

Fundamental Travel Demand Model Example

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Abstract. Instances of transportation models are abundant and detailed “how to” instruction is available in the form of transportation software help documentation. The purpose of this paper is to look at the fundamental inputs required to build a transportation model by developing an example passenger travel demand model. The example model reduces the scale to a manageable size for the purpose of illustrating the data collection and analysis required before the first step of the model begins. This aspect of the model development would not reasonably be discussed in software help documentation (it is assumed the model developer comes prepared). Recommendations are derived from the example passenger travel demand model to suggest future work regarding the data collection and analysis required for a freight travel demand model.

INTRODUCTION

In simple terms of supply and demand, the transportation network is the supply and the need to travel is the demand. The complexity of the transportation system is due to the fact that the demand has a multipurpose and the supply is inherently multimodal. The model of such a system attempts to forecast the travel demand of people by automobile (single occupancy or high occupancy) and by public transit (bus, subway, or intercity rail) when they choose not to travel by walking, biking, or airplane [1]. A second category of travel demand is freight. The supply is multimodal (ship, rail, and truck) and the demand has a multipurpose (each commodity is a purpose). The objective of this paper is to look at the inputs required and illustrate the basic process for modeling the first category of travel demand. Models of large, complex geographical regions already exist. These examples are useful for illustrating simulation techniques. The example presented in this paper is smaller in scale and allows a more manageable study of the supporting data and the development of the model itself using Cube software by Citilabs.

GENERATION

Trip generation is a data collection and analysis process that is used to estimate the number of trips each region will produce and attract. In order to accomplish this, the region is divided into zones and zonal data is collected. Next, a trip survey assesses the travel habits of the population. Finally, regression analysis provides coefficients for trip purpose equations which are used to calculate the number of trips produced and attracted by each zone.

1 - Zones and Zonal Data

In this example, the study area is divided into three regions: city, suburb, and rural. These regions are subdivided into smaller traffic analysis zones (TAZs). The sizes of TAZs are typically driven by population, hence smaller and more numerous TAZs in the city region. Each TAZ has a homogeneous land use and can be described by only a few variables. In this example, these variables are the number of households (HH), the total population, the area in square miles (SQ_MI), the mean household size (MEANHHSIZE), a factor which represents the density of the population (DENTHOU), the number of people that work in the area regardless of whether they live there (TOTAL_EMP), and the mean number of vehicles per household (VEH_HH). Typically, a metropolitan planning organization (MPO) collects zonal data for a study area. The study area in this example is heuristically developed using the 2007 Data Book compiled by the Hampton Roads Planning District Commission. Variables of interest in the Data Book include population, area in square miles, mean household size, total employment, and total number of vehicles registered. Additional variables are required to translate the characteristics of real world zones to the zones in the example: density (Equation 1.1), an employment factor expressing the number of people working in terms of area (Equation 1.2), the number of households (Equation 1.3), and the mean number of vehicles per household (Equation 1.4).

$$\text{DENTHOU} = \frac{\text{POPULATION}}{1000 \times \text{SQ_MI}} \quad (1.1)$$

$$\text{EMP_SQMI} = \frac{\text{EMP}}{\text{SQ_MI}} \quad (1.2)$$

$$\text{HH} = \frac{\text{POPULATION}}{\text{MEANHHSIZE}} \quad (1.3)$$

$$\text{VEH_HH} = \frac{\text{NUM_VEH}}{\text{HH}} \quad (1.4)$$

The map is drawn to scale using ArcMap and the area of each zone is determined. Based on the author's familiarity with the Hampton Roads region, seven real world areas are selected to represent the characteristics of various area types. Based on each example zone's area type (i.e. rural, suburb, or city), the following real world variables are assigned: DENTHOU, MEANHHSIZE, EMP/SQ_MI, and VEH_HH. The following additional variables were calculated: population (Equation 2.1), the number of households (Equation 1.3), and total employment (Equation 2.2).

$$\text{POPULATION} = (\text{DENTHOU} * 1000) * \text{SQ_MI} \quad (2.1)$$

$$\text{TOTAL_EMP} = \text{EMP_SQMI} * \text{SQ_MI} \quad (2.2)$$

2 - Trip Survey

A relationship must be established between these variables and the number of trips. The number of trips is determined by circulating a trip survey to a representative sample of the population. A typical survey collects information about each household (number of people, number of vehicles, etc) and then asks them to keep a trip diary. Simple linear regression analysis determines the relationship between the dependent variable (number of trips) and the independent socioeconomic variables. The example model surveyed 3% of the population. The number of surveys collected from each zone is proportional to the fraction of the total population living in that zone in the model. As additional constraints: the average number of vehicles per household in the survey closely matched the VEH_HH for the corresponding zone in the model, while the average number of people per household in the survey closely matched the MEANHHSIZE size for corresponding zone in the model. The dependent variable (number of trips) is manipulated to create a significant relationship with VEH_HH and MEANHHSIZE (Figure 1).

3 - Trip Purpose Equations

In this example, there is only one trip purpose. The trips are home-based-work (HBW) and are produced according to the availability of a car and the number of people in a household factored by socioeconomic data that indicates 60% of the population is part of the work force; represented by Equation (3). The attraction for these HBW trips is a factor of the employment in a particular zone; represented by Equation (4).

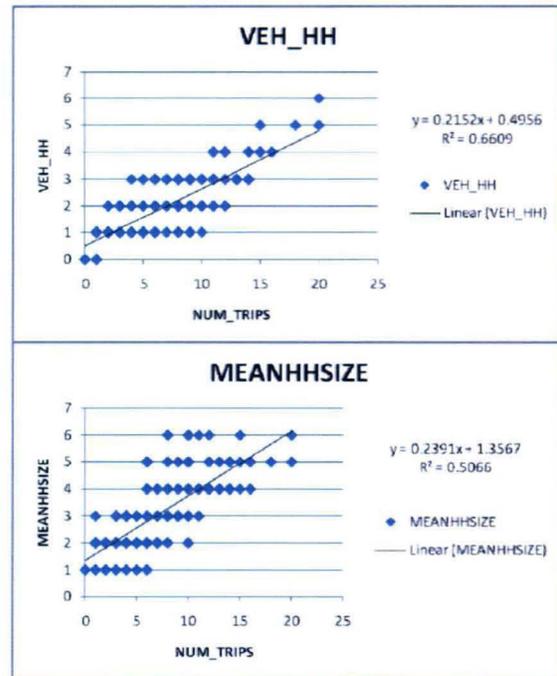


Figure 1. Regression Analysis

$$((0.4956 + 0.2152 * \text{VEH_HH}) + ((1.3567 + 0.2391 * \text{MEANHHSIZE}) * 0.6) * \text{HH}) \quad (3)$$

$$(\text{TOTAL_EMP} / 360342) \quad (4)$$

4 - Generation Table

The result of the Generation program in Cube is a simple text file. The first column contains the zone number, each subsequent pair of columns contains the values for the number of trips produced and attracted for each trip purpose. In this example there is only one trip purpose (Table 1).

Table 1: Generation

1	8901	5707
2	38423	70290
3	41518	37644
4	90411	90534
5	60464	44518
6	8104	4449
7	36533	31213

DISTRIBUTION

Trip distribution is the process used to estimate how the trips that each zone will produce and attract are distributed across the other zones. The required inputs are the trip generation table, a level of service (LOS) matrix, and a friction factor table.

1 - Level Of Service

This matrix is obtained through a process called skimming. During skimming, the Cube Highway program extracts the costs (i.e. time and distance) of journeys between zones. In order to do this, the highway program requires a highway network file. A network is built from a zonal map (polygon shape file) developed for trip generation and a highway map (line shape file). For this example, a highway map was developed with several speed classifications represented by two digit codes. The first digit represents facility type (i.e. freeway, major arterial, or minor arterial). The second digit represents the area type (i.e. rural, suburban, or city). Cube combines the two maps and calculates the centroid for each zone and builds centroid connectors to the highway. This "new" map is the highway network.

2 - Friction Factors

Travel function values are contained in a lookup file. The lookup file is formatted as a series of curves; one for each trip purpose. In this example the friction values increase with time until a trip of greater time than 60 minutes will not be distributed.

3 - Origin/Destination Matrix

Utilizing these three inputs, the Cube Distribution program produces the trip Origin/Destination matrix.

ASSIGNMENT

Trip assignment is the process used to estimate the routes that will be used to travel from origin to destination. The inputs required are the Origin /Destination matrix file and the Highway network file. Also a cost function should be specified. In this example the cost function gives a lesser weight to DISTANCE (see Equation 5). The result is illustrated by the map in figure 2. Note that the high congestion is in the city and low congestion in the rural area. Because this example does not include external trips; the links leading out of the region are unused. This may also explain the low congestion on the freeway.

$$\text{TIME}^*1 + \text{LI.DISTANCE}^*0.3 \quad (5)$$

CONCLUSION

It should be apparent from this example that the greatest preparation for the model precedes the first step: trip generation. Zones must be defined, zonal data collected, trip counts determined, and finally, a relationship must be established between some socioeconomic variable or land use variable and the number of trips. Each trip purpose will have a unique relationship. Although the example in this paper does not include a public transit network, it is desirable to model the public transportation system with a fourth step and simulate the choice of people to utilize that alternative. Together, these four steps (Trip Generation, Trip Distribution, Mode Choice, and Traffic Assignment) are referred to as the "four-step model" [2]. It is also desirable to model the freight transportation system and forecast the travel demand of freight. The choice of freight to compete with people on the highway network is of particular interest.

FUTURE WORK

The premise for freight-travel-demand is fundamentally different from people-travel-demand: the purpose of the trip is to move a commodity from origin to destination. The concept of a trip survey would be very different and may not even be applicable. The origins and destinations of commodities encompass a region of far greater scale. It is noteworthy that TAZs are not valid for freight trip generation. Freight Analysis Zones (FAZs) must be developed and the corresponding zonal data must be determined [3]. The trip generation of FAZs would be followed by trip distribution. Mode split would simulate the choice of freight to compete with people on the highway network. Because commodity trips may utilize the highway network for a sub-link of the trip, a model of the freight system would need to include logistic nodes to simulate mode splits. Finally, trips that are coarsely distributed across FAZs must be finely distributed across TAZs in the region of interest, followed by simple all-or-nothing assignment. Again, the portion of trips utilizing the highway network would be of particular interest. Future work needs to be done to find variables that have significant relationships to commodities (land use, socioeconomic, or some hybrid). It is important to know what data is needed and to collect the right data, before attempting to model freight travel demand.

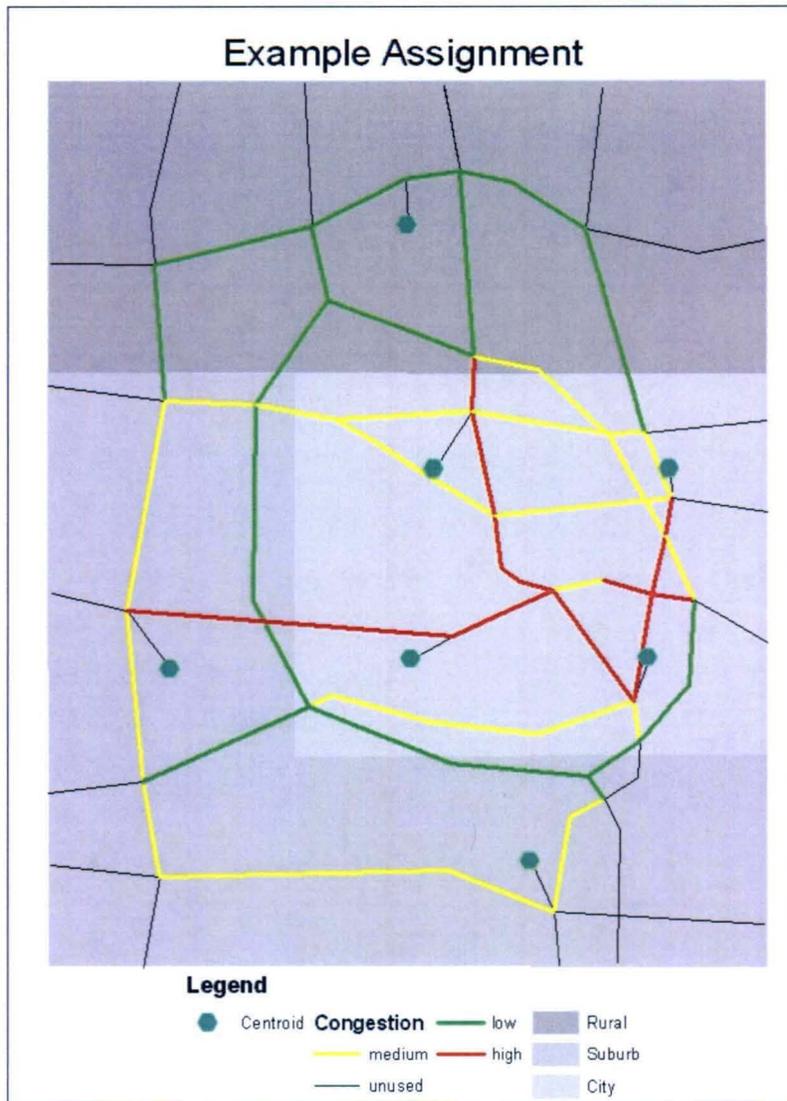


Figure 2. Assignment

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