DETERMINANTS OF RESIDENTIAL LOCATION DEMAND:
IMPLICATIONS FOR TRANSPORTATION POLICY

by

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Abstract

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Submitted to the Department of Civil Engineering on June 30, 1978 in partial fulfillment of the requirements for the degree of Master of Science.

The residential location and housing choices of urban residents have large implications for residential densities, travel patterns, demand for urban services, and transit demand. This is a study of intra-urban residential mobility and the behavior of movers in the choice of a location, housing type, and auto ownership. A sequential model framework is used to divide household decisions into three groups: (1) moving and housing submarket decisions, (2) the capital expenditure-related decisions of a home (housing type and location) and an auto ownership level, and (3) travel mode and destination decisions for work and non-work travel.

Previous empirical research is reviewed to highlight the different nature of moving and residential location decisions. Using the 1970 Minneapolis -St. Paul home interview survey, a sequential-recursive logit model of these decisions is then calibrated. Implications of the model coefficients for public policy, and use of the model for transportation policy, are briefly discussed.

Key elements of this study are:

(1) The model of residential location and housing choice is dynamic, since only the marginal change in location and housing choice patterns is estimated.
(2) The specifications of factors in location demand is expanded beyond economic considerations to include estimates of the effect of crime, school quality, neighborhood land use, and demographic composition, as well as search distances, on the location choice of movers.
(3) A recursive model is utilized, in which moving decisions depend in part on the estimated utility of current and alternative locations, and location and auto ownership decisions depend in part on estimates of the travel accessibility for every alternative choice.

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CHAPTER 1

INTRODUCTION AND SUMMARY

This is a study of the residential location behavior of urban households. It is motivated by the broad policy implications of future land use patterns, and a belief that future residential location may be best understood in terms of the changes from current patterns brought about by individual moving decisions. Section 1.1 is a discussion of the basic policy motivation of the study, and an argument for the importance of understanding the determinants of residential location patterns. The perspective for studying housing, location and auto ownership decisions of consumers is outlined in Section 1.2, along with the unique elements of this analysis. Findings from the statistical models estimated are summerized in Section 1.3 An overview of the remaining chapters is presented in Section 1.4.

1.1 Implications of Residential Land Use for Policy and Planning

Policy Implications

The dispersed pattern of urban growth of the last 30 years has been associated with profound changes in travel patterns, lifestyles, and the distribution of urban services. Residential location patterns, in particular, have clear implications for the efficiency of local public services. The post-World War II residential decentralization of cities has created the need for larger coverage areas for school locations, police and fire services, water, sewer and power systems, and road networks. The additional operating expenses borne by local governments from dispersed, large-lot single-family home development instead of, for example, clustered townhouse development, has been estimated to be as high as 100% for street costs, 42% for utilities and 18% for school costs (Real Estate Research Corp., 1977). Perhaps most dramatic, however, is the large scale effect of decentralized residential growth on metropolitan-wide travel.

Transportation, as the spatial link between urban activities, occupies a significant proportion of the land in American urban areas. Streets alone occupy 25 - 30% of the developed areas of most cities, and over 55% of the land in lower density cities like St. Petersburg, Florida (Bartholomew, 1955; Niedercorn & Hearl, 1965). Part of the reason for higher transit operating costs per passenger in recent years is the trend toward longer length trips with more dispersed ridership -- a direct result of suburbanization.

The effect of alternative urban forms on trip lengths and mode of travel has been the subject of a number of studies (Balkus, 1967; Rice, 1978). The provision and use of transit services can be directly related to residential densities (Black, 1967; Pushkarev and Zupan, 1977). Reviewing transit ridership in the U.S. urban areas, Pushkarev and Zupan find that transit service is minimal at densities below 7 dwellings/acre, but rises to account for over half of all person trips where densities exceed 60 dwelling/acre. Similarly, auto ownership rates are lower in areas of higher residential density, even after controlling for household size and income differences.

Residential land use policy affects transit use through its effect on distances between urban activities, besides population density. Increasing residential density close to a downtown can generate far more transit demand than a similar residential density located farther away. Pushkarev and Zupan estimate that, for a downtown with 10 million sq. ft., doubling a residential density from 5 to 10 dwellings/acre within one mile of downtown would increase transit trips by 17 times as much as if that residential density increase occured 10 miles from downtown. The lesson for transit planners, then, is that while recent policy to improve the efficiency of existing transportation facilities (TSM) may be useful, effective solutions to urban transportation problems are likely to require the formulation and implementation of good development plans.

Interest in encouraging public transit use as an alternative to private auto travel stems from desires to minimize traffic congestion, air pollution, and the large amounts of urban land taken up by auto-related uses, as well as reduce national energy consumption. The relationship between residential land use and transit demand suggests that land use policies may in the long run be more successful than transit fare, schedule or route changes as a means of increasing transit use and decreasing auto use. Then too, as Wilfred Owen (1976) points out, land use policies that reduce distances between housing and jobs can save significant amounts of energy aside from any transit shift. For transit planners, there is a clear need to better understand the effects of residential densities, urban structure, and socio-economic factors on travel.

The relationship between land use and transportation system characteristics is not unidirectional. Not only do urban density and distances affect travel demand, but transportation system access could have real effects on urban development. For land use and urban growth planners, it is important to understand the role of transportation systems in influencing residential and commercial development. The fact that accessibility to other activities is an important consideration in residential (and commercial) location is proven by the very existence of cities. There is also strong historical evidence that suburban growth was initially facilitated by the introduction of streetcars around the turn of the century (Warner, 1962), and expanded in the post-World War II period as road system improvements and auto ownership increases made dispersed suburban living feasible (Schaeffer and Sclar, 1975).

While the historical relationship between transportation access and suburban growth does not imply that increased public transportation investment can reverse residential decentralization, this is exactly what some public transit interests would like to believe.

This desire is understandable, both because the growth of transit services requires residential densities to become sufficiently high to generate reasonable demand, and because transit system expansion subsidies need a benefit rationale that goes beyond their contribution to improving mobility for small segments of the population. "The mission of UMTA" has even been stated as "to encourage efficient land use patterns and restore central cities" (Kenneth Orksi, 1977). This has lead to new UMTA programs for coordinated high-density residential and commercial development of land use around transit stations. The true impact of transit service on improving the attractiveness of residential areas as places to live is still not well understood.

Implications for Travel Forecasting

The dependency of transportation demand on land use has been recognized at least since Mitchell and Rapkin (1954), and land use forecasts have been a part of transportation planning models in the large urban transportation studies of the 1960's (e.g., Chicago, 1960; Penn-Jersey, 1965) and the currently-used Urban Transportation Planning System. Long-run mode choice prediction requires "permitting travel mode shifts from changes in land-use activities and socio-economic characteristics as well as transportation level-of-service" (Rice, 1978). Unfortunately, the prediction of future residential densities and land use, and their sensitivity to public policy, is still crude.

The potential for change in residential location patterns is very real. Approximately 20% of the U.S. population changes dwelling every year (Moore, 1972). Over the 1970-1975 period, 42% of the population moved at least once. Nearly half (45%) of the moves were intra-urban (U.S. Bureau of the Census, 1975). While housing supply is inelastic in the short run, there is still the potential for shifts in housing demand between suburban and central city areas.

The critical nature of consumer residential location decisions comes from the fact that urban travel characteristics are very dependent on the spatial characteristics of urban activities. Within the control of individual families, these spatial characteristics include distances from home to work, shopping and other activities (as determined by residential location choices), and residential densities (as determined in part by housing type choices). Residential location choices are often interrelated with auto ownership decisions, which also clearly affect urban travel characteristics.

It has been argued that there is a need by planners and decision-makers to better understand how transportation investment creates change in land use, as well as how existing land use patterns or development plans create transportation needs. As residential land use in the long run hinges on the preferences of individual residents for various housing types and locational environments, this leads to a series of important policy questions about individual behavior responses to transportation policy:

1. What are the impacts of major transit investment on households' locational decisions and related auto ownership levels?

2. Will rising gasoline costs and auto prices lead households to relocate nearer to their workplaces and/or reduce auto ownership?

3. How would the imposition of carpool and bus lanes (which lead to overall decreases in road capacity for private auto travel) affect residential location patterns and related auto ownership rates?

4. How would automobile restrictions affect the viability of central city areas as a residential location?

To estimate the impact of such transportation policies on location and mobility-related consumer decisions, a predictive model of residential location demand is necessary. A more realistic model of household location behavior would also take into account the role of crime rates, physical characteristics of the housing stock, lot sizes, school quality, and population diversity as factors encouranging population decentralization from central city areas, and hence discouraging transit use. It is possible, then, that transit demand may remain low as long as high density development in general, and central city areas in particular, are viewed as unattractive by many people. Population recentralization and long-run transit demand may be more sensitive to the social and physical aspects of city neighborhoods than to urban transportation system characteristics. If so, housing and land use policy may be as effective in influencing transportation demand as direct transportation investment. Transportation planners might do better to accept individuals' locational life style preferences and turn from heavy investment in radial travel to the implementation of transportation systems that can serve widely dispersed activity locations.

1.2 Perspective: Understanding Consumer Behavior in Location-Related Decisions

After a review of theories and empirical studies of the motivations and behavior of urban households in their residential choice, an empirical model of residential location and auto ownership rates is presented. It is based on two key assumptions:

(1) Aggregate changes in residential location patterns are nothing more than the sum of individual household location decisions.

(2) Future location patterns depend on the decisions made by future movers and new households. Current land use patterns are products of historical factors and equilibria that may no longer exist.

The incremental nature of the future residential location patterns is dependent on residential mobility rates. Most current residential location models shed little information on factors why some households decide to move to new residential locations while others do not. As Moore (1972) points out:

> "Study of individual changes of residence provides many insights into the ways the broader urban structure contrains individual behavior. However, if we focus our attention at a different scale, we can see that these same changes of residence also modify the broader structure. It is the relocation of large numbers of households with varying characteristics which provides the basic mechanism for changes in the composition of neighborhoods... An understanding of the processes which generate these flows and an evaluation of the net outcome of flow and counter flow provide and essential input to the development of dynamic models of urban structure."

It is clear that the projection of future residential location patterns and transportation demand can benefit from a better understanding of consumer residential choice decisions and moving behavior. For transportation policy analysis, it is important to understand the relative importance of transportation factors versus other factors in determing urban location patterns. Accordingly, a disaggregate behavioral model of residential location and auto ownership decisions is estimated. A choice model methodology is used to predict:

- Who will move in a given year?
- Where will they move from, and where will they relocate?
- What type dwelling unit structure and tneure type will they choose?
- What will be their auto ownership level?

Logit analysis is applied to estimate the role of (1) household characteristics, (2) housing attributes, (3) neighborhood quality dimensions, and (4) transportation accessibility to workplace and shopping in determining the residential location of recent movers.

The location decisions of individuals are modeled in terms of a sequence of:

(1) the decision to alter one's residential location and the choice of tenure type submarket;

(2) the choice of residential location, housing type and auto ownership, given mobility and tenure type decisions.

The basis of the location choice model is the assumption that, within a given urban area, households face a finite set of alternative places to live. A sequential approach to residential mobility and location choice is adopted because theoretical and empirical research on household moving behavior indicate that residential mobility and location choice decisions are influenced to a considerable extent by different sets of factors. The sequential approach involves prediction of the decision to move and then prediction of location choice given the decision to move.

The attractiveness of multi-family apartment buildings relative to single family homes is one dimension of housing choice that can have important consequences for future .

residential densities. Housing type choice is modeled jointly with location choice in part because housing types and residential locations are highly correlated. Auto ownership level is modeled jointly with location choice because it is auto ownership level and location that together determine household accessibility to work, shopping, and other activities.

Present residential location models as a group suffer from the omission of those behavioral factors underlying the dynamic nature of residential mobility and neighborhood change. As a result, urban spatial implications of policy issues may be erroneously predicted by use of present models and forecasting techniques.

Unique elements of the models developed here are:

1) The modelling of residential location is dynamic, in that only marginal change in location patterns from the current situation is estimated. Residential mobility and location choice are related in a sequential-recursive framework. Since location choice is estimated only for recent movers, problems of households in long-term housing consumption disequilibria that nevertheless do not move are eliminated.

2) A better specification of behavioral factors in location choice and neighborhood change is offered, including as independent variables:

   - estimates of the role of various locational aspects ---crime, school quality, neighborhood land use and population characteristics;

- an estimate of differential household knowledge about spatial alternatives in terms of the distance of alternative locations from the previous residential location;
- estimates of preference for avoidance of crime and locational accessibility costs in terms of the change from the prior situation;
- Measures of spatial opportunities in terms of housing (structure types, size, and tenure type) submarkets; and
- an estimate of the difference between current housing, location and accessibility consumption and the expected utility of alternative spatial opportunities as a factor in residential mobility decisions.

The residential location model presented is an attempt to measure the effect on location patterns of socio-economic class migration movements and neighborhood quality factors, as well as the better-understood time and cost factors that make up traditional economic models of consumer behavior. The attempt is to evaluate the relative roles of transportation service and non-transportation factors in residential location demand, and hence, urban land use patterns.

There is a clear need for far more work on the calibration of models to predict future residential location demand. The analysis presented in this study can only estimate the direction of effects of policies on location demand. Improved location models would be useful to help define consistent measures of long-run consumer benefit from transportation investments that result in improved accessibility.

1.3 Summary of Findings

Use of a sequential or recursive logit model for moving, location, and travel choices was found to yield results consistent between the three steps. The extension of housing and location decisions to a dynamic framework is thus very feasible as a means of forecasting marginal change in location demand. Despite an argument made for separating mode-to-work travel choices from housing, location and auto ownership decisions, though, coefficient estimates indicate that a joint framework for modelling those decisions would do equally as well as the sequential approach.

Measures of search distance, relative crime level, age differential, and income differential factors were all found to yield significant negative effects on demand for given locations. Evidence of the positive effects of school quality and accessibility were also found. Attempts to relate property taxes and housing values to housing and location demand were, however, less successful. Taxes and housing values are likely to be related to still unmeasured municipal and housing quality attributes.

The housing-type choice of a house over an apartment was highly related to number of children in the household, while auto ownership level was a positive function of income and number of licensed drivers in the household. The addition of interaction terms for various housing type and auto ownership combinations assures that any change in either of those dimensions of choice will affect choice decisions along the other dimension.

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The estimation of tenure type choices, which placed movers into owner or rental submarkets prior to the estimation of housing structure and location choice, reduced the number of housing type alternatives and allowed use of separate measures of housing structure and location attributes for each submarket. Tenure type choice was found to be dependent on age of household head, number of children, and household income.

For an analysis of location change over time, a key component is the estimation of moving decisions. Besides the negative effects of age on moving, the generalized attraction of locational alternatives had a significant positive effect on the propensity to move. Use of such a weighted function of location and housing attributes appears to be a useful means of relating moving rates to changes in housing market, neighborhood quality and/or travel accessibility.

The estimated model parameters yield elasticities of demand for location, housing types, and auto ownership levels. In this way, it is shown that neighborhood quality and transportation services can have effects on the moving, residential location and density decisions of various prototypical households. These models of consumer behavior can also be applied to predict changes in aggregate patterns of residential location and density demand.

1.4 Overview of Remaining Chapters

Chapter 2 is a review of theoretical and empirical research on the residential mobility and location choice behavior of urban households. It focusses on the different nature of factors affecting moving decisions and location choice, and highlights the importance of demographic and

neighborhood quality considerations that are often ignored in traditional economic models of residential location behavior. Chapter 3 discusses different modelling perspectives for the time dimension in residential location behavior, and the definition of location choice sets. The joint and sequential forms of the multinomial logit model are then examined.

A specific sequence of models for moving, housing, location, auto ownership and travel choices is presented in Chapters 4 and 5. Chapter 4 outlines the sequential model structure and presents definitions of the explanatory variables. Coefficient estimates are presented and discussed in Chapter 5. Implications of the models for transportation policy are briefly discussed in Chapter 6.

CHAPTER 2

REVIEW OF THEORETICAL AND EMPIRICAL RESEARCH

Urban residential location patterns have been studied by social scientists from different disciplines using different techniques. It is therefore not surprising that there is a lack of consensus about the residential location process. Methodologies have varied from simple crosstabulation analysis to multivariate econometric models to comprehensive regional land use simulations. Levels of sophistication have differed greately, as have findings. Comparability between studies is a thus major problem. Theoretical models and land use simulations may be found guilty of assuming a priori that only a certain set of factors affect patterns of location behavior. Simple tabulations and correlations may be criticized for their naive failure to control for related factors. Retrospective surveys may be faulted by a tendency of respondants towards self-justification. Despite all of these obstacles to comparability, this section attempts to summarize the factors that have generally been recognized in the literature as affecting residential mobility and location patterns.

The traditional economic (bid-rent) model of residential location is reviewed in Section 2.1, as well as some urban land use simulation models. These models have in common the assumption that the commute to work is a major factor in the residential location decision of households. Sections 2.2 and 2.3 review empirical analyses of residential location patterns and moving behavior. These studies, many of them conducted by geographers and sociologists, generally find that housing unit and neighborhood considerations as well as household characteristics, play a major role in the residential mobility and location choice of households. These findings cast doubt as to the validity of location models that are based primarily on travel to work considerations. Nevertheless, evidence suggesting that accessibility may be a factor in the relocaion decisions of some households is offered in Section 2.4, which reviews studies of accessibility changes associated with moves. Conclusions from this chapter are discussed in Section 2.5.

2.1 Behavioral Assumptions in Theoretical and Simulation Models of Residential Location

In contrast to studies designed to merely examine relationships between various factors and residential location patterns, location models purport to explain or predict individual or aggregate behavior in urban residential location. Both theoretical models and comprehensive land use models are examined here.

Bid-Rent Theory

The earliest models of urban location were based on the principle that workers seek to minimize distance to work by locating close to their workplace. Wingo (1961) described the marginal value of residential land in terms of two characteristics -- "a natural endowment", and a quality of location with respect to an array of economic activities. Accessibility is the relative quality accruing to a parcel of land from its relationship to the transportation system. Since the journey to work is considered to be both the most significant form of personal movement and that with the lowest price elasticity of demand, a gradient of residential density is obtained based on the value of space at each location and the transportation cost of commuting to work from that location.

Closely related is the bid rent theory of location, as expressed in terms of land value by Alonso (1964) and Wheaton (1974), and in terms of housing value by Mills (1972) and Muth (1969). The model is based on the classical assumption that each household has a utility function (U) for various goods, which it tries to maximize subject to the limits of its income (y). The narrow nature of these models is revealed by the categorization of goods consumed. In its basic form, households face the decision of consumption among three goods: the quantity of land used for housing (q), the distance to the central city (t), and a composite of all other commodities (z). Land and the composite good are superior goods (i.e., they are positively valued) while travel cost to the central city is an inferior good (i.e. it is negatively valued). Thus,

$$\frac{du}{dq} > 0, \frac{du}{dz} > 0, \frac{du}{dt} < 0 .$$

Households maximize their utility

$$U = u\ (q,t,z)$$

subject to the budget constraint of a fixed income

$$y = p(t)\ q + K(t) + P_z\ Z$$

where: $P(t)$ = price of land at distance t

$K(t)$ = cost of community from distance t

P_z = price of z.

The theory explains residential location patterns through household preferences for living space and convenient access to employment. Equilibrium location involves trading off accessibility to the central employment zone with the demand for housing or land. Assuming strong tastes for housing and/or land, higher income households can more easily afford to incur commuting costs because they are able to save on the total cost (location rent) by consuming larger qualities of land or housing at outlying locations. The result is a tendency for higher income households to bid for places further out from the central city employment center.

Bid-rent models have been extended to include non-travel location factors. Wheaton (1974) estimated utility functions for different socio-economic groups in terms of the size and age of dwelling units, average community income, and shopping access as well as travel time to work. That model, however, was limited to workers in the CBD, thus perserving the dubious assumption of a monocentric city.

Urban Simulation Models

The series of comprehensive land use models based on Lowry (1966) are mathematically more sophisticated but behaviorally as simplistic as the basic bid-rent theory. The Lowry models (including Bass, Tomm, Plum) (see Goldner, 1971) iteratively allocate the population among locations in the urban area, based on the location of basic (manufacturing) employment and resulting levels of population-serving (i.e., commercial and service) employment. The residence distribution of employees working in a given zone is allocated as a function of distance for that employment location to various residential locations, as determined by a gravity (or intervening opportunities) accesibility model. The Lowry model, while based on a multiple employment centers and actual trip characteristics to employment, still has a major assumption that "residential site-selection is powerfully influenced by the location of the residents' place of work". Omitted in such models is the role of housing prices, differential housing types, neighborhood types, neighborhood services, property taxes, and neighborhood demographic composition as factors affecting the desirability of residential locations.

Another product of the mid 1960's was the EMPIRIC model, originally developed for Boston (Traffic Research Corporation, 1967). EMPIRIC was an improvement over other land use models in that the allocation of households to locations was affected by the demographic composition of location zones. Unlike the Lowry models, however, EMPIRIC allocated households to locations on the basis of a generalized measure of accessibility rather than accessibility to a known employment location. As in other models, housing prices, housing types, neighborhood services and quality factors were totally omitted.

The National Bureau of Economic Research (NBER) Urban Simulation Model (Ingram et. al., 1972) is a more recent urban spatial model, and focuses more on housing issues then land use. Housing market demand and supply are each explicity modelled separately. Residential mobility is predicted by socio-economic group, while housing type choice is based on socioeconomic characteristics and previous housing prices (which include transportation costs of location). Location for each housing unit type is then allocated by means of a linear programming model that seeks to minimize system-wide travel costs. Based on the economic theory of a competitive market in which optimums resource allocation is achieved when each household maximizes its benefit, residential location is again posited as a transportation cost problem.

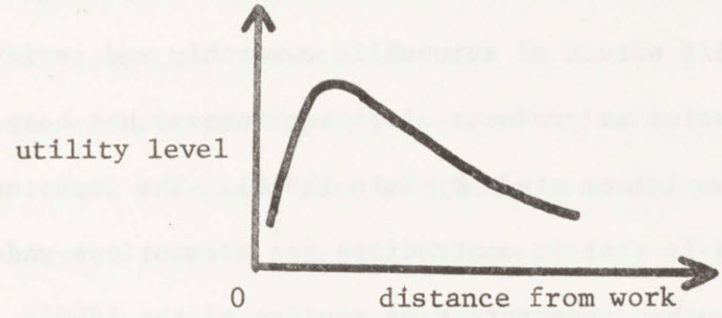
The role of travel time and cost to the workplace is a basis for most residential location models. This paridigm is unfortunately, of none or questionable relevance for a large proportion of the population. In the 1968 Washington, D.C. Council of Governments survey, just 60% of the households fit the classic economic model of a single worker household, while 30% had multiple workers and 10% no workers (Lerman, 1975). By comparison, the 1970 Minneapolis-St. Paul Metropolitan Council survey--which is used for the analysis in Chapters 5 and 6--showed that 66% of the households had one worker, while 13% had multiple workers and 21% had no workers (see Chapter 6). Empirical studies suggest that residential location and the workplaces of secondary workers in the household are related, but less strongly and in different ways than the role of the primary workplace (see Section 2.4). For households with no workers, the journey to work is an irrelevant factor, so residential location must be determined by other location factors or past employment situations.

2.2 Static Studies of Residential Location Patterns

Journey to Work Considerations.

The bid-rent theory of location explains residential location patterns in terms of household tradeoffs between the marginal savings in location rents and the marginal increases in transport costs associated with living further out from the central employment zone. In reality, accessibility and locational valuation are not always inversely related. Redding (1970) found that high proximity as well as low accessibility to work or amenities produces a situation of dissatisfaction, and suggested that living too near downtown, shopping, schools, or work may be associated with undesirable attributes such an noise, traffic, or industrial smells. Household valuation of location from workplace may thus be as shown in Figure 2-1. Controlling for the existence of such aesthetic problem areas, however, the pure effect of distance on the household valuation of location would still be montonically decreasing.

FIGURE 2-1.



It should also be noted that travel time and cost are not necessarily proportional to distance. In many metropolitan areas today, expressways make urban services and activities more accessible to suburban residents than central city residents. In this respect, suburban families may not have to trade off accessibility in order to save on housing and land rents.

Ultimately, household characteristics affect location and mobility decisions. Wilson (1976) found the length of journey to work to be dependent on age, job tenure, and prior residential mobility, as well as mode of travel and distance from the CBD in the region.

Because cost of transportation to work is such an important factor in theories of residential location, the auto ownership decision must also be considered insofar as automobiles increase the accessibility of those areas with poor transit service. Since accessibility can be purchased by means of either auto ownership or proximity of residence to public transportation, auto ownership and residential location are in the long run a joint decision.

The joint nature of automobile ownership and residential decentralization as products of rising incomes has been substantiated in an empirical study by Kain (1966). The importance of this finding is that it contradicts the assumptions made in most of the urban transportation studies of the 1960's, which assumed auto ownership to be entirely dependent on net residential density patterns rather than a part of those same trends. Further analysis of the aggregate relationship between residential land use patterns, auto ownership, and mode to work by Kain and Fauth (1976) reveals that -- even after controlling for household size, age and income -- there still exists a positive relationship between auto usage and both lower residential density and longer commuting distance. A city's highway mileage was found to have a positive effect on auto ownership but not auto usage. Total bus route mileage, on the other hand, was found to encourage transit ridership but not discourage auto ownership.

With length or cost of worktrips considered an important factor in residential location, the worktrip destination (job location) arises as another element of the long-run location auto ownership decision. In the event of multiple worker families, it is the employment of the primary wage earner which is the more important factor in the location decision. For secondary wage-earners, employment may be endogenous to the selection of residential location. Supporting this is Kain's (1969) finding that female workers consistently were more likely to reside nearby to their workplace than were male workers. Contradicting this is Barrett's (1974) finding that secondary workplaces tend to be further away from the residence than primary workplaces.

While the relationship between residential location choice and transportation access has been the object of a number of modeling attempts, Most such models of residential patterns have been limited to relating length of trip to work with residential patterns on an aggregate scale. Little information is shed about the nature of "consumers" whose locations are predicted. The bid-rent models of utility maximization assume that all households locate simultaneously with perfect information about all alternatives. Equally important, such economic efficiency models totally ignore the role of housing amenities and neighborhood quality in location decisions. The assumption in land use models such as the Lowry models, Herbert-Stevens (Penn-Jersey) model, and the NBER Urban Simulation model that residential locations are distributed around workplaces is thus no proof that journey to work is the most important consideration in the residential location decisions of households.

The Role of Neighborhood and Household Characteristics. In the bid rent type models of location, the household is described as choosing a quantity of land or housing. In reality, the residential location decision includes other factors such as quality of schools, social status of the neighborhood, and overall quality of site environment. More precisely, it may be recognized that residential choice involves a bundle of dwelling unit characteristics, neighborhood characteristics, and location characteristics.

Multivariate analyses of the residential location choices of urban households have been performed using regression by Mayo (1973), and using logit by Friedman (1975), Lerman (1975), and Pollakowski (1975). Each of these studies estimated the probability of choosing given locations on the basis of housing, neighborhood, and access attributes. Mayo and Friedman's analyses were designed as empirical tests of the Tiebout (1956) hypothesis that household location decisions between communities are made in accordance with individual preferences for level of public services. Lerman's model focused on the impacts of transportation policies on location, auto ownership and mode to work choices. Pollakowski's analysis was aimed particularly at the effect of household characteristics on location choice.

General findings of Mayo and Friedman are that education, police, fire, and recreation services of communities play only a minor role in location choice. Journey to work considerations are found by Pollakowski and Lerman to be an insignificant factor. By comparison, Mayo found worktrip commuting costs to be a statistically significant factor in location choice. Friedman also found the journey to work to be a significant factor, but of lesser importance in location choice than housing attributes.

An important feature of all four of these statistical location models is a stratification by household characteristics, allowing analysis of the extent to which locational attributes are weighted differently by different population groups. Mayo stratified households by income and number of workers; Friedman stratified by income; Pollakowski stratifed by income, household size, and age, and Lerman stratifies by income, houshold size and number of workers. All found evidence of a differential in weights of locational attributes between population strata. Higher income households were found to more highly weight neighborhood quality than other households, and to particularly avoid high density areas. Mayo found that the importance of travel time to work was highest for low income households. Pollakowski found that housing cost considerations are most important to large households, and least important to high income households. Lerman found that single worker households and multiple worker households have similar preferences for higher school expenditures and lower residential density. The location of single-worker households, however, was found to be more sensitive to shopping access, neighborhood income, and race than multiple worker households, and their auto ownership more sensitive to the number of drivers in the family.

The simple relationship between household income and residential distance from the central business district has been brought into question by other studies. In particular, family life cycle plays a role in residential location through a preference for low density living by families with children, while those without children exhibit a stronger preference for accessibility. Rhoda (1977) used contingency table analyses to show that these living near the central business district tend to be childless as well as of lower income. Mayo (1971), controlling for age and household size, showed that, in Milwaukee, groups with similar income do not cluster, nor do households always locate in rings of increasing income as distance from the city center increases. Butler et al. (1969) found that age, while having an important effect on residential mobility, has little apparent effect on locational choice.

Models of residential location have predominantly been static explanations of location patterns in terms of household characteristics and employment locations. It is clear from even static models, however, that any change in household characteristics (e.g., change in household size) or employment situation (e.g., change in job location) can make the household's situation no longer the utility-maximizing one. Static models by definition assume instantaneous adjustment to equilibrium. This is highly unlikely in residential location. Adjusting the housing and location characteristics of a household typically involves the household moving to a new residence. Most residential location models developed to date have failed to recognize the dynamic nature of household location change. Attempts to incorporate dynamic aspects into static location models (e.g., Putman, 1975) still ignore mobility decision factors. The dynamics of moving decisions thus become important for an understanding of the extent to which residential location patterns subject to change over time.

2.3 Residential Mobility

Residential location patterns are ultimately the result of the moving decisions of households. Changes in residential location demand are thus dependent on rates of residential mobility. As discussed in the following pages, studies of moving behavior (e.g., Butler et.al., 1969; Moore, 1972) confirm that residential mobility is affected by different factors than locational choice.

Analysis of factors affecting residential mobility is complicated by the use in studies of different measures of mobility. Retrospective and longitudinal studies examine actual moving behavior; other studies analyze desired or expected mobility. Difference between desired and actual mobility, together with evidence that residential mobility and location choice are different processes, has lead to a characterization of the moving process in terms of a sequence of decisions. Rossi (1955) suggested that there exists a three-stage process of: (1) the decision to move, (2) searching, and (3) the choice of a home. Speare et,al. (1974) suggest a different order of stages: (1) the desire to move (2) the selection of a new location, and (3) the decision to move. Alternatively, L.A. Brown and Moore (1970) suggest a two-stage process of: (1) the decision to seek a new residence, and (2) the decision where to relocate.

In terms of place utility -- the utility derived from the current housing and location bundle - the decision to search for a new place signifies dissatisfaction with the current bundle relative to perceptions or expectiations of a superior situation elsewhere. This evaluation of actual and potential housing bundles is typically characterized by sociologists in terms of satisfaction and by economists in terms of a utility function disequilibrium between actual and optimal consumption levels. Alternatively, geographers have defined moving decisions in terms of housing stress, in which the decision to look for alternative housing is triggered when stress exceeds a threshold level (Morrison, 1972; Brown and Moore, 1970). These definitions are equal if stress is defined as a measure of the attractiveness of the current residence relative to alternative locations.

The existence of residential stress or relative dissatisfation will not in itself trigger moving to a new location, however, if the costs of moving are viewed as greater than the benefits to be derived (Quigley and Weinberg, 1976). Besides monetary and time costs, moving may involve psychological costs from breaking social bonds and having to establish a new social situation in the new location. Stress thresholds may differ between individuals, and are also dependent on the kind of stress encountered. Lack of perfect information about the housing market also contributes to the stochastic nature of dissatisfaction thresholds.

Moore (1972) has categorized the motivating forces underlying the decision to seek a new residence as follows:

A. Push Factors: Negative reaction to the present dwelling and its environment

1. dwelling space
2. housing cost
3. condition of dwelling and neighborhood
4. accessibility characteristics of present location
5. social composition of the neighborhood

B. Pull Factors: Positive attractions of alternative locations

1. consumption-oriented aspirations (proximity to amenities)
2. social prestige-oriented aspirations
3. Family-oriented aspirations (right for children)
4. cômmunity-oriented aspirations (life style habits)

Other factors listed by Moore as affecting the decision to seek a new residence include: resistance to movement (due to tenure, duration fo residence inertia, and strength of social networks), and life style aspirations.

Importance of Current Location in Moving Decisions

The static urban location models previously discussed have generally assumed that accessibility to employment is a key factor in residential choice decisions. Surveys of movers, however, suggest that accessibility is not the most important factor in residential mobility decisions. Numerous surveys have found housing characteristics (particularly living space) and neighborhood quality to be more frequently cited as reasons for moving (or desiring to move) than locational accessibility considerations (Rossi, 1955; Barrett, 1974; Michelson, 1977; Speare, 1974). The national survey of urban household analyzed by Lansing and Mueller (1966), while not limited to intra-urban mobility, was also consistent with these findings. Similarly, Stegman (1969) and Morrison (1972) found neighborhood consideration more important to residential locations than accessibility to place of work. Barrett notes that of the 787 reasons given by 380 households, only 21 (i.e., 2.7%) stated that desire to live closer to work was even one of the deciding factors in their decision to move. In Michelson's study, only 7% of the sample cited general access as one of their reasons for moving. Accessibility to workplace was also found to be an insignificant factor in moving by Speare et. al. (1974) and Moore (1972), although Brown & Kain (1972) found that it did have a significant effect.

The importance of housing characteristics relative to neighborhood attributes in residential mobility is unclear. Rossi (1955) in his survey of low income households, and Barrett (1974), surveying a sample representative of the entire population, both found space complaints to be a more frequent reason for desire to move than cost, neighborhood or locational complaints. Studies by Michelson (1977) and Lansing and Mueller (1966) also found housing consideration to overide neighborhood ones. Speare (1974) on the other hand, found neighborhood considerations more important than housing in determining mobility. In a detailed study of desired mobility, Butler et.al. (1969) also found attitudes about neighborhood quality to be more important factor in the desire to move than dwelling unit or accessibility attitudes. Among neighborhood quality factors, schools were found to be important for families with school-age children, while public transportation was important only for low income households. Friendliness of neighbors was also important. There was no difference between planned movers and stayers with respect to such neighborhood characteristics as level of public services or traffic density. Surprisingly, factor analysis showed that accessibility to personal and retail services were more highly correlated with overall satisfaction level than accessibility to work or schools (which are traditionally assumed to be major concerns). In a study of low income renters, Weinberg et. al. (1977) found the existence of public transportation to have no significant effect on overall neighborhood satisfaction ratings.

Instead of examining reasons for moving, an alternative approach to understanding the determinants of mobility decisions is the examination of reasons why households choose not to search. Survey results from the Housing Allowance Demand Experiment (Weinberg et. al., 1977) show that among low income renters, housing, neighborhood and financial considerations were far more important than proximity to various trip destinations in the desire to remain at the current residence. Interestingly, proximity of current home to friends, relatives and schools were cited more frequently than proximity to workplace as a reason for not searching (see Table 2-1 below).

TABLE 2-1

Reasons for Not Searching for Alterntive Housing

	Percent of Households Citing Each Reason	
Didn't expect to find better housing	47%	
Financial reasons	41%	
Neighborhood/Location reasons (all types)	63%	
didn't want to leave neighborhood		36%
present location close to friends		21%
present location close to relatives		22%
present location close to school		23%
present location close to work		14%
Other reasons	6%	

(Source: Weinberg et.al, 1977)

Effect of Household Characteristics on Moving

There is a wealth of evidence that residential choice and moving behavior are systematically related to household characteristics. Of particular interest is that some households have a greater propensity to move than others. Prior mobility is thus a strong predictor of future mobility. This "cumulative inertia" in the residential mobility of households has been observed by Butler (1969), Speare (1974) Goodman (1976) and Weinberg et. al. (1977). It has been interpreted both as an indication of household ability to actualize moving plans (Van Arsdol et. al., 1968) and as a spurious correlation caused by unobserved factors(Quigley and Weinberg, 1978). Cumulative inertia can also be viewed as a negative relationship between moving and length of current tenure, a relationship perhaps related to the rent increase savings (tenure discounts) enjoyed by renters who remain in the same dwelling unit for many years (Merrill, 1977).

The propensity to move is related to a number of factors. An important one is the household's existing tenure. Those already owning a home are far less likely to move than renters (Speare et. al., 1974; Rossi, 1955; Brown & Kain, 1972; Kain & Quigley, 1975; Butler et.al., 1969). This is not surprising, given that home ownership represents a major capital investment, and the transaction cost involved in turning over this investment is far greater than the cost of changing units for renters. The annual mobility rate of renters in the U.S. is 41%; for homeowners it is only 10% (1975 Annual Housing Survey, U.S. Bureau of Census).

Life cycle of households has also been linked to moving behavior. A good description of the classic life cycle behavior is offered by Hawley (1971):

> "The young couple usually starts married life in an apartment, moves to a small house as children begin to appear, shifts to a larger home in the suburbs as the family reaches maximum size, and returns to small residential quarters, often in the central city, when the children leave to establish homes of their own."

Perhaps because they tend to have less job and family commitments, younger people are more mobile than older people (Butler et.al. 1969; Rossi,1955; Speare et. al., 1974; Maisel,1968; Brown & Kain, 1972; Weinberg et. al., 1977). Aggregate residential mobility rates tend to be higher in central cities than in suburban areas primarily because of a higher proportion of younger and smaller households in central districts.

Stability of employment at the same workplace also affects mobility. Weinberg (1975), using a 10 year moving history of San Francisco area households, found a positive relationship between workplace change and residential mobility. Consistent with this, Kain and Quigley (1975) found that households with retired workers are the least likely to move.

Besides the propensity to move, the outcomes of moves are also related to households characteristics. While age of head may be the most important variable in predicting mobility, it has been found to have little apparent effect on locational outcomes. Race and income, on the other hand, have been found to exert substantial influence on residential choice. The study of Butler et. al. (1969) found that lower income households and non-whites were likely to move shorter distances, more likely to locate in the central city, rent apartments, have fewer rooms, and pay lower rent or own cheaper housing. The observation that blacks are less likely to move outside their neighborhoods is also made by McAllister et.al. (1971); this may be attributable to the existance of racial discrimination in housing markets.

The Dynamics of the Search Process

The traditional bid-rent or utility maximization model of static location patterns is based on the assumption the households choose residences so as to maximize fulfillment of their desires and needs, given their budgets. In reality, however, many households remain in situations of disequilibrium--not moving to better places to live. Others that do move have been constrained in their choice of places to those that do not perfectly meet household needs. This is important in that it sheds doubt about the ability of static location models to accurately predict residential locations.

There are numerous reasons for desequilibrium in residential location. Besides the time lag involved in searching for new housing and then moving to it, some households cannot find acceptable alternative places due to housing market conditions. Others choose not to move due to considerations of the financial and psychological costs involved in relocating. Of even greater policy interest, however, is the fact that both the ability to find a new place to live and the choice set of possible alternatives may be affected by the existance of a number of problems encountered in the attempt to find new housing.

The process of searching for an alternative dwelling is best understood in terms of choice theory. While bid-rent and other consumer theories of residential location assume that households are able to choose the amount of housing and the combination of locational attributes so as to exactly maximize utility, choice theory is based on the recognition that there is a finite set of alternative housing-location bundles from which to choose. Housing markets, rather than single unified entities, are segmented by spatial and social barriers. Households searching for alternative housing is also restricted to choice among alternatives that they are aware of. The set of locations about which households have some knowledge has been referred to by Geographers and Sociologists as the "awareness space","contact space" or "action space" (Speare et.al., 1974; Goodman & Vogel, 1975; Barrett, 1973). Consistent with the importance of awareness space, Simmons (1968) and Barrett (1973) points out that most moves are short in distance and within previously-familiar territory.

Utility theory predicts that households will move only if they find a place sufficiently superior to their current situation (in terms of utility increase) so as to justify the monetary and psychological costs of relocating. Similarly, then, households will decide to search for alternative housing only if -- from their present knowledge -- they consider it likely enough that they will find such a superior place so as to justify the monetary and time costs of searching, as well as the expected costs of moving. Perhaps because of the sizable costs involved in searching for new housing, it has been suggested that most searchers adopt a conservative strategy of "taking a vacancy which is acceptable rather than continuing to look for the 'best possible outcome' (Moore, 1972). Consistent with this, studies of homeowners (Barrett, 1974) and renters (Weinberg et.al., 1977) both show that most searchers look at no more than half a dozen housing units before moving. Of course, the choice of neighborhoods and housing units to consider for searching is typically make on the basis of different information sources than knowledge of the insides of units. By driving through a neighborhood and consulting friends, newspapers, and real estate agents, a household can in fact have considered a very large number of places to live.

The choice set available to households depends on characteristics of the households. Low income diminishes the set of feasible alternatives available. Race or ethnicity may also restrict the choice set of available alternatives by constraining minorities to lower quality housing and locations at higher prices due to housing market discrimination. Large households may likewise face price discrimination due to landlord discrimination against children. In addition, there is often only a very small supply of available large size rental units (at low or moderate prices) in many housing markets.

Survey results from the Housing Allowance Demand Experiment (Weinberg et.al., 1977) indicate that households looking for new housing encountered problems due to lack of knowledge about where to look, discrimination (racial and against children), financial difficulty, and difficulty getting out to look due to lack of transportation, and discrimination problems had significant negative impacts on the success of searchers in finding alternative dwellings. Separate logit models of the decision to search and the mobility of searches revealed that blacks were more likely to search, but less likely to find a place, than whites.

Besides barriers in the search process, some movers choose homes out of equilibrium with current household needs because of anticipated family changes. Rothenberg (1975) suggests that young families overbuy the quantity of housing needed because of anticipated changes in family size or aspirations for a higher life style. Myers (1978) presents evidence for the San Francisco area that younger families are being forced into the suburbs as older families remain occupying central area housing units that are now larger than they need.

2.4 Accessibility Changes Associated with Moving

Frequency, length, and mode of trips are important outcomes of residential location. It can therefore be expected that household valuations of the importance of travel to various locations is reflected in residential choice. There is some evidence that the relative importance of locational accessibility in moving decisions is related to the direction of the move. Stegman (1969) found that accessibility to other parts of the metropolitan area was considered less important than neighborhood quality particularly for those households moving form the city to the suburbs. Complementary to this is the finding of Butler et. al. (1969) that space considerations were reported more frequently than convenience to work as a reason for moving by all movers <u>except</u> those that moved from the suburbs to the central city. The group that moved from suburb to city also tended to report a smaller time distance to work than other recent movers.

Nevertheless, these survey responses may be of questionable use to the extent that reported reasons for moving result from post hoc rationalization of households' locational choices.

There is some evidence that although movers rarely reported travel time or distance to work as an important factor in moving decisions, neverthless, moving behavior did appear to be affected by it. Butler found that while there was no linear relation between travel time to work and the decision to move, those living more than 40 minutes from work had a substantially higher propensity to move than those living less than 40 minutes from work. Barrett (1974), while reporting that accessibility to workplace was seldom offered as a reason for moving (as discussed previously), finds that when households do move, the mean distance to work for both primary and secondary workplaces tends to decrease slightly (see Table 2-2 below).

TABLE 2-2

Mean Block Distance of Journey to Work

	before move	after move
to prime workplace	8.0 miles	7.4 miles
to secondary workplace	13.3 "	12.3 "

(Source: Barret, 1974)

Simmon's (1968) study of intra-urban moving patterns in Toronto shows the residence of workers to be distributed around the workplace location both before and after moving, but with a greater tendency toward residential dispersion by workers in the central business district.

There are, of course, other travel destinations besides workplace. While these may differ among movers with different origin and destination locations, it is not clear that they are an important factor in residential choice. In the Butler sample, those moving from suburb to city had a shorter time distance to grocery store and downtown from their new residence than those moving intra-city, intra-suburbia, or city to suburb. This same group also had a longer time distance travel to parks than the others. Overall, however, Butler concludes that there is "no striking difference between households in central cities and suburbs in the distribution of mean journey times to other activities of importance to them."

It should be noted that nowhere in the analysis of moving behavior is auto ownership or mode choice cited by movers as factors, in residential mobility decisions. This suggests that while auto ownership and mode to work may affect the long run choice set of residential locations feasible for households, they are not considered a simultaneous component of short run adjustment of residential location.

2.5 Summary

The common economic models of residential location explain the location decisions of households on the basis of commuting and housing cost expenditures, made within budgetary constraints of household income. Empirical analyses of residential location patterns suggests that neighborhood quality and housing cost considerations, as well as race, household income and life cycle, play roles in location dedisions. Commuting costs appear to play a more minor role, except perhaps for low — income households.

There is strong evidence that household moving decisions involve different factors that location choice decisions. Survey results consistently reveal that neighborhood quality and size of housing unit are far more common reasons for moving than considerations of locational accessibility. Examination of household search and moving behavior highlights the role of search costs, search area ("awareness space"), and housing market constraints on moving and location choice. Through these factors, age, household size, income, race and tenure status all affect moving behavior. Static models of residential location patterns are faulted by their omission of the role of changes in household size, marital status, income, and employment location as factors in residential location change.

Many of the studies cited in this chapter are based on simple tabulations or correlations with no account for the effects of other variables. There is, for example, a general consensus that accessibility to work and other activities plays only a minor role in the location behavior of most households: Controlling for all other variables affecting location and stratifying by household characteristics, however, it is likely to be found that travel considerations vary widely in importance between population segments. It is clear that more analysis with market segmentation or population stratification is needed.

For this study, the key findings from the literature review are the importance in residential location decisions played by: (1) the dynamics of household search and moving processes, and (2) considerations of population characteristics, crime, and other social aspects of neighborhood quaility. Both of these classes of factors are often overlooked in residential location models.

CHAPTER 3

ISSUES IN MODELLING METHODOLOGY

It was noted in the previous chapter that past studies of residential location patterns have employed a variety of different methodological techniques. It is equally important to note that the differing statistical techniques often reflect differing perspectives for viewing the problem. Urban residential location patterns may be analyzed as large scale patterns or disaggregated to the level of individual household decisions. Future location patterns can be modelled in terms of static equilibrium conditions or a process of dynamic change. The spatial allocation of urban residences can be treated as either a continuous or discrete choice problem. These three issues are respectively discussed in Sections 3.1 -3.3. An argument is made for the appropriateness of analyzing residential location as a dynamic process of consumer choice, modelled as a discrete choice problem. That is the basic perspective for the model of residential location choice presented in Chapter 4.

Statistical issues in disaggregate choice models are the subject of the second half of this chapter. Section 3.4 summarizes the statistical techniques and sample restrictions of some earlier location choice models, and then reviews basic assumptions underlying the multinomial logit model. Given an interest in modelling residential mobility and auto ownership decisions, in addition to location choice, Section 3.5 briefly discusses the difference between joint choice estimation and a sequential approach. Extension of the static sequential approach to a dynamic recursive model is also outlined.

Inherent in spatial location choice models in the issue of how the land space is divided into a set of discrete alternatives. The residential location choice made by households is ultimately a choice of an individual home. For an analysis of urban residential locations, it is clearly necessary to aggregate residential choices into location zones. In general, the smaller the zone size, the more likely it is for average zone characteristics to accurately reflect attributes of individual housing opportunities within the zone. While it is therefore useful to express location choices in terms of a large number of small zones, it is also computationally cumbersome (and of questionable behavioral realism) to estimate models of consumer choice among hundreds of alternatives. The issue of limiting the number of alternatives in spatial choice sets is addressed in Section 3.6. Methods of correcting for differential levels of housing opportunities between zones (i.e., differential levels of aggregation) are discussed in Section 3.7.

3.1 Reasons for Modelling Consumer Choice

In attempting to identify determinants of residential location patterns, there are very good reasons to examine individual residential location choice. Aggregate land use forecasting models that have been developed since the 1960's (e.g. Lowry Models, Penn-Jersey) have been designed primarily for region-wide planning, and their predictions of zonal change or demographic group behavior are of limited use for subregional and individual project planning. As such, they are not responsive to policy issues of socio-economic impact or market segment behavior.

Aggregate changes in residential location patterns are, of course, nothing more than the sum of individual household location decisions. Analysis of individual choice lends itself to behavorial models better than does aggregate pattern prediction. With models of consumer choice, the potential exists for analysis of behavior responses to contemporary policies involving energy, life style, and quality of transportation service -- none of which are easily predicted from aggregate models based on zonal correlations.

Predictions from micro-level models of behavior by different socio-economic groups can be summed to produce predictions of aggregate behavior. Such a process can account for differing mixes of household types in different areas, and thus avoid "aggregation bias" problems of representing population characteristics in terms only of zonal averages in non-linear relationships. Analysis of individual behavior in terms of individual household characteristics instead of average zonal population characteristics reduces the need for large scale surveys in order to calibrate the predictive models.

3.2 Dynamic vs. Static Views of Residential Location

Traditional economic models of consumer behavior in housing and/or location choice (e.g., bid-rent theory, hedonic price indices) attempt to explain static equilibrium conditions. Spatial location patterns are formed simultaneously rather than incremental over time. They assume that housing prices frictionlesly adjust to reconcile consumer tastes with current stock, leading to an equilibrium condition in which consumers are indifferent among alternatives.

Realistically, at any given point in time, many households are not in equilibrium between their current housing and residential location and their desires for housing, neighborhood quality, and accessibility. This introduces a degree of error into any static equilibrium model of residential location, limiting its ability to account for the housing and location characteristics of individual households. Reasons for the disequilibrium between household desires (or needs) and current housing and location may be due to changes in a household in employment location, auto ownership, or the time lag involved in finding a new place and then moving. Households also may not consider moving because they consider the financial and psycholocical costs involved in searching for a new place and/or moving to a new neighborhood to out-weigh potential benefits. In addition, the choice set available for some households is constrained by financial considerations, discrimination problems or lock of transportation access to look at alternative locations. Of course, too, response of housing markets to consumer demand may be slow to adjust, and even circumvented by speculation, arbitrage, "block busting", etc.

Future location patterns depend on the decisions made by future movers and new households. For prediction, there is no need to explain current land use patterns, which after all are products of historical forces that may no longer exist. A dynamic model of residential location change is still based on the assumption that the preference function of household types is stable over time. The key difference is that such models allow for readjustment of residential location patterns in response to shifts in age, family size, and jobs over time.

3.3 Discrete vs. Continuous Representation of Locational Alternatives

Spatial patterns of urban activities may be viewed from different perspectives: as location along continuous surfaces, or as location in discrete sectors.

Theories that describe the surface of urban land use location include bid-rent theory (Alonso) and its predecessors, central place theory and density gradient studies. Whether viewing urban location demand in terms of rents or density levels, these theories were motivated by observations that the economic class of the population tended to be higher with increasing distance from the central business district, reflecting a tradeoff between land prices and costs of travel to the central district.

Early work of urban geographers focused on description zone diagrams instead of demand surfaces. The Concentric Zone theory (Hurd, 1903; Burgess, 1925) describes in discrete steps the type of location pattern that is explained in terms of a continuous surface by bid-rent theory (Figure 3-1). A recognition that urban spatial activities vary in more dimensions than just distance from the CBD was introduced by the Sector theory of Hoyt (1939), which divided the urban surface into descrete wedges of corridors (Figure 3-2), and the multiple nuclei description presented by Harris and Ullman (1945) (Figure 3-3).

Figure 3-1
Concentric Ring Description

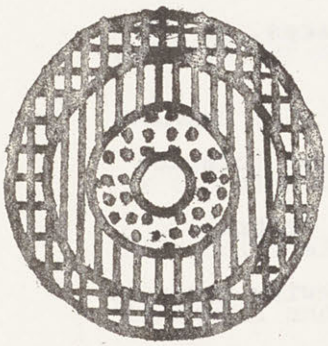


Figure 3-2
Sector Theory Description

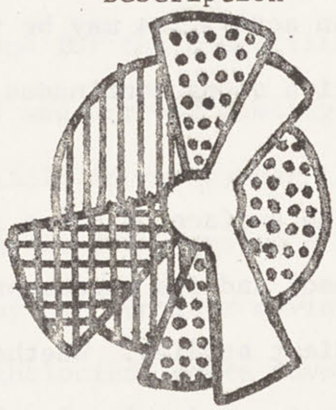
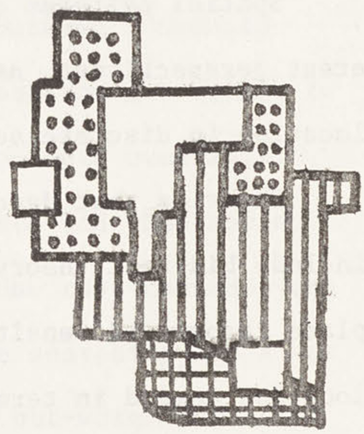
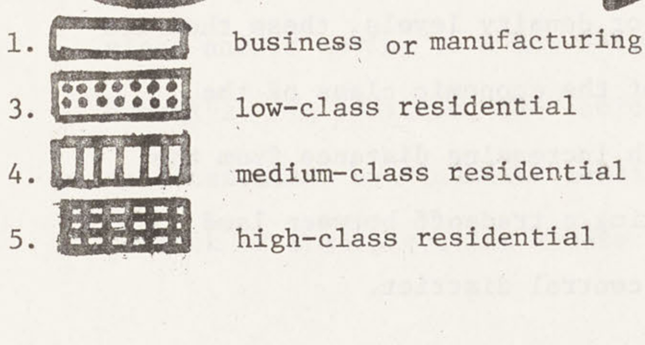


Figure 3-3
Multiple Nuclei Description





While bid-rent theory was originally based on a monocentric city, an especially dubious assumption today, there is no reason why it cannot be extended to multi-centered urban areas or made to reflect non-uniform variation in the attractiveness of locations.

The basic bid-rent curve (Figure 3-4) reflects an assumption that location costs vary only in terms of costs of travel to the CBD, which are assumed to be proportional to the distance. The simplifying assumption that urban areas are featureless plains may, however, be dropped. Travel costs may be represented as non-linear functions of distance, and reflect the existence of traffic congestion sources (Figure 3-5). In accordance with the theory of bid-rents, location costs may also reflect the coexistenct of pollution sources (Figure 3-6), and discrete differences in the value of local public services between jurisdictions (Figure 3-7). Bid-rents in an urban area with multiple business or employment centers is shown in Figure 3-8.

The standard bid-rent surface illustrated in Figure 3-4 reflects land values (or location rents) at any point in the urban area in terms of its distance form the CBD. The existence of point sources of cost, or additional non-CBD areas of employment, makes Figures 3-5 through 3-8 reflect land values along only a single line of direction from the city center. Extending the multi-centered representation in Figure 3-8 to a three-dimensional representation can yield a pattern of land values as illustrated in Figure 3-9.

Figure 3-4: Standard Bid-Rent Surface

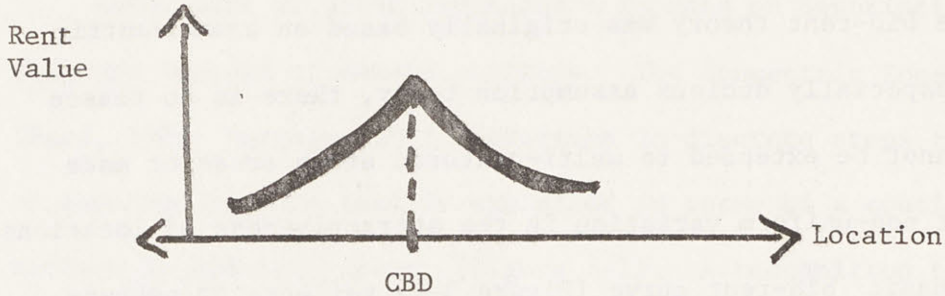


Figure 3-5: Bid-Rents with Traffic Congestion

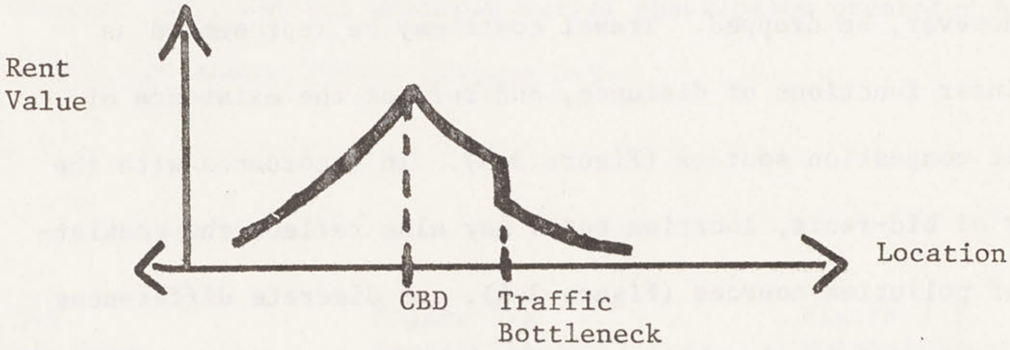


Figure 3-6: Bid-Rents with Air Pollution Source

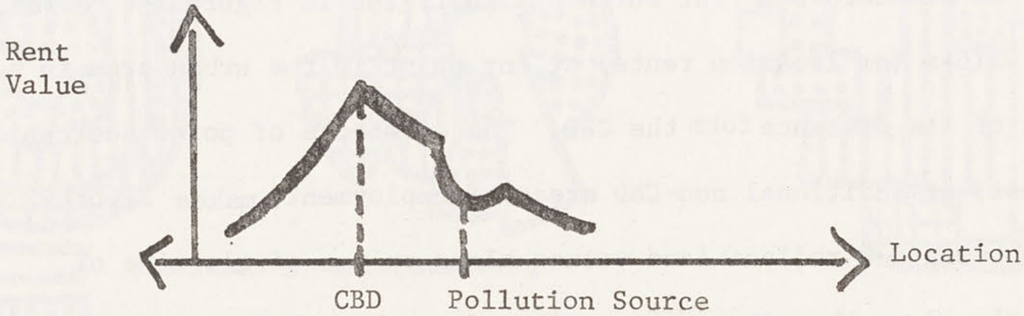


Figure 3-7: Bid-Rents with Jurisdictional Differences in Public Services

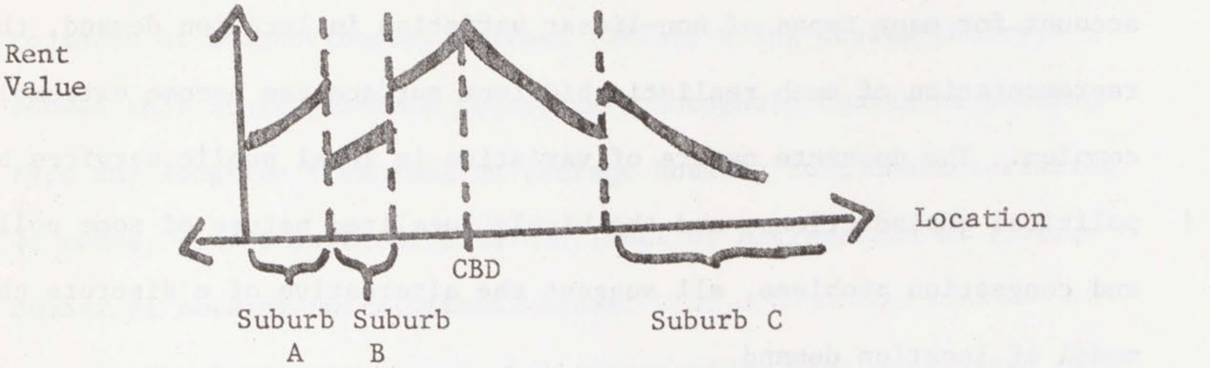


Figure 3-8: Rid-Rents with Multiple Activity Centers

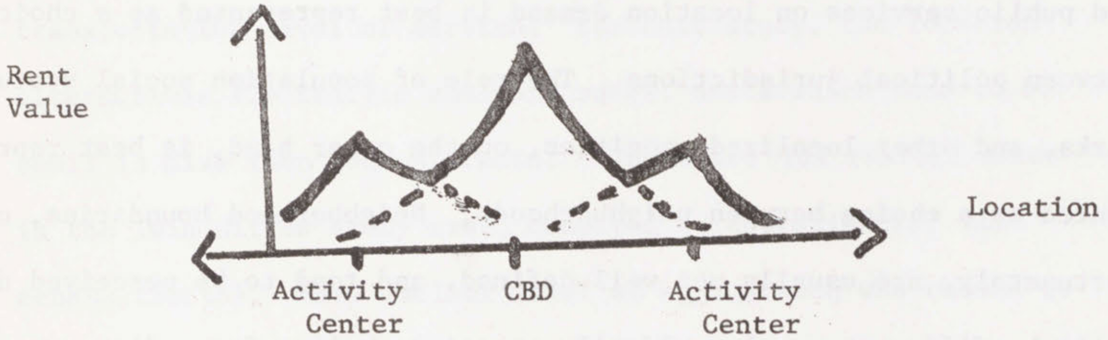
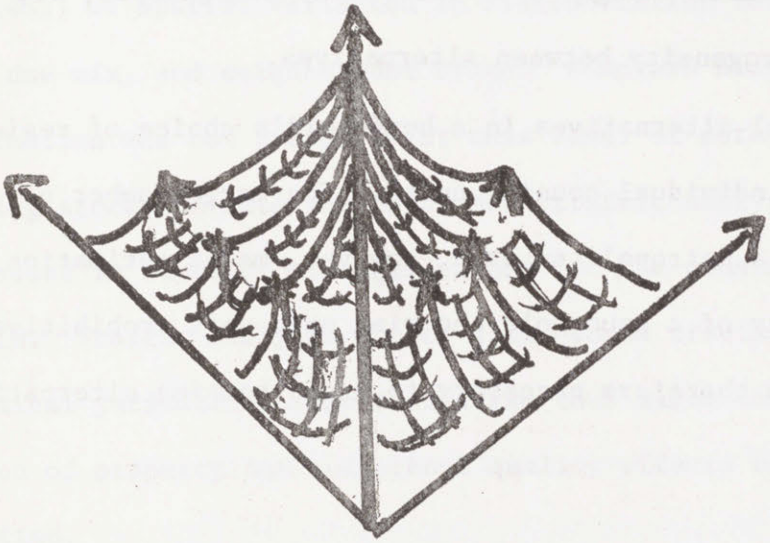


Figure 3-9: Patterns of Land Values with Multiple Activity Centers



It should be apparent that while bid-rent model can theoretically account for many types of non-linear variation in location demand, the representation of such realistic bid-rent surface can become extremely complex. The descrete nature of variation in local public services between political jurisdictions, and the highly localized nature of some pollution and congestion problems, all suggest the alternative of a discrete choice model of location demand.

The level of detail of a discrete representation of spatial choice depends on the purpose of the location demand analysis. The role of taxes and public services on location demand is best represented as a choice between political jurisdictions. The role of population social status, parks, and other localized amenities, on the other hand, is best represented as a choice between neighborhoods. Neighborhood boundaries, unfortunately, are usually not well defined, and tend to be perceived differently by different people. Ideally, spatial choices for a discrete choice model should be small enough to be internally homogeneous, but large enough to preserve heterogeneity between alternatives.

The elemental alternatives in a household's choice of residence are, of course, individual housing units. The large number of housing units in a metropolitan area, however, makes estimation of the probability of a household choosing each unit prohibitively expensive. It is therefore necessary to group housing alternatives to zones or neighborhoods. Lerman (1975), using choice theory, showed that it is possible to estimate household choice of housing type and location from data on average housing unit characteristics of zones, plus a correction for the level of aggregation of (i.e., number of housing units within) zones.

In the Lerman study, spatial alternatives were aggregated to a choice of census tracts, each characterized by average tract characteristics of housing stock, neighborhood amenities, and transportation level of service. For this study, the location alternatives are traffic analysis zones, units which tend to be small in size than census tracts. (There are 702 traffic zones in the Twin Cities Study area, compared to approximately 400 census tracts). This smaller level of aggregation was chosen to allow use of finer level of detail (i.e., more accurate characterizations) of spatial variation in transportation level of service, land use mix, and neighborhood crime. Complete housing stock information was not available at this level of detail Instead, housing stock characteristics of each traffic analysis zone are expressed in terms of averages values for the census tract it lies within. Traffic analysis zones, like census tracts, never cross political jurisdiction boundaries and thus allow consistent estimation of property tax and school quality effects on residential location.

3.4 Techniques for Spatial Choice Prediction

A. Previous Residential Location Choice Models

Discrete choice models are in theory not unconsistent with representations of continuous rent surfaces. Mayo (1971) estimated the probability that a household would choose a given location as the probability that the given location will have a higher bid-rent than all others for that household. While it is a multiple choice problem, location probabilities are estimated by means of a linear probability function. Mayo's analysis is noteworthy, however, in that it recognized multiple workplaces and estimates the role of population characteristics, housing amenities, land use, shopping accessibility and public services in location choice.

Ellis (1966) used discriminent analysis for classification of housing type choice for households. Aldana (1971) estimated household location, auto ownership, and mode choice decisions, but still as a sequence of binary choices. More recently, multiple choice logit analysis has come into use. Multinomial logit estimation of choice among housing unit types was performed by Quigley (1973). Application of multinomial logit for location choice models has been done by Friedman (1975), Pollakowski (1975), and Lerman (1975). The Friedman and Pollakowski studies utilize San Francisco data to examine only white homeowners who work in the CBD. The Pollakowski study focused on housing factors in location choice, with independent variables including estimated location cost (from a "hedonic price" model), housing type availability, vacancy rates, and travel time to work as well as race, income and household size. Friedman's model concentrated on the effect of local public services on choice among communities. Independent variables included school expenditures, fire stations, crime rates, tax rates, race, travel time to work, and the quantity of housing available at given prices. Lerman's study focuses on urban mobility --the joint nature of auto ownership and mode to work decisions with location and housing choice. That model did include renters as well as homeowners, and households with workplaces outside of as well as within the CBD. Independent variables in that model include many travel-related factores (travel time, distance, workplace location, licensed drives, generalized shopping access) plus a limited number of neighborhood or municipal factors (population income and race, net residential density taxes and school expenditures).

B. Statistical Assumptions in Choice Modelling Techniques

Choice theory is based on the behavioral assumption that a decisionmaker chooses from a set of feasible alternatives the one that maximize his/her utility. Utility is here merely a term for the extent to which that choice fulfills the individual's needs and desires. The utility of a choice alternative, then, is a function of its attributes, and differs among individuals. In reality, it is impossible to obtain accurate measures of all possible attributes of alterntives nor can we perfectly predict variations in preferences across individuals. We nevertheless assume that one's choice among alternatives will be consistent with the relative utilities of those choices. As we can predict only the probability of a given alternative being chosen, choice estimators can be referred to as "random utility" models. Reviews of issues in choice theories may be found in Ben-Akiva (1973) and Manski (1973).

The general form of a random utility model is that for a given individual, t, the probability of choosing an alternative (i) from a set (A) is equal to the probability that the alternative has a higher utility then any other alternative (j) in the set A. Thus:

$$Pr_t(i:A) = Prob\ (U_{it} > U_{jt}),\ \text{for all j in set A}$$

U_{it} is function of the attributes of alternative i and individual $_t$. Since we can never know U_{it} with complete certainty, it must be estimated, so

$$U_{it} = V_{it} + \varepsilon_{it},$$

where V_{it} is the systematic component and ε_{it} is the random variation or unexplained random error. The Choice probability may thus be rewritten as:

$$Pr_t(i:A) = Prob\ (V_{it} + \varepsilon_{it} \geq V_{jt} + \varepsilon_{jt},\ \text{for all } j \neq i \text{ in } A)$$

$$= Prob\ (V_{it} - V_{jt} \geq \varepsilon_{jt} - \varepsilon_{it},\ \text{for all } j \neq i \text{ in } A)$$

There is a range of probability density functions which may be adopted. These include cumulative normal (probit), logisitic (logit) and angular (trigonometric) functions. The logit function is here used because of its closed computational form, ease of use, cost, and prior recognition as a viable form. For logit, it is assumed that the random components of the alternatives (error terms) are independently and identically distributed (IID) with a negative exponential (Gumbell) distribution: For any given w,

$$Pr\ (\varepsilon \leq w) = e^{-e^{-(\alpha + w)}}$$

(where α = parameter of the distribuiton)

The choice probability function for the multinomial logit model is:

$$Pr_t\ (i:A) = \frac{e^{V_i}}{\sum_{j \varepsilon A} e^{V_j}}$$

For a three-choice situation for example, the choice probability function may be written as:

$$\Pr\ (a\colon A=abc) = \frac{e^{Va}}{e^{Va} + e^{Vb} + e^{Vc}} = \frac{1}{1 + e^{Vb-Va} + a^{Vc-Va}}$$

A unique attribute of logit models is that, since choice probabilities are proportional to the exponent of relative utilities (V), the relative odds of choosing between given alternatives are unaffected by the existence or non-existence of additional alternatives. This is the independence from irrelevant alternatives (IIA) assumption underlying logit. In the above example, the odds of choosing alternative (a) over alternative (b) is only a function of the difference in their utilities ($V_b - V_a$). The introduction of a new alternative, then, will not change the relative probability of choice within the old set of alternatives. For spatial choice problems, where proximity of one location alternative to other location alternatives may affect choice probabilities, the behavioral realism of the IIA assumption may be questioned.

An alternative to the utility theory explanation is the description of logit as a technique for estimating the probability of alternative events occuring on the basis of the difference in independent variables values between alternatives. The utility (V) of an alternative (i) is usually expressed in a form linear in in the parameters, so that:

$$V_i = B_1X_{i1} + B_2X_{i2} + B_3X_{i3} + \ldots + B_nX_{in}$$

In the example of a three-choice situation, with two independent variables, the choice probability function may be estimated as:

$$Pr(a{:}A{=}abc) = \frac{1}{1 + e^{B_1(X_{b1}-X_{a1}) + B_2(X_{b2}-X_{a2})} + e^{B_1(X_{c1}-X_{a1}) + B_2(X_{c2}-X_{a2})}}$$

The absolute magnitude of the variables (X_1, X_2) have no effect at all on the coefficients (B_1, B_2). It can be shown that only the difference in independent variable values between each alternative and the chosen one has any effect on the coefficients.

McFadden (1977) has shown that a linear in the parameter logit, with maximum likelihood estimation (MLE), yields consistent parameter estimates that are asymptotically both efficient and normally distributed. The characteristics of logit models are reviewed at greater length in Ben-Akiva (1973), McFadden (1973), and Domencich and McFadden (1975).

3.5 Sequential vs. Joint Estimation

Theoretical Considerations

It is clear from previous studies that residential location choice can be related to decisions concerning housing type, tenure status, residential mobility, employment location, auto ownership levels, and travel behavior. These relationships can be viewed as either the result of long run joint decisions.

The essence of a sequential model is the splitting of joint probabilities to be the product of marginal and conditional probabilities. A number of studies have used a sequential structure for estimating household decisions concerning employment, moving, housing unit type, and location choices. The order of the sequencing, however, has differed between studies, as shown in Table 3-1.

Sequence of Choices for Residential Location-Related Decisions

NBER Urban Simulation Model (Ingram et. al., 1972)	"Megharp" Regional Housing System Simulation (Sears et. al., 1975)	Pollakowski (1975)	Lerman (1975)
1). employment location	1). given employment location	1). given employment location	1).given employment location
2) moving probabilities	2). decision to move	2). tenure choice	2) joint choice: location zone (census tract), housing unit type, auto ownership level, mode to work
3). housing unit type choice	3). selection of a location zone (political jurisdiction)	3). choice of a region	
4). residential location selection	4). housing unit choice	4). joint choice of a housing unit and package of public services	

NOTE: As the Pollakowski and Lerman models are static location models, residential mobility is not relevant for them.

A sequential representation of household decisions makes sense when there is reason to believe the factors involved differ between the decisions, or the choice set for one decision is conditional on the outcome of a prior decision. Prior studies of residential mobility and tenure choice, for example, suggest that those decisions are determined largely by life cycle and income factors that are very different from factors involved in residential location choice. As a behavioral model, new residential location decisions are made only by those who choose to move. Tenure choice is important as a means of market segmentation -- determining which subset of housing or spatial opportunities are even considered (feasible) by a searcher considering moving. Far less certain, however, is the appropriateness of considering housing type and spatial location as sequential choices. It is not clear whether people first pick a housing type and then find appropriate spatial locations with that type home (as in NBER model), or they first limit their location choice set and then pick a housing type within that area (as in the Megharp and Pollakowski models). It may therefore be appropriate to consider housing type and spatial location as joint choices.

In the very long run, employment location is as adjustable as residential location. Time series data on changes in the employment locations of individuals, however, has been scarce. Weinberg (1975) using a 10 year longitudinal study in the San Francisco area, did find evidence of the joint nature of employment and residential location. In reality, housing (& residential location) choice might be simultaneous with employment relocation for inter-urban moves. For intra-urban moves, however, it is more likely that employment changes are a cause of residential relocation than a result of it. It may thus not be a bad assumption to consider employment location to be a decision prior to residential mobility and relocation.

Insofar as the time and monetary cost of travel to work is considered an important factor in residential location decisions, the auto ownership decision must also be considered. Since accessibility can be purchased by means of either auto ownership or proximity of residence to public transportation, auto ownership and residential location may be considered a joint decision in the long run.

The dependency of auto ownership and mode to work on residential location have been considered in the sequential models of Kain (1964) and Aldana (1971). The first joint model of auto ownership and mode the work was developed by Cambridge Systematics (1974). This joint choice model was extended to include both housing type and location by Lerman (1975). Following a dichotomy between long time mobility choices and short-run travel choices suggested by Ben-Akiva (1973), Lerman's model includes mode to work as a long-run decision in the joint choice, but considers non-work travel decisions to be short-run choices conditional on the auto ownership and mode to work.

Statistical Issues

The difference between a sequential and a joint decision structure may be illustrated by the example of two related decisions, the choice of residential location (l) and auto ownership level (a).

A sequential structure implies a hierarchy of decisions, where one decision is dependent on the outcome of another. The joint probability of a given location and auto ownership combination is then the product of the marginal probability of the first decision and the conditional probability of the second decision. It can be expressed as either:

$$P(l,a) = P(l) * P(a \mid l)$$

$$P(l,a) = P(a) * P(l \mid a)$$

The joint structure by contrast, assumes dependency between decisions in both directions. Conditional probabilities of the two choices here yield insufficient information to compute the joint probability. Instead, a choice model must be estimated with each combination of location and auto ownership considered as a single alternative.

A sequential logit decision structure is a recursive formulation, for the estimation of each decision includes an account of the expected utility of subsequent steps which are otherwise indeterminate at that stage. Assume, for example, a sequential structure where auto ownership choice is made conditional on location choice. In that case, the evaluation of alternative locations should include a generalized measure of the aggregate utility from all possible auto ownership levels, for each given location. In terms of the logit models, the sequential structure may be rewritten as shown below. The second step, auto ownership, is estimated first, with the outcome of the first step (location) known.

$$P(a|l) = \frac{e^{V_{la}}}{\sum_{a'} e^{V_{la'}}}$$

The first step (location) is then estimated using the natural log of the denominator from the second step (auto ownership) as a location attribute.

$$P(l) = \frac{e^{V_l + \beta * \ln(I_l)}}{\sum_{l'} e^{V_{l'} + \beta * \ln(I_{l'})}}$$

$$\text{where } I_{l'} = \sum_{a'} e^{V_{la'}}$$

(β is aparameter, where $0 \leq B \leq 1$)

The coefficient (β) reflects the independence of auto ownership choice from location choice. It can be shown that if $B = 1$, then the sequential logit yields the same results as a joint or simultaneous logit estimation, although less effeciently. This sequential or logit formulation is further discussed in McFadden (1977).

The sequential formulation can be useful as a means of measuring the simultaneity of decisions. As a simplifying assumption for treatment of multiple decisions, however, it can be cumbersome and inefficient.

For a static analysis -- where there is no time demension separating the decisions, and a relationship with no clear directionality between the decisions (as in the example of auto ownership and location choice for movers), a joint choice model is likely to be more appropriate.

The Dynamic-Recursive Structure

In contrast to its limited usefulness for static analyses, the sequential structure can be very appropriate for processes of dynamic change. The sequence of (1) the moving decisions, and (2) the spatial location decision (given the decision to move) together yield a model of residential location change. Separation of the two decisions into a sequential structure is justified because:

(1) There is a wealth of evidence that moving and location decisions are affected by different factors (see Chapter 2).

(2) The estimation of future location decisions is relevant only for those who decide to relocate. (For non-movers, future residential location will be the same as the current location.)

The moving decision introduces a dynamic element into the residential location estimation because the probability of a household moving is time-related. Residential mobility models typically estimate the probability of a move occuring within a given period of time, often one year. Incrementing one year at a time, one can then estimate:

(1) the probability of a household moving within the period, and

(2) the likelihood of alternative residential locations given the decision to move.

Such a model would be recursive because the moving decision would depend in part of the estimated aggregate utility or attractiveness of locational alternatives, as determined from the location choice estimation. Another recursive element is introduced insofar as moving decisions in earlier time periods affects the population attributes of alternative locations for the location choice estimation. (Such a sequential model can not, of course, be incremented over time without the addition of exogenous inputs about future housing supply conditions.)

The sequence of moving and location choice decisions can be considered a dynamic-recursive model. In contrast to a comparative-static structure, which re-estimates all residential locations in every new time period, this sequential model estimates just the marginal change in locations over time. The sequential structure many include measures of differential household response time to changes in household or neighborhood characteristics, depending on whether or not lagged response terms are included as explanatory variables.

Chapter 4 presents a model of residential location-related decisions which includes both joint and sequential aspects.

3.6 Limiting the Number of Alternatives on Spatial Choice Sets

Residential location choice between zones in an urban area can involve a large number of spatial alternatives. The model estimated in Chapter 4 involves choice between 702 location zones, 2 housing types and 3 auto ownership levels. This yields up to 4212 alternative combinations for each household to choose from. It is desirable to reduce the size of this choice set for two reasons:

(1) It is behaviorably unlikely that anyone actually makes one decision between 4212 alternatives.

(2) It is both computationally cumbersome and (for logit) of questionable statistical value to estimate a 4212 alternative choice model.

Behavioral Issues

Analysis of search behavior, as well as intuitive reasoning, indicate that households choose where to live from a narrowly-defined set of neighborhoods or housing units they have under active consideration. As discussed in Chapter 3, empirical studies have shown that the process of searching for a new home typically involves looking at only a handful of housing units (Moore, 1972; Weniberg et. al., 1977). This is not really surprising, in part because both household characteristics and attributes of alternatives make some choices of doubtful relevance or feasibility. Examples of household attributes tending to narrow choices are:

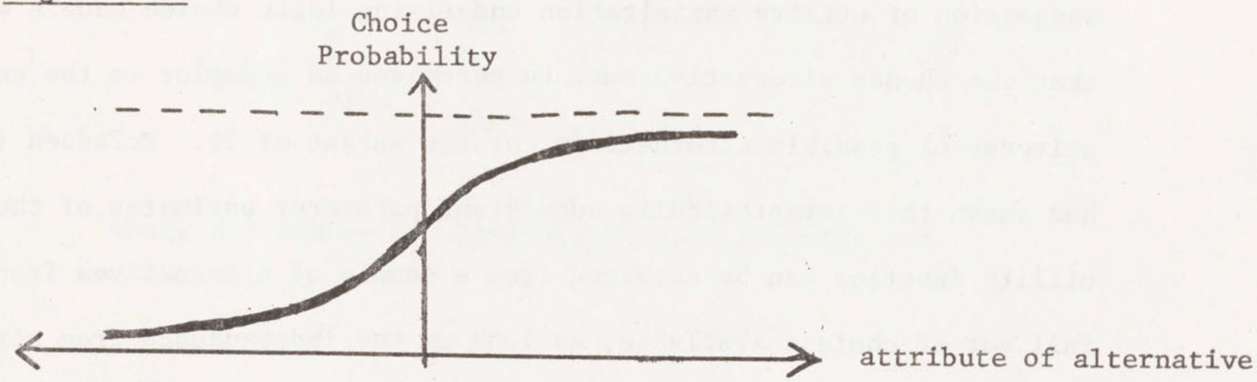
- Young families are not likely to choose to own three or more cars.
- Poor families are not likely to choose to own three or more cars.
- Families where the principle worker is employed downtown are not likely to choose to own zero cars and yet live in an outlying area with no transit service.
- Large families are less likely to choose small apartments.

Studies of moving behavior further suggest that intra-urban moves tend to be of relatively short distances (Simmons, 1968). Housing search tends to occur primarily in familiar neighborhoods relatively close to the current home (Speare et. al., 1975). One can thus expect that:

. Families are more likely to move to homes closer to their current neighborhoods than to farther away locations.

In any of the above situations, certain choices are unlikely to be chosen. These are probabilistic judgements, however, and in none of these cases can any alternatives be excluded with certainty from the choice set available to a household. Certain combinations of housing type and location zone may, of course, not exist in the study area. The key problem, however, is the existance of certain combinations of "housing type - location - auto ownership" which are possible but not likely to be considered within the "feasible" choice set under active consideration by some households. If choice probabilities are computed as a logit type function, then even the unlikeliest alternatives are assigned small positive probabilities of being chosen (see Figure 3-10).

Figure 3-10



It is possible that exclusion of low probability alternatives in the estimation of a choice model can lead to under-estimates of attribute (coefficient) elasticities. There is, however no well-defined boundary between "highly-unlikely" alternatives and more feasible alternatives.

In this study, alternatives that are expected to be unlikely are not excluded from the choice model, although attempts are made to identify some of these choice combinations, and statistically estimate their likeliness of being chosen. This information can contribute to a better knowledge of the extent and types of alternatives in the tails of the probability distribution. Only with such information is it possible to evaluate the potential for estimation bias introduced by the exclusion of such alternatives.

Statistical and Computational Issues

Computer estimation of a maximum likelihood choice model for 4200 alternatives can be very expensive. It can also be unnecessary. The assumption of utility maximization underlying logit choice models means that the chosen alternative must be perceived as superior to the entire universe of possible alternatives, or any subset of it. McFadden (1977) has shown that asymptotically-consistent parameter estimates of the logit utility function can be obtained from a sample of alternatives from the full set of choices available, as long as the independence from alternatives assumption is valid. To estimate the contribution of various housing, locational, and transportation attributes to residential location behavior, one need only estimate choice between the chosen alternative and a sample of other alternatives.

Given: i = chosen alternative

A = full choice set of alternatives available

S = subset of alternatives (j) from A

Subset S can be assigned to include the chosen alternative (i) plus a <u>uniform</u> <u>sample</u> of alternatives (j) from the full choice set A, obtained by independently considering each element of A with a constant probability P.

Defining: $P = \text{Prob}\,(j|A)$

Then: $\text{Prob}\,(i|A) = \text{Prob}\,(i|s) * \sum_{j \varepsilon s} P$

As long as choice probabilities meet the logit assumption of independence from irrelevant alternatives, it can be shown that the likelihood function for choice from the subset of alternatives is equal to the standard likelihood function:

$$L_N = \frac{1}{N} \sum_{n=1}^{N} \log \frac{e^{V_i}}{\sum_{j \varepsilon A} e^{V_j}}$$

where N = number of alternatives in the choice set

Non-Uniform Sampling

When ~~uniformly~~ sampling alternatives, there exists the possibility that some classes of alternatives in the full choice set will not be represented in the sampled subset. This is most likely for classes of alternatives that account for relatively few members of the full choice set. Reliability of parameter estimates, however, benefits from the sample of alternatives being representative of the range of choices actually available.

Non-uniform sampling is a way of insuring representation of certain classes of alternatives in a reduced chice set. Two methods of non-random sampling are:

(1) Partitioning the full choice set into classes of alternatives (on the basis of common attributes) and then randomly selecting alternatives from each partitioned set. The probability of an alternative in the full choice set surviving to the reduced choice set thus differs between partitioned classed, although it is identical within classes.

(2) Selecting alternatives from the full choice set with a probability that systematically varies with certain attributes of those alternatives.

The first method of limiting alternatives for multinomial logit estimation was used by Friedman (1975) in his study of community and dwelling unit type in the San Francisco area. In that study, alternative dwellings were sampled from choice set groups partitioned by community and major dwelling type. McFadden (1977) argued that logit estimation from a reduced choice set sampled from such partitioned classes will yield consistent estimates of all parameters only if either (a) the likelihood function is modified to account for the differential number of dwellings in each class, or (b) sufficient class-specific parameters are estimated in the model to absorb the effect of the sampling mechanism.

The second method of limiting alternatives may be employed in location choice models to correct for underrepresentation of certain types of locations that result from the definition of zones and their boundaries. For an analysis of urban location, for example, random sampling from a grid of location zones over the entire metropolitan area can lead to a relatively large representation of suburban and rural zones with few central city zones. While a location model estimated from such a reduced choice set will have consistent parameter estimates, standard errors of coefficients may be higher than if the choice set had more representation for high-density central city locations.

The two non-random sampling methods presented are not really different. The first method (sampling among partitioned classes of alternatives) may be considered as a special case of the second method (systematically varying selection probabilities), where sampling probabilities vary in discrete steps. Alternatively, the second method may be considered an example of the first method, where the choice set is partitioned into a large number of extremely fine classes. This means that sampling by systematically varying selection probabilities, like the class partition approach, requires the existence of explanatory variables in the logit model that absorb the effect of the sampling method in order to insure consistent parameter estimates.

3.7 Correcting for Zonal Aggregation

While residential location may be modelled as a choice between location zones, the ultimate choice is actually that of a particular housing unit. Location zones are thus just aggregations of elemental (housing unit) alternatives. All else equal, those zones with the most housing units in them will naturally be the most frequently chosen residential location zones. The number of elemental alternatives in a zonal alternative is often referred to as the zone size. It is here referred to as the level of zonal aggregation in order to avoid confusion with the spatial area of location zones.

Unlike the behavior-based hypotheses concerning the likelihood location choice, there is no uncertainty in the relationship between level of zonal aggregation and choice probabilities. If housing units are the elemental alternatives and zones are internally homogeneous, then the probability of a given location zone choice will be directly proportional to the level of aggregation (i.e., number of housing units) of that zone. There are two ways of correcting differential zone aggregation in choice models:

(1) If sampling alternatives, directly compensate for this bias by oversampling large zones for the reduced choice sets in individuals.

(2) Include a zone aggregation correction term in the utility estimation for alternative zones.

The strategy of oversampling those zones with large numbers of housing units is based on the corollary that if such "larger" zones will be more likely than other zones to be chosen because of their aggregation level, they will also be more likely to be in the reduced set of feasible alternative locations under active consideration by households. If zone size and zone boundaries were totally arbitrary, this strategy might be reasonable. For metropolitan areas, zone aggregation levels (whether for the traffic analysis zones used in this study or for census tracts) tend to be correlated with zone attributes. For example, those zones with the smallest number of housing units in them tend to be located in suburban areas; those with the most housing units tend to be in higher density central city areas. To preserve a range of density and location of alternatives, it is perferable not to sample by zone sizes or aggregation, other than to avoid the inclusion of rural regions in the urban location choice set.

The preferred method of correcting for differential zone aggregation , rather than utilizing non-uniform sampling, is to constrain the estimation of coefficients so that the probability of choosing a given zone is directly proportional to zone aggregation level:

$$(4) \quad \text{Prob}(i) = \frac{e^{V_i} * S_i}{\sum_{j=1}^{J} e^{V_j} * S_j}$$

Where: Prob(i) = probability of choosing alternative i

V_i = utility of alternative i (based on non-size attributes of alternative i)

S_i = size of alternative i (e.g., number of elemental alternatives it is comprised of)

This method was employed in a model or residential location choice by

Lerman (1975). This zone aggregation correction is accomplished by defining the natural log of the zone size as a zonal attribute in the linear additive utility function, with its coefficient constrained to 1:

(5) If $V_i' = B_1X_{1i} + B_2X_{2i} + \ldots + B_nX_{ni} + 1*\ln(S_i)$

where: B_n = coefficient of (non-size) attribute n

X_{ni} = value of attribute n for zone i

$\ln S_i$ = natural log of size of zone i

Then $e^{V_i'} = e^{(\sum_n B_n X_{ni}) + \ln S_i} = e^{(\sum_n B_n X_{ni})} * S_i$

The discussion so far has been based on the notion of a single measure of zonal aggregation level -- the total number of housing units in the zone. If the choice model is expanded from simple location choice to the joint choice of location and housing type, then the zone aggregation measure for choice alternatives is the number of housing units of the given housing type that are in each location zone.

CHAPTER 4

A CHOICE MODEL OF RESIDENTIAL LOCATION, HOUSING AND AUTO OWNERSHIP

The object of this analysis is to evaluate the relative importance of various factors in determining individual household choices of moving, residential location, housing structure tenure type and auto ownership. More specifically, the key elements to be estimated are:

- Who will move in a given year?
- Where will they move from and where will they locate?
- What type dewlling unit structure (house or apartment) and tenure type (rent or own) will they choose?
- What will be their auto ownership level?

The study is limited to intra-metropolitan moving behavior.

An empirical model of these choices, using data from the 1970 Twin Cities (Minnesota) Home Interview Survey, is developed. The analytic framework or model structure is discussed in Section 4.1. Section 4.2 presents a model specification in terms of a set of exploratory variables, and presents an analysis of the inter-relationships between various transportation-related and non-transportation attributes of locations.

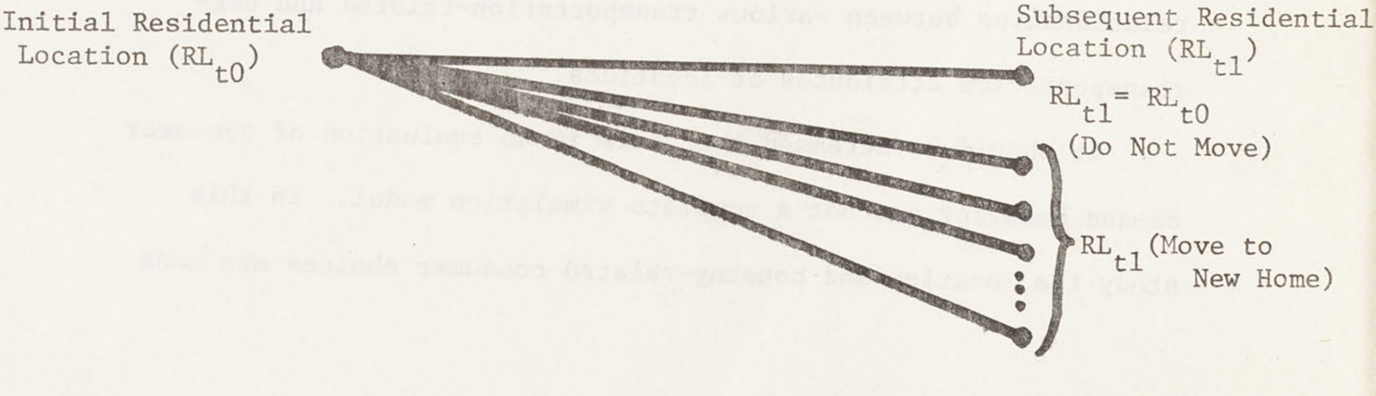
It should be stressed that this is an evaluation of consumer demand behavior and not a complete simulation model. In this study the location and housing-related consumer choices are made given current housing alternatives. Since housing supply characteristics may change in the long run, the location choice utility estimates can only predict "demand tendencies". Insofar as producers of new housing do, however, attempt to meet perceived demand characteristics (within the constraints of economic profitability), marginal change in residential location choice can offer an importnat insight into the spatial nature of long-run changes in residential location patterns of cities.

4.1 Model Structure

Moving and Location Choice Sequence

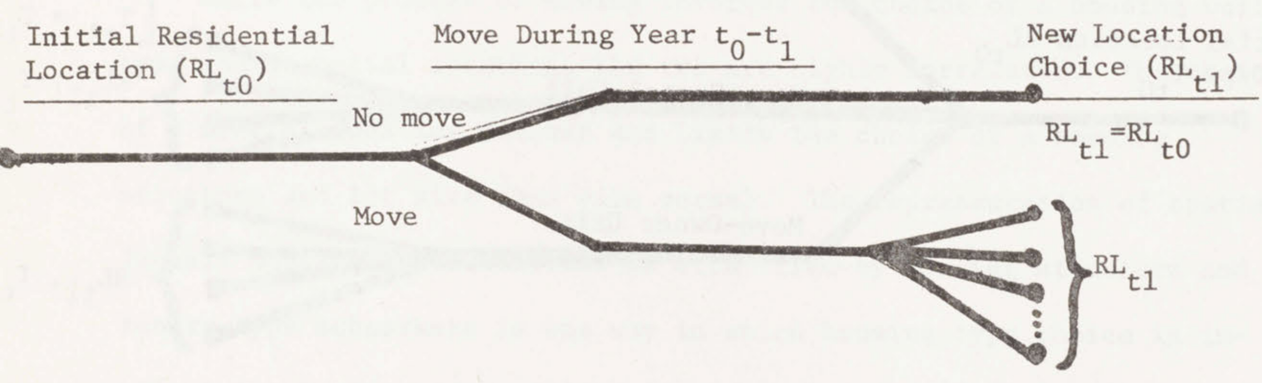
In predicting the intra-urban residential location of individual households, there is a finite set of alternative places to live, as shown in Figure 4.1.

Figure 4-1



As discussed in Chapter 2, empirical research on household moving behavior indicates that residential mobility and location choice decisions are influenced to a considerable extent by different sets of factors. Moving rates, for example, have been related to age, tenure status, place attachment and stress (push) factors. Location choice, by contrast, can be related to income, race and life style aspiration (pull) factors. This suggests a sequential approach, independently predicting decisions to move and then predicting location choices given the decision to move (see Figure 4-2).

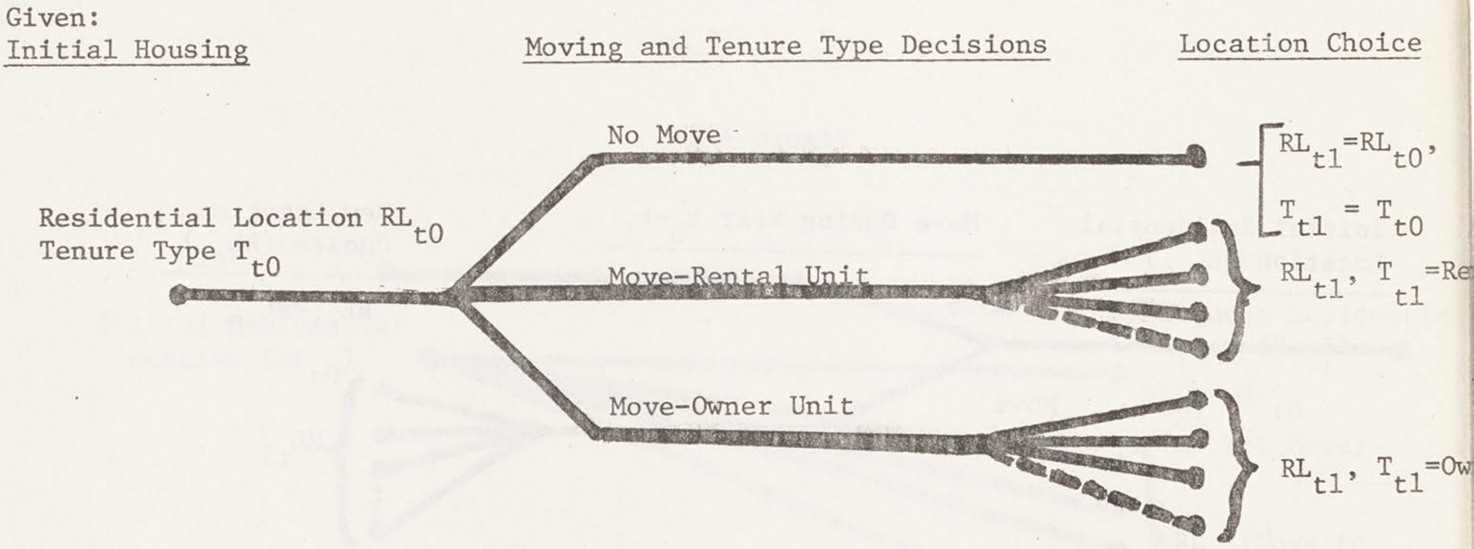
Figure 4-2



Housing Submarkets

In very general terms, residential location choice can be viewed as depending on attributes of locational alternatives and their attractiveness relative to household needs and desires. An important complication is that the set of locational alternatives and their attributes is not the same for all households. The most apparent submarket distinction is between the rental and owner housing markets. Locational choice, then, is conditional not only on the decision to move, but also on the choice of tenure type, as shown in Figure 4-3.

Figure 4-3



Housing structure choice is similarly very dependent on tenure type submarket, as apartment buildings tend to have rental units and single family homes tend to be owner units. This relationship is confirmed for the 1970 Minneapolis-St. Paul study, as shown in Table 4-1.

One can identify additional housing submarkets is less distinct. To some extent, racial discrimination limits spatial opportunities for blacks and whites, while different housing needs can create different markets for small and large housing units. Although the existence of such market differentiation should be taken into account in any representation of locational attributes, one cannot arbitrarily limit the spatial alternatives of housholds to racial or housing size submarkets. (Instead, it is preferable to statistically estimate such effects through measures of housing submarket availability for different household groups, and measures of the role of demographic homogeneity in location choice.)

The Joint Nature of Housing, Location, and Auto Ownership Decisions

While the process of moving involves the choice of a housing unit type and a spatial location, the two are highly correlated. The choice of a spatial location defines and limits the choice of a housing structure and lot size (and vice versa). The representation of spatial (zonal) housing opportunitites as stratified by housing structure and tenure-type submarkets is one way in which housing type choice is implicit in the location model.

TABLE 4-1

HOUSING STRUCTURE BY TENURE TYPE

Housing Unit Type	Percent Owned	(Total-N)
Single Family House	78.5%	(368)
in Two Family House	19.6%	(92)
in Multiple Unit Bldg.	0.6%	(352)

Sample: Households that moved within the past 15 months in the Twin Cities metropolitan area

Source: 1970 Minneapolis-St. Paul Home Interview Survey

The relationship between housing type choice and motivations for moving is shown in Table 4-2. Households that moved into houses were more likely to have moved because of desires for a larger dwelling unit, home ownership, or better neighborhood. Those that moved into apartments, on the other hand, were more likely to have moved because of desires for convenience to work or because of a recent change in marital status. Housing structure choice is thus not independent of neighborhood quality and accessibility considerations.

Mode of travel for home-based trips depends on both household auto ownership levels and the spatial accessibility attributes of residential location. Given a workplace location, one can in the long run meet work-trip access needs through either a residential location convenient for walk or transit, or the availability of an auto. For this reason, one can consider auto ownership as a long-run decision made jointly with housing and residential location choice.

Table 4-3 illustrates the relationship between auto ownership and housing and tenure type. Apartment renters are far more likely than others to have no cars. Of course, the driving force behind this apparent relationship is residential location. Apartment renters tend more than house dwellers to be located in the central city, where there is better transit and walk access to stores, work, and other activities. Apartment renters also often have lower incomes than house dwellers.

TABLE 4-2

REASONS FOR MOVING BY HOUSING STRUCTURE CHOICE

REASONS FOR MOVING[a]	% of Households		
	Moving into house	Moving into Apartment	All Movers
Move to Larger Home	32.6%	21.1%	27.6%
Tenure Change: Rent to Own	35.9	0.3	20.5
Tenure Change: Own to Rent	2.8	6.0	4.2
Convenience to Work	6.3	14.0	9.6
Neighborhood Quality	11.3	9.7	10.3
Change in Marital Status	7.2	21.4	13.5
Presence of Parks	0.4	0.3	0.4
School Quality or Proximity	2.0	1.7	1.1
Convenience to Public Transportation	0.7	1.7	1.1
Other	13.9	27.4	19.7
	(459)	(348)	(809)

[a]Households were asked for their two most important reasons for moving.

NOTE: percentages sum to more than 100% due to multiple responses.

Sample: households that moved within the past 15 months

Source: 1970 Minneapolis-St. Paul Home Interview Survey

TABLE 4-3

AUTO OWNERSHIP LEVEL BY HOUSING AND TENURE TYPE

HOUSING & TENURE TYPE	MEAN AUTO OWNERSHIP	% WITH NO AUTOS	(N)
Single or Two Family House-Owned	1.43	2%	(307)
Single or Two Family House-Rented	1.18	12%	(153)
Apartment-Rented	0.98	25%	(350)

Sample: households that moved within the past 15 months

Source: 1970 Minneapolis-St. Paul Home Interview Survey

<u>The Relationship of Mode Choice to Location and Auto Ownership</u>

Residential location and auto ownership choices together define travel choices and often determine mode to work. Mode to work decisions have been estimated jointly with housing, location, and auto ownership decisions by Lerman (1975). The combination of these four choices were referred to as a specific "mobility bundle."

For this analysis, travel decisions are considered as conditional on location and auto ownership, in a sequential or recursive framework. There are several reasons for this. Housing (the combination of structure type and location) and auto ownership are major household investments. Such decisions are qualitatively of a different nature from travel decisions of frequency, mode and destination. Given a location and auto ownership level, households typically have some flexibility in their travel choices. This can be true even for mode to work, which for most people is not frequently varied.

Viewed another way, the accessibility attributes of residential locations for a given household may depend on that household's probable travel behavior from that location. In a sequential logit framework (as discussed in Section 3.5), the log of the sum of the mode choice utility estimates may be included in the location choice as a measure of accessibility. More specifically, this is a measure of the expected maximum access utility of each location alternative, given household characteristics and expected mode choice at that location. The sequential framework cuts down the number of variable coefficients estimated simultaneously, as one accessibility term reflects a weighting of all the various aspects of travel cost, in-vehicle travel time and out-of-vehicle travel time. With a sequential approach, separate estimates of accessibility for different types of travel can be included without an unwieldly number of explanatory variables. For this model, separate measures are included for accessibility to primary worker's workplace, secondary worker's workplace, shopping activities, and social recreation activities. The shopping and social-recreation accessibility measures are based on an estimation of destination as well as mode choice.

Overall Sequential Structure

Figure 4-4 summarizes the sequential structure proposed by the preceding pages. The focus of this analysis is on housing and auto ownership investment decisions. The model is of marginal change in those investments, as housing type and location choice are estimated conditional on moving and tenure choices.

Employment considerations are considered to be of a qualitatively different nature than housing and auto investment decisions. Employment status and job location are accepted as a prior stage and not modelled, as the data base used here contains no such information on job change over time. Housing market conditions are also exogenously given.

Household decisions are estimated in a sequence of: (1) moving and tenure joint choice, (2) location, housing type and auto ownership joint choice, and (3) travel choices. The travel choices are three independent

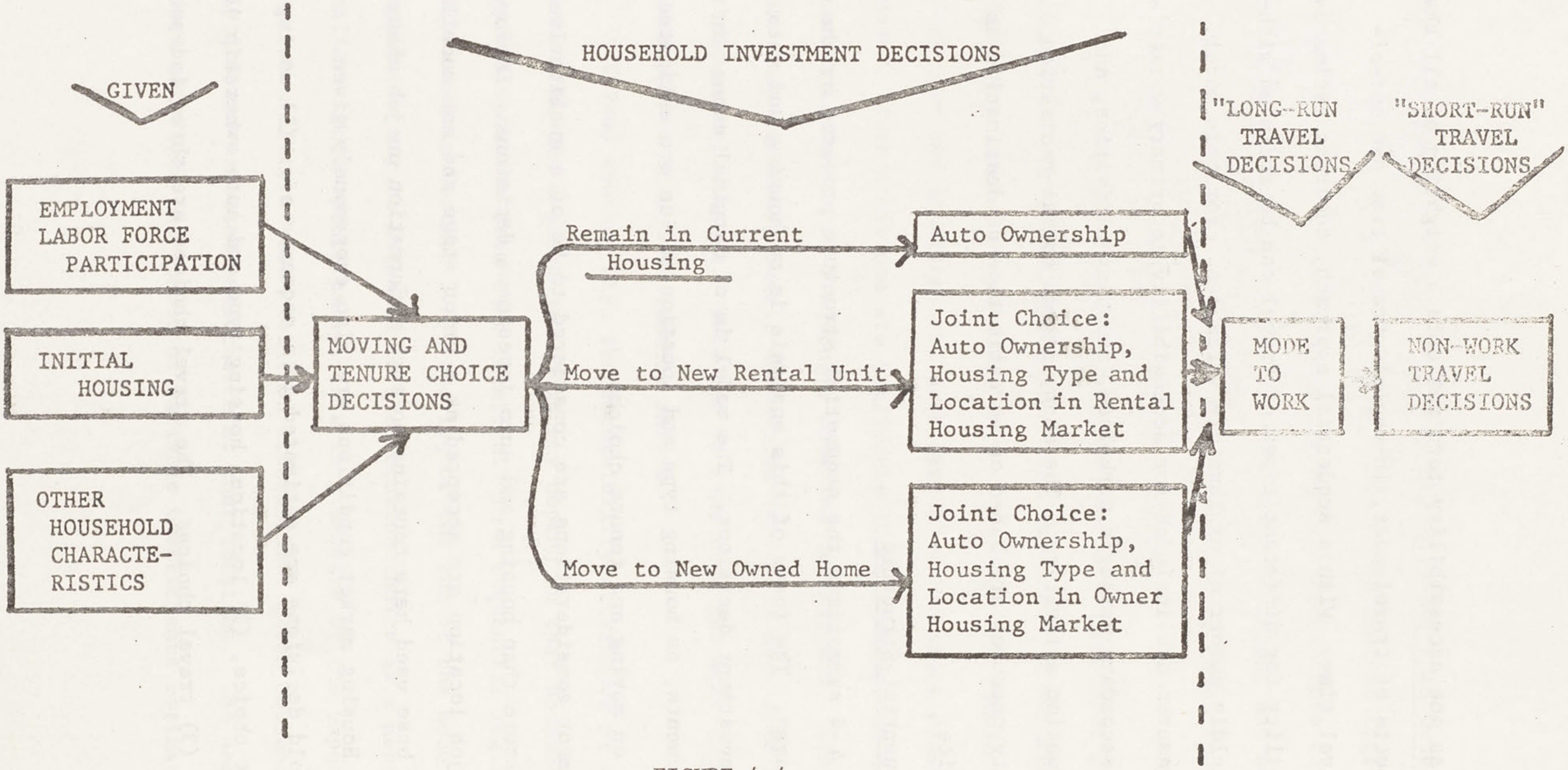


FIGURE 4-4

SEQUENTIAL DECISION STRUCTURE

models (previously estimated by others) of mode to work, joint choice of mode and destination for shopping, and joint choice of mode and destination for social/recreation activities. As a sequential or recursive model, the estimate of each of the first two steps depends in part on the expected utility of subsequent choices. The three steps of the sequence are thus estimated in reverse order. One factor in the location choice model, then, is a measure of the expected utility of access from each alternative location (for each individual household) to work, shopping and social/recreation. Similarly, one factor in moving choice is then a measure of the expected utility of current housing and locational alternatives, as computed from coefficients of the housing, location and auto ownership choice model.

4.2 Explanatory Variables

Types of Factors

The review of empirical findings and theories of residential mobility, location, tenure choice, and auto ownership (in Chapter 2) yields a series of expectations about factors affecting such decisions. These are summarized in Table 4-4.

TABLE 4-4

FACTORS IN MOVING, TENURE, HOUSING TYPE,

LOCATIONS AND AUTO OWNERSHIP DECISIONS

FACTORS IN RESIDENTIAL MOBILITY DECISION

1. Age (Elderly are less mobile)
2. Number of children (Large households face higher moving costs and fewer opportunities)
3. Attractiveness of current housing and neighborhood characteristics
4. Expectation of attractiveness of housing and location alternatives

FACTORS IN TENURE CHOICE

1. Life Cycle/Age (Older families are more likely to own)
2. Number of Children (Families with children are more likely to own)
3. Income (Wealthier families are more likely to own)

FACTORS IN LOCATION CHOICE

1. Demographic Composition: Age, Household Size, Income (Household tendency toward locations with similar demographic characteristics)
2. Neighborhood Quality: Crime, Taxes, High density, proximity to industry (avoidance), school quality (important for households with children)
3. Housing: Cost, Type
4. Accessibility (level of service) to work, shopping and social/ recreation (given auto ownership)
5. Knowledge about Location: Distance from previous residence (Most searches encompass small distances)

TABLE 4-4 (Cont'd)

FACTORS IN AUTO OWNERSHIP CHOICE

1. Income (Wealthier families own more cars)
2. Number of licensed drivers
3. Accessibility (level of service) to work, shopping, social/ recreation

FACTORS IN HOUSING STRUCTURE CHOICE

1. Number of children (Families with children are more likely to own single-family homes)
2. Tenure Choice Factors
3. Location Choice Factors

Omitted from the list are factors for which information was not available in the data base. This includes the role of length of tenure in moving, the role of previous tenure type in the tenure choice of movers, the role of race in location choice, and the role of housing unit size and age on housing type choice. (Aggregate data on average housing unit size and age by location zones was available, but yielded insignificant results in the estimated model).

Categories of explanatory variables, and their roles in the joint and sequential aspects of the model system, are illustrated by the general model specification. The probability of a given location (l), housing type (h) and auto ownership level (a) is expressed as:

$$\text{Prob}\ (l,h,a \mid LHA) = \frac{e^{(V_l + V_h + V_a + V_{lh} + V_{la} + V_{ha} + V_{lha})}}{\sum_{LHA} e^{(V_{l'} + V_{h'} + V_{a'} + V_{lh'} + V_{la'} + V_{ha'} + V_{lha'})}}$$

Where V_l = a function of factors that differ among locations = $\beta_l * X_l$

V_h = " " " " " housing types = $\beta_h * X_h$

V_a = " " " " " auto ownership levels = $\beta_a * X_a$

V_{lh} = " " " " " locations and housing types = $\beta_{lh} * X_{lh}$

V_{la} = " " " " " locations and auto ownership levels = $\beta_{la} * X_{la}$

V_{ha} = " " " " housing types, and auto ownership levels: $\beta_{ha} * X_{ha}$

V_{lha} = " " " " " locations, housing types, & auto ownership levels = $\beta_{lha} * X_{lha}$

and: β = a vector of coefficients

x = a vector of explanatory variables

The dependent variable to be estimated is the joint choice of: (1) location among 702 traffic analysis zones in the Minneapolis-St. Paul urbanized area; (2) housing type choice of a single (or two)-family home vs. an apartment, an (3) auto ownership choice between 0, 1, and 2 or more autos. It is estimated only for movers; and assumes that tenure type (own or rent) is already known.

For the prior stage in the sequence the probability of a moving (b) and tenure choice (c) combination is expressed as:

$$\text{Prob}\ (b,c|BC) = \frac{e^{(V_b + V_c + V_{bc})}}{\sum_{BC} e^{(V_{b'} + V_{c'} + V_{b'c'})}}$$

where: V_b = a function of factors in moving choice = $\beta_b * X_b$

V_c = a function of factors in tenure type choice = $\beta_c * X_c$

V_{bc} = a function of factors in moving & tenure choice = $\beta_{bc} * X_{bc}$

The dependent variable to be estimated is the choice between three alternatives: (1) Remain in current residence, (2) move and purchase a new home, and (3) move and rent a new home.

<u>Variable Definitions and Coefficient Hypotheses for Location, Housing Structure and Auto Ownership Model:</u>

<u>Extent of Search</u>

Due to costs of information collection, both the search for a new home and the subsequent (intra-metropolitan) move tend to be within relatively modest distances from the previous residence. For a model of the location choice of movers, it is expected that the distance of a location alternative from the previous residence should exert a negative influence on the probability of choosing that location. An attribute of location alternatives is thus defined as:

1. "Distance from Prev. Residence" = Distance from the previous residence to the given location alternative.

As this variable does not make sense in a static location model, it may be considered an important element of the dynamic model structure. It is hypothesized that this variable should exert a strong negative effect on the locational utility function (and hence, on the probability of choosing the given location).

<u>Neighborhood Quality Measures</u>

Crime, congestion and pollution are locational attributes that most people try to avoid. Crime can be viewed as a "push" factor, in that it may be a motivating factor in the decision to move. High rates of assaults and personal robberies are also likely to be correlated with other aspects of neighborhood decay. It is expected that movers will primarily consider locations where the fear of criminal attack is smaller or at least no worse than the previous location. As a locational attribute, this can be measuered as:

2. "Crime Relative to Prev. Residence" = rate of Assaults and Robberies per thousand population at the given location, as difference from the rate at the previous location.

This variable should exert a negative influence on demand for the given location. A similar measure for Burglaries was explored but rejected from the final model specification because of a high correlation between its estimated parameter and the parameter of the Assault and Robbery Variable. Burglaries, which by definition involve no confrontation between criminal and victim, are also less likely to be associated exclusively with physically deteriorating residential neighborhoods.

Residential density measures the degree of crowding of residences. It is usually highest for areas with high-rise apartments, and lowest for areas with large-lot single-family homes, and thus is positively correlated with central city areas. While high-rise apartments can be attractive to some families, it is true that the higher cost of parking and greater congestion of people and vehicles is a negative aspect of high density living. Residential density is defined as:

3. $\text{"Residential Density"} = \dfrac{\text{Zone Population}}{\text{Residential Acreage in the Zone}}$

It is expected to exert a negative influence on the locational utility function.

Proximity of residence to industrial land is often associated with air pollution and/or negative visual aesthetics. It is thus expected to exert a negative influence on demand for a given location. Only a crude measure of this locational attribute is here available.

4. $\text{"Ratio of Industrial Land"} = \dfrac{\text{Industrial Acreage in the Zone}}{\text{Residential Acreage in the Zone}}$

Ideally, one would prefer a measure of the extent of industry within a given distance from the location zone.

Demographic Characteristics of Locations

Social considerations can play a major role in location choice, as evidenced by the tendency for separation of ethnic groups into different neighborhoods. In general, it is expected that movers will tend to locate with neighbors most like themselves. This can hold for race, age, income, or household type. To capture such effects, the demographic characteristics of zones are measured relative to each household's characteristics.

For income, there is reason to believe that individuals seek to avoid living in neighborhoods poorer than themselves more than they seek to avoid living in richer neighborhoods. Separate measures are developed for positive and negative differentials between average zonal income and the household income of the mover.

5. "Squared Pos. Income Differential" =(Household Income-Median Zone Income)^2 if Household Income > Median Zone Income; = 0 (otherwise)

6. "Squared Neg. Income Differential" =(Median Zone Income-Household Income)^2 if Household Income <Median Zone Income; = 0 (otherwise)

It is expected that positive income differentials will exert a greater negative influence on demand for given locations than will negative income differentials.

Among household types, it is expected that families with children, and singles or childless couples, will each tend to locate with similar type households. Accordingly, the difference between average zone household size and household size of the mover is measured:

7. "Household Size Differential" = |Household Size-Median Zone Household Size|

It is expected that zones with a larger household size differential are less likely than others to be chosen.

For age, it is expected that young households are more likely than older households to avoid living in areas where many elderly people live. Separate measures of the proportion of zone population that is elderly are developed for elderly and non-elderly movers.

8. "Percent Elderly in the Zone (for elderly households)" =

% of Census Tract Population > 62 years old (if head of moving household > 62 years old) = 0 (otherwise)

9. "Percent Elderly in the Zone (for non-elderly households)"=

% of Census Tract Population > 62 years old (if head of moving household < 62 years old);= 0 (otherwise)

It is expected that the latter variable will exert a negative effect on location choice probabilities. The coefficient of the former variable is less certain, as it is unclear whether the elderly view living with other elderly people as a positive feature.

<u>Local Government: Taxes and School Quality</u>

For families with children, school quality should be a positive factor in the evaluation of alternative places to live. School quality is here measured as:

10. "Teacher/Pupil Ratio" = $\frac{\text{teachers (full time equiv.)}}{\text{pupils}}$

An alternative measure of school quality is the rate of instructional expenditures per pupil. Prior analysis showed the former measure to contribute far more than the latter measure to explaining location choice.

Costs of location can be expressed in a number of alternative ways. Property tax rates (adjusted for differential valuation levels) is a common measure, although property tax costs to a household can depend on housing value more than on tax rates. Property tax per household captures both tax rate and housing value effects, and is here measured as:

11. "Property Tax per HH" = (Municipal Property Tax Rate/Valuation Rate) X Median Zone Housing Value

Median housing value is computed separately by building type and tenure type. It is hypothesize that, controlling for housing type and housing cost, households attempt to minimize property tax cost in their location choice. Because level of school and other municipal services is, however, a direct function of property taxes, tax levels may also reflect the quality and/or quantity of local services.

Family Size

It is expected that the number of children in a household is the overriding factor in the decision to buy a single (or two)-family house rather than live in an apartment. The effect is measured through the variables:

13. "No. Children" = $\frac{\text{Number of children under age 18 without full time jobs}}{\text{Number of people in the household}}$ (for house alternatives)

= 0 (for apartment alternatives)

This variable is expected to have a large positive influence on the probability of choosing a house alternative instead of an apartment alternative.

Auto Ownership Factors

It is expected that both income and number of licensed drivers in the household will have positive effects on the probability of choosing higher auto ownership levels. These variables are here defined as:

15. Licensed Drivers (for 1 auto alts.)

= No. of licensed drivers in the household (for single auto alternatives)

= 0 (for other alternatives)

18. Licensed Drivers (for 2+ auto alts.)

= No. of licensed drivers in the household (for 2+ auto alternatives)

= 0 (for other alternatives)

16. Income (for 1 auto alts.)

= gross household income (for single auto alternatives)

= 0 (for other alternatives)

19. Income (for 2+ auto alts.)

= gross household income (for 2+ auto alternatives)

= 0 (for other alternatives.)

Acessibility: Accessibility is a generalized measure of the time and cost involved in travelling from home to work, shopping, and/or other activities. Accessibility to work can be defined in terms of travel to all possible employment centers or in terms of travel for each individual worker to his/her own workplace. The latter, more specific, definition is adopted here.

Accessibility can be a function of both residential location and mode of travel used, and is expected to be a positive attribute in the evaluation of location and auto ownership choice alternatives. As mode to work is indeterminent at the stage of location and auto ownership choice, one can only estimate its expected probabilities. Using a worktrip mode choice model, accessibility to work can be defined in terms of an utility expected value for all possible mode to work options. Consistent with the sequential logit structure (see Section 3.5), accessibility to work for each household at each of its locational alternatives is defined as a "log sum utility" (i.e., the natural log of the logit denominator from the mode choice model):

$$\text{Accessibility to work} = \ln\left(\sum_m e^{V_m}\right)$$

where m = mode alternative

$$V_m = \sum_m B_m X_m$$

B = vector of coefficients in mode choice model

X_m = vector of independent variables for mode m

Accessibility to work is here defined for both the primary worker and a secondary workers in each household. If present, the working husband or male head of household is defined to be the primary worker. If none is present, the primary worker is the working wife or female head of household. These variables are defined as follows:

20. Worktrip Access (Primary Worker) = "Accessibility to Work" for primary worker (if present)
= 0 (if no primary workers is prese

21. Worktrip Access (Secondary Worker) = "Accessibility to Work" for secondary worker (if present)
= 0 (if no secondary worker is present)

"Accessibility to Work" is defined as above, using coefficients (B) and modes (m) from the mode-to-work logit model developed by Pratt (1976) and shown in Table 4.5. This model was callibrated using the same 1970 Twin Cities data, and thus allows extension of the residential location and auto ownership model to a subsequent stage of mode choice.

Accessibility to shopping and social/recreation activities is more complex than worktrip accessibility because the destination as well as the

TABLE 4-5

Twin Cities Worktrip Mode Choice Model
(3 Modes: Transit, Auto-Drive Alone, Auto-Shared Ride)

Modes Applicable	Explanatory Variable[b]	Logit Coefficient[c]
All	In-vehicle Time	-.0032
All	Travel Cost (transit fare, highway cost)	-.002
T	OVTT -- wait for 1st bus	-.0032
T	OVTT -- walk + wait for 2nd subsequent buses	-.0044
DA	OVTT -- parking & unparking time	-.0257
SR	OVTT -- parking & unparking time	-.0342
T	Auto Required for Transit Access	-.9568
DA	Income	.5649
SR	Income	-.3362
SR	Highway Distance	-.0086

$\rho^2 = .34$

Source: R.H. Pratt Associates (1976)

[a] T = transit; DA = auto drive alone; SR = shared ride.

[b] Time is measured in tenths of a minute; cost in tenths of a cent; distance in tenths of a mile; income in terms of an index of quartiles. OVTT = out of vehicle travel time.

[c] t-statistics for all coefficients are significant at better than the .05 level.

mode for shopping and social/recreation trips is not known for a given individual. Accessibility to shopping and social/recreation is thus computed on the basis of destination-mode joint choice models for those trip purposes.

22. Shopping Access = $\ln (\sum_m \sum_d e^{V_{md}})$

where m = mode alternative (auto, transit)

d = destination alternative (40 randomly chosen zones)

$V_{md} = \sum_n B_n X_{mdn}$

B_n = coefficient in shopping trip model

23. Social/Recreation Access = $\ln (\sum_m \sum_d e^{V_{md}})$

where $V_{md} = \sum_n B_n X_{mdn}$

and B_n = coefficient in social/recreation trip model

Separate destination-mode choice models for shopping and for social/recreation were calibrated for the 1970 Twin Cities data by Jacobson (1978). Their coefficients are presented in Tables 4 - 6 and 4 - 7.

As "log sums", the coefficients of these accessibility variables reflect the degree of dependence (β=1) or independence (β=0) between travel behavior and the location/housing/auto ownership choices modelled here (see McFadden, 1977).

<u>Housing Cost</u> Housing cost depends on many factors, including size and quality of housing unit and whether it is owned or rented, as well as location. It is expected that the higher income households are willing to pay more in housing costs per room than others. Controlling for income, however, one can hypothesize that households have some desire to hold down housing costs. As a simple measure, one can define:

24. Housing Value/Rooms/Income = $\dfrac{\text{Zone Median House Value}}{\text{Zone Median Size of Owned Homes}} \Big/ \text{Income of Mover}$

(if household is in owner submarket)

= 0 (if household is in renter submarket)

TABLE 4-6

SHOPPING MODE AND DESTINATION CHOICE MODEL

Modes applicable	Explanatory Variable	Logit Coefficient
Auto only	Auto Constant	-8.134
Auto only	Autos Owned	+.7291
All (Auto & Transit)	Zonal Retail Employment Density[a]	-.1761
All (Auto & Transit)	ln (Zonal Retail Employment)	+1.000
All (Auto & Transit)	Out of Vehical Travel Time/Distance[b] from Home	-.187
All (Auto & Transit)	ln (Total Travel Time)[c]	-8.894
All (Auto & Transit)	Travel Cost/Income[d]	-.070

a 100 persons/commercial acre
b minutes/mile (for one-way trip)
c minutes of travel in and out of vehicle (for one-way trip)
d ¢ (for one-way trip)/income decile (where 1 =$0-3000, 2 = $3-4000, 3 = $4-6000, 4 = $6-8000, 5 = $8-10000, 6 = $10-12000, 7 = $12-15000, 8 = $15-20000, 9 = $20-25000, 10 = over $25000)

Note: Model based on sample of 128 households. For each household, destination choice was estimated on the basis of the chosen and 40 sampled zones.

Source: Jacobson (1978)

TABLE 4-7

SOCIAL/RECREATION MODE AND DESTINATION MODEL

Modes applicable	Explanatory Variable	Logit Coefficient
Auto only	Auto Constant	+2.554
All (Auto & Transit)	ln(Dest. Zone Population)	+.0018
All (Auto & Transit)	ln(Dest. Zone Employment)	+.00096
All (Auto & Transit)	ln(Dest. Zone Vacant Acreage)	+.0036
All (Auto & Transit)	Out of Vehicle Travel Time / Distance from Home	-.378
All (Auto & Transit)	ln (Total Travel Time)[a]	-.355
All (Auto & Transit)	Travel Cost/Income[a]	-.00731

[a]Travel time is measured in one-way minutes, distance in one-way miles, travel cost in one-way cents, and income in deciles (as defined for Table 4-6)

Note: Model based on sample of 77 households. For each household, destination choice was estimated on the basis of the chosen and 40 sampled zones.

Source: Jacobson (1978)

25. $\text{Rent/Rooms/Income} = \dfrac{\text{Zone Median Rent}}{\text{Zone Median Size of Rented Homes}} \Big/ \text{Income of Mover}$

(if household is in renter submarket)
= 0 (if household is in owner submarket)

An alternative means of measuring effects of cost on housing, location and auto ownership choices is to define a single measure:

Income Remaining = Annual Household Income- Annualized Housing Cost- Annual Property Taxes-Annualized Auto Ownership Costs-Annual Costs of Travel to Work.

This type of approach was adopted by Lerman (1975), in his joint model of location, housing type, and auto ownership. It can be hypothesized that households attempt to maximize income remaining. This specification, however, ignores any preference of higher income households to spend more money to obtain a higher quality or larger size housing unit rather than minimize costs. It also assumes that the marginal effect of an extra dollar of housing cost has the same effect as an extra dollar of property tax costs on choice probabilities. That may not be true. For this analyses, it was found that the inclusion of separate measures for housing costs, taxes, and accessibility to work explained more of consumer behavior than the income remaining method.

Zone Aggregation Level. It should be the case that, all else equals, those housing type and location alternatives with more homes in them more likely to be chosen than choice alternatives with fewer homes. This is the problem of differential aggregation of elemental alternatives, and was discussed in Section 3.7. To capture this effect, it is necessary to define:

26. Housing opportunities per alternative = Natural log of # of housing units of given structure type in given zone.

Transferrability of the logit choice model to other location zone schemes than the one used here requires that the logit coefficient of this variable be constrained to 1. This assumes that zone size (i.e. the level of zone aggregation) is not correlated with unmeasured zone attributes.

Constants. Rounding out the specification of explanatory variables are constant terms for the housing and auto ownership dimensions of the housing/location/auto ownership joint choice. These are defined as follows:

12. House Constant = 1 for House alternatives
= 0 for Apartment alternatives

14. Single Auto Constant = 1 for 1+ auto alternatives
= 0 for 0 or 2+ auto alternatives

17. Multiple Auto Constant = 1 for 2+ auto alternatives
= 0 for 0 of 1 auto alternatives

27. Apartment and Single Auto Constant = 1 for Apartment-- 1 Auto alternatives.
= 0 for all other alternatives

28. House and Multiple Auto Constant = 1 for House-- 2+ Auto alternatives

Coefficients of these constant terms have no direct behavioral interpretation. The base or mean probability of a given housing or auto ownership choice cannot be computed without also controlling for household characteristics and housing cost factors.

Sources of data, units of measurement, and expected coefficient signs for the 28 explanatory variables in housing/location/auto ownership choice are summarized in Table 4-8.

TABLE 4-8

VARIABLE SOURCES, UNITS OF MEASUREMENT, AND EXPECTED COEFFICIENTS
(FOR LOCATION/HOUSING/AUTO OWNERSHIP MODEL)

	Variable	Data Source[a]	Units of Measurement	Expected Coeff
1.	Squared Distance from Previous Residence	C	.01 miles	-
2.	Crime Relative to Previous Residence	G	offenses/1000 pop.	-
3.	Net Residential Density	B	100 persons/acre	-
4.	Proximity to Industrial Land	B	ind. acres/ 100 resid. acres	-
5.	Squared Pos. Inc. Differential	A,D	$10000	-
6.	Squared Neg. Inc. Differential	A,D	$10000	?
7.	Household Size Differential	A,D	.1 persons	-
8.	% Elderly (for elderly HH's)	A,D	percentiles	+
9.	% Elderly (for non-elderly HH's)	A,D	percentiles	-
10.	Teacher/Pupil Ratio (for HH's with children)	A,E	pupils/teacher	+
11.	Property Tax per HH	F	$100	-
12.	Constant (for House Alternatives)	--	--	
13.	No. Children (for House Alternatives)	A	persons	+
14.	Constant (for 1-auto alternatives)	--	--	
15.	No. Drivers (for 1-auto alternatives)	A	persons	+
16.	Income (or 1-auto alternative)	A	$1000	+
17.	Constant (for 2+ auto alternatives)	--	--	
18.	No. Drivers (for 2+ auto alternatives)	A	persons	+(>var.
19.	Income (for 2+ auto alternatives)	A	$1000	+(>var.
20.	Worktrip Access - primary worker	A,C	(utility scale)	+ ($\leq$1)
21.	Worktrip Access- secondary worker	A,C	(utility scale)	+ ($\leq$1)
22.	Shopping Access	A,C	(utility scale)	+ (<1)
23.	Social-Recreation Access	A,C	(utility scale)	+ ($\leq$1)
24.	Housing Value/rooms per income	D	$100/$1000	-
25.	Rent/rooms per Income	C	$/$1000	-
26.	Housing Units (of given type) per zone	B,D	dwelling units	+1
27.	Constant (for apt., single auto)	--	--	
28.	Constant (for House, 2+ auto)	--	--	

[a] Data Sources:

A = 1970 Twin Cities Metropolitan Area Home Interview Survey
B = land use data supplied by Metropolitan Council of the Twin Cities Area
C = skim trees and zone travel characteristics supplied by the Metropolitan Council of the Twin Cites Area
D = 1970 U.S. Census of Population and Housing (Fourth Count)
E = Minnesota State Department of Education
F = Minnesota State Department of Taxation
G = Minnesota State Department of Public Safety, Minneapolis Police Department and St. Paul Police Department

Variable Definitions and Coefficient Hypotheses for Moving and Tenure Choice Model

Household Characteristics

There has been a wealth of evidence from prior studies that household moving and tenure choice decisions are strongly affected by family life cycle position. Age has been found to have a strong negative effect on the propensity of a household to move. Among movers, however, older persons would be more likely than young persons to purchase a home rather than rent their housing. Four age variables are thus defined:

1. "Age of Head > 62 (for move-own alt.)
   = 1 if age of household head* > 62; = 0 otherwise
   (for move, purchase home alternative)
   = 0 (for other alternatives)

10. "Age of Head > 62 (for move-rent alt.)"
   = 1 if age of household head* > 62; = 0 otherwise
   (for move, rent alternative)
   = 0 (for other alternatives)

2. "Age of Head < 29 (for move-own alt.)"
   = 1 if age of household head* < 29; = 0 otherwise
   (for move, purchase home alternative)
   = 0 (for other alternatives)

11. "Age of Head < 29 (for move-rent alt.)"
   = 1 if age of household head* < 29; 0 otherwise
   (for move, rent alternative)
   = 0 (for other alternatives)

*for a married couple, the male is designated as household head

The negative effect of age of moving should hold regardless of tenure choice. Measured relative to the base alternative -- not moving, both of these variables are thus expected to have a negative sign. Reflecting the positive effect of age on home ownership, however, variable 2 is expected to have a higher coefficient (i.e., less negative) than variable 3.

Family size or number of children in the household has been recognized as a major factor in tenure choice. Families with several children would be more likely than singles or childless couples to live in houses rather than apartments. This can be explained by both a preference of many families to have a yard for their children to use, and by the relative lack of apartments suitable for large families in most housing markets. Six variables are here defined for family size:

3. "1 or 2 Children (for move-own alt.)"
   = 1 if 1 or 2 children* are present; = 0 otherwise (for move, purchase home alternative)
   = 0 (for other alternatives)

12. "1 or 2 Children (for move-rent alt.)"
   = 1 if 1 or 2 children* are present; = 0 otherwise (for move, rent alternative)
   = 0 (for other alternatives)

4. "3 or More Children (for move-own alt.)"
   = 1 if 3 or more children*are present; = 0 otherwise (for move, purchase home alternative)
   = 0 (for other alternatives)

13. "3 or More Children (for move-rent alt.)"
   = 1 if 3 or more children* are present; = 0 otherwise (for move, rent alternative)
   = 0 (for other alternatives)

5. "Single Person Household (for move-own alt.)"
   = 1 if household size is 1; = 0 otherwise (for move, purchase home alternative)
   = 0 (for other alternatives)

14. "Single Person Household (for move-rent alt.)"
   = 1 if household size is 1; = 0 otherwise (for move, rent alternative)
   = 0 (for other alternatives)

* A child is defined as a member of the household, age $<$ 18, excluding those with full-time jobs.

There is no strong hypothesis for the effect of family size or number of children on the overall propensity to move. It is expected here that the number of children increases the likelihood of purchasing a new home and decreases the likelihood of renting a new home, relative to not moving at all.

Lower income households face more limited housing alternatives and cannot easily afford to purchase homes. Household income is thus expected to have a positive effect on both moving in general and on purchasing a home relative to renting. To measure this effect, the following variables are defined:

6. Income (for Move-Own alt.) = Gross Household Annual Income (for Move, Purchase Home alternative)
   = 0 (for other alternatives)

15. Income (for Move-Rent alt.) = Gross Household Annual Income (for Move, Rent alternative)
   = 0 (for other alternatives)

Attributes of Spatial Alternatives

The link between residential mobility and subsequent location choice is the perceived attraction of locational alternatives. Evidence from attitudinal surveys suggests that considerations of housing quality, neighborhood quality, and accessibility can all play roles in a household's locational satisfaction and hence, its propensity to move. The location/housing/auto ownership model (previously outlined) contains measures of land use, accessibility, crime, housing, demographic and tax attributes of locations, and coefficients for weighting the contribution of each factor to locational choice.

Consistent with a sequential or recursive logit structure (Section 3.5b), the expected maximum utility for all owner or rental locational alternatives (and all housing types and auto ownership levels) is defined on the basis of the coefficients form the location/housing/auto ownership model. It is computed as the natural log of the denominator from that model (i.e., the log sum of the exponents of the estimated utilities of all alternative housing, location and auto ownership combinations):

7. Utility of Owner Unit Spatial Alternatives

$$= \ln \sum_{L} \sum_{A} \exp(\beta X_{lha}) \quad \text{(for the Move, Purchase Home alternative)}$$

= 0 (for other alternatives)

16. Utility of Rental Unit Spatial Alternatives

$$= \ln \sum_{L} \sum_{H} \sum_{A} \exp(\beta X_{lha}) \quad \text{(for the Move, Rent alternative)}$$

= 0 (for other alternatives)

where L = location zones

H = housing structure types (house, apartment) (apartments are available only as rental units in the model)

A = auto ownership levels (0, 1, 2+)

β = vector of coefficients (presented in Table 5-3)

X_{lha} = vector of independent variables for each location (l), housing type (h), and auto ownership level (a) (see Table 4-8, also 5-3).

Attributes of spatial alternatives are computed for each household on the basis of five randomly-assigned location zones. For households that did move, their subsequent residential location is included in the set of five randomly-chosen location alternatives.

It is, of course, expected that the estimated attraction of spatial alternatives has a positive effect on the probability of moving. The interpretation of these variables are,however, more complicated than that. As "log sums", the coefficients of these utility measures reflect the degree of statistical dependence (β=1) or independence (β=0) between location /housing/auto ownership behavior and the mobility/tenure type choices modelled here. Since subsequent location and housing choice is relevant only for movers, however, the "log sums" have no value for the no-move alternative. This in itself represents no problem, except that it complicates the interpretation of these variables as pure measures of locational attraction, since their magnitude is positively affected by the household attributes of number of children, number of drivers, and household income. The coefficients of these variables thus reflect effects of household attributes on mobility in addition to the role of locational attraction. The existence of separate variables for household size, drivers, and income makes it possible to unsort these two types of factors. Measures of household size and income have already been introduced. Number of drivers in the household is here explicitly introduced as a factor in moving and tenure choices only as a control for the effect of that household characteristic on the log sum utility measures.

8. Number of Drivers (for Move-Own alt.) = number of licensed drivers in the household (for the Move, Purchase Home alternative); = 0 (for other alternatives)

17. Number of Drivers (for Move-Rent alt.) = number of licensed drivers in the household (for the Move, Rent alternative); = 0 (for other alternatives)

<u>Attributes of Current Location</u>

The propensity of a household to move has been linked by previous studies to dissatisfaction with the current dwelling unit and/or neighborhood. While the location/housing/auto ownership model yielded a set of coefficients for estimating the utility of spatial alternatives, this procedure is not necessarily applicable for the current housing. Two components of the utility measure, the number of housing units available in that zone and their cost, is of little relevance for the evaluation of a housing unit that one is already living in. In addition, it is not assumed here that the relative importance of crime, neighborhood socio-economic homogeneity, and access to work are necessarily the same for moving as for subsequent location choice. Accordingly, six attributes of the household's current location are defined. All else equal, is is expected that a higher crime rate and greater differences between the household and zone average age, income, and household size all exert a positive influence on the probability of a household moving. Accessibility to the workplace, on the other hand, is expected to diminish the probability of moving.

19. Crime Rate = Assaults and Robberies per thousand population at the current resident zone (for Move alternatives)
= 0 (for no-move alternatives)

20. Squared Pos. Income Diff. = $(\text{Household Income} - \text{Median Income})^2$ at the current zone (if Household Income > Median Zone Income); = 0 otherwise (for Move alternatives)
= 0 (for No-Move alternative)

21. Worktrip Access - Primary Worker = "Accessibility to Work" (as defined on p. 111) for the primary worker (if present); = 0 otherwise (for Move alternatives)
= 0 (for No-Move alternative)

22. Worktrip Access - Secondary Worker = "Accessibility to Work" (as defined on p. 111) for the secondary worker (if present); = 0 otherwise (for Move alternatives)
= 0 (for No-Move alternative)

23. % elderly (for non-elderly HH) = % of current zone population > 62 years old (if head of household < 62 years old); = 0 otherwise (for Move alternatives)
= 0 (for No-Move alternative)

24. Household Size Differential = Absolute Value (Household Size - Median Household Size in Current Zone) (for Move alternatives);
= 0 (for No-Move alternative)

Constants

Constant terms for moving and tenure choice alternatives are measured as:

9. Constant (Move-Own alt.) = 1 for Move, Purchase Home alternative
= 0 for other alternatives

18. Constant (Move-Rent alt.) = 1 for Move, Rent Home alternative
= 0 for other alternatives

Coefficients of these variables have no direct interpretation.

Sources of data, units of measurement, and expected coefficients signs for the 24 explanatory variables in the moving/tenure choice model are summariazed in Table 4-9.

TABLE 4-9

VARIABLE SOURCES, UNITS OF MEASUREMENT, AND EXPECTED COEFFICIENTS

(for Moving and Tenure Choice Model)

Variable	Data Source[a]	Units of Measurement	Expected Coeff.
(Variables for the Move-Own Alternative)			
1. Age of Head >62	A	0,1	-(> var. 10)
2. Age of Head < 29	A	0,1	+(< var. 11)
3. 1 or 2 Children	A	0,1	(> var. 12)
4. 3 or More Children	A	0,1	(> var. 13)
5. Single Person Household	A	0,1	-(< var. 14)
6. Household Income	A	$1000	+(> var. 15)
7. Utility of Spatial Alternatives	B	Utility Scale	+ (0-1)
8. No. Drivers in Household	A	persons	
9. Constant Term	--	--	
(Variables for the Move-Rent Alternative)			
10. Age of Head>62	A	0,1	-(< var. 1)
11. Age of Head<29	A	0,1	+(> var. 2)
12. 1 or 2 Children	A	0,1	-(< var. 3)
13. 3 or More Children	A	0,1	-(< var. 4)
14. Single Person Household	A	0,1	+(> var. 5)
15. Household Income	A	$1000	(< var. 6)
16. Utility of Spatial Alternatives	B	Utility Scale	+ (0-1)
17. No. Drivers in Household	A	persons	
18. Constant Term	--	--	
(Variables for the Move Alternatives; attributes of the current location)			
19. Crime Rate	C	offenses/1000 pop.	+
20. Squared Pos. Income Diff.	A,D	$10000	+
21. Worktrip Access - Primary Worker	A,E	Utility Scale	-
22. Worktrip Access - Secondary Worker	A,E	Utility Scale	-
23. % Elderly (for Non-Elderly HH)	A,D	percentiles	+
24. Household Size Differential	D	.1 persons	+

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[a]Data Sources:

A = 1970 Twin Cities Metropolitan Area Home Interview Survey
B = Variables listed in Table 4-9; Coefficients presented in Table 5-3
C = Minn. State Dept. of Public Safety, Minneapolis and St. Paul Police Depts.
D = 1970 Census of Population and Housing (Fourth Count)
E = skim trees and zone travel characteristics supplied by the Metropolitan Council of the Twin Cities Area

CHAPTER 5
EMPIRICAL RESULTS

The model of residential mobility, location, housing, and auto ownership decisions described in Chapter 4 was calibrated using the 1970 Twin Cities, Minnesota home interview survey. A description of the study area, along with definitions of the moving behavior and spatial choice measures, is presented in Section 5.1. Section 5.2 contains analysis of the correlation between various location choice characteristics. Coefficient estimates for the moving/tenure choice model and the location/housing structure/auto ownership model are respectively presented in Section 5.3 and 5.4.

5.1 The Spatial Choice Set

The 1970 Twin Cites Metropolitan Area Survey was a survey of 1% of all households in the 7 county Minneapolis-St. Paul Metropolitan area. The seven counties -- Hennepin, Ramsey, Anoka, Washington, Dakota, Scott and Carver -- together comprise an area of greater then 60 miles across. Much land in the peripheral portions of the area is rural (Metropolitan Council, 1974). For this analysis of intra-metropolitan moving and location, the study area is more narrowly defined to eliminate most of the less urbanized area. Eliminated from the analysis were Carver and Scott counties, for which published tract-level data was not available in the 1970 Census of Population and Housing. Also eliminated from the analysis were towns in the other counties for which complete information on property taxes, school quality, and crime rates was not available. Most of these towns are small in population.

Figure 5-1 is a map of the seven-county metropolitan region, along with an outline of the boundaries of the study area for this analysis. This study area can be compared with the Transit and auto accessibility

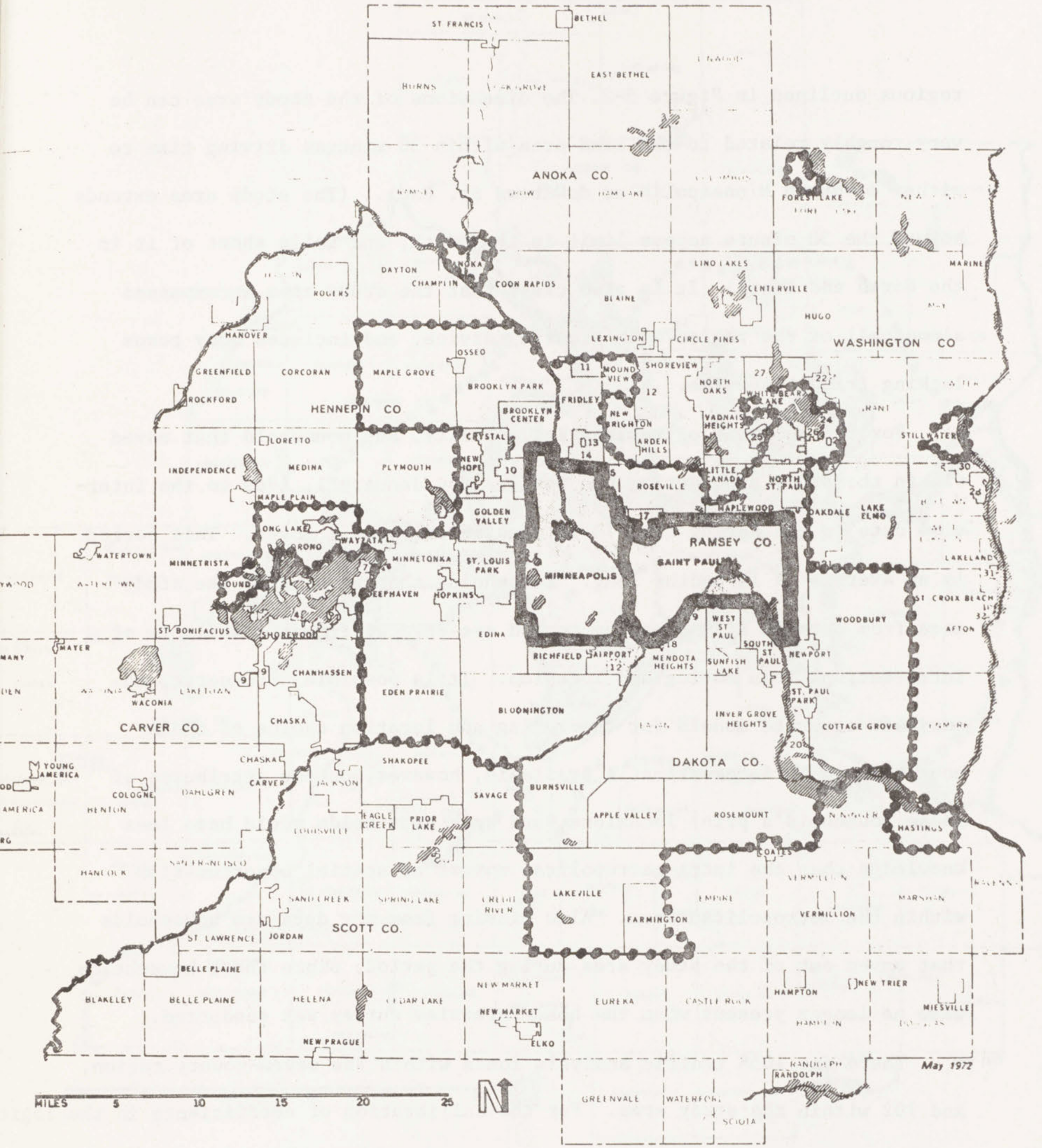

FIGURE 5-1: THE STUDY AREA
.... spatial choice set for residential location analysis
▬ central cities of Minneapolis and St. Paul
* cental business districts

regions outlined in Figure 5-2. The dimensions of the study area can be very roughly related to the land area within 30 minutes driving time to either downtown Minneapolis or downtown St. Paul. (The study area extends beyond the 30 minute access limit in the South, and falls short of it in the North and East.) It is also clear that the study area encompasses almost all of the region with transit service, and includes many towns lacking transit service.

For the analysis of residential mobility, any household that moved within the study area during the period from January 1, 1969 to the interview date in the Spring of 1970 is considered to be a mover. This period is an average of 17 months long. Households that moved into the study area from outside it during the period are deleted from the analysis of intra-metropolitan moving and location. It is possible, of course, to estimate separate models for the moving and location choice of those households. No information is available, however, on the attributes of those household's prior locations, and such households would have less knowledge than the intra-metropolitan movers of spatial opportunities within the metropolitan area. Also missing from the data are households that moved out of the study area during the period, since those households were no longer present when the home interview survey was conducted.

There are 1058 traffic analysis zones within the seven-county region, and 702 within the study area. For the callibration of coefficients in the logit model of location decisions, choice is estimated for each mover from a "choice set" comprised of the location zone subsequently chosen and four randomly-selected other location zones. Characteristics of the households and location zones in this study are summarized in Table 5-1.

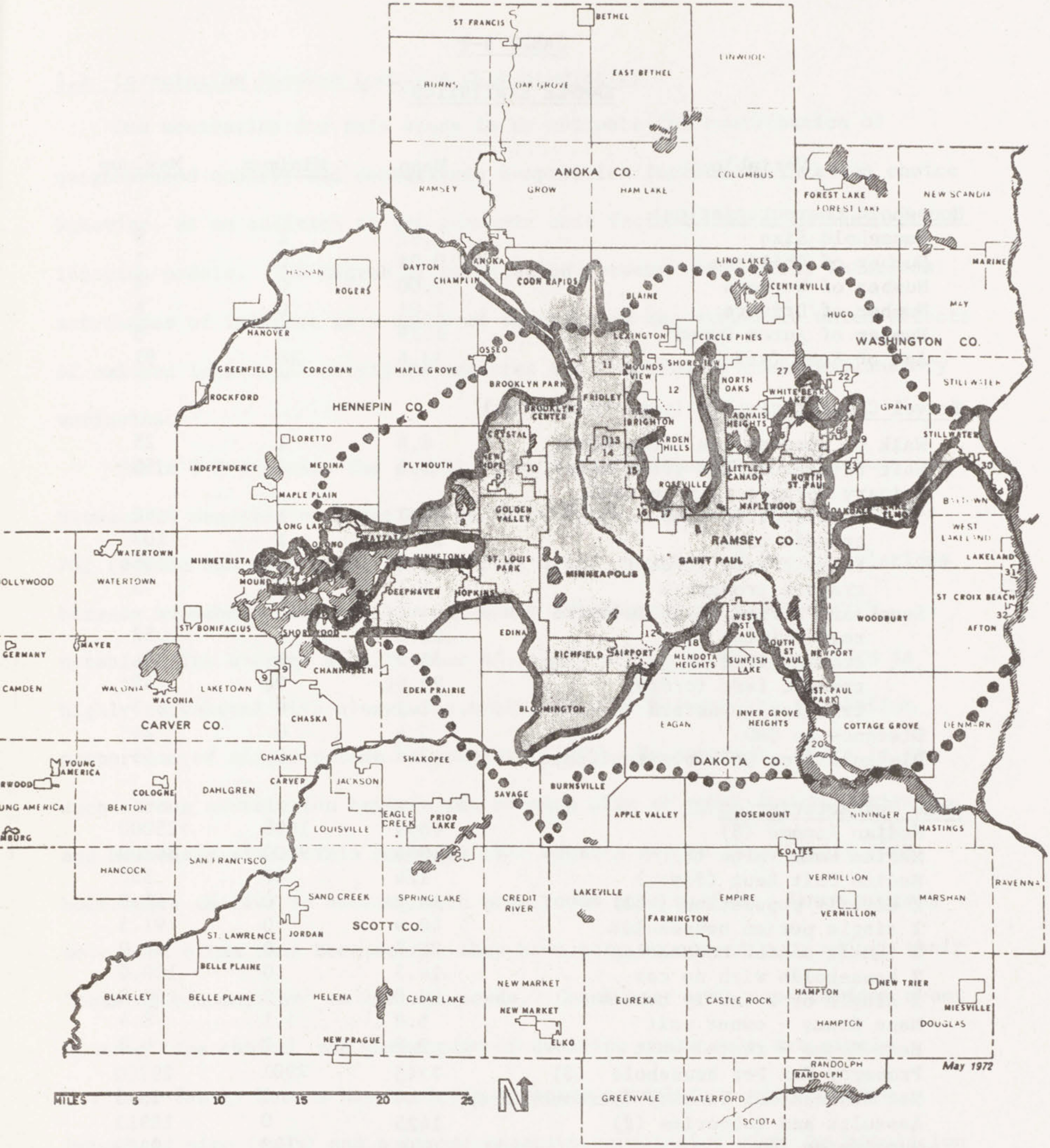

FIGURE 5-2: 1970 TRANSIT AND AUTO ACCESSIBILITY
transit service area
.... area within 30 min. driving time to either Minneapolis or St. Paul CBD center.
(Source: Metropolitan Council, 1974)

TABLE 5-1

SAMPLE STATISTICS

Variable	Mean	Minimum	Maximum
Household Characteristics:			
Household Size	2.92	1	9
Number of Children	0.98	0	7
Number of Workers	1.00	0	4
Number of Drivers	1.61	0	6
Number of Autos Owned	1.19	0	5
Age of Head (yrs.)	33.6	18	91
Travel Characteristics (time in minutes)			
Walk to nearest bus (from home)	6.6	1	25
Wait to nearest bus (from home)	9.6	1	50
Primary Worker; trip to work:			
road driving time	20.7	1	68
transit time	35.8	1	103
transit fare (¢/day)	29.8¢	0¢	56¢
transit transfers	1.1	0	5
Secondary Worker; trip to work:			
road driving time	22.0	2	52
transit time	36.0	1	84
transit fare (¢/day)	29.6¢	0¢	49¢
transity transfers	1.1	0	3
Distance to CBD	5.4	0	24
Distance from previous residence	7	0	45
Zone Characteristics			
Median Income ($)	9039	1698	>25000
Median Home Value ($)	21054	9000	86200
Median Unit Rent ($/mo.)	126	47	350
% elderly population (>62)	15.2	0	41.8
% single person households	40.9	0	91.5
% female-headed households	22.7	0	36.0
% households with no car	14.7	0	100.0
% single or 2-family houses	68.0	0	100.0
Mean Rooms - owner unit	5.8	3.1	8.4
Mean Rooms - rental unit	3.8	1.2	6.8
Property Tax Per Household ($)	7345	2001	29700
Net Residential Density (persons/acre)	44	0	2335
Assaults and Robberies (#)	1425	0	18913
Burglaries (#)	1919	128	20334
Total Acres	431	2	5321

5.2 Correlation Between Location Characteristics

One motivation for this study is to estimate the contribution of neighborhood quality and demographic composition factors to location choice behavior, as an addition to the economic cost factors common in residential location models. The degree of correlation between the various locational attributes of interest as a means of identifying the extent to which effects of omitted locational attribute measures are absorbed by other explanatory variables.

Table 5-2 presents the simple Pearson produce-moment correlations between 24 measures of location zone attributes. The observation are the 702 traffic analysis zones in the study area. Several of the correlations between household size and housing stock attributes are particularly notable. The average size (number of rooms) of rental housing units is highly correlated with average household size (+.81) and the population proportion of single-person households (-.84). By contrast, there is no such strong correlation between the average size of owner housing units and household size. This suggests that renters may be less likely than homeowners to live in housing with more rooms than needed. Since renters move more often than homeowners, they have more opportunity to adjust their "housing consumption" to current needs. Consistent with expectations about housing type choice, the percentage of dwelling units that are single (or two)-family houses has a strong positive correlation with average household size (+.85) and a strong negative correlation with the population proportion that is single-person households (-.90).

Also notable is the strong positive correlation between average household income and both average housing unit value and rent. School quality

TABLE 5-2
CORRELATION BETWEEN LOCATION ZONE ATTRIBUTES

	Avg. Household Size	Avg. Income	Avg. Value (Owner Unit)	Avg. Rent	% 1 or 2-Family Units	% Built Before 1940	5-yr. Population Change	Avg. Rooms (Owner Units)	Avg. Rooms (Rental Units)	% Elderly	% Single Person HH	Property Tax Rate	Property Tax per HH	Pupil/Teacher Ratio	School Exp./Pupil	Net Residential Density	Assaults & Robberies	Burglaries	Recreation/Resid. Land	Industrial/Resid. Land	Commercial/Resid. Land	% HH's without Auto
Avg. Income	+.79																					
Avg. Value (Owner Units	+.47	+.74																				
Avg. Rent	+.49	+.74	+.65																			
% 1 or 2-Family Unit	+.86	+.70	+.32	+.34																		
% Built Before 1940	-.66	-.75	-.61	-.70	-.37																	
5-yr. Population Change	-.48	-.49	-.15	-.16	-.72	+.12																
Avg. Rooms (Owner Units)	+.44	+.53	+.71	+.44	+.38	-.26	-.13															
Avg. Rooms (Rental Units)	+.81	+.64	+.39	+.44	+.84	-.37	-.47	+.52														
% Elderly	-.72	-.57	-.42	-.51	-.42	+.67	-.02	-.29	-.48													
% Single Person HH	-.94	-.78	-.43	-.52	-.90	+.60	+.51	-.46	-.84	+.64												
Property Tax Rate	+.20	+.22	+.16	+.24	+.13	-.27	+.03	+.05	+.19	-.26	-.16											
Property Taxes/HH	+.43	+.43	+.41	+.36	+.34	-.35	-.16	+.37	+.37	-.38	-.39	+.20										
Pupil/Teacher Ratio	+.60	+.61	+.49	+.52	+.36	-.66	-.13	+.26	+.36	-.58	-.50	+.34	+.30									
School Exp./Pupil	-.58	-.51	-.44	-.28	-.37	+.53	+.15	-.27	-.34	+.50	+.45	-.13	-.27	-.74								
Net. Residential Density	-.32	-.28	-.14	-.16	-.32	+.19	+.19	-.21	-.31	+.19	+.35	-.07	-.04	-.16	+.14							
Assaults & Robberies	-.47	-.47	-.37	-.33	-.46	+.38	+.22	-.35	-.39	+.31	+.54	-.08	-.18	-.30	+.27	+.19						
Burglaries	-.45	-.52	-.43	-.37	-.39	+.46	+.20	-.33	-.30	+.33	+.48	-.07	-.22	-.39	+.36	+.14	+.85					
Recreation/Resid. Land	+.02	+.03	-.00	-.01	+.04	-.02	-.07	-.00	+.04	+.00	-.03	-.03	+.05	-.03	+.03	-.02	-.03	-.02				
Industrial/Resid. Land	-.06	-.08	.00	-.04	-.04	+.04	+.05	-.09	-.05	+.01	+.06	-.05	-.14	-.11	+.10	+.10	+.08	+.11	+.04			
Commercial/Resid. Land	-.16	-.09	-.03	-.01	-.21	+.01	+.11	-.11	-.20	+.07	+.19	+.06	-.05	-.01	+.05	+.20	+.12	+.09	-.00	+.16		
% Without Auto	-.64	-.66	-.45	-.52	-.58	+.57	+.35	-.33	-.50	+.50	+.66	-.14	-.35	-.45	+.39	+.40	+.42	+.37	-.08	+.01	+.09	
School Children/HH	+.23	+.22	+.13	+.23	+.16	-.22	-.11	-.08	+.17	-.20	-.19	+.08	+.17	+.18	-.17	-.11	+.00	-.04	-.03	-.09	-.09	-.22

(Educational Expenditures and the inverse of the Pupil/Teacher ratio) is negatively correlated with older housing units. Lower income, smaller families, and older buildings are typically attributes of central city locations. Central city school systems often have higher fixed costs and greater remedial services then suburban school districts.

Table 5-3 presents the simple correlations between some travel characteristics of location choice and non-travel location attributes. It is motivated by the concern that location models based primarily on travel-to-work considerations may be really capturing effects of non-travel location attributes that are correlated with travel characteristics.

Not surprisingly, it is found that zone distance from the CBD (whichever is closer of the Twin City CBD's) is correlated with larger household sizes (.63), higher incomes (.60), higher proportions of single family houses (.49), newer homes (.56), higher property taxes (.44), and lower crime rates (.38). Residential location models based on assumptions of a monocentric city can thus be biased by the correlation between the distance to CBD measure and other social and demographic factors.

The residential location model presented in Chapter 4 does not assume CBD-based workplaces, but instead includes measures of accessibility to workplace for all alternative residential locations. Accessibility to work, however, depends on the specific workplace locations of the workers in each household. Accessibility for shopping and social/recreation events is also measured dependent on characteristics of individual households. For the choice model analysis, of interest is the degree of correlation between household accessibility and other location zone attributes <u>of locational</u>

TABLE 5-3
CORRELATION BETWEEN TRAVEL AND NON-TRAVEL LOCATION ZONE ATTRIBUTES

Travel Characteristic	Avg. Household Size	Avg. Income	% 1 or 2-Family Units	% Built Before 1940	Avg. Rooms (Rental Units)	% Elderly	Property Tax Rate	Net Residential Density	Assaults & Robberies	Commercial/Resid. Land	% HH's Without Auto	School Children per HH
General Zone Characteristic:												
Distance to CBD	+.63	+.60	+.49	-.56	+.52	-.07	+.44	-.21	-.38	+.05	-.43	+.18
Avg. Wait Time at Bus Stop	-.34	-.36	-.19	+.38	-.21	-.01	-.15	+.01	+.14	+.05	+.27	-.05
Avg. Walk Time to Bus Stop	+.27	+.34	+.18	-.39	+.15	-.06	+.12	-.12	-.19	-.01	-.26	+.08
Characteristic of Travel to Specific Workplace of Primary Worker - (randomly assigned residences)												
Bus Time to Work	+.26	+.26	+.18	-.28	+.15	-.07	+.10	-.11	-.16	-.03	-.14	+.08
Auto Time to Work	+.26	+.24	+.19	-.24	+.20	-.08	+.07	-.06	-.19	-.02	-.13	+.06
Bus Fare to Work	+.13	+.15	+.04	-.14	+.06	-.01	-.04	+.01	-.05	-.00	-.06	+.07
Generalized Accessibility (randomly assigned residences)												
Primary Worker Accessibility to Work	+.20	+.22	+.13	-.25	+.09	+.00	+.06	-.08	-.17	-.00	-.14	+.07
Secondary Worker Accessibility to Work	-.00	+.01	+.04	-.00	-.01	+.22	-.03	+.00	-.01	+.01	-.07	+.01
Household Accessibility to Shopping	+.07	-.01	+.02	-.03	+.01	+.13	+.02	-.00	+.01	-.01	-.10	-.08
Household Accessibility to Social/Recreation	+.05	+.00	+.04	+.01	+.03	+.15	+.00	-.01	+.01	.01	-.14	-.07

NOTE: The following location zone attributes were not correlated with any travel characteristics by more than .10:

- 5 yr. population change
- Avg. Rms.-Owner units
- % single person HH's
- school exp., pupil/teacher ratio
- ratio: Recreation/residential land
- retail employment

alternatives, rather than of the final choices of households. Correlations between location zone attributes and accessibility characteristics for each type worktrip were thus computed by placing each of 525 recent movers into two randomly-selected locations in the study area.

In general, it is found that there are no large correlations between non-travel location attributes and the estimated accessibility to workplace of the primary worker or workplace of the secondary worker, shopping, or social/recreation activities. Although the correlations were weak, household accessibility for each trip purpose (and the travel time and cost components of accessibility to primary workplace) all tended to be highest for areas with suburban qualities.

5.3 Logit Estimates of the Location, Housing Structure and Auto Ownership Model

Table 5-4 presents logit coefficients and associated t-statistics for the 28 explanatory variables in the joint choice of location zone, housing structure, and auto ownership level. The sign and significance of the coefficients are discussed here. The magnitude of logit coefficients reveal the effect of each variable on the logit utility, or the natural logarithm of the relative likilihood of choosing a given alternative. As that has little intuitive meaning, the magnitude of independent variable effects on choice probabilities is discussed in terms of elasticities of choice in Chapter 6.

Coefficients of location zone attributes generally supported the prior hypotheses. Location zone distance from the previous household residence had a significant negative effect on location choice. This supports the "search distance" hypothesis that a searcher is less likely to consider, or even be aware of, locational alternatives located at a distance from the

TABLE 5.4

LOGIT ESTIMATION OF

LOCATION, HOUSING TYPE AND AUTO OWNERSHIP CHOICE

Variable	Coefficient	t-statistic
I. X_l (Factors That Vary Among Locations)		
1. Squared Distance from Previous Residence	-1.412	-9.71
2. Crime Relative to Previous Residence	- .066	-1.79
3. Net Residential Density	- .066	-0.54
4. Proximity to Industrial Land	+ .002	0.13
5. Squared Pos. Income Differential	-1.066	-3.40
6. Squared Neg. Income Differential	+ .321	0.63
7. Household Size Differential	+ .031	1.93
8. % Elderly (for elderly HH's)	+ .035	0.90
9. % Elderly (for non-elderly HH's)	- .020	-1.70
10. Teacher/Pupil Ratio (for HH's w/children)	+ .014	1.72
11. Property Tax per HH	- .023	-0.51
II. X_h (Factors That Vary Among Housing Types)		
12. Constant (for House alternatives)	-2.818	-9.30
13. No. Children (for House alternatives)	+ .862	5.99

TABLE 5.4 (Cont'd)

	Coefficient	t-statistic	
III. X_a (Factors That Vary Among Auto Ownership Choices)			
14. Constant (for 1 auto alternatives)	-2.388	-4.68	
15. No. Drivers (" " ")	+2.741	8.11	
16. Income (" " ")	+ .216	4.21	
17. Constant (for 2+ auto alternatives)	-7.508	-11.30	
18. No. Drivers (" " ")	+3.979	10.09	
19. Income (" " ")	+ .286	5.23	
IV. X_{la} (Factors That Vary Among Location and Auto Ownerships Choices)			
20. Worktrip Access - primary worker	+1.326	3.94	0.97[a]
21. Worktrip Access - secondary worker	+ .887	1.81	0.23[a]
22. Shopping Access	- .020	0.47	23.70[a]
23. Social-Recreation Access	+ .008	0.13	16.57[a]
V. X_{lh} (Factors That Vary Among Location and Housing Choices)			
24. (Housing Value/Size) per income	+ .820	0.51	
25. (Rent/Size) per income	-1.276	-2.15	
26. ln (Housing opportunities per alternative)	+1.000	----	
VI. X_{ha} (Factors That Vary Among Housing and Auto Ownership Choices)			
27. Constant (for apt., 1 auto alternatives)	- .899	-2.97	
28. Constant (for house, 2+ auto alternatives)	+1.229	3.46	

TABLE 5.4 (Cont'd)

N = 523 households, 7406 cases

$\ln L(0) = -1299$

$\ln L(\hat{\beta})$ -838

$\rho^2 = .35$

% right = 45.7

$\chi^2 = 922$ (28 d.f.)

Note: t-statistics reflects significance of coefficient from 0, unless otherwise noted

[a]t-statistic for significance of coefficient from 1

household's last residence.

The rate of assaults and robberies relative to that of the last residence also showed a negative effect on location choice. This effect (significant at the .05 significance level for a 1-tailed test), suggests that movers do attempt to minimize crime in their location choice.

The role of land use considerations in location choice appeared weak. Neither residential density nor proximity to industrial land showed an effect on location choice significantly different from zero. The negative sign for the coefficient of net residential density was, however, consistent with expectations. The measure of proximity to industrial land may have failed to capture the intended effect because it was not sensitive to the existence of industrial land in adjoining zones.

Income and age considerations were found to be important in location choice. Movers were found to avoid neighborhoods with lower incomes than they, but not to avoid higher income neighborhoods. Younger households were found to avoid living in neighborhoods with a large proportion of elderly residents. The coefficient of the "household size differential" variable, however, failed to support the hypothesis that households tend to choose neighbors of a similar household size as themselves. Such an effect might be revealed by a different variable specification, such as separate estimates of the effect of neighborhood household size for large and small households. The school quality measure of teacher/pupil ratio showed a negative effect on location choice. School quality is a particularly difficult concept to measure because perceived school quality may very well be more a function of the socio-economic status of the neighborhood than a function of the instructional inputs of the school. A high teacher/pupil ratio may be undesirable for many households insofar as it reflects a poor neighborhood with more remedial education programs.

The effects of household characteristics on housing type and auto ownership choices were as expected. Households with many children were more likely than others to choose houses over apartments. Both income and number of licensed drivers had positive effects on auto ownership level. The latter variable, in particular, increased the likelihood of multiple car ownership.

Worktrip accessibility for both the primary and secondary workers had coefficients significantly defferent from 1 (at the .05 significance level). This implies that worktrip accessibility is a positive consideration in location choice, and is in fact jointly considered with location and auto ownership choices. Shopping and social/recreation accessibility, on the other hand, had coefficients significantly different from 1 and not significantly different from zero. There was thus no evidence that either shopping accessibility or social/recreation accessibility were important considerations for the residential location or auto ownership choices of households. This finding must be qualified, however, by the recognition that these two elements of accessibility are measured much more crudely than worktrip accessibility, since both shopping and social/recreation destinations for a given individual from alternative residential locations can only be estimated.

Housing cost variables showed mixed results. Controlling for both dwelling unit size and household income in a linear fashion, there was evidence that renters do attempt to minimize their housing costs. No such evidence was found for homeowners. This is understandable, insofar as owner units tend to be more heterogeneous in features and quality than rental units. More work is necessary, however, to further understand the complex relationship between housing costs, dwelling unit size, household size, and income.

The effect of zonal housing opportunities on housing and location choice was constrained to 1 to allow model transferability to other zonal schemes in other metropolitan areas. This constraint assumes homogeneity within location zones and independence between the magnitude of zonal opportunities and unobserved location or housing attributes.

In summary, it can be concluded that search distance, crime, and socio-demographic homogeneity are important factors in the location choice of movers, in addition to the economic factors of worktrip accessibility and housing costs.

5.4 Logit Estimates of the Moving and Tenure Choice Model

Table 5-5 presents logit coefficients and associated t-statistics for the 24 explanatory variables in the joint choice of moving and tenure type. The demographic variables all show significant and expected effects. Age decreased the likelihood of a household moving (regardless of tenure choice), and also decreased the likelihood of a mover renting instead of purchasing a home. Families with many children are shown to be more likely to move and purchase their home, and less likely to move and rent their home, than not to move at all. The reverse is true for single person households. As expected, income had a significant effect on the likelihood of homeownership.

The estimated utility of locational alternatives had a positive

TABLE 5-5

LOGIT ESTIMATION OF MOVING AND TENURE CHOICE

Variable	Coefficient	t-statistic
I. Factors in Move-Own Decision		
1. Age of Head >62	-1.04	-1.79
2. Age of Head <29	+1.80	6.98
3. 1 or 2 Children	+ .34	0.95
4. 3 or More Children	+ .16	0.32
5. Single Person Household	-1.52	-1.92
6. Household Income	+.0068	0.20
7. Utility of Owner-Unit Spatial Alts.	.17	2.61
8. No. Drivers in Household	-1.04	-4.28
9. Constant Term	-1.38	-2.84
II. Factors in Move-Rent Decision		
10. Age of Head >62	-1.54	-3.90
11. Age of Head <29	+2.56	11.02
12. 1 or 2 Children	- .71	-2.36
13. 3 or More Children	-1.32	-2.93
14. Single Person Household	+ .70	2.10
15. Household Income	-1.04	-3.03
16. Utility of Rental-Unit Spatial Alts.	+ .13	2.30
17. No. Drivers in Household	-1.09	-5.26
18. Constant Term	+1.21	2.84
III. Factors in Moving Decision (attributes of current location)		
19. Crime Rate	-.00067	-0.02
20. Squared Pos. Income Differential	+ .24	1.60
21. Worktrip Access - prim. worker	- .30	-1.54
22. Worktrip Access - sec. worker	- .60	-2.58
23. % elderly (for non-elderly household)	+.0047	0.48
24. Household Size Differential	- .018	-2.00

Sample: 50% movers, 50% non-movers

N = 875 households,
1705 cases

LnL(0) = -961.0

$LnL(\hat{\beta}) = -686.6$

$\rho^2 = .29$

% right = 65

$\chi^2 = 549.4$ (24 d.f.)

effect on moving, as expected. As this measure is the "log sum" of utilities of randomly-selected locations, based on coefficients from the location/housing type/auto ownership model, its coefficients should fall within the 0-1 interval. While the coefficients were significantly different from 0, their small magnitude indicates a degree of independence between the location, housing and auto ownership decisions and the moving and tenure type decisions.

Among attributes of the current residence, accessiblity to workplace decreased the likelihood of moving. Difference between the household and the neighborhood average income and age both increased the likelihood of moving, although only the income effect was significant. Crime rates had no measurable effect on moving.

Chapter 6

Policy Implications and Future Work

The models presented in Chapters 4 and 5 represent an integrated system which could be used to estimate the effects of a variety of transporation, neighborhood quality, and demographic factors on the residential location and travel behavior of households. Section 6.1 discusses the potential use of these models for predicting effects of public policies on urban residential location and travel patterns. Section 6.2 presents demand elasticities computed from the logit model coefficients. These elasticities reflect the sensitivity of housing, location and auto ownership choice probabilities to changes in various household characteristics and urban spatial attributes. Aggregate forecasting from the models is also briefly discussed. Some potential model improvements are discussed in Section 6.3.

6.1 Policy Sensitivity of the Models

The sequential logit model system presented in the previous two chapters consists of three key components:

(1) "Residential Mobility Model" -- the logit model of household moving and tenure type choice (Table 5-5).

(2) "Location Model" -- the logit model of residential location, housing type, and auto ownership choice for recent moves (Table 5-4).

(3) "Travel Models" -- a series of previously callibrated logit models for predicting mode choice for worktrips (Table 4-5) and both mode and destination choice for shopping trips (Table 4-6) and social/recreation trips (Table 4-7).

Operationally, household choices are forecast in the above sequence of models, as was graphically portrayed in Figure 4-4 (page 98). The recursive relationship between these models, however, insures that policies affecting later stages will in turn cause adjustments in the outcomes of the earlier steps.

These models cannot in themselves forecast future urban change, in that they only predict household demand given a fixed set of transportation network characteristics, housing supply, and neighborhood quality attributes. They can, however, predict household behavior responses to marginal changes in those given conditions. There is a wide range of transportation-related policies that these models are sensitive to. Such policies include:

- transit route, schedule, and fare changes
- road system modifications: expansion, reduction, and/or change in traffic flow patterns
- reserved carpool or bus lanes
- parking controls: supply changes, price changes
- auto restricted zones
- gasoline price changes, auto gas mileage changes
- automobile prices

All of the above policies involve changes in time and/or cost characteristics of urban travel. The Travel Models can predict changes in the mode and destination choices of households in response to such changes in travel characteristics. This in turn will affect the accessibility attribute measures of alternative residential locations in the Location Model. Resulting changes in the estimated utility of alternative locations can affect both residential mobility predictions and location choice predictions. (This occurs through variables 20-23 in the Location Model and variables 7,16,21,22 in the Residential Mobility Model). In this way, one could predict the marginal effect of transportation policies on change in urban residential location patterns and on residential mobility -- the rate at which such neighborhood change is occuring.

The model system can also be used to predict residential location change and travel behavior impacts from a variety of non-transportation urban policies. The Location Model includes a number of spatial attribute variables that are sensitive to a variety of urban development, crime, and education policies. Some typical urban policies, and their impact on Location Model variables, are listed below:

- new residential development (through Residential Density - variable 3; Housing Costs - variables 24, 25)
- rent control or other housing cost control (through Housing Costs - variables 24,25)
- crime enforcement program (through Relative Crime -variable 2)
- school district budgets (through Teacher/Pupil ratio - varible 10)

Shifts in the relative attractiveness of locational alternatives and attribute of the current residence can in turn cause changes in predictions from the Residential Mobility Model. Shifts in the predicted residential locations of households can affect travel behavior through resulting changes in the time and cost characteristics of travel to work, shopping, and social/recreation activities.

While the employment locations of individual workers are assumed fixed for these models, the shopping and social/recreation Travel Models are sensitive to retail and other employment attributes of spatial locations. The model system can thus predict changes in residential mobility and location behavior in response to changes in the spatial attributes of shopping and/or social/recreation accessibility.

A last use of the model system is for exploring effects of marginal changes in the demographic distribution of the population on location and travel behavior. Income is a factor in the Residential Mobility Model, and all three Travel Models. Both age and household size (or number of children) are factors in the Residential Mobility Model and the Location Model.

6.2 Demand Elasticities and Aggregate Forecasting

The coefficients for the Location and Residential Mobility models have two uses: (1) They can be converted to either probability derivatives (gradients) or elasticities, which reflect the relative sensitivity of household choice probabilities to changes in each independent variable in the models; (2) They can be used to forecast aggregate changes in location patterns, by simulating the location and mobility choices of each household in response to alternative future scenarios. In this section, coefficient elasticities are presented, and aggregate forecasting uses of the models are discussed.

Logit coefficients have no direct interpretation as a reflection of the effects of independent variables on choice probabilities. As a non-linear function, logit has the property that the marginal effect of any independent variable on the probability of a given choice varies depending on the starting probability of that choice. The slope of the logit function is always smaller at very low or very high choice probabilities (the tails of the logit distribution) than at more intermediate probabilities. In general, the marginal change in a choice probability in response to an independent variable change is computed as follows:

"Direct Derivative" -- derivative of probability of choice J with respect to variable X, an attribute of choice J:

$$\frac{d(P_J)}{d(X)} = \beta_X P_J (1 - P_J)$$

where, P_J = probability of choice J

B_X = coefficient of variable X

Elasticities are a means of narmalizing the probability derivatives in terms of percentage changes;

$$\frac{d(P_J)\ /\ P_J}{d(X)\ \ /\ X} = \beta_x X_i (1-P_j)$$

where, X_i = value of variable X for household i

Derivatives and elasticities are of limited use for predicting aggregate impacts. The choice probability derivative with respect to a given independent variable will typically differ between locations, depending on their current probabilities. The elasticity of demand for locations will further differ depending on their independent variable attributes. Even for a single location, the demand elasticity will differ between households with different characteristics. Table 6.1 presents derivatives and elasticities of demand for location, housing type, auto ownership, and moving choices. Location choice probabilities are dependent on the size of the zone. For example, evaluated assuming 10% probability of choice and avg. zone attributes, these elasticities show that a density increase of 1 person/acre would in itself reduce the probability of choosing a location to 9.4%, while an additional $100 property tax would reduce that probability from 10% to 9.8%. Corresponding demand elasticities show that rent and age distribution shifts can discourage households from choosing a location alternative much more than an equal percentage increase in crime. An additional child would increase the overall probability of choosing a house (instead of apartment) from .68 to .87. Household age emerges as the most important household characteristic factor in moving decisions.

TABLE 6-1

DERIVATIVES AND ELASTICITIES OF CHOICE PROBABILITY FOR MOVING, LOCATION, HOUSING TYPE, AND AUTO OWNERSHIP

Independent Variable	Derivatives and Elasticities of Location Choice[a]			
	Derivative	Corresponding Elasticity		
		Avg. Zone[b]	Suburban Zone[b]	Inner City Zone[b]
Net Residential Density (pop./acre)	+.006	+.025	+.032	+.015
Crime Rate (#/1000 pop.)	-.0006	-.0083	-.047	-.0061
% elderly pop. (for non-eld. movers)	-.002	- .341	-.054	-.288
(for elderly movers)	+ .003	+.612	+.095	+.504
Median Rent ($) (for apt. alts.)	-.0033	- 4.25	-3.33	-2.22
Property Tax per HH ($100's)	-.002	- .155	- .33	- .12
Distance from Prev. Residence (mi.)	- .018	- 1.13		
Travel Time to Work (minutes)				
(for 1 Worker Household)	- .008	- .02		
(for 2 Worker Household)	- .010	- .03		

	Derivative of Auto and Housing Choices[c]		
	1 Auto	2 + Auto	House
Income ($1000's)	+.052	+.070	
No. Children			.19
(Mean Prob.)	(P = .59)	(P = .26)	(P = .68)

	Derivative of Moving and Tenure Choice[d]	
	Move-Own Home	Move-Rent Home
Age 18-29	+.06	+.46
Age 62+	-.03	-.08
1 or 2 Children	+.03	-.05
Over 3 Children	-.00	-.08
Single Person Household	-.03	+.07
Income ($1000's)	-.00	-.01
(Prob. for reference group)	(P = .04)	(P = .11)

---

a evaluated for the mean value of independent variables, given a base probability of .10

b zone characteristics:

	Income	Crimes	Rent	Property Tax per HH	% Renters	% Elderly	Pop. Dens.
Avg. zone	$9026	1.38	$126	$730	38	19	41
Suburban zone	$21080	1.02	$230	$1550	4	3	25
Inner City zone	$7450	7.85	$ 89	$576	43	16	55

c evaluated for the mean value of independent variables, at mean probabilities (given).

d evaluated relative to a reference group of a married couple, age 30-61, with no children, a $9000 income, and currently living in an average zone.

While derivatives and elasticities can reveal that location demand is more sensitive to some factors than others, they cannot very well address spatial form impacts. Of major policy interest is the effect of public policies on encouraging population movements to the central city relative to population dispersion at the suburbs. For such purposes, one is more interested in aggregate population shifts between location regions than in the probability of a given household type choosing a given type zone.

Aggregate forecasting can be accomplished by means of "sample enumeration", summing over all households the probability of each choice alternative under a given set of conditions. The Residential Mobility Model predicts the number of movers in each zone; the Location Model predicts the locations of their new residences. The resulting forecasts of net change in the spatial distribution of the population are typically presented for regions, representing aggregates of zones. The forecasts are scaled up from the home interview sample (1%) to the total population (100%). Because the basis of the forecasts are individual households, zonal populations and population change can be profiled in terms of household characteristics (e.g., income, multiple workers, and age) and other choice outcomes (i.e., housing typ and auto ownership). The models can be utilized, for example, to predict change in the demographic mix and auto ownership attributes of each area in the city as well as the spatial population shift.

6.3 Future Work

This study represents an initial attempt towards developing a dynamic-recursive model of residential location change, also incorporating housing, auto ownership and travel choices. There is clear room for model improvement. The Location Model could benefit from an exploration of alternative measures of: (1) household size or household type homogeneity factors, (2) proximity of industrial zones, (3) school quality, and perhaps most important, (4) the relationship between housing costs, housing unit size, and household income. The Residential Mobility Model could benefit from further study of the role of housing and location attributes on the probability of moving.

The measure of the attraction of spatial alternatives in the Residential Mobility Model as a "log sum" utility from the Location Model assumes that the relative weighting of various attributes of locational alternatives for moving decisions is the same as for residential location decisions. It is not clear that this is necessarily the case. Similarly, the use of measures of accessibility computed from the Travel Models assume that the decision process in evaluating mode choice considerations for residential location is the same as the actual mode choice decision subsequently made. Again, this may not be true. While the three modes of drive alone, carpool and transit may all be considered in mode choice, the evaluation of accessibility in location choice may be a binary "Do I need a car or not?". In that case, considerations of drive alone vs. carpool would not be relevant for location choice, and hence the use of a log sum utility from a three-mode worktrip model would be inappropriate. There is room for further analyses of the relative weights of travel time and cost in residential mobility and location decisions, as well as the relative weights of neighborhood attributes in moving decisions.

The joint nature of residential location and auto ownership decisions can also become problematic in a dynamic model of residential location change While residential location and auto ownership are clearly related in determining accessibility and travel patterns, households do not necessarily change their housing unit and auto ownership level simultaneously. Changes in auto ownership that occur subsequent to recent moves may be missed by the household survey, and can thus be a source of error in the location/housing/auto ownership choice model.

Data limitations prevented this study from examining changes in workplace location as an alternative to or cause of changes in residential locations. Ideally, job tenure or changes should play a role in models of residential location change.

Despite the clear room for further model development, the analysis presented here demonstrates the feasibility of a dynamic model of residential location change, and the usefulness of a sequential-recursive framework for relating the moving, location, auto ownership, and travel decisions of households. While time and cost constraints prevented the application of these models to forecasting procedures, the models, as estimated, can be useful for predicting the effects of a varety of transportation-related policies on changes in residential location patterns.

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