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Assessing the Impact of Proposed Transit Investments and Public Policy Choices on Land Use Patterns (A Simulation Approach with UrbanSim)

Final Report

October 2012

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PREPARED FOR
Florida Department of Transportation



Center for Urban Transportation Research
University of South Florida
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Assessing the Impact of Proposed Transit Investments and Public Policy Choices on Land Use Patterns (A Simulation Approach with UrbanSim)

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Metric Conversion

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m ³
yd³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	$5 (F-32)/9$ or $(F-32)/1.8$	Celsius	°C

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16. Abstract <i>Transit systems, such as commuter rail, light rail, bus rapid transit, and high speed rail, can generate significant impacts on land development patterns over time. As an aid to local decision-making, it would be very helpful to have an evaluation tool which can be developed, validated, and calibrated with local data to forecast the impacts of proposed transit investments on land use patterns and to assist in determining which policy choices might achieve a desired result. This study aims to develop an UrbanSim model to assess the changes that might result in a specific geographic area from a decision to construct a Bus Rapid Transit investment in Hillsborough County, Florida. UrbanSim has the potential to be a powerful tool in evaluating the benefits of transit investments because it works on a much smaller geographic scale than other alternative systems and can simulate location decisions made by individual business and families. Data on parcels, households, jobs, and land plans were collected for the base year (2010) from various data resources, such as the county appraiser, census database, InfoUSA, etc. The Tampa Bay Regional Planning Model (TBRPM) model was used to produce a traffic pattern forecast. The model was validated by comparing the simulation results to the projected demographic data in the Hillsborough County MPO 2035 Long Range Transportation Plan (LRTP). Four scenarios with different ridership levels were created of the proposed Bus Rapid Transit (BRT) investment using a short-term period (2010-2012) and a long-term period (2010-2020). The scenarios were compared to the ones without the proposed BRT route in the same years. This study found that the change in land use patterns is complex due to implementing the BRT service, either in a short-term (2010-2012) or a long-term period (2010-2020). The proposed BRT service has significant impacts on land use patterns in a long-term period (2010-2020).</i>					
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Executive Summary

Transit systems, such as commuter rail, light rail, bus rapid transit, and high speed rail, can generate significant impacts on land development patterns over time. As an aid to local decision-making, it is very helpful to have an evaluation tool which can be developed, validated, and calibrated with local data to forecast the impacts of a proposed investment and to assist in determining which policy choices might achieve a desired result. UrbanSim is a software-based simulation system for supporting, planning, and analysis of urban development. Through the incorporation of interactions between land use and travel demand models, UrbanSim has the potential as a tool to evaluate the impacts of proposed transit investments on variables of interest, such as population, demographics, the local economy, the real estate market, land use, the environment, and travel patterns. While land use models provide an understanding of the causes and consequences of land use changes, travel demand models can be used to forecast the ridership of new transit systems, which change the accessibility of properties. This is significant for land use changes because they may affect individuals' choices on the location of their household and employment.

This study aims to determine the feasibility of using UrbanSim to assess changes that could result from a transit investment in an urban area, and if this use is feasible, to examine the impacts of a proposed Bus Rapid Transit (BRT) investment in Hillsborough County, Florida. To these ends, a case study of this investment is used as the basis of this project. UrbanSim has the potential to be a powerful tool in evaluating the benefits of transit investments because it works on a much smaller geographic scale, such as parcel, than other alternatives and can simulate location decisions made by individual businesses and families. The objectives for this study include the following:

1. Perform a literature review to examine previous assessments of the impacts of proposed transit investments and public policy choices on land use patterns
2. Select a proper study area and assess the data requirement for the UrbanSim model
3. Collect required data
4. Develop an UrbanSim model
5. Design and test scenarios
6. Develop supporting tools for data collection and model development

7. Summarize findings

In this study, a parcel-based UrbanSim model was adopted. The parcel version requires 22 to 25 data tables which can be organized into 5 categories: Geography, Buildings, Households, Employment, and Real Estate. These data were retrieved from various sources, including county appraisers, InfoUSA, the Census Summary and Public Use Microdata Sample (PUMS) from the American Community Survey (ACS), and the Hillsborough Planning Commission Future Land Use Element. The Tampa Bay Regional Planning model was used to produce travel patterns. All of these data were linked and imported into the UrbanSim model to create a base scenario (2010). Ten sub-models were also selected to integrate into the UrbanSim model to simulate individual agent's (person) behavior in the housing and employment market. The model was validated by comparing simulation results with the zonal demographic projection of the Hillsborough MPO 2035 Long Term Regional Transportation Plan (LRTP). In total, four scenarios were developed, including two short-term (2010-2012) BRT ridership scenarios (1 percent trip shift and 5 percent trip shift) and two long-term (2010-2020) BRT ridership scenarios (1 percent trip shift and 5 percent trip shift). The scenarios were simulated and compared to the simulation results without the BRT service in the same years. Based on the build/no build scenarios, the following findings were concluded:

- **UrbanSim is a powerful tool for simulating land use changes.**

UrbanSim is based on theories of market economics and discrete choice behavior, and captures both the impacts of market forces as well individuals' choices on land development processes. The household and job-based simulation makes its forecasting more realistic, both spatially and temporally. The UrbanSim model developed provides a reasonable prediction based on the differences observed between the simulated land use patterns and the projections in the 2035 LRTP. It is noted that some errors between the two projections are expected since the projection method used in UrbanSim is different to that used in the 2035 LRTP.

- **Data preparation is the key step in implementation of the UrbanSim model.**

UrbanSim requires a great deal of effort and resources to prepare the required data. In addition, some required data are not readily available. A major component of the data preparation was to synthesize household and building data using the Iterative Proportional Updating (IPU) algorithm, a synthesis population generation algorithm. Since the resolution of the algorithm is

Census Blockgroup, it is larger than Traffic Analysis Zone (TAZ) and parcel levels, which created a lack of marginal distributions at the zone and parcel levels. Researchers addressed this by randomly assigning the synthesized households and persons to zones, parcels, and buildings. Users of UrbanSim should be aware that this random assignment may influence the accuracy of the UrbanSim simulation. The simulation would be improved by the development of a new assignment algorithm considering relationships between household characteristics and parcel attributes; for example, households with higher incomes tend to occupy the higher value parcels/buildings.

- **The proposed BRT service has significant impacts on land use patterns in the long-term period (2010-2020).**

The model predicts that the population and number of households in the study area will increase by about 15% due to implementing the BRT service in a long term period (2010-2020); the unit price of housing in the study area will increase by 4% due to implementing the BRT service in a long term period (2010-2020). Compared to the impacts of the BRT investment on jobs and housing unit prices (4% and less than 1%, respectively), the impacts on population and households in 2020 were larger (15% and 12%, respectively). In UrbanSim, population and households are predicted by the Household Location Choice Model, which adopted the system default structure and coefficients in this study due to a lack of survey data for Hillsborough County. A possible reason for the “large” impacts on population and households is the “non-localized” Household Location Choice Model. The study also adopted the system default coefficients for the sub-models. More accurate coefficients could be derived from a survey to calibrate the coefficients of the household/employment location choice models. Models localized for Hillsborough County are expected to improve the accuracy of the UrbanSim model.

- **Adequate support by the travel demand model is critical.**

In current travel planning models for Hillsborough County, such as the Tampa Bay Regional Planning Model (TBRPM) or Transit Boardings Estimation and Simulation Tool (TBEST), the BRT mode is not available. Thus, the research team had to assume the ridership of the proposed BRT route to create the scenarios. The scenarios should be updated with the availability of the BRT mode in travel planning models to provide a more reasonable assessment of the impacts of the proposed BRT route. In the UrbanSim model developed in this study, the impact of BRT

services on traffic patterns is represented by the number of trips attracted away from the auto mode, as auto mode is the only one included in the sub-models. A new model structure should be developed to contain transit variables in order to directly represent transit impacts.

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1. INTRODUCTION

Transit systems, such as commuter rail, light rail, bus rapid transit, and high speed rail, can generate significant impacts on land development patterns over time. According to the Transit Cooperative Research Program (TCRP) Report 35 - "Economic Impact Analysis of Transit Investments," land development and changes in property values are listed as a redistributive impact on transit investments (1). Most efforts to assess the potential impacts of a proposed transit investment on a neighborhood are made by comparing the proposed transit investment plan to other communities that have already made similar investments. Although this type of analysis is informative, it is also of somewhat limited value because a particular transit investment's impacts on a specific neighborhood or area are the result of complex interactions between existing conditions; local market forces; choices made by individual businesses and families; and land use decisions made by the local government that vary significantly from region to region.

As an aid to local decision-making, it would be very helpful to have an evaluation tool which can be developed, validated, and calibrated with local data to forecast the impacts of a proposed investment and to assist in determining which policy choices might achieve a desired result. It is believed that such a tool may also assist in minimizing potential conflicts over proposed transit investments because more is known about the future with some level of confidence.

The integration of land use and travel demand models creates a tool that can recognize the interaction between land development and travel patterns, and evaluate the impacts of proposed transit investments on the population, demographics, the local economy, the real estate market, land use, growth policies, and the environment. Land use models provide an understanding of the causes and consequences of land use changes. Accessibility of properties plays a key role in land use changes because it can significantly affect individuals' choices on the location of their household and employment. Travel demand models can be used to forecast the ridership of new transit systems which will change accessibility of properties. Travel demand models require socioeconomic data in the horizon years for future forecasts to predict future travel patterns based on future land use forecasts, sometimes with the aid of a land use model. The accuracy of a

land use forecast greatly affects that of a demand forecast model. Figure 1-1 shows the feedback mechanism between land use models and travel demand models.

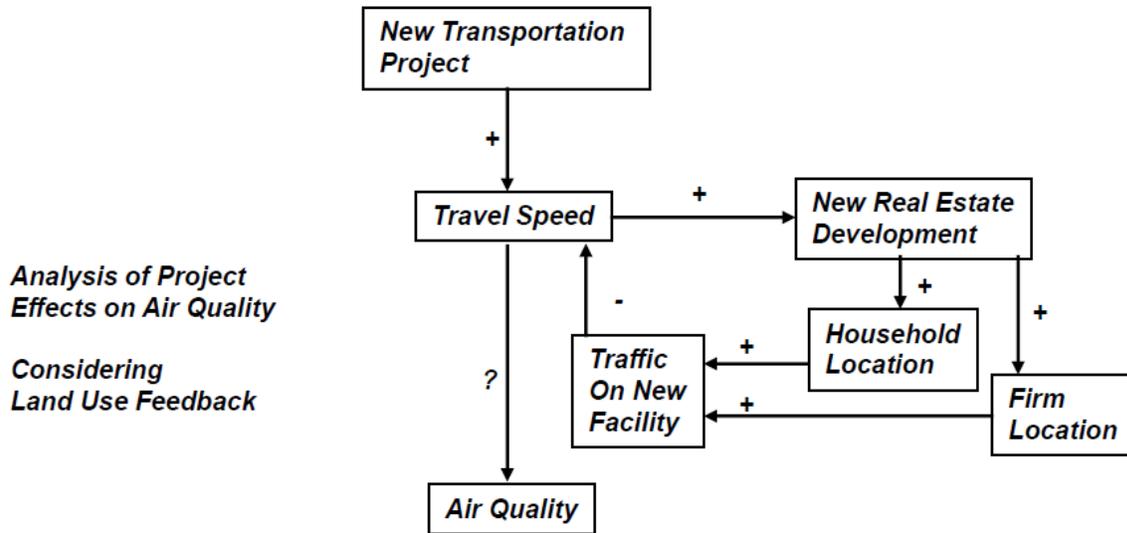


Figure 1-1 Feedback Mechanism between Land Use Models and Travel Demand Models
(Source: www.urbansim.org)

Existing land use models range from rule-based programs that provide information and guidance on the process of allocating growth to different subareas, to sophisticated models that incorporate economic theories and market mechanisms.

UrbanSim was originally developed by Paul Waddell of the University of Washington. UrbanSim simulates land use changes by considering factors such as changes in population, demographics, structure of the local economy, the real estate market, land use and growth policies, environmental constraints, etc. It is based on disaggregate activity-based models that consider individuals' choices on residential and employment locations, as well as the real estate market. Additionally, it is a freeware while most of the other operational land use models are either proprietary or unavailable.

This study aims to develop a model using UrbanSim to assess whether the changes that might take place in a specific geographic area are from a transit investment. UrbanSim has the potential to be a powerful tool in evaluating the benefits of transit investments because it works on a much smaller geographic scale than other alternative systems and can simulate location decisions made by individual businesses and families.

1.2 Objectives

The objectives for this study include the following:

1. Perform a literature review to examine previous assessments of the impacts of proposed transit investments and public policy choices on land use patterns
2. Select a proper study area and assess the data requirement to develop an UrbanSim model
3. Collect required data
4. Develop an UrbanSim model
5. Develop and test scenarios with the model
6. Summarize findings

In the remainder of this report, literature on proposed and operational land use models is reviewed and summarized in Chapter 2. The emphases of the literature review are underlying theories, methodologies, and applications of the models. Chapter 3 describes the study area, Hillsborough County, Florida. The study area must be an area with recent household survey data and up-to-date GIS data, including parcel-level property data, and it also must be relatively self-contained. Data collection and processing are also described in Chapter 3. Data collected include property parcels, business establishments, census, urban area boundaries, environmental and political planning boundaries, and Traffic Analysis Zones (TAZs).

Chapter 4 discusses the specifications of the sub-models. The process of the UrbanSim model assembly and debugging is also described in Chapter 4. Chapter 5 describes the UrbanSim simulation process for Hillsborough County. The simulation results based on the base year (2010) are compared to the projected socioeconomic data from the Bureau of Economic and Business Research (BEBR), University of Florida to validate the UrbanSim model.

Chapters 6 and 7 present two case studies based on alternatives of the Hillsborough County transit improvement plan and assumptions of future demographic and economic growth. Comparisons between scenarios with and without a Bus Rapid Transit (BRT) service in the target years (2012 and 2020) are described in the chapters to evaluate the impacts of the proposed transit system. Finally, conclusions and recommendations regarding the future adoption of UrbanSim in Florida for transit investment evaluation are provided in Chapter 8.

2. LITERATURE REVIEW

While transit investments aim to improve mobility of the public, it is recognized that the investment can also generate significant economic benefits. Continuous efforts have been made to improve methods used to measure the economic impact of the transit investment; therefore, there is a growing interest in assessing the impacts of those investments on land use in an effective and efficient manner. Four-step travel demand models are used to measure the impact of transportation/transit investments on the transportation system and travel behavior. These models include four sequential steps to calculate the travel demand: the number of trips generated, how they are allocated, what modes are used, and what transportation links are used for the trip. They measure the change in travel time, operating cost, mode choice, route choice, and traffic volumes of the transportation network. These results are then used in various economic impact and land use models to estimate the economic benefits of the investment (attractiveness of the area, cost of living, access of business to labor markets, etc.) and also the impact on land use patterns. The approaches used to capture the impact of transit investments on economic activities, development density, mix of uses and land use patterns (urban form and design) are as follows:

2.1 General Methods to Assess the Impact of Transit Investments

- **Input-Output (I-O) Models**

Input-output models use regression equations to measure the impact on business activities in the broader economy due to expansion/contraction of a given industry (e.g, transit). An I-O model is a matrix, which uses inter-industry purchasing and import information from the U.S. Bureau of Economic Analysis (BEA) national input-output table (nearly 500 industries) as an input. The outputs obtained from these models are expressed in terms of three measures of economic activity: earnings (wages and salaries), Gross National Product (GNP), and jobs. These models also provide inter-industry outputs by industry sector. The most commonly used I-O models are the Regional Input-Output Modeling System (RIMS II) and IMpact analysis for PLANning (IMPLAN).

- **Regression Models**

Regression models are widely used to evaluate the impact of transit investments on economic conditions. These models measure impacts, such as changes in employment, land value, and/or

building square footage, due to explanatory variables, like transit service levels or transit investments.

The most commonly used regression analysis tools are hedonic price models and logistic regression, which both reveal people's preference. As a change in property value due to transit investment represents a change in accessibility of that particular property, the hedonic price model is used to measure the change in property value due to transit investment. It uses property values or change in property values (2, 3, 4, and 5) as the dependent variable and home characteristics (area, age of the property, number of bedrooms, bathrooms, etc.), neighborhood characteristics (income, race, ownership, etc.), and location characteristics (proximity to transit station) as the explanatory variables. Linear, semi-logarithmic, and log linear specifications are employed to model the economic impact of transit investment on discrete dependent variables, such as mode choice and land use category. These models capture the transit impact using property cross sections, whereas some studies (3, 5, 6, 7) suggest use of repeat sales value of a property. This helps analyze the actual object of the analysis, property price appreciation, rather than analyzing the causes of property price appreciation. These regression models serve as the basis for capturing the predictive impacts, using techniques such as input-output, economic forecasting, and simulation models.

Since the most commonly used ordinary least square (OLS) hedonic models do not take into account spatial dependencies and heterogeneity, studies (8, 9, 10, 11,12) suggest using spatial autoregressive (SAR) and geographically weighted regression (GWR) approaches to develop spatial hedonic models.

The SAR hedonic approach incorporates spatial effects in the regression model based on the assumption that response variables at each location are a function not only of the explanatory variable at that location, but of the response at neighboring locations as well. SAR models are classified into three types (SAR lag model, SAR error model, and SAR mixed model) based on where the spatial autoregressive process is believed to occur.

The GWR approach also incorporates geographic information into the regression model by estimating separate models for each data point and developing a series of distance-related weights. The GWR approach gives a heightened understanding of relationships between variables across space, as the output of this model is a set of parameters that can be mapped in

geographic space. GWR is an alternative to SAR models as it performs best with regards to model fit, but the issue of correlated coefficients gives favor to SAR.

- **Statistical Comparisons**

If data needed for regression analysis are not available, simple statistical comparisons can be made before and after the transit investment based on data of development, employment, wages, and other variables. In this method, comparable neighborhoods' and subareas' transit corridors are used as a control and a comparative analysis is performed between the control and study area before and after the transit investment. The following equation represents the method:

$$\text{Effect of Transit} = (I_{TA} - I_{TB}) - (I_{CA} - I_{CB}) \quad (1)$$

where:

I = Economic impact of transit

T = Transit corridor being studied

C = Transit corridor used as a control

B = Before transit investment

A = After transit investment

- **Economic Forecasting and Simulation Models**

Economic forecasting and simulation models link the input-output model to an econometric model by adding the ability to forecast future changes in prices and costs of labor, housing, transportation, or business on a yearly basis. They use travel time savings information from regional transportation models, and employment, wage, and salary data as inputs. They are primarily used to predict the short term and long term impacts of the transit investment on sales, business output, personal income, employment, population, and productivity.

These models consist of systems of simultaneous regression equations and stepwise regression with a relatively straightforward structure. Studies (1, 13, 14) have used models such as Regional Economic Models, Inc. (REMI), Regional Dynamics Model (REDYN), and Transportation Economic Development Impact System (TREDIS) to capture economic impacts of public transportation investments. Models like REMI also incorporate the spatial dimension of the economy by capturing benefits due to the concentration or agglomeration of economic activities.

2.2 Integrated Land Use Models

Integrated land use models are used to capture the impact of transportation investments on land use patterns, which can be defined in terms of population, employment, and density of developments. Based on the methodology adopted and classification proposed by Waddell (2004), land use models are classified into spatial interaction, spatial input-output, linear programming, micro-simulation, discrete choice modeling, cellular automata, and rule-based. There have been several studies (15, 16, 17, 18) that have summarized most of the land use models.

Land use models are quite similar to economic forecasting models, as both provide forecasts of employment by zone; however, land use models do not provide fine level details on categories of business. These models give fine level details on building space and geographic zones. MEPLAN, UrbanSim, Production Exchange and Consumption Allocation System (PECAS), and Transportation Economic and Land Use Model (TELUM) are some of the widely used integrated land use models.

- **MEPLAN**

MEPLAN is a proprietary software package developed by Marcial Echenique and Partners Ltd. in the United Kingdom. Hunt (19) describes its framework as the interaction between two parallel markets: a land market and a transportation market. Behavior in each system is modeled as a response to price or price-like signals (including travel disutility). It provides the following outputs:

- Employment by sector
- Population by income group
- Households by car ownership group
- Land area by activity
- Floor space by activity
- Price by floor space/land type

- **UrbanSim**

UrbanSim is a disaggregate simulation model used to simulate the commercial and residential development of a region both spatially and temporally. It is linked to traditional four-step travel demand models that provide a static equilibrium traffic assignment. UrbanSim is further explained in Section 2.5.

UrbanSim uses land or real estate price data, which gives the real market valuation of each property as compared to rent data used by hedonic models. However, finding data sources for real estate transaction prices is a challenge. The UrbanSim simulation system provides the following outputs:

- Households by income, age, size, and presence of children
- Employment by industry and land use type
- Acreage by land use
- Dwelling units by type
- Square feet of nonresidential space by type
- Real estate prices

2.3 Other Methods to Assess the Impact of Transit Investments

- **Fiscal Impact Models**

Fiscal impact models are specialized financial models which measure the impact of economic changes due to proposed land use decisions on government (local, county and state) revenues and expenses (tax revenues). They estimate tax revenues from future development, employment, and income due to proposed transportation investment. They use information from the local government budget, census, property appraiser, and employment data to predict cost and revenues associated with the comprehensive plan or individual projects.

Fiscals, STAMP, and Fiscal Impact Analysis Model (FIAM) are the most commonly used fiscal impact models. While I-O and economic forecasting models like IMPLAN and REMI give estimates of tax revenues due to economic changes, they do not provide as detailed information as provided by fiscal impact models.

- **Case Comparisons**

Case comparisons examine how transit investments have affected economic growth and development in other communities and then compare how similar investments might affect another community. This is achieved by studying literature and conducting interviews with planners, etc. Inputs measured include the following: changes in square feet of development within a corridor by land use, employment, property value, personal income, and retail sales revenue. Case comparisons are used for predictive studies.

- **Interviews / Focus groups / Surveys**

Local experts, corporate leaders, business owners, developers, and community members are interviewed or surveyed to predict and evaluate the economic impact of transit investments.

- **Physical Condition Analysis**

This analysis is focused on identifying opportunities for development within a proposed transit corridor. Field surveying is a method of assessing development conditions. This analysis measures transit impacts in terms of square feet of development by land use type and potential property tax revenue. Physical condition analysis is most effective when used in combination with case comparisons, interviews/focus groups/surveys, and real estate market analysis.

- **Real Estate Market Analysis**

This analysis is used to measure the impact of an investment on transit corridors' development potential. It is measured in terms of rent and land value premiums, vacancy rates, and net absorption (sqft of development). Data sources used include government sources, building permits, tax assessment records, local newspapers, and data from private data vendor market profiles.

Table 2-1 summarizes the various methods that can be applied to measure the impacts of transit investments.

Table 2-1 Methods Used to Capture Impacts of Transportation Investments

Category	Description	Typical Model	Advantage	Disadvantage
Input-Output (I-O)	Uses regression equations to measure impacts on business activities in the broader economy due to expansion/contraction of a given transit system.	RIMS II, IMPLAN	Prevents the need to conduct expensive surveys, widely used for impact studies	Expertise required to use, not able to forecast impact on local economy
Regression Models	Measures impacts such as changes in employment, land value or building square footage due to explanatory variables like transit service levels or transit investments.	Hedonic Model, Logit Mode, SAR, GWR	Widely recognized and accepted approach	Data intensive, expertise required to use, not able to capture the impact on economic activities effectively
Economic Forecasting and Simulation	Links the input-output model to an econometric model by adding the ability to forecast future changes in prices and costs of labor, housing, transportation or business on a yearly basis.	REMI, REDYN, INFORUM, TREDIS	Powerful tool to understand economic impacts over time (dynamic), less computer time to run	Expertise required to use, acquisition of data can be time consuming
Integrated Urban Land Use Models	Captures the impact of transportation investments on land use patterns, which can be defined in terms of population, employment, and density of developments.	MEPLAN, UrbanSim, PECAS, TELUM	Unknown	Unknown
Statistical Comparisons	Simple statistical comparisons can be done based on data of development, employment, wages, and other variables from both before and after data on transit investments.		Less data-intensive, expertise is not required	Control areas are difficult to find
Fiscal Impact Models	Measures impact of economic changes due to proposed land use decisions on government (local, county and state) revenues and expenses (tax revenues).	Fiscals, STAMP, FIAM	Detailed estimates of financial benefits of a transportation project, basis for future budget projections	Careful methodology examination is required as the resource allocation may be based on this analysis
Case Comparisons	Compares how transit investment has affected economic growth and development in other communities with how similar investment might affect another community.		Easy to administer, low cost, helps in identifying additional steps required to capture the impact of transit investment	Mislead decision makers, impacts of such investment is unique for each area

Table 2-2 (continued)

Category	Description	Typical Model	Advantage	Disadvantage
Interviews / Focus groups / Surveys	Local experts, corporate leaders, business owners, developers, and community members are interviewed or surveyed to predict and evaluate economic impacts of transit investment.		New perspective which may not be apparent to researcher, easy and inexpensive to use	It is based on opinions and perceptions which may lead to bias
Physical Condition Analysis	Identifies opportunities for development within a proposed transit corridor. Field survey is the method of assessing the development conditions. The SBD Zones		Cost effective, not data intensive	Not practical on a larger (regional) scale
Real Estate Market Analysis	Measured in terms of rent and land value premium, vacancy rates land assembly, and net absorption (sq. ft. of development). Data sources used include government sources; building permits and tax assessment records, local newspapers, and data from private data vendor market profiles.		Less time consuming, relatively low cost, easy to understand	Can be data demanding, inconsistencies in required data, can be easily biased

2.4 Impact of BRT Investments on Land Use

Munoz-Raskin (20) studied the relation of BRT and residential property values within walking distance to the system in Bogota's TransMilenio (Colombia). This study uses data on 130,692 new multifamily properties provided by the Bogotá Department of Housing and Control from 2001 to 2004 to find out the impact of BRT on multifamily properties. It concludes that properties within the immediate proximity of feeder lines (0–5 minute walk, $\leq \frac{1}{4}$ mile) were valued more than those requiring a 5–10 minute walk.

Breakthrough Technologies Institute (21) performed a detailed review of developments around BRT corridors in four cities: Brisbane (Australia), Cleveland (Ohio), Boston (Massachusetts), and Ottawa (Ontario). It also conducted written surveys and personal interviews with local developers and public agencies to assess their attitudes on BRT and development. The results indicated that BRT services can lead to commercial growth and a rise in land values.

Rodríguez and Mojica (22) developed a before-and-after hedonic model to evaluate the network effects of an extension to Bogotá's BRT system. This study attempted to capture the impact of the extension of Bogotá's BRT on property values using a hedonic model. The study found increases in the price of the properties within 500 meters of the BRT.

Diaz et al. (23) evaluated the major elements, system performance, and system benefits of the BRT system and provided transportation planners and decision makers with basic information and data to support the development and evaluation of bus rapid transit concepts.

Rodriguez and Targa (24) examined the impact of the proximity to Bogota's BRT on asking prices for apartment rentals. The authors found increases of 6.8 to 9.3 percent for every 5 minutes of walking time closer to a TransMilenio BRT station. They also found that properties on the bus route, but not necessarily close to a TransMilenio station, had a lower increase, presumably due to the negative noise and pollution effects of bus traffic.

Kittelsohn & Associates Inc. (25) reviewed existing documentation of land development impacts associated with recent BRT projects, as well as public agency and developer perceptions of how BRT service and BRT components impact land development location, design, and decision-making. The perceptions were obtained from a BRT land development survey conducted for two existing BRT systems: the Transitway in Ottawa and the Silver Line in Boston.

Transit-oriented development (TOD) policies were obtained from Ottawa and Pittsburgh. Guidelines are provided for assessing the likely land development impacts of new BRT systems (or system improvements) and determining what land development policy and design standards might be applied to encourage TOD around BRT facilities.

Parsons Brinckerhoff Quade & Douglas, Inc (26) conducted a detailed review of the land use and transportation policies that supported development activities around busway stations at six international locations from 1974 to 1995. Their report concluded that the busway investments had been used to guide employment and commercial growth in the region.

Perdomo et al. (27) assessed property values from cadastral data for 1,547 properties within 1 km of TransMilenio BRT stations. The study found that property prices increased between 0.12 and 0.38 percent (depending on the distance to the BRT), for every 5 minutes of walking time closer to a BRT station. Kaplowitz (28) analyzed if BRT provides similar incentives to developers as light rail. The author concluded that BRT does attract development as rail transit but if BRT features attractive stations and offers good quality service, they can attract new developments equivalent to those attracted by rail transit. However, this study seems to draw conclusions based on limited evidence and does not include interviews with developers.

The reported land use benefit of BRT interments is summarized in Table 2-2.

Table 2-3 Reported Land Use Benefit of BRT

BRT System	Land Development Benefits
Adelaide Guided Busway	The Tea Tree Gully area is becoming an urban village
Bogotá TransMilenio	For every 5 minutes of additional walking time to a BRT station, the rental price of a property decreases between 6.8% and 9.3% after controlling for structural characteristics and neighborhood attributes
Boston Silver Line (rebuilt Washington Street)	\$700+ million in new investments within two to three blocks of BRT line
Brisbane South East Busway	Up to 20% gain in property values near busway. Property values in areas within 6 miles of station grew two to three times faster than those at greater distances. Higher increase in median home values around busway than other suburban areas
Ottawa Transitway System	\$1 billion (Canadian) in new construction at Transitway Stations
Pittsburgh East Busway	59 new developments within 1,500 feet of stations, \$302 million in land development benefits of which \$275 million was new construction, 80% clustered at stations.

2.5 UrbanSim

UrbanSim is a software-based simulation system for supporting planning and analysis of urban development and incorporating the interactions between land use, transportation, the economy, and the environment (29). It is intended for use by Metropolitan Planning Organizations (MPOs), cities, counties, non-governmental organizations, researchers, and students interested in exploring the effects of infrastructure and policy choices on community outcomes, such as motorized and non-motorized accessibility, housing affordability, greenhouse gas emissions, and the protection of open space and environmentally sensitive habitats. The urban simulation process reflects the broad scope of interactions among households, firms, developers, and governments within markets for real estate, labor, and goods and services.

In any given simulation year, the UrbanSim model predicts how the individual actors make decisions that culminate in the annual land development and location decisions.

- Developers use land to construct housing and nonresidential floor space that are demanded by households and businesses, which are also interacting in the labor market and the markets for goods and services.
- Governments provide infrastructure and services, regulate, and in some cases alter prices for the use of land and infrastructure.
- The key agents that generate or respond to the policies outlined are households, individuals, employers, developers, and governments.
- Households make a cluster of interdependent long-term lifestyle choices, including when to move, neighborhoods to locate within, type of housing to rent or purchase, and number of vehicles to own. Individuals within households choose their labor force and educational status, job mobility and job search, daily activity schedule, and transportation mode and route.
- Employers choose to start and close establishments, site locations, size of employment, and types and quantities of real estate to rent or purchase.
- Developers choose to undertake real-estate development projects and the scale and locations of those projects.
- Governments set policies and make investments that affect the choices of other agents, and also make development choices regarding public facilities, including type, location, and scale of development.

The UrbanSim components and data flow is given in Figure 2-1.

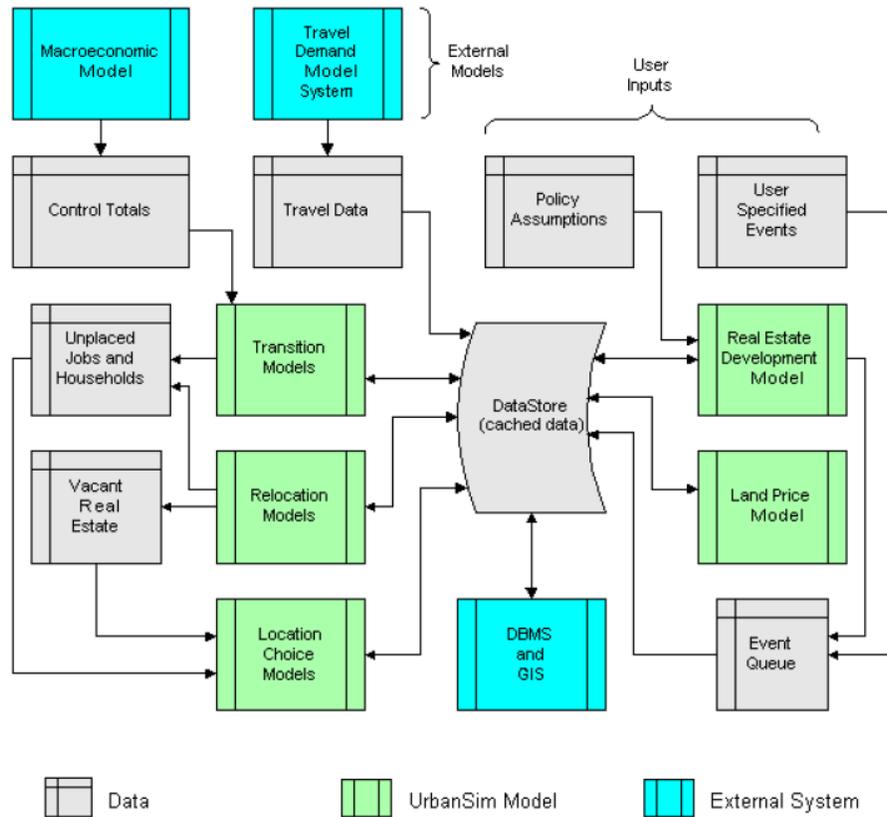


Figure 2-1 UrbanSim Model Components and Data Flow
(Source: www.urbansim.org)

UrbanSim requires high quality data input, including:

- Regional Control Totals
- Parcel Data
- Business Establishments
- Household Data (Census, Travel Survey)
- Land Use Plan
- Environmental Constraints

Meanwhile, UrbanSim provides the flexibility to aggregate/disaggregate households, businesses, and land use at parcel, zone, or grid cell level for output, including:

- Future year distributions of population

- Households by type (e.g., income, age of head, household size, presence of children, and housing type)
- Businesses by type (e.g., industry and number of employees)
- Land use by type (user-specified)
- Units of housing by type
- Square footage of nonresidential space by type
- Densities of development by type of land use
- Prices of land and improvements by land use

The primary input and output data in UrbanSim are shown in Figure 2-2.

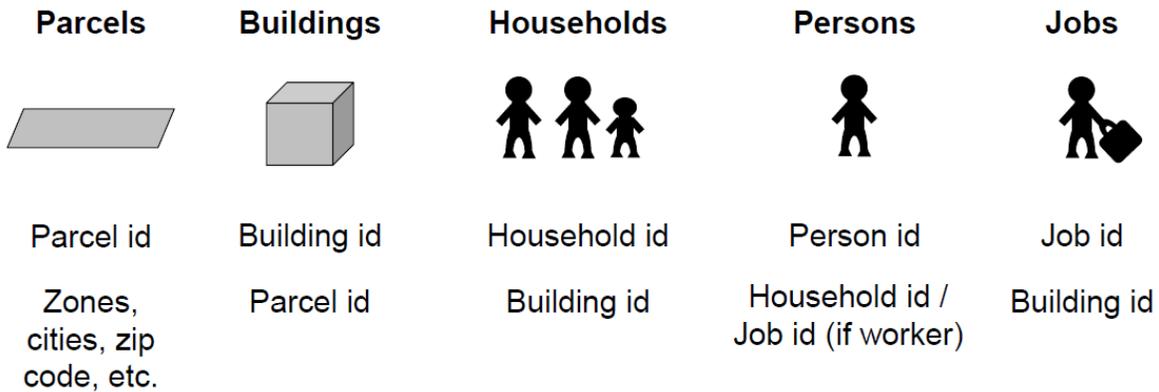


Figure 2-2 Primary UrbanSim Input and Output Data
(Source: www.urbansim.org)

Currently, UrbanSim provides three versions in different geographic resolutions:

- Grid-cell Version

The grid-cell version of UrbanSim was the first version, followed by the parcel and zone versions. The grid-cell approach to developing the data for UrbanSim, as the name suggests, begins with the decision of a resolution to use for a grid to overlay the study area. There is no definitively correct grid cell resolution, and a pragmatic choice of 150 meters by 150 meters was chosen in early UrbanSim applications, mainly as a compromise between the high level of resolution desired and the increased computational demands made by higher resolution data. The data relationship in the grid-cell version is shown in Figure 2-3.

The main disadvantage of the grid-cell data structure has already been mentioned: It requires unnaturally splitting the underlying parcel information and recombining it in ways that create artificial representations of the data. This problem also makes it difficult to apply information on development regulations from general plans, since those are also based on polygons, and in fact, apply to parcels.

- **Parcel-based Version**

To address some of the limitations of the grid-cell data structure, recent improvements to the UrbanSim software have adopted a data structure based on parcels. The parcel-based UrbanSim application uses a data model that reflects parcels, buildings, households, and jobs as the primary objects and units of analysis. Households and jobs choose locations by selecting a specific building, which is associated with a specific parcel. Real estate development is based on development projects occurring on specific parcels. The data relationship is shown in Figure 2-3.

- **Zone-Based Version**

Given the available flexibility in configuring models in UrbanSim, an alternative data structure can be readily substituted for parcel or grid-cell based data. Locations can be defined by zones used in the travel demand models to make them consistent with current-generation zone-based travel demand models. This approach can also be used to create a rather simple model system using less geographic detail. By using the same data structure for households, jobs, and buildings, the only change needed for a zone-based model system is to assign locations to buildings at a coarser level of detail. This retains all of the accounting systems in the UrbanSim model: households and jobs are still located in buildings, and buildings can be linked spatially to zones. The data relationship is shown in Figure 2-3.

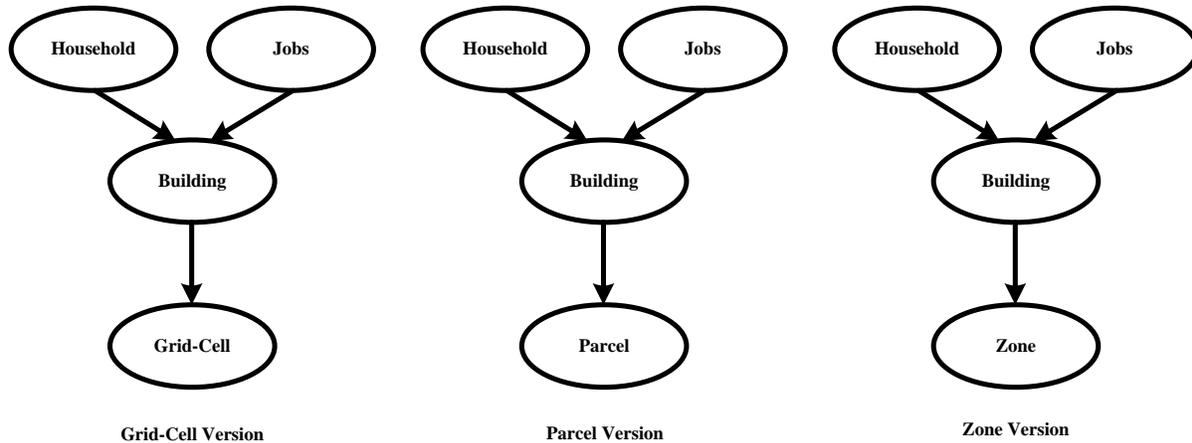


Figure 2-3 Data Relationship in UrbanSim

Two major exogenous input that are not predicted directly by UrbanSim are obtained from external model systems: a macroeconomic model to predict future macroeconomic conditions such as population and employment by sector, and a travel demand model system to predict travel conditions such as congested times and composite utilities of travel between each interchange. The latter is loosely coupled to UrbanSim, with land use predictions input to the external travel demand models, and travel conditions input to subsequent annual iterations of the UrbanSim land use model system (source: UrbanSim User Manual).

The travel demand models used by Metropolitan Planning Organizations are almost all traditional four-step travel demand models. The first model in the process is the trip generation model, which uses zonal population and employment characteristics. When UrbanSim is connected to a travel demand models system, it generates a summary of the household and job data to a zone level in order to create the summary input data needed by the travel demand models (source: UrbanSim User Manual).

When the travel demand models completes the fourth step of traffic assignment to a transportation network, it can produce ‘skims’ from zone to zone that summarize key model predictions, such as the following (source: UrbanSim User Manual):

- Travel time by mode by time of day by purpose
- Trips by mode by time of day by purpose
- Composite utility of travel using all modes by purpose
- Generalized costs (time + time equivalent of tolls) by purpose

-
- Logsums, or composite utilities, from the mode choice model, by purpose and time of day

These skims can be combined with the spatial information in UrbanSim regarding the location of households and jobs to produce a variety of accessibility measures, which in turn can influence UrbanSim models of residential location, workplace location, employment location, real estate prices, and real estate development. Figure 2-4 summarizes the interactions between UrbanSim and the travel demand models system.

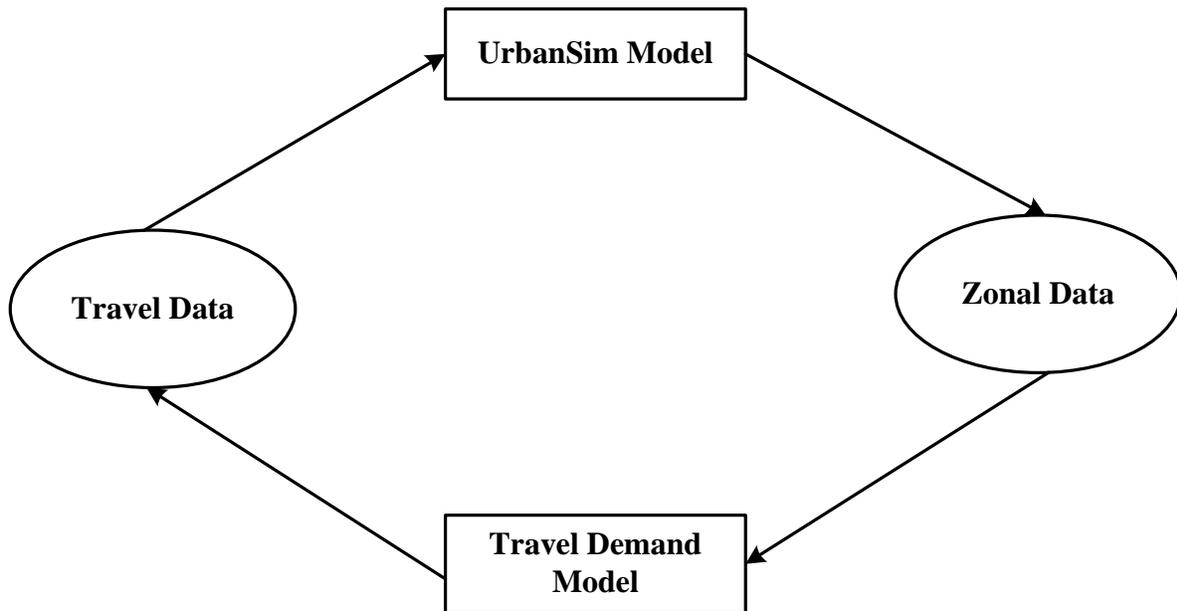


Figure 2-4 Interactions between UrbanSim and Travel demand models system

2.6 UrbanSim Implementation

- **Austin, TX (30)**

With an annualized population increase of 3.5% per year over the past 10 years, Austin is one of the fastest growing mid-size regions in the U.S. Such shifts, coupled with major transportation investments and variations in transport, land use, and energy policies, significantly impact the region's future land use patterns, traffic conditions, greenhouse gas emissions (GHG), housing affordability, environmental encroachment, and other key facets of community life. In 2011, UrbanSim was used to model land use patterns of the Austin, Texas, region for 2030 at fine spatial resolution (typically 150 m × 150 m grid cells). Three tasks, including data preparation, model specification, and scenario testing, were conducted. The data preparation included:

- **Household and Employment Data**

The household data set consists of a list of all households with current locations (by gridcell), household size (number of members), age of the household head, race, and number of workers, children and autos. Household data was synthesized using iterative proportional fitting techniques at the level of year-2000 Census block groups.

The employment data consists of a list of all jobs (by sector), their cell locations, and building type occupied. This data set was generated from a file of firm point locations provided by CAMPO.

- **Built Space and Transportation Data**

The Travis County Appraisal District (TCAD) provided residential unit locations (and year-built information), as well as square footage (and year-built information) of all commercial and industrial establishments within the region's central county. These data were used to estimate the proportions of each type of residential unit, square footage, and age distributions for buildings in Hays and Williamson counties.

UrbanSim requires network travel times to the region's CBD (Central Business District) and major airport from each TAZ centroid, along with Euclidean distances to the nearest arterials and freeways from TAZ and gridcell centroids. These values were computed using CAMPO's 1997 network.

- **Energy Data**

The 2005 Residential Energy Consumption Survey data (RECS) and 2003 Commercial Buildings Energy Consumption Survey data (CBECS) were obtained from the Energy Information Administration (EIA) and used to estimate energy per square foot to apply to UrbanSim's 2030 outputs.

Future land use patterns depend on household and job location choices, which in turn depend on the supply, quality, and price of built space, access to jobs and other destinations, household income, industry sector, and so forth. The following key sub-models were specified:

- Household Location Choice Model (HLCM)
- Employment Location Choice Models (ELCMs)
- Modeling Land Prices

Several scenarios were implemented to test the sensitivity of UrbanSim to various policies. These scenarios included:

- No Travel Demand Model (No TDM) scenario
UrbanSim simulated a 30-year horizon without TDM integration (so travel costs stay constant over the forecasting horizon and accessibility indices do not vary as much as they would with a TDM in place).
- Business as Usual (BAU) scenario
Austin's 1997 network held constant over the forecast period.
- Urban Growth Boundary (UGB) scenario
New development was not permitted in zones outside boundary.
- Addition of a 49.2-mile bypass freeway (SH130) to the network

As expected, several land use results (e.g., population densities), travel patterns, and energy consumption results responded to scenario contexts. Local access variables (within 600-meter Euclidean distances) also enjoy significant relevance in this implementation of UrbanSim.

- **Puget Sound Regional Council (PSRC), WA (31)**

Land use forecasting at the PSRC has undergone significant changes over the last few years. Since 2003, the Regional Council has been implementing UrbanSim as the framework for land use forecasting. The PSRC land use model is a parcel-based urban simulation process reflecting the broad scope of interactions among households, firms, developers, and governments within

markets for real estate, labor, and goods and services. The PSRC land use model and the travel demand models have an interactive relationship, as outputs of one model become inputs to the other, enabling the PSRC to directly model and assess the impacts of land use on travel forecasts, and the influence of the transportation system on the land use patterns of the region over time.

The land use model (UrbanSim) and the EMME model, which is a complete travel demand modeling system for urban, regional and national transportation forecasting, have been coupled/integrated such that modeling of land use and transportation policy assumptions interact with each other. The land use policy assumptions are introduced through the characterization of future year land use designations or zoning regulations, while the transportation policies are implemented through modifications of the region's transportation network and demand model assumptions.

- **SustainCity, Europe** (32)

SustainCity is an EU-funded project with twelve European research institutions. The aim of SustainCity is to extend the integrated land use model UrbanSim to the so-called version UrbanSimE, being adapted to the European context of cities: new choice models will be calibrated and additional models for households, demographics and employment will be created. UrbanSim was used in three case studies: Brussels, Paris and Zurich. The data requirement and collection scheme is shown in Figure 2-5.

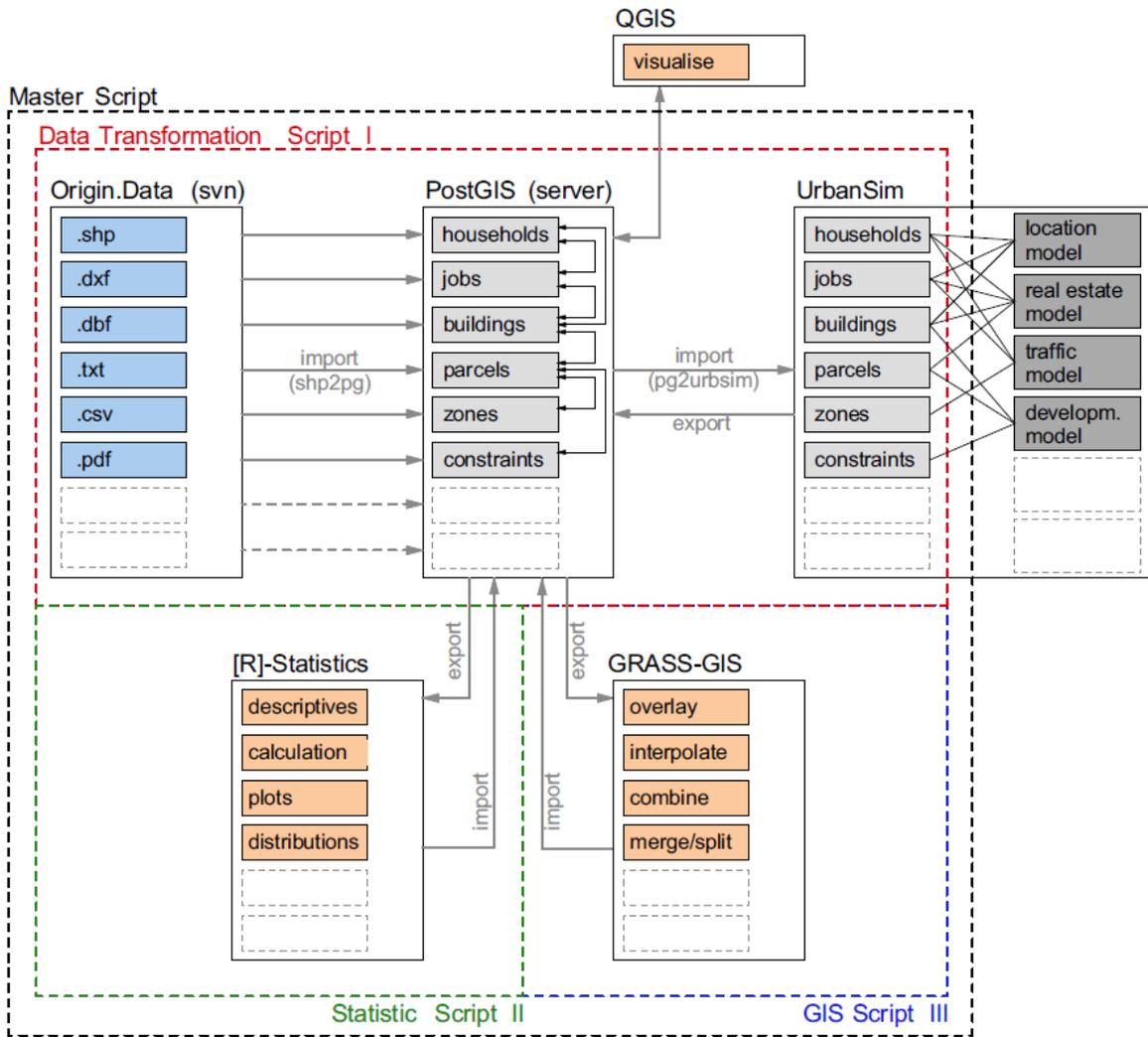


Figure 2-5 Data Processing Scheme in SustainCity

After conditioning data and implementing a base model in UrbanSim including only dummy variables, the next step concerns the implementation of the basic model structure for more technical details. The focus lies on the estimation of the following models for SustainCity:

- Household location model, transition and relocation choice,
- Employment location model, transition and relocation choice,
- Land development model: Real estate price model, development proposal choice, building construction, process pipeline events,
- Parcel transition model.

For reasons of better data disposability, this project shifted the base year of the simulation from 1997 to 2000. The simulation period is set to be from 2000 to 2030 and will use the latest register information (2010) for validation.

- **Volusia County, FL (18)**

FSUTMS (Florida Standard Urban Transportation Model Structure) requires future land use forecasts as input data to predict future travel demand and transportation needs. Given that the performance of the FSUTMS models relies heavily on the accuracy of land use forecasts, there is a strong desire by planners to improve model input, especially for future forecast years. The purpose of this study was to survey the current practices used in Florida, as well as to investigate the potential of UrbanSim as a land use model for Florida applications. In this project, UrbanSim was applied to Volusia County, Florida, based on five scenarios of growth and transportation improvements. The model was validated by comparing the simulation results to the socioeconomic and demographic data adopted in the 2020 Long Range Transportation Plan (LRTP) and the 2005 InfoUSA employment data.

The scenarios that were applied to UrbanSim, in conjunction with the FSUTMS, were developed based on the LRTP and socioeconomic projections provided by BEBR. The scenarios examined were the following:

- Scenario 1: The final plan in the 2020 LRTP with a mid-range projection.
- Scenario 2: The alternative 2 in the 2020 LRTP with a mid-range projection.
- Scenario 3: The alternative 3 in the 2020 LRTP with a mid-range projection.
- Scenario 4: The final plan in the 2020 LRTP with a low-range projection.
- Scenario 5: The final plan in the 2020 LRTP with a high-range projection.

Based on the model development and scenario testing, they concluded that UrbanSim can simulate land use changes reasonably well. Feedback from the travel demand models to UrbanSim influences the land development patterns. It will be useful to measure the sensitivity of UrbanSim to accessibility to determine the necessary frequency of the feedback. Through feedback, UrbanSim also has the potential of testing the effects of different project schedules on both land use and transportation. A detailed user manual on data processing is needed.

In addition to the UrbanSim projects mentioned above, the UrbanSim model has also been deployed or is starting to be deployed in several areas, including:

- Detroit, MI
- Durham, NC
- Eugene-Springfield, OR
- Honolulu, HI
- Houston, TX
- Phoenix, AZ
- Salt Lake City, UT
- San Francisco, CA
- Tucson, AZ
- Amsterdam, Netherlands
- Rome, Italy
- Taipei, Taiwan
- Tel Aviv, Israel
- Turin, Italy
- Cape Town, South Africa
- Ethekwini, South Africa
- Gauteng, South Africa
- Nelson Mandela Bay, South Africa
- Accra, Ghana

3. Data Preparation

UrbanSim requires vast amounts of data from various sources. The quality and integrity of data preparation determines the accuracy of the UrbanSim simulation. Data preparation is the key step in UrbanSim model development, and it is also the most time consuming task. UrbanSim currently uses three types of databases:

- **baseyear database** – defining the initial state of a simulation in a particular base year.
- **scenario database** – defining changes to a base year (or another scenario) database.
- **output database** – optional repository for simulation results.

UrbanSim gets its input data from either a base year database or a scenario. A base year database contains a snapshot of the base information defining the initial state before the UrbanSim simulation. Most of the data is about a particular year, e.g., geographic information, initial household data, job information, etc. A scenario database contains additional and augmenting information to alter the base year data when simulating a particular scenario such as new transportation links, an expanded urban growth boundary, etc. Any of the tables may be placed in either of the databases, although typically most are placed in the base year database. The scenario databases typically only contain tables specifying different possible futures, e.g., tables of exogenous events scheduled for future years. This chapter provides an overview of the data preparation and compilation for applying UrbanSim to Hillsborough County, Florida in the base year (2010). A detailed description of the data collection includes identifying data requirements, addressing data resources, developing the data collection environment, selecting the study area, processing data collection, and assembling data tables.

3.1 Data Requirement

It is important to recognize that the data needed for an UrbanSim simulation system are dependent on the UrbanSim models and their specifications. UrbanSim is an evolving set of models, some of which have been adapted to different data structures and geographic units of analysis, such as gridcells, parcels, and zones. Each of these models, depending on how the user specifies the model, creates its own data requirements. In this study, the parcel-based version of UrbanSim was adopted. The parcel-based version requires 22 to 25 data tables which can be organized into 5 categories: Geography, Buildings, Households, Employment, and Real Estate.

Each table contains a number of attributes (data fields) and the tables are linked by key variables. The required data was obtained through the following steps:

1) Identify Data Source

The first step of data processing is to identify the data source for each data field in each data table. The data sources may include the county maintained appraisal databases, travel demand models, census information, InfoUSA data, synthesized data, etc.

2) Retrieve Data

The second step is to retrieve the required data items from the original data sources using ArcGIS, SPSS, or the codes developed by the research team. These retrieved data were imported to a project database powered by Microsoft SQL server 2005, as shown in Figure 3-2.

3) Translate Data

The data types in UrbanSim databases include identification data, categorical data, and numeric data. Identification data, a unique number labeling the data item in each table, were assigned by the research team. Collected data were converted from the original formats to UrbanSim formats.

4) Assign Data

The data items might be organized at a geographic unit which is different from the objective geographic unit. These data were aggregated or disaggregated into the objective unit based on certain algorithms.

5) Produce Data Tables

The assigned data were organized into the data tables that are required in the UrbanSim model. The data tables were stored in the project database.

6) Link Data Tables

The data tables were matched by “key” variables, which were usually the identification data.

7) Export Data Tables

UrbanSim can link to MySQL, MS SQL server, or text files (CSV format). In this study, the produced data tables were exported to CSV files for UrbanSim input because this method is simple and effective. The CSV files were imported into UrbanSim as the base year database.

It is well-known that data preparation for the UrbanSim model is a demanding process which requires a great deal of resources and effort. In this study, a support platform was developed to automate the data preparation. This platform is a Windows standalone package based on the Microsoft .NET framework. All data operations were executed using SQL commands to access the project server, which is powered by Microsoft SQL server 2005. Other tools used for data preparation included ArcGIS and SPSS. The user interface and system architecture are given in Figure 3-1 and 3-2, respectively.

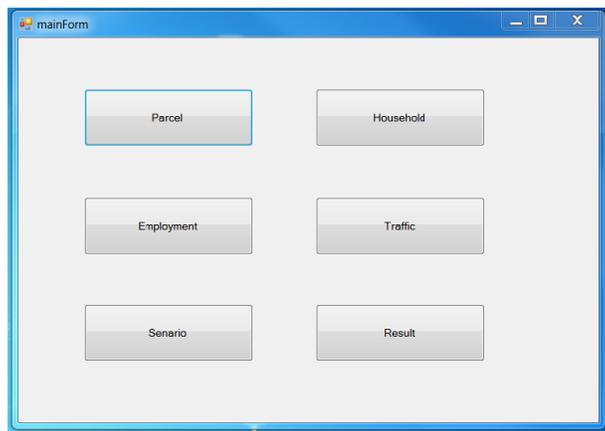


Figure 3-1 User Interface of Support Platform

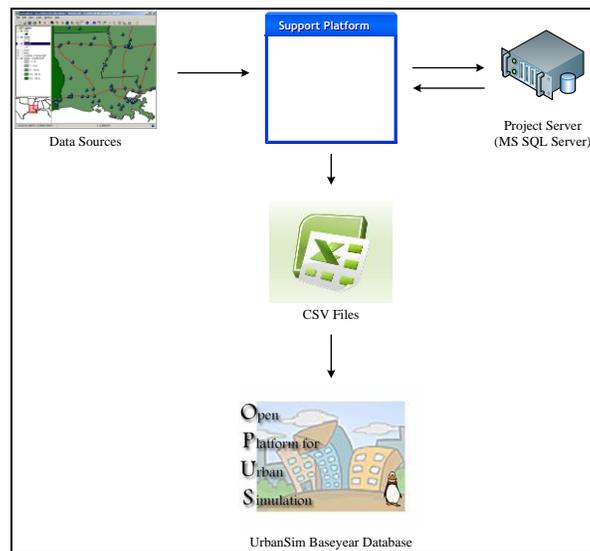


Figure 3-2 System Structure of Support Platform

3.2 Study Area

To evaluate the applicability of UrbanSim to Florida’s urban areas and investigate model application for evaluating transit investments, the new BRT line project in Hillsborough County

was selected as the study case. Hillsborough County met the selection criteria, as the study area has up-to-date geographic information system (GIS) data, parcel-level property data, employment data, and new transit investment plans (BRT).

Hillsborough County is located midway along the west coast of Florida and has 1,048 square miles of land and 24 square miles of inland water area, for a total of 1,072 square miles. The unincorporated area encompasses 909 square miles, or more than 84 percent of the total county area. Municipalities account for 163 square miles. Incorporated cities are Tampa, Temple Terrace, and Plant City. In 2010, the total population, households, and labor forces in Hillsborough County were 1,229,226; 474,030; and 600,967 respectively. The county has GIS data, including parcel data, which are essential to calibrating an UrbanSim model. Figure 3-3 shows the location of Hillsborough County.

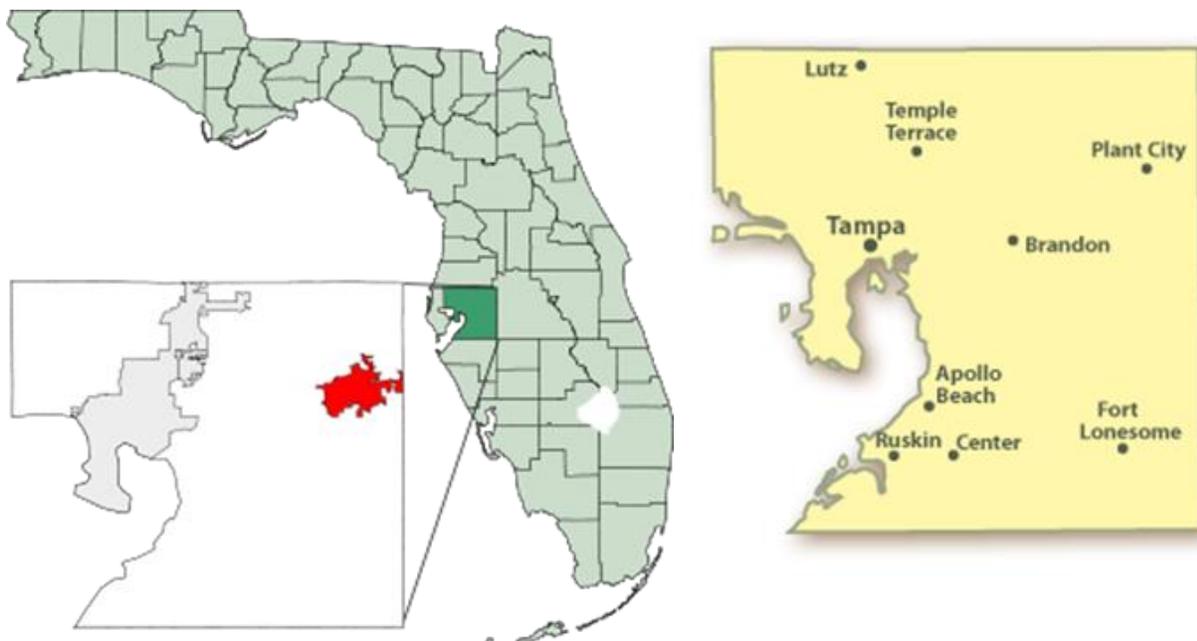


Figure 3-3 Hillsborough County Boundaries

Hillsborough Area Regional Transit (HART) Authority, a regional transportation authority and special tax district charged with planning, financing, constructing, and operating public transit facilities and service within Hillsborough County, provides fixed route local and express bus services to most of Hillsborough County. Bus rapid transit (BRT) has been included in local and regional plans in the Tampa Bay Area as an element of the regional congestion reduction

strategy. The North-South BRT corridor was selected for implementation in this study based on ridership projections and connectivity to other existing HART routes.

The North-South BRT corridor begins at the Marion Transit Center (MTC), travels south along the Marion Street Transit Parkway (MSTP), then turns east along the one-way pair of Kennedy Avenue and Jackson Avenue, turns north on Nebraska Avenue, then turns east of Fletcher Avenue, and finally terminates near the Fletcher Avenue and Interstate 75 interchange at a Park and Ride facility, shown in Figure 3-4. The BRT route will operate in mixed traffic, with the exception of the MSTP, and several existing HART routes will either share the proposed stations or will have stops in close proximity to a proposed station to facilitate transfers.

This study evaluated the impact of the proposed North-South BRT route on its adjacent areas. These areas were delimited as the traffic analysis zones that are influenced by the North-South BRT route, as shown in Figure 3-5. In this study, a parcel-based UrbanSim simulation model was developed for the entire Hillsborough County area. A model validation and evaluation of the BRT route was conducted on the study zones.



Figure 3-4 North-South Corridor BRT in Hillsborough County
 (Source: HART North/South Corridor BRT Project Development and Environmental Study)

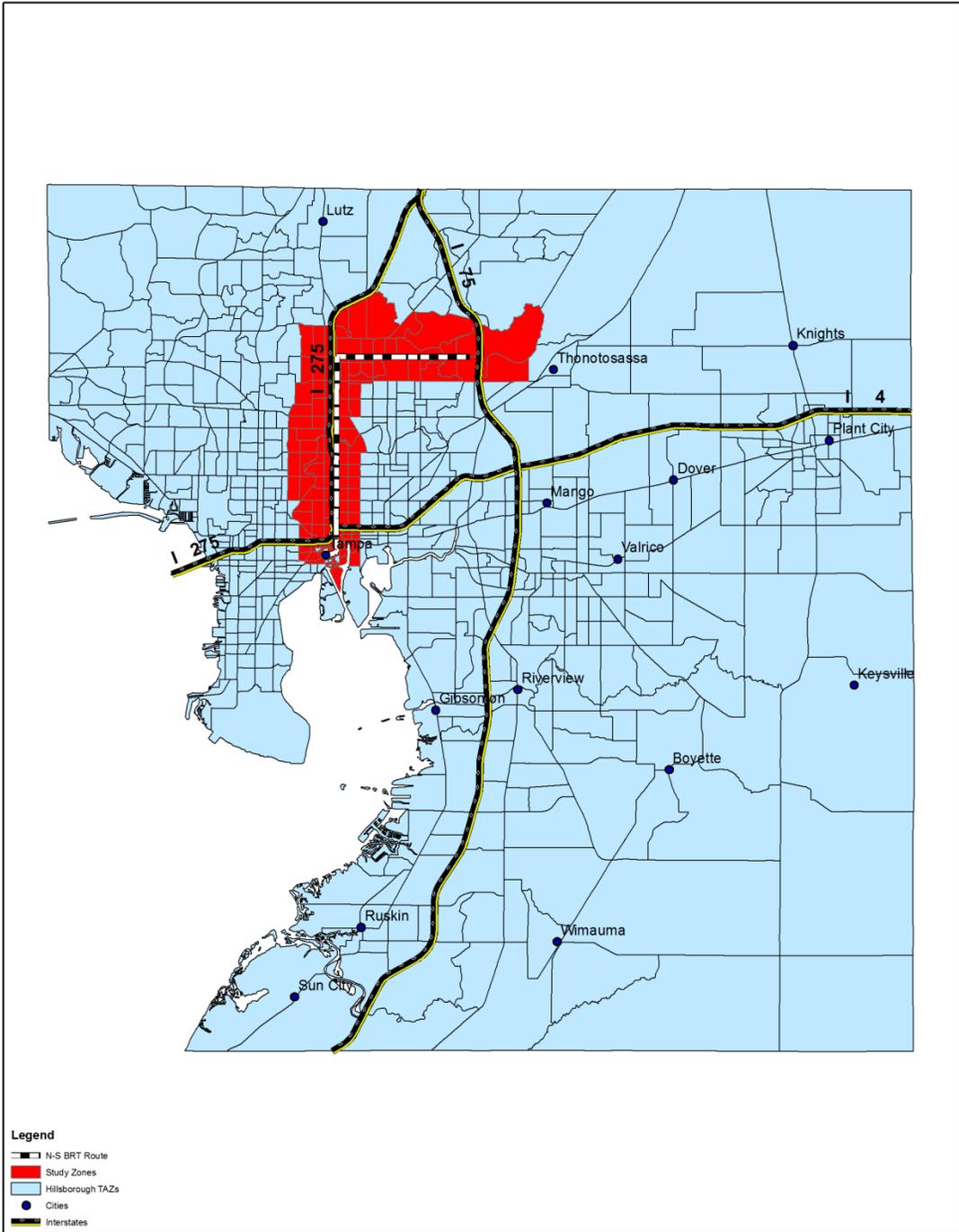


Figure 3-5 TAZs and Study Zones in Hillsborough County

3.3 Geographic Data

The Geography category contains the geographic information at the parcel level, which is the basic geographic unit in the parcel-based UrbanSim version. Each parcel may contain one or more buildings which have associated households and/or jobs. Parcels can be aggregated to a higher geographic level, such as zones (TAZ), census block groups, and city. The spatial relationship among the geographic units in the UrbanSim model is shown in Figure 3-6.

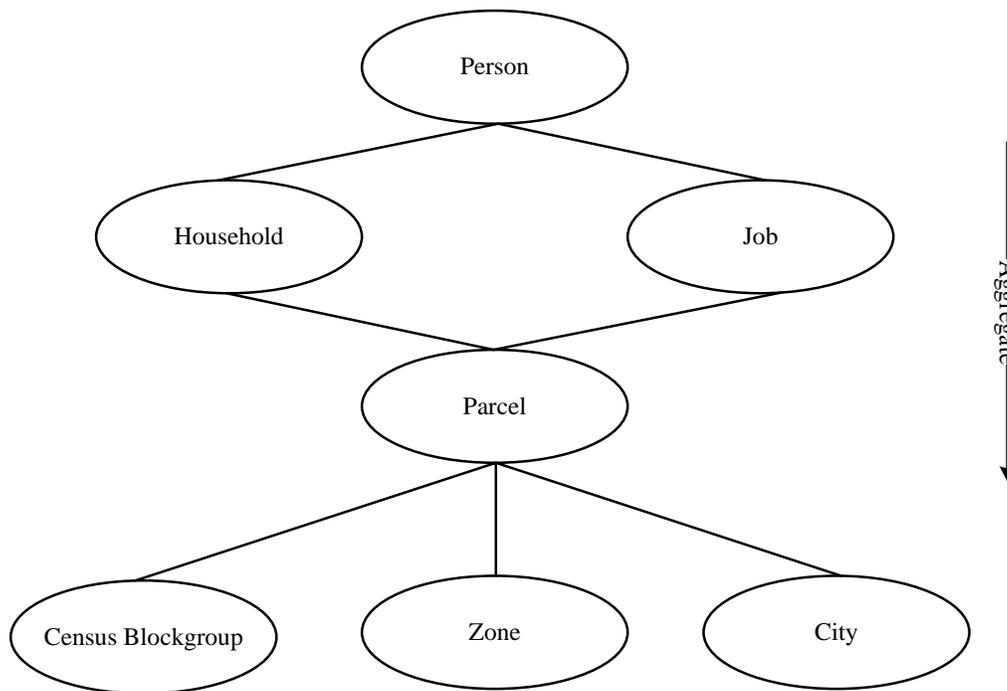


Figure 3-6 Spatial Relationship among Geographic Units

The parcels table contains attributes of individual parcels. The most commonly used parcels are based on ownership since most relevant data (like land and improvement value) is associated with ownership records. It should also be noted that additional geographic data may be added by the user to the parcel table, using the same approach as below. This section gives a detailed description of the preparation of parcel related data, as shown in Figure 3-7.

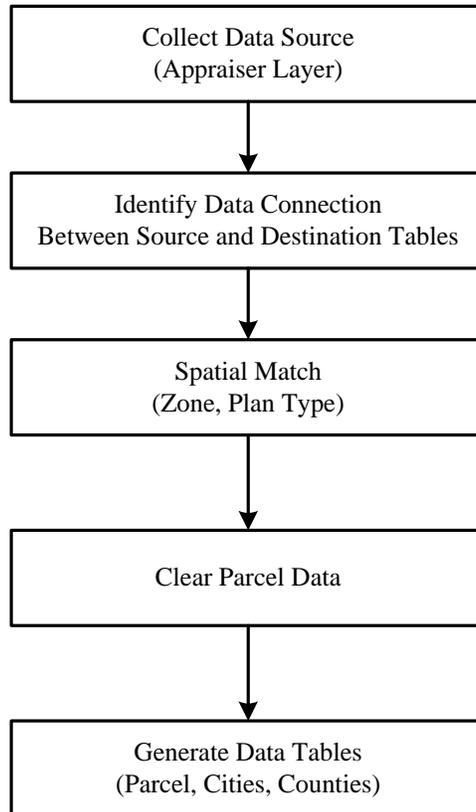


Figure 3-7 Procedure of Geographic Data Preparation

- **Data Source**

Hillsborough County maintains a property appraiser database, which contains all parcels with related attributes in GIS format. In this study, the property appraiser database for 2010 was used to retrieve parcel data. In total, 471,890 parcels were found in this database with owner, address, area, building number, year, value, tax, and coordinate information. A unique variable, namely “STRAP,” identified each parcel item in the database. The parcel map is shown in Figure 3-8. Two initial steps were made:

- Retrieve data
The parcel data were retrieved from the original property appraiser database and stored in the project database for future use.
- Transform GIS map

In the original GIS layer, parcel data were described as polygons. For spatial matching, the parcel data were transformed from polygons to points based on the centroid of parcel polygons using ArcGIS.

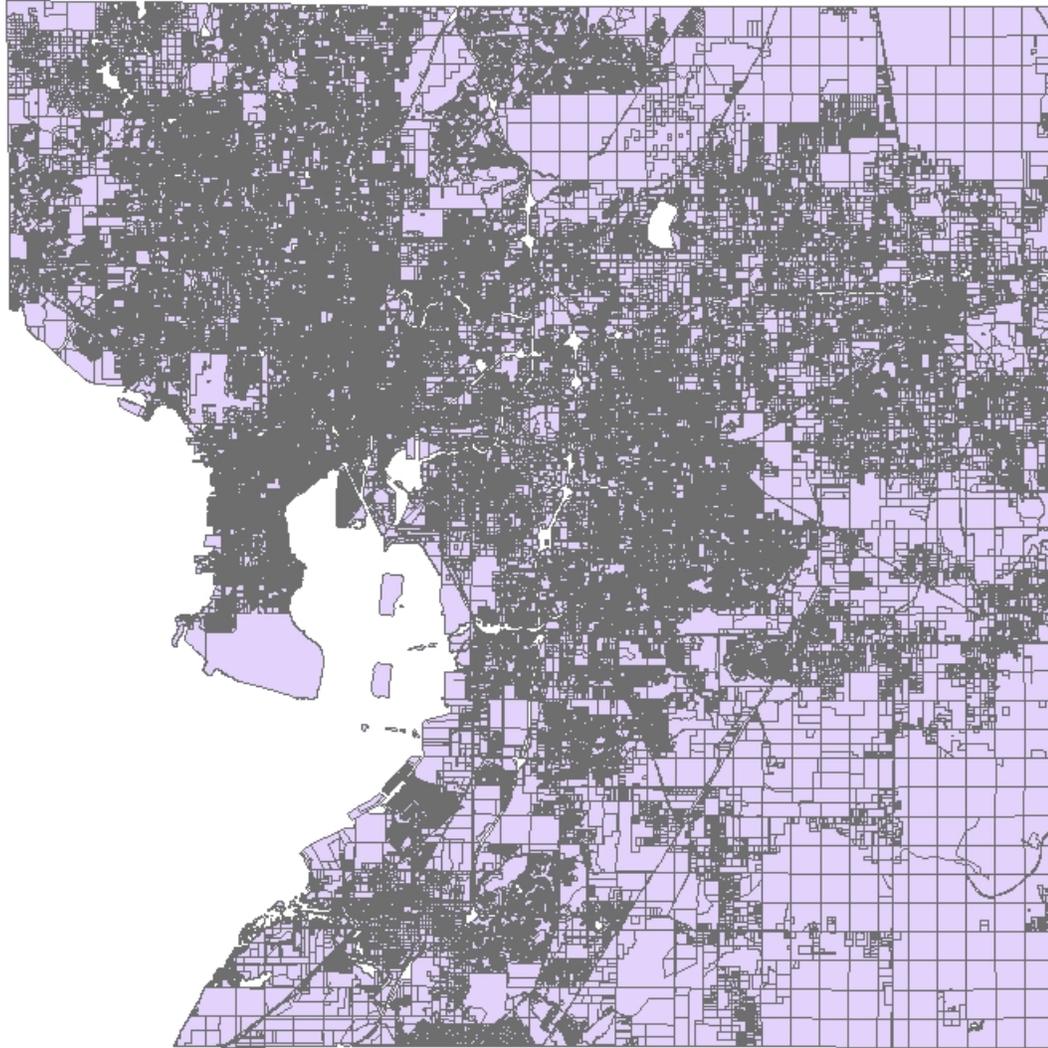


Figure 3-8 Parcels in Hillsborough County

- **Identify Data Connection**

The second step was to create connections between original data fields and required data fields in the UrbanSim parcel table. The data fields in the UrbanSim parcel table and associated original data fields are given in Table 3-1.

Table 3-1 Parcel Table

Variable Name	Data	Description	Source Database	Source Item
parcel_id	Integer	Unique id for parcels	Assignment	
parcel_id_local	String(20)	Users may want to store a local parcel id from the assessor's office	Property Appraiser	STRAP
land_use_type_id	Integer	Unique id of the land use type of the parcel	Property Appraiser	DOR_UC
land_value	Integer	Assessed value of the land on the parcel	Property Appraiser	LND_VAL
parcel_sqft	Integer	Land area of the parcel in square feet	Property Appraiser	LND_SQFOOT
plan_type_id	Integer	Unique id of the land use plan type of the parcel (regulatory designation)	Spatial Matching to FLUE	
centroid_x	Integer	X-coordinate of the parcel centroid, usually in a projection measured in feet	Property Appraiser	X
centroid_y	Integer	Y-coordinate of the parcel centroid, usually in a projection measured in feet	Property Appraiser	Y
tax_exempt_flag	Integer	Optional 1 if tax exempt, 0 otherwise	Property Appraiser	TAX_EXEMPT_FLAG
city_id	Integer	Unique id of the city in which the parcel is located	Property Appraiser	PHY_CITY
county_id	Integer	Unique id of the county in which the parcel is located	Constant	57
zone_id	Integer	Unique id of the zone (as used in the travel demand models) in which the parcel is located	Spatial Matching to TAZ	

The “parcel_id” is a unique integer number used to identify each parcel item in the parcel table. It is functionally equivalent to “STRAP” in the original database. However, UrbanSim cannot recognize the format of “STRAP,” thus, a new data item, “parcel_id,” was assigned by researchers and “STRAP” was reserved in the parcel table as “parcel_id_local”. Land use of a parcel was indicated by the variable “land_use_type_id” and linked to the land use type table. Other linking variables included “plan_type_id” and “zone_id”.

- **Spatial Match**

There are no variables in the original database to represent the zone and plan type that a parcel associates. The GIS layers of Florida traffic analysis zones and Future Land Use Element (FLUE) are available. Thus, the parcel layer was matched to the zone and FLUE layers using a spatial join. The GIS layers of zones and FLUE are polygon maps, while the parcel layer is point map. The spatial join was conducted to find the zone or FLUE in/to which a parcel falls or is closest. The addressed “zone_id” or “plan_type_id” were assigned to the parcel.

- **Parcel Clearance**

In the original property appraiser database, some parcels have “empty” data items or could not be matched to other UrbanSim entities. These parcel data were removed from the parcel table. The final parcel table included 459,571 parcels.

- **Generate Tables**

Three tables were produced: parcel, counties, and cities.

3.4 Building Data

The Building category contains the information of buildings, including building property, type, and demolishing cost.

- **Building Table**

The building table in the parcel version of the UrbanSim model represents data for an individual building located on a parcel. There can be multiple buildings on a parcel (a many to one relationship). Buildings that are mixed use, such as retail on the first floor and apartments above, can be represented as two separate buildings on the same parcel. The land area would generally be assigned by the user to each component as a prorated amount.

Because data for built structures are limited to what is available in the Hillsborough County property appraiser database, this study synthesized buildings based on number of buildings on each parcel (NO_BULDNG) in the database. If a parcel has one or more buildings, the support application developed by the researchers produced new corresponding data rows in the building table and assigned a unique integer to each data item as “building_id”. The data fields were calculated or transferred from the property appraiser database. In total, 436,390 buildings were produced. The calculation procedure and data connections are given in Table 3-2.

Table 3-2 Building Table

Variable Name	Data Type	Description	Source Database	Source Item
building_id	Integer	Unique id of building (one per zone and building type)	Assigned	
building_type_id	Integer	Unique id of the building type of this building	Property Appraiser	DOR_UC
improvement_value	Integer	Value in dollars of buildings on parcel	Property Appraiser	$\frac{LND_VAL}{NO_BULDNG}$
land_area	Integer	Land area in square feet used by the building	Property Appraiser	LND_SQFOOT
non_residential_sqft	Integer	Total non-residential square feet in building	Property Appraiser	DOR_UC >= 10: $\frac{LND_SQFOOT}{NO_BUILDNG}$ Otherwise: 0
parcel_id	Integer	Unique id of the parcel in which this building is located	Parcel Table	parcel_id
residential_units	Integer	Total residential units in building	Property Appraiser	NO_RES_UNT
sqft_per_unit	Integer	Average square feet per residential unit in building	Property Appraiser	DOR_UC < 10: $\frac{LND_SQFOOT}{NO_RES_UNT}$ Otherwise: $\frac{LND_SQFOOT}{NO_BULDNG}$

Variable Name	Data Type	Description	Source Database	Source Item
year_built	Integer	Average year built of this aggregated building	Property Appraiser	ACT_YR_BLT

- **Building Type Table**

The building type table provides a list of the unique building types used to classify buildings. This table was derived from the codes of “DOR_UC” in the property appraiser database. The final table is given in Table 3-3.

Table 3-3 Building Type Table

ID	Name	Generic Type Description	Generic Type ID	Is Residential (1 = Yes)	Unit Name
1	single_family_residential	residential	1	1	building_sqft
2	mobile_home	residential	1	1	building_sqft
3	multi_family_residential	residential	1	1	building_sqft
4	group_quarters	group_quarters	2	1	building_sqft
5	office	commercial	3	0	building_sqft
6	recreation	commercial	3	0	parcel_sqft
7	commercial	commercial	3	0	building_sqft
8	warehousing	industrial	4	0	building_sqft
9	transport	industrial	4	0	parcel_sqft
10	industrial	industrial	4	0	building_sqft
11	agricultural	agricultural	5	0	building_sqft
12	school	institutional	6	0	building_sqft
13	military	government	7	0	building_sqft
14	hospital	government	7	0	building_sqft
15	civic_public	government	7	0	parcel_sqft
16	government	government	7	0	building_sqft
17	parking	other	8	0	building_sqft
18	right_of_way	other	8	0	parcel_sqft
19	vacant	other	8	0	parcel_sqft
20	vacant	other	8	0	parcel_sqft
21	water	other	8	0	parcel_sqft

- **Demolition cost data**

The demolition cost table provides information to UrbanSim models about the costs of demolition by building type. These numbers are used to calculate the cost of demolition of

existing development so that a more accurate cost of redevelopment can be calculated. In this study, the demolition cost data was derived from <http://buildingjournal.com/>.

3.5 Household and Person Data

Household level data are required to run UrbanSim. Since this type of data is unavailable, in this study the data were synthesized using PopGen, which is an innovative software package developed by Arizona State University. This section describes the procedure of household and person data preparation, as shown in Figure 3-9.

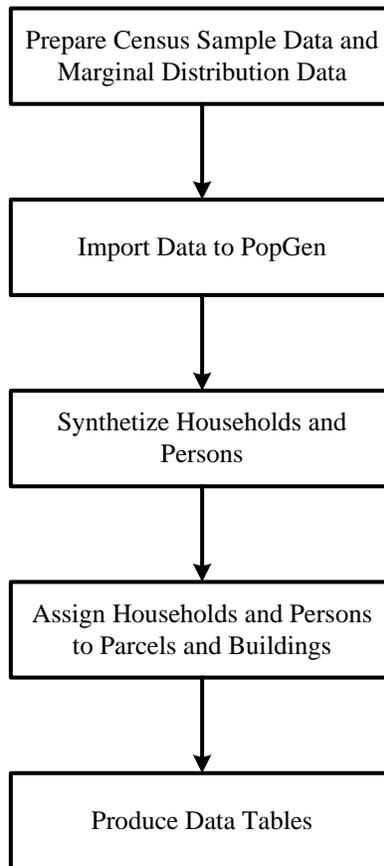


Figure 3-9 Procedure for Household and Person Data Preparation

- **Synthesis and Census Data**

PopGen incorporates a new Iterative Proportional Updating (IPU) algorithm to disaggregate household and person socio-demographic data for the entire population of a model region, which

is generally not available (33). PopGen needs two known statistical distributions on the population as input for synthesizing a regional population:

- Disaggregate data for a sample of the population
Public Use Microdata Samples (PUMS) are computer-accessible files containing records for a sample of housing units, with information on the characteristics of each housing unit and the people in it. The basic unit in PUMS is an individual housing unit or person. In this study, Census 2000 PUMS were used and organized into 3 sample files: household sample file, group quarter sample file, and person sample file.
- Marginal distributions for the entire region
The American Community Survey (ACS) Summary File is a unique data product that includes all the estimations and margins of error covering demographic, social, economic, and housing subject areas. The most commonly used census data are the Census 2000 Summary File 1 (SF 1) 100-Percent Data, Census 2000 Summary File 2 (SF 2) 100-Percent Data, Census 2000 Summary File 3 (SF 3) Sample Data, and Census 2000 Summary File 4 (SF 4) Sample Data.

The sample data and marginal data were imported into PopGen and translated to PopGen’s format. The variables for household samples and person samples used in PopGen are given in Table 3-4. Since the marginal distributions were given for the year 2000, they needed to be adjusted to represent the estimations in the base year (2010). The adjustment factor was derived based on the population projection in the “2035 Long Range Transportation Plan,” given as follows:

$$\text{Adjustment Factor} = \frac{\frac{\text{Target Year}-2006}{2025-2006} \times (\text{Population in 2025}-\text{Population in 2006})}{\text{Population in 2000}} \quad (2)$$

where population is the total population of Hillsborough County in a target year. Since the household projection in the “2035 Long Range Transportation Plan” is calculated from the population with a constant household size, this adjustment factor was used to adjust the persons and households in Hillsborough County for 2010 with the assumption that the increasing rates are the same in all census geographic units.

Table 3-4 Marginal Variables in Household and Person Synthesis

Household Marginal Variable	Person Marginal Variable
Household incoming	Age
Household size	Gender
Household type	Race
Number of children	Employment
Head age	
House ownership	
Household race	

- **Import Census Data and Run Synthesizer**

The sample data and revised marginal data were imported into PopGen and the program was run, as shown in Figure 3-10. The geographic resolution was configured as census block groups, which are clusters of census blocks having the same first digit of their four-digit identifying numbers within a census tract. Block groups generally contain between 600 and 3,000 people, with an optimum size of 1,500 people. Most block groups were delineated by local participants as part of the U.S. Census Bureau's Participant Statistical Areas Program. The block groups in Hillsborough County are given in Figure 3-11. Block group units are labeled as Tract ID + Block Group ID.

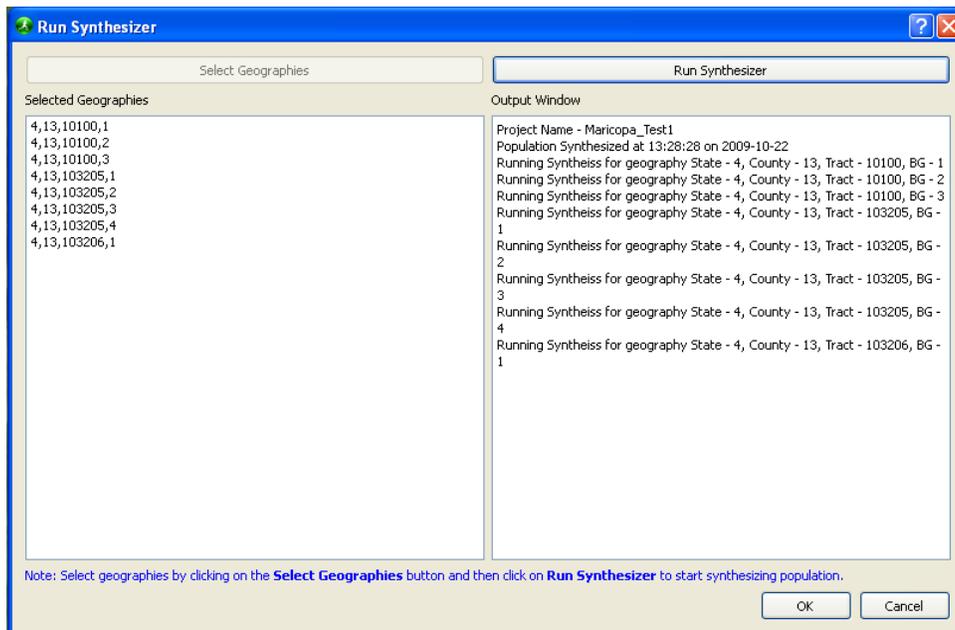


Figure 3-10 Run PopGen Synthesizer

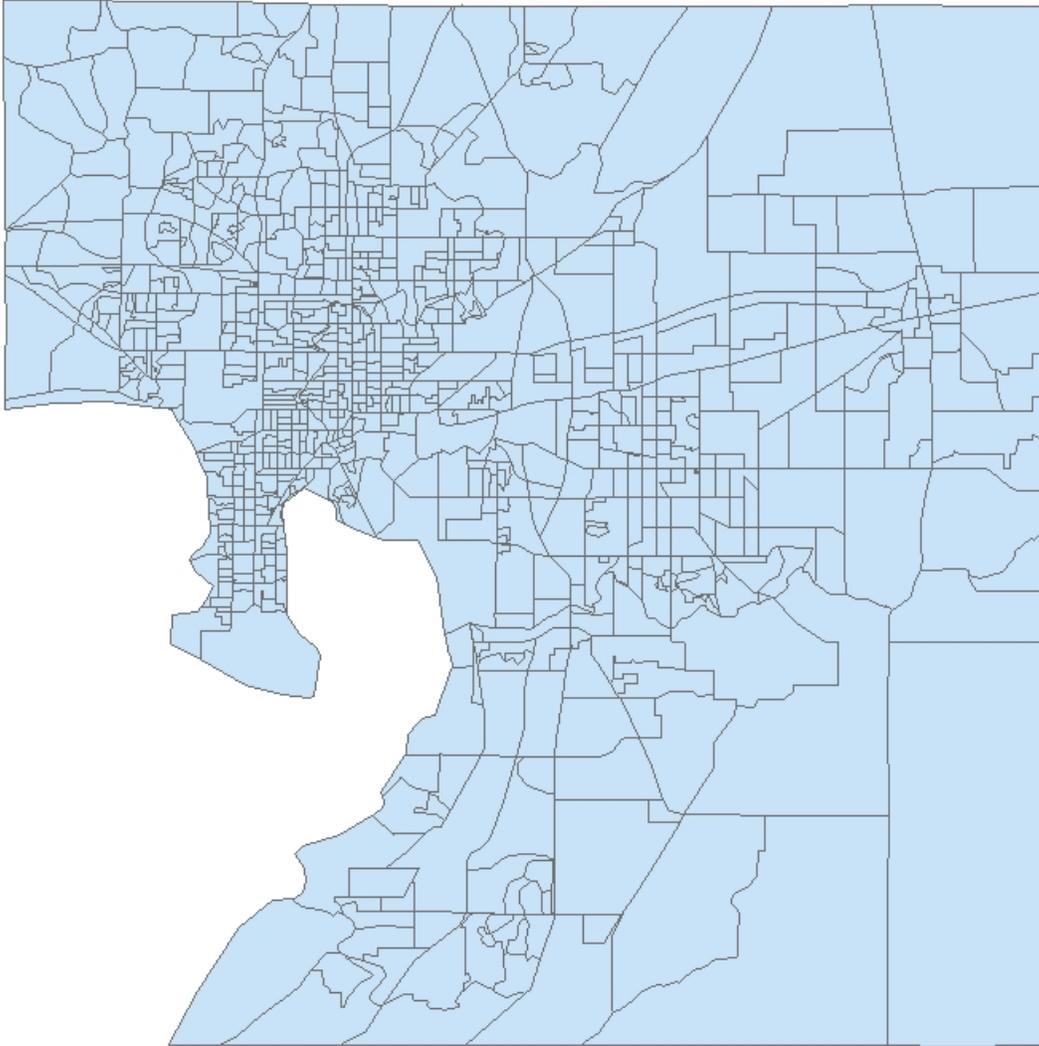


Figure 3-11 Census Block Groups in Hillsborough County

The output of the PopGen Synthesizer was two data tables: a household table and a person table. The household table contained the synthesized individual households with the household attributes listed in Table 3-4. The person table contained the synthesized individual persons with the person attributes listed in Table 3-4 and associated with each household in the household table. Both tables included geographic variables to indicate which tract + block group the individual household/person belongs to.

- **Spatial Match**

The parcel-based UrbanSim model requires households and persons be connected to parcels and buildings, while the synthesized data are associated with census block groups. The inconsistency of geographic units can lead to matches between the synthesized households/persons and parcels/buildings. The procedure for data matching is given as follows:

Step 1: Spatial Match between Parcels and Census Block Groups

A census block group may contain one or more parcels. The GIS layers of census block groups and parcels were spatially joined using ArcGIS. Since the parcel layer had been transformed as a point map, the parcel points were joined to the closest block group (polygon). The matched Tract ID + Block Group ID were assigned to each parcel in the parcel table. The relationship between parcels and block groups are shown in Figure 3-12.

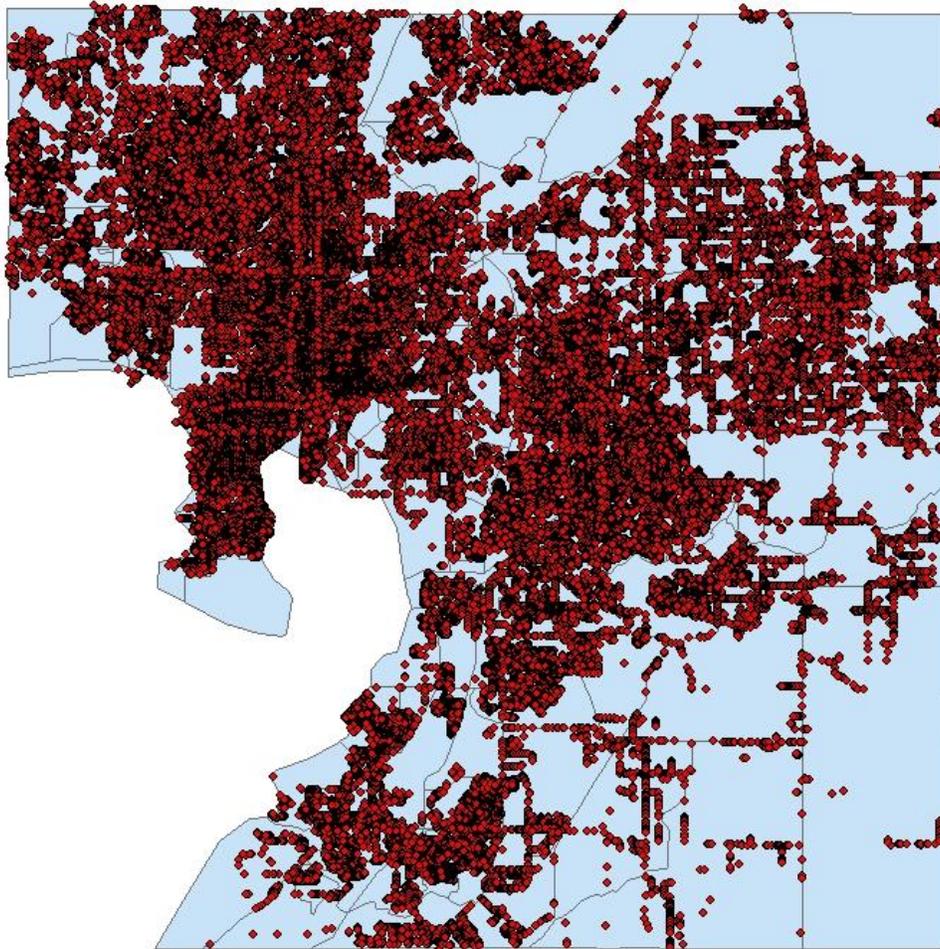


Figure 3-12 Spatial Relationship between Census Block Groups and Parcels

Step 2 Assign Parcels and Buildings to Households

The connection between the synthesized households and parcels/buildings is a typical “many to many” relationship, shown in Figure 3-13.

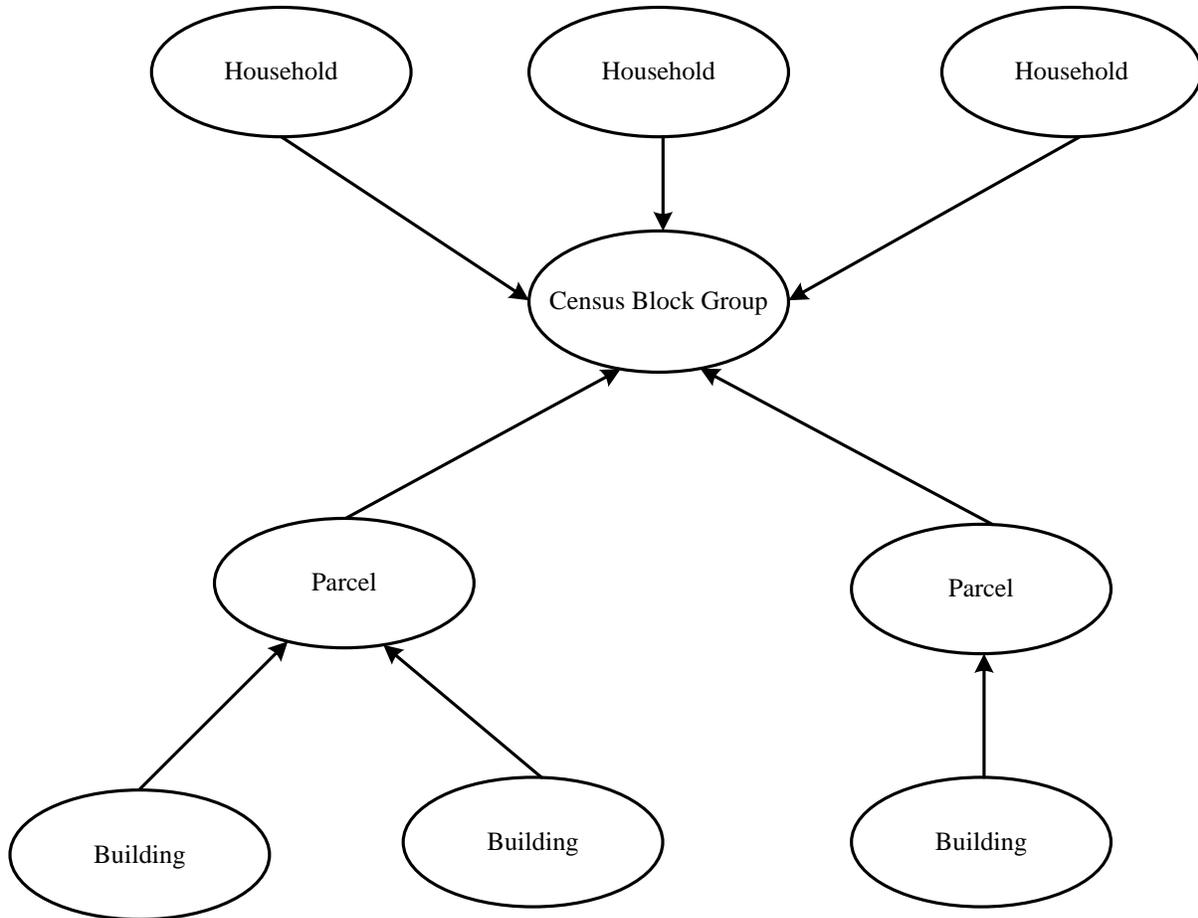


Figure 3-13 “Many-to-Many” Relationship between Synthesized Households and Parcels/Buildings

It is impossible to match households and parcels/buildings directly. Thus, a “two-stage” assignment was used in this study to connect households and parcels/buildings. In the first stage, parcels were assigned to households; in the second stage, buildings were assigned to households. Because no marginal distributions of households/persons are available at the parcel and building levels, a random assignment algorithm was adopted. The assignment flow chart is given in Figure 3-14.

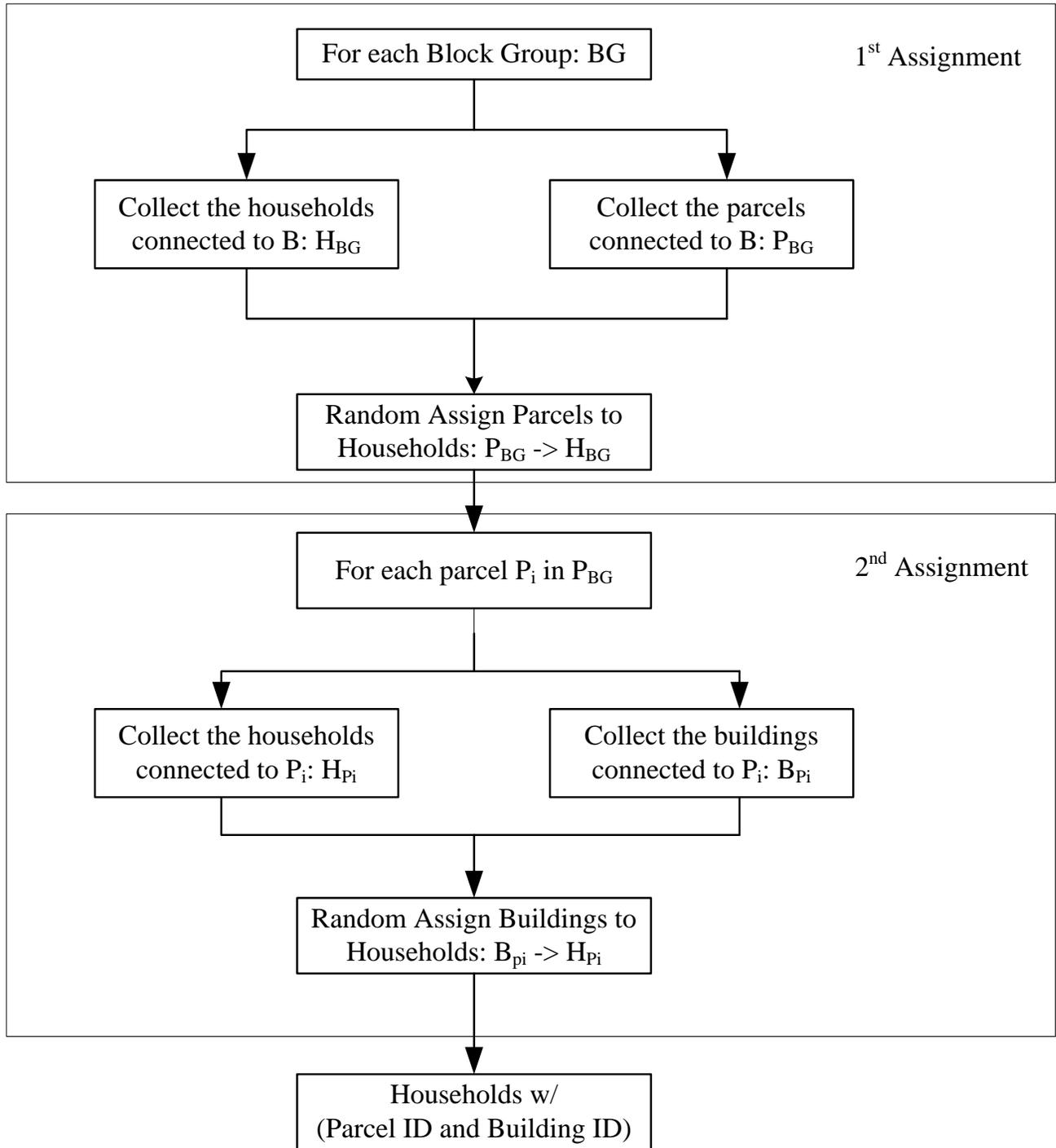


Figure 3-14 Assignment of Parcels/Buildings to Households

- **Produce Data Tables**

The tables of households and persons were produced based on the synthesized data and assignment results. The description of the two tables is given in Tables 3-5 and 3-6, respectively.

Table 3-5 Household Table

Variable Name	Description	Source Database	Source Item
household_id	Unique household id	User defined	
building_id	Unique id of the building in which the household is located	Building table	Building_id
persons	Number of persons in the household	Census 2000	NP
income	Total annual income of the household	Census 2000	HINCP
age_of_head	Age of the head of the household (according to the census)	Census 2000	AGEP
race_id	Unique id of the race of the head of the household	Census 2000	RAC1P
workers	Number of workers in the household	Census 2000	WIF
children	1 if children are present, 0 otherwise	Census 2000	NOC
cars	Number of cars owned by the household	Census 2000	VEH

Table 3-6 Person Table

Variable Name	Description	Source Database	Item Name in Source Database
person_id	Unique id for each person	User defined	
household_id	Unique household id	Household table	household_id
relate	Relationship of person to census survey respondent	Census 2000	Relate
age	Age of person in years	Census 2000	Age
sex	Coded as 1=male, 2=female	Census 2000	Sex
race_id	Unique id of the race category of the person	Census 2000	Race
student	1 if person is a student, 0 otherwise	Census 2000	Enroll
worker	1 if person is a worker, 0 otherwise	Census 2000	Esr
edu	Educational attainment of person	Census 2000	Educ

3.6 Employment Data

Employment data for 2010 are available from a proprietary source (InfoUSA) purchased by the Florida Department of Transportation (FDOT). Founded in 1972, InfoUSA is a provider of business and consumer information products, database marketing services, data processing services, and sales and marketing solutions. InfoUSA maintains a proprietary database of 250 million consumers and 14 million businesses. The database is continuously updated from over 5,000 public sources and more than 20 million phone calls are made per year to verify and collect additional information. In developing the database, 5,200 phone books, annual reports, and other business directories are continuously reviewed to find information. Public record data from county courthouse filings, U.S. Securities and Exchange Commission (SEC) and 10-K filings, and the U.S. Secretary of State data are used; and every month the USPS National Change of Address, ZIP+4, and Delivery Sequence files are matched to standardize and keep addresses current.

According to the InfoUSA employment data, there were a total of 46,819 public entities and private establishments in Hillsborough County in 2010. Each entity may provide one or more job positions, which are labeled as “ACTUAL_LOCATION_EMPLOYMENT_SIZE” in InfoUSA.

In total, 590,384 jobs were found in Hillsborough County in 2010. Another important factor is employment type (employment sector) labeled by “NAICS_CODE” (North American Industrial Classification System Code) in InfoUSA. Table 3-7 gives the description of “NAICS_CODE” and employment sector codes used in the UrbanSim model. InfoUSA provides spatial information of employment data as points in a GIS layer. UrbanSim requires employment data to be connected to each building. This study conducted a spatial match between jobs and parcels in ArcGIS and assigned the buildings to jobs within each parcel. The procedure for employment data preparation is given in Figure 3-15. As a result, the job table is described in Table 3-8.

Table 3-7 Employment Sectors Classification – NAICS Codes

NAICS_CODE	Description (name)	UrbanSim Code (sector_id)
11	Agriculture, Forestry, Fishing and Hunting	1
21	Mining, Quarrying, and Oil and Gas Extraction	2
22	Utilities	3
23	Construction	4
31-33	Manufacturing	5
42	Wholesale Trade	6
44-45	Retail Trade	7
48-49	Transportation and Warehousing	8
51	Information	9
52	Finance and Insurance	10
53	Real Estate and Rental and Leasing	11
54	Professional, Scientific, and Technical Services	12
55	Management of Companies and Enterprises	13
56	Administrative and Support and Waste Management and Remediation Services	14
61	Educational Services	15
62	Health Care and Social Assistance	16
71	Arts, Entertainment, and Recreation	17
72	Accommodation and Food Services	18
81	Other Services (except Public Administration)	19
92	Public Administration	20
99 & missing	Non-classified Establishments	21

Table 3-8 Job Table

Column Name	Description	Source Database	Source Item
job_id	Unique id for each job	User defined	
building_id	Unique id for the building in which the job is located	Building Table	building_id
home_based_status	1 if the job is home-based, 0 otherwise	InfoUSA	WORK_AT_HOME
sector_id	Unique id of the employment sector of the job	InfoUSA	NAICS_CODE

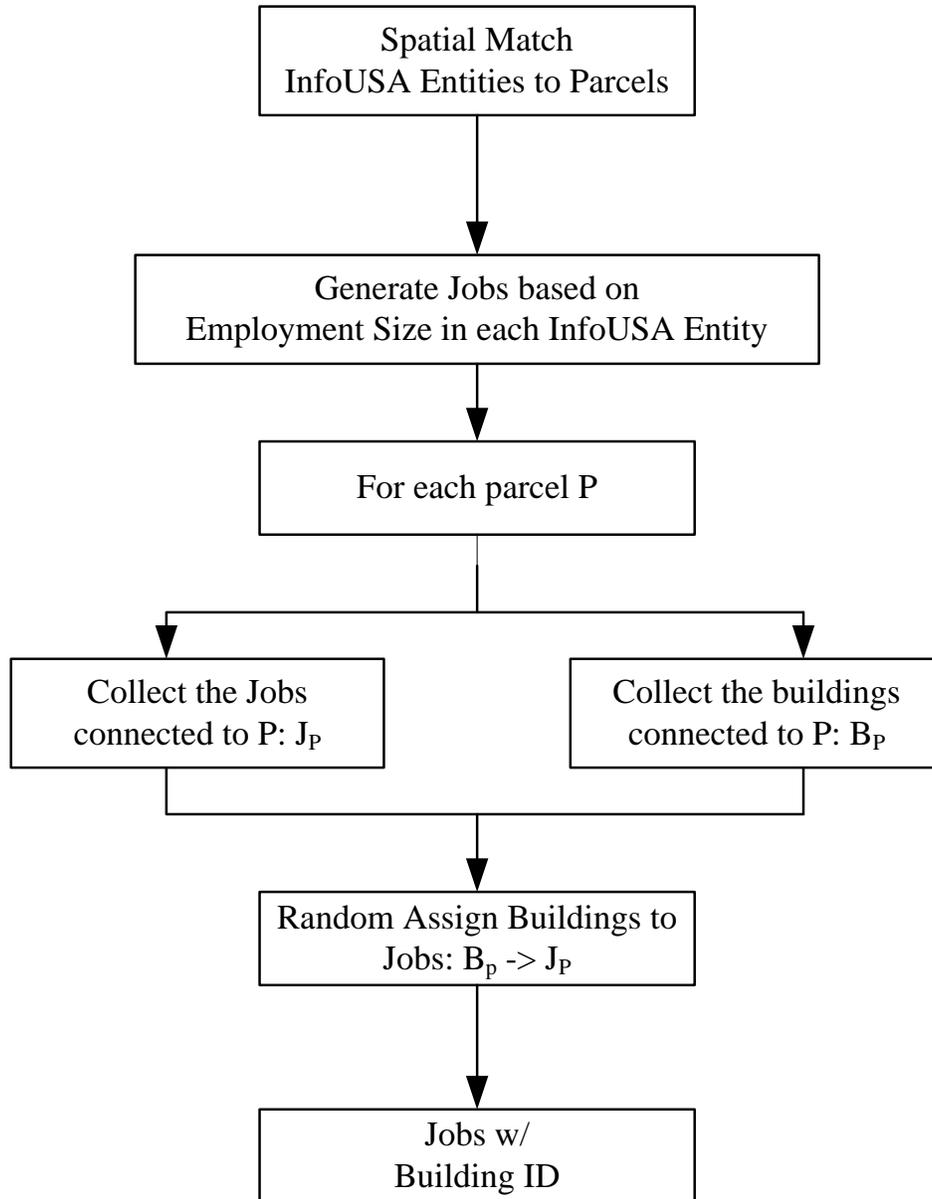


Figure 3-15 Procedure of Job Data Preparation

3.7 Land Use Development Data

This section describes land use development data which cover future land use plans. There are two choices in the parcel-based UrbanSim model to prepare the land use development data:

- To provide a comprehensive data set, including individual land use development plans;
- To provide land use plan templates and constraints, but not individual land use development plans. The UrbanSim model will randomly generate development plans based on the templates and constraints.

The first choice can provide “real” future land use patterns, but requires very detailed data at the parcel level. A major data source of land use development is the Developments of Regional Impact (DRI) from the Tampa Bay Regional Planning Council, which provides a large-scale development list affecting many jurisdictions. DRI categories include: airports, attractions, hotels, industrial plants/parks, commercial developments, residential developments, and multi- or mixed-use projects. After reviewing the DRI database and reports, researchers found that the geographic units that are used in DRI projects are too big to locate land development on parcels. Thus, in this study, development templates and constraints were collected to allow the UrbanSim to produce development plans

The development constraint defines constraints to restrict development on parcels. Each row in the table defines a unique constraint. The Development Project Proposal Sampling Model (DPPSM) generates proposals for a parcel by using the constraint(s) and by selecting appropriate records from the development templates that will fit on the available land of the parcel. The DPPSM determines the applicable constraint(s) for a parcel by selecting a record in the development constraints based on the parcel's plan type. A parcel may have a constraint for Floor Area Ratio (FAR) and/or Units_per_Acre.

The development constraints were summarized by reviewing the Comprehensive Plan Future Land Use Elements (FLUE) for the cities of Tampa, Temple Terrace, Plant City, and the unincorporated areas of Hillsborough County. In these reports, the land use type and the policies to ensure the character and location of land uses optimizes the combined potentials for economic benefit and environment protection are described. Meanwhile, community development patterns are also provided, including area type (urban, suburban, or rural), land use type (residential, industry, or mixed), housing, transportation, and public service. Figure 3-16 gives a sample of a

community development pattern. The patterns were summarized and translated to development constraints in the UrbanSim model. The preparation of constraint data and plan type data is given in Tables 3-9 and 3-10.

Table 3-9 Constraint Data

Variable Name	Description	Source Database	Source Item
constraint_id	A unique id for the constraint	User Defined	
constraint_type	The density measure for the constraint. The value must be either 'units_per_acre' for residential land or 'far' for nonresidential land.	FLUE	FAR/Units_per_acre
plan_type_id	The id of the plan_type	FLUE	Match to Plan data
minimum	The minimum density allowed by the constraint	FLUE	0 if not defined
maximum	The maximum density allowed by the constraint	FLUE	Review report

Table 3-10 Plan Data

Variable Name	Description	Source Database	Source Item
plan_type_id	The id of the plan_type	User defined	
plan_type_name	The minimum density allowed by the constraint	FLUE	Development Pattern Code

FUTURE OF HILLSBOROUGH RURAL-RESIDENTIAL LAND USE CLASSIFICATION			
Residential-1 (RES-1)			
RESIDENTIAL GROSS DENSITY	TYPICAL USES	MAXIMUM FLOOR AREA RATIO OR SQUARE FEET	SPECIFIC INTENT OF CATEGORY
Up to 1.0 dwelling units per gross acre. Alternative methods for calculating density of certain uses are specified in the land development regulations. Density bonuses and credits may be considered in this category and are described in the Plan.	Farms, ranches, residential uses, rural scale neighborhood commercial uses, offices, and multi-purpose projects. Commercial, office, and multi-purpose uses shall meet locational criteria for specific land use projects.	Rural scale neighborhood commercial, office multi-purpose projects limited to 30,000 sq. ft. or .25 FAR, whichever is less intense. Actual square footage limit is dependent on classification of roadway intersection where project is located.	To designate areas for rural residential uses, compatible with short-term Agricultural Uses Other uses including rural scale neighborhood commercial, office and multi-purpose projects may be permitted when complying with the Goals, Objectives and Policies of the Land Use Element and applicable development regulations and conforming to established locational criteria for specific land use.
No minimum lot size is required to support the concept of clustering and preservation of open spaces left in a natural state. See related policies regarding clustering.	Agricultural uses may be permitted pursuant to policies in the agricultural objective areas of the Future Land Use Element.		

Figure 3-16 Sample of Community Development Pattern in FLUE

3.8 Socioeconomic Control Data

In order to forecast the future land use pattern, UrbanSim requires the socioeconomic projections for future years for the whole region. The socioeconomic control data include the annual number of households, annual household relocation rate, annual employment number, and annual employment relocation rate.

- **Annual Household Control Total**

The annual household number contains the control totals, or aggregate targets, for the number of households by family size for each future year. In this study, the annual household number by family size in the base year (2010) was retrieved from the Census Summary Files. The annual household control number for the future year (2011 to 2020) was calculated taking the following steps:

Step 1 Calculate Population in future years

In the “2035 Long Range Transportation Plan,” the population projection for Hillsborough County is given for 2006, 2025, 2035, and 2050. The total population for 2011 - 2020 was calculated by the linear function:

$$\text{Population for Target Year} = \frac{\text{Target Year} - 2006}{2025 - 2006} \times (\text{Population for 2025} - \text{Population for 2006}) + \text{Population for 2006} \quad (3)$$

Step 2 Calculate Households in future years

Assuming the average family size in Hillsborough County is 2.55 persons per household in 2010 (Source: <http://edr.state.fl.us/Content/area-profiles/county/hillsborough.pdf>), the total household number in Hillsborough County is calculated by:

$$\text{Total Households for Target Year} = \frac{\text{Population for Target Year}}{2.55} \quad (4)$$

Step 3 Calculate Households by Family Size in future years

Assuming the percentage of family size is constant in future years, the households by family size for future years is calculated by:

$$\begin{aligned} \text{Households for Family Size I in Target Year} = & \\ & \frac{\text{Households for Family Size I in Base Year}}{\text{Total Households in Base Year}} \times \\ & \text{Total Households in Target Year} \quad (5) \end{aligned}$$

- **Annual Household Relocation Rate**

The annual household relocation rates contain estimates of the probabilities of moving within the region for a one-year time frame. UrbanSim users can use any range or categorical variable (primary or computed) defined for households. By default, the model includes households of different incomes and ages of head of household categories. Since researchers did not find this information in the available databases, the system default relocation rates were used.

- **Annual Employment Control Total**

The annual employment control totals contain the control totals or aggregate quantities of employment that will be used to set the total employment in the model system for each year. Totals by employment sector are split into home-based and non-home based components, on separate records.

The annual employment control totals were calculated based on the employment projection in the “2035 Long Range Transportation Plan” using a method similar to calculating annual household control totals.

Employment Total for Target Year =

$$\frac{\text{Target Year}-2006}{2025-2006} \times (\text{Employment Total for 2025} - \text{Employment Total for 2006}) + \text{Employment for 2006} \quad (6)$$

The employment total was split by home-based and non-home-based based on the ratio of the two categories in the base year (2010).

- **Annual Employment Relocation Rate**

The annual employment relocation rates represent the probabilities that a job in a sector will relocate within the region within a one-year time frame. This study compared the employment number by sectors in InfoUSA 2007 and InfoUSA 2010, and calculated the annual rate of change for employment by sector in Hillsborough County.

Relocation Rate for Sector i =

$$\frac{\text{Jobs for Sector } i \text{ in InfoUSA 2010} - \text{Jobs for Sector } i \text{ in InfoUSA 2007}}{\text{Jobs for Sector } i \text{ in InfoUSA 2007}} / (2010 - 2007) \quad (7)$$

3.9 Traffic Pattern

Accessibility, which is defined as how easy it is for individuals to access activities they need or want to engage in from a geographic unit (parcel, zone, etc.), has long been known to influence the location of firms and households' activities. Firms reduce transport costs to labor, suppliers, and consumers; while households trade off transport costs for work and shopping against housing costs and other amenities. In addition, accessibility strongly influences land prices and density:

- Auto use supports a low-density, dispersed urban form, which reinforces auto use;
- Transit ridership increases with high density, mixed use development, nodal urban form, and high walking access; and
- Walking access to shopping increases pedestrian activity, which increases pedestrian oriented retail.

Accessibility of zone i can be calculated by:

$$Accessibility_i = \sum_{j=1}^J (Jobs_j e^{Logsum_{ij}}) \quad (8)$$

where $Jobs_j$ is employment activities in zone j ; $Logsum_{ij}$ is the logsum for households from TAZ i to TAZ j ; and J is the number of TAZs (TAZ is Traffic Analysis Zone).

UrbanSim requires the retrieval of logsum values (traffic patterns) from a transportation planning model. In Hillsborough County, the travel demand model is the Tampa Bay Regional Planning Model (TBRPM) powered by Cube Voyager. The preparation procedure for traffic data is shown in Figure 3-17.

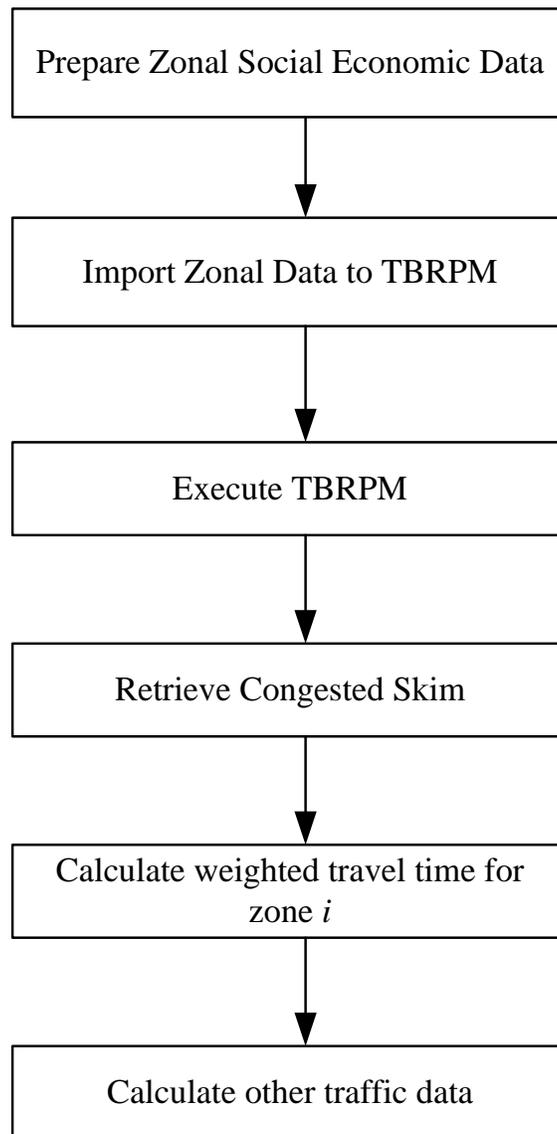


Figure 3-17 Data Preparation for Traffic Data

- **Prepare Zonal Socioeconomic Data**

Two zonal socioeconomic datasets are included in the TBRPM model: ZDATA1, consisting of population, dwelling units, and hotel/motels information; and ZDATA2, consisting of employment and school enrollment information. In TBRPM ver 7.1, three scenarios were created for 2006, 2025, and 2035. To calculate the zonal data for a target year, the following linear function was used:

$$\begin{aligned} &\text{zonal data for target year} = \\ &\frac{\text{Target Year} - 2006}{2025 - 2006} \times (\text{Zonal Data for 2025} - \text{Zonal Data for 2006}) + \\ &\text{Zonal Data for 2006} \end{aligned} \tag{9}$$

The ZDATA1 and ZDATA2 were recalculated for 2010 using this equation and were imported into the TBRPM model to create a new scenario (2010BASE).

- **Retrieve Congested Skim**

The new scenario was executed to produce traffic costs and trips among origins and destinations. In this study, the traffic cost was defined as the zonal travel time during peak hours (congested) which can be retrieved from the “CONGSKIM_Ayy.MAT” after conducting trip distribution. The travel impedance (TIME2) in this matrix includes travel time, turn penalties, toll equivalent time, and acceleration / deceleration delay time. This matrix was transformed to a table that represents zone-to-zone congested travel time.

Cube (Licensed to University of South Florida) - [CONGSKIM_A06.MAT-19 TIME2 (C:\FSUTMS\D7\TBRPM_7.0\BASE\Year_2006_Alt6B\Output)]

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TBRPM7 cat	1 TIME1	2 DISTANCE	3 CARTOLL	4 SVCMINUTES	5 SVCSECONDS	6 DELAY	7 TERMTIME	8 TOLLEQ	9 TIME2	10 FFTIME	11 DSTBTIME	12	
Scenarios	Sum	1	2	3	4	5	6	7	8	9	10	11	12
Base	866876744.79	234260.35	231397.29	233950.26	232346.78	225357.38	222717.38	229166.49	223261.48	219032.92	224106.29	222331.05	222326.39
-Year_2014_EC	1	234117.88	2.40	7.37	14.92	19.13	24.70	14.10	4.79	8.67	17.42	16.93	26.22
-Year_2025_CA	2	230728.27	7.38	2.49	11.23	15.44	21.01	19.41	8.63	7.85	4.97	15.89	13.24
-Year_2035_CA	3	232913.67	14.89	11.19	2.83	7.86	13.43	26.92	16.14	15.36	8.22	23.40	5.66
-Year_2035_Alt	4	231127.24	19.10	15.40	7.87	2.51	9.89	31.12	20.35	19.57	12.43	23.49	5.02
-Year_2006_Alt	5	224093.52	24.67	20.97	13.45	9.90	2.92	33.14	25.93	22.88	18.01	19.08	8.89
-Year_2006_Alt6B	6	222188.35	14.17	19.50	27.05	31.25	33.37	2.13	13.45	14.96	18.36	21.91	29.05
-Year_2006_Alt6B	7	228517.01	4.79	8.65	16.20	20.41	25.98	13.38	2.40	5.71	7.52	15.22	18.21
-Year_2006_Alt6B	8	223186.97	7.90	7.88	15.43	19.63	23.15	15.03	5.71	2.36	4.73	9.88	17.43
-Year_2006_Alt6B	9	218526.48	8.67	4.97	8.24	12.44	18.01	18.30	7.52	4.72	2.36	7.73	10.24
-Year_2006_Alt6B	10	222772.38	17.14	15.64	23.19	23.49	19.07	21.75	14.94	9.60	7.55	3.44	18.64
-Year_2006_Alt6B	11	221136.22	16.90	13.20	5.67	5.02	8.89	28.92	18.15	17.37	10.23	18.66	2.51
-Year_2006_Alt6B	12	220860.02	26.19	22.49	14.97	11.42	7.00	29.74	24.73	19.48	17.44	15.69	6.57
-Year_2006_Alt6B	13	220206.46	22.05	20.55	18.69	15.14	10.72	26.67	19.86	14.52	12.47	10.72	10.29
-Year_2006_Alt6B	14	219756.44	12.84	11.33	18.89	23.09	20.32	16.78	10.64	5.30	5.39	7.06	19.90
-Year_2006_Alt6B	15	218867.51	17.50	16.00	23.55	21.74	17.32	20.95	14.81	9.96	7.92	8.39	16.89
-Year_2006_Alt6B	16	223523.48	20.44	18.94	22.54	18.99	14.57	25.05	18.25	12.90	10.86	9.10	14.15
-Year_2006_Alt6B	17	219990.81	26.76	25.10	17.57	14.02	9.60	30.69	24.57	19.22	17.18	15.42	9.17
-Year_2006_Alt6B	18	216428.37	14.27	15.14	22.69	26.89	26.10	9.92	9.91	9.07	11.99	14.64	24.69
-Year_2006_Alt6B	19	221094.37	17.35	17.01	24.57	24.97	20.55	16.33	12.99	10.95	10.01	10.49	20.13
-Year_2006_Alt6B	20	209460.81	19.53	19.41	26.97	24.96	20.54	16.82	15.18	13.35	16.02	15.47	20.11
-Year_2006_Alt6B	21	209923.55	24.36	22.86	27.26	23.72	19.30	18.39	20.73	16.83	14.78	14.23	18.87
-Year_2006_Alt6B	22	212512.90	21.25	19.76	24.16	20.62	16.20	23.03	16.90	13.73	11.68	11.13	15.77
-Year_2006_Alt6B	23	214274.91	22.74	21.60	24.14	20.59	16.17	24.51	18.38	15.56	13.52	11.99	15.74
-Year_2006_Alt6B	24	216691.08	24.66	23.53	24.02	20.47	16.06	26.44	20.31	17.49	15.44	13.91	15.63

Figure 3-18 Zone-to-Zone Travel Time in Hillsborough County

As shown in Figure 3-19, TBRPM also produced zone-to-zone trips by purpose: HBW (home-based work), NHBW (non-home-based work), and so on. These trip matrices were retrieved from the output of the TBRPM model organized by travel purposes.

Cube (Licensed to University of South Florida) - [PSNTRIPS_A06.MAT-1 HBW (C:\FSUTMS\D7\TBRPM_7.0\BASE\Year_2006_Alt6B\Output)]

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TBRPM7 cat	1 HBW	2 HBSH	3 HBSR	4 HBSC	5 HBO	6 NHBW	7 NHBO	8 LTRK	9 HTRK	10 TAXI	11 EI	12 ARPT	13 UNIV	14 LOS	
Scenarios	Sum	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Base	2797062	579	185	631	296	128	1569	360	739	433	784	1239	1060		
-Year_2014_EC	1	803	20	2	3	0	1	5	7	7	3	2	5	1	
-Year_2025_CA	2	1864	13	10	9	3	1	5	7	17	11	6	16	5	
-Year_2035_CA	3	2823	7	3	55	11	3	4	4	9	10	5	62	18	
-Year_2035_Alt	4	1672	3	1	13	14	2	2	2	4	3	4	34	13	
-Year_2006_Alt	5	735	1	0	3	2	2	1	0	1	1	2	7	6	
-Year_2006_Alt6B	6	6732	9	1	2	1	0	214	5	8	3	6	4	3	
-Year_2006_Alt6B	7	1771	19	3	4	2	0	11	25	17	7	6	7	3	
-Year_2006_Alt6B	8	1340	7	3	3	1	1	5	6	25	8	7	6	5	
-Year_2006_Alt6B	9	1254	5	3	6	2	1	4	4	13	11	8	11	5	
-Year_2006_Alt6B	10	4514	8	3	5	3	2	10	6	22	14	74	15	21	
-Year_2006_Alt6B	11	1626	3	2	16	8	2	2	2	4	5	4	46	16	
-Year_2006_Alt6B	12	1452	1	1	4	2	2	1	1	2	2	4	14	27	
-Year_2006_Alt6B	13	163	0	0	1	0	0	0	0	1	0	1	1	1	
-Year_2006_Alt6B	14	2723	7	3	4	1	1	9	6	27	12	21	8	9	
-Year_2006_Alt6B	15	1047	1	1	1	0	1	2	1	4	2	6	3	5	
-Year_2006_Alt6B	16	2076	2	1	4	2	1	3	2	7	5	13	11	15	
-Year_2006_Alt6B	17	290	0	0	1	0	0	0	1	0	0	1	1	2	
-Year_2006_Alt6B	18	1750	2	1	1	0	1	9	3	6	2	3	2	2	
-Year_2006_Alt6B	19	1518	2	0	1	1	0	5	1	5	3	5	3	3	
-Year_2006_Alt6B	20	5569	4	1	3	1	1	13	5	12	4	8	4	7	
-Year_2006_Alt6B	21	1610	1	0	1	0	0	3	1	2	1	3	2	3	
-Year_2006_Alt6B	22	3898	2	1	3	1	1	5	3	7	4	11	6	9	
-Year_2006_Alt6B	23	2820	2	0	2	1	1	3	2	4	2	7	5	7	
-Year_2006_Alt6B	24	173	0	0	0	0	0	1	0	0	0	0	1	0	

Figure 3-19 Zone-to-Zone Trips by Purpose in Hillsborough County

- **Aggregate Zonal Traffic Pattern**

Six zonal traffic patterns were produced in this study: zone-to-zone congested traffic costs, weighted average zonal traffic time, weighted average zonal HBW traffic time, weighted average zonal NHBW traffic time, weighted average zone-to-CBD traffic time, and weighted average zone-to-Airport traffic time. The zone-to-zone congested traffic costs were retrieved from the TBRPM model output directly. The other patterns were calculated by following equations.

Weighted average zonal traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{Trips for } i \text{ to } j}$$

$i \neq j, J = \text{Number of Zones}$ (10)

Weighted average zonal HBW traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{HBW Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{HBW Trips for } i \text{ to } j}$$

$i \neq j, J = \text{Number of Zones}$ (11)

Weighted average zonal NHBW traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{NHBW Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{NHBW Trips for } i \text{ to } j}$$

$i \neq j, J = \text{Number of Zones}$ (12)

Weighted average zone-to-CBD traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{Trips for } i \text{ to } j}$$

$i \neq j, j \in \text{CDB Zones}, J = \text{Number of CBD Zones}$ (13)

The CBD Zones are shown in Figure 3-20.

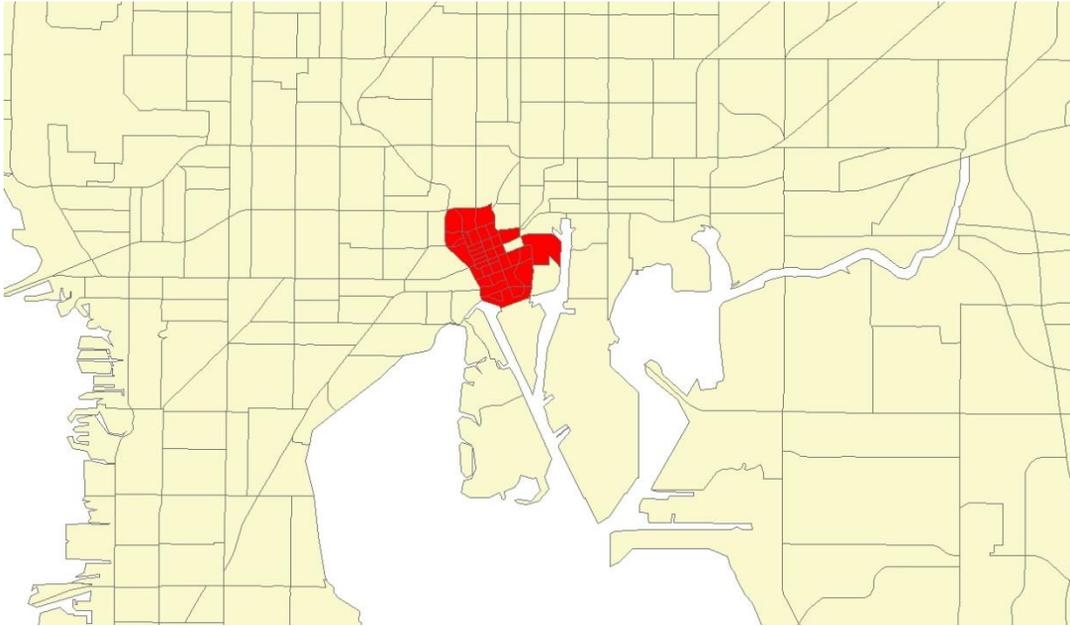


Figure 3-20 Zones in Tampa CBD Area

Weighted average zone-to-AirPort traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{Trips for } i \text{ to } j}$$

$$i \neq j, j \in \text{Air Port Zones}, J = \text{Number of Air Port Zones} \quad (14)$$

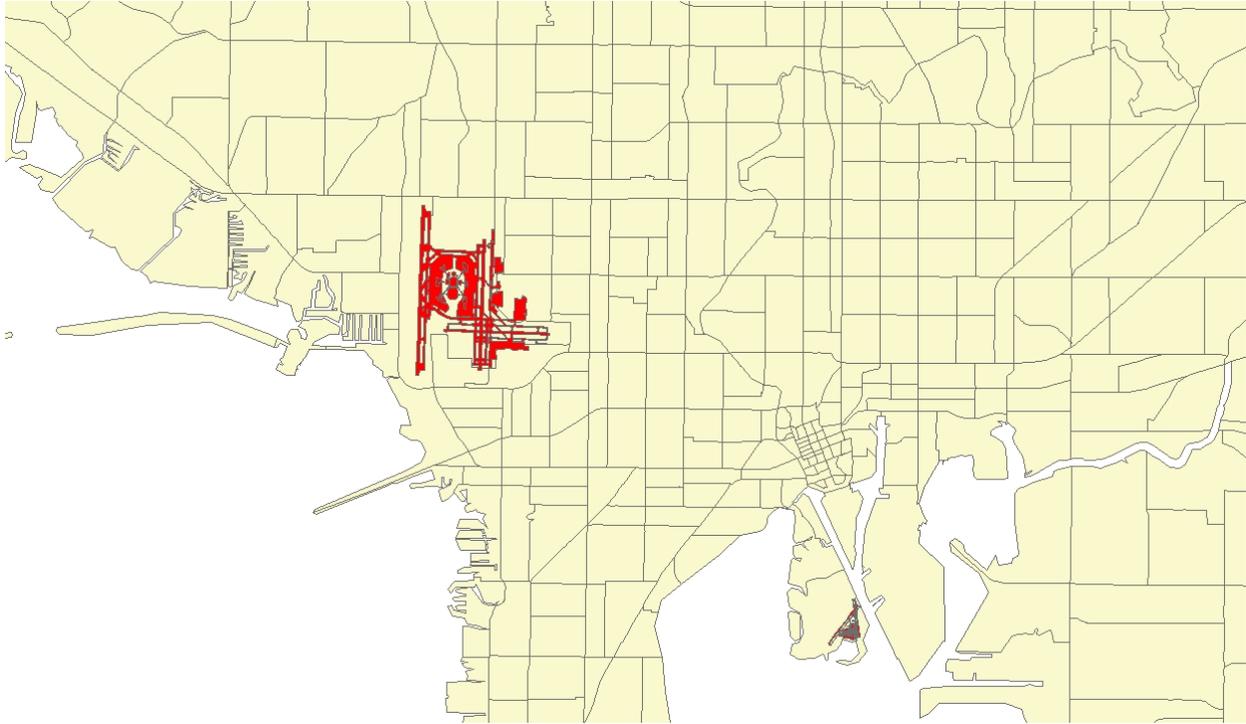


Figure 3-21 Air Port (Tampa International Airport) Zones

- **Output Data Tables**

Two data tables were produced to represent the traffic patterns. “Traffic_data” is used to describe zone-to-zone congested travel time in seconds. “Zones” contain weighted average zonal traffic time, weighted average zonal HBW traffic time, weighted average zonal NHBW traffic time, weighted average zone-to-CBD traffic time, and weighted average zone-to-Airport traffic time for each zone in Hillsborough County.

3.10 Data Compilation

After the data were prepared, they were compiled to generate input tables for the UrbanSim model. The data compilation included converting the data to UrbanSim format, producing data tables, connecting data tables by “key” variables, and outputting UrbanSim input files (CSV format). Detailed information on the format of input tables is provided in Appendix I. The input tables are listed below.

- ANNUAL_EMPLOYMENT_CONTROL_TOTALS – employment forecasts, by location (home-based or non-home based) for each simulated year;
- ANNUAL_HOUSEHOLD_CONTROL_TOTALS – households forecasts, by household size for each simulated year;
- ANNUAL_RELOCATION_RATES_FOR_HOUSEHOLDS – relocation rates of households, by household head age, and by household income;
- ANNUAL_RELOCATION_RATES_FOR_JOBS – relocation rates of jobs, by sector;
- BUILDING_SQFT_PER_JOB - amount of space each job will take in a particular building type, by zone;
- BUILDING_TYPES - unique building types used to classify buildings;
- BUILDINGS - individual building located on a parcel;
- CITIES - the name of cities included in the study area;
- COUNTIES - the name of counties included in the study area;
- DEMOLITION_COST_PER_SQFT - costs of demolition by building type;
- DEVELOPMENT_CONSTRAINTS - constraints to restrict development on parcels;
- DEVELOPMENT_TEMPLATE_COMPONENTS - buildings or parts of buildings included in a particular template;
- EMPLOYMENT_SECTORS - employment sectors used to classify jobs by industrial sector;
- GENERIC_LAND_USE_TYPES - generalized land use classification used for models;

-
- HOUSEHOLD_CHARACTERISTICS_FOR_HT - classification used in the annual_household_control_totals table to determine how many households of particular categories will be in the region in a simulation year;
 - HOUSEHOLDS - synthesized households for the region. It typically reflects an expansion of the Public Use Microdata Samples (PUMS) to approximate a 100% sample of households;
 - JOBS - inventory of jobs for the region;
 - LAND_USE_TYPES - land use classification for all parcels in the region;
 - PARCELS - attributes of individual parcels;
 - PERSONS - synthesized population for the region;
 - PLAN_TYPES - classification of land use regulations defining permissible uses and densities of future development;
 - TARGET_VACANCIES - structural or target vacancies - trigger development when vacancies fall below this, by building type for each simulated year;
 - TRAVEL_DATA - zone-to-zone skims from the travel demand models, for accessibility variables;
 - ZONES - attributes of traffic analysis zones used in the travel demand models.

4. Model Development

UrbanSim is a model system to support land use, transportation planning, and environmental planning. It is a full micro-simulation model system, simulating choices of agents: households, businesses, and developers. UrbanSim is based on the following theories:

- Random Utility Theory (McFadden)
 - ✓ Theoretical basis for discrete choice models (such as mode choice): agents choose among alternatives based on the relative utility of the available options
 - ✓ Multinomial and nested logit models, more general forms relaxing the Irrelevant Alternatives (IIA) property
- Urban Economics/Bid Rent Theory (Alonso, Mills, Muth)
 - ✓ Explains land use outcomes (density, rents, etc.) as outcomes of bidding processes based on willingness to pay for locational amenities: trade-off travel time vs. housing cost
- Hedonic Price Theory (Rosen)
 - ✓ Observed prices of composite goods, like housing, can be ‘decomposed’ to the implicit prices of their attributes; widely used to measure the market valuation of locational amenities or disamenities.
- Dynamic Market Equilibrium, Price Adjustment, Disequilibrium
 - ✓ Markets are rarely in equilibrium, especially real estate due to supply lags and high transactions costs; information is imperfect and speculation can lead to bubbles
 - ✓ Current housing market crisis is an excellent example of market disequilibrium
- Micro-simulation (Orcutt)
 - ✓ Initially a computational framework to explore individual level impacts of policies; later found more computationally efficient than complex aggregate models

The process of agent choice in urban markets is shown in Figure 4-2.

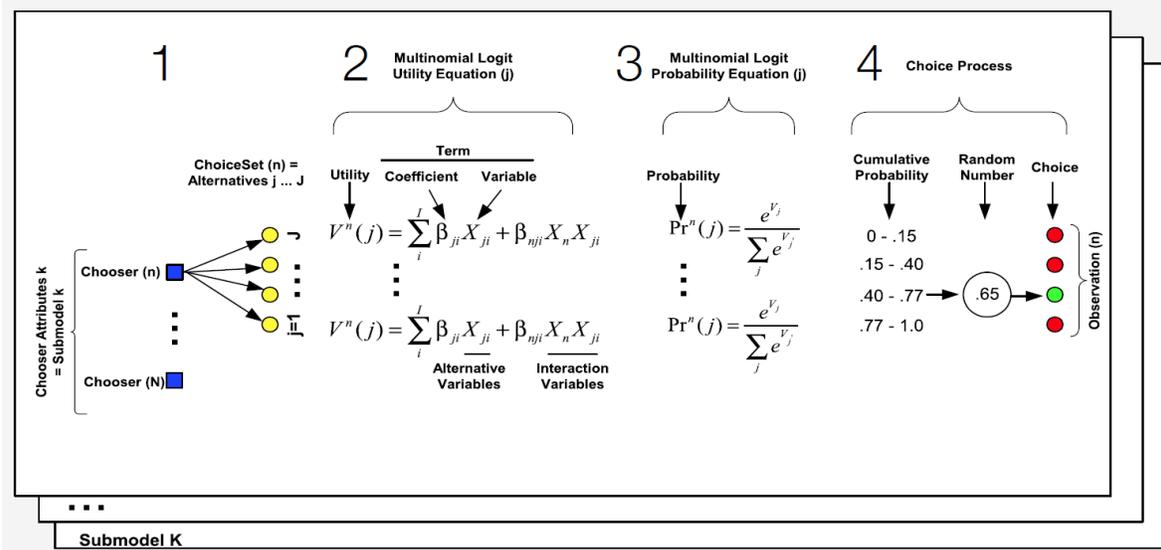


Figure 4-2 Agent Choice in UrbanSim
(source: www.urbansim.org)

4.1 UrbanSim Sub-Models Structure

UrbanSim provides a flexible strategy to allow users to select sub-models from a candidate list consisting of 35 sub-models, and even create new models. By considering feasibility, necessity, and cost, ten sub-models were selected to develop in this study, as shown in Figure 4-3. UrbanSim runs the sub-models in the sequence shown in Figure 4-3 and allows researchers to calibrate the real estate price model, household location choice model, and employment location choice model using local data.

Real Estate Price Model	<i>Predicts price of land if vacant, price of land + buildings if parcel is developed</i>
Expected Sale Price Model	<i>Generates possible development proposals for each eligible parcel, and the predicted return on investment</i>
Development Proposal Choice Model	<i>Selects proposals based on return on investment, current vacancy rates</i>
Building Construction Model	<i>Adds new buildings / demolishes redeveloped ones</i>
Household Transition Model	<i>Adds or subtracts households to the region to match the annual control totals from the user – subtractions are randomly selected, additions are not yet placed in a parcel or building. Employment same as Household with controls at the sector level</i>
Employment Transition Model	<i>Adds or subtracts households to the region to match the annual control totals from the user – subtractions are randomly selected, additions are not yet placed in a parcel or building. Employment same as Household with controls at the sector level</i>
Household Relocation Model	<i>Selects households that will move based on user's probability inputs</i>
Household Location Choice Model	<i>Chooses vacant dwelling units for households added through Transition model and households moving via the Relocation model</i>
Employment Relocation Model	<i>Same function as Household Relocation model</i>
Employment Location Choice Model	<i>Same function as Household Location Choice model, but jobs choose building spaces (ie cubicles)</i>

Figure 4-3 Developed Sub-Models in UrbanSim

Real Estate Price Model (REPM)

UrbanSim uses real estate prices as the indicator of a match between demand and supply of land at different locations and with different land use types. It also uses real estate prices for relative market valuations for attributes of housing, nonresidential space, and location. This role is important to the rationing of land and buildings to consumers based on preferences and the ability to pay, and is a reflection of the operation of actual real estate markets. Since prices enter the location choice utility functions for jobs and households, an adjustment in prices will alter

location preferences. All else being equal, this will in turn cause higher price alternatives to become more likely to be chosen by occupants who have lower price elasticity of demand. Similarly, any adjustment in land prices alters the preferences of developers to build new construction by the type of space and the density of the construction.

Real estate prices are modeled using a hedonic regression of the log-transformed property value per square foot on attributes of the parcel and its environment, including land use mix; density of development; proximity of highways and other infrastructure; land use plan or zoning constraints; and neighborhood effects. The hedonic regression equation encapsulates interactions between market demand and supply, revealing an envelope of implicit valuations for location and structural characteristics. The independent variables influencing land prices can be organized into site characteristics, regional accessibility, and urban-design scale effects, including development type; land use plan; environmental constraints; access to population and employment; land use mix and density; and proximity to highway and arterials.



Figure 4-4 Input and Output of Real Estate Price Model

Expected Sales Price Model (ESPM)

The Expected Sales Price Model (ESPM) predicts the price per unit of each proposed development project. The model uses the same specifications and estimated parameters from the Real Estate Price Model to predict expected prices. The dependent variable is the Log of the price per unit (per housing unit for residential, per square foot for non-residential buildings). The independent variables include attributes of the building: density, accessibility, and zonal composition of households and employment.



Figure 4-5 Input and Output of Expected Sales Price Model

Development Proposal Choice Model (DPCM)

The Development Proposal Choice Model predicts the selection of proposed development projects to be constructed on parcels. This model can be seen as a choice being made by a financial agent, determining whether to approve construction financing for possible projects. The model begins by evaluating each parcel, based on its remaining vacant land and the plan type that is on the parcel. It then makes an assessment for each of the “development templates” as to whether that template would be permitted by land use regulations, and would fit on the parcel. Any of the templates that pass both of these tests are then configured as development proposals. Once all parcels have been evaluated and a full list of proposals has been generated, the model uses the Expected Sales Price Model to predict the market value for the proposal. The development costs for constructing the proposal are also calculated, and a resulting Return on Investment (ROI) is computed. The model treats the ROI as the profit (the counterpart of utility for firms) based on a Multinomial Logit formulation.



Figure 4-6 Input and Output of Development Proposal Choice Model

Building Construction Model (BCM)

The Building Construction Model (BCM) constructs (adds) buildings based on projects selected by the Development Proposal Choice Model and the velocity functions that specify the rate at

which development occurs. It uses a customized algorithm to load development projects, compare them to time-tables specified in velocity functions, and to add records to the building dataset with an appropriate quantity of the development within each project.

The output of the BCM is to add records to this buildings dataset; the inputs have buildings, development projects, and velocity functions. The data tables used by the BCM are given in Table 4-3.



Figure 4-7 Input and Output of Building Construction Model

Household Transition Model (HTM)

The Household Transition Model (HTM) predicts new households migrating into the region, or the loss of households, migrating out of the region. The model compares the total number of households (possibly by type) in the households table at the beginning of a simulation year, to the total number of households (by type) specified by the user in the annual household control totals for that year. If the control total value is higher, the model adds the necessary number of households to the household table by sampling existing households (of the same type) and duplicating them. If the control totals indicate a declining household count (by type) then the appropriate number of households in the data are selected at random and removed. The role of this model is to keep the household data in the simulation synchronized with aggregate expectations of population and households. Note that the model can be configured by the user's choice of specification of the annual control totals. If no household characteristics are included in the control totals, then the synchronization is done for the total number of households. Otherwise it is done by the categories present in the control totals.



Figure 4-8 Input and Output Household Transition Model

Employment Transition Model (ETM)

The Employment Transition Model predicts new jobs being created within, or moved to, the region by businesses, or the loss of jobs from businesses in the region - either through downsizing, closure of a business, or relocation out of the region. The model compares the total number of jobs by sector in the jobs table at the beginning of a simulation year to the total number of jobs by sector specified by the user in the annual employment control totals for that year. If the control total value is higher, the model adds the necessary number of jobs to the jobs table by sampling existing jobs of the same sector and duplicating them. If the control totals indicate a declining job count for a sector, then the appropriate number of jobs in the data are selected at random and removed. The role of this model is to keep the jobs data in the simulation synchronized with aggregate expectations of employment in the region. In most current applications, control totals are separately specified for each sector and split by a proportion that is assumed to be home-based employment vs. non-home-based employment. These two are handled by different model groups in the employment location choice model.



Figure 4-9 Input and Output of Employment Transition Model

Household Relocation Model (HRM)

The Household Relocation Model predicts the relocation of households within the region during each simulation year. The Household Relocation Model is implemented as a cross-classification rate-based model, with a probability of moving by age and income category applied to each

household in the synthetic population, each simulation year. The outcome of the model is implemented as follows: If a household is determined to be a mover because the random draw is greater than 1 (their move probability), then they are moved out of their current location. In practical terms, their “building_id”, which identifies where they are located, is simply reset to a null value. They remain in the household table but do not have a location.



Figure 4-10 Input and Output of Household Relocation Model

Household Location Choice Model (HLCM)

The Household Location Choice Model predicts the probability that a household that is either new (from the transition component) or has decided to move within the region (from the mobility component), will choose a particular location defined by a residential building. The form of the model is specified as multinomial logit, with random sampling of alternatives from the universe of available (vacant) housing units, including those units vacated by movers in the current year. Once a household has chosen a location, that location is committed to the household (like a rental contract or closing on a purchase of a house) and the residential unit becomes unavailable for any other households until the time that the occupying household is predicted to move.

The independent variables can be organized into housing characteristics, regional accessibility, and urban-design scale effects, including prices (interacted with income), development types (density, land use mix), housing age, job accessibility by auto-ownership group, travel time to CBD/airport, neighborhood land use mix/density, and neighborhood employment.

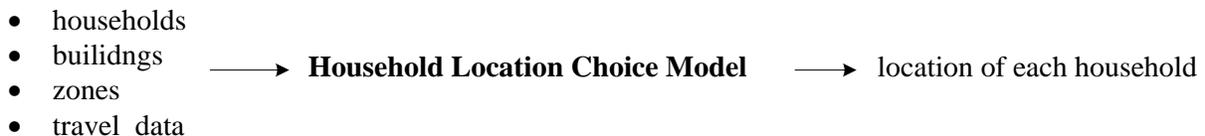


Figure 4-11 Input and Output of Household Location Choice Model

Employment Relocation Model (ERM)

The Employment Relocation Model predicts the relocation of households within the region during each simulation year. The model is implemented as a cross-classification rate-based model, with a probability of moving by employment sector applied to each job and each simulation year. The outcome of the model is implemented as follows: if a job is determined to be a mover because the random draw is greater than 1 (their move probability), then they are moved out of their current location. In practical terms, their “building_id”, which identifies where they are located, is simply reset to a null value. They remain in the jobs table but do not have a location.

- annual_job_relocation_rates
 - jobs
- > **Employment Relocation Model** —————> probability of a job relocation

Figure 4-12 Input and Output of Employment Relocation Model

Employment Location Choice Model (ELCM)

The Employment Location Choice Model (ELCM) predicts the probability that a job that is either new (from the Economic Transition Model) or has moved within the region (from the Employment Mobility Model), will be located at a particular site. Buildings are used as the basic geographic unit of analysis in the current model implementation. Each job has an attribute of space it needs, and this provides a simple accounting framework for space utilization within buildings. The number of locations available for a job to locate within a building will depend mainly on the total square footage of nonresidential floor space in the building, and on the density of the use of space (square feet per employee). The model is specified as a multinomial logit model, with separate equations estimated for each employment sector.

The independent variables used in the employment location choice model can be grouped into the categories of real estate characteristics, regional accessibility, and urban-design scale effects, including prices, development type (land use mix, density), access to population, travel time to CBD/airport, and proximity to highway and arterials.

-
- jobs
 - employment_sectors
 - buildings
 - zones
 - travel_data
- > **Employment Location Choice Model** —————> location of each job

Figure 4-13 Input and Output of Employment Location Choice Model

4.2 Model Specifications

Three sub-models, including the Real Estate Price Model, Household Location Choice Model, and Employment Location Choice Model, can be re-estimated by users based on local data. In this study, the three aforementioned sub-models were used with the system default specifications due to the following reasons:

- The data sets for model calibration need “real” geographic data, demographic data, and employment data at the parcel level. These data are usually derived from surveys to collect samples of households, jobs, and buildings. It is difficult to obtain the “real” data in Hillsborough County. In particular, the location information is required at the parcel level and the historic price information is required at the building level. This information could not be obtained from the current travel survey.
- The base year data (2010) contains many synthesized data, for example, households and buildings. The matching algorithm between these data was randomly assigned (households-to-buildings, jobs-to-buildings, etc.) because the marginal distributions were unavailable. Thus, the base year data could not be used for model estimation.

Thus, the system default model specifications and coefficients were used in this study.

4.3 UrbanSim Model Assembly and Debug

After preparing base year data and configuring model specifications, the UrbanSim model was assembled in the Open Platform for Urban Simulation (OPUS) platform. The process of model assembly is given as follows:

- Install the UrbanSim/OPUS platform on computers

-
- Test the UrbanSim/OPUS platform using the sample dataset
 - Import the base year data and model specifications
 - Create the base year scenario
 - Debug the UrbanSim model

Install UrbanSim

The UrbanSim package is powered by Python and its math library has been run and tested on Windows, Linux, and Mac OS X systems. The current version is 4.4 and can be downloaded from www.urbansim.org. In this study, the UrbanSim package for Windows 64-bit was used to simulate the land use in Hillsborough County. Since no binary installer for 64-bit Windows is available, all supporting packages were installed manually.

Test with Sample Dataset

To ensure the installed UrbanSim package was fully functional, a sample dataset provided by the authors was used to test the installed UrbanSim.

Import the base year data and model specifications

A parcel-based UrbanSim project was created based on a project template, as shown in Figure 4-14. The template defines the project directory, variable library, and model templates as XML files. These configurations were revised according to the needs in this study.

When the project was created, the prepared data tables (as shown in Section 3.11) were imported in the project using the UrbanSim CSV importing tool, as shown in Figure 4-15.

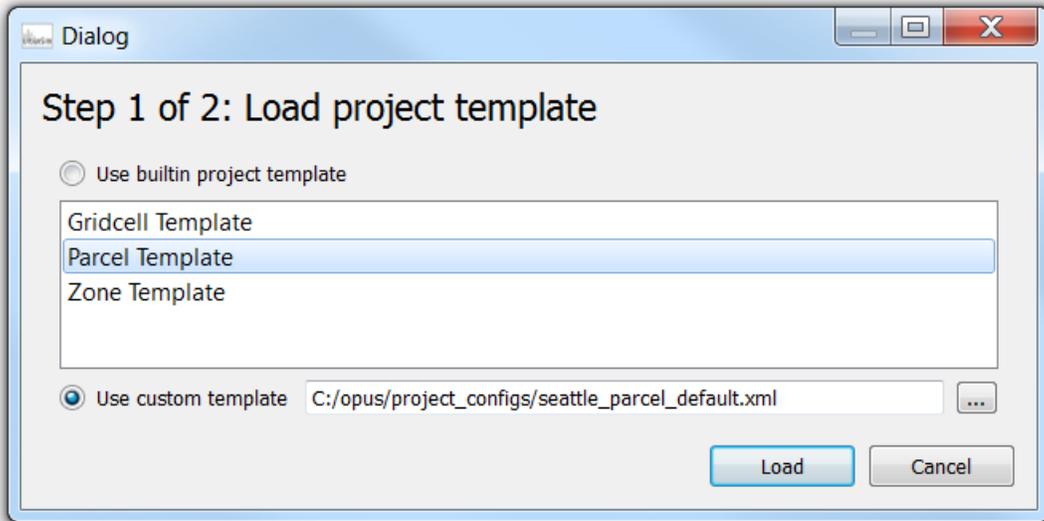


Figure 4-14 Create Parcel-Based UrbanSim Project

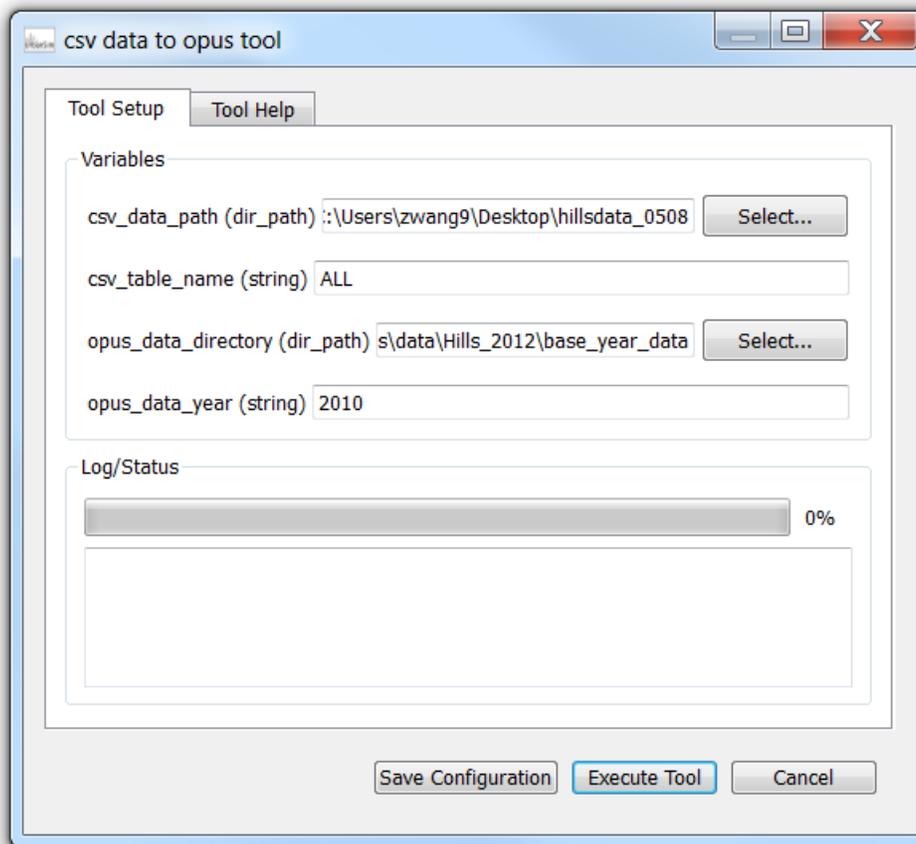


Figure 4-15 CSV Data Importing Tool

Create Base Year Scenario

After importing data and models, researchers selected and specified the ten sub-models in UrbanSim, as shown in Figure 4-16. This scenario was used as the baseline to create new scenarios.

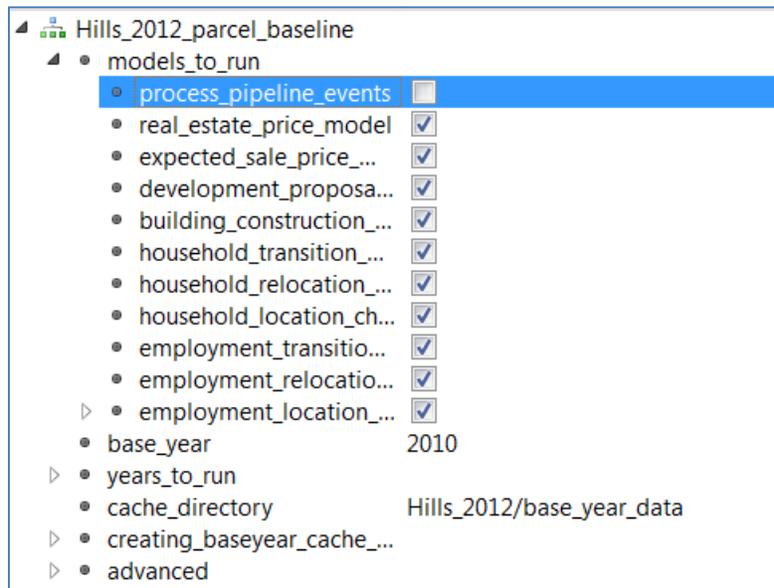


Figure 4-16 Base Year Scenario

Debug UrbanSim Model

The developed UrbanSim Model was tested using the base year scenario (2010). It was a challenging task because UrbanSim is an open source platform and still in development. Unlike commercial software, lack of documents and technical support was an obstacle in implementation. In addition, UrbanSim has high requirements for data formatting and error messages are weak in assisting users to address errors. Researchers had to spend a significant amount of time to add the data tables and models one by one to address the errors using exclusive methods.

Finally, all bugs were eliminated from the UrbanSim model. The base year scenario was ready for validation.

5. MODEL VALIDATION

Model validation was conducted to verify the simulation accuracy based on the scenarios of the base year (2010) and forecasted years (2016 and 2020). For validation purposes, the assembled UrbanSim model was run with the scenarios, and the associated traffic patterns were generated by the TBRPM model. The forecasted number of households was compared with the number of households which were projected in the 2035 LRTP on the study zones. The comparisons with the number of households were made for the years of 2010 (Base Year), 2016, and 2020.

The zonal population was compared between the simulation in UrbanSim prediction and the projection in the 2035 LRTP. The comparison process is given as follows:

I. Produce household projection

In the 2035 LRTP, zonal population projections are available in 2006 and 2025. The target years of validation are 2010, 2016, and 2025. The zonal household projections for the three years were calculated by

$$\begin{aligned} &\text{Zonal Households for Target Year} = \\ &\left\{ \frac{\text{Target Year} - 2006}{2025 - 2006} \times (\text{Zonal Population for 2025} - \text{Zonal Population for 2006}) + \right. \\ &\left. \text{Zonal Population for 2006} \right\} / 2.55 \end{aligned} \quad (15)$$

II. Prepare scenarios

The base year (2010) scenario was created during data collection and model assembly. Two new scenarios (2016 and 2020) were created based on the base scenario. Since socioeconomic and demographic data were controlled by two data tables: ANNUAL_EMPLOYMENT_CONTROL_TOTALS and ANNUAL_HOUSEHOLD_CONTROL_TOTALS, only traffic patterns needed to be revised. The TBRPM model was executed for 2016 and 2020 using the method described in Section 3-10. The traffic patterns were imported into the UrbanSim model to produce the scenarios for 2016 and 2020.

III. *Generate household indicator*

The scenarios were executed, and the population indicators were created, to aggregate households from parcels to zones based on the running results.

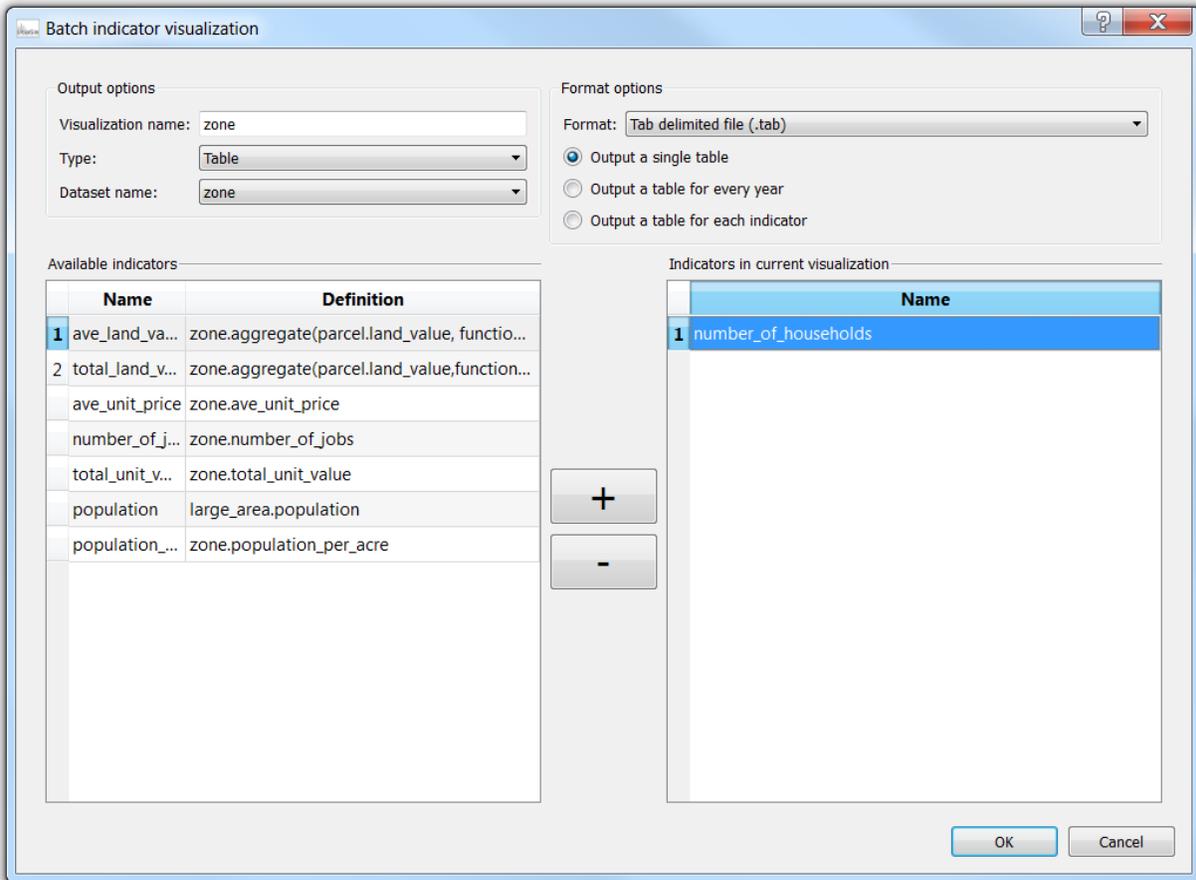


Figure 5-1 UrbanSim Indicators

IV. *Calculate cumulative percentage of household difference between 2035 LRTP and UrbanSim*

The zonal households predicted by UrbanSim were compared to those produced from the 2035 LRTP. Since the control totals are the same as those adopted in the 2035 LRTP, the total population number from UrbanSim was very close to that of the socioeconomic and demographic data for the 2035 LRTP. The cumulative percentage of TAZs is graphed against the household differences between UrbanSim forecasts and the 2035 LRTP (Difference = Households in UrbanSim – Households in LRTP) in Figure 5-2. This study found that the differences of zonal households between UrbanSim and the LRTP are very similar for the three

years. The errors at the zonal level range from -200 to 200 and represent over 70 percent of the TAZs. The spatial distributions of zonal household differences in the study zones for 2010, 2016, and 2020 are shown in Figures 5-3, 5-4, and 5-5 respectively.

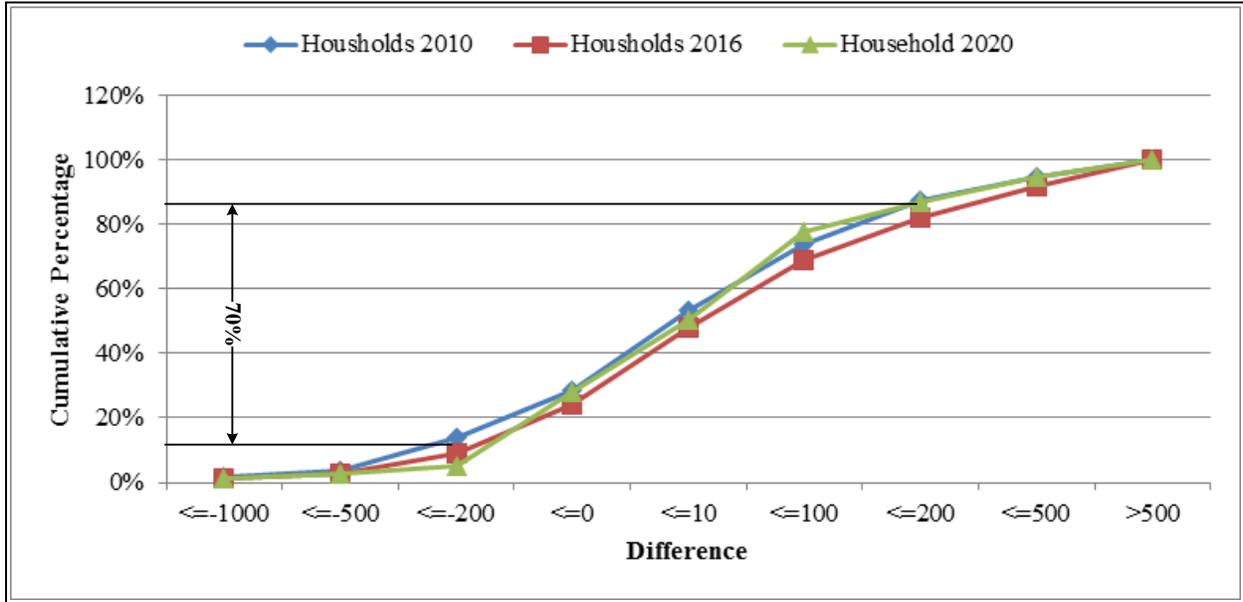


Figure 5-2 Cumulative Percentage of Household Difference

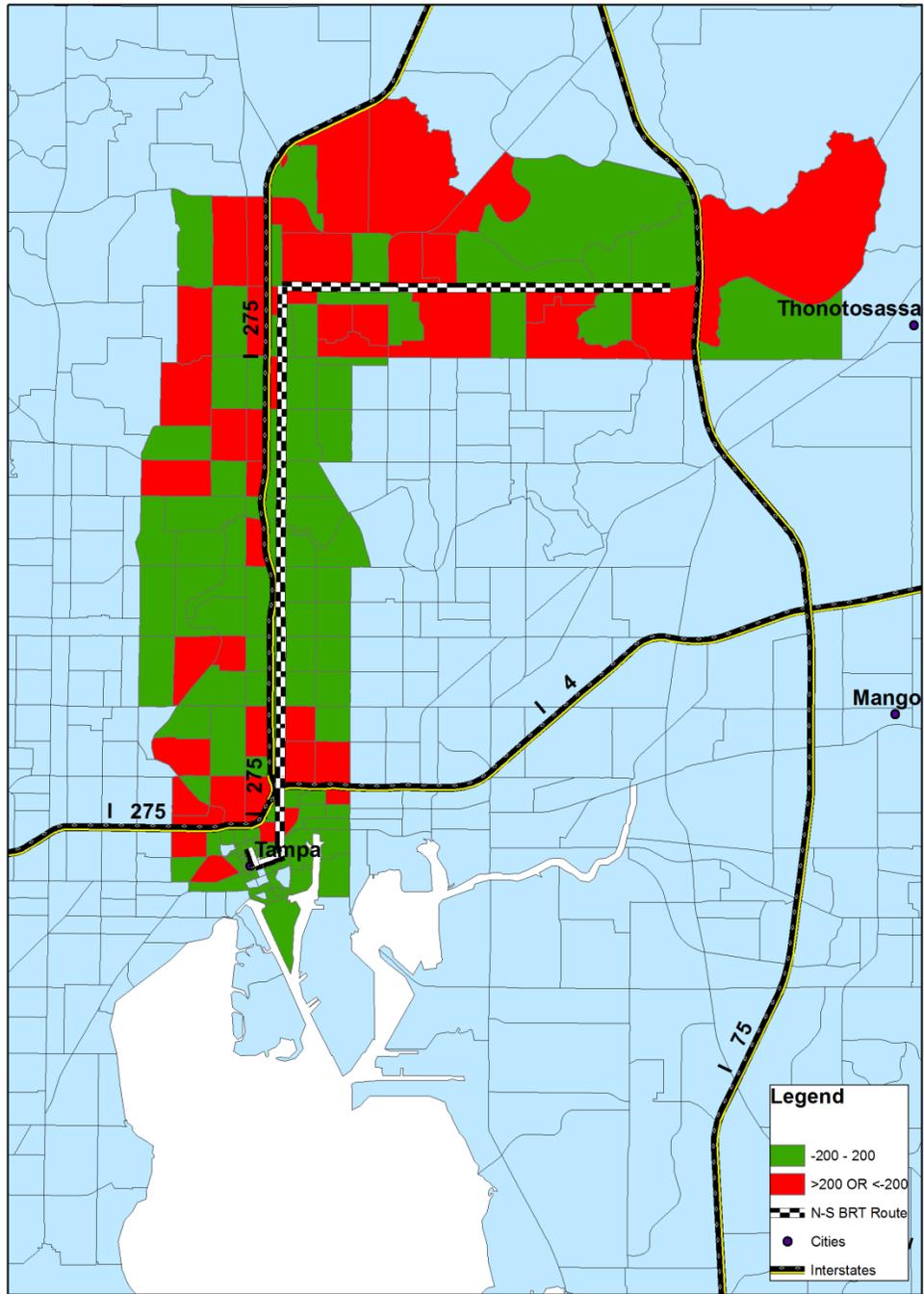


Figure 5-3 Zonal Household Difference between UrbanSim and 2035 LRTP in 2010

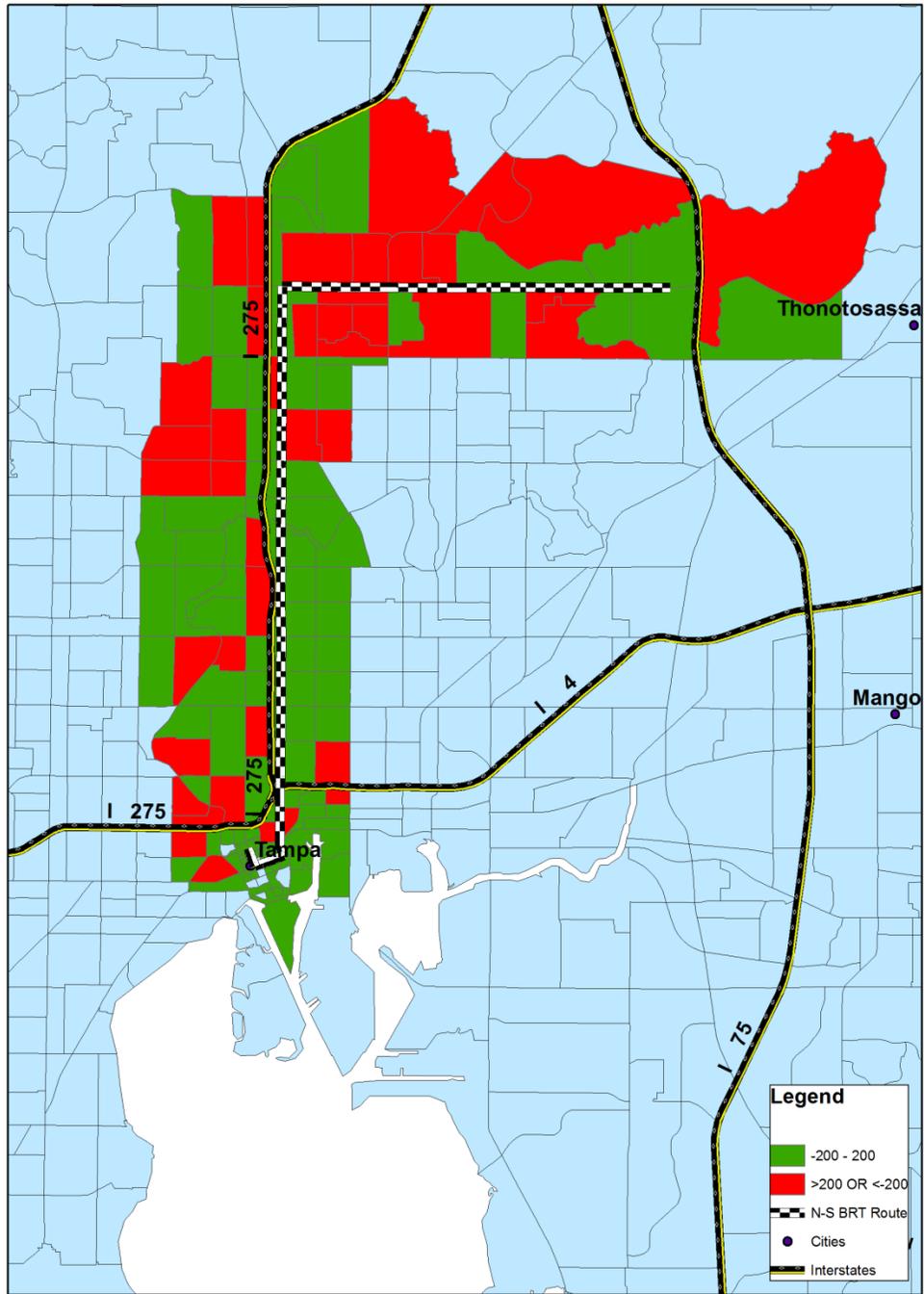


Figure 5-4 Zonal Household Difference between UrbanSim and 2035 LRTP in 2016

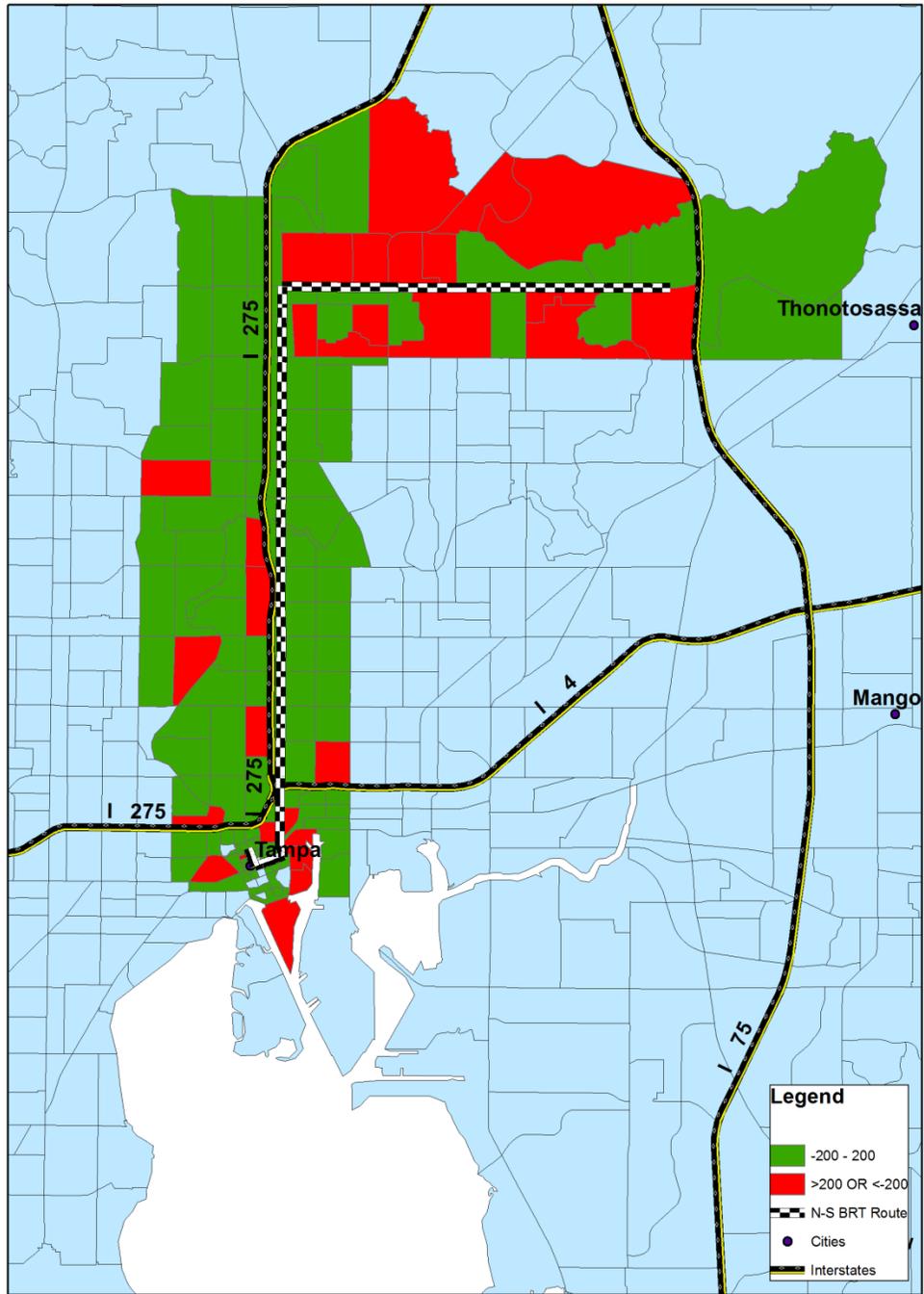


Figure 5-5 Zonal Household Difference between UrbanSim and 2035 LRTP in 2020

6. SCENARIO TESTING (BRT)

The objective of this study is to evaluate the impact of a proposed transit investment on the land use pattern using the developed UrbanSim model. The HART North-South BRT route was selected for evaluation. The basic idea was to compare the land use pattern of the study area with and without implementing the BRT route. Accessibility is a significant factor influencing a person's choices on the location of their household and employment. Implementation of the BRT route may attract more persons to take trips by transit systems, rather than by auto; this attraction, consequently, changes the traffic pattern and the accessibility of properties in its influence area. Thus, land use patterns, such as populations, households, employments, and/or land prices, are impacted by introducing a BRT route.

The typical method of obtaining a change in traffic patterns due to implementing a transit route is using the travel planning model to forecast the ridership of the transit route. However, the BRT mode is not available in current versions of transportation planning models for Hillsborough County, in either TBRPM or TBEST. Thus, the research team assumed that the BRT route attracts a certain percentage of trips from auto mode and compared the land use patterns between the scenario with the BRT service and the scenario without the BRT service. Four scenarios were created and examined as follows:

- Scenario 1: The BRT route with a one percent trip attraction in a short-period projection (2012)
- Scenario 2: The BRT route with a five percent trip attraction in a short-period projection (2012)
- Scenario 3: The BRT route with a one percent trip attraction in a long-period projection (2020)
- Scenario 4: The BRT route with a five percent trip attraction in a long-period projection (2020)

6.1 Scenario 1 (The BRT route with a one percent trip attraction in a short-period projection)

In Scenario 1, it was assumed that the BRT route attracted one percent of trips from the auto mode within the study zones. The following variables representing accessibility were recalculated based on the BRT attraction:

Weighted average zonal traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{Trips for } i \text{ to } j}$$

$i \neq j, J = \text{Number of Zones}$ (16)

Weighted average zonal HBW traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{HBW Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{HBW Trips for } i \text{ to } j}$$

$i \neq j, J = \text{Number of Zones}$ (17)

Weighted average zonal NHBW traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{NHBW Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{NHBW Trips for } i \text{ to } j}$$

$i \neq j, J = \text{Number of Zones}$ (18)

Weighted average zone-to-CBD traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{Trips for } i \text{ to } j}$$

$i \neq j, j \in \text{CDB Zones}, J = \text{Number of CBD Zones}$ (19)

Weighted average zone-to-AirPort traffic time:

$$\text{Traffic Time for Zone } i = \frac{\sum_{j=1}^J (\text{Trips for } i \text{ to } j \times \text{Traffic Time for } i \text{ to } j)}{\sum_{j=1}^J \text{Trips for } i \text{ to } j}$$

$i \neq j, j \in \text{Air Port Zones}, J = \text{Number of Air Port Zones}$ (20)

Based on the original traffic pattern data, the trips from zone i to zone j were reduced by one percent. The variables were recalculated by substituting the new zonal trips, and a new traffic pattern data table was produced. The new traffic table was imported into the UrbanSim model to create a scenario with the impact of BRT. (*Note: only the zones within the study area were recalculated in this study*) The UrbanSim model ran for the target year (2012) and the land use patterns were extracted from the model output (indicators) as follows:

- Zonal Population
- Zonal Household
- Zonal Jobs
- Zonal Unit Price

The four measures with the BRT impact were compared with those without the BRT impact and summarized in Figure 6-1.

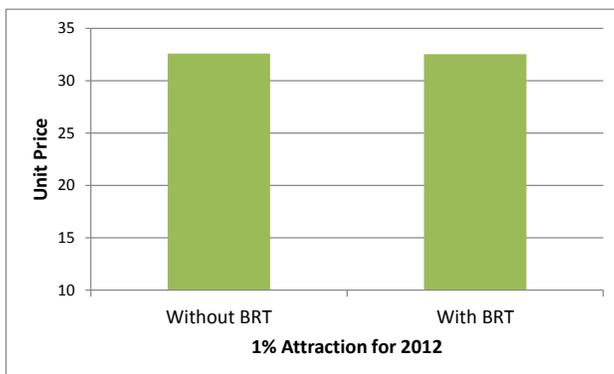
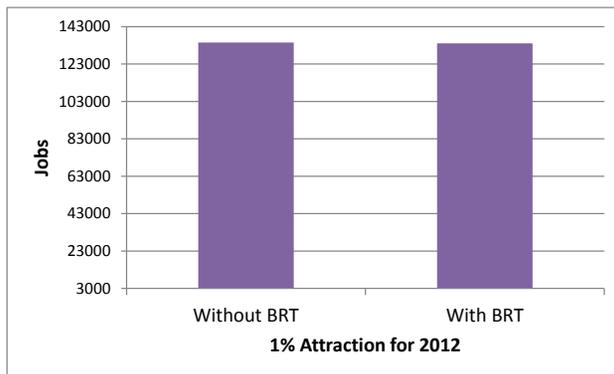
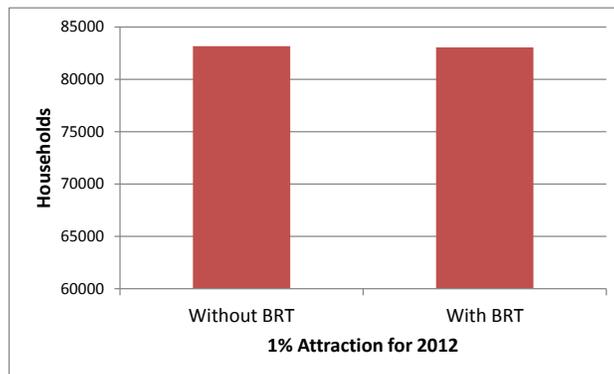
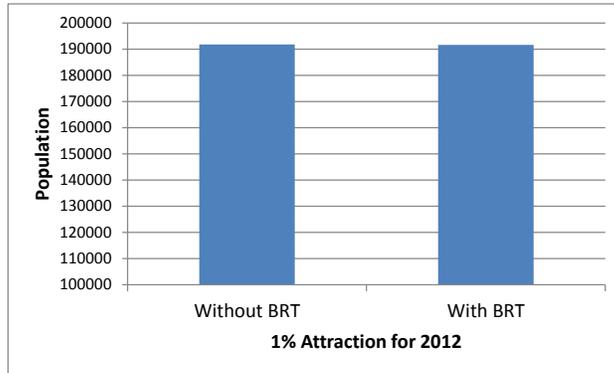


Figure 6-1 Land Use Patterns With and Without Implementation of BRT (1% Trip Attraction) in 2012

Figure 6-1 shows that implementing the BRT route (assuming 1% trip attraction) had no significant impact on land use patterns in the study zones in 2012. The population, households, jobs, and unit price were almost equal (difference < 1%) with and without implementing the BRT route with 1% trip attraction in a short-term period (2010-2012).

The spatial difference of land use patterns (population, household, jobs) due to implementing the BRT service in 2012 is shown in Figures 6-2 to 6-5. The calculation equation is given as:

$$\text{Difference} = \text{Measure with BRT (x\% Trip Attraction)} - \text{Measure without BRT} \quad (21)$$

where x=1 or 5

The variety of population, households, and jobs due to the BRT service is complex: the measures may increase in some zones, decrease in other zones, or remain constant with and without implementing the BRT service. The measure of unit price is the same in a great portion of the zones with and without the BRT service.

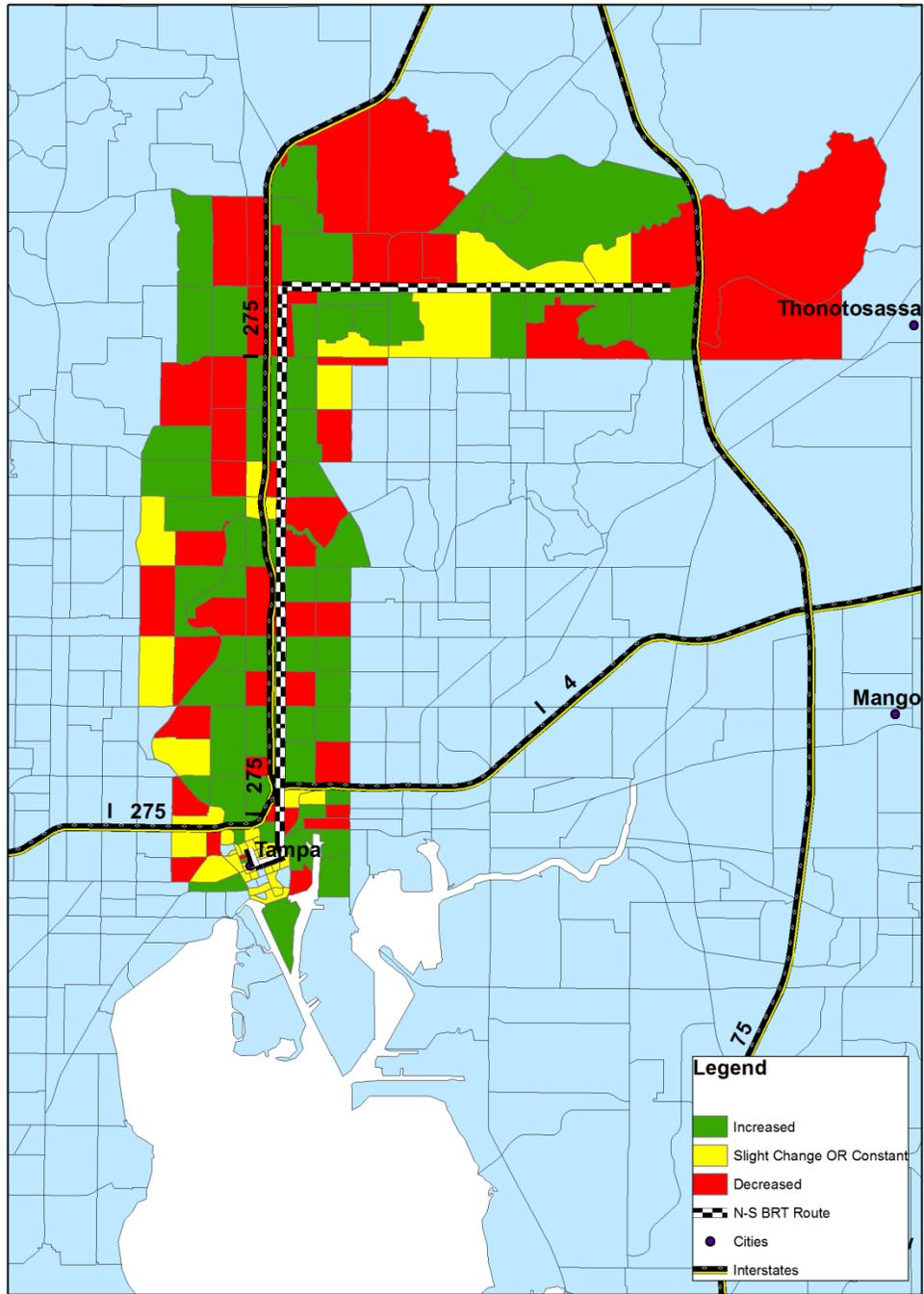


Figure 6-2 Zonal Change in Population due to Implementation of BRT (1% Trip Attraction) in 2012

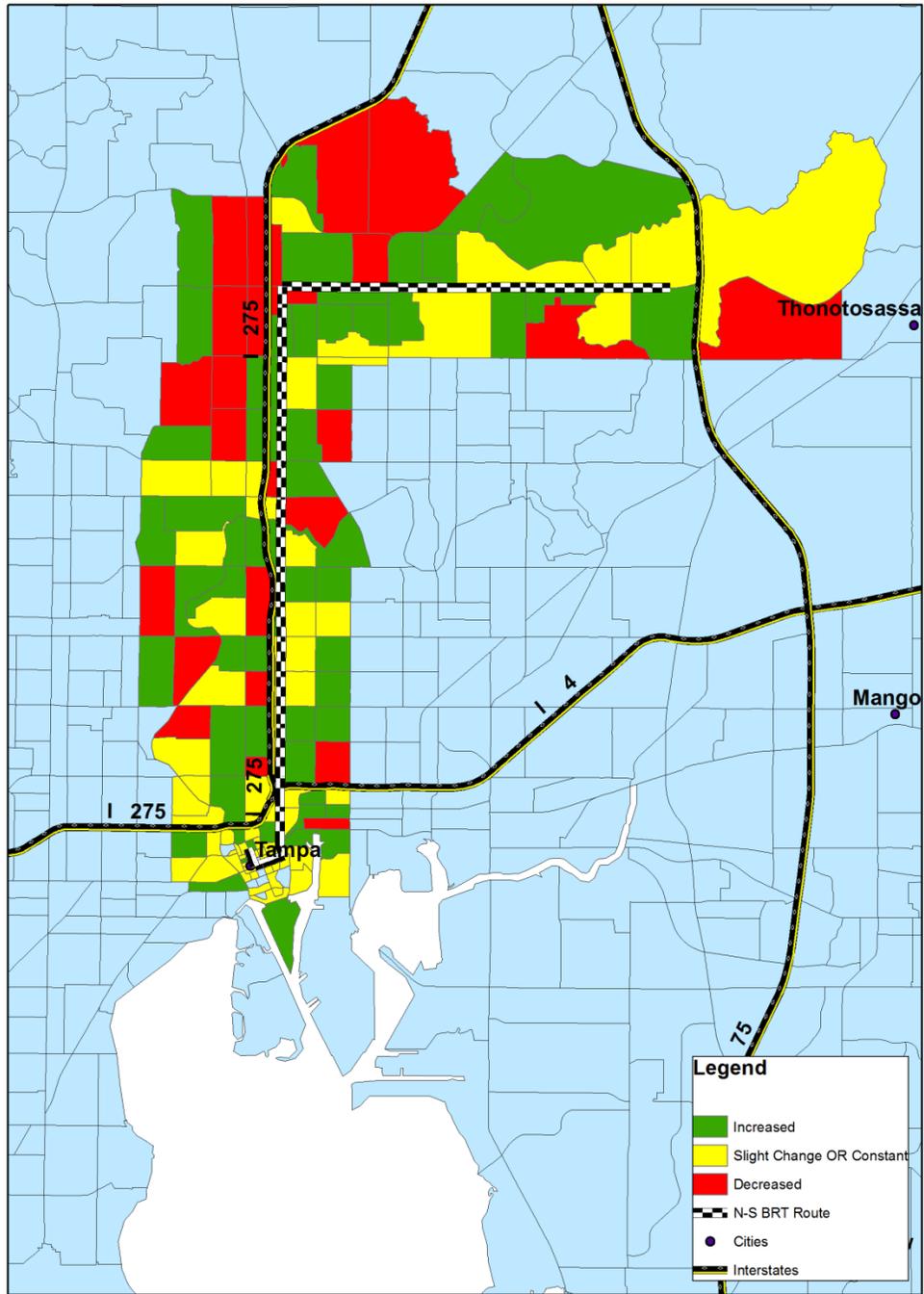


Figure 6-3 Zonal Change in Households Due to Implementation of BRT (1% Trip Attraction) in 2012

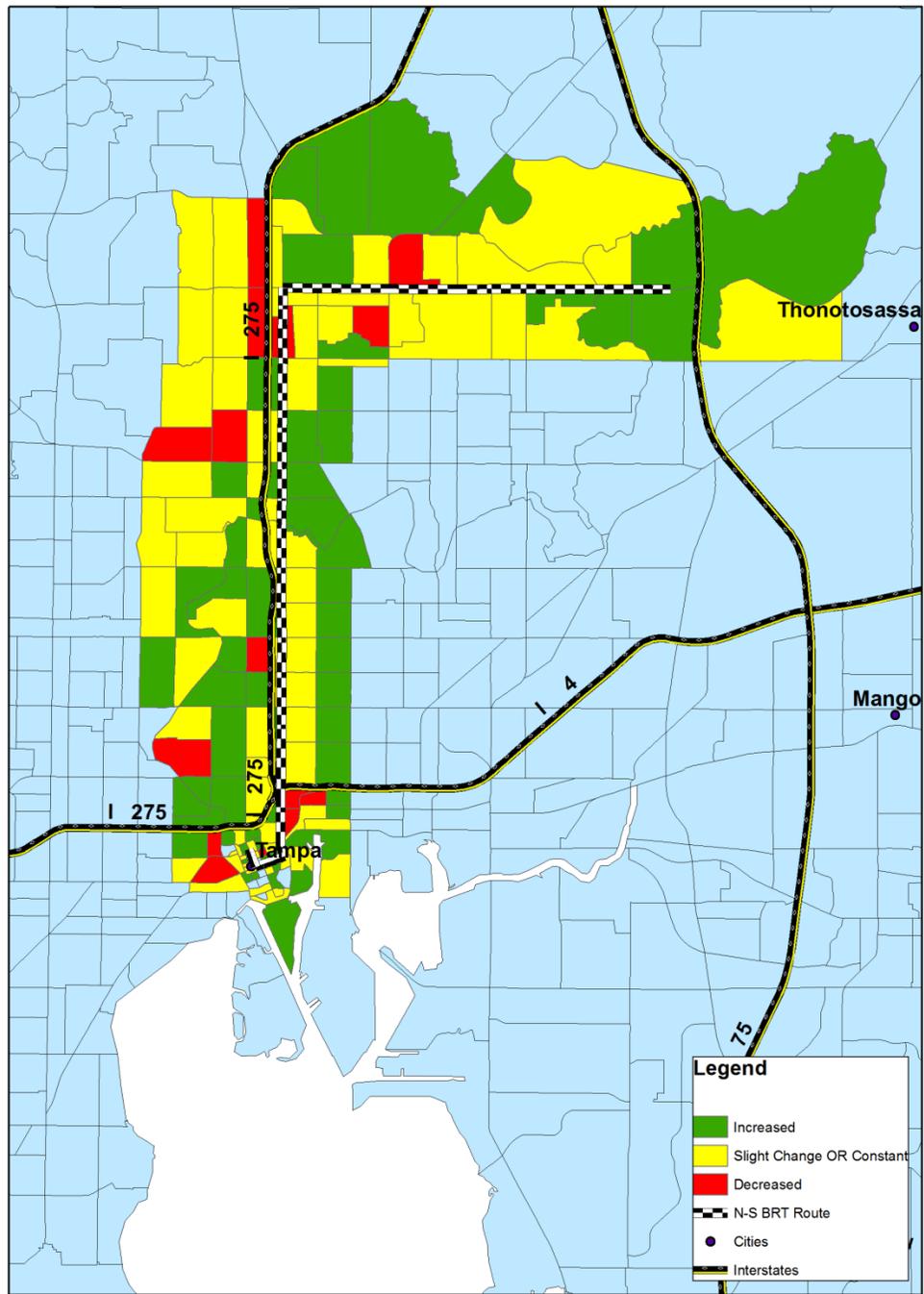


Figure 6-4 Zonal Change in Jobs due to Implementation of BRT (1% Trip Attraction) in 2012

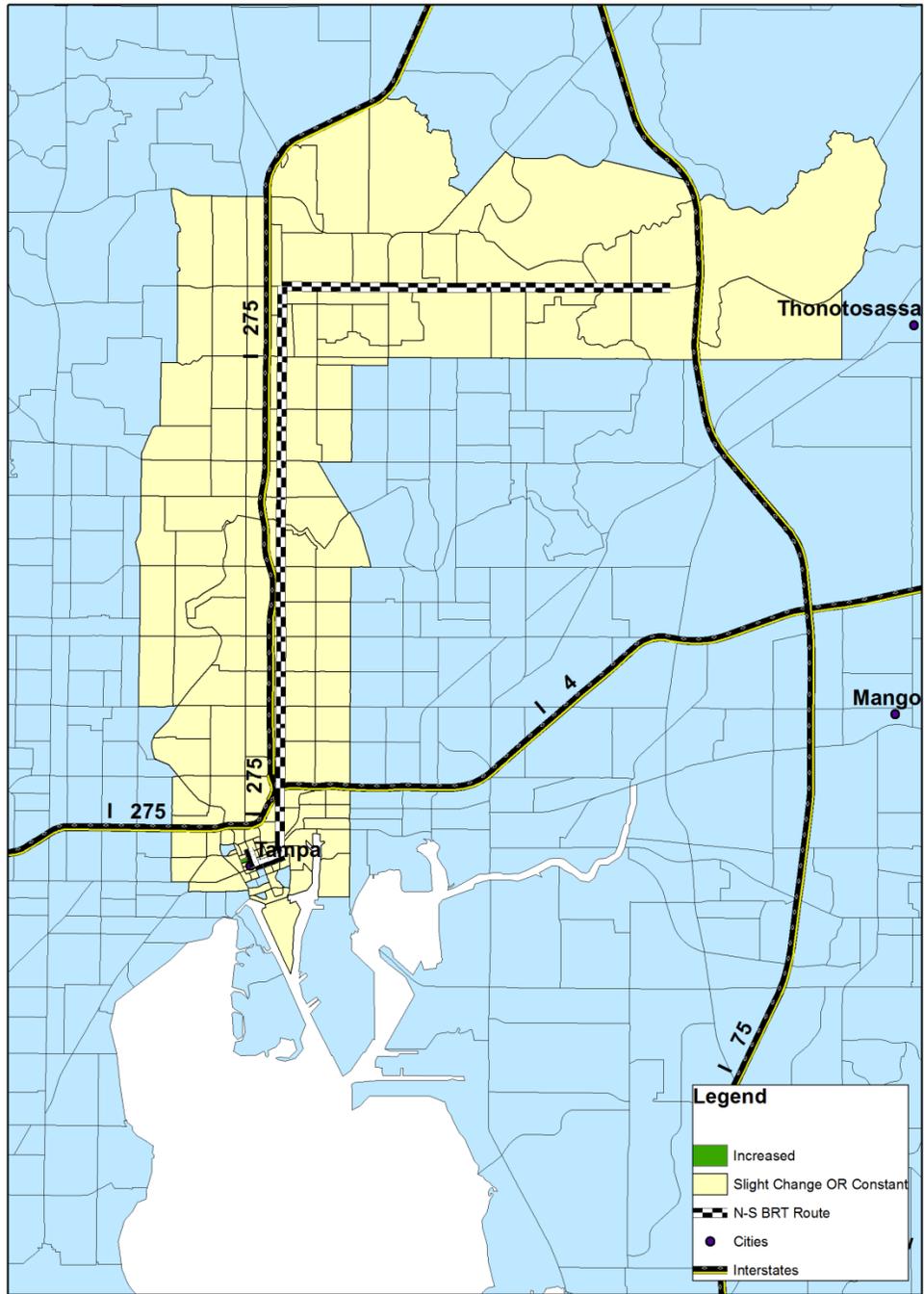


Figure 6-5 Zonal Change in Unit Price due to Implementation of BRT (1% Trip Attraction) in 2012

6.2 Scenario 2 (The BRT route with a five percent trip attraction in a short-period projection)

The 2012 traffic patterns were revised using the method described in Section 6.1 assuming that the BRT route attracted five percent of trips from auto trips within the study zones. The scenario of the BRT with a five percent trip attraction in a short-period projection (2010-2012) was created and examined using the UrbanSim model. The comparison of population, households, jobs, and unit price with and without implementation of the BRT route (5% trip attraction) for 2012 is shown in Figure 6-6.

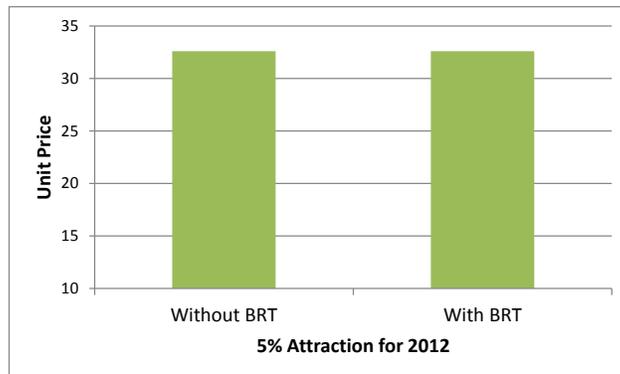
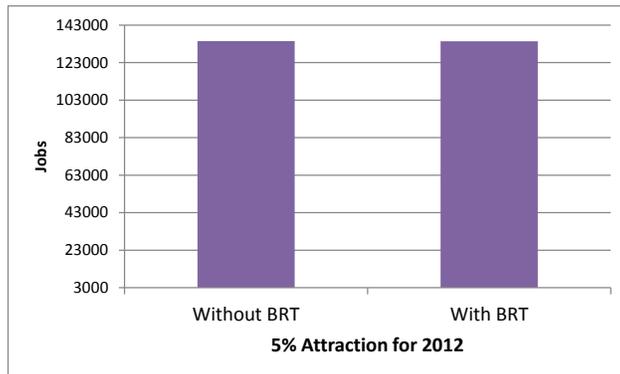
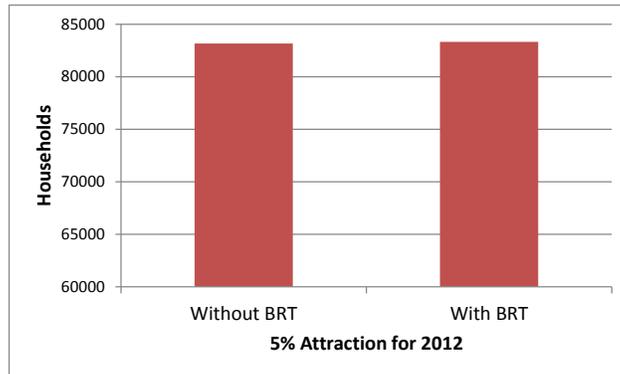
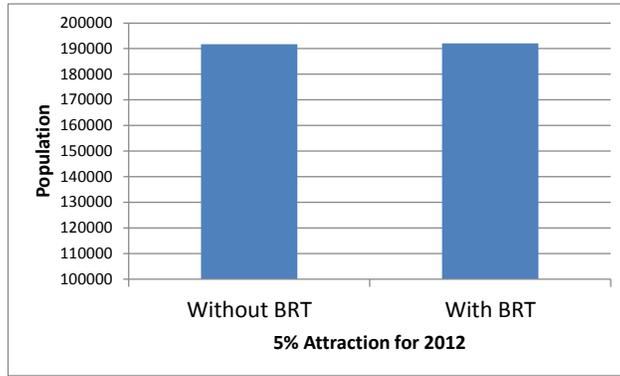


Figure 6-6 Land Use Patterns With and Without Implementation of BRT (5% Trip Attraction) in 2012

Figure 6-6 shows that implementation of the BRT route increases population and households in the study zones in 2012; however, the increase is very small and can be ignored (the population increases by 0.1%, and the households increase by 0.2%). The jobs and unit price with and without implementation the BRT route with 5% trip attraction are almost equal.

The spatial changes in zonal population, households, and jobs due to the BRT service are displayed in Figures 6-7 to 6-10. It can be seen that with a five percent trip attraction, there are more zones that have an increase in population, households, jobs, and housing unit price than the zones with a one percent trip attraction. It can also be seen that with a five percent trip attraction, the number of zones that have a decrease in population, households, jobs and land unit price is less than those with one percent trip attraction. .

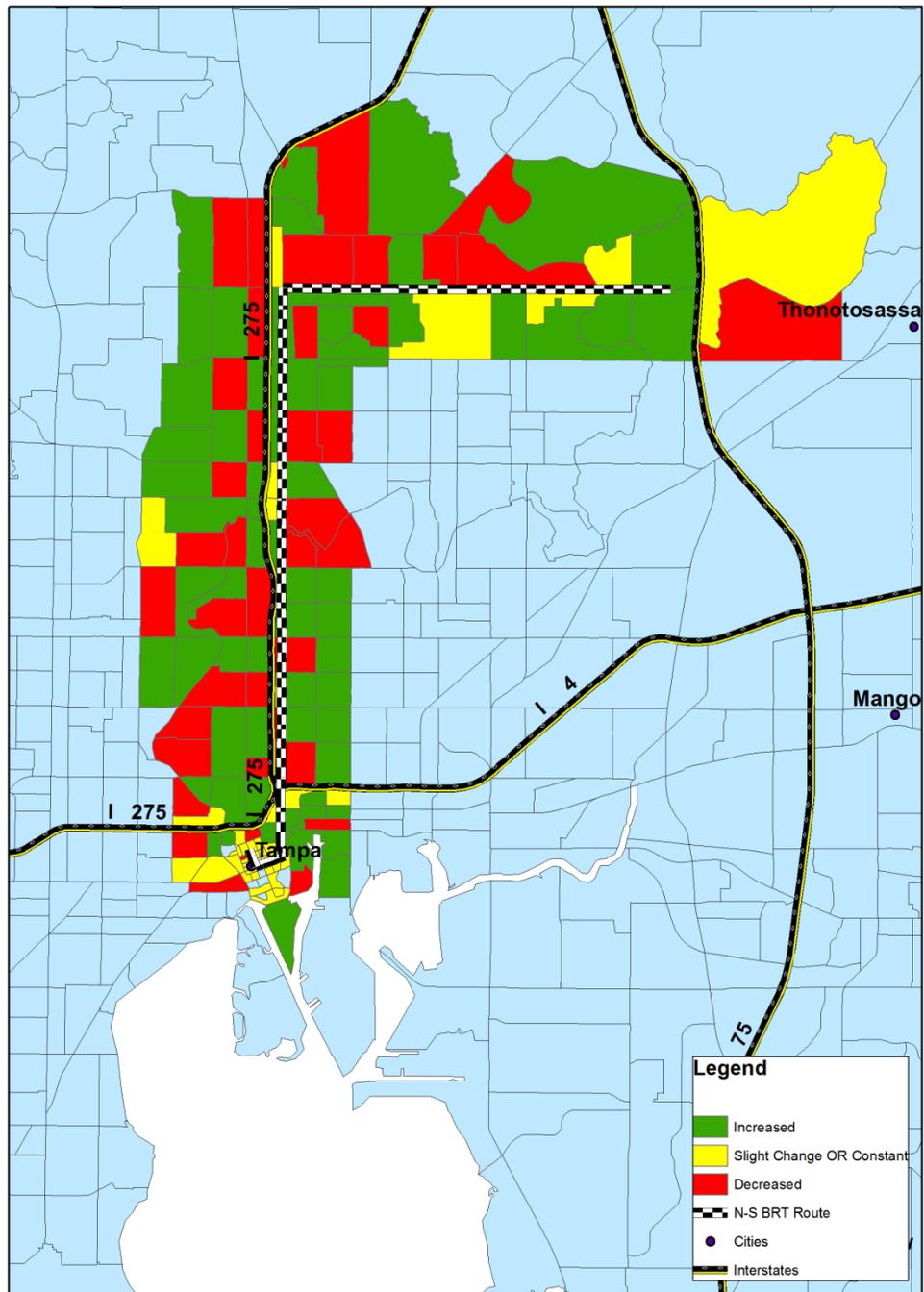


Figure 6-7 Zonal Change in Population due to Implementation of BRT (5% Trip Attraction) in 2012

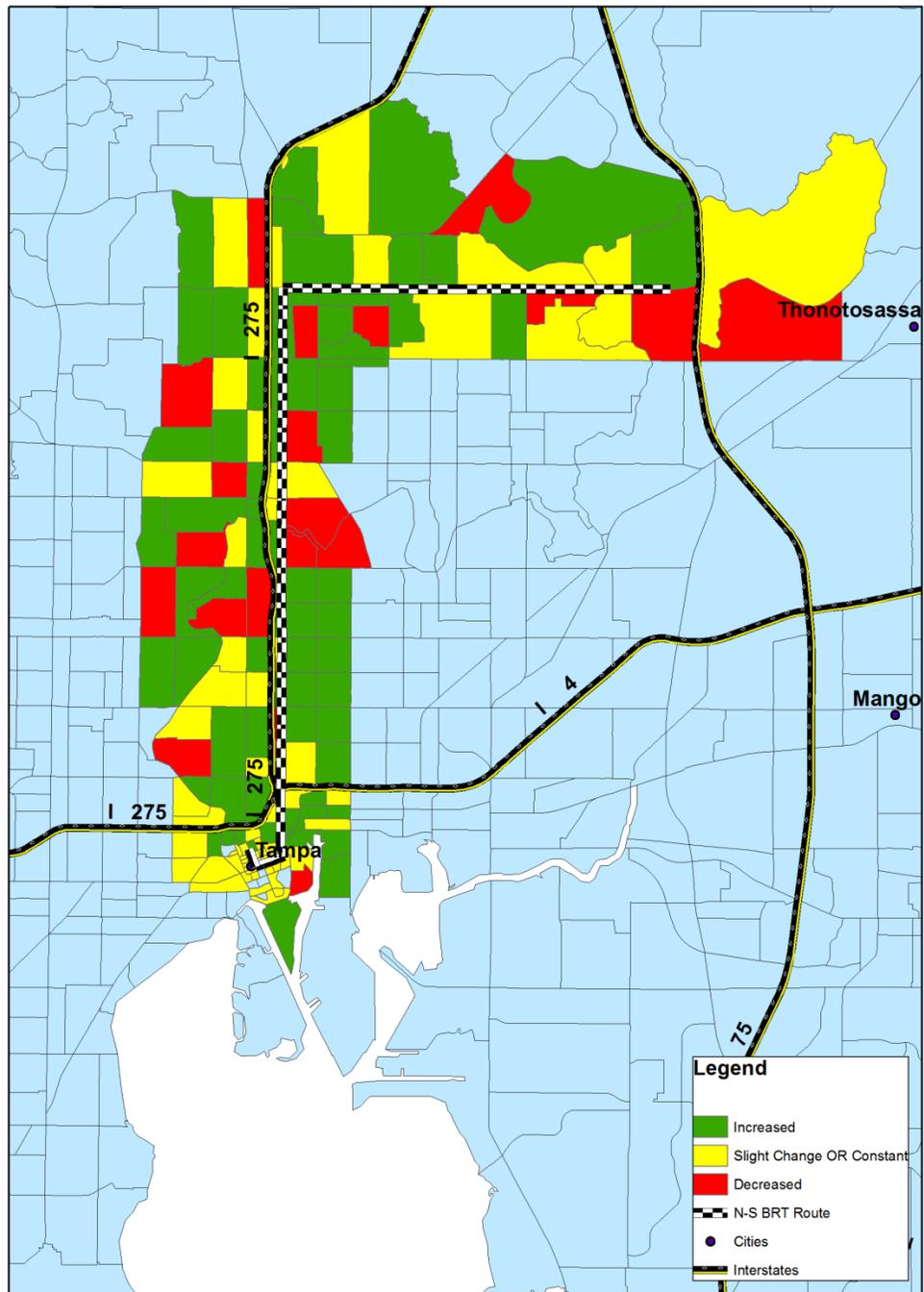


Figure 6-8 Zonal Change in Households due to Implementation of BRT (5% Trip Attraction) in 2012

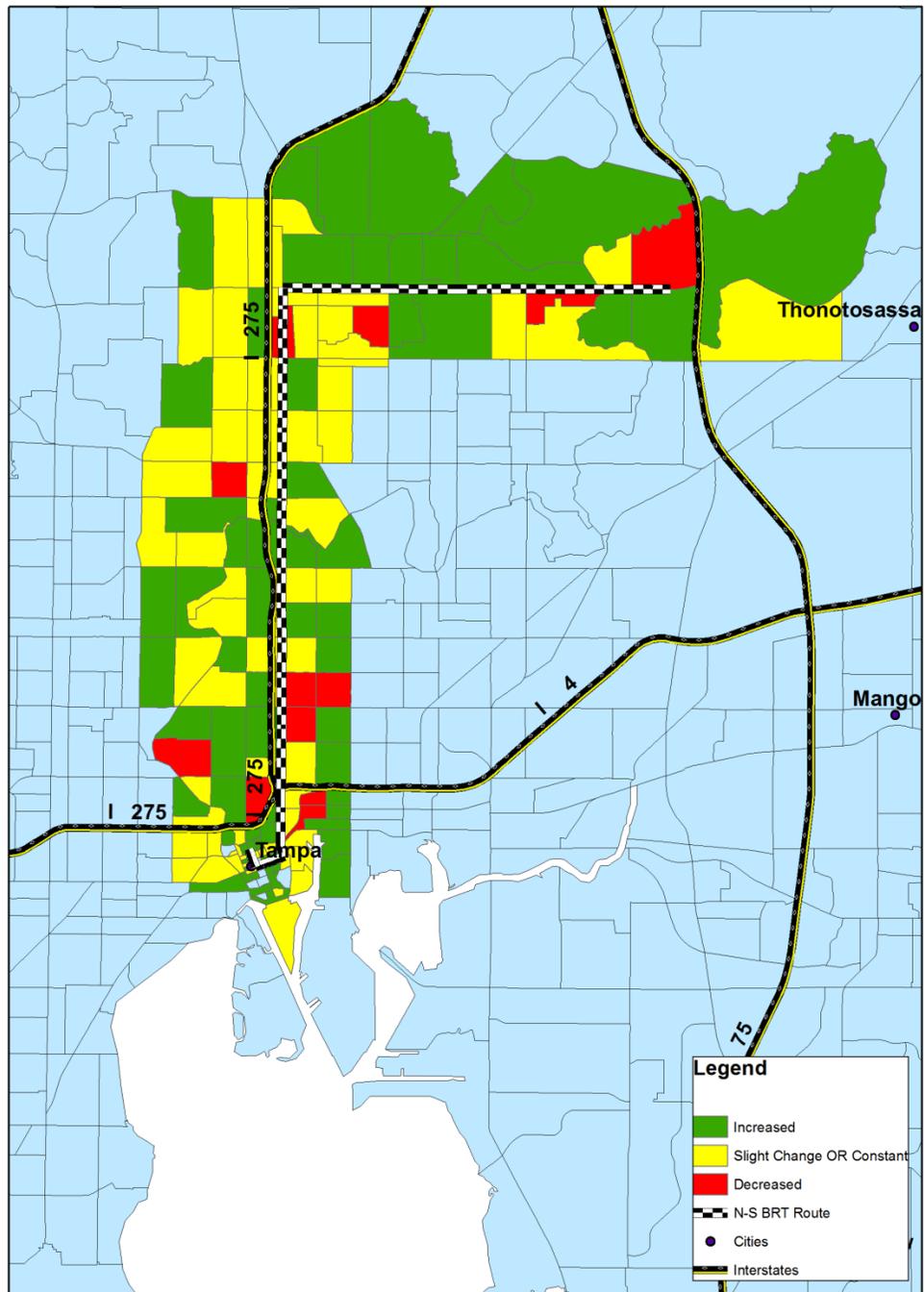


Figure 6-9 Zonal Change in Jobs due to Implementation of BRT (5% Trip Attraction) in 2012

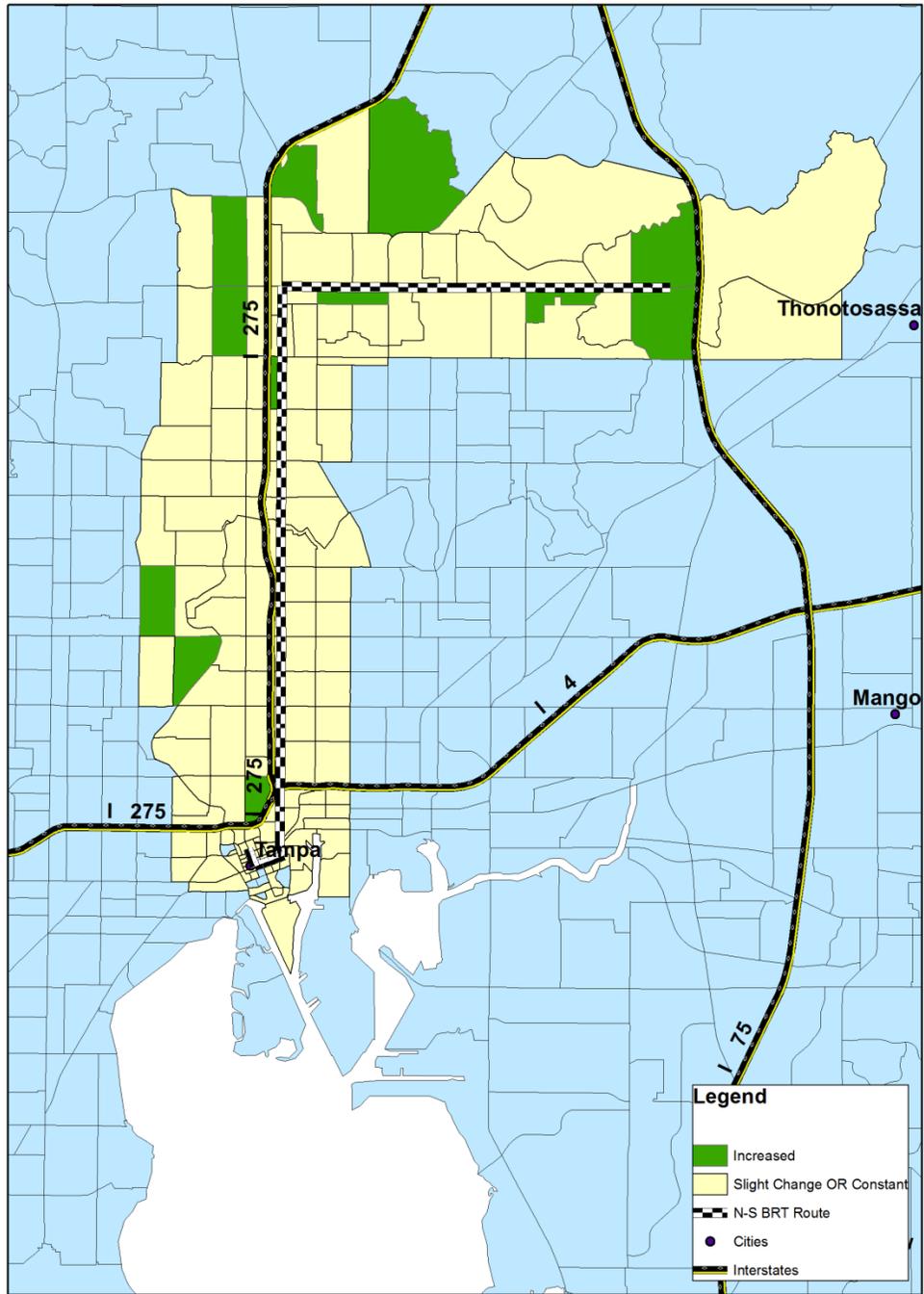


Figure 6-10 Zonal Change in Unit Price due to Implementation of BRT (5% Trip Attraction) in 2012

6.3 Scenario 3 (The BRT route with a one percent trip attraction in a long-period projection)

The traffic patterns of 2020 were revised using the method described in Section 6.1 assuming that the BRT route attracted one percent of the trips from auto trips within the study zones. The scenario of the BRT with a one percent trip attraction in a long-period projection was created and examined using the UrbanSim model. The comparison of population, households, jobs, and unit price with and without implementation of the BRT route (1% trip attraction) for a long-term period (2010-2020) is shown in Figure 6-11.

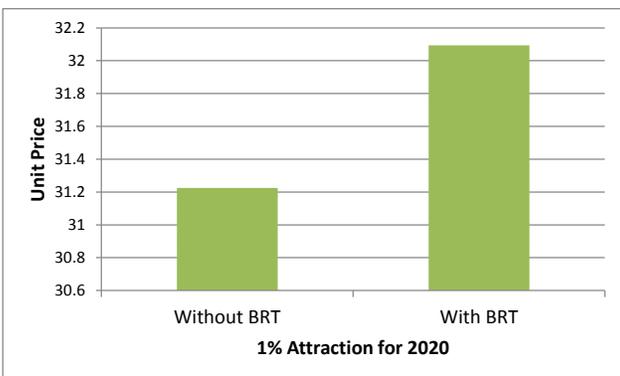
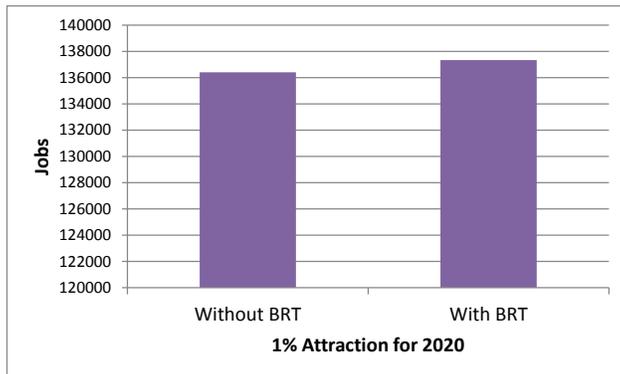
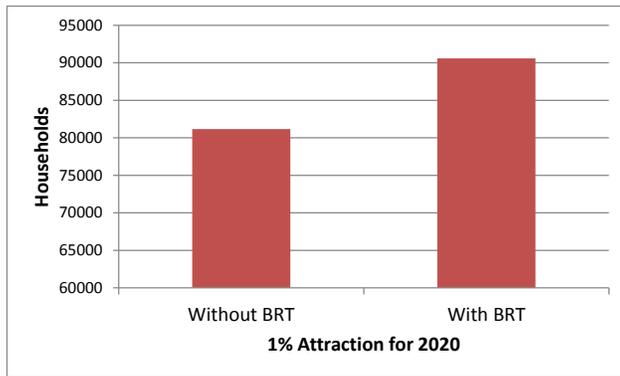
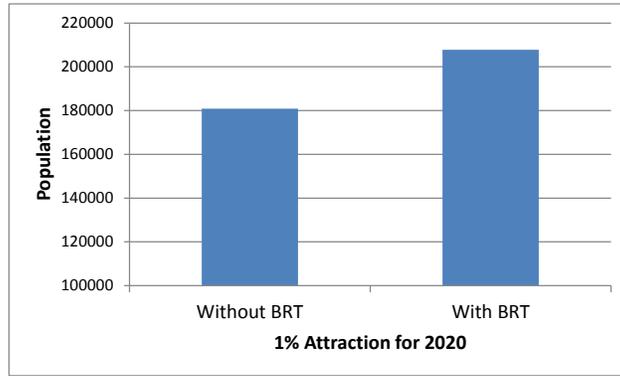


Figure 6-11 Land Use Patterns With and Without Implementation of BRT (1% Trip attraction) in 2020

Figure 6-11 shows that implementation of the BRT route (assuming 1% trip attraction) increases population, households, unit price, and jobs in the study zones in 2020. The population increased by 15%; households increased by 12%; unit price increased by 3%; and jobs increased by 0.68%. The spatial differences of the four zonal land use patterns are displayed in Figures 6-12 to 6-15.

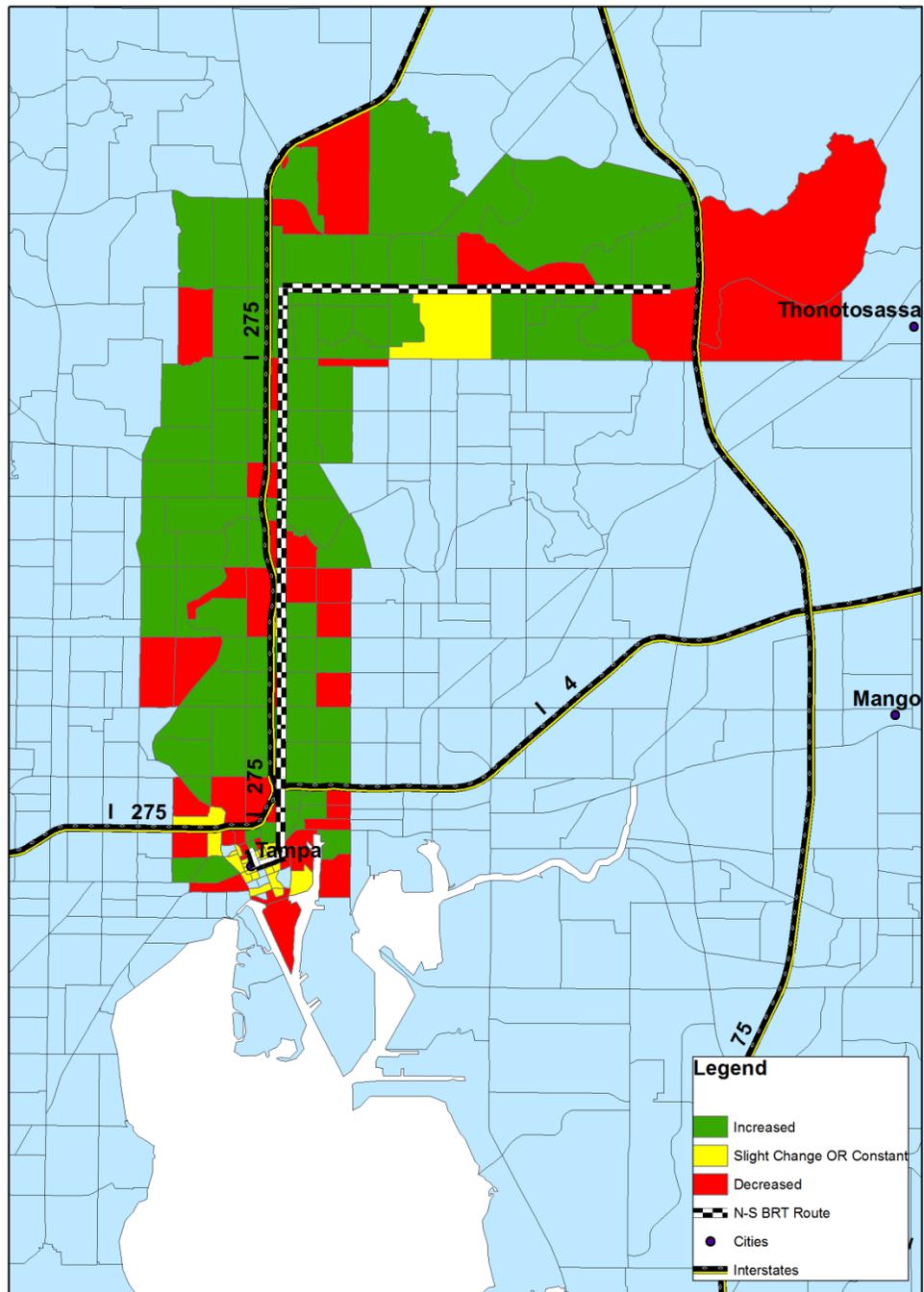


Figure 6-12 Zonal Change in Population due to Implementation of BRT (1% Trip Attraction) in 2020

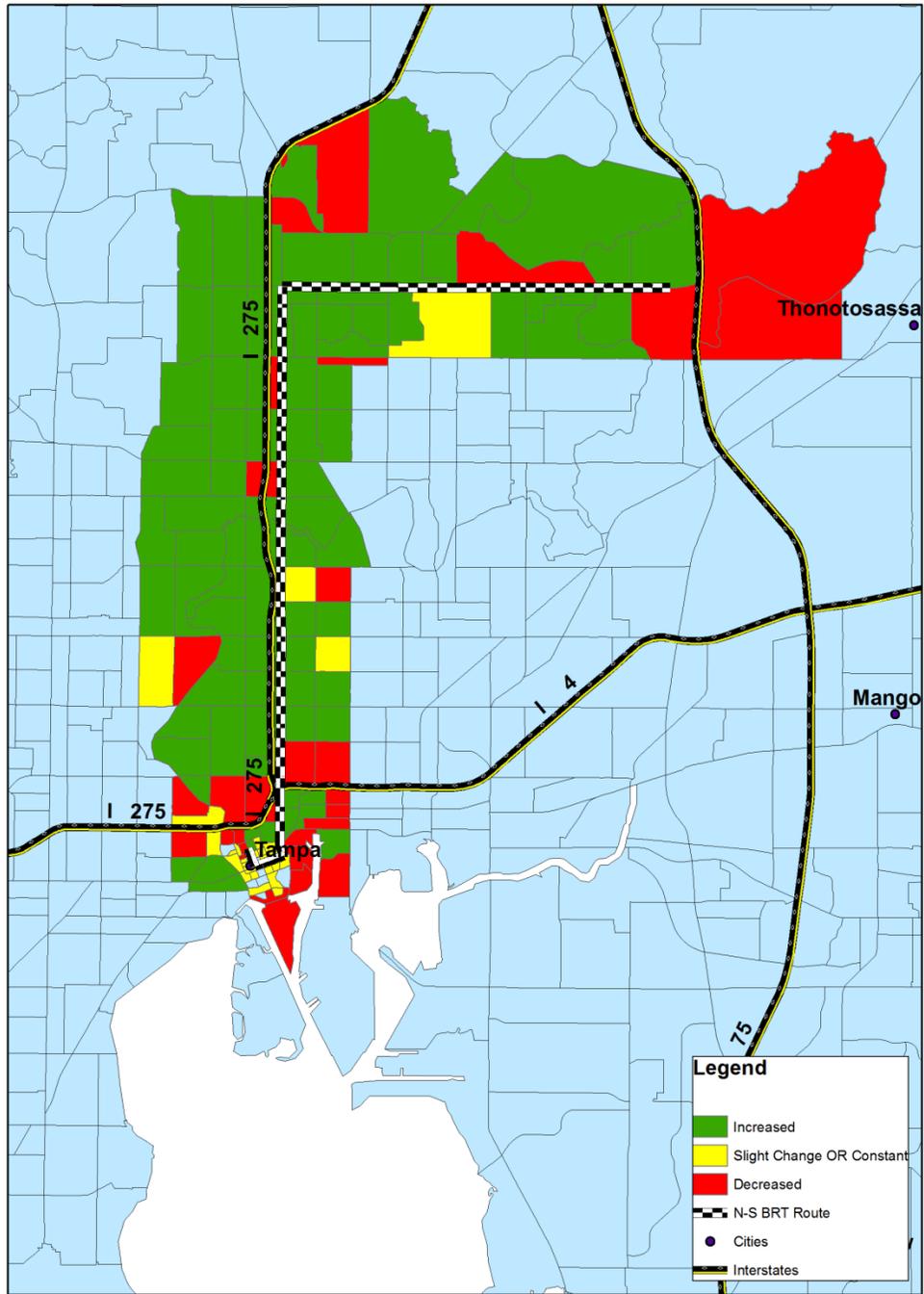


Figure 6-13 Zonal Change in Households due to Implementation of BRT (1% Trip Attraction) in 2020

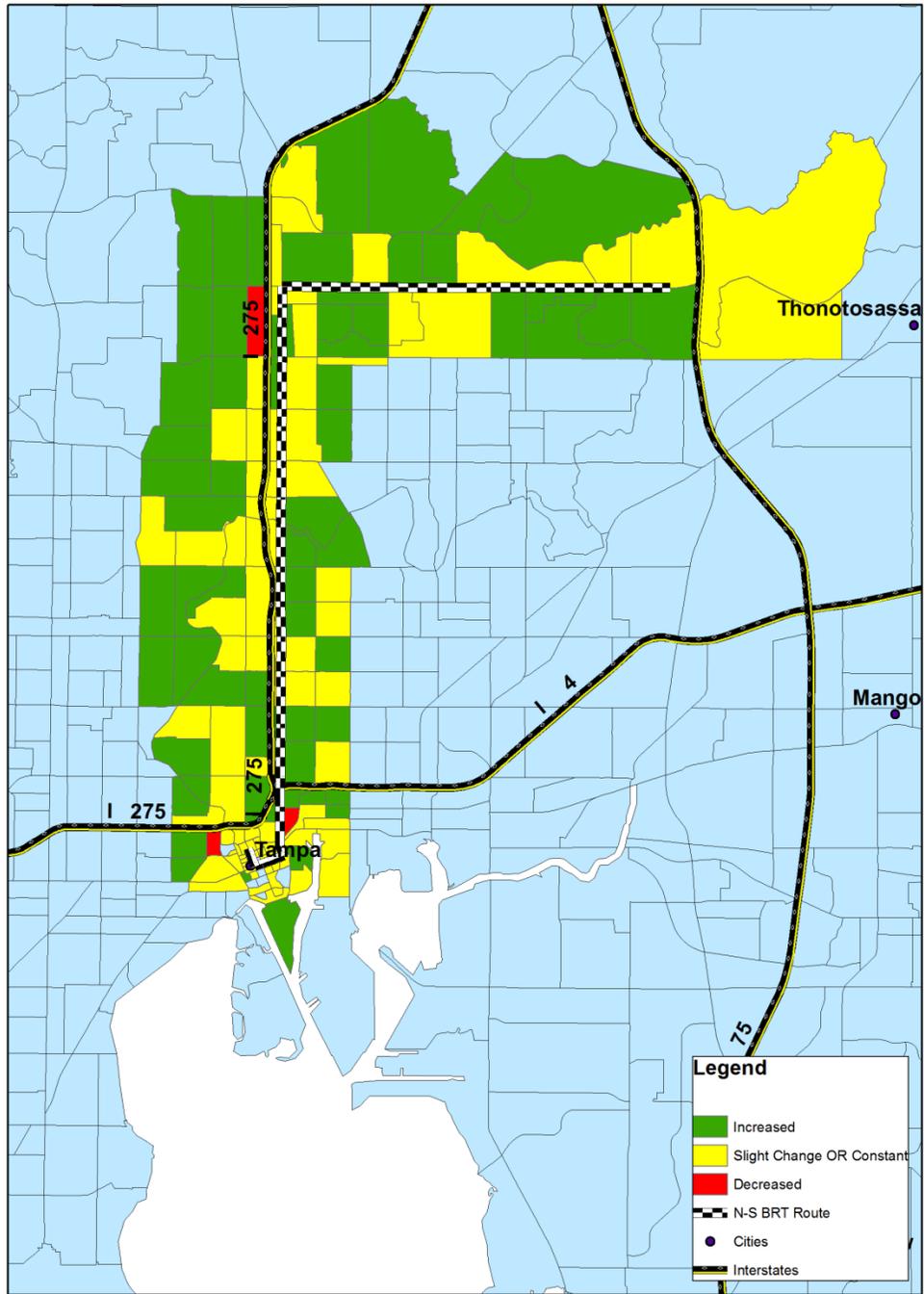


Figure 6-14 Zonal Change in Jobs due to Implementation of BRT (1% Trip Attraction) in 2020

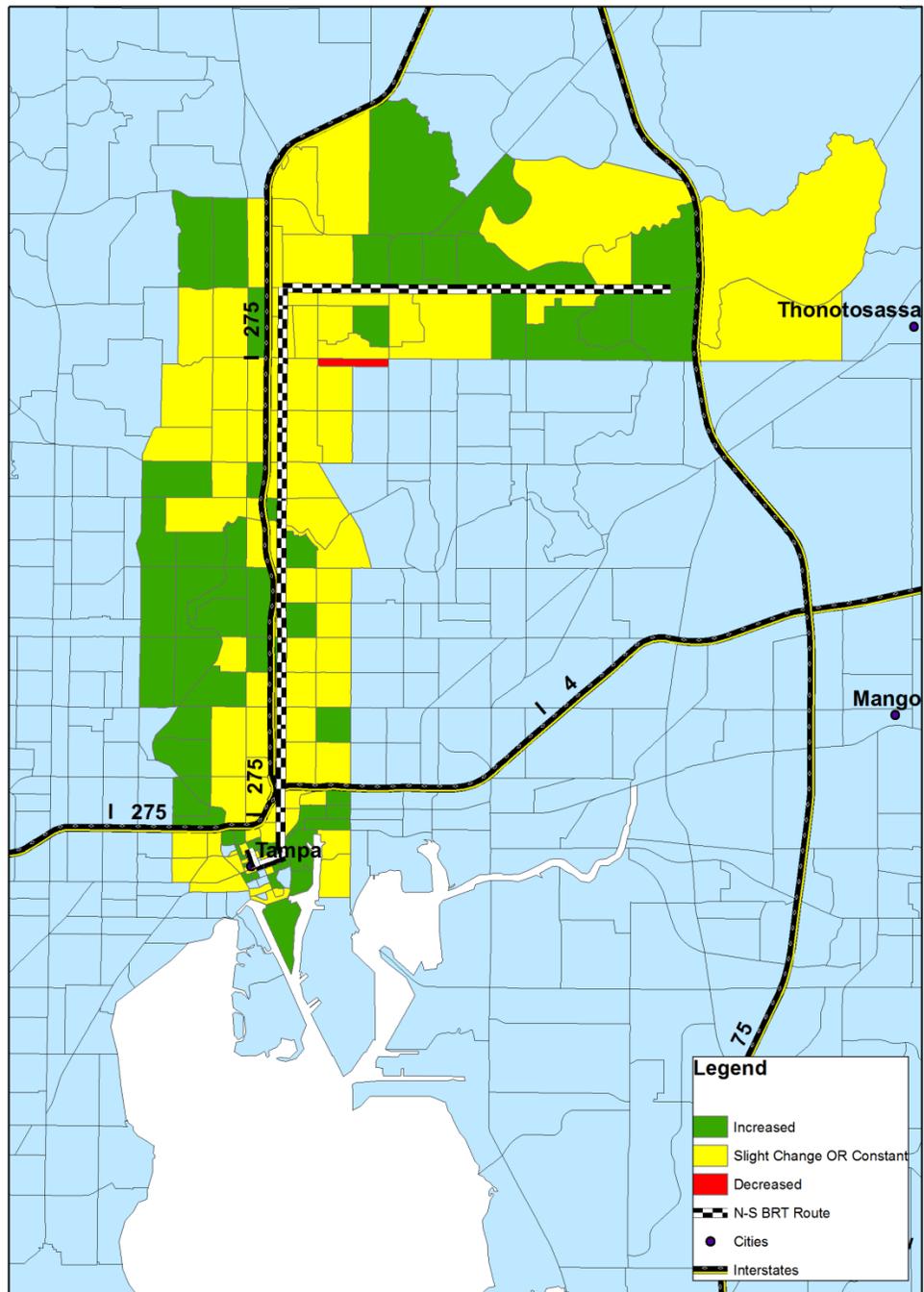


Figure 6-15 Zonal Change in Unit Price due to Implementation of BRT (1% Trip Attraction) in 2020

6.4 Scenario 4 (The BRT route with a five percent trip attraction in a long-period projection)

The traffic patterns of 2020 were revised using the method described in Section 6.1 assuming that the BRT route attracted five percent of the trips from auto trips within the study zones. The scenario of the BRT with a five percent trip attraction in a long-period projection was created and examined using the UrbanSim model. The comparison of population, households, jobs, and unit price with and without implementation of the BRT route (5% trip attraction) for 2020 is shown in Figure 6-16.

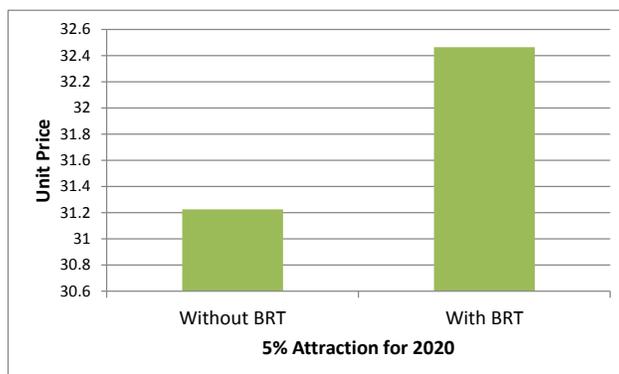
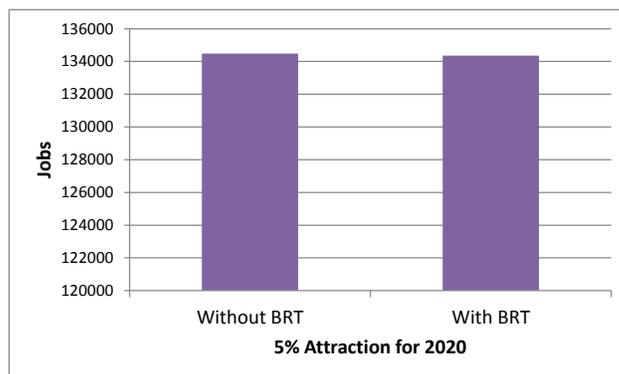
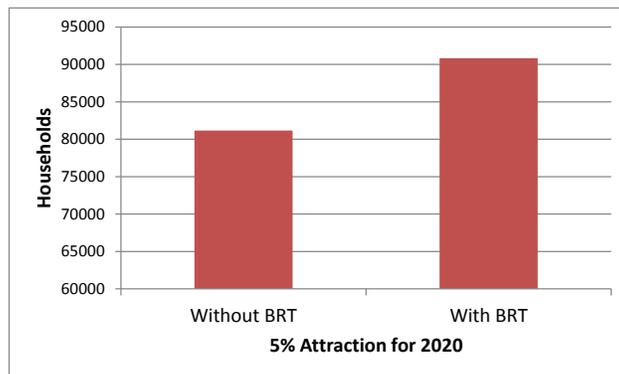
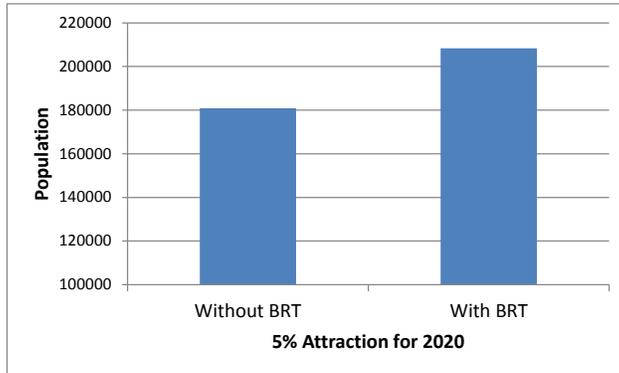


Figure 6-16 Land Use Patterns With and Without Implementation of BRT (5% Trip Attraction) in 2020

Figure 6-16 shows that implementation of the BRT route (assuming 5% trip attraction) increases population, households, and jobs in the study zones in 2020. The population increased by 15%; households increased by 12%; unit price increased by 4%; and jobs increased by 0.85%. The spatial differences of zonal land use patterns are displayed in Figures 6-17 to 6-20.

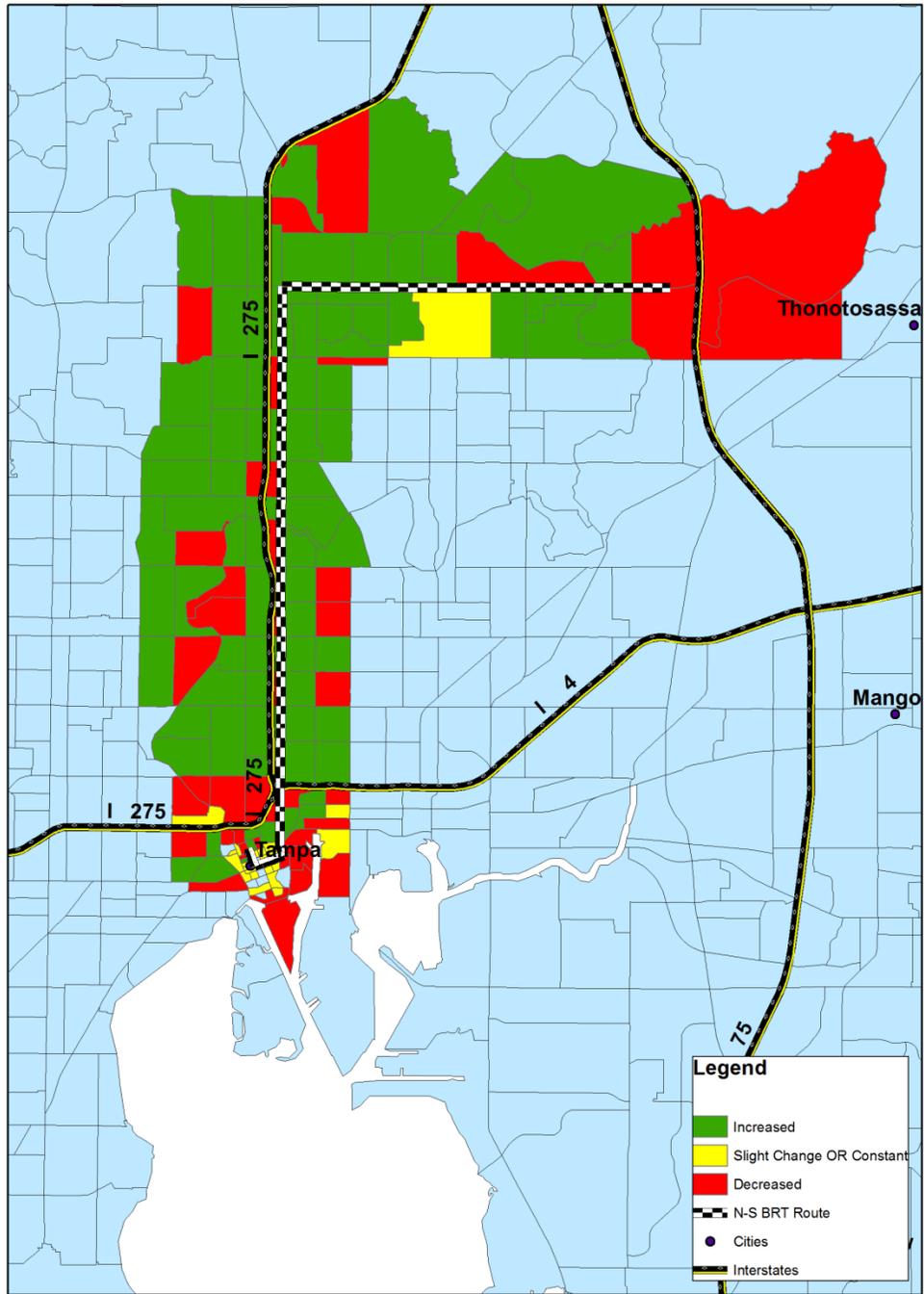


Figure 6-17 Zonal Change in Population due to Implementation of BRT (5% Trip Attraction) in 2020

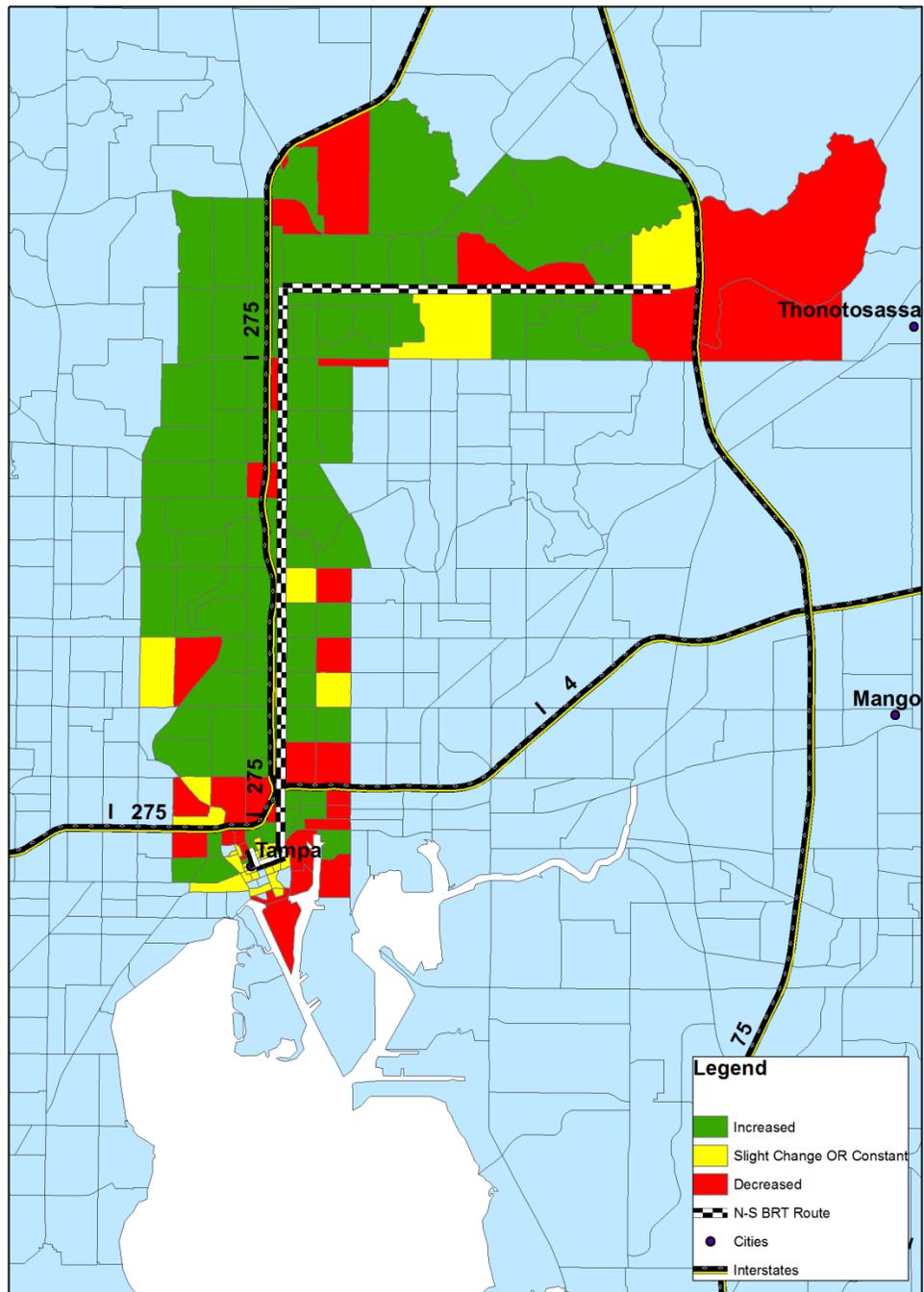


Figure 6-18 Zonal Change in Households due to Implementation of BRT (5% Trip Attraction) in 2020

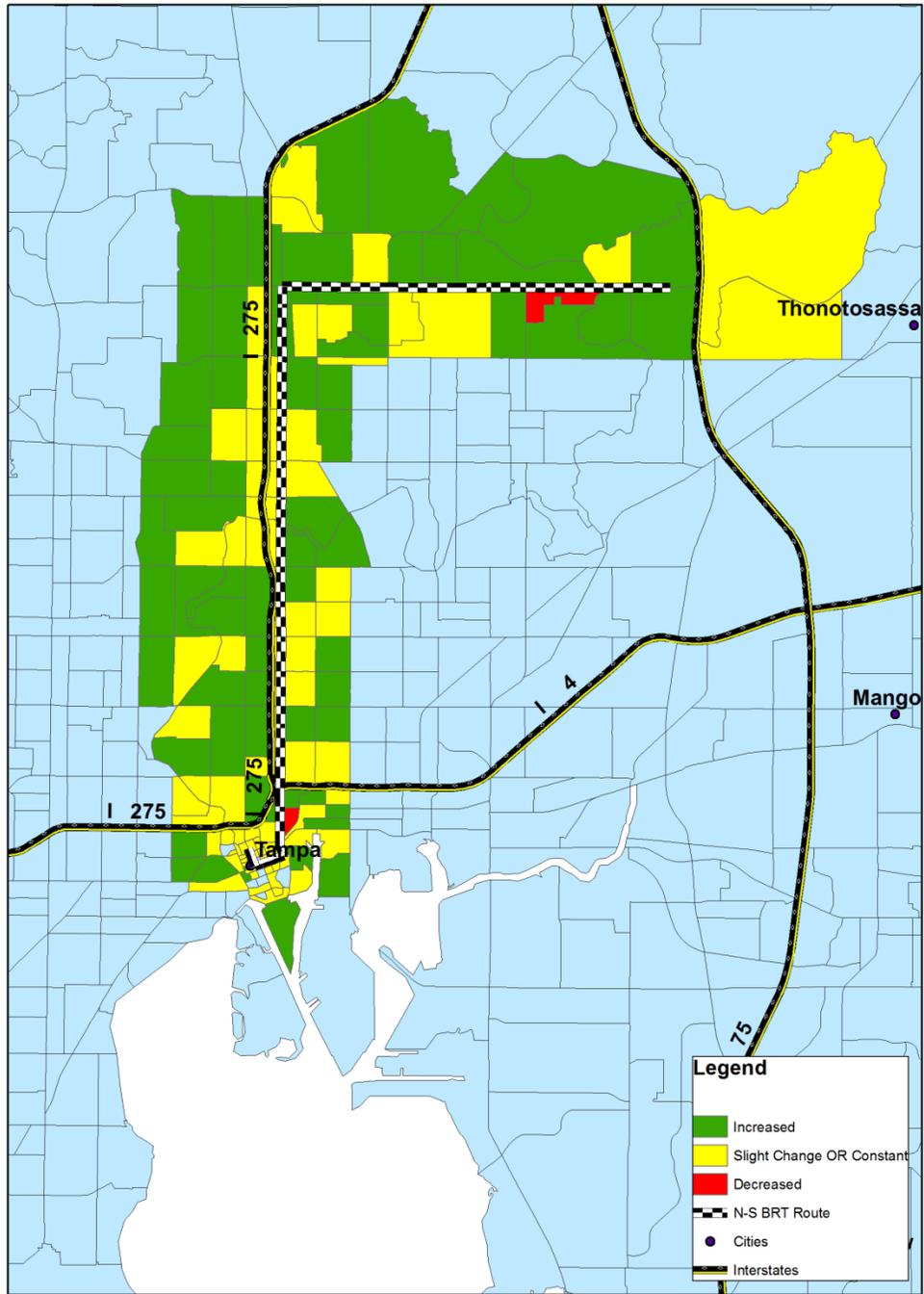


Figure 6-19 Zonal Change in in Jobs due to Implementation of BRT (5% Trip Attraction) in 2020

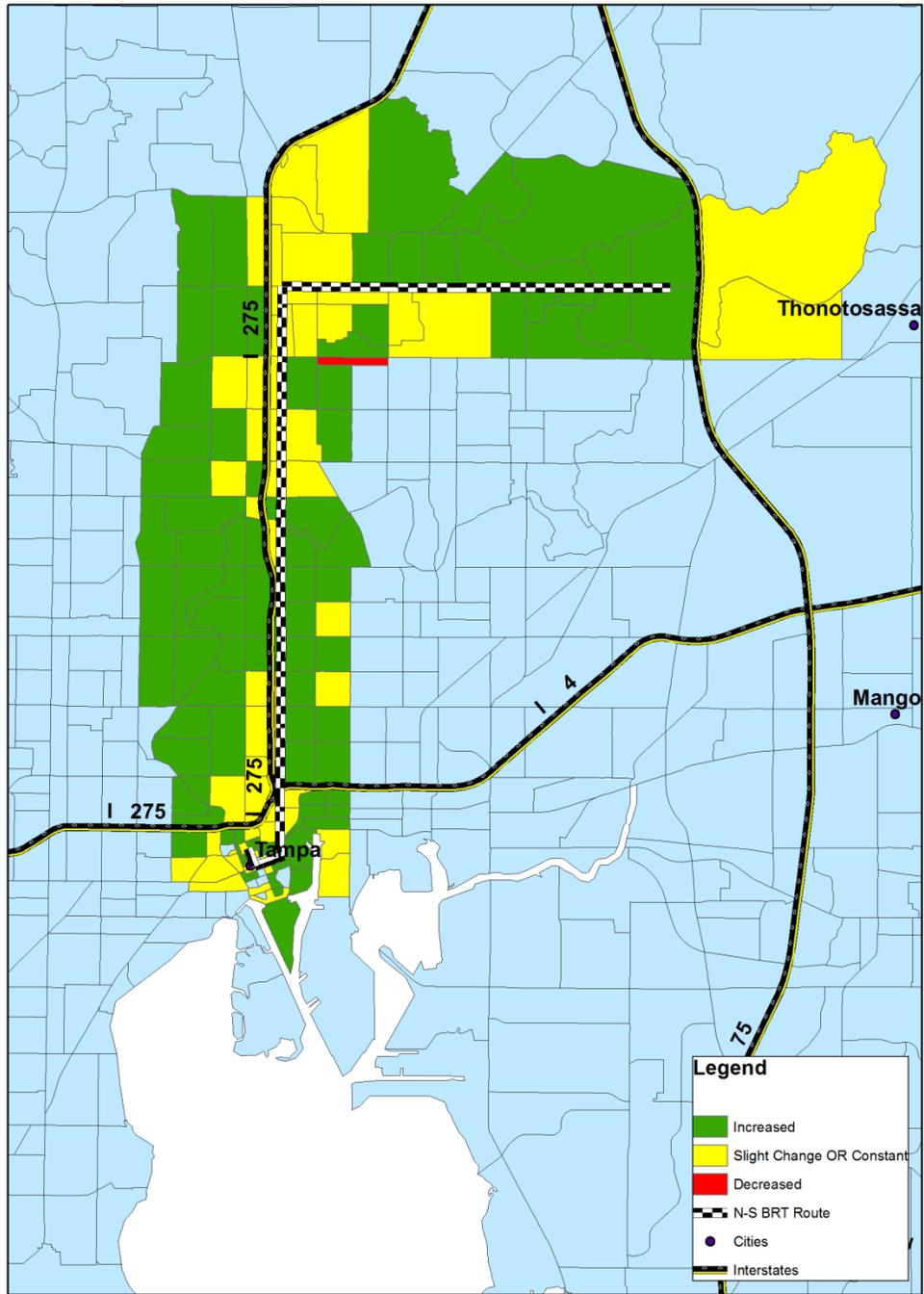


Figure 6-20 Zonal Change in Unit Price due to Implementation of BRT (5% Trip Attraction) in 2020

6.5 Analysis

Based on the simulation results, it was learned that implementation of the North-South BRT route will introduce a complex transformation in land use patterns. Time is the most important factor contributing to the land use transformation. As shown in Figure 6-21, the changes in population, households, unit price, and jobs due to implementation of the BRT service are close to zero (<1%) in 2012, assuming one percent and five percent trip attraction. It appears that land use patterns are not sensitive to the implementation of the BRT service in a short-term period.

However, in 2020, the differences in population, households, and unit price due to implementation of the BRT service are significant. The average increases in percentages are 15% (population), 12% (households), and 3.57% (unit price) within the study zones. The increasing percentages of jobs due to the BRT service in 2020 are 0.68% (1% trip attraction) and 0.85% (5% trip attraction). From these results, it can be said that the BRT service has a significant impact on the land use patterns (population, households, and unit price) in a long-term period.

Compared to the impacts of the BRT investment on jobs and housing unit prices (4% and less than 1% respectively), the impacts on population and households in 2020 were larger (15% and 12% respectively). In UrbanSim, population and households are predicted by the Household Location Choice Model which adopted a system default structure and coefficients in this study due to the lack of survey data for Hillsborough County. A possible reason for the “large” impacts on population and households is the “non-localized” Household Location Choice Model. To improve the estimation accuracy, the Household Location Choice Model needs to be re-developed using localized structure and coefficients for Hillsborough County.

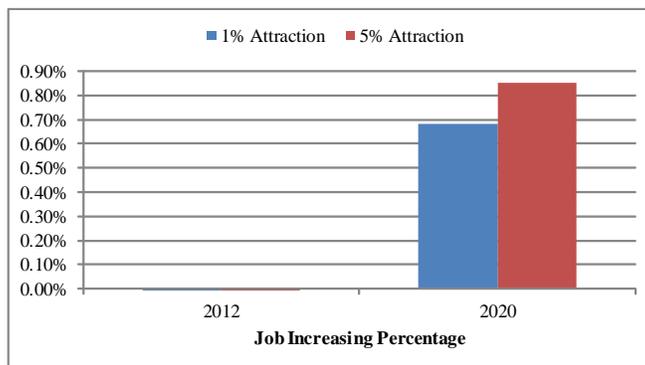
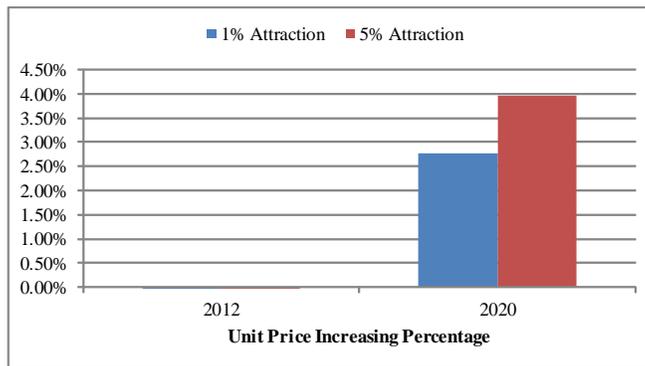
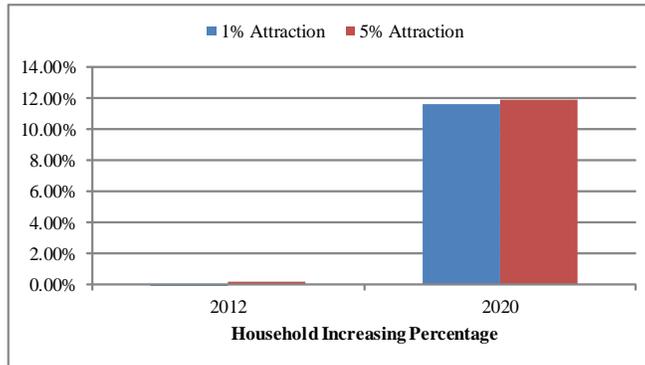
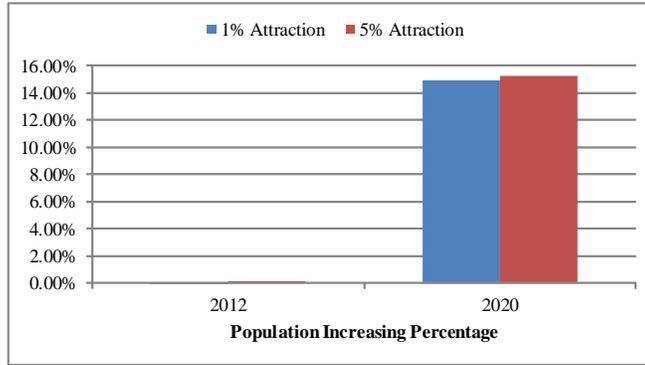


Figure 6-21 Changes in Land Use Pattern due to Implementation of BRT Service

7. Scenario Testing II (HART Route 2)

Another scenario testing was conducted to assess the impact of an upgrade of a bus route on land use in Hillsborough County. The HART Route 2, as shown in Figure 7-1, was selected for this test. The HART Route 2 includes two lines (North-to-South and South-to-North) that connect the two central ends: University Area Transit Center and Marion Transit Center, along the Nebraska corridor. In this study, it was assumed that Route 2 was upgraded to an express bus from its current mode. The major upgrades are shown in Table 7-1.

Table 7-1 Upgrade of Route 2

Item	Current	Upgrade
Mode	Local Bus	Express Bus
Peak Hour Headway	15 min	10 min
Peak-Off Headway	30 min	15 min

The Transit Network module of the TBRPM model was changed based on the upgrade plan. The TBRPM model was executed with the upgraded transit network to forecast the travel patterns for two target years (2012 and 2020). These travel patterns were imported into the UrbanSim model to predict the land use patterns in the two target years. The land use patterns were compared to those in the same years without the upgrade travel patterns to assess the impact of the upgrade on land use.

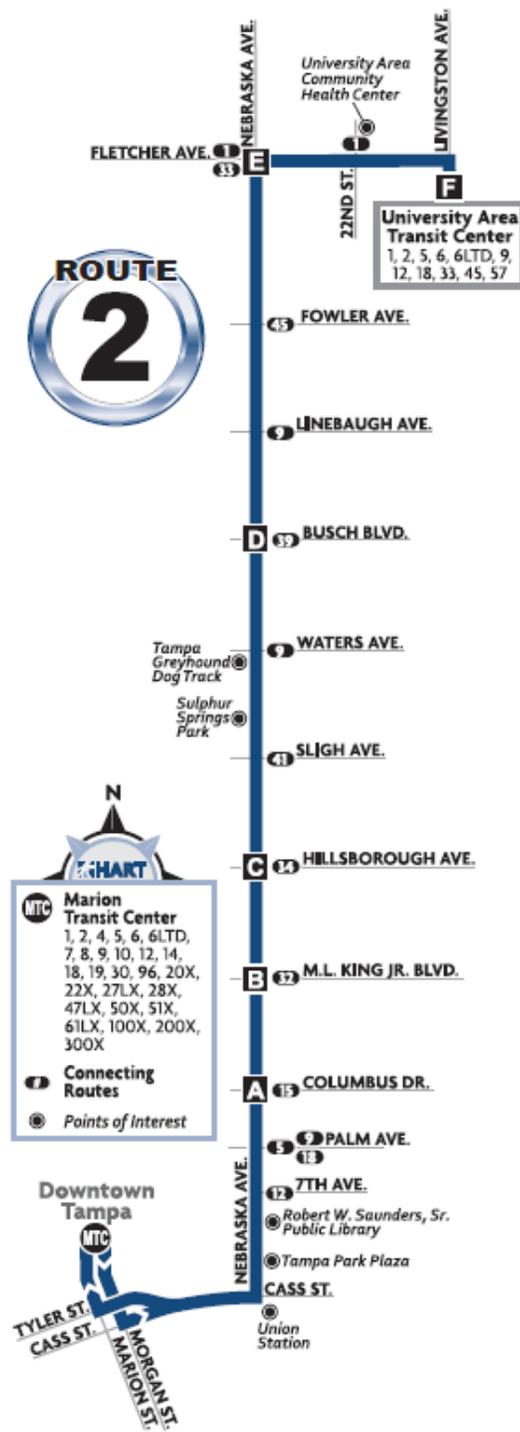


Figure 7-1 HART Route 2 (Source: <http://www.gohart.org>)

7.1 Study Zones

This study evaluated the impact of the HART Route 2 on its adjacent areas. These areas were delimited as the traffic analysis zones that are influenced by the route, as shown in Figure 7-2. The influence area is defined as the zones within a 2-mile radius around the route. In total, 70 zones were defined as the study zones.

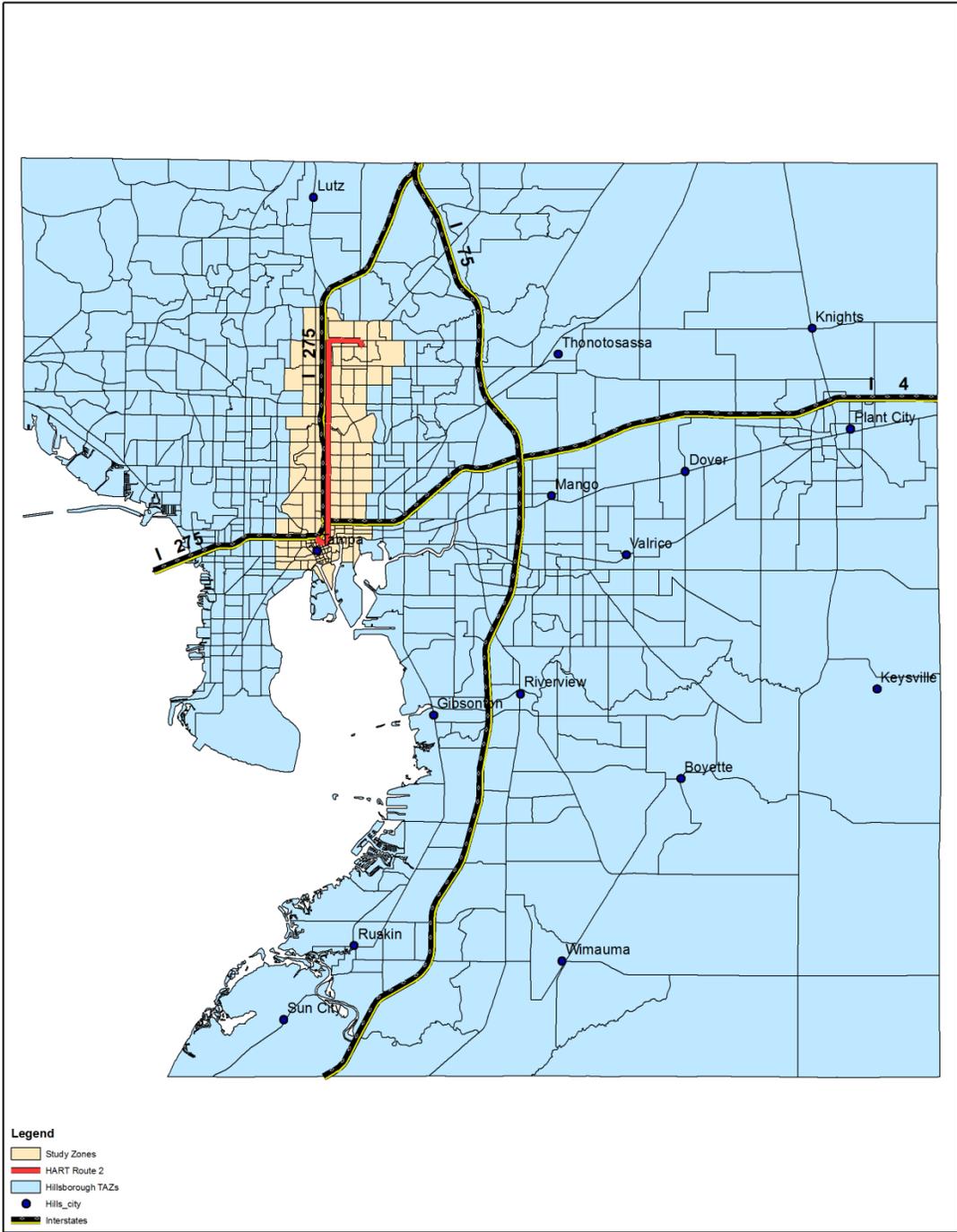


Figure 7-2 Influence Zones of HART Route 2 (2-mile buffer)

7.2 Land Use Pattern in 2012

The UrbanSim model, with the upgraded Route 2, ran for the target year (2012) and the land use patterns were extracted from the model output (indicators), including:

- Zonal Population
- Zonal Household
- Zonal Jobs
- Zonal Unit Price

The four measures with the express bus upgrade impact were compared with those without the upgrade and are summarized in Figure 7-3.

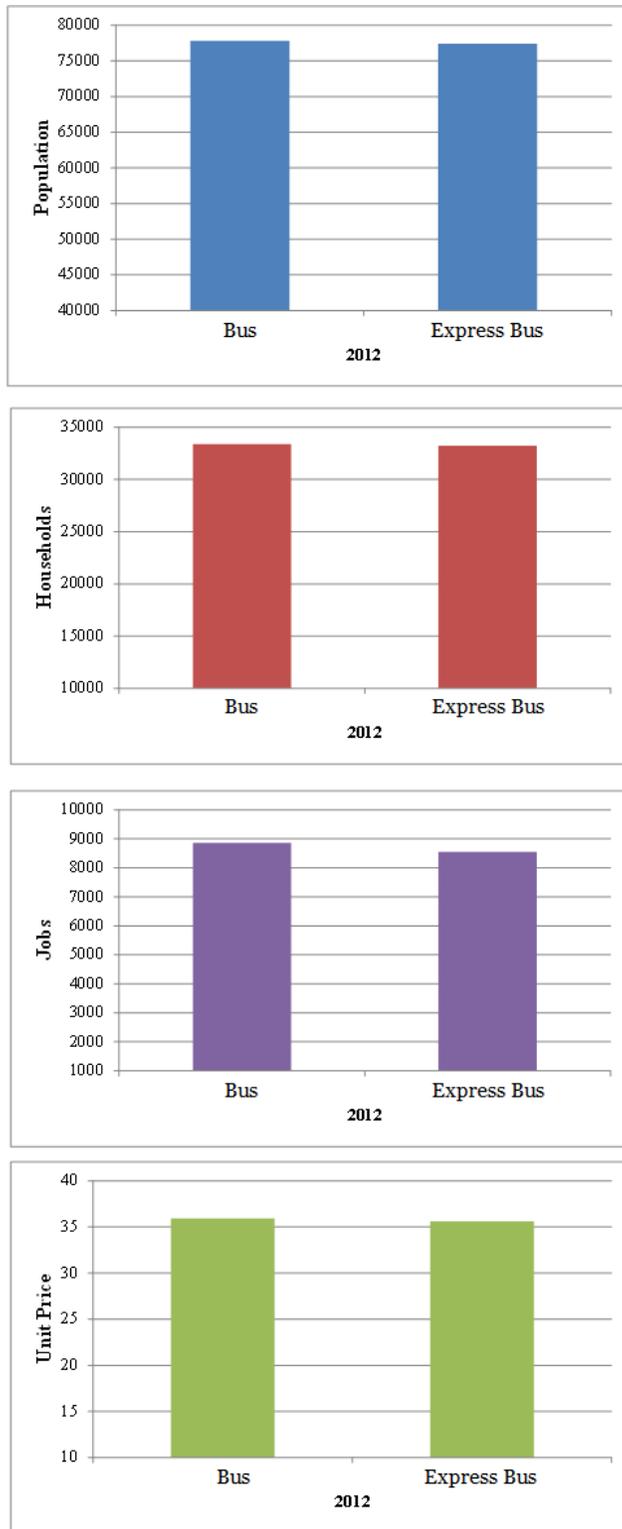


Figure 7-3 Land Use Patterns With and Without Upgrading HART Route 2 in 2012

Figure 7-3 shows that upgrading HART Route 2 to an express bus has no significant impact on land use patterns in the study zones in a short-term period (2012-2020). The population, households, jobs, and unit price are almost equal (difference < 1%) with and without upgrading the HART route in 2012.

7.3 Land Use Pattern in 2020

The scenario of the upgraded HART Route 2 in 2020 was created and examined using the UrbanSim model. The comparison of population, households, jobs, and unit price with and without upgrading the HART route for 2020 is displayed in Figure 7-4.

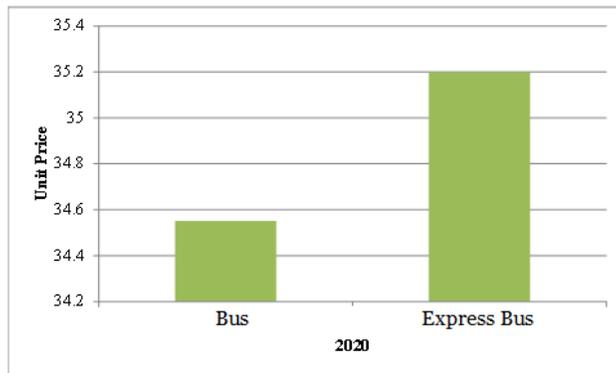
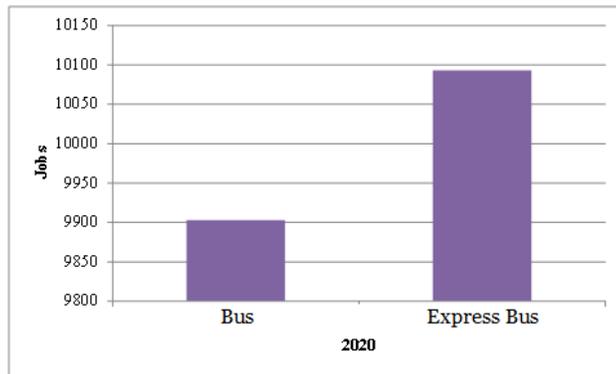
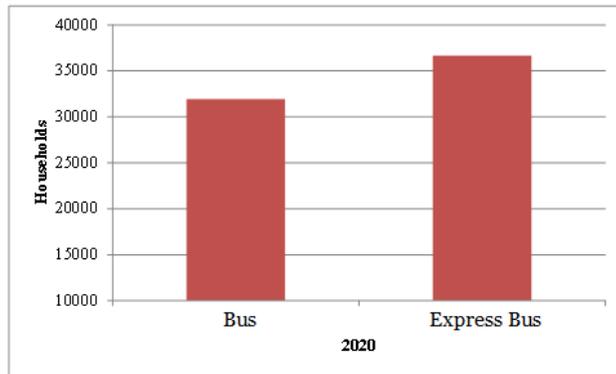
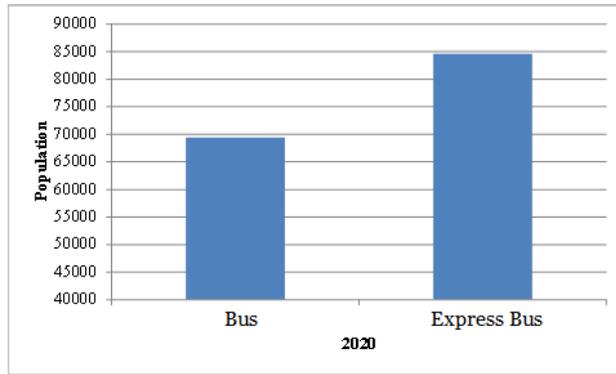


Figure 7-4 Land Use Patterns With and Without Upgrading HART Route 2 in 2020

Figure 7-4 shows that upgrading HART Route 2 to an express bus has a significant impact on the land use pattern of the influence zones in a long-term period. The population, households, jobs, and unit price increase by 22%, 15%, 2%, and 2% respectively due to upgrading the HART Route 2 in 2020. This finding confirms the conclusion derived from Chapter 6 that improving transit service will impact the land use pattern positively in the long-term, especially for population and household.

8. CONCLUSIONS AND RECOMMENDATIONS

This study applied the UrbanSim package to evaluate the impact of transit investments on land use patterns in Hillsborough County, Florida. The socioeconomic, demographic, and geographic data were collected from various data sources for the base year (2010). These data and the specified sub-models were assembled in the UrbanSim platform to create a simulation model. The TBRPM model was used to forecast traffic patterns in target years. Based on the base year data, four scenarios with assumed BRT ridership (trip attraction from auto mode) were examined to simulate the choice behavior of individual agents (persons, households, companies, etc.) with and without a proposed BRT service. With and without comparisons were conducted on land use patterns (population, households, jobs, and unit price) based on the simulation results. The following conclusions were found from this study:

- UrbanSim is a powerful tool to simulate land use changes. It is based on theories of market economics and discrete choice behavior, and captures both the impacts of market forces as well individuals' choices on land development processes. The household and job-based simulation makes its forecasting more realistic spatially and temporally. The UrbanSim model provides a reasonable prediction based on the difference between simulated land use patterns using UrbanSim and the projections in the 2035 LRTP. It is necessary to point out that differences are expected since these projections are produced by using different methods.
- The proposed BRT service has significant impacts on land use patterns in a long-term period (2010-2020). The population and households in the study area would increase by about 15% and 12%, respectively, due to implementing the BRT service in 2020; the housing unit price in the study area would increase by 4% due to implementing the BRT service in 2020.
- Compared to the impacts of the BRT investment on jobs and housing unit prices (4% and less than 1% respectively), the impacts on population and households in 2020 were larger (15% and 12% respectively). In UrbanSim, population and households are predicted by the Household Location Choice Model, which adopted system default structure and coefficients in this study due to lack of survey data for

Hillsborough County. A possible reason for the “large” impacts on population and households is the “non-localized” Household Location Choice Model.

- The change in land use patterns is complex due to implementing the BRT service, in both a short-term and a long-term period. For example, as shown in Figure 6-17, about 20% of zones decrease in population assuming five percent trip attraction by the BRT service, although the total population in the study will increase by 15%. It can be said that individuals’ choices are complicated and impacted by several joint factors.

Some recommendations are provided as follows:

- Data preparation is the key step in implementation of the UrbanSim model. In particular, household data and building data were synthesized using the IPU algorithm. Since the resolution of the algorithm is Census Blockgroup, which is larger than TAZ and parcel, researchers had to randomly assign the synthesized households and persons to zones, parcels, and buildings because of the lack of marginal distributions at zone and parcel levels. The random assignment may influence the accuracy of the UrbanSim simulation. In the future, it would be necessary to develop a new assignment algorithm considering relationships between household characteristics and parcel attributes; for example, households with higher incomes tend to take the higher value parcels/buildings.
- The study adopted the system default coefficients for the sub-models because the “real” data at parcel level are unavailable in Hillsborough County. In the future, a comprehensive survey is recommended to calibrate the coefficients of household/employment location choice models. Models localized for Hillsborough County would improve the accuracy of the UrbanSim model.
- In the UrbanSim model developed in this study, the impact of BRT services on traffic patterns are represented by the number of trips attracted from the auto mode, since only the variable of auto mode is included in the sub-models. A new model structure should be developed to contain additional transit variables in order to represent transit impacts directly.

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- In the current travel planning model for Hillsborough County (TBRPM or TBEST), the BRT mode is not available. Thus, researchers had to assume the ridership of the proposed BRT route to create scenarios. The scenarios should be updated with the availability of the BRT mode in travel planning models to provide a more reasonable assessment on the impacts of the proposed BRT route.

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Appendices

Appendix I Input Files for Parcel-Based UrbanSim

annual_employment_control_totals

The “annual_employment_control_totals” table contains the control totals, or aggregate quantities, of employment that will be used to set the total employment in the model system for each year. Totals by employment sector are split into home-based and non-home based components, on separate records.

Table A-1 annual_employment_control_totals

Column Name	Data Type	Required	Description
year	Integer	Y	simulation year
sector_id	Integer	Y	unique id for the employment sector
home_based_status	Integer	Y	flag for home-based employment
number_of_jobs	Integer	Y	control total

annual_household_control_totals

The “annual_household_control_totals” table contains the control totals, or aggregate targets, for the number of households for each year.

Table A-2 annual_household_control_totals

Column Name	Data Type	Required	Description
year	Integer	Y	simulation year
age_of_head	Integer	N	Optional age of head category
persons	Integer	N	Optional number of persons category
income	Integer	N	Optional income category
total_number_of_households	Integer	Y	total number of households

annual_household_relocation_rates

The “annual_household_relocation_rates” table contains estimates of the probabilities of moving within the region during a one-year time frame. The rates can be obtained from analyzing Current Population Survey data. Users can use any range or categorical variable (primary or computed) defined for households. By default, it includes households of different incomes and ages of head of household categories.

Table A-3 annual_household_relocation_rates

Column Name	Data Type	Required	Description
age_of_head_min	Integer	Y	Start of age range. Optionally age_min
age_of_head_max	Integer	Y	End of age range. Optionally age_max
income_min	Integer	Y	Start of income range
income_max	Integer	Y	End of income range
probability_of_relocating	Float	Y	annual relocation probability (between 0 and 1)

annual_job_relocation_rates

The “annual_job_relocation_rates” table contains the probabilities that a job in a sector will relocate within the region within a one-year time frame.

Table A-4 annual_job_relocation_rates

Column Name	Data Type	Required	Description
sector_id	Integer	Y	Unique id of employment sector
job_relocation_probability	Float	Y	Probability of a job relocating within a year (between 0 and 1)

buildings

The “buildings” table in the parcel version of the model system is an individual building located on a parcel. There can be multiple buildings on a parcel (a many to one relationship). Buildings that are mixed use, such as retail on the first floor and apartments above, can be represented as two separate buildings, on the same parcel. The land area would generally be assigned by the user to each component as a prorated amount.

Table A-5 buildings

Column Name	Data Type	Required	Description
building_id	Integer	Y	Unique id of building (one per zone and building type)
building_quality_id	Integer	Y	Building quality that can be used in development templates
building_type_id	Integer	Y	Unique id of the building type of this building
improvement_value	Integer	Y	Value in dollars of buildings on parcel
land_area	Integer	Y	Land area in sqft used by the building
non_residential_sqft	Integer	Y	Total non-residential sqft in building
parcel_id	Integer	Y	Unique id of the parcel in which this building is located
residential_units	Integer	Y	Total residential units in building
sqft_per_unit	Integer	Y	Average square feet per residential unit in building
stories	Integer	N	Number of stories in the building
tax_exempt	Integer	N	1 if tax-exempt building, 0 otherwise
year_built	Integer	Y	Average year built of this aggregated building

building_sqft_per_job

The “building_sqft_per_job” table contains information on the amount of space each job will take in a particular building type, by zone.

Table A-6 building_sqft_per_job

Column Name	Data Type	Required	Description
zone_id	Integer	Y	The zone id of the record
building_type_id	Integer	Y	The building type id of the record
building_sqft_per_job	Integer	Y	The number of sqft per job for jobs with the corresponding zone_id and building_type_id

building_types

The “building_types” table provides a list of the unique building types used to classify buildings. These typically are derived from local land use codes or building typologies.

Table A-7 building_types

Column Name	Data Type	Required	Description
building_type_id	Integer	Y	Unique id for building types
is_residential	Integer	Y	1 if residential, 0 otherwise
building_type_name	String	Y	Short name of the building type
building_type_description	String	N	Description of the building type
unit_name	String	Y	Used to denominate per_unit variables like price. Values: building_sqft, parcel_sqft
generic_building_type_id	Integer	Y	Unique id for generic (aggregated) building type
generic_building_type_name	String	N	Description of the generic building type

cities

The “cities” table provides a list of cities in the region and is typically used for computing indicators by city.

Table A-8 cities

Column Name	Data Type	Required	Description
city_id	Integer	Y	Unique id for each city
city_name	String(50)	Y	Name of the city

counties

The “counties” table contains a unique list of the counties in the region. These are mainly used for computing indicators.

Table A-9 counties

Column Name	Data Type	Required	Description
county_id	Integer	Y	Unique id for each county in the region
county_name	String(50)	Y	Name for the county

demolition_cost_per_sqft

The “demolition_cost_per_sqft” table provides information to the developer model about the costs of demolition by building type. These numbers are used to calculate the cost of demolition of an existing development so that a more accurate cost of redevelopment can be calculated.

Table A-10 demolition_cost_per_sqft

Column Name	Data Type	Required	Description
building_type_id	Integer	Y	The building type id
building_type_name	String	N	A description of the building type
demolition_cost_per_sqft	Integer	Y	The cost in dollars to demolish one square foot of the building type

development_constraints

The “development_constraints” table defines constraints to restrict development on parcels. Each row in the table defines a unique constraint. The Development Project Proposal Sampling Model (DPPSM) generates proposals for a parcel using the constraint(s) and by selecting appropriate records from the “development_templates_table” that will fit on the available land of the parcel. The DPPSM determines the applicable constraint(s) for a parcel by selecting a record in the “development_constraints” table based on the parcel's “plan_type_id” (not “generic_land_use_type_id”). A parcel may have a constraint for “far” and/or “units_per_acre”. Note that this table is substantially different than its gridcell counterpart due to the differences in the real estate models of these versions.

Table A-11 development_constraints

Column Name	Data Type	Required	Description
constraint_id	Integer	Y	A unique id for the constraint
constraint_type	String	Y	The density measure for the constraint. The value must be either 'units_per_acre' for residential land or 'far' for nonresidential land.
generic_land_use_type_id	Integer	Y	The id of the generic land use.
plan_type_id	Integer	Y	The id of the plan_type
minimum	Integer	Y	The minimum density allowed by the constraint
maximum	Integer	Y	The maximum density allowed by the constraint

development_templates

The “development_templates” table, along with the corresponding records in the “development_template_components” table, represents templates that can be used to define virtually any size and configuration of a development project. The template structure is robust enough to include projects from a single house on an infill lot to a large subdivision, to a mixed use project with retail on the first floor and condominiums above.

Templates are selected if the density and “land_use_type_id” fit within the constraints of a parcel with enough available land. Note that the “land_use_type_id” of a template does not need to match the “land_use_type_id” of a parcel. Instead, there must be a record in the “development_constraints” table with a “generic_land_use_type_id” that corresponds to the “land_use_type_id” of the template, and has a “plan_type_id” that matches the parcel.

Table A-12 development_templates

Column Name	Data Type	Required	Description
template_id	Integer	Y	A unique identifier for the template
percent_land_overhead	Integer	Y	The percent of land required for purposes other than buildings, e.g. landscaping, parking
land_sqft_min	Integer	Y	The minimum land area needed for the template
land_sqft_max	Integer	Y	The maximum land area used by the template
density_type	String	Y	The density measure for the template. The value must be 'units_per_acre' or 'far'
density	Float	Y	The density of the template
land_use_type_id	Integer	Y	The land use type id of the template
development_type	String	N	A description of the development type, e.g. single-family residential, retail, office

development_template_components

The “development_template_components” table represents buildings or parts of buildings included in a particular template. The records in this table are combined with the records in the “development_templates” table to generate project proposals. By breaking development templates into components, development project templates can be configured as hierarchies or combinations of building blocks, providing a very flexible means of representing a wide variety of development types. Note that the templates can be generated using real or hypothetical data, since they will be compared to regulatory constraints and the size constraints of parcels. This table is roughly equivalent to the “development_project_proposal_components” table.

Table A-13 development_template_components

Column Name	Data Type	Required	Description
component_id	Integer	Y	A unique identifier for the component
template_id	Integer	Y	The id of the corresponding template in the development_template table
building_type_id	Integer	Y	The building type id of the component
percent_building_sqft	Integer	Y	The percent of the building area the component constitutes
construction_cost_per_unit	Integer	Y	The cost of the template per square foot
building_sqft_per_unit	Integer		The square feet per unit for residential buildings

employment_sectors

The “employment_sectors” table contains definitions for the employment sectors used to classify jobs by industrial sector. In the U.S., these are typically based on either the older Standard Industrial Classification (SIC) system or the newer NAICS (North American Industrial Classification System).

Table A-14 employment_sectors

Column Name	Data Type	Required	Description
sector_id	Integer	Y	Unique id for the employment sector
name	String(20)	Y	Descriptive name for the employment sector

generic_land_use_types

The “generic_land_use_types” table contains the generalized land use classification used for models such as the Real Estate Price Model.

Table A-15 generic_land_use_types

Column Name	Data Type	Required	Description
generic_land_use_type_id	Integer	Y	Unique id for the generic land use type
generic_description	String(50)	Y	Descriptive name

household_characteristics_for_ht

The “household_characteristics_for_ht” table contains the classification used in the “annual_household_control_totals” table to determine how many households of particular categories will be in the region in a simulation year. Any attribute on the household table may be used.

Table A-16 household_characteristics_for_ht

Column Name	Data Type	Required	Description
characteristic	String(11)	Y	Name of the attribute on the household table (must match exactly)
min	Integer	Y	Start of user-defined class range
max	Integer	Y	End of user-defined class range

households

The “households” table contains the synthesized households for the region. It typically reflects an expansion of the Public Use Microdata Sample (PUMS) to approximate a 100% sample of households. Households may optionally be linked to individual persons, particularly for use in coupling to activity-based travel demand models.

Table A-17 households

Column Name	Data Type	Required	Description
household_id	Integer	Y	Unique household id
building_id	Integer	Y	Unique id of the building in which the household is located
persons	Integer	Y	Number of persons in the household
income	Integer	Y	Total annual income of the household
age_of_head	Integer	Y	Age of the head of the household (according to the census)
race_id	Integer	Y	Unique id of the race of the head of the household
workers	Integer	Y	Number of workers in the household
children	Integer	Y	1 if children are present, 0 otherwise
cars	Integer	Y	Number of cars owned by the household

jobs

The “jobs” table contains an inventory of jobs for the region. It is usually derived from either ES202 Unemployment Insurance data which monitors businesses by state for unemployment insurance purposes (and have had issues historically with under-reporting self-employed and proprietor employment, and also with headquarter reporting of jobs in multi-establishment firms) or from commercial sources such as InfoUSA (which have different issues of rolling updates).

Table A-18 jobs

Column Name	Data Type	Required	Description
job_id	Integer	Y	Unique id for each job
building_id	Integer	Y	Unique id for the building in which the job is located
home_based_status	Integer	Y	1 if the job is home-based, 0 otherwise
sector_id	Integer	Y	Unique id of the employment sector of the job

land_use_types

The “land_use_types” table contains the land use classification for all parcels in the region. It contains “unit_name” used to determine the type of unit to use in the “real estate price model”.

Table A-19 land_use_types

Column Name	Data Type	Required	Description
land_use_type_id	Integer	Y	Unique id for the land use type
description	String(40)	Y	Descriptive name
land_use_name	String(25)	Y	Name
unit_name	String(15)	Y	Unit type
generic_land_use_type_id	Integer	Y	Plan type

parcels

The “parcels” table contains attributes of individual parcels.

Table A-20 parcels

Column Name	Data Type	Required	Description
parcel_id	Integer	Y	Unique id for parcels
parcel_id_local	String(20)	N	Users may want to store a local parcel id from the assessor's office
land_use_type_id	Integer	Y	Unique id of the land use type of the parcel
land_value	Integer	Y	Assessed value of the land on the parcel
parcel_sqft	Integer	Y	Land area of the parcel in square feet
plan_type_id	Integer	Y	Unique id of the land use plan type of the parcel (regulatory designation)
centroid_x	Integer	Y	X-coordinate of the parcel centroid, usually in a projection measured in feet
centroid_y	Integer	Y	Y-coordinate of the parcel centroid, usually in a projection measured in feet
tax_exempt_flag	Integer	N	Optional 1 if tax exempt, 0 otherwise
city_id	Integer	N	Unique id of the city in which the parcel is located
county_id	Integer	N	Unique id of the county in which the parcel is located
zone_id	Integer	Y	Unique id of the zone (as used in the travel demand models) in which the parcel is located
census_block_id	string	N	Optional unique id of the census block in which the parcel is located

persons

The “persons” table contains the synthesized population for the region, linked to households. It typically reflects an expansion of the Public Use Microdata Sample (PUMS) to approximate a 100% sample of households and persons.

Table A-21 persons

Column Name	Data Type	Required	Description
person_id	Integer	Y	Unique id for each person
household_id	Integer	Y	Unique household id
member_id	Integer	N	Unique id of the person within a household
relate	Integer	N	Relationship of person to census survey respondent
age	Integer	N	Age of person in years
sex	Integer	N	Coded as 1=male, 2=female
race_id	Integer	N	Unique id of the race category of the person
student	Integer	N	1 if person is a student, 0 otherwise
worker	Integer	N	1 if person is a worker, 0 otherwise
hours	Integer	N	Usual hours worked per week by person, if worker
work_at_home	Integer	N	1 if person works at home, 0 otherwise
edu	Integer	N	Educational attainment of person
earning	Integer	N	annual earnings (wages) of person from employment
job_id	Integer	N	Assigned by workplace choice model, if used

plan_types

The “plan_types” table contains the list of “plan_types”, reflecting some classification of land use regulations defining permissible uses and densities of future development.

Table A-22 plan_types

Column Name	Data Type	Required	Description
plan_type_id	Integer	Y	Unique id for plan type
name	String(50)	Y	Description of the plan type

target_vacancies

The “target_vacancies” table is used by the development proposal choice model. It gives the model information about acceptable vacancy rates. The table has one row for each year the simulation runs. Each row gives target values for the residential and nonresidential vacancies for that year, which are defined below. Only data after the base year is used.

Table A-23 target_vacancies

Column Name	Data Type	Required	Description
building_type_id	Integer	Y	The building type id
target_vacancy_rate	Float	Y	The ratio of unused space to total building space
year	Integer	Y	The simulation year

travel_data

The “travel_data” table contains zone-to-zone morning peak period travel times for vehicles traveling in mixed flow lanes.

Table A-24 travel_data

Column Name	Data Type	Required	Description
from_zone_id	Integer	Y	origin zone
to_zone_id	Integer	Y	destination zone
am_single_vehicle_to_work_travel_time	Integer	Y	zone-to-zone morning peak period travel time for vehicles traveling in mixed flow lanes

velocity_functions

The “velocity_functions” table is designed to hold the velocity functions that specify the rate at which development occurs. A Development Project Proposal has a calculated variable called “units_proposed” that is the total number of units that will be built. The calculated variable “annual_construction_schedule” on the Development Project Proposal Components dataset uses “units_proposed” to select which of the velocity functions in this table should apply based on the “building_type_id” and “units_proposed” of the Development Project Proposal Component. The user can specify a record from this table, using the “velocity_function_id”, to specify the construction schedule for projects specified in the “development_project_proposal” base year table.

Table A-25 velocity_functions

Column Name	Data Type	Required	Description
velocity_function_id	Integer	Y	A unique identifier
annual_construction_schedule	String	Y	A numbered list in brackets of the form, '[p1, p2,...,pn]', indicating with each entry the percentage complete of the project each year from its start. The last entry must be '100'.
building_type_id	Integer	Y	The building type id for the velocity function
minimum_units	Integer	Y	The minimum number of units for the velocity function
maximum_units	Integer	Y	The maximum number of units for the velocity function

zones

The “zones” table contains attributes of traffic analysis zones used in the travel demand models.

Table A-26 zones

Column Name	Data Type	Required	Description
zone_id	Integer	Y	unique id for each zone
city_id	Integer	N	unique id for each city
county_id	Integer	N	unique id for each county
faz_id	Integer	N	unique id for each forecast analysis zone or any user-specified aggregation of zones

Appendix II Source Codes for Household/Person Assignment

II.1 Assign Parcel to Household

```
Dim ds As New DataSet
    Dim countMatched As Integer = 0
    Dim countDup As Integer = 0

    Using conn As New
        SqlConnection("server=131.247.11.247;uid=wonstran;pwd=288496;database=census")
            conn.Open()

            IMess.Text = "Retrieving bg data ..."
            IMess.Refresh()

            Dim commandString4 As String = "SELECT distinct(tract),bg from households"
            Dim command4 As New SqlCommand(commandString4, conn)
            Dim adapter4 As New SqlDataAdapter
            adapter4.SelectCommand = command4
            adapter4.Fill(ds, "bg")

            IMess.Text = "Retrieving household data ..."
            IMess.Refresh()

            Dim commandString1 As String = "SELECT
tract,bg,household_id,parcel_id,parcel_id_local from households"
            Dim command1 As New SqlCommand(commandString1, conn)
            Dim adapter1 As New SqlDataAdapter
            adapter1.SelectCommand = command1
            adapter1.Fill(ds, "household")

            IMess.Text = "Retrieving parcel-bg data ..."
            IMess.Refresh()

            Dim commandString2 As String = "SELECT parcel_id_local, parcel_id, tract2, blkgroup
from parcel_bg"
            Dim command2 As New SqlCommand(commandString2, conn)
            Dim adapter2 As New SqlDataAdapter
            adapter2.SelectCommand = command2
            adapter2.Fill(ds, "parcel")

            Dim totalNum As Integer = ds.Tables("bg").Rows.Count
            Dim count As Integer = 0

            Dim tabBG As DataTable = ds.Tables("bg")
            Dim tabHH As DataTable = ds.Tables("household")
```

```

Dim tabP As DataTable = ds.Tables("parcel")

Using conn2 As New
SqlConnection("server=131.247.11.247;uid=wonstran;pwd=288496;database=census")
conn2.Open()

For Each row As DataRow In tabBG.Rows

    Dim tract As String = row.Item("tract").ToString.PadLeft(6, "0")
    Dim bg As String = row.Item("bg").ToString.Trim

    Dim express As String = "tract2=" + tract + "" + " and " + "blkgroup=" + bg + ""
    Dim rows() As DataRow = tabP.Select(express)

    Dim express2 As String = "tract=" + tract + " and " + "bg=" + bg
    Dim rows2() As DataRow = tabHH.Select(express2)

    If rows.Length > 0 Then
        countMatched += 1
    Else
        countDup += 1
    End If

    count += 1

    AssignHousehold2Parcels_2(rows2, rows, conn2, count)

Next

End Using

End Using

MessageBox.Show("Matched:" + countMatched.ToString + "," + countDup.ToString)

Private Sub AssignHousehold2Parcels_2(ByRef hhs As DataRow(), ByRef parcels As
DataRow(), ByVal conn As SqlConnection, ByVal count As Integer)

    Dim numHHs As Integer = hhs.Count
    Dim numParcels As Integer = parcels.Count

    Dim parcel_id As String
    Dim parcel_id_local As String

    Dim command As New SqlCommand

```

```

command.Connection = conn

Dim j As Integer = 0

For i As Integer = 0 To numHHs - 1

    If numParcels > 0 Then

        If j >= numParcels Then
            j = 0
        End If

        parcel_id = parcels(j).Item("parcel_id").ToString.Trim
        parcel_id_local = parcels(j).Item("parcel_id_local").ToString.Trim

        j += 1

    Else
        parcel_id = "0"
        parcel_id_local = "0"
    End If

    Dim hh_id As String = hhs(i).Item("household_id").ToString.Trim

    command.CommandText = "UPDATE households SET parcel_id='" + parcel_id + "',
parcel_id_local='" + _
        parcel_id_local + "' WHERE household_id='" + hh_id + "'"
    'command.ExecuteNonQuery()
    If parcel_id_local = "1928091H70000000000007A" Then
        Dim s As String = ""
    End If

    IMess.Text = "Updating: " + count.ToString + "-" +
hhs(i).Item("household_id").ToString + "--" + i.ToString + "/" + numHHs.ToString
    IMess.Refresh()

Next

End Sub

```

II.2 Assign Building to Household

```
Dim ds As New DataSet
    Dim countMatched As Integer = 0
    Dim countDup As Integer = 0

    Using conn As New
        SqlConnection("server=131.247.11.247;uid=wonstran;pwd=288496;database=urbansim")
            conn.Open()

            Using conn3 As New
                SqlConnection("server=131.247.11.247;uid=wonstran;pwd=288496;database=census")
                    conn3.Open()

                    IMess.Text = "Retrieving parcel data ..."
                    IMess.Refresh()

                    Dim command1 As New SqlCommand
                    command1.Connection = conn3
                    command1.CommandText = "SELECT distinct(parcel_id) FROM households "
                    Dim adapter1 As New SqlDataAdapter
                    adapter1.SelectCommand = command1
                    adapter1.Fill(ds, "parcel")

                    Dim totalNum As Integer = ds.Tables("parcel").Rows.Count
                    Dim count As Integer = 0

                    IMess.Text = "Retrieving building data ..."
                    IMess.Refresh()

                    Dim command2 As New SqlCommand
                    command2.Connection = conn
                    command2.CommandText = "SELECT building_id, parcel_id from buildings"
                    Dim adapter2 As New SqlDataAdapter
                    adapter2.SelectCommand = command2
                    adapter2.Fill(ds, "building")
                    Dim tableBud As DataTable = ds.Tables("building")

                    IMess.Text = "Retrieving household data ..."
                    IMess.Refresh()

                    Dim command3 As New SqlCommand
                    command3.Connection = conn3
                    command3.CommandText = "SELECT parcel_id, household_id, building_id from
households"
```

```

Dim adapter3 As New SqlDataAdapter
adapter3.SelectCommand = command3
adapter3.Fill(ds, "household")
Dim tableHH As DataTable = ds.Tables("household")

Using conn2 As New
SqlConnection("server=131.247.11.247;uid=wonstran;pwd=288496;database=census")
conn2.Open()

Dim command4 As New SqlCommand
command4.Connection = conn2

For Each row As DataRow In ds.Tables("parcel").Rows

Dim parcel_id As String = row("parcel_id").ToString.Trim

Dim express1 As String = "parcel_id=" + parcel_id + ""

Dim rows_building As DataRow() = tableBud.Select(express1)
Dim rows_hh As DataRow() = tableHH.Select(express1)

countMatched += 1

AssignHousehold2Buildings(rows_hh, rows_building, command4)

count += 1

IMess.Text = "Assigning: " + count.ToString + "/" + totalNum.ToString
IMess.Refresh()

Next

End Using

End Using

End Using

MessageBox.Show("Matched:" + countMatched.ToString + "," + countDup.ToString)

Private Sub AssignHousehold2Buildings(ByRef hh As DataRow(), ByRef buildings As
DataRow(), ByRef command As SqlCommand)

Dim numHH As Integer = hh.Count
Dim numBuildings As Integer = buildings.Count

```

```
Dim building_id As String

For i As Integer = 0 To numHH - 1

    If numBuildings > 0 Then
        Dim randomBuilding_index As Integer = Fix(Rnd() * numBuildings)
        building_id = buildings(randomBuilding_index).Item("building_id").ToString.Trim
    Else
        building_id = "0"
    End If

    command.CommandText = "UPDATE households SET building_id=" + building_id + "
WHERE household_id=" + hh(i).Item("household_id").ToString + ""
    command.ExecuteNonQuery()

Next

End Sub
```