# MODELS FOR RECREATION TRAFFIC ESTIMATION WITHIN A NATIONAL FOREST

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A set of travel demand models was developed to estimate recreation traffic on the transportation system of a national forest. These models were calibrated and tested on travel pattern data collected at Tahoe National Forest in California. This paper describes the models and documents their use to reproduce the observed pattern of trips to forest campgrounds. The project illustrated a two-stage approach to recreation traffic estimation by tying into statewide recreation traffic estimates produced by a second set of "macro-allocation" models. The models proved capable of reproducing 88 percent of the variation in the observed data. The set of models contains capabilities for trip generation and for trip distribution and assignment. The principal distribution and assignment model is an intervening opportunities model formulated to take the travel time between attractors explicitly into account.

•IN DEVELOPING recreation traffic estimation models for national forest planning, one quickly recognizes the significant differences between the nature of this problem and the nature of the urban and interurban problems to which planning models have traditionally been applied. Although the functions of the various models can be essentially the same—that is, one may envision procedures to perform trip generation, trip distribution, and trip assignment—it is clear that the classical and simple model sequence, beginning with generation and ending with assignment, is entirely inadequate.

A new sequence of intermodel linkages was therefore devised. The structure of these new linkages is shown in Figure 1. The figure shows five types of travel patterns that are modeled separately and then aggregated to an estimate of total national forest recreation traffic. The characteristics of these five patterns are as follows:

No. 1 is the pattern of travel from external population centers to the study forest as a whole. Because the level of detail for this analysis is considerably more aggregate than for the intraforest analyses, this problem, called "macro-allocation," is treated independently from the others. The models developed for macro-allocation are described elsewhere (1).

No. 2 is the pattern by which overnight visitors to the forest travel to their forest camping locations from convenient hypothetical locations near the forest boundary called "gates."

No. 3 is the pattern by which single-day visitors travel to their day-use recreation areas within the forest from the forest gates.

No. 4 is the pattern by which overnight visitors travel from their campgrounds to day-use recreation areas within the forest.

No. 5 is the pattern by which forest area residents travel from their homes to recreation areas in the forest.

Because of the complexity of the overall problem, work was undertaken to develop a group of models that would include techniques to handle the various trip purposes and travel patterns involved. These models are the subject of this paper.

The following two sections discuss the trip generation models and a trip distribution and assignment technique that was developed to estimate traffic for purposes such as sightseeing and hiking. The succeeding sections present in detail an intervening opportunities type of distribution model derived to be applicable to modeling recreation trips

such as those made for camping, swimming, and fishing. This is followed by an account of the calibration of this model for camping and fishing trips.

## TRIP GENERATION MODELS FOR INTRAFOREST RECREATION TRAFFIC ESTIMATION

Considerable thought was given to selecting an approach to trip generation for intraforest recreation travel analysis (10). Two of the patterns shown in Figure 1 require this capability: pattern No. 4, in which trips are generated at campgrounds, and pattern No. 5, in which trips are generated at forest area residences. In both cases it was decided that the best approach is to employ trip rates at the highest possible level of disaggregation. For campgrounds, the analysis considers trip rates for camping parties; for residences, it considers trip rates per household. These rates are stratified on the basis of trip-maker socioeconomic characteristics, generation location (i.e., campground, residence) characteristics, and trip type characteristics.

The cross-classified-rates approach to trip generation was chosen because it retains the maximum amount of the original behavioral information present in the data and also because it is easy to understand and use. In this situation the latter characteristic is especially desirable because these analytical techniques are being developed not for a single study but as general planning tools to be used eventually in many national forests.

## A TRIP DISTRIBUTION AND ASSIGNMENT MODEL FOR TOURING TRAVEL

Efforts were undertaken to develop a distribution and assignment model for trips that have no well-defined destinations and for which travel difficulty is a relatively small influence. These trips are called "tours" and correspond to purposes such as sightseeing, trail-bike riding, and hiking.

This model is a significant departure from traditional approaches to traffic estimation. Rather than dealing with origin-destination volumes, the model directly estimates the traffic flow on every link of the transportation network. This is done by attempting to satisfy a priori estimates of relative link popularity using a linear program to minimize the differences between a priori and calculated popularity. The traffic is determined subject to constraints on trip generation levels, average trip length, and conservation of network flows. This model, which is the subject of another paper by the author (8), is not described further here.

## THE IMPEDANCE-DEPENDENT OPPORTUNITY MODEL

In selecting a method to perform trip distribution to well-defined forest recreation areas such as campgrounds and lakes, it was decided that no existing model was really suited to the problem at hand. Specifically, it seems that the principal existing models are too simplistic in their manners of representing the spatial patterns of destinations. Both of the two most popular distribution models, the gravity and intervening opportunities models, use but a single metric to account for relative position. The metric employed in each model is different, however; travel impedance (distance, cost, and/or time) is used in the former and a measure of bypassed destination opportunities in the latter (2, 3).

In study areas containing a dense pattern of destinations, there has been shown to be very little difference, in practice, between the two principal measures of relative location (4). This is because both of the measures tend to change in fixed proportion to one another. Therefore, in such situations, if one accounts for one of the two phenomena, he actually accounts for both. This fact explains the similar degrees of success achieved by gravity and opportunity models in performing urban trip distribution.

But under the conditions found in a national forest, the alternative methods of measuring relative location are not at all equivalent. Because of clustering and topographic irregularities, there is no proportionality between the travel impedance overcome and the number of potential destinations intercepted. For this reason it was felt that the

proper model for the national forest situation would be one that explicitly considered both opportunities and travel impedance in determining the distribution of trips. Such a model was derived using the entropy-maximizing procedure advocated by Wilson (5, 6). This new model was christened the "impedance-dependent opportunity model" (7).

This is not the first time that the separate measures of travel impendance and bypassed opportunities have been combined in the same model. However, the only other similar combination that was found appears in a short paper by Harris (4) where he concerns himself with the mathematical form that a distribution model takes if impedance and bypassed opportunities are either (a) proportional or (b) separate independent phenomena. In the latter case, he derives a distribution model similar to the impedance-dependent opportunity model, the difference being in the assumption that, here, the two measures are separate but non-independent quantities.

The impedance-dependent opportunity model operates by calculating the probabilities of trips stopping at destinations according to their relative proximity to the trips' origins. As in the intervening opportunities model, the probability of stopping at a destination is related to its relative attractiveness and to the total attractiveness of all destinations closer to the origin. Unlike the standard model, however, the probability of stopping is also related to the extra travel that would be incurred in passing up the given destination to go at least as far as the next one. The model is therefore sensitive to two characteristics that seem to affect the destination choices of trip-makers—the order in which the destinations can be reached and the impedance experienced in reaching them.

## DERIVATION OF THE IMPEDANCE-DEPENDENT OPPORTUNITY MODEL

The derivation of the model requires that the following symbols be defined:

$i$—A subscript identifying a particular trip origin, that is, a location where trips are generated ($i = 1, 2, \ldots, M$).

$j$—A subscript denoting the rank of a particular trip destination in relative proximity to a given origin ($j = 0, 1, 2, \ldots, N$). ($j = 0$ denotes the origin itself.) Note that a given destination's $j$ value is a function of the origin under consideration and consequently cannot be used to uniquely identify the place itself.*

$t_{ij}$—The number of trips between origin $i$ and destination $j$.

$\{t_{ij}\}$—The set of $t_{ij}$'s for all $(i, j)$. This set is called the "trip distribution pattern."

$S_{ij}$—The number of trips between origin $i$ and all destinations farther away from $i$ than destination $j$. [Note that this is the variable employed to derive the intervening opportunities model (3).]

$\{S_{ij}\}$—The set of $S_{ij}$'s for all $(i, j)$. This set also is called the "trip distribution pattern" because it is equivalent to $\{t_{ij}\}$. One can always compute $\{t_{ij}\}$ from $\{S_{ij}\}$, and vice versa, as follows:

$$t_{ij} = S_{ij-1} - S_{ij}$$

$$S_{ij} = \sum_{\ell=j+1}^{N} t_{i\ell}$$

$S$—The sum $\sum_{i=1}^{M} \sum_{j=0}^{N} S_{ij}$.

$M$—The total number of origins.

$N$—The total number of destinations.

Note that, in general, the number of origins is not equal to the number of destinations.

*Strictly speaking, the subscript $j$ should be written to show its dependence on $i$—for example, as $j(i)$ or $j_i$. However, to avoid cluttering the derivation with subscripts upon subscripts or other cumbersome devices, the relationship between $j$ and $i$ is left implicit.

Given these definitions, one can write an expression for the likelihood of a trip distribution as follows:

$$\frac{S!}{\prod_{ij}(S_{ij}!)} \tag{1}$$

This is an expression for the number of ways the total quantity of S units can be divided into the M × N bundles of certain size, $S_{ij}$, that constitute a particular trip distribution, $\{S_{ij}\}$.* Since the quantities of interest in a trip distribution are the sizes of the bundles (i.e., the quantities $S_{ij}$) and not the individual units themselves, Eq. 1 represents the likelihood of occurrence of the set of bundles, $S_{ij}$, under the assumption that, in the absence of constraints, each of the S units is as likely to be found in one origin-destination state as another. On the basis of the argument that the expression for the likelihood of a trip distribution is proportional to its probability, Wilson maximizes Eq. 1 to find the most probable trip distribution. If one assumes that the most probable distribution is the one observed in the real world, the expression representing that distribution is employed as its model.

When one maximizes Eq. 1 subject only to $\Sigma S_{ij} = S$, one finds that the most probable distribution is that for which all the $S_{ij}$'s are equal. In order to make the distribution nontrivial, it is necessary to specify a set of constraints to impose the desired reality upon the trip pattern. Before doing this, it is necessary to define some additional symbols:

$O_i$—The number of trips emanating from origin i $\left(O_i = \sum_j t_{ij}\right)$.

$D_j$—A measure of the inherent attractiveness of destination j. In the case of national forest traffic estimation, this measure is computed by a factor analysis technique described elsewhere (9). This measure is considered to represent the number of opportunities for trip purpose satisfaction present at destination j.

$A_j$—The sum of the measures of attractiveness at destination j and all destinations closer to the origin than j:

$$\left(A_j = \sum_{\ell=1}^{j} D_\ell\right)$$

$Q_j$—The impedance to travel between a given destination, j, and the next available destination farther away from the origin.

Given these, it is possible to define the three constraints that determine the structure of the impedance-dependent opportunity model:

Constraint 1: The number of trips distributed from each origin is a fixed known quantity, $O_i$. Thus,

$$\sum_{j=0}^{N} S_{ij} = k_i O_i \quad \text{for } i = 1, 2, \ldots, M \tag{2}$$

where the $k_i$ are parameters with values between 1 and N.

The interpretation of the $k_i$ is that each is the average rank of the destinations relative to origin, i, weighted by the numbers of trips to those destinations. That is,

*It is not obvious how one should interpret units of S. It seems to be easiest to conceptualize them as "destination bypassing activities." However interpreted, it is essential that these quantities be viewed as collections of discrete units that can theoretically be rearranged in a large number of different ways.

$$k_i = \frac{t_{i1} + 2t_{i2} + 3t_{i3} + \ldots + Nt_{iN}}{\sum_{j=1}^{N} t_{ij}} \tag{3}$$

Note that, by inserting Eq. 3 into Eq. 2 and substituting $\sum_{\ell=j+1}^{N} t_{i\ell}$ for $S_{ij}$, Eq. 2 becomes

$$\sum_{j=1}^{N} t_{ij} = O_i \tag{2'}$$

which is a more easily understood form for this constraint.

Constraint 2: The number of trips from an origin to any destination is influenced by the order in which all destinations can be reached from that origin and also by the impedance that must be overcome in passing up a given destination to travel at least as far as the next one.

Sensitivity to the order in which destinations can be reached is imposed upon the model by introducing a fixed limit on the amount of bypassing of opportunities that can occur in a travel pattern. The constraint on bypassing opportunities is made sensitive to additional impedance by setting different limits on the amount of bypassing that can occur at destinations having different impedances:

$$\sum_{i=1}^{M} \sum_{j\epsilon\{J_m\}} A_j S_{ij} = P_m, \quad \text{for } m = 1, 2, \ldots, R \tag{4}$$

where

$\{J_m\}$—The set of all j subscripts for which $Q_j$, the impedance, falls within a range of values identified by the subscript m. There are R such sets, one of which identifies the set of destinations where the quantity $Q_j$ is not explicitly defined—that is, destinations at the extremities of the network. This concept is shown in Figure 2.

$P_m$—A constant limit on the total number of opportunities that may be bypassed at destinations with subscripts in the set $\{J_m\}$.

R—The number of sets $\{J_m\}$.

Constraint 2 can be called the "opportunity model constraint." Wilson (5) has shown how maximizing Eq. 1 subject to these first two constraints (without the "m" subscripts in constraint 2) leads to the standard expression for the intervening opportunities model.

Constraint 3: The number of trips that bypass a given destination is inversely related to the difficulty of traveling to the next available destination. The structure of this constraint is analogous to that of constraint 2:

$$\sum_{i=1}^{M} \sum_{j=0}^{N} Q_j S_{ij} = C \tag{5}$$

Here C represents a fixed limit on the total travel cost that can be consumed in the system. Like the $P_m$ of constraint 2, it is not necessary to actually know the value of C, but simply to acknowledge that, under a given equilibrium of supply and demand, such a limit exists. The interpretation of C becomes easier if Eq. 5 is expressed in terms of $t_{ij}$:

$$\sum_{i=1}^{M} \sum_{j=0}^{N} Q_j S_{ij} = C \tag{5}$$

$$\sum_{i=1}^{M} \sum_{j=0}^{N} Q_j \left( \sum_{\ell=j+1}^{N} t_{i\ell} \right) = C$$

$$\sum_{i=1}^{M} \sum_{j=1}^{N} \left( \sum_{\ell=0}^{j-1} Q_\ell \right) t_{ij} = C^* \tag{5'}$$

Note that $\sum_{\ell=0}^{j-1} Q_\ell$ is the total impedance between the origin and the jth destination.

The impedance-dependent opportunity model can now be derived by maximizing Eq. 1 subject to the three constraints (Eqs. 2, 4, and 5). Because of the complexity of Eq. 1, it is more convenient to maximize its logarithm. The logarithm is

$$\ln S! - \sum_{ij} \ln S_{ij}! \tag{1'}$$

Expression 1′ is further simplified by employing Stirling's approximation (i.e., $\ln N! \approx N \ln N - N$) to obtain

$$\ln S! - \sum_{ij} (S_{ij} \ln S_{ij} - S_{ij}) \tag{1''}$$

Expression 1″ is maximized subject to the constraints by taking the partial derivative, with respect to $S_{ij}$, of

$$R = \ln S! - \sum_{ij} \left( S_{ij} \ln S_{ij} - S_{ij} \right) + \sum_{i} \lambda_i \left( k_i O_i - \sum_{j} S_{ij} \right)$$

$$+ \sum_{m} L_m \left( P_m - \sum_{i} \sum_{j \in \{J_m\}} A_j S_{ij} \right) + \beta \left( C - \sum_{i} \sum_{j} Q_j S_{ij} \right)$$

where the $\lambda_i$'s, the $L_m$'s, and $\beta$ are Lagrange multipliers. This yields

$$\frac{dR}{dS_{ij}} = - \ln S_{ij} - \lambda_i - L_m A_j - \beta Q_j = 0$$

which gives

$$S_{ij} = \exp(-\lambda_i - L_m A_j - \beta Q_j) \tag{6}$$

By substituting Eq. 6 into Eq. 2, the Lagrange multipliers $\lambda_i$ can be determined as follows:

$$\sum_{j} \exp(-\lambda_i - L_m A_j - \beta Q_j) = k_i O_i$$

$$\exp(-\lambda_i) = k_i O_i \Big/ \left[ \sum_{j} \exp(-L_m A_j - \beta Q_j) \right]$$

Then, by defining

$$K_i = k_i \Big/ \left[ \sum_{j} \exp(-L_m A_j - \beta Q_j) \right] \tag{7}$$

Eq. 6 can be rewritten as

$$S_{ij} = K_i O_i \exp(-L_m A_j - \beta Q_j) \tag{6'}$$

Equation 6′ is the theoretical form of the impedance-dependent opportunity model. The model is more conveniently expressed in terms of trips, as follows:

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*The step from the second equation to Eq. 5′ is not obvious unless one expands the summations of the former and then regroups the terms according to the summations of the latter.

**Figure 1. The components of national forest recreational travel.**

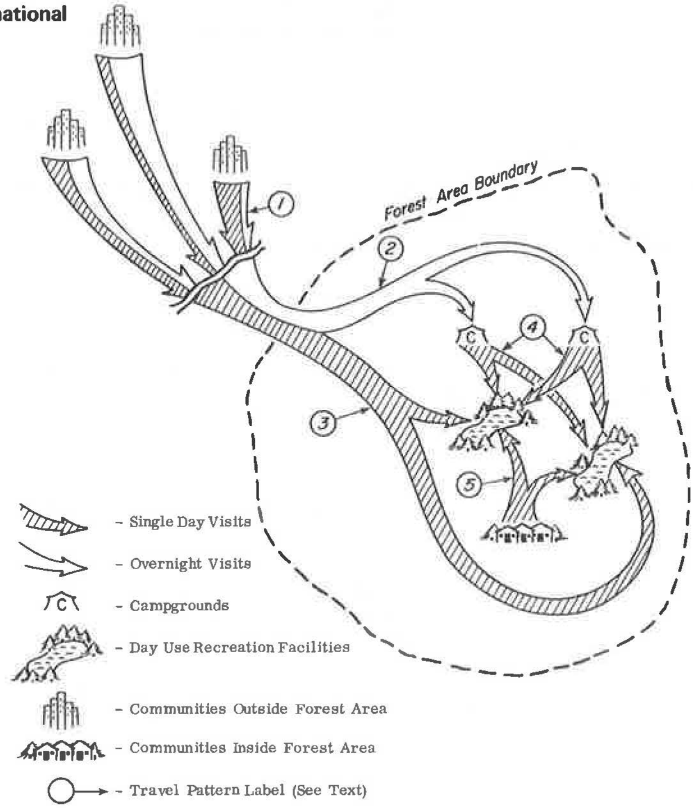
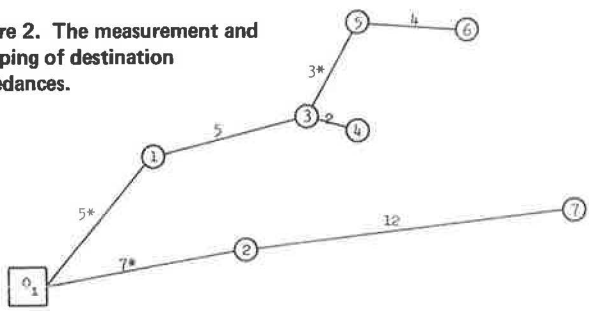



**Figure 2. The measurement and grouping of destination impedances.**




| Destination | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Associated Impedance, $Q_j$ | 5 | 12 | 2 | # | 4 | # | # |

| Grouping (m=) | 1 | 2 | 3 |
|---|---|---|---|
| Impedance Range ($Q_j$=) | 0 - 4 | 5 - ∞ | extremities |
| Included Destinations $\{J_m\}$ | 3, 5 | 1, 2 | 4, 6, 7 |

Legend:

represents the trip generator

represents ranked destinations

# indicates a destination on the network extremity

The numbers on the links are their impedance values

$$t_{ij} = K_i O_i \left[ \exp(-L_{m'} A_{j-1} - \beta Q_{j-1}) - \exp(-L_m A_j - \beta Q_j) \right] \tag{8}$$

To facilitate calibration and to overcome the difficulty of having no explicit measures of the impedances $Q_j$ for destinations at extremities of the transportation network, the model terms $\beta Q_j$ were replaced by parameters represented by $B_m$. A value of $B_m$ is computed for each set of destinations $\{J_m\}$ with similar impedance characteristics. This yields the final practical expression for the model,

$$t_{ij} = K_i O_i \left[ \exp(-L_{m'} A_{j-1} - B_{m'}) - \exp(-L_m A_j - B_m) \right] \tag{9}$$

where m′ identifies the set $J_{m'}$ that includes destination j - 1.

## MODEL CALIBRATION RESULTS

As a test of its suitability for recreation travel, the new distribution model was applied to reproducing the intraforest portions of trips by overnight forest visitors to their campgrounds—that is, travel pattern No. 2 of Figure 1. This trip type was chosen for the first model calibration attempt because it is clearly the most important with respect to investment decisions for forest recreation facility development. It is also a key trip type with respect to other travel pattern analyses, because any estimates of campground-based trip-making are necessarily dependent on prior determination of campground occupancy.

The use of the first camping trip to illustrate the applicability of the model to forest recreation travel is especially challenging. There is a risk that, after driving a substantial distance to reach a national forest, travelers are then no longer sensitive to differences in the relative proximity of campgrounds within that forest. An extra hour of travel time may not be important in the campground selection of a recreationist planning a 3- or possibly 4-hour home-to-campground trip. If differences in distance traveled within the forest are, in fact, irrelevant with respect to campground selection, then that would completely invalidate the assumptions on which the model is based. As it turned out, there is cause to anticipate a lack of sensitivity to intraforest travel time on the part of some travelers. However, it was found that insensitivity to impedance is apparently restricted to a subset of travelers who patronize special highly attractive campground developments, and camping trips that do not fall into this category are very amenable to being simulated by the new model.

The method of calibration for the impedance-dependent opportunity model is similar to that of the intervening opportunities model. First, the model is expressed in terms of the variables $S_{ij}$, as follows:

$$t_{ij} = S_{ij-1} - S_{ij} \tag{10}$$

where

$$S_{ij-1} = K_i O_i \exp(-L_{m'} A_{j-1} - B_{m'})$$

and

$$S_{ij} = K_i O_i \exp(-L_m A_j - B_m)$$

Dividing through by $K_i O_i$ and taking the logarithm yield the general relationship

$$\ln(S_{ij}/K_i O_i) = -L_m A_j - B_m$$

During model calibration the normalization constant, $K_i$, is unity and can be dropped. To determine the values of the parameters, a straight line is fitted for each group of destinations, $\{J_m\}$, having similar impedance characteristics. The $L_m$ and $B_m$ are computed as the slope and intercept respectively of each line.

An attempt was made to fit the impedance-dependent opportunity model to roadside interview survey data describing 2,058 trips from 3 major forest gates to 43 camp-

grounds within Tahoe National Forest [see Fig. 1 of Kanafani (11)]. For trips of this nature, it seemed reasonable to stratify the destination campgrounds into three groups:

1. Campgrounds that can be bypassed without a significant travel penalty because another campground is close by—specifically, within a 10-minute drive;
2. Campgrounds whose bypassing involves a noticeable travel penalty, that is, 10 minutes or more;
3. Campgrounds that cannot be bypassed because they are at extremities of the network with respect to the locations of the forest gates. In a sense, the impedance penalty associated with these destinations is equivalent to the reluctance to backtrack.

The capacities of the campgrounds, in terms of the numbers of units available, were used to measure the bypassed opportunities. Note that these capacities bear only a weak relationship to the numbers of trips actually attracted to the various campgrounds. The model, therefore, serves as a campground utilization model as well as a trip distribution model.

When the trip data were plotted preparatory to computing the intercepts, $B_n$, and slopes, $L_n$, a curious phenomenon manifested itself in each of the three diagrams corresponding to the three impedance groups. The points, rather than falling along the anticipated straight line, clearly fell along a curve. This is shown for one of the three impedance groups in Figure 3.

Further analysis was undertaken to investigate this phenomenon. In doing so, an interesting conclusion was reached that pertains to the calibration of intervening opportunities models in general. It was determined that the cause of the nonlinearity was the fact that at least some of the trip-making represented in the data does not attenuate over distance. In other words, a significant number of trips exhibit lack of sensitivity to the spatial pattern of the destinations. This type of distribution can be described by a simple proportional model of the form

$$t_{ij} = O_i D_j \Big/ \sum_{k=1}^{N} D_k \tag{11}$$

It can be shown that this expression is equivalent to

$$S_{ij}/O_i = 1 - A_j/A_n \tag{11'}$$

which, upon taking the logarithms, yields the shape of the curve in Figure 3.

The implication of this finding is that there are campers who are insensitive to the difficulty of reaching their destinations. Since it does not seem reasonable to believe that all campers behave this way, an effort was made to find an identifiable subset of impedance-insensitive camping trips that could be isolated from the rest. Upon analysis, it was found that insensitivity to impedance is primarily found among trips made to lakeside campgrounds, a set dominated by four extremely attractive and rather inaccessible developments. When these trips were removed, the remaining 1,024 trips, those to 27 non-lakeside campgrounds, fitted the structure of the impedance-dependent opportunity model very well.

Figures 4, 5, and 6 show the final calibration curves for the three impedance groups. Note that these patterns correspond very closely to the theoretical linearity. The computed parameter values are as follows:

| Impedance Group | $L_n$ | $B_n$ | Sample | Correlation Coefficient | Standard Error |
|---|---|---|---|---|---|
| 0 to 9.99 min | 0.0203037 | 0.0815182 | 15 | 0.9803 | 0.00333 |
| 10 min and greater | 0.0180142 | 0.1546793 | 19 | 0.9757 | 0.00099 |
| Network extremities | 0.0201420 | 0.1449599 | 18 | 0.9390 | 0.00361 |

Once calibrated, the model was used to reproduce the observed trip pattern. Figure 7 shows the cell-by-cell comparisons between the observed and model-reproduced trip

**Figure 3. Calibration curve for 43 campgrounds—impedance less than 10 minutes.**

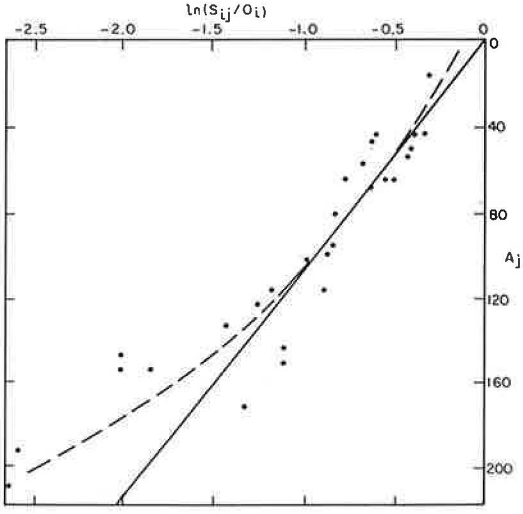



**Figure 4. Calibration curve for 27 campgrounds—impedance less than 10 minutes.**

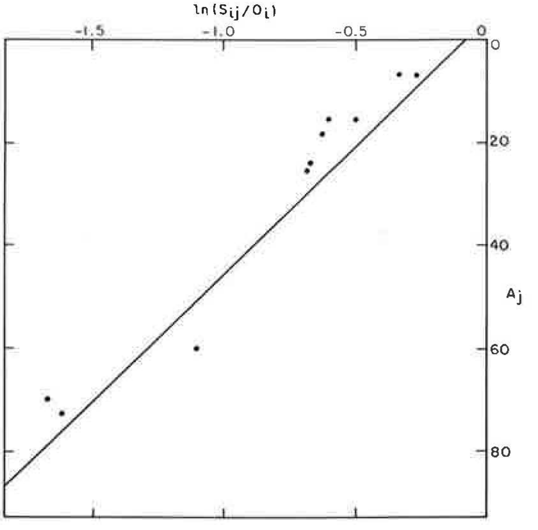



**Figure 5. Calibration curve for 27 campgrounds—impedance 10 minutes and more.**

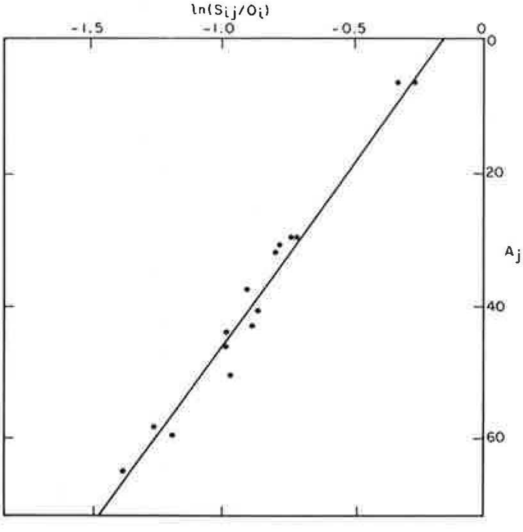



**Figure 6. Calibration curve for 27 campgrounds—destinations at network extremities.**

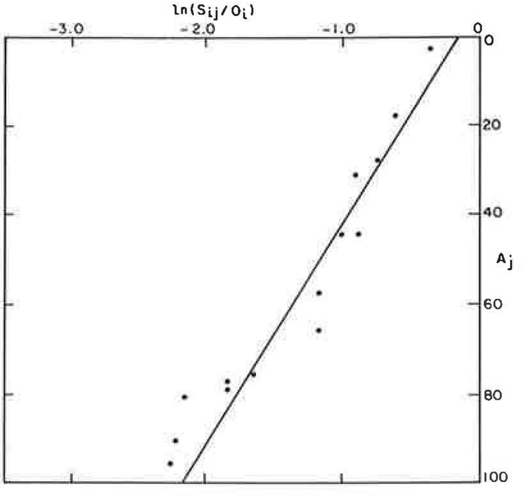


**Figure 7. Comparison of modeled versus observed trip interchanges for 27 campgrounds.**

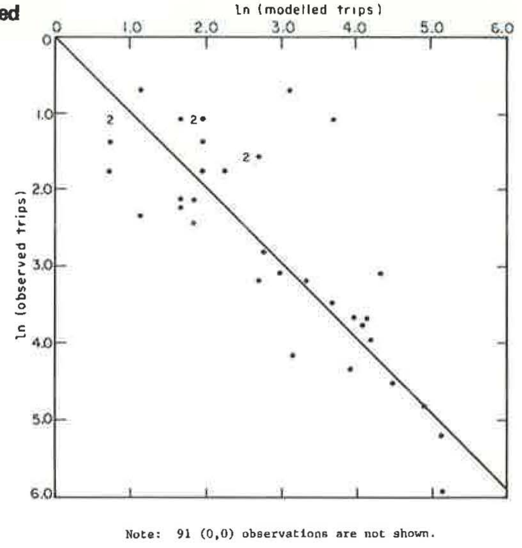



**Figure 8. Observed trip length frequency diagram for 27 campgrounds.**

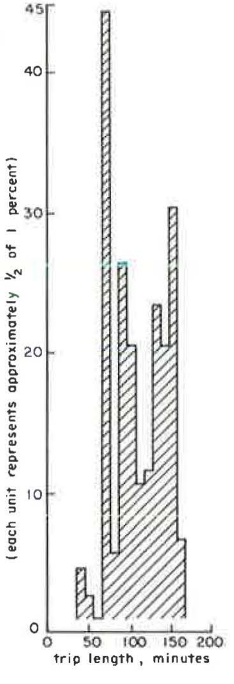
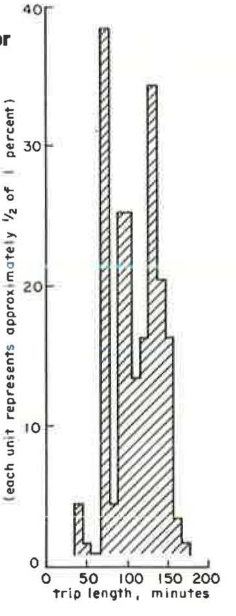



**Figure 9. Modeled trip length frequency diagram for 27 campgrounds.**



interchanges. The correlation coefficient between the observed and model-reproduced trips is 0.94, an $R^2$ of over 0.88, which indicates that over 88 percent of the variation in the data is explained by the model. Figures 8 and 9 show the observed and model-reproduced trip length frequency distributions. Note that, in this case, the model almost exactly reproduced the average trip length, estimating 102.61 minutes compared to the observed value of 102.55. This was achieved without the use of ad hoc parameter adjustments often employed in the calibration of trip distribution models.

To test the reproducibility of the trips that could not be modeled by the impedance-dependent opportunity model, the simple proportional distribution model, Eq. 11, was employed. This model reproduced the observed pattern with a correlation coefficient of 0.82, which is an $R^2$ of about 0.67. Although this fit is not as good as the former, it is considered adequate for the planning applications to which these models are put.

The degree of success achieved in this initial attempt to model an intraforest recreation travel pattern appeared to verify the basic assumption that, at this level of aggregation, the activities of forest visitors are sufficiently regular that mathematical planning models can be applied.

The impedance-dependent opportunity model is theoretically applicable to any travel pattern in which the destinations are well defined and substitutable and where the difficulty of travel influences the destination choice. A number of travel patterns in national forests have these characteristics. To further test its capabilities, the model was applied to the intraforest portions of single-day fishing trips to lakes. This pattern is type 3 as shown in Figure 1.

After a calibration process similar to that already described, it was found that the model reproduced the fishing-trip travel pattern with a correlation coefficient of 0.74—that is, an $R^2$ of about 0.55. The model estimated the average trip length as 90.79, as compared to the observed average length of 91.01. Although the model was not as successful in reproducing this pattern as it was in the case of camping trips, it seems reasonable to suggest that this level of accuracy is commensurate with that normally accepted for planning models. In the future, additional experience gained in fitting this model to other travel patterns in different forests will fully define the range of its applicability.

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