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REVIEW OF THE CURRENT DALLAS-FORT WORTH REGIONAL TRAVEL DEMAND MODEL

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16. Abstract

This report discusses each of the forecasting steps — trip generation, trip distribution, mode choice, and assignment — of the current Dallas-Fort Worth Regional Travel Model (DFWRTM).

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1. INTRODUCTION

The North Central Texas Council of Governments (the Dallas-Fort Worth metropolitan planning organization, or MPO) undertook a revision of its travel demand forecasting model in 1986 in coordination with the State Department of Highways and Public Transportation (SDHPT, now known as TxDOT), Dallas Area Rapid Transit (DART), and the Fort Worth Transit Authority. The travel demand model is based on the commonly used four-step Urban Transportation Model System (UTMS). The model parameters are estimated using the 1984 Home Interview Survey, Workplace Survey, and Transit On-Board Survey, as well as the 1980 U.S. Census journey-to-work data.

The spatial coverage of the Dallas-Fort Worth Regional Travel Model (DFWRTM) spans a planning area of approximately 4,980 square miles (12,898 km^2) and includes the existing Dallas-Fort Worth urbanized area and the contiguous area expected to be urbanized by the year 2020. The DFWRTM is based on the delineation of the planning area into a hierarchy of spatial units. The most aggregate spatial unit is a jurisdiction (JUR). The jurisdictions are subdivided into 418 Transportation Analysis Districts (TADs), which are then subdivided into 960 Regional Analysis Areas (RAAs). The RAAs are further subdivided into 2,951 Local Analysis Districts (LADs) and finally into 5,999 Traffic Survey Zones.

The DFWRTM forecasting process classifies all trips into one of four trip purposes: (1) home-based work (HBW) purpose, including trips from home to work or work to home; (2) home-based nonwork (HNW) purpose, including all nonwork trips beginning or ending at home; (3) nonhome-based (NHB) purpose, including trips with home as neither the origin nor the destination; and (4) other purposes, including truck/taxi trips and all trips originating and/or ending outside the metropolitan area.

The DFWRTM includes four sequential steps. The first step, trip generation, involves the estimation of the number of home-based and nonhome-based person-trips produced from, and attracted to, each zone in the study area. The second step, trip distribution, determines the trip interchanges (i.e., number of trips from each zone to each other zone). The third step, mode choice, splits the person-trips between each pair of zones by travel mode, obtaining both the number of vehicle trips and number of transit trips between zones. The fourth step, assignment, assigns the vehicle trips to the roadway network to obtain link volumes and travel times and the person-trips to the transit network. In addition, the DFWRTM includes a Congestion Management System (CMS) module, which assesses travel trends and system performance and generates transportation control strategies.

In the subsequent four sections, we discuss each of the forecasting steps of the DFWRTM in more detail. In Section 6, we briefly discuss the speed feedback process and the transit assignment procedure. Detailed documentation of each of the steps, and of the entire modeling procedure, is available in a report by the North Central Texas Council of Governments (NCTCOG, 1999).

2. TRIP GENERATION

The trip generation model takes as input zonal socioeconomic data and translates this data into person-trips produced and attracted to each TSZ by trip purpose. A cross-classification model that applies trip production/attraction rates (estimated from the 1984 Home Interview Survey) to each combination of explanatory variables is used in forecasting.

2.1 Trip Production Modeling

The explanatory variables for trip production modeling are income quartile and household size for all trip purposes except the "other" trip purpose. The cross-classification model provides an estimated rate of person-trips at a household level for each combination of income quartile and household size.

For the "other" trip purpose category, the explanatory variables are zonal area type and employment type. The zonal area type variable is represented by categorizing each zone into one of five activity density classes: Central Business District (CBD), Outer Business District, Urban Residential, Suburban Residential, and Rural. Employment type is represented by the activity categories of Basic, Retail, Service, and Household sectors. The cross-classification model for the "other" trip purpose category provides the estimated rate of person-trips per employed person for each combination of employment type and area type.

For forecasting zonal trip productions for trip purposes besides the "other" category, the distribution of households by income quartile and by household size is needed. This distribution is obtained in two steps. In the first step, individual marginal distributions for income and for household size are computed using curves that provide the income distribution as a function of the ratio of zonal median income to regional income and the household size distribution as a function of the average zonal household size. These curves are estimated from census data. Once the individual distributions have been determined, the joint distribution of household size and income quartile is obtained in a second step by implementing an iterative proportional-fit procedure using the 1980 census data as the starting point.

For forecasting zonal trip productions for the "other" trip category, the area type and employment type mix of a zone for future years is needed. The area type of a zone is itself determined based on the projected zonal population density and employment density. These population- and employment-related forecasts are obtained from a land-use model.

2.2 Trip Attraction Modeling

The explanatory variables used in the cross-classification model for trip attractions are area type and employment type for all trip purposes except home-based work trips. For home-based work trips, the model is stratified by area type, employment type, and income quartile. The trip attraction rates are based at a person-trip-per-employee level and are estimated from the 1984 Workplace Survey data.

For forecasting trip attractions to each zone for trip purposes other than home-based work, projections of the area type and employment mix of each zone are needed. These projections are obtained from land-use models. For forecasting trip attractions to each zone for the home-based work purpose, an additional projection of the distribution of household income among employees in the zone is needed. This distribution is based on household income projections in and around the zone under consideration.

Six categories of special generator trips are also identified in the attraction-end modeling process; these categories include trips to regional shopping malls, universities and colleges, hospitals, commercial airports, regional recreation facilities, and military installations. The trips attracted by these generators are computed by applying the trip attraction rates to the employment at the respective sites and adding extra incremental trips associated with each category of special generator. The number of incremental trips for each special generator type is obtained by taking the difference of the cross-classification model-generated trip rates and the trip rates obtained from the Regional Travel Survey.

Regional production and attractions are finally balanced for each trip purpose. Home-based work trips are balanced to the estimated trip attractions by income quartile. All other purposes are balanced to the estimated trip productions. The balancing for nonhome-based-trips is, however, a little more involved. The trip production model estimates the number of nonhome based trips made by households in each zone, but it is unable to locate the trip ends of these nonhome-based trips. The NCTCOG adopts a procedure in which the total production of nonhome-based trips in each zone is set equal to the total attractions in that zone.

3. TRIP DISTRIBUTION

The general gravity model is used in trip distribution. The trip distribution model takes as input the total trips produced from and attracted to each zone and determines the zone-to-zone trip interchanges using the zone-to-zone minimum travel times as the controlling determinant.

The approach to computing the zone-to-zone minimum travel times is a rather tedious process; we provide a step-by-step summary of the approach below.

1) A roadway network is developed using a geographic information system (GIS) platform.

2) A TSZ identifier is assigned to each link based on the TSZ in which the origin node of the link lies.

3) The area type of the TSZ assigned to the link is identified and associated with the link.

4) Each link is classified into one of nine functional classes: zone centroid connectors (approach links), freeways, principal arterials, minor arterials, collectors, local streets, ramps, frontage roads, and high-occupancy vehicle lanes.

5) The free speed (uncongested speed) for each link is calculated using speed limit, area type, functional class, number of intervening controls, and the type of traffic control (i.e., whether there is no control, a traffic signal, a yield sign or an expressway on-ramp, a four-way stop, or a two-way stop) at each of the two nodes of the link.

6) Estimated loaded speeds (ELS) on each link are next obtained from the traffic assignment run in a feedback process. For the initial run of the model system, the loaded speeds have to be estimated explicitly. This is done by multiplying the free speed on a link by an ELS factor, which is based on speed data obtained from the most recent traffic forecasts. The ELS factor is stratified by link functional classification, the number of lanes on the link, the location of the link in the planning area, and time of day (peak or off-peak period).

7) Approach links are constructed to connect the roadway network to the centroids of each zone. These approach links simulate local streets and represent pathways for the passage of traffic from/to the zone centroid to/from the planning roadway network.

8) Finally, zone-to-zone minimum travel time paths are developed for the forecast year from the (a) estimated link loaded speeds and the approach link selections for the forecast year road network, and (b) estimated terminal time, including the time required to locate a parking space, to walk from the car to the destination, and to walk to the car from the origin (the terminal time is estimated from the 1984

Workplace Survey and is stratified by trip purpose, area type, and whether the trip end is a production end or an attraction end).

The zonal trip-interchanges for the forecast year are determined from the zonal productions and attractions (from the trip generation step) and the zone-to-zone minimum travel time paths using a gravity model structure:

$$T_{ij} = P_i \frac{F(t_{ij})A_j}{\sum_z F(t_{iz})A_z} \qquad (1)$$

where:

T_{ij} = the number of trips produced by zone i and attracted to zone j.

P_i = the total number of trip productions for zone i.

F() = the decay function, which represents the rate at which a zone's attractiveness declines with increasing travel time.

t_{ij} = the zone-to-zone minimum travel time.

A_j = the number of trip attractions for zone j.

z = an index for zones in the system.

The decay function adopted in the DFWRTM has a Bessel functional form (which is similar to the exponential functional form). The Bessel parameter in this decay function is calibrated separately for each trip purpose using trip length and orientation data from the 1984 Home Interview and Workplace surveys. The same Bessel parameter is applied in forecasting for any future year and for any zonal configuration.

The formulation of the gravity model in Equation 1 does not immediately guarantee that the number of trips terminating in a zone will equal the zonal trip attractions estimated in the trip-generation step. To ensure consistency, a typical row-and-column factoring scheme is adopted.

The unique trip-making patterns associated with the Dallas/Fort Worth International Airport (DFW) are recognized in the trip-distribution process by applying person-trip K-factors for home-based nonwork and nonhome-based trips. These K-factors are developed by comparing the observed data that were part of the Origin/Destination Survey conducted by the NCTCOG at DFW in 1991 and the modeling results. The trip table is affected only for those HNW and NHB trips that have DFW as a trip end.

4. MODE CHOICE

The mode choice model applies the familiar multinomial logit structure to determine the splits among modes for the trip interchanges. The exogenous variables in the mode choice model include level-of-service variables, socioeconomic variables, and trip characteristics.

The mode choice model is estimated separately for each trip purpose. For the home-based work-trip purpose, five modal alternatives are used: drive alone, two-person shared-ride, three-or-more-person shared-ride, transit with walk access, and transit with auto access. For home-based nonwork and nonhome-based trip purposes, the two-person shared-ride and three-or-more-person shared-ride modes are collapsed into a single shared-ride category.

The mode choice alternatives available for an individual trip are determined based on two considerations. First, the drive alone and the transit-with-drive-access modes are not available for an individual's trip if the individual's household does not have a car. Second, the transit mode is not included in the consideration set of individuals who are managers or are self-employed. These two "rules" for limiting the choice set were based on a descriptive review of mode shares for a variety of socio-demographic subgroups.

The NCTCOG excludes all trips that have only a subset of the universal modal choice set and estimates mode choice models using only those trips with the full-choice set. In forecasting mode, the fraction of zone-to-zone person-trips that have limited choice sets is first determined using "look-up" tables derived from survey data. The estimated choice model is then applied separately for person-trips with the full-choice set and for person-trips with a limited choice set; these results are then aggregated.

The trip observations for the mode choice model estimation are obtained from the 1984 Home Interview and On-Board Transit surveys. Each observation includes information on the actual mode choice for the trip and relevant characteristics of the traveler and his or her household. The level-of-service (LOS) measures (travel times and travel costs) for each of the travel modes for each trip are also needed for estimation. The LOS measures for the “drive alone” mode are already determined in trip distribution. These measures are appropriately adjusted to obtain times and costs for the shared-ride modes. If separate high-occupancy vehicle (HOV) lanes are available for part of certain trips, reduced travel times are used for the shared-ride modes. Further, an additional variable specific to the shared-ride modes that captures the improved travel-time reliability is included in the presence of HOV lanes. However, this variable is not estimated; the coefficient on this variable is borrowed from the Shirley Highway HOV models in suburban Washington, D.C. The development of LOS measures for the walk-access-to-transit and drive-access-to-transit modes involves a tedious transit network preparation and transit path building process. These issues are discussed in detail in the report by the NCTCOG (1999).

A number of alternative variable specifications are tested during model calibration, and the final specifications are obtained based on considerations of parsimony, intuitiveness of the effect of variables, and data fit. Four classes of variables are included: LOS measures, location-specific effects (i.e., if the trip production or attraction end is a CBD or a rural area), socioeconomic attributes of the individual making the trip, and mode-specific constants.

After estimation, the mode choice model is validated in two different ways. First, the estimated model’s ability to replicate individual choices, as well as aggregate mode shares, is evaluated using four sources of data: (1) the 1984 Home Interview and On-Board Survey disaggregate data, (2) trip tables from the 1984 surveys stratified by the purpose of trips and presence of choice set limitations, (3) the 1980 Urban Transportation Planning Package (UTPP) data from the census bureau for the Dallas-Fort Worth metropolitan area, and (4) the 1986 highway and transit count data in the Dallas-Fort Worth region. Second, the aggregate elasticity effects of each level-of-service variable are computed and compared against compilations of elasticities from other national sources.

5. ROADWAY ASSIGNMENT

The NCTCOG uses an incremental loading procedure to assign traffic onto the road network. A generalized link impedance, which combines link travel time, link length, and link toll costs, is used in the assignment process. The assignment model is run separately for hourly volumes representative of peak periods (morning and afternoon peaks) and for hourly volumes representative of overall daily conditions.

The hourly volumes for the peak periods are obtained by applying peak period distribution factors to the daily vehicle trip interchanges (obtained from the mode choice step). The peak period distribution factors vary by time of day (morning versus afternoon), trip purpose, and trip orientation (production versus attraction). The hourly volumes representing average daily conditions are obtained by applying a factor of 0.11 for high-capacity facilities and a factor of 0.14 for low-capacity facilities.

The travel time component of the generalized link impedance is initially computed using a speed value that is 10 percent higher than the posted link speed. The minimum zone-to-zone generalized impedance path from each origin zone to each destination zone is computed next. The assignment process then loads a portion of the trip interchanges from each origin zone to each destination along the minimum path. Speed-delay functions are then used to compute revised travel times after the loading of the first portion of trip interchanges, and the generalized link impedances are updated. Minimum zone-to-zone paths are again computed for the loading of the second installment of trip interchanges; this procedure is continued until all trip interchanges are loaded. The DFWRTM allows the user to control the proportion of trip interchanges to be loaded in each iteration of the incremental loading process.

The speed-delay functions used in roadway assignment take the form shown below:

$$\text{Delay} = \text{Min}\{\, A * \exp[\, B * \text{hourly volume/ hourly capacity}], C\} \quad (2)$$

where A, B, and C are parameters that differ based on time of day and on whether the link is a high-capacity facility or a low-capacity facility.

In the presence of HOV facilities, an additional precursor step is added to the assignment procedure discussed above. The precursor step assigns a portion of the shared-ride trip interchanges for the work-trip purpose (estimated from the mode choice model) to the HOV facilities. The portion assigned depends on the type of HOV facility. Seventy-eight percent of shared-ride trips are assigned to HOV facilities that allow usage for vehicle occupancy levels of two or more, while 84 percent of shared-ride trips with three or more people are assigned to HOV facilities that restrict usage to vehicle occupancy levels of three or more. After this assignment to HOV facilities, the HOV lanes are removed from the network and the remainder of the vehicle trips are assigned using the capacity-restrained approach discussed earlier.

The link volumes obtained from the traffic assignment procedure are processed using speed-delay curves in a speed postprocessing step to obtain the link speeds. The speed-delay curves used in this post-processing step have the same form as the ones in traffic assignment, but the parameters in the speed-delay function differ from those in traffic assignment. Because the parameters are calibrated in traffic assignment to replicate field-observed volumes, they may not provide accurate speeds. The parameters in the postprocessing stage are obtained from traditional volume-speed curves.

6. SPEED FEEDBACK AND TRANSIT ASSIGNMENT

The link speeds obtained from the speed postprocessing step may differ from those used in developing the zone-to-zone link paths for trip distribution and mode choice. To ensure consistency, the NCTCOG develops new zone-to-zone link paths from the speeds obtained at the end of the postprocessing step for use in trip distribution and mode choice. The iterative process is continued until the link speeds from the postprocessing step and those used earlier in trip distribution/mode choice are within about 5 percent of each other.

The final step in the DFWRTM system involves assignment of transit trips to the transit network.

REFERENCES

1. “Dallas-Fort Worth Regional Travel Model (DFWRTM): Description of the Multimodal Forecasting Process,” Transportation Department, North Central Texas Council of Governments, February 1999.