Simulating the Effect of Light Rail on Urban Growth in Phoenix: An Application of the UrbanSim Modeling Environment

Himanshu Joshi, Subhrajit Guhathakurta, Goran Konjevod, John Crittenden, and Ke Li

THE task of planning urban land-use and transportation systems has become more challenging in the face of an increasing set of dynamic influences on the behavior of households and businesses. The integration of the global economy, leading to both a quantitative and qualitative change in flows of information, capital, people, and goods, has, in part, led to a realignment of land uses. While some traditional industries have become de-centered within the urban context, other forms of economic activities are leading to re-centering around new nodes. On one hand, increasing affluence among many households has increased demand for land for housing and caused a dispersion of households farther away from the center. On the other hand, however, households that are being marginalized by globalizing processes are finding more segregated quarters and a limited ability to access urban amenities. In Phoenix, Arizona such processes are evident in the continued development of large, master-planned communities at the periphery, together with the movement of jobs to new employment clusters along major transportation corridors. At the same time, downtown Phoenix is also receiving significant attention as the location for a new campus

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of Arizona State University and for T-Gen, the biotechnology research cluster. The adoption of a light-rail transit system within this context has raised several concerns about its potential viability and suitability in a rapidly changing urban region.

The concern about the Phoenix Light Rail transit system cannot be addressed without knowing the future with some level of confidence. Although the experiences of other urban areas that have established light-rail transit systems are informative, each region is unique. Hence, the experiences of other regions cannot provide definite answers to questions about the suitability of the Phoenix Light Rail system within the specificity of the Phoenix metropolitan region. In this study, we adopt a more robust form of futures analysis that takes advantage of a comprehensive urban simulation model called UrbanSim. Micro-simulation models such as UrbanSim allow planners to examine simulated futures based on knowledge about the behavior of various urban actors and their interactive relationships as they play out in changing the urban fabric. For example, UrbanSim explicitly models the behavior of households, employees, and developers, as they choose their activity location based on the collective choices made by other households, employees, and developers within a given policy environment. Each individual household and employee is a decision-making agent and is modeled separately within the simulated environment. Since UrbanSim generates overarching patterns of urban growth based on the aggregation of decisions of individual "agents," it belongs in the category of models known as "agent-based" models.

Waddell
Waddell and Borning
Waddell and Ulfarsson

The literature of transit accessibility on land-use change has, in general, supported the theory that higher accessibility to rail transit leads to higher land values around transit stops, which in turn results in higher densities of development. However, little is known about the effect of transit accessibility on gentrification. It may be reasonably expected that attractiveness of locations with improved accessibility will follow different dynamic processes in high-income vs. low-income areas. Areas with a high percentage of low-income renters can be expected to "turn over" quickly to higher-income rental or owned housing. This study of the Phoenix metro area provides a simulation of such a process and discusses its implications.

We examine the impact of the introduction of a light-rail transit system in Phoenix by observing the changes in the number and types of households adjacent to the proposed transit line in 2015. Given that the light-rail system in Phoenix is expected to start operation in 2008, the simulated future in

2015 provides adequate time for observing long-term changes in households and land-use patterns around station areas. The impact of light rail in the Phoenix metropolitan region is estimated by comparing a scenario that includes light rail with the null scenario (in which light-rail transit is not introduced). The results suggest that most areas adjacent to light-rail stations increase in household density as we would expect based on the literature. But there are some surprising declines in household density in other areas, especially in the high-density corridor next to Arizona State University. We show that such unexpected results are consistent with urban economic theory as well.

Light-Rail Transit in the United States

In the later half of the twentieth century, many cities in North America adopted light rail as a convenient transit system. Today more than 50 cities in the United States provide rail transit as a means of regional public transportation. There are two types of light-rail systems. The first system involves light cars, sometimes called trolleys, trams, or streetcars, which run along the street and share space with motor vehicles. Such systems exist in San Diego (in part), New Orleans, and Charlotte, N.C. The second kind of light-rail system consists of multicar trains that operate along their own rights of way and are separated from roadways. St. Louis, Portland, Pittsburgh, San Jose, and Buffalo all have this
Garrett second type of light-rail system. The Phoenix Light Rail system will be of this later type.

Property Values Adjacent to Transit

Economic theory suggests that accessibility afforded by public transit can add to the amenities associated with adjacent activities. For example, residents who use the transit system may enjoy reduced travel time while businesses near a transit station can expect lower costs and agglomeration benefits. Thus, traditional location theory would predict that the cost benefits resulting from proximity to transit will be capitalized in the values asso-
Alonso ciated with residential and business land uses. Some property
Muth owners may suffer a penalty from the nuisance effects of a rail
Mills system, which imparts some ambiguity to the net effect of

transit proximity. However, empirical examination has shown that in a majority of the cases, residential, office, retail, and industrial properties close to rail transit enjoy significant positive premiums.

Federal Transit Administration

Studies in Boston, Philadelphia, Portland, San Francisco, Arlington/Washington, D.C., Atlanta and San Diego found that residential properties with close proximity to rail stations had higher property values than those farther away. But higher residential property values adjacent to light rail are not apparent in San Jose, Sacramento, and Miami. These rail systems probably were not as high quality as the others or they enjoyed very low ridership. Higher system ridership tends to increase positive property premiums throughout the transit area. Light-rail transit has enhanced residential property values by anywhere from 2 to 18 percent in various cities, including Portland, Sacramento, San Diego, and Santa Clara, with larger changes in cities with commuter rail systems. But not all residences benefit equally. Properties located too near a station may suffer, and in California, the largest premiums accrue to owners of multifamily residential properties. Of the few commercial property markets studied, it appears that there are premiums of from 4 to 30 percent for office, retail, and industrial buildings located near rail transit in Santa Clara, Dallas, Washington, D.C., Atlanta, and San Francisco.

Landis et al. 1994
Landis et al. 1995
Cervero and Duncan
Al-Mosaind Musaad et al.
Armstrong
Weinstein and Clower

Nelson
Cockerill and Stanley
Landis et al. 1995

Light Rail and Urban Form

The characteristics of a region in terms of the relative patterns and layout of employment centers with respect to residential areas have been a significant factor determining transit use. Compact cities with a dominant center have higher transit use than more dispersed urban areas with multiple employment centers. All rail systems in the United States are focused on the Central Business District (CBD) and are designed to bring employees to downtown jobs. In the case of the San Francisco Bay Area, Cervero and Landis found that although the average commuting distances did not change much when firms relocated to the suburbs, work trips by transit plummeted by a factor of almost 20. This switch from transit to auto for suburban jobs is also corroborated by studies in England and Houston. However, other researchers have also shown that, despite the loss of jobs in the CBD, a significant proportion of new and relocating job centers have sought out rail transit corridors such as those along transit systems in

Transit Cooperative Research Program

Transit Cooperative Research Program

Daniels
Rice Center for Urban Mobility Research

Cervero 1995
JHK and Associates

Chicago and Washington, D.C. Hence, concentrating both jobs and housing on rail transit corridors can substantially increase transit ridership.

The Effects of Increasing Density and Mixing Land Use

Giuliano
Wachs et al.
Levinson and Kumar
Cervano 1996
Frank and Pivo

Nelson/Nygaard Consulting Associates

Transit Cooperative Research Program

There is clear evidence that increasing density and mixing land uses around transit stations lead to higher transit ridership. Several studies in the early 1990s showed that jobs and housing tend to co-locate in order to improve employment accessibility, which, in turn, reduces congestion and improves transit ridership. In a seminal paper examining transit demand in Portland, Oregon, authors Nelson and Nygaard note that "of 40 land-use and demographic variables studied, the most significant for determining transit demand are the overall housing density per acre and the overall employment density per acre. These two variables alone predict 93 percent of the variance in transit demand among different parts of the region." Research conducted for the Transit Cooperative Research Program of the Federal Transit Administration in 1996 examined data on 19 light-rail transit systems and 47 commuter-rail systems and concluded that station boardings (transit usage) was positively correlated with both station area residential density and CBD employment density.

Transit Cooperative Research Program

Cervero 1989
Cervero 1996
Hooper and JHK and Associates
Nowlan and Stewart
Ewing
1000 Friends of Oregon 1993
1000 Friends of Oregon 1994
1000 Friends of Oregon 1995
Frank
Transit Cooperative Research Program

Mixed land uses also encourage transit usage but its effect is noted as being less significant than density. Several studies on suburban activity centers have shown that a balance of employment and housing in the area causes higher transit usage with corresponding reductions in auto trips. Other researchers have also found similar positive impacts on transit ridership when the number of retail jobs in a zone is considered. Empirical estimates of the land-use mix and transit ridership connection from Seattle, Washington and the San Francisco Bay Area also come to similar conclusions. Therefore, planning for complementary and mixed land uses around station areas has become accepted practice in all metropolitan areas with transit systems.

The UrbanSim Implementation for Maricopa County

Several state-of-the-art modeling approaches have been incorporated into the design of the UrbanSim simulation package. UrbanSim simulates the behavior of individual agents such as households, businesses, developers, and governments (as policy inputs) and charts their interactions in the real estate market. By focusing on the principal agents in urban markets and the choices they make about location and development, the model deals directly with behavior that planners, policy makers, and the public can easily understand and analyze. The structure allows users to incorporate policies explicitly and to evaluate their effects.

UrbanSim is not a single model. It is an urban simulation system, which consists of a family of models interacting with each other, not directly, but through a common database. There are several different models within UrbanSim (economic transition model, demographic transition model, employment and household mobility models, employment and household location choice models, and the real estate development model). A more detailed description of each of these models and their underlying theories are available at http://www.urbansim.org/index.html. Here we focus on the specific implementation of UrbanSim for Maricopa County.

The Database

The input data included in the data store consist of parcel file information from the county assessor's office, employment data from the Maricopa Association of Governments (MAG), census data, detailed land use and land valuation data, boundary layers showing environmental, political, and planning boundaries also from MAG, and a chronological list of development events. A set of software tools such as ArcGIS and MySQL was used to extract the data from input files, calculate values, and construct the model database in the specified format.

The data store contains all households in Maricopa County, starting with the base year 1990. Each household is a separate entry in the households table with associated characteristics such as: household income, size, age of head of household, presence and number of children, number of workers, and the number of cars. In addition, the data store contains every job present in Maricopa County by location (i.e., grid ID), job sector, and whether the job is home-based or not. Altogether UrbanSim requires about 60 data tables that are used in the complete database. Each table has a well defined structure. The model components include a script to check the consistency of tables, which, when run, provide warnings and error messages if any table is incorrectly formatted for UrbanSim.

Creating the Database for Running UrbanSim

The process of creating the Maricopa County database for UrbanSim required the following steps:

1. Defining project boundary (Maricopa County)
2. Defining the base year for data (we used 1990)
3. Generating a grid (9511 grid cells, 1mile x 1mile each were generated for Maricopa County)
4. Assigning a unique ID to each cell
5. Producing GIS Overlays: Parcels on grid; transportation analysis zones (TAZ) on grid
6. Allocating parcel characteristics to the grid
7. Assigning employment to the grid
8. Reconciling non-residential space and jobs
9. Synthesizing households and locating them by Grid ID
10. Generating diagnostics and resolving inconsistencies
11. Assigning development types
12. Converting environmental features to the grid
13. Converting planning boundaries to the grid
14. Loading the database into MySQL
15. Running consistency checker.

In this paper, we do not attempt to describe each of these steps in detail, but the steps are well documented in the UrbanSim manual available at www.urbansim.org. There is, however, one step, Step 9 above, that requires special attention given that it is an extraordinary process when compared to most land-use projection models. As mentioned earlier, the UrbanSim database requires information for every household in Maricopa County by its special attributes. There is no single source from which all this data can be obtained. For this reason, UrbanSim provides a utility called a "Household Synthesis Utility." As its name suggests, this utility synthesizes the household data with the help of an *iterative proportional fitting algorithm*. The utility synthesizes households separately by family types for each Public Use Micro Area (PUMA) at the level of the block group. Data sources required for the household synthesis utility are: 1) Sample of households by age of head, income, race, workers, number of children, and number of cars for families as well as non-families at the level of PUMAs from 5 percent Public-Use Micro-data; and

2) Block group level data for the marginal distribution tables from U.S. Census Summary Tape file STF-3A. The algorithm iteratively matches the marginal totals at the level of block groups to varying sets of households represented in the 5 percent PUMA sample. When a selected set of households match the aggregate block group statistics closely, that household set is assumed to belong in that block group. Subsequently, households in the block groups are associated with the grid-IDs. In this manner, the households table is populated and the synthetic process of household allocation closely approximates actual household locations.

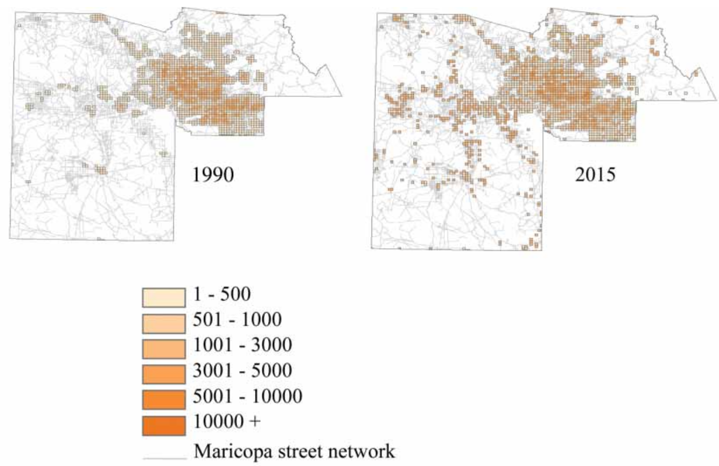
Another important aspect of this modeling approach is the use of accessibilities as a critical driver of jobs and household locations. The information about trips between transport analysis zones (TAZs) in Maricopa County at various points in time was obtained from the Maricopa Association of Governments (MAG). These data allowed us to calculate logsums by travel mode from which accessibilities were derived for incorporation in to the UrbanSim data store. UrbanSim is usually run in tandem with an external travel model, so that the accessibilities can be updated at regular intervals. For our purposes, we used three sets of accessibilities (1993, 1998, and 2008) based on the output from the travel model used by MAG.

Model Estimation

Given that UrbanSim is actually a group of models that communicate with each other through a data store, the estimation process involves separate calibrations of each individual model. Most of the models are of a "discrete choice" nature and are estimated through multinomial logit regressions (e.g., household location choice model, developer choice model, and employment location choice model). The land price model is different from the previous set since it is the only model that is estimated through a linear regression. The model parameters are derived with the help of external packages such as Limdep and SPSS.

Each of the models requires several data tables from the UrbanSim database. For example, for the household location choice model, households are partitioned into seven dimensions (car ownership, income, minority status, number of children, age of head, number of persons in household, and number of workers in household) and various combinations of these dimensions are then separated into "bins." For each bin, a set of possible locations (grid cells) is selected together with their logit

FIGURE 1
Household Simulation Using "Business as Usual" Scenario



Source: Created by authors

probabilities, based on various characteristics of these grid cells (the probability of a particular household belonging to a bin to choose any of the selected locations). Using the Monte Carlo sampling procedure from the probability distributions for each bin, all households in a bin are assigned to grid cells. A similar method is followed for assigning jobs to locations. The developer model follows a different logic. In this case, the decision of a developer to develop various types of structures or not to develop in a grid cell is simulated. These decisions are determined by land prices, constraints imposed by local policies, and characteristics of the grid cell.

Using the estimated parameters, two model configuration tables were generated for each model—the model specification table and the model coefficient table. These tables are usually the last tables to be generated. Once these tables are populated with appropriate parameters, UrbanSim model runs can be accomplished. Figure 1 provides the 1990 and 2015 household location results for one UrbanSim run using the "business as usual" scenario.

Model Validation

Model validation is a crucial process for building confidence in the modeling results. For this paper, the UrbanSim model is run from

TABLE 1
Correlation of Simulated to Observed 2000 Values

	Cell	*TAZ*
Employment	0.8	0.71
Households	0.76	0.66
Housing Units	0.79	0.64

Source: Created by authors

1990 through 2000 and the simulated results are compared to the observed data to check the validity of the model. Practical constraints on the creation of historical data for use in validation often preclude the feasibility of historical validation of this sort, but this remains one of the most informative ways to assess the model before putting it into operational use. The simulation results are compared to observed data at two units of geography. As seen in Table 1, the correlation between the simulated and observed is close to 80 percent at the level of the grid cell. This validation result provides us with a reasonable level of confidence in the model forecasts. This result compares well with the test data on Eugene-Springfield, Oregon that is provided by the developers of UrbanSim. In the test case, the correlations between actual and simulated values for 1980-1994 population, households, and housing units in Eugene-Springfield, Oregon were reported to be .81, .805, and .83, respectively (http://www.informatik.uni-hamburg.de/SWT/attachments/LUTermine/Folien-Alan-Borning.pdf).

Scenario Analysis: Impact of Light Rail on the Phoenix Metropolitan Area

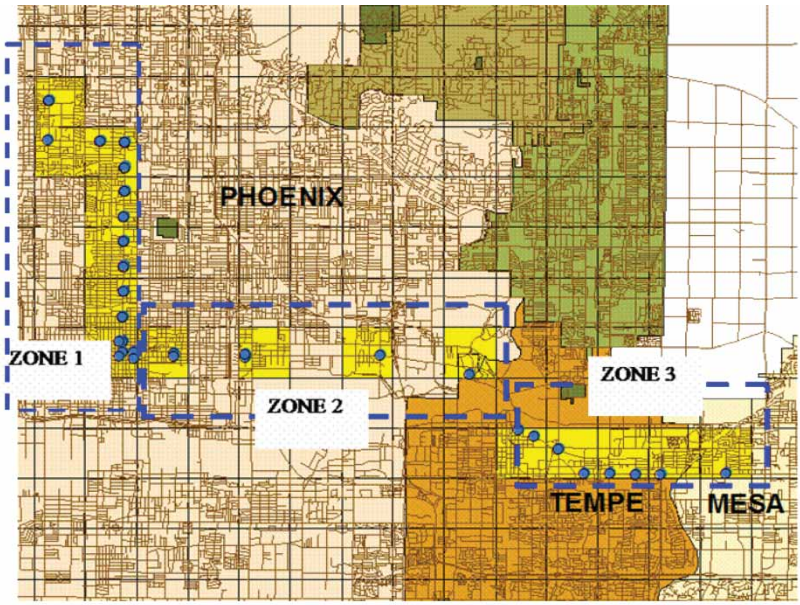
The Central Phoenix/East Valley Light-Rail Transit Project, which is now under construction, will provide convenient and comfortable transportation between Phoenix's central business district, Sky Harbor International Airport, Arizona State University, several community college campuses, and event venues that currently draw about 12 million people each year from the region. The first phase of the project will include a 20.3-mile line that connects significant destinations in three cities—Phoenix, Tempe, and Mesa. It is expected that this phase of the project will be completed by 2008. In light of the new transportation option that will become a reality in fewer than three years, planners in the three cities are actively engaged in planning and redesigning the areas around the transit stops. The scenarios tested in this study take into account many of the planned interventions around the transit stations, mostly in terms of introducing mixed-use and higher-density developments. Figure 2 shows a map of the overall planned system in relation to the various cities in the Phoenix metropolitan area.

The first phase of the Phoenix Light Rail project will include 32 transit stations within the cities of Phoenix, Tempe, and Mesa. These station areas are shown in Figure 3. Given that transit stops are designed to be closer together than the 1-mile grid used in the UrbanSim model, we have allocated three analysis zones, each having distinct characteristics. Zone 1 radiates north from Phoenix downtown and includes most of the Phoenix downtown business district and the uptown arts district. This region includes some of the oldest neighborhoods in this metropolitan region and a

FIGURE 2
Planned Light-Rail Corridors in the Phoenix Metropolitan Area

Source:http://www.valleymetro.org/rail/Future%20Extensions.html

FIGURE 3
Delineation of Three Zones for Phoenix Light-Rail Study



Source: Created by authors

fairly large downtown core. Zone 2 is currently a low-density corridor that is adjacent to the commercial airport and includes many industries that have located to take advantage of proximity to the airport. This corridor also includes several low-income neighborhoods and areas with high concentrations of minorities. Zone 3 is dominated by Arizona State University and activities supporting the university. The concentration of student housing is high in this area. This zone also includes several ethnic retail establishments catering to a large international student community attending Arizona State University. The following analysis compares the transition of households in the three delineated zones based on scenarios with and without light-rail transit for year 2015. Table 2 provides some basic descriptive information about each of the three zones.

The scenario for different levels of transit use was generated by changing the modal split for all the transport analysis zones (TAZs) that include the 32 stations mentioned earlier. Accessibilities for all the TAZs (not just the ones including the 32 stations) were recalculated such that for the 5 percent scenario, 5 percent of

TABLE 2
Some Attributes of the Three Zones of Study

Zone	*Population Density*	*Percent White*	*Percent Hispanic*	*Percent Other*	*Median Household Income*	*Household Size*
1	8,806	63	42	17	$38,953	1.9
2	1,957	49	74	37	$35,058	2.0
3	11,177	70	26	14	$34,517	2.0

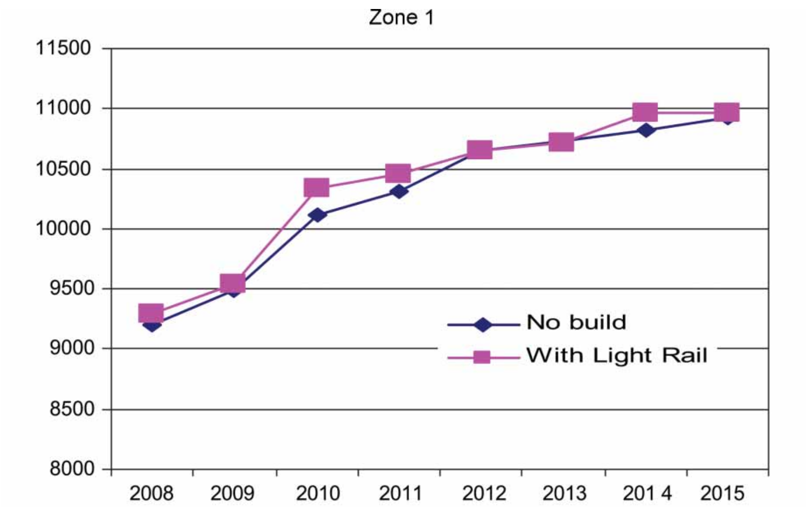
Source: Created by authors

the total number of auto trips in the transit-affected TAZs (around the 32 stations) was added to transit and subtracted from auto. A similar procedure of increasing transit ridership was adapted for the 15 percent and 25 percent scenarios. These scenarios were tested against "no build," where light rail is not built and the existing mode split continues into the future. Also, cities will be rezoning the station areas for high-density, mixed-use developments. To account for this land-use change, development types of the grid cells falling under stations have been changed to high-density and mixed-use development type. The particular light-rail scenario discussed below assumes the mid-range of the three scenarios tested; that is, 15 percent of trips to and from the areas adjacent to light rail will be on the proposed Phoenix Light Rail system.

Analysis of UrbanSim Scenarios With and Without Light Rail

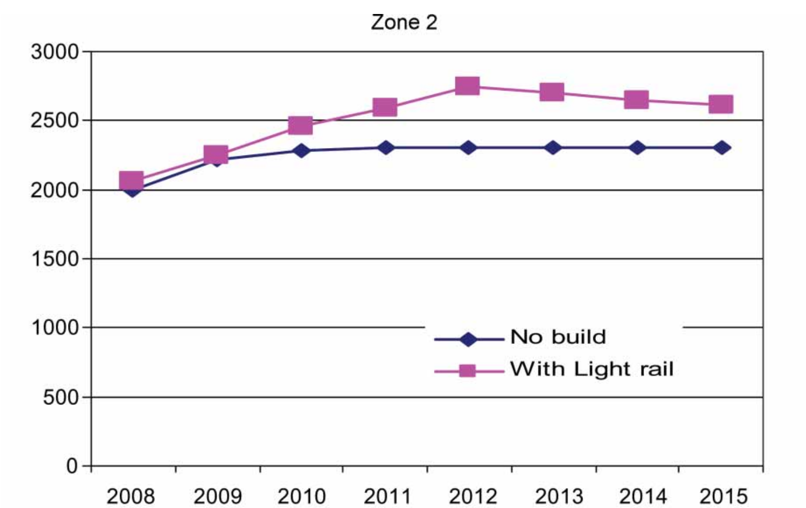
The introduction of light rail in the Phoenix metropolitan area seems to increase the number of households in Zones 1 and 2 when compared to a future without light rail. Between 2008 and 2015, the number of households in Zones 1 and 2 increased 19 percent and 15 percent, respectively, without light rail. Zone 3 also registers an increase in the number of households in this scenario by 6 percent. In contrast, the scenario with light rail assigns very slight changes to household numbers in Zone 1, but significant increases in Zone 2. The number of Zone 2 households increases by 12 percentage points during that same period when compared to the no-light-rail scenario. Figures 4, 5 and 6 show the changes in households by year for the two scenarios described above.

FIGURE 4
Comparing Household Growth in Zone 1 Between "No-Build" and Light-Rail Scenarios



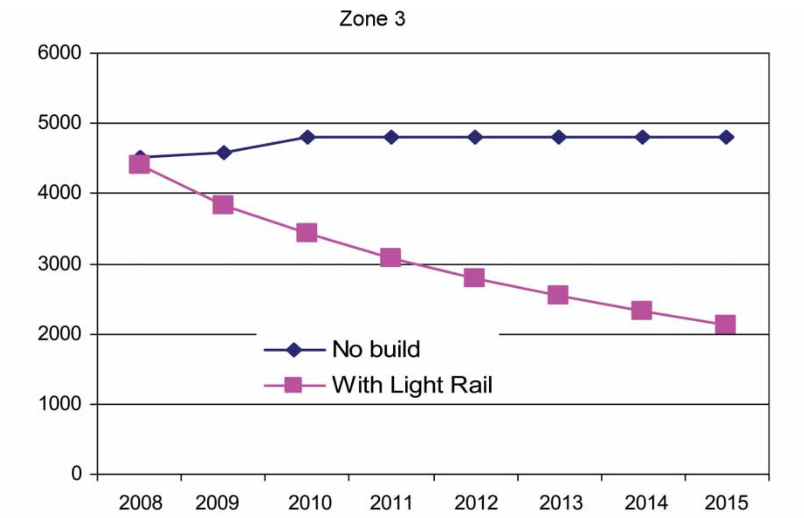
Source: Created by authors

FIGURE 5
Comparing Household Growth in Zone 2 Between "No-Build" and Light-Rail Scenarios



Source: Created by authors

FIGURE 6
Comparing Household Growth in Zone 3 Between "No-Build" and Light-Rail Scenarios



Source: Created by authors

A surprising result is noticed for Zone 3, which includes large concentrations of high-density student housing. The scenario with light rail seems to decrease the number of households in the seven years after the commencement of light rail in the Phoenix metropolitan area. Compared to the "no build" scenario, the introduction of light rail results in a decline of households by over 50 percent in Zone 3. Although the reduction in household density seems surprising, the model is responding to capitalization of the amenity provided by light-rail transit in home values, which may lead to new up-market developments that push out the lower-income student population and make room for higher income families who prefer slightly larger quarters. This projected household transition becomes even more apparent when we examine the type of households who would prefer to live adjacent to transit stops as predicted by UrbanSim.

Household Transition Due to Light Rail

Characteristics of households in the three zones show different trends based on scenarios with and without the introduction of light-rail transit in 2008. In this paper, we report on two of the important characteristics of projected future households adjacent to light-rail station areas—income and race.

The three zones delineated for the study include, on average, low- to moderate-income households and the "no build" scenario does not change that overall character. Under the "no build" scenario, Zone 1 registers the highest income of the three zones during the period of projection. Zone 2 remains the lowest in terms of average household incomes of the three zones. Both Zones 1 and 2 show slight declines in real average incomes over the seven-year period of projection. Zone 3, however, registers a significant decline in real average household income of about 8 percent during this period. This result changes dramatically in the scenario with light rail, especially for Zone 3.

The scenario with light rail has significant yet differential impacts on Zone 1 and Zone 3. Households in Zone 2, in contrast, are less likely to be of a different income group with or without light rail. Average household income in Zone 1 is projected to decline significantly in the seven years after the initiation of light-rail transit. In contrast, Zone 3, which includes the student community around Arizona State University, is projected to scale up in average income levels during the same period. While households in Zone 1 remain the highest in average incomes of the three zones without light rail, they give up that top position to households in Zone 3 when light rail is introduced. Zone 2 households remain at the bottom in average income in either scenario.

With changes in household incomes, the racial and ethnic composition of the households in the three zones also changes, depending upon the introduction of light rail. In all but one scenario, the percentage of White households (as determined by the racial attribute of the head of household) decline from 2008 to 2015. White households comprise about 72 percent of all households in Zones 1 and 2, and 64 percent in Zone 3 in 2008. In the scenario without light rail, the highest decline in the percentage of White households is in Zone 2 (6 percentage points) followed by Zone 1 (3 percentage points) and Zone 3 (1 percentage point). This decline is almost entirely at the expense of percentage growth of households in the "other" racial category. The "other" category is a residual category used in the U.S. Census for those individuals who do not choose among the dominant racial categories for various reasons including unwillingness to disclose or being of mixed races.

The racial make-up of the three zones seems to be very different in the scenario with light rail than the previous scenario. The decline of White households in Zone 1 is now more pronounced (10 percentage points). However in Zone 2, which had the largest decline of White households in the previous scenario, the percentage of White households now declines by only 4 percentage points. More surprisingly, the percentage of White households in Zone 3 actually trends up in the scenario with light rail by a significant 6 percentage points. In essence, Zone 3 will be the most affected area with the introduction of light rail, partly due to gentrification.

The Final Analysis

The scenarios evaluated to test the impact of light rail on adjacent neighborhoods in the Phoenix metropolitan area show different effects in different zones. The findings are mostly in line with the literature on transit and land-use connections, but also add some surprising caveats to this literature. While, as expected, Zones 1 and 2 register slight increases in residential density over seven years after the introduction of light rail, household densities in Zone 3 actually decline under this scenario. This result can be explained in light of the current characteristics of Zone 3 and its unique location. The household density in Zone 3 is already among the highest in the state and includes a high percentage of student households. Given the income profile of this young student population, the housing available is mostly rental, aimed at low- to mid-market clients. In addition, this area is among the most "jobs rich" areas in the state being close to the largest university in the United States as well as to downtown Tempe. Therefore, the perceived accessibility of this area is already high and the introduction of light-rail transit provides the additional amenity that would make it more desirable to up-market clients. The light-rail project and the associated developments will perhaps tip the scales in favor of gentrification in an area that already is amenity rich.

The projected gentrification of Zone 3 is unwelcome for the student population who would gradually be pushed out to areas farther from the university. Given this possible scenario, both the city of Tempe and Arizona State University will have to plan for more affordable student housing. The university has already embarked on an extended plan to increase on-campus student housing. The city also needs to closely monitor land-use changes and real estate values in Zone 3 and look for innovative approaches for developing as well as keeping affordable housing. Regardless, this area seems to be ripe for redevelopment and the introduction of light rail will perhaps jump-start the process.

An important caveat to keep in mind is that simulation models are useful tools for understanding the interaction of contextual elements and decision-making agents, but they are limited in their capacity to anticipate processes that have no antecedents. This limitation is more pronounced in very long-range projections. The simulation results reported in this paper are well within the period in which projections can be justifiably made, given well verified models. However, the results should be treated as informational and not definitive, since human social behavior changes through time due to adaptation and learning. In addition, significant development proposals are now being reviewed by various cities on the light-rail route, especially in the downtown Phoenix area, that may change the underlying parameters of the model resulting in a different projected output. Regardless, planning for the future requires us to anticipate it, and the careful use of simulation and/or modeling tools is indispensable for this endeavor.

Acknowledgments

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