Socioeconomic Data, TAZ 4

To aid the planning process, RVARC staff compiles transportation planning data under the direction of RVAMPO. Transportation planning data for the Roanoke Metropolitan Planning Area is a special tabulation of socioeconomic information intended to aid transportation planners in designing responsive and needed transportation services and facilities in their communities. Transportation planners and design agencies use this data in a three-step Unified Transportation Planning process to assess the impact of changes in the transportation system on present demand. This process is important to Roanoke Valley's development and evaluation of urban transportation plans and policies.

The transportation planning data serves many other related transportation and regional planning purposes. The data provides dependable background information for large sub-area studies, public transportation and facilities plans, transportation demand analysis, and land use and rezoning studies. Historical comparisons of the Transportation Planning Data provide an indicator of the ongoing health of the region's socioeconomic assets.

Transportation planning data for prior years is known as the Data Maintenance Report (DMR) for the Roanoke Urban Study Area. Methodologies for the preparation of the DMR were published in fiscal years 1972, 1977, and 1998. It appears that previous DMRs were timed to coincide with the publication of the 1970 and 1980 census figures for the region. The availability of the Census data greatly simplifies the data collection process and provides the most reliable source of data for modeling the Roanoke urban area transportation system.

Transportation Planning Data

Census Transportation Planning Package

Base data is obtained from the US Census Bureau's Census Transportation Planning Package (CTPP). Historically, this product is released four to six years after each decennial census. For example, the 1990 CTPP was released in 1996, and the 2000 CTPP was released in 2003-2004. The CTPP is a special set of tabulations designed primarily for transportation planners, policy analysts, and engineers. It is developed by the Bureau of the Census using decennial census data and provides detailed population, housing, worker, and commuter characteristics for a number of geographic levels. The CTPP data is compiled by place of work and by place of residence.

The urban element of the CTPP contains selected information at the Traffic Analysis Zone (TAZ) level and is designed specifically to assist MPOs in carrying out their planning responsibilities. In 1999, commission staff participated in the US Census Bureau's "TAZ-Up" program to better define TAZ boundaries based on Census block boundaries. The 2000 and later TAZ boundaries and data should fix many errors that existed in prior data sets.

Traffic Analysis Zones (TAZ)

As previously mentioned, information collected for the Transportation Planning Data is published at the Traffic Analysis Zone (TAZ) level. TAZs are geographic units representing sizable portions of the region which impact, or in some cases are predicted to impact, the transportation and transit networks. For this reason, TAZs in more heavily developed areas and rapid growth areas tend to be smaller than those in outlying zones. Ideally, TAZs have distinct geographic boundaries with relatively few access points to the region's overall transportation network. Ideal boundaries often include limited access highways, railroad lines, water boundaries, and ridgelines. Because the impact of different types of trips (e.g. home to work, home to shopping, etc.) may be assessed, TAZs should be of fairly homogeneous land use. Of course, no urban area follows this ideal criteria. Therefore, a good deal of judgment is involved in determining appropriate TAZ boundaries. Two principles should be observed in delineated TAZ boundaries. First, TAZ boundaries should coincide with jurisdictional boundaries. Second, in order to compare previously developed Transportation Planning Data, adjusting TAZ boundaries should be avoided, if possible. This does not preclude the subdivision of existing zones, a natural process of individual zone urbanization.

The US Census Bureau defines a TAZ the following way:

"A traffic analysis zone (TAZ) is a special area delineated by state and/or local transportation officials for tabulating traffic-related data- especially journey-to-work and place-of-work statistics. A TAZ usually consists of one or more census blocks, block groups, or census tracts."

2035 Boundary Adjustments

The MPO study area boundary was reviewed as part of the 2035 projections. The boundary has to include all areas that were urbanized in the 2000 Census and should include areas that are expected to be urbanized (as defined by the US Census Bureau) within the projected time frame. Several areas in Bedford County previously not part of the MPO study area were added as a result.

Botetourt County provided input to remove TAZ 400 and a section of 411. These two areas were forested mountain areas that are not expected to be developed. A new TAZ (420) was added to Botetourt County. In Roanoke County, TAZ 368 was rolled into TAZ 367 and a new TAZ 368 was created. TAZs 379, 371, 372, and 373 were also added to Roanoke County. The boundary of 366 was adjusted. TAZ 2 in downtown Roanoke was split into TAZ 2 and TAZ 46 (the number 46 was not used in the 2000 Census.) TAZs for Bedford County were 500-506. TAZ 506 is small, but had to be added to include a 2000 urbanized area in Bedford County.

The resulting map is at the end of this chapter.

Methodology for 2000 and 2005 Updates

Population

The population for each TAZ was calculated by aggregating the 2000 census block data for each TAZ. Estimates for 2005 were made by using both local government input and documented county and city growth rates.

Employment

Employment data from the 2000 CTPP was used for most localities. Employment data from the US Census for Botetourt and Bedford counties did not seem accurate, so previous estimates were used. (Please refer to the 2025 Long-Range Plan-Technical Document chapter 2 for more information.) Employment data for 2005 was estimated using employment data obtained from the Virginia Employment Commission (VEC). Each locality was given the option to review the data and provide input on the increase or decrease of small businesses by TAZ.

Methodology for 2035 Projections

Population

The Virginia Employment Commission has projected population for each county to 2030. MPO staff created a linear regression that took population estimates for 2000-2030, in five-year increments, and projected them another five years to 2035. The resulting locality-wide growth rates were applied to each TAZ. Each locality reviewed the data and made changes to account for projected high and low growth areas. Overall growth rates and totals by locality can be seen in the figures on the following page.

Employment

The Virginia Employment Commission has projected employment by locality to 2012. Using the growth rate from 2000-2012, in tandem with population growth rates, the employment for each TAZ was estimated. Each locality reviewed and adjusted the individual numbers as necessary. Estimated employment growth rates and overall totals by locality can be seen in the figures on the following page.

Locality*	2000-2035 Population Growth	2000-2035 Employment Growth
Roanoke city	1.6%	13.0%
Salem City	7.5%	9.2%
Town of Vinton	5.2%	5.0%
Roanoke County*	18.4%	27.8%
Botetourt County*	60.0%	80.0%
Bedford County*	60.0%	50.0%

*Portions in MPO only.
Roanoke County data does not include Town of Vinton

Locality*	2000 US Census Population	2000 Employment Estimates**	2005 Population Estimate	2005 Employment Estimate	2035 Population Estimate	2035 Employment Estimate
Roanoke city	94911	74630	93586	70305	96432	84330
Salem City	24747	23740	25143	21841	26603	25922
Town of Vinton	7782	3547	7931	3582	8183	3724
Roanoke County*	73089	27644	76743	27920	86537	35317
Botetourt County*	15771	5213	17348	5213	25234	9383
Bedford County*	2822	197	2991	197	4515	296

*Portions in MPO only. Roanoke County data does not include Town of Vinton
Estimates made by the Roanoke Valley-Alleghany Regional Commission, 2006

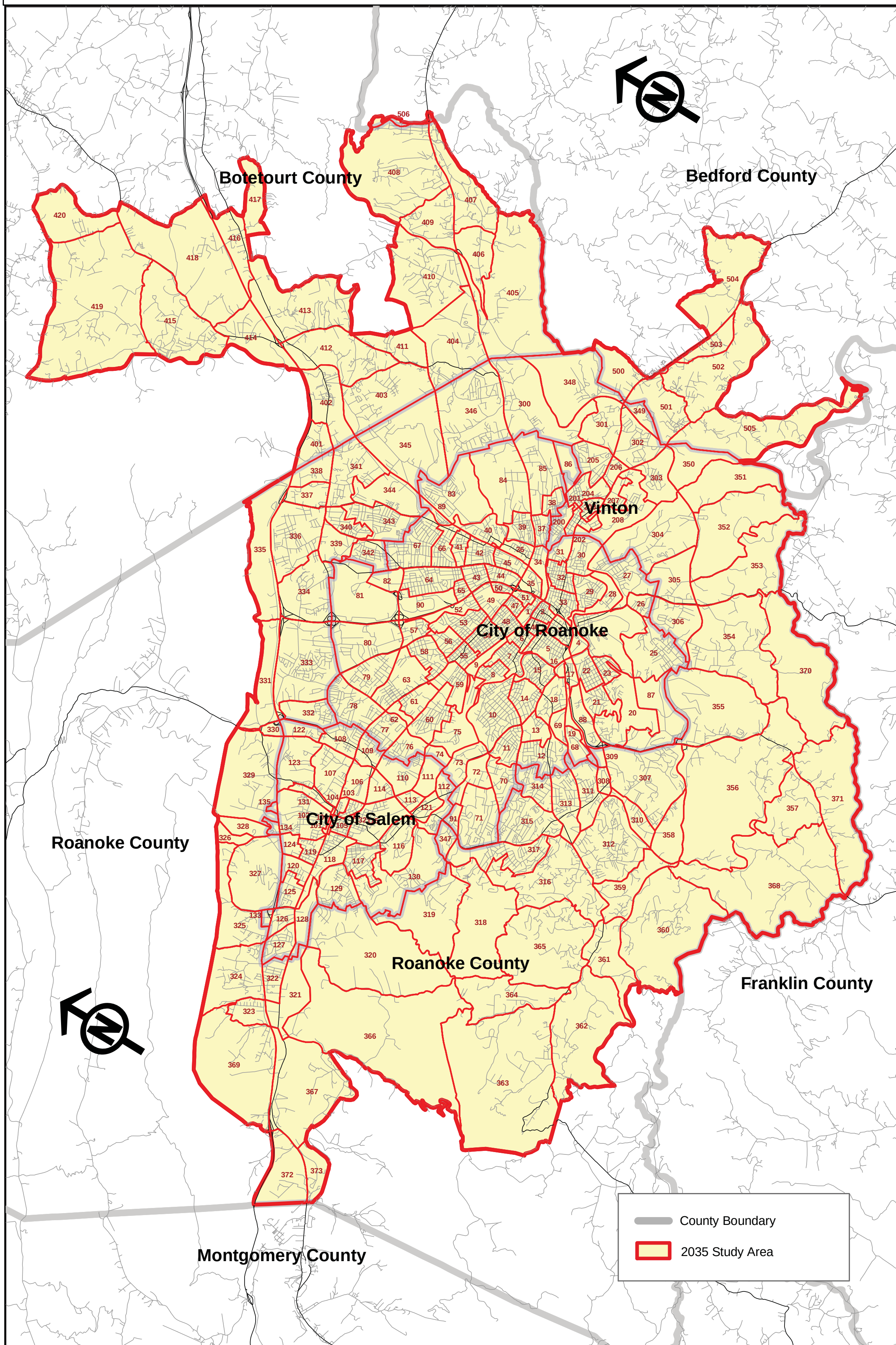
Locality and Public Input

Each locality was given several opportunities to review proposed boundary changes and projected TAZ data. Input was received from most member localities. A public information meeting was advertised and held in July 2006 to solicit public comment on the boundary and TAZ data, but the public meeting did not have any attendees.

TAZ Detailed Data (Appendix A)

The tables in Appendix A contain population and employment data for each TAZ in the 2035 study area. Refer to the map on the following page for TAZ locations. In general, TAZ 1-91 are in the City of Roanoke, TAZ 100-135 are in the City of Salem, TAZ 200-208 are in the Town of Vinton, TAZ 300-369 are in Roanoke County, TAZ 400-420 are in Botetourt County, and TAZ 500-506 are in Bedford County.

Roanoke Valley Area MPO 2035 Study Area Boundary



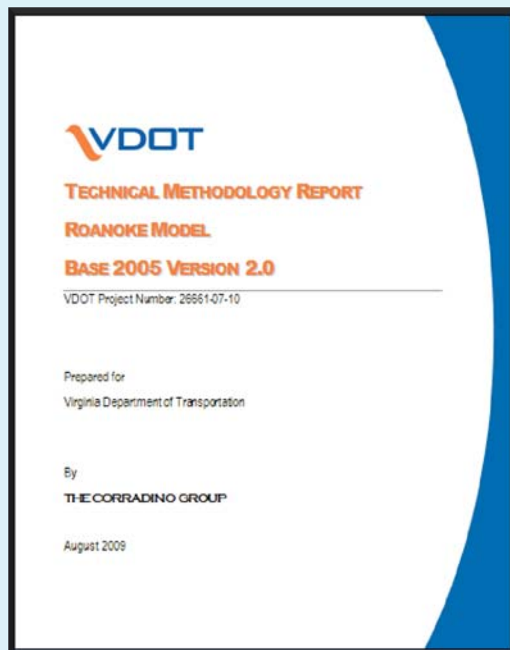
Travel Demand Model 5

This chapter contains technical information about the Travel Demand Model used to predict future travel demand using the transportation planning data featured in chapter 4. For readers who would like to skip the technical details, proceed to chapter 6.

To estimate travel demand, the RVAMPO Travel Demand Model follows a standard four-step process which includes trip generation, trip distribution, and highway assignment.

Trip generation determines the total number of trips produced and attracted each day for each trip purpose. Trip distribution finds the number of person trips that go between all pair of zones. Highway assignment determines which route highway and transit trips will follow.

Most of the information in this chapter is copied or adapted from the VDOT Technical Methodology Report written by The Corradino Group, a consulting group that is a national leader in transportation engineering.


VDOT

TECHNICAL METHODOLOGY REPORT

ROANOKE MODEL

BASE 2005 VERSION 2.0

VDOT Project Number: 26661-07-10

Prepared for

Virginia Department of Transportation

By

THE CORRADINO GROUP

August 2009

Overview of Model

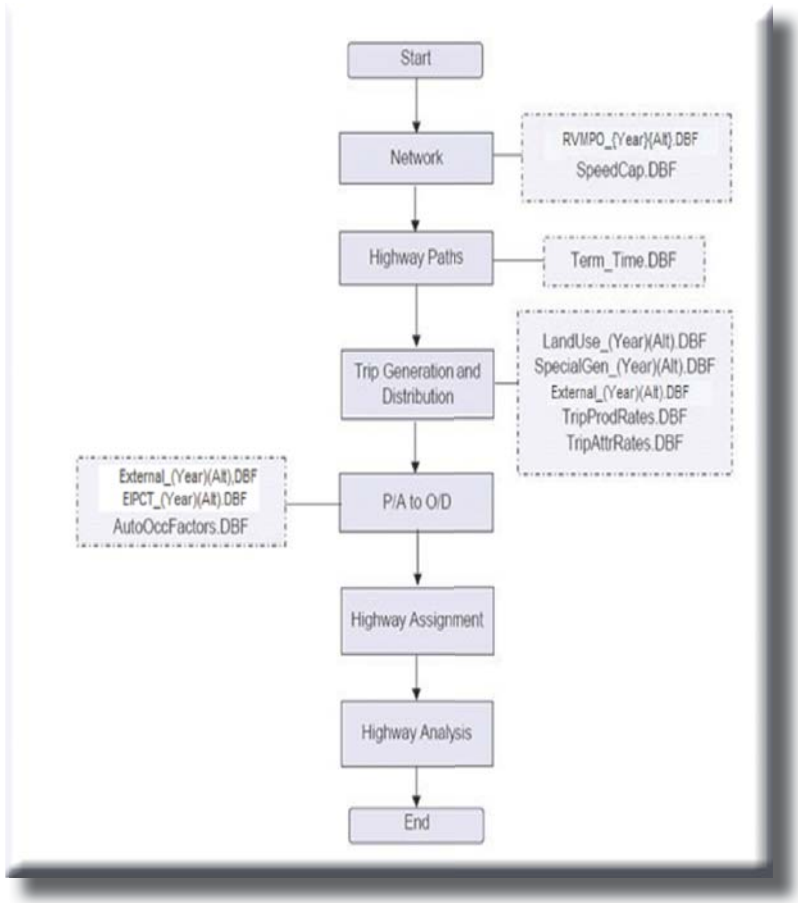
Introduction

The figure below shows the macro flow chart of the RVAMPO Travel Demand Model and identifies all the user-supplied input files that are used by each of the modules. It also shows all RVAMPO specific programs used in these modules.

The RVAMPO model quantifies the travel anticipated on the transportation system. The results are then used to estimate the impact of constructing new or improved highway and transit facilities and of implementing new transportation services or demand management activities.

The year-2000 RVAMPO Travel Demand Model was updated to a base year of 2005 for the Cube Voyager transportation forecasting platform. It had two main tasks: identifying and implementing short term improvements.

The 2005 RVAMPO Travel Demand Mode follows the guidelines as established in the Virginia Travel Demand Modeling Policies and Procedures Manual (PPM). However, guidelines regarding data storage formats and directory structure have not yet been specified in the PPM guidelines. VDOT and The Corradino Group staff jointly established standards for these missing guidelines, and these guidelines have been implemented in other VDOT models -- such as those in Fredericksburg and Hampton Roads -- as well as in the RVAMPO Travel Demand Model.



Full Model Macro Flow Chart

While the Fredericksburg Area MPO (FAMPO) model served as a basis for the RVAMPO model, the RVAMPO model includes several enhancements and new features.

Model Enhancement Summary

The following is a list of the key enhancements and new features of RVAMPO model:

- The speeds and capacities are now contained in an external file, which is read by the NETWORK and HIGHWAY step scripts.

- The trip generation program has been borrowed from the FAMPO model after customizing it for the Roanoke region. The new code does not include any hard-coded values for trip rates and other general parameters. All the system parameters are either accessed from Catalog Keys or from external files. The new program uses land use data from a Dbase file. The production and attraction rates are accessed from TripProdRates.DBF and TripAttrRates.DBF files, respectively.

- The trip generation program now includes special generator trips for all purposes. In the previous version, trip generation program could only handle HBW special generator trips. The special generator trips have been more extensively used in the Roanoke model.

- A new Fratar model was developed for creating the analysis year external-external trip table. This is done by developing traffic estimates for external stations for future years. The base year trip table resides in the “Calibration Constants” folder, while the external traffic count file, (External_(Year)(Alternative).DBF, is a scenario specific file.

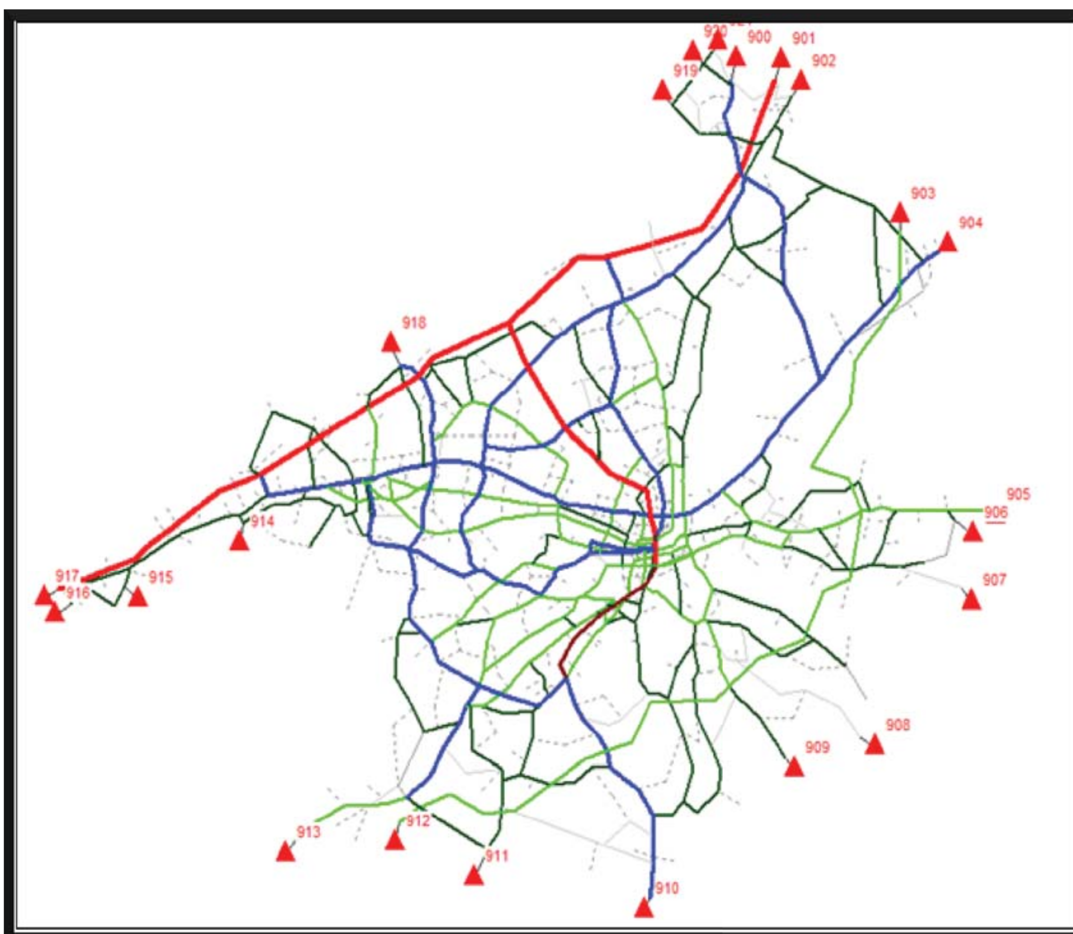
- The auto occupancy rates are now part of a Dbase file (AutoOccFactors.DBF), which resides in the “Calibration Constants” folder.

- The convergence criteria for the highway assignment process have been revised and now include new features available in Cube Voyager 5.0.2

Trip Generation

Trip generation determines the number of person trips that originate or are produced in any specific zone and those that are destined for or attracted to that zone. This section highlights several key processes of the RVAMPO trip generation process and summarizes the validated rates and results. The initial step of the model applies the Fratar model, an iterative proportional fitting model, to factor external survey trips to a year-2000 base, which used a combined matrix for external to external (E-E) and external to internal (E-I) trips. Highway external trips are divided into E-I person trip ends and E-E through vehicle trip ends. E-I trip ends are further divided by type of trip end (trip productions and trip attractions.) The E-I trip productions and attractions by trip purpose are distributed and assigned with the I-I trip ends.

External stations are intersections between the network and the study area boundary. These stations serve as ports of entry and exits to/from the study area. Each station was coded with a TAZ number (900 to 921). Two of these stations (903 & 912) represent the Blue Ridge Parkway and are not used to simulate any external traffic. External stations are shown in the figure below.



External Station Traffic Counts

Model Enhancements and Validation

Future year scenarios in the RVAMPO model have been modified substantially to make better use of available information on traffic flows and to be easier for the user to configure as new data on travel patterns become available. The new process, which starts with a separate E-E matrix, uses a regression model for predicting the E-I trips. The year 2000 E-E matrix serves as the seed matrix, and the analysis year matrix is developed by factoring the seed matrix using a Fratar model, so that the row and column totals match the user supplied traffic counts for E-E trips at that station. These traffic counts contain both E-E and E-I trips. These two trip purposes are allocated by predetermined factors specific to each external station.

The enhancements to both I-E and E-E processes that were adopted in the 2000 model update were also continued in the current model update study. The modified process identifies I-E and E-I as separate trip purposes. The I-E/E-I trips in the modified process were modeled as part of the internal trip purpose.

Validation of the E-E trips file was based on extrapolation and professional judgment. The E-E trips file validation generally relied upon recently collected roadside or cordon line surveys to determine the proportion of the vehicle traffic that passes through the study area. The final EETRIPS file is summarized in the table at right.

External Station	Traffic Count
900	11,100
901	37,000
902	5,300
903	-
904	15,600
905	8,000
906	3,000
907	4,000
908	100
909	5,400
910	24,500
911	1,400
912	-
913	7,200
914	1,200
915	1,100
916	8,600
917	49,100
918	9,200
919	2,560
920	950
921	1,150

External to External Trips

Initial external station productions and attractions for I-E person trips were developed from traffic counts. After the completion of a simulation run, the assigned volume at the external links may not sum to the counts. The validation of the external model adjusted both the I-E person trips and E-E vehicle trips to match the assigned volumes with the traffic counts.

The distribution process determined the number of I-E trips (present in the internal trip tables.) Some adjustments to productions and attractions were made so that the model produced the desired volumes at the external stations. The travel times on the external connectors represent the average time from the station to a typical destination outside the study area. The trips produced at an external station are assumed to be equal to the attractions (a very standard assumption), which is equal to half the daily volume on that link.

Results and Comparisons

The I-E trip ends were developed by subtracting the E-E trip ends from the count. The I-E trip ends were then divided by two to obtain the directional values and multiplied by an auto occupancy rate to obtain person trips. The splits of I-E and E-I trips are summarized in the table on the below.

External Station	Traffic Count	Percent External Internal	External Internal Trips
900	11,100	93%	10,367
901	37,000	40%	14,652
902	5,300	95%	5,009
903	-	0%	-
904	15,600	86%	13,369
905	8,000	95%	7,592
906	3,000	98%	2,931
907	4,000	100%	4,000
908	100	99%	99
909	5,400	55%	2,970
910	24,500	100%	24,476
911	1,400	82%	1,144
912	-	74%	-
913	7,200	100%	7,178
914	1,200	99%	1,192
915	1,100	77%	844
916	8,600	95%	8,196
917	49,100	60%	29,607
918	9,200	98%	9,016
919	2,560	98%	2,506
920	950	100%	950
921	1,150	100%	1,150

External Internal Traffic Counts - Base Year (2005) Model

Adjustments were made at some external stations. The actual I-E trip ends at each external zone were determined by the trip distribution. The trip ends thus had to be adjusted so that post distribution trip ends more closely matched traffic counts.

Several runs were made to validate the external station volumes. The I-E productions, attractions, and extra-regional times for each external station were modified through the validation runs to replicate each of the external station volumes to traffic counts. With the exception of a few low volume roads (within one percent), all external station volumes closely match the actual traffic counts.

This section provides a brief description of the modified trip generation program by explaining the functions of each subroutine. It then provides a discussion of several key issues related to the lifestyle trip generation program.

A combination of simple linear and multiple regression models were used in RVAMPO's trip generation model. Simple regression models were used for all trip purposes but one, Non-Home Based. The household and population data at the zonal level was classified into different household occupancy levels. The trip production file contains county specific trip rates corresponding to different household occupancy levels. Different trip rates were then applied to the household data for all home based trips and employment data from the non-home based trips. The trip generation model estimates productions (trip ends at a person's home) and attractions (trip ends at the non-home end of a trip.) NCHRP 365 suggests using different trip rates for different household occupancy levels because "the variation in trips between household sizes is so large that models without this variable are inferior in approximating travel patterns in a region."

Trip Productions

The trip productions rates from the FAMPO model were applied to the zonal data to get the trip productions. The table below shows the trip production rates for Roanoke. Currently, only trip rates for county 3 are being used for the Roanoke region.

Trips were ultimately categorized into the four traditional purposes of Home Based Work (HBW), Home Based Shopping (HBSH), Home Based Other (HBO), Non-Home Based (NHB), integrating Internal External (IE) and External Internal (EI) counts.

County	1 Person per HH	2 Person per HH	3 Person per HH	4 Person per HH	5 Person per HH	% IX HBW	% IX HBSH	% IX HBO	% IX NHB	% HBW	% HBSH	% HBO
1	3.43	6.68	12.10	15.60	21.70	0.54	0.08	0.15	0.28	0.18	0.18	0.30
2	3.00	6.20	11.00	15.40	21.20	0.22	0.08	0.15	0.28	0.18	0.18	0.30
3	4.12	7.80	11.40	16.00	19.10	0.20	0.08	0.15	0.28	0.18	0.18	0.30
4	3.48	6.87	11.90	16.50	21.10	0.32	0.08	0.15	0.28	0.18	0.18	0.30
5	3.00	5.90	9.48	13.30	23.30	0.40	0.08	0.15	0.28	0.18	0.18	0.30

Trip Production Rates

Trip Attractions

The HBW trip attraction rates for each of the trip purposes are shown on the next page. The attractions were also borrowed from the FAMPO model. Note that the coefficients for the HBW, HBSH, and HBO trip equations are derived so that the total productions are equal to the total attractions for the respective purpose. Just as in trip production, the Roanoke model uses trip attraction rates from county 3 in the following table.

County	HBW	HBSH	HBO HH	HBO Non-Retail	NHB Retail	NHB Non-Retail	NHB HH	% IX HBW	% IX HBSH	% IX HBO	% IX NHB
1	1.40	6.00	1.90	0.80	7.20	0.70	1.10	0.19	0.06	0.10	0.19
2	1.40	6.00	1.90	0.80	7.20	0.70	1.10	0.22	0.06	0.10	0.19
3	1.40	6.00	1.90	0.80	7.20	0.70	1.10	0.20	0.06	0.10	0.19
4	1.40	6.00	1.90	0.80	7.20	0.70	1.10	0.32	0.06	0.10	0.19
5	1.40	6.00	1.90	0.80	7.20	0.70	1.10	0.40	0.06	0.10	0.19

Trip Attraction Rates

Generator Process

Activity within some zones is significantly different from the regional averages. The differences in predicted trips would be large enough to change planning decisions on specific roadways or transit facilities. These facilities might include some airports, recreation and amusement areas, regional shopping centers, military and government complexes, hospitals, and colleges and universities. These facilities are often treated as special generators. The result is that the sums of productions and attractions are equal, and the special generator portions of a TAZ's trip attraction are not adjusted. The RVAMPO model has a process in which the special generated trips, which are user inputs, are added to the final trips at a zonal level.

Results and Comparisons

The number of unadjusted and adjusted productions and attractions in the 2005 validated model are presented in the following table. In the 2005 model, more than 700,000 person trips are generated. The overall trips per household and employee are 7.28 and 5.23, respectively. The trips per household and trips per employee are lower than recommended by NCHRP, but the characteristics of the Roanoke area and the final model calibration, in which we compare the model reported volume and ground traffic counts, justify such low trip numbers.

Trip Purpose	Trips
Home Based Work	123,331
Home Based Shopping	142,618
Home Based Other	219,854
Non-Home Based	215,832
Total	**701,635**

Person Trips per Household	7.28
Person Trips per Employee	5.23

Trip Generation Summary RVAMPO Model - Base Year (2005)

Trip Distribution

Except for through vehicles, RVAMPO uses the Cube Voyager distribution program to distribute trips between the production and attraction zones for all trips and purposes. The results of the trip distribution step become an input to the P/A to O/D conversion step, where person trips are converted to vehicle trips. RVAMPO trip distribution uses a standard gravity model. The distribution is done using uncongested travel time as a measure of spatial separation.

Highway Paths and Skims

This section describes the enhancements that were used in model validation and then presents the key modeling data. Minimum impedance travel paths are calculated using time over the highway network. In building paths, a turning penalty file is used. Paths are not built through prohibited movements. Initial paths are built using the link free-flow speeds. Terminal times and intrazonal times are also added.

The RVAMPO highway path module uses standard Cube Voyager procedures to build time and distance skim matrices for highway paths. The highway paths are defined as the shortest time path through the portion of the highway network available to all vehicles.

To check the network for coding errors and to ensure reasonable paths were built through the network, Cube Voyager determines the shortest path using the network impedance of time or distance with the summation of link impedances computed. Numerous paths were drawn on the computer screen to make sure that paths drawn were "reasonable".

In RVAMPO, in-vehicle travel time variables are considered as significant in determining the minimum paths between any given pair of zones. In-vehicle travel (IVT) time is the primary variable, which is determined as a function of distance and input speed.

Model Enhancements

Enhancements were made to the RVAMPO distribution model by improving the key inputs to the model. These enhancements include the following:

- Conversion of Friction Factors format to DBase
- Frequency distribution of trips with time

Attention has been given to refining production and attraction data as well as trip purpose data and to improving the measure of spatial separation to be sensitive to the impacts of future congestion. The following subsections describe the enhancements incorporated into the trip distribution process.

Internal External (I-E) and External-Internal (E-I) trips are instead included in the internal trip productions and attractions. Thus, the external TAZs (900-921) have productions and attractions associated with them. The trip distribution model determines the number of I-E trips. K factors are not used to influence travel between any origin and destination zones.

Treating external-to-internal and internal-to-external trips as internal trips is one of the key enhancements to RVAMPO. Benefits realized from this enhancement include the following:

- Permits trips generated inside of study area to be attracted to locations outside.
- Routine external-internal trip productions can now compete with internal-internal trips for attractions.
- Routine internal-external trip attractions can now satisfy some internal trip productions.
- Trip length distributions from external stations will vary based upon the types of trips made at those points.
- The total number of trips generated by a household is no longer influenced by its location in the study area.

Model Calibration and Validation

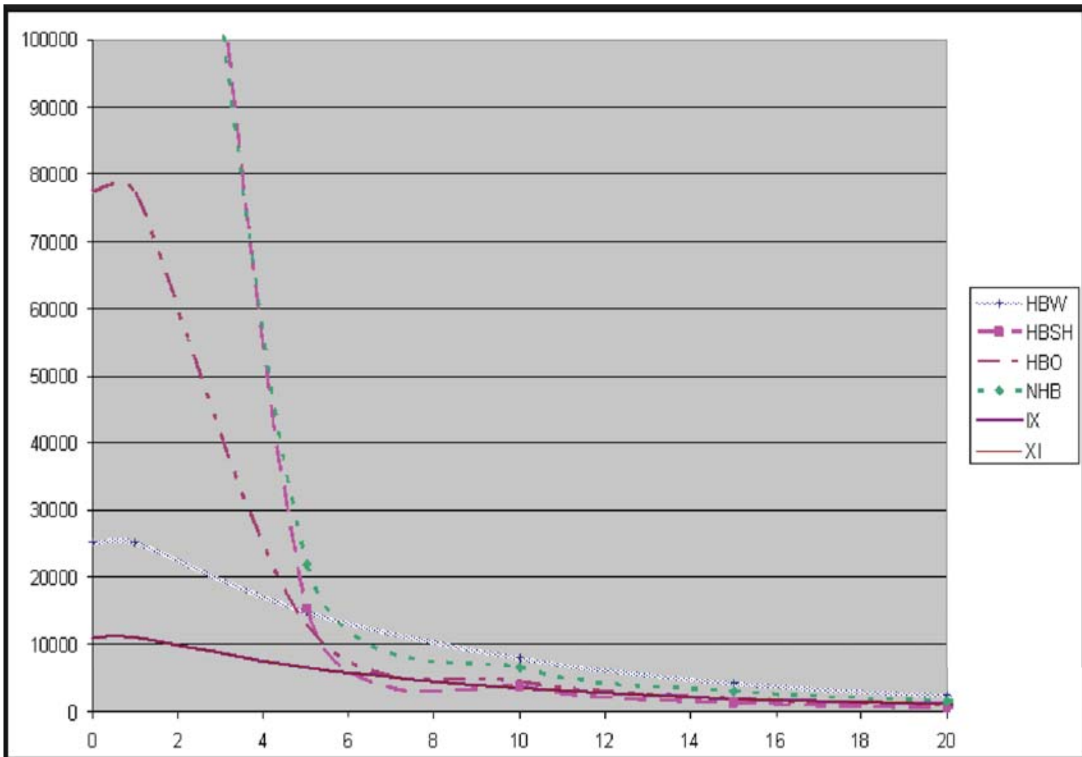
The gravity model formulation includes friction factors, and calibration of the gravity model centers on the adjustment of the friction factor component of the equation. For RVAMPO, K-factors were not considered due to the reasonable aggregate performance of the gravity model with friction factors alone.

The trip distribution model was calibrated using the guidelines from NCHRP 365. The calibrated friction factors are shown in the figure on the next page.

The 2005 validation of the model started with the calibrated gamma function parameters. The trip distribution validation procedure is an iterative process, where a set of travel time factors is developed for each trip purpose. The model computed trip length statistics, which were then compared to the observed/target trip lengths. Based on the results shown in the following table, no further adjustment was made to the friction factors.

Trip Purpose	Average Trip Length (min)	
	Model	NCHRP
Home-based Work	14.81	13-15
Home-based Shopping	13.07	13-15
Home-based Other	12.45	10-14
Non-home-based	12.85	13-15
Internal-External	22.43	-

Trip Length and Intrazonal Percentages RVAMPO Model - Base Year (2005)



Calibrated Friction Factors RVAMPO Model - Base Year (2005)

The validation process generally used in other models could be followed if further validation was warranted. The process of this validation uses an iterative adjustment to the friction factors through use of a "Gamma" function (a function most commonly used for synthesized friction factors). The gamma function is defined in the following form:

$$F(I)_p = a_p * (I ** - b_p) * EXP(-c_p * I)$$

Where,

a_p, b_p, and c_p	=	calibration coefficients for trip purpose "p",
$F(I)_p$	=	friction factor for impedance value "I" and trip purpose "p",
I	=	impedance value, and
EXP	=	exponential function (the base of natural logarithm).

The gamma function usually does a very good job for trip distribution. Further validation of the calibrated friction factors could be done using the "Gamma" function through a non-linear curve fitting technique. This will give the starting point for any adjustment to the calibration coefficient.

The parameter "a" (known as scale factor) can be varied without changing the distribution and is usually not subject to change in model validation. The coefficients b and c, known as shape factors, are usually varied iteratively to match against the target trip lengths and trip length distribution.

Results and Comparisons

In addition to interzonal travel time, the gravity model requires two additional measures of time – intrazonal travel time and out-of-vehicle travel (terminal time). Intrazonal travel time is the time needed for a trip between two sites within the same zone. This time is usually smaller than the interzonal time. Cube Voyager estimates intrazonal time based on the Nearest Neighbor Theory. The theory states that intrazonal travel time is proportional to the amount of time it takes to get to the nearest adjacent zone or zones. The half of the nearest zone IVT time is taken as measure of intrazonal time. In RVAMPO, 2 adjacent zones are used to compute the intrazonal travel time during the trip distributions.

Intrazonal trips are not loaded onto network and are effectively subtracted from total trips before assignment. They play a significant role in estimating the local VMT for air pollution analysis. Calibration of intrazonal trips is not easy unless a good sample size of shorter trips exists in the observed database. These trips, in general, are underreported in most household surveys.

Terminal times are the average times required to get in a vehicle and go from the driveway to the street at the origin (production) end of the trip, or to get the average time required to park the vehicle and reach the final destination point at the destination (attraction) end of the trips. Terminal times vary according to the area type of a zone. The values applied for terminal times in the RVAMPO are shown in the following figure.

Area Type	Terminal Time (minute)	
	Origin	Destination
1. Urbanized Area	*2*	*2*
2. Residential	*1*	*1*
3. Rural	*1*	*1*

Terminal Times (Minutes)

Terminal times are added to the in-vehicle travel time for both ends of a trip, resulting in total travel time between a pair of zones. The resulting travel times are ready for input into the gravity model.

Trip length statistics (average and standard deviation) as well as intrazonal trip percentages are summarized for final trip distribution. Since there were no survey reported trip lengths for Roanoke area, the trip lengths were generally compared to NCHRP recommended trip lengths for areas the size of Roanoke.

Auto Occupancy Factors

Based on the close match between the model trip lengths and target trip lengths as well as reasonable intrazonal trip percentages, calibrated friction factors were not adjusted further in the model validation phase.

Although the final model forecasts only highway auto travel, the initial person-trips developed in the trip generation phase of the model must still be converted to vehicle trips. For the I-E portion of the HBW trips, the auto occupancy factors were derived from the Fredericksburg model, which in turn derived the target numbers from VRE survey data from the Department of Rail and Public Transportation – DPRT. The mode split also includes 1,600 persons (40 busesx40 persons) reported to be using buses (data from GWRPC). This mode split is significant only for the I-X work trips, since this is the only trip purpose with a significant shift to modes other than auto.

The following table shows the final auto occupancies used in the model for all trip purposes. For the internal work trips, the Census and the survey indicated average auto occupancy of 1.14 and 1.13 persons per vehicle, respectively. For the E-I work trips, a value of 1.43 was used since it is probable that less transit and car-pooling would occur for these trips than for the I-E work trips. For the HBO trip purpose, the NCHRP 365 recommends an auto occupancy rate of 1.62 persons per vehicle. The auto occupancy numbers in the Roanoke model are close to NCHRPO recommended numbers.

Purpose	Auto Occupancy Factors
HBW	1.16
HBsh	1.38
HBO	1.55
NHB	1.49
IE	1.43
EI	1.43

Auto Occupancy Factors - Base Year (2005) RVAMPO Model

Highway Assignment

The last step of the four-step modeling process is assignment. Highway assignments are normally performed on a daily basis with trips factored to a peak hour for volume-to-capacity calculations. The RVAMPO model uses an equilibrium assignment process. Evaluation of the highway assignment model is based on comparisons between traffic counts and model assigned volumes. Simulated traffic volumes are compared to traffic counts in several different ways to determine whether the coded highway network accurately represents the highway systems, and to determine whether the various assumptions used in the model chain are reasonable.

Model Enhancements

The highway assignment model uses an equilibrium assignment algorithm. In equilibrium, all travelers are assigned to their optimum path; no traveler can have a shorter path available. Each assignment of trips from all zones is considered one assignment iteration. Typically, multiple iterations are required before networks can reach full equilibrium. After each assignment's iteration, link speeds are adjusted and the next assignment is performed.

Multiple BPR Curves

$$T_c = T_f + \alpha * (v/c)^{\beta}$$

Where,

T_c = congested link travel time

T_f = link free-flow travel time

v = assigned volume

c = link capacity

α,β = BPR parameters

Link Class	α	β
Centroid Connectors	0.15	4
Freeways/Arterials	0.2	10
Local Streets	0.05	10

An iterative equilibrium technique is used in RVAMPO. In this type of assignment, all of the trips are loaded, the paths are revised, the trips are again loaded, and the procedure is repeated until equilibrium is reached. This technique uses the BPR formulation, in which link travel time is recomputed using the following relationship:

$$S_c = S_f / \{1 + \alpha (v/c)^{\beta}\}$$

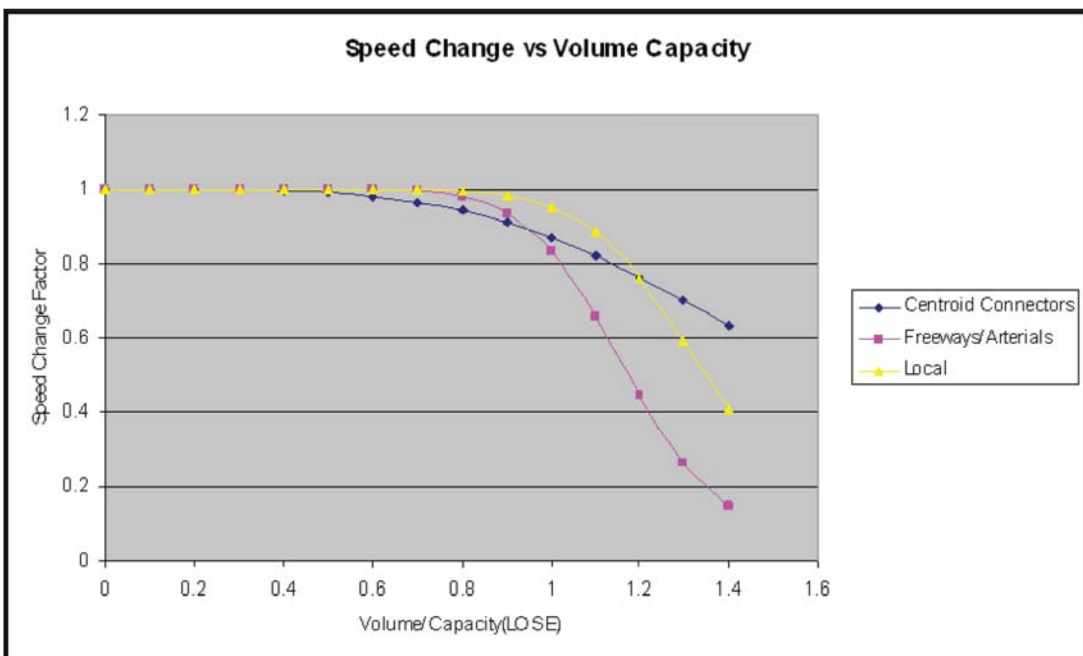
Where,

S_c = estimated congested speed

S_f = link free-flow speed

Another enhancement in the RVAMPO highway assignment process is the incorporation of different BPR curves for different types of facilities. This recognizes that each facility type has its own unique characteristics for responding to congestion. For example, freeways can generally handle a higher level of congestion than surface streets before speeds begin to deteriorate. However, with more congestion, speeds deteriorate to stop-and-go conditions much more quickly on freeways than they do on surface streets. It should be noted that the BPR curve is not sensitive to the impacts of signal spacing, timing, and coordination.

The BPR curves determine both the level of congestion (the volume/capacity ratio at which speeds begin to deteriorate) and the rate at which they deteriorate as congestion increases. The adjustment to the BPR curves was done by changing the alpha and the beta values. In addition, speeds and capacities were also adjusted. The facility specific BPR curves, used in the 2005 validated model, are shown in the following Figure. A relatively steeper curve was used for freeways, while the curves for arterials were comparatively less steep.



Volume-Delay Curves - Base Year (2005) RVAMPO Model

For the 24-hour model, Capacity conversion factor (CAPCONFAC) is the ratio between the peak hour traffic and the daily traffic. The programs use the CONFAC parameter to convert hourly capacity to a daily value so that a 24-hour assignment can be made. Historically, the method for obtaining daily capacity restrained traffic assignments has been to multiply the hourly capacity by CAPCONFAC (say, 10) to reflect the daily highway capacity.

Model Calibration

Calibration of a traffic assignment involves an examination of several statistics, most of which are related to actual ground counts taken on various links throughout the network. The traffic counts for RVAMPO were identified through a variety of sources. One key to successful highway model validation is the availability of accurate traffic counts, in sufficient quantity. Efforts were made to insure that sufficient counts were included in the model for all available area type and facility type combinations. The percentages of the links with traffic counts by the facility and area types were shown previously in this chapter. Overall, 15 percent of the links have traffic counts. The statistics of number of links and percent of links with traffic counts will be very useful in evaluating the validation results presented in this chapter. For example, there will be less confidence in the evaluation results (say volume-over-count ratio) in locations where fewer links have traffic counts. These counts provide the basis for highway assignment evaluation, and are input into the model as link attributes.

Volume-over-Count and %RMSE (Percent Root Mean Square Error) Statistics

Several indicators are available for determining the overall performance of the highway assignment model. Volume-over-count (V/C) statistics are one of the key indicators. The simple ratio of assigned volume over count was recorded. A ratio of 1.0 indicates exact agreement between the assignment and the traffic count.

PPM recommends a ±15 percent accuracy for assigned VMT to count VMT. It is assumed that each combination of area/facility/number of lanes and link group contains a statistically valid number of links. For link groups having less than 100,000 VMT, only a ±25 percent accuracy level is desired. Assigned V/C ratios by their facility and area type were also analyzed. The analysis was based on a ±10 percent accuracy level, as was recommended for screenlines and cutlines.

The previous version of the model had a very high percent root mean square error (RMSE). The RMSE was equal to 38.6 percent. The consultant observed that error statistics were skewed because of the high number of low volume links. On investigation it was observed that many low volume counts were not taken as point observations, and instead of just being on the actual traffic count station link, they were propagated to the surrounding links as well. This observation was reported to VDOT, and its staff conducted an extensive effort to reconcile count locations with the corresponding links that must store the traffic count information.

Since this project involves short-term improvements, the consultant primarily focused on the traffic volume to count relationship. To check the validity of the trip generation and trip distribution characteristics was beyond the scope of this project and will be part of the future efforts on this model. After the count locations were reconciled, the RMSE dropped to 29.3 percent, which was a positive sign. The consultant observed that the traffic flow to malls in the Roanoke area did not match the ground reality. This was improved by the use of special generator trips. Adjustments were also made to the E-I trips to produce a better match of model volume to traffic counts on I-81.

The overall percent RMSE value is 29.3 percent, which is within the VTM threshold of 30 percent.

The next table shows the volume over count ratios by roadway facilities. It also shows that, with the exception of facility type 6, all facilities (which are local streets) are within five percent and meet the VTM guidelines.

Functional Group	Model Volume	Traffic Count	Volume/ Count	PPM Recommendation	Number of Observations
1	1,202,525	1,150,302	1.05	0.9 to 1.10	19
2	313,582	307,128	1.02	0.85 to 1.15	5
3	1,575,596	1,533,320	1.03	0.80 to 1.20	78
4	1,276,048	1,286,982	0.99	0.75 to 1.25	117
5	595,939	623,345	0.96	0.75 to 1.25	116
6	20,930	29,184	0.72	0.75 to 1.25	8
All	4,984,620	4,930,261	1.01	.95-1.05	361

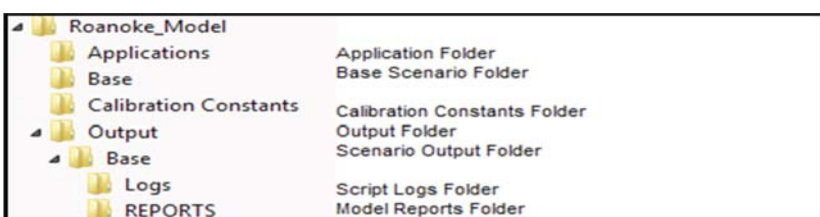
Volume/Count Ratios by Facility Types

Model Directory Structure

The consultant has made many improvements to the directory structure of the RVAMPO model. The structure of the previous version of the model contained a separate directory for each analysis year. There were two analysis years, 2005 as the base year and 2035 as the future year. The directory of each analysis year contained separate Cube applications and scripts. These applications and scripts were accessed from the same catalog file. This was not consistent with the basic idea of Cube catalogs and applications. The Cube Voyager models must have common applications and scripts for all scenarios which, in turn, have their independent data.

The new structure of the RVAMPO model has been divided into three sub-folders which reside under the parent folder, "Roanoke Model." These three folders contain data files, applications, and script files. The catalog file for the model resides in the "Roanoke_Model" folder.

A snapshot of the model directories follows:



Roanoke Model Folder

This folder contains the Cube Voyager Catalog file, "Roanoke_Regional_Model.cat." It also contains three subfolders, Applications, Base and Calibration Constants.

Applications

This folder contains all the associated applications and scripts for this model. This folder is also known as the working folder of the model because this is where all the intermediate output files are stored. All application files in this folder have an extension *.app and all the script files have an extension *.s.

Base

This folder is called the scenario folder. This folder is created when the first scenario is created from the Scenario Manager in the Cube Catalog. The scenario folder can be accessed from the script by using the {Scenario_dir} key. This folder contains all the scenario-specific input files for this model. All the scenario-specific files have been given a suffix, which is a combination of the scenario year and the one letter scenario identifier. For example: 2000 year scenario B will have a suffix "2000B" at the end of the file name. It should be noted that this suffix is not the extension of the file name. The file name extensions correspond to the file type. A DBase file will have a *.dbf extension.

The files contained in this folder are shown in the following table.

File Name	Contents
RVAMPO_(Year)(Alternative).NET	The Input Highway Network
Landuse_(Year)(Alternative).DBF	Land Use Data (Household and Employment)
SpecialGen_(Year)(Alternative).DBF	Special Generator
External_(Year)(Alternative).DBF	External-External Data
EIPCT_(Year)(Alternative).DBF	External-Internal Data

Contents of Input Data Folder

Calibration Constants

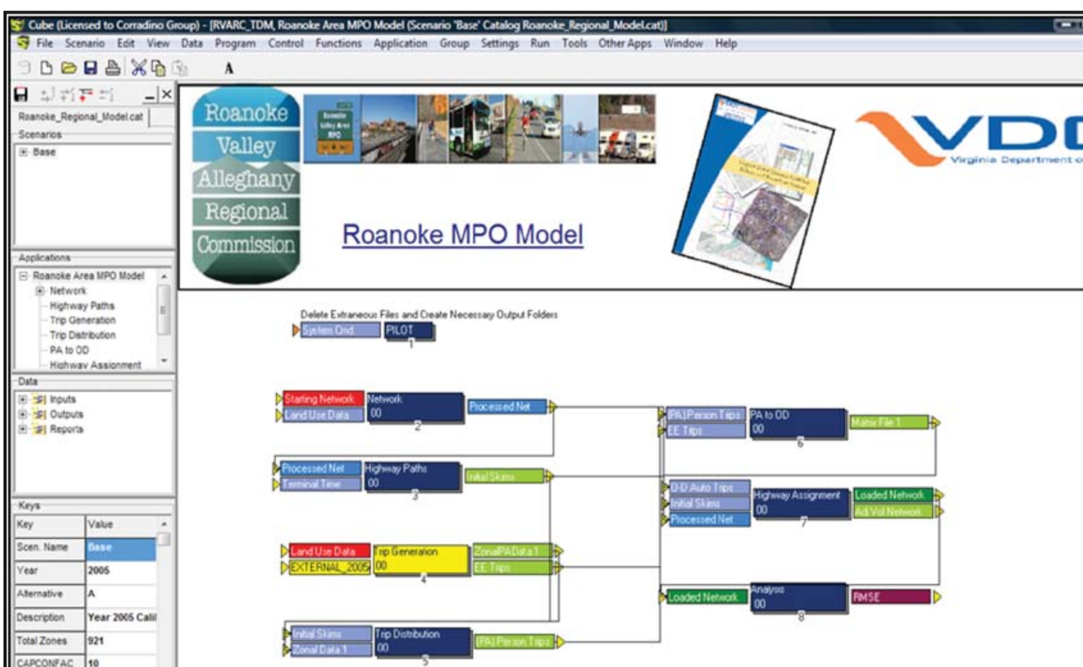
This folder contains files that are common across all scenarios and were finalized during model calibration and validation process. These files should not be changed unless there is a need to adjust model behavior across all scenarios. The contents of this folder are shown in the table on the next page.

File Name	Contents
AutoOccFactors.DBF	Auto Occupancy Factors
FFACTORS.DBF	Friction Factors
SPEEDS.DBF	Speed
Term_Time.DBF	Terminal Time
TripAttrRates.DBF	Trip Attraction Rates
TripProdRates.DBF	Trip Production Rates
CAPACITY.DBF	Highway Capacities

Contents of Calibration Constants Folder

RVAMPO Model's New Features

As stated earlier, the previous version of the RVAMPO Cube catalog contained two applications: one for the base year 2005, and the other one for the future year 2035. Generally, a model should be developed so that there is only one application. This single application should be applied to multiple scenarios. Scenarios may be different years, networks, or comprehensive alternatives (years, networks, costs, and other assumptions). Sometimes one-time or infrequent procedures are stored as another application, but applications should not generally be used in place of the scenarios. So, the catalog was restructured to use a single parent application. A snapshot of the RVAMPO model is shown in the following figure.



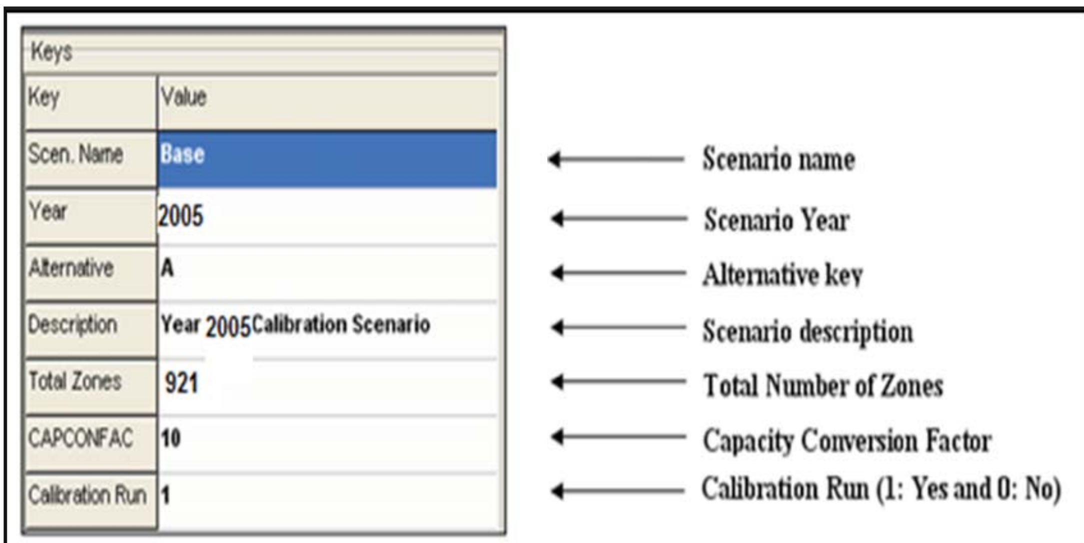
RVAMPO Model Catelog and Parent Application Snapshot

Various applications in the old RVAMPO model were not designed to exploit the full potential of features in Cube Voyager. One of these features is Catalog Keys. The consultant identified all the places in the scripts that needed common values. One example is value of total number of zones, which was hard-coded in the scripts. The consultant replaced all these common values by Catalog Keys to reduce the chances of error by a model user.

The application set has not been changed. There are still as many applications as there were in the previous version. However, changes have been made to link files between various applications. File linking has been made at the parent application. Most of the important input and output files have been made "public," which means that they are visible from the parent model application. This helps a model user better understand the flow of data between various applications and steps. Also for the same reason, wherever applicable, file linking has been made inside applications as well.

The applications in the Catalog window have been given self-explanatory names. The data section in the Catalog has been used to provide quick links to some of the main input and output files. These links have been made scenario specific.

Some new catalog keys have been introduced. These catalog keys can be changed for every scenario. There are a few keys that are scenario specific. The keys are listed in the following Figure.



RVAMPO Model Catalog Keys

Network

In the previous version of the model, the Network application had two steps. The first step converted a MINUTP network to a Voyager network. The second step processed the Voyager network for use in path building. The first step was eliminated because the starting Voyager networks for the base year and the future year are available now, and the second step has been given more functionality.

The Network step now extracts speeds and capacities from speed and capacity tables in SPEEDS.DBF and CAPACITY.DBF, respectively, which reside in the Calibration Constants folder. The speeds and capacities are added to the network based on the speed-capacity classification specified on the links.

Highway Paths

The only change made to this application was removal of hard-coded values of speeds for path building purposes. As mentioned in the Network application, this functionality has been transferred to the Network application.

Trip Generation and Distribution

This application contains both Trip Generation and Trip Distribution. The trip generation script was rewritten to make it more efficient and less prone to errors. The script in the previous version contained repetitive lines of code which were calculating trips by using hard-coded values for coefficients for various zonal data like population and employment. The generation step now reads the zonal socioeconomic, special generator and external-internal data from Dbase files that reside in the Input Data folder inside the scenario folder. These changes to the code have reduced it to a third of its original size. Another important change to this step is removal of the hard-coded values for different purpose-specific trip production and attraction coefficients. These coefficients are now being read from external files, TripProdRates.DBF and TripAttrRates.DBF. These files reside in the Calibration Constants folder and are common across all scenarios.

The distribution step was changed to read friction factors from a Dbase file instead of an ASCII text file. The friction factors file, FFACTORS.DBF, resides in the Calibration Constants folder.

Conversion of P/A to O/D

This application converts the P/A tables to O/D format, and prepares the trip tables for highway assignment. The major change to this step has been addition of a FRATAR step which will create the future external-external trip matrix by "fratarting" the base year trip table to external station traffic volumes specified in External_{Year}(Alternative).DBF.

Highway Assignment

The Highway Assignment application has been modified in consultation with VDOT staff. The lines of code that assigned hard-coded values of speed and capacities for link volumes have been removed. Instead, the speeds and capacities are now being added on the highway network in the Network application. Other changes made to the script involve changes to convergence methodology. In this setup Voyager's Highway program parameters RGAP and RGAPCUTOFF have been used in the CONVERGE phase.