A STUDY OF SHOPPING TRIP PARKING BEHAVIOR USING CHOICE MODEL

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Abstract

To establish an effective parking management policy, it is essential to understand how drivers make their decision on parking. This study models the parking choice behavior of drivers who make a shopping trip to Siam Square, Bangkok, Thailand. The parameters are estimated from the result of stated preference questionnaires in the form of utility function. Data were successfully collected from 228 decisions of 76 respondents. The study found that the drivers who park from 0 to 3 h make decisions based on similar factors and sensitivity. The most influential factors included the parking fee and walking distance. Meanwhile the long-term parking decisions were based on the aforementioned 2 attributes and also the search time.

Keywords: **Parking behavior, choice model, stated preference, random utility**

Introduction

Parking lots are a crucial element in traffic planning and management. All private vehicle trips requires a place to “terminate” the trip in the same manner that planes require an airport, trains need a railway station, and buses demand a bus terminal. Parking spaces are very important for cities. Development projects must have sufficient parking spaces to accommodate their residents and visitors. Parking management strategy must be applied to ensure that the parking activities will not generate a negative impact to the adjacent street network. While airports, train stations, and ports are normally designed from a strategic transportation planning viewpoint, parking lots are usually designed to match marketing forecasted demand, and more often provide a small cushion beyond that.

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Siam Square is one of the most famous shopping districts in the city center of Bangkok. It is located between Pathumwan and Chalerm Pao Intersections. It borders Rama I Road in the north and Soi Chulalongkorn 62 in the south with a total area of 63 acres. A large number of economic and social activities in the Siam Square area attracts trips from all directions. Siam Square is served by a network of main roads namely Phayathai, Rama 1, and Henri Dunant Roads. The Bangkok Mass Transit System elevated skytrain also facilitates easy access to the site with the major Siam Interchange Station where passengers can transit between the Sukhumvit and Silom lines. A large number of bus routes passing through the area accommodate trips from all corners of the city to Siam Square. Despite all these transportation services, Siam Square and the surrounding area still experience severe traffic congestion due to excessive motor vehicle demand and the scarce parking supply.

Siam Square offers a few types of parking facilities including curb parking, underground parking at Siam Square One, and parking structures at Wittayakit and Siamkit buildings, as shown in Figure 1. The root of traffic congestion may not be due to the shortage of parking spaces but induced demand from the parking supply itself. Offering a great number of cheap parking spaces encourages visitors to drive instead of making use of the existing transit system. The parking demand statistics at Siam Square area are shown in Figure 2. The average numbers of parked cars are approximately 16020 vehicles per day (source: Chula Property Office, 2016).

Parking will become a part of the market economy. Appropriate pricing will manage parking demand and congestion including traffic circulation, parking type assignment, and other parking regulations (Weinberger *et al*., 2010). The effectiveness of these parking planning policies depends on influencing the parking choice upon various conditions. Thus, to establish parking policies, one has to understand the drivers'preferences and needs. This study evaluates the Siam Square shoppers'sensitivity to various influential factors affecting their parking decisions. It focused on parking with different characteristics in terms of cost, type, and location at Siam Square. The aim of this study is to evaluate factors affecting the drivers' behavior in choosing parking spots for shopping trips under various circumstances.

Literature Review

The individual decisions depend on various factors. Choice modeling is an alternative model to describe behavior and individual decisions, and to acquire the factors affecting satisfaction and the willingness to pay of customers. Choice modeling is a family of survey-based methodology for modeling preferences for goods, where the goods are described in terms of their attributes and levels (Hanley *et al*., 2001). Choice theory has been widely used in the mode choice model which

Figure 1. Surrounding study area

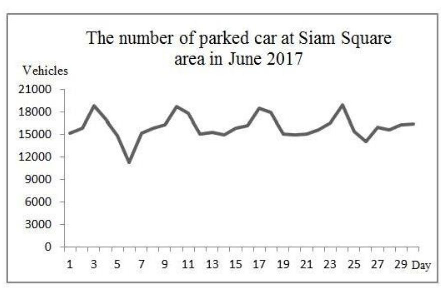


Figure 2. The number of parked cars at Siam Square area in June 2017 (Source: Chula Property Office, 2016)

replicates how the travelers make decisions on which mode of transport to take in order to analyze mode choice behavior and predict the probability that a randomly selected individual with given values of the observed factors will choose a particular alternative. The conceptual framework for choice modeling is the characteristic theory of value which assumes those consumers' use for goods can be converted into use for composing characteristics. This concept shows that the quality factor or attribute of a product causes a random utility (Lancaster, 1966).

Random utility theory explains the individual characteristics of customers identical in all respects who may decide to consume different products/services when under similar circumstances. Similarly, the consumers may decide to consume the same or different services when in the same situation, but in a different time period. Random utility is used to analyze choice behavior and predict the probability that a randomly selected individual with given values of the observed factors will choose a particular alternative (Ben-Akiva and Lerman, 1985).

One of the choice modeling methods is discrete choice modeling. The discrete choice models that are mostly used are based on the random utility theory. The approach of discrete choice modeling is describing behaviors of decision makers by comparing and choosing among a set of alternatives. Discrete choice is a popular technique in transportation because it gives researchers the ability to understand people's stated choices of alternative products and services (Train, 2009).

Individual data obtained from 2 methods include the revealed preference method and stated preference method. The revealed preference method explores the behavior of the respondents in an actual situation. The stated preference method explores the behavior of the respondents in hypothetical choice situations by simulating a series of choice scenarios. A parking behavior study in Germany and England found that when using the revealed preference it was very difficult to distinguish the influences in the attributes. The stated preference method can solve this situation by specifying the choice set for respondents and could adjust the value of the attributes influencing the choice since the stated preference method was a simulation to collect data when the respondents were in hypothetical choice situations (Axhausen and Polak, 1991). There were other parking studies that used the stated preference method such as those of Hensher and King (2001); Hess and Polak, (2004); Ibeas *et al*., (2014). Decision making is a random process. Therefore, the efficient design of policy requires knowledge about drivers' needs and decisions which are rather specific to countries, regions, cities, or districts.

Based on a study of parking behavior it was found that attributes affecting parking choice were in the form of time and distance. The attribute that was referred to in all studies is the parking fee. A study in China pointed out that the parking fee was the most important attribute because the parking fee was a direct cost. Another attribute that was referred to in this study was the walking distance. The walking distance referred to the distance from the parking place to the final destination. It could be considered by a group of drivers with regard to convenience, such as a group of drivers who make a trip for shopping or entertainment (Ruisong *et al*., 2009). A study in Italy just considered the parking fee, walking distance, and search time as the main factors for the parking behavior (Dell'Olio *et al*., 2009). The next attribute to affect parking behavior was search time. Search time was identified as the time from arrival until the driver had parked. Search time involves cost because finding a parking place uses fuel energy, and time, especially when there are many passengers in a vehicle (Shoup, 2005). Units of search time were found such as minutes, probability of finding a vacant space, and the number of vehicles at the parking location. Determining search time as a unit of probability of finding a parking space was found in a parking behavior study in the Netherlands (Chaniotakis and Pel, 2015).The researcher divided this into probability upon arrival and probability 8 min after arrival.The researcher believed that the uncertainty of a parking spot helps in understanding the parking behavior of drivers. Additionally, the cost of parking behavior also included accessibility. Accessibility has been defined with several meanings. The study in Australia defined travel time as from a vehicle's current location to the parking space (Thompson and Richardson, 1998). In addition, there was a parking study which defined accessibility as the travel time from home to the parking space. Such a definition was identified as having an incomplete range because there was too much difference between the lowest time and highest time (Axhausen and Polak, 1991). A study in the Netherlands defined travel time as the period from when the driver enters the study area to the parking entrance. This definition was more sensible than previous definitions because a parking study maybe consider only this attribute about the parking process (Chaniotakis and Pel, 2015). The next attribute is parking type. Parking type has often been used to make a difference in each scenario of the stated choice in many studies. Parking can be classified as on-street, off-street, and underground parking (Thompson and Richardson, 1998).Safety was usually ignored except in a study in which respondents had to decide between on-street and off-street parking (Ruisong *et al*., 2009).

In order to understand drivers' parking behavior choice, a series of stated preference experiments were conducted in the questionnaire. The methodology involved selecting parking attributes, designing the questionnaire and survey, and estimating the discrete choice parameters.

Methodology

Parking Attributes

Parking attributes were selected based on a literature review and consistency of the characteristics of the study area. These include the parking fee, walking distance, search time, and access distance. The parking fee is in units of baht/hour. Walking distance is defined as the distance from the parking spot to the final destination, measured in meters. Search time is essentially the time from arriving at a parking zone until finding a vacant parking space, measured in minutes. Accessibility is defined as the distance from entering the study area to parking. Accessibility was then measured in distance (meters). Defining accessibility in terms of time is uncertain because it is based on traffic at that time. Since this research designed the questionnaire according to the labeling in the questionnaire, parking type is not explicitly defined. The attributes and levels that were used to create the choice situations in the questionnaire are shown in Table 1.

Designing Questionnaire and Survey

The data collection was conducted by the questionnaire using a stated preference approach to collect data on drivers' responses to changes in parking attributes. The majority of the parkers are non-regular. This study only focused on non-registered parking. The questionnaire consisted of 2 parts:personal characteristics and parking decision in stated situations.

The first part contains questions on the personal characteristics including gender, age, education level, total income per month, and parking duration.

The second part contains questions on parking decisions under various circumstances. The various scenarios are presented as choice tasks for drivers who make a shopping trip to Siam Square. Each scenario in the questionnaire includes 4 alternatives, i.e. 4 parking locations at the study area, namely Siam Square curb, Siam Square One, Wittayakit building, and Siamkit building.

Scenarios are created by the Ngene software. Attributes' determination is based on an orthogonal design. Orthogonality guarantees that the effect of 1 factor or interaction can be estimated separately from the effect of any other factor or interaction in the model. From the data in Table 1, the Ngene software yields 36 scenarios, grouped into 8 different blocks. There are 3 choice sets in each block. Examples of the first choice sets in the questionnaire are shown in Figure 3.

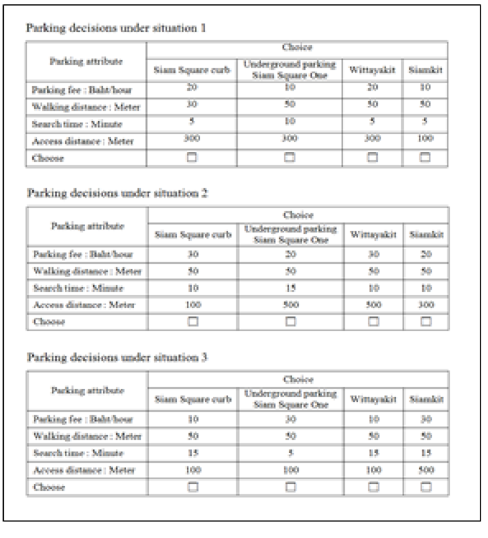
The minimum number of respondents is calculated according to the method by Cochran (2007). It is shown in Equation 1:

$$n \geq \frac{p\,(1\text{-}p\,)\,Z^2}{e^2} \qquad (1)$$

where *n* is the minimum sample size, *p* is the population proportion, *e* is the acceptable sampling error, and *z* is normally distributed with a mean of 0 and a standard deviation of 1. Define p = 0.5, e = 0.1, and z = 1.96, as in Equation 1. The minimum sample size is 97 sample units. This study defines that each decision maker will answer 3 questions: thus, the minimum number of decision makers is $\frac{97}{3}$=33 sample units. This study separates sample units into 2 groups: drivers who park less than 3 h and those who park over 3 h. Thus the minimum sample size should involve 66 respondents. The actual survey data would be increased by 10% of the minimum sample size. Hence, the total sample size is 73 respondents.

However, 76 respondents were questioned to make up for survey dropouts and thus there are 228 decisions. Summaries of the personal characteristics of the respondents are shown in Table 2.

The responses indicate that more than half of the respondents decided to choose a covered parking building which consisted of 65 decisions for Siamkit building (28.26%) and 62 decisions for Wittayakit building (26.95%). The other 57 decisions opted for Siam Square One (25.21%) and the least popular option was the curb parking with 44 decisions (19.56%). The parking location preference shares are shown in Figure 4.



Parking decisions under situation 1

Parking attribute	Choice			
	Siam Square curb	Underground parking Siam Square One	Wittayakit	Siamkit
Parking fee : Baht/hour	20	10	20	10
Walking distance : Meter	30	50	50	50
Search time : Minute	5	10	5	5
Access distance : Meter	300	300	300	100
Choose	☐	☐	☐	☐

Parking decisions under situation 2

Parking attribute	Choice			
	Siam Square curb	Underground parking Siam Square One	Wittayakit	Siamkit
Parking fee : Baht/hour	30	20	30	20
Walking distance : Meter	50	50	50	50
Search time : Minute	10	15	10	10
Access distance : Meter	100	500	500	300
Choose	☐	☐	☐	☐

Parking decisions under situation 3

Parking attribute	Choice			
	Siam Square curb	Underground parking Siam Square One	Wittayakit	Siamkit
Parking fee : Baht/hour	10	30	10	30
Walking distance : Meter	50	50	50	50
Search time : Minute	15	5	15	15
Access distance : Meter	100	100	100	500
Choose	☐	☐	☐	☐

Figure 3. The first choice sets in questionnai

Estimating Discrete Choice Parameters

The choice model was established based on stated preference experiments. A definition of all the parking attributes is shown in Table 3. The utility function can be written as follows:

$$U_i = \beta_{fee} x_{fee,\,i} + \beta_{walk} x_{walk,\,i} + \beta_{search} x_{search,\,i} + \beta_{access} x_{access,\,i} + ASC_i \qquad (2)$$

where $U(i)$ is the utility of alternative i and ASC_i is the alternative specific constant of alternative i. Alternative specific constant identifies the advantages and disadvantages of

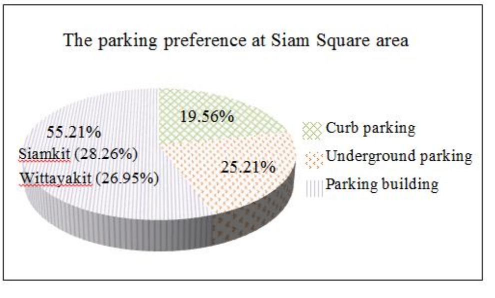


Figure 4. The total parking preferences at Siam Square area

Table 1. Parking attributes and level values

Attributes	Unit	Levels	Level values
Parking fee	Baht/hour	3	10/20/30
Walking distance	Meter	4	50/100/300/500
Search time	Minute	3	5/10/15
Access distance	Minute	3	100/300/500

an alternative when the attributes of all alternatives are equal. The parameters in the utility function are estimated by the maximum likelihood method.

Statistics related to parameter estimation include the *p*-value and *z*-statistic. Assuming a 95% confidence level, alpha equals 0.05. If the *p*-value is less than the determined level of alpha, the researcher rejects the hypothesis and concludes that the parameter is not statistically equal to 0. If the *p*-value is greater than the level of alpha as assigned by the research, it indicates that a parameter is statistically equal to 0. The *z*-test is used to explain attribute sensitivity. At a 95% confidence interval, the critical value is 1.96. If the absolute value of the *z*-test in the output is greater than the critical value, the researcher rejects the hypothesis that the parameter equals 0 and concludes that the variable is statistically significant. On the other hand, if the absolute value of the *z*-test statistic in the output is less than the critical value, the researcher cannot reject the hypothesis and conclude that the variable is not statistically significant.

Result and Discussion

The utility function models are calibrated according to parking durations as a model parking of less than 3 h and a parking of more than 3 h. The model result of drivers who park less than 3 h indicates that they are concerned

Table 2. The personal characteristics of respondents

Personal characteristics	Percent
Gender	
- Male	35.90
- Female	64.10
Age	
- 18-24	32.07
- 25-34	26.92
- 35-44	15.38
- 45-55	21.79
- over 55	3.84
Education	
- Associate degree	10.25
- Bachelor degree	66.67
- Master degree	21.79
- Upper Master degree	1.29
Monthly income level	
- Under 25,000 Baht	53.84
- 25,001-50,000 Baht	20.52
- Over 50,000 Baht	25.64
Parking duration	
- 0-1 h	11.53
- 1-2 h	20.51
- 2-3 h	17.95
- 3-4 h	21.80
- Above 4 h	28.21

Table 3. Defining all parking attributes

Attributes	Variable	Unit
Parking fee	x_{fee}	Baht per hour
Walking distance	x_{walk}	Meters
Search time	x_{search}	Minutes
Access distance	x_{access}	Meters

by the parking fee and walking distance and there is no advantage or disadvantage in each parking location in this model. The model result of those who park more than 3 h indicates that they are concerned by the parking fee, walking distance, and search time. The ASC of the Siam Square curb parking is -0.871. It implies that under the same circumstances and attributes they would not like to park at the Siam Square curb. This could be a result both from the parking price structure which is expensive, and hot and rainy weather, which are not likely to encourage outdoor parking.

The researchers realize that the parking duration has an influence on the parking decision. Thus, the respondents are grouped according to parking duration for the suitability of the grouping. The first group is drivers who park less than 1 h. The model results indicate that drivers who park less than 1 hour are concerned only with the parking fee. Those who park between 1-3 h are concerned by the parking fee and walking distance but not the parking location. Those who park 3-4 h are concerned by the parking fee and walking distance at a 95% confidence level, and by the search time at a 90% level of confidence. Those who park more than 4 h are also concerned by the parking fee, walking distance, and search time. The detailed result of each model is shown in Table 4.

It can be visualized that all drivers who park for less than 3 h react to the affecting factors in the same way. Similarly, drivers who park for more than 3 h show the same sensitivity within the group. Hence, 2 models are defined for those who park for less than and more than 3 h, respectively.

Parking Model Estimation: Parking Duration Less Than 3 h

The model with the coefficients and the corresponding statistics is shown in Table 5. The parameters in Table 5 show that search time and access distance do not influence parking decisions. The p-values of these attributes are greater than 0.05. It is concluded that search time and access distance are not significant with a 95%confidence interval in this model. As a result, the final model estimation output of drivers who park less than 3 h is shown in Table 6. The model parameter is obtained by estimation with the parking fee and walking distance. The estimation model is conducted by eliminating the attribute which has the least significance first as search time and access distance, respectively. The model result indicates that the value of the ASC is not significant, thus the form of the utility function

Table 4. The detailed result of each model

Parking duration	Parking attribute
0-1 h	parking fee
1-3 h	parking fee, walking distance
Over 3 h	parking fee, walking distance, search time

Table 5. The model with the coefficients and the corresponding statistics (less than 3h)

	Coefficient	*z*-statistic	*p*-value
Parking fee	-0.08353	-5.19	0.0000
Walking distance	-0.00281	-3.80	0.0001
Search time	-0.01095	-0.38	0.7026
Access distance	-0.00113	-1.66	0.0964
ASC_A	-0.02777	-0.10	0.9240
ASC_B	0.16993	0.58	0.5634
ASC_C	0.23749	0.83	0.4063

is the same for all alternatives. The utility function is as follows:

$$U_{<3,\,curb} = -0.079x_{fee,\,curb} - 0.002x_{walk,\,curb} \quad (3)$$

$$U_{<3,\,underground} = -0.079x_{fee,\,underground} - 0.002x_{walk,\,underground} \quad (4)$$

$$U_{<3,\,Wittayakit} = -0.079x_{fee,\,Wittayakit} - 0.002x_{walk,\,Wittayakit} \quad (5)$$

$$U_{<3,\,Siamkit} = -0.079x_{fee,\,Siamkit} - 0.002x_{walk,\,Siamkit} \quad (6)$$

Coefficients of attributes which affect behavior inform with a negative value. It means that increasing those attributes makes the utility value decrease. The absolute *z*-value of the parking fee and walking distance in Table 6 are 5.36 and 3.89, respectively. It implies that drivers are more sensitive to the parking fee than the walking distance.

Parking Model Estimation: Parking Duration Over 3 h

The model with the coefficients and the corresponding statistics is shown in Table 7. It shows that the *p*-value of access distance is greater than 0.05; thus, it does not influence parking decisions. It can be concluded that access distance is not significant with a 95% confidence interval in this model. As a result, the final model estimation output of drivers who park more than 3 h is shown in Table 8. The model parameter is obtained by estimation with the parking fee, walking distance, and search time. The estimation model was conducted by eliminating access distance. In addition, Table 8 indicates that there is an ASC of the Siam Square curb. The absence of the ASC for Siam Square One, Wittayakit, and Siamkit implies that, given all being equal, there are no differences between parking at Siam Square One, Wittayakit, and Siamkit. The utility function of those who park over 3 h can be written in equations as follow:

$$U_{>3,\,curb} = -0.096x_{fee,\,curb} - 0.004x_{walk,\,curb} - 0.077x_{search,\,curb} - 0.871'' \quad (7)$$

$$U_{>3,\,underground} = -0.096x_{fee,\,underground} - 0.004x_{walk,\,underground}\ 0.077x_{search,\,underground} \quad (8)$$

$$U_{>3,\,Wittayakit} = -0.096x_{fee,\,Wittayakit} - 0.004x_{walk,\,Wittayakit} - 0.077x_{search,\,Wittayakit} \quad (9)$$

$$U_{>3,\,Siamkit} = -0.096x_{fee,\,Siamkit} - 0.004x_{walk,\,Siamkit} - 0.077\ x_{search,\,Siamkit} \quad (10)$$

Table 6. The model estimation output of drivers who park less than 3 h

	Coefficient	***z*-statistic**	***p*-value**
Parking fee	-0.07933	-5.36	0.0000
Walking distance	-0.00283	-3.89	0.0001
ASC_A	0.01013	0.04	0.9720
ASC_B	0.16509	0.57	0.5700
ASC_C	0.27733	0.99	0.3216

Table 7. The model with the coefficients and the corresponding statistics (more than 3 h)

	Coefficient	***z*-statistic**	***p*-value**
Parking fee	-0.09618	-5.49	0.0000
Walking distance	-0.00458	-5.32	0.0000
Search time	-0.07927	-2.56	0.0105
Access distance	-0.00121	-1.52	0.1291
ASC_A	-0.84643	-2.47	0.0136
ASC_B	-0.25450	0.86	0.3909
ASC_C	-0.25457	0.85	0.3980

Coefficients of attributes which affect behavior inform with a negative value. It means that increasing those attributes makes the utility value decrease. The absolute *z*-values of the parking fee, walking distance, and search in Table 8 are 5.52, 5.32, and 2.54 respectively. It implies that drivers are most sensitive to the parking fee followed by the walking distance and search time, respectively.

Utility functions will be applied in the multinomial logit model to forecast parking duration and congestion.

Conclusions

Understanding parking behavior is essential to establish effective parking management policy. The parking location choice behavior of drivers affects the amount of traffic and distribution of traffic flows. This paper presents the results derived from 228 decisions of 76 respondents on parking location choice when making make a shopping trip. The questionnaire consisted of questions on personal characteristics and stated preferences. The parking choice models were separately analyzed by estimating the utility function of 2 models, i.e. a model for drivers who park less than 3 h and a model for those who park over 3 h. The parameter estimation indicates that the group of drivers who park less than 3 h are concerned by the parking fee and walking distance. Increasing those attributes makes the utility value decrease. There is no advantage or disadvantage in each parking location in this model. In other words, they can park anywhere that is not expensive. They choose to cruise to find a parking space that is near their final destination to reduce walking distance. However, those who park over 3 h are concerned by parking fee, walking distance, and search time. They are most sensitive to the parking fee. The second and the third most sensitive factors are walking distance and search time, respectively. It implies that they do not want to pay for expensive parking, nor do they want to waste time with search time and access distance. In addition, under the same circumstances and attributes they do not like to park at the Siam Square curb. This could be the result from the parking price structure which is more expensive than Wittayakit and Siamkit buildings. Moreover, the hot and rainy weather are not likely to encourage outdoor parking.

Thus, efficient parking management has to manage parking attributes that affect parking behavior including parking fee, walking distance, and search time.

Recommendation

Parking Policy with Parking Fee

The study shows that the parking fee is the most important attribute in a parking decision. It is usually the parking price structure that is considered to be a management policy in controlling demand. Since the study area is located around a shopping mall, various pricing structures, including price per hour and a progressive rate, are applied to allow the maximization of parking facility utilization. By charging a higher hourly meter rate for each additional hour, short- term parking is encouraged and turnover increases, while providing flexibility and convenience to users.

Table 8. The model estimation output of drivers who park more than 3 h

	Coefficient	*z*-statistic	*p*-value
Parking fee	-0.09459	-5.52	0.0000
Walking distance	-0.00458	-5.32	0.0000
Search time	-0.07748	-2.54	0.0112
ASC_A	-0.87152	-2.59	0.0097
ASC_B	-0.28386	0.97	0.3302
ASC_C	-0.32585	-1.11	0.2685

Parking Policy with Walking Distance

The study shows that the walking distance is the second most important factor. A policy that responds to this finding focuses on improving connectivity from parking to activity sources. The pedestrian network should be accessible to all. Sidewalks, pathways, and crosswalks should ensure the mobility of all users by accommodating the needs of people regardless of age or ability. The facilities should be safe and should be designed and built free of hazards such as vehicular conflicts.

Parking Policy with Search Time

The last element affecting a parking decision involves the search time. A search time management approach can be achieved by using a smart parking system to indicate the amount of vacant space at a parking entrance. The drivers will receive the amount of vacant space data when they arrive at the parking entrance from use of a signal. A green signal represents a vacant space and a red signal represents an occupied space. Those signals are attached to all spaces.

In addition, parking search time can be reduced by the introduction of a smartphone application. A parking study in San Francisco invented the smart parking system that integrated traffic count data, from entrance and exit sensors at a station parking lot. The smart parking facilitated pre- trip planning by permitting users to reserve a space up to 2 weeks in advance. All drivers can reserve parking spaces over the smartphone with the goal of decreasing parking search time and traffic congestion (Rodier and Shaheen, 2010).

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