DEVELOPMENT OF A SIMULATION MODEL FOR REGIONAL RECREATIONAL TRAVEL

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A simulation model for recreational travel was developed for use in analyzing the impact of outdoor recreational travel by residents of a 9-state Upper Midwest region to Michigan, Minnesota, and Wisconsin. Travel data were collected for 6,441 randomly selected households by using a telephone home-interview survey procedure. After the trips were stratified into summer-vacation and summer-weekend categories, cross-classification analysis was used to relate household trip-making frequencies to the socioeconomic characteristics of the household and its accessibility to recreational attractions within the study area. Gravity models then were calibrated to distribute recreational trips within a county-level system of demand and supply zones. Zone trip productions were estimated by applying the cross-classification model to those households within each demand zone; zone trip attractions were established synthetically on the basis of the reported trip ends from the telephone home-interview survey and the distribution of seasonal homes across the region. The gravity-model trip tables then were assigned to a regional highway corridor network for comparison with automatic-traffic-recorder data.

•TOURISM and outdoor recreation are key elements in the economy of the sparsely developed Upper Great Lakes region, which consists of the upper half of the states of Michigan, Minnesota, and Wisconsin. To help meet the growing leisure-time demand of the heavily populated Upper Midwest states, the water-based recreational potential of the area is being furthered by the development and expansion of private, state, and U.S. parks and recreational facilities. Of concern to planners, public officials, and environmentalists is the resulting increased population pressure that will be exerted on environmentally sensitive locations.

If critical land and water use problems are to be anticipated and overcome, officials at the federal, state, and local levels must have information on future levels of recreational demand. This becomes a complex, long-range planning problem because of the many factors that influence recreational travel and participation. Among these are transportation network improvement plans; state and federal recreational development plans; energy conservation policies such as reduced highway speed limits and fuel allocation programs; and the growth and spatial distribution of the regional population.

To address these problems, a multidisciplinary, recreational planning study was undertaken for the Upper Great Lakes Regional Commission (8). The research reported in this paper concerns the simulation model for regional recreational travel that was developed in the transportation phase of the study.

DATA COLLECTION

Several early constraints were placed on the development of the recreational travel simulation model because of earlier work that had been completed on the phase of the project concerning the recreational demand survey and forecasts. Most of the demand for outdoor recreation to the Upper Great Lakes region was assumed to originate in the 9-state Upper Midwest region (UMR) consisting of North Dakota, South Dakota, Minnesota, Iowa, Wisconsin, Illinois, Michigan, Indiana, and Ohio. Travel originating beyond these states would not be measured in the study. In addition, the University of Wisconsin Survey Research Laboratory had been hired to develop an interview procedure by which residents of the UMR could be questioned about their participation in outdoor recreational activities. A telephone home-interview survey was being pretested when authorization was received to proceed with the transportation phase of the project. Several final modifications to the questionnaire then were made so that it might provide certain origin-destination (O-D) information considered essential for the development of the travel simulation model. One of these was a request by the 3 state transportation agencies to consider travel to any point within the entire states of Michigan, Minnesota, and Wisconsin, the Great Lakes region (GLR).

Recreational Travel Patterns

The survey questionnaire then was applied to a sample of 6,441 households from the UMR during the late summer and fall of 1972. Households were selected from a computer-generated frame of all possible telephone numbers in the 9 states. Each respondent was to provide information about 2 types of outdoor recreational trips: those that involved at least 5 days away from home and those that involved at least 2, but not more than 4, days away from home. This essentially defined vacation trips and weekend trips respectively. Although all respondents were to submit information about each outdoor recreational trip taken by a member of the household during the 12 months preceding the interview, detailed data pertaining to their travel and activity participation were collected only for trips that occurred during the five "summer" months of May through September and that were destined to or passed through the GLR.

It was found subsequently that trips made by children under 18 years of age by themselves could not be included in the model because of a lack of sufficiently complete O-D data. Although the survey revealed a large number of person trips by children, most of these likely involved some type of group excursion such as travel to a summer camp or a weekend scouting camp-out. Trips of this nature generally would be made by bus and therefore would play a minor role in the simulation of vehicle travel.

Because each reported trip was a round trip, the return portion of each trip was assumed to follow the same path as the outbound portion and the majority of travelers were assumed to follow a somewhat direct, or minimum-path, route to and from their main destination. These assumptions were not considered overly restrictive because the objective of the study was to simulate travel over major corridors of a 3-state region, and any minimum-path routing over this network generally would encompass a relatively wide band of potential, intermediate recreational stops.

Transportation Network

Before establishing the corridor network, we defined a system of county-level traffic analysis zones. Within the 3-state GLR, each of the 243 counties represented 1 traffic analysis zone. For the remaining 6 states, 41 multicounty zones were defined on the basis of population distribution and distance from the GLR. Zone centroids were selected by considering the location of population centers, major highways, and prominent recreational facilities.

The Interstate Highway System and the major state arterial highways within the 3-state GLR were used to define the recreational travel corridors for the region. This network was more generalized than a complete statewide highway traffic assignment network would be, and yet it provided a more realistic identification of major corridor travel flows than a spiderweb network linking adjacent county centroids would provide. Although the study was concerned only with corridors in the GLR, the network was extended in a similar fashion throughout the remaining 6 states of the UMR study area. Corridor links in these states were defined for the most part by the Interstate Highway System.

Link lengths were determined from state highway maps for the various states. The average travel speed for each link was based on the location and functional classification of the corridor. If a particular link represented 2 or more parallel highways or if it was characterized by 2 or more distinct subsections having different average travel speeds, the multiple sections were weighted by their length or travel speed or both to yield a single average link. Each zone centroid then was connected to the network by 1 or more dummy links depending on the nature of the local transportation system.

Recreational Supply

Because the study was concerned with travel to the 3-state GLR, an inventory was made of the availability of recreational supply data on a county-level basis for the region. Although detailed data were maintained by each state, there was a lack of uniformity in the type of information that was recorded and the units of measurement that were used. As an alternative, the Public Outdoor Recreation Areas and Facilities Inventory (9) undertaken in 1972 was used. Although this survey could provide detailed data on state- and U.S.-administered recreational facilities in each county, no comparable data set was available for the extensive supply of privately operated recreational facilities throughout the GLR.

As a result, the problem of measuring the recreational attractiveness of a county was approached on a generalized basis by assuming that privately owned and privately operated recreational facilities were likely to predominate in those counties that also possessed certain natural recreational resources. If the total attractiveness of a county could be estimated by simply measuring natural recreation resources, such as lakes and major public recreational areas, then detailed recreational supply data would be unnecessary. Therefore, the total area of state- and U.S.-administered parks plus the total area of lakes was established as the county-level recreational supply variable. Water area for those counties bordering one of the Great Lakes included an area of that lake equivalent to the length of its shoreline times 0.5 mile (0.8 km).

TRIP GENERATION

The recreational trip making frequencies of the sample dwelling units are given in Table 1. It is important to note that, for all categories of vacation and weekend recreational trips, most respondents made either 1 trip or no trips. Looking specifically at summer trips to the GLR, one finds that only 1.5 percent of the households made more than 1 vacation trip and that only 4.1 percent made more than 1 weekend trip. This had the effect of making recreational trip production a dichotomous variable.

Although subsequent phases of the recreational travel simulation model would require zone trip productions as input data, the small O-D survey sampling rate (approximately 0.05 percent) precluded the development of a zone trip production model. Instead, effort was directed toward the formulation and testing of a household trip production model based on the 6,441 dwelling units that had been surveyed. The frequency of summer recreational trips per dwelling unit to the GLR was assumed to be a function of the socioeconomic characteristics of the household, the relative supply of outdoor recreational facilities available to the household, and the relative travel cost associated with taking a trip to a recreational attraction in the GLR.

The recreational supply and travel cost parameters for the trip-generation model were formulated as an accessibility index:

$$AI_i = \sum_{j=1}^{m} \left[\frac{S_j}{t_{ij}^{1.5}}\right] \tag{1}$$

where

AI_i = accessibility of a dwelling unit in production zone i to the recreational supply of the GLR,
m = total number of attraction zones in the GLR,
S_j = total area of lakes plus state and U.S. parks in attraction zone j, and
t_{ij} = minimum-path travel time from the centroid of zone i to the centroid of zone j.

Because the small sample size used in the telephone home-interview survey did not permit the building of a base-year O-D trip table, computing a set of gravity-model friction factors for the travel time function could not be done. The value of 1.5 for the travel-time exponent was selected on the basis of a correlation analysis between the trip-rate variables and alternative formulations of the accessibility index.

Cross-classification analysis then was selected as the technique by which summer recreational trip productions to the GLR would be related to household socioeconomic characteristics and recreational-attraction accessibilities. Because the accessibility index represented a zone characteristic, all dwelling units in a given zone were assumed to have the same accessibility to recreational attractions in the GLR. To compare and evaluate the several models that were to be tested, an analysis of variance was performed on the trip-rate variable for each model. Consideration also was given to the ease with which the distributional characteristics of the independent variables could be measured and forecast on a county-level basis.

Of the several cross-classification trip-production models that were formulated, the 2 selected for use in the travel-simulation model expressed summer-vacation trips and summer-weekend trips as a function of family income, occupation of head of household, and accessibility to the recreational attractions of the GLR. The complete sets of tables for both models are available from the authors. Each model has the same structure: 5 classes of family income, 10 classes of occupation of head of household, and 5 classes of accessibility index.

Figure 1 shows the relationship between family income and recreational trip rate. As income increases to $25,000/year, both vacation and weekend outdoor recreational trip rates increase. This supports the frequently observed tendency for higher income families to make more trips of all types. The decline in both trip rates for families with annual incomes of more than $25,000 probably is due to their ability to take a more expensive type of trip than one involving outdoor recreation in the GLR.

Figure 2 shows the relationships between occupation of head of household and recreational trip rate. The figure shows that those occupations that traditionally provide higher incomes are associated with higher trip rates. However, the fact that occupation also reflects the nature of the leisure time available to the head of the household possibly is of greater importance. People in occupations associated with high trip rates (especially those who are professionals or are in business) ordinarily can set their own working hours. This would not be the case for people who are employees. Although the farmer ordinarily is self-employed, his or her free time is confined generally to the winter months, which results in the fact that summer trip rates for farm families are the lowest for all occupation categories.

Figure 3 shows the relationship between accessibility to recreational attractions and trip rate. As accessibility to the recreational areas of the GLR increases, the likelihood of a family's making a recreational trip to the area also increases, particularly for weekend trips in which a high premium is placed on minimizing travel time. This relationship underlines the importance of an efficient transportation system to those regions whose economies are tied closely to tourism and outdoor recreation.

The coefficients of determination (r^2's) for the vacation-trip and weekend-trip models are 0.11 and 0.17 respectively. Although zone-level trip-production models have yielded r^2 values above 0.90, they have been shown to be equivalent to household-level trip-production models with r^2 values near 0.25 because of the nature of the variance that is being explained (10). As a demonstration of the effect of level of aggregation on the variance explanation of recreational trip rates, a set of zone-level trip-production models were formulated. Multiple linear regression analysis then was used to relate

Table 1. Percentage of sample dwelling units that took summer recreational trips in 1972.

Type of Trip	Number of Trips 0	1	2	3	4	5	6
Vacation							
All trips	64.3	28.4	6.0	1.0	0.2	0.1	–
Trips to GLR	87.2	11.2	1.2	0.3	–	–	–
Weekend							
All trips	72.8	18.9	5.7	1.7	0.9	0.3	0.3
Trips to GLR	85.3	10.7	2.5	0.8	0.5	0.2	0.1

Figure 1. Family income versus trip rate.

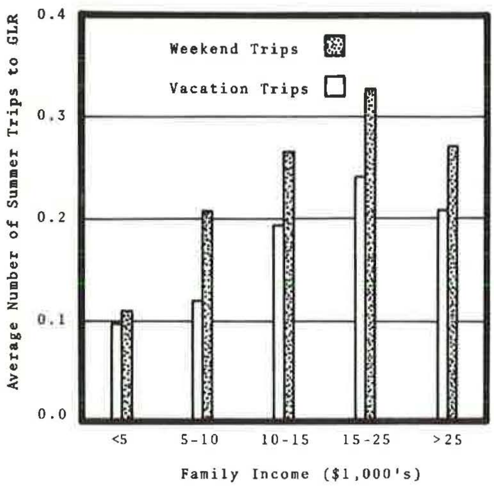


Figure 2. Occupation of head of household versus trip rate.

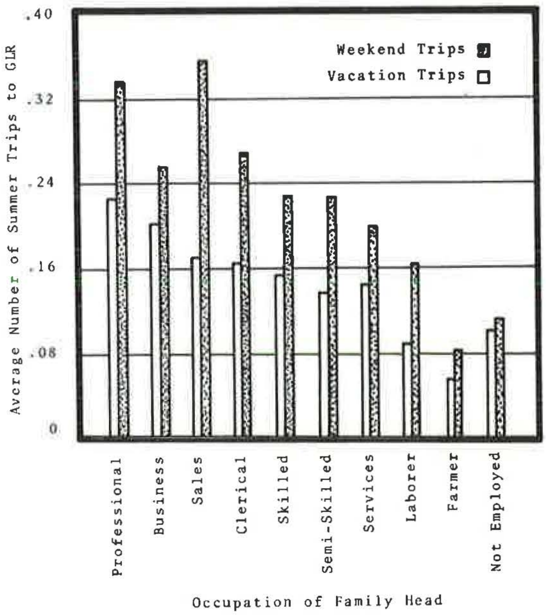
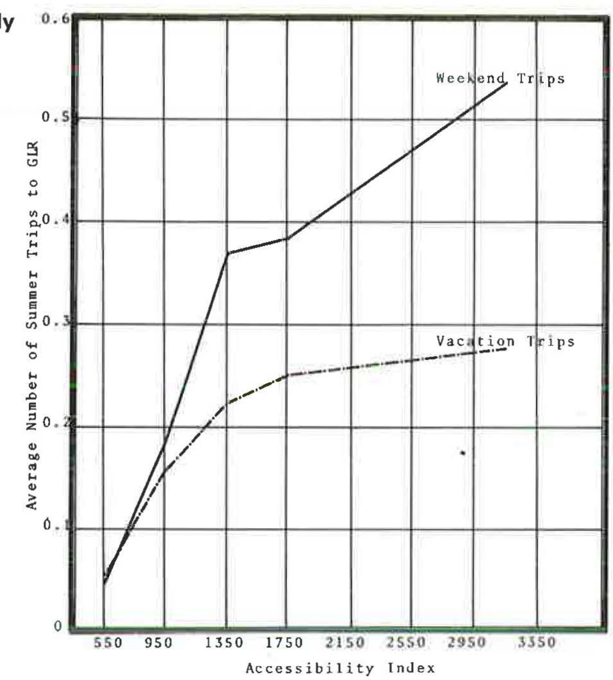


Figure 3. Accessibility to recreational supply versus trip rate.



the 1970 estimated zone trip productions to the total population of zone i (POP_i), average family income of zone i (INC_i), and AI_i of the zones. Models for vacation and weekend trips were tested in log form, and a summary of them is given in Table 2. The regression statistics reveal that, when the within-zone trip-production variance is removed, 78 to 92 percent of the remaining between-zone variance can be explained by the selected zone characteristics.

The basically unstable nature of outdoor recreational trips is another explanation of the low variance of the cross-classification models. Work trips are predictable on an hourly and daily basis, but a household's recreational travel can exhibit a large variation in destination from year to year even though it may begin on a certain day of the week or month with some consistency. This characteristic creates a built-in variance within a recreational travel model that has been estimated to be as much as 20 percent (2).

TRIP DISTRIBUTION

The gravity model was selected for allocating zone recreational trip productions to the 243 county-level recreational supply zones in the GLR.

Trip Productions and Attractions

Because only 0.05 percent of the dwelling units in the UMR had been interviewed (the number of summer recreation trips to the GLR totaled 961 vacation trips and 1,386 weekend trips), many zones were found to have no reported trip ends whatsoever. As a result, base-year trip productions and attractions had to be developed synthetically. Summer-vacation and weekend trip productions for each of the 284 UMR zones were estimated by applying the cross-classification model to 1970 household data. The resulting 1970 zone trip productions for the 9-state UMR totaled 1.59 million vacation trips and 2.34 million weekend trips over the 5-month period of May through September. Base-year trip attractions for the 243 zones in the GLR then were established by using a 2-stage procedure. First, total base-year trip productions were allocated to each of 36 districts proportional to the trips reported by the survey respondents:

$$A_k = \left(\sum_i P_i\right) \left[\frac{D_k}{\sum_k D_k}\right] \tag{2}$$

where

A_k = number of summer-vacation or weekend recreational trips attracted to district k,
P_i = number of summer-vacation or weekend recreational trips produced in zone i, and
D_k = mean number of reported summer-vacation or weekend recreational trips to district k.

Second, the trip-attraction total of each district was allocated to the individual zones comprising each district on the basis of the number of seasonal homes in the zones within a given district:

$$A_j = A_k \left[\frac{S_{jk}}{\sum_j S_{jk}}\right] \tag{3}$$

where

A_j = estimated zone trip attractions, and
S_{jk} = number of seasonal homes in zone j within district k.

Although the availability of seasonal home data was not discovered until late in the study, it proved to be a conceptually sound and statistically significant indicator of the recreational attractiveness of an area.

The relationship between A_j and selected zone characteristics then was tested in log form by using multiple linear regression analysis. Independent variables included number of seasonal homes SH_j, total area of lakes plus state and U.S. parks REC_j, and accessibility of the zone to the population of the UMR AI_j. The accessibility variable was computed as

$$AI_j = \sum_{i=1}^{n} \left[\frac{POP_i}{t_{ij}^{1.5}}\right] \quad (4)$$

where n = total number of zones in UMR. The resulting regression models for vacation and weekend zone trip attractions are tabulated as follows (level of significance is 5 percent):

Type of Trip	Model	Number of Observations	r^2
Vacation	$\log A_j = 0.78 \log SH_j + 0.35 \log REC_j$	243	0.99
Weekend	$\log A_j = 0.78 \log SH_j + 0.42 \log AI_j$	243	0.99

The regression statistics indicate that the models explain 99 percent of the variance in the estimated trip attractions for the 243 zones in the GLR. In comparing the 2 models, one finds that the number of seasonal homes in a zone has a significant influence on both vacation and weekend recreational trip attractions. Also vacation trips tend to be attracted to those zones with extensive natural recreation resources, and weekend trips tend to be attracted to those zones that are most accessible to regional population concentrations. These relationships demonstrate a trade-off between the drawing power of major recreation areas and the impedance of travel time. For extended recreational trips, people are willing to spend more time traveling to reach prominent outdoor recreational attractions. For weekend recreational trips, however, travel time becomes more important than the character of the recreational supply at the point of destination.

Gravity-Model Calibration

After the estimated number of base-year (1970) zone trip productions and zone trip attractions for both vacation and weekend recreational trips were established, 2 sets of gravity-model friction factors were calibrated by using 30-min travel-time intervals (5). The calibrated friction factors for both vacation and weekend recreational trips are shown in Figure 4. A comparison of the associated trip-length frequency distributions shown in Figures 5 and 6 again reveals the previously noted influence of travel time on recreational-travel patterns. The mean trip length for summer-vacation trips is 261 min. For summer weekend trips, it is 170 min. This is a difference of 1.5 hours or approximately 90 miles (144 km) of additional 1-way travel.

Because of the structure of the gravity-model trip-interchange equation, large devia-

Table 2. Zone trip-production models for summer recreational trips to the Great Lakes region.

Type of Trip	Population	Model	Number of Observations	r^2
Vacation	<500,000	$\log P_i = -6.61 + 1.52 \log INC_i + 0.82 \log POP_i$	259	0.78
	>500,000	$\log P_i = -10.5 + 1.37 \log INC_i + 1.02 \log POP_i + 1.08 \log AI_i$	24	0.92
Weekend	<500,000	$\log P_i = -8.11 + 1.12 \log INC_i + 0.84 \log POP_i + 1.02 \log AI_i$	259	0.90
	>500,000	$\log P_i = -12.4 + 1.72 \log INC_i + 0.96 \log POP_i + 1.39 \log AI_i$	24	0.89

Note: Level of significance is 10 percent.

Figure 4. Calibrated gravity-model friction factors.

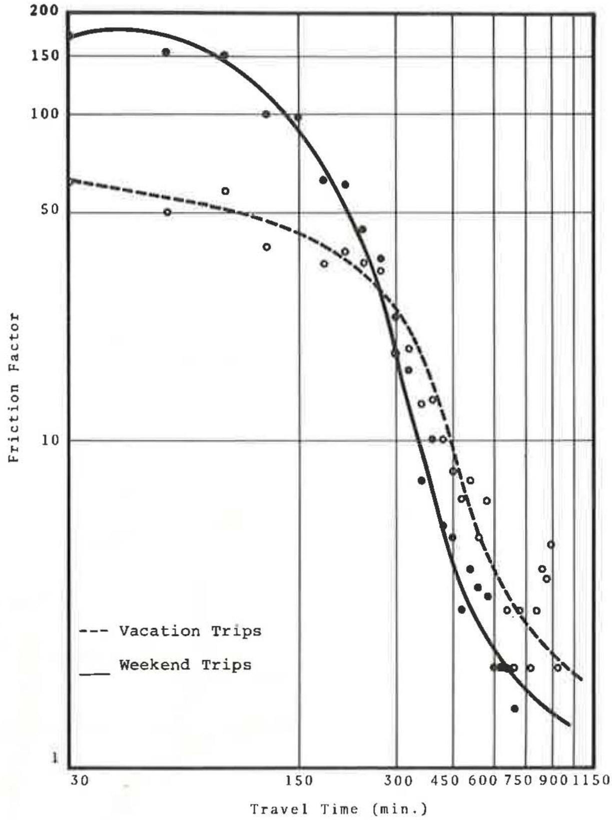
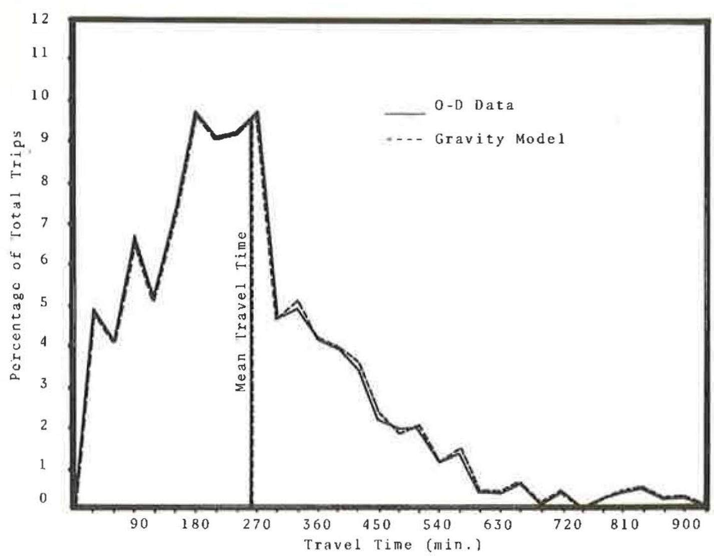


Figure 5. Gravity model versus origin-destination trip-length distributions for vacation trips.



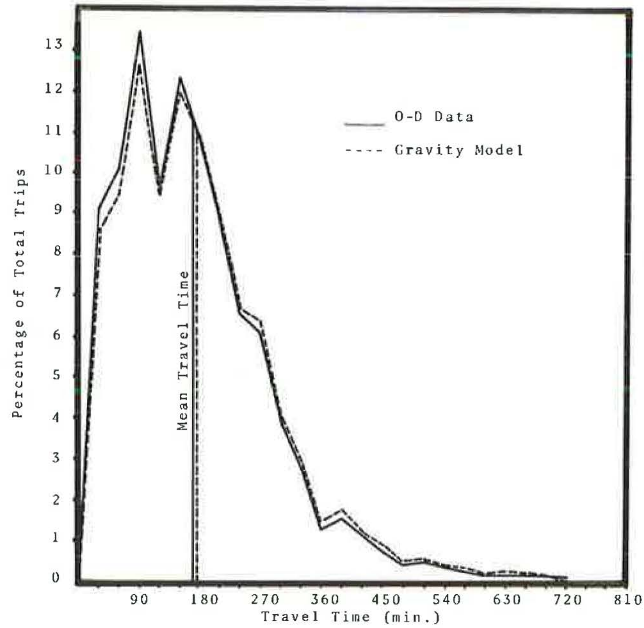


Figure 6. Gravity model versus origin-destination trip-length distributions for weekend trips.

Figure 7. Simulated 1970 peak-weekend-day recreational traffic flow for Wisconsin.

tions existed between the synthesized trip attractions and the distributed trips when they were compared on a district level. The zone trip attractions therefore were adjusted and another iteration of the gravity model was performed (10). The results of the second iteration revealed that a reasonably good balance had been achieved, although a slight increase in trip length did occur. Because those districts that received too few trip ends generally were in the more remote parts of the region and those that received too many trip ends were located close to major metropolitan centers such as Chicago and Detroit, it was judged that further iterations of the model would yield only an improved trip-end balance at the expense of an imbalance in trip-length distribution.

Therefore, the simulated trip interchanges from the second iteration were accepted as a reasonable and sufficient estimate of base-year recreational travel to the GLR.

TRAFFIC ASSIGNMENT

In the final stage of the simulation model, the combined trip table for the estimated 1970 summer recreational trips to the GLR was assigned to the corridor network by using an all-or-nothing assignment (10). The trip table represented 1-way summer recreational trips from zone of residence to zone of main destination. On the basis of the peaking and modal characteristics of the trips reported in the telephone home-interview survey, the assigned trips were factored to represent the peak nondirectional vehicle-travel flow on an average weekend day in July or August. Figure 7 shows the resulting estimated 1970 recreational traffic flow pattern for Wisconsin.

An important aspect of the entire recreational travel simulation process was the testing of the link assignments. The usual statistical accuracy criteria could not be applied directly because of a lack of traffic count data for recreational travel. As an alternative, a series of comparisons were made between the assigned link volumes and the total traffic counts at cut lines defined by selected automatic-traffic-recorder stations in each of the 3 states.

A total of 87 stations located on the Interstate Highway System and the state highway systems were identified as being compatible with a particular link of the corridor assignment network. The average Saturday and Sunday volumes for July and August then were averaged for each station and compared with the corresponding link volumes for an average weekend day in July and August. The results of the cut-line analysis revealed that the assigned link volumes generally varied from 5 to 60 percent of the total traffic count at the automatic-traffic-recorder stations. Those links representing routes with a high functional classification tended to have a higher percentage of recreational traffic than did other corridors offering a lower level of mobility, which supports the assumption that recreationists want to minimize the travel costs incurred in reaching their final destination.

Some of the assigned link volumes in the extreme northern part of the region were relatively low because travel to Canada was not incorporated in the model. Inspection of traffic-flow maps for the region revealed sizable volumes of traffic on routes that lead directly into Canadian provinces. Subsequent modeling and assignment of these trips would increase the percentage of recreational traffic along these corridors to the expected higher levels.

APPLICATION OF THE SIMULATION MODEL

Although the cut-line analysis was quite subjective, the recreational travel simulation model was considered to offer a reasonable level of accuracy for system-level corridor planning purposes in the GLR. Furthermore, because the cross-classification trip-production models and the multiple regression zone trip-attraction models are sensitive to the level of service provided by the regional transportation system, analyses can be made of the impact of alternative transportation investment and pricing policies on levels of recreational travel demand. When analyzing specific highways within a corridor, one can make the corridor flow proportional to parallel highways through the use of travel-time diversion curves. However, these flows will reflect only overnight recreational travel from place of residence to point of main destination and return.

An additional use of the corridor flow data is in the analysis of the direction and magnitude of external traffic entering and leaving a given local study area. This can be of aid in the planning and development of major thoroughfares that provide access to prominent recreational attractions. However, the trip-attraction models were developed by using synthesized trip-end estimates for the established zones. This approach was followed because the telephone home-interview survey procedure could not provide a sufficient sample of trips for direct expansion to total trip attractions.

Although measures of privately operated recreational attractions, quality of recreational facilities, or degree of crowding within the county-level zones could not be included, trip-attraction forecasts nevertheless can be adjusted subjectively to account for such factors.

CONCLUSION

The experience gained during the course of this study indicates that the application of traditional urban transportation planning methods can offer a workable approach to the analysis of statewide recreational travel. However, additional research is needed in a number of areas. For example, the most efficient methods of collecting recreational travel data need to be established. This problem is related closely to the need to achieve a better understanding of recreational travel behavior, especially trip frequency and choice of destination. Little is known about the role played by promotional campaigns, degree of crowding, and quality of recreation in attracting travelers to various locations. And how recreational and nonrecreational travel models can be integrated to provide a composite view of total statewide travel patterns needs to be established.

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