2.0 Literature Review

2.1 Introduction

In order to accomplish the research objectives mentioned in Chapter 1, a review of relevant literature was performed. The main focus of this effort was on the various synthetic O-D formulations that have been previously developed. Early approaches to O-D problem relied primarily on linear or non-linear regression analysis to construct demand models assuming gravity-type flow patterns. These models required data on zone-specific variables such as, population, employment, average income etc. A later group of models based their estimation of trip matrices on a network traffic equilibrium approach, with the main aim of including the effects of congestion. Another group attempted to extract the most likely trip matrix, consistent with measured link volumes, by maximum entropy or minimum information approaches. Another group of models utilizes the statistical techniques to produce future estimates, based on prior information. Recent research has attempted techniques such as linear programming, neural networks and fuzzy weights to solve this problem. The continued interest in this problem is evident by recent reports of further enhancements and refinements to these solutions and the wide array of techniques that are used to try to solve the problem.

2.2 Classification of Models

The problem, of obtaining the trip tables for a peak period based on link flows, is in reality, a dynamic systems problem. In practice, dynamic systems are very hard to study and it is difficult to obtain a desired solution. In order to derive O-D trip tables the traffic flow is usually considered to be static or time independent. Even though real traffic is not static it can be argued that obtaining a solution for a static case is a step towards obtaining solutions in the dynamic case. There is evidence which supports such an idea.

Firstly, it can be shown that the flow pattern is independent of time if the system is in equilibrium or satisfies an equilibrium state. Secondly, if the system is considered for a very short period of time then it can be approximated to a static system. Further a static treatment of a dynamic system can be thought as a first step towards understanding the complexity of the problem.

Based on theory used, these models are divided into the following types (Easa 1993). For further details and a critical discussion of these models the reader is referred to O'Neill's (1987) dissertation and the specific documents herein.

I.   Gravity-Based Models

Historically, the need for static O-D was for long term network planning. The prediction of trip productions and attractions were based on land use properties. The productions and attractions were matched based on impedance such as travel distance or travel time.

These types of models are often called Parameter Calibration Models. In these models the entries of the O-D matrix are assumed to be functions of the traffic counts, measure of travel cost or impedance and other parameters. Various regression techniques and flow conservation laws at nodes are applied to calibrate the various parameters, such that the difference between the observed volumes and computed volumes is minimized. These models can be divided into two types namely, linear and non-linear regression models. Models formulated by Low (1972), Overgaard et al. (reviewed in Bendtsen, 1974), Holm et al. (1976), Gaudry and Lamarre (1979), and Smith and McFarlane (1978) fall under the linear regression type. All models except the one developed by Holm et al. (1976), adopt a proportional all-or-nothing assignment. The other differences between models can be attributed to variable definitions and parameter selections. The main drawback of these models is the requirement of estimation of external trips to the study area, which are to be subtracted from observed counts.

Models formulated by Robillard (1975) and Hogberg (1976) fall under the non-linear regression type. Robillard's model uses a proportional assignment technique and does not consider capacity constraint. Hogberg's model employs all-or-nothing assignment. The drawbacks of these models is that they require a large amount of input data, and become outdated when there is a change in land use. The other drawback is that these models fail to take into consideration the equilibrium assignment principle which is relevant in relation to congestion.

II.   *Entropy Models*

More recently, models have started using observed link flows to obtain O-D trip tables. This is an advantage over the gravity based models, for the link volumes are easy to obtain without much error, where as obtaining trips for the gravity models, using trip generation is not very accurate. Hence proximity is not necessarily related to the magnitude of O-D trips. The above approach, for estimating a trip table from link counts, force the trip table to conform a gravity type pattern or cause them to be as close as possible to prior trip table as possible.

Van Zuylen and Willumsen (1980) criticized this approach by saying that these strategies do not make full use of the information contained in the link volumes. Since prior trip table information is used by other approaches to take care of the under specification problem, Van Zuylen and Willumsen suggest that this could be solved by introducing minimum external information.

Following this idea the authors have put forward two approaches based on information minimization and entropy maximization concepts. Entropy maximization and information minimization are equivalent to each other. In case of entropy maximization we call the likelihood as entropy and maximize it, where as in the case of information minimization, the negative natural logarithm of the likelihood is minimized. Thus both the approaches are equivalent. In the information minimizing approach, an attempt is made to chose a

trip table that adds as little information as possible to the knowledge contained in the general equation for the trip table estimation from link counts. Van Zuylen and Willumsen, (1980) proposed a maximum entropy approach to solve the problem. Here, the most likely trip matrix is defined as the one having the greatest number off micro-states associated with it. These approaches typically make one major assumption, namely that the total number of trips is a constant. This assumption may not be valid for all cases. This method is explained in detail in Chapter 4.

III. *Equilibrium Models*

These models are based on the principle of user optimization of traffic flow, called "Equilibrium Principle" or "Wardrops's principle" (Wardrop 1952). These types of models are more suitable for congested area analysis. Usually, the routes between a given O-D pair are assumed to be known a priori. In these models, the solution tends to approach the given prior information which is made the target. Adjustments are made to reproduce observed link volumes. Here the main aim is to obtain an equilibrium trip table that is as close as possible to the target matrix. Hence, these models utilize both link volumes and routes between O-D pairs. The models iterate between O-D generation and traffic assignment until a solution is obtained i.e. we solve for O-D trip table as well as the routes.

These include LINKOD (Nguyen 1977, Gur 1980), SMALD (Kurth et al. 1979) and LP (Sivanandan 1991, Sherali et al 1994). Based on tests on small networks, Nguyen claims that his models produce trip tables that closely reproduce observed trip tables when assigned to the network using user equilibrium principle. The main drawback of this approach is that there can be multiple O-D solutions which can reproduce the same traffic pattern. Hence, a distribution assumption is needed to get the most likely trip table from the alternate solutions.

The LP model had a limitation in that it required the specification of volume information for all the links of the network. Such complete data may not always be available. Consequently further enhancements were done by Narayanan (1995) which produces trip tables when a partial set of link volume information is available.

These models incorporate the desired equilibrium assignment problem, but their highly nonlinear nature, as in the case of LINKOD, leads to problems with regard to convergence. The computational effort, as in the case of LP approach, that is required to obtain an acceptable solution for large networks is usually very high. For this reasons the equilibrium models are currently not very popular.

IV.   *Statistical Models*

These models attempt to estimate the trip tables directly from the prior information based on statistical techniques. The models employ Bayesian inference methods or least squares estimation techniques to achieve their objective. The maximum entropy or the minimum information techniques give little weight to variability or a measure of degree of confidence in the prior information. The models find O-D matrix that 'best' fits link flows. This 'best' fit depends on the assumptions about link flow error distribution. The statistical models try to overcome this drawback. In the category of least squares estimation approaches, Carey et al. (1981), McNeill and Hendrickson (1985), and Cascetta (1984) have proposed alternative models. The main advantage of these type of models is that they take into consideration the stochastic nature of the data, but ignore the likelihood of the trip being made.

V.   *Neural Network Models*

Muller and Reinhardt (1990) introduced the neural network approach to determine O-D trip tables from traffic counts. Yan et al. (1992) adopted a feed-forward neural network for synthesizing O-D flow for a four-way intersection and a short freeway segment. Chin

et al. (1994) describe a neural network model for obtaining O-D information from link volumes. Neural network models are unable to synthesize traffic flow data for patterns for which they have not been trained. As the models are relatively new further testing is recommended for evaluation.

VI. Fuzzy Weights Models

Another recent approach has been the utilization of fuzzy weights to obtain O-D trip tables. Instead of applying the all or nothing assumption made in most models, fuzzy weight approaches apply some kind of "fuzziness" to link data (Xu and Chan, 1992), thus imprecision is introduced into the system. This model was tested with the Eastern Highway Corridor network, and was found to give good results. The authors recommend further testing and evaluation to support the controlled experimentation reported.

2.3 Solution Algorithms

Various algorithms have been utilized to obtain trip tables according to the models discussed above. The following is a review of the algorithms utilized by these models.

The linear parameter calibration models typically utilizes multiple linear regression, where as the non-linear parameter calibration models utilize the non-linear least squares method to obtain the O-D matrix. The LINKOD model, which falls under the equilibrium models, uses the modified Frank-Wolfe algorithm for solving the problem. The maximum entropy model and LP models have their own specific computer programs, which solve the given problem. The statistical models generally utilize the generalized least square method to obtain the O-D matrix.

Most research papers, revolve around the formulation of the synthetic O-D problem. Therefore, they usually do not indicate the solution algorithm which could be employed

to solve the given formulation. As ultimately one desires to compare answers for similar problems, this is not possible based on considering the formulations alone.

2.4 Summary of Literature Review

The above review, of the various approaches to obtain O-D matrices from link counts, illustrates the complexity of the problem. Each method has its own advantages and disadvantages. The minimum information or maximum entropy techniques used to obtain trip tables based on link counts is one of the widely used methods. Even though these techniques impose restrictions, such as consistency of flows, they are still very popular and widely used. Questions about the impact of approximations do remain, and one must examine the impact of these approximations under various conditions.

All the research papers concentrate on static O-D estimation. Some of the models utilize a priori routes in their computation. Thus, understanding the static O-D estimation is the first step in developing models to obtain O-D in the dynamic case, where the routes change over time. Hence if we are unable to obtain O-D matrix for the static O-D case we cannot move further towards developing models for the dynamic case.

Link flow continuity, is required by some of the models, but real world data typically do not provide link flow continuity. The statistical models take care of this uncertainty in the link volumes. Some models redistribute the link flow error to get processed data which satisfies link flow continuity. This processed data is used to obtain O-D matrix.

The gravity model used in trip distribution is very similar to the synthetic O-D generation. In the case of trip distribution, the link volumes on the zone connectors are the input, whereas in case of synthetic O-D generation it is the link volumes in the en-route links and zone connectors that are the inputs.

This thesis will primarily focus on the various assumptions, limitations and solution techniques of the maximum entropy or information minimization approach. Various improvements have been made to the original formulation by Van Zuylen and Willumsen (1980). In Chapter 4 the improvements and suggested modifications are dealt in detail.

The following Chapter talks about the various sub problems which, need to be taken into consideration first before, extracting the O-D matrix based on link counts.