North Central Texas Council of Governments
Transportation Department
Model Development and Data Management Group

DFX Model Description Summary

Version 4.3.0

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North Central Texas Council of Governments
March 2012

Chapter
1

Introduction

This document describes the logic behind the Dallas-Fort Worth Regional Travel Model for the expanded area (DFX). The DFX is the North Central Texas Council of Governments' (NCTCOG) official travel demand model. The DFX is a four-step trip-based travel demand model which models a 10,000 square mile area in North Central Texas.

The software application is a collection of components that implements a four-step trip-based travel demand model on the TransCAD 5.0 platform. The software is developed and maintained by the Model Development Group in the Transportation Department at NCTCOG. The parameters, coefficients, and models in this application are calibrated based on the following data sources:

- 2005 external stations survey;
- 1994 workplace survey;
- 2004 Texas Department of Transportation (TxDOT) traffic saturation counts;
- 1996 Dallas-Fort Worth household survey;
- 2008 Fort Worth Transportation Authority (FWTA) and Denton County Transportation Authority (DCTA) transit onboard surveys;
- 2007 Dallas Area Rapid Transit (DART) transit onboard survey;
- 1999 automatic traffic count stations;
- 1999 SkyComp freeway density, speed and volume study; and
- 2001 Dallas/Fort Worth International Airport survey.

The DFX accepts the following input files: demographic data, roadway network including toll roads and HOV lanes, transit supply system including rail lines and park-and-ride facilities, and airport and external stations forecasts. It produces traffic volumes and speeds on roadways and transit usage data on the transit system. In addition to flexible coding tools, a streamlined menu system for performing model runs, and extensive reports, the software provides a comprehensive file management system for the organization of input and output data.

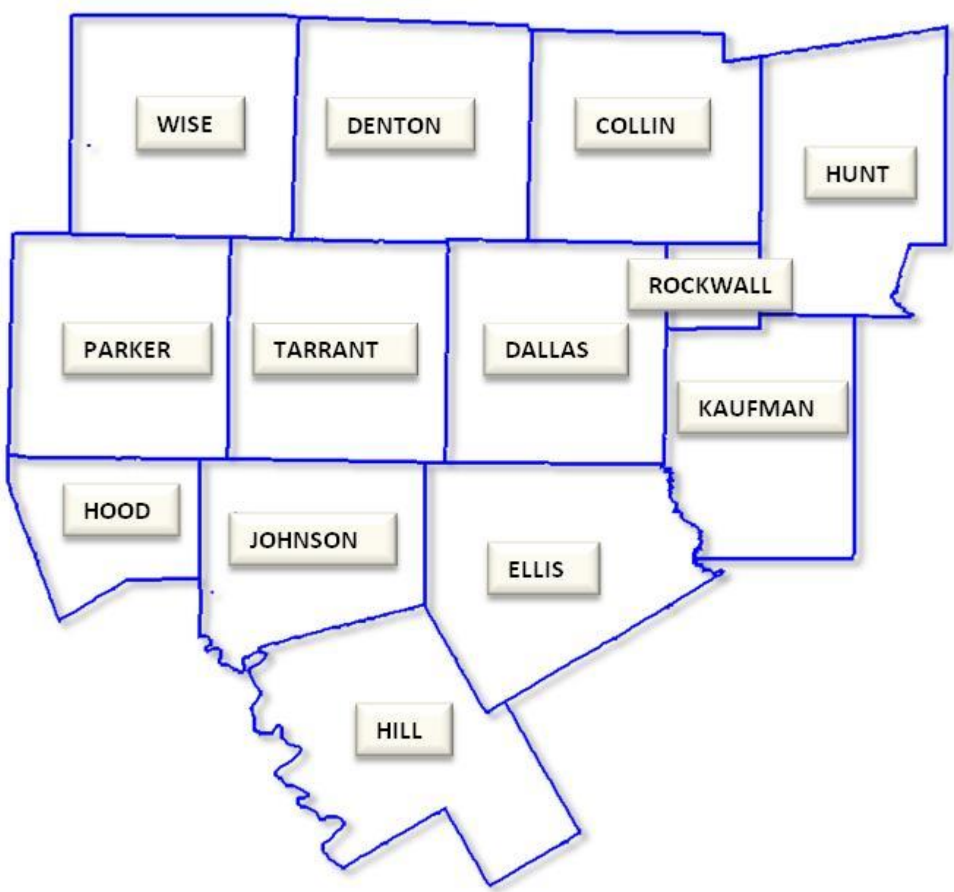
In this chapter, we will present a brief summary of each of the four major steps and other intermediate steps of the model. They are presented in the following order:

1. Zone Structure
2. Trip Generation (Step 1)
3. Roadway Network Coding and Preparation
4. Roadway Skim and Trip Distribution (Step 2)
5. Transit Network Coding and Transit Skims
6. Mode Choice (Step 3)
7. Transit and Traffic Assignment (Step 4)

Zone Structure

The modeling area of DFX includes the entire counties of Collin, Dallas, Denton, Ellis, Hill, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, Tarrant and Wise. Exhibit 1-1 illustrates the modeling areas within the North Central Texas region.

Exhibit 1-1: Modeling Area Within the North Central Texas Region

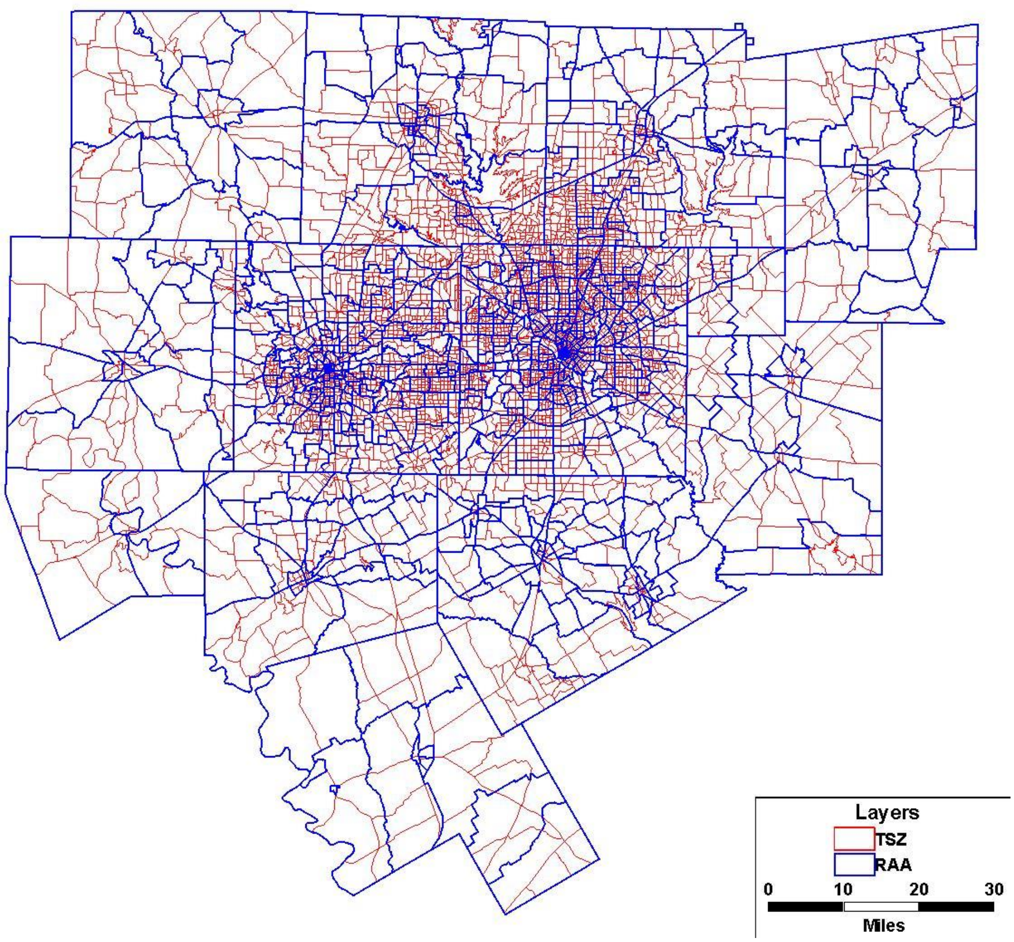


The modeling area has been divided into 5,386 travel survey zones (TSZ) of which 5,303 are internal zones and 83 are external zones.

The purpose of having a large number of zones in the area is to avoid splitting the zones for sub-area and corridor analyses. A stable zone structure creates convenience in model runs and consistency in the comparison of different projects.

The TSZ structure remains unchanged during the process of future projections and model analysis. Communication with the model users for zonal data input and output is based on the TSZ structure. Most of the internal model components directly use the TSZ zone structure with the exception of the income and household size distribution component in the trip generation module. The distribution of households among income groups and household sizes are based on the aggregation of the TSZs into 720 regional area analysis (RAA) zones. Exhibit 1-2 shows the TSZs and RAA zones in the modeling area.

Exhibit 1-2: TSZs and RAA Zones in the Modeling Area



Trip Generation

The first step in the 4-Step Model is Trip Generation. The function of the Trip Generation module is to convert demographic data into person trips productions and attractions for different trip purposes. Inputs to the trip generation module have to be predictable and geographically tied to the zone structure. The prediction of the inputs to the trip generation module is the function of the land use model.

The demographic data for the trip generation module includes population, the number of households, median household income, the number of basic, retail and service employments and special generator employments, the household income distribution and the household size distribution for each TSZ.

The outputs of the trip generation program are balanced production and attraction person trips from and to each TSZ for four trip purposes: Home-Based Work (HBW), Home-Based Non-Work (HNW), Non-Home-Based (NHB) and internal truck trips (OTH). In the output, the HBW trip productions and attractions are separated into the four income groups defined in the model. The outputs are used in the trip distribution step along with roadway skims.

The Trip Generation module is described in detail in Chapter 2.

Roadway Network Coding and Preparation

The transportation network of DFX is a GIS database that represents the actual roadway and rail links for the year of analysis. The network is the underlying database for all other steps in the DFX. The transportation network file is a series of links that are connected through nodes representing railroad tracks, roads, and intersections.

Generally, the roadway network is coordinated with the TSZ layer, so that the number of links inside the TSZ area is minimized. As mentioned in the zone structure description, the zone structure is designed to remain unchanged for different analyses years and scenarios. This makes the roadway coding rules for inclusion of links in the modeling network clear and consistent among roadway networks.

The Roadway Network Coding step includes checks on the integrity of the network and interdependence of the fields; the addition of the roadway network database fields for use later within DFX; creation of centroid connections to link the TSZ layer to the coded roadway network; and the calculation of loaded speeds, loaded travel times, operating costs, walk time, toll values, and cost of link travel. At the end of the roadway coding and preparation, the network is ready for providing initial travel time skim tables to be used in trip distribution.

The Roadway coding is described in detail in Chapter 3.

Roadway Skim and Trip Distribution

The second step in the 4-Step Model is Roadway Skim and Trip Distribution.

Roadway Skim

The Roadway Skim module is designed to find the shortest paths from origin centroids to destination centroids for auto modes. The number and types of the travel time skims needed are determined by the number of trip purposes, the number of peak periods, and the traffic assignment vehicle classes, which are dependent on mode choice module. There are a total of four roadway skim matrices produced which represent different time periods of interest (a.m. peak and off-peak) and whether or not HOV facilities are utilized for skimming; the matrices are named PK_HOV (Peak HOV), PK_NOHOV (Peak No HOV), OP_HOV (Off-Peak HOV), and OP_NOHOV (Off-Peak No HOV).

Trip Distribution

The Trip Distribution module determines the number of trips between each origin and destination zone for which trip production, trip attraction, and skims are known. For internal trips, the DFX adopts a form of the gravity model for trip distribution. Each set of parameters is calibrated for each trip purpose, so there are a total of seven gravity models (four for HBW in each income quartile, HNW, NHB, and OTH trips). There are three types of inputs to feed into the gravity models: a friction factor table, production/attraction totals, and an impedance matrix. The gravity model outputs are trip matrices indicating where trips are generating from and where there are destined to, for each trip purpose. The airport trip sub-module estimates the number of HNW and NHB trips to and from the commercial airports based on the number of enplanements at each airport.

The TSZ productions and attractions are outputs of the trip generation module.

Transit Network Coding and Transit Skims

The Transit Network represents existing transit service in the year of analysis. It is a GIS database built on the roadway network. Actual transit service is the integration of several routes with different vehicle technologies, boarding and alighting stations, fare structure, transfer policies, and service times.

Transit Network Coding

The DFX models the transit service for the a.m. peak period of 6:30 a.m. to 8:59 a.m. (AM) and the off-peak period of 9:00 a.m. to 2:59 p.m. to represent transit service and transit use in a 24-hour weekday.

Transit lines are grouped into several modes. The modes are created generally based on technology used, fare system, or operating characteristics of the routes. Commonly used modes are local bus, express bus, commuter rail, and light rail.

Transit Skims

Transit skim tables provide the shortest path times through the transit network. The determination of transit paths and travel times is based on the TransCAD Pathfinder algorithm.

The output of the Transit Skims are twelve matrices describing the different transit networks (Bus Only, Rail Only, Bus and Rail Only) during the peak period with park-and-ride, peak period with no park-and-ride, off-peak period with park-and-ride, and off-peak period with no park-and-ride. Each matrix has tables describing costs and times for travel. These tables are used in the mode choice module, along with other inputs, to calculate the mode shares.

The details of the Transit Network and Transit Skim Modules are not in the scope of this document.

Mode Choice

The third step in the 4-Step Model is Mode Choice. The mode choice modules determine the portion of trips that use different modes and are applied to the trip table outputs of the trip distribution process. The modes considered in the DFX are drive alone, shared-ride with 2 occupants (SR 2), shared-ride with 3 or more occupants (SR 3+), transit with walk access, and transit with drive access.

Trips are segmented based on trip purposes. Nested logit models are used for HBW, HNW, and NHB trips. The output of the mode choice module are sets of person trip tables using the modes Drive Alone, SR 2, SR 3+, Bus Only Transit with Walk Access, Rail Only Transit with Walk Access, Bus and Rail Transit with Walk Access, Bus Only Transit with Auto Access, Rail Only Transit with Auto Access and Bus and Rail Transit with Auto Access for the HBW, HNW, and NHB trip purposes.

The details of the Mode Choice modules are not in the scope of this document.

Roadway Traffic Assignment and Transit Assignment

The traffic assignment is the last step in the 4-step travel demand modeling. The DFX includes 5 feedbacks from traffic assignment back to trip distribution. Each feedback starts with free-flow travel times. The traffic assignment is run for the a.m. peak and off-peak periods in the first five feedbacks. During the last feedback, the roadway traffic is assigned under the a.m. peak, p.m. peak, and off-peak period demands, and the transit assignment is run for the peak and off-peak periods.

Roadway Traffic Assignment

The inputs for roadway traffic assignment are vehicle trip tables by time-of-day. There are three time-of-day periods: the a.m. peak period from 6:30 a.m. to 8:59 a.m. (AM); the p.m. peak period from 3:00 p.m. to 6:29 p.m. (PM); and the off-peak period (9:00 a.m. to 2:59 p.m. and 6:30 p.m. to 6:29 a.m.). The DFX considers four vehicle classes: drive-alone vehicles (DA), shared-ride vehicles with access to HOV facilities (SRHOV), shared-ride vehicles with no access to HOV facilities (SRNOHOV), and trucks (TRUCK). The DFX adopts a generalized cost method for multi-modal multi-class roadway assignment. Different vehicle classes have different sets of roadway networks to access and different parameters for value-of-time. The Roadway Assignment modules are described in detail in Chapter 4.

The output of the roadway traffic assignment are total traffic volumes and times stored in the roadway network file, and estimated volumes for each class stored in separate output files.

Transit Assignment

The Transit Assignment step uses the TransCAD PathFinder algorithm. Transit assignment is only run after the last feedback is completed in the model run.

Transit assignment includes twelve separate assignment sub-modules. Six assignment sub-modules assign HBW Bus Only, Rail Only and Bus and Rail transit walk-access and drive-access trip tables to the peak transit network with and without park-and-ride included. Six assignment sub-modules assign the total of HNW and NHB Bus Only, Rail Only, and Bus and Rail transit walk-access and drive-access trip tables to the off-peak transit network with and without park-and-ride included. Transit trip tables are assigned in a 24-hour production-attraction format to the networks. The Transit Assignment details are not in the scope of this document.

Chapter
2

Trip Generation

The Trip Generation model converts population, household, income, and employment data to the number of person trips. The model includes two modules: trip production and trip attraction. The trip production module estimates the number of trips produced from a zone and the trip attraction module estimates the number of trips attracted to a zone. The module uses the cross-classification model for both trip production and trip attraction models. The trip productions are cross-classified by household size and household income. The trip attractions are determined by employment type, area type, and income.

The inputs for trip generation are zonal demographics including population, household, and employment. In the DFX, we use two input sources: the Traffic Survey Zone (TSZ) geographic file and the demographic data file DATA.DBF.

The model outputs are trip productions and attractions for each TSZ in the region, stratified by seven trip purposes:

- Home-based work trips for low income households (HBW1)
- Home-based work trips for low-median income households (HBW2)
- Home-based work trips for high-median income households (HBW3)
- Home-based work trips for high income households (HBW4)
- Home-Based Non-work trips (HNW)
- Non Home-Based trips (NHB)
- Other, mainly service truck trips (OTHER)

This chapter describes the trip generation program including inputs, outputs, and the trip production and trip attraction modules.

Model Inputs and Output

The geographic file TSZ.DBD is saved in folder TCMODEL\TSZGeographic\GEO. The file presents a GIS-generated zone structure at the finest level: Traffic Survey Zones (TSZ). In the DFX, the trip generation model is performed on a TSZ level. Exhibit 2-1 describes the contents of the TSZ geographic file.

The demographic data file DATA.DBF is saved in TCMODEL\TSZGeographic\GEO\ACT. This file lists a set of socio-economic measures for each TSZ, including population, households, and median income in a table format. These demographic variables, except the income variable, correspond to the study year. The median income is in 1999 dollar value. The field descriptions of the table are presented in Exhibit 2-2.

Exhibit 2-1: Field Descriptions for TSZ.DBD

Field	Descriptions
Area	Area of the TSZ in square miles
TSZ	TSZ ID
RAA	ID of Regional Area Analysis Zone (RAA) which the TSZ belongs to
County	Name of the county which the TSZ belongs to, “External” if the TSZ is an external zone
Model_Area	Model area of the TSZ in square miles
DART	1 if the TSZ is within the Dallas Area Rapid Transit service area, 0 otherwise
FWTA	1 if the TSZ is within the Fort Worth Transportation Authority service area, 0 otherwise
DCTA	1 if the TSZ is within the Denton County Transportation Authority service area, 0 otherwise
Airport	“DFWAirport” or “ LoveField” if there is an airport in the TSZ, “NonAirport” otherwise
MPA9	1 if the TSZ is inside the legacy 4,874 zone structure in DFWRTM, 0 otherwise
MPA12	“Inside” if the TSZ is inside the 12-county MPA, “Outside” otherwise
External	1 if the TSZ is an external zone, 0 otherwise
None of the Above	Legacy fields, not to be used with the 5386 zone structure

Exhibit 2-2: Field Descriptions for DATA.DBF

Field	Descriptions
TSZ	TSZ ID
XCOOR	X coordinate of the TSZ centroid
YCOOR	Y coordinate of the TSZ centroid
MEDINC	Median household income of TSZ in 1999 dollars
HHOLD	Number of households in TSZ
POP	Number of population in TSZ
BASIC	Number of basic type employment
RETAIL	Number of retail type employment
SERVICE	Number of service type employment
SGBASIC	Number of basic employment of the special generator
SGRETAIL	Number of retail employment of the special generator
SGSERVICE	Number of service employment of the special generator
SGUNIT	Number of units of the special generator
SGNAME	Name of the special generator
SGTYPE	Type of the special generator
SGHBWRATE	Home-based work trip rate of the special generator
SGHNWRATE	Home-based non-work trip rate of the special generator
SGNHBRATE	Non-home-based trip rate of the special generator
SGTRKRATE	OTHER trip rate of the special generator

The model output file PATRIPS.DBF is saved in TCMODEL\TSZGeographic\GEO\ACT. The outputs include trip productions as well as trip attractions from and to each TSZ. The fields in this table are described in Exhibit 2-3.

Exhibit 2-3: Field Descriptions for PATRIPS.DBF

Field	Descriptions
H1WP	Productions of HBW person trips by low income households
H1WA	Attractions of HBW person trips by low income households
H2WP	Productions of HBW person trips by low-median income households
H2WA	Attractions of HBW person trips by low-median income households
H3WP	Productions of HBW person trips by high-median income households
H3WA	Attractions of HBW person trips by high-median income households
H4WP	Productions of HBW person trips by high income households
H4WA	Attractions of HBW person trips by high income households
HNWP	Productions of HNW person trips
HNWA	Attractions of HNW person trips
NHBP	Productions of NHB person trips
NHBA	Attractions of NHB person trips
OTHP	Productions of OTHER person trips
OTHA	Attractions of OTHER person trips

The process of trip generation can be outlined as follows:

- Create a household income distribution
- Create a household size distribution
- Create a joint household size and income distribution
- Define TSZ area type
- Create a household income distribution for employees by employment type
- Calculate trip productions
- Calculate trip attractions
- Calculate special generators' trips
- Balance the production and attraction trips

Each task is described in detail in the following sections.

Household Income Distribution

The trip production model is a cross-classification model by household size and household income. Therefore, it is necessary to estimate the joint distribution of household size and household income for each TSZ. We estimate the joint distribution based on two independent distributions: household income distribution and household size.

The household income distribution reveals how many households exist in each income quartile for the Regional Area Analysis Zones (RAAs). It is based on the ratio of the zonal median income to the regional median income, as illustrated in Exhibit 2-4. For instance, if the zonal median income is 100 percent higher than the regional median income (ratio = 2), then 15 percent of all households would be in income quartile 1 (low income), 16 percent in income quartile 2 (low-median income), 26 percent in income quartile 3 (high-median income), and 43 percent in income quartile 4 (high income) in this RAA. After the income quartile distributions are calculated for all the

RAAs, the model then checks whether the total number of households in each quartile for the whole region is 25 percent. It then normalizes the distributions for each zone so that regional income distribution remains 25 percent for each quartile.

Household Size Distribution

The household size distribution reveals the number of households in each household size category for the RAAs. Households are distributed based on average household size for each TSZ. Exhibit 2-5 shows the distribution of household size based on average household size derived from the 1990 census. The underlying assumption is that the distribution of households relating to any household size in a zone remains unchanged in future years. For instance, if the zonal average household size is 3, 15 percent of households would be in household size 1; 29 percent in household size 2; 21 percent in household size 3; 19 percent in household size 4; 10 percent in household size 5; and 6 percent in household size 6 plus. Unlike the household income distribution, there is no need for normalization, since there is no control total by household size in the region.

Joint Household Size and Income Distribution

Once the individual distributions have been established, a joint distribution of household size and income quartile is created. Exhibit 2-6 presents the joint household size and income distribution for the whole region. It is used as a starting point in the Iterative Proportional Fitting (IPF) process to estimate the joint household size and income quartile distribution for each RAA. The control totals in the IPF are the number of households in each household size category and the number of households in each income quartile for each RAA.

All the joint distributions are established at the RAA level and it is assumed that within each RAA, the joint distribution remains constant across TSZs. Therefore, for each TSZ, the joint distribution is obtained as well as the number of households by household size and income quartile.

Exhibit 2-4: Household Income Distribution

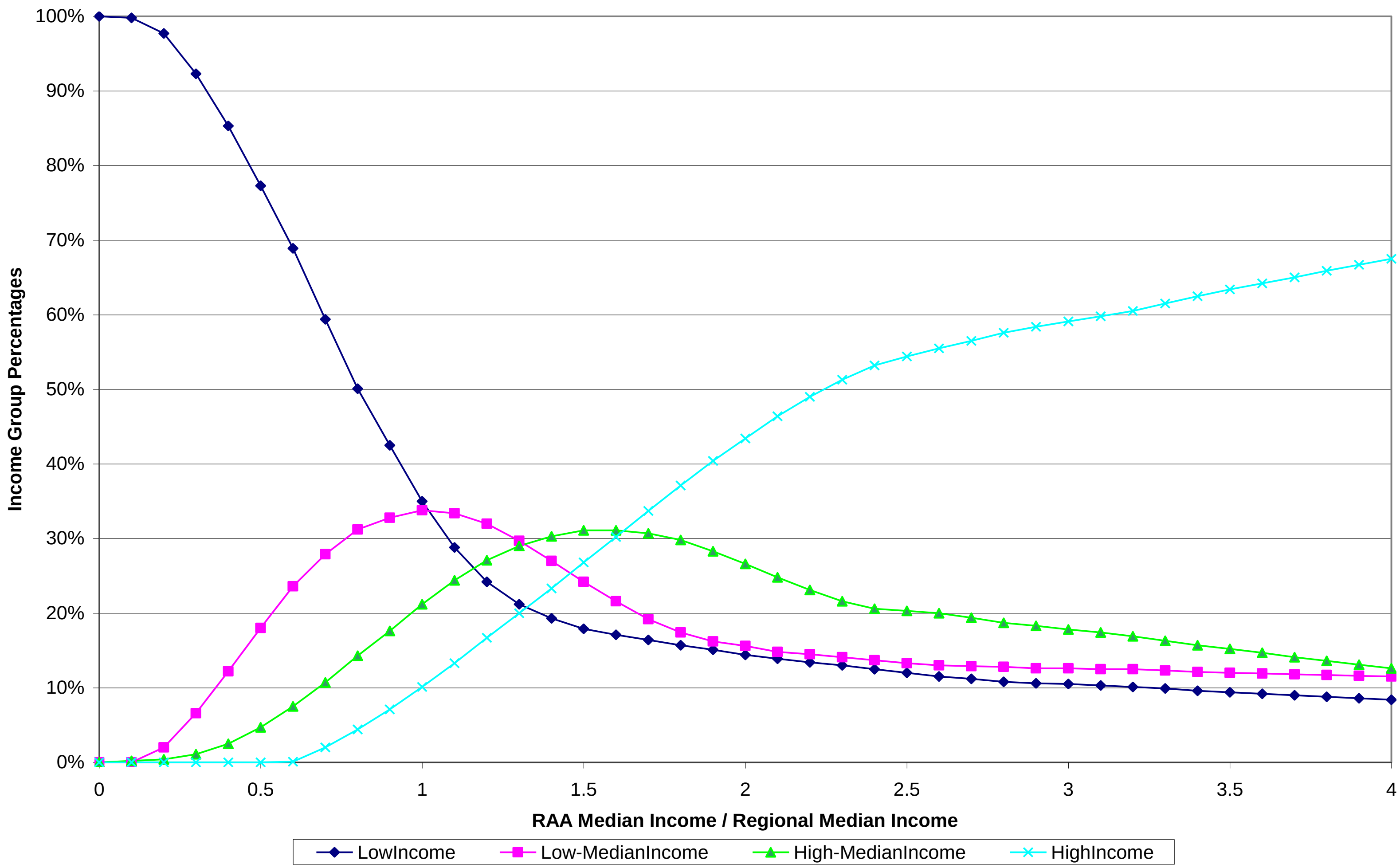


Exhibit 2-5: Household Size Distribution

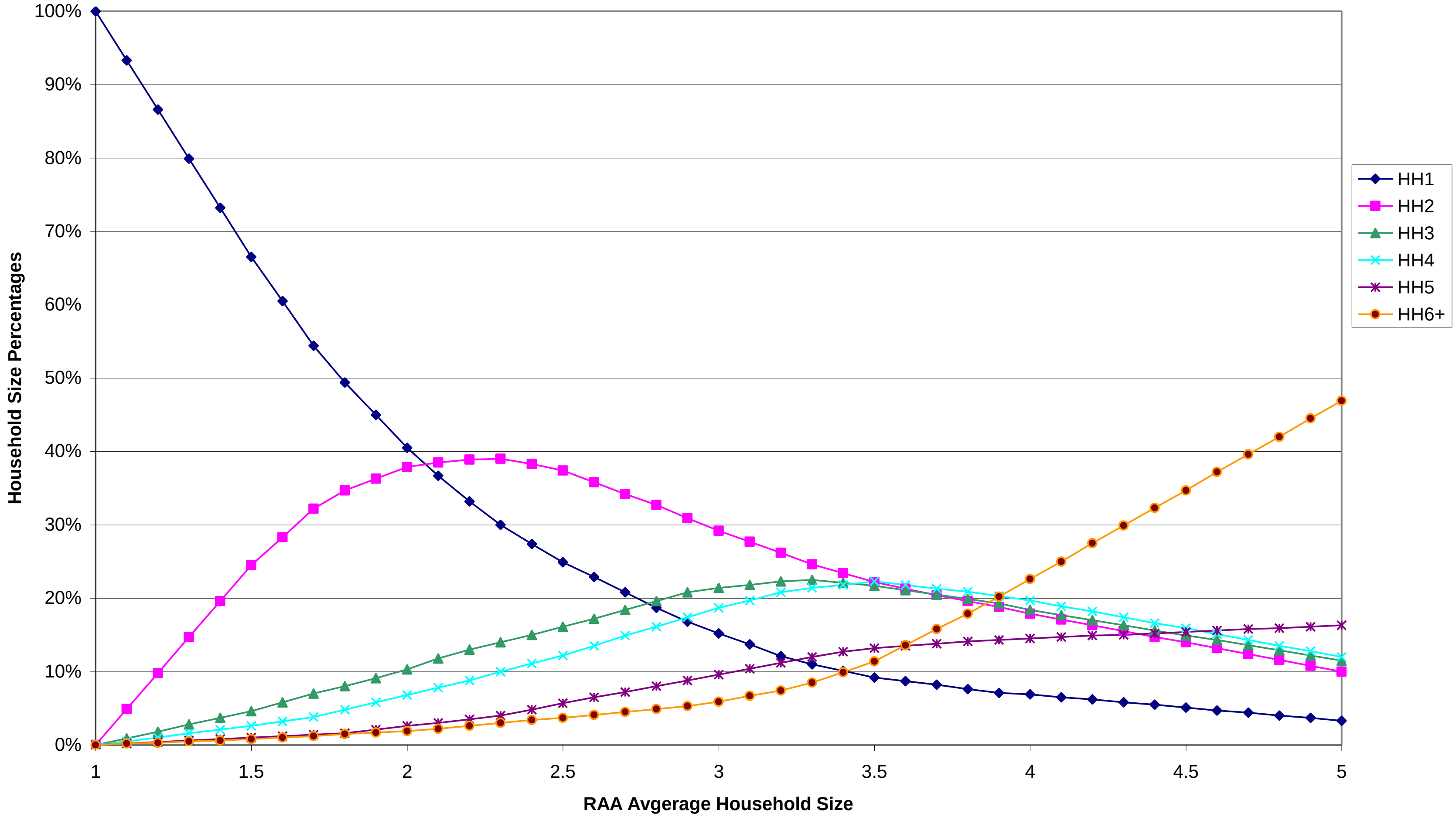


Exhibit 2-6: Joint Distribution of Income and Household Size for the Region

Household Size	Income Quartile			
	1	2	3	4
1	0.2006	0.2466	0.2685	0.2843
2	0.1686	0.2199	0.2841	0.3275
3	0.1389	0.1987	0.2968	0.3656
4	0.1664	0.2381	0.2857	0.3097
5	0.2186	0.2446	0.2871	0.2496
6+	0.1585	0.216	0.2924	0.3331

Area Type

The trip attraction model is a cross-classification model by area type and employment type. We define area type by the activity density at the RAA level. It is assumed that, within each RAA, the area type remains constant across TSZs. The activity density is defined as follows:

$$ADEN_i = (POP_i + B * EMP_i) / AREA_i \, , \tag{2-1}$$

where $ADEN_i$ is the activity density for RAA *i*; POP_i is the population of RAA *i*; EMP_i is the total employment of RAA *i*; $AREA_i$ is the total area of RAA *i*; and *B* is the regional population to employment (P/E) ratio. In the DFX Version 3, B equals 1.589993, corresponding to year 1999 regional P/E ratio. The area type is then defined in Exhibit 2-7:

Exhibit 2-7: Area Type and Activity Density

Area Type	Description	Activity Density Range (Per Acre)
1	Central Business District	> 125
2	Outer Business District	30-125
3	Urban Residential	7.5-30
4	Suburban Residential	1.8-7.5
5	Rural	<1.8

It should be noted that there are 144 RAAs where their area types are adjusted after the activity density is calculated. The main reason for this adjustment is to keep an RAA's area type consistent with the surrounding RAAs. Exhibit 2-8 lists the RAAs that have a pre-defined area type.

Exhibit 2-8: RAAs and Pre-Defined Area Type

RAA	Area Type	RAA	Area Type	RAA	Area Type
57	3	254	3	462	2
77	2	255	3	701	3
81	2	256	3	734	4
88	3	266	2	760	3
92	3	268	4	761	3
98	3	272	2	292-308	1
116	3	276	2	1-49	1
122	4	277	2	306	1
125	3	278	3	307	1
128	3	279	3	308	1
150	2	285	3	310	1
155	4	331	3	311	1
163	2	332	3	313-330	1
165	3	333	3	359	1
171	3	337	4	488	1
209	4	355	4	489	1
210	4	360	3		
212	4	364	4		
219	4	369	4		
226	2	371	2		
228	2	373	4		
239	4	379	2		
244	4	444	2		
246	4	445	3		
249	2	460	2		

Employment Income Distribution

The trip attraction model for HBW is a cross-classification model by area type and household income quartile at the workplace. This model requires an estimation of household income distribution for employees at their workplace. The DFX first estimates the employment income distribution at the RAA level. It is assumed that within an RAA the employment income distribution remains constant across TSZs and employment income distribution at TSZ level is subsequently obtained.

The employees' income distribution is estimated on the basis of the income level of households located in and around the zone. First we calculate the employment income quartiles by the following formulas:

$$PctEmp_{j1} = 0.115 + 0.04486 * HH670_1 / 0.25 + 0.0352 * HE75_{1j} \quad (2\text{-}2)$$

$$PctEmp_{j2} = 0.15892 + 0.07858 * HH670_2 / 0.25 \quad (2\text{-}3)$$

$$PctEmp_{j3} = 0.17 + 0.05969 * HH670_3 / 0.25 \quad (2\text{-}4)$$

$$PctEmp_{j4} = 0.41 + 0.06893 * HH670_4 / 0.25 - 0.00629 * HE50_j \quad (2\text{-}5)$$

where subscript *j* represents basic, retail, and service employment respectively and subscripts *1* to *4* represent income quartiles. For example, $PctEmp_{ji}$ is the percentage of employment type *j* in income quartile *i* in the zone. $HH670_i$ is the percentage of households in income quartile *i* within 6.70 miles; $HE75_{ij}$ is the ratio of households in income quartile *i* to the total employees of employment type *j* within 0.75 mile; and *HE50* is the ratio of total households to the total employment within 0.50 mile.

Second, the employment income quartile percentages are normalized so that the sum of income quartile percentages equals 1 for each employment type. Third, an iterative proportional fitting procedure is applied for each employment type respectively to ensure that the regional employment totals and regional employment income distribution over the four income quartile follows the ratio: 0.2019: 0.2588: 0.2670: 0.2723.

Trip Production Model

Trip production rates for HBW, HNW, and NHB trips are defined as the number of person trips per household and are stratified by income quartile and household size. The production rates for OTHER trips are defined as the number of person trips per employee/household stratified by zonal area type. The estimation of trip productions requires the application of trip rates to the number of households in a zone, stratified by income quartile and household size. Exhibits 2-9 through 2-12 show the trip production rates used in the Trip Generation Model. The "OTHER" trip rates are not stratified by household size and income quartile, but by area type and the employment/household mix with which they are most closely associated.

Exhibit 2-9: HBW Trip Production Rates

Income Quartile	Household Size					
	1	2	3	4	5	6
1	0.87	1.347	2.082	2.354	2.003	2.003
2	1.288	1.916	2.491	2.583	2.908	3.524
3	1.288	2.192	2.756	2.771	3.168	3.168
4	1.288	2.192	2.866	2.866	3.213	4.458

Exhibit 2-10: HNW Trip Production Rates

Income Quartile	Household Size					
	1	2	3	4	5	6
1	1.578	3.44	5.192	7.337	9.067	13.314
2	1.308	3.715	5.78	8.467	13.249	13.837
3	1.556	3.122	5.397	9.173	11.375	14.903
4	1.396	3.22	5.746	9.363	12.426	14.903

Exhibit 2-11: NHB Trip Production Rates

Income Quartile	Household Size					
	1	2	3	4	5	6
1	1.191	2.054	2.285	2.285	2.285	3.907
2	1.847	2.075	2.505	2.765	3.375	3.907
3	1.691	2.773	3.285	3.859	3.859	4.575
4	1.376	2.651	3.585	4.127	4.799	4.799

Exhibit 2-12: OTHER Trip Production Rates

Employment /Household	Area Type				
	1	2	3	4	5
Basic	0.128	0.128	0.128	0.128	0.128
Retail	0.14	0.14	0.14	0.14	0.14
Service	0.09	0.09	0.09	0.09	0.09
Household	0.053	0.053	0.053	0.053	0.053

Trip Attraction Model

Trip attractions are defined as the number of person trips attracted to a zone. They are stratified by area type, employment type and number of households, and, in the case of the HBW trip purpose, income quartile. Once the area type is defined and the income distribution of employees has been established, person trip attractions are calculated using the rates shown in Exhibits 2-13 through 2-18.

Exhibit 2-13: HBW Trip Attraction Rates for Basic Employment

Employment Income	Area Type				
	1	2	3	4	5
1	1.378	1.302	1.113	1.252	1.15
2	1.312	1.358	1.219	1.301	1.292
3	1.544	1.408	1.433	1.193	1.197
4	1.513	1.35	1.505	1.121	1.16

Exhibit 2-14: HBW Trip Attraction Rates for Retail Employment

Employment Income	Area Type				
	1	2	3	4	5
1	1.04	0.981	0.993	0.993	1.473
2	0.886	0.95	1.048	0.855	1.652
3	1.01	1.057	1.187	0.848	1.496
4	0.955	1.001	1.152	0.848	1.079

Exhibit 2-15: HBW Trip Attraction Rates for Service Employment

Employment Income	Area Type				
	1	2	3	4	5
1	1.438	1.448	1.166	1.166	1.427
2	1.65	1.383	1.181	1.349	1.676
3	1.705	1.459	1.214	1.599	1.599
4	1.843	1.472	1.326	1.695	1.695

Exhibit 2-16: HNW Trip Attraction Rates

Employment Type	Area Type				
	1	2	3	4	5
Basic	0.215	0.315	0.315	0.222	0.222
Retail	2.155	2.479	6.682	8.598	11.124
Service	1.494	1.504	2.525	4.937	5.363
Households	0.288	0.288	0.288	0.288	0.288

Exhibit 2-17: NHB Trip Attraction Rates

Employment Type	Area Type				
	1	2	3	4	5
Basic	0.575	0.575	0.737	0.737	0.737
Retail	1.034	1.378	2.271	3.092	4.316
Service	0.961	1.043	1.693	2.178	2.178
Households	0.251	0.251	0.251	0.251	0.251

Exhibit 2-18: OTHER Trip Attraction Rates

Employment Type	Area Type				
	1	2	3	4	5
Basic	0.128	0.128	0.128	0.128	0.128
Retail	0.14	0.14	0.14	0.14	0.14
Service	0.09	0.09	0.09	0.09	0.09
Households	0.053	0.053	0.053	0.053	0.053

Special Generators

Special generators, such as shopping malls and hospitals, attract more trips to the zone than the attraction rates presented in the previous section. In the case of NHB trips, the special generators also produce more trips. It is necessary to consider the impact of special generators to properly capture the travelers' trip-making behavior.

The DFX considers three types of special generators:

- Regional Shopping Malls with over 500,000 square feet
- Universities and Colleges with over 1,500 enrolled students
- Hospitals with over 300 service employees

The trip generation input data is DATA.DBF, which identifies inputs for special generators. The inputs for special generators are listed in Exhibit 2-19.

The field SGUNIT is defined differently based on different types of special generators. For regional shopping malls, this field is defined as a thousand square feet. For universities and colleges, it is defined as the number of students. For hospitals, this field is defined as the number of service employment which also is equal to field SGSERVICE.

Exhibit 2-19: Inputs for Special Generators

Fields	Descriptions
SGBASIC	Number of basic employment of the special generator
SGRETAIL	Number of retail employment of the special generator
SGSERVICE	Number of service employment of the special generator
SGUNIT	Number of units of the special generator
SGNAME	Name of the special generator
SGTYPE	Type of the special generator
SGHBWRATE	HBW trip rate per unit for the special generator
SGHNWRATE	HNW trip rate per unit for the special generator
SGNHBRATE	NHB trip rate per unit for the special generator
SGTRKRATE	OTHER trip rate per unit for the special generator

In the DFX, the program first calculates the regular trip attraction totals based on special generators' employment figures and trip attraction rates previously presented in the trip attraction section. Second, the special generators' actual trip attractions are obtained by multiplying each special generator's trip rate by the total number of special generator units in the zone. Subsequently, the differences between the regular trip attractions and the special generators' trip attractions are calculated for each zone. For HBW, HNW, and OTHER trip purposes, the increments are added to the zonal trip attractions. For NHB trips, half of the increments are added to the trip productions and the other half are added to the trip attractions.

In addition to regional shopping malls, universities, and hospitals, airports and external stations are also special generators requiring extra attention in the modeling process. In the DFX, special treatments for airport trips and external trips are incorporated in the Trip Distribution module.

Trip Balancing

Regional trip productions and attractions are balanced for each trip purpose. This step is required because there is no guarantee that the estimated regional production equals the regional attraction totals. For HBW trips, the trip productions for each zone are proportionally adjusted so that the regional productions are equal to the regional attractions. For HNW, NHB, and OTHER trip purposes, the zonal trip attractions are proportionally adjusted so that the regional attractions are equal to the regional productions. Furthermore, NHB trips go through one additional step in which the trip productions of each zone are set equal to the attractions in that zone.

Chapter
3

Roadway Network

After a roadway network is coded, it must be brought into the DFX system before it can be used in a model run. The “Create Roadway” program brings the roadway network into the model system by checking required fields and putting the file into the expected format. The “Copy Approach Links” program creates the zone centroids and approach links which will be used to load the traffic onto the network.

This chapter discusses the “Create Roadway” and “Copy Approach Links” programs and how they are used to prepare the roadway network within the NCTCOG modeling process. This documentation was written with the intention to be used by a person within the agency and within the DFX platform. Therefore, there might be inconsistencies in the input units that are corrected within the DFX application.

Create Roadway

This program can import an E00 file or a TransCAD line geographic file, which is created through the roadway coding process, into a TransCAD link file that will be used for travel demand model runs. The input file contains the coded roadway and rail links for a specific year or scenario. The program creates a TransCAD file with node IDs more than 50,000 and checks the reasonableness of the input network. The program also creates a metadata file that is based on the descriptive information entered by the user and a report file that is based on the file contents. It also creates a general purpose TransCAD Network file to be used for transit coding.

Inputs

1. E00 file or TransCAD line geographic file (name and address) that contains the coded roadway and rail links.

2. Roadway network file description for which this network is built. The description should contain the information that singles out this network from other networks. This will be part of the metadata of this file.

3. Name and program area of the person running the program. This will be part of the metadata of this file.

Steps

1. Get the name and location of the input file through browsing.

2. Create a folder under TCMODEL\RoadwayNetwork using the name provided in input 2. Make sure the name ends with the "RDWY" suffix. This is the location of all products of this program. If such a folder exists, the program displays a pop-up warning message to the user stating "Folder name [RDWY folder name] exists, please specify another name or exit the program."

3. Copy the input file into the new folder and save it as RDWY.DBD.

4. Check the existence of the required fields and their types in the link layer as specified in Exhibit 2-1. If any required field is missing or its type does not match, report the error in an error log file and stop the program.

<u>Exhibit 2-1: Required Fields for Roadway Link Layer</u>

No.	Field Name	Type	Description	Value
1	LNKNM	INT	Link Name	>= 0
2	TRDIR	INT	Direction code	1, one-way link and the topological direction is the same as traffic direction 2, two-way link
3	FUNCL	INT	Functional classification	1, Freeway 2, Principal Arterial 3, Minor Arterial 4, Collectors 6, Freeway Ramp 7, Frontage Road 8, HOV 9, Rail
4	STREET	STRING	Street name	<> null
5	DIVID	INT	Traffic directional division code	1, directionally divided or one-way road 2, directionally undivided road
6	INTVN	INT	Number of intervening controls	Set all values to zero, this field is no longer used in the program but still needs to exist for backward compatibility
7	CNTRLA	INT	Traffic control device code at node A	1, No Control 2, Traffic Signal 5, Yield 6, Four-Way Stop 7, Two-Way Stop
8	CNTRLB	INT	Traffic control device code at node B	1, No Control 2, Traffic Signal 5, Yield 6, Four-Way Stop 7, Two-Way Stop
9	USER_LENGTH	INT	User specified link in miles multiplied by 100, overwriting geographical link length	> 0, null
10	PKLNA	INT	number of lanes in peak period for AB direction, this should include the auxiliary lanes on freeway links	>= 0 and =< 6
11	PKLNB	INT	number of lanes in peak period for BA direction, this should include the auxiliary lanes on freeway links	>= 0 and =< 6
12	OPLNA	INT	number of lanes in off-peak period for AB direction, this should include the auxiliary lanes on freeway links	>= 0 and =< 6
13	OPLNB	INT	number of lanes in off-peak period for BA direction, this should include the auxiliary lanes on freeway links	>= 0 and =< 6
14	SPLTA	INT	speed limit in mph for AB direction	> 0
15	SPLTB	INT	speed limit in mph for BA direction	> 0

No.	Field Name	Type	Description	Value
16	TOLLA	INT	toll value in cents for AB direction at toll booth	Set all values to zero, this field is no longer used in the program but still needs to exist for backward compatibility
16	TOLLB	INT	toll value in cents for BA direction at toll booth	Set all values to zero, this field is no longer used in the program but still needs to exist for backward compatibility
17	TOLLMILE	INT	toll value in cents per mile	Set all values to zero, this field is no longer used in the program but still needs to exist for backward compatibility
18	TOLLA_AM	INT	toll value in cents in AM peak period for AB direction at toll booth	>= 0
19	TOLLA_PM	INT	toll value in cents in PM peak period for AB direction at toll booth	>= 0
20	TOLLA_OP	INT	toll value in cents in OP period for AB direction at toll booth	>= 0
21	TOLLB_AM	INT	toll value in cents in AM peak period for BA direction at toll booth	>= 0
22	TOLLB_PM	INT	toll value in cents in PM peak period for BA direction at toll booth	>= 0
23	TOLLB_OP	INT	toll value in cents in OP period for BA direction at toll booth	>= 0
24	TOLLMILE_AM	INT	toll value in cents per mile in AM peak period in both AB and BA directions	>= 0
25	TOLLMILE_PM	INT	toll value in cents per mile in PM peak period in both AB and BA directions	>= 0
26	TOLLMILE_OP	INT	toll value in cents per mile in OP period in both AB and BA directions	>= 0
27	TOLLROAD	INT	code specifying the type of toll road the link belongs to	0, link is not part of the toll road 1, access to or part of toll road with toll booth (TOLLA or TOLLB specifies the toll value) 2, access or part of toll road without toll booth (TOLLMILE specifies the toll value) 3, managed lanes (HOV with toll)
28	CAPACITY	INT	link capacity in vehicles/hour/lane, overwriting default capacity values	>= 0
29	EXC_TRUCK	INT	Truck exclusion code	> 0, trucks cannot use the link = 0, trucks can use the link
30	AMLN	INT	number of lanes for directional links in AB direction, overwriting PKLNA and makes PKLNB zero for AM period	>= 0
31	PMLN	INT	number of lanes for directional links in AB direction, overwriting PKLNA and makes PKLNB zero for PM period	>= 0

5. Perform the range of value checks specified in Exhibit 2-2. Report the errors and warnings in the error log file. If errors are found, stop the program and refer the user to the error log file. If no errors are encountered, proceed to the next step. All the requirements for TOLLA, TOLLB, and TOLLMILE also apply to TOLLA_*, TOLLB_*, and TOLLMILE_*, where * = {“AM”, “PM”, “OP”}, respectively.

Exhibit 2-2: Range of Values for Roadway Link Required Fields

No.	Field Name	Value	Status	Message (1)
1	LNKNM	[60000000, 70000000) for HOV [80000000, 90000000) for Rail Unique LNKNM Else	WRN WRN WRN WRN	WRN_L1-1 WRN_L1-1 WRN_L1-1 WRN_L1-1
2	TRDIR	[1, 2] else	OK ERR	N/A ERR_L1-1
3	FUNCL	[1,4] ,[6, 9] else	OK ERR	N/A ERR_L1-1
4	DIVID	[1,2] else	OK ERR	N/A ERR_L1-1
5	INTVN	[0,2] >2 else	OK WRN ERR	N/A WRN_L1-1 ERR_L1-1
6	CNTRLA	[1,2] or [5,7] else	OK ERR	N/A ERR_L1-1
7	CNTRLB	[1,2] or [5,7] else	OK ERR	N/A ERR_L1-1
8	USER_LENGTH	>0, null else	OK ERR	N/A ERR_L1-1
9	PKLNA	[0,6] >6 else	OK WRN ERR	N/A WRN_L1-1 ERR_L1-1
10	PKLNB	[0,6] >6 else	OK WRN ERR	N/A WRN_L1-1 ERR_L1-1
11	OPLNA	[0,6] >6 else	OK WRN ERR	N/A WRN_L1-1 ERR_L1-1
12	OPLNB	[0,6] >6else	OK WRN ERR	N/A WRN_L1-1 ERR_L1-1
13	SPLTA	[0,65] >65 else	OK WRN ERR	N/A WRN_L1-1 ERR_L1-1
14	SPLTB	[0,65] >65 else	OK WRN ERR	N/A WRN_L1-1 ERR_L1-1
15	TOLLA	>=0 else	OK ERR	N/A ERR_L1-1
16	TOLLB	>=0 else	OK ERR	N/A ERR_L1-1
17	TOLLMILE	>=0 else	OK ERR	N/A ERR_L1-1
18	TOLLROAD	[0,3] else	OK ERR	N/A ERR_L1-1
19	CAPACITY	>=0 else	OK ERR	N/A ERR_L1-1
20	EXC_TRUCK	>=0 else	OK ERR	N/A ERR_L1-1
21	AMLN	>=0 else	OK ERR	N/A ERR_L1-1
22	PMLN	>=0 else	OK ERR	N/A ERR_L1-1

(1) WRN_L1-1 = Unexpected value for LINKID = *LINKID,* field name = *fieldname*
ERR_L1-1 = Value out of range for LINKID = *LINKID,* field name = *fieldname*

6. Perform the interdependence value checks as specified in Exhibit 2-3. Report the errors and warnings in the error log file. If errors are found, stop the program and refer the user to the error log file. If no error is encountered, proceed to the next step. All the requirements for TOLLA, TOLLB, and TOLLMILE also apply to TOLLA_*, TOLLB_*, and TOLLMILE_*, where * = {“AM”, “PM”, “OP”}, respectively.

Exhibit 2-3: Interdependence Field Value Check for Roadway Link Fields

No	TRDIR	DIVID	FUNCL	INTVN	AMLN	PMLN	PKLNA	PKLNB	OPLNA	OPLNB	SPLTA	SPLTB	TOLLA	TOLLB	Status	Message
1	1	2	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	All one-way links must be divided
2	1	1	9	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	All rail links must be two-way
3	1	1	1, 8	>0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	WRN	Freeway or HOV links cannot have intervening controls
4	1	1	1, 8	0	>0	0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for AM or PM directional Freeway and HOV
5	1	1	1, 8	0	>0	>0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for AM or PM directional Freeway and HOV
6	1	1	1, 8	0	>0	>0	>0	>0	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNB must be = 0 for directional links
7	1	1	1, 8	0	>0	>0	>0	0	>0	>0	N/C	N/C	N/C	N/C	ERR	OPLNB must be = 0 for directional links
8	1	1	1, 8	0	>0	>0	>0	0	>0	0	0	N/C	N/C	N/C	ERR	SPLTA must be > 0 for directional links
9	1	1	1, 8	0	>0	>0	>0	0	>0	0	>0	>0	N/C	N/C	ERR	SPLTB must be = 0 for directional links
10	1	1	1, 8	0	>0	>0	>0	0	>0	0	>0	0	N/C	>0	ERR	TOLLB must be = 0 for directional links
11	1	1	1, 8	0	>0	>0	>0	0	0	>0	N/C	N/C	N/C	N/C	ERR	OPLNB must be = 0 for directional links
12	1	1	1, 8	0	>0	>0	>0	0	0	0	0	N/C	N/C	N/C	ERR	SPLTA must be > 0 for directional links
13	1	1	1, 8	0	>0	>0	>0	0	0	0	>0	>0	N/C	N/C	ERR	SPLTB must be = 0 for directional links
14	1	1	1, 8	0	>0	>0	>0	0	0	0	>0	0	N/C	>0	ERR	TOLLB must be = 0 for directional links
15	1	1	1, 8	0	0	>0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for AM or PM directional Freeway and HOV
16	1	1	1, 8	0	0	0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for one way Freeway and HOV
17	1	1	1, 8	0	0	0	>0	>0	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNB must be = 0 for one way Freeway and HOV
18	1	1	1, 8	0	0	0	>0	0	0	N/C	N/C	N/C	N/C	N/C	ERR	OPLNA must be > 0 for one way Freeway and HOV
19	1	1	1, 8	0	0	0	>0	0	>0	>0	N/C	N/C	N/C	N/C	ERR	OPLNB must be = 0 for one way Freeway and HOV
20	1	1	1, 8	0	0	0	>0	0	>0	0	0	N/C	N/C	N/C	ERR	SPLTA must be > 0 for one way Freeway and HOV
21	1	1	1, 8	0	0	0	>0	0	>0	0	>0	>0	N/C	N/C	ERR	SPLTB must be = 0 for one way Freeway and HOV
22	1	1	1, 8	0	0	0	>0	0	>0	0	>0	0	N/C	>0	ERR	TOLLB must be = 0 for one way Freeway and HOV
23	2	1	1	N/C	N/C	N/C	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for two way Freeway

Exhibit 2-3: Interdependence Field Value Check for Roadway Link Fields

No	TRDIR	DIVID	FUNCL	INTVN	AMLN	PMLN	PKLNA	PKLNB	OPLNA	OPLNB	SPLTA	SPLTB	TOLLA	TOLLB	Status	Message
24	2	1	1	N/C	N/C	N/C	>0	>0	0	N/C	N/C	N/C	N/C	N/C	ERR	OPLNA must be >0 for two way Freeway
25	2	1	1	N/C	N/C	N/C	>0	>0	>0	>0	0	N/C	N/C	N/C	ERR	SPLTA must be >0 for two way Freeway
26	2	1	1	N/C	N/C	N/C	>0	=0	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNB must be >0 for two way Freeway
27	2	1	1	N/C	N/C	N/C	>0	>0	>0	=0	N/C	N/C	N/C	N/C	ERR	OPLNB must be >0 for two way Freeway
28	2	1	1	N/C	N/C	N/C	>0	>0	>0	>0	>0	=0	N/C	N/C	ERR	SPLTB must be >0 for two way Freeway
29	1	1	[2,7]	N/C	>0	0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for AM or PM directional links
30	1	1	[2,7]	N/C	>0	>0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for AM or PM directional links
31	1	1	[2,7]	N/C	>0	>0	>0	>0	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNB must be =0 for directional links
32	1	1	[2,7]	N/C	>0	>0	>0	0	>0	>0	N/C	N/C	N/C	N/C	ERR	OPLNB must be = 0 for directional links
33	1	1	[2,7]	N/C	>0	>0	>0	0	>0	0	0	N/C	N/C	N/C	ERR	SPLTA must be > 0 for directional links
34	1	1	[2,7]	N/C	>0	>0	>0	0	>0	0	>0	>0	N/C	N/C	ERR	SPLTB must be = 0 for directional links
35	1	1	[2,7]	N/C	>0	>0	>0	0	>0	0	>0	0	N/C	>0	ERR	TOLLB must be = 0 for directional links
36	1	1	[2,7]	N/C	>0	>0	>0	0	0	>0	N/C	N/C	N/C	N/C	ERR	OPLNB must be = 0 for directional links
37	1	1	[2,7]	N/C	>0	>0	>0	0	0	0	0	N/C	N/C	N/C	ERR	SPLTA must be > 0 for directional links
38	1	1	[2,7]	N/C	>0	>0	>0	0	0	0	>0	>0	N/C	N/C	ERR	SPLTB must be = 0 for directional links
39	1	1	[2,7]	N/C	>0	>0	>0	0	0	0	>0	0	N/C	>0	ERR	TOLLB must be = 0 for directional links
40	1	1	[2,7]	N/C	0	>0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for AM or PM directional links
41	1	1	[2,7]	N/C	0	0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for one-way links
42	1	1	[2,7]	N/C	0	0	>0	>0	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNB must be =0 for one-way links
43	1	1	[2,7]	N/C	0	0	>0	0	0	N/C	N/C	N/C	N/C	N/C	ERR	OPLNA must be >0 for one-way links
44	1	1	[2,7]	N/C	0	0	>0	0	>0	>0	N/C	N/C	N/C	N/C	ERR	OPLNB must be =0 for one-way links
45	1	1	[2,7]	N/C	0	0	>0	0	>0	0	0	N/C	N/C	N/C	ERR	SPLTA must be >0 for one-way links
46	1	1	[2,7]	N/C	0	0	>0	0	>0	0	>0	>0	N/C	N/C	ERR	SPLTB must be =0 for one-way links
47	1	1	[2,7]	N/C	0	0	>0	0	>0	0	>0	0	N/C	>0	ERR	TOLLB must be = 0 for one-way links
48	2	N/C	1	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	WRN	Two way freeway links
49	2	N/C	8	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	WRN	Two way HOV links
50	2	N/C	9	N/C	>0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	AMLN must be =0 for rail links
51	2	N/C	9	N/C	0	>0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PMLN must be =0 for rail links
52	2	N/C	9	N/C	0	0	<>1	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be =1 for rail links
53	2	N/C	9	N/C	0	0	1	<>1	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNB must be =1 for rail links
54	2	N/C	9	N/C	0	0	1	1	<>1	N/C	N/C	N/C	N/C	N/C	ERR	OPLNA must be =1 for rail links

Exhibit 2-3: Interdependence Field Value Check for Roadway Link Fields

No	TRDIR	DIVID	FUNCL	INTVN	AMLN	PMLN	PKLNA	PKLNB	OPLNA	OPLNB	SPLTA	SPLTB	TOLLA	TOLLB	Status	Message
55	2	N/C	9	N/C	0	0	1	1	1	<>1	N/C	N/C	N/C	N/C	ERR	OPLNB must be =1 for rail links
56	2	N/C	9	N/C	0	0	1	1	1	1	0	N/C	N/C	N/C	ERR	SPLTA must be >0 for rail links
57	2	N/C	9	N/C	0	0	1	1	1	1	>0	0	N/C	N/C	ERR	SPLTB must be >0 for rail links
58	2	N/C	[2,7]	N/C	>0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	WRN	AMLN must be =0 for two-way links
59	2	N/C	[2,7]	N/C	0	>0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	WRN	PMLN must be =0 for two-way links
60	2	N/C	[2,7]	N/C	0	0	0	N/C	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNA must be >0 for two-way links
61	2	N/C	[2,8]	N/C	0	0	>0	0	N/C	N/C	N/C	N/C	N/C	N/C	ERR	PKLNB must be >0 for two-way links
62	2	N/C	[2,7]	N/C	0	0	>0	>0	0	N/C	N/C	N/C	N/C	N/C	WRN	OPLNA must be >0 for two-way links
63	2	N/C	[2,7]	N/C	0	0	>0	>0	>0	0	N/C	N/C	N/C	N/C	WRN	OPLNB must be >0 for two-way links
64	2	N/C	[2,7]	N/C	0	0	>0	>0	>0	>0	0	N/C	N/C	N/C	ERR	SPLTA must be >0 for two-way links
65	2	N/C	[2,7]	N/C	0	0	>0	>0	>0	>0	>0	0	N/C	N/C	ERR	SPLTB must be >0 for two-way links
66			[8,9]												ERR	User-length value missing for funcl>=8
67															ERR	Tollmile value missing for tollroad=2
68															ERR	LENGTH <= 0.00999 and USER-LENGTH = null

(1) N/C = No checks required for the field
N/A = Not applicable

7. Renumber node IDs sequentially starting from 50,000.

8. Add the fields specified in Exhibit 2-4 to the node layer. These fields are not populated in this program.

Exhibit 2-4: Added Fields to Coded Node Layer

No.	Field Name	Type	Description	Value
1	CENTROID	INT	Specifies if a node is a centroid	=1, if node is a centroid =null, otherwise
2	PANDR	INT	Specifies if a node is a park-and-ride node	=1, if node is a park and ride node =null, otherwise
3	TRXFER	INT	Specifies if a node is a transit transfer station	=1, if node is a transfer station =null, otherwise

9. Add fields to the link layer and populate them as specified in Exhibit 2-5.

Exhibit 2-5: Added Fields to Coded Line Layer

No	Field Name	Type	Description	Value
1	PKLN_AB	INT	Number of lanes in peak period for AB direction	Look at Calculation Procedure 1
2	PKLN_BA	INT	Number of lanes in peak period for BA direction	Look at Calculation Procedure 1
3	OPLN_AB	INT	Number of lanes in OP period for AB direction	Look at Calculation Procedure 1
6	OPLN_BA	INT	Number of lanes in OP period for BA direction	Look at Calculation Procedure 1
7	SPLT_AB	INT	Speed limit for AB direction	= SPLTA
8	SPLT_BA	INT	Speed limit for BA direction	= SPLTB
9	TOLL_AB	INT	Toll value in cents for AB direction at toll booth	= TOLLA, set null values to 0
10	TOLL_BA	INT	Toll value in cents for BA direction at toll booth	= TOLLB, set null values to 0
11	RTSTEMP	INT	Temporary field used for Transit coding	= 1
12	LinkMode	INT	Used in transit modeling	= 1
13	A_PK	REAL	Volume delay function parameter A for a.m. and p.m. periods	= 0.015, if FUNCL = 1,6,8 = 0.05, if FUNCL = 2,3,4,7 this field is no longer used in the program but still needs to exist for backward compatibility
14	B_PK	REAL	Volume delay function parameter B for a.m. and p.m. periods	= 6.0, if FUNCL = 1,6,8 =3.9, if FUNCL = 2,3,4,7 this field is no longer used in the program but still needs to exist for backward compatibility
15	C_PK	REAL	Volume delay function parameter C for a.m. and p.m. periods	= 4.0, if FUNCL = 1,6,8 = 5.0, if FUNCL = 2,3,4,7 this field is no longer used in the program but still needs to exist for backward compatibility
16	A_OP	REAL	Volume delay function parameter A for off-peak period	= 0.015, if FUNCL = 1,6,8 = 0.05, if FUNCL = 2,3,4,7 this field is no longer used in the program but still needs to exist for backward compatibility
14	B_OP	REAL	Volume delay function parameter B for off-peak period	= 6.0, if FUNCL = 1,6,8 =3.9, if FUNCL = 2,3,4,7 this field is no longer used in the program but still needs to exist for backward compatibility
15	C_OP	REAL	Volume delay function parameter C for off-peak period	= 4.0, if FUNCL = 1,6,8 this field is no longer used in the program but still needs to exist for backward compatibility = 5.0, if FUNCL = 2,3,4,7
16	MODEL_LENGTH	REAL	Link length in miles	= User_length/100, if User_length>0 = Length, otherwise

10. Build a network from a line layer geographic file with the parameters as described below. The complete Create Network form is shown in Exhibit 2-6.

    a. Create a selection set of links using the query “FUNCL>0 AND FUNCL<=9”; name this selection “FUNCL 1-9”

    b. Create a network file with the following settings:

        i. Create links from: FUNCL 1-9

        ii. Read length from: RTSTEMP

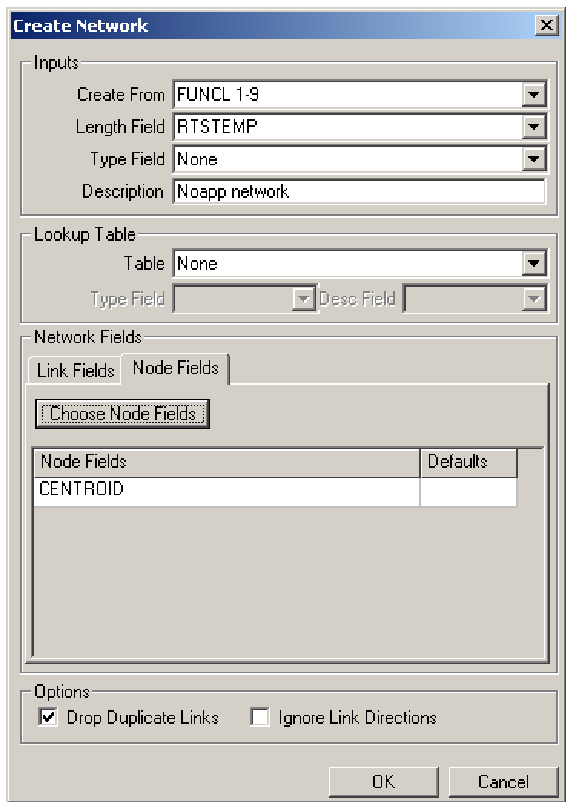
        iii. Other node fields: CENTROID

        iv. Check “drop duplicate link” option

        v. Input network description: “Noapp network”

    c. Press OK and save this network as ALLNET.net.

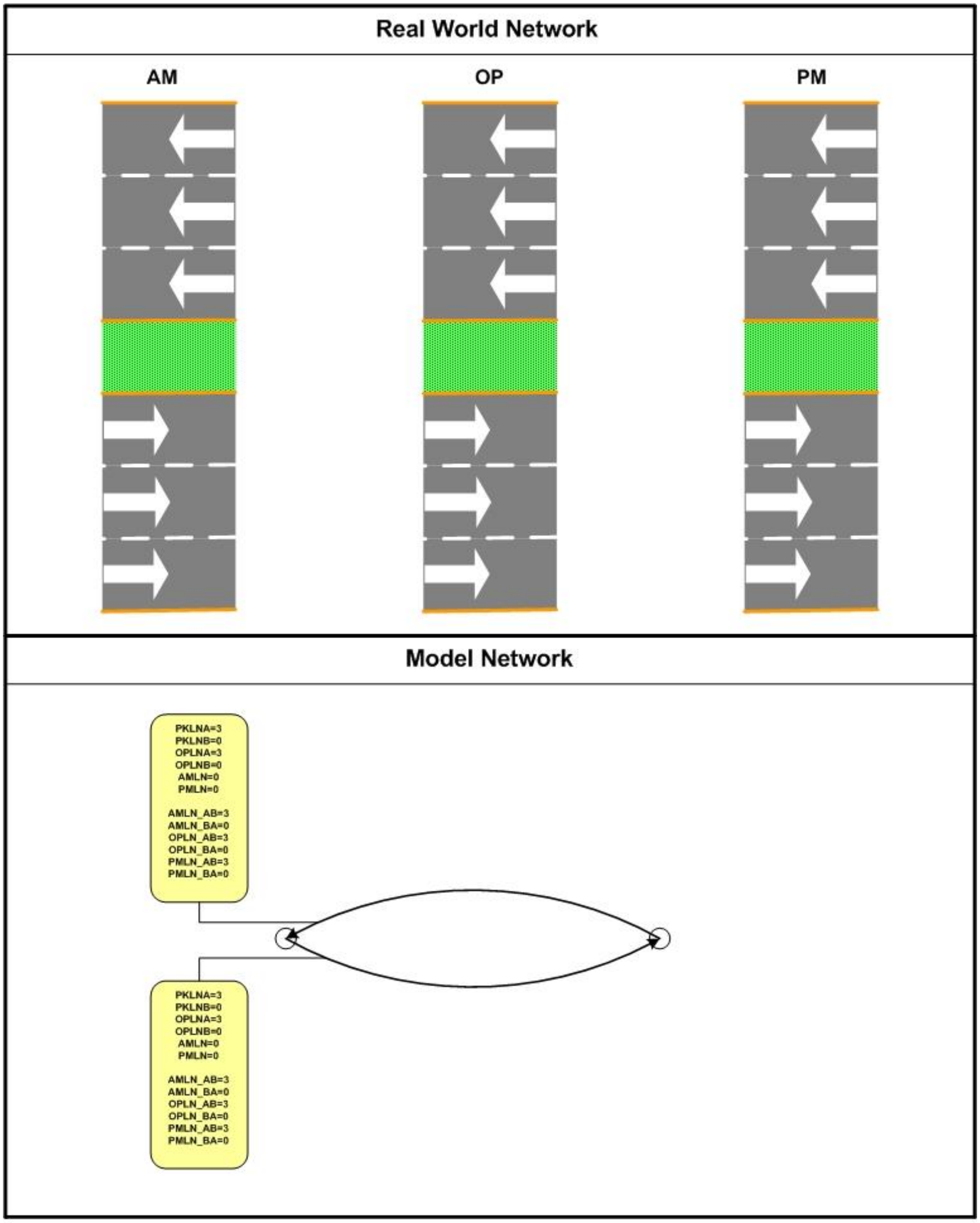
Exhibit 2-6: Create Network Form



Examples

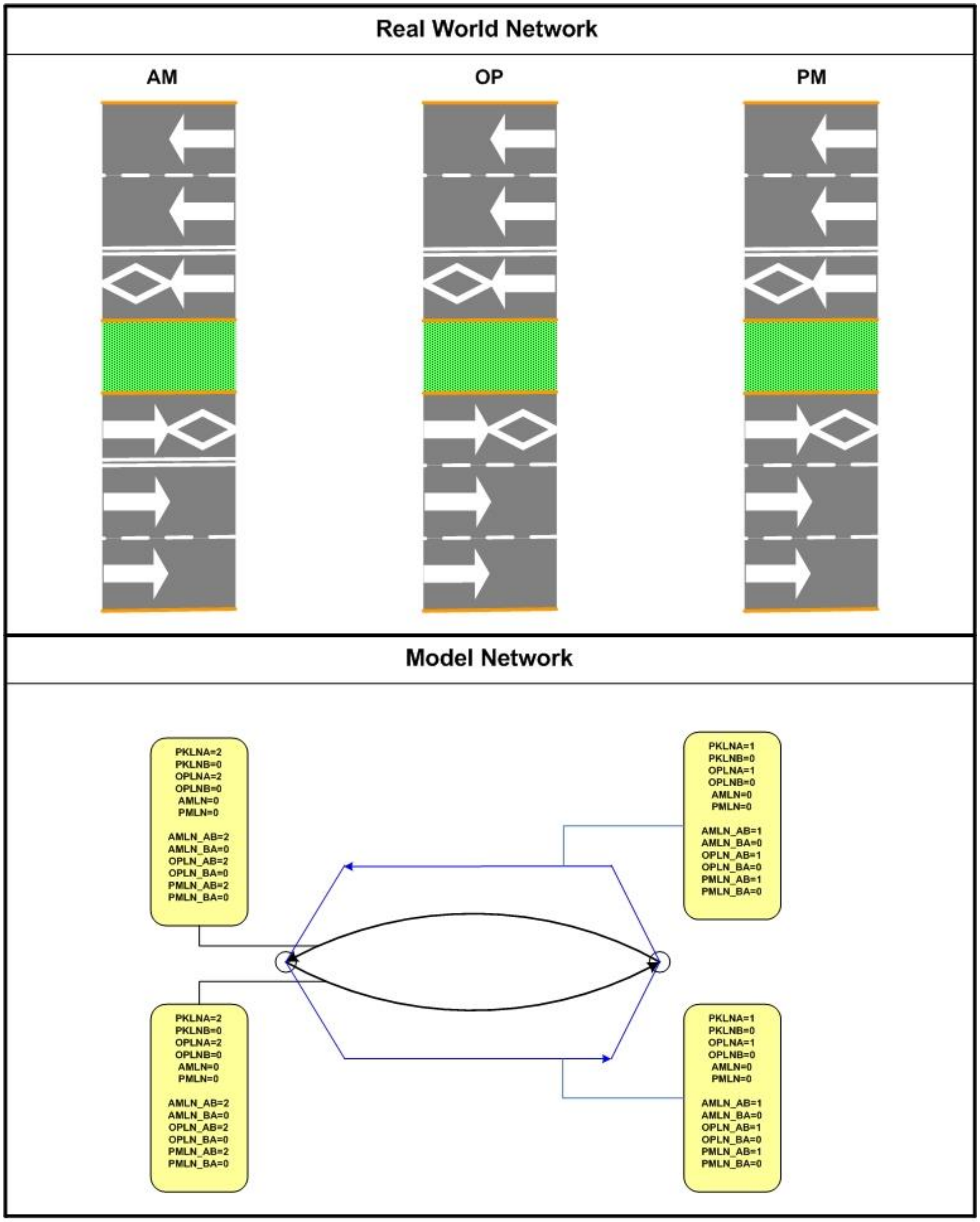
Examples of coding the number of lanes for a regular freeway section, a regular HOV section, and a directional HOV section are shown in Exhibits 2-7, 2-8, and 2-9, respectively.

Exhibit 2-7: Number of Lanes Coding Example – Regular Freeway Section



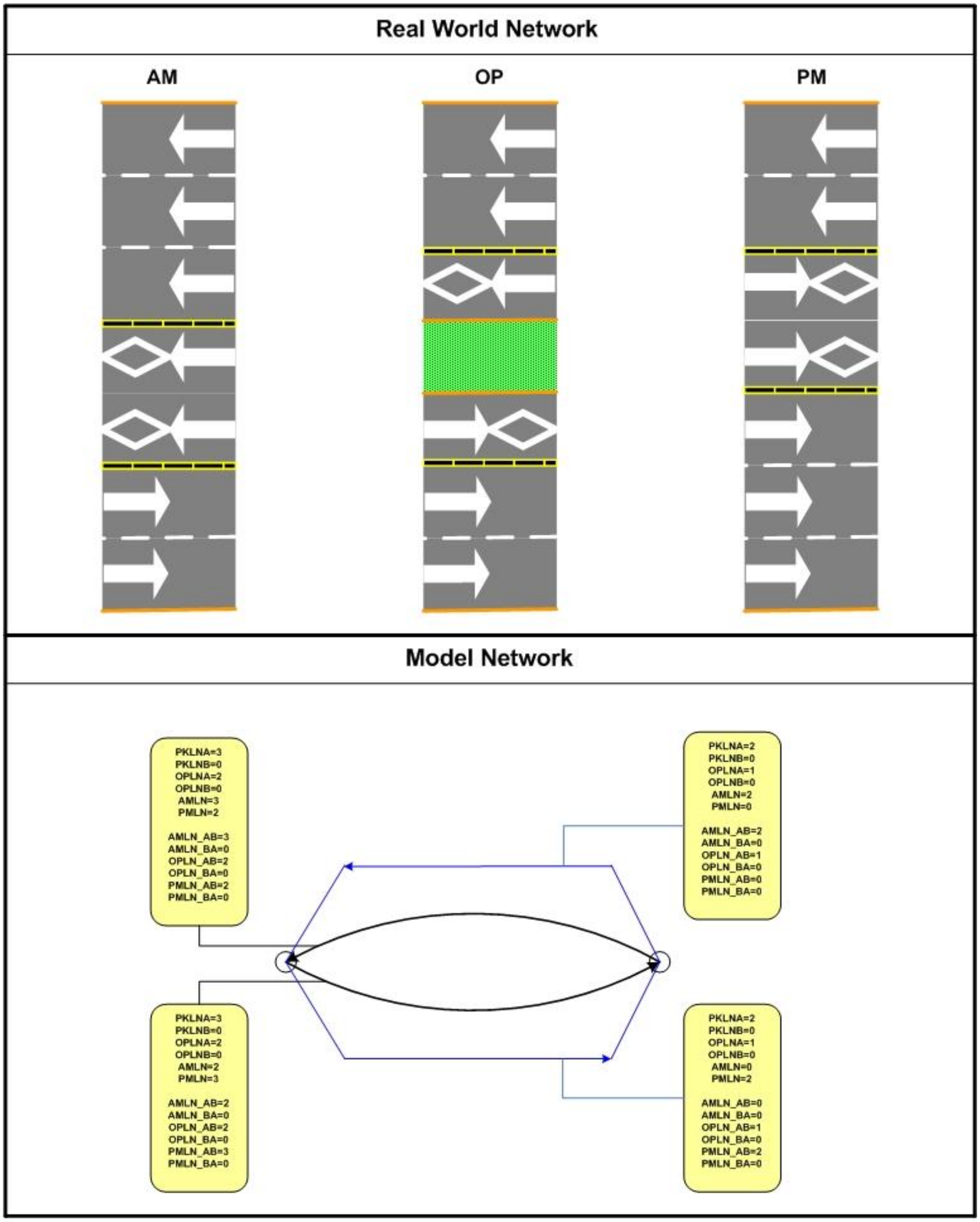
Regular Freeway Section

Exhibit 2-8: Number of Lanes Coding Example – Regular HOV Section



Regular Freeway - Regular HOV Section

Exhibit 2-9: Example of Coding Number of Lanes for a Directional Freeway – Directional HOV Section



Directional Freeway - Directional HOV Section

Copy Approach Links

Approach links are an important component of a roadway network. In four-step travel demand modeling, all the trips originate or end at the centroids and are distributed to the network through the approach links (also called centroid connectors).

Zones in the roadway network are represented as zone centroid points. Centroids are often the center of gravity of the zone, and their coordinates are calculated mathematically. However, if the zone shape is concave, the center of gravity may fall outside of the boundary of the zone; since this placement is undesirable, the centroid is located manually in these cases.

Approach links provide a connection between the zone layer and the roadway and transit network layers. Unlike other links, these links do not match any physical entity in the real world. The number and positions of the approach links determine how the traffic is loaded onto the network. In order to replicate real life traffic conditions, there is generally more than one approach link for each zone. The current implementation of the program only connects the approach links to the nodes in the network; an alternative method would be to allow mid-block connections which connect to the middle of a link.

The approach links of the base year network, 2004, were created with the help of the TransCAD centroid connector generator and edited manually. While zonal boundaries are basically kept constant in DFX, roadway networks could change in different analyses scenarios. The Copy Approach Link program enables the user to copy centroid connectors from an existing network with centroid connectors to a new roadway network. This process provides consistency among different model runs, since the loading of demand to the network is kept similar. Note that this process does not provide the exact replication of the centroid connectors that could happen due to changes to the roadway network. Manual inspection of the output is necessary, particularly where the two roadway networks are different. To help the user check for reasonable connectors, the program generates an approach link text report which provides centroid numbers where problems may have occurred.

Inputs

1. RDWY.DBD – Roadway Network file that contains the demographic and roadway network.

2. TSZ.DBD – Zone Layer file which defines the model zonal boundaries.

3. APPRDWY.DBD – “Copy From” Roadway Network; this file contains centroids and centroid connectors (approach links). The approach links will be copied from this network to the “Copy To” roadway network defined by RDWY.DBD.

Output

1. APPRDWY.DBD – Roadway Network, RDWY.DBD, with centroids and centroid connectors added.

2. APPLINKREP.TXT – Approach Link program report file. It lists the inputs to the program, the number of approach links in the source roadway, the number of approach links transferred, and a list of centroids that were involved in any approach link transfer errors.

Logic

The steps for the copy approach links process are detailed below. The flow chart in Exhibit 2-10 also summarizes this process.

- First, the information in the RDWY.DBD is copied to create the new APPRDWY.DBD.

- Then, the centroid nodes of the “Copy From” network are selected (selection in the node layer: CENTROID>0), and added to the new APPRDWY.DBD. The copied information for each centroid includes the coordinates and the TSZ id; the TSZ id will become the node’s id. The centroid field of the node is also filled with the value 1 to show that it is a centroid.

- Open the approach link layer of the “Copy From” network. For each approach link in the network, do the following:

    - Get the two end nodes of the approach link. For each approach link, one node is a centroid and the other is a regular node. Find out which one is the centroid and which is not and get their coordinates.

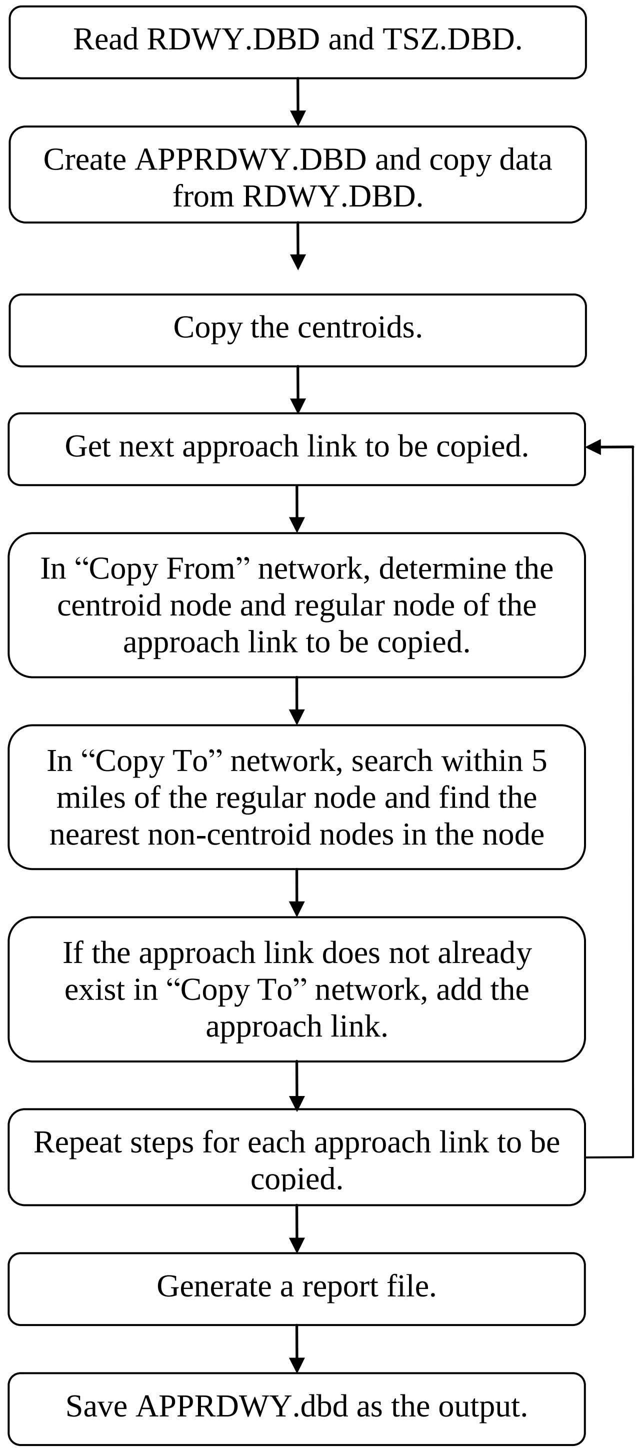
    - Search in the node layer of the new APPRDWY for the nodes that are nearest to the regular node within a certain distance (5 miles). If the nearest one is a centroid, then discard it and try the next nearest node until a non-centroid node is found. If a non-centroid node cannot be found within the distance, then the particular approach link will not be copied.

    - To prevent duplication of approach links, check if the approach link has already been created. If there is no duplication, the approach link is added.

    - Because of network changes or node location changes, there may be some approach links that are not transferred; the total number of approach links in the new network is always equal to or less than that the number in the “Copy From” or source network.

    - Repeat the process for the each approach link in the “Copy From” network (source network).

Exhibit 2-10: Flow Chart for Copy Approach Links Program

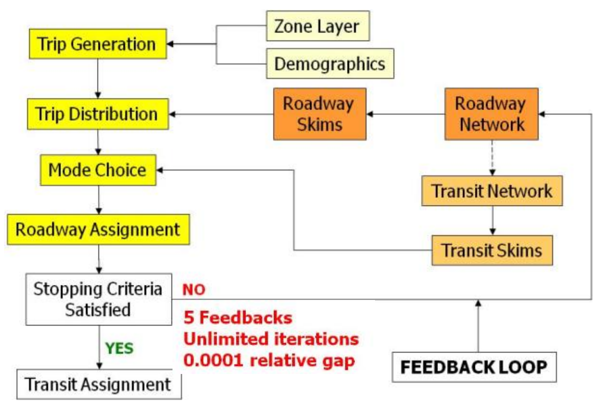


Chapter
4

Traffic Assignment

The traffic assignment is the last step in the 4-step travel demand modeling. DFX includes five feedbacks from traffic assignment back to trip distribution. Each feedback starts with free-flow travel times. The traffic assignment is run for the a.m. peak and off-peak periods in the first five feedbacks. The roadway travel times (PKTIME_AB/BA and OPTIME_AB/BA) are updated based on the results of these traffic assignments. During the last feedback, the roadway traffic is assigned under the a.m. peak, p.m. peak, and off-peak period demands, and the transit assignment is run for the peak and off-peak periods, as shown in Exhibit 4-1. This chapter describes the roadway traffic assignment procedures. This documentation was written with the intention to be used by a person within the agency and within the DFX platform. Therefore, there might be inconsistencies in the input units that are corrected within the DFX application.

Exhibit 4-1: 4-Step Travel Demand Modeling at NCTCOG

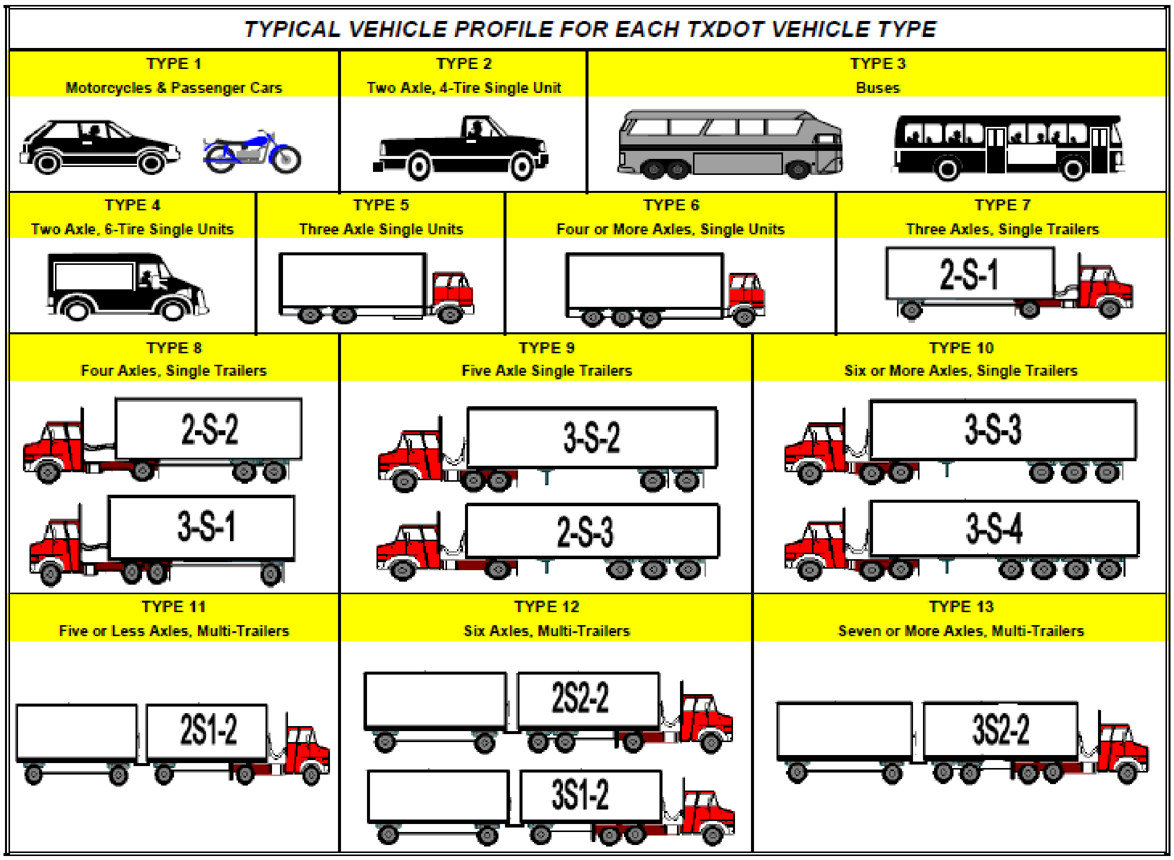


Roadway Traffic Assignment

The inputs for roadway traffic assignment are vehicle trip tables by time-of-day. There are three time-of-day periods: AM Peak (6:30 a.m. to 8:59 a.m.), PM Peak (3:00 p.m. to 6:29 p.m.), and Off-Peak (9:00 a.m. to 2:59 p.m. and 6:30 p.m. to 6:29 a.m.) periods. The DFX considers four vehicle classes: drive-alone vehicles (DA), share-ride vehicles with access to HOV facilities (SRHOV), share-ride vehicles with no access to HOV facilities (SRNOHOV), and trucks (TRUCK). Trucks should have a consistent meaning in both air quality and transportation models, using the vehicle type definition by TxDOT, as shown in Exhibit 4-2, vehicle class Drive alone and Shared ride apply to vehicle profile types 1 and 2, and Truck is defined as types 4-13. The DFX adopts a generalized cost method for multi-modal multi-class roadway assignment. The outputs of the roadway traffic assignment are the following: AMFLOW, OPFLOW, and PMFLOW. These files are binary files that record traffic volumes of different vehicle classes as well as average speed and volume-capacity ratio for each link. The DFX chooses the user equilibrium (UE) generalized cost method. The UE method is theoretically proven and widely adopted in practice around the world. The generalized cost component considers path choice by a combined measure of roadway operating cost, toll cost, and travel time. Furthermore, the congested travel time is sensitive to the capacity and traffic volume of the roadway.

One important component in traffic assignment is the volume-delay function. The DFX uses a customized volume-delay function: nctcog_cid_rii.vdf (conical, integrated delay, revision 2). The VDF components are a function of link traffic volume and capacity or saturation flow rate. The next section describes this function in more detail.

Exhibit 4-2: Vehicle Types by TxDOT



Volume Delay Function

The volume-delay function (VDF), which is sometimes referred to as the performance function, calculates a congested travel time that reflects the free speed travel time and the delays due to the impact of traffic volume on the link. As shown in Exhibit 4-3, the customized NCTCOG VDF in DFX has two main components: congestion delay and traffic control delay. The congestion delay has a conical form. The traffic control delay is further divided into signalized and un-signalized delays that utilize the uniform delay term from Webster's signalized intersection delay formulation and a simple linear function, respectively. Any VDF has to be monotonically increasing, differentiable, and defined for over-saturated links as well.

The general form of NCTCOG's volume-delay function is as follows:

$$T = T_0 + C_d + S_d + U_d \qquad (4\text{-}3)$$

Where:

T = congested travel time;
T_0 = free flow travel time;
C_d = volume-dependent congestion delay;
S_d = volume-dependent approach delay at signalized intersection; and
U_d = volume-dependent approach delay at un-signalized intersection.

Roadway Link Operating and Toll Cost

Two types of costs are assigned to each roadway link: vehicle operating cost and toll cost. While vehicle operating costs can include both long-term costs (insurance, car payments, repairs, etc.) and short-term out-of-pocket costs (primarily fuel cost), the DFX mainly considers the short-term costs because the Model Development Group believes that the short-term costs have a significant impact on the travelers' route choice decisions in the assignment module. The auto operating cost is assumed to be 15 cents per mile, expressed in constant 2007 dollars.

Tolls can be considered within the model by two methods: a fixed dollar value for a link, or a dollar per mile value. When the location of toll plazas and the amount of the toll are known, the fixed value is used. Otherwise, the unit toll cost (toll per mile) is used and toll cost on the link is subsequently calculated. In both cases, the link toll cost is adjusted to constant 2007 dollars. Toll adjustment factors are the Consumer Price Index (CPI) adjustment factors listed in Exhibit 4-6 and displayed in Exhibit 4-7. The fixed tolls are defined for each time-of-day and direction separately (TOLL*_AB/BA), and the toll per mile is defined only by time-of-day (TOLLMILE_*).

Managed lane facilities are HOV lanes that can be used by the Drive Alone (DA) class by paying a toll, but are free for Shared Ride classes. They have a higher cost for the DA class; this is reflected in the roadway network file in field OPERCOST*DA_AB/BA.

Based on the toll cost and operating cost, the direct dollar cost of traveling through each link is calculated as follows:

$$AdjustedToll = [FixedToll + (TollMile)(Length)](AdjustmentFactor_{yr}) \qquad (4\text{-}4)$$

$$OperatingCost = (Length)(CostMile) + AdjustedToll \qquad (4\text{-}5)$$

where $AdjustmentFactor_{yr}$ is the adjustment factor to convert year *yr* toll cost to 2007 Dollars; *CostMile* is the operating cost per mile for all links and is set as 0.15 Dollars/Mile across all links.

Link cost attributes are stored in the network file in the following fields:

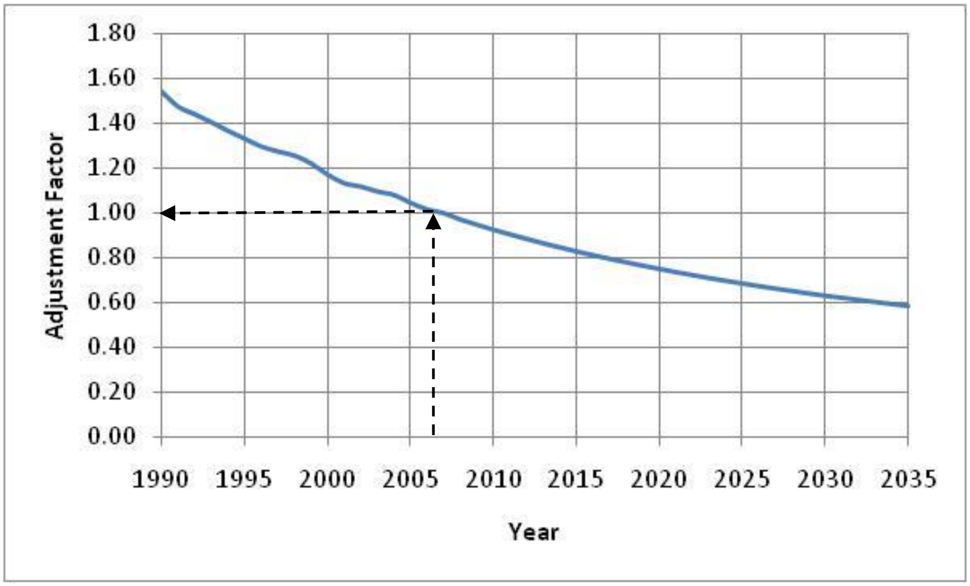
- TOLL*_AB/BA: fixed toll cost in cents at the toll booth;
- TOLLMILE_*: toll cost per mile in cents;
- OPERCOST*_AB/BA: Adjusted dollar cost for passing through a link for non-Drive Alone classes in Dollars;
- OPERCOST*DA_AB/BA: Adjusted dollar cost for passing through a link for Drive Alone class in Dollars;
- TOLLROAD: Code field used for managed lane facilities; and
- MODEL_LENGTH: Length of the link in miles.

The * character in the above toll fields can take one of the elements of the array {AM, PM, OP}.

Exhibit 4-6: Consumer Price Index (CPI) Adjustment Factor Based on 2007 Dollars

Year	CPI Adjustment Factor
1990	1.54
1991	1.48
1992	1.44
1993	1.41
1994	1.37
1995	1.33
1996	1.30
1997	1.28
1998	1.26
1999	1.22
2000	1.17
2001	1.13
2002	1.12
2003	1.10
2004	1.08
2005	1.05
2006	1.02
2007	**1.00**
2008	0.97
2009	0.95
2010	0.93
2011	0.90
2012	0.88
2013	0.86
2014	0.85
2015	0.83
2016	0.81
2017	0.80
2018	0.78
2019	0.76
2020	0.75
2021	0.74
2022	0.72
2023	0.71
2024	0.70
2025	0.68
2026	0.67
2027	0.66
2028	0.65
2029	0.64
2030	0.63
2035	0.58

Exhibit 4-7: Toll Adjustment Factor Based on 2007 Dollars



Generalized Cost and Value-of-Time

The value-of-time (VOT) parameter combines the impact of travel time, vehicle operating cost, and toll cost in the traffic assignment. Estimating an appropriate value-of-time is often a difficult task because there are many factors that influence an individual's perception of the value-of-time. For instance, higher income households generally have a higher value-of-time than lower income households. The VOTs used in the DFX traffic assignment are as follows:

- $14/hour ($0.233/minute) for auto-based vehicle classes (DA, SRHOV, and SRNOHOV)
- $17/hour ($0.283/minute) for trucks

The total travel cost on a roadway link is then calculated as shown in Exhibit 4-8.

$$GeneralizedCost = OperatingCost + (VOT)(TravelTime) \qquad (4\text{-}8)$$

Implementing Roadway Traffic Assignment in TransCAD

The traffic assignment module in the DFX is fully automated. This section describes the process for manually running it, using the a.m. peak period as an example. The assignment process components are the following: creation of a roadway network, and execution of a multi-modal multi-class assignment.

The following steps are taken to create the AM network for the a.m. peak period:

1. Open the roadway geographic file ACTRDWY.DBD;
2. Create a selection of links with "AMHRCAP_AB > 0"; name this selection "AMLinks";
3. Create a selection of nodes with "CENTROID > 0"; name this selection "Centroids";
4. Create a network file with the following settings: (see Exhibit 4-9):
   a. Create links from: AMLinks
   b. Read length from: MODEL_LENGTH
   c. Other Link fields : AMCAP_AB/BA, AMSatFlow_AB/BA, SPar_AB/BA, UPar_AB/BA, Unsig_MinDelay, A_PK_Conical, VDF_Shift, MODEL_LENGTH, OPERCOSTAMDA_AB/BA, OPERCOSTAM_AB/BA, PKFRTIME_AB/BA

d. Check “Drop Duplicate Links” option; and
e. Save this network as AM.NET.

5. Open the network setting dialog box, under the Centroids section in the General tab, choose the “Create from selection set” radio button and select the “Centroids” selection set (see Exhibit 4-10).
6. Click OK.

<u>Exhibit 4-9: Create AM Network File</u>

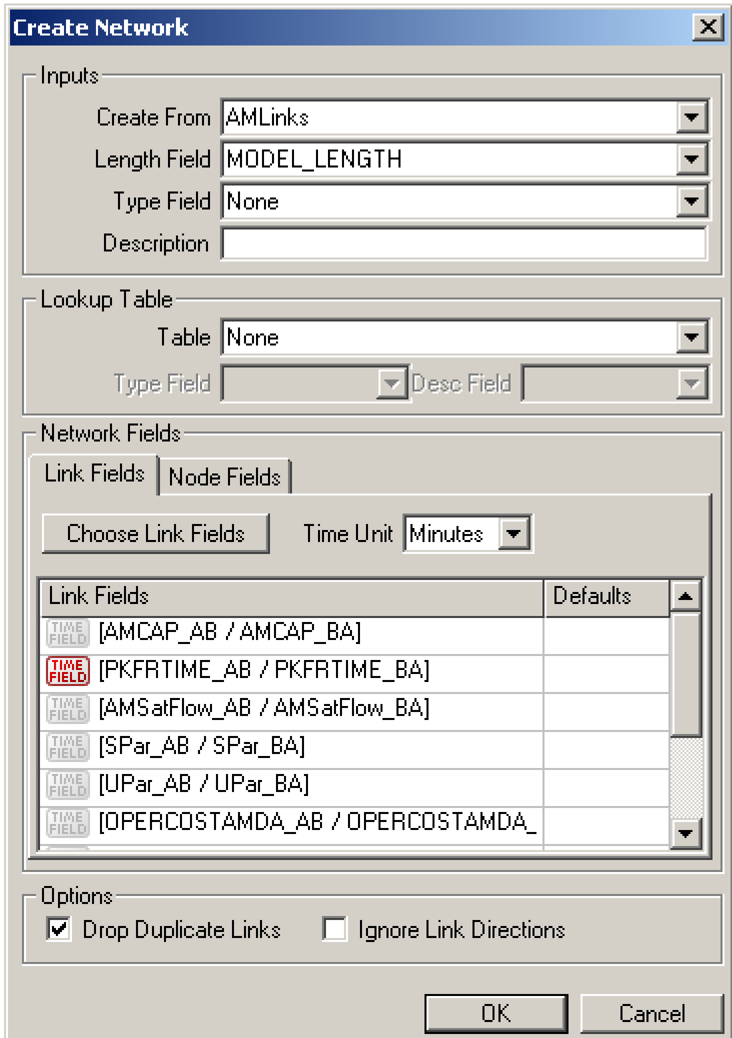
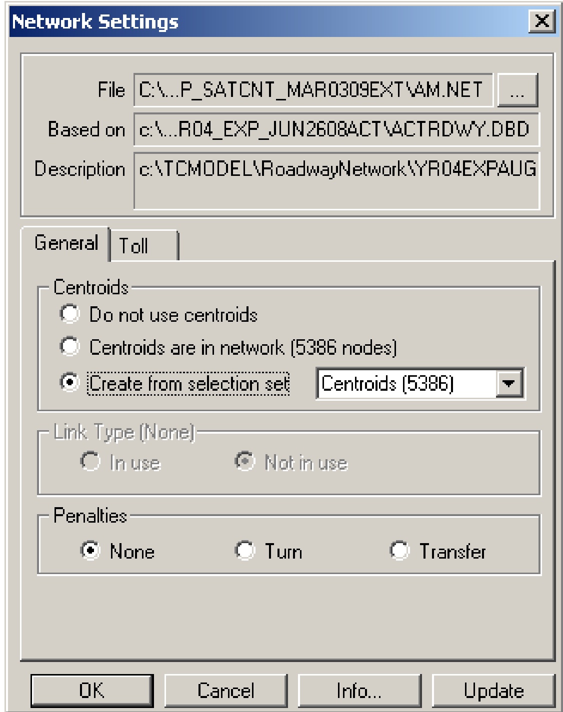


Exhibit 4-10: Network General Settings for AM Network File



After creating the network for the a.m. peak period and defining network settings, run the multi-modal multi-class assignment using the following steps:

1. Load the ACTRDWY.DBD file;
2. Load the AM.NET file;
3. Load the AM.MTX file (contains AM vehicle trip tables for four classes);
4. Create a selection of links with “AMHRCAP_AB > 0”; name this selection “AMLinks”;
5. Create a selection of links with “AMHRCAP_AB > 0 and FUNCL = 8 and TOLLROAD <> 3”; name this selection “ExclusionSetDA”;
6. Create a selection of links with “AMHRCAP_AB > 0 and FUNCL = 8”; name this selection “ExclusionSetSRNOHOV”;
7. If the “exc_truck” field exists in the link layer, create a selection of links with “AMHRCAP_AB > 0 and (FUNCL = 8 or exc_truck = 1)”. If the “exc_truck” field does not exist, create a selection of links with “AMHRCAP_AB > 0 and FUNCL = 8”; name this selection “ExclusionSetTruck”;
8. Bring up the Multi-modal Multi-class Assignment dialog box and use the following settings (see Exhibits 4-11 and 4-12):
   a. Press the Network button to bring up the Network Settings Window.
      i. Under Toll tab, choose the Toll Links “In Selection Set” radio button, and select AMLinks (see Exhibit 4-13).
      ii. Press OK.
   b. Delay Function: NCTCOG_011409
   c. Method: User Equilibrium
   d. O-D Matrix: AM

Exhibit 4-11: Multi-Modal Multi-Class Assignment for AM Period (Top Part)

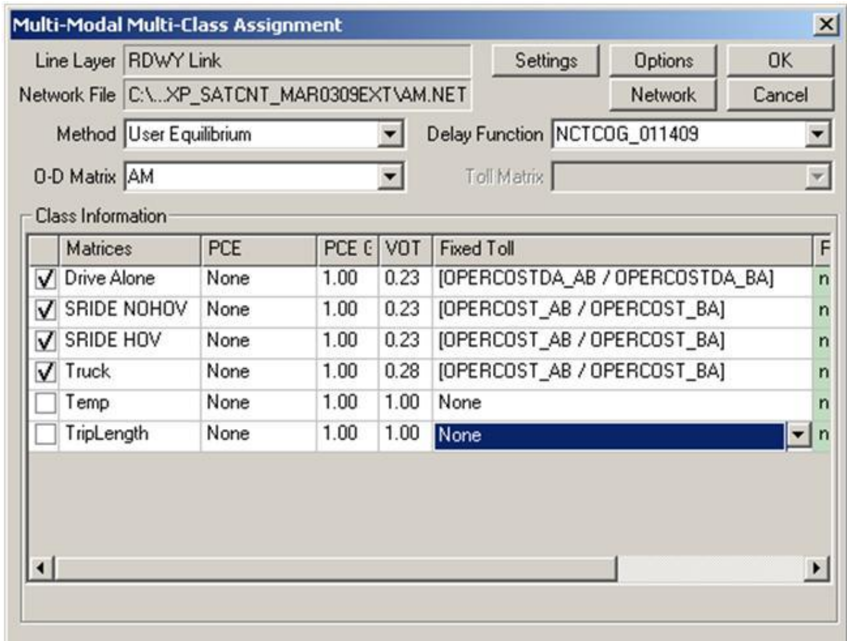


Exhibit 4-12: Multi-Modal Multi-Class Assignment for AM Period (Bottom Part)

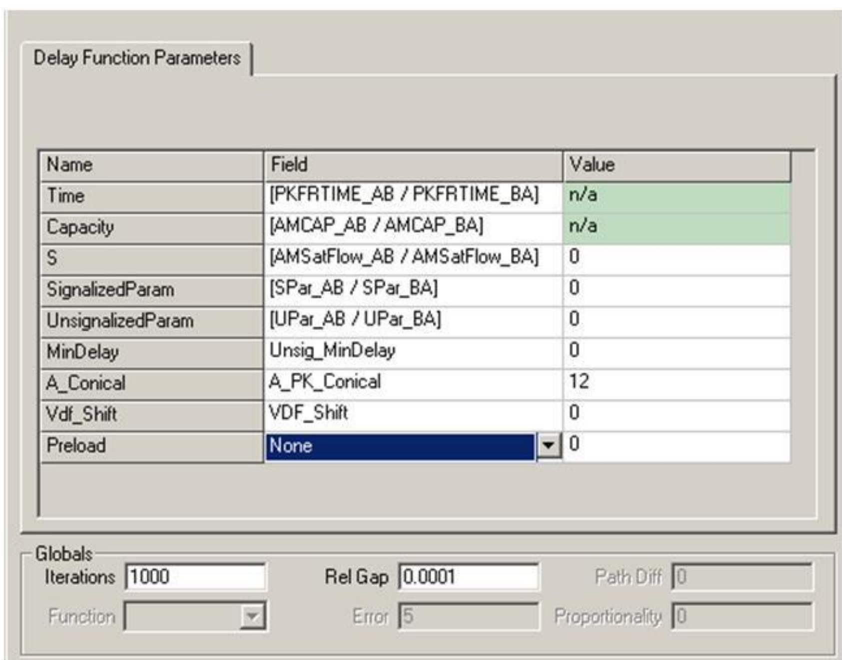
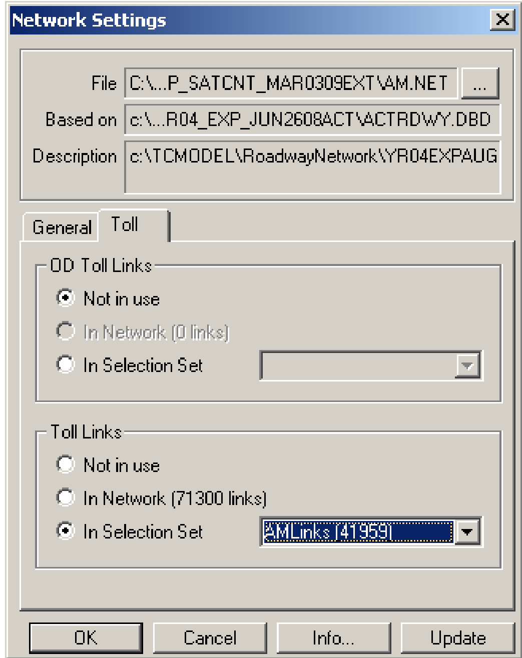


Exhibit 4-13: Network Settings for AM Network File for Toll Links



e. Use the table in Exhibit 4-14 for vehicle class information.

Exhibit 4-14: Vehicle Class Settings for AM Assignment

Matrices	PCE	VOT	Fixed Toll	Exclusion Set
Drive Alone	1.0	0.233	OPERCOSTDA_*	ExclusionSetDA
ShareRide NO HOV	1.0	0.233	OPERCOST_*	ExclusionSetSRNOHOV
ShareRide HOV	1.0	0.233	OPERCOST_*	-
Truck	1.0	0.283	OPERCOST_*	ExclusionSetTruck

f. Use the entries in Exhibit 4-15 to define the volume-delay function parameters.
g. Set the number of iterations to 1000 and the relative gap to 0.0001.
h. Press OK, and specify the output file locations.

Model Outputs

Similar steps, with adjustments according to time periods, are taken for running Off-Peak and PM traffic assignments. The VDF variables for all the time periods are shown in Exhibit 4-15. After the traffic assignment is done for each time period, estimated volumes for each class are stored in the output files.

In DFX the total traffic volume for each time period is calculated and stored in the roadway network file. If a feedback run is still needed for a model run, estimated link travel times are used for skim matrices. Total link volumes and average travel times and speeds are stored in the fields listed below:

- AMVOL_AB/BA: Total link volume in the AM peak period.
- PMVOL_AB/BA: Total link volume in the PM peak period.
- OPVOL_AB/BA: Total link volume in the OP period.
- PKTIME_AB/BA: Average loaded link travel time in the AM peak period.
- PMTIME_AB/BA: Average loaded link travel time in the PM peak period.
- OPTIME_AB/BA: Average loaded link travel time in the OP period.
- PKSPD_AB/BA: Average loaded link speed in the AM peak period.
- PMSPD_AB/BA: Average loaded link speed in the PM peak period.
- OPSPD_AB/BA: Average loaded link speed in the OP period.

Exhibit 4-15: VDF Settings in Different Analysis Time Periods

Field Name	**AM**	**PM**	**OP**
Time	PKFRTIME_AB/PKFRTIME_BA	PMFRTIME_AB/PMFRTIME_BA	OPFRTIME_AB/OPFRTIME_BA
Capacity	AMCAP_AB/AMCAP_BA	PMCAP_AB/PMCAP_BA	OPCAP_AB/OPCAP_BA
S	AMSatFlow_AB/AMSatFlow_BA	PMSatFlow_AB/PMSatFlow_BA	OPSatFlow_AB/OPSatFlow_BA
SignalizedParam	SPar_AB/SPar_BA	SPar_AB/SPar_BA	SPar_AB/SPar_BA
UnsignalizedParam	UPar_AB/UPar_BA	UPar_AB/UPar_BA	UPar_AB/UPar_BA
MinDelay	Unsig_MinDelay	Unsig_MinDelay	Unsig_MinDelay
A_Conical	A_PK_Conical	A_PK_Conical	A_OP_Conical
Vdf_Shift	VDFShift	VDFShift	VDFShift
Preload	None	None	None

Chapter
5

Feedback and Time-of-Day Distribution

The Feedback process exists to achieve internal consistency in the model. During this process, the travel time skims are transferred from the traffic assignment step back to trip distribution. This chapter describes the Feedback process.

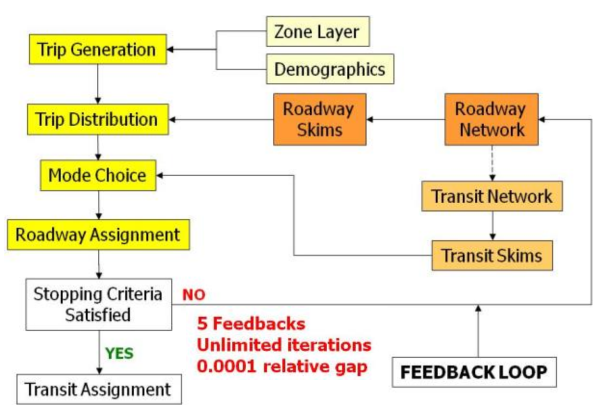
Feedback

The Feedback procedure involves feeding the travel time after assignment back into the trip distribution process to assure travel time consistency. In a well-defined feedback process, the values of the input variables and output variables should converge. The selection of appropriate convergence criteria is necessary to inform modelers when the iterative application of the feedback loop can be ended and the final assignment result can be used. The two most important variables for determining if equilibrium is achieved in the feedback process are volumes on links and average operating speeds on links. Because of the way in which speeds are estimated in traditional travel forecasting models, volume and speed are directly related through a functional relationship, so convergence with respect to volume implies convergence with respect to speed. The flow chart of the 4-step travel modeling at NCTCOG is shown in Exhibit 5-1.

The current DFX model setup incorporates five feedbacks loops. The travel time skims are fed back in to the trip distribution and the three steps of trip distribution, mode choice, and traffic assignment are repeated in each feedback loop. Unfortunately, there is no mathematical guarantee that the feedback process for the model from trip distribution to traffic assignment will converge.

Five feedback was chosen based on the tests that were performed which indicated it will result in reasonably stable link volumes in a reasonable amount of time, taking in to account the computing hardware that was available at the time of the tests (dual quad-core Intel Xeon, 4GB RAM, Windows XP-32 bit, TransCAD 5.0 build 1730).

Exhibit 5-1: Feedback Process Flow Chart



Time of Day Distribution

The DFX uses an observed time-of-day distribution for a.m. peak (AM), p.m. peak (PM), and off-peak volumes. The model uses AM and OP time in each feedback for trip distribution and mode choice; as a result, they need to be updated at the end of each feedback.

The time of day distribution for AM, PM, and off-peak is shown in fractions in Exhibits 5-2 through 5-4, respectively. The AM, PM, and off-peak periods are broken down into half-hour periods. Half-hour periods are used because there are two cases where an hour is split over different peak periods. The 6:00 – 6:30 a.m. period is off-peak, but 6:30 – 7:00 a.m. period is part of the a.m. peak period. The 6:00 – 6:30 p.m. period is part of the p.m. peak period, and the 6:30 – 7:00 p.m. period is off-peak. Note that the volume factors do not change based on the forecast year.

Exhibit 5-2: AM Fractions

Time Interval	AM Fraction
6:30-7:00	0.176
7:00–7:30	0.222
7:00-8:00	0.222
8:00–8:30	0.190
8:30-9:00	0.190
Total	**1.000**

Exhibit 5-3: PM Fractions

Time Interval	PM Fraction
15:00-15:30	0.131
15:30-16:00	0.131
16:00-16:30	0.150
16:30-17:00	0.150
17:00-17:30	0.155
17:30-18:00	0.155
18:00-18:30	0.128
Total	**1.000**

Exhibit 5-4: OP Fractions

Time Interval	OP Fraction
18:30-19:00	0.053
19:00-19:30	0.040
19:00-20:00	0.040
20:00-20:30	0.031
20:30-21:00	0.031
21:00-21:30	0.026
21:30-22:00	0.026
22:00-22:30	0.021
22:30-23:00	0.021
23:00-23:30	0.015
23:30-0:00	0.015
0:00-0:30	0.009
0:30-1:00	0.009
1:00-1:30	0.006
1:30-2:00	0.006
2:00-2:30	0.005
2:30-3:00	0.005
3:00-3:30	0.005
3:30-4:00	0.005
4:00-4:30	0.007
4:30-5:00	0.007
5:00-5:30	0.023
5:30-6:00	0.023
6:00-6:30	0.051
9:00-9:30	0.043
9:30-10:00	0.043
10:00-10:30	0.040
10:30-11:00	0.040
11:00-11:30	0.042
11:30-12:00	0.042
12:00-12:30	0.043
12:30-13:00	0.043
13:00-13:30	0.044
13:30-14:00	0.044
14:00-14:30	0.048
14:30-15:00	0.048
Total	**1.000**