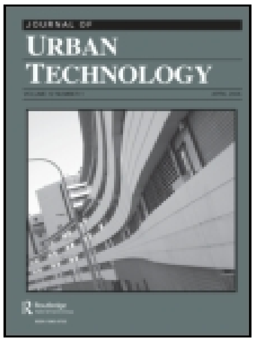

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Urbanization and Resort Regions: Creating an Agent-Based Simulation of Housing Density in "Ski Country"

Li Yin and Brian Muller

THE economy of recreation and retirement is an important creator of urban form in many regions across the United States and worldwide. Demands for recreation and retirement stimulate cycles of infrastructure and housing investment that lead rural and resource-based regions through progressive phases of immigration and economic change. As recreation communities mature, they diversify and take on the more complex features of urban areas. The growth patterns in many U.S. cities can be explained partly by waves of retirees and trends in recreation. Large parts of the Mediterranean, all three coasts of the United States, and the Rocky Mountain region are still being transformed through the maturing of recreation and retirement communities.

Muller et al.

Prideaux

Abbott

Non-metro counties in the United States experienced a significant population increase during the 1990s; in recreation counties the rate of increase was 20.2 percent. Mountain resort communities have responded to population growth through changes in housing mix, infill, and a variety of growth management tools. Many of these communities were semi-deserted mining or ranching towns 40 years ago but with rapid rates of growth during the 1980s and 1990s, they have developed into small urban centers. Researchers have pointed out the appearance of high-density development in mountain resort communities. We

Johnson and Beale

Theobald and Kneeland

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go further in this paper to argue that density increase is a central element of urban change in such places. Densification processes in recreational communities occur in distinctive patterns because of the unusual housing needs associated with service workers and short-term stays, the imperatives to protect amenities, and the character of local growth politics. Research on these densification processes is important in explaining the dynamics of this significant urban form and in helping such communities manage the balance between high rates of population growth and protection of the amenities that initially made them attractive. Yin

Many of the previous studies on regional population distribution and density are based on census boundaries or focus on traffic analysis zones or Metropolitan Statistical Areas. This approach tends to miss fine-grained processes of densification because census tracts and higher-level census geographies assume development densities are uniform for all cells or land units within an area. Moreover, analysis by census or traffic analysis geography typically does not capture density preferences of different types of households such as service workers and short-term stayers. On the other hand, fully-attributed parcel datasets frequently are not available to researchers, either because they have not been completed as in many rural areas or are too costly as in many metropolitan areas. Theobald 2005 Yeh and Li

In this paper, we develop a hybrid approach in which we use census and state data sources to complete a poorly-attributed parcel dataset. This hybrid data approach and the agent-based approach support the description of relatively fine-grained differentiation of patterns of land use change and simulation of different types of actors and their roles in the densification process, but at the same time take advantage of population and housing data derived at a census-block level. Our model differs from many agent-based models of urban change because of its focus on densification processes and its foundation on empirical data from the study area. Franklin and Graesser

High-Density Mountain Resort Development and Densification Actors

The attractors of development in mountain resort communities include access to organized recreational activities such as ski areas and golf courses, availability of certain urban amenities such as restaurants, and the presence of natural amenities. Price et al.

Recreational areas attract not only visitors but also permanent residents. Ann Satterwaithe wrote that recreation is individually important in self-fulfillment, self-testing, and temporary escape from the humanized world. Because of changes in employment, including increased mechanization, shorter hours, and higher Davis pay, people have more time to devote to recreation. Research suggests that local residents in ski areas care more about the environmental health of the area, while tourists are more concerned about the quality of the skiing trip (which is based upon the facilities and services offered), the relaxation of the experi- Holden ence, and the "thrill factor" of the skiing.

The difference in activities and attitudes between local residents and tourists are blurring, however. Stewart and Stynes found that if people like an area, they tend to make return visits. Some may eventually buy second homes, even establish their primary residence in the area. Timeshares are an increasingly-common instrument for purchase of second homes. They involve limited and shared ownership, typically in a resort apartment, associated with the right to occupy the apartment for a specific period of time. The apartment is generally managed by a local firm and rented during periods when it is not occupied by owners. Timeshare markets have seen considerable growth globally in recent years although more than half of the world's time Hovey share resorts are located in the United States.

The booming of the resort industry has also boosted local economies. Ski resorts and other mountain recreational sites tend to stimulate real estate development and the creation of Duane new service industries. Researchers have found that the presence Ringholz of ski areas significantly increases the aggregate income of a Booth county. Service industries are an essential element of the functioning of this tourist economy; they include restaurants, bars, hotels, motels, mobile catering, and other recreation- related activities. These industries are labor intensive and generate a large number of relatively-low wage jobs. For example, a resort in Scotland was found to create 90 direct jobs and an additional Holden 3,000 indirect jobs. A significant portion of service jobs are part-time or seasonal, including cooks, servers, counter people, bartenders, ticket agents, cleaners, catering staff, and maintenance staff.

Scenic amenities are another important attractor of growth to mountain recreation communities. One study of amenities in the United States found that areas with high amenity levels such as lakes, mountains, and forests doubled their population between

1970 and 1996. In general, areas with "pleasant" climates (warm, sunny winters, and cool, low-humidity summers) rate high on the amenity scale. Also, proximity to bodies of water and to a landscape that has varying terrain is important to people choosing locales for natural amenities. Places with high levels of natural amenities also tend to have a concentration of recreation or retirement activities. Many studies have indicated that second home owners prefer sites with natural amenities and more space.

McGranahan 1999

McGranahan 1999

Davis et al.
Nelson

Until recently, most mountain resort towns and other recreational communities in the western United States have had relatively dispersed populations and relied largely on the automobile for transportation. In recent years, however, residential densities have increased in many parts of the Rocky Mountains. New urban centers are emerging out of pressures for development around recreational and natural amenities and generate a variety of job opportunities for residents, which in turn, create demand for housing, services, and infrastructure.

Theobald and Kneeland

This paper uses an agent-based approach to explore location decision-making of three distinctive types of households: owners of detached single-family homes, time-share owners, and service workers. We examine the transition of multi-family units through time-share ownership to service worker rentals as a process of housing filtering. We also include the transition of single-unit housing to multi-family units in the model. Locational decisions both for ownership and rentals are made in the spatial context of resort amenities and related employment opportunities. Our case study area is a growing urban corridor in Summit County Colorado, including the towns of Breckenridge and Frisco, about 70 miles west of Denver. (See Figure 1.)

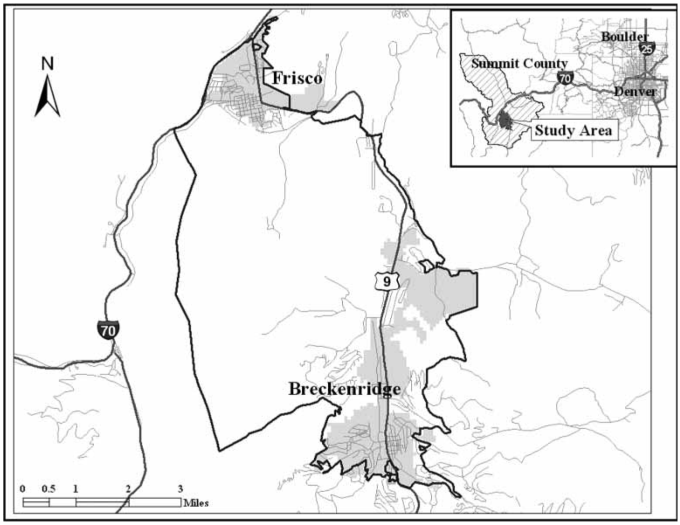
Lowry

Summit County, Colorado

Summit County is a four-season recreational center including four ski areas: Breckenridge, Copper Mountain, Keystone, and the Arapahoe Basin. Even in 1990 Summit County had a very high density of second homes, with over 10 second homes per square mile. Since 1990, Summit County has seen a sharp rise in population. (See Table 1.) This population increase is in large part the result of the county's varied recreational attractions. It has cold winters, ample snow, a large number of sunny days, and rugged

Hart

FIGURE 1
Study Area



terrain for ski runs of all types. Summit County also has moderate summers and dramatic scenery, attracting spring, summer, and fall recreation. It is rated the highest on the amenity scale developed by McGranahan for the United States. Moreover, the area is highly accessible from Denver and Denver International Airport. Interstate 70 spans the county on its east-west axis. (See Figure 1.)

TABLE 1
Growth in Population and Housing Units in Summit County and Selected Towns (1990 – 2000)

Category	*1990*	*2000*	*Percent Change*
Total County Population	12,881	23,548	+82.8%
Total County Housing Units	17,091	24,201	+41.6%
Vacant County Housing Units	11,796	15,081	+27.8%
Median County Housing Unit Value	$121,500	$317,500	+161.3%
Total Breckenridge Population	1,285	2,408	+87.4%
Total Frisco Population	1,601	2,443	+52.6%
Total Silverthorne Population	1,768	3,196	+80.8%
Total Dillon Population	553	802	+45.0%

Source: U.S. Census 1990, 2000

I-70 is the only direct route through the Rocky Mountains to much of the Colorado ski country. More than 35,000 cars pass through the Eisenhower/Johnson Memorial Tunnel near the eastern border of Summit County on an average day. Johnson

The county as a whole increased in population by 82.8 percent and in housing units by 41.6 percent between 1990 and 2000. (See Table 1.) The towns of Breckenridge, Frisco, Silverthorne, and Dillon also saw substantial increases in population. The total county vacant housing units, however, increased by 27.8 percent during this period. A high percentage of housing units in the county (62.3 percent) were vacant in 2000. Nationwide, the average vacancy rate is only 9.0 percent. There are more housing units in the county than residents. This vacancy rate is largely due to the high proportion of people who own houses or units in Summit County but maintain their permanent residences elsewhere, e.g., second home owners and owners of time-share condominiums. In Frisco, only 37 percent of the housing units were owned by people living in the county. Using information provided by U.S. Economic Census, we found that the number of service workers in construction, transportation, lodging, and other service industries increased by 50 percent from 1991 to 2000. Northwest Colorado Council of Government United States Census Bureau 2000 Northwest Colorado Council of Government

Other noteworthy characteristics of Summit County are the median housing value and housing density. The median value of housing more than doubled between 1990 and 2000. The housing density of Summit County is especially high in comparison to other non-metro recreational counties and even metro counties in Colorado. (See Table 2.) About 42 percent of the housing units in the county are located in structures with 10 or more units, much higher than the comparable rate in Colorado (15.3 percent) and even higher than Denver (31.9 percent).

The transportation of skiers and service workers to and from the ski hills has been a major planning challenge for Summit. In 1989, Summit County created Summit Stage, a bus system linking the county towns and the four major ski areas. Bus service is free. According to Summit Stage, total riders doubled in the past five years. The Town of Breckenridge has also set up a smaller system for its jurisdiction, again with the main purpose of feeding skiers to the ski runs. With the expansion of ski areas and the local population boom, politicians and activists are looking for a development pattern that will reduce the negative effects of growth. Johnson

TABLE 2
Housing Density

Region	*County*	*Total Housing Units*	*Housing Units in Structures (Percentage)*	
			1 Unit, Detached	*10 or more Units*
Metro	Boulder	119,900	61.9%	15.9%
Counties	Denver	251,435	47.5%	31.9%
Non-metro	Eagle	22,111	32.6%	20.7%
Recreation	Pitkin	10,096	45.2%	20.3%
Counties	Summit	24,201	28.6%	42.1%
Colorado	All Counties	1,808,037	62.1%	15.3%

Source: U.S. Census, 2000

Building an Agent-Based Density Increase Model

This paper presents an agent-based simulation model designed to examine patterns of housing density change in a mountain resort environment by linking micro-level density increase, resulting from individual responses to different land-use density, amenity, and accessibility with macro-level density increase.

Data Collection and Processing

The data were collected from a variety of sources (See Table 3) and stored in a raster database using a geographic information system (GIS). In addition to GIS files, we also collected information on selected amenities including ski area entrances, areas of high restaurant density, bus routes, and bus stops in various forms such as orthophotos and hard copy maps. Four GIS data sets on selected amenities were created by digitizing this collected information.

A major challenge to using the parcel data for this study is that these data were only available with a limited amount of information attached. They did not have the attributes typically required for this kind of analysis, e.g., the year a structure was built and the number of units. We had to use the generally-available census block-level data, parcel boundary data, and water well data to estimate parcel-level land use changes and housing densities for year 1999, which was used as the model input data.

Parcel boundaries were identified using the parcel geometry. We relied on the combination of parcel and water well data to identify land use and development in 1990 although water well

TABLE 3
Data Sources

Data Set	*Source*
Parcels	County Assessors Offices
Wells	County Engineering Office
Streets and Roads	TIGER (US Census)
Highways	TIGER (US Census)
Interstate Highway Ramps	TIGER (US Census)
Census Blocks	TIGER (US Census)
Streams	TIGER (US Census) and USGS
Land Ownership	Bureau of Land Management
Ski Area Entrances	Digitized
Areas of High Restaurant Density	Digitized
Bus Routes	Digitized
Bus Stops	Digitized

data is primarily useful for identifying land use change in rural areas where no central water is available. Census data provided information on population and housing units counted to the block level. In order to estimate housing density in 1990, we used parcel boundary, type of land use, and land development for each parcel. Housing density at the parcel level was estimated as total housing units in a census block divided by total acres of developed parcels in that census block. Housing density was then assigned to each grid cell for use in an agent-based model.

After assembling data in ArcGIS, we usedRePast, a Java-based software framework designed for creating agent-based simulations, to build an agent-based model in the study area. This software program provides a mechanism to read ASCII files exported from ArcGIS and allows users to customize the program easily. We added a component that supports the exporting of simulation results to an ASCII file so that the results can be read and displayed in ArcGIS.

Why Agent-Based Model?

The agent-based approach has emerged as a simulation method in a growing number of fields over the last several decades. Instead of uniformly applying aggregate rules across system components to predict the behavior of an entire system, agent-based models consider how agents or individual components of a system interact according to their preferences or behavior rules.

Parker et al.
Batty
Yin and Muller

Batty

Joshi et al.

Gilbert and Troitzsch

J.T. Sargent
DeAngelis and Gross
Parket et al.
Sembolonia et al.
Goldstein et al.

Agent-based models provide a framework in which individuals and their behaviors are modeled in a more direct and realistic way with respect to the system environment and other individuals in a system. In such models, system components or agents are assigned different behaviors. These behaviors can influence the decision making of other agents over time depending on the spatial relationship among agents. Therefore, space, time, and non-linear dynamics can be incorporated more easily in comparison to traditional modeling approaches. Due to its ability for simulating sophisticated social phenomena, agent-based models have been adopted by researchers in economics, ecology, and land use/cover changes.

This paper uses an agent-based model to investigate the dynamics of housing density change emerging from location decision-making of different players or individuals in a mountain resort town system. Moreover, the level of densification in the previous iteration makes a site more or less attractive to different agents in the next iteration. These decision-making and densification processes might be more difficult to address using traditional analytical models. With an agent-based approach, the properties of the aggregate population in these resort towns are not a simple collection or an average of all behaviors of all players.

Model

The density change model in this study includes four components: agents, the rules they follow, the environment in which they interact, and density thresholds. There are three types of agents in the model: service workers, owners of time-share condominiums, and second-home owners. We examine the transition of multi-family units from time-share ownership to service worker rentals as a process of housing filtering.

Lowry

Service workers are employed in businesses such as hotels and restaurants, many of which provide food, lodging, and recreational services primarily to vacationers. Second-home owners have their primary residence elsewhere. Time-share vacation homes became popular as escalating property prices made it difficult for many people to own a vacation home by themselves. Time-share owners have access to the shared condominiums for a limited period of time, usually one week each year. In this research, we focus on three main types of households that are the main drivers of the density change in these resort towns. We consider that the location preferences of other residents resemble one of these three key households and are distributed among these three categories.

The design of types of agents and rules that structure agents' behavior are based on locational and density preferences derived from the results of three community "value" surveys undertaken by local governments in the area during 2003 and from a literature review. Different agents have different preferences for recreational amenities, natural amenities, neighborhood density, and urban amenities/services and infrastructure. (See Table 4.) Agents' locational preferences are limited by their income levels. Therefore, their roles in the densification process are various. These preferences were transformed into attributes attached to the grid cells that form the environment with which agents interact and rules that agents followed to develop lands at different densities.

Northwest Colorado Council of Government
Price et al.
Yin and Muller
Lowry
Davis et al.
U.S. Census Bureau 1990
U.S. Census Bureau 2000
Hart
Johnson
Joshi et al.

The unit of analysis is one-hectare size cells. In other words, our study area is divided into a grid with a resolution of 100 x 100 meters per grid cell. This grid allows the creation and computation of the variables listed in Table 4: distance to the nearest ski area, distance to areas of high restaurant density, distance to bus stops, distance to the nearest local roads, distance to public land, distance to lakes, distance to streams, etc.

A simulation was run for the development between 1990 and 2000. The agent-based simulation started with the estimated cell-level density in 1990 and ended with a model-predicted cell density for 2000. We then aggregated cell-level densities (year 2000) from our model to a census block-level density surface, and compared it with the existing housing density at the census block level using Census 2000 data to see how good our

TABLE 4
Agents' Preferences

Preferences	*Attributes of Cells/Variables*
Recreational Amenities (R)	Distance to the nearest ski area
	Distance to areas of high restaurant density
Urban Amenities (Service Centers & Infrastructure) (U)	Distance to bus stops
	Distance to the nearest local roads
	Distance to the nearest highway ramp within city limits
Natural Amenities (N)	Proximity to public land
	Proximity to lakes and streams
Neighborhood Density (ND)	Distance to the nearest neighbor
	Neighborhood development density

model was in terms of simulating patterns of density change. (See Figure 2.)

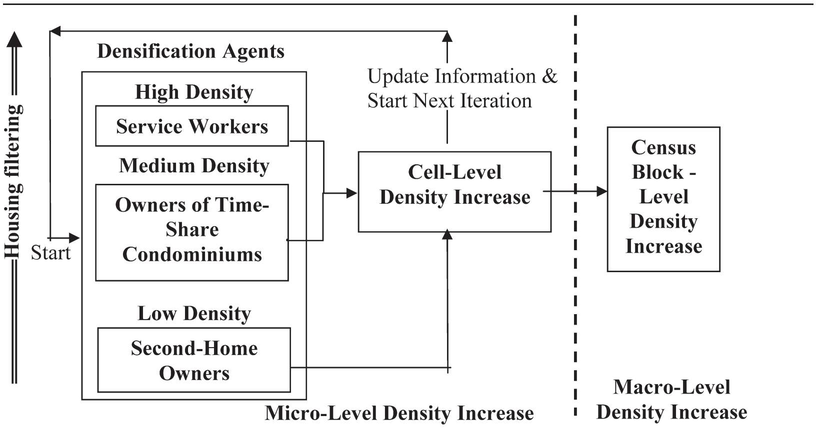
The dependent variable in the model is measured as land conversion from a lower density level to a higher one, including from undeveloped land to a site developed by any type of agents/residents [Equation 1]. Density is determined based on the number of housing units built on each site and types of agents/residents occupying that site. Because density information is not available at the parcel level for the study area, we used housing density for each census block in 1990 and 2000 respectively, to calculate grid cell-level density as the model input data ($t = 0$), to calibrate the model parameters, and to compare it to the model output that is equivalent to year 2000. Thus:

$$D(x, y, h, t) = f\{R(x, y, h), U(x, y, h), N(x, y, h), ND(x, y, h, (t-1)), D(x, y, h, (t-1)\} \quad (1)$$

D is the density level of a site with its center defined by x and y coordinates at time (step) t and occupied by household type h. A site is undeveloped if $D = 0$. The initial state of the simulation is set up when $t = 0$, which is equivalent to the housing density of year 1990 in our model.

On the right side of equation 1, R, U, and N are collections of amenity variables including recreational, urban, and natural

FIGURE 2
Model Structure



amenities respectively. Variables used in each of these three categories are listed in Table 4. These variables were static and were not changed during the simulation. They were computed using Arc/Info AML and read into RePast as ASCII files. ND is a collection of variables representing the density level of a cell's neighborhood at the time of step $t-1$, including distance to the nearest neighbor from the cell and its neighborhood development density. Neighborhood of a site is defined as a window of 13 by 13 cells around the site. The initial state of these variables (when $t = 0$) was calculated using Arc/Info. These variables were then calculated and updated in RePast after each time step to reflect the impact of the neighborhood density level at time $t-1$ on households' densification decision making at time t. The density level D at time $t-1$ for a site was used to determine whether this site can be densified and by which types of agents if it can be. The inclusion of D at time $t-1$ reflects the housing filtering process and the impact of a household's income level on the density threshold. This equation reflects how space, time, and households' different location preferences influence the housing densification process.

Equation 1 was operationalized as locational preference rules for selecting cells to be developed and deciding the density levels of the selected cells for three types of agents included in the model. Different types of agents evaluate all of the sites and select a cell according to their priorities and constraints listed in Table 5 and Table 6. Table 6 listed the density threshold for each of the three types of agents. In this project, we focused on current zoning densities to model trends in future density. Based on current zoning, we scaled density in three categories: 20 units per acre (high); one unit per 20 acres (low); and 3 units per acre (medium). This roughly captures the primary density categories in the towns of Breckenridge and Frisco and Summit County.

Service workers are willing to locate in high-density housing units near job centers, such as ski areas and restaurants because of their income and time constraints. They also prefer to be close to bus stops providing easy access to their work through free public transportation. Second-home owners prefer large and quiet lots as well as access to natural amenities. Thus, they prefer the lowest density housing. As neighborhood density levels increase, second-home owners emigrate, making higher-density locations available to other types of agents.

Owners of time-share condominiums have more neutral preferences in comparison to service workers and second-home

TABLE 5
Locational Preference Rules of Different Types of Agents or Households

Service Workers:
1. Determine already developed sites that can be densified (density under the threshold).
2. Determine proximity to jobs and transit stations.
3. Find location to satisfy: a) land that can be densified; b) land that is closest to jobs, bus stops, and bus routes.

Owners of Time-Share Condominiums:
1. Determine developable sites that are either undeveloped or already developed at low density (density under the threshold).
2. Determine accessibility to recreational amenities.
3. Determine accessibility to urban amenities.
4. Determine neighborhood density.
5. Find location to satisfy: a) land that can be densified; b) closest to recreational amenities; c) closest to urban amenities; d) neighborhood density is not high.

Second-Home Owners:
1. Determine developable lands that are undeveloped (density under the threshold).
2. Determine neighborhood density.
3. Determine proximity to natural amenities and recreational amenities.
4. Find location to satisfy: a) undeveloped land; b) closest to natural amenities; c) lowest neighborhood density; d). closest to recreational amenities.

owners. In order to be close to ski areas and some urban amenities like restaurants, they have to make compromises on density. In other words, they are more willing to live in higher density areas than second-home owners but lower density areas than service workers. (See Table 6.)

Second-home owners develop only on undeveloped land and the highest density is one unit per 10 acres. Owners of time-share condominiums develop on either undeveloped land or land previously developed by second-home owners. Service workers only develop on previously developed land, either by second-home owners or owners of time-share condominiums. Any

TABLE 6
Density by Agent Types

Agent/Household Types	*Density Threshold*
Service Workers	20 units/acre
Owners of Time-Share Condominiums	4 units/acre
Second-Home Owners	1 unit/10 acres

previously developed cell/site with a density of fewer than 20 units could be developed up to 20 units per acre by service workers if the cell satisfies service workers' needs. In other words, sites previously occupied by owners of time-share condominiums could be densified by service workers up to 20 units per acre. In the same vein, low-density, second-home owners' sites could be densified by owners of time-share condominiums up to four units per acre.

Findings

The result of our simulation was a density map at the cell level for the year 2000. To find out whether there is a reasonable correlation between model-predicted and existing development in the area, we created Figure 3 and Table 7. The development densities are displayed ranging from white, to gray, to black symbolizing densities from low, to medium, to high. The first map in Figure 3 presents the results of the census block-level density aggregated from the model prediction on cell-level densities for 2000. The second map shows existing census block housing density for the same year.

Comparison of the model results with historical and existing land-use patterns in the region visually and statistically is used by

FIGURE 3
Density in 2000: Predicted vs. Existing Development

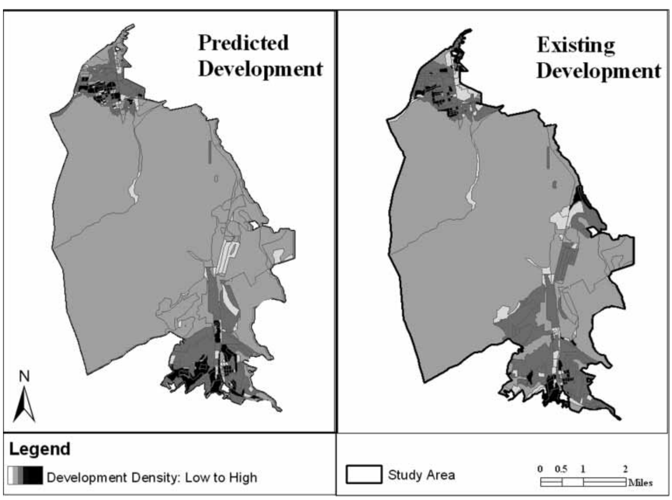


TABLE 7
Density Comparison: Predicted vs. Existing Development

Measures	*Value*	*Significance (2-sided)*
Pearson Chi-Square	9851.84	0.0
Linear-by-Linear Association	48.118	0.0
Spearman R.	0.395	0.0

Rand et al.
Parker et al.
Robinson
G.R. Sargent

many researchers to validate simulation models. Figure 3 shows that the overall density patterns derived from our model correspond to the existing census block density patterns visually, especially in the resort towns, Frisco and Breckenridge. In both maps, there are small clusters of dark areas in these towns representing high-density development. These high-density nodes are close to bus stops, bus routes, and high restaurant density areas.

For further validation of the model, we included the results of the comparison between predicted and existing development at the census-block level in Table 7 using Chi square and correlation. Both are non-parametric tests used to measure the relationship between two or more variables. The Pearson Chi square value in Table 7 indicates that our model prediction aggregated to census-block level is not significantly different from the exiting census block densities. Table 7 shows the value of Spearman R is 0.395 at the significance level of 0.0 representing strong positive correlation between our model—predicted densities and the existing census block housing densities in 2000. All three measures suggest that our model and existing development represent similar density patterns.

The distance to bus stops and bus routes as well as high restaurant density areas are found to be correlated with density change. Preferences of service workers and owners of time-share condominiums are associated with increasing density in this agent-based model. The development of service worker apartments and time-share condominiums help to form a development pattern characterized by housing density increase at multiple small nodes. Thus, the dynamics of density increase are intensified because both service workers and recreational populations are seeking higher density residential locations and use public transit. The housing filtering process included in this agent-based model and the location interactions among the three types of agents help explain the patterns of housing densification in the study area.

There are over-predicts and underestimates in our model as shown in Figure 3. Many studies have suggested, however, that because of stochastic uncertainty, no model can predict with a high degree of certainty. Wu suggested that the validation of models built on complex theory, including cellular automata and agent-based models, is related to the purpose of model building. This model aimed to explore patterns of density change with respect to three distinctive types of households in resort communities, not to predict density correctly for each specific cell. This model predicted reasonably well and is a good fit according to the results of visual and statistical comparison despite the variation, which may be due to our method of allocating the census block-level data to parcels. Although not perfect, the results show that this is a reasonable and feasible method when micro-level (parcel-level) data are not available or when building a model for a data poor area.

Brown et al.

Wu

Discussion and Conclusion

For this study, we built an agent-based model to explore patterns of housing densification with respect to location preferences of three different types of densification actors in a mountain resort community where there are unusual housing needs associated with service workers and short-term stays. Our model shows that activities and preferences by varied households including amenity and recreation-seekers as well as service workers create demand for multi-unit housing markets. The agent-based approach is shown as a useful approach to explore the dynamics of density increase resulting from individual choices on density and accessibility. Such models can also be applied to study the dynamics of land-use density change in not only other resort communities but also major metropolitan areas. In addition, we demonstrate a method for building a micro-level model appropriate to data-poor areas.

Service workers and owners of time-share condominiums are active players in the densification process in this agent-based model. The bus line and bus stops are also associated with densification of development, both for tourists (time sharers) and service workers. If the proportion of service workers and short-term recreation users in the population continues to increase, we may expect continued increase of housing densities and continued expansion of growth nodes in Breckenridge and Frisco. Over the next decade, the four-way dynamic between service worker location, time-share location, transit investment and development of town-based amenities is likely to continue or even intensify assuming current growth trends.

At the same time, there is a deep tension in the local land-use planning debate between the protection of natural amenities and growth. While outside our model, future land-use regulation may also reduce the amount of land available for development. In short, pressures for density increase are building in several dimensions. Over the long run, mountain resort communities, not only in the United States, but all over the world, face the challenge of increasing density while sustaining attractiveness to residents and tourists. The challenge for mountain communities is to guide this density increase so that they protect their recreational cachet and amenity values, while simultaneously providing a reasonable standard of life for workers and residents. Agent-based models have the potential not only to help planners understand the dynamics of density increase in these small mountain resorts cities in the past decade, but also to allow them to envision and study the future growth of these areas by projecting possible future development density patterns and by building scenarios to test different policies.

The model built in this paper can be replicated in other areas after collecting data on land use and tailoring density preferences of actors in different study areas according to local demographic and historical information. The analysis of the drivers of density increase helps explain the dynamics by which resort communities evolve and may help resort communities manage the balance between population growth and demands by both residents and the tourist industry to sustain the amenities that initially made these communities attractive.

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