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Assessing Indirect Spatial Effects of Mountain Tourism Development: an Application of Agent-based Spatial Modeling

Li Yin
State University of New York at Buffalo - USA

Abstract Many resort communities in the U.S. Rocky Mountain West are experiencing rapid in-migration and growth because the natural and built amenities in those areas attracted people and investment. This study uses an agent-based model to explore how homeowners' investment and reinvestment decisions are influenced by the level of investment and amenities available in their neighborhoods in a case study area of town of Breckenridge, Colorado to help understand the dynamics and the indirect spatial impacts of amenity-led mountain tourism development. This paper found that individual level of appreciation of amenities and continuing investment in a neighborhood attracted investment and reinvestment, and created pressure for high density resort housing development at the aggregate level. Agent-based model is a useful tool to simulate the dynamics behind the housing investment and reinvestment and to investigate the indirect spatial effects of high-density resort development.

1. Introduction

Housing markets are booming in many resort communities in the U.S. Rocky Mountain West as a result of various investment decisions of speculators, developers, as well as second home owners and urban transplants who are craving the rural lifestyle and amenities (Johnson and Rasker, 1995). This paper aims to explore the application of the agent-based approach in studying the dynamics behind the housing investment and reinvestment to help understand the indirect spatial effects of the high-density resort development; specifically, this paper uses the agent-based approach to explore how investment and reinvestment decisions are influenced by the level of investment and amenities available in a neighborhood configured with a three-dimensional structure to reflect high density development, and how those decisions created pressure for high density development to keep the housing market thriving.

The US Rocky Mountain West is renowned for nature tourism experiences. Appreciation of the natural environment has been identified by the Colorado Department of Tourism as the primary reason for visitors coming to the state (Colorado Department of Tourism, 2006). The attractions that draw people to the area also create a market to support numerous businesses and development. The rampant tourism development in the mountain valleys offered important alternatives to the historic boom-and-bust cycles of the region on one hand; on the other, it might change the character of the landscape and the social conditions that attracted visitors in the first place. Little has been done, however, researching how tourism development has reshaped these mountain towns in terms of the spatial impacts.

Butler (1980), Weaver (1990), and Lutz and Prosser (1994) posit that resort development follow an S-shaped life cycle, from introduction, growth, maturity, to decline. To avoid decline, resorts modify products that they offer and go through multiple phases of investment and reinvestment (Russel, 2004; Gill, 2000; Strapp, 1988). Second-home ownership may be one way to counterbalance declines in conventional tourism (Strapp, 1988; Foster, et. al., 1991). A significant proportion of property owners in many rapidly growing resort communities maintain the primary place of residence elsewhere (US Census, 1990; 2000). Most of these second-home owners are upper and middle-class. They invest in these towns, and contribute to the

booming housing markets because the vacation spots these towns have present opportunities for skiing, camping, fishing, and other leisure activities. In recent years, the number of second-home purchases in the region grows faster than any other places in the U.S.
High density development can be another product to offset the decline in the resort life cycle. Tourism destinations often have physical capacity or limits to growth. Some are located in a mountain valley. Thus, their physical growth is limited in the relatively flat areas. Some are located near a lake or a sea. Their growth is bounded by the water body and tends to cluster along the lake shore or sea beach. At certain stage of development because of the limited amount of land with access to amenities that attract investment, development may go from horizontal to vertical to accommodate growth. In Breckenridge, scarce recreation land and high development pressure created a successive product in the form of multi-story buildings following low density housing development. The high density development helps to maintain the high growth rate in the area (Figure 1).

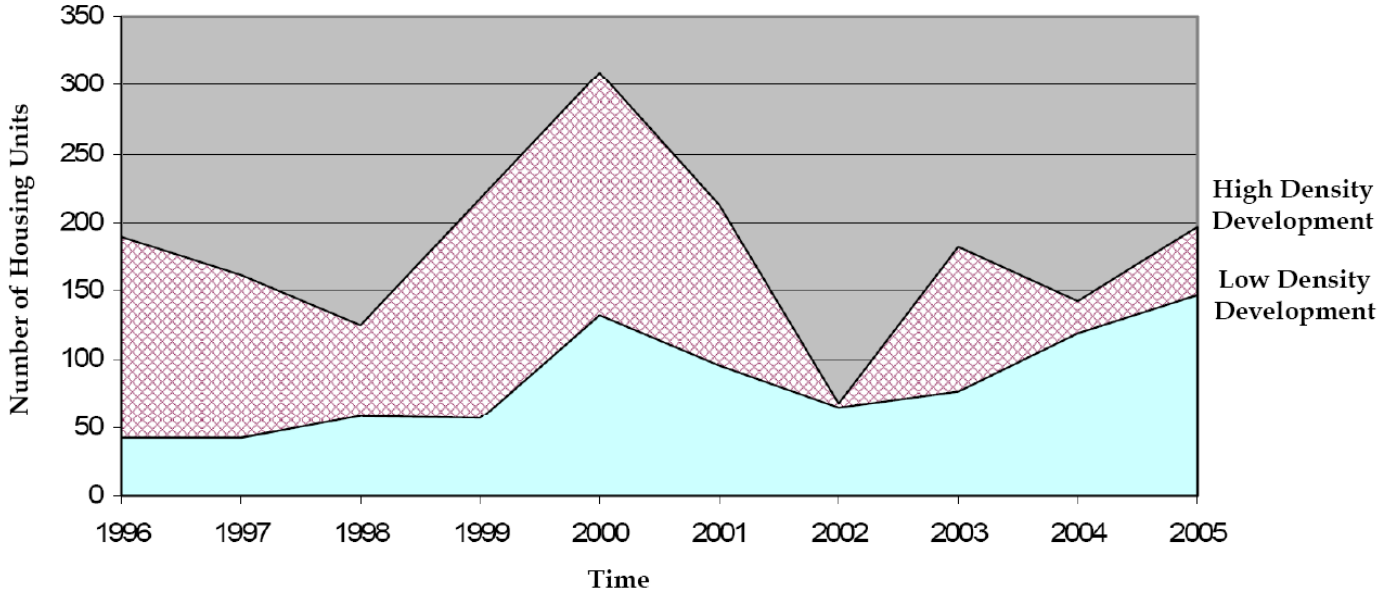

Figure 1. Housing Development in the Town of Breckenridge Colorado

The high density development in the form of multistoried buildings calls for an approach that can be used to model investment and reinvestment decisions and their effects on land development in both two-dimensional and three-dimensional spaces. The agent-based approach is a potentially useful tool to simulate the dynamics behind high density development as a result of numerous individual investment and reinvestment decisions. Agent-based modeling is a primary methodology of complexity theory. Complexity theory helps understand dynamic processes involving the interaction of many actors and how the aggregate level phenomenon emerges from those actors and their interactions (Batty, 2005; Brown et. al., 2005). This theory and methodology are recently applied widely due to the rapid development of computational power.

This paper seeks to use an agent-based model (ABM) in helping examine the indirect spatial impacts of the recent tourism development in mountain resort communities by conducting a case study in the town of Breckenridge, Colorado, one of the four largest Summit County resort towns. This study focuses on a small area located in Breckenridge to study the dynamics behind the housing investment and reinvestment at both the housing unit level and the parcel level. The results of this study can help the town understand the investment dynamics of the housing market to develop programs to continue the economic variability and preserve the town's unique history and character.

2. Background

The scarce recreation land and speculative investment drive up land cost and home prices since investors see the benefit of not only accessing rich amenities but also getting high investment payoffs offered by these areas. In the Rocky Mountain West, housing prices in the areas close to ski hills as well as places bordering national forest or lakes have increased greatly. More efficient use of land by densifying existing neighborhoods may ease price pressures in high-cost resort towns and keep housing market active; however, unplanned high density development, such as multistoried buildings in these areas, in the long run might change view quality of the town and block important view corridors. Therefore, tourism planning should be examined spatially and discussed in its long-term context.

2.1 Breckenridge, Colorado

Breckenridge is a 147-year-old Victorian town situated in the Rocky Mountains west of the Continental Divide. Breckenridge is the town with the fastest development in Summit County in terms of population and housing values (Table 1). All four largest towns in the county increased in population between 1990 and 2000, but at smaller rates than the whole county, except the town of Breckenridge. Population increased by 87.4%, and median housing prices are tripled from 1990 to 2000 in Breckenridge while more than doubled in other towns. Sixty-eight percent of housing units in the town are used for seasonal and recreational use, higher than other towns in the county. As one of the nation's year-round resorts that provide incredible selection of recreational activities, the total number of housing units increased from 325 in 1970 to 4270 in 2000, and 6351 by the end of 2002. High density development kept the high growth rate of housing units and kept the housing market from declining after most of developable areas were occupied. Breckenridge's permanent residents and peak population increased dramatically in the last few decades. Growing tourism business and booming downtown housing market encourage private economic investment and sustain economic prosperity. The results from comparing changes of population, total housing units, and housing values in the period from 1990 and 2000 for the county and all major towns in the county suggest selecting an area in Brackenridge for my case study.

Breckenridge sits in a U-shaped valley about 86 miles west of Denver and 34 miles east of Vail. The Blue River runs south to north through the center of the town, and runs parallel to the Main Street, the downtown core, as well as the historic district along Ridge Street (Figure 1). The town is 7 miles long and 2 miles wide with a total acreage of 2,998. Town-owned parks accounts for 13% of the land. The peaks surrounding the town reach up to 12,998 feet and the town of Breckenridge lies at about 9,603 feet above sea level. Sitting in a valley surrounded by mountains on the west, south, and east side, Breckenridge's physical growth is limited in the relatively flat areas shaped by the mountains and by the public lands. Development was driven from horizontal to vertical in the area close to the ski hills because of the competition for the limited flat land with easy access to amenities.

Table 1. Population and Housing Units in Summit County and Towns

Category		County	Breckenridge	Frisco	Silverthorne	Dillon
Population	1990	12,881	1,285	1,601	1,768	553
	2000	23,548	2,408	2,443	3,196	802
	% Change	+82.8%	+87.4%	+52.6%	+80.8%	+45.0%
Total Housing Units	1990	17,091	3,316	1,628	975	1,087
	2000	24,201	4,270	2727	1,582	1,280
Seasonal/recreational Housing Units	1990	9392	2,598	720	115	373
	2000	13,235	2,906	1,485	369	852
Median Home Value	1990	$121,500	$194,400	$118,000	$96,600	$155,400
	2000	$317,500	$580,100	$298,800	$264,300	$364,300
	% Change	+161.3%	+198.4%	+153.2%	+173.6%	+134.4%

Source: US Census, 2000

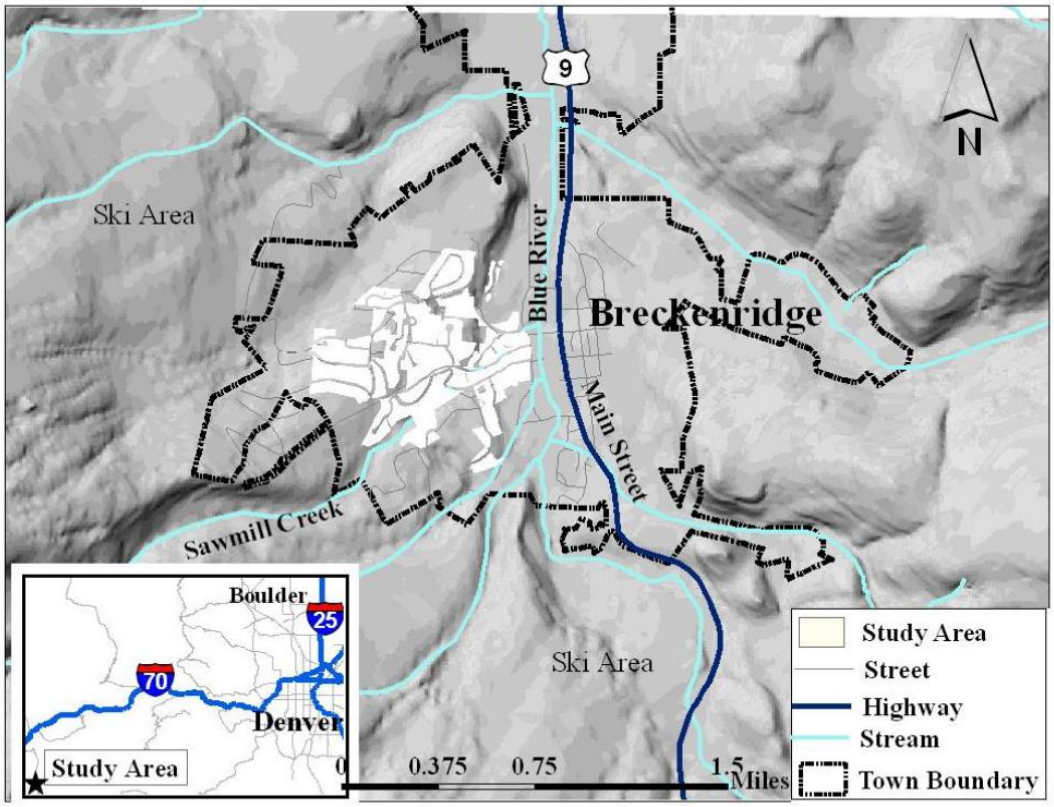

Figure 2. Study Area

The study area is west of Main Street and the Blue River, and right east to the mountains with 146 ski trails (Figure 2). This area has a combination of single family housing and higher density town houses and condominiums. It has rich amenities — views of mountain vistas and the forested hillsides, and close to public lands as well as downtown commercial settings. Some of the condos and houses were built with unblocked view of the ski trails. The major shopping area, Main Street, the creek, public transportation, and parking places are all minutes away by foot. Many condominiums have been sold a number of times since it was built and prices increased dramatically in the past decade. According to the town zoning map, this is one of the areas with the highest density allowed. Several of the parcels are filled with multistory buildings with about 100 units inside. As public highly treasure the views of the mountain peaks and preservation of small town character (Northwest Colorado Council of Governments, 2006), continuing building multistory condominiums in this area may in a long run impair view corridors and cause uneasiness leading to unfavorable results and less investment.

2.2 Neighborhood Influences

As a destination matures, reinvestment is needed to help keeping the tourism industry flourishing. Real estate investment and reinvestment play an important role in resort town tourism industry and local economy. Decisions of entrepreneur and homeowners are responsible for much of the development and redevelopment in resort towns and for keeping a thriving tourism industry. The housing sales are through a free and open bidding process. Homeowners' evaluations of the dwellings and neighborhoods, as well as their expectations about what other investors in the neighborhood are likely to do in conjunction determine whether and how much they will invest. Households often expect to reap from investing or reinvesting in housing, which is influenced by the aggregate amount of housing investment and reinvestment in nearby properties. For example, homeowners who observed that existing homeowners in the neighborhood are not willing to invest in their housing units may try to avoid capital losses and be unlikely to invest there. On the other hand, if they see the potential of a prosperous housing market and they like the amenities avail-

able in the neighborhood, they would be more willing to invest.

Investment on a housing unit depends on the unit's state and history as well as the state and history of its neighbors. The dwelling and neighborhood conditions, as well as local environmental externalities on which investment decisions are based are different across the housing market. They include current condition of the dwelling, accessibility to natural and urban amenities, and housing conditions of neighbors. In an area with multi-story buildings due to pressures for development around limited recreation lands, investors need to evaluate not only neighbors on other parcels nearby, but also the neighbors on the same parcel, in the same multi-story building.

Location models often assume each cell or parcel is occupied by one owner and this owner's decision is affected by its neighbors on other cells or parcels. Several possible neighborhood structures for two-dimensional agent-based or cellular automata models are widely used (Packard and Wolfram, 1985; Wootters and Langton, 1990), such as Rook's and Queen's neighborhoods. On a square cellular matrices, Rooks includes four directional cells that are adjacent to a cell and Queens consider all eight cells around a cell. These neighborhood structures, however, ignored the impacts of their immediate neighbors living in the same building when the building is multistory in high density development areas. If the neighbors in the same building reinvest to upkeep the units to sell them with a higher price, a household may be more willing to invest or reinvest to maintain the unit for a potential profit.

Batty (2005) suggested that spatial development may be explained by a combination of five drivers including random event, historical accident, physical constraint on development, natural advantage, and some comparative advantage. Historical development patterns, physical constraint of growth, natural and recreational amenities, and neighborhood investment activities can help examine the spatial development patterns in many mountain resort towns. The development at the aggregate level emerge from numerous decisions on whether and how high home owners are willing to pay based on these evaluations. The variety of the factors and neighbor-influences that affect households' investment decisions calls for a disaggregate and interactive perspective to examine the dynamic resort housing market. A benefit of agent-based models is that they are dynamic (Torrens, 2001) and they allow to simulate the interaction of neighbors' investment behaviors and capture emergent phenomena.

2.3 The Agent-based Approach

Agent-based models are based on a conceptual framework developed by Von Neumann in the late 1940s (Von Neumann, 1966) and was speeded up by the advent of the microcomputer. ABM is a bottom-up approach to model the whole system as the aggregate result of myriad interaction of the system components called agents. Unlike many predominate models of housing market, ABM can characterize a system as a result of dynamical interactions between rule based agents (Batty, 2005). Agent-based model can be used to create an artificial world to explore the dynamics of housing market in the town of Breckenridge as the result of numerous interacting individual housing investment and reinvestment decisions, by applying rules on households the same way as robots are programmed to follow detailed instructions to perform certain tasks. It is a method that can help planners to understand the dynamics of the tourism development in a town and its spatial effects.

Since ABM is individual based, it allows each agent to assess its situation and makes decision on the basis of a set of rules. It allows building a model with a nested neighborhood structure, in which agents interact with neighbors in both horizontal and vertical dimensions; in other words, neighbors on other parcels and on the same parcel are both considered. The dynamics of the housing investment in resort towns result from the behavior of many interacting investors, leading to emergent phenomena that can be best understood by using a bottom-up approach, that is, ABM.

3. Research Method

3.1 Data Collection and Preparation

Data was collected from a variety of state and local sources and processed in ArcGIS 9.1. Parcel geometry data was collected to identify parcel boundaries. Bus routes, bus stops, public land, shopping area, and ski resort entrance are digitized according to the pdf files provided by the county government and information on the county's website. Road and stream data was from TIGER. Processing of these datasets include reprojection and clipping. Network-based distance analysis was then performed to get accessibility measures from each parcel to the nearest ski entrance, shopping areas, and etc.

Detailed information about each parcel was downloaded from the Summit County government's website (Summit County, 2006). Data was available for each unit with information on parcel number, owner's

name, number of stories, number of units, year of built, numbers of sales, sales prices, etc. This information allows identification of the land use, density, value change, and number of sales transactions of each parcel[1]. Parcels with multiple records, such as parcels with condominiums were linked to external database for information on the units located on them. After processing data were converted to grids, exported, defined as a matrix, linked to coordinates, analyzed through a set of JAVA routines, and visualized in RePast and ArcMap.

In the study area, 62.8% of the 1308 units in multistory buildings and more than half of the 590 single units are owned by people who are not maintaining their primary residences in Colorado. Median housing value is $602,844. Maximum number of sale transactions for a single condominium is 12, and 7 for single family unit in the past 30 years. The number of transactions will be used for building the agent-based model to see the dynamics of investment and reinvestment over the years and how they affect the spatial fabrics of the town.

3.2 Agent-based Model

This study built an agent-based model to simulate the housing investment and reinvestment decisions by agents or owners of single family housing and condominiums. The agent-based approach was used to model how the interactions among agents and agents' preference on amenities influence investment decisions in a resort housing market. Three main components of the model are environments, agents, and agent interactions. The environment is a lattice of uniform squares. Each square is either developed or not developed. If developed and it is on a single unit parcel, it is occupied by one housing unit; Otherwise it is occupied by multiple housing units. The initial state of the simulation is same as the housing development in the year of 1990. In other words, cells contain housing units' information as of year 1990. Characteristics of the environment include location of natural beauty and shopping settings, availability of ski buses, and neighborhood investments such as number of sale transactions and sale value changes. Some of the variables are endogenous, that is, they change during the course of the simulation while static variables remain constant. Neighborhood density and investment level, as well as overall types and amount of available land change at every step, which are based on previous agent's actions from previous time steps or iterations (Figure 3). These changes influenced any decision-making in the next iterations, and therefore contributed to the emergence of the aggregate level housing density pattern that is more than the sum of all variables.

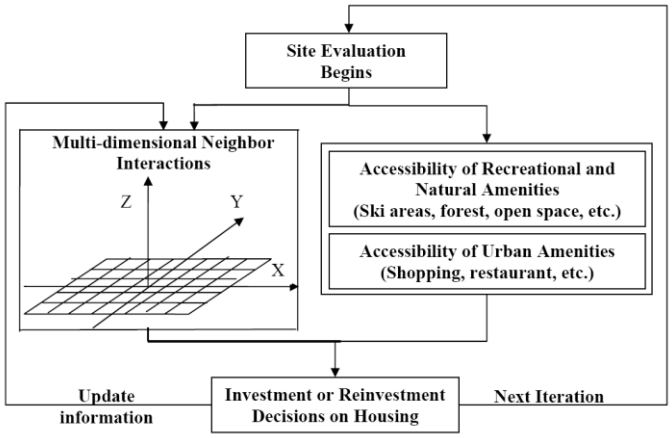

Figure 3 A Framework of Agent-based Model of Housing Investment and Reinvestment

Agents are home investors. They have preferences on adjacency to natural beauty, near shopping settings and ski buses, and active housing investment in the neighborhood. One agent will invest on one housing unit every time step or iteration. They choose the location with the highest utility for their preferences and correspond to the last updated endogenous variables [equation 1]. After each time step, the endogenous variables are updated. The total number of housing units invested during the study period is 3121, equivalent to the total number of housing sales transactions between 1990 and 2005.

The agent-based model built in this study has a nested neighborhood structure in which neighbors on other parcels and on the same parcel are both considered. In other words, the neighbors are considered on both horizontal and vertical grids (Figure 3) and model is run at both housing unit and parcel level. The added third dimension changes the neighborhood structure and modifies the number of neighbors that each cell has. An agent will evaluate the location of the dwelling with respect to natural amenities, shopping, and the investment activities in the neighborhood be-

[1] This information, however, can be downloaded only one record at a time. For single unit parcels, every record represents a parcel while for multi-unit parcels, there are multiple records for each parcel, each record for one unit. The information for each record was pulled off from internet as an excel file. A total of 2263 files were downloaded, cleaned, transformed, and combined into one dbase table using a Microsoft Visual FoxPro script. The downloaded parcel file was matched and joined to the GIS parcel geometry file.

fore making their own investment decisions. The decision is made using a decision algorithm as represented by equation 1, which is applied to each cell.

$$S_{it} = f_x(A_{it}, IN_{nt}) \quad (1)$$

Where S is the total investment possibility score for cell *i* at time step *t* for an agent. A is the level of natural and built amenities for cell *i* at time step *t*, and IN is the level of investment and reinvestment in the neighborhood *n* in which cell *i* is located at time step *t*. A is consistent through the duration of the simulation. IN is updated every time step to reflect the investment and reinvestment level in a neighborhood, which influences other agents' location decisions. The recursion on equation 1 leads to the growth in the town.

4. Discussion

The result of the agent-based simulation is presented in Figure 4a and 4b. The existing development and the model result are both placed in Figure 4 for comparison. Light gray area was developed before 1990 and dark gray was development from 1990 to 2005. The second map is created using the output exported from RePast agent-based simulation. The model result reflects the development patterns emerged from investors' evaluation on the amenities, and level of investment or reinvestment in a neighborhood. It shows roughly the same pattern as the existing development. In both maps, there are concentrations of development in the southern edge of the study area, reflecting investment interest on the areas that are close to the ski resorts and that maintain a high level of investment and reinvestment activities. Consistent investment in the area attracted more investment and drove development to high density. Brown, et al. (2005) and Batty (2005) posited that land use models are unable to predict completely accurate because of path dependence and stochastic uncertainty. The purpose of the model built in this paper is to explore patterns of density change emerged from individual's investment and reinvestment decisions. In this sense, this model is plausible. By simulating housing investors' decision at the individual level, this agent-based model was able to capture the investment and reinvestment dynamics that drove high density development in the area.

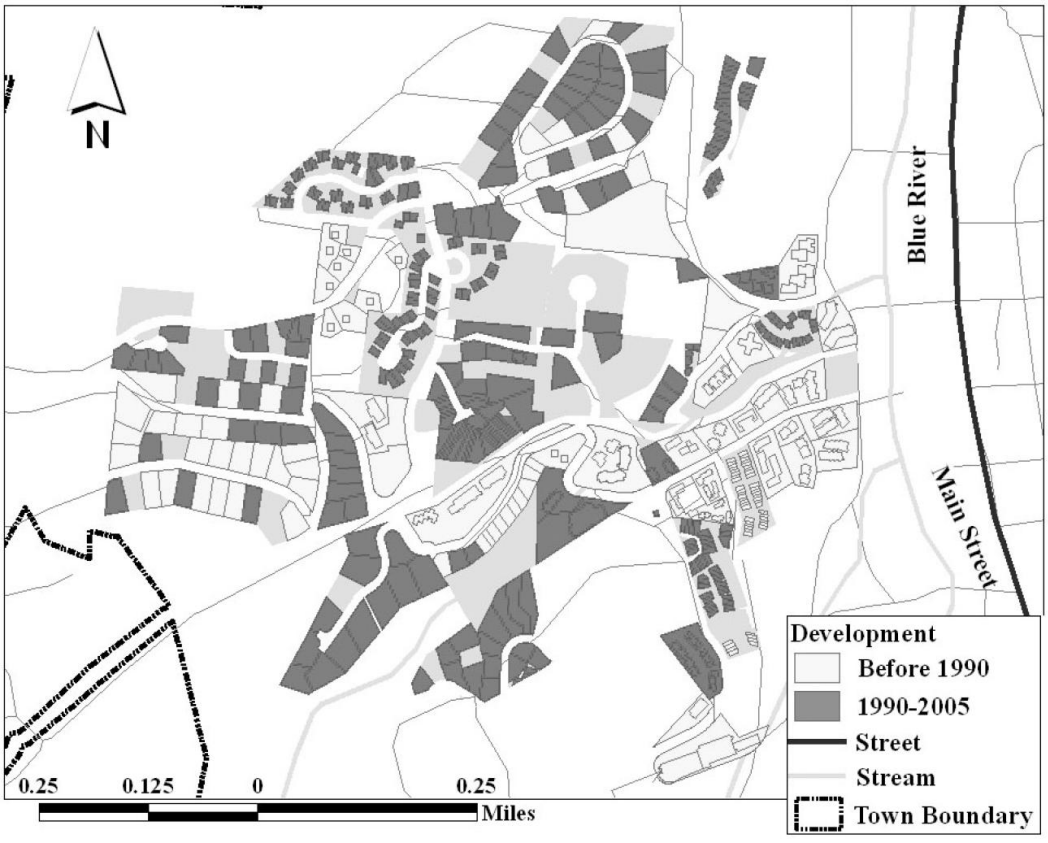

Figure 4a. Results of the Simulation – Existing Development

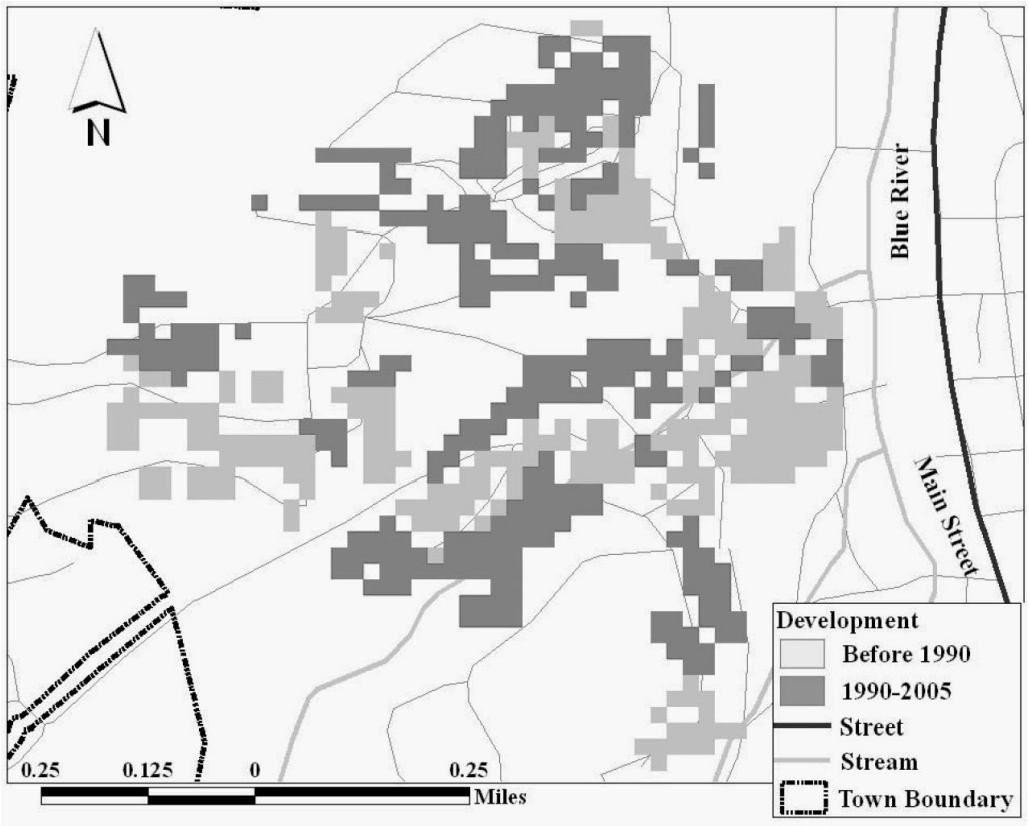

Figure 4b. Results of the Simulation – Model Results

The physical constraints and increased demand for residences and in resort towns, especially secondary residences by outsiders has led to an increase in prices of housing and land, as well as an increase in the development density. Agent-based models provide a framework in which individuals and their behaviors in relation to the system environment and other individuals in a system can be modeled in a more direct and realistic way. By introducing a nested neighborhood structure with both two and three-dimensional neighbors, this paper demonstrates how agent-based models can be used to explore the investment and reinvestment dynamics in a high density resort housing market and shows the potential use of this kind of models to observe the behavior of agents in response to different strategies and other agents' behaviors. A spreadsheet model or many other modeling techniques are inadequate to generate the same deep insights as ABM, because the behavior of the market emerges out of the interactions of the players, who in turn may change their behavior in response to changes in the market. This paper found that individual level of appreciation of amenities and continuing investment in a neighborhood attracted more investment and reinvestment, and created pressure for high density resort housing development at the aggregate level.

The method used in this study can help planners to understand the dynamics of the tourism development in a town and its spatial effects; and therefore, help provide insights into the Rocky Mountains' tourism industry which could aid in the development of strategies, policies and systems for influence the location and density of development, as well as implementing and managing tourism.

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