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**CHARACTERISTICS AND MODELS OF  
OUTDOOR RECREATIONAL TRAVEL**

by

**Jerry G. Pigman**  
Research Engineer  
Kentucky Bureau of Highways

and

**John A. Deacon**  
Associate Professor of Civil Engineering  
University of Kentucky

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## CHARACTERISTICS AND MODELS OF OUTDOOR RECREATIONAL TRAVEL

### Abstract

The purpose of this investigation was to examine the characteristics of outdoor recreational travel and to evaluate models of travel flow from population centers throughout the United States to outdoor recreational areas in Kentucky. Data were obtained by means of a license-plate, origin-destination survey at 160 sites within 42 recreational areas and by means of a continuous vehicle counting program at eight of these sites.

Among those characteristics of outdoor recreational travel which were examined in more detail were vehicle occupancies, vehicle classifications, and trip-length distributions. Vehicle occupancy was found to depend on the type of recreational area, distance traveled, and vehicle type. Occupancy increased with increasing distance and was greatest for those vehicles pulling camping trailers. Percentages of the various vehicle types were also influenced by the type of recreational area and the distance traveled. The proportion of camping units in the traffic stream increased with increasing distance of travel. In general, trip lengths were quite short as evidenced by the fact that 60 percent of all vehicles traveled less than 50 miles. However, trip-length distribution was highly dependent on the type and location of the recreational area. Analysis of the distribution of traffic over time verified that recreational travel is much more highly peaked than other forms of highway travel and, with the exception of holidays, is concentrated on Sundays during the spring and summer months. This time period appears most appropriate for the design of highways

and parking facilities to serve recreational areas. It is highly recommended that future data collection programs be concentrated on the average summer Sunday to enable collection of the maximum amount of usable traffic data with a minimum of effort. Much of the data reported herein can be used in initial efforts to characterize travel to similar types of recreational areas outside of Kentucky.

In the modeling phase of the study, attempts to simulate distributed travel flows concentrated on various single-equation models, a cross-classification model, and gravity and intervening opportunities models. The cross-classification model was found to be an acceptable means for simulating and predicting outdoor recreational travel flows and was decidedly superior to the other models. From the cross-classification model, per capita distributed flows were found to 1) decrease at a decreasing rate with increasing population of the origin zone, 2) increase at a variable rate with increasing attractions of the recreational area, and 3) decrease at a decreasing rate with increasing distance. The intervening opportunities model was found to be unacceptable as a distribution model since it could not effectively accommodate the widely differing sizes of the 42 recreational areas. The gravity model, on the other hand, was quite effective in distributing actual productions and attractions. Problems associated with the gravity model were limited to difficulties in accurately estimating trip productions and attractions in the trip generation phase of analysis.

# CHARACTERISTICS AND MODELS OF OUTDOOR RECREATIONAL TRAVEL

<sup>a</sup>Jerry G. Pigman, Associate Member, I.T.E.

<sup>b</sup>John A. Deacon, Member, I.T.E.

## INTRODUCTION

In 1970, the Kentucky Department of Highways initiated a study to examine the characteristics of travel to outdoor recreational areas in Kentucky and to develop a model for simulating these flows. Results of these efforts have been reported in detail elsewhere (1, 2, 3). The purpose of this paper is to summarize characteristics of outdoor recreational travel which are of particular interest to highway engineers and to describe a comprehensive evaluation of several models of travel flow from population centers throughout the United States to outdoor recreational areas in Kentucky.

## SURVEY PROCEDURES

Travel data were collected by means of a license-plate origin-destination (O-D) survey at 160 recreational sites in Kentucky during the summer of 1970 and by means of a volume survey using continuous automatic traffic recorders at eight of these sites.

Travel to most outdoor recreation facilities in Kentucky typically peaks on summer Sundays. The O-D survey was, therefore, conducted on Sundays and modeling efforts concentrated on average summer Sunday flows, a flow period which is suitable for planning and design of both recreational and highway facilities. Surveys were conducted at each site from 10 a.m. to 8 p.m. by one to three persons, depending on the level of recreational activity anticipated. Data recorded for each observed vehicle included direction of movement (arriving or departing), vehicle type, number of persons per vehicle, and license-plate identification.

The license-plate identification was used to approximate the origin of the vehicle. A total of 190 origin zones were identified -- 120 counties in Kentucky, ten zones in Ohio, eight zones in Indiana, six zones in Tennessee, three zones in Michigan, and one zone for each of the remaining 43 contiguous states.

<sup>a</sup>Head, Traffic and Safety Section, Division of Research,  
Kentucky Bureau of Highways

<sup>b</sup>Associate Professor of Civil Engineering, University of  
Kentucky

Each of the 160 survey sites was associated with one of 42 recreational areas. The sites were carefully selected so that the sum of the flows passing all the sites associated with a given recreational area accurately represented the total flow to that area. These 42 areas, representing the major part of outdoor recreation activity in Kentucky, are characterized in Table 1. That characteristic termed "regional impact" was evaluated from two measures of travel obtained from the O-D survey -- the coefficient of variation of the actual number of trips produced by the 190 origin zones and the percentage of trips having lengths greater than 50 miles. Coefficients of variation for those areas having large (L), medium (M), and small (S) regional impact averaged 280, 480, and 720, percent, respectively. Corresponding average percentages of trips having lengths greater than 50 miles were 66.7, 35.7, and 23.7 percent, respectively.

The license-plate O-D study was found to be a very efficient way to obtain useful flow data. Concentration on the period of peak flow, that is, the summer Sunday, proved extremely efficient and completely compatible with data requirements of this study.

Traffic volume data were obtained from continuous automatic traffic recorders located at eight sites considered to be most representative of Kentucky outdoor recreational areas. The punched-tape counters, employing inductive loops for vehicle detection, recorded two-way volumes continuously from July 1970 through June 1971. In each case, the recorder was located on a major access road to the recreational area in such a manner as to intercept only recreation-oriented travel.

## TRAVEL CHARACTERISTICS

A total of 130,653 vehicles were observed as a part of the O-D survey. Considering those small intervals during each 10-hour period when the surveyors were otherwise occupied, it was estimated that a total of 147,000 vehicles actually passed the survey sites during the survey period. A further adjustment was made to account for the few instances in which inclement weather prevailed, bringing the total estimated flow to 151,300 vehicles.

At the eight traffic counter sites, a total of about 3,000,000 vehicles were recorded during the one-year survey. This represented an average of about 380,000 vehicles annually per site.

TABLE 1

## IDENTIFICATION OF RECREATIONAL AREAS

NUMBER <sup>a</sup>	AREA NAME	REGIONAL IMPACT	SCENIC ATTRACTIVENESS <sup>b</sup>	LAKE <sup>c</sup>	DAY-USE FACILITIES <sup>d</sup>	OVERNIGHT ACCOMMODATIONS <sup>e</sup>	OTHER <sup>f</sup>
1	Columbus-Belmont S.P.	S	N	N	M	M	
2*	Kentucky Lake-Barkley Lake	L	H	L	L	L	G, OD, SP, SB
3	Lake Beshear-Pennyrite Forest	S	N	S	L	L	G, SP, SB
4	Audubon S.P.	S	N	S	L	M	G, SB
5	Lake Malone S.P.	S	N	L	L	M	SB
6*	Rough River Reservoir	S	N	L	L	L	G, SP, SB
7	Doe Valley Lake	S	N	S	S	S	SB
8	Otter Creek Park	S	N	N	L	L	SP
9	Nolin Reservoir	S	N	L	M	M	
10*	Mammoth Cave N.P.	L	P	N	M	L	
11	Shanty Hollow Lake	S	N	S	S	S	
12	Barren River Reservoir	S	N	L	L	L	G, SB
13	My Old Kentucky Home S.P.	M	P	N	L	M	G, OD
14	Green River Reservoir	S	N	L	M	S	
15	Dale Hollow Reservoir	M	N	L	M	M	SB
16	Lake Cumberland	M	N	L	L	L	G, SP, SB
17	Natural Arch and Rockcastle Areas	M	P	N	M	M	
18	Cumberland Falls S.P.	L	P	N	M	L	SP
19	Wilgreen Lake	S	N	S	S	S	
20	Herrington Lake	M	N	L	S	L	
21	Old Fort Harrod S.P.	L	P	N	M	S	OD
22*	Beaver Lake	S	N	S	S	S	
23	Gulst Creek Lake	S	N	S	S	S	
24	General Butler S.P.	M	N	S	L	L	G, SP, SB
25	Eimer Davis Lake	S	N	S	S	S	
26	Lake Boltz	S	N	S	S	S	
27	Big Bone Lick S.P.	S	N	S	M	L	
28	Williamstown Lake	S	N	S	S	L	
29	Blue Licks Battlefield S.P.	M	H	N	M	S	SP
30*	Fort Boonesboro S.P.	M	H	N	M	M	SB
31*	Levi Jackson S.P.	S	N	N	L	L	SP
32	Pine Mountain S.P.	S	N	S	L	M	G, OD, SP
33	Cumberland Gap N.P.	L	P	N	L	L	OD
34	Natural Bridge S.P.	L	P	S	M	L	SP
35	Sky Bridge and Kooser Ridge	L	P	N	M	M	
36*	Carter Caves S.P.	M	H	S	L	S	G, SB
37	Greenbo Lakes S.P.	S	N	S	L	L	SB
38	Grayson Reservoir	S	N	L	M	S	
39	Buckhorn Lake	S	N	L	M	L	SB
40*	Jenny Wiley S.P.	S	N	L	L	L	G, OD, SP
41	Kingdom Come S.P.	S	N	S	M	S	
42	Fishtrap Reservoir	S	N	L	M	S	

<sup>a</sup>Asterisks indicate areas at which continuous traffic recorders were operated on major access roads.

<sup>b</sup>P, primary attractiveness is of a scenic or historic nature; H, high scenic or historic attractiveness with a balance of other recreational activities; N, normal scenic or historic attractiveness.

<sup>c</sup>L, Lake acreage  $\geq 500$ ; S,  $0 < \text{lake acreage} < 500$ ; N, no lake.

<sup>d</sup>L, availability of golf course and/or picnic tables  $> 150$ ; M,  $0 < \text{picnic tables} \leq 150$  and no golf course; S, no picnic tables and no golf course.

<sup>e</sup>L, units (cottages + lodge rooms + camping sites)  $\geq 90$ ; M,  $15 \leq \text{units} < 90$ ; S, units  $< 15$ .

<sup>f</sup>G = golf; OD = outdoor drama; SP = swimming pool; SB = swimming beach.

### Time Distribution of Flows

Data from the eight representative locations were analyzed to ascertain the various distribution of vehicular flows over time. Table 2 summarizes certain average and highest volumes for various time periods. The 30th highest hourly volumes, as shown in Table 2, ranged from a high of 82.9 percent of the ADT at Fort Boonesboro to a low of 24.0 percent at Beaver Lake and averaged 38.8 percent at the eight sites. As anticipated, the 30th highest hourly percentages were considerably greater than those commonly observed for normal urban or rural travel, thus indicating the extreme peaking commonly associated with recreational travel. The highest peaking was observed at Fort Boonesboro State Park, a predominantly day-use facility attracting significant numbers of visitors only during the summer months. Lowest peaking was observed at Mammoth Cave National Park, a scenic attraction of national importance, and Beaver Lake, a small fishing lake attracting local fishermen during the spring, summer and fall months.

The summer Sunday peak-hour flows varied from a low of 8.6 percent of the total daily Sunday flow at Beaver Lake to a high of 12.7 percent at Barkley Lake. The peak hour usually occurred within the period of 1 to 5 p.m. and most typically between 2 and 4 p.m. The flow observed during the 10-hour survey period of 10

a.m. to 8 p.m. averaged approximately 80 percent of the daily flow and ranged from a low of 64.4 percent at Beaver Lake to a high of 88.2 percent at Lake Barkley.

The daily distribution of the weekly summer flows is depicted on Figure 1. Sunday was the peak day at each of the eight locations. The Sunday flows averaged 25.1 percent of the weekly flows and varied from a low of 16.8 percent at Mammoth Cave to a high of 35.3 percent at Boonesboro State Park. Saturday was the second most active day of the week. There was very little difference among the remaining five days, with the exception of Friday which was typically the third most active day at areas which attracted significant number of weekend visitors.

In view of the extreme peaking associated with recreational travel, it seems impractical to design highways serving recreational areas to accommodate the 30th highest hourly volumes. A more practical basis for design would be the peak-hour volume on the average summer Sunday, which on the average corresponds with the 70th to 75th highest hourly volume. Concentration on the average summer Sunday also greatly facilitates data collection programs.

TABLE 2

AVERAGE AND HIGHEST VOLUMES

TIME PERIOD	TYPE OF VOLUME	VOLUME EXPRESSED AS MULTIPLE OF AVERAGE DAILY TRAFFIC								
		AREA 2	AREA 6	AREA 10	AREA 22	AREA 30	AREA 31	AREA 36	AREA 40	AVERAGE
Week	Maximum	14.3	19.1	17.6	13.4	22.2	15.6	14.7	15.6	16.6
Week	4th Highest	13.0	17.1	14.5	10.9	19.0	12.2	13.4	12.8	14.1
Week	8th Highest	11.3	14.0	13.1	10.5	15.2	11.1	12.1	9.8	12.1
Week	Summer Average	8.3	12.3	13.0	8.0	11.7	10.9	11.4	10.8	10.8
Weekend	Maximum	6.62	11.71	6.26	6.15	14.77	7.10	9.56	6.82	8.62
Weekend	4th Highest	5.54	9.89	5.64	5.31	11.28	5.52	6.43	5.75	6.92
Weekend	8th Highest	4.66	7.64	4.36	4.51	8.04	5.07	5.70	4.61	5.57
Weekend	Summer Average	3.53	6.28	4.43	3.30	6.14	4.94	5.24	4.81	4.83
Weekend	Annual Average	2.99	3.49	2.64	3.00	3.93	3.25	3.34	3.06	3.21
Day	Maximum	3.72	6.61	3.50	3.32	8.89	3.47	5.00	3.68	4.77
Day	5th Highest	2.91	5.50	2.73	2.60	7.06	2.93	3.69	2.84	3.78
Day	10th Highest	2.39	4.08	2.58	2.42	5.03	2.58	3.02	2.47	3.07
Day	20th Highest	2.13	2.92	2.34	2.00	3.08	2.11	2.46	2.15	2.40
Day	Summer Sunday Average	2.18	3.66	2.16	1.56	4.12	2.54	2.98	2.53	2.72
Hour	Maximum	0.430	0.839	0.372	0.496	1.212	0.612	0.674	0.425	0.632
Hour	15th Highest	0.350	0.602	0.264	0.273	0.912	0.310	0.428	0.353	0.436
Hour	30th Highest	0.303	0.503	0.254	0.240	0.829	0.284	0.395	0.294	0.388
Hour	50th Highest	0.279	0.410	0.242	0.213	0.627	0.262	0.367	0.253	0.332
Hour	100th Highest	0.243	0.321	0.222	0.176	0.404	0.217	0.292	0.214	0.261

Vehicle Occupancy

A summary of O-D survey data revealed that occupancy rate was a function of the type of recreational area, distance traveled, and vehicle type. The average occupancy rate for all vehicles was found to be 3.06 persons per vehicle.

Table 3 demonstrates the effect of recreational-area type on average vehicle occupancy. Lowest occupancy rates of 2.87 to 2.88 persons per vehicle occurred at predominantly day-use, water-oriented facilities; intermediate rates of 3.13 to 3.26 persons per vehicle

occurred at multiple-use facilities; and the highest rates of 3.36 to 3.41 persons per vehicle occurred at scenic areas catering to families and having nationwide interest. Table 3 also indicates that location of origin affects vehicle occupancy. The average occupancy rate for Kentucky vehicles was 2.94 persons per vehicle and that for the seven primary states outside of Kentucky was 3.41 persons per vehicle. This suggests that occupancy rates may be related to distance traveled, a hypothesis that seems plausible considering that many out-of-state vehicles contain vacationing families.

Table 4 illustrates the effects of both distance and vehicle type on occupancy rate. Despite large variability in the data, occupancy rate generally increased with increasing distance of travel. The effects were most pronounced for vehicles traveling rather short distances. In addition, sensitivity of occupancy rate to distance was greatest for camping vehicles and least for vehicles with boats. Highest occupancy rates were observed for cars pulling camper trailers, and lowest rates were observed for the "other" vehicle category which includes primarily service trucks and motorcycles. The fact that single-unit campers had much lower occupancy rates than cars pulling camper trailers is probably due to a combination of 1) erroneous surveys in which some persons riding in the single-unit campers could not be detected by the surveyors and 2) a certain bias caused by rather extensive use of pickup campers by fishermen traveling in small groups.

Vehicle Classification

As expected, a large proportion of the vehicles were cars or cars with trailers (96.7 percent). The remainder were single-unit campers (2.1 percent) and motorcycles and trucks (1.2 percent). Altogether, 3.4 percent of the vehicles had camping units attached and 5.8 percent had boats. Vehicle classification was found to depend both on the origin of the vehicle and on the type of recreational area. To illustrate, 2.1 percent of the Kentucky vehicles had camping units and 6.0 percent had boats while the respective percentages for Michigan vehicles were 10.4 percent and 3.9 percent. A high percentage of vehicles with boats were observed at water-based facilities (a high of 12.3 percent at Corps of Engineers facilities compared to a low of 0.6 percent at the national parks). The percentage of vehicles with camping units depended in large part on the nature of available

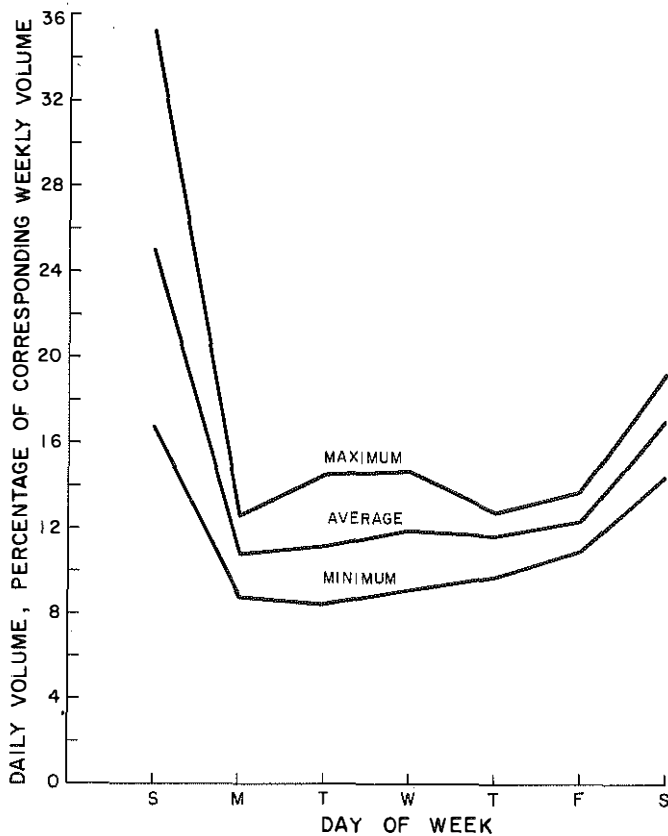


Figure 1. Volume Variation Among Days Throughout Average Summer Week.

TABLE 3

EFFECTS OF TYPE OF RECREATIONAL AREA AND  
LOCATION OF ORIGIN ON AVERAGE VEHICLE OCCUPANCY<sup>a</sup>

ORIGIN	STATE PARKS	NATIONAL PARKS	CORPS OF ENGINEERS FACILITIES	KENTUCKY LAKE (TVA)	LAND-BETWEEN-THE-LAKES (TVA)	DANIEL BOONE NATIONAL FOREST	OTHER AREAS	TOTAL
Kentucky	3.02	3.22	2.84	2.70	3.18	3.44	2.82	2.94
Ohio	3.47	3.37	3.11	3.69	3.61	3.33	3.00	3.37
Indiana	3.34	3.56	3.08	3.23	3.35	3.63	3.16	3.31
Illinois	3.68	3.57	3.43	3.39	3.54	3.38	3.38	3.57
Tennessee	3.40	3.29	3.13	3.39	3.23	3.43	3.82	3.32
Michigan	3.50	3.94	3.16	2.97	3.10	4.14	3.31	3.52
Missouri	3.61	3.44	3.14	3.03	3.32	6.00	2.33	3.40
W. Virginia	3.60	3.40	3.30	2.86	2.00	6.00	2.40	3.61
All Origins	3.13	3.36	2.88	2.87	3.26	3.41	2.87	3.06

<sup>a</sup>Persons per vehicle.

TABLE 4

EFFECTS OF DISTANCE AND VEHICLE TYPE ON  
AVERAGE VEHICLE OCCUPANCY

VEHICLE TYPE	DISTANCE INTERVAL (MILES)											AVERAGE (ALL DISTANCES)
	1-20	21-40	41-60	61-80	81-100	101-150	151-250	251-400	401-700	701-1300	1301-3000	
Car	2.78	3.02	3.28	3.27	3.31	3.29	3.20	3.45	3.39	3.25	3.11	3.07
Car with Boat and Trailer	3.02	3.14	3.12	3.25	3.13	3.15	3.45	3.19	3.16	3.18	3.60	3.16
Car with Boat on Top	2.72	3.14	3.05	2.79	3.00	3.09	3.92	3.31	3.00	2.50	2.50	3.04
Car with Camper Trailer	3.06	3.20	3.28	3.45	3.44	3.61	3.63	3.66	4.06	3.60	3.82	3.63
Single-Unit Camper	2.70	2.55	2.83	3.11	3.06	3.00	2.92	2.99	3.39	3.46	3.36	2.97
Single-Unit Camper with Boat	2.75	2.79	2.71	2.71	2.70	3.27	2.65	3.36	2.94	3.30	4.25	2.96
Other	2.16	1.61	1.92	2.19	5.30	1.63	1.69	4.78	1.57	1.75	20.50	2.67
Average (All Vehicles)	2.76	3.02	3.26	3.25	3.30	3.28	3.21	3.45	3.41	3.26	3.28	3.06

camping facilities (a high of 11.2 percent at the Land-Between-the-Lakes compared to a low of 3.0 percent at the state parks). Tables 5 and 6 summarize some vehicle classification percentages that were observed.

#### Trip-Length Distribution

Travel to Kentucky outdoor recreational facilities was predominantly of the short-distance type. The average trip length for all vehicles was found to be 109 miles. However, 60 percent of all vehicles traveled distances less than 50 miles and 72 percent traveled less than 100 miles. Ungar <sup>(4)</sup> also showed that outdoor recreational travel is predominantly of the short-distance type. He reported that 50 percent of the recreationists in Indiana traveled distances less than 50 miles and in Kansas, less than 40 miles. The corresponding distance for travel in Kentucky was found to be 38 miles.

Trip lengths were found to be a function of the type and location of the recreational area. Figure 2 shows trip-length distributions for three state parks representative of large regional impact areas (Cumberland Falls), medium regional impact areas (My Old Kentucky Home), and small regional impact areas (Jenny Wiley). Mean trip lengths for those areas classified in Table 1 as having large, medium, and small regional impact averaged 176, 89, and 70 miles, respectively. Corresponding average percentages of trips having lengths less than 50 miles were 33.3, 64.3, and 76.3 percent, respectively.

Also of considerable interest is the influence of vehicle type on

the distribution of trip lengths (Figure 3). Cars pulling camper trailers generally traveled the greatest distances. Single-unit campers traveled somewhat shorter distances due in part to the considerable use of single-unit campers by fishermen. Cars without either boats or trailers generally traveled the shortest distances of any vehicle type.

#### MODELING TRAFFIC FLOWS

Recreational travel flow can be visualized as a delicate equilibrium between the demand for recreational experiences, the supply of recreational opportunities, and the price of recreation as modified by the competitive nature of the system and other miscellaneous considerations. Two primary tasks of traffic flow modeling are to identify the most relevant, quantifiable, independent variables and to select a suitable function or algorithm for relating the dependent with the independent variables. The four types of models investigated herein included single-equation, cross-classification, gravity, and intervening opportunities models.

The number of vehicles departing a recreational area during the 10-hour survey period on the average summer Sunday was chosen as the dependent variable of the modeling efforts. Departing flows were chosen to avoid a bias toward Sunday-arriving day users. In all cases, the number of vehicles departing during this period was, for all practical purposes, equal to the number of vehicles arriving during the same period. Use of the average summer Sunday avoided

TABLE 5

EFFECT OF LOCATION OF ORIGIN ON  
PERCENTAGES OF VARIOUS VEHICLE TYPES

ORIGIN	CAR	CAR WITH BOAT AND TRAILER	CAR WITH BOAT ON TOP	CAR WITH CAMPER TRAILER	SINGLE UNIT CAMPER	SINGLE UNIT CAMPER WITH BOAT	OTHER
Kentucky	90.89	5.27	.40	.61	1.08	.37	1.38
Ohio	86.46	5.34	.63	3.35	2.62	.62	.97
Indiana	87.57	4.51	.62	2.38	3.15	.87	.90
Illinois	88.11	3.36	.88	3.20	2.72	.86	.88
Tennessee	90.99	3.44	.32	1.59	1.62	1.05	.99
Michigan	85.74	2.28	.70	6.08	3.33	.94	.94
Missouri	88.67	4.03	.77	2.82	2.63	.51	.58
W. Virginia	88.51	2.31	.79	5.61	1.45	.46	.86
All Origins	89.95	4.91	.46	1.36	1.58	.48	1.26

TABLE 6

EFFECT OF TYPE OF RECREATIONAL AREA ON  
PERCENTAGES OF VARIOUS VEHICLE TYPES

TYPE OF FACILITY	PERCENTAGE OF CARS <sup>a</sup>	PERCENTAGE OF CAMPING VEHICLES <sup>b</sup>	PERCENTAGE OF VEHICLES WITH BOATS
State Parks	97.36	2.95	3.22
National Parks	95.56	6.51	0.58
Corps of Engineers Facilities	95.71	3.29	12.31
Kentucky Lake (TVA)	96.31	3.81	6.14
Land-Between-The- Lakes (TVA)	90.84	11.24	12.02
Daniel Boone National Forest	96.22	2.99	3.25
Other Areas	97.84	2.59	7.15
All Areas	96.67	3.42	5.84

<sup>a</sup>Includes cars with boat and camper trailers.

<sup>b</sup>Includes cars with camper trailers and single-unit campers.

extreme peaks associated with summer holidays. At the same time, summer Sunday flows occur with sufficient frequency to justify their use in planning and design. The 10-hour, departing vehicular flow has little direct use in highway planning and design. However, it may be readily factored, as shown elsewhere <sup>(3)</sup>, to yield estimates of more relevant flow variables.

TOTAL FLOW MODELS

The gravity and intervening opportunities models required, as input, estimates of the number of trips produced at each origin zone that are destined to Kentucky outdoor recreational areas and estimates of the number of trips attracted to each recreational area. Such estimates are usually based on total flow models evaluated using regression techniques.

Productions

Origin-zone variables chosen for evaluation herein were 1) total population, 2) motor vehicle registration, 3) total number of dwelling units, 4) number of dwelling units per square mile, 5) average effective

buying income per household, and 6) accessibility to recreational opportunities. When the Kentucky origin zones were analyzed, very large linear correlations were found among the first four of these independent variables. Accordingly, population was chosen to represent this set of variables in order to avoid potential difficulties. Accessibility to recreational opportunities was expressed as

$$AR_i = \sum_j A_j F_{ij} \quad (1)$$

in which  $AR_i$  = accessibility of origin zone  $i$  to recreational opportunities,  $A_j$  = number of trips attracted to recreational area  $j$ , and  $F_{ij}$  = F-factor of the gravity model corresponding to the distance between  $i$  and  $j$ .

Separate models were developed for out-of-state origin zones and in-state (Kentucky) origin zones to reflect the distinctively different patterns in trip production. Among several production equations evaluated, the following were judged to be the most suitable:

$$P_i = 803.1 \text{ POP}_i^{1.05} I_i^{4.19} AR_i^{1.03} \text{ for out-of-state zones } (2)$$

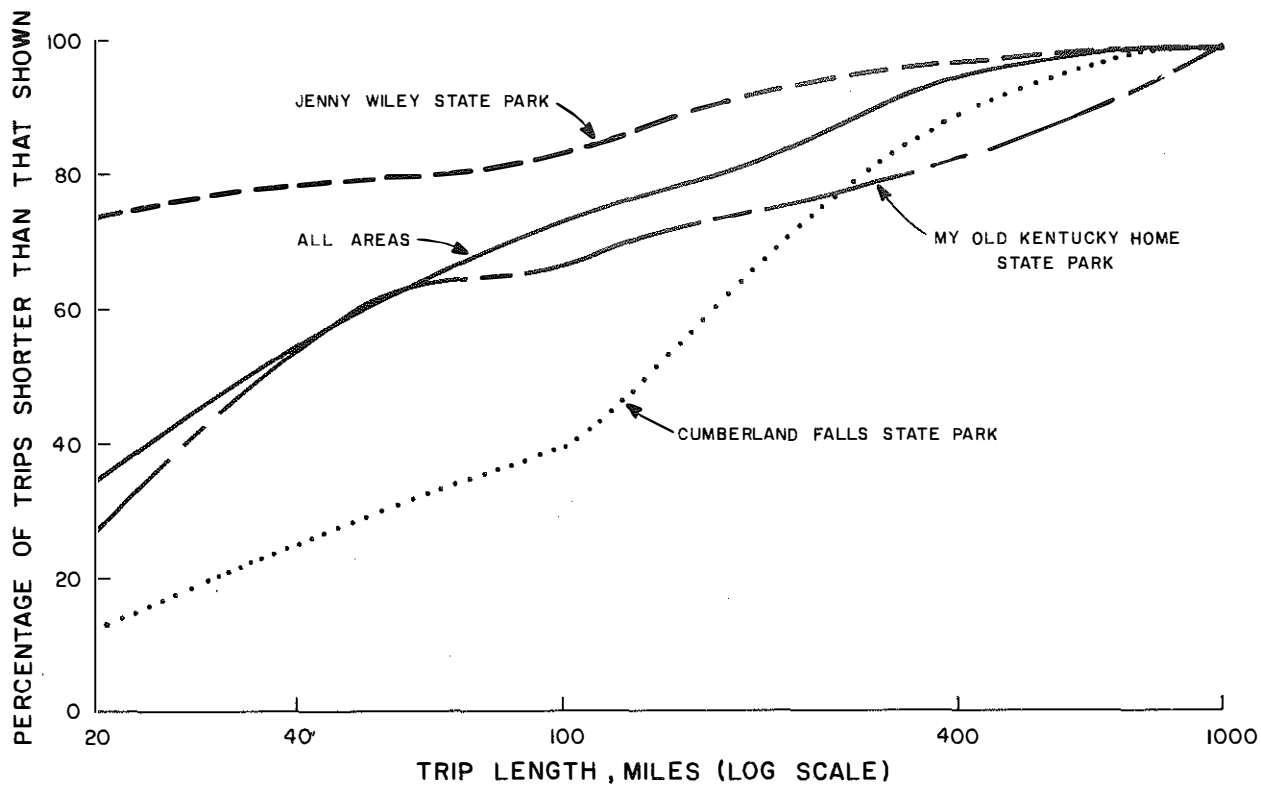


Figure 2. Trip Length Distributions for Different Recreational Areas.

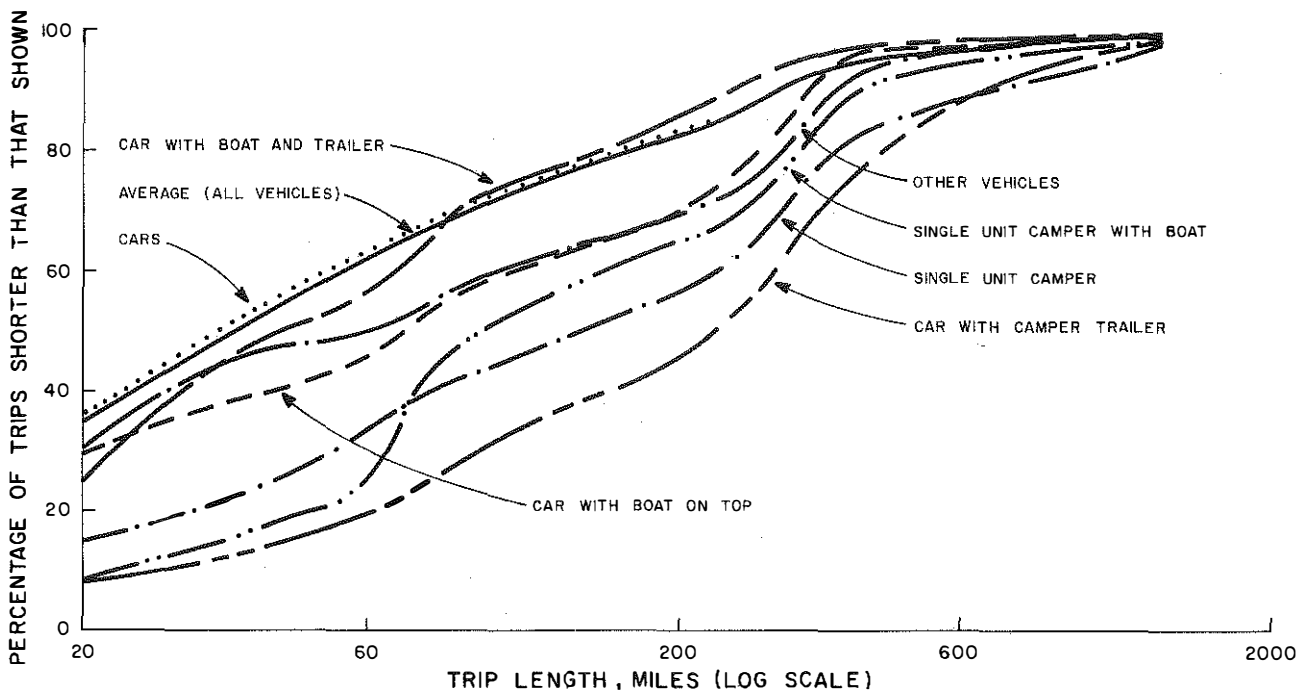


Figure 3. Trip Length Distribution for Different Vehicle Types.



$$P_i = 4050.3 \text{ POP}_i^{0.93} \text{ AR}_i^{0.54} \text{ for in-state zones} \quad (3)$$

in which  $P_i$  = productions of origin zone destined to Kentucky recreational areas,  $\text{POP}_i$  = total population of the zone in millions,  $I_i$  = average effective buying income per household of the zone in ten thousands of dollars, and  $\text{AR}_i$  = accessibility of zone to Kentucky recreational areas in millions of accessibility units. Population and accessibility were important for both in-state and out-of-state zones while family income significantly improved the accuracy only for out-of-state productions. Equations 2 and 3, combined with projections of future per capita recreational travel (5), enable predictions of future productions of trips destined to Kentucky outdoor recreational areas.

### Attractions

Development of a model to accurately simulate attractions was particularly difficult due to the wide variety among the 42 recreational areas. Independent variables that have been used by others to estimate trip attractions and that were considered for use herein included: 1) measures of the extent of water-oriented facilities, 2) measures of the availability of overnight accommodations, 3) measures of the development of day-use facilities, 4) measures of the accessibility to population centers, and 5) measures of the quality of the physical environment including historic, cultural, and scenic attractions.

The extent of water-oriented facilities was measured in terms of lake acreage (LAKE), lineal feet of swimming beach (BEA), and square feet of swimming pools (POOL). Overnight accommodations were expressed as the sum of the numbers of campsites, cottages, and motel or lodge rooms (ON). Number of golf holes (GH), number of picnic tables (PIC), number of drama seats (DRAM), miles of hiking trails (HIK), and miles of horseback trails (HB) were used as appropriate measures of the development of day-use facilities. Accessibility to population centers was defined as

$$\text{AP}_j = \sum_i \text{POP}_i F_{ij} \quad (4)$$

in which  $\text{AP}_j$  = accessibility of recreational area  $j$  to population. It was impossible to devise suitable measures of the quality of the physical environment and this factor had to be omitted from the analysis.

Linear regression analysis yielded the following simple equation for estimating attractions:

$$\begin{aligned} A_j = & 10.2 \text{ GH} + 3.28 \text{ PIC} + 0.324 \text{ ON} + 0.0643 \text{ DRAM} + \\ & (0.17) \quad (2.08) \quad (0.14) \quad (0.10) \\ & 2.24 \text{ HIK} + 8.17 \text{ HB} + 0.293 \text{ BEA} + 0.227 \text{ POOL} + \\ & (0.15) \quad (0.45) \quad (0.83) \quad (1.92) \\ & 0.0986 \text{ LAKE}. \quad (5) \\ & (4.46) \end{aligned}$$

The t-ratio for each regression coefficient, defined as the ratio of the value of the coefficient to its standard error, is shown in

parentheses. Regression coefficients significantly different from zero at the 95-percent confidence level have t-ratios in excess of about 2.0. Unfortunately, Equation 5 contains several independent variables not significantly different from zero at the 95-percent confidence level. Development of a similar equation in which all the independent variables are statistically significant yields the following:

$$A_j = 4.09 \text{ PIC} + 0.211 \text{ POOL} + 0.111 \text{ LAKE}. \quad (6)$$

(4.09)            (2.16)            (7.26)

Accuracy obtained with both Equations 5 and 6 was reasonably good as evidenced by squared correlation coefficients of approximately 0.88. The squared correlation coefficient was increased to 0.92 when the accessibility term, defined by Equation 4, was included in either an additive or multiplicative form. However, use of this accessibility term was considered unacceptable due to the unreasonable negative coefficient in the additive equation and the similarly unreasonable negative exponent in the multiplicative equation. Equation 5 or 6, combined with projections of future per capita recreational travel (5), enables suitable predictions of future attractions for most recreational areas. However, attractions will generally be underestimated for recreational areas of high scenic appeal or areas that are very close to large population centers.

## DISTRIBUTED FLOW MODELS

### Single-Equation Models

Independent variables of the single-equation models were chosen to be origin-zone population as an indicator of recreational demand, recreational-area attractions as an indicator of the supply of recreational facilities, and the distance separating the origin zone from the recreational area as an indicator of the price of the recreational experience. Minimum path distances from each origin zone to each recreational area were determined from a spider web network using ICES TRANSET I (6).

Having selected the independent variables, the form of the expression to be evaluated was

$$V_{ij} = f(\text{DIS}_{ij}, \text{POP}_i, A_j) \quad (7)$$

in which  $V_{ij}$  = 10-hour, departing vehicular flow between recreational area  $j$  and origin zone  $i$ ,  $f$  = some function,  $\text{DIS}_{ij}$  = distance in miles between the recreational area and the origin zone,  $\text{POP}_i$  = population of the origin zone in thousands, and  $A_j$  = estimated attractions of the recreational area as defined by Equation 6.

The first phase of the analysis simulated flows at individual recreational areas, disregarding effects of varying attractions by treating each area separately. Results of this analysis for three of the recreational areas are summarized in Table 7. In all cases, the attempt to use linear regression analysis on a transformed nonlinear equation proved futile. Hence, results from only nonlinear regression analyses are reported herein. A similar difficulty has been noted previously by Matthias and Grecco (7).

TABLE 7  
REGRESSION ANALYSIS FOR THREE  
RECREATIONAL AREAS

Equation Number (See Text)	Squared Correlation Coefficient		
	Columbus-Belmont State Park	Kentucky Lake- Lake Barkley Complex	Lake Beshear- Pennyrile State Park
8	0.01	0.09	0.02
9	0.76	0.66	0.59
10	0.76	0.66	0.60
9 <sup>a</sup>	0.76	0.71	0.61
11	0.95		
12	0.71	0.57	0.60

<sup>a</sup>Separate calibrations were made for three data subsets based on distance intervals of 0 to 100 miles, 100 to 300 miles, and greater than 300 miles.

First, the basic linear equation,

$$V_{ij} = k_1 + k_2 \text{DIS}_{ij} + k_3 \text{POP}_i \quad (8)$$

was tested to verify the suspected nonlinearity. Next, a relationship of the type reported and used successfully by Tussey (8) was investigated:

$$V_{ij} = k_1 \text{DIS}_{ij}^{k_2} \text{POP}_i \quad (9)$$

Table 7 indicates the notable improvement in accuracy which Equation 9 offered as compared with Equation 8. It was suspected, however, that the simple expression for the effect of distance in Equation 9 would not be valid for such a wide range in distances as encountered in this study. A simple means for treating such a situation is to use dummy variables as indicated in the following equation:

$$V_{ij} = k_1 \text{DIS}_{ij}^{x_1 k_2 + x_2 k_3 + x_3 k_4} \text{POP}_i \quad (10)$$

in which  $x_1 = 1$  for  $0 < \text{DIS}_{ij} \leq 100$  and 0 otherwise,  $x_2 = 1$  for  $100 < \text{DIS}_{ij} \leq 300$  and 0 otherwise, and  $x_3 = 1$  for  $\text{DIS}_{ij} > 300$  and 0 otherwise. Little or no improvement in accuracy resulted from the use of dummy variables.

Concern for the effects of distance persisted, however, and it was decided to separate the data set into three parts based on short-range, medium-range, and long-range intervals and to evaluate Equation 9 separately for each of these data subsets. Results of this evaluation, also shown in Table 7, yielded no significant improvement over Equation 10 or the first use of Equation 9. It was concluded, therefore, that the effect of distance on distributed travel flows was adequately expressed by Equation 9.

Preliminary examination of the O-D data had revealed that the per capita flows seemed to depend on the population of the origin zone, increasing population causing a decreasing per capita flow. This suggested that an equation of the following form might prove beneficial:

$$V_{ij} = k_1 \text{DIS}_{ij}^{k_2} \text{POP}_i^{k_3} \quad (11)$$

A nonlinear regression analysis was performed using Equation 11 and data from Columbus-Belmont State Park. While substantial improvement was noted in  $R^2$ , the exponent on the population term was negative. Such an exponent fails to meet the test of reasonableness and suggests a high collinearity between the population and distance variables. Because of this unreasonableness and operational difficulties encountered in the regression analysis for the other two recreational areas of Table 7, further attempts to examine Equation 11 were abandoned.

A final equation of significant interest was reported by Matthias and Grecco (7) and is of the following form:

$$V_{ij} = k_1 e^{k_2 \text{DIS}_{ij}} \text{POP}_i \quad (12)$$

in which  $e$  = base of natural logarithms. Equation 12, while producing satisfactory results as noted in Table 4, proved slightly inferior to Equation 9.

It was next necessary to modify the form of the model to accept attractions (Equation 5) as an independent variable measuring the supply of recreational opportunities. For these analyses, the data were separated into two subsets -- one for distances less than or equal to 100 miles and the other for distances greater than 100 miles -- in an attempt to reduce the population-distance collinearity and to recognize the large number of very small distributed flows for the longer distances. Since there were so many zero flows associated with the long-distance subset, cross-classification techniques were selected as the most acceptable means of analysis. The cross-classification matrix consisted of 180 cells representing all possible combinations of six distance groups, five population groups, and six attractiveness groups. Each distributed flow was entered into the appropriate cell as a departing flow per thousand population and the weighted mean of all flows within each cell was recorded as the representative value.

The first model to be evaluated for the short-distance subset by nonlinear regression represented the following modification of Equation 9:

$$V_{ij} = k_1 \text{DIS}_{ij}^{k_2} \text{POP}_i A_j^{k_3} \text{ for } \text{DIS}_{ij} \leq 100. \quad (13)$$

The total  $R^2$  resulting from the use of this model was 0.28 and only

17 percent of the individual  $R^2$ 's for the 42 recreational areas exceeded 0.50. These results were considered to be unsatisfactory and the following model was suggested as a possible improvement:

$$V_{ij} = k_1 \text{DIS}_{ij}^{k_2} \text{POP}_i^{k_3} A_j^{k_4} \text{ for } \text{DIS}_{ij} \leq 100. \quad (14)$$

Unlike prior efforts to raise the population term to a power, this effort succeeded in producing the following acceptable least-squares equation:

$$V_{ij} = 1.107 \text{DIS}_{ij}^{-1.083} \text{POP}_i^{0.441} A_j^{0.868} \text{ for } \text{DIS}_{ij} \leq 100. \quad (15)$$

A total  $R^2$  of 0.40 resulted from the use of this model. Detailed comparison of simulated versus actual flows indicated the model consistently underestimated the larger flows and overestimated the smaller ones. However, all attempts to develop more accurate nonlinear regression models were unsuccessful.

#### Cross-Classification Model

Development and application of a cross-classification model is almost a trivial matter once the independent variables have been identified. For the analysis reported herein, the same independent variables were used as for the single-equation models. The dependent variable was the 10-hour, departing flow per 1,000 population of the origin zone. Table 8 shows the complete model and identifies the categories into which the independent variables were classified. A  $R^2$  of 0.68 was obtained using this model. From the cross-classification model, per capita distributed flows were found to 1) decrease at a decreasing rate with increasing population of the origin zone, 2) increase at a variable rate with increasing attractions of the recreational area, and 3) decrease at a decreasing rate with increasing distances.

#### Gravity Model

The gravity model in all of its varied forms is certainly the most widely used trip distribution model. The model employed herein is of a form described by the Federal Highway Administration (9):

$$V_{ij} = P_i A_j F_{ij} / \sum A_k F_{ik}. \quad (16)$$

In practice, the attractions ( $A_j$ ) of Equation 16 are replaced by "adjusted" attractions ( $AA_j$ ) to yield

$$V_{ij} = P_i AA_j F_{ij} / \sum AA_k F_{ik}. \quad (17)$$

Equation 17 was applied iteratively until the following constraining equality was satisfied:

$$\sum V_{ij} = A_j. \quad (18)$$

Adjusted attractions were calculated as

$$AA_j = AA_j' A_j / \sum V_{ij}' \quad (19)$$

in which  $AA_j'$  = adjusted attractions from the prior iteration and

$V_{ij}'$  = distributed flows from the prior iteration. A maximum of ten iterations was required in this study to satisfy Equation 18 and thereby balance the trip ends.

To apply the gravity model, it must first be calibrated; that is, the F-factors determined as a function of distance. This was also an iterative, numerical procedure. A set of F-factors was first assumed and the distributed flows ( $V_{ij}$ ) were estimated using the actual productions and attractions from the O-D survey. During calibration, the average trip length estimated by the model was required to be within three percent of the average trip length obtained from the O-D survey. In addition, the percentage of trips occurring within each of 19 distance intervals as estimated by the model was required to be within five percent of the corresponding value obtained by survey. If these conditions were not satisfied, new factors were estimated as follows:

$$\text{New F} = \text{Old F} \frac{\% \text{ of trips in interval by O-D survey}}{\% \text{ of trips in interval by latest model distribution}} \quad (20)$$

The process was then repeated until the convergence criteria based on average trip length and trip-length distribution were satisfied.

F-factors obtained from the calibration phase are summarized in Table 9. They are approximately related to distance as follows:

$$F_{ij} = k / \text{DIS}_{ij}^{2.4}. \quad (21)$$

For purposes of comparison, F-factors developed by Smith and Landman (10) and Ungar (4) are also shown on Table 9. With the exception of the shorter distances, F-factors developed herein compared quite favorably with those of Ungar. However, they showed little similarity to the irregular F-factors developed by Smith and Landman.

The gravity model, using the F-factors of Table 9 and actual O-D survey productions and attractions, simulated trip interchanges quite accurately as evidenced by an  $R^2$  of 0.89. Average trip length and trip-length distribution were also acceptable. However, when using simulated productions (Equations 2 and 3) and attractions (Equation 5), the  $R^2$  decreased to 0.52, indicating that the greater problem in using the gravity model for recreational travel is not the distribution model itself but rather the trip generation phase in which productions and attractions are estimated.

#### Intervening Opportunities Model

Like the gravity model, the intervening opportunities model is a distribution model requiring trip-end data as input. The model can be stated mathematically as (11):

$$V_{ij} = P_i (e^{-LA} - e^{-L(A + A_j)}) \quad (22)$$

in which  $L$  = probability that a random destination will satisfy the needs of a particular trip and  $A$  = sum of attractions of all recreational areas closer to origin  $i$  than recreational area  $j$ . The opportunities model of Equation 22 does not automatically distribute all of the

**TABLE 8**  
**DISTRIBUTED VEHICLE FLOWS PER 1000 PEOPLE**  
**FROM CROSS-CLASSIFICATION ANALYSIS**

POPULATION (THOUSANDS)		0-10	10-100	100-1000	1000-10000	10000-100000
ATTRACTIVENESS INDEX FACTOR GROUP	DISTANCES (MILES)					
0- 100	0- 20	0.95898163	0.37657559	0.16223729	0.0	0.0
	20- 40	0.07621366	0.04382936	0.09810883	0.0	0.0
	40- 60	0.03046736	0.00665962	0.01014474	0.02425961	0.0
	60- 80	0.00447205	0.00213163	0.00075684	0.00793951	0.0
	80- 100	0.00501749	0.00136144	0.00087748	0.00135821	0.0
	100- 150	0.0	0.00209034	0.00086263	0.00042550	0.0
	150- 250	0.10236395	0.00113672	0.0	0.00008044	0.0
	250- 400	0.0	0.00194506	0.0	0.0	0.0
	400- 700	0.0	0.0	0.0	0.00001943	0.0
	700-1300	0.0	0.0	0.0	0.00002829	0.00000457
1300-3000	0.0	0.0	0.0	0.00001465	0.00000711	
100- 250	0- 20	1.13544655	5.72978306	0.0	0.0	0.0
	20- 40	0.50813011	0.64762914	0.16062135	0.0	0.0
	40- 60	0.09077013	0.07542700	0.19504023	0.0	0.0
	60- 80	0.00946701	0.04417120	0.03474323	0.0	0.0
	80- 100	0.00978377	0.02821740	0.01148133	0.0	0.0
	100- 150	0.01283454	0.01465168	0.00521773	0.01120973	0.0
	150- 250	0.0	0.01779335	0.00267404	0.00496950	0.0
	250- 400	0.00974108	0.01038040	0.00106779	0.00049610	0.00026823
	400- 700	0.0	0.0	0.0	0.00023177	0.00013441
	700-1300	0.0	0.0	0.0	0.00014438	0.00004732
1300-3000	0.0	0.0	0.0	0.00001783	0.00003980	
250- 500	0- 20	13.60512066	2.15327835	1.69190311	0.0	0.0
	20- 40	0.45618343	0.84385180	0.0	0.05734091	0.0
	40- 60	0.07118195	0.20437711	0.05361288	0.0	0.0
	60- 80	0.08550048	0.09662765	0.02636402	0.0	0.0
	80- 100	0.08959763	0.07254964	0.11188710	0.00930038	0.0
	100- 150	0.12461966	0.03304999	0.04490374	0.00147254	0.0
	150- 250	0.06225098	0.03363845	0.01346620	0.01168360	0.00223527
	250- 400	0.10596339	0.00172808	0.00508884	0.00435554	0.00706346
	400- 700	0.0	0.0	0.00032421	0.00202752	0.00088352
	700-1300	0.0	0.0	0.00074924	0.00085544	0.00085450
1300-3000	0.0	0.0	0.00032310	0.00038885	0.00028194	
500- 1000	0- 20	17.07408142	14.42647648	4.35972214	0.0	0.0
	20- 40	1.23048572	0.98168427	0.06762052	0.0	0.0
	40- 60	0.34941846	0.26402664	0.11306220	0.0	0.0
	60- 80	0.08732462	0.07660019	0.69479340	0.0	0.0
	80- 100	0.04565455	0.04019441	0.06184201	0.04536866	0.0
	100- 150	0.07295334	0.03790832	0.01202674	0.01365991	0.0
	150- 250	0.02795955	0.02301007	0.00477299	0.00526530	0.0
	250- 400	0.01548490	0.00816158	0.00185738	0.00121748	0.000260782
	400- 700	0.0	0.0	0.0	0.00050416	0.00029665
	700-1300	0.0	0.0	0.00008404	0.00026949	0.00026645
1300-3000	0.0	0.0	0.0	0.00010759	0.00011941	
1000- 2000	0- 20	19.37711944	5.39795580	0.0	0.0	0.0
	20- 40	1.09620857	1.13166714	0.49716857	0.0	0.0
	40- 60	0.22912484	0.44439262	0.34142214	0.0	0.0
	60- 80	0.05523006	0.12133151	0.40397137	0.08435732	0.0
	80- 100	0.06004418	0.04563305	0.04844257	0.09810972	0.0
	100- 150	0.02573594	0.04007056	0.01873372	0.01772470	0.0
	150- 250	0.03705391	0.01600631	0.00513345	0.00448848	0.0
	250- 400	0.01967793	0.00619185	0.00224304	0.00144763	0.00132626
	400- 700	0.0	0.0	0.00062903	0.00060745	0.00077247
	700-1300	0.0	0.0	0.00013438	0.00035780	0.00025655
1300-3000	0.0	0.0	0.00027983	0.00028034	0.00013434	
2000- 4000	0- 20	9.30527592	16.86503601	0.0	0.0	0.0
	20- 40	1.61003971	2.61544514	1.88730049	0.0	0.0
	40- 60	0.24922538	0.68204987	0.00874927	0.0	0.0
	60- 80	0.23705786	0.32020891	0.04441848	0.0	0.0
	80- 100	0.10578489	0.10133439	0.09276676	0.0	0.0
	100- 150	0.18476230	0.10318834	0.05605559	0.05523141	0.0
	150- 250	0.07273781	0.08328956	0.02152548	0.03683314	0.0
	250- 400	0.15019166	0.04602881	0.01176453	0.00443741	0.00067058
	400- 700	0.0	0.0	0.00090592	0.00138012	0.00214037
	700-1300	0.0	0.0	0.00047370	0.00087972	0.00033799
1300-3000	0.0	0.0	0.00041116	0.00012996	0.00023882	
4000-10000	0- 20	4.85889149	21.91233826	0.0	0.0	0.0
	20- 40	0.74458832	27.33007813	0.0	0.0	0.0
	40- 60	0.0	2.28969002	0.0	0.0	0.0
	60- 80	0.93365526	1.73152637	0.00729106	0.0	0.0
	80- 100	0.55367606	0.55589758	1.63489532	0.0	0.0
	100- 150	0.29150647	0.23062080	0.19563627	0.0	0.0
	150- 250	0.31635976	0.20414138	0.07663280	0.16524690	0.0
	250- 400	0.0	0.0	0.04418130	0.00874706	0.00047054
	400- 700	0.0	0.0	0.00181183	0.00149137	0.00092559
	700-1300	0.0	0.0	0.0	0.00086951	0.00094638
1300-3000	0.0	0.0	0.00088904	0.00042389	0.00044779	
10000-20000	0- 20	107.38320923	111.47634888	0.0	0.0	0.0
	20- 40	41.39472961	21.06471252	0.0	0.0	0.0
	40- 60	6.48586330	20.13973999	0.66606885	0.0	0.0
	60- 80	5.38302994	6.34304714	0.0	0.0	0.0
	80- 100	1.85128021	2.99995136	0.0	0.0	0.0
	100- 150	0.99966675	0.72808444	0.64073777	0.08552021	0.0
	150- 250	0.49463910	0.54417735	0.32898664	0.06843203	0.0
	250- 400	0.25180978	0.30700815	0.06867200	0.05273020	0.19035572
	400- 700	0.0	0.0	0.02297622	0.01006312	0.0
	700-1300	0.0	0.0	0.00599426	0.00490166	0.00383404
1300-3000	0.0	0.0	0.00365747	0.00344839	0.00119410	

TABLE 9

F-FACTORS FOR GRAVITY MODEL

Distance Interval (Miles)	F-Factor <sup>a</sup>		
	Developed Herein	Smith and Landman (10)	Ungar <sup>(4)</sup>
0-10	10735.62		1545
11-20	3400.18	4290	1267
21-30	917.27	4090	750
31-40	483.68	2540	376
41-60	162.22	2790	180
61-80	90.21	90.2	90.2
81-100	36.09	22.9	54.4
101-125	21.01	-11.5	34.6
126-150	11.60	4.69	22.9
151-200	8.86	0.70	13.6
201-250	5.07	0.00	6.2
251-325	3.11		
326-400	1.40		
401-550	0.65		
551-700	0.29		
701-1000	0.20		
1001-1300	0.12		
1301-1700	0.08		
1701-3000	0.05		

<sup>a</sup>F-Factors of Smith and Landman and Ungar were modified by factoring to achieve conformity at a distance of about 70 miles.

reproductions. This potential difficulty can be readily overcome by adding a constant, K, as follows (12):

$$V_{ij} = K P_i [e^{-LA} \cdot e^{-L(A + A_j)}] \quad (23)$$

in which

$$K = 1/(1 - e^{-L \sum_k A_k}) \quad (24)$$

Trip-end balancing is also required with the opportunities model to assure that

$$\sum_j V_{ij} = A_j \quad (25)$$

To accomplish this, Equation 23 is rewritten in terms of "adjusted" attractions (AA and AA<sub>j</sub>) as

$$V_{ij} = K P_i [e^{-L AA} \cdot e^{-L(AA + AA_j)}] \quad (26)$$

Equation 26 was applied iteratively until the trip ends were balanced, that is, Equation 25 was satisfied. Adjusted attractions were computed following each iteration using Equation 19.

Calibration of the opportunities model entails selection of the value of the probability parameter, L, which yields the best simulation of the actual O-D trip interchanges. Smith and Landman (10) suggested an iterative process whereby an initially assumed value of L is adjusted so that the simulated average trip length is nearly equal to the actual average trip length. For each iteration, a new L is calculated as follows:

$$\text{New } L = \text{Old } L \frac{\text{Calculated average trip length (prior iteration)}}{\text{Actual average trip length}} \quad (27)$$

This method of determining L was originally attempted herein but convergence was extremely slow. Therefore, a new method was used whereby the initially assumed estimate was modified by a given increment in successive iterations and the optimum L selected as that which maximized R<sup>2</sup>. This incremental method proved much more effective than the method suggested by Smith and Landman. The best value of L was found to be 0.00033. This compared with a value of 0.00069 as reported by Smith and Landman (10). The large difference between these two L-values was due in part to the large difference in the total number of attractions between the two studies.

Using actual attractions and productions, the calibrated model simulated trip interchanges with an R<sup>2</sup> of 0.70. This was considerably less than that achieved with the gravity model. A second evaluation was made using the opportunities model in which trip ends were not forced to balance. This yielded an improved R<sup>2</sup> of 0.79 but, of course, violated the constraint of Equation 25. It was concluded that the low accuracy achieved with this model was probably due to the fact that the 42 recreational areas demonstrated such a wide range in attractions from a low of 45 to a high of 18,220. Pyers (12) has reported a similar problem and suggested it might be overcome by using two different values of L -- one for small generators and one for large generators. This possibility was not investigated herein.

When simulated productions and attractions were used with the opportunities model, the accuracy with which trip interchanges were simulated, as measured by R<sup>2</sup>, was 0.40. The large reduction in R<sup>2</sup> from 0.70 when actual productions and attractions were used further indicated that trip generation was a greater problem in recreational travel modeling than trip distribution.

COMPARISON OF MODELS

Adequacy of the four distributed flow models can be evaluated in many ways. Perhaps the best way is to compare the accuracy with which the 7,980 trip interchanges of the O-D survey can be simulated by each of the models. The squared correlation coefficient (R<sup>2</sup>), a measure of this accuracy, is summarized for each of the model types in Table 10. The cross-classification model, which explained approximately 68 percent of the observed variance, was definitely the most accurate of the four models. A similar measure of accuracy is the percentage of the 42 recreational areas for which the models can simulate trips with an R<sup>2</sup> of at least 0.50. Based on this measure, the superiority of the cross-classification model is again indicated in Table 10.

Good distributed flow models will likewise accurately simulate average trip length and trip-length distribution. Table 10 shows that, with the exception of the opportunities model, all models were satisfactory in simulating average trip length. A comparison of the actual and simulated trip-length distributions is shown by Figure 4. The cross-classification model was superior for simulating trip-length distribution and the gravity model was adequate. However, the

Model	Total $R^2$ <sup>a</sup>	Percentage of Recreational Areas with $R^2 \geq 0.50$ <sup>b</sup>	Average Trip Length <sup>c</sup> (Miles)
Cross Classification	0.679	45	113.7
Gravity	0.519	31	115.9
Single Equation <sup>d</sup>	0.403	19	110.3
Opportunities	0.396	10	126.1

TABLE 10  
MODEL EVALUATION

<sup>a</sup>Determined on basis of 7,980 distributed flows.

<sup>b</sup>Percentage of the 42 recreational areas having individual  $R^2 \geq 0.50$ .

<sup>c</sup>Actual average trip length was 109.0 miles.

<sup>d</sup>Eq. 15 for distances less than or equal to 100 miles and a cross-classification model for greater distances.

single-equation and opportunities models produced simulated distributions that significantly departed from the actual both in position and in shape.

All models were calibrated essentially on the basis of average conditions. The degree to which the flows at any particular recreational area could be accurately simulated depended to a significant degree upon how much that area deviated from average. Thus, for recreational areas that had significant day-use activity commonly associated with shorter trips, such as Lake Cumberland and Lake Barkley, the models predicted a longer than actual average trip length. On the other hand, for areas of primarily national interest, such as Mammoth Cave, the models predicted a shorter than actual average trip length. The manner in which this difficulty can be overcome is not readily apparent unless a stratification based on trip

purpose can be used. This is obviously impossible with data obtained from a license-plate, O-D survey such as reported herein.

Other factors useful in comparing model types are simplicity and ease of application. All of the models were rather simple and posed no difficulty in their application. However, the single-equation and cross-classification models offered certain advantages over the gravity and opportunities models. These included more limited input data requirements and the possibility for making predictions without the use of a computer. Additionally they allowed less restrained use of independent judgement and permitted a single recreational area to be examined by itself.

In comparing only the gravity and opportunities models, the gravity model was considerably more accurate and simulated the

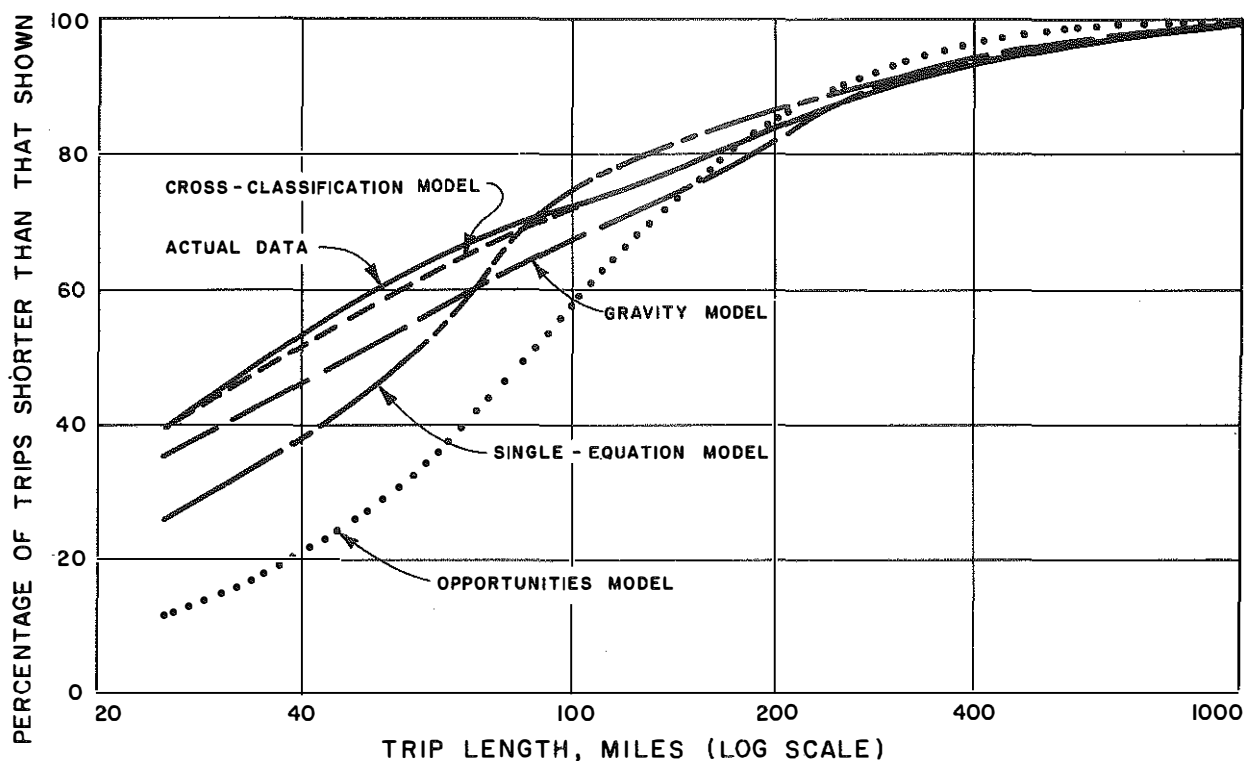


Figure 4. Trip Length Distributions.

actual trip-length distribution much better. It was also considerably less costly to calibrate and apply. In general, computer cost for the opportunities model was found to be three or four times more than that for the gravity model. The gravity model was able to handle the wide variety in sizes of the recreational areas while the opportunities model was not.

Based on the above evaluations, the cross-classification model was certainly the best of the four models investigated herein. Development of this model makes available for the first time an acceptable technique for simulating travel flows to outdoor recreational facilities in Kentucky. When coupled with projections of trends in per capita recreational activity (5), the cross-classification model should prove most effective in predicting future flows to either existing or proposed recreational facilities. Any type of outdoor recreational area can be considered as long as it is possible to estimate its attractions either by comparison with existing facilities or by the use of Equation 5 or 6. The specific Kentucky model may have limited potential for use outside the state since recreational demand, the mix of available recreational facilities and activities, and consumer preferences vary regionally.

#### SUMMARY AND CONCLUSIONS

The purpose of this study was to examine characteristics of travel to outdoor recreational areas in Kentucky and to evaluate different models for simulating average summer Sunday flows. Recreational travel, like many other types of travel, is highly complex and very much dependent upon local conditions. Therefore, much of the specific data assembled herein is sensitive to the nature of the recreational area and its location relative to the various origin zones throughout the United States. Some of the principal findings and conclusions of the study follow.

1. To evaluate the impact of recreational travel in a way that is beneficial to highway planners, it is necessary to estimate distributed vehicular flows among all origin zones and all recreational areas during a short time period such as a day. The average summer Sunday is the day of most intense interest since outdoor recreational travel typically peaks on summer Sunday afternoons.
2. Overall results indicate the license-plate, O-D survey is a satisfactory way to gather O-D data of the type required herein. The time selected for the O-D survey, 10 a.m. to 8 p.m. on summer Sundays, proved to be completely acceptable. However, to be most useful, the O-D survey must be supplemented by a continuous traffic counting program.
3. Vehicle occupancy, which averaged 3.06 persons per vehicle, is larger for outdoor recreational travel than for normal highway travel. Occupancy was found to be a function of the type of recreational area, distance traveled, and vehicle type. Smallest rates were observed at areas

having large day-use activity. Among the various vehicle types, occupancy was largest for cars pulling camping trailers while sensitivity of occupancy rate to distance traveled was greatest for camping vehicles. Occupancy rate increased with increasing distance traveled for all vehicle types.

4. A large proportion of the vehicles were cars, (96.7 percent). The remainder were single-unit campers (2.1 percent) and motorcycles, trucks, and buses (1.2 percent). Altogether, 3.4 percent of the vehicles had camping units attached and 5.8 percent had boats. The nature of the recreational facilities had a decided impact on the proportion of camping units and boats. The proportion of camping units also increased significantly as distance of travel increased. Boat usage peaked in the distance range of 60 to 90 miles.
5. Trips to outdoor recreational areas of the type found in Kentucky are relatively short as evidenced by the fact that 60 percent of all vehicles traveled less than 50 miles. Trip lengths were definitely dependent upon the type and location of the recreational area, however, and for areas having a large regional impact, average trip length was found to be quite large. Vehicles with camping units travel on the average much longer distances than other types of vehicles.
6. The distribution of recreational traffic over time is highly dependent on the nature of the recreational area, the nature of the recreationists, and the location of the areas in relation to population centers. In any case, however, recreational travel is more variable over time than other forms of highway travel.
7. Design of highway facilities serving recreational travel to accommodate the 30th highest hourly volume appears in many cases to be impractical. A more practical basis for design is the peak-hour volume on the average summer Sunday. This volume on the average corresponded with the 70th to 75th highest hourly volume.
8. Sunday was always the peak day of the summer week except for holidays and, on the average, 25 percent of the weekly volume was observed on Sunday. The peak hourly volume on summer Sundays occurred within the interval of 1 to 5 p.m. and averaged 11 percent of the 24-hour Sunday flows.
9. The pattern of trip production to outdoor recreational areas in Kentucky differed between in-state and out-of-state origin zones. For in-state zones, population (POP) and accessibility to recreational opportunities (AR) were the most significant indicators of productions. For out-of-state zones, population, average income (I), and accessibility to recreational opportunities were found to be significant. The best equation for simulating productions (P) was found to

he of the following general form:

$$P = k_1 \text{POP}^{k_2} \text{AR}^{k_3} \text{A}^{k_4} \quad (28)$$

However, such an equation explains only about 70 percent of the variance for in-state zones and about 84 percent of the variance for out-of-state zones.

10. Attractions (A) to recreational areas of varying types and sizes can be reasonably approximated by a linear equation involving the nature and extent of recreational facilities. The following facilities, listed in the order of highest to lowest significance, were identified as having important effects on attractions and were judged essential for encompassing the wide range of recreational areas studied: water area, picnic tables, swimming pools, horseback trails, beach, golf, hiking trails, overnight accommodations, and outdoor drama. The linear equation utilizing these variables explained about 89 percent of the variance in attractions. However, this equation proved unsuitable for simulating attractions at areas deviating significantly from the average, such as those of high scenic interest and those highly accessible to large population centers.
11. Four types of travel models, including single-equation, cross-classification, gravity, and intervening opportunities models, were evaluated herein. The cross-classification model was found to be the most acceptable means for simulating and predicting distributed outdoor recreational travel flows. In virtually any travel modeling effort, cross-classification analysis can be gainfully employed if only for the purpose of visually depicting the effects of various independent variables.
12. The cross-classification model demonstrated that per capita distributed flows 1) decrease at a decreasing rate with increasing population of the origin zone, 2) increase at a variable rate with increasing attractions of the recreational area, and 3) decrease at a decreasing rate with increasing distance.
13. The best single-equation model for simulating flows ( $V_{ij}$ ) for short-range travel was of the form:

$$V_{ij} = k_1 \text{DIS}_{ij}^{k_2} \text{POP}_i^{k_3} \text{A}_j^{k_4} \quad (29)$$

in which  $\text{DIS}_{ij}$  = distance between origin zone  $i$  and recreational area  $j$ . This nonlinear flow equation, as was investigated herein, had to be evaluated using nonlinear regression analysis. Linear regression using transformed (linearized) equations proved totally unsuitable.

14. The gravity model is a simple and effective model for distributing recreational trips. Accuracy of the trips so distributed depends in large part on the accuracy of estimating productions and attractions. F-factors developed

in the gravity-model calibration are a convenient and useful means for explaining the effects of distance on travel impedance.

15. The intervening opportunities model can be calibrated very effectively by incrementing the probability parameter,  $L$ , in such a way as to maximize the accuracy of the trip-interchange simulation. However, the opportunities model was found to be decidedly inferior to the gravity model. The intervening opportunities model cannot produce satisfactory results with only one value of  $L$  if recreational areas of widely differing attractions are present in the study area.
16. For flow models using distinct trip generation and distribution phases, trip generation was found to be the most critical problem in outdoor recreational travel modeling.

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