This chapter focuses on the Roadway Traffic Assignment module of the Dallas-Fort Worth Regional Travel Model (DFWRTM). Based on the input vehicle trip tables, roadway link attributes, and link performance functions, the traffic assignment output contains the roadway link flows. Commonly referred to as link traffic volumes, the link flows are estimates of the number of vehicles on each link. Each vehicle trip table introduces a different vehicle class in the assignment process. The traffic assignment procedure estimates the link volume (by vehicle class) for non-fixed-route vehicle types that choose their paths. In other words, fixed-route vehicles, such as transit buses, are not directly considered in this procedure. The interaction between roadway and transit travel times is explained in the transit assignment chapter.

The following is the description of the overall design of the traffic assignment process, including the inputs created in previous stages of the DFWRTM. After model time periods and vehicle classes are introduced, a brief discussion about selection of the user equilibrium (UE) method for traffic assignment is provided. The link volume-delay performance functions, value of time assumptions, and generalized cost procedures are also explained. The chapter ends with documentation of the traffic assignment implementation within the TransCAD environment.

Overall Design

“Traffic Assignment” consists of a set of procedures after the “Time of Day” module and before either the “Update Time” or “Transit Assignment” modules (depending on whether feedback to trip distribution is performed). Figure 1 shows the position of traffic assignment in the full model run flow chart.

The objective of a Base Year traffic assignment validation is to load the origin-destination (OD) vehicle trip demand tables onto the roadway network in such a way that the resulting traffic volumes on the roadways provide a realistic estimate of actual traffic counts. Since drivers’ travel behavior and/or roadway system conditions may change depending on the time of day of travel and the type of user, there needs to be a breakdown of trips into time of day and vehicle classes.
Time Periods

A time-of-day (TOD) breakdown of weekday vehicle trips is important because roadway flows vary significantly for different hours of the day. The application of TOD traffic assignments results in more realistic estimates of both volumes and speeds by time period. Such detailed information is used for many transportation studies, including an air quality conformity analysis that requires TOD link speed and vehicle classification volumes. Three time periods are used for preparation of three TOD vehicle trip tables that are then used for three separate traffic assignments:

- **AM**: Morning peak period, 6:30 AM to 8:59 AM (2.5 hours)
- **PM**: Evening peak period, 3:00 PM to 6:29 PM (3.5 hours)
- **OP**: Off-peak times, 9:00 AM – 2:59 PM and 6:30 PM – 6:29 AM (18 hours)
Vehicle Classes
The roadway network consists of some facilities that are not used by all drivers, e.g., a typical HOV lane is open only to a specific group of vehicles. In some cases (such as an Air Quality analysis), the model user needs statistics for specific groups of vehicles such as trucks. To address roadway network restrictions for different vehicle groups and output requirements of the model, four classes of vehicles in the traffic assignment are used. The vehicle classes and their corresponding roadway network are:

- **DA**: the “drive alone” vehicles with only a driver in them, can use all links except rail and regular HOV links
- **SRHOV**: the “shared-ride” vehicles with more than one person in them, can use all links except rail links
- **SRNOHOV**: the “shared-ride” vehicles with more than one person in them, can use all links except rail and HOV links [Note: the factors used to distribute SR vehicles into HOV and NOHOV groups was established from a model calibration exercise]
- **TRUCK**: commercial vehicles with six or more tires, can use all links except rail and HOV links (or other links specifically identified by the model users)

Assignment Method
Different algorithms can be used to estimate link traffic volumes. The User Equilibrium (UE) generalized cost method is adopted for the DFWRTM for three reasons:

- The UE method represents standard good modeling practice in the United States
- Paths are based on roadway operating costs, toll costs, and travel times
- The congested travel times are sensitive to the capacity and volume of a roadway

The behavioral assumption of the UE method is that each vehicle travels on the zone-to-zone path that minimizes that vehicle’s generalized cost of travel. This choice rule implies that, at equilibrium, the link flow pattern is such that the travel times on all used paths connecting any given Origin-Destination pair will be equal; the travel time on all of these used paths will also be less than or equal to travel time on any of the unused paths. At this point, the network is in user equilibrium. This method is formulated as an optimization program, which converges toward the equilibrium condition through iterative adjustment of link volumes for each vehicle class. UE provides a stable and consistent method for traffic assignment.
The Incremental Assignment method was used in the previous Dallas Fort-Worth regional travel model, in which a fixed portion of the trip table is loaded onto the network at each iteration. The link travel times are then updated and an additional portion of the trip table is then loaded onto the network. The result of an incremental assignment may resemble an equilibrium assignment when many increments are used, but an incremental assignment can never guarantee a true UE solution.

The selected method of assignment, user equilibrium with generalized cost, requires performance function for each link to estimate link travel time, cost value for each link, and value of time for each vehicle class to convert time to cost and calculate generalized cost.

**Volume Delay Functions**

Since roadway facilities have limited capacities for carrying traffic, the purpose of the traffic assignment volume-delay function is to calculate a link travel time for the “next UE assignment iteration” that takes into account the link’s capacity and previous iteration volume. As the number of vehicles using a facility increases, the interaction of vehicles decreases the performance (speed) of that facility. The volume-delay or “performance” function calculates a congested travel time that reflects the uncongested “free” speed travel time and the delay time in terms of volume over capacity (vol/cap) ratio of the roadway link.

In theory, the assigned link volume should never exceed the available link capacity, so the link travel time calculated for a case where the volume exceeds the capacity should be infinite. Nonetheless, traffic assignment models are used for general planning rather than detailed vehicle operations studies, so the typical volume-delay function used in most regional models allows for the assigned volume to exceed the capacity. The DFWRTM volume-delay function is similar in form to the BPR-type functions used in other regional models, in that link speed decreases as the vol/cap ratio increases. However, NCTCOG’s equation includes a “maximum minutes of delay per mile” assumption that effectively limits the drop in link speed that can occur, as the vol/cap ratio increases. The general form of NCTCOG’s volume-delay function is as follows:

\[
\text{TravelTime} = \text{FreeFlowTime} + (\text{Length}) \min\{Ae^{B\left(\frac{\text{vol}}{\text{cap}}\right)}, C\}
\]
Values for A, B, and C for Freeway and non-Freeway links are shown in Table 1. Figure 2 shows the relation between speed and vol/cap ratio for Freeway and Arterial links assumed in the traffic assignment.

### Table 1: Delay function parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Freeway</th>
<th>Arterial</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.015</td>
<td>0.05</td>
</tr>
<tr>
<td>B</td>
<td>6.0</td>
<td>3.90</td>
</tr>
<tr>
<td>C</td>
<td>4.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

![Delay Functions Graph](image)

**Figure 2: Speed versus volume / capacity ratio for roadway links**

Values for capacities and times are stored in the network file under the following fields:

- AMCAP_*: Capacity for AM period
- PMCAP_*: Capacity for PM period
- OPCAP_*: Capacity for OP period
- PKFRTIME_*: Free flow time for AM and PM periods
- OPFRTIME_*: Free flow time for OP period
Roadway Link Toll and Cost

Two types of costs are assigned for each roadway link: Vehicle operation-related costs and roadway tolls. While vehicle operating costs can include both long-term costs (insurance, car payments, repairs, etc.) and short-term “out of pocket” costs (primarily the fuel cost), the NCTCOG strategy is to consider only short-term costs as an influence on choosing a path in the assignment module. The auto operating cost is assumed to be 7.3 cents per mile, expressed in constant 1999 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. In other cases, the toll per mile can be entered for a roadway link and subsequently calculated internally as a link toll. In both cases, the link tolls are adjusted to constant 1999 dollars. Toll adjustment factors are shown in Figure 3. Managed lane facilities (HOV lanes that can be used by the Drive Alone class by paying a toll but free for Share Ride classes), have a higher cost for DA class, which is reflected in the roadway network file in a different field.

Based on these two cost values, the direct dollar cost of traveling through each link is calculated as:

$$\text{AdjustedToll} = \left[ \text{FixedToll} + (\text{TollMile})(\text{Length}) \right] \times \text{AdjustmentFactor}_{yr}$$

$$\text{OperatingCost} = (\text{Length})(\text{CostMile}) + \text{AdjustedToll}$$

$\text{AdjustmentFactor}_{yr}$: Adjustment factor for tolls to convert the toll values for the year yr to 1999 Dollar

$\text{CostMile}$: Operating cost per mile for all links, constant 0.073 Dollar/Mile

Cost values for links are stored in the following fields in the network file:

- TOLL_*: Value of fixed toll at Toll booth in Cents
- TOLLMILE: Value of toll per mile in cents
- OPERCOST_*: Adjusted dollar value for passing through a link for non-Drive Alone classes in Dollar
- OPERCOSTDA_*: Adjusted dollar value for passing through a link for Drive Alone class in Dollar
- TOLLROAD: Code fields used for managed lane facilities, value 3 means manages lane
Toll Adjustment Factor

![Toll Adjustment Factor graph](graph.png)

**Figure 3: Toll Adjustment Factor based-on 1999 Dollar**

**Generalized Cost and Value of Time**

For UE optimization, each link’s generalized cost is composed of travel time, an auto operating cost (7.3 cents per mile in 1999 constant dollars), and the toll cost (expressed in 1999 constant dollars). Since the generalized cost for a specific link must be expressed as a single value, the travel time on each link needs to be converted to a 1999 constant dollar amount by means of a value of time (VOT) assumption. Calculation of the correct or “most appropriate” VOT for use with traffic assignments is often a difficult undertaking because there are many factors that may influence an individual person’s VOT (e.g., trip purpose and the socio-economic characteristics of the traveler). The VOTs used in the DFWRTM traffic assignment are based on a 1999 Base Year model calibration process that resulted in a good match between the modeled and observed toll road volumes. The resulting VOTs were as follows:
$10 / hour ($0.167 / minute) for each of the three auto-based vehicle classes (DA, SRHOV, and SRNOHOV)

$12/ hour ($0.2 / minute) for the truck class

The total cost of traveling though a roadway link is calculated as:

\[
GeneralizedCost = OperatingCost + (VOT)(TravelTime)
\]

Generalized cost is used in UE assignment module.

Implementation of Roadway Traffic Assignment in TransCAD

As noted previously, the DFWRTM consists of AM Peak, PM Peak, and Off-peak traffic assignment runs. For each assignment there are two key steps: first a TransCAD network file is created, and then, the TransCAD UE “multi-modal multi-class” assignment is run.

For the AM peak time period, the following steps are taken to create the AM network:

1. Load ACTRDWY.DBD file (the roadway link geographic file)
2. Create a selection of links with AMHRCAP_AB > 0, call this selection “AMLinks”
3. Create a selection of nodes with CENTROID > 0, call this selection “Centroids”
4. Create a network file with these settings:
   a. Create links from: AMLinks
   b. Read length from: MODEL_LENGTH
   c. Other Link fields: A_PK, B_PK, C_PK, MODEL_LENGTH, AMCAP_*, OPERCOSTDA_*, OPERCOST_*, PKFRTIME_*
   d. Check “drop duplicate link” option
   e. Save this network as AM.NET
5. Open the network setting dialog box, under Centroid section, choose “Create from selection set” radio button and select “Centroids” selection set.
6. Click OK.

The network file is created and Centroids are identified in it. Screen shots for the creation of AM network file and its setting are shown below:
For the AM peak time period, the following steps are taken to run the AM peak assignment:

Traffic Assignment 9 NCTCOG Regional Model
1. Load ACTRDWY.DBD file
2. Load AM.NET file
3. Load AM.MTX file (contains AM vehicle trip tables for four classes)
4. Create a selection of links with AMHRCAP_AB > 0, call this selection “AMLinks”
5. Create a selection of links with AMHRCAP_AB > 0 and FUNCL = 8 and TOLLROAD <> 3, call this selection “ExclusionSetDA”
6. Create a selection of links with AMHRCAP_AB > 0 and FUNCL = 8, call this selection “ExclusionSetSRNOHOV”
7. If “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 “exc_truck” field does not exist, create a selection of links with AMHRCAP_AB > 0 and FUNCL = 8. Call this selection “ExclusionSetTruck”
8. Bring up Multi-modal Multi-class Assignment dialog box and use the following setting:
   a. Press Network button, under Toll tab, choose Toll Links in selection set radio button and select AMLinks
   b. Delay Function: NCTCOG
   c. Method: User Equilibrium
   d. O-D Matrix: AM
   e. Class information, use following table

<table>
<thead>
<tr>
<th>Matrices</th>
<th>PCE</th>
<th>VOT</th>
<th>Fixed Toll</th>
<th>Road Toll</th>
<th>Exclusion Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Alone</td>
<td>1.0</td>
<td>0.167</td>
<td>OPERCOSTDA_*</td>
<td>-</td>
<td>ExclusionSetDA</td>
</tr>
<tr>
<td>SRIDE NOHOV</td>
<td>1.0</td>
<td>0.167</td>
<td>OPERCOST_*</td>
<td>-</td>
<td>ExclusionSetSRNOHOV</td>
</tr>
<tr>
<td>SRIDE HOV</td>
<td>1.0</td>
<td>0.167</td>
<td>OPERCOST_*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Truck</td>
<td>1.0</td>
<td>0.2</td>
<td>OPERCOST_*</td>
<td>-</td>
<td>ExclusionSetTruck</td>
</tr>
</tbody>
</table>

   f. Delay Function Parameters, use following table

<table>
<thead>
<tr>
<th>Name</th>
<th>Field</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>PKFRTIME_*</td>
<td>N/A</td>
</tr>
<tr>
<td>Capacity</td>
<td>AMCAP_*</td>
<td>N/A</td>
</tr>
<tr>
<td>Length</td>
<td>MODEL_LENGTH</td>
<td>N/A</td>
</tr>
<tr>
<td>A</td>
<td>A_PK</td>
<td>0.015</td>
</tr>
<tr>
<td>B</td>
<td>B_PK</td>
<td>6.2</td>
</tr>
<tr>
<td>C</td>
<td>C_PK</td>
<td>60</td>
</tr>
<tr>
<td>Preload</td>
<td>None</td>
<td>N/A</td>
</tr>
</tbody>
</table>

   g. Press Option button, under other options, check class flows
   h. Use 30 for number of iterations and 0.00 for convergence value
i. Press OK, and specify the output file locations

Traffic assignment may take 3 hours to run for AM period. Screen shots of TransCAD dialog boxes for traffic assignment are shown in Figure 5 and 6.

Similar steps, with adjustment related to time periods, are taken for running OP and PM traffic assignments. After the traffic assignment is done for each time period, estimated volumes for each class are stored in the output files. Total traffic volume for each time period is calculated and stored in the roadway network file. Also, the volumes are used in a post-processed procedure for link travel time estimation, which are also stored in the roadway network file. If a feedback run is needed for a model run, new link estimated times are used for skim matrices. Total volumes and times are stored in the following fields:

- AMVOL_*: Total link volume for AM period
- PMVOL_*: Total link volume for PM period
- OPVOL_*: Total link volume for OP period
- PKTIME_*: Loaded link travel time in AM period
- PMTIME_*: Loaded link travel time in PM period
- OPTIME_*: Loaded link travel time in OP period
Figure 6: Screen shot for changing the setting of AM network file for Toll links

Figure 7: Screen shot for reporting assigned vehicle classes in the output file
Figure 8: Screen shot for MMA setting for AM assignment