Reinventing mountain settlements: A GIS model for identifying possible ski towns in the U.S. Rocky Mountains

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Abstract

Former mining and ranching settlements in the U.S. Rocky Mountains frequently seek to reinvent themselves as the industries that created them have declined. Redevelopment as ski resorts is a common strategy that can successfully revive the economies of mountain settlements but this approach, if undertaken without careful advanced planning, can also have negative consequences, damaging fragile alpine environments, overwhelming social and housing services and distorting local economies. This study develops a GIS-based model that follows a systematic sequential elimination procedure to identify those Rocky Mountain settlements most likely to be attractive to ski resort development, based on the location criteria of existing ski areas. Results show that while no single settlement is an obvious candidate for development by the ski industry, a number of places are contenders in a way that can be systematically measured and evaluated. Moreover, the methodology used can be applied to additional areas subject to winter sports growth worldwide.

Introduction

The location of ski resorts in mountain communities often produces major economic, environmental and cultural consequences (Chipeniuk, 2005; Gill, 2000; Kariel, 1989; Lasanta, Laguna, & Vicente-Serrano, 2007; Orens & Seidl, 2009; Purdue, 2004; Riebsame, Gosnell, & Theobald, 1996; Theobald, Gosnell, & Riebsame, 1996). Some communities may possess local entrepreneurs who actively organize their appeal to developers (Miller & Blevins, 2005). Alternatively, developers may scour the landscape in search of suitable locations for ideal ski conditions (Rothman, 1998: pp. 187–188; Smith, 2003). In either case, the resulting selection of sites for winter resort development does not appear to be subject to any systematic process (Hudson, 2000). Yet, given the transformative effects of ski resort development, there is value in anticipating where environmental and accessibility characteristics are most likely to attract investment. The purpose of this paper is to present a model to identify potential sites that could be attractive to ski resort development in the Rocky Mountains. Anticipation of such development may allow communities time to plan for the inevitable consequences resorts bring: revitalizing economies while impacting fragile mountain environments and creating social strains among the population (Blevins and Jensen, 1998; Hansen et al., 2002; Riebsame et al., 1996: p. 398; Ringholz, 1996).

Background

The United States ski industry is increasingly concentrated, having undergone considerable contraction and corporate reorganization. While nationally, the number of resorts has declined from a peak of 622 in 1987 to 481 in 2007, annual ski
visits have remained stable during the past decade, averaging 56.7 million, with the Rocky Mountain region the most popular, accounting for 35% of the total (NSAA, 2008). Estimates suggest the 50 largest firms now earn 80% of the $2 billion annual revenue generated by the ski industry while owning 20% of ski facilities (Business Wire, 2007). Despite this concentration, operating profit margins for the industry as a whole for the 2006–2007 season were 24.8%. For the largest resorts, this figure rose to 29.2%. Overall, pre-tax profit for the industry rose two-thirds over the previous five-year period (NSAA, 2007).

Although no systematic data are available at the regional and state level, several studies on the impact of the ski industry report that in 2005–2006, the industry produced $692 million in revenue and generated a further $281 million in indirect earnings in Utah (State of Utah, 2007); Colorado’s ski industry generated 31,000 jobs in 2002–2003 (Walsh, 2004); and in 2005–2006 Montana received 1.35 million ski visits (Nickerson & Bruns-Dubois, 2008).

The greatest impact of the ski industry is found at the local level. The original 19th century communities in the Rocky Mountains were prompted by the discovery of gold, silver, copper and other metals, ranching in the high mountain basins to supply food and animal power, and timber extraction. A few owed their origin to the growth of mountain tourism when a later reassessment of the meaning of wilderness produced recreation centers such as Estes Park, Colorado and health spas such as Colorado Springs (Wyckoff & Dilsaver, 1995: p. 41). But the dominant reliance on natural resources subjected most Rocky Mountain settlements to the boom and bust cycles of exogenous commodity markets. After the 1880s, a long structural decline in mining set in that saw a slow shrinking of many mountain settlements in the Rocky Mountain region (Power, 1996: pp. 31–38; Lorah & Southwick, 2003: pp. 258–259; Wyckoff, 1999: p. 73). Some sites became ghost towns, devoid of inhabitants while others struggled to reinvent themselves through reinterpretation of their natural resources and distinctive architecture. (Dorward, 1990; Ringholz, 1996: pp. 113–123; Stoehr, 1975). In the forefront of this renaissance was the ski industry (Coleman, 2004; Fry, 2006; Rothman, 1998).

Skiing began as a practical means of communication for snowbound residents of towns like Steamboat Springs and developed as a pastime for wealthy visitors who sought a wilderness experience with luxurious accommodations epitomized by the first major ski resort in Sun Valley, Idaho, opened in 1936 (Rothman, 1998: pp. 186–201). Following World War II, skiing became an increasingly middle-class recreation, popular with both locals and a growing national market. The world’s longest chairlift opened in 1947 in Aspen, a mining town that had foundered after the silver panic of 1893 but revived as a ski center (Rothman, 1998: pp. 206–211). In the 1950s, a new inward flow of people seeking leisure activities appeared in the mountain region. These “amenity migrants” were drawn by opportunities for hunting, outdoor sports, and visions of a clean environment and peaceful mountain existence (Chipeniuk, 2004; Jobs, 1995; Price, Moss, & Williams, 1997: p. 249). They were followed by suburban escapists seeking second homes, later converted to permanent residences (McHugh, 1990). Many of these newcomers were first exposed by the region as skiing visitors (Cuba, 1989). The demand for skiing and residential development combined in a new type of resort, increasingly controlled by regional and national corporate, rather than local, capital (Clifford, 2002). Vail in 1962 and Snowmass in 1967 were early examples of this new wave of ski resort that began to proliferate across the Rocky Mountain region.

The consequences have been significant. Throughout the Mountain West, per capita income in counties with ski areas exceeded those without by $3900 in 1997 (Booth, 2002: p. 55). In Summit County, Colorado, home to six major resorts, winter tourism in 2003–2004 contributed 39% of basic spending and 46% of county employment (NCCG, 2004). One estimate suggests that the development of Bitterroot Resort in Missoula county, Montana, would be the county’s fifth largest employer in tourism in 2003–2004 contributed 39% of basic spending and 46% of county employment (NCCG, 2004). One estimate suggests that the development of Bitterroot Resort in Missoula county, Montana, would be the county’s fifth largest employer (Muller, Yin, & Alexandrescu, 2008: p. 1740). The influx of visitors and new permanent residents often clashed with the interests of old-timers who saw the loss of open space, traffic congestion, pollution and dramatic property inflation as too high a price to pay (Ringholz, 1996: pp. 64–85; Vias & Carruthers, 2005). In Vail, only one-fifth of the police and firefighters can afford to live in the town while three-quarters of the dwellings are second homes, occupied for only a few months each year (Howe, McMahon, & Propst, 1997). In Jackson Hole, low-paid hotel workers unable to pay rents in town are forced to commute across Teton Pass from more affordable accommodations in Driggs and Victor in Idaho (Beyers & Nelson, 2000: p. 470; Power, 1996). Careful planning in advance of resort development might help ameliorate these impacts but often town leaders believe they can address growth problems once they occur, or they lack the expertise and ability to resist the demands of corporate developers (Chipeniuk, 2005).

The history of Telluride, Colorado illustrates these trends (Fetter and Fetter, 1982; Ringholz, 1996: pp. 93–97). Silver deposits in a remote region of Colorado’s San Juan Mountains were discovered in 1878, prompting the establishment of several mining camps but not until rail access was achieved in 1890 did the town of Telluride begin to flourish. Three years later the Silver Panic closed mines and population dwindled. Mining continued into the first half of the 20th century as deposits of copper, gold and zinc were uncovered but they were rapidly exhausted and on April 27th, 1953, the last mine closed, forcing 230 miners into unemployment. Two weeks later another company purchased the Telluride mines and re-started production. However, local citizens were apprehensive for the town’s future and sought other ways to diversify its economy. National Historic Landmark status was obtained and discussion began about a winter resort. A wealthy Californian, Joe Zoline, seized the opportunity to turn this remote but beautiful setting into a ski resort. In 1968, rejecting what he considered the excesses of growth and sprawl in Aspen (Coleman, 2004: p. 184), Zoline developed a master resort plan with strict controls on land development, residential growth and the number of skiers. Building codes limited building height and
restricted signage. As the resort began to grow, Main Street attracted new shops with restaurants and boutiques filling its Victorian streetscape. However, despite attempts to control resort development, land prices soared, and long-time residents began to be forced out. Old Victorian houses were selling for $900,000 and some resort employees could only afford car camping in nearby forests and city parks (Ringholz, 1996: p. 95). Others were forced to commute from Montrose, CO, 75 miles away (Beyers & Nelson, 2000: p. 470). By 2003, Telluride’s permanent population had grown to 2500 and despite its remoteness daily visitors reached into the thousands. Growth spilled beyond the historic box-canyon town site and Telluride Mountain Village, a sprawling new community that evolved to service the resort, lacked the original town’s strict controls (Coleman, 2004: p. 196).

Telluride’s rich history raises the question: how many other Rocky Mountain settlements are likely to be transformed from economies based on resource extraction to ones relying on recreation with the inevitable policy conflicts over the value of economic revival, the social costs of property inflation and the need for environmental protection? Expansion of existing ski resorts and development of new projects continue, despite the global economic downturn that began in 2008. In addition to the aforementioned Bitterroot resort in Montana, planned for the size of Park City in Utah, other projects under discussion include a world-class resort in the Oquirrh mountain range, 15 min from the Salt Lake City airport, and Battle Mountain resort near Pueblo, CO (Denver Post, 2009; Fullmer, 2008). A number of existing resorts continue to grow. Real estate expansion and new ski runs are planned or underway in Sun Valley, Breckenridge, Vail, Grand Targhee and Steamboat Springs in 2009, despite the continuing poor national economy (Berwin, 2009; Skiresortsmarket.com, 2009). Anticipating where this transformation of Rocky Mountain communities by the ski industry might next occur offers both a local and regional planning tool.

**Building a GIS model of ski resort prediction**

Modeling the location of economic phenomena has a long history (Isard, 1956; Owen & Daskin, 1998). Studies consider the geographic variation of manufacturing cost phenomena (Bae, 2009; Rathelot & Sillard, 2008), the role of proximity to regions of similar economic specialization (Andersson and Hellerstadt, 2009; Porter, 2003) and criteria influencing the behavior of decision-makers (Hätönen, 2009; Strauss-Kahn & Vives, 2009). Use of Geographic Information Systems/Science (GIS) allows an even more robust analysis of spatial behavior. Examples include Weber and Chapman (2009) who rated London districts by labor supply, facilities and business support structure and used GIS to identify business sector clusters suitable for different types of industry; and Cheng, Heng, and Ling (2007) who created an interactive inquiry model for potential shopping malls, based on minimum distance, maximum demand coverage and maximum incomes to identify the location of optimal sites. In both examples, GIS allows evaluation of the location of criteria businesses would use to make site choices.

Only one study using GIS was found that addressed the ski industry. Geneletti (2008) assessed the environmental impact of proposed ski resorts in the northeastern Italian Alps. A geographical environmental sensitivity index was mapped against the location of proposed ski resort sites. However, in this study, the location of the ski resorts is already known. In the present paper, a GIS model is proposed that predicts the potential sites of future resorts using criteria that existing resorts appear to have chosen as demonstrated by the location they select. As the UNEP-WCMC (2002: p. 65) study advocated, “GIS databases can be used as decision support systems...to develop scenarios of possible future changes [in mountain environments]. These can be produced for different management options, providing assessment of possible consequences.”

The model developed for this study covers the U.S. Rocky Mountain region, defined as parts of New Mexico, Colorado, Utah, Wyoming, Idaho and Montana, and potential sites for ski resorts include former mining towns, ranching communities and other still-populated mountain settlements. Presently unpopulated locations could also have been evaluated but were excluded from the present study because of interest in how existing settlements lacking resorts might reinvent themselves and be affected by new development.

There is no standard definition of a ski “resort” and no definitive database of existing resorts. Two sources were used in this study: The White Book of Ski Areas (Enzel, 2005) and Ski Town Resort Guide (Mountain Resort Guides, 2007). They list 81 and 85 resorts, respectively, operating in the Rocky Mountain region. Because the location of a ski resort may be some distance from the named settlement listed as its corporate address, the exact coordinate locations for each existing resort were determined through a visual aerial survey using Google Earth®. During this process, duplicate sites, as well as some missing from the inventories, were identified. A modified listing was compiled of 85 stand-alone ski resorts believed to be operating during the 2006–2007 season in the Rocky Mountain region. These are used as the basis for the present study (Fig. 1). Each resort was evaluated according to four criteria: seasonal snowfall quantity, potential ski season, proximity to National Forest land, and accessibility to population centers that would represent the market for skiers and other visitors.

**Estimating snowfall**

Adequate snowfall is the minimum requirement for a ski resort, and the advertisements for many resorts make extravagant claims for the amounts of snow they receive. Snow quantity depends on sufficiently low temperatures, the number of precipitation events and local climate factors such as the lake effect snowfall experienced east of the Great Salt Lake. But skiing is also affected by snow quality. Low relative humidity of air masses during precipitation produce the fine powder snow skiers seek while more humid air creates wetter snow that is less favored and can make snow-covered slopes more susceptible to avalanches. Slope aspect can influence surface temperatures although Lazar and Williams (2008) found that whether north- or south-facing, aspect had little influence on snow density. The number of freeze/thaw cycles that occur early in the season influence the snow pack,
which should be at a minimum depth of 30 cm (11.8 inches) for downhill skiing and snowboarding (Breiling & Charamaza, 1999: p. 12). Human action can influence these natural processes. Snow pack compression can be aided with grooming machines that often soften snow, break up ice and remove rocky obstacles, a practice common in New England but also followed by many resorts in the Rockies. Trees can be strategically planted to retain snow and shade slopes, thereby reducing surface melt (Scott & McBoyle, 2007: p. 1418). Machine-made snow can supplement the natural supply if nighttime temperatures are ideally less than 24°F (−4 °C), but at least below freezing, and sufficient water supplies are available (Gosnell & Preston, 2006: p. 59). The variability of factors influencing snow quality prohibit its evaluation at the scale of the six-state Rocky Mountain region and instead should be reserved for micro-scale analysis of particular locations.

The present study therefore relies on snow quantity, although even here, snowfall measurement is an uncertain science (Doesken & Judson, 1997). Given the diversity of terrain in the Rockies, snowfall amounts over a short horizontal distance can be highly variable, depending on whether data are collected at the peak or the base of a mountain slope or some mid-way point where drifts can exaggerate inaccuracies. Moreover, the location of the two main sources for snow data, National Weather Service first order and co-operative weather stations (NCDC, 2008) and SNOTEL (NRCS-USDA, 2009) sites, are inadequate for evaluating ski resort sites. Snowfall measurements from co-operative sites are reported by trained volunteers, the stations are frequently found some distance from ski resorts and recorded snowfall can vary substantially between the two locations. The mean distance between existing ski areas and the nearest co-operative station in the Rocky Mountain region was approximately 9.6 km, using a nearest neighbor analysis in ArcGIS, while the maximum distance was over 35 km. SNOTEL collection points are located on mountain crests and operated by the National Resource Conservation Service (NRCS). Designed to help calculate annual snowmelt run-off as a means of estimating water supply, SNOTEL sites record snow depth rather than snowfall. Furthermore, the mean distance from existing ski areas to the nearest SNOTEL site was found to be 10.2 km with a maximum distance of over 80 km. Resorts themselves are another potential source of data. Of the 85 resorts evaluated, a majority claim to receive more than 100 inches (254 cm) of snowfall annually, however, this information is based on self-reporting and cannot be considered reliable because a standardized technique prescribing specifically how snowfall data is to be collected by trained resort employees is not used. Thus, existing resort reports may inadvertently introduce bias because it is beneficial for a resort to report a high snowfall amount for marketing purposes.

To achieve consistency, therefore, what is needed is a source that interpolates snowfall amounts over a continuous surface. For the present study, Climate Atlas of the Contiguous United States data from the National Climatic Data Center is used (NCDC, 2007). The Climate Atlas data provides interpolated snowfall amounts for the entire United States, derived from existing
Temperatures in New England during the past century rose 2.15 to 30% above that elevation by 2020 (Hennessey et al., 2008). A study in Australia suggests climate change will decrease the ski season length by 10–60% at sites below 1600 m and from experience of resorts is not possible because many are required to close at a specific date determined by their Forest Service (Mountains) was 7.6, with 58% of resorts falling within one standard deviation. Comparing this result with the actual dataset, the mean number of months between September and May (the outside limits of measurable snowfall in the Rocky Location criteria values for existing ski resorts. Potential ski season

Besides snowfall amount, the length of the skiing season is a prominent feature of resort literature. For some resorts, National Forest Service contracts require them to close on specific dates. For others, the persistence of adequate snow cover is the governing factor (Scott and Kaiser, 2004). The ability of a location to maintain snow can be influenced by micro-scale changes in solar radiation, aspect, orientation, prevailing winds, rain-shadow effects and temperature. Only the latter variable is easily determined across a region as large as the Rockies and the length of season for a site is influenced by the number of days that temperatures remain below freezing, limiting surface snow melt and allowing the ability for machine-made snow. The need for interpolation of temperature over intervening spaces between station points poses the same problem as described for snowfall. Therefore, for the period 1961–1990, Climate Atlas data were again used. A measurement of the potential length of the skiing season was calculated by taking the mean daily minimum temperatures for each month at or below 32 °F (0 °C). The potential season for a resort was determined to be the sum of the months. For the 85 ski resorts in the dataset, the mean number of months between September and May (the outside limits of measurable snowfall in the Rocky Mountains) was 7.6, with 58% of resorts falling within one standard deviation. Comparing this result with the actual experience of resorts is not possible because many are required to close at a specific date determined by their Forest Service permits, which are based on non-climate factors such as environmental preservation (Clifford, 2002).

Influence of global warming on future snow data

The issue of global warming raises a question about the use of snowfall averages from a 30-year past record to evaluate locations for future ski resort choices. Beniston, Keller, Kofi, and Goyette (2003a) states that in the Swiss Alps, snow cover duration is reduced 15–20 days for each 1 °C of wintertime warming and an anticipated 3 °C warming by 2050 would push the snowline upwards by 400 m (Beniston, Keller, Kofi, & Goyette, 2003b; Elsasser & Bürki, 2002; Haeberli & Beniston, 1999). Temperatures in New England during the past century rose 2.1 °C, much of the rise since 1970, and the center of gravity of New Hampshire’s ski industry has moved northwards as a consequence (Hamilton, Rohall, Brown, Hayward, & Keim, 2003). A study in Australia suggests climate change will decrease the ski season length by 10–60% at sites below 1600 m and from 5 to 30% above that elevation by 2020 (Hennesssey et al., 2008).

In the Rocky Mountains, however, the impact of global warming scenarios is less certain. Global climate models (GCMs) evaluated by Smith and Wagner (2006) were in general agreement that temperature increases would occur in the Rockies below 9000 feet, but more in summer than in winter. Less agreement was found regarding precipitation. Some GCMs predicted an increase in winter precipitation while the one regional climate model considered predicted drier winters and wetter summers. Five models used by Lazar and Williams (2008) for Aspen, CO produced general agreement about temperature, with estimates of increased warming ranging from 1.8 to 2.5 °C by 2030. Predicting precipitation was again more variable, with estimates by 2030 ranging from one to eighteen% drier. These findings contrast with those of Beniston et al. (2003b: p. 27) whose models for the European Alps predicted that warmer winters would bring more precipitation as snow above 1700–2000 m.

### Table 1

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<th>Location criteria values for existing ski resorts.</th>
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<td>Mean value of all resorts</td>
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<tr>
<td>Annual snowfall (inches)</td>
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<td>Potential ski season (months)</td>
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<td>Distance to national forests (miles)</td>
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<td>Accessibility index (min)a</td>
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<td>Distance of existing ski areas to nearest settlement (min)</td>
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* Calculated using ESRI network analyst closest facility tool.
Peopin and Losleben (2002) criticize GCMs for relying on free air temperature lapse rates for their calculations rather than surface temperature recordings. They argue that the high alpine regions of the Rockies are becoming a progressively stronger heat sink, perhaps because of increased snow cover, enhanced air movement over the surface or decreased solar radiation input. Their findings support Barry's (1990) theory of climate change that enhanced warming of free air in higher elevations is not being transferred to a surface that experiences cooler temperatures with increased precipitation and cloud cover.

The complexity associated with predicting future patterns of snowfall and seasonal longevity with any accuracy that could impact the behavior of the ski industry is reinforced by the position that the high elevation and northerly latitude of much of the Rocky Mountain region makes the area less susceptible to global warming effects than other parts of North American and European ski destinations (Breiling and Charamaza, 1999: p. 12; Bistic, Hanak, & Valletta, 2009: p. 32). Mote, Hamlet, Clark, and Lettenmaier (2005: p. 45) observe that while some locations in the interior West and Rocky Mountains are susceptible to warming, most are so cold that a warm winter has little effect on spring snowpack. This position is reiterated by Gosnell and Preston (2006: p. 74) who state “ski areas in the Central Rockies are probably the most resilient to climate change simply because, in this continental climate, winter storms are accompanied by very cold temperatures well below the threshold for snow instead of rain.”

Two additional reasons for deferring attempts to incorporate climate change predictions into the present model involve human actions. First, several studies have examined how machine-made snow can help offset the impact of warmer temperatures on the ski industry. Scott and McBoyle (2007) quote the NSAA that reports 89% of Rocky Mountain ski areas now have snowmaking equipment although it is used on only 11–13% of the skiable terrain. In New England and Quebec, snowmaking extended the average season from 55 to 120 days over the period 1960–1991 (Scott, McBoyle, Minogue, & Mills, 2006; Scott, McBoyle, & Minogue, 2007). Other studies in Europe and Australia also support the ability of machine-made snow to slow to not completely offset the impacts of global warming in the near-term to 2020 (Bicknell and McManus, 2006; Hennessey et al., 2008; Hoffman, Sprengel, Ziegler, Kolb, & Abegg, 2009). Second, there is considerable evidence that skiers recognize and react to short-term daily-to-annual conditions of snowfall and season length that are subject to far greater fluctuations than the gradual average long-term trend of global warming (Gosnell and Preston, 2006: p. 57; Shih, Nicholls, & Holescek, 2009). This observation is reflected in the ski industry’s own actions (Hoffman et al., 2009; Scott and McBoyle 2007: p. 1426) “found little evidence that ski areas were engaged in long-term business planning in anticipation of future changes in climate.”

Proximity to national forest land

In addition to space for the ski lodge and parking, resorts require substantial amounts of land to support snow sports. The geographical co-existence of resorts and federal forest land has often been noted (Clifford, 2002; Coleman, 2004: pp. 138–142). The U.S. Forest Service permits ski areas to operate on 62 national forests in 18 states and even promotes the operation of private ski activities for profit on public land through low-cost, long-term renewable leases. Reforms in 1996 lengthened and standardized leases to 40-year terms with flexibility to interpret environmental review. Regulations, however, do still restrict construction of base facilities on public land such that in many instances ski resort companies own or acquire private land adjacent to the publicly owned Forest Service. They then seek permits for public land where most skiing occurs. The permitting process has become more onerous for the ski industry as opposition from environmentalists has provided a counterbalance to corporate interests (Casselman & McLaughlin, 2008; Tenenbaum, 2001).

Existing ski resorts were evaluated by measuring the straight-line distance between each resort location and the edge of the nearest National Forest. Distances were calculated using ET Geo Wizards (Ianko Tchoukanski) on a U.S. Equidistant Conic map projection that best preserved distances and minimized errors. Sixty-five percent of Rocky Mountain ski areas were found bordering National Forest land. Because of complex land agreements, variable lease terms and the precise location of base facilities, it is difficult to determine how many resorts utilize Forest Service property, however, the mean distance from public lands for all resorts was 0.75 miles (1.2 km), with 89% falling within one standard deviation. Given this close association, the distribution of National Forests was used in this analysis to represent the available land on which most ski areas were likely to operate.

Accessibility to the market for skiers

Most skiers originate in major metropolitan areas within the Rocky Mountain region or come from more distant parts of the country and even overseas. Information regarding the exact market areas of ski resorts is proprietary so a surrogate measure was necessary to determine accessibility. A ski resort’s market was considered to be composed of local visitors, who resided in settlements of at least 10,000 population, regional visitors from cities with at least 50,000 population, and national and international visitors. Because the latter group’s origins are so indeterminate, it was assumed that airports within the region that accommodated commuter or long-distance aviation services would serve as the point of contact for those more distant visitors. Thus, while the outer edge of a ski resort’s market area could theoretically be the entire world (i.e. a skier could come from anywhere), access to reach that market was represented by a resort’s proximity to the nearest settlement of 10,000, city of 50,000 and available airport. Information on the location of commercial airports were taken from the National Atlas of the United States and U.S. Geological Survey; local population centers (>10,000 people) and regional population centers (>50,000 people), were obtained from ESRI Cities 2000 Census (ESRI, 2006).
An accessibility index was determined by a combined measure of travel time and distance to the three locations. The closest facility tool in ESRI Network Analyst® was used to calculate an accessibility value. The tool first calculates the shortest distance highway route between each ski resort and various market points and then the average time required to traverse that route, based on a road-speed classification. The result, expressed in minutes, is considered more representative of actual accessibility than direct “as-the-crow-flies” miles between points. The mean driving time from all existing resorts to commercial airports was 55 min. Equivalent figures for local population and regional population centers were 77 and 123 min, respectively. Ideally, the contribution of each measure to the accessibility index should be proportional to the degree to which ski resorts draw a local, regional and national population for their clientele, but this information is not systematically available. Orens and Seidl (2009: p. 225) sampled the ski population of Crested Butte and found that the median one-way travel time (excluding local Gunnison County residents) was 12 h with a median travel distance of 950 miles. Two-thirds of visitors came from places 1000–1200 miles away. Bunting, Wagner, & Jones (2005) found that 71% of skiers at Mt. Spokane, WA and Lookout Pass, Silver Mountain and Schweitzer Mountain resorts in Idaho originated from the Inland Northwest region during the 2000–2004 seasons. But such isolated studies provide no broadly useful indicators of the geographical breakdown of the ski visitor market. Lacking this information, the index in this study assumes that local, regional and national/international markets each contribute one-third. Should more precise measurement of the ski market origin become available, the model can easily accommodate a different percentage contribution. Combining these scores provided a representation of the level of accessibility of each resort. Among the 85 resorts, accessibility varied from 530 to 17 min. The mean index score for all resorts was 255 min, with 61% falling within one standard deviation.

**Applying the model and analysis**

**Refining the database of potential settlements**

The model is composed of two parts (Fig. 2). In the first, previously described, a database of 85 existing ski resorts was created, and the resorts ranked according to the four described criteria to determine standard measures. In the second part, the results were applied to all populated settlements in the Rocky Mountain region to evaluate each place as a potential for

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**Fig. 2.** GIS model for identifying potential ski resorts.
new ski resort development, based on the standard measures of existing resorts. However, not all existing ski resorts are located at the site of named settlements. Some can be found up to 70 min driving time away. Among existing ski resorts, the mean driving time between a resort and the closest named settlement is 16 min with 79% of resorts falling within one standard deviation (1–31 min) (Table 1). In the application of the model, therefore, communities were considered potentially subject to new resort development if criteria reflecting conditions at existing ski resorts were found not just at a given named settlement but at any location up to 31 min driving time from its center.

Procedures for identifying potentially impacted settlements began with a database obtained from ESRI’s Populated Place dataset (ESRI, 2006). Within the six Rocky Mountain States, 1555 places were found with population totals ranging from one in Lost Springs, WY to over one-half million in Denver. As constituted, the database included places already impacted by existing ski resorts. The database was queried and 214 locations were found that were within 31 min driving time of a ski resort. These were removed and the remaining 1341 settlements in the database subjected to the model’s analysis.

The next step involved querying the database to identify all areas in the Rocky Mountain region where the minimum criteria for a ski resort could be found. Areas designated were those where seasonal snowfall, potential ski season and distance to National Forests fell within one standard deviation of the scores of existing ski resorts. All 1341 settlements were then measured by driving-time minutes to the nearest area boundary. Those with values greater than 31 were eliminated because they exceeded one standard deviation of the driving-time distance of existing ski resorts to the nearest settlement and were considered to be too far from locations offering the minimum criteria for ski resorts. This action reduced the database to 467 settlements.

An accessibility index was then calculated for the settlements remaining in the database and 72 places were identified with values that exceeded one standard deviation of the accessibility scores of existing ski resorts. These were removed because while they possessed the minimum criteria for a ski resort, they were considered too remote from the ski market, leaving a final reduced list of 395 communities. These remaining settlements exhibited the minimum attributes of existing ski areas at a location somewhere within 31 min driving time and were within reach of a ski visitor market, yet were not presently operating as ski towns.

Identifying settlements most likely to be impacted by ski resort development

An additional sequential elimination procedure was then applied to the reduced list of 395 settlements to identify those with the greatest potential for resort development. For this next step in the analysis, the criteria were strengthened and possible sites were compared with the values of existing ski resorts that fell above one standard deviation for snowfall (211 inches) and potential ski season (8.68 months), and at or less than the mean distance from National Forest land. The decision to stiffen the criteria allowed identification of the top candidates for development but the database as constructed for this study could be queried for any set of qualifying values deemed appropriate. Repeating the analytical steps described above with a higher threshold of criteria values eliminated an additional 371 settlements, leaving a final list of 24 places (Fig. 3).

Further refining of the database of 24 candidate settlements depends on the business model followed by a ski resort company with regard to market area accessibility and distance from competing ski resorts. One scenario might emphasize proximity to the market, relying on a high volume of day skiers from nearby communities and regional metropolitan areas to generate income. In such a case, a company would want to consider those settlements with the fewest total driving-time minutes to reach the market for skiers. A second scenario, one similar to that taken by the developers of Telluride, might emphasize geographical exclusivity, the objective being to find a remote location that would require longer overnight stays and appeal to higher income skiers whose greater expenditures would offset lower customer volume. In this scenario, a company would select from settlements with the highest number of driving-time minutes to reach their markets. A third scenario might emphasize the importance of reducing competition by locating a new resort as far as possible from existing ski resorts. A fourth scenario could involve the opposite strategy in which a company would choose to locate as close as possible to existing ski resorts, thereby sharing an enlarged geographical market. Such a strategy takes advantage of the tendency of skiers to enjoy skiing in a variety of neighboring nearby resorts, utilizing reciprocal lift fees and other discounts.

Querying the reduced settlement database for these four scenarios, based on the two variables of distance from existing ski resorts and the accessibility score, identified Dayton, Wyoming as the settlement most likely to be susceptible to ski resort development (Table 2, Fig. 4). It had the third best accessibility score and thus was close to the market for skiers (scenario one) and was also third most distant from existing resorts that might produce competition (scenario two). Dayton is a small town of 713 inhabitants located close to the Montana-Wyoming border in the eastern foothills of the Big Horn range. Founded in the 1880s near a branch of the Tongue River, its main economy today involves support for nearby cattle ranching and alfalfa feedlot operations. Although it houses a high school for the more than nine-hundred square mile Sheridan County School District, Dayton’s retail establishment contains only a corner grocery store, café and bar. It has no hotel and no bank. Although possessing a city government, the town’s zoning ordinance has no published provisions for subdivision development. As such, Dayton is the classic small community that would be quite unprepared for the economic and social impact of a nearby major ski resort.

While the database analysis identifies Dayton as a likely candidate for growth, it does not suggest that it fulfills all the criteria perfectly. In fact, to a considerable extent the database indicates that accessibility to market and reduced competition are mutually exclusive (Fig. 4). For instance, seven settlements were above the median of 24 for higher levels of accessibility...
(scenario one) but also were above the median for close competition from existing resorts. An additional seven settlements were among the most remote, being above the median for driving-time minutes to reach their markets (scenarios two and three), but were below the median for market accessibility. Finally, five settlements were above the median for proximity to existing resorts (scenario four) but were also below the median for accessibility to the ski visitor market.

Identifying other potential candidates for development in addition to Dayton therefore required considering those settlements that had a balanced ranking of relatively strong accessibility and distance from competing resorts. This approach yielded four additional potential sites within the Rocky Mountain region. Island Park, Idaho had the sixth best accessibility index and ranked second best in distance from competing ski resorts. Located west of Yellowstone National Park, Island Park

<table>
<thead>
<tr>
<th>ID</th>
<th>Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Albany WY</td>
</tr>
<tr>
<td>2</td>
<td>Auburn WY</td>
</tr>
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<td>Bedford WY</td>
</tr>
<tr>
<td>4</td>
<td>Buena Vista CO</td>
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<td>5</td>
<td>Central City CO</td>
</tr>
<tr>
<td>6</td>
<td>Dayton WY</td>
</tr>
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<td>7</td>
<td>Ena WY</td>
</tr>
<tr>
<td>8</td>
<td>Fairplay CO</td>
</tr>
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<td>Grover WY</td>
</tr>
<tr>
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<td>Island Park ID</td>
</tr>
<tr>
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<td>Kremmling CO</td>
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<tr>
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<td>Pagosa Springs CO</td>
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<tr>
<td>13</td>
<td>Philipsburg MT</td>
</tr>
<tr>
<td>14</td>
<td>Red Feather Lakes CO</td>
</tr>
<tr>
<td>15</td>
<td>Ridgway CO</td>
</tr>
<tr>
<td>16</td>
<td>Samak UT</td>
</tr>
<tr>
<td>17</td>
<td>Sheridan CO</td>
</tr>
<tr>
<td>18</td>
<td>Star Valley Ranch WY</td>
</tr>
<tr>
<td>19</td>
<td>Thayne WY</td>
</tr>
<tr>
<td>20</td>
<td>Turnerville WY</td>
</tr>
<tr>
<td>21</td>
<td>Victor ID</td>
</tr>
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<td>22</td>
<td>Walden CO</td>
</tr>
<tr>
<td>23</td>
<td>West Yellowstone MT</td>
</tr>
<tr>
<td>24</td>
<td>Woods Landing-Jelm WY</td>
</tr>
</tbody>
</table>

Fig. 3. Rocky Mountain settlements fulfilling criteria for ski resort development.
serves as a center of fly-fishing on the Henry’s Fork of the Snake River and a winter cross-country skiing destination in the nearby Caribou-Targhee National Forest. Its early history is associated with the establishment of hunting lodges and guest ranches beginning in the late 19th century. Today, it has a small population of only 215, extensive areas of open land around the town center and is touted by its chamber of commerce as “an ideal winter destination.” Although governed by a county planning commission comprehensive plan and zoning code, controls on development are mainly concerned with environmental mitigation rather than the pressure on infrastructure and housing that would accompany a major resort development (Fremont County Comprehensive Plan, 2008; Fremont County Development Code, 2003).

Red Feather Lakes, Colorado ranked eighth best in accessibility to the market while occupying a location farthest from existing Rocky Mountain ski resorts among the 24 considered. An unincorporated community in Larimer County, Red Feather Lakes was founded in 1871 as a center of logging and ranching but grew in the 1920s when local landowners envisaged development of a large resort community and subdivided much of the surrounding land. Since then, about half the residential lots have been developed but over 4000 acres of land surrounding the community remains in private hands and subject to potential development (Red Feather Lakes Area Plan, 2006). At present, with a population of 596, Red Feather Lakes serves residents, many from Fort Collins, 40 miles to the south-east, who are attracted by the nearby scenic mountain lakes within the Roosevelt National Forest. A broad spectrum of housing ranges from historic mountain cabins to a gated community surrounding an 18-hole golf course. The settlement offers lodging, a few restaurants, three churches, a supermarket, elementary school, library and post office. Development regulations are controlled by Larimer County and the State of Colorado but absent changes to the present codes, major development in the Red Feather Lakes area would severely overload existing water, sewer and local road infrastructure (Null Alternative, Red Feather Lakes Area Plan, 2006).

West Yellowstone, Montana, ranked 11th in accessibility and fifth most distant from existing ski resorts, is already a well developed town of 1177 permanent residents (2000 Census), although that number swells ten-fold with visitors as an estimated two million annually enter Yellowstone National Park via the west gate. The incorporated town already contains a privately-developed Grizzly Discovery Center composed of a natural habitat for grizzly bears and gray wolves, numerous motels, art galleries, retail stores and an IMAX movie theater (Geske, 1997). In winter, it becomes the self-styled “snowmobile capital of the world” with over 1000 vehicles for rent to support the 60% of all visitors who use this form of transportation to enter Yellowstone Park (Sacklin, Legg, Creachbaum, Hawkes, & Helfrich, 2000). The area is noted for unrestrictive land use policies and large-lot subdivision that will likely further stress the surrounding rural environment bordering the town should a nearby ski resort be added to the already substantial development (Gude, Hansen, Rasker, & Maxwell, 2006).

A final candidate settlement, Etna, Wyoming, ranked 12th in accessibility and 11th in distance from competition, is a small community of 136 people, part of a number of settlements that make up the Star Valley along the Wyoming-Idaho border, 30 miles as the crow flies to the southwest of Jackson. Etna is surrounded by the Bridger-Teton, Targhee and Caribou national forests and sits at an elevation of 5827 feet, yet is less than 5 miles from Stewart Peak with an elevation of 10,026 feet. Settled in the 1870s by Mormon Pioneers, the valley’s communities relied on dairying in the early 20th century before the agricultural economy gave way to tourism and recreation. There is a Mormon church, a motel and an elementary school in the town, although it is also within several miles of Star Valley Ranch, a self-contained community with restaurants, two golf courses and its own planning authority. Etna’s unincorporated status places its development policies under those of Lincoln County.

Table 2
Selected settlements ranked by accessibility index scores and distance from competitors.

<table>
<thead>
<tr>
<th>Settlement</th>
<th>State</th>
<th>Accessibility index (distance-time mins)</th>
<th>Accessibility rank</th>
<th>Nearest ski area (distance-time mins)</th>
<th>Nearest ski area rank</th>
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<tbody>
<tr>
<td>Albany</td>
<td>WY</td>
<td>229.66</td>
<td>9</td>
<td>44.98</td>
<td>8</td>
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<tr>
<td>Auburn</td>
<td>WY</td>
<td>342.45</td>
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<td>80.98</td>
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<td>Bedford</td>
<td>WY</td>
<td>329.61</td>
<td>19</td>
<td>76.7</td>
<td>17</td>
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<tr>
<td>Buena Vista</td>
<td>CO</td>
<td>293.88</td>
<td>14</td>
<td>48.82</td>
<td>10</td>
</tr>
<tr>
<td>Central City</td>
<td>CO</td>
<td>117.64</td>
<td>2</td>
<td>35.4</td>
<td>2</td>
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<td>Dayton</td>
<td>WY</td>
<td>167.5</td>
<td>3</td>
<td>104.58</td>
<td>22</td>
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<tr>
<td>Etna</td>
<td>WY</td>
<td>270.08</td>
<td>12</td>
<td>56.86</td>
<td>13</td>
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<tr>
<td>Fairplay</td>
<td>CO</td>
<td>276.16</td>
<td>13</td>
<td>39.77</td>
<td>6</td>
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<tr>
<td>Grover</td>
<td>WY</td>
<td>334.01</td>
<td>20</td>
<td>78.17</td>
<td>18</td>
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<td>205.78</td>
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<td>Kremmling</td>
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<td>48.41</td>
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<td>Ridgway</td>
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<td>66.85</td>
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<td>66.14</td>
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<td>Turnerville</td>
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<td>Walden</td>
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<td>West Yellowstone</td>
<td>MT</td>
<td>231.93</td>
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<td>78.23</td>
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<tr>
<td>Woods Landing-Jelm</td>
<td>WY</td>
<td>180.82</td>
<td>5</td>
<td>55.59</td>
<td>12</td>
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</table>
Wyoming. A recent evaluation of the major highway through the Star Valley identified the need for significant upgrades as communities served shifted from agricultural to residential development, yet also noted that room for an alternative route was absent (Lincoln County Comprehensive Development Plan, 2009). Any significant resort development would therefore require major infrastructure improvements beyond the scope presently planned.

Conclusion

The purpose of the present study was to develop a GIS-based model and analytical procedure to identify settlements in the Rocky Mountain region that possess the attributes of existing ski areas and might be suitable candidates for reinvention as ski resort towns. Each step in the procedure required a degree of investigator judgment. The available data on annual snowfall and potential ski season both have limitations in the way information is reported and because interpolation values for intervening locations are constructed from a number of fixed-point data collection sites, considerable room for error can result. Accessibility criteria were based on reasonable assumptions that could not be confirmed because actual ski area market data is proprietary and difficult to obtain. Selection of the measures of existing ski areas using values above or below one standard deviation of the group as a whole were statistically valid but not selected on the basis of any factual criteria. On the other hand, the GIS-based model allowed these parameters to be transparent and was constructed so that the task of running the model with different criteria and improved data would be relatively simple. Similarly, the sequential elimination procedure could be easily run with different values, depending on the objectives of a particular investigation.

An additional characteristic of the present study was the evaluation of existing Rocky Mountain populated settlements as possible sites for ski resort development, rather than considering all locations in the region. Many additional sites that once supported settlements are now ghost towns yet if they possess the attributes of current ski resorts, their revival is possible. While the lack of data points can pose difficulties in interpolating accurate snowfall and potential length of season throughout the entire region, the logic of the model would still allow identification of sites meeting the criteria for ski resort development, regardless of whether or not they were occupied by an existing settlement. For instance, should climate change...
ultimately impact industry decision-making, the model could be calibrated to identify climatically advantaged ski locations with high elevation terrain potential where development would be more likely.

A final caveat concerning the model involves the selection of specific named settlements as those most likely to experience development. The study identified five possible candidates and suggested four possible business scenarios that could be followed, which would each result in different solutions. Moreover, from the brief descriptions of those communities identified as final candidates based on a balanced ranking approach, it is clear that at this point the model produces an important initial sorting function but detailed field observation would still be needed to judge the ultimate suitability of a particular site for resort development. Further investigations could consider localized climates, terrain potential, town and site aesthetics and environmental issues. Nonetheless, by providing a systematic analytical procedure, the study does offer environmental and preservationist advocacy groups, as well as town boosters seeking to reinvent the fortunes of economically declining communities in the Rocky Mountain region, the opportunity to anticipate prospects for change. Equally, the procedures followed in this study have applicability to other winter sports regions worldwide or to other forms of landscape change where identifying environmental, cultural and economic location criteria of existing phenomena can be the basis for evaluating alternative but yet-to-be developed sites.

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