DEMAND RATE AND ELASTICITY OF THE URBAN TAXI SERVICE BASED ON THE STATED PREFERENCE DATA

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Abstract: This paper presents findings of a research on the demand for an urban taxi service with the case study in Bandung. The emphases are characteristics of taxi trips, the trip rate of taxi demand, and the demand elasticity of taxi trip. A person-category trip generation analysis was done employing conventional and multiple classification methods. The analysis on the taxi choice behavior was carried out using stated preference data. Stated preference data were gathered for a number of factors that affect the behavior of taxi travelers, namely the change of household income to represent the characteristic of travelers and changes of travel time, fare, and service quality to represent the taxi service attributes. The utility function and the binary logit model for the taxi travel can then be obtained. Sensitivity analysis is undertaken to evaluate the responsiveness of individuals in choosing a taxi for their travel.

Key words: travel demand model, category analysis, stated preference data, demand elasticity

1. INTRODUCTION

Taxi as the means of urban transportation differs from other public transportation in certain characteristics. The taxi service is a demand responsive system and provides more flexible, door-to-door, services. Convenience is the main attribute to offer with respect to service time, routes, and stop points. The demand for taxi services in urban areas of larger cities in Indonesia is considerably high especially among middle and upper class societies that demand higher mobility, convenience, and safety.

Previous researches on taxi services in large cities showed that the average taxi occupancy was quite low, namely 2 passengers/vehicle (Lembaga Teknologi FTUI, 1997, Suhardono, 1999). The number of researches on taxi services in Indonesia, however, has been very low. In the mean time, understanding the nature of the problems, operational aspects, and demand characteristics of the taxi services are essential to improving the system as part of the planning of overall urban transportation system. This research was conducted in light of these thoughts.

This paper presents findings of a research on some aspects of the demand for urban taxi services. The study area is the city of Bandung, one of the densest city in Indonesia with some 2.4 millions inhabitants or 145 inhabitants/hectare of population density and the study emphasizes on the demand characteristics, trip rates, and analysis of the demand elasticity.

2. URBAN TAXI SYSTEM

Taxi is form of public transportation and its operation is characterized as by hire, non-fixed route and schedule, and demand responsive (Vuchic, 1981). A taxi refers to a vehicle in which the driver is controlled by the passenger who decides the destination and the fare is determined by the travel time and distance. Most taxis are for hire individually, but in some areas shared taxis, by which different individuals with different destinations are sharing the service, are also found.

Three important aspects are interrelated in the operation of taxi (Foerster and Gilbert, 1979). First, the demand for a taxi service is not only a function of price, but also varies with level of service. Second, not all costs associated with the provision of taxi transportation are incurred during the actual carriage of passengers. Finally, there is a sequence of states of vehicle usage consisting vehicle availability, dispatching to pickup, and utilization, all of which are necessary for provision of passenger transportation. Consumer decision can expect to be influenced by both price and vehicle availability (at least in the long rum), and supplier decisions must be made under the assumption that taxi operators influence vehicle availability (and therefore demand), but that they have only indirect control over vehicle utilization levels.

The taxi system has been in operation in many developed cities for a long time. Berlin, for example, has been providing the system since 1930. In Indonesia, the taxi service started in 1960 and the one in Bandung began by offering inter-city shared taxis. Today six companies are operating 991 urban taxis in Bandung.

The operation of taxi in Indonesia is under the following regulations:

a. Government Decree (*Peraturan Pemerintah*) No. 41/1993 about Road Transportation.
   This defines taxi as a public transportation utilizing passenger vehicles, indicated by a particular sign, and equipped by an argometer.

b. Ministry of Communication Decree (*Keputusan Menteri Perhubungan*) No. 68/1993 about The Operation of Public Transportation on Roads.
   The taxi services are operated with following characteristics:
   - Unscheduled;
   - Using passenger vehicles and equipped by an argometer;
   - Door-to-door services;
   - Operated in a designated (urban) area.

3. METHODOLOGY

3.1 Demand Rate and Categories

A person-category method is used to analyze trip demand rates. This method makes it possible to employ cross categories utilizing several important variables and simple to predict the changes based on projections of explanatory variables.

If t_j denotes the trip generation rate, namely the number of trips in a certain period of time made by persons of the category j, T_i denotes total trips made by all people in zone i (all categories), N_i denotes the number of people in zone i, and α_{ji} is the percentage of people in zone i with category j, then we have the following relationship:

$$T_i = N_i \sum_j \alpha_{ji} t_j \qquad (1)$$

For this purposes, trips may be classified into home-based and non-home-based, and further into different trip purposes.

3.2 Binary Logit Model

In general discrete choice models postulate that the probability of an individual choosing a given option is a function of their socioeconomic characteristics and the relative attractiveness of the option (Ortuzar and Willumsen, 1990). To represent the attractiveness of the alternatives the concept of utility is used. Every individual seeks to maximize the utility. Alternatives do not produce the utility: this is derived from their characteristics and those of individuals (Lancaster, 1966, as quoted by Ortuzar and Willumsen, 1990).

The utility function is defined as a linear combination of variables as follows:

$$U_j = \theta_0 + \theta_1 X_1 + \theta_2 X_2 + ... + \theta_n X_n \qquad (2)$$

where:

	U_j	: utility of option j
	$X_1 ... X_n$	: attributes of the option
	$\theta_0 ... \theta_n$	: model parameters

The influence describing the contribution of an alternative is represented by the parameters $\theta_1 ... \theta_n$. Parameter θ_0 represents the influence of characteristics of the alternative and individuals that are not included in the function.

In order to predict if an alternative will be chosen, the value of its utility must be contrasted with those of alternative options and transformed into a probability value between 0 and 1. The choice model employed in this research is binary logit model for its simplicity and widely used. This is applied for a choice with two alternatives. The model is specified as in Equation (3).

$$P_1 = \frac{\exp^{U_1}}{\exp^{U_1} + \exp^{U_2}} = \frac{\exp^{U_1 - U_2}}{1 + \exp^{U_1 - U_2}} \qquad (3)$$

where: P_1 = probability of 1
U_1 = utility of alternative 1 (in this case choosing the taxi)
U_2 = utility of alternative 2 (choosing other than taxi)

And $\frac{P_1}{P_2} = \exp^{U_1 - U_2}$,

or, this may be transformed into a linear form as follows.

$$U_1 - U_2 = \ln\left[\frac{P_1}{P_2}\right] = \ln\left[\frac{P_1}{1-P_1}\right] \quad (4)$$

3.3 Stated Preference Technique

Stated preference technique is an approach to analyze individuals' responses to hypothetical situations. For this purpose an experimental design is set up to form a series of alternative hypotheses. Individuals' responses are asked when faced with the situations, namely what would their preferences of the options offered to them are or how would they rank the options.

The stated preference technique has the following characteristics (Pearmain et al., 1991):

a) This involves the presentation of alternative options to individuals (respondents).
b) The options represent packages of different attributes that usually represent a particular product or service.
c) The values of the attributes in each option are specified by the researcher and usually presented in the context of respondents' present situation.
d) The options are constructed on the basis of an experimental design that ensures that variations in the attributes are statistically independent from one another.
e) The respondents state their preferences toward each options by either:
    - Ranking them in order of importance;
    - Rating them on a scale indicating strength of preference;
    - Choosing the most preferred option from a pair or a group of options.

a. Attributes

Factors taken as attributes in the utility function consist of the socio economic background of the travelers and taxi service attributes. A pilot survey was conducted and its findings were taken into consideration when designing the attributes and levels. The attributes and the levels are detailed in Table1 that specifies two levels of hypothetical options compared to the present condition. The change of household income represents the characteristic of travelers and changes of travel time, fare, and service quality represent the taxi service attributes.

Table 1. Attributes of Choosing Taxi Services

Attribute	Change of Attribute Levels	
	Low (-)	High (+)
1. Household income	+ 25 %	+ 50 %
2. Average travel time	- 10 minutes	- 20 minutes
3. Average fare	+ Rp 5,000.00	+Rp 2,500.00
4. Service quality	Constant	Improved

With the above attributes and levels, the full design (full factorial) consists of 2^4 or 16 alternative options.

b. Survey Form Design

It is believed that using the full factorial design with 16 options will be difficult to be exercised by respondents, especially among ones who are not used to this kind of activity, and therefore increases the response error. A half factorial design with 8 options is then used. The selected pattern of options (Box et al., 1978) is presented in Table 2.

Table 2. A Half Factorial Experimental Design

Option	Change of Attribute Levels			
	Income	Travel Time	Fare	Service
1	-	-	+	+
2	-	-	-	-
3	-	+	+	-
4	-	+	-	+
5	+	-	+	-
6	+	-	-	+
7	+	+	+	+
8	+	+	-	-

Note: + Change of attribute levels: low
- Change of attribute levels: high

The survey form design defines the respondents' preferences in a 5-rating semantic scale, namely:

1. Surely choosing taxi
2. Probably choosing taxi
3. Indifferent
4. Probably choosing another mode
5. Surely choosing another mode

In the further analysis the semantic scale is converted into a numerical scale. For this purpose a symmetric scale of respectively 0.1, 0.3, 0.5, 0.7, and 0.9, which is considered a practical standard for transport application (Ortuzar and Garrido, 1993), is used.

The difference of utility functions as specified by the above experimental design, following Equation (2), can be written as in Equation (5).

$$U_{PT} - U_{PL} = a_o + a_1\,(\Delta INC) + a_2\,(\Delta TIME) + a_3\,(\Delta FARE) + a_4\,(\Delta SERV) \qquad (5)$$

where:
U_{PT} : utility function of taxi service
U_{PL} : utility function of other mode's service
ΔINC : difference of income
$\Delta TIME$: difference of travel time
$\Delta FARE$: difference of fare
$\Delta SERV$: difference of service quality

3.4 Elasticity

The term of elasticity is used to state the relative change of a given demand (responsiveness of demand) with respect to factors affecting the demand. Elasticity is measured through changes in the relevant independent variables. This entity reveals information on the sensitivity of the demand with respect to the dependent variables and is frequently used in connection with policies of the dependent variables under consideration.

The elasticity is defined in Equation (6):

$$e_{xi} = \frac{\Delta y / y}{\Delta x_i / x_i} \qquad (6)$$

where Δy is the change of demand y, and Δx is the change of an independent variable x_i. The elasticity in this definition is also termed arc elasticity.

Elasticity of the probability of a mode choice may be written as follows:

$$E_{P_{ji},X_{jni}} = \frac{\Delta P_{ji}}{\Delta X_{jni}} \frac{X_{jni}}{P_{ji}} \qquad (7)$$

where:

$E_{Pji,Xjni}$ = elasticity of probability of choosing mode-j, with respect to the change of the n-th attribute in the utility function for individual-i

X_{jni} = the n-th attribute of mode-j for individual-i

P_{ji} = probability of choosing mode-j (Equation (3)) for individual-i

4. DATA COLLECTION

The survey was conducted in March 1999 with the number of respondents was 500; 250 of which were in-time taxi passengers when the survey was going on and the rest were other-time taxi passengers indicated from their statements that they have been taxi passengers some time before. Respondents under the category of in-time taxi passengers were picked on their taxi travel with the help of drivers from the six taxi operators in Bandung. The number of respondents picked from each operator was proportional to the number vehicles in operation.(the number of taxi licensed to operate in Bandung was 991). Respondents of other-time taxi passengers were directly interviewed in five public locations where taxi services are usually demanded. These locations were the Railway Terminal, a Shopping Center, the City Square, the Main City Hospital, and the Airport Terminal.

5. PASSENGER CHARACTERISTICS

Urban taxi passengers as found from the above mentioned survey in Bandung could be characterized as follows.

a. Origin and Destination

Most taxi travels were from home (35.0 %) and terminal (31.0 %), and followed by shopping center (12.0 %) and office (10.0 %). Most destinations were home (36.0 %) and office (20.0 %), and followed by terminal (14.0 %) and shopping center (13.0 %).

b. Socio Economic Characteristics

With respect to age, 73.0 % of taxi travels were made people in their productive age (16-34 years old). Majority of passengers were working people, namely state employee (38.4%), private company workers (27.6 %), and students (23.4 %).

The survey also showed that 46,0 % of passengers have a monthly household income in the range Rp 500,000.00 – 1,000,000.00, 42.7% above Rp 1,000,000.00, and 11.3 % below Rp 500,000.00. With respect to household car ownership, 45.3 % respondents do not own any car, 43.9 % own 1 car, and 10.8 % own 2 cars or more.

c. Average Occupancy

Average taxi occupancies are showed in Table 3.

Table 3. Taxi Occupancy (%)

No.of Passenger	Relationship among passengers		
Per Vehicle	Family	Friend	Total
1 person	38.9	-	38.9
2 person	8.7	10.1	18.8
3 person	12.2	14.3	26.5
4 person	7.1	5.1	12.2
> 4 person	2.5	1.1	3.6

Based on the above distribution of occupancies, the calculated average occupancy was 2.2 passengers per taxi.

d. Reasons of Using Taxi

Majority passengers took taxi for time saving (56.1 %), then convenience (19.1 %), comfort 18.6 %, and the rest for safety, the only means, and other reasons.

e. Travel Frequency

Average taxi travel frequency as revealed from the survey were 22.0 % taking 1 trip or more per day, 29.2 % taking 2-4 trips per week, 20.5 % taking 1 trip per week, and the rest (28.3 %) taking less than 1 trip per week.

6. TAXI TRIP RATES AND ELASTICITY

Trip (demand) rates of taxi services are analyzed on the framework of cross-classification employing independent variables with strong relationship to the trip generation. The trip rates are then calculated in two ways: conventional method and Multiple Classification Analysis (MCA) (Stopher and McDonald, 1983).

The stated preference data are used to calibrate the utility function of taxi passenger choice model. The calibration method is the standard regression analysis. A sensitivity analysis carried out to evaluate the response of taxi travel with respect to utility changes.

6.1 Taxi Trip Rates

a. Variables

The dependent variable in the analysis of demand for taxi travel is the number of trips per week. A closer evaluation to data collected from the survey leads to an estimation that taxi trip generation is strongly correlated to household income, car ownership, and family size. Taking this into consideration two models of cross-classification is formed, namely:
1) Using car ownership and family size as the independent variables (model 1);
2) Using household income and family size as the independent variables (model 2).

b. Conventional Classification and Multiple Classification Analysis (MCA)

Calculation of trip generation rates by the conventional method is undertaken according to the standard definition that trip rate is the number of trips per a certain period of time with respect to the relevant category of travelers.

The MCA is an extension to the analysis of variance with the main application on the two-way analysis. Steps of MCA (Stopher and McDonald, 1983) are as follows:
Consider a model with a continuous dependent variable, for example the trip generation rate, and two discrete independent variables, for example family size and car ownership, then
- Firstly, the grand (total) mean of the sample dependent variable is calculated.
- Secondly, the group means are estimated for each column and row of the cross-classification matrix. Mean values of each group can be regarded as the deviation from the total mean.
- Thirdly, considering the sign (+ or -) of the deviation, the value of each cell can be estimated by adding row and column deviation to the total mean according the cell position.

One of the main advantages of MCA, as Stopher and McDonald (1983) showed it, is the method provides a statistically sound procedure for estimating cell means, which reduces the inherent variability of rates computed from different sample sizes of households and is capable of providing estimates for some cells where data may be lacking in the base data set. Besides, the method takes into account the interaction among the alternative independent variables, which is not taken into account in standard cross-classification models.

c. Resulting Trip Rates

Results of the two methods for cross-classification model 1 are presented in Table 4 and Table 5 consecutively and those for cross-classification model 2 in Table 6 and Table 7.

One cell in Table 4 is unfilled, namely of the category of a family with 1 member and 2^+ car ownership. It seems very rare or rather unrealistic to find families that fall into this category and if there were, logically they would likely use public transport very little.

Comparing Table 4 and Table 5 shows that the unfilled cell of Table 4 is filled in Table 5. This may be regarded as a weakness of MCA method. But, besides statistical advantages, it can be noted that the values of the cell are not only influenced by the sample size of the related category, but also the total mean, and two or more group means that are obtained from all data of every group relevant to the cell value.

Table 4. Trip Rates of Cross-Classification Model 1 by Conventional Method (Trips/week/household)

Car ownership	Family size (persons)				
	1	2	3	4	5^+
0	2.250	2.655	3.225	2.857	2.402
1	2.550	3.023	3.818	3.520	2.530
2^+	-	4.375	4.857	2.591	3.400

Table 5. Trip Rates of Cross-Classification Model 1 by MCA Method (Trips/week/household)

Car ownership	Family size (persons)				
	1	2	3	4	5^+
0	2.038	2.650	3.316	2.891	2.369
1	2.471	3.083	3.749	3.324	2.802
2^+	2.843	3.455	4.121	3.696	3.174

Table 6. Trip Rates of Cross-Classification Model 2 by Conventional Method (Trips/week/household)

Household Income (Rp/month)	Family size (persons)			
	1-2	3	4	5^+
< 500,000	1.405	2.417	2.300	0.500
500,000-1,000,000	2.631	3.913	3.478	2.841
> 1,000,000	3.355	3.580	2.943	2.825

Table 7. Trip Rates of Cross-Classification Model 2 by MCA Method (Trips/week/household)

Household Income (Rp/month)	Family size (persons)			
	1-2	3	4	5^+
< 500,000	1.033	2.151	1.726	1.204
500,000-1,000,000	2.682	3.800	3.375	2.853
> 1,000,000	2.629	3.747	3.322	2.800

The use of combination of income and family size as independent variables (model 2: Table 6 and 7) rather than combination of car ownership and family size (model 1: Table 4 and 5) has improved the reasonableness of trip rate estimates in terms of no likely unrealistic cell is found in model 2.

The differences between results of the conventional method and MCA are evaluated by using some statistical tests as seen on Table 8. The resulting Root Means Square Errors (RMS) shows that the deviation between the conventional method and MCA for model 2 is lower than that for model 1. Another test, Chi-square test (χ^2), is used to assess if there is a significant difference between the results of the conventional method and MCA. The χ^2 test shows that for both model 1 and model 2 the results are not significantly different.

Table 8. Statistical Tests on Differences between the Conventional Method and MCA Results

Parameter	Model 1	Model 2
RMS	0.853	0.383
χ^2	1.57	0.938
χ^2 table (α= 0,05)	15.507 (not different)	12.592 (not different)

Based on the reasonableness of trip rates estimates and statistical tests as discussed above, and taking into consideration the advantages of MCA method (sub-section **b.**), the taxi trip generation rates of ***cross-classification model 2 by MCA method*** (Table 7) is considered to provide better results. The presentation of these in bar charts is shown in Figure 1. It may be worth noting here that the household trip rates of families with Rp 500,000,00 – 1,000,000,00 income is quite similar with those of >Rp 1,000,000,00 income.

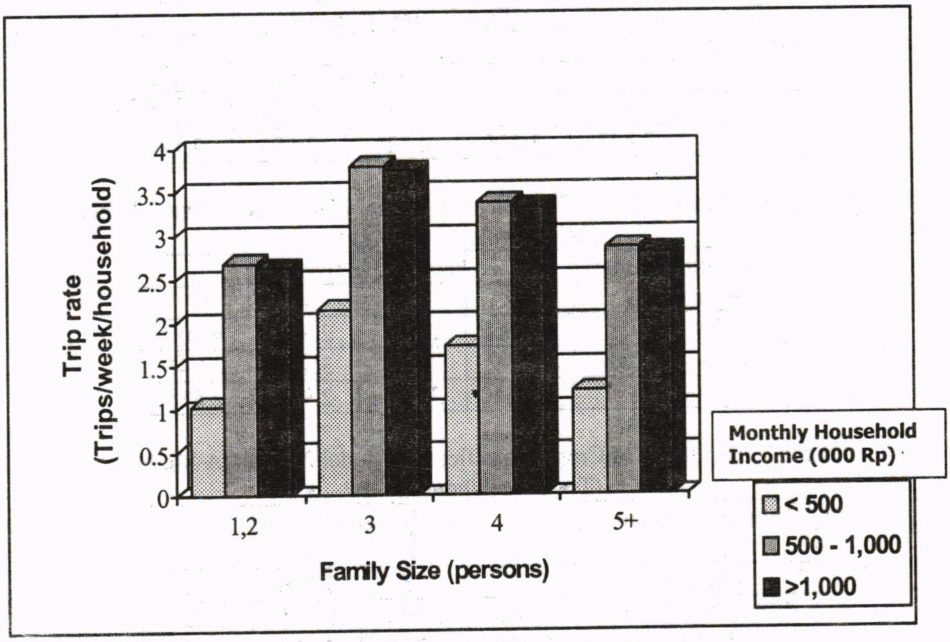

Figure 1. Taxi Trip Generation Rates

6.2 Resulting Utility Function

For the purpose of model calibration, the binary logit model is transformed into a linear form as written in Equation (4). If PT and PL denote taxi and other mode respectively, the linear form is written in Equation (8).

$$U_{PT} - U_{PL} = \ln\left[\frac{P_{PT}}{1 - P_{PT}}\right] \tag{8}$$

The term of U_{PT}-U_{PL} is as specified in Equation (5). Model parameters of this utility difference function are then estimated by a linear regression. Data from the stated preference survey as set up for various hypothetical options are used to calibrate the model. The resulting utility function is seen in Equation (9).

$$\begin{aligned} U_{PT} - U_{PL} =& \\ 0.19369 + 0.01567\ \Delta INCOME &- 0.04095\ \Delta TIME - 0.00027\ \Delta FARE + 0.03197\ \Delta SERVICE \\ (2.03) \quad (11.06) \quad &\quad (-11.56) \quad\quad (-18.80) \quad\quad (22.57) \end{aligned} \tag{9}$$

($R^2 = 0.244$, figures in parenthesis are t-statistics)

The estimated binary logit model (in the linear form) is obtained by combining Equation (8) and (9) as follows.

$$\ln\left[\frac{P_{PT}}{1-P_{PT}}\right] = 0.19369 + 0.01567\Delta INCOME - 0.04095\Delta TIME - 0.00027\Delta FARE + 0.03197\Delta SERVICE \tag{10}$$

The estimated parameters are statistically significant and the sign of each parameter is reasonable, but the coefficient of multiple determination (R^2) is low. One conceivable main reason contributing to the low value of R^2 based on the evaluation of the survey process and collected data is different perceptions or difficulties of understanding the questionnaire that affects the consistency of responses. Another possibly important reason is that taxi travels under survey were varying very widely with respect to origin-destination, travel distance, trip purpose, and so forth. It cannot easily be overcome since taxi travels are highly flexible and not attached to a particular pair of origin-destination, for example.

On the t test, for $\alpha = 0.05$ with the number of observation n= >120, the number of parameters k=4, we obtain $t_{critical} = 1.960$. For all parameters $t_{stat} > t_{critical}$, this means all attributes are significant in the mode utility. The F-test for $\alpha = 0.05$ we obtain $F_{critical} = 2.10$. Of the model the resulting F_{stat} is 279.67, which means that all attributes are simultaneously significant in explaining the utility function.

The resulting probability function (Equation (10)) can then be used calculate the probability of choosing taxi or other mode for different situations. This is illustrated in Figure 2 that plots the probability of choosing a mode as a function of the utility difference.

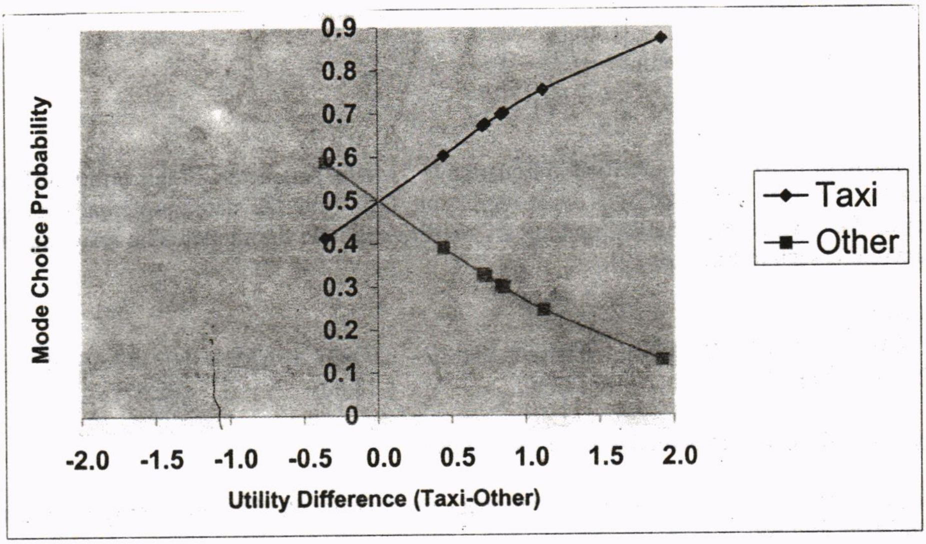

Figure 2. Taxi Choice Probability Curve

6.3 Elasticity

Direct elasticity of taxi choice probability is analyzed with respect to its particular service attributes. Changes of attributes for this evaluation are as defined in Table 1. Using these changes and the obtained utility function, the probability of choosing taxi can then be calculated. The direct elasticity is calculated by using Equation (7), which is an arc-elasticity, and the results are presented in Table 9.

Table 9. Direct Elasticity of Taxi Choice Probability

	Attribute			
	INC	TIME	FARE	SERV
Δx	25 %	-10 minutes	Rp 2,500	25 %
ΔP_{PT}	0.0842	0.0871	-0.1413	0.1814
Direct elasticity	0.131	-0.135	-0.368	0.083

As seen in Table 9 the probability of choosing taxi service is more sensitive towards fare changes rather than travel time, income, and service quality changes.

7. CONCLUSION

Some conclusions can be drawn from this research as follows.

- The best taxi trip generation model is obtained for a cross-classification of family sizes (4 categories: 1-2, 3, 4, 5 or more persons) and monthly household income (3 categories: under Rp 500,000.00, Rp 500,000.00 – 1,000,000.00, over Rp 1,000,000.00), which all produce 12 cross-categories. The resulting trip rates are in the range of 1.03 – 3.80 trips/week/household.

- The stated preference data have made it possible to develop the utility function of taxi service and the consecutive probability of choosing taxi based on the binary logit model. The estimated model parameters have been statistically significant and met reasonableness, though the coefficient of multiple determination is low.
- Seen from the value of elasticity, probability of choosing taxi service is most sensitive towards fare changes (elasticity –0.368) rather than, in decreasing order of sensitivity, travel time changes (-0.135), income changes (0.131), and service quality changes (0.083).
- Factors that need to be explored or refined in further researches include alternative cross-categories based on traveler's socio economic background and the experimental design regarding the attributes, levels of attributes, and the questionnaire set in order to alleviate misperception by respondents.

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