Forming a Comprehensive Transportation Flows Model

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• DURING THE 1950's a number of urban transportation studies have been carried out by special ad hoc agencies or other organizations in an increasingly comprehensive manner. Significant improvements in both basic study philosophy and analysis methodology have greatly contributed to increased understanding of the complexity and peculiarities of the urban transportation problem.

One of the main objectives of a transportation study is to reproduce or "simulate" (within accepted limits of accuracy) traffic flows within the region based on present or future land-use characteristics. This process of simulation has developed during the past few years and several different approaches have been used by various study groups. These different approaches represent different philosophies regarding the nature of transportation movement and its relationship with lane-use patterns and transportation systems. These relationships are expressed in a "transportation flows model" (Fig. 1) which incorporates various techniques to simulate the over-all pattern of movement at any given time and in response to given inputs of fundamental importance to the entire process.

When the Penn-Jersey Transportation Study started its work early in 1960 various models in actual use by other major studies included components that were well developed as well as components in a preliminary stage of development. It was soon realized that changes made to any of the several component parts of a model would in turn affect the form and structure of the entire model. This realization made it apparent that it would not be possible to outline a new (or a final) transportation flow simulation model satisfactorily before outlining basic methods of analysis. There was the alternative, of course, of adapting the complete model package of some other study, but even forgetting for the moment the philosophical issues of approach within the transportation model, analysis techniques used to determine some of the main components of these transportation models were still in the development stage and thus within the range of constructive debate. Besides, Penn-Jersey techniques for predicting intraregional changes of lane-use activity were basically different in design than those used by any other study, a fact which was further complicating any quick adaptation of other studies' techniques. (Penn-Jersey Transportation Study has undertaken to project future land-use patterns with the aid of a mathematical elaboration of verified locational relationships within the region. This attempt, referred to as a "regional growth model" is to encompass all the other submodels of the study. Thus the "transportation flow simulation model" is one submodel within the regional growth model.)

In response to the previous considerations, efforts were oriented to design a transportation flow simulation model that (a) would be expressing the authors' philosophical approach, and (b) would consist of techniques that would explicitly indicate relationships to be investigated and clarify the analytical process to be followed in each case.

Some of these techniques represent departures from the comparable steps in existing models or are new elements introduced by the Penn-Jersey staff. Their brief elaboration might serve to explain their relative importance and at the same time make clear the analysis they indicate. Portions of this model have been used in simulating 1947 travel patterns and are in the Philadelphia region currently being used in simulating 1960 travel patterns within this region.

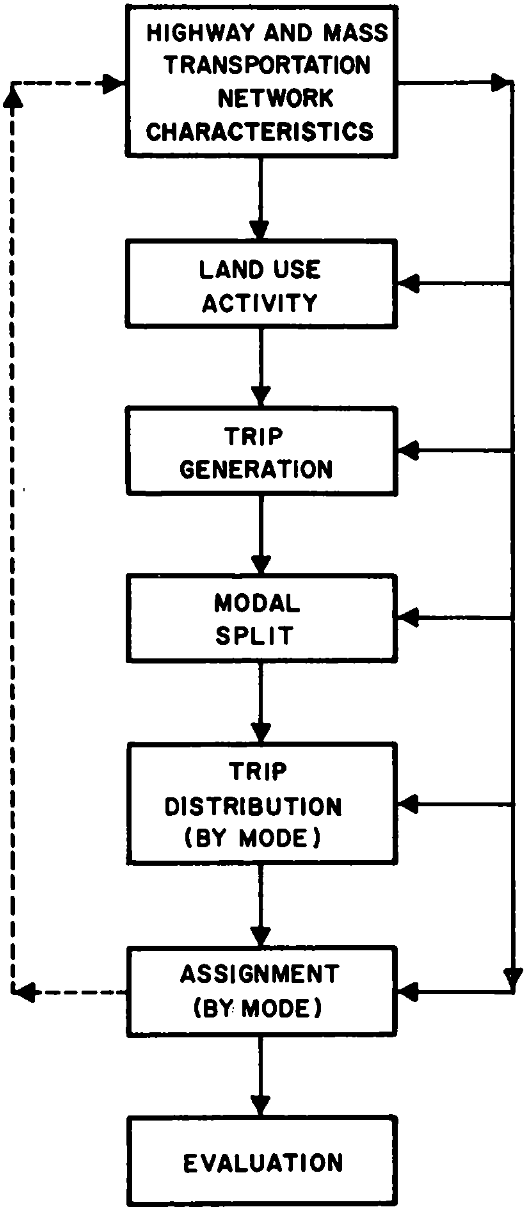

Figure 1. Simplified chart of transportation flows model.

TRIP GENERATION ANALYSIS

In general, the first step in a transportation flow model is the simulation of total trips generated (produced and attracted) within the various parts of the region. The multiple regression technique used in this analysis is the one established by other transportation studies.

The output of the trip generation model component should be the total person-trips generated by each activity and in turn by each subarea of the region, without regard to travel mode. Mass transit trips are included in the projection of total trips because this inclusion expresses an approach according to which the total person-trips generated by an activity are estimated as the basic unit of the trip generation propensities of an activity. This approach was chosen primarily because of a belief that the total person-trips generated by a unit of an activity is a more stable and meaningful estimate than any estimate of auto and transit trips taken separately. It can also be said that in many respects total person-trips can be more confidently projected to a future year than a segmental projection of trips by particular modes or for particular trip purposes. (However, this statement should not be interpreted that, after the projection of total person-trips has been carried out, subsequent estimations of trips by purpose should not or could not be carried out.)

Another point in the analysis approach is the inclusion of accessibility factors which affect the total trip generation propensities of an activity in an area. These accessibility measures are correlated with the amount of trips generated by each activity, and are described in terms of the amount of jobs, retail trade, and population located within certain increments of driving and riding time.

The third significant point is the separate generation of truck trips expressed as an aggregate of truck trips generated by the combination of all activities located within each subarea of the region. Only for special large-scale activities with a sufficient number of data observations is there an attempt to estimate truck trip generation rates per unit of activity.

MODAL SPLIT

The second step of the transportation flows model deals exclusively with the manner in which mass transportation trips in a region can be simulated and in turn be projected at any given time in the future.

The amount of travel in any area by public and private modes of travel has been considered to be primarily dependent on three major variables:

1. Automobile ownership.
2. Intensity of land use.
3. Relative time and cost of travel by mass transportation vs the automobile.

Methods used in other studies to estimate future mass transportation trips are either the automobile ownership-residential density method or the travel time ratio diversion curve method. Neither method, if used alone, can satisfactorily explain the division of total trips into modes of travel.

The approach here is to express mass transportation trips as a percentage of the total trips generated in each subarea. With this percentage as the dependent variable various characteristics of the subarea itself are used as independent variables in a multiple correlation analysis.

These characteristics include three groups of variables which could be classified as "user variables," "area variables," and "accessibility variables." User variables are those expressing the "kind" of people living in a district; e.g., income, automobile ownership, education level, population, and age distribution.

A number of variables express the "area type" in general terms. These variables are the net residential and employment densities and the school population (enrollment) in the district.

The "accessibility variables" comprehensively express the relative accessibility provided to an area by each of the two major transportation systems, namely, the highway network and the mass transportation network. One of these variables defines a concept of "time accessibility" and the other a concept of "cost accessibility." They are determined as follows. The trip generation analysis provides total person-trip destinations in each subarea. Each subarea is referenced to all others by travel time, by mode determined from the highway and transit networks coded in a computer assignment program. A set of bands (called time codes) is formed of trip ends within certain upper and lower time limits from each area. This is done for auto travel as well as for mass transit travel. Then ratios are calculated for each area between the cumulative total person-trip desitnations within each auto time code and its corresponding transit time code. The arithmetic mean of these ratios enters the analysis as one continuous variable.

A similar procedure establishes a set of ratios and an arithmetic mean of a number of "cost codes" in the region, using cost rather than time increments for both systems. These two variables are of particular importance because they introduce aspects of the urban environment (e.g., the distribution of trip opportunities in the region) into the analysis and also incorporate any proposed changes in routes, speeds, or costs of travel in either of the two transportation systems.

Conceptually, this approach of generating mass transit trips does not require a separate analysis of mass transit trips by special purposes (e.g., to school) or to special destinations (such as the CBD).

TRIP DISTRIBUTION

When all aspects of the trip generation analysis by mode of travel are completed, the third step of the transportation flow model is to distribute trip ends for auto person trips, mass transit trips, and truck trips. Two particular points should be elaborated further.

The first of these is the introduction of a new method of trip-end distribution. The theory on which this model of trip distribution is based is being presented at this meeting in another paper (1). It would, perhaps, be sufficient to mention that the new method is based on the theory of probability and also utilizes several concepts developed by users of gravity models. To a certain extent, the new method bridges the gap between the present schools of thought. In any case, the new method distributes trips by mode (or any other stratification desired) provided a high enough number of events (interchanges) is always retained so as to minimize the effects of the law of chance.

The second point is the independent distribution of truck trips. Although it is possible to express truck trips as equivalent vehicle trips somewhere early in the analysis and thereafter distribute "vehicle" trips, in this approach distribution of truck trips is attempted separately just as they are "generated" separately.

TRIP ASSIGNMENT

The last observation leads to the fourth step which involves assignment of trips onto networks, both highway and transit. This process is now in the testing stage, and the authors are currently choosing between diversion and all-or-nothing assignment, and deciding if time or total cost (including a monetary value of time plus operating costs or fares) should be used as the path trace variable. By including operating costs, the paths traced tend to be more reasonable in terms of over-the-road distances than those traced on time alone.

Perhaps the traveler places some or even more emphasis on total cost, including a value for his time, in reaching a decision as to where to terminate his trip and how to get there. It has been found, for example, that the limited number of toll crossings of the Delaware River have a marked effect on trip distribution patterns.

Also, the need for a feedback process or operational loop in the model is being investigated. Traffic assignment is based on a set of minimum paths. A minimum path, however, is subject to the degree of utilization of each link in the path because there is a need to adjust travel times on links in the highway network when volumes assigned to these links approach capacity. This would then affect the transportation network characteristics incorporated in each preceding component of the model.

EVALUATION

The model includes an estimation of travel in terms of mileage, time and costs incurred on each system tested. A three-way evaluation of any proposed future transportation system is then made. Penn-Jersey has advanced five exogenously derived alternative transportation systems. These systems would be loaded with the traffic demand at a given date. The traffic demand in each case would have been adjusted in terms of magnitude, directions, and modes according to the influence of the transportation system under the testing procedures specified. The evaluation of the system would involve three tests: (a) a sufficiency test comparing future travel demands with system capacity, (b) cost-benefit analysis of operating costs vs total investment expenditures, coupled with a cost-benefit analysis between modes of travel, and (c) an accessibility evaluation that would specify the number of trip opportunities that can be reached within certain time intervals from each area by mode.

SUMMARY

Many of the concepts expressed in this paper are not new. Certainly the over-all flow model design incorporating trip generation, modal split, trip distribution, assignment and evaluation has been pioneered by other transportation studies. The major differences lie within the components or submodels themselves.

The transportation networks, both highway and transit, are conceptually permitted to influence every submodel. (This transportation network consideration is also introduced into the determination of future land use activity in the over-all regional growth model, of which the transportation flow model is a part.) They are used to condition the amounts of trips generated. They play a major role in determining the split between modes of travel. They influence the distribution of trips as well as their usual role in assignment. It appears necessary to establish different travel demands for each new transportation network advanced for testing.

Much research remains to be done, but the design of such research to incorporate transportation network variables in all phases of the model appears significant.

REFERENCE

1. Tomazinis, A. R. "A New Method of Trip Distribution in an Urban Area." HRB Bull. 347, 77-99, (1962).