A STUDY OF THE DISTRIBUTION OF RECREATIONAL TRIPS TO FEDERAL RESERVOIRS IN KANSAS

by

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INTRODUCTION

Only two decades ago, there were no federal reservoirs in Kansas. By 1964, nine reservoirs had been completed and a number were under construction. Kanopolis and Fall River Reservoirs were completed in 1949 with Cedar Bluff added in 1951. Spurred by the 1951 flood, a number of flood control projects were initiated by the U. S. Army Corps of Engineers. Of these, Toronto was completed in 1960, Tuttle Creek in 1963 and Pomona in 1964.

Recreational activities were not a consideration in the justification of the earlier projects. However, even before some of these projects were completed, various groups were promoting recreational activities which would take advantage of the impounded bodies of water. Parallel to this, the Corps of Engineers began to show interest in developing the tremendous recreational potential of the reservoirs. In cooperation with the various government agencies, numerous boat docks, marinas and picnic and camp grounds have been developed and the waters have been stocked with a number of species of fish.

During the time that these reservoirs were being developed, the population of nearly all urban areas, both in and near Kansas, was showing substantial growth. Besides the increase in population, reservoir activities have increased because there is more leisure time than ever before. Table 1 shows the population growth for the state of Kansas since 1945 along with the reservoir visitations during the same period of time.

Because of the increased demand, authorities who are responsible for developing the recreational areas at these reservoirs must know how many facilities are needed, what kind are needed, where they are needed and how soon after the reservoir begins to impound water they must be completed. Agencies such as the State Highway Commission and county engineers must know the type and location of roads that are necessary.

In order that the above mentioned development can be accomplished, legislative bodies must provide the needed financial support. This can be done only if there is adequate planning at all levels of control.

PURPOSE

As more and more facilities are being built, the user and the potential user have a much larger choice of reservoirs to visit. It would be very advantageous for the developer to know the relationship of a particular reservoir with respect to all others. To do this, one must be able to measure the response of the reservoir user to how far he must travel and what he finds when he gets there.

The purpose of this research project was to develop and test a procedure for reproducing, mathematically, the response of the people of Kansas to recreational opportunities at federal reservoirs.

SCOPE

This study was limited to the calibration and testing of the gravity model and opportunity model based on the data collected in 1963 and 1964 at nine federal reservoirs in Kansas and Harlan County Reservoir in Nebraska, Fig. 1. Only those trips produced in the 105 counties of Kansas, 44 counties of Nebraska, and the Kansas City area of Missouri were used as data. (See Table A of the Appendix) This research is but a part of a research contract entered into by the Civil Engineering Department of Kansas State University, the State Highway Commission of Kansas and the U. S. Department of Commerce, Bureau of Public Roads (now the Department of Transportation).

Table 1

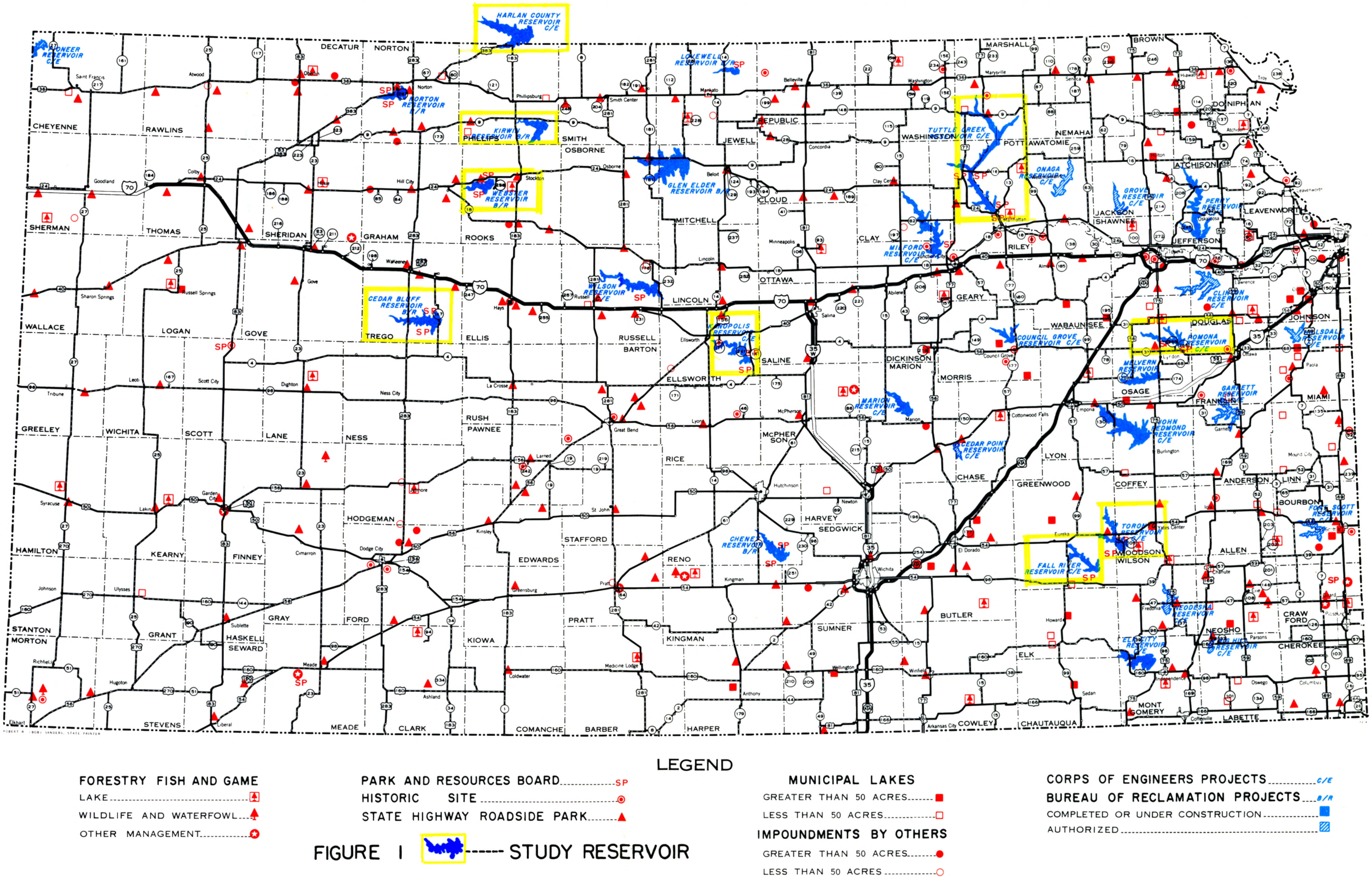
Population and Reservoir Attendance

Year	Kansas (1) Population	Annual (2) Reservoir Attendance
1948	1,873,843	230,000
1949	1,912,545	450,000
1950	1,904,584	700,000
1951	1,942,060	653,000
1952	1,980,073	589,000
1953	1,965,112	771,000
1954	1,999,457	707,000
1955	2,050,478	804,000
1956	2,077,711	1,040,000
1957	2,081,654	1,322,000
1958	2,100,665	1,680,000
1959	2,115,441	1,973,000
1960	2,130,579	2,033,000
1961	2,146,154	2,369,000
1962	2,165,009	3,213,000
1963	2,172,296	3,277,000
1964	2,180,533	4,155,000

(1) - State Board of Agriculture.

(2) - Kansas Water Resources Board.

STATE HIGHWAYS LEADING TO KANSAS RECREATION AREAS



BACKGROUND

Gravity Model

One of the important tools of the urban transportation planner is the gravity model. This model is a formula that is based on Newton's law of universal gravitation, which states that the force between two bodies is directly proportional to their masses and inversely proportional to the square of the distance between their centers of gravity.

The gravity concept of human interactance stipulates that the movement of persons between two centers is directly proportional to the size or magnitude of population of each of the centers and inversely proportional to some function of the spatial separation of the two centers.

This theory of interactance can be stated on mathematical notation by:

$$I_{IJ} = \frac{P_I P_J}{F(D_{IJ})}$$

Where: I_{IJ} is the interactance between population centers I and J.

P_I and P_J are the population of centers I and J.

F is a functional notation.

D_{IJ} is the spatial separation of population centers I and J.

H. C. Carey (6)* was the first to introduce the concept of human interactance and spatial separation during the early part of the 19th century. This theory received very little attention until E. G. Ravenstein (1) suggested that migration from sources of population to centers of absorption is directly proportional to the population of the source and inversely related to the distance between the two locations. The relationship is expressed in

*Numbers in parentheses refer to items in the list of references.

mathematical terms as:

$$ {}_{I}M_{J} = \frac{F(P_{I})}{D_{IJ}} $$

Where: ${}_{I}M_{J}$ is the migration from source I to center of absorption J.

$F(P_{I})$ is a function of the population I.

D_{IJ} is the distance from source I to center J.

The interactance theory was brought closer to transportation by a social scientist named George K. Zipf (2,3). He hypothesized that intercity movements were directly related to the product of the populations of the two cities and inversely proportional to the intercity distance. Upon testing his hypothesis, Zipf found that intercity bus travel was reasonably predictable by the formula:

$$ T_{IJ} = \frac{P_{I}P_{J}}{D_{IJ}} $$

Where: P_{I}, P_{J} are the population of the two cities.

D_{IJ} is the distance between the two cities.

It was found that there was some correlation between the variables when rail and air travel were considered, but there was a good deal of variation displayed.

Later, work that was done by researchers such as Dodd and Cavanaugh (4) used modifications and refinements of the same general interactance formula. These various versions were tested on movements of goods, credit, long distance telephone calls and trade areas.

One significant step was made by Fred Ikle' (14), who suggested that the distance relationship could better be described by an inverse non-linear function. Stated mathematically, his relationship yielded the following equation:

$$H_{IJ} = \frac{P_I P_J}{(D_{IJ})^B}$$

Where: H_{IJ} is the number of trips between cities I and J during a given time period.

$P_I P_J$ is the product of the populations of the cities I and J.

D_{IJ} is the distance between cities I and J.

B is a constant exponent which reflects the area wide influence of distance upon the propensity to make trips.

The form of the gravity model which is used in transportation planning today was developed by Alan Voorhees (5). The formula that Voorhees developed is the following:

$$T_{IJ} = P_I \frac{\frac{A_J}{D_{IJ}^B}}{\frac{A_1}{D_{I1}^B} + \frac{A_2}{D_{I2}^B} + \cdots + \frac{A_N}{D_{IN}^B}}$$

Where: T_{IJ} is the number of trips between zone I and zone J.

P_I is the number of trips produced by zone I.

A_J is the number of trips attracted by zone J.

D_{IJ} is the spatial separation between zones I and J.

B is an empirically determined exponent which expresses the average area wide effect of spatial separation between zones on the amount of trip interchange.

N is the number of zones.

In urban areas Voorhees found that the exponent, b, differed with trip purpose. He found that distance had less influence on a work trip than on a shopping trip. However, he also found that the exponent varied with distance. This led to the use of the travel time factors or friction factors (F-Factors). The F-Factor for a given distance is proportional to the inverse of the distance function of the following formula or:

$$FF(d) \approx \frac{1}{d^b}$$

Where: FF(d) are a set of numbers with a range over all possible lengths of trips within the study area.

Opportunity Model

A second form of trip distribution models is embodied in the opportunity models, of which the intervening model is the best known. This model is based on the theory that a trip maker desires to keep his trip as short as possible but will search for more distant destinations until an acceptable one is found. The formula for this model is:

$$T_{IJ} = O\ (e^{-L(D)} - e^{-L(D-D_J)})$$

Where: T_{IJ} is the number of trips between zone I and zone J.

O_I is the number of trips with origins at zone I.

e is the base of the natural logarithm (2.71828).

L is the measure of probability that a random destination will satisfy the needs of a particular trip.

D is the sum of destinations that has already been considered.

D_J is the number of trips with destinations at zone J.

This model was developed by Morton Schneider while working for the Chicago Area Transportation Study (7, 8). The opportunity model that was developed by Schneider uses origins and destinations instead of productions and attractions, as in the gravity model. In addition, it uses a different trip stratification than the gravity model. Whereas the gravity model uses a trip purpose stratification, in its usual form, the opportunity model has long residential, long non-residential and short trips. The long residential trips are those trips from home to the central business district or to work. The long non-residential trips are the reverse of long residential and the short trips are all the rest. Other than that work trips are generally longer than non-work trips, the names long and short have nothing to do with trip length.

The competing opportunities model is an attempted compromise between the gravity model (G.M.) and the intervening opportunities model (I.O.M.) It was developed during the Penn-Jersey Study (10) and later tested by the Bureau of Public Roads (11) on the Washington, D. C. origin-destination data. As yet, it has not produced as suitable results as has the G.M. or the I.O.M.

As a result of the evaluation of the different models by the Bureau of Public Roads, the distributions produced by the G.M. and the I.O.M. showed that the differences are insignificant for urban travel forecasting. It was within the scope of the research project sponsored by the Highway Commission to test only these two distribution models.

DATA COLLECTION

A part of the data for this research was collected during the summer of 1964 in connection with an agreement between the Civil Engineering Department of Kansas State University and the State Highway Commission. Another portion was obtained from the U. S. Army Corps of Engineers who made similar interviews the same summer at reservoirs under their control. The remainder of the data was collected the previous summer (1963) by the Highway Commission as part of its work program.

The basic element of the data was the interview. These roadside interviews were made at all of the federal reservoirs in Kansas and Harlan County Reservoir in Nebraska that were considered to be sufficiently developed in 1964 to be attractive to recreational traffic. The stations were so located that traffic entering the recreation or park areas could be interviewed.

The interviewer was instructed to determine the following information:

1. Origin of trip.
2. Activities in which the visitor would be involved.
3. Duration of visit.
4. Approximate number of visitations per year.

By observation, the interviewer could determine:

1. The time the interview was made.
2. Number of persons in vehicle.
3. If the vehicle was pulling a boat or camping trailer.

It was noted on the form if this vehicle had been interviewed anywhere at that reservoir earlier in the day or if the trip did not involve a recreational activity at the reservoir.

Figure 2 shows a reproduction of the interview form that was used by the Highway Commission in 1964. The form used in 1963 and the one used by the

Corps were different, but the information obtained was very similar.

STATE HIGHWAY COMMISSION OF KANSAS - HIGHWAY PLANNING DEPARTMENT

RESERVOIR TRAFFIC SURVEY

SHEET NO. (27, 28)

DAY OF WEEK

HIGHWAY PLANNING PROJECT 606

PROJECT (RESERVOIR)	AREA (STATION NO.)	DATE: DAY, MO, YR
HER:	COMMENCED	COMPLETED	MADE BY:

ER OF VEHICLES SURVEYED — TOTAL VEHICLES DURING SURVEY PERIOD

	NUMBER OF PERSONS		TRAILER: BOAT	TRAILER: CAMP	TYPE OF VISITOR: DAY - USE ACTIVITIES: BOAT	FISH	HUNT	PICNIC	SIGHTSEE	SKI	SWIM		OVER NIGHT: CAMPING ON PROJECT	STAYING IN AREA	DURATION OF VISIT: DAYS	HOURS		PLACE OF ORIGIN: CO.			STATE		CITY				
30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55		
1																											
2																											
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5																											

FIGURE 2

INTERVIEW FORM

After the interview forms were brought in from the field, the interview was checked and a numerical code for the county and state of the origin of the trip was added. Each interview was then punched on data processing cards and verified.

A second element of data collection was the traffic counts made at each reservoir. Through the cooperation of Dr. B. L. Smith, Civil Engineering Department, Kansas State University, and Mr. Glenn Sutton, Assistant Engineer of Planning and Mr. E. O. Chapman, Field Surveys Engineer, both from the Planning and Research Department, State Highway Commission, a series of control and coverage counts were made during 1964. These counts were made at locations around the reservoirs in order to intercept most of the reservoir bound traffic. It was estimated that 95 percent of the trips were counted at Corps-controlled reservoirs. It was the judgment of persons familiar with the Bureau of Reclamation reservoirs, that about the same coverage (95 percent) was obtained at Bureau reservoirs.

Because the traffic counters counted both inbound and outbound trips and there was 95 percent coverage, the counts were divided by (0.95 x 2) to obtain reservoir attendance.

In order to combine the data collected from interviews with the counter information, it was necessary to adjust the counter reading from pairs of axles to vehicles. This was necessary because of the extra axles of the trailers (boat and others). The single or tandem axle trailer would count as an extra half or whole vehicle, respectively, as it crossed a counter.

An additional adjustment was necessary to factor the non-recreational vehicles out of the counts. The adjustment factor "Z" in the following equation factors total vehicles to recreational vehicles.

$$Z = \frac{R_I}{T_I}$$

Where: $T_I = R_I - RRV - NRV$

R_I = Number of interviewed recreational vehicles.

RRV = Number of re-entry recreational vehicles interviewed.

NRV = Number of non-recreational vehicles interviewed.

This equation expanded the usable recreational interviews to include that portion of the refusals and passed vehicles that were assumed to be recreation trips. The equation was formulated on the assumption that the split between recreational and non-recreational was the same for the refusals and passed vehicles as it was for those that were interviewed.

By multiplying the "Z" for each reservoir times the number of vehicles entering the reservoir area, the attendance at the reservoir was determined in vehicles per average summer Sunday. The average summer Sunday attendance was then divided by the recreational interviews to obtain a card expansion factor for each reservoir that was punched in each card.

Other data, such as population and economic characteristics of the counties and the physical characteristics of the reservoirs were collected as part of the research project, their use goes beyond the scope of this paper. (13)

Table 2 shows the number of interviews made at each reservoir and the average summer Sunday attendance. It can be seen in the table that the sample rate varied from over 90 percent at Cedar Bluff to less than 10 percent at Fall River and Pomona.

Table 2

Reservoir Attendance and Interviews

Reservoir	Number of Interviews	Number of Average Summer Sunday Trips
Cedar Bluff	760	830
Kanopolis	1,020	2,142
Toronto	452	1,248
Tuttle Creek	1,424	4,513
Lovewell	396	602
Kirwin	356	451
Webster	305	614
Fall River	154	1,954
Pomona	294	4,448
Harlan County	740	3,048
Total	5,901	19,850

STUDY PROCEDURE

In order to calibrate and analyze a distribution model, several fixed parameters are necessary. These include:

1. Trip productions (trip ends).
2. Trip attractions (trip ends).
3. Trip table (trips).
4. Skim trees (county to reservoir distances).

Other parameters are necessary, depending on the model.

The trip table was built from the origin-destination (O-D) interview cards by summarizing by county, by reservoir. This was a partial table because trips produced by counties in the study area to reservoirs other than those studied were unknown and therefore not included. The trip end totals for both the reservoirs and the counties for this research, however, were obtained by summing rows and columns of the trip matrix.

Another "fixed" parameter which is needed, regardless of the model, is the spatial separation of the productions and the attractions. Because of the grid system of roads in Kansas, it was decided that the distance could be described by the "dogleg" or "L" distance in miles between each county and each reservoir.

The distance was computed by adding the differences in the "X" coordinates to the differences in the "Y" coordinates between the centroids (center of activity) of the counties and the reservoirs. The coordinate system used was devised by the Highway Commission.

Although the O-D trip length frequency distribution is not a parameter of the gravity model, it is used to calibrate the F-Factors. The distribution is stated in terms of the percent of total trips occurring in each ten mile increment of trip length. This was done by relating and then summing each county to reservoir interchange to the "L" distance between county and reservoir.

The calibration of trip distribution models involves a process of iteration in which the variable parameters are adjusted. These adjustments make it possible for the model to reproduce the O-D distribution.

Gravity Model

The following equation is the form of the gravity model that was used early in this research.

$$T_{IJ} = \frac{P_I A_J F(D_{IJ}) K_{IJ}}{\sum_{X=1}^{N} A_X F(D_{IX}) K_{IX}}$$

Where: T_{IJ} is the estimated trip interchange between county I and reservoir J.

P_I is the production of county I in trip ends.

A_J is the attraction of reservoir J in trip ends.

$F(D_{IJ})$ is the travel time factor for the distance from county I to reservoir J.

K_{IJ} is a specific county to reservoir adjustment factor to allow for the incorporation of the effect on travel patterns of factors not otherwise explained by the gravity model formulation.

N is the number of reservoirs.

As can be seen by the definition of terms, the model was used to distribute from county to reservoir.

The values for the productions and attractions were the county and reservoir trip end summaries of the O-D trip table. The travel time factors or friction factors were taken from the report "Calibrating a Gravity Model for a Small City in Kansas." (12) The ordinate of the curve was changed from travel time in one minute increments to distance in ten mile increments.

There was no indication at the beginning of this study that there was a need to use any K-Factors. The values for the K-Factors were therefore assumed to be equal to 1.00.

Trip End Balancing

After making one iteration of the gravity model with the original parameters, the resulting trip table was summed by reservoir to determine the number of trip ends each reservoir received. Although the gravity model distributes exactly 100 percent of the trips from each production, there is no guarantee that each attraction will receive the correct number of trip ends.

The trip end balancing process was merely one of making the model send more or less trips to a reservoir in order to match the actual attendance. The balancing was accomplished by the following equation:

$$A_J(\text{NEW}) = \frac{(A_J(\text{O-D}))^2}{\sum_{I=1}^{N} T_{IJ}}$$

Where: $A_J(\text{NEW})$ is the attraction for the next iteration.

$A_J(\text{O-D})$ is the reservoir attendance from the O-D study.

$\sum_{I=1}^{N} T_{IJ}$ is the computed number of trips sent to reservoir J from N counties.

An examination of this formula shows that it was derived from a more general balancing equation.

$$A_J(\text{NEW}) = \frac{A_J(\text{PRESENT})\ (A_J(\text{O-D}))}{\sum_{I=1}^{N} T_{IJ}}$$

Where: $A_J(\text{PRESENT})$ is the attraction used to obtain the computed trip ends found in the denominator.

It can be seen that only between the first and second iterations when $A_J(\text{O-D})$ and $A_J(\text{PRESENT})$ are equal, that squaring the O-D trip ends produces a valid procedure.

In the calibration process it was found that the two iterations required to balance the attractions in urban area models were not satisfactory for distribution of reservoir trips. Instead of summing within one percent after the second iteration as in urban studies, the computed trip ends varied up to 50 percent from the data.

At this point it was concluded that the form of the gravity model that is defined and used in present urban studies was not acceptable for distribution of recreation trips to reservoirs.

The form of the gravity model that was proposed and tested within the scope of this research is:

$$T_{IJ} = \frac{P_I AI_J F(D_{IJ})}{\sum_{X=1}^{N} AI_X F(D_{IX})}$$

Where: T_{IJ}, P_I, $F(D_{IJ})$ are as previously defined, and AI_J is the attractive index of reservoir J.

The term (K_{IJ}) was considered to be unity and was therefore dropped from the equation.

The difference between this form and others is that the attraction term of this model is a measure of the cause of attractiveness, whereas, the attraction term of existing models is a measure of the result of the attractiveness (attendance).

The first estimate of a set of attractive indexes was the actual attendance of the reservoirs. After the first iteration of the gravity model, the following equation was used to estimate a new set of attractive indexes that would better describe the attractiveness of each reservoir.

$$AI_J^M = \frac{AI_J^{(M-1)} X \ A_J}{\sum_{I=1}^{N} T_{IJ}}$$

Where: AI_J^M is the attractive index for reservoir J for the next iteration.

M is the iteration number of the next iteration.

$AI_J^{(M-1)}$ is the attractive index from the previous iteration.

A_J is the reservoir attendance in trip ends.

$\sum_{I=1}^{N} T_{IJ}$ is the computed trip ends summed for reservoir J.

With reference to the balancing procedure discussed previously, this form of the gravity model is the same as the one used in the earlier part of this research, only during the first and second iterations, that is, when the attractive index for the previous (first) iteration is the actual or O-D attendance.

Travel Time Factors

The second part of the calibration process for the gravity model involves measuring the effect of distance on the trip making characteristics of the reservoir users. As in the trip end balancing, this is also an iterative procedure.

As mentioned previously, a set of F-Factors from another research project was used for the first estimate. As the model was being calibrated, each new set of estimates was computed by:

$$F(D)^{M'} = F(D)^{M'-1} X \frac{\text{ACTUAL T.L.F. (D)}}{\text{COMPUTED T.L.F. (D)}}$$

Where: $F(D)^{M'}$ is the set of F-Factors for the next iteration for all values of D from 10 to 500 miles by 10-mile increments.

M' is the iteration number for the next iteration.

$F(D)^{M'-1}$ is the set of F-Factors used in the previous iteration.

ACTUAL T.L.F. (D) is the observed percent of the total trips occurring in each increment of trip length (D).

COMPUTED T.L.F. (D) is the computed percent of the total trips occurring in each increment of trip length (D).

The entire set of numbers (over all values of distance (D)) is called trip length frequency distribution, actual or computed.

The new set of F-Factors, when plotted, did not produce a smooth curve. In order to have a set of factors which would be of value in forecasting, a smooth curve was drawn through the computed points and then points on the smooth curve were used for the next iteration.

The total calibration of the model included adjustment of both the attractive indexes and the travel time factors. The procedure followed in the research was to balance the trip ends three times and then recompute new

F-Factors. This process was repeated until the model reproduced the observed trip length frequency distribution as nearly as possible and sent the proper number of trips to each reservoir.

Opportunity Model

The theory of the opportunity model states that the probability that a trip from one zone will find a destination in another zone is equal to the probability that an acceptable destination exists there times the probability that an acceptable destination has not been found (7, 8). This says that the trip maker prefers to make the shortest possible trip, but will, however, consider more distant destinations, if a suitable one has not been found.

In order to adapt the I.O.M. to the distribution of recreational trips to reservoirs, several changes had to be made.

1. Origins and destinations were changed to productions and attractions.
2. The trip purpose stratification that is normally used for the I.O.M. was dropped in favor of total trips.
3. The stratification that has been used in recent studies in association with residential density was dropped.
4. The model was made sensitive to distance by ordering the attractions with respect to distance rather than time.

With reference to change number one (1) above, there was no difference mathematically. In concept, origins and destinations refer to directional trips. This would infer that the toward-home trip for the reservoir user might have a different distribution than the reservoir-bound trip. Although the hypothesis was not tested, it was assumed that all trips must return directly home. Hence, the trip distribution was controlled entirely by the choice of reservoirs.

However, because only trips bound to the reservoir were considered, origins were the same as productions and destinations were the same as attractions.

As a result of the above modifications, the formula for the I.O.M. was:

$$T_{IJ} = P_I(E^{-L(A)} - E^{-L(A-A_J)})$$

Where: T_{IJ}, P_I are as previously defined.

L is the measure of probability that a random destination will satisfy the needs of a particular trip.

A is the sum of the attractions that have been previously considered at nearer reservoirs.

A_J is the attraction of the reservoir under consideration.

As in the original form of the gravity model used in this research, the attractions were measured in terms of reservoir attendance or actual O-D attraction trip ends. However, it was anticipated that the problem encountered with the gravity model in balancing attractions would also be a problem in the I.O.M. After only a short time, it was found that the same problem did exist and the formula for the I.O.M. was changed to:

$$T_{IJ} = P_I(E^{-L(AI)} - E^{-L(AI-AI_J)})$$

Where: T_{IJ}, P_I, L are as previously defined.

AI is the sum of the attractive indexes that have been previously considered at nearer reservoirs.

AI_J is the attractive index of the reservoir under consideration.

The calibration of the I.O.M. is basically the same as for the G.M. in that the parameters of the model are adjusted to properly respond to the effect of distance and the attractiveness of each reservoir.

<u>Calibration of the "L" Value</u>

As can be seen by the I.O.M. formula, distance is not a direct parameter. However, the order of destinations is made by first distributing trips to the closest reservoir and then to each successive one. By changing the "L" value and making it more or less probable for a trip to find a suitable destination at the closest possible destination, the average trip length of the distribution will be changed. The calibration process used to determine the correct "L" was an iterative procedure in which the value of "L" was changed until the computed average trip length of the distribution was the same as the average trip length of the O-D data. The "L" for each iteration was computed by the following equation:

$$L_M = L_{M-1} \times \frac{CATL}{ATL}$$

Where: L_M is the value of "L" for the next iteration.

L_{M-1} is the value of "L" used on the previous iteration.

CATL is the computed average trip length from the previous distribution.

ATL is the average trip length of the O-D data.

As can be seen in the equation, when the computed average trip length equals the actual, the value of "L" will not change from one iteration to the next.

In order to have a somewhat realistic value of "L" to begin the calibration, interview data were substituted into the opportunity model formula. Because the trip interchange between Sedgwick County and Fall River Reservoir was the largest single movement, it was used in the calculation.

Substituting known values into the opportunity model formula, it becomes:

$$1371 = 1882(E^{-L(0)} - E^{-L(0-1954)})$$

Where: $T_{IJ} = 1371$ (trip interchange)

$P_I = 1882$ (productions of Sedgwick County)

$AI_J = 1954$ (trip ends attracted to Fall River Reservoir)

Since $E^0 = 1$

$$E^{-L(0)} - E^{-L(0-1954)}) = 1 - E^{-1954L}$$

$$\text{Then } L = \frac{-LOG(1 - \frac{1371}{1882})}{1954} = 0.000647$$

The value of 0.000647 was used for the first iteration of the calibration of the opportunity model.

Like the gravity model, the I.O.M. does not assure that the proper number of trips will be sent to each attraction. A part of the calibration of the I.O.M. also was to determine a set of attractive indexes which would cause the model to distribute the same number of trips to each reservoir as was determined from the O-D survey.

The procedure for balancing and recomputing the attractive indexes for the I.O.M. is identical to the method previously described for the G.M.

RESULTS

The purpose of calibrating a distribution model is to estimate parameters that will reproduce observed data. The results of these attempts to calibrate the G.M. and the I.O.M. are shown in the following section in the form of tables and graphs.

Gravity Model

As mentioned in the study procedure, the G.M. used the observed trip length frequency distribution as a basis to adjust the travel time factors. The O-D and the computed trip length frequency distribution are shown in Fig. 3.

The end product of the calibration of the gravity model is a set of travel time or F-Factors which describe the influence of trip length on the desire to make trips and a set of attractive indexes, which describes the relative attractiveness of each reservoir. Figure 4 shows the plot of the F-Factors which resulted from the balancing process of the next to last iteration of the model. Because the calibrated distribution model will be used as a predictive tool an irregular F-Factor curve is not acceptable. The smooth curve in Fig. 5 is the hand fitted curve through the irregular points that were used to make final iteration.

Although a favorable comparison of the O-D and computed T.L.F. distributions does not guarantee a good distribution, it does tell whether the given F-Factor curve was able to produce a trip table with as many 10 mile, 20 mile, etc., trips as the O-D data.

The county to reservoir trip interchange for the calibrated gravity model is shown in Table B of the appendix.

FIGURE 3

TRIP LENGTH FREQUENCY DISTRIBUTION
GRAVITY MODEL CALIBRATION

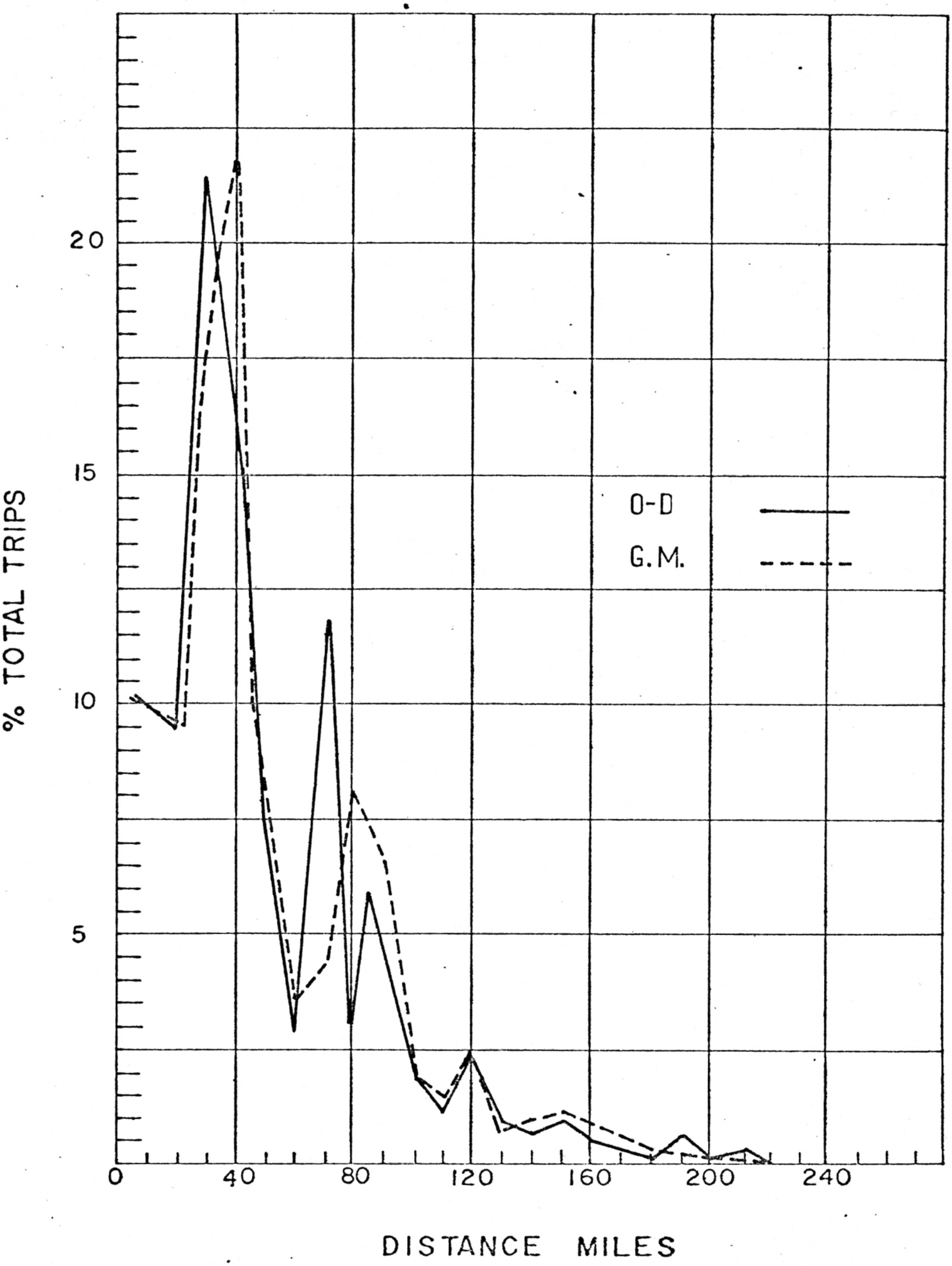


FIGURE 4

GRAVITY MODEL F-FACTORS
CALIBRATED MODEL (BALANCED)

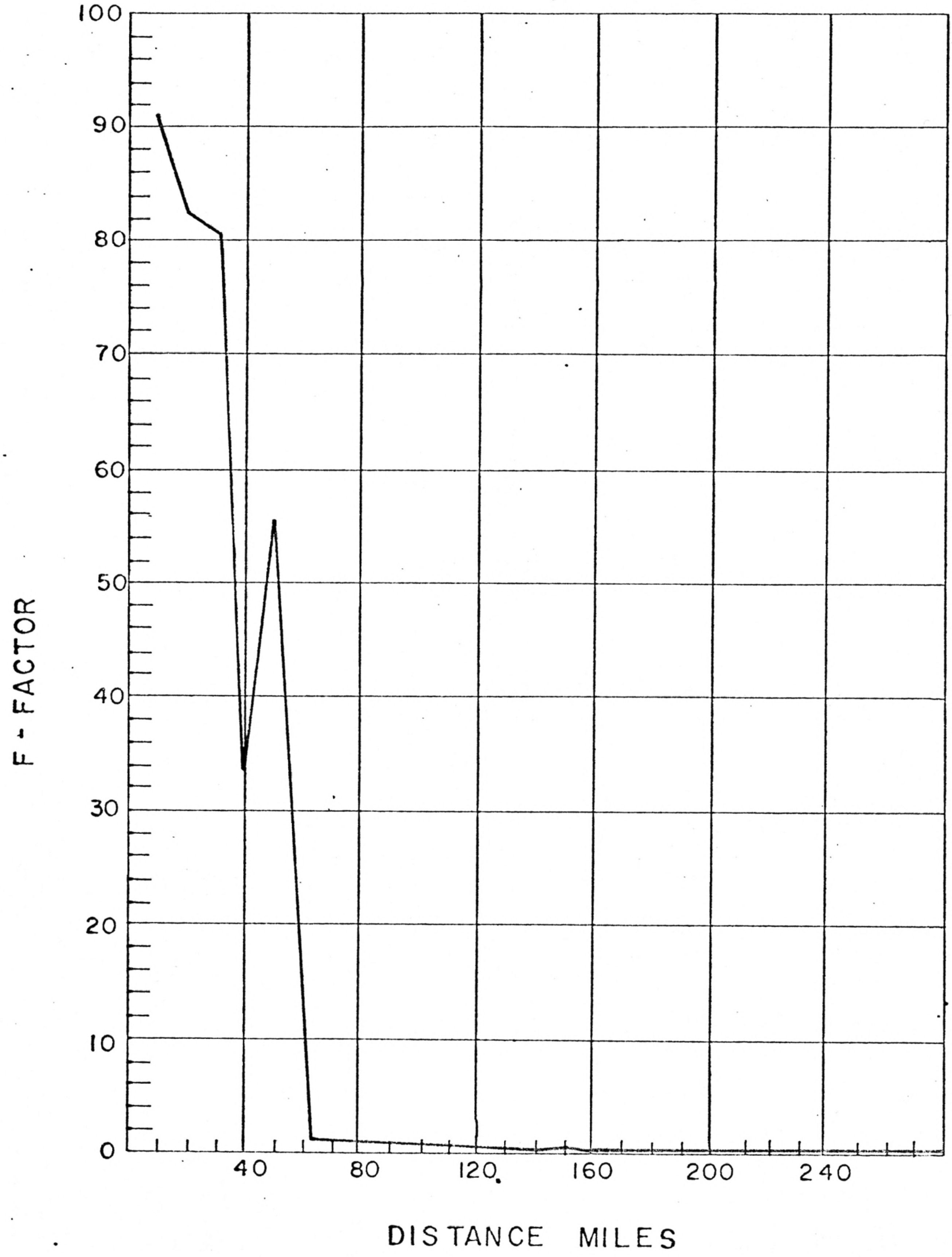
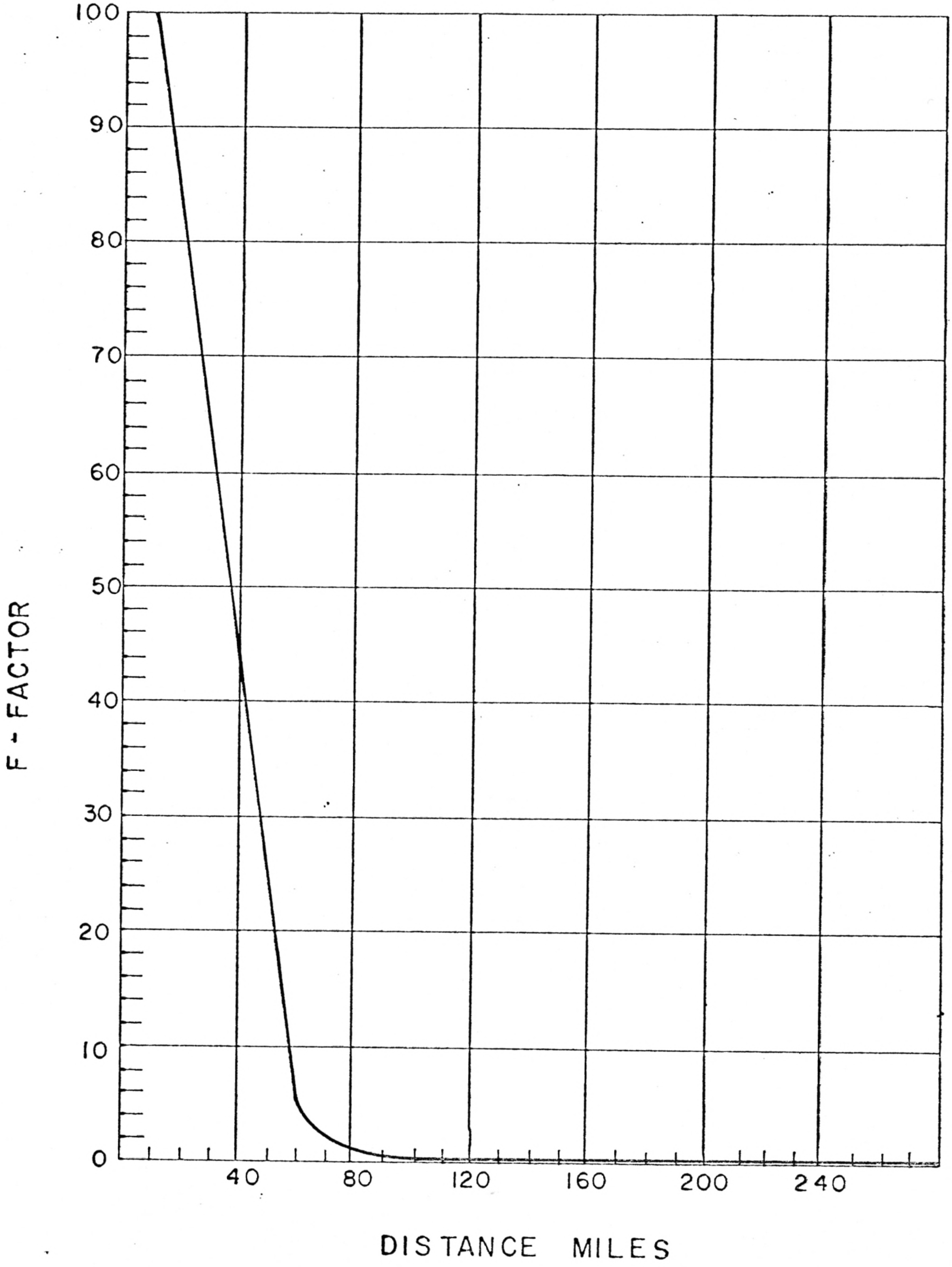


FIGURE 5
GRAVITY MODEL F-FACTORS
CALIBRATED MODEL (SMOOTHED)

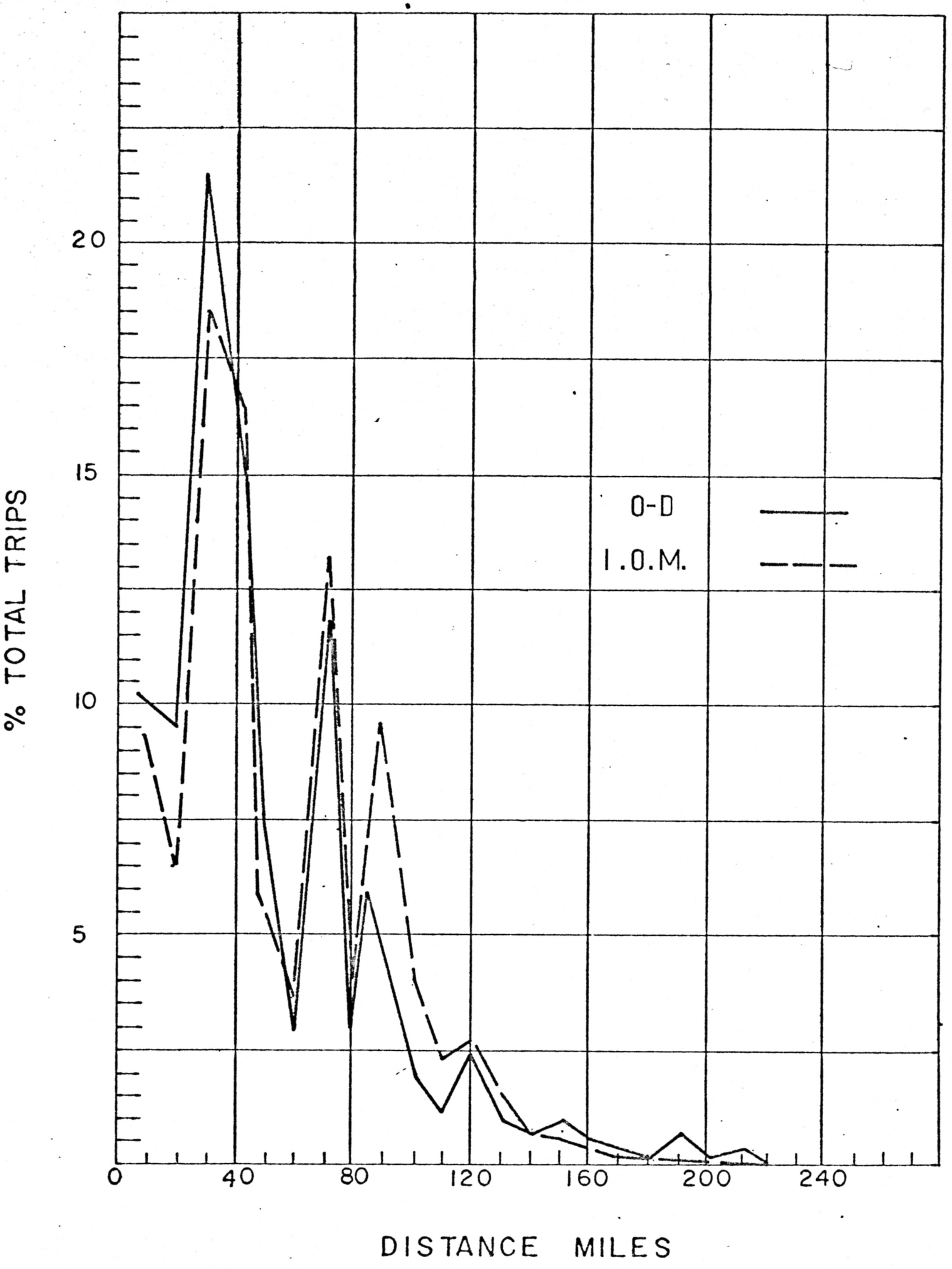


Opportunity Model

The successful calibration of the I.O.M. is a result of an iteration process in which the parameters are changed to represent actual conditions. It was found during calibration than an "L" value of 0.000690 did the best job of producing a distribution with the same average trip length as the O-D data.

Although there is no direct relationship between the calibration of the I.O.M. and the trip length frequency (T.L.F.) distribution, the comparison of the actual and computed T.L.F. distribution is useful in determining if a good fit is actually being accomplished. Figure 6 shows the T.L.F. distribution of the calibrated I.O.M. and the actual O-D data.

FIGURE 6
TRIP LENGTH FREQUENCY DISTRIBUTION
OPPORTUNITY MODEL CALIBRATION



ANALYSIS OF RESULTS

Part of the evaluation of the ability of a distribution model to reproduce observed data is relative and a matter of judgment. Some of the statistical tests which are popular in testing results cannot be applied because the models do not produce independent estimates. The estimated trip interchanges are not independent because both the G.M. and the I.O.M. are entirely made up of ratios and balancing. Therefore, only generalized statements, based on judgment can be made about certain phases of the calibration process of both models.

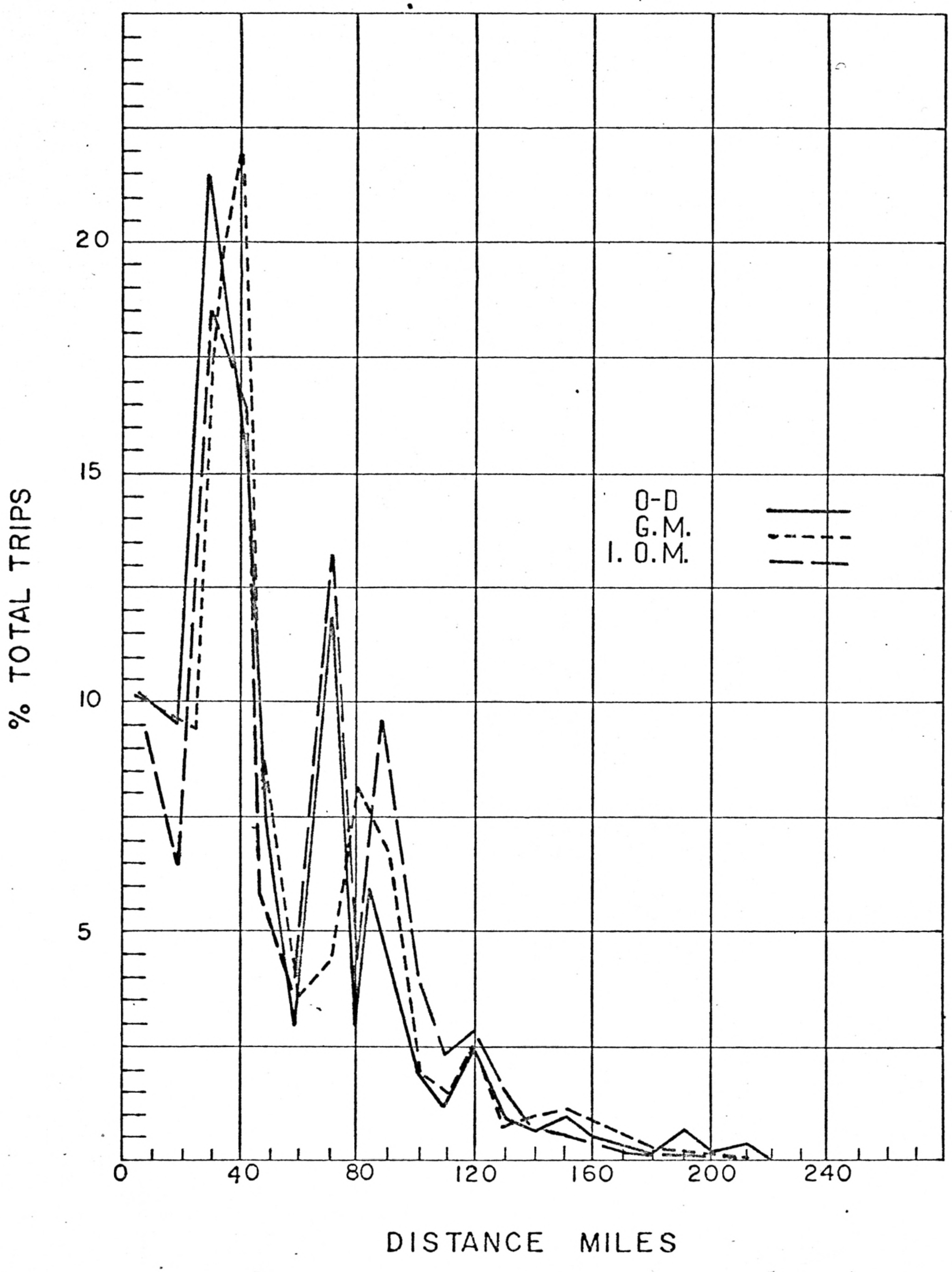
Although the calibration of each model was made independently, the analysis of each model is difficult without making a comparison between the two.

Trip Length Frequency Distribution

Figure 7 shows a plot of the T.L.F. distribution for both models and the O-D data. Both models were able to reproduce the O-D distribution quite well. As can be seen, each model was able to reproduce certain sections of the curve better than the other.

The average trip length produced by each model was essentially the same. However, the lengths used in the G.M. were rounded to the nearest ten miles.

FIGURE 7
TRIP LENGTH FREQUENCY DISTRIBUTION



Balancing Trip Ends

Because of the limited number of reservoirs, the distribution of destinations for trips was much less homogeneous than the distribution of an urban area. Because of this some of the attendances tended to be misleading in indicating the attractiveness of that reservoir. A reservoir that is located near a large urban area may be less attractive than a reservoir that is many miles from population centers. However, because the one is close and handy to get to, attendance may be much more than to the more attractive reservoir. This actually appeared to be the case with the reservoirs under study. Both models reacted the same to the condition mentioned.

At the time the interviews were made, there was almost no development at Pomona. An analysis of trip ends by trip purpose, in Table C of the appendix, showed that nearly three-fourths of the trips made to Pomona were for sightseeing. Most of these people were attracted to see a new reservoir that had just recently filled.

A condition just the opposite of Pomona existed at the Harlan County Reservoir in Nebraska. It is one of the oldest reservoirs in this area and is said to be one of the most attractive. Harlan County is a long distance from any population centers and also has a large amount of competition from other reservoirs.

By using the attractive index to explain the fact that the reservoir attendance does not necessarily indicate its attractiveness, it was possible to explain the excess amount of balancing necessary to balance trip ends. It can be seen from Table 3 for the G.M. and Table 4 for the I.O.M. that the attractiveness of Pomona was very low with respect to its attendance. On the other hand both models indicated that the attractiveness of Harlan County was very much higher than the attendance indicated.

When comparing the two models, it can be seen that some of the attractive indexes vary in opposite directions. An explanation of this might be that the condition existing at certain reservoirs was easier for one model to reproduce than the other.

The attractive indexes which resulted from the calibration of the G.M. are shown in Table 3. Across from the index for each reservoir are the actual number of trip ends and the computed number of trip ends which resulted from the use of that attractive index.

Table 3

Attractive Indexes
Gravity Model

Reservoir	No.	Attractive Index	O-D Trip Ends	Computed Trip Ends
Cedar Bluff	1	1,764	830	745
Kanopolis	2	1,399	2,142	2,278
Toronto	3	2,320	1,248	1,259
Tuttle Creek (S)	4	4,946	3,784	3,844
Lovewell	5	300	602	550
Kirwin	6	907	451	402
Webster	7	1,114	614	534
Fall River	8	2,497	1,954	1,962
Pomona	9	2,108	4,448	4,783
Harlan County	10	5,259	3,048	2,755
Tuttle Creek (N)	11	1,100	729	729
Total		25,705	19,850	19,841

The form of the G.M. used by others requires that the total productions equal total attractions. However, in this form of the G.M., the sum of the attractive indexes do not have to equal total productions.

Table 4 shows the attractive index for each reservoir which resulted from the calibration of the I.O.M. The computed trip ends are shown for each reservoir along with the O-D trip ends. Part of the calibration process involved the determination of a set of attractive indexes which would attract the proper number of trips to each reservoir.

Table 4

Attractive Indexes
Opportunity Model

Reservoir	No.	Attractive Index	O-D Trip Ends	Computed Trip Ends
Cedar Bluff	1	2,453	830	825
Kanopolis	2	2,255	2,142	2,185
Toronto	3	1,041	1,248	1,273
Tuttle Creek (S)	4	2,818	3,784	3,775
Lovewell	5	742	602	662
Kirwin	6	880	451	452
Webster	7	2,326	614	523
Fall River	8	1,798	1,954	2,048
Pomona	9	2,302	4,448	4,826
Harlan County	10	7,206	3,048	2,553
Tuttle Creek (N)	11	1,101	729	686
Total		24,823	19,850	19,808

As with the G.M., there was no attempt to make the attractive indexes equal to the production. It could have been accomplished in the above case by factoring each attractive index down by a ratio of 19,850 over 24,823.

F-Factors

Because the I.O.M. does not use F-Factors, this analysis is made only for the G.M. and no comparison can be made. It can be seen in Fig. 7 that the F-Factor used did an acceptable job of reproducing the O-D trip length frequency. However, to be of any value as a forecasting tool, there should not be any abrupt changes in the curve. The following example is given to show the weakness of the F-Factor curve that resulted from this research.

A county produced 100 recreational trips which are attracted to two existing reservoirs and one proposed reservoir. One reservoir is 40 miles away and has an attractive index of 1,000 and the other reservoir is 80 miles from the county and has an attractive index of 4,000. The new reservoir has an attractive index of 2,000 and is 54 or 55 miles from the production, depending on how the centroid is located. This example will show the influence of the one mile difference in the location of the centroid.

Case 1 County to Reservoir Distance of 54 Miles
Production = 100 Trip Ends

Reservoir	Attractive Index	Distance	F-Factors	$AI_J \times F(D_{IJ})$	Trips
1	1,000	40	40.00	40,000	40
2	4,000	80	1.00	4,000	4
3	2,000	50	27.50	55,000	56
				99,000	100

Case 2 County to Reservoir Distance of 55 Miles
Production = 100 Trip Ends

Reservoir	Attractive Index	Distance	F-Factors	$AI_J \times F(D_{IJ})$	Trips
1	1,000	40	40.00	40,000	68
2	4,000	80	1.00	4,000	7
3	2,000	60	7.50	15,000	25
				59,000	100

As can be seen from the two cases above in which the calibrated set of F-Factors are used, the model is too sensitive to distance. This sensitivity would not be nearly as acute if the F-Factors were defined for each mile of distance rather than for each ten miles. However, because the county to reservoir distance cannot be computed accurately to the nearest mile, the accuracy of the F-Factor table to the nearest mile cannot be justified.

L-Factor

The value of "L" of 0.000690 which resulted from the calibration of the I.O.M. did a satisfactory job of reproducing the trip length frequency distribution. Because one value of "L" describes the whole decay curve, this is a very good model to use for forecasting. However, if two reservoirs are very nearly the same distance from the production, the model distributes to the closest one without any regard to the other, even though it may be very competitive.

Trip Interchange

The ultimate test of a distribution model's ability to reproduce the actual O-D data is to compare the individual trip interchange of the model to the O-D. Because there were 1,650 possible movements considered in the research, it would be difficult to make any conclusions about the results from a manual comparison. The procedure used to compare the trip interchange of the models to the O-D data was to square the difference of the two values and then sum the squares by volume group and by reservoir.

The county to reservoir trip interchange for the computed I.O.M. is listed in Table B of the appendix.

Although the method used to measure the differences between actual and computed interchanges is rather crude, normal statistical tests cannot be used. The computed trip interchanges are not independent estimates because both the actual and computed interchanges add to the same total for each reservoir.

In order to see if one model could reproduce certain volume groups better than the other, the sums of squares were tabulated by O-D volume group without regard to reservoir. Table 5 shows the results of the gravity model and Table 6 shows the results of the opportunity model. The zeros in the cells of both tables indicate that an interchange of that volume group did not exist for that reservoir.

Table 5

Gravity Model Distribution
Frequency Distribution and Analysis of Differences
Sum of Squares
Volume Group

Res*	0/ 24	25/ 49	50/ 74	75/ 99	100/ 149	150/ 199	200/ 299	300/ 499	500/ 999	1000/ 1499
1	746	221	2962	0	4	49	0	0	0	0
2	407	1995	2909	1600	1	16	2401	16	6889	0
3	2020	789	2177	784	0	10669	38416	0	0	0
4	10689	493	0	3965	0	0	0	17689	10000	361
5	3429	989	36	848	900	0	0	0	0	0
6	6190	818	0	1936	0	0	30276	0	0	0
7	773	196	325	484	0	0	7921	0	0	0
8	9433	1853	1053	5184	100	0	0	0	0	81724
9	7596	0	1089	0	49	1089	0	400	81	84296
10	5119	5158	5483	1	35802	0	180	4685	3481	0
11	4618	11948	0	2209	10609	0	784	0	0	0

Table 6

Opportunity Model Distribution
Frequency Distribution and Analysis of Differences
Sum of Squares
Volume Group

Res*	0/ 24	25/ 49	50/ 74	75/ 99	100/ 149	150/ 199	200/ 299	300/ 499	500/ 999	1000/ 1499
1	2011	25	1925	0	361	324	0	0	0	0
2	3282	1652	2690	12100	441	1156	144	2809	2209	0
3	12567	6198	1606	1089	0	8761	784	0	0	0
4	10610	317	324	10345	0	0	0	31760	8100	2601
5	30272	269	400	5329	5476	0	0	0	0	0
6	1555	482	0	196	0	0	2809	0	0	0
7	1106	1369	260	625	0	0	676	0	0	0
8	15327	1167	953	1	169	0	0	0	0	1156
9	27245	0	256	0	49	36	0	67162	25921	75192
10	8939	3236	4159	0	19518	0	8104	19604	9	0
11	9596	3185	0	7056	7569	0	3661	0	0	0

* See reservoir names in Table D of the appendix.

It can be seen from Table 7 that for certain reservoirs, the gravity model did a better job of reproducing the movements to some reservoirs than the opportunity model. However, at other reservoirs, such as Kirwin and Fall River, the opportunity model was better. In looking at the total sums of squares of the differences, the gravity model was slightly better. Because of the small sample taken at Fall River and Pomona, see Table 2, the large sums of squares may really be caused by weak data rather than the models.

Table 7

Comparison of Model Distribution
Sums of Squares by Reservoir

Reservoir	No.	Gravity Model	Opportunity Model
Cedar Bluff	1	3,982	4,646
Kanopolis	2	16,234	26,483
Toronto	3	54,855	31,005
Tuttle Creek (S)	4	43,197	64,057
Lovewell	5	6,202	41,746
Kirwin	6	39,220	5,042
Webster	7	9,699	4,036
Fall River	8	99,347	18,773
Pomona	9	94,600	195,861
Harlan County	10	59,909	63,569
Tuttle Creek (N)	11	30,168	31,067
Total		457,413	486,285

Table 8 shows the results of a comparison of sums of squares by volume group. The gravity model was able to reproduce four of the volume groups much better than the opportunity model. However, it appears that in the other six groups, the opportunity model had the edge.

Table 8

Comparison of Model Distribution Sums of Squares by Volume Group

Volume Group	Gravity Model	Opportunity Model
0/24	51,020	122,510
25/49	24,460	17,900
50/74	16,034	12,573
75/99	17,011	36,741
100/149	47,465	33,583
150/199	11,823	10,277
200/299	79,978	16,178
300/499	22,790	121,335
500/999	20,451	36,239
1,000/1,499	166,381	78,949
Total	457,413	486,285

CONCLUSIONS

The purpose of a mathematical model is to explain or reproduce a complicated real life situation by means of a rather simple formula. In order to be a satisfactory model, it must first of all reproduce the real life circumstance within some prescribed limit. In addition to being accurate, the parameters of the model must be obtainable, it must be easily calibrated and it must be easily solved and understandable. Finally, if the model is to be truly useful, it must have the ability to predict some future occurrence.

In reviewing the results of the analysis of the two distribution models, these conclusions became apparent:

1. It is evident that the gravity model is slightly more accurate than the opportunity model.
2. The parameters of both models are nearly the same and present little difficulty in obtaining.
3. Neither model could be calibrated using the reservoir attendance as the attraction.
4. Both models could be calibrated if the attractive index concept was used.
5. Because of the speed of electronic data processing systems, the ease of solution is of little importance. Therefore, the numerous and complex calculations of both models were handled with ease.
6. It is apparent from the literature that the gravity model has much more documentation than the opportunity model. It was, therefore, surmised that the G.M. is more easily understood than the I.O.M.

7. Although there were no actual field data available to support this conclusion, it became apparent from the experience gained in the calibration of the two models and through the example problem, that the opportunity model was a better predictive tool than the gravity model.

Because of the need for a predictive tool in estimating future recreational travel patterns to reservoirs, the results of this research appear to support the intervening opportunities model as being the better of the two models.

SUGGESTIONS FOR FURTHER RESEARCH

The extensive use of mathematical models is relatively new. Their use has paralleled the development of the high speed electronic data processing systems. Because of their infancy, most of the models are rather crude and sometimes their application is rather awkward.

From the experience gained from this research, several avenues of thought have certainly emerged. They are:

1. Data should be collected over a period of time to test the effect of competition with new reservoirs.
2. Because of the effect of the wind on the open water of the reservoir, much of the activities take place in the coves. Also, because of the sizes of many of the reservoirs, distance is an important consideration even after one reaches the reservoir. For these reasons, it would seem that a distribution model could be calibrated using individual areas and parks at the reservoirs as attractions.
3. Because the reservoirs are served by highways of various quality, additional work should be done, using travel time as a measure of spatial separation.

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APPENDIX

Table A

County Names and Codes

County	Seq. No.	Odd No.	State No.*	County	Seq. No.	Odd No.	State No.*
Allen	1	1	15	Greeley	36	71	15
Anderson	2	3	15	Greenwood	37	73	15
Atchison	3	5	15	Hamilton	38	75	15
Barber	4	7	15	Harper	39	77	15
Barton	5	9	15	Harvey	40	79	15
Bourbon	6	11	15	Haskell	41	81	15
Brown	7	13	15	Hodgeman	42	83	15
Butler	8	15	15	Jackson	43	85	15
Chase	9	17	15	Jefferson	44	87	15
Chautauqua	10	19	15	Jewell	45	89	15
Cherokee	11	21	15	Johnson	46	91	15
Cheyenne	12	23	15	Kearny	47	93	15
Clark	13	25	15	Kingman	48	95	15
Clay	14	27	15	Kiowa	49	97	15
Cloud	15	29	15	Labette	50	99	15
Coffey	16	31	15	Lane	51	101	15
Comanche	17	33	15	Leavenworth	52	103	15
Cowley	18	35	15	Lincoln	53	105	15
Crawford	19	37	15	Linn	54	107	15
Decatur	20	39	15	Logan	55	109	15
Dickinson	21	41	15	Lyon	56	111	15
Doniphan	22	43	15	McPherson	57	113	15
Douglas	23	45	15	Marion	58	115	15
Edwards	24	47	15	Marshall	59	117	15
Elk	25	49	15	Meade	60	119	15
Ellis	26	51	15	Miami	61	121	15
Ellsworth	27	53	15	Mitchell	62	123	15
Finney	28	55	15	Montgomery	63	125	15
Ford	29	57	15	Morris	64	127	15
Franklin	30	59	15	Morton	65	129	15
Geary	31	61	15	Nemaha	66	131	15
Gove	32	63	15	Neosho	67	133	15
Graham	33	65	15	Ness	68	135	15
Grant	34	67	15	Norton	69	137	15
Gray	35	69	15	Osage	70	139	15

* 15 - Kansas; 26 - Nebraska; 24 - Missouri

Table A (continued)

County Names and Codes

County	Seq. No.	Odd No.	State No.*	County	Seq. No.	Odd No.	State No.*
Osborne	71	141	15	Adams	106	001	26
Ottawa	72	143	15	Buffalo	107	019	26
Pawnee	73	145	15	Butler	108	023	26
Phillips	74	147	15	Cass	109	025	26
Pottawatomie	75	149	15	Chase	110	029	26
Pratt	76	151	15	Clay	111	035	26
Rawlins	77	153	15	Colfax	112	037	26
Reno	78	155	15	Dawson	113	047	26
Republic	79	157	15	Dodge	114	053	26
Rice	80	159	15	Douglas	115	055	26
Riley	81	161	15	Dundy	116	057	26
Rooks	82	163	15	Fillmore	117	059	26
Rush	83	165	15	Franklin	118	061	26
Russell	84	167	15	Frontier	119	063	26
Saline	85	169	15	Furnas	120	065	26
Scott	86	171	15	Gage	121	067	26
Sedgwick	87	173	15	Gosper	122	073	26
Seward	88	175	15	Hall	123	079	26
Shawnee	89	177	15	Hamilton	124	081	26
Sheridan	90	179	15	Harlan	125	083	26
Sherman	91	181	15	Hayes	126	085	26
Smith	92	183	15	Hitchcock	127	087	26
Stafford	93	185	15	Jefferson	128	095	26
Stanton	94	187	15	Johnson	129	097	26
Stevens	95	189	15	Kearney	130	099	26
Sumner	96	191	15	Lancaster	131	109	26
Thomas	97	193	15	Lincoln	132	111	26
Trego	98	195	15	Merrich	133	121	26
Wabaunsee	99	197	15	Nemaha	134	127	26
Wallace	100	199	15	Nuckolls	135	129	26
Washington	101	201	15	Otoe	136	131	26
Wichita	102	203	15	Pawnee	137	133	26
Wilson	103	205	15	Perkins	138	135	26
Woodson	104	207	15	Phelps	139	137	26
Wyandotte	105	209	15	Polk	140	143	26

* 15 - Kansas; 26 - Nebraska; 24 - Missouri

Table A (continued)

County Names and Codes

County	Seq. No.	Odd No.	State No.*	County	Seq. No.	Odd No.	State No.*
Redwillow	141	145	26	Thayer	146	169	26
Richardson	142	147	26	Washington	147	177	26
Saline	143	151	26	Webster	148	181	26
Saunders	144	155	26	York	149	185	26
Seward	145	159	26	Missouri	150		24

* 15 - Kansas; 26 - Nebraska; 24 - Missouri

TABLE B
COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
1	3	94	61	66
1	4	0	3	0
1	8	25	41	51
1	9	0	13	2
2	2	2	0	0
2	3	16	13	5
2	4	0	3	1
2	8	0	9	5
2	9	106	99	113
3	2	2	0	0
3	4	3	0	3
3	9	0	4	2
3	11	0	1	0
5	1	64	24	10
5	2	61	110	114
5	3	0	0	1
5	4	6	0	2
5	6	2	0	3
5	7	2	4	4
5	9	0	0	1
5	10	4	1	5
6	3	14	7	6
6	8	0	5	6
6	9	0	2	2
7	4	0	1	6
7	9	0	8	2
7	11	10	1	2
8	1	2	0	0
8	2	0	2	0
8	3	30	52	20
8	4	0	12	1
8	8	63	35	81
8	11	6	0	0
9	4	3	3	2
9	8	0	0	1

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
14	2	2	2	0
14	4	22	22	40
14	5	0	1	0
14	10	21	0	0
14	11	10	29	15
15	2	6	3	2
15	4	6	20	16
15	5	47	34	31
15	6	1	0	1
15	7	4	0	2
15	10	0	0	2
15	11	19	27	30
16	3	50	59	49
16	4	0	3	0
16	7	2	0	0
16	8	0	8	38
16	9	61	45	28
16	11	3	0	0
18	1	2	0	0
18	2	0	6	2
18	3	3	7	14
18	4	6	1	3
18	6	1	0	0
18	8	38	36	30
18	9	0	0	1
18	11	0	0	1
19	3	8	18	16
19	4	0	1	0
19	8	13	13	18
19	9	15	4	2
20	1	1	0	2
20	5	2	0	0
20	6	3	14	4
20	7	2	14	5
20	10	25	3	21

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
21	2	46	6	3
21	4	3	44	44
21	7	2	0	0
21	8	0	0	1
21	9	0	1	0
21	11	0	1	3
22	4	0	0	2
22	6	1	0	0
22	9	0	4	2
22	11	3	0	0
23	1	1	0	0
23	2	2	0	0
23	3	11	2	1
23	4	10	42	7
23	8	0	1	1
23	9	197	191	230
23	11	19	4	0
24	1	19	18	14
24	2	0	1	2
24	4	3	0	0
24	6	0	0	1
24	7	0	3	2
24	8	0	0	1
24	10	0	0	2
25	3	3	4	13
25	4	0	1	0
25	8	25	20	15
25	9	0	3	0
26	1	182	200	175
26	2	8	0	0
26	4	0	0	1
26	5	2	0	0
26	6	1	4	3
26	7	52	36	62
26	10	0	5	5

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
27	1	0	20	1
27	2	115	94	116
27	4	3	0	0
27	5	0	2	0
27	6	0	0	1
27	7	0	2	0
27	11	0	0	1
28	1	15	14	14
28	2	2	1	0
28	6	0	0	1
28	7	0	3	2
29	1	58	57	55
29	2	0	2	3
29	6	1	0	1
29	7	2	10	7
29	10	8	0	3
30	1	1	0	0
30	2	0	1	1
30	3	28	100	9
30	4	3	24	5
30	8	0	68	10
30	9	923	762	932
30	11	3	2	1
31	1	1	0	0
31	2	6	50	2
31	3	0	1	0
31	4	903	813	803
31	5	0	1	0
31	7	0	0	1
31	8	0	1	1
31	9	0	11	2
31	11	38	72	140
32	1	36	33	26
32	6	0	1	1
32	7	4	6	10

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
32	10	0	1	3
33	1	9	12	27
33	4	0	0	1
33	6	4	1	3
33	7	58	60	43
33	10	4	2	1
34	1	1	4	5
34	7	0	1	0
34	10	4	0	0
36	1	1	1	1
37	3	169	133	99
37	4	0	6	0
37	8	89	90	161
37	9	0	29	0
37	11	3	1	0
38	1	4	4	4
38	7	0	1	0
39	2	2	2	1
39	5	0	0	1
40	1	1	0	1
40	2	52	69	42
40	3	5	9	9
40	4	0	2	11
40	8	25	6	19
40	9	0	0	3
40	11	3	0	2
41	1	4	4	4
41	7	0	1	0
42	1	16	13	16
42	7	0	2	0
43	4	0	1	1
43	9	0	0	1
43	11	3	2	1
45	2	0	0	2
45	4	3	0	1

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
45	5	97	42	69
45	6	1	29	17
45	7	4	0	2
45	10	0	34	14
45	11	0	0	1
46	2	0	1	1
46	3	6	3	9
46	4	51	69	51
46	6	1	0	0
46	8	0	2	10
46	9	303	312	315
46	11	32	6	6
48	1	0	0	1
48	2	13	16	11
48	3	0	1	3
48	4	0	0	1
48	8	0	3	4
48	10	4	0	0
48	11	3	0	0
49	1	3	4	2
49	2	0	0	1
49	7	2	1	1
49	10	0	0	1
50	3	3	16	19
50	4	0	1	0
50	6	1	0	0
50	8	13	11	11
50	9	15	4	2
51	1	19	15	18
51	2	0	1	0
51	7	0	3	0
51	10	0	0	1
52	1	1	0	0
52	4	3	4	11
52	8	0	0	1

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
52	9	15	18	9
52	11	3	0	2
53	2	31	37	42
53	4	0	1	2
53	5	8	4	1
53	6	1	1	0
53	7	0	5	0
53	8	0	0	1
53	11	6	0	0
54	3	3	0	1
54	8	0	0	1
54	9	0	2	1
55	1	8	16	13
55	2	2	0	0
55	6	0	0	1
55	7	10	3	3
55	10	0	0	3
56	1	4	0	0
56	2	4	0	0
56	3	30	7	12
56	4	3	2	1
56	8	25	5	47
56	9	0	56	10
56	11	3	0	1
57	1	0	0	1
57	2	304	251	308
57	3	0	0	1
57	4	13	58	4
57	5	0	4	0
57	6	1	0	0
57	8	0	0	2
57	9	0	2	1
57	10	0	0	1
57	11	0	3	0
58	2	11	15	4

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
58	3	6	0	2
58	4	0	3	6
58	8	0	0	3
58	9	0	0	3
58	11	3	0	1
59	2	2	0	0
59	4	22	25	46
59	5	2	2	0
59	7	2	0	0
59	9	0	2	0
59	11	35	34	17
60	1	1	3	3
60	2	2	0	0
61	1	1	0	0
61	3	0	2	0
61	8	0	1	0
61	9	15	13	16
62	2	0	28	7
62	4	3	0	5
62	5	30	24	32
62	6	11	3	5
62	7	6	3	4
62	10	8	0	3
62	11	0	0	3
63	3	58	56	82
63	4	0	3	0
63	8	51	38	24
63	9	0	12	3
64	4	10	21	17
64	8	0	0	1
64	9	15	3	6
64	11	0	0	1
66	4	6	6	10
66	6	1	0	0
66	9	0	1	1

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
66	10	0	0	1
66	11	6	7	2
67	3	39	40	37
67	4	0	2	0
67	7	2	0	0
67	8	38	27	41
67	9	0	9	1
68	1	103	84	101
68	2	0	3	0
68	7	0	15	1
68	10	0	0	1
69	1	2	0	3
69	6	35	46	12
69	7	2	0	17
69	10	62	55	69
70	2	0	2	1
70	3	16	120	31
70	4	0	28	15
70	8	0	81	17
70	9	1135	916	1085
70	11	0	3	2
71	1	1	0	1
71	4	0	0	1
71	5	2	5	1
71	6	33	52	50
71	7	75	50	53
71	10	4	7	8
72	2	29	25	24
72	4	0	6	7
72	5	3	0	0
72	11	0	0	1
73	1	30	30	19
73	2	6	5	6
73	4	0	0	1
73	6	0	0	2

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
73	7	0	1	4
73	10	0	0	5
74	1	1	0	1
74	6	244	191	70
74	7	38	1	52
74	10	136	227	296
75	4	29	40	42
75	7	2	0	0
75	9	0	2	0
75	11	16	4	5
76	1	2	2	2
76	2	8	10	5
76	3	3	0	1
76	6	0	0	1
76	7	0	0	1
76	8	0	0	2
76	10	0	0	1
78	1	8	5	1
78	2	286	274	335
78	3	3	38	3
78	4	22	1	2
78	5	0	4	0
78	6	0	0	1
78	8	25	25	3
78	9	0	0	1
78	11	3	0	1
79	2	2	2	2
79	4	3	14	9
79	5	91	43	83
79	6	3	14	2
79	7	2	0	1
79	10	4	0	6
79	11	3	34	5
80	1	3	35	1
80	2	195	161	199

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
80	3	0	0	1
80	4	3	0	1
80	5	2	3	0
80	6	1	0	0
80	7	0	4	1
80	9	0	0	1
81	1	2	0	0
81	2	6	20	1
81	3	3	2	0
81	4	1655	1604	1636
81	5	0	2	0
81	7	4	0	0
81	8	0	1	1
81	9	0	100	3
81	10	0	0	1
81	11	202	143	230
82	1	8	0	5
82	2	2	0	1
82	4	3	0	0
82	6	6	26	53
82	7	256	230	167
82	10	12	31	61
83	1	40	36	40
83	2	2	1	1
83	6	1	0	0
83	7	0	6	2
83	10	0	0	1
84	1	50	68	51
84	2	8	12	9
84	4	0	0	1
84	6	3	0	7
84	7	18	3	10
84	10	4	0	5
85	1	8	6	4
85	2	779	732	862

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
85	3	3	0	1
85	4	80	168	37
85	5	8	5	3
85	6	0	0	1
85	7	6	0	2
85	8	13	0	2
85	9	0	1	4
85	10	4	0	3
85	11	29	15	9
86	1	22	33	32
86	2	0	1	2
86	6	0	0	1
86	7	0	6	4
86	8	13	0	0
86	10	4	0	2
87	1	12	0	8
87	2	99	209	139
87	3	251	279	447
87	4	99	48	145
87	5	0	0	3
87	6	1	0	0
87	7	2	0	0
87	8	1371	1337	1089
87	9	0	3	25
87	10	8	0	0
87	11	38	4	26
88	1	0	2	2
88	2	2	0	0
89	2	8	2	1
89	3	50	11	10
89	4	307	279	174
89	7	2	0	0
89	8	13	8	11
89	9	1105	1270	1391
89	11	112	25	9

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
90	1	0	1	1
90	7	6	5	5
91	1	0	2	3
91	4	3	0	0
91	6	1	0	1
91	7	6	8	4
91	10	0	0	2
92	5	20	0	6
92	6	78	64	34
92	7	2	0	2
92	10	41	76	99
93	1	10	5	5
93	2	15	24	12
93	3	0	0	1
93	4	0	0	2
93	6	0	0	2
93	7	6	1	2
93	8	0	0	3
93	10	0	0	3
95	1	1	8	9
95	2	2	0	0
95	4	6	0	0
95	7	0	1	0
96	1	1	0	0
96	2	6	3	4
96	3	3	5	7
96	4	6	1	3
96	6	1	0	0
96	8	13	22	15
96	9	0	0	1
96	11	0	0	1
97	1	2	4	4
97	6	1	0	2
97	7	12	19	11
97	10	8	0	7

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
98	1	58	58	52
98	2	2	0	0
98	6	1	1	0
98	7	10	10	19
98	10	0	1	0
99	4	29	43	47
99	9	15	3	1
99	11	6	4	2
100	1	1	1	1
101	4	0	4	3
101	5	11	3	1
101	6	1	0	0
101	10	4	0	1
101	11	0	9	11
102	1	2	3	4
102	7	2	1	0
103	3	155	131	143
103	4	0	6	0
103	8	102	89	112
103	9	0	29	1
103	11	0	1	0
104	3	171	88	96
104	4	0	4	0
104	8	0	59	73
104	9	0	19	2
105	2	2	1	0
105	3	8	7	37
105	4	343	167	340
105	6	1	0	0
105	8	0	5	41
105	9	499	758	483
105	11	99	15	52
106	1	0	0	2
106	2	0	0	3
106	4	3	0	5

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
106	5	11	153	36
106	6	0	1	22
106	7	0	1	6
106	10	366	226	304
106	11	0	0	2
107	6	0	0	2
107	10	70	69	68
108	4	0	1	2
108	5	0	2	0
108	10	4	0	1
108	11	0	1	1
109	4	0	7	12
109	9	0	1	1
109	10	16	0	0
109	11	0	9	3
111	2	0	0	1
111	4	0	0	1
111	5	12	31	58
111	7	0	0	1
111	10	66	46	16
111	11	0	0	1
113	6	0	0	1
113	7	0	0	1
113	10	25	25	23
114	4	0	1	2
114	7	2	0	0
114	11	0	1	0
115	4	6	25	46
115	5	0	2	2
115	9	0	2	4
115	10	53	0	0
115	11	3	34	11
117	2	0	0	1
117	4	0	0	6
117	5	9	12	6

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
117	6	0	0	1
117	7	0	0	1
117	10	21	8	12
117	11	0	9	3
118	4	0	0	1
118	5	0	1	3
118	6	0	2	51
118	7	0	1	4
118	10	506	503	447
120	6	1	0	1
120	7	0	0	1
120	10	99	99	98
121	4	6	18	22
121	5	6	1	1
121	10	29	2	1
121	11	3	24	20
123	2	0	0	1
123	4	0	0	1
123	5	0	30	4
123	6	0	0	3
123	7	0	0	1
123	10	74	44	63
123	11	0	0	1
124	2	0	0	1
124	4	0	0	2
124	5	0	10	9
124	6	0	0	1
124	7	0	0	1
124	10	25	15	10
124	11	0	0	1
125	6	0	1	22
125	7	0	1	7
125	10	366	364	337
126	7	0	0	1
126	10	4	4	3

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
127	6	3	0	0
127	10	0	2	2
128	2	0	0	1
128	4	3	15	22
128	5	33	25	6
128	6	0	0	1
128	9	0	0	1
128	10	25	2	7
128	11	0	20	23
130	6	0	0	1
130	10	148	147	147
131	4	6	49	58
131	5	1	3	2
131	7	4	0	0
131	9	0	0	2
131	10	111	5	10
131	11	0	65	51
132	6	0	0	1
132	7	0	0	1
132	10	16	16	14
133	4	0	0	1
133	5	0	3	1
133	6	0	0	1
133	10	8	5	5
134	4	0	3	4
134	9	0	0	2
134	10	8	0	0
134	11	0	4	2
135	2	0	0	1
135	4	0	0	2
135	5	137	63	107
135	6	0	0	1
135	7	0	0	1
135	10	21	93	45
136	3	0	0	1

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
136	4	0	6	9
136	5	3	0	0
136	8	0	0	1
136	9	0	1	1
136	10	12	0	1
136	11	0	8	2
137	4	0	2	2
137	9	0	0	1
137	10	4	0	0
137	11	0	2	1
139	6	0	1	5
139	7	0	1	1
139	10	251	249	245
140	4	3	0	3
140	5	0	3	0
140	6	0	0	1
140	10	4	2	2
140	11	0	2	1
141	6	0	0	1
141	7	0	0	1
141	10	17	16	14
142	4	0	1	3
142	9	0	7	4
142	10	8	0	0
142	11	0	1	1
143	4	0	3	4
143	5	3	4	1
143	6	0	0	1
143	10	8	0	2
143	11	0	4	3
144	4	0	8	14
144	5	0	1	1
144	10	21	1	0
144	11	0	11	6
145	4	0	3	6

COUNTY TO RESERVOIR

TRIP INTERCHANGE

CNTY	RES	O-D TRIPS	IOM TRIPS	GM TRIPS
145	5	0	2	1
145	10	12	0	3
145	11	0	7	2
146	2	0	0	1
146	4	0	0	9
146	5	61	41	67
146	6	0	0	1
146	10	41	28	20
146	11	0	32	4
148	1	1	0	0
148	5	2	92	13
148	6	0	0	2
148	10	226	136	214
149	4	0	0	3
149	5	1	4	1
149	6	0	0	1
149	10	8	3	4
149	11	0	3	1
150	3	0	1	6
150	4	0	23	34
150	8	0	1	7
150	9	0	104	78
150	11	0	2	5

Table C

Trip Ends by Trip Purpose

Res.*	Trip Purpose** BT 1	FS 2	HT 3	PC 4	SS 5	SK 6	SW 7	OT 8	Total
1	120.3	55.8	7.3	164.2	128.4	77.9	248.7	21.0	830.0
2	326.9	303.6	0.0	284.1	626.8	119.2	476.8	1.0	2142.2
3	194.6	63.5	0.0	202.9	332.5	150.7	177.4	26.6	1153.7
4	460.0	650.1	10.4	342.3	978.5	140.8	1145.1	27.6	3783.5
5	111.5	52.1	0.0	102.9	143.7	53.4	121.6	13.3	601.7
6	45.6	73.5	.6	79.5	114.2	19.6	114.5	2.7	451.0
7	51.9	122.1	3.7	88.6	227.2	26.3	92.0	1.4	613.6
8	340.6	351.5	3.1	364.0	234.8	248.8	409.3	0.0	1954.1
9	527.0	247.0	0.0	186.5	3222.6	264.8	0.0	0.0	4448.0
10	518.7	1020.2	0.0	500.7	711.6	78.9	208.7	0.0	3048.3
14	114.0	147.0	0.0	179.8	216.0	37.5	22.4	2.6	719.3

* See Reservoir Code Table D
** See Trip Purpose Code Table E

Table D

Reservoir Names and Codes

Name	Reservoir	Code
Cedar Bluff	CB	1
Kanopolis	KN	2
Toronto	TR	3
Tuttle Creek (South)	TCS	4
Lovewell	LV	5
Kirwin	KR	6
Webster	WB	7
Fall River	FR	8
Pomona	PM	9
Harlan County	HC	10
*Tuttle Creek (North)	TCN	14

*TCN was used as reservoir No. 11 (sequential) in the analysis.

Table E

Trip Purpose Code

Trip Purpose	Code
Boat	BT 1
Fish	FS 2
Hunt	HT 3
Picnic	PC 4
Sightsee	SS 5
Ski	SK 6
Swim	SW 7
Other	OT 8

A STUDY OF THE DISTRIBUTION OF RECREATIONAL TRIPS TO FEDERAL RESERVOIRS IN KANSAS

by

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B. S., Kansas State University, 1963

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ABSTRACT

Many multi-purpose reservoirs have been built primarily for flood control in the past two decades. The reservoirs attract vast numbers of people to their camping and picnic facilities and marinas each year. It was the purpose of this research to develop and test a procedure for reproducing, mathematically, the response of the people to recreational opportunities at federal reservoirs in Kansas.

The basic data were obtained from traffic counters and origin-destination interviews. The O-D data were then factored to an average summer Sunday attendance and accumulated by county and reservoir to obtain production and attractions, for use in developing and comparing the gravity and intervening opportunity trip distribution models.

Both models were calibrated by means of iteration, by using reservoir attendance as the attraction. Neither model calibrated satisfactorily. Both models were then refined to use a term called "attractive index" as the attraction to better represent the true attractiveness of the reservoir.

The computed distributions of the calibrated models were compared to the actual data by means of the sums of squares of the differences between each actual and computed interchange. It was found from this comparison that no significant difference existed between the two models in the ability to reproduce O-D data. In an analysis of the predictive ability of the two models, the opportunity model appeared to be the better. Because the primary advantage of using a mathematical model is to predict future occurrences, it was concluded that the opportunity model was an acceptable distribution model for reservoir trips.