A Report from the University of Vermont Transportation Research Center

Vermont Travel Model 2011-2012 (Year 4)

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Vermont Travel Model 2011-2012 (Year 4) Report

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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) in the 2011-2012 year of the contract. The primary objective of the project was to continue to improve the Vermont Travel Model toward the goal of being a comprehensive, effective predictor of travel behavior of Vermonters. The purpose of this report is to document the improvement activities which were completed toward this goal in the 2011-2012 (Year 4) year of the contract. Other activities undertaken in Year 4 of the contract are documented separately.

The Vermont Travel Model is a series of spatial computer models which uses the land use and activity patterns of traffic analysis zones (TAZs) within Vermont to estimate the travel behavior of Vermonters. Origin and destination tables are created which describe the number of expected trips between each pair of zones. Accommodations are made for commercial-truck trips, trips made by non-automobile modes, 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 936 zones and 5,250 miles of highway network (Figure 1).

In Year 3, the TRC updated the Model with data from the 2009 National Household Travel Survey and the Vermont Department of Labor. In Year 4, land-use characteristics in the model were updated with new residential information from the 2006-2010 American Community Survey (ACS) and the 2010 US Census, and new employment information for 2009 from the Bureau of Economic Analysis (BEA). Land-use characteristics updated included using the cross-classification of number of household members and number of household workers by town, the number of households by Census block, and the number of jobs by industry by County. Road network characteristics were also updated, reflecting modifications or improvements to the network since 2000. The characteristics of roadways that were updated included speed limits, alignments, and capacities.

In addition, the TRC began the investigation into the development of the freight component of the Vermont Travel Model. The findings of this initial investigation, along with the TRC's recommendations for the Model, are summarized in this report.

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 in this update (Section 3), a description of the methods used to process data for use in improving the Model (Section 4), a summary of the results of the update (Section 5), and a summary of the results of the investigation into the development of a freight component to the Model (Section 6).

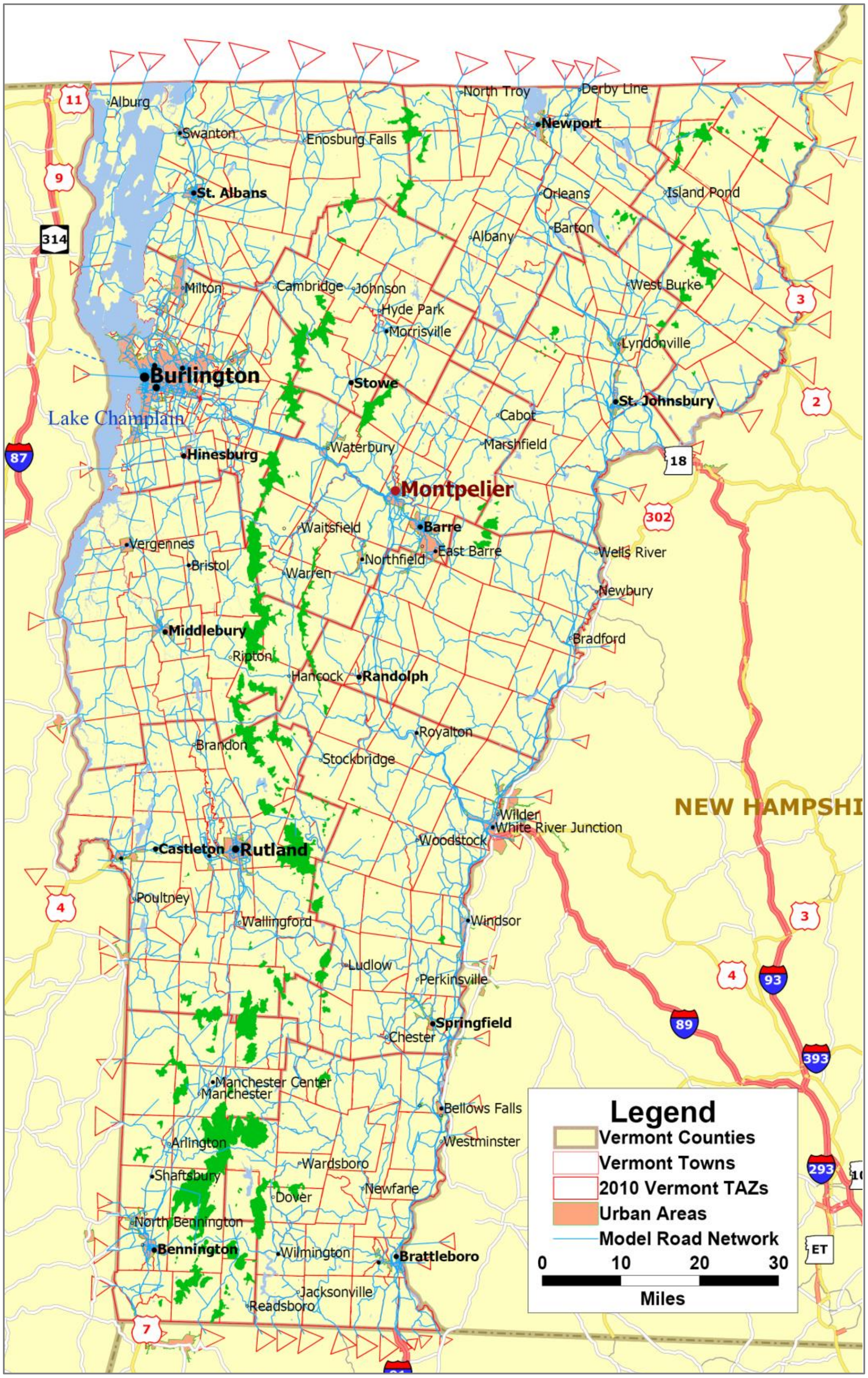

Figure 1 Zones and Road Network in the Vermont Travel Model

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. Daily travel demand is estimated by the model between traffic analysis zones (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).

It is important to note, though, that the Model can only estimate travel demand between TAZs, not between specific locations, and it can only estimate link flow on the roads that are included in the Model, which are interstate highways, federal highways, state highways, federal urban area routes and some major collectors. Still 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 and the University of Vermont Transportation Research Center – all which rely on the model for transportation planning, research, and educational activities.

Less-populated towns are divided into as many as 5 TAZs, while larger towns and cities in the state have considerably finer zonal resolution. Trip generation information 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) based on the 2010 US Census, the 2009 National Household Travel Survey, the 2006-2010 American Community Survey, 2009 data from the Department of Employment and Training of the Vermont Department of Labor (VDOL), and 2009 data from the Federal Bureau of Economic Analysis (BEA). Trip distribution is accomplished using a gravity model. The traffic assignment phase of the model uses a user-equilibrium assignment process.

The travel model described above also 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. These other modes are accounted for in a post-processing reduction of traffic volumes, which is shown to improve the Model's fidelity.

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 model 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).

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).

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, which indicated that the addition of Exit 12B would not have a significant effect on north-south corridor travel between

Burlington and Middlebury, were documented in a technical memo, dated February 26, 2010, and delivered to VTrans on March 3, 2010.

A preliminary travel analysis was also conducted for the Route 22A Corridor near Fair Haven, Vermont in association with a VTrans contractor. 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 documented in a technical memo, dated and delivered to Stantec and VTrans on July 2, 2010.

As the data from the National Household Travel Survey (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.

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 American Community Survey (ACS), new employment information for 2009 from the Vermont Department of Labor (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 Vermont Department of Labor which may not have been readily available in 2000.

2.2 Functionality of the Model

The figures in Appendix A illustrate the processes which comprise the Trip Generation and Trip Distribution modules of the model. In the figures, model inputs and outputs are shown as boxes, whereas model processes are indicated by block arrows. The parameters inside the block arrows are used in the process represented by the arrow. The Mode Choice and Traffic Assignment modules of the model are simpler processes and contain fewer parameters that can be updated with current data sources.

The trip-generation module starts by combining the TAZ-based land-use characteristics with the town-based fractions of no. of workers / no. of workers cross-classifications to calculate home-based trips produced by each internal TAZ. 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, each of which utilizes a different set of employment and/or population field(s) from the TAZ characteristics table. For example, the equation for home-based work (HBW) trips attracted is based on all of the employment fields in the TAZ characteristics table, but the equation for home-based shopping (HBSHOP) trips is 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.

Productions and attractions for zones external to Vermont are calculated differently. First, external TRUCK trips are taken to be the ADT for the external zones listed in the TAZ characteristics table (presumably taken from traffic counts) multiplied by the truck percentages from the TAZ characteristics table - these are split evenly as productions and attractions. The total for other external vehicle-trips (VTs) is taken as the remaining fraction of the ADT for each external zone listed in the TAZ characteristics table. 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 by the other 5 trip purposes using the fractions in the external trip-fractions table.

Ultimately, this process outputs a table of productions and attractions for each of the five trip purposes in the model for each of the 936 internal and external zones. However, since the production and attraction estimates for the internal TAZs came from different sources for each of the four home-based trip purposes, they do not match. This mismatch is typical for most 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 to 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 five trip purposes in the model for each zone.

2.2.1 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 to develop a matrix of productions and attractions between all zones. The set of impedance functions for the production-constrained gravity-model used to distribute trips is shown in Table 1.

Table 1 Impedance Functions in the Vermont Travel Model

Trip Purpose	Impedance Function		a	b	c
HBO	Gamma	$f(c_{ij}) = a * t_{ij}^{-b} * e^{-c(tij)}$	34,560	1.658	0.061
HBSHOP	Exponential	$f(c_{ij}) = e^{-c(tij)}$			0.111
HBW	Gamma	$f(c_{ij}) = a * t_{ij}^{-b} * e^{-c(tij)}$	901	0.398	0.086
NHB	Gamma	$f(c_{ij}) = a * t_{ij}^{-b} * e^{-c(tij)}$	94,608	1.317	0.101
TRUCK	Exponential	$f(c_{ij}) = e^{-c(tij)}$			0.065

The result of this step is a matrix of productions and attractions between all zones. The final step in the trip-distribution application is to convert this matrix into a matrix of origin-destination (O-D)-based trips. 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 transposed, added to the original, and then all cells are halved. The result is a diagonally-symmetric O-D matrix of PTs.

2.2.2 Mode Choice

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, and no definable data source for the transit demand could be located, and the 2009 NHTS does not support the development of 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 2.

Table 2 Vehicle Occupancy Rates in the Vermont Travel Model

Trip Purpose	Internal Trips	Internal to External & External to Internal Trips
Home-Based Work	1.13	1.05
Home-Based Shopping	1.48	1.93
Home-Based Other	1.75	1.85
Non-Home-Based	1.51	1.78

Truck	1.00	1.00

2.2.3 Traffic Assignment

The final matrix, including all external vehicle-trips, is assigned to the road network in the traffic assignment sub-module. Free-flow travel speed on each link is assumed to be the 5 miles per hour over the speed limit, and the user-equilibrium traffic assignment is used.

3 Description of the Data

This section contains a description of all data sources used in this Model update, and how they were pre-processed for use in the update.

3.1 The 2009 Employment Estimates from the Bureau of Economic Analysis

The BEA regional economic accounts provide statistics about gross domestic product (GDP) for states and metropolitan areas, as well as personal income for states, counties, metropolitan areas, micropolitan areas, metropolitan divisions and combined statistical areas, and BEA economic areas. BEA's annual estimates of personal income for local areas provide the only detailed, broadly inclusive economic time series for local areas that are available. These estimates are used by state and local governments for economic planning and by businesses to evaluate marketing strategies. The personal income of a local area is the income received by, or on behalf of, the residents of the area. BEA prepares estimates for 3,111 counties, 363 metropolitan statistical areas, 576 micropolitan statistical areas, 123 combined statistical areas, 29 metropolitan divisions, and 179 BEA economic areas. The estimates of compensation and earnings by place-of-work indicate the economic activity of business and government within an area and the estimates of personal income by place of residence provide a measure of fiscal capacity of an area. The county employment estimates are a complement to the place-of-work earnings estimates. Earnings is estimated on a place-of-work basis, by North American Industry Classification System (NAICS) three-digit subsector beginning in 2001 and by Standard Industrial Classification (SIC) two-digit industry for 1969 to 2000, and net earnings (net of contributions for government social insurance) is estimated on a place-of-residence basis for the sum of all industries. The employment estimates are designed to conform conceptually and statistically with the place-of-work earnings estimates; the same source data—generally from administrative records—are used for both the earnings and employment estimates whenever possible. The earnings estimates reflect the scale and industrial structure of an area's economy rather than the income of the area's residents. Therefore, the employment estimates measure the number of jobs in a county, instead of the number of workers who perform the jobs. The characteristics of the county employment estimates follow from this concept and from the characteristics and limitations of the available source data. For Year 4 of the Model update, the BEA estimate of total full-time and part-time employment by NAICS industry by County for 2009 was used.

3.2 The 2010 United States Census

The U.S. Census counts every resident in the United States. It is mandated by Article I, Section 2 of the Constitution and takes place every 10 years. The data collected by the decennial census is used to determine the number of seats each state has in the U.S. House of Representatives and is also used to distribute federal funds. The 2010 Census represented the largest participation movement ever witnessed in Census history. Approximately 74 percent of the households returned their census forms by mail; the remaining households were counted by census workers walking neighborhoods throughout the United States. National and state population totals from the 2010 For Year 4 of the Model update, the 2010 US Census count of total households by Census block were aggregated to a count of households by TAZ for the entire state of Vermont.

3.3 The 2006 – 2010 American Community Survey

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 on a smaller scale than the decennial census to provide up-to-date (but less reliable) information about the social and economic needs of American communities.

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. For Year 4 of the Model update, cross-classification of the no. of workers and no. of household members by town in Vermont for the pooled years 2006-2010 were used.

3.4 Downtown Speed Zones from the Vermont Center for Geographic Information

The layer of speed zones in Vermont used in the Year 4 update was developed by the Vermont Center for Geographic Information to delineate designated speed zones along highways. Speed zones represent reductions in typical highway speeds which occur within a village or downtown, or near a school, with a corresponding recovery to typical speeds when the focus of the zone is passed. Mile markers of speed zones were provided to VCGI by VTrans in 2003, and VCGI converted the data to geographic coverage and created FGDC compliant metadata. The resulting layer contains 793 independent speed zones along interstates and state and federal highways in Vermont.

3.5 VTrans Project Information

In order to obtain a list of roadway projects that may have affected link speeds and capacities, the VTrans Project Information site was used. The website provides project status information pertaining to Agency projects, including all projects in the FY2011 Capital Program and Project Development Plan, using a selection interface. For the Year 4 update, a preliminary list of major roadway projects whose construction had begun before 2011 were included in the search.

4 Freight Model Investigation

4.1 Background

Freight models at the statewide level in the US contain varying levels of specificity, depending on the data availability and needs of the associated agencies. The coarsest level of modeling includes only the inclusion of commercial truck flows in a single category, and is based primarily on truck-classification counts, from which commercial freight demand is estimated. The Vermont Travel Model includes this level of resolution. A more sophisticated freight model might include trucks in several categories, based on the specific truck classification made when truck counts are collected. More sophisticated truck classification data is available in Vermont, but this finer truck classification has not been incorporated into the Model. The most sophisticated freight models are based on commodity flows at the same time, in tonnage or monetary value. These commodity flows are then disaggregated by mode into truck, truck drayage, barge, container, rail and air modes. The truck trips can be calibrated against truck counts, based on truck-classification sizes and approximations of the capacity usage of each vehicle – full truckload, less-than-truckload, etc. Additional data sources are needed to develop the commodity-flow component of the freight model.

Current freight models which include commodity flows typically follow a 4-step process similar to passenger-car travel-demand models. The process for commodity-flow modeling uses econometric data to develop attractions and productions between origin and destination pairs, and freight flows are estimated in units of tonnage or dollar value for a categorization of commodities, typically using Standard Classification of Transported Goods (SCTG) two-digit coding. Freight data is generated from a variety of sources, both publicly and privately available, depending upon the level of spatial and categorical disaggregation desired. Obtaining commercial freight-commodity data with a high degree of spatial accuracy for Vermont would be challenging given low population and associated low industrial activity.

Estimation of commodity productions commonly relies on employment data similar to the data used to update the passenger-car travel model for NAICS categories. To develop attractions, benchmark input/output (I/O) 'accounts' from the Bureau of Economic Analysis (BEA) are used. These I/O accounts result in a matrix of SCTG commodity input by NAICS industry output in dollar value, which can be further synthesized to result in a similar matrix of coefficients, whose rows and columns sum to 1. Trip distribution is then accomplished using a traditional gravity model as is done with passenger-car trips in the Vermont Travel Model. Trips are then assigned to links where trucks are permitted using all-or-nothing techniques to avoid the simulation of congestion. These link-specific commodity flows (in kilotons) are then translated to truck-traffic volumes through payload regressions, resulting in payload-specific volumes.

4.2 Freight Flows in Vermont

4.2.1 Summary of Freight Flow Types

In order to develop a better understanding of the potential need for augmented freight modeling in Vermont, a cursory investigation of the freight flows in the state was conducted. The primary source of freight flow data for this investigation was the Freight Analysis Framework 3 (FAF3) module, provided by the FHWA. The FAF3 estimates commodity movements by truck and weight for truck-only, long distance moves over specific highways in the United States. Models are used to disaggregate interregional flows from the FAF Origin-Destination Database into flows between localities and to assign these flows to individual highways using average payloads per truck, and truck counts on individual highway segments.

Using the FAF database, four Origin-Destination categories were generated for 42 STCG categories of freight for Vermont – Internal, Outbound, Inbound and Through flows for the 2010 base year. Domestic flows in the FAF3 module are classified as state- or MSA-based or import/export for international flows. Therefore, a total of seven types of freight O-D pairs are possible, as shown in Table 3.

Table 3 Origin-Destination Pairs from the FAF3 Module

Origin	Destination	Classification	Description
Vermont	Vermont	Internal (I-I)	Domestic
Vermont	Other states in the US	Outbound (I-E)	Domestic
Vermont	Canada	Outbound (I-E)	International
Other states in the US	Vermont	Inbound (E-I)	Domestic
Other states in the US	Canada	Through (E-E)	International
Canada	Other states in the US	Through (E-E)	International
Canada	Vermont	Inbound (E-I)	International

Due to the limitations of the FAF3 module, it is not possible to generate domestic Through flow for Vermont, whose origin and destination are domestic and pass through Vermont. Thus, Through flow as modeled here is limited to international flows. A tabulation of the total SCTG commodity flows aggregated to Origin-Destination pair types are shown below in Table 4.

Table 4 2010 FAF3 Commodity Flows by Origin-Destination Pair, in Kilotons

		Flows (in kilotons)			
SCTG Code	Commodity Description	E-E	E-I	I-E	I-I
1	Live animals/fish	4.6	11.6	5.1	37.3
2	Cereal grains	11.2	338.3	1351.1	773.1
3	Other ag prods.	72.9	396.8	842.1	610.3
4	Animal feed	8.3	391.5	314.3	884.1
5	Meat/seafood	0.9	125.5	3.5	35.9
6	Milled grain prods.	20.7	184.7	41.6	43.2

		Flows (in kilotons)			
SCTG Code	**Commodity Description**	**E-E**	**E-I**	**I-E**	**I-I**
7	Other foodstuffs	64.3	421.9	741.8	313.2
8	Alcoholic beverages	16.2	49	109.7	157.7
9	Tobacco prods.	0	0.1	3.1	3.3
10	Building stone	0	11.9	65.4	43.6
11	Natural sands	0	194.8	11.8	429.2
12	Gravel		631.3	550.5	2589.3
13	Nonmetallic minerals	110.5	194.1	165.4	1413.5
14	Metallic ores	0.2	0.1	0	0.1
15	Coal	0	4.2	0.1	1.8
16	Crude petroleum	0	0	0	0
17	Gasoline	0	956	90	885.5
18	Fuel oils	0	724.6	33.7	502.8
19	Coal-n.e.c.	162.6	1150.1	73.4	452.6
20	Basic chemicals	29.3	584.4	17.3	41.9
21	Pharmaceuticals	0	1.7	4.4	6.5
22	Fertilizers	2	14.5	14.1	130.6
23	Chemical prods.	13.2	39.4	32.8	33.5
24	Plastics/rubber	88.5	114.4	70.2	22.2
25	Logs		38.1	7.3	1735.9
26	Wood prods.	575.2	422.9	381.5	236.9
27	Newsprint/paper	244.8	64	133.1	52.9
28	Paper articles	441.1	83.7	71.7	22.4
29	Printed prods.	4.7	25.1	35.3	26.3
30	Textiles/leather	24	22.7	10.1	18.6
31	Nonmetal min. prods.	186.9	548	363.8	2497.6
32	Base metals	92.6	247.2	39.4	20.7
33	Articles-base metal	45.4	64	25.5	96.3
34	Machinery	30.3	41.2	56.5	188.4
35	Electronics	24.9	20.3	100.3	17.8
36	Motorized vehicles	13	98.3	35.2	56.2
37	Transport equip.	2.8	0.1	0.2	1.5
38	Precision instruments	1.3	0.5	0.9	1.3
39	Furniture	17.7	27.3	25.1	15.4
40	Misc. mfg. prods.	7.5	49.1	76.3	35.2
41	Waste/scrap		77.7	148.7	1661.2
43	Mixed freight	26.8	558.2	298.1	184.6
99	Unknown		15.2	23.9	419.1
	TOTALS	**2,344**	**8,945**	**6,374**	**16,700**

For this investigation, these flows were disaggregated to the County level internally, but only to the state level externally. The outputs of the FAF3 module for domestic I-E flows are aggregated for all commodities to the state in Figure 2.

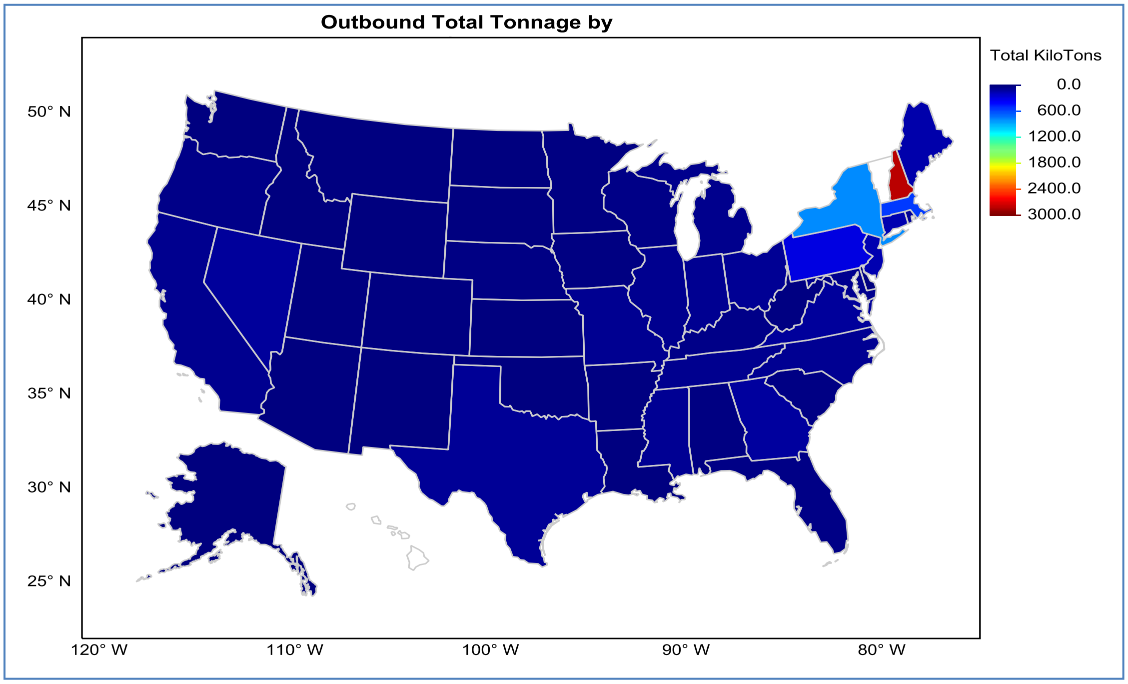

Figure 2 Total Domestic I-E Flows for Vermont

Figure 3 highlights the states whose share of Vermont's domestic I-E flows is greater than 0.5%.

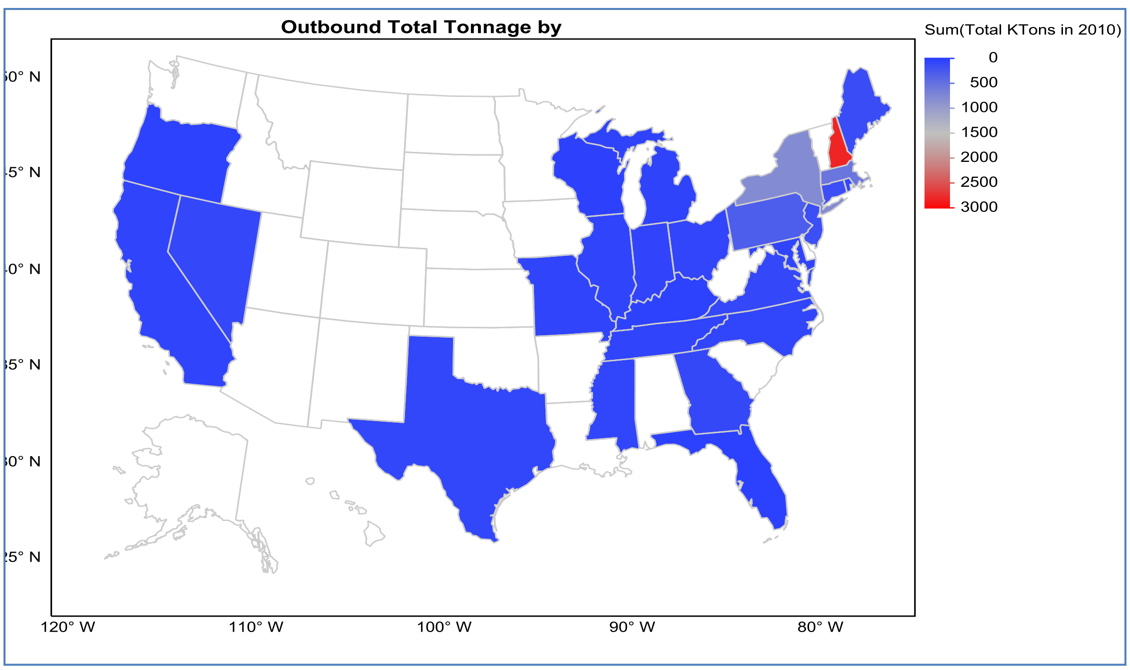

Figure 3 States whose share of Vermont's domestic I-E flows is greater than 0.5%

The states shown in white in Figure 2 total less than 2% of Vermont's I-E domestic flows combined. Externally, US states can be aggregated further by region, to indicate their criticality to Vermont, as shown in Figure 4.

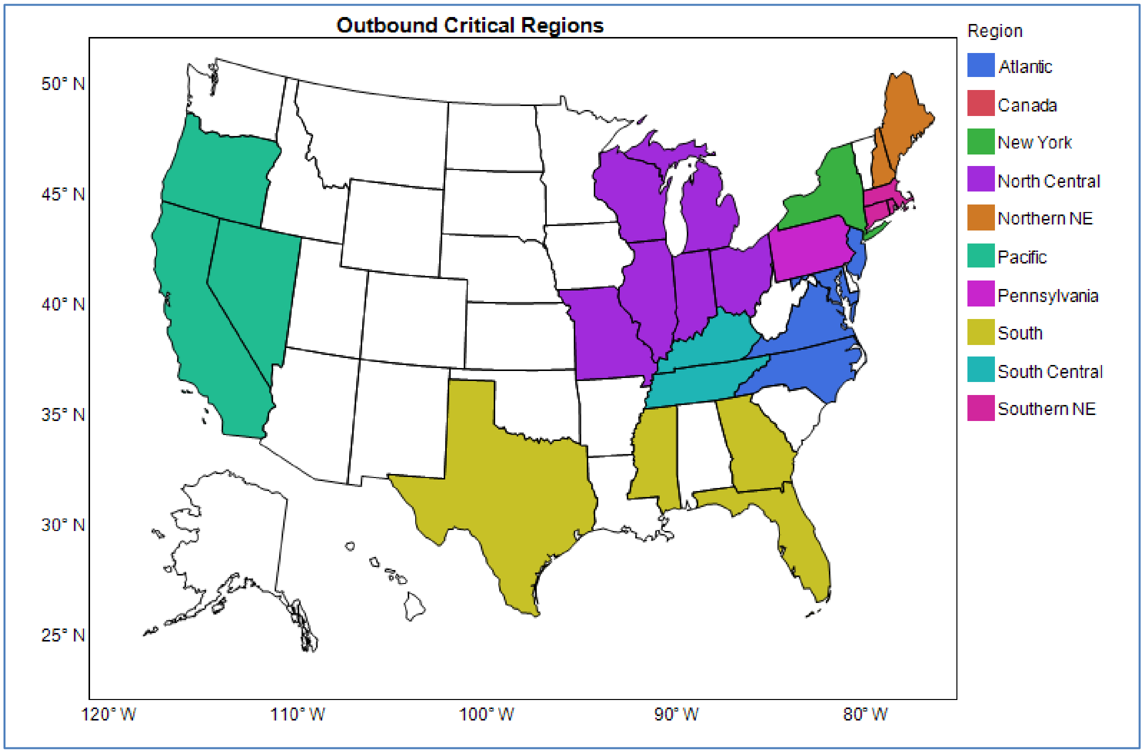

Figure 4 Critical Regions for Vermont's Domestic I-E Commodity Flow

4.2.2 I-E and I-I Commodity Productions

Using the Outbound commodity flows from Table 4, commodity productions are disaggregated to the county level using employment data for industries typically associated with the production of a given commodity. Productions are identified as I-E and I-I commodity flows in Tables 3 and 4. First, a "crosswalk" (Southworth et. al., 2011) provides the connection between each SCTG commodity and an associated NAICS producing industry. NAICS industry codes have a hierarchical structure, with the number of digits indicating the level of refinement. While the finest resolution of categorical employment data is desired to most accurately assign commodity volume, this information is not universally available due to data suppression in areas with low employment numbers. Here, broader NAICS codes are used, which achieves sufficient levels of categorization for use in regional commodity flow models.

The amount of commodity produced by each NAICS industry located in Vermont is further disaggregated based upon the relative employment in each NAICS industry within each of Vermont's 14 counties. These disaggregated commodity productions are provided by NAICS industry in Table B-1 in Appendix B. The resulting base-year 2010 annual production flows for each county were then determined. Total commodity productions by county, with all commodity types aggregated are shown in the chart in Figure 5 and the map in Figure 6.

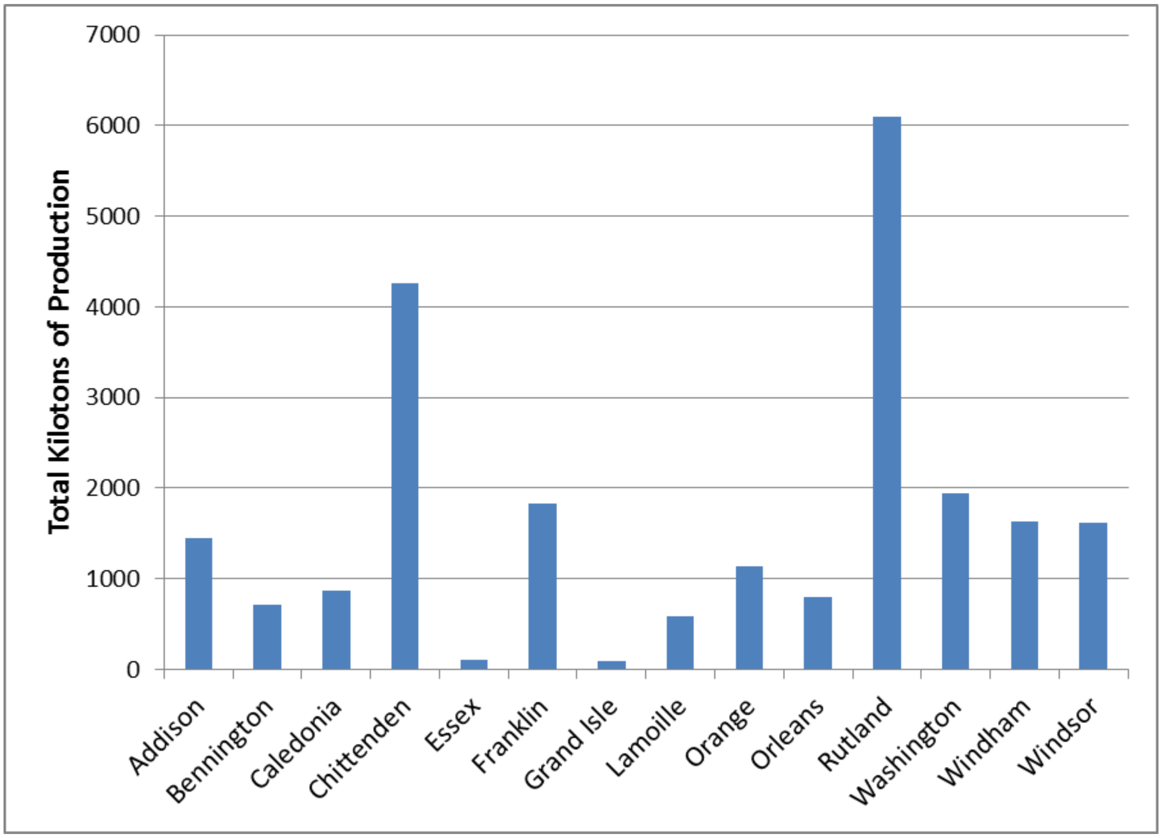

Figure 5 Total I-E and I-I Commodity Productions in Vermont by County

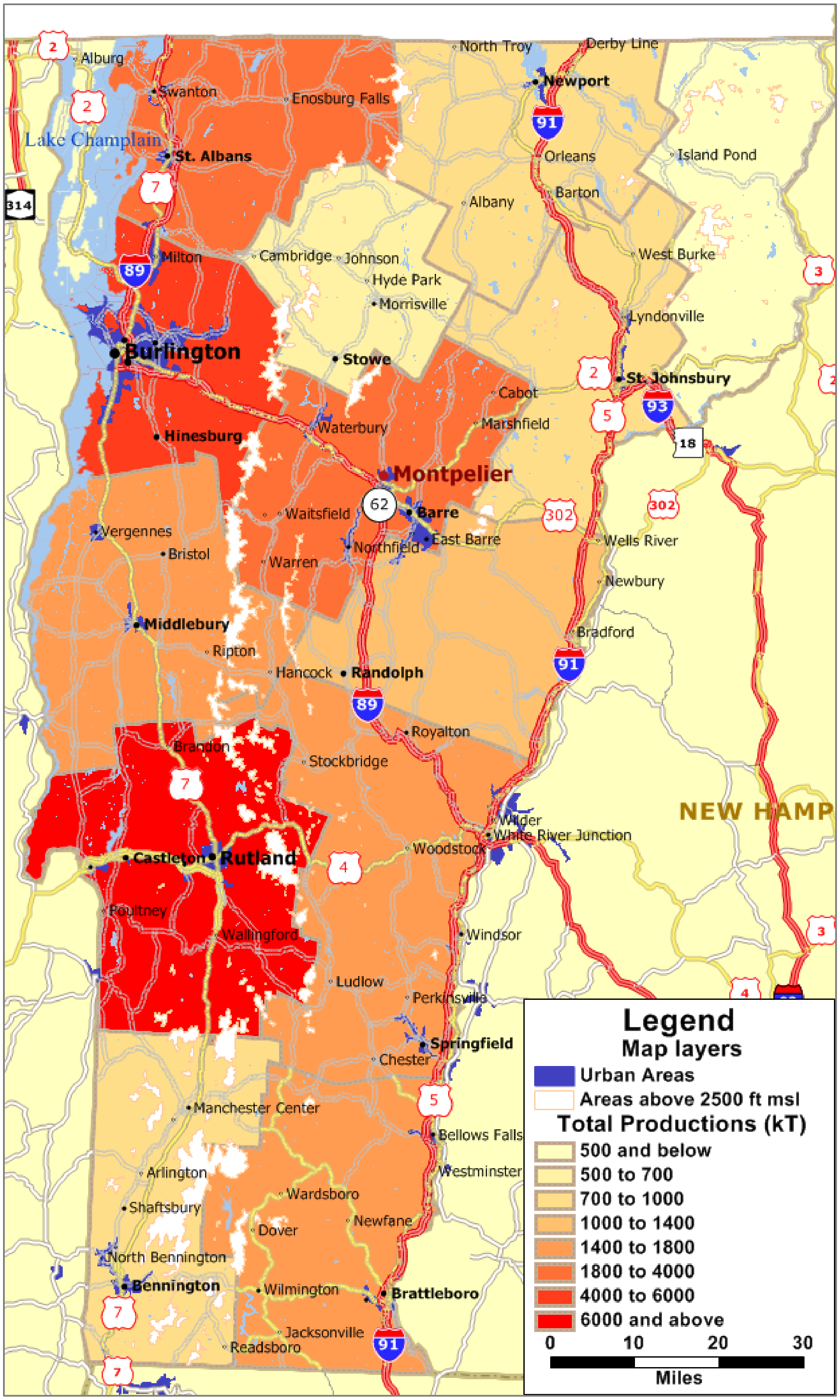

Figure 6 Total I-E and I-I Commodity Productions in Vermont by County

The importance of the relationship between employment type and commodity production is evidenced by the relationship between total kilotons of production for Chittenden and Rutland counties. Although Chittenden has more total employment than Rutland (over 95,000 jobs and about 28,000 jobs, respectively), much of it's employment is in sectors that are not directly associated with commodity production, like education, health care, and technical services (at IBM). In addition, much of the estimate of Rutland's production involves commodities, like gravel that are relatively heavy when shipped as freight. Therefore, Rutland leads the state in total kilotons of commodity production.

4.2.3 E-I and I-I Commodity Attractions

Commodity attractions within or destined for the state are disaggregated to the county level as well, but the process is considerably more complex than the production method. Following methodology applied in several studies and freight guidelines (Mitra and Tolliver, 2009; Vilain et. al., 1999; Beagan et. al., 2007), freight attractions are modeled based upon characteristics of the receiving industries and/or the 'end-users' which consume commodities within the state. The linking of commodities to consuming end-users and industries is achieved using a supply-side table of commodities by industry 'input-output' (I/O), as specifically outlined by Vilain et al (1999). The I/O table provides a comprehensive economic snapshot of activities across all industries at the national level, but must first be regionalized to Vermont. The national I/O table is a matrix of 38 commodities by 38 industries (Vilain et. al., 1999). Because the economic model applied here is a relatively novel use of the commodity and industry categorical distributions, the original SCTG and NAICS categories must be modified to suit use in the matrix. The sum of each of the rows of the matrix – the commodity category – is equal to one, reflecting the unity of all industrial and end-user outputs for a specific commodity.

In order to more appropriately reflect industrial processes specific to Vermont, a series of location-quotients are developed to reflect the relative share of employment in a specific industry-sector and to regionalize the matrix. Location-quotients are defined as:

$$LQ_{state} = \frac{\%\ of\ total\ state\ employment\ in\ industry\ i}{\%\ of\ total\ U.S. employment\ in\ industry\ i}$$

The following assumptions are made for the regional disaggregation of commodity productions (Mitra and Tolliver, 2009):

- All plants in the same commodity group have production in proportion to the number employed at each site; and
- All receivers in the same industry share the resulting commodity flow proportionally

The resulting regionalized matrix is further balanced to ensure that the resulting row-sum for each of the 38 commodities is again equal to one. Once balanced, the Vermont I/O matrix is multiplied by the total commodity attractions statewide. The result is a breakdown of commodity flow attractions (in kilotons) in Vermont for each of the 38 industries.

The statewide breakdown is further disaggregated to each of the Vermont counties by multiplying these flows by the county-level distribution of employment for each of the 38 industries. These disaggregated commodity attractions are provided by NAICS industry in Table B-2 in Appendix B. The resulting county-level tabulation of these 38 commodities for 38 industries is then converted back to the original SCTG categorization. This final tabulation of Vermont county-level SCTG commodity attractions, a total of 8,929 kilotons, is shown by county total in the chart in Figure 7 and in the map in Figure 8.

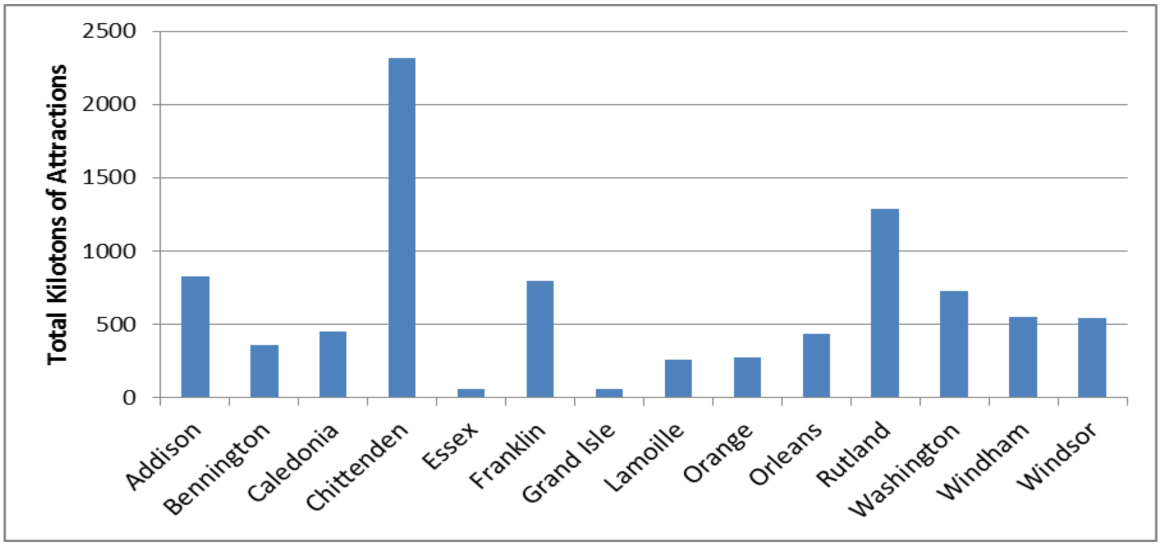

Figure 7 Total E-I and I-I Commodity Attractions in Vermont by County

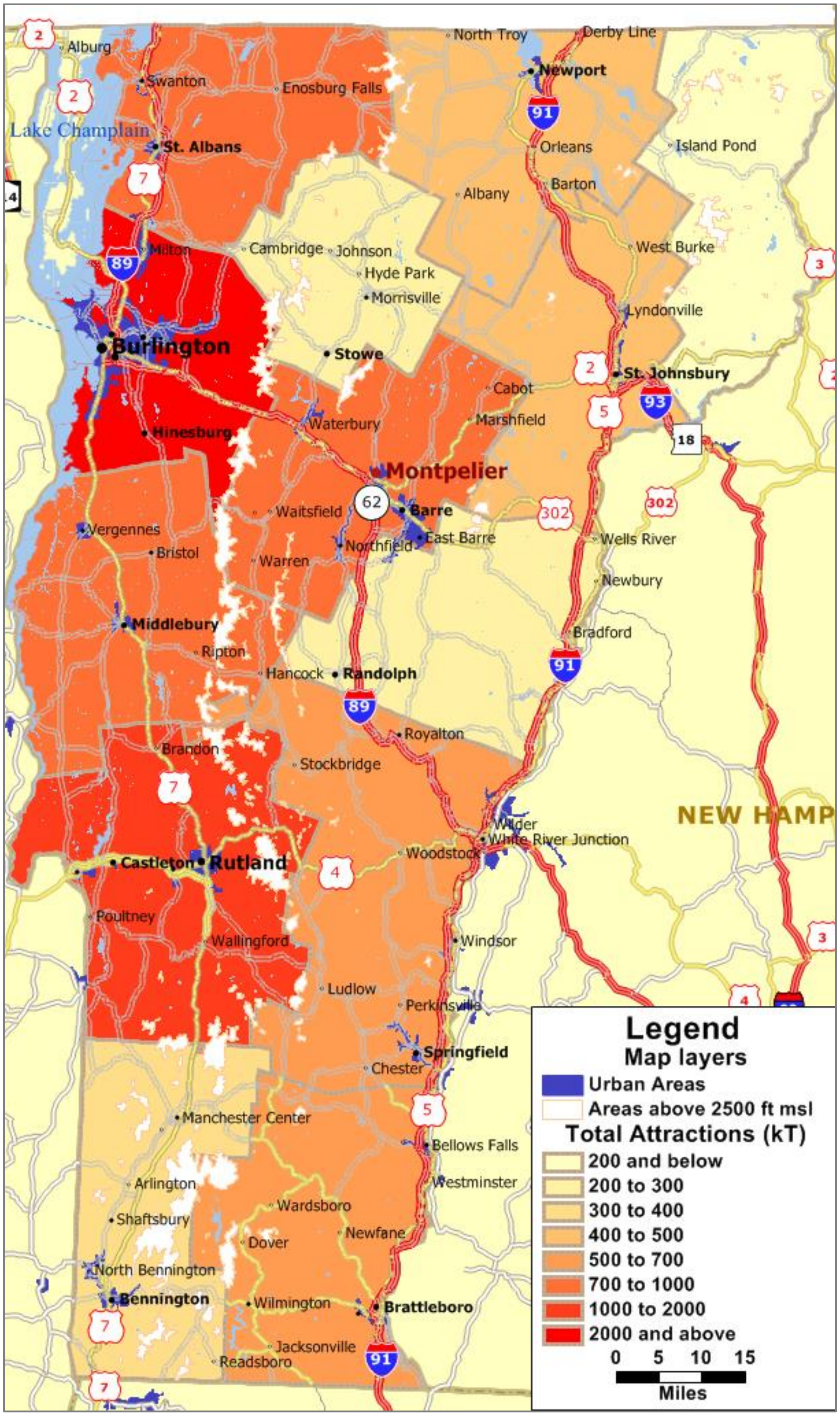

Figure 8 Total E-I and I-I Commodity Attractions in Vermont by County

5 Improvements Methodology and Results

5.1 Land-Use Characteristics Update

5.1.1 Employment Update

Employment data, used in the Model to estimate the relative attractiveness of destination, from the BEA is stratified by NAICS industry. These industries were mapped to the employment categories used by the Model as shown in Table 5.

Table 5 NAICS Classification Mapping to Model Categories

<table>
<tr><th colspan="3">NAICS Industries used by VDOL</th><th rowspan="2">NAICS Industries used by BEA</th><th rowspan="2">Mapped to Model Category…</th></tr>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td rowspan="5">Goods Producing</td><td colspan="2">Manufacturing</td><td>Manufacturing</td><td>MANUFACTURING</td></tr>
<tr><td colspan="2">Construction</td><td>Construction</td><td rowspan="5">NON-MANUFACTURING</td></tr>
<tr><td colspan="2" rowspan="3">Natural Resources and Mining</td><td>Forestry, fishing, and related activities</td></tr>
<tr><td>Farm employment</td></tr>
<tr><td>Mining</td></tr>
<tr><td rowspan="9">Service Providing</td><td rowspan="5">Trade, Transportation, and Utilities</td><td>Wholesale trade</td><td>Wholesale trade</td></tr>
<tr><td>Retail trade</td><td>Retail trade</td><td>RETAIL</td></tr>
<tr><td>Transportation / Warehousing</td><td>Transportation and warehousing</td><td rowspan="7">NON-MANUFACTURING</td></tr>
<tr><td rowspan="2">Utilities</td><td>Administrative and waste management services</td></tr>
<tr><td>Utilities</td></tr>
<tr><td colspan="2">Information</td><td>Information</td></tr>
<tr><td colspan="2" rowspan="2">Financial Activities</td><td>Real estate and rental and leasing</td></tr>
<tr><td>Finance and insurance</td></tr>
<tr><td colspan="2">Professional and Business Services</td><td>Management of companies and enterprises</td></tr>
</table>

<table>
<tr><th colspan="3">NAICS Industries used by VDOL</th><th rowspan="2">NAICS Industries used by BEA</th><th rowspan="2">Mapped to Model Category…</th></tr>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td rowspan="7"></td><td colspan="2"></td><td>Professional, scientific, and technical services</td><td></td></tr>
<tr><td rowspan="4">Education and Health Services</td><td>Elementary and Secondary Schools</td><td rowspan="2">Educational services</td><td>PRIMARY SCHOOL</td></tr>
<tr><td>Colleges and Universities</td><td>UNIVERSITY</td></tr>
<tr><td>Health care and social assistance</td><td>Health care and social assistance</td><td>NON-MANUFACTURING</td></tr>
<tr><td>Government Not Public Education</td><td>Government and government enterprises</td><td>GOVERNMENT</td></tr>
<tr><td colspan="2" rowspan="2">Leisure and Hospitality</td><td>Accommodation and food services</td><td rowspan="3">NON-MANUFACTURING</td></tr>
<tr><td>Arts, entertainment, and recreation</td></tr>
<tr><td></td><td colspan="2">Other Services Except Public Administration</td><td>Other Services Except Public Administration</td></tr>
</table>

Because the BEA data is based on earnings, it includes all forms of employment, not just the employment and wages subject to unemployment insurance. Therefore, the BEA data acts as a correction to the Vermont Department of Labor data used in Year 3. Having data at the County level is not directly useful since the Model relies on geographies (TAZs) that are smaller than its Counties. Therefore, the BEA job numbers by County were used to develop correction factors, when compared to the corresponding VDOL job totals on the County level. A summary of these corrections by Model employment category and County is provided in Table 6.

Table 6 BEA Correction Factors by Model Employment Category

County	Retail	Manufacturing	Non-Manufacturing	Government	Education
Addison	1.4	2.9	1.6	3.6	2.0
Bennington	1.3	1.5	1.5	2.6	0.9
Caledonia	1.4	1.3	1.8	2.5	0.8
Chittenden	1.1	2.4	1.2	2.6	0.4
Essex	4.1	1.1	1.6	3.4	1.0
Franklin	1.3	1.2	1.8	2.2	0.1
Grand Isle	2.3	-	2.4	3.3	1.1
Lamoille	1.3	2.3	1.5	3.6	0.2
Orange	1.7	1.8	2.1	2.4	0.4

County	Retail	Manufacturing	Non-Manufacturing	Government	Education
Orleans	1.3	1.9	1.7	2.6	0.3
Rutland	1.3	1.3	1.4	2.9	0.3
Washington	1.3	1.6	1.4	1.4	1.1
Windham	1.4	1.1	1.6	2.6	1.3
Windsor	1.4	1.7	1.6	1.8	0.4

Data identified as withheld due to disclosure limitations ("D") in the BEA estimates was distributed to the appropriate Model employment category in proportion to the totals from the VDOL data. For Grand Isle, there were so few Manufacturing jobs identified in the BEA that it was impossible to develop a correction factor. In this case, the VDOL estimate was left as is.

Jobs in the primary school and university categories in the BEA data did not relate consistently or logically with the VDOL job totals in these categories. The BEA estimates, in most cases, was actually lower than the corresponding VDOL total. Therefore, it was assumed that the BEA estimates were in error for all school-related employment, possibly due to the propensity of these jobs to be unrelated to personal income and earnings. For the "TotalSch2009" category, the BEA estimates were disregarded and the VDOL job totals from the Year 3 update were left as is. All other BEA totals by County were considerably higher than those of the VDOL, by an average of 67%, as expected. These other VDOL job totals were multiplied by the corresponding correction factor, for the job category in the County where the TAZ is located.

5.1.2 Number of Households Update

The advantage of the 2010 US Census data is that its spatial resolution is finer than the resolution of the TAZs in the Model. This relationship is illustrated in Figure 9.

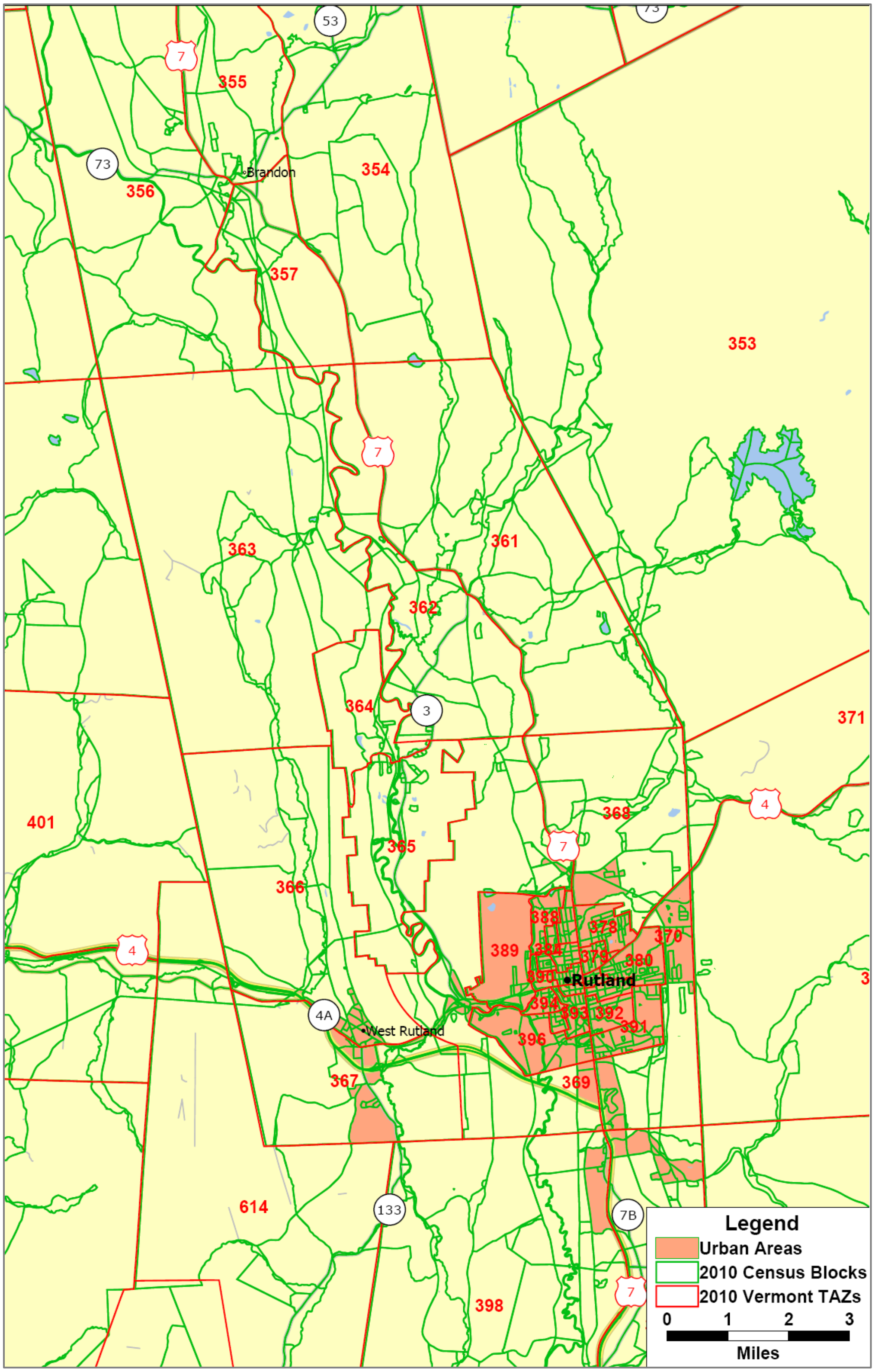

Figure 9 2010 Census Blocks and TAZs in the Rutland, Vermont Area

Therefore, the US Census household totals by Census block simply had to be aggregated to the TAZ in which they reside to arrive at an improve total for the number of households within each TAZ. In addition, since the Census figures are based on actual counts, not estimated values like the ACS, the totals are more accurate. For example, the ACS estimate for the total number of households in Vermont in 2009 was 250,275, whereas the US Census count of occupied housing units for 2010 was 256,442.

5.2 Regression Equations Update

Since new employment estimates were developed from the BEA estimates and new household counts were extracted from the 2010 Census, the process of estimating regression equation coefficients was repeated. For all of the regression equation updates performed in Year 4, the factors assumed to be significantly related to trip production or attraction were the same as those in the existing equations, as shown in Table 7.

Table 7 Existing Model Regression Equation Coefficients

<table>
<tr><th rowspan="3">Variable (No. of…)</th><th colspan="6">β (regression coefficients)</th></tr>
<tr><th rowspan="2">NHB (Productions)</th><th colspan="5">Attractions</th></tr>
<tr><th>NHB</th><th>HBW</th><th>HBSHOP (Urban)</th><th>HBSHOP (Rural)</th><th>HBO</th></tr>
<tr><td>Households</td><td>✓</td><td>✓</td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>Retail Jobs</td><td>✓</td><td>✓</td><td rowspan="7">✓</td><td>✓</td><td>✓</td><td rowspan="7">✓</td></tr>
<tr><td>Manufacturing Jobs</td><td>✓</td><td>✓</td><td rowspan="6"></td><td rowspan="6"></td></tr>
<tr><td>Non-Manufacturing Jobs</td><td>✓</td><td>✓</td></tr>
<tr><td>Government Jobs</td><td>✓</td><td>✓</td></tr>
<tr><td>Primary School Jobs</td><td>✓</td><td>✓</td></tr>
<tr><td>University Jobs</td><td>✓</td><td>✓</td></tr>
</table>

For all of the updates, the internal person-trip table developed previously from the NHTS was used to regress trip-making characteristics against employment and households by TAZ. The regression estimation results at the TAZ level are shown in Table 8.

Table 8 TAZ-Level Regression Equation Update Results

<table>
<tr><th rowspan="4">Variable (No. of…)</th><th colspan="6">β (regression coefficients)</th></tr>
<tr><th colspan="2">Non-Home-Based</th><th colspan="4">Attractions for Home-Based…</th></tr>
<tr><th rowspan="2">Productions</th><th rowspan="2">Attractions</th><th rowspan="2">Work</th><th colspan="2">Shopping</th><th rowspan="2">Other</th></tr>
<tr><th>Urban</th><th>Rural</th></tr>
<tr><td>Households</td><td>**2.24**</td><td>**0.86**</td><td></td><td></td><td></td><td>**2.09**</td></tr>
<tr><td>Retail Jobs</td><td>**1.05**</td><td>**2.51**</td><td rowspan="4">**0.40**</td><td>**1.94**</td><td>**0.75**</td><td rowspan="4">**0.18**</td></tr>
<tr><td>Manufacturing Jobs</td><td>-0.30</td><td>0.37</td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>Non-Manufacturing Jobs</td><td>-0.04</td><td>**0.40**</td></tr>
<tr><td>Government Jobs</td><td>-0.15</td><td>**0.81**</td></tr>
</table>

	β (regression coefficients)					
	Non-Home-Based		Attractions for Home-Based…			
				Shopping		
Variable (No. of…)	Productions	Attractions	Work	Urban	Rural	Other
Primary School Jobs	1.05	0.05				
University Jobs	-1.12	0.10				
R-squared	*0.44*	*0.64*	*0.44*	*0.29*	*0.06*	*0.55*

Values shown in **bold** contributed significantly to the model fit, at a tolerance level of 0.05

Coefficients for home-based shopping trip attractions were performed separately for urban and rural TAZs, as was done in the existing model. The existing distinctions between urban and rural TAZs in the model were maintained for this analysis. Coefficients whose t-statistic revealed that they contributed significantly (at the 0.05 tolerance level) to the fit of the model are shown in bold, as is the r-squared statistic. Most of the r-squared values for these regressions improved upon the r-squared values yielded in the Year 3 update. Based on the r-squared values and the number of coefficients which significantly contributed to the model fit, it was determined that only the coefficients for NHB attractions (with an r-squared of 0.64) would be used from the TAZ-level regression estimate to update the Model. This decision meant that those coefficients would also apply to the NHB productions, since the model assumes that NHB productions and attractions are equal at the TAZ level. The regression equation was then re-estimated using only the significant variables, so the final coefficients changed slightly, as shown in Table 9.

Table 9 Final Non-Home-Based TAZ-Level Regression Equation Update Results

Variable (No. of…)	NHB (Productions & Attractions)
Households	0.89
Retail Jobs	2.56
Manufacturing Jobs	
Non-Manufacturing Jobs	0.41
Government Jobs	0.86
Primary School Jobs	
University Jobs	
R-squared	*0.64*

Each of the remaining regression estimates (for HBW, HBSHOP (urban and rural), and HBO attractions) was carried forward to be analyzed at a more aggregate spatial scale. Due to the low r-squared values yielded by the TAZ-level analysis, it was expected from the Year 3 update experience, that the town-level analysis would not improve the estimates very much, so the next step was to estimate the regression coefficients for HBW, HBSHOP, and HBO at the County level. The results of this analysis are shown in Table 10. R-squared values for the regressions generally improved upon the Year 3 estimates, and all of the variables shown contributed significantly to the model fit, at a tolerance level of 0.05.

Table 10 County-Level Regression Equation Update Results

<table>
<tr><th rowspan="3">Variable (No. of…)</th><th colspan="4">β (regression coefficients)</th></tr>
<tr><th colspan="4">Attractions for Home-Based…</th></tr>
<tr><th>Work</th><th>Shopping (Urban)</th><th>Shopping (Rural)</th><th>Other</th></tr>
<tr><td>Households</td><td></td><td></td><td></td><td>0.67</td></tr>
<tr><td>Retail Jobs</td><td rowspan="6">0.59</td><td>4.74</td><td>2.26</td><td rowspan="6">0.96</td></tr>
<tr><td>Manufacturing Jobs</td><td rowspan="5"></td><td rowspan="5"></td></tr>
<tr><td>Non-Manufacturing Jobs</td></tr>
<tr><td>Government Jobs</td></tr>
<tr><td>Primary School Jobs</td></tr>
<tr><td>University Jobs</td></tr>
<tr><td>R-squared</td><td>0.97</td><td>0.86</td><td>0.52</td><td>0.99</td></tr>
</table>

Foreseeing that the estimation for Rural Shopping trips could be improved, town-level regression was run for that purpose, and a new coefficient of 5.06 resulted, with a further improved r-squared value of 0.55. So the new regression estimates had improved R-squared values in almost every case. Including this value, then, the final set of regression coefficients used for this update is shown in Table 11.

Table 11 Final Regression Equation Update Results

<table>
<tr><th rowspan="4">Variable (No. of…)</th><th colspan="5">β (regression coefficients)</th></tr>
<tr><th rowspan="3">NHB (Productions & Attractions)</th><th colspan="4">Attractions for Home-Based…</th></tr>
<tr><th rowspan="2">Work</th><th colspan="2">Shopping</th><th rowspan="2">Other</th></tr>
<tr><th>Urban</th><th>Rural</th></tr>
<tr><td>Households</td><td>0.89</td><td></td><td></td><td></td><td>0.67</td></tr>
<tr><td>Retail Jobs</td><td>2.56</td><td rowspan="5">0.59</td><td>4.74</td><td>5.06</td><td rowspan="5">0.96</td></tr>
<tr><td>Manufacturing Jobs</td><td></td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>Non-Manufacturing Jobs</td><td>0.41</td></tr>
<tr><td>Government Jobs</td><td>0.86</td></tr>
<tr><td>Total School-Related or Education-Service-Related Jobs</td><td></td></tr>
<tr><td>R-squared</td><td>0.64</td><td>0.97</td><td>0.86</td><td>0.55</td><td>0.99</td></tr>
</table>

5.3 Household Cross-Classification Update

The cross-classification of the number of workers and number of household members by town in Vermont for the pooled years 2006-2010 of the American Community Survey was used to update the existing input table in the Model. The existing cross-classification table in the Model likely dated back to 2000. Table 12 summarizes the fraction of Vermont households in each cross-classification category.

Table 12 Cross-Classification Summary for Vermont

Classification of Household		Composition of Vermont Households
No. of People	No. of Workers	
1	0	13%
1	1	15%
2	0	9%
2	1	12%
2	2	17%
3	0	1%
3	1	5%
3	2	7%
3	3	2%
4 or more	0	1%
4 or more	1	5%
4 or more	2	9%
4 or more	3 or more	4%

5.4 Road Network Improvements

5.4.1 Link Updates

The first improvement to the road network was the update of attributes of existing links which have been augmented since 2000. Projects which had the potential to change the alignment, number of lanes, or capacities of roadways were selected from the VTrans Project Information website. The following link updates were made:

- Alignment, number of lanes, and capacities of the Bennington By-Pass Western Segment were updated (Project Number NH 019-1(51)), but the Northern Segment (Project Numbers NH 019-1(5)) of the By-Pass was not added since it is not scheduled to be complete until after 2012.
- Alignment, number of lanes, and capacities of Route 2 in Danville (Project Number FEGC 028-3(32)) were updated, but the full new construction was not added since it was not complete at the end of 2010.
- Number of lanes, capacities and speeds for Route 7 between Pittsford and Brandon were updated (Project Numbers NH 019-3(495 & 496)).
- Number of lanes, capacities and speeds for Route 7 between South Burlington and Shelburne were updated (Project Number NH EGC 019-4(27).
- Capacities and speeds for Town Highway 3 (VT143) between Springfield and the intersection with Route 5 (Project Number STP 0136(1)) were updated.

- The alignment, numbers of lanes, and capacities of roads in downtown Winooski as a result of the "Circulator" construction, funded by FHWA under Project Number E2VT03 of the Transportation, Community, and System Preservation Program, were updated.

The locations of these projects are shown in Figure 10.

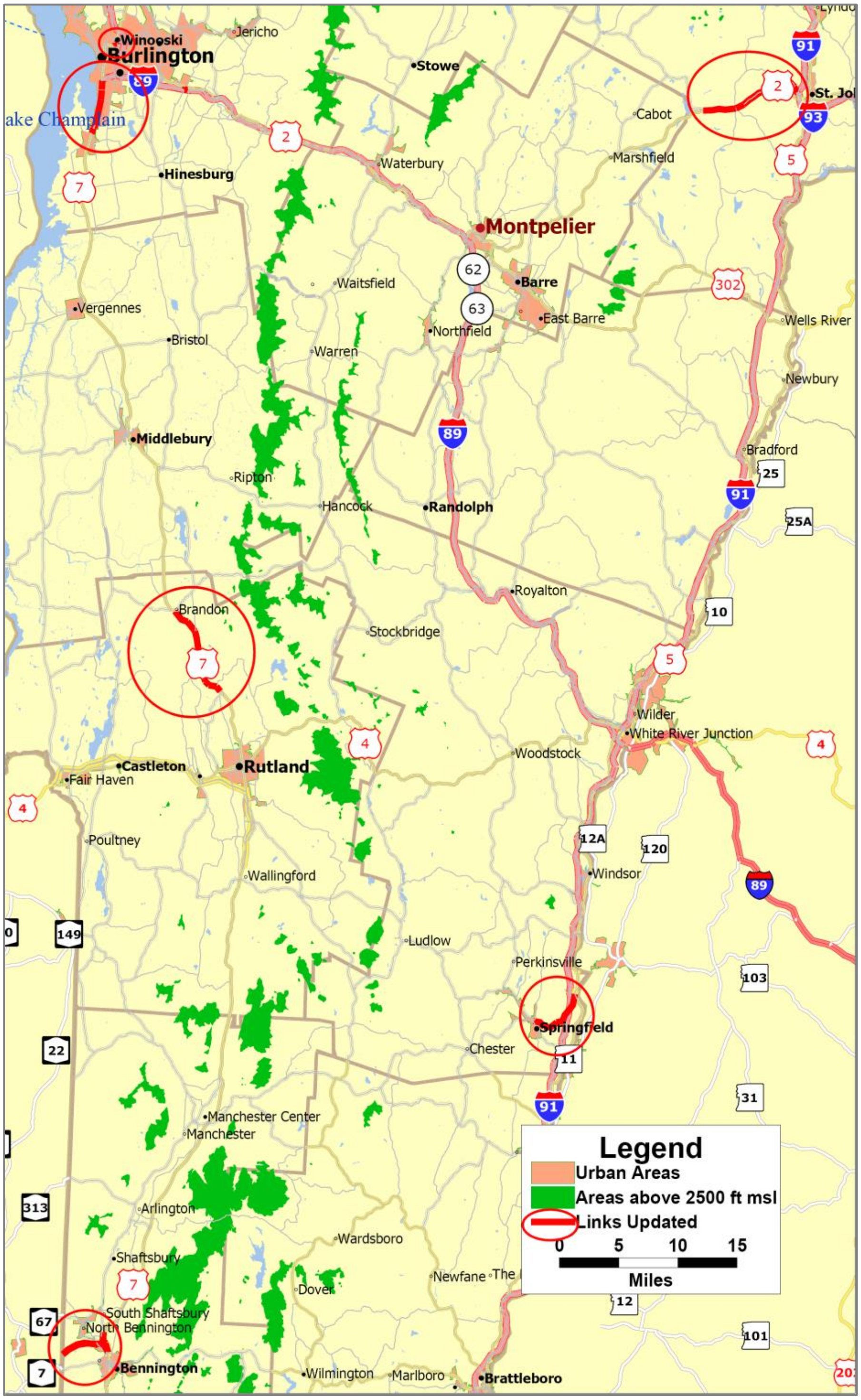

Figure 10 Links Updated in Year 4

Current speeds and numbers of lanes were obtained by viewing the relevant roadways with Google Maps' ground-level photos.

The road network was also checked for non-functional nodes, or nodes which divided a continuous link unnecessarily where no intersection was present. Where non-functional nodes were discovered, they were eliminated and the links merged.

Finally, the VCGI line layer of speed zones was used to correct downtown and school speed limits wherever possible. "Bands" were created around the speed zones, then links from the Model road network that were completely within the speed-zone bands were selected. From this set, links from the Model road network whose speeds were different from those shown in the speed zones layer were sub-selected, and updated with the speeds from the speed zones layer.

5.4.2 Inclusion of Omitted Links

It is not uncommon for travel-demand models to include only major roadways, like highways, arterial roads and major collector roads. This inclusion of links based on functional class may result in exclusion of minor roadways which provide access to critical residential or business locations. In some cases, these minor roads carry significant traffic volumes.

In this project, two separate processes were used to identify potentially significant links which had been omitted from the Model road network but should be included. First, following the traffic assignment step for the TRUCK purpose performed in Year 3, a detailed analysis of links with a significant discrepancy between truck flows from the Model and truck counts from the AADTs was performed. In some cases, these discrepancies are caused by the placement of centroid connectors. When centroid connectors meet a roadway at a location where there is no true intersection, then the volumes on that link may be higher than the counts. This discrepancy is caused by the aggregation of multiple smaller flows on minor roads into a single flow on the connector, and it can often be fixed by adjusting the location where the connector meets the roadway, or by adding another centroid connector which allows flow to enter the network at a different location. An example of this practice is provided in Figure 11. The two centroid connectors shown in green were added to provide two additional locations for flow to/from centroid 370 to enter the road network. Previously, centroid 370, like 391 and 392, had only one location where it connected to the network, onto Curtis Avenue and Stratton Road. However, AADTs of these smaller roads for 2009 were much lower than the flow coming from the Model. Further investigation revealed that the TAZ represented by centroid 370 includes travel activity due to the Diamond Run Mall on Route 7, and the residential area in the northern portion of the TAZ. Therefore, additional connectors (shown in green) were added to allow these flows to enter the network more realistically. Following the addition of these connectors, the Model flows and the AADTs came into alignment.

In other cases, significant discrepancies existed in areas where centroid connectors are not present. This occurrence is often due to the omission of a minor road from the network, which in reality serves to divert significant flow, creating a lower AADT than the travel model would predict. An example of this practice is provided in Figure 12.

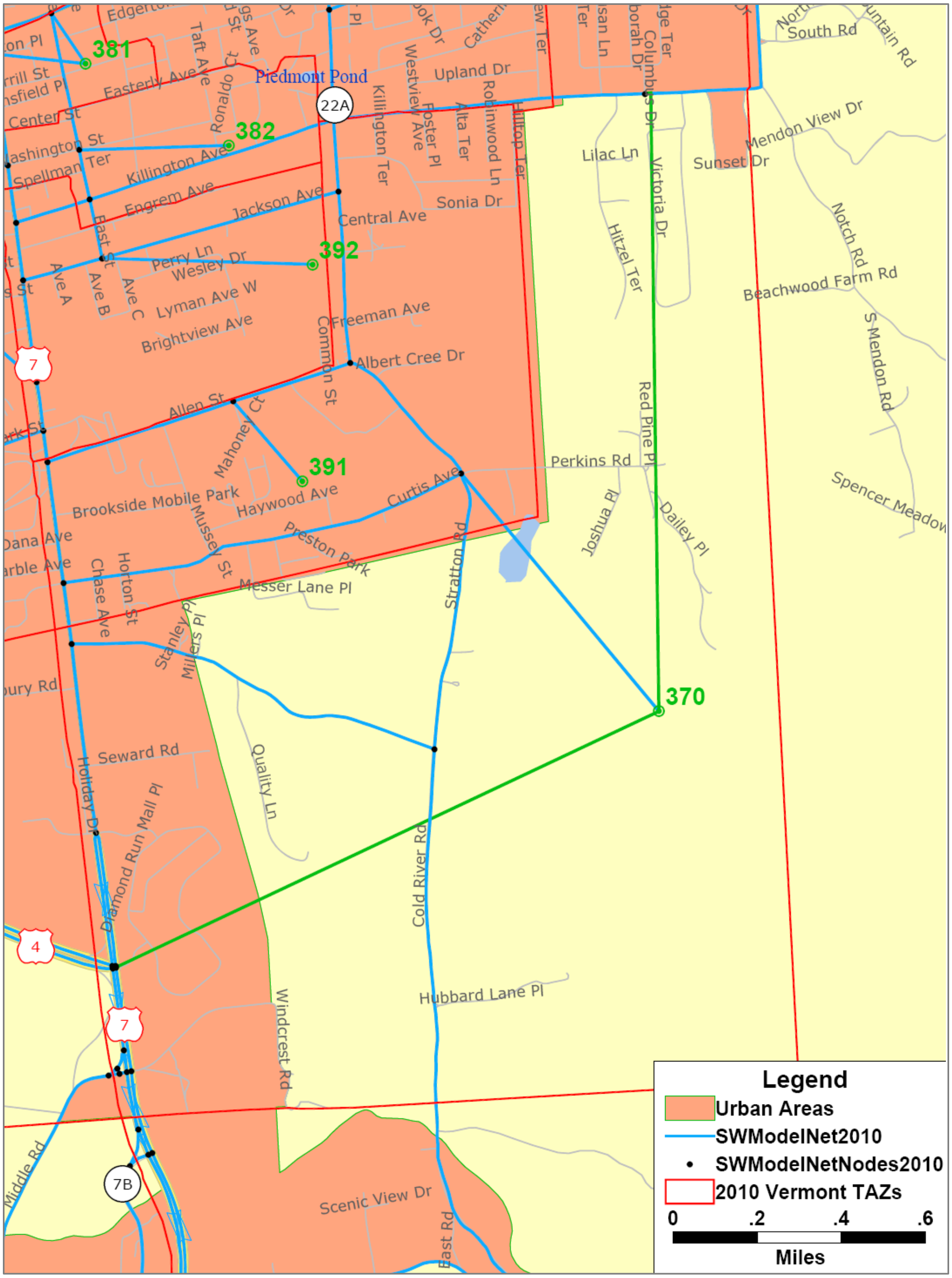

Figure 11 Example of Centroid Connectors Added to Balance Model Flows and AADTs

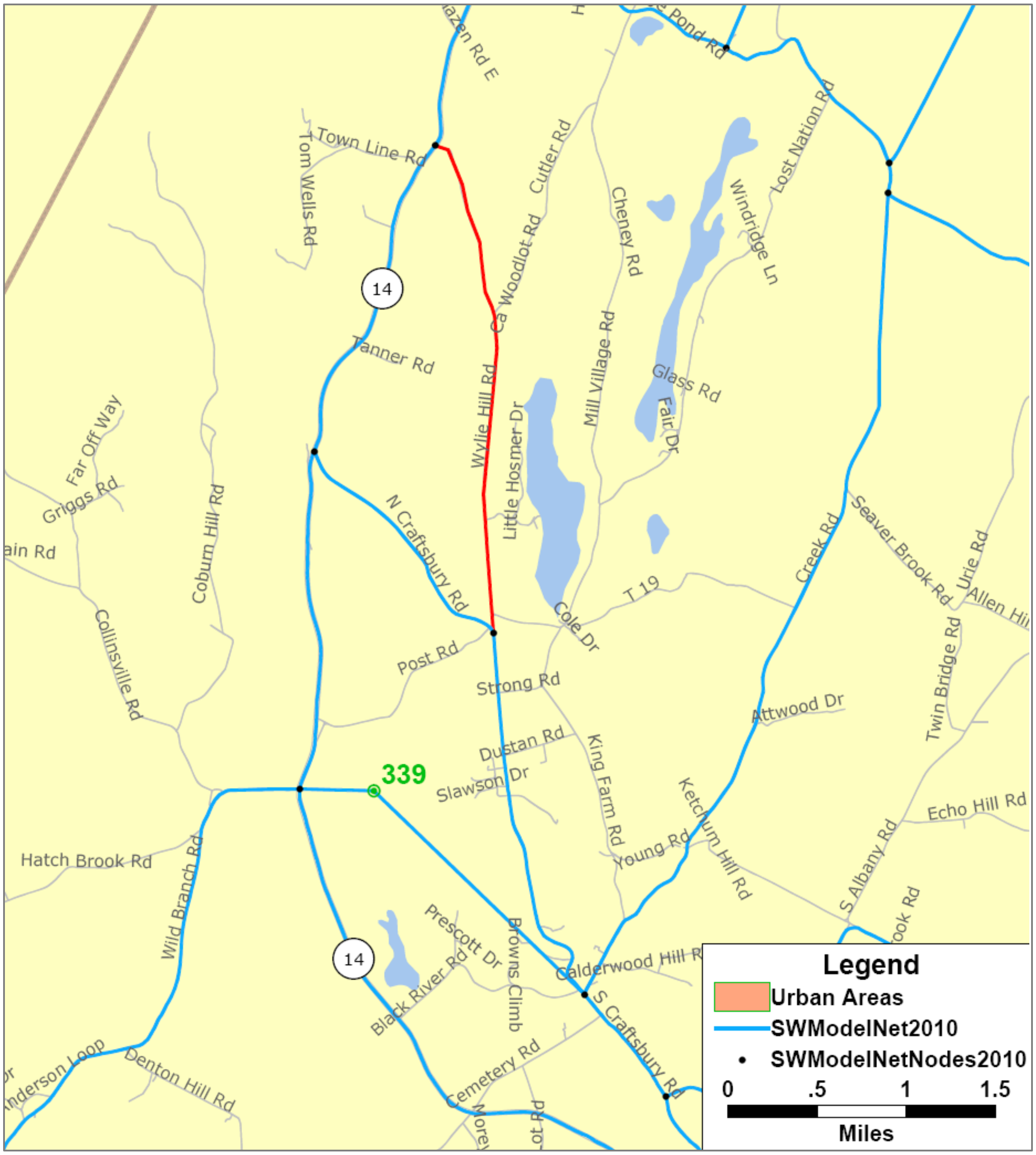

Figure 12 Example of a Minor Road Added to Balance AADTs and Model Flows

Wylie Hill Road, shown in red, was added to address a discrepancy between Model flows and the AADT on North Craftsbury Road, north of the Post Road intersection. The AADT on North Craftsbury Road changes by about 75% at the Post Road intersection, but the Model flows were the same on without the routing option offered by Wylie Hill Road. After the addition of this link to the Model road network, Model flows and AADTs were better aligned.

The final analysis of omitted links consisted of the application of a methodology, described by Sullivan et. al. (2012), to identify potentially significant, omitted links. This methodology uses a traditional measure of link-vulnerability to identify areas where potentially significant omitted links may be present, then tests those that are present for their significance to the overall network. The procedure described by Sullivan et. al. (2012) identified 10 potentially significant omitted links in Vermont. The Network Robustness Index (NRI) was used to test their level of significance. The results are shown in Table 13.

Table 13 Results of the Test for Significance of Omitted Links

Scenario No., Town, and Road Name(s)			NTR (hours/day -trip)[1]	Change in NTR[2]	R^2 of Ranks[3]	Significant Link?
Base Network			0.51672			
1	Rutland	Curtis Ave.	0.51606	0.22%	1.0000	Yes
2	Rutland	Jackson Ave.	0.51660	0.12%	0.9998	Yes
3	Barre	Perry St.	0.51618	0.20%	1.0000	Yes
4	Barre	Allen St.	0.51720	0.00%	1.0000	No
5	Barre	Pleasant St.	0.51720	0.00%	1.0000	No
6	St. Albans	Oakland Station Road / Loomis Road / Conger Rd	0.51588	0.26%	0.9950	Yes
7	St. Albans	Messenger Street / Lakeview Terrace	0.51708	0.02%	1.0000	No
8	Lyndon	Back Center Rd	0.51534	0.36%	0.9970	Yes
9	Georgia	Ballard Rd	0.51720	0.00%	1.0000	No
10	St. Johnsbury	Old Center Road / Hospital Rd (22A)	0.51582	0.27%	0.9983	Yes
11	Scenarios 1, 2, 3, 6, 8, and 10		0.51006	1.38%	0.9903	Yes

Notes:
1. NTR is the sum of all NRIs for the scenario divided by total demand, which was held constant.
2. Change in NTR is relative to the NTR of the base-network scenario, which does not include any of these links.
3. R^2 values compare the scenario NRI data with the NRI data for the base-case scenario.

Roads which significantly affected either the Network Trip Robustness (NTR) (Sullivan et. al., 2010), or the correlation of the ranks of the links in the network were determined to be significant, as indicated by a "Yes" in the final column of the table. The final scenario assessed evaluated the inclusion of the links represented by scenarios 1, 2, 3, 6, 8, and 10 together. As indicated by the result for this scenario (11), these links provide a 1.38% improvement in the robustness of the

Model road network, which is significant for traffic analysis. Therefore, these links will also be permanently added to the Model road network.

5.4.3 Inclusion of TAZs from the Chittenden County Regional Planning Commission Travel Model

Increased resolution of the TAZs from the CCRPC Travel Model was incorporated into the Model by merging the TAZ layers and eliminating duplicates. In all, 225 new TAZs were added to the SW Model in Chittenden County. This brings the total number of TAZs in the SW Model up to 936. TAZ characteristics for new TAZs were determined by checking for splits in the two geographies. Where new TAZs roughly matched TAZs from the statewide model before the alignment, the same TAZ characteristics were used. Where an old TAZ had to be split, the old TAZ characteristics were split in proportion to the characteristics of the CCMPO TAZs upon which the split was based.

5.4.4 Inclusion of Links from the Chittenden County Regional Planning Commission Travel Model

The increased resolution of the CCRPC Travel Model road network was incorporated into the SW Model by merging the layers and eliminating duplicates, including centroid connectors, and previously omitted links from the CCRPC road network (Sullivan et. al., 2012). This brings the total number of centroid connectors in the Model up to 1,440 (from 920), and the total number of links up to 5,349 (from 4,344).

5.5 Trip Generation Update

New characteristics (number of households and number of jobs) for the 936 TAZs in the improved Model were used to repeat the trip-generation sub-module, making use of the improved regression equations and the updated cross-classification table. The trip-generation update resulted in a new total person-trips produced/attracted in the state for each purpose, as shown in Table 14.

Table 14 Updated Trip-Generation Totals

Trip Purpose	No. of Person-Trips per Day	Percentage of Person-Trips per Day
Home-Based Work	240,276	11%
Home-Based Shopping	396,125	19%
Home-Based Other	710,555	34%
Non-Home-Based	611,586	29%
TRUCK	142,023	7%

Based on the new estimates of trips produced and attracted by each TAZ, an updated set of balance factors could be calculated, as shown in Table 15.

Table 15 Balance Factors Resulting from the Year 4 Update

	Balance Factor (P/A)	
Trip Purpose	Using HH Size and No. of Vehicles (Year 3)	Using HH Size and No. of Workers (Year 4)
Home-Based Work	0.879	0.899
Home-Based Shopping	1.589	1.601
Home-Based Other	1.178	1.131
Non-Home-Based	1.000	1.000
TRUCK	1.000	1.000

5.6 Trip-Distribution Impedance Function Update

Repeating the trip-distribution sub-module of the Model requires the table of balanced productions and attractions and an impedance matrix of free-flow travel times between all TAZs. Using the new updated Model road network, a new impedance matrix was generated using the "Multiple paths…" function in TransCAD with new network which includes all of the improvements described above and turning prohibitions at all ramp connections with 2-way links. Intra-zonal travel times for each TAZ were estimated as the average travel time to its 2 nearest TAZs. The resulting matrix has an average shortest path in the network of 82 minutes. To complete the impedance matrix, terminal times, or the times taken at the origin and the destination to gain access (parking, loading/unloading, walking to/from the car, etc.) was added as follow:

- For urban TAZs, 2 minutes were added at origins and 4 minutes at destinations
- For rural TAZs, 1 minute was added at origin and destination

After these additions, the average travel time in the entire impedance matrix was 85 minutes, as compared to the average travel time of 106 minutes in the matrix for the Year 3 road network. This reduction corresponds to the inclusion of additional zones in the more urbanized portions of Chittenden County, whose inter-zonal travel times are much less than the previous statewide average.

The impedance matrix and the new table of productions and attractions was used with the gravity-model calibration function in TransCAD. The results of the impedance function update that resulted are shown in Table 16.

Table 16 Existing and Updated Model Impedance Function Coefficients

Trip Purpose	Existing Model Impedance Function Coefficients			Updated Impedance Function Coefficients (Year 3)			Updated Impedance Function Coefficients (Year 4)		
	a	b	a	a	b	c	a	b	c
HBO	139,173	1.285	0.094	34,560	1.658	0.061	19,954	1.420	0.068
HBSHOP			0.150			0.111			0.110

Trip Purpose	Existing Model Impedance Function Coefficients			Updated Impedance Function Coefficients (Year 3)			Updated Impedance Function Coefficients (Year 4)		
	a	b	a	a	b	c	a	b	c
HBW	28,507	0.020	0.123	901	0.398	0.086	660	0.2562	0.091
NHB	219,113	1.332	0.100	94,608	1.317	0.101	87,565	1.338	0.098
TRUCK			0.065			0.065			0.065

The changes in the impedance functions have generally served to make the shape of the function more "flat", indicating a greater propensity for longer-distance trips than might be typical nationally. This tendency is expected for a statewide model with a relatively low population and longer distances between destinations. This gradual "flattening" of the impedance function is illustrated in the plots shown in Figure 13, using home-based work as an example.

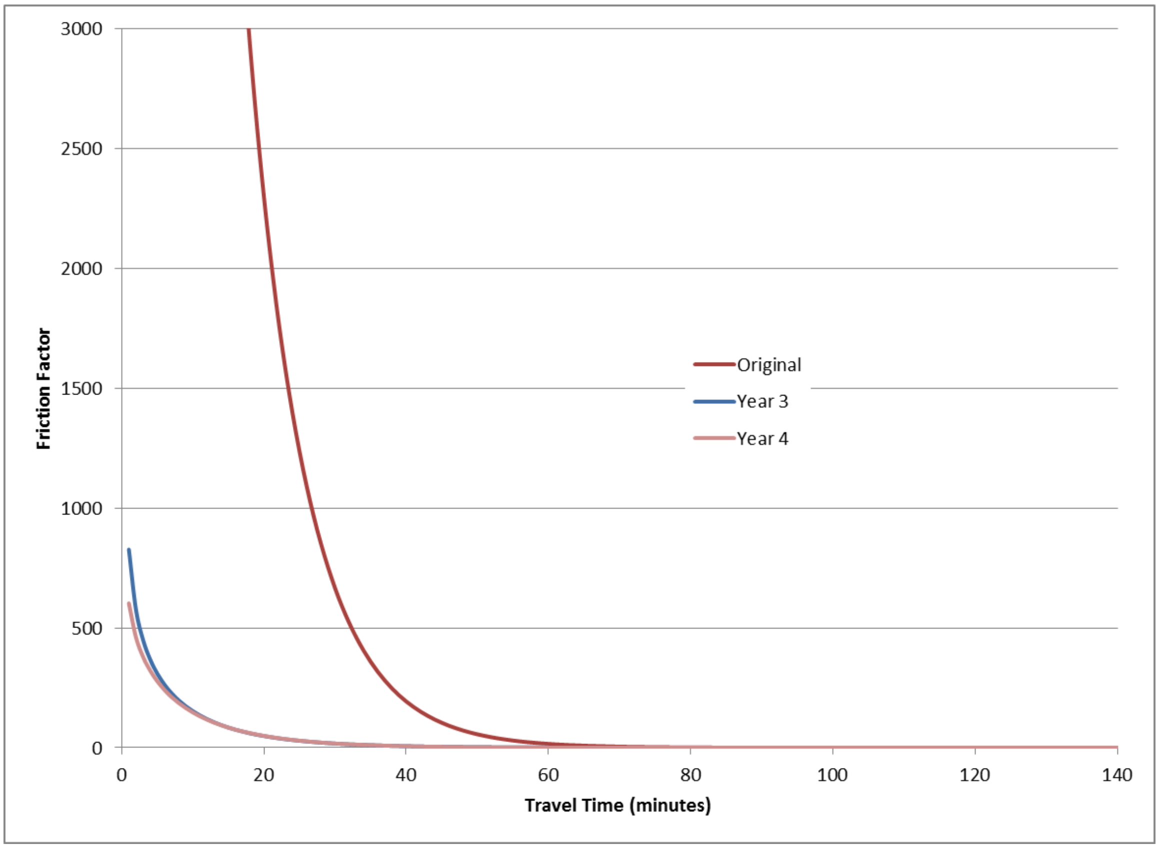

Figure 13 Evolution of the Impedance Function for Home-Based Work Trips

The resulting set of person-trip matrices for all five trip purposes in the Model were made into symmetrical daily matrices by transposing each, adding it with its original, and dividing the result by 2. The symmetrical person-trip matrices were then converted to vehicle-trips using the existing vehicle occupancy characteristics. The resulting trip totals are shown in Table 17.

Table 17 Total Person-Trips and Vehicle Trips in the Vermont Travel Model

Trip Purpose	Total Person-Trips per Day	Internal Vehicle Occupancy	External Vehicle Occupancy	Total Vehicle-Trips
Home-Based Work	240,276	1.13	1.05	213,921
Home-Based Shopping	396,125	1.48	1.93	257,093
Home-Based Other	710,555	1.75	1.85	403,655
Non-Home-Based	611,586	1.51	1.78	388,158
Truck	142,023	1.00	1.00	142,023

5.7 Traffic Assignment Update

Trips are assigned to the road network as passenger vehicles, using the Traffic Assignment function in TransCAD. The five vehicle-trip matrices are summed and the resulting matrix is assigned to the network with a user-equilibrium minimization of travel-time. A summary of the link lengths in the Model and travel speeds resulting from the assignment is shown in Table 18.

Table 18 Summary of Link Flows and Travel Speeds

Functional Classification		No. of Links In the Model Network	Average:	
ID	**Description**		**Length (miles)**	**Speed (mph)**
1	Rural Interstate	336	1.7	52.5
2	Rural Principal Arterial	280	1.3	50.1
6	Rural Minor Arterial	440	1.7	44.4
7	Rural Major Collector	945	2.1	44.2
8	Rural Minor Collector	270	3.0	35.6
9	Rural Local Road	54	1.7	37.1
11	Urban Interstate	148	0.8	46.5
12	Urban Freeway (not Interstate)	82	0.6	51.0
14	Urban Principal Arterial	478	0.3	39.7
16	Urban Minor Arterial	458	0.4	40.8
17	Urban Collector	418	0.5	35.3
19	Urban Local Road	20		
20	Centroid Connector	1,420		
All		**5,349**	**1.3**	**42.9**

With new data obtained this year, the mean length of links in the network has been reduced from 1.4 to 1.3 miles, due to the finer resolution in the more urbanized core of Chittenden County provided by the inclusion of the CCRPC model network.

After the user-equilibrium traffic-assignment (50 iterations; relative gap of 0.001), the overall root-mean-square-percent-error (RMSPE) is calculated for a subset of the links on the network using the link-specific flow and the corresponding link specific AADT. There are a total of 5,353 links in the entire road network, but centroid connectors, links without an AADT, and links with flows less than 1,000 vpd are not included in the calculation. Centroid connectors are not actual roads, so AADTs are not available for them, nor are they available for many rural and small urban roads. In addition, links with less than 1,000 vehicles per day (vpd) are excluded from the calculation even if they have an AADT available. Since the assignment method is not stochastic, smaller volumes are not routed on links unless they are on a shortest-path between two TAZs. In addition, the presence of centroid connectors, or dummy links, on the network can create 0-flow links that are necessary to balance the flows elsewhere in the network. The initial RMSPE calculation resulted in an overall value of 58%. However, after making a unilateral 10% reduction in flow volumes throughout the network, the agreement between the total AADTs and flows statewide improves. This improvement might indicate the effect of modes like walking, biking, and transit being omitted from the Model. Following this reduction, the overall RMSPE is at 48%. RMSPEs of the individual road types are shown in Table 19.

Table 19 RMSPE Summary by Functional Classification

Functional Classification		No. of Links:		Average:		
ID	Description	In the Model Network	Used to Calculate RMSPE	2009 AADT	Link Flow (vpd)	RMSPE (%)
1	Rural Interstate	336	76	6,089	5,112	42.9
2	Rural Principal Arterial	280	206	5,953	6,224	33.2
6	Rural Minor Arterial	440	358	4,862	4,470	43.2
7	Rural Major Collector	945	571	2,974	3,214	52.9
8	Rural Minor Collector	270	17	3,534	2,358	61.8
9	Rural Local Road	54	1	2,430	2,311	14.4
11	Urban Interstate	148	33	12,790	9,834	57.5
12	Urban Freeway (not Interstate)	82	37	6,209	6,268	32.6
14	Urban Principal Arterial	478	380	12,740	12,737	35.8
16	Urban Minor Arterial	458	342	7,764	6,425	47.8
17	Urban Collector	418	208	4,639	3,692	61.6
19	Urban Local Road	20				
20	Centroid Connector	1,420				
All		**5,349**	**2,229**	**6,417**	**6,061**	**48**

The RMSPE calculation is an aggregated comparison of the flow volumes from the model and the AADTs for the corresponding roadways:

$$RMSPE = \frac{\sqrt{\frac{\sum_{i=1}^{N}[(x_i - y_i)^2]}{N}}}{\frac{\sum_{i=1}^{N} x_i}{N}}$$

Where x_i is the AADT and y_i the modeled volume, both on link i, for all of the N links used in the calculation.

AADTs are estimated from counts collected at different times during the year, so they may be biased seasonally if adequate annual representation is not present.

Since the Model is aimed at representing an annual average day, it might be doing a better job of that than the AADTs. In addition, the counts themselves include error inherent to the counting process used and the data collection methodology. In some cases, this counting error has been estimated at as much as 20% (Wright et. al., 1997). AADTs also are not “balanced” at intersections, nor are they balanced to a complete trip. The flows in the Model result from the completion of complete trips – to and from a destination, and as such represent a simulation, so they would not be likely to match AADTs completely.

For these reasons, the sum of the AADTs on the set of links used for the RMSPE calculation is 14,100,938, but the sum of all link flows from the Model on the same set of links is 12,155,395. AADTs may be counting the same vehicle on the same trip more than once, but the Model flows account for each vehicle-trip only once. Therefore, it is not effective to overfit the Model volumes to the AADTs, but it makes more sense to use the AADTs to identify links in the Model which may be coded incorrectly, aligned incorrectly, or missing from the Model. Using this approach, no obvious errors in the road network could be found, so the RMSPE of 48% was accepted.

6 Summary of Model Improvements and Recommendations for Future Improvements

6.1 Summary

The Model updates completed in Year 4 bring its base year up to 2009-2010. The TRC updated land-use characteristics in the Model 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).

The primary data source use for the Model update was the National Household Travel Survey (NHTS) (Sullivan, 2011). Therefore, the initial check for reasonableness includes specific comparisons of the NHTS averages and the Model averages for selected inputs. Table 20 provides a comparison of the classification of Vermont households by the size for the NHTS and the Model.

Table 20 Comparison of the Classification of Vermont Households by Size

No. of People in Household	NHTS	Model
1	28%	28%
2	38%	38%
3	15%	15%
4	13%	
5	5%	19%
6	1%	

The two classification match because the weights used in the NHTS were scaled to population data from the American Community Survey, which is basis for the household data in the Model. Table 21 provides a comparison of the classification of Vermont household by number of workers for the NHTS and Model.

Table 21 Comparison of the Classification of Vermont Household by Number of Workers

No. of Workers in Household	NHTS	Model
0	25%	25%
1	40%	36%
2	30%	33%
3	4%	6%
4	1%	

Here it becomes apparent that the number of workers per household was not used in the weighting of the NHTS data. Therefore, significant discrepancies exist, particularly for households with 1 or 2 workers. These discrepancies are not expected to significantly impact the travel behavior estimates in the Model.

The next reasonableness check involved a comparison of the flow volumes which were output by the traffic assignment step of the Model and the traffic counts on corresponding links. Table 22 provides a comparison of the relationship between these values and acceptable standards published by FHWA (Cambridge Systematics, 2010).

Table 22 Comparison of the Relationship Between Link Volumes and Traffic Counts

Roadway Category	Model Result for Volume/Count	Acceptable Standard for Volume/Count
Freeway	- 15.2%	+/- 7%
Divided Arterial	+ 1.0%	+/- 15%
Undivided Arterial	- 13.7%	+/- 15%
Collector	- 3.0%	+/- 25%

The FHWA standards are achieved for 3 of the 4 roadway classes tested. It is not surprising that the only exceedance of the FHWA standards is for freeways, since 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, resulting in a discrepancy for that set of links of over 50%. Additional investigation of specific infractions in the road network in Year 5 will resolve this exceedance.

6.2 Recommendations

6.2.1 Passenger-Car Model Components

Although the base-year of the Model has been updated, continued improvements are expected to bring the Model closer to its goals for functionality and effectiveness. However, the end of Year 4 marks a milestone in the development of the Model, and a suitable time to seek a peer review of the Model and a commentary on the plan for the future improvements. Therefore, the first priority in Year 5 should be to coordinate a peer review through the Travel Model Improvement Program (TMIP) of the FHWA.

One of the requirements for the TMIP process, though, is that the applicant has a proposed plan for the Model for the reviewers to comment on. Pursuant to this requirement, the UVM TRC proposes four Model improvements for the TMIP process review to consider. Two of these improvements take advantage of previous work done by other Divisions at VTrans. This previous work can benefit the Model by aiding calibration to improve its fidelity. The third improvement focuses on a particular aspect of Vermont that may make the Model inaccurate in its current incarnation. Vermont's unique climate and attractions have dramatic effects on seasonal travel behaviors, both in the state, and to/from points outside of the state. These large traffic generators such as ski resorts are not accounted for specifically in the Model. These effects are likely to be greater than seasonal effects observed in other states.

The following improvement tasks are recommended for Year 5:

- Calibrate/update the trip-generation module of the Model with the results of the 2010 Vermont Trip Generation Manual.
- Calibrate/update the traffic assignment module of the Model with speed/density curves derived from speed data logged by weigh-in-motion (WIM) stations and road-weather information system (RWIS) stations.
- Explore the need for seasonal and special-generator components to the Model including, at a minimum, an average winter day, an average summer day, and an annual average day.
- Develop a freight module for the model based on the method and guidance provided by Sorrantini and Smith (2000) consisting of commodity flows between Counties, out of the state, and into the state, with a qualitative allocation of these flows to truck volumes which are currently in the Model at the TAZ level.
- Implement other recommendations of the peer-review report as possible within Year 5.

6.2.2 Commercial Truck Model Components

The Vermont Travel Model includes the coarsest level of freight modeling, with commercial truck flows in a single category based primarily on truck-classification counts, from which commercial-truck demand is estimated. The current level of modeling of commercial truck travel in Vermont can be augmented to include commodity-flow attractions and productions by county. Friction factors for commodity flows must be developed as well based upon available literature (Sorrantini and Smith, 2000) or based upon available VTrans truck survey data in order to distribute the flows throughout the state.

These commodity flows can be assigned to the road network and allocated to a variety of commercial trucks based upon payload factors. However, this allocation would require updated vehicle inventory and use surveys (VIUS). The national VIUS program was discontinued by the US Economic Census in 2002, so this data would need to be collected in Vermont. The primary benefit of this investment would be an improved understanding the of truck weights travelling on Vermont's roads and bridges. This understanding of the weights of commercial trucks on Vermont roads will allow the Agency to understand how commercial trucks contribute to the state of disrepair of its roads and bridges.

An alternate approach to the truck allocation can be proposed, particularly given the high resolution of commercial destinations available in Vermont from the E911 structures GIS, and the relatively low number of large manufacturing and employment destinations in the state. The availability of single-destination-specific data of this kind makes an understanding of the major freight movement in the state more feasible.

An improved understanding of the movement of freight, including specific commodities and truck weights, will be a critical step in supporting Strategy E. of Policy Goal 2 of the Vermont Long Range Transportation Business Plan (VTrans, 2009). This goal, which seeks to optimize the transportation system management and operation to make the best use of its existing assets, recommends that the Agency "facilitate the ability of the transportation system to safely and efficiently accommodate both freight and person movement by collaborating with public and private entities to understand and address multimodal freight access needs for major destinations & economic hubs." In order to effectively implement a targeted facilitation of this strategy, it will be necessary to understand where commodities are being moved by truck and rail, and where efforts to integrate rail and truck should be focused. This improved understanding will allow the Agency to better focus efforts to increase the amount of freight moved by rail, offsetting the corresponding movement of freight by truck.

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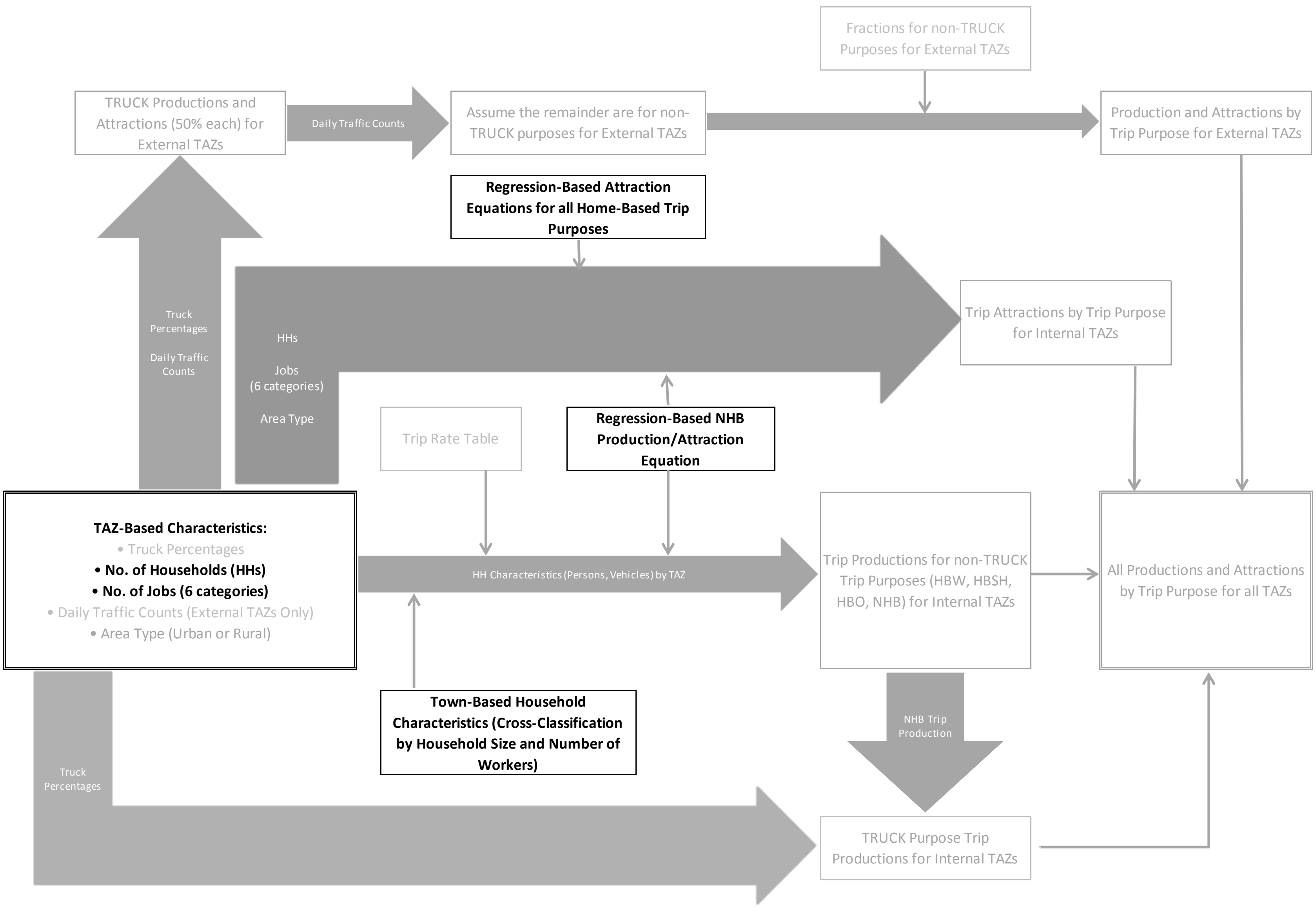
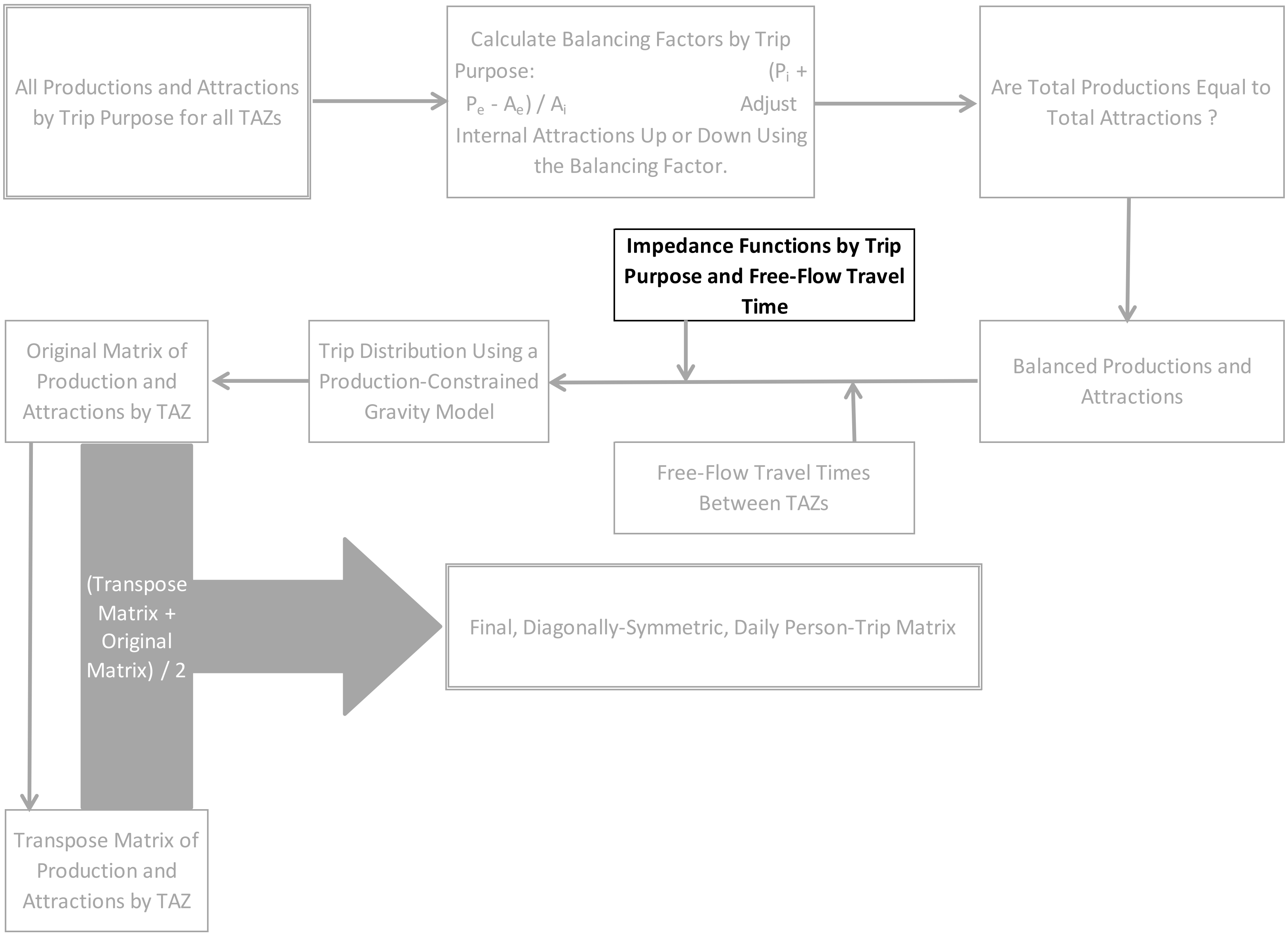
Appendix A


Fractions for non-TRUCK Purposes for External TAZs
TRUCK Productions and Attractions (50% each) for External TAZs
Daily Traffic Counts
Assume the remainder are for non-TRUCK purposes for External TAZs
Production and Attractions by Trip Purpose for External TAZs
Regression-Based Attraction Equations for all Home-Based Trip Purposes
Truck Percentages
Daily Traffic Counts
HHs
Jobs (6 categories)
Area Type
Trip Attractions by Trip Purpose for Internal TAZs
Trip Rate Table
Regression-Based NHB Production/Attraction Equation
TAZ-Based Characteristics:
• Truck Percentages
• No. of Households (HHs)
• No. of Jobs (6 categories)
• Daily Traffic Counts (External TAZs Only)
• Area Type (Urban or Rural)
HH Characteristics (Persons, Vehicles) by TAZ
Trip Productions for non-TRUCK Trip Purposes (HBW, HBSH, HBO, NHB) for Internal TAZs
All Productions and Attractions by Trip Purpose for all TAZs
Town-Based Household Characteristics (Cross-Classification by Household Size and Number of Workers)
NHB Trip Production
Truck Percentages
TRUCK Purpose Trip Productions for Internal TAZs


All Productions and Attractions by Trip Purpose for all TAZs
Calculate Balancing Factors by Trip Purpose: (Pi + Pe - Ae) / Ai Adjust Internal Attractions Up or Down Using the Balancing Factor.
Are Total Productions Equal to Total Attractions ?
Impedance Functions by Trip Purpose and Free-Flow Travel Time
Original Matrix of Production and Attractions by TAZ
Trip Distribution Using a Production-Constrained Gravity Model
Balanced Productions and Attractions
Free-Flow Travel Times Between TAZs
(Transpose Matrix + Original Matrix) / 2
Final, Diagonally-Symmetric, Daily Person-Trip Matrix
Transpose Matrix of Production and Attractions by TAZ

Appendix B

Table B-23 2010 Commodity Productions by Vermont County (in kilotons)

Commodity	Total	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Live animals / fish	42	7	1	2	3	0	8	0	2	2	3	1	5	6	3
Cereal grains	2,124	122	47	59	366	0	575	9	12	21	73	123	563	107	51
Other agricultural products	1,453	153	47	85	146	6	159	17	92	64	56	54	186	278	119
Animal feed	1,198	34	13	17	103	0	162	2	3	605	21	35	159	30	14
Meat / seafood	39	3	1	2	4	0	6	0	2	1	2	1	6	8	4
Milled grain products	85	5	2	2	15	0	23	0	0	1	3	5	22	4	2
Other foodstuffs	1,055	90	12	93	174	0	143	9	9	5	18	151	167	82	103
Alcoholic beverages	267	23	3	23	44	0	36	2	2	1	5	38	42	21	26
Tobacco products	6	1	0	1	1	0	0	0	0	0	0	1	0	1	1
Building stone	109	3	0	0	9	0	0	0	0	3	0	84	0	0	10
Natural sands	441	14	0	0	36	0	0	0	0	10	0	338	0	0	42
Gravel	3,140	100	0	0	259	0	0	0	0	73	0	2410	0	0	299
Nonmetallic minerals	1,579	50	0	0	130	0	0	0	0	37	0	1212	0	0	150
Metallic ores	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Crude petroleum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gasoline	976	107	0	69	284	0	62	0	17	0	68	321	36	0	12
Fuel oils	537	59	0	38	156	0	34	0	9	0	37	177	20	0	7
Coal-n.e.c.	526	58	0	37	153	0	33	0	9	0	36	173	19	0	7
Basic chemicals	59	14	3	5	22	0	2	1	1	0	1	2	1	7	0
Pharmaceuticals	11	2	1	1	4	0	0	0	1	0	1	1	0	1	0
Fertilizers	145	35	6	11	54	0	5	1	3	0	3	5	3	18	1

Commodity	Total	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Chemical products	**66**	16	3	5	25	0	2	1	1	0	1	2	1	8	0
Plastics / rubber	**92**	10	15	4	26	0	5	0	3	1	4	5	1	7	11
Logs	**1,743**	95	39	70	257	37	35	8	125	64	95	111	38	593	191
Wood products	**618**	22	39	34	164	14	22	0	13	15	42	126	27	39	62
Newsprint / paper	**186**	5	6	7	51	0	43	0	5	2	12	15	2	28	9
Paper articles	**94**	2	2	3	19	0	30	0	0	1	5	8	1	18	5
Printed products	**62**	7	2	1	26	1	5	0	1	2	1	4	7	3	2
Textiles / leather	**29**	1	2	2	15	0	1	0	0	2	1	3	2	1	1
Nonmetal mineral products	**2,861**	223	200	109	725	10	193	0	139	80	149	350	353	124	206
Base metals	**60**	1	4	4	38	0	3	0	1	1	3	2	1	1	0
Articles-base metal	**122**	3	8	7	69	0	6	0	4	3	7	6	2	5	2
Machinery	**245**	8	30	14	75	0	11	0	7	4	13	32	11	26	14
Electronics	**118**	5	15	5	50	0	3	0	1	2	3	13	5	11	7
Motorized vehicles	**91**	10	43	7	13	0	0	1	0	3	2	8	1	4	1
Transport equipment	**2**	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Precision instruments	**2**	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Furniture	**41**	1	3	2	11	1	1	0	1	1	3	8	2	3	4
Misc. manufacturing products	**112**	4	6	6	47	0	6	0	8	2	10	9	2	8	5
Waste / scrap	**1,810**	107	107	90	453	18	138	20	71	84	79	178	172	129	164
Mixed freight	**483**	28	29	24	121	5	37	5	19	22	21	48	46	34	44
Unknown	**443**	26	26	22	111	4	34	5	17	20	19	44	42	32	40

Table B-24 Commodity Attractions by Vermont County (in kilotons)

Commodity	Total	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Live animals / fish	**12**	2	0	1	2	0	2	0	0	1	1	1	1	1	1
Cereal grains	**338**	33	16	16	72	3	41	3	10	14	15	29	39	24	24
Other agricultural products	**397**	77	11	18	46	3	69	3	10	19	23	24	41	33	21
Animal feed	**392**	76	10	17	45	3	68	3	10	19	23	23	40	32	21
Meat / seafood	**126**	12	6	6	27	1	15	1	4	5	6	11	14	9	9
Milled grain products	**185**	18	9	9	39	1	22	2	6	8	8	16	21	13	13
Other foodstuffs	**422**	42	20	19	89	3	51	4	13	17	19	36	48	30	30
Alcoholic beverages	**49**	5	2	2	10	0	6	0	2	2	2	4	6	3	4
Tobacco products	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Building stone	**12**	1	0	1	3	0	1	0	0	0	1	4	1	0	0
Natural sands	**195**	20	1	13	56	0	13	0	3	0	12	63	10	1	3
Gravel	**631**	65	3	42	181	0	41	0	10	0	38	205	31	5	11
Nonmetallic minerals	**194**	20	1	13	56	0	13	0	3	0	12	63	9	1	3
Metallic ores	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal	**4**	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Crude petroleum	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gasoline	**956**	70	44	47	261	7	74	8	32	33	43	126	80	62	67
Fuel oils	**725**	53	33	36	198	6	56	6	24	25	33	96	61	47	51
Coal-n.e.c.	**1150**	85	53	57	314	9	90	9	39	39	52	152	96	75	81
Basic chemicals	**584**	60	32	30	172	3	48	4	16	19	21	55	39	49	36
Pharmaceuticals	**2**	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Fertilizers	**15**	1	1	1	4	0	1	0	0	0	1	1	1	1	1

Commodity	Total	Addison	Bennington	Caledonia	Chittenden	Essex	Franklin	Grand Isle	Lamoille	Orange	Orleans	Rutland	Washington	Windham	Windsor
Chemical products	**39**	4	2	2	12	0	3	0	1	1	1	4	3	3	2
Plastics / rubber	**114**	8	9	5	40	1	8	1	2	3	4	10	9	8	7
Logs	**38**	10	1	2	3	0	6	0	1	3	3	2	2	3	2
Wood products	**423**	16	16	14	147	4	21	2	10	9	32	57	19	42	34
Newsprint / paper	**64**	4	3	2	22	0	4	0	2	2	2	5	7	4	5
Paper articles	**84**	6	3	4	21	0	18	0	1	2	2	5	7	9	4
Printed products	**25**	2	1	1	9	0	2	0	1	1	1	2	3	2	2
Textiles / leather	**23**	1	1	2	9	0	1	0	1	1	1	2	2	1	1
Nonmetal mineral products	**548**	56	3	36	157	0	35	0	9	0	33	178	27	4	9
Base metals	**247**	14	15	13	64	2	19	3	10	11	11	24	23	17	22
Articles-base metal	**64**	4	4	3	16	1	5	1	2	3	3	6	6	5	6
Machinery	**41**	3	3	2	11	0	3	0	1	2	2	4	3	3	3
Electronics	**20**	1	2	1	8	0	1	0	1	1	1	2	1	1	1
Motorized vehicles	**98**	6	9	5	25	1	7	1	3	4	4	9	9	7	8
Transport equipment	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Precision instruments	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furniture	**27**	2	2	1	7	0	2	0	1	1	1	3	3	2	2
Misc. manufacturing products	**49**	3	3	2	15	0	3	0	2	2	2	4	4	3	4
Waste / scrap	**78**	4	5	3	24	1	5	1	3	3	3	7	8	5	6
Mixed freight	**558**	39	32	28	152	5	44	5	19	23	24	54	51	39	44