Parking Choices and Pricing Preferences

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Abstract

Parking is often priced to recover costs or increase revenue for cities and private parking operators. It is also an effective transportation demand management tool for reducing energy use, emissions and congestion. The type of parking pricing policies will impact parking demand differently. Results from a multinomial logit model show that a flexible parking permit is the most preferred parking option. Parking options with shorter walking times are highly attractive. The value of walking time is estimated to be $14.71 per hour, implying that commuters are willing to pay $0.25 to park a minute closer to their workplace.

1. Introduction

Parking pricing is an influential tool in regulating private vehicle use, both in terms of number of trips and vehicle miles traveled (VMT), as well as to better allocate parking resources. The marginal cost of driving can be affected by parking pricing, which will influence the attractiveness of driving when compared to other transportation modes, such as transit. Since commute travel and its associated parking duration are relatively inflexible compared to non-commute trips, parking pricing can have a significant impact on commute mode choices. However, parking pricing may have a limited effect when there is more than one parking option, especially when there are less costly parking alternatives serving as competitors, as seen in areas surrounding the periphery of the University of California (UC), Berkeley campus. Most UC Berkeley employees have fixed cost annual or monthly parking permits, purchased at a below market rate, which does not vary with how often an employee parks on campus. Understanding how employees are affected by parking pricing and incentives and what factors are most influential in affecting mode choice will provide insights that would be of use in developing more effective transportation and parking pricing policies for major employers.

The impact of parking pricing has not been studied as extensively as other forms of transportation pricing, such as congestion pricing. Instead of analyzing the differences in parking demand between free parking and a fixed price point, this study contributes to current literature by creating four parking payment and location types, in addition to different levels of prices, to examine their impact on parking demand. Each parking option is also coupled with other transportation incentives to provide choices that are more multidimensional.

1.1 Current Studies

Parking pricing or parking choices studies that have applied a stated preference (SP) approach are fewer in number compared to revealed preference (RP) methods, which are mostly used to examine the effect of parking costs and times on mode choice without considering specific spatial location and the different types of parking available (Feeney, 1989). A study by Axhausen and Polak (1991) defined possible types of parking choices and applied a SP approach to examine the choice of parking type in Birmingham City Center, UK and in the city of Karlsruhe, Germany, using disaggregated data on travelers' responses to changes in parking attributes. In their survey, they listed three alternatives, free on-street, metered and illegal parking, each with four attributes, access time, search time, egress time, and parking fee. Both of their logit models (UK and Germany) were found to be realistic models of parking choice and their results were comparable to RP analysis.

Albert and Mahalel's (2006) study on how congestion tolls and parking fees can affect travel behavior used the SP method to analyze the impact of parking pricing. Their study provided an evaluation of attitudes toward congestion tolls and parking fees in Haifa, Israel and found that there was a higher willingness to pay for parking fees than congestion tolls. The study showed that 54 per cent of the drivers in the sample would prefer not to pay for parking, while 72 per cent of the drivers would prefer to use other options in order to avoid paying a congestion toll.

The impact of parking pricing on travel demand and behavior is affected by the value of time. The higher the value of walking time from parking location to the final destination, the lower the impact of parking pricing on location choice. Parking behavior will be less affected by changes in parking pricing when the value of walking time is high. A common calculation of the value of time is based on a utility maximization approach developed by Becker (1965), where time is a constraint. Becker's theory has resulted in the value of time being associated with wage rate (Small, 2006). The higher the value of time, the more an individual could be willing to pay for a parking space that is closest to the final destination. It is generally accepted that the value of time for a specific trip increases with income (Raux and Souche, 2004; Nakamura and Kockelman, 2002). The elasticity of value of time with respect to income has been estimated to be 0.72, while it is 0.13 with trip distance (Wardman, 2001).

Anderson et al. (2006) have found that higher income individuals are willing to spend $0.70 ($0.82 in 2014 price) to park each additional minute closer to the destination, while lower income individuals were only willing to spend $0.35 ($0.41 in 2014 price). The value of time across income groups depends on various factors and there could be circumstances where a low value of time does not necessarily imply low income and vice versa. All travelers, regardless of income, could have a high value of time under certain circumstances (Ward, 2001). When studying the demographics on the SR 91 Express Lanes, Sullivan (1998) found that lower income groups travel on the Express Lanes, which are tolled, and they have a high value of time when choosing to do so. Although lower income groups do not travel on the Express Lanes as frequently as higher income groups (Sullivan, 1998), there are situations when their value of time is just as high as travelers in higher income groups. This could also apply to parking, where a high value time is not necessarily always an indicator of high income.

2. Methodology

A new and original transportation and parking survey was designed for the purpose of this study to understand parking behavior across user groups as parking pricing changes, using the UC Berkeley campus as a study site. UC Berkeley is a major employer in the San Francisco Bay Area with substantial parking demand and supply located in a community and region, where travel alternatives are readily available for many University affiliates. UC Berkeley currently manages its parking services through a combination of price and regulation. A variety of parking permits are available, but for employees, annual permits are the most common choice. Daily parking permits are also available but they are priced at a rate that does not encourage their use for employees who drive regularly to campus.

2.1 Data Collection

The recruitment of respondents was done electronically, where the link of the survey was sent to the entire UC Berkeley faculty and staff population with electronic mail accounts, via a campus-wide messaging service. The invitation to participate in the survey was mailed electronically during the second week of December 2013, and a reminder electronic message was sent to the same population a week after the first survey invitation was sent.

According to the most recent UC Berkeley Work Force Census, there were 14,286 paid employees, excluding student employees, in 2012 (UC Berkeley, 2012). It is known that some

UC Berkeley employees, mostly in the custodial, food services, groundskeeping, and maintenance titles, do not have University e-mail accounts. Therefore, the survey was mailed electronically to approximately 12,000 employees. The total number of employees who responded to the survey was 4,188, implying that the response rate was approximately 35 per cent (margin of error of ±1.22 per cent significant at the 95 per cent confidence interval). Out of all the 4,188 survey responses, 3,210 surveys were fully completed, i.e. the respondent responded to every question through the end of the survey.

2.2 Transportation and Parking Survey

This study uses SP data to analyze choices across a new set of parking pricing structures that are currently unavailable. The effects of these new parking alternatives that provide incentives for reducing driving and parking cannot be captured using RP data.

The transportation and parking survey had a total number of 37 RP and SP questions, though not every question was relevant to all respondents. This survey covered topics such as the respondent's personal and household characteristics, job characteristics, work-related travel for a week and parking choices on the day they last commuted to campus, and reactions to a series of parking pricing scenarios, which included transit incentives and other attributes.

The survey presented SP questions in the form of five choice sets, each with four parking options, as well as its respective attributes, namely, the cost of parking, refund (if any) for days not parked, availability of free transit pass, and walking time between parking space and primary workplace on campus. An example of the SP choice set is shown in Figure 1. A constant fifth option (without any attributes), "None of the Options" was also provided for respondents who did not choose to drive to campus or drive but park elsewhere.

In the following question, you will be shown four types of parking options and you will be asked to indicate which one of the four options would you choose, assuming that these are the only paid parking options available. *You may select "None of the Options" if you choose not to drive to campus or drive but park elsewhere.*

Option A: A monthly campus parking permit with unlimited access. If you are carpooling, a **carpool** permit costs **34%** of the cost of parking shown in the table below, which is comparable to the current campus parking pricing for each carpool user.
Option B: A monthly restricted campus parking permit for parking **3 days a workweek** (unlimited on weekends). If you are carpooling, a **carpool** permit costs **34%** of the cost of parking shown in the table below, which is comparable to the current campus parking pricing for each carpool user.
Option C: A daily campus parking permit, **without any restriction** on the number of permits that can be purchased annually. Daily permits can be purchased from parking machines at any campus parking garage/lot.
Option D: Hourly parking at an off-campus location with **no time limit enforcement**.

	Option A	Option B	Option C	Option D
Cost of Parking	$99/month	$71/month	$9/day	$1.25/hour
Parking Fee Refund for Days Not Parked	$2/day	0	0	0
Free Monthly Pass for AC Transit and BART	Yes	Yes	No	No
Walking Time from Parking Space to Office	1 min	1 min	18 min	5 min

Which one of the four parking options would you choose?

Option A ◯ Option B ◯ Option C ◯ Option D ◯ None of the Options ◯

Figure 1. An example of a stated preference choice set for parking option.

Note. There were 384 choice sets in total (derived from a full factorial choice experiment based on the number of attributes and their respective levels) and each respondent was shown five randomly selected choice sets. Hence, the values shown in the table changed with each survey. In addition, the combination of the five choice sets was also different for each respondent.

2.3 Stated Preference Experiment Design

In SP surveys, attributes are specified and given to the respondents, together with their values, which are also called "attribute levels" (Louviere et al., 2000). Figure 1 shows an example choice set that includes both attributes and levels. Parking Option A is a conventional campus parking permit choice that offers unlimited parking at a monthly cost, Option B is a restricted monthly campus parking permit that allows for parking three days (B-3) a week or four days (B-4) a week (half of the choice sets had a three day a week parking restriction, while the other half had a four day a week restriction), Option C is a daily campus parking permit, and Option D is an hourly parking option at an off-campus location. The “Parking Fee Refund for Days Not Parked” attribute only applies to Parking Option A, while the “Free Monthly Pass for AC Transit and BART” only applies to Options A and B. Half of the choice sets included in the survey excluded the Bay Area Rapid Transit (BART) in the transit pass attribute to examine the significance of a free BART pass.

The costs of Parking Options B and C were based on the cost of Option A to prevent one option from being distinctively more attractive than others. This is also to ensure that the monthly costs of Parking Options B and C will not be higher than the monthly cost of Parking Option A, since the latter provides unlimited monthly parking. However, if the monthly costs for Options B and C were converted to daily costs, they could be higher or lower than the daily cost for Option A. This was deliberately designed to both reflect the current campus parking structure, where annual or monthly parking permits have a lower daily rate than daily parking permits, as well as to provide new options and variability in the SP choice sets. Every attribute was altered under different choice scenarios according to the levels shown in Table 1.

As shown in Table 1, eight levels were created for the price of each parking option (8), three levels for the parking fee refund attribute (3), two levels for the availability of a free transit pass (2), and eight levels for walking time (8). There were 64 (8*8) possible parking costs for Parking Options B and C because they were pivoted against the cost of Parking Option A, which means each of the eight cost levels for Parking Option A had generated eight more for Parking Options B and C. Based on the number of attributes and their respective levels, the total number of choice sets created using a full factorial experimental design was 384 ((8^2)*3*2). The profile combinations are orthogonal if every possible combination of the various attributes and their levels only occur exactly once (Street and Street, 1987). While the number of choice sets shown to survey respondents could range from one to 20 or more (Bliemer and Rose, 2011), each respondent in this study was shown five randomly selected choice sets out of 384 possible choice sets to reduce survey fatigue.

Table 1. Attributes and Levels for Stated Preference Choice Sets

Attributes	Levels
Parking Option	A, B, C, D
Cost	
Parking Option A $90/month (Base Price)	Percentage Increase (%): 0, 10, 25, 40, 70, 100, 120, 150
Parking Option B-3 (3 days/week parking permit) Pivoted against Option A	Percentage Increase (%): 48, 50, 58, 60, 72, 78, 86, 95
Parking Option B-4 (4 days/week parking permit) Pivoted against Option A	Percentage Increase (%): 60, 65, 74, 80, 86, 89, 93, 97
Parking Option C Pivoted against Option A	Percentage Increase (%): 17, 18, 19, 20, 22, 27, 30, 36
Parking Option D $0.30/hour (Base Price)	Percentage Increase (%): 0, 100, 67, 25, 20, 17, 14, 13
Parking Fee Refund for Days Not Parked	0, $1/day, $2/day
Free Monthly Pass for AC Transit (and BART)	Yes, No
Walking Time from Parking Space to Office	1 min, 3 min, 5 min, 8 min, 10 min, 15 min, 18 min, 20 min

Note. There were eight levels for the cost of each parking option. However, since the costs of Parking Options B and C were pivoted against the cost of Parking Option A, there were 64 (8*8) possible parking costs for Parking Options B and C. The attribute "Parking Fee Refund for Days Not Parked" was only associated with Parking Option A. The availability of a free transit pass was either "Yes" or "No" regardless of whether it included BART or not. Half of the surveys had a free monthly transit pass for AC Transit and BART, while the other half excluded BART. This attribute was only associated with Parking Options A and B.

3. Stated Preference Parking Choice Analysis

The SP data collected from the transportation and parking survey were used to estimate a multinomial logit (MNL) model, which is a form of discrete choice analysis (McFadden, 1974, Train, 2009), for parking choice analysis.

Each respondent was provided with five different choice sets in the SP section of the survey, which implied that the sample size for the parking choice MNL model has a maximum number of 20,940 observations (4,188 * 5), resulting in a panel data that represent repeated choices. Not all respondents completed all five SP choice set questions and some did not respond to any of the choice sets. As a result, the final number of observations in the SP parking choice model is 13,376.

3.1 Model Specification

There are five alternatives in the SP parking choice model as shown in Table 2. Each parking alternative is associated with its own set of attributes, apart from Parking Option E, which does not have any predetermined attributes presented in the choice set. The parking choice model has five parking alternatives, including one that refers to none of the parking options, which could mean drive alone to campus but park elsewhere or not drive to campus at all. There are four constants in the model, as one alternative, Parking Option D, was normalized to zero (Equation 7), which means Parking Option D, the hourly parking option has a zero constant and is the base that all the other alternatives would be compared to.

Table 2. Alternatives in Parking Choice Model

Number	Code	SP Model Alternative
1	PA	Parking Option A (Monthly Parking Permit Option)
2	PB	Parking Option B (Restricted Monthly Parking Permit Option)
3	PC	Parking Option C (Daily Parking Permit Option)
4	PD	Parking Option D (Hourly Off Campus Parking Option)
5	PE	Parking Option E (None of the Parking Options)

A simple, restricted model was first estimated with two explanatory variables, parking cost and walking time from parking location to primary workplace (final destination) on campus. These two variables were assumed to have a strong impact on the utility of parking options and were included in all utility functions, apart from Parking Option E's. Parking Option E is an alternative where its parking cost and walking time were undefined in the SP choice set. The parameters of parking cost and walking time were constrained to be the same, as the effects of time and cost are likely to be equal across all alternatives. In other words, walking time and parking cost will affect each utility (parking choice) the same way. In this parking choice model, both parking cost and walking time were constrained across all alternatives, i.e. there was only one parking cost parameter and one walking time parameter for Parking Options A, B, C, and D. Additional explanatory variables were added to the restricted parking choice model to further explain parking behavior. Parameters used for socioeconomic variables that reflect individual characteristics were not constrained across all utility functions. This is because individual characteristics were assumed to have a different impact on each alternative.

3.2 Cost of Parking Option

Although the costs of Parking Options A, B, C, and D were presented as monthly, daily and hourly costs in the SP choice sets, all of them were converted to an uniform daily parking cost in the parking choice model. It was assumed that there are 20 working days in a month and eight working hours in a day. Hence, the cost of Parking Option A was divided by 20, the cost of Parking Option B was divided by 12 (3 parking days per week * 4 weeks per month) or 16 (4 parking days per week * 4 weeks per month) depending on the question presented in the survey and the hourly cost of Parking Option D was multiplied by eight.

4. Results

The MNL model estimation results are presented in this section, as well as the value of walking time and the price elasticity of parking demand, which were derived from the results of the parking choice model.

4.1 Model Estimation Results

Table 3 shows the restricted MNL parking choice model estimation results with two explanatory variables. In this simple model, the alternative specific constant for Parking Option A is the highest, which means that a conventional, unlimited monthly parking permit is the most popular choice among all alternatives and UC Berkeley employees may not switch to other types of parking options unless there are substantial changes in parking cost or walking time. Both parking cost and walking time parameters are highly significant and negative. The parameters for parking cost (-0.182) and walking time (-0.045) estimated in the restricted model (Table 3) were used as starting values in the final model to estimate a new set of parameters.

Table 3. Parking Choice Model Estimation Results (Restricted Model)

Explanatory Variables	Parameter Estimates	T-test	P-value
Alternative specific constants			
Parking Option A – Unlimited monthly parking permit	0.693	17.49	0.00
Parking Option B – Restricted monthly parking permit	0.476	11.52	0.00
Parking Option C – Daily parking permit	0.502	12.11	0.00
Parking Option D – Hourly parking option	-	-	-
Parking Option E – None of the given parking options	-0.323	-5.26	0.00
Attributes in choice set			
Parking cost ($/day)	-0.182	-35.32	0.00
Walking time (min)	-0.045	-21.83	0.00
Summary Statistics			
Number of observations	13,376		
Log-Likelihood (O)	-21,528		
Log-Likelihood (Model)	-18,378		
Likelihood ratio test	6,300		
Rho square	0.021		

The parameters of individual characteristics of the respondents were specified to differ according to the utility function in the final model. These parameters include both scheduling and socioeconomic characteristics of respondents, as presented in Table 4. A likelihood ratio test was conducted to determine if the additional variables added to the final model contributed further explanatory power. As previously described, the restricted parking choice model (Table 3) has two explanatory variables, i.e. parking cost and walking time, six parameters and a log-likelihood of -18,378. The final model has 50 parameters and a log-likelihood of -17,722 (Table 4). The likelihood ratio test statistic is therefore, -2 * (-18,378 – (-17,722)) = 1,312. The degrees of freedom is 50 – 6 = 44, which gives a Chi-Squared value of 69 for p = 0.01. Since 1,312 is greater than 69, the null hypothesis that the additional variables does not contribute to the model is rejected with 99 per cent confidence. Hence, it is important to include the additional variables in the final parking choice model to better understand parking behavior.

Results from the final parking choice model show that Parking Option D, the hourly parking cost option, has the highest utility, which means it is the most preferred alternative. The parameters for parking cost and walking time remain highly significant in this final model and both have negative signs, which imply that utility increases when cost and walking time decrease. Parking fee refund and the availability of a free transit pass have positive parameters and are significant variables that can influence the utilities of both monthly parking options (Parking Options A and B). In other words, when incentives in the form of a parking fee refund for days not parked or a free transit pass are bundled together with changes in parking pricing, they make the parking options more attractive. Whether or not a transit pass includes BART is important too. The BART pass dummy variable is significant and makes the two monthly parking options more attractive than without.

Scheduling characteristics were represented by seven different types of explanatory variables with varying levels of significance across parking alternatives (Table 4). The only variable in this category that is significant for all four alternatives is the availability of a second office. The utilities of all four parking alternatives are higher when respondents do not have a second office on or off campus. Arrival time is significant for the monthly parking options, where the later the arrival time, the more likely an employee will choose to park on campus and pay for monthly parking permits compared to an hourly parking option. Departure time is also significant for the two monthly parking options, but it has a negative sign, which implies that the later the departure time, the less likely respondents will choose to park on campus using monthly parking permits compared to the hourly parking option.

The difference between arrival and departure time is the time spent on campus, i.e. the number of hours on campus per day. This variable is significant for monthly parking permits and choosing none of the parking options, where the greater the number of hours spent on campus, the more likely employees will choose to use the monthly parking permits than a daily parking permit. Similarly, the number of days on campus variable is significant for the monthly parking permits and choosing none of the parking options, where the more frequently the employees are on campus per week, the more likely they will choose the monthly parking permits or not choose any of the parking options presented with respect to an hourly parking option. The hourly parking option becomes unattractive once frequent driving and parking are required.

There are three significant socioeconomic variables in the full model. First, age is significant only for the unlimited monthly parking option. Older respondents are more likely to choose the unlimited monthly parking options than the hourly parking option. They would prefer the convenience of paying for a monthly permit rather than paying on an hourly basis. Their work schedules may also require them to spend on time on campus, which will make paying by the hour less efficient. The faculty dummy variable has a negative sign and is significant for both monthly parking options. Hence, staff members will tend to choose the unlimited monthly parking option and daily parking option over the hourly parking option.

Total annual household income is significant across all four alternatives. The higher the income, the more likely the monthly and daily parking options will be preferred over the hourly parking option. Also, the lower the income, the more likely the employee will not choose to drive alone to campus or drive alone but not park using any of the given parking options, compared to the hourly parking option.

Table 4. Parking Choice Model Estimation Results

Explanatory Variables	Parameter Estimates	T-test	P-value
Alternative specific constants			
Parking Option A – Unlimited monthly parking permit	-4.810	-13.49	0.00
Parking Option B – Restricted monthly parking permit	-0.953	-3.15	0.00
Parking Option C – Daily parking permit	-0.477	-1.64	0.10
Parking Option D – Hourly parking option	-	-	-
Parking Option E – None of the given parking options	-1.560	-5.73	0.00
Attributes in choice set			
Parking cost ($/day)	-0.188	-35.95	0.00
Parking fee refund in Parking Option A ($)	0.091	3.33	0.00
Free transit pass in Parking Option A (yes = 1, no = 0)	0.277	6.28	0.00
Free transit pass in Parking Option B (yes = 1, no = 0)	0.469	9.48	0.00
Walking time (min)	-0.046	-21.77	0.00
BART pass dummy in Parking Options A and B (yes = 1, no = 0)	0.138	3.66	0.00
Scheduling characteristics of respondents			
Arrival time - Unlimited monthly parking permit	0.308	2.33	0.02
Arrival time - Restricted monthly parking permit	0.269	2.13	0.03
Arrival time - Daily parking permit	0.120	0.85	0.39
Arrival time - None of the given parking options	0.210	1.73	0.08
Departure time - Unlimited monthly parking permit	-0.375	-2.83	0.00
Departure time - Restricted monthly parking permit	-0.335	-2.63	0.01
Departure time - Daily parking permit	-0.101	-0.71	0.48
Departure time - None of the given parking options	-0.246	-2.02	0.04
Hours on campus (hours / day) - Unlimited monthly parking permit	0.499	3.61	0.00
Hours on campus (hours / day) - Restricted monthly parking permit	0.424	3.20	0.00
Hours on campus (hours / day) - Daily parking permit	0.195	1.33	0.18
Hours on campus (hours / day) - None of the given parking options	0.323	2.55	0.01

Explanatory Variables	Parameter Estimates	T-test	P-value
Days on campus (days / 5-day workweek) - Unlimited monthly parking permit	0.790	14.93	0.00
Days on campus (days / 5-day workweek) - Restricted monthly parking permit	0.161	4.47	0.00
Days on campus (days / 5-day workweek) - Daily parking permit	0.010	0.29	0.77
Days on campus (days / 5-day workweek) - None of the given parking options	0.225	6.50	0.00
Off-campus trips (yes = 1, no = 0) - Unlimited monthly parking permit	-0.263	-2.64	0.01
Off-campus trips (yes = 1, no = 0) - Restricted monthly parking permit	-0.027	-0.26	0.79
Off-campus trips (yes = 1, no = 0) - Daily parking permit	0.014	0.14	0.89
Off-campus trips (yes = 1, no = 0) - None of the given parking options	0.198	2.17	0.03
Availability of second office (yes = 1, no = 0) - Unlimited monthly parking permit	-0.272	-2.58	0.01
Availability of second office (yes = 1, no = 0) - Restricted monthly parking permit	-0.243	-2.23	0.03
Availability of second office (yes = 1, no = 0) - Daily parking permit	-0.331	-3.02	0.00
Availability of second office (yes = 1, no = 0) - None of the given parking options	-0.490	-5.06	0.00
Changes in summer schedule (yes = 1, no = 0) - Unlimited monthly parking permit	-0.248	-2.39	0.02
Changes in summer schedule (yes = 1, no = 0) - Restricted monthly parking permit	-0.185	-1.73	0.08
Changes in summer schedule (yes = 1, no = 0) - Daily parking permit	-0.377	-3.57	0.00
Changes in summer schedule (yes = 1, no = 0) - None of the given parking options	-0.555	-5.81	0.00
Socioeconomic characteristics of respondents			
Age - Unlimited monthly parking permit	0.074	2.40	0.02
Age - Restricted monthly parking permit	-0.042	-1.32	0.19
Age - Daily parking permit	-0.011	-0.36	0.72
Age - None of the given parking options	0.017	0.59	0.55
Faculty dummy (faculty = 1, staff = 0) - Unlimited monthly parking permit	-0.331	-2.85	0.00
Faculty dummy (faculty = 1, staff = 0) - Restricted monthly parking permit	-0.407	-3.32	0.00
Faculty dummy (faculty = 1, staff = 0) - Daily parking permit	-0.099	-0.85	0.40
Faculty dummy (faculty = 1, staff = 0) - None of the given parking options	-0.089	-0.84	0.40
Total annual household income ($) - Unlimited monthly parking permit	0.144	6.97	0.00
Total annual household income ($) - Restricted monthly parking permit	0.062	2.83	0.00
Total annual household income ($) - Daily parking permit	0.080	3.70	0.00

Explanatory Variables	Parameter Estimates	T-test	P-value
Total annual household income ($) - None of the given parking options	-0.046	-2.29	0.02
Summary Statistics			
Number of observations	13,376		
Log-Likelihood (O)	-19,578		
Log-Likelihood (Model)	-17,722		
Likelihood ratio test	3,711		
Rho square	0.009		

4.2 Value of Walking Time

The value of walking time was calculated using the parking cost and walking time parameters estimated from the parking choice models. The marginal rate of substitution of walking time from parking location to the primary workplace building on campus ($MRS_{Walking\ Time\text{-}Cost}$) of a linear utility function can be expressed as the following.

$$MRS_{Walking\ Time-Cost} = \partial U / \partial Walking\ Time_{PB}\ / \ \partial U / \partial Cost_{PB}$$

$$= \beta_{Walking\ Time}\ /\ \beta_{Parking\ Cost} \quad (1)$$

The value of walking time for the full sample was estimated using parameters for walking time and parking cost derived in the parking choice models (Tables 3 and 4). Another unrestricted model with three non-linear travel cost variables (interacted with income) was estimated to calculate the value of walking time by income, i.e. Parking Cost * Low Income (-0.206), Parking Cost * Medium Income (-0.179) and Parking Cost * High Income (-0.173). All estimated values of walking time are presented in Table 5.

Table 5. Value of Walking Time Estimates

	Value of Walking Time ($/min)	Value of Walking Time ($/hr)
Full Sample (Restricted Model)	0.25	14.87
Full Sample (Final Model)	0.25	14.71
Low Income: less than $90,000	0.22	13.43
Medium Income: $90,000 - $119,000	0.26	15.45
High Income: greater than $119,000	0.27	15.99

The value of walking time for the full sample is $0.25 per minute, which suggests that respondents are willing to spend $0.25 more to save a minute less of walking time. In other words, they are willing to pay $0.25 more to park a minute closer to where they work. This suggests that a 10 minute walk is worth \$2.50 a day, or for a 20 working day month, \$50. On the other hand, a walk of an additional two minutes would be worth only \$10 per month and a one minute difference would be worth only \$5 per month or less.

When compared to the hourly wage rate at UC Berkeley (2014), the value of walking time for the full sample is 44 per cent of the average wage, which is lower than estimates from existing studies (Anderson et al., 2006; Purvis, 1997; Small and Yan, 2001). The value of walking time varies across income groups, which reflects the income effect. Table 5 shows that the higher the income, the greater the value of walking time. However, the differences in the estimates are relatively small for the income categories used in this analysis. Once the annual household income reaches \$90,000 or above, the value of walking time for employees becomes very similar.

4.3 Price Elasticity of Parking Demand

Demand elasticity is defined as the percentage change in the use of a transportation service resulting from a one per cent change in an attribute such as price or travel time (Small and Winston, 1999). In this study, the outputs of the parking choice models were used to measure the changes in parking demand based on changes in parking cost. The value of demand elasticity depends on which point it is at along the demand curve and this point elasticity of demand (E) can be expressed as,

$$E = (\partial Q/\partial P)*(P/Q) \qquad (2)$$

where Q refers to the quantity demanded and P is the price or any other variable. ∂Q is the change in the quantity demanded and ∂P is the change in price.

The disaggregate elasticity, which represents the responsiveness of an individual's choice probability to a change in the value of an attribute in a logit model can be calculated using Equation 3.

$$E_{x_{ink}}^{p_n(i)} = [\partial P_n(i)/\partial x_{ink}] * [x_{ink}/ P_n(i)]$$
$$= \partial lnP_n(i)/\partial lnx_{ink}$$
$$= [1 - P_n(i)]x_{ink}\beta_k \quad (3)$$

where, $P_n(i)$ denotes the probability of respondent *n* choosing alternative i, x_{ink} is the attribute associated with alternative *i* that decision maker *n* chose with *k* unknown parameters, while β_k represents the parameter for the attribute, which can be derived from the choice model (Domencich and McFadden, 1975; Ben-Akiva and Lerman, 1985).

Since it is also important to know the responsiveness of the sample as a whole instead of just an individual, aggregate elasticities can be used to capture expected changes in choices due to a one per cent change in a given variable, which in this case is parking cost. The aggregate elasticity formula for the logit model is as follows (Domencich and McFadden, 1975; Ben-Akiva and Lerman, 1985),

$$E_{x_{ik}}^{\bar{P}(i)} = \sum_{n=1}^{N} P_n(i)\, E_{x_{ink}}^{p_n(i)} / \sum_{n=1}^{N} P_n(i) \quad (4)$$

where $\bar{P}(i)$ is the expected share of the sample choosing alternative i, $E_{x_{ink}}^{p_n(i)}$ is the disaggregate elasticity from Equation 16, and *N* is the number of observations in the sample.

Equation 4 is also the weighted average of the individual elasticities using the choice probabilities as weights. The aggregate elasticity estimates of Parking Options A, B, C, and D, with respect to parking cost, were calculated using Equations 3 and 4 and presented in Table 6. Elasticity for Parking Option E was not estimated because this alternative is not associated with any parking cost. The price elasticity estimate for the overall results of this study using the full sample was calculated using the parameter for parking cost ($\beta_{Parking\ Cost}$), which is -0.188, as derived from the SP parking choice model (Table 4), while elasticities by income were calculated using the parameter estimates of Parking Cost * Low Income (-0.206), Parking Cost * Medium Income (-0.179) and Parking Cost * High Income (-0.173) from another identical parking choice model with additional interaction variables.

Table 6. Price Elasticity Estimates of Parking Options

	Option A: Unlimited Monthly Parking	Option B: Restricted Monthly Parking	Option C: Hourly Parking	Option D: Daily Parking
Full Sample	-0.97	-1.10	-1.19	-1.22
Low Income: less than $90,000	-1.06	-1.21	-1.30	-1.34
Medium Income: $90,000 - $119,999	-0.92	-1.05	-1.13	-1.16
High Income: greater than $119,999	-0.89	-1.02	-1.09	-1.12

Parking Option A, a monthly parking permit, has the lowest price elasticity among all four parking options. Parking Option B, which is also a monthly parking permit but with a restriction on the number of days parked per week, has the second lowest elasticity estimate (Table 6). Parking Options C and D have higher elasticities compared to Parking Options A and B, suggesting that employees are more sensitive to changes in parking pricing for more flexible parking options. Parking Options C and D offer daily and hourly parking options respectively. These are shorter term decisions compared to Parking Options A and B, which require at least a one month commitment. Hence, their demand would fluctuate much more in the short term compared to Parking Options A and B.

The elasticity estimates for all four parking options show the same trend across three income categories, lowest for the monthly parking permit, Parking Option A and highest for the hourly parking option, Parking Option D. Respondents in the less than $90,000 annual household income category have the highest elasticity estimates for all four parking options. This is an income group whose parking behavior will be most affected by changes in parking pricing and are most likely to switch to off-campus parking locations with lower parking prices. However, since their elasticity estimate for the monthly parking option is still the lowest compared to other parking options, those who do not have flexible work schedules may continue to park on campus.

5. Discussion and Conclusions

Results in the parking choice model have shown that faculty members tend to not choose a monthly parking option when given the choice of other parking options. This is due to the fact that they have more flexible work schedules and are on campus less frequently than staff members. The flexibility of work schedules can thus influence parking payment type and parking location choice. In addition, faculty members also tend to have more transportation options and live in residential locations that allow for non-driving mode choices. More flexible parking permits are therefore more attractive to faculty members, which will not only be more fitting for employees who are on campus for less than five days a week but also for employees who do not drive every day. Flexible parking options should be provided, not just at UC Berkeley, but other major employers with campus communities too. For more effective parking demand management, flexible parking options should also be priced at a daily rate that is comparable to or less than conventional monthly permits. Employees should not be penalized for driving and parking occasionally. Higher priced monthly parking permits could then provide incentives for regular but flexible drivers to commute to campus using other modes and drive only when necessary. This will then create a more equitable parking pricing structure that addresses the varying levels of parking demand and not just employees with high driving frequency and parking demand.

The value of walking time for the full sample in the final model is $14.71 per hour. This value is less than 50 per cent of the average wage rate at UC Berkeley and considered to be much lower than the value of travel time. This could be due to the fact that once an individual has already decided to drive, the willingness to pay for a closer but more expensive parking location will be lower than the willingness to pay to travel a shorter time. Employees could also perceive walking as a healthy exercise and be more willing to spend a few more minutes to walk to their final destination once they have parked, which is different from spending more time commuting in their vehicles. Hence, individuals with high values of travel time may not necessarily have high values of walking time. This implies that variable parking pricing based on walking distance to a central work location will not reduce total parking revenue due to the relatively low value of walking time.

Lower income respondents have the lowest value of walking time and lowest price elasticity of parking demand across all income groups. Although it is possible that low income respondents may shift their mode choice and not drive alone when parking pricing changes, there could be some who would still choose to drive but change their parking locations to less costly options. If they already park at locations that cost significantly less than the campus parking rates, low income employees, especially those who do not have any other feasible travel alternatives will then not change their parking behavior.

Additionally, lower income employees generally fall within job categories that have less flexible work schedules, in terms of arrival time, number of days on campus per week and the number of hours on campus per day. This implies that lower income employees need to be on campus for at least seven or eight hours a day. In this case, parking options that offer hourly or daily rates will be less attractive to low income employees who choose to drive to campus. As a result, increases in parking pricing will not affect low income employees substantially, but will greatly affect those who still choose to drive. The social impact of parking pricing in terms of welfare or efficiency loss is still relatively unknown and should be included in future parking pricing studies. Employer based parking policies should always consider the availability of parking alternatives that are located off site. These alternatives serve as competitors and can affect parking revenue, as well as the impact of parking pricing on travel demand and parking behavior. The availability of parking alternatives will also influence future parking management strategies, as total parking demand could be greater than existing on-campus parking demand.

The impact of parking pricing will vary according to the existing transportation demand and parking behavior of employees. Employers may be concerned with a decrease in revenue generated by parking permits when monthly parking options are switched to more flexible alternatives. Flexible parking options that offer daily or hourly payment choices should be adopted as a way to regulate transportation demand. At the same time, it has to be implemented together with higher parking prices that reflect less subsidies, to order to significantly reduce drive alone mode share.

Changes in parking policy should also be coupled with transit incentives that will encourage employees to drive less frequently to campus. A free BART pass has been shown to be a significant factor in determining parking choice. It is also an attractive benefit to employees, as BART users are approximately double the number of bus users at UC Berkeley. When introducing free transit passes, it is important to first examine the actual use of such passes. Instead of offering free transit passes to all employees, it is more appropriate to offer them to those who live in residential locations that are accessible by transit, who would use transit regularly and who have relatively reasonable transit travel time. This will then reduce the possibility of employees switching from transit to driving alone when future changes in parking pricing, income levels, life situations, or work schedules occur.

Incentives, such as a parking fee refund for days not parked, should be given to employees who drive alone to campus less than average or less than five days a week. This will be beneficial to employees, who have flexible work schedules and are already on campus for less than five days a week, or those who use a combination of different modes and do not drive regularly. This should be bundled with campus parking options to increase the incentive for not driving alone every day once an employee has purchased a fixed priced monthly parking permit. The successful application of parking pricing as a tool to manage transportation demand is affected by complex travel behavior, the value of walking time and existing parking preferences, which are influenced by the availability of feasible parking alternatives. With a better understanding of employees' transportation demand and preferences, it is possible to design an efficient parking pricing structure that is capable of reducing private vehicle use, while maintaining a steady flow of revenue for the employer.

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