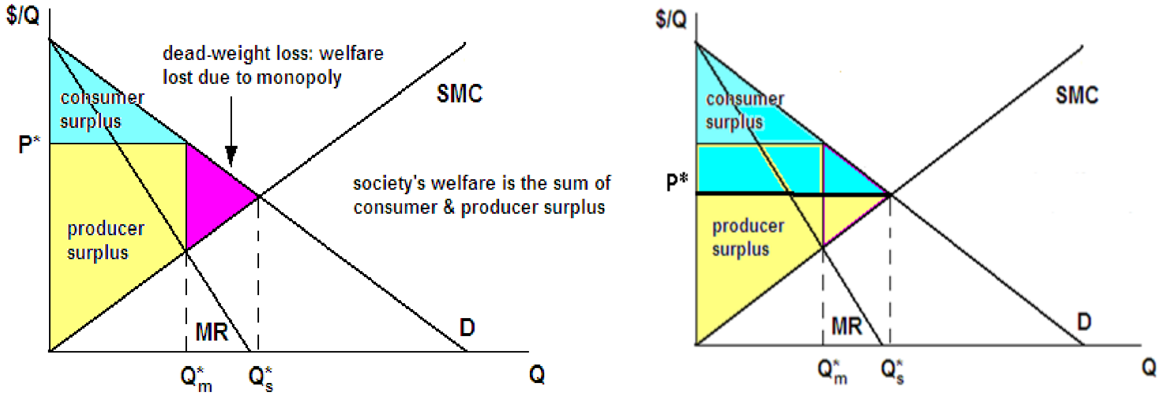


Figure 7: Monopoly Pricing (Left) and Efficient Pricing (Right)

On-street parking demand or willingness to pay was calculated using participants' maximum payment choices in each scenario. Price elasticity of demand is calculated as follows.

$$\varepsilon = \frac{dQ}{dP} . \frac{P}{Q}$$

Elasticity is the responsiveness or sensitivity of customers' quantity demanded of a goods or service to its price change. Elasticity specifies the percentage change in quantity demanded in response to a 1% change in price ceteris paribus.

In monopoly pricing, *MR=MC* and $P = \frac{MC}{1 + 1/\varepsilon}$ which implies ε < -1. This means a monopolistic agent chooses an output level at which demand is elastic and revenue increases by raising the price. However, this can be avoided by efficient pricing.

Efficient pricing happens when all users pay the exact amount of their usage. Cruising for parking as well as traffic congestion are examples of inefficiency due to excessive demand. Inefficiency can usually be traced to improper pricing. An efficient or optimal price is one that causes producers to offer exactly the variety of services and in exactly the correct amounts to best satisfy consumer demands. When cruising for parking happens, it means that the demand for parking exceeds the supply and therefore, price needs to be increased to reduce the demand.

Findings

Demographic descriptions of the participants

In total, 238 participants filled out the survey. The majority of them are geographically distributed across the U.S. There are six participants from other countries. Among participants, 28.6% are from Blacksburg, VA, 27.3% are from the Baltimore, MD area, 18.5% are from Northern Virginia, and 8% are from Washington, D.C. Other cities include Los Angeles, CA (3.8%) and San Diego, CA (3.4%). The following section is a description of the demographic features of the survey participants. Note that in this document, responses such as "Not available" or "Not indicated" are omitted. Therefore, some of the figures may not have their percentages totaling 100%.

More than half of the participants are males (Figure 5). Age distribution, race and education are shown in Figure 6. Figure 7 shows the car ownership and number of drivers. As can be seen, the majority of the responders are aged 45 or below. More than half of the participants have post-graduate degrees. A small amount of survey participants do not own a car or do not have drivers in their family.

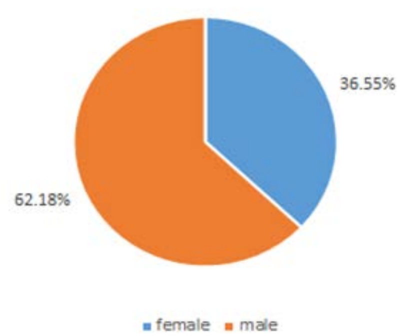


Figure 8: Gender Distribution

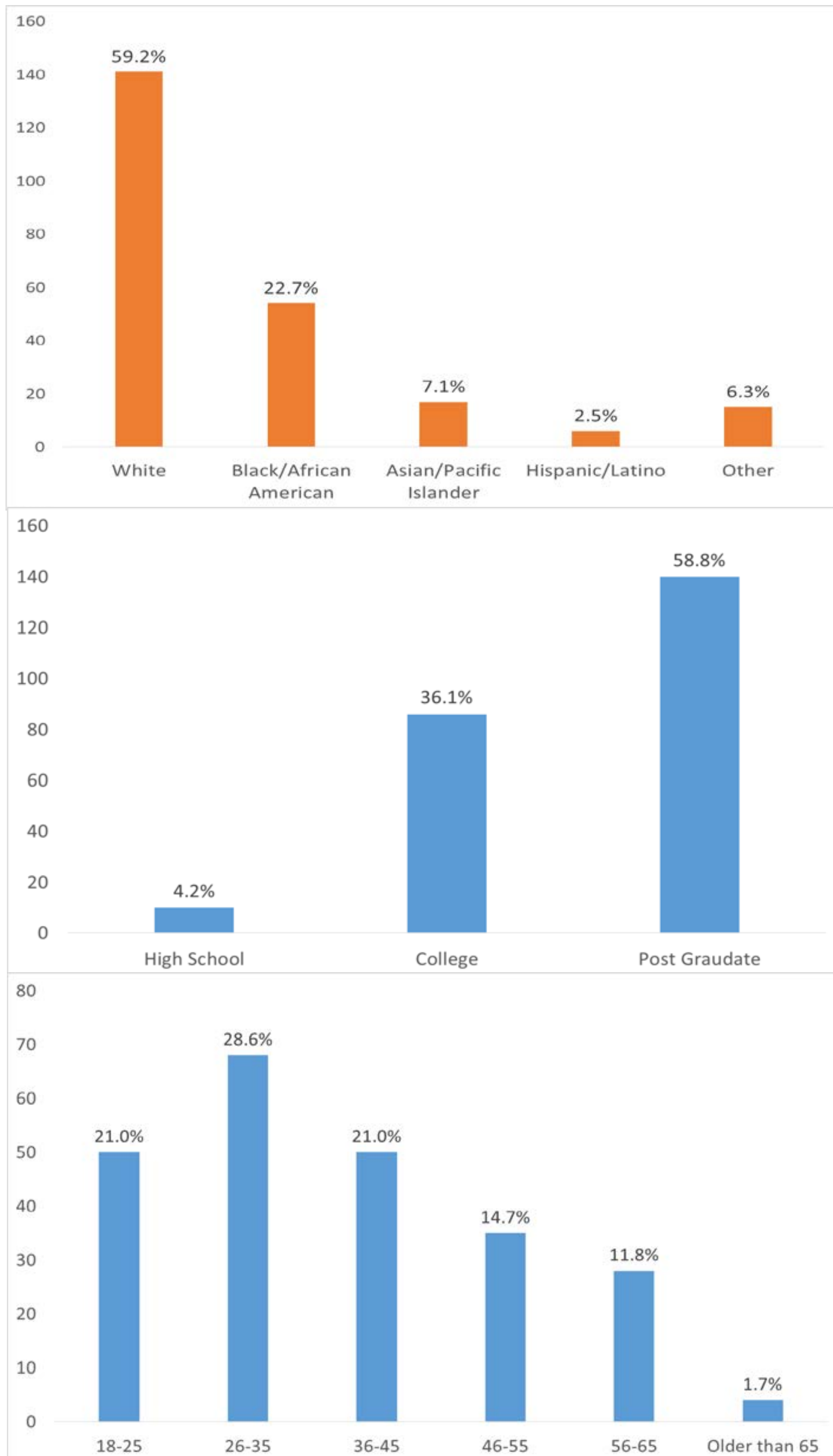


Figure 9: Demographic Data of the Participants

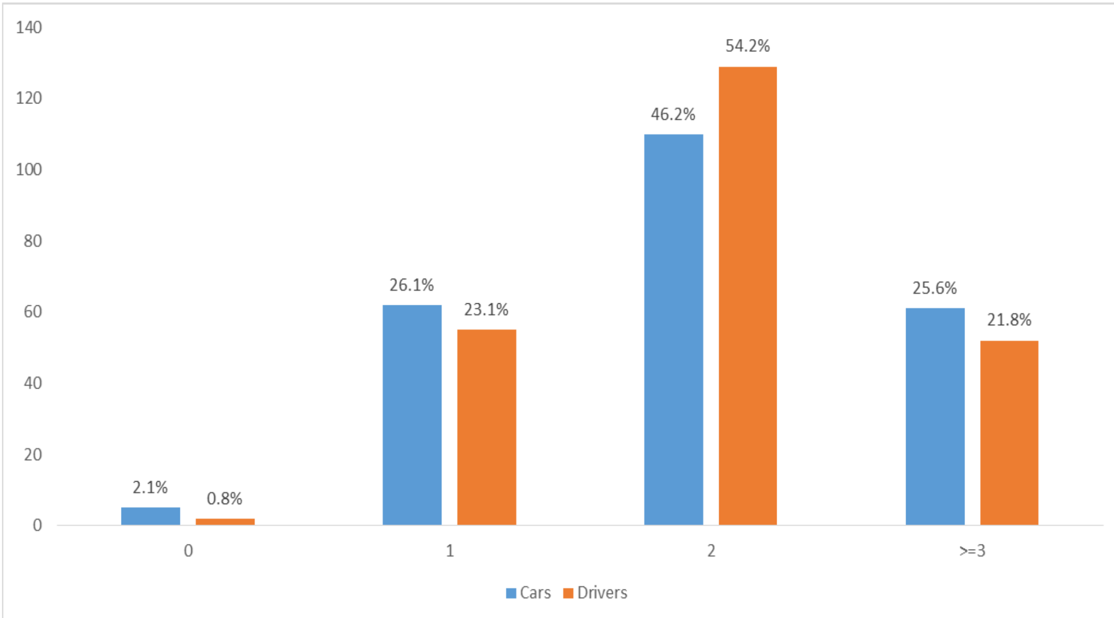


Figure 10: Car Ownerships and Number of Drivers

Opinions and preferences of parking

The questionnaire is designed to investigate peoples' willingness to pay progressive rate parking. This section discusses the participants' responses.

Maximum fixed rate

This series of questions asks for participant's willingness to pay a fixed rate per hour if their business in downtown will take 1) Up to 1 hour, 2) Up to 2 hours, or 3) Up to 3 hours (shown in Figure 8). Three sets of paired T-tests were conducted to find out if participants make significantly different choices when they are facing varied lengths of possible parking time. The results shown in Table 2 illustrate that participants did not show any significant differences when choosing a fixed rate in accordance with different lengths of parking time.

Forty percent of Blacksburg residents stated that they are willing to pay less than $2 per hour, while only 10% of Baltimore residents are willing to pay less than $2 an hour. On the other hand, only 3% of Blacksburg residents are willing to pay $5 per hour, while 13% of Baltimore residents are willing to pay that amount. This verifies willingness to pay is highly correlated to the location.

Table 7: Paired T-tests Results

	One Hour vs. Two Hours	Two Hours vs. Three Hours	One Hour vs. Three Hours
Degree of Freedom	237	237	237
T-Value	0.0	-0.41	0.25
Pr > |t|	1.0	0.6850	0.8039

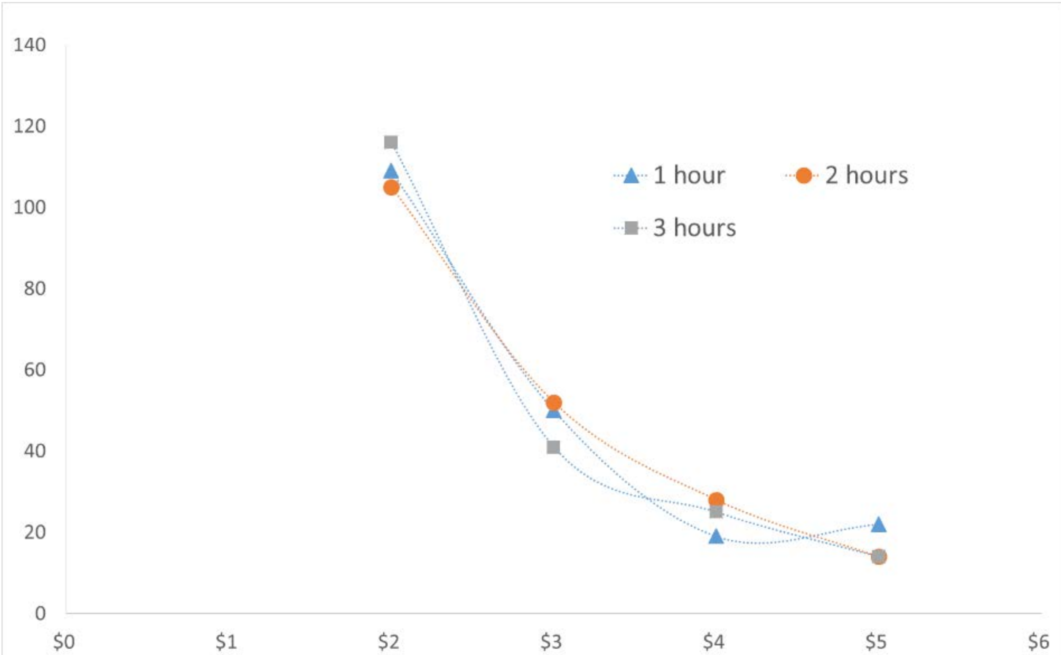


Figure 11: Willingness to Pay at Different Length of Parking Time

Willingness to pay formulas for each parking time and price elasticity of demand is calculated as follows. Q is quantity demanded, P is price, and ε is the elasticity.

Up to one hour parking:

$$Q = 15.5P^2 - 137.7P + 322.7$$
$$\varepsilon = \frac{31P^2 - 137.7P}{15.5P^2 - 137.7P + 322.7}$$

The elasticities are -0.53, -1.38, -2.73, -2.75, and 3.99 for P=$1, $2, $3, $4, and $5.

Up to two hours parking:

$$Q = 394.03e^{-0.666P}$$
$$\varepsilon = -0.666P$$

The elasticities are -1.66, -1.33, -2, -2.66, and -3.33 for P=$1, $2, $3, $4, and $5.

Up to three hours parking:

$$Q = 536.92P^{-2.26}$$
$$\varepsilon = -2.26$$

Current Parking Conditions

Several questions in the survey are designed to visualize the existing parking conditions of the participants. Since many of the responders are from Blacksburg, VA, which is a university town, a large portion of the participants indicated that they have free parking. Furthermore, many respondents live in suburban areas that offer free on-street parking. When asked "How many hours a week do you use a free street parking," more than 60% of participants said that they have at least some hours of free street parking. For participants who paid for their on-street parking, Figure 9 shows the percentage of paid street parking per week. As can be seen, the majority of the participants paid less than 5 hours per week for on-street parking. Figure 10 illustrates a similar trend for paid parking lots or garages. Excluding the 60% of the participants who do not pay for their parking lot or garage (which is not shown in the figure), participants who paid for parking lots or garages were asked to estimate the cost of their parking and number of hours of paid parking. Figure 10 shows that on average people pay up to $35/week for parking in a parking lot or a parking garage. Apparently, due to location, the rate varies significantly from less than $5 to nearly $40. This observation indicates that the locations of the workplace or home of the participants may affect their choices of parking options significantly.

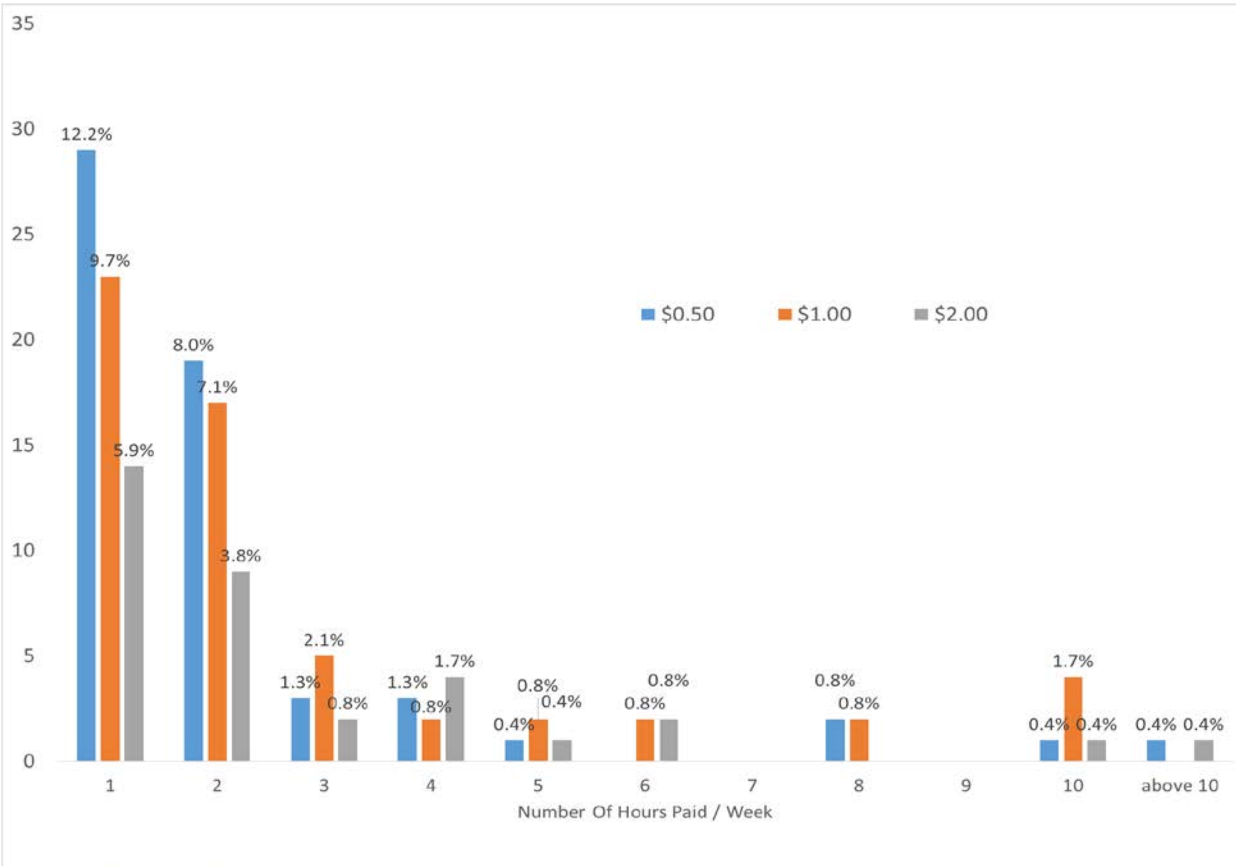


Figure 12: Paid On-Street Parking

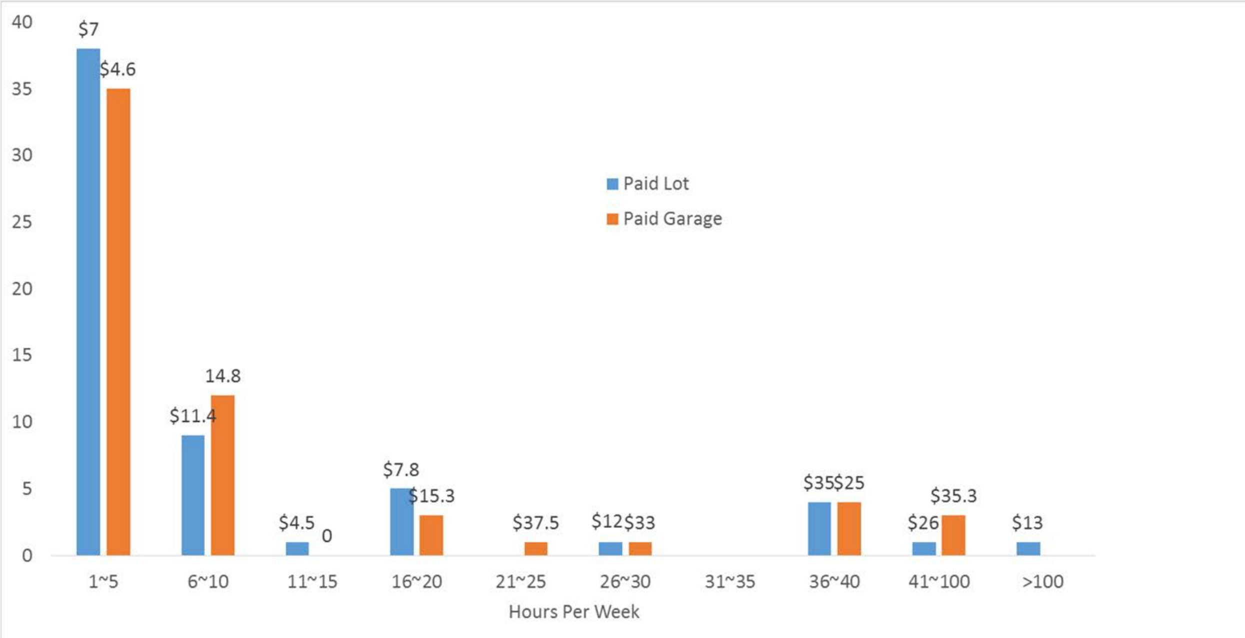


Figure 13: Paid Lot/Garage Parking

Preferred Prepaid Amount

When asked about the prepaid amount for personal business that may take about 1 hour but may range from 30-90 minutes, a majority of the participants choose either more than the maximum possible length of time needed (90 minutes) or a garage that is not pre-paid. As can be seen in

Figure **11**, only 13.2% chose to pay for only 60 minutes and return to pay more if needed.

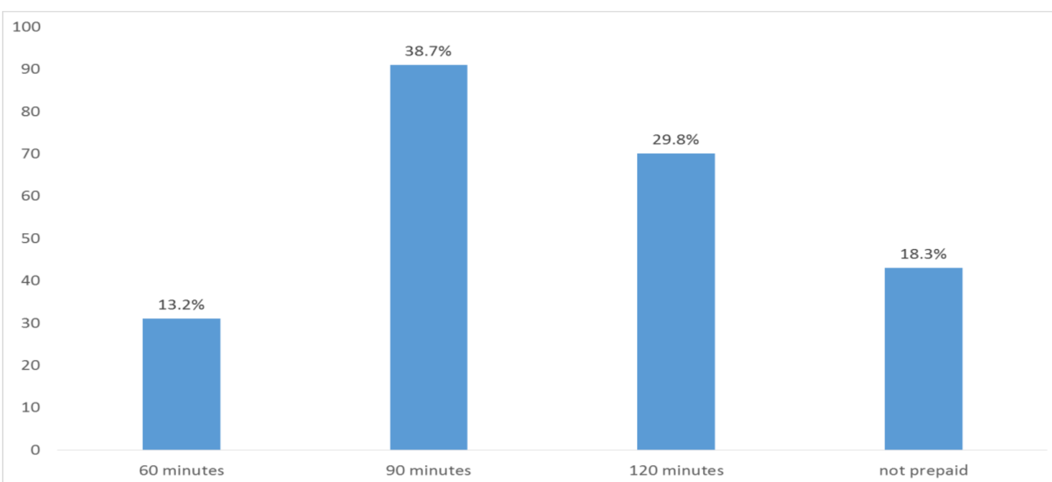


Figure 14: Willingness to Pay for a 30-90 Minutes Personal Business

Importance of Factors

What factors affect parking choices is another interesting question the team wants to explore The participants were asked to scale the importance of the following factors shown in Figure 12 with a score of 1 to 5 to indicate how important those factors are as they choose parking options. As can be seen, people care less about boosting business or fairness or equity when they make decisions about parking options. Importance scales are much higher in the first 4 factors. In the boxplot, a red line is the median, and the edge of box is the 25% and 75% percentile, individually. When asked about preferences for parking garage options, a majority of the participants (64.7%) chose the garage that is farther away but costs half the price of the alternative garage, as shown in Figure 13, indicating the cost of parking plays a very important role in parking decisions.

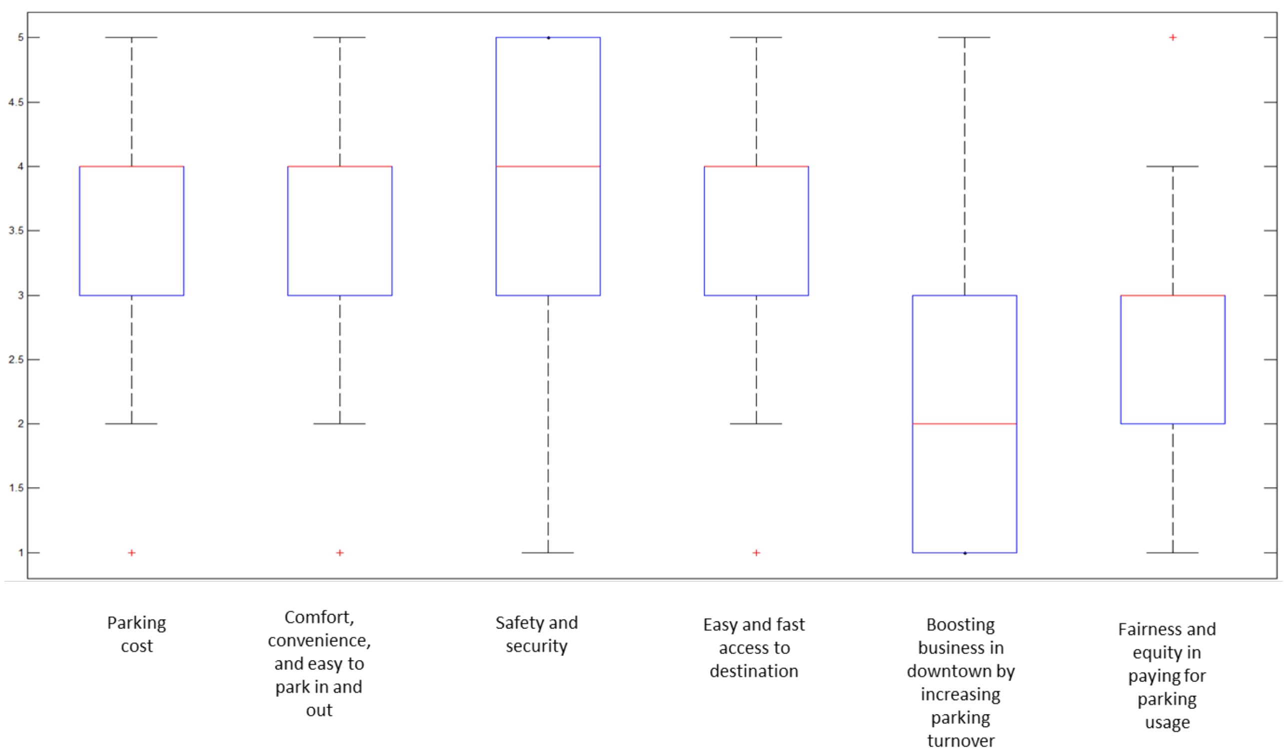


Figure 15: Importance of Factors

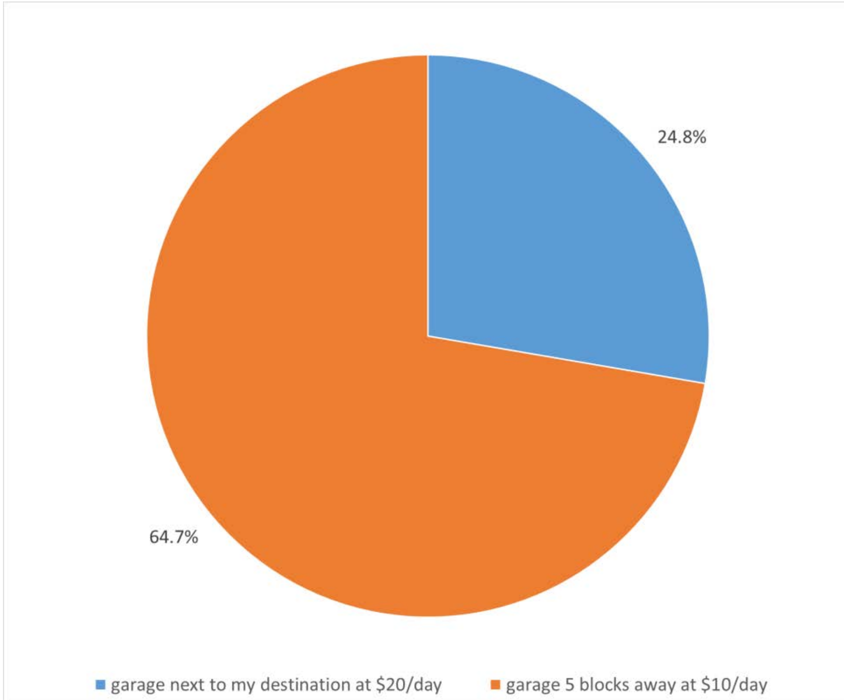


Figure 16: Parking Garage Preferences

A similar trend is observed in the responses to the questions “How satisfied are you with the following parking meter fee-collection systems.” Participants gave a higher score for “Pay-after-return with flat rate” compared to “prevailing pre-paid system with flat rate with time restriction” and “A pay-after-return system with dynamic rate (rate increases each hour),” as shown in Figure 14. Participants’ responses revealed that the cost of parking is a very important factor affecting their parking choices. Furthermore, they seem to feel more comfortable when the rate is flat instead of dynamic. The next section will further discuss participants’ choices in a series of questions designed to investigate customer choices when faced with different parking rates.

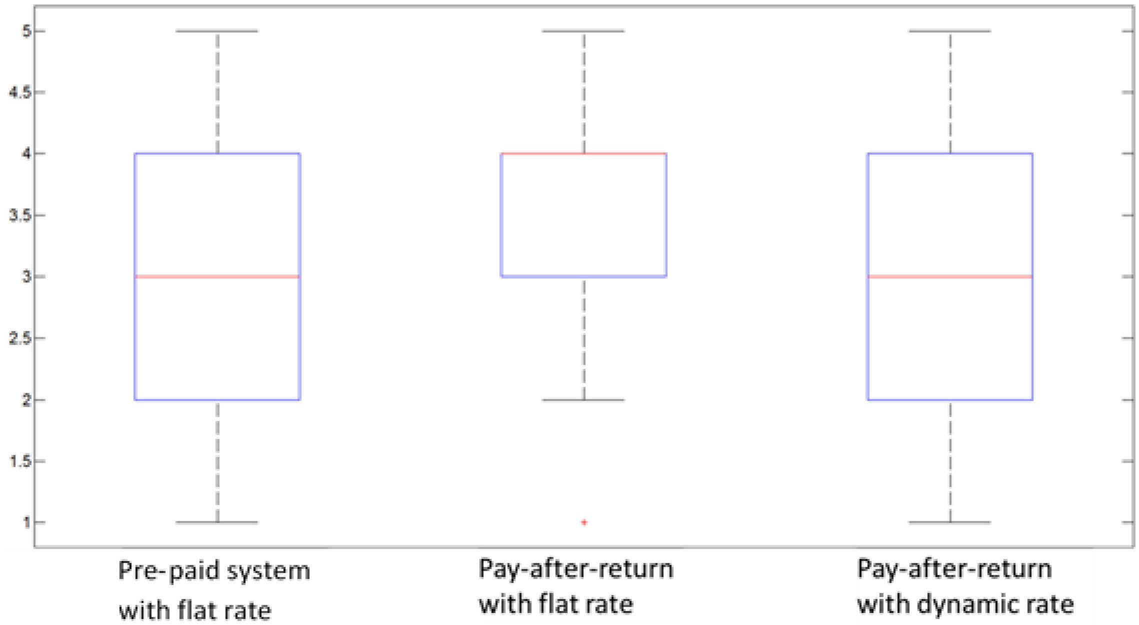


Figure 17: Satisfaction of Parking-meter Fee-collection Systems

Violations of the Previous Year

The survey also asked participants how many parking meter violations they had had in the previous year, how many times they appealed for trial, and, on average, how much they paid for the parking citation. This can be used by the team as an indicator of participants' acceptance of a dynamic payment system. Figure 15 shows the results. As can be seen, the amount of parking violation fine can be surprisingly high, adding up to more than $2,000 a year.

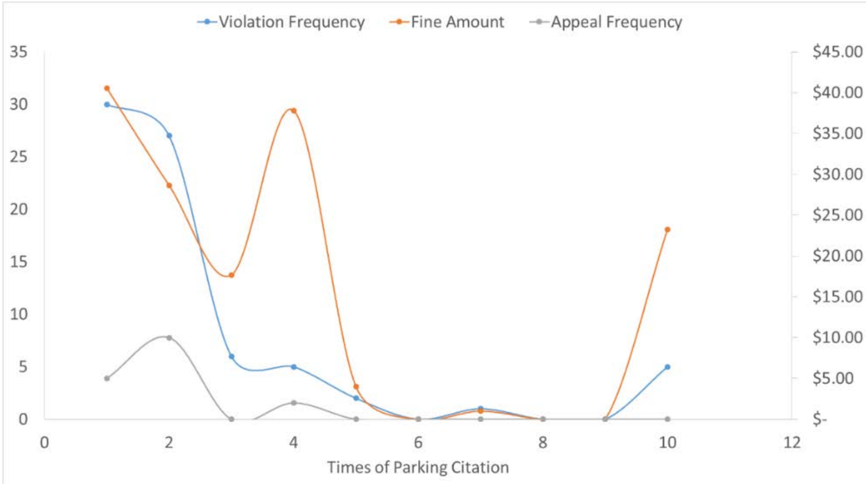


Figure 18: Parking Violations, Appealing, and Fine Amount

Selections of Payment Options

Six scenarios are provided in the questionnaire to ask participants to select from: 1) a flat rate, 2) a dynamic rate, and 3) a maximum rate for a parking garage that he/she would like to pay. The six scenarios vary in the hourly rate of flat rate and dynamic rate combinations, resulting in a different total cost for different parking time. The tabular numbers of the total cost for the flat rate and dynamic rate for a stay length of 1 to 6 hours are provided along with the graphic illustration of the total cost for all of the six scenarios (Please refer to the survey questionnaire for the details of the six payment option scenarios.). They are all based on the assumption that the parking is for a personal business in downtown that may need 2-5 hours of stay. Figure 16 shows the preferences of the participants for the six option payments. One obvious observation from a preliminary examination is that people prefer flat-rate parking under most of the scenarios except for payment scenario 3, where the dynamic rate charges absolutely lower than the flat rate for all possible parking hours from 1-5. This observation leads to a further exploration of the data with several statistical tests.

In payment options 1 and 6, the dynamic rate is always greater than or equal to the flat rate, therefore the dynamic rate option choice is in its minimum (around 13%). In payment option 2, 4, and 5, in which the dynamic rate is cheaper than the flat rate for the first 3 hours, the choice of the dynamic rate increases to over 30%. The dynamic rate is lower in the first 5 hours in payment option 3; therefore, 63% of respondents choose it. Still, interestingly, 28% of respondents chose the flat rate which is more expensive. The reason could be the simplicity of flat rate and that participants are more familiar with it. The questionnaire showed the prices using a graph and a table to make sure participants understood the pricing methods.

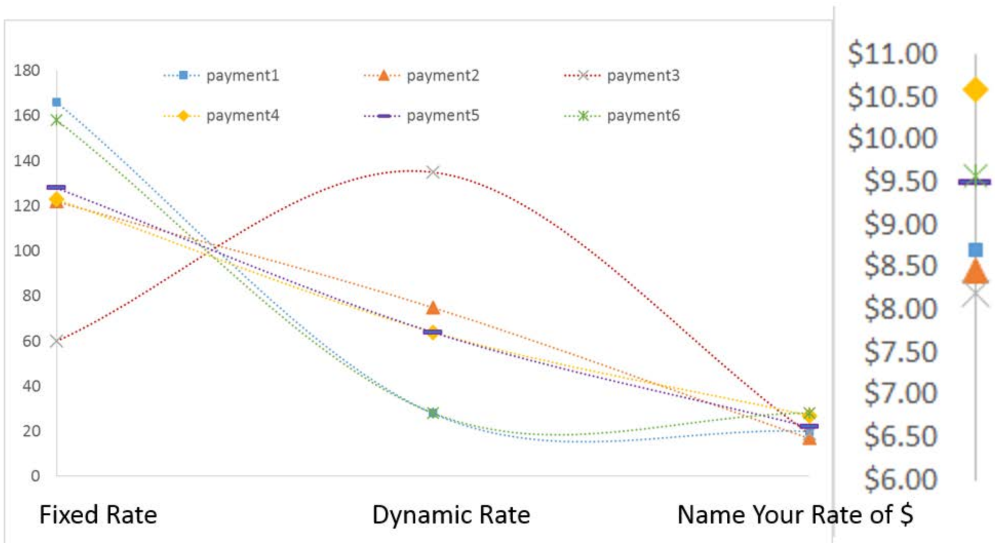


Figure 19: Six Payment Options

Paired-T tests for the six payment options

Figure 16 shows that payment option 1 and payment 6 are very close (group 1). Payment 2, payment 4, and payment 5 are very similar (group 2). Only option 3 is significantly different from all the other options. Paired T-tests were conducted to see if the participants made significantly different choices among each pair of payment options. As expected, options within each group are significantly different from any other options in another group. For example, payment option 1 and payment option 6 are significantly different from option 3. The results of the paired T-tests are listed in Table 3.

Table 8: Paired T-tests Results

Paired Payment Options	Within Group	T-value	Pr> |t|
Option 2 vs Option 1	No	5.07	<0.0001
Option 2 vs Option 6	No	2.63	0.0092
Option 3 vs Option 1	No	11.07	<0.0001
Option 3 vs Option 6	No	9.36	<0.0001
Option 4 vs Option 1	No	5.37	<0.0001
Option 4 vs Option 6	No	3.78	0.0002
Option 5 vs Option 1	No	4.1	<0.0001
Option 5 vs Option 6	No	3.16	0.0018
Option 2 vs Option 3	No	-7.81	<0.0001
Option 4 vs Option 3	No	-5.76	<0.0001
Option 5 vs Option 3	No	-7.28	<0.0001
Option 1 vs Option 6	Yes	-1.75	0.0808
Option 2 vs Option 4	Yes	1.1	0.2725
Option 2 vs Option 5	Yes	-0.12	0.9084
Option 4 vs Option 5	Yes	1.39	0.1661

Categorical variable modifications

To further investigate how the demographic features, existing parking conditions, and previous parking experiences affect participants' choice of parking payment options, GLM is conducted to identify significant variables. Since some categorical variables have very small numbers in some of the categories, minor modifications are made to ensure that these categorical variables have minimum observations in each of their subset. For example, number of violations is grouped into two categories: with violations or not. Details of the modified categorical variable values are listed in Table 4. Modified parts are bold and italic.

Table 9: Categorical Variable Adjustments

Variable Name	Original Categories/Definition	Modified Categories
Age	<18; 18-25; 26-35; 36-45; 46-55; ***56-65; ≥65***	<18; 18-25; 26-35; 36-45; 46-55; ***>=56***
Education	***High School; Some college;*** Post graduate	***College or Below***; Post graduate
Race	White; ***Hispanic; Latino;*** Black/African American; ***Asian/Pacific Islander; Other***	White; Black/ African American; ***Others***
Employment	***Retired/don't work; Unemployed, looking;*** Self-employed; Employed (part-time); Employed (full-time)	***Not Work;*** Self-employed; Employed (part-time); Employed (full-time)
Paid Street Parking	***# of hours per week***	***Yes/No***
Paid Lot/Garage	***# of hours per week***	***Yes/No***
Number of Violations	***Exact # of violations***	***0; 1~2 times; 3~4 times; More than 4***
Number of Appeals	***Exact # of appeals***	***Yes/No***
Fine Paid	***Exact $ Amount***	***$0; $100 or Less than $100; More than $100***
City Category 5	***Town/City Name***	***5 categories depending on city/town sizes and locations***
City Category 2	***Town/City Name***	***Blacksburg/Not Blacksburg***

Tentative GLM Analysis

Selection of Significant Variables

Since there are missing values, GLM tests are conducted instead of ANOVA analysis for each of the six payment options. The objective is to identify the significant independent variables for each payment option. The results are listed in Table 5 through Table 8. Each payment option has its own significant independent variables: Significant variables in one case are not necessarily the same as the significant variables of another. The independent variables for each payment option are highlighted. In cases where there are no significant independent variables, variables with relatively smaller P-values are used (they are marked in red). As stated before, the three variables, "Fixedrate1," "Fixedrate2," and "Fixedrate3" are correlated. Therefore, when more than one out of these three variables is significant, only one is used in the final modeling.

Table 10: GLM Results – Payment Option 1

Independent Variable	F Value	Pr > F	Independent Variable	F Value	Pr > F
Gender	1.02	0.3139	**Paidlothours**	0.88	0.3500
Age	2.5	0.0436	**Paidgaragehours**	3.08	0.0807
Race	3.44	0.0339	**Violation**	0.52	0.6689
Education	0.94	0.3335	**Appeal**	0.05	0.8256
Income	0.69	0.6325	**Fine**	0.52	0.5975
Employment	1.12	0.3415	**City Group 5**	2.26	0.0502
Paidstreetparking_1	0.03	0.8520	**City Group 2**	2.88	0.0914
Paidstreetparking_2	0.49	0.4846	**Fixedrate1**	0.47	0.7544
Paidstreetparking_3	0.28	0.5943	**Fixedrate2**	0.27	0.8998
Paidstreetparking_4	1.29	0.2566	**Fixedrate3**	0.64	0.6352

Table 11: GLM Results – Payment Option 2

Independent Variable	F Value	Pr > F	Independent Variable	F Value	Pr > F
Gender	0.84	0.3615	**Paidlothours**	1.70	0.1941
Age	1.82	0.1272	**Paidgaragehours**	0.90	0.3448
Race	0.53	0.5922	**Violation**	0.14	0.9378
Education	0.26	0.6132	**Appeal**	1.15	0.2845
Income	0.26	0.9367	**Fine**	0.18	0.8327
Employment	0.95	0.4198	**City Group 5**	1.21	0.3039
Paidstreetparking_1	0.46	0.5005	**City Group 2**	0.37	0.5444
Paidstreetparking_2	0.29	0.5906	**Fixedrate1**	0.81	0.5171
Paidstreetparking_3	0.00	0.9600	**Fixedrate2**	2.65	0.0344
Paidstreetparking_4	0.06	0.8102	**Fixedrate3**	2.05	0.0892

Table 12: GLM Results – Payment Option 3

Independent Variable	F Value	Pr > F	Independent Variable	F Value	Pr > F
Gender	3.10	0.0796	**Paidlothours**	0	0.9625
Age	0.80	0.5243	**Paidgaragehours**	0.29	0.5901
Race	0.31	0.7325	**Violation**	0.53	0.6618
Education	5.01	0.0262	**Appeal**	0.71	0.4016
Income	0.49	0.7835	**Fine**	1.91	0.1510
Employment	1.51	0.2117	**City Group 5**	1.84	0.1057
Paidstreetparking_1	0.07	0.7945	**City Group 2**	0.85	0.3586
Paidstreetparking_2	1.59	0.2083	**Fixedrate1**	2.39	0.0517
Paidstreetparking_3	1.19	0.2763	**Fixedrate2**	2.93	0.0217
Paidstreetparking_4	0.98	0.3231	**Fixedrate3**	2.51	0.0427

Table 13: GLM Results – Payment Option 4

Independent Variable	F Value	Pr > F	Independent Variable	F Value	Pr > F
Gender	2.97	0.0863	**Paidlothours**	0.03	0.8691
Age	1.01	0.4026	**Paidgaragehours**	0.52	0.4719
Race	0.26	0.7677	**Violation**	0.47	0.7022
Education	0.01	0.9280	**Appeal**	0.03	0.8694
Income	0.37	0.8659	**Fine**	1.03	0.3606
Employment	2.14	0.0961	**City Group 5**	1.21	0.3034
Paidstreetparking_1	0.1	0.7490	**City Group 2**	0	0.9499
Paidstreetparking_2	0.13	0.7233	**Fixedrate1**	1.27	0.2839
Paidstreetparking_3	0.11	0.7366	**Fixedrate2**	1.96	0.1025
Paidstreetparking_4	0.21	0.6504	**Fixedrate3**	2	0.0962

Table 14: GLM Results – Payment Option 5

Independent Variable	F Value	Pr > F	Independent Variable	F Value	Pr > F
Gender	2.26	0.1339	**Paidlothours**	0.6	0.4399
Age	0.96	0.4309	**Paidgaragehours**	0.8	0.3722
Race	0.07	0.9330	**Violation**	0.87	0.4552
Education	2.96	0.0869	**Appeal**	0.07	0.7915
Income	0.39	0.8546	**Fine**	0.78	0.4582
Employment	0.29	0.8359	**City Group 5**	1.55	0.1771
Paidstreetparking_1	0.03	0.8562	**City Group 2**	0	0.9499
Paidstreetparking_2	2.06	0.1530	**Fixedrate1**	1.23	0.2992
Paidstreetparking_3	1.79	0.1825	**Fixedrate2**	2.98	0.0201
Paidstreetparking_4	0.05	0.8207	**Fixedrate3**	2.46	0.0462

Table 15: GLM Results – Payment Option 6

Independent Variable	F Value	Pr > F	Independent Variable	F Value	Pr > F
Gender	2.06	0.1527	**Paidlothours**	1.4	0.2380
Age	2.2	0.0698	**Paidgaragehours**	0.03	0.8519
Race	0.67	0.5115	**Violation**	1.29	0.2778
Education	0.9	0.3439	**Appeal**	0.06	0.8042
Income	0.37	0.8692	**Fine**	0.98	0.3754
Employment	0.62	0.6038	**City Group 5**	1.5	0.1914
Paidstreetparking_1	0.49	0.4837	**City Group 2**	0.28	0.6003
Paidstreetparking_2	0.6	0.4391	**Fixedrate1**	2.31	0.059
Paidstreetparking_3	0.13	0.7151	**Fixedrate2**	2.14	0.0775
Paidstreetparking_4	0.05	0.8294	**Fixedrate3**	2.3	0.0597

Table 16: GLM Results

Dependent Variable	**Independent Variables**	**R-Square**
Payment Option 1	Age, Race, City Group 5	0.11
Payment Option 2	Fixedrate2	0.05
Payment Option 3	Fixedrate2, Education	0.07
Payment Option 4	Gender, Fixedrate3, Employment	0.08
Payment Option 5	Fixedrate2, Education	0.06
Payment Option 6	Age, Fixedrate1	0.08

Willingness to Pay Model

The average willingness to pay street parking among participants was $2.65 for an hour. Although the overall willingness to pay values did not vary by different usage times (i.e., a one-hour, two-hour, or three-hour duration), some specific trends in drivers' opinions were identified as parking duration changed. The majority of respondents (54 percent) preferred a fixed-rate street parking rate regardless of parking duration. This means 54 percent of the participants had the same willingness to pay street parking for one, two, or three hours usage. Twenty-five percent of the drivers preferred a decreasing rate for additional parking usage. However, 15 percent were willing to pay more for the additional hours they occupy a parking space. The latter group believed the second parking hour should be more expensive than the first hour. The responses of the remaining 5 percent did not show a consistent pattern and their choices showed a mixed willingness of increase and decrease in the parking rates over the period of usage.

Correlation analysis was performed to evaluate the level and strength of association between the willingness to pay variables and the explanatory variables. Significance level of 0.05 was set in this step to decide whether a variable is statistically significant. Analysis results revealed that drivers' willingness to pay a fixed street parking rate significantly associated with their income category and their current average weekly expenditure on chargeable parking lots and garages. As expected, both appeared with a positive coefficient. "Fairness and equity in parking usage payment" criterion showed a strong correlation with the willingness to pay parking meters. While the majority of independent variables showed a consistent correlation pattern with the willingness to pay street parking across a range of various parking durations (up to 1 hour, 2 hours, or 3 hours), the importance of "parking cost" factor appeared to be significant only in 2 hours and 3 hours parking usage. In other words, cost was not a significant factor when drivers intended to park up to 1 hour; however, it became important when parking duration increased. This fact was not readily interpretable by looking at the averages of willingness to pay for different parking usages as the averages were relatively the same.

To better evaluate the drivers' willingness to pay, regression models were calibrated for all three parking durations individually. It is worth mentioning that for modeling purposes, transformation of raw variables was performed to provide a better model fit. Some categories in variables such as Age Group and Employment Status were merged, and dichotomous variables, such as Gender and *Zipcar* membership were used in a dummy format. Table 12 shows a summary of model calibration results for each parking period. Missing values were excluded pairwise due to the small sample size.

As expected, drivers' income level played a major role in their willingness to pay street parking. This variable appeared significant in all of the three models, and was the most important for the first hour. Paid parking lot usage was another significant predictor in all three models. The higher the expenditure on parking lots was equivalent to the higher willingness to pay street parking. Parking citation history deemed to be significant only in the one-hour parking model. Both ticket numbers and citation amount in the past year were required to remain in the model to counterbalance the effect of one another. While ticket numbers appeared in the model with a positive coefficient, dollar amount paid on these violations appeared with a negative coefficient. None of the models earned a rigorous goodness-of-fit.

Table 17: Willingness to Pay Street Parking Model for Various Parking Durations

Variable	1 hour parking			2 hour parking			3 hour parking		
	coef.	t stat	sig.	coef.	t stat	sig.	coef.	t stat	sig.
Constant	1.844	6.72	0.000	1.851	6.66	0.000	1.881	6.23	0.000
Income level	0.171	2.79	0.006	0.161	2.61	0.010	0.142	2.12	0.036
Parking lot usage	0.027	3.04	0.003	0.031	3.48	0.001	0.033	3.41	0.001
Parking ticket history	0.124	2.12	0.035						
Parking ticket amount	-0.006	2.21	0.028						
Model R^2	0.110			0.092			0.080		
F test (sig.)	5.49 (0.000)			9.37 (0.000)			7.99 (0.000)		

Satisfaction with the Existing and Proposed Methods

As illustrated in the preliminary analysis section of this report, study participants declared an overall of 57 percent satisfaction with the existing parking fee collection system (a pre-paid, flat rate with time restrictions). Participants were asked about two new parking fee collection systems. While the satisfaction rate with a “pay-after-return” system with a flat rate rose to 78 percent (20 percent increase), the satisfaction rate did not significantly change for a “pay-after-return” system with a dynamic rate (56 percent).

Analysis results revealed that those who were highly satisfied with the “prevailing pre-paid parking meter system” (a flat rate with time restrictions), had significantly lower willingness to pay street parking cost at any given parking usage period. Conversely, drivers who preferred “pay-after-return system” (a dynamic rate where rate increased every hour), were willing to pay significantly higher amount for any given parking usage duration.

When choosing a flat rate system, drivers’ race appeared to be a significant factor. Drivers’ employment status was positively correlated with their satisfaction with the “pay-after-return” system with a flat rate system. Surprisingly, those who had higher willingness to pay street parking showed lower satisfaction with the existing flat rate system; however, they showed higher satisfaction with the “pay-after-return” system with a dynamic rate. Drivers who preferred to pay more for a nearby parking garage (rather than paying less and walking a couple of blocks) also showed higher satisfaction with the “pay-after-return” system under a dynamic rate. Drivers with higher amounts of past parking citations and drivers with *Zipcar* membership revealed lower satisfaction with the “pay-after-return” system with a flat rate.

Risk-Seeking Behavior in Feeding Parking Meters

Drivers’ risk-seeking behavior with regard to how much they would rather feed a pre-paid parking meter was also analyzed in this study. In a correlation analysis, drivers’ age group, income category, weekly expenditure on chargeable parking garages, parking citation history, and *Zipcar* membership were deemed to be significant factors. Also, the importance of “comfort, convenience, and easiness of parking maneuver,” “safety and security,” “fast access to destination," and "fairness and equity in parking usage payment" criteria demonstrated significant correlation with the amount that a user might feed a pre-paid parking meter in advance.

On one hand, a driver risked receiving a ticket if he/she exceeded the paid usage time in such system, and on the other hand, if a driver returned to the spot early, he/she lost the extra amount that was paid to avoid a parking citation. In this trade-off, young drivers and drivers from lower income groups were more of a risk taker (preferred to pay less) than older drivers or drivers from higher income groups. Intuitively, drivers who had a worse history of receiving parking citations were more of a risk taker and tried not to pay more than the duration that they initially approximated they would need.

Priority Analysis of Different Criteria on Parking Decision

Six different criteria were defined in the survey to be the major parameters when a driver makes a parking decision. These criteria were: "parking cost," "comfort, convenience, and easiness of parking maneuver," "safety and security," "fast access to destination," "boosting business by increasing parking turnover," and "fairness and equity in parking usage payment." Statistical inference techniques were used to identify intercorrelation among these components. Factor analysis, a data reduction technique, was applied to transform six criteria into a lesser number of *linearly uncorrelated* factors. All the variables have a similar scaling scheme from 1 to 5, indicating the least to the most important factor, respectively. Table 13 shows the correlation matrix of these six variables and demonstrates a strong interdependency among most of these variables. Eleven of 15 pairs have a strong correlation with a significance level less than 0.01. This means that these six criteria are not inherently independent in the minds of participants when they make parking decisions.

Kaiser-Meyer-Olkin (KMO) and Bartlett's test results are presented in Table 14 to measure the strength of association among the six variables. The KMO measure (0.71) is high enough for a satisfactory factor analysis. The Bartlett's test is statistically significant, resulting in the rejection of the null hypothesis. It indicates that the correlation matrix is not an identity matrix.

Table 18: Correlation Coefficients of Different Criteria

	Cost	Comfort	Safety	Accessibility	Turnover	Fairness
Cost	1	0.136 *	0.140 *	0.092	0.093	0.187 **
Comfort		1	0.570 **	0.556 **	0.288 **	0.264 **
Safety			1	0.440 **	0.334 **	0.319 **
Accessibility				1	0.264 **	0.263 **
Turnover					1	0.644 **
Fairness						1

* Significance level < 0.05
** Significance level < 0.01

Table 19: KMO and Bartlett's Test Results

KMO measure of sampling adequacy		0.708
Bartlett's test of sphericity	Approx. Chi-Squared	355.54
	Degree of freedom	15
	Sig.	0.000

Factor analysis revealed that two factors can explain nearly 63 percent of the total variance. Table 15 presents the components extractable from the factor analysis, the eigenvalues, each factor's explained variance, and cumulative variance explained. As seen, only the first two factors are significant where they account for 44 and 19 percent of the variance, respectively. The scree plot in Figure 17 confirms that only two independent factors can significantly explain the variance of the whole six variables. The curve starts to flatten after the second factor and the third factor has an eigenvalue less than one.

Finally, the component (factor) matrix is shown in Table 16. This table shows the loadings of the six criteria on the two factors extracted. While factor 1 is more contributing to the “comfort” and “safety” criteria, factor 2 is more contributing to the “fairness” and “preserving parking turnover” criteria. “Accessibility,” “fairness” and “preserving parking turnover” criteria are also important contributors into factor 1. Surprisingly, parking cost is the least important variable in both factors.

Table 20: Total Variance Explained by the Components

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of var.	Cum %	Total	% of var.	Cum %
1	2.63	43.87	43.87	2.63	43.87	43.87
2	1.12	18.71	62.58	1.12	18.71	62.58
3	0.95	15.86	78.44			
4	0.55	9.26	87.70			
5	0.39	6.55	94.24			
6	0.35	5.76	100.00			

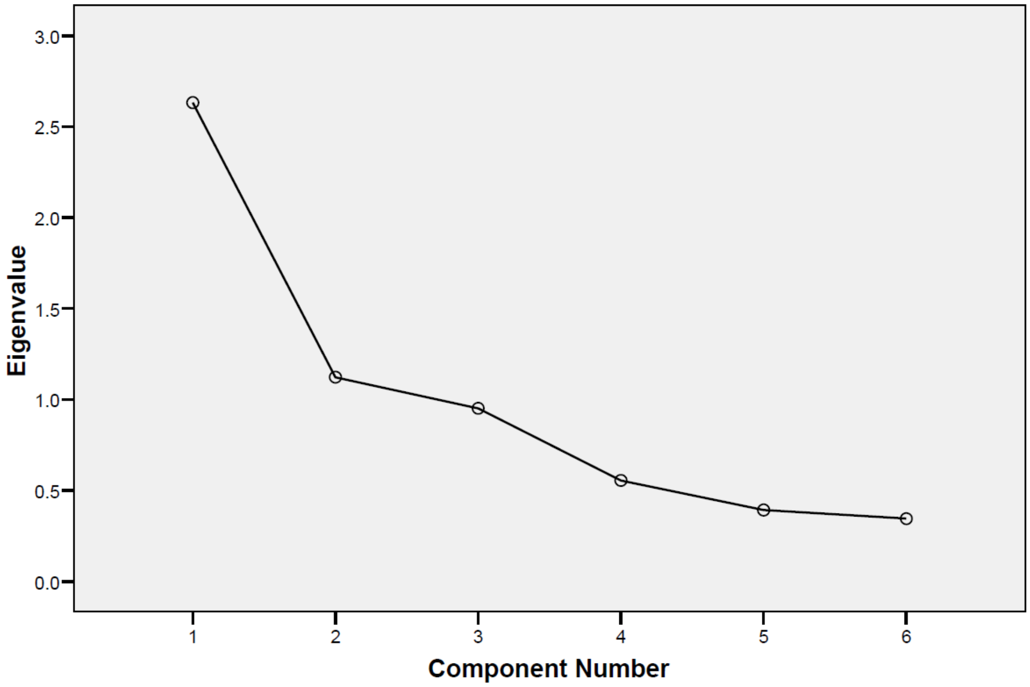


Figure 20: Factor Analysis Scree Plot

Table 21: Component Matrix

Variables	Component (Factor)	
	1	2
Cost	0.284	0.194
Comfort	0.754	–0.437
Safety	0.749	–0.284
Accessibility	0.696	–0.415
Turnover	0.685	0.544
Fairness	0.684	0.588

Parking Options Choice Analysis

Two main payment options (flat versus dynamic rates) were presented to the participants in the survey to assess the acceptability of the proposed progressive parking rate system. There was also a third option of a parking garage for those who preferred not to park curbside. Therefore, people who opt to park in a garage in the real world did not bias our sample as they were not obligated to pick among the static and dynamic rate options. Six payment scenarios were designed as a meaningful combination of three flat rates ($1, $1.50, and $2 per hour) and four dynamic rate patterns (all increasing by time). Total parking costs was calculated for the every duration of 1, 2, 3, 4, 5, and 6 hours for each payment option for all of the scenarios. To better understand the variation among the 6 scenarios, Table 17 and Table 18 show the cumulative parking cost at each scenario for a flat rate and a dynamic rate option, respectively. The rate of flat rate option rose from scenario 1 to 3 and remained constant afterward. A similar dynamic rate pattern was presented for the first 3 scenarios and a variety of progressive patterns were introduced in scenarios 4 to 6.

Table 22: Cumulative Parking Cost for Flat Rate Option in Each Scenario ($)

Parking Duration (hr)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	1	1.5	2	2	2	2
2	2	3	4	4	4	4
3	3	4.5	6	6	6	6
4	4	6	8	8	8	8
5	5	7.5	10	10	10	10
6	6	9	12	12	12	12

Table 23: Cumulative Parking Cost for Dynamic Rate Option in Each Scenario ($)

Parking Duration (hr)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	1	1	1	1.5	1	2
2	2.5	2.5	2.5	3.5	3	4
3	4.5	4.5	4.5	6	6	7
4	7	7	7	9	10	10
5	10	10	10	12.5	15	14
6	13.5	13.5	13.5	16.5	21	18

The relative difference between flat and dynamic rates at each scenario is speculated to be more influential on drivers' parking choices than the individual price schemes. Figure 18 illustrates how the difference between flat and dynamic rate options varied over the hours of usage in every scenario. The vertical axis in this Figure shows how much a dynamic rate option costs more than a corresponding static rate option for the same parking duration. As indicated in the preliminary analysis section, scenario 3 presents the most appealing dynamic rate option. Also, as it can be viewed, options 2 and 4 present the same pricing scheme although their individual rates are not identical (see Table 17 and Table 18).

The charts and tables for each scenario in the survey questionnaire illustrated the total cost for a parking duration ranging from 1 to 6 hours. Participants' choices between the two major payment options of flat rate and dynamic rate systems were made, however, based on their own conjecture about an average parking duration. Correlation analysis was performed to find out what parking duration had the highest association when the users were making parking choices. Figure 19 demonstrates that there is a strong correlation between all parking durations and choices of both options. As expected, both flat and dynamic options are equally significant across all parking durations. The crest of both curves occurred at the 3rd hour indicating that participants were considering 3 hours as their most likely parking duration.

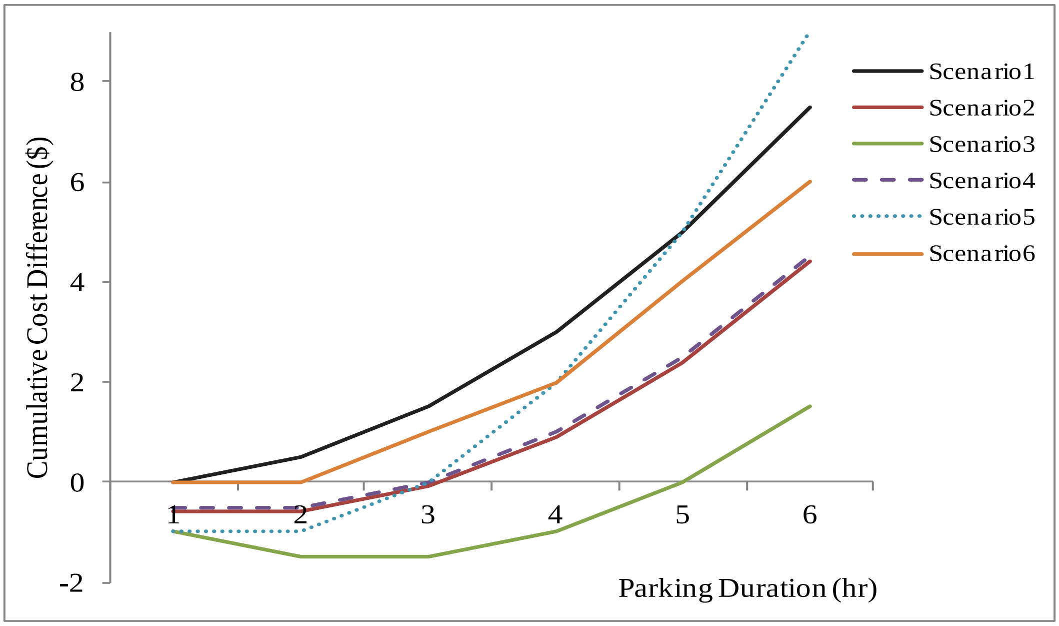


Figure 21: The Difference between the Cumulative Costs of Flat and Dynamic Rates

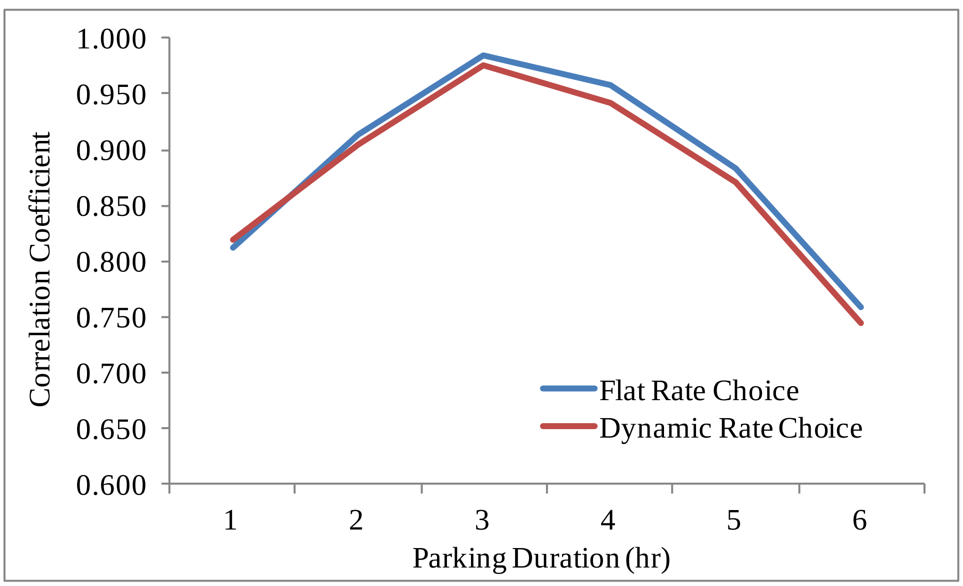


Figure 22: Correlation Coefficient of Parking Options with Parking Durations

While the first 3 scenarios presented similar dynamic rate patterns, flat rate increased from $1 to $2 per hour gradually (i.e. 1, 1.5, and 2 $/hr, respectively). Table 19 demonstrates the sensitivity of choices towards the increase of flat rate. While the rate is $1/hr, the choice probability of flat and dynamic rate options are 0.771 and 0.131, respectively. When the rate increases to $2/hr, the choice probability of flat rate option drops to 0.570 and the chance of choosing dynamic option raises to 0.350. For the $2/hr scenario, flat rate option choice probability decreases dramatically to 0.280 and dynamic option choice probability boosts up to 0.631. This substantial fluctuation proves the high sensitivity of users to manage their street parking costs.

Given those that had chosen flat rate in the base scenario of $1/hr, 69.1 percent remained committed to the flat rate option and 30.3 percent of them chose dynamic rate option when the flat rate increased to $1.5/hr. This swap is more significant when the rate increases to $2/hr. Only 32.1 percent of the users who had selected the flat rate under the $1/hr option continued to choose that option when the flat rate doubled and 65.5 percent of them preferred to choose the dynamic rate option. For those who had selected the flat rate option under both first and second scenarios (i.e. $1/hr and $1.5/hr), 41.2 percent preferred to stay with the flat rate option when the rate increased to $2/hr, while 57.9 percent switched to the dynamic rate option.

Table 24: Conditional Probabilities of Choosing Flat Rate versus Dynamic Rate Options

	Scenario1	Scenario2	Scenario3
P (FR)	0.771	0.570	0.280
P (DR)	0.131	0.350	0.631
P (FR|FR1)	_	0.691	0.321
P (DR|FR1)	_	0.303	0.655
P (FR|FR1,2)	_	_	0.412
P (DR|FR1,2)	_	_	0.579

P (FR): Probability of Choosing Flat Rate
P (DR): Probability of Choosing Dynamic Rate
P (X|Y): Probability of X given Y
FR1: Flat Rate chosen in Scenario1
FR1,2: Flat Rate chosen in Scenario1 and 2

Conversely, the flat rate remained constant in scenarios 3 through 6. Table 20 shows the choice probability of dynamic rate option in these 4 scenarios along with the cost of a 3-hour parking duration. Pricing details of these scenarios are presented in Table 18. As can be seen, there is a positive association between the cost and users' choices. The overall conclusion can be drawn is that users are more inclined toward a dynamic rate parking option that starts with a low rate where the hourly rate increases reasonably.

Figure 20 presents 6 scatterplots of dynamic rate option choice probability over the last 4 pricing scenarios (3 through 6, where the flat rate is constant). The 6 plots belong to the 6 different parking durations. Coefficient of determination (R^2) of each trend line is also shown to evaluate the goodness-of-fit of each line. As depicted, 3-hour parking duration produced the best fit emphasizing that 3-hour is the best parking duration for future cost-benefit estimates and economic analysis. While scenarios 4 and 5 proposed the same total cost for a 3-hour parking, the aggregate choice probability of both scenarios happened to be equal.

Table 25: Conditional Probabilities of Choosing Flat Rate versus Dynamic Rate Options

	Scenario3	Scenario4	Scenario5	Scenario6
P (DR)	0. 631	0.299	0. 299	0.131
3-hr Parking Fee	$ 4.50	$ 6.00	$ 6.00	$ 7.00

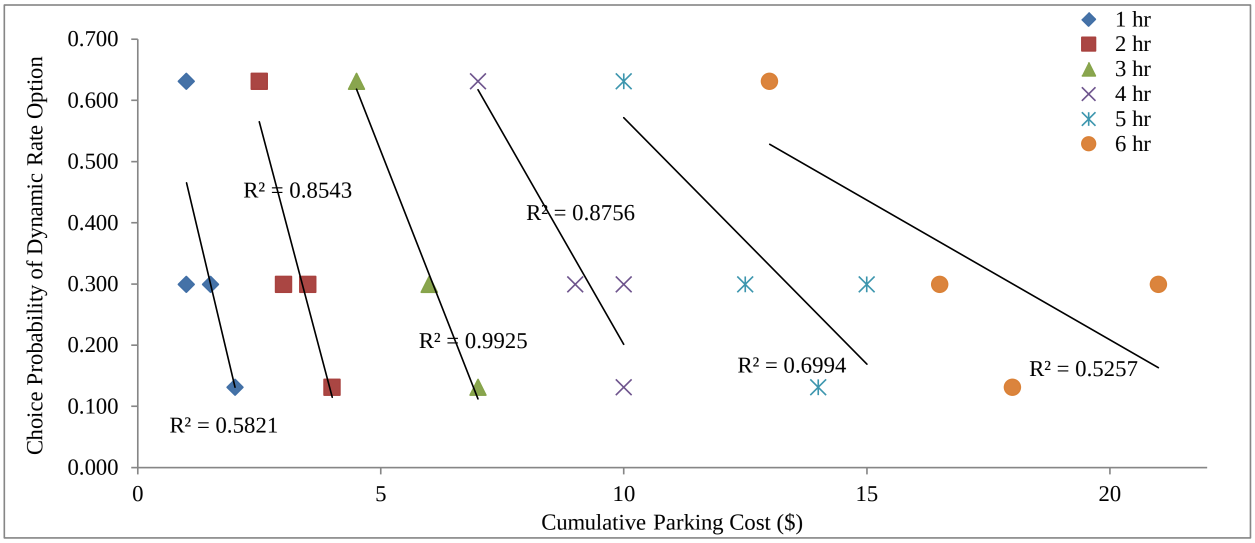


Figure 23: Correlation Coefficient of Parking Options with Parking Duration

Conclusion and Recommendation

This study utilized the stated preference method to find drivers' willingness to pay for on-street parking. Some 238 individuals from different regions and socio-economic backgrounds responded to the survey questionnaire. The research team analyzed the data and constructed willingness to pay models.

The analysis demonstrates that income level and average weekly payment for parking lots/garages positively affect drivers' willingness to pay a fixed street parking rate. The parking rate did not appear to be an important factor for one-hour parking; however, it becomes more important with parking duration. Furthermore, race, age, the city of residence, and current payment for parking lot/garage affect parking option choices. The amount of parking ticket had a negative correlation with willingness to pay. Participants preferred a fixed rate to a dynamic rate for street parking, but they chose a dynamic rate parking option if it started with a low rate and the rate increased reasonably. The majority of participants would rather have a "pay-after-return" system in which they don't have to be worried about parking expiration. The demand elasticity for parking was calculated to be -2.26, and average willingness to pay was $2.65.

In the case of the current street parking method in which drivers have to estimate how long they will use the parking and pay accordingly, younger drivers and drivers from lower income groups were more of a risk taker (preferred to pay for less time) than older drivers or drivers from higher income groups. In addition, drivers who had a worse history of receiving parking citations were higher risk takers. The most likely parking duration was 3 hours, and a dynamic rate, rather than enforcement, can increase parking turnover and reduce parking duration.

The study demonstrated that the “pay-after-return” system will be well accepted by the public. People prefer to pay a higher parking rate but not be worried about getting a ticket for an expired meter. Although the majority preferred a flat rate, a dynamic rate can be used to control parking turnover and parking duration. The dynamic rate can be applied not only to parking duration but also to time of day (i.e., a higher rate in peak periods) to reduce traffic congestion by making some drivers switch to parking lots/garages and stay for less time in the parking spot so that other drivers can use the parking spot.

The research team recommends parking authorities and municipalities such as Baltimore city to implement the proposed progressive “pay-after-return” system. The progressive (more general, dynamic) pricing could benefit both the public and the parking authorities as follows.

1) Alleviate public anxiety and stress by eliminating parking expiration tickets and charging people reasonably and fairly.
2) Reduce cruising for parking and so reduce traffic congestion and air pollution by charging an efficient pricing to alter parking demand and reach equilibrium between parking supply and parking demand.
3) Maintain parking authority and municipality’s revenue (if not increase revenue) in spite of eliminating parking expiration citations (Ardeshiri and Jeihani, 2013).

In conclusion, the proposed pricing plan will increase social welfare. The research team recommends a field test before full implementation. Albany Parking authority has shown an interest in conducting the field test in few parking meters in downtown area.

References

Adiv, A., Wang, W. (1987). On-street Parking Meter Behavior. U.S. Department of Transportation, *Urban Mass Transportation Administration*, Washington D.C., UMTA-MI-0009-02.

Ardeshiri A., Jeihani, M. (2013). A Novel Street Parking Fee Collection to Eliminate Unfair Citations, *Transportation Research Board Annual Meeting*, Washington, D.C.

Rowse, A. J. (1999). Modeling parking, *Journal of Urban Economics* 45 (1): 97–124.

Bagloee, S. A., Asadi, M. and Richardson, L. (2012). A Practical Parking Modeling and Pricing Methodology Tailored to TIS Projects. *Transportation Research Board Annual Meeting*, Washington, D.C.

Baltimore City (2011). *Data Catalog*, Parking Citation. data.baltimorecity.gov. Accessed on 06-21-2011.

Barata, E., Cruz, L., Ferreira, J. P. (2011). Parking at the UC campus: Problems and solutions. *Cities*, 28(5): 406-413.

Boyer, K. D. (1998). Principles of Transportation Economics, *Addison-Wesley*. USA.

Caicedo, F. (2012). Charging parking by the minute: What to expect from this parking pricing policy? *Transport Policy*, 19 (1): 63-68.

Calthrop, E., Proost, S. (2006). Regulating on-street parking. *Regional Science and Urban Economics*, 36 (1): 29-48.

Federal Reserve System (2011). The 2010 Federal Reserve Payments Study, Noncash Payment Trends in the United States: 2006 – 2009.

Gallo, M., D`Acierno, L., and Montella B. (2011). A multilayer model to simulate cruising for parking in urban areas. *Transport Policy*, 18 (5): 735-744.

Gifford, J. L., Yermack, L., and Owens, C. A. (1996). E-ZPass: Case Study of Institutional and Organizational Issues in Technology Standards Development. *Transportation Research Record: Journal of the Transportation Research Board*, 1537: 10-14.

Grazioli, A., Picone, M., anichelli, F., and Amoretti, M. (2013). Collaborative Mobile Application and Advanced Services for Smart Parking. IEEE 14th International Conference on *Mobile Data Management*, Milan, Italy, 2: 39-44.

Howe, R. (2005). Parking Fine Collection, Internal Controls Review, *City of Seattle*.

Lambe, T. A. (1989). A policy for inducements to pay parking fines. *Socio-Economic Planning Sciences*, 23(3): 99-113.

Liu, J. C. (2010). Comprehensive Annual Financial Report of the Comptroller, *The City of New York*.

Maryland Census. 2010. Census Data. http://census.maryland.gov/. Accessed on 05-21-2012.

Mitra, T., Ok, E. A. and Kockesen, L. (1998). Popular Support for Progressive Taxation and the Relative Income Hypothesis. *Economics Letters* 58 (1): 69-76.

Oishi, S., Schimmack, U., and Diener, E. 2012. Progressive Taxation and the Subjective Well-Being of Nations. *Psychological Science* 23 (1): 86–92.

Ommeren J. V., Wentink, D., and Dekkers, J. (2011). The real price of parking policy. *Journal of Urban Economics*, 70 (1): 25–31.

Petiot, R. (2004). Parking enforcement and travel demand management. *Transport Policy*, 11 (4) : 399–411.

Pratt, R.H. (1999). Traveler Response to Transportation System Changes. Interim Handbook, *TCRP Web Document 12*.

Saltzman, R. M. (1994). Three proposals for improving short-term on-street parking. *Socio-Economic Planning Sciences*, 28 (2): 85-100.

Schaller, B. (2010). New York City's Congestion Pricing Experience and Implications for Road Pricing Acceptance in the United States. *Transport Policy*, 17 (4): 266-273.

Shoup, D. (2006). Cruising for parking. *Transport Policy*, 13(6): 479-486.

Shaheen, S. A., Martin, E. (2012). Value Pricing Pilot Program, Smart Parking Value Pricing Pilot Project (VPPP) on the COASTER Commuter Rail Line in San Diego, California. *Report to the San Diego Association of Governments*.

TCRP (Transit Cooperative Research Program), Report 95. (2005). Chapter 13: Parking Pricing and Fees, Traveler Response to Transportation System Changes. *Transportation Research Board*, Washington D.C.

Tsai, J. F., Chu, C. P. (2006). Economic analysis of collecting parking fees by a private firm. *Transportation Research Part A: Policy and Practice*, 40(8): 690–697.

APPENDIX 1:

Survey Questionnaire

Dear participant,

We greatly appreciate your participation in our research to develop a realistic pricing scheme for a new parking meter fee collection system. The survey takes approximately 15 to 20 minutes and your participation is of great importance. Please select the appropriate answer for each question. Thank you! You can also access the online version of the survey if it is more convenient to you at: http://parkingfee.cloudssi.com/login.html

1. What is your gender?
   ☐ Female ☐ Male

2. What is your age group?
   ☐ <18 ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ ≥65

3. What is your highest level of education?
   ☐ High School ☐ Some college ☐ Post graduate

4. What is your race/ethnicity?
   ☐ White ☐ Hispanic/Latino ☐ Black/African American
   ☐ Asian/Pacific Islander ☐ Other

5. What is your household annual income? (arbitrary)
   ☐ ≤ $20K ☐ $20-30K ☐ $30-50K ☐ $50-75K ☐ $75-100K ☐ ≥ $100K

6. How many cars does your household own?
   ☐ 0 ☐ 1 ☐ 2 ☐ 3 or more

7. How many licensed drivers are there in your household?
   ☐ 0 ☐ 1 ☐ 2 ☐ 3 or more

8. What best describes your employment status?
   ☐ Retired/don't work ☐ Unemployed, looking ☐ Self-employed
   ☐ Employed part-time ☐ Employed full-time

9. What is the maximum *fixed* rate you would pay for a street parking meter if you have personal business in downtown that will take:
   9.1. **Up to 1 hour**.
   ☐ $2/hr ☐ $3/hr ☐ $4/hr ☐ $5/hr
   ☐ Other rate (please indicate the rate): $____/hr

9.2. **Up to 2 hours.**

☐ $2/hr (=$4) ☐ $3/hr (=$6) ☐ $4/hr (=$8) ☐ $5/hr (=$10)

☐ Other rate (please indicate the rate): $____/hr

9.3. **Up to 3 hours.**

☐ $2/hr (=$6) ☐ $3/hr (=$9) ☐ $4/hr (=$12) ☐ $5/hr (=$15)

☐ Other rate (please indicate the rate): $____/hr

10. Suppose that you have personal business in downtown that normally takes 1 hour; however, it may actually take from 30 to 90 minutes. Which payment option would you prefer for a street **pre-paid** parking meter? Note that there is a chance of getting ticket if you exceed the time you have paid.

☐ I pay for 1 hour and will return to feed the meter if it is taking more than 1 hour.

☐ I pay for 90 minutes.

☐ I pay for 2 hours.

☐ I prefer to use off-street parking options (such as garage) that are not pre-paid.

11. Please rate the importance of the following factors when you make a parking decision. (from 1: the least important to 5: very important factor)

____Parking cost

____Comfort, convenience, and easy to park in and out

____Safety and security

____Easy and fast access to destination

____Boosting business in downtown by increasing parking turnover

____Fairness and equity in paying for parking usage

12. Suppose that you have personal business in downtown, but are not certain how long you will be required to stay (2 to 5 hours). Street parking is available and you pay the parking fee when you return with no penalty. Which pricing scheme would you choose in each of the following options? Total costs are calculated for different hours of usage and are plotted for the two options of flat and dynamic rates.

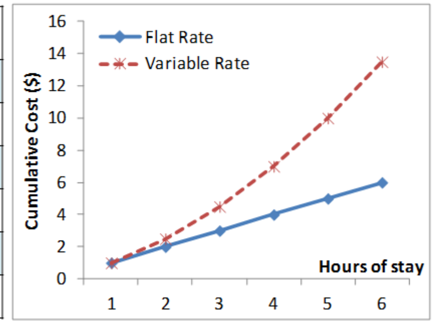
12.1. Payment Option1:

☐ Flat rate meter: **1$/hr**

☐ Dynamic rate meter: **$1 for the 1st hr; $1.5 for the 2nd hr; $2 for the 3rd hr; …**

☐ Parking garage for a higher fixed price [if select this, what is your max rate: _____ $/day]

Hours of stay	Flat rate cost ($)	Variable rate cost ($)
1	1	1
2	2	2.5
3	3	4.5
4	4	7
5	5	10
6	6	13.5



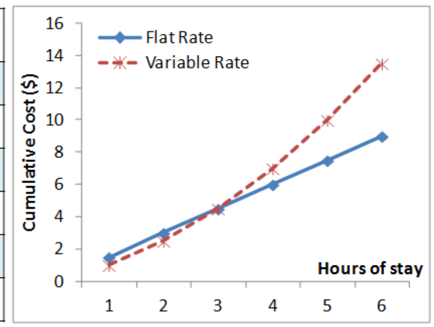
12.2. Payment Option 2:

☐ Flat rate meter: **1.5$/hr**

☐ Dynamic rate meter: **$1 for the 1st hr; $1.5 for the 2nd hr; $2 for the 3rd hr; …**

☐ Parking garage for a higher fixed price [if select this, what is your max rate: _____ $/day]

Hours of stay	Flat rate cost ($)	Variable rate cost ($)
1	1.5	1
2	3	2.5
3	4.5	4.5
4	6	7
5	7.5	10
6	9	13.5



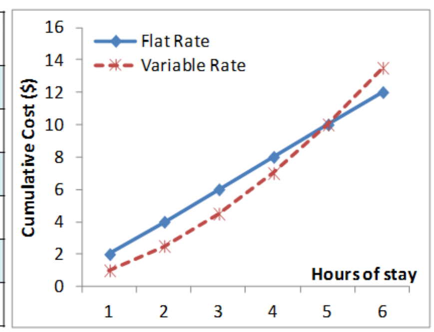
12.3. Payment Option 3:

☐ Flat rate meter: **2$/hr**

☐ Dynamic rate meter: **$1 for the 1st hr; $1.5 for the 2nd hr; $2 for the 3rd hr; …**

☐ Parking garage for a higher fixed price [if select this, what is your max rate: _____ $/day]

Hours of stay	Flat rate cost ($)	Variable rate cost ($)
1	2	1
2	4	2.5
3	6	4.5
4	8	7
5	10	10
6	12	13.5

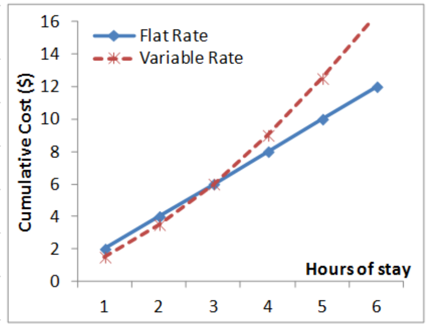


12.4. Payment Option 4:
☐ Flat rate meter: 2$/hr

☐ Dynamic rate meter: **$1.5 for the 1st hr; $2 for the 2nd hr; $2.5 for the 3rd hr**; …

☐ Parking garage for a higher fixed price [if select this, what is your max rate: ____$/day]

Hours of stay	Flat rate cost ($)	Variable rate cost ($)
1	2	1.5
2	4	3.5
3	6	6
4	8	9
5	10	12.5
6	12	16.5

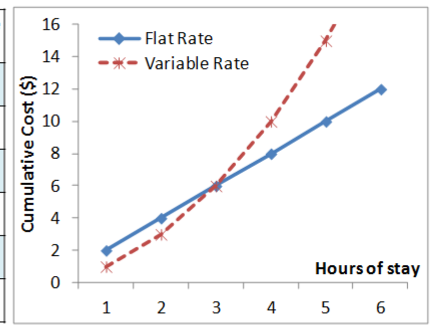


12.5. Payment Option 5:
☐ Flat rate meter: 2$/hr

☐ Dynamic rate meter: **$1 for the 1st hr; $2 for the 2nd hr; $3 for the 3rd hr**; …

☐ Parking garage for a higher fixed price [if select this, what is your max rate: ____ $/day]

Hours of stay	Flat rate cost ($)	Variable rate cost ($)
1	2	1
2	4	3
3	6	6
4	8	10
5	10	15
6	12	21

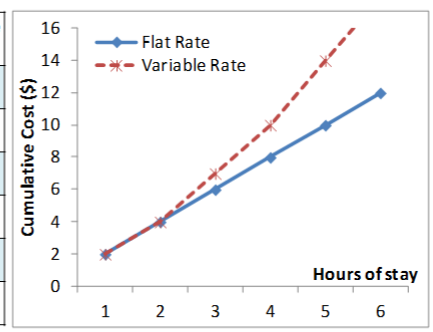


12.6. Payment Option 6:
☐ Flat rate meter: 2$/hr

☐ Dynamic rate meter: **$2 for the first 2 hrs; $3 for the 3rd & 4th hrs; $4 for the 5th & 6th hrs**; …

☐ Parking garage for a higher fixed price [if select this, what is your max rate: ____ $/day]

Hours of stay	Flat rate cost ($)	Variable rate cost ($)
1	2	2
2	4	4
3	6	7
4	8	10
5	10	14
6	12	18



13. Which parking garage option do you usually prefer?
☐ Garage next to my destination at $20/day ☐ Garage 5 blocks away at $10/day

14. In general, how satisfied are you with the following parking-meter fee-collection systems? (rate from 1: *very unsatisfied* to 5: *very satisfied*)
____ The prevailing pre-paid system with flat rate and time restriction

____ A pay-after-return system with flat rate
____ A pay-after-return system with dynamic rate (rate increases each hour)

15. What is the area/zip-code of your residence? _______________

16. What is the area/zip-code of your common workplace? _______________

17. On average, how many hours a week do you use a **free street** parking (exclude nighttime parking)? _______________

18. On average, how many hrs a week do you use a **paid street** parking with the following meter rates:
_____ hours per week of 0.50 $/hr parking meters
_____ hours per week of 1.00 $/hr parking meters
_____ hours per week of 2.00 $/hr parking meters
_____ hours per week of parking meters with a different rate (please indicate the rate:) _________

19. On average, how many hours a week do you use a **free garage/parking <u>lot</u>** (exclude nighttime parking)? _______________

20. On average, how many hours a week do you use a **paid** parking **<u>lot</u>**? _______________
How much do you pay for a **paid** parking **<u>lot</u>** per week? $_____________

21. On average, how many hours a week do you use a **paid** parking **<u>garage</u>**? _______________
How much do you pay for a **paid** parking **<u>garage</u>** per week? $_____________

22. In the past year, due to parking meter violation such as expired parking meter:
22.1. How many times did you receive a parking citation? ____________
22.2. How many of them did you appeal for trial? ____________
22.3. How much did you pay for parking citation? ____________

23. Do you have any type of membership with *Zipcar* (or any other car sharing services)? __________
If yes, how much is your monthly membership rate? $___________

24. On average, how many hours a week do you use and how much do you pay for a car sharing service: I use _____ hours per week and I pay $_____ per week.

25. Please type your comments in the space below. Thank you!