Chapter 5: Future Directions for Simulation of Recreation Use

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Introduction

As the case studies in Chapter 4 illustrate, simulation modeling can be a valuable tool for recreation planning and management. Although simulation modeling is already well developed for business applications, its adaptation to recreation management is less developed. Relatively few resources have been devoted to realizing its potential. Further progress is needed in refining the models, and their inputs and outputs. Equally important is work to assess the validity of models as well as to understand the precision of model estimates and the appropriateness of using model outputs for various purposes. Finally, there is substantial potential to link models of recreation behavior to transportation modeling and to models of biophysical impacts to provide more holistic perspectives.

Software Development

One of the keys to making simulation modeling of recreation a more easily used tool is to automate as many of the steps in data entry, model development, and model output as possible. That has been a primary focus of work on RBSim, given its development as an application specific to recreation. For example, users can navigate through the program using drop-down menus. More generic software packages, such as Extend, could also be more automated and focused on specific recreation applications. While this would require substantial work, it is a means of taking advantage of the considerable developmental effort that has already gone into the generic software package and would greatly improve its usability.

The ability to use simulation modeling could also be improved by specifying the most useful generic data inputs and outputs, along with efficient means of collecting data and displaying model outputs. For example, table 19 lists most of the common types of data needed to develop a computer simulation model. The case studies illustrate some of the ways such data can be collected. More comprehensive and detailed descriptions of data collection methods might be useful. Table 20 lists some of the more important outputs that can be displayed. Software developed in such a way that common types of data are easily input and outputs are readily produced would be a major step forward.

Other needed improvements include linkage to Geographic Information Systems (GIS) and the ability to produce visualizations. The ability to import data directly from GIS files would greatly decrease the time required to get models up and running, while the ability to automatically display outputs on maps developed using GIS would increase the interpretability of model results. Visualization capabilities also increase the utility of the modeling as a communication device. Linkage to GIS and visualization capabilities have been fundamental aspects of component architecture in the development of RBSim. Linkages to GIS and visualization in the models based on Extend are also being developed.

Current simulation modeling requires contracting with academic or consulting institutions. Much can be learned from working with academics and consultants, but much of the value of simulation modeling lies in the ability of managers and planners to use it routinely. It must become a tool that managers themselves can develop and use. Although we are currently far from that capability, if there is sufficient interest in simulation modeling, procedures and software could be developed to make it a reality. Recent experience with Geographic Information Systems (although clearly more broadly useful) provides an example of the possibilities for modeling in the future.

Table 19—Common data inputs for simulation models of recreation.

1. Network Information
   a. headways (trailhead,…)
   b. links (trail segment, road segment, river segment,…)
   c. nodes (campsite, picnic site, attraction site, trail junction,…)
   d. travel routes
2. Environmental Data (desirable but not always necessary)
   a. digital elevation model
3. User Information
   a. proportion of groups with differing modes of travel
   b. proportion of groups with differing group sizes
   c. other means of differentiating between groups
4. Travel Route Information
   a. when groups arrive at headways by user type (mode of travel, group size…) may vary by season within year, week within season, day within week and hour within day
   b. travel routes (links and nodes visited) that groups take by user type (mode of travel, group size…)—may vary by season, week, day of the week and hour of the day
   c. travel speeds on links
   d. delay times at nodes
5. Data for Verification Purposes
   a. encounters per unit of time per link and/or node (encounters need to be carefully specified—they can be defined in various ways)
   b. amount of use per unit of time per link and/or node

Table 20—Common outputs from simulation models that are useful in recreation management.

1. Amount of use per unit of time for each link and/or node, as well as aggregations of links and nodes
   a. common time units are per season/year, per day/night and at-one-time (PAOT, PPV)
   b. metrics can include both measures of central tendency (mean, median, mode) and distribution (maximum, minimum, proportion of days/nights/instances with varied encounter levels or above or below some standard)
   c. differences by group type (mode of travel, group size…) might also be desirable
2. Encounters per group per unit of time for each link and/or node, as well as aggregations of links and nodes
   a. common time units are per trip and per day/night
   b. metrics can include both measures of central tendency (mean, median, mode) and distribution (maximum, minimum, proportion of days/nights/instances with varied encounter levels or above or below some standard)
   c. encounters need to be carefully specified—they can be defined in various ways (for example, visual on link, overtaking on link, meeting on link, node)
   d. differences by group type (mode of travel, group size…) might also be desirable
3. Identifying maximum use levels that can enter without violating some standard
4. Queuing times

Improved Data Collection

Data input can be improved by making the collection of visitor data more routine and by taking advantage of improvements in technology. In many parks and protected areas, data on natural resources are collected routinely, while the collection of data on people is ignored. Such data are important, not only because recreationists can significantly degrade the integrity of natural resources but also because management is often charged with providing opportunities for quality recreation experiences. Several techniques for monitoring visitors are well established (Watson and others 2000); they simply need to be applied more frequently and more consistently.

New technologies are also emerging to simplify the process of collecting visitor data (Cessford and Muhar 2004). In particular, there have been recent improvements in the utility of video, time recording of use distribution data, and the ability to download data remotely, reducing the frequency of onsite equipment maintenance. Chip technology and tracking devices have advanced to the point where they can sometimes be used to obtain data on the routes that visitors take. Further development of these technologies will increase the cost effectiveness of model development.

Improved Model Outputs

The case studies in the preceding chapter illustrate the wide range of recreation situations that can be modeled, as well as some of the important applications of model output. However, the appropriateness of different types of simulation models and model outputs as means of addressing the issues facing recreation managers needs attention. The current state of computer simulation of recreation is better able to address some of these situations and applications than others.

Currently, procedures for conducting terminating simulations are better developed than those for conducting steady-state simulations. Terminating simulations are clearly well suited to modeling day use; however, it is unclear whether or not steady-state simulations would be a better way to model what is happening during periods of peak use by visitors on multiday visits. If we should deem steady-state simulation to be appropriate, there are some further challenges that must be addressed. One of the most difficult challenges of steady-state simulation is determining the appropriate runtime length needed to generate statistically valid model outputs (that is, outputs that are not biased by start-up effects or autocorrelation). Centeno and Reyes (1998) have developed techniques to establish steady-state runtime lengths needed to achieve specified levels of accuracy for model outputs, but they were designed primarily for manufacturing applications and may be of limited utility in recreation applications. For example, the 2,000-day runtime length for the steady-state simulations used in the John Muir case study had to be selected arbitrarily. While intuitively one would expect this runtime length to be adequate, the methods developed in the simulation literature could not be used to test our intuition. Before the full potential of computer simulation can be realized for outdoor recreation management, more research is needed to develop and standardize methods to establish steady-state simulation runtime lengths.

The precision of model estimates has not been adequately estimated in recent applications. For example, we hope to use computer simulation as a means of estimating encounter rates in the interior of large backcountry areas, without needing to directly monitor encounters within the area. This should be possible if model estimates are precise enough. Current models can produce estimates of encounters (as illustrated in the case studies), but we do not know whether the estimates are precise enough to be useful for this purpose.

To explore precision further, we employed a procedure proposed by Freese (1960), based on a chi-square test, for computing the potential error associated with model estimates in relation to observations of the real world. We used the validation data collected at Arches National Park presented in Chapter 4. The number of cars at parking lots was observed for 4 days and compared with model estimates of cars in parking lots. At the Delicate Arch parking lot, the mean number of cars observed was 29 when the model predicted 25. Freese's procedure indicates that, at a 95 percent confidence level, the error associated with model estimates is 24 percent or about 7.7 cars. This error estimate can be used to interpret the finding in the Arches study that the maximum number of hikers who can visit Delicate Arch in a day, without violating standards, is 315. Given a 24 percent error, the maximum that can be allowed is somewhere between 240 and 390 hikers per day—not necessarily 315. Even this estimate of error should be used with caution, however, because 4 days of observation at parking lots may not be sufficient to provide an accurate estimate of real-world conditions. With a larger sample, we would have a more accurate estimate to compare with the model.

Validation

A related but different issue is validation, how well the model mimics the real world. The difference between problems with precision and the need for model validation can be clarified with an example. We may use a simulation model to estimate the maximum persons-at-one-time (PAOT) at a recreation site for which we have a standard of no more than 100 PAOT. Our model may estimate, based on the mean of numerous simulation runs, that currently the PAOT does not exceed 90. Either low precision or an invalid model can reduce the utility of this estimate. For example, perhaps this estimate has an error of about 50 percent (it is not very precise)—the real estimate could be anywhere between 45 and 135. If this were the case, it would be impossible to conclude from a mean model estimate of 90 whether the standard has been exceeded or not. The mean model estimate would have to be greater than 150 before we could confidently conclude that the standard was exceeded. An invalid model is similarly problematic. If the model estimates a mean PAOT of 90 when the estimate should be 110, results are not very useful. Validation is a means of assessing the likely accuracy of model outputs.

In the case studies presented in Chapter 4, model validation is generally limited to techniques that rely on intuitive judgments. For example, in the John Muir case study, sensitivity analyses conducted with the simulation model suggest that when total simulated use is increased, estimates of hiking and camping use and encounters increased. This analysis supports the internal and face validity of the simulation model. The model works the way that experts believe it should and outputs seem reasonable. However, such analysis is less useful for making conclusions concerning how well the simulation model outputs correspond with data for the real world—the actual trail and campsite system. Due to lack of sufficient data concerning actual hiking and camping use and encounters, quantitative validation techniques were not possible in the John Muir case study.

The above example underscores the need to collect data that can be used not only as inputs to a computer simulation model, but as the basis for quantitative validation of the simulation model. Furthermore, while there is a relatively extensive body of literature describing validation techniques for simulation models of manufacturing systems, there is a lack of recent research concerning the appropriateness of alternative statistical techniques for validation of computer simulation models of parks, wilderness, and related outdoor recreation systems. More research is warranted to develop standardized, quantitative methods to assess the validity of computer simulation models designed for outdoor recreation management.

Linkage to Transportation Models

Park planning could be greatly improved by linking recreation models to transportation models. Historically, the term “modeling” has been used in the transportation planning and engineering field to refer to travel forecasting models. Applications of transportation forecasting models have focused primarily on urban environments with complex transportation systems; however, forecasting models have been developed to forecast vehicle traffic volumes for Yosemite National Park. In general, transportation networks within National Parks and related areas are relatively simple in comparison to typical applications of forecasting models. Data used to develop forecasting models for urban areas include trip diaries describing travel patterns within the transportation network, data on the characteristics of the transportation system, land use and/or activity data, and census data.

More recently, transportation modeling applications have broadened to include simulation modeling. In many ways, transportation simulation modeling resembles the recreation simulation modeling techniques described in this report. In particular, both are probabilistic. In other words, simulation results will vary across simulation runs or replications in a manner that represents the stochasticity or uncertainty and time-varying nature of the system being modeled. While transportation and recreation simulation modeling approaches have comparable capabilities, transportation modeling software may not be as well suited to park management applications because it has been purpose-built to represent urban transportation system elements such as streets, highways, and light-rail transit lines. In contrast, simple spreadsheet modeling is usually deterministic, meaning that for a given parameter value (such as total daily use level) the model output will be the same for each replication. In this way, spreadsheet modeling is similar to regression modeling and other statistical or mathematical modeling approaches.

The output from transportation models should correspond closely with the input to the recreation simulation models described in this report. Hence, development of linkages between the two sets of models is equivalent to developing a more comprehensive model.

Linkage to Biophysical Impacts

Another possibility, fraught with both promise and pitfalls, is linking models of visitor distribution with models of biophysical impact. If successful, such a linkage would make it possible to estimate and/or predict impacts across both space and time from easily collected data on visitor inputs to the system. Alternative management scenarios and futures could be evaluated on the basis of detailed information about where and when different types of impact might occur. This capability could improve the ability to assess environmental impacts, within planning contexts, by an order of magnitude.

The most obvious barrier to achieving this potential is inadequate knowledge about the relationship between visitation and resultant biophysical impacts. Lack of investment in research on recreation impacts is a fundamental contributor to this problem, as is the complexity of the variables that interact to explain variation in impact levels. The relationship between the amount of use and the amount of impact is nonlinear (Cole 2004). Moreover, variables such as visitor behavior and environmental characteristics commonly explain at least as much of the variation in impact as amount of use. Some of the impacts of most interest and concern, such as long-term effects on the viability of animal populations, are difficult to study. Despite these challenges, the potential insight that could be gained by linking visitation and biophysical impact models suggests that it is worth attempting.

Conclusions

As this report illustrates, computer simulation modeling of recreation can contribute significantly to recreation planning and management. Valid models of visitor distribution and flow can be developed and linked with transportation models and possibly with models of biophysical impact. The result would be a greatly improved ability to assess the operation of entire systems (as opposed to single elements in isolation), with continuous information across space (as opposed to discrete locations) and across time (as opposed to discrete times) for measures that may be difficult to assess directly. Such a comprehensive perspective would vastly improve the ability to plan and manage wisely.

Progress to date has been exciting. But it has also been limited, opportunistic, and not well coordinated. Funding of the collaborative work that resulted in this report provided the opportunity to improve coordination and mutual learning, to assess the current state-of-the-art, and to make progress on a few issues. As is often the case, this effort identified many issues that need additional attention. Software needs to be further developed and made more user-friendly. Data need to be more routinely and carefully collected. More modeling projects need to be undertaken, with funding sufficient to better assess the precision of estimates and the validity of models. Finally, the kinds of information that models can provide need to be more commonly incorporated in decisionmaking processes.

References

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