PARKING BEHAVIOR IN CENTRAL BUSINESS DISTRICT A STUDY CASE OF SURABAYA, INDONESIA

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abstract : The lack of information about parkers' behavior in choosing a parking location in the Central Business District makes it difficult to develop an effective parking policy. The purpose of this study is to understand parkers' behavior in choosing a parking location in the CBD of Surabaya. Three types of parking location choice models were developed, namely Parking Demand Regression Models, Analytic Hierarchy Process and Multinomial Logit Models. The parkers' behavior in choosing a parking location is mainly influenced by the availability of parking spaces, trip purpose, search & queue time, walking time, parking fee, security, and comfortability.

1. INTRODUCTION

The activities in a city is mainly concentrated in the Central Business District (CBD). These activities demand more parking spaces but increasing the number of parking spaces is restricted by the limitation of land area. Parkers' behavior in choosing a parking location, such as on road parking, on surface and in multistory building, are distinct by trip purpose and other factors. It reveals that the effectiveness of the parking location usage can be improved if the parkers' behavior in choosing parking location is known. For planning purposes, knowledge about parkers' behavior can also support the allocation of parking demand according to the parking location.

In Surabaya's Central Business Districts, the parking management lack knowledge about parking behavior in the choice of a parking location. The lack of information about parkers' behavior and preference in choosing a parking location in the Central Business District area, especially for commuting, business and shopping trips, makes it difficult to develop effective parking policies. Understanding parking behavior is an effective way to analyze the effects of parking policy measures. The purpose of this study is to develop parking location choice models and to understand parkers' behavior in choosing a parking location in the Central Business District of Surabaya.

2. METHODOLOGY

2.1 The Study Area

The choice of the study area was done by considering the availability of different types of parking locations and a 2 km radius or less for alternative parking locations. At least the

study area should have one multistory building, one on surface parking and one on-road parking location. These qualifications lead to the choice of Pasar Atum - Indo Plaza - Praban - Tunjungan - Genteng Kali and their surrounding areas as survey locations. These areas are in the Central Business District and their land uses were mainly market areas and business centers.

Table 1 shows the parking capacity in the study areas. Totally there are 1110 (50%), 828 (37%) and 299 (13%) spaces for building, surface and on-road parking locations respectively.

Table 1. Parking Capacity in The Study Areas

Location	Type	Capacity (cars)
Pasar Atum	Surface	362
	Building	667
Indo Plaza	Surface	247
	Building	152
Semut Megah	Surface	150
Waspada	On-Road	28
Stasiun Kota	On-Road	121
Tunjungan Center	Building	291
Aurora	Surface	69
	On-Road	52
Genteng Kali	On-Road	51
Gemblongan	On-Road	71
Tunjungan	On-Road	17
Praban	On-Road	30

The "UPDP Parkir (Unit Pelaksana Daerah Pengelola Perparkiran) Agency" is the executive body which manages parking in the city. The on-road parking is managed directly by the agency, while the off-street parking is handled by private owners under the control of the agency. On-street parking is managed directly by the City government, while off-street parking places are managed by private owners for public use. For on-street parking, a car's parking fee is Rp. 300 (± US $0.15) for one time parking. Off-street parking is regulated to have a progressive parking fee. The progressive parking charge system charges the same price for the first one or two hours and additionally charged a half of the parking price (Rp.150) per hour.

2.2 Data Collection

In general, data collection can be divided into three sections:
(1) Parking user, which are can be divided into two parts:
    (a) Parker's behavior; the actual things they do to choose parking places.
    (b) Parker's preference; the ideal factors they consider in choosing parking places.
(2) Parking condition; the actual condition of the parking places.
(3) The recent government parking policy and the future programs that may be implemented.

To get the parking user data, a questionnaire interview survey was done in the study area. The interview was conducted for 4 weeks on working days (Monday through Saturday),

from 9:00 am to 5:00 p.m. The parker's behavior questionnaire includes three parts: parkers' characteristics, trip and parking information, and evaluation of the parking locations. Parker's characteristics are general information about sex, age and net income per month. Trip & parking information is about trip purpose, car ownership, location of parking place, number of visited places, parking habit, and parking place information. The actual parkers' behavior was taken by letting them evaluate the parking space, according to several factors such as closeness to destination, ease to park, walking condition, parking fee, parking duration, parking space availability and security. The actual walking distances were measured from the map attached in the questionnaires.

Parker's Preferences interviews included the part of parker's characteristic, trip & parking information and parker's opinion. The first two parts are the same as parkers' behavior interview, while parkers' opinions are executed for comparison and rating of the factors for choosing parking places and the hypothetical parking facilities. The willingness of parkers to walk and pay the parking fee are also included. After reducing the missing and invalid data, 528 parkers' behavior and 402 parkers' preference data was collected.

Actual condition of parking places that have been evaluated by the users was observed. This data was used to check the validity of the parking behavior data. The recent government parking policy and the future programs were collected by interviewing the government officials who were in charge of parking policy.

3. RESULTS AND ANALYSES

3.1 Parking Location Choice Factors

The factors which influence parkers in choosing the parking location can be categorized into tangible and intangible factors. Tangible factors are factors that are visible or can be measured directly by physical measurement. They can be classified into trip characteristics, socio-economic characteristics, and parking conditions. The main factor for trip characteristics is trip purpose. The major socio-economic factors are gender, income and age. Parking conditions, such as parking fee, walking time, duration, and search and queue time, are the factors that can be measured by physical measurement. Intangible factors (such as proximity, comfortability, convenience, security, safety, availability of parking space) are invisible or difficult to measure by physical measurement, but they can be rated or compared to other factors.

There are three types of parking locations in CBD Surabaya:
1. on-road parking,
2. off-street at surface parking, and
3. off-street on multistory parking.

Table 2 shows the distribution of usage of the three parking locations and the capacity of parking space in the study area. The number of respondents were obtained from the questionnaire interview, while the parking capacity from the parking condition survey. Table 2 shows that almost a half of the parkers use multistory parking in the Central Business District because the capacity of the building parking location also occupy a half of all parking location. The parking location usage distribution of parkers is almost similar

with the distribution of the parking capacity. It indicates that the people use parking location according to the availability of parking spaces. Among these three types of parking location, on road parking has the lowest usage.

Table 2. Parking Location Distribution

Parking Location	Capacity (spaces)	Number of Respondents
On road	299 (13%)	104 (20.0%)
At surface	828 (37%)	168 (32.2%)
On multistory building	1110 (50%)	249 (47.8%)
Total	2237 (100%)	528 (100 %)

3.2 Trip Characteristics

Table 3 shows the distribution of trip purposes of the parkers in CBD Surabaya. From the four major trip purposes coming to the CBD, shopping and working trips are more common than business or recreation trips.

Table 3 Distribution of Respondent Trip Purpose of Coming to CBD Area

Trip Purpose	Frequency	Per cent
Shopping	253	48.4
Business	85	16.3
Working	111	21.2
Recreation	74	14.1
	523	100.0

People who came for shopping, business and recreation mostly chose parking on the building, while people who come for work preferred to use surface parking places inside the market. Recreation trips in the CBD area usually are window shopping. Table 4 also describes the relationship between trip purpose and parking location. It can be seen that for business and recreation trips, there is no significant difference in choosing on road and surface parking place.

Table 4. Relationship between Parking Location and Trip Purpose

Trip Purpose		Parking Location			
		Road	Surface	Building	Total
Shopping	(48.4 %)	19.2 %	28.4 %	52.4 %	100 %
Business	(16.3 %)	25.0 %	28.6 %	46.4 %	100 %
Working	(20.9 %)	17.6 %	48.1 %	34.3 %	100 %
Recreation	(14.3 %)	20.3 %	23.0 %	56.8 %	100 %

Pearson χ^2 = 19.96916 df: 6 α = 0.0028

Parking location choice and trip purpose are dependent on each other. By independence test, the null hypothesis that these two variables are independent is rejected. Thus, parking location choice depends on trip purpose.

3.3 Socio Economic Factors

Personal characteristics such as income, gender and age were tested in relation to the parker's choice of parking location. The relationship between parking location and gender

is insignificant because the chi-square test with level of significance α = 14.9%, greater than 5% .

Table 5. Relationship between Parking Location and Income

Net Income /Month (Thousand Rupiahs)		Parking Location			
		Road	Surface	Building	Total
< 175	(35.7 %)	20.7 %	31.0 %	48.3 %	100 %
175 - 400	(32.0 %)	19.2 %	34.6 %	46.2 %	100 %
400 - 800	(18.4 %)	18.9 %	30.0 %	51.1 %	100 %
> 800	(13.9 %)	25.0 %	27.9 %	47.1 %	100 %

Pearson χ^2 = 2.04759 df = 6 α =0.91527

Independence test between net income per month and parking location, as shown in Table 5, indicates that the null hypothesis is failed to be rejected. There is no difference in behavior between low, medium and high income people in choosing parking location.

Table 6. Relationship between Parking Location and Age

Age		Parking Location			
		Road	Surface	Building	Total
< 20 yr.	(11.0 %)	17.5 %	19.3 %	63.2 %	100 %
20 - 40 yr.	(69.6 %)	18.0 %	32.7 %	49.3 %	100 %
> 40	(19.5 %)	28.7 %	37.6 %	33.7 %	100 %

Pearson χ^2 = 15.82192 df = 4 α = 0.00327

There is a difference in behavior however, between young parkers (less than 40 years old) and older people (more than 40 years old) in choosing parking location, as shown in Table 6. Younger parkers prefer multistory buildings as parking place. The older parkers treat the three types of parking location almost equally.

3.4 Parking Condition

There are four estimated parking condition factors that can explain the parkers' behavior in parking location choice. The factors are walking time, parking duration, parking fee and time to queue (for getting ticket) and search for an empty parking space. Two kinds of values of those four factors were found, actual value and perceived value. The actual value is useful for getting model for policy analysis purposes, while the their perception is useful for the design of the ideal parking place. Table 7 shows the mean values of parking condition factors. One-way analysis of variance has been done toward those factors and the results are shown in the table. The F-ratio of parking fee factor is 1.58 smaller than F-ratio table value (3.04), this indicates that there is no difference in actual parking fee between parking on road, surface and building.

Table 7. Mean value of Actual Parking Condition Factors by Parking location

Parking Condition Factors	F ratio	Parking Location		
		Road	Surface	Building
Walking time (min.)	11.37	4.17	3.66	4.99
Duration (hours)	4.23	2.51	3.47	3.09
Parking fee (Rp/hour)	22.10	256	183	162
Search and queue time (min.)	2.59	5.47	5.13	6.13

Figure 1 shows the result of the analysis of variance as Ellipse diagrams for each factors of parking condition with level of significance $\alpha = 10\%$. The farther right the location in the diagrams, the bigger the value of each factor. An ellipse states one homogeneous subset. Homogeneous subsets are subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range (10%) for a subset of that size. If two or more road types are in one subset, it denotes that there is no significant difference between road types for each parking condition factor. For parkers on the road and surface, walking time is not much significant for them unlike parkers in the building which has a significant value. For actual parking duration, however, parkers on the surface gave a high value and on road parkers are indifferent to this factor. Both building and surface parkers are indifferent to the parking fee while road parkers give much value to this factor, it may be because of the progressive parking charge for on road parkers. Moreover, there is a difference in the mean value of search and queue time between parking in the building and on surface because to park in a building, a longer time is need to search for an empty parking space than at surface.

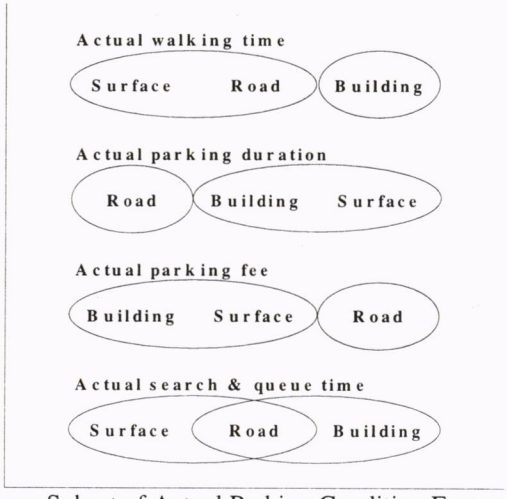

Figure 1. Homogeneous Subset of Actual Parking Condition Factors by Parking Location

Mean value of parking condition factors separated by trip purposes are shown in Table 8. The F-ratios from the analysis of variance are also shown in the table.

Table 8. Mean Value of Parking Condition Factors by Trip Purpose

Parking Condition Factors	F ratio	Trip Purpose			
		Shopping	Business	Working	Recreation
Walking time (min.)	9.52	4.89	3.70	3.53	5.14
Duration (hours)	109.91	1.83	3.56	6.08	2.43
Parking fee (Rp/hour)	6.43	204	193	143	186
Search&queue time (min.)	6.53	6.29	5.25	4.19	6.41

There is no significant difference between actual walking time of working and business purposes as well as shopping trip and recreation. Working and business trips have shorter actual walking time from parking place to destination than shopping and recreation trips. The very interesting result is that there is a significant difference between parking duration by trip purpose. Each trip purpose has its own parking duration. Table 8 also shows that a

big F-ratio indicates the differences of parking duration to trip purpose. Parking duration for shopping and recreation trips are shorter than business trip while the working trip has the longest duration. It also indicates parkers who come for work are willing to pay a higher parking fee because they are restricted to come. The time value of the parkers who come for shopping or recreation is less than that for the parkers who come for working or business. The search and queue time for shopping and recreation trips have big values because they need more time to search for an empty parking space (more relaxed). Usually, the parkers who come for work come in the off peak (morning), when the parking demand is less. Therefore, they need shorter search and queue time.

4. PARKING DEMAND MODELS

Parking demand models are built based on parkers' willingness concerning parking behavior. This model be utilized to analyze the relationship between parking behavior and demand. The demand represents the cumulative percentage of parkers who are willing to park under the values of parking condition factors. The cumulative frequencies of parkers' willingness for each parking condition factor (such as maximum walking distance, maximum walking time, maximum search and queue time and parking duration) are modeled by regression to get the parking demand model. The results of these regressions are summarized in Table 9. The demand (Q) indicate the cumulative percentage of parkers who are willing to use the parking location which have characteristic X. These parking demand models represent the potential demand for parking in a particular location when the parkers are not obligated to come to that location due to many alternative parking locations. If there are many choices of parking location, in a particular area such as CBD, these parking demand models have a very important role to compare the potential demand of one particular parking location over another. It is also very useful to determine the potential parking demand that will change according to the changing parking policies.

Table 9. Summary of Parking Demand Models

Independent Variable X	model	R^2	t value	Eq. No
Walking Distance (m.)	$Q = 17.4678\ X^{(-0.9335)}$	0.93	-13.58	(1)
Walking Time (min.)	$Q = 1.1527 + LN\ (\ X^{(-.3422)}\ )$	0.95	-15.75	(2)
Search & Queue Time (min.)	$Q = 1.32\ e^{(-0.0995\ X)}$	0.94	-18.04	(3)
Parking Fee Index	$Q = 1.65\ e^{(-0.8492\ X\ )}$	0.94	-14.31	(4)
Add. Parking Fee Index	$Q = 1.66\ e^{(-0.6317\ X)}$	0.95	-12.08	(5)
Duration for Shopping (hr.)	$Q = LN\ (1.286\ X^{0.456})$	0.93	-11.65	(6)
Duration for Business (hr.)	$Q = LN\ (1.361\ X^{0.366})$	0.97	-21.08	(7)
Duration for Working (hr.)	$Q = 0.0085\ X^{1.964}$	0.96	-23.68	(8)
Duration for Recreation (hr.)	$Q = LN\ (0.979\ X^{0.416})$	0.90	-14.37	(9)

The models were calibrated by two statistical tests, R^2 and t- test. The larger R^2, the better the fitted equation explains the variation in the data. It can be seen that the value of R^2 is close to one, indicate that the model are well fit. It can be seen that the value of t-test is greater than ± 1.96, indicates that the parameter of the independent variables are statistically not equal to zero. If the factor is walking distance from parking location to destination, the demand represents the cumulative percentage of parkers who are willing to walk that distance or less. For example, the demand (Q) as a function of walking distance X=100

meter is 24%. It means that 24% of the parkers who come to the CBD in Surabaya are willing to walk within 0 to 100 meters from their parking location to destination.

5. MULTINOMIAL LOGIT MODELS

Multinomial Logit Model (MNL) is built based on the parking behavior survey. The dependent variable is the probability that a parker's choice of a particular parking location (road, surface or building). The development of MNL model used a trial and error method. Three kinds of variables were considered as follow:

(1) Personal characteristics; sex, income, age.
(2) Trip characteristics; trip purpose, the existence of guard, the existence of professional driver, the usage of personal vehicle, number of parking place visited before got the parking space, number of place the parkers going to visit.
(3) Parking condition characteristics; search and queue time, parking fee per hour, walking time and walking distance from parking location to destination, and parking duration.

The model estimation outputs to be examined are the signs, the relative values of the coefficients estimates, the significance of the individual coefficient and the percent correctly predicted. Table 10 shows the model with the coefficients and the corresponding statistics. It can be seen that out of the fourteen variables used in the model, only three has an effect on the parking location choice. The variables which affect the parking location choice are: search and queue time, walking time, and parking fee.

Table 10. Multinomial Logit Model for Working and Business Trips

Independent Variables	Estimated Coefficient	Standard Error	t-Statistic
Search & queue time (specific to Road)	-0.87705	0.18124	-4.8391
Search & queue time (specific to Building)	-0.26737	7.97E-02	-3.35393
Walking time (specific to Surface)	-0.28617	0.11351	-2.5211
Parking fee / hour (specific to Road)	-4.38E-03	1.80E-03	-2.43834
Parking fee / hour (specific to Surface)	-3.20E-03	1.73E-03	-1.84673
Parking fee / hour (specific to Building)	-6.82E-03	3.02E-03	-2.25986
Constants (specific to Road)	2.22629	1.33789	1.66403
Constants (specific to Surface)	-0.91607	0.77642	-1.17987

auxiliary statistics	at convergence	initial
log likelihood	-153.39	-210.93
number of observations	192	
percent correctly predicted	75.521	
$-2\,[L(o)-L(\beta)]$	115.08	$> \chi^2_{0.05,8} = 21.96$
$\rho^2 = 1 - L(\beta)/L(o)$	0.273	> 0.2

Equations 10 to 13 show the form of MNL model. The t-statistics are shown below each factor in the parenthesis.

$$U_R = \underset{(-4.84)}{-0.87705 * SQT_R} \underset{(-2.44)}{- 4.38e\text{-}003 * PFH_R} \underset{(+1.66)}{+ 2.22629} \qquad (10)$$

$$U_S = -0.28617*WT_S - 3.20e\text{-}003*PFH_S - 0.91607 \quad (11)$$
$$(-2.52) \qquad (-1.84) \quad (-1.18)$$

$$U_B = -0.26737*SQT_B - 6.82e\text{-}003*PFH_B \quad (12)$$
$$(-3.35) \qquad (-2.26)$$

$$P(U_i) = e^{U_i} / (\Sigma_i e^{U_i}) \quad (13)$$

where,
U_i = utility function of i parking location.
SQT_i = Search and queue time of i parking location (minutes)
WT_i = Walking time from parking location i to destination (minutes)
PFH_i = Parking fee per hour of i parking location (Rp./hour)
$P(U_i)$ = Probability that a parker will choose parking location i.
i = on-road (R),or surface (S),or multistory building (B) parking location.

Two statistical tests and one informal test are applied to calibrate the model. Under the null hypothesis that all the coefficients are zero, that is, $\beta_1 = \beta_2 = ... = \beta_k = 0$, the statistic $-2[L(o)-L(\beta)]$ is distributed with K degree of freedom. K is the number of estimated coefficient. It can be seen that the null hypothesis is strongly rejected. It means that the model is statistically fit with the population. The t-statistic of all coefficient, except a constant for surface, are greater than ± 1.65. Therefore, the null hypothesis that each of the parameter values is equal to zero at the 10% level of significance, can be rejected. Therefore coefficients are significant and the model fits the data well. Informal goodness-of-fit test ρ^2 is greater than the minimum value of 0.20 which also shows that the model is well fit to the real world population.

6. ANALYTIC HIERARCHY PROCESS MODELS

Parkers' preference was mainly analyzed by Analytic Hierarchy Process (AHP). Quantitative scales of factors' importance were gotten as the result. The parking choice models by AHP were developed using Expert Choice package software. There were two hierarchy levels of AHP analysis, as shown in Figure 2, which is judged by the respondent through pairwise comparison. The goal of the judgment is to choose the best parking location. The first level compares the importance of the factors with each other concerning the goal. There were seven factors that were compared to each other. These comparisons can make one judgment matrix. The second level, compares the alternative parking location, according to each factor, concerning the goal. Each factor can be formed into one judgment matrix. Totally there are 8 judgment matrices filled by every respondent. The priority of these factors were obtained by calculating normalized weight of each factor toward the alternatives.

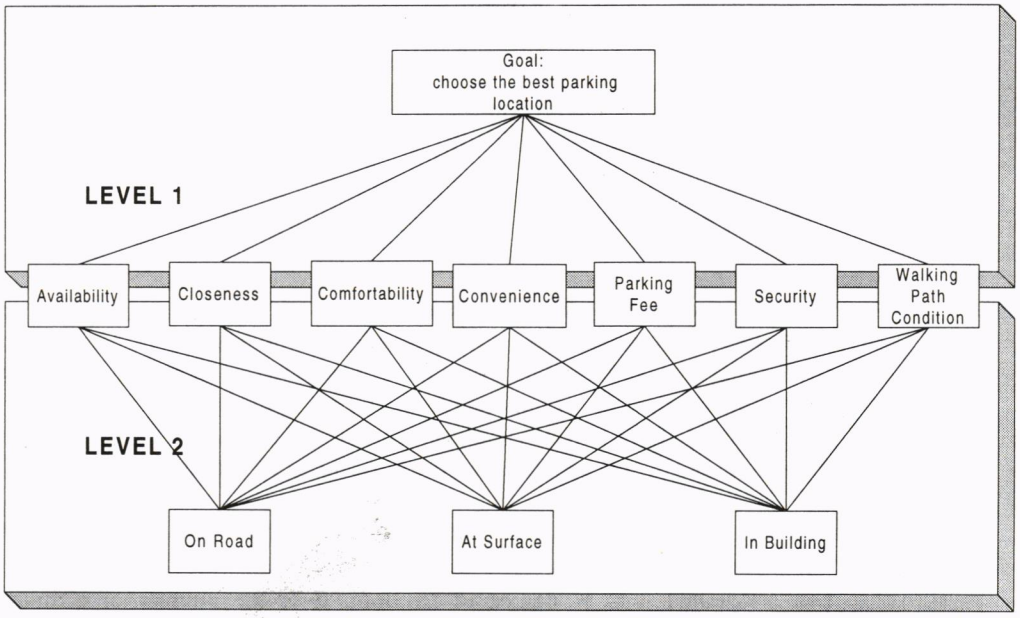

Figure 2. Structure of AHP Analysis

Figure 3 shows the aggregations by arithmetic mean of AHP results for each factor. The numbers of mean for each factor indicate a ratio value. For example, it shows that security is 30.86% and parking fee is 8.98%, which means that people consider security is (30.86/8.98 =) 3.4 times more important than parking fee.

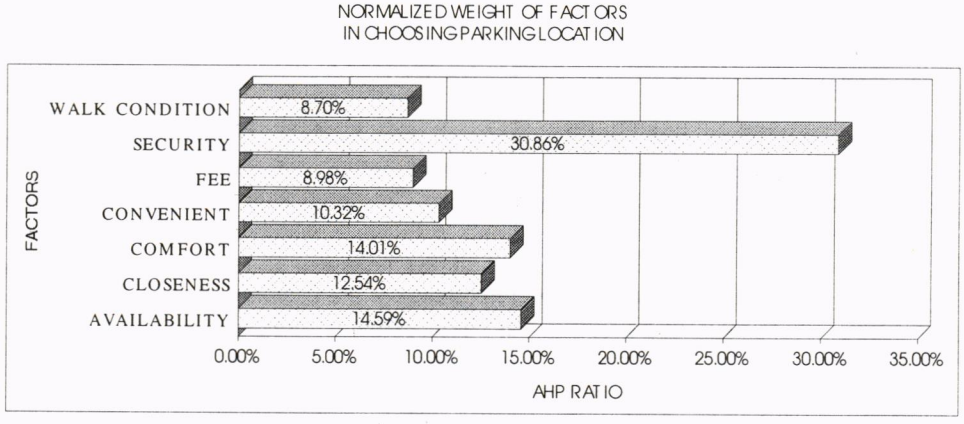

Figure 3. Aggregation of Each Factor from AHP Analysis

Figure 3 also indicates the factors that influence parkers to choose parking location. It shows that parkers choose that particular parking location mainly because of the security. They do not consider walking path condition and parking fee much because of a relatively cheap parking fee and short distance to destination place.

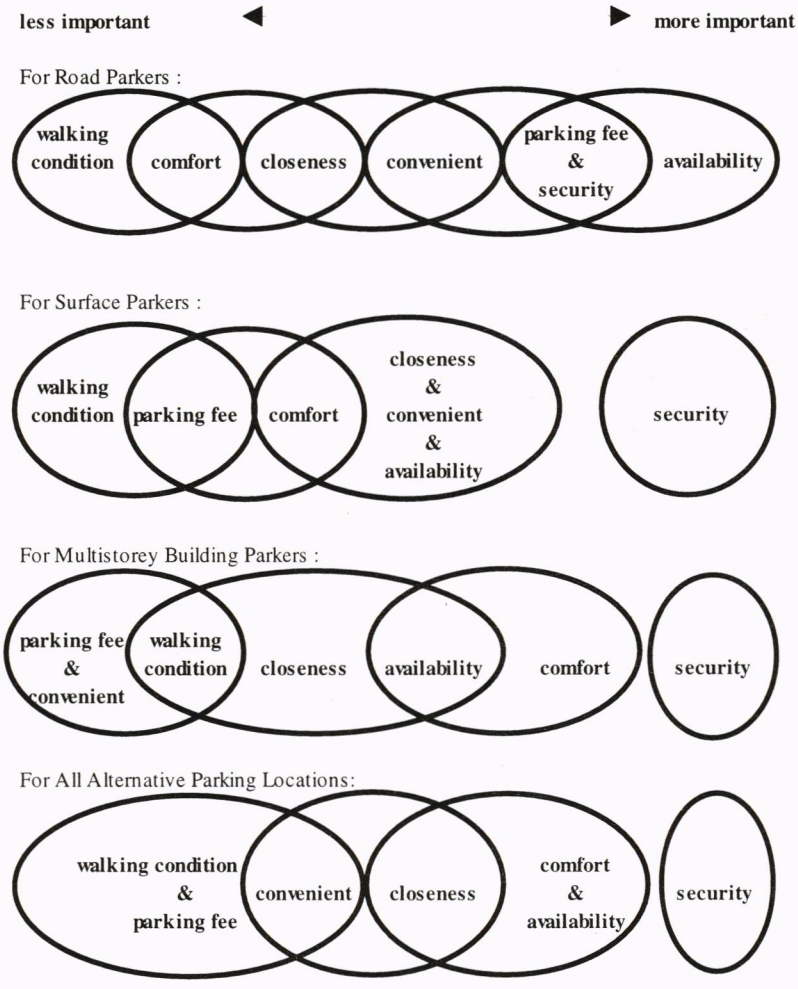

Figure 4. Comparison of Each Factors of AHP Analysis by Parking Location

Analysis of variance was done to get the homogeneous subset of AHP factors by parking location and all alternatives parking location. The results are shown in Figure 4. For the parkers who choose road as parking location, availability of parking space is the most important factor, while the parkers who park on surface or buildings consider security as the most important factor. Parking fee is less important for parkers in off street parking, but quite important for on road parkers. Walking path condition is the least important for all parkers. In general, for all alternative parking locations, there are 4 homogeneous subsets, with level of significance α = 10%. The first subset contains security. The second subset contains comfortability, availability of parking space and closeness to destination. There is no significant difference among these three factors. The third subset explains that there is no significant difference between closeness and convenience (ease of parking). The last subset contains walking path condition (comfortability and safety), parking fee and convenience. These last three factors are considered as less important factors.

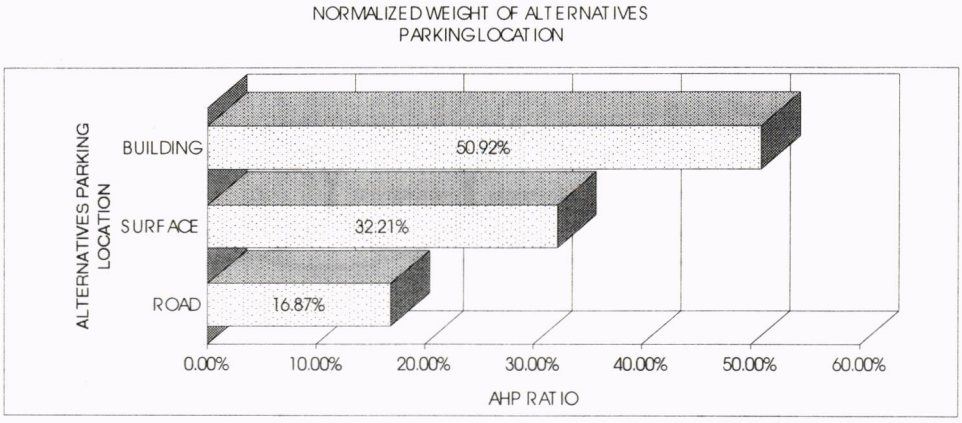

Figure 5. Aggregation of Each Alternative Parking Place

The concluding result of AHP analysis, as shown in Figure 5, is the aggregation of each alternative parking place. In the ideal condition of the parkers, building is preferred 1.6 times more than surface and 3.0 times more than road.

Analytic Hierarchy Process models are built based on pairwise comparison of seven parking condition factors. The models have a form as in Equation 14. The dependent variables are the percentage of parkers who choose an alternative parking location. Each alternative parking location i (road, surface and building) is explained by the summation of the priority of the factors X_j times the coefficient of each factor a_{ij}, as shown in Equation 14. The coefficient of each factor is the aggregation value of the priority for each alternative. These coefficients have been found from the Table 11.

$$A_i = \Sigma_j \; a_{ij}.X_j \tag{14}$$

where,
A_i = Alternative i (i= road, surface, building)
a_{ij} = The coefficient of each factor j for alternative i
X_j = The priority (weight) of factor j

Table 11. The Coefficients and Factors of AHP Models

Factors (j)	The priority of Factor (X_j)	Coefficients (a_{ij}) of Model for		
		Road	Surface	Building
Availability	14.59%	25.09%	30.88%	44.03%
Closeness	12.54%	17.64%	31.43%	50.93%
Comfort	14.01%	10.45%	31.13%	58.42%
Convenience	10.32%	25.44%	43.63%	30.93%
Parking fee	8.98%	33.36%	30.84%	35.80%
Security	30.86%	9.74%	31.07%	59.18%
Walk path condition	8.70%	10.35%	29.27%	60.39%

The total of all alternatives is equal to one or 100%. These properties might give an idea about the probability of choosing each alternative parking location.

7. CONCEPT OF THE MODEL APPLICATIONS

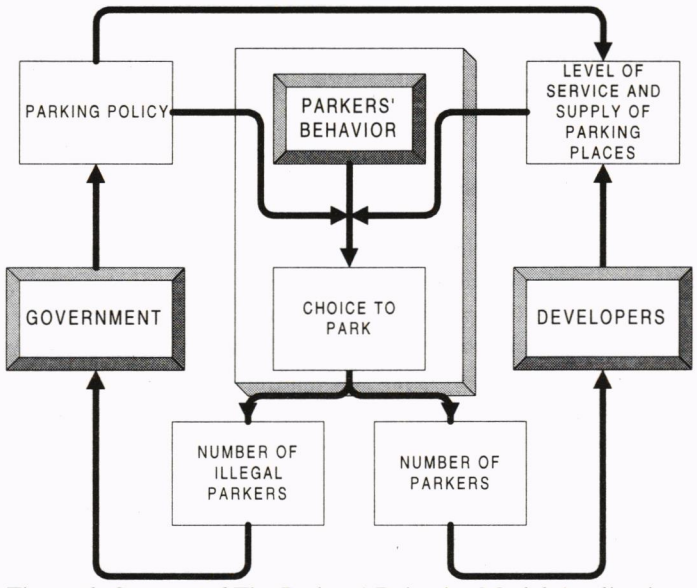

Figure 6. Concept of The Parkers' Behavior Model Applications

If one examines Figure 6, it can be seen that the parkers' behavior models are useful for estimating the choice of parking locations. These choices influence the demand of the parking locations. It is represented by the number of illegal parkers and number of parkers. The number of illegal parkers increases if the parking supply is lower than the parking demand. In the government side, it is desirable to reduce the number of illegal parking by making a parking policy. The parking policy will affect the parkers' behavior to choose parking location and level of service of the parking location and the parking supply. The pattern of the policy is controlled by parking fee and parking space. By increasing or reducing parking fee, the number of parking demand can be managed. For Surabaya's case, the government can establish a new parking fee for the whole city as before or give a free hand to the owner of parking location to determine their own parking fee based on the market price. Parking space can be controlled by the re-determination of the standard of the number of parking supply in the building/market in the CBD. The standard may encourage or discourage the developer to provide parking supply. For the government of Surabaya, the road parking spaces are controlled directly by the government. It is easier to control the number of on road parking space. The changes in the availability of parking space may modify the search and queue time for parking. The modifications of both parking fee indicate the changing of the level of service, while altering the parking space indicates the change in the parking supply. This change finally also affect the parkers' behavior in choosing the parking location. On the developers' side, the decreasing number of parkers will effect them to provide better level of service of the parking location (by changing the factors such as comfortability and security) to gain more demand. The increasing number of parkers affect them to provide more parking space as parking supply. It means the purpose of parking analysis for developers' side is to get more demand. If the government gave them opportunity to determine their own parking fee based on the market price the owners of the parking location can decide their parking fee. However, in recent

situations, the parking fee is only based on government standard. In this case, the change in parking level of service will exclude parking fee as one of the factors. The practical applications of the models are analyzing parking policies to predict the increasing or decreasing potential parking demand where the parkers are not obliged to come only in that location. For instance, if there are many choices in shopping center, the number of parkers of that location can be encouraged or hindered by changing the factors.

7.1 Characteristic of the Models

Table 12 shows the characteristic of the models that have been developed. The parking demand models are useful to analyze the developer or owner of the parking location side. The model can be used for determining the changing of potential parking demand of one parking location. This model assumes that other parking location factors remain constant. The reason behind the assumption is that the analysis using this model is the comparison of the present situation (as base values) and the changing situation (because of the new policy). The AHP models might be used for both government and developers' side to analyze the shifted demand from one parking location to other locations. However, the model qualitatively compares one parking location factor to another. The meaning of the factors are just the changing of parkers consideration due to some parking policy. For example if the parking fee increase very much, the parkers consideration about parking fee will also increase compared to the other factors.

MNL models can be used for parking policy analysis of government side. Similar to AHP model, MNL model is also useful to analyze the shifted demand from one parking location to other locations. The value of the independent variables can be different for each alternative, hence this model is more flexible than AHP model. However, AHP model is more comprehensive because it considers many factors. The independent variables of the MNL model are mainly time and fee, while AHP model also considers many qualitative factors, such as security and comfortability. The MNL models that have been derived can be used for working and business trip only. Considering the concept of the model application and the characteristics of the models, seven cases of parking policy can be analyzed. The policy can be classified into two categories: government side and developers' side. Some examples of the practical parking policy analysis that is discussed in the following sections. By knowing the main factors of the parkers' behavior in choosing parking location, the effective parking policies can be made.

Table 12. The Characteristic of Parking Location Choice Models

Model	Characteristic
Demand Models	Useful for knowing the changing potential demand of one parking location compare to others • One quantitative factor each model
AHP Models	Useful for knowing the shifted demand among parking locations • Compare more comprehensive factors • Changing one qualitative factor together for all model
MNL Models	Useful for knowing the shifted demand among parking locations • Flexible to change the factors • Only for working & business trip • The factors are mainly time and fee

7.2 Government Side

In the government's point of view, reducing the number of on-road parkers is the objective of the parking policy. Reducing number of on-road parkers in CBD is to reduce the traffic congestion. When the demand of road is changing, the percentage of shifted demand to other parking locations are necessary to know. The understanding of the shifted demand may provide information for the government to decide the development of other parking locations and the parking tax share of each parking location. For instance, most demand is shifted to building parking location, the development of building parking location may be encouraged and the parking tax for building parking location may also increase greatly as the increase of the shifted demand.

All Parking Fee Increase

The present government parking fee standard in Surabaya is flat Rp 300 per hour for all parking location. If the government increase the parking fee with same multiplication factor, the parking demand of each parking location will alter. If the parking fee increase, many of the restricted parkers (working and business trip) will shift to the surface parking location. Table 13 shows that for restricted parkers, the demand of the on-road and building parking location is decreasing while parking fee increase. This table is calculated by MNL model by alter the parking fee of the three parking location, while other variables are kept constant. It can be seen that increasing the parking fee for all parking locations two and four times from the present standard, may deter the on-road parkers 2 points and 10 points respectively.

Table 13. Parking Fee Increase with same amount of multiplication for all parking type

Parking Fee Rp/Hour	P(R)	P(S)	P(B)
300	21%	54%	25%
600	19%	70%	11%
900	15%	81%	4%
1200	11%	87%	2%
1500	8%	91%	1%

Note: For Working & Business Trip

Changing of Off-Street Parking Fee

If the city government of Surabaya still controlled all the parking fee standard as the present situation, analysis of changing of off-street (surface and building) parking fee may be useful to determine whether the change of off-street parking fee may deter on-road parking. Table 14 shows the results of the analysis. The analysis is using MNL models for working and business trip (restricted parkers) and kept the on-road parking fee as the present standard Rp 300/hour. Both increased and decreased cases are analyzed. The decreasing off-street parking fee may reduce the number of restricted parkers of on-road and surface parking locations. The decreasing off-street parking fee increase the utility of building parking location. On the contrary, the increasing off-street parking fee may shift the demand of off-street parking into on-road parking. When the off-street parking fee reduces, the parkers compare the three parking locations to decide their choice. Comparing building and road parking location, building is cheaper, so they choose building. Comparing building and surface parking location, they are thinking of the trade-off

between convenience and comfortability. The parkers who consider convenience as greater than comfortability will choose surface, while the parkers who choose building consider comfortability more than convenience.

Table 14. Changing of Off-Street Parking Fee

Parking Fee Rp/Hour	P(R)	P(S)	P(B)
300	21%	54%	25%
100	9%	46%	44%
250	17%	53%	30%
400	28%	54%	18%
500	37%	51%	12%

Note: For Working & Business Trip
On-Road Parking Fee = Rp 300/ Hour

Reducing the off-street parking fee Rp 50/hour from the present condition may deter 5 points of on-road parking, while reducing off-street parking fee Rp 200/hour from the present condition can decrease on-road parkers 11 points. The results are lesser than the previous policy scenario. Reduction of the off-street parking fee may reduce the earning of the government from the parking tax. Comparing the three scenario policies of changing parking fee by the government side, increasing the on-road parking fee is the most effective way to deter on-road parking.

Parking Fee & Space

On road parking prohibition is very effective to deter on-road parkers, however the combination of the increasing off-street parking fee and on-road parking prohibition are one of the alternative parking policies. Table 15 shows that if on-road parking is prohibited, increasing of parking fee may increase the number of restricted parkers in surface parking location, but decreasing the number of parkers in building parking location.

Table 15. On road Parking Prohibited; Off-Street Parking Fee Increase

Parking Fee Rp/Hour	P(R)	P(S)	P(B)
Present Condition	21%	54%	25%
300	0%	68%	32%
600	0%	86%	14%
900	0%	95%	5%
1200	0%	98%	2%
1500	0%	99%	1%

Note: For Working & Business Trip
The Present Condition Based On Parking Fee = Rp 300/hour

7.3 Developers' Side

For the owners of markets or business center or recreational area, increasing number of parkers means increasing the number of customers. The objective of their parking policy is increasing the number of parkers to that particular parking location. If the developers can decide their own parking fee according to the market price, they may also think of reducing the number of parkers to gain more profit from the parking fee or to gain more parking

space. By knowing the main factors of parkers' behavior in parking location choice, the improvement of the level of service of the parking location can be more effective.

Parking Duration Limitation

Parking duration limitation can be a very useful policy to reduce the number of parkers, especially for working parkers. The parking duration limitation can be done by using parking meter or progressive parking fee or parking ban at peak hours. The impact of the reducing the number of parkers may increase the parking spaces and it may also reduce the search & queue time.

Parking duration is different by trip purpose. The combination of several activities (trip purpose) in one time parking may make the parking duration longer. Table 16 shows the change of the potential demand due to parking duration limitation. The objective of parking duration limitation is to deter long time parkers and to encourage short time parkers. The parkers who come for shopping and business trip are short time parkers, while working trips are usually long time parkers. By holding the objective of the policy, it can be seen that the optimum parking duration limitation is three hours.

Table 16. Changing Parking Duration Limitation

Parking Duration Limitation	Changing of Potential Demand For			
	Shopping	Business	Working	Recreation
present condition	0%	0%	0%	0%
1 hour	-39%	-33%	-37%	-65%
2 hours	-7%	-7%	-35%	-36%
3 hours	12%	7%	-31%	-20%
4 hours	25%	18%	-25%	-8%
8 hours	56%	43%	12%	21%

Note: The Present Condition Based On Perceived Parking Duration:

- 2 hours 19 minutes for shopping trips
- 2 hours 26 minutes for business trips
- 6 hours 65 minutes for working trips
- 4 hours 48 minutes for recreation trips

Lift and Escalator

Table 17. Changing of Walking Time From Parking Location To Destination

Walking Time Reduction Factor	Changing of Potential Demand
1.0	0%
1.1	4%
1.2	8%
1.5	14%
2.0	24%
3.0	38%

Note: Based On Perceived Walking Time = 7.8 minutes

By improving the pedestrian facilities, such as provide lift or elevator, from parking location to the market or business center, it may decrease the walking time and increase the potential demand. If a lift or elevator may reduce the walking time from the parking place

to the destination 10% to 100%, the change of potential number of parkers is shown in Table 17. The difference-reduction of walking time by 100% from the original value means that the walking time is reduced two times and it may increase the potential demand to 24 points because of better service of the facility.

Parking Insurance

Knowing that the current most important factor is security, the improvement of the security of parking location, such as provide a car parking insurance, may attract more users. On the present parking condition in Surabaya, there is no insurance of security. The parking fee is just a rent a location for car park. However, the people considers that if their car were stolen, they may get compensation 1000 times the parking fee. The normalized weight of AHP factors can be used to put the monetary value of security factor. The normalized weight of the security is 30.86%, while the normalized weight of parking fee is 8.98%. By keeping the ratio between security and parking fee 3.4 (=30.86%/8.98%), it would not have any significant impact to the number of parkers. Increasing the parking fee can be applied when security is increased qualitatively with the same ratio. For example if the owner of parking location want to increase the parking fee by trading off with the security, the providing parking insurance toward cars' stolen 3.4 times the people's consideration may not deter the number of parkers.

Parking Spaces

If the developer is going to build more parking spaces, it may reduce the search and queue time. Assuming that each additional 10 parking spaces will reduce search and queue time two times, the changing of potential demand will increase 33 points. If the parking demand is over parking supply, the search and queue time may increase from the parkers perception. If the increasing search and queue time is 20%, the number of parkers will reduce potentially 9 points.

Table 18. Changing of Search & Queue Time for Parking Spaces

Search & Queue Time Reduction Factor	Changing of Potential Demand
1.0	0%
2.0	33%
3.0	49%
0.8	-9%
0.9	-5%

Note: Based On Perceived Search & Queue Time = 12 minutes

Increasing parking fee from present condition to Rp 500/hour may reduce the number of parkers to 30%. However, the reduction of the number of parkers may increase the availability of parking space and reduce the search and queue time, say it is two times reduction. The reduction of search and queue time may increase again the number of potential parkers 33%. Thus the final number of parkers still increase even the parking fee is increased.

8. CONCLUSION

The following conclusion can be drawn based on the findings and analysis of this study. The actual behavior of parkers to choose a parking location is mainly influenced by the availability of parking spaces, trip purpose, search & queue time, walking time and parking fee. The main potential factors that influence the preference of parkers a parking location choice are security, availability of parking space, comfortability and closeness of parking place to their destination. Parkers who come for shopping, business and recreation mostly choose parking on the building, while parkers who come for work prefer to use surface parking place inside the market. The parking location choice models can be used for analysis of parking policy by both government and developers' side. The government can control the number of on-road parkers by parking fee and spaces to decrease the traffic congestion. The developers can increase the number of customers by parking fee policy, improve the service of parking facility and build more parking spaces. Evaluation of parking locations can be used to develop level of service standards for parking facilities. The results of the ideal factors in this paper may be useful to support development of the standard. The simulation of the results of the parking usage study can be developed to optimize the parking policy for the developers' side.

REFERENCES

Austin, T.W. (1973) Allocation of Parking Demand in a CBD. **Highway Research Record 444**, 1-8.

Axhausen, K.W. And Polak,J.W. (1991), Choice of Parking: Stated Preference Approach. **Transportation 18**, 59-81.

Dunne, J.P., (1985), Desegregate Mode Choice Models and the Aggregation Issue: Some Empirical Results. **Transportation Research Part A Vol. 19A no. 4**, 315-324.

Ellis, R.H. et all. (1972), Development and Implementation of a Parking Allocation Model. **Highway Research Record no 395**, 5-20.

Ergun, G. (1971), Development of a Downtown Parking Model. **Highway Research Record 369**, 118-134 .

Freeney, B.P. (1986), A Review of Impact of Parking Policy Measures on Travel Demand. **VTI rapport 308A**, Statens vag-och trafik institut, Linkoping.

Gensch, D.H., (1980), Choice Model Calibrated on Current Behavior Predicts Public Response to New Policies. **Transportation Research Part A, Vol. 14A**, 137-142.

Gillen, D.W. (1978), Parking Policy, Parking Location Decisions and the Distribution of Congestion. **Transportation 7**, .69-85.

Goot, D.VAN DER. (1982), A Model to Describe the Choice of Parking Places. **Transportation Research Part A, Vol. 16A, 2**, 109-115.

Hunt, J.D. and Teply, S. (1993), A Nested Logit Model of Parking Location Choice. **Transportation Research Part B**, **Vol. 27B, 4**, 253-265.

Lambe, T.A. (1969), The Choice of Parking Location by Workers in the Central Business District. **Traffic Quarterly 23**, 397-411.

Mattson, J.O. (1955), What Parking means to Business. **Highway Research Board**.

Rennie Park & Associates and BIEC International, Inc (1991), **A transportation Strategy for Surabaya 1990-2000**, Regional Cities Urban Transport Project, (*unpublished report*).

Saaty, R.W. (1987), The Analytic Hierarchy Process-What It Is and How It Is Used. **Journal of Mathematical Modeling Vol. 9 no 3-5**, 161-176.

Wells, G.R. (1975), **Comprehensive Transport Planning**, Charles Griffin & Co.Ltd., London.