Appendix F: Future Conditions and TDM Methodology

GREATER HARTFORD MOBILITY STUDY

CONNECTICUT DEPARTMENT OF TRANSPORTATION

Purpose

The Travel Demand Model (TDM) Methodology Memo has been prepared as background information to describe the industry standard planning-level technical assessment methodology used as a basis for the Greater Hartford Mobility Study (GHMS). It describes the Capitol Region Council of Governments (CRCOG) travel demand model used to project multimodal travel behavior within the study area for the 2050 design year. A brief overview of the model structure is presented along with comparisons between 2020 base year and 2050 design year model inputs and outputs.

Key Components

The TDM Methodology Memo focuses on the following topics:

1. Modifications made to the model specific to GHMS
2. TDM Inputs
3. TDM Steps and Outputs
4. 2020 Base Year Assessment
5. Future Volume Projection Methodology
6. 2050 No-Build Future Year Assessment

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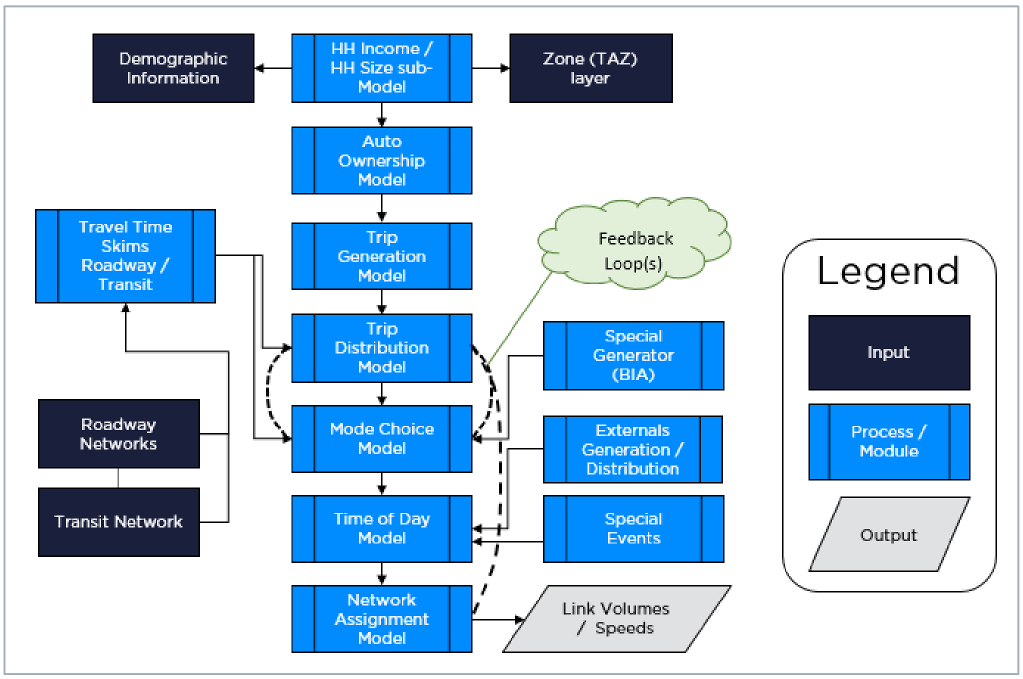
Travel Demand Model Overview

The CRCOG regional TDM is a four-step model similar to those used by many other Metropolitan Planning Organizations (MPOs). The foundation of the model can be found in its traffic analysis zone (TAZ) system, multimodal transportation networks, and socio-economic data (SED). Building from this foundation are models to estimate trip generation, trip distribution (destination choice), mode choice, and traffic assignment. In addition to these steps the model also includes:

- sub-models for household income and size;
- a special events model;
- feedback loops between mode choice and destination choice; and
- a time-of-day component.

A flowchart depicting the CRCOG regional model is shown in Figure 1: CRCOG Model Flow Chart. For a detailed description of the CRCOG TDM please see Appendix A -Technical Memorandum: Travel Demand Modeling System-Wide Calibration.

Figure 1: CRCOG Model Flow Chart

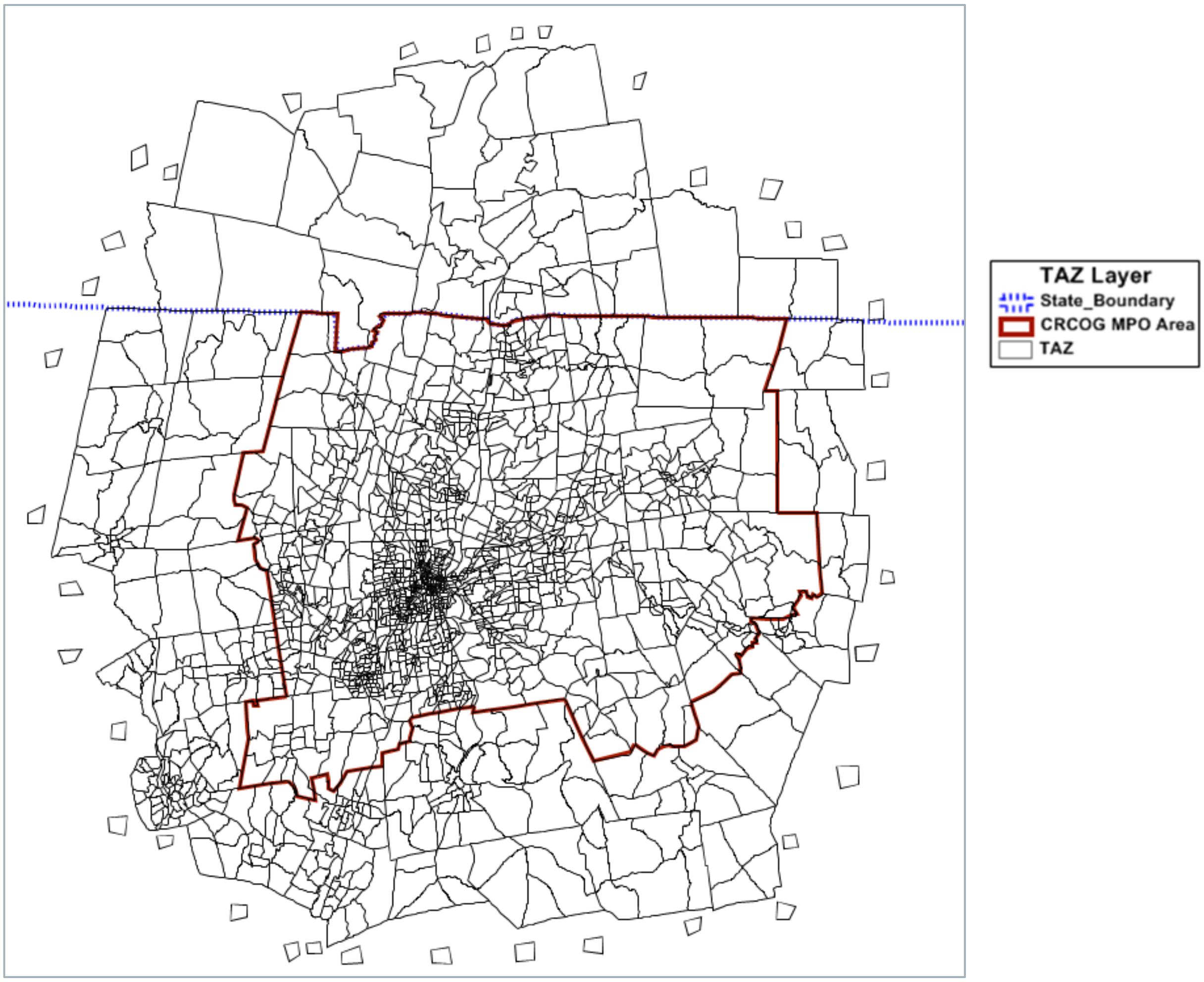


Travel Demand Model Input Data

Traffic Analysis Zone (TAZ) Structure

TAZs are the standard unit of geography used in travel demand forecasting. They provide the means to spatially organize the SED used by the Trip Generation model as well as organize inputs and outputs throughout the modeling process. TAZ boundaries are typically based on census geography but can be based on other geography as well, e.g., Public Land Survey System (PLSS). Within a model, TAZ will vary in size depending upon development levels. In higher density areas, TAZs will be smaller and more numerous. In lower density areas, TAZs will be larger and less numerous. Individual TAZs are typically bounded by roadways or other physical features, e.g., rivers. The TAZ system for the CRCOG model area is shown in Figure 2. It covers Hartford and Tolland counties in their entirety, and portions of Fairfield, Litchfield, Middlesex, New Haven, New London, and Windham counties as well as a portion of southwest Massachusetts. In total there are 2,028 TAZs including 1,991 internal TAZs and 37 external stations. The TAZ structure remains constant in the base and future years.

Figure 2: CRCOG Traffic Analysis Zone Structure



Socio-Economic Data (SED)

2020 and 2050 SED from the Connecticut state-wide model was provided by the Connecticut Department of Transportation, Bureau of Policy & Planning. Information was extracted from these data for the CRCOG model area. SED for the part of the CRCOG model area in Massachusetts was provided by the Pioneer Valley Planning Commission. A comparison of regional demographics between the 2020 base year and 2050 design year is presented in **Table 1**. The same data for each GHMS corridor is presented in Figure 3. Overall, regional growth (as measured by the sum of households and employment) across the planning horizon is expected to be a little over 12 percent. Growth in households (~15 percent) is expected to exceed growth in total employment (~10 percent). As with employment, population is expected to grow approximately 10 percent. The greater growth in households, compared to population, suggests a decline in average household size is expected. Finally, growth in non-retail employment is expected to exceed growth in retail employment by approximately one percent.

Among the GHMS corridors, overall growth is expected to be the greatest in the South Corridor where the sum of households plus employment is forecasted to increase 15,722 (18 percent) between 2020 and 2050. This growth reflects an increase of 5,392 (16.1 percent) in households and 10,330 (18.9 percent) in total employment.

Next in order of growth, after the South Corridor, is the Study Core followed by the North Corridor and the Southwest Corridor. Overall growth in the Study Core is forecasted to be 10,247 (4.9 percent). Contributing to this growth is an increase of 4,968 (7.5 percent) in households and 5,278 (3.6 percent) in total employment. North Corridor growth is expected to reach 9,280 (15.7 percent) by 2050 resulting from an increase in households of 2,692 (14.8 percent) and 6,515 (16.1 percent) in employment. The fourth largest amount of growth (8,894 / 9.3 percent) is projected for the Southwest Corridor where the number of households is expected to increase by 3,507 (8.8 percent) along with an increase of 5,388 (9.7 percent) in total employment.

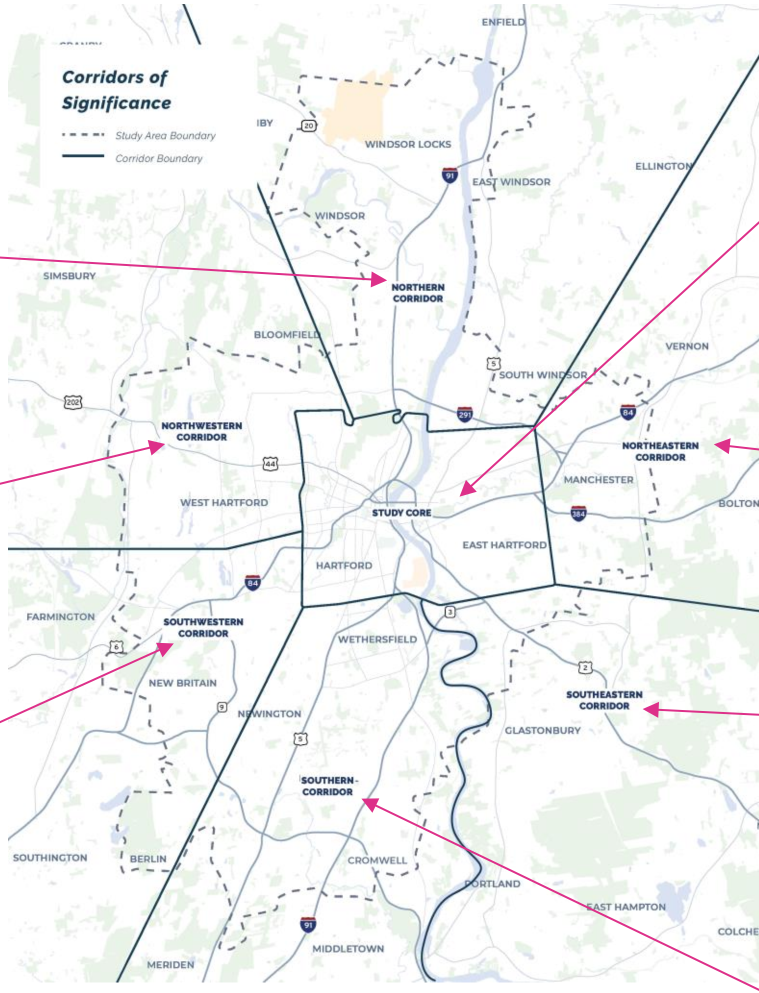
Overall growth in the Northeast Corridor is expected to reach 6,621 (16 percent) by 2050. This growth reflects an increase in households of 2,583 (15.5 percent) and in total employment of 4,038 (16.7 percent).

The least amount of growth, among the GHMS Corridors, is projected in the Southeast Corridor (4,605 / 30.1 percent) and the Northwest Corridor (4,212 / 7.7 percent). Growth in the Southeast Corridor reflects an increase in the number of households of 1,057 (25.9 percent) and an increase in total employment of 3,549 (31.6 percent). While in the Northwest Corridor the number of households is expected to grow by 2,697 (10.9 percent) along with an increase of 1,515 (5.1 percent) in total employment.

Table 1: CRCOG Model Area Socio-Economic Forecast

Demographic	2020	2050	Change	
			Number	Percent
Households	822,560	947,411	124,851	15.2%
Total Population	**2,099,047**	**2,300,079**	**201,032**	**9.6%**
Household Population	2,036,192	2,228,856	192,664	9.5%
Group Quarters Population	62,855	71,223	8,368	13.3%
Retail Employment	156,874	170,740	13,866	8.8%
Non-Retail Employment	831,107	914,637	83,530	10.1%
Total Employment	**987,981**	**1,085,377**	**97,396**	**9.9%**
Households + Total Employment	**1,810,541**	**2,032,788**	**222,247**	**12.3%**

Figure 3: GHMS Corridor Socio-Economic Forecast



NORTH CORRIDOR

Data	2020	2050	Change	
			Number	Percent
Households	18,220	20,912	2,692	14.8%
Total Pop	49,863	54,759	4,897	9.8%
Retail Emp	3,899	4,614	715	18.3%
Non-Retail Emp	36,670	42,470	5,800	15.8%
Total Emp	40,569	47,084	6,515	16.1%
Households + Total Emp	58,789	67,997	9,208	15.7%

NORTHWESTERN CORRIDOR

Data	2020	2050	Change	
			Number	Percent
Households	24,699	27,396	2,697	10.9%
Total Pop	61,342	64,665	3,324	5.4%
Retail Emp	5,433	5,482	49	0.9%
Non-Retail Emp	24,527	25,993	1,466	6.0%
Total Emp	29,960	31,475	1,515	5.1%
Households + Total Emp	54,659	58,871	4,212	7.7%

SOUTHWESTERN CORRIDOR

Data	2020	2050	Change	
			Number	Percent
Households	39,755	43,262	3,507	8.8%
Total Pop	100,939	104,033	3,094	3.1%
Retail Emp	7,545	8,016	471	6.2%
Non-Retail Emp	48,087	53,004	4,917	10.2%
Total Emp	55,632	61,020	5,388	9.7%
Households + Total Emp	95,387	104,281	8,894	9.3%

STUDY CORE

Data	2020	2050	Change	
			Number	Percent
Households	66,320	71,287	4,968	7.5%
Total Pop	175,388	179,025	3,637	2.1%
Retail Emp	8,720	9,008	288	3.3%
Non-Retail Emp	135,993	140,983	4,990	3.7%
Total Emp	144,713	149,991	5,278	3.6%
Households + Total Emp	211,033	221,278	10,246	4.9%

NORTHEASTERN CORRIDOR

Data	2020	2050	Change	
			Number	Percent
Households	16,715	19,298	2,583	15.5%
Total Pop	38,510	42,916	4,407	11.4%
Retail Emp	8,800	10,040	1,240	14.1%
Non-Retail Emp	15,369	18,167	2,798	18.2%
Total Emp	24,169	28,207	4,038	16.7%
Households + Total Emp	40,884	47,506	6,621	16.2%

SOUTHEASTERN CORRIDOR

Data	2020	2050	Change	
			Number	Percent
Households	4,086	5,143	1,057	25.9%
Total Pop	9,414	11,436	2,022	21.5%
Retail Emp	2,097	2,799	702	33.5%
Non-Retail Emp	9,130	11,978	2,847	31.2%
Total Emp	11,228	14,776	3,549	31.6%
Households + Total Emp	15,314	19,919	4,605	30.1%

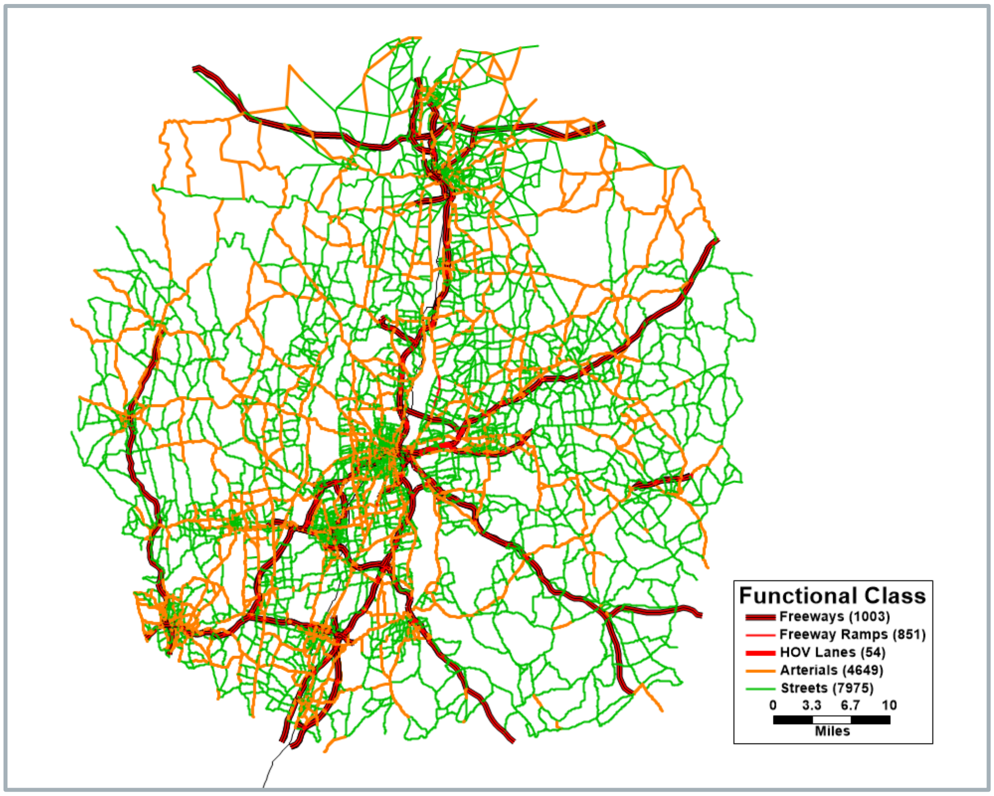
SOUTHERN CORRIDOR

Data	2020	2050	Change	
			Number	Percent
Households	33,489	38,881	5,392	16.1%
Total Pop	82,307	90,326	8,019	9.7%
Retail Emp	10,313	12,251	1,938	18.8%
Non-Retail Emp	44,391	52,783	8,392	18.9%
Total Emp	54,704	65,034	10,330	18.9%
Households + Total Emp	88,193	103,915	15,722	17.8%

Highway Networks

Roadway facilities are coded in the model area to include freeways, HOV lanes, freeway ramps, arterials, and streets. Centroid connectors provide for movement between the TAZ and the transportation network. The network was checked for connectivity, directionality, range of attribute values, shortest paths, and trip loading on centroid connectors, freeways, and ramps. An illustration of the 2020 base year highway network is presented in Figure 4.

Figure 4: 2020 Base Year Highway Network



In addition to the 2020 base year highway network a 2050 no-build highway network was also coded. This network includes facilities from the 2020 base year network plus all projects, identified through a review of the current Transportation Improvement Program (TIP) expected to be constructed by 2050. Projects were coded according to the best information available from reports, web sites, and other formal sources. The list of projects added to the 2020 base year network appears in **Table 2.**

Table 2: 2050 Committed Highway Network Projects

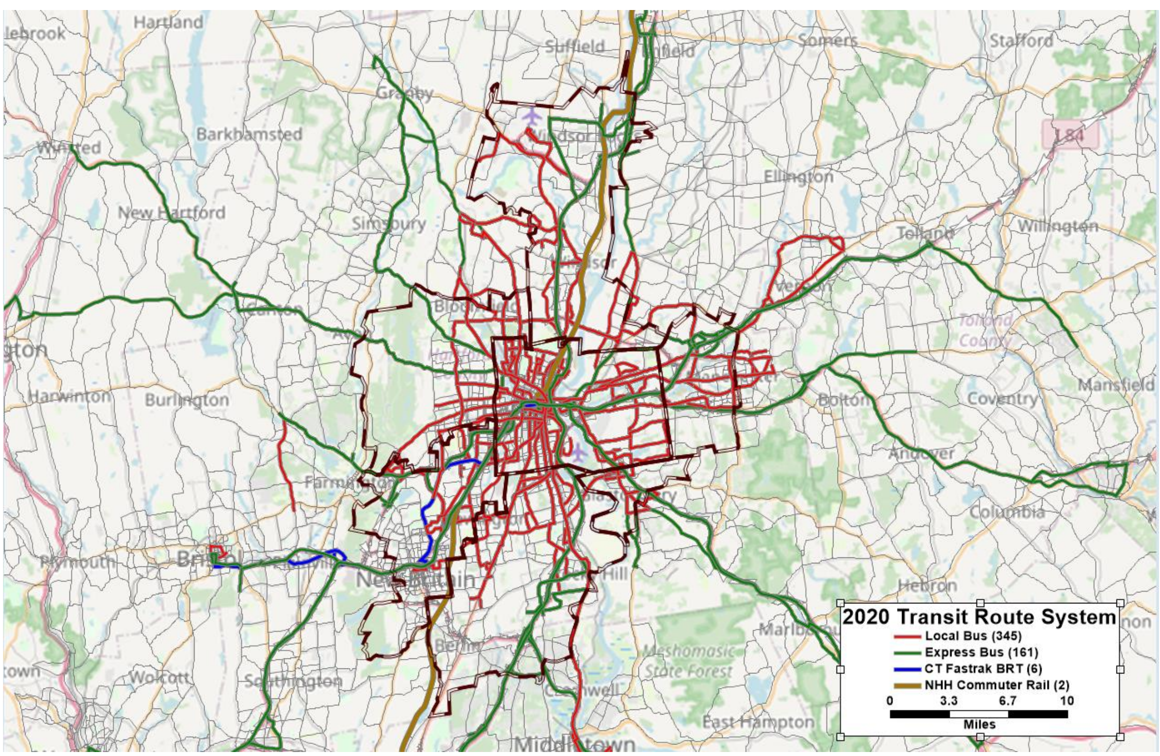
Town	GHMS Corridor	Type	Recommendation Description
Hartford	Study Core	Add Lane	I-91/Wilbur Cross Highway/Charter Oak Bridge from Murphy Road ramp to Route 502
East Granby	North	New Roadway	Airport Park Road Extension between Nicholson Road and Russell Road
Windsor Locks	North	Reconfiguration	Bradley Airport internal roadway improvement (lane reduction)
Rocky Hill	South	New Roadway	Between Elm Street and Route 411
West Hartford	Southwest	Add Lane	I-84 Eastbound, between Ridgewood Road and South Main Street
West Hartford	Southwest	Add Lane	I-84 Westbound, between Park Road and South Main Street ramps
West Hartford	Southwest	Add Lane	I-84 Westbound, between South Main Street and Ridgewood Road ramps
West Hartford	Northwest	Add Lane	Park Road, I-84 ramp to Trout Brook Drive
Bristol	Rest of Region	Add Lane	Eastbound Farmington Avenue from Page Avenue to Jerome Avenue and from Morris Avenue to Brook Street
Granby	Rest of Region	Add Lane	Hartford Avenue at Salmon Brook Street

Town	GHMS Corridor	Type	Project Description
Plainville	Rest of Region	Add Lane	New Britain Avenue between Hooker Street and Cooke Street
Wallingford	Rest of Region	Add Lane	Colony Road, between John Street and Ward Street
Wallingford	Rest of Region	Add Lane	North Colony Road (US 5), between Barnes Road and Yale Avenue
Wallingford	Rest of Region	Add Lane	Route 5 from Old North Colony Road to Olive Street
Waterbury	Rest of Region	Add Lane	I-84 (Yankee Expressway) ramp Baldwin Street to Washington Street
Simsbury	Rest of Region	New Roadway	Connecting Ely Lane at Hoskins Road to Hopmeadow Street (US 202 / CT 10) and Wolcott Road
Suffield	Rest of Region	New Roadway	Northern Bradley Connector
Middletown	Rest of Region	Reconfiguration	St John's and Route 9 with grade separated eastbound-to-northbound left turn
Southington	Rest of Region	Reconfiguration	Bridge over Meriden-Waterbury removed, Norton Street closed, and new intersection at Cheshire Road and Meriden-Waterbury Turnpike

Transit Networks

The transit route system includes representations of CT*transit* routes operating in the CRCOG model area during the AM Peak and Midday time periods. The transit network includes 42 local bus routes, 23 express bus routes, three CT*fastrak* BRT routes, and one commuter rail route. A map showing the extent of the transit route system appears in Figure 5.

Figure 5: 2020 CRCOG Transit Route System



Two changes were made to the 2020 transit route system to represent the 2050 no-build transit route system:

- Headways on the Route 30 Bradley Flyer were decreased from 40 to 30 minutes during the AM and mid-day time periods; and
- stations were added to the Hartford Line at Enfield, West Hartford, and Newington.

Travel Demand Model Steps and Outputs

Trip Generation (Trip Productions)

Trip generation is the first step in the conventional four-step transportation forecasting process. Typically, trip generation models utilize SED, such as the number of households and employment, to understand the trip generation potential of the TAZ. The CRCOG trip generation model estimates the number of trips produced in a TAZ for three trip purposes: Home Based Work (HBW), Home Based Other (HBO), and Non-Home Based (NHB). The trip generation rates for HBW and HBO purposes are segmented based on household income and auto sufficiency and can be summarized as:

- zero auto households
- low-income households where the number of autos is less than the number of workers (low insufficient)
- low-income households where the number of autos is greater than or equal to the number of workers (low sufficient)
- high income households where the number of autos is less than the number of workers (high insufficient)
- high income households where the number of autos is greater than or equal to the number of workers (high sufficient)

Neither NHB, truck, nor internal/external trip rates are market segmented.

Table 3 shows the total trips generated by the trip generation model for 2020 and 2050. Overall, the number of trips generated by the model appear consistent with the expected growth in households and employment. Resident trips (HBW, HBO, and NHB) increase 14.3 percent between 2020 and 2050 while Non-Resident trips (truck and internal /external trips) increase approximately 12 percent. Overall, the total number of trips generated increase almost 14 percent from 8,194,044 in 2020 to 9,335,312 in 2050.

Table 3: 2020 and 2050 CRCOG Model Regional Daily Trip Generation

Trip Purpose/ Market	2020	2050	Change	
			Number	Percent
Resident Trips				
HBW_zero	68,366	72,280	3,914	5.7%
HBW_low_insufficient	66,004	65,160	-845	-1.3%
HBW_low_sufficient	233,587	258,749	25,162	10.8%
HBW_high_insufficient	88,897	91,270	2,373	2.7%
HBW_high_sufficient	737,909	833,883	95,974	13.0%
HBO_zero	287,567	321,630	34,063	11.8%
HBO_low_insufficient	119,855	117,747	-2,108	-1.8%
HBO_low_sufficient	1,145,836	1,331,471	185,636	16.2%
HBO_high_insufficient	158,927	163,092	4,164	2.6%
HBO_high_sufficient	2,194,718	2,571,845	377,127	17.2%
NHB	1,663,087	1,905,031	241,944	14.5%
Sub Total	6,764,753	7,732,159	967,405	14.3%

Trip Purpose/ Market	2020	2050	Change	
			Number	Percent
Non-Resident Trips				
HBWP_IX	113,160	126,144	12,984	11.5%
HBWP_XI	123,107	134,377	11,270	9.2%
NWIXP	278,021	323,198	45,176	16.2%
NWXIP	329,375	377,455	48,080	14.6%
TIIP	509,206	558,793	49,587	9.7%
TIXP	37,657	40,935	3,278	8.7%
TXIP	38,764	42,252	3,487	9.0%
Sub Total	**1,429,291**	**1,603,154**	**173,863**	**12.2%**
Grand Total	**8,194,044**	**9,335,312**	**1,141,268**	**13.9%**

Trip Distribution (Destination Choice)

The CRCOG TDM employs a destination choice model in place of the gravity model which was historically used in similar regional TDMs. There are several advantages to implementing a destination choice model compared to a gravity model. A destination choice model is a logit model which allows for the consideration of a greater number of independent variables for estimating trip distribution, including the LogSum variable output from the mode choice model. Further, the destination choice model, unlike the gravity model, is sensitive to transit, income, and auto sufficiency. This greater sensitivity improves the resulting trip tables and overall model performance. The destination choice model predicts the probability of choosing any given zone as the trip attraction (i.e., destination end of a trip).

Table 4 presents the results of the destination choice model in the form of origin-destination (OD) matrices for 2020 and 2050. For both origins and destinations trips are aggregated by the seven GHMS corridors and the rest of the CRCOG model area outside of the study area. Metrics are presented for the total number of trips between each origin and destination and the row percent showing the percent of trips from an origin to each possible destination.

Table 4: 2020 and 2050 CRCOG Model Regional Daily Trip Distribution

2020 Resident Trips										
GHMS Corridor	**Metric**	**Study Core**	**N**	**NE**	**SE**	**S**	**SW**	**NW**	**Rest of Region**	**Total**
Study Core	Number	399,602	9,996	15,423	11,358	20,614	24,782	25,673	40,880	548,328
	Row Percent	72.90%	1.8%	2.8%	2.1%	3.8%	4.5%	4.7%	7.5%	100.0%
N	Number	27,448	75,537	4,990	1,080	3,923	3,766	7,431	46,363	170,538
	Row Percent	16.1%	44.3%	2.9%	0.6%	2.3%	2.2%	4.4%	27.2%	100.0%
NE	Number	21,203	3,619	79,756	2,060	3,493	2,706	2,307	36,069	151,214
	Row Percent	14.0%	2.4%	52.7%	1.4%	2.3%	1.8%	1.5%	23.9%	100.0%
SE	Number	10,059	590	1,589	16,743	2,998	1,104	642	8,855	42,580
	Row Percent	23.6%	1.4%	3.7%	39.3%	7.0%	2.6%	1.5%	20.8%	100.0%
S	Number	44,582	3,235	3,371	4,558	144,621	36,375	6,014	60,493	303,249
	Row Percent	14.7%	1.1%	1.1%	1.5%	47.7%	12.0%	2.0%	19.9%	100.0%
SW	Number	41,933	2,679	2,467	1,492	31,024	175,345	21,928	54,672	331,540
	Row Percent	12.6%	0.8%	0.7%	0.4%	9.4%	52.9%	6.6%	16.5%	100.0%
NW	Number	61,787	5,371	2,155	1,000	5,797	25,074	78,947	31,425	211,556
	Row Percent	29.2%	2.5%	1.0%	0.5%	2.7%	11.9%	37.3%	14.9%	100.0%
Rest of Region	Number	190,091	86,057	88,947	28,708	120,205	122,391	60,801	4,308,549	5,005,749
	Row Percent	3.8%	1.7%	1.8%	0.6%	2.4%	2.4%	1.2%	86.1%	100.0%
Total	**Number**	**796,706**	**187,084**	**198,697**	**66,999**	**332,676**	**391,543**	**203,741**	**4,587,307**	**6,764,754**
	Row Percent	**11.8%**	**2.8%**	**2.9%**	**1.0%**	**4.9%**	**5.8%**	**3.0%**	**67.8%**	**100.0%**

2050 Resident Trips										
GHMS Corridor	**Metric**	**Study Core**	**N**	**NE**	**SE**	**S**	**SW**	**NW**	**Rest of Region**	**Total**
Study Core	Number	419,013	11,387	17,280	14,274	22,886	26,445	27,101	45,652	584,039
	Row Percent	71.7%	1.9%	3.0%	2.4%	3.9%	4.5%	4.6%	7.8%	100.0%
N	Number	29,756	88,005	6,110	1,455	4,739	4,250	8,317	54,276	196,909
	Row Percent	15.1%	44.7%	3.1%	0.7%	2.4%	2.2%	4.2%	27.6%	100.0%
NE	Number	22,671	4,355	93,467	2,812	4,119	2,994	2,451	42,564	175,432
	Row Percent	12.9%	2.5%	53.3%	1.6%	2.3%	1.7%	1.4%	24.3%	100.0%
SE	Number	11,238	720	1,979	23,474	3,671	1,280	729	11,795	54,886
	Row Percent	20.5%	1.3%	3.6%	42.8%	6.7%	2.3%	1.3%	21.5%	100.0%
S	Number	46,675	3,753	4,005	5,985	174,415	39,996	6,458	73,218	354,505
	Row Percent	13.2%	1.1%	1.1%	1.7%	49.2%	11.3%	1.8%	20.7%	100.0%
SW	Number	44,030	3,030	2,835	1,890	35,498	189,235	23,435	61,103	361,058
	Row Percent	12.2%	0.8%	0.8%	0.5%	9.8%	52.4%	6.5%	16.9%	100.0%
NW	Number	65,616	6,362	2,453	1,323	6,760	28,483	84,109	36,825	231,931
	Row Percent	28.3%	2.7%	1.1%	0.6%	2.9%	12.3%	36.3%	15.9%	100.0%
Rest of Region	Number	207,843	104,651	107,844	39,716	148,744	138,890	67,553	4,958,156	5,773,397
	Row Percent	3.6%	1.8%	1.9%	0.7%	2.6%	2.4%	1.2%	85.9%	100.0%
Total	**Number**	**846,843**	**222,264**	**235,974**	**90,929**	**400,832**	**431,573**	**220,153**	**5,283,589**	**7,732,159**
	Row Percent	**11.0%**	**2.9%**	**3.1%**	**1.2%**	**5.2%**	**5.6%**	**2.8%**	**68.3%**	**100.0%**

Observations regarding the OD patterns:

- In 2020 and 2050 the largest proportion of trips originating in any GHMS corridor or the rest of the region are intra-zonal trips, i.e, these trips begin and end in the same area as highlighted in the above table.
- In 2020 and 2050 a majority of trips originating in the Study Core, the Northeast Corridor, the Southwest Corridor as well as the rest of the region are intra-zonal trips.
- Almost three-quarters of the trips originating in the Study Core have a destination in the Study Core.
- In 2020, excluding intra-zonal trips, the largest proportion of trips originating in the Study Core, the North Corridor, the Northeast Corridor, the South Corridor, the Southwest Corridor have destinations outside of the GHMS Study Area in the rest of the region. In 2050, this holds true as well for the Southeast Corridor.
- In 2020 the second most likely destination for trips from the Southeast Corridor and the Northwest Corridor is the Study Core. By 2050 this is true only for the Northwest Corridor.
- The largest number of trips in either 2020 or 2050, between OD pairs which do not include either the Study Core or the Rest of the Region, are between the South and Southwest corridors and the Southwest and Northwest Corridors.

Non-resident trips are described by their purpose, e.g., HBW, and whether they begin or end within the region, I.e., internal (I) to the CRCOG model area, or outside of the region, I.e., external (X). The CRCOG model includes the following non-resident trip types: HBW IX, HBW XI, NW IX, NW XI, Truck II, Truck IX, Truck XI, and Thru XX. **Table 5** summarizes the origins destination of non-resident home based work and non-work trips.

Table 5: Work and Non-Work Internal-External (IX) and External-Internal (XI) Trip Summary

GHMS Corridor	Origin of IX Trips				Destination of XI Trips			
	2020	2050	Change		2020	2050	Change	
			Number	Percent			Number	Percent
Study Core	8,611	9,220	609	7%	20,513	21,724	1,210	6%
North	3,315	3,767	452	14%	6,669	7,668	999	15%
Northeast	1,992	2,310	318	16%	3,466	4,122	656	19%
Southeast	955	1,206	252	26%	1,769	2,369	601	34%
South	6,366	7,503	1,138	18%	12,642	15,452	2,810	22%
Southwest	6,371	6,913	542	9%	8,678	9,655	977	11%
Northwest	3,110	3,394	285	9%	4,042	4,363	320	8%
Rest of Region	360,462	415,027	54,564	15%	394,704	446,480	51,776	13%
External	N/A	N/A	--	--	N/A	N/A	--	--
Total	**391,182**	**449,342**	**58,160**	**15%**	**452,482**	**511,832**	**59,350**	**13%**
GHMS Total	**30,719**	**34,315**	**3,596**	**12%**	**57,778**	**65,352**	**7,574**	**13%**
Internal-External trips originate within the CRCOG model region and are destined, for the purposes of the model, to one of the external zones outside of the region. Thus, by definition there can be no external origins for IX trips.								
External-Internal trips originate at one of the external zones, outside of the CRCOG model region, and are destined to a TAZ within the CRCOG region. Thus, by definition there can be no external destinations for XI trips.								

Observations regarding the origin and destinations of non-resident HBW and NW trips:

- Not surprisingly, the largest number of Internal-External (IX) trips originate from the area outside of the GHMS Study Area in the Rest of the Region.
- Within the GHMS Study Area the largest number of trips originate within the Study Core, South Corridor, and Southwest Corridor.

- Among GHMS Corridors the largest growth in trips destined outside of the region is expected in the South Corridor (1,138, 18 percent).
- Overall, the growth in trips from the GHMS Study Area destined outside of the region is projected to be 12 percent.
- Within the GHMS Study area the largest number of trips originating outside of the region are destined for the Study Core or South Corridor.
- The greatest growth in work and non-work XI trips is also expected in the South Corridor and the Study Core.
- Overall, trips from outside the region to the GHMS Study Area are expected to increase 13 percent between 2020 and 2050.

Table 6: 2020 and 2050 Truck, II, IE, EI, and Thru Trips

2020 Non-Resident Truck II, IE, EI, and Thru Trips											
GHMS Corridor	**Metric**	**Study Core**	**N**	**NE**	**SE**	**S**	**SW**	**NW**	**Rest of the Region**	**External**	**Total**
Study Core	Number	33,176	2,540	2,829	1,447	4,852	4,716	4,715	9,395	1,228	64,898
	Row Percent	51.1%	3.9%	4.4%	2.2%	7.5%	7.3%	7.3%	14.5%	1.9%	100.0%
N	Number	2,799	7,142	498	90	348	281	703	6,852	638	19,351
	Row Percent	14.5%	36.9%	2.6%	0.5%	1.8%	1.5%	3.6%	35.4%	3.3%	100.0%
NE	Number	2,751	540	3,184	238	366	194	247	4,328	129	11,977
	Row Percent	23.0%	4.5%	26.6%	2.0%	3.1%	1.6%	2.1%	36.1%	1.1%	100.0%
SE	Number	1,470	90	254	654	544	144	86	1,257	93	4,592
	Row Percent	32.0%	2.0%	5.5%	14.3%	11.8%	3.1%	1.9%	27.4%	2.0%	100.0%
S	Number	4,873	358	350	556	8,930	3,381	578	6,892	657	26,575
	Row Percent	18.3%	1.3%	1.3%	2.1%	33.6%	12.7%	2.2%	25.9%	2.5%	100.0%
SW	Number	4,633	243	198	144	3,430	9,971	2,143	7,618	553	28,932
	Row Percent	16.0%	0.8%	0.7%	0.5%	11.9%	34.5%	7.4%	26.3%	1.9%	100.0%
NW	Number	4,711	642	227	85	576	2,168	4,299	3,428	242	16,378
	Row Percent	28.8%	3.9%	1.4%	0.5%	3.5%	13.2%	26.2%	20.9%	1.5%	100.0%
Rest of Region	Number	9,432	6,230	4,322	1,271	6,905	7,585	3,423	300,874	34,119	374,161
	Row Percent	2.5%	1.7%	1.2%	0.3%	1.8%	2.0%	0.9%	80.4%	9.1%	100.0%
External	Number	1,305	591	163	125	724	603	249	35,004	69,777	108,542
	Row Percent	1.2%	0.5%	0.2%	0.1%	0.7%	0.6%	0.2%	32.2%	64.3%	100.0%
Total	**Number**	**65,150**	**18,375**	**12,025**	**4,609**	**26,676**	**29,043**	**16,442**	**375,649**	**107,434**	**655,405**
	Row Percent	**9.9%**	**2.8%**	**1.8%**	**0.7%**	**4.1%**	**4.4%**	**2.5%**	**57.3%**	**16.4%**	**100.0%**

2050 Non-Resident Truck II, IE, EI, and Thru Trips											
GHMS Corridor	**Metric**	**Study Core**	**N**	**NE**	**SE**	**S**	**SW**	**NW**	**Rest of the Region**	**External**	**Total**
Study Core	Number	34,193	2,682	2,972	1,705	5,145	4,857	4,796	9,330	1,267	66,946
	Row Percent	51.1%	4.0%	4.4%	2.5%	7.7%	7.3%	7.2%	13.9%	1.9%	100.0%
North	Number	2,947	8,360	550	105	379	285	774	7,845	702	21,947
	Row Percent	13.4%	38.1%	2.5%	0.5%	1.7%	1.3%	3.5%	35.7%	3.2%	100.0%
Northeast	Number	2,895	625	3,884	325	363	181	241	5,080	148	13,743
	Row Percent	21.1%	4.5%	28.3%	2.4%	2.6%	1.3%	1.8%	37.0%	1.1%	100.0%
Southeast	Number	1,740	109	335	1,065	635	151	91	1,684	120	5,931
	Row Percent	29.3%	1.8%	5.7%	18.0%	10.7%	2.5%	1.5%	28.4%	2.0%	100.0%
South	Number	5,129	385	410	645	11,405	3,674	595	7,702	772	30,717
	Row Percent	16.7%	1.3%	1.3%	2.1%	37.1%	12.0%	1.9%	25.1%	2.5%	100.0%
Southwest	Number	4,759	244	193	150	3,769	11,092	2,333	7,830	597	30,967
	Row Percent	15.4%	0.8%	0.6%	0.5%	12.2%	35.8%	7.5%	25.3%	1.9%	100.0%
Northwest	Number	4,811	695	211	86	607	2,383	4,620	3,565	255	17,234
	Row Percent	27.9%	4.0%	1.2%	0.5%	3.5%	13.8%	26.8%	20.7%	1.5%	100.0%
Rest of Region	Number	9,380	7,188	5,054	1,710	7,672	7,807	3,587	332,771	37,074	412,244
	Row Percent	2.3%	1.7%	1.2%	0.4%	1.9%	1.9%	0.9%	80.7%	9.0%	100.0%
External	Number	1,347	656	188	161	854	652	263	38,130	69,777	112,029
	Row Percent	1.2%	0.6%	0.2%	0.1%	0.8%	0.6%	0.2%	34.0%	62.3%	100.0%
Total	**Number**	**67,203**	**20,946**	**13,798**	**5,954**	**30,830**	**31,083**	**17,300**	**413,940**	**110,713**	**711,765**
	Row Percent	**9.4%**	**2.9%**	**1.9%**	**0.8%**	**4.3%**	**4.4%**	**2.4%**	**58.2%**	**15.6%**	**100.0%**

Observations regarding the non-resident truck trip demand matrix:

- In both 2020 and 2050, within the GHMS Study Area, the largest number of trip origins and destinations occur in the Study Core.
- Of trips that originate in the Study Core in 2020, 16.4 percent leave the GHMS Study Area for either the rest of the region (14.5 percent) or destinations outside of the CRCOG region (1.9 percent). The remainder (86.4 percent) are destined for either the Study Core or another GHMS Corridor.
- In 2020 the percentage of trips originating in a GHMS Corridor with a destination outside of the region are estimated to range from 1.1 percent (Northeast) to 3.3 percent (North) while the proportion of trips destined for locations outside of the Study Area, but within the CRCOG region, range from 14.5 percent (Study Core) to 36.1 percent (Northeast).
- Of 2020 trips that originate outside of the GHMS Study Area, but still within the region, the overwhelming majority are estimated to have destinations outside the Study Area as well with 80.4 percent destined for the rest of the region and 9.1 percent to an external destination.
- Among GHMS Corridors the Northeast Corridor is estimated to have the largest proportion of truck trips leaving the study area for either the Rest of the Region or an external destination while the Study Core has the largest number of trips.
- Between 2020 and 2050 the total number of truck and thru trips is projected to increase by over 56,000 trips (8.5 percent) with overall patterns remaining relatively stable.

Mode Choice

The mode choice model in the CRCOG TDM uses a nested logit structure. The model reflects the mode choice options available to travelers in the Capitol Region including drive alone, shared ride 2, shared ride 3+, local bus, express bus, BRT, commuter rail, and non-motorized (walk and bike) forms of travel. Access to and egress from transit also reflects the range of available options including park-and-ride, kiss-and-ride, walk, and bike. The model was calibrated using data from the 2016 Connecticut Household Travel Survey (CSTS), 2016 CRCOG On-Board Transit Survey, and the U.S. Census ACS / CTPP data.

The mode choice model includes independent variables such as cost, in-vehicle time, and transit wait time. The model parameters are segmented by income and auto sufficiency for HBW and HBO but not for NHB trips. Each mode also has a constant that represents the effect of attributes that are not directly reflected in the model's independent variables. Examples of such attributes for transit are comfort, travel time reliability, availability of real-time next vehicle information, frequency of off-peak service (for peak trips), and vehicle and station amenities. Table 7 presents results from the CRCOG TDM mode choice analysis for 2020 and 2050.

Table 7: 2020 and 2050 CRCOG Model Mode Choice

Mode	2020		2050		2020 - 2050 Change	
	Number	Percent	Number	Percent	Number	Percent
Drive Alone	3,372,928	49.9%	3,855,366	49.9%	482,438	14.3%
Shared Ride	2,623,108	38.8%	3,013,793	39.0%	390,684	14.9%
Walk	647,649	9.6%	729,704	9.4%	82,055	12.7%
Bike	76,652	1.1%	86,135	1.1%	9,483	12.4%
Local Bus	30,911	0.5%	32,111	0.4%	1,200	3.9%
Express Bus	2,750	0.0%	3,142	0.0%	392	14.2%
Bus Rapid Transit	8,766	0.1%	9,192	0.1%	426	4.9%
Commuter Rail	1,990	0.0%	2,716	0.0%	727	36.5%
Transit Subtotal	**44,417**	**0.7%**	**47,161**	**0.6%**	**2,744**	**6.2%**
Total All Modes	**6,764,754**	**100.0%**	**7,732,159**	**100.0%**	**967,405**	**14.3%**

Observations regarding mode choice:

- The distribution of trips among modes is expected to be virtually unchanged between 2020 and 2050.
- Between 2020 and 2050 the proportion of shared ride trips increases slightly while the proportion of transit trips decreases slightly.
- Growth in trips by mode is roughly consistent with the growth seen in households and employment except for express bus, bus rapid transit, and transit overall.
- Growth in total transit trips is less than the growth seen in households and employment.
- The growth in commuter rail trips is greater than the growth in households and employment while the growth in express bus trips is comparable.

Highway Assessment

The algorithms used in traffic assignment attempt to replicate the process of choosing the best path between an origin and destination. The CRCOG model uses an equilibrium assignment. This is a widely accepted, best practice approach, which produces link loadings by optimally seeking user-equilibrium path loadings that reflect user path choices as influenced by network congestion. During this process, the trip table is assigned to the highway network over multiple iterations. After each iteration link travel times are recalculated, using the total link demand, and compared to the link travel times of the previous iteration. The aggregate change of link travel times between the current iteration and the previous is compared against the convergence criteria. The maximum number of iterations is determined by the user[1].

[1] The maximum number of iterations for the highway assignment in the CRCOG TDM was set at 1,000. The convergence criteria is 0.0001 relative gap.

Table 8: 2020 and 2050 Total Daily Model Traffic Flow

CRCOG Region Functional Class	2020 Model Traffic Volume	2050 Model Traffic Volume	Change	
			Number	Percent
Arterials	53,591,731	59,975,494	6,383,763	12%
Freeway Ramps	5,931,101	6,432,778	501,677	8%
Freeways	37,777,136	40,419,527	2,642,391	7%
HOV Lanes	135,827	170,943	35,116	26%
Streets	35,037,049	40,364,026	5,326,977	15%
Grand Total	**132,472,845**	**147,362,768**	**14,889,923**	**11%**
GHMS Corridor	**2020 Model Traffic Volume**	**2050 Model Traffic Volume**	**Change**	
			Number	**Percent**
Study Core	21,318,805	23,016,076	1,697,271	8%
North	7,705,706	8,476,975	771,269	10%
Northeast	3,578,541	4,095,831	517,290	14%
Southeast	1,410,837	1,703,361	292,524	21%
South	8,265,010	9,326,600	1,061,590	13%
Southwest	9,070,734	9,860,615	789,881	9%
Northwest	5,132,643	5,671,906	539,263	11%
GHMS Subtotal	**56,482,276**	**62,151,364**	**5,669,088**	**10%**
Rest of Region	75,990,566	85,211,406	9,220,840	12%
Grand Total	**132,472,843**	**147,362,770**	**14,889,927**	**11%**

Observations regarding total daily flow:

- The increase in total vehicle flow (11 percent) is consistent with the growth in households, employment, and regional trip generation.
- The increase in flow is greatest on HOV Lanes (26 percent) followed by Streets (15 percent), Arterials (12 percent), and Freeways (7 percent).
- Among the GHMS corridors the largest percent increase in flow is forecasted in the Southeast Corridor but, in terms of total flow, this is also the smallest of the corridors.
- The largest increases in total flow are expected in the Study Core (1,697,271 / 8 percent) and the South Corridor (1,061,590 / 13 percent).
- Outside of the Study Core, the Southwest Corridor has the largest total flow which is expected to increase by 789,881 or 9 percent between 2020 and 2050.

Table 9: 2020 and 2050 Total Daily Vehicle Miles of Travel (VMT)

CRCOG Region Functional Class	2020 VMT	2050 VMT	Change	
			Number	Percent
Arterials	14,189,854	16,024,132	1,834,278	13%
Freeway Ramps	1,484,324	1,623,064	138,740	9%
Freeways	22,682,770	24,342,842	1,660,072	7%
HOV Lanes	120,706	148,004	27,298	23%
Streets	12,533,772	14,727,825	2,194,053	18%
Grand Total	**51,011,425**	**56,865,867**	**5,854,442**	**11%**

GHMS Corridor	2020 VMT	2050 VMT	Change	
			Number	Percent
Study Core	3,644,417	3,922,422	278,005	8%
North	2,840,837	3,094,170	253,333	9%
Northeast	1,122,507	1,274,958	152,451	14%
Southeast	355,511	441,725	86,214	24%
South	3,090,666	3,407,594	316,928	10%
Southwest	2,192,788	2,378,613	185,825	8%
Northwest	1,128,097	1,255,039	126,942	11%
GHMS Subtotal	**14,374,822**	**15,774,521**	**1,399,699**	**10%**
Rest of Region	36,636,605	41,091,344	4,454,740	12%
Grand Total	**51,011,427**	**56,865,865**	**5,854,438**	**11%**

Observations regarding total daily VMT:

- The increase in total vehicle miles of travel (VMT) of 11 percent is consistent with the growth in households, employment, and regional trip generation.
- The increase in VMT is greatest on HOV Lanes (23 percent) followed by Streets (18 percent), Arterials (13 percent), Freeway Ramps (9 percent), and Freeways (7 percent).
- Among the GHMS corridors the largest percent increase in VMT is expected in the Southeast Corridor but, in terms of total VMT, this is also the smallest of the corridors.
- The largest increase in VMT, among all the corridors, is expected in the South Corridor (316,928 / 10 percent) followed by the Study Core (278,005 / 8 percent), and the North Corridor (253,333 / 9 percent)

The bridges crossing the Connecticut River in the Study Core clearly play an important role in serving the mobility needs of travelers in the GHMS Study Area as well as the entire region.

Table 10: 2020 and 2050 Study Core Bridge Crossings Assignments

Bridge Crossings	Direction	2020 Daily Modeled	2050 Daily Modeled	Change		
				Number	Directional Percent	2-Way Percent
I-291	WB	37,674	42,609	4,936	13.1%	11.5%
	EB	33,694	36,986	3,292	9.8%	
I-84 Bulkeley Bridge	WB	70,995	74,048	3,053	4.3%	3.3%
	EB	73,988	75,719	1,730	2.3%	
Rt-2 Founders Bridge	WB	20,218	21,341	1,123	5.6%	5.3%
	EB	18,770	19,716	947	5.0%	
US-5 Charter Oak Bridge	WB	35,421	37,798	2,377	6.7%	15.0%
	EB	39,369	48,194	8,825	22.4%	
Rt3 Putnam Bridge	WB	35,154	41,690	6,536	18.6%	13.9%
	EB	32,932	35,866	2,935	8.9%	
All Bridges	**WB**	**199,462**	**217,486**	**18,024**	**9.0%**	**9.0%**
	EB	**198,753**	**216,482**	**17,729**	**8.9%**	

Observations regarding total daily flow on the Study Core bridges:

- Of the five bridges, the I-84 Bulkeley Bridge is the busiest, carrying on average almost 145,000 vehicles per day in 2020. Volume on this bridge is forecasted to increase approximately 3.3 percent (4,783 vehicles) by 2050 to almost 150,000 vehicles per day.
- While the Bulkeley Bridge is clearly the busiest, the bridges expected to see the greatest growth are the I-291, US-5 Charter Oak, and Rt3 Putnam bridges.
- Between 2020 and 2050 the I-291 Bridge is forecasted to experience more than an 11 percent increase (approximately 8,200 vehicles) in volume. In like manner, the Route 3 Putnam Bridge and the US-5 Charter Oak Bridge are also expected to experience double digit growth. All together these three bridges are forecasted to carry approximately 243,000 vehicles per day by 2050.
- The remaining bridge, the Route 2 Founders, is expected to see an increase in volume of over 5.0 percent to just over 41,000 vehicles per day.
- In total, traffic on the five bridges is expected to increase 9.0 percent between 2020 and 2050.

Transit Assignment

Transit assignment is the process of routing linked passenger trips, including all transit access and egress modes, over the available transit network. Transit assignment differs from highway assignment in that flow in the transit assignment reflects passengers, not vehicles. The impedance functions for transit include a larger number of level-of-service variables than the impedance function for highway, including in-vehicle time, wait time, walk access and egress time, auto access time, fare, and transfer activity. The path choice in transit assignment often has complex associated choices between competing routes, or between express and local service.

The CRCOG model uses a path-finder transit assignment methodology, a widely accepted approach that produces transit boardings and alightings by optimally seeking user path choices as influenced by transit level of service. The path builder finds multiple "efficient" paths through the transit network based on criteria such as walk time, drive time, wait time, transfer time, transfer penalties, egress time, and fare. The multipath method may include multiple paths for each interchange even if the alternate paths do not minimize total travel impedance. The inclusion or exclusion of alternate paths is based on a specified set of decision rules. This assignment procedure better captures ridership across competing routes. Transit assignment results are presented in ***Table 11: 2020 and 2050 Daily Transit Assignments.***

Table 11: 2020 and 2050 Daily Transit Assignments

Transit Mode	Daily Trips		Change	
	2020	2050	Number	Percent
The Hartford Line	1,989	2,716	727	37%
CT*fastrak* BRT	8,984	9,732	748	8%
Express Bus	3,007	3,466	459	15%
Local Bus	47,459	49,588	2,129	4%
Total	**61,439**	**65,502**	**4,063**	**7%**

Observations regarding the 2020 – 2050 change in transit ridership:

- Overall, transit ridership is expected to increase 7 percent between 2020 and 2050 which is somewhat less than the forecasted growth in households and employment.
- The largest percent increase in ridership (37 percent) is expected to be on The Hartford Line (commuter rail).
- The largest growth in riders (2,129) is expected to be on the local bus system. This represents 4 percent growth, less than the growth expected in households and employment.
- Ridership is forecasted to grow 15 percent on the express bus system and eight percent on the CTfastrak (BRT).

Travel Demand Model Updates

Updates made to the CRCOG TDM during the course of the Greater Hartford Mobility Study are listed below.

1. Graphical User Interface (GUI) Update
   - File name: 0_CRCOG_Main_GUI.rsc: Lines 9-11 & 72-132
   - CRCOG model GUI was reorganized so it looks more appealing.
   - The TransCAD version required for the model was specified.
2. Terminal Time – Highway Skimming
   - File name: 1b_HighwaySkimming.rsc: Lines 191-194 & 282-285
   - The terminal time matrix core index was "TAZ" based while the highway distance and travel time matrix indices are "ID" field based in the node layer. These two indices are inconsistent while 70% of zones have matching zone numbers from both indices.
   - Impact: Highway terminal time values were incorrectly added to the highway in-vehicle times for about 30% of total zones. Seventy percent of zones in the model region have matching numbers in both index number systems.
   - Fix: Highway skimming script "1b_HighwaySkimming.rsc" was updated for the zone number system that is consistent with node layer ID field for centroids. Lines 191-194 and 282-285 in the highway skimming script were revised to fix the issue.
   - Also, production end and attraction end terminal times were swapped while developing highway skims – production end terminal time was read as attraction end terminal time and vice versa. The highway skimming script lines 191-194 and 282-285 were updated to correct this issue.
3. Transit Skimming

   3.1 Wait Times
   - File name: 1d_TransitSkimming.rsc: Lines 48-49
   - Minor change to wait time calculations. Results should not change from the prior version.

   3.2 PNR Lots
   - File name: 1d_TransitSkimming.rsc: Lines 218-221
   - Park and Ride Lots specification was updated in the highway network node layer. Transit skimming script was updated so it reads correct PNR lots for each transit mode.

   3.3 Skimming Parameters
   - File name: 1d_TransitSkimming.rsc: Lines 242
   - Mode to mode transfer penalty is now used.
   - File name: 1d_TransitSkimming.rsc: Lines 252
   - Global transfer wait time parameter changed to 2.50
4. Mode Choice

   4.1 Non-Motorized Travel Distance
   - 3b_ModeChoicePreparation.rsc: Lines 47-48, 94-95, 101-102, 326-341, 364-379
   - The issue was that the time coefficients were applied to distances in utility calculations for two non-motorized mode choice alternatives: walk and bike.
   - GISDK code was revised to convert walk and bike distances to time values to use in mode choice calculations.

4.2 Parking Cost

- File name: 3c_ModeChoiceLogsums.rsc: Lines 229, 243, 322
- Parking cost variable name in the TAZ layer was changed to 'ParkingCost' from 'WORK PARK $'. 'NONWORK PARK $' variable was removed from the TAZ layer as it wasn't used in the model. Model code was updated accordingly.
- CBD Parking Cost was reduced from $31.00 to $9.00.

4.3 Access Drive Distance

- File name: 3c_ModeChoiceLogsums.rsc: Line 318
- Access drive distance value should be used in the mode choice utility calculations. Earlier access drive time value was used.

4.4 KNR Drive Cost

- File name: 3c_ModeChoiceLogsums.rsc: Line 573
- This change was required due to the code updates described in section 4.1 above. Kiss and Ride drive cost parameter no longer needed factoring.

5. Highway Assignment – SOV/HOV

- File name: 5b_HighwayAssignment.rsc: Line 47
- The problem was that SOV trips were getting assigned to HOV links during the highway assignment. There was a bug in the code where HOV links were supposed to be excluded from the SOV trip assignment, but it wasn't the case.
- Model code was revised to fix this issue and SOV trips are no longer assigned to HOV facilities.

6. TransCAD Version

- Model code was updated to run with TransCAD version 8. The model previously ran with TransCAD version 6.

7. Transit Route System Coding

- Route 30 (Bradley Flyer) was simplified so that only one northbound and one southbound route are active in the network. 2020 headway is 40 minutes. 2050 headway is 30 minutes.
- Route 903/913 one park and ride lot was made available to route 903.
- Route 950 changes to two park and ride lots so that riders can access route 950.
- Transit route system: Several changes were made in the route system layer.
- 'Mode' variable was updated with mode codes for several routes including CT*fastrak*.
- 'FARE' – transit route level fares were updated.
- 'AM_HDWY' & 'MD_HDWY' – AM peak and Midday period headways were updated for many routes
- Two routes were added. AHS-R and route 913 & 913-R.
- ModeTable.bin in the modechoice directory was revised. BRT mode code was updated for consistency purposes – no impact on results due to this change.
- mode_xfer.bin file with revised transfer penalties and transfer fares. Additional rows were inserted to include all mode-to-mode combinations. Transfer time weight was also changed to 2.5.
- mode_choice_parameters.csv: mode choice parameters after calibration.

8. TAZ Layer Coding

- The 'WORK PARK $' variable was renamed to 'ParkingCost' and 'NONWORK PARK $' variable was deleted. See item 4.2 above.

9. Highway Node Layer Coding
   - Node layer was edited with PNR lot specification. PARK variable description shows types of PNR lots as follows:
     1- local bus
     2- local and express bus
     3- local bus, express bus, bus rapid transit, and commuter rail
     4- bus rapid transit
     5- express bus
     6- commuter rail

Estimating No-Build Volumes and Speeds

Scaling TDM Outputs

For the purposes of traffic analysis, the most relevant TDM outputs are traffic volume and congested speed, represented in the model as link flow and loaded speed, respectively. While it is possible to directly use the TDM outputs without scaling, the model is only an abstraction of the real-world road network, and better results are obtained when the TDM is used to supplement actual measurements, rather than to replace them. There are three simple methods that are commonly used for this purpose: the ratio method, the difference method, and the combination method.

Ratio Method

The ratio method looks at the proportional increase or decrease in a TDM output, then applies that same proportion to existing real-world data to arrive at an estimated future metric. For example, if actual existing speeds are 20 mph, the existing (2020) TDM shows a speed of 24 mph, and the no-build (2050) TDM shows a speed of 18 mph, the proportion 18/24 (75%) is applied to the existing 20 mph, resulting in an estimated future speed of 15 mph. The ratio method can be applied to traffic volume or travel speed.

$$\frac{2050\ estimated\ speed}{2020\ actual\ speed} = \frac{2050\ modeled\ speed}{2020\ modeled\ speed}$$

And thus:

$$2050\ estimated\ speed = 2020\ actual\ speed * \left(\frac{2050\ modeled\ speed}{2020\ modeled\ speed}\right)$$

Difference Method

The difference method is similar to the ratio method, but instead of multiplying the proportional increase or decrease in a metric by the actual measured data, it simply adds the difference to the actual measured data. For example, if a road carries 650 vehicles per hour in real life, the existing (2020) TDM shows a link flow of 400 vph, and the no-build (2050) TDM shows a link flow of 440 vph, the modeled increase in traffic (40 vph) is added to the existing count, resulting in an estimated 2050 volume of 690 vph. This method is applicable to traffic volumes and is especially useful when considering the impact of a proposed development on traffic patterns. However, if the model is not a good match for the real-world road network, it is possible to end up with negative volumes using the difference method.

$$2050\ estimated\ volume - 2020\ actual\ volume = 2050\ modeled\ volume - 2020\ modeled\ volume$$

And thus:

$$2050\ estimated\ volume = (2050\ modeled\ volume - 2020\ modeled\ volume) + 2020\ actual\ volume$$

Combination Method

The two aforementioned techniques each have their advantages and limitations. They are frequently used together in the combination method, which takes the results from the ratio method and difference method and averages them. The resulting equation, while a bit cumbersome, can be implemented in a single spreadsheet cell and rapidly applied to every link:

$$2050\ estimated\ volume = \frac{2020\ actual\ volume * \left(1 + \frac{2050\ modeled\ volume}{2020\ modeled\ volume}\right) + 2050\ modeled\ volume - 2020\ modeled\ volume}{2}$$

For the Greater Hartford Mobility Study, TDM-derived loaded speeds were scaled with the ratio method to produce 2050 no-build estimated speeds, and TDM-derived link flows were scaled with the combination method to produce 2050 no-build estimated volumes.

Time Periods

TDM outputs are produced for four time periods: morning peak (AM), mid-day (MD), evening peak (PM), and overnight (NT). The two most relevant time periods for traffic analysis, AM and PM, are each modeled as 3 hours long. In order to derive hourly volumes from these 3-hour periods, it was assumed that the peak hour would represent the same proportion of the peak period in both the existing (2020) and no-build (2050) scenarios. In mathematical terms:

$$\frac{2020\ peak\ hour}{2020\ peak\ period} = \frac{2050\ peak\ hour}{2050\ peak\ period}$$

And thus:

$$2050\ peak\ hour = 2050\ peak\ period * \left(\frac{2020\ peak\ hour}{2020\ peak\ period}\right)$$

For average vehicular speeds, the TDM outputs were scaled using the ratio method as described above. The 2020 actual speed used in the equation was the lowest hourly average speed during the peak period. This means that the output, 2050 estimated speed, is already a representation of the most congested hour and does not need to be adjusted any further.

Important Considerations

A key assumption in this process is that future hourly traffic patterns will continue to match existing hourly traffic patterns. In reality, congested roads will tend to exhibit peak spreading, where increases in traffic volumes occur before and after the peak hour. Conversely, when capacity is added and congestion is reduced, traffic from other parts of the day may move their trips to the peak hour. Performing a finer-grained demand analysis using a tool such as dynamic traffic assignment could potentially provide more accurate results, but at the expense of a much greater amount of data input and calibration.

For the purposes of the 2050 no-build analysis, these approximations are sufficient to estimate traffic flow at a regional scale. The evaluation of individual build alternatives may require a more detailed travel demand analysis.

Manual Adjustments

Estimated 2050 traffic volumes and speeds were reviewed to flag anomalously high or low values. These can arise due to differences between the TDM and the real-world road network and are very rare, generally only occurring when there are major changes to the road network, such as new interchanges or widening.

These flagged volumes and speeds were manually adjusted to appropriate values. Average speeds were limited to the measured 2020 free-flow speed plus five mph. This approach can be re-evaluated for potential build scenarios where free-flow speed is expected to significantly increase.

2050 No-Build Traffic Operations

Changes in Traffic Volumes

The road network has only minor changes between 2020 and the 2050 No-Build. Demographic changes are also relatively small, with a 12.3% increase in households and employment, as shown in Table 1, page 2. Correspondingly, most road segments are projected to experience a modest increase in peak period traffic volumes between 2020 and 2050, shown in Table 9, page 15.

On freeways, which experience significant recurring congestion during peak periods, increases in traffic volumes are typically 5-10%. Heavily congested locations, like I-84 in Hartford, are expected to experience growth below 5%, while outlying area that currently operate below capacity, such as I-84 in Vernon, are expected to see peak period growth of 10-20%.

On non-freeways, traffic growth is generally higher, with 10-15% increases in peak period traffic common. Generally, these roads show the same pattern as the freeways – in dense urban areas, growth is lower, while it can be much higher in outlying areas where ample capacity is available.

Changes in Travel Speeds

If road capacity is not increased, then increases in traffic volumes tend to result in decreases in travel speed. The relationship between volume and speed is nonlinear: on a road that operates far below capacity, a small increase in volume will have little effect on speeds, but on a road operating close to capacity, the same small volume increase will have a much larger impact.

A change in road capacity, such as adding or removing lanes or traffic signals, can also result in a dramatic change in speeds. TransCAD predicts that adding auxiliary lanes on I-84 in West Hartford and the I-91 NB improvements in Hartford's South Meadows will result in an increase in average speeds on those segments of both interstates.

Priority Corridors (I-84, I-91, and Route 2) are forecast to experience the following changes in speed between 2020 and the 2050 No-Build:

Table 12: Priority Corridor Speed Change 2020 to 2050

Study Corridor	Routes	AM Peak	PM Peak
Study Core	I-84, I-91, Route 2	-5.0%	-7.3%
North	I-91	-5.2%	-7.6%
Northeast	I-84	-6.4%	-8.1%
Southeast	Route 2	-9.8%	-9.6%
South	I-91	-8.5%	-10.4%
Southwest	I-84	-4.6%	-8.7%
Full Study Area	**I-84, I-91, Route 2**	**-5.8%**	**-8.0%**

These travel speed changes are averaged throughout the study corridor and include both directions of freeway travel. The average speeds drop by 4-11% depending on time period and direction, with an average of 5.8% in the morning peak and 8.0% in the evening peak. Speeds drop by the largest amount in the Northeast, Southeast, and South Study Corridors, which are anticipated to have the largest growth in trips, as shown in Table 12.

Priority Corridors

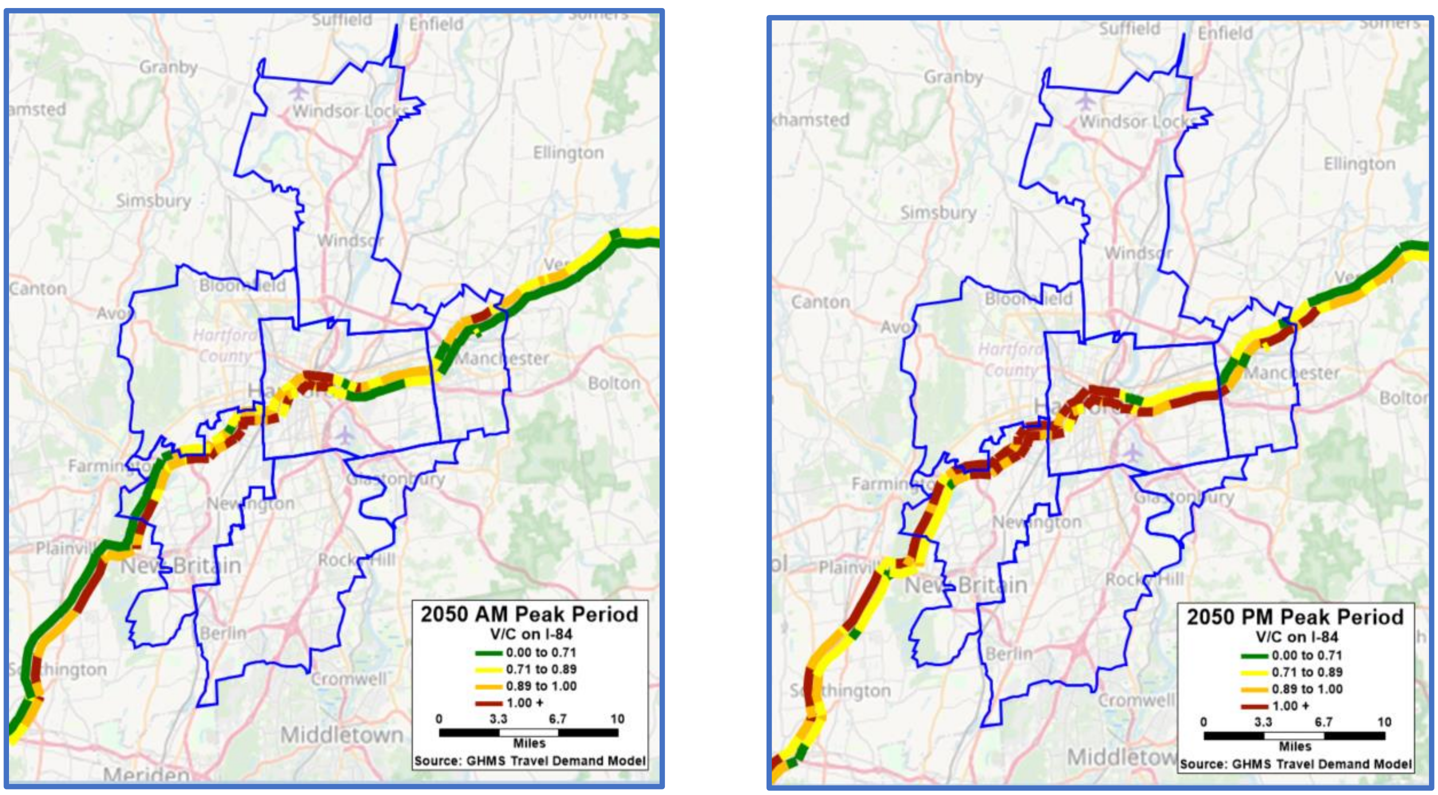
Interstate 84

I-84 is expected to see a modest increase in peak-period congestion by 2050. In areas with upcoming auxiliary lane projects, such as West Hartford and Manchester, speeds are projected to increase, partially offsetting the general slowdown throughout the rest of the study area. The general congestion trend will remain the same, with congestion highest in the morning heading towards Hartford and congestion highest in the evening departing Hartford. Travel times through the Study Area are forecast to increase as follows:

Table 13: 2050 No-Build Travel Time (% increase over 2020)

Direction	AM Peak	PM Peak
I-84 Eastbound	31.6 minutes (+4%)	40.0 minutes (+7%)
I-84 Westbound	27.6 minutes (+7%)	36.7 minutes (+9%)

Figure 6: Peak Period Distributions on I-84 (AM and PM)



A few segments of I-84 within the Study Area are projected to reach their capacity by 2050, while the aforementioned auxiliary lane projects are expected to improve operations on others. The overall result is a moderate increase in congestion on an already congested route.

Table 14: 2050 No-Build Volume to Capacity Ratio (V/C), Change from 2020

I-84 Vehicle Miles Traveled (VMT) X V/C				
V/C	**AM Peak**		**PM Peak**	
	VMT	**Percent**	**VMT**	**Percent**
VOC LE 0.71	-12,159	-5.2%	-33,438	-27.1%
VOC 0.71 to 0.89	-72,720	-25.5%	-18,868	-6.0%
VOC 0.89 to 1.00	71,453	51.5%	15,777	10.4%
VOC 1.00 +	66,789	49.8%	97,215	32.2%
Total	**53,363**	**6.7%**	**60,686**	**6.8%**

Source: GHMS Travel Demand Model

Figure 7: 2050 No-Build, I-84 Speed Maps

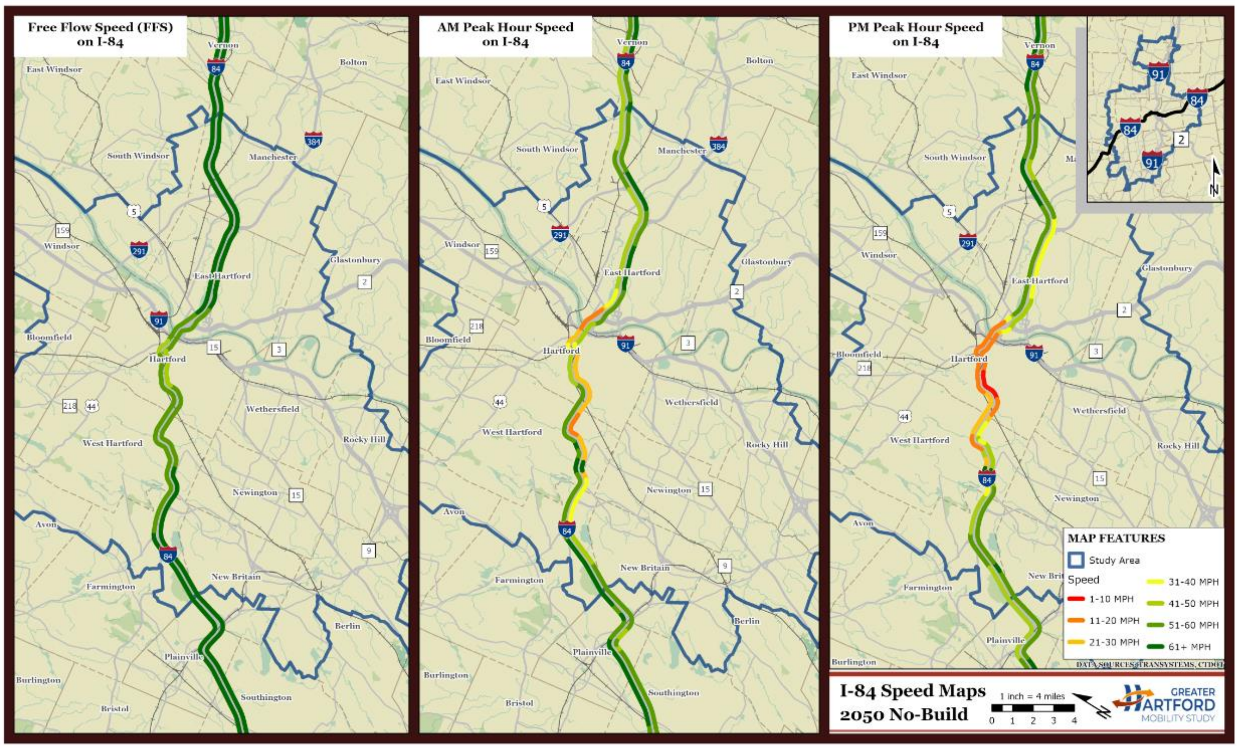
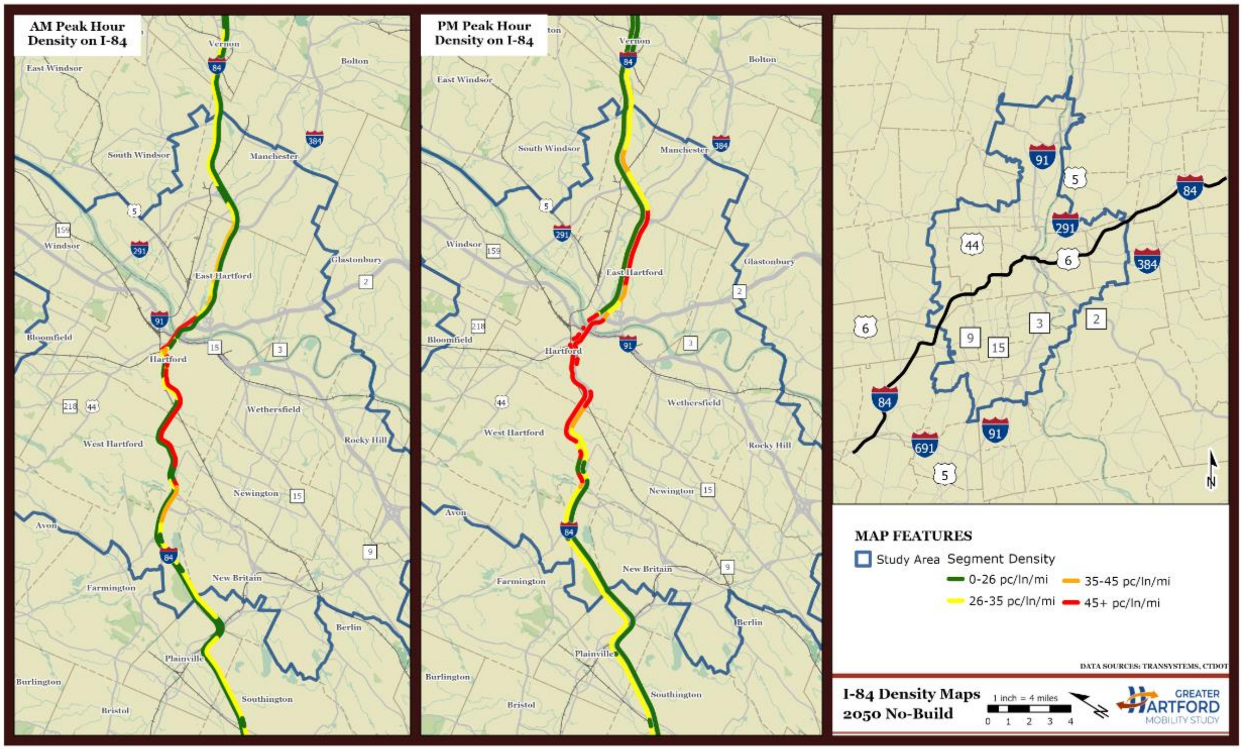


Figure 8: 2050 No-Build, I-84 Density Maps



Interstate 91

I-91 is expected to see a modest increase in peak-period congestion by 2050. This increase occurs throughout the study area, with the exception of I-91 Northbound in Hartford's South Meadows, where the recently completed Interchange 29 project has greatly reduced delays. The general congestion trend will remain the same, with congestion highest in the morning heading towards Hartford and congestion highest in the evening departing Hartford. Travel times through the Study Area are forecast to increase as follows:

Table 15: 2050 No-Build Travel Time (% increase over 2020)

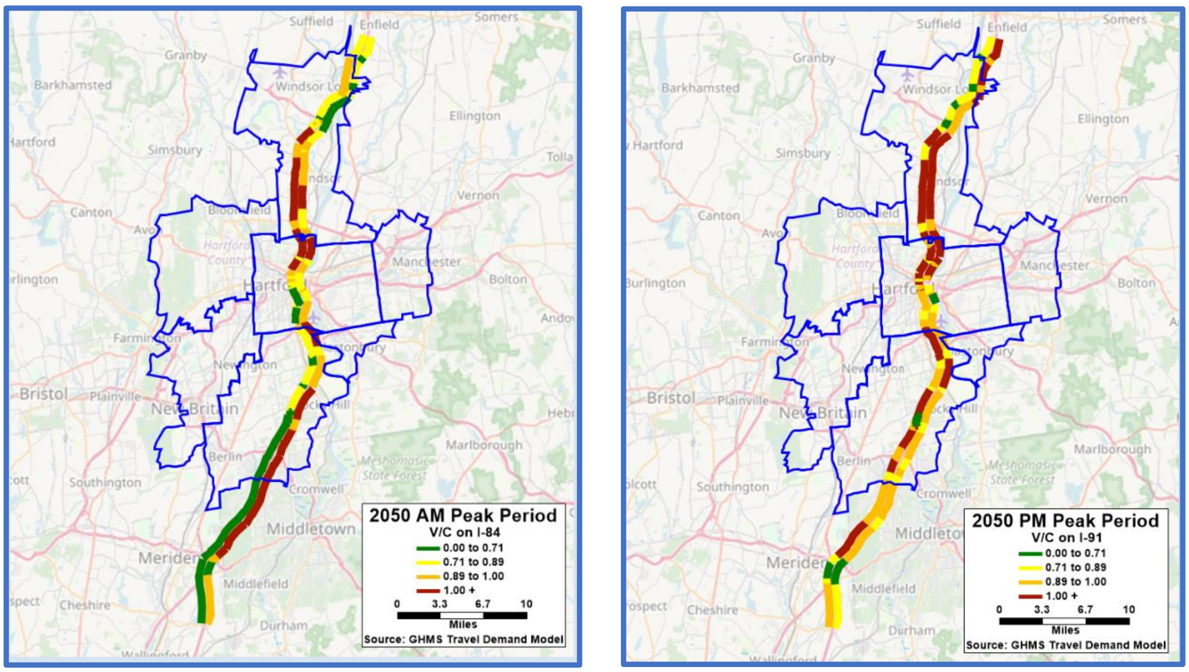
	AM Peak	PM Peak
I-91 Northbound	35.3 minutes (+2%)	38.0 minutes (+7%)
I-91 Southbound	39.5 minutes (+9%)	48.4 minutes (+8%)

Table 16: 2050 No-Build Volume to Capacity Ratio (V/C), Change from 2020

I-91 Vehicle Miles Traveled (VMT) X V/C				
V/C	AM Peak		PM Peak	
	VMT	Percent	VMT	Percent
VOC LE 0.71	-10,752	-6.4%	-48,018	-54.9%
VOC 0.71 to 0.89	-18,204	-8.4%	-25,587	-10.3%
VOC 0.89 to 1.00	-43,404	-19.0%	5,096	1.9%
VOC 1.00 +	114,407	60.0%	124,022	42.9%
Total	**42,047**	**5.2%**	**55,513**	**6.2%**

Source: GHMS Travel Demand Model

Figure 9: Peak Period Distributions on I-91 (AM and PM)



Several segments of I-91 are anticipated to reach capacity by 2050. Most of these segments are in Windsor, Wethersfield, and Rocky Hill.

Figure 10: 2050 No-Build, I-91 Speed Maps

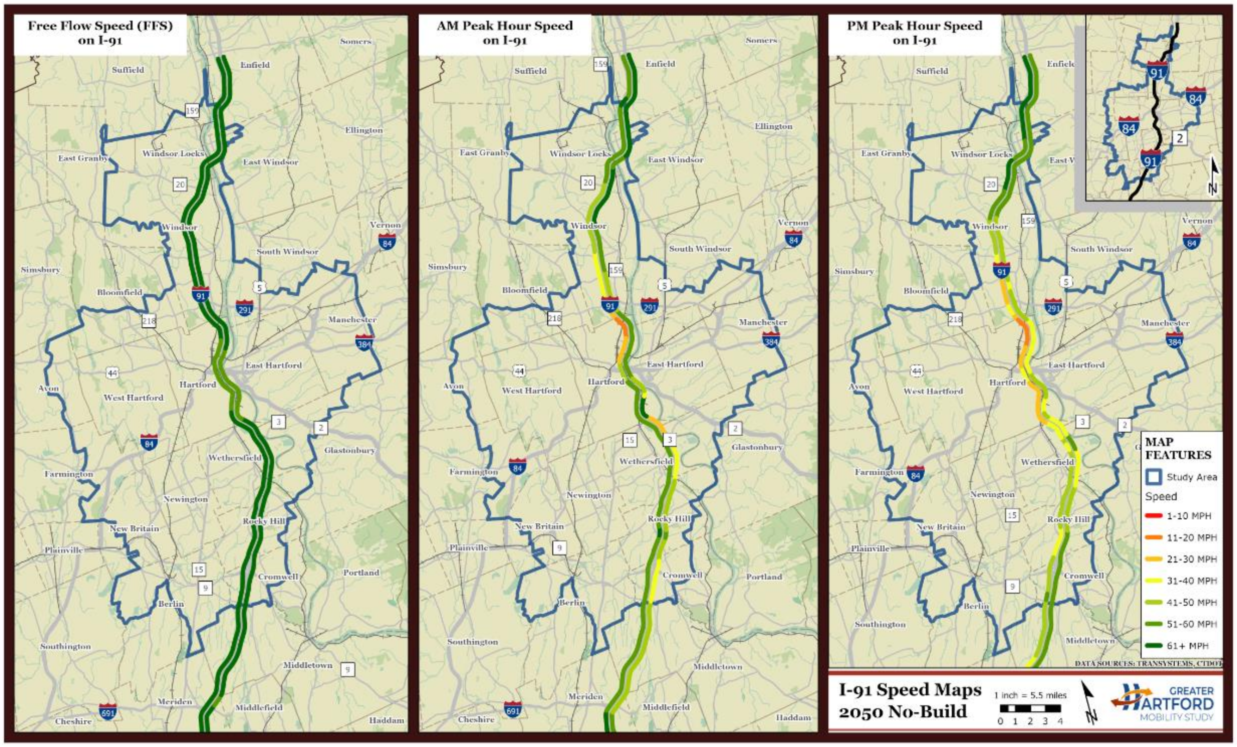
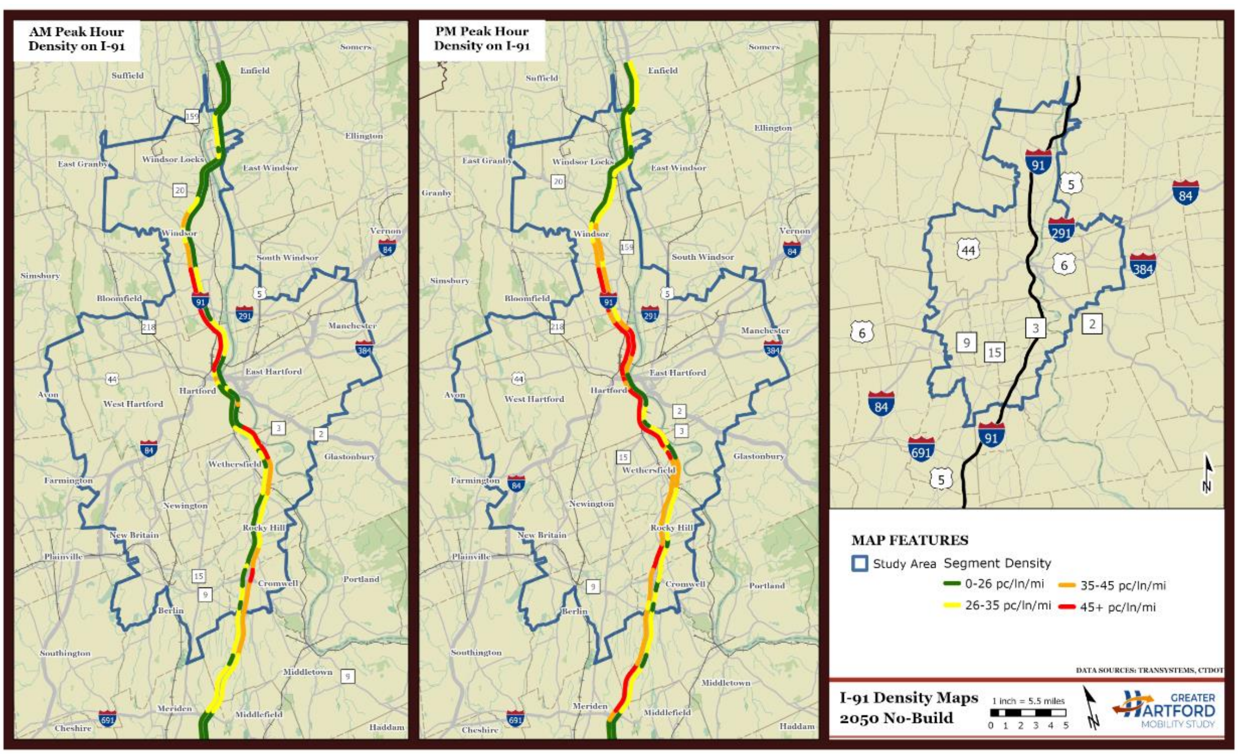


Figure 11: 2050 No Build, I-91 Density Maps



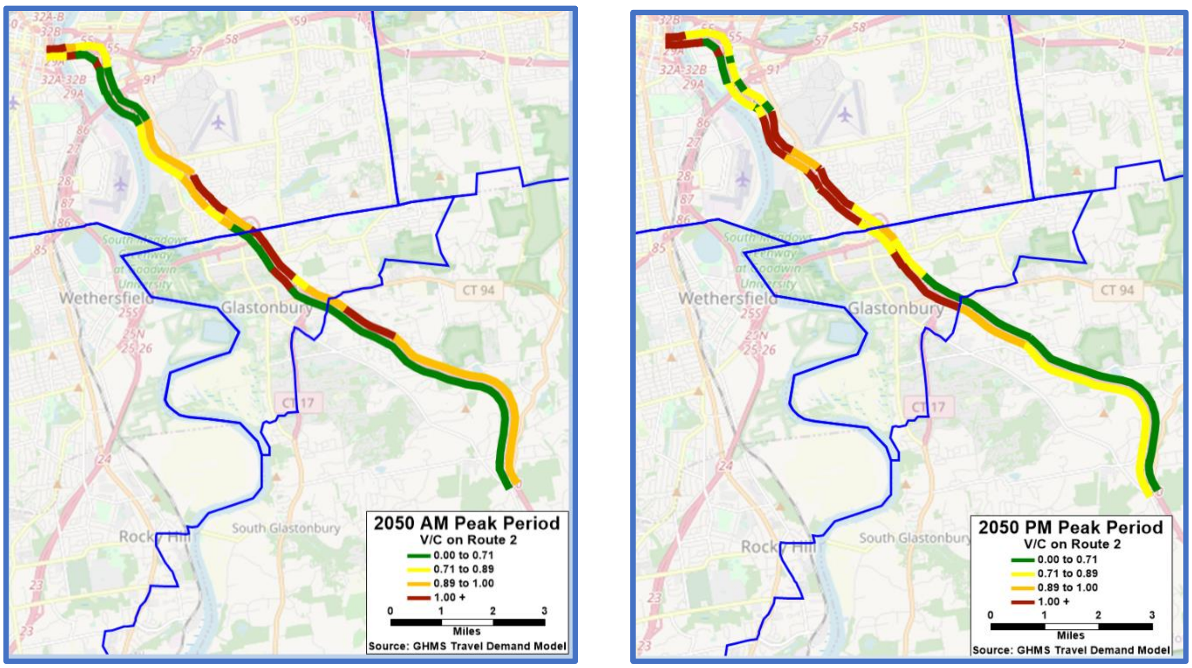
CT Route 2

Route 2 is expected to see a moderate increase in peak-period congestion by 2050. The general congestion trend will remain the same, with westbound congestion highest in the morning and eastbound congestion highest in the evening. Travel times through the Study Area are forecast to increase as follows:

Table 17: 2050 No-Build Travel Time (% increase over 2020)

	AM Peak	PM Peak
Route 2 Eastbound	6.8 minutes (+33%)	10.4 minutes (+13%)
Route 2 Westbound	12.2 minutes (+7%)	10.0 minutes (+9%)

Figure 12: Peak Period Distributions on Route 2 (AM and PM)



Several segments of Route 2 are projected to reach their capacity by 2050, especially Route 2 Westbound in Glastonbury.

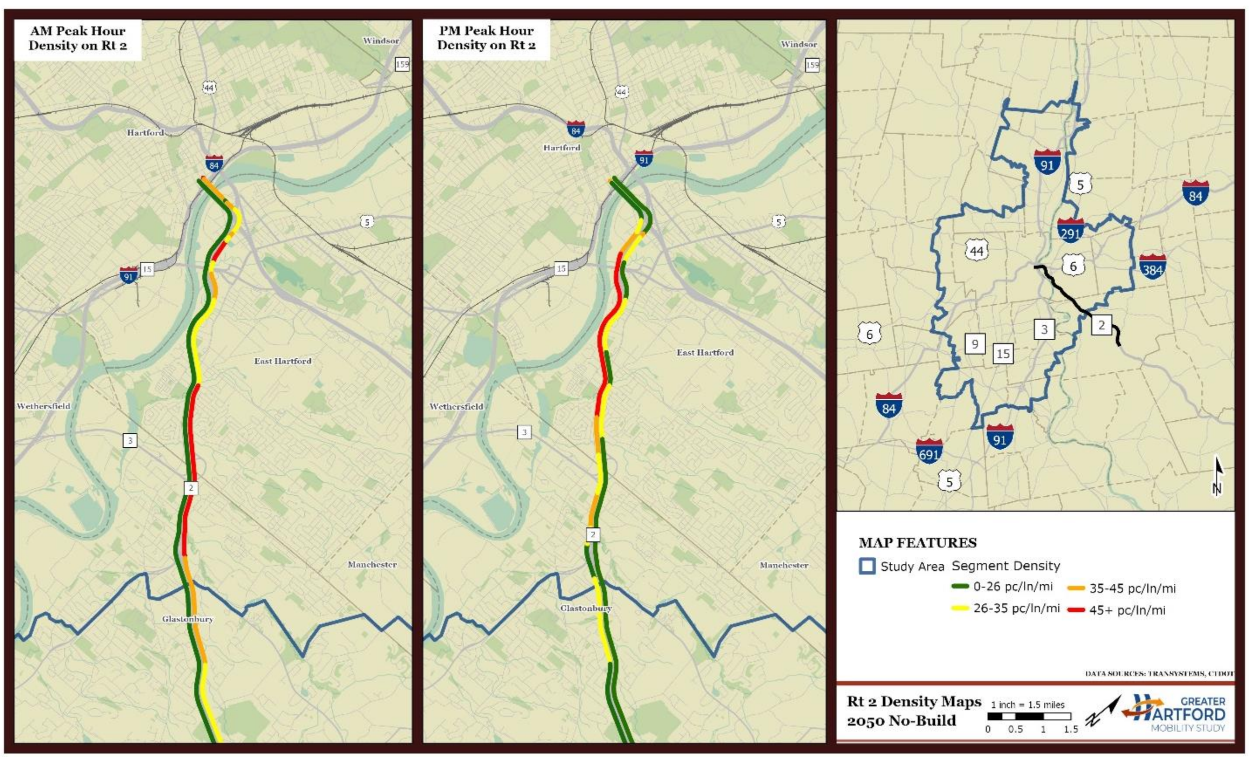
Figure 13: 2050 No-Build Volume to Capacity Ratio (V/C), Change from 2020

Route 2 Vehicle Miles Traveled (VMT) X V/C				
V/C	AM Peak		PM Peak	
	VMT	Percent	VMT	Percent
VOC LE 0.71	2,157	6.8%	-187	-0.6%
VOC 0.71 to 0.89	-3,466	-15.1%	4,933	9.6%
VOC 0.89 to 1.00	-9,805	-19.6%	-5,216	-37.9%
VOC 1.00 +	20,856	267.5%	9,989	33.3%
Total	**9,743**	**8.7%**	**9,519**	**7.5%**

Source: GHMS Travel Demand Model

Figure 14: 2050 No Build, Route 2 Speed Maps

Figure 15: 2050 No-Build, Route 2 Density Maps



Contributing Corridors

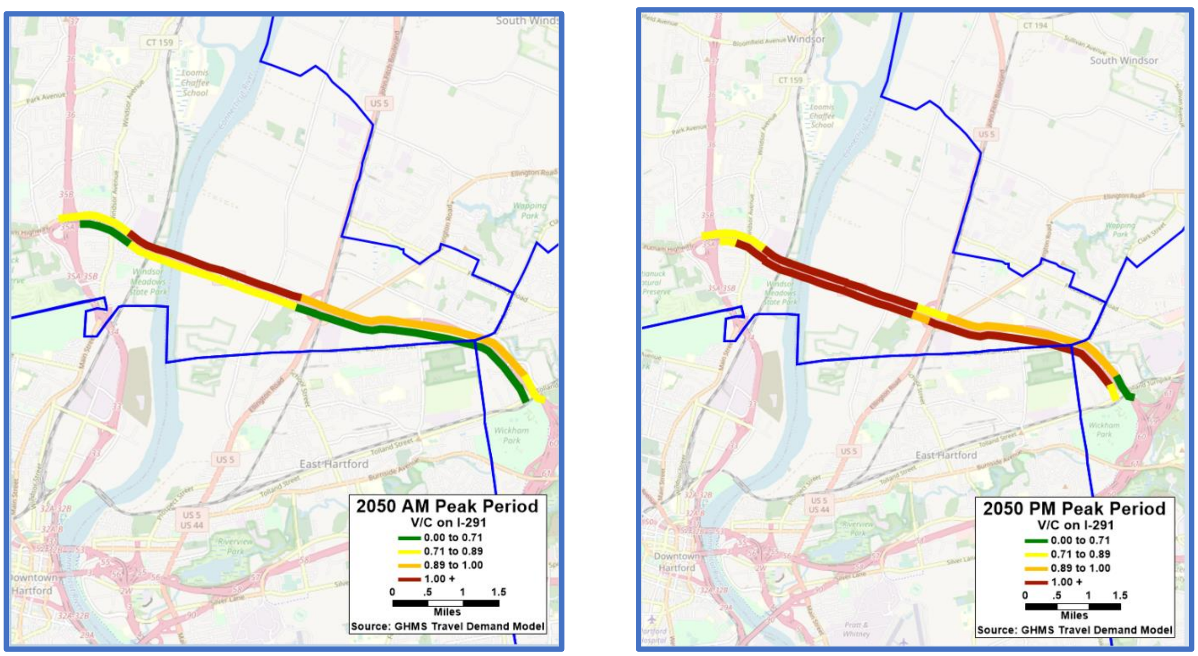
Interstate 291

I-291 is expected to see a large increase in peak-period congestion by 2050. This is a continuation of a decades-long trend of traffic taking circumferential routes to avoid Hartford. The increase occurs all along I-291. The general congestion trend will remain the same, with westbound congestion highest in the morning and eastbound congestion highest in the evening. Travel times through the Study Area are forecast to increase as follows:

Table 18: 2050 No-Build Travel Time (% increase over 2020)

	AM Peak	PM Peak
I-291 Eastbound	6.1 minutes (+3%)	9.4 minutes (+12%)
I-291 Westbound	8.2 minutes (+18%)	6.5 minutes (+16%)

Figure 16: Peak Period Distributions on I-291 (AM and PM)



All segments of I-291 are expected to see higher volume-to-capacity ratios by 2050, especially in the PM peak period. Nearly the entire length of I-291 Eastbound is forecast to reach capacity during the PM peak.

Table 19: 2050 No-Build Volume to Capacity Ratio (V/C), Change from 2020

I-291 Vehicle Miles Traveled (VMT) X V/C				
V/C	**AM Peak**		**PM Peak**	
	VMT	**Percent**	**VMT**	**Percent**
VOC LE 0.71	-10,176	-45.3%	-2,932	-61.5%
VOC 0.71 to 0.89	-4,328	-21.3%	5,792	32.7%
VOC 0.89 to 1.00	19,188	0.0%	-21,505	-93.7%
VOC 1.00 +	2,315	13.2%	26,627	72.6%
Total	**6,999**	**11.6%**	**7,982**	**9.7%**

Source: GHMS Travel Demand Model

Figure 17: 2050 No Build, I-291 Speed Maps

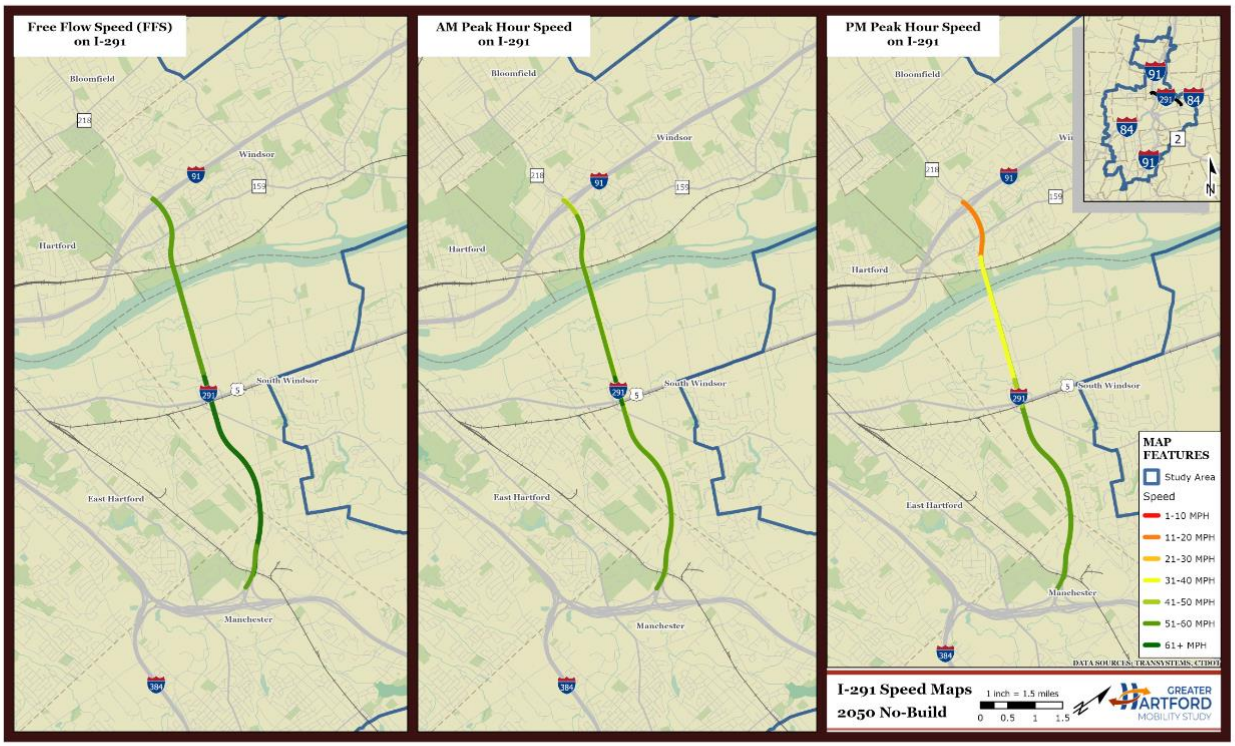
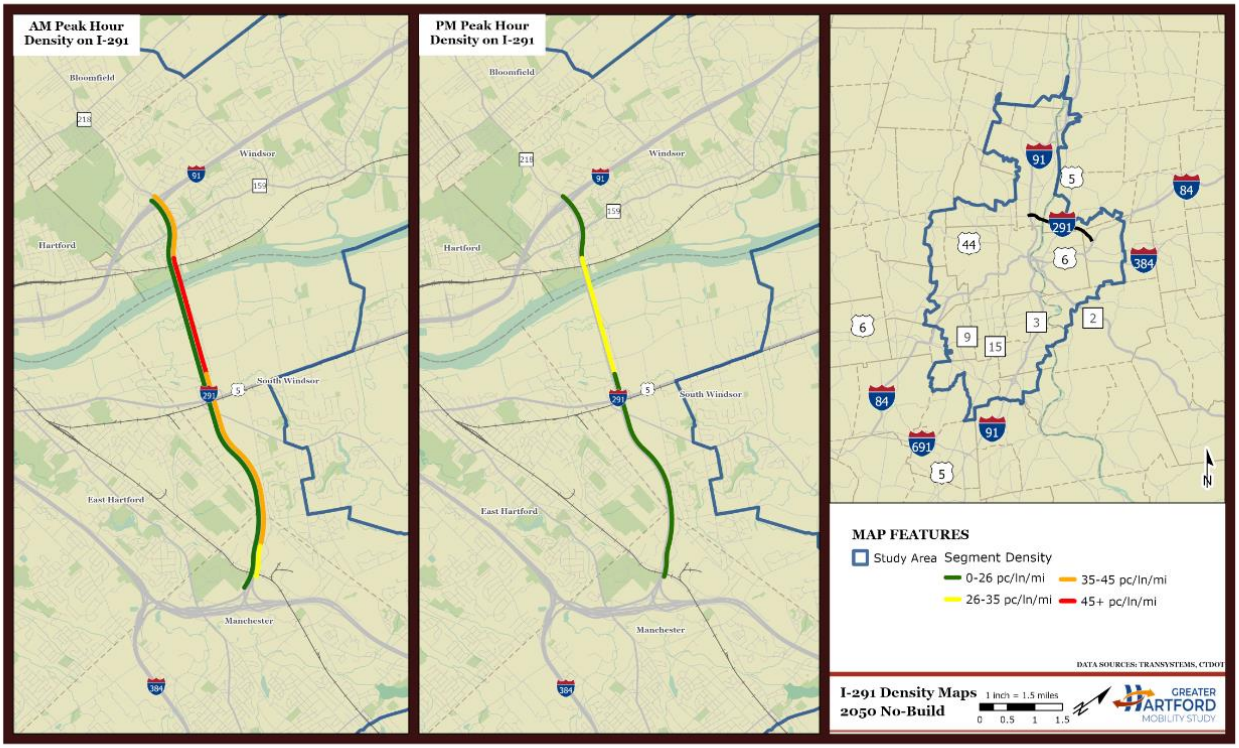


Figure 18: 2050 No-Build, I-291 Density Maps



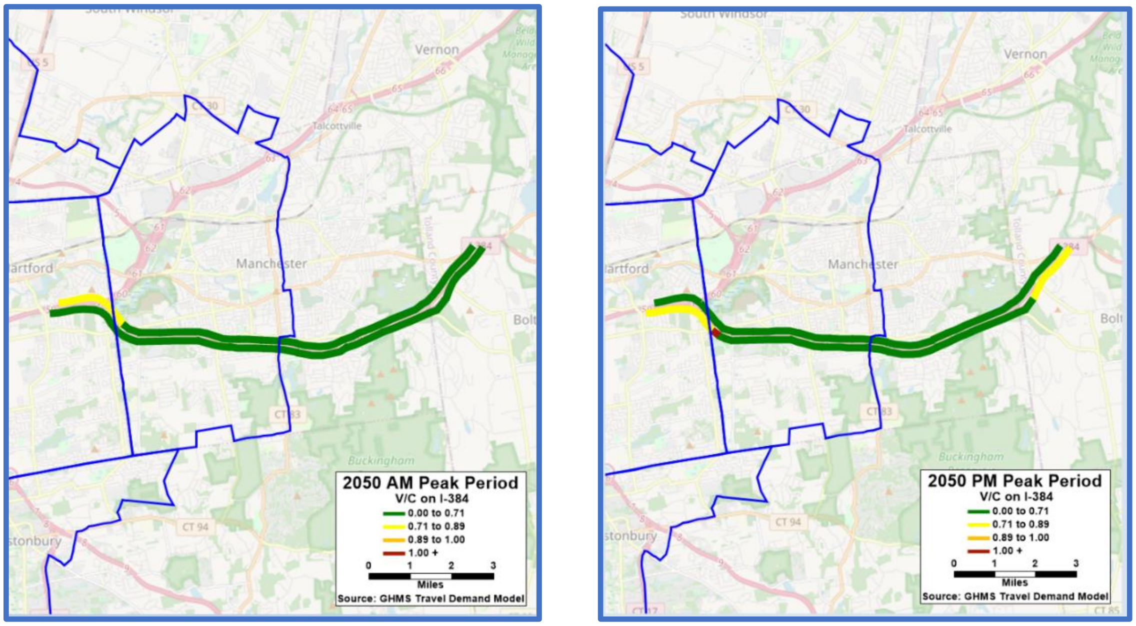
Interstate 384

I-384 is not expected to experience any significant congestion by 2050. Speeds are expected to decrease by a small proportion, but travel is generally close to free-flowing in both directions and peaks. Travel times through the Study Area are forecast to increase as follows:

Table 20: 2050 No-Build Travel Time (% increase over 2020)

	AM Peak	PM Peak
I-384 Eastbound	8.5 minutes (+1%)	8.9 minutes (+7%)
I-384 Westbound	8.3 minutes (+6%)	7.9 minutes (+2%)

Figure 19: Peak Period Distributions on I-384 (AM and PM)



Even with increases in traffic, I-384 is expected to operate well below capacity in 2050.

Figure 20: 2050 No-Build Volume to Capacity Ratio (V/C), Change from 2020

I-384 Vehicle Miles Traveled (VMT) X V/C				
V/C	AM Peak		PM Peak	
	VMT	Percent	VMT	Percent
VOC LE 0.71	8,615	11.9%	1,110	1.2%
VOC 0.71 to 0.89	3,246	66.4%	10,777	214.9%
VOC 0.89 to 1.00	0	0.0%	0	0.0%
VOC 1.00 +	0	0.0%	73	8.5%
Total	**11,861**	**15.3%**	**11,960**	**12.3%**

Source: GHMS Travel Demand Model

Figure 21: 2050 No-Build, I-384 Speed Maps

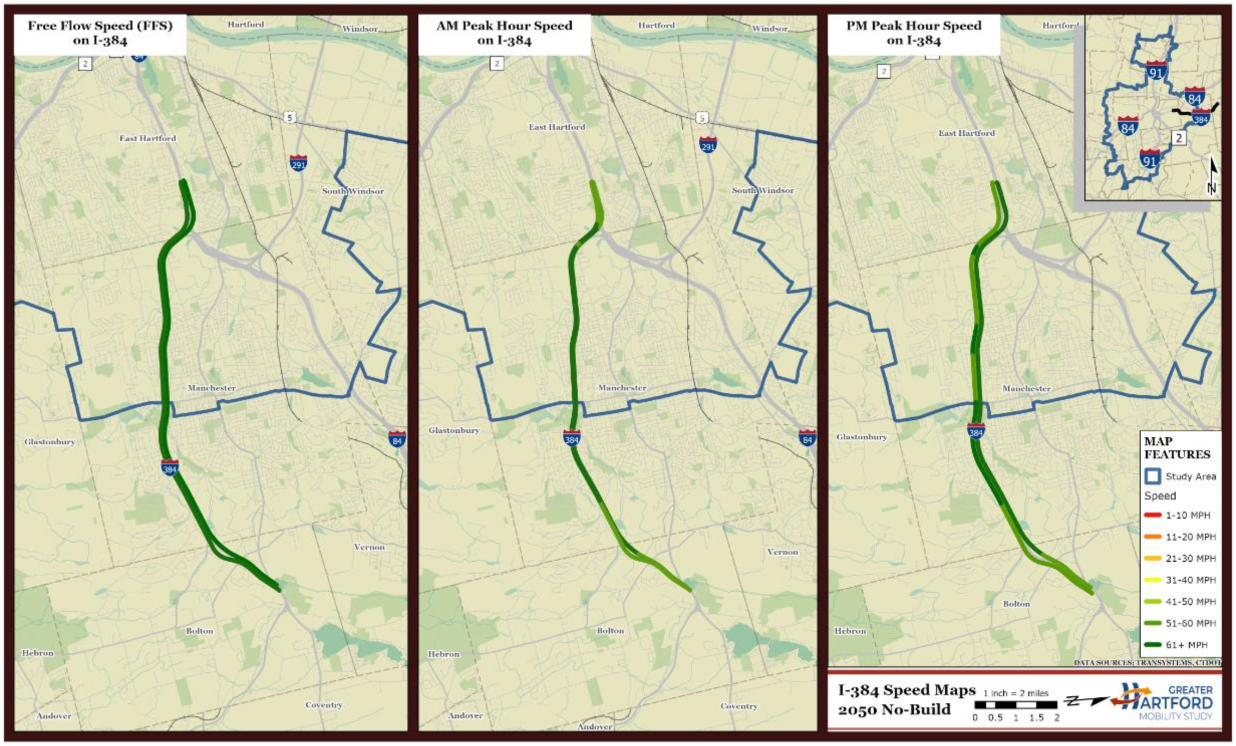
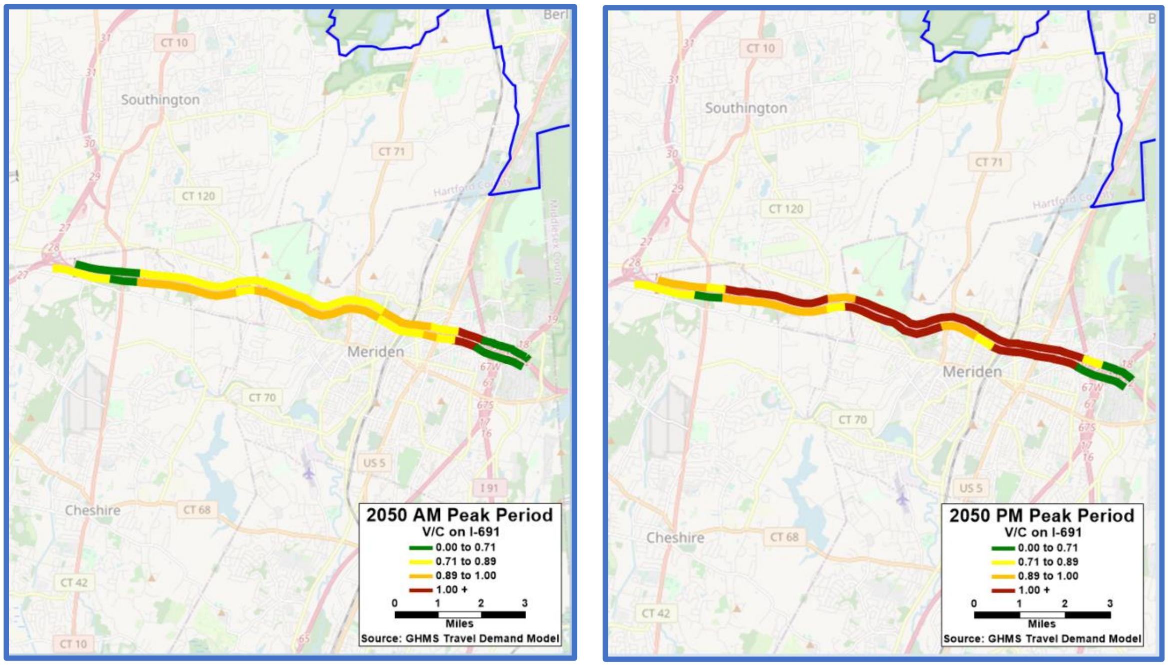


Figure 22: 2050 No-Build, I-384 Density Maps

Interstate 691

I-691 is entirely outside the Study Area, so travel times are not provided. However, it is clear that increased volumes will result in slower speeds and higher densities by 2050. The general congestion trend will remain the same, with eastbound congestion highest in the morning and westbound congestion highest in the evening.

Figure 23: Peak Period Distributions on I-691 (AM and PM)



Volume-to-capacity ratios are expected to increase substantially by 2050, especially during the PM peak. Nearly all of I-691 in Meriden will reach capacity during the evening peak in 2050.

Table 21: 2050 No-Build Volume to Capacity Ratio (V/C), Change from 2020

I-691 Vehicle Miles Traveled (VMT) X V/C				
V/C	**AM Peak**		**PM Peak**	
	VMT	**Percent**	**VMT**	**Percent**
VOC LE 0.71	-2,696	-16.2%	566	8.1%
VOC 0.71 to 0.89	-10,002	-16.7%	-7,495	-34.4%
VOC 0.89 to 1.00	15,669	76.1%	-32,765	-54.0%
VOC 1.00 +	3,599	101.2%	47,090	163.6%
Total	**6,570**	**6.5%**	**7,397**	**6.3%**

Source: GHMS Travel Demand Model

Figure 24: 2050 No-Build, I-691 Speed Maps

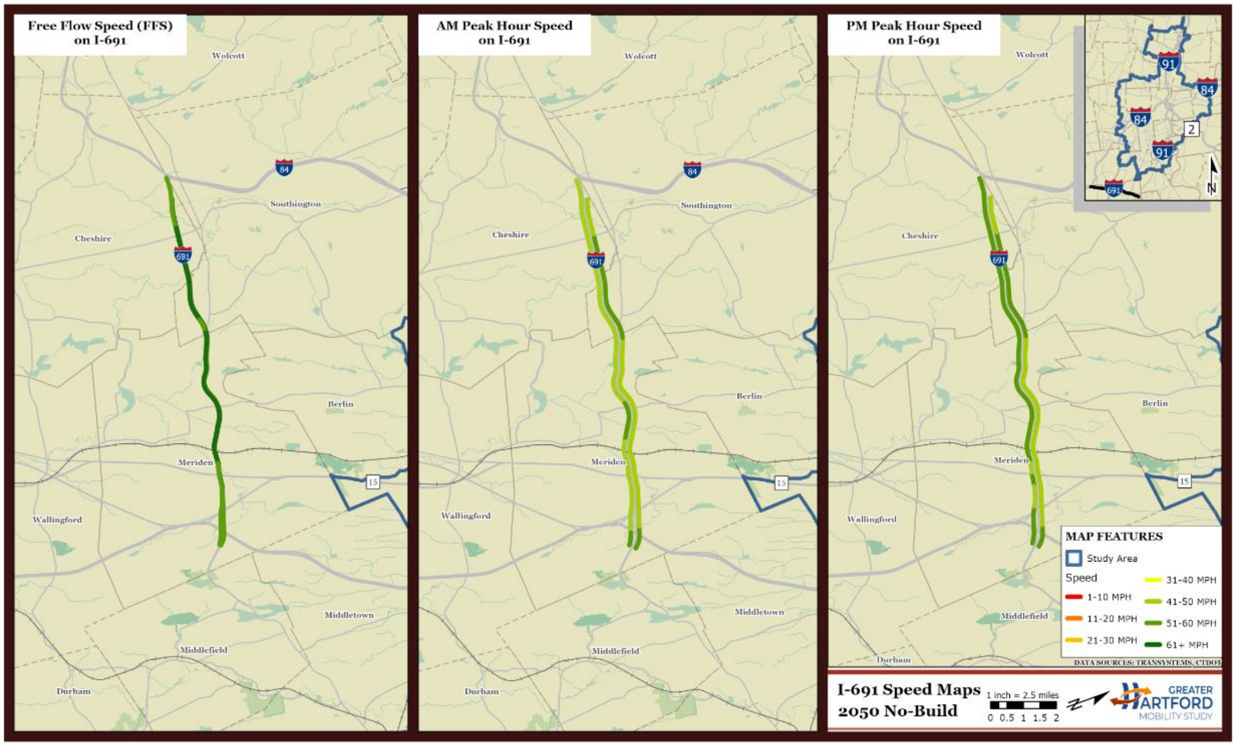


Figure 25: 2050 No-Build, I-691 Density Maps

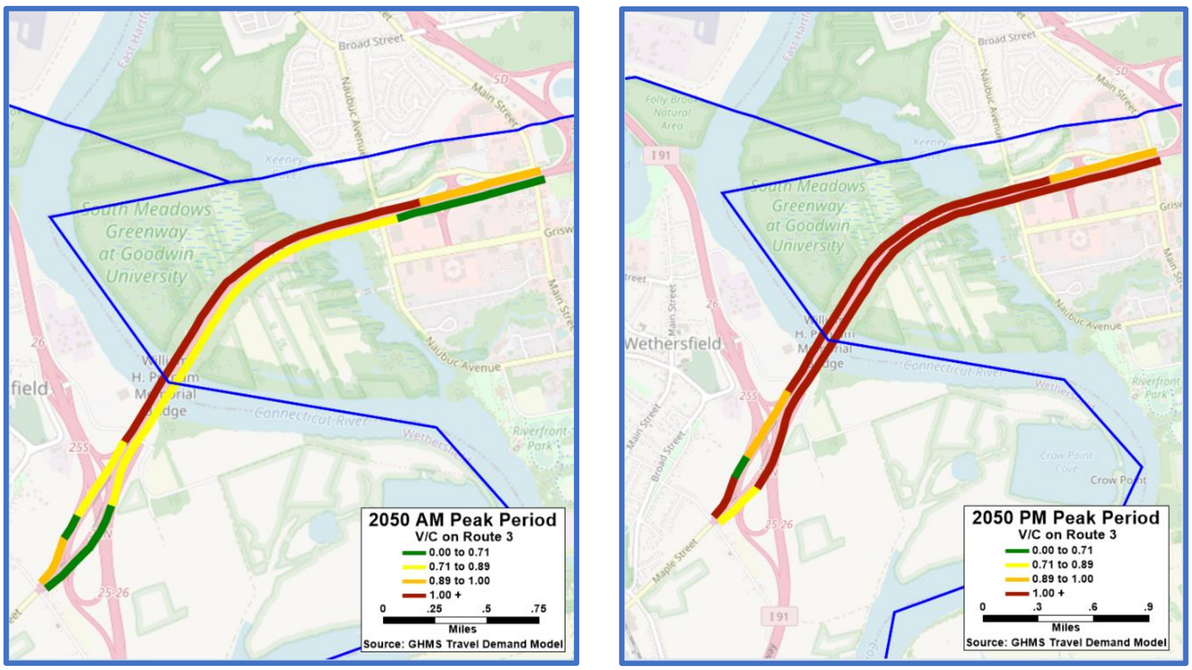
CT Route 3

Route 3 is expected to see a large increase in peak-period congestion by 2050. This is a continuation of a decades-long trend of traffic taking circumferential routes to avoid Hartford. The increase occurs all along the freeway portion of Route 3 (i.e., the Putnam Bridge and its approaches). The general congestion trend will remain the same, with moderate southbound congestion in the morning and bidirectional congestion in the evening. Travel times through the Study Area are forecast to increase as follows:

Table 22: 2050 No-Build Travel Time (% increase over 2020)

	AM Peak	PM Peak
CT 3 Northbound	3.1 minutes (+2%)	5.0 minutes (+11%)
CT 3 Southbound	3.7 minutes (+32%)	4.2 minutes (+25%)

Figure 26: Peak Period Distributions on Route 3 (AM and PM)



As much of Route 3 has already reached capacity by 2020, there is not much room for change. The segments that experienced congestion in 2020 will encounter more of the same in 2050.

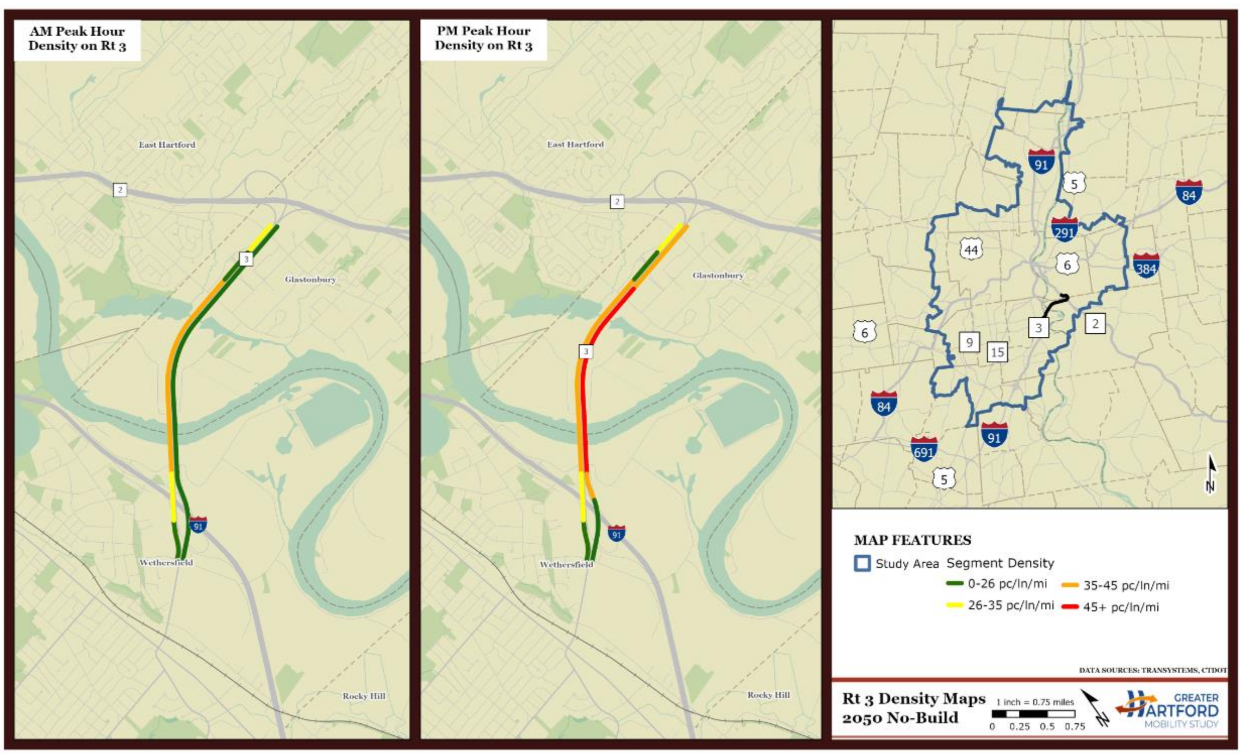
Table 23: No-Build Volume to Capacity Ratio (V/C), Change from 2020

Route 3 Vehicle Miles Traveled (VMT) X V/C				
V/C	AM Peak		PM Peak	
	VMT	Percent	VMT	Percent
VOC LE 0.71	533	17.1%	146	76.8%
VOC 0.71 to 0.89	-2,677	-19.9%	-3,535	-71.7%
VOC 0.89 to 1.00	4,005	0.0%	4,817	505.0%
VOC 1.00 +	2,120	16.7%	2,782	7.3%
Total	**3,982**	**13.6%**	**4,209**	**9.5%**

Source: GHMS Travel Demand Model

Figure 27: 2050 No-Build, Route 3 Speed Maps

Figure 28: 2050 No-Build, Route 3 Density Maps



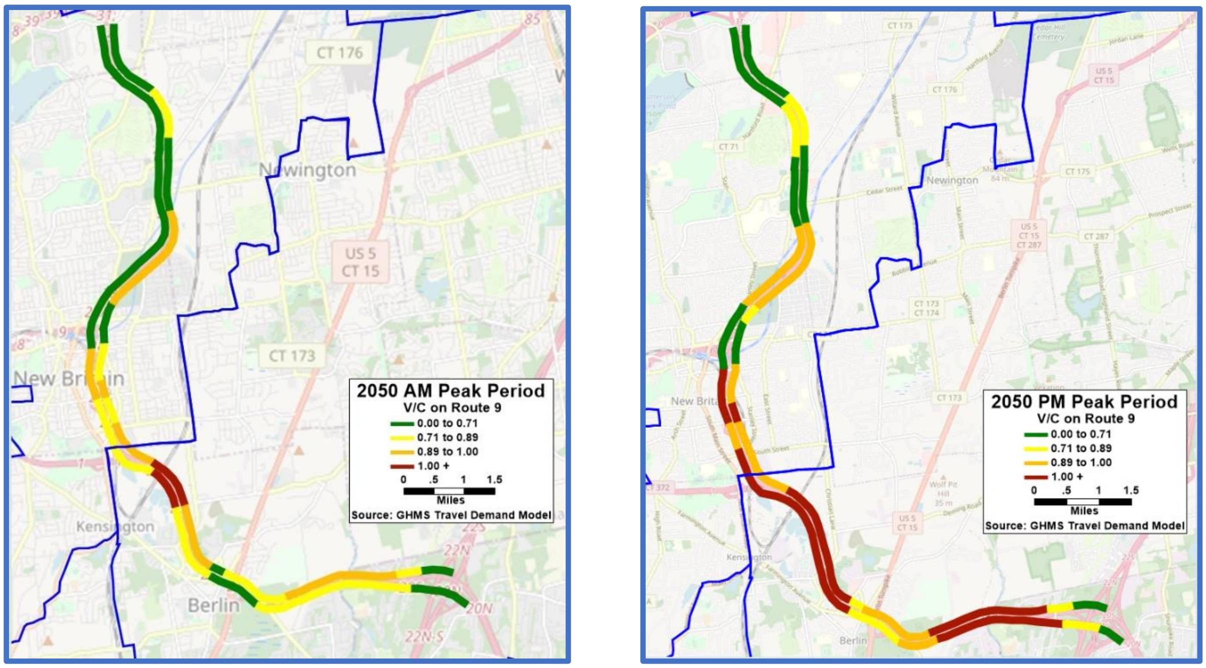
CT Route 9

Route 9 is expected to see a modest increase in peak-period congestion by 2050. The increase occurs primarily in Berlin. The general congestion trend will remain the same, with similar operations in both directions and heavier congestion during the evening peak. Travel times through the Study Area are forecast to increase as follows:

Table 24: 2050 No-Build Travel Time (% increase over 2020)

	AM Peak	PM Peak
CT 9 Northbound	12.1 minutes (+6%)	14.2 minutes (+8%)
CT 9 Southbound	12.2 minutes (+6%)	13.0 minutes (+8%)

Figure 29: Peak Period Distributions on Route 9 (AM and PM)



Several segments of Route 9 are expected to reach capacity by 2050. These segments are primarily between I-91 in Cromwell and CT 571 in Berlin, where Route 9 has two through lanes in each direction.

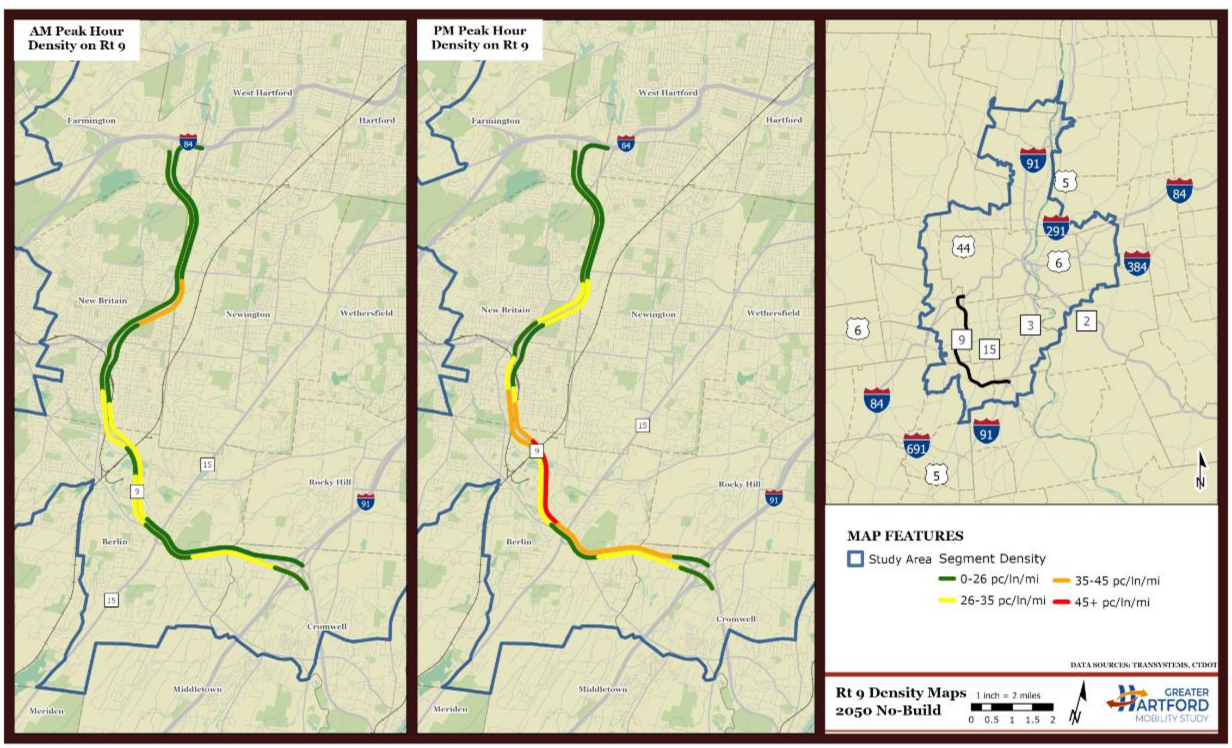
Table 25: No-Build Volume to Capacity Ratio (V/C), Change from 2020

Route 9 Vehicle Miles Traveled (VMT) X V/C				
V/C	AM Peak		PM Peak	
	VMT	Percent	VMT	Percent
VOC LE 0.71	-11,014	-22.6%	1,922	7.9%
VOC 0.71 to 0.89	-9,304	-18.0%	-21,042	-51.0%
VOC 0.89 to 1.00	19,608	101.3%	-4,219	-9.0%
VOC 1.00 +	9,436	0.0%	32,662	101.4%
Total	**8,727**	**7.3%**	**9,323**	**6.4%**

Source: GHMS Travel Demand Model

Figure 30: 2050 No-Build, Route 9 Speed Maps

Figure 31: 2050 No-Build, Route 3 Density Maps



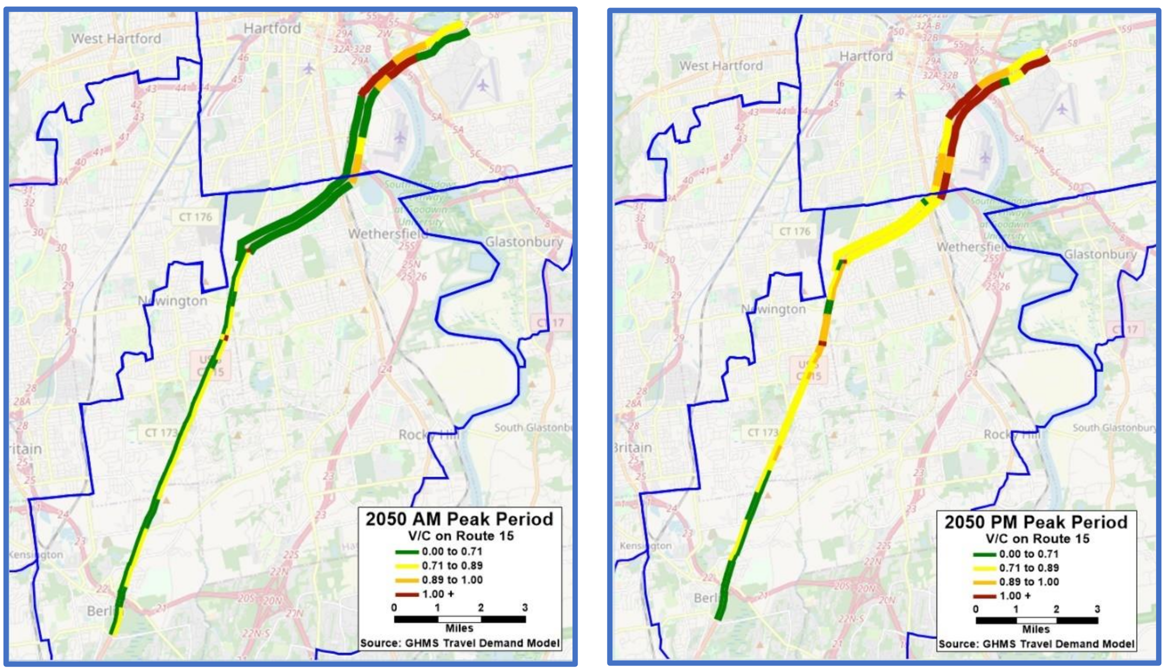
CT Route 15

Route 15 is expected to see a modest increase in peak-period congestion by 2050. The increase occurs primarily in Hartford and East Hartford, on Route 15's freeway segments. The general congestion trend will remain the same, with similar operations in both directions and heavier congestion during the evening peak. Travel times through the Study Area are forecast to increase as follows:

Table 26: 2050 No-Build Travel Time (% increase over 2020)

	AM Peak	PM Peak
CT 15 Northbound	21.0 minutes (+3%)	25.6 minutes (+16%)
CT 15 Southbound	20.9 minutes (+6%)	27.4 minutes (+9%)

Figure 32: Peak Period Distributions on Route 9 (AM and PM)



A few segments of Route 15 are expected to reach capacity by 2050. These segments are all on Route 15 Northbound between Route 99 in Wethersfield and I-84 in East Hartford. All segments that operated at capacity in 2020 will continue to experience congestion in 2050.

Table 27: No-Build Volume to Capacity Ratio (V/C), Change from 2020

Route 15 Vehicle Miles Traveled (VMT) X V/C				
V/C	AM Peak		PM Peak	
	VMT	Percent	VMT	Percent
VOC LE 0.71	1,250	2.9%	-20,951	-65.7%
VOC 0.71 to 0.89	1,029	5.0%	11,693	32.7%
VOC 0.89 to 1.00	5,038	385.6%	1,974	26.8%
VOC 1.00 +	655	6.7%	21,523	161.4%
Total	7,972	10.8%	14,238	16.1%

Source: GHMS Travel Demand Model

Figure 33: 2050 No-Build, Route 15 Speed Maps

Figure 34: 2050 No-Build, Route 15 Density Maps