# Tradeoffs in residential location decisions: Transportation versus other factors

by Glen Weisbrod*, Moshe Ben-Akiva** and Steven Lerman**

**Cambridge Systematics, Inc., Cambridge, Massachusetts; and **Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA*

*original version, September 1978; later published in Transportation Policy and Decision-Making*, V.1, N.1, 1980.

**Abstract.** There has been a substantial discussion among planners in North America concerning the role that transportation can play in affecting the residential development patterns of urban areas. The purpose of this paper is to analyze consumers' tradeoffs in the decision to move and the selection among alternative residential locations. The paper focuses on the role of transportation level-of-service changes relative to various aspects of neighborhood quality, including crime, taxes, school quality, and demographic factors. This study is based on an analysis of the actual moving decisions and residential choices of individual households. The empirical results suggest that households make significant tradeoffs between transportation services and other public service factors in evaluating potential residences, but that the role of both in determining where people choose to live is small compared with socioeconomic and demographic factors. This suggests that the potential of most available public policies for altering residential location demand may be limited, and that the coordination of policies to achieve desired changes in residential patterns may prove useful.

## Motivation

Urban areas in the United States during the past 30 years have experienced an increasing move of their population away from central city areas to low density suburban areas. For example, in 1950, less than 42% of the total population of U.S. metropolitan areas resided in suburban areas; by 1978, this figure was over 58% [25-27] . This relatively rapid population dispersal has resulted in a fiscal and economic decline of many central cities, while in many cases costs of providing public services in outlying areas have increased. The additional operating expenses borne by local governments because of dispersed, large-lot, single-family home development rather than clustered townhouse development have been estimated to be as high as 100% for street costs, 42% for utilities, and 18% for school costs [22]. Low-density residential developments also have had the effects of increasing trip lengths [2, 21, 23], with the resulting increases in energy consumption and air pollution. Finally, as both workplaces and residences have become more dispersed, the provision of cost-effective public transit has become increasingly difficult.

Given the history of little or no effective land-use control on the metropolitan level in the United States, and the political difficulties of putting such controls into effect, local planners have had to examine other, less-direct means of influencing urban spatial structure. In particular, improvements in the relative accessibility of downtown areas (via enhanced transit

and restricted highway systems) have often been viewed as potential means of encouraging greater downtown activity. Indeed, one of the missions of the U.S. Urban Mass Transportation Administration (UMTA) has been stated as `to encourage efficient land-use patterns and restore central cities' [18]. This has lead to new UMTA programs for encouraging high-density residential" and commercial developments around transit stations.

Other federal and local efforts have either explicitly or implicitly focused on improving the attractiveness of downtown areas in other ways. For example, housing subsidies, improved law enforcement, federal grants allowing reduced property taxes, and aid to urban school systems all have the potential for decreasing net migration out of large central cities. For policy and decision makers, the crucial questions in choosing an allocation of resources among these various options has to do with their relative efficacy in achieving desired goals. To the extent that one of those goals is reducing suburbanization, policy and decision makers must be given insight into how much each of these options can influence residential mobility and urban location decisions.

Unfortunately, the underlying process by which firms and households reach decisions to relocate and move to suburban sites is not particularly well understood. It is evident that the decisions of firms and households interact, typically in a mutually reinforcing fashion. In this paper, we will attempt to contribute to decision makers' understanding of the relative effects of various policy options by summarizing the implications of a detailed study of one aspect of this urban location process: the relocation of urban households.

The importance of consumer housing and location preferences as a factor in urban development patterns is increased by the high rate of residential mobility in the United States. Approximately 20% of the nation's population changes its place of residence every year, and 42% move within a five-year period [16, 26, 27] . Nearly half (45%) of these moves are within the same metropolitan area. Thus, at least in terms of consumer demand, there is a strong potential for rapid shifts in housing patterns between suburban and central city areas, and perhaps equal potential for slowing or even reversing current trends.

It should be made clear at the outset that our goal is limited to better understanding households' location and related choices, and not the complete (and extraordinarily complex) interplay between job and residence location. While this to some extent limits the scope of our study, we believe that the insights into consumer behavior provided by this study can in themselves play a useful role in sharpening the focus of many policy debates.

The remainder of this paper is structured into four distinct sections. The second section reviews and critiques the relevant literature on the tradeoffs between accessibility and other factors in determining residential mobility and location decisions. The third section briefly summarizes the study from which the conclusions discussed in this paper were made. The fourth section describes some of the empirical results of relevance from that study, and the fifth section presents the conclusions of relevance to policy making that can be drawn.

**Studies of tradeoffs in residential location**

The actual importance of transportation accessibility as a determinant of residential location and housing choices is still not well understood. Consumers make personal choices regarding residential density and location based on a series of housing, neighborhood, job, and transportation tradeoffs. It is clear that transportation is only one element of what has been termed the `total activity system' in which each household is involved.

The concept of tradeoffs between transportation accessibility and other housing and location characteristics is not new. Formal economic `bid-rent' theories [1, 15, 17] were based on the intuitive concept that the residential location choices of individuals are based on a tradeoff between the increasing costs of commuting to work and the decreasing unit prices of housing and land that are associated with living further out from a central area of employment. These theories offer explanations of the apparent paradox that in the United States, low-income households tend to locate on high-priced urban land, while higher-income households choose suburban locations where land is cheaper. The explanation lies in the relative preference of high-income households for large residential lots and their greater willingness to pay for transportation over long distances to and from work.

Besides transportation accessibility, however, there is a variety of other residential location attributes that may affect the housing and location choices of households. These may include the age, income, and racial composition of neighborhoods, residential density, and the size, quality, condition, and price of the housing stock. In the United States, the level of public services such as schools, police, fire, and recreational services are determined at least in part through local property taxes, and thus vary widely between communities. For example, within any one metropolitan area, it is not unusual for per-pupil school expenditures, for instructional (as opposed to administrative) purposes, to vary by a factor of 2.

More recently, there have been two distinct groups of studies that have examined the tradeoffs between transportation access and other factors. Studies in the first group have explored the market price differentials among parcels of residential real estate. For example, Boyce et al. [6] , Dornbusch [7] , and Lerman et al. [l l ] have explored the impact of rail transit systems on real estate prices in Philadelphia, San Francisco, and Washington, respectively. These studies are typically multivariate regression analyses that attempt to infer the relative contribution of various determinants of property values. Generally, as a group, they have concluded that transportation has a small but statistically significant impact on the prices paid for residential real estate.

Another group of recent empirical studies by Mayo [12] , Friedman [8], Lerman [10], and Pollakowski [19] have examined the impact of socio-economic factors and the level of public services on the actual location decisions (as opposed to prices paid) of households. As a group, these studies provide evidence for several conclusions:

(1) The levels of community expenditures on police, fire, education, and recreation services are less important factors in location choice for most households than is transportation accessibility to work.
(2) The effect of transportation access on location choice decisions is overshadowed by household income and size considerations.
(3) Household auto ownership level decisions are related to residential location decisions.

More recently, studies of the new BART rail system in San Francisco have found its impact on residential location patterns in the area to be smaller than expected, indicating that the role of transportation in determining location choices was overestimated (Metropolitan Transportation Commission, 1977). Much similar evidence compiled for a range of transit systems by Knight and Trygg [9] substantiates this result.

The previous studies of household residential location choices have two major drawbacks that limit their usefulness for transportation policy analysis. First, they were based on analyses of 'static' (in place) location patterns of all households, regardless of when they last moved. In reality, there is only reason to believe that recent movers may be in some form of equilibrium with respect to their tradeoffs of various housing and neighborhood attributes of their residences. It is misleading to analyze the tradeoffs for households that have not moved in recent years, since job location, household size, household income, and neighborhood characteristics in the intervening years may have changed from the time the original tradeoff decision was made. Households' adjustments to these changes are not instantaneous, because of the high transaction costs associated with moving. This is particularly the case for owner-occupiers and elderly households, for whom the physical and psychological burden of moving may be significant.

Most of the previous economic studies also have the drawback that transportation service attributes were represented by measures of travel distance without measurement of wait time, out-of-pocket costs, and probable mode choice. The Lerman study [10] was the first residential location analysis to both incorporate more complete level-of-service data and to estimate mode choice and location choice within a joint model framework.

## Description of study

Building upon Lerman's analysis framework, we have estimated the relative importance of various transportation and nontransportation attributes in the residential mobility and location decisions of movers in one metropolitan area. The study was based on an analysis of the 1970 survey of 6000 households in the Minneapolis/St. Paul, Minnesota, metropolitan area.

The residential mobility and location study was performed by using a logit analysis of discrete choice to estimate the contribution of various locational attributes and household characteristics in determining each household's decision of whether or not to move within an 18-month period, and for the movers, the choice of residential location from among 702 zones in the metropolitan area.' (The model of whether or not to move also includes the decision of whether to buy or rent a residence if a move is made.) This study is described in detail in Weisbrod [28] and Ben-Akiva et al. [5] .

In the analysis, each household is assumed to select residential mobility choice and (for movers) the alternative location/housing bundle which maximizes its utility. This utility is expressed as a function of attributes of the alternative (e.g., prices, transportation services, neighborhood quality measures, and housing type) and the attributes of the household itself .(e.g., age, income, and household size). The coefficients of this function are statistically inferred from the actual decisions made by households. This specific analysis was based on the choices of 791 households that either did not move within the previous 18 months, or moved within the metropolitan area as defined by the Twin Cities Metropolitan Council Z For each of the 702 location zones, complete information was collected on housing prices (by type), the stock of various building types and housing unit sizes, the income and demographic characteristics of the current population, and the levels of taxes and crime.

The measure of accessibility used in the study is known as a `logit logsum' or `inclusive utility' measure. It explicitly accounts for both the workplaces of the workers in the household and the possibility that the workers could use either transit, some form of ride sharing, or their own automobile without any passengers. This measure was derived in different ways by Ben-Akiva [3], Ben-Akiva and Lerman [4] , and Williams [29] , and its use in this study is discussed in detail in Weisbrod [28] . For the purposes of this article, it suffices that the measure is a weighted function of in-vehicle travel time, out-of-vehicle time, and out-of-pocket cost for all major modes available to the workplaces of employed members of the household. In addition, it is a function of the household's socioeconomic characteristics. The accessibility measure is further explained in the Appendix to this article.

For the purposes of distinguishing among workers in multiworker households, one worker was designated as primary. This is typically the head of the household if he or she is employed full time. Other workers are termed secondary, and their accessibility to work is treated as a separate independent variable in the study.

**Empirical results**

The 702 location zones collectively span the jurisdiction of 39 local governments, which in 1970 ranged in population from 1300 to 434,000. There is considerable variation between these 39 communities in terms of tax levels and measures of neighborhood quality such as average income and crime rates. At the more-detailed zonal level, there is even greater variation between the neighborhoods in terms of demographic and economic characteristics. The range of location zone characteristics is shown in Table 1. This table also provides the average zonal values, unweighted by zonal population.

Table 1. Range of location zone attributes

| Attributes | Low | High | Unweighted average of zones |
|---|---|---|---|
| Annual property tax per household | | $200.10 | $1970.00$734.50 |
| Median rent (per month) | $50 | $350 | $126 |
| Median home value | $9000 | $86,200 | $21,054 |
| Crime rate: assaults and robberies per year per 1000 population | 0 | 6.8 | 1.38 |
| School expenditures per pupil | $431 | $773 | $602 |
| Pupil/teacher ratio | 16.4 | 22.7 | 20.5 |
| Median annual household income | $1700 | > $25,000 | $9000 |

To understand the tradeoffs that households make in their residential location decisions, it should be recognized that transportation and nontransportation attributes of locations tend to be correlated. As distance increases, there tends to be a reduced level of transportation accessibility simultaneously with changes in a variety of other locational characteristics. like most metropolitan areas in the United States, the study area exhibits the characteristics that higher travel time to work (by both bus and auto), higher travel cost to work, and lower overall accessibility to work all tend to be correlated with the demographic characteristics of outlying suburban from the central business district3 areas: younger and larger families with higher incomes, low-density development of newer single family homes, higher auto-ownership levels and lower crime rates.

The average in-vehicle travel time from home to work for workers considered in. the study was 20 min for auto trips and 37 min for bus trips. The usual bus fare paid was 30 cents per trip. In the formulation of the accessibility measure, relative effects of auto and bus levels of service on locational choice are affected by the mode split probabilities for commute trips. Since 95%

of all vehicular trips to work (for the primary worker) were by auto, the impacts of auto travel time and cost on residential mobility and locational choice will tend to be much greater than the corresponding impacts of bus service characteristics.

Coefficients from the logit analysis are presented in the Appendix to this article. The major findings regarding the tradeoffs that movers make in choosing their residences are as follows:

(1) The analysis indicates that a 5% reduction in automobile commute time (averaging 1 min) has an effect on locational attractiveness for the surveyed movers that is equivalent to:
   (a) for renters, a 1.5% decrease in monthly rent (equivalent to less than $2 from the average of $256 per month for a four-room unit)
   (b) for homeowners, a 3.8% decrease in home value (equivalent to about $685 from the average value of $21,000 for a six-room house), and an 8.4% decrease in local property taxes (equivalent to about $61 from the annual average of $750);
   (c) a 28% decrease in the rate of assaults and robberies per capita.

(2) For bus, a 5% reduction in commute travel time (averaging 2 min) has been estimated to have an effect on locational attractiveness for the surveyed movers that is equivalent to:
   (a) for renters, a 0.3% decrease in monthly rent (equivalent to about 30 cents from the average of $126 for a four-room unit);
   (b) for homeowners, a 0.5% decrease in home value (equivalent to about $110 from the average value of $21,000 for a six-room house), and a 1.1% decrease in local property taxes (equivalent to about $8 from the average of $750);
   (c) a 3.8% decrease in the rate of assaults and robberies per population.

(3) The analysis indicated that the teacher/pupil ratio as a measure of local school quality was not a statistically significant determinant of location choice. While this finding was consistent with that of some previous studies which measured local school quality by the instructional expenditures per pupil, it is possible that neither measure accurately represents school quality. Further, school expenditures are reflected as a major component of local property taxes, and hence tend to be highly correlated with them.

(4) Household composition considerations overwhelm all other tradeoffs among housing cost, taxes, transportation access, and crime level. No reduction in auto travel time or bus travel time could compete with the locational effect caused by the propensity of households with children to choose single-family, detached houses.

For the decision to move, the analysis approach was based on the assumption that relative importances among attributes of alternative locations are the same as described above for location choice among movers. In addition, however, the following findings regarding tradeoffs made by households emerge in determining residential mobility:

(1) Negative attributes of the current location are at least as important as positive attributes of locational alternatives in encouraging the decision to move. A 5% reduction (averaging 1 min) in automobile commute time to the primary workplace for the current residential location decreases the probability of moving and purchasing a new home that is equal to:
   (a) a 1-min average increase in automobile commute time for all other locational alternatives, and
   (b) a 4.1 % decrease in the rate of assaults and robberies for the current location, or a 28% increase in the same crime rate for other locational alternatives.

   The decision to move and rent is even less sensitive to the attributes of other locational alternatives than is the decision to move and purchase a home (by a factor of 4). The impact of bus travel time is again smaller than the impact of automobile travel time, due to the 95% auto mode split.

(2) Age and household composition factors are very strong determinants of the propensity to move. Regardless of changes in travel time to work, crime rates, school quality, or housing costs, the analysis indicates that older persons and families with several children still have lower probabilities of moving than younger or smaller households.

**Conclusions for policy**

The above results represent estimates of the tradeoffs that households made in a single U.S. city at a single point in time. Given this, there are obvious limitations to how firm any policy-related conclusions derived from the study can be. Given, however, that many policy and decision makers must of necessity choose among alternative actions that have either explicit or implicit effects on the spatial distribution of urban residences, the study at least suggests the following:

(1) It is clear that housing costs are a very important aspect of residential location decisions. A small change in housing costs can have an effect on residential location decisions equivalent to the effect of a larger proportional change in travel time. Since many U.S. cities are experiencing rapid increases in real housing prices, it is important to recognize

the potential impact of shifting price patterns. Depending on how they are structured, rent control, rent subsidies, tax advantages, mortgage ceilings, and other price-related policies can potentially offset or enhance the impacts of transportation investments.

(2) To the extent that transit usage is very low relative to auto usage, the overall effects of bus travel time on location demand are significantly smaller than the locational effects of auto travel time.

(3) Public expenditures to reduce crime rates (and possibly other aspects of the living environment) may contribute to increasing the attractiveness of some locations as much as proportional improvements in transit travel time.

(4) Factors beyond the scope of public policy, such as the desire for single-family, detached homes among families with children, and the reduced moving rates for older persons and families with several children, all affect mobility and location patterns more than other factors related to public expenditures. Thus, there may be large changes in residential preferences which are for the most part only marginally influenced by available policies.

In short, while this study (as well as others) provides evidence that transportation does indeed influence residential location preferences, its influence should not be oversold. In many cases, transportation policies may at best mitigate the negative effects of underlying demographic forces. Much of the rapid suburbanization of the post-World War II period in the United States is probably attributable to the rapid growth in household incomes, family formation, and other household characteristics giving rise to strong preferences for low-density housing. To attribute all of this suburbanization to transportation infrastructure changes (particularly federally funded highway investments) overstates their influence. Similarly, the widely. discussed in-migration of relatively small numbers of affluent, young households to central city areas may be more due to changing demography, particularly the increasing number of multiworker households without children, than to any public action.

Policy makers should also recognize that a coordinated group of public policies involving transportation, housing, and other actions will have far greater influence on residential preferences than any single-action alone. Such coordination may be difficult to achieve, given the highly sectorial orientation of most planning and funding agencies, but the benefits may well be substantial.

In terms of future research, there is a great need for a better understanding of the complex interactions between residential location and other aspects of urban spatial structure, particularly changes in workplace. This is particularly relevant for evaluation of the long-term effects of various actions, where large changes in employment patterns are possible.

## Appendix: Logit Analysis Coefficients

The analysis is based on a set of three multinomial logit models, representing:

(1) moving and tenure type joint choice,
(2) residential location, housing type and auto ownership joint choice (given moving and tenure type choices), and
(3) mode to work travel choices (given location choice)

**Table 2. Logit estimation of moving and tenure choice** .

| Variable | | Coefficient | *t*-Statistic |
|---|---|---|---|
| Factors in move-own decision | | | |
| 1) | Age of head > 62 (dummy variable) | - 0.823 | -1.34 |
| 2) | Age of head < 29 (dummy variable) | 1.884 | 6.54 |
| 3) | 1 or 2 children (dummy variable) | 0.877 | 0.27 |
| 4) | 3 or more children (dummy variable) | - 0.647 | -1.37 |
| 5) | Single-person household (dummy variable) | - 1.479 | -1.82 |
| 6) | Household income ($1000) | - 0.157 | - 3.63 |
| 7) | Utility of uwner-unit spatial alternatives | 0.297 | 0.559 |
| 8) | Number of drivers in household | -1.280 | - 5.86 |
| 9) | Constant term | 0.652 | 0.98 |
| Factors in move-rent decision | | | |
| 10) | Age of head > 62 (dummy variable) | -1.439: | - 3.34 |
| 11) | Age of head < 29 (dummy variable) | 2.698 | 10.38 |
| 12) | 1 or 2 children (dummy variable) | - 0.438 , | -1.66 |
| 13) | 3 or more children (dummy variable) | - 0.744 | -1.91 |
| 14) | Single-person household (dummy variable) | 0.724 | 2.01 |
| 15) | Household income ($1000) | - 0.188 | - 4.65 |
| 16) | Utility of rental-unit spatial alternatives (utility scale) | 0.069 | 2.84 |
| 17) | Number of drivers in household | - 0.791 | - 5.00 |
| 18) | Constant term | 2.363 | 3.74 |
| Factors in moving decision (attributes of current location) | | | |
| 19) | Crime rate (offenses/1000 population) | 0.158 | 5.00 |
| 20) | Squared pos. income differential (if household income > zone average income) in units of $100 | \| | |
| 21) | Work-trip access - primary worker (utility scale) | - 0.287 | - 2.15 |
| 22) | Work-trip access - secondary worker (utility scale) | - 0.784 | - 3.07 |
| 23) | % Elderly (for nonelderly household) | 0.006 | 0.55 |
| 24) | Household size differential (household size - zone average household size) | - 0.022 | |

Number of households = 791 (61% movers, 39% nonmovers)
Total number of alternatives (including chosen) = 2373 Log likelihood when all coefficients are zero =- 869
Log likelihood at estimates =- 586

**Table 3. Logit estimation of location, housing type, and auto ownership choice**

| | Coefficient | t-Statistic |
|---|---|---|
| Factors that vary among locations | | |
| 1) Squared distance from previous residence (0.01 miles) | -1.362 | -11.02 |
| 2) Crime relative to previous residence (offenses/1000 population) | - 0.076 | - 2.17 |
| 3) Net residential density (100 persons/acre) | - 0.501 | - 2.42 |
| 4) Proximity to industrial land (industrial land/ residential land) | -0.020 | -1.31 |
| 5) Squared positive income differential (if household income > zone average income) in units of $10,000' | -1.400 | - 4.88 |
| 6) Squared negative income differential (if household income < zone average income) in units of $10,000' | -0.713 | -1.54 |
| 7) Household size differential (household size - zone average household size) | 0.040 | 2.82 |
| 8) % Elderly (for elderly households) | 0.073 | 2.35 |
| 9) % Elderly (for nonelderly households) | - 0.030 | - 2.96 |
| 10) Teacher/pupil ratio (for households with children) | 0.092 | 1.37 |
| 11) Property tax/household ($100) | - 0.049 | -1.36 |
| Factors that vary among housing types | | |
| 12) Constant (for house alternatives) | - 2.568 | - 7.55 |
| 13) Number of children (for house alternatives) (persons) | 1.072 | 5.99 |
| Factors that vary among auto ownership choices | | |
| 14) Constant (for 1 auto alternative) | - 2.328 | - 4.41 |
| 15) Number of drivers (for 1 auto alternative) | 2.492 | 7.44 |
| 16) Income (for 1 auto alternative) ($1000) | 0.274 | 4.37 |
| 17) Constant (for 2 + auto alternatives) | - 7.538 | -10.93 |
| 18) Number of drivers (for 2 + auto alternatives) | 3.671 | 9.30 |
| 19) Income (for 2 + auto alternatives) ($1000) | 0.351 | 5.35 |
| Factors that vary among location and auto ownership choices | | |
| 20) Primary worker work-trip access (utility scale) | 1.324 | 9.21 |
| 21) Secondary worker work-trip access (utility scale) | 1.062 | 2.49 |
| Factors that vary among location and housing choices | | |
| 22) (Housing value/size) per income ($100/$1000) | - 0.255 | - 0.20 |
| 23) (Rent/size) per income ($/$1000) | - 0.566 | -1.13 |
| 24) In [housing opportunities/alternative] (utility scale) | 1.000 | NA |
| Factors that vary among housing and auto ownership choices | | |
| 25) Constant (for apartment, 1 auto alternative) | -1.010 | - 3.06 |
| 26) Constant (for house, 2 + auto alternatives) | 1.313 | 3.39 |

Number of households = 487
Total number of alternatives (including chosen) = 14,814
Log likelihood when all coefficients are zero =-1593
Log likelihood at estimates = -1050

In the general form of the logit model, the probability that any alternative i is chosen is as follows:

$$\text{Prob}(i/Jt) = \frac{e^{B}Xit}{\sum_{Jt} e^{B}Xjt}$$

where: Jt is the set of alternatives available to household t,
Xit is a vector of variables describing alternative i and household t
B is a vector of parameters.

While the three logit choice models form a sequence, the steps are integrated through a recursive or nested structure in which the estimation of each step depends on the expected utility of subsequent choices. Thus, one factor in the residential location choice model is a measure of the accessibility to work for each individual household for each alternative location. This measure is a function of the level of service attributes of all available modes for each alternative location, and is computed as the natural logarithm of the denominator from the mode choice logit model, given the specific location zone. Similarly, one factor in the residential mobility choice is a measure of the utility of all other locational alternatives, computed as the natural logarithm of the denominator from the location, housing type, and auto ownership joint choice model. (For more information on the nested logit model, see McFadden [14] or Ben-Akiva and Lerman [4] ).

Independent variables and logit coefficients for each of the three model steps are presented in Tables 2-4. The mode choice model was developed by Pratt [20] . The other two models are discussed in detail in Weisbrod [28] and Ben-Akiva et al. [5]; the coefficients shown here are a slightly modified version of those models, as presented in Wolfe [30] .

Table 4. Twin Cities work-trip mode choice model (three modes: transit, auto-drive alone, and auto-shared ride)

| Explanatory variable | Logit Coefficient* |
|---|---|
| In-vehicle time (min) for all modes | - .032 |
| Travel cost (a) for all modes | -.020 |
| Wait time for first bus (min) for transit mode | -.032 |
| Walk + wait time for second bus and subsequent buses (min) for transit mode | -.044 |
| Parking + unparking time (min) for auto-drive alone | -.257 |
| Parking + unparking time (min) for auto-shared ride | -.342 |
| Auto required for transit access (dummy variable) for transit mode | -.957 |
| Income (index of quartiles) for auto-drive alone | .565 |
| Income (index of quartiles) for auto-shared ride | .337 |
| Highway distance (miles) for auto-shared ride | -.086 |

*Note: The t-Statistics for all coefficients are significant at better than the 0.05 level

## Notes

1. Readers interested in further description of this form of modeling are referred to McFadden [13] for a general overview of logit analysis, and to McFadden [14] for a discussion of nested logit and its application to residential location.
2. The Twin Cities metropolitan area comprises 7420 square kilometers.
3. The `twin cities' of Minneapolis and St. Paul each have reasonably well-defined central business districts, though the former is larger than the latter.
4. Note that all costs are in 1970 U.S. dollars.

## References


1. Alonso W (1964) *Location and Land Use.* Cambridge: Harvard University
2. Balkus K (1967) Transportation implications of alternative sketch plans. *Highway Research Record 180.* Washington DC: Highway Research Board
3. Ben-Akiva M (1973) *Structure of passenger travel demand models.* PhD dissertation, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge
4. Ben-Akiva M, Lerman SR (1979) Disaggregate travel and mobility choice models and measures of accessibility. In: Hensher D, Stopher P (eds) *Behavioral travel modeling.* London: Croom Helm
5. Ben-Akiva M, et al. (1979) *Understanding, prediction and evaluation of transportation-related consumer behavior.* Phase I report prepared for US Department of Transportation; the Center for Transportation Studies, Massachusetts Institute of Technology, Cambridge (July)
6. Boyce D; Allen B, Mudge RR, Stater PB, Isserman AM (1972) *The impact of rapid transit on suburban residential property values and land development analysis of the Philadelphia high speed line.* Regional Science Department, University of Pennsylvania, NTIS no. PB 220 693, November
7. Dornbusch DM (1976) BART-induced changes in property values and rents. *Land use and urban development project, phase 1, BART.* Working papers WP 21-5-76, US Department of Transportation and US Housing and Urban Development
8. Friedman Joseph (1975) *Housing location and the supply of local public services.* PhD dissertation, Department of Economics, University of California, Berkeley
9. Knight RL, Trygg L (1977) Evidence of land use impacts of rapid transit systems. *Transportation* 6:231-47
10. Lerman S (1975) *A disaggregate behavioral model of urban mobility decisions.* Center for Transportation Studies Report no. 75-5, Massachusetts Institute of Technology, Cambridge
11. Lerman S, et al. (1977) *The effect of the Washington metro on urban property values. CS* Report no. 77-18, Center for Transportation Studies, Massachusetts Institute of technology, Cambridge (November)
12. Mayo S (1973) *Local public goods and residential location: an empirical test of the Tiebout hypothesis.* Washington DC: Metropolitan Governance Committee, Resources for the Future
13. McFadden D (1973) Conditional logit analysis of the qualitative choice behavior. In: Zarembka P (ed) *Frontiers in econometrics.* New York: Academic
14. McFadden D (1978) Modelling the choice of residential location. In: Karquist, et al. (eds)

15. Mills ES (1972) *Studies in the structure of the urban economy*. Washington DC: Resources for the Future
16. Moore EG (1972) *Residential mobility in the City Association of American Geographers.* Washington DC: Resource Paper no. 13
17. Muth R (1969) *Cities and housing.* Chicago: University of Chicago
18. Orski CK (1977) The need for coordinated transportation and urban development. *Land Use and Transportation Newsletter.* Washington DC: Transportation Research Board
19. Pollakowski *M (1975) A conditional logit model of residential choice.* Presented at winter meetings of the Econometric Society (December)
20. Pratt RH, Associates, Inc.; DTM, Inc. *(1976) Development and calibration or mode choice models for the Twin Cities area.* Prepared for the Metropolitan Council of the Twin Cities
21. Pushkarev B, Jeffrey *Z (1977) Public transportation and land use policy*. Bloomington: Indiana University
22. Real Estate Research Corporation *(1974) The costs of sprawl: a literature review and bibliography of detailed cost analysis in executive summary*. Washington DC: US Government Printing Office
23. Rice *RG (1978) Evaluation of road and transit system requirements for alternative urban forms.* Presented at the annual meeting of the Transportation Research Board, Washington DC (January)
24. Tiebout *C (1956)* A pure theory of local expenditures. *Journal of Political Economy 64* (October)
25. *US* Bureau of the Census *(1975) Historical statistics of the United States: colonial times to 1970*. Washington DC: US Government Printing Office
26. *US* Bureau of the Census *(1975) Current Population Reports, Population Characteristics.* Ser *P-20*, no. *285*
27. *US* Bureau of the Census *(1978) Current Population Reports.* Ser *P-20*, no. *336*
28. Weisbrod *G (1978) Determinants of residential location demand: implications for transportation policy,* MS thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge
29. Williams HCWL *(1977)* On the formation of travel demand models and economic evaluation measures of user benefit. *Environment and Planning [A] 9*
30. Wolfe R *(1979) Policy sensitive simulation with disaggregate models of moving and tenure choice; location, housing type and auto ownership level; and mode choice.* Department of Civil Engineering, Massachusetts Institute of Technology