Demand-Estimating Model for Transit Route and System Planning in Small Urban Areas

Marvin Golenberg, SG Associates, Inc., Boston
Steven Pernaw, Alan M. Voorhees and Associates, Inc., Boston

A simplified model for directly estimating transit route and system patronage for small urban areas is presented. A category approach is used to determine basic transit trip generation by automobile-ownership classification. The basic rate is then modified by a series of adjustment relations for trip length, walking distance, and service frequency to arrive at an estimate of patronage for the service alternative under study. The model can be manually applied and used to assess new service, extension of existing service, or improvements in the existing level of service.

A principal component of transit planning and development studies centers on procedures for estimating demand and patronage. These procedures are important because they are the main means of assessing (a) benefits of new service or modifications to existing service; (b) financial feasibility of new or modified service; (c) mobility impacts on population that result from service changes; (d) potential impacts on areas served by new or modified transit services, areas such as central business districts (CBDs) and public service complexes; and (e) potential impacts on other transportation modes or transportation-related social, environmental, and economic factors.

Patronage-estimating procedures are well developed for large urban areas, particularly for long-range, capital-intensive transit improvements. These techniques have proved relatively successful because of a combination of one or more of the following factors characteristic of transit improvements in larger urban areas: (a) major system changes; (b) large travel markets in which transit service can have significant impacts; and (c) dominance in systems or corridor studies of travel that is diverted to transit rather than captive travel or latent transit demand. In addition, large urban areas generally have available a wealth of travel data for both highway and transit travel, data that represent a fairly wide range of conditions and permit the development of reasonably stable and statistically accurate forecasting relations.

Smaller urban areas present somewhat different problems in transit planning, both in the scale of proposed transit development and in the data base from which to derive forecasting relations. Transit improvements in smaller areas are less dramatic than those in larger areas, both in level-of-service changes and in overall impact on the total transportation system. Adding a new local bus route in a corridor or increasing service frequency on a local bus route—each an example of typical small-area transit improvements—is far less dramatic than building a rapid transit line in a corridor. In small urban areas, the smaller-scale changes in transit service, the relatively small travel markets, the lower potential for diversion of travel to transit, and the comparative dominance of the captive-rider and latent-demand market generally cause changes in the level of demand that cannot be satisfactorily addressed by competitive mode-forecasting techniques.

Techniques for direct estimation of transit patronage are more appropriate for smaller urban areas and also for comparatively minor service changes, for the following reasons:

1. Transit service improvements in small urban areas and minor changes in large urban areas generally have a greater impact on the generation of new travel than on diverting travel; new demand is mainly generated travel and only a minor amount is diverted travel.
2. The amount of new patronage, although significant in transit planning (mainly because of low existing patronage), does not have a significant effect on highway traffic volumes in relation to highway planning decisions.
3. Mode-share models are generally unsatisfactory for estimating the relatively small changes in patronage that occur as a result of the level-of-service changes most common in small-area and short-term transit improvements.

There is a need for a technique of estimating demand and patronage that is appropriate to the characteristics and commensurate with the requirements of small areas and comparatively minor transit service improvements. As with more traditional mode-share techniques, this technique must be sensitive to the policy-related factors inherent in transit planning: frequency, coverage, fares, and travel time. In addition, the comparative size of existing travel markets, characteristics of potential trip makers, and latent demand generation potential should be accounted for. Other considerations are the desire to simplify application of the technique to increase its utility as a planning tool by reducing the data requirements, the application effort, and reliance on senior professional staff.

A desirable technique is one that

1. Is responsive to all major policy issues;
2. Is sensitive to trip-maker and level-of-service characteristics;
3. Is intuitively simple;
4. Has minimal data requirements (can be used with census data and planning descriptions of transit service);
5. Can be applied efficiently as a manual technique for route or small-system planning but, if need be, can be computerized to simplify bookkeeping for repetitive or larger-system applications; and
6. Is intuitively correct (e.g., patronage changes are intuitively consistent with the direction of change in a particular service characteristic).

PAST EXPERIENCE

A number of approaches to the estimation of demand and patronage have been developed for small-area transit planning. These have generally been of two types: estimation of areawide system patronage and route-corridor estimation. Techniques for both have ranged from simple (standard productivity rates with specified route mileage and hours) to complex [behavioral system models developed by the New York State Department of Transportation (1-3)]. A number of the more widely used approaches or variations are briefly described here.

One simplified aggregate systemwide approach is based on use of an annual per-capita transit ridership that corresponds to a typical average, overall transit operation for a small urban area. The per-capita trip rate is modified for variations in systemwide frequency and fare from the per-capita-trip-rate reference condition. Data are empirically derived from a number of smaller urban areas. Route planning cannot be done by using this technique.

The approach developed by Hillegass (4) is a simplified technique based on major corridor or route structure for travel to the CBD. The premise of the approach is that in smaller urban areas the predominant type of transit trips is trips to the CBD, which are largely work trips. A generalized relation between mode split and automobile-occupancy and income and automobile ownership, developed from national statistics, is used to estimate systemwide (and corridor) travel to the CBD for a given estimate of CBD person work travel for the urban area. The procedure explicitly addresses the area of transit route coverage and user characteristics but does not contain specific relations to reflect frequency and fare variations.

Procedures developed in Massachusetts—in the Merrimac Valley (5) and Northern Middlesex (6) transit development programs (TDPs)—are both variations and extensions of the approach advanced by Hillegass. The Merrimac Valley approach is a corridor technique that implies a radial CBD-dominant transit system. Basic transit trip rates within a 0.8-km (0.5-mile) coverage band for separate automobile-ownership categories are used to estimate a base route demand. Relations for service frequency and fare changes developed in other studies are used to modify the base route demand. The Northern Middlesex technique is similar but uses a trip rate based on income. Adjustments for frequency and fare variations are again based on relations developed in national studies.

All of the above techniques stress simplification in application and a complexity in balance with the demand-forecasting problem. The four approaches have similar inherent assumptions that are not always explicitly presented. All are based on a radial route structure that focuses on the CBD. Transit travel is predominantly home-based travel to the CBD; there is little crosstown or non-CBD corridor travel. Routes are fairly short in length and generally do not extend beyond the older, denser residential core; few routes extend to newer, low-density residential areas. Consequently, these techniques are intended to be used primarily for direct travel to a single dominant activity center over fairly short [6.4-km (4-mile)] maximum travel distances.

Each of the approaches is intuitively acceptable, and each contributes to the state of the art. Collectively, they form a good basis for further extension of a simplified forecasting technique.

CONCEPTUAL ASPECTS OF MODEL DEVELOPMENT

A number of conceptual hypotheses are presented that establish the structure for model development. These are based partly on previous work, on general findings from analysis of transit data, and from intuitively derived relations based on observation of transit and travel data.

The nature of transit trip making in smaller urban areas and, to a degree, new trip making associated with transportation system management (TSM) type of improvements to bus service in any area argues strongly for a demand-estimating technique that emphasizes generation of trips rather than mode splitting of existing demand. This establishes the approach for model development.

Specification Guidelines

The objective of the process of model development is to produce a set of relations that can be applied at the planning level to determine potential ridership levels for variations in service as well as service to activity centers of different sizes. Conceptually, the variations that should be addressed are route relocation, route extension, frequency changes, route speed changes, changes in fare levels, route coverage, trip-maker characteristics, and activity location and size. It is desirable to structure these relations so that they can quickly and easily be used to evaluate transit service improvements. Graphic and tabular representations, rather than mathematical equations, are desirable. Model development is directed toward this format.

The model is in the form of direct transit trip generation and is structured as a set of separate but integrated relations. The components are

1. A basic transit trip generation rate by socioeconomic category and
2. Relations for modifying trip generation by (a) variation in walking distance to service, (b) distance from the attraction center, (c) change in service frequency, (d) change in fare levels, (e) change in schedule running speed, (f) size of activity center, and (g) size of urban area.

Model development does have some basic constraints. These are primarily dictated by available empirical data. The source of empirical data on ridership is on-board travel surveys for conventional fixed-route, radially oriented surface bus systems. The basic data limitations are that (a) the model is for conventional transit service and should not be extended to paratransit services and (b) the model is for trips to an activity center at the focus of radially oriented transit service. The second limitation reflects the CBD data bias. However, introduction of concepts of trip-rate adjustment, based on both the absolute and the relative size of an activity center, and use of the principle of superposition allow CBD-based data to be extended and used for transit planning in areas that contain multiple activity centers.

Basic Trip Generation Rates

Transit trip generation rates have been shown to be related to such socioeconomic characteristics of trip makers as income and automobile ownership. Both variables have been shown to be highly correlated. Since information on automobile ownership taken from survey data is more reliable than data on income, it is selected as the basic variable. In addition, automobile-ownership distributions are readily available from census data, there are fewer variable stratifications, and impacts of energy crises will be more readily reflected in automobile ownership than in income.

The basic trip rate should be for each category of automobile ownership: households with no automobile, households with one automobile, and households with two or more automobiles. Trip generation is based on trips per household (since this is a short-term forecasting technique, the apparent trend toward lower household size can be ignored). To ensure that trip generation reflects "effective" transit service, only data from covered areas are used in developing trip rates. Each trip-rate value will inherently reflect "averages" of the other parametric values, such as trip length and distance from a route. A basic trip-rate table is shown in Figure 1.

Trip Length

Transit trip generation rates should vary with distance from the CBD. This reflects two phenomena: trip distribution and mode share. Both concepts are described below.

A hypothetical radial travel corridor to the CBD is used to show the effect of trip distribution. The corridor consists of four zones of equal length and width; all zones have identical socioeconomic and trip generation characteristics. The width of the corridor is taken as being equal to the coverage of a transit route—approximately 0.8 km (0.5 mile)—as shown in Figure 2.

The generalized distribution of trip length and frequency for each zone can be estimated by using trip distribution theory and empirically based observation. In Figure 3, zone 1 sends a trips to the CBD, zone 2 sends b trips, zone 3 sends c trips, and zone 4 sends d trips, where $a > b > c > d$. If trips to the CBD from the corridor were plotted by distance from the CBD, a trip-length distribution of CBD-oriented trips would result. For example, Figure 4 shows that travel from a zone to the CBD decreases as the distance from that zone to the CBD increases.

The implications of the relations shown in Figures 3 and 4 for procedures for forecasting the transit trip rate are significant. For example, if the transit trip rate were taken as a constant value, it would imply either increasing mode share or greater latent demand generation or both. This is contrary to empirical evidence.

Generalized mode-share relations along the corridor can be hypothesized from mode-share theory and empirical evidence. A generalized mode-share profile is shown in Figure 5. Transit is not an attractive mode for short trips, primarily because of the relatively high waiting times; walking and the automobile are more attractive, and hence mode split or transit trip generation would be lower for short trips. At the other extreme—long trips—transit begins to lose its attractiveness as line-haul time and cost begin to favor the automobile; the mode share for transit then decreases.

A conceptual relation of variation in transit trip generation rates along a transit service corridor can be derived from the above characteristics. This relation should also show differences for different strata of automobile ownership. Total person-trip-length distribution by distance will vary by category of automobile ownership because of the comparative difficulty in reaching the same spatial opportunities in the same travel time for each category. Two-automobile households have a superior mode available for trip making and can "cover more ground" in the same time as zero-automobile households, which are more dependent on "inferior" modes such as transit, taxi, and shared ride. Generalized profiles of trip-length distribution by category of automobile ownership in a trip production zone are shown in Figure 6. The relation between variation in transit trip generation along a corridor and distance from the CBD is shown in Figure 7.

All of these concepts can be applied to any trip attraction subarea, such as shopping centers and public service complexes.

Trip Frequency

Empirical observation, elasticity studies of transit system characteristics, and research based on behavioral mode-share models have all shown mode split to be sensitive to frequency of service. The relation between transit trip rate and headway, based on disutility mode-split findings, is shown in Figure 8. Separate response surfaces are indicated for each category of automobile ownership.

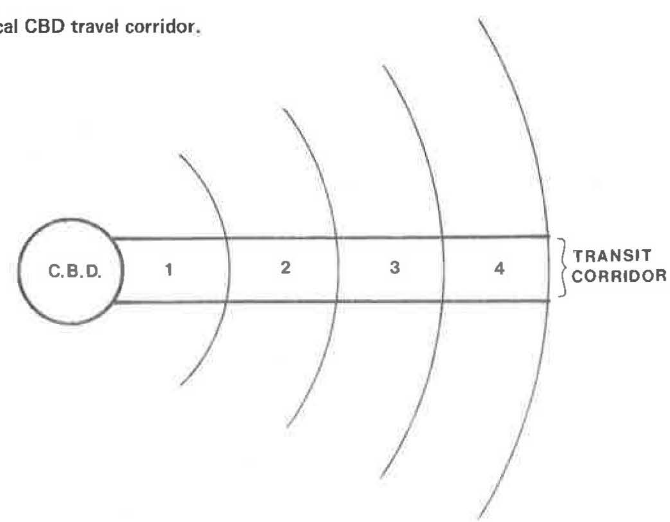
Fare

Transit trip generation (mode share) has been shown to vary with the fare charged. The relation between transit trip generation rate and fare, derived from existing mode-share and elasticity research, is shown in Figure 9.

Figure 1. Basic trip rate.

0 Auto	1 Auto	2+Auto
x.x	y.y	z.z

Figure 2. Prototypical CBD travel corridor.



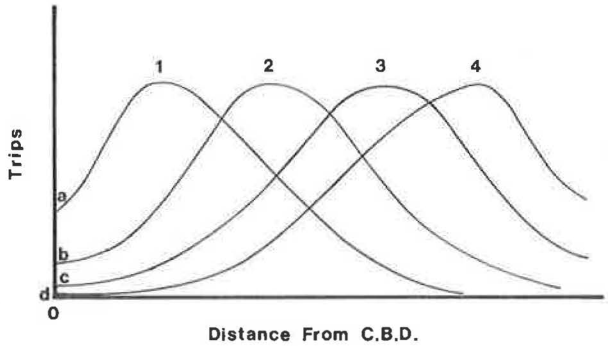


Figure 3. Generalized distribution of trips for an origin zone.

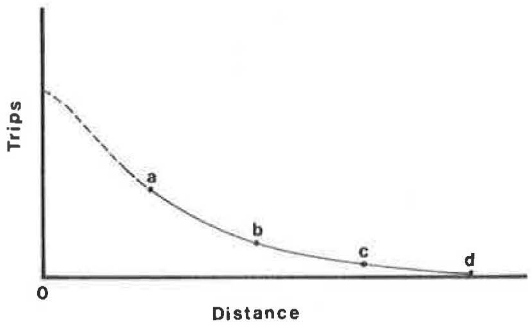


Figure 4. Trips to the CBD by distance of origin from the CBD.

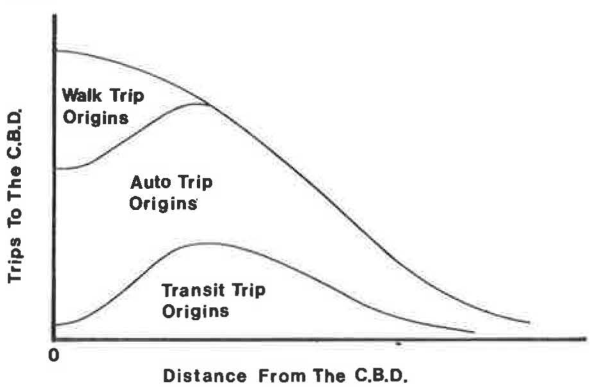


Figure 5. Generalized distribution of trip origins for trips to the CBD.

Walking Distance

Analysis of empirical data has shown that the walking distance between a potential trip origin and a transit stop has an effect on the rate of transit ridership. A generalized form of the relation between walking distance and transit trip rate is shown in Figure 10.

Trip Line-Haul Speed

Mode-split model analysis has shown transit demand to vary with changes in line-haul transit service time, all other factors remaining constant. Generally, as travel time by transit improves, the trip rate increases. A

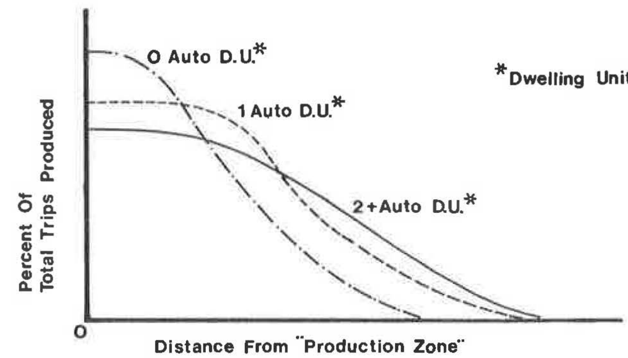


Figure 6. Generalized distribution of trips from a zone by automobile ownership.

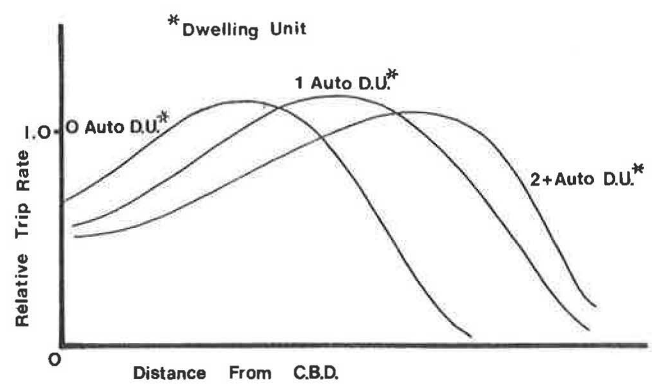


Figure 7. Relative transit trip generation rates for travel to the CBD by distance from the CBD.

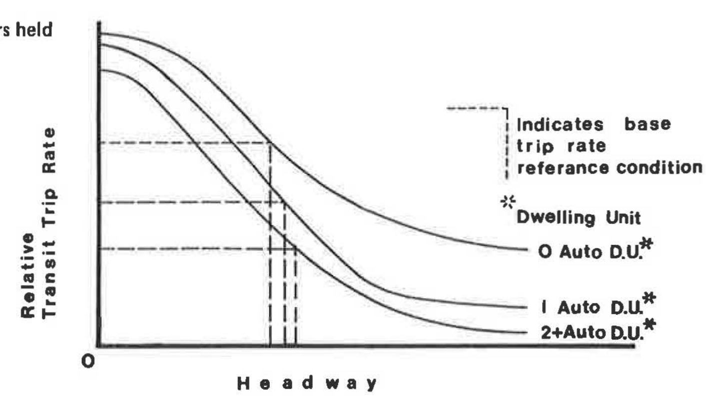


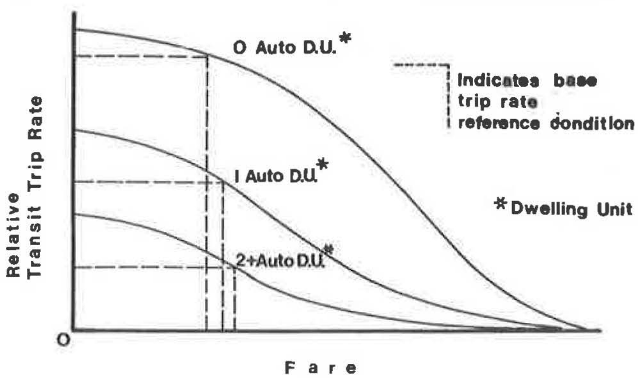
Figure 8. Transit trip rate versus headway (all other factors held constant).

hypothesized relation between speed and trip rate for a constant person-trip length is shown in Figure 11.

Size of Urban Area

Data on transit trip rates from several urban areas of different size but with approximately the same quality of transit service indicate variation in trip rates. An a priori hypothesis is that city size may be a factor in transit trip generation rates. This may be a result of a number of factors that become more pronounced as city size increases, such as increases in traffic congestion and parking cost and decreases in parking space and in walking as a primary mode of travel. Although many of these factors may be directly or indirectly accounted for in other hypotheses, a general conceptual relation between transit trip rate and size of the urban area is shown in Figure 12.

Figure 9. Fare versus transit trip rate (all other factors held constant).



Size of Attraction Subarea

The size of the attraction subarea measured in the number of trip attractions and in the proportion of total urban-area trip attractions should have an impact on transit trip generation rates. These measures reflect trip distribution, the size of the trip market, and traffic congestion as well as the cost and difficulty of parking in the subarea. It is hypothesized that, as both the percentage of area attractions and the absolute number of attractions in a subarea increase, the transit trip rate should increase, transit service parameters remaining constant. Figure 13 shows the relation between transit trip rate and urban-area attraction activity.

This hypothesis has added significance. The specification for the proposed model is for the estimation of transit trips to a single attraction subarea (the CBD). With the exception of the trip-length adjustment, the estimate of transit trip generation is independent of transit travel to any other location. It is therefore possible, and conceptually valid, to develop a number of separate estimates that correspond to transit service to other specific attraction subareas and combine them in an additive manner to yield route and system estimates for areawide travel by transit. An adjustment factor to scale the basic trip rate according to relative subarea activity would permit this.

Principle of Superposition

Superposition occurs when events taking place in the same environment are independent of one another in their effect on the environment. Impacts of each event are additive, having a linear cumulative effect. The model specification is defined to take advantage of superposition to simplify use of the model. The discussion above on estimating transit demand for more than one attraction area is an example of superposition.

Figure 10. Relative transit trip rate versus walking distance from transit route.

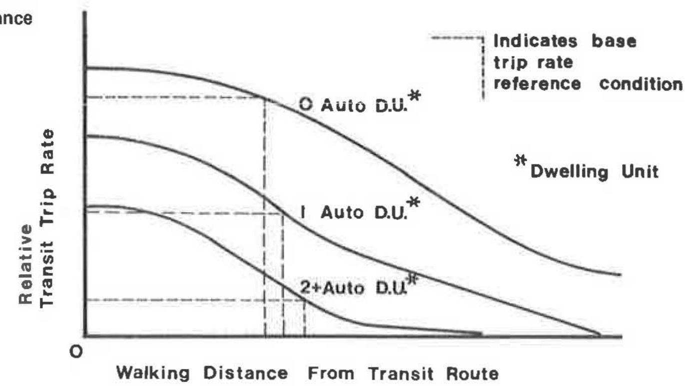


Figure 11. Route line-haul speed for a person trip of constant distance versus relative transit trip rate.

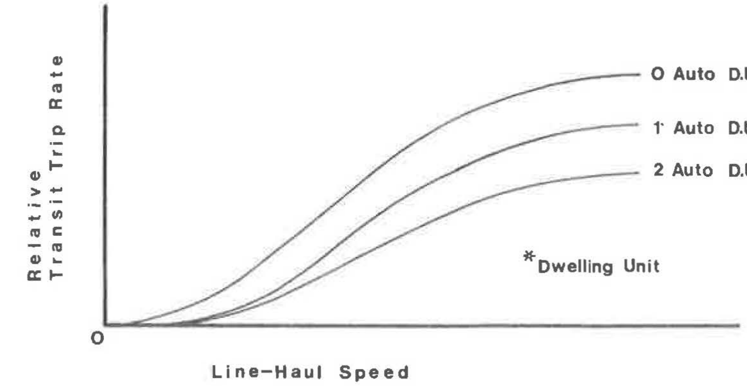


Figure 12. Relative transit trip rate versus size of urban area.

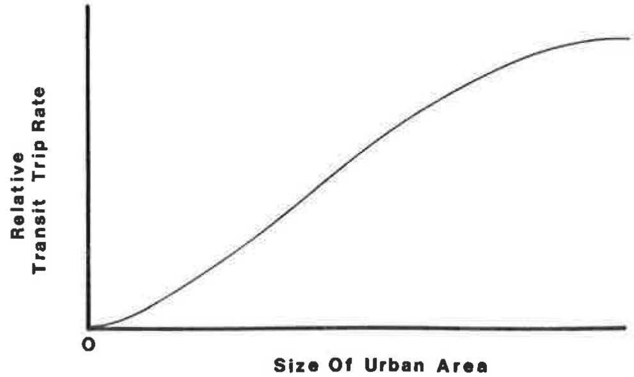


Figure 13. Relative transit trip rate versus urban-area attraction activity.

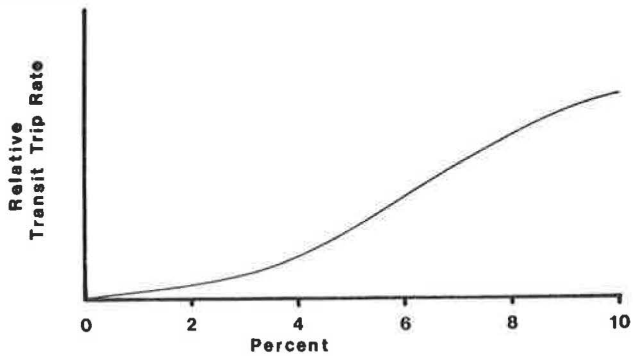
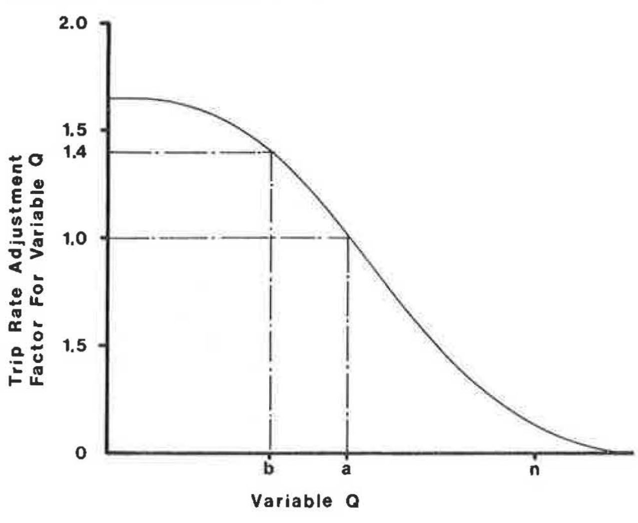


Figure 14. Trip-rate adjustment factor versus variable Q.



Application Concept

The model is intended to be applied on a route or corridor basis. It can be applied on an aggregate system basis if average route characteristics and areawide socioeconomic characteristics and percentage coverage are used.

In using the model to estimate route demand, the basic trip generation rate for each category of automobile ownership is successively modified by an adjustment factor that reflects the route characteristics, the spatial relation of the trip origin zone to the attraction subarea, and the size of the urban area and the attraction subarea. This is expressed as follows:

$$T_k = \sum_{i=1}^{n} \sum_{j=1}^{m} T_{ijk}$$

$$= \sum_{i=1}^{n} \sum_{j=1}^{m} (H_{ij})(R_j)(F_j)(W_{ij})(Q_j)(D_{ij})(SP_{ij})(A_k)(U) \quad (1)$$

where

T_k = total trips generated on the route to attraction k,
T_{ijk} = trips from zone i by trip-maker category j to attraction k,
H_{ij} = number of households of type j in zone i,
R_j = basic transit trip generation rate for trip-maker category j,
F_j = fare adjustment factor for the route for trip-maker category j,
W_{ij} = walk-distance adjustment factor for trip-maker category j in zone i,
Q_j = frequency adjustment factor for trip-maker category j,
D_{ij} = distance adjustment factor for trip-maker category j in zone i,
SP_{ij} = route-speed adjustment factor for trip-maker category j in zone i,
A_k = adjustment factor for subarea size and concentration, and
U = adjustment factor for urban-area size.

As can be seen from this expression, the application is very similar to Highway Capacity Manual procedures for calculating intersection capacity (7).

The basis of this approach is that each adjustment factor is referenced to the value each variable had for calculation of the basic trip rate. This is accomplished by normalizing each of the relations by dividing trip rates by the average basic trip rate. The value of the variable at a normalized trip rate of 1.0 is the reference condition. A generalized curve for the relation between the variable and the trip-rate adjustment factor is shown in Figure 14. (In the figure, a is the value of variable Q, corresponding to the base trip generation rate; thus, the adjustment factor for a is 1.0. If the proposed service improvement resulted in a value of b for variable Q, the base trip generation rate would be multiplied by an adjustment factor of 1.4.)

Use of the procedure implies measuring the transit system variables as the trip maker sees them. When a zone is served by only one route, there is no measurement problem; characteristics of only that route are used. However, when a zone is served by two or more routes for travel to the attraction subarea, the effective combined service characteristics must be used. This will almost always be limited to the frequency variable. As an example, a zone with two 30-min services is treated as having one 15-min service.

MODEL DEVELOPMENT

Data Base

The data base for model development consisted of an on-board transit O-D survey of approximately 1000 interviews, a description of the transit system, and socioeconomic census data from the Montachusett, Massachusetts, regional planning agency (RPA).

Figure 15. Walking-distance adjustment factor.

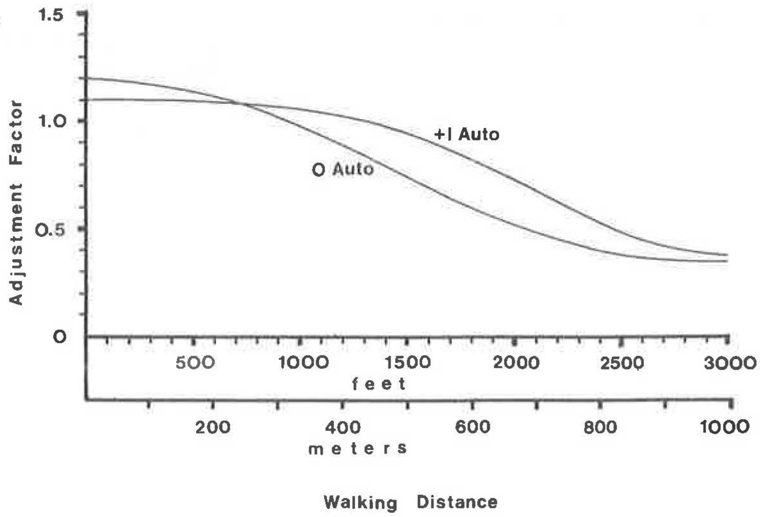


Figure 16. Trip-length adjustment factor.

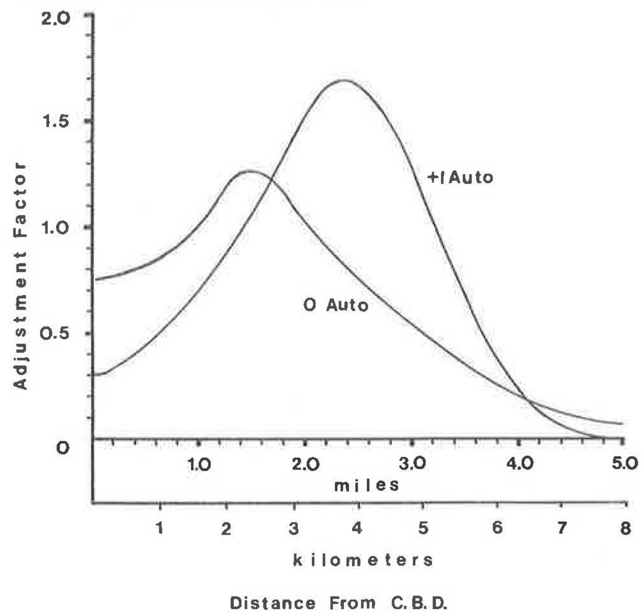
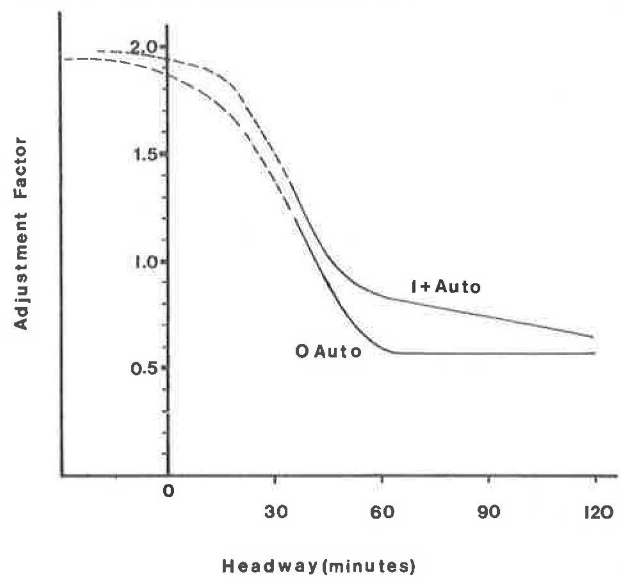


Figure 17. Trip-frequency adjustment factor.



Relations Investigated

Limitations imposed by the data restricted direct analysis to basic trip rate, trip length, walking distance, and service frequency. Fare-change relations were approached by using findings from other studies. Analysis of the effect of route speed was not possible because of a lack of suitable observations. An attempt was made to study subarea relations by using the Fitchburg and Leominster CBDs within the RPA, but this analysis was inconclusive because of problems encountered in structuring the analysis. Because of the single-area data set, the effect of city size could not be investigated.

Data Definition, Preparation, and Analysis

Trip generation was defined on standard gravity model notation, home-based and non-home-based. Only home-based trip productions were used in the model. Non-home-based trips were not included because of difficulty in associating causative factors and because these trips represented a small proportion of total transit trips. Trip attractions were not explicitly addressed; consideration of only the CBD as a trip attraction area and use of only trips to this subarea implied both distribution and balanced trip generation. This was also necessary to conform to the single-attraction focus of the model specification.

Home-based trips were not stratified by purpose, primarily because of the thin data base. Use of a single, combined home-based purpose appears sufficient for estimating transit patronage for CBD travel, but models by purpose should be more useful, particularly for estimating trips to more homogeneous subareas such as shopping centers, medical/health-care complexes, and large industrial parks.

Use of the home-based production definition produces a round-trip estimate that results in the estimate for a route in nondirectional total passengers. Directional loads and load profiles are estimated by splitting total trips equally into boardings and alightings and loading these on the route. Non-home-based trips are accounted for by factoring the home-based trips by the ratio of non-home-based to home-based trips developed from the survey data. This is an approximation but provides a working estimate that is sufficient for planning.

Analysis was done by using aggregate and semi-disaggregate techniques. Trip and socioeconomic data were referenced to traffic zones. This was done for two reasons: to provide a convenient reference for measuring transit system characteristics and to modify trip rates for each automobile-ownership category to reflect non-transit-trip-making households in that category. Within each zone, the data were treated in a semidisaggregate manner. Only households in the zone within "coverage" walking distance were included in the analysis. By using census data and other socio-economic data prepared by the RPA, an estimate was made of the number of zero-, one-, and two-automobile households in each of the traffic zones.

Transit system characteristics were estimated for each zone by using the transit route map and timetable. Distance to each zone from the CBD was measured along the route from the center of the CBD to a midpoint location in the zone. Frequency of service for the zone was taken as the combined effective frequency of all service between the zone and the CBD. A parallel resistance formula was used for the calculation. Walking distance to the route, as measured, was used to determine the limit of route coverage and was the criterion for the inclusion of data in the analysis. Walking distance as reported in the survey was used in the analysis of the effect of walking distance. Fare was constant.

Basic Trip Rate

Zonal average trip generation rates for each category of automobile ownership were graphically analyzed. Trip rates were taken as the total for the automobile-ownership categories in the zone, and there was no additional cross classification. The analysis indicated a distinct difference in trip generation rates between households with no automobile and those with one or more automobiles. Trip rates for households with two or more automobiles appeared not to be statistically reliable because of the small number of responses in that category. For this reason, households with one automobile and households with two or more automobiles were combined. The resulting basic trip generation rates are given below:

Number of Automobiles per Household	Daily Trip Rate per Household
0	0.21
≥1	0.04

Walking Distance

Trip-rate data within each of the two automobile-ownership categories were cross-tabulated by reported walking distance. Hand-fitted curves were normalized by dividing the trip rates by the basic trip rate for each automobile-ownership category; these curves are shown in Figure 15. The apparent inconsistency in the curves is produced by the normalization procedure. Normalization is within the strata, and the factor indicates the relation to the basic trip rate. Apparent inconsistency results from plotting both against internal relative scales. If the curves were each multiplied by their respective basic trip generation rates and replotted on a trip-generation-rate scale, the inconsistency would disappear.

Trip Distance

Trip-rate data by each category of automobile ownership were cross-tabulated by distance from the CBD. Curves were hand-fitted and then normalized by dividing by the respective basic trip generation rates (see Figure 16). The apparent inconsistency in the curves is attributable to the normalization approach.

Service Frequency

Automobile ownership was cross-tabulated by service-frequency trip rates to develop the normalized service-frequency curves, which are shown in Figure 17.

Validation

The initial basic trip rates and adjustment relations were applied in the Fitchburg-Leominster area to test if the model could estimate base-condition transit travel. Input data were the number of households by category of automobile ownership in each zone and measures of transit service to that zone. Estimation errors were found in the initial test, and modifications were made to the factor adjustment curves. Two additional interactions of testing and revision were required before all model components were judged to be acceptable for planning application. All information given in the text table above and in Figures 15-17 are for the final relations. The prediction accuracy of the model for zonal trip productions is shown in Figure 18.

Ancillary Models

Use of a semidisaggregate or fully disaggregate model requires specific estimates of the independent variables by the same discrete classification as that used in model development. For the Fitchburg-Leominster model, the only ancillary model required was one to estimate automobile-ownership strata from estimates of average zonal automobile ownership. This was developed from census data. An example of this relation is shown in Figure 19.

Applications

The model was applied in the Montachusett regional TDP to estimate patronage for various service improvements. In application, the model produced rational demand estimates for the proposed types of improvements. For one alternative—restoration of service to previous levels—the estimated demand was similar to actual patronage levels experienced when the service was still in effect.

The model was also used to estimate patronage for the Midstate Connecticut TDP. There was no existing transit service, and therefore patronage estimation had to be developed from "borrowed" relations. Application of this model produced demand estimates that were typical of patronage levels found in cities of a similar size and a similar level of transit service.

APPLICATION PROCEDURE

The steps followed in making an estimate for a transit line that serves an attraction subarea are presented below. Where a second or third line also provides service to zones served by the subject line, all services must be taken into account when the trip estimate for the zone is calculated; the zone trips are then split equally between each of the lines that serve the zone. If an estimate is to be made for more than one attrac-

Figure 18. Observed versus estimated zonal trips.

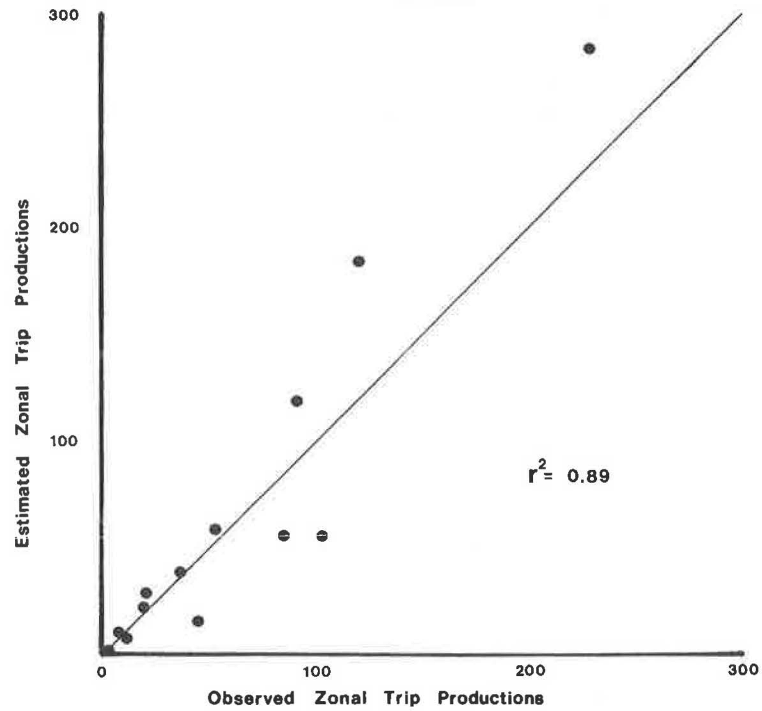
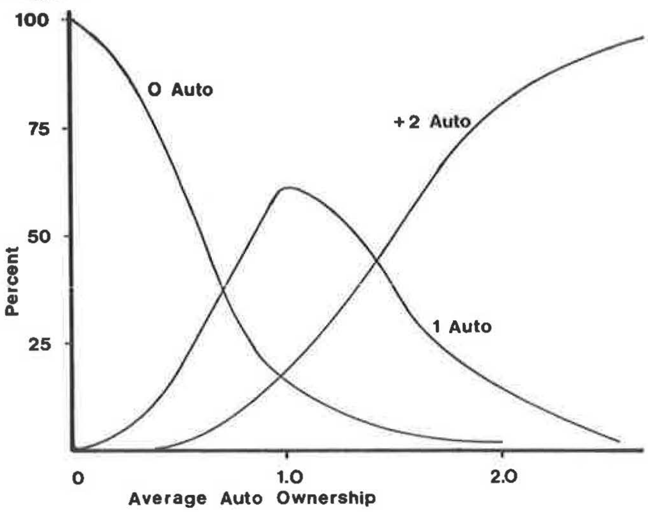


Figure 19. Average automobile ownership by automobile-ownership categories.



tion subarea served by the line, separate estimates are made for each and added together. The procedural steps are these:

1. Lay out the subject transit line on a zone map.
2. Define the coverage band of the line, approximately 0.8-1.2 km (0.5-0.75 mile) on each side of the line.
3. Note each of the zones included within the coverage band.
4. Estimate the number of households with no automobile and one or more automobiles in each zone in the covered area; this can be done by simply using a dwelling-unit density factor for the zone and a representative average automobile ownership derived from a census-tract-level estimate.
5. Estimate the average walking distance to the line; for small zones a single value is probably sufficient, but for larger zones it may be necessary to subdivide the zone into walking-distance bands. The adjustment factor for each band by automobile ownership for each zone is determined from the adjustment curve.
6. Measure the distance along the route from the attraction subarea to approximately a midpoint location of the route in the zone; select the appropriate adjustment factor for distance for each category of automobile ownership in the zone.
7. Estimate the service frequency from the zone to the attraction subarea, not the presence of multiple-line service. Select the appropriate automobile-ownership-category adjustment factors.
8. Calculate the transit trip estimate for each zone. This is done by multiplying the basic trip rate by the number of dwelling units and each of the factors. The line estimate is the sum of all individual "served" zone trip estimates, with allowance for multiple served zones.
9. Estimate total line demand by adding all activity center estimates and then factoring for non-home-based trips.
10. Estimate, if desired, route loading profiles, by converting the trip production estimate for each zone into two trips, one from the zone to the attraction subarea and one from the attraction subarea to the zone. Trips are manually assigned to produce the load profile.

EXTENSIONS AND REFINEMENTS

The results of the development, validation, and application of the model indicate that the conceptual framework and specification for the demand-estimation approach appear to be reasonable. Based on this, it is proposed that the findings be further tested by following this same approach in one or more other small urban areas. If the same results are found, the next steps should be to pursue other concepts that could not be addressed in this study: fare adjustment, urban-area size, route speed, and relative size of the attraction subarea. In addition, stratification of separate work, shopping, and other trip purposes might warrant further study.

ACKNOWLEDGMENT

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Simulation of Travel Patterns for Small Urban Areas

Jerry G. Pigman and Robert C. Deen, Bureau of Highways, Kentucky Department of Transportation, Lexington

A study conducted to simulate travel patterns in small urban areas is reported. The purpose of the study was to develop models that would simulate internal-external trips and external-external (through) trips. Regression analysis and cross classification of data were tested in an attempt to predict the number of internal-external trips and the percentage of through trips. Regression analysis was used in the development of a through-trip distribution model. Grouping data for analysis created some problems; however, trial-and-error evaluation enabled the selection of variables that produced reasonable results. The variables found to be most significant in the development of internal-external-trip models are population and employment. For through-trip models, the variables used are population, functional classification, average annual daily traffic at the external station, and percentage of trucks. In developing through-trip distribution models, the variables of significance are average annual daily traffic at the destination station, percentage of trucks at the destination station, percentage of through trips at the destination station, and ratio of destination average annual daily traffic to total average annual daily traffic at all stations (value squared). Overall, for ease of application and accuracy, the models developed appear to be adequate for planning purposes.

Agencies responsible for determining when and where to construct new urban highways and streets, or to improve existing ones, must consider many factors in the decision-making process. One such factor is the purpose and volume of the traffic that can be expected to use the facilities in the future. Estimates of future traffic patterns are made by various traffic simulation models, usually some mathematical expression with parameters and constants to simulate traffic flow. Alternative transportation systems can be evaluated in terms of costs and benefits by entering socioeconomic descriptors into a simulation model to determine traffic patterns and volumes.

Travel patterns within an urban area are divided into three categories:

1. External-external or through trips—trips that originate and terminate outside the area,
2. Internal-external trips—trips that originate inside the area and terminate outside the study area or vice versa, and
3. Internal-internal trips—trips that originate and terminate within the area.

Historically, travel data for these three types of trips have been obtained from origin-destination (O-D) surveys. The external O-D survey, in which drivers of vehicles are interviewed at the study area boundary, provides data for internal-external and external-external trips. Internal-internal trip data are generally obtained by using home-interview, truck, and taxi surveys. The collecting, coding, editing, processing, and summarizing of these data often represent a major portion of the time and cost of conducting a transportation study. However, a review of completed studies has indicated that there are many similarities in models developed for trip generation and trip distribution that involve internal-internal trips, and this makes it possible to synthesize internal-internal trips by modeling. Many similarities are also apparent in internal-external and external-external trips. Synthesis of the trips involves applying values from O-D studies to other urban areas that have similar population and socioeconomic characteristics.

The models discussed in this paper were developed for simulating internal-external and external-external trips by emphasizing previously tested procedures and by selecting variables that characterize small urban areas in Kentucky.