

**Incorporating Non-motorized Mode and Neighborhood Accessibility in an Integrated Land
Use and Transportation Model System**

Paul Waddell
University of Washington
Daniel J. Evans School of Public Affairs
University of Washington
Box 353055
Seattle, WA 98195
Fax: 206-285-9044
Phone: 206-221-4161
Email: pwaddell@u.washington.edu

Firouzeh Nourzad
Urban Analytics
1022 First Ave W.
Seattle, WA 98119
Fax: 206-378-1575
Phone: 206-378-1505
Email: nourzad@uanalytics.com

Submitted on August 1, 2001
Final Revision March 30, 2002

Manuscript Word Count: 4571, 2 Tables, 5 Figures (6071 total)

ABSTRACT

This paper presents a model of residential location estimated as part of a larger integrated land use and transportation model development effort in the Wasatch Front area of Utah. The main contributions of the paper are the testing of the effects of neighborhood and regional accessibility on residential location, controlling for housing and neighborhood characteristics, and using a spatially disaggregate model. The results are relevant to the assessment of policies related to land use and transportation interaction, and the methods significantly advance our ability to examine neighborhood-scale effects on location choice.

INTRODUCTION

The effect of accessibility on residential location is a research topic with a long and venerated tradition in the literature within urban economics, planning, geography, and transportation. The recent surge of interest in integrated land use and transportation planning and modeling and in the potential for new-traditional neighborhood design to curb Americans' appetite for auto travel, or at least to stimulate more walking, have renewed research activity on this topic. The question that this paper seeks to answer is how accessibility at a traditional regional scale interacts with accessibility at the local neighborhood scale to influence residential location choices. Households must trade off multiple dimensions of a residential location choice, including commute times to work, access to shopping and other maintenance and leisure activities, the quality and price of housing, and other amenities associated with the location of housing.

This is the first paper to our knowledge to explore the degree to which local, or neighborhood accessibility (1) influences residential location, controlling for regional accessibility and other housing and neighborhood characteristics. We also examine the interaction between auto ownership and regional accessibility in influencing residential location. The approach presented in this paper significantly extends an earlier approach to modeling residential location (2), by adding substantially greater geographic detail and examining neighborhood effects and vehicle ownership.

The setting for the analysis is the Wasatch Front region of Utah, centered on Salt Lake City, and running between the edge of the Wasatch Front mountain range and the shores of the Great Salt Lake and Lake Utah, from Ogden in the north to Provo-Orem in the south, as shown in Figure 1. This is the setting for the 2002 Winter Olympics, and an area that is among the fastest growing metropolitan regions in the nation. It is also a place in which urban development is on the one hand constrained by natural boundaries, but on the other hand is developing at relatively low density.

The context for the study is the development of a fully integrated land use and transportation model system, under the rubric of a project named Quality Growth Enhancement Tools by the Governor's Office of Planning and Budget (GOPB), in coordination with the Mountainlands Association of Governments (MAG) and the Wasatch Front Regional Council (WFRC), the two designated MPOs within the project area. The land use component of the model system is based on UrbanSim (3), and the travel model component is an enhanced four-step travel model with recent innovations to add non-motorized modes (4). The component of the model system that is the focus of this paper is the residential location model within the UrbanSim model system.

The paper is organized as follows. Following the introduction, the specification of the residential location model and its role within the UrbanSim model system is described, as well as the mode choice component of the travel model system with which UrbanSim is interfaced for this application. This is followed by a summary of the data used in the analysis, and discussion of the results of model estimation.

MODEL SPECIFICATION

Overview of the Land Use – Transportation Model System

The residential location model described in this paper is a component of a larger integrated land use and transportation model system. The land use models are collectively described as the UrbanSim model system, which is linked to a recently updated travel demand model system in Utah that integrates the models of WFRC and MAG, and adds non-motorized modes to the model. Figure 2 depicts the model components and their relationships. The UrbanSim model system and software architecture is described in detail elsewhere (3, 5, 6), and is available as Open Source software at www.urbansim.org. Further documentation of the new travel model system is also available (4).

The interchange between the land use and transportation model systems is loosely coupled, with outputs from the land use model provided as inputs to the trip generation models, and outputs from the mode choice model provided to the land use models. The land use model system operates as a dynamic model with annual steps. Typically, the travel demand model system will be run every five years or as needed to reflect significant changes in transport supply or travel characteristics. We turn now to a brief description of the mode choice model, which is the source of the regional travel accessibility information for the land use model system, including the residential location model that is the principal focus of this paper.

The Mode Choice Model

The travel model system for the Wasatch Front region was recently updated, integrating the models from the WFRC and MAG MPO planning areas, and incorporating non-motorized modes (4). The home-based work (HBW) mode choice model is stratified by auto ownership category. As a result, composite utilities, or logsum values, were computed by auto ownership level for households with zero, one, and two or more cars.

The HBW nested logit mode choice model allocates work and work-related person trips, outcome of HBW Trip Distribution model, between motorized and non-motorized modes and their respective sub-modes. The model addresses the following modes, and the structure is shown in Figure 3:

1. Drive Alone: single-occupant auto trips;
2. Shared Ride 2: double-occupancy auto trips;
3. Shared Ride 3+: auto trips with three or more occupants;
4. Transit-Walk to Local Bus
5. Transit – Walk to Express Bus
6. Transit – Walk to Light Rail
7. Transit - Walk to Commuter Rail
8. Transit – Drive to Local Bus
9. Transit – Drive to Express Bus
10. Transit – Drive to Light Rail
11. Transit – Drive to Commuter Rail
12. Walk-only trips
13. Bicycle trips

Non-Motorized Modes (walk and bicycle): The HBW model considers non-motorized as well as motorized modes in splitting person trips among the alternative modes. The non-motorized component of the Mode Choice models of Portland, Oregon; Sacramento, California; Salem, Oregon; and Montgomery County, Maryland were examined in determining the appropriate structure for use in the new inter-regional model for the Salt Lake region.

The structure of Sacramento's non-motorized mode choice component, which was adapted from the Portland Model Choice model, was selected for use in the revised HBW model. During the model validation phase, it was deemed necessary to rescale some of the original coefficients of the Sacramento model, as well as eliminating a number of variables associated with various household categories. The final non-motorized model is made of transportation variables (i.e., walk time and bike distance), and urban form/land use variables, i.e., employment density and pedestrian environmental factors (PEF). The PEF reflect a 1 to 3 rating of the pedestrian environment, combining continuity of streets and walkways, and provision of sidewalks, at both the trip origin and destination.

Market Segmentation by Auto Ownership – The HBW model is stratified into the following auto ownership categories: zero-car households, one-car households, and households with two or more cars. Although model structures, variables, and coefficients are the same among the three sub-models, they differ in the constant terms across the three car ownership categories. Each of the three models is applied to the share of the trips of the corresponding car ownership group. Currently, driving alone is a viable option in the Mode Choice model for the zero-car household auto ownership category, even though by definition, they have no cars available to them. This feature of the model was retained from the previous Mode Choice model due to constraints on time and the available observed data, and can result in potential underestimation of transit ridership for this group of households. Provision of a limited motorized choice set (i.e., shared ride and transit) for zero-car households is a more appropriate model structure and should be considered in the next round of model upgrades, when more detailed and up-to-date

observed data is available. The use of the travel model outputs in the residential location model, including the computation of multi-modal access indicators, is discussed in the following sections.

The Residential Location Model

In this model we predict the probability that a household will choose a housing unit at a location defined by a grid cell of 150 by 150 meters. We assume that if multiple housing units occupy a grid cell, they are identical. The form of the model is specified as multinomial logit. This represents a highly disaggregate choice model, with over 500,000 housing units in the inventory. Since the number of alternative choices is equivalent to the number of available housing units, the size of the choice set is too large to estimate the model using the full universe of alternatives, so we use random sampling of alternatives (one chosen and 9 non-chosen) from the universe of available (vacant) housing units to estimate the model, a procedure that has been shown to produce consistent estimates of model parameters (7).

The model is specified as a multinomial logit of the form:

$$P_i = \frac{e^{aH_i + bR_i + gN_i}}{\sum_j e^{aH_j + bR_j + gN_j}}$$

where H represents an array of housing characteristics, R represents regional accessibility, and N reflects neighborhood-scale effects.

The data used in this analysis draw principally from a household travel survey conducted in the region in 1997. Approximately 4,000 households were surveyed throughout the region. The data from the travel survey were supplemented with housing and spatial context variables by geographically assigning the survey coordinates to a grid cell, and associating the housing and spatial characteristics of the grid cell, and regional access variables that are associated with the traffic analysis zone in which the household is located.

The variables used in the model are drawn from the literature in urban economics, urban geography, and urban sociology. An initial feature of the model specification is the incorporation of the classical urban economic trade-off between transportation and land cost. This has been generalized to account not only for travel time to the classical monocentric center, the CBD, but also to more generalized access to employment opportunities and to shopping. These accessibilities to work and shopping are measured by weighting the opportunities at each destination zone with a composite utility of travel across all modes to the destination based on the logsum from the mode choice travel model. This procedure is described in more detail in the following section.

The independent variables are organized into the three categories of housing characteristics, regional accessibility, and neighborhood-scale effects as shown below. All independent variables are endogenous to the model system – that is, they are predicted by other parts of the model system shown in Figure 2, and therefore, predicted values are provided in future years for the application of the model system over periods of 20 to 30 years.

Housing Characteristics (H)

- Prices (interacted with income)
- Development types (density, land use mix)
- Housing age

Regional accessibility (R)

- Job accessibility by auto-ownership group
- Travel time to CBD and airport

Neighborhood (N)

- Neighborhood land use mix and density
- Neighborhood employment

The variables used in the residential model estimation, and the results of the model estimation, are presented in Table 1. The first variable, BCIR, captures the effect of the relationship between local housing price in the cell to the income of the household. We use the average housing value, approximated as an annualized stream of rental payments, and divided by the annual household income. This approximates the cost burden faced by the household if they locate in a given location. We expect that households attempt to reduce their housing cost burden, once we adequately control for the amenities of housing and location that make particular locations attractive. The next set of variables included are dummy variables for development types that are defined by the mix and density of real estate in the cell, as shown in Table 2. The six development types included as dummy variables reflect low to moderate density, principally residential use cells. High density residential, mixed-use, and principally commercial or industrial use cells are in the omitted category. This set of variables is likely to interact with variables reflecting the density of housing in the cell and neighborhood, and land use mix in the neighborhood, so interpretation must be done in combination with those effects.

We expect, *a priori*, that households prefer lower housing density, all else being equal, since urban economic theory and substantial empirical evidence suggest that as incomes rise, land consumption increases (8). But we explore variation in the responsiveness of different types of households to density based on the presence of children, and household size. Households with children and larger households may have stronger preferences for low density housing and neighborhoods, so we test for these potential interactions by interacting household characteristics with cell and neighborhood characteristics. In particular, a separate slope for the cell housing density is estimated for households that have children, and household size is interacted with the average density of housing within a neighborhood of 600 meters from the cell under consideration. There is reason to expect both of these coefficients to be negative. We also test the possibility that younger households (head of household under 40) differ from other households in their taste for density, all else being equal, by interacting a dummy for young households with dummies for development types 6-8, representing higher density residential housing. Preferences regarding density are also anticipated to interact with the household auto ownership, since households with more cars are likely to prefer auto-oriented (low density) environments, and households with fewer cars may prefer more transit-oriented (higher density) locations.

We expect households with higher income to prefer higher quality housing, which we approximate by the average improvement value per housing unit (which excludes the land value that should reflect locational amenities), and prefer to avoid industrial and commercial land uses within their immediate neighborhood (measured using the square feet of industrial and commercial square feet within 600 meters), due to the localized spillover of traffic, noise and other possible effects from significant industrial and commercial activity. We further expect that all households prefer proximity to higher valued properties, which we measure using the average land value per acre within a neighborhood of 600 meters from the cell under consideration.

The next group of variables tested includes regional accessibility to employment and population. We use access to employment, stratified by household ownership category, as defined earlier in the description of regional accessibility. These are expected to be positive effects on the probability of residential location. We also include regional access to population, but with no expectation of the sign of the coefficient, since this variable interacts with housing density and regional access to employment.

The final variables attempt to capture the influence of local accessibility, after controlling for regional accessibility to employment and population, and for housing price and density, and other neighborhood characteristics as described above. While a number of variables have been proposed in the literature to measure local accessibility (1, 9), we use a simple measure of retail jobs within 600 meters of a location. Since walking access to shopping within a neighborhood is a potential substitute for driving to shopping within or outside the neighborhood, we test for the interaction of auto ownership with local access to shopping. This is done by interacting local access to shopping with dummy variables representing whether there are fewer cars than workers in the household, or whether there are at least as many cars as workers in the household. If households do potentially substitute local walking trips to shopping for longer-distance driving to shopping, then neighborhoods with walk access to shopping should be more attractive to households with relatively low auto ownership. Local retail access also implies opportunities for work that can be accessed by walking, further reinforcing the potential to give up a vehicle in these neighborhoods. We expect that households with fewer cars than workers will have a stronger preference for locations with more local retail, but that all households will favor these locations, all else being equal.

Regional and Local Accessibility

Regional Accessibility

We operationalize the concept of regional accessibility for a given location as the distribution of opportunities weighted by the composite utility of all modes of travel to those destinations, defined as the logsum from the mode choice model for each origin-destination pair for a given auto-ownership category. The resulting access measure A_{ai} for each location i is thus:

$$A_{ai} = \sum_j^J D_j e^{L_{aij}}$$

where

D_j is the quantity of activity in location j

L_{aij} is composite utility, or logsum, for vehicle ownership category a , from location i to j , scaled to a maximum value of 0 for the highest utility interchange.

The accessibility component reads the composite utilities (logsums) from the travel model and the land use distribution for a given year, and creates accessibility indices for use in the household and business location choice models. For one and two-plus car households a composite logsum is produced for each zone interchange by weighting the logsums for motorized and non-motorized modes by their respective shares. For example, if 25% of the trips from zone A to zone B are by non-motorized mode, then the composite logsum would reflect 25% of the non-motorized logsum, and 75% of the motorized logsum. In the mode choice model for the zero-car market segment, the drive alone mode is still considered, even though this mode should not be available by definition. To compensate for this bias, we use the logsum from the transit and non-motorized modes for zero-car households, normalizing the mode shares considered to add up to 100% and weighting the logsums as before.

Local Accessibility

Local accessibility has been defined in various ways, but in general it measures access to activities by non-motorized mode within a neighborhood scale (10, 11). There is no consensus about what constitutes a maximum distance that most people will consider walking for daily activities such as grocery shopping or going to a video store or restaurant, estimates proposed in the literature range from one quarter to one half mile. Clearly, these would vary based on many conditions of the local setting, such as weather, terrain, street and sidewalk configuration, and safety, in addition to personal characteristics such as age and health status. In spite of these ambiguities surrounding the measurement of local accessibility, it has emerged as a topic of considerable interest in land use and transportation planning. Much, though certainly not all, of the appeal of new urbanism, or neo-traditional urban design, is based on the expectation that neighborhoods with higher density, mixed use, and walkable designs will promote walking as a mode of access to satisfy many daily activities, and may significantly reduce auto travel, though there is considerable disagreement about these claims (see 11 for a review).

For the purposes of this study, we define a neighborhood scale as a radius of 600 meters, or roughly one third of a mile. We use this radius to query the locations surrounding each grid cell, to establish the neighborhood characteristics that lie within this radius. Retail establishments represent likely destinations for activities that can be satisfied by walking from home. We therefore query the total retail jobs in grid cells that lie within 600 meters of a selected grid cell, to determine the amount of retail activity that is accessible by walking. While this does not consider street and sidewalk design, signalization, safety, terrain, and other factors that might encourage or inhibit walking, it nevertheless serves as a reasonable measure of the kind of local access that motivates suggestions of altered travel behavior in the literature. Figure 4 depicts a selected grid cell in downtown Salt Lake City, with a circle representing a 600 meter radius, and the spatial distribution of business establishments.

By including local access measures such as retail employment within 600 meters in a residential location model, we are able to estimate the partial effects of local accessibility on residential location, controlling for regional accessibility by auto and transit, and other housing and neighborhood characteristics.

Results and Conclusions

The results shown in Table 1 are almost all statistically significant at the 5% confidence level, and generally consistent with the preceding expectations. We concentrate on the key variables of interest in this paper, those related to regional and local access, and related density effects.

Control variables include housing cost and quality. The housing price effect, in relation to income (BCIR), was negative. Housing quality in relation to income (BILIVU) was positive. Regional access to employment (BCLAE0, BCLAE1, BCLAE2) was positive and significant for each household auto ownership class, with a larger coefficient for two plus car households. Access to population (BLAPO), after controlling for access to employment and other effects, was negative but smaller in magnitude than regional access to employment. This result is likely a combination of high correlation with regional access to employment, and the general preference of households for lower density locations, which tend to have lower population accessibility.

Variables reflecting local access performed well, with households that have fewer cars than workers (BCARLRET) showing a higher preference for locations that had more walk-access to retail than households that had more cars than workers (BCARGRET). But both effects were positive and significant, confirming the value of local accessibility in the residential location choice.

The density effects were compelling, as well. Households showed an overall preference for lower density (BLTUN, BD01-BD06), and this finding was more pronounced for households with children (BCHILDN) and those with larger household sizes (BSIZUNI). Interestingly, younger households favored higher density residential locations (BR678A40), even in a low-density metropolitan area such as this. And households with fewer cars showed more willingness to consider dense locations than those with more cars (BC1LRD, BC2LRD, BC3LRD).

While the signs and significance of the variables is clear from the results presented in Table 1, the interactions among variables and different scales of the variables make a more behavioral interpretation difficult. Elasticities of the key variables would be a reasonable computation to provide a more direct interpretation, but due to the method of random sampling of alternatives, elasticities between alternatives would not be meaningful. In order to facilitate interpretation, we have developed a sensitivity analysis, selecting a systematic sample of sites across the study area that range from very dense urban sites to exurban ones. For each of the ten selected sites shown in Figure 1, the characteristics of the sites were drawn from the database, and the estimated coefficients were used to predict the probabilities that households with differing socioeconomic and demographic characteristics would choose these sites. The results of this analysis are shown in Figure 5, for three different household types.

The pattern of results from the sensitivity analysis is consistent with the interpretation of the individual coefficients, but provides a more intuitive interpretation. Wealthier households with children are very unlikely to choose the most urban sites, and all three household types tested were relatively unlikely to choose exurban sites (with the exception that the probabilities were higher for 2 car households to choose exurban sites). Probabilities of location increase for the higher income groups at more suburban and 'small town' locations, especially for the more affluent communities. The lower income and childless household, especially if they own no vehicle, is predicted to have a much higher likelihood than the other two household types of choosing the most urban sites, which happen to be dense multi-family housing.

In short, these findings support the research literature that suggests that there is significant market segmentation with respect to residential location, and that both local and regional accessibility are significant influences on the residential location choice. Density effects are mixed, with some segments of the population preferring higher density locations, while the general pattern was a preference for lower density locations.

The integrated land use and transportation model system described in this paper is potentially the most sensitive operational model system yet implemented in a major metropolitan area to non-motorized modes and neighborhood accessibility. These are topics of major public policy interest, and the state of the practice is evolving rapidly to address these interests. The approach taken in this paper is based on linking the current state of advanced practice in both land use and four-step travel modeling. The limitations of the current four-step travel models, and advances in activity-based travel modeling suggest that over the next few years we will begin to see the emergence of more fundamentally integrated land use and activity-based travel models (12, 13). Residential location choices are, after all, highly interdependent with the labor force choices of household members, the vehicle ownership

choices of the household, and the activity and travel patterns chosen. Further research on these interdependencies and their representation in operational models presents an important challenge.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grants CMS-9818378, EIA-0090832, BCS-0120024, and EIA-0121326, and by the Governor's Office of Planning and Budget (GOPB), the Wasatch Front Regional Council (WFRC), the Mountainlands Association of Governments (MAG). In particular, we wish to acknowledge the assistance of Peter Donner and Natalie Gochnour of the GOPB, Stuart Challender (formerly with Utah AGRC), Mick Crandall and John Britting at WFRC, and Carl Johnson at MAG for their assistance.

REFERENCES

- (1) Handy, S. Regional Versus Local Accessibility: Implications for Nonwork Travel. *Transportation Research Record*. 1400, 1993.
- (2) Waddell, P. (2000). A behavioral simulation model for metropolitan policy analysis and planning: residential location and housing market components of UrbanSim. *Environment and Planning B: Planning and Design* 27, 2, 2000, pp. 247 – 263.
- (3) Waddell, P. UrbanSim: Modeling Urban Development for Land Use, Transportation and Environmental Planning. *Journal of the American Planning Association*, forthcoming.
- (4) Nourzad, F. Final Report on Mode Choice Model, report prepared for the Wasatch Front Regional Council, 2001.
- (5) Waddell, P., A. Borning, M. Noth, N. Freier, M. Becke, G. Ulfarsson. UrbanSim: A Simulation System for Land Use and Transportation. *Networks and Spatial Economics*, forthcoming.
- (6) Noth, M., A. Borning and P. Waddell. An Extensible, Modular Architecture for Simulating Urban Development, Transportation, and Environmental Impacts. *Computers, Environment and Urban Systems*, forthcoming.
- (7) Ben-Akiva, M. and S. Lerman. Discrete Choice Analysis: Theory and Application to Travel Demand. The MIT Press: Cambridge, MA., 1987.
- (8) O'Sullivan, A. *Urban Economics*. Irwin McGraw-Hill: New York, 2000.
- (9) Cervero, R. and K. Kockelman, *Travel Demand and the Three Ds: Density, Diversity, and Design*. Transportation Research, Part D, 1997. 2(2): p. 199-219.
- (10) Crane, R., *The Influence of Urban Form on Travel: An Interpretative Review*. Journal of Planning Literature, 2000. 15(1): p. 3-23.
- (11) Ewing, R. and R. Cervero. *Travel and the Built Environment: Synthesis*. in *Transportation Research Board*. 2001. Washington, D.C.
- (12) Waddell, P. Towards a Behavioral Integration of Land Use and Transportation Modeling, in *The Leading Edge in Travel Behavior Research*, D. Hensher, ed., Pergamon, 2001.
- (13) Waddell, P., M. Outwater, C. Bhat, and L. Blain. Design of an Integrated Land Use and Activity-Based Travel Model System for the Puget Sound Region, *Transportation Research Record*, 2002.

TABLE 1 Residential Location Model Estimation Results

Variable	Variable Definition	Coefficient	Std Error	z-statistic (b/std err)
BCIR**	((Total residential value / Total units) / 10) / Income	-0.0627	0.0229	-2.74
BD01**	Dummy for development type 1	-1.1830	0.2281	-5.19
BD02**	Dummy for development type 2	-0.8148	0.1387	-5.87
BD03**	Dummy for development type 3	-0.5823	0.1004	-5.80
BD04**	Dummy for development type 4	-0.3413	0.0868	-3.93
BD05	Dummy for development type 5	-0.1181	0.0751	-1.57
BD06**	Dummy for development type 6	-0.2619	0.0809	-3.24
BLTUN**	Ln(Total number of units in cell)	-0.7431	0.0494	-15.05
BILIVU**	Ln(Total improvement value) * income	3.1E-05	4.1E-06	7.70
BCLAE0**	Ln(Transit access to employment) if household has no cars	0.9385	0.2349	4.00
BCLAE1**	Ln(Access to employment for 1 car households) if household has 1 car	1.2165	0.2755	4.42
BCLAE2**	Ln(Access to employment for 2 car households) if household has 2 cars	1.2716	0.2739	4.64
BC0LRD**	Ln(Number of units within 600 m) if household has no cars	0.6502	0.2423	2.68
BC1LRD**	Ln(Number of units within 600 m) if household has 1 car	0.8567	0.1016	8.43
BC2LRD**	Ln(Number of units within 600 m) if household has 2 cars	0.3851	0.0958	4.02
BLAPO**	Ln(Access to population)	-2.5541	0.2770	-9.22
BCHILDN**	Number of units in cell if household has children	-0.0054	0.0013	-4.29
BINCLSIN**	Income(\$)*Ln(Industrial sqft within 600 m)	-5.7E-07	2.9E-07	-1.97
BINCLSCO**	Income(\$)*Ln(Commercial sqft within 600 m)	-4.6E-07	2.1E-07	-2.16
BLLVA**	Ln(Land value/acre within 600 m)	0.2983	0.0908	3.29
BSIZLUNI**	Household size * Ln(Units within 600 m)	-0.0684	0.0171	-4.01
BR678A40**	Dummy for age of head of household under 40, in Devtype 6-8	0.4723	0.0957	4.94
BCARLRET**	Ln(Retail emp. within 600 m) if number of household cars < workers	0.1283	0.0372	3.45
BCARGRET**	Ln(Retail emp. within 600 m) if number of household cars >= workers	0.0714	0.0174	4.09

** Significant at the 5% level

Number of observations	2520		
Log likelihood function	-5039.887		
Log-L for Choice model	-5039.8872		
R2=1-LogL/LogL* Log-L fcn	R-sqrd		RsqAdj
No coefficients	-5802.5144	.13143	.13051
Constants only	-5530.2268	.08867	.08770

TABLE 2 Definition of Residential and Mixed Use Development Types

Development Type	Units From	Units To	Sq Ft From	Sq Ft To
R1	1	1	0	999
R2	2	4	0	999
R3	5	9	0	999
R4	10	14	0	2,499
R5	15	21	0	2,499
R6	22	30	0	2,499
R7	31	75	0	4,999
R8	76	65,000	0	4,999
M1	0	9	1,000	4,999
M2	10	30	2,500	4,999
M3	10	30	5,000	24,999
M4	10	30	25,000	49,999
M5	10	30	50,000	9,999,999
M6	31	65,000	5,000	24,999
M7	31	65,000	25,000	49,999
M8	31	65,000	50,000	9,999,999

From and To represent the range of housing units and non-residential square feet used to classify a grid cell into a unique Development Type.

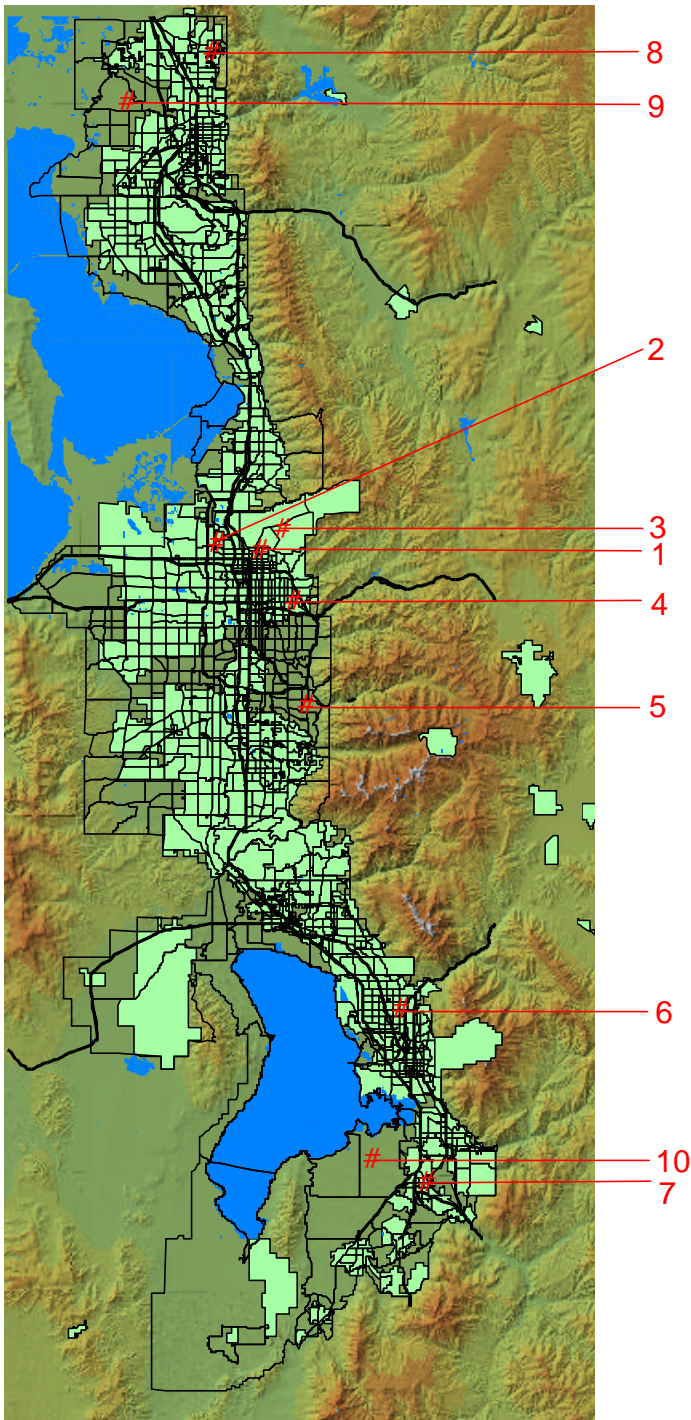


FIGURE 1 Wasatch Front Study Area and Sample Locations for Sensitivity Analysis

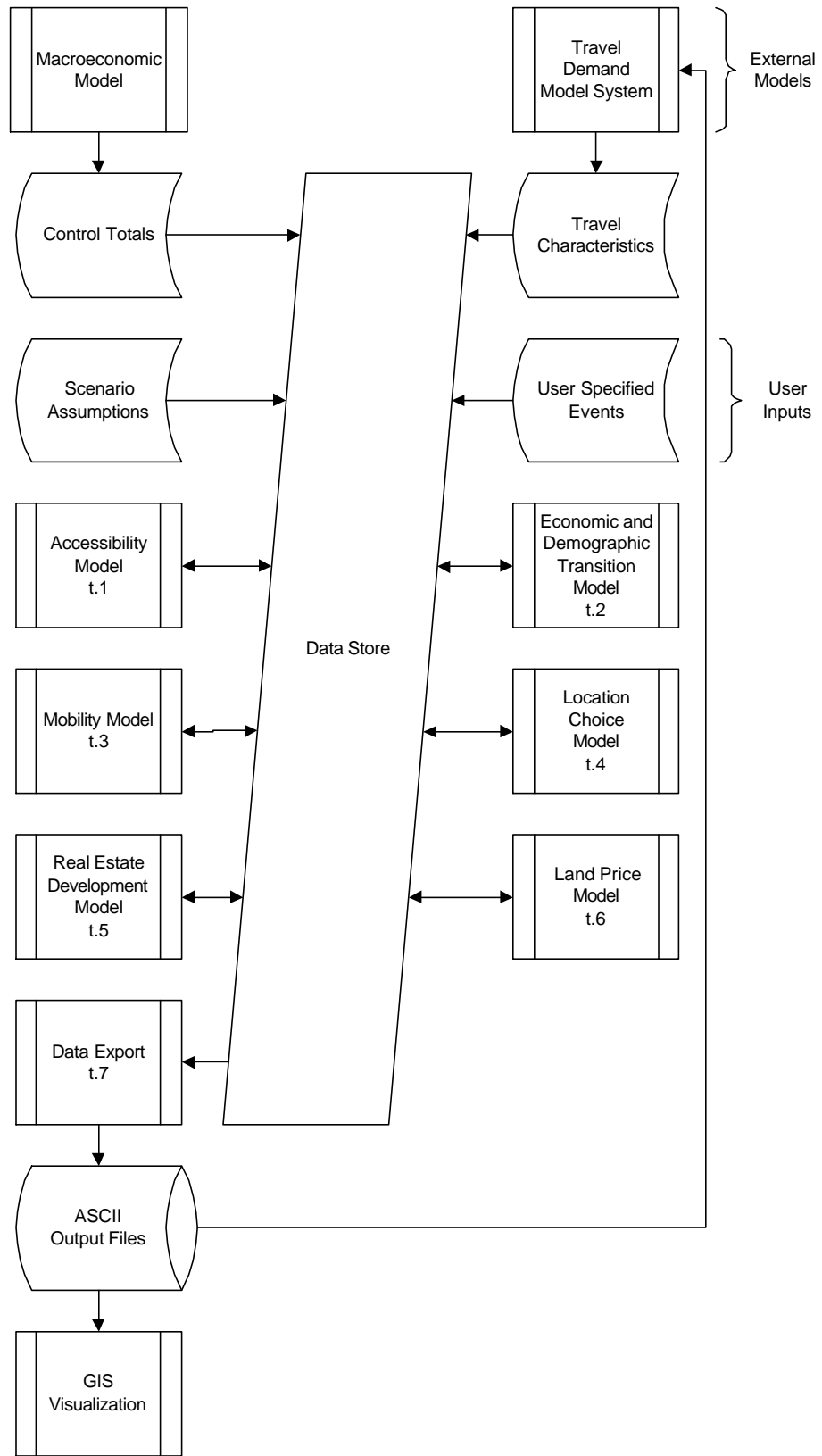


FIGURE 2 UrbanSim Model System and Interaction with Travel Model System

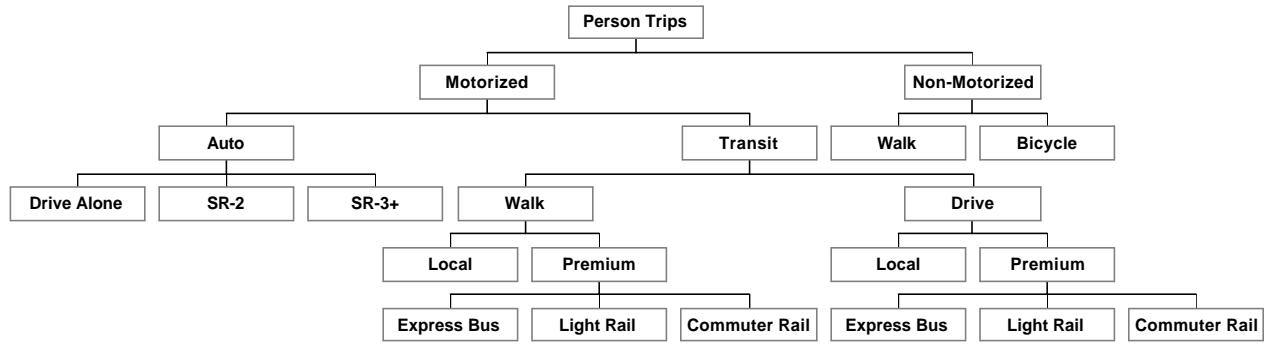


FIGURE 3 HBW Mode Choice Model Structure

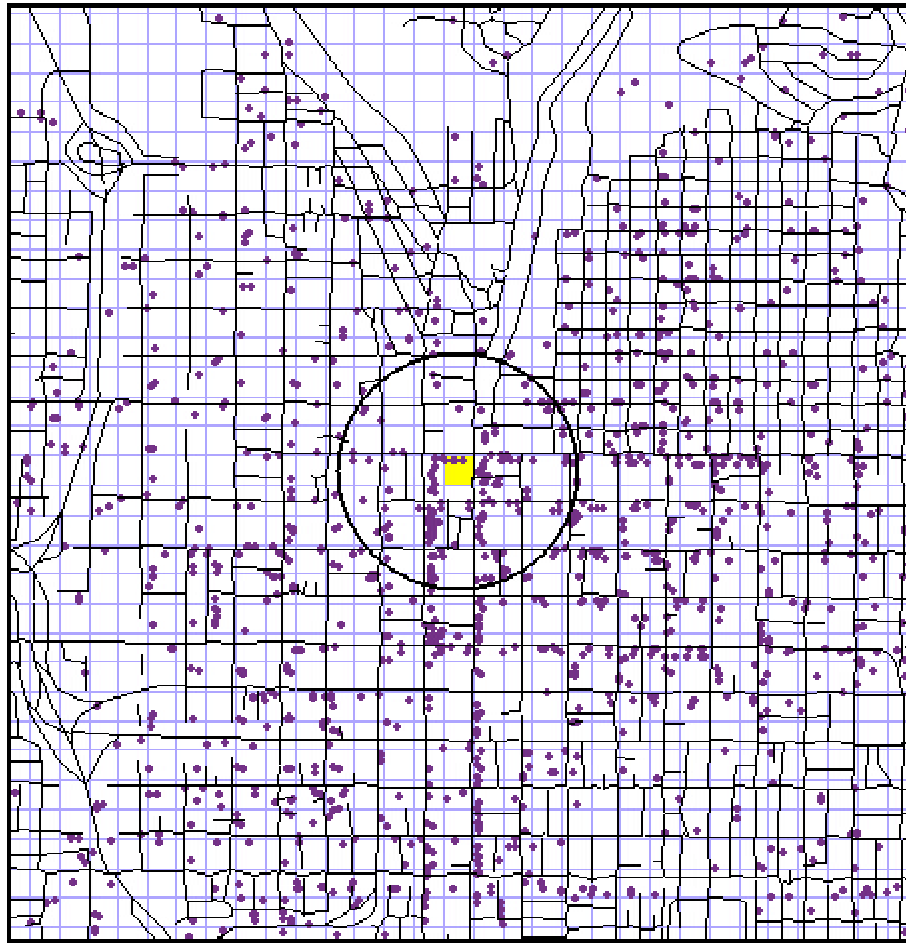


FIGURE 4: 600 Meter Radius from a Selected Cell in Central Salt Lake City, with Streets and Businesses

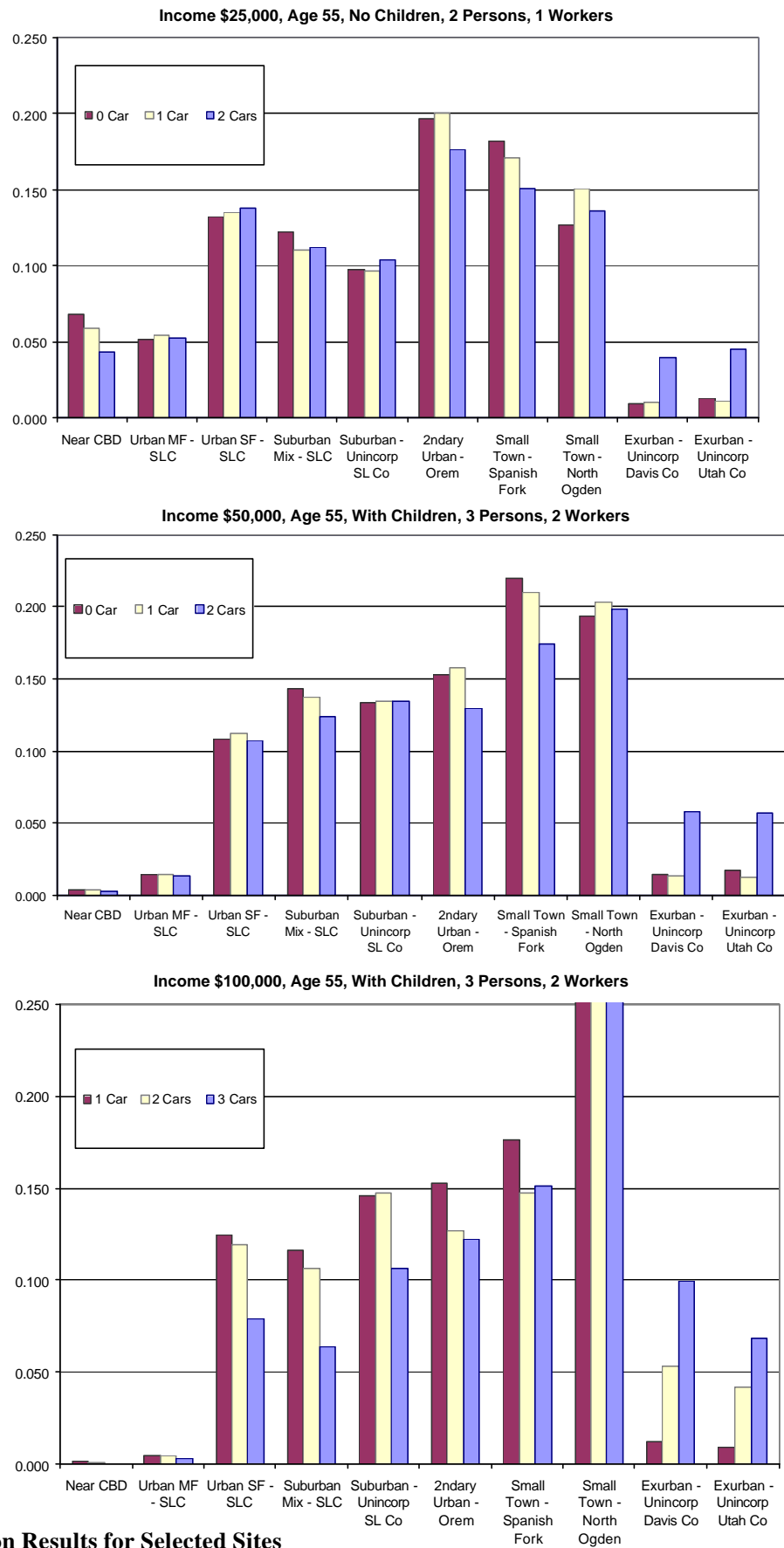


FIGURE 5: Simulation Results for Selected Sites