ACTIVITY-ACCESSIBILITY MODELS OF TRIP GENERATION

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This paper examined the effect of activity-accessibility variables on trip generation. A second aspect of accessibility was studied by stratifying the zones of the study area by location. Data from the transportation study in Indianapolis were used to develop 4 sets of trip-generation regression equations for each of 13 trip purposes. A comparison of the developed models revealed that location always improved the statistical strength of the trip-generation models and relative accessibility variables improved the statistical strength of trip-attraction models more than that of trip-production models. Stratification alone improved the models more than relative accessibility variables only. 1985 forecasts of demographic, socioeconomic, and land use variables together with estimates of travel time on the proposed future network were inputs to the 4 sets of developed models to forecast trip productions and attractions. More trips for zones of the noncentral area and fewer trips for zones of the central area were forecast by stratified models than by unstratified models.

•IN recent years urban transportation planning activities have increased in many American cities. This increased activity was in response to the challenging urban transportation problem, one of the major problems of contemporary cities. The safe and efficient intracity movement of goods and people is very essential for the social, cultural, and economic health of an urban area.

The urban transportation problem is the product of many interacting factors. The enormous population growth in urban areas and their expanding areal extent as a result of the redistribution of population, the improved standard of living due to increased affluency, and the subsequent greater reliance on private automobiles are only some of those factors. Together with those size-related features of the problem, the temporal aspects induce periodic high demands for transportation. This, of course, is due to the interdependency of human activities that occur essentially during the 8-hour workday, starting and ending at rather definite times.

A recognition of the immense complexity and the vast dimensionality of the urban transportation problem is a prerequisite of any attempt to solve the problem.

Apart from the socioeconomic, demographic, and land use forecasts, trip generation constitutes the first step toward establishing the future travel pattern. The accuracy of the future trip distribution in forecasting design-year trip interchange cannot be any better than the accuracy of the trip-generation forecasts.

The ultimate purpose of the trip-generation analysis is to arrive at an estimate of the trip ends generated at each analysis unit of the study area. Trip-generation techniques try to establish a relation between the demographic and socioeconomic characteristics of the population of an analysis unit and its trip generation. Similarly, the intensity, character, and location of different land uses are related to trip-making of the analysis units. These procedures are based on the hypothesis of a causal relation between population characteristics, land use, and trip-making behavior of people.

Traditionally, trip-generation forecasts are established independently of any direct consideration of the transportation network. This, of course, assumes that trips produced at or attracted to a zone are a function only of the attributes of the zone itself and are not directly a function of the transportation network on which the trips were made. The traditional trip-generation process is shown in Figure 1.

PURPOSE AND SCOPE

The purpose of this research was to study the trip-generation process and specifically to investigate the effect of the transportation system on the rate of trip-making. Conceptually, there is no strong basis for assuming that trip-making is independent of the transportation system. On the contrary, it seems that trips produced by or attracted to a zone should be a function of the relative accessibility of the zone to different land uses in addition to the characteristics of the zone itself.

Trip-making is a product of the desire for human interaction and the necessity for having to perform different daily activities at different locales. Basically, the rate of trip-making is a function of 2 categories of variables: One tends to increase the potential of trip-making, and the other tends to restrict it. The availability of vehicles to the residents of a zone, the percentage of the residents in the labor force, the number employed in a zone, and the amount of floor area of different land uses are examples of the first category of variables. They measure the potential of trip production or trip attraction. The penalties incurred by travel measured in cost, travel time, or travel distance are variables that belong to the second category.

This study utilized data obtained from the surveys for the Indianapolis Regional Transportation and Development Study (IRTADS). Multiple linear regression predictive models of person-trip productions and attractions by purpose were developed. The developed models differ from the traditional trip-generation models. The independent variables were not restricted to socioeconomic and land use measures of the zones but included also measures of the relative accessibility of the zone to different activities and land uses.

The locational aspects that affect trip generation were also investigated. It was hypothesized that central locations in the study area, generally, afford greater accessibility; and the convergence of the street network on the city center favors the core location. The zones of the study area were stratified into 2 groups: central and noncentral. This stratification was entered as an independent dummy variable in the trip-generation analysis.

A comparison was made of the forecast trip generation by the suggested approach and the forecast by the traditional approach.

ACTIVITY-ACCESSIBILITY CONCEPT IN TRIP GENERATION

As stated earlier, the rationale of trip generation has been based on the demographic, economic, and land use characteristics of the zone; no consideration has been given to the status of the transportation system. This research was based on the concept that trips generated by a zone of the study area are also a function of the status of the transportation subsystem that serves a zone and connects it to the other zones of the study area. The effect of the transportation system on trip generation was investigated in the light of the relative accessibility of each zone to various urban activities and of the spatial relation of the different zones to each other.

There are many instances where researchers have realized the existence of a feedback from the transportation system to the trip-generation phenomenon (7, p. 18; 6, pp. 201-202; 11, p. 75; 1, p. 66; 15, p. 98; 9, p. 166; 2, p. 38; 3, pp. 73-74; 10; and 8). In spite of the large number of references noted above, actually little has been done to measure those effects.

The hypothesis proposed by this research is that the number of trips generated by a zone is a function of the transportation subsystem that connects the zone under consideration with the other zones of the study area. For this purpose, the term "relative accessibility" will be defined conceptually and operationally.

It was hypothesized earlier that the trips produced by or attracted to a zone are a function of the causal or symptomatic variables modified by the relative ease in overcoming space between that zone and all other zones. Zones with relatively more accessible destinations should, in general, produce more trips; similarly, zones that are relatively more accessible to origins should, in general, attract more trips. The term "relatively" refers to the zone under consideration as compared to all other zones of the study area. This implies a competitive consideration among zones in generating

Figure 1. Traditional trip-generation process.

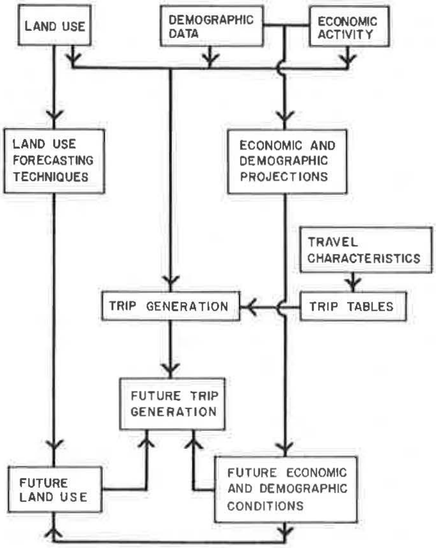


Table 1. Dependent variables for which trip-generation equations were developed.

Person-Trip Production		Person-Trip Attraction	
Purpose	Number	Purpose	Number
Home-based work	1	Home-based work	8
Home-based shop	2	Home-based shop	9
Home-based school	3	Home-based other	10
Home-based other	4	Non-home-based work	11
Non-home-based work	5	Non-home-based nonwork	12
Non-home-based nonwork	6	Total	13
Total	7		

Figure 2. Generated relative accessibility variables.

MEASURES OF ACTIVITY	TRIP PURPOSE					
	HBWK 1	HBSHP 2	HBSCL 3	HBOTR 4	NHBWK 5	NHBNWK 6
Total Employment	P			P – A	P – A*	
Retail Employment						
Service Employment						
Retail Floor Area		P		P – A	P – A	P – A
Educational Floor Area			P	P – A	P – A	P – A
Dwelling Units		A		P – A		
Labor Force	A			P – A		
Population		A		P – A		
Cars				P – A		
Single Family Dwellings		A		P – A		

* P (and/or A) in cells indicates that the corresponding relative accessibility variable was considered in developing models of trip productions (and/or attractions) for the indicated trip purpose

trips. Zones of similar-sized activities will attract trips differently according to their locational and accessibility advantages.

As a measure of the ease or difficulty of overcoming space, this study used the set of friction factors developed from the calibrated gravity model of trip interchange for the study area. This had the advantage of avoiding the use of a constant exponent of distance or time. Friction factors as developed by the calibration of the gravity model are a function of travel time and are classified by trip purpose.

This study's definition of relative accessibility is a modification of Hansen's. In notational form, relative accessibility is computed as follows:

$$A_{i\,.\,k(\ell)} = \sum_{j=1}^{n} S_{jk}\, F_{ij}(\ell)$$

$$RA_{i\,.\,k(\ell)} = A_{i\,.\,k(\ell)} \Bigg/ \left[\sum_{i=1}^{n} \sum_{j=1}^{n} S_{jk}\, F_{ij}(\ell)\right] \cdot 100 = A_{i\,.\,k(\ell)} \Bigg/ \left[\sum_{i=1}^{n} A_{i\,.\,k(\ell)}\right] \cdot 100$$

where

i = zone under consideration ($i = 1, 2, \ldots, n$);
j = any zone in the study area, including zone i ($j = 1, 2, \ldots, i, \ldots, n$);
k = activity under consideration ($k = 1, 2, \ldots, m$);
ℓ = trip purpose ($\ell = 1, 2, \ldots, p$);
S_{jk} = size of activity k in zone j;
$F_{ij}(\ell)$ = friction factor corresponding to the travel time from zone i to zone j for purpose ℓ;
$A_{i\,.\,k(\ell)}$ = accessibility of zone i to activity k for purpose ℓ; and
$RA_{i\,.\,k(\ell)}$ = relative accessibility of zone i to activity k for purpose ℓ.

The value of the relative accessibility of zone i to activity k for purpose ℓ, as it is possible to infer from its formulation, could be different for a future year if any or all of the following study area parameters change:

1. Interzonal travel time, consisting of interzonal driving time, terminal time, and intrazonal time; or
2. Size of activity k in any or all zones of the study area.

The value of the relative accessibility of a zone to the same activity could be different for different trip purposes. The reason is that the friction factors, corresponding to a certain travel time, are usually different for different trip purposes.

Another aspect of accessibility, directly related neither to travel time nor to size of activity, is considered. The relation to trip-generation characteristics is investigated by stratifying the zones of the study area into 2 sets: central and noncentral. The conceptual basis is that "central sites afford maximum accessibility..." (2, p. 108). The central area is also, more or less, equally accessible to the various zones of the study area because of the convergence of the street system on the city center. This stratification introduces a qualitative factor describing the general arrangement of the land uses and the configuration of the street system.

STUDY DESIGN AND ANALYTICAL PROCEDURES

The following methodology was used in this investigation. Trip-generation models that take into account accessibility variables were developed from data of an operational transportation study. Those models were then compared with the conventional models developed as part of the transportation study. Both sets of models were used to forecast 1985 trip generation. The 2 sets of forecasts were compared by testing for any significant differences, on a zone-by-zone basis, between the 2 forecasts.

Models that take into consideration the stratification of the zones of the study area into central and noncentral sets were also developed. This stratification was investigated for the models developed by the transportation study and those developed by this investigation.

The main purpose of this investigation was to compare the sets of developed models that used accessibility variables and stratified zones into central and noncentral sets with the traditional models developed by an operational transportation study. Care was taken to keep any factors that might disturb the comparison out of the developed models so that the comparisons would be most valid. Furthermore, the decision to develop multiple linear regression models of trip generation by using data summarized by zone was mainly in the interest of keeping the results of this investigation comparable with those of the operational transportation study.

Data Preparation

The data used in this investigation were obtained in the IRTADS surveys. The study was at a stage where most, if not all, of the analyses were completed, the forecasts established, and the proposed networks evaluated. In the trip-generation analysis, all the models were developed for total person trips (except for truck and taxi equations). The dependent variables were in the form of productions and attractions suitable for distribution by the gravity model. Nineteen trip-generation equations were developed by IRTADS; 2 were for truck and taxi trip ends, 4 were for control totals, and the others were for person-trips productions and attractions by purpose.

Dependent Variables—This investigation was limited to 6 trip-production purposes, 5 trip-attraction purposes, and 2 control totals (1 for all productions and 1 for all attractions). Trip-generation equations were developed for the dependent variables given in Table 1. It was not possible to develop an equation for home-based school person-trip attractions because the key independent variable, school enrollment, was not available.

Socioeconomic and Land Use Variables—Twenty-nine socioeconomic and land use variables were originally considered by IRTADS in its trip-generation analysis; only 15 were, however, eventually retained in the final equations. Moreover, only 10 of these were available for this study for both the survey year and the forecast year. The following socioeconomic and land use variables were available and used by this study as independent variables in developing multiple linear regression models of trip generation: total employment, retail employment, service employment, retail floor area, educational floor area, dwelling units, labor force, population, cars, and single-family dwelling units.

Accessibility Variables—Different measures of relative accessibility to be used as independent variables in trip-generation regression models were established. The operational definition of relative accessibility stated earlier was used. The required inputs are the size of various activities in each zone and skim zone-to-zone friction factor trees.

Size of Activities—The definition of activity was extended for this purpose to include all the 10 socioeconomic independent variables that were available from the IRTADS surveys. If the information had not been available from that source, the size of activities would have been collected from various sources, e.g., employment data from the State Employment Securities Division, floor area information from the land use survey, and other data from the home interview survey or census records.

Skim Zone-to-Zone Friction Factor Trees—A set of friction factors for each of 6 trip purposes was available from the results of the IRTADS calibrated gravity model.

A binary zone-to-zone tree tape was made available by IRTADS for this investigation. This binary tape was updated (intrazonal and terminal times added) and skimmed to give skim zone-to-zone travel time binary trees. Six skim zone-to-zone friction factor trees were built, 1 for each of 6 trip purposes.

Only the highway network was considered in developing relative accessibility variables. Although the trip-generation models were for person trips, using the highway network only would not introduce any appreciable bias in the case of IRTADS mainly because transit passenger trips constituted only 4.1 percent of all the person trips (3). Moreover, the transit in IRTADS area was entirely bus service on the city streets.

Generated Relative Accessibility Variables—With 10 activity measures (the available independent variables) and 6 sets of friction factors (1 for each trip purpose), 60 measures of relative accessibility could be generated. However, not all 60 possible combinations were generated; only those that were meaningful to the trip generation analysis were used. For example, the relative accessibility of a zone to retail floor area could be meaningful in conjunction with home-based shopping person-trip productions. Also, the relative accessibility of a zone to single-family dwellings would be meaningful in conjunction with home-based shop person-trip attractions. Twenty relative accessibility variables were generated and considered in the analysis; these are shown in Figure 2. The same measure of relative accessibility could be meaningful in conjunction with both the productions and attractions of some of the trip purposes.

Delimiting the Central Area

As indicated earlier, this investigation considered stratifying the study area into central and noncentral areas. It was assumed that the central and noncentral areas might reflect 2 different trip-generation patterns because of the shape of the study area, its historical quasiannular urban growth, and the configuration of the transportation system. This differentiation of the central and noncentral areas was categorical instead of numerical and could best be treated through stratification.

The rationale behind the procedure developed to delimit the central area was tied to the expected character and attributes of a central area. A large proportion of the land in a central area is expected to be in urban use. A relatively small proportion of the land in a central area is expected to be devoted to residential uses. Conversely, a relatively high proportion of the land in the central area was expected to be in uses that are known to seek central location.

Land was considered to be in urban use if it did not belong to any of the following classifications: quarry and mining, automobile junkyard, water, agriculture, or vacant. The percentage of urban land in residential use was the measure of the intensity of residential activity. The percentage of land in urban use was the measure of urbanity. Among the different trade and service uses on which IRTADS had floor area information, the following were chosen as those that seek a central location: wholesale trade (without warehousing); general retail trade; automobile retail; apparel, furniture, and appliance retail; retail use not otherwise classified; finance, business, and professional services; contract construction services; governmental services; personal services; and services not otherwise classified. Educational services were excluded because schools do not necessarily seek central locations. The floor area of each use in hundreds of square feet per acre of land in urban use was calculated for each district. This ratio measures not only the amount but also the intensity of use.

The measures given above were used to set the following conditions for delimiting the central areas:

1. The delimitation should be performed at the district level (a district is a contiguous group of zones).
2. The central area should probably include all of the central business districts and some of the qualifying surrounding districts.
3. The districts of the central area should all be contiguous and connected.
4. A qualifying district must be at least two of these: in the lower quartile of all the districts of the study area in percentage of urban land in residential use, in the upper quartile of all the districts of the study area in the percentage of land in urban use, or in the upper quartile of all districts of the study area in the ratio of hundreds of square feet of uses usually seeking central location to acres of urban land in each district.

The study area was stratified into central and noncentral areas (Fig. 4). The districts of the central area comprised 105 zones out of the 395 in the study area.

MODEL BUILDING

Guidelines for Model Building

Multiple linear regression models of trip generation were developed by using the computer program BMD-2R, stepwise regression. In addition to the desired statistical qualities of the developed models, other important factors were also considered.

Conceptual Validity—The consideration of relative accessibility was mainly to achieve a sounder conceptual basis for trip generation. In addition, only independent variables that were logically related to the specific dependent variable under consideration were allowed to enter when regression equations were developed for that dependent variable. The causal-logical relation was considered prior to the mere statistical correlation analysis. Association and correlation do not prove causality; causality should only be hypothesized on theoretical or conceptual grounds.

Model stability is one of the desirable products of conceptual validity. Relations that are not conceptually valid, if established from today's data, are more apt not to hold in the future. Predictive equations of trip generation should hold for the future to have any forecasting capability.

Another facet of conceptual validity is the sign of the regression coefficient. Because of collinearity in the variables, the coefficient of one of the independent variables could be contrary to the theoretical relation, and this condition might be statistically acceptable. In spite of this, it was decided to delete those variables whose coefficients had signs contrary to conceptual expectations. This should increase the statistical validity of the model as it tends to reduce the effects of collinearity.

Simplicity—The models were kept as simple as possible by avoiding unnecessary transformations of and interactions among the original independent variables. Interactions beyond the product of 2 independent variables were considered difficult to interpret and thus were avoided unless the third variable of the product was the dummy variable defining the location of a zone in the central or noncentral areas.

Keeping the structure of the model as simple as possible by not going to higher order interactions curtails the propagation of measurement errors. Another aspect of simplicity is parameter parsimony. Although it is valuable to include all relevant independent variables and thus reduce specification errors, it is doubtful that it would be advantageous to do so when, as is the case for transportation studies, the input data are inherently plagued by measurement errors. As an emphasis of this research, the number of independent variables in the model was kept to a minimum.

Stability—So that the developed models would be stable during a time period, the prerequisite of allowing a variable to enter the model was a hypothesized causal relation rather than a mere correlation.

Stability was also sought over the range of the values of the independent variables. This could be quite a difficult criterion to account for during model building. A study of the range of the independent variables for the forecast year was undertaken, and possible problem zones were identified. Recommendations will be made to ameliorate this condition.

Sensitivity—It is desirable that the response of the dependent variable be sensitive to changes in each of the independent variables in the model. The cost of adding 1 more independent variable would not be justifiable if the dependent variable is not sensitive to changes in the added independent variable. The sensitivity of the dependent variable to each of the independent variables in the model was tested by calculating the standardized regression coefficients (the regression coefficients multiplied by the ratio of the standard deviation of the independent variable under consideration to the standard deviation of the dependent variable).

Statistical Considerations

Stepwise Regression—The computer program used by this research, as mentioned earlier, was BMD-2R, stepwise regression. Several procedures are available to develop multiple regression models. The "tear-down" or "backward elimination" method starts with a model containing all the available independent variables and subsequently eliminates some of the independent variables until a model with predescribed statistical features is reached. The "build-up" or "forward selection" procedure strives for a similar final outcome but works in the opposite direction by inserting 1 more independent variable at a time. Stepwise regression is an improved version of forward selection procedure. The independent variables in the model are reexamined at the end of each step. The variable that might have been the best single variable to enter at an earlier step might prove to be unnecessary at a later stage because of the relation between it and other variables now in the equation. Thus, at each step, the partial F-test for each variable in the equation was evaluated and compared to a preselected percentage point of the appropriate F-distribution. Stepwise regression evaluates the contribution of each independent variable in the model at the end of each step, regardless of whether the independent variable has entered at the last step or at any earlier step.

Partial F- or Sequential F-Test—By far, the most important statistic in conjunction with regression analysis is the multiple coefficient of determination, R^2. It measures the proportion of total variability in the dependent variable explained by the regression model. R^2 varies between 0 and 1: A value of 0 indicates a complete lack of fit, while a value of 1 implies a perfect correlation. In stepwise regression, a test is needed at each step to check whether the increase in R^2 contributed by each added independent variable in the equation is significantly different from 0. The following F-statistic tests whether the contribution of the k independent variables is significantly greater than 0.

$$F_{k,n-k-1} = (R_k^2/k)/[(1 - R_k^2)/(n - k - 1)]$$

where

n = number of observations,
k = number of independent variables, and
R_k^2 = coefficient of multiple determination of a model with k independent variables.

The calculated F-statistic is compared to a tabulated $F_{k,n-k-1,1-\alpha}$, where α is the probability of a type I error, or the level of significance. The level of significance chosen should depend on the consequences of rejecting a true hypothesis. The level of significance was set at 0.010 for including a variable and at 0.005 for deleting a variable. The selection of these values is based on acceptance of a relatively high risk of including a variable that does not belong. Once this variable has been accepted, there is a lower risk acceptable for its retention in the equation based on the entry of other independent variables.

The blind use of the F-test may result in the development of a regression model that involves more independent variables than are of practical significance. In transportation studies, the number of observations is large and results in an F-statistic that is statistically significant even when the absolute increase in R^2 is very small. The criterion of a significant increase in R^2 proved to be superfluous in most cases; other criteria such as simplicity, parsimony, and reasonableness controlled the number of variables to be included in the model.

Standard Error of Estimate—Another statistic of interest is the standard error of the estimate, s. It is the square root of the residual mean square. The smaller the value of this statistic is, the more precise the predictions will be. The criterion of reducing s must be used cautiously because s can be made small by including enough parameters in the model, just as R^2 can be increased. As more independent variables are included in the equation, the decrease in s will be at a decreasing rate. Reduction of s is desirable if many degrees of freedom for error are remaining.

Another way of looking at the reduction in s is to consider it in relation to the dependent variable, namely, as a percentage of the mean value of the dependent variable. Standard error of estimate as a percentage of the mean of the dependent variable is referred to as the coefficient of variation.

t-Test on Regression Coefficients—It is sometimes desirable to test whether each of the estimated regression parameters is significantly different from 0. The ratio of each regression coefficient to its standard error is distributed as student-t. If the regression coefficient of one of the independent variables does not pass the t-test, it can be deleted from the equation.

The 3 criteria of R^2, s, and significance of the regression coefficient are not independent. Usually, the decision can be made on the basis of R^2 alone.

Model Identification

The first set of models that was developed by this investigation was a rerun for each of the 13 dependent variables using the same independent variables established by IRTADS for its equations (3). In the interest of compatibility and comparability, data from all the 395 zones were used to reestimate the parameters of the models developed by IRTADS. Those models, essentially developed by IRTADS, were used as a basis for comparison with other developed models.

A second set of models that include relative accessibility variables was attempted for each of the 13 dependent variables. The first 2 sets of models were developed with data from the 395 zones with no distinction relative to location in the central or noncentral areas. Two more sets of models were developed: one corresponding to the set developed by IRTADS and the other to the set of models developed by this investigation. These latter models contained a dummy variable defining the location of a zone in the central or noncentral areas.

Basically, 4 sets of models were developed. Two had no relative accessibility variables among their independent variables: one of those, set W-U, was developed by the traditional procedures for IRTADS and the other, set W-S, contained a dummy variable that defined the zone location or some of the interaction of the dummy variable with the other independent variables in the equation or both of these. Of the remaining 2 sets, set A-U had relative accessibility variables, and set A-S also had relative accessibility variables and was calibrated with stratified data. Figure 3 shows a system for the identification of the developed models. It was not possible to develop models for each dependent variable in every set, as indicated.

COMPARISON OF THE DEVELOPED MODELS

The statistical strength of the models was compared by comparing their corresponding coefficients of multiple determination. The model sets compared to determine improvements by the actions indicated were as follows:

1. A-U versus W-U, introducing relative accessibility variables to the basic IRTADS models;
2. W-S versus W-U, calibrating the models with data stratified according to the zone location over the basic IRTADS models; and
3. A-S versus W-U, introducing both relative accessibility variables and calibrating the model with stratified data over the basic IRTADS models.

The results of the statistical tests of the significance of the increase in R^2 of each developed model over the corresponding basic IRTADS model are given in Table 2. Comparative summary statistics of all developed models are given in Table 3.

CONCLUSIONS

Based on the preceding results and analyses, the following conclusions can be drawn:

1. Among all of the relative accessibility variables considered, the following variables were included in the trip-generation models that were developed: accessibility to employment in conjunction with home-based work productions and non-home-based work attractions; accessibility to labor force in conjunction with home-based work attractions; accessibility to single-family dwellings in conjunction with home-based shop attractions and home-based other attractions; and accessibility to educational floor area in conjunction with home-based school productions and non-home-based nonwork attractions. The preceding accessibilities were each calculated with the friction factor corresponding to the same trip purpose as the model under consideration.
2. Relative accessibility variables in trip-generation models improved the statistical strength of models of person-trip attractions more than that of models of person-trip productions. Competition is a more important locational consideration for high-attraction zones, which indicates their need for greater accessibility.
3. Calibrating trip-generation models with data stratified according to the location of the zone in the central or noncentral areas always improved the statistical strength

Figure 3. Trip-generation models developed.

THE DEPENDENT VARIABLES	WITHOUT ACCESSIBILITY W		WITH ACCESSIBILITY A	
	UNSTRATIFIED U	STRATIFIED S	UNSTRATIFIED U	STRATIFIED S
1. HOME_BASED WORK PERSON_TRIP PRODUCTIONS (HBWKP)	W_U_1	W_S_1	A_U_1	☒
2. ,, ,, SHOP ,, ,, ,, (HBSHPP)	W_U_2	☒	☒	☒
3. ,, ,, SCHOOL ,, ,, ,, (HBSCLP)	W_U_3	W_S_3	A_U_3	A_S_3
4. ,, ,, OTHER ,, ,, ,, (HBOTRP)	W_U_4	☒	☒	☒
5. NON HOME_BASED WORK_ORIENTED PERSON_TRIP PRODUCTIONS (NHBWKP)	W_U_5	W_S_5	A_U_5	A_S_5
6. NON HOME_BASED NON WORK_ORIENTED PERSON_TRIP ,, (NHBNWP)	W_U_6	W_S_6	A_U_6	A_S_6
7. TOTAL PERSON_TRIP PRODUCTIONS (TOTP)	W_U_7	W_S_7	A_U_7	A_S_7
8. HOME_BASED WORK PERSON_TRIP ATTRACTIONS (HBWKA)	W_U_8	W_S_8	A_U_8	A_S_8
9. ,, ,, SHOP ,, ,, ,, (HBSHPA)	W_U_9	W_S_9	A_U_9	A_S_9
10. ,, ,, OTHER ,, ,, ,, (HBOTRA)	W_U_10	W_S_10	A_U_10	A_S_10
11. NON HOME_BASED WORK_ORIENTED PERSON_TRIP ATTRACTIONS (NHBWKA)	W_U_11	W_S_11	A_U_11	A_S_11
12. NON HOME_BASED NON WORK_ORIENTED PERSON_TRIP ,, (NHBNWA)	W_U_12	W_S_12	A_U_12	A_S_12
13. TOTAL PERSON_TRIP ATTRACTIONS (TOTA)	W_U_13	W_S_13	A_U_13	A_S_13

☒ INDICATES THAT NO SATISFACTORY MODEL WAS DEVELOPED.

Table 2. Results of comparisons of sets of models.

Trip Purpose	A-U Versus W-U	W-S Versus W-U	A-S Versus W-U	Trip Purpose	A-U Versus W-U	W-S Versus W-U	A-S Versus W-U
1	N	S	*	8	N	N	**
2	*	*	*	9	**	S	S
3	S	S	S	10	S	S	S
4	*	*	*	11	**	S	**
5	**	S	**	12	**	S	**
6	**	S	**	13	**	S	S
7	**	S	**				

Note: N = increase in R^2 is not significant at $\alpha = 0.0005$, S = increase in R^2 is significant at $\alpha = 0.0005$, * = no satisfactory models were developed, and ** = models were developed but no statistical testing was possible.

Table 3. Comparative statistics for all sets of models.

Trip Purpose	Coefficient of Multiple Determination				Coefficient of Variation (percent)				Number of Independent Variables in Model			
	W-U	W-S	A-U	A-S	W-U	W-S	A-U	A-S	W-U	W-S	A-U	A-S
1	0.974	0.975	0.977	*	16.30	16.00	15.52	*	1	2	3	*
2	0.887	*	*	*	38.38	*	*	*	2	*	*	*
3	0.630	0.659	0.670	0.699	80.28	77.14	75.95	72.66	1	2	2	3
4	0.903	*	*	*	31.99	*	*	*	2	*	*	*
5	0.748	0.767	0.748	0.790	53.83	51.89	53.89	49.41	4	7	5	9
6	0.650	0.806	0.643	0.797	70.43	52.69	71.10	53.91	5	8	5	9
7	0.961	0.965	0.958	0.962	17.89	17.15	18.61	17.83	4	6	4	6
8	0.839	0.840	0.840	0.842	54.93	54.74	54.72	54.54	1	2	2	3
9	0.442	0.705	0.553	0.639	158.64	115.63	141.99	127.92	2	4	2	4
10	0.679	0.716	0.682	0.719	53.05	50.04	52.90	49.94	5	7	6	9
11	0.738	0.757	0.739	0.780	54.01	52.22	54.15	49.84	4	8	7	10
12	0.636	0.799	0.645	0.801	73.67	55.05	72.90	54.70	5	8	6	7
13	0.771	0.844	0.801	0.848	46.68	38.71	43.58	38.27	5	8	5	9

* = no satisfactory model developed. Degrees of freedom ranged from 382 to 392.

Figure 4. Noncentral area zones where basic IRTADS models underforecast trips.

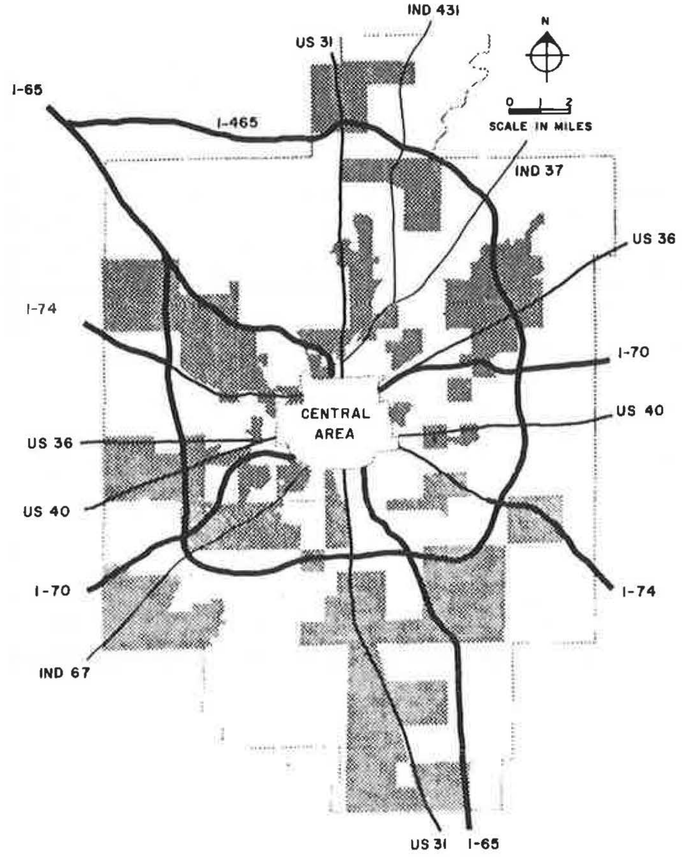
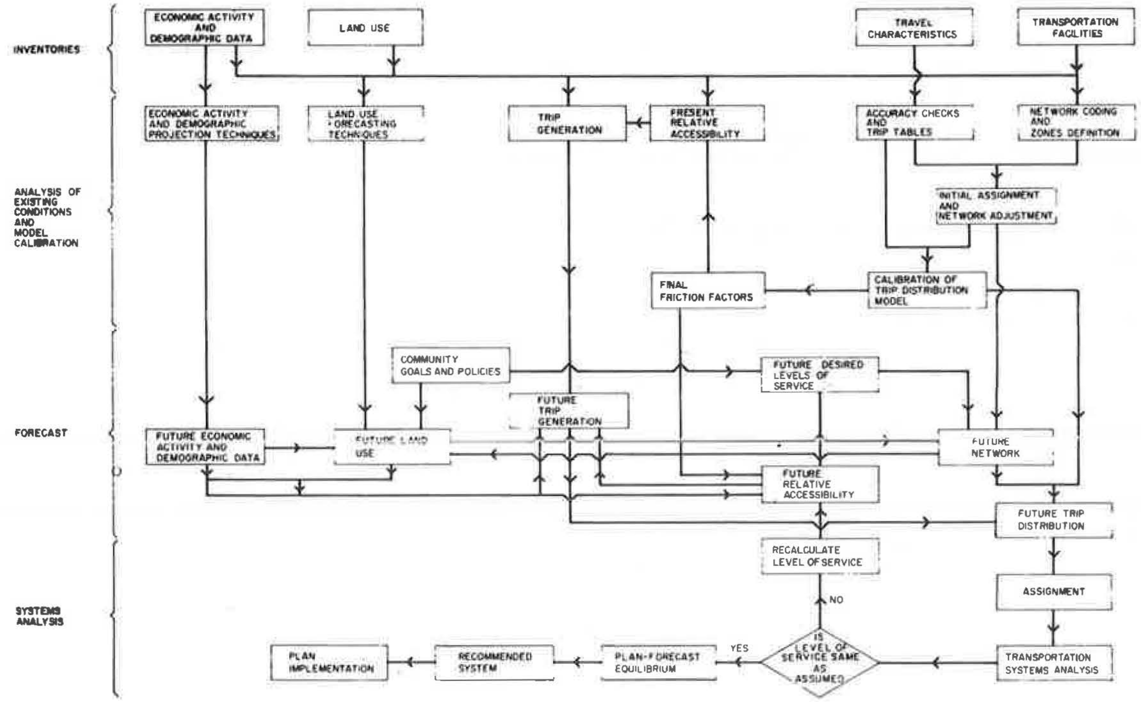


Figure 5. Proposed trip-generation process.



of the models whether the models had accessibility variables or not. Models of home-based work person-trip productions or attractions were improved least by including relative accessibility variables or stratification or both. This is expected because work trips are inelastic to trip length because of their regularity and necessity. Furthermore, it indicates substantially similar attracting characteristics for work trips by zones in the central and noncentral areas.

4. In general, the statistical strength of the developed models was better achieved by stratification alone than by including relative accessibility variables only.

The 4 sets of developed models were solved with the 1985 forecast values of the independent variables. The forecasts were analyzed to identify comparative forecasting trends of the different models. The following conclusions were drawn.

5. It was observed that stratified models consistently forecast more trip productions and attractions for zones of the noncentral area and fewer for zones of the central area than models without stratification. Stratified models are thus sensitive to the situation of equilibrium and saturation being reached in the central area and also the faster rate of traffic growth in the noncentral area.

6. 1985 forecasts of person-trip productions and attractions by models that had relative accessibility variables and that were calibrated with stratified data were significantly different from forecasts by basic IRTADS models. There was not a detectable trend as to the sign of the mean difference between zones of the central and noncentral areas. Further analysis indicated that stratified models with relative accessibility variables forecast more productions and attractions than were forecast by basic IRTADS models, in general, for zones located in the vicinity and along corridors defined by the major thoroughfares of the study area. This reflects a possible locational aspect of trip generation in addition to the central-noncentral stratification. This is shown in Figure 4.

The trip-generation models proposed by this research are functions of the status of the transportation system. In an operational transportation study, future forecasts of trip generation would then be affected by the nature of the proposed transportation network. Because the proposed network should be designed to serve future trip generation, an iterative process should be followed. It would be terminated when an equilibrium between the future supply of transportation (proposed plan) and the demand for transportation (travel forecast) is reached. This iterative process is shown in Figure 5.

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