Accessibility and Residential Location:
The Interaction of Workplace, Residential Mobility, Tenure, and Location Choices[1]

Presented at the 1996 Lincoln Land Institute TRED Conference

Paul Waddell
University of Texas at Dallas, P.O. Box 830688, GR 3.1, Richardson, TX 75083-0688, U.S.A.

Introduction

Accessibility has long been identified as the central influence in urban theory of residential location, with Alonso (1964) and others formalizing the trade-off between housing and commuting costs in the monocentric model. During the past three decades, however, the assumptions of monocentricity, single-worker households, and exogenous workplace location underlying the monocentric and related urban models are increasingly at odds with empirical observation. Suburban employment centers have overtaken central business districts in importance, a dramatic rise in female labor force participation has made dual-earner households more prevalent than single-worker households, and non-work trips now outnumber home-based work trips. What are the implications of these trends for urban transportation and land use, and how should urban models be modified to account for them?

This paper examines the interactions within single and dual-worker households between workplace location, residential mobility, housing tenure, and location choice. We hypothesize that homeownership and the presence of a second worker both add constraints on household

choices which should lead to a combination of lower mobility rates and longer commutes.

Analyzing a travel survey of Honolulu, Hawaii, we confirm these expectations. We also examine gender differences in dual-earner households, in terms of commute distances and the relative influence of commutes of the male and female workers on the residential location.

Gender differences in travel behavior have been explored previously, with most of the published work concluding that women work closer to home and have shorter commuting times than men (Hanson and Johnston 1985; Howe and O'Connor 1982; Rosenbloom 1988). Some have attributed these differences to the role of women in childrearing, and the resulting need to minimize travel time in order to devote more time to family responsibilities (Madden and White 1980). Others have concluded that the presence of children does little to explain these gender differences (Hanson and Johnston 1985; Madden 1981; Gordon et al. 1989). The

1 This paper is based on data obtained as part of a land -use and travel model development project for the Oahu Metropolitan Planning Organization (OMPO). In particular, we appreciate the assistance of Steve Young, Planning Department at the City and County of Honolulu, and Gordon Lum, Executive Director of OMPO, for their support of this research.

differences have led some to postulate that there is a spatial entrapment of women (Hanson and Pratt 1988; Nelson 1986) that limits their job search and employment opportunities. These findings of shorter work trips for women suggest that women will be more likely to have to change jobs when the family changes residence, and may choose to constrain the job search to locations closer to the residence. Our results confirm the earlier findings of shorter commutes among women in dual-earner households, and that the female work commute has less influence on the residential location choice than the male commute, a result which is consistent with a higher probability of a job change for the female worker following a residential move.

The contribution of the paper, in addition to these specific substantive results, is in the development and estimation of a model that integrates the treatment of several related household choices in a unified framework that can be used for assessing the influence of accessibility on residential location. In particular, treating mobility as a linked choice with tenure and residential location choices allows for more realistic assessment of the potential impacts of transportation or other policies by providing a dynamic framework for assessing marginal changes in residential location. In this context, the paper is a step toward more behaviorally integrated urban models for use in metropolitan planning and policy analysis of land use and transportation interactions.

The paper is organized as follows. The policy and planning context to which this research is relevant is described first. The next section develops the model to be estimated and motivates its specification. A description of the empirical results follows, and a concluding section summarizes the results, relates them to the policy and planning context, and identifies directions for further research.

The Policy and Planning Context

Since the passage of the Clean Air Act Amendments and the Intermodal Surface Transportation Efficiency Acts of the early 1990's, there has been a considerable increase in policy and planning interest in integrated analysis of land use and transportation interactions. While the traditional transportation planning process focuses on the transportation impacts of changes in the distribution of population and employment, the feedback of transportation investments and policies on the distribution of land uses, densities, and prices have not been well addressed by the operational models available to planners and policymakers, such as the DRAM/EMPAL spatial-interaction models (Putman, 1983). In part, this deficiency is due to poor data available for developing such integrated models, but this deficiency is being rapidly addressed by aggressive investments in new large scale household travel surveys and in Geographic Information Systems and parcel-level databases. Many of the newer metropolitan travel surveys are being designed to address emerging travel model requirements for modeling travel behavior from an activity-based perspective, and as a byproduct, are collecting unusually rich detail about the jobs and workplaces of the workers in the households, as well as their shopping, school and other activities outside the home.

A second reason for the deficiency in current models is the relatively non-behavioral foundation of models such as the spatial-interaction class of models that rely on the traditional assumptions of exogenous workplace and single-worker households, the cross-sectional application of the models, and the absence of any representation of the land or housing markets. These deficiencies seriously limit the ability of policy analysts and planners to examine the potential feedback of transportation policies on land use outcomes. The cross-sectional estimation and application of models of residential location implies that all households may costlessly and instantly relocate to adjust to changes in their environment or household conditions. The reality of marginal increments to a durable housing stock, high cost transactions – particularly for homeowners, and limited information about alternatives, make the use of cross-sectional techniques dubious as a basis for policy-relevant predictions.

Earlier papers using cross-sectional estimation of the joint choices of workplace and residence location include Waddell (1993a, 1993b) and Merriman (1994). Others that have examined these linkages include Simpson (1980) and Siegel (1975). The temporal and causal linkages between workplace and residential location choices are complicated by the presence of dual-worker households, and to our knowledge, have not yet been addressed in the literature. In this paper, we do not model the choice of workplace or other labor market decisions, but examine their implications.

We report in this paper on the first phase of a project to develop and apply new metropolitan land use and travel models for Honolulu, Hawaii, based on a new 4,000 household survey conducted in the Fall of 1995 and Spring of 1996. The paper focuses on only one component of the model development: residential mobility and location choices. Other components of the OMPO model under development include a business location component, a land development component, a market clearing component, and a full travel modeling system with which the land use model components will be integrated. The model is based on random utility theory, and is estimated using nested logit techniques.

The paper addresses the question of how households with one and two workers compare in their structure of choices of residential mobility, housing tenure, and location, given the workplace choices made by the individual workers. In this construction, the model is intended to provide an empirical test of whether dual-worker households differ from single-worker households in their mobility, tenure, and location choices, as well as exploring the relationship between these choice dimensions. We attempt to develop a model structure that will support the analysis of the impact of accessibility changes on household choices, given the interdependence of these choices.

Specification of the Model

The model is based on the description of a household location choice as a bundle of choices that include the decision to move, and the subsequent selection of a housing tenure and location. These choices could be made in sequence or jointly, but are clearly interdependent. One motivation for the treatment of mobility and location choice as separate but linked choices is that we intend to model marginal changes in residential location as a function of changes over time in household characteristics and locational characteristics, including such policy-relevant factors as accessibility and housing prices. The model is conceived as a dynamic adjustment to changing conditions, rather than as a cross-sectional static or equilibrium solution. Housing is assumed to be a highly durable good, and residential change at a neighborhood scale is assumed to result from a combination of the mobility of households out of neighborhoods, and from the locational choices made by moving households. The attractiveness of alternative locations might influence the decision to move, however, so the model should allow for some measure of feedback between the tenure and location choices and the decision to move. Tight housing markets and high prices might inhibit mobility, and ample housing alternatives at lower prices might be expected to encourage mobility.

The concept of residential location as a bundle of choices is an extension of the treatment of housing as a bundle of housing services, as is done in much of the literature on hedonic regression of the housing market (see, e.g. Waddell, Berry, and Hoch, 1993). To the extent that the selection of a location involves inseparable attributes associated with the location, the selection of the location inherently involves a simultaneous selection of the bundle of these attributes. We suggest that the hedonic decomposition of housing prices into the implicit prices for the component attributes of the housing has a parallel in the hedonic decomposition of a residential location decision into the component probabilities of selecting the attributes of the location.

We assume that households maximize the utility function given by:

$$U_{ml} = \tilde{V}_m + \tilde{V}_t + \tilde{V}_l + \tilde{\varepsilon}_{mtl}, \quad \forall (m,t,l) \in C_n \qquad (1)$$

where

U_{mtl} is the total utility of the mobility choice m, tenure choice t, and residential location l

$\tilde{V}_m$ is the systematic component of the utility of mobility alternative m

$\tilde{V}_t$ is the systematic component of the utility of tenure alternative t

$\tilde{V}_l$ is the systematic component of the utility of residential location l

$\tilde{\varepsilon}_{mtl}$ is the random component of the utility of alternative (m,t,l)

C_n is the full choice set available to the nth household

If we assume independently and identically Gumbel-distributed random terms, a multinomial logit specification is implied of the form:

$$P(m,t,l) = \frac{e^{\mu(\tilde{V}_m + \tilde{V}t + \tilde{V}_l)}}{\sum_{(m't'l') \in C_n} e^{\mu(\tilde{V}_m + \tilde{V}t + \tilde{V}_l)}} \qquad (2)$$

where m is a scale parameter, assumed equal to 1 in the joint choice multinomial logit model.

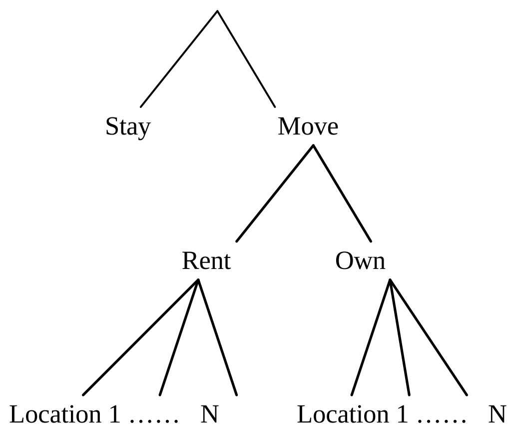
The multinomial logit model assumes that the errors are Independently and Identically Distributed (IIA), which indicates that the alternatives share only observed attributes, and no subset of alternatives share unobserved attributes. A commonly known problem with the multinomial logit model is potential violation of the IIA assumption by problems known as 'red bus-blue bus' problems. These are circumstances in which we add an alternative (e.g. red bus) that is fundamentally equivalent to an existing alternative (e.g. blue bus), and the resulting prediction draws market share from other alternatives that are fundamentally different (e.g. auto). What should happen is that the red and blue bus, which are identical substitutes in every way except color, should split the prior share held by the blue bus alternative.

The typical solution to this problem is to structure the model as a nested logit model, which represents the alternatives as a hierarchy of choices. While it does not necessarily imply a temporal sequence of choices, the nesting structure should capture patterns of correlation among the errors among subsets of alternatives that are more similar to each other. In the context of the proposed model, there are several potential alternative nesting structures, some of which can be logically excluded, and others of which must be empirically tested.

It would be plausible to construct a two-tiered model in which residential mobility (the decision to move) is made, and contingent on the outcome of that choice, a choice of residential location and tenure is made. An alternative structure would be a three-tiered model in which a mobility choice is made, and conditional on the choice to move a tenure choice is made, and conditional on the choice to rent or own, a location choice is made. The appropriateness of these alternative nesting structures can be compared, not only from the perspective of the overall goodness of fit of the model as identified by the Log-Likelihood Ratio, but also from the perspective of the theoretically consistent range of the 'inclusive value' between zero and one. The inclusive value provides an estimate of the attractiveness of the bundle of alternatives under one branch of a nested logit structure. If the inclusive value is 0, then the tiers of choices may be considered totally independent. It the value is one, then the model degrades to a the special case of the multinomial logit model, which would be a joint choice model.

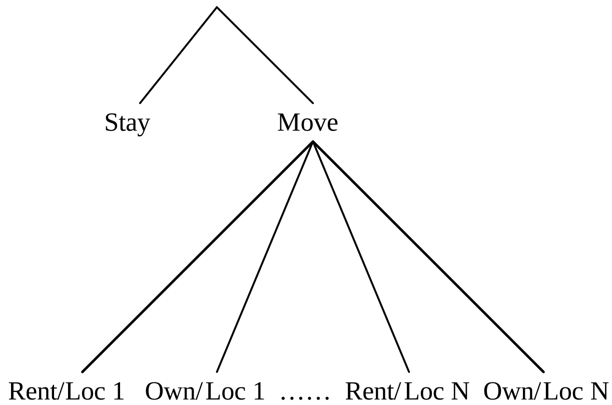
In testing alternative specifications of the model, the three tiered model alternatives had inclusive values that were above one, indicating a misspecification of the model. With a two-tiered structure of mobility choice and the conditional joint choice of tenure and location, the model produced within-range estimates of the inclusive values. Figure 1 below illustrates the structure of the three-tiered nested logit model of mobility, tenure, and location choice.

Figure 1:
Three-tier Nested Choice Structure



The two-tier structure, shown in Figure 2, combines tenure and location as joint choices.

Figure 2:
Two-tier Nested Choice Structure



The three-level nested logit choice probability can be expressed as the product of marginal and conditional choice probabilities, each of which is itself a logit model:

$$P(mtl) = P(l|mt)\,P(t|m)\,P(m) \tag{3}$$

where,

$$P(l|mt) = \frac{e^{\left(\tilde{V}_l + \tilde{V}_{tl} + \tilde{V}_{ml} + \tilde{V}_{mtl}\right)\mu^l}}{\sum_{t' \in L_{mt}} e^{\left(\tilde{V}_{l'} + \tilde{V}_{tl'} + \tilde{V}_{ml'} + \tilde{V}_{mtl'}\right)\mu^l}}, \tag{4}$$

$$P(t|m) = \frac{e^{\left(\tilde{V}_t + \tilde{V}_{tl} + V'_{mt}\right)\mu^t}}{\sum_{t' \in T_t} e^{\left(\tilde{V}_{t'} + \tilde{V}_{tl} + V'_{mt'}\right)\mu^t}}, \tag{5}$$

$$P(m) = \frac{e^{\left(\tilde{V}_m + V'_m\right)\mu^m}}{\sum_{m' \in M_n} e^{\left(\tilde{V}_{m'} + V'_{m'}\right)\mu^m}}, \tag{6}$$

and where

$$V'_{mt} = \frac{1}{\mu^l} \ln \sum_{l \in L_{nmt}} e^{\left(\tilde{V}_l + \tilde{V}_{tl} + \tilde{V}_{ml} + \tilde{V}_{mtl}\right)\mu^l}, \tag{7}$$

$$V'_m = \frac{1}{\mu^t} \ln \sum_{t \in T_{nm}} e^{(\tilde{V}_t + \tilde{V}_{mt} + V'_{mt})\mu^t}. \qquad (8)$$

In order to satisfy the assumptions of the nested logit model, the ratios μ^t/μ^l and μ^m/μ^t must both be positive and less than or equal to 1. This would satisfy the condition that the variances of the random utilities is the smallest at the lowest level of the tree, and cannot decrease from a lower to a higher level:

$$\mu^m \leq \mu^t \leq \mu^l.$$

In the special case in which

$$m^m = m^t = m^l,$$

we obtain the joint logit model (Ben-Akiva and Lerman, 1993).

The household variables hypothesized to influence the mobility choice include the household type, including presence of children, age of adults, the number of full time workers, the number of years each worker has held their current jobs, and income. The number of workers provide a measure of the sensitivity of the mobility choice to multiple workers. It could be argued that multiple-worker households will have a lower propensity to relocate, due to the constraints of a second worker being affected by a relocation. Alternatively, a two-worker household has perhaps a higher likelihood that a job change in either worker will occur, possibly triggering a relocation. The sign and significance of this effect is therefore ambiguous a priori. The presence of children might stimulate or inhibit a move, depending on the residential location. The stage of life cycle of the household, proxied in this case by the age of the primary worker, or male worker in a dual-worker household, is expected to reduce the probability of moving. Older households are less likely to move. The length of employment provides a measure of the linkage between job and residence. To the extent that residential location is closely tied to workplace, the length of employment should be negatively associated with residential mobility.

Attributes of locations expected to influence locational preferences include housing costs by tenure, the income distribution of the neighborhood, commuting distance of the primary workers, and generalized accessibility to employment and population. These locational characteristics would be expected to be preferred differently by households with varying characteristics, so the household income is interacted with housing costs, and separate models are estimated for single-worker and dual-worker households, with separate coefficients for renter and owner households on the locational characteristics within each model. Employment and population accessibility were computed as the distance-discounted sum of employment and population, respectively, across all zones j for each zone i. For each zone j, the employment is divided by the network travel distance from zone i (in tenths of miles), and this value is summed across all zones j. This measure provides a generalized accessibility to employment, which also serves as a general proxy for degree of suburbanization. The population accessibility variable is computed the same way.

$$Access_i = \sum_{1}^{J} \frac{Activity_j}{(Impedance_{ij})}$$

The monocentric model predicts that households will trade off longer commutes for greater space in more suburban locations. The model we estimate generalizes this trade-off to account for the case of dual-worker households, allowing the individual commutes of both workers to influence residential location choices, and balancing these against locational amenities and housing costs.

Since income is a household characteristic that does not vary across alternatives in the model, it cannot be entered independently, but is instead interacted with other variables that do vary across alternatives. The housing cost variable was interacted with income in the form of a cost to income ratio, e.g. the annualized median monthly rent or mortgage (depending on the housing tenure) divided by the annual household income. There is ample reason to expect that households do not minimize their expenditures on housing, however. Since housing is considered a normal good, households are expected to translate income gains into residential moves into more expensive housing with greater amenities. A second variable was constructed to capture the degree to which households translate income gains into residential location choices that maintain their cost to income ratio within a preferred range. This was computed as the absolute value of the difference between the mean cost to income ratio and the observed cost ratio for the individual household.

A similar measure was conceived to identify the degree to which households choose neighborhood locations based on the degree of similarity between their socio-economic characteristics and those of the neighborhood. This measure was constructed as a dissimilarity measure of the household income to the neighborhood median household income, or more specifically, as the absolute value of the difference between the household income and the median household income of the neighborhood. Due to the high correlation between median income and median housing costs by neighborhood, however, this measure also correlates highly with the earlier measure of housing cost. While both variables would be useful to enter in the model, the correlation between the two at the scale of the census tract (the level at which the median housing costs and incomes were available) precludes their simultaneous use in the model. As a result, only the results using the housing cost ratio are reported here. It is hoped that more disaggregate zonal information in the future will allow both measures to be included.

The model is estimated using maximum likelihood, with models estimated separately for households with one full-time worker and for those with two or more full-time workers. In the case of multiple-worker households, commute information was used only for the respondent and spouse. Non-family multiple worker households were omitted from these estimates. In dual-worker households, the data were arranged to place male workers as the first, and female workers as the second worker, as a matter of convenience to distinguish workers by gender. In the single-worker households, the results on worker characteristics combine male and female workers.

Data Preparation

A few comments on the arrangement of the data for estimation are useful for clarification. The unit of locational choice is the Traffic Analysis Zone (TAZ), defined for transportation planning purposes as groups of census blocks, and representing 761 discrete locations. Since this would be an extremely large set of alternatives to include in the model estimation, and since it has been shown by Ben-Akiva and Lerman (1993) that a random sampling of alternatives generates consistent parameter estimates, we adopt a random sampling strategy.

We combine the chosen alternative with four non-chosen alternatives, randomly sampled from the universe of zones, with replacement. We then merge locational characteristics to the non-chosen alternative records, and compute commute distances for workers from their workplace to the zone of residence in each non-chosen alternative. The travel distances are from a distance skim of the transportation planning network. At the time of this analysis, congested travel time estimates were not available, so network distances were used instead.

The resulting dataset contains five alternatives for each household. The first alternative is designated as the stay alternative, and is coded with a one in the dependent variable, choice, if the household moved into its current residence before 1990. If the household moved in in 1990 or later, it is classified as a mover household for the purpose of model estimation, and is coded as zero in the dependent variable for the stay alternative. The alternatives were arranged such that households that did not move had their actual choice placed in alternative one, households that moved and chose to rent had their choice placed randomly in alternatives two or three, and households that moved and chose to own had their actual choice located randomly in alternatives four or five. In the rent alternatives, housing costs and housing unit counts were based on median contract rent and rental units, and in the own alternatives, these variables were based on median monthly owner costs and owner-occupied housing units. The data, in short, were structured to identify five elemental choices: stay, rent1, rent2, own1, and own2. This arrangement allowed for estimation of nested logit models using the full-information maximum-likelihood procedure in the Limdep econometric software package.

Results

The model estimates for the two-level nested logit model for single and dual-worker households are presented below in Table 1. The coefficients and asymptotic z-scores (a maximum-likelihood analog of the OLS t-statistic) for each variable are presented for single and dual-worker households. Coefficients were estimated for renters and owners on each locational variable, by identifying separate coefficients in the utility function for the rent and own alternatives.

The results of the mobility level of the two-level nested logit provide logical results and confirm the appropriateness of a nested logit specification for the model, with inclusive values on the stay alternative between zero and one on both models, and statistically significant. Recall that the three-tiered model structure was estimated but the inclusive value estimates were above the value of one, indicating a misspecification. Hence, only the two-level results are presented.

The base probability of the stay alternative, captured by the alternative-specific constant, was virtually identical in the single-worker and dual-worker model estimates. Modifying the base probability are age and years at current job. One difference between the two models estimated is that single-worker households had a larger effect of age on the probability of choosing to stay, whereas the dual-worker households appeared to distribute this effect between the age variable and the years at current job of both workers.

The base probability of renting, captured by the alternative-specific constant on the second and third alternatives, indicates similar base probabilities for single-worker and dual-worker households. Income appears to be the only significant influence on the probability of renting, with the expected negative sign.

Turning to the coefficients related to the location choice, we find that the commuting distance of the primary workers are consistently significant, and very systematic in the magnitude of the coefficients. The coefficients indicate the degree that a given increase in commuting distance is translated to a lower probability of selecting a location. The largest coefficients on commuting

Table 1: Results of Nested Logit Estimation

	Single-Worker Households		Dual-Worker Households	
Variable	Coefficient	z (b/s.e.)	Coefficient	z (b/s.e.)
Stay (alt-specific	-1.3165	-3.844**	-1.2694	-4.644**
Stay*Income	-0.799E-05	-1.729*	-0.356E-06	-0.107
Stay*YrsJob1	0.543E-02	0.747	0.239E-01	3.256**
Stay*YrsJob2	---	---	0.398E-01	2.725**

Stay*Age	0.705E-01	6.334**	0.390E-01	4.129**
Stay*Child	0.287E-01	0.242	0.1013	1.039
Rent (alt-specific	3.2407	3.925**	4.032	4.045**
Rent*Income	-0.295E-04	-6.102**	-0.207E-04	-3.957**
Rent*Age	-0.183E-02	-0.144	-0.129E-01	-0.865
Rent*Child	0.357E-01	0.242	-0.1251	-0.833
Commute1-Renter	-0.173E-01	-10.422**	-0.166E-01	-9.901**
Commute1-Owner	-0.104E-01	-5.986**	-0.104E-01	-4.630**
Commute2-Renter	---	---	-0.883E-02	-5.846**
Commute2-Owner	---	---	-0.417E-02	-2.277**
EmployAccess-Renter	-0.348E-04	-1.943*	-0.980E-04	-3.815**
EmployAccess-Owner	-0.303E-05	-0.052	-0.163E-03	-1.850*
PopulatAccess-Renter	-0.901E-04	-2.878**	-0.953E-04	-2.175**
PopulatAccess-Owner	-0.842E-04	-1.169	0.863E-05	0.088
AbsHousCost-Renter	-0.9574	-1.547	-4.9810	-4.846**
AbsHousCost-Owner	-0.6874	-1.194	-4.0630	-5.058**
HousingUnits-Renter	0.305E-02	9.170**	0.273E-02	6.628**
HousingUnits-Owner	0.499E-03	3.779**	0.507E-03	3.607**
Nomove (inclusive	1.000	---	1.000	---
Move (inclusive value)	0.8137	6.522	0.5110	5.269**
Log-Likelihood				
Estimated	-810.8		-782.9	
Restricted	-1262.2		-1181.1	
Rho-squared	.357		.337	
N	813		820	

** Indicates significance at the 5% level
* Indicates significance at the 10% level

distance are for single-worker households, with almost identical coefficients for the male worker in dual-worker households. The magnitude of the commute distance coefficients is almost twice as large for renters as for owners in both single-worker and dual-worker households, which suggests that renters, with lower transactions costs for moving, and perhaps fewer neighborhood attachments, are more likely to move and select a residential location that reduces their commute distance. This finding holds for both single-worker and dual-worker households.

The commute distance coefficient for female workers in dual-worker households is approximately one half of the magnitude of the coefficients for the male worker, and for the single worker households (regardless of gender of the single worker). This smaller coefficient on commute distance does not mean that female workers have a higher tolerance for commuting. In fact, the opposite appears to be true. A simple comparison of mean travel distances for male and female workers in dual-worker households shows that the females commute almost half the distance, on average, as do the male workers in these households. See Table 2 below for these mean commute distances. A plausible explanation that reconciles these two findings is that the female workers are more likely to change jobs after a residential move, and would select a new job with a shorter commute.

The employment accessibility variable, measuring both generalized job access and the degree of urbanization or density, had negative coefficients for both single-worker and dual-worker renter households, with larger effects for dual-worker households. Owner dual-worker households had a negative coefficient significant at the 10% level, and renter single-worker households did not

Table 2: Mean Commute Distances by Tenure and Household Type

	Single-Worker Households	Dual-Worker Households
Renter	5.4	Male: 6.9
		Female: 4.4
Owner	7.8	Male: 9.9
		Female: 6.6

have a significant coefficient on this variable. The pattern suggests that, controlling for the actual job accessibility of the individual workers, households prefer lower density locations, with homeowners more constrained than renter households in realizing their locational preferences through relocation, and single-worker owner households least able to do so. The population accessibility variable produced somewhat similar results, with negative and significant coefficients for renters in both single-worker and dual-worker households, but insignificant results for owner households of both types.

The housing cost ratio variables, measuring the degree of deviation from the mean cost ratio of the respective single-worker or dual-worker group, had less than significant negative coefficients for single-worker households, but highly significant negative coefficients for dual-worker households. Interestingly, the magnitude of the coefficients is quite similar between owner and renter dual-worker households. These results may suggest that single-worker household have a higher degree of variance in their housing cost ratio, perhaps owing to more heterogeneity within the group. For example, female single-parent families are included in the same group as male single-person households, though these groups may sustain quite different average housing cost ratios. An alternative specification using the simple ratio of annualized housing costs to annual household income was attempted, but provided insignificant results on this variable.

The coefficients on the quantity of housing units of the relevant tenure were all quite significant and positive, as expected. These variables simply provide a scale effect for the number of potential housing opportunities available within a zone. The magnitude of the renter coefficients were almost identical between the single-worker and dual-worker results, and were quite substantially larger in magnitude than the owner coefficients on housing quantity. This result may be due to the relative concentration of rental housing opportunities within high density multi-family complexes within relatively fewer zones.

Conclusions and Directions for Further Research

The results reported here are the first in a series of results that will be reported from the development of an integrated urban simulation model for the Oahu Metropolitan area. Several refinements will be made to the residential mobility and location model reported here, and additional model components will be developed representing business location, developer construction and redevelopment activity, market clearing for land, housing and nonresidential space, and an integrated travel model system. The model is intended to begin to address the need for more behaviorally realistic models that incorporate market and policy representations, allowing regional planners to begin to address in a more integrated fashion the feedbacks between urban development and transportation systems and policies.

Among the specific improvements to the models will be a series of tests of alternative stratifications of households for model estimation. Candidates include some subset of the cross-classifications of income, number of workers, age of adults, and presence of children.

A second area needing substantial attention is the degree to which we attempt to link the individual workers to their workplaces. Keeping this linkage potentially forces the use of microsimulation techniques, and raises substantially the complexity of the models. To the extent that an extended travel model is envisioned based on an activity-based approach, this linkage may be needed to support the travel models. Preserving the linkage also requires a more rigorous and complex model of the many potential nesting structures of labor market and housing market outcomes, including the decision of individuals in the household to work, and if so, whether to work full or part-time, when to retire, when to change jobs, which job to accept, etc.; in addition to the residential outcomes modeled here. This realism may come at substantial cost in complexity, and must be compared to a simpler model on the basis of the accuracy of the predictions made and the feasibility of obtaining reasonable model estimation results.

A third area that will be substantially enhanced is the specification of additional measures of accessibility, including transit and highway access measures. This will await the completion of the travel network and model calibration in order to obtain reasonable travel times and costs. It may also require further work to disaggregate the description of the residential locations. Here we used census tract medians for housing costs, and no housing quality or size measures. These measures are available at a the parcel level from the City and County of Honolulu geographic information system, and could be summarized to either the census block or traffic analysis zone. Only by further spatial disaggregation can we hope to avoid some of the correlation problems that prevent us from separating spatial attributes of locations at a higher level of aggregation.

The results reported here confirm the reasonableness of the proposed approach of modeling residential mobility and tenure and location choice using a nested logit formulation. The results are consistent with other research findings, for example, in the area of gender differences in travel, and confirm the hypothesis that dual-worker households exhibit different preferences in the housing market than do single-worker households. Models assuming single-worker households may provide unrealistic predictions, particularly in reference to the influence of accessibility on residential location. Finally, the linked treatment of mobility and locational choices appears to provide a sound basis for developing a capacity to estimate the marginal impacts of transportation and other policies on residential location outcomes.

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Table 3: Variable Definitions

Variable	Description
Stay (alt-specific	Alternative-specific constant for the stay (not move) alternative
Stay*Income	Stay dummy interacted with household income
Stay*YrsJob1	Stay dummy interacted with years on job of worker 1
Stay*YrsJob2	Stay dummy interacted with years on job of worker 2 (female)
Stay*Age	Stay dummy interacted with age of respondent
Stay*Child	Stay dummy interacted with number of children
Rent (alt-specific	Alternative-specific constant for rent
Rent*Income	Rent dummy interacted with household income
Rent*Age	Rent dummy interacted with age of respondent
Rent*Child	Rent dummy interacted with number of children
Commute1-Renter	Commute distance (.1 miles) for worker 1 if renter
Commute1-Owner	Commute distance (.1 miles) for worker 1 if owner
Commute2-Renter	Commute distance (.1 miles) for worker 2 (female) if renter
Commute2-Owner	Commute distance (.1 miles) for worker 2 (female) if owner
EmployAccess-Renter	Employment accessibility (gravity with exponent 1) if renter
EmployAccess-Owner	Employment accessibility (gravity with exponent 1) if owner
PopulatAccess-Renter	Population accessibility (gravity with exponent 1) if renter
PopulatAccess-Owner	Population accessibility (gravity with exponent 1) if owner
AbsHousCost-Renter	Absolute value of housing cost to income ratio - average, if
AbsHousCost-Owner	Absolute value of housing cost to income ratio - average, if
HousingUnits-Renter	Number of renter-occupied housing units
HousingUnits-Owner	Number of owner-occupied housing units
Nomove (inclusive	Inclusive value for nomove branch, fixed at 1.00
Move (inclusive value)	Inclusive value for move branch, estimated