Comparative Analysis of the Transferability of Disaggregate Automobile-Ownership and Mode-Choice Models

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ABSTRACT

In this paper the study of model transferability is extended to disaggregate models of automobile-ownership level. Models of automobile ownership and mode to work are estimated and transferred among sectors of a metropolitan region. The transfer effectiveness of these models is evaluated by using previously developed disaggregate and aggregate measures of model transfer effectiveness. The automobile-ownership models are found to have a high degree of transfer effectiveness in this context, higher than the transfer effectiveness of mode-choice models in the same context. It is concluded that previous findings about the effectiveness of model transfer, based on studies of mode-choice models, can be extended to automobile-ownership models.

The application of travel demand models estimated on observed data for prediction of conditional future behavior in the same or other context is commonly undertaken as part of the transportation systems analysis process (1). The application of a model in a context other than that in which it was originally estimated is described as model transfer. Model transfer is likely to be effective in predicting behavior in the application context if the transferred model will contain useful information about the behavioral phenomenon of interest in the application context. Models that contain such useful information are described as transferable. Model transferability is necessarily conditional on similarity of the underlying behavioral process in the estimation and application contexts and the adequacy of the model to represent that behavior (2). A number of studies of transferability of disaggregate travel choice models have been undertaken in recent years. Most of these studies consider mode choice (2-5), whereas some examine frequency choice (6,7).

The goal of this study is to extend the analysis of the transferability of travel choice models to the related choice of automobile ownership. The transferability of automobile-ownership choice models is analyzed and the transferability of these models is compared to that of mode-choice models. These analyses were undertaken in the context of an artificial transfer situation created by dividing the Washington, D.C., region into three geographically distinct sectors. These sectors are distinctly different in terms of the demographic characteristics of their populations, such as household size, household income, and automobile ownership, and with respect to travel time and cost to the central business district (CBD) by both car and bus transit (2).

Automobile-ownership and mode-choice models are estimated for each sector, and the transfer effectiveness of each model to the other two sectors is examined. This analysis was undertaken within a single urbanized area to reduce the confounding effect of differences in variable definition, measurement of level-of-service variables, and sampling procedures between metropolitan areas. Previous studies of the transferability of disaggregate mode-choice models suggest that the results of intra-area transfer studies are indicative of inter-area transfer effectiveness.

MODEL STRUCTURE AND ESTIMATION

Models of Travel and Related Choices

Travel behavior is commonly analyzed in the four steps embodied in the traditional aggregate urban transportation model system: trip generation, trip distribution, modal split, and network assignment (1,8,9). The comparable choices for disaggregate analysis are trip frequency (whether or not to make a trip), destination, mode, and path choice. An important issue in travel analysis revolves around the structure of these choices and the models that represent them.

Charles River Associates (10,11) derived a sequential formulation of the choice process and applied it to estimation of choices of shopping trip frequency, mode, destination, and time of day. Ben-Akiva (12) argued that certain of these choices are behaviorally joint and that they should be represented by a joint or simultaneous choice model. He also demonstrated that sequential model estimations may be quite different from those obtained by estimation of the corresponding simultaneous model. However, the differences in parameter estimates reported were not statistically significant at any reasonable level, and the goodness-of-fit measures for the simultaneous and sequential models were essentially the same. Ben-Akiva and Lerman (13) extended the individual choice structure to form a hierarchical model of travel and travel-related choices. In this hierarchy mobility choices, including residential location, automobile ownership level, and breadwinner mode choice to work, are assumed to be made jointly. Decisions on trip frequency, destination, and mode for nonwork trips are assumed to be made jointly but conditional on the higher-level mobility choices.

The discussion of choice model structure is based on behavioral conjecture about the sequence of the (unobserved) decision process employed by the tripmaker. More recently, McFadden (14) suggested an alternative theoretical basis for mathematically structuring multidimensional choice models. Specifically, he formally derived the nested logit model that takes account of similarity among alternatives with respect to excluded variables. In this structure, the mathematical form of the choice model represents an interdependence among a subset of alternatives due to the sharing of common unobserved attributes rather than a sequential dependence among choices. This theoretical approach leads to a similar mathematical form of the choice model as that obtained based on choice sequence.

Choice of Automobile Ownership and Mode to Work

These concepts were applied to the choice of automobile-ownership level and breadwinner mode to work. In this paper the component models of a sequential choice model, with mode choice conditional on automobile ownership, are examined. Excluded as conceptually unreasonable were mutual independence of these choices and the sequential model with automobile ownership conditional on mode choice to work. In a previous paper (15) the authors estimate and evaluate the joint choice model of automobile ownership and mode to work, and compare transferability of the joint and sequential model structures. The utility of a joint automobile ownership/mode to work alternative is defined by

$$U_{A,M} = V_{A,M} + \epsilon_{A,M} \qquad (1)$$

where

$U_{A,M}$ = utility of automobile ownership A and mode M,
$V_{A,M}$ = systematic portion of that utility, and
$\epsilon_{A,M}$ = unobserved stochastic portion of that utility.

A sequential model of the choice of automobile ownership and mode to work can be developed by assuming that the stochastic component of utility in Equation 1 can be additively separated. The nested logit model is obtained under the assumption that

$$\epsilon_{A,M} = \epsilon_A + \epsilon_{AM} \qquad (2)$$

where ϵ_{AM} is that portion of the stochastic utility that jointly varies over automobile ownership and mode and is Gumbel distributed with parameter λ^{-1}, and ϵ_A is that portion of the stochastic utility that varies only over automobile ownership and is distributed such that the sum $\epsilon_M + \epsilon_{AM}$ is Gumbel distributed with parameter 1.

In this case the conditional mode and marginal automobile-ownership choice models are of the form

$$P(M/A) = \exp[(V_M + V_{AM})/\lambda] / \sum_{M'/A} \exp[(V_{M'} + V_{AM'})/\lambda] \qquad (3)$$

and

$$P(A) = \exp(V_A + \lambda\tilde{\Gamma}_A)/\sum_{A'} \exp(V_{A'} + \lambda\tilde{\Gamma}_{A'}) \qquad (4)$$

where

$P(M/A)$ = probability of choosing mode M conditional on automobile ownership A,
$P(A)$ = marginal probability of choosing automobile ownership A,
V_A = that portion of observed utility that is strictly related to automobile-ownership level,
V_M = that portion of observed utility that is strictly related to mode,
V_{AM} = remaining portion of observed utility that is determined jointy by automobile ownership and mode,
λ = measure of dissimilarity between pairs of mode alternatives conditional on automobile ownership, and
$\tilde{\Gamma}_A$ = expected value of choosing the best mode given automobile ownership A.

The mathematical definition of $\tilde{\Gamma}_A$ is given by

$$\tilde{\Gamma}_A = \ln \sum_{M'/A} \exp[(V_{M'} + V_{AM'})/\lambda] \qquad (5)$$

The estimation procedures for the sequential model structure are well developed and are documented in the literature (12,14,16). The basic procedure is to

1. Estimate the conditional portion of the model described in Equation 3 (note that λ cannot be estimated, but ratios of β/λ can be estimated, where β is a parameter in the utility function),
2. Compute the expected value of the set of conditional alternatives by using Equation 5, and
3. Estimate the marginal choice model as represented in Equation 4.

The estimation process is based on maximum likelihood procedures in steps 1 and 3.

RESEARCH DESIGN

Data and Model Specification

The data used were collected by the Washington Council of Governments in 1968 as part of a general effort to develop models of travel demand and transport system operations. A portion of these data was used, which describes breadwinners who made a work trip from their residence to work place in the CBD. (Note that breadwinners are defined as the household member working in the highest job category.) The data set includes a total of 2,654 persons and includes characteristics of the individual and household; level-of-service data for the work trip by drive alone, shared ride, and transit; and the mode chosen.

Previous studies of disaggregate choice models employed data from the Washington, D.C., data set. In particular, Lerman and Ben-Akiva (17) used these data to estimate joint choice models of automobile ownership (zero, one, two cars) and mode to work (car, transit). The specifications used in the present research are based on this previous work. The specification of a joint choice model is selected initially and compatible specifications are developed for the conditional and marginal choice models.

The choices of interest in this study are automobile-ownership level and breadwinner mode to work. The alternatives for automobile ownership are defined as zero, one, or two or more cars. The alternatives for mode to work include drive alone, shared ride, and transit. Two assumptions are made about the availability of particular alternatives. First, it is assumed that a household with no licensed drivers cannot choose to own an automobile. Second, if the work tripmaker does not have a driver's license, he is assumed not to be able to choose the drive-alone alternative.

There are no other assumed restrictions on alternative availability. The data set includes only individuals living in areas served by transit. Thus the transit alternative is available to everyone. Shared ride is assumed to be available to everyone. It is not assumed that the level of household income places any restriction on the maximum number of cars owned or available to the household.

Next, the utility function for each alternative is formulated. It is expected that the joint choice of automobile ownership and mode choice to work will be influenced by the level-of-service characteristics of the work trip by ride alone, shared ride, and transit; the differential travel capabilities of the household with different levels of automobile ownership; and the socioeconomic characteristics of the individual and household.

The general specification adopted by Lerman and Ben-Akiva (17) was followed, but modified to account for differences in alternatives (three mode-choice alternatives were included in this research) and limitations in the data available to the authors. First, transportation level-of-service variables were included. These are in-vehicle and out-of-vehicle travel time and out-of-pocket travel cost. Second, housing attributes are represented in terms of whether the residence is a single-family house. This characteristic is selected to take account of the availability of parking space, and this variable is associated with the two-or-more-automobile ownership alternative. Third, three socioeconomic variables were included. Household income is used to modify the importance of out-of-pocket travel costs. Number of licensed drivers is used to modify the utility of different levels of automobile ownership (the utility of owning increased numbers of vehicles increases with the number of drivers in the household). An indication that an individual is a government worker is used to represent the effect of work place incentives on the value of the shared-ride mode. Finally, the average effect of excluded variables is represented by constants for different automobile-ownership levels and different mode choices.

These specifications exclude two variables used by Lerman and Ben-Akiva (17): automobile-ownership costs and accessibility to nonwork locations for households with and without automobiles. The Washington data set does not include information on automobile-ownership costs. It was preferred to exclude this variable rather than include a fixed average annual cost per vehicle that is invariant across households. The accessibility measure used by Lerman and Ben-Akiva (17) represents the value of increased automobile ownership in improving household access to the opportunities other than work in the spatial environment. Although this is a useful variable, the data necessary to formulate it were not available to the authors.

A description of each variable included in the specifications of the automobile-ownership and mode-choice models is presented in Table 1. The generalized price variable (Equation 5) is included to capture the effect of modal utilities on automobile-ownership choice.

TABLE 1 Specification of Conditional Mode and Marginal Automobile-Ownership Choice Models

Explanatory Variable	Description of Variable	Conditional Mode-Choice Model	Marginal Automobile-Ownership Choice Model
DUMA and DUMSR	Dummy variables, specific to drive-alone and shared-ride alternatives	X	
DUM1CAR and DUM2CAR	Dummy variables, specific to the one- and two-car alternatives		X
CDA and CSR	Number of cars, drive-alone and shared-ride interaction variables	X	
GWSR	Dummy variable that indicates if the breadwinner is a government worker; specific to the shared-ride alternatives	X	
STRDUM	Dummy variable that indicates whether the household resides in a single-family structure; specific to the one- and two-car alternatives		X
IDLIC	The inverse of the number of driver's licenses in the household for the one-car alternatives; twice the inverse of the number of driver's licenses for the two-car alternatives		X
TTT	Round trip total travel time (min)	X	
OVTTD	Round trip out-of-vehicle travel time (min) divided by one-way distance (miles)	X	
OPTCINC	Round trip out-of-pocket travel cost (cents) divided by annual household income ($000s)	X	
GENPRICE	Generalized price of mode of travel for a given level of automobile ownership		X

Note: An X indicates that the explanatory variable is included in the particular model.

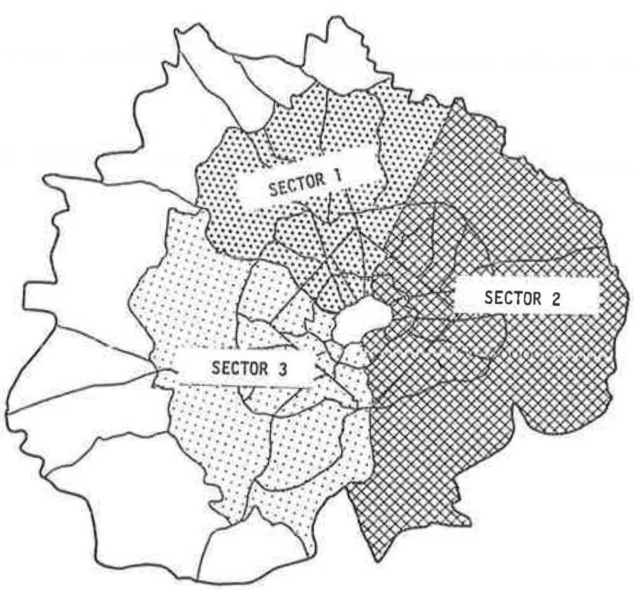

FIGURE 1 Estimation sectors in Washington region.

Analysis of Model Transferability

An artificial environment was created for transferability analysis by dividing the Washington area into three geographically distinct sectors, as shown in Figure 1. That is, the opportunity to examine transferability was created in a situation where there are no differences in variable definitions, data-collection methods, and characteristics of the metropolitan area environment. These advantages are important in developing an understanding of transferability. It is recognized that the issue of intraregional transferability is less of a concern than that of interregional transferability. However, earlier studies indicate that intraregional transfer results are indicative of interregional transfer effectiveness (18,19). The marginal automobile-ownership and conditional mode-choice models were estimated for each of these three sectors, and the transferability of each model to the other two sectors was examined.

The transferability of the different models was evaluated in terms of the ability of the transferred model to describe the observed behavior in the application context. This is accomplished by examining the accuracy of disaggregate and aggregate predictions using the transferred model in the application context in absolute terms and relative to the predictive accuracy of the corresponding locally estimated model. The specific measures to be used and their properties are developed in earlier work (2). A summary description of these measures is presented here. The disaggregate transferability measures (Table 2) are based on the likelihood that the data observed in the application environment were generated by the choice process described by the transferred model. The transfer likelihood ratio index is analogous to the conventional likelihood ratio index or rho-square measure (20). It compares the log likelihood of the transferred model to the log likelihood of a base (equally likely or market-shares) model. The transfer index compares the prediction effectiveness of the transferred model over the base model relative to the prediction effectiveness of a locally estimated model.

The aggregate measures of transferability (Table 3) evaluate the ability of the model to replicate observed choice frequencies in prediction for aggregate groups, using the explicit enumeration aggregation procedure (21). This is done by measuring the difference between the observed and predicted number of individuals selecting each alternative in each aggregate group. Specifically, the root-mean-square-error (RMSE) measure is used to represent the expected relative or proportional error in a typical aggregate prediction (22), and the relative aggregate transfer error is the ratio of transfer and local RMSE.

The disaggregate and aggregate transfer test statistics developed by Koppelman and Wilmot (2) are not reported here because these statistics were found to be less useful in the analysis of transferability than the index measures previously discussed. The transfer test statistics are reported in Koppelman and Pas (15).

EMPIRICAL RESULTS

Estimation Results

Models of mode choice conditional on automobile ownership and of marginal automobile-ownership choice are estimated for each of the three sectors by using the specifications previously described. The estimation results are given in Tables 4 and 5, respectively. These models are all significant at high levels relative to both the equally likely and market-share base models and account for a reasonable proportion of the behavioral variation in the data. Note that the marginal automobile-choice models have substantially higher likelihood ratio index (rho-square) values than the mode-choice models, despite the limited specification of the automobile-ownership model.

All the parameters in the conditional mode-choice models are highly significant ($p < 0.01$), except those associated with out-of-pocket travel cost and out-of-vehicle travel time. All the parameters in the marginal automobile-ownership choice models are statistically significant ($p < 0.01$), except the parameter of the inclusive price of travel mode in the automobile-ownership model for sector 2. Thus, from a statistical perspective, the models are extremely satisfactory. Furthermore, all parameter estimates that are statistically different from zero have acceptable signs. The parameters for the generalized price of mode of travel in the automobile-ownership models are expected to be between zero and one. Although the parameters obtained in two sectors are greater than one, they are not significantly different from one.

TABLE 2 Disaggregate Indices of Transferability

Measure	Definition	Description
Transfer likelihood ratio index, $\rho_i^2(\beta_j)$	$\rho_i^2(\beta_j) = 1 - [LL_i(\beta_j)/LL_i(BASE)]$ where $LL_i(\beta_j)$ is the log likelihood that the behavior observed in context i was generated by the model estimated in context j (with parameters β_j)	This index is similar in form to the commonly used rho-square measure proposed by McFadden *(20)*; the index is bounded by one; the base model may be an equal-shares or market-shares model
Transfer index, $TI_i(\beta_j)$	$TI_i(\beta_j) = [LL_i(\beta_j) - LL_i(BASE)]/[LL_i(\beta_i) - LL_i(BASE)]$	This index measures the predictive accuracy of the transferred model relative to a locally developed model; the index has an upper limit of unity; the base model may be an equal-shares or market-shares model; the transfer index is related to the transfer likelihood ratio index by $TI_i(\beta_j) = \rho_i^2(\beta_j)/\rho_i^2(\beta_i)$

TABLE 3 Aggregate Indices of Transferability

Measure	Definition	Description
Root-mean-square error (RMSE)	$RMSE_i(\beta_j) = \left(\sum_{m,z} \hat{N}_{mz} REM_{mz}^2 / \sum_{m,z} \hat{N}_{mz}\right)^{1/2}$ where REM_{mz} is the relative error measure in prediction alternative m in group z; i.e., $REM_{mz} = (\hat{N}_{mz} - N_{mz})/\hat{N}_{mz}$ where $\hat{N}_{mz}$ is the number of persons in group z predicted to choose alternative m, and N_{mz} is the number of persons in group z observed to choose alternative m.	This index measures the average relative error in prediction weighted by the size of the prediction element
Relative aggregate transfer error (RATE)	$RATE_i(\beta_j) = RMSE_i(\hat{\beta}_j)/RMSE_i(\hat{\beta}_i)$	This index measures the aggregate error of the transferred model relative to the local model

TABLE 4 Estimation Results: Conditional Mode-Choice Model

Variable	Estimated Parameter Values (t statistics) Sector 1	Sector 2	Sector 3
DUMDA	-2.71 (7.31)	-1.79 (4.81)	-3.19 (7.26)
DUMSR	-2.35 (10.91)	-1.87 (9.63)	-2.36 (7.78)
CDA	1.67 (8.35)	1.57 (7.35)	2.08 (8.45)
CSR	1.20 (7.72)	1.33 (9.23)	1.43 (6.75)
GWSR	.77 (5.01)	.48 (3.33)	.60 (3.77)
TTT	- .038 (6.06)	- .018 (3.63)	- .021 (3.84)
OVTTD	.78 (.13)	- .052 (.88)	- .096 (1.23)
OPTCINC	.19 (1.44)	.0018(.17)	.014 (.84)
Number of Cases	944	961[a]	746
Number of Observations	2648	2582	2165
Log Likelihood			
At Zero	-962.5	-933.7	-790.0
At Market Share	-904.4	-899.7	-771.6
At Convergence	-778.0	-812.6	-690.5
Likelihood Ratio Statistic			
Zero Base	368.9	242.3	198.9
Market Share Base	252.8	174.2	162.2
Likelihood Ratio Index (ρ^2)			
Zero Base	.192	.130	.126
Market Share Base	.140	.097	.105

[a]There were three cases in the data set in which the household reported having zero drivers and also reported having one car available. Because these cases selected a non-feasible alternative, they were omitted from the analysis.

TABLE 5 Estimation Results: Marginal Automobile-Ownership Model

Variable	Estimated Parameter Values (t statistics) Sector 1	Sector 2	Sector 3
DUM1CAR	4.46 (8.83)	4.79 (9.01)	6.24 (7.83)
DUM2CAR	4.50 (4.72)	5.59 (5.44)	5.47 (3.31)
STRDUM	1.00 (4.96)	.92 (5.12)	1.19 (5.63)
IDLIC	-4.60 (10.73)	-4.23 (11.57)	-5.64 (8.95)
GENPRICE	1.32 (3.92) (0.95)[a]	.40 (1.16) (1.74)[a]	1.79 (3.02) (1.33)[a]
Number of Cases	855	832	718
Number of Observations	2565	2496	2154
Log Likelihood			
At Zero	-939.3	-914.0	-788.8
At Market Share	-781.1	-776.6	-577.4
At Convergence	-596.6	-622.6	-426.6
Likelihood Ratio Statistic			
Zero Base	685.4	582.9	724.3
Market Shares Base	369.0	308.0	301.6
Likelihood Ratio Index (ρ^2)			
Zero Base	.365	.319	.459
Market Share Base	.236	.198	.261

[a]T-statistics for the generalized price variable are formulated against the null hypotheses of $\beta = 0$ and $\beta = 1.0$.

Transferability Analysis

The transferability of the conditional mode and marginal automobile-ownership choice models is examined through use of the measures previously outlined. The transferability of the estimated models is evaluated in terms of parameter transferability, disaggregate prediction accuracy, and aggregate prediction accuracy. Examination of the hypothesis that the estimated model parameters describe the population behavior in the application context (15) rejects the transferability of the alternative specific constants in both the automobile-ownership and mode-choice models. Thus in this paper partial, rather than full, model transfer is considered. That is, the transferability analysis results that follow are based on models in which the alternative specific constants are adjusted to match the aggregate choice shares in the application context.

Disaggregate Transferability Prediction Indices

The ability of the conditional mode and marginal automobile-ownership choice models estimated in each sector to predict the disaggregate behavior observed in each of the other sectors is examined by use of the transfer likelihood ratio index and the transferability index evaluated against a market-share reference. These results are given in Tables 6 and 7 for each sector pair and with pooled values across all transfers (19). The transfer rho-square measures highlight two interesting facets of this analysis. First, it is observed that the rho-square values are highest for transfers into contexts that have high rho-square values for locally estimated models. For example, the automobile-ownership model provides the best fit to the sector 3 data, and the transfer rho-square measures are higher for transfers into sector 3 than into sectors 1 and 2. Second, it is observed that the transfer rho-square measures for the marginal automobile-choice model are consistently higher than those for the conditional mode-choice model, despite the apparently limited specification used for automobile ownership.

The transfer indices reported for the different models across sector pairs are generally quite high (greater than 0.86 in every case). The transfer indices for the marginal automobile-choice model are generally higher (four of six cases) than for the conditional mode-choice model. The pattern of transfer indices among sector pairs (which directional pairs have higher or lower transferability) varies between the two models. However, it appears that high transferability index values are obtained for transfer into sectors with a high local rho-square for the corresponding model. That is, it appears that model transferability measured by the transfer index is best in contexts in which behavior can be most effectively described by the particular model specification.

Overall, the disaggregate transferability prediction indices indicate that both conditional mode-choice and marginal automobile-ownership models are highly transferable between sector pairs. These results also indicate that transferability is generally higher for transfer into sectors that have high local rho-square values.

Aggregate Transfer Prediction Indices

RMSE is used to summarize the aggregate prediction error in both local and transfer prediction, and the relative values of RMSE are used to describe the degree to which transferred models increase aggre-

TABLE 6 Disaggregate Transferability Prediction Indices: Conditional Mode-Choice Model

		PREDICTING ON		
		Sector 1	Sector 2	Sector 3
ESTIMATED ON	Sector 1	.140 (1.00)	.083 (0.86)	.097 (0.92)
	Sector 2	.130 (0.93)	.097 (1.00)	.100 (0.95)
	Sector 3	.133 (0.95)	.092 (0.95)	.105 (1.00)

Composite Measures[a]

Transfer Likelihood Ratio Index = .106

Transfer Index = .93

Note: The base for computation of the transfer likelihood ratio index and the transfer index measures reported here is the market-shares model.

[a]Composite measures are weighted averages of the corresponding measures across multiple transfers *(19)*.

TABLE 7 Disaggregate Transferability Prediction Indices: Marginal Automobile-Ownership Choice Model

		PREDICTING ON		
		Sector 1	Sector 2	Sector 3
ESTIMATED ON	Sector 1	.236 (1.00)	.186 (0.94)	.258 (0.99)
	Sector 2	.228 (0.97)	.198 (1.00)	.246 (.094)
	Sector 3	.230 (0.98)	.168 (0.86)	.261 (1.00)

Composite Measures[a]

Transfer Likelihood Ratio Index = .216

Transfer Index = .94

Note: The base for computation of the transfer likelihood ratio index and the transfer index measures reported here is the market-shares model.

[a]Composite measures are weighted averages of the corresponding measures across multiple transfers *(19)*.

gate prediction error over that produced by the locally estimated model. The aggregate prediction groups employed in this study are the traffic analyses districts identified in the study area. Sectors 1 and 3 contain 16 districts and sector 2 contains 19 districts.

RMSE and the relative aggregate transfer error for the mode to work and automobile-ownership choice models are given in Tables 8 and 9. The RMSEs average 22 and 24 percent for the conditional mode-choice and marginal automobile-ownership choice models, respectively.

It is interesting to observe that the best (lowest) measures of RMSE for local prediction occur in those sectors for which the locally estimated model had the best (highest) rho-square values in Tables 4 and 5. These results suggest a reasonable level of consistency between these different measures.

TABLE 8 Aggregate Transferability Prediction Indices: Conditional Mode-Choice Model

		PREDICTING ON		
		Sector 1	Sector 2	Sector 3
ESTIMATED ON	Sector 1	.186 (1.00)	.241 (1.08)	.219 (1.01)
	Sector 2	.202 (1.09)	.222 (1.00)	.227 (1.04)
	Sector 3	.197 (1.06)	.224 (1.01)	.219 (1.00)

Composite Transfer Measures[a]

Transfer Root Mean Square Error = .219

Relative Aggregate Transfer Error = 1.05

[a]Composite measures are weighted averages of the corresponding measures across multiple transfers *(19)*.

TABLE 9 Aggregate Transferability Prediction Indices: Marginal Automobile-Ownership Choice Model

		PREDICTING ON		
		Sector 1	Sector 2	Sector 3
ESTIMATED ON	Sector 1	.245 (1.00)	.248 (1.01)	.171 (1.04)
	Sector 2	.281 (1.15)	.246 (1.00)	.205 (1.24)
	Sector 3	.238 (0.97)	.250 (1.02)	.165 (1.00)

Composite Transfer Measures[a]

Transfer Root Mean Square Error = .237

Relative Aggregate Transfer Error = 1.00

[a]Composite measures are weighted averages of the corresponding measures across multiple transfers *(19)*.

The relative aggregate transfer errors are low for all model transfers. They are less than 1.1, except for two transfers of the marginal automobile-ownership model. Further, the pooled values for this measure (1.05, 1.00) indicate a small increase in aggregate prediction error attributable to model transfer.

These results suggest that the use of disaggregate models for aggregate prediction is quite satisfactory. More important, for the purpose of this study, the increased error in aggregate prediction associated with use of transferred models is relatively small.

Overall, both the absolute and relative aggregate prediction measures indicate that transferred disaggregate choice models are effective in predicting aggregate choice shares.

DISCUSSION AND CONCLUSIONS

The mode and automobile-ownership choice models estimated in each sector are statistically significant and account for a reasonable proportion of the variation in the observed choices. An interesting feature of the estimation results is that the automobile-ownership models have substantially better likelihood ratio index (rho-square) values than the mode-choice models, despite the somewhat limited specification of the automobile-ownership model. Specifically, the rho-square values for the automobile-ownership models are generally twice as large as for the mode-choice models. This observation raises the question of whether the better fit of the automobile-ownership model has any impact on the relative transferability of the automobile-ownership and mode-choice models. This question is addressed in the following paragraphs, where the discussion centers on the transferability of models in which the alternative specific constants are adjusted to match the aggregate choice shares in the application environment.

The disaggregate transferability results are evaluated in absolute terms by the transfer likelihood ratio index and in relative terms by the transfer index. The transfer likelihood ratio index values for both the automobile-ownership and mode-choice models are in the same magnitude range as for the corresponding locally estimated models. That is, (a) the transferability for both sets of models is good and (b) the transferred automobile-ownership models are roughly twice as effective as the mode-choice models. On the other hand, the transfer index results indicate that, relative to locally estimated models, the mode-choice and automobile-ownership choice models are equally transferable. The result that improved fit of a model in the estimation environment appears to lead to improved transferability in absolute but not relative terms parallels the results reported by Koppelman and Wilmot (23) in connection with the impact of improved specification on model transferability.

The disaggregate transferability analyses also indicate that transferability is generally higher for transfer into sectors that have high local rho-square values. For example, the automobile-ownership model fits the observed data in sector 3 better than in the other two sectors. The transfer rho-square values reported in Table 7 indicate that the automobile-ownership model is more transferable into sector 3 than into sectors 1 and 2.

These results all indicate that model transfers are most effective when the transferred model is one that would be highly satisfactory if it were estimated in the application environment. Unfortunately, the only way to obtain this information is to estimate the corresponding model in the application environment, which eliminates the need for model transfer. However, the comparative results of the transferability of mode-choice and automobile-ownership models indicate that if there is evidence to suggest that models of particular choice behaviors are generally satisfactory, it is reasonable to infer that such models could be transferred effectively.

The aggregate transfer prediction analyses show little discrimination between the transferability of mode-choice and automobile-ownership models. These results do indicate, however, that the increased error in aggregate prediction associated with the use of transferred models is small (less than 10 percent in 10 of 12 transfers reported). Thus transferred disaggregate mode and automobile-ownership choice models appear to be able to predict aggregate shares satisfactorily, both in absolute terms and relative to locally estimated models.

The transferability analyses reported in this paper provide no clear indication of which sector pairs provide better estimation transfer contexts for transfer of disaggregate choice models in Washington, D.C. This result is not surprising, given that model transfer appears to depend on the fit of a locally estimated model in the application context, and the fact that the mode-choice model provides the best estimation goodness-of-fit in sector 1, whereas the automobile-ownership model provides the best estimation goodness-of-fit in sector 3.

The study reported in this paper leads to two basic conclusions. First, it is concluded that the findings of earlier research concerning the transferability of disaggregate mode-choice models can be extended to automobile-ownership choice models. Both automobile-ownership and mode-choice models exhibit a high degree of transferability at the disaggregate and aggregate levels in the intraurban transfer situations examined in this study.

The second basic conclusion reached in this study is that model transfer is more effective in those choice situations where behavior can be explained better by the mathematical model used to describe choice behavior. That is, if a given choice behavior can, in general, be well represented by a model, transfer of that model will generally be satisfactory. Although this conclusion is consistent with prior expectations, it is valuable that such expectations be confirmed empirically. Further, this study indicates that automobile-ownership level choice is predicted well by a relatively simple disaggregate choice model specification.

ACKNOWLEDGMENTS

The study reported in this paper is a portion of a research project investigating "Conditions for the Effective Transferability of Discrete Choice Models." The project is being undertaken at the Transportation Center of Northwestern University under contract with the U.S. Department of Transportation. James Ryan of the Urban Mass Transportation Administration, who is contract monitor, has provided important advice, encouragement, and support to the research team. Important contributions have been made to the research project by Chester G. Wilmot, Geok-Koon Kuah, Geoffrey Rose, and Albert Lunde. Jo Ann Scott of the Civil and Environmental Engineering Department at Duke University prepared the manuscript.

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Travel Regularities and Their Interpretations: A Discussion Paper

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ABSTRACT

The regularities in travel behavior analyses are examined in this paper. Reasons are investigated for different interpretations of travel regularities caused by (1) differences in basic assumptions, model specification, and selection of analysis unit; (b) differences in selection and evaluation of empirical material; and (c) differences in data used. Criteria for evaluation of meaningfulness and applicability of travel regularities are proposed. Travel-time budget analyses and studies of travel behavior of homogeneous groups of persons are compared as alternative approaches to investigate differences in travel regularities and diversity of their interpretations.

Detecting regularities and establishing relationships in any analyzed phenomenon, process, or behavior is always an important and interesting part of any research effort. Discovering regularities is normally a first sign of understanding the analyzed problem. Often these regularities have useful applications. In human travel behavior, regularities confirmed by several studies from different metropolitan areas can constitute a basis for geographically transferable models and can be used in travel demand forecasts and policy analyses.