A Method for Developing Through Trip Matrices for Small Urban Areas

Marwan AL-Azzawi
Principal Transport Planner
Scott Wilson Scotland Ltd, UK
Also at Napier University, UK

Abstract

An often overlooked, but essential, element of traffic forecasts for small urban areas is the preparation of through trip matrices. Planning practice has been to build through trip matrices by factoring an existing sampled through trip matrices or by judgment.

Obtaining a set of sampled through trip matrices is an expensive and error-prone undertaking for areas with many entry/exit stations in their networks. Creating a synthetic through trip matrix using conventional trip distribution theory (e.g., the gravity model) has not worked well, and there is rarely sufficient data to build good through trip matrices purely from observations of traffic counts. Smaller urban areas, in particular, have a need for robust through trip matrices, because through trips can constitute a sizable part of the traffic in an area.

Through trip matrix estimation is a conceptually difficult problem that has not been given much attention in the professional literature. The location of through traffic on a network is inherently a problem that should be solved with traffic assignment but is traditionally modelled using the methods and philosophy of trip distribution.

The need for a good through trip matrix is greatest for small- to medium-sized study areas, which have a comparatively larger amount of through traffic.

A complete construction of a through trip matrix also involves determining the fraction of trips at an entry/exit station that are through trips, as opposed to trips having one end internal to the study area.

This paper develops and tests a first-cut model for through traffic that relies almost entirely on (1) a gross description of the geography of the study area and its environs, and (2) estimates of through trip volumes at each entry/exit station. The model's data requirements are very modest, especially for a simplified form that applies to many small-area applications. This simplified form of the model is applied to a real-life application, and the results of the model are compared with an actual, sampled through trip matrix in the case study.

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1 Introduction

An often overlooked, but essential, element of traffic forecasts for small urban areas is the preparation of through trip matrices. Planning practice has been to build through trip matrices by factoring an existing sampled through trip matrices or by judgment.

Obtaining a set of sampled through trip matrices is an expensive and error-prone undertaking for areas with many entry/exit stations in their networks. Creating a synthetic through trip matrix using conventional trip distribution theory (e.g., the gravity model) has not worked well, and there is rarely sufficient data to build good through trip matrices purely from observations of traffic counts.

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Through trip matrix estimation is a conceptually difficult problem that has not been given much attention in the professional literature. The location of through traffic on a network is inherently a problem that should be solved with traffic assignment but is traditionally modelled using the methods and philosophy of trip distribution.

The need for a good through trip matrix is greatest for small- to medium-sized study areas, which have a comparatively larger amount of through traffic. A complete construction of a through trip matrix also involves determining the fraction of trips at an entry/exit station that are through trips, as opposed to trips having one end internal to the study area.

This paper develops and tests a first-cut model for through traffic that relies almost entirely on (1) a gross description of the geography of the study area and its environs, and (2) estimates of through trip volumes at each entry/exit station.

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2 Discussion

It stands to reason that the rudimentary geography of the urban area would have considerable influence over the values in a through trip matrix. For example, it is reasonable to hypothesize that two entry/exit stations in close proximity to each other would be less likely to exchange through trips than two entry/exit stations at opposite sides of the urban area.

The need for a good through trip matrix is greatest for small- to medium-sized communities, which have a comparatively larger amount of through traffic. Furthermore, the problem of obtaining good through trip matrices has been compounded by a growing interest in truck movements in urban areas.

A complete construction of a through trip matrix also involves determining the fraction of trips at an entry/exit station that are through trips, as opposed to trips having one end internal to the study area.

The "Scottish Transport Appraisal Guidance" (STAG) [1] recommends that through trip matrices be estimated by a set of doubly-constrained trip matrix equations similar in structure to a gravity model, but where friction factors are replaced by subjective weights. Since this method is the starting point for the current research, it will be explained in some detail. The through trip matrix may be approximated by:

$$t_{ij} = O_i D_j X_i Y_j w_{ij} \qquad (1)$$

$$X_i = 1 / ?_j D_j Y_j w_{ij} \qquad (2)$$

and

$$Y_j = 1 / ?_i O_i X_i w_{ij} \qquad (3)$$

where

t_{ij} is the number of trips between origin station i and destination station j;

O_i is the number of trips from origin station i;

D_j is the number of trips to destination station j;

X_i, Y_j are balancing factors so the trip matrix is consistent with all O_i's and D_j's; and

w_{ij} is an external weight associated with station pair i and j.

The external weights, w_{ij}, are determined subjectively with the guidance of a few rules. They should initially be set to 1.0, except for OD pairs that are unlikely to share trips for which w_{ij} should be set to zero. Examples of pairs of entry/exit stations not sharing trips include:

- Pairs of entry/exit stations on paths leading from the region to the same neighbouring city
- Pairs of entry/exit stations on two sides of the same divided highway
- Pairs of entry/exit stations where both are on paths leading to rural or suburban locations

After a trial computation of t_{ij}, it may be necessary to subjectively adjust the external weights. The use of a doubly-constrained set of trip matrix equations assures that the through trip matrix will have the proper structure, but the method for setting the external weights is not very precise or reproducible.

3 The Proposed Approach to Estimating Through Trip Matrices

We have assumed the following information is available to build a synthetic through trip matrix:

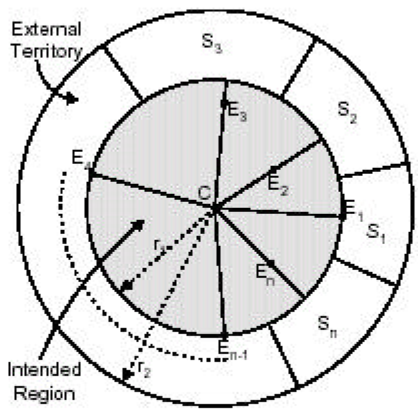
- Number of through trips for each direction at each entry/exit station
- The physical location of each entry/exit station
- The general geography of the internal and external study areas
- The traffic network internal to the study area
- The functional class of each road at an entry/exit station
- The orientation of links that pass through boundaries of the area

The problem then becomes one of determining a good set of external weights from the type of information listed above.

With the data described above, the process is set out in 7 steps:

Step 1 Approximate the Study Area
Define a catchment area for each entry/exit station (see Figure 1). A catchment area consists of all lands beyond the study area that are likely to contain the true (but unknown) origins or destinations of trips passing through a single entry/exit station.

Figure 1: Definition of Study Area and Surrounding Entry/Exit Stations Catchments



Step 2 Approximate the External Area
Define the external area by a circle having the same center *C* and radius r_2 such that $r_1 < r_2$ (see figure 1). Divide the external area into as many catchment areas as the number of entry/exit stations under consideration. Suppose that there are N entry/exit stations under consideration. The catchment areas are defined in such a manner that any trip originating or terminating in catchment area i uses entry/exit station i for making any trip between catchment areas i and the rest of the external territory.

Step 3 Construct Catchment Areas for each Entry/Exit Station
The number of catchment areas is equal to the number of entry/exit stations. Define catchment areas S_1, S_1, ..., S_n, where each exclusively uses its own entry/exit station *N*, whenever the trips travel through the study area.

Step 4 Determine the Probability of a Trip between Each Pair of Catchment Areas that Pass through the Intended Region
For each pair of catchment areas the trips between each OD pair will be treated as the line segment joining these two points.

Step 5 Set Up a Starting Weight Matrix
Prepare a weight matrix with all weights initially set to 1, except the diagonal elements which should be set equal to zero ($w_{ij} = 1$ for $i \neq j$, and = 0 otherwise).

Step 6 Estimate External Weights
Estimate an external weight, w_{ij}, in the same manner as a friction factor in a gravity model (i.e. it is the propensity of an origin and a destination to share trips). These external weights do not have units, only their relative sizes matter. From field tests, the following equation was found to give good results:

$$w_{ij} = 0.1e^{-0.1U_{ij}}$$

where U_{ij} = over-the-network travel time in minutes between entry/exit stations i and j

Step 7 Calculate Weights Using a Furness procedure

Set the weights equal to the probability that a trip between i and j crosses the entry/exit station. Run a Furness procedure to assure that the observed and estimated destination totals are reasonably equal for each entry/exit station. We found fifteen iterations a reasonable maximum number of runs.

4 Case Study: South Ayrshire Model

Here we describe a case study chosen to illustrate the major steps in finding external weights to calculate a through trip matrix. The emme/2 model is for the South Ayrshire area[2], whose network consists of 160 zones (130 internal zones and 30 external). We will not describe the transport model here, only the results of the test using the above procedure.

We tested the new procedure and two others as recommended in current guidelines, including STAG and the DMRB[3]. The Furness procedure was run for fifteen iterations in all three cases to assure that the observed and estimated destination totals were reasonably equal for each entry/exit station. Then for each case, the total sum of squares of errors were computed to obtain the percent of total variation (R^2) in observed trips about their mean value explained.

The percent of total variation explained in each case is summarized in table 1.

Table 1: Percent of Variation Explained by Three Tests

Method	**R^2 values**
A. Our Procedure	92.5%
B. All Unity	81.6%
C. Traditional Gravity Model Friction Factors	77.2%

As can be seen from table 1, the new process seems to give the better results. However, it is acknowledge that this is only one test using only one model network. Other tests need to be carried out before any firm conclusions can be made, but this is atleast a promising start.

5 Conclusions

It is possible to estimate a through trip matrix from knowledge of through traffic volumes at each entry/exit station and the rudimentary geography of a region. The trip matrix is most easily calculated when the region is convex, and is even easier to calculate when the area can be approximated as a circle.

Through trip matrix estimation does not necessarily require information from a traffic network, although the orientation of links as the boundaries of the region may help in identifying problems and special cases. A simplified procedure for through trip matrix estimation was applied without any calibration to a case study, achieving excellent results.

The quality of these results exceed those of earlier modelling efforts and greatly exceed those obtainable from a traditional gravity model. However, it is acknowledge that more tests are needed before any firm conclusions can be made, but this is atleast a promising start.

References

1 Scottish Transport Appraisal Guidance, Scottish Executive, 2001

2 South Ayrshire Transport Model, South Ayrshire Council, 2001

3 Design Manual for Roads and Bridges (DMRB), DTLR, 1997

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