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Disclaimer

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1 Introduction

This report was prepared under the “Improvement and Operation of the Vermont Travel Model” contract with the Vermont Agency of Transportation (VTrans) for the 2014-2015 year (Year 7) of the contract. The primary objective of the project is to continue maintaining the Vermont Travel Model, ensuring that it remains a comprehensive, effective predictor of travel behavior of Vermonters. The purpose of this report is to document the activities which were completed in the 2014-2015 year (Year 7) of the contract. Other support activities undertaken in Year 7 of the contract using the Model to support VTrans efforts are documented separately.

The Vermont Travel Model is a series of computer sub-models which uses the land use and activity patterns within Vermont to estimate the typical travel behavior of Vermonters. Origin and destination matrices are created which describe the number of expected trips between geographical areas, known as traffic analysis zones. Accommodations are made for commercial-truck trips and the occupancy characteristics of passenger vehicles. The final outputs are traffic volumes by roadway link in the state-wide roadway network. The Model currently includes 943 traffic analysis zones (TAZs) and 5,327 miles of highway-network links (Figure 1).

This report contains a description of the Vermont Travel Model (Section 2), including its history and its current functional capabilities, a description of the data used this year (Section 3), a description of the methods used and the results of the update (Section 4), and a summary of the results of this year’s improvements with recommendations for Year 8 (Section 5).

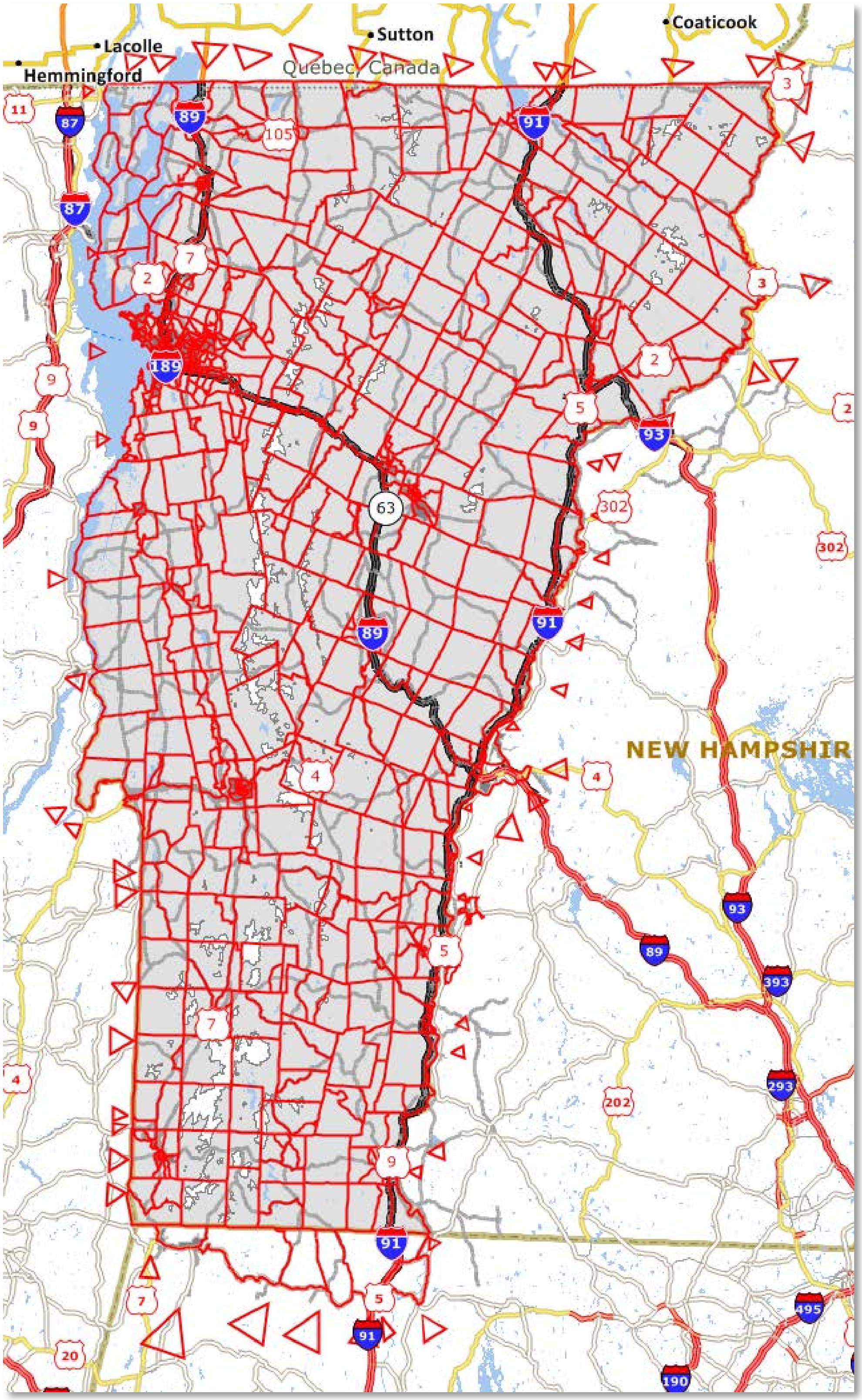

Figure 1 TAZs and Road Network in the Vermont Travel Model

2 Description of the Model

The purpose of the Vermont Travel Model ("the Model") is to estimate travel demand and link flow throughout the state using general spatial characteristics of the Vermont population. The Model is an important planning tool, beneficial not only to the Agency of Transportation but to regional planning commissions, the Chittenden County Metropolitan Planning Organization (CCMPO) and the University of Vermont Transportation Research Center (UVM TRC) – all of which rely on the Model for transportation planning and/or research. Daily travel demand is estimated by the Model between TAZs by the purpose of a trip. From this travel demand, trips are routed and the flow of traffic on each link in the Model road network is estimated. Appendix A provides a schematic representation of the Model inputs (boxes) and model processes (block arrows).

Trip generation (productions and attractions) is estimated for each of five trip-purposes: home-based work, home-based shopping, home-based other (including school travel, social & recreational trips), non-home-based, and truck; and two distance classifications: long-distance and short-distance. Trip generation estimations are based on the 2010 US Census, the 2009 National Household Travel Survey (NHTS), the 2006-2010 American Community Survey (ACS), 2009 data from the Department of Employment and Training of the Vermont Department of Labor (VDOL), and 2009 data from the Bureau of Economic Analysis (BEA). Trip distribution is accomplished using a production-constrained Gravity Model. The traffic assignment module of the Model implements a multi-class user-equilibrium assignment process with two classes – all passenger vehicles, and trucks. The multi-class assignment process is used because some of the minor links in the road network have truck exclusions. Therefore, the multi-class assignment is used to allow passenger cars to use the entire network while preventing trucks from using links where they are prohibited.

The Model includes truck traffic by incorporating "Truck" as a trip purpose. However, no comprehensive freight model has been developed to break truck travel down into medium- and heavy-commercial trucks, and to investigate commodities moved in an average day. Rail transport, passenger transit, and non-motorized travel modes are also not currently part of the functional sub-modules of the Model.

2.1 History of the Model

The original statewide model was developed in the 1990s. At that time, the Model processes were run in the SAS Model Manager 2000 platform, and the network was in the TRANPLAN software format. The base-year 2000 version of the statewide model was updated beginning in 2003. The update was completed by transitioning the Model into a GIS-based framework using the CUBE software package in 2007 (VHB, 2007). During the 2003 – 2007 update, newly proposed or constructed links, like the Circumferential Highway in Chittenden County and the Bennington By-Pass, were added to the road network. Minor adjustments were also made to trip generation coefficients to bring initial balancing factors closer to 1.0. Other adjustments were made to improve the relationship between model outputs and validation data, which was down to 50.2% after the 2007 improvements (VHB, 2007).

2.1.1 Year 1

In October of 2008, the Vermont Travel Model was moved to the Transportation Research Center at the University of Vermont. For most of the 2008-2009 contract-year, the TRC conducted an evaluation of the Model's utility, components, and current software platform. A report was completed in May of 2009 with details of the evaluation and its preliminary findings (Weeks, 2010). The goals of the evaluation were to:

- Identify the current and potential uses for the Model based on VTrans planning practices and needs.
- Recommend updates to the Model to meet future implementation.
- Compare the existing software platform with other widely-used software packages

The UVM TRC also conducted a literature review of statewide travel-demand modeling practices in other states, including general model structure, operation, and maintenance, and a discussion of emerging trends in travel-demand modeling (Weeks, 2010).

In addition, selected model applications were performed in 2008-2009 in response to requests from VTrans staff. Bridge closures were explored, comparing traffic volumes before & after the closure, for the following locations:

- Chester, Vermont
- VT-11 & VT-106

- Springfield, Vermont (2 locations)
- US-5 & US-11 (2 locations: I-91 SB & NB Ramps)

The UVM TRC also performed an emissions analysis of 5+–axle trucks along a segment of US-7 and a parallel route on I-89 in the Burlington area. A local trucking company was contacted to assist with the analysis and a data collection of truck driving cycles on the analysis segments was performed on July 21, 2009 using a tractor-trailer truck provided by a local shipping company. The truck drive-cycle data, including second-by-second velocity, acceleration, and grade was compiled and the emissions analysis was conducted using the Comprehensive Modal Emissions Model (USEPA, 2003) with eight drive cycles, two per route per direction. UVM TRC Report No. 09-006 was completed in September of 2009 with details of the analysis and the findings (Weeks, 2009).

2.1.2 Year 2

In 2009-2010, the UVM TRC conducted a travel analysis of the Burlington-Middlebury Corridor to evaluate the potential effects of the addition of the proposed Exit 12B. The travel analysis included four scenarios, two base-year scenarios (2000, with and without Exit 12B) and two forecast scenarios (2030, with and without Exit 12B). The results of the analysis indicated that the addition of Exit 12B would not have a significant effect on north-south corridor travel between Burlington and Middlebury.

A preliminary travel analysis was also conducted for the Route 22A Corridor near Fair Haven, Vermont in support of a consultant working for VTrans. The analysis provided a breakdown of travel in the corridor by trip purpose. The results of this travel analysis, which included queries of the Model for link-specific data, was delivered to Stantec and VTrans on July 2, 2010.

As the data from the NHTS was released in the late summer of 2010, the UVM TRC prepared a work plan for the task of updating the Model to a new base-year. The update was initiated by compiling statistics on auto-occupancy and trip generation rates from the NHTS and this stage was completed by the end of Year 2.

2.1.3 Year 3

The Model update continued in Year 3 of the UVM TRC contract with new information from the 1,690 households in Vermont surveyed in the 2009 NHTS, new demographic information from the 2005-2009 ACS, new employment information for 2009 from the VDOL, and new traffic counts for 2009 from VTrans. In addition, sub-modules in the Model were re-evaluated and process improvements were made. Of the four tables delivered with the NHTS (household, person, vehicle, and person-trip), only the household and the person-trip tables were used in this update. Using the household table from the NHTS, the trip-rate table for all home-based trip productions was updated. With the person-trip table from the NHTS, the following were updated:

1. Trip-production and attraction regression equations in the Model
2. Vehicle occupancy rates by trip purpose
3. External trip-fractions by trip-purpose
4. Truck percentages by TAZ
5. Friction-factors in the trip-distribution module of the Model

The 2009 Average Annual Daily Traffic (AADT) for most of the major roads in the state was also used to make updates to the Model. This data was obtained in a geographic information system (GIS) from VTrans and used to update the TRUCK purpose O-D using an ODME process on the AADTs for truck and the daily trip counts for all external TAZs in the Model. Finally the land-use characteristics in the Model were also updated using the 2005-2009 ACS (for numbers of households) and the employment statistics from the VDOL (for numbers of jobs by category).

The importance of these updates was immediately apparent in the fidelity of the Model. For example, the base-year 2000 Model included 240,637 households in its 628 TAZs, with an expected growth to 295,126 households by 2020. The 2009 update showed that there were closer to 250,000 households in Vermont at that time, indicating that the expected growth had been grossly overestimated. Employment growth, however, was underestimated in 2000. The total employment volume of 333,409 in 2000 was expected to grow to 428,353 by 2020. However, the 2009 update revealed a total of 431,280 jobs in Vermont, already surpassing the 2020 estimate. Part of this discrepancy could be due to improved job totals from the VDOL which may not have been readily available in 2000.

In addition, selected Model applications were performed in 2010-2011 in response to requests from VTrans staff.

2.1.4 Year 4

The Model updates completed in Year 4 brought its base year up to 2009-2010. Land-use characteristics were updated in Year 4 with new information from the 2006-2010 ACS, the 2010 US Census, and the 2009 employment estimates from the BEA. The improvements created by these updates were evaluated by checking the Model outputs for "reasonableness" in accordance with FHWA guidance (Cambridge Systematics, 2010). FHWA standards for comparing Model flows with traffic counts were achieved for 3 of the 4 roadway classes tested. The only exceedance of the FHWA standards was for freeways. Most of the freeways in the Model are coded as two separate links, one for each direction of travel, to accommodate coding of ramps at freeway interchanges. However, the AADT data used to validate the Model is coded as single-links throughout the state, even for freeways. This discrepancy creates a susceptibility for the traffic counts to be mistakenly applied when the coding of the links is not taken into account.

In addition, selected Model applications were performed in 2011-2012 in response to requests from VTrans staff.

2.1.5 Year 5

The Model improvements conducted in Year 5 included Model-process improvements, significant improvements to the network representation of the state-maintained roadways in the Model, and forecast-year Model runs for 2025 and 2035. Each of these improvements took advantage of data available in other Sections at VTrans, and much of the data had to be pre-processed for use in the Model's GIS environment. These improvements resulted in an overall improvement in the ability of the Model to simulate a typical day of travel in the state. The forecast-year Model runs were conducted with realistic representations of the state-maintained roadway network in 2025 and 2035, based on long-term transportation plans prepared by VTrans and the RPCs.

A TMIP peer review of the Model was conducted by FHWA in Year 5, resulting in a comprehensive set of recommendations for Model improvements for Year 6 and beyond. Selected subtasks were recommended based on the short-term recommendations from the peer review to achieve this goal:

1. Break up HBO and NHB trips in the Model with sub-categories (personal-discretionary, personal non-discretionary, and business) and/or distance classes (long and short) as data supports, in accordance with NCHRP guidance

2. Test the validity of leaving the trip matrices asymmetrical, particularly for NHB travel, since NHB trips do not necessarily return to their origin daily

3. Re-assess all centroid connectors locations and resolution of TAZs

4. Explore the need for seasonal trip tables

5. Develop a Validation Plan for the Model, along with a user's guide and technical reference

6. Expand the spatial boundary of the Model as necessary to include important "halo" populations

7. Develop a statewide model users' guide and technical reference

8. Consider dynamic traffic assignment to assess traffic patterns in emergency response

9. Identify metrics for emergency scenario comparison to guide model development

This report includes descriptions of the Model improvement activities performed to address items 1, 2, and 3 above.

In addition, selected Model applications were performed in 2012-2013 in response to requests from VTrans staff.

2.1.6 Year 6

The Model improvements conducted in Year 6 included Model-process improvements and improvements to the network representation of the state-maintained roadways in the Model.

The Agency decided to change the software platform for the Model in Year 6, from CUBE Voyager to TransCAD. This decision was based on the following points:

1. The Chittenden County Regional Travel Demand Model is in TransCAD, so this change would facilitate synchronization of the two models

2. The UVM TRC, which hosts the Model, has developed other transportation and land-use models, like the roadway snow and ice control routing model, for Vermont in TransCAD, so this change would facilitate potential integrations of those models and the Vermont Travel Model

In addition to migrating the code, other refinements were made to the Model code in TransCAD, and new features were added. The most significant refinement was a change to the way that truck trips are estimated in the

Model. Since TransCAD has a macro for utilizing an origin-destination matrix estimation (ODME) procedure, that procedure was incorporated into the Model code. The original procedure was less accurate, because it used truck traffic counts but in a more aggregate way, and then applied those counts to the overall trip counts to extract an estimate of truck trips by TAZ. With the ODME procedure, truck traffic counts are used directly to estimate truck trips for the entire state at once, based on an initial “seed” matrix. This refinement improved both the speed and the accuracy of the Model. The accuracy improvement that comes about as a result of the ODME procedure was documented in the Year 3 Report.

New features added to the Model included a menu-based user-interface with full specification of the input files, a forecast-period specification, and the addition of a root-mean-square percent error (RMSPE) output table. A new menu-interface was added to help the user explicitly understand how and when the Model is run, and to allow the user more explicit control over the Model runs. The forecast-period specification allows the Model to be run to any forecast year the user chooses, creating a sub-folder in the output folder identified by the forecast year with the associated Model outputs. A new output table was added to the Model to help users see the RMSPE and link-specific squared errors (SE) more efficiently. These statistics are useful for validating the Model, so having them produced in a stand-alone output table allows the Model to be re-estimated and/or updated more efficiently. These improvements resulted in an overall improvement in the ability of the Model to simulate a typical day of travel in the state.

Following the recommendation of the peer-review panel from Year 5, a comprehensive analysis of long-distance travel in Vermont was conducted, with the goal of creating a new classification of trips in the Model based on distance. A new distance-classification was explored with a cut-off distance of about 40 miles, with trips longer than 40 miles considered “long-distance” trips. However, existing data resources, like NCHRP 735, for creating a long-distance trip sub-model were found to be inaccurate for Vermont and inadequate for a complete specification of long-distance travel.

Improvements to the network representation of the Model road network included adjustments to the locations of centroid connectors in the vicinity of the University of Vermont, one of the largest employers in the state. A few other links with no flow were found to have incorrect speed limits, leading to unusually high assumed travel times across them. Speed limits were checked and fixed using the Google Street View Hyper-Lapse and the results improved significantly. The TAZ resolution was assessed by focusing on those TAZs in the network with the highest total trip counts as an origin or a destination. The top 5 TAZs for trip counts were found and two of them were split to create a new TAZ at each location. These splits were necessary because of significant development that has occurred in previously rural locations at the edges of the cities of St. Albans and Barre.

In addition, selected Model applications were performed in 2013-2014 in response to requests from VTrans staff.

2.2 Functionality of the Model

The figures in Appendix A illustrate the processes which comprise the Trip Generation, Trip Distribution, and Traffic Assignment modules of the Model.

2.2.1 Trip Generation

The trip-generation module starts by combining the TAZ-based land-use characteristics with the town-based fractions of no. of persons / no. of workers per household cross-classifications to calculate home-based trips produced by each internal TAZ for both long- and short-distance classifications. It then calculates trip attractions for each internal TAZ by purpose and trip-productions for the non-home-based (NHB) purpose using purpose-specific regression equations for both long- and short-distance classifications, each of which utilizes a different set of employment and/or population field(s) from the TAZ characteristics table. For example, the equations for home-based work (HBW) trips attracted are based on all of the employment fields in the TAZ characteristics table, but the equations for home-based shopping (HBSHOP) trips are based solely on the retail employment field. Truck (TRUCK) productions and attractions are calculated simply by multiplying the truck percentages from the TAZ characteristics table by the production and attraction totals for the other four trip purposes. The distance classification is not applied to the estimation of truck trips in the Model.

Productions and attractions for zones external to Vermont are calculated differently. First, external TRUCK trips are taken to be the Truck AADT for the external zones and split evenly as productions and attractions. The total for other passenger-car external vehicle-trips (VTs) is taken as the non-truck AADT for each external zone. The external vehicle-occupancy rate (as an input) is applied to this total to derive non-TRUCK external person-trips (PTs). Total non-TRUCK external PTs are then subdivided into the other 8 trip purposes (4 main purposes x 2 distance classifications) using the following fractions:

- HBW – short-distance: 10%

- HBW – long-distance: 2%
- HBSHOP – short-distance: 19%
- HBSHOP – long-distance: 3%
- HBO – short-distance: 26%
- HBO – long-distance: 6%
- NHB – short-distance: 28%
- NHB – long-distance: 6%

Ultimately, this process outputs a table of productions and attractions for each of the ten trip purposes in the Model for each of the 943 internal and external zones. However, since the production and attraction estimates for the internal TAZs came from different sources, they do not match. This mismatch is typical for demand-forecasting models where separate regression models are estimated for production and attraction across a full study area with unique predictor variables. Balance factors are calculated as the ratio of trip productions destined for internal zones to the corresponding trip attractions in internal zones by trip purpose. Balancing is accomplished by zone by multiplying the balancing factors by the internal trip attractions only so that they match total productions (internal and external) by trip purpose. The end result is a table of balanced productions and attractions for each of the ten trip purposes in the Model for each zone. Summary statistics of the balanced trip production/attraction table are provided in Table 1.

Table 1 Summary Statistics of the Balanced Trip Table

Trip Purpose	Class	Sum	Min	Max	Mean	Std Dev.
HBW-SD	No. of Trips Produced	283,129	0	1,281	325	227
HBW-LD		15,097	0	148	17	15
HBSHOP-SD		444,860	1	2,175	508	351
HBSHOP-LD		20,793	0	587	24	46
HBO-SD		638,238	1	3,325	729	515
HBO-LD		42,552	0	748	49	61
NHB-SD		526,873	0	4,753	574	552
NHB-LD		25,925	0	744	28	68
TRUCK		240,342	0	1,763	269	197
HBW-SD	No. of Trips Attracted	283,129	0	3,992	308	466
HBW-LD		15,097	0	194	16	25
HBSHOP-SD		444,860	0	9,049	485	959

Trip Purpose	Class	Sum	Min	Max	Mean	Std Dev.
HBSHOP-LD		20,793	0	587	23	54
HBO-SD		638,238	0	3,325	695	502
HBO-LD		42,552	0	748	46	83
NHB-SD		526,873	0	4,753	574	552
NHB-LD		25,925	0	744	28	68
TRUCK		240,342	0	3,314	256	388

2.2.2 Trip Distribution

The trip-distribution sub-module takes the balanced trip table, a matrix of free-flow travel times between TAZs and a set of impedance functions or friction factors to develop a matrix of trips between all zones. For short-distance trips, impedance functions are used but for long-distance trips the estimated impedance functions have been turned into a table of friction factors for HBO and NHB trips, so long-distance trips are prevented from being distributed to TAZs closer than 40 miles. The set of impedance functions used to distribute short-distance trips is shown in Table 2.

Table 2 Short-Distance Impedance Functions in the Vermont Travel Model

Trip Purpose	Impedance Function		a	b	c
HBW-SD	Gamma	$f(t_{ij}) = a \cdot t_{ij}^{-b} \cdot e^{-c(t_{ij})}$	0.07	0.86	0.095
HBSHOP-SD	Gamma	$f(t_{ij}) = a \cdot t_{ij}^{-b} \cdot e^{-c(t_{ij})}$	0.099	1.15	0.128
HBO-SD	Gamma	$f(t_{ij}) = a \cdot t_{ij}^{-b} \cdot e^{-c(t_{ij})}$	0.029	1.2	0.126
NHB-SD	Gamma	$f(t_{ij}) = a \cdot t_{ij}^{-b} \cdot e^{-c(t_{ij})}$	0.11	0.75	0.116
TRUCK	Exponential	$f(t_{ij}) = e^{-c(t_{ij})}$			0.065

The impedance functions used to calculate friction-factors for long-distance trips are shown in Table 3.

Table 3 Long-Distance Impedance Functions in the Vermont Travel Model

Trip Purpose	Impedance Function		a	b	c
HBW-LD	Gamma	$f(t_{ij}) = a \cdot t_{ij}^{-b} \cdot e^{-c(t_{ij})}$	0.07	0.86	0.095
HBSHOP-LD	Gamma	$f(t_{ij}) = a \cdot t_{ij}^{-b} \cdot e^{-c(t_{ij})}$	0.099	1.15	0.128
HBO-LD	Exponential	$f(t_{ij}) = e^{-c(t_{ij})}$			0.012
NHB-LD	Exponential	$f(t_{ij}) = e^{-c(t_{ij})}$			0.011
TRUCK	Exponential	$f(t_{ij}) = e^{-c(t_{ij})}$			0.065

As seen in Table 3, the Model was found to perform better when the distance-classification threshold was not applied to the distribution of HBW or

HBSHOP trips. Therefore, the impedance functions for long- and short-distance trips for these purposes are identical.

The result of this step is a matrix of productions and attractions between all zones. Since the Model is a daily model, all trips are assumed to return, meaning that all trips originating in one zone and destined for another must also originate in the destination zone and terminate in the origin zone. This assumption requires that the final matrix be diagonally symmetric. To accomplish this, the matrix is added to its transpose and then all cells are halved. The result is a diagonally-symmetric O-D matrix of PTs.

In the past, the O-D matrix of PTs was reduced by the expected transit demand before allocating the remaining trips to passenger vehicles. However, the existing matrix of transit demand may date back as far as 1997, so no defensible data source for transit demand exists, and the 2009 NHTS does not support the development of a full O-D matrix of transit demand statewide. Therefore, transit demand is no longer considered directly in the Model. Instead, the full O-D matrices resulting from the trip-distribution step are divided by a vehicle-occupancy to convert them from person-trips to passenger vehicle-trips. The vehicle occupancies currently used in the Model, derived from the 2009 NHTS, are shown in Table 4.

Table 4 Vehicle Occupancy Rates in the Vermont Travel Model

Trip Purpose	Internal Trips	Internal to External & External to Internal Trips
Home-Based Work – SD	1.12	1.05
Home-Based Shopping – SD	1.48	1.79
Home-Based Other – SD	1.75	2.00
Non-Home-Based - SD	1.53	1.52
Home-Based Work – LD	1.38	1.16
Home-Based Shopping – LD	1.71	3.06
Home-Based Other – LD	1.57	1.95
Non-Home-Based – LD	1.43	1.94
Truck	1.00	1.00

2.2.3 Traffic Assignment

The final matrix, including all passenger vehicle-trips (all of the non-TRUCK matrices summed) and truck trips (all TRUCK trips), is assigned to the road network in the traffic assignment sub-module. Free-flow travel speed on each link is assumed to be 5 miles per hour over the speed limit, and the user-equilibrium multi-class traffic assignment is used. The multi-class assignment allows trucks and passenger vehicles to be assigned to a separate road network, with the truck network incorporating exclusions wherever trucks are prohibited on the road network. The assignment results in daily traffic flows in each direction for passenger vehicles and trucks on every link in the 2010 road network, as well as the RMSPE calculated by comparing these link volumes with AADTs on a subset (2,240 of 5,670) of the links in the network. Links excluded from the calculation include:

- Centroid connectors
- Links representing roadways for which an AADT was not determined
- Links with high variations in directional flow (the AADT is not distinguished by direction of flow)

The current RMSPE of the Model run for its base-year of 2010 is 42.5%.

2.2.4 Forecasting and Scenario Modeling

Forecasting for scenario modeling in the Vermont Travel Model is accomplished using fixed growth rates derived from statewide and local economic forecasts for employment and population. Employment growth by sector & county and population growth by county are specified in an input table, as shown in Table 5.

Table 5 Forecast Annual Growth Rates for the Vermont Travel Model

County	Retail	Manufacturing	Non-Manufacturing	Government	Education	Population
Addison	0.009	-0.011	0.008	0.002	0.003	0.003
Bennington	0.007	-0.012	0.006	0.000	0.003	-0.001
Caledonia	0.009	-0.007	0.008	0.002	0.003	0.003
Chittenden	0.009	0.000	0.009	0.002	0.004	0.006
Essex	0.007	-0.012	0.004	0.000	0.003	0.001
Franklin	0.009	0.000	0.008	0.002	0.003	0.006
Grand Isle	0.01	0.000	0.012	0.002	0.003	0.01
Lamoille	0.011	0.000	0.014	0.002	0.003	0.008
Orange	0.009	-0.006	0.008	0.002	0.003	0.003
Orleans	0.009	0.000	0.009	0.002	0.003	0.004

County	Retail	Manufacturing	Non-Manufacturing	Government	Education	Population
Rutland	0.007	-0.012	0.006	0.002	0.003	0.000
Washington	0.007	-0.006	0.007	0.002	0.003	0.002
Windham	0.006	-0.012	0.005	-0.003	0.003	-0.001
Windsor	0.007	-0.012	0.005	-0.002	0.003	0.000

Using these annual growth rates, any forecast-year can be selected and run. When a forecast-year is selected, the Model simply recalculates TAZ-level employment and households for the forecast year by applying the growth rate by county, and runs the Model using the updated TAZ characteristics. For forecasts beyond 2025, a modified road network is used for the traffic assignment which includes new roadways expected to be completed by then. For forecasts beyond 2035, additional projects are added to the 2025 network for the forecast-year run. Any Model outputs available for the base-year are available for the forecast-year, and the Model automatically calculates the change in traffic flows on each link between the base-year and the forecast-year.

3 Description of the Data

This section contains a description of the data sources used in the Model improvement activities for Year 7.

3.1 The 2010 U.S. Census Urban Areas

The new external-travel sub-module was built with the support of the GIS of 2010 U.S. Census Urban Areas (UAs) within 100 miles of Vermont (USCB, 2010a). These include UAs in Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, and Rhode Island. American Census Urbanized Areas (UA) having boundaries within 100 miles of Vermont's border and Census Urban Clusters (UC) having boundaries within 50 miles of Vermont's border were identified as potential origins or destinations of highway travel crossing Vermont's borders. The UAs and UCs selected are listed in Table 6.

Table 6 American Urbanized Areas and Urban Clusters

Urbanized Areas	Urban Clusters	
Albany-Schenectady, NY	Hoosick Falls, NY	Lebanon-Hanover, NH-VT
Boston, MA-NH-RI	Ticonderoga, NY	Hudson, NY
Bridgeport--Stamford, CT-NY	Greenfield, MA	Keene, NH
Danbury, CT-NY	Warrensburg, NY	Corinth, NY
Dover-Rochester, NH-ME	Laconia, NH	Lake Placid, NY
Glens Falls, NY	Concord, NH	Saranac Lake, NY
Hartford, CT	Brattleboro, VT-NH	Catskill, NY
Kingston, NY	Stafford Springs, CT	Ravena, NY
Leominster-Fitchburg, MA	Granville, NY--VT	Gloversville, NY
Lewiston, ME	Valatie, NY	Greenwich, NY
Manchester, NH	Coxsackie, NY	North Brookfield, MA
Nashua, NH-MA	Peterborough, NH	Amsterdam, NY
New Bedford, MA	Claremont, NH	Charlestown, NH
New Haven, CT	Hillsborough, NH	North Conway, NH
New York-Newark, NY-NJ-CT	Plattsburgh, NY	Franklin, NH
Norwich-New London, CT-RI	Newport, NH	Berlin, NH
Pittsfield, MA	Athol, MA	Malone, NY
Portland, ME	Ware, MA	North Adams, MA-VT
Portsmouth, NH--ME	Littleton, NH	Windsor, VT-NH
Poughkeepsie-Newburgh, NY-NJ	Plymouth, NH	
Providence, RI-MA	Bellows Falls, VT-NH	
Saratoga Springs, NY	Great Barrington, MA	
Springfield, MA-CT	Lee, MA	

Urbanized Areas	Urban Clusters
Utica, NY	Jaffrey, NH
Waterbury, CT	Rumford, ME
Worcester, MA-CT	South Deerfield, MA

The UA boundary files are simplified representations from the TIGER geographic database. When possible, generalization is performed with intent to maintain the hierarchical relationships among geographies and to maintain the alignment of geographies within a file set for a given year. To improve the appearance of UAs, areas are represented with fewer vertices than detailed TIGER equivalents. Some “holes” or discontinuities are removed for clarity at the regional level. Included in the GIS are the Name, Type (Urbanized Area or Urbanized Cluster), Area (sq. mi.), Land Area, and Water Area of each UA or UC (USCB, 2010a).

3.2 The 2006 – 2010 American Community Survey

The UA and UC boundaries were associated with demographic data from the American Community Survey (ACS) estimates for 2006 to 2010 (USCB, 2010b). The American Community Survey (ACS) is an ongoing survey by the U.S. Census Bureau that began in 2005 and provides data every year. The intention is to give communities the current information they need to plan investments and services. The ACS is conducted every year to provide up-to-date information about the social and economic needs of American communities between the decennial censuses.

The geographic representation of a single-year ACS for a rural state like Vermont will typically be very poor. However, ACS pooled-data can be used to obtain improved demographic, social, economic, and housing characteristics data. Since 2005, ACS data has been pooled over multiple years to produce stronger estimates for areas with smaller populations. Data are combined to produce 12 months, 36 months or 60 months of data. These are called 1-year, 3-year and 5-year data. Although single-year ACS estimates are typically only valid for areas with populations over 65,000, the pooled 5-year data is valid for populations of almost any size.

3.3 2011 Canadian Census

Canadian designated Census Metropolitan Areas (CMA) and Census Agglomerations (CA) having boundaries within 100 miles of the Vermont border were also selected as potential origins or destinations for trips crossing Vermont's borders (Statistics Canada, 2011a). A list of the CMAs and CAs selected is provided in Table 7.

Table 7 Canadian Census Metropolitan Areas (CMA) or Census Agglomerations (CA)

Name	Province
Cornwall	Ontario
Cowansville	Quebec
Drummondville	Quebec
Granby	Quebec
Hawkesbury	Ontario-Quebec
Joliette	Quebec
Lachute	Quebec
Montreal	Quebec
Ottawa-Gatineau	Ontario
Saint-Georges	Quebec
Saint-Hyacinthe	Quebec
Saint-Jean-sur-Richelieu	Quebec
Salaberry-de-Valleyfield	Quebec
Shawinigan	Quebec
Sherbrooke	Quebec
Sorel-Tracy	Quebec
Thetford Mines	Quebec
Trois-Riviures	Quebec
Victoriaville	Quebec

3.4 2011 Canadian National Household Survey

The CMA and CA boundaries were associated with demographic data from the 2011 Canadian National Household Survey (NHS) estimates for 2006 to 2010 (Statistics Canada, 2011b). The NHS was initiated in Canada in 2011 to replace its previous long-form census questionnaire, by soliciting 30%, or about 4.5 million, of Canadian households. Its scope and form are considerably more far-reaching than the ACS, with a questionnaire covering the following topics:

- demographics
- language
- socio-cultural information
- mobility
- education
- labor force
- occupation
- industry

3.5 Pooled Data from the 2009 National Household Travel Survey

Following on the long-distance trip analysis conducted in Year 6 (Sullivan and Dowds, 2014), the long-distance trip data used in Year 7 comes from a set of pooled data from a group of Vermont's peer states. These peer states consist of a collection of states with geographic and demographic features that are similar to Vermont. The pooled data was used to increase the size of the data set of long-distance trips in the 2009 NHTS. To support the use of data from peer states to represent travel behavior in Vermont, a comparative analysis of a set of 7 potential peer states was conducted - Maine, North Dakota, South Dakota, West Virginia, New Hampshire, Wyoming, and Montana.

Four comparative measures were developed for the 2009 NHTS sample households from each state, and the similarities of these measures were evaluated. The comparative measures included (1) percentage of households in each cross-classification of household size and number of workers (weighted and unweighted), and (2) percentage of households in each cross-classification of residential density and urban/rural categorization (weighted and unweighted). The evaluation consisted of a qualitative comparison of polynomial curves fit to each distribution across household-type categories. AN example of the analysis is illustrated in Figure 2.

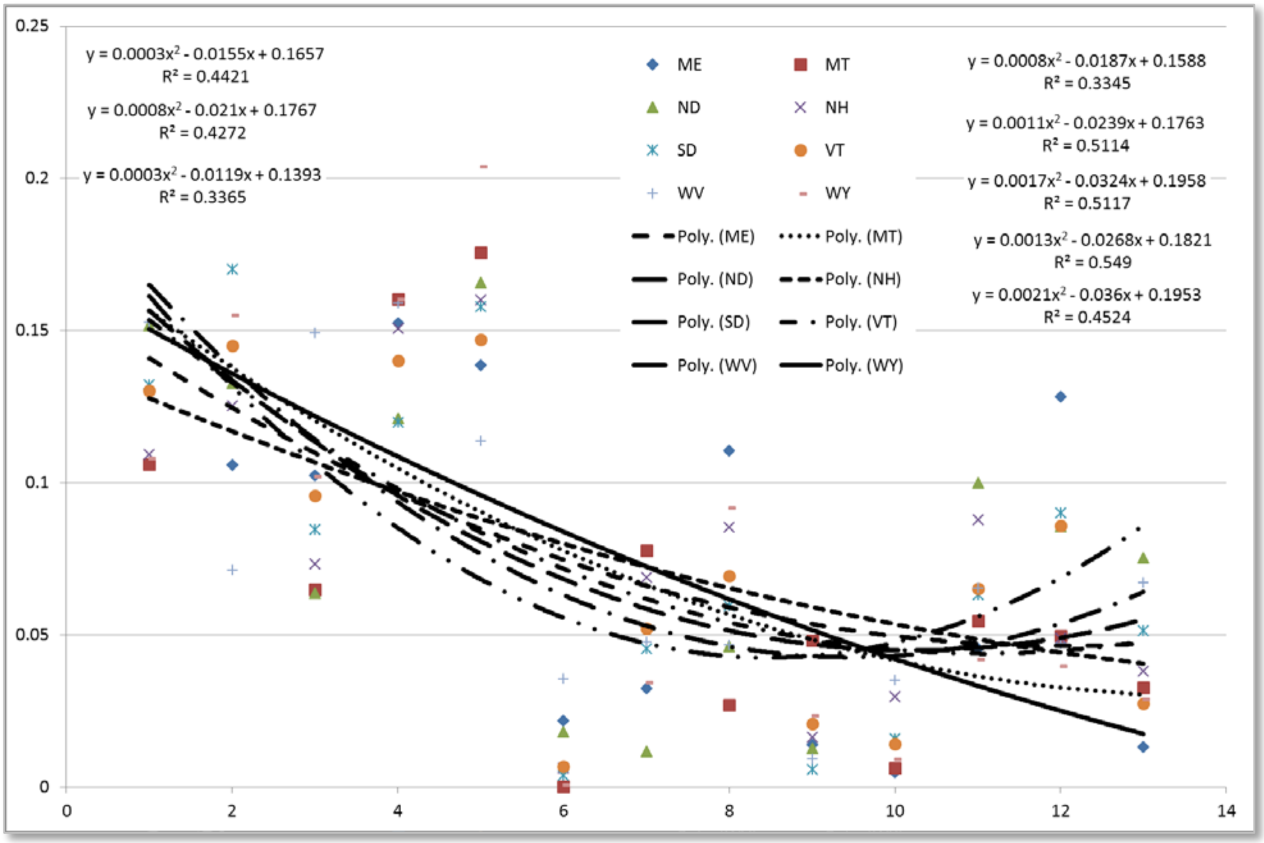

Figure 2 Analysis of Potential Peer States for % of Households in Each of 13 HH Size / No. of Workers Categories

The figure shows the percentage of households in each state's NHTS sample that fall into each of the categories of household size & number of workers shown in Table 8.

Table 8 Categories of HH Size & No. of Workers

Category	HH Size	No. of Workers
1	1	0
2	1	1
3	2	0
4	2	1
5	2	2
6	3	0
7	3	1
8	3	2
9	3	3+
10	4+	0
11	4+	1
12	4+	2
13	4+	3+

The percentages across the categories exhibited a pattern that appeared distinctive to each of the states, so they were fit with the polynomial functions shown in the figure. The curvature of the polynomial fit lines, and the magnitude of the first term in each function provided a basis for identifying similarity. Vermont and a few of its potential peer states featured functions that are curved upward as the categories advance, with initial terms between 0.0003 and 0.0008 (functions at the top left corner), whereas other potential peer states featured curves that were flatter, with initial terms between 0.0008 and 0.0021 (functions at the top right corner). These distinguishing features allowed the states to be grouped by similarity for each of four comparative measures. When the results of all four comparative measures were evaluated together, only Maine, North Dakota, South Dakota, and West Virginia were found to be similar to Vermont. The other states potential peer states (New Hampshire, Wyoming, and Montana) were only similar for one of the four comparative measures used. Therefore, Maine, North Dakota, South Dakota, and West Virginia were chosen to create a pooled set of long-distance data of 1,237 person-trips.

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4 Improvements Methodology and Results

Model improvements undertaken in Year 7 were in accordance with the recommendations provided by the peer review panel during the TMIP Peer Review during Year 5. The following Model improvements were completed:

1. Scripted the Long-Distance Trip Classification into the Model
2. Conducted a Preliminary External-Travel "Halo" Analysis of the Model Boundary
3. Developed a User's Guide for the scripted Model
4. Developed a Validation Plan for the Model

4.1 Scripting the Long-Distance Trip Classification into the Model

Scripted edits were made to the opening dialog box for the Model, new trip purposes were added for the "long-distance" category, and the previous "all-distance" categories were changed to "short-distance". New vehicle occupancies and new external fractions now appear on the opening screen of the Model, as shown in Figure 2.

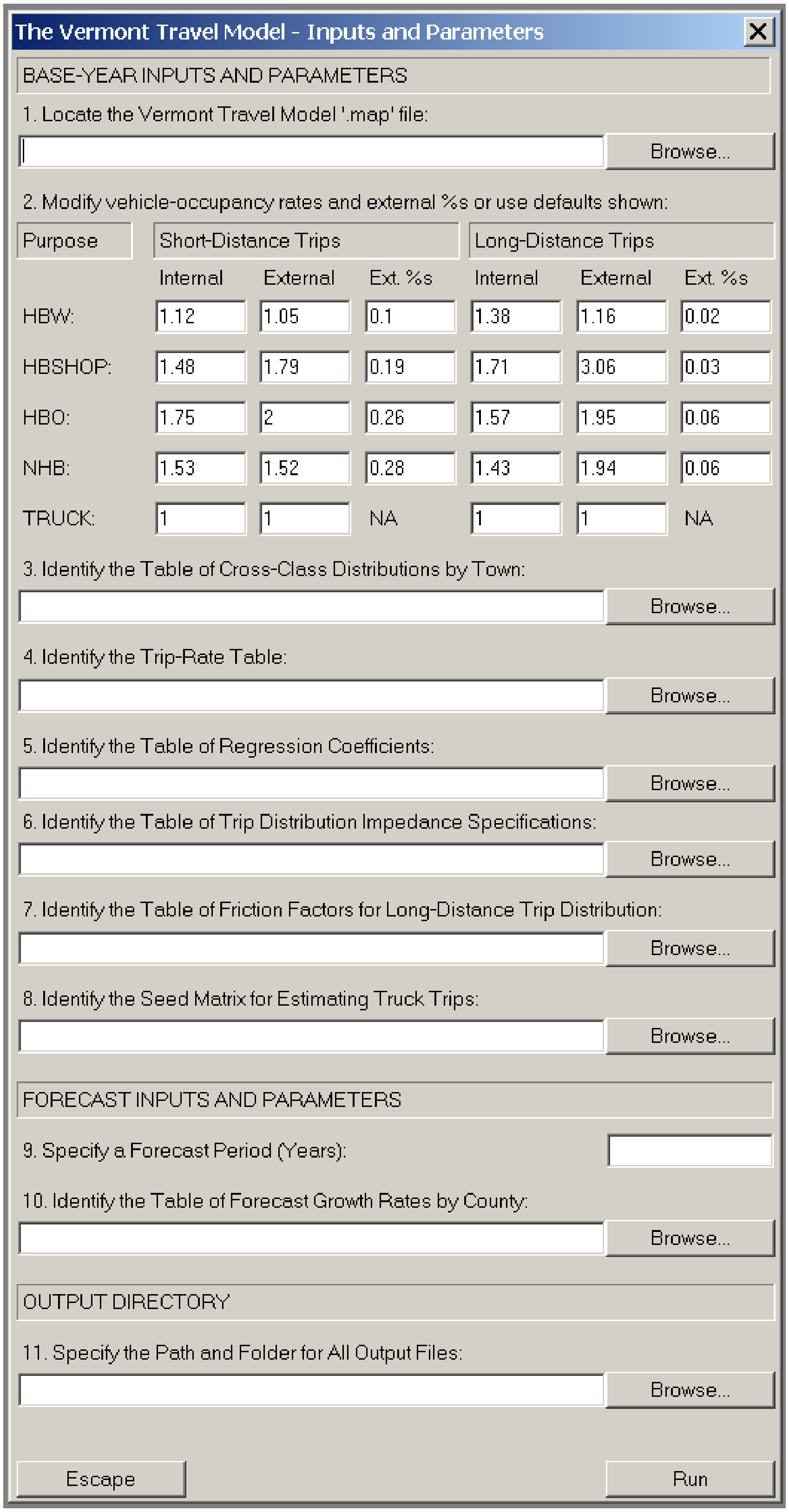


Figure 3 Vermont Travel Model Opening Screen

New trip rates and regression coefficients are invoked as input tables (Items 4. and 5. on the initial screen in Figure 2). In order to update the trip-distribution impedance functions, a two-step process was needed to re-estimate functions for long- and short-distance trips in the Model. The two-step process was required because the TransCAD functional form for the gamma distribution uses a constant for *a*, whereas the *a* variable for a true gamma distribution is based on *b* and *c*. Therefore, the long-distance trip data was fitted first to a true gamma distribution in ARENA, then the constants *b* and *c* were held constant and used to estimate *a* as a constant using SOLVER in Excel. Other functional forms were also tested using SOLVER to ensure the best fit. All of the best-fit functional forms for long-distance travel in the pooled NHTS data were found to be exponential, which is equivalent to TransCAD's gamma distribution function when *a* is fixed at 1 and *b* is fixed at 0:

$$f\,(t_{ij}) = a \cdot t_{ij}^{-b} \cdot e^{-c(t_{ij})}$$

The exponential parameters shown in Table 8 were estimated from the long-distance trip data for Vermont and the pooled states together.

Table 9 Exponential Parameters Estimated from the Pooled-State Data

Trip Purpose	Functional Form	a	b	c	t_0 (min.)
HBO	Exponential	1	0	0.012	30
HBSHOP	Exponential	1	0	0.015	30
HBW	Exponential	1	0	0.011	40
NHB	Exponential	1	0	0.011	28

For the actual Model specification for long-distance trips, a friction factor table was generated and all friction factors below t_0 were set to 0. This approach ensures that long-distance trips are not distributed to TAZs closer than t_0. In effect, it creates a new functional form for the impedance functions for long-distance trips:

$$f\,(t_{ij}) = t_0 + e^{-c(t_{ij})}$$

Using the same approach, the equations and parameters shown in Table 9 were estimated from the short-distance trip data for Vermont.

Table 10 Equations and Parameters Estimated from Short-Distance Data

Trip Purpose	Functional Form	a	b	c
HBO	Gamma	0.029	1.200	0.126
HBSHOP	Gamma	0.099	1.150	0.128

Trip Purpose	Functional Form	a	b	c
HBW	Gamma	0.070	0.860	0.095
NHB	Gamma	0.110	0.750	0.116

The functional forms of the previous impedance functions, and the new distance-classified functions, are shown in Figure 3.

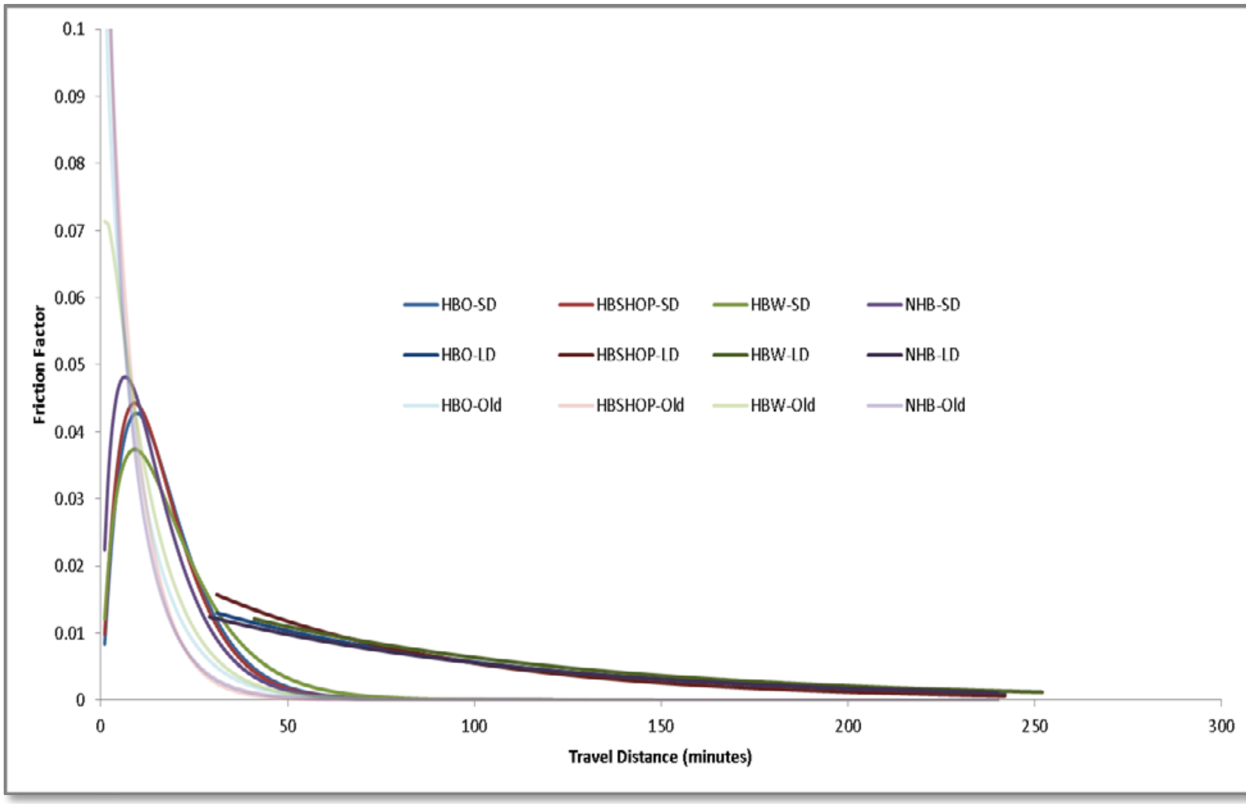


Figure 4 Functional Forms of Previous and New Distance-Classified Impedance Functions

The new distance-based classification, above and below 40 miles, creates a more traditional gamma functional form, with a tail that is a flattened exponential, whereas the previous functional forms, with trips of all distances included, exhibited a sharper initial decay and more curvature in the tail. The differences are most pronounced for HBO and NHB trips. The HBSHOP curves come closest to reproducing the previous all-distance exponential. Running the Model with these new specifications brought the RMSPE down to 43.0%.

As a quality assurance step, the specific fits of the new impedance functions shown in Figure 3 were evaluated and compared to the old fits without the distance classification, also shown in Figure 3. The R-squared fit statistics were used to compare the fits, and indicated the relationships between the actual trip distribution frequencies and the friction factors that result from solving the impedance functions. The results of this comparison are shown in Table 10.

Table 11 Comparison of Impedance Function Fits

Trip Purpose	R-Squared of Friction Factors		
	All – VT[1]	SD – VT[2]	LD–Pooled[3]
HBO	0.95	0.64	**0.92**
HBSHOP	0.99	0.91	0.73
HBW	0.92	0.94	0.79
NHB	0.93	0.90	**0.96**

Notes:

1. **All–VT:** R-squared between the trip data and the friction factors resulting when all Vermont NHTS data are used to determine impedance functions
2. **SD–VT:** R-squared between the trip data and the friction factors resulting when short-distance Vermont NHTS data only are used to determine impedance functions
3. **LD–Pooled:** R-squared between the trip data and the friction factors resulting when long-distance pooled-state NHTS data are used to determine impedance functions

As indicated in the table, only HBO and NHB trip purposes had an R-squared for the pooled long-distance data that was comparable to the R-squared for all Vermont data. This is not surprising because long-distance trips of these types had been determined in Year 6 to be more frequent than HBSHOP or HBW long-distance trips. For NHB trips in particular, the fit of both distance-classified sets of friction factors is comparable to, or better than, the fit for the previous set of friction factors with all-distance trips in Vermont included. This is notable because the sample sizes for the long-distance trip data set, even including the pooled data, are much smaller than the sample size for Vermont's short-distance trips or all-distance trips. Based on this finding, it would appear that NHB trips are the most critical for a long-distance travel classification in Vermont.

Re-running the new Model specification confirms that the NHB and HBO trip purposes are the most significant for the long-distance classification. When the NHB and HBO trips are recognized with separate long- and short-distance classifications, but the HBW and HBSHOP purposes are left without a distance classification, the Model fit improves even further (to 42.5%). Adding the distance classification for HBW or HBSHOP causes the fit to go back up to 43.0%. Therefore, the final Model specification invokes a long-distance friction factor table (Item 7. in Figure 2) which includes friction factors based on the impedance function specifications shown in Table 3.

Table 12 Final Long-Distance Impedance Function Model Specification

Trip Purpose	Functional Form	a	b	c
HBO	Exponential	1	0	0.012
HBSHOP	Gamma	0.099	1.150	0.128
HBW	Gamma	0.070	0.860	0.095
NHB	Exponential	1	0	0.011

Note that the impedance functions for HBSHOP and HBW for long-distance trips is identical to the impedance function for short-distance trips.

4.2 Preliminary External-Travel “Halo” Analysis of the Model Boundary

One of the short-term recommendations that came from the TMIP peer review of the Vermont Travel Model in Year 5 was to expand the spatial boundary of the Model as necessary to include important "halo" populations. This analysis consisted of the identification of urban areas and highways to consider for inclusion in the Model boundary, and then the addition of important contiguous UAs as internal TAZs and critical nearby roadways as links in the Model road network.

4.2.1 Identification of Urban Areas and Highways for Inclusion in the Model Boundary

The preliminary “halo” analysis began with a comprehensive evaluation of each external TAZ in the Model, for consideration as a new internal TAZ. Two types of adjustments were made to external TAZs based on a careful inspection of the base-year AADTs, the likely urban areas or towns accessed from them, and the road network configuration at the Vermont border.

First, the external traffic volume to TAZ 991 was changed to 1,490, to reflect the traffic volume at the intersection nearest the border, as opposed to the traffic volume on the border. External AADT for TAZ 956 was changed to the estimated average annual ridership on the Charlotte-Essex Ferry (800 vehicles).

Second, TAZs 966 and 999 were removed from the Model because no physical crossing is present at these locations. Centroid connectors from these TAZs were also removed from the Model road network, and the remaining links were merged to eliminate unnecessary nodes. TAZ 992 was also removed, since the crossing for this external link is a very low capacity covered bridge, with almost no meaningful network connectivity provided.

For the remaining external TAZs, their shapes were changed in the GIS layer from the ambiguous triangles shown in Figure 1 to the boundaries of the town(s) and/or urban area(s) in New England, New York, and Canada that might be accessed via highways leaving the state. This change will help improve the visualization of the Model structure and the scope of a potential external travel sub-module.

A route-mapping exercise was conducted to identify the town(s) and/or urban area(s) in New England, New York, and Canada that might be accessed via highways leaving the state. This route-mapping involved checking preferred routes from a variety of regional origins in Vermont with Google Maps. When a preferred route included the use of an external link in the Model, the urban area represented by the destination was identified as part of that external TAZ. The results of this exercise are shown in Table 12, along with the base-year AADT (or estimated daily ferry ridership) for the highway leaving the state to/from that external TAZ.

Table 13 Route-Mapping of External TAZs to Destinations in Quebec, New York, and New England

TAZ ID	Town(s) or Urban Area(s) in New England, New York or Quebec Accessed	2009 AADT
930	New York-Newark, NY--NJ--CT; Albany-Schenectady, NY; Glens Falls, NY	3960
931	Plattsburgh, NY (via Grand Isle – Plattsburgh Ferry)	1480[1]
932	New York-Newark, NY--NJ--CT; Poughkeepsie-Newburgh, NY--NJ; Saratoga Springs, NY; Albany-Schenectady, NY; Warrensburg, NY; Glens Falls, NY; Ticonderoga, NY	3200
933	Ticonderoga, NY	7510
934	New York-Newark, NY--NJ--CT; Poughkeepsie-Newburgh, NY--NJ; Saratoga Springs, NY; Albany-Schenectady, NY; Warrensburg, NY; Glens Falls, NY; Granville, NY--VT	4030
935	New York-Newark, NY--NJ--CT; Poughkeepsie-Newburgh, NY--NJ; Albany-Schenectady, NY	10640
936	Pittsburg, NH	2660
937	Boston, MA--NH--RI; Nashua, NH--MA; Manchester, NH; Laconia, NH; Concord, NH; Franklin, NH; Plymouth, NH; Littleton, NH; Berlin, NH	3350
938	Boston, MA--NH--RI; Nashua, NH--MA; Manchester, NH; Laconia, NH; Concord, NH; Franklin, NH; Plymouth, NH; Littleton, NH; Berlin, NH	5530
939	Laconia, NH; Franklin, NH; Plymouth, NH; Littleton, NH	7480
940	Lebanon--Hanover, NH--VT	**14,560**
941	Boston, MA--NH--RI; Nashua, NH--MA; Lebanon--Hanover, NH--VT; Manchester, NH; Concord, NH	**37,320**
942	Claremont, NH; Newport, NH	9010
943	Boston, MA--NH--RI; Nashua, NH--MA; Manchester, NH; Keene, NH	**12,790**

TAZ ID	Town(s) or Urban Area(s) in New England, New York or Quebec Accessed	2009 AADT
944	Keene, NH	10,700
945	Hartford, CT; Springfield, MA--CT; South Deerfield, MA; Pittsfield, MA; Lee, MA; North Adams, MA--VT; Greenfield, MA	6990
946	Albany-Schenectady, NY; Hartford, CT; Springfield, MA--CT; South Deerfield, MA; Pittsfield, MA; Lee, MA; North Adams, MA--VT; Greenfield, MA	2660
947	New York--Newark, NY--NJ--CT; Bridgeport--Stamford, CT--NY; Hartford, CT; Springfield, MA--CT; New Haven, CT; Boston, MA--NH--RI; South Deerfield, MA; Greenfield, MA	**16,700**
948	Hartford, CT; Springfield, MA--CT; New Haven, CT; Boston, MA--NH--RI; South Deerfield, MA; Greenfield, MA; Athol, MA	1280
949	Montreal, QC	3160
950	Montreal, QC	600
951	Sherbrooke, QC	2000
952	Sherbrooke, QC	690
953	Haverhill, NH; Warren, NH	2260
954	Boston, MA--NH--RI; Nashua, NH--MA; Manchester, NH; Charlestown, NH; Keene, NH	4920
955	Plattsburgh, NY (via Burlington – Port Kent Ferry)	2800[1]
956	Plattsburgh, NY (via Charlotte - Essex Ferry)	800[1]
957	New York--Newark, NY--NJ--CT; Poughkeepsie--Newburgh, NY--NJ; Saratoga Springs, NY; Albany--Schenectady, NY; Warrensburg, NY; Glens Falls, NY; Ticonderoga, NY	240
958	New York--Newark, NY--NJ--CT; Poughkeepsie--Newburgh, NY--NJ; Saratoga Springs, NY; Albany--Schenectady, NY; Warrensburg, NY; Glens Falls, NY; Ticonderoga, NY	3050
959	Granville, NY--VT	1390
960	New York--Newark, NY--NJ--CT; Poughkeepsie--Newburgh, NY--NJ; Saratoga Springs, NY; Greenwich, NY; Granville, NY--VT	610
961	Saratoga Springs, NY; Glens Falls, NY; Greenwich, NY	1480
962	Cambridge, NY	1550
963	Saratoga Springs, NY; Hoosick Falls, NY	2950
964	Albany--Schenectady, NY; Hoosick Falls, NY	1670
965	Colebrook, NH	160
967	Boston, MA--NH--RI	1180
968	Berlin, NH	220
969	Littleton, NH	1090
970	Concord, NH; Franklin, NH; Plymouth, NH; Littleton, NH	750
971	Boston, MA--NH--RI; Nashua, NH--MA; Manchester, NH; Laconia, NH; Concord, NH; Franklin, NH; Plymouth, NH; Littleton, NH	120
972	Boston, MA--NH--RI; Manchester, NH; Laconia, NH; Concord, NH; Franklin, NH; Plymouth, NH	2160

TAZ ID	Town(s) or Urban Area(s) in New England, New York or Quebec Accessed	2009 AADT
973	Boston, MA--NH--RI; Manchester, NH; Laconia, NH; Concord, NH; Franklin, NH; Plymouth, NH	3440
974	Plymouth, NH	2070
975	Boston, MA--NH--RI; Nashua, NH--MA; Lebanon--Hanover, NH--VT; Manchester, NH; Concord, NH	**12,690**
976	Claremont, NH	2720
977	Charlestown, NH	5540
978	Boston, MA--NH--RI; Nashua, NH--MA; Manchester, NH; Charlestown, NH; Keene, NH	3200
979	North Adams, MA	200
980	Pittsfield, MA; North Adams, MA--VT	230
981	Hartford, CT; Springfield, MA--CT; South Deerfield, MA; Greenfield, MA	1080
982	Hartford, CT; Springfield, MA--CT; South Deerfield, MA; Pittsfield, MA; North Adams, MA--VT; Greenfield, MA	860
983	Montreal, QC	380
984	Montreal, QC	250
985	Montreal, QC	550
986	Montreal, QC	320
987	Montreal, QC	250
988	Potton, QC	470
989	Sherbrooke, QC	930
990	Sherbrooke, QC	990
991	Cookshire-Eaton, QC	1490[2]
992	Boston, MA--NH--RI; Nashua, NH--MA; Manchester, NH; Laconia, NH; Concord, NH; Franklin, NH; Plymouth, NH; Littleton, NH; Berlin, NH	50
993	Sherbrooke, QC	320
994	Boston, MA--NH--RI; Nashua, NH--MA; Manchester, NH; Laconia, NH; Concord, NH; Franklin, NH; Plymouth, NH; Littleton, NH; Berlin, NH	360
995	Rowe, MA	100
996	Hartford, CT; Springfield, MA--CT; South Deerfield, MA; Greenfield, MA	200
997	Hartford, CT; Springfield, MA--CT; South Deerfield, MA; Greenfield, MA	200
998	Hitchcock Center & Northfield-Mount Hermon School (MA)	200

[1]Estimated annualized average daily ridership on Lake Champlain Ferries
[2]AADT changed to better reflect the Model road network configuration

The “halo” analysis involved identifying areas outside of Vermont to include in the Model. This process involved (1) looking for urban areas on Vermont’s border which are a common origin/destination of travel that occurs in Vermont, and (2) looking for other areas outside Vermont’s border where critical alternate routes exist for travelers in Vermont.

Evidence of urban areas on or near Vermont’s border to include in the Model were found by examining possible origins/destinations of external links with relatively high AADT. An examination of the AADTs shown in Table 12 revealed several external TAZs with high daily traffic counts (over 11,000 vehicles per day, shown in bold). These links likely lead to urban areas which should be included in the Model network, if one or more of the primary external destinations of that traffic is within Vermont's "halo", or close to its border.

A primary candidate for inclusion in the Model within Vermont's "halo" is a primary destination of external traffic to/from TAZs 940, 941, and 975 - the Lebanon-Hanover, NH-VT Census urban area (UA). External links crossing Vermont's border at these TAZs carry 64,500 vehicles per day through the Lebanon-Hanover, NH-VT UA, and we know very little about the behavior of these travelers outside of Vermont.

A secondary candidate for inclusion in the Model is a destination of external traffic to/from TAZs 945, 946, and 979-982 - the North Adams, MA-VT UA. External links crossing Vermont's border at these TAZs carry 12,020 vehicles per day through the North Adams, MA-VT UA, and we know very little about the behavior of these travelers outside of Vermont. Both of these UAs also stretch into Vermont, further attesting to their significance to travel by Vermonters. Another candidate for inclusion in the Model is the Greenfield, MA UA, which lies along I-91 just south of the Vermont border.

Critical alternate routes outside of Vermont for Vermont travelers can be identified through qualitative inspection of the road network within 10 miles of Vermont's border. This inspection was performed using Google Maps. Certain regions, like western-central Vermont, might seem to have viable alternate routes just outside the state border when we consider the corridor between Middlebury and Rutland (see Figure 4).

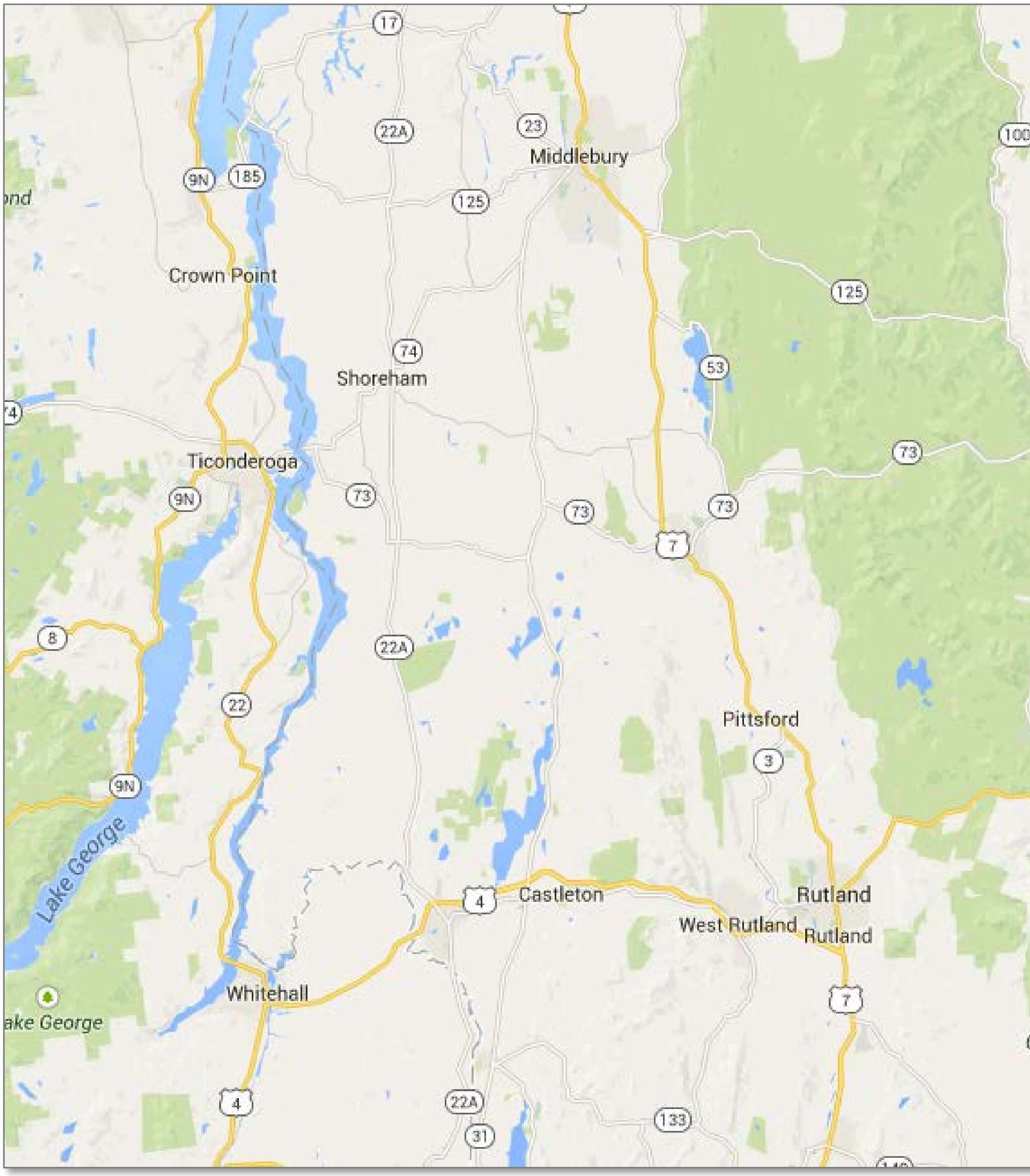


Figure 5 VT Route 22A Corridor along the West-Central Vermont Border with New York State

At first inspection, the corridor defined by State Routes 9N and 22 in New York State might seem to provide a critical alternate route for Vermont travelers on VT Route 22A. However, U.S. Route 7 in Vermont already provides VT Route 22A with sufficient redundancy, so NY Routes 9N and 22 are not in fact critical. On the other hand, U.S Route 3 in northern New Hampshire does provide critical redundancy for VT Route 102 along the northeastern border of Vermont (see Figure 5).

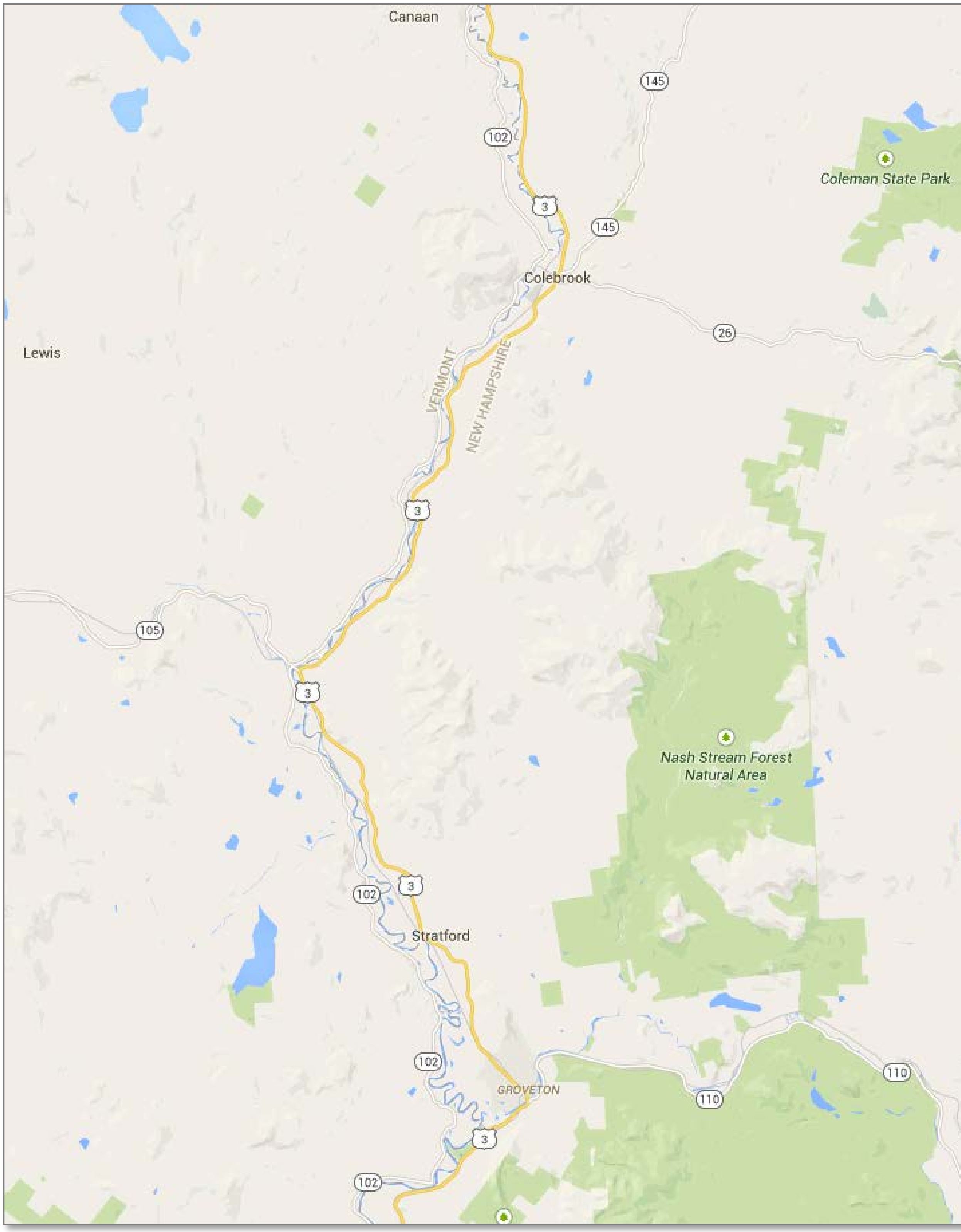


Figure 6 VT Route 102 Corridor along the Northeastern Vermont Border with New Hampshire

Since the road network is extremely sparse on both sides of the border in this area, U.S Route 3 represents a viable alternate route for VT Route 102.

Based on these findings, the following highways were included in the road network of the Vermont Travel Model:

- U.S Route 3 between Lancaster, New Hampshire (and the intersection with U.S. Route 2) and Stewartstown, New Hampshire (and the intersection with VT Route 114)
- U.S. Route 2 between Williamstown, Massachusetts (and the intersection with U.S. Route 7) and Greenfield, Massachusetts (and the exchange at I-91) (see Figure 6).

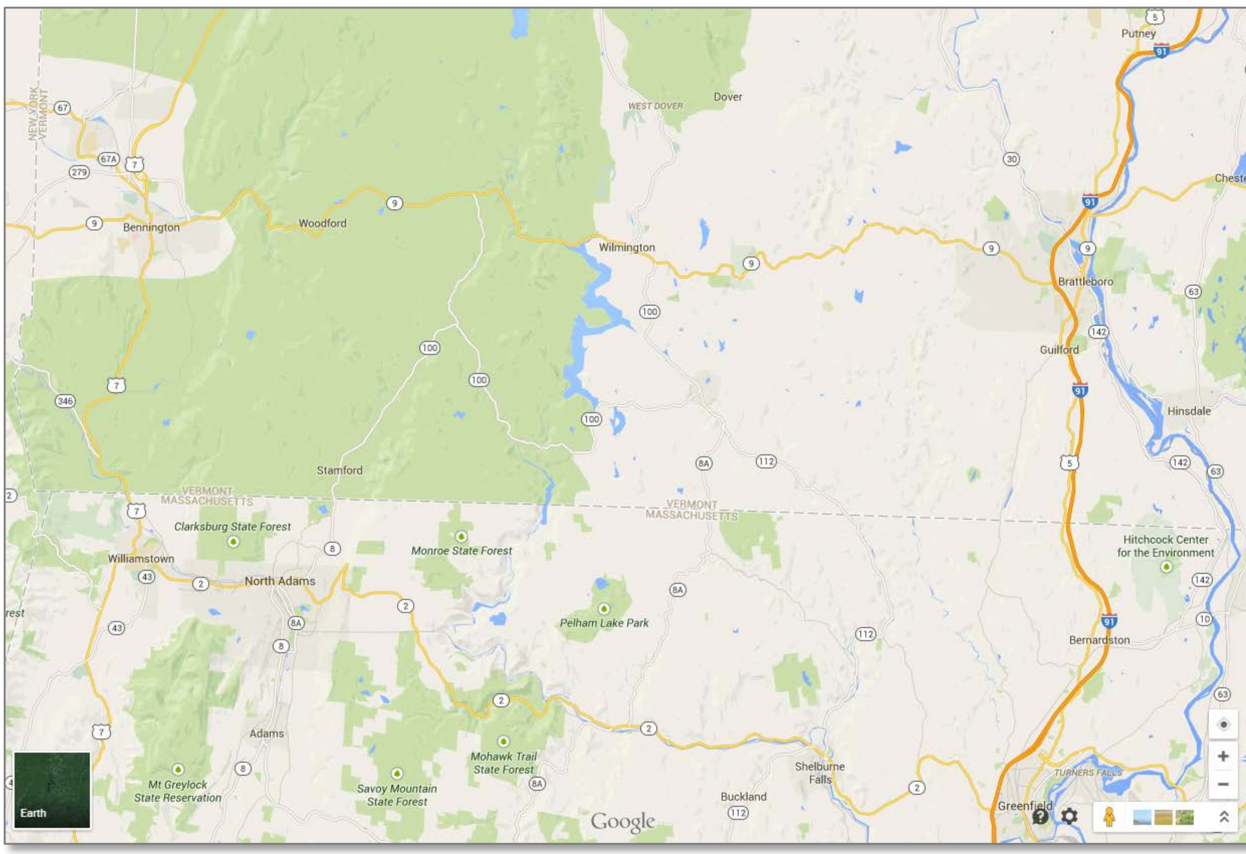


Figure 7 U.S. Route 2 between Williamstown and Greenfield, Massachusetts

The U.S. Route 2 corridor recommended for inclusion in the Model passes through the North Adams, MA-VT UC.

4.2.2 Addition of Urban Areas and Highways to the Model and Extension of the Model Boundary

The actual links representing U.S Route 3 between Lancaster and Stewartstown were added to the road network by copying the link topology from the Census TIGER data. This addition made the external linkages to TAZs 967 and 994 obsolete, because each of these linkages represents access to U.S. Route 3, not access to a unique town or UA. Therefore, TAZs 967 and 994 were removed from the Model. TAZ 967 was re-introduced in Lancaster, NH to connect the Model road network to Berlin, NH. Five (5) other TAZs were adjusted outward to connect the expanded network to UAs and UCs in New Hampshire at more meaningful nodes.

The actual links representing U.S Route 2 between Williamstown and Greenfield were added to the road network by copying the link topology from the Census TIGER data. This addition made the external linkages to TAZs 981 and 995 obsolete, because each of these linkages represents access to U.S. Route 2, not access to a unique town or UA. Therefore, TAZs 981 and 995 were removed from the Model. TAZ 966 was re-introduced as an external link from U.S Route 2 leaving Greenfield, MA. Seven (7) other TAZs were adjusted outward to connect the expanded network to UAs and UCs in New York and Connecticut at more meaningful nodes. Eight (8) new internal TAZs were also added to the Model for the towns of North Adams, Rowe, Heath, Colrain, Leyden, and Greenfield, Massachusetts which were absorbed by this extension to road network.

Based on the findings of the “halo” analysis, three UAs were recommended to be absorbed into the boundary of the Model. Two of the three UAs, though (North Adams and Greenfield, MA) had already been absorbed by the addition of the U.S Route 2 and its linkages to the road network for the Model. The boundary of the Lebanon-Hanover UA was transferred to the Model TAZ layer and new TAZs were delineated to allow travel to be assigned to/from these locations. Additional new roadways were added to create linkages between these new UAs and the rest of the Model road network. TAZs 940, 975, and 941 were adjusted outward to connect to the road network at more meaningful nodes. External TAZs 981 and 992 were re-introduced to connect the expanded network to UAs and UCs in New Hampshire at more meaningful nodes. Two (2) new internal TAZs were added to represent the towns of Hanover and Lebanon, NH.

4.2.3 Summary of New Internal TAZs in the Model and External Urban Destinations

As a result of the “halo” analysis, ten (10) new internal TAZs were created in the Model. All of these TAZs are entirely beyond Vermont’s border, in the neighboring states of New Hampshire and Massachusetts. A summary of the new internal TAZs is provided in Table 13.

Table 14 New Internal TAZs Added from the "Halo" Analysis

New TAZ ID	Town or City	State
870	Rowe	Massachusetts
871	Heath	Massachusetts
872	Colrain	Massachusetts
873	North Adams	Massachusetts
874	Leyden	Massachusetts
875	Greenfield	Massachusetts
876	Bernardston	Massachusetts
877	Gill	Massachusetts
878	Hanover	New Hampshire
879	Lebanon	New Hampshire

The final set of urban destinations for external travel to/from Vermont includes all of the UAs, UCs, CAs, and CMAs that had been considered as destination originally, with the UAs absorbed into the Model excluded. Figure 7 provides an illustration of the expanded boundary of the Model, and the set of urban destinations that will be considered for the development of an external sub-module.

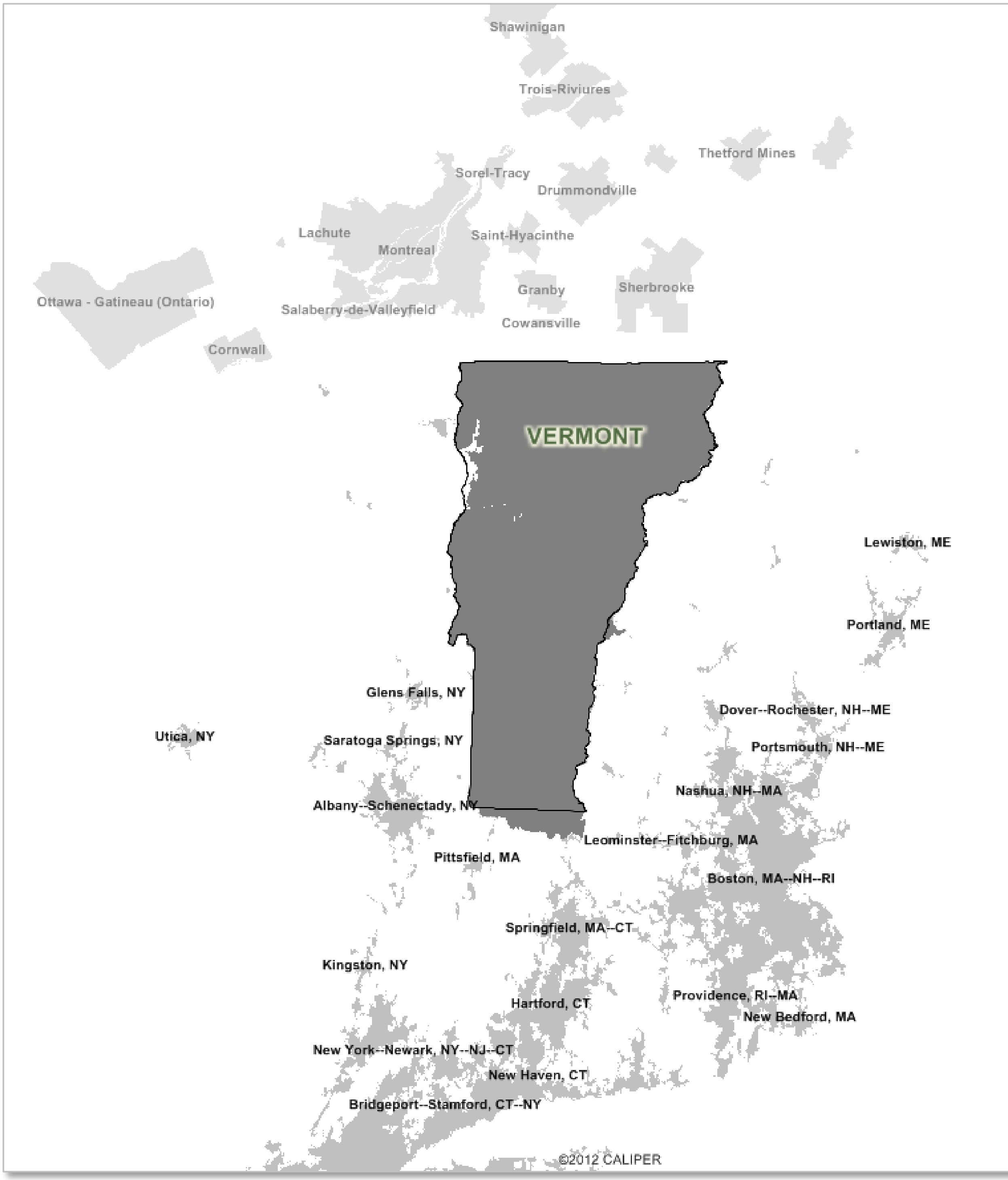


Figure 8 Expanded Model Boundary and External Urban Destinations for Highway Travel

4.3 Users' Guide

Another of the short-term recommendations that came from the TMIP peer review of the Vermont Travel Model in Year 5 was to develop a User's Guide to make the Model more transferable within the Agency.

4.3.1 Model Platform and Files

The Vermont Travel Model is a GISDK scripted "macro" in the TransCAD software platform that invokes many of TransCAD's built-in menu-driven processes to simulate a typical day of travel in Vermont:

- Trip Production / Cross-Classification…
- Trip Attraction / Apply a Model…
- Trip Distribution / Gravity Application… & Gravity Calibration…
- O-D Matrix Estimation / Single-Class Matrix Estimation…
- Static Traffic Assignment / Multi-Modal, Multi-Class Assignment…

The Model consists of the geographic layers representing the road network and the TAZ layer saved in TransCAD's native "map" (*.map) file format, along with TransCAD's native "network" (*.net) file representing the road network topology, and its complementary "turn penalty" table representing prohibited turns in the network topology. Binary-format input tables ("*.bin") used by the Model include:

- Cross-classification of household types by number of workers and number of household members for each Vermont town
- Trip-rate table by number of workers and number of household members
- Forecast annual growth rates for employment and population by County
- Coefficients of the regression equations by trip purpose for trip attraction calculations
- Constants for the gamma and exponential trip distribution equations by trip purpose
- Friction factors for long-distance classifications by trip purpose

The Model also requires a "seed" matrix, in TransCAD's native matrix file format (*.mtx) for the base year in order to initiate the O-D Matrix

Estimation process. Lastly, future road-network configurations are provided for 2025 and 2035 in TransCAD's network (*.net) file format to enforce the future topology for forecast-year simulations.

The names of each of these files are provided in Table 15.

Table 15 Vermont Travel Model File Names

File Description	Name	Type
Native map file which opens the road network, the TAZ layer, and the network topology	Vermont Travel Model	TransCAD map (.map)
Road network geographic file	2010 Model Links	TransCAD standard geographic file (.dbd)
TAZ layer geographic file	2010 Vermont TAZs	.dbd
Network topology file representing the road network in the base year	2010ModelNet	TransCAD network (.net)
Complementary "turn penalty" table representing prohibited turns in the network topology	TurnPenalties	Binary table (.bin)
Cross-classification of household types by number of workers and number of household members for each Vermont town	HHTypeByTown_2009	.bin
Trip-rate table by number of workers and number of household members	VTM Trip Rate Table	.bin
Forecast annual growth rates for employment and population by County	Growth Rates	.bin
Coefficients of the regression equations by trip purpose for trip attraction calculations	RegressionCoefficients	.bin
Constants for the gamma and exponential trip distribution equations by trip purpose	TripDistImpedanceSpecs	.bin
Friction factors for long-distance classifications by trip purpose	LDFrictionFactors	.bin
Base-year seed matrix for the O-D matrix estimation process	2009-Truck-Seed	TransCAD matrix (.mtx)
Network file representing the topology of the road network in 2025	fymodelnet (distinguished by its location, in the *2025 Forecast Year* folder)	.net
Network file representing the topology of the road network in 2035	fymodelnet (distinguished by its location, in the *2035 Forecast Year* folder)	.net

The new menu interface is called up by activating the GISDK Toolbox (Figure 8).

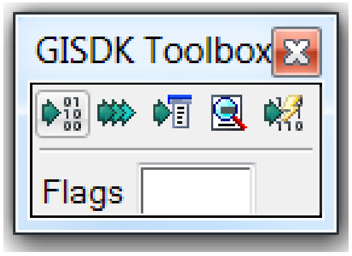


Figure 9 TransCAD GISDK Toolbox

Selecting the button on the far left (a single arrow pointing to 0s and 1s) allows the user to compile the Model code, then selecting the next button to the right (three overlapping arrows) opens the dialog box used to open the initial Model menu (Figure 9).

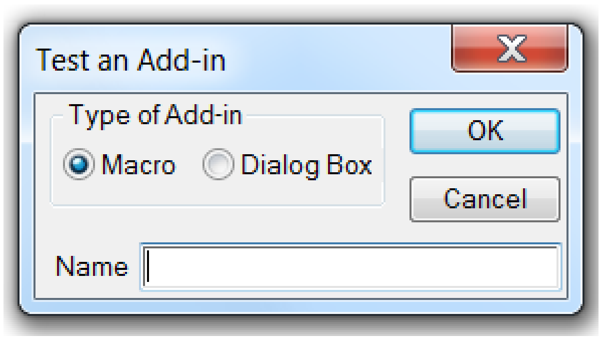


Figure 10 TransCAD Add-In Dialog Box

To open the initial Model menu, the user enters “The Vermont Travel Model” (leaving the “Macro” radio button selected) and clicks OK. Once this is done, the initial Model menu appears (Figure 10).

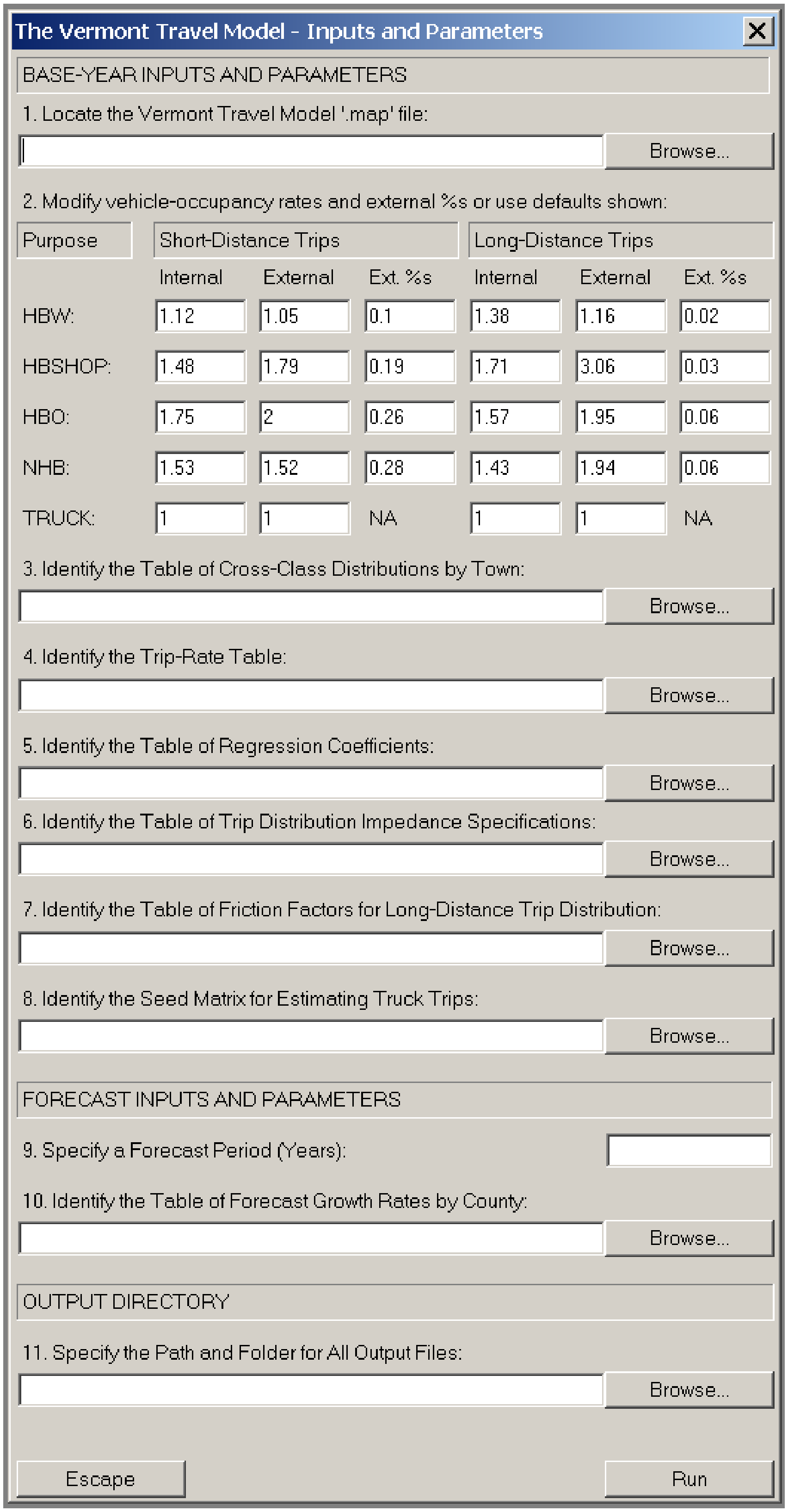


Figure 11 Initial Model Menu

The menu contains eleven (11) items for the user to enter for the Model run:

1. The Vermont Travel Model ".map" file – currently called "Vermont Travel Model.map" and contains the TAZ layer, the road network layer, and the base-year network file (.net)
2. Vehicle-occupancy rates and external fractions – defaults shown are taken from the 2009 NHTS, but they can be altered for a scenario run
3. Table of Cross-Class Distributions by Town – currently called "HHTypeByTown_2009.bin" and contains the breakdown of household-structures, by workers and members, for each town in the state
4. Trip-Rate Table – currently called "VTM Trip Rate Table.bin" and contains the trip-production rates for each of the household structures in the breakdown in "HHTypeByTown_2009.bin"
5. Table of Regression Coefficients – currently called "RegressionCoefficients.bin" and contains the coefficients for regression equations used to calculate trip productions and attractions
6. Table of Coefficients for Trip Distribution Functions – currently called "TripDistImpedanceSpecs.bin" and contains the coefficients to be used in the impedance functions for short-distance trip distribution to determine the destinations of trips from each TAZ
7. Table of Friction-Factors for Long-Distance Trip Distribution – currently called "LDFrictionFactors.bin" and contains the friction factors corresponding to the impedance functions for long-distance trip distribution
8. Seed Matrix for Estimating Truck Trips – currently called "2009-Truck-Seed.mtx" and contains the initial truck-trip matrix that the ODME procedure will use to estimate a new truck trip matrix
9. Forecast Period – user-specified number of years to forecast travel to, assuming a base year of 2010 (any integer)
10. Table of Forecast Growth Rates – currently called "Growth Rates.bin" and contains the annual growth rates for each employment category and households by Vermont County
11. Output Directory – user-specified directory where output files will be saved after the Model run

This full specification of the Model input files means that the files will not have to be in a specific location on the user's computer for the Model to run.

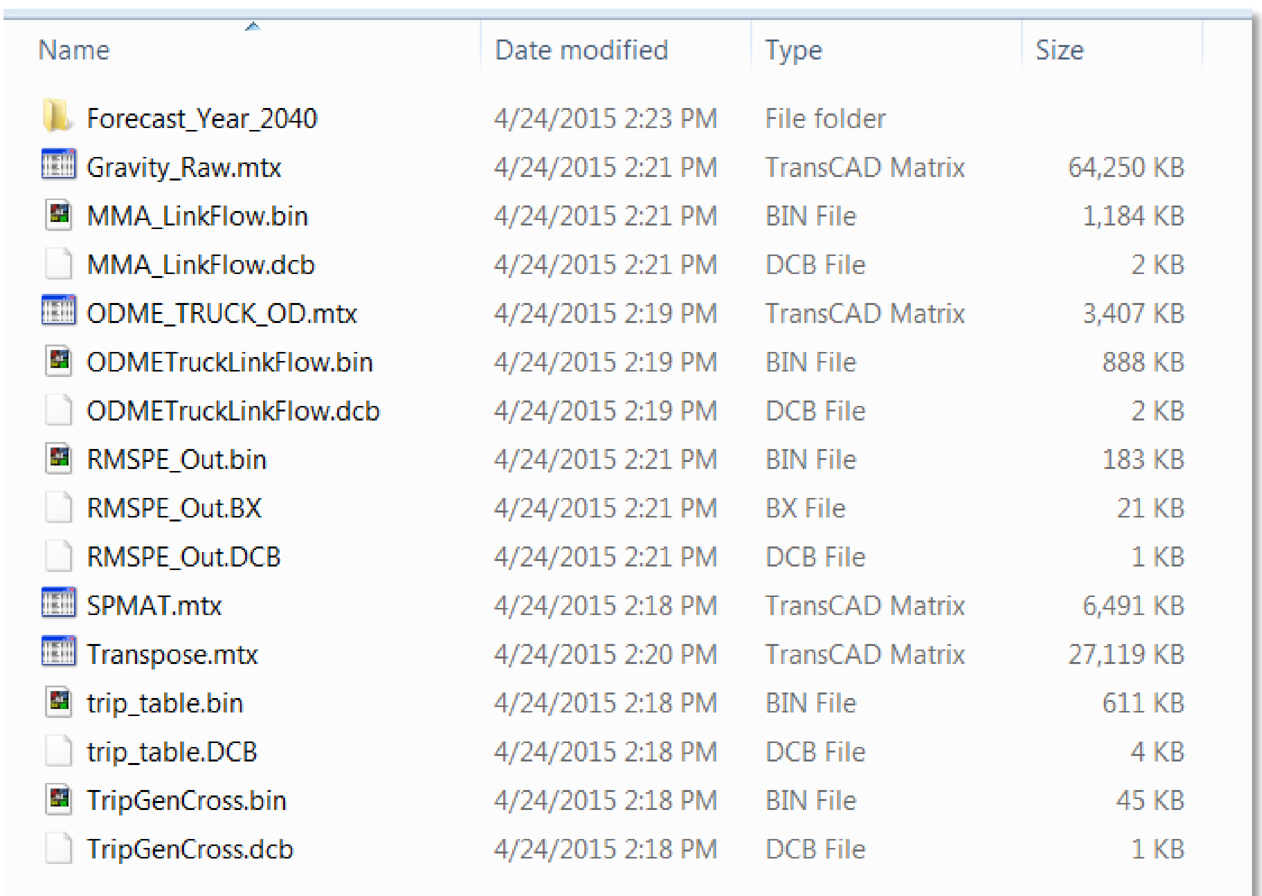
The input files can be anywhere. As long as a path and filename is provided for each input file in this menu, the Model will run successfully.

The forecast-period specification allows the Model to be run to any forecast year the user chooses, creating a sub-folder in the output folder identified by the forecast year with Model outputs for the forecast year. To run multiple forecasts, the user can repeat the Model run with a new forecast-period, and a new forecast-output folder will be created and populated.

Once all of the items are populated, the Model is initiated by clicking the "Run" button at the bottom right corner of the Initial Model Menu.

4.3.2 Output Files

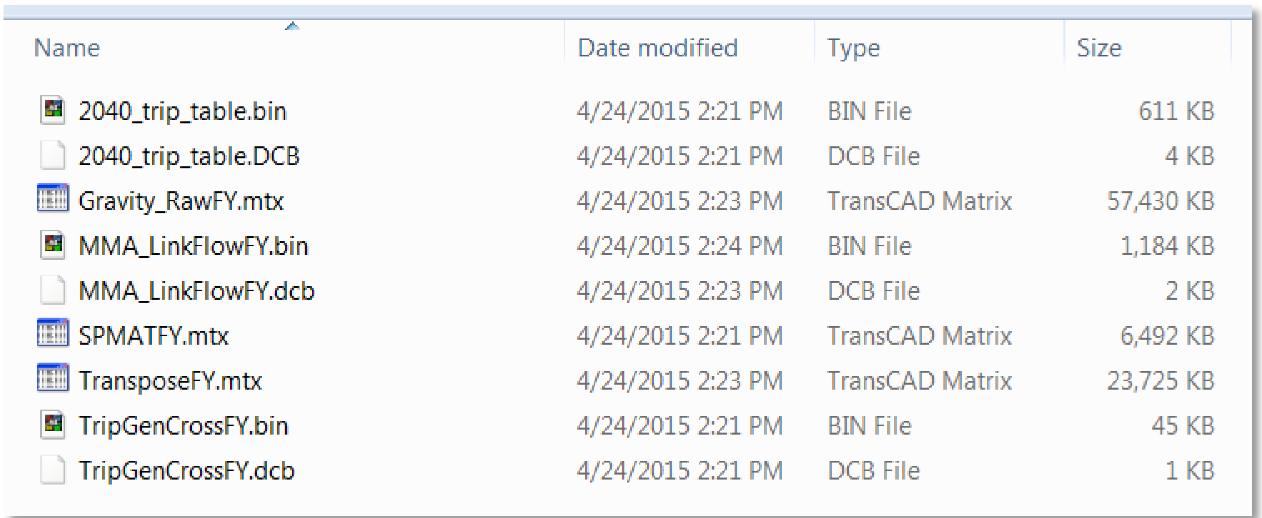
All Model output files are placed in the folder identified on the initial menu by the user. Figure 12 shows an example of a full set of output files from a Model run.



Name	Date modified	Type	Size
Forecast_Year_2040	4/24/2015 2:23 PM	File folder	
Gravity_Raw.mtx	4/24/2015 2:21 PM	TransCAD Matrix	64,250 KB
MMA_LinkFlow.bin	4/24/2015 2:21 PM	BIN File	1,184 KB
MMA_LinkFlow.dcb	4/24/2015 2:21 PM	DCB File	2 KB
ODME_TRUCK_OD.mtx	4/24/2015 2:19 PM	TransCAD Matrix	3,407 KB
ODMETruckLinkFlow.bin	4/24/2015 2:19 PM	BIN File	888 KB
ODMETruckLinkFlow.dcb	4/24/2015 2:19 PM	DCB File	2 KB
RMSPE_Out.bin	4/24/2015 2:21 PM	BIN File	183 KB
RMSPE_Out.BX	4/24/2015 2:21 PM	BX File	21 KB
RMSPE_Out.DCB	4/24/2015 2:21 PM	DCB File	1 KB
SPMAT.mtx	4/24/2015 2:18 PM	TransCAD Matrix	6,491 KB
Transpose.mtx	4/24/2015 2:20 PM	TransCAD Matrix	27,119 KB
trip_table.bin	4/24/2015 2:18 PM	BIN File	611 KB
trip_table.DCB	4/24/2015 2:18 PM	DCB File	4 KB
TripGenCross.bin	4/24/2015 2:18 PM	BIN File	45 KB
TripGenCross.dcb	4/24/2015 2:18 PM	DCB File	1 KB

Figure 12 Typical Output Files from a Model Run

In this example, a 30-year forecast was run, so the forecast-year output folder is automatically named "Forecast_Year_2040". Clicking on the forecast-year folder reveals the additional output files shown in Figure 13.



Name	Date modified	Type	Size
2040_trip_table.bin	4/24/2015 2:21 PM	BIN File	611 KB
2040_trip_table.DCB	4/24/2015 2:21 PM	DCB File	4 KB
Gravity_RawFY.mtx	4/24/2015 2:23 PM	TransCAD Matrix	57,430 KB
MMA_LinkFlowFY.bin	4/24/2015 2:24 PM	BIN File	1,184 KB
MMA_LinkFlowFY.dcb	4/24/2015 2:23 PM	DCB File	2 KB
SPMATFY.mtx	4/24/2015 2:21 PM	TransCAD Matrix	6,492 KB
TransposeFY.mtx	4/24/2015 2:23 PM	TransCAD Matrix	23,725 KB
TripGenCrossFY.bin	4/24/2015 2:21 PM	BIN File	45 KB
TripGenCrossFY.dcb	4/24/2015 2:21 PM	DCB File	1 KB

Figure 13 Typical Forecast-Year Output Files from a Model Run

Table 16 provides descriptions of each of the output files generated by a typical Model run.

Table 16 Output File Descriptions

File Name	File Description
TripGenCross.bin (and matching *.dcb)	A fixed-format binary table of trip productions by TAZ for the 6 home-based trip purposes
trip_table.bin (and matching *.dcb)	A fixed-format binary table of trip productions and attractions by TAZ for the 8 non-TRUCK trip purposes
SPMAT.mtx	A TransCAD matrix file consisting of the shortest travel-time paths between all TAZs in the Model
ODME_Truck_OD.mtx	A TransCAD matrix file consisting of the final O-D matrix core of TRUCK trips resulting from the O-D Matrix Estimation step
ODMETruckLinkFlow.bin (and matching *.dcb)	A fixed-format binary table of link TRUCK flows resulting from the O-D Matrix Estimation step for every link in the Model network
Gravity_Raw.mtx	A TransCAD matrix file consisting of 19 matrix cores with the output of the trip distribution step for each of the 9 trip purposes in person-trips and vehicle-trips, concluding with a core of the diagonally-symmetric total vehicle-trips for the traffic assignment

File Name	File Description
Transpose.mtx	A TransCAD matrix file which is the transpose of the assymetric total vehicle-trip matrix, used to make the diagonally-symmetric matrix of total vehicle trips
MMA_LinkFlow.bin (and matching *.dcb)	A fixed-format binary table of link flows resulting from the multi-class traffic assignment for every link in the Model network
RMSPE_Out.bin (and matching *.dcb)	A fixed-format binary table of squared errors between the link flows and AADTs every link in the Model network that has an AADT, and the RMSPE of the Model run
TripGenCrossFY.bin (and matching *.dcb)	A fixed-format binary table of **forecast-year** trip productions by TAZ for the 6 home-based trip purposes
YYYY_trip_table.bin (and matching *.dcb)	A fixed-format binary table of **forecast-year** trip productions and attractions by TAZ for the 8 non-TRUCK trip purposes
SPMATFY.mtx	A TransCAD matrix file consisting of the shortest travel-time paths between all TAZs in the Model for the **forecast-year network**
Gravity_RawFY.mtx	A TransCAD matrix file consisting of 19 matrix cores with the output of the trip distribution stepfor the **forecast-year** for each of the 9 trip purposes in person-trips and vehicle-trips, concluding with a core of the diagonally-symmetric total vehicle-trips for the traffic assignment
TransposeFY.mtx	A TransCAD matrix file which is the transpose of the assymetric total vehicle-trip matrix for the **forecast-year**, used to make the diagonally-symmetric matrix of total vehicle trips
MMA_LinkFlowFY.bin (and matching *.dcb)	A fixed-format binary table of link flows resulting from the multi-class traffic assignment in the **forecast-year** for every link in the Model network

The RMSPE output table was added to the Model to help see the RMSPE and link-specific squared errors (SE) more efficiently. These statistics are useful for validating the Model, so having them produced in a stand-alone output table allows the Model to be re-estimated and/or updated more efficiently.

Model outputs in the output folder get over-written each time the Model is run, so this information should be saved to a new folder each time the Model is run. If a different forecast-year is used, the old forecast-year outputs will remain in the old forecast-year output folder, so in that case there is no need to save the outputs separately to a new folder.

4.4 Validation Plan

Another short-term recommendation that came from the TMIP peer review of the Vermont Travel Model in Year 5 was to develop a Validation Plan so that a third-party validation of the Model could be more easily initiated and performed. The following resources were consulted to compile a Validation Plan for the Vermont Travel Model:

- Final Report: Validation and Sensitivity Considerations for Statewide Models (NCHRP, 2010)
- Travel Model Validation and Reasonableness Checking Manual, Second Edition (FHWA, 2010)

Recommendations for validation steps relevant to the Vermont Travel Model from these guidance documents are provided in this section, along with recommendations for validation steps using Vermont-specific data.

4.4.1 Recommendations from *Validation and Sensitivity Considerations for Statewide Models*

From Table 3.3 in the NCHRP guidance document (NCHRP, 2010), the following characteristics and socio-economic ratios should be used to compare Vermont to other states with statewide models:

- Number of zones
- Number of links
- Links per zone
- Persons per household
- Jobs per capita
- Passenger vehicles per household
- Population per zone (for internal zones only)

From Table 3.4 in the NCHRP guidance document (NCHRP, 2010), the following ratios should be used to compare Vermont to the other states:

- Person-trips per zone
- Person-trips per person
- Person-trips per household

- HBW person-trips per household
- Person trips per worker

From Table 3.5 in the NCHRP guidance document (NCHRP, 2010), compare the trip-purpose distribution for the Vermont Travel Model to those for other states. From Table 3.6 in the NCHRP guidance document (NCHRP, 2010), compare the average trip-lengths by purpose for the Vermont Travel Model to other states. From Table 3.7 in the NCHRP guidance document (NCHRP, 2010), compare fractions of intra-zonal trips by purpose for the Vermont Travel Model to other states. From Table 3.8 in the NCHRP guidance document (NCHRP, 2010), compare average passenger-vehicle occupancy by purpose for the Vermont Travel Model to other states. From Table 3.9 in the NCHRP guidance document (NCHRP, 2010), compare the Vermont Travel Model to other states for RMSPE by link-volume range.

4.4.2 Using Vermont-Specific Data

Other unique Vermont-specific data can be used to validate the specifications of the Model. Data on the total number of employees of Vermont's 13 largest employers was obtained from the Vermont Business Magazine for 2008 and 2012, as shown in Table 15.

Table 17 Major Employers in Vermont

Employer	No. of 2008 Employees[1]	No. of 2012 Employees[2]	Town	Model TAZ(s)
Fletcher Allen Health Care & the University of Vermont	8,518	8,294	Burlington	638-645 & 123-125
International Business Machines Corp.	5,400	5,000	Essex Junction	710
GE Aircraft Engines	1,300	1,000	Rutland	389
Rutland Regional Medical Center	1,300	1,530	Rutland	391
Central Vermont Medical Center	1,200	1,400	Barre	437
Middlebury College	1,145	1,089	Middlebury	25 & 26
Southwestern Vermont Medical Center	877	877	Bennington	66
Sugarbush Resort	800	750	Killington	375
National Life Group	750	900	Montpelier	446
Ben & Jerry's Homemade, Inc.	735	735	S. Burlington	824
Goodrich Corp.	700	700	Vergennes	7
VA Medical Center	700	700	White River Junction	555
Stowe Mountain Resort`	650	650	Stowe	284 & 285

[1]Vermont Business Magazine, November 2008.

[2]Vermont Business Magazine, Volume 40, Issue 10.

These employment totals allow a spot-check of the TAZ-specific employment numbers in the Model against the specific known locations of these employers. Banks and supermarkets are not included in the list because their specific employment locations tend to be different from the location of the company's headquarters.

Vermont's E911 database and geographical information system (GIS), which consists of the location and functional classification of each habitable structure in the state, can also be used to augment the validation of the employment characteristics in the Model. The Vermont E911 data includes residential locations (single-family, multi-family, seasonal, and mobile homes) and non-residential locations (commercial, industrial, educational, governmental, health-care and public gathering), which should correspond roughly to locations of households and employment. Vermont is unique in that this E911 database is publicly available to support emergency-response personnel statewide via the Vermont Center for Geographic Information (VCGI).

For the Model, we can compare TAZ-level employment data to locations of non-residential buildings from the E911 GIS. Each job in a TAZ should have at least one non-residential building associated with it, and each building should have at least one job. Checking for consistency in these assumptions across the state can reveal mis-identified employment locations.

We can also compare TAZ-level households data to locations of residential buildings from the E911 GIS. Each household in a TAZ should have at one residential building associated with it, and each residential building should have at least one household, after accounting for vacancy rates, which are available from the U.S. Census.

The 2009 NHTS data used to specify and calibrate the Model can also be used in validation. Specific vehicle-trips and specific household characteristics, selected at random from the NHTS respondent households in Vermont, can be compared to the aggregate data for the TAZ in which they reside. Specific characteristics in the NHTS sample should fall within the expected range of variation for the aggregate characteristics of the TAZ. For specific vehicle-trips, modeled routes and travel times, particularly for HBW trips, can be compared to travel times reported by respondents in the NHTS. For specific household characteristics, household-level aggregate trip rates in the Model can be compared to the actual trip rates revealed by the NHTS respondent for their travel day.

Finally, we can take advantage of our regional travel-demand model for the Chittenden County MPO to compare daily volumes on its external links to daily internal volumes on the same roadways in the Vermont Travel Model.

This comparison may reveal validation characteristics of the MPO model as well.

4.4.3 Recommendations from *Travel Model Validation and Reasonableness Checking Manual, Second Edition*

A few of the recommendations from the FHWA guidance document (FHWA, 2010) can be used in the validation of the Vermont Travel Model. Plotting, mapping and checking the continuity of residential densities by TAZ statewide can help reveal possible inconsistencies in the assignment of households to TAZs. Similarly, plotting, mapping and checking roadway characteristics for continuity can reveal inconsistencies as well. Roadway characteristics like number of lanes, speeds and capacities should be reasonably continuous, or inconsistencies should be explained by roadway features like reduced speed zones, bottlenecks like bridges, and short-term addition of passing lanes.

4.4.4 Persistent Problems with the Model Specification

Persistent problems still exist in the Model specification, and continue to reduce its effectiveness. These problems should be evaluated for their severity and scope during the validation. Particularly around special generators in Chittenden County – like the "box stores" in Williston, the UVM campus, and the Champlain College campus in Burlington.

Problems derive from the lack of specificity in our knowledge of the employment categories statewide. They are exacerbated in areas with special types of generators based on employment. For example, in the retail categories, the average ITE trip attraction rate is 53 trips per employee. However, in the Vermont Travel Model the average number of trips attracted per retail job is only 9.4. However, at the same time when the Model flows are reduced by 5% the RMSPE improves by about 1%, indicating that the Model is generally overestimating the number of trips taken statewide. The reasons for this inconsistency and recommendations for resolving it would be of value to the future Model specification.

A standing problem with Model flows is illustrated by the comparison of flows on parallel routes Route 127 and North Avenue in Burlington. The Model flows here show that more travelers use Route 127, due to its higher speed limit and more direct alignment connecting Burlington's Old North End and New North End. Traffic counts, however, show that more travelers choose to use North Avenue to get from the Old North End to the New North End of Burlington. The reason for this tendency is likely the presence of the city's high school along North Avenue, which serves as a drop-off point for drivers delivering their children to/from school. However, school travel is not treated as a separate trip purpose in the Model, nor are trip-tours modeled explicitly. Therefore, the Model continues to mis-estimate routes by ignor9ing potential intermediate destinations like schools. Recommendations for resolving this issue would also be of value to the future Model specification.

5 Summary and Recommendations

The Model improvements conducted in Year 7 included significant improvements to the way trips are distributed to destination by distance class. New rates and parameters which include a long-distance classification for HBO and NHB trips were incorporated into the Model platform in Year 7. This improvement resulted in an overall improvement in the ability of the Model to simulate a typical day of travel in the state. The overall RMSPE of the Model is currently at 42.5%.

A TMIP peer review of the Model was conducted in Year 5, resulting in a comprehensive set of recommendations for Model improvements for the years ahead. Selected subtasks are recommended for Year 8 based on the short-term recommendations from the peer review and the accomplishments in Year 7:

- Consider dynamic traffic assignment to assess traffic patterns in emergency response
- Identify metrics for emergency scenario comparison to guide model development
- Explore the need for seasonal trip tables

Additionally, the “halo” analysis initiated in Year 7 will be continued in Year 8 by developing an external highway travel sub-module for trips leaving/entering Vermont to/from urban destinations in New England, New York, and Canada. Year 8 will include these efforts to continue the improvement of the basic Model functionality, accuracy, and effectiveness, all within its base-year of 2009-2010. Continued improvements will bring the Model closer to its goals for functionality and effectiveness.

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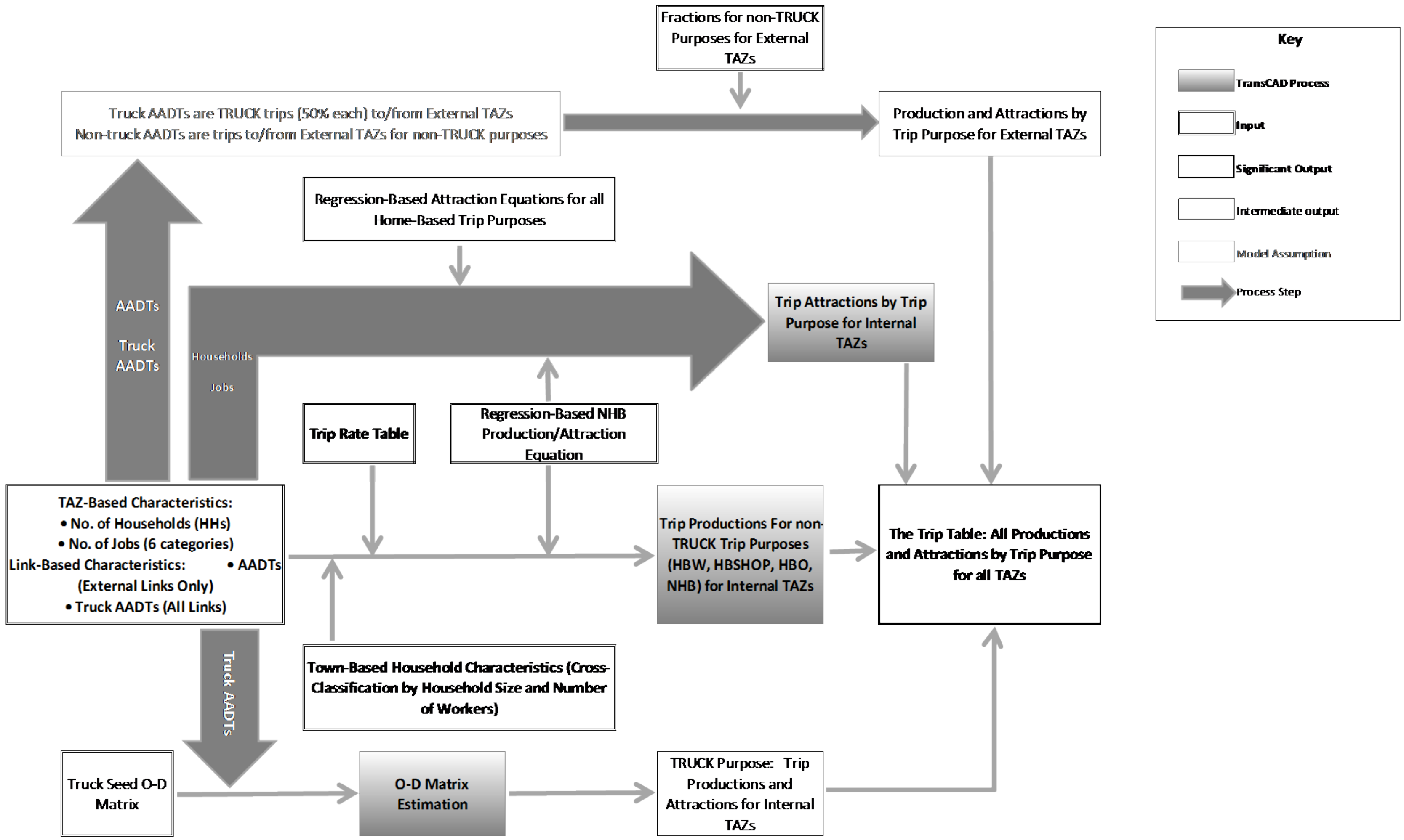
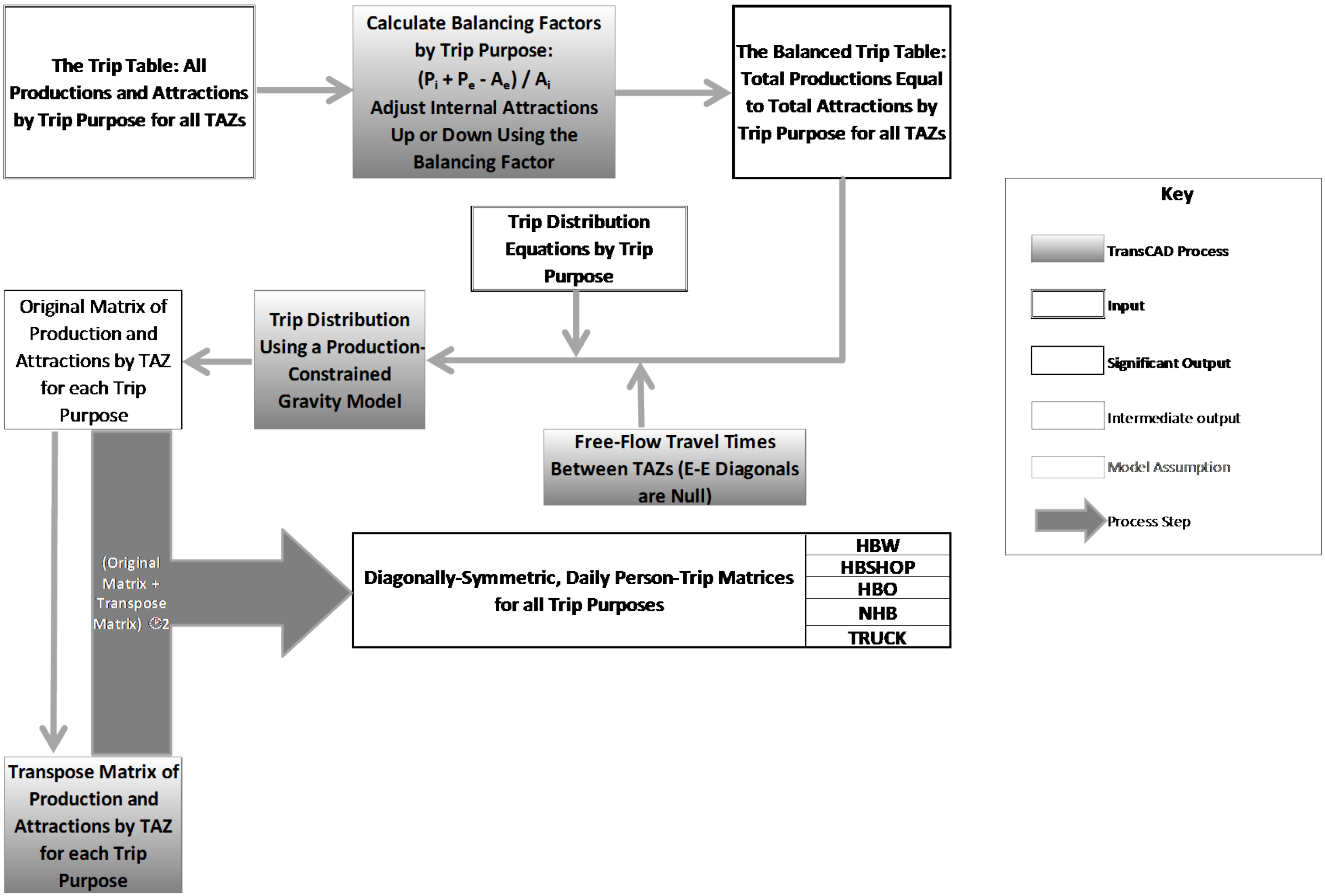
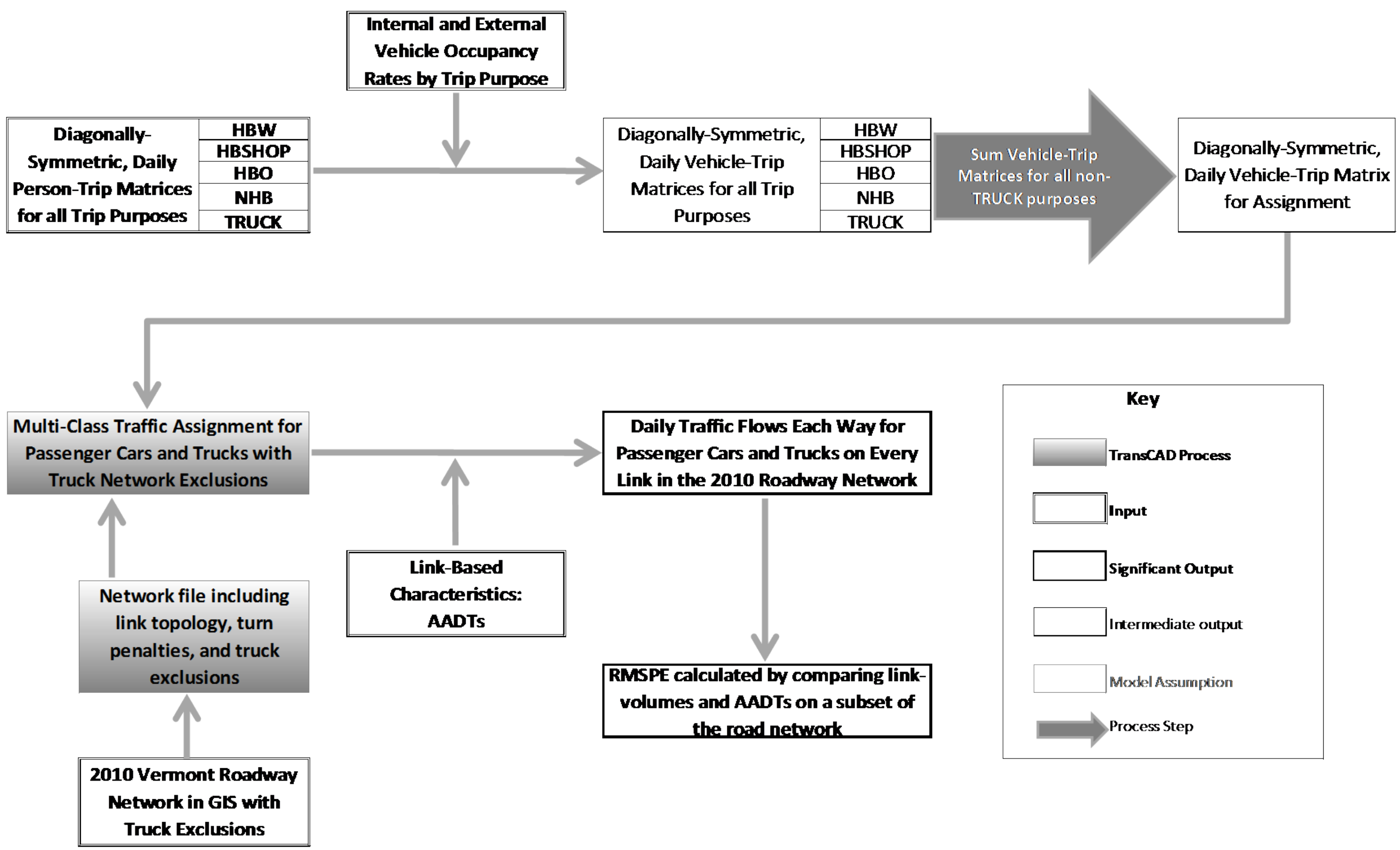
Appendix A


Fractions for non-TRUCK Purposes for External TAZs
Truck AADTs are TRUCK trips (50% each) to/from External TAZs
Non-truck AADTs are trips to/from External TAZs for non-TRUCK purposes
Production and Attractions by Trip Purpose for External TAZs
Regression-Based Attraction Equations for all Home-Based Trip Purposes
AADTs
Truck AADTs
Households
Jobs
Trip Attractions by Trip Purpose for Internal TAZs
Trip Rate Table
Regression-Based NHB Production/Attraction Equation
TAZ-Based Characteristics:
• No. of Households (HHs)
• No. of Jobs (6 categories)
Link-Based Characteristics: • AADTs (External Links Only)
• Truck AADTs (All Links)
Trip Productions For non-TRUCK Trip Purposes (HBW, HBSHOP, HBO, NHB) for Internal TAZs
The Trip Table: All Productions and Attractions by Trip Purpose for all TAZs
Truck AADTs
Town-Based Household Characteristics (Cross-Classification by Household Size and Number of Workers)
Truck Seed O-D Matrix
O-D Matrix Estimation
TRUCK Purpose: Trip Productions and Attractions for Internal TAZs
Key
TransCAD Process
Input
Significant Output
Intermediate output
Model Assumption
Process Step



The Trip Table: All Productions and Attractions by Trip Purpose for all TAZs
Calculate Balancing Factors by Trip Purpose:
$(P_i + P_e - A_e) / A_i$
Adjust Internal Attractions Up or Down Using the Balancing Factor
The Balanced Trip Table: Total Productions Equal to Total Attractions by Trip Purpose for all TAZs
Trip Distribution Equations by Trip Purpose
Original Matrix of Production and Attractions by TAZ for each Trip Purpose
Trip Distribution Using a Production-Constrained Gravity Model
Free-Flow Travel Times Between TAZs (E-E Diagonals are Null)
(Original Matrix + Transpose Matrix) ÷2
Diagonally-Symmetric, Daily Person-Trip Matrices for all Trip Purposes
HBW
HBSHOP
HBO
NHB
TRUCK
Transpose Matrix of Production and Attractions by TAZ for each Trip Purpose
Key
TransCAD Process
Input
Significant Output
Intermediate output
Model Assumption
Process Step


Internal and External Vehicle Occupancy Rates by Trip Purpose
Diagonally-Symmetric, Daily Person-Trip Matrices for all Trip Purposes
HBW
HBSHOP
HBO
NHB
TRUCK
Diagonally-Symmetric, Daily Vehicle-Trip Matrices for all Trip Purposes
HBW
HBSHOP
HBO
NHB
TRUCK
Sum Vehicle-Trip Matrices for all non-TRUCK purposes
Diagonally-Symmetric, Daily Vehicle-Trip Matrix for Assignment
Multi-Class Traffic Assignment for Passenger Cars and Trucks with Truck Network Exclusions
Daily Traffic Flows Each Way for Passenger Cars and Trucks on Every Link in the 2010 Roadway Network
Network file including link topology, turn penalties, and truck exclusions
Link-Based Characteristics: AADTs
RMSPE calculated by comparing link-volumes and AADTs on a subset of the road network
2010 Vermont Roadway Network in GIS with Truck Exclusions
Key
TransCAD Process
Input
Significant Output
Intermediate output
Model Assumption
Process Step