Toward Measurement of Community Impact: The Utilization of Longitudinal Travel Data To Define Residential Linkages

RAYMOND H. ELLIS, Peat, Marwick, Livingston and Company; and
RICHARD D. WORRALL, Northwestern University

The concept of residential linkages has previously been proposed as the basis for a strategy for quantitatively estimating the community or social consequences of transportation projects. The objective of this paper is to present a method for empirically defining existing residential linkages and linkage patterns. It is suggested that linkage definition involves the analysis of two data sets: the activity patterns of the household and the set of destination points which the household defines as important. Activity patterns are determined by analyzing an average of $3\frac{1}{2}$ weeks of travel data for each of 35 households residing in Skokie, Illinois. Household interviews would be used to identify the set of destination points that the household defines as important. A discriminant iterations analysis is then used to refine the initial classification used by the household and to insure that the set of developed linkage definition criteria are uniformly applied to each activity pattern. It is concluded that the proposed analytical methodology could be operationally employed to define linkages as part of an effort to estimate the community impact of transportation projects.

•RECENT events have emphasized the importance of incorporating consideration of the community consequences of the transportation program into the planning methodology. Numerous political controversies have developed throughout the country regarding the design of major urban transportation facilities. Examination of these controversies would demonstrate that the social and environmental impact of the transportation system is frequently the most important issue in these controversies (3). Because of the dimension of the problems of the American city and the level of public and private expenditures devoted to urban transportation, decision-makers are increasingly requesting transportation planners to analyze the contribution of the transportation program to the achievement of social, environmental, and other goals.

A review (15) of the community impact literature (1, 13, 17) would suggest that researchers and planning groups have been using a restricted approach to measuring community or social consequences. Significant variables have been only partially identified and little is known of the basic structure of the impact process. Two measures of the outcome of the impact process, property value and mobility, are being examined but they do not provide insight into the impact process nor do they provide information to aid in the location and design of new facilities. While considerable technical progress is being made on measuring the noise and air pollution produced by operation of the transportation processor, the consequences of these by-products are not well understood. Everyone has an opinion on the aesthetics of the transportation system, but little progress has been made toward introducing quantitative estimates of aesthetics into the design process. The problem of integrating environmental

Paper sponsored by Committee on Community Values and presented at the 48th Annual Meeting.

impact over a social and physical space so that a given transportation program may be evaluated has barely been considered.

In order to effectively consider community consequences, it is necessary to understand the transportation impact process and not to treat it as a "black box." This black box approach is reflected in the observation that in spite of the fact that social consequences should be defined in terms which are "relevant" to both the social process and the transportation system, there presently appears to be a tendency to estimate social impact using metrics such as "number of trees" or " number of historic monuments" removed. Such a strategy is unfortunate in that it utilizes a measure of the quality of the physical environment as a surrogate for social impact. If the park in which the trees are located is not visited, there would appear to be little justification in defining "preservation of trees" as a social consequence.

In previous papers (5, 6, 7), it was suggested that one approach to identifying the relevant social consequences may be based on a theoretical perspective which views the community as a system which has certain social and physical requirements for proper functioning and within which a process of interaction takes place among the residents. The social consequences of a transportation program, then, are changes in the system which may be estimated by measuring perturbations in the process of interaction. An activity map, which defines the individual's allocation of resources in generalized spatial and activity purpose dimensions, is one methodological approach which may be utilized to empirically define the interaction process (7).

However, a metric providing a more precise spatial definition is needed, particularly to measure the community impact of transportation facilities on the areas through which they pass. This requirement is met by the use of residential linkages (6) which are defined as ties between the housing site of the individual and other points which are of importance to the individuals involved. In the next section, the residential linkage concept is presented in greater detail.

The objective of this paper is to present a prototypical methodology to define existing residential linkages so that linkage patterns may be used to estimate the social consequences of alternative transportation programs. A prototypical methodology which employs longitudinal travel data, attitudinal data, and a discriminant iterations analysis to define existing linkage patterns is presented in the third section of the paper. The remaining sections describe a case study in which the prototypical methodology was applied to define linkage patterns in Skokie, Illinois. It is emphasized that this empirical investigation is concerned with describing household activity and linkage patterns and not with examining the impact process per se. Thus, the application of residential linkages to the measurement of social consequences will not be demonstrated in this paper and remains a topic for further investigation.

RESIDENTIAL LINKAGES AS A STRATEGY FOR MEASURING COMMUNITY IMPACT

Residential linkages may be defined as ties between the housing site of the household and other spatially distinct points which are of importance to the individuals involved. The specification that a linkage exists implies that communication, but not necessarily a movement of people or goods, will take place between the housing and activity site. In the vocabulary of the transportation engineer, the residential linkage is a "desire line" for communication. The aggregation of the desire lines for all of the individuals in the community represents the process of interaction from the viewpoint of the individuals involved.

The impact of a new transportation facility on a linkage would appear to be a function of the mode of communications being used. Clearly, the impact of a new freeway on mail or telephone service is comparatively minor, as compared to its potential impact on the pedestrian and public and private transportation subsystems. Thus, it could be argued that when estimating community consequences, the empirical determination of linkages should be confined to situations in which a physical transfer of people or goods takes place between activity sites. While data on vehicle trips have been obtained for metropolitan areas throughout the United States, walking trip data are comparatively rare.

To estimate community or social impact, it is useful to determine the importance of the linkage to the individual, although this is difficult since it involves measurement of levels of satisfaction. The importance of a linkage would appear to be related to its substitutability, which may be defined as the facility with which an alternate linkage could be developed.

At least three factors appear relevant in estimating linkage substitutability: the characteristics of the existing linkage pattern, the availability of alternative activity sites, and the characteristics of the household. Important aspects of the existing linkage pattern include the linkage type, the mode of travel, and the frequency of communication. Unless a store serves other than commercial functions, it is comparatively simple to stop shopping at one store and begin shopping at another, but establishing a new linkage at a church or school or with an individual involves considerably more cost. It is hypothesized that the latter linkages are less substitutable and, therefore, more important to the individual. Within each linkage type, importance would appear to be a function of the frequency of interaction and the mode of communications. Although trip rate is important, the considerable variance in travel behavior among households makes a given trip rate, such as 0.25 person trips per day, for an activity site difficult to interpret. A low trip-making household might place considerable importance on this activity site while a high trip-making household might place little or no importance. Linkages involving automobile travel would appear to be intrinsically more flexible and less subject to disruption than linkages involving public transportation or walking. Further, activity opportunities for which public transportation or walking are the principal modes may be extremely limited. Thus, existing activity patterns involving nonautomobile principal modes may be more important than those for which the car is the principal mode.

In defining the availability of alternate activity sites for purposes of estimating linkage substitutability, it is necessary to consider the activity type and its accessibility by each travel mode. Finally, it is important to recognize that linkage substitutability will vary as a function of the people involved and that it is necessary to consider the social characteristics of the group in estimating the social or community consequences of a transportation program. Wachs (18, 19) found some relation between socioeconomic level and perception of the benefits or disbenefits of a nearby freeway. Gans, in discussing recreation facilities adjacent to a densely populated area of low rent housing notes: "most West Enders thought of these facilities as being outside of the area: physically, because they were separated by a busy expressway; and socially, because they had been put there by people from the outside world" (10). These citations illustrate the importance of considering the characteristics of the people involved when evaluating the community consequences of the transportation program.

To this point, the discussion has focused on linkage patterns from the perspective of the housebold terminus. Since each destination point may have a unique identification number, linkages could also be analyzed at the nonhousehold terminus. Destination points generating high levels of activity could be interpreted as major community institutions, whose integrity should be protected when planning public improvements. The assumption underlying this approach is that the dollar value of land may not always be a good proxy for its social value. Some activity sites, such as parks or community meeting halls, may have an intrinsic social importance and for these cases, the activity focused on the site may be a useful measure of social importance. Some form of spatial aggregation appears critical for a complete analysis of community institutions. Further, it may be necessary to have the interaction criterion used to define an institution be a function of the type of activity under consideration. Finally, attention must be devoted not just to the nonhome site, but to the pattern of interaction associated with that site and, in particular, to the spatial and modal characteristics of travel.

Implicit in the residential linkage concept is the observation that the household places considerable value on maintaining a tie to only a portion of the total set of points with which it interacts. During the course of the longitudinal travel survey used in this study, the sample of 35 households visited a total of 1263 destination points ranging from an annual visit to a specialty shop to almost daily travel to a worksite or school. Clearly, considerable differences exist in the importance which households attach to interaction with various activity sites. In order to derive a reliable estimate of community consequences from the analysis of activity patterns, it is necessary to evaluate the relative importance of various activity sites.

One approach to defining differential importance would assign some value to every activity site, letting the weight be a function of the socioeconomic characteristics of the household, the type of activity, and the rate of interaction. Evaluation then implies summing the weighted impacts for all the activity sites of all households, for each alternative. While conceptually seductive, this approach places an unnecessary strain on evaluation procedures which are already both complex and expensive. It is wasteful to devote enormous resources to defining impacts which will not contribute heavily in the summation process. The sample of households had trip rates of less than 0.05 person trips per day for over 60 percent of the activity sites and it is difficult to argue that there is a substantial impact on an activity pattern with such a low rate of interaction. An explicit decision not to consider all activity patterns could lead to the development of more efficient data mechanisms. Finally, considerable methodological difficulties would be encountered in developing the set of weights.

An alternative and more promising approach is based on the assertion that only a segment of the set of activity patterns is of substantive importance to the household. These are defined as residential linkages and analysis may be confined to defining the residential linkages of the households in an area and to estimating a facility's impact on these linkages. This approach is based on an integer assignment procedure: an activity pattern is or is not a linkage. In the next section, a prototypical linkage definition methodology is presented.

MEASURING RESIDENTIAL LINKAGES: A DISCRIMINANT ITERATIONS APPROACH

The objective of this section is to develop a rational procedure to define the set of residential linkages associated with a household. The approach suggested below is viewed as an experimental step necessary to develop an efficient linkage definition methodology. Eventually, it may be desirable to follow an approach which directly isolated the residential linkages and eliminated the intermediate step of defining the complete set of activity sites visited by the household.

The linkage definition methodology has four major steps:

1. A longitudinal travel survey is used to identify the complete set of destination points visited by the household and the characteristics of travel associated with these destination points;
2. The household is asked in a carefully structured interview to identify the set of activity sites which it considers important to be able to interact with and these are a priori defined as its linkages;
3. A discriminant iterations analysis is carried out to identify the criteria underlying the household's choice of certain destination points as linkages; and
4. The discriminant procedures developed in the discriminant iterations analysis are applied directly to the activity patterns defined in longitudinal travel surveys of other households for which attitude data are not available, thus providing a systematic analytical basis to define linkages directly from a longitudinal travel survey without requiring the use of an attitude survey.

Procedures for conducting a longitudinal travel survey and an attitudinal survey have been discussed (11, 18, 23) and the reader is referred to other sources for a discussion of these topics. Two data sets, one defining the household's activity sites or activity vectors and the other specifying its residential linkages, would then be available. Presumedly, some unspecified rationale motivated the household to denote certain activity vectors as linkages and the objective of this discussion is to explore one approach to identify and simulate this rationale.

Members of the family would probably identify linkages using an interconnected set of criteria relating to both the individual activity vector and the household activity pattern. Desirable attributes of a methodology to define linkages from activity vectors would include:

1. Identification of the set of criteria used by the household;
2. Removal of irrational and random choices from the original classification by uniformly applying the criteria to develop a revised classification which is in agreement with the set of identified criteria and the data set; and
3. A capability to apply the defined set of criteria to the activity vectors of households for which survey data on linkage definition is unavailable.

The issue of linkage definition may be viewed as a taxonomic problem. In effect, two sets of activity vectors have been defined. One set contains those activity vectors which the household defined as linkages while the other contains the remaining activity vectors. The objective of the taxonomic analysis is to utilize various measures of: (a) the existing activity and linkage pattern, (b) alternate activity sites, and (c) the socioeconomic characteristics of the household to optimally discriminate between linkage and nonlinkage activity vectors and to classify previously unassigned activity vectors. Several authors have discussed the analytical techniques which may be applied to classification problems of this type (4, 16, 20).

Casetti's technique of discriminant iterations is particularly applicable to the problem at hand. Discriminant procedures may be defined as "a set of rules for allocating a new object to one of the classes of a classification" (2). Discriminant iterations involve the repeated development of discriminant procedures until an optimal classification and optimal discriminant procedures are achieved. A discriminant analysis is performed on a set of data which has been initially classified, for example those activity vectors defined as linkages and those which are not. The discriminant procedures developed are used to determine the probabilities of group membership for each of the data points used to calibrate the function. Some data points may have group membership probabilities which are higher for another group than the one they are in. These points are reassigned to the group for which they have exhibited the highest group membership probability and a new discriminant procedure is developed. The process iterates in this fashion until each data point has its highest probability of group membership for the group to which it was assigned when calibrating the discriminant procedure and this is called the limit or optimal classification.

This approach may be directly applied to the residential linkage identification problem noted previously. Several measures of the characteristics of each activity vector are obtained. The classification of linkage and nonlinkage activity vectors furnished by the household is utilized as input to the first discriminant analysis and discriminant iterations are performed until the limit classification is achieved. Discriminant procedures used to develop the limit classification may then be utilized to classify activity vectors which were not employed in the calibration. Discriminant iterations are particularly applicable to the linkage definition problem because they refine the initial classification used by the household and insure that the set of criteria developed are uniformly applied to each activity vector. In the following sections, the suggested methodology is utilized to define residential linkages using a longitudinal travel survey conducted in Skokie, Illinois.

MEASURING RESIDENTIAL LINKAGES: DATA ACQUISITION AND PREPARATION

During the autumn of 1965 and winter of 1966, a sample of households was asked to prepare travel diaries in which each person in the household recorded all of his trips for a 4-week period. The design of the study and an intensive analysis of the tripmaking characteristics of the respondent households have been reported elsewhere (11).

Household activity and linkage patterns may be extremely complex and involve multi-element sets of related trips and considerable care must be exercised in the coding of activity data so that patterns may be identified and analyzed. Three activity patterns for a three person, one car household are shown in Figure 1a. In the morning the wife drives the husband to work, and the child to school, and returns home (pattern 1). In the evening, she reverses the journey, stopping at the supermarket before picking up the child (pattern 2). On weekends, the family goes from church to the domicile of the husband's parents and then returns (pattern 3).

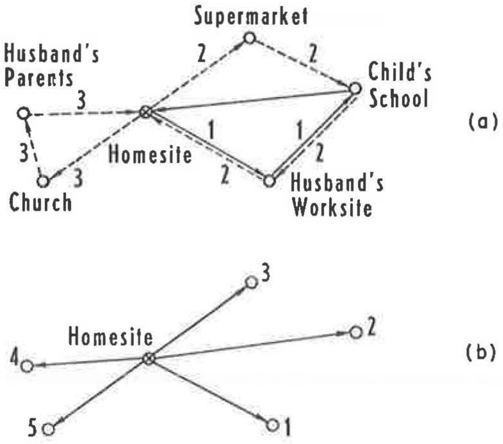

Figure 1. Representation of household activity patterns: (a) the activity pattern, and (b) representation of activity pattern.

Activity patterns are described in this analysis by assigning a vector to each destination point visited by the households, as shown in Figure 1b. The vector for each destination point originates at the homesite and contains elements describing the characteristics of the activity site, such as geographic location and type of activity, and measures describing the household's interaction with that site, such as trip rate, mode and travel time.

Admittedly, the computational flexibility provided by this representation is achieved at the cost of some loss of information on travel between two nonhome activity sites. Vector representation is most appropriate for either two-leg or three-leg activity patterns (patterns 1 and 3 in Fig. 1a), since information would be available on the time required to travel from and/or to the homesite, to and/or from the activity site for these trip sets. This information would not be available for four-leg patterns (pattern 2 in Fig. 1a), since the time required to travel from the homesite to the second destination point (the child's school in pattern 2) would not be available.

Data organization and analysis for the entire study are based on this vector representation of activity patterns. An activity vector is defined by the interaction of a given household with a given activity site and is uniquely identified by a five digit code, two digits to specify the household and the remaining three to denote the activity site. In

TABLE 1

DEFINITION OF ACTIVITY CATEGORIES AND CHARACTERISTICS OF ACTIVITY PATTERNS

Category and Mode	Percent of Total Trips	Percent of Total Destination Points	Trips per Destination Point	Trips per Household	Destination Points per Household
Activity Categories:					
1. Regular, full-time work	16.5	3.7	0.63	0.84	1.34
2. School	11.3	2.5	0.65	0.58	0.89
3. Part-time work, religious	12.1	4.6	0.37	0.62	1.66
4. Shopping	31.8	49.3	0.09	1.62	17.80
5. Passive and participant recreation	6.1	7.4	0.12	0.31	2.66
6. Informal socializing	10.0	11.7	0.12	0.51	4.22
7. Restaurants	7.4	10.5	0.10	0.38	3.77
8. Community activities and formal socializing and other	4.8	10.4	0.07	0.24	3.74
Principal Mode:					
Car	79.4	86.8	0.13	4.06	31.34
Public transportation	10.7	4.0	0.37	0.53	1.46
Walk and other	9.9	9.2	0.15	0.50	3.29

addition to the identification number, elements of the activity vector include the activity type, the daily person trip rate, the weekend day trip rate, the mode or modes used, and the distance, time, and speed required for a trip from the homesite to the destination point.

MEASURING RESIDENTIAL LINKAGES: RESULTS AND ANALYSIS

For the purposes of this study, a set of 35 travel diaries containing high-quality travel data for the longest time period was selected. All of the characteristics of each activity vector for each of the 35 households were measured and the results are given in Table 1. Various multivariate grouping techniques were used to develop the set of eight activity types.

Following the development of two data sets, the set of activity vectors and the set of activity vectors defined as linkages, a discriminant iterations analysis is used to identify the linkage definition criteria used by the household, to remove irrational and random choices, and to develop a set of procedures for defining linkages solely from activity patterns. It was suggested above that the initial classification of linkage and nonlinkage activity vectors should be determined by interviewing the households from which the activity data were gathered. Unfortunately, constraints on the resources available for this study rendered such an approach infeasible. Seven households were randomly selected from the 35 for which activity data had been coded and the 278 activity vectors associated with these households were individually examined to determine if they should be defined as linkages. Several criteria, of which the most important were

TABLE 2

VARIABLES USED IN DISCRIMINANT ITERATIONS ANALYSIS

Variable Number	Mnemonic	Interpretation
1	DAYDAT	Length of surveillance period for the household with activity vector
2	WORK	Dummy variable for work purpose
3	SCHOOL	Dummy variable for school purpose
4	CHURCH	Dummy variable for religious purpose
5	SHOP	Dummy variable for shopping purpose
6	P/PREC	Dummy variable for passive or participant recreation purpose
7	INFSOC	Dummy variable for informal social purpose
8	REST	Dummy variable for restaurant and related activities purpose
9	FORSOC	Dummy variable for formal social and community purposes
10	TTRATE	Daily person trip rate
11	WKRATE	Daily person trip rate for weekend trips
12	PCCAR	Percent of the trips which were by car when this was the most popular mode
13	PCPUPT	Percent of the trips which were by public transportation when this was the most popular mode
14	PCWALK	Percent of the trips which were by other than car or public transportation when this was the most popular mode
15	PCWKTR	Percent of the total trips which were made on weekend days
16	DIST	Distance from the homesite to the activity site
17	SPEED	Average speed of travel from the homesite to the activity site
18	PCTPUR	The ratio of the trip rate for this activity vector over the trip rate for all of the household's activity vectors in this purpose category
19	DPTPUR	The ratio of one over the total number of activity vectors of the household for this purpose category
20	CAR	Dummy variable for car being the principal mode
21	PUBTR	Dummy variable for public transportation being the principal mode
22	WALK	Dummy variable for mode other than car or public transportation being the principal mode
23	AVTIME	Average time in minutes for travel from homesite to activity site
24	TTRPUR	Total trips by the household for this activity purpose

activity purpose, trip rate, principal mode, and total household travel, were employed to make the initial classification. These criteria were not precisely specified and no attempt was made to uniformly apply the set of criteria to all households. Therefore, the discriminant procedures developed to define a residential linkage represent the value set of the authors and not the value set of the households, and for this reason this analysis should be viewed as only an illustrative application of discriminant iterations methodology to the linkage definition problem.

In spite of this reservation, it is useful to consider the results of the discriminant iteration analysis and to examine the set of residential linkages which was developed. While the initial classification used may not be identical to the one which the households would specify, considerable overlap would exist since households would probably use many of the criteria employed by the writers. Although the numerical results of this work are partially invalid, it is useful to illustrate the types of analysis and output which can be developed. A total of 95 out of 278 activity vectors, or 34 percent, were initially defined as linkages.

Twenty-four measures, defined in Table 2, were used to specify the characteristics of each activity vector for the experimental discriminant iteration analysis. Eight dummy variables were employed to represent the eight activity purpose categories (Table 1). Three dummy variables were used to represent choice among the automobile, public transportation, and other modes. Kendall notes that, although discrimination problems often arise in which dummy variables are employed, "the method is rather rough" (14). In view of the relatively large number of variables employed in the analysis, this problem is somewhat less serious than might first appear.

TABLE 3

SCALED DISCRIMINANT VECTOR AND GROUP CENTROIDS FOR EACH ITERATION

		1	2	3	4	5	6
1	DAYDAT	----	0.39	0.48	----	----	----
2	WORK	----	-1.24	-1.15	-1.64	-1.66	-1.66
3	SCHOOL	----	----	----	-1.26	-1.32	-1.32
4	CHURCH	----	-0.50	-0.54	-1.55	-1.53	-1.54
5	SHOP	1.95	1.94	2.91	0.18	0.03	----
6	P/PREC	----	-0.37	0.61	----	0.01	----
7	INFSOC	----	----	1.36	----	----	----
8	REST	1.07	1.35	1.88	----	----	----
9	FORSOC	----	----	1.75	0.11	0.04	----
10	TTRATE	-3.35	-2.09	-1.48	0.11	0.22	0.22
11	WKRATE	----	----	----	-0.66	-0.91	-0.92
12	PCCAR	----	----	----	----	----	----
13	PCPUBT	----	----	----	----	----	----
14	PCWALK	-0.89	----	-2.86	-2.63	-2.43	-2.39
15	PCWKTR	----	----	-0.17	-0.16	0.06	-0.05
16	DIST	----	----	----	0.06	----	----
17	SPEED	----	----	----	-0.03	----	0.03
18	PCTPUR	----	----	----	----	----	----
19	DPTPUR	----	----	----	----	----	----
20	CAR	----	----	-0.03	0.16	0.15	0.15
21	PUBTR	----	----	----	----	----	----
22	WALK	----	-1.81	0.43	0.83	0.67	0.64
23	AVTIME	----	----	----	----	----	----
24	TTRPUR	----	----	----	----	----	----
	Centroid for points defined as linkage	-0.22	-0.42	-0.38	-0.53	-0.52	-0.51
	Centroid for nonlinkage points	0.11	0.22	0.40	0.06	0.04	0.04

Results of the discriminant iterations are given in Table 3, which contains scaled vectors which show the relative contribution of each variable to the discriminant function and the location of the group centroids. The signs and relative importance of coefficients for variables in a discriminant function are interpretable. Throughout the analysis, the centroid for points defined as linkages was negative and the centroid for nonlinkage points was positive. Variables with a negative coefficient therefore contribute to defining a point as a linkage, while variables with a positive coefficient have the opposite effect.

Only four variables, SHOP, REST, TTRATE, and PCWALK, entered the discriminant function in the first iteration. The larger the trip rate and the larger the proportion of walking trips, the greater the probability that a given activity vector would be defined as a linkage. All activity categories, except shopping and restaurants, etc., were of equal importance. Activity sites in these two categories are more substitutable, and there should be some bias against defining vectors with these purposes as linkages. These results represent an accurate quantitative mapping of the qualitative criteria used to establish the initial classification. The manner in which these criteria were refined and the underlying criteria established through the discriminant iterations analysis is illustrated by examining the discriminant vector for the sixth iteration.

Ten variables entered the discriminant function calibrated in the sixth iteration. The relationship of activity purpose and trip rate to linkage definition was reversed during the iterations. As noted, trip rate was the most important variable influencing linkage definition in the first iteration, but its impact on shopping or restaurant activity vectors was reduced by the appearance with opposite signs of the dummy variables for these categories. The influence of dummy variables for work, school, and church on the final discriminant function is to cause the vector to be defined as a linkage. The coefficient for the trip rate in this iteration has the opposite effect. Since many shopping trips have a high trip rate, the effect of these four variables is to discriminante between work, school, and church vectors with a high trip rate and shopping vectors with a high trip rate.

Other variables entered the discriminant function in a logical manner. A high weekend trip rate helped vectors to be defined as linkages. The automobile is a more flexible mode of travel than public transportation or walking. Hence, activity sites for which the principal mode of travel is by car are inherently less important to the household. Therefore, the coefficient associated with principal mode car (CAR) has an appropriate positive sign.

Discriminant procedures developed in the sixth iteration were applied to the 985 activity vectors of the 28 households which were not included in the discriminant iterations analysis. Linkage patterns for the sample of 35 households were tabulated in the same format used to tabulate activity patterns, and the two patterns are compared in Table 4. Only 7.5 out of the 36.2 destination points visited by the average household during its surveillance period were chosen as linkages. This 79 percent reduction in number of activity vectors resulted in only a 51 percent reduction in daily person trips.

TABLE 4

COMPARISON OF ACTIVITY AND LINKAGE PATTERNS

	Total Trip Rate—Linkages / Total Trip Rate—All Destination Points	No. of Linkages / No. of Destination Points
Activity Type:		
1. Work	0.99	0.98
2. School	1.00	1.00
3. Religious, part-time work	0.98	0.98
4. Shopping	0.12	0.11
5. Recreation	0.18	0.09
6. Informal socializing	0.26	0.18
7. Restaurants	0.16	0.14
8. Community activities and formal socializing	0.07	0.07
Total all activity types	0.49	0.21
Principal Mode:		
Car	0.38	0.11
Public transportation	0.84	0.55
Walk and other	1.00	1.00

	Activity Patterns (Units = Destination Points)	Linkage Patterns (Units = Linkages)
Total trip rate-unit/household	5.09	2.48
Units/household	36.2	7.5
Total trip rate/unit	.14	.33

An average of 0.33 trips per day are made to each linkage as compared to only 0.14 daily trips to each destination point. Interaction with activity sites defined as linkages is considerably more intensive than interaction with the average destination point.

EVALUATION

The analyses presented here have achieved a qualified success in exploring the use of longitudinal travel and attitudinal data to define residential linkages. The assertion made in a previous paper (6) that residential linkages may be defined empirically has been substantiated. Further, the analytical methodology developed in that paper has been applied successfully to an operational situation.

The success of the analyses is limited, however, in global terms by the quality of the available data. The available sample of 35 households is clearly far too small and too concentrated geographically to permit the development of significant inferences concerning the total population of households in the Chicago metropolitan area. The discriminant iterations analysis of linkage definition was based solely on measures of activity; the quality and content of the data precluded inclusion of household characteristic measures and/or measures of the availability of alternative activity sites. Further, the initial classification for the discriminant iterations was established arbitrarily by the writers, rather than by the households whose behavior was observed.

Further tests of the methodology should desirably be made for a larger, more spatially diffuse sample of households. Additional attention should also be directed to three other interrelated areas: (a) development of a more efficient data collection mechanism; (b) initiation of a continuing program to evaluate the social consequences of urban transportation investment under conditions of at least partial experimental control; and (c) formulation and validation of a set of "social consequence" models based on the evaluation program outlined above.

An average of 26 days of travel data was analyzed for each of the sample households in this study. The cost of obtaining and coding these data was relatively high—approximately $5 per household per day. The total cost of obtaining equivalent data for a sample of the size required for a fully operational study would clearly be extremely high, unless significant modifications were made in the data acquisition and coding process.

Although the topic is not addressed here, it is feasible to consider developing linkage patterns from cross-sectional travel data, provided information is available on walking trips. One relatively inexpensive way of collecting the necessary data, therefore, would be the acquisition of home-based walking trip data during the home interview travel survey conducted by all major transportation studies. Alternatively, one of the authors has for some time belabored the notion that the analysis of urban travel demand should be based at least partially on longitudinal rather than purely cross-sectional data. If such data were acquired as part of the urban transportation planning process, the marginal cost of utilizing this information to estimate activity and linkage patterns would clearly be small. A variety of sampling devices have been proposed (24), including shortening the time duration of the longitudinal sample, the use of monitored recall data and the use of partial and full overlap designs, which would cut costs considerably. Some of these techniques have been tested empirically in a recent study in Chicago (25).

Once an efficient data acquisition technique has been identified, a range of continuing experiments may be readily conceived to test the social consequences of specific transportation projects. These experiments may be structured to examine specifically the sensitivity of household activity patterns to changes in the transportation system and in other public investment programs. Such experiments may also have a larger objective.

At present, planners do not have a realistic basis for assigning any normative content to changes in the activity patterns of different groups. If a relationship could be established, on the basis of continuing, controlled observation between activity perturbation and measures having an obvious normative content (e. g., health and pathological behavior) a normative information base may be brought at least a step nearer. Limited studies of this type have been conducted to investigate the consequences of rehousing families in Boston (8, 9) and Baltimore (21, 22).

Finally, we may remark that any realistic consideration of social impact within the transportation planning process, requires an ability to forecast the consequences of alternative transportation programs on a very broad base. This suggests a need, albeit a very ambitious one, for predictive models which are sensitive to the differential effects of alternative programs, their incidence on different population groups, and their staging over time. This paper represents a rather faltering step toward such a goal.

ACKNOWLEDGMENTS

The research reported in this study was carried out while the authors were associated with the transportation programs of the Civil Engineering Department and The Transportation Center, Northwestern University. We would like to thank Dr. Donald S. Berry, Dr. Duane F. Marble and Dr. George L. Peterson for the constructive criticism and valuable suggestions which they provided at several points during the research. Paul Rassam, a colleague at Peat, Marwick, Livingston and Co., made numerous suggestions which greatly improved the presentation of material in the first draft of this paper. Throughout the period during which the work was carried out, Mr. Ellis was supported by a National Science Foundation Engineering Traineeship. Funding for the data coding effort and computer time was provided by the Civil Engineering Department, Northwestern University (50 percent), the Research Division, Transportation Center at Northwestern University (25 percent), and the Education Division, Transportation Center at Northwestern University (25 percent).

REFERENCES

1. Bureau of Public Roads. Highways and Economic and Social Changes. U. S. Government Printing Office, Washington, 1964.
2. Casetti, Emilio. Multiple Discriminant Functions. Tech. Report No. 11, ONR Task No. 389-135, Office of Naval Research, Geography Branch, Northwestern Univ. May 1964.
3. Comptroller General of the United States. Problems Associated with Location and Design of Segments of the Interstate Highway System in Major Metropolitan Area Areas. Federal Highway Administration, Department of Transportation. Report to the Congress of the United States, Washington, 1967.
4. Cooley, William W., and Lohnes, Paul R. Multivariate Procedures for the Behavioral Sciences. Chapters 6 and 7, John Wiley and Sons, 1962.
5. Ellis, Raymond H. Toward Measurement of the Community Consequences of Urban Transportation Investment. Unpublished Ph. D. dissertation, Northwestern Univ., 1968.
6. Ellis, Raymond H. Toward Measurement of the Community Consequences of Urban Freeways. Highway Research Record 229, p. 38-52, 1968.
7. Ellis, Raymond H. Some Comments on Social Impacts and Urban Transportation Planning. Proc., ASME/NYASC 1968 Transportation Engineering Conference, ASME, New York, 1968.
8. Fried, Marc, and Gleicher, Peggy. Some Sources of Residential Satisfaction in an Urban Slum. Jour. American Institute of Planners, Vol. 27, p. 305-315, 1961.
9. Fried, Marc. Grieving for a Lost Home. In The Urban Condition, p. 151-171, Leonard J. Duhl, Ed., Basic Books, New York, 1963.
10. Gans, Herbert J. The Urban Villagers. The Free Press of Glencoe, New York, p. 150, 1962.
11. Garrison, William L., and Worrall, Richard D. Monitoring Urban Travel. Final Report of NCHRP Project 2-8, Civil Engineering Dept. and The Transportation Center, Northwestern Univ., Aug. 1966.
12. Hemmens, George C. The Structure of Urban Activity Linkages. Center for Urban and Regional Studies, Univ. of North Carolina, Sept. 1966.
13. Horwood, Edgar M., Zellner, C. A., and Ludwig, R. L. Community Consequences of Highway Improvement. NCHRP Report 18, Highway Research Board, 1964.

14. Kendall, M. G. A Course in Multivariate Analysis. Hefner, New York, p. 170, 1961.
15. MacDorman, Littleton C., and Ellis, Raymond H. Community Impact. Transportation Systems Evaluation (draft report), Report of Committee 6M, ITE.
16. Stowers, Joseph P. A Contribution to a Model of the Urban Residential Site Selection Process: A Taxonomy of Families and Decision Rules for Locating Subpopulations. Ph. D. dissertation, Civil Engineering Dept., Northwestern Univ., Chap. 4, 1968.
17. Thiel, Floyd I. Social Effects of Modern Highway Transportation. HRB Bull. 327, p. 1-20, 1962.
18. Wachs, Martin. Evaluation of Engineering Projects Using Perceptions of and Preferences for Project Characteristics. Ph. D. dissertation (published as a Research Report) The Transportation Center, Northwestern Univ., 1967.
19. Wachs, Martin. Relationships Between Drivers' Attitudes Toward Alternative Routes and Driver and Route Characteristics. Highway Research Record 197, p. 70-87, 1967.
20. Wegmann, Frederick J. Review of Literature Concerning Regionalization and Grouping Methods. Further Thoughts Regarding Grouping and Improvement of a Grouping. Civil Engineering Dept., Northwestern Univ., 1965.
21. Wilner, Daniel M., Walkley, Rosabelle P., Pinkerton, Thomas C., and Tayback, Matthew. The Housing Environment and Family Life: A Longitudinal Study of the Effects of Housing on Morbidity and Mental Health. Johns Hopkins Press, 1962.
22. Wilner, Daniel M., and Walkley, Rosabelle P. Effects of Housing on Health and Performance. In The Urban Condition, p. 215-228, Leonard J. Duhl, Ed., Basic Books, New York, 1963.
23. Worrall, Richard D. A Longitudinal Analysis of Household Travel, Unpublished.
24. Worrall, Richard D. The Urban Panel as a Longitudinal Data Source. Highway Research Record 194, p. 62-77, 1967.
25. Worrall, R. D., and Peterson, G. L. Cross-Town Expressway Neighborhood Impact Study. Final Report, Cross-Town Associates, City of Chicago, Aug. 1968.

Discussion

FLOYD I. THIEL, Federal Highway Administration—Many readers will no doubt agree with this paper's recognition of some of the shortcomings of earlier efforts to analyze social and economic effects of highways. But for readers who are not familiar with the community impact literature, which the authors indicate they have reviewed, the references to this literature in the paper may provide an inaccurate understanding. For example, it is stated that "Two measures of the outcome of the impact process, property value and mobility, are being examined but they do not provide insight into the impact process. . . . " This statement seems unclear for at least two reasons.

First, such measures as property value and mobility can surely provide some insight about community impact. Many of the researchers at MIT, Harvard University, Texas A&M University, George Washington University, Pennsylvania State University, University of Washington, University of Connecticut, University of Illinois, and elsewhere who have included land value analysis in their studies of highway effects would undoubtedly maintain that land value analysis can help provide insight; such analyses were especially useful during the period when today's study techniques and financial and management support were not available. To gain such insight, these researchers have analyzed land values to discern:

1. Undesirable highway effects (which might not be reflected in some other measures);
2. How parkway effects differed from effects along other highways;

3. The rate of mortgage foreclosures for highway affected property;
4. Whether and how highway beautification measures affect property owners;
5. Resale rates and values for highway affected property, etc.

Second, land values and mobility are by no means the only measures that have been examined in impact studies. Other measures of impact which the paper seems to ignore include:

1. Commuting patterns;
2. Participation rates in school, church, clubs and other organizations, recreation, etc.;
3. Attitudes of those affected (including attitude change differentials between citizens and community leaders);
4. Land use changes;
5. Living accommodations and mortgage indebtedness for relocated families;
6. Shopping patterns;
7. Land development patterns;
8. Business starts and stops;
9. Public service effects; and
10. Availability of mobile and drive-in products and services.

The authors refer to the problem of estimating social impact using "number of trees or historic monuments." They state "If the park in which the trees are located is not visited, there would appear to be little justification in defining 'preservation of trees' as a social consequence."

Earlier, the authors referred to social and environmental impact, which seems to suggest that effects of a general nature are being considered. Trees or monuments surely do not equal social consequences, as the authors suggest. But the quotation suggests that a social consequence occurs only if the place (e.g., the park) is physically visited. Surely the authors do not maintain that parks (or museums, schools, churches, etc.) have no social consequences for those who do not visit these facilities. Perhaps these effects are regarded as environmental and outside the residential linkage concept of the paper.

"The automobile is a more flexible mode of travel than public transportation or walking. Hence, activity sites for which the principal mode of travel is by car are inherently less important to the household."

Except that walking is pretty flexible (at least as far as time and routing are concerned), the first sentence seems to be so. But the second sentence appears to have so many exceptions one wonders whether the general statement is so or whether it is being misunderstood. For example, several activity sites for which the principal mode of travel is by car seem inherently more important to households (e.g., trips for hospital, doctor, wedding, or funeral purposes) than some trips by public transportation or walking (e.g., recreational trips within walking distance or that are accessible by mass transit). Emergency trips aside, the second sentence may be generally correct. The auto is the principal mode for both recreation and the journey to work, but more so for the former than the latter. And the recreation trip is probably inherently less important to the household than the work trip. Perhaps (as a colleague of mine, G. Broderick, notes), the authors' statement can be taken as an hypothesis should be recast to suggest that the more important a trip is to a hosehold the more likely it is that alternative means to make the trip will exist.

Some of the questions raised here should cause a reader to wonder whether he has understood what preceded the portion questioned. I have wondered about this and admit that the questions raised may result from my failure to understand portions of the paper in the context of the whole paper. Even so, it may be that understanding for other readers would also be increased if the authors could clarify some of the matters referred to above.

R. H. ELLIS and R. D. WORRALL, Closure—The authors would like to thank Mr. Thiel for his remarks, and to briefly reply to three of the points which he raises in his discussion. Our comments will focus on (a) the existing body of highway impact literature, (b) the use of visitation frequency as a value measure in analyzing community impact, and (c) the relative sensitivity of automobile and nonautomobile linkages to severance by highway construction.

Limitations of space in the original paper precluded a thorough discussion of the extensive and somewhat diffuse literature of community impact. Our collection of references simply represented those which we considered most germane to the theme of the paper, namely, the use of household activity analysis as a mechanism for estimating one dimension of community impact. We certainly agree with Mr. Thiel that "such measures as property value and mobility can surely provide some insight about community impact" and that "such analyses were especially useful during the period when today's study techniques were not available." Our differences, if any, are essentially ones of degree. We believe that the large majority of existing impact studies, although they include a broader range of measures than we may have implied in our comments, and although they served a useful purpose at the time the studies were conducted, are essentially too coarse to be fully responsive to some of the important questions which are currently being raised concerning the location and design of urban freeways. The objective of our research was simply to propose one, and only one, method of analysis which might add something to our total analytical ability in this area. We did not intend to imply that our work was a substitute for all previous studies, but rather that it represents a useful complement.

A comment by Horwood (13) is perhaps relevant here. He divides the existing impact literature into three broad classes: "by-pass studies," "urban circumferential studies," and "urban radial freeway studies"—our work being most closely related to the third of these categories. He then comments that the principal variables investigated in the "classic" radial freeway impact studies (26, 27, 28, 29) have been land value and land use, and remarks: "The radial corridor studies known about appear to have three distinct shortcomings—the use of assessed valuation as a criterion, the bias of the sample of land values, and the nature of the control areas" (13).

Elsewhere one of the authors (7) has suggested that the "transportation impact process" has been generally viewed as a "black box." Measures such as land value have been used as surrogates for the wide range of transportation impacts on the quality of the traversed environment. It is our hypothesis that, in order to treat the question of community consequences meaningfully, it is necessary to understand the details of the social impact of highway investment more clearly and to treat these details directly within the evaluation model. This cannot be achieved through the use of systemic black box analysis. This theme has been developed by both of the authors in some detail elsewhere (7, 11), the latter reference dealing explicitly with questions of sample design, and the monitoring of highway impact as a continuous process.

Mr. Thiel took some exception to our simple paradigm concerning trees or parks which may or may not be visited by the residents of the community. Our example was perhaps unfortunately phrased. The point which we wished to make was simply that considerable insight may be gained into the potential impact of a new road or transit line on the region through which it passes by viewing community structure in terms of a set of "activity linkages." The value to the community of a given facility or institution such as a park, school, church, or museum may be measured at least in part by its use, although this does not imply that the facility be used by all residents of the community. It is not unreasonable to argue that facilities which are used frequently are of perhaps slightly greater value to the community as a whole than those facilities which are used infrequently.

Perhaps the paper should have more strongly emphasized our distinction between the importance of an activity, such as work or recreation, and the importance of that activity taking place at a given geographic location. Earlier in this paper, we suggest that the importance of a linkage would appear to be related to its substitutability, which may be defined as the facility with which an alternative linkage could be developed. In this sense, one may argue that as linkages involving walking as the travel mode necessarily cover a smaller area, and hence are likely to have a relatively smaller "opportunity space" of alternative destination points than those involving the auto mode, they are also likely to be less substitutable and hence potentially more important than the latter. Further, there would appear to be considerable validity to the basic assumption underlying this argument, namely that the disadvantaged, young, and old residents of our central cities cannot substitute an automobile trip for a walking trip simply because they do not have a car available to them.

Mode of interaction is only one of a number of variables suggested in the paper as a surrogate for the importance of a linkage and the consequences of its severance for the community Additional measures, not all of which were discussed in the paper, include the frequency of visitation, the number of different destination points visited by a household for the same activity, the total number of opportunities for performing a given activity within a particular distance of the household's location, and the existing use of more than one mode of travel for a given activity/linkage type. This methodology was used with some success by one of the authors in a study of probable household impact of the Chicago Crosstown Expressway. This study suggested strongly that the concept of residential linkages as an empirical device for implementing the concept of household activity analysis provides a valuable additional analytical tool to the urban highway designer (30). Again, it should be emphasized that this analysis was not designed to replace all other techniques of highway impact analysis, but rather to serve as a useful supplement to a wide range of detailed studies of land acquisition costs, traffic patterns, land value analysis, retail trade and market area structure, employment patterns, etc.

In closing, we would like to thank Mr. Thiel for his comments and hope that our remarks may lead to a clearer understanding of the paper.

References

26. Adkins, W. G. Effects of the Dallas Central Expressway on Land Values and Land Use. Bull. 6, TTI, Sept. 1957.
27. Adkins, W. G., and Tieken, A. W. Economic Impact of Expressways in San Antonio. Bull. 11, TTI, Aug. 1958.
28. Lemly, J. H. Expressway Influence on Land Use and Value—Atlanta 1941-1956. Research Paper No. 10, Bureau of Business and Economic Research, Georgia State College, Nov. 1968.
29. Norris, L. V., and Elder, H. W. A 15-Year Study of Land Values and Land Use Along the Gulf Freeway in Houston, Texas. Texas Highway Dept. Planning Survey, 1956.
30. Worrall, R. D., and Peterson, G. L. Chicago Crosstown Design Team, Neighborhood Impact Study. Final Report to the Crosstown Design Team, 1969.