TN 30: A WORK PLAN FOR THE DEVELOPMENT OF A MATHEMATICAL MODEL TO PREDICT AND EXPLAIN OVERNIGHT USE OF PARKS

based on a research proposal by
H.A. MACDONALD, A.H. NETHERTON, AND F.J. CESARIO
revised as a TN by J. BEAMAN, S. SMITH, AND H.K. CHEUNG

ABSTRACT

This paper is about developing an overnight use model by using data collected in park visitor surveys. The mathematical models presented are ultimately meant to assist park planners to predict the number of visitors who will stay one night or more at new or modified parks.

The Macdonald, Netherton, and Cesario report on which this TN is based was prepared because a proposal for a CORDS study could not be pursued since appropriate data were not available. The original document included such items as a list of tasks and a work plan flow chart. Only modelling considerations for actually developing overnight camping models are kept. As well, the material from the report "A Work Plan for the Development of a Mathematical Model to Predict and Explain Overnight Use of Parks", by MacDonald, Netherton and Cesario has been augmented by Smith and Beaman to focus attention on matters which they considered need more discussion since the purpose of the new report *is* not the same as that of the original report. Furthermore, Ewing, in the review section of this chapter, comments on this formulation and relates it to other modelling in Chapter 2, particularly to TN 11. Ewing raises issues and offers alternative approaches to generalizing modelling by Cesario (TN 4).

Incidentally, examination of the Saskatchewan CORD Study data and other potential data showed that these data were not good enough to merit the use of the kinds of models proposed in the "Work Plan". This is the reason the "Work Plan" was never followed.

PURPOSE

The purpose of this paper is to present considerations for the development of an "overnight use" model to estimate park visitor flows. Data requirements and operational forms of the model will be discussed. The model developed is developed for camping.

INTRODUCTION

The first model developed by the Canadian Outdoor Recreation Demand Study was Cheung's main-destination day-use model (see TN 1; Cheung 1972). Cheung recognized that if a single equation was to be used to predict behaviour that behaviour had to be fairly homogeneous (see #Reference27). The model also had to apply to specific facility types offering the same general recreation service. Cheung's modelling was based on such criteria. However, outdoor recreation involves overnight stays as well as day use. Overnight outdoor recreation trips (as opposed to day-use) tend to involve more travel and have greater environmental impact and economic ramifications. Thus, to meet needs of planners and administrators, it was desirable that researchers develop an overnight-use model.

THEORETICAL CONSIDERATIONS

Overnight users of parks may be divided into several categories. Two of the more common classifications schemes involve considering: (1) type of facility used (tent, trailer, pickup camper, motor home, etc.) and (2) travel characteristics (e.g. weekend). Frequently a park can handle *a* mix of camper vehicles and shelters (e.g., within allowed development policies). For planning purposes, one may have campers using various equipment styles in one campground (e.g. with some separation for large “camping” vehicles. Excluding costs and development issues related to providing electricity and sewage connections to campsites, one can meet camping needs with a fairly homogeneous offering of sites. Operationally, important planning differences, however, arise when one compares a transient camper, for example, with one staying at *a site* for a week. Overhead can rise when one services lots of short stay visitors. If many campers are enroute visitors or frequent repeat visitors, service requirements or even opportunity to present a park to visitors can vary radically from first time visitors coming to learn about and experience a park.

CAMPER TRAVELER TYPES

This article suggests that, in general, based on *traveler type* campers can be divided into four rather diffuse groups:

(1) transient or enroute
(2) commuter
(3) destination .
(4) quasi-second home

(For further comments on camper classification see #Reference 4, 14, 21.)

Transient or Enroute Campers

This type of camper is on a relatively long trip and uses a campground on *a* single-night basis. A party’s travel pattern can be one of "hopping" from one campground to another. However, two different types of enroute campers can be identified. One considers enroute campsites *as* rest stops on a trip between his origin and some destination point or region. For example, a camper from Ontario heading for Banff National Park might consider stops on the Prairies primarily as rest stops. In this situation the Prairies would be viewed as an obstacle to be overcome as quickly as possible. Enroute stops would be chosen that were as close *as* possible to the fastest route from his origin to his destination.

Alternatively, an enroute camper might consider certain areas in the Prairies as attractive sub-destinations and would be willing to take *a* more indirect route in order to pass through or stop at these areas. Different models would be required to predict the behaviour of these two types of enroute overnight campers. Still one is not considering a multiple destination trip (choice of a circuit that includes staying at several destinations. In the discussion that follows, only the “strictly” enroute campers receive attention. This is probably the more common type of enroute camper and is certainly the easier to model. This type of enroute camper can be expected to look for *a* campground that is readily accessible to major through-routes and will accept minimal facility development (hook-ups for his equipment, a small store offering items such *as* flashlight batteries, postcards, aspirins, and a pool or small pond). Since enroute campers in a campground may be from any section of Canada or the United States, the "source of visitors" for modelling purposes is the adjacent highway(s), and not one particular centre of population. The relevant costs of enroute camping are the distance between the adjacent highway and the park and the charge for the overnight use of the campground. There are, of course, roadside campgrounds which cater exclusively to the transient or enroute camper. But many other parks, especially many provincial and state parks, also serve this function.

A model incorporating primarily traffic volume on major highways adjacent to parks and the number of alternative parks should be adequate to estimate the number of visitors to a park serving enroute people (see TN 18). In the more complex cases (e.g. provincial parks), total overnight use estimates require inputs from two or three use-equations so one has uses for all camper types. (See TN 40, Figures 4, 5, and 6.)

Commuter Campers

The commuter camper utilizes a park near her/his home and place of work. Typically, the family will stay at a park for several days while a wage-earner or earners commute daily to a place(s) of employment. The commuter camper looks for a facility that, in addition to being close to his workplace, offers an attractive environment with some development such as swimming and fishing facilities. A "general store" is not always necessary, since the family can continue to follow its normal shopping patterns and replenish its supplies from home.

Destination Campers

Destination campers are probably the most diverse of the groups considered here. One individual may spend several days of his vacation as an enroute camper and then, upon arrival in a major tourist area, become a "destination camper" for several days. On returning home, such a camper may again become an enroute camper. If the destination campground offers attractions such as a body of water, trails or beautiful scenery and a developed camping infrastructure (laundry, grocery store, other camper services) the camper might possibly stay a week or more.

Another type of destination camper may have no single destination point in mind. Instead he considers a region such as Nova Scotia and New Brunswick to be his destination, within which he plans a tour. In this case his overnight use of any one campground will be a function of not only attractiveness of that particular site but probably more importantly of the surrounding area and indeed of the whole region being toured. (See the comments on the meanings of attractiveness measures in TN 9 and on alternative-site functions in TN 3.) In other words, use of a particular park can depend more on-regional characteristics than on the characteristics of the park. Thus a model for this kind of camper must incorporate information on the intended/likely use/visiting of attractions in an area. And, as if this isn't difficult enough, in many cases the utility of a tour is not simply equal to the sum of the utilities of its parts. The latter situation might arise when a camper may wish a varied diet of activities and places to see. The result is that one activity (such as a day at the beach) may be more desirable (have greater utility) if it follows a day's river fishing than it would if the camper did nothing else but camped and lay on the beach. Because of these complications, the proposed model of overnight park use will be limited to destination campers with a single main destination, rather than a set of destinations with a variety of activities.

A second major distinction among destination campers is the duration of their stays away from home or work. The main effect of trip duration is likely to be that distance between home and destination plays a more important role as trip duration decreases. In other words, the distance traveled on a trip becomes increasingly critical as a camper has less time for the trip. No structural differences, however, are assumed necessary to adapt the models to different trip durations. But, without information on the break-down of total trip durations for each origin and each destination, it is difficult to predict the different trip durations. Calibrating a single model for all destination campers irrespective of trip duration is likely to produce predictions biased toward the mean or median trip length. In this regard Dice (see #Reference15) estimated that in Michigan 75 percent of campers camp on 25 percent of the days, primarily on weekends and public holidays. Such a high proportion of 2-day or 3-day trip durations suggest that it might not be too inappropriate, lacking more detailed data on trip duration, to perform only one calibration of an overnight destination model for Michigan using all overnight destination data.

Destination campers are confronted with travel costs proportional to distance, road tolls, extra meals on the road, and park fees. Since distances are larger and play a more important role here than for enroute campers (who may have traveled just as far, but whose origin - for planning purposes - is the “jump off” point for going off a highway to a campground), income and other socio-economic data should be included in the destination camper travel model. Other factors to include are, of course, the quantity and quality of facilities at and around a destination, and a measure of the effect of competing alternatives.

Quasi-Second Home Campers

This last group of campers is a growing one, and one that is a fairly new phenomenon. The group is characterized by the storage of their camping equipment at a site, usually within a day's drive of home, for a season or for the year. They travel to a site for weekends and extended vacations throughout the year. Their strategy frees them (1) of having to load up their equipment every time they wish to make a trip, and (2) of the problem of where to store a motor home or camper. Since this group is still quite small, many parks do not permit year-round or seasonal storage, and their criteria for choosing a particular site may differ considerably from the other three groups. This group of campers is not considered in this study.

CAMPGROUND TYPES

The above discussion has given profiles for different types of campers; the question can be raised as to whether there are different types of campgrounds. To an unknown extent, yes there are. Clearly, some campgrounds are oriented vehicle access and well suited for enroute stops. Campgrounds only accessible by foot, canoe or boat are at another extreme, even if some of these are oriented for longer stay and some are “enroute” stops on a hiking or canoeing adventure. Even someone not connected with the design, development or operation of a campground would suspect that the location and level of development of some facilities reflects the character of the user. For example, a campground located near a limited access highway interchange with few trees, a small pond, a small store and no other development (except for individual campsites) is designed to serve the enroute traveler. A campground in a remote park with excellent opportunity for backpacking, riding, fishing, hunting, swimming, and nature study plus a complete camper store can be expected to draw mostly destination campers. In so far as park reflects the nature of camping provided, parks can thus be classified according to the same paradigm used for campers.

However, just as campers can exhibit a variety of behaviours on one trip or throughout a camping season, so too campgrounds can exhibit different characteristics. Large, well-developed parks located near highways or urban areas may attract a mix of destination, enroute and commuter campers. The immediate implication is that, for some parks, one type of travel model would not be adequate for projection purposes. It is of course necessary that the planner be able to accurately determine the character of a park. For an existing park there can be an on-site visit, visitor records, design specifications and location attributes. If (1) a group of parks with different traveler characteristics or (2) one park with a variety of users, is being studied, a complex model with a series of equations relating to the different camper types is clearly necessary. (See TN 40, Figures 4, 5 and 6.)

In the discussion that follows, destination and commuter campers are treated as one group and enroute campers *as* another. As will become clear below, it is felt that the criteria used by for choosing *a* campground that are being used by the two groups being considered are sufficiently different to necessitate two structurally different models to predict their choice behaviour. The same model can be used for destination and commuter campers because both are choosing a destination by similar criteria (given that two different gravity functions are needed to actually predict behaviour at alternative destinations with needed accuracy, the assumption is not valid – one is making an approximation). However, different equations are developed for commuter and destination campers because it is assumed that the commuter camper puts more weight on distance than either the weekend or longer-duration destination camper. In other words, the difference in the importance of distance requires separate calibration of the same model for each group (and can require more groups when e.g., the mix of commuters and destination campers involves an average of very different distance functions and parks being considered vary from largely local service parks to parks serving a high percent of visitors from "remote" locations).

MODEL

Two sets of equations, one for enroute campers and one for main-destination campers are derived. The problem of predicting visitor flow volumes is twofold. First, given the number of potential camper parties in any population centre, i, it is necessary to predict the actual number of camping party trips, N(i). Next, it is necessary to predict what proportion of party trips, Ψ(i,j) from origin i, will involve an overnight stop at park j.

Given values for N(i) and Ψ(i,j), the number of camper party trip from origin i to park j in a given time period, V(i,j), is:

(1) $V(i,j)=N(i)\Psi(i,j)$

It is now necessary to obtain some methods for calculating N(i) and Ψ(i,j). Since the enroute camper model involves a simplification of the main-destination model, the following discussion concentrates on the main-destination model. Once the main-destination model has been derived, the equivalent enroute model is formulated.

PARTICIPATION COMPONENT

In the case of main-destination campers, participation is assumed to be a function of (1) the population and socio-economic characteristics of a population centre and (2) the accessibility attractiveness of camping facilities. Following the development in `Cesario, Goldstone, and Knetsch` (1969) a participation function for such park use is:

(2) $N(i)= \boldsymbol{\kappa} S(i)^{\alpha} P(i)^{\beta} \left(\Sigma_n A(n)/C(i,n)^{\gamma}\right)^{\eta}$

WHERE

i = centre i

j = park

N(i) = the number of camper party trips per time

P(i) = the population of centre i;

S(i) = the average family income in centre i, used as a surrogate for the socio-economic characteristics of centre i;

A(j) = the "attractiveness" of park j;

C(i,J) = the cost of travel from origin i to park j, defined in terms of time or money;

m = the number of parks;

$\boldsymbol{\kappa}$, α, β, γ, φ = parameters to be estimated and

summation is over all parks (n=1 to m).

Equation (2) is option 1 of a participation component in the main-destination model. It states that if S(i) and P(i) are held constant, N(i) is a non-linear function of the sum of all parks' attractiveness/ accessibility ratios. (See TN 3 and 11 and Chapter I Review of this Volume for a further discussion of the role of such factors in destination-use models.) An alternative formulation of the participation component, option 2, is developed by considering formula 3 as having two elements:

(3) $N(i) = \boldsymbol{\kappa}\ S(I)^{\alpha} P(i)^{\beta}\ F(A(1), \ldots A(m), C(i,1), \ldots, C(i,m))$

WHERE

F(A(j), C(i,j)) = the probability of a potential party trip from i being to park j,

with attractiveness is A(n) and accessibility C(i,n) being for all m parks (n=1 to m);

and the other terms are as defined above.

The implication of the formula is that the number of potential party trips is some function of S(i) and P(i). The probability of a party trip being to a particular park in a given time unit is specified to be a function of the attractiveness and accessibility of all parks. Thus, unlike option 1, the probability of participation is explicitly considered and is defined in terms of the attractiveness and accessibility of all parks.

The probability term, F(A(J), C(i,j)), in Equation 3 is determined as follows. First, compute the probability of a camper deciding to visit no park at all. Represent this Probability as: G(A(ᵽ), C(i,ᵽ)). If we can assume that F(A(j), C(i,j)) for each park is independent of the probability function of other parks, the rule of multiplication from conditional probability theory enables G(A(ᵽ), C(i,ᵽ)) to be defined as:

(4) $G(A(ᵽ), C(i,ᵽ)) = \prod_n [1-F(A(n),C(i,n))]$

WHERE

1 - F(A(n), C(i,n)) = the probability of a camper from centre i deciding not to visit park n,

m = number of parks, and

probability is calculated over all parks (n=1 to m).

Given that the probability of visiting any park at all is one minus the probability of not visiting any park at all:

(5) $F(A(j), C(i,j)) = 1 - G(A(ᵽ), C(i,ᵽ))$

It follows from Equations 4 and 5 that Equation 3 can be rewritten as:

$N(i) = \boldsymbol{\kappa}\ S(i)^{\alpha} P(I)^{\beta} [1 - \prod_n F(A(n),C(i,n))]$

As developed in Cesario et al. (1969), let:

(6) $F(A(j), C(i,j)) = \lambda\ A(j)/C(i,j)^{\gamma}$

WHERE

λ = the "elasticity" of the probability of a visit with respect to accessibility.

Therefore, Equation 5 can be rewritten as:

(7) $N(i)= \boldsymbol{\kappa}\ S(i)\alpha\ P(i)\beta\ [1-\prod_n (1- \lambda\ A(n)/C(i,n)^{\gamma})]$ WHERE the product is calculated over m parks (n=1 to m).

This is Option 2 for a participation component of the main-destination model.

DISTRIBUTION COMPONENT

When estimates of participation in camping are known for all the origins in the system, the trips are distributed to all the parks in the system. The attractiveness of, and the 'cost' of reaching, the parks in the system from the origins will determine the camping use that a particular park receives. Following the development in Cesario et al. (1969), the probabilistic distribution function for main-destination campers, and enroute campers, is:

(8) $V(i,j)=N(i)\ (A(j)C(i,j)^{\gamma})/\ (\Sigma_n A(n)C(i,n)^{\gamma}))$

WHERE

V(i,j)= the number of overnight camper parties that park j receives from origin i during a period of time;

the other variables are as previously defined; and

the summation is over all parks.

The function is probabilistic in that for a sum over parks, k, for any one park, j, the expression $(A(j)/C(i,j)^{\gamma})/\ (\Sigma_n (A(n)/C(i,n)^{\gamma}))$ defines the probability of *a* camper from centre i visiting park j.

Now incorporating the two options for the participation component, Equations 2 and 7, into the distribution function, Equations 9 and 10, give the two alternative use models for main-destination campers:

(9)- MODEL 1

$V(i,j)=\boldsymbol{\kappa} S(i)\alpha P(i)^{\beta}(\Sigma_k A(k)/C(i,k)^{\gamma})^{\eta}\{(A(i,j)/C(i,j)^{\gamma})/(\Sigma_k A(k)/C(i,k)^{\gamma})\}$

$=\boldsymbol{\kappa}\ (S(i))^{\alpha}P(i)\beta(\Sigma_k A(k)/C(i,k)\gamma)^{\eta-1}(A(j)/C(i,j)^{\gamma})$

WHERE the summations are over all parks.

(10)- MODEL 2

$V(i,j)= \boldsymbol{\kappa} S(i)^{\alpha}P(i)^{\beta}(1-\prod_n(1-\lambda A(j)/C(i,n)^{\gamma})$

WHERE the summation is calculated over m parks (n=1 to m).

For enroute campers, only one modification is made in Equations 9 and 10. Participation in this case is assumed to be a function of both the volume of camper vacation traffic and the overall attractiveness and accessibility of parks to the routes followed by that traffic. Unlike the main-destination model which uses origin socio-economic data to estimate camper trip population, the camper party trip population (potential visitors) is defined in the enroute model as the volume of camper traffic on a particular highway. Therefore, the socio-economic variables used in Equations 9 and 10 are irrelevant in estimating the participation component of the enroute camper model. However, the term defining the overall attractiveness and accessibility of parks to routes used by camper vacation traffic is still relevant. Accordingly, the enroute model omits S(i) in Equations 9 and 10 and defines P(i) in these equations as the volume of potential camper vacation traffic on route segment i.

If it is assumed that all camper vacation traffic will make an overnight stop at one of the parks under study, then a simplified form of the enroute camper model can be used, specifically:

(11) $V(i,k)= \boldsymbol{\kappa}P(i)j)C(,j)^{\gamma}/(\Sigma_k A(k)C(i,k)^{\gamma})$

As the total number of camper party visits has been estimated by the model as V(i,j), and number of nights per party is obtainable from on-site records of surveys, it is reasonable to consider these as two different phenomena. Camper party-nights is a figure representing the number of camper parties multiplied times the *average* number of nights per visit:

Total party nights = V(ij) x average nights/party.

This simple calculation is meaningful for e.g. main destination use of a campground but for enroute-camping the average length of stay at a campground can be close to 1.0.

DATA NEEDED

The following data are needed to operationalize Equations 9 and 10 for both main-destination and enroute campers:

1. The total number of parties from origin i visiting park j in a given time period.

2. The quantity (and qualities, if possible) of the facilities of park j.

3. The quantity (and qualities, if possible) of camping facilities of park j.

4a. The distance between origin i and park j. And/or

4b. The time required to travel the distance from origin i to park j. And/or

4c. The money cost of traveling the distance between origin i and park j, and the camping permit fee.

5a. The distance between park j and the nearest point on an arterial or major highway carrying vacation traffic. And/or

5b. file time required to travel the distance from the nearest point on an arterial highway to park j. And/or

5c. The money cost of traveling the distance from the nearest point on an arterial highway to park j, and the camping permit fee.

6. The average family income of origin i.

7. The population size of origin i.

8. The volume of camper vacation traffic on arterial highway segment i.

DISCUSSION AND CONCLUSION

As already mentioned in the section, Theoretical Considerations, the models defined in Equations 9 and 10 refer only to enroute campers who are making a ‘bee-line’ for a particular destination, and not to those who are willing to make a detour to one or more places of interest off their main route. Similarly, with main—destination campers, the models refer only to those campers for whom the attributes of a particular park (including its distance) are the sole criterion for choosing a particular camping destination. The latter restriction could be partially relaxed if attributes of the region in the immediate vicinity of the park were measured and used to define A(j). However, the models would still not cover those campers whose destination is a wider region within which several distinct destinations exist, since in that case the choice of one destination is not independent of the others chosen. To model such touring campers would require a structurally more complex model, as well as more detailed itinerary information.

As mentioned, it is clear that trip duration affects the choice of destination. Specifically, the more time a camper has, the greater the range of alternative destinations available to him. In terms of the models developed, the exponent on C(i,j) is expected to decrease as trip duration increases. However, it is also conceivable that the importance attached to different features of a park which influence its attractiveness will vary with trip duration. Thus, while back-packing facilities may be an important feature in a park for those contemplating a stay of three or more days, these facilities may assume much less importance than would, say, a campsite with a lake frontage for a weekend camper. While these variations do not necessitate any structural change in Equations 9 and 10, it is suggested that calibrating such equations using all camper visits irrespective of total trip duration might result in poorer predictive accuracy than if separate calibrations were performed. The latter, of course, would necessitate data disaggregated by trip duration (or segmentation based on activities of interest).

Although the enroute model assumes that data on the volume of vacation traffic on highways adjacent to a particular park defines a user population and that the number of overnight stops at a park is a direct function of that volume, there is one instance in which this assumption may produce sizeable errors.

Let the word "origin" refer, for the moment, not necessarily just to home or work location but to the starting point for any day's journey. For example, for an enroute camper going from Ontario to Alberta, his origin on a given day may be the park he stopped at the previous night. If, for the volume of vacation traffic measured on any highway segment the distribution of distances to origins is the same as for any other highway segment, then there is no problem in directly relating V(i,j) to that volume of vacation traffic. However, there are few obvious and important highway segments that will have distributions of distances from origins that are decidedly different from those of other highway segments. An example should help clarify this. On the highway segment immediately north of Toronto leading towards Sudbury and the west, a large percentage of camper vacationers heading towards Sudbury will have originated in Toronto. Thus, although the volume of vacation traffic may be very high on that route, it is unlikely that many will make their first overnight stop within, say, 50 to 100 miles of Toronto, even if they left Toronto only late that afternoon. If on any highway segment a relatively large percentage of vacation travelers comes from a nearby origin, the proportion making an overnight enroute stop at a park in the vicinity of that highway will be less than would normally be predicted from that volume of traffic. Clearly, this problem will be most acute in the vicinity of metropolitan areas. The point is that the simple volume count of vacation traffic on a highway segment is likely to be a much poorer predictor of the number of enroute stops at an adjacent park than the use of frequency distribution of distances to those travelers' origins for the day.

A final problem that can be noted is that both Equations 9 and 10 are non-linear functions with, respectively, four and three parameters to be solved for. The values of park attractiveness are assumed to be defined exogenously. If A(j) values are to be estimated within the model then it is not certain that any reliable and efficient solution technique exists. A heuristic non-linear regression algorithm is unlikely to converge on a solution in any reasonable time. *One can note that* advances in non-linear regression and computing from since the 70's mean that computing time is not an issue. Convergence can still be an issue because parameter combinations can result in local maxima and minima that are not optimal solutions. Or, a best solution can involve meaningless parameter values. This can occur because the model is a poor approximation of the "real" system being modeled (e.g., because segments with different models are being aggregated). Today (in the second millennium) likely that a non-linear regression procedure could be used effectively, however, ad hoc use is like to lead to models that fit but have no meaning when extrapolated to situations other than those for which they are estimated.

In conclusion, the proposed models of enroute and main-destination overnight park use have been argued to be applicable to a certain well-defined type of main-destination park user and a certain type of enroute park user. Insofar as there are many minor variations in camper types, it may be reasonable to consider developing a more general model which could subsume the types considered in this paper as special cases. In the process of deriving such a model, care should be taken to see that the model formulated can be estimated.