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Choice of Mode for the Worktrip in a Third World City: Karachi

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The paper is an analysis of the demand for different travel modes in the city of Karachi. The model analyses the probability that an individual makes a certain choice as a function of the mode characteristics and transport system and the socio-economic characteristics of the individual traveller. The analysis focuses on the worktrip. The model used is the disaggregated probabilistic choice and it is estimated through the maximum likelihood multinomial logit technique. The data for the analysis comes from a sample of 5696 workers in the city of Karachi.

The main determinants of the mode choice analysed are: transport-related characteristics (travel time, official transport, shared transport, peak-hour travel) and socio-economic characteristics (number of dependents, income, head-of-households status, sex, type of occupation). The results show that the overall model is robust and has high prediction accuracy. The estimated model is useful since it is responsive to most variables and can be used to calculate the effect of changes in the various attributes on the demand for different travel modes. Estimates of the model can also be of value to planners, who can predict probabilities for different modes and calculate the effect of specific policy changes on the demand for travel.

1. INTRODUCTION

Very little work has been done on the demand for passenger travel in developing countries. But understanding and predicting urban travel demand is crucial to transport planning and design of urban areas, especially in the rapidly growing developing countries. Mode choice is perhaps the most policy-oriented element in the whole process of analysing and forecasting demand for urban travel. In particular, the analysis of workers' choice of modes is intended to provide information about the effects of various policies, like fare structures, taxes on petrol, adding buses, planning routes, improving roads, etc. The information can be used along with other information in deciding which policies are to be implemented and which are likely to be more effective. For example, in planning for the bus system, the mode choice model can be used to forecast the number of workers who will use the

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system. It is, therefore, central to the achievement of a more efficient use of the available capacity, which has direct implications for the level of resources invested in expanding the system.

This paper is an analysis of the demand for different travel modes in the city of Karachi. The model analyses the probability that an individual makes a certain choice as a function of attributes of the mode and the transport system and the socio-economic characteristics of the individual. Attention is focused on the work-trip because it is of primary importance in urban travel, and it is the most regularised behaviour of the urban traveller. The model is a disaggregated probabilistic choice model and is estimated using data from a sample of workers in Karachi.

The paper is organised in the following way. The next section provides a brief review of the literature, while Section 3 discusses the methodology and data collection. In Section Four, the results and their interpretations are discussed. Policy implications of the results are given in Section 5.

2. REVIEW OF LITERATURE

Most of the research done on mode choice is for developed countries. Basically, three different types of models are estimated. First, a simple mode choice model based on the mode characteristics and the characteristics of the individual are estimated. Secondly, auto ownership and its determinants are analysed. Later models incorporate the simultaneity of the two choices and estimate the joint probability of mode choice and auto-ownership. Warner (1962); Quarmby (1967); Lisco (1967) include auto ownership in their models with the implicit assumption that the number of autos is exogenous to the mode choice. In other models [e.g., Lave (1969)], auto ownership is treated as endogenous. Train (1976), in his analysis for the U.S., uses both approaches and estimates the mode choice model with and without the auto ownership variable, with an explicit account taken of the interaction between the two choices.

More recently, mode choice models incorporating parking spaces are being estimated in developed countries. The effects of incentives designed to promote ride-sharing (car-pooling and van-pooling) on worktrips–to reduce congestion and pollution–are estimated using data on workers' commuting behaviour [Feeney (1989); Willson and Shoup (1990); Hwang and Giuliano (1990); Stevens (1990)].

Both the aggregate and the disaggregate models have been used for the analysis of the mode choice. Discrete choice models have been a popular method. Empirical advances have been made in the application of the probabilistic discrete choice models to problems of travel mode after the works of McFadden (1978) and Domencich and McFadden (1975). The contribution and properties of these models are discussed elsewhere [Anas and Chu (1984)]. Simple probability choice models, based on the probit and logit maximum likelihood techniques, multinomial logit and probit, and conditional and nested logit techniques, have been adopted to analyse the problems. Recent research on the topic has laid more emphasis on the disaggregate, probabilistic behavioural models of the mode choice focusing on the individual rather than on the origin and destination zones. The objective of these models has been to predict the probability of alternate mode choices. More recently, the effect of qualitative variables like comfort, convenience, safety, and dependability of the choice of mode have been analysed.

The major determinants of the mode choice and the auto ownership models in the literature focus on the impact of mode characteristics, locational characteristics, transport system characteristics, and the socio-economic characteristics of the individual. The most commonly used variable in the analysis is the time variable. Both waiting-time and the time taken to travel are used. In some studies, a more policy-oriented time variable is used, and is decomposed in the time spent waiting for transit and the time spent walking to and from transit [Train (1976)].

Considerably less attention is devoted to the affect of demographic variables on travel behaviour. El Pas (1984) examines the effect of role, life-cycle, and life-style attributes of individuals and households. Selected socio-demographic characteristics like age, marital status, employment status, education level, presence of young children, auto ownership, income, and residential density are the explanatory variables included in the analysis for Baltimore, U.S.A. The statistical results demonstrate that specific socio-demographically defined segments of the urban market have differential likelihood of undertaking particular daily travel activity patterns. Koppelman *et al.* (1978) confirmed the importance of occupational and marital roles with respect to travel mode choice behaviour. Other studies have examined the role of these variables on shopping and other aspects of travel-related behaviour [Robinson and Vickerman (1976)].

Most studies on travel demand in developing countries are descriptive in character and look at commuting patterns. Work on mode choice models in these countries is almost non-existent. Thobani's (1984) study for the city of Karachi is the most well-known. He estimates a probabilistic joint mode choice and auto ownership model. He estimates demand elasticities for time (access and in-vehicle) and travel costs. The author applies the nested logit maximum likelihood technique to a sample of 400 travellers in the city of Karachi. The study reveals that the decision to own a car is made simultaneously with the decision about which mode to take to work. The results of the study suggest that (i) heads of household have greater utility from the use of the car, (ii) car travel time is less onerous than bus travel time, (iii) suburban dwellers have lower values for time than urban dwellers (supporting Train's results), (iv) the elasticity with respect to out-of-vehicle time is high, and (v) cross elasticities between bus and minibus, which are close substitutes, are low.

3. METHODOLOGY AND DATA COLLECTION

The maximum likelihood multinomial technique is used where the dependent variable is mode choice for the worktrip. Five discrete choices are considered in the multinomial analysis, namely, the car, motorbike/scooter, minibus, minibus/bus, and bus. Thus the coefficients of the reference choice travel by bus are set equal to zero. The model is disaggregate and the unit of analysis is the individual worker. The probability of choosing the transport mode is given by:

$$\underset{j=1,2,3,4}{Pij} = (Y_i = j) = \alpha_0 + \sum_{i=1}^{n} \beta_i Z_i + \mu_i^1$$

where:[1]

P = Probability of the mode choice for the worktrip;
Z_i = vector of independent variables that influence the above choices;
β_i = parameters to be estimated; and
U_i = error term.

The multinomial logit model (MNL) is used since it is the most widely used model of multiple responses. The MNL model is also chosen because the probability function is of a simple form and strictly concave, hence the vector of coefficients has a unique solution and is easily estimable, using the standard maximum likelihood techniques. The MNL specification, therefore, enables us to estimate directly the effect of different characteristics on travel mode choices and to simulate the effect of changes in these characteristics on mode choices. Although the model permits easy computation and interpretation, empirical tractability is obtained at the expense of strong underlying assumptions, especially of property IIA (Independence of Irrelevant Alternatives). However, empirical experience is that the MNL model is relatively robust as measured by the goodness-of-fit or prediction accuracy.

The data to estimate the equation are obtained through a primary socio-economic survey of over 6000 households in the city of Karachi. The survey was undertaken by the Applied Economics Research Centre, University of Karachi, in 1987-88. The data were collected through a multi-stage stratified sampling technique. The sample of households was spatially distributed throughout the city of Karachi and included both the planned and the non-planned areas of the city. The

[1]The probabilities are specified by

$$P_{ij} = \frac{e\, Z_{ij}\, \beta_{ij}}{1 + e \sum_{i=1}^{n} Z_{ij}\, \beta_{ij}}$$

data included detailed information on socio-economic and demographic as well as travel characteristics of the households. The workers' sub-sample of 5696 was used to estimate the model. (See Appendix A for sampling methodology and details of data collection.)

Explanatory variables included in the analysis are transport-related characteristics, transport system characteristics, and socio-economic characteristics of the household and the individual. Transport-related characteristics are represented by the mode characteristic (time and cost of travel) and a dummy variable for shared transport. These variables attempt to capture the effect of the mode-related characteristics and the mode choice. Time[2] and cost are the standard variables affecting the decision to use alternative modes and are shown to be the most widely used variables in the literature on mode choices. The higher the cost of travel both in terms of money and time, the less the likelihood of that mode being used.

The other mode characteristic used in the analysis is the official transport variable. The hypothesis with regard to this variable is that since the mode is provided and paid for by the employer, what might otherwise have been chosen could be quite different. Particularly in developing countries, the contrast between the type of mode that an individual may be able to afford and that provided through the employer as official transport may be large.

Previous research on the choice of mode for worktrip in developed countries shows that shared transport is becoming increasingly popular in these countries because of the heavy pressure of traffic congestion. To see if the mode choice varies importantly with transport which is shared in developing countries, a variable which takes the value of 1 if transport is otherwise shared is induced in the analysis.

Peak-hour travel is the other transport-related characteristic included in the analysis. Both morning and evening peaks are considered. As it is not clear *a priori* which mode of travel is likely to be favoured by the peak-hour, therefore we cannot be certain what sign the coefficient will take.

A number of socio-economic explanatory variables are included in the analysis. The choice of variables is obvious in some cases; while in others, relevance to the situation in developing countries and data availability are what determined the selection. The number of dependents in the household is the first variable selected, and the hypothesis is that workers who have larger households to support will tend to prefer the public modes of transport, which are less costly.

Most studies on the choice of mode and travel behaviour consistently show a significant effect of the income variable. Two separate measures of income are used,

[2]Time variable used in most developed country studies is broken up into waiting-time and travelling-time, and has greater policy significance in the mode choice models. Here just the total time variable is used because of data unavailability. Ideally for developing countries, the Time variable should be divided into walking-time, waiting-time, and in-vehicle travelling-time.

namely workers income, and total household income. Higher-income individuals or households are likely to select modes which are costlier and which take up less time to travel given a higher value of time for the individual worker.

The three other characteristics included in the analysis are the characteristics of the individual traveller, and these are head of household, sex, and occupational status. The choice of status of the individual traveller may importantly affect the choice of mode in developing countries, where the majority of the households are one-car owner households.

4. ESTIMATION OF THE MODEL

The results of the analysis are presented in Table 1. There are four sets of coefficients, each relating to a mode. The first set refers to the mode car, the second to motorbike/scooter, the third to the minibus mode, and the fourth to the combined minibus/bus mode.[3] The major determinants of the choice are transport-related characteristics, like mode characteristics; the characteristics of the transport system; and socio-economic characteristics of the household and of the individual worker.

Transport-related Characteristics

Mode Characteristics

Three mode-related characteristics are included in the analysis. One is the time taken to travel to work (TIME) and the other is the cost of travel (COST). The cost variable is adjusted for income, by dividing it by per capita income of the household, to allow for the value of time to vary with income.[4] The TIME variable is highly significant at the 99 percent level in the first and the second set of coefficients, with a negative sign. The variable is not significant in the third set and is again significant at the 90 percent level in the fourth set, but with a positive association with travel by minibus/bus. The negative association of the TIME variable with both the private modes of travel indicates that travel to work by these modes takes less time than the travel by bus. The above result is as expected, and is consistent with the results from other studies, where travel by the preferred mode, car, is less onerous.

The other mode characteristic, travel cost (COST), has a highly significant coefficient and takes increasing values for the first, second, third, and fourth mode alternatives. Since the most inferior mode is the excluded category, the positive coefficient makes sense. As expected and shown by other studies, the cost variable

[3]For the purposes of analysing the transport system, those walking to work were excluded from the analysis.

[4]Initially, the travel cost variable was used. The results are available from the author on request.

Table 1

Multinomial Logit Estimates of Worker Mode Choice

	(1)		(2)		(3)		(4)	
Variables	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic	Coefficient	T-statistic
CAR								
TIME	–0.712E-01	–9.752***	–0.557E-01	–14.191***	0.709E-01	–9.753***	–0.553E-01	–14.307***
COST	143.43	14.28***	136.395	22.686***	142.214	14.309***	135.597	22.854***
OFFTRAN	29.870	0.012	30.158	0.001	29.743	0.011	29.458	0.010
D1	1.208	4.484***	0.512	3.188***	1.189	4.475***	0.450	2.874
PEAK	0.747	1.864*	0.688	2.758	0.938	2.327**	0.899	3.617***
DEP	–0.206	–4.784***	–0.281	–10.244***	–0.204	–4.763***	–0.287	–10.709***
MINCOME	0.130E-02	16.271***	–	–	0.135E-02	16.965***	–	–
MTTINC	–	–	0.382E.03	22.298***	–	–	0.409E-03	23.96***
HH	–1.375	–5.243***	0.753	5.032***	–1.389	–5.333***	0.818	5.575***
SEX	–1.324	–1.950*	–1.469	–3.854***	–1.095	–1.615*	–0.953	–2.539***
CLER	–0.757	–2.892***	–1.195	–7.689***	–	–	–	–
PROD	–1.446	–3.983***	–2.361	–8.904***	–	–	–	–
TYPJOB	–	–	–	–	–0.727	–1.504	–1.519	–4.427***
CONSTANT	–2.025	–2.194	–1.424	–2.632	–2.089	–2.246	–1.388	–2.241
MOTORBIKE/SCOOTER								
TIME	0.687E-01	–13.926***	–0.546	–18.679***	–0.685E-01	–13.866***	–0.548E-01	–18.732***
COST	101.63	12.777***	97.117	19.311***	103.477	12.794	99.886	19.495
OFFTRAN	5.783	0.001	5.081	0.001	5.857	0.001	4.955	0.001
D1	–0.279E-01	–0.153	–0.538	–4.228***	–0.313E-01	–0.171	–0.511	–4.000***
DEPAK	0.349	1.486	0.448	2.791***	0412	1.737*	0.482	2.995***

Continued–

Table 1– (*Continued*)

Variables	(1) Coefficient	(1) T-statistic	(2) Coefficient	(2) T-statistic	(3) Coefficient	(3) T-statistic	(4) Coefficient	(4) T-statistic
DEPT	–0.934	–3.605	–0.150	–8.323***	–0.881E-01	–3.301***	–0.149	–8.175***
MINCOME	0.809	12.219***	–	–	0.814E-03	12.446***	–	–
MTTINC	–	–	0.239E-03	15.969***	–	–	0.248E-03	16.449***
HH	–1.009	–6.088***	0.147E-01	0.142	–1.033	–6.194***	0.140E-01	0.135
SEX	–2.881	–3.845***	–3.002	–5.67***	–2.655	–3.590***	–2.771	–5.255
CLER	–0.136	–0.783	–0.215	–1.96*	–	–	–	–
PROD	–0.762	–3.736***	–0.733	–5.358***	–	–	–	–
TYPJOB	–	–	–	–	–1.744	–4.787***	–1.759	–7.017***
CONSTANT	2.115	2.485	2.033	3.430	3.405	3.430	3.311	5.235
MINIBUS								
TIME	–0.307E-02	–1.302	–0.110E-01	–0.637	–0.317E-02	–1.341	–0.107E-02	–0.661
COST	24.346	3.579***	13.946	2.842***	24.555	3.611***	14.019	2.859***
OFFTRAN	1.641	0.001	1.467	0.001	1.739	0.001	1.544	0.001
D1	–1.102	–0.780	0.687	0.761	–0.971E-01	–0.744	0.749E-01	0.829
PEAK	–0.288	–1.961**	–0.363	–3.591***	–0.307	–2.094**	–0.368	–3.645***
DEPT	0.526	0.287	–0.403E-02	–0.300	0.124E-01	0.672	–0.194E-02	–0.143
MINCOME	0.108E-05	0.015	–	–	–0.182E-04	–0.261	–	–
MTTINC	–	–	–0.449E-04	–2.432***	–	–	–0.494E-04	–2.685***
HH	–0.834	–0.684	0.544	0.064	–0.801E-01	–0.657	–0.116E-02	–0.014
SEX	–0.784	–2.518**	–0.851E-01	–0.476	–0.808	–2.617***	–0.108	–0.610
CLER	–0.954	–0.669	–0.329E-01	–0.341	–	–	–	–
PROD	0.619	0.433	0.110	1.088	–	–	–	–
TYPJOB	–	–	–	–	–0.304	–1.903*	–0.551E-01	–0.502
CONSTANT	–0.186	–0.427	–0.804	–2.897	0.179	0.401	–0.683	–2.386

Continued–

Table 1– (*Continued*)

MINIBUS/BUS				
TIME	0.701E-02	1.883*	0.642E-02	2.334**
COST	20.871	1.887*	18.557	2.207**
OFFTRAN	2.263	0.001	2.730	0.001
D1	–0.578	–2.288**	–0.439	–2.404**
PEAK	0.233	–0.898	–0.378	–0.018
DEP	0.273E-02	0.084	–0.163E-01	–0.652
MINCOME	0.185E-04	0.159	–	–
MTTINC	–	–	0.283E-04	1.014
HH	–0.247	–1.175	–0.162	–1.048
SEX	–0.302	–0.173	–0.122	–0.407
CLER	–0.153	–0.671	–0.218	–1.341
PROD	–0.507	–1.983**	–0.618	–3.127***
TYPJOB	–	–	–	–
CONSTANT	–2.105	–3.145	–2.618	–5.313
# CASES	5696		5696	
LOG LIKELIHOOD	–2379.4		–5173.2	
RESTRICTED (SLOPES = 0) LOG-L	–7429.4		–7429	
CHI SQUARE	10099		4512.5	
% CORRECT PREDICTIONS	68		66	

* Significant at 90 percent level.
** Significant at 95 percent level.
*** Significant at 99 percent level.

–0.698E-01	1.882*	0.636E-02	2.320*
21.768	1.973*	18.355	2.196*
2.335	0.001	2.547	0.001
–0.569	–2.255**	–0.441	–2.411**
–0.214	–0.826	0.130E-01	0.064
0.709E-02	0.216	–0.169E-01	–0.673
0.346E-04	0.309	–	–
–	–	0.404E-04	1.461
–0.246	–1.167	–0.131	–0.847
–0.175	–0.419	0.123E-01	0.041
–	–	–	–
–	–	–	–
–0.420	–1.432	–0.189	–0.868
–2.049	–2.925	–2.857	–5.509
5696		5696	
–2381.4		–5211.8	
–7429.4		–7429.4	
10097		4435.3	
68		66	

is the dominant variable, and a significant explanatory variable, in all specifications of the equation.

The third mode characteristic included in the analysis is the official transport variable (OFFTRAN), which is a dummy variable taking the value 1 if the worker is travelling by transport provided by the employer; 0 otherwise. Although this, by itself, is not significant, yet it is left in the equation because its omission changes the values of coefficients on other variables and its inclusion leads to a statistically significant improvement in goodness of fit, the chi square statistic. One of the reasons for the insignificance of the variable may be that it is associated more closely with only one of the modes of travel, i.e., car.

Shared Transport

The shared transport variable is shown to have a significant impact on travel behaviour. However, in the context of developing countries, the concept of sharing transport may be slightly different. Transport is usually shared by members of the same family when they are travelling to the same destinations. In the case of family businesses, the destination of more than one worker may be the same and may well prove to be an added incentive to travel together.

The variable used in the analysis to capture the above effect is the D1 variable, taking the value of 1 if the transport is shared, 0 otherwise. Reported results in Table 1 are as expected. There is a very significant and positive association of car mode to the D1 variable, the coefficient is high in magnitude and significant at the 99 percent level of significance. The variable is insignificant in the second set (Column 1 and Column 3), showing that shared transport does not affect travel by motorcycle or minibus. The variable has a negative association in the second set (Column 2 and Column 4). As expected, the estimated coefficient of the term decreases for the fourth alternative of the combined minibus/bus mode. The coefficient is highly significant at the 99 percent level in this set.

Peak

Another variable (PEAK) used in the analysis is the peak variable which takes the value of 1 if travel is either in the morning peak or afternoon peak, 0 otherwise. The reported results on the variable are mixed. The coefficient is significant at the 95 percent level in the first set, with a positive coefficient of more than 0.65, showing that the probability of choosing a car increases with peak-hour travelling. In the third set, peak-hour travel is significantly but negatively associated with the minibus mode, showing that as compared to the bus, more workers travelling by minibus travel at off peak-hours. The peak variable has an insignificant association with the motorbike and the combined minibus/bus mode. The above results may be useful in planning for timing for public transport, and in dealing with the problem of heavy peak-hour traffic in the city.

Socio-economic Characteristics

Two types of socio-economic characteristics are included in the analysis. The first is the characteristics of the household (number of dependents), and the second is the characteristics of the individual traveller (sex, occupation status, income earned).

Number of Dependents

The results presented in Table 1 show that the number of persons in the family affects the demand for different modes of travel. The number of dependents variable (DEP) is highly significant in the first two sets of coefficients in all the tables, with negative signs as expected. The public modes are not significantly affected by the number of dependents. These results show that the larger the number of dependents in the household, the greater the likelihood that private modes of travel will not be used.[5]

Income

Most studies on the choice of mode and travel behaviour consistently show a significant effect of the income variable. The mode choice model is used here to determine the effect of a change in income on the probabilities of mode choice. Two separate measures of income are used: workers income (MINCOME) Columns 1 and 3 in Table 1, and total household income (MTTINC) in Columns 2 and 4 in Table 1. The income variable is highly significant at the 99 percent level in the first two sets, with a positive association with the car and the motorbike modes, indicating that high-income households are more likely to choose these two modes for travelling to work. Workers' personal income does not affect the choice between travelling by bus or by minibus/bus. The negative and significant association of MTTINC with the third alternative, however, indicates that higher family income reduces the probability of choosing the minibus for worktrips.

Head of Household Status

Choice of mode may be affected by the status of the traveller especially in developing countries, where a large proportion of the households may be one car owners. The HH variable taking value of 1 if worker head of household is other than head, 0 otherwise is used. Results show that the variable is highly significant in the first two set of coefficients, with a negative sign, when included with the

[5]Originally the family-size variable was used, but the number of dependents variable gave better results and was retained.

MINCOME (Columns 1 and 3) variable, and significant and positive in the first set only when included with the total household income variable (Columns 3 and 4). The head status variable has the largest absolute coefficient of all the variables in the analysis, showing its dominant effect. The coefficient for the first two sets is higher than the one for the motorbike and bus modes. These results show that the effect of the variable is according to expectations when included with the total household income variable, and that this may be a more relevant specification of mode choice in the case of Karachi.

Sex

The sex (SEX) variable taking value of 1 for females, 0 otherwise, is used to see the gender effect on the travel mode choices. The sex of the worker is significant in the first two sets of coefficients, indicating that it is a significant determinant of these mode choices. These private modes have a negative association with the variable. The SEX variable also has a significant negative effect on the third alternative when included with individual worker's income.

Occupation Status

Two different occupation dummies are included, one for Clerical workers (CLER) and the other for Production workers (PROD).[6] The excluded category is that of professional workers. The results presented in Table 1 show mixed effects but confirm the importance of occupation with respect to the travel mode choice. In the first set of coefficients, relating to the car mode, both the occupation variables are highly significant, with negative signs. This result is as expected, indicating that more of the professionals travel by car and that clerical and other production workers use other modes. The PROD variable is significant in the second set, with a negative coefficient, indicating that as compared to the bus mode more workers in this category travel by motorbikes. Both the occupation variables are insignificant in the third set. The PROD variable is negatively but significantly associated with the fourth minibus/bus combined mode alternative.

Another measure of the occupation of the worker is used–which may be more relevant in the context of developing countries–and it relates to the type of job (TYPJOB). The variable takes the value of 1 for temporary jobs, 0 for permanent ones.[7] The results are reported in Columns 3 and 4, Table 1. They show that travelling by car is closely associated with permanent jobs. The coefficient for the vari-

[6]The latter mostly includes skilled workers employed in factories.

[7]The temporary type of jobs include workers without a fixed job and a regular income and mostly consist of daily wage workers who get paid on a daily basis.

able is positive for minibus, indicating that more casual workers use this mode. The ease of use of the minibus may be associated with the fact that most minibus routes either start from or end in *Katchi Abadis.* The coefficient for the variable is again negative for the combined minibus/bus mode, showing an association with permanence of jobs. Workers who use these combined multiple mode are probably travelling to specific locations like the Steel Mills situated in the periphery, or the factories in the SITE (industrial) area.

The results presented in Table 1 indicate that all the specifications have a very high value for the chi-square, goodness-of-fit measure. Although some of the coefficients on variables are contrary to expectations, yet the overall models are robust and have a high prediction accuracy.

Based on the estimated coefficient of different specifications of the model, the overall probabilities of choosing the alternative modes are calculated and presented in Table 2. These probabilities are calculated at mean values of the variables. They are useful as points of comparison for a possible sensitivity analysis.

Table 2

*Estimated Probabilities**
(Based on Logit Coefficients in Table 1)

	(1)	(2)	(3)	(4)
Car	0.19	0.04	0.52	0.39
Motorbike	0.24	0.34	0.18	0.19
Minibus	0.44	0.49	0.29	0.33
Minibus/Bus	0.13	0.13	0.01	0.09

*Probabilities are based on logit coefficients and are estimated at mean values of variables.

5. CONCLUSIONS AND POLICY IMPLICATIONS

The basic objective of this research was to construct a mode choice model which would provide useful information to the policy-makers and transport planners. The estimated model may prove to be useful to the planners in the sense that it is behavioural and responsive to most variables, and can, therefore, be used to calculate the effect of changes in the various attributes or the specific policy changes of the demand for each of the modes. For instance, based on the results of this analysis, the probabilities of choosing an improved or alternative transport system can be calculated for each worker in the sample on the basis of time and cost of his worktrip. A sensitivity analysis is also possible to observe the effect of specific changes in the cost and time taken to travel by different modes.

Results indicating the significant effect of peak-hour travel and of shared transport can be used to forecast and to improve the current transport system. Clearly, socio-economic and demographic variables affect the choice of travel mode. Coefficients for variables like income, family size, occupation, etc., can be used to predict traffic flows in the city and to help identify the congestion points. This information can then be used to predict the changes in probabilities of different modes and in planning and designing an urban area that enhances the overall quality of life in the city.

Appendices

APPENDIX A

SAMPLING METHODOLOGY AND DATA COLLECTION DETAILS

A survey of 6275 households was conducted by the Applied Economics Research Centre, University of Karachi, in 1987-88. This research is based on the results of the above survey and uses a sample of workers who used different transport modes. Those who walked to work or worked at home have been excluded. Sampling strategy adopted for the survey is described below.

The sample for the survey was spatially distributed throughout the city of Karachi. It was allocated to different areas (planning zones) of the city on the basis of their population. The sample within the zones was allocated to different types of houses on the basis of net residential area under each type of use.

Sixty-five percent of the sample was allocated to the Planned Areas and thirty-five percent to the *Katchi Abadis*. The sample for *Katchi Abadis* was lower than their population share in the city due to a considerable degree of homogeneity in terms of socio-economic, neighbourhood, and other characteristics of these areas.

In the Planned Areas, zones were divided into clusters on the basis of plot-sizes and the sample was distributed in proportion to the number of plots by size. In the case of flat sites, one household on each floor was selected from each block in a housing complex. Since no information on the number of plots is available in the *Katchi Abadis*, the sample there was spatially distributed between the clusters of predominant housing types. Within each cluster, the starting-points for the selection of households were determined randomly. One starting-point was selected for every 30 households. From each starting-point, the interviewing team moved in all four directions. A Monte Carlo experiment was done, which indicated that movement in all directions from the starting-points was the best strategy. Whether to turn left or right at every intersection was decided by the toss of a coin. Then every fifth house was chosen for interview. With houses on both sides of the street, toss of a coin again decided whether to select the house on the right or on the left.

In the case of subdivision of plots or different households living on separate floors, all households living in the selected structure were interviewed.

APPENDIX B

Mean and Standard Deviation of Variables

	Mean	Standard Deviation
TIME	42.577	24.9
COST	0.012	0.015
OFFTRAN	0.078	0.271
D1	0.248	0.432
PEAK	0.865	0.342
DEP	5.775	3.32
MINCOME	2120.7	2582.3
MTTINC	4704.2	4870.5
HH	0.488	0.50
SEX	0.053	0.223
CLER	0.378	0.485
PROD	0.27	0.444
TYPJOB	0.119	0.323

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