On the Possibility of Transferring the Parameters of Transportation Demand Models: A Case Study

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Demand estimation and model building are important, as well as costly and time-consuming steps in most transportation problem analyses. Thus, a great deal of effort is made to bypass these processes. One way to do this is to transfer the models built for a place to another place of study. This paper discusses the possibility of transferring trip generation and distribution models for two real cases studied in 1987 and 1990. It is found that the models built for one of the places closely follow the predictions of the respective models built for the other place. This paper also suggests a procedure for identifying the situation to which a model may be transferred, and discusses ways to validate it in the new situation.

INTRODUCTION

Demand estimation is an important and major step in most transportation problem solving exercises, e.g. comprehensive transportation studies of large cities. In the well-known four-step urban transportation planning process, demand estimation problems are basically tackled within the trip generation, trip distribution and mode choice steps, the results of which are then taken to step four, traffic assignment, where demand and supply of transportation are crossed to estimate the equilibrium flows on the links of a transportation network.

Demand estimation is a time-consuming and costly effort in transportation problems [1]. It is comprised of the laborious and expensive activity of data collection, as well as the time-consuming and sensitive stage of model building or calibration. Of course, it is the data collection stage which is the most prohibitive in model building. It is for this very reason that numerous methods have been devised, and extensive research has been carried out to bypass the data collection stage. Among these methods are the various procedures of estimating O/D demand from link flows regarding both the mathematical and statistical points of view (a comprehensive list of references in these areas may be found in [2]).

Nguyen [3] presents another comprehensive review of the models and methods for estimating trip matrices from traffic counts. Watling and Maher [4], and List and Turnquist [5] present two recent articles in this area of research; Carey and Revelli [6] discuss ways to estimate the parameters of direct demand functions and trip matrices simultaneously. The problem of estimating O/D demand from available or cheaply and easily available information has been extensively dealt with since the early work of Robillard [7]; the research still contin-

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Scientia Iranica, Vol. 2, No. 3, © Sharif University of Technology, October 1995.

ues at a rapid pace because of the importance of the problem and the growing need for the results of the solutions.

Another way to avoid the high cost of demand estimation process is to use transferable models built for a comparable situation elsewhere. Ortuzar and Willumsen [8] introduce the problem of model transfer, present a brief discussion of model transference and updating issues and give references regarding several aspects of the problem. This paper reports a case in which trip generation and distribution models built for one city were found to have the potential to be transferred to another city of comparable size, characteristics and function, though of different geographical location, physical shape and degree of industrialization.

BACKGROUND INFORMATION

Two independent origin-destination (O/D) studies have been conducted in Iran, in Isfahan (November 1987) and Shiraz (November 1990). The two study areas are shown in Figure 1.

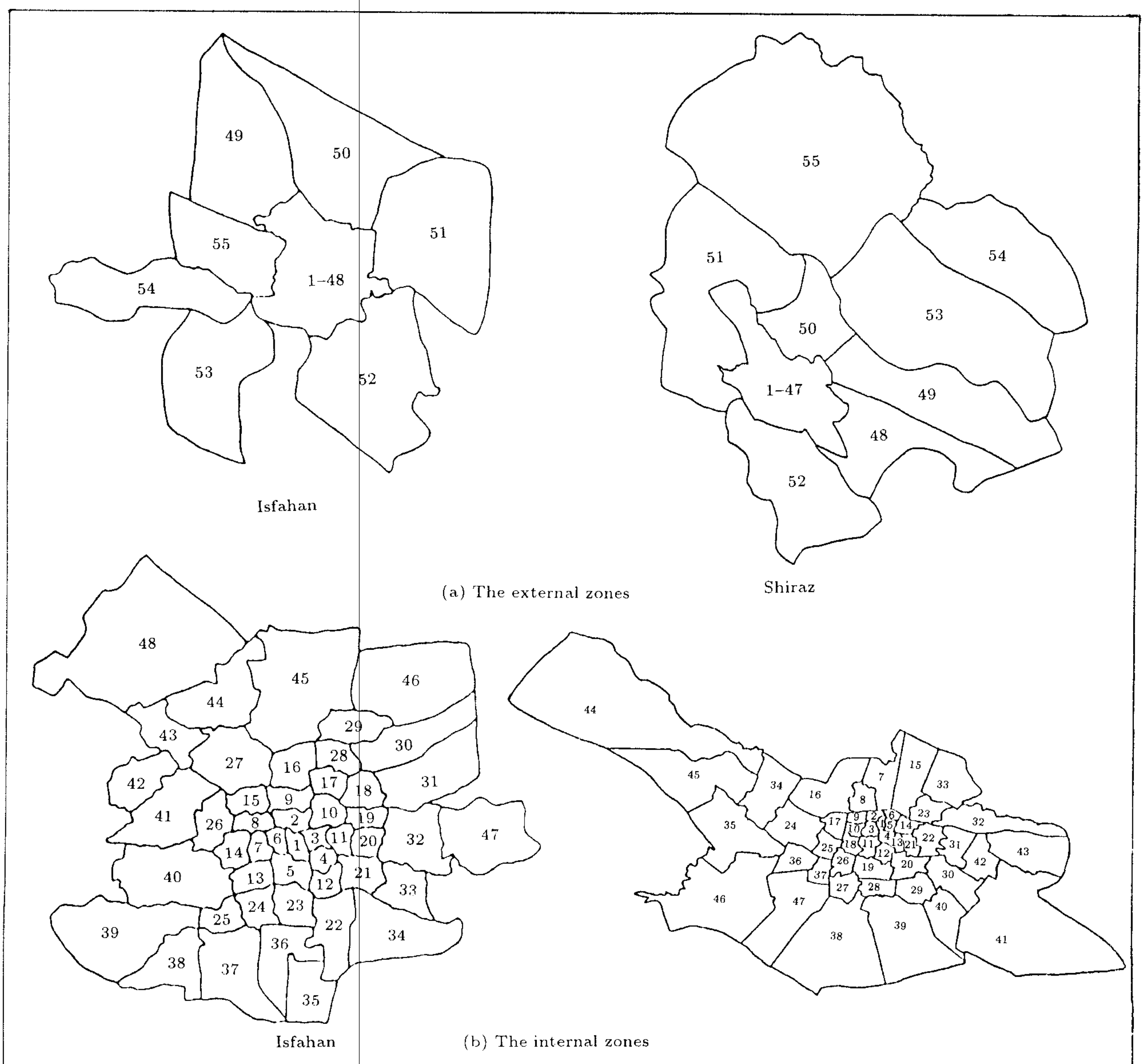

Figure 1. The study areas of Isfahan and Shiraz.

These O/D studies have been carried out quite independently, but by the same method of data collection, a brief description of which will shortly follow.

Table 1 presents some general statistics of the two study regions. As it is evident from this table, the two cities are similar to each other in simple statistics such as population, employment and size of the region, and in compound statistics such as population density, population/employment ratio and nonbasic employment/population, as well as trip statistics

Table 1. General statistics of Isfahan and Shiraz study areas.

Statistics		Study Area	
		Isfahan	**Shiraz**
Study Year		1987	1990
Population (million)	Internal Zones	1.03	1.04
	Study Area	1.62	1.40
Employment at the Place of Residence (×1000)	Internal Zones	249	243
	Study Area	389	320
Population/Employment Ratio	Internal Zones	4.13	4.28
	Study Area	4.16	4.38
Area (km^2)	Internal Zones	218	317
	Study Area	1804	4620
Population Density (persons/km^2)	Internal Zones	4725	3281
	Study Area	898	303
Employment at the Place of Work in Study Area (×1000)	Basic*	151	173
	Nonbasic*	210	144
Nonbasic Employment* per Person in Study Area		0.130	0.103
Average Daily Trips by Vehicle per Person		1.41	1.37
Trip Purpose Distribution (%)	Work	34	34
	School	24	24
	Shop	14	14
	Visit	9	11
	Medical	4	4
	Business	2	2
	Recreation	3	2
	Others	10	9
Mode Split (%)	Private Auto/Pickup	21	21
	Taxi	23	31
	Bus (All Kinds)	14	17
	Minibus	8	14
	Motor-Bike	12	8
	Bicycle	16	6
	Others	6	3

* According to the Lowry [9] definition.

such as average daily trips by vehicle per day, trip purpose distribution and mode split.

The method of O/D study used to gather trip information and basic socio-economic data in these two study areas is described in [2]. The method is basically a home interview technique, carried out by 8th grade (14–16 year old) male students. These students were trained by their teachers to interview their family members and the members of the right-hand-side neighboring family at night, regarding the trips they made during the same day. The neighboring families were chosen such that not to have any 8th grade male student. Figure 2 shows the type of information gathered in this interview.

Training the students, submitting and collecting the questionnaires were done by about 220 teachers in Isfahan and 225 teachers in Shiraz, who trained about 13000 students and 12300 students, respectively. The number of acceptable and sound collected questionnaires were respectively, 11001 and 10099 for the neighboring families. To complete the sample to include families with 8th grade male students a random sample of questionnaires were chosen from the bulk of the student's family questionnaires with a size proportional to their share in the population (about 3.5%). This process produced a total number of 11365 and 10474 questionnaires for Isfahan and Shiraz respectively.

The sample size was 3.3% for Isfahan, and 3.9% for Shiraz. The samples may be regarded as fairly random ones, because the geographical distribution of the families with 8th grade mail students is uniform and, moreover, their neighbors could be any random family with any socio-economic characteristics.

TRIP GENERATION AND DISTRIBUTION

The collected data was analyzed for building trip generation and distribution models which are of the aggregate type. The models are built for each of the following four major trip purposes: work (w); school (s) including all school and university trips, as well as all other trips made for learning any expertise; shop (sh) including trips made to buy any goods or services; and recreation (r) including visiting friends or relatives. These four major purposes comprise about 90% of all trips.

01. General information of the household members			
Row no.	Sex	Age	Occupation
Household member	Man/Woman	Year	(by type)

02. No. of vehicles owned by the household	
Type of vehicle	No. owned

03. The nearest point to the household residence mentioned in the address sheet.

(a) page 1: socio-economic data of the household members.

Age of trip-maker	Time of starting trip		Type of vehicle	Trip origin	Trip destination	Trip purpose
Year	Hour of starting trip		1. Private auto 2. Taxi 3. Minibus 4. Bus 5. Motor-bike 6. Bicycle 7. Others	The nearest point to the origin of the trip mentioned in the address sheet.	The nearest point to the destination of the trip mentioned in the address sheet.	0. Work 1. School 2. Shop 3. Business 4. Medical 5. Visit 6. Recreation 7. Going home 8. Return trip 9. Others
	Hour: Min	Am/Pm				

(b) Page 2: trip data of the household members.

Figure 2. A typical questionnaire used in the two case studies.

The independent variables of the models come from a Garin-Lowry type spatial distribution model: employment at the place of residence (E), at the place of work (e) and population (P). Employment could be basic (b) or nonbasic (nb). Other variables include the area of the zone (A), the aerial distance between centroids of the zones of the region under study (D), as well as some compound variables (made of the above-mentioned variables). One major reason for this choice of variables was the possibility of estimating their values for a distant future.

Trip Generation Models

The variables of the trip generation (production) models in an urban area usually come from upper level models, such as land use and car ownership models. In the two cases under discussion, these variables are as defined below. Let,

$T_i^p =$ volume of trips (non-walk) generated in zone i of the region for trip purpose p (represented by w, s, sh and r, for work, school, shopping and recreation trips, respectively) per day (24 hours).

$P_i =$ population of zone i (persons).

$E_i^k =$ employment at the place of residence of type k (represented by b and nb for basic and nonbasic employment, respectively) in zone i (persons).

$e_i^k =$ employment at the place of work of type k (represented by b and nb) in zone i (persons).

$A_i =$ effective area of zone i.

$D_{ij} =$ (aerial) distance of zone i to zone j, centroid to centroid (km), $i \neq j$.

$D_i = D_{ii} =$ A measure of the size of zone i, or intrazonal travel distance (km).

$=$ radius of a circle equivalent to zone i in area.

and D_i is given an upper bound of 2 km, according to experimental results.

Table 2 presents the estimates of the parameters of the best models among those tested for the two study areas. The estimation method

Table 2. The trip generation models of the two study areas.

Trip Purpose (P)	city	P_i	E_i^b	E_i^{nb}	e_i^{nb}	E_i/D_i	e_i/P_i	E_iA_i	P_i/D_i	P_iA_i	$P_ie_i^{nb}$	$SSR^\star$ ($\times 10^7$)
Work (W)	Isfahan		0.246 (1.67)	1.624 (14.53)	0.152 (4.18)			-0.679×10^{-3} (-3.52)				2.97
	Shiraz		0.390 (9.97)	1.971 (20.16)		-0.035 (-1.70)	179.2 (1.42)					1.66
School (S)	Isfahan	0.201 (19.01)								-0.316×10^{-3} (-4.68)		1.85
	Shiraz	0.202 (24.35)								-0.317×10^{-3} (-8.59)		9.67
Shop (SH)	Isfahan	0.0913 (11.94)			0.295 (6.16)						2.92×10^{-6} (5.21)	5.75
	Shiraz	0.088 (17.92)			0.420 (10.32)						4.63×10^{-6} (8.13)	1.53
Recreation (R)	Isfahan	0.0769 (10.95)			0.224 (5.44)					-0.85×10^{-4} (-2.57)		4.21
	Shiraz	0.064 (12.22)			0.277 (5.48)				0.858×10^{-2} (2.43)			2.05

⋆ Sum of squared residual

was least square, using GAUSS [10]. The models are designed to be intrinsically linear:

$$T_i^p = \sum_j \alpha_j X_{ij} \ , \qquad (1)$$

where T_i^p is as defined above, X_{ij} is the value of the j^{th} variable for zone i and α_j's are the model parameters. The value inside the parentheses in Table 2 are the t-statistics of the respective parameters.

The interpretation of the variables is presented elsewhere [11,12]. However, for the sake of clarity, it is worth to briefly mention certain points regarding these variables. First, it is important to note that the variables in the trip generation models in the two case studies are designed based on the outputs of a Garin-Lowry model [13], e.g. population (P) and employment (E^k and e^k, $k = b, nb$), since the latter model was used as the "land-use" model in both cases.

Clearly, population (P) is the driving force for most of the generated trips, such as those for school, shop and recreation. This force for work trips is better represented by employment at the place of residence (E). Since basic employment (E^b) has different effect on the dependent variable than nonbasic employment (E^{nb}), they are considered separately. The nonbasic employment at the place of work (e^{nb}) is used to explain the non-home-based trips.

Some of the compound variables, i.e. E/D, $E \cdot A$, P/D and $P \cdot A$, are used to scale the variables E and P for the surrounding zones which have larger area than the internal zones. Some of the surrounding zones even include the small, and more-or-less self-supported, towns around the city under study, in which more trips are made by walking rather than by vehicles. Another compound variable, e/p, is used to indicate whether a zone is basically occupied by various activities or is a residential one. And finally the compound variable $P \cdot e^{nb}$ tries to capture the interactive part of the effects of P and e^{nb} in the respective models.

All estimated parameters shown in Table 2 have the correct sign. Moreover, most of the estimated parameters are significant at levels above 95% (according to the values of the t-statistics of the parameters) and those below this level were deliberately kept in the models because of their causal importance. Figure 3 shows a good degree of ability of the four models of each of the cases under study to replicate the respective observed trip volumes. From now

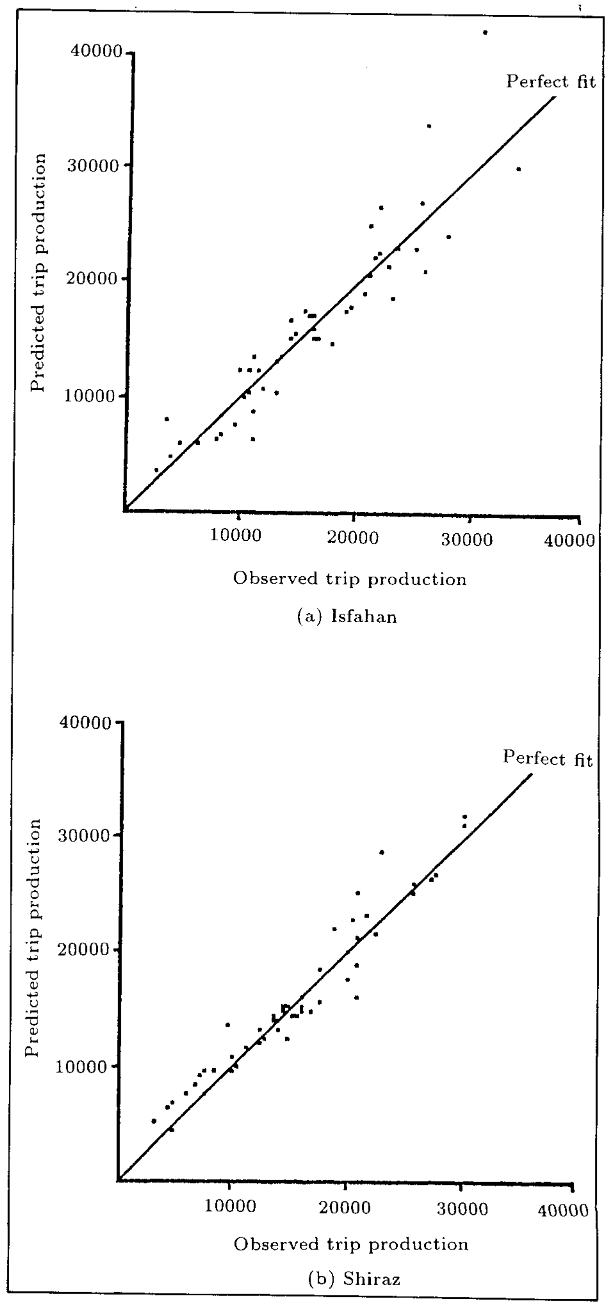

Figure 3. The ability of the trip generation models for the four major trip purposes to replicate the respective observed values in each of the two case studies.

on, let the symbols "$\wedge$" and "$\sim$" on a variable denote the predicted and observed values of that variable, respectively. In this figure the predicted values of the trips generated in zone i, $\hat{T}_i$, for the four major purposes are drawn versus the respective observed values, $\tilde{T}_i$. The 45° lines in this figure show the perfect fit. The closer the data points to this line, the better the fit. Figure 3 also shows that the models fit the reality quite well. This may be seen by the following regression equation parameters:

Isfahan:

$$\hat{T}_i = \underset{(43.9)}{0.964}\,\tilde{T}_i + \underset{(1.2)}{679.681} \quad , R^2 = \%97.3 \ , \tag{2}$$

Shiraz:

$$\hat{T}_i = \underset{(38.5)}{0.930}\,\tilde{T}_i + \underset{(2.9)}{1424.34} \quad , R^2 = \%96.6 \ . \tag{3}$$

Clearly, perfect fit should show that the coefficient of $\tilde{T}_i$ is significant with a value of 1.0 and that the constant has negligible value compared with the $\hat{T}_i$ values and is insignificant. Similar results are obtained when the model for each trip purpose is analyzed separately [see 11,12].

Trip Distribution Models

The trip distribution models discussed in this paper are of the logit type:

$$P_{ij}^p = P_i^p\{j \mid J\} = \exp(V_i^p(j)) \,/\, \sum_{K\in J} \exp(V_i^p(K)) \ , \tag{4}$$

where:

$P_i^p\{j \mid J\}$ = The probability (proportion) that a person in zone i chooses destination in zone j among the choice set J for the purpose p of the trip, abbreviated by P_{ij}^p.

$V_i^p(j)$ = The deterministic utility of zone j for a person in zone i for the trip purpose p.

The utility function has the key role in this type of models. Among the different functional types which have been tested, the following general function has been found to be the most suitable [11]:

$$V_i(j) = \alpha \ln(Max\{1, X_j + \beta P_j\}) + (\gamma a_{ij} + \theta b_{ij} + \delta)\, D_{ij}^{\phi} \ , \tag{5}$$

where the superscript p, for the purpose of trip, has been suppressed for simplicity and where:

a_{ij}= 1 if $i = j$ and i = internal zone, and 0 otherwise,

b_{ij}= 1 if $i = j$ and i = external zone, and 0 otherwise,

X_j= level of activity in zone j,

$\alpha, \beta, \gamma, \theta, \delta$ and ϕ = model parameters.

The rest of the variables are as defined before. The reasons for the choice of such shape of utility function and the variables are discussed in [11,12]. However, it is worth mentioning that a key factor in the choice of the variables was the possibility of estimating them reliably for a distant future. A proxy variable for X_j may be e_j or its constituents, e_j^b and e_j^{nb}. In general, $X_j + \beta P_j$ in $V_i(j)$ of Equation 5 (e.g. $e_j + \beta P_j$) is an indicator of the activity level and type in zone j, where both employment and population are present. These variables are the output of the Garin-Lowry model [13], as explained before. The inter-zonal distance (D_{ij}) is used as a proxy variable for the cost of travel. This was because transportation services are heavily subsidized in Iran and thus, its range of variation in the models would not explain passengers' behavior.

The models have been calibrated by two different methods using GAUSS [10]: the maximum likelihood (ML) method and a nonmaximum likelihood (NML) method. In both cases the estimates of the NML method have been found marginally better than those of the ML method so far as the replicability of the observed trips for a specific trip purpose is concerned. The measure for the strength of the replication is as defined before for the trip generation models: Let $\hat{T}_{ij}^{p}$ and $\tilde{T}_{ij}^{p}$ be the predicted and observed values of the total (non-walk) trips made from zone i to zone j for purpose p (T_{ij}^{p}) during the time span under considerations. If $\hat{T}_{ij}^{p}$ is regressed against $\tilde{T}_{ij}^{p}$, then:

$$\hat{T}_{ij}^{p} = \alpha \tilde{T}_{ij}^{p} + \beta \, . \tag{6}$$

The closer α is to 1.0 and the more significant, the closer β is to 0 (relative to the magnitude of the average values of $\tilde{T}_{ij}^{p}$) and the more insignificant and the higher the R^2 value of the regression line in Equation 6, the better the replication of the observed trip distribution by the model.

The NML method chosen is as suggested by Mansky and McFadden and presented in [14]:

$$\underset{\theta\in\Theta}{\text{Min}} \sum_{m=1}^{n} \left[S_i(m) - P\{i(m)|\ z(m),\theta\}\right]^2 \ , \tag{7}$$

where:

$S_i(m) =$ 1, if alternative i is chosen in the m$^{\text{th}}$ observation, and 0 otherwise,

$P\{i(m)\,|\,z(m),\theta\} =$ The probability of choosing alternative i, given the characteristic $z(m)$ of the alternatives and the parameter θ, $\theta \in \Theta$.

For the concerned trips,

$T_{ij} =$ volume of trips from zone i to zone j,

$P_{ij} =$ the probability of choosing j as the destination from i (assumed to be according to a logit model, as in Equation 4),

$K^i(m) =$ destination chosen in the m$^{\text{th}}$ observation from i,

$S\left(K^i(m)\right) =$ 1, if the destination is the chosen destination and 0 otherwise.

Then, for a disaggregate trip distribution model, one may write Statement 7 as:

$$\underset{\theta\in\Theta}{\text{Min}} E = \sum_{i=1}^{n} \sum_{m=1}^{M_i} \sum_{j=1}^{n} \left[S\left(K^i(m)\right) - P_{ij}\right]^2 \ , \tag{8}$$

where n is the number of zones in the study area, M_i is the number of observations for the origin zone i and $S\left(K^i(m)\right)$ is 1 if $K^i(m)$ is the chosen destination from the origin zone, i, in the m$^{\text{th}}$ observation. If an aggregate trip distribution model is desired, one may write Statement 8 as follows:

$$\text{Min} \sum_{i=1}^{n} \sum_{j=1}^{n} \left\{ T_{ij} \sum_{q=1}^{n} \left[S\left(K^i(j)\right) - P_{iq}\right]^2 \right\} \ , \tag{9}$$

where $S\left(K^i(j)\right) = 1$ if $j = q$ and 0 otherwise. The objective function in Statement 9 is the basis for the estimation of the parameters of the logit model of trip distribution, the model in Equation 4, in this paper. The results of the estimation process are summarized in Table 3 for both of the cases under study. As before, in this table, the figures in parentheses are the t-statistics of the respective parameter values.

Since this paper does not concern itself with the interpretation of the results, only few remarks are made here. First, the signs of the estimated parameters are all correct, or are according to our expectations. Second, all parameters are highly significant. Third, in each case of Isfahan or Shiraz, the parameter values vary according to our expectations across the trip purposes. For example, trip cost (distance) looses its significance in the utility function (lower δ and ϕ) as the trip purpose tends to be more restrictive with less options, e.g. from recreation to shop, school and work (it is worth noting that at the time of the two case studies, specific regulations restricted the students to go to the schools close to their homes). Fourth, for more restricted trip purposes (e.g. work) and more important and structural variables (e.g. e_j), the parameter values of the two case studies are quite similar or in the same order of magnitude (note that dummy variables are

Table 3. The estimated parameters of the logit type trip distribution models for the two cases under study.

Trip Purpose (P)	city	Variable X_j	$V_i(j)=\alpha ln(Max\ \{1, x_j+\beta P_j\})+(\gamma a_{ij}+\theta b_{ij}+\delta)\ D_{ij}^{\phi}$						opt. obj fun. ($E^{\star}$)
			α	β	γ	θ	δ	ϕ	
Work (W)	Isfahan	e_j	1.100 (83.5)	0.023 (7.9)	0.453 (26.1)	-0.205 (-7.2)	-2.234 (-25.0)	0.381 (38.6)	323852
	Shiraz	e_j	0.829 (62.1)	-0.063 (-34.6)	0.158 (3.9)	0.945 (18.7)	-1.644 (-15.9)	0.364 (26.3)	284102
School (S)	Isfahan	e_j^{nb}	0.916 (54.4)	0.005 (2.1)	0.565 (48.7)	-1.144 (-41.5)	-1.693 (-40.5)	0.659 (70.6)	199238
	Shiraz	e_j^{nb}	0.680 (67.0)	-0.046 (-1741)	-0.721 (-27.6)	-0.279 (-4.3)	-4.086 (-23.4)	0.311 (33.0)	201694
Shop (SH)	Isfahan	e_j^{nb}	1.022 (73.5)	-0.008 (-4.1)	-0.035 (-1.6)	0.019 (0.5)	-3.601 (-18.9)	0.312 (25.5)	182753
	Shiraz	e_j^{nb}	1.074 (127.3)	-0.046 (-1978)	-0.911 (-18.0)	-1.174 (-32.7)	-0.764 (-27.1)	0.717 (75.4)	166980
Recreation (R)	Isfahan	e_j^{nb}	1.166 (56.3)	0.099 (19.6)	0.151 (5.6)	0.023 (0.4)	-2.414 (-13.5)	0.367 (19.4)	120039
	Shiraz	e_j^{nb}	1.011 (36.0)	0.055 (11.8)	-0.502 (-8.0)	1.311 (16.8)	-2.813 (-8.4)	0.236 (11.6)	120622

less structural in nature, i.e. they are usually case-specific).

To show the predictive power of the trip distribution models, Figure 4 is of some help. This figure shows the relationship between the observed and predicted O/D trips for four trip purposes under considerations. A perfect fit line (45° line), as well as the 90 and 95 percent confidence intervals of the mean of $\hat{T}_{ij}^p$ for given $\tilde{T}_{ij}^p$ in the following regression equation for the four major trip purposes under considerations are shown in the figure,

$$\hat{T}_{ij}^p = \alpha \tilde{T}_{ij}^p + \beta \ . \tag{10}$$

Table 4 presents the estimated parameters of Equation 10 for various trip purposes as well as for the four trip purposes in total for both cases under study. The figures in parentheses in this table are the t-statistics of the respective parameters. As may be seen in Table 4 (through high values of R^2, values of α significant and close to 1.0 and negligible values of β) the models possess the necessary power to explain the variance in the trip distribution patterns of the two cases under study. This is also shown in Figure 4.

THE TRANSFERABILITY OF THE MODELS

In this section of the paper the possibility for the transferability of the trip generation and distribution models will be discussed.

Transferability of Trip Generation Models

Table 2 presents the trip generation models of the two cities under study. It is shown in previous sections that the models replicate the respective observations quite satisfactorily. To show the transferability of the trip generation models built, the following are first observed:

- The variables of the respective models for the two cases are basically the same, except for some of them, which are of less importance.

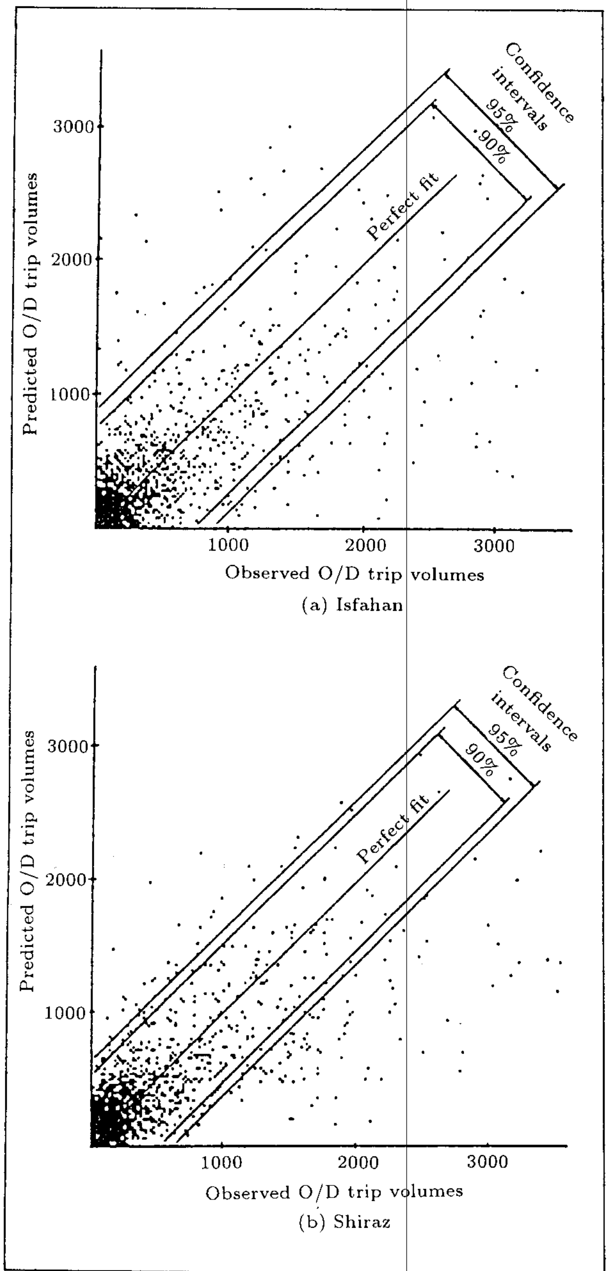

Figure 4. The predictive power of the trip distribution models in the two case studies: all four trip purposes.

- The estimated parameters of the respective variables in the two models are similar.

Next, one set of models, e.g. those of Isfahan, will be used to replicate the predictions of the other set of models, e.g. those of Shiraz. Figure 5 shows the comparisons for the four trip purposes schematically. The following regression equation may show the same comparisons statistically:

$$T_i^p(Sh) = \alpha T_i^p(I) + \beta \ , \tag{11}$$

where $T_i^p(Sh)$ and $T_i^p(I)$ are the predicted volumes of trips produced in zone i ,for the trip purpose p in Shiraz by Shiraz and Isfahan models, respectively. α and β are the parameters of the equation. Table 5 presents the estimated values of the two parameters in Equation 11 for the four trip purposes, both individually and in total. In this table, the figures in parentheses are t-statistics of the estimated parameters. As it is evident from this table, the R^2 values are very high for all five equations, showing the strength of the Isfahan trip production models to replicate the predictions of the respective Shiraz models. The estimated values of the parameter α is close to 1.0 and highly significant and the values of β are negligible (relatively close to zero).

Table 4. The estimated parameters of Equation 10 for various trip purposes.

Trip Purpose	**city**	$\hat{T}_{ij}^p = \alpha \tilde{T}_{ij}^p + \beta$		R^2
		α	β	(%)
Work	Isfahan	1.001 (240.8)	-1.331 (-0.4)	95.0
	Shiraz	0.924 (245.2)	6.657 (3.3)	95.2
School	Isfahan	1.006 (150.8)	-1.900 (-0.4)	88.3
	Shiraz	1.087 (122.6)	-8.351 (-2.9)	83.3
Shop	Isfahan	0.983 (226.6)	3.695 (1.3)	94.4
	Shiraz	0.994 (193.5)	0.664 (0.3)	92.5
Recreation	Isfahan	1.036 (176.6)	-5.087 (-2.6)	91.2
	Shiraz	1.041 (181.3)	-3.876 (-2.8)	91.6
All Four Purposes	Isfahan	1.014 (298.0)	-4.786 (-0.6)	96.7
	Shiraz	1.013 (264.2)	-8.686 (-1.5)	95.8

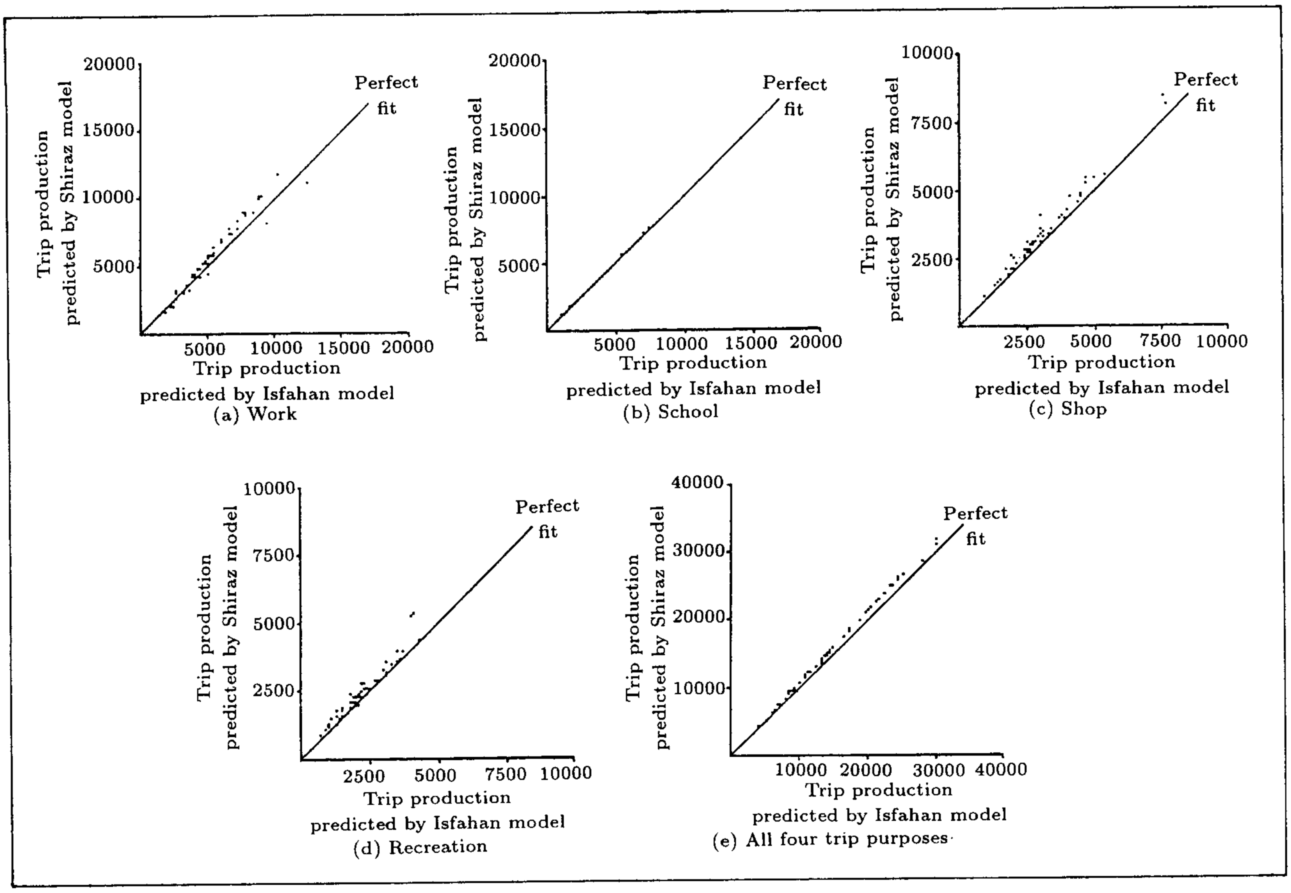

Figure 5. Prediction of Shiraz zonal trip production by Isfahan and Shiraz models for various trip purposes.

Table 5. The estimated parameters of Equation 11 for various trip purposes.

Trip Purpose	$T_i^p(Sh) = \alpha T_i^p(I) + \beta$		R^2 (%)
	α	β	
Work	0.959 (41.3)	632.282 (3.9)	96.99
School	1.005 (3632.6)	-0.282 (-0.2)	99.99
Shop	1.153 (98.1)	-130.077 (-2.6)	99.45
Recreation	1.265 (38.4)	-293.242 (-3.3)	96.54
All Four Purposes	1.059 (272.7)	200.062 (2.8)	99.93

Transferability of Trip Distribution Models

Table 3 presents the trip distribution models built for the two cities of Isfahan and Shiraz. It was shown before that these models satisfactorily reproduce the respective observations. To show more evidence about the transferability of the trip distribution models, a similar procedure as for trip generation models will be followed.

First, the power of the Isfahan models in replicating the respective predictions of the Shiraz models is examined. To do this, estimates of the independent variables for Shiraz are substituted in both Isfahan and Shiraz models to predict the trip distribution among the zones of the Shiraz study area. The results are as shown in Figure 6. For each trip purpose, corresponding predictions of the respective Isfahan and Shiraz models are points in this figure. Figure 6 also depicts the 45° (perfect fit) line, as well as the 90% and 95% confidence intervals to facilitate the judgment about the transferability of the models. As may be seen in Figure 6, most of the data points are

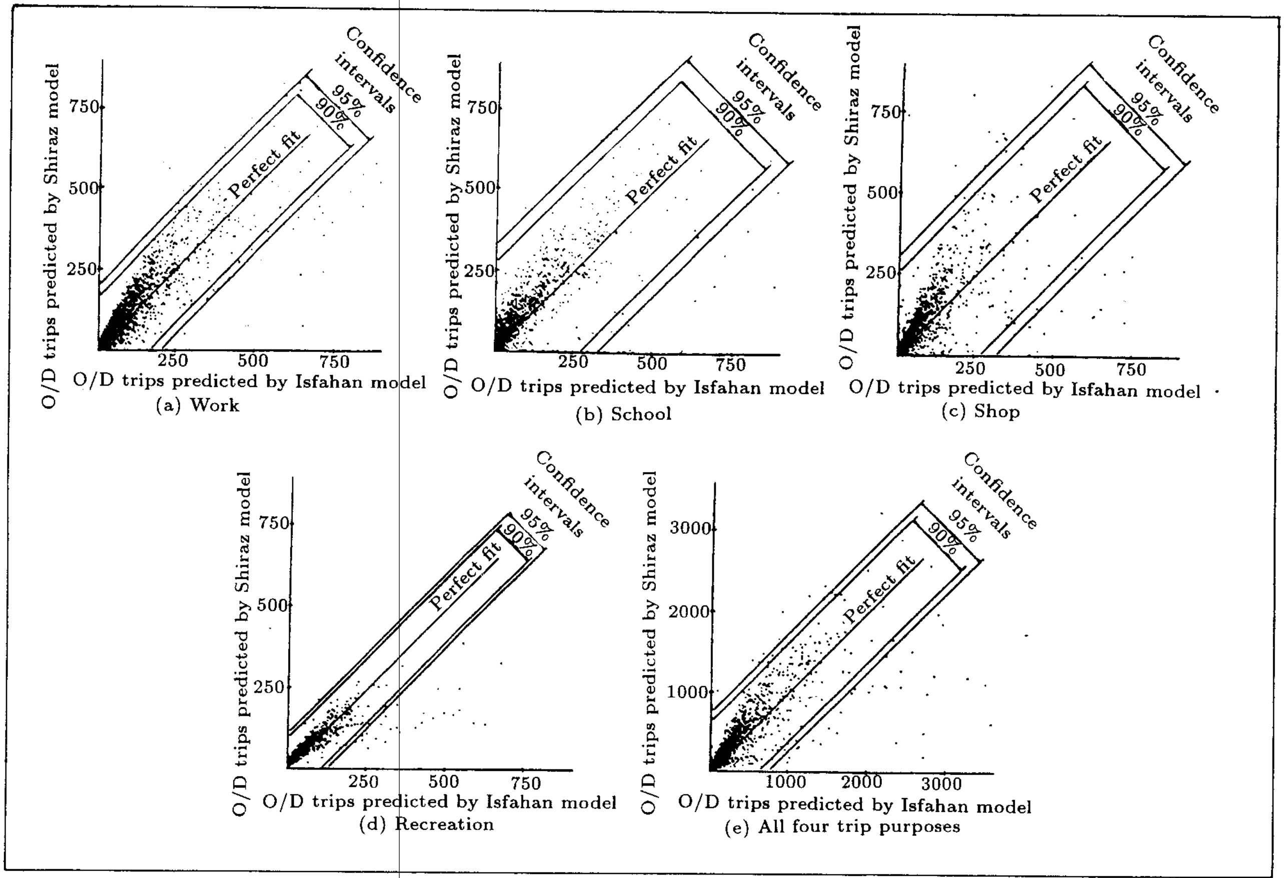

Figure 6. Prediction of Shiraz zonal trip distribution by Isfahan and Shiraz models for various trip purposes.

within the two boundaries of these confidence intervals, which are reasonably apart from the mean of estimated O/D trips by Shiraz models for a given estimate of the Isfahan model.

In evaluating the transferability of the models, the following regression analysis may help as before:

$$T_{ij}^p(Sh) = \alpha T_{ij}^p(I) + \beta \ , \qquad (12)$$

where $T_{ij}^p(Sh)$ and $T_{ij}^p(I)$ are the predicted volumes of trips from zone i to zone j for trip purpose p in Shiraz and Isfahan models, respectively. α and β are the two parameters of the equation. Table 6 presents the results of a regression analysis for each of the trip purposes under consideration. As may be seen in Table 6, the estimates of α are quite close to 1.0 and highly significant, and those of β are (relative to the values of the trips) close to 0. High R^2 values are evidence of the transferability of the models.

Table 6. The estimated parameters of Equation 12 for various trip purposes.

Trip Purpose	$T_{ij}^p(Sh) = \alpha T_{ij}^p(I) + \beta$		R^2 (%)
	α	β	
Work	1.117 (391.8)	-20.199 (-13.4)	98.1
School	1.092 (117.3)	-7.873 (-2.6)	82.0
Shop	0.895 (142.0)	0.191 (0.1)	87.1
Recreation	0.823 (265.2)	2.626 (3.5)	95.6
All Four Purposes	1.021 (220.2)	-27.143 (-3.9)	94.1

DISCUSSION

In the section devoted to the transferability of the models, the potential for the transferability of the trip generation (production) and distribution models of the city of Isfahan to the city of Shiraz has been discussed, and one may expect similar results for transferring Shiraz models to Isfahan. The question now arises that under what conditions one may transfer the model of one city to another. One may decide about the transfer of a model from one place to another through the following procedure.

First, compare the aggregate data of the two places (the place to which the models belong, and the place where they are to be transferred). The aggregate data may include information from the census (e.g. population, employment and various related rates and densities) and the geographical features of the two places (e.g. areas of various regions or zones) as shown in Table 1. Moreover, this comparison may be strengthened by various aggregate trip data, such as per capita trips per day, mode split, distribution of trips by purpose etc. If the two cities, or cases, are found to be similar in nature as measured by the aforementioned general statistics and according to certain prespecified standards of similarity, one may use the available models to predict the trips for the new place under study. Comparisons of the predictions of the models with the respective observations of the new study area by, e.g. the kind of analyses shown in the this paper, may show the suitability of use of the models transferred to the new place. Such predictions may be for trips generated from certain zones or subareas, flows on the networks, flows through screen lines and other data which are easy to collect.

Before closing this section, it is worth noting that it is not expected that a transferred model perfectly explains a new situation, as the model itself is an abstract representation of the reality in its original study area. A search for transferable models is a search for easily obtainable resources and cheaply available information. Thus, in this respect one should not expect to find perfectly transferable models with equal respective parameters in the original and new environments [8].

The body of literature contains suggested procedures for enhancing the quality of information transferred by a model, depending on the type of information available in the new environment (see, e.g [15-17]). Moreover, tests of model parameter equality and model performance have also been proposed in the literature (see, e.g. [8] and the references cited therein).

SUMMARY AND CONCLUSIONS

This paper discusses the issue of transferability of models from one city to another city with similar characteristics, in general. The importance of this finding stems from the prohibitive costs (both of money and time) of collecting and analyzing O/D data, as well as of model building process. Moreover, transferability of model parameters is an indication of model validity.

First, two rather independent studies were introduced, which were supported by similar procedures of O/D data collection. The two case studies dealt with cities which are quite similar in general statistics (Table 1). Next, the trip generation and distribution models built for the two cases for four major trip purposes were presented and validated. Then, the transferability issues of the models were raised and discussed for each trip purpose through various means of comparing the prediction of two respective models for a single case.

The results show good evidence of the transferability of the model parameters: Tables 2 and 3 show similarities in the values of the parameters of the common variables of the respective models for the two cases under study. Figures 5 and 6, and Tables 5 and 6 show good replication of the power of one model for predicting demands of a study area by the respective model of the other study area. This potential of transferability was present despite the fact that the two cases were studied at two different times (1987 and 1990) in a rapidly changing environment.

ACKNOWLEDGMENT

The studies in Isfahan and Shiraz were funded by the Organization for Transportation and Traffic of the respective cities. Mr. S. Nader Shetab-Booshery and Mr. Yousef Shafahi have contributed significantly in building the original versions of the models of Isfahan and Shiraz, respectively, and have run the computer programs for calibrating those model parameters.

REFERENCES

1. Taylor, M.A., Young, W., Wigan, M.R. and Ogden, K.W. "Designing a large-scale travel demand survey: New challenges and new opportunities", *Transpn. Res.- A*, **26 A**(3), pp 247-261 (1992).

2. Poorzahedy, H. and Aashtiani, H.Z. "A new method for conducting O/D survey", *I.J. of Science and Technology,* **16**(2,3), pp 155-171 (1992).

3. Nguyen, S. "Estimating origin-destination matrices from observed flows", *Transportation Planning Models,* Florian, M., Ed., Elsevier Science Publishers, B.V. Amsterdam, North-Holland (1984).

4. Watling, D.P. and Maher, M.J "A statistical procedure for estimating a mean origin-destination matrix from a partial registration plate survey", *Transpn. Res.- B,* **26B**(3), pp 171-193 (1992).

5. List, G.F. and Turnquist, M.A "Estimating multi-class truck flow matrices in urban areas", Paper prepared for presentation at the 1994 Annual TRB Meeting (1993).

6. Carey, M. and Revelli, R. "Constrained estimation of direct demand functions and trip matrices", *Trans. Sci.,* **20**(3), pp 143-152 (1986).

7. Robillard, P. "Estimating O/D matrix from observed link volumes", *Transpn. Res.,* **9**, pp 123-128 (1975).

8. Ortuzar, J. de D. and Willumsen, L.G. *Modelling Transport,* John Wiley and Sons, Chichester, England (1994).

9. Lowry, I.S. "A model of metropolis", Report No. RM-4035-RC, the Rand Corporation, CA, USA (1964).

10. Edlefsen, L.E. and Jones S.D." GAUSS version 1.49 B", Apteen System Inc., Kent, WA, USA (1986).

11. Poorzahedy, H., Aashtiani, H.Z. and Shetab-Booshehry, S.N. "Trip generation and distribution models for the city of Isfahan", Isfahan Transportation and Traffic Organization (1990)

12. Aashtiani, H.Z., Poorzahedy, H. and Shafahi, Y. "Demand models for the city of Shiraz", Report No. TR7201135, Institute for Research in Planning and Development, Tehran, I.R. Iran (1992).

13. Garin, R.A. "Matrix formulation of the Lowry model for intra-metropolitan activity allocation", J. *American Institute of Planners,* **32**(6), pp 361-364 (1966).

14. McFadden, D. "Quantitative methods for analyzing travel behavior of individuals: Some recent developments", Working Paper No. 7704, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, UC, Berkeley, USA (1977).

15. Ben Akiva, M.E. and Bolduc, D. "Approaches to model transferablility and updating: The combined transfer estimator", *Transportation Research Record,* 1139, pp 1-7 (1987).

16. Koppelman, F.S., Kuah, G-K and Wilmot, C.G. "Transfer model updating using disaggregate data", *Transportion Research Record,* 1037, pp 102-7 (1982).

17. Koppelman, F.S., Kuah, G-K and Rose, G. "Transfer model updating with aggregate data", the 64th Annual TRB Meeting, Washington, DC, USA (1985).