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BASIC PRINCIPLES OF TRAFFIC DEMAND ANALYSIS

If transport planners wish to modify a highway network either by constructing a new roadway or by instituting a programme of traffic management improvements, any justification for their proposal will require them to be able to formulate some forecast of future traffic volumes along the critical links. Particularly in the case of the construction of a new roadway, knowledge of the traffic volumes along a given link enables the equivalent number of standard axle loadings over its lifespan to be estimated, leading directly to the design of an allowable pavement thickness, and provides the basis for an appropriate geometric design for the road, leading to the selection of a sufficient number of standard width lanes in each direction to provide the desired level of service to the driver. Highway demand analysis thus endeavors to explain travel behavior within the area under scrutiny, and, on the basis of this understanding, to predict the demand for the highway project or system of highway services proposed. The prediction of highway demand requires a unit of measurement for travel behavior to be defined. This unit is termed a trip and involves movement from a single origin to a single destination. The parameters utilized to detail the nature and extent of a given trip are as follows:

1. Purpose
2. Time of departure and arrival
3. Mode employed
4. Distance of origin from destination
5. Route travelled.

DEMAND MODELLING

Demand modelling requires that all parameters determining the level of activity within a highway network must first be identified and then quantified in order that the results output from the model has an acceptable level of accuracy. One of the complicating factors in the modelling process is that,for a given trip emanating from a particular location, once a purpose has been established for making it, there are an enormous number of decisions relating to that trip, all of which must be considered and acted on simultaneously within the model. These can be classified as:

1. Temporal decisions – once the decision has been made to make the journey, it still remains to be decided when to travel
2. Decisions on chosen journey destination – a specific destination must be selected for the trip, e.g. a place of work, a shopping district or a school
3. Modal decisions – relate to what mode of transport the traveller intends to use, be it car, bus, train or slower modes such as cycling/walking
4. Spatial decisions – focus on the actual physical route taken from origin to final destination. The choice between different potential routes is made on the basis of which has the shorter travel time.

If the modelling process is to avoid becoming too cumbersome, simplifications to the complex decision-making processes within it must be imposed. Within a basic highway model, the process of simplification can take the form of two stages:

1. Stratification of trips by purpose and time of day
2. Use of separate models in series for estimating the number of trips made from a given geographical area under examination, the origin and destination of each, the mode of travel used and the route selected.

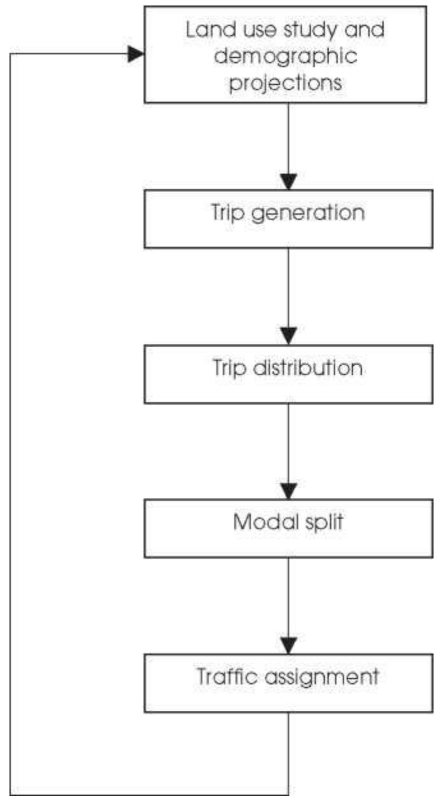

Figure 1: Sequence of transport demand model.

LAND USE MODELS

The demand for movement or trip making is directly connected to the activities undertaken by people. These activities are reflected in both the distribution and type of land uses within a given area. By utilizing relationships between present day land uses and consequent movements in a given area, estimates of future movements given on land-use projections can be derived. The derivation of relationships between land uses and people movements are thus fundamental to an effective transport planning process. A land use model will thus estimate the future development for each of the zones within the study area, with estimates relating not only to predictions regarding the different land uses but also to those socio-economic variables that form the basic data for trip generation, the first of the four-stage sequential models. Input by experienced land-use planners is essential to the success of this phase. The end product of the land-use forecasting process usually takes the form of a land use plan where land-use estimates stretching towards some agreed time horizon, usually between 5 and 25 years, are agreed. The actual numerical relationship between land use and movement information is derived using statistical/mathematical techniques. A regression analysis is employed to establish, for a given zone within the study area, the relationship between the vehicle trips produced by or attracted to it and characteristics derived both from the land use study and demographic projections. This leads us on directly to the first trip modelling stage – trip generation.

TRIP GENERATION

Trip generation models provide a measure of the rate at which trips both in and out of the zone in question are made. They predict the total number of trips produced by and attracted to its zone. Centers of residential development, where people live, generally produce trips. The denser the development the greater the average household income is within a given zone; the more trips will be produced by it. Centers of economic activity, where people work, are the end point of these trips. The more office, factory and shopping space existing within the zone, the more journeys will terminate within it. These trips are 2-way excursions, with the return journey made at some later stage during the day. It is an innately difficult and complex task to predict exactly when a trip will occur. This complexity arises from the different types of trips that can be undertaken by a car user during the course of the day (work, shopping, leisure, etc.). The process of stratification attempts to simplify the process of predicting the number and type of trips made by a given zone. Trips are often stratified by purpose, be it work, shopping or leisure. Different types of trips have different characteristics that result in them being more likely to occur at different times of the day. The peak time for the journey to work is generally in the early morning, while shopping trips are most likely during the early evening. Stratification by time, termed temporal aggregation, can also be used, where trip generation models predict the number of trips per unit timeframe during any given day. An alternative simplification procedure can involve considering the trip behavior of an entire household of travelers rather than each individual trip maker within it. Such an approach is justified by the homogeneous nature, in social and economic terms, of the members of a household within a given zone. Within the context of an urban transportation study, three major variables govern the rate at which trips are made from each zone within the study area:

1. Distance of zone from the central business district/city centre area
2. Socio-economic characteristics of the zone population (per capita income, cars available per household)

3. Intensity of land use (housing units per hectare, employees per square metre of office space).

TRIP DISTRIBUTION

The previous model determined the number of trips produced by and attracted to each zone within the study area under scrutiny. For the trips produced by the zone in question, the trip distribution model determines the individual zones where each of these will end. For the trips ending within the zone under examination,the individual zone within which each trip originated is determined.The model thus predicts zone-to-zone trip interchanges. The process connects two known sets of trip ends but does not specify the precise route of the trip or the mode of travel used. These are determined in the two last phases of the modelling process. The end product of this phase is the formation of a trip matrix between origins and destinations,termed an origin-destination matrix. There are several types of trip distribution models, including the gravity model and the Furness method.

Zone of origin	Zone of destination				
	1	2	3	4	....
1	T_{11}	T_{12}	T_{13}	T_{14}	....
2	T_{21}	T_{22}	T_{23}	T_{24}	....
3	T_{31}	T_{32}	T_{33}	T_{34}	....
4	T_{41}	T_{42}	T_{43}	T_{44}	....
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	

Table 1: Origin destination matrix (e.g. T14 = number of trips originating in zone 1 and ending in zone 4)

MODAL SPLIT

Trips can be completed using different modes of travel. The proportion of trips undertaken by each of the different modes is termed modal split. The simplest form of modal split is between public transport and the private car. While modal split can be carried out at any stage in the transportation planning process, it is assumed here to occur between the trip distribution and assignment phases. The trip distribution phase permits the estimation of journey times/costs for both the public and private transport options. The modal split is then decided on the basis of these relative times/costs. In order to simplify the computation of modal split, journey time is taken as the quantitative measure of the cost criterion. The decision by a commuter regarding choice of mode can be assumed to have its basis in the micro-economic concept of utility maximization. This model presupposes that a trip maker selects one particular mode over all others on the basis that it provides the most utility in the economic sense. One must therefore be in a position to develop an expression for the utility provided by any one of a number of mode options. The function used to estimate the total utility provided by a mode option usually takes the following form:

$$U_m = \beta_m + \sum \alpha_j z_{mj} + \varepsilon$$

where

Um = total utility provided by mode option m

bm = mode specific parameter

zmj = set of travel characteristics of mode m, such as travel time or costs

aj = parameters of the model, to be determined by calibration from travel survey data e=stochastic term which makes allowance for the unspecifiable portion of the utility of the mode that is assumed to be random.

Based on these definitions of utility, the probability that a trip maker will select one mode option, m, is equal to the probability that this option's utility is greater than the utility of all other options. The probability of a commuter choosing mode m (bus, car, train) can thus be represented by the following multinomial logit choice model:

$$P_m = \frac{e^{(um)}}{\sum e^{(um')}}$$

where Pm = probability that mode m is chosen

m¢=index over all modes included in chosen set

Where only two modes are involved, the above formula simplifies to the following binary logit model:

$$P_1 = \frac{1}{1 + e^{(u_2 - u_1)}}$$

TRAFFIC ASSIGNMENT

Traffic assignment constitutes the final step in the sequential approach to traffic forecasting. The output from this step in the process will be the assignment of precise quantities of traffic flow to specific routes within each of the zones. Assignment requires the construction of a mathematical relationship linking travel time to traffic flow along the route in question. The simplest approach involves the assumption of a linear relationship between travel time and speed on the assumption that free-flow conditions exist,i.e.the conditions a trip maker would experience if no other vehicles were present to hinder travel speed. In this situation, travel time can be assumed to be independent of the volume of traffic using the route. (The 'free-flow' speed used assumes that vehicles travel along the route at the designated speed limit.) A more complex parabolic speed/flow relationship involves travel time increasing more quickly as traffic flow reaches capacity. In this situation, travel time is volume dependent. In order to develop a model for route choice, the following assumptions must be made:

1. Trip makers choose a route connecting their origin and destination on the basis of which one gives the shortest travel time
2. Trip makers know the travel times on all available routes between the origin and destination.

If these two assumptions are made, a rule of route choice can be assembled which states that trip makers will select a route that minimizes their travel time between origin and destination. Termed Wardrop's first principle, the rule dictates that, on the assumption that the transport network under examination is at equilibrium, individuals cannot improve their times by unilaterally changing routes (Wardrop, 1952). If it is assumed that travel time is independent of the traffic volume along the link in question, all trips are assigned to the route of minimum time/cost as determined by the 'all-or-nothing 'algorithm.