

TRANSPORTATION ANALYSIS TECHNIQUES FOR NATIONAL FOREST PLANNING

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During the past 3 years a major research program at ITTE has developed an extensive package of techniques to perform transportation systems analysis within the framework of resource management planning for national forests. These techniques include travel-demand models, network-analysis models, and procedures for data collection and management. Two interacting sets of travel-demand models were developed to analyze recreation trip-making to national forests. The "macro-allocation" models estimate aggregate statewide recreation traffic volumes to every national forest. The "micro-allocation" models estimate the traffic volumes on the transportation system of one particular study forest. Network-analysis models were developed to analyze the efficiency of a forest transportation system for low-volume nonrecreation traffic. This paper describes the role of these analytical techniques in a proposed process for national forest planning. Each of these models and supporting techniques is described, and their interactions are discussed.

•PLANNING for resource management in a national forest is performed by a group of Forest Service personnel representing the professional disciplines involved in its management. The members of the multidisciplinary group and the responsible decision-maker pool their diverse skills to create a single comprehensive plan that includes mutually consistent directions for all aspects of forest operations. The formal sequence of activities that is followed to develop a forest management plan is called the "resource management planning process."

The purpose of this paper is to present an overview description of a package of analytical techniques that have been developed to aid in this planning process. Because many of the techniques involve mathematical abstractions of the physical world, they are called "models." Although one could perform a planning process without models, and, indeed, much planning is performed that way, the size and complexity of the forest system is such that analytical models are desirable.

The planning models presented are designed primarily to facilitate the analysis of forest transportation system alternatives. However, because transportation is not an end in itself but supports other activities such as timber harvest, recreation, and fire protection, transportation analysis models must relate to these other activities and be useful for their analyses. Performing joint analyses of diverse forest activities is essential to producing a comprehensive plan.

THE STRUCTURE OF THE PLANNING PROCESS

Figure 1 shows the major components of the resource management planning process. This process is an application of the "systems approach," which is a problem-solving method unsurpassed in objectivity and orderliness. The arrows in the figure represent interdependencies among the various components. The broken arrows represent special interdependencies called "feedback loops," which allow the process to cycle repeatedly through its various components until an acceptable plan is obtained.

The first component of the planning process is the definition of explicit goals and objectives. Goals and objectives are the driving force of the process, because, until

one defines an end toward which to work, there is no need for a plan. The goals and objectives are necessarily explicit in order to resolve, at the outset, any differences that may exist among the planning group members. Fortunately for the national forest planning process, this agreement among participants is more readily achievable than in the analogous urban and regional planning situations.

The second component of the process begins once the planning objectives are established. The planners determine exactly what should be known about the probable effects of any plan in order to evaluate it effectively. The measurements that represent these effects are called "measures of effectiveness." Because the adoption of a measure of effectiveness is controlled by the availability of acceptable analytical methods to determine its value, the selection of analytical techniques is performed at the same time. Given the requirements of typical national forest planning process, the selection of analytical techniques would include some and possibly all of those described in this paper.

The third component of the process is the definition of alternatives. Several significantly different courses of action are identified for each aspect of forest operations, and these are then combined in realistic ways to create a number of alternative comprehensive plans.

If there is one lesson to be learned from the large metropolitan area transportation planning studies, it is with respect to the collection of planning data, the fourth process component. It is essential that sufficient information be accumulated to provide an understanding of the situation being studied. However, collection of data must always be related closely to subsequent use. Only enough data must be collected to meet the identified needs of the planning process, plus any well-defined needs in administrative or public relations areas.

The fifth component of the planning process is the analysis of alternatives. "Analysis" is estimating the measures of effectiveness, that is, the consequences, of every alternative plan. Planning models, as well as other quantitative and qualitative techniques, are used to obtain these estimates.

The sixth component is the evaluation of alternatives. "Evaluation" means pulling together the products of analysis into a form that facilitates convenient and meaningful comparison of the alternatives. Consequences involving monetary costs and benefits at different points in time are made comparable by discounting techniques. Voluminous data describing the qualitative and quantitative consequences of every alternative at many different locations are distilled to their essentials and meaningfully displayed. The effects of different implementation schedules for each alternative are considered, and the sensitivities of the various consequences to scheduling and to other factors are determined.

The final component of the process is the selection of a plan. Typically, the accumulated evidence suggests the consideration of a plan different from any of the alternatives that were studied. If these differences are minor, their implications are generally determined by returning to either analysis or evaluation. If the differences are greater, a new formal alternative may be defined. The process continues to cycle in this way until an acceptable final plan is obtained.

The plan developed through this process is used thereafter as an evolving guide to decision-making. Because no plan can fully anticipate the future, as time passes the plan is modified to account for increased knowledge and changing policies. At periodic intervals, reviews and occasionally complete revisions of the plan are performed within the formal framework of the planning process.

ANALYTICAL TECHNIQUES IN THE PLANNING PROCESS

The analytical techniques introduced in this paper are used within the planning process to analyze transportation and its interaction with other forest activities. The techniques described may not all be applicable in each forest. In each case the techniques that are suited to the character of the forest activities are used. For example, if a study forest is far from large population centers and has little recreational use, the recreational models may be deemphasized or possibly eliminated from the planning

process. This package of techniques is therefore seen not as a fixed sequence of steps for analyzing a particular problem but as a toolbox from which planners can draw whatever capabilities are appropriate to the analyses to be performed.

Two principal groups of models have been developed: those that are used to estimate the recreational traffic on forest transportation networks, called "recreational travel models," and those that are used to determine the efficiencies of forest transportation networks for other types of traffic, called "nonrecreational travel models." These two groups are described in the following sections.

RECREATION TRAVEL MODELS

It was decided that the most useful measures for evaluating the impact of recreational activities on a national forest transportation system are estimates of the recreational traffic associated with the alternative plans. Consequently recreational travel demand models were developed to estimate the probable traffic volumes under alternative sets of future conditions. These conditions include:

1. The locations and characteristics of forest resources and recreational areas;
2. The characteristics of the forest transportation network;
3. The locations and characteristics of population centers within a reasonable journey time to the forest;
4. The characteristics of the regional transportation system that links the population centers to the forest;
5. The locations and characteristics of "competing" recreation complexes in the region; and
6. Information about the travel behavior of recreationists.

Recreational traffic estimation is treated as a two-stage problem. First, there is the problem of how many visitors will be attracted to the forest from surrounding population centers. Second, there is the problem of how these visitors, once they are there, will disperse to the many recreation areas located therein. Related to the latter is the additional problem of how people who are staying overnight in the forest, such as campers, will travel about during their stay. To deal with the two-stage nature of the problem, two distinct but interacting groups of recreational travel-demand models were developed. There are the "macro-allocation" models, which estimate aggregate travel demand from population centers to the forest, and there are the "micro-allocation" models, which estimate traffic on the forest's roads and to its recreation areas.

The two groups of recreational travel models have analogous properties. Both groups contain "generation" models and "distribution" models and use a common "attraction model." The "generation" models estimate the number of recreational trips that will occur. The "distribution" models predict their destinations. And the "attraction model" computes the relative inherent drawing power of forest resources and developed facilities. The interrelationships among these models are shown in Figure 2.

The specific characteristics of the attraction model and of the models in the macro-allocation and micro-allocation groups are discussed in the following paragraphs.

The Attraction Model

The attraction model (5, chapter 7) is not really a travel-demand model. It is concerned not with traffic estimation per se but rather with the characteristics of the areas that attract the traffic. The technique is almost identical to that employed in an Ontario recreation study by Ellis (8). It employs factor analysis to reduce the many variables describing facilities and natural resources to a few representative factors. For a given area, the factor loadings—that is, the relative weights of the facilities and resources present—are combined to yield a single measure that fairly represents that area's relative wealth in the various characteristics assumed to determine inherent attractiveness. These measures are used to represent the characteristics of destinations in both macro- and micro-allocation. The attraction model can be used to estimate both the relative attractiveness of competing areas within a study forest and the relative attractiveness of an entire study forest relative to all competing recreation complexes.

Figure 1. The resource management planning process.

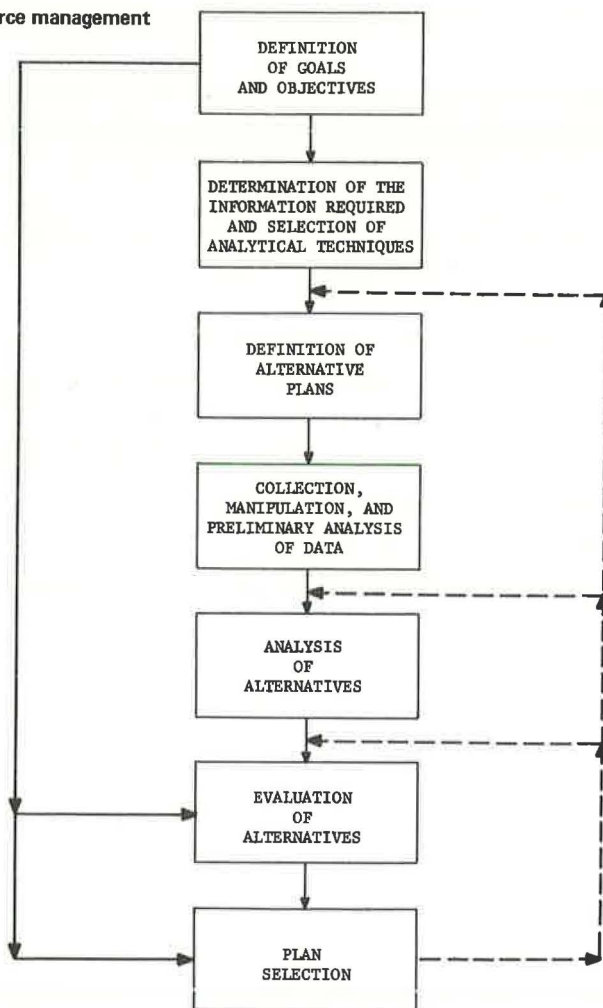
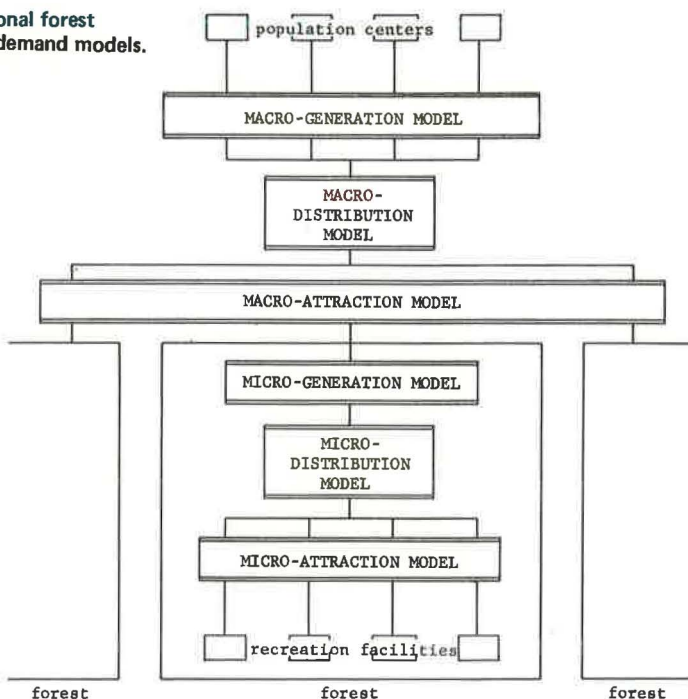


Figure 2. The national forest recreational travel-demand models.



The Macro-Allocation Models

The macro-allocation models estimate the aggregate numbers of recreationists who will visit a forest from outside the immediate forest area. The macro models do not consider visits from nearby residents since these can be estimated more accurately by micro-allocation procedures. The models are designed to make estimates from whatever data are available describing the attributes of the study forest and the competing recreation complexes.

The macro-generation model estimates the aggregate demand at each population center for recreational travel to the study forest and to the competing recreation complexes. This demand is based on the demographic characteristics of the center. Because it is infeasible to send data collection teams out to the various population centers to measure recreational trip-generation rates directly, these quantities are estimated by employing the macro-distribution model backward in order to determine the population center trip-end volumes that would explain the pattern of forest visits observed in a forest recreation travel survey (5, chapter 8). These estimated trip-end volumes are then used to fit a traditional type of regression model to population center demographic variables.

The macro-distribution model (2) considers the aggregate demand at the population centers, the cost of travel over the regional transportation system, and the relative attractiveness of the study forest and all competing recreation complexes to determine the probable number of trips that will be made to the study forest. It is a systems model, such as that used in previous work by Ellis (8), and is analogous to methods for computing flow quantities in electrical and other physical systems.

The macro-allocation models are general enough to estimate recreational travel to any set of competing recreation complexes, which may include either national forests alone or national forests plus state and national parks and major private facilities. Of course, the more competing complexes that are brought into the analysis, the greater the data needs. The planning team determines which types of competition are important influences on the aggregate recreational demand in their forest and then defines the scope of the macro-allocation analysis accordingly.

The outputs of the macro-allocation models are estimates of total trips for aggregate trip purposes, such as "single-day visits" and "overnight visits." The aggregate purposes are consistent with the level of detail of the available data. Following macro-allocation analysis, these estimates are disaggregated to equivalent estimates for specific recreational trip purposes and used as inputs to the more detailed micro-allocation analyses.

The Micro-Allocation Models

The purpose of the micro-allocation models is to estimate the volumes of trips attracted to individual forest recreation areas and to determine the corresponding traffic volumes on the local transportation network (3). The use of disaggregate trip purposes—for example, camping, lake fishing, and hiking—is necessitated by the widely varying characteristics evident in different kinds of recreational travel.

In terms of the two-stage traffic estimation problem, the macro-allocation models can be seen as playing the role of a micro-generation model. The micro-distribution models treat trips to the forest from the outside population centers as if they were generated at known nearby locations called "gates." This mechanism eliminates the need to represent components of vastly different scale, such as campgrounds and metropolitan areas, in the same model.

Separate micro-generation models exist to estimate the numbers of trips originating at forest area overnight accommodations, such as campgrounds, motels, and cabins (5, chapter 10). These models are trip-making rates stratified by trip purpose, trip-maker characteristics, and characteristics of the locations where the trips originate. The structure of these models is based on the experiences and lessons learned in trip-generation analyses performed in urban and regional studies.

The task of micro-distribution—that is, determining where the generated trips will go—requires a range of models to deal with the diverse travel characteristics of

different trip patterns and purposes. Currently, there are three distribution models developed for the planning process:

1. The "impedance-dependent opportunity model" is an intervening opportunities model modified to be sensitive to the increment of travel impedance incurred in by-passing destinations (3, 6). The model is therefore sensitive to two measures of spatial orientation: opportunities intercepted and impedance overcome. The technique is suited to estimating trip patterns where the attracting recreation areas are well defined and substitutable and where travelers are reluctant to travel farther than they need to satisfy their trip purposes. Examples of trips in this category are swimming and fishing trips and most camping trips.

2. The "simple proportional model" is essentially an extension of the attraction model (3, 6). It distributes a total number of trips among recreation areas in proportion to their inherent relative attractiveness. This model is used where the attracting areas are well defined and substitutable and where the relative distances to be traveled have little effect on the traveler's choice. Examples of trips in this category are camping trips to a limited number of highly developed campgrounds.

3. The "touring travel model" is a linear programming formulation that directly estimates network flows for trips having destinations that are not well defined and for which travel difficulty is a relatively minor consideration (7). The model operates by attempting to satisfy a priori estimates of relative link popularity, subject to constraints on trip-end volumes at origins, the average trip length, and conservation of network flows. Examples of trip types for which this model is suited are sightseeing, hiking, and trail bike riding trips.

NONRECREATIONAL TRAVEL MODELS

There are two approaches that might be taken in developing models to analyze nonrecreational travel. The first is to develop travel-demand models that estimate the volume of nonrecreational travel in a manner similar to the recreational-travel models. The second is to develop models that determine the efficiency of alternative plans for nonrecreational travel, given likely levels of traffic. The models that were developed for the national forest planning process are of the second type. They are called "network-analysis models."

Network-analysis models were chosen to analyze nonrecreational travel for two reasons. First, indicators of transportation network efficiency with respect to nonrecreational travel are more relevant for decision-making than estimates of the relatively small traffic volumes that are characteristic of nonrecreational travel. Second, nonrecreational traffic is usually so sporadic that there is little hope of finding the statistical regularities required to construct a reliable demand model.

Two nonrecreational travel models have been developed (4). They are useful for analyzing transportation network efficiency for timber harvest travel and for forest administrative travel. A brief description of each follows.

The Timber Transport Model

The timber transport model is a technique that computes the shortest routes for hauling timber from cutting locations to railheads via mills. Three different routes can be determined, based on minimizing travel distance, travel time, and travel cost. The projected cuts at every location are then combined with the measures of route efficiency to compute an overall measure of timber transport efficiency for a given alternative resource management plan.

In addition to its role in planning, the timber transport model is useful for analyzing the efficiency of day-to-day timber operations. Theoretically, operators can be compelled by contract to move their cuts along the most efficient routes, thereby maximizing revenues for both themselves and the Forest Service.

The Forest Administrative Travel Model

The forest administrative travel model employs an integer programming algorithm to compute the most efficient routes and schedules for meeting the regular service requirements in a national forest. The model determines the least-cost solution, subject to a maximum workday length constraint. Except for the requirement that the personnel must begin and end each working day at a single dispatch point, this model is the same as the classical "traveling salesman" problem (9). There is currently a significant limitation on the size of the network that can be analyzed, and work to expand the model's capability is continuing.

As in the case of the timber transport model, the forest administrative travel model is useful for analyzing the efficiency of day-to-day operations.

DATA REQUIREMENTS FOR ANALYSIS

This section briefly describes the data needs of the planning models. Although a large data base is required, efficient techniques of data collection and data management can be employed to reduce data costs. The roles of survey design procedures and data management systems are also discussed in this section.

The data described here do not represent the total needs of the resource management planning process. They are only the needs of the planning models described in this paper. The other components of the process, especially evaluation and definition of alternatives, have their own data needs, but these are not considered here.

There are two general types of data required by the models: inventory data and activity data.

Inventory Data Requirements

Inventory data represent what is known about the physical system under consideration. Although the planning process is concerned generally with a single national forest, there is need to collect less detailed information about the portions of the outside world that interact significantly with the forest.

Because the planning models are oriented to the analysis of the forest transportation system, it is natural that an inventory of that system be required. Because of the level of detail at which many of the models operate, it is necessary to have data on all relevant sections of forest roads and trails as well as information on other permanent transportation links, such as ferry boats and aerial logging systems. In general, the location, length, and service characteristics of each link are required. For macro-level recreational travel estimation, an inventory of the regional transportation system is also required. The regional transportation system would, of course, be inventoried in considerably less detail than that of the national forest.

The second major class of inventory data describes the resources and facilities in the forest. A major subset of these data is the inventory of recreation area characteristics required by the attraction model. This need is met largely by the "resource inventory management system," a facilities-inventory scheme used in national forests. The principal need is for study forest data, but the macro-allocation models also require some data describing the resources and facilities of competing recreation complexes. Other inventory data, such as the locations and characteristics of timber stands, mills, high fire-danger areas, and assignments of personnel, are required for the various nonrecreational travel models.

Another class of inventory data describes the locations and characteristics of the population centers that interact with the study forest by generating recreational travel. This demographic information is all available from publications of the U.S. Bureau of the Census.

Activity Data Requirements

Activity data describe the type, amount, and nature of the use made of the physical system. The principal use of activity data is in the calibration and testing of the recreational travel-demand models. In addition, information on timber-cutting activities is

employed by the timber transport model. Other less extensive activity data are required by the administrative travel model.

The principal activity data requirement of the recreation models is information on the use of forest resources and facilities. For a given forest, this information can be obtained both by direct measurement, such as by counting traffic entering and leaving facilities, and by asking visitors to itemize their use of forest facilities. Both sources of information contribute to the needs of the models. Head and axle counts gathered regularly in all national forests provide the aggregate use data needed to calibrate and test the macro-allocation models. Interviews with recreationists, expanded by means of traffic counts, provide the detailed use information needed to calibrate and test the micro-allocation models (1).

The Roles of Survey Design and Data Management Systems

Techniques of survey design and systematized data management are employed to reduce significantly the costs of using sophisticated planning models. In fact, without such techniques, it would be almost impossible to do all that must be done within reasonable budgetary constraints.

Survey design consists of applying probability theory to deciding how many data should be collected, when, and where. When such techniques are not used, there is a natural tendency to collect too much data and in such a way that many of them are redundant. Among the techniques of survey design, there are schemes for sampling at different locations in time and space so that most data requirements can be fulfilled economically. The techniques of survey design are especially applicable to the task of counting traffic and of conducting interviews with recreationists (1).

Data management systems are formal frameworks that control the collection, storage, editing, basic manipulation, and retrieval of data. In the case of large masses of data, these systems are generally computerized. When developing a data management system, one faces a dilemma in whether to have a very flexible system, which can handle many forms of data with variable efficiency, or to have a task-specific system, which can handle one form of data very efficiently. There is no pat answer, for the correct balance between flexibility and efficiency must be determined individually for every situation. Data management systems have been developed to facilitate the collection and use of the data required by the planning models. The characteristics of these systems reflect attempts to face at all times the question of balance between flexibility and efficiency.

SUMMARY AND CONCLUSION

The package of planning models and supporting techniques introduced in this paper is used by a multidisciplinary planning group to answer pertinent questions about the consequences of alternative forest plans. To a great extent, the various models are independent of one another, thereby permitting the various parts of the package to be used in the manner that best fits the planning requirements of a given forest. The supporting survey design procedures and data management systems also are modular in design.

These developments represent a significant addition to the set of capabilities available to those who must plan in order to meet the increasing demands of society on our fixed supply of undeveloped land. However, the package should not be considered finalized. A package of this type should always be subject to a process of growth and updating. Even as these techniques are being used in planning processes, work will be under way to monitor the degree to which the analytical needs of the processes are being met. Appropriate changes will be made to improve both the accuracy and the convenience of existing techniques and to introduce new analytical techniques as different planning issues become relevant.

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