Monitoring and Management of Visitor Flows in Recreational and Protected Areas
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Simulation of Recreational Use in Backcountry Settings: an Aid to Management Planning

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Abstract: Simulation models of recreation use patterns can be a valuable tool to managers of backcountry areas, such as wilderness areas and national parks. They can help fine-tune existing management programs, particularly in places that ration recreation use or that require the use of designated campsites. They can assist managers in evaluating the likely effects of increasing recreation use and the implementation of new management programs. They also can be used as a monitoring tool, being particularly helpful in predicting encounter levels in the interior as a function of easily measured counts of recreationists entering the area. The first backcountry travel simulation models were developed in the 1970s. They were never widely used, however, primarily because simulation runs were costly and difficult. Recent improvements in computer technology have ushered in a new era of travel simulation modeling.

INTRODUCTION

Although most outdoor recreation occurs at developed sites, growth in dispersed recreation has been rapid, particularly in backcountry areas, such as in wilderness areas and national parks. Management of such places presents some unique challenges. Because backcountry areas are typically large and remote, contacting and counting visitors is difficult, as is monitoring and controlling the distribution and behavior of visitors. Moreover, management objectives for backcountry areas typically stress the importance of minimizing both contact between visitor groups and regimentation of behavior.

Where growth in recreation use of backcountry has been substantial, managers have often responded by attempting to control amount of use and influence the distribution of use. In many areas, standards for acceptable numbers of encounters between visitor groups have been developed within management plans. Managers seek to monitor encounter levels and implement actions needed to keep conditions in compliance with standards. In many areas, visitors want to camp away from other groups but are required to camp only in designated campsites. If too many groups plan to camp in the same general area on the same night, this can be problematic. Groups are either forced to share a single campsite or one group must move on to the next available campsite or create a new campsite nearby.

All of these management actions depend on having an understanding of the spatial distribution of use within a backcountry area. In a number of backcountry areas, overnight visitors are required to provide a fixed itinerary for their visit and to stick to that itinerary. In these places, the spatial distribution of overnight use can be estimated. However, even in such places, many visitors do not stick to their itinerary (Stewart, 1989) and day visitors are not included. Moreover, requiring visitors to stick to a fixed itinerary reduces opportunities for exploration and spontaneity, important elements of the recreation experience. Consequently, fixed itinerary requirements are often among the most undesirable management approaches for many visitors. Where fixed itineraries are not required, information about the spatial distribution of use is typically anecdotal at best.

This suggests the value of models capable of predicting the spatial distribution of use within a backcountry area and how this distribution might respond to various management scenarios. This value has been recognized and explored since the 1970s. Romesburg (1974) proposed the use of mathematical decision modeling to develop management scenarios that minimize encounters among users, given a constant level of recreation use. Peterson at al. (1977) used a Markov-based linear programming model to predict interior use levels within the Boundary Waters Canoe Area Wilderness, Minnesota, USA, as a function of the number of groups entering various peripheral trailheads. This model was subsequently used to establish quotas for trailheads, designed to keep interior encounter levels within acceptable limits. In more recent work, scientists at Mount Rainier National Park, Washington, USA, are using regression modeling to predict the number of hikers at one time on interior trails as a function of vehicle counts at entrance gates.

Most attention, however, has been devoted to simulation modeling. In this paper I, first, describe some of the important potential uses of simulation modeling of backcountry recreation use and, second, provide a brief historical overview of efforts to date.

USES FOR TRAVEL SIMULATION

There are at least three ways in which simulation modeling of recreation use can contribute to improved management. First, it can help fine-tune existing management programs. Where amount of recreation use is rationed, simulation models can help backcountry managers develop rationing programs that optimize the tradeoff between amount of use and crowding within the backcountry and minimize loss of freedom and spontaneity. In contrast to rationing programs that utilize fixed itineraries, programs that utilize trailhead quotas minimize loss of freedom and spontaneity, because recreationists are free to travel wherever and whenever they want once they gain access to the area. With trailhead quotas, the challenge to the manager is to set quotas such that total use is maximized without causing unacceptable levels of congestion at specific locations within the backcountry area. This is difficult to do given the complexity of travel patterns and the minimal information available about travel patterns. Simulation models allow the manager to "experiment" with different trailhead quota schemes to identify a program of trailhead quotas that optimizes the tradeoff between amount of use and congestion.

Simulation models can also help fine-tune management programs in which camping is only allowed at a limited number of designated campsites. The challenge with designated sites is to control use levels and distribution such that (1) the total number of designated sites needed to accommodate a given amount of use is minimized and (2) unoccupied sites are available to all groups, so that few groups need to either camp with another group on a designated site or make a new campsite. Most backcountry areas with designated sites require recreationists to create and adhere to a fixed itinerary of designated campsites. This approach accomplishes the objectives just described, but it severely constrains freedom and spontaneity and, perhaps in response, many recreationists deviate from their itinerary (Stewart, 1989). Simulation modeling can help managers achieve these same objectives without having to resort to fixed itineraries. Simulations can be used to predict the number of groups per night within different interior camping locations as a function of number of groups entering different trailheads. This understanding can be used to either alter the number of designated campsites in different interior locations or to adjust trailhead quotas on the basis of the current number and distribution of designated campsites.

A second use of simulation modeling is to evaluate alternative future scenarios. Simulation could be used to estimate how travel patterns and the number of encounters between groups might change with increased use in the future. It could also be used to assess the effects of an action taken to reduce use through a rationing program. It can help evaluate actions that might influence the spatial and temporal distribution of use, such as changing trailhead quotas, building or closing trails, or scheduling the timing of trips. Trial and error could also be used to evaluate any of these actions but simulation avoids many of the problems inherent to trial and error.

Finally, simulation models can be an important part of a monitoring program. In particular, many areas have developed management plans that include standards for a maximum acceptable number of encounters per day on interior trails and campsites. This indicator has proven to be extremely difficult to monitor effectively. Simulation makes it possible to use easily measured indicators (e.g., the number of groups entering at different trailheads) to monitor hard-to-measure parameters (e.g., number of encounters in the interior).

EARLY SIMULATION MODELS

In a paper published in 1975, Cesario (1975) describes a simulation modeling approach that utilized GPSS (General Purpose Systems Simulator), a simulation language designed to deal with scheduling problems. At about the same time, International Business Machines (IBM), Resources for the Future, and the Forest Service collaborated in development of a wilderness travel simulation model, also using GPSS language. The model was dynamic, stochastic and discrete, meaning that it represented a system that evolves over time, incorporates random components, and changes in state at discrete points in time (Law & Kelton, 2000). Two generations of the model were developed. The first generation (Smith & Krutilla, 1976) developed the basic model structure and was applied to a limited data set collected in the Spanish Peaks Primitive Area, Montana. The second-generation model involved adaptations to accommodate a wider range of situations and provide additional outputs (Schechter & Lucas, 1978). The need for these changes became clear when the model was applied to a more extensive data set for the Desolation Wilderness, California, an area that is much more heavily used than the Spanish Peaks.

The model included a replica of an area's travel network, its entry points, trails, cross-country routes and campsites. It distinguished between the travel patterns of different kinds of users (different group sizes and modes of travel) and of groups arriving at various times (different weeks, different days of the week and different times of the day). Each simulation involved generating groups of different kinds and different travel patterns arriving at various entry points, where they are assigned a specific travel route (set of trail segments and campsites). They move along this route, overtaking and passing slow groups, encountering groups moving in the opposite direction or camping along the trail and they camp at campsites, where they also may encounter other groups.

The data needed to make the model operational include detailed information on the travel network, visitors, and the travel patterns of different types of visitors. This data was generated through the use of surveys of visitors that included information on their characteristics and their travel patterns. Often a trip diary was used. Typically a number of simulation runs were conducted for different management scenarios. Summary statistics provide information on use patterns and number of encounters by type of encounter, type of group, and by individual trail segment and campsite. A variety of validity tests, based on data from the Desolation Wilderness, contributed a substantial degree of confidence to the model (Schechter & Lucas, 1980).

One unique aspect of the effort to develop the wilderness travel simulation model was the effort expended on working with wilderness managers in model development and testing, in encouraging others to utilize it and in developing user manuals and conducting training. Model developers clearly hoped the model would be widely used by many managers capable of building and running the model themselves. Indeed, the model was adapted and applied to river recreation (McCool et al., 1977) and a long-distance trail (Potter & Manning, 1984). On the Colorado River in Grand Canyon National Park, Arizona, Underhill et al. (1986) used the model to evaluate the effect of upstream dam operations on downriver whitewater boating patterns. In Yosemite National Park, California, and elsewhere in the Sierra Nevada the model was modified to simplify data collection requirements and used to generate trailhead quotas for some of the more popular wilderness areas in the United States (van Wagtendonk & Coho, 1986).

Despite this promising beginning, the wilderness travel simulation model never lived up to its original promise and fell into disuse. Much of this can be blamed on the cost and difficulties of running computer simulations in the 1970s and early1980s. Simulations often had to be run on remote mainframe computers, with individual simulations costing $100. With the advent of the personal computer, all this has changed. By the mid-1980s, Rowell (1986) reported that he had modified the wilderness travel simulation model so that it could be run on a personal computer. He also built in the capability to graphically represent output data in map form, making it spatially explicit. However, there was little effort to encourage use of this model and land managers apparently have never used it.

RECENT INNOVATIONS

Simulation modeling remains a needed tool to help backcountry managers fine-tune existing management programs and test hypothetical alternative management scenarios for managing encounter levels and the quality of the recreation experience. Recently, researchers assisting park and backcountry managers have developed new travel simulation models to assist in improving management programs. Two alternative approaches will be briefly described.

Manning and his associates have built simulation models for use in their “carrying capacity” research for several national parks, using the general-purpose simulation package, Extend (1996). Their models have much in common with the wilderness travel simulation models developed in the 1970s, but can be run on personal computers. In particular, simulated groups are assigned entire travel routes. For example, data collected on carriage roads in Acadia National Park identified 381 unique travel routes, which are randomly assigned to simulated groups on the basis of frequencies reported by survey respondents (Wang & Manning, 1999). The assignment of routes also takes into account variation in travel routes between different travel modes (walking or biking) and different group sizes.

Validity tests suggest the model provides a reasonably accurate representation of the system. Moreover, model output can be related to management planning standards that set maximum levels of congestion on the carriage roads, suggesting the levels of use likely to violate standards. The model has also been used (1) to assess how the scheduling of bus transportation in Yosemite Valley will influence levels of congestion at popular destinations (Budruk et al., 2001), (2) to relate the number of vehicles entering Arches National Park, Utah, to the persons-at-one-time at Delicate Arch, and (3) to adjust entry quotas at arrival points at Isle Royale National Park, Michigan, to minimize the problem of multiple groups having to use individual designated campsites on the same night.

Gimblett, Itami and their associates have taken a different simulation approach in applied research for land management agencies in Australia and the United States. Employing an object-oriented, individual-based simulation approach, they have developed the Recreation Behavior Simulator (RBSim). Instead of assigning groups entire travel routes, autonomous agents make decisions, on the basis of behavioral “rules” derived from visitor surveys, along the way, responding to what is encountered (Gimblett et al., 2000, 2001). Their approach couples the use of multi-agent systems with geographic information systems (GIS) to produce simulation models which are much more flexible and complex than previous models. Interestingly, they have developed models for the Sierra Nevada and the Colorado River (Daniel & Gimblett, 2000) two of the places where the original wilderness travel simulation model was developed.

Data input requirements for RBSim include the same types of data needed to operationalize other simulation models. However, to realize the advantages of more complex decision-making that RBSim allows for, additional information is needed to develop the "rules" that drive the artificial intelligence techniques employed. Typically, rules are initially derived from expert opinion, but are subsequently modified on the basis of observation of patterns of inputs and outputs of the model, under a variety of operating conditions (Gimblett et al., 2000). To the extent that "rules" vary substantially between areas, additional model development and programming will be needed to apply RBSim in a new place.

RBSim can produce the same types of information about travel patterns, encounters, and other measures of congestion that other simulation models can. It also provides spatially explicit visualization capabilities that can be very helpful in gaining insight into the behavior of recreationists, as well as the spatial pattern of use. Perhaps of most importance, RBSim should be more capable of predicting the effect of management scenarios far removed from the present situation. For example, RBSim is capable of assessing the effect of building new trails, something other approaches cannot do.

CONCLUSION

Clearly, backcountry managers could profit from ready access to models capable of simulating travel patterns and recreation behavior. Managers of any backcountry area could utilize the ability to monitor interior conditions by simply measuring visitor use at trailheads. Those with significant concerns about managing recreation use would profit from the ability to explore the conditions likely to result from different choices between management scenarios. Those managers that have implemented rationing systems or that require the use of designated campsites could use simulation to fine-tune their systems. The recent innovations in simulation technology described above suggest the potential to provide managers with ready-access to this tool. When the wilderness travel simulator was developed in the 1970s, considerable effort was expended on developing a generic tool, supported by training manuals and training sessions, to make the tool readily available for use by managers. A similar technology development and transfer effort, based on recent improvements in technology, seems vitally important at this time. Although it will never completely replace the need for ongoing innovation and research-driven improvements to simulation technology, there is a substantial need for a simulation tool that managers can use without having to contract the work to researchers.

To develop such a tool, it seems timely to describe the types of outputs needed from a generic simulation tool. Then, the data input and programming requirements, as well as the output possibilities, of alternative simulation technologies could be compared. Hopefully, one (or a few) technologies would meet the criteria of (1) providing most of the requisite outputs, (2) having data input and programming requirements that can be met by the personnel of land management agencies, and (3) being user-friendly enough to be used by land management personnel. If so, programming work could be done to develop a generic tool with front-end interfaces that make it easy for the nonexpert user to parameterize the model. Training manuals could then be written describing data requirements, how to run the model and how to generate and interpret output. Finally, training courses could be provided and effort expended to encourage the use of the tool.

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