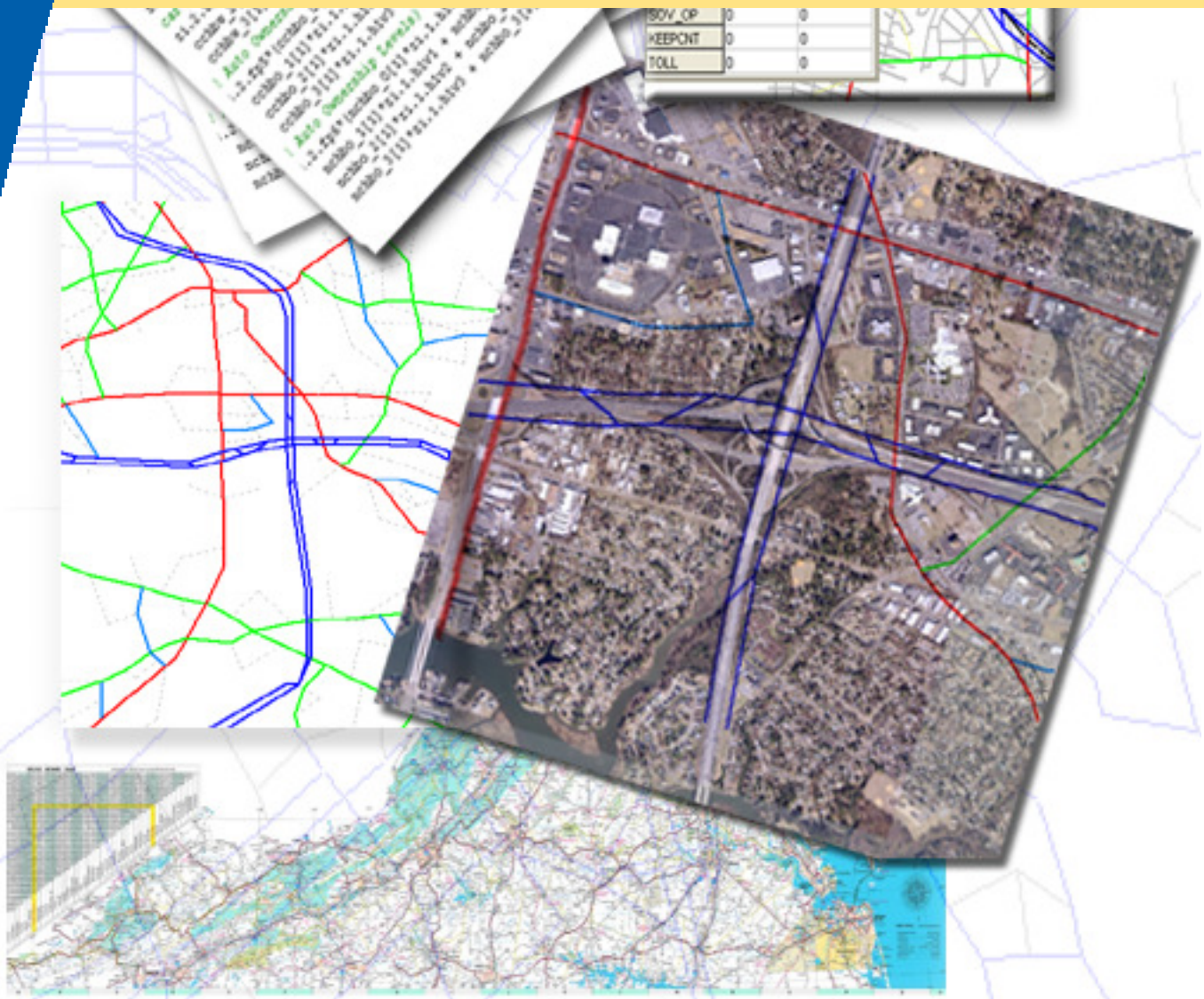
Virginia Department of Transportation

Transportation and Mobility Planning

Version 1.30 – May, 2009

Virginia Transportation Modeling (VTM) Policies and Procedures Manual



Foreword

The Virginia Travel Demand Modeling Policies and Procedures Manual describes the Virginia Transportation Modeling (VTM) policies, procedures and standards required to perform urban travel demand forecasting for metropolitan areas in Virginia. Travel demand forecasting is a complex subject with many different techniques and areas of research. It is important to note, however, that this manual is not intended to be an exhaustive guide to travel demand forecasting procedures and techniques. Rather, it is intended to establish specific and uniform Travel Demand Modeling policy and procedures for use in model development and application by VDOT, Metropolitan Planning Organizations (MPO) and Planning District Commissions (PDC) in Virginia.

This manual is the first of its kind for travel demand models in Virginia. This manual develops guidelines and standards for acceptable and recommended travel demand modeling practice for large and small model regions in Virginia. While none of the current models in Virginia meet all the recommendations of this manual, it is the intent that in the short term, all models will meet acceptable practice and that in the long term, subject to available resources, they will meet recommended practice.

Although other types of models related to urban travel demand forecasting exist, such as land use models, local jurisdiction travel demand models, and statewide travel demand models, this document is not intended to be a manual on these types of modeling tools. Additionally, the manual assumes the reader is familiar with basic travel demand modeling terms and procedures and does not explain these in great detail. Readers desiring additional knowledge of the basics of travel demand forecasting should take the introductory training courses offered periodically by FHWA and the National Highway Institute (NHI) to review available literature and resources. A List of Websites for obtaining more information about travel demand modeling is provided in the Appendix.

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1. Introduction to Travel Demand Modeling in Virginia

The VTM System policy and procedures manual is intended for readers who have a basic understanding of travel demand modeling concepts and procedures. For the remainder of the document, the terms "modeling" and "models" will refer to travel demand models. The first chapter provides an overview of modeling in Virginia. It begins with a brief explanation of modeling and concludes by discussing the legal issues affecting modeling in Virginia, and the purpose and application of this policy and procedures manual. A glossary of travel demand modeling terms used in this manual is included in the Appendix. The Appendix also contains a list of web sites for obtaining more information on travel demand modeling resources.

What is Travel Demand Modeling?

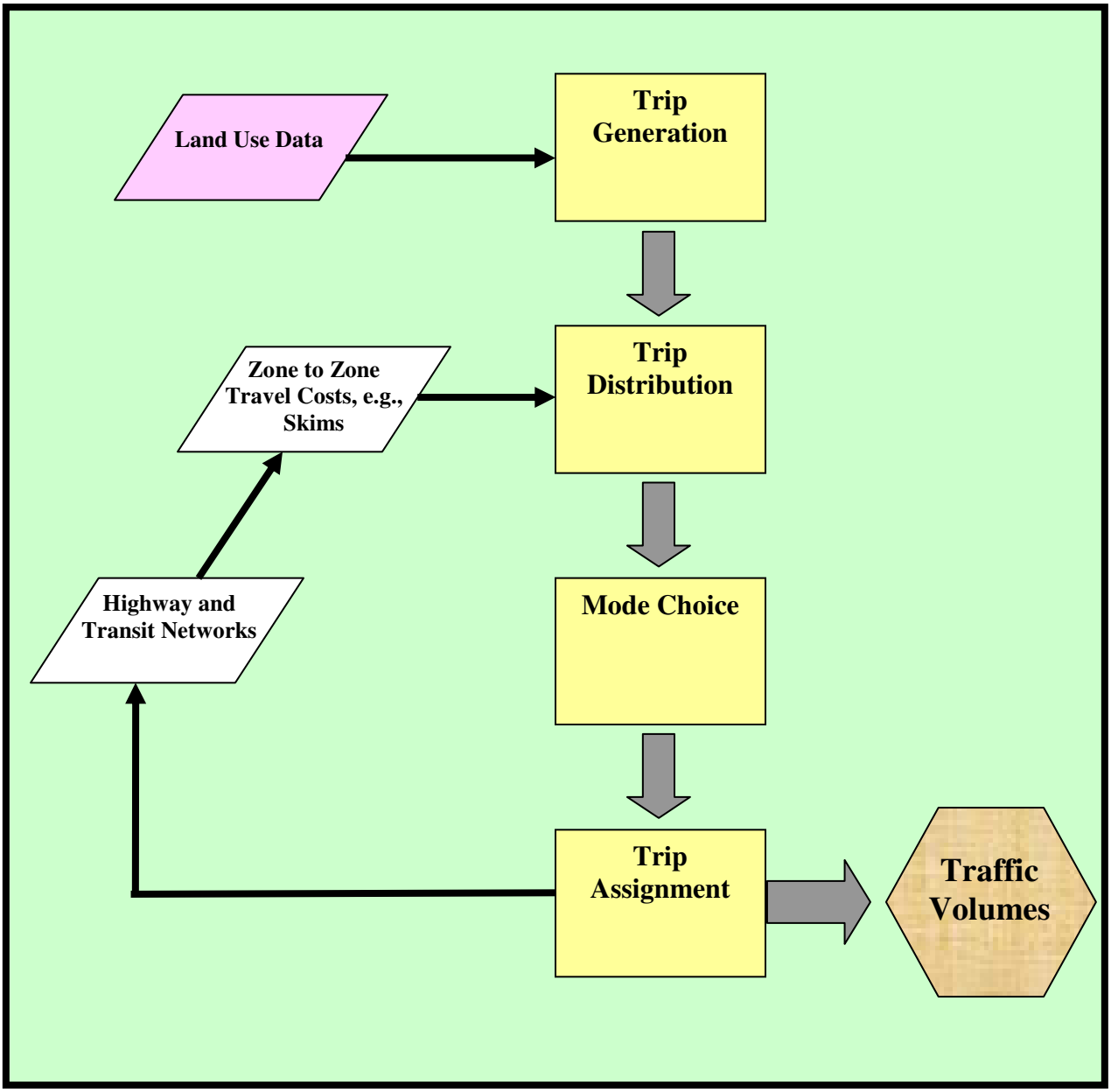
Modeling is a tool used to support the transportation planning process. It can be used to develop traffic forecasts, test alternative transportation scenarios, and evaluate transportation systems. Models are developed using demographic, survey, and transportation network data. Demographic and survey data are used to develop the mathematical equations necessary for modeling. Highway and transit data are used to develop the transportation network such as number of lanes, speed limit, road capacity, transit schedules and fares, etc. A typical Travel Demand Model in Virginia has between 10 and 30 input files and several output files.

Several different methodologies exist to perform modeling. The most common method used worldwide and in the United States is the traditional four-step approach. This approach is an aggregate sequential process with four steps:

1. Trip Generation = How many trips will be made?
2. Trip Distribution = Where will the trips go?
3. Mode Choice = What mode of transportation will the trips use?
4. Trip Assignment = What route will the trips take?

Demographic and other necessary model data is aggregated to Transportation Analysis Zones (TAZs) to be input into the model. TAZs generally follow census geography and are typically a combination of census blocks and/or census block groups.

Figure 1: Four-Step Travel Demand Forecasting Process



Regulatory Requirements Affecting Transportation Modeling in Virginia

The following Federal and State regulations and requirements affect modeling in Virginia:

1. Virginia Employment Commission Population Control Totals
2. Federal Metropolitan Planning Regulations
3. Federal Transportation Conformity Regulations
4. Federal Transit Administration Regulations

Virginia Employment Commission Population Control Totals

The Virginia Employment Commission (VEC) is the designated state agency for developing population projections as stated below in the Code of Virginia in 60.2-113, section 5. As a result, travel demand modeling efforts in Virginia are required to use VEC population control totals.

§ 60.2-113. Employment stabilization.
The Commission shall take all necessary steps through its appropriate divisions and with the advice of such advisory boards and committees as it may have to:
1. Establish a viable labor exchange system to promote maximum employment for the Commonwealth of Virginia with priority given to those workers drawing unemployment benefits;
2. Maintain a solvent trust fund financed through equitable employer taxes that provide temporary partial income replacement to involuntarily unemployed covered workers;
3. Coordinate and conduct labor market information research studies, programs and operations, including the development, storage, retrieval and dissemination of information on the social and economic aspects of the Commonwealth and publish data needed by employers, economic development, education and training entities, government and other users in the public and private sectors;
4. Determine and publish a list of jobs, trades, and professions for which a high demand of qualified workers exists or is projected by the Commission. The Commission shall consult with the Virginia Workforce Council in making such determination. Such information shall be published biennially and disseminated to employers; education and training entities, including public two-year and four-year institutions of higher education; government agencies, including the Department of Education and public libraries; and other users in the public and private sectors;
5. Prepare official short and long-range population projections for the Commonwealth for use by the General Assembly and state agencies with programs which involve or necessitate population projections;
6. Encourage and assist in the adoption of practical methods of vocational guidance, training and retraining; and
7. Establish the Interagency Migrant Worker Policy Committee, comprised of representatives from appropriate state agencies, including the Virginia Workers' Compensation Commission, whose services and jurisdictions involve migrant and seasonal farmworkers and their employees. The Committee shall coordinate its activities with the Migrant and Seasonal Farmworkers Board established in § 2.2-2407. All agencies of the Commonwealth shall be required to cooperate with the Committee upon request.

(Code 1950, § 60-34; 1968, c. 738, § 60.1-39; 1986, c. 480; 1989, c. 108; 1999, c. 357; 2004, cc. 14, 154, 592.)

Federal Metropolitan Planning Regulations

Federal law governing the metropolitan planning process is stated in 23 CFR 450.322 which is shown below and is commonly called: "Title 23". For easier reference, key parts of the regulation are in bold:

TITLE 23--HIGHWAYS

CHAPTER I--FEDERAL HIGHWAY ADMINISTRATION, DEPARTMENT OF TRANSPORTATION

PART 450_PLANNING ASSISTANCE AND STANDARDS--Table of Contents

Subpart C_Metropolitan Transportation Planning and Programming

Sec. 450.322 Metropolitan transportation planning process: Transportation plan.

(a) The metropolitan transportation planning process shall include the development of a transportation plan addressing at least a twenty-year planning horizon. The plan shall include both long-range and short-range strategies/actions that lead to the development of an integrated intermodal transportation system that facilitates the efficient movement of people and goods. *The transportation plan shall be reviewed and updated at least triennially in nonattainment and maintenance areas and at least every five years in attainment areas to conform its validity and consistency with current and forecasted transportation and land use conditions and trends and to extend the forecast period, except that the transportation plan for the New York Metropolitan Transportation Council that was reviewed and updated on September 30, 1999, shall be reviewed and updated no later than September 30, 2005. The transportation plan must be approved by the MPO.*

(b) In addition, the plan shall:

(1) Identify the projected transportation demand of persons and goods in the metropolitan planning area over the period of the plan;

(2) Identify adopted congestion management strategies including, as appropriate, traffic operations, ridesharing, pedestrian and bicycle facilities, alternative work schedules, freight movement options, high occupancy vehicle treatments, telecommuting, and public transportation improvements (including regulatory, pricing, management, and operational options), that demonstrate a systematic approach in addressing current and future transportation demand;

(3) Identify pedestrian walkway and bicycle transportation facilities in accordance with 23 U.S.C. 217(g);

(4) Reflect the consideration given to the results of the management systems, including in TMAs that are nonattainment areas for carbon monoxide and ozone, identification of SOV projects that result from a congestion management system that meets the requirements of 23 CFR part 500;

(5) Assess capital investment and other measures necessary to preserve the existing transportation system (including requirements for operational improvements, resurfacing, restoration, and rehabilitation of existing and future major roadways, as well as operations, maintenance, modernization, and rehabilitation of existing and future transit facilities) and make the most efficient use of existing

transportation facilities to relieve vehicular congestion and enhance the mobility of people and goods;

(6) Include design concept and scope descriptions of all existing and proposed transportation facilities in sufficient detail, regardless of the source of funding, in nonattainment and maintenance areas to permit conformity determinations under the U.S. EPA conformity regulations at 40 CFR part 51. In all areas, all proposed improvements shall be described in sufficient detail to develop cost estimates;

(7) Reflect a multimodal evaluation of the transportation, socioeconomic, environmental, and financial impact of the overall plan, including all major transportation investments in accordance with Sec. 450.318;

(8) For major transportation investments for which analyses are not complete, indicate that the design concept and scope (mode and alignment) have not been fully determined and will require further analysis. The plan shall identify such study corridors and subareas and may stipulate either a set of assumptions (assumed alternatives) concerning the proposed improvements or a no-build condition pending the completion of a corridor or subarea level analysis under Sec. 450.318. In nonattainment and maintenance areas, the set of assumed alternatives shall be in sufficient detail to permit plan conformity determinations under the U.S. EPA conformity regulations (40 CFR part 51);

(9) Reflect, to the extent that they exist, consideration of: the area's comprehensive long-range land use plan and metropolitan development objectives; national, State, and local housing goals and strategies, community development and employment plans and strategies, and environmental resource plans; local, State, and national goals and objectives such as linking low income households with employment opportunities; and the area's overall social, economic, environmental, and energy conservation goals and objectives;

(10) Indicate, as appropriate, proposed transportation enhancement activities as defined in 23 U.S.C. 101(a); and

(11) Include a financial plan that demonstrates the consistency of proposed transportation investments with already available and projected sources of revenue. The financial plan shall compare the estimated revenue from existing and proposed funding sources that can reasonably be expected to be available for transportation uses, and the estimated costs of constructing, maintaining and operating the total (existing plus planned) transportation system over the period of the plan. The estimated revenue by existing revenue source (local, State, and Federal and private) available for transportation projects shall be determined and any shortfalls identified. Proposed new revenues and/or revenue sources to cover shortfalls shall be identified, including strategies for ensuring their availability for proposed investments. Existing and proposed revenues shall cover all forecasted capital, operating, and maintenance costs. All cost and revenue projections shall be based on the data reflecting the existing situation and historical trends. For nonattainment and maintenance areas, the financial plan shall address the specific financial strategies required to ensure the implementation of projects and programs to reach air quality compliance.

(c) There must be adequate opportunity for public official (including elected officials) and citizen involvement in the development of the transportation plan before it is approved by the MPO, in accordance with the requirements of Sec. 450.316(b)(1). Such procedures

shall include opportunities for interested parties (including citizens, affected public agencies, representatives of transportation agency employees, and private providers of transportation) to be involved in the early stages of the plan development/update process. The procedures shall include publication of the proposed plan or other methods to make it readily available for public review and comment and, in nonattainment TMAs, an opportunity for at least one formal public meeting annually to review planning assumptions and the plan development process with interested parties and the general public. The procedures also shall include publication of the approved plan or other methods to make it readily available for information purposes.
(d) In nonattainment and maintenance areas for transportation related pollutants, the FHWA and the FTA, as well as the MPO, must make a conformity determination on any new/revised plan in accordance with the Clean Air Act and the EPA conformity regulations (40 CFR part 51).
(e) Although transportation plans do not need to be approved by the FHWA or the FTA, copies of any new/revised plans must be provided to each agency.

[58 FR 58064, Oct. 28, 1993, as amended at 61 FR 67175, Dec. 19, 1996; 67 FR 62373, Oct. 7, 2002]

Travel demand models are one of the more commonly used tools to satisfy the metropolitan planning requirements of Title 23. Other sketch planning methods and tools such as forecasting traffic based on historical trends can also be used in lieu of a travel demand model in certain circumstances.

Federal Transportation Conformity Regulations

The Clean Air Act of 1990 established the first national air quality standards. These standards were amended in 1997 and renamed the national ambient air quality standards (NAAQS) to include some additional pollutants. The list of pollutants addressed by the NAAQS is:

1. Ground Level Ozone (O_3 1-Hour and 8-Hour)
2. Carbon Monoxide (CO)
3. Nitrogen Dioxide (NOx)
4. Lead (Pb)
5. Sulfur Dioxide (SO_2)
6. Particulate Matter (PM-10)
7. Fine Particulate Matter (PM-2.5)

Metropolitan areas that do not meet NAAQS are designated as non-attainment areas.

shows MPO urban areas in Virginia that are in non-attainment of the NAAQS as of April, 2005.[1]

Table 1: NAAQS Status of MPO Urban Areas in Virginia

MPO Urban Area	2000 Census Population[2&3] (Virginia area only) (in thousands)	Attainment Status[4]	NAAQS Problem
Northern Virginia[5]	2,094	Non-Attainment	Moderate: 8-Hour Ozone PM-2.5 & Maintenance for CO (Arlington & Alexandria only)
Hampton Roads	1,569	Non-Attainment	Marginal: 8-Hour Ozone
Richmond/Tri-Cities	997	Non-Attainment	Marginal: 8-Hour Ozone
Fredericksburg	241	Non-attainment	Moderate - 8-Hour Ozone
Roanoke	236	Attainment	Early Action Compact: 8-Hour Ozone
Lynchburg	215	Attainment	
Charlottesville	160	Attainment	
Danville	110	Attainment	
Harrisonburg	108	Attainment	
Blacksburg	83	Attainment	
Winchester	83	Attainment	Early Action Compact: 8-Hour Ozone
Bristol[6]	35	Attainment	
Kingsport[7]	10	Attainment	

[1] EPA Green Book, April, 2005.
[2] Census population often differs from Model Region population because of different urban area boundary definitions.
[3] Census population is one of 11 factors that are considered when designating an area to non-attainment status, but it is not the basis for the NAAQS
[4] Attainment status as of January 1, 2006. At the time of this writing, regulations are pending to re-designate Fredericksburg, Hampton Roads & Richmond to 8-hour ozone maintenance areas.
[5] Population total for Washington Area (VA-WV-DC-MD) excluding Baltimore and Hagerstown is 4,923,000.
[6] Population total for Bristol Area (TN-VA) is 91,000.
[7] Population total for Kingsport Area (TN-VA) is 120,000.

Non-attainment areas are required to adopt State Implementation Plans (SIP) to achieve and maintain attainment. For transportation projects in a particular area to receive federal assistance under Title 23, the MPO for the area must perform air quality analysis to assess the impact of the planned improvements. This analysis is performed on the MPO's adopted long range transportation plan and transportation improvement program (TIP) utilizing a combination of Travel Demand Management (TDM) & Air Quality (AQ) modeling processes. The vehicle emissions estimated from these plans must conform to the emissions budgets established by the SIP. Regional air quality analysis must meet additional requirements for metropolitan planning areas with populations greater than 200,000 and that are in non-attainment for serious, severe, or extreme ozone or serious carbon monoxide. These requirements are stated in 40 CFR §93.122, as amended by 62 FR 43814, on August 15, 1997:

40 CFR §93.122, as amended by 62 FR 43814, August 15, 1997
(b) Regional emissions analysis in serious, severe, and extreme ozone non-attainment areas and serious CO non-attainment areas must meet the requirements of paragraphs (b)(1) through (3) of this section if their metropolitan planning area contains an urbanized area population over 200,000.

(1) By January 1, 1997, estimates of regional transportation-related emissions used to support conformity determinations must be made at a minimum using network-based travel models according to procedures and methods that are available and in practice and supported by current and available documentation. These procedures, methods, and practices are available from DOT and will be updated periodically. Agencies must discuss these modeling procedures and practices through the interagency consultation process, as required by §93.105(c)(1)(i). Network-based travel models must at a minimum satisfy the following requirements:

(i) Network-based travel models must be validated against observed counts (peak- and off-peak, if possible) for a base year that is not more than 10 years prior to the date of the conformity determination. Model forecasts must be analyzed for reasonableness and compared to historical trends and other factors, and the results must be documented;

(ii) Land use, population, employment, and other network-based travel model assumptions must be documented and based on the best available information;

(iii) Scenarios of land development and use must be consistent with the future transportation system alternatives for which emissions are being estimated. The distribution of employment and residences for different transportation options must be reasonable;

(iv) A capacity-sensitive assignment methodology must be used, and emissions estimates must be based on a methodology which differentiates between peak- and off-peak link volumes and speeds and uses speeds based on final assigned volumes;

(v) Zone-to-zone travel impedances used to distribute trips between origin and destination pairs must be in reasonable agreement with the travel times that are estimated from final assigned traffic volumes. Where use of transit currently is anticipated to be a significant factor in satisfying transportation demand, these times should also be used for modeling mode splits;

(vi) Network-based travel models must be reasonably sensitive to changes in the time(s), cost(s), and other factors affecting travel choices.

(2) Reasonable methods in accordance with good practice must be used to estimate traffic speeds and delays in a manner that is sensitive to the estimated volume of travel on each roadway segment represented in the network-based travel model.

(3) Highway Performance Monitoring System (HPMS) estimates of vehicle miles traveled (VMT) shall be considered the primary measure of VMT within the portion of the non-attainment or maintenance area D-6-2 and for the functional classes of roadways included in HPMS, for urban areas which are sampled on a separate urban area basis. For areas with network-based travel models, a factor (or factors) may be developed to reconcile and calibrate the network-based travel model estimates of VMT in the base year of its validation to the HPMS estimates for the same period. These factors may then be applied to model estimates of future VMT. In this factoring process, consideration will be given to differences between HPMS and network-based travel models, such as differences in the facility coverage of the HPMS and the modeled network description. Locally developed count-based programs and other departures from these procedures are permitted subject to the interagency consultation procedures of §93.105(c)(1)(i).

Additionally, the preamble of 40 CFR, as amended by 62 FR 43790, August 15, 1997 contains some additional guidance:

EPA believes that network modeling requirements are most important for large urbanized areas....
EPA believes that network modeling is not always appropriate in rural or urban areas with smaller populations, and therefore, should not be required in these areas...

The conformity rule requires (40CFR 93.122c) areas that are already using network models to continue using them, even if they are not serious or above areas or have a population less than 200,000. EPA and DOT will consider the specific technical needs of smaller areas when developing future modeling guidance.

These regulations state that travel demand modeling is most important for urban areas with populations of greater than 200,000 and are not necessary for small or rural areas with less than 200,000 unless they are already using a travel demand model.

Federal Transit Administration Planning Regulations

The Federal Transit Administration (FTA) New Starts Program contains some additional requirements beyond those specified for metropolitan planning and conformity. The New Starts project application process requires user benefits to be developed from multimodal travel forecasts. A travel demand model with a fully functioning mode choice component is the accepted tool for satisfying this requirement. The New Starts requirements are specified in 49 CFR 611 (Appendix A):

Appendix A to Part 611—Description of Measures Used for Project Evaluation.
PROJECT JUSTIFICATION
FTA will use several measures to evaluate candidate new starts projects according to the criteria established by 49 U.S.C. 5309(e)(1)(B). These measures have been developed according to the considerations identified at 49 U.S.C. 5309(e)(3) ("Project Justification"), consistent with Executive Order 12893. From time to time, FTA has published technical guidance on the application of these measures, and the agency expects it will continue to do so. Moreover, FTA may well choose to amend these measures, pending the results of ongoing studies regarding transit benefit evaluation methods. The first four criteria listed below assess the benefits of a proposed new start project by comparing the project to the baseline alternative. Therefore, the baseline alternative must be defined so that comparisons with the new start project isolate the costs and benefits of the major transit investment. At a minimum, the baseline alternative must include in the project corridor all reasonable cost-effective transit improvements short of investment in the new start project. Depending on the circumstances and through prior agreement with FTA, the baseline alternative can be defined appropriately in one of three ways. First, where the adopted financially constrained regional transportation plan includes within the corridor all reasonable cost-effective transit improvements short of the new start project, a no-build alternative that includes those improvements may serve as the baseline. Second, where additional cost-effective transit improvements can be made beyond those provided by the adopted plan, the baseline will add those cost-effective transit improvements. Third, where the proposed new start project is part of a multimodal alternative that includes major highway components, the baseline alternative will be the preferred multimodal alternative without the new start project and associated transit services. Prior to submittal of a request to enter preliminary engineering for the new start project, grantees must obtain FTA approval of the definition of the baseline alternative. Consistent with the requirement that differences between the new start project and the baseline alternative measure only the benefits and costs of the project itself, planning factors external to the new start project and its supporting bus service must be the same for both the baseline and new start project alternatives. Consequently, the highway and transit networks defined for the analysis must be the same outside the corridor for which the new start project is proposed. Further, policies affecting travel demand and travel costs, such as land use, transit fares and parking costs, must be applied consistently to both the baseline alternative and the new start project alternative. The fifth criterion, "existing land use, transit supportive land use policies, and future patterns," reflects the importance of transit-supportive local land use and related conditions and policies as an indicator of ultimate project success.
(a) Mobility Improvements.
(1) The aggregate travel time savings in the forecast year anticipated from the new start project compared to the baseline alternative. This measure sums the travel time savings accruing to travelers projected to use transit in the baseline alternative, travelers projected to shift to transit because of the new start project, and non-transit users in the new start project who would benefit from reduced traffic congestion.
(i) After September 1, 2001, FTA will employ a revised measure of travel benefits accruing to travelers.
(ii) The revised measure will be based on a multi-modal measure of perceived travel times faced by all users of the transportation system.
(2) The absolute number of existing low income households located within 1/2-mile of boarding points associated with the proposed system increment.
(3) The absolute number of existing jobs within 1/2-mile of boarding points associated with the proposed system increment.
(b) Environmental Benefits.

(1) The forecast change in criteria pollutant emissions and in greenhouse gas emissions, ascribable to the proposed new investment, calculated in terms of annual tons for each criteria pollutant or gas (forecast year), compared to the baseline alternative;
(2) The forecast net change per year (forecast year) in the regional consumption of energy, ascribable to the proposed new investment, expressed in British Thermal Units (BTU), compared to the baseline alternative; and
(3) Current Environmental Protection Agency designations for the region's compliance with National Ambient Air Quality Standards.
(c) Operating Efficiencies. The forecast change in operating cost per passenger-mile (forecast year), for the entire transit system. The new start will be compared to the baseline alternative.
(d) Transportation System User Benefits (Cost-Effectiveness).
(1) The cost effectiveness of a proposed project shall be evaluated according to a measure of transportation system user benefits, based on a multimodal measure of perceived travel times faced by all users of the transportation system, for the forecast year, divided by the incremental cost of the proposed project. Incremental costs and benefits will be calculated as the differences between the proposed new start and the baseline alternative.
(2) Until the effective date of the transportation system user benefits measure of cost effectiveness, cost effectiveness will be computed as the incremental costs of the proposed project divided by its incremental transit ridership, as compared to the baseline alternative.
(i) Costs include the forecast annualized capital and annual operating costs of the entire transit system.
(ii) Ridership includes forecast total annual ridership on the entire transit system, excluding transfers.
(e) Existing land use, transit supportive land use policies, and future patterns. Existing land use, transit-supportive land use policies, and future patterns shall be rated by evaluating existing conditions in the corridor and the degree to which local land use policies are likely to foster transit supportive land use, measured in terms of the kinds of policies in place, and the commitment to these policies. The following factors will form the basis for this evaluation:
(1) Existing land use;
(2) Impact of proposed new starts project on land use;
(3) Growth-management policies;
(4) Transit-supportive corridor policies;
(5) Supportive zoning regulations near transit stations;
(6) Tools to implement land use policies;
(7) The performance of land use policies; and
(8) Existing and planned pedestrian facilities, including access for persons with disabilities.
(f) Other factors. Other factors that will be considered when evaluating projects for funding commitments include, but are not limited to:
(1) Multimodal emphasis of the locally preferred investment strategy, including the proposed new start as one element;
(2) Environmental justice considerations and equity issues,
(3) Opportunities for increased access to employment for low income persons, and Welfare-to-Work initiatives;
(4) Livable Communities initiatives and local economic activities;
(5) Consideration of alternative land use development scenarios in local evaluation and decision making for the locally preferred transit investment decision;
(6) Consideration of innovative financing, procurement, and construction techniques, including design-build turnkey applications; and
(7) Additional factors relevant to local and national priorities and to the success of the project, such as Empowerment Zones, Brownfields, and FTA's Bus Rapid Transit Demonstration Program.
LOCAL FINANCIAL COMMITMENT
FTA will use the following measures to evaluate the local financial commitment to a proposed project:
(a) The proposed share of project capital costs to be met using funds from sources other than the 49 U.S.C. 5309 new starts program, including both the local match required by Federal law and any additional capital funding ("overmatch"). Consideration will be given to:
(i) The use of innovative financing techniques, as described in the May 9, 1995, Federal Register notice on FTA's Innovative Financing Initiative (60 FR 24682);
(ii) The use of "flexible funds" as provided under the CMAQ and STP programs;
(iii) The degree to which alternatives analysis and preliminary engineering activities were carried out without funding from the §5309 new starts program; and

(iv) The actual percentage of the cost of recently-completed or simultaneously undertaken fixed guideway systems and extensions that are related to the proposed project under review, from sources other than the section 5309 new starts program (FTA's intent is to recognize that a region's local financial commitment to fixed guideway systems and extensions may not be limited to a single project).
(b) The stability and reliability of the proposed capital financing plan, according to:
(i) The stability, reliability, and level of commitment of each proposed source of local match, including inter-governmental grants, tax sources, and debt obligations, with an emphasis on availability within the project development timetable;
(ii) Whether adequate provisions have been made to cover unanticipated cost overruns and funding shortfalls; and
(iii) Whether adequate provisions have been made to fund the capital needs of the entire transit system as planned, including key station plans as required under 49 CFR 37.47 and 37.51, over a 20-year planning horizon period.
(c) The stability and reliability of the proposed operating financing plan to fund operation of the entire transit system as planned over a 20-year planning horizon.

VDOT's Role and Responsibility in Supporting Modeling

VDOT staff collectively maintains several urban Travel Demand Models and one statewide model. VDOT maintains two modeling groups. Both VDOT modeling groups work together to advance the practice of travel demand modeling within the state. The first staff is based in VDOT's Central Office location in Richmond and is responsible for establishing statewide modeling policies and procedures and for the development and maintenance of the statewide model and all urban travel demand models except those in the Northern Virginia Region. The Central Office is currently responsible for ten urban models located throughout the state, and the Virginia Statewide Model (VSM).

Table 2: Existing Urban Travel Demand Models Maintained by VDOT

Model Region	Area (Sq. Miles)	Number of TAZs
Northern Virginia[8]	6,482	1,972[9]
Hampton Roads	1,871	1,059
Richmond/Tri-Cities	1,792	979
Fredericksburg	1,394	878
Roanoke	216	224
Lynchburg	352	282
Charlottesville	212	246
Winchester	425	167
Blacksburg	155	207
Danville	197	181
Harrisonburg	106	174

The second staff is based in VDOT's Northern Virginia District Office location in Chantilly and is responsible for modeling in the Northern Virginia (NOVA) district. District staff work closely with the National Capital Region Transportation Planning Board (NCRTPB) to perform

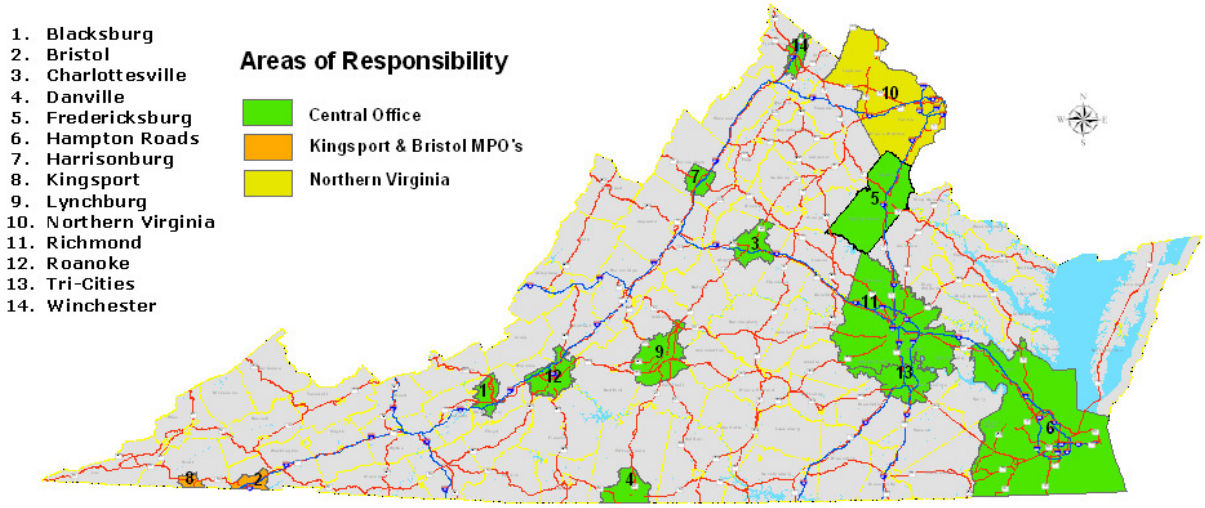
[8] Includes entire Northern Virginia modeling area: Virginia-West Virginia-Maryland-District of Columbia
[9] Northern Virginia Model uses NCRTPB TAZ structure for Trip Generation and Trip Distribution, but has a sub-zone system of 4,643 zones used for Trip Assignment.

modeling in the NOVA district. District staff also assist local governments with their modeling activities. Urban models maintained by VDOT staff are shown in Table 2 and Figure 2.

Purpose and Use of Policy and Procedures Manual

Virginia is currently the 12th most populous state with over 7.4 million population[10] and is experiencing rapid growth and increasing traffic congestion in many urban areas. As a result, the need for additional and more sophisticated models to serve Virginia's transportation planning requirements has grown in recent years. More development and congested travel has resulted in a greater need for consistency in model development and the requirement for guidelines on acceptable modeling practice. The purpose of this manual is to establish specific and uniform modeling policy and procedures for the state of Virginia for use in model development and application by VDOT, MPOs, PDCs, and their consultants. This manual applies to all models in the state of Virginia used for MPO planning activities with the exception of the three multi-state MPOs: National Capital Region Transportation Planning Board (NCRTPB), Bristol, and Kingsport. For the Northern Virginia District area, NCRTPB staff maintains the Washington, DC MPO model while Northern Virginia District Staff maintains the modeling tools used for subarea studies. The cities of Bristol, TN and Kingsport, TN each provide the support necessary to maintain the models in their respective MPO regions.

Figure 2: Virginia Travel Demand Modeling Regions by Areas of Responsibility



The policies and procedures documented in this manual are grouped into two categories: acceptable and recommended practice. Acceptable practice is the minimum standard for Modeling. **Acceptable practice applies to all existing Models and can apply to future Models if resources do not permit meeting recommended practice guidelines. Recommended practice is the preferred standard of practice and should apply to all future model updates if resources permit.**

[10] 2004 Census Bureau estimate is 7,460,000. 2000 Census was 7,078,000.

Additionally, a distinction between small and large model regions is made for both acceptable and recommended practice. Small model regions are model regions with less than 500,000 population which do not overlap with any large model region. Large model regions are (1) metropolitan statistical areas (MSAs) of population greater than or equal to 500,000 or (2) have at least 200,000 population and are part of a MSA with a population of more than 500,000.

Table 3 displays the existing small and large model regions in Virginia. All large model regions have more than 500,000 population with the exception of Fredericksburg which is included in the large category because it is part of the MSA for Washington, DC.

Table 3: Existing Small and Large Model Region in Virginia

Small Model Regions < 500,000	Large Model Regions > 500,000
Roanoke	Northern Virginia
Lynchburg	Hampton Roads
Charlottesville	Richmond/Tri-Cities
Winchester	Fredericksburg[11]
Blacksburg-Christiansburg	
Danville	
Harrisonburg	

[11] Fredericksburg had a 2000 population of 241,000 and is classified as large because it is part of the Washington, DC MSA.

2. Travel Demand Model Usage in Virginia

This chapter describes the general usage of travel demand models in Virginia.

Purpose and Need of Modeling in Transportation Planning Analysis

Modeling can be a useful technical tool in many types of transportation planning analyses. Some examples of modeling usage are:

1. Evaluate Transportation System Performance
2. Long Range Transportation Planning, e.g., MPO area, State Plan
3. Short Range Transportation Planning, e.g., TIP, SYIP
4. Support Air Quality Conformity Analysis
5. Support Alternative Analysis

Travel Demand Models can also be costly to develop, apply, and maintain. Planning agencies considering developing a model should carefully weigh the development and maintenance costs. For small urban areas, other technical and sketch planning tools for traffic forecasting should be considered before creating a model.

Modeling Software

The official software platform for model usage in Virginia is Citilabs' CUBE Base and CUBE Voyager. The preferred model setup using this software is the CUBE catalog format.

Type of Model Needed

As stated in chapter one, the most common type of modeling used in transportation planning applications is the traditional 4-step approach. If a traditional model does not have a mode choice component, it is sometimes called a 3-step model. Other approaches such as tour based models, activity based models, and advanced disaggregate models such as those employed by the TRANSIMS software also exist and are currently the subject of much research and development. The type of model selected for a transportation planning application should meet the transportation planning needs and policy directions for the study area while being cost effective and practical for study area applications. At this time, a standard 3 or 4 step model or advanced traditional 4-step model are the preferred approaches for model applications in Virginia. More sophisticated approaches may become acceptable or preferred in the future as they become more developed and widely accepted by the transportation planning community.

Model Specification

Model specification refers to the features and capabilities of a given model component. Model components should be specified to meet the transportation planning needs for the study area in the foreseeable future while being cost effective and practical for application. For example, a sophisticated mode choice model able to analyze the impacts of tolls, HOV lanes, and various transit options makes good sense for a large urban area, but probably does not make good sense for a small urban area with limited transit and no foreseeable toll or HOV lanes.

Model Improvement Process

Model improvement includes a broad range of different types of model changes from creating new models to correcting minor errors with model inputs and scripts. VDOT's two modeling groups: Central Office and Northern Virginia are each responsible for any model improvements to the models that their respective staff maintain. This section classifies model improvement into the three categories shown in Table 4: model development, major revision, and minor revision. Table 4 also shows the scope, frequency, and examples of each type of model improvement. The list of examples is not an exhaustive list, but rather a representative sample.

Table 4: Classification of Type of Model Improvement

Type of Model Improvement	Scope	Frequency	Examples
Model Development	Changes to structure which require extensive calibration and validation	At least once every 10 years	Recalibrate model based on new survey data New trip generation model New trip distribution model New mode choice model New trip assignment model
Major Revision	Adding modules or revising inputs or parameters with only minimal changes to structure. Some calibration and validation may be required.	Review for need at least once every 5 years and perform as necessary	New BPR Curve New Speeds/Capacities New Trip Purpose New Truck Model New Toll Model New GIS based Network New Occupancy Rates New Trip Rates
Minor Revision	Minor changes to correct errors and update model inputs and files based on the latest assumptions. Some validation may be required.	Review for need annually and perform as necessary. Should be performed in advance of major model applications.	Correcting a Land Use error Correcting a Network error Correcting a minor error in a model script Updating a network based on revised short term plan assumptions

Model Development

Model development is large scale in scope and stems from either the creation of new models or redevelopment of existing models. Model development involves extensive calibration and validation efforts based on recent survey data sources. It is undesirable for a base year model validation to extend beyond a ten-year horizon due to likely changes in trip making characteristics and new demographic trends and growth patterns, especially in larger urban areas and rapidly growing regions. Model development must occur at least once every ten years and should be coordinated with the availability of major federal data sources such as the Census, Census Transportation Planning Package (CTPP), and survey data. Model development should also include updated data inputs, TAZ structure, AWDT counts, and model parameters for each step of the modeling process as appropriate. Model development can be extremely time consuming and require extensive data collection and analysis. As such, it is highly undesirable to combine model development efforts with other transportation planning activities. **The timing of model development efforts should not coincide with or occur immediately before major model applications**.

Major Revision

Major revisions are medium scale in scope and include adding new modules to existing models, e.g., new truck model, or extensively revising model inputs or parameters, e.g., network, occupancy rates, etc. Major revisions can result in some minor changes to model structure and some calibration and validation. The major differentiation between major revisions and model development is that major revisions do not result in significant changes to model structure whereas model development does.

Models should be reviewed by the VDOT project manager at least once every five years from the most recent model development effort to determine if a major revision is needed before the next model development effort. Major revisions should be performed as needed.

All model regions should have a model update at least once every five years, that at a minimum, incorporates updated land use, AWDT counts, and transportation networks. Model updates should be completed as part of large scale model applications such as MPO long range plans and corridor studies. By the conclusion of the MPO long range planning process, model transportation networks and other components should be updated based on the adopted long range plan.

Minor Revision

Model revisions are small updates to model inputs and files needed to correct minor errors, e.g., network, land use, etc., or changes in model assumptions, e.g., projects included in short range plan change. The VDOT project manager should maintain a continuous list of minor changes that need to be included in the next model revision. The VDOT project manager should review this list annually and review known upcoming model applications. If a major model application is coming up in the next year, a minor revision should be performed on the model in advance of the upcoming application. Examples of major model applications include:

1. MPO Long Range Plan: CLRP
2. MPO Short Range Plan: TIP
3. Air Quality Conformity
4. Project Studies

If no major model application is coming up in the next year, the project manager should make a judgment on whether or not the revision is needed at that particular time.

Version Naming System for Model Improvements

The Virginia version naming system for the three types of model improvements documented in the previous section is illustrated in the example in Table 5. Model development is the most major type and consequently occurs the least frequently. Model development initiates a new version name with this format: "Base" "Year" Version 1.0. For example, a new model created with a 2000 base year would be called Base 2000 Version 1.0. Major revisions and minor revisions can not change the base year, but alter the version number. A major revision causes the version number to increase to the next integer. For example, a major revision to the Base 2000 Version 1.01 model, would result in a new model called Base 2000 Version 2.0. Minor revisions simply increase the version number in increments of one hundredth. For example, a new minor revision to the Base 2000 Version 1.0 model, would result in a new model called Base 2000 Version 1.01. Table 5:

Table 5: Example of Version Naming System for Types of Model Improvements

Type of Model Improvement	Original Base Year	Year of Model Improvement	Version Names
Model Development	2000	2002	Base 2000 Version 1.0
Minor Revision	2000	2003	Base 2000 Version 1.01
Major Revision	2000	2005	Base 2000 Version 2.0
Minor Revision	2000	2007	Base 2000 Version 2.01
Minor Revision	2000	2008	Base 2000 Version 2.02
Major Revision	2000	2009	Base 2000 Version 3.0
Minor Revision	2000	2010	Base 2000 Version 3.01
Model Development	2010	2012	Base 2010 Version 1.0
Minor Revision	2010	2014	Base 2010 Version 1.01

Request Process

If a VDOT district, MPO, or PDC desires that a model serving their area undergo model development, major revision, or minor revision, they should contact the appropriate VDOT staff member to discuss their needs. A list of staff contacts for the different modeling areas in Virginia is shown in the Staff Modeling Contacts section of the Appendix.

Creation and Expansion of Models

If a VDOT district, MPO, or PDC that is not served by any existing model desires that a new model be created for their planning area, they should first contact the VDOT to discuss their needs. If the planning area is adjacent or close to an existing model, it is preferable to expand the existing model to include the additional planning area. For rural areas, transportation planning needs could potentially be addressed through the use of the Virginia Statewide Model (VSM) or other technical tools.

For instances where a VDOT district, MPO, or PDC desires that an existing model be expanded to include a new area these guidelines exist:

1. Expansion should only include entire jurisdictions.
2. Data needed to support the model expansion should be available using existing funding and resources.
3. New jurisdictions added to the model should be within the state limits of Virginia unless approval is obtained from MPOs, local jurisdictions, and State DOTs affected in any of the states or districts adjacent to Virginia: West Virginia, Kentucky, Tennessee, North Carolina, Maryland, or the District of Columbia.

Requesting Travel Demand Model Data and Files

Travel Demand Model data and files can be requested from VDOT staff using the Travel Model Data Request Form

Model data and files cannot be obtained without filling out this form. This form is available on the VDOT intranet site and is in the Appendix of this document. For questions regarding this process, contact the VDOT .

3. Data Inputs

This chapter describes the policies and procedures for developing data inputs for models in Virginia. After a brief introduction to the data development process, this chapter describes acceptable and recommended practice for travel demand modeling.

Introduction

Problems and errors with data inputs are the most common source of errors in travel demand forecasts. When performing model development and application, it is imperative that a careful and comprehensive examination of all the data inputs to the travel demand forecasting process be made and approved by the designated VDOT project manager before being used in travel demand modeling. These data inputs include, but are not limited to:

1. Transportation Analysis Zone (TAZ) Structure
2. Land Use Data
3. Transportation Networks and Centroid Load Points
4. Household Travel and Other Types of Surveys
5. Traffic Counts

Additionally, consultants performing modeling work for VDOT may be asked to review or revise data inputs to the travel demand modeling process if model results do not appear to be reasonable during model calibration or validation.

Transportation Analysis Zone (TAZ) Structure

Table 6: Transportation Analysis Zone Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended	
	Small	Large	Small	Large
Boundaries	Census 2000	Census 2000	Census 2000	Census 2000
Numbering	Sequentially nested within jurisdiction to the greatest extent possible	Sequentially nested within jurisdiction to the greatest extent possible	Sequentially nested within jurisdiction	Sequentially nested within jurisdiction
Number of TAZs	N/A	N/A	One per 1,000 population	One per 1,000 population
Average TAZ size (for non-external stations)	N/A	N/A	< 10,000 Trips/TAZ	< 15,000 Trips/TAZ
Maximum size of a TAZ[12] (for non-external stations)	< 50,000 Trips/TAZ	< 50,000 Trips/TAZ	< 25,000 Trips/TAZ	< 25,000 Trips/TAZ
Inclusion of a roadway as an External Station TAZ	Regionally significant and has an ADT of at least 500	Regionally significant and has an ADT of at least 1,000	Regionally significant and has an ADT of at least 500	Regionally significant and has an ADT of at least 1,000

Boundaries

TAZ boundaries must follow the census geography for the most recently completed census year. Preferably, TAZs should follow block group boundaries and be block groups or combinations of block groups. In some instances, however, it is necessary to create TAZ geography at a sub-block group level. In these instances, TAZ geography must follow block boundaries and be a combination of census blocks. Areas with high employment, but relatively low population and fast growing suburban areas will most likely have block group sizes too large for TAZs since census geography is primarily based on past population.

Numbering

It is highly desirable to number TAZs sequentially within jurisdiction for ease of use. It is acceptable practice to have TAZs sequentially numbered within jurisdiction to the greatest possible extent. Exceptions to sequential numbering should be documented. It is recommended that all model regions adopt a numbering scheme for their TAZs that are sequentially nested within jurisdiction with external stations being numbered at the end. A gap range should be left in the numbering between jurisdictions so that additional TAZs can be added without disrupting

[12] Exceptions to this policy should be documented carefully.

the overall numbering system. Table 7 shows an example of the recommended TAZ numbering system versus a system that is not acceptable.

Table 7: TAZ Numbering Recommended Versus Not Acceptable Practice

Jurisdiction Number	TAZ Numbering	
	Recommended Practice	Not Acceptable Practice
033	1-75	1-33, 111, 124, 167-179, 197, 318-326, 333, 411-412, 462-475
038	100-159	34-56, 104-110, 112-123, 180-196
043	200-254	57-93, 125-128, 327-332, 334, 346-351
046	300-402	94-96, 129, 211-224, 234-248, 267-279, 404-410, 413-461
051	500-585	99, 101, 197-210, 370-403, 467-501
Externals	600-623	465-466, 502-523

Number for a Model Region

Having more TAZs in a model is always desirable, but is not always practical due to computational or technical constraints. For example, doubling the number of TAZs for a model from 100 to 200 causes the number of cells in matrices for the model, e.g., skims, to increase four fold from 10,000 to 40,000. In general with today's computers, once a model has over 1,000 TAZs it becomes so large that it cannot be run quickly. Complex models such as that for Washington, DC with its 1,972 TAZs[13] can take a full day to run. The New York City model with its approximately 3,500 TAZs can take almost a full week to run. As a result, there needs to be a balance between adding TAZs and being able to run the model in a reasonable length of time.

The traditional heuristic guideline for the number of TAZs for a modeling region is one for every 1,000 population. For example, a small urban area with 200,000 population would be expected to have at least 200 TAZs. A medium urban area of 1,000,000 population would be expected to have at least 1,000 TAZs. In practice, this guideline works best for medium sized urban areas. For small urban areas, more TAZs are generally needed than this guideline. For large urban areas this guideline is often not feasible given the need to be able to run the model in a reasonable time.

Average TAZ Size

In modeling, it is important to have a TAZ structure that is homogeneous to the greatest extent possible to ensure consistency in the modeling process. TAZs should be homogeneous in terms of land use, e.g., population, employment, etc., and number of person trips. GIS can be a useful tool to check for homogeneity in population, employment, and other land use variables by TAZ. Additionally, it is important to check for TAZ homogeneity with regard to person trips, e.g., trip

[13] This figure is the number of internal TAZs. The maximum TAZ number for the NCRTPB model is 2,191.

productions or trip attractions. TAZs with person trips that are much higher or lower than the regional average can adversely affect model results. As a result it is desirable to keep average TAZ size within reasonable limits. For all small model regions, it is recommended practice that average TAZ size should not exceed 10,000 person trips per non-external station TAZ. For large model regions, average TAZ size should not exceed 15,000 person trips per non-external station.

Maximum Size of a TAZ

In modeling, it is important to avoid having TAZs with extremely large numbers of trips to the greatest extent possible. For all model regions, it is acceptable practice that individual TAZ size not exceed 50,000 trip production or trip attractions per non-external station TAZ. It is recommended practice that individual TAZ size not exceed 25,000 trips per non-external station TAZ. Exceptions to these practices should be documented and should only be permissible for TAZs which cannot be split due to institutional or census geography constraints. Institutional constraints generally exist at large government facilities that cannot be subdivided, e.g., prisons, military bases, pentagon, etc. Additionally, census geography can limit or prevent TAZ splits in urban areas particularly in and around Central Business Districts (CBD).

Inclusion of a Roadway as an External Station

The decision on whether or not to include a roadway as an external station should depend on the roadway's regional significance and traffic volume. For a roadway to be regionally significant as an external station, its inclusion must have a significant impact on a model's forecast volumes over a large section of the model. It is acceptable and recommended practice for all model regions that external station locations be regionally significant and have an ADT volume of at least 500 for small urban areas and 1,000 for large urban areas.

Land Use Data

Table 8: Land Use Practice for Virginia Travel Demand Models*

Component	Acceptable		Recommended	
	Small	Large	Small	Large
Responsibility	Local Agencies	Local Agencies	Local Agencies and VEC control totals	Local Agencies and VEC control totals
Employment classification system	SIC	SIC	NAICS	NAICS
Employment/Labor Force Ratio	< 1.15	< 1.15	< 1.15	< 1.15
Land Use Density Methodology	N/A	N/A	Yes, at least 3 classifications	Yes, at least 3 classifications

*Washington, DC MPO Region is exempt from this guideline.

Responsibility

It is acceptable and recommended policy that local agencies be responsible for the land use base year and forecast data necessary for travel demand forecasting. This data should be consistent with local land use plans and zoning as well as accepted sources such as the US Census Bureau and the established Virginia Employment Commission (VEC) population control totals.

Employment Classification System

Employment types used in trip generation should be defined in terms of a known industrial classification system. It is acceptable practice for all model regions to use employment data and forecasts based on the 1987 U.S. Standard Industrial Classification (SIC) system. The SIC system has recently been replaced by the North American Industry Classification System--United States (NAICS) as a result of the NAFTA agreement to promote greater consistency and comparability in business statistics between Mexico, Canada, and the United States. As a result, it is recommended practice that new models in all model regions adopt the NAICS employment classification system. The NAICS definitions for the various employment types, e.g., retail, non-retail, industrial, etc., should follow accepted practice for land use forecasting.

Employment/Labor Force Ratio

For all model regions, it is important that demographic data for employment and labor force be consistent with one another. Employment is defined as the number of jobs forecast for a model region while labor force is defined as the number of able, working age, workers for a model region. Labor force should generally be higher than employment for model regions that are not importing large numbers of workers. For model regions which import large amounts of employment the ratio of employment to labor force should not exceed 1.15. Discrepancies may be minimized by improving employment forecasts, or by enlarging the model region.

Land Use Density Methodology

Land Use Density (LUD) is defined as a classification system for designating different land use types in a model region. LUD is a function of employment and population density and is commonly used in travel demand modeling in trip generation and for look up tables for network attributes, e.g., speed, capacity, etc. It is acceptable practice for model regions not to use a LUD methodology in their travel demand models. It is recommended practice that at a minimum, all model regions adopt a LUD system that contains at least three classifications: Central Business District (CBD), Suburban, and Rural. Large model region should consider additional classifications. An example for Richmond is shown in Table 9. A recommended density formula for determining LUD is shown in Figure 3:

Figure 3: Recommended Land Use Density Formula

$$LUD_i = \frac{Households_i + (Employment_i * (K))}{Area_i (acres)}$$

where LUD_i = *Land Use Density for TAZ i*
K = Ratio of regional households divided by regional employment (scales employment to households)

Table 9: Example Land Use Density System for Richmond, VA

LUD	Description	General Parking Situation	Richmond Area Example
1	Central Business District (CBD) = Most Dense	Scarce and sometimes costly	Downtown Richmond and Petersburg
2	Urban	Limited	Fan and Church Hill
3	Exurban (Dense Suburban)	Adequate	Munford and Near West End
4	Suburban	Abundant	Glen Allen and Midlothian
5	Rural = Least Dense	Abundant	Goochland and Hanover counties

Transportation Networks and Centroid Load Points

Transportation networks and centroid load points are very important inputs to the travel demand forecasting process. Transportation network and centroid load point development must be coordinated with Metropolitan Planning Organizations (MPOs) and their member jurisdictions. MPOs and their member jurisdictions are responsible for reviewing transportation networks for their areas and submitting written comments to VDOT listing recommended changes. VDOT's Traffic Monitoring System (TMS) is a good source for highway network data. Regional transit agencies such as the Greater Richmond Transit Corporation (GRTC) in Richmond should be contacted for transit network data. Field inventory surveys may be taken if data is not readily available from existing data sources and with the approval of the VDOT project manager.

When developing travel demand models, the following transportation networks must be created for all model regions:

1. Base Year
2. Existing and Committed (E&C)
3. Constrained Long Range Plan (CLRP)

Additionally, for model regions requiring air quality conformity analysis, additional interim transportation networks may be required. Other networks such as Vision Long Range Plan (VLRP) and interim years other than those prepared for by air quality conformity, are not required. Acceptable and recommended practice for highway networks is shown in Table 10 and for transit networks in Table 15.

Highway Networks

Table 10: Highway Network Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended	
	Small	Large	Small	Large
Extent of Roadway Representation	Major Collector and above	Major Collector and above	Minor Collector and above	Minor Collector and above
Representation of roadway dualization, ramps, and interchanges	None	None	Yes	Yes
Centroid Connector Placement	Placement done using GIS	Placement done using GIS	Placement done using GIS	Placement done using GIS
Turning Penalties	Yes, where applicable	Yes, where applicable	Yes, where applicable	Yes, where applicable
Link Distances	N/A	N/A	State Database	State Database
Input Speeds	Free-flow speed		Free-flow speed based on look up table	
Roadway Capacities	Current HCM LOS E based on look up table		Current HCM LOS E based on look up table	
Link Variables	N/A	N/A	See list in discussion	See list in discussion

Extent of Roadway Representation
It is acceptable practice for all model regions to consistently include major collectors and all higher functional classes in their transportation network. Minor collector and local roads can also be included as needed.

It is recommended practice that all model regions consistently include all non-local roadways, e.g., minor collectors and all higher functional classes, in their transportation network. Local roadways should also be included as needed, but are not required to be consistently included in the network.

Representation of Roadway dualization, ramps, and interchanges
It is acceptable practice for all model regions to not represent roadway dualization, ramps, and interchanges in their transportation networks. It is recommended practice that all model regions include this level of detail in their networks to the greatest extent feasible. Dualization should be generally restricted to controlled access facilities such as freeways and major roadways with interchanges.

Centroid Connector Placement
For all model regions GIS should be used to assist in the process of placing centroid connectors on the transportation network. Aerial photography and other land use GIS layers should be used

as needed to identify logical access points for centroid connectors. While TAZs should generally have at least two centroid connectors to provide adequate access to the highway network, there are some situations where only one centroid connector is appropriate.

Turning Penalties
For all model regions, it is acceptable practice to have no turning penalties. It is recommended practice for all model regions that turning penalties be included in the model where applicable.

Link Distances
For all model regions, it is acceptable practice to use existing "previously coded" distances in modeling. It is recommended, however, that all model regions use GIS tools to more accurately determine link distances.

Input Speeds
For all model regions, it is acceptable to use free flow speeds as the basis for the input speeds used by the modeling process. Acceptable data sources for input speeds are speed limits and speed studies.

It is recommended practice that all model regions use speed lookup tables as the basis for input speeds. Speed lookup tables can be developed from speed limits or available speed data. Speeds should be assigned to each facility type in the network using the established speed lookup table for that particular region. The facility types should correspond to those shown in Table 14. A fictitious example of a speed lookup table with five land use density classifications is shown in Table 11.

Table 11: Example Speed Lookup Table

Facility Type	Land Use Density (LUD) Speeds (mph)				
	1	2	3	4	5
Interstate/Principal Freeway	55	58	62	65	68
Minor Freeways	50	55	58	60	62
Principal Arterial/Highway	25	28	35	43	50
Major Arterial/Highway	25	28	33	40	45
Minor Arterial/Highway	25	28	30	35	40
Major Collector	25	25	28	32	35
Minor Collector	25	25	28	30	30
Local	25	25	25	30	30
High Speed Ramp	50	55	58	60	62
Low Speed Ramp	20	20	25	25	25
Centroid Connectors	15	15	20	25	25
External Station Connector	25	25	25	25	25

Roadway Capacity
For all model regions, it is acceptable and recommended practice to use the most recent version Highway Capacity Manual (HCM) as the basis for roadway capacities. It **is not acceptable** to

use older versions of the HCM or arbitrary figures for roadway capacities. Roadway capacities should be assigned to each facility type in the network using the established capacity lookup table for that particular region. The facility types should correspond to those shown in Table 14. It is both acceptable and recommended practice that all capacities be Level of Service (LOS) E. An example of a fictitious capacity lookup table with five land use density classifications is shown in Table 12.

Table 12: Example Capacity Lookup Table

Facility Type	Land Use Density (LUD) Capacities (Vehicles/lane/hour)				
Interstate/Principal Freeway	1,600	1,800	2,000	2,100	2,200
Minor Freeways	1,600	1,700	1,800	1,900	2,000
Principal Arterial/Highway	1,200	1,300	1,400	1,500	1,600
Major Arterial/Highway	1,100	1,150	1,200	1,300	1,400
Minor Arterial/Highway	1,000	1,050	1,100	1,150	1,200
Major Collector	800	850	900	950	1,000
Minor Collector	700	750	800	850	900
Local	600	650	700	750	800
High Speed Ramp	1,600	1,700	1,800	1,900	2,000
Low Speed Ramp	1,400	1,500	1,600	1,700	1,800
Centroid Connectors	10,000	10,000	10,000	10,000	10,000
External Station Connector	100,000	100,000	100,000	100,000	100,000

Link Variables

It is acceptable practice for all model regions to not include a standard list of link variables. It is recommended practice for all model regions, to use the list of link variables shown in Table 13 for their next major revision. This list represents the minimum required link input variables necessary for the modeling process. If data **is not** available for a particular variable, e.g., number 19 Screenline Identifier, the variable should still be included and populated with null values. **It is important to note that a "zero" value should never be substituted in place of a null value.** Link output variables are discussed later in this document in chapter eight. Model regions may store additional link input variables in their transportation networks as needed or desired. All additional link variables must be reviewed and approved by the VDOT project manager prior to being used in any model.

Several link attributes have only a certain set of potential values. For the FACTYPE link attribute, these values are shown in Table 14. Set values also exist for the link attributes shown below. Model developers should contact the VDOT project manager to obtain the appropriate values for each link attribute.

1. MPO_ID
2. FEDFUNC
3. LANDUSE
4. HWYSYS
5. HOVTYPE
6. TOLLTYPE

Additionally, link attributes have specific formats they must be in as shown in the description and data type columns of Table 13. A few other notes concerning link attributes also warrant mention. For TOLLCOST link attribute, the cost must be in base year dollars for all possibilities.

For the SCREEN_ID link attribute, the format is character (1). The purpose of this attribute is to serve as a flag for links that are part of a screenline, cutline, or cordon line. This attribute is not intended to identify individual screenlines, cutlines, or cordon lines from one another. VDOT maintains a separate database file which lists the Link A and B nodes for all screenline, cutline, and cordon line links for every model region.

Table 13: Recommended Link Attributes for Virginia Travel Demand Models[14]

No.	Link Variable	Description	Data Type	Need
1	ANODE	Beginning node of model network link	Character	Model uses
2	BNODE	Ending node of model network link	Character	Model uses
3	MPO_ID	Identifier for which MPO region	Character(4)	Reporting
4	JURIS_NO	VDOT's city/county jurisdiction code	Character(3)	Reporting
5	RTE_NO	Official State highway route # (Federal Aid Number)	Character(5)	Network Coding
6	RTE_NAME	Local street name (911)	Character	Network Coding
7	DISTANCE	Highway Link distance in miles	Numeric(4,2)	Model uses
8	LANES	Number of DIRECTIONAL through lanes	Numeric(1)	Model uses
9	FACTYPE	Facility Type used for Modeling Only	Character(2)	Model uses
10	FEDFUNC	Federal functional class	Character(2)	Reporting
11	LANDUSE	Land use ID	Character(3)	Reporting
12	HWYSYS	Highway System ID (5 possibilities)	Character(1)	Reporting
13	POST_SPD	Posted Speed Limit in miles per hour (mph)	Numeric(2)	Network Coding
14	SPDCLASS	Speed class code from speed lookup table for the region	Numeric(2)	Model uses
15	CAPCLASS	Capacity class code from capacity lookup table for the region	Numeric(4)	Model uses
16	HOVTYPE	Identifier for special types of HOV Roadway	Character(1)	Model uses
17	TOLLTYPE	Identifier for special types of Toll Roadway	Character(1)	Model uses
18	TOLLCOST	Official cost to enter tolled facility	Numeric(2,2)	Model uses
19	SCREEN_ID	Screenline Identifier	Character(1)	Reporting
20	PROJ_YR	Estimated year highway project open for traffic	Character(4)	Network Coding
21	CNT_STA	Count Station ID (TMS Linked)	Character(5)	State Database Connection
22	JRSTAG	Jurisdiction Tag ID	Character(11)	State Database Connection
23	RTE_ID	HTRIS Route ID	Character(14)	State Database Connection
24	BEGIN_MP	Beginning Mile point of a link	Character(5,2)	State Database Connection
25	END_MP	Ending Mile point of a link	Character(5,2)	State Database Connection
26	CNT_VOL	Observed 24 hour AWDT count for Base Year	Numeric(6)	Reporting
27	CNT_YR	Base Year that count has been adjusted to	Numeric(4)	Reporting

[14] Colors represent the function of the network attribute in the model system

Table 14: Required FACTYPE Link Attribute Values for Virginia Travel Demand Models

FACTYPE	Brief Description	Additional Description	Example
1	Interstate/Principal Freeway	Controlled Access	I-95, I-81, VA 76: Powhite Pkwy. (Richmond)
2	Minor Freeway	Controlled Access; Not necessarily built to Interstate standards	Chippenham Pkwy (Richmond)
			US 29 Bypass (Danville)
			George Washington Pkwy (NOVA)
3	Principal Arterial/Highway	Limited Access, Multilane Divided	US 301 N. of Bowling Green, US 360
4	Major Arterial/Highway	Highway with Posted Speed ≥ 50 mph or a Multilane Arterial	US 33, Monument Ave. (Richmond)
5	Minor Arterial/Highway	Highway with Posted Speed < 50 mph or a Single lane Arterial	Huguenot Rd. Bridge, Three Chopt Rd. (Richmond)
6	Major Collector	Posted Speed ≥ 35 mph; Some through traffic	VA 655: Beach Rd. Pump Rd. (Richmond)
7	Minor Collector	Posted Speed < 35 mph; Little through traffic	Most Smaller City/Suburban/Rural Streets
8	Local	Only serves local traffic	Local City/Subdivision Streets
9	High Speed Ramp	Posted Speed ≥ 45 mph	Interstate to Interstate Ramps
10	Low Speed Ramp	Posted Speed < 45 mph	Most Interstate to Non-Interstate Ramps
11	Centroid Connector		
12	External Station Connector		

Transit Networks

Table 15: Transit Network Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended	
	Small	**Large**	**Small**	**Large**
Representation in the Network	No	Yes	No	Yes
Modes Included	N/A	All intraregional fixed guide way and major bus routes	N/A	All intraregional fixed guide way and major bus routes. Other modes if regionally significant.
Network Travel Speeds and Times	N/A	From schedule for fixed guide way. From highway network for modes in mixed traffic.	N/A	From schedule for fixed guide way. From highway network for modes in mixed traffic.
Representation of Walk and Drive Access to Transit	N/A	Yes	N/A	Yes
Representation of Park and Ride Lots	N/A	No	N/A	Yes, for facilities served by transit included in the model.

Representation in the Network

It is acceptable and recommended practice for small model regions to not include transit representation in their transportation network. For large model regions, it is both acceptable and recommended practice to include transit representation in their transportation network.

Modes Included

For large model regions, it is acceptable practice to include all intraregional fixed guide way and major bus routes including commuter rail services. It is recommended practice to include additional modes, e.g., special bus, ferry, etc., if they are regionally significant. To be regionally significant in this context, the model must meet one of the following conditions:

- Comprises at least 1% of regional trips
- Comprises at least 1% of home-based work trips
- Comprises at least 10% of transit trips
- Accounts for at least 10,000 daily trips

Network Travel Speeds and Times
For large model regions, it is both acceptable and recommended practice to determine network travel speeds from schedules for fixed guide way facilities and from the highway network for modes in mixed traffic, e.g., buses.

Representation of Walk and Drive Access to Transit
For large model regions, it is both acceptable and recommended practice to include walk and drive access to transit.

Representation of Park and Ride Lots
For large model regions, it is acceptable practice to not represent Park and Ride lots in the transportation network. It is recommended practice that Park and Ride lots served by transit be included in the model. Major Park and Ride lots used by travelers may be included if they are regionally significant, e.g., facilities used by commuters in northern Virginia near HOV facilities. Small Park and Ride lot facilities used exclusively for carpooling are generally not worth including in the modeling process. If Park and Ride trips are included in the modeling process, they should comprise a separate trip table and be assigned to the highway and transit network.

Surveys

Table 16: Survey Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended	
	Small	Large	Small	Large
Household Travel Survey Data	No	No	Yes, every 10 years	Yes, every 10 years
Transit On Board Survey Data	No	Develop from Section 15 FTA Reporting	No	Yes, every 10 years
External Origin-Destination Survey	No	No	No	Yes, every 10 years
Truck Survey	No	No	No	No
Tourist Survey	No	No	No	Yes, every 10 years if regionally significant
Special Generator Survey	No	No	On a limited basis as needed	On a limited basis as needed

Household Travel Survey Data

It is acceptable practice for all model regions not to have a current Household Travel Survey (HTS). A HTS is an important data source for determining travel behavior in urban areas. Since HTS are costly to perform and mostly benefit large urban areas, it is recommended practice for large model regions to conduct a HTS once every ten years. It is also recommended practice to conduct HTS for small model regions at least once every ten years, however, if resources are scarce, large model regions should be given the priority over small model regions in having HTSs performed. The timing for a HTS should coincide with a model validation and the release of new census data. If resources are not available to conduct HTS for small model regions, these regions are encouraged to use survey information from accepted national data sources such as NCHRP 365 or NHTS or use parameters transferred from similar areas. Use of national data or transferred parameters should be approved by the VDOT project manager.

Transit On Board Survey Data

Transit On Board Surveys are important data sources for model regions where transit usage is regionally significant. It is acceptable practice for all model regions not to have a current Transit On Board Survey. For small model regions, a Transit On Board Survey **is not** recommended practice since transit usage is generally not regionally significant. For large model regions, it is acceptable practice to develop transit survey data from boarding and alighting surveys conducted in connection with Section 15 reporting that transit agencies are required to do for the Federal Transit Administration (FTA). For large model regions, it is recommended practice to conduct a

Transit On Board Survey once every ten years in conjunction with a model validation, provided sufficient resources exist.

External Origin-Destination Survey

It is acceptable practice for all model regions not to have a current External Origin-Destination Survey. It is recommended practice for large model regions to conduct a new survey every ten years in conjunction with a model validation. The survey should only be conducted for external stations serving major roadways: interstates, freeways, and major arterials. Minor arterials and other roadways should only be surveyed if they have an AWDT greater than 5,000. For small model regions, an external survey **is not** recommended practice.

Truck Survey

Because of the difficulty and high cost associated with conducting truck surveys, it **is not** accepted or recommended practice to conduct truck surveys for all model regions. Instead, it is recommended that truck and commercial vehicle models be developed using matrix estimation techniques based on classified count data.

Tourist Survey

It is acceptable practice for all model regions to not have a current Tourist Survey. For large model regions, it is recommended practice to conduct a tourist survey if tourist trips are "regionally significant" to regional travel behavior. A tourist survey can be used as a data source for developing seasonal variation in a model. The following criteria should be met in order for a model region to establish that tourist travel is regionally significant:

1. Contains at least one major international airport
2. Contains at least one major tourist attraction that attracts over 100,000 visitors per year.
3. A high percentage of the perceived tourist travel comes from outside the model region.
4. Tourist travel is significant year round and is not limited to certain months or seasons.

Special Generator Survey

Special generators should be reserved for trip generators with significant trip making that cannot be readily captured in the standard trip generation modeling process. It is acceptable and recommended practice for small model regions to not conduct any special generator surveys. It is also acceptable practice for large model regions to not conduct any special generator surveys. It is recommended that large model regions conduct special generator studies on a limited basis as needed. The following should be used for determining if a special generator is appropriate:

- Candidate special generator should be an identifiable location where cordon counts can be readily conducted.
- Candidate special generator should be for a location where traffic is missing on a daily basis throughout the entire year.
- Research has documented that model is underreporting trips for the location by at least 50,000/day.

Traffic Counts

Table 17: Traffic Count Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended	
	Small	Large	Small	Large
Primary Count Source	VDOT TMS	VDOT TMS	VDOT TMS	VDOT TMS
Count Adjustment	Yes	Yes	Yes	Yes
Non-Centroid Count Coverage	N/A	N/A	20% of Links	10% of Links
Screenline, Cordon Line, and Cutline Count Coverage	N/A	N/A	10% of Links	5% of Links
Systematic Count Program	Yes	Yes	Yes	Yes

Primary Count Source

VDOT's Traffic Monitoring System (TMS) is VDOT's official traffic count system and should be used as the primary count source for all model regions for all model development and application. Requests for special counts for model development or application are discouraged and must have their need clearly documented to be considered for approval by the VDOT project manager.

Count Adjustment

Adjusting raw count data for daily, weekly, and seasonal variation for the model base year is a vital part of the count development process. For all model regions, it is accepted and recommended practice to adjust any raw counts collected for model development and application for daily, weekly, and seasonal variation in accordance with acceptable VDOT TMS count practice.

Non-Centroid Count Coverage

Having an adequate count coverage for model development and application is a critical part of the modeling process. Modeling efforts should make extensive use of VDOT TMS and other available data sources and tools to maximize count coverage and quality. Non-centroid links are defined as links that are part of the model region transportation network that are not centroid connectors or external station links. It is recommended practice to have a count coverage of 20% of non-centroid links for small model regions and 10% for large model regions.

Screenline, Cordon Line, and Cutline Count Coverage

Screenlines are large analysis lines used for model validation that bisect the entire model region. Cordon lines completely encircle a subarea within the model region. Cordon lines are generally used around major CBDs and activity centers, at beltways, and at city jurisdictional limits. Cutlines are a smaller type of analysis that lie entirely within the model region and include three

or more roadways. Cutlines can be subsets of screenline locations, but should never include external station locations. Having an adequate screenline and cutline coverage is essential to the modeling process. All model regions should at a minimum have one north-south screenline, one east-west screenline, and screenlines along all major geographic barriers, e.g., large bodies of water, rivers, and mountains. All model regions should also have at least one cordon line around the central city limits or CBD. Cities with more than 25,000 population should have a cordon line around both the central city limits and the CBD. If the model region contains several cities, e.g., Richmond/Tri-Cities, separate cordon lines should be developed for each city. Cutlines can be developed to include portions of cordon lines around principal beltways, cities, CBDs, and activity centers. Cutlines should be used to capture radial travel patterns between cities and suburbs and circumferential travel patterns among suburbs. It is recommended practice that small model regions include at least 10% of their non-centroid links in their screenline, cordon line, and cutline coverage. For large model regions, it is recommended that at least 5% of their non-centroid links be included in their screenline, cordon line, and cutline coverage.

Systematic Count Program

Having a systematic count program for collecting the necessary count data needed for screenline and cutline analysis and for external stations is vital to the modeling process. For all model regions, it is both acceptable and recommended practice to have a database of count locations and data which is regularly maintained and reviewed during the model improvement process.

4. Trip Generation

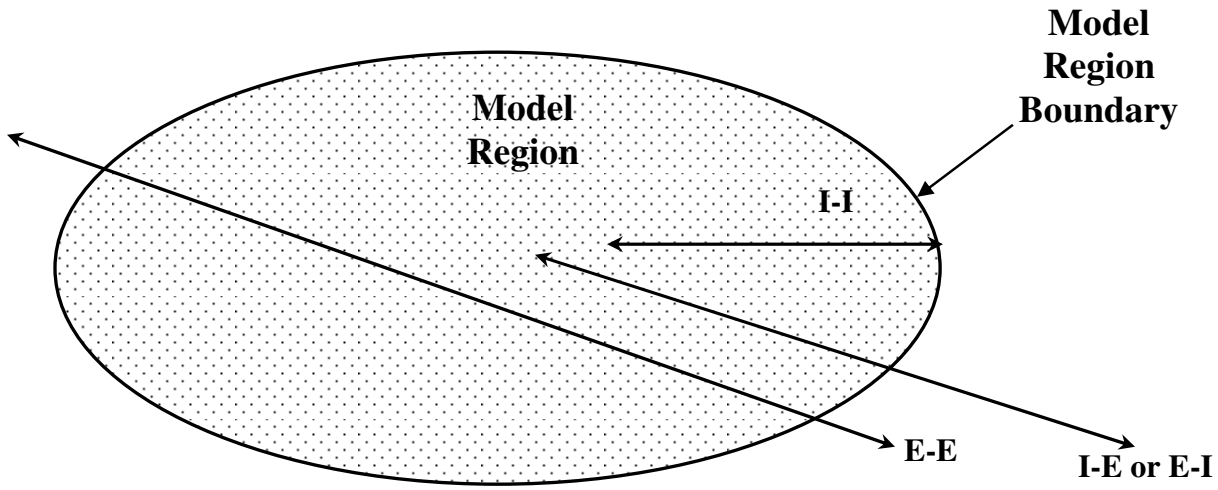
This chapter describes the policies and procedures for developing and calibrating trip generation models in Virginia. After a brief introduction to the trip generation process, this chapter describes acceptable and recommended practice for trip generation modeling and calibration.

Introduction

Trip generation is the first step of the traditional four-step modeling process and measures the amount and type of travel for a particular region. Trip making behavior is complex and is influenced by a number of factors such as employment, household characteristics, and location characteristics. In travel demand modeling, the concept of trip productions and attractions is used instead of trip origins and destinations. Productions are always at the home end of a home-based trip and at the origin end for a non-home-based trip. Conversely, attractions are always at the non-home end of a home-based trip and the destination end for a non-home-based trip.

Trip generation models predict the number of trips being produced and attracted to each individual Transportation Analysis Zone (TAZ) in a model region. These include Internal to Internal trips (I-I): trips beginning and ending in the model region, Internal to External (I-E) trips: trips beginning in the model region and ending outside the model region, and External to Internal (E-I) trips: trips beginning outside the model region and ending within the model region. External-External trips (E-E), or through trips, which travel through the model region, but do not stop, are technically not part of the trip generation modeling process, but are discussed in this chapter. E-E trips are modeled using an external trip table which is developed from traffic counts, external surveys, and/or the statewide model. Figure 4 illustrates the difference between the three types of trips.

Figure 4: Different Types of Trip Generation Trips



Trip Generation Practice

Table 18 displays the policies and procedures for trip generation practice in Virginia.

Table 18: Trip Generation Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended*	
	Small	Large	Small	Large
Trip Purposes	HBW HBO NHB	HBW HBO NHB Heavy CV	HBW HBUC HBO NHB Heavy CV Others as needed	HBW HBS HBUC HBSH HBO NHB Light CV Heavy CV Others as needed
Unit of Travel	Vehicle Trips	Vehicle Trips	Person Trips	Person Trips
Trip Production Model Form	Cross Classification or Regression	Cross Classification or Regression	Cross Classification	Cross Classification or Choice Models
Trip Attraction Model Form	Cross Classification or Regression	Cross Classification or Regression	Cross Classification or Regression	Cross Classification or Choice Models
Sensitivity to wealth variables (either income or auto ownership)	None	Yes, at least one such variable with socioeconomic stratification.	Yes, at least one such variable with socioeconomic stratification.	Yes, at least one such variable with socioeconomic stratification.
Sensitivity to Land Use mix	No	No	Yes	Yes
Sensitivity to Non-motorized modes	No	No	Yes, if non-motorized travel is regionally significant	
Balancing Trip Productions and Attractions before Trip Distribution	Home Based Trip Purposes balanced to Productions and Non-Home Based Purposes to Attractions.		Home Based Trip Purposes balanced to Productions and Non-Home Based Purposes to Attractions.	
External-External Trips	External Surveys and/or Traffic Counts		External Surveys, Statewide Model and/or Traffic Counts	

*Recommended characteristics are subject to resource constraints such as data availability as well as time and budget

Trip Purposes

A trip generation model estimates the number of person or vehicle trips from each TAZ. Trip generation models are improved when major types of trips are identified and modeled separately. The three most commonly used trip types are Home-Based Work (HBW), Home-Based Other (HBO), and Non-Home Based (NHB). Examples of other trip types used in practice are Home-Based Shopping (HBSH), Home-Based School (K-12) (HBS), Home-Based University/College (HBUC), and Commercial Vehicles (trucks, buses, taxis, etc.). Commercial Vehicles should be defined such that heavy vehicles, e.g., heavy trucks, are clearly separated from light vehicles, e.g., light trucks and taxis. For a particular trip type to be considered for inclusion as a separate trip purpose in a trip generation model, it should comprise at least five percent of total trip generation for the model region and have significantly different characteristics from existing trip purposes, e.g., trip distance, distribution, travel time, etc.)

It is acceptable practice for small model regions to have three separate trip purposes: Home-Based Work (HBW), Home-Based Other (HBO), and Non-Home-Based (NHB). For large model regions, it is acceptable practice to include the Heavy Commercial Vehicle (HCV) trip purposes in addition to the trip purposes required for small regions. The HCV trip purpose should include trucks with 3+ axles, buses, and RVs. The truck component of HCV should include all traffic in vehicle classifications six through thirteen of the federal vehicle classification system and buses and RVs should include all traffic in classification four of that system. If data necessary to develop a HCV trip purpose is too costly to collect, a HCV model may be borrowed from another area with the approval of the VDOT project manager.

It is recommended practice that small model regions have five trip purposes with the Home-Based University/College (HBUC) and Heavy Commercial Vehicle (HCV) purposes being included in addition to the three purposes required for small regions. The HBUC trip purpose can be of particular importance in small urban areas with large universities and/or student population, e.g., Blacksburg, Charlottesville, Harrisonburg, etc.

For large model regions, it is recommended that the Home-Based School (K-12) (HBS), Home-Based Shopping (HBSH), and Light Commercial Vehicle (LCV) purposes be included in addition to the five recommended for small regions. The HBS trip purpose is of particular importance in larger urban areas. The HBS trip purpose should include trip making from primary and secondary schools (K-12) and school enrollment should be the primary independent variable used to estimate it. The LCV trip purpose includes all 2+ axle, 6 tire light trucks (Federal vehicle classification number 5), and smaller light trucks and cars being used for business purposes such as utility companies, postal workers, emergency vehicles, delivery vehicles, taxis, etc. If data necessary to develop a LCV trip purpose is too costly to collect, a LCV model may be borrowed from another area with the approval of the VDOT project manager.

Unit of Travel

It is acceptable practice to use vehicle trips as the unit of travel for all model regions. Due to the increasing need to be able to use travel demand models to evaluate transportation options such as high-occupancy vehicle lanes, ridesharing, or transit, it is recommended that all future models use person trips as the unit of travel.

Trip Production and Attraction Model Form

Trip production and attraction models should be based on household travel surveys, models transferred from areas with similar characteristics in terms of size, travel behavior, etc., or national guidelines established by the Transportation Research Board (TRB) or USDOT. The use of site specific trip rates for travel demand modeling **is not an acceptable** practice. TRB's publication: NCHRP Report 365 is a good national data source for use in trip attraction model development. For large model regions, it is desirable to have a recent household travel survey to use for model development.

For both trip production and attraction models, either cross classification tables or regression equations are acceptable approaches for estimating trip generation. Cross classification tables should be organized according to household size and automobile ownership and/or income. TAZ data should be segmented into household markets reflected in cross-class categorization or variables included in regression estimation.

For small model regions, it is recommended that new models use cross classification for trip productions and either cross classification or regression for trip attractions. For large model regions, it is recommended that either cross classification or choice models be used for trip productions as well as for trip attraction models.

Sensitivity to Wealth Variables

Including wealth variables such as income and automobile ownership is an important factor in estimating trip generation and it is desirable that these variables be segmented into at least three different socioeconomic strata, e.g., low income, medium income, and high income. If automobile ownership is one of the wealth variables being included, it is desirable that an automobile ownership model be developed to better forecast this variable.

A model lacking sensitivity to a wealth variable is acceptable practice only for small model regions. It is recommended practice that small model regions include sensitivity to at least one wealth variable and include socioeconomic stratification. For large model regions, it is both acceptable and recommended practice to include sensitivity to at least one wealth variable and include socioeconomic stratification.

Sensitivity to Land-Use Mix

An existing trip generation model that lacks sensitivity to land-mix, e.g., pedestrian environment, density, diversity, etc., is acceptable practice for all model regions. It is recommended practice for all model regions that new models should include some sensitivity to land-use mix, particularly in areas with high transit potential or usage.

Sensitivity to Non-Motorized Modes

Traditional four-step travel demand models are not well suited to analyze non-motorized travel given their aggregate TAZ structure. TAZs are generally too large to use for bicycle or pedestrian forecasting since most non-motorized trips will be intrazonal. A model that lacks sensitivity to non-motorized travel is acceptable model practice for all model regions and recommended model practice for small model regions. But for all model regions where non-motorized travel is regionally significant, some sensitivity to non-motorized travel is recommended practice. Non-motorized travel is defined as being regionally significant in urban areas if one of the following criteria is met:

1. Urban area includes universities and colleges with combined student enrollment of over 20,000.
2. A grouping of at least 20 contiguous Transportation Analysis Zones having the two highest Land Use Density classifications: CBD and Urban, exist in the model region.

Balancing Trip Productions and Attractions before Trip Distribution

The accepted and recommended practice for all model regions is that for home based trip purposes, attractions should be scaled to productions and for non-home based trip purposes, productions should be scaled to attractions. This is done because for home based purposes, there is generally better data available on the home or production end of the trip. For non-home based trips, however, there is generally better data available for the non-home or attraction end of the trip.

External-External Trips

Accurately measuring external-external trips, or through trips, is an important part of the travel demand modeling process, particularly in view of the large increase in through traffic in recent years on routes such as I-81 and I-95. External-external trips are generally based on external traffic origin-destination surveys and/or traffic counts. With the development of the Virginia statewide model, however, a new tool now exists to help determine external travel through all urban travel demand models in Virginia. Using just external surveys and/or traffic counts to develop external-external trips is acceptable practice for all model regions. Using external surveys and/or traffic counts in conjunction with statewide model results is recommended practice for all model regions.

Trip Generation Calibration

As the first and perhaps most important step of the 4-step modeling process, ensuring that trip generation models are producing reasonable forecasts is essential to acceptable travel demand modeling. Table 19 describes several potential problem areas which should be checked and remedied if necessary when developing or updating trip generation models.

Table 19: Trip Generation Calibration Procedures for Virginia Travel Demand Models

Calibration Procedural Check	Model Region Size		Guideline/ Standard
	Small	Large	
Person Trips/TAZ	< 10,000	< 15,000	Guideline
Unbalanced Production/Attraction Ratio	0.90 – 1.10	0.90 – 1.10	Standard
Trip Rate Reasonableness	NCHRP 365 and Household Travel Survey	NCHRP 365 and Household Travel Survey	Guideline
Reasonableness by Area	NCHRP 365 and Household Travel Survey	NCHRP 365 and Household Travel Survey	Guideline
Activity Centers	Activity surveys, Household Travel Survey, or ITE data	Activity surveys, Household Travel Survey, or ITE data	Guideline

Person Trips/TAZ

Person Trips/TAZ is a measure of average TAZ size for a model region. If average TAZ size is too large or too small, it can distort model results. Person Trips/TAZ is also an important measure for comparing the relative sizes of particular TAZs within a model region. If a particular TAZ has person trips/TAZ measure much higher or much lower than the model region average, this could also distort model results. As a result, it is important to have guidelines for evaluating average TAZ size. For small model regions, the number of person trips/TAZ should be less than 10,000 person trips. For large model regions, this measure should be less than 15,000. For all model regions, the vast majority of TAZs should have between 5,000 and 25,000 person trips/TAZ. TAZs with more than 25,000 person trips/TAZ should be strongly considered for future zone splits. There are some cases in which a large TAZ size as measured by person trips/TAZ is permissible given census constraints in splitting TAZs. For example, military bases, major institutions, major employment centers, and industrial centers often have a high number of person trips/TAZ, but lack the census geography necessary to create additional TAZ splits since the density of census geography is generally based on household density.

Unbalanced Production/Attraction Ratio

For all model regions, before balancing is performed, estimated trip attractions should be within ± 10% of trip productions for every trip purpose. If this is not the case for a particular trip purpose, the trip attraction model should be carefully examined and recalibrated.

Trip Rate Reasonableness

Trip rates per household should be compared with results from any available household travel surveys for the model region for reasonableness. If no household travel survey exists, or the survey(s) available are unsuitable for use in modeling, trip rates should be compared to results from other comparable areas for reasonableness. This comparison should preferably be made for both person and vehicle trips. This comparison should be made against other comparable models within the state of Virginia, at least three other comparable areas in the United States outside of Virginia, and the national standards set forth in NCHRP 365. If trip rates per household do not appear reasonable, they may be adjusted to better reflect travel in the model region with changes from previous trip rates being documented.

Reasonableness by Area

Trip generation should be evaluated for reasonableness in the entire model region, by jurisdiction, by district if available, and by TAZ. Any significant abnormalities must be documented. Identifying such abnormalities can assist in the evaluation of potential special generators. NCHRP 365 and household travel surveys are two data sources that can be used as guidelines for this analysis.

Activity Centers

The trip making in activity center areas such as major airports, regional shopping malls, major universities, CBDs, and major intermodal freight facilities should be examined for reasonableness. If an area has significantly more or less trip making activity than should be expected, the land use files and other inputs should be carefully checked. If the input files appear reasonable, the model trip rates and percentages by trip purpose should be examined for reasonableness. If these appear reasonable, trip making should be examined for the model region, jurisdiction, and if possible, by district for reasonableness to ascertain whether or not any systematic bias exists in trip making activity, e.g., too little in urban areas or too much in suburban areas. If these also appear reasonable and no bias is found, but trip making at activity centers is still significantly high or low, the activity center should be considered for special generator status. Special generators should only be designated in areas where despite all efforts, the general trip generation model significantly over or under estimates travel in that area and the number of trips being over or underestimated is regionally significant to the modeling region. If an activity center is selected for special generator consideration, the reasons for it being selected should be documented and additional data collection should be conducted as needed and subject to resource availability. Activity surveys, e.g., cordon surveys, household travel surveys, and ITE data are potential data sources that can serve as guidelines for this analysis.

5. Trip Distribution

Trip distribution is the second step of the traditional four-step modeling process and determines where the trips calculated in the trip generation model will go. Specifically, it forecasts the number of trips occurring between one geographic area, typically a TAZ, and all other areas of a particular model region. This chapter describes the policies and procedures for developing and calibrating trip distribution models in Virginia.

Trip Distribution Practice

The policies and procedures for trip distribution practice in Virginia are shown below in Table 20.

Table 20: Trip Distribution Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended*	
	Small	Large	Small	Large
Model Form	Gravity Model	Gravity Model	Gravity Model	Gravity Model or Destination Choice Model
Impedance Measure	Highway Travel Time	Highway Travel Time	Highway Travel Time	Composite impedance that includes transit and any other significant modes
Income Segmentation	No	No	No	Yes for HBW
Singly vs. Doubly Constrained	Singly or Doubly Constrained		HBW: Doubly or Singly Constrained. Other Purposes: Singly Constrained	
Use of K-Factors	Use sparingly and must clearly document.		Use sparingly and must clearly document.	

*Recommended characteristics are subject to resource constraints such as data availability and budget

Model Form

The gravity model is still the predominant model form for trip distribution models. The gravity model was adapted from Newton's Law of Gravitation that determined that the gravitational attraction between two objects was directly proportional to the mass of the two objects and inversely proportional to the distance between them. Applying this concept to trip distribution modeling, the number of trips occurring between TAZ i and TAZ j, is directly proportional to the number of attractions generated by the TAZ j and inversely proportional to the impedance (travel time and cost) between TAZ i and TAZ j. The impedance measure is expressed by a friction factor (FF). Friction factors are higher as travel time decreases. The higher the friction factors and the number of attractions, the greater the relative attractiveness of the TAZ. The standard gravity model formula is shown in Figure 5:

Figure 5: Standard Gravity Model Equation

$$Trips_{ij} = \frac{P_i * A_j * FF_{ij} * K_{ij}}{\sum_n A_j * FF_{ij} * K_{ij}}$$

Where:
Origin TAZ Number = i
Destination TAZ Number = j
Number of TAZs = n
Trip Productions = P
Trip Attractions = A
Friction Factor = FF
Socioeconomic Factor = K

It is acceptable practice for all model regions to use a gravity model as their trip distribution model form. It is recommended practice that small model regions continue to use the gravity model form for trip distribution. It is recommended practice that large model regions use either a destination choice or gravity model as their trip distribution model form. The destination choice model form is more difficult to develop and calibrate than a gravity model, but can be more sensitive to socioeconomic factors such as land use mix, employment characteristics, etc.

Impedance Measure

The impedance measure is the path of least resistance between pairs of TAZs. Several factors can be used to help determine travel impedance including highway and transit travel times, distances, and user costs, e.g., tolls, parking, etc. It is acceptable practice to use highway travel time as the impedance measure for trip distribution modeling for both small and large model regions. Highway travel time is also the recommended impedance measure for small model regions. For large model regions, however, it is recommended that composite impedance be used. Composite impedance takes into account out of vehicle travel time (OVTT) as well as in vehicle travel time (IVTT). In small areas, rural areas, and auto oriented suburban areas, most automobile travel time is IVTT and transit and other alternative modes generally comprise a very small percentage of trips. In large urban areas, particularly near the CBD, however, OVTT for automobile trips can be quite large due to parking or other factors. In these areas, composite impedance is of greater importance since transit and other modes are relatively more attractive. If composite impedance is used, the model should also include congested feedback from assignment.

Additionally, in urban areas with tolls, additional model enhancements should be considered to better forecast the impact of tolls on travel patterns. These enhancements can include, but are not limited to, adjusting travel impedances for tolls based on an acceptable value of time for the urban area. Model adjustments for tolls should be performed broadly to consider potential adjustments to trip distribution, mode choice, and trip assignment.

Income Segmentation

For trip generation, socioeconomic segmentation by trip purpose has become standard practice in many areas and is desirable for all trip purposes. Further segmentation by trip purpose in trip distribution is not as common, but is considered good practice, particularly for larger areas. It is acceptable practice for all model regions and recommended practice for small model regions to have no income segmentation. For large model regions, however, it is recommended that income segmentation be included for the Home Based Work (HBW) trip purpose. At last three stratifications of income segmentation are recommended: low, medium, and high with the thresholds for each range dependent on the income characteristics of the model region in question.

Singly vs. Doubly Constrained

A gravity model can be applied in either a singly constrained or doubly constrained manner. In a singly constrained application, the number of trips distributed to a production TAZ is set equal to the number of productions forecast by the trip generation model for that TAZ, but no attempt is made to do likewise for trips distributed to attraction TAZs. In a doubly constrained application, distribution models attempt to match both trip productions and trip attractions to trip generation results by TAZ. Production totals are held fixed and the model is run iteratively until a reasonable convergence on attraction totals is reached.

Traditionally, most gravity models used in United States urban areas are doubly constrained. There is broad consensus in the modeling community that trip distribution models should be constrained on the production end, but differing opinions on the value of constraining the attraction end. The reason for this is that demographic information is more reliable on the production or home end of the trip compared to the attraction or non-home end of the trip. Home Based Work (HBW) trips have the greatest reliability of any trip purpose on the attraction end of the trip and are the trip purpose best suited for double constraint. If employment estimates are unrealistic, e.g., too high, single constraint can somewhat self correct this problem by not forcing distributed attractions to match trip generation attractions by TAZ. For HBW, it is recommended that the model developer assess the accuracy of trip generation employment data and evaluate the model using both the singly and doubly constrained method, before making a recommendation to the VDOT project manager of what method to use in the model.

Other trip purposes, such as Home Base Shop (HBSH), have more variability on the attraction end of the trip. A common example is that of two shopping malls of identical size and employment totals. The first mall has good highway and transit accessibility due to a new interchange and bus line, but the second one has poor accessibility. Trip distribution takes accessibility into account as measured by travel time, but most trip attraction models do not. As a result, a singly constrained trip distribution model would distribute more attractions to the first shopping mall than to the second. But a doubly constrained trip distribution model would match TAZ attractions to that for the trip generation attraction model so that both malls would attract the same number of trips! Because of this type of variability, it is recommended practice that non-HBW trip purposes only use singly constrained approaches to trip distribution.

It is acceptable practice for all model regions to use either the singly or doubly constrained approach to trip distribution. It is recommended practice for all model regions, that the Home Based Work (HBW) trip purpose be singly or doubly constrained, while other trip purposes be singly constrained.

Use of K Factors

The use of K factors, which includes barrier penalties and arbitrary time penalties on individual links, should be limited and their widespread or systematic use is unacceptable. K Factors have traditionally been used as calibration adjustment factors for areas or roads that systematically over or underestimate traffic. For example, the standard gravity model equation in Figure 5 contains a K factor which should generally be equal to 1.0, indicating it is not being used. If this K factor is used to calibrate the model, its use should be clearly documented. It is both accepted and recommended practice that K factors be used sparingly in all model regions and that they be clearly justified and documented.

Trip Distribution Calibration

Trip distribution is the second step of the 4-step modeling process and the next most important step to producing reasonable forecasts after trip generation. Table 21 describes several potential calibration checks which should be evaluated and remedied if necessary when developing or updating trip distribution models.

Table 21: Trip Distribution Calibration Procedures for Virginia Travel Demand Models

Calibration Procedural Check	Model Region Size		Guideline/ Standard
	Small	Large	
Intrazonal Trips	< 8%	< 10%	Standard
Average Trip Length by Trip Purpose	HTS, CTPP	HTS, CTPP	Guideline
Trip Length Frequency Distribution by Trip Purpose	HTS, CTPP Coincidence Ratio: HBW: > 0.80 Other purposes: > 0.70	HTS, CTPP Coincidence Ratio: HBW: > 0.80 Other purposes: > 0.70	Guideline
Area to Area Flows of Trips by Jurisdiction	HTS, CTPP	HTS, CTPP	Guideline

Intrazonal Trips

Intrazonal trips are trips that are produced and attracted to the same TAZ. Since the 4-step modeling process uses an aggregate zonal approach which assumes that all travel activity occurring within a TAZ occurs at the zone centroid, intrazonal trips are not assigned to the transportation network. A small number of intrazonal trips is natural for 4-step trip generation models. Too many intrazonal trips, however, can result in significant undersimulation of travel in a model area or model region. As a result, it is important that the percentage of intrazonal trips for a given TAZ not be too large. For small model regions, it is recommended that the total number of intrazonal trips be less than eight percent of the total number of Internal-Internal trips for the model region. For large model regions, it is recommended that the total number of intrazonal trips be no more than ten percent of the total number of Internal-Internal trips. If a model region fails to meet this requirement, it is an indication that the TAZ size is too large which can be remedied by adding additional TAZs.

Average Trip Length by Trip Purpose

Average trip length by distance and time is a standard guideline for evaluating trip distribution models. A household travel survey (HTS) is the best data source for making this comparison, if it is available. In the absence of a HTS, the Census Transportation Planning Package (CTPP) should be used to obtain average trip length for the Home-Based Work trip purpose. The way in which a typical travel survey and the CTPP define work trips is generally different and should be taken into account when making this comparison by the analyst. A direct comparison between HTS and CTPP results **is not** recommended.

For small model regions, the average trip length for HBW should generally be 15 to 20 minutes while trip lengths for the non-HBW and non-Truck trip purposes should be 75% to 85% of that for HBW. For large model regions, the average trip length for HBW should generally be 20 to 30 minutes while the trip lengths for the non-HBW and non-Truck trip purposes should be 60% to 70% of that for HBW.[15] For large congested areas such as Washington, Los Angeles, or New York City, HBW average trip lengths in excess of 30 minutes are possible. If a comparison of modeled to observed trip lengths does not produce satisfactory results, the friction factors should be examined carefully. Friction factors can be adjusted by trip purpose to produce an acceptable comparison of average trip length for each trip purpose. But friction factor adjustments should not be done on an individual TAZ basis.

Trip Length Frequency Distribution by Trip Purpose

The trip length frequency distribution is the most common measure used to evaluate trip distribution models. A HTS is the best data source for making this comparison. In the absence of a HTS, the CTPP can be used for the HBW trip purpose. Figure 7 shows an example of a trip length frequency distribution (TLFD) comparison for HBW. In Figure 7, the TLFD for an observed HTS and the trip distribution model results are compared. A statistical measure called the coincidence ratio should be used to evaluate the difference between the observed and model curves. The formula to calculate the coincidence ratio is defined in Figure 6:

Figure 6: Coincidence Ratio Formula

$$\text{Coincidence} = \sum_{t=1}^{T} \min\left\{\frac{f^m(t)}{F^m}, \frac{f^o(t)}{F^o}\right\}$$

$$\text{Total} = \sum_{t=1}^{T} \max\left\{\frac{f^m(t)}{F^m}, \frac{f^o(t)}{F^o}\right\}$$

$$\text{Coincidence Ratio} = \frac{Coincidence}{Total}$$

Where $f^m(t)$ = frequency of trips at time t from the model

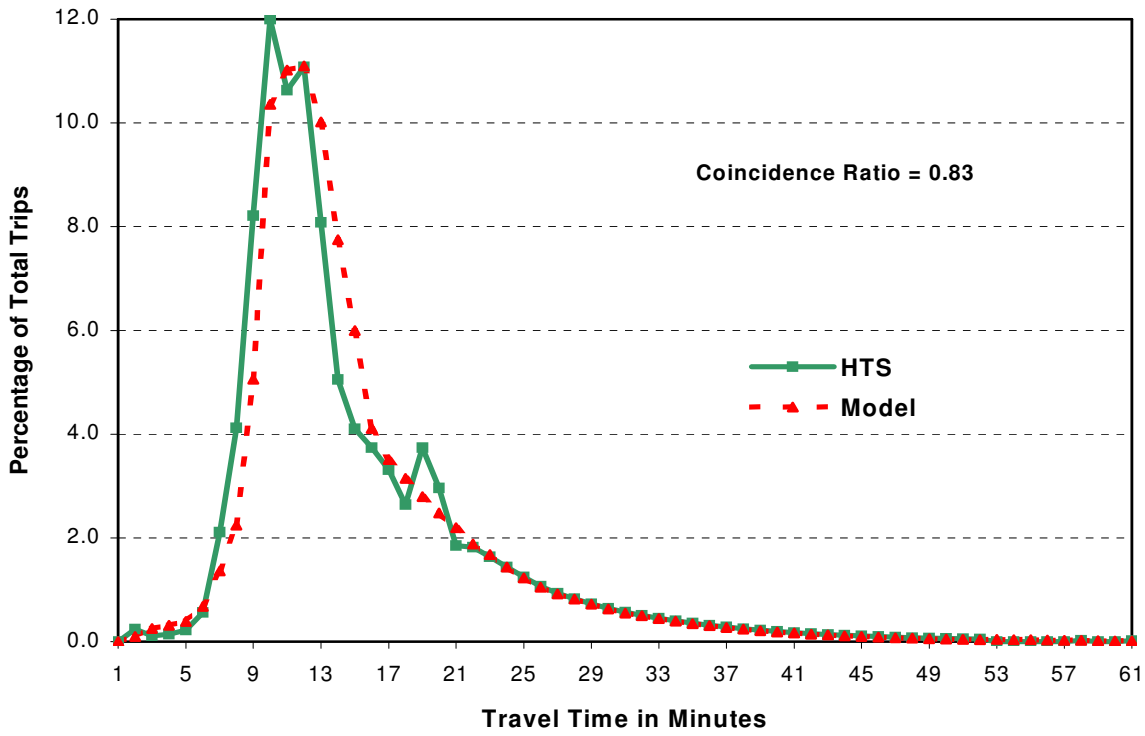
$f^o(t)$ = frequency of trips at time t from the observed survey data

[15] NCHRP 365 pg. 40-41

F^m = total trips distributed from the model

F^o = total trips distributed from the observed survey data

Figure 7: Example of a Home-Based Work Trip Length Frequency Distribution Comparison



For the Home-Based Work trip purpose, the coincidence ratio should be above 0.80. For other trip purposes, the coincidence ratio should be above 0.70.

Area to Area Flows of Trips by Jurisdiction

Checking the area to area flow of trips by jurisdiction is a standard check of trip distribution models. A HTS is the best data source to use to ensure that model results are reasonably replicating the HTS results. The larger the HTS, the better it is for deriving area to area flows. For small scale HTS, it is not always possible to derive area to area flows. If a HTS is not available or adequate for this measure, the CTPP can be used for HBW trips. The differences in the way the Census defines HBW trips in Journey to Work data versus that typically used in household travel surveys should be considered and taken into account by the analyst when making this comparison. A direct comparison of CTPP to model results **is not** recommended.

6. Mode Choice

Mode Choice is the third step of the traditional four-step modeling process and splits the person trip tables into mode specific trip tables, e.g., Single Occupant Vehicle (SOV), High Occupancy Vehicle (HOV), Bus, Rail, etc. Mode choice modeling is the most complicated part of the four-step travel demand forecasting process and need not be performed for small model regions where transit and HOV usage are not regionally significant. A mode choice model is recommended as part of the travel demand forecasting process if transit and HOV regional significance is established by at least one of the following five criteria being met:

1. Model Region has existing HOV facilities.
2. Model Region has existing transit services that account for at least 2% of the model region's person trips.
3. The MPO portion of the model region is in non-attainment for Air Quality Conformity.
4. Model region is part of a larger consolidated metropolitan statistical area (CMSA) with a population of over 3,000,000.
5. A major transit or HOV project is being considered for a transportation plan or study.

For small model regions where neither transit nor HOV usage are regionally significant, a simple vehicle occupancy calculation is sufficient for each trip purpose based on the best occupancy data available to convert the person trip tables to vehicle trips. In the absence of local data, national rates from NCHRP 365 or other sources may be used. The remainder of this chapter will discuss the policies and procedures for mode choice modeling and calibration for model regions where transit or HOV usage is regionally significant.

Mode Choice Practice

The policies and procedures for mode choice practice in Virginia are shown in Table 22:

Table 22: Mode Choice Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended*	
	Small	Large	Small	Large
Model Form	None	Logit, Nested Logit or Multinomial Logit	None	Nested Logit or Multinomial Logit
Travel Modes	Auto	Auto and Transit	Auto	Auto SOV Auto HOV Major transit modes, e.g., bus, rail, etc., with drive and walk access
Impedance Measures	N/A	Time and Cost	N/A	Time, Cost, and Other attributes as needed
Socio-Economic Sensitivity	None	Yes	None	Yes

*Recommended characteristics are subject to resource constraints such as data availability and budget

Model Form

It is acceptable and recommended practice for small model regions not to have a mode choice model. For large model regions, acceptable practice is for the model form to be logit, nested logit, or multinomial logit while recommended practice is to only use nested logit or multinomial logit. An example of a multinomial logit structure is shown in Figure 8. In this example, the probability that a commuter will choose the bus from among three competing modes: Bus, Rail, and Auto, is determined. U_{Bus} is a mathematical function that represents a commuter's utility in riding the bus. Factors that would influence a commuter's riding the bus include travel time, fare, wait time, drive access to transit stations/stops, etc.

Figure 8: Example of a Multinomial Logit Structure

$$P_{Bus} = \frac{\exp(U_{Bus})}{\exp(U_{Bus}) + \exp(U_{Rail}) + \exp(U_{Auto})}$$

Where U_{Bus}=Function(Travel Time, Fare, Wait Time, Drive Access, etc.)

Special care needs to be taken in developing mode choice models, particularly if the model will need to be used for any Federal Transit Administration (FTA) Transit New Starts projects. In this case, the mode choice model needs to be carefully reviewed to ensure that all FTA requirements are met.

Travel Modes

It is acceptable and recommended practice for small model regions to include automobiles as a travel mode. For large model regions, it is acceptable practice to include two travel modes: automobile and transit. It is recommended practice that large model regions have additional travel modes, such that automobile SOV and HOV travel is modeled separately and all major transit modes are included, e.g., bus, rail, etc. Further breakdowns of bus and rail are permissible, e.g., express bus, bus rapid transit, light rail, commuter rail, etc. if the subcategories are regionally significant and found to have significantly different travel characteristics from other travel modes included in the model. Other specialized modes, e.g., ferry, water taxi, and interregional passenger service, e.g., AMTRAK, Greyhound bus, etc., should not be included in the model unless they are regionally significant. Drive and walk transit access should be included in the mode choice model and transit access should be included in the transportation network.

Impedance Measure

An acceptable practice for large model regions is to use time and cost as the impedance measures in the mode choice model for allocating trips between automobile and transit. It is recommended practice that other impedance attributes be included as needed, such as distinguishing between in vehicle travel time (IVTT) vs. out of vehicle travel time (OVTT).

Socio-Economic Sensitivity

It is acceptable and recommended practice for small model regions not to include socio-economic sensitivity. It is acceptable and recommended practice that large model regions include socio-economic sensitivity, e.g., income, automobile ownership, etc.

Mode Choice Calibration

Calibration is important to ensure that the mode choice model developed is producing reasonable results. Surveys and other data used to calibrate the mode choice model should be used for this effort. Table 23 describes several calibration checks which should be evaluated and remedied if necessary when developing or updating mode choice models.

Table 23: Mode Choice Calibration Procedures for Virginia Travel Demand Models

Calibration Procedural Check	Model Region Size		Guideline/ Standard
	Small	Large	
Total Transit Ridership	< 2% From observed data	< 1% From observed data	Standard
Total Transit Ridership by Jurisdiction	Population Thresholds < 50K: < 20% 50 to 200K: < 10% ≥ 200K: < 5%		Standard
Area to Area Flows of Trips	Surveys	Surveys	Guideline
Mode Shares by Trip Purpose	Surveys	Surveys	Guideline
Average Vehicle Occupancy by Trip Purpose	Surveys	Surveys	Guideline

Total Transit Ridership

Total transit ridership should be within two percent of regional transit control totals in small model regions and within one percent of regional transit control totals in large model regions. If the survey data set differs significantly from transit ridership data gathered from transit agencies, the VDOT project manager will decide which data set to use for model calibration after consultation with VDOT, MPO, and Transit Agency staff. If no survey data was collected for model development, transit ridership should be calibrated to match established ridership data from the transit agencies serving the region.

Total Transit Ridership by Jurisdiction

The total transit ridership should be within twenty percent of transit control totals for jurisdictions with less than 50,000 population. For jurisdictions with populations ranging from 50,000 to 200,000, transit ridership should be within ten percent of control totals. For jurisdictions with populations of over 200,000, transit ridership should be within five percent of control totals.

If the survey data set differs significantly from transit ridership data gathered from transit agencies, the VDOT project manager will decide which data set to use for model calibration after consultation with VDOT, MPO, and Transit Agency staff. If no survey data was collected for

model development, transit ridership should be calibrated to match established ridership data from the transit agencies serving the region.

Area to Area Flows of Trips

Area to area flows of trips should be compared against the survey data set used for model calibration for reasonableness. In the absence of survey data, the CTPP could be used for HBW mode choice calibration. This analysis should be performed using both proportions and absolute numbers to allow for easier comparison of the data sets.

Mode Shares by Trip Purpose

Mode shares by trip purpose should be compared against the survey data set used for model calibration for reasonableness.

Average Vehicle Occupancy by Trip Purpose

Automobile occupancy is an important factor affecting travel demand forecasts. Average vehicle occupancy should be compared against available survey data for reasonableness. In the absence of local surveys, national data such as that in NCHRP 365 can be used for model calibration.

7. Trip Assignment

Trip Assignment is the final step of the traditional four-step modeling process. Trip assignment determines what transportation route will be used by traffic traveling from one area to another. Specifically, trip assignment is the process of allocating a set of trip interchanges to a given roadway network.

Trip Assignment Practice

Table 24 describes acceptable and recommended practice for trip assignment models in Virginia.

Table 24: Trip Assignment Practice for Virginia Travel Demand Models

Component	Acceptable		Recommended*	
	Small	Large	Small	Large
Assignment Algorithm	Any Capacity Restraint Method	Any Capacity Restraint Method	Any Capacity Restraint Method	Any Capacity Restraint Method
Time Periods Modeled	Daily	Daily	Daily	Daily; AM, PM, and Off-Peak
Peak Hour Model	None	None	None	None
Peak Spreading	None	None	None	Yes, if regionally significant
Speed, Flow and LOS Relationship	BPR Equation	BPR Equation	Modified BPR calibrated by Functional Class	Modified BPR calibrated by Functional Class

*Recommended characteristics are subject to resource constraints such as data availability as well as time and budget

Assignment Algorithm

Any capacity restraint method is acceptable and recommended practice for trip assignment for all model regions. Incremental assignment and equilibrium assignment are the two most commonly used methods. Equilibrium assignment is theoretically the most sound method, but has the practical drawback of being overly sensitive to small network changes and having less stable model results. One solution to this shortcoming is to apply the number of iterations needed to bring about convergence in equilibrium assignment to incremental capacity restraint. For example, if 20 iterations are needed to bring convergence in equilibrium assignment, incremental capacity restraint would use 20 loadings of 5% each. This solution allows for more stable model results that are less sensitive to small network changes.

Time Periods Modeled

It is acceptable practice for all model regions to perform only a daily traffic assignment. Additionally, for small model regions, it is recommended practice that the model only perform a daily traffic assignment. But it is recommended that for large model regions, peak period assignments be developed in addition to the daily assignment. At a minimum, the daily

assignment should be broken down into AM Peak Period, PM Peak Period, and Off Peak Period. Additional periods may need to be added to evaluate peak spreading. Local survey data is the best source for developing period trip tables from the daily trip table.

Peak Hour Model

It is acceptable and recommended practice for all model regions not to have a peak hour model as part of their travel demand models.

Peak Spreading

It is acceptable practice for all model regions not to include peak spreading in their travel demand models. Additionally, peak spreading **is not** recommended for small model regions. Peak spreading is recommended for large model regions with heavily congested peak periods that last over three hours.

Speed, Flow and LOS Relationship

The speed, flow, and Level of Service (LOS) Relationship is critical to determining the level of congestion permitted in the travel demand model and should be set during model development. It is acceptable practice for all model regions to use speed, flow, and LOS relationships based on the standard BPR equation or a variation of it. The traditional value for the coefficient *a* is 0.15 and 4 is the traditional exponent value used for *b*. In recent years, higher exponent values of *b* have become more common, particularly in larger metropolitan areas with heavy congestion. LOS used by the model should be based on LOS E in the current HCM. The standard BPR equation is shown in Figure 9:

Figure 9: Standard BPR Equation

$$T = T_0\left[1 + a\left(\frac{v}{c}\right)^b\right]$$

where:

a = coefficient
T = Actual Travel Time
T_0 = Free Flow Travel Time
$\frac{v}{c}$ = Volume to Capacity Ratio
b = exponent

It is recommended practice for all model regions that a modified BPR be created and calibrated by functional class. At a minimum, there should be one BPR curve for freeways and another for arterials and other roads. Current practice favors a significantly higher *b* exponent than the standard value of four. Figure 10 shows BPR equations for freeway and non-freeway roads from NCHRP 387.[16] Current HCM LOS E capacities should be used when performing these

[16] NCHRP 387, Planning Techniques to Estimate Speeds and Service Volumes for Planning Applications. 1997.

calculations. Figure 11 shows an example of speed-volume BPR curves for a free flow speed of 60 mph and a capacity of 2,000 vehicles/lane/hour. Higher exponents on the (v/c) component of a modified BPR equations cause the curve to decrease to zero much more quickly as volume, and presumably congestion, increase.

Figure 10: Example BPR Equations for Freeways and Non-Freeways

For Freeways:

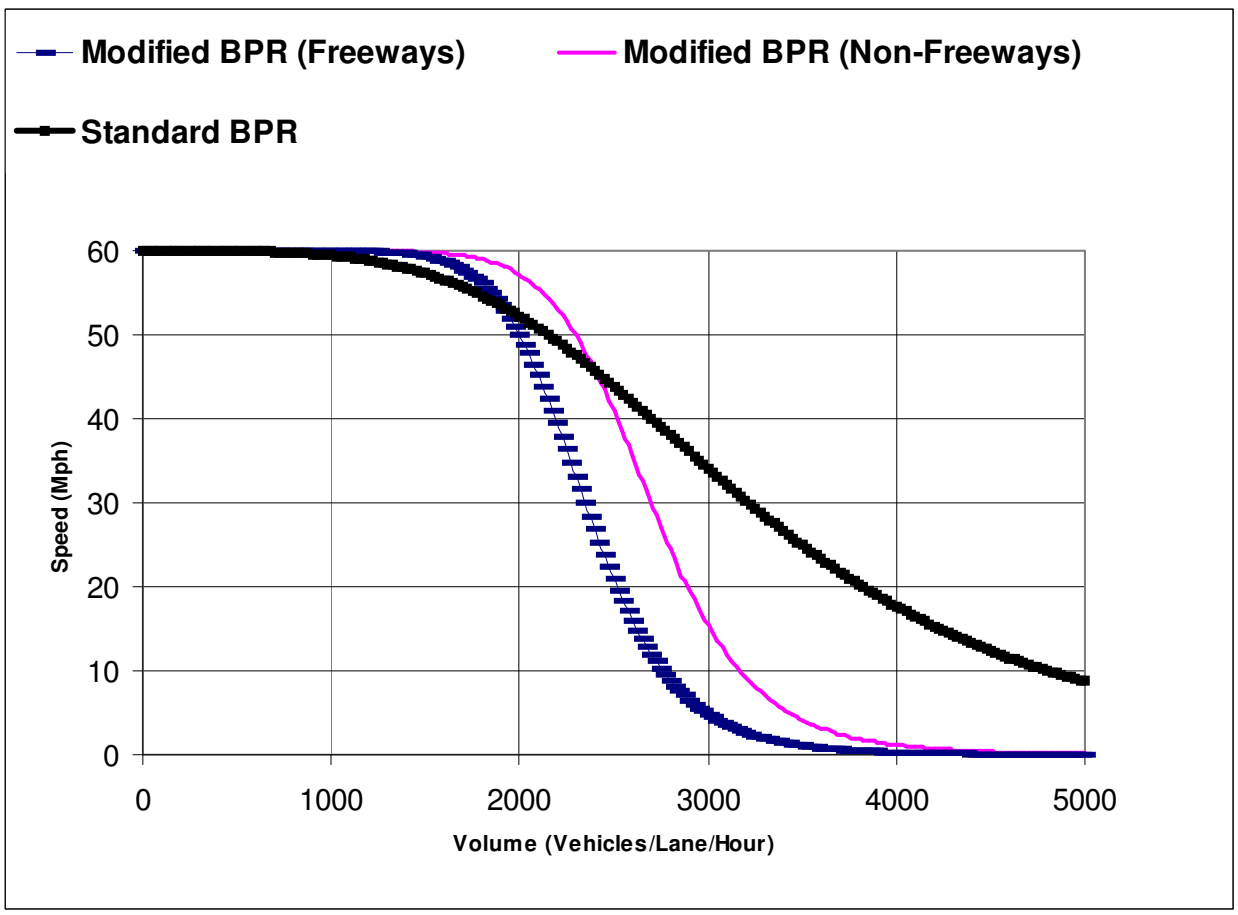
$$T = T_0\left[1 + 0.20\left(\frac{v}{c}\right)^{10}\right]$$

For Non-Freeways:

$$T = T_0\left[1 + 0.05\left(\frac{v}{c}\right)^{10}\right]$$

where
T = Actual Travel Time
T_0 = Free Flow Travel Time
$\frac{v}{c}$ = Volume to Capacity Ratio

Figure 11: Example of Speed-Volume BPR Curves for a Free Flow Speed of 60 Mph[17]



[17] Standard BPR assumes *a* value of 0.15 and *b* value of 4.

Trip Assignment Calibration

Calibration is important to ensure that the trip assignment model developed is producing reasonable results. Surveys and other data used to calibrate the mode choice model should be used for this effort. Table 25 describes several calibration checks which should be evaluated and remedied if necessary when developing or updating mode choice models.

Table 25: Trip Assignment Calibration Procedures for Virginia Travel Demand Models

Component	Acceptable		Recommended	
	Small	Large	Small	Large
Highway Network Continuity	Check for continuity problems		Check for continuity problems	
Highway and Transit Network Paths	Reasonable from CBDs and Regional Activity Centers		Reasonable from CBDs and Regional Activity Centers	
Total Traffic Volume by Facility Type	See Table 26	See Table 26	See Table 26	See Table 26
Total VMT by Facility Type	See Table 27	See Table 27	See Table 27	See Table 27

Highway Network Continuity

Highway network errors are a common cause of trip assignment problems, but are often overlooked. Discontinuity problems are one of the most serious types of network errors. The three major types of discontinuity problems are:

1. Dangling Links
2. Wrong Way Links
3. Inaccurate Turning Prohibitions

Dangling links are links that should connect to at least one other link at a node but do not due to a network coding error. Wrong way links are links that are coded in the wrong direction, e.g., a one-way road coded in the wrong direction. Inaccurate turning prohibitions can also create discontinuity problems by preventing legal movements at intersections. Examples of each are shown in Figure 12 which depicts a simple freeway diamond interchange. In Figure 12, a dangling link error exists between nodes D and E. Link AB has a wrong way link error where the freeway ramp is orientated in the BA direction instead of the AB direction. Freeway interchange movements and ramp coding need to be carefully reviewed for accuracy when performing trip assignment calibration. Additionally, an inaccurate turning prohibition prevents the left turn movement FGB at the end of the expressway ramp.

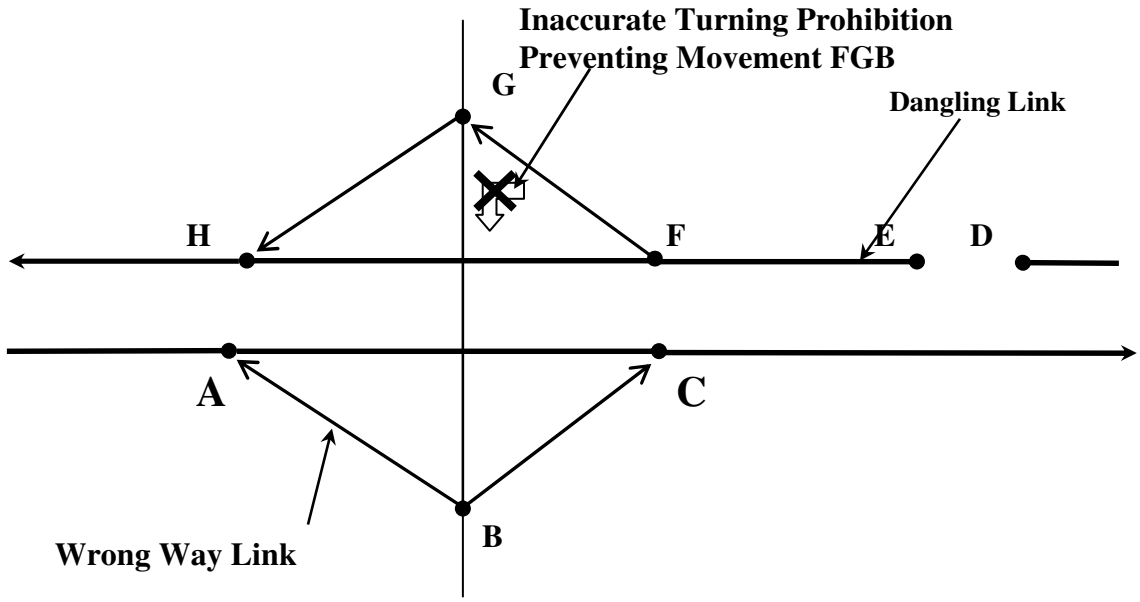
Many network errors, however, are not perceptible from a visual examination of the highway network and need to be tested using GIS, database, or network analysis tools in travel demand forecasting software. A good standard test for discontinuity problems is the zero link test. The zero link test is performed by assigning a trip table to the network and highlighting all links with

zero volume. The analyst should be aware that there are instances when links can have zero volumes not due to network discontinuity errors:

1. Lower Functional Class Facilities. e.g., Collectors and Local Roadways.
2. Errors in travel impedances, e.g., speeds or tolls.
3. Errors in roadway capacity, e.g., number of lanes, capacity per lane.

But the majority of zero link problems are due to network discontinuity errors. Searching for these types of errors and correcting for them can be a time consuming and iterative process, but is an extremely valuable check to perform to ensure reasonable trip assignments.

Figure 12: Example of Network Continuity Errors



Highway and Transit Network Paths

Evaluating highway network paths for reasonableness is an important check during trip assignment calibration and can reveal network or modeling errors. Acceptable and recommended practice for all model regions is that paths be built in the network using congested travel times between Central Business Districts (CBDs) and regional activity centers to check for reasonableness in route selection. Building a few paths that bisect the model region from external station to external station also should be done.

Evaluating transit network paths for reasonableness is also an important check and can be performed by assigning available transit survey data and checking that assigned paths match reported survey paths. Similar to highway network path checking, paths should be checked between CBD and regional activity centers for reasonableness in route selection. This analysis can show many potential problems with transit assignment, e.g., transfer penalties, fares, network discontinuity, etc.

Total Traffic Volume by Facility Type

It is important when evaluating and calibrating trip assignment models that the traffic assignment be consistent by facility type, e.g., no one particular facility type is being significantly over- or under-assigned relative to other facility types. In particular, freeways should be carefully compared to other facility types to check if freeways are being over or under assigned relative to other roadways. It is acceptable and recommended practice for all model regions that total traffic volumes by facility type be within the guidelines specified in Table 26. The network attribute for facility type in the VTM system is called FACTYPE[18] and the targets corresponding to each Facility Type are shown in Table 26. Centroid Connector and External Station Connector volumes **should be excluded** from this analysis. Acceptable practice are the FHWA trip assignment calibration targets which have commonly been used in travel demand modeling in the past. Recommended practice are the calibration targets established by the Michigan Department of Transportation.

Table 26: Percent Difference Targets for Daily Traffic Volumes by Facility Type

Facility Type	FACTYPE Code(s)	Acceptable[19] Practice	Recommended[20] Practice
Interstate & Freeway	1-2	± 7%	± 6%
Major Arterial/Highway	3-4	± 10%	± 7%
Minor Arterial/Highway	5	± 15%	± 10%
Collector & Local	6-8	± 25%	± 20%
All Roads	1-10	± 10%	± 5%

Total VMT by Functional Type

The estimated model region from HPMS or other sources should not include VMT from facility types not entirely included in the transportation network. This rule should only exclude Local roads from being included in VMT analysis since Local roads are the lowest FACTYPE included in VTM transportation networks. Centroid Connector and External Station Connector VMT **should also be excluded** from this analysis. Acceptable and recommended practice is that the simulated VMT by functional type be within the targets specified in Table 27.

Table 27: Percent Difference Targets for Daily VMT by Facility Type

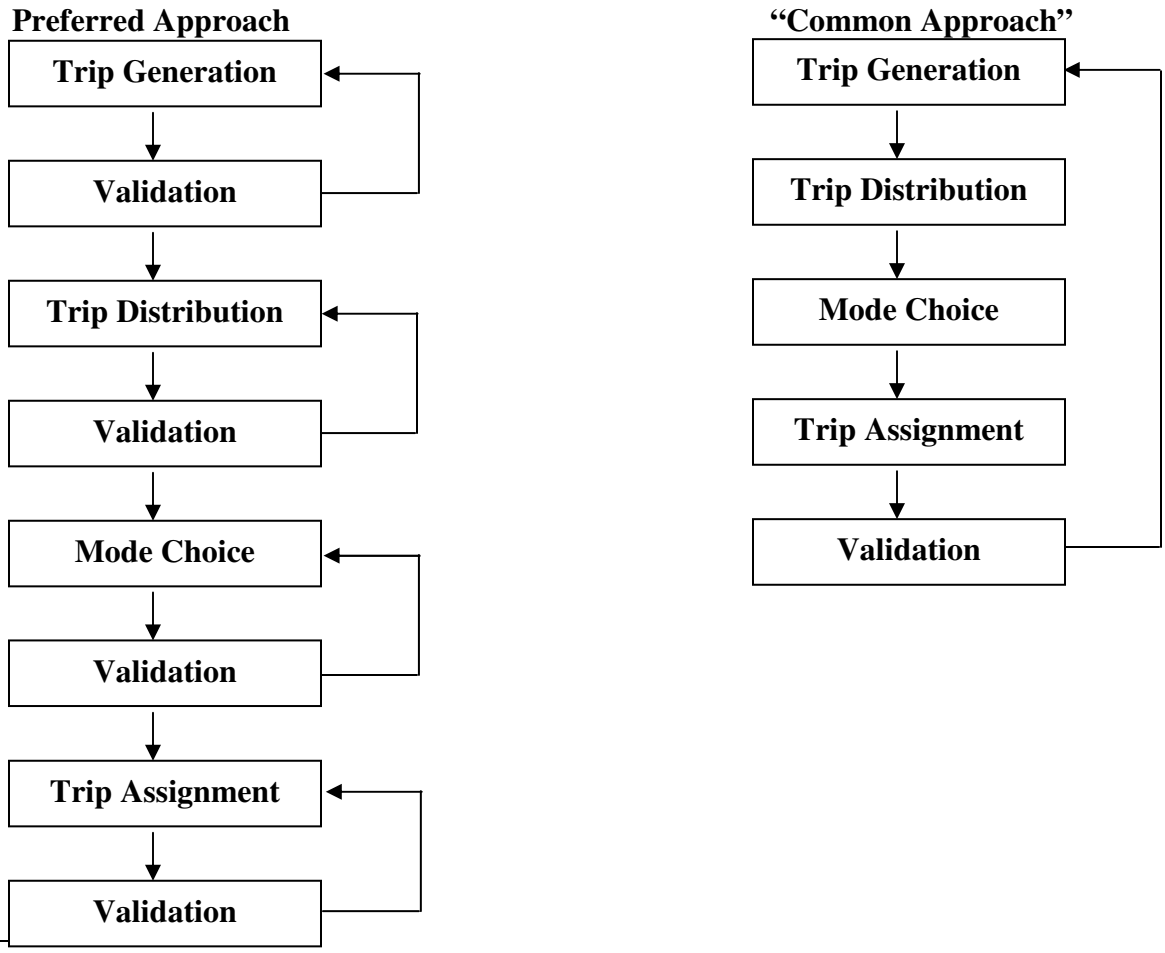
Facility Type	FACTYPE Code(s)	Acceptable Practice	Recommended Practice
Freeway	1-2	± 10%	± 5%
Major Arterial	3-4	± 15%	± 10%
Minor Arterial	5	± 20%	± 15%
Collector	6-7	± 25%	± 20%
All Roads	1-10	± 10%	± 5%

[18] See Table 14.
[19] Source: FHWA Calibration and Adjustment of System Planning Models, 1990.
[20] Source: Michigan Department of Transportation (MDOT), Urban Calibration Targets, June 10, 1993.

8. Validation

Travel Demand Model validation is a major shortcoming of many travel demand model development efforts and is frequently confused with model calibration. Model calibration refers to the development of model parameters and coefficients. Model validation refers to the process of testing a model's ability to replicate base year conditions and its predictive capabilities. The validation to base year conditions is called "static validation" and is performed by comparing simulated results to observed data not used to develop or calibrate the model. Testing the model's predictive capabilities is called "dynamic validation" and involves testing the model's sensitivity to changes in data inputs and parameters and testing the reasonableness of future forecasts. Validation should be performed for each step of the modeling process as shown in the preferred approach Figure 13[21]. The common approach is to only validate the entire set of models which can lead to misleading results since compounding errors from one model step to another can cause error propagation and disguise errors.

Figure 13: Preferred vs. Common Validation Approach



[21] Advanced Travel Demand Forecasting Course, FHWA 2001.

Static Validation for the Base Year

The static validation for the base year is the most common type of validation effort and consists of comparing model simulation results with observed data sets not used to develop or calibrate the model. Static validation measures for each of the four steps of the modeling process are shown in Table 28 through 30.

Trip Generation

At a minimum, the three trip generation measures shown in Table 28 should be evaluated when validating trip generation models. Guidelines for each measure are based on the latest national studies conducted by the Transportation Research Board (TRB) for the National Cooperative Highway Research Program (NCHRP).[22] These three measures are guidelines for person trips per household, vehicle trips per household, and percentage of average daily trips by purpose. NCHRP specifies these measures according to four urban area population sizes: 50,000 to 200,000, 200,000 to 500,000, 500,000 to 1,000,000, and over 1,000,000. Fredericksburg is included in the over 1,000,000 category since it meets the large area criteria specified in chapter 1 of this document.

Table 28: Trip Generation Validation Guidelines from NCHRP[23]

		Urban Area Size In Thousands			
		50-200	**200-500**	**500-1,000**	**1,000+**
Measures	**Virginia MPO Areas**	Charlottesville Danville Harrisonburg Blacksburg Winchester Bristol Kingsport	Roanoke Lynchburg	None	Northern Virginia Fredericksburg Hampton Roads Richmond/Tri-Cities
Person Trips Per Household		9.2	9.0	8.7	8.5
Vehicle Trips Per Household		8.1	7.8	7.5	6.9
Percentage of Average Daily Trips by Purpose		HBW: 20% HBO: 57% NHB: 23%	HBW: 21% HBO: 56% NHB: 23%	HBW: 22% HBO: 56% NHB: 22%	HBW: 22% HBO: 56% NHB: 22%

[22] These guidelines are based on NCHRP 365.
[23] NCHRP 365, p. 24-30

Trip Distribution

Validation data for trip distribution that is independent from any survey data used to develop and calibrate trip distribution models is usually limited and is often confused with calibration data sets. Data sets that can be used for trip distribution validation include the Census Transportation Planning Package (CTPP) for work trips, the National Household Transportation Survey (NHTS), and household travel surveys done for other areas of similar size and travel characteristics. Table 29 shows validation measures for trip distribution.

Table 29: Trip Distribution Validation Measures

Validation Procedural Check	Model Region Size		Guideline/ Standard
	Small	Large	
Average Trip Length for Work Trips	CTPP or Surveys from other similar areas	CTPP or Surveys from other similar areas	Guideline
Average Trip Length for Non-Work Trips	NHTS or Surveys from other similar areas	NHTS or Surveys from other similar areas	Guideline
Area to Area Flows of Work Trips	CTPP	CTPP	Guideline

Average Trip Length for Work Trips

The CTPP is the preferred validation data sources for examining model results for Home-Based Work Trips (HBW). Alternatively, survey results from other areas of similar size and travel characteristics to the modeled area can be used for this comparison. The analyst should consider any differences between the CTPP definition of work trips and that used by the model when making this comparison. If model results vary significantly from the CTPP or other areas, the analyst should evaluate the model's trip length frequency distributions and friction factors for reasonableness and make adjustments as necessary.

Average Trip Length for Non-Work Trips

For non-work trips, either NHTS or survey results from other areas can be used to evaluate model results. This evaluation serves as a guideline to test the reasonableness of model results. If model results vary significantly from the NHTS or other areas, the analyst should evaluate the model's trip length frequency distributions and friction factors for reasonableness and make adjustments as necessary.

Area to Area Flows of Work Trips

Assuming that the CTPP was not used as a data source for trip distribution calibration, the CTPP can provide data independent from travel surveys on area to area flows of work trips. The areas evaluated can be entire jurisdictions or smaller districts that follow census tract geography. Because of differences in the way in which the CTPP and travel surveys define work trips, this is usually not an exact comparison. But this analysis can reveal discrepancies between CTPP and model results, e.g., not enough trips going from a major suburban jurisdiction to the downtown

CBD. Major discrepancies should be researched to determine the reason for the difference and whether or not adjustments to the model should be made.

Mode Choice

Validation data sets that can be used for mode choice validation include the Census Transportation Planning Package (CTPP) for work trips, the National Household Transportation Survey (NHTS), travel surveys done in the model region that were not used for model development or calibration, and travel surveys done for other areas of similar size and travel characteristics. Table 30 shows validation measures for mode choice.

Table 30: Mode Choice Validation Measures

Validation Procedural Check	Model Region Size		Guideline/ Standard
	Small	Large	
Average Vehicle Occupancy by Trip Purpose	NCHRP 365 and surveys from other similar areas	NCHRP 365 and from other similar areas	Guideline
Mode Share	If transit is included in the model. CTPP or available surveys.	CTPP or available surveys.	Guideline

Average Vehicle Occupancy by Trip Purpose

Vehicle occupancy is sometimes overlooked as an important mode choice validation measure and can be a major source of problems with HOV and transit modeling if it is not accurate. Average vehicle occupancy by trip purpose should be compared to national rates from NCHRP 365 and from other similar areas for reasonableness. But this test **should not be used** if vehicle occupancy is not modeled, e.g., small model regions using a standard factor to convert person trips to vehicle trips.

Mode Share

For small model areas, this analysis need only be performed if transit is included in the model. There are several ways to examine mode share when performing mode choice validation. Mode share analysis should be done by trip purpose, by a wealth variable, e.g., income or automobile availability, and by geography. The CTPP or available surveys should be used as validation data sources. Model results should be carefully examined for reasonableness.

Transit mode share to/from CBD(s) or major activity centers is an especially critical element to consider, particularly for large model regions. It is important to note that modern CBD(s) are not always in the traditional downtown area of cities. Large edge city activity centers, e.g., Tyson's Corner, can sometimes also function as CBD(s). This analysis can be performed for work trips using CTPP data and with other available surveys for other trip purposes. Cordon surveys are an excellent data source for this analysis if available, particularly for large model areas. For models

with transit components, observed versus modeled results should be evaluated for reasonableness.

Trip Assignment

Trip assignment validation includes both highway and transit assignments. Validation data for trip assignment is generally the most readily available of the four steps. Table 31 shows the required validation measures for trip assignment. This list is not intended to be exhaustive and for project level analysis, particularly that related to major transit projects, additional analysis may be necessary.

Table 31: Trip Assignment Validation Measures

Validation Procedural Check	Model Region Size		Guideline/ Standard
	Small	Large	
Highway Screenlines	< 54,000: ± 10% ≥ 54,000 & < 250,000: Figure 15 & Figure 16 ≥ 250,000: ± 5%		Guideline
Highway Cordon Lines	< 54,000: ± 10% ≥ 54,000 & < 250,000: Figure 15 & Figure 16 ≥ 250,000: ± 5%		Guideline
Highway Cutlines	< 250,000: Figure 15 & Figure 16 ≥ 250,000: ± 5%		Guideline
R^2 for Model Region	> 0.92	> 0.90	Standard
Percent RMSE for Model Region	< 30%	< 40%	Standard
Percent RMSE by Functional Type: Freeways Principal Arterials Minor Arterials Collectors	 < 20% < 30% < 40% < 70%	 < 20% < 35% < 50% < 90%	Standard
Estimated vs. Observed Speed	For uncongested conditions	For congested and uncongested conditions	Guideline
Assigned vs. Observed Traffic Assignment	Scattergram compared to a 45 degree line	Scattergram compared to a 45 degree line	Guideline
Transit Ridership by Mode and Route	Observed vs. estimated ridership, if transit is included in the model	Observed vs. estimated ridership	Guideline
Transit Ridership Cutline Analysis by Corridor	For major transit corridors if transit is included in the model	For major transit corridors	Guideline

Highway Screenlines

As stated in chapter three under the traffic count section, screenlines are large traffic analysis lines which bisect the entire model region. All model regions should at a minimum have one north-south screenline, one east-west screenline, and screenlines along all major geographic barriers, e.g., large bodies of water, rivers, mountains, etc. For both small and large model regions, the estimated volume for highway cordon lines should be within 10% of observed count volumes for cordon volumes with less than 54,000 observed count volume. Higher volume cordon lines should follow the same guidelines used for highway cutlines shown in Figure 15 and Figure 16. For cordon lines with observed count volumes greater than 250,000, cordon line volume should be within 5% of observed count volumes.

Highway Cordon Lines

As stated in chapter three under the traffic count section, cordon lines are analysis lines which completely encircle a subarea within the model region and include at least three roadways. Cordon lines can be subsets of screenline locations, but should never include external station locations. Cordon lines are generally used for measuring traffic in and out of major CBDs, activity centers, at beltways, and at city jurisdictional limits. At a minimum, the major city of any model region or MPO should have one cordon line around its downtown CBD. If multiple cities exist within a model region, cordon lines should be included for every city with at least 25,000 population. Additional cordon lines may be considered based on the characteristics of the model region at the discretion of the VDOT project manager. For both small and large model regions, the estimated volume for highway cordon lines should be within 10% of observed count volumes for cordon volumes with less than 54,000 observed count volume. Higher volume cordon lines should follow the same guidelines used for highway cutlines shown in Figure 15 and Figure 16. For cordon lines with observed count volumes greater than 250,000, cordon line volume should be within 5% of observed count volumes.

Highway Cutlines

As stated in chapter three under the traffic count section, cutlines are a smaller type of analysis that lie entirely within the model region and include three or more roadways. Cutlines can be subsets of screenline locations, but should never include external station locations. Having adequate cutline coverage is essential to the modeling process. Cutlines should be used to capture radial travel patterns between cities and suburbs and circumferential travel patterns among suburbs. It is recommended practice that small model regions include at least 10% of their non-centroid links in their screenline, cordon line, and cutline coverage. For large model regions, it is recommended that at least 5% of their non-centroid links be included in their screenline, cordon line, and cutline coverage.

The allowable deviation in cutlines should vary according to the total volume of the cutline. Lower volume cutlines should have higher allowable deviations while higher volume cutlines have lower allowable deviations. NCHRP 255 contains an equation that traditionally has been used by model analysts to calculate allowable deviations for cutlines. This equation is shown in Figure 14. The NCHRP 255 equation and curve has become less popular in recent years because the allowable deviation is considered to be too high to provide meaningful standards by many users of travel demand modeling results. In response to this, some agencies have adopted set

standards that do not vary by volume, e.g., 5% for all cutlines. This approach has the disadvantage of sometimes being too rigid, e.g., low volume cutlines, and having no variance by the count volume of the cutline. As a result, VDOT staff developed a revised NCHRP 255 equation and curve for allowable cutline deviation for the VTM System which is shown in Figure 15 and Figure 16. This curve maintains flexibility for low volume cutlines while providing meaningful guidelines for cutline analysis. For cutlines with observed count volumes of 250,000 or greater, cutline volume should be within 5% of observed count volumes.[24] The curve based on the equation is shown in Figure 16.

The NCHRP 255 equation and curve has become less popular in recent years because the allowable deviation is considered to be too high to provide meaningful standards by many users of travel demand modeling results. In response to this, some agencies have adopted set standards that do not vary by volume, e.g., 5% percent for all cutlines. This approach has the disadvantage of sometimes being too rigid, e.g., low volume cutlines. As a result, VDOT staff developed a revised NCHRP 255 equation and curve for allowable cutline deviation for the VTM System which is shown in Figure 15 and Figure 16 which continues to provide flexibility for low volume cutlines while creating meaningful guidelines for cutline analysis. For cutlines with observed count volumes greater than 250,000, cutline volume should be within 5% of observed count volumes.

Figure 14: Equation for Maximum Allowable Deviation in Cutlines from NCHRP 255

$$\text{Maximum Allowable Deviation} = \frac{43 * \mathrm{E}^{(-0.028 * C/1000)} + \left((-0.037) * (C/1000)\right) + 25}{100}$$

Where C = Cutline Count Total

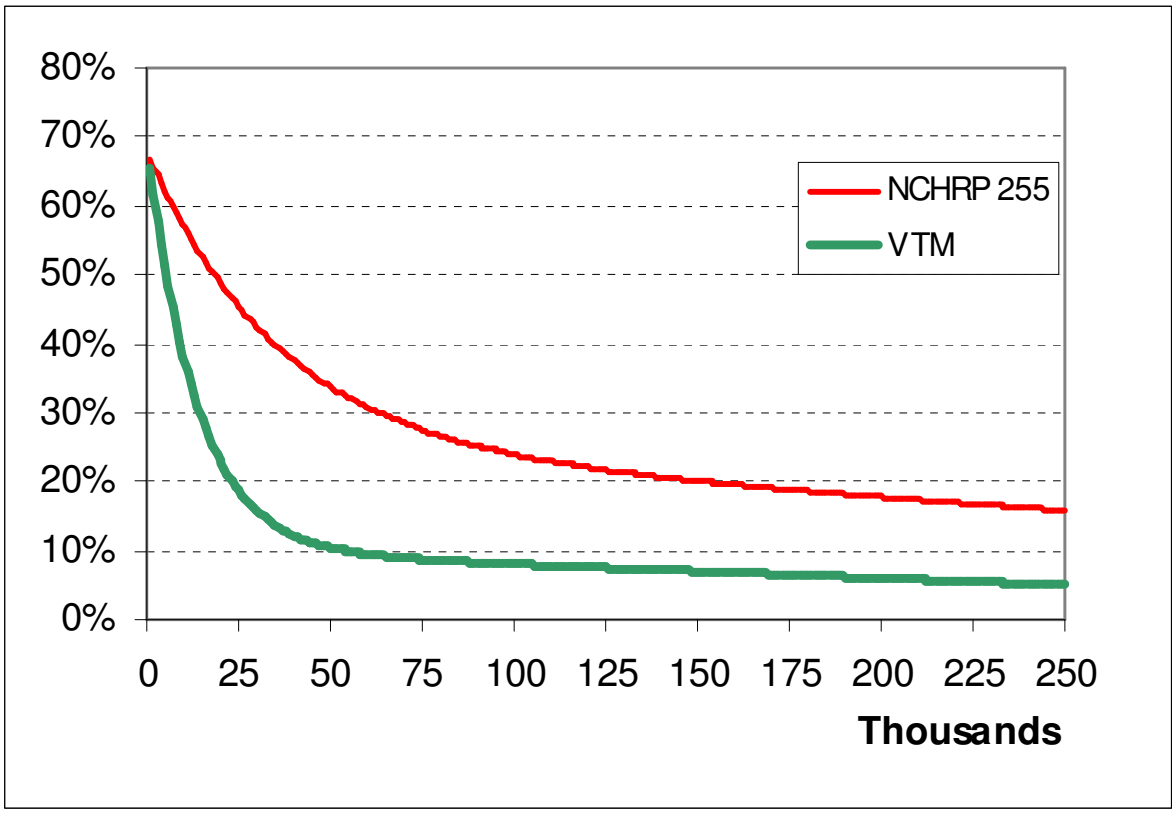
Figure 15: Equation for Determining Maximum Allowable Deviation in Cutlines Using VTM System

$$\text{Maximum Allowable Deviation} = \frac{60 * \mathrm{E}^{(-0.075 * C/1000)} + \left((-0.02) * (C/1000)\right) + 10}{100}$$

Where C = Cutline Count Total

[24] This curve comes from Figure A-9 on page 49 of NCHRP 255: Highway and Traffic Data for Urbanized Area Project Planning and Design.

Figure 16: Maximum Allowable Deviation in Total Cutline Volumes Using VTM vs. NCHRP 255 Curves



R^2 For Model Region

R^2 represents a statistical measure called the coefficient of determination. R^2 has a range of zero to one with a value of one indicating a perfect match between observed and estimated values. For large model regions, R^2, should be greater than 0.90. For small model regions, R^2, should be greater than 0.92. R^2 can also be calculated for subsets of links by functional class, volume range, district, or subarea at the discretion of the VDOT project manager.

Percent RMSE For Model Region

RMSE represents a statistical measure called the Root Mean Square Error. The higher the percent RMSE, the greater the difference between observed and estimated values. For small model regions, a percent RMSE of less than 30% is recommended. For large model regions, a percent RMSE of less than 40% is recommended. Percent RMSE should be performed for all screenline, cordon line, and cutline count locations and should not include external station count locations.

Percent RMSE by Functional Type

In addition to being analyzed for an entire model region, percent RMSE should be evaluated by functional type. This analysis should be conducted for freeways, principal arterials, minor arterials, and collectors using the validation targets displayed in Table 32 for small and large model regions. Percent RMSE by Functional Type should be performed for all screenline,

cordon line, and cutline count locations and should not include external station count locations. Table 32 shows which VTM Factypes correspond to each functional type for determining Percent RMSE by Functional Type.

Table 32: Factypes to be used for Percent RMSE by Functional Type

Functional Type	VTM Factype	Small Regions	Large Regions
Freeways	1-2	< 20%	< 20%
Principal Arterials	3-4	< 30%	< 35%
Minor Arterials	5	< 40%	< 50%
Collectors	6-7	< 70%	< 90%

Estimated Versus Observed Speed

Estimated versus observed speed is a useful validation measure if observed speed data exists. Observed speed data can be obtained by using the floating car technique or from intelligent transportation system (ITS) technology. If observed speed data is available, this analysis should be done for uncongested conditions for small model regions and for both congested and uncongested conditions for large model regions.

Assigned Versus Observed Traffic Assignment

Assigned versus observed traffic assignment is a useful validation measure to identify problem areas or systematic forecasting biases. Assigned versus observed traffic is plotted using a scattergram and compared to a 45 degree line. If the assigned and observed value are the same, the point will lie exactly on the 45 degree line. If the majority of the scattergram points appear to be above the 45 degree line, the model is overestimating traffic whereas if the majority of the scattergram points lie beneath the line, the model is underestimating traffic. This analysis should at a minimum be performed for all traffic. At the VDOT project manager's discretion, this analysis may also be required by trip type, for all roadways in a given jurisdiction, by functional type, etc.

Transit Ridership by Mode and Route

The analyst should obtain observed ridership data for all transit lines included in the mode choice model. Observed ridership data should be compared against simulated ridership data for every transit line for reasonableness. Significant differences should be carefully examined and remedied if possible.

Transit Ridership by Corridor

Major transit corridors containing three or more transit lines should be identified for the model region. Major transit corridors will be more prevalent for large model regions and may be few or nonexistent for small model regions. The analyst should obtain observed ridership data for all transit lines included in the mode choice model and identify critical transit cutlines. Observed versus simulated transit ridership data should be compared for reasonableness and adjustments made accordingly for significant differences.

Dynamic Validation

Static validation has been the traditional approach to validating travel demand models where simulated results are compared to observed results for the base model year. The static validation approach indicates the model's ability to replicate a static base year condition, but does not indicate how the model would respond to a change in inputs. To examine a model's ability to forecast changes in inputs, dynamic validation is needed. Dynamic validation tests a model's sensitivity to changes in key model inputs such as population, employment, transit fares, etc., and the reasonableness of future year forecasts. By testing a model's responsiveness to these types of changes, dynamic validation can reveal problems with models that are not evident from static validation. If a model is not producing reasonable results when inputs are changed, it may be an indicator of underlying problems with model assumptions or structure.[25] This section is divided into two parts. The first part discusses the sensitivity of a model to changes in data inputs. The second part discusses the reasonableness of a model's future year forecasts. It is important to note that for many dynamic validation measures, the test for reasonableness is at the discretion of the analyst. For these instances, the VDOT project manager is responsible for assessing the reasonableness of all forecasts. It is also highly desirable to create model structures and tools to enable analysts to more easily perform dynamic validation tests.

Sensitivity to Changes in Data Inputs

The dynamic validation measures for testing a travel demand model's sensitivity to changes in data inputs are shown in Table 33 through Table 36.

Table 33: Land Use
Table 34: Highway Network
Table 35: Travel Cost
Table 36: Transit Service

Land Use

One of the most important inputs to travel demand models is land use and consequently, land use changes are one of the most common input changes models are used to evaluate. Table 33 shows the land use measures which should be used when performing dynamic validation. These measures evaluate the model's sensitivity to changes in trip generation inputs. The first two measures add and subtract population or households, depending on which demographic variables are being used in the model, from a single TAZ in a suburban and city setting. If both population and households are model inputs, both should be evaluated independently of one another. The VDOT project manager is responsible for choosing the TAZs for this analysis.

The third measure adds and subtracts retail employment from a single suburban TAZ. The expected change in model output for vehicle trips should be the average number of vehicle trips per retail employee for the suburban area multiplied by the number of jobs added or subtracted. The expected change in model output for VMT should be proportional to the change in employment. If more than 1,000 employees are added, traffic should increase on all nearby links. The fourth measure adds and subtracts non-retail employment from a single CBD TAZ and

[25] "Dynamic Validation of Travel Demand Models" Donald Hubbard, Ronald Milam, and Chang Hwan Park.

should reflect similar sensitivity to changes in vehicle trips and VMT to that for retail employment in the suburban TAZ.

Table 33: Land Use Dynamic Validation Measures

Input Change to Evaluate	Model Region Size		Evaluation Measures
	Small	Large	
Add/subtract either population or households to a single suburban TAZ	± 1 ± 10 ± 100 + 1,000 + 10,000	± 1 ± 10 ± 100 + 1,000 + 20,000	Vehicle Trips VMT
Add/subtract either population or households to a single city TAZ	± 1 ± 10 ± 100 + 1,000 + 10,000	± 1 ± 10 ± 100 + 1,000 + 20,000	Vehicle Trips VMT
Add/subtract retail employment to a single suburban TAZ	± 1 ± 10 ± 100 + 1,000 + 5,000	± 1 ± 10 ± 100 + 1,000 + 10,000	Vehicle Trips VMT
Add/subtract non-retail employment to a single CBD TAZ	± 1 ± 10 ± 100 + 1,000 + 5,000	± 1 ± 10 ± 100 + 1,000 + 10,000	Vehicle Trips VMT

Highway Network

Highway networks are one of the principal inputs to travel demand models and are perhaps the input most subject to change in transportation planning applications. As a result, a few basic sensitivity tests should be performed on highway networks to evaluate the reasonableness of the model as shown in Table 34.

The first test which should be performed is to remove a major highway link. This link should be a major arterial or freeway for a large model region and preferably a major arterial for a small model region. Alternate routes should receive increased traffic as a result of the highway link being remove and should be examined for reasonableness. The second test is the converse of the first, to add a major highway link. This can again be evaluated for reasonableness by examining the impact on alternate routes.

The third test is to add a lane of capacity to both directions of a major highway. The impact to the major highway and for alternate routes should be assessed for reasonableness. The fourth test

is to change the model's free flow input speed along a major highway. Both of these tests should be done for a series of links stretching at least five miles to enable a cumulative effect to be seen. The impact to the major highway and to alternate routes should be examined for reasonableness.

Table 34: Highway Network Dynamic Validation Measures

Input Change to Evaluate	Model Region Size		Evaluation Measures
	Small	Large	
Remove a major highway link	Major arterial	Major arterial, or a Freeway	Alternate Route Impact
Add a major highway link	Major arterial	Major arterial or a Freeway	Alternate Route Impact
Add a lane of capacity to a major highway for both directions	Major arterial	Major arterial or a Freeway	Impact to major highway and to alternate routes
Change the free flow input speed along a major highway	± 5 or 10 mph	± 5 or 10 mph	Impact to major highway and to alternate routes

Travel Cost

Travel cost is an important factor in forecasting travel behavior which has become increasingly important in recent years as a result of travel demand modeling requests focusing more on traffic operations and alternative travel demand management strategies, e.g., HOV/HOT lanes, value pricing, etc. Dynamic validation analysis for travel costs can only be performed for model regions that include these inputs as part of their modeling process.

The first measure is to add a toll on a major highway link such as an expressway or major arterial. Toll increase of $1, $2, and $5 should be evaluated with the impact on the tolled highway and alternate routes carefully checked for reasonableness. As the toll cost increases, traffic diversion to other routes should also increase.

The second measure is to increase the value of time for households by fifty percent. The effect of this should be to increase vehicle trips and automobile mode share while causing small decreases in mode share for transit and other non-automobile modes.

The effect of rising gas prices on forecasting results has become a popular topic in recent years. Dynamic validation should be performed for six scenarios to ascertain the models' sensitivity to changes in gas prices as shown in Table 35. For each of these scenarios, vehicle trips, VMT, and modal share should be evaluated for reasonableness. As gas prices increase, vehicle trips and VMT should decrease while transit and other non-automobile mode shares increase.

Table 35: Travel Cost Dynamic Validation Measures

Input Change to Evaluate	Model Region Size		Evaluation Measures
	Small	Large	
Add a toll on a major highway link	$1.00 $2.00 $5.00	$1.00 $2.00 $5.00	Impact to major highway and to alternate routes
Value of Time	+ 50 %	+ 50 %	Vehicle Trips Modal Share
Increase Gas Cost	± 25 cents ± $1.00 + $5.00	± 25 cents ± $1.00 + $5.00	Vehicle Trips VMT Modal Share

Transit Service

The transit service dynamic validation measures only apply to model regions which have transit included in their models. The first test which should be performed is to evaluate the model's sensitivity to changes in Transit Fare. These four scenarios should be evaluated for all model regions: free transit, increase/decrease transit fares by 20%, and increasing transit fares by 100%, e.g., doubling the cost. Transit ridership is inelastic with respect to changes in transit fare so that percent changes in fare should cause significantly smaller percent changes in ridership. Empirical studies generally show that the percent change in transit ridership is less than half the percent change in transit fare, e.g., a 20% decrease in transit fare would result in a less than 10% increase in transit ridership.

A good heuristic rule of thumb for evaluating model sensitivity to changes in transit fare is the Simpson-Curtin rule which holds that transit fare elasticity is about -0.30. This means that a 10% increase in transit fare, should result in about a 3% decrease in transit ridership.[26] Using this rule, for the four scenarios shown in Table 36, changing the transit fare should change the ridership by the amounts shown in Table 37. This rule should serve as a guideline for model reasonableness, rather than an absolute standard when performing dynamic validation work.

Changing transit fares should affect automobile traffic such that an increase in transit fares should cause some increase in automobile traffic as measured by vehicle trips, but the increase is generally small and significantly smaller than the corresponding reduction in transit ridership. The converse of this guideline should hold for instances of decreases in transit fares.

[26] NHI Course No. 15260: "Advanced Urban Travel Demand Forecasting" p. 11-21.

Table 36: Transit Service Dynamic Validation Measures

Input Change to Evaluate	Model Region Size		Evaluation Measures
	Small	Large	
Transit Fare	(For areas with Transit included in the model) Free Transit ± 20% + 100%	Free Transit ± 20% + 100%	Transit Ridership Vehicle Trips Modal Share
Transit Headways	(For areas with Transit included in the model) ± 50%	± 50%	Vehicle Trips VMT Modal Share Transit Ridership
Add a new transit line to a major corridor	(For areas with Transit included in the model) A new Bus Line	A new Bus Line A new Rail Line (if included in model)	New route ridership Impact on alternate routes Modal Share Transit Ridership

Table 37: Expected Transit Fare Changes

Transit Fare Change	Simpson-Curtin Rule Expected Change
Make Free (Decrease 100%)	+30%
Decrease by 20%	+6%
Increase by 20%	-6%
Double the Fare (Increase 100%)	-30%

Changing transit fares should affect mode share such that an increase in transit fares should cause a corresponding decrease in transit mode share and a smaller increase in automobile mode share. The converse of this guideline should hold for instances of decreases in transit fares.

Reasonableness of Future Year Forecasts

Travel demand models are developed to serve as future year forecasting tools. As a result, it is important to evaluate the reasonableness of these forecasts before applying the model. For model regions that are in non-attainment for air quality conformity and do not have early action compact status, the reasonableness of all future year forecasts should be evaluated. That is, for the current long range plan horizon year and all interim years required for air quality conformity. For all other model regions, it is sufficient to only evaluate the reasonableness of the forecast for the long range plan horizon year.

The following measures should be determined for each forecast year and compared to one another, base year model results, and demographic trends for reasonableness:

1. Person Trips (if person trips are calculated in the model)
2. Person Trips per capita (if person trips are calculated in the model)
3. Vehicle Trips
4. Vehicle Trips per capita
5. VMT
6. VMT per capita
7. Transit Ridership (if transit is included in the model)
8. Modal Shares

Additionally, traffic volumes for highway screenline, cordon line, and cutlines should be calculated for the long range plan horizon year for all model regions and compared with the corresponding base year model results for reasonableness.

9. Documentation and Deliverables

This chapter discusses the policies for providing documentation and deliverables for model validations and updates. Both of these are often shortcomings of model improvement efforts, and should not be overlooked. Receiving good documentation and all the necessary model deliverables is essential to model users and important for informing interested parties on how model processes function during model applications and reviews.

Model Documentation

Model documentation should thoroughly document the policies and procedures used in model development, calibration, and validation. This document may serve as a template for structuring validation reports. Additionally, documentation should present calibration and validation results. Documentation should be presented to VDOT in hardcopy and electronic format as specified by the VDOT project manager.

Model Deliverables

Model deliverables should include all files needed to develop, use, and understand the completed model. They should include all data inputs such as TAZ structure, surveys, and traffic counts, all files necessary to run the model in CUBE catalog format, files showing final model results, and documentation files. Table 38 shows a checklist of the files that should be provided to VDOT at the conclusion of model improvement projects.

Table 38: Checklist of Deliverables needed for Model Improvement Projects

Item	Deliverable	Description
1	TAZ Structure	Shape file
2	Travel Survey	Geocoded and in O-D format as a dbase file if applicable
3	External Station Survey	Geocoded and in O-D format as a dbase file if applicable
4	Transit On Board Survey	Geocoded and in O-D format as a dbase file if applicable
5	Other Survey Results	Geocoded and in O-D format as a dbase file if applicable
6	Transportation Network	Current VDOT Citilabs' format
7	Land Use Files	For Base and Future Years in dbase format.
8	Traffic Counts	A file with all traffic counts used for model development including external stations with a link to the transportation network.
9	Required Model Files	All required files for using model in CUBE Catalog format. CUBE Catalog must be provided in Developer's mode.
10	Software Source Code	For any software developed for a modeling project, the complete source code must be provided to VDOT.
11	Model Results	Loaded network and trip tables from validation model runs for base and future years in a format compatible with a CUBE Catalog.
12	Model Documentation	For model development, validation, and use.

The deliverables shown in Table 38 are required provided that they were part of the model development effort unless specified otherwise by the VDOT project manager. The file format for model deliverables should be compatible and consistent with established VDOT practice. Model files should be delivered in a format compatible with the current Citilabs' software used by VDOT. Model documentation files should be delivered to VDOT in both Microsoft Word and PDF format.

10. Application and Analysis

Once a travel demand model is validated, it is ready for use in transportation planning application and analysis. But a travel demand model is not always the best technical tool for every situation and the results of these models need to be interpreted and used in the proper context to ensure sound planning practice. This chapter discusses the policies and procedures for developing model outputs for presentation and using model results for project planning applications.

Developing Model Outputs For Presentation

Traffic Volumes

Traffic volumes taken directly from travel demand models should be carefully examined before use in presentation or project planning. The refinement techniques documented in the National Cooperative Highway Research Program Report (NCHRP) 255 should be used to make adjustments to future year forecasts based on traffic counts.[27]

Another important consideration when preparing traffic volumes for presentation is rounding. All traffic forecasts should be rounded to the nearest 100 and displayed in hundreds, e.g., 14,237 becomes 142, to enhance visual display and provide consistency. This can be done quite easily using Citilab's CUBE software or using ESRI's ArcGIS software for making plots of traffic assignments.

Vehicle Miles Traveled

Vehicle Miles Traveled (VMT) is a standard model output, but the analyst should be careful in simply comparing this output directly to observed VMT data. The two major sources of observed VMT data are traffic counts and the Highway Performance Management System (HPMS).

Observed traffic counts from VDOT's Traffic Monitoring System (TMS) is a good source of traffic count data. Other counts sources can include local jurisdiction counts and special study counts. VMT estimates can be developed from available count data to compare to simulated VMT. When performing this comparison, however, it is important to make sure the comparison is as consistent as possible in terms of facility types being included in the comparison, geographic area covered, and simulated vs. observed time period. This last item is particularly important as many travel demand models are calibrated to simulate average weekday traffic (AWDT), but most count data is average daily traffic (ADT). Accepted TMS methods should be used to convert ADT to AWDT equivalents.

With HPMS data it is important to note that most travel demand models do not include local road VMT whereas HPMS data does include this. For total VMT, it is generally best to compare the non-local model total to the non-local total for HPMS. Additionally, travel demand model

[27] Highway Traffic Data For Urbanized Area Project Planning and Design, NCHRP 255. Pedersen and Samdahl. 1982.

functional class definitions may not match those in HPMS. As a result, VMT estimates should be carefully compared to HPMS estimates and adjustments made as appropriate to ensure that reported model results are consistent with HPMS to the greatest extent possible.

Congestion

Areas of congestion in travel demand models are generally best quantified by using Volume/Capacity (V/C) ratios. When quantifying Level of Service (LOS) levels from model results, the ranges should be consistent with the most recent version of the Highway Capacity Manual (HCM). For models using LOS E capacities, congestion should be defined as roadways with LOS E or F. For models still using LOS C capacities, it is permissible to extend this definition to also include LOS C and D.

Using Model Results for Project Planning Applications

Travel demand models were originally developed to evaluate the impact of major highway improvements in urban areas. They have also been used extensively to provide regional level traffic forecasts to support the statewide and metropolitan transportation planning process. Long range plan development has become one of the primary uses of these models. These long range plans serve as the basis for more detailed project level planning studies which often use a combination of travel demand models and other types of analytical tools. As a result, it is important to consider what tool is best for the application.

Using a Travel Demand Model vs. other tools

Using a travel demand model versus other technical tools is an important consideration when performing project planning applications. Which tool would be best for a given situation depends on the level of detail required. Below are the three most common project planning applications that generate travel demand modeling requests:

1. Corridor Studies
2. Subarea Analysis
3. Intersection Analysis

Corridor Studies

Travel demand models can be a good technical tool for major corridor studies that stretch along several miles of roadway. Such studies look at the regional or system wide impacts of a project that would generally exceed the ability of microscopic tools to handle. When performing this type of application, it is important to review the transportation network and TAZ structure for the study area so that additional detail can be added for the study. Additional TAZs and network detail are generally added when performing this type of analysis. It is also important to carefully review land use assumptions for consistency with study assumptions.

Subarea Analysis

Travel demand models are macroscopic tools designed for regional or system wide planning. As such, they are not always well suited for subarea analysis. When they are used for this type of analysis, it is necessary to add additional road detail and TAZs to the study area which can take considerable time and not necessarily produce satisfactory results. In general, a travel demand

model can only be expected to produce reasonable forecasts for one facility type higher than the lowest facility type consistently modeled throughout the model region. For example, if major collector[28] is the lowest facility type consistently modeled, the model should not be expected to produce reasonable forecasts on major collectors and other lower facility types.

For subarea analysis, it is recommended that microscopic tools such as VISSIM or CUBE Dynasim be considered. The size of the study area will determine whether or not microscopic tools are appropriate. Microscopic tools can also be used in conjunction with travel demand models, although this is not required. When they are used in conjunction with one another, travel demand models can be used to forecast traffic into and out of the study area for both base and forecast years. Forecast in/out flows should be adjusted according to base year observations to produce better results.

Intersection Analysis

By their nature, travel demand models are designed for regional planning analysis and do not contain the level of detail necessary to perform intersection analysis such as turning movements or signal timing analysis directly from model results. Microscopic modeling tools such as VISSIM, CORSIM, Synchro, etc., are much better suited for this type of application. A travel demand model can, however, be used in conjunction with a microscopic tool to forecast flows into an intersection from one or more directions. Microscopic tools, however, should be used to balance turning movements to match observations and conduct planning analysis.

The choice of an appropriate microscopic tool depends on the type and number of intersections being evaluated. But regardless of what tool is used, it is important to emphasize that intersection analysis is heavily influenced by land use in the immediate vicinity of the intersection, particularly in commercial areas. No model will be able to produce acceptable results if local land use assumptions are not valid.

Evaluation of Travel Demand Models Used in Planning Applications

It is important for VDOT staff to be able to evaluate travel demand models being used for transportation planning applications. To promote quality control and consistency in travel demand model evaluation, TMPD staff have developed a travel demand model application checklist. This Checklist is located in the Appendix of this document. VDOT staff are encouraged to use this checklist when evaluating travel demand modeling results performed by consultants and other non-VDOT staff.

[28] Table 14: Required FACTYPE Link Attribute Values for Virginia Travel Demand Models

Appendix

Staff Modeling Contacts

Staff Contact	Agency	Model Area/Issue	Telephone	E-mail
Paul Agnello VDOT Travel Demand Modeling Manager	VDOT Central Office	Model requests and questions, VTM Policies & procedures, software, training, and user's group Fredericksburg, Harrisonburg, & Virginia Statewide Model	(804) 786-2531	Paul.agnello@vdot.virginia.gov
Juyin Chen	VDOT Central Office	Charlottesville & Winchester	(804) 225-3564	Ju-yin@vdot.virginia.gov
Jaesup Lee	VDOT Central Office	Danville, Hampton Roads, & Tidewater	(804) 371-4871	Jaesup.lee@vdot.virginia.gov
Nelson Newton	VDOT Central Office	Blacksburg-Christiansburg, Fredericksburg, Lynchburg, & Roanoke	(804) 371-4877	Nelson.newton@vdot.virginia.gov
Jeremy Raw	VDOT Central Office	Richmond/Tri-Cities, Hampton Roads, & Tidewater	(804) 786-0998	Jeremy.raw@vdot.virginia.gov
William Mann	VDOT NOVA District	Northern Virginia & Washington, DC Area Models	(703) 383-2211	Bill.mann@vdot.virginia.gov

Transportation & Mobility Planning Division

Travel Model Data Request Form

Firm/Organization: _____

Requested by: _____

Address: **Street:** _____

City/State/Zip: _____

Phone/Fax: _____

E-mail: _____

Model to be used: [ ]

Project/Application:

Purpose/Use of requested data: _____

_____

_____

I understand and agree to the following terms related to the use of the requested data:

Travel model files prepared by the VDOT Transportation and Mobility Planning Division, including the associated input and prescribed output files, were developed for use by VDOT exclusively. VDOT assumes no responsibility for the usage of the files, their state, or suitability for use, outside the agency. The files are provided "as is" and in no event shall the Commonwealth of Virginia or its agencies be held liable for any damages arising from their use. The accuracy, validity, or reliability of the files is not guaranteed in any way. The Commonwealth of Virginia and its agencies disclaim all warranties, express or implied, including but not limited to liability for quality and fitness for a particular purpose arising out of the use of or inability to use the files. VDOT welcomes verifiable modifications necessary to enhance the integrity of the files.

The requested data is released by VDOT with the condition that it shall only be used for the specific project and purposes as stated in this form.

Signed _____ **Date:** _____

Mail or Fax to: VDOT–TMPD
Planning Systems
1401 E. Broad St.
Richmond, VA 23219
Fax: (804) 225-4785

Transportation and Mobility Planning Division Virginia Department of Transportation 1401 East Broad Street Richmond, VA 23219	**File creation date: 10.11.2006** This checklist was produced by the VDOT Transportation and Mobility Planning Division (TMPD). TMPD retains the right to update/modify the information at any time without notice. TMPD shall not be liable for modifications to this checklist, or results produced by any person/entity utilizing the information. This checklist is not conclusive and is for informational purposes only.

VDOT Travel Demand Model Application Checklist

VDOT currently uses the procedures listed in this checklist for in-house evaluation of travel demand models used in planning or decision-making processes, and distributes this checklist to consultants and other jurisdictions in the region, free of charge. We recommend use of the checklist to guide travel demand model forecasting analyses, to help track travel demand model work, and as a guide in drafting project scopes of work.

Our goal is to help promote quality control and consistency for travel demand model forecasting throughout the region. If you have suggestions for additional criteria or other specific requirements, or if you need help drafting a scope of work or checking final products against this checklist, please contact a member of the VDOT Travel Demand Modeling Application Checklist staff:

Paul Agnello (804) 786-2531 paul.agnello@vdot.virginia.gov
Jeremy Raw (804) 786-0998 jeremy.raw@vdot.virginia.gov

VDOT Travel Model Application Checklist

1. Scope of Study

_____ Is the study area identified by the consultant wide enough to cover the area significantly impacted by the project? (If not, recommend that the study area be expanded.)

_____ Are there any other SYIP (Six-Year Improvement Program) projects in the area that need modeling/forecasting information in the near future? (Research the SYIP list).

_____ Have you coordinated with other SYIP projects in the study area to combine your study efforts? (If not, please coordinate).

_____ Have you checked to see what modeling efforts have been done in the study area in the past? (Please check for air quality conformity analyses, traffic studies, or Environmental Impact Statements done for any project in the study area within the last few years).

2. VDOT model assumptions

_____ Has the consultant reviewed the study area land use and network assumptions in the VDOT model?
___Base year
___Future year

_____ Does the consultant have better information or has the consultant chosen different assumptions than the VDOT model? If yes:
___Has the consultant reviewed the new information with VDOT staff?
___Has the consultant documented the differences?

_____ Has the consultant reviewed area SYIP assumptions and reached agreement with VDOT staff on the projects and configurations to be included in future scenarios?

3. Study area enhancements to VDOT model

_____ Has the consultant provided better land use/network information or chosen different assumptions than the VDOT model within the study area? (The consultant needs to expand network detail, review and modify land use as needed, and modify the zone system within study area as needed). If yes:
___Has the consultant reviewed the new information with VDOT staff?
___Has the consultant documented the differences?

_____ Has the consultant reviewed the study area zone system in the VDOT model, and provided additional zone detail where necessary? (The consultant needs to split zones, distribute land use within new zones, and document their work).

_____ Has the consultant provided land use comparisons of VDOT and new study area zones (if any) for validation?

_____ Has the consultant reviewed the following model network components, but not limited, within area impacting the study area? ___Speeds, ___Centroid locations, ___Centroid connectors, ___Capacities, ___Local streets, ___Turn penalties

_____ Has the consultant provided a list and a map identifying locations of all changes?

_____ Has the VDOT staff reviewed and agreed with the proposed changes?

_____ Has the consultant reviewed the following assumptions?
___Trip rates,
___Special generators,
___Peak factors (3 hour to 1 hour, daily to 3 hours).
    ___Has the consultant made any new recommendations?
    ___Has the consultant reviewed these new recommendations with VDOT staff?
    ___Has the consultant documented these new recommendations?

_____ Has the consultant made changes to any network attributes which affect modeled travel times? ___Link Length, ___Speed, ___Capacity, ___Volume/Delay functions, ___Others (specify)

_____ Has the consultant provided a list and a map identifying locations of all changes?
___If yes, did the consultant rerun the trip distributions? (This includes base year calibration as well as all future year alternatives).
___Did the consultant rerun the traffic assignment? (This includes base year calibration as well as all future year alternatives).
___Has the consultant review resulted in any land use changes and if so, has the trip generation model been rerun?

4. Screenline/Cutline Validation

_____ Has the consultant discussed the location of screenlines and cutlines with VDOT Staff before preparing calibration documentation?

_____ Has the consultant discussed with VDOT staff which screenline and cutline results will be acceptable in their final evaluations?

___ Has the VDOT staff agreed with the consultants' recommendations?

___ Has the consultant documented these agreements?

_____ Do the final screenline and cutline results match original expectations?

___If not, has the consultant documented its evaluation?

_____ Has the consultant provided link-by-link screenline and cutline results and totals?

5. Post-processing

_____ Will turn movements be adjusted by link or individual turn movement counts?

_____ Are intersections balanced to match link forecasts?

_____ Will the post-processing ensure consistent forecasts along intersections in the same corridor?

6. HOV

_____ Will base HOV assumptions come from VDOT model or another source?

___Has the consultant provided any documentation?

_____ How will mode shift impacts be determined for different alternatives?

___Has the consultant provided any documentation?

7. Forecasts beyond the model year

_____ Will the growth factor be calculated by area or by link?

___Has the consultant discussed this with VDOT staff?

_____ If link based, how will factors be calculated for links that are not in the VDOT model?

___Has the consultant provided any documentation?

8. Additional comments

_____ Has the consultant provided an overall evaluation of the model and calibration results for reasonableness?

_____ Has the consultant checked to see if results from the new study are consistent with the work done in the past in the same study area?

___If the results are different, has the consultant documented the reasons why?

_____ How will the model be used to analyze the impacts of non-capacity related projects?

List of Websites Pertinent to Travel Demand Modeling in Virginia

Website Description	Website
Census Bureau	http://www.census.gov/
Census Transportation Planning Packager (CTPP)	http://www.fhwa.dot.gov/ctpp/
Citilabs	http://www.citilabs.com/
Federal Highway Administration (FHWA)	http://www.fhwa.dot.gov/
National Highway Institute (NHI) Training	http://www.nhi.fhwa.dot.gov/training/train.aspx
National Household Transportation Survey (NHTS)	http://nhts.ornl.gov/
Transportation Research Board (TRB)	http://trb.org/
Travel Model Improvement Program (TMIP)	http://tmip.fhwa.dot.gov/

Glossary of Travel Demand Modeling Acronyms and Terms

ADT = Average Daily Traffic

AQ = Air Quality Conformity

AWDT = Average Weekday Daily Traffic

BPR = Bureau of Public Roads (former name for FHWA)

CBD = Central Business District

Centroid = The point within a TAZ at which all travel activity is assumed to begin/end. This point is generally not the geographic centroid of the TAZ.

Centroid Connector = links that connect TAZ centroids with the transportation network.

CLRP = Constrained Long Range Plan

CMSA = Consolidated Metropolitan Statistical Area

CO = Carbon Monoxide

CTPP = Census Transportation Planning Package

E&C = Existing and Committed. Used to identify the type of transportation network being used. Existing refers to projects already completed by the current year and committed refers to projects included in the state's six year improvement program (SYIP).

FF = Friction Factor

FHWA = Federal Highway Administration

FTA = Federal Transit Administration

GIS = Geographic Information System

HBW = Home Based Work

HBO = Home Based Other

HBS = Home Based School

HBSH = Home Based Shopping

HCM = Highway Capacity Manual

HCV = Heavy Commercial Vehicle

HOV = High Occupancy Vehicle

HPMS = Highway Performance Monitoring System

HTS = Household Travel Survey

ITS = Intelligent Transportation System

IVTT = In Vehicle Travel Time

LCV = Light Commercial Vehicle

LOS = Level of Service

LUD = Land Use Density

Mode Choice = 3rd step in the 4-step travel demand modeling process which predicts the share of travel by mode, e.g., auto vs. bus vs. rail.

MPO = Metropolitan Planning Organization

MSA = Metropolitan Statistical Area

NAAQS = National Ambient Air Quality Standards

NAICS = North American Industry Classification System

NCHRP = National Cooperative Highway Research Program

NCRTPB = National Capital Region Transportation Planning Board

NHB = Non-Home Based

NHI = National Highway Institute

NOVA = Northern Virginia District area which includes Arlington, Fairfax, Loudon, and Prince William counties and their surrounding cities.

NHTS = National Household Transportation Survey (formerly called the NPTS)

NOx = Nitrogen Dioxide

OVTT = Out of Vehicle Travel Time

PDC = Planning District Commission

SIC = 1987 U.S. Standard Industrial Classification System

SIP = State Implementation Plan

Skim = A table or matrix summarizing TAZ to TAZ travel times, costs or other quantities.

SOV = Single Occupant Vehicle

TAZ = Transportation Analysis Zone

TAZs = Transportation Analysis Zones

TIP = Transportation Improvement Program

TLFD = Trip Length Frequency Distribution

TMS = Traffic Monitoring System. Serves as the Virginia Department of Transportation's official traffic database.

Transportation Analysis Zone = A unit of geography developed from census geography designed for use in land use and transportation planning.

TRB = Transportation Research Board

Trip Assignment = 4th step in the 4-step travel demand modeling process which predicts the routes that will be used for travel.

Trip Distribution = 2nd step in the 4-step travel demand modeling process which predicts the origins/destinations where trips will travel to/from.

Trip Generation = 1st step in the 4-step travel demand modeling process which predicts the number of trips that will be made by TAZ.

TDFM = Travel Demand Forecasting Model

VDOT = Virginia Department of Transportation

VEC = Virginia Employment Commission

V/C = Volume to Capacity Ratio

VHT = Vehicle Hours of Travel

VLRP = Vision Long Range Plan. This is a long range plan that includes the entire list of projects an organization desires without any financial constraint.

VMT = Vehicle Miles of Travel

VTM = Virginia Transportation Modeling

VSM = Virginia Statewide Travel Demand Model