Application of the Wilderness Travel Simulation Model to the Appalachian Trail in Vermont

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ABSTRACT / The wilderness travel simulation model estimates complex recreation use patterns in park and wilderness environments. The model was applied to a section of the Appalachian Trail in Vermont, a linear, long-distance, multiple-access trail system characteristic of the eastern United States. Many portions of the trail, including the study area, are now experiencing high use. The model estimated the average number of trail encounters per party day to be 3.3 and the average number of camp encounters per party night to be 2.3. Other measures of recreation use were also estimated that should prove useful to trail management and administration. Three trail management scenarios were tested, providing several preliminary insights to managers: the desirability of use redistributions as opposed to across-the-board reductions and needed emphasis on spatial use patterns and campsite encounters. Only minor modifications to the program were needed in applying the model to the trail environment and the model functioned accurately according to the validity tests performed.

Park and wilderness areas are complex systems. Comprised of hundreds, thousands, or even hundreds of thousands of acres, park and wilderness systems operate on a scale that defies direct, systematic observation. Moreover, these complex systems often behave nonlinearly and unintuitively. The impacts of recreation on the physical/biological resources of soil and vegetation, for example, have been shown to be disproportionally heavy in their early stages, and involved a number of cyclic and indirect effects (Manning 1979).

Perhaps even more complex than physical/biological relationships is the social system of recreation use. In the typical park or wilderness setting, recreationists are presented with a number of access points through which they may enter and exit, and a network of trails and campsites over which they may travel. Recreationists may select, then, from a large number of travel routes. Use patterns are further complicated by findings indicating recreationists distribute themselves over an area in a highly uneven fashion with regard to both space and time (Stankey and others 1976).

Unsystematic observation and manager intuition are often inadequate for assessing complex recreation use patterns or for evaluating the effects of alternative management actions designed to alter visitor use patterns. To deal with this problem, the wilderness travel simulation model (WTSM) was developed (Shechter 1975). The WTSM is a computer-based simulation model of recreation use in a park, wilderness, or other large-scale outdoor recreation setting. The basic purpose of the model is to estimate recreation use patterns, particularly the number of encounters that occur between recreation parties. An encounter is defined as contact between two recreation parties. Encounters may occur at campsites or along trails, with the latter being either meeting encounters (parties approaching each other from opposite directions) or overtaking encounters (one party overtakes and passes another).[1] These detailed records of recreation use patterns and encounters indicate how recreation facilities are currently used and the degree of crowding that exists. The model also allows for quick testing of a variety of management practices designed to reduce crowding and congestion.

KEY WORDS: Wilderness management; Recreation; Computer simulation; Trail management

The model is designed to give detailed breakdowns on the number of encounters between different party types (e.g., hikers and horseback riders, day users and overnight users, cross country skiers and snowmobilers, commercial and private groups, small and large groups), and the date and location of encounters. Other data are provided as well, such as use and encounter levels of each trail segment and campsite, and user arrival and departure times.

To obtain these output data, a number of input variables must be determined and coded to a computer format. Among the more significant input data needed are:

1) Definition of travel routes taken in the area by recreation parties.
2) Estimated hiking time over each trail segment.
3) Distribution of recreation party arrivals over the days of the week.
4) Distribution of recreation parties over the available trailheads or access points.
5) Number of recreation parties using the area distributed among appropriate party types.

These input data may be obtained from trail registers or user permits or, if these are not available or adequate, a survey of a sample of recreation parties may be conducted.

After input variables have been defined and coded, the model program begins generating recreation parties. Several data-based tables are produced at this point to check whether the model is operating as specified by the user. The model then schedules and controls the passage of these parties through the trail network by using a random number generator to control the probabilistic functions of the model. Throughout this process, the model records and reports the number and type of encounters between hiking and camping parties. The model is written in the general purpose simulation system (GPSS) computer language.

Development of the WTSM

The first application of the model was begun in 1970 by Smith and Krutilla (1974 and 1976). This application was done as part of the development of the original simulation model and focused on the Spanish Peaks Primitive Area, Montana. Model input consisted primarily of existing data for the area supplemented by a user survey. A four-week peak use period was simulated and hiking parties were found to have an average of 3.3 trail encounters per day. Several procedures were used to attempt to test the validity of the model. An important finding of these tests was a linear relationship between total use level and mean encounters as would be expected intuitively.

A second, but limited, application of the model was conducted in 1974 by Smith and Headly (1975) on the West Canada Lakes Wilderness Area in the Adirondack Forest Preserve. The principal limitation of this study concerned model input; although a user survey was employed as a primary source of input data, only 22 parties for a total of 76 people were interviewed. A four-week peak use period was simulated and hiking parties were found to have an average of 2.2 trail encounters per day. As with the Smith and Krutilla study discussed above, a linear relationship was found between total use level and mean encounters, thus supporting the validity of the model.

Based on these early applications and a workshop with wilderness managers from the US Forest Service and the National Park Service, several modifications were made to the model. These included additional output data on trail and campsite use levels, development of the visual encounter routine, and changes to the internal workings of the model to increase its efficiency and allow for applications to more complex field areas. The model then received its most extensive application to date; simulation of recreation use on the Desolation Wilderness Area, California (Shechter and Lucas 1978). This application was more extensive than previous ones due to the complex nature of the study area (more entry points, trail segments, campsites, and routes traveled, and heavier recreational use), the number of management scenarios tested (19), and the efforts undertaken to validate the model.

The primary source of input data for this application was derived from mandatory wilderness permits. Visitor surveys and field checks of permit compliance, campsite locations, and trail segment transit times were conducted to supplement permit data. A one-week peak use period was simulated and hiking parties were found to have an average of 10.8 trail encounters per day. A number of procedures were used to test the validity of the model, perhaps the most important being a goodness-of-fit test comparing encounter levels predicted by the model with those reported in the visitor survey. Predicted and reported encounter levels were not significantly different for trail encounters, but were significantly different for camp encounters. The authors attribute the overestimation of camp encounters principally to the way in which campsites were defined by the model: campsites were often defined as too large in geographic area so that two parties in the same campsite might not actually encounter each other. The authors conclude the validity tests confirm "a substantial degree of confidence in the model" (Shechter and Lucas 1978, p. 109). Finally, tests of a number of management scenarios involving controlling the number and location of visitor entries demonstrated the ability of managers to significantly reduce trail and camp encounter levels.

A final application of the model was conducted on the Green and Yampa rivers in Dinosaur National Monument, Utah and Colorado (McCool and others 1977, Lime and others 1978). Because of the linear and one-way nature of recreation travel on white-water rivers, several small modifications were made in the way in which input data were treated. A number of "artificial segments," for example, were coded into the "trail" system to represent the numerous stops made by river floaters to explore side attractions and scout rapids. Model input was derived from mandatory river trip permits and a user survey. A one-week peak use period was simulated and float parties were found to have an average of 1.2 river encounters per day and 1.5 camp encounters per night. These predicted values were not significantly different than those reported by river users and campsite records maintained by the management agency. Six management scenarios were tested, illustrating the effects of increased use levels, changes in temporal use patterns, and alterations to the campsite system on river and camp encounters.

Study Objectives

The overall purpose of this study was to extend application of the WTSM to a section of the Appalachian Trail. The objectives of this application were twofold.

The first was to illustrate the potential usefulness of the model for Trail management. The Appalachian Trail was the nation's first long-distance trail; as such, it has enjoyed wide public awareness and use and has developed attendant management problems (Burch 1979). While comprehensive use data are not available due to the diversity of trail management organizations, relatively reliable data are collected for a portion of the Trail in Vermont. These data are collected by the Green Mountain Club for the Long Trail, which "piggybacks" the Appalachian Trail through the southern third of the state. From the late 1960s through 1976, use of the Long Trail increased at an annual rate of between 10% and 20%. The most heavily used portion of the Trail, Stratton Pond, is located in that section which coincides with the Appalachian Trail. The overnight shelter at Stratton Pond averaged nearly 22 campers per night during the months of July and August 1976.[2] An application of the WTSM model to this portion of the Trail might demonstrate to managers its potential usefulness in relieving crowding and congestion.

The second objective of the study was to examine the adaptability and validity of the WTSM to a long-distance, linear trail system characteristic of the eastern United States. While the fundamental linear and long-distance characteristics of the Appalachian Trail are similar to the river study area examined by McCool and others (1977) and Lime and others (1978), travel proceeds in both directions, substantially complicating recreation use patterns. In addition, the Appalachian Trail contains numerous access points characteristic of eastern recreation areas; this further adds to the complexity of recreation travel. Finally, as noted above, the Appalachian Trail accommodates relatively high use levels characteristic of many eastern recreation areas.

Methods

A 63-mile section of the Appalachian Trail in southern Vermont was chosen as the study area. This section of the Trail is served by 15 major access points including ten marked and maintained side trails and five Trail-road intersections. The study area includes three heavily used ponds and 16 primitive shelters designated for overnight camping.

Sampling

Information on recreation use patterns gathered through field survey techniques was used as input data to the model. A sample of hiking parties, stratified by trailhead according to relative use level, was surveyed at the ten major trailheads in the study area from 22 July 1979 to 9 September 1979. Trailheads estimated to receive the most use were sampled on four weekdays and four weekend days, while lesser used trailheads were sampled on two weekdays and two weekend days.

The survey was conducted as a personal interview. During each sampling day, interviewers were stationed at the appropriate trailheads from 7:00 AM to 7:00 PM.[3] Interviewers administered the questionnaire to all hiking parties departing the study area. A hiking party was a group that arrived and departed the study area together. One member from each group was randomly selected for the interview. Respondents were approximately 16 years of age and older. A total of 299 hiking parties were interviewed. Also, interviewers recorded the number and size of hiking parties entering the study area to estimate overall use levels.

The Survey

Two survey instruments were used: a map diary and a questionnaire. On a map of the study area and its trail network, respondents were asked to indicate (1) their point of entry into the study area, (2) time and date of entry, (3) route of travel, (4) major daytime rest stops and their duration, (5) campsites utilized and the number of nights spent at each, (6) point of departure from the study area, and (7) the time and date of departure. Information was collected via survey questionnaire on the size and type of hiking groups and the number of other hiking groups encountered along the trail and at campsites while in the study area.

Two other sources of information were also employed in the development of data for model input. The first was the Long Trail Guide Book[4] (Green Mountain Club 1977), which provided most of the information needed on the trail network. It also supplied estimates on transit times for the various trail segments. The second source of additional information was a field check of campsites in the study area. To define campsites, it was first necessary to field check heavily used camping areas. Campsites were defined on the basis of whether or not they were within sight and sound of another campsite. Those sites not within sight and sound of one another were treated as unique campsites and coded into the trail network description as such.

Results and Discussion

The Base Case

To economize computer time, it is customary when applying the WTSM not to simulate an entire recreation use season, but rather a portion of that period. For the purpose of this study, we chose to simulate a two-week period that would be characteristic of peak use conditions. The first week was used to initialize[5] the model and output was tabulated from the simulation of week two. From the field survey it was estimated that 550 hiking parties used the study area during a two-week peak period and this was established as the total use level. The

Table 1. Trail and camp encounters for the base case.

Party size/type	Party size/type: Small day use parties	Large day use parties	Small overnight parties	Large overnight parties	Camp encounters[a]
Small day use parties	199	77	132	93	0
Large day use parties	77	27	53	31	0
Small overnight parties	132	56	442	249	437
Large overnight parties	93	31	249	101	237
Total encounters	501	191	876	474	674
	2042				

[a]Includes both shelters and campsites.

Table 2. Summary statistics for management scenarios.

Scenario	Total use level	X_t[a]	t[b]	Sig.	X_c[c]	t	Sig.
1 Even distribution of use over the trailheads	550	2.1	7.876	0.001	1.6	4.439	0.001
2 Even distribution of use over the days of the week	550	3.0	1.787	0.10	2.2	0.641	NS
3 Decreased use by 100 parties	450	3.0	5.882	0.001	2.0	1.887	0.10
Base case	550	3.3	---	---	2.3	---	---

[a]Average number of trail encounters per party day.
[b]Students' t compared to base case values.
[c]Average number of camp encounters per party night.

model allows for designation of several recreation party sizes and types. From the field survey, two distinct party types were identified—day-use parties (50%) and overnight parties (50%)—along with two party size categories—small (three or fewer people—71%) and large (29%). Hiking parties used 210 different travel routes and these were used in the simulation.

After coding this and other input data into computer format, the model was used to develop the "base case." The base case is a reconstruction of actual use patterns that existed during the survey period. Highlights of the results of the base case are shown in Table 1.[6] From these data, it can be determined that the model estimates 2042 trail encounters occurred between hiking parties during a one-week peak use period. An additional 674 encounters occurred at shelters and campsites that together comprise camp encounters. Table 1 also shows how these encounters were distributed among the four party size-types. The number of trail and camp encounters must be put in perspective by relating them to the number of party days and party nights[7] supported by the area over the simulation period. When the number of party days, 619, is divided into the number of trail encounters, 2042, we find that hiking parties encountered an average of 3.3 other parties on the trail per day. Similarly, when the number of party nights, 293, is divided into the number of camp encounters, 674, we find that the average number of camp encounters per party night is 2.3.

While a principal focus of the model is estimation of encounter levels, a variety of other output data are also available, including use levels of trail segments and campsites. Much of this information has potential management implications such as determining where patrol and maintenance activity is needed and where visitor use redistribution efforts may be most effectively focused.

Trail Management Scenarios

The ability of the WTSM to test the effectiveness of management strategies is its greatest value to managers for it minimizes the need for time-consuming and expensive trial-and-error approaches to management in the field. Management scenarios can be created and tested with the model simply by altering model input data. To examine the usefulness of the model for management planning, a number of management scenarios were developed and run to see what, if any, management insights were gained for the study area. Management scenarios included limitations on overall use level and spatial and temporal redistributions of use, all of which might be considered by management agencies. Only three management scenarios are reported on here for illustration purposes. The results of these scenarios are shown in Table 2, along with results for the base case for comparison purposes.

Scenario 1 specified that entering hiking parties be evenly distributed over all the trailheads in the study area. This management strategy might be accomplished through a permit system or approached more closely through an information–education program to hikers. This scenario was very effective in reducing encounter levels; both X_t and X_c were significantly lowered from base case levels.

Scenario 2 specified that arriving hiking parties be evenly distributed over the days of the week. Again, this management strategy might be accomplished through a permit system or approached through an information or differential fee program. This scenario also lowered X_t and X_c from base case levels, but was not as effective as scenario 1. The difference in X_t from the base case level was significant only at the 0.10 level, while X_c was not significantly different from the base case level.

Scenario 3 simply reduced the total use level by 100 parties. As with the other scenarios, this might be accomplished through a permit system or by pricing. This scenario lowered X_t and X_c from base case levels, but was not as effective as scenario 1. The difference in X_t from the base case level was significantly lower, while X_c was lower than the base case only at the 0.10 level of significance.

These three relatively simple scenarios provide several important management insights that may not have been intuitively apparent to managers:

1) Temporal and spatial redistributions of use in the study area are potentially more effective management practices than simple across-the-board decreases in use. Management scenarios 1 and 2 demonstrate that trail encounters can be substantially reduced through changes in user arrival patterns without reducing the number of parties allowed to use the area. A simple across-the-board cut in the number of parties allowed in the area would have to approach 100 parties or an 18% reduction to achieve similar results in trail and camp encounters.
2) In this study area, changes in spatial use patterns appear to be more effective in reducing encounter levels than changes in temporal use patterns. This may indicate that management attention focused on the spatial aspects of visitor use would be an efficient use of limited management resources.
3) In this study area, camp encounters appear to be a more limiting factor than trail encounters. Only scenario 1 was able to reduce X_c beyond a significance level of 0.10. This may indicate that management attention focused on reducing crowding at campsites, perhaps through provision of additional camping areas, would be an efficient use of limited management resources.

Applying the Model

Several problems were encountered in applying the model to the Appalachian Trail study area. The first concerned the number of access points that can be accommodated by the model. As originally written, the model has the capability to accommodate a maximum of ten access points. Typical of eastern recreation areas, however, is their numerous points of access. The study area described here comprises only 63 miles of trunkline trail, yet has well over ten unique entry points. It was found, however, that additional trailheads could be accommodated through minor modifications of the program.[8]

A similar problem was encountered with the description of routes traveled by hiking parties in the study area. The original model design allows for a maximum of 170 unique travel routes to be defined. However, considerably more routes were needed for this application due, in part, to the relatively high number of access points noted above and the two-way direction of travel on the trail. Again, though, this problem can be easily overcome through minor modification of the program.

A more difficult problem stemmed from how hiking parties are represented in the model with regard to their type and size. As currently written, the model allows for two party type categories and three party size categories. In this study, party types were defined as day hikers and overnight hikers and two party sizes were defined, small and large. This breakdown is not as realistic as it might be in its representation of long-distance trail users. Our survey data indicate that three party types—day hikers, short-trip overnight hikers, and long-distance overnight hikers—rather than two would be more useful for trail planning and management purposes. While the model has the theoretical capability to represent party types in this manner, needed modifications to the program would be substantial.

Model Validity

Application of a simulation model requires consideration of the validity of model operation. While validation of simulation models is an inherently difficult undertaking, several validity tests have been suggested (Miller 1975, Naylor and Finger 1967, Emshoff and Sisson 1970). We relied on four:

Content validity concerns the realism of (a) the model as represented by the defined relationships among variables and parameters and (b) the data base. The former has been addressed rigorously in development and original testing of the model as described by Shechter and Lucas (1978). The latter is more appropriately addressed as a part of each application of the model. A substantial effort was made in this study to ensure the reliability of model input data through an extensive field survey. This survey was designed to provide recreation use data representative of the study area during the peak use period. Moreover, key descriptive variables from the survey such as size and type of hiking parties, socioeconomic characteristics of hikers, and use trends at selected locations were compared with similar studies (Murray 1974, Rupe 1978[9]; Plumley et al 1978) with high levels of agreement found among all studies.

Face validity refers to the intuitive judgment of the user of the realistic nature of model output. As this was the first test of trail and camp encounters in the study area, there was little basis upon which to make such judgments. However, part of

Figure 1. Simulated and reported distribution of trail encounters.

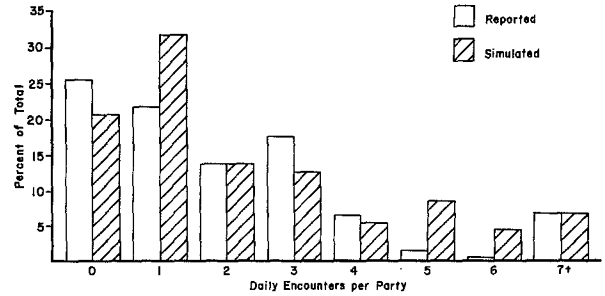

Figure 2. Simulated and reported distribution of camp encounters.

the model output includes a series of tables that report campsite arrival times and study area departure times for hiking parties. These output data are based on key input variables such as trailheads used, routes traveled, and hiking or transit times specified. These output data were highly realistic with most (71.1%) hiking parties arriving at campsites between 12:00 noon and 7:00 PM and most (64.8%) parties finishing their hiking trips and departing the study area between 12:00 noon and 7:00 PM.

Perhaps the most powerful test of the validity of a simulation model is the degree to which model output coincides with historical observations. This comparison is known as the historical *goodness of fit.* A handy way to carry out this test was devised by asking survey respondents how many encounters they had actually experienced along trails and at campsites in the study area during the survey period. This information was then compared with model output for the base case. In the discussion of the base case results above, it was noted that the model estimated the average number of trail encounters per party day (X_t) to be 3.3 and the average number of camp encounters per party night (X_c) to be 2.3. These figures coincide quite closely with reported encounter levels of 3.1 and 2.4 for trails and campsites, respectively. The slightly higher model estimate for trail encounters might be expected, given other research that shows that recreationists tend to underestimate travel encounters (Colvin and Shelby 1979).

A more rigorous test of goodness of fit concerns the frequency distributions of trail and camp encounters. Estimated and reported frequency distributions of trail encounters are displayed in Figure 1. The same information for camp encounters is shown in Figure 2. Both sets of data were tested by using the two-sample Kolmogorov-Smirnov Test (Bloomers and Lindquist 1960) to determine whether they were significantly different (i.e., whether the estimated and reported data were derived from different populations). The results indicate that both trail encounter distributions ($D = 0.04$; $\alpha = 0.001$) and camp encounter distributions ($D = 0.07$; $\alpha = 0.001$) were not derived from different populations. This suggests that the model is accurate in its portrayal of recreation use patterns in the study area, at least with regard to encounters.

Sensitivity tests were a final means of validating the model. In sensitivity testing, selected input variables are experimentally manipulated to determine whether model output changes are reasonable and logical. The focus of the sensitivity tests was on the input variable of total use level and the output measures of X_t and X_c. Increasing and decreasing total use level by 100 parties illustrates model output is sensitive to such input changes (Figure 3). Theoretically, there should be a positive linear relationship between total use level and encounters. This relationship is borne out in Figure 3, adding evidence to the validity of the model.

Summary and Conclusions

The inherent complexity of recreation use patterns in park and wilderness environments lends itself to relatively powerful analytic techniques such as computer-based simulation. For this reason the WTSM was developed. The model was applied in this study to a section of the Appalachian Trail in Vermont to examine its usefulness in current management planning and to extend application of the model to this type of environment.

The model provided estimates of a variety of measures of existing recreation use patterns including encounter levels and trail and shelter–campsite use. Most of these measures were previously unknown to trail managers and should prove useful in management programs. Moreover, the model predicted the effect of three management alternatives in reducing encounters, indicating several potentially effective strategies to reduce crowding. Finally, the model was applied with only minor modifications needed and functioned accurately according to the validity tests performed.

Additional changes to the model are recommended that will allow more flexibility in recreation party size/type designations. This will provide an added element of realism to the

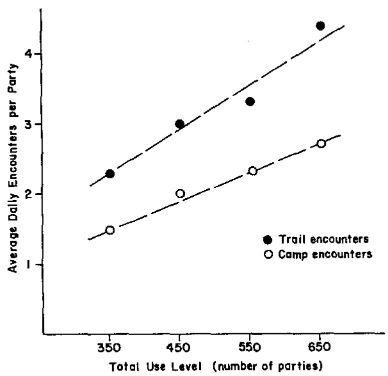

Figure 3. Relationship between total use level and average number of trail and camp encounters.

model. In addition, it should be cautioned that management actions should not be undertaken based solely on model output; the model is only a tool that should be combined with other considerations such as user input, resource constraints, and management discretion. Nevertheless, the model is a potentially important management tool. Further management applications of the model are recommended where recreation use patterns are too complex to observe directly or evaluate intuitively.

Notes

1. A fourth type of encounter, visual encounters, may also be estimated by the model. A visual encounter occurs when one party, whether on a trail or in camp, sights another party traveling on a different trail segment or occupying a different campsite, and none of the other, more direct types of contact noted above occur. Visual encounters were not used in this study because of the screening effect of dense vegetation and steep topography typical of the study area.
2. Unpublished data on file at the Green Mountain Club, Montpelier, Vermont.
3. Slight variations occurred in this schedule due to differences in required travel time.
4. The Long Trail, maintained by the Green Mountain Club, and the Appalachian Trail follow the same route through the study area.
5. Initialization refers to the period used to get a simulation model started and up to a state where it operates at real use levels.
6. Simulation results presented in this study are averaged over three replications of the same scenario. Shechter and Lucas (1978) found that results averaged over three or four replications were as statistically valid as results averaged over more than four replications.
7. A party day is a day or any portion thereof spent in the study area by a hiking party. A party night is the passing of one night in the study area by a hiking party.
8. Information on these and other modifications is available from the authors.
9. Rupe, M. L. 1978. Opinions of hikers toward current and alternative management policies for the Camel's Hump section of Vermont's Long Trail. Unpublished MS thesis, University of Vermont, Burlington.

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