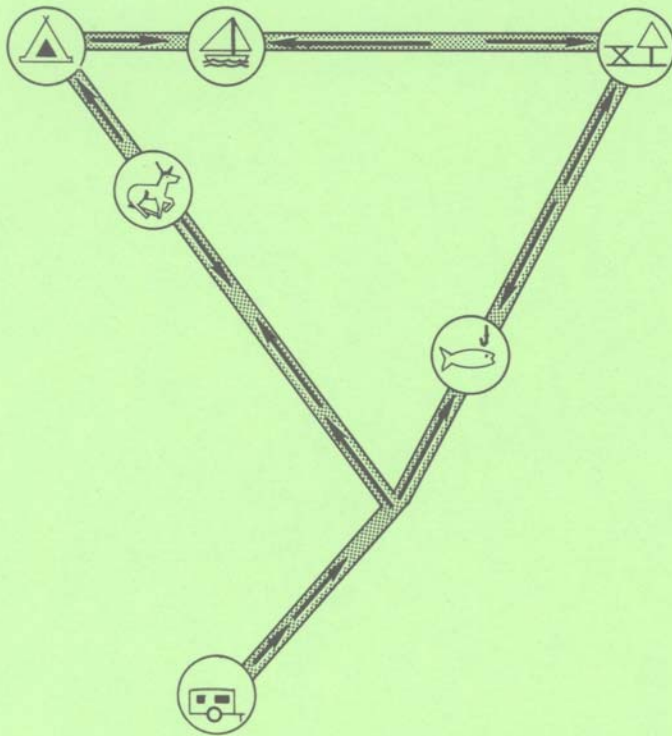


PACIFIC SOUTHWEST Forest and Range Experiment Station

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701



PREDICTING TRAFFIC LOAD IMPACT OF ALTERNATIVE RECREATION DEVELOPMENTS

Gary H. Elsner

Ronald A. Oliveira

CONTENTS

	<i>Page</i>
Summary	1
Introduction	3
Method	3
Theory and Definitions	3
Computation Method	4
Harney Peak Area Analysis	10
Nodes and Highway Links	10
Ranking Input Data	10
Reliability of Estimates	11
Simulation Results	11

The Authors

are assigned to the Station's forest recreation and landscape management research unit, with headquarters in Berkeley, California. **GARY H. ELSNER**, in charge of the unit, received a B.S. degree (1962) in Agricultural Economics at the University of Arkansas, and an M.S. (1964) and a Ph.D. (1966) at the University of California, Berkeley. He joined the Forest Service in 1966. **RONALD A. OLIVEIRA**, an economist, earned degrees in agricultural economics at the University of California at Berkeley (B.S., 1968) and at Davis (M.S., 1969; Ph.D., 1973). Before joining the Station staff in 1972, he was assigned to the Forest Service's Rocky Mountain Region, Denver, Colorado.

ACKNOWLEDGMENTS

Discussions with George W. Tourtillott of the Rocky Mountain Region, U.S. Forest Service, Denver, Colorado, and Roy W. Feuchter, now with the U.S. Forest Service Division of Recreation, Washington, D. C., resulted in the definition of the research objective. Giuseppe Rensi, University of California, Berkeley, aided in the development of the simulation technique and specifically suggested the method used to calculate the p_{ij} values. Jerry Schneider of the University of Washington, Seattle; and Michael R. Travis and Peter Wong of the U.S. Forest Service, Berkeley, California, made helpful review comments and suggested attractive and useful display formats. Kenneth C. Scholz and Charles C. Hathaway, both of the Black Hills National Forest, Custer, South Dakota, provided the necessary coordination and working conditions for estimating and testing the method.

SUMMARY

Elsner, Gary H., and Ronald A. Oliveira

1973. **Predicting traffic load impact of alternative recreation developments.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 12 p., illus. (USDA Forest Serv. Res. Paper PSW-96)

Oxford: 907.2.

Retrieval Terms: recreation areas; automobiles; traffic load; road systems; simulation techniques; Harney Peak area; South Dakota.

Creation of a new recreation facility has a necessary impact on the local traffic load. Planners need to be able to predict the magnitude of such an impact.

To analyze the impact of an additional recreational development in the Harney Peak—Sylvan Lake area in South Dakota, a method was devised which could consider several alternative options. This report describes the method in general and in algebraic terms, and its application to the Harney Peak area.

In the approach used here, the spatial points between which travel occurs are called *nodes*, and are classified as recreation attractions, overnight accommodations, or in- or out-terminals. Travel types are defined as internal in the recreation system, inflowing, outflowing, or both. Routes, composed of road links, connect the nodes. Information on the facilities available at each node is used to compute a rank for each node to indicate its drawing power. Rank, combined with proportions (probabilities) of cars estimated to be traveling for the four travel types, and total number of cars in the system, gives values for the number of cars traveling between any two nodes. The load on each link of the selected route is calculated as a summation of all cars traveling on that link to reach any node.

To simulate a change in the system, it is necessary only to recompute the ranking information, the probability and number of cars traveling between the

nodes, and the link loads, according to the modification. Expected percentage change in loads can then be obtained.

The computer operation, as illustrated in a simple example, converts raw data to a normalized ranking for the nodes, and allows calculation of t_{ij} , the total number of cars going between node i and node j during a given unit of time. Calculation of the traffic load on each link of the system is possible by using a routing matrix of 0's and 1's which define which links are included in each route. All the values for the links in the appropriate rows of the routing matrix are multiplied by the corresponding t_{ij} , and the columns of the matrix are then summed.

The Harney Peak area involved 12 nodes and 25 links. The percent changes resulting from each of six alternative development options, as shown in the summary table, give a usable prediction of the effects of these plans on recreation traffic loads. Although the estimates are theoretical, and unconstrained, they are based on data that are often available.

The simulation technique is particularly useful in evaluating alternatives. The effect of changes in recreation facilities and attractions may be simulated before final plans for land use are drawn up. The results of this study were a significant input to a meeting on May 12, 1970, held by the U.S. Forest Service and open to the public, to discuss land-use planning in the Harney Peak area.

Creation of a new recreation facility will usually result in impacts on the local recreation system. If the change attracts more visitors, there will be an increased traffic load on the existing highway system. This additional load may be of little consequence if the system is underutilized, but if it is already heavily used, bottlenecks and other traffic disorders may result. Careful calculation of the expected impact under alternative land-use plans will simplify planning and future management. The recreational planner must not only measure future demand levels, but also determine their spatial distribution. Changes proposed for a recreational system will distort a spatial pattern that is the result of complex interactions. Planners need to “be able to determine in advance, what shape such distortions are likely to have, what magnitudes they might be, and to evaluate whether the distortions are beneficial or not.”¹

This paper describes the results of an attempt to estimate the impact of an additional recreation complex on an existing scenic highway system in the Harney Peak—Sylvan Lake area in South Dakota, which includes Mount Rushmore. The system is heavily used during the summer months, mainly by persons seeking outdoor recreation. In addition to

analyzing the impact of a new development in the Sylvan Lake area, this study also considered several alternative additional development options, including increases in parking facilities at Mount Rushmore and in campsites at Horse Thief Lake.

Most earlier studies attempting transportation system simulation have dealt with larger networks than the one considered here, and distance (usually measured in travel time) has largely determined the selection of destinations and routes. In smaller networks it may be possible to travel from any point to any other point in much less than half a day. Thus distance need not determine recreation destinations in a small network, but may influence the selection of routes.

This observation required the development of a new simulation technique, which is described in both general and algebraic terms. When this technique was applied to the problem of planning for the Harney Peak area, the traffic impact of proposed developments became evident. The impact takes the form of a difference between the computed present two-way traffic load on each link of the highway system and the estimated load under each of the alternative recreation development plans. The computed percent change can be given for each link.

METHOD

Theory and Definitions

To calculate the traffic loads on a highway system, the probability of travel of various types between any two spatial points must be estimated. In the approach used here, the spatial points between which travel occurs are designated as *nodes* and are classified by location and function. A node may be within the system or a connection of the system with the rest of the world. Nodes within the system may be further classified by function as overnight accommodation areas (takeoff bases) or tourist attractions (visiting points). Some nodes may of course combine these functions.

Nodes on the outside or boundary of the system

may be further classified as entrance or exit terminals (in-terminals or out-terminals), or both at the same time, which is usual. It is also reasonable for a node to be a “rest of the world” terminal and yet provide overnight accommodations to the system.

Travel types are defined as follows:

1. *Travel within the system*, consisting exclusively of routes from an overnight accommodation to an attraction to the same overnight accommodation (two ways).
2. *Inflowing travel*, consisting exclusively of routes from an in-terminal to an overnight accommodation (one way).
3. *Outflowing travel*, consisting exclusively of routes from an overnight accommodation to an out-terminal (one way).
4. *Inflowing-outflowing travel*, in the same given unit of time, consisting exclusively of routes from an in-terminal to an attraction to an out-terminal (two ways).

¹Ellis, Jack B., and Carlton S. Van Doren. *A comparative evaluation of gravity and system theory models for statewide recreational traffic flows*. J. Reg. Sci. 6(2): 57-70.

A *route* is defined as that portion of the highway system that is used in travel from one node to another. A *circuit* is the route from one node to another plus the return route, which may be different. A *link* is a segment of the major road system that connects either two nodes or a node and a highway intersection or two intersections.

Information on the facilities available at each node in the system serves as raw data input for the computation of a ranking value in percent for each node, as an indicator of its drawing power; that is, the probability of travel of one or more of the specified types to that node. Additional computer inputs are the total number of cars in the system, and the proportions of cars estimated to be traveling for each of the four travel types. By combining these data with the node ranking, the computer produces values for the number of cars traveling between any two nodes.

To obtain the traffic load on a specific highway link, a route, consisting of selected links between nodes, must be designated. The selection of links comprising each route is considered in this study as basic data input. Selection may be based on historical observations, travel time on each link, scenic and recreation attractions along each link, or other reasons. The load on each link is calculated as a summation of all cars traveling on that link to reach any node.

To simulate a change in the system, it is necessary only to recompute the ranking information, the probability and number of cars traveling between the nodes, and the link loads, according to the modification. The new link loads may then be compared with the base loads as originally calculated, to find the expected percentage change resulting from the change in the system.

The procedure just described is based on the assumption that if, at any given time, there are a given number of cars in a system, for a given travel type, their allocation will be proportional to the ranking of the nodes appropriate to that travel type.

The method of computation in algebraic terms is illustrated in the next section by a simple example. The more complex Harney Peak area analysis, as presented here, may be understood, however, without reference to the algebraic illustration.

Computation Method

The computer uses as data input the number and kind of nodes, the travel types, and the number of cars in the system, as described above. To explain the procedure, we will use a miniature hypothetical recreation travel system (*fig. 1*) composed of four nodes and four highway links.

First, each node i is ranked according to its over-all attractiveness (tourist drawing power), a_i ; overnight (bedroom) preference, b_i ; entrance preference, e_i ; and exit preference, x_i . A zero is assigned to each rank if it is not applicable, that is, $a_j = 0$ if node j is exclusively an overnight accommodation or terminal and has no tourist attractions. Each rank must be greater than or equal to 0 and less than or equal to 1. In addition, the ranks in each category must sum to 1. Summarized, the node rankings are

$$\begin{aligned} a_1, a_2, \dots, a_n \\ b_1, b_2, \dots, b_n \\ e_1, e_2, \dots, e_n \\ x_1, x_2, \dots, x_n \end{aligned}$$

in which

$$\sum a_i = \sum b_i = \sum e_i = \sum x_i = 1, i = 1, 2, \dots, n, \text{ and}$$

$$0 \leq a_i, b_i, e_i, x_i \leq 1.$$

Historical data obtained on the system in Our illustration indicate that node 1 has recreation attractions receiving 5,000 visits a year, overnight accommodations (camping) for 30 people, and no direct inflow and outflow from nodes outside this system. Therefore, since node 1 is used as neither an entrance nor an exit, e_1 and x_1 will both be 0. Node 2 has a major recreation attraction receiving 45,000 visits a year.

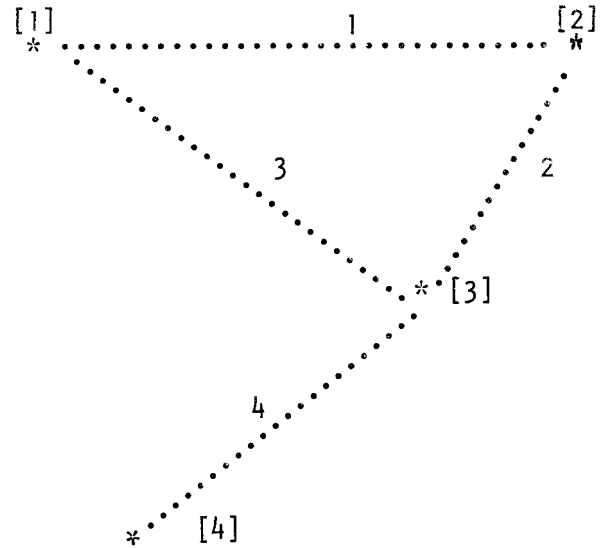


Figure 1—A simple recreation travel system, consisting of four nodes (*) joined by four highway links.

Node 3 has neither a recreation attraction nor any overnight accommodations but is a node connecting this system with the outside world. It averages 40 cars in and 40 cars out per day. Node 4 has only overnight accommodations for 30 people.

Next, we consider the cars in the system and the known proportions for each travel type:

T = total number of cars in the system

T_1 = number of cars driving for travel type 1 (internal)

T_2 = number of cars driving for travel type 2 (inflow)

T_3 = number of cars driving for travel type 3 (outflow)

T_4 = number of cars driving for travel type 4 (in-out)

where

$$T = T_1 + T_2 + T_3 + T_4$$

The proportion of cars in the system traveling for travel type i is P_i , in which

$$P_i = \frac{T_i}{T} \quad i = 1, 2, 3, 4.$$

The example input data indicate that there are an estimated 100 cars in the system (T) and that 80 percent of these stay in the system for this time period (PINTRN or P_1), 5 percent enter the system (PINFLO or P_2), and 5 percent leave the system (POUTFL or P_3), and 10 percent both enter and leave the system (PINOUT or P_4). Thus $P_1 = 0.80$, $P_2 = 0.05$, $P_3 = 0.05$, and $P_4 = 0.10$.

The input data as they appear on the computer printout are given in *figure 2*. Columns 1 through 4 of the “Unnormalized Ranking Information” summarize the input data on recreation use (number of visits), overnight accommodations, traffic inflow, and traffic outflow, respectively. The ranks, a_i , b_i , e_i , and x_i , obtained from this raw data are given in columns 1 through 4 of the “Normalized Ranking Information,” a matrix obtained by dividing each element of the “Unnormalized” matrix by its column sum. For example,

$$a_2 = \frac{45,000}{5,000 + 45,000} = 0.9$$

The rankings are used with the P_i 's defined earlier to compute P_{ij} , the proportion of the cars in the system going from node i to node j during a representative unit of time. (The number p_{ij} may also be viewed as the probability of a car within the system going from node i to node j during a representative unit of time.) This may be visualized as the summation of the proportions of each of the four types of travel occurring between node i and node j multiplied times the number of cars in the system. The

proportions or probabilities, p_{ij} , are calculated according to the following formula:

$$\begin{aligned} P_{ij} = & P_1 \cdot (b_i \cdot a_j) \cdot (0.5) \\ & + P_1 \cdot (a_i \cdot b_j) \cdot (0.5) \\ & + P_2 \cdot (e_i \cdot b_j) \\ & + P_3 \cdot (b_i \cdot x_j) \\ & + P_4 \cdot (e_i \cdot a_j) \cdot (0.5) \\ & + P_4 \cdot (a_i \cdot e_j) \cdot (0.5) \end{aligned}$$

in which

$(P_1 \cdot b_i \cdot a_j)$ = proportion of cars in the system that are of travel type 1 originating at bedroom i and allocated at attraction j ;

$(P_1 \cdot a_i \cdot b_j)$ = proportion of cars in the system that are of travel type 1 originating (on the way back) at attraction i and allocated at bedroom j .

$(P_2 \cdot e_i \cdot b_j)$ = proportion of cars in the system that are of travel type 2 originating at in-terminal i and allocated at bedroom j ;

$(P_3 \cdot b_i \cdot x_j)$ = proportion of cars in the system that are of travel type 3 originating at bedroom i and allocated at out-terminal j ;

$(P_4 \cdot e_i \cdot a_j)$ = proportion of cars in the system that are of travel type 4 originating at in-terminal i and allocated to attraction j ;

$(P_4 \cdot a_i \cdot x_j)$ = proportion of cars in the system that are of travel type 4 originating at in-terminal i and allocated to out-terminal j .

Since travel type 1 involves a complete circuit (i.e., from i to j to i or vice versa), P_1 occurs twice in the formula for p_{ij} and is given a weight of 0.5 each time. The same reasoning is applied to P_4 . The computational formula for p_{ij} may be clarified by viewing the various ranks as probabilities. For example, the probability of travel type 3 originating at bedroom i and allocated at out-terminal j is the joint probability of three independent events: (1) the probability of travel type 3 occurring, (2) the probability of bedroom i being selected or used, and (3) the probability of out-terminal j being selected.

For the illustration, the probabilities or proportions of cars going from any node i to any node j (p_{ij} 's) have been calculated (*fig. 2*). The printout shows that the highest probability of travel is from node 4 to and from 2 (p_{24} and p_{42}) and from node 1

TEST SET OF DATA ,..... 'ORIGINAL' SET,

NUMBER OF LINKS = 4 NUMBER OF NODES = 4
TOTAL CARS IN SYSTEM = 100,

PINTRN = .800 PINFLO = .050 POUTFL = .050 PINOUT = .100

UNNORMALIZED RANKING INFORMATION

NODE ONE	5000.	30.	0.	0.
NODE TWO	45000.	0.	0.	0.
NODE THREE	0.	0.	40.	40.
NODE FOUR	0.	30.	0.	0.

NORMALIZED RANKING INFORMATION

NODE ONE	.100000	.500000	.000000	.000000
NODE TWO	.900000	.000000	.000000	.000000
NODE THREE	.000000	.000000	1.000000	1.000000
NODE FOUR	.000000	.500000	.000000	.000000

PROBABILITY OF TRAVEL BETWEEN NODES

	NODE ONE	*NODE TWO*	*NODE THREE*	*NODE FOUR*	
NODE ONE	.0400	.1800	.0300	.0200	1
NODE TWO	.1800	.0000	.0450	.1800	2
NODE THREE	.0300	.0450	.0000	.0250	3
NODE FOUR	.0200	.1800	.0250	.0000	4
	1	2	3	4	

TRAVEL BETWEEN NODES

	NODE ONE	*NODE TWO*	*NODE THREE*	*NODE FOUR*	
NODE ONE	4,0000	18,0000	3,0000	2,0000	1
NODE TWO	18,0000	.0000	4,5000	18,0000	2
NODE THREE	3,0000	4,5000	.0000	2,5000	3
NODE FOUR	2,0000	18,0000	2,5000	.0000	4
	1	2	3	4	

Figure 2—Computer printouts show input data for the system in figure 1, leading to normalized ranking and estimates of travel between nodes.

to and from node 2 (p_{12} and p_{21}). This is as expected, as nodes 1 and 4 have only overnight accommodations (both having a capacity of 30) and node 2 has the largest recreation attraction in the system. It

should be noted that the probability p_{11} , is greater than zero, indicating that the "travel" of some of the people staying overnight at node 1 will in fact be use of the recreation area at this node.

The total number of cars going between node i and node j is estimated as

$$t_{ij} = T \cdot p_{ij}$$

The t_{ij} values for the illustration are also shown in the printout (fig. 2).²

As noted earlier, the above computational procedure assumes that if there are T_k cars in the system during any given time period for travel type k , their allocation between nodes, that is, the t_{ij} 's, is proportional to the ranks of these nodes for those categories relevant to travel type k . For example, the number of cars of travel type 3 (outflowing) originating at bedroom i and allocated at out-terminal j is a function of the importance or ranking of node i as a bedroom (b_i), the ranking of node j as an out-terminal (x_j), the number of cars of travel type 3 (P_3), and the total number of cars in the system (T).²

Calculation of the traffic load on each link of the system requires a routing matrix composed of 0's and 1's to indicate whether a highway link is excluded or included in a route from node i to node j . (The route from j to i is not necessarily the same as that from i to j .) The routing, which is basic data input, is influenced by the character of nodes and links. Thus, for the illustration (fig. 3) the route (b_3) between node 1, a recreation attraction, and node 3, an in-out terminal, in the recreation attraction node 2, although the distance covered on links 1 and 2 is somewhat greater than that on link 3, the direct route.

To calculate the traffic load on each link, all the values for the links in the appropriate rows of the routing matrix (fig. 3) are multiplied by the corresponding t_{ij} , and the columns of the matrix are then summed.

Using the calculated estimations as the base for comparison, alternative plans may be simulated. For this illustration, simulation I examines the effect of building a larger recreation attraction at node 1 (with the same number of cars in the system). Node 1 now attracts 30,000 visits a year instead of 5,000. The

²The number of trips for each of the four types between nodes i and j can also be computed

Type	Number of trips =
1	$P_1 \cdot [b_i \cdot a_j + a_i \cdot b_j] \cdot T \cdot (0.5)$
2	$P_2 \cdot [e_i \cdot b_j] \cdot T$
3	$P_3 \cdot [b_i \cdot x_j] \cdot T$
4	$P_4 \cdot [e_i \cdot a_j + a_i \cdot e_j] \cdot T \cdot (0.5)$

This elaboration of the computational procedure, suggested by Peter Wong, U.S. Forest Service, Berkeley, California is not included, however, in the computerized model.

ROUTING MATRIX

ROUTE	:	LINKS			
		1	2	3	4
(1, 2)	:	1	0	0	0
(2, 1)	:	1	0	0	0
(1, 3)	:	1	1	0	0
(3, 1)	:	1	1	0	0
(1, 4)	:	0	0	1	1
(4, 1)	:	0	0	1	1
(2, 3)	:	0	1	0	0
(3, 2)	:	0	1	0	0
(2, 4)	:	0	1	0	1
(4, 2)	:	0	1	0	1
(3, 4)	:	0	0	0	1
(4, 3)	:	0	0	0	1

Figure 3—Computer printout of routing matrix for the system in figure 1.

printouts (figs. 4, 5) show the results of this simulation. On the diagrammatic map (fig. 5) the link traffic loads for the original data and the simulation data are shown next to the corresponding links. For example, for link 2 the estimated load from the original data (as given in figs. 2 and 3) is 51, whereas the estimated load for link 2 in simulation I is 30. The percent change in traffic load on each link is included in the printout.

As might be expected, because node 3 provides the inflow and outflow from the outside world, there is an increase in the proportion of travel from node 3 to node 1 and a decrease in the proportion of travel from node 3 to node 2, although the latter is still the larger value. This may not be a reasonable simulation, however, if the visitors at node 2 are not expected to decrease because of the development at node 1. If 30 additional cars are attracted to the system ($T = 130$), the highway traffic in the area of node 2 (links 1 and 2) will be equal to that originally estimated. The results of simulating this increase of cars in the system plus the development of additional recreation attractions at node 1 are shown in figures 6 and 7. The estimated link loads from simulation II, (lower number) are compared with those from the original data (upper number) as given in figures 2 and 3.

The results (fig. 7) show a 420 percent increase in the traffic on link 3 and a 30 percent increase in the traffic on link 4 (with insignificant changes on links 1 and 2). These results provide quantitative estimates of

TEST SET OF DATA.....'SIMULATION' SET I,

NUMBER OF LINKS = 4 NUMBER OF NODES = 4
TOTAL CARS IN SYSTEM = 100,

PINTRN = .800 PINFLO = .050 POUTFL = .050 PINOUT = .100

UNNORMALIZED RANKING INFORMATION

NODE ONE	30000,	30,	0,	0,
NODE TWO	45000,	0,	0,	0,
NODE THREE	0,	0,	40,	40,
NODE FOUR	0,	30,	0,	0,

NORMALIZED RANKING INFORMATION

NODE ONE	.400000	.500000	.000000	.000000
NODE TWO	.600000	.000000	.000000	.000000
NODE THREE	.000000	.000000	1.000000	1.000000
NODE FOUR	.000000	.500000	.000000	.000000

PROBABILITY OF TRAVEL BETWEEN NODES

	NODE ONE	*NODE TWO*	*NODE THREE*	*NODE FOUR*	
NODE ONE	.1600	.1200	.0450	.0800	1
NODE TWO	.1200	.0000	.0300	.1200	2
NODE THREE	.0450	.0300	.0000	.0250	3
NODE FOUR	.0800	.1200	.0250	.0000	4
	1	2	3	4	

TRAVEL BETWEEN NODES

	NODE ONE	*NODE TWO*	*NODE THREE*	*NODE FOUR*	
NODE ONE	16,0000	12,0000	4,5000	8,0000	1
NODE TWO	12,0000	.0000	3,0000	12,0000	2
NODE THREE	4,5000	3,0000	.0000	2,5000	3
NODE FOUR	8,0000	12,0000	2,5000	.0000	4
	1	2	3	4	

Figure 4—Computer printout of computation of travel between nodes, for the system shown in figure 1, under simulation I calling for a larger recreation attraction at node 1.

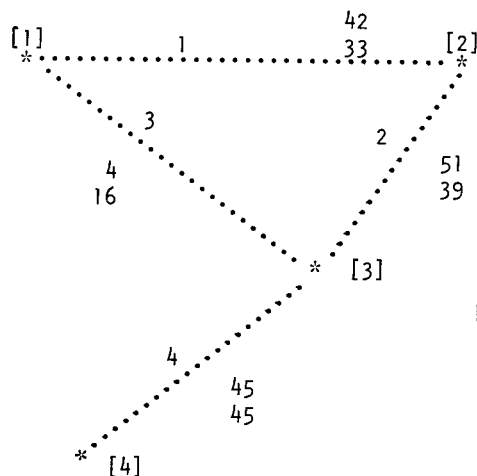


Figure 5—Results of simulation I showing changes in traffic loads. Upper number is original base data, lower number simulation data.

PERCENT CHANGE IN LOAD ON EACH LINK

-21,4286	LINK	1
-23,5294	LINK	2
300,0000	LINK	3
,0000	LINK	4

the expected effects on link loads of increased recreation attractions and cars in the system.

Although the computations for this small system

may seem simple, for systems of a more realistic size the computations are complex, as illustrated in the Harney Peak analysis which follows.

HARNEY PEAK AREA ANALYSIS

This analysis examines proposed developments in the Harney Peak and Sylvan Lake area. For the study, system boundaries were defined as Sheridan Lake to the north, Wind Cave to the south, Jewel Cave to the west and Rapid City to the northeast.

Nodes and Highway Links

Recreation facilities such as campgrounds exist throughout the area, but the facilities and attractions are largely concentrated at 12 sites, or nodes (*fig. 8*):

1. Rapid City
2. Recreation complex, on highway 16 south of Rapid City
3. Sheridan Lake
4. Hill City
5. Mount Rushmore
6. Horse Thief Lake
7. Sylvan Lake
8. Custer
9. Stockade Lake
10. Custer State Park
11. Jewel Cave
12. Wind Cave

Four of these nodes, Rapid City, Sheridan Lake, Jewel Cave, and Wind Cave, were considered to provide significant amounts of highway traffic inflows and outflows for the system. Except for Rapid City, these nodes also provide significant recreation attractions; all four provide overnight accommodations as well.

Twenty-five highway links were defined and routes were selected for travel between each of the 12 nodes. As noted earlier, the method allows for the specification of a different route for the return journey (i.e., node *j* to *i* different from node *i* to *j*). Thus, 132 possible routes could be defined if the "routes" from node *i* to node *i* were not included.

Ranking Input Data

The raw data input for computation of the ranking value for recreation attraction was the total number of recorded visits at each recreation point in the node area. For several nodes this included visits to a major

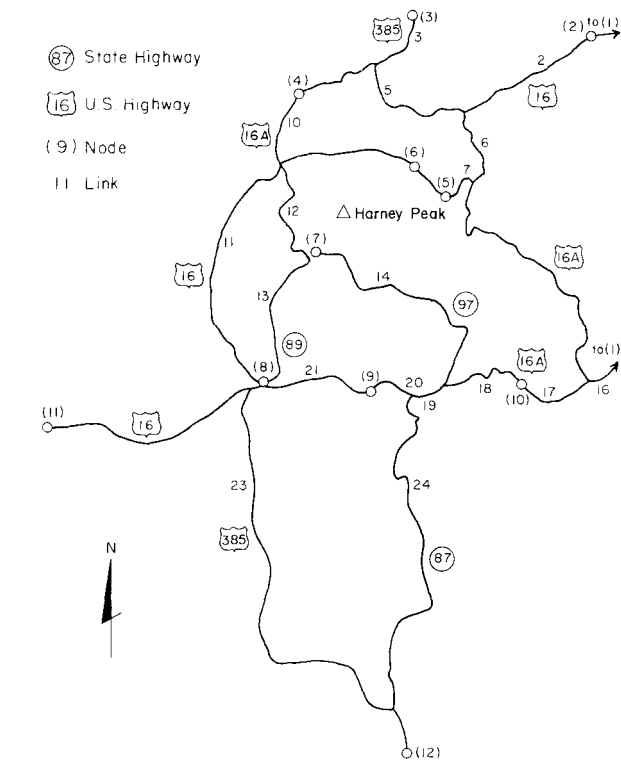


Figure 8—Map of recreation travel network near Harney Peak (triangular symbol), South Dakota. The system includes 12 nodes and 25 highway links.

attraction as well as to several picnic grounds. For the overnight accommodation rating, it was an estimate of the number of people who could stay overnight in the node area. This typically included the capacity of several campgrounds and possibly some motels or a hotel (as at Sylvan Lake). The other nodes, such as Rapid City, provided motel accommodations primarily.

For inflow and outflow rankings, input consisted of estimates of inflows and outflows of vehicles into

the system. These estimates and one for total cars in the system (T = 27,872) were based on an average July day; July is the peak travel month for this system.³

Reliability of Estimates

To evaluate the success of the method of analysis described here in predicting traffic load on the scenic highway system, we compared the predicted values with observed values. The most recent complete set of traffic data available at the time of the analysis was used to supply these observed values: the data were collected in 1968.⁴ The link traffic load estimates were generally close to the observed values, but in some instances a significant difference may indicate the need for better input data.

Simulation Results

Once the model is estimated and calibrated, input changes can be easily introduced and their effect on the predictions can be examined. The effect is measured as percent change in load on each link. Six types of simulations were computed, analyzing possible recreation developments in the Harney Peak-Sylvan Lake area (*table 1*). In each analysis, the percentage effect upon the load of each link in the system was higher for the three links connecting the Sylvan Lake node to the rest of the system. These links are numbered 12, 13, and 14, and are (highway 89-87 to the north, highway 89 to the southwest, and the Needles highway, 87, to the southeast).

The simulations are based on information specifying two levels for the proposed recreation developments in the Harney Peak-Sylvan Lake area. One level of development was designed for 200,000 visits per year and the other level for 500,000 visits per year. The first three simulations assume annual visits of 200,000 people.

The first of this group assumes that only the recreation complex is developed and no other changes are made in the system. That is, no additional cars are attracted into the system and other major developments do not occur. With an increased recreation at-

Table 1—Estimated percent increase in traffic load on links adjacent to Sylvan Lake, Harney Peak area, South Dakota, as a result of simulated changes in recreation system

Simulated changes in the recreation system	Increase on links . . .		
	12	13	14
	<i>Percent</i>		
Harney Peak Development--200,000 visits a year	12	30	13
Harney Peak Development-200,000 visits a year; 28,272 cars	14	32	15
Harney Peak Development-200,000 visits a year; 30,659 cars; Mount Rushmore Parking Expansion-2,116,800 visits; Horse Thief Lake Development-4,000 visits, 260 overnight accommodations	28	40	26
Harney Peak Development-500,000 visits a year	29	73	33
Harney Peak Development-500,000 visits a year; 29,072 cars	35	80	39
Harney Peak Development-500,000 visits a year; 30,659 cars; Mount Rushmore Parking Expansion-2,116,800 visits; Horse Thief Lake Development-4,000 visits, 200 overnight accommodations	46	84	46

traction at Sylvan Lake and the same cars in the system, we might expect a heavier load on the links around Sylvan Lake and possibly lighter loads elsewhere. This is generally borne out in the results.

The second simulation for this level of development assumes that Sylvan Lake is developed and there is an increase of cars in the system. The link loads in the vicinity of Mount Rushmore National Memorial are assumed to be about equal to their original estimates.

The third simulation assumes not only that the Sylvan Lake area is developed (with the expected visits of 200,000) but also that an increase in parking at Mount Rushmore National Memorial results in a 20 percent increase in visits to 2,116,800, and that Horse Thief Recreation area has additional picnic facilities (receiving 4,000 visits) and more overnight accommodations (260). In addition to these changes it is assumed that 10 percent more cars (from 27,872 to 30,659) are in the system.

The last three simulations examine the same changes, with the expected level of use at Sylvan Lake set at 500,000, visits, however.

The following appendixes showing printouts of the computational results for the basic model estimation and of each of the six computer simulations are available upon request to: Director, Pacific Southwest

³South Dakota Department of Highways. *Automatic traffic research data—a comparison of the average daily traffic volumes for each month of 1968 and 1969*. (Form DHRP 327, revised 1968)

⁴South Dakota Department of Highways, Research and Planning Division. *Diagrammatic rural traffic flow map—showing annual 24-hour average traffic, 1968*. 1968.

Forest and Range Experiment Station, P. O. Box 245,
Berkeley, California 94701, Attention: Computer
Services Librarian:

Horse Thief Lake, 260 accommodations, and
cars increasing by 10 percent.

<i>Appendix</i>	<i>Description</i>
A	Listing of computation results for basic model estimation
B	Simulating development in Harney Peak area receiving 200,000 visits
C	Simulating development in Harney Peak area receiving 200,000 visits and cars increasing to 28,272
D	Simulating development in Harney Peak area receiving 200,000 visits; Mount Rushmore, 2,116,800 visits; Horse Thief Lake, 4,000 visits, Horse Thief Lake, 260 accommodations; and cars increasing by 10 percent
E	Simulating development in Harney Peak area receiving 500,000 visits
F	Simulating development in Harney Peak area receiving 500,000 visits and cars increasing to 29,072
G	Simulating development in Harney Peak receiving 500,000 visits; Mount Rushmore, 2,116,800 visits; Horse Thief Lake, 4,000 visits,

The approach developed is conceptually simple and requires data that are frequently available. The analysis covers the effect of recreation developments on only one variable, however—recreation traffic load. Also, the estimates are of course theoretical. In the real world, unaccounted-for changes in the system may occur. Further, estimates are interpreted as unconstrained use increases in link loads. Capacity limits on certain links may result in an unexpected increase on other links. Nevertheless, the method described allows useful predictions of the effects of alternative sets of recreation developments on highway traffic.

The effect of changes in recreation attractions, and facilities, including roads, campgrounds, picnic areas, and lodging, may be simulated before final plans on land-use are drawn up. The technique is particularly useful in evaluating alternatives and in providing information on alternatives to land managers and others. The results of this study were a significant input to a meeting held on May 12, 1970, by the U.S. Forest Service and open to the public to discuss land-use planning in the Harney Peak area.

TEST SET OF DATA.....'SIMULATION' SET II.

NUMBER OF LINKS = 4 NUMBER OF NODES = 4
TOTAL CARS IN SYSTEM = 130.

PINTRN = .800 PINFLO = .050 POUTFL = .050 PINOUT = .100

UNNORMALIZED RANKING INFORMATION

	30000.	30.	0.	0.
NODE ONE	30000.	30.	0.	0.
NODE TWO	45000.	0.	0.	0.
NODE THREE	0.	0.	40.	40.
NODE FOUR	0.	30.	0.	0.

NORMALIZED RANKING INFORMATION

	.400000	.500000	.000000	.000000
NODE ONE	.400000	.500000	.000000	.000000
NODE TWO	.600000	.000000	.000000	.000000
NODE THREE	.000000	.000000	1.000000	1.000000
NODE FOUR	.000000	.500000	.000000	.000000

PROBABILITY OF TRAVEL BETWEEN NODES

	NODE ONE	*NODE TWO*	*NODE THREE*	*NODE FOUR*	
NODE ONE	.1600	.1200	.0450	.0800	1
NODE TWO	.1200	.0000	.0300	.1200	2
NODE THREE	.0450	.0300	.0000	.0250	3
NODE FOUR	.0800	.1200	.0250	.0000	4
	1	2	3	4	

TRAVEL BETWEEN NODES

	NODE ONE	*NODE TWO*	*NODE THREE*	*NODE FOUR*	
NODE ONE	20,8000	15,6000	5,8500	10,4000	1
NODE TWO	15,6000	.0000	3,9000	15,6000	2
NODE THREE	5,8500	3,9000	.0000	3,2500	3
NODE FOUR	10,4000	15,6000	3,2500	.0000	4
	1	2	3	4	

Figure 6—Computer printout of computation of travel between nodes for the system in figure 1 under simulation II, calling for a larger recreation attraction at node 1 with the addition of cars to the system

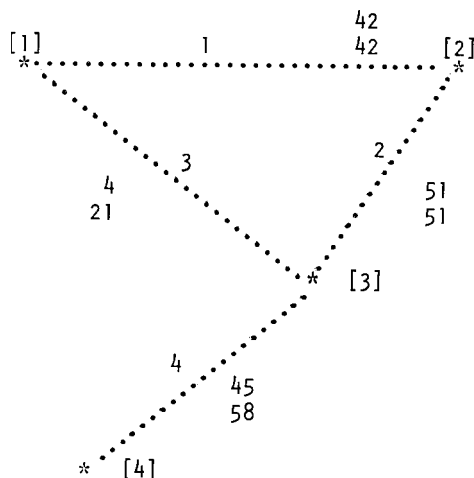


Figure 7—Results of simulation II showing changes in traffic loads. Upper number is original base data, lower number simulation data.

PERCENT CHANGE IN LOAD ON EACH LINK

2,1429	LINK	1
-,5832	LINK	2
420,0000	LINK	3
30,0000	LINK	4



The Forest Service of the U.S. Department of Agriculture

- . . . Conducts forest and range research at more than 75 locations from Puerto Rico to Alaska and Hawaii.
- . . . Participates with all State forestry agencies in cooperative programs to protect and improve the Nation's 395 million acres of State, local, and private forest lands.
- . . . Manages and protects the 187-million-acre National Forest System for sustained yield of its many products and services.

The Pacific Southwest Forest and Range Experiment Station

represents the research branch of the Forest Service in California and Hawaii.

Elsner, Gary H., and Ronald A. Oliveira

1973. **Predicting traffic load impact of alternative recreation developments.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 12 p., illus. (USDA Forest Serv. Res. Paper PSW-96)

Traffic load changes as a result of expansion of recreation facilities may be predicted through computations based on estimates of (a) drawing power of the recreation attractions, overnight accommodations, and in- or out-terminals; (b) probable types of travel; (c) probable routes of travel; and (d) total number of cars in the recreation system. Once the basic model has been established, development alternatives may be simulated to provide percent change estimates of probable traffic load effects on each link of the road system. Illustrative estimates are made for six alternatives for the Harney Peak area of South Dakota.

Oxford: 907.2

Retrieval Terms: recreation areas; automobiles; traffic load; road systems; simulation techniques; Harney Peak area; South Dakota.

Elsner, Gary H., and Ronald A. Oliveira

1973. **Predicting traffic load impact of alternative recreation developments.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 12 p., illus. (USDA Forest Serv. Res. Paper PSW-96)

Traffic load changes as a result of expansion of recreation facilities may be predicted through computations based on estimates of (a) drawing power of the recreation attractions, overnight accommodations, and in- or out-terminals; (b) probable types of travel; (c) probable routes of travel; and (d) total number of cars in the recreation system. Once the basic model has been established, development alternatives may be simulated to provide percent change estimates of probable traffic load effects on each link of the road system. Illustrative estimates are made for six alternatives for the Harney Peak area of South Dakota.

Oxford: 907.2

Retrieval Terms: recreation areas; automobiles; traffic load; road systems; simulation techniques; Harney Peak area; South Dakota.

Elsner, Gary H., and Ronald A. Oliveira

1973. **Predicting traffic load impact of alternative recreation developments.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 12 p., illus. (USDA Forest Serv. Res. Paper PSW-96)

Traffic load changes as a result of expansion of recreation facilities may be predicted through computations based on estimates of (a) drawing power of the recreation attractions, overnight accommodations, and in- or out-terminals; (b) probable types of travel; (c) probable routes of travel; and (d) total number of cars in the recreation system. Once the basic model has been established, development alternatives may be simulated to provide percent change estimates of probable traffic load effects on each link of the road system. Illustrative estimates are made for six alternatives for the Harney Peak area of South Dakota.

Oxford: 907.2

Retrieval Terms: recreation areas; automobiles; traffic load; road systems; simulation techniques; Harney Peak area; South Dakota.

Elsner, Gary H., and Ronald A. Oliveira

1973. **Predicting traffic load impact of alternative recreation developments.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 12 p., illus. (USDA Forest Serv. Res. Paper PSW-96)

Traffic load changes as a result of expansion of recreation facilities may be predicted through computations based on estimates of (a) drawing power of the recreation attractions, overnight accommodations, and in- or out-terminals; (b) probable types of travel; (c) probable routes of travel; and (d) total number of cars in the recreation system. Once the basic model has been established, development alternatives may be simulated to provide percent change estimates of probable traffic load effects on each link of the road system. Illustrative estimates are made for six alternatives for the Harney Peak area of South Dakota.

Oxford: 907.2

Retrieval Terms: recreation areas; automobiles; traffic load; road systems; simulation techniques; Harney Peak area; South Dakota.