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The dynamics of land development in resort communities: a multiagent simulation of growth regimes and housing choice

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Abstract. Over the past thirty years, recreation communities in many parts of the globe have gone through cycles of diversification and integration into complex recreation regions. As resort communities mature, they face increasing pressures on scarce recreational resources, demands for economic diversification, and changing attitudes toward tourism on the part of local residents. A variety of land-use management practices and economic development initiatives has emerged in resort towns in response to resource congestion and other growth issues. In this paper we explore alternative growth strategies through a simulation of housing decisions by primary actors in resort land markets. We use a multiagent system to model the dynamics of growth regimes, assess the influence of recreational and town amenities, and evaluate the effect of alternative growth processes on long-term development patterns. Our case study area is Steamboat Springs and surrounding parts of Routt County, a four-season recreational region in northwestern Colorado.

1 Introduction

Over the past thirty years, recreation communities in many parts of the globe have gone through cycles of diversification and integration into complex recreation regions. These cycles are shaped by inflows of national and international resort capital, infrastructure investments such as airports and highways, and the action of local entrepreneurs. With diversification, resort communities are attracting new populations including tourists interested in four-season amenities, long-distance commuters, retirees, second-home owners, and service worker populations. These economic shifts dramatically influence patterns of landscape change. Resort communities are now adding huge complexes of condominiums, hotels, and golf courses. Outside of town, agricultural and natural landscapes are giving way to 'McMansions'. Planning efforts in these towns increasingly focus on issues such as the availability of public transportation or affordable housing, and the shaping of urban form so that it simultaneously serves the resort industry, second-home dwellers, service workers, and long-term residents. A variety of growth management regimes and growth promotion initiatives has emerged as resort communities across the Rocky Mountain West debate how to build the recreation industry and sustain the local quality of life (Gill, 2000).

In this paper we explore alternative growth strategies in resort communities through a simulation of residential location processes. As resort communities mature, they face not only exogenous pressures from competing demands for scarce recreational resources but also endogenous pressures from local residents' changing attitudes toward tourism. These pressures are often discussed by researchers in terms of

various forms of cyclical or growth theories (Butler, 1980; Gee et al, 1997; Long et al, 1990; Papatheodorou, 2004; Ritchie, 2004; Stankey and McCool, 1984). In this research we examine the dynamics of land competition among immigrants to resort communities and local residents, and the effects of their location choices on change in both urban and rural landscapes. We develop methods in two areas to support this research. First, we build a multiagent system (MAS) model describing the life-cycle effects of competition among key social agents in resort communities (Bradshaw and Muller, 2004; Yin and Muller, 2004). Using this MAS, we simulate the interactions of four primary types of homebuyers and renters (service sector workers, weekenders, entrepreneurs and professionals, and large lot amenity seekers). Second, we evaluate the effect of different growth trajectories of availability of land for workers in the service sector. Our case study area is Steamboat Springs and the Yampa River valley in northwestern Colorado.

2 Background

In many communities across the Rocky Mountain West, recreation is a primary engine for real estate development, business and employment growth, and in-migration. The recreation industry began soon after the region was settled, stimulated by the development of trains and other transportation links. Through World War II, the federal government played a major role in guiding the growth of this industry through the formation of national parks, protection of lands such as the National Wildlife Refuge System, and multiple-use management practices in the United States Forest Service. Since World War II, ski areas have also acted as a primary attractor for recreation development in the region. The emergence of four-season resorts over the past twenty years along with a multitude of other recreational activities (eg backcountry skiing, mountain biking, and rafting) provides further stimulus to recreational communities in the region. Over the past decade, many resort communities have begun to make stronger use of planning and development tools including urban design programs, transit investments, affordable housing policies, economic development initiatives, and land-use controls. Strategies for 'small town' urban design and conservation of surrounding landscapes, linking ecological, aesthetic, and commercial values, have become an important factor for strengthening local economic advantages. These strategies incorporate both growth promotion elements and growth management elements, and are presented as a response to population growth, weakness in recreational economies, perceived threats to quality of life, and sustainability of historically defined places.

Researchers have adopted several conceptual frameworks to explain processes of growth and decline in resort areas. The growth promotion literature focuses on the role of land development and the activity of a local entrepreneurial class (Canan and Hennessy, 1989; Logan and Molotch, 1987; Molotch, 1976; 1993). The growth management literature emphasizes factors such as demographic change, shifts in political regimes, and the effect of increasing congestion on amenities (Dubbink, 1984; Feiock, 2004; Gill, 2000). In 'life-cycle' theory, policy transitions are closely linked to processes of economic evolution as resorts struggle to maintain competitive advantage. Resorts move through multiple phases of reinvestment, modifying the kinds of products they offer tourists in order to expand their markets and avoid decline (Butler, 1980; Gill, 2000; Russel and Faulkner, 2004; Weaver, 2000). Several types of life-cycle models have been introduced to explain the evolution of tourism (Butler, 1980; Christaller, 1963; Gee et al, 1997; Prideaux, 2004). Six stages of resort community life cycle were identified by Butler: exploration, involvement, development, consolidation, stagnation, and poststagnation (stabilization, rejuvenation, or decline). Decline is a product of market saturation, congestion, and overuse of resources. Some life-cycle researchers emphasize

resort diversification processes; for example, declines in conventional tourism may be offset by a rise in second-home ownership or primary residential development in resort areas (Foster and Murphy, 1991; Strapp, 1988). Critics focus on the empirical methods used in the life-cycle research, theory of the role of consumer demand, and the potential for multiple alternative developmental paths; many researchers both acknowledge these shortcomings and continue to find value in life-cycle approaches (Agarwal, 1997; di Benedetto et al, 1993; Goncalves et al, 1997; Hovinen, 2002; Lundtorp and Wanhill, 2001; Moore and Whitehall, 2005; Prideaux, 2004; Tooman, 1997).

For analysis at a finer grain, however, life-cycle theory must be scaled down so that it is sensitive to the nuances of how different social groups compete within a physical environment and land-use policy framework. The detail of these interactions may dramatically influence the emergence of specific landscapes. Location decisions in resort communities are heterogeneous in three dimensions. First, heterogeneity is a product of patterns of existing ownership and the actions of specific social groups who are buying and selling land, building houses, and more generally attempting to reorganize the city to meet their purposes. Second, it is a result of flows of people and capital into resort communities and the resulting changes in configurations of ownership and preference. Third, heterogeneity is created not only by variable preferences but also by differential access to economic and political power. In all three dimensions, growth policy regimes in resort communities are dynamic. In other words, different regime paths have cumulative effects on land-use change.

Immigrants are attracted to mountain communities because of access to recreational activities (eg ski areas and golf courses), availability of town amenities (eg restaurants and shopping districts), and the presence of natural amenities (eg scenery) (Booth, 1999; Duane, 1999). Proximity to public lands and the aesthetic character of landscapes serve as major attractions. Both location and recreation decisions are affected by viewpoints, topography, climate, safety, size of the natural area, distance to other natural destinations, availability of parking, type of accommodation provided, attitude of resort service workers, availability of marked nature trails, and distance from trip origin to the recreational site (Hudson et al, 2004; Ormiston et al, 1998; Termansen et al, 2004). In conjunction with this complex spatial environment, locational choices of different types of resort immigrants are diverse. A variety of social classifications has been developed to describe these patterns of occupational status, recreational interests, and amenity preference related to housing choice (Gill, 2000; Perdue, 2004; Rocharungsat, 2004; Sautter and Leisen, 1999). Sautter and Leisen (1999) classified eight stakeholder groups in resort communities: residents, activists, tourists, national business chains, local businesses, competitors, government, and employees. Gill (2000) identified six stakeholder groups: professional and skilled workers, service-sector workers, resident entrepreneurs, telecommuters, retirees, and second-home owners. Perdue (2004) classified residents in Colorado ski resort communities including 'traditional' ski bums, who are usually young and transient; 'new' ski bums, who are older and enjoy the resort town itself; and the 'other resident' category such as consultants, entrepreneurs, and trust fund babies.

As social groups compete over time for scarce housing locations, their interactions have cumulative effects on the character of resort communities. Different immigration streams may exert different types of pressures on natural landscapes, resort infrastructure, and availability of housing. In this research, we construct an agent-based model to explore the effects of heterogeneous location choices of immigrants to resort communities. We use life-cycle and regime theory as a framework within which we nest microlevel theory describing housing market decisions by heterogeneous actors.

Land conversion has been evaluated through a variety of spatial methods including discrete choice statistics and pattern-based models (eg Landis and Zhang, 1998). Agent-based methods are suited to this project because we are interested in dynamic landscape processes and interactions among typified actors (Otter et al, 2001; Parker et al, 2003). An agent-based approach is also tractable because our case study is a small community with relatively simple land markets. This model structure permits us to examine the formation of alternative development paths as a product of cumulative location decisions.

3 Study area

Routt County is located in northwestern Colorado, encompassing 2231 square miles of high peaks, mountain valleys, and rough rolling hills. It includes a larger town, Steamboat Springs, and three smaller incorporated communities, Hayden, Oak Creek, and Yampa. From 1970 to 2002, the county's population increased by 13 635 people, an annual rate of about 3.5%.[(1)] The county is unusual among major Colorado resorts because it continues to have an active ranching economy and the pastoral landscape is still visually intact across much of the county. This landscape includes both dry, upland grazing areas and hay meadows and riparian lands along the Yampa River. Recreational amenities include a major ski resort, backcountry ski terrain, hiking, mountain biking, and cross-country ski trails, and hunting and fishing areas. About one half of the land in Routt County is owned by federal or state governments including the Medicine Bow – Routt National Forest and four state parks (see figure 1).

Figure 1. Location of study area within Routt County.

[(1)] US Census Bureau, 2000, Summary File 3 (SF 3); American Factfinder (http://factfinder.census.gov/); and US Census Bureau, "Population of counties by Decennial Census: 1900 to 1990" published 27 March 1995 (http://www.census.gov/population/cencounts/co190090.txt).

The economic foundations of Routt County have been shifting for many years from agriculture and resource extraction to recreational services. Steamboat Springs is now the location of 70 restaurants and bars, and 250 shops and boutiques, and has 11 139 hotel beds.[2] Along with the shift from agriculture to recreation, per capita income in Routt County grew from about $18 282 in 1970 to $36 976 in 2002. Housing costs are inflating rapidly: the median value of housing in Routt County increased by more than 178% between 1990 and 2000; 29% of housing units were listed in the US Census 2000 as vacant or second homes (in comparison with 8% for the state of Colorado as a whole).[3] We evaluated Routt County assessor records to determine the percentage of units that are owned by non-Routt-County residents. This tabulation indicates that 39% of housing units in Routt County have nonresident owners. Second-home owners report spending an average of about 9.3 weeks per year in Steamboat primarily in the summer (69%) and winter (75%) seasons.[4]

Public discussion about housing affordability in Routt County has become heated over the past few years, particularly regarding the availability of housing for service workers. Many in the community express concerns about changing existing zoning and city boundaries out of fear that housing expansion will stimulate a growth surge and dissipate the area's unique qualities.[5] The corporate owners of the ski hill and others argue that the area needs more affordable housing, in part for service workers. After several years of discussion, the city council agreed on a plan to annex new territory west of the city to be zoned in part for service worker housing including multifamily housing and trailer parks. Similar debates about service worker housing have become typical of ski areas across the western United States and other resort communities across the world.

4 Methods

In this research, we build a multiagent simulation of demand for new housing locations in Routt County and its effect on the availability of service worker housing. The study area is a rectangle encompassing the cities of Steamboat Springs and parts of Hayden and Oak Creek as well as a variety of county subdivisions, large lot developments, and traditional ranch houses. It is a matrix containing 121 695 cells or hectares (470 square miles). Agents locate in single-family houses, apartments, or condominiums contained within 1 ha grid cells. These grid cells are constructed on top of one or more parcels and are identified according to the institutional and planning attributes of these parcels. Each grid cell is also defined according to other primary social and geographical characteristics. We simulate potential future development to identify growth options and pressures in the region. We assess the results of this simulation in terms of potential shortages in zoned land available for the construction of service worker housing defined as multifamily housing and mobile homes.

4.1 Agent typology

We create a typology of agents based on categories derived from the work of Gill (2000) and Perdue (2004) as well as survey research about land markets in Central

[2] Steamboat Springs Chamber of Commerce, "Steamboat Springs facts and figures" (http://www.steamboat-chamber.com/info/facts.asp).

[3] US Census Bureau, 2000, Summary File 3 (SF 3); American Factfinder (http://factfinder.census.gov/).

[4] RRC Associates, "2002 Steamboat Springs Community Survey" (http://www.steamboatsprings.net/uploads/media/sbs_comm_surv_results.swf).

[5] see footnote (4).

Colorado ski towns.[6] Gill's typology emphasizes the role of agents as stakeholders in planning debates. In this research, agents are defined according to their occupations and activity in housing markets, described in terms of tenure, length of occupancy, and demand for housing type. We have reduced Gill's typology to four primary agents in order to simplify the model. These are (1) service-sector households, a category that we have expanded to include retail and construction labor; (2) local entrepreneurial and professional households; (3) households seeking large lots and natural amenities; and (4) weekenders. We assume that the first two types of agents are actively employed and primarily work inside the county. These occupational categories in part reflect financial resources available for housing. Agent behaviors in the model are guided by heuristics and calibrations identified through previous research. Other types of households such as ranch owners are also making location or relocation decisions; we assume that their preferences are distributed randomly among our four household types. The preferences and activities described below are a synopsis of the community value surveys cited above. The work of Gill, Perdue, and others also informs these classifications (see table 1).

Service sector households tend to be most constrained in their location choices both because of income and because of the character of their work. These workers generally have lower wages although construction wages can be substantial. Moreover, they are generally employees of the resort itself as well as of restaurants, hotels, shops, and construction firms, with relatively rigid commuting requirements in comparison with other agents in the model. Many service workers live at relatively high densities. Some are housed in company dormitories; others are housed in mobile-home parks, in apartment buildings, or at higher densities in single-family houses. We assume in this model that service worker households tend to be clustered and seek neighborhoods with relatively low rents.

Table 1. Agent descriptions.

Agent type	Occupation [a]	Length of occupancy	Tenure type	Housing type
Service sector workers	service, sales, construction	seasonal, year-round	mostly renters, small number of owners	mobile home, multifamily housing
Entrepreneurs and professionals	management, professional, technical	year-round	owners and renters	single-family and multifamily housing
Large lot amenity seekers	retiree, second-home owner	year-round, seasonal	owners	large lot single-family housing
Weekenders	second-home owner	seasonal	owners	condominiums, single-family housing
Others	farming, production, other	year-round	owners and renters	all

[a] Standard occupational classifications from the US Population and Housing Census, 2000.

[6] Sources include the 2003 Frisco Community Survey, 2003 Silverthorne Community Survey, 2003 Dillon Community Survey (Northwest Colorado Council of Government) and 2002 City of Steamboat Springs Community Survey (RRC Associates). Housing affordability was identified in the Steamboat Springs survey as the most important housing issue for the community.

Entrepreneurial and professional households have mixed housing preferences including desire for natural, town, and resort amenities. They tend to have more resources for purchase of housing than service worker households, although wage levels vary. These agents work within the county as well as outside through long-distance commuting, telecommuting, and consulting arrangements. Because of flexible work arrangements, some of these households may also have more flexibility in housing location than service workers. Entrepreneurial and professional households primarily reside in detached single-family homes and tend to prefer access to local services.

Large lot amenity seekers come to the county for retirement, leisure, or recreation, although some continue to telecommute. These households make location decisions primarily with respect to space and the availability of natural amenities. They are the most aggressive consumers of landscape amenities. These agents tend to have high incomes, live at the lowest densities of all in-migrants, include a high proportion of retirees, and have well-defined landscape preferences for views, proximity to riparian areas, and proximity to protected and public lands. At the high end, these agents purchase working farms and ranches and within the context of the data available to this project are virtually indistinguishable from historical farm and ranch populations.

Weekenders make location decisions with respect to the availability of nearby resort services. These include both condominium dwellers and second-home owners. In many cases, they spend relatively few weeks out of the year in the area, sometimes purchasing condominiums as time-shares. They are interested in intensive recreation and leisure activities—most important, skiing and golf. They are more likely to be dependent on walking or public transportation than other households are except for service workers; thus, close proximity to restaurants and other amenities is also important. At an extreme, these agents may prefer high levels of proximity—that is, the opportunity to ski from their front door to the ski lift.

Figure 2 shows trends from 1960 to 2000 for each household type. Numbers of large lot amenity seekers and weekenders are derived from the vacant housing units for seasonal, recreational, or occasional use, divided into condominium (weekenders) and other (large lot amenity seekers). Numbers of service sector workers and entrepreneurs

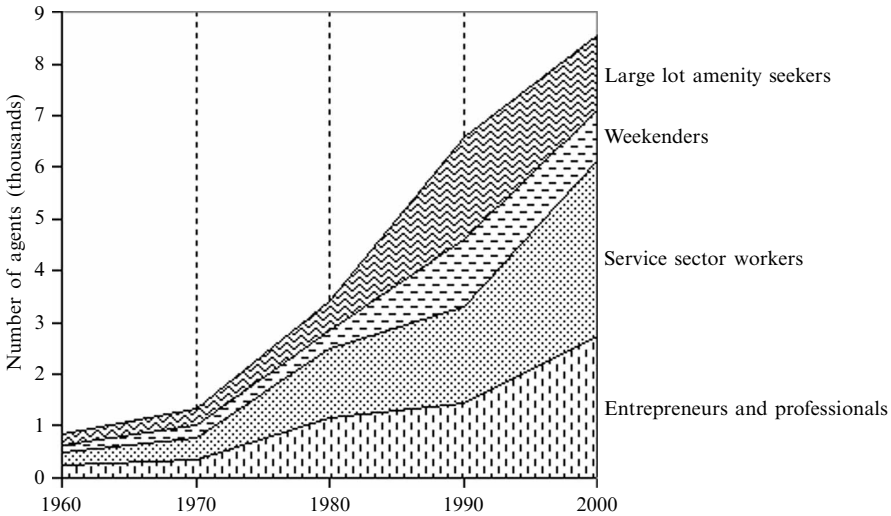


Figure 2. Routt County residential market segments.

and professionals are calculated from occupation data in the US census. We use historical proportions of household types as a basis for calculating the profile of different agent types that demand housing locations at each one-year model step. At future model steps, proportions of household types are multiplied by estimates of the total number of new households locating in the study area according to the Colorado Department of Local Affairs projections.[7]

4.2 Model design

Our model design focuses on the influence of resort amenity variables over residential location decisions. The model is presented in five sections: overall design; data sources and variables; land-use policy rules; model comparison and accuracy tests; and policy simulation.

We classify resort amenity variables into four groups: natural amenities including open space; small town amenities including a historic district; developed resort amenities including restaurant and the ski hill; and related policy rules. In this model, each agent entering residential housing markets in the study area is assigned preferences for amenity access according to heuristics defined in the literature and through interviews. The household with the highest preferences index for a target cell establishes residency. Preferences are compiled in an attractiveness index, as follows.

$$\mathbf{A}_a = k_{a1}\mathbf{J} + k_{a2}\mathbf{N} + k_{a3}\mathbf{R} + k_{a4}\mathbf{H} + k_{a5}\mathbf{P} \ , \quad (1)$$

where

J are jurisdiction, neighborhood, and site attributes;
N are natural amenities;
R are resort development amenities;
H are historic center amenities;
P are growth policy attributes.

$\mathbf{A}_a$ is the attractiveness index of a cell to agent of type a; $k_{a.}$ is the weight agent a gives to the variable. The matrix containing As for each cell is then multiplied by a matrix containing 1s for available land and 0s for areas that cannot be developed. Agents select cells with the highest attractiveness index. Ratio variables are normalized through division by the maximum value of each variable.

The logic of household preferences in this model depends on how different social types in resort towns respond to the availability and accessibility of amenities. For example, large lot owners seek natural and pastoral amenities available in low-density neighborhoods with high levels of proximity to public lands. Weekenders and professionals tend to seek in-town locations and walking access to restaurants, commercial services, and the old town. The old town is also heavily marketed for its traditional Western charm. Service workers tend to have limited access to vehicles, making accessibility to bus stops and the ski hill important for their journey to work. Marketing literature suggests that access to ski hills, including 'ski-in, ski-out' condominiums, is a strong attraction for weekenders.

4.3 Definition of variables

Distance variables are measured over road and street networks. Point and polygon locations including ski areas, bus stops, the old town area, zoning designations, and restaurant concentrations are digitized by hand based on hard-copy maps. Neighborhood density is measured by 1990 structure locations generalized to a 13 by 13 grid.

[7] Colorado Department of Local Affairs, 2005, "Forecasts", available at http://www.dola.state.co.us/Demog/PopoulationTotals.cfm.

Table 2. Key variables.

Variable	Measure	Large lot amenity seekers	Service sector workers	Entrepreneurs and professionals	Weekenders
Neighborhood density	13×13 raster neighborhood	−	0	0	+
Service worker density	US census blockgroup	0	+	0	0
Bus stop distance	network measure	0	−	0	0
Stream proximity	buffer (dummy)	+	0	0	0
City jurisdiction	region	0	+	+	+
Public land proximity	buffer (dummy)	+	0	0	0
Old town distance	network measure	0	0	−	−
Ski area distance	network measure	0	+	0	−
Restaurant distance	network measure	0	0	−	−
High-density zoning	region	−	+	0	0

Public land includes all federal and state lands as well as some local public lands; proximity is measured by a half-mile buffer (see table 2).

Data are collected from a variety of federal, state, and local sources and processed in ArcGIS and SQL. Data-processing steps include reprojection, reclassification, tiling, network-based distance analysis, buffering, and sampling. Data discrepancies are also addressed. For example, parcel records for Routt County and the city of Steamboat Springs are generalized to address discrepancies along the city boundary. After processing, these data are exported, defined as a matrix, linked to coordinates, analyzed through a set of JAVA routines, and visualized in MASON and ArcMAP. Most data sources have constant values during 1990 – 2000. However, neighborhood density and overall levels and types of available land change at every step based on previous actions.

4.4 Land-use rules

Land-use policy rules in this project are defined according to a mixed regulation/economic promotion regime characteristic of many resort communities in Colorado. Routt County and the city of Steamboat Springs roughly follow this pattern:

(1) zoning restrictions limit mobile-home or apartment building development in the unincorporated part of the county;

(2) lot split rules also promote low densities in unincorporated areas. We mimic a constitutional amendment in Colorado that restricts subdivision review on parcels greater than 35 acres. Large lot households select the cell with the highest attractiveness within a parcel if its size is less than 70 acres. If the parcel is larger than 70 acres in size, it is split into 35-acre fragments. Households select the most attractive cell from each developable parcel fragment;

(3) mobile homes and multifamily dwellings are restricted within cities to MH (mobile home), RN-2 (medium-density residential neighborhood), RN-3 (high-density residential neighborhood), MF-2 (medium-density multifamily residential), and MF-3 (high-density multifamily residential) zones;
(4) service worker locations are restricted to mobile homes and multifamily dwellings, and weekenders are prohibited from location outside city boundaries except in special use districts described below;
(5) we assume continued integrity of protected open space and designated historical and recreational areas. Development is not permitted in OR (open space and recreation) areas, and CO (commercial old town);
(6) we assume continuation of single use areas through development prohibitions in CN (commercial neighborhood), CC (community commercial), and I (industrial) zones;
(7) economic development districts are used in Routt County to support recreational development through provision of infrastructure to hotels, condominiums, resort company housing, and other activities connected directly to the ski hill. We positively weight these districts for location by weekenders and service workers;
(8) each type of agent builds at densities characteristic of historical patterns in the county. Service workers locate at densities of 19 units per grid cell. Professionals locate at densities of 2.47 units per grid cell. Weekenders locate at densities of 12.36 units per grid cell. Large lot agents select one cell within a parcel of less than 35 acres in size.

4.5 Model comparison and accuracy

We test four models against historical data (see table 3). Our base model (1) incorporates variables related to site attributes, transportation accessibility, neighborhood effects, jurisdiction effects, and proximity of natural amenities. We compare the base model with three additional models that include variables related to developed commercial recreational amenities, the old town, and growth restrictions. Model 2 introduces accessibility of resort development amenities. Model 3 introduces proximity to the old town, a historic commercial district with a small town atmosphere. Model 4 introduces zoning that restricts residential location by type to single-family and higher density areas. Model 4 includes all variables described above.

We employ the 'year built' field in the county assessor's data to establish patterns of historical land-use change between 1990 and 2000 against which we validate the model. Validation for agent-based models can be problematic (Parker et al, 2003). Development predictions are particularly difficult in the context of Routt County because: (1) only a tiny proportion of available private land in the county is developed in each cycle; (2) growth policies are relatively permissive; and (3) much of the growth occurs on well water and septic systems. All of these factors may tend to disperse development, which could reduce model accuracy. We use visual inspection

Table 3. Model descriptions.

Model	Type	Description
1	simple	includes natural, site, neighborhood, and transportation attributes.
2	resort development amenities	accessibility to restaurants and ski hill.
3	old town amenities	accessibility to historic center.
4	growth management	includes zoning and other planning features.

of predicted and observed change between 1990 and 2000 to support model design and exploration of model alternatives. We test the accuracy of our models through comparison of predicted and observed development using an error matrix (Congalton and Green, 1999) and κ values. In order to examine potential scale effects we test κ values at different window sizes (Pontius, 2002). The 7 by 7 window size (0.49 km^2) is a useful resolution for evaluating the accuracy of these models because this grain most closely approximates the average parcel size in the study area (0.47 km^2).

4.6 Policy simulation

As a final step in this project, we construct a simple policy simulation—an evaluation of the effect of alternative growth paths on housing availability for service workers. We explore policy effects using scenarios designed to represent key elements of future development paths. These are layered on top of the MAS and land-use rules described above, and structure additional model runs. In this paper we describe simple, two-dimensional scenarios that simulate the effects of (1) municipal annexation policy and (2) alternative rates of population increase. The current plan to add affordable housing units in the west of Steamboat Springs area reflects the city's effort to provide service worker housing. However, full implementation of the plan is not assured because it relies on substantial public and private sector participation. We consider both the approved annexation plan and the potential that the plan will not be fully implemented in our analysis below. We also assume that there are no other market constraints on construction and affordability of service worker housing, and that service workers prefer to avoid long distance commuting: in other words, they would choose to live in Routt County if housing were available. Growth scenarios include the low-growth trajectory defined by the Colorado Department of Local Affairs projection, and the high-growth trajectory defined by the recent experience of rapid growth resort regions in Colorado such as Summit County.

5 Results

The κ values in table 4 indicate that the accuracy of our models improves modestly with the addition of resort amenity, old town amenities, and growth-regime-related variables. Site, jurisdiction, and neighborhood variables have the largest influence on the predictive accuracy of the model. Commercial recreational amenities and growth management factors have a relatively small effect. Proximity to the old town has a slightly larger effect. Model 4, our full model, has the highest κ value in all window sizes. We also test all four models for a slope effect to determine whether new development is attracted to higher slopes that may tend to have better views. Slope variables have negligible influence in all four models. In general, these model outcomes suggest that pressures for a compact urban form existed in Steamboat Springs during the 1990–2000 period. Jurisdiction boundaries, zoning rules, proximity to the old town,

Table 4. Accuracy tests.

Model	Type	Overall [a]	κ values		
			1×1	7×7	13×13
1	Simple	0.99005	0.0933	0.3836	0.4819
2	Resort development	0.99018	0.1053	0.3957	0.5056
3	Old town amenities	0.99081	0.1622	0.4296	0.5205
4	Growth management	0.99083	0.1626	0.4566	0.5650

[a] Number of correctly predicted cells divided by the total number of cells, based on a 1×1 window resolution. Each 1×1 window is 1 ha in size.

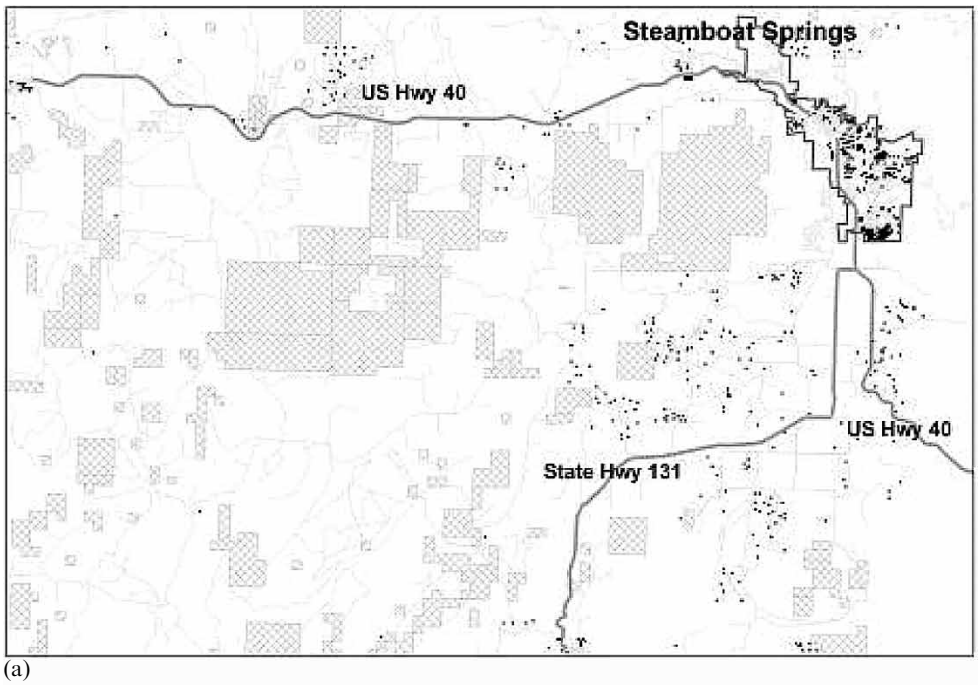
and other factors tended to concentrate development at least by weekenders, professionals, and service worker household types.

The overall accuracy of the model, defined in this paper as the number of correctly predicted cells divided by the total number of cells, is more than 0.99. Figure 3 presents the comparison of observed and predicted development during this period based on model 4 described above. Structures represented in figure 3(a) are observed (actual development); structures in figure 3(b) are predicted. Visual inspection suggests that the overall patterns of predicted development are generally faithful to observed growth (eg development concentrates plausibly within the appropriate areas of Steamboat Springs and around the ski hill). Not surprisingly, the model may predict development less accurately in the county areas than it does in the cities.

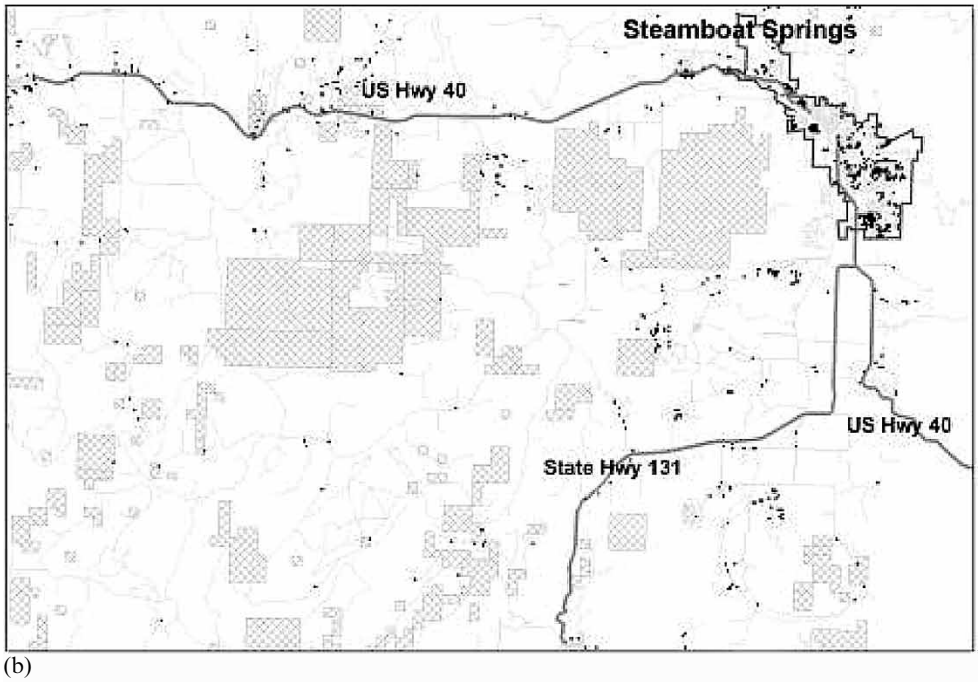
The κ value tests in table 4 suggest that our model is only moderately accurate as a predictor of historical development. Several factors may dampen the κ value scores in this model. Most important, much of the rural landscape in our study area is developable with respect to topography, ownership pattern, and regulation. In other words, we are predicting residential location for a relatively small number of immigrants within a large and relatively unconstrained study area. Moreover, we are modelling varied development processes across urban and rural landscapes and two jurisdictions (Steamboat Springs and Routt County).

Our policy simulation indicates that land supply for service worker housing is strongly sensitive to annexation and zoning constraints. Table 5 shows demand for service worker under alternative growth regimes. According to the low-growth scenario, a shortage of available land for service worker housing will not occur for about eleven years under the conservative assumption that the city is not able to fully implement the proposal to annex the designated area west of Steamboat Springs. If the city fully implements its current plan, zoning will not restrict service worker housing through the life of the low-growth simulation. The high-growth scenario presents a different outcome. Without annexation, Steamboat Springs will exhaust its supply of appropriately zoned land in five years. The shortage will grow to 3773 service worker units in 2020. To accommodate growth in this scenario, the city will have to significantly expand infill development and revise its urban growth boundary in order to annex more land. If the city fully implements the current annexation plan, shortages of land for service worker housing will increase gradually under all scenarios represented above. In the high-growth scenario, the number of service workers forced to commute long distances to work increases rapidly and continuously after the fifth year of the simulation.

Two types of interaction effects are created in this simulation. These are intensified because of the relatively compact development patterns around Steamboat Springs during the 1990s, our historical reference period. First, new development at each step generates new patterns of density, and households respond at each step to the changing levels of density in their neighborhoods. Moreover, households interact in this model through competition for land. Interaction of this kind emerges primarily in the high growth scenario where competition among different types of households may tend to squeeze out service worker households. Weekender and professional households are affected to a lesser extent. In this model, large lot agents experience relatively little site competition with the other agents, perhaps because ample land is still available for dispersed development in the county.



(a)



(b)

Figure 3. (a) Actual growth and (b) predicted growth between 1990 and 2000.

Table 5. Availability of housing for service workers by scenario (2020) (source: US Population and Housing Census, 2000. Projections based on the extrapolation of current proportions of service, retail, and construction workers according to Standard Occupational Classification categories).

Indicators	Low growth	High growth
Effect of zoning constraints without annexation (years before current area for service housing filled up).	11	5
Demand for service worker housing without annexation (additional units needed to house service workers in 2020).	1013	3773

6 Discussion

Resort communities such as Steamboat Springs delicately balance demands for sustaining pastoral landscapes and small-town community life while feeding their economic engine, the recreational economy. Agent-based models have qualities that make them useful for examining research issues associated with these growth dilemmas. The model that we built for this project generates a reasonably faithful simulation of actual development patterns using four agents (weekenders, large lot amenity seekers, service workers, and people in local professional, management, and technical occupations). The performance of the model and scenarios suggest that planning tools built on agent-based models may also have a useful practical role in assessment of growth management policies and their effects.

We have attempted to construct a bridge in this research between growth policy regimes, life-cycle processes, and the dynamics of competition between different actors in resort land markets. Higher level growth theories such as regime and life-cycle theories are sometimes difficult to apply to fine-grain processes of landscape change. In this project, we use a general conceptual framework borrowed from life-cycle theory to evaluate threats implicit in the process by which resort economies mature. These threats include overexploitation of natural amenities such as open space and heritage landscapes, and congestion effects associated with rapidly increasing demands on housing markets, land supply, and resort infrastructure. Resorts respond to these threats by developing hybrid growth management and growth promotion regimes and specializing in specific real estate and recreational markets. These policy regimes and market strategies guide patterns of competition in local land markets, which have cumulative effects on land-use change.

Our agent-based model is built on the supposition that location decisions in resort communities respond to the close proximity of multiple types of amenities. We tested three types of amenities in this model against historical patterns of landscape change: natural amenities such as open space; commercial and recreational amenities such as accessibility to restaurants and the ski area; and small town amenities such as historic architecture. As anticipated, all these amenities influence development decisions to some degree. Growth management rules also have some effect on location decisions. Overall, we predict development with moderate levels or accuracy according to both visual browsing and statistical tests. Most important, our model captures the relatively compact development pattern of Steamboat Springs during in 1990s. This provides a useful framework for understanding the constraints within which future congestion effects may emerge.

In Routt County, as with many resort areas, political and economic pressures could lead the community along multiple developmental paths. We construct a simple characterization of key development trajectories that are plausible in the area and simulate related growth processes. This evaluation suggests that, in a high-growth

scenario and without the current annexation plan, the city will confront land shortages for service worker housing in about five years. Other scenarios are less dire, however, and there are no obvious critical thresholds on the horizon. Most important, the jurisdictions in the study area have been adapting land-use policy incrementally to their changing environment. The area may be in a better position than many resort communities across the western United States because it still has a substantial amount of undeveloped private land and some flexibility in how it handles planning issues.

In general, this research suggests that life-cycle and regime analysis may provide a useful foundation for conceptualizing development scenarios and evaluating the activities of heterogeneous land market agents. In particular, regime and life-cycle theory can help to contextualize these activities in a cumulative geography of social interactions. These cumulative interactions represent a social process, and time series spatial data stored in a related GIS describe not only individual behaviors but also socially generated growth systems. These simulations are rooted in fundamentally different assumptions about growth processes than are the static models of individual policy response often employed in land-use decision making. This paper suggests that dynamic, regime-based simulations may be useful for analyzing heterogeneous systems and related growth-policy problems.

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