Capital Region Council of Governments Travel Demand Model

The Capitol Region Council of Governments (CRCOG) travel demand model is a state-of-the-practice traditional 4-step travel model.

The following is a summary of the attached compendium of modeling documentation reports.

Part 1: Calibration (Pg. 3)

This document provides and overview of the entire modeling process as implemented for CRCOG. This includes discussion on the model structure and software used, as well as the following standard modeling components:

- Highway Network,
- Transit Route Systems,
- Traffic Analysis Zones and Socioeconomic Data,
- Trip Generation Model,
- Trip Distribution Model (Destination Choice),
- Mode Choice Model,
- Time of Day Model,
- Special Events Model, and
- System-Wide Calibration.

Each of the modeling components is documented to include what changes were made to the model component from the previous version of the model, what data was used and how the models are implemented.

The model documentation is written in the context of a general model update for use in the I-84 Hartford Project. As such some aspects of the documentation as specific to this project and not the overall model. Technical memorandums and appendices developed as part of the model update process are also included in this transmittal. These documents have been combined to a single document which provides greater detail on each of the model components.

Part 2: Attached Technical Memos

Technical Memorandum
Travel Demand Modeling System-Wide Calibration

March 8, 2019

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP
ETC Institute

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1. INTRODUCTION

This document is the technical documentation for the Capital Region Council of Governments (CRCOG) regional travel demand model. This model is an update of the previous CRCOG model and was undertaken in conjunction with the I-84 Viaduct project in Hartford, CT. Within the report key model inputs such as the Traffic Analysis Zone (TAZ) system, transportation networks, and socioeconomic data are documented. Individual model components are discussed including their parameters and validation. A User's Guide has also been developed to assist others with running the model as a stand-alone document.

This report contains the following chapters:

1. Introduction
2. Traffic Analysis Zones, Networks, and Socioeconomic Data
3. Trip Generation Model
4. Mode Choice Model
5. Destination Choice Model
6. Time of Day
7. Special Event Model
8. System-wide Calibration and Validation

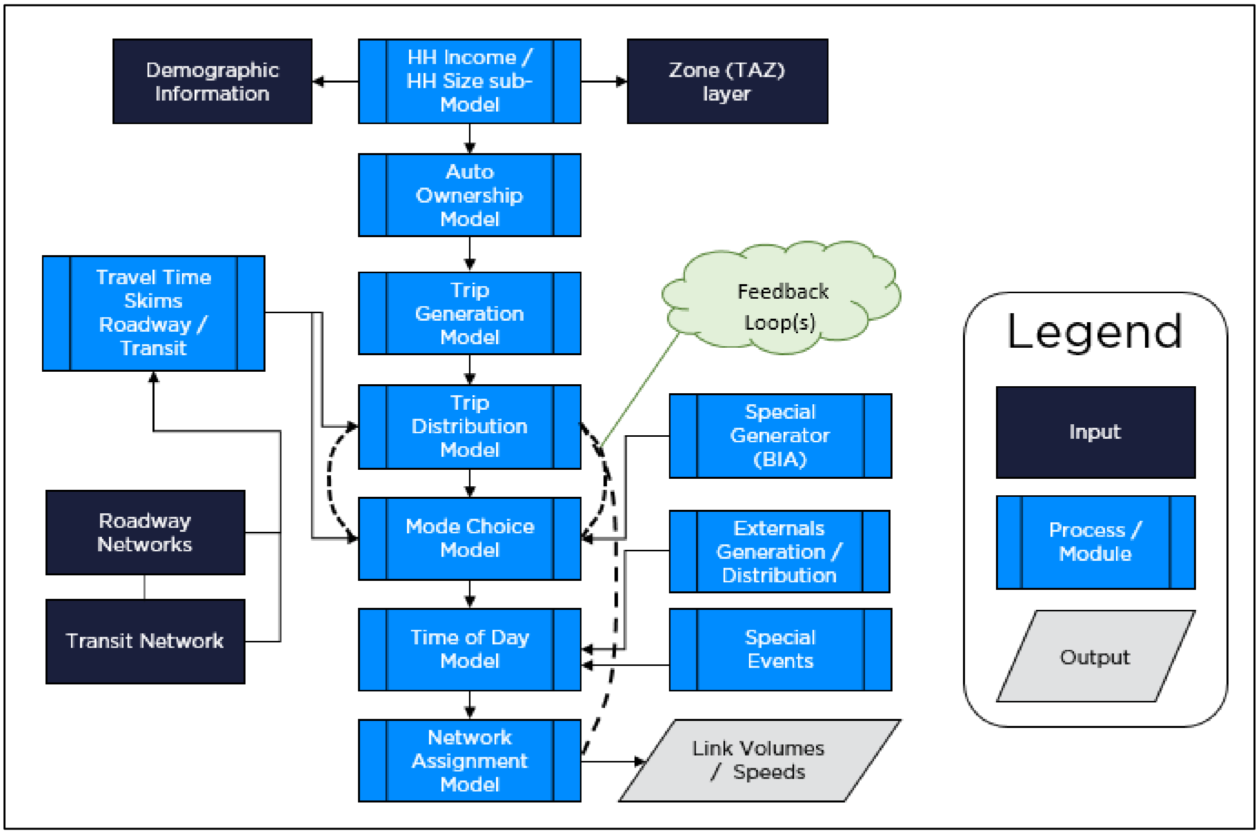
In addition, there are appendices that discuss the Transit On-Board Survey, parking lot choice modeling, and time of day analysis.

1.1 MODEL STRUCTURE

The CRCOG regional travel demand model is a four-step model similar to models used by many other Metropolitan Planning Organizations (MPO). The foundation of the model can be found in its Traffic Analysis Zones (TAZ) System, transportation networks, and socioeconomic data. Building from this foundation are models to estimate trip generation, destination choice, mode choice, and traffic assignment. In addition to these steps the model also includes:

- Submodels for household income and size;
- Special Events Model;
- Feedback loops between mode choice and destination choice; and
- Time of Day Component.

Figure 1: CRCOG Model Flow Chart



A flow chart depicting the CRCOG Model is shown in Figure 1. A more detailed flowchart is in Appendix A.

It is anticipated that the CRCOG travel demand model will be used for a variety of transpiration planning and policy analyses including:

- Impact of changes in land development patterns on the demand for transportation services.
- Sensitivity of the transportation systems to changes in system components, e.g., expanded roadway and transit services.
- Provide input to operational analysis in conjunction with infrastructure investment including maintenance of traffic strategies.

1.2 MODEL SOFTWARE

The CRCOG model was developed using TransCAD Version 6.0 r2 Build 9025 32-bit. The model runs on computers operating under Windows XP, Windows 7, or Windows 10. Specific system requirements are shown in Table 1 and more detail on the software and initiation of the interface can be found in the User Guide.

Table 1: System Requirements

Operating System	Windows XP, Windows 7, or Windows 10 A 64-bit operating system is recommended.
Processor	Intel Core 2 processor or later Note: Multiple cores will significantly improve model run times.
Memory	32GB – 64 GB Note: At least 8 GB of memory is recommended.
TransCAD Software	Version 6.0 r2 Build 9025 32-bit
Microsoft Office	Version 2007 or later
Disk Space (Installation and input data)	50MB
Disk Space (Scenario output)	10-20 GB for each scenario / year (depends on number of selected queries)

2. HIGHWAY NETWORK

2.1 HIGHWAY NETWORK

The highway network for the CRCOG model update was based on the network coded for the previous model. The CRCOG model covers Hartford and Tolland counties in their entirety, and a portion of Fairfield, Litchfield, Middlesex, New Haven, New London, and Windham counties as well as a portion of southwest Massachusetts.

Roadway facilities are coded in the model area to include all Interstate, principal arterials, minor arterials and collectors. Facility coding was checked to assure a balance between the modeled roadway system and the traffic analysis zones and to provide connectivity between routes. Centroid connectors were coded and revised as necessary to match a modified TAZ system. The network was checked for connectivity, directionality, range of attribute values, shortest paths, and trip loading on centroid connectors, freeways, and ramps.

The network is coded with a set of input attribute data as defined in Table 2. Additional data fields required by the model are calculated using GISDK scripts, these fields are summarized and defined in Table 3. There are also several attribute fields available for manual checks/overwrites in scenario management.

Table 2: User Input Highway Attribute Data

Attribute Name	Full/Name Description
ID	ID - unique id
Length	Length in miles of link
Dir	Direction
MODE	Type of link: 90-Connector to/from TAZ centroid 91- Roadway 92-Bus Rapid Transit (BRT) 93-Rail 98-walk to BRT/Rail
AB SPDC	Lookup value for Speed (range of 70 values)
BA SPDC	Lookup value for Speed (range of 70 values)
AB CAPC	Lookup value for Capacity (range of 70 values)
BA CAPC	Lookup value for Capacity (range of 70 values)
Area Type	Area Type - Land Use code 1 – Central Business District 2 - Urban 3 – Suburban 4 - Rural
Facility Type	Facility Type Code Range from 1-7 for roadway links 1 - Principal Arterial - Interstate 2 - Principal Arterial - Other Freeway 3 - Principal Arterial - Other 4 - Minor Arterial

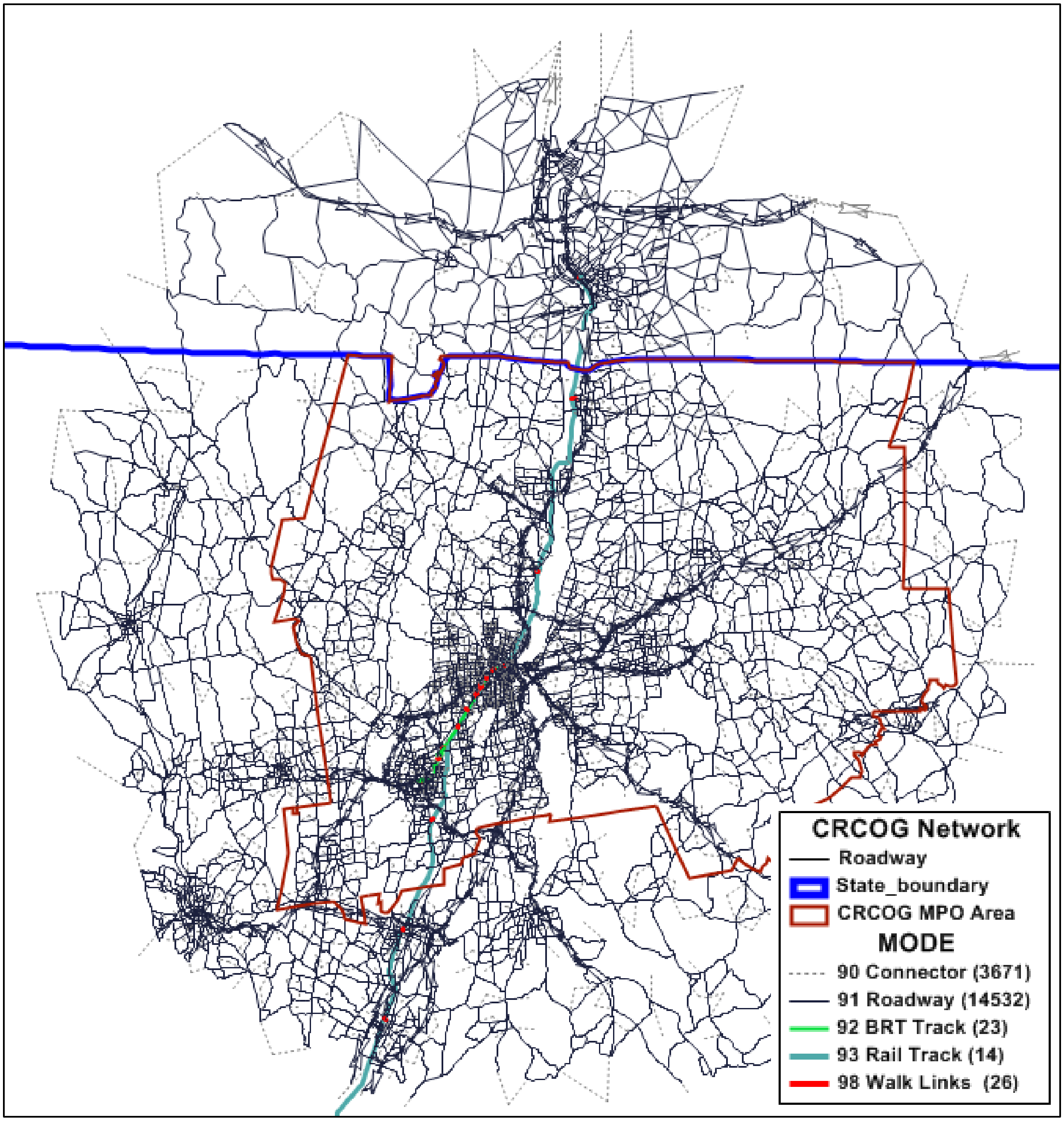
Attribute Name	Full/Name Description
	5 - Minor Arterial / Major Collector 6 - Minor Collector / Local 7 - Ramp / Frontage Road
AB LANE	Number of Lanes
BA LANE	Number of Lanes
AB HOVLINK	Number of Lanes if HOV
BA HOVLINK	Number of Lanes if HOV
ST_NAME	Street Name
ABBA_DOT_Count_ID	Count ID to match CTDOT traffic TCLP IDs
AB_BA	Values: AB, ABBA, null
Accuracy	Accuracy levels of traffic count data collected: values 1-3: 1 - very accurate – Continuous Counter 2 - somewhat accurate – includes count profile and 3-7 days counts 3 - least accurate - daily or 48-hr counts
AB_AM_Count	One direction AM Count
BA_AM_Count	One direction AM Count
AM_Tot_Count	Sum of both directions or if total only collected
AB_MD_Count	One direction MD Count
BA_MD_Count	One direction MD Count
MD_Tot_Count	Sum of both directions or if total only collected
AB_PM_Count	One direction PM Count
BA_PM_Count	One direction PM Count
PM_Tot_Count	Sum of both directions or if total only collected
AB_NT_Count	One direction NT Count
BA_NT_Count	One direction NT Count
NT_Tot_Count	Sum of both directions or if total only collected
AB_Daily_Count	Sum of periods by direction
BA_Daily_Count	Sum of periods by direction
Daily_Tot_Count	TOTAL 24-hr counts

Table 3: Calculated Highway Attribute Data

Attribute Name	Full/Name Description
AB FF SPD	Free Flow Speed
BA FF SPD	Free Flow Speed
AB TIME FF	Free Flow Time = Distance/Free Flow Speed
BA TIME FF	Free Flow Time = Distance/Free Flow Speed
AB_TIME_AM	AB calculated congested peak time (AM & PM)
BA_TIME_AM	BA calculated congested peak time (AM & PM)
AB_TIME_MD	AB calculated congested off peak time (MD & NT)
BA_TIME_MD	BA calculated congested off peak time (MD & NT)
AB ALPHA	Constant (Lookup value based on Capacity Class)
BA ALPHA	Constant (Lookup value based on Capacity Class)
AB BETA	Constant (Lookup value based on Capacity Class)
BA BETA	Constant (Lookup value based on Capacity Class)
AB_AMCap	AM Period (3hrs) capacity
BA_AMCap	AM Period (3hrs) capacity
AB_MDCap	MD Period (6hrs) capacity
BA_MDCap	MD Period (6hrs) capacity
AB_PMCap	PM Period (3hrs) capacity
BA_PMCap	PM Period (3hrs) capacity
AB_NTCap	NT Period (12hrs) capacity
BA_NTCap	NT Period (12hrs) capacity
AB_TrnTime_AM	Peak Transit Time
BA_TrnTime_AM	Peak Transit Time
AB_TrnTime_MD	Off Peak Peak Transit Time
BA_TrnTime_MD	Off Peak Peak Transit Time
WalkSet	Identify roadways that permits walking
WalkDist	Calculated walk distance
WalkTime	Calculated walk time

The final 2015 highway network is shown in Figure 2

Figure 2: CRCOG Highway Network



Area type and functional classification are key variables that are combined to determine the roadway capacity of a link and the free flow speed. A map of area types in the region is shown in Figure 3. Lookup tables are used to determine the roadway capacities and free flow speeds of each link. Table 4 illustrates the Area Type and Functional Classification used in the model, while Table 5 and Table 6 provide the capacity range and speed by roadway functional classification and area type.

Figure 3: Highway Network by Area Type

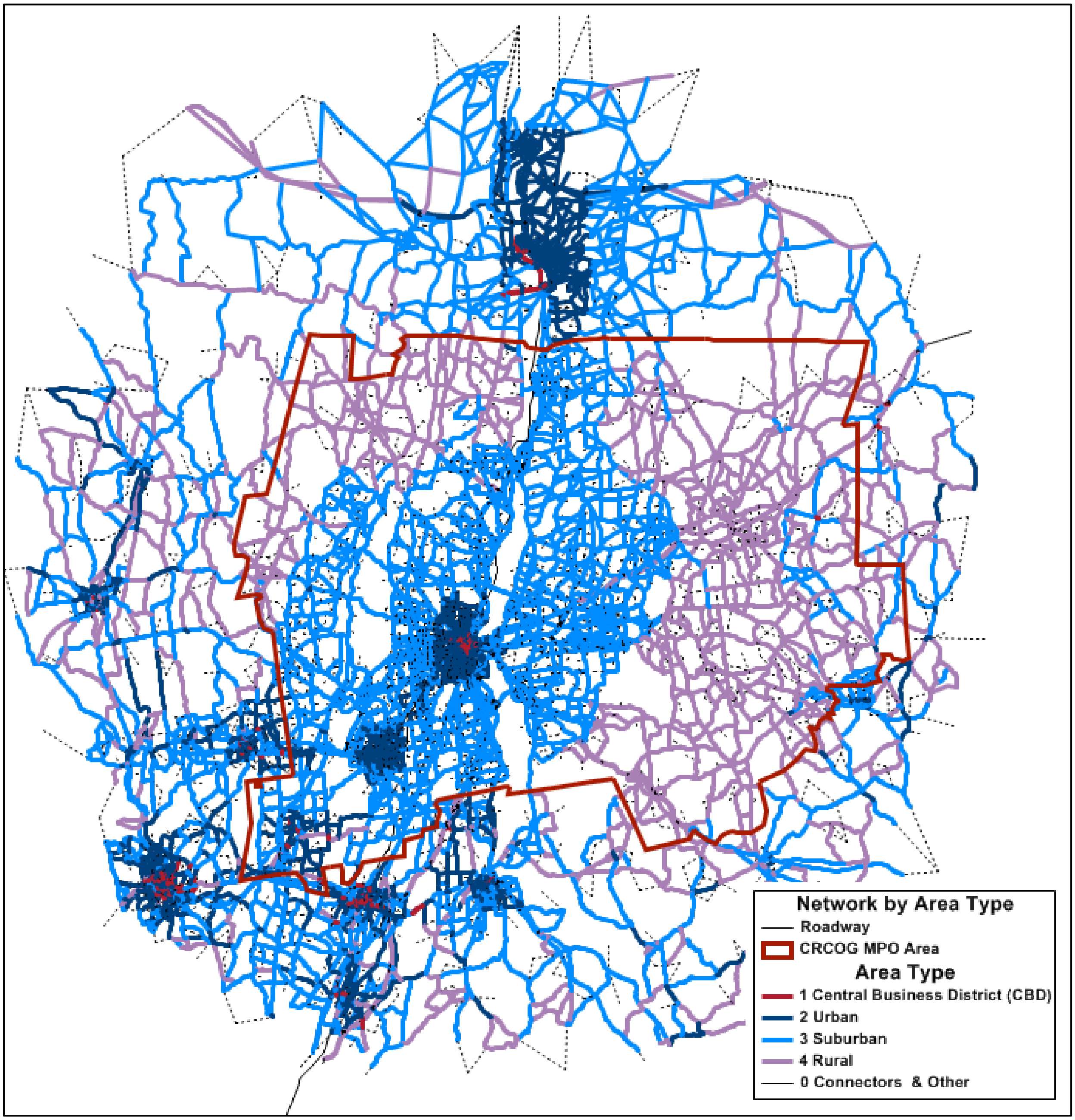


Table 4: CRCOG Classification Code: Area Type and Functional Class Description

Area Type (ID)	Facility Type	Functional Class	Functional Classification
CBD (1)	1	1,11,13,14,16,17	Principal Arterial – Interstate
	3	1,7,11,13,14,16,17,19	Principal Arterial – Other
	4	1,7,11,13,14,16,17,19	Minor Arterial
	5	11,13,14,16,17,19	Collector
	6	14,16,17,19	Local System
Urban (2)	1	11,13,14,16,17, 19	Principal Arterial – Interstate
	3	1,6,7,9,11,13,14,16,17, 19	Principal Arterial – Other
	4	1,6,7,8, 9,11,13,14,16,17, 19	Principal Arterial – Other - Buffer Zone
	5	1,6,7,8, 9,11,13,14,16,17, 19, 40	Minor Arterial / Collector
	6	1,6,7,8, 9,11,13,14,16,17, 19, 40	Collector
	7	1,7,11,13,14,16,17, 40	Ramps & Frontage Rd
Suburban (3)	1	1,2,6,7,8, 9,11,13,14,16,17, 40	Principal Arterial – Interstate
	2	1,2,7,8,11,13,14,16,17, 40	Principal Arterial – Other (Rt-5, Berlin Tpke)
	3	1,2,6,7,9,11,13,14,16,17, 19	Principal Arterial – Other
	4	1,2,6,7,9,11,13,14,16,17, 19	Principal Arterial – Other - Buffer Zone
	5	1,2,6,7,8,9,11,13,14,16,17, 19	Minor Arterial / Collector
	6	1,6,7,8,9,11,13,14,16,17, 19	Collector
	7	13,14,17, 40	Ramps & Frontage Rd
Rural (4)	1	1,6,7,8, 9,11,13,14,16,17, 19	Principal Arterial – Interstate
	3	1,2,6,7,9,11,13,14,16,17, 19	Principal Arterial – Other
	4	1,6,7,8, 9,11,13,14,16,17, 19	Principal Arterial – Other - mostly Buffer Zone
	5	1,6,7,8, 9,11,13,14,16,17, 19	Minor Arterial / Collector
	6	1,6,7,8, 9,11,13,14,16,17, 19	Collector / Buffer zone (for the most part)
(null)	7	1,6,7,8,9,11,13,14,16,17, 19,40	Ramps & Frontage Rd
	9	99, 1,6,7,8,9,11,13,14,16,17, 19,40	Centroid Connector

Table 5: CRCOG Link Capacity by Functional Classification and Area Type

Facility Type		1 CBD	2 Urban	3 Suburban	4 Rural
1	Interstate	1,233 – 1,294	1,242 – 1,311	1,000 – 1,346	1,346 – 1,346
2	Principal Arterial - Other Freeway	-	-	733 - 901	932
3	Principal Arterial - Other	630 - 733	386 - 800	630 – 1,311	725 - 821
4	Minor Arterial	556 - 569	386 - 647	497 - 821	556 - 821
5	Minor Arterial / Collector	372 - 386	335 - 800	372 - 800	497 - 497
6	Collector / Local	335 - 347	373 - 569	372 - 447	360
7	Ramp / Frontage Road	-	673 – 1,277	673	673 – 1,277

Table 6: CRCOG Link Free Flow Speed by Functional Classification and Area Type

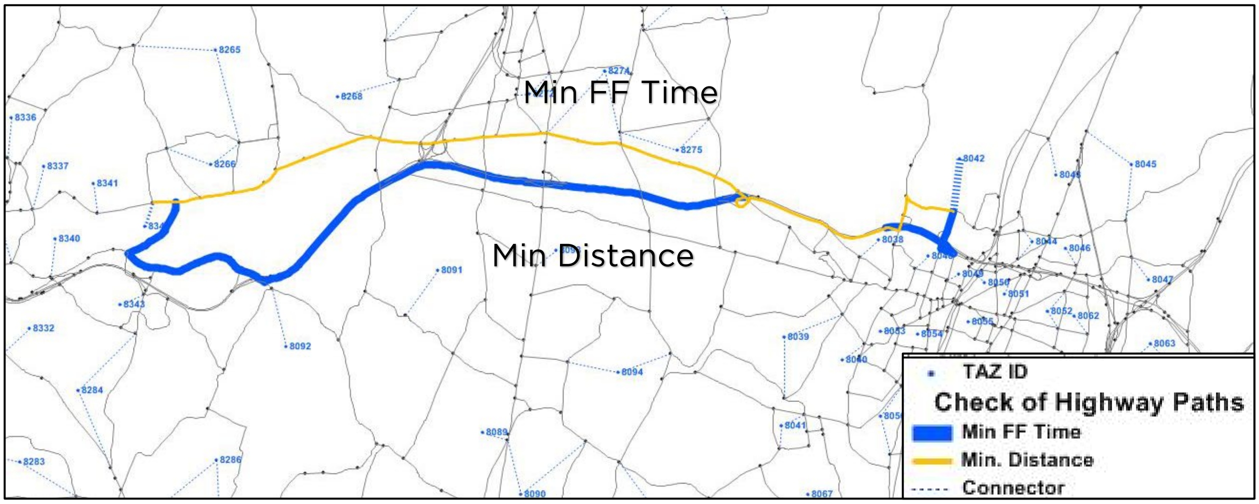
Facility Type		1 CBD	2 Urban	3 Suburban	4 Rural
1	Principal Arterial - Interstate	60 - 63	60 - 68	60 - 68	68 - 68
2	Principal Arterial - Other Freeway	-	-	32 - 46	50
3	Principal Arterial - Other	14 - 32	14 - 37	14 - 68	40 - 45
4	Minor Arterial	14 - 17	14 - 32	14 - 45	14 - 45
5	Minor Arterial / Major Collector	12 - 15	11 - 37	12 - 37	40
6	Minor Collector / Local	11 - 14	15 - 24	12 - 32	36
7	Ramp / Frontage Road	-	36 - 50	36	36 - 50

2.2 DEVELOPMENT AND CHECKING OF HIGHWAY PATHS

A number of checks were made to the highway network in order to ensure that coding errors had been minimized. The first was to create a simple, Origin-Destination matrix that assumed one trip between every zone. This was then assigned to the street network. This method allowed the quick identification of zero-volume links. Normally, these links are caused by connectivity issues or by errors in the attribute data, which are then corrected.

The second check involved testing paths between zones manually. For a reasonable sample of zone pairs, the TransCAD shortest-path tool was used to perform manual checks. Figure 4 shows an example of minimum paths between two zones. The first is the path that minimizes travel time, while the second minimizes distance

Figure 4: Path Check example



3. TRANSIT ROUTE SYSTEM AND SUPPORTING INFORMATION

3.1 TRANSIT NETWORK

Following the review and checking of the highway network, in total there are: 32 local routes, 8 CT*fastrak*, and 22 express routes.

In addition, an effective fare was calculated for each route, although a difference can be observed only with the express routes. The effective fare is preferred over the stated fare as it takes into account discount programs offered by the transit operators.

Table 7 provides a summary of the base year routes coded into the model, including route description, effective fare and peak/off peak headway.

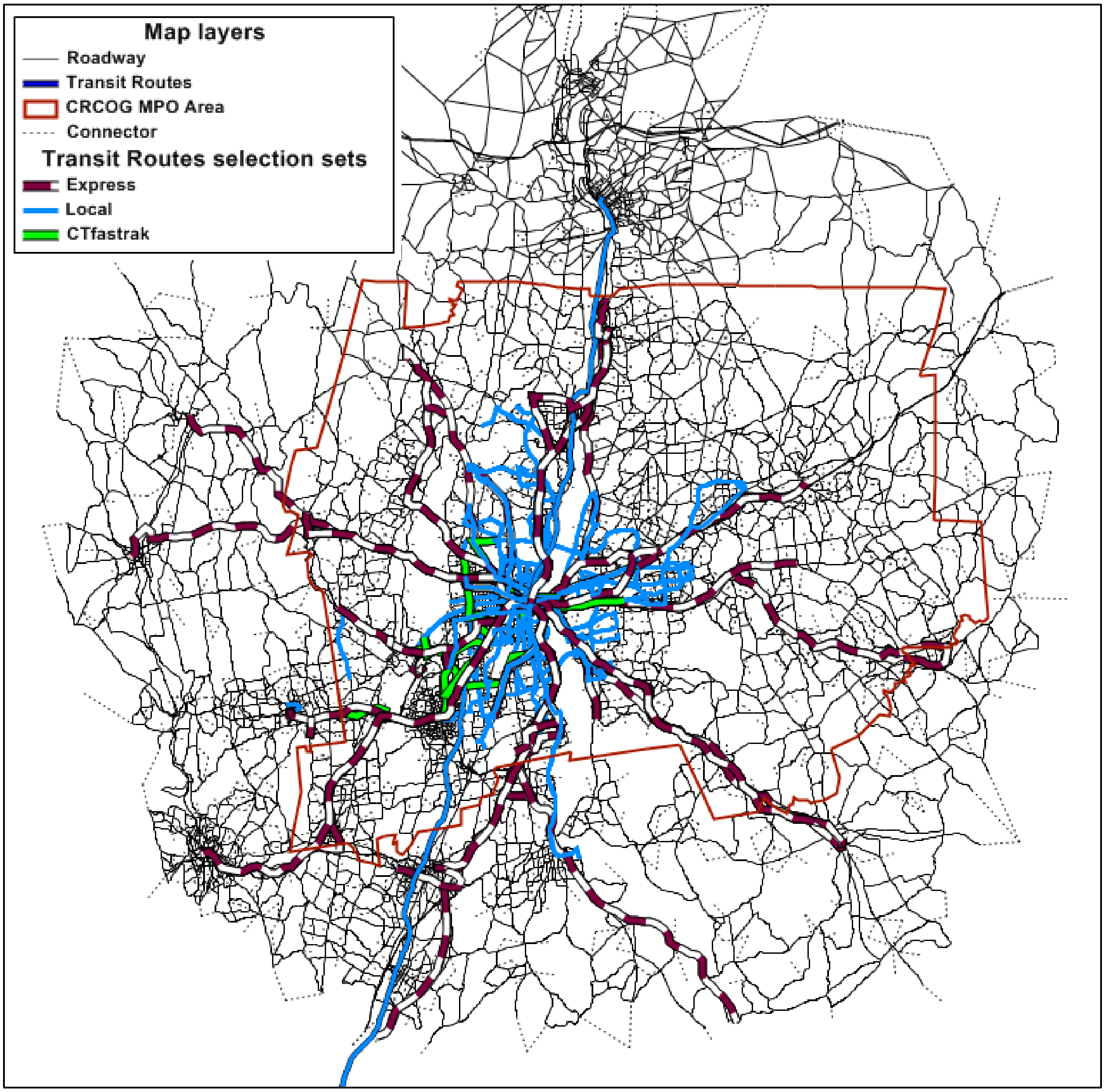
Table 7: Base Year Transit Routes

Route	Full Name	Fare	Forward Peak Headway	Reverse Peak Headway	Forward Off Peak Headway	Reverse Off Peak Headway
30	30 Bradley Flyer	$ 1.75	45	72	135	72
31-33	31-33 Park Street	$ 1.75	75	104	20	20
32-36	32-36 Windsor Avenue	$ 1.75	94	109	150	146
37-39	37-39 New Britain Avenue	$ 1.75	39	40	53	38
38	38 Weston Street	$ 1.75	30	45	108	151
40-42	40-42 North Main Street	$ 1.75	32	20	75	20
41	41 New Britain	$ 1.75	20	33	16	30
43	43 Campfield Avenue	$ 1.75	22	33	48	195
44	44 Garden Street	$ 1.75	30		36	56
45	45 Berlin Turnpike Flyer	$ 1.75	150	360	150	360
46	46 Vine Street	$ 1.75	11	19	11	19
47	47 Franklin Avenue	$ 1.75	103	124	23	45
50-54	50-54 Blue Hills Avenue	$ 1.75	65	143	50	150
53-55	53-55 Wethersfield Ave/Middletown	$ 1.75	48	162	86	110
56-58	56-58 Albany/Bloomfield Avenue	$ 1.75	109	100	84	97
59	59 Locust Street	$ 1.75	30	60	30	60
60-66	60-66 Farmington Avenue	$ 1.75	96	48	89	72
61	61 Broad Street	$ 1.75	92	164	60	161
63	63 Hillside Avenue	$ 1.75	103	60	101	60
69	69 Capitol Avenue	$ 1.75	113	30	140	62
72	72 Asylum Avenue	$ 1.75	41	90	41	184
74	74 Granby Street	$ 1.75	105	45	75	113
76	76 Ashley Street	$ 1.75	16	49	14	63
82-84	82-84 Tolland Street	$ 1.75	95	60	103	56
83	83 Silver Lane	$ 1.75	110	216	145	74

Route	Full Name	Fare	Forward Peak Headway	Reverse Peak Headway	Forward Off Peak Headway	Reverse Off Peak Headway
86-88	86-88 Burnside Avenue-Manchester	$ 1.75	108	203	25	71
85	85 MCC Flyer	$ 1.75	60	90	60	90
87	87 Brewer Street	$ 1.75	68	216	113	210
91	91 Forbes Street Crosstown	$ 1.75	60	60	45	72
92	92 Tower Avenue Crosstown	$ 1.75	75	90	180	60
94-96	94-96 Park Avenue/John Fitch Blvrd	$ 1.75	92	315	53	200
95	95 Glastonbury	$ 1.75	116	218	124	248
101	101 Hartford/New Britain	$ 1.75	6	12	6	12
102	102 Hartford/New Britain-Bristol	$ 1.75	30	51	26	51
121	121 MCC/Hartford/Uconn	$ 1.75	20	197	20	80
128	128 Hartford/Westfarms/New Britain	$ 1.75	20	30	20	30
140	140 CCSU Shuttle	$ 1.75	30	38		
144	144 Wethersfield/Westfarms	$ 1.75	60	60	60	60
153	153 Flatbush-Copaco	$ 1.75	60	60	60	60
161	161 St. Francis/Hartford Hospital	$ 1.75	14	20	16	19
901	901 Avon/Canton Express	$ 2.70	135	360	68	360
902	902 Corbins/Farm Springs Express	$ 2.70	180		113	
903	903 Buckland Express	$ 2.70	60		77	
904	904 Glastonbury Express	$ 2.70	120		68	
905	905 Windsor Locks-Enfield Express	$ 2.70	126	360	173	360
906	906 Cromwell Express	$ 2.70	36	360	68	360
907	907 Newington Express	$ 2.70	180		90	
909	909 Unionville Express	$ 2.70	180		90	
910	910 Century Hills Express	$ 2.70	60	360	135	360
912	912 Simsbury Express	$ 2.70	180	198	113	360
914	914 Marlborough/Colchester Express	$ 2.70	203		48	360
917	917 Vernon Express	$ 2.70		180	133	
918	918 Willimantic/Coventry Express	$ 2.70		180	140	
919	919 Meriden Express	$ 2.70			90	
921	921 Middletown-Old Saybrook Express	$ 2.70		360	60	
950	923 Bristol Express	$ 2.70	180	180	30	360
923	924 Southington/Cheshire Express	$ 3.20			36	
924	925 Cheshire/Waterbury Express	$ 3.20			45	
925	926 Winstead Express	$ 3.20			90	
926	927 Torrington Express	$ 2.70			90	
927	928 Southington/Cheshire/Waterbury	$ 2.70	60	60	180	60
928	950 New Haven/Hartford Express	$ 3.20	60	360	60	360

In addition Figure 5 shows the modeled routes by the three categories: local, CT*fastrak*, and express.

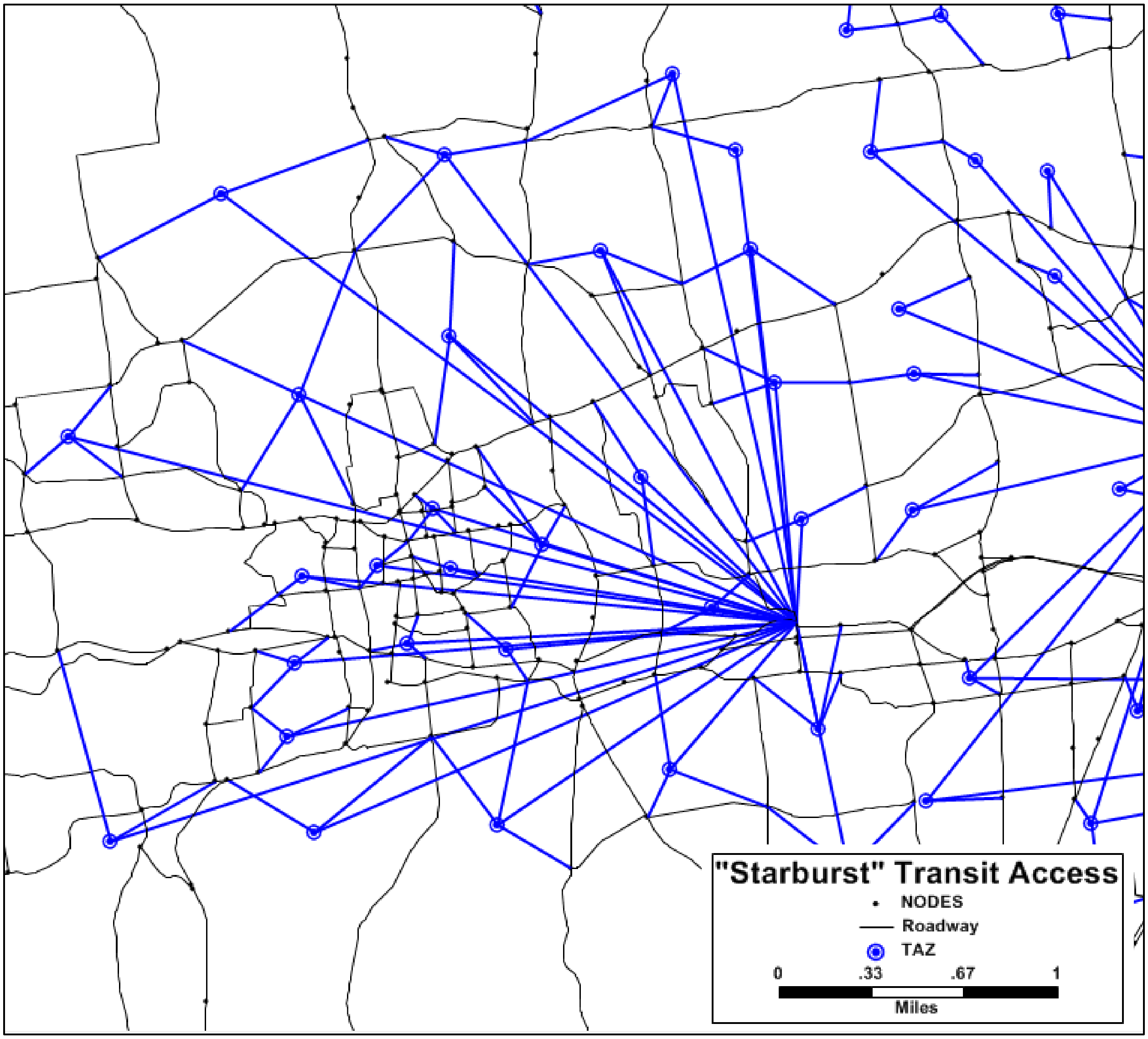
Figure 5: CRCOG Model Bus Routes



3.2 ACCESS LINKS

Access links are needed to build walk and drive access paths to the transit route system. Traditional practice is the coding of straight-line access links from the zone centroid to the bus stops along the route, see Figure 6. Original CRCOG model had utilized this approach, but later decided against using this approach due to the following considerations:

Figure 6: Traditional "Starburst" Approach to Transit Access



- Recent research (New Orleans, Indianapolis, and Phoenix) into using the traditional "starburst" approach to coding walk and drive access as compared to utilizing walk and drive times over the coded highway network has shown that the starburst coding poorly represents access, and subsequently, actual path assignment as observed in the assignment of the on-board survey data.
- In the traditional approach, the access and egress connectors generated from the zone centroid to the bus stop are coded with a travel time reflective of the average walking speed and the distance of the connector (which may be capped for very long connectors). This approach results in walk access links that may be nearly indistinguishable from each other. This leads to inaccuracies in the best path selected by the transit path builder with respect to evaluating walk penalties.

- Problems may be encountered for one-way routes where access connectors get built only to the nearest one-way alignment, but not to the reverse direction for the route. Not having access to the same bus stop for both directions of the one-way route can lead to the building of paths that are longer than those actually observed, which can in turn impact ridership.
- Last, CRCOG region's highway network could be coded for terrain, and inherently capture geographic constraints and barriers that result in a lack of connectivity in the street system. The starburst approach would not automatically capture these unique characteristics requiring manual review and editing of the final link coding.

For these reasons outlined above, the approach recommended and implemented in the final CRCOG model utilizes the full network coverage with walk and drive specific times for transit access. In addition along the BRT track, a walk / bike access links were coded with unique mode code of 98.

3.3 TRANSIT SPEEDS

Transit speeds are computed through the use of a lookup table that applies a rule based system by facility type and area type to adjust to the speed of the bus relative to the speed on the roadway. For example, there is no reduction in bus speed on a freeway facility as the bus does not make any stops and is able to travel along with the highway traffic. At the other end of the spectrum, urban arterials have the largest adjustment between highway speed and bus speed as the bus must stop not only to pick up and drop off passengers, but also for signalized intersections where the bus acceleration and deceleration play a larger role in average speed. The final bus speed relationship reflected in the model was informed by the final transit trip assignment and validation.

4. TRAFFIC ANALYSIS ZONE SYSTEM AND SOCIOECONOMIC DATA

4.1 TRAFFIC ANALYSIS ZONES

Traffic Analysis Zones (TAZ) 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 a means to organize model inputs and outputs throughout the modeling process.

TAZ boundaries are typically based on census geography and 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. TAZs should also be consistent with the underlying transportation networks and be bounded by roadways. In the CRCOG Model the TAZ structure remains constant in the base and future years.

TAZs are linked to the model network by means of centroids and centroid connectors. A centroid is a special class of node that represents the starting point and ending point for all trips generated by a TAZ. Each centroid is connected to the network by means of a centroid connector. Centroid connectors represent local streets, within a TAZ, and permit trip movement from a centroid to the model roadway network.

Travel demand models also include a special type of TAZ known as an external station. Because the model cannot stretch on endlessly, external stations are used to help represent the boundary of the model area and the physical locations at which vehicles can enter or exit the region. Rather than land-use and socioeconomic data, these externals are coded with trip ends categorized to be consistent with the model structure. Table 8 provides a list of all attributes utilized in model coding.

Table 8: TAZ Attributes

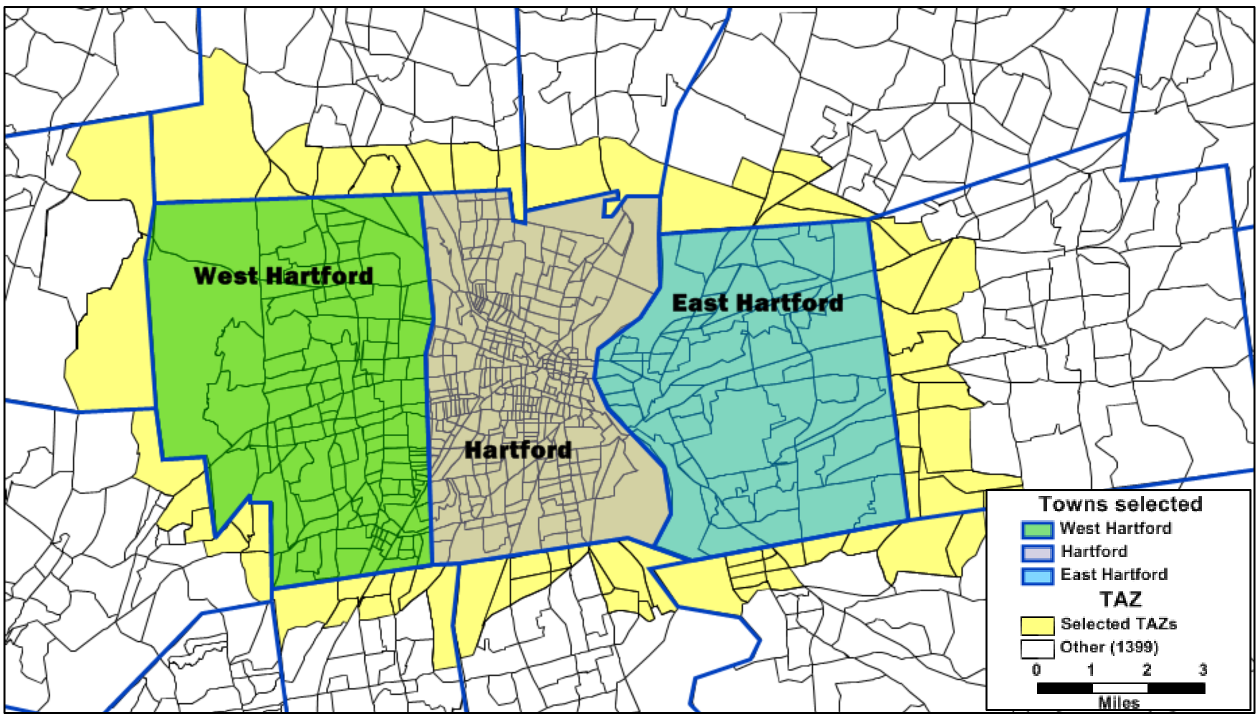
Attribute Name	Full/Name Description
ID	ID - unique id
Area	Area in square miles
TAZ	TAZ ID
ID_node	Centroid Connector could have difference ID
Parent TAZ	TAZ ID before split
TYPE_Update	some areas were updated to reflect changes in land use
AREA_IND	Airport HFD_CBD HFD Non_CBD Non_HFD (Null/Blank)
Within_CRCOG	0- outside CRCOG 1-CRCOG Null/Blank - MA Buffer
TOWN	Town Name

Attribute Name	Full/Name Description
DISTRICT	101-701
STATE	CT or MA
IE_Ind	Internal / External TAZ External detached /imaginary and not part of land
DOT_TAZ	Cross reference to CTDOT TAZ system
AreaType	only 1 as value
CBD_IND	0- Not CBD / 1- CBD
WORK PARK $	0, 4, 31
NONWORK PARK $	273'0,28, 40, 45, 100, 150, 170, 193, 243, 273
TERMINAL TIME P	0,1,2,3
TERMINAL TIME A	0,1,2,3,4,5,6
BS_WB_PCT_POP	0-100
BS_WB_PCT_EMP	0-100
BS_WR_PCT_POP	0 value
BS_WR_PCT_EMP	0-100
BW_WB_PCT_POP	0-100
BW_WB_PCT_EMP	0-100
BW_WR_PCT_POP	0-100 with 0-10 in 2 increments, 10-100 in 5 increments
BW_WR_PCT_EMP	0-100 with 0-10 in 2 increments, 10-100 in 5 increments
HH	2015 Household values
TotPop	2015 Population
HHPop	2015 Household Population
GQPop	2015 Group Quarters Population (dormitories, prison, etc.)
Ret	2015 Retail Employment
NRet	2015 Non-Retail Employment
HH25	2025 Household values
TotPop25	2025 Population
HHPop25	2025 Household Population
GQPop25	2025 Group Quarters Population (dormitories, prison, etc.)
Ret25	2025 Retail Employment
NRet25	2025 Non-Retail Employment
HH40	2040 Household values
TotPop40	2040 Population
HHPop40	2040 Household Population
GQPop40	2040 Group Quarters Population (dormitories, prison, etc.)
Ret40	2040 Retail Employment
NRet40	2040 Non-Retail Employment

As part of the model update, TAZ in and around the I-84 Hartford Project area were reviewed. Each TAZ within the towns of Hartford, East Hartford, and West Hartford, (See Figure 7) as well as a ring of TAZs surrounding these towns, was examined to determine the desirability of modifying TAZ boundaries. The decision to modify any TAZ was based on the following considerations:

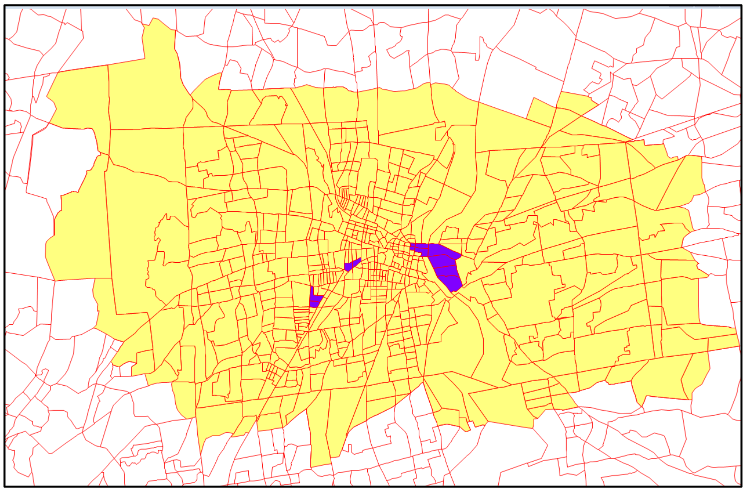
- Maintain consistency with the previously developed I-84 Hartford Project Subarea Model.
- Recognize the alignment of probable I-84 alternatives. TAZ boundaries were modified so as to limit the possibility of a TAZ being split by the alignment of an alternative being considered for project.
- Accommodate major developments within the project area, e.g., the DoNo Development
- Add greater detail in the towns of Hartford, East Hartford, and West Hartford.
- Increase consistency with the roadway network and minimize situations where a TAZ was divided by a roadway.

Figure 7: The Towns of East Hartford, Hartford, and West Harford



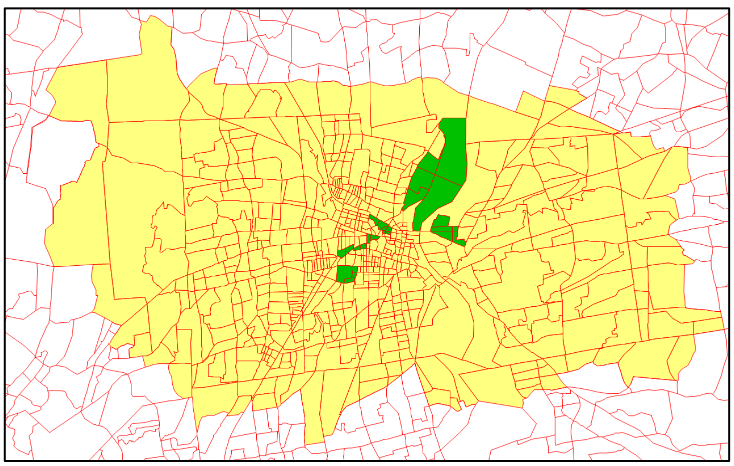
The subarea model was used extensively for the analysis of literally hundreds of alternatives during earlier stages of the project. This model, originally developed by an independent consultant, was based on a version of the 2014 regional CRCOG model. During the development of the subarea model the following regional TAZs were subdivided: 375, 2111, 2112, 2042, and 2059 (Figure 8)

Figure 8: TAZ Subdivided for the Subarea Model



The TAZs highlighted in Figure 9 were subdivided to accommodate alternative ramp locations as well as various alignment options. The TAZ subdivided for this purpose are: 86, 87, 374, 2018, 2024, 2033, 2042, 2074, 2036, and 2135.

Figure 9: TAZ Split to Avoid Alignment Conflicts



DoNo (Downtown North) Hartford development area (Figure 10) is bounded by Chapel Street and Morgan Street to the south, Market Street to the east, Pleasant Street to the north, and High Street to the west. The center of the redevelopment will include a minor league baseball stadium in the area bounded by Main Street, Trumbull Street, Pleasant Street, and Windsor Street. The mixed-use development will also include residential, retail, and restaurant components. Regional TAZs 88 and 275 were subdivided to accommodate the new development (See Figure 11).

Figure 10: DoNo Development Plan

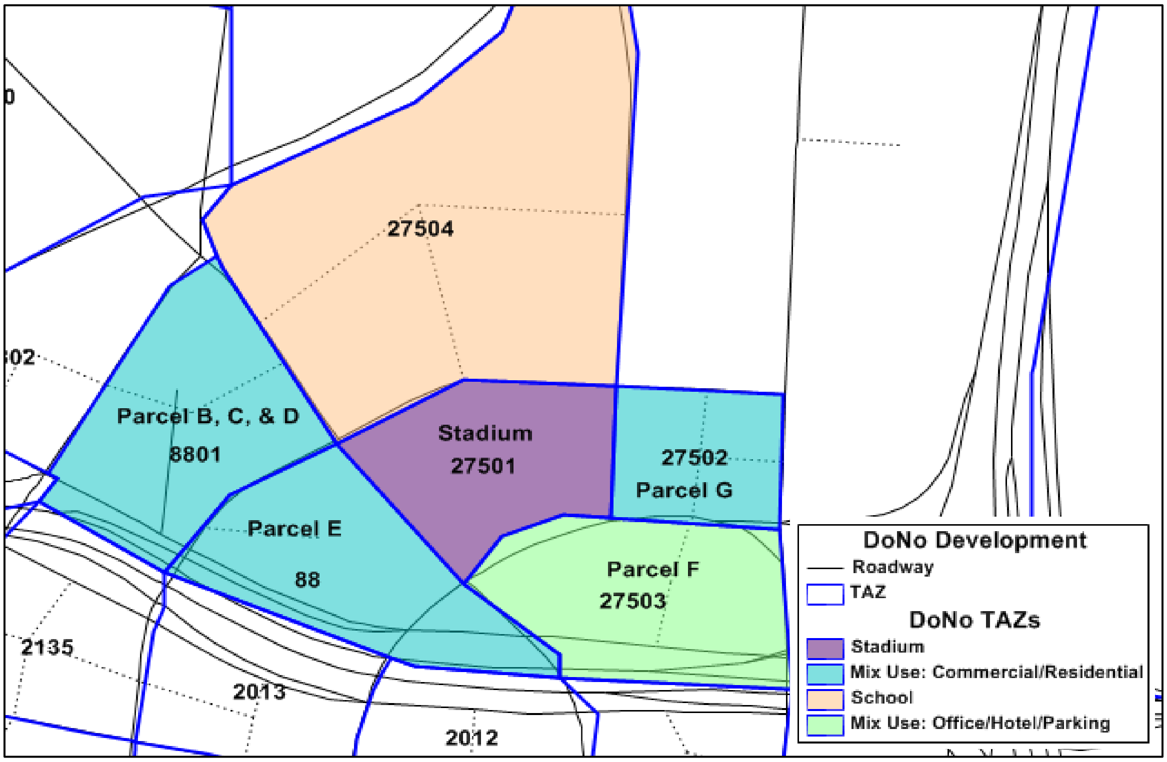
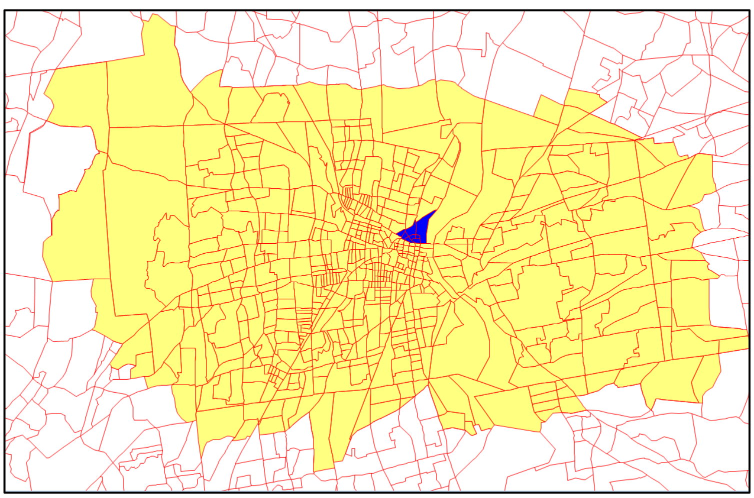
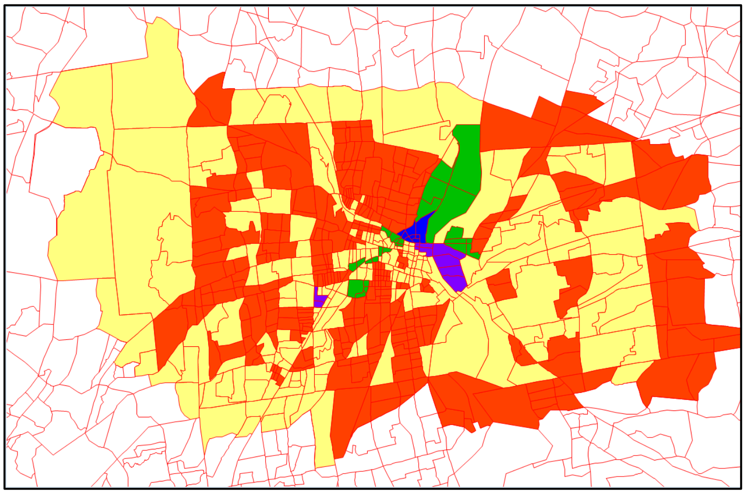


Figure 11: TAZ Subdivided for the DoNo Development



As noted above, all of the TAZs within the towns of East Hartford, Hartford, and West Hartford, along with a ring of TAZs around these towns, were considered for possible subdivision. Figure 12 illustrates all of the TAZs that were subdivided for the purposes of the CRCOG Model Update.

Figure 12: All TAZ Subdivided for the CRCOG Model Update



For any TAZ modified, socioeconomic data was distributed among the parent and children TAZs based on size of the resulting TAZ, Census data, and/or visual inspection. Original population, household, and employment data were held constant.

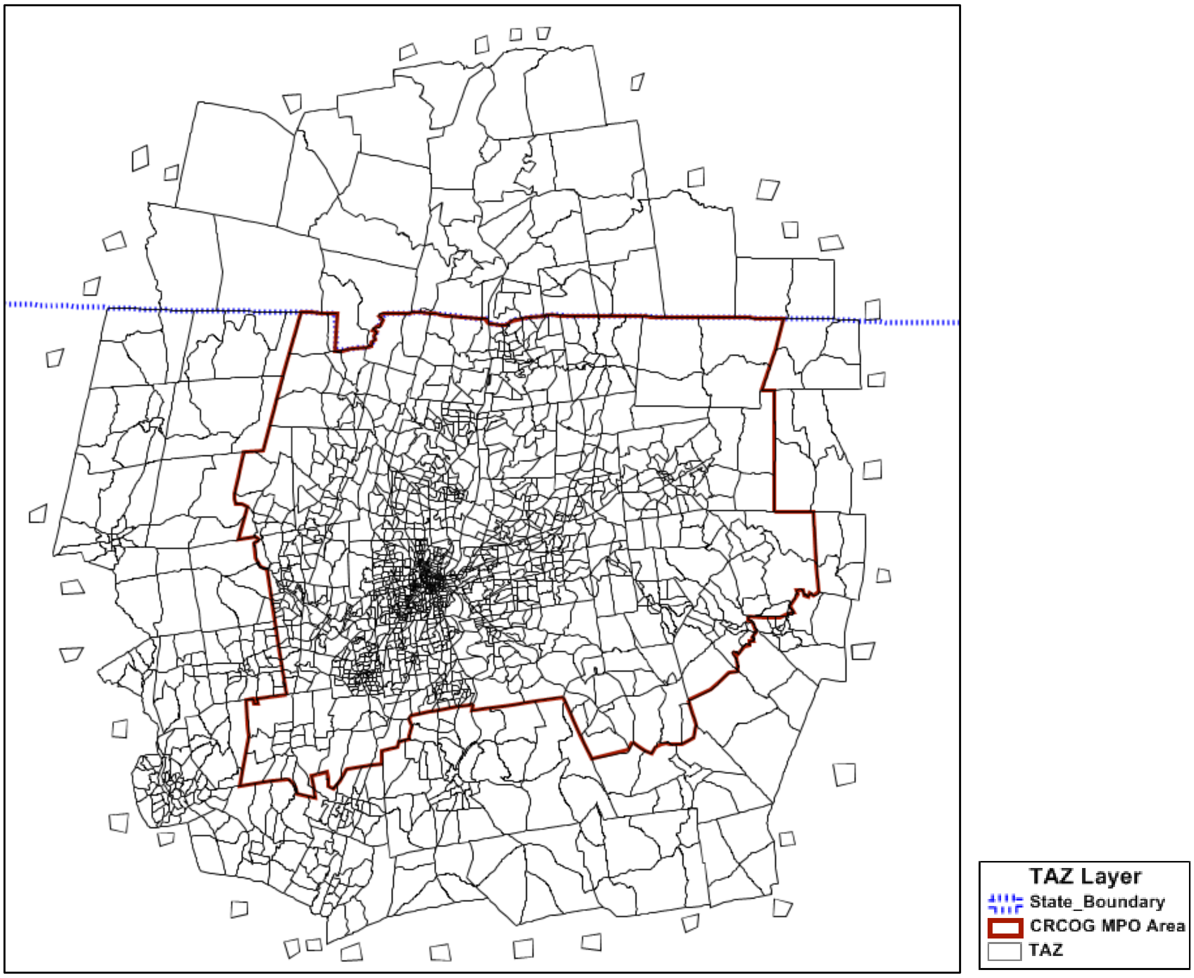
Table 9 summarizes the changes made to the TAZ structure by town. A total of 214 TAZs were added in the three town covered by the review. The largest number of TAZ, (144) were added in the city of Hartford, 53 TAZ were added in the town of West Hartford, and 19 in the town of East Hartford. Thirty TAZ were added within the perimeter of the three towns in the Ring area. Within the area reviewed, the average TAZ area decreased from 0.27 to 0.14 square miles.

Table 9: TAZ Review and Modification Summary

Area	Number of TAZ		Average Area	
	Old	New	Old	New
East Hartford	56	75	0.33	0.25
Hartford	194	336	0.09	0.05
West Hartford	90	143	0.43	0.16
Ring	46	75	0.69	0.41
Totals	**386**	**629**	**0.27**	**0.14**

As a result of the model update and TAZ review there are now 2,028 TAZ in the CRCOG model. This includes 1,991 internal TAZ and 37 external stations. The TAZ system for the CRCOG Region is shown in Figure 13.

Figure 13: Final CRCOG TAZ



4.2 TRAFFIC ANALYSIS DISTRICTS

Traffic Analysis Districts (Districts) are aggregations of contagious TAZ into larger geographic units. They have no direct connection to the model, as do TAZ, but are rather used primarily as an aid in model development as well as the reporting and evaluation of model results. For example, Districts can be useful in evaluating OD matrices, facilitating the identification of patterns that would not be possible looking at a full OD matrix.

As with the TAZ, the District system used in the CRCOG model was also revised. The primary objective behind these revisions was to reduce the number of Districts from 40 (as in the previous model) to a number felt to be more manageable. The revised system has 25 districts. In addition, a system of Super Districts was also developed to further aid in model development and evaluation. A summary of the revised Districts and Super Districts appears in Table 10.

Table 10: District Summary

Super-District	District	Location	Number of TAZs	Notes
101	101-104	Hartford	336	Combine the 4 original Hartford districts (CBD, N / S /E /W of CBD)
201	201-202	West Hartford	143	TOWN of West Hartford
301	301-302	East Hartford	75	Town of East Hartford
401	401-403, 405	Northern CRCOG	337	Towns of Canton, Simsbury, Granby, Suffield, East Granby, Windsor, Bloomfield, East Windsor, Windsor Locks, Enfield, Somers, and Ellington
402	404, 406, 407	Southeastern CRCOG	302	Towns of Rocky Hill, Wethersfield, Glastonbury, Manchester, South Windsor, Vernon, and Bolton
403	408-412	Southwestern CRCOG	288	Towns of Southington, Berlin, New Britain, Newington, Plainville, Farmington, and Avon
404	405, 415	Eastern CRCOG	130	Towns of Marlborough, Hebron, Andover, Columbia, Coventry, Mansfield, Tolland, Willington, and Stafford
501	401, 410, 411, 413, 414, 501, 502	West Buffer	268	Towns of Colebrook, Hartland, Barkhamsted, Winchester, Torrington, New Hartford, Harwinton, Burlington, Bristol, Plymouth, Thomaston, Wolcott, Waterbury, Prospect, Cheshire, Wallingford, Meriden, Middlefield, Durham, Middletown, and Cromwell
502	502,406	East Buffer	64	Towns of Haddam, East Haddam, East Hampton, Portland, Colchester, Salem, Lebanon, Windham, Chaplin, Ashford, and Union
601	601	Massachusetts	48	Towns in Massachusetts: Blandford, Granville, Montgomery, Russell, Southampton, Southwick, Tolland (MA), Westfield, Agawam, Chicopee, East Longmeadow, Easthampton, Granby (MA), Hampden, Holyoke, Longmeadow, Ludlow, South Hadley, Springfield, West Springfield, Wilbraham, Wales, Holland, and Monson
701	701	External	37	Externals

4.3 SOCIOECONOMIC DATA

Statewide socioeconomic data for 2010, 2025, and 2040 was provided by the Connecticut Department of Transportation, Bureau of Policy & Planning. Information was extracted from this data for the CRCOG model area. Socioeconomic data for that part of the CRCOG model area in Massachusetts was carried over from the previous CRCOG model. Table 11 is a summary of this data.

Consideration was given to updating the 2010 Base Year data with 2015 information; however, an investigation into data available through the U.S. Census Bureau's Population Estimate Program showed there to be little or no growth in the region between 2010 and 2015. For example, in the Hartford-West Hartford-East Hartford Metropolitan Statistical Area (MSA) the population declined by 1,063 persons (-0.09%) from 1,212,387 to 1,211,324, while in the

Springfield MA MSA the population only grew by 10,277 persons (1.7%) from 621,705 in 2010 to 631,982 in 2015. Combined, these two MSA grew by 9,214 persons or 0.50%. In light of this data, the decision was made to move forward with the socioeconomic data unchanged and refer to it as 2015 Base Year data.

Table 11: CRCOG Region Socioeconomic Data

SED	2015 Base Year	2025	2010 - 2025 Change		2040	2025 - 2040 Change	
			Number	Percent		Number	Percent
Households	802,832	866,736	63,904	7.96%	924,595	57,859	6.68%
Population	2,067,580	2,188,838	121,258	5.86%	2,289,137	100,299	4.58%
Retail Employment	141,888	149,983	8,094	5.70%	157,319	7,336	4.89%
Non-Retail Employment	767,693	817,728	50,035	6.52%	859,257	41,528	5.08%

Validation of the socioeconomic data was accomplished by means of a comparison between model socioeconomic data and the same data from the U.S. Census Bureau Transportation Planning Program (CTPP) and Longitudinal Employer-Household Dynamics (LEHD) program. The following CTPP tables were referenced for the comparison to population and household data:

- A101100 – Population (1) (All persons),
- A112107 – Population in Households (1) (Population in households),
- A112100 – Total Households (1) (Households), and
- A103100 – Total Workers in Households (1) (Workers 16 years and over in households).

Data for comparison of employment totals came from the LEHD program. For Connecticut, 2010 estimates of all jobs was used. Massachusetts did not start to participate in the program until 2011, therefore, the employment data was estimated as follows:

2010 MA Employment = 2010 CT Employment * (2011 MA Employment / 2011 CT Employment)

A comparison, between model and census data, of population, population in households, households, workers, and employment is presented in Table 12. For the most part, differences between the two data sets are relatively small (< 1.0 percent difference). The only exceptions being the number of workers in Massachusetts (8.29 percent), Connecticut employment (2.62 percent), and Massachusetts employment (1.12 percent). Overall, however, the results were deemed to be acceptable and reasonable.

Table 12: Socioeconomic Data Validation

SED	Model	CTPP / LEHD	Difference	
			Number	Percent
CT Population	1,575,577	1,565,960	9,617	0.61%
MA Population	492,003	490,745	1,258	0.26%
Total Population	**2,067,580**	**2,056,705**	10,875	**0.53%**
CT Population in HH	1,516,043	1,508,110	7,933	0.52%
MA Population in HH	475,019	471,770	3,249	0.68%
Total Pop in HH	**1,991,062**	**1,979,880**	**11,182**	**0.56%**
CT Households	611,336	607,350	3,986	0.65%
MA Households	191,496	189,675	1,821	0.95%
Total HH	**802,832**	**797,025**	**5,807**	**0.72%**
CT Number of Workers	745,356	750,945	-5,589	-0.75%
MA Number of Workers	233,520	214,150	19,370	8.29%
Total Workers	**978,877**	**965,095**	**13,782**	**1.41%**
CT Employment	711,073	729,733	-18,660	-2.62%
MA Employment	198,508	196,279	2,230	1.12%
Total Employment	**909,581**	**926,012**	**-16,430**	**-1.81%**

5. TRIP GENERATION MODEL

Trip generation is the first step in the conventional four-step transportation forecasting process. Typically, trip generation models utilize socioeconomic data (SED), such as the number of households and employment in a TAZ, to understand the trip generation potential associated with the zone. Other models rely upon land use information, such as square feet of commercial space, to estimate trips. The CRCOG model is SED based.

A comparison of the model specifications for the previous CRCOG model and the updated CRCOG model is presented in Table 13.

Table 13: CRCOG Model Enhancements to Trip Generation

No.	Model Component	Existing Specification	Revised Specification
1	Household Segmentation	HHs by 0, 1, 2+ autos and by 7 income categories	HHs by 0, 1, 2, 3+ autos, by 4 income categories, by size 1, 2, 3, 4+ and by 0, 1, 2, 3+ workers.
2	HBW and HBO Productions	HBW trip production rates by 0, 1, 2+ cars HBO trip production rates are not segmented	Trip production rates by auto sufficiency with the following market segments: **Zero**: zero auto households; **Low Insufficient**: low income and workers > autos: **Low Sufficient**: low income and workers <= autos; **High Insufficient**: high income and workers > autos; and, **High Sufficient**: high income and autos <= workers.
3	NHB Trip Productions	Rates not segmented	No change
4	External and Truck Trips	Separate modules for these trips	No change
5	Trip Attractions	Trip attraction rates by purpose	Destination Choice model will have size terms that eliminate the need for calculating trip attraction rates

Note: ">" greater than, "<=" less than or equal.

5.1 HOUSEHOLD CLASSIFICATION MODELS

For the updated CRCOG model, the trip generation rates are segmented by household income and auto sufficiency categories. Shown in Table 13 but also listed again here, the travel market segmentations are:

- 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)

To apply the rates, the number of households in each of the five categories within each TAZ must be known.

The CRCOG socio-economic data has, for each TAZ, the number of households by income and auto-ownership categories. This data, however, does not have the number of workers (0, 1, 2, 3+), which is needed to determine the number of households within each combination of income/autos/workers listed above. Once the number of households by income category, auto ownership category, and number of workers category is known, a three-dimensional matrix balancing exercise (also known as Fratar) is performed to determine the cross-classification. For each TAZ, the number of households by are used as the control total, and the cross-tabulation of households is used to seed each cell of the matrix. The matrix balancing procedure scales the cells in each dimension of the matrix in turn until the number of households in the combined income/auto/worker category is determined and the control totals of each individual category is respected (within a certain tolerance). Then, the cells of the matrix are aggregated based on the segmentation definitions given above for each TAZ. For example, all households with 0 autos, regardless of income or number of workers are included in the 0-auto segment. Low income households with 1 auto and 2 workers or 1 auto and 3+ workers are included in the low insufficient category. Similarly, low income (income categories 1 and 2) households with 1 auto and 1 worker, or 2 autos and 1 worker, or 2 autos and 2 workers, or 3 autos and 1 worker, or 3+ autos and 2 workers, or 3+ autos and 3+ workers are included in low sufficient category. High income (income categories 3 and 4) households are categorized in the same manner. The trip generation rates are then applied to the number of households in each segment. Each step of this process is explained in more detail below.

5.1.1 Number of Workers

Three steps were required to determine the number of households by each workers category (0, 1, 2, 3+) for each TAZ. First, a regression model was used to compute the average number of workers per household in each TAZ based on average household size. The CRCOG SED data provides the total number of households as well as the total population of each TAZ, and from that the average household size for each TAZ can be calculated. Based on that average household size, the average number of workers per household is calculated using the following equation (which was estimated using ACS data for the region):

$$\text{Avg \# of workers} = 0.42 \times (\text{average HH size}) + 0.18$$

Table 14 summarizes the resulting worker model and the associated R^2 statistics.

Figure 14 demonstrates the fit of the number of workers estimated by the model against the ACS data.

Table 14: Worker Model

Term	Coefficient	t.Stat	R Square
Intercept	0.18	4.70	0.44
HH Size	0.42	27.04	

Figure 14: ACS Workers and Estimated Workers

The next step was to develop a look-up table using ACS data that provides the distribution of 0, 1, 2, and 3+ worker households based on the average number of workers per household in each ACS TAZ. Figure 15 shows the raw data from ACS, Figure 16 shows the smoothed curves and the equations used to develop the look-up table, and Table 15 shows a few rows of the final look-up table that was developed.

Figure 15: ACS Data – Household Shares by Workers per Household:

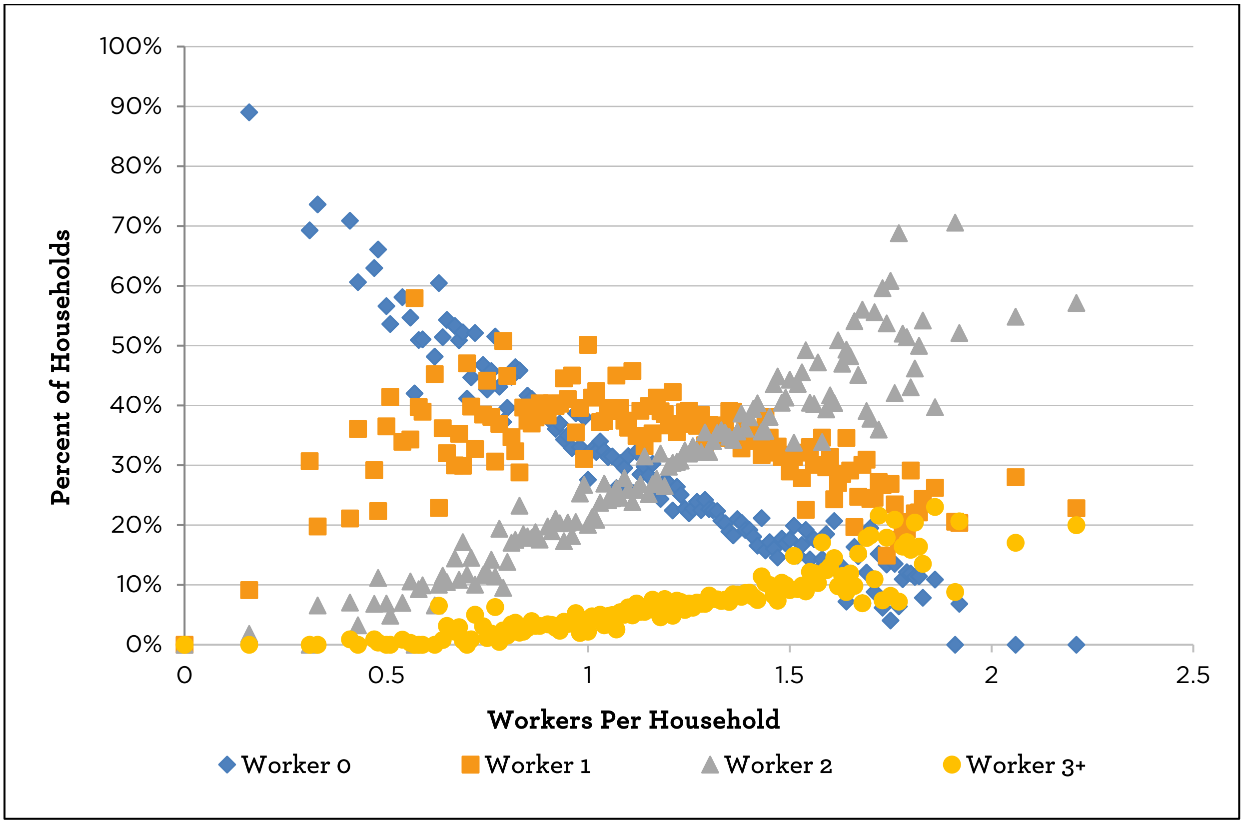
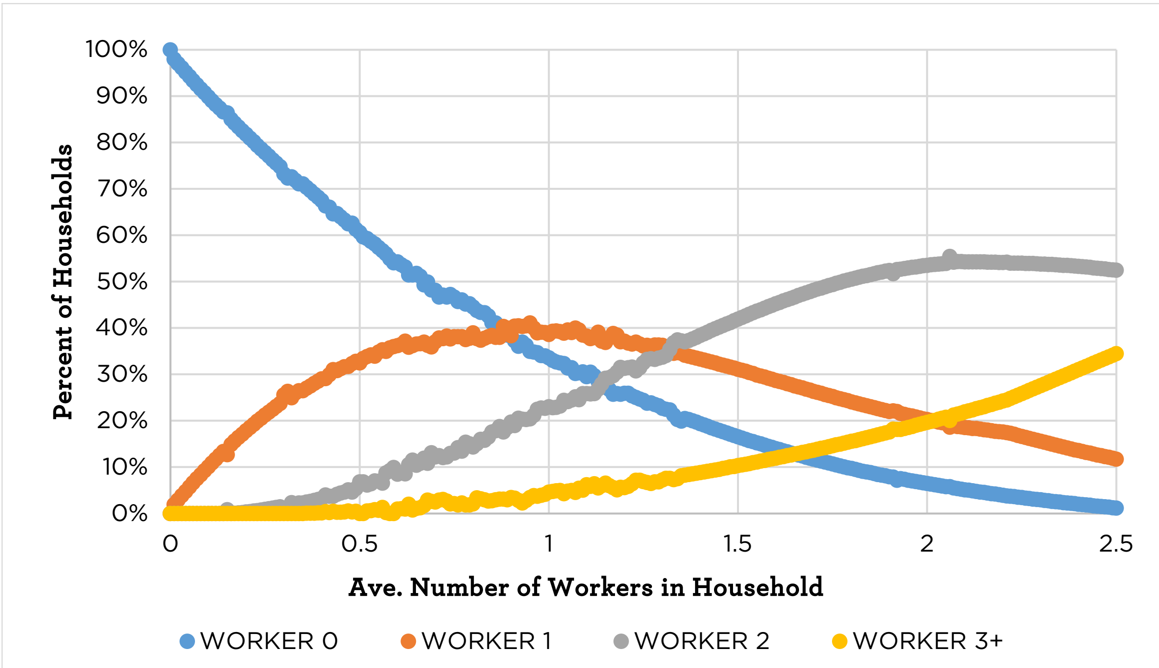


Figure 16: Workers per Household Classification Curves:



Variable	Equation	Root Square (R^2)
Worker 0	$y = -0.0271x^3 + 0.2656x^2 - 0.8799x + 0.9762$	$R^2 = 0.9998$
Worker 1	$y = 0.0961x^3 - 0.548x^2 + 0.789x + 0.0501$	$R^2 = 0.9853$
Worker 2	$y = -0.0774x^3 + 0.2489x^2 + 0.0895x - 0.0244$	$R^2 = 0.9951$
Worker 3+	$y = 0.0085x^3 + 0.0332x^2 + 0.0006x - 0.0019$	$R^2 = 0.9992$

Table 15: Workers per Household Lookup table (sample)

Workers per Household	Worker 0	Worker 1	Worker 2	Worker 3+
0.60	0.5429	0.3626	0.0848	0.0097
0.61	0.5368	0.3651	0.0878	0.0103
0.62	0.5317	0.3722	0.0861	0.0100
0.63	0.5149	0.3589	0.1058	0.0204
0.64	0.5145	0.3621	0.1155	0.0079
0.65	0.5183	0.3656	0.1047	0.0114

The final step in determining the number of households for each worker category in each TAZ is to find the row in the look-up table that corresponds to the average number of workers for that zone and multiply the total number of households by the distribution (percent) of households per worker category. This will then determine the number of households with 0, 1, 2, 3+ workers for that zone.

5.1.2 Income and Auto Ownership

As mentioned above, the joint distribution of households by income and auto categories is already provided for in the SED input file. These distributions were developed using public-use micro-sample

(PUMS) data. The distribution uses four auto categories (0, 1, 2, 3+) and four income quartiles and replaces the previous distribution which had three auto categories (0, 1, 2+) and 7 income groups. Household income quartiles were identified based on data from the U. S. Census Bureau, American Community Survey 2006 – 2010 Five-year Period Estimates available through the Census Transportation Planning Program. The household income classifications used in this model update appear in Table 16.

Table 16: Household Income Classification

Income Groups	Household Income
1	Less than $29,999
2	$30,000 - $59,999
3	$60,000 - $99,999
4	$100,000 or more

Each TAZ was assigned to a specific PUMS zone if the geographic center of the TAZ fell within the PUMS zone boundary. The CRCOG model area was covered by 19 PUMS Zones. The number of households in each PUMS Zones ranged from 10,084 to 65,021 with a median number of households per PUMS Zones of 44,372. The distribution of households by autos, by income for any TAZ was determined by applying the same characteristics of the PUMS Zone to which that TAZ was assigned. A summary of number of households by auto and income category is provided in Table 17.

Table 17: Households by Auto Ownership and Income Quartile

Auto	Income Group	Households
0	1	62,199
	2	13,150
	3	4,468
	4	3,179
1	1	100,183
	2	98,803
	3	54,915
	4	23,114

Auto	Income Group	Households
2	1	23,877
	2	62,486
	3	89,764
	4	121,983
3+	1	5,107
	2	16,140
	3	34,838
	4	88,628

5.1.3 Joint Distribution of Households by Income and Auto Sufficiency

The final step in determine the number of households in each income/auto sufficiency category is to first determine the number of households within the joint distribution of income, autos and workers. A three-dimensional matrix [dimension 1 is income (1, 2, 3, 4), dimension 2 is autos (0, 1, 2, 3+) and dimension 3 is workers (0, 1, 2, 3+)], is seeded with the joint distribution from PUMs. (See Table 18)

Table 18: Household Seed Submodel

Autos	Income Group	Workers			
		0	1	2	3+
0	1	1.317	1.109	0.146	0.015
	2	0.168	0.336	0.259	0.022
	3	0.069	0.128	0.161	0.040
	4	0.033	0.040	0.223	0.066
1	1	2.138	2.674	0.565	0.018
	2	1.820	3.152	1.116	0.131
	3	0.569	1.901	1.105	0.201
	4	0.266	0.617	0.799	0.175
2	1	1.321	1.262	0.649	0.040
	2	2.481	3.670	3.462	0.295
	3	1.729	4.480	7.967	0.843
	4	0.959	4.254	14.406	1.197
3+	1	0.244	0.270	0.168	0.047
	2	0.492	1.113	1.218	0.445
	3	0.390	1.591	3.714	2.036
	4	0.288	2.036	7.836	7.719

The matrix is then "balanced" by scaling each dimension iteratively to match the TAZ-level control total (the joint distribution of income and autos as given in the SED input data and the number of households by workers as calculated using the procedure explained above). Once the matrix balancing procedure is complete, the number of households in each combination of income, autos and workers (for example, the number of income 1, autos 0, worker 2 households) is known. The matrix cells are then collapsed, and the values summed based on the household segmentation as defined above and in Table 18.

This process is done for the base year as well as each scenario year as the joint distribution of households by income and autos changes as does the average household size and thus the average number of workers per household and thus the number of households by worker category.

5.2 TRIP PRODUCTION MODEL

This section describes the development and validation of the trip production model. In terms of model sequence, this model represents the first step in the traditional 4-step process. The trip production model uses the results from the household classification submodels to estimate trip production for households in each TAZ. The outputs from the trip production model are fed into the destination choice models.

> Traditional 4 steps:
>
> 1: Trip Production (Generation) - estimates the number of trips that are produced or originate in each Traffic Analysis Zone (TAZ).
>
> 2: Trip Distribution - where matches between origins and destinations are developed. Trip ends are linked to create complete trips.
>
> 3: Mode Choice - predicts the choices that individuals or groups make in selecting their transportation modes. An important objective is to predict the share of trips attracted to public transportation.
>
> 4: Trip Assignment - is to determine the routes travelers choose to reach their destinations.
>
> Note, destination choice model is a type of trip distribution or spatial interaction model which is formulated as discrete choice model, typically logit models. This can be thought of as a generalization of the traditional and widely used gravity /4-step model.

5.2.1 Model Structure

The model maintained the primary trip purposes from previous CRCOG model generating trips for the following trip purposes:

- Home-based-work (HBW)
- Home-based-other (HBO)
- Non-home-based (NHB)

The rates for the HBW and the HBO purposes are segmented based on household income and auto sufficiency, as defined in Section 5.1, and summarized as:

- Zero-car households, all income groups
- Households with insufficient autos and low income
- Households with sufficient autos and low income
- Households with insufficient autos and high income
- Households with sufficient autos and high income

This replaces the market segmentation used in the previous CRCOG model, which had three auto and seven income categories.

The NHB trip rates are not segmented. Trip production procedures for trucks, internal/external trips, and airport trips were kept as in the previous model.

Trip attractions, in the context of a destination choice model, are incorporated directly during the calculation of the utility equation and will be discussed in section 6 - Destination Choice.

5.2.2 Trip Production Rates

Trip production rates for resident trip purposes (HBW, HBO, and NHB) were estimated based on the 2016 HTS. These rates were used to generate trips for the CRCOG model area, which were then compared to the trip totals from the previous CRCOG model. The rates were applied and adjusted until the resulting trip totals were a match to the previous CRCOG model totals.

Table 19 presents a comparison of the trip production totals from previous CRCOG model with the totals from the updated trip rates.

Table 19: Trip Production Totals

Previous CRCOG Model		CRCOG Model Update	
Purpose	**Productions**	**Purpose**	**Productions**
HBW_0Car	68,062	HBW_zero	68,062
HBW_1Car	295,720	HBW_low_insufficient	65,965
HBW_2Car	820,955	HBW_low_sufficient	231,799
		HBW_high_insufficient	87,678
		HBW_high_sufficient	731,233
HBW Sub-Total	1,184,737		1,184,737
HBW_IX	109,120	HBWP_IX	109,120
HBW_XI	118,902	HBWP_XI	118,902
HBW IXXI Sub-Total	228,022		228,022
		HBO_zero	284,824
		HBO_low_insufficient	119,355
		HBO_low_sufficient	1,132,315
		HBO_high_insufficient	156,622
		HBO_high_sufficient	2,174,028
HBO Sub Total	3,867,144		3,867,144
NHB Sub Total	1,646,763		1,646,763
NWIX	275,463	NWIXP	275,463
NWXI	325,790	NWXIP	325,790
BIA_Airport	6,153	BIAP	6,153
TII	496,949	TIIP	496,949
TIX	36,820	TIXP	36,820
TXI	37,943	TXIP	37,943
Truck Sub Total	571,712		571,712
Total Trip Production	8,105,783		8,105,783

Table 20 thru Table 22 illustrate the survey trip rates, developed from the 2016 HTS, and the calibrated trip rates for HBW, HBO, and NHB trips used in the trip production model. The reader will note that the income groups noted in Table 16 have been collapsed in number from four to two for the purposes of the trip generation rates. This was done as a result of too few observations being available from the 2016 HTS on which to base rates for all 64 cells in the full table for each trip purpose.

Table 20: Home-Based-Work Trip Production Rates (HBW)

Autos	Income Group	Survey Rates				Calibrated Rates			
		Workers				Workers			
		0	1	2	3+	0	1	2	3+
0	1 & 2	0	0.82	2.65	2.65	0	0.92	2.99	2.99
	3 & 4	0	1.61	1.83	1.83	0	1.82	2.07	2.07
1	1 & 2	0	1.11	2.15	2.32	0	1.18	2.29	2.47
	3 & 4	0	1.19	2.20	2.49	0	1.27	2.34	2.65
2	1 & 2	0	1.34	2.03	2.03	0	1.42	2.16	2.16
	3 & 4	0	1.29	2.31	3.61	0	1.37	2.46	3.84
3+	1 & 2	0	1.29	2.06	3.74	0	1.38	2.19	3.98
	3 & 4	0	1.28	2.44	3.90	0	1.36	2.60	4.15

Table 21: Home-Based-Other Trip Production Rates (HBO)

Autos	Income Group	Survey Rates				Calibrated Rates			
		Workers				Workers			
		0	1	2	3+	0	1	2	3+
0	1 & 2	2.72	3.38	4.10	4.10	2.91	3.62	4.39	4.39
	3 & 4	2.72	3.56	4.10	4.10	2.91	3.81	4.39	4.39
1	1 & 2	3.55	2.97	3.49	6.31	3.80	3.18	3.74	6.76
	3 & 4	3.67	2.60	3.83	4.67	3.93	2.78	4.10	5.00
2	1 & 2	4.60	4.57	4.51	6.81	4.92	4.89	4.83	7.29
	3 & 4	5.19	6.10	5.55	6.49	5.56	6.53	5.94	6.95
3+	1 & 2	4.85	5.06	6.27	5.30	5.20	5.42	6.72	5.68
	3 & 4	5.98	6.27	5.67	5.58	6.40	6.71	6.07	5.98

Table 22: Non-Home-Based Trip Production Rates (NHB)

Autos	Income Group	Survey Rates				Calibrated Rates			
		Workers				Workers			
		0	1	2	3+	0	1	2	3+
0	1 & 2	1.22	1.63	1.68	1.68	0.92	1.24	1.27	1.27
	3 & 4	1.22	1.51	3.02	3.02	0.92	1.14	2.28	2.28
1	1 & 2	2.20	2.29	2.71	2.07	1.66	1.73	2.05	1.57
	3 & 4	2.21	2.19	3.32	5.14	1.67	1.66	2.51	3.89
2	1 & 2	1.99	2.70	2.96	3.37	1.50	2.04	2.24	2.55
	3 & 4	2.63	2.99	3.47	2.29	1.99	2.26	2.62	1.73
3+	1 & 2	1.84	2.62	4.96	7.27	1.39	1.98	3.75	5.50
	3 & 4	2.85	3.63	3.34	3.65	2.16	2.74	2.53	2.76

Validation of the trip generation model included a check of common ratios based on person trip totals and socioeconomic data to those seen in other modeling efforts. While it is difficult to validate the disaggregate rates by market segment, the final results of the Trip Generation model were compared to trip rates per household seen in other HH surveys or in the NHTS. As shown in Table 23 below, the results produced by the CRCOG model compare reasonably well with the typical rates observed from other modeling efforts.

Table 23: Validation Ratio Checks

Ratio Checks	Model	Typical Rates	Source
Workers to Employment	1.08	1.04	U.S. Census
Persons to Households	2.48	2.48	
Workers to Households	1.22	1.21	
HBW Productions per Worker	1.21	< 2	
HBW Productions per Household	1.48	1.55	TMIP Travel Model Validation and Reasonableness Checking
Total Productions by HH	10.1	8 to 18	
Total Productions by Person	4.1	3.5 to 4.0	NCHRP Report 365
HBW Productions per HH	1.6	1.7 to 2.3	
HBO Productions per HH	4.8	3.5 to 4.8	
NHB Productions per HH	2.1	1.7 to 2.9	

6. DESTINATION CHOICE MODEL

The destination choice model replaces the gravity model used in the previous version of the CRCOG regional model. 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. Unlike the gravity model, the destination choice 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 (end of a trip). The destination choice model is preceded by the trip production models, which forecast the number of trip productions by zone for different market segments, identified by trip purpose, income, and auto sufficiency, as defined in Section 5.1. The market segments used in the CRCOG model are shown in Table 24 and discussed further in section 6.

Table 24: CRCOG Market Segmentation

Purpose	Household Income	Household Auto Sufficiency
Home-Based-Work	All Incomes	Zero Auto
Home-Based-Work	< $60,000	Auto Insufficient
Home-Based-Work	< $60,000	Auto Sufficient
Home-Based-Work	>= $60,000	Auto Insufficient
Home-Based-Work	>= $60,000	Auto Sufficient
Home-Based-Other	All Incomes	Zero Auto
Home-Based-Other	< $60,000	Auto Insufficient
Home-Based-Other	< $60,000	Auto Sufficient
Home-Based-Other	>= $60,000	Auto Insufficient
Home-Based-Other	>= $60,000	Auto Sufficient
Non-Home-Based	No Market Segmentation	

6.1 SUPPORTING DATA

The 2016 'Let's Go CT' Household Travel Survey (HTS) was key to the development of the target values that are the core of the estimation data used for calibration of the destination choice model. Information regarding trip characteristics obtained from the HTS includes trip purpose, household income, number of workers, and auto ownership. The HTS also provided the observed trip length frequency distributions necessary for model calibration.

Using data from the HTS for the CRCOG MPO area, the trip length distributions by trip purpose and market segment were determined. These distributions were assumed to represent the entire CRCOG model area. Then, for each trip purpose and market segment, the proportion of trips by distance was applied to the total trips by purpose and market segment generated by the trip production model. The resulting distribution represented the target values used in the calibration of the destination choice model.

Required network impedance information came from the mode choice logsums and distance skims from the CRCOG model. In addition, Census Transportation Planning Products (CTPP) data based on the 2006-2010 5-year American Community Survey (ACS) were used to assess the Home Based Work (HBW) trip distribution.

6.2 MODEL STRUCTURE

The utility (U_{ij}) of choosing a trip attraction destination (j) for a trip produced in zone (i) is a function of mode choice logsums, distance between zone *i* and zone *j*, distance factors, and an indicator variable for intrazonal production-attraction (PA) pairs. This is expressed as:

$$U_{ij} = \beta_{LS} * logsum + Size\ Term + \beta_d * distance + \sum_{d=1}^{7} \beta_{DF_d} * (1\ if\ i\ and\ j\ \epsilon\ d) + \beta_{IZ} * (1\ if\ i = j)$$

In the utility equation above, β_{DF_d} is the coefficient for distance factor *d*. Other distance terms such as distance squared or distance cubed, if included, enter the utility equation in exactly the same way as the distance term. For brevity those terms are not shown in the utility equations above. Also note that the beta coefficients are unique to each trip purposes. Finally, the size factors used for each trip purpose are shown in Table 25.

Table 25: Size Factors by Trip Purpose

Trip Purpose		Retail Employment	Non-Retail Employment	Households
HBW	Zero	0.52	0.0385	0
	Low insufficient	0.52	0.0385	0
	Low sufficient	0.52	0.0385	0
	High insufficient	0.48	0.615	0
	High sufficient	0.48	0.615	0
HBO	Zero	0.01379	0.01011	0.00677
	Low insufficient	0.01379	0.01011	0.00677
	Low sufficient	0.01379	0.01011	0.00677
	High insufficient	0.01388	0.01178	0.01154
	High sufficient	0.01388	0.01178	0.01154
NHB		0.0571	0.01347	0.0109

Once the utility for each PA pair is obtained from the utility equation above, they are used to construct the probability using a multinomial logit model (MNL). The MNL probability expression is given by:

$$P_{ij} = \frac{\exp(U_{ij})}{\sum_k U_{ik}}$$

In the above expression, the index *k* takes all the available attraction zones in the region.

The destination choice utilities are a function of mode choice logsums, and they are applied consistently, in the sense that the same coefficients and constants that are used for mode split are also used for calculating the logsums. Shadow prices are used to constrain the HBW attractions to a given zone to be proportional to the employment in that zone, thus, shadow prices are calculated only for the HBW purpose. Total employment data is first scaled to total number of attractions for all five market segments. Shadow prices for all zones are calculated using the following equation. The Shadow price procedure is implemented for a maximum of 15 iterations with a convergence criteria of 1%.

Shadow price = log(scaled employment / total attractions) for all zones

Shadow prices are estimated during the trip distribution procedure, specifically during the HBW destination choice model. The shadow prices are calculated for each scenario / forecast year run.

This means that after the location probabilities are calculated on the basis of the utility functions, a shadow price is added to the utility of each destination with the objective of matching a pre-specified number of trip attractions to the zone. Employment is usually a standard input to travel models and is considered largely independent of the household travel survey. The shadow price addition is shown below:

$$U'_{ijm} = U_{ijm} + sp_j$$

In the equation above U_{ijm} is the base utility from production zone *i* to attraction zone *j* for purpose *m* and sp_j is the shadow price for attraction zone *j*. U'_{ijm} is the final utility.

The mode choice logsum coefficients were asserted based on experience with the estimation of other destination choice model, and typical values used in other metropolitan area. All other coefficients in the destination choice model were calibrated to obtain good fit with the calibration targets. The distance factors are constant terms added to the utility if the distance between production and attraction falls within a particular distance band. Seven distance factors, for the first seven one mile distance bands were used in the calibration.

6.2.1 Model Calibration

The calibration of the destination choice model involves making small incremental adjustments to the distance coefficients to better match observed trip patterns. The models are first calibrated to match first-order calibration targets for trip length frequency and average trip lengths by trip purpose. Segmented distance terms are often needed to match the short distance portion of the observed trip length frequency curve. The distance cap is also often adjusted during model calibration to ensure that the model reproduces the tail (longer trips) of the trip length frequency distribution. The CRCOG model also included intrazonal coefficients.

The CRCOG destination choice models were calibrated to reproduce observed trip patterns, including trip length frequency distributions and average travel times based on the HTS, and intrazonal percentages from the previous CRCOG model.

6.2.2 Calibration Targets

The following calibration targets were developed for this effort:

- Intrazonal percentage by trip purpose
- Average trip lengths by trip purpose and market segmentation
- Trip length distributions by trip purpose and market segmentation

Table 26 provides a summary of the destination choice model calibration by trip purpose. The coincidence ratio is a measure of the goodness-of-fit of the calibrated trip length distribution compared to the observed (target) trip length distribution. It is preferable for the coincidence ratio for each trip purpose to be at least 70 percent[1]. The coincidence ratio shows a good fit for all three trips purposes with a ratio of 0.86 for Home Based Work (HBW), 0.89 for Home Based Other (HBO), and 0.69 for Non Home Based (NHB) trips.

The percentage of total trips that are attracted to the production zone (intrazonal trips) is also compared between the model and the target data in Table 28. For each trip purpose the match between the target proportion of intrazonal trips and model results is reasonably good. For all three trip purposes the model results are within 3 percent of the target percentage. The model predicted average trip length (miles) is within 2 percent of the target value for HBW and HBO trips and less than 1 percent for NHB trips.

Table 26: Goodness of Fit Measures

Purpose	Coincidence Ratio	% 02Intrazonal trips				Average Trip Length (Miles)			
		Target	Model	Difference		Target	Model	Difference	
				Number	Percent			Number	Percent
HBW	0.86	7.5	7.49	-0.01	-0.13%	11.84	11.66	-0.18	-1.52%
HBO	0.89	8.7	8.95	0.25	2.87%	5.09	5.03	-0.06	-1.18%
NHB	0.69	8.2	8.37	0.17	2.07%	7.7	7.66	-0.04	-0.51%

A comparison between the target and modeled average trip distances for the HBW and HBO trips by market segment, as well as NHB trips, is shown in Table 27. Across all trip purposes and market segments, the model average trip lengths are within 3 percent of the target values. Among HBW trips modeled trip length is 2.9 percent greater than the target for the zero auto market and within 1 percent for all other markets. For HBO trips, the modeled trip length is 2 percent greater than the target for the zero auto market, 1.3 percent lower for the low income sufficient market, and within 1 percent for all other market segments. The modeled average trip length for NHB trips is -0.5 percent different from the target value.

[1] *Travel Model Validation and Reasonableness Checking Manual, Second Edition*. Federal Highway Administration, Travel Model Improvement Program, September 24, 2010. Page 6-15.

Table 27: Average Trip Length by Market Segment

Market Segment		Average trip length (miles)		Difference	
		Target	Modeled	Number	Percent
HBW	Zero	7.14	7.34	0.2	2.90%
	Low insufficient	6.51	6.57	0.06	0.90%
	Low sufficient	9.84	9.81	-0.03	-0.30%
	High insufficient	12.36	12.29	-0.07	-0.60%
	High sufficient	13.01	13.04	0.03	0.20%
HBO	Zero	3.2	3.27	0.06	2.00%
	Low insufficient	3.95	3.94	-0.01	-0.40%
	Low sufficient	4.98	4.92	-0.06	-1.30%
	High insufficient	4.23	4.26	0.03	0.70%
	High sufficient	5.47	5.43	-0.04	-0.70%
NHB		7.7	7.66	-0.04	-0.50%

6.2.3 Destination Choice Calibration

Household survey data was processed into trip length frequency distributions and prepared as targets to be compared to the destination choice output. The trip length frequency curves were visually analyzed and compared using a normalized coincidence index. The calibrated destination choice model coefficients are shown in Table 28.

The match between the model calibrated trip length profile and the target trip length profile for HBW, HBO, and NHB trips can be observed in Figure 17 thru Figure 19.

Table 28: Calibrated Coefficients

Market Segmentation		Distance Coefficients		Intrazonal Term	Distance K-Factors						
		c_dist	c_dist^2	c_iz	c_KF01	c_KF12	c_KF23	c_KF34	c_KF45	c_KF56	c_KF67+
HBW	Zero	-0.155	0	0.63	-0.09	-0.15	-0.02	0.14	-0.08	-0.52	0.65
	Low insufficient	-0.195	0	-0.31	0.41	-0.35	-0.03	-0.97	-0.19	0.09	-0.72
	Low sufficient	-0.115	0	0.98	-0.13	0.26	0.09	0.08	-0.13	-0.45	-0.15
	High insufficient	-0.083	0	1.19	0.27	0.22	-0.28	0.22	-0.96	-0.09	-0.11
	High sufficient	-0.08	0	1.72	0.03	-0.07	0.13	0.10	-0.02	-0.13	0.12
HBO	Zero	-0.545	0	-2.03	0.56	-0.76	-1.11	-1.05	0.17	0.88	1.19
	Low insufficient	-0.365	0	-1.60	0.77	-0.61	-0.83	-0.40	-1.00	0	-1.01
	Low sufficient	-0.28	0	-1.32	0.96	-0.19	-1.02	-0.83	-1.08	-1.07	-0.76
	High insufficient	-0.42	0	-0.95	0.26	-0.16	-0.56	-0.22	-1.04	-1.36	1.04
	High sufficient	-0.28	0	-0.67	0.72	-0.02	-0.32	-0.65	-0.78	-0.91	-0.56
NHB			-0.14	0	-0.75	1.13	-0.04	-0.30	-0.66	-0.82	-0.85

Note: Data in Distance K-Factors cells, are grouped and organized in 1-mile increments, thus "c_KF01" provides coefficients for 0-1 mile, "c_KF12" provides coefficients for 1-2 mile, etc., with seven defined distance bins. Intrazonal trips have separate coefficients.

Figure 17: HBW Trip Length Frequency Distribution

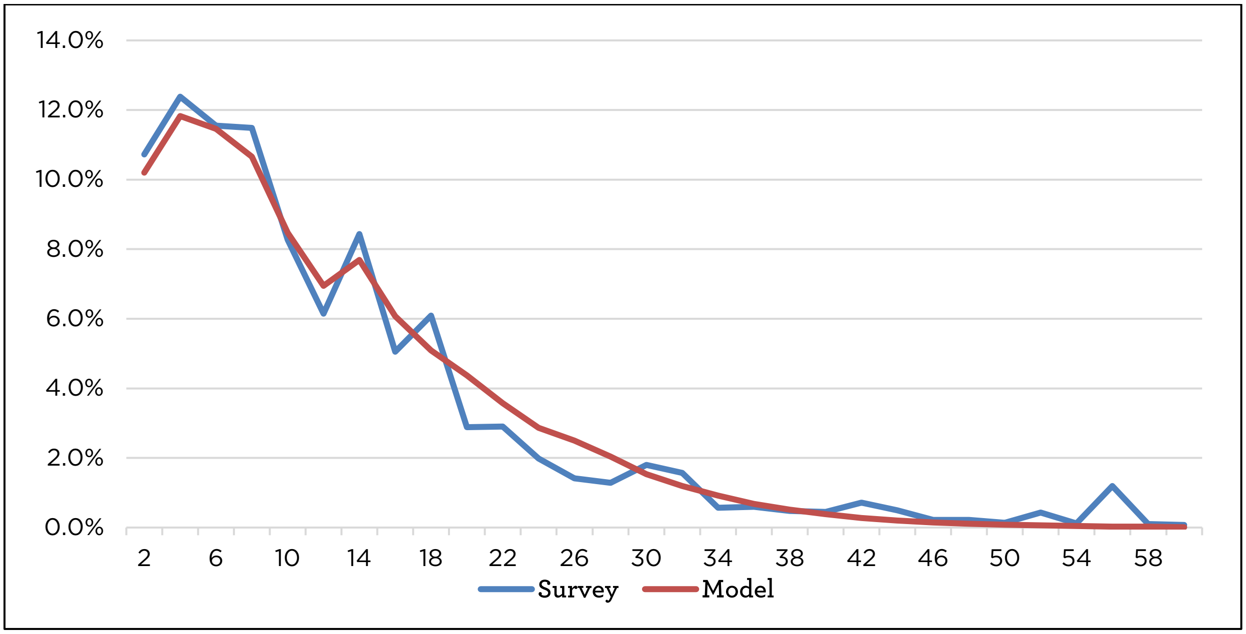


Figure 18: HBO Trip Length Frequency Distribution

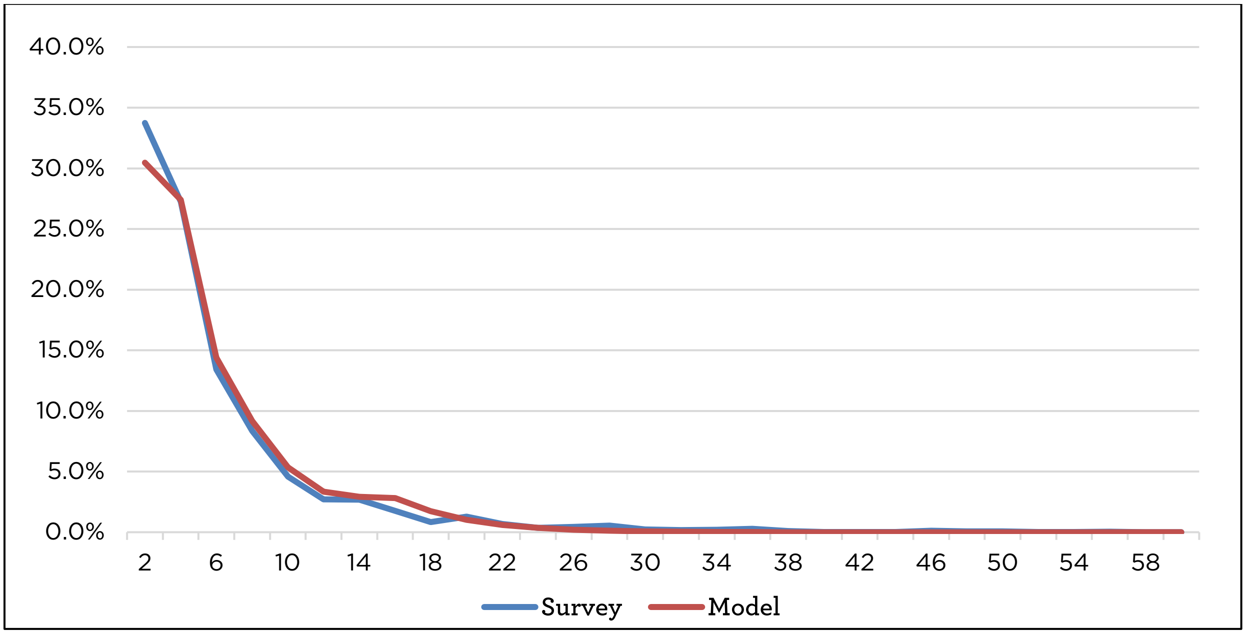
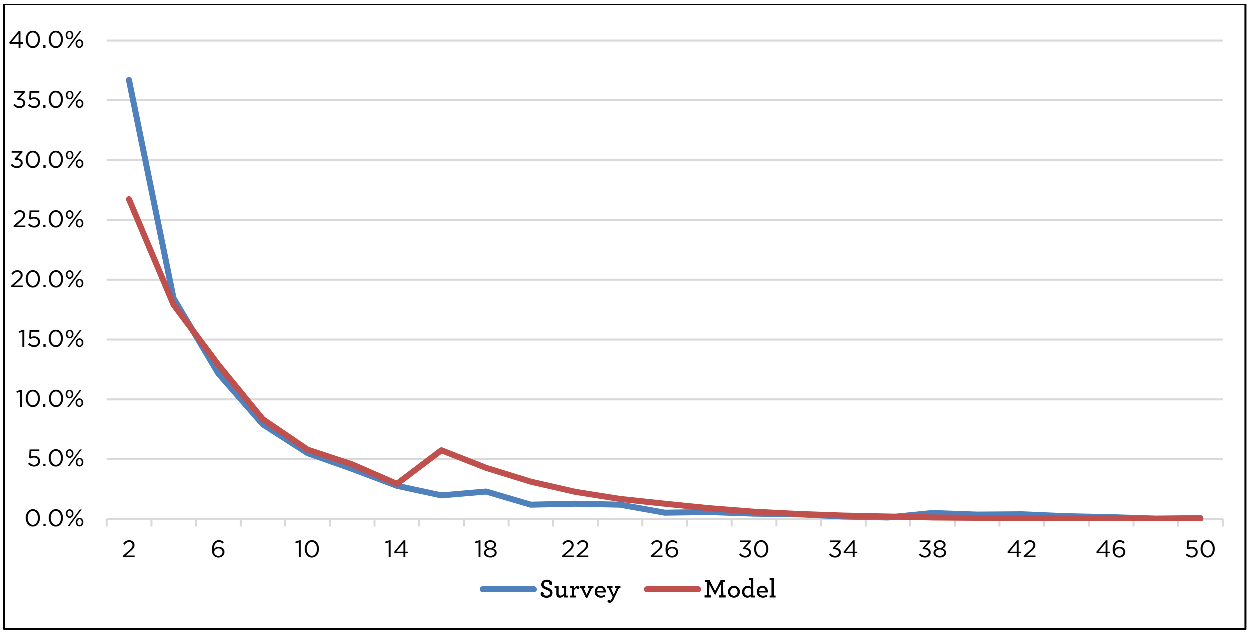


Figure 19: NHB Trip Length Frequency Distribution

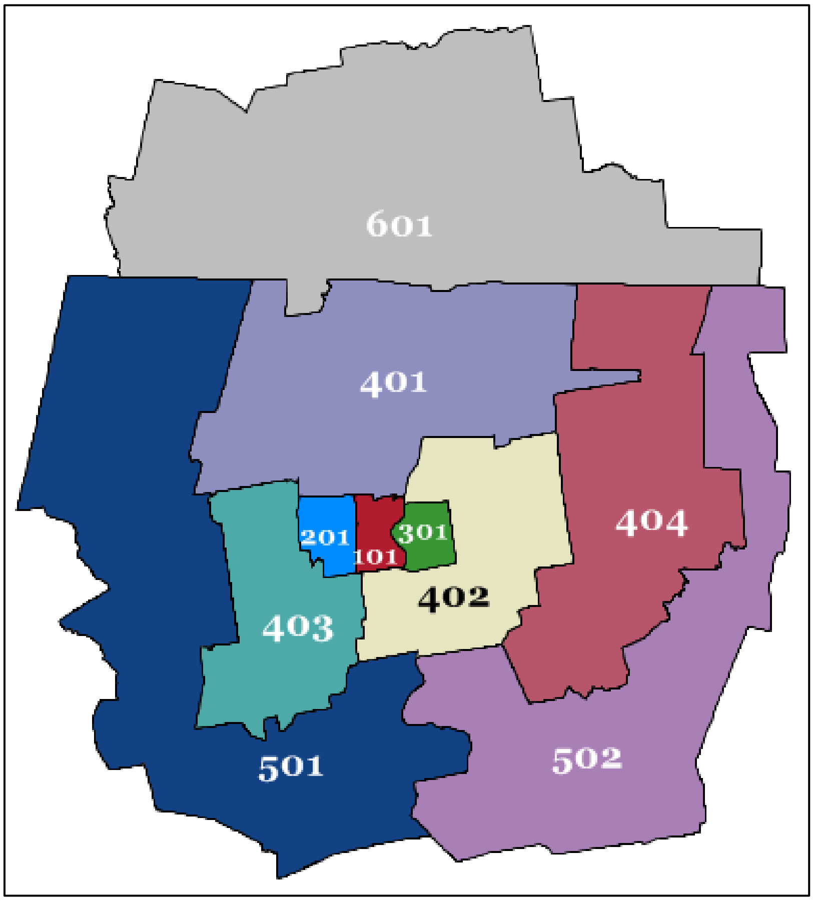


6.2.4 District to District Flow Comparison

District to district flows were also compared as part of the destination choice calibration. The goal of this exercise is to compare person movements between the study districts using the trip tables output from destination choice calibration. For the purposes of this exercise, the CRCOG Districts were aggregated into 10 Super Districts shown in Figure 20. A list of the Districts is presented in Table 29.

Limited geocoding information was available from the HTS for the purposes of the CRCOG model update. A district-to-district flow comparison was only completed, therefore, for HBW trips using Census Transportation Planning Program (CTPP) data. The CTPP has multiple geographic layers available for data analysis. These include TAZs, which can be readily aggregated into larger geographies such as Districts. The geographic information made available with the HTS included only County and MPO layers. Neither of these was felt suitable for a flow analysis.

Figure 20: CRCOG Super Districts



Note: Super Districts 501, 502 and 601, while outside of the CRCOG MPO area, are within the CRCOG model area.

Table 29: CRCOG Super Districts

Super District	Name
101	Hartford
201	West Hartford
301	East Hartford
401	Northern CRCOG
402	Southeastern CRCOG
403	Southwestern CRCOG
404	Eastern CRCOG
501	West Buffer
502	East Buffer
601	Massachusetts

6.2.5 HBW Flow Analysis

Table 30 shows flows obtained from the CTPP normalized to the row totals from the calibrated model HBW trip table. Table 31 presents the HBW trip flows from the calibrated model.

Table 30: CTPP Work Flow by Super District

CTPP		Attraction Districts										
		101	201	301	401	402	403	404	501	502	601	Total
Production Districts	101	28,573	5,390	2,832	8,015	7,188	6,228	416	1,611	87	173	60,514
	201	11,126	10,595	849	4,090	2,552	5,718	0	2,272	206	394	37,802
	301	6,459	1,359	5,457	3,839	7,517	2,972	416	1,328	214	23	29,583
	401	18,492	4,632	3,879	61,432	10,535	9,381	2,077	4,376	291	7,477	122,574
	402	22,095	3,587	9,340	13,840	48,187	9,040	4,942	6,910	1,028	1,011	119,979
	403	15,608	6,488	2,988	9,635	8,398	68,379	733	20,950	369	429	133,977
	404	5,491	754	2,617	4,557	9,096	2,148	20,390	1,605	3,756	571	50,983
	501	15,239	4,120	4,137	11,814	9,225	37,867	1,186	208,018	1,974	474	294,054
	502	5,177	855	2,135	2,047	5,709	3,638	6,756	9,221	22,937	111	58,586
	601	3,952	396	1,106	18,976	2,414	1,447	799	1,074	173	246,347	276,684
Total		**132,211**	**38,176**	**35,340**	**138,244**	**110,821**	**146,818**	**37,715**	**257,365**	**31,035**	**257,011**	**1,184,737**

Note: the values are normalized by model row totals

Table 31: Model Work Flow by Super District

HBW Trips		Attraction Districts										
		101	201	301	401	402	403	404	501	502	601	Total
Production Districts	101	30,384	5,082	4,269	5,746	5,775	5,602	329	2,253	221	854	60,514
	201	11,623	4,490	2,007	5,133	3,330	7,197	294	2,707	200	822	37,802
	301	9,759	1,155	3,891	2,928	6,539	2,285	437	1,668	258	663	29,583
	401	15,707	4,017	3,978	47,365	12,311	9,502	2,750	5,919	716	20,309	122,574
	402	23,172	3,955	8,828	14,201	38,001	11,761	4,439	9,238	2,022	4,363	119,979
	403	16,396	6,671	3,534	10,052	10,710	54,153	701	29,043	874	1,842	133,977
	404	5,297	1,013	2,068	5,813	9,209	2,433	13,688	2,305	5,245	3,912	50,983
	501	18,108	5,829	4,601	14,365	15,102	50,169	1,063	178,847	2,333	3,638	294,054
	502	5,371	1,043	1,948	3,254	7,315	4,144	7,027	9,124	18,075	1,286	58,586
	601	6,084	1,384	1,734	30,979	6,110	3,178	2,960	2,750	609	220,897	276,684
Total		**141,900**	**34,639**	**36,857**	**139,836**	**114,404**	**150,423**	**33,689**	**243,853**	**30,552**	**258,585**	**1,184,737**

The comparison of district interchanges focused on those interchanges where the absolute difference between model and CTPP interchange trip totals was greater than 0.50 percent of the total number of HBW trips (5,924) and the percent difference between the model and CTPP interchange trip totals was more than 50 percent. For the most part, the comparison between the modeled trip flows and the CTPP trip flows showed reasonable correlation. The exceptions involve trips within Super District 201 (West Hartford) and interchanges between Super District 401 (Northern CRCOG) and Super District 601 (Massachusetts). These district interchanges have been flagged in Table 32. Particular attention will be paid to these areas during the system wide model calibration and validation steps to determine if further measures can be taken to address these discrepancies.

The calibration process is still on going, and further refinement to the destination choice model calibration will be pursued. It is likely that additional changes and improvements will be made to the destination choice model during the final step of highway and transit assignment validation and overall model calibration. The result of these efforts will be reported in the final model development report.

Table 32: Estimated vs. CTPP Work Trips – Flagged Super District Interchanges

Interchange Flags		Attraction Districts									
		101	201	301	401	402	403	404	501	502	601
Production Districts	101	-	-	-	-	-	-	-	-	-	-
	201	-	Review	-	-	-	-	-	-	-	-
	301	-	-	-	-	-	-	-	-	-	-
	401	-	-	-	-	-	-	-	-	-	Review
	402	-	-	-	-	-	-	-	-	-	-
	403	-	-	-	-	-	-	-	-	-	-
	404	-	-	-	-	-	-	-	-	-	-
	501	-	-	-	-	-	-	-	-	-	-
	502	-	-	-	-	-	-	-	-	-	-
	601	-	-	-	Review	-	-	-	-	-	-

7. MODE CHOICE MODEL

The mode choice models were developed with information from the 2016 'Let's Go CT' Household Travel Survey (HTS), 2016 CRCOG On-Board Transit Survey (On-Board), U.S. Census American Community Survey (ACS) and Census Transportation Planning Program (CTPP). This data served as the foundation for the development of mode choice calibration targets. The model formulation is a nested logit model. Based upon the proposed structure and asserted coefficient values, calibration target values were constructed from the observed data.

7.1 TRAVEL MARKET SEGMENTATION

The auto sufficiency market segments used in the CRCOG model are shown in 24 (Section 6) Auto sufficiency is market segmentation by household income, number of workers in the household, and number of autos in the household.

7.1.1 Calibration Targets

In order for the mode choice model to accurately reflect observed travel patterns, the model must be calibrated to observed conditions. These observed conditions typically come from a household travel survey, on-board transit survey, or ideally a combination of the two. The calibration process consists of adjusting the terms in the mode choice utility equations to match observed data in the form of calibration targets. For the CRCOG mode choice calibration process, calibration targets were needed by mode, travel market segment, and trip purpose. The preparation of the calibration targets relied primarily upon the outputs from the CRCOG trip generation model, the On-Board survey, and the HTS.

The HTS captured weekday travel between March 2016 and May 2016 from a sample of 8,403 households accounting for 17,605 trip records in the CRCOG region. While the household survey does contain transit trip records, the number of transit trip records is fairly small (600) and potentially not representative of the true transit trip patterns in the region. The On-Board survey captured weekday travel between March 2016 and April 2016, and collected 7,027 trip samples in the CRCOG region.[2] Combined, these data sets provide insight into the travel markets in the CRCOG region with respect to geography, trip purpose, demographics, mode, and mode access.

In the CRCOG model, the total number of trips in the region is taken from output of the trip generation model calibrated to match the trip total from the previous CRCOG model. The expanded On-Board survey is taken as the total number of transit trips for the region because of a sampling plan that was developed by route, direction, and time of day, and weighted and expanded to represent the universe of transit users in the Hartford District.

[2] The survey, which included over 100 local bus, express bus, and BRT (CTfastrak) routes, was the largest and most comprehensive origin and destination survey conducted by CRCOG. The goal of the survey effort was to obtain useable surveys from approximately 8-10% of transit riders. The actual number of usable surveys collected was 7,027.

See Appendix C for additional information on the On-Board survey. The HTS is used to inform the distribution of non-transit trips within each market segment to the vehicular and non-motorized modes.

Table 33 provides a summary of information from the trip generation model and the On-Board survey indicating the total number of trips, as well as the split between transit and non-transit, for each of the travel market segments for each trip purpose. These trip totals serve as the overall control totals for the development of the mode choice calibration targets.

The results from the trip generation model show a total of 6,698,644 total daily resident trips in the CRCOG region. Of these trips, 1,184,737 are HBW, 3,867,144 are HBO, and 1,646,763 are NHB trips. Based on the expanded linked trips from the On-Board survey, there are 49,093 daily transit trips using the CT*transit* Hartford District (the transit network represented in the CRCOG model), of which 22,694 are HBW trips, 21,857 are HBO trips, and 4,542 are NHB trips. The difference between the trip generation and the expanded on-board survey trips are vehicular and non-motorized trips which total 1,162,043 HBW trips, 3,845,287 HBO trips, and 1.642,221 NHB trips.

The next steps in the process of developing the mode choice calibration targets by include:

- Determining the proportion of vehicular and non-motorized trips made by single occupant vehicles (SOV), shared ride (SR), shared ride 3+ (SR3+), bike and walk;
- Determining the proportion of transit trips made by each of the main transit modes - local bus, express bus, and bus rapid transit (BRT); and
- Determining the mode of access, i.e., Walk, Park-and-Ride (PnR), and Kiss-and-Ride (KnR), to each of the main transit modes.

Table 33: Trip Totals by Market Sector and Mode

Trip Purpose	Travel Market Segment	Total Trip Generation	On-Board Survey Transit Trips	Vehicular and Non-Motorized Trips
HBW	Zero	68,062	9,279	58,783
	low insufficient	65,965	6,028	59,936
	low sufficient	231,799	3,161	228,639
	high insufficient	87,678	828	86,849
	high sufficient	731,233	3,398	727,835
	Total	**1,184,737**	**22,694**	**1,162,043**
HBW	Zero	284,824	12,363	272,462
	low insufficient	119,355	6,836	112,519
	low sufficient	1,132,315	1,604	1,130,711
	high insufficient	156,622	637	155,984
	high sufficient	2,174,028	417	2,173,611
	Total	**3,867,144**	**21,857**	**3,845,287**
NHB		1,646,763	4,542	1,642,221
TOTAL		**6,698,644**	**49,093**	**6,649,551**

7.1.2 Auto and Non-Motorized Trip Calibration Targets

For each market sector the vehicular and non-motorized trips were split between SOV, SR, SR3+, walk and bike. An example of how this was done is shown below and summarized in Table 34. Using the HBW – Low Insufficient market segment as an example:

1. Determine the proportion of trips by each mode for the travel market segment based on the expanded Household Survey.
2. Calculate the proportion of trips made by each mode for the travel market segment.
3. Calculate an initial adjustment to the number of trips for each non-transit mode using the proportion from Step 2 and the total number of trips for the market sector from trip generation. For example, the initial estimate for the number of SOV trips equals 67.5% of 65,965.
1. Calculate the final adjustment to the number of trips for each non-transit mode as:
    a. Initial Adjustment X ((Trip Generation Total – Total Transit Trips) / Initial Adjustment Total)
    b. Using the data for the HBW Low Insufficient Travel Market, the final estimate for the number of SOV trips is: 44,540 X ((65,965-6,028) / 60,080).

Table 34: Example: Non-Transit Trips by Mode for HBW Low-Insufficient Travel Market

Mode	(1) Household Survey Trips	(2) Proportion of Trips	(3) Initial Adjustment	(4) Final Adjustment
SOV	11,444	67.5%	44,540	44,433
SR2	413	2.4%	1,609	1,605
SR3 +	3,241	19.1%	12,612	12,582
Walk	339	2.0%	1,319	1,316
Bike	-	0.0%	-	-
Transit	1,512	8.9%		6,028
Total	**16,949**	**100%**	**60,080**	**65,965**

The same process was applied to each travel market segment. The final mode choice targets for auto and non-motorized modes are shown in Table 35.

Table 35: Auto and Non-Motorized – Mode Choice Targets

Purpose	Mode	Total	Zero	Low-Insufficient	High Insufficient	Low Sufficient	High Sufficient
HBW	DA	984,743	8,715	44,433	195,369	64,230	671,995
	SR2	91,049	35,943	1,605	21,049	8,426	24,027
	SR3+	46,240	4,431	12,582	6,297	10,709	12,221
	Walk	29,670	6,808	1,316	4,682	1,886	14,978
	Bike	10,341	2,885	-	1,243	1,599	4,614
	Total	**1,162,043**	**58,782**	**59,936**	**228,640**	**86,850**	**727,835**
HBO	DA	1,547,643	43,067	34,742	527,769	59,778	882,287
	SR2	877,278	80,785	23,629	248,128	29,425	495,311
	SR3+	924,935	42,526	36,561	230,956	50,196	564,695
	Walk	442,734	77,239	16,587	115,138	16,182	217,588
	Bike	52,697	28,846	1,000	8,719	403	13,729
	Total	**3,845,287**	**272,463**	**112,519**	**1,130,710**	**155,984**	**2,173,610**
NHB	DA	858,959	NHB Trips are not Market Segmented				
	SR2	332,363					
	SR3+	268,820					
	Walk	169,469					
	Bike	12,611					
	Total	**1,642,222**					

7.1.3 Transit Trip Calibration Targets

Table 36 presents a summary of the expanded transit trips for the three transit modes.

Table 36: Auto and Non-Motorized – Mode Choice Targets

Transit Mode	Transit Trips	
	Number	Percent
Local Bus	39,029	79.5%
Bus Rapid Transit (BRT / CT*fastrak*)	6,411	13.1%
Express Bus	3,653	7.4%
Total	**49,093**	**100.0%**

The On-Board survey included questions on trip purpose, household income, and auto ownership. This allowed the transit trips to be allocated by transit mode to the CRCOG Model travel market stratification. Table 37 shows the expanded On-Board transit trips by trip purpose, mode, and market stratification.

Table 37: Expanded on Board Survey Transit Trips by Trip Purpose, Mode, and Market Stratification

Purpose	Mode	Total Trips	Trips by Market Segment				
			Zero	Low-Insufficient	High-Insufficient	Low-Sufficient	High-Sufficient
HBW	Local Bus	16,953	8,096	5,274	1,954	551	1,078
	Express Bus	3,238	260	158	829	148	1,842
	BRT	2,503	923	595	377	129	477
	Total	**22,694**	**9,279**	**6,028**	**3,161**	**828**	**3,398**
HBO	Local Bus	18,403	10,605	5,784	1,278	461	276
	Express Bus	215	54	75	7	44	36
	BRT	3,239	1,704	978	319	132	106
	Total	**21,857**	**12,363**	**6,836**	**1,604**	**637**	**417**
NHB	Local Bus	3,673	NHB Trips are not Market Segmented				
	Express Bus	199					
	BRT	670					
	Total	**4,542**					

The On-Board survey also gathered information on how riders access the transit system. Table 38 shows how Hartford District riders access each transit mode (BRT, express bus, and local bus) in the system. Table 39 shows a further breakdown of the access data by transit mode, trip purpose, mode of access, and market segment. This data represents the calibration targets for transit and transit access mode in the mode choice model.

Note that the transit access mode data presented in Table 38 and Table 39 is presented in Production-Attraction (PA) format. The trip tables input into the mode choice model are in PA format as dictated by the trip distribution / destination choice model. Further, as is standard practice, transit person trips are assigned in PA format in order to maintain consistency with the transit networks used to inform the mode choice model (AM conditions for peak trips and mid-day conditions for off-peak trips).

In PA format, the home end of a trip is considered the production end so the choice of mode is based on the travel impedances that the trip sees from the production zone to the attraction zone. For highway trips this is not an issue, as there is no concern that a PA trip, when converted to an OD trip, will not be able to find a return path (there will always be links to drive on). However, for transit, this is a concern because a PA trip, when converted to an OD trip, might not be able to find a return path due to the PM and Evening networks potentially being inconsistent with the AM and Mid-day networks that the PA trip saw when making its choice of mode. This would result in those trips being unassigned. As further explanation, consider the following example.

Assume a rider takes Bus A to and from work. This would result in two 2 PA bus trips assigned to Bus A. Further, assume that the bus taken is an East-West route which in the TransCAD model network is coded as two separate routes: Bus A East and Bus A West. The PA trips will both be assigned to Bus A East assuming the work location is east of the home location. Thus, in this example, Bus A West does not get assigned any trips. However, in OD format Bus A East would be assigned a trip in the morning and Bus A West would be assigned a trip in the afternoon. How is this reconciled?

What is typically done to report transit boardings by route is to add up the boardings from the eastbound route and the westbound route and report the total for Bus A (instead of separately by East and West). So while Bus A East had 2 trips and Bus A West had 0, in total Bus A had two trips, which is correct. Similarly, for stop-level analysis, the boardings and alightings are added up at each stop and divided by 2 to get even boardings and alightings at that stop. Note that this is standard practice and accepted by the Federal Transit Administration (FTA).

Table 38: Expanded on Board Survey Transit Survey Mode of Access (PA Format)

Mode of Access	BRT		Express Bus		Local Bus		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Walk	5,704	89.0%	1,089	29.8%	38,517	98.7%	45,310	92.3%
PnR	499	7.8%	1,989	54.4%	175	0.4%	2,663	5.4%
KnR	208	3.2%	575	15.7%	337	0.9%	1,120	2.3%
Total	**6,411**	**100%**	**3,653**	**100%**	**39,029**	**100%**	**49,093**	**100%**

Note: Common Acronyms: PnR – Park and Ride, KnR – Kiss and Ride

Table 39: Expanded Transit Mode of Access Targets (PA Format)

Mode	Purpose	Access	Total Trips	Market Segmentation				
				Zero	Low Insufficient	High Insufficient	Low Sufficient	High Sufficient
BRT	HBO	Walk	3,087	1,697	919	310	81	80
		PnR	27	4	0	0	23	0
		KnR	126	3	59	9	29	26
	HBW	Walk	1,962	923	571	250	99	119
		PnR	470	0	2	127	15	326
		KnR	69	0	22	0	15	32
	NHB	Walk	655	NHB Trips are not Market Segmented				
		PnR	2					
		KnR	13					
Express	HBO	Walk	154	42	75	7	16	14
		PnR	33	0	0	0	11	22
		KnR	29	12	0	0	17	0
	HBW	Walk	768	196	79	242	50	201
		PnR	1,925	16	42	340	55	1,472
		KnR	544	48	37	247	42	170
	NHB	Walk	167	NHB Trips are not Market Segmented				
		PnR	30					
		KnR	3					
Local	HBO	Walk	18,233	10,542	5,733	1,253	438	267
		PnR	17	2	5	10	0	0
		KnR	152	60	46	15	23	8
	HBW	Walk	16,661	8,045	5,208	1,892	537	979
		PnR	146	0	9	42	0	95
		KnR	147	51	57	20	14	5
	NHB	Walk	3,622	NHB Trips are not Market Segmented				
		PnR	12					
		KnR	38					

7.2 MODE CHOICE MODEL DESCRIPTION

Mode choice models are mathematical expressions which are used to estimate the modal shares of the travel market given the time and cost characteristics of the various competing modes, the demographic and socio-economic characteristics of the travelers, and the excluded attributes of the modes represented in the model. Mode choice models are designed to be an integral link in the travel demand chain, with possible feedback mechanisms to a number of related model components such as trip generation, trip distribution, and (modal) trip assignment.

The CRCOG mode choice 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, and non-motorized (walk and bike) forms of travel. Access to and egress from transit also reflects a range of available options including park and ride, kiss and ride, walk, and bike. The mode choice model was calibrated using data from the 2016 'Let's Go CT' Household Travel Survey, 2016 CRCOG On-Board Transit Survey, and the U.S. Census ACS / CTPP data.

The variables included in the utility equation include cost, in-vehicle time, transit wait time, and an intrazonal shares variable. With the exception of the nesting coefficients, the model parameters will be segmented by income and auto sufficiency for HBW and HBO but will not be segmented for NHB trips. Finally, each mode will have an alternative-specific constant that represents the effect of mode attributes that are not included in the mode choice utility function. Examples of excluded 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, among others.

7.2.1 Basic Logit Model Mathematics

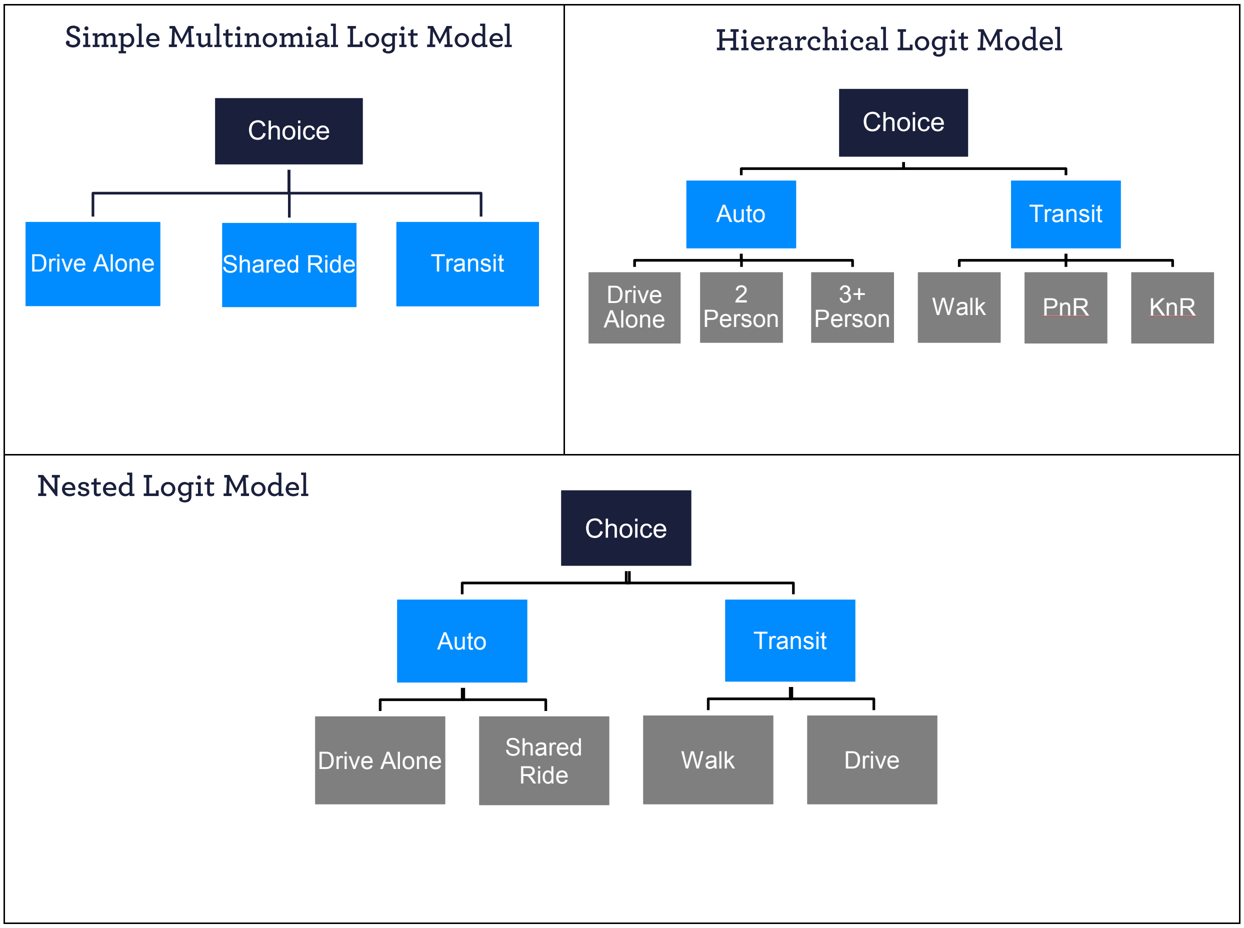
There are three types of Logit models: multinomial logit, hierarchical logit, and nested logit. The mode choice model structure used for the CRCOG mode choice model is a nested logit structure.

The multinomial logit model assumes that there is equal competition among alternatives. This allows for the "shifting" of trips to and from other modes in proportion to the initial estimates of these modes. A common problem associated with the multinomial structure is the potential for violation of the Independence of Irrelevant Alternatives (IIA) axiom.

The hierarchical logit model is a variation of the multinomial model that allows for the subsequent splitting (or allocation) of trips to a set of sub-modes. In most structures of this type a LogSum variable (or the denominator of the lower level choice) is used in the upper level choice together with other (typically socio-economic) explanatory variables. In this manner, the lower level sub-modes are reflected in the upper level choice, but as if they were equally competing modes with the other primary mode(s) (i.e., with a LogSum coefficient of 1.0).

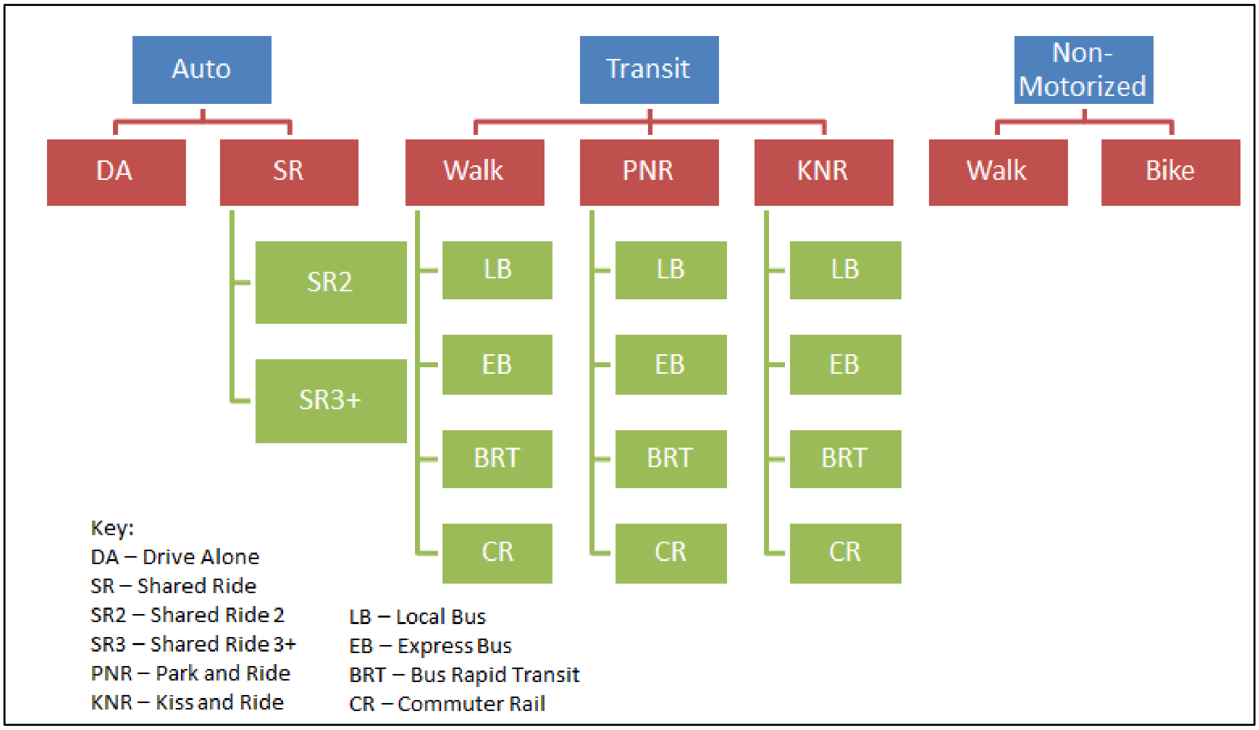
A nested logit model, as used in the CRCOG mode choice model, recognizes the potential for something other than equal competition among modes. This structure assumes that modes, sub-modes, and access modes are distinctly different types of alternatives that present distinct choices to travelers. Its most important departure from the multinomial structure is that the lower level choices are more elastic than they would be in the multinomial or hierarchical structures. Thus, an improvement in walk access to transit would alter the existing diversions between walk and drive access to transit the most. This same improvement in walk access would also shift travelers from auto to transit, but with elasticities that are equal to the elasticities found in the multinomial logit models; therefore, the elasticities for access choice are higher. This increased sensitivity is reasonable if the modes included in a single level of the nest are reasonably related. It seems intuitive that a person who has already decided to use transit would be more sensitive to a change in transit travel time or cost, than would be a person who is deciding to use transit or not. Figure 21 illustrates the differences between the various mode choice model structures.

Figure 21: Three Types of Logit Models



The final mode choice model structure applied in the CRCOG model is graphically displayed in Figure 22.

Figure 22: CRCOG Nested Logit Model Choice Model Structure



At the upper level of the nesting structure are non-motorized modes, highway modes (auto) and transit. In the non-motorized nest, bicycle and direct walk are represented. The auto mode nest addresses the auto occupancy choice including drive alone, shared ride 2, (two person carpools) and shared ride 3+ (3+ person carpools).

In the transit nest walk, park-and-ride, and kiss-and-ride are represented. In the lower level nest are local bus (LB), express bus (EB), and bus rapid transit (BRT). This design recognizes that, in many instances, the various transit modes offer travelers a competitive choice. It also allows the model to reflect the important differences in excluded attributes offered by each of the primary transit modes. An access choice nest differentiates primarily between walk and drive access to each primary transit mode. As discussed in section 7.2.2 the mode choice model also represents commuter rail service in the CRCOG region. At the time this model was being prepared, this service was not yet operational. However, the model has been designed with sufficient flexibility to allow incorporation of this service as part of the on-going maintenance and updating of the model.

7.2.2 Mathematical Formulation for Logit Models

The standard logit formulation can be expressed as:

$$P_i = \frac{e^{U_i}}{\sum_k e^{U_i}}$$

Where:

P_i = is the probability of a traveler choosing mode i

U_i = is a linear function of the attributes of mode i that describe its attractiveness

$\sum e^{Ui}$ = is the summation of the linear functions of the attributes over all the i

k = alternatives (k) for which a choice is feasible

The utility expression for each available mode (i) is specified as a linear function which incorporates a range of variable types, including time, cost, locational measures, and the socio-economic characteristics of the traveler. For example:

$$U_i = \beta_1 * Time_i + \beta_2 * Cost_i + \beta_3 * Location_{Var} + \beta_4 * SE + \beta_0$$

Where:

U_i = is the utility for mode i

β_0 = is a constant specific to mode i that captures the overall effect of any significant variables that are missing or unexplained in the expression which may include, for example, comfort, convenience, and safety

β_1 = is a set of coefficients describing the level-of-service (in travel time) provided by mode i such as in-vehicle time, wait time, and walk time

β_2 = is a set of coefficients describing travel cost which may include, for example, transit fare, automobile operating cost, and parking costs

β_3 = is a set of coefficients describing the specific attributes of the trip interchange such as a Central Business District (CBD) destination or park and ride lot use

β_4 = is a set of coefficients describing the influence of each socio-economic characteristic of the traveler such as income group and auto ownership

The travel time variables are typically disaggregated into in-vehicle and out-of-vehicle time at a minimum. Out-of-vehicle time is further stratified into walk time, initial wait, and transfer wait time – the latter two categories being applicable to the transit modes only. Similarly, travel cost is often disaggregated into the more general out-of-pocket cost, which may include for example, automobile operating cost, transit fare, and destination parking cost.

Locational variables in utility expressions are used to reflect a set of unique geographically based characteristics, such as a CBD. Alternatively, these geographic attributes may be represented in the form of land use variables such as employment or population density. A wide variety of variables are possible in the socio-economic category (SE) including variables that measure the relative wealth of the trip maker, such as income or auto sufficiency, or reflect other household characteristics such as workers per household. Finally, an alternative specific constant reflects the unexplained behavior, or the excluded attributes of that mode. The individual coefficients associated with each variable reflect the relative importance of each attribute.

In the simple example nested model structure shown in Figure 22 the formulation employs three multinomial logit models, one for the primary choice of mode among auto and transit, a second level choice among auto sub-modes (drive-alone and shared-ride) and another second level choice among transit access modes (walk and drive access). In application, the model independently addresses auto sub-mode and transit access choice first. This is expressed as:

$$P_{DA} = \frac{e^{U_{DA}}}{e^{U_{DA}} + e^{U_{SR}}} \quad \text{and} \quad P_{w} = \frac{e^{U_{w}}}{e^{U_{w}} + e^{U_{D}}}$$

A composite of the utilities of the auto sub-mode and transit access choices then represent auto and transit respectively in the upper tier of the model structure. This composite measure is the natural logarithm of the denominator of the logit model, often termed the "LogSum". The LogSum term is effectively the total utility provided by the sub-modes of a particular primary mode. A LogSum is calculated for each of the second level nests as:

$$LogSum_{A} = -\ln[e^{U_{DA}} + e^{U_{SR}}] \quad \text{and} \quad LogSum_{T} = -\ln[e^{U_{w}} + e^{U_{D}}]$$

The LogSum terms for the auto sub-modes and transit access choice then appear in the utility expression for the primary mode level as:

$$P_{T} = \frac{e^{\beta_{T}*LogSum_{T}}}{e^{\beta_{T}*LogSum_{T}} + e^{\beta_{A}*LogSum_{A}}}$$

The value of the LogSum coefficients in the upper tier of the model (auto versus transit), is an indicator of the degree to which the lower level choices form a sub-choice that is distinct from the primary mode alternatives. A value of 1.0 indicates that the lower level modes are not a sub-choice but rather are full options equally competitive with the primary modes. In this instance, these lower level choices can be simplified or included directly in the upper level. A value of 0.0 would indicate that the lower level choices are perfect substitutes for each other. Values between 0.0 and 1.0 indicate the extent to which the lower level choices represent a sub-choice.

The mode choice model structure includes commuter rail as a transit choice. At the time the data that forms the basis for this model was collected, there was no commuter rail service operating in the CRCOG model area. However, in anticipation of the Hartford line service, it was included in the model as a transit choice. It is anticipated that the continued updating and maintenance of the model will include this service in the future, either at its initial service level, or at its proposed full-service operation.

In order to include and calibrate the Hartford Line commuter rail service it will be necessary to collect the required data once regional travel patterns have had an opportunity to adjust to the new service and demand has stabilized.

As an interim alternative, the model could be modified to include data generated by the FTA's Simplified Trips on Projects Software (STOPS), which would provide calibration targets. STOPS is a limited application of the traditional four step travel demand model geared to transit analysis. It was developed and calibrated using national data from cities with a variety of transit modes, including commuter rail, and relies upon readily available local data, such as the CTPP and on-board transit surveys, to allow the software to understand local travel patterns. The STOPS has a fixed guideway focus but also provides a detailed system-wide representation of transit ridership. STOPS was designed to be easier to implement that a typical 4-step model and may be set up and calibrated in approximately six to eight weeks. Calibration targets developed from STOPS forecasts may provide a useful placeholder until such time as actual data is available to further calibrate the CRCOG mode choice model.

7.2.3 Market Segmentation Considerations

There are three basic trip purposes for mode choice modeling: Home-Based-Work, Home-Based-Other, and Non-Home-Based. This simplification stems from the notion that household and individual travel behavior properties, as translated into elasticities, are relatively similar when considering the choice of mode.

Another element often used for market segmentation is the stratification of alternative specific constants by an indicator of wealth or socio-economic status. Historically, either auto ownership or income has been used for this purpose. The design of the CRCOG mode choice model utilizes a method of stratification called auto sufficiency. The HBW and HBO purposes are segmented based on household income and the relationship between the number of vehicles the household has and the number of workers (auto sufficiency) as shown below:

- Zero-car households, all income groups
- Households with insufficient autos and low income
- Households with sufficient autos and low income
- Households with insufficient autos and high income
- Households with sufficient autos and high income

Households that have zero autos, fewer autos than workers, or an auto for each worker have distinct mode choice patterns, especially when it comes to transit ridership.

The NHB purpose is not segmented.

7.2.4 Model Coefficients

Table 40 presents the recommended set of mode choice coefficients for the three trip purposes in the CRCOG model. Logical and consistent nesting coefficients are applied at each level of the nest. Auto operating costs were established at 16.8 cents per mile for all purposes.

Table 40: Mode Choice Model Coefficients

Variable Description	HBW	HBO	NHB
In-Vehicle Travel Time	-0.02500	-0.01500	-0.02000
Initial Transit Wait Time < 5.0 minutes	-0.05625	-0.03375	-0.04300
Initial Transit Wait Time >= 5.0 minutes	-0.02500	-0.01500	-0.02000
Transit Transfer Wait Time	-0.06250	-0.03750	-0.05000
Drive to transit in-vehicle time	-0.05625	-0.03375	-0.04300

7.2.5 Wage Rate and Cost Coefficients

Purpose-specific cost coefficients are derived directly from the value of time and are shown in the table below. The value of time for each trip purpose/income group combination was computed from the Hartford regional median income values, obtained from the 2015 CTPP data. The Hartford regional median income value is $68,047 for all households, $47,809 for low income households, and $86,443 for high income households. The low income value is used for three market segments: zero-car, low income insufficient, and low income sufficient. The high income value is used for the high income insufficient and high income sufficient market segments. The value of time for all purposes and market segments is calculated and subsequently cost coefficients are computed. The mode choice cost coefficients are shown in Table 41.

Table 41: Mode Choice Cost Coefficients

Market Segment	Home Based Work		Home Based Other		Non-Home Based	
	VOT ($/hr)	Coefficient	VOT ($/hr)	Coefficient	VOT ($/hr)	Coefficient
Zero Auto	9.19	-0.16315	3.68	-0.24472	6.54	-0.18340
Low Income Insufficient	9.19	-0.16315	3.68	-0.24472		
Low Income Sufficient	9.19	-0.16315	3.68	-0.24472		
High Income Insufficient	16.62	-0.09023	6.65	-0.13535		
High Income Sufficient	16.62	-0.09023	6.65	-0.13535		

7.3 MODE CHOICE CALIBRATION

7.3.1 Calibration Process

Model calibration is the process of establishing proper values for the alternative specific constants. The calibration of the mode choice model was done manually. The process started with all alternative specific constants set to zero. Then the trip distribution and mode choice model steps were run. The number of trips produced by the model for each mode and market segments were compared to the identified targets, the values of the alternative specific constants adjusted, and the trip distribution and mode choice steps rerun. The process continued until the model results matched the mode target values reasonably well. Table 42 shows key calibrated values for the mode choice model. Note that the market stratifications are active for both HBW and HBO. Non-Home Based trips were estimated for all market segments as one.

Table 42: Mode Split Constants by Trip Purpose and Market Segmentation

Market Segment	Constants for Shared Ride										
	HBW					HBO					NHB
	Zero	Low-I	Low-S	High-I	High-S	Zero	Low-I	Low-S	High-I	High-S	
SR2	0.98	-1.92	-1.56	-1.30	-2.29	0.51	-0.10	-0.42	-0.30	-0.27	-0.58
SR3	-0.13	-1.00	-2.26	-1.27	-2.72	0.15	0.07	-0.51	-0.07	-0.24	-0.75
Market Segment	Constants for Walk and Bike										
	HBW					HBO					NHB
	Zero	Low-I	Low-S	High-I	High-S	Zero	Low-I	Low-S	High-I	High-S	
Walk	-1.18	-4.52	-4.16	-3.58	-3.84	0.03	-1.33	-1.95	-1.73	-1.75	-1.95
Bike	-1.78	-9.55	-5.09	-3.69	-4.66	-0.66	-3.29	-3.76	-4.31	-3.68	-3.77
Market Segment	Constants for Local Bus										
	HBW					HBO					NHB
	Zero	Low-I	Low-S	High-I	High-S	Zero	Low-I	Low-S	High-I	High-S	
Walk	5.39	3.02	-0.34	-0.70	-2.02	2.50	2.11	-2.10	-1.33	-4.02	-1.52
PnR	-4.19	-3.78	-3.64	-5.58	-4.11	-4.97	-4.70	-6.96	-6.24	-9.40	-7.27
KnR	-2.49	-4.06	-5.07	-4.63	-6.86	-2.97	-3.18	-6.79	-4.49	-7.88	-6.59
Market Segment	Constants for Express Bus										
	HBW					HBO					NHB
	Zero	Low-I	Low-S	High-I	High-S	Zero	Low-I	Low-S	High-I	High-S	
Walk	4.49	2.07	0.67	-0.17	-1.43	2.80	3.25	-2.25	0.41	-2.45	0.62
PnR	0.06	-0.16	0.30	-0.77	-0.05	2.46	0.05	-3.24	1.44	-1.33	0.15
KnR	-0.26	-2.05	-1.52	-2.00	-2.94	4.17	0.05	-3.24	1.70	-3.49	-1.50
Market Segment	Constants for Bus Rapid Transit										
	HBW					HBO					NHB
	Zero	Low-I	Low-S	High-I	High-S	Zero	Low-I	Low-S	High-I	High-S	
Walk	4.85	2.57	-0.74	-0.87	-2.58	2.85	2.31	-1.73	-1.12	-3.57	-1.49
PnR	-4.01	-4.32	-2.55	-3.74	-3.04	-4.33	-5.13	-7.73	-4.06	-8.85	-7.87
KnR	-4.60	-4.71	-6.54	-4.58	-5.76	-4.43	-2.74	-6.64	-4.00	-6.76	-6.84

Note: Market Segmentation: **Zero** are zero auto households; **Low – I** are households with low income and fewer autos than workers; **Low – S** are households with low income and with autos greater than or equal to workers; **High – I** are households with high income and with fewer autos than workers; and **High - S** are households with high income and with autos greater than or equal to workers.

7.3.2 Calibration Results

Table 43 provides an overview of the mode choice calibration results. This table shows a reasonably good fit of target trips to the calibrated mode choice modeled trips. Fifty-one percent 51% of daily trips are made using the drive alone mode. Non-motorized travel (bike and walk) makes up about 11% of the region's average weekday travel. Transit is represented by linked trips, not unlinked trips which are more equivalent to boardings, and is less than one percent of the region's average weekday travel.

Table 43: Top Level Mode Choice Calibration

Mode	Trips		Difference	
	Target	Modeled	Number	Percent
Drive Alone	3,391,345	3,391,173	-172	-0.01%
Shared Ride 2	1,300,690	1,300,690	0	0.00%
Shared Ride 3+	1,239,995	1,240,062	68	0.01%
Walk	641,873	641,913	40	0.01%
Bike	75,650	75,665	15	0.02%
Local Bus	39,033	39,060	27	0.07%
Express Bus	3,659	3,659	0	0.00%
Bus Rapid Transit	6,417	6,421	3	0.05%
Total	**6,698,661**	**6,698,644**	**-17**	**0.00%**

Table 44 illustrates the mode choice results by trip purpose. This table shows that the target number of trips by trip purpose is closely replicated by the modeled mode choice results.

Table 44: Top Level Mode Choice Calibration by Purpose

Mode	HBW		HBO		NHB	
	Calibration Trips		Calibration Trips		Calibration Trips	
	Targets	Modeled	Targets	Modeled	Targets	Modeled
Drive Alone	984,743	984,689	1,547,643	1,547,524	858,959	858,959
Shared Ride 2	91,049	91,066	877,278	877,261	332,363	332,363
Shared Ride 3+	46,240	46,241	924,935	925,001	268,820	268,820
Walk	29,670	29,674	442,734	442,771	169,469	169,469
Bike	10,342	10,343	52,697	52,711	12,611	12,611
Local Bus	16,955	16,977	18,405	18,411	3,673	3,673
Express Bus	3,238	3,238	221	221	199	199
Bus Rapid Transit	2,506	2,508	3,242	3,243	670	670
Total	**1,184,743**	**1,184,737**	**3,867,155**	**3,867,144**	**1,646,763**	**1,646,763**

The detailed versions of the same mode choice output by trip purpose and market stratification are shown in the following tables. HBW and HBO results are displayed for each of the travel market segments. The NHB purpose was not stratified and is displayed as a single market segment.

Table 45 shows the mode choice results for the Home-Based-Work trips:

- **Overall:** Overall the modeled and target values match well including in the Zero Auto and Low income market stratifications. Further investigation of the Home Interview Survey resulted in a reduction in the number of drive alone trips made by zero auto households and an increase in Shared Ride 2 trips.
- **Drive**: As expected, the Drive Alone mode dominates the drive nest, with high income showing the highest share of Drive Alone trips.
- **Transit**: There are three transit modes currently operating in the Harford District that have been included in the model: Local Bus, Express Bus, and Bus Rapid Transit (CTfastrak). (As discussed above, the Hartford Line has not been included, as the data sources pre-date its operation). Most transit trips occur on the local bus network. The share of bus trips is highest for Zero Auto and Low Insufficient households.
- **Non-Motorized**: The model is accurately predicting non-motorized travel. The highest share of walk and bike trips is in the Zero Auto market.

Table 45: HBW Mode Choice Calibration

Mode		Zero	Low Insufficient	Low Sufficient	High Insufficient	High Sufficient
Drive Alone	Target	8,715	44,433	195,369	64,230	671,995
	Modeled	8,676	44,424	195,367	64,229	671,994
Shared Ride 2	Target	35,943	1,605	21,049	8,426	24,027
	Modeled	35,959	1,605	21,049	8,426	24,027
Shared Ride 3+	Target	4,431	12,582	6,297	10,709	12,221
	Modeled	4,432	12,583	6,297	10,709	12,221
Bike	Target	6,808	1,316	4,682	1,886	14,978
	Modeled	6,811	1,316	4,682	1,886	14,979
Walk	Target	2,885	0	1,243	1,599	4,614
	Modeled	2,886	0	1,243	1,599	4,614
Local Bus	Target	8,097	5,274	1,954	552	1,078
	Modeled	8,110	5,282	1,954	552	1,079
Express Bus	Target	260	158	829	148	1,842
	Modeled	260	158	829	148	1,842
Bus Rapid Transit	Target	925	595	378	129	477
	Modeled	926	596	379	129	478
Total	**Target**	**68,065**	**65,965**	**231,800**	**87,679**	**731,233**
	Modeled	**68,062**	**65,964**	**231,800**	**87,678**	**731,233**

Table 46 shows the mode choice results for Home-Based-Other trips.

- **Overall:** Overall the modeled and target values match well, including auto trips in the high income, insufficient auto ownership stratifications.
- **Drive**: Drive Alone trips dominate in the auto sufficient market stratifications for both low and high income households.
- **Transit**: The largest share of transit ridership comes from the low income, insufficient market but the largest number of transit trips is in the zero auto market.
- **Non-Motorized**: Bike trips dominate non-motorized trips. The largest proportion of these trips occur in zero auto households.

Table 46: HBO Mode Choice Calibration

Mode		Zero	Low Insufficient	Low Sufficient	High Insufficient	High Sufficient
Drive Alone	Target	43,067	34,742	527,769	59,778	882,287
	Modeled	42,957	34,741	527,766	59,777	882,284
Shared Ride 2	Target	80,785	23,629	248,128	29,425	495,311
	Modeled	80,769	23,629	248,128	29,425	495,311
Shared Ride 3+	Target	42,526	36,561	230,956	50,196	564,695
	Modeled	42,593	36,561	230,956	50,196	564,695
Bike	Target	77,239	16,587	115,138	16,182	217,588
	Modeled	77,276	16,586	115,138	16,182	217,588
Walk	Target	28,846	1,000	8,719	403	13,729
	Modeled	28,860	1,000	8,719	403	13,729
Local Bus	Target	10,605	5,784	1,278	462	277
	Modeled	10,610	5,784	1,278	462	277
Express Bus	Target	55	77	9	44	37
	Modeled	55	77	9	44	37
Bus Rapid Transit	Target	1,704	979	320	132	107
	Modeled	1,705	979	320	132	107
Total	**Target**	**284,825**	**119,358**	**1,132,318**	**156,623**	**2,174,031**
	Modeled	**284,824**	**119,355**	**1,132,315**	**156,621**	**2,174,028**

Table 47 summarizes the Non-Home Based trips purpose. No income categories were established for this purpose.

- **Overall:** Overall the modeled and target values match well for this trip purpose.
- **Drive Alone:** A little more than half of NHB trips are Drive Alone trips.
- **Non-Motorized:** NHB trips are much more likely to be made by bike or walk modes than transit.

Table 47: NHB Mode Choice Calibration

Mode		NHB
Drive Alone	Target	858,959
	Modeled	858,959
Shared Ride 2	Target	332,363
	Modeled	332,363
Shared Ride 3+	Target	268,820
	Modeled	268,820
Bike	Target	169,469
	Modeled	169,469
Walk	Target	12,611
	Modeled	12,611
Local Bus	Target	3,673
	Modeled	3,673
Express Bus	Target	199
	Modeled	199
Bus Rapid Transit	Target	670
	Modeled	670
Total	**Target**	**1,646,763**
	Modeled	**1,646,763**

8. TIME OF DAY

In recent years, there has been increasing interest in the ability of travel demand models to estimate travel not only for the average weekday, but for different time periods within the day. Travel demand models are increasingly required to be analysis tools for a broad range of issues on transportation policy and project alternatives. These issues often require detailed analysis, not only spatially, but temporally as well.

Time-of-day was recognized in division of the daily auto trip table into AM Peak (two hours), Midday (six hours), PM Peak (three hours), and Nighttime (thirteen hours) components. Although a transit network was created, no transit trip tables or transit assignments were computed.

During this update of the CRCOG regional travel demand model, revisions to this approach were considered. This included the possibility of developing a choice model for forecasting peak spreading. Such a model, similar in approach to a mode choice model, would seek to capture the behavioral response of drivers to increasing congestion through a shift in their departure time. After careful consideration, it was determined that a choice model was neither necessary, based on observed travel patterns, nor the best option given CRCOG's approach to the traditional four step model. A simple modification to the time period definitions will be sufficient to meet CRCOG's modeling needs.

This section presents a brief overview of time of day modeling in travel demand forecasting, discusses how time of day is considered in the updated CRCOG model structure, and reviews the traffic count and other data that supports the current time of day approach.

8.1 APPROACHES TO TIME OF DAY MODELING

The approach used in the Capital Region Council of Governments (CRCOG) model is typical of methods used to address time of day in four-step travel demand forecast models. Although there are other approaches, they all have the same objective, which is to take the daily trips generated by the model and allocate them appropriately to different times of the day. Traditionally, in the context of a four-step travel demand model, this involves the use of factors derived from traffic counts or survey data.

Discussions regarding time-of-day modeling have been published in several readily available reports. The Second Edition (2010) of the *Travel Model Validation and Reasonableness Checking Manual*, published by the Federal Highway Administration (FHWA) Travel Model Improvement Program (TMIP) contains a chapter on time of day. It includes an overview of various methods (including choice models), as well as sources of data and guidelines for the development and checking of time-of-day model components. Among Fixed Factor Methods, the most common method, the Manual lists several ways in which time-of-day factors may be applied:

- Pre-distribution: daily trips are factored between the trip generation and the trip distribution steps;
- Post-distribution: factors are applied after trip distribution and before mode choice;

- Post-mode choice: factors are applied after mode choice and before assignment; and
- Post-assignment: factors are applied after assignment.

Time of Day Modeling Procedures Report (FHWA) [3] published in 1997 presents a discussion of the standard factoring approaches to time of day modeling. The report also covers several innovative approaches that go beyond factoring to address peak spreading and approaches that attempt to model time choice in the same manner as mode choice. Table 48, from this report summarizes the approach, advantages, and disadvantages of each method.

Travel Demand Forecasting: Parameters and Techniques NCHRP 716 (2012) includes a discussion of time of day modeling within the context of the four step model. This report states that, while many analysts prefer to perform the daily to TOD conversion prior to mode choice, there is no consensus as to the best point in the modeling process to carry out this conversion.

The *Travel Model Validation and Reasonableness Checking Manual* also discusses time-of-day choice models noting that a shortcoming of the fixed factoring methods is that time-of-day choice is insensitive to transportation level of service. While there has been research into incorporating variables that represent level of service it has had limited success when used with a four-step model. The time-of-day choice model approach appears better suited to tour and activity based models.

The National Cooperative Highway Research Program (NCHRP) Report 765 (2014) *Analytical Travel Forecasting Approaches for Project-Level Planning and Design,* updates NCHRP 255, and contains a chapter on improving the temporal accuracy of traffic forecasts. This report includes discussion on the development of activity based models incorporating time-of-day choice models, the use of dynamic traffic assignment to analyze the temporal nature of travel, approaches to evaluating peak spreading, as well as factoring approaches to time-of-day.

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[3] *Time-of-Day Modeling Procedures Report*, Prepared for: Federal Highway Administration – Travel Model Improvement Program. Prepared by: Cambridge Systematics, Inc. Final Report: February 1997.

Table 48: Assignment Types for Time of Day and Peak Spreading

Method	Approach	Advantages	Disadvantages
TIME OF DAY (TOD) Approaches			
TOD Assignment after Trip Assignment	Run daily 4-step model, factor daily volume outputs to obtain hour/period values	• Simple, quickest method to apply. (ex. Use K and D factors) • Accounts for different peaking /directional characteristics by subregions/roadways. • Allows for the possibility of link-based peak spreading but not trip based peak spreading or time of day choice	• Daily equilibrium assignments are performed for period that is not homogenous- speeds vary greatly over an average weekday (i.e. assignments are based on daily speeds, which are not every meaningful.) • Insensitive to future changes in land use or composition of traffic (through vs. local) • Peaking is unrelated to congestion levels – application of fixed factors to forecast year daily volumes may results in unrealistically high peak volumes.
TOD Assignment Between Mode Choice and Trip Assignment	Run trip generation, distribution, and mode choice on a daily basis, factor trip tables by purpose and mode to obtain peak hour / period trips tables, assign trip tables for each period to appropriate networks.	• Simple method to apply – trip table manipulation functions, factors derived from surveys, calibrated to time of day counts. • Assignments can be done for relatively homogenous periods (speeds within a peak or off-peaks periods vary much less than daily speeds.) • Mode can be considered in time of day factoring – transit could have explicitly different peaking characteristics than auto. • Allow for the possibility of trip based or link-based peak spreading, or time of day choice.	• Mode choice and trip distribution are still performed using daily speeds. • Applying a single set of regional factors causes inaccuracies due to different peaking characteristics across the region, but it's difficult to derive sub regional factors. • Peaking is not directly related to congestion levels – assigning trips tables based on the application of fixed factors to forecast year daily trip tables could results in unrealistically high peak volumes. This problem could be mitigated by using feedback; however, the feedback process is complicated when assignment travel time outputs are peak/off-peak but distribution/mode choice travel time inputs are daily.
TOD Assignment Between Trip Distribution and Mode Choice	Run trip generation, distribution on daily basis, factor person trip tables by purpose to obtain peak hour / period trips tables, perform mode choice and assignment for each period using appropriate networks	• Assignments can be done for relatively homogenous periods (speeds within a peak or off-peaks periods vary much less than daily speeds.) • Mode choice (but not distribution) is performed for the peak/off-peak periods using appropriate networks. • Allows for the possibility of trips-based or link-based peak spreading, or time of day choice (this assumes factors are not fixed).	• Trip distribution still using performed using daily speeds. • Applying a single set of regional factors causes inaccuracies due to different peaking characteristics across the region, but it's difficult to derive sub regional factors. • Difficult to justify using inconsistent procedures between trip distribution and mode choice procedures – distribution uses daily speeds, mode choice uses peak/off-peak speeds. • Peaking is not directly related to congestion levels – assigning trips tables based on the application of fixed factors to forecast year daily trip tables could results in unrealistically high peak volumes. This problem could be mitigated by using feedback; however, the feedback process is complicated when assignment travel time outputs are peak/off-peak but distribution/mode choice travel time inputs are daily.
TOD Assignment Between Trip Generation and Trip Distribution	Run trip generation on a daily basis, factor person trip tables by purpose to obtain peak hour / period trips tables, perform trip distribution, mode choice, and assignment for each period using appropriate networks.	• Assignments can be done for relatively homogenous periods (speeds within a peak or off-peaks periods vary much less than daily speeds.) • Mode choice and trip distribution are performed for the peak/off-peak periods using appropriate networks, consistent with the trip assignment approach. • Allows for the possibility of trips-based or link-based peak spreading, or time of day choice (this assumes factors are not fixed). • The use of feedback is facilitated since assignments travel time outputs and inputs to trip distribution and mode choice are all for the same peak/off-peak periods.	• Applying a single set of regional factors causes inaccuracies due to different peaking characteristics across the region, but it's difficult to derive sub regional factors. • Peaking is not directly related to congestion levels – assigning trip tables based on the application of fixed factors to forecast year daily trip tables could results in unrealistically high peak volumes. This problem could be mitigated by using feedback. • If time of the day choice is used, zone-to-zone measures of congestion cannot be considered since factors are applied to trip ends, not trip tables.

Method	Approach	Advantages	Disadvantages
Peak Spreading Approaches			
Spreading within the Peak Period: Linked based Approach	Obtain peak period assignments, estimate relationships between VOC ratios and ratio of peak hour / peak period percentages, apply to peak period link volumes from assignment.	• Simple method to apply (spreadsheet or simple program); peaking-congestion relationships can be estimated from time of day count information. • Accounts for congestion at the link level and diverts trips to the "shoulder" hours on either side of the peak	• Procedure is insensitive to many factors effecting peak spreading, including trip purpose and length. • Resulting peak hour volumes among links may not be consistent (i.e. volume entering a node may not equal the volume leaving the node) • Addresses neither spreading of trips outside the peak period nor the redefinition of peak periods over time. • Applying a single set of regional factors causes inaccuracies due to different peaking characteristics across the region, but it's difficult to derive sub regional factors. • Peaking is not directly related to congestion levels – assignment trip tables based on the application of fixed factors to forecast year daily trip tables could results in unrealistically high peak volumes. This problem could be mitigated by using feedback. • If time of the day choice is used, zone-to-zone measures of congestion cannot be considered since factors are applied to trip ends, not trip tables.
Trip-Based Peak Spreading based Approach	Obtain peak period trip tables, estimate relationships between ratio of peak hour/peak period percentages and other variables such as trip purpose and length, apply to peak period trip tables prior to peak hour assignments.	• Simple method to apply (spreadsheet or simple program); peaking-congestion relationships can be estimated from time of day count information. • Good foundation for approach; relationship between peak spreading and other variables is well documented.	• Procedure has not been tested using congestion as a variable. • Addresses neither spreading of trips outside the peak period nor the redefinition of peak periods over time • Does not account for changes in traveler behavior due to congestion. • Not sensitive to traffic congestion on specific links or specific origin-destination flows as well as to different trip purposes.
System-Wide Peak Spreading	Apply a model that relates the percentage of trips in the peak period to variable such as congestion, trip length geography, and socioeconomic variables. Apply the resulting percentages on a zone-to-zone basis to the person trip tables by purpose and mode that are outputs from mode choice, and run assignments for peak and off peak periods. Considers the system-wide excess travel demand and delay and distributes excess travel demand between the individual travel hours that comprise the peak period	• The effects of congestion on peak spreading can be explicitly considered. • Assignments can be done for relatively homogenous periods (speeds within a peak or off-peak period vary much less than daily speeds) • Mode can be considered in time of day factoring; transit could have explicitly different peaking characteristics than auto.	• Not sensitive to different trip purposes • Not sensitive to traffic congestion on specific links or specific origin-destination flows • Data required include TOD factors that describe the distribution of trips in each of the three analysis hours that comprise the peak period. Also a set of VOC limits (by facility type) that differentiates between temporal and spatial diversion • Mode choice and trips distribution are still performed using daily speeds. • Feedback process is complicated when assignments travel time outputs are peak /off-peak but distribution/ mode choice travel time inputs are daily. • Has not been developed for non-work trips.

8.2 TRAFFIC DATA ANALYSIS

An analysis of traffic data was undertaken based on continuous count and traffic monitoring data available from the Connecticut Department of Transportation (CTDOT). Appendix D contains some definitions and figures pertinent to the traffic analysis. The first objective of the traffic data analysis was to determine if there was evidence of peak spreading in the Hartford area. Evidence of peak spreading would help to inform the discussion regarding consideration of developing a peak spreading model either now or in the future. A second objective of the analysis was to determine if there had been a shift in the peak period that might necessitate the need for adjusting the time of day definitions currently used in the CRCOG model.

CTDOT maintains 40 continuous traffic count sites throughout the state. Eight of these sites are within the CRCOG Metropolitan Planning Organization (MPO) region and an additional eight are in the CRCOG model “buffer zone” shown in Figure 23 and Table 49.

Figure 23: Continuous Traffic Counts Locations

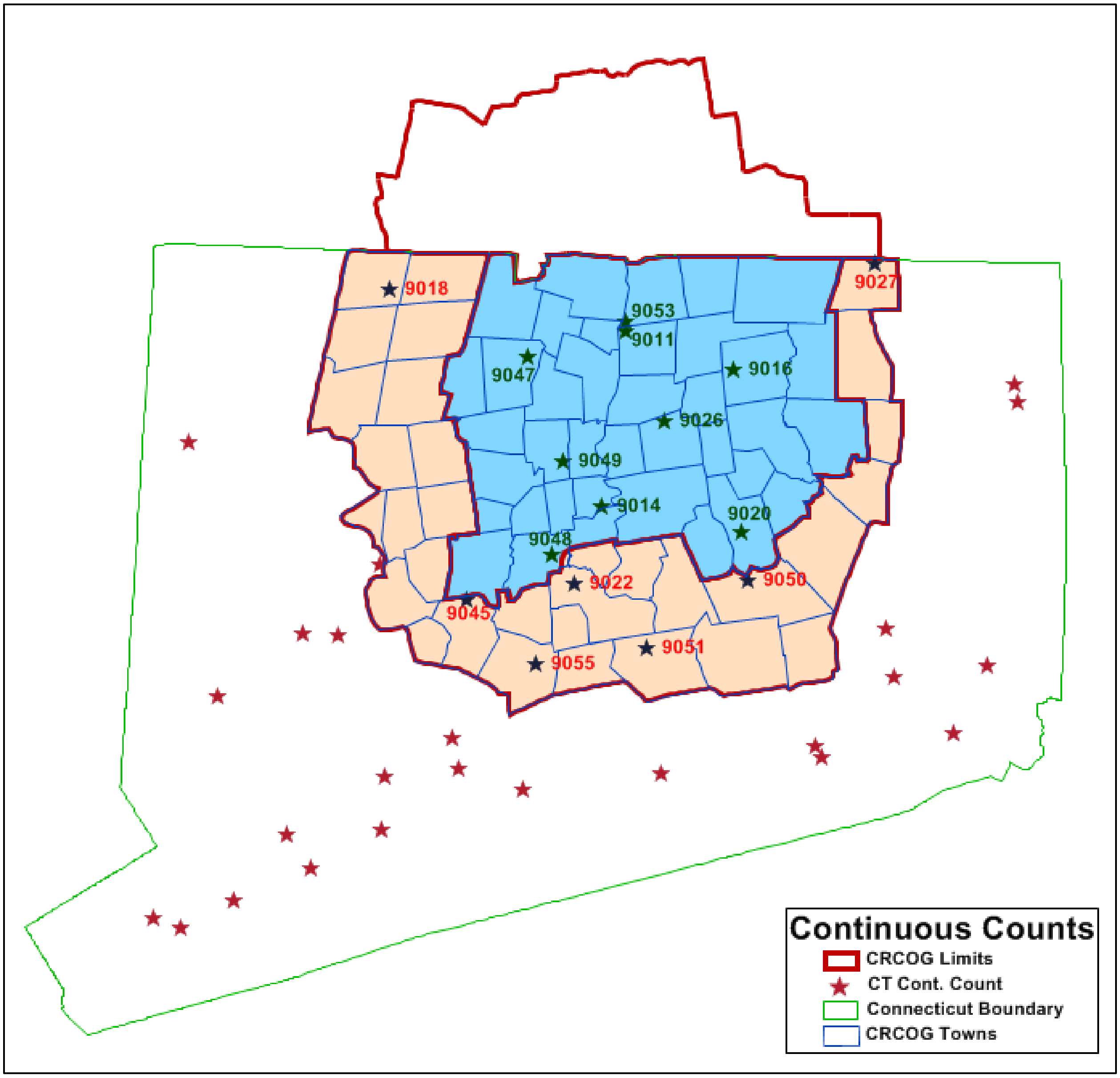


Figure 24 and Figure 25 show hourly counts from the continuous count site in West Harford (Count ID 9049), the site closest to the I-84 project area, for 2011 and 2015. These counts display expected temporal profiles. Morning demand increases from a very low level to a pronounced peak about mid-morning, heavily influenced by the travel-to-work trip purpose. Demand then drops during the late morning and early afternoon until another peak occurs when individuals return home from work, school, or other activities. After the evening peak, demand again drops to a relatively low level until morning.

In the eastbound direction, in 2011 and 2015, similar predominant peaks are evident at 8:00 AM with smaller peaks visible at 3:00 PM in the afternoon and 7:00 PM in the evening. In the westbound direction, the prominent peak occurred during the evening at 6:00 PM in 2011 and 5:00 PM in 2015. A smaller peak also occurred during the morning in the westbound direction at 10:00 AM in 2011 and 9:00 AM in 2015.

Table 49: Continuous Traffic Counts Locations

Count ID	Direction	Route No.	Road Type	Functional Class	Town	CRCOG Model Area
9011	North / South	Rt-5	Urban	Principal Arterial (Other)	East Windsor	MPO Region
9014	North / South	I-91	Urban	Principal Arterial (Interstate)	Wethersfield	MPO Region
9026	East / West	I-84	Urban	Principal Arterial (Interstate)	Manchester	MPO Region
9047	North / South	Rt-10	Urban	Principal Arterial (Other)	Simsbury	MPO Region
9049	East / West	I-84	Urban	Principal Arterial (Interstate)	West Hartford	MPO Region
9053	North / South	I-91	Urban	Principal Arterial (Interstate)	Enfield	MPO Region
9016	North / South	Rt-30	Urban	Collector	Tolland	MPO Region
9020	East / West	Rt-66	Rural	Principal Arterial (Other)	Hebron	MPO Region
9048	North / South	Rt-15	Urban	Principal Arterial (Other Expressway)	Berlin	Buffer Zone
9018	North / South	Rt-8	Rural	Minor Arterial	Colebrook	Buffer Zone
9023	North / South	Rt-8	Urban	Principal Arterial (Other Expressway)	Watertown	Buffer Zone
9022	North / South	Rt-217	Urban	Minor Arterial	Middletown	Buffer Zone
9051	North / South	Rt-9	Urban	Principal Arterial (Other Expressway)	Haddam	Buffer Zone
9045	East / West	I-691	Urban	Principal Arterial (Interstate)	Cheshire	Buffer Zone
9055	North / South	I-91	Urban	Principal Arterial (Interstate)	Wallingford	Buffer Zone
9050	East / West	Rt-2	Urban	Principal Arterial (Other Expressway)	Colchester	Buffer Zone
9027	East / West	I-84	Rural	Principal Arterial (Interstate)	Union	Buffer Zone

ADT at this site declined by 800 vehicles (0.61%) between 2011 and 2015. This is evident in the relative position of the curves for the two years. In addition, there appears to have been a slight shift in travel times to earlier time periods, most likely in response to congestion on I-84. Peak spreading results in the expansion of peak period of traffic, from original peak period to include additional shoulder-hours, in response to traffic levels that exceed capacity. Hence, the peaks in the demand profile would appear flatter and include more time periods. Given that the 2011 and 2015 curves have approximately the same shape there does not appear to be evidence of peak spreading.

Figure 24: West Hartford Continuous Traffic Count Data (I-84 East)

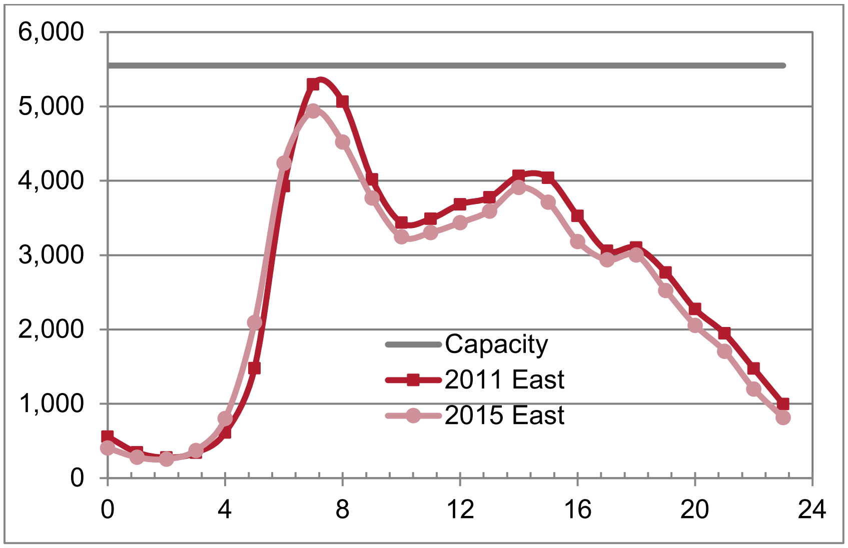
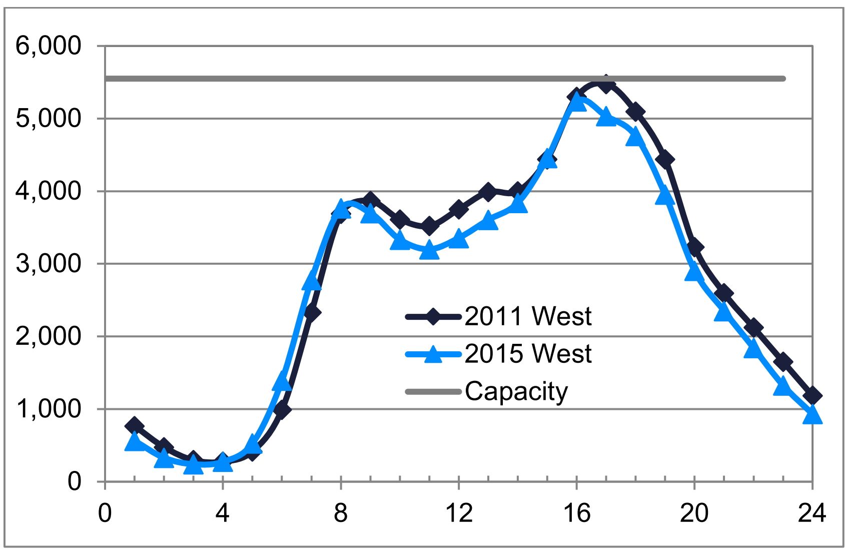


Figure 25: West Hartford Continuous Traffic Count Data (I-84 West)



Count profiles for all of the continuous counts sites in the CRCOG model area are in Appendix D. Across all the sites there is modest growth over the last five years, with 1 percent or less of Average Annual Percent Change (AAPC) on interstates and 1 to 3 percent AAPC on principal arterials. Table 50 illustrates the change in traffic volumes in the I-84 corridor between 2001 and 2015.

8.2.1 Traffic Monitoring Data

In addition to the continuous count stations (CCS) data, historical average daily traffic (ADT) for I-84 and I-91 was collected from CTDOT's Traffic Monitoring Volume Information Traffic Count Data. Table 50, displays 15 years of ADT data, from 2001 to 2015.

Table 50: Historical Average Daily Traffic Volumes

Year	I-84: Bulkeley Bridge	I-91		I-84				
		Between Exits 33 and 34	South HOV Ln Between Exits 33 and 34	WB: Off-Ramp to I-91 NB (Exit 51)	EB: Off-Ramp to I-91 SB (Exit 52)	EB: On Ramp from I-91 SB	WB: On Ramp from I-91 NB	EB: Off Ramp to I-91 NB (Exit 51)
2001	141,800			10,200	14,500	21,900	-	
2002			7,000				23,300	11,200
2003							-	
2004	141,400			11,300	15,500	23,600	-	
2005			9,400				23,100	12,400
2006			8,100				-	
2007	141,400			9,400	13,100	20,500	-	
2008					14,500		21,300	11,900
2009		129,900	8,000				21,900	12,500
2010	141,100	135,400	8,600	10,900	14,500	22,000	23,000	
2011							23,100	11,800
2012		133,200	9,600	11,300	14,500	22,900	-	
2013	141,700			10,800	14,900	22,100	22,900	
2014								
2015		144,000	6,200		14,800			
CHANGE FROM FIRST TO LAST YEAR IN EACH SERIES								
Number	-100	14,100	-800	600	300	200	-400	600
Percent	-0.07%	10.85%	-11.43%	5.88%	2.07%	0.91%	-1.72%	5.36%
CAGR	-0.01%	1.48%	-0.86%	0.44%	0.14%	0.07%	-0.14%	0.58%

Note: CAGR is the Compound Annual Growth Rate, calculated as: = ((End Value / Start Value) ^ (1/Periods) -1

Overall, the table shows an irregular pattern of change in ADT volumes across the years and at the locations listed. Daily traffic volumes on I-84 over the Bulkeley Bridge have remained fairly constant over time with ADTs between 141,100 and 141,800 vehicles per day. This is likely due to the recurring congestion throughout Hartford. Most of the city's freeways have operated at or near capacity for decades, leaving little room for growth. While the peak periods have shifted into traditionally off-peak hours, the overall daily volumes have not increased substantially, reflecting the time-sensitive nature of commuter traffic. In addition to this mainline location, another mainline location and a High Occupancy Vehicle (HOV) connector location plus five ramps connecting I-91 and I-84 are shown. The other mainline location has seen growth in traffic increasing by 10.85 percent between 2009 and 2015. Most of the ramps have seen little or no growth during the 15 years. The largest growth, 5.36 percent, was on the I-84 eastbound off-ramp to I-91 northbound (Exit 51) while the I-84 westbound on-ramp from I-91 northbound saw a decline in traffic of 1.72 percent.

8.2.2 Final Time-of-Day Adjustment

The phenomenon of peak spreading is the result of a shift in travel demand away from an historic peak hour to earlier or later times (the peak shoulders) resulting in a longer peak period. In the CRCOG region, while there is congestion, there does not appear to be a peak spreading response to this congestion. There is some evidence that there has been a shift of some peak period traffic to non-traditional peak hours. In addition, there has also been for the most part, little or no growth in traffic during the recent past.

Figure 24 illustrates typical traffic patterns found in the Hartford area with a shift in peak hour traffic to earlier times but no evidence of peak spreading. A review of the daily and peak hour traffic profiles found in Appendix D from CTDOT's continuous count program would also seem to support this observation. Finally, little or no growth in traffic volumes coupled with little or no population growth over the last several years, leads to the conclusion that peak spreading will not be a significant response to congestion in the near future.

These observations led to the conclusion to modify the time-of day segments slightly by expanding the AM peak period from two hours to three hours, along with a corresponding reduction in the Nighttime period from 13 to 12 hours. As a result of these changes the CRCOG Model now utilizes the following four time periods:

- AM Period: 6:00AM- 9:00AM (3 hours)
- MD Period: 9:00AM- 3:00PM (6 hours)
- PM Period: 3:00PM- 6:00PM (3 hours)
- NT Period: 6:00PM- 6:00AM (12 hours)

8.3 CRCOG TIME-OF-DAY METHODOLOGY

The approach to the temporal distribution of daily trips is unchanged from the previous CRCOG model. However, while the approach is unchanged, there has been a modification to the definition of the time periods used to divide the daily auto trip table. The time of day factors used in this process are based on observed traffic counts, transit on-board survey data, and household survey data. Furthermore, the development of a mode choice model with a working transit component introduces an element into the model structure that influences results by time-of-day.

After the mode choice model is run, the auto trip matrices are converted from PA to OD format. The Time of Day component is the first step in the highway assignment and results in the OD trip matrices being divided into four time periods. The four time periods are: AM Peak (three hours), Midday (six hours), PM Peak (three hours), and Nighttime (12 hours). As noted above, this is a modification from the previous CRCOG Model for the AM Peak from two to three hours and for the nighttime period from 13 to 12 hours.

8.3.1 Diurnal Factors by Trip Purpose

The diurnal factors for each trip purpose were estimated using the 2016 Let's Go CT Household Travel Survey. Each individual trip record was segmented into one of the following trip purposes using origin and destination responses:

- Home-Based-Work (HBW)
- Home-Based-Other (HBO)
- Non-Home-Based (NHB)

Each trip record was assigned one of two directions: PA or AP. Home-Based trips, with home as the destination, were designated as AP trips, home-based trips with home as the origin were assigned as PA trips. All non-home-based trips were nominally designated as PA trips, and the PA/AP split was set at 0.5/0.5 for each time period.

The Resident time of day factors are shown in Table 51. These factors are based on information from the CT DOT 2016 Let's Go CT Household Travel Survey. Only a limited set of geographic identifiers were provided with the home interview survey data. As a result, the CRCOG MPO area was used to represent the entire model region which includes the MPO area, the Buffer Area in Connecticut, and TAZ's in Massachusetts.

TOD factors for the non-resident trip purposes are shown in Table 52. Non-resident trips include the following purposes:

- Home-Base-Work Internal – External and External – Internal trips (HBW-IX/XI)
- Non-Work Internal – External and External – Internal trips (NW-IX/XI)
- Truck trips including Internal – Internal, Internal - External, and External – Internal trips (TRUCK-II/IX/XI)
- Thru trips.

No data was available on which to base estimation of the TOD factors for the non-resident trip purposes. Therefore, HBW-IX/XI trips are assumed to have the same TOD distribution as HBW resident trips. In similar fashion, NW—IX/XI trips are assumed to have the same TOD distribution as HBO trips. Finally, TOD splits for Truck and Through trips were based on the previous model splits and adjusted during final system-wide calibration to match observed flow totals.

Table 51: Resident Time of Day Factors

Resident Time of Day Assignment						
Purpose	Direction	AM	MD	PM	NT	Daily
HBW	AP	0.034	0.068	0.244	0.155	0.500
HBW	PA	0.268	0.140	0.028	0.064	0.500
HBO	AP	0.035	0.118	0.118	0.229	0.500
HBO	PA	0.119	0.253	0.068	0.060	0.500
NHB	AP	0.062	0.273	0.123	0.042	0.500
NHB	PA	0.062	0.273	0.123	0.042	0.500

Table 52: Non-Resident Time of Day Factors

Non-Resident Time of Day Assignment						
Purpose	**Direction**	**AM**	**MD**	**PM**	**NT**	**Daily**
HBW_IX	OD	0.092	0.154	0.552	0.202	1.00
HBW_XI	OD	0.629	0.137	0.025	0.209	1.00
NW_IX	OD	0.070	0.300	0.252	0.378	1.00
NW_XI	OD	0.193	0.378	0.240	0.189	1.00
TII	AP	0.059	0.167	0.147	0.127	0.50
TII	PA	0.059	0.167	0.147	0.127	0.50
TIX	OD	0.073	0.562	0.145	0.221	1.00
TXI	OD	0.308	0.407	0.059	0.225	1.00
THRU	AP	0.074	0.231	0.070	0.125	0.50
THRU	PA	0.074	0.231	0.070	0.125	0.50

9. SPECIAL EVENT MODEL

Travel by residents and visitors to events such as baseball games, festivals, convention centers and other similar venues falls under the umbrella of special event travel. Historically, the focus of regional travel demand models has been on daily weekday travel for trip purposes such as Home Based Work (HBW), Home Based Other (HBO) and Non-Home Based (NHB). As a result, these models do not directly address travel to and from special events.

As part of the CRCOG model update a Special Events Model (SEM) has been incorporated into the CRCOG regional model structure. The impetus for this effort comes from the successful introduction of CTfastrak in the Hartford region where special event patrons constitute a significant portion of the ridership.

The special event sub-model was added to the CRCOG model to generate trips to and from a special event location, i.e. TAZ. The special event model step occurs just prior to the assignment step in the model. The special event trips are added to the existing trip tables for residents and non-residents by time of day and mode. The details of the model implementation are discussed in the following sections.

9.1 SPECIAL EVENT VENUES

Special events in the Hartford region range from weekend festivals that attract local residents to large sporting events, which bring thousands of visitors into the region. Given the large number of special events that occur each year, it is not practical to collect data and create models for each individual event. Therefore, the special events in the region were reviewed in light of the following characteristics:

- Predicted Attendance
- Event Frequency
- Regular versus Periodic Event
- Venue Type
- Event Start and End Time
- Single versus Multiple Days
- Day of Week
- Event Market Area
- Local versus Regional Attendance

As a result of the initial review, and the large number of events that occur in a single year, it was decided to focus on special event venues that attract at least 6,000 patrons. In addition, the following criteria were considered in bringing the list down to six venues where data collection was necessary (and conducted):

- Importance of capturing impacts of special events on the transit system
- High attendance events at several large stadiums and sports complexes
- Good representation within each of the nine characteristics noted above
- Importance of seasonality of special events

Table 53 illustrates the venues, capacity or size, and assumed event attendance for the six venues considered. Note: CT Science Center hosts small venues, however the square footage support much later events. The location was pre-selected with average attendance less than 6,000 patrons.

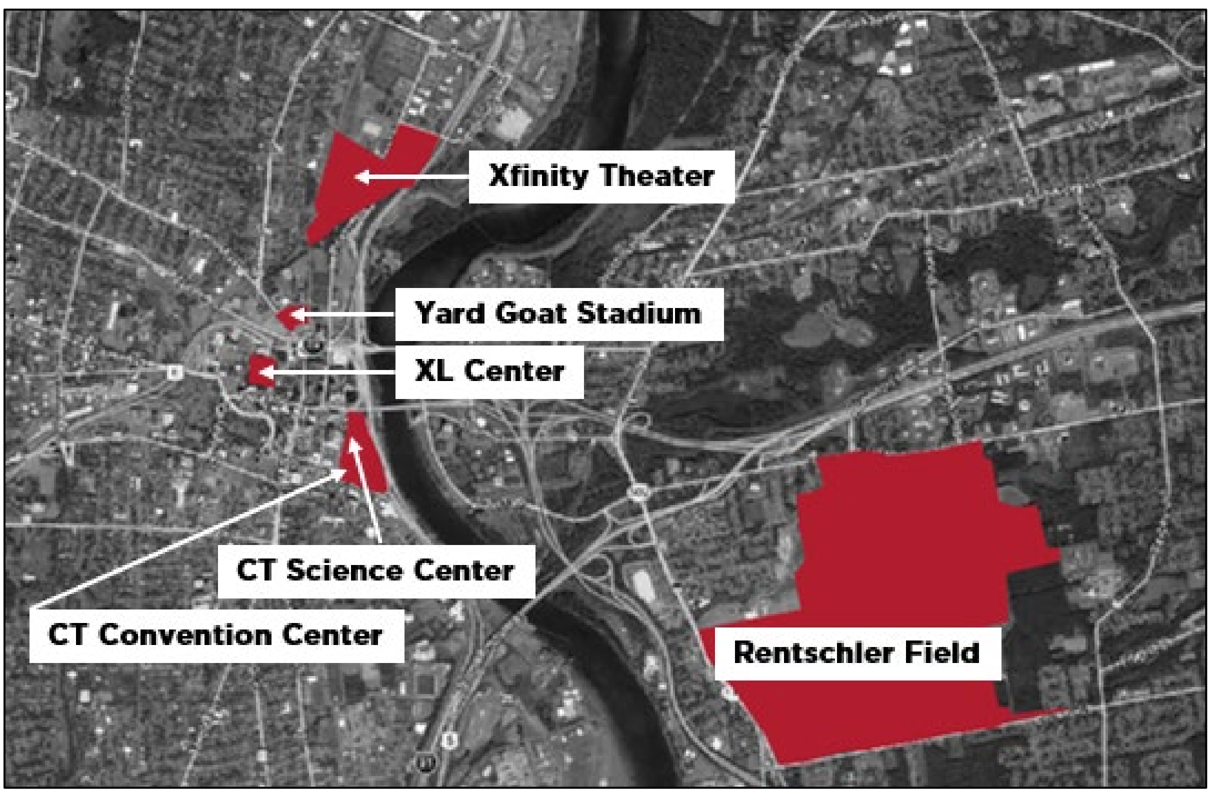
Figure 26 shows the TAZ in which each of the venues is located.

Table 53: Venue, TAZ, Capacity and Assumed Attendance

Venue	TAZ	Venue Capacity or Venue Size	Assumed Venue Attendance
XL Center	2014	16,600 people	16,600
Yard Goat Stadium	27501	6,050 people	6,050
Xfinity Theatre	8602	30,000 people	30,000
Rentschler Field	178	40,600 people	40,600
CT Science Center	2107	154,000 Sq. Ft.	2,000
CT Convention Center	2106	540,000 Sq. Ft.	12,800
Bradley International Airport	906	3,500 people	3,500
Bradley International Airport	122	14,000 people	14,000

Note: CT Science Center hosts small venues, however the square footage support much later events. The location was pre-selected with average attendance less than 6,000 patrons. Also Bradley International Airport overall as a facility supports more than the minimum required of 6,000 patrons.

Figure 26: TAZ Location of Special Event Venues



9.2 METHODOLOGY

The special event sub-model uses the daily attendance (SE_ATTEND) field from the model's socio-economic data file. SE_ATTEND is the estimated or expected number of people participating in a specific special event within a specific traffic analysis zone (TAZ). To create a set of trips that can be assigned to the network, the following attributes need to be computed:

- Location:
  - Origin location for participants coming to the special event.
  - Destination location from special event after the event is over.
- Mode:
  - Modes for trips to the special event
  - Modes for trips from the special event
- Time-of-day periods:
  - For trips to the special event
  - For trips from the special event

The total number of trips generated by each special event is twice the number of SE_ATTEND as every participant makes two trips: a trip to the special event and a trip from the special event. In this model, the trips to the special event are outbound trips and trips from the special event are inbound trips. Due to unavailability of a special event survey, reasonable coefficients were asserted for the choice models.

9.2.1 Location

The origin location for outbound trips is determined using a reverse destination choice model and inbound trips are determined using a standard destination choice model. Typical to any location choice model, the origin choice for outbound trips and destination choice for inbound trips is determined based on the size term and the impedance term.

The size term captures the supply side of travel behavior. The size term for the special event origin and destination choice model is a combination of the number of households by income level, the amount of retail employment, and the amount of non-retail employment. The size term for the origin location for outbound trips was different than the destination location size term for inbound. This was based on the rationale that the share of participants coming from their workplace to the special event would be different than the share of participants going back to their workplace after the special event. In particular, it is assumed that there is a greater share of one end of the trip to be home for trips from special events thus demanding a larger coefficient on number of households by income level for inbound trips. The coefficients on different components of the size term are listed in Table 54.

The impedance term captures the impact of level-of-service on location choice. Special event trips typically have a fixed schedule/location and thus are not particularly sensitive to travel conditions/distances. Due to such unique properties of these trips, only highway distance with a relatively small coefficient is used as an impedance term in the location choice model. The coefficient (c_dist) was set to be -0.1.

Table 54: Size Term Components for Location Choice Model

Size Term Component (socio-economic variable)	Outbound (trips to special events)	Inbound (trips from special events)
# of Households Income Group 1	0.2	0.3
# of Households Income Group 2	0.2	0.3
# of Households Income Group 3	0.3	0.5
# of Households Income Group 4	0.3	0.5
Retail Employment	0.5	0.1
Non-Retail Employment	0.5	0.1

The output of this step is two daily person trip tables:

- Outbound trip table ("...\CRCOG\Base\outputs\specialevent\Trip_SE_out.mtx") and
- Inbound trip tables ("...\CRCOG\Base\outputs\specialevent\Trip_SE_in.mtx")

9.2.2 Time-of-day

The next step is to split the daily trip table into four time-of-day periods: AM, MD, PM, and NT. Logical time-of-day factors for outbound and inbound were used to split the trip tables by time-of-day periods. Similar to the location choice model logic, these factors were set to be different by direction due to inherent chronology associated with these trips. Since inbound trips are always after outbound trips, the time-of-day factors for late periods for inbound trips is set to be higher than that of outbound trips. The time-of-day factors are listed in Table 55.

Table 55: Time-of-Day Factors by Direction

Time of Day (Period)	Outbound (trips to special events)	Inbound (trips from special events)
AM (6:00AM- 9:00AM)	0.1	0.05
MD (9:00AM- 3:00PM)	0.1	0.05
PM (3:00PM- 6:00PM)	0.5	0.4
NT (6:00PM- 6:00AM)	0.3	0.5

9.2.3 Mode

After splitting the person trip tables by time-of-day, the next step is to split by trip modes. For simplicity and due to lack of special event mode share data, the person trip tables are assumed to be auto trips; however, this model has the flexibility to be enhanced in a future effort if additional modal information becomes available.

The mode share factors were asserted such that the auto occupancy is higher for trips from special events, which is consistent with the assumption in location choice model that the share of trips to home would be higher for inbound trips, and thus more likely to be carpooled with a household member. These mode share factors are listed in Table 56.

Table 56: Mode Share Factors by Direction

Mode	Outbound (trips to special events)	Inbound (trips from special events)
SOV	0.3	0.2
HOV2	0.45	0.5
HOV3+	0.25	0.3

The final output of the special event model is eight time-of-day specific person trip tables with cores specific to the person trip modes:

- Trip_AM_SE_in.mtx and Trip_AM_SE_out,
- Trip_MD_SE_in.mtx and Trip_MD_SE_out,
- Trip_PM_SE_in.mtx and Trip_PM_SE_out,
- Trip_NT_SE_in.mtx and Trip_NT_SE_out.

These trip tables are then added to trip tables generated by the core demand model before assigning to the highway network.

10. SYSTEM-WIDE CALIBRATION

The final step in the travel demand model is trip assignment. This is the process of assigning the zone to zone trips to the individual links in the highway network and the transit route system. This step is performed iteratively, with overall model calibration and validation. When overall model calibration and validation is achieved, as measured by established performance measures, the trip assignment step provides the data needed for:

1) Testing alternative transportation plans
2) Establishing priorities between different transportation investment strategies
3) Analyzing alternative locations for roadway improvements
4) Forecasting design volumes needed to adequately design and construct new roadway facilities

The reliability of the output from this step is dependent upon the reliability of all the proceeding steps.

This section describes the system-wide calibration and validation of the completed model. It presents comparisons of initial highway model flows to observed traffic counts, and the results of the final highway assignment, transit assignment, and sensitivity analysis based on the completion of system-wide calibration and validation.

10.1 HIGHWAY

10.1.1 Highway Assignment

The algorithms used in traffic assignment attempt to replicate the process of choosing the best path between a given origin and destination. For the CRCOG model, the algorithm used is an equilibrium assignment. This is a widely accepted, best practice approach that produces link loadings by optimally seeking user-equilibrium path loadings reflecting user path choices as influenced by congestion on the network. During this process, the trip table is assigned to the highway network over multiple iterations. At the end of 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 number of iterations is determined by a user defined closure parameter up to a predefined maximum number of iterations.

For each iteration, the volume-delay function is used to update the link speeds based on the previous iteration's vehicle demand and the link capacity. The formulation of this function is shown below. The corresponding alpha and beta parameters by facility type used for the CRCOG MPO model are shown in Table 57.

$$T_c = T_0 * (1 + \alpha(V / C)^{\beta})$$

Where:

T_c = congested link travel time
T_0 = initial link (free flow) travel time
V = assigned traffic volume
C = link capacity
α, β = calibration parameters

Table 57: CRCOG Model Alpha and Beta Parameters

Facility Type	Alpha	Beta
Interstate	0.880	2.50
Principal Arterial	0.720	4.00
Minor Arterial	0.560	4.00
Collector	0.560	4.00
Local	0.560	4.00
Ramps	0.800	4.00

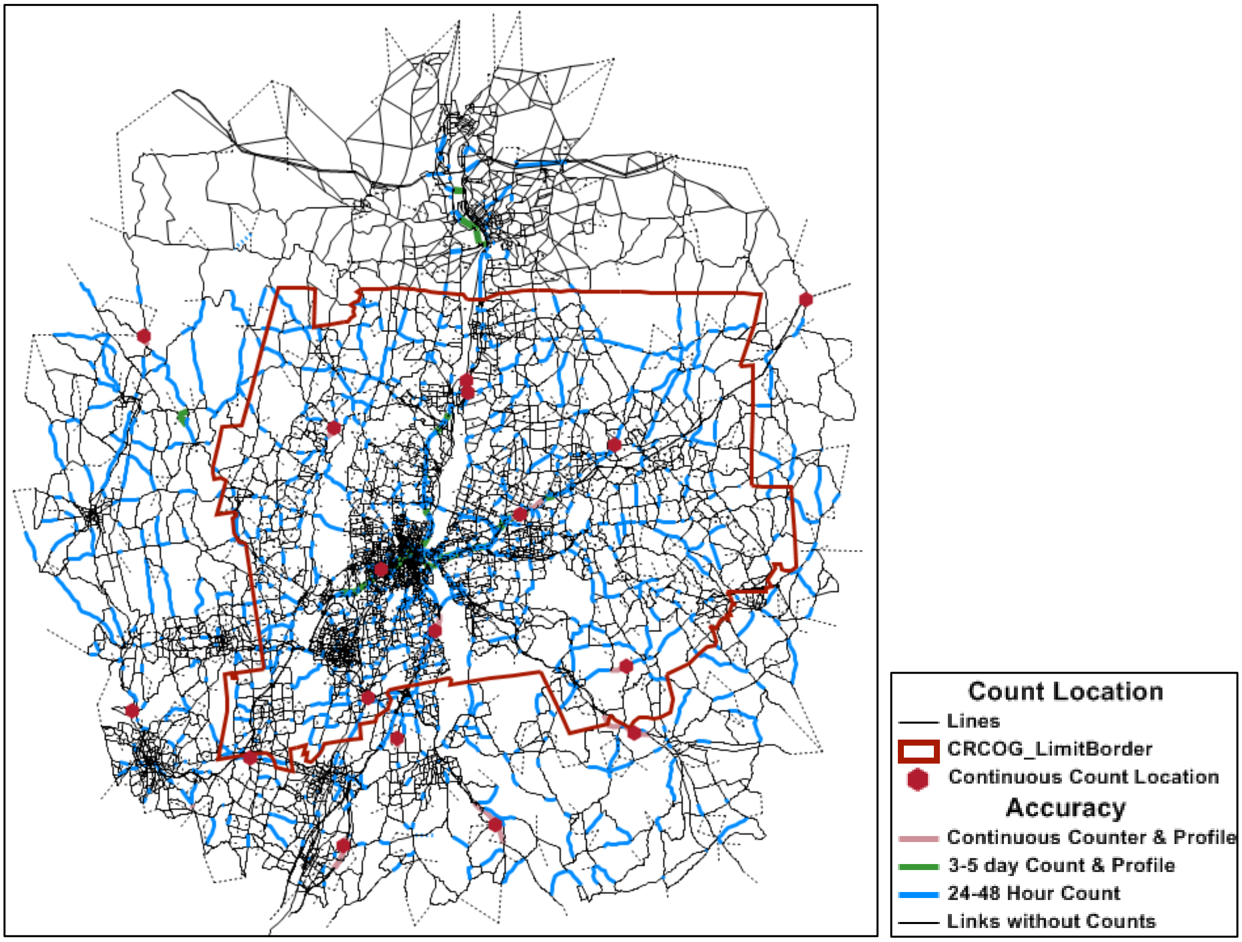
Highway trip assignment is performed separately for the AM peak period, Midday period, the PM peak period, and the Night time period.

10.1.2 Traffic Counts

To support the system wide calibration and validation a total of 1,667 CTDOT traffic counts were collected. Included in this set were data from 34 continuous count sites, 76 three-to-five day count locations, and 1,557 one-to-two day count locations. Figure 27 shows the locations of these count sites.

The data was reviewed in a search for outliers and to ensure reasonable data ranges given a roadway's facility type. Counts were also factored to represent a 2015 Base Year. A count database was developed that includes a unique count ID, highway network link ID, count type, count source, roadways, location description, and average weekday count (AWDT) reflecting 2015. Data permitting, directional counts were estimated for the not only for a daily period but also the AM Peak Period, Midday Period, PM Peak Period, and Nighttime Period.

Figure 27: Count Locations and Count Type



10.1.3 Initial Highway Assignment Results

Percent Root Mean Square Error (%RMSE) is a common calculation performed in the highway assignment validation and calibration process to determine how modeled volumes match observed counts. The measure expresses the RMSE as a percentage of the average count value and is calculated as follows:

$$\text{RSME} = \sqrt{\frac{\sum_{i=1}^{n}(Count_i - Model_i)^2}{\text{N}}} \quad \text{and} \quad \%\text{RSME} = \frac{\text{RSME}}{\sum_{i=1}^{n}(Count_i)\ /\ \text{N}} x100$$

Where:

- $Count_i$ = the observed count for link *i*
- $Model_i$ = the modeled volume for link *i*
- N = the number of links with counts

When applied to model flow versus observed count comparisons, lower values of %RMSE describe a situation where model flows are more similar to counts, on a link-by-link basis. The expectation is that the model will achieve a lower %RMSE on more heavily traveled facilities such as Interstates, than on less traveled facilities such as collectors or local roads.

To assess the model's performance, comparisons have been made between the initial modeled highway flows and observed counts. These comparisons are:

- %RMSE by time of day and facility type
- %RMSE by observed volume group
- Ratio of Model Flows to observed counts by time of day and facility type
- Scatter Plots of model flows and observed counts

Table 58 shows the %RMSE results by facility type and time of day for the initial highway assignment. As expected for an initial run, the %RMSE values were fairly high. Also, the %RMSE values were lower on the more heavily traveled facilities, and highest on local roads. This is expected, and an indication that the model is performing correctly, overall.

Table 58: Percent RMSE by Facility Type (Initial Model Run)

Facility Type	N	Daily	AM	MD	PM	NT
Interstate	204	25.07	36.75	25.45	30.92	29.43
Principal Arterial	593	46.62	46.21	48.81	53.39	56.01
Minor Arterial	183	58.08	65.21	64.01	57.03	63.53
Collector	393	80.82	82.76	86.25	77.37	95.2
Local	44	122.17	142.7	130.61	125.07	108.34
Ramps	250	56.78	57.31	61.57	62.54	72.55
Total	**1667**	**46.24**	**56.29**	**48.54**	**52.72**	**54.52**

Table 59 shows the %RMSE by volume group, based on total observed daily volume. As expected, lower volume facilities are not performing as well as higher volume facilities. In addition, these facilities have a flow-to-count ratio of 0.58, which is relatively low when compared to the other volume groups. This is an indication that these facilities should generally be carrying more traffic. By comparison, the highest volume group has the lowest %RMSE (14.28) with a flow-to-count ratio of 1.06. Again, this meets expectations, and indicates that the overall model is functioning correctly.

Table 59: Percent RMSE by Volume Group (Initial Model Run)

Observed Daily Volume	N	%RMSE	Flow / Count
Less than or equal to 5,000	558	112.53	0.58
5,001 to 10,000	443	52.4	0.89
10,001 to 20,000	416	39.42	0.96
20,001 to 40,000	147	31.65	1
40,001 to 60,000	42	21.49	1.11
Greater than 60,000	61	14.28	1.06

The flow-to-count ratios by facility type and time of day are in Table 60. Overall, these results are positive in that the ratios for Total Daily as well as each of the time periods are generally close to 1.00. The PM Period is a somewhat high at 1.14. Flow-to-count ratios for Principal Arterials are somewhat high for all time periods while for Local roads the ratio is somewhat low.

Table 60: Flow-to-Count Ratio by Facility Type (Initial Model Run)

Facility Type	N	Daily	AM	MD	PM	NT
Interstate	204	1.02	0.89	1.04	1.06	1.04
Principal Arterial	593	1.15	1.12	1.12	1.25	1.1
Minor Arterial	183	1.06	1.16	1.05	1.13	0.95
Collector	393	0.96	0.95	0.92	1.1	0.84
Local	44	0.87	0.96	0.79	1.01	0.74
Ramps	250	1.01	0.88	1.02	1.07	1.05
Total	**1667**	**1.06**	**0.99**	**1.06**	**1.14**	**1.03**

Scatterplots are useful validation tools and are often combined with R^2 statistics. The scatter plots are a graphic presentation of the relationship between the model flows and observed counts. Scatterplots are useful for showing how well model and observed volumes coincide and in identifying outlier links where the flow to count comparison is problematic. R^2 is a standard statistical measure of the amount of variation between the traffic counts and corresponding model flows. According to the FHWA's TMIP Reasonableness Checking and Validation Manual, R^2 can be a useful measure for comparing model results between iterations when calibrating travel models since the bases (i.e., the sets of links considered) for calculating the measure should be the same between iterations. The R^2 statistics should be calculated for links with similar characteristics, such as facility type or volume group.

The following figures are examples of scatterplots and R^2 statistics based on the initial model run. Figure 28 shows the daily model results for all facility types, and Figure 29 and Figure 30 show examples of scatterplots for Interstate and Principal Arterial facilities separately.

Figure 28: Model Flow vs. Observed Volumes, Daily

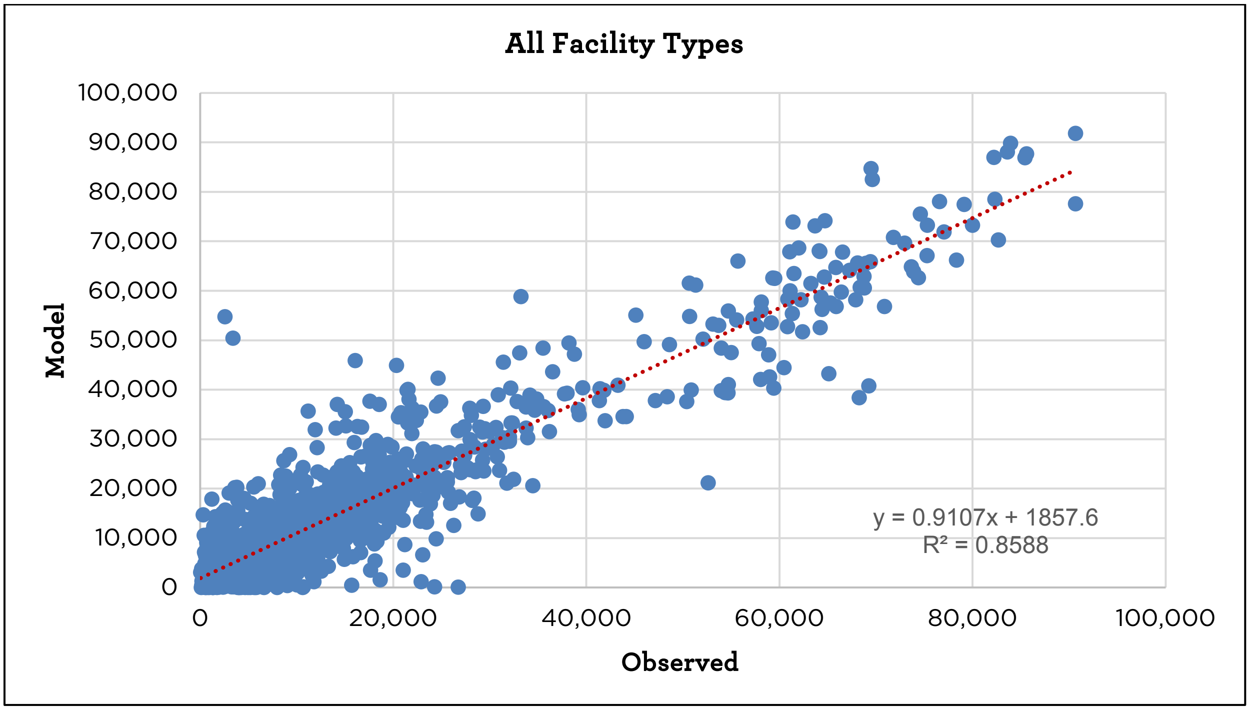


Figure 29: Model Flow vs. Observed Volumes, Daily

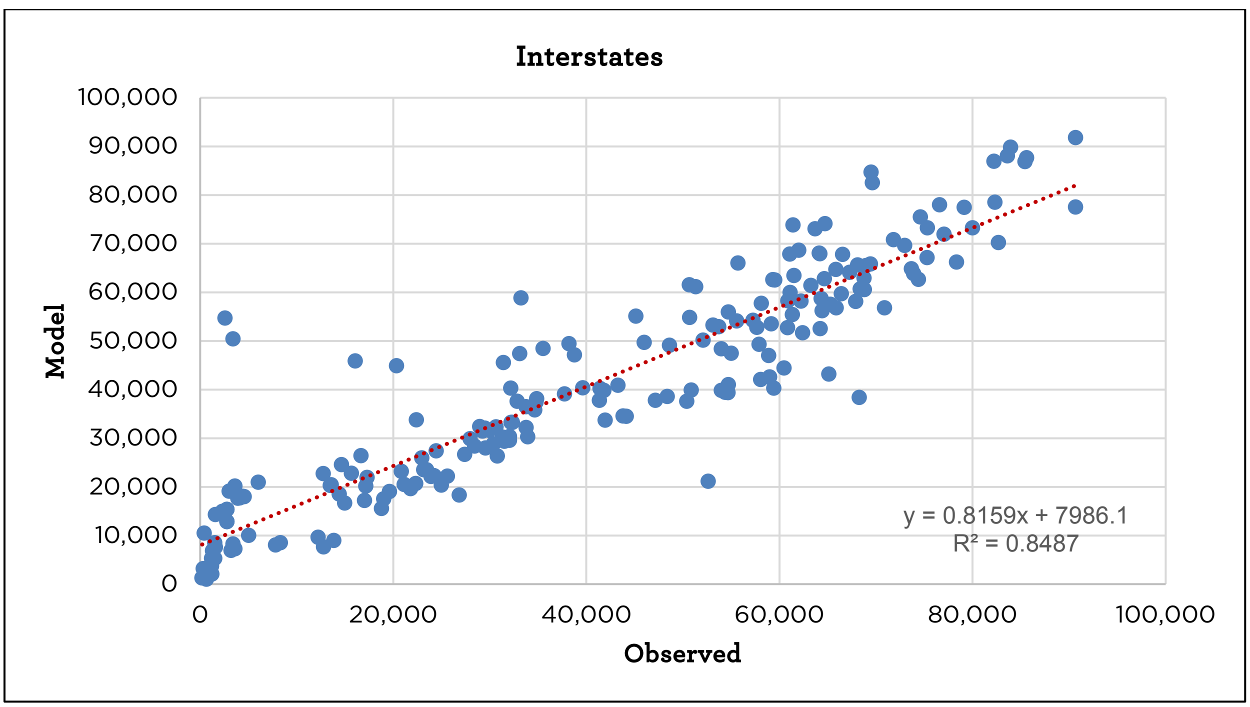
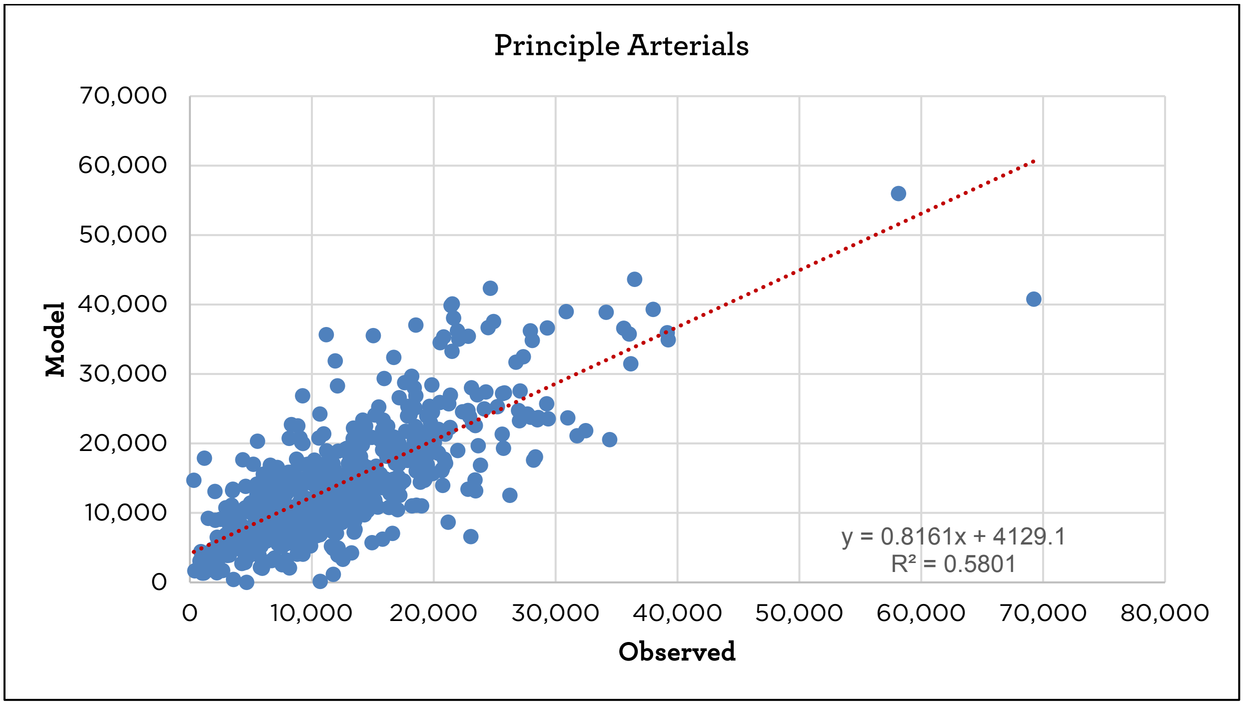


Figure 30: Model Flow vs. Observed Volumes, Daily



10.1.4 Final Highway Assignment Results

This section presents results for the current status of the highway mode validation. As in the previous section, the model performance is assessed by means of comparisons between modeled highway flows and observed counts. Strategies to improve model performance included:

- Adjustments to the model time-of-day factors to improve the flow-to-count ratio by time of day
- Adjustments to the alpha and beta coefficients of the volume-delay function to help improve the distribution of traffic by facility type
- Examination of scatter plots of model flows to observed counts and the identification of outliers to help locate network coding issues

As with the initial model results, model performance was examined by looking at:

- %RMSE by time of day and facility type
- %RMSE by observed volume group
- Ratio of Model Flows to observed counts by time of day and facility type

The initial model results showed an imbalance in the total flow-to count ratios between each of the four model time periods (see Table 60). To address this imbalance, the time-of day splits were adjusted until the total flow-to-count ratios for each of the time periods better approximated the daily total flow-to-count ratio. The revised time-of-day splits are presented in Table 61 and Table 62.

Table 61: Revised Resident Time-of-Day Factors

Resident Time of Day Factors						
Purpose	Direction	AM	MD	PM	NT	Daily
HBW	AP	0.0341	0.0677	0.2436	0.1545	0.50
	PA	0.2677	0.1402	0.0284	0.0637	0.50
HBO	AP	0.0352	0.1181	0.1179	0.2288	0.50
	PA	0.1189	0.2530	0.0680	0.0601	0.50
NHB	AP	0.0623	0.2729	0.1227	0.0420	0.50
	PA	0.0623	0.2729	0.1227	0.0420	0.50

Table 62: Revised Non-Resident Time-of-Day Factors

Non-Resident Time of Day Assignment						
Purpose	Direction	AM	MD	PM	NT	Daily
HBW_IX	OD	0.0925	0.1539	0.5516	0.2019	1.00
HBW_XI	OD	0.6290	0.1371	0.0249	0.2090	1.00
NW_IX	OD	0.0701	0.2999	0.2520	0.3780	1.00
NW_XI	OD	0.1929	0.3782	0.2396	0.1893	1.00
TII	AP	0.0594	0.1665	0.1474	0.1266	0.50
TII	PA	0.0594	0.1665	0.1474	0.1266	0.50
TIX	OD	0.0725	0.5616	0.1446	0.2213	1.00
TXI	OD	0.3084	0.4070	0.0592	0.2254	1.00
THRU	AP	0.0743	0.2307	0.0703	0.1248	0.50
THRU	PA	0.0743	0.2307	0.0703	0.1248	0.50

Further improvements to the flow-to-count ratios by facility type were made through adjustments to the alpha and beta parameters of the Bureau of Public Roads volume-delay function. The final volume delay function parameters are presented in Table 63.

Table 63: Revised CRCOG Model Alpha and Beta Parameters

Facility Type	Alpha	Beta
Interstate	0.812	10.000
Principal Arterial	1.000	2.100
Minor Arterial	0.757	3.001
Collector	0.414	3.001
Local	0.150	6.000
Ramps	1.000	3.001

The resulting flow-to-count ratios are presented in Table 10.8. Note that a comparison of Table 60 and Table 64 shows a difference in the total N (number of observed counts) because during system-wide calibration some questionable counts were identified and removed from consideration.

Overall, the results are improved over the results from the initial run. Each of the time period totals are within .02 of the daily total of 1.04. The PM period, which was previously 1.14, now stands at 1.02. In addition, the flow-to-count ratios for Principal Arterials are now much closer to 1.00 than in the initial results.

Table 64: Flow-to-Count Ratio by Facility Type

Facility Type	N	Daily	AM	MD	PM	NT
Interstate	203	1.08	0.98	1.16	0.97	1.17
Principal Arterial	589	0.99	1.03	0.95	1.03	0.98
Minor Arterial	183	1.04	1.23	1.04	1.01	0.92
Collector	393	1.00	1.10	0.97	1.10	0.87
Local	44	0.94	1.16	0.89	0.98	0.81
Ramps	248	1.10	1.00	1.14	1.08	1.17
Total	**1660**	**1.04**	**1.03**	**1.05**	**1.02**	**1.06**

Table 65 shows the %RMSE results by facility type and time of day. Compared to the initial model run there has been improvement. Total results are better for the AM, MD, and PM time periods and unchanged for the NT period. Similarly, the results are improved for the Interstate and Principal Arterial facility types for the Daily and all time periods except for Interstate during the NT time period.

Table 65: Percent RMSE by Facility Type

Facility Type	N	Daily	AM	MD	PM	NT
Interstate	203	19.49	31.80	25.07	24.63	31.91
Principal Arterial	589	40.75	39.43	44.07	44.14	51.16
Minor Arterial	183	59.28	72.05	65.93	54.81	63.80
Collector	393	83.53	87.59	89.13	79.86	96.86
Local	44	124.67	151.51	132.57	25.26	108.93
Ramps	248	43.64	50.30	49.37	52.47	60.91
Total	**1660**	**40.20**	**50.56**	**46.35**	**44.76**	**54.43**

Table 66 shows the %RMSE results by volume group based on total observed daily volume. Compared to the initial model run there has been improvement in all volume groups with the exception of the lowest volume roads. The highest volume group has a %RMSE of 10.05, compared to 14.28 in the initial run, and a flow-to-count ratio of 1.04 compared to 1.06 in the initial run.

Table 66: Percent RMSE by Volume Group

Observed Daily Volume	N	%RMSE	Flow / Count
Less than or equal to 5,000	557	150.79	1.64
5,001 to 10,000	444	49.37	1.05
10,001 to 20,000	416	38.53	0.94
20,001 to 40,000	144	30.92	0.99
40,001 to 60,000	42	15.96	0.98
Greater than 60,000	60	10.05	1.04

Figure 31 to Figure 33 show scatter plots of the model flow to observed volumes for the daily results for all facility types, Interstates and Principle Arterials. Compared to the initial plots there has been a reduction in outliers for All Facilities and Interstates, and the R^2 has improved for All Facilities from 0.8588 to 0.8990, for Interstates from 0.8487 to 0.9232, and Principle Arterials from 0.5801 to 0.5818.

Figure 31: Model Flow vs. Observed Volumes, Daily All Facility Types

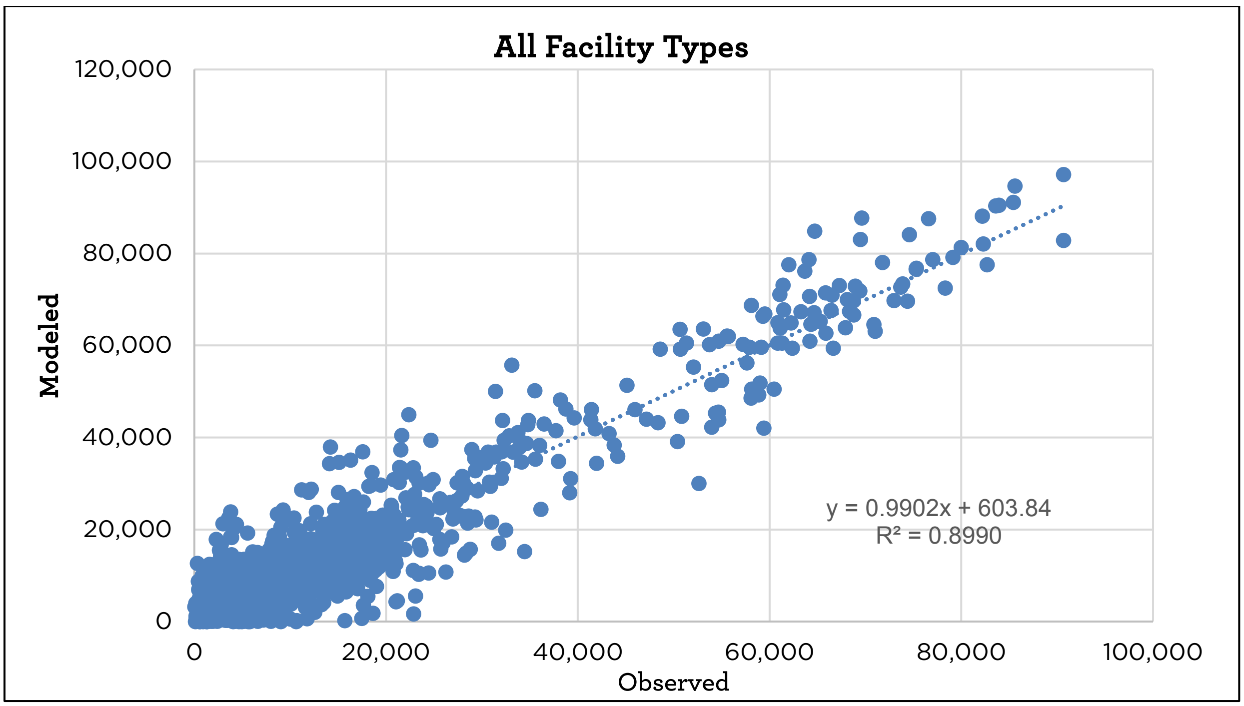


Figure 32: Model Flow vs. Observed Volumes, Daily Interstates

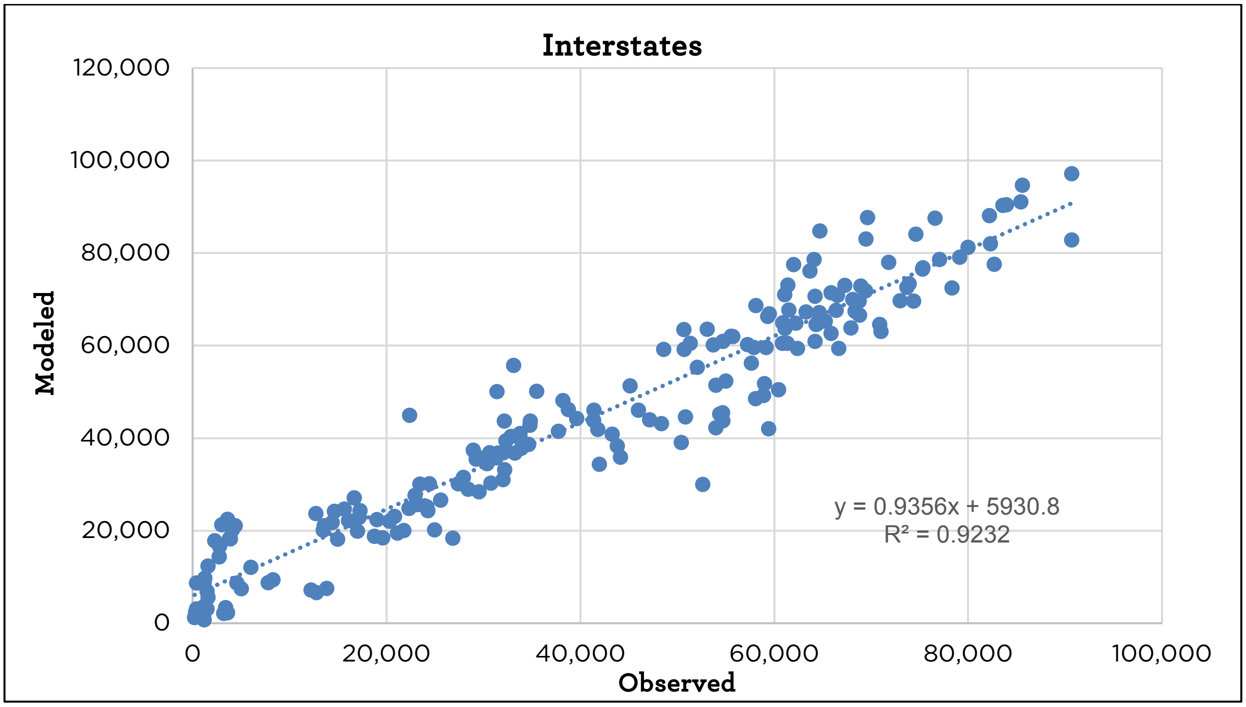
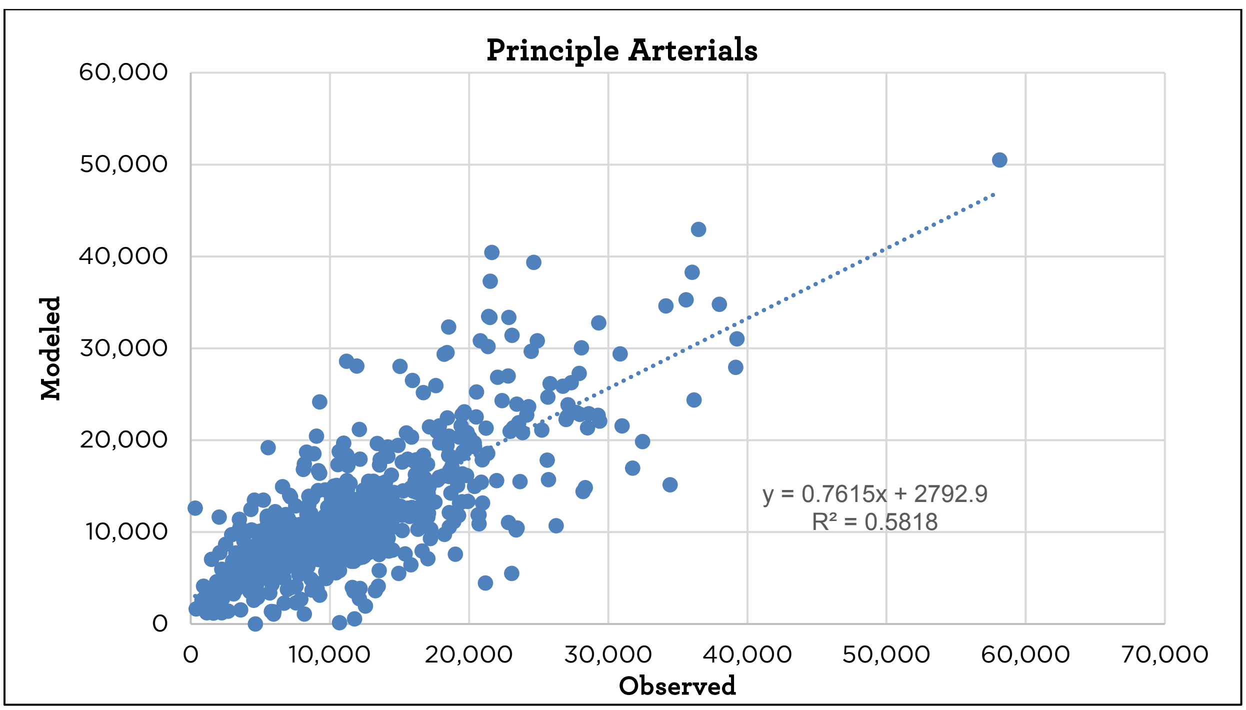


Figure 33: Model Flow vs. Observed Volumes, Daily Principle Arterials



10.2 TRANSIT RESULTS

Transit assignment is the process of routing linked passenger trips over the available transit network, including all transit access and egress modes. 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. The transit assignment results are reported as estimated and observed ridership by route. Validation measures are reported for the region and by system: local, CT*fastrak*, and express.

Transit assignment results by system and for the Hartford region are reported in Table 67. The overall results for the region are within an acceptable percentage range, though by system the results are over-estimated by close to 7,730 boardings. Much time and effort was invested to improve this forecast from the initial model output. Summarized below are the detailed investigations and recommended potential future strategies for the CRCOG transit assignment:

Table 67: Transit Assignment by System (Model vs. Observed)

Mode	Model	2015 Daily Ridership	% Difference
Local	58,774	51,605	114%
CT*fastrak*	8,796	8,053	109%
Express	3,365	3,549	95%
Total	**70,935**	**63,208**	**112%**

Investigations and Potential Future Steps:

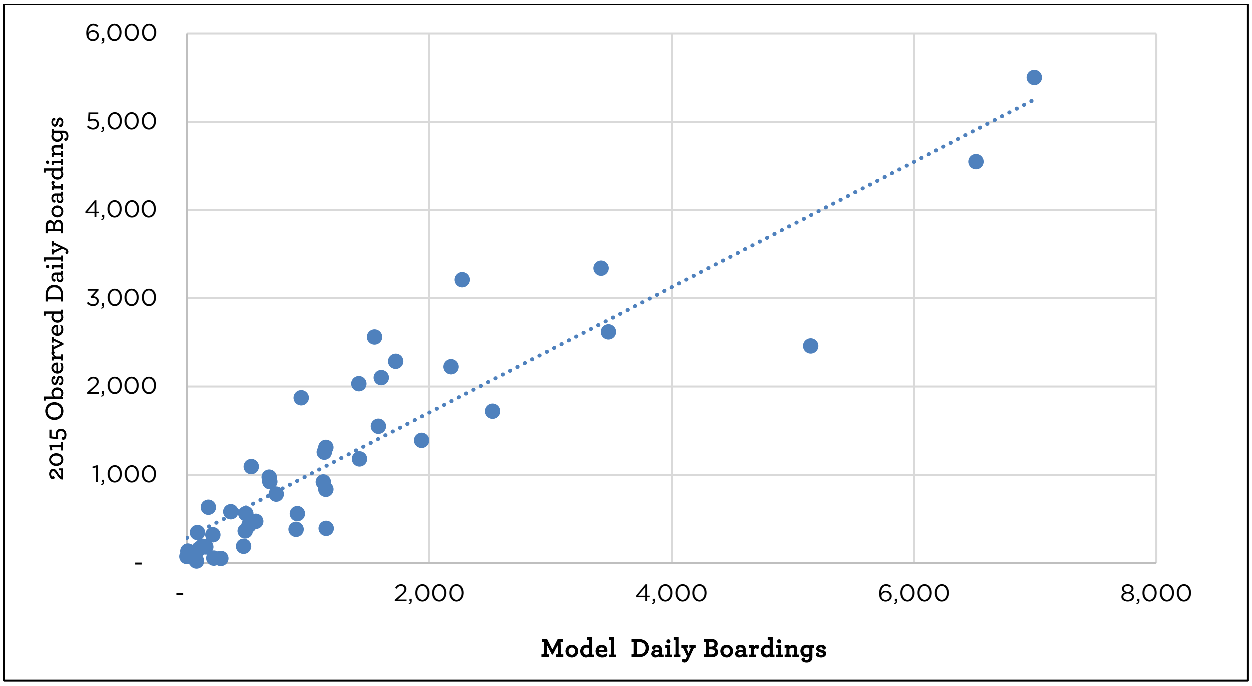
1. The assignment of the transit on-board survey is used to set and validate transit path parameters for walk weights, max run time, max access/egress distance, transfer penalties, fares, the combination factor, and other general path settings. The results validate the path settings for the system.
2. Calibration of the mode choice model resulted in model results that match the person trips reported in the on-board survey. However, during the assignment we were unable to match the survey reported number of transfers (1.47 vs 1.29). More investigation is warranted to confirm locations of higher transfer rates within downtown Hartford.
3. The following checks and improvements were made to improve the overall transit assignment results: checked paths, revised walk access & egress distances, revised fares to reflect more closely fare zones, revised transit speeds, introduced intra-zonal constant, introduced downtown constants, ran a program trace to identify and

understand the source of differences between the Hartford downtown and New Britain downtown utilities, probabilities, and transit shares.

4. Advanced investigations that would require efforts are:
   a. The existing on-board survey excluded data collection of New Britain transit system. Additional processing and investigations, and inclusion of this data set would be necessary to better understand the downtown New Britain transit market. Currently, it only reflects CT*fastrak*.
   b. Additional processing and investigations of the on-board survey data to profile the specific transit riders and to try and better understand the downtown Hartford transit market. If there are differences discovered in the transit rider profiles, then constants could be introduced and calibrated to better capture the behavior of these specific rider types (e.g. high income, zero car households, etc.)
   c. The mode choice program trace analysis showed that the potential transit riders in Hartford, New Britain, and West Hartford also have access to a very good walk network; as a result, many of these trips that could be using transit actually walk to their destinations. Downtown East Hartford also has a road network that facilitates walking between origins and destinations, but the current coding of the highway network and traffic analysis zone structure in downtown East Hartford does not capture that very well. As a result, trips that could and should be walk trips, become transit trips. Modifications could be made to increase this walk share through the coding of a walk network, by adding more detail to the highway network and zone system, or through the introduction of a downtown walk constant.

The final step of validation focused on transit assignment results. Overall, the results of transit assignment were reasonable, as shown in Figure 34, which plots observed versus modeled transit boardings by transit line. For calibration and validation purposes, certain express routes had to be combined, as their paths overlap, and bus riders could have taken either bus route to complete their trip. The largest local route outlier is route 86-88 with 2,460 counted vs. 5,149 modeled, an over-assignment by a factor of 2. For Express routes, where ridership boardings were much lower, the worst over-assignment was by a factor of 5 for route 918 (53 counted vs. 280 modeled). The examination of transit corridors was not a focus of the model update, but it is likely that a more detailed analysis of various transit lines, including the BRT lines, would result in better validation results.

Figure 34: Observed vs. Modeled Transit Daily Boardings



The results above focus on the 2015 base year, which does not include the CT rail line that opened in 2018. At the time this model was being prepared, this service was not yet operational. However, the model has been designed with sufficient flexibility to allow incorporation of this service as part of the on-going maintenance and updating of the model.

10.3 SENSITIVITY ANALYSIS

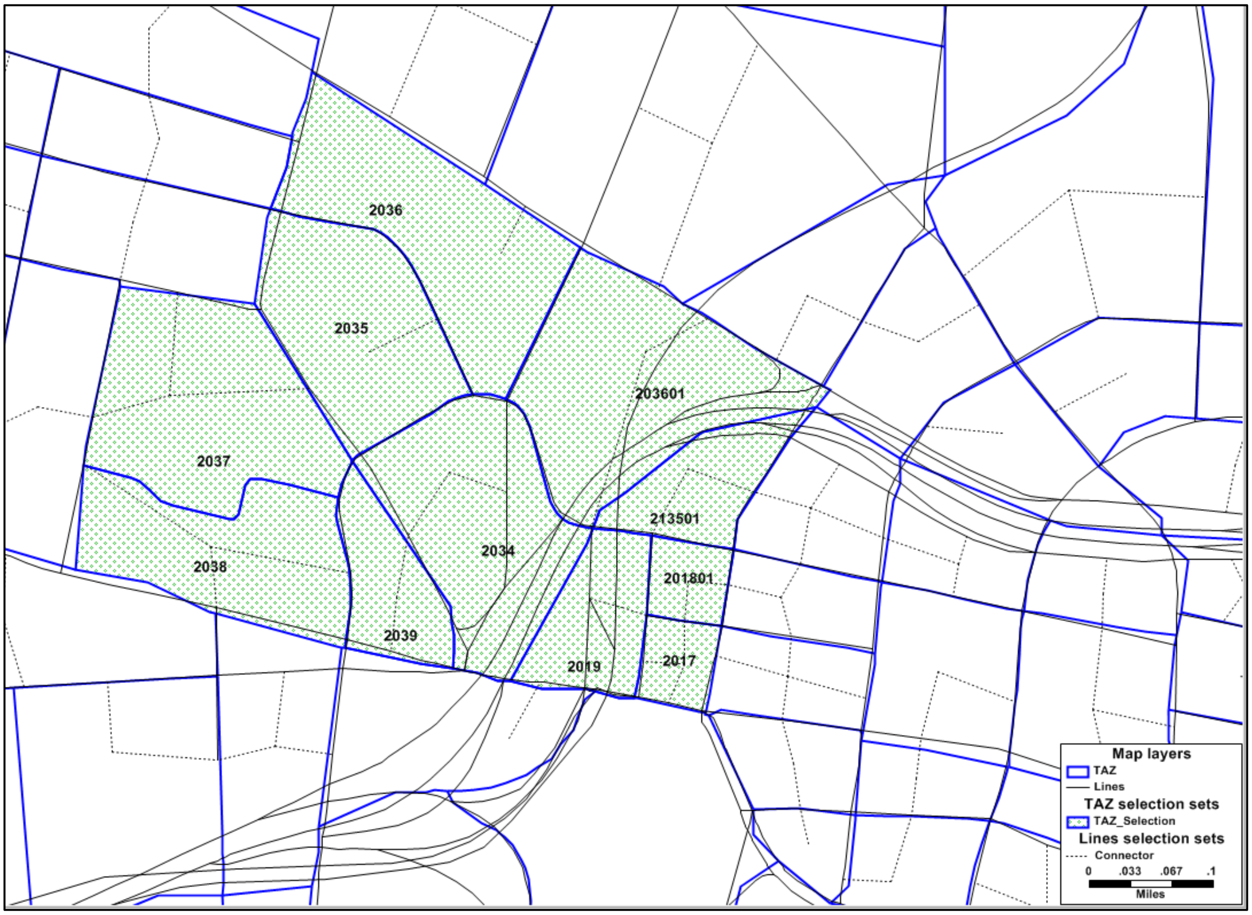
Sensitivity testing evaluates the model's readiness for application by determining whether or not the model responds in a rational way to changes in inputs. Sensitivity tests were performed by making changes to the highway network, transit route system and socio-economic information, and then reviewing the associated model outputs for reasonableness. For the CRCOG TDM, sensitivity testing was also used to evaluate the model's response to trail transit, a mode which is not available in the base year.

In order to test the sensitivity of the model to future year land use and transportation supply changes, a future year model run was performed using 2040 land use and zonal data while holding the base year highway and transit route system constant.

10.3.1 Increased Employment and Population Data for selection of Traffic Analysis Zones (TAZs)

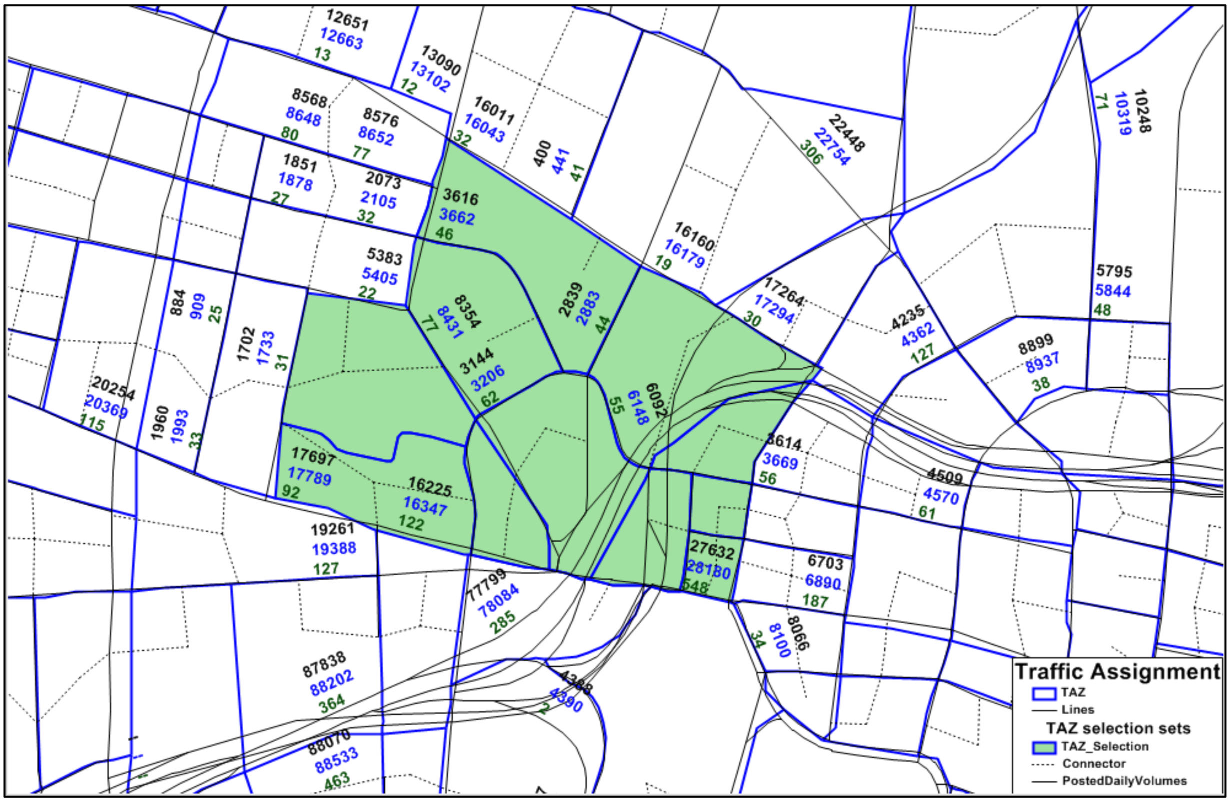
To test the model's response to increases in employment data and population, a selection of TAZs in Hartford was used. The selection, shown in Figure 35, included 11 zones that were increased by 15% for population and 25% for overall employment. This translates to an additional 79 households, with an additional 119 individuals, and 1,475 additional employment positions.

Figure 35: Selected TAZs for Sensitivity Test (Population 115%, Employment 125%)



For this evaluation, it was expected that an increased number of Home Based Other (HBO) and Non-Home-Based (NHB) trips would be attracted to these TAZs and that roadway volumes would increase slightly. In the base scenario, the destination choice model allocated 130 HBO trips to the selected TAZs. Figure 36 illustrates the difference in daily traffic assignments. This test shows that the model is sensitive to changes in population and employment data at a small scale.

Figure 36: Comparison of Traffic Assignment (Before / After/ Difference)



10.3.2 Evaluation of Transportation Supply – New Capacity

In order to evaluate the model's responsiveness to new capacity and path options in a congested network, a new location roadway was coded into the 2015 network. The new location roadway was for testing purposes only and does not represent any project on the current long range plan. The new roadway was coded parallel to an existing congested facility, with similar attributes. The expectation for this test was that the congestion and travel time on the existing facility would improve as the traffic spread out to utilize both facilities, and that the VOC ratio on the existing facility would improve significantly. In addition, it was expected that under highly congested traffic conditions, the two parallel roadways would have comparable traffic flows assigned.

For the test, the new roadway was placed across the Connecticut River parallel with the Founders Bridge. In application, the new facility did alleviate congestion on the existing roadway. The congested speed across Founders Bridge improved from approximately 49 miles per hour (mph) without the facility to 53 mph with the new facility during AM peak. The reduction in congestion is demonstrated through a comparison of the VOC ratio, as shown below in Figure 37.

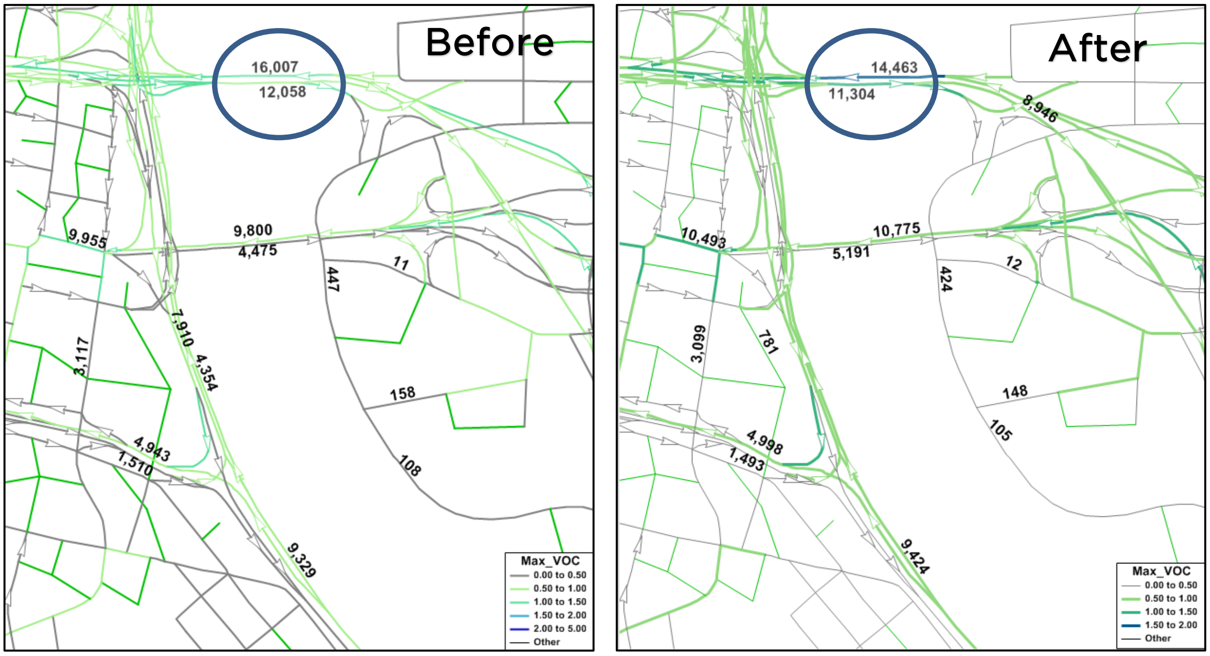
Figure 37: Comparison of AM Peak Traffic Assignment (Before / After New Facility)

10.3.3 Evaluation of Transportation Supply – Reduced Capacity

Similarly, to evaluate model's responsiveness to changes to the network, a reduced capacity option was performed on the Bulkeley Bridge (I-84 over Connecticut River). The test included a reduction in the number of lanes to half capacity as well as the complete elimination of the bridge, which would require rerouting of transit buses to neighboring bridge crossings (mostly to the Founders Bridge, but also impacting the Charter Oak Bridge and the Bissell Bridge). The reduction of capacity and complete elimination was for testing purposes only and does not represent any project on the current long range plan. The expectation for this test was that the congestion and travel time on the existing facility would degrade as the traffic that wants to cross Connecticut River has less available alternative facilities, and that the VOC ratio on the existing facility would degrade significantly.

Figure 38 illustrates that by reducing number of lanes on the Bulkeley Bridge, there is some reduction of traffic on the bridge during the AM peak (approximately 1500 vph westbound and 1000 vph eastbound). The Founders Bridge absorbs approximately 2000 trips (1000 in each direction). The VOC ratios in both instances are over 1, which indicates over capacity conditions. By reducing the bridge crossing number of lanes by half, the VOC ratios increase from 1.04 to 1.94. Essentially, the model will continue to assign traffic even though, the capacity is met and over assigned. The observed congested speed increases from 30mph to 10mph.

Figure 38: Comparison of AM Peak Traffic Assignment (Before / After)



10.3.4 Land Use and New Transit Network

The CRCOG mode choice model includes a nest for the Hartford local bus system, CT*fastrak* / bus rapid transit (BRT), and express bus. Although CT Rail began operation of the Hartford Line in 2018, providing commuter rail service between New Haven, Connecticut and Springfield, Massachusetts, it has not been included as a modal choice because the data used to build this model pre-dates its operation. The model, however, does provide for inclusion of this service during future updates and maintenance. In order to ensure that the model will operate correctly when the Hartford Line is included, it was important to perform a sensitivity analysis on all four transit modes at this time.

One separate model run was performed to account for the Hartford Line. The purpose was to see if the model would generate reasonable transit skims and forecast ridership within a reasonable range. This was particularly important, since the coefficients for commuter rail modes were included based on experience and understanding of Federal Transit Administration guidelines on mode choice modeling. Base year calibration could not be conducted because observed ridership data did not yet exist. With the peak period headway set at 60 min, 8,166 daily trips were generated in the southbound direction and 6,947 daily trips were generated in the northbound direction. These ridership results fall within reasonable ranges, and provide confidence in the model's ability to incorporate the modelling of the Hartford Line in the future.

Summary of Sensitivity Analysis

Performing a sensitivity analysis of a travel demand model prior to application is a critical component of understanding the predictive nature of the model. Unfortunately this step is far too often lost in the focus on overall model calibration and validation. A model that is insensitive to changes in land use and transportation supply, or that forecasts unrealistic results in response to such a change is not an effective tool for supporting transportation planning analysis. The tests performed on the CRCOG Transportation Model show that it is appropriately sensitive to changes in the major inputs, performs reasonably in the application mode, and is ready to be used to evaluate land use and transportation scenarios.

A : APPENDIX A: DETAIL FLOW CHART OF CRCOG MODEL

B : APPENDIX B: REVIEW OF PREVIOUS CRCOG MODEL

C : APPENDIX C: TRANSIT ON BOARD SURVEY

D : APPENDIX D: OBSERVED TRAFFIC DATA

E : APPENDIX E: PARKING LOT CHOICE MODEL

Flow Chart

CRCOG Model Review

January 12, 2019

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

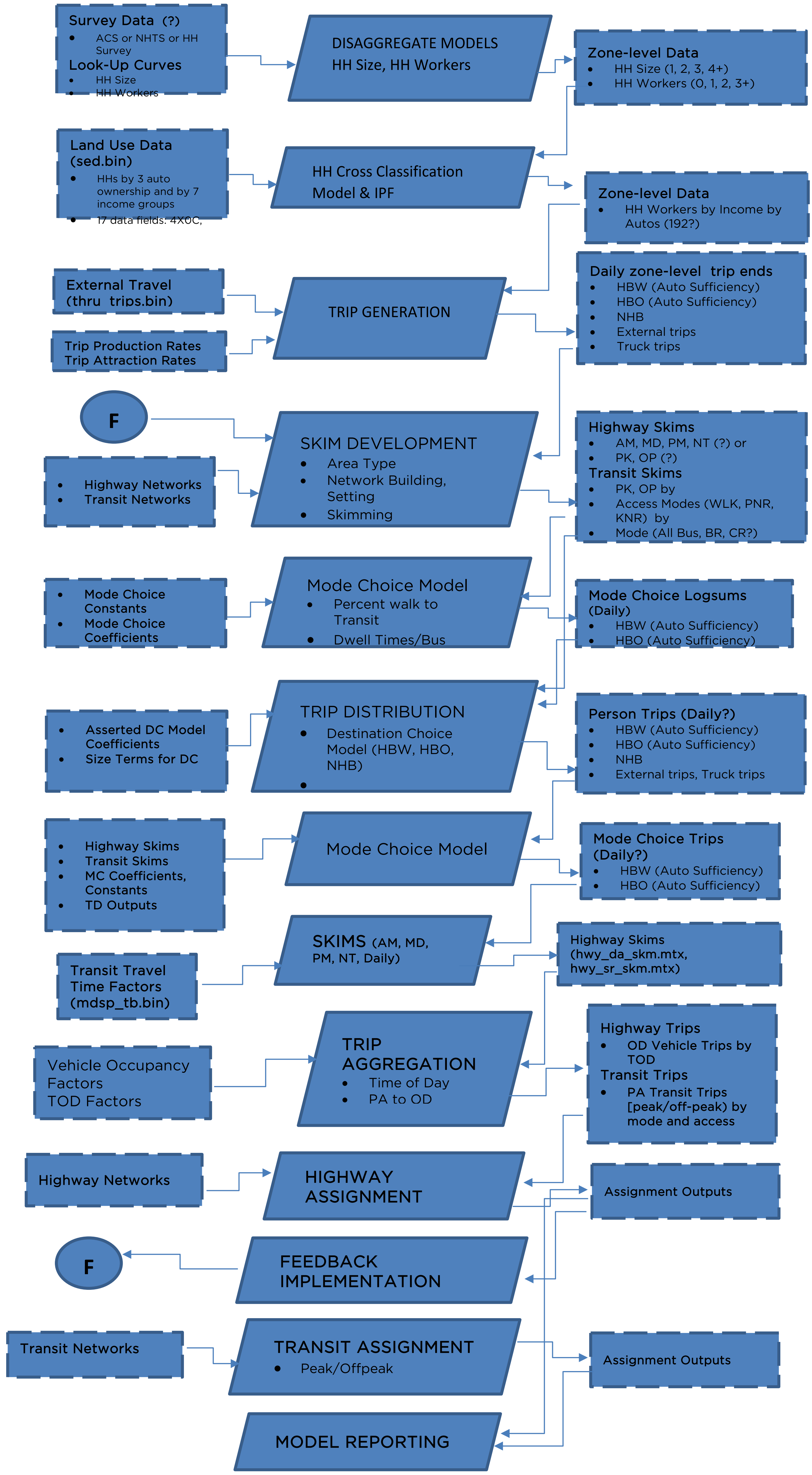
CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff

Figure 1: Proposed CRCOG Model Flow Chart II



Technical Memo #1

CRCOG Model Review

May 5, 2016

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
A. DiCesare Associates, P.C.
AECOM
Fitzgerald and Halliday, Inc.
Goody Clancy
WSP | Parsons Brinckerhoff

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INTRODUCTION

Technical Memo #1 describes the results of a review of the base year travel demand forecasting model code undertaken as part of the Capital Region Council of Governments (CRCOG) model update project. The purpose of this review is to gain a comprehensive understanding of current CRCOG model inputs, processes, and outputs necessary to move forward with the model update. The text boxes to the right of the main paragraphs call out information and steps that will be addressed in Technical Memo #2 – CRCOG Model Enhancement as part of the model enhancement work. In general, the sequence of chapters and sub sections in this document follows the sequence of steps within a model run. A flow chart of the model is shown on the last two pages of this memo (Figure 4)

1. Trip Generation

Trip generation uses cross classification implementation of trip production rates on household data by auto ownership and income categories. Trip attractions are calculated based on employment data by retail and non-retail employment types. Table 1 shows aggregate totals of base year and future year socioeconomic data from the TAZ layer (sed.bin). Household data are available by auto ownership and income groups. Employment data are available for two categories – retail and non-retail employment.

Table 1 2010 & 2040 Socio Economic Input Data

SE Data	2010	2040
HH by Auto		
0 Car	85,531	91,872
1 Car	276,158	304,376
2+ Car	441,374	501,885
Total	803,063	898,134
HH by Income		
INC1	91,647	99,133
INC2	20,936	22,929
INC3	41,821	45,675
INC4	49,655	54,106
INC5	97,491	106,798
INC6	231,773	257,788
INC7	357,807	408,009
Total	891,130	994,438
Employment		
Retail	142,302	158,188
Non Retail	769,333	864,935
Total	911,635	1,023,123
Population		
	2,068,814	2,314,743

HHs by Auto/Income Category are given.

SE data does not have HHs by Workers so curves will have to be estimated from the HHs by Income and HHs by Auto data.

Attraction calculations must be modified to be suitable for destination choice size terms

1.1. HOME-BASED WORK (HBW) TRIP GENERATION

Initial trip production rates by purpose, income and auto ownership are shown in Table 2. Trip production rates by income group and auto-ownership are used for the HBW purpose but HBO and NHB rates are segmented only by auto-ownership other purposes. HBW trip production equations use households by auto ownership and income groups and production rates from the Table 2. Trip attractions equations use population and employment levels with attraction rates from Table 2.1.

Table 2 Trip Production Rates

Purpose/ Income	Auto Ownership		
	0 Car	1 Car	2+ Car
HBW			
INC1	1.0000	1.0900	1.1957
INC2	1.0000	1.2535	1.5544
INC3	1.0000	1.3625	1.7565
INC4	1.1300	1.4933	1.9789
INC5		1.6350	2.2372
INC6		1.7658	2.7442
INC7			2.8411
Other Purposes			
	Auto Ownership		
Purpose	0 Car	1 Car	2+ Car
HBO	2.3473	3.7664	5.5713
NHB	2.168		

Table 3.1 Trip Attraction Rates

Purpose	Population	Retail Emp	Non-Retail Emp	Total Emp
HBW	N/A	N/A	N/A	1.43
HBO	0.8477	6.1761	0.3673	N/A
NHB	0.2675	1.4069	0.2741	N/A

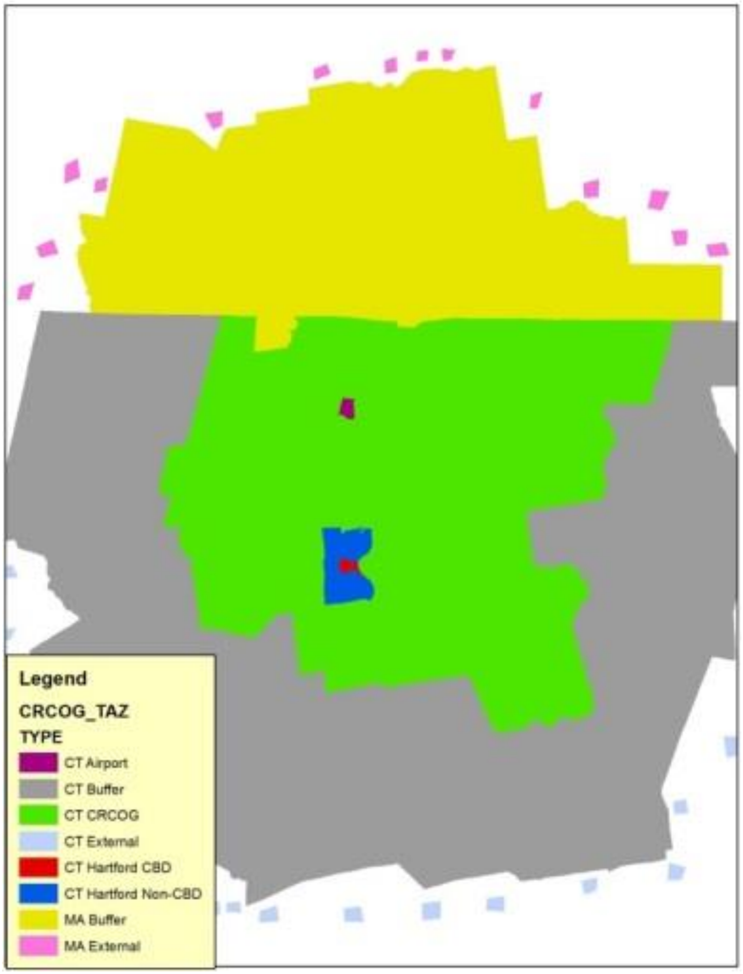
- 3 auto ownership categories (0, 1, 2+)
- 3 purposes (HBW, HBO, NHB)
- 7 income categories (1-7)
- HBW trip production rates segmented by Inc/Auto
- HBO trip production rates segmented by Auto
- NHB production rate not segmented

Updated model will replace HBW cross-class and HBO auto own-segmented rates with auto-sufficiency-based rates as follows:

- 0-car, all income
- Insufficient, low
- Insufficient, high
- Sufficient, low
- Sufficient, high

Numerous adjustments for HBW trip productions and attractions were implemented by auto ownership, trip type (internal-internal, internal-external & external-internal), and geographic region. Figure 1 shows a map of the regions used in these refinements. These adjustments will be reviewed during the model enhancement phase and if new household survey data becomes available.

Figure 1: Map Showing TAZ TYPE Geographies



1.2. HOME-BASED OTHER (HBO) TRIP GENERATION

HBO trip production rates are segmented by auto-ownership while trip attraction rates reference total population and employment by type.

Trip production rates for HBO purpose are shown in Table 2 and the equation is below.
HBO Productions = 2.3473 * HH_{0CAR} + 3.7664 * HH_{1CAR} + 5.5713 * HH_{2CAR} .

Note that HH_{*CAR} is an aggregation of household by auto-ownership and income group where:

HH_{0CAR} = HH_0C_Inc1 + HH_0C_Inc2 + HH_0C_Inc3 + HH_0C_Inc4
HH_{1CAR} = HH_1C_Inc1 + HH_1C_Inc2 + HH_1C_Inc3 + HH_1C_Inc4 + + HH_1C_Inc5 + HH_1C_Inc6
HH_{2CAR} = HH_2C_Inc1 + HH_2C_Inc2 + HH_2C_Inc3 + HH_2C_Inc4 + HH_2C_Inc5 + + HH_2C_Inc6 + HH_2C_Inc7

Trip attraction rates for the HBO trip purpose are shown in Table 2.1 and the equation for the HBO trip purpose is below.

HBO Attractions = 0.8477 * (Total Population) + 6.1761 * (Retail Emp.) + 0.3673 * (Non Retail Emp.)

Several adjustments for HBO trip productions and attractions were implemented by trip type (internal-internal, inter-external, & external-internal) and geographic region.

1.3. NON-HOME-BASED (NHB) TRIP GENERATION

NHB trip production rates consider total households while attraction rates reference total population and employment by type.

The trip production equation for the NHB trip purpose is below.
NHB Productions = 2.1680 * Total Households

The trip attraction equation for the NHB trip purpose is below.
NHB Attractions = 0.2675 * (Total Population) + 1.4069 * (Retail Emp.) + 0.2741 * (Non Retail Emp.)

Several adjustments for NHB trip productions and attractions were implemented by trip type (internal-internal, inter-external, & external-internal) and geography region.

These will change. When finished with updates we will do our standard set of checks on the trip rates. CRCOG is doing a HH survey so observed rates by auto sufficiency segment may be available. Results, however, are not expected until late 2016 so asserted values may be used.

1.4. TRIP GENERATION SUMMARY

Trip productions and attractions for each purpose are balanced and the final aggregate summary by purpose is shown in the Table 3.

Table 4 Trip Generation Outputs (pa_trips.bin) – Year 2010

Purpose	Productions/Attractions
HBW_0Car	68,062
HBW_1Car	295,720
HBW_2Car	820,955
HBW_IX	109,120
HBW_XI	118,902
HBO	3,867,144
NHB	1,646,763
NWIX	275,463
NWXI	325,790
BIA_Airport	6,153
TII	496,949
TIX	36,820
TXI	37,943
Total	8,105,783
Primary Purposes (Internal)	
HBW	1,184,737
HBO	3,867,144
NHB	1,646,763
Total	6,698,644

2. Trip Distribution

2.1. K-FACTOR DEVELOPMENT

K-Factor matrix is developed and K-Factor values change by geographic region. With the destination choice enhancement, these k-factors will no longer be used. The parameters and/or constants for the destination choice model may need to be segmented by geographic region to capture the observed behavior. K-factors are not typically used in conjunction with a destination choice model.

Scope says we will replace Trip Distribution with an asserted Destination Choice Model

HBW and HBO will have segmentation by Auto Sufficiency Category

Keep HBW doubly-constrained, not sure about HBO and NHB being doubly-constrained

GISDK code will need to be completely replaced.

2.2. HIGHWAY SKIM CREATION

Initial version of highway skim is created. TIME_LSC data field is used in the highway skim creation. These are "Level of Service C" speeds (approximately 75% of free flow speed) that are used in place of a feedback loop from assignment back to trip destination. These "congested speed" skims are used in both mode choice and trip distribution.

2.3. GRAVITY MODEL DISTRIBUTION

Gravity Model is run for HBW_1Car, HBW_2Car, HBW_IX, HBW_XI, HBO, NHB, NWIX, NWXI, BIA, TII, TIX, and TXI trip productions/attractions. Trip distribution outputs are summarized in the Table 4.

Observations:

- Gravity model is doubly constrained.
- HBW zero car trips are not part of trip distribution at this stage.

Table 5 Trip Distribution Outputs (pa_12c.mtx) – Year 2010 & 2040

Purpose	Trips (2010)	Trips (2040)
HBW_1C	295,720	325,430
HBW_2C	820,955	931,902
HBW_IX	109,120	124,500
HBW_XI	118,902	138,156
HBO	3,867,144	4,341,342
NHB	1,646,763	1,845,078
NWIX	275,463	309,882
NWXI	325,790	363,129
BIA	6,153	7,998
TII	496,949	557,132
TIX	36,820	40,838
TXI	37,943	42,215
Total	8,037,722	9,027,603

3. Mode Choice

3.1. HIGHWAY PRELOADS

There is no feedback between the assignment procedure and the trip distribution and mode choice models. Thus, person trips are distributed and processed so that they can be assigned to the highway network in order to produce congested link speeds. These speeds are in turn skimmed and used in the mode choice models. Sections 3.1.1 through 3.1.3 explain the steps for converting person trips to vehicle trips, splitting them between SOV and HOV using carpool factors, transforming trips from PA to OD format, and finally sorting into time periods using factors determined based on counts. Those trips are then assigned to the network, resulting in congested speeds, which are then skimmed and used in the Mode Share Computation.

The mode choice process (current model has 8 different GISDK scripts for the various pieces) will be revised.

With the addition of feedback, these steps will no longer be necessary.

3.1.1. Vehicle Occupancy Factors by Time Period

Vehicle occupancy factors for each time period are shown in Table 5. These factors are further classified by three geographic regions – non Hartford region, Hartford non-CBD region, and Hartford CBD region. Figure 2 depicts these three geographic regions. All the factors shown in the Table 5 were borrowed from Table 38 in TRB 365 report. Trip distribution output matrices are converted from person trips to vehicle trips using these factors. The output vehicle trip tables are shown in Table 6.

Table 6 Vehicle Occupancy Factors by Time of Day and Purpose

	HBW 1 Car			HBW 2+ Car			HBW		HBO	NHB	Non-Work	
Time	Non-	Hartford		Non-	Hartford							
Period	Hartford	Non-CBD	CBD	Hartford	Non-CBD	CBD	I_X	X_I	I-I	I-I	I_X	X_I
AM	1.107	1.180	1.450	1.107	1.360	1.400	1.130	1.210	1.280	1.300	1.570	1.570
MD	1.007	1.080	1.350	1.007	0.990	1.300	1.130	1.210	1.280	1.300	1.570	1.570
PM	1.147	1.220	1.490	1.147	1.370	1.480	1.130	1.210	1.280	1.300	1.570	1.570
NT	1.067	1.140	1.410	1.067	1.290	1.790	1.130	1.210	1.280	1.300	1.570	1.570
DAILY	1.077	1.150	1.420	1.077	1.150	1.420	1.130	1.210	1.280	1.300	1.570	1.570

Figure 2: Map showing Area Indicator Geographic Regions

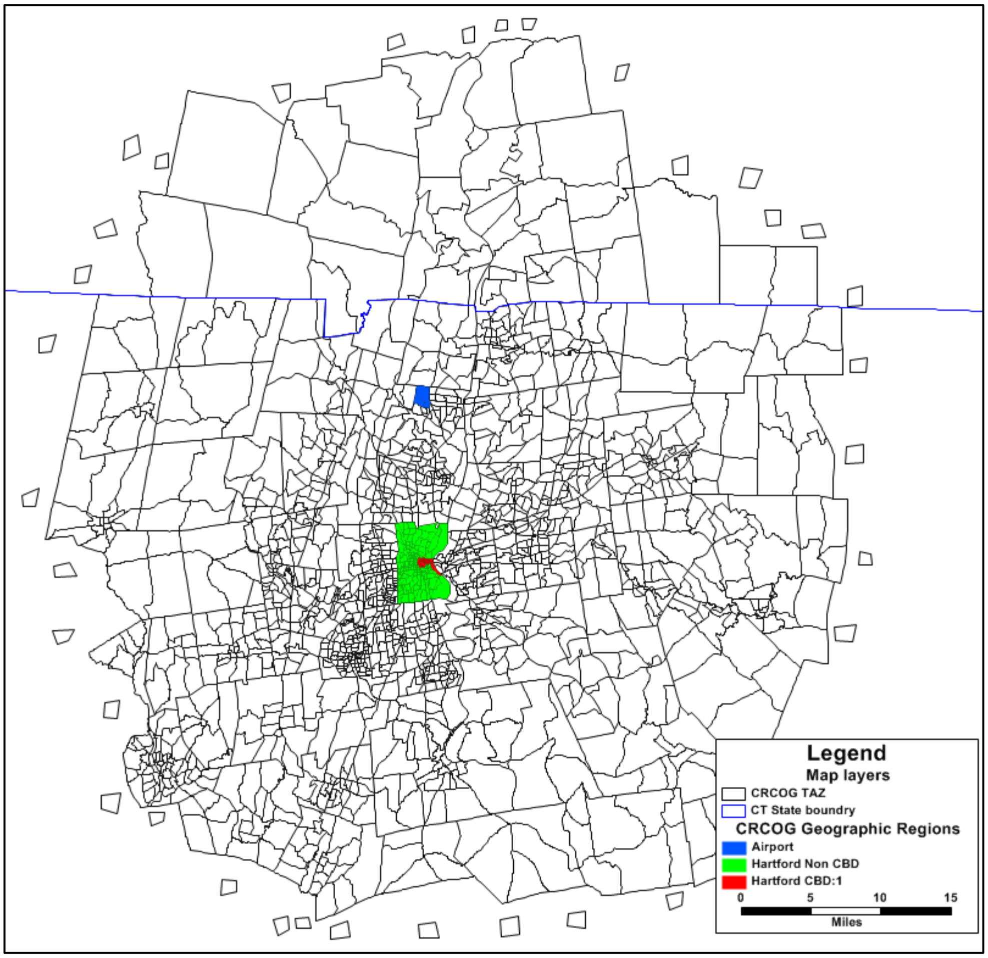


Table 7 Vehicle Trips in PA Format

Purpose	AM	MD	PM	NT
HBW_1C	262,302	287,937	253,285	271,986
HBW_2C	724,050	804,799	699,080	742,602
HBW_IX	96,566	96,566	96,566	96,566
HBW_XI	98,266	98,266	98,266	98,266
HBO	3,022,695	3,022,695	3,022,695	3,022,695
NHB	1,268,187	1,268,187	1,268,187	1,268,187
NWIX	175,454	175,454	175,454	175,454
NWXI	207,673	207,673	207,673	207,673
BIA	6,153	6,153	6,153	6,153
TII	496,949	496,949	496,949	496,949
TIX	36,820	36,820	36,820	36,820
TXI	37,943	37,943	37,943	37,943
Total	6,433,058	6,539,442	6,399,071	6,461,295

Note that the vehicle trip values in Table 6 are actually daily totals, not actual time period totals. The slight variation in the four time period totals is merely due to the variation in the factors shown in Table 5.

The next step in the model process is to compute the HOV share of trips for the HBW purpose using carpool factors. Vehicle trip tables in PA format after separating HBW carpool trips are shown in Table 7. Vehicle trips in Table 7 also represent daily values.

Table 8 Vehicle Trips in PA Format – Carpool trips separated

Purpose	AM	MD	PM	NT
HBW DA	1,047,868	1,142,585	1,017,751	1,074,729
HBW carpool	133,315	144,982	129,446	134,692
HBO	3,022,695	3,022,695	3,022,695	3,022,695
NHB	1,268,187	1,268,187	1,268,187	1,268,187
Other Veh	960,993	960,993	960,993	960,993
Total Veh	6,433,058	6,539,442	6,399,071	6,461,295

3.1.2. Time of Day Factors

Time of day factors and PA to OD format conversion factors by purpose are shown in Table 8. Time period definitions are giving below.

Count data will be used to validate these time periods. They will be redefined if warranted.

AM Peak: 7am to 9am
MD: 9am to 3pm
PM Peak: 3pm to 6pm
NT: 6pm to 7am

Table 9 Time of Day Factors

Time Period	HBW		HBO		NHB/BIA/Truck/Thru	
	PA	AP	PA	AP	PA	AP
AM	0.185	0.008	0.060	0.014	0.030	0.030
MD	0.137	0.099	0.153	0.154	0.235	0.235
PM	0.063	0.202	0.144	0.155	0.114	0.114
NT	0.183	0.123	0.120	0.200	0.121	0.121
DAILY	0.500	0.500	0.500	0.500	0.500	0.500

Output vehicle trip table totals in OD format by time period are shown in Table 9.

Table 10 Vehicle Trips in OD Format

Purpose	AM	MD	PM	NT	Daily
Total Veh	559,669	2,245,332	1,681,743	1,835,591	6,322,334
HBW carpool	25,730	34,216	34,303	41,216	135,465
Total Veh	585,399	2,279,548	1,716,046	1,876,806	6,457,799

3.1.3. Preload Assignment

Highway assignment is performed by time of day. Vehicle trips from Table 9 are used for the highway assignment by time of day. User Equilibrium method is used in the preload highway assignment.

After highway assignment, congested times are updated to the highway network. Congested link times by time period vary due to the difference in input vehicle trip tables. Four individual output folders are maintained in the model – one for each time period.

Feedback between assignment and trip distribution will be implemented.

Transit travel time functions will be updated

Drive access links will be reviewed

3.2. HIGHWAY SKIM DEVELOPMENT

The work described in Section 3.1 above is all in support of the creation of congested highway skims. Two highway skims are created for each time period – SOV skim and HOV skim

3.3. TRANSIT SKIM DEVELOPMENT

3.3.1. Transit Speeds

Congested link travel times are multiplied with mid-day speed factors (mdsp_tb.bin) to calculate link transit travel times. The mdsp_tb.bin file has transit time factors for 63 link classes.

3.3.2. Drive Access links

Drive access links are coded as straight lines to the PNR lots. The base network itself has these drive access links.

3.3.3. Transit Path/Skim Definitions

A total of three transit skims in the base scenario and 7 transit skims in the build scenario are developed. Walk to local bus skim (#1 below) is used only for distributing zero car household trips. The transit skims are:

1. WBOP: Walk to local bus skim used only to distribute zero car household trips (HBW 0 Car)
2. WBWB: Walk to all bus skim (walk/bus at both ends)
3. DTWB: Drive to all bus skim (drive access, walk/bus egress)

In addition to these three skims, four more skims are developed in the build scenario.

4. WRWR: Walk to rail skims (rail access, rail egress)
5. WBWR: Walk to rail skims (walk/bus access, rail egress)
6. WRWB: Walk to rail skim (rail access, walk/bus egress)
7. DTWR: Drive to rail skim (drive access, rail egress)

The transit skims will change – new modes will be added (BRT) and other transit network attributes will be skimmed.

Access modes will include walk, park and ride, kiss and ride.

Transit mode definitions are defined in the modes.bin file which is shown in Table 10. A value of 1 means the mode is used and zero means not used in the transit skim development process.

Table 11 Mode Table for Transit Skims

Mode Name	MODE ID	USE_PK_WLK	USE_PK_WLK_BW	USE_PK_PNR	USE_PK_PNR_BW	USE_OP	ACCE_WB	ACCE_WR	ACCE_PNR
Local Bus	2	1	1	1	1	1			
Express Bus	4	1	1	1	1	0			
Rail	5	0	1	0	1	1			
Highway	91	1	1	1	1	1	1		0
Busway	92	0	0	0	0	1	0	0	0
WACC	95	1	1	0	1	1	0	1	
Drive	96	0	0	1	1	0	0	0	1
DACC	97	0	0	1	1	0	0	0	1
XFER	98	1	1	1	1	1	0	0	0
Walk	99	1	1	1	1	1		1	0
C. Connector	90	1	1	1	1	1	1		0

A clear mapping, between the set of seven transit skims and the mode table, is shown in Table 11. This table defines which transit modes, access modes, and egress modes are allowed in each type of transit path.

As an example, Table 11 says that the WBWB skim, which is “walk to bus – walk from bus”, uses the “PK_WLK modes” to create the skims. In Table 10, reading down the column of “USE_PK_WLK”, the 1’s show that the following modes/links are used to form the transit paths that are then skimmed: local bus, express bus, the highway links, the walk access links, the transfer links (xfer), the walk links and the centroid connectors. Notice that the WBWB skim does not allow rail to be used in the transit path.

Table 12 Mapping between Transit Skim and Mode Table

Skim Type	Scenario	Mode Used	Access	Egress
WBOP	Base/Build	USE_OP	ACCE_WB	ACCE_WB
WBWB	Base	USE_PK_WLK	ACCE_WB	ACCE_WB
WBWB	Build	USE_PK_WLK_BW	ACCE_WB	ACCE_WB
DTWB	Base	USE_PK_PNR	ACCE_PNR	ACCE_WB
DTWB	Build	USE_PK_PNR_BW	ACCE_PNR	ACCE_WB
WRWR	Build	USE_PK_WLK_BW	ACCE_WR	ACCE_WR
WBWR	Build	USE_PK_WLK_BW	ACCE_WB	ACCE_WR
WRWB	Build	USE_PK_WLK_BW	ACCE_WR	ACCE_WB
DTWR	Build	USE_PK_PNR_BW	ACCE_PNR	ACCE_WR

3.3.4. Transit Path Parameters

The transit route system has two headway variables – HDWY1 and HDWY2. Regardless of time period and mode, HDWY1 is always used. Transit path build parameters are shown in Table 12.

Table 13 Transit Path Parameters

Parameter		Value
Walk speed (mph)		3
Maximum walk access distance (miles)		0.35
Maximum walk egress distance (miles)		0.35
Walk time weight		2
Initial wait time (minutes)		
	Minimum	2
	Maximum	15
	Weight	2
Transfer wait time (minutes)		
	Minimum	2
	Maximum	60
	Weight	2
Transfer penalty time (minutes)		5
Maximum no. of transfers		2
Maximum path time (minutes)		200
Value of time ($/hour)		4.8
Path threshold / Combination factor		1
Maximum drive access time (minutes)		30
Drive time weight		2

Observations on the transit parameter values:

- *Walk access/egress distance is capped at 0.35 miles which translates into 7 minutes.*
- *Combination factor is set at a maximum value of 1. We generally set this value at 0.1*
- *Out of vehicle travel time weights are relatively low at 2.0*

3.3.5. Post Process of Transit Skims

Three matrix cores were derived from the multiple transit skim cores:

1. In-vehicle time
2. Out of vehicle time
3. Fare

Initial wait time is split into two components→ first wait (<=7.5 minutes) and second wait (>7.5 minutes). First wait time is aggregated with out of vehicle time and second wait time is aggregated with in-vehicle time.

There appears to be a bug in the code. Second wait component is double counted → being added to both in-vehicle time and out of vehicle time.

3.4. ZERO CAR HH TRIP DISTRIBUTION

One combined impedance value is calculated from the three impedance components listed below:

1. Transit impedance: weighted transit time from walk to local bus (WBOP) skim
2. Walk impedance: weighted walk time for ij distance less than 2 miles
3. Intra-zonal impedance: walk time for intra-zonal

Using the combined impedance matrix, trip distribution is run using a UTPS-Style Gravity model for HBW 0 Car household market. HBW 0 car market has a total of 68,062 trips.

There will not be a separate process for 0-car households in mode choice or destination choice.

3.5. ASSEMBLE TRIP TABLES

This procedure reads two trip matrix files:

- Trip distribution output file summarized in Table 4 – person trips in PA format
- Home-based work for 0-car households person trip file described in section 3.4

Two adjustments for the trip tables are implemented during this process:

- Airport trip adjustment: Input person trips for the three airport zones are multiplied by a factor of 2.03
- Non-work trip adjustment: HBO and NHB trip tables are post processed using the walk to local bus (WBOP) skim file. For zone pairs where the generalized cost equals 0, the HBO and NHB person trips are set to zero.

These adjustments will be reviewed

An output trip summary, after the two adjustments described above, is shown in Table 13. It should be noted that the HBO and NHB trips are significantly lower when compared with trip numbers in Table 4 because of the non-work trip adjustment explained above. Output trip file name is ptwt_mat.mtx in each time period folder.

Table 14 Person Trip Summary

Purpose	AM	MD	PM	NT
HBW 0C	68,193	68,196	68,205	68,193
HBW 1C	297,079	297,079	297,079	297,079
HBW 2C+	824,745	824,745	824,745	824,745
HBO	647,012	646,940	647,146	647,063
NHB	337,974	337,952	338,004	337,983
Total	2,175,002	2,174,911	2,175,178	2,175,062

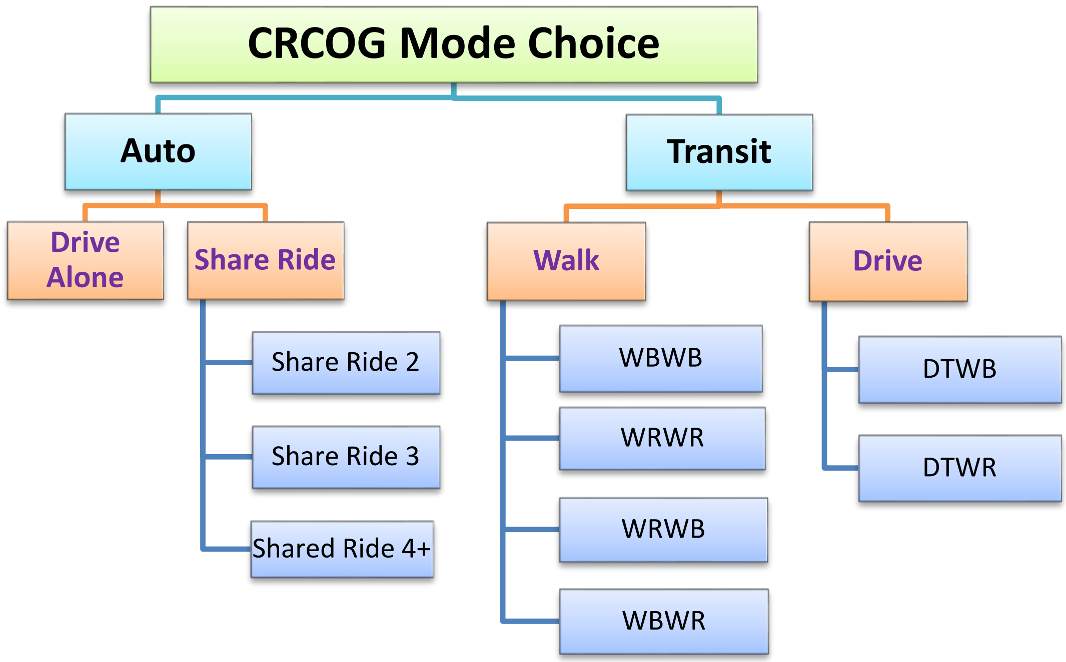
Note again that the values in Table 13 are daily totals, not the actual time of day totals. The time period designation is a reference to which skims were used to produce congested skims for destination and mode choice. The daily volumes are assigned.

3.6. MODE SHARE COMPUTATION

The mode choice model nesting structure is shown in Figure 2. There are three market segments: 0 car households, 1 car households, and 2+ car households with different parameters and constants for each segment. The mode choice model has four auto alternatives plus six transit alternatives:

- Auto Alternatives:
  - Drive Alone, Shared Ride 2, Shared Ride 3, Shared Ride 4+
- Transit Alternatives:
  - Walk Access: WBWB, WRWR (build), WRWB (build), WBWR (build)
  - Drive Access: DTWB, DTWR (build)

Figure 3: Mode Choice Model Nesting Structure



The mode choice model coefficients are presented in the Table 14. Below are a few observations:

- Mode choice coefficients do not vary by trip purpose.
- Top level nest coefficients are not the same: auto nest is 0.85 and transit nest is 0.65
- Lower level nest coefficients are not the same: shared ride nest is 0.75 and walk/drive access nest is 0.4

Mode choice calibrated constants are shown in the Table 15. Drive access and transit constants vary by three auto markets.

A CBD attraction constant is applied for drive to transit alternatives.

The market segmentation will be auto sufficiency.

The nesting structure will change.

Table 15 Mode Choice Coefficients

Variable Description	Units	All Purposes
In-Vehicle Travel Time (IVTT)	Minutes	-0.0250
Out-of-Vehicle Travel Time (OVTT)	Minutes	-0.0500
Cost Coefficient (Transit Fare)	Cents	-0.0044
Terminal Time for Auto	Minutes	-0.0500
Auto Operating Costs (Distance)		
Drive Alone	Miles	-0.0528
Shared Ride 2	Miles	-0.0264
Shared Ride 3	Miles	-0.0176
Shared Ride 4+	Miles	-0.0123
Parking Costs (work)		
Drive Alone	Dollars	-0.0495
Shared Ride 2	Dollars	-0.0248
Shared Ride 3	Dollars	-0.0165
Shared Ride 4+	Dollars	-0.0110
Logsum / Nesting Coefficients		
Auto Nest	Level 1	0.85
Shared Ride	Level 2	0.75
Transit Nest	Level 1	0.65
Walk / Drive Access Nest	Level 2	0.40

Upper level will include Auto, Transit and Non-motorized; Transit nest will include local bus, express bus, commuter rail, and BRT – with walk, P&R, K&R access modes.

The coefficients will vary by purpose and will be asserted, while alternative specific constants will be calibrated.

Table 16 Mode Choice Constants

Variable Description	Constant
Shared Ride	-3.5100
Shared Ride 3	-1.4726
Shared Ride 4+	-1.8105
Drive Access (KDACC)	
0 Car	0.0000
1 Car	-1.8100
2+ Car	-1.5100
Transit Constant (KTRAN)	
0 Car	2.2800
1 Car	-1.2200
2+ Car	-1.7200

This process writes out the mode choice model utility and probability matrices by auto ownership. Table 16 shows list of matrix cores that are written out from the mode choice model by alternative, auto ownership, and transit access type in the base year scenario. It should be noted that these utilities and probabilities are not by purpose.

Table 17 Mode Choice Model Utilities and Probabilities

Alternative	WBWB Matrices			DTWB Matrices		
	0 Car	1 Car	2+ Car	0 Car	1 Car	2+ Car
Utilities						
Auto	Yes	Yes	Yes	Yes	Yes	Yes
DA	No	Yes	Yes	No	Yes	Yes
SR	Yes	Yes	Yes	Yes	Yes	Yes
2-CP	Yes	Yes	Yes	Yes	Yes	Yes
3-CP	Yes	Yes	Yes	Yes	Yes	Yes
4+CP	Yes	Yes	Yes	Yes	Yes	Yes
Transit	Yes	Yes	Yes	No	Yes	Yes
Walk	Yes	Yes	Yes	No	No	No
WBWB	Yes	Yes	Yes	No	No	No
Drive	No	Yes	Yes	No	Yes	Yes
DTWB	No	Yes	Yes	No	Yes	Yes
Probabilities						
DA	No	Yes	Yes	No	Yes	Yes
2-CP	Yes	Yes	Yes	Yes	Yes	Yes
3-CP	Yes	Yes	Yes	Yes	Yes	Yes
4+CP	Yes	Yes	Yes	Yes	Yes	Yes
WBWB	Yes	Yes	Yes	No	No	No
DTWB	No	Yes	Yes	No	Yes	Yes

3.7. SPLITTING WORK TRIPS

3.7.1. Initial Market Shares

A set of data fields from the TAZ layer are used as input to calculate initial market shares and they are:

- BS_WB_PCT_POP (base)
- BS_WB_PCT_EMP (base)
- BS_WR_PCT_POP (base)
- BS_WR_PCT_EMP (base)
- BW_WB_PCT_POP (build)
- BW_WB_PCT_EMP (build)
- BW_WR_PCT_POP (build)
- BW_WR_PCT_EMP (build)

The above data fields in the TAZ layer have percent values related to population and employment but it is not clear how these data were developed. A list of expressions utilized to obtain initial market shares are given below.

The HBW and HBO/NHB trip splitting described in the next two sections will be made obsolete by the mode choice changes the scope has proposed.

Initial market share expressions:

The final result of the mode choice model will still be trips by mode by purpose.

WBWB (base) = [(BS_WB_PCT_POP - BS_WR_PCT_POP) *
* (BS_WB_PCT_EMP - BS_WR_PCT_EMP)] / 10000

WBWB (build) = [(BW_WB_PCT_POP - BW_WR_PCT_POP) *
* (BW_WB_PCT_EMP - BW_WR_PCT_EMP)] / 10000

DTWB (base) = [(100 - BS_WB_PCT_POP) * (BS_WB_PCT_EMP –
- BS_WR_PCT_EMP)] / 10000

DTWB (build) = [(100 - BW_WB_PCT_POP) * (BW_WB_PCT_EMP –
- BW_WR_PCT_EMP)] / 10000

WRWR (build) = [(BW_WR_PCT_POP * BW_WR_PCT_EMP)] /
/ 10000

WBWR (build) = [(BW_WB_PCT_POP - BW_WR_PCT_POP) *
* (BW_WR_PCT_EMP)] / 10000

WRWB (build) = [(BW_WR_PCT_POP) * (BW_WB_PCT_EMP –
- BW_WR_PCT_EMP)] / 10000
DTWR (build) = [(100 - BW_WB_PCT_POP) * (BW_WR_PCT_EMP)] / 10000

3.7.2. Availability Matrices

Availability matrices are developed using mode choice utilities from the 1-car category. Six availability matrices are developed:

Avail1 = 0 if utility for 1-car WBWB is null, else 1

Avail2 = 0 if utility for 1-car DTWB is null, else 1

Avail3 (build) = 0 if utility for 1-car (WRWR is null & WBWR is null & WRWB is null & WBWB is null) else 1

Avail4 = 0 if utility for 1-car (WBWR is null & WBWB is null), else 1

Avail5 = 0 if utility for 1-car (WRWB is null & WBWB is null), else 1

Avail6 = 0 if utility for 1-car (DTWR is null & WBWB is null), else 1

3.7.3. Final Market Shares

The final market shares for six transit alternatives are developed and the expressions related to these six market shares are listed below.

Base scenario expressions:

MSWBWB = [IMSWBWB * (PWBWB) of WBWB* Avail1]

MSDTWB = [IMSWBWB * (PDTWB) of WBWB * Avail1] + [IMSDTWB *
* (PDTWB) of DTWB * Avail2]

MSWRWR = 0

MSWBWR = 0

MSWRWB = 0

MSDTWR = 0

Build scenario expressions:

MSWBWB = [IMSWBWB * (PWBWB) of WBWB* Avail1] +
+ [IMSWRWR * (PWBWB) of WRWR* Avail3] +
+ [IMSWBWR * (PWBWB) of WBWR* Avail4] +
+ [IMSWRWB * (PWBWB) of WRWB* Avail5]

MSDTWB = [IMSWBWB * (PDTWB) of WBWB * Avail1] +
+ [IMSDTWB * (PDTWB) of DTWB * Avail2] +
+ [IMSWRWR * (PDTWB) of WRWR* Avail3] +
+ [IMSWBWR * (PDTWB) of WBWR* Avail4] +
+ [IMSWRWB * (PDTWB) of WRWB* Avail5] +
+ [IMSDTWR * (PDTWB) of DTWR* Avail6]

MSWRWR = [IMSWRWR * (PWRWR) of WRWR* Avail3]

MSWBWR = [IMSWRWR * (PWBWR) of WRWR* Avail3] +
+ [IMSWBWR * (PWBWR) of WBWR* Avail4]

MSWRWB = [IMSWRWR * (PWRWB) of WRWR* Avail3] +
+ [IMSWRWB * (PWRWB) of WRWB* Avail5]

MSDTWR = [IMSWRWR * (PDTWR) of WRWR* Avail3] +
+ [IMSWBWR * (PDTWR) of WBWR* Avail4] +
+ [IMSDTWR * (PDTWR) of DTWR* Avail6]

Where:

MS → Market Share
IMS → Initial Market Share
P → Probability
Avail → Availability

The above market share expressions are used for 1-car and 2+-car categories. For the 0-car category; drive to transit expressions (DTWB, DTWR) get zeros and all other expressions are the same as the above.

The market share computation is performed in two ways. There is a flag in the code called 'MatchMCFortranCode'. For a 'True' case, the mode choice availabilities are computed as shown in section 3.7.2 and these availabilities are used in the market share computation equations shown above. For a 'False' case, mode choice availabilities are not calculated and subsequently not used in the market share expressions. The default value for this flag is "True".

3.7.4. HBW Trips by Mode

HBW purpose trip tables are calculated using the market shares derived in section 3.7.3, person trips shown in the Table 13, and the probabilities.

Transit trips by alternative:

HBW_{WBWB} = PersonTrips * MS_{WBWB}
HBW_{DTWB} = PersonTrips * MS_{DTWB}
HBW_{WRWR} = PersonTrips * MS_{WRWR}
HBW_{WBWR} = PersonTrips * MS_{WBWR}
HBW_{WRWB} = PersonTrips * MS_{WRWB}
HBW_{DTWR} = PersonTrips * MS_{DTWR}

Transit Trips = HBW_{WBWB} + HBW_{DTWB} + HBW_{WRWR} + HBW_{WBWR} + HBW_{WRWB} + HBW_{DTWR}
Auto Trips = Person Trips – Transit Trips

Auto probabilities are calculated using the following expressions:

P_{Auto} for 0 Car = P_{2CP} + P_{3CP} + P_{4CP} from WBWB probability matrix
P_{Auto} for 1 & 2+ Car = P_{DA} + P_{2CP} + P_{3CP} + P_{4CP} from WBWB probability matrix

Where:

P → Probability
CP → Car Pool

Auto trips by mode are computed as below:

Shared Ride 2 Trips = Auto Trips * (P_{2CP} /P_{Auto})
Shared Ride 3 Trips = Auto Trips * (P_{3CP} /P_{Auto})
Shared Ride 4+ Trips = Auto Trips * (P_{4CP} /P_{Auto})
Drive Alone Trips for 0 Car = 0
Drive Alone Trips for 1 & 2+ Car = Auto Trips * (P_{DA} /P_{Auto})

HBW trips by mode and auto ownership categories for the four time periods are summarized and shown in Table 17. Again, these are daily totals and NHB trips are not included, thus the sum of person trips in Table 13 are not the same as the totals in Table 17. Please note that the HBO trips are described in section 3.8.1.

Table 18 Mode Choice Output Trip Summary for HBW and HBO

Purpose/Mode	AM				MD				PM				NT			
	0 Car	1 Car	2+ Car	Total	0 Car	1 Car	2+ Car	Total	0 Car	1 Car	2+ Car	Total	0 Car	1 Car	2+ Car	Total
HBW SOV	-	284,888	797,238	1,082,126	-	284,858	797,062	1,081,920	-	284,830	796,739	1,081,570	-	284,880	797,209	1,082,088
HBW 2-POOL	49,270	5,779	16,712	71,761	49,288	5,826	16,854	71,967	49,620	5,984	17,289	72,893	49,267	5,781	16,724	71,772
HBW 3-POOL	7,314	666	1,967	9,948	7,372	674	1,991	10,037	7,484	698	2,063	10,245	7,313	667	1,969	9,949
HBW 4-POOL	5,624	436	1,308	7,367	5,702	442	1,328	7,472	5,828	461	1,386	7,675	5,622	436	1,309	7,367
HBW WRWR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HBW WBWR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HBW DTWR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HBW WRWB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HBW WBWB	5,985	4,701	5,064	15,750	5,834	4,665	5,010	15,509	5,273	4,484	4,742	14,499	5,991	4,705	5,068	15,764
HBW DTWB	-	608	2,455	3,063	-	614	2,499	3,113	-	620	2,526	3,147	-	610	2,465	3,075
HBW AUTO	62,208	291,770	817,225	1,171,202	62,362	291,800	817,235	1,171,397	62,932	291,974	817,477	1,172,382	62,202	291,764	817,211	1,171,177
HBW TRAN	5,985	5,309	7,520	18,813	5,834	5,279	7,509	18,622	5,273	5,105	7,268	17,645	5,991	5,315	7,533	18,839
HBO AUTO	40,342	208,513	370,112	618,967	39,353	209,118	370,814	619,285	35,673	211,726	373,873	621,271	40,347	208,516	370,138	619,001
HBO TR	20,191	1,999	1,878	24,068	19,824	1,989	1,865	23,678	18,140	1,946	1,812	21,898	20,205	2,001	1,879	24,085
NHB AUTO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NHB TR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aggregate By																
HBW	68,193	297,079	824,745	1,190,016	68,196	297,079	824,745	1,190,019	68,205	297,079	824,745	1,190,028	68,193	297,079	824,745	1,190,016
HBO	60,533	210,512	371,990	643,035	59,177	211,107	372,678	642,963	53,812	213,672	375,685	643,169	60,552	210,517	372,017	643,086
NHB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Auto	102,550	500,283	1,187,336	1,790,170	101,715	500,918	1,188,049	1,790,682	98,604	503,700	1,191,349	1,793,653	102,549	500,280	1,187,349	1,790,178
Transit	26,176	7,308	9,398	42,882	25,658	7,268	9,374	42,300	23,413	7,051	9,080	39,544	26,196	7,315	9,413	42,924
Total	128,726	507,591	1,196,735	1,833,051	127,373	508,186	1,197,423	1,832,982	122,017	510,751	1,200,429	1,833,197	128,745	507,595	1,196,762	1,833,102

3.8. SPLITTING NON WORK TRIPS

3.8.1. HBO Trips

The HBO trip split process is not similar to HBW split described in the section 3.7. The following process, used to split HBO trips into Auto and Transit modes, is quite unconventional.

HBW transit trip shares by auto ownership categories are computed using the following expressions. These shares are capped at value of 1.0.

$(\text{HBW Share})_{0CAR} = (\text{HBW Transit Trips})_{0CAR} / (\text{HBW Person Trips})_{0CAR}$
$(\text{HBW Share})_{1CAR} = (\text{HBW Transit Trips})_{0CAR} / (\text{HBW Person Trips})_{1CAR}$
$(\text{HBW Share})_{2CAR} = (\text{HBW Transit Trips})_{0CAR} / (\text{HBW Person Trips})_{2CAR}$
$(\text{HBW Share})_{TOTAL} = (\text{HBW Transit Trips})_{TOTAL} / (\text{HBW Person Trips})_{TOTAL}$

Using the highway skim distance, four trip length categories are created with break points at 1, 5, 10 and 500 miles.

Table 18 shows a set of ratios for HBW and HBO purposes by auto ownership. It is unclear what these ratios are.

Table 19 Ratios by Purpose and Auto Ownership

Purpose	0 Car	1 Car	2+ Car
HBW	0.44	1.49	2.32
HBO	2.18	3.44	5.01

HBO trip shares are computed using the following equations.

$(\text{HBO Share})_{0CAR} = [(\text{HBW Person Trips})_{0CAR} / (\text{HBW Ratio})_{0CAR}] * (\text{HBO Ratio})_{0CAR}$
$(\text{HBO Share})_{1CAR} = [(\text{HBW Person Trips})_{0CAR} / (\text{HBW Ratio})_{1CAR}] * (\text{HBO Ratio})_{1CAR}$
$(\text{HBO Share})_{2CAR} = [(\text{HBW Person Trips})_{0CAR} / (\text{HBW Ratio})_{2CAR}] * (\text{HBO Ratio})_{2CAR}$
$(\text{HBO Share})_{TOTAL} = (\text{HBO Share})_{0CAR} + (\text{HBO Share})_{1CAR} + (\text{HBO Share})_{2CAR}$

Normalized value is computed as below.

$\text{HBO}_{NORM} = \text{HBO Person Trips} / (\text{HBO Share})_{TOTAL}$ if the denominator > 0 else 1.0

HBO share values calculated above are revised using the normalized value as shown below.

$(\text{HBO Share})_{0CAR} = (\text{HBO Share})_{0CAR} * \text{HBO}_{NORM}$
$(\text{HBO Share})_{1CAR} = (\text{HBO Share})_{0CAR} * \text{HBO}_{NORM}$
$(\text{HBO Share})_{2CAR} = (\text{HBO Share})_{0CAR} * \text{HBO}_{NORM}$
$(\text{HBO Share})_{TOTAL} = (\text{HBO Share})_{0CAR} + (\text{HBO Share})_{1CAR} + (\text{HBO Share})_{2CAR}$

Table 19 shows factors by distance bins and purpose. As noted at the beginning of this section, the splitting described in these sections will be replaced by the enhanced mode choice model which will be segmented by purpose.

Table 20 Distance Factors by Purpose and Auto Ownership

Trip Distance	HBO 0 Car	HBO 1 Car	HBO 2+ Car	NHB
0 - 1 miles	0.526	0.237	0.237	0.133
1 - 5 miles	0.642	0.181	0.181	0.133
5 - 10 miles	0.624	0.161	0.161	0.133
10 - 500 miles	0.516	0.151	0.151	0.127

HBO split factors are computed using the following expressions:
$(\text{HBO Factor})_{0CAR} = [(\text{HBW Share})_{0CAR} * (\text{Distance Factor})_{0CAR} * \text{AdjHBO}]$
if $(\text{HBW Person Trips})_{0CAR} > 0$ else $0.015 * \text{AdjHBO}$
$(\text{HBO Factor})_{1CAR} = [(\text{HBW Share})_{0CAR} * (\text{Distance Factor})_{1CAR} * \text{AdjHBO}]$
if $(\text{HBW Person Trips})_{1CAR} > 0$ else $0.015 * \text{AdjHBO}$
$(\text{HBO Factor})_{2CAR} = [(\text{HBW Share})_{2CAR} * (\text{Distance Factor})_{2CAR} * \text{AdjHBO}]$
if $(\text{HBW Person Trips})_{2CAR} > 0$ else $0.015 * \text{AdjHBO}$
Where, Distance Factor is from Table 19 and AdjHBO = 1.004

HBO transit trips are computed using the following expressions:
$(\text{HBO Transit Trips})_{0CAR} = (\text{HBO Share})_{0CAR} * (\text{HBO Factor})_{0CAR}$
$(\text{HBO Transit Trips})_{1CAR} = (\text{HBO Share})_{1CAR} * (\text{HBO Factor})_{1CAR}$
$(\text{HBO Transit Trips})_{2CAR} = (\text{HBO Share})_{2CAR} * (\text{HBO Factor})_{2CAR}$

HBO auto trips are computed using the following expressions:
$(\text{HBO Auto Trips})_{0CAR} = (\text{HBO Share})_{0CAR} - (\text{HBO Transit Trips})_{0CAR}$
$(\text{HBO Auto Trips})_{1CAR} = (\text{HBO Share})_{1CAR} - (\text{HBO Transit Trips})_{1CAR}$
$(\text{HBO Auto Trips})_{2CAR} = (\text{HBO Share})_{2CAR} - (\text{HBO Transit Trips})_{2CAR}$

HBO Total Transit Trips = $(\text{HBO Transit Trips})_{0CAR} + (\text{HBO Transit Trips})_{1CAR} +$
$+ (\text{HBO Transit Trips})_{2CAR}$
if HBW Total Person Trips > 0 else 0.0
HBO Total Auto Trips = HBO Total Person Trips – HBO Total Transit Trips

Table 17 shows the output HBO trips by mode and time of day.

HBO trips are split into only auto and transit trips and not by 10 mode choice model alternatives.

3.8.2. NHB Trips

The NHB trip split process is somewhat similar to the HBO split process but the NHB purpose is not stratified by auto ownership.

NHB factors are computed using the following expressions.

NHB Factor = [(HBW Share) * (Distance Factor) * AdjNHB]
if (HBW Person Trips) > 0 else 0.0055 * AdjNHB
Where:
Distance Factor is from Table 19
HBW Share is from section 3.8.1
AdjNHB = 2.895

NHB transit trips are computed using the following expression.

(NHB Transit Trips) = (NHB Person Trips) * (NHB Factor)
if HBW Total Person Trips > 0 else 0.0

NHB Auto Trips = NHB Person Trips – NHB Transit Trips

NHB auto and transit trips are shown in Table 20. Aggregate totals of HBW and HBO purpose trips by mode are also shown in Table 20.

Table 21 Mode Choice Aggregate Trip Totals by Purpose

Purpose/Mode	AM	MD	PM	NT
HBW SOV	1,082,126	1,081,920	1,081,570	1,082,088
HBW 2-POOL	71,761	71,967	72,893	71,772
HBW 3-POOL	9,948	10,037	10,245	9,949
HBW 4-POOL	7,367	7,472	7,675	7,367
HBW WRWR	-	-	-	-
HBW WBWR	-	-	-	-
HBW DTWR	-	-	-	-
HBW WRWB	-	-	-	-
HBW WBWB	15,750	15,509	14,499	15,764
HBW DTWB	3,063	3,113	3,147	3,075
HBW AUTO	-	-	-	-
HBW TRAN	18,813	18,622	17,645	18,839
HBO AUTO	622,944	623,262	625,247	622,978
HBO TR	24,068	23,678	21,898	24,085
NHB AUTO	329,675	329,746	330,167	329,678
NHB TR	8,299	8,206	7,837	8,305
Aggregate By				
HBW	1,190,016	1,190,019	1,190,028	1,190,016
HBO	647,012	646,940	647,146	647,063
NHB	337,974	337,952	338,004	337,983
Auto	2,123,821	2,124,405	2,127,797	2,123,833
Transit	51,181	50,506	47,380	51,229
Total	2,175,002	2,174,911	2,175,178	2,175,062

4. Highway Assignment

Auto person trip tables are converted into vehicle trips for highway assignment. Vehicle occupancy conversion factors by mode are shown in the Table 21. Three sets of input trip tables are utilized in developing the highway vehicle trip tables:

- Mode choice trip outputs (shown in Table 20): HBW Drive Alone, Shared Ride2, Shared Ride 3 and Shared Ride 4+ trip tables are directly used from the mode choice outputs and converted into vehicle trips.
- Trip distribution outputs (shown in Table 4): HBW IX (internal-external) and HBW XI (external-internal) trip tables are directly taken from trip distribution and converted into vehicle trips. For HBO and NHB II (internal-internal) trips, total HBO and NHB transit trips are subtracted from the trip distribution outputs and then converted into vehicle trips. Non-Work IX, Non-Work XI, Airport, and Truck trips are directly taken from trip distribution outputs and converted into vehicle trips.
- Through Trips: Through trips are also added into highway vehicle trips

Table 22 Vehicle Occupancy Factors by Mode

Mode	Veh. Occ. Factor
SOV	1.000
HOV2	2.000
HOV3	3.000
HOV4+	6.200
WRK IX	1.130
WRK XI	1.210
HBO	1.280
NHB	1.300
NWRK IX	1.570
NWRK XI	1.570
Airport	1.000
Trucks	1.000

Vehicle occupancy factors are adjusted for Hartford CBD zones for HBW Shared Ride 4+, HBW IX, and HBW XI trips. Eventually two highway vehicle trip classes are developed, LOV and HOV, for assignment. The LOV class consists of the SOV, IX-XI (90% of HBW, 100% of HBO and NHB IX-XI trips), HBO, NHB, Airport, and Truck vehicle trips. The HOV class includes the HOV3, HOV4+, and 10% of HBW I-X & X-I trips. PA to OD conversion is performed as well. Table 22 shows the summary of vehicle trip tables used in the daily highway assignment.

Table 23 Highway Vehicle Trip Total Summary

Vehicle Class	AM	MD	PM	NT
LOV	6,545,321	6,545,491	6,546,816	6,545,266
HOV	59,856	60,006	60,570	59,862

5. Transit Assignment

It should be noted that the HBW transit trips are available by six transit mode alternatives – WBWB, DTWB, WRWR, WRWB, WBWR, and DTWR. But the HBO and NHB total transit trips are inferred, as shown in section 3.8, and these are not stratified by six transit mode alternatives. Hence the following approach is used to assign the HBO and NHB transit trips to the four walk to transit mode alternatives (WBWB, WRWR, WRWB, WBWR).

The transit assignment procedure will change as the revised mode choice model will give HBO and NHB trips by mode and by access mode and they can be directly assigned to the transit network.

Base scenario:

All the HBO and NHB transit trips are assumed to be walk to bus transit trips and they are added to HBW WBWB transit trips. Drive to bus (DTWB) trips are the same as HBW DTWB trips. WRWR, WRWB, WBWR, and DTWR trips are zeros as expected.

Build scenario:

A composite minimum-skim (best path) indicator matrix is developed using four walk to transit skims. Perceived total times are calculated for each of the four walk to transit skims (WBWB, WRWR, WRWB and WBWR) using the following expression.

Perceived Time (PT) = [2*(Total Walk Time + Initial Wait Time + Transfer Wait Time)] +
+ In Vehicle Time

Best path indicator matrix is derived using the Perceived Time from four walk to transit skims using the following expression.

If [(PT_{WRWR} <= PT_{WBWR}) & (PT_{WRWR} <= PT_{WRWB}) & (PT_{WRWR} <= PT_{WBWB})] then best = 1
Else if [(PT_{WBWR} <= PT_{WRWB}) & (PT_{WBWR} <= PT_{WBWB})] then best = 2
Else if [(PT_{WRWB} <= PT_{WBWB})] then best = 3
Else if [(PT_{WBWB} > 0)] then best = 4 else best = 0

Where, PT, is perceived Time

Based on the value in the best path indicator matrix, HBO and NHB transit trips are aggregated with HBW walk to transit trips, as shown below.

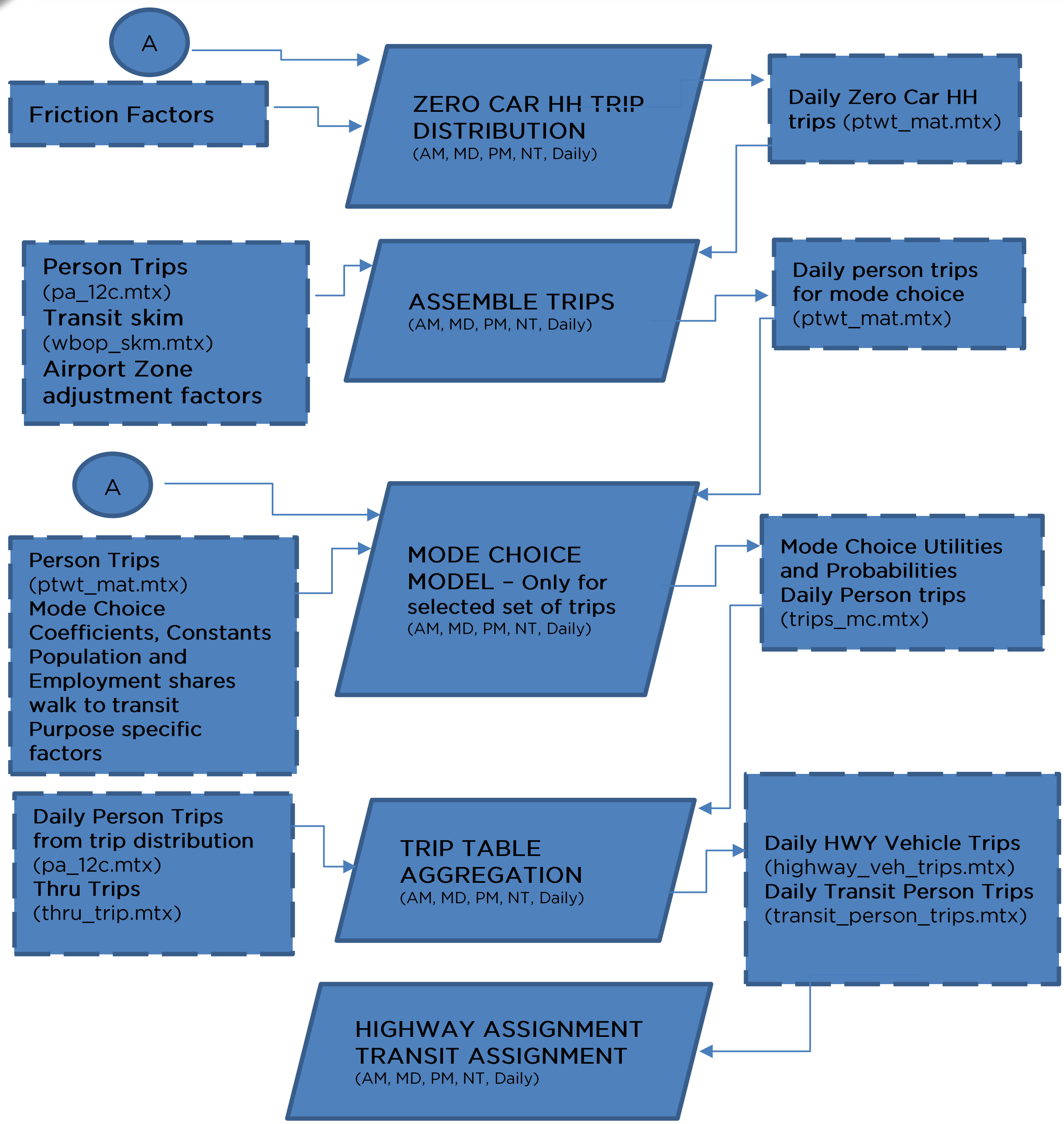
If best = 1, WRWR Transit = HBW WRWR Trips + HBO Transit + NHB Transit
else HBW WRWR Trips
If best = 2, WBWR Transit = HBW WBWR Trips + HBO Transit + NHB Transit
else HBW WBWR Trips
If best = 3, WRWB Transit = HBW WRWB Trips + HBO Transit + NHB Transit
else HBW WRWB Trips

If best = 4 or 0, WBWB Transit = HBW WBWB Trips + HBO Transit + NHB Transit
else HBW WBWB Trips
DTWR Transit = HBW DTWR Trips
DTWB Transit = HBW DTWB Trips

Eventually, transit assignment is performed for the six transit path categories with the aggregated transit trip tables.

Figure 4 is a flow chart of the current CCRCOG Model process. Data inputs are in the rectangles on the left. In the center, parallelograms indicate model processes. Rectangles on the right illustrate data outputs. Arrows are used to illustrate the flow of information among inputs, processes, and outputs

Figure 4: CRCOG Model Flow Chart


A
Friction Factors
ZERO CAR HH TRIP DISTRIBUTION
(AM, MD, PM, NT, Daily)
Daily Zero Car HH trips (ptwt_mat.mtx)
Person Trips (pa_12c.mtx)
Transit skim (wbop_skm.mtx)
Airport Zone adjustment factors
ASSEMBLE TRIPS
(AM, MD, PM, NT, Daily)
Daily person trips for mode choice (ptwt_mat.mtx)
A
Person Trips (ptwt_mat.mtx)
Mode Choice Coefficients, Constants
Population and Employment shares walk to transit
Purpose specific factors
MODE CHOICE MODEL – Only for selected set of trips
(AM, MD, PM, NT, Daily)
Mode Choice Utilities and Probabilities
Daily Person trips (trips_mc.mtx)
Daily Person Trips from trip distribution (pa_12c.mtx)
Thru Trips (thru_trip.mtx)
TRIP TABLE AGGREGATION
(AM, MD, PM, NT, Daily)
Daily HWY Vehicle Trips (highway_veh_trips.mtx)
Daily Transit Person Trips (transit_person_trips.mtx)
HIGHWAY ASSIGNMENT
TRANSIT ASSIGNMENT
(AM, MD, PM, NT, Daily)

Technical Memorandum #2
CRCOG Model Enhancement

June X, 2016

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff

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1. INTRODUCTION

In order to effectively evaluate the full range of alternatives and strategies likely to be considered during the I-84 Project and their impact on the regional transportation system, the CRCOG Model needs to be updated to incorporate all transit services, including local bus, Bus Rapid Transit (CTfastrak), express bus, and commuter rail (The Hartford Line), to account for the cost of parking in Hartford, and to provide reasonable baseline and future forecasts of roadway and transit usage for comparison.

This Technical Memorandum #2 discusses the proposed updates and modifications to the Capital Region Council of Governments (CRCOG) regional travel demand forecasting model. Specifically, it discusses updates to the transit and highway networks, traffic analysis zones, and socioeconomic databases that provide required inputs to any travel demand forecasting models. These data will need to be enhanced and modified to account for the planned increased fidelity of the overall modeling system. It will also present a proposed specification for each element of the updated CRCOG travel demand forecasting model. The updates, driven by the need to assess mode shifts between auto modes (single occupant and HOV) and transit, will include a revision of the household market segmentation, updated trip generation rates by auto-sufficiency categories, change from a trip distribution model to a destination choice model, implementation of a feedback loop between assignment and the destination and mode choice models, as well as the implementation of assignment by time of day. Finally, networks and socioeconomic data will be prepared to facilitate the use of the model for analysis focused on the following years: 2015 (model validation), 2025 (I-84 start of construction), and 2040 (I-84 build / plan horizon).

This technical memorandum is organized into the following sections: Data Collection, Traffic Analysis Zones, Transit Network, Highway Network, Socioeconomic Data, and Travel Demand Model Specification. Within each section, the proposed changes to the current CRCOG Model and the data needs will be discussed.

2. DATA COLLECTION

Data to be collected will include, but not necessarily be limited to: traffic counts, highway geometrics and operating characteristics; transit operations, service, and survey information; local development plans and programs; and, U.S. Census decennial census, American Community Survey (ACS), and Census Transportation Planning Package (CTPP) data. Where local data is either missing or incomplete, data from other sources will be utilized to support the modeling effort.

Traffic Counts and Turning Count Movements

The Consultant will review and inventory existing historical count data and turning count movements along 1-84, 1-91, Whitehead Highway, Founders Bridge, Route 1 5, and local roadways in the Hartford. These counts will be re-formatted and balanced for further use in model development. Roadway Geometrics and Operating Characteristics

Transportation Program Elements

The Consultant will collect information on planned roadway improvements included in the local Transportation Plans and Improvement Programs.

Transit Data

The Consultant will review and inventory the current operating conditions and levels of service of Transit through Hartford. This includes transit routes and stops shapefile data, block data, and ridership data for transit and rail.

Census Transportation Planning Package (CTPP) Data

The Consultant will review the CTPP data which is a set of special tabulations designed by transportation planners using large sample surveys conducted by the Census Bureau. For our efforts, it will provide statewide and/or region wide characteristics on demographics, home and work locations and journey to work travel flows.

American Community Survey (ACS)

The Consultant will review the available ACS data applicable to Connecticut and Hartford region as it is a sample of United States population. The ACS data similarly to CTPP provides detailed demographic characteristics along with journey-to work data. The Consultant will determine applicable sample and determine how the higher uncertainty levels affect their analyses, and will develop effective ways of presenting information with uncertainty.

Longitudinal Household – Employer Dynamics

The Longitudinal Employer-Household Dynamics (LEHD) program is part of the Center for Economic Studies at the U.S. Census Bureau. The LEHD program produces new, cost effective, public-use information combining federal, state and Census Bureau data on employers and employees under the Local Employment Dynamics (LED) Partnership. The program creates statistics on employment, earnings, and job flows at detailed levels of geography and industry and for different demographic groups. In addition, the LEHD program uses these data to create partially synthetic data on workers' residential patterns.

INRIX Speed Data

Data collected for the I-84 project will be used to help verify roadway speeds.

Stated Preference Survey Data

The model enhancements discussed within this technical memo will result in a state of the practice model that can be used to forecast highway volumes and transit boardings for a wide variety of scenarios. However, the initial application of the model, to forecast the changes in traveler preferences during the I-84 reconstruction, will require additional enhancements due to the unique nature of the application. A typical model application would compare a base condition to a build condition, where the build scenario has increased roadway capacity or increased transit service. For the I-84 scenarios, the opposite is true: the base condition (no construction) will see more capacity than the build condition (I-84 under construction with associated full or partial lane closures). The goal of the model application will be to quantify the effects of various construction conditions including duration of construction and full or partial lane closures on travel choices (generation, distribution, mode and route). To understand these sensitivities, a stated preference survey is being developed and will be performed in 2016. Respondents will be asked about their ability to delay the start of their trip, their willingness to switch to a different mode, their willingness to endure freeway delay or take a different route. With this data, a model application procedure will be developed whereby the build choices for a given scenario will pivot off of the base choices in accordance with the behavior "observed" in the stated preference survey.

3. TRAFFIC ANALYSIS ZONES (TAZ) REVIEW

The current TAZ structure will be reviewed to insure that it is adequate for the purposes of this study. TAZs will be aggregated or disaggregated as necessary. Socioeconomic data associated with each TAZ will be adjusted as appropriate to match with any modified TAZs.

The decision to modify TAZ will be based on several considerations. These include:

- Maintain consistency with the previously developed I-84 Project Subarea Model.
- Recognize proposed I-84 alternative alignments. TAZ boundaries will be drawn so as to limit the possibility of a TAZ being split by any new alignment being considered for I-84 in the project area.
- TAZ will be modified to accommodate major proposed new developments within the project area, e.g., the DONO Development
- TAZ will be modified to add detail in the more densely developed sections of the project area, e.g., the Hartford CBD

4. TRANSIT NETWORK

The transit networks contained in the current version of the CRCOG Model will need to be updated. Based on the information gathered for this study, transit routes and services in the Hartford Area Capital Region, including access to those routes and services, will be coded into the TransCAD software to best represent the services provided. The revised model will incorporate BRT (CTfastrak), commuter rail (The Hartford Line), local bus service, and express bus service. The transit network will be coded into TransCAD. The use of GTFS feeds and APC/AVL data will be investigated and incorporated into the transit modeling to the extent possible. It is our understanding, however, that APC data may not be available for the purposes of this study since the system is currently being implemented. Manual count data will be substituted for APC data as necessary.

The Consultant Team will update the CRCOG Model to be able to test different mass transit pricing scenarios and be sensitive to mode shift under various maintenance and protection of traffic alternatives. The model will also be capable of evaluating the impact of various infrastructure improvement alternatives for mass transit, e.g., increasing ridership with additional stations, trains, buses and station parking.

4.1. DATA NEEDS

Information will be required to adequately represent the transit network for the Base Year, 2025, and 2040. Information required will include, but not necessarily be limited to, the following for local bus, express bus, BRT, and commuter rail service:

- Transit Stops;
- Transit Routes;
- Transit Schedules, i.e., frequency of service, headways. Dwell times, etc.;
- Transit Fares, i.e., regular, passes, discount, transfer; and
- Parking lot location and capacity.

The transit networks and attributes will then provide the information necessary to generate updated transit skims which will be used in the mode choice model. .

4.2. TRANSIT TRAVEL TIME

The transit travel time function for the transit modes will be updated to the recently established FTA recommendation. Transit times depend on highway speeds and stop dwell times as follows:

*Transit Time = Auto Time + (Dwell Time * Stop)*

Where:

Transit Time is the transit travel time on the link,

Auto Time is the auto travel time on the link commiserate to the time period,

Dwell Time is the average dwell time for the route, and

Stop has a value of “0” if there is no stop coded on the link and “1” if there is a stop on the link.

Separate relationships may be developed for different facility and area types.

4.3. TRANSIT ACCESS CODING

Closely linked to size of TAZs is the approach and process of transit access coding. The method used to connect TAZ centroids to transit stops, via walk links, is as important as the service frequency checks, transit time function and zone size issues. Fundamentally, there needs to be consistency between walk connectors and the percent of the zone within walking distance of transit. The thresholds for short and long walk typical for the Hartford area will be determined based upon data from the on-board survey. It is also important to understand how TransCAD is building walk access and egress using the underlying network. Sample path traces will be an integral part of defining these critical parameters.

The walk and drive access links as currently coded and/or defined in the model will be revised. The traditional “starburst” pattern of drive access links will be replaced by a selection set of the actual highway line layer. The restriction of only certain zones having drive access to Park and Ride lots will be removed. Walk access links will be similarly selected from the highway links and trips from each TAZ will be segmented by no walk, short walk or long walk depending on the size of the TAZ.

5. ROADWAY NETWORK

A review of the CRCOG regional model roadway networks will be conducted to identify inconsistencies and errors. It is assumed that the networks are up to date. Therefore, outside of the I-84 Project Area a cursory review will be conducted. Inside of the project area a more thorough review will be conducted to insure that the networks closely depict existing conditions. Network link attributes such as speed, capacity, and volume-delay functions (VDF) parameters will be reviewed for consistency and compared to observed data where it is available. Network errors will be corrected as they are discovered. To aid model validation, available current traffic counts will be gathered and entered into the TransCAD roadway database.

The development of future year networks will be based on a review of transportation plans and programs available from the region's planning and operating agencies. Both, 2025 and 2040 roadway networks will be developed. The intermediate year "2025 Existing plus Committed (E+C) roadway networks" will be built upon the Base Year roadway network. Projects expected to come on-line between 2025 and 2040 will be added to the 2025 network to create the "2040 E+C network".

5.1. DICTIONARY OF LINK ATTRIBUTES

Link attributes currently in the CROG model network will be inventoried. For each attribute the following will be noted:

- Name;
- Description; and
- Range of current values.

The objectives of this exercise are to become familiar with the attributes currently contained in the network, detect attributes that may no longer be needed, and identify new attributes needed to accommodate the new model structure.

5.2. GENERAL NETWORK SUMMARIES

The characteristics of the network will be summarized using thematic mapping and summary tables. These summaries will provide detail on the region and the I-84 project area. Mapping will be used to provide displays of the following types of information:

- Number of lanes;
- Functional class;
- Area Type;
- Link capacities;
- DIR (one-way vs. two-way);
- Volume Delay Function; and
- Other attributes as necessary.

These displays will be useful when surveying the network to search for any possible inconsistent or inaccurate link data. The thematic mapping will be supplemented with data tables where appropriate. The tables will allow for cross-classification of attributes where this may be useful such as to depict lane miles by functional class, capacity by facility type, and lane miles by area type.

5.3. NETWORK SPEEDS

Particular attention will be paid to network speeds. Posted speeds and congested speeds will be compared and contrasted. Congested and uncongested travel times will be summarized for trips between key origins and destinations. Where overserved data is available model speed data, i.e., posted speeds, will be validated.

INRIX data will be used to…. Verify that the starting free flow speeds and the post-assignment congested speeds are consistent with observed behavior. If not, adjustments to the volume-delay functions will be made during the model calibration and validation process.

5.4. PARKING LOT CAPACITIES

Readily available information on parking lot capacities will be gathered. These data will be entered into the model database as link, node, or TAZ attributes as appropriate.

Park and ride lots will be coded as a node on the highway network. Commercial lots will be coded into the TAZ layer.

5.5. CENTROID CONNECTORS

Within the project area the placement of centroid connectors will be closely reviewed to insure that access options available in the real world are reflected as closely as possible. Outside of the project area a more cursory review of connector placement will be undertaken. In both cases the attempt will be to insure that the placement of centroid connectors reflects best practices and:

- Do not connect directly to intersections
- Do not connect directly to highways, i.e., limited access facilities, or ramps
- Reflect parking lot/garage access points.

Connector length will also be reviewed.

5.6. CONNECTIVITY

Network connectivity will be checked using TransCAD's network connectivity and point to point shortest path tools.

5.7. VALIDATION DATA

Current available count data will be gathered and entered into the highway database. These data will be used to establish screenlines to help assess the models ability to replicate existing travel patterns.

5.8. FUTURE YEAR HIGHWAY NETWORKS

Future year highway networks will be created for 2025 and 2040. The 2025 network will be used to assess travel impacts during construction and test various maintenance of traffic strategies. The 2040 network will be used to evaluate I-84 build alternatives and assess long term travel impacts.

Information from local plans and programs, e.g., comprehensive plans, STIP, and TIP, will be used to identify proposed projects that may be coded into the future year network. Projects such as new roads, add lanes, parking lots, and new transit services will be identified. The team will compile as much detail as necessary to accurately depict the projects in the future networks. Where such detail is not readily available the modeling team will use its professional judgement to make reasonable assumptions. This information will be used to guide the coding of new projects into the model network. New links will be added and existing links modified as necessary to depict the new facility. Centroid connectors will be modified if necessary.

6. SOCIOECONOMIC DATA

The socioeconomic data contained in the current CRCOG model have been partially updated to reflect the results of the 20I0 Census. It is our understanding that data pertaining to average household size and the distribution of households by income and auto ownership have not been updated. Therefore, the data on population, households, and employment that are key to estimating trip generation will be reviewed and updated as necessary. Available data sources to perform these validations include the American Community Survey (ACS) 2009-2013 release (both summary tables and Public Use Microdata Sample), the 20I0 Census, and the most recent Longitudinal Employer-Household Dynamics (LEHD) dataset, and the Census Transportation Planning Package Journey to Work data (20I0). The 2040 socioeconomic assumptions in the current CROG model will also be reviewed. These data will be examined by means of thematic mapping and preparation of tabular summaries by appropriate geographic areas, e.g., region, county, and city/town, to create a clear picture of the base year and future year development patterns and the differences between them.

6.1. 2040 SOCIOECONOMIC DATA

Summaries similar to those prepared for the 2010 socioeconomic data will be developed. In addition, summaries of the changes anticipated between 2010 and 2040 will be prepared.

Consultation with CRCOG and/or CTDOT will be necessary to review the 2040 forecasts in order to insure these data reflect the current best thinking as to future development of the region. Modification to the 2040 forecasts will be made as necessary.

Carry over changes in average household size, household income, and auto ownership made in Base Year model to 2040 model.

Finalize the 2040 socioeconomic forecast file and prepare summaries comparing and contrasting with the 2010 data.

6.2. 2025 SOCIOECONOMIC DATA

The socio-economic forecasts will be developed based on historical trends, economic growth projections and existing long-range plans for the region. The statewide model will be used to provide control totals for population and employment and the disaggregation of the results to the TAZs will be done with input from CTDOT and CRCOG.

7. TRAVEL DEMAND MODEL SPECIFICATION

7.1. General Model Update Approach

In addition to reviewing and updating the socio-economic data and the highway and transit networks, the project team also reviewed the existing CRCOG regional model, which was documented in Tech Memo #1. After reviewing the existing CRCOG model we are proposing a significant restructuring and redefining of the model components in order to be able to fulfill the purpose of this study which is to be able to evaluate the travel demand impacts of the various I-84 Viaduct Project Alternatives in Hartford as well as various maintenance of traffic strategies being considered for the construction phase of the project. The key changes are summarized in Table 1, and the sections following will describe these changes in more detail. A flow chart illustrating the structure of the proposed model is presented in Figure 1.

Technical Memo #3

Transit On Board Survey Analysis

January 12, 2017

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff
ETC Institute

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1. INTRODUCTION

Technical Memo #3 describes the results of on-board surveys conducted as part of travel demand forecasting model update.

Capital Region Council of Governments (CRCOG) conducted a transit on-board survey between March 2016 and June 2016. The purpose of this survey was to gather updated travel behavior data from transit users in the Hartford area. The data gathered will be used for the following reasons:

- Compile statistically accurate information about transit customers and how they use the transit system;
- Generate reliable linked origin-destination data needed by CRCOG and the Connecticut Department of Transportation (CTDOT) to support computerized travel demand modeling and transportation network simulation activities for purposes of regional air quality forecasting and long-range transportation planning;
- Assess changes in trip characteristics and ridership profiles of transit passengers by comparing the 2016 Transit Passenger Survey results with those from previous surveys;
- Assist in fulfilling the requirements of a "Before and After Study" of the effects on transit ridership resulting from CT*fastrak;*
- Meet the Title VI Civil Right Requirements per the latest Federal Transit Administration (FTA) guidance; and,
- Survey results will be utilized for the (National Transit Database) NTD reporting.

The survey, which included over 100 local bus, express bus and BRT (CTfastrak) routes, was the largest and most comprehensive origin and destination survey conducted by CRCOG. The goal was to obtain useable surveys from approximately 8-10% of transit riders. The actual number of usable surveys was 7,027. The magnitude of the survey will allow regional planners to better understand the needs and travel patterns of many specialized populations. For example, the final database contains responses from:

- Almost 3,500 males and 3,525 females
- More than 3,460 people who do not have cars and 2,965 individuals who do not have a driver's license
- More than 500 people under age 18
- More than 1,200 people age 50 or older
- More than 2,300 people living in households with incomes of less than $25,000 per year
- More than 5,300 people who were employed full or part time.

2. SURVEY DESIGN

Survey Development Process

The survey development process began by having representatives from CRCOG and CT*transit* in cooperation with TranSystems (TSC) and ETC Institute (ETC) review the data requirements for the transit on-board survey. Since the primary objective for the project was to improve the regional transit ridership forecasts produced by CRCOG's travel demand model, many of the questions focused on collecting data that will support current and future transportation forecasting efforts. After multiple iterations of input and review, the survey instrument was shared with representatives of the FTA to ensure all Federal requirements and expectations for the design of the survey were met. All of the suggestions from the FTA staff were incorporated into the final version of the survey. The final version of the paper questionnaire is included in Appendix A.

Types of Data Collected

To ensure the length of the survey did not negatively affect the response rate, the survey questions were divided into two categories: "required" and "desired" data as described below.

Required data

Required data involved questions for which a response from a respondent was required in order for the survey to be considered complete. At a minimum, the full intercept survey was designed to gather the following information:

- Origin address
- Destination address
- Boarding location
- Alighting location
- Home address
- Access mode
- Egress mode
- Trip purpose/type of place at the origin
- Trip purpose/type of place at the destination
- Number of transfers
- Transfer routes
- Time of Day Trip was completed
- Direction of travel
- Distance walked from the origin to the transit system (if applicable)
- Distance walked to the destination from transit system (if applicable)

- Access location to transit
- Egress location from transit
- Method of payment
- Trip frequency
- Number of vehicles available to the household
- Number of household occupants
- Student status /Employment status
- Driver's license(s) status
- Age
- Disability status
- Race/Ethnicity
- Gender
- Income
- English language ability & primary language spoken at home.

Desired data

Desired data involved questions for which a response from a respondent was desired, but was not required in order for the survey to be considered complete. Desired data is listed below:

- Distance walked from the origin to the transit system (if applicable)
- Distance walked from the transit system to the destination (if applicable)
- Park and ride location (if applicable) on either end of the trip
- Name of the school where the respondent attends college or school (if applicable)

Description of Survey instruments

The survey instrument was designed to be administered as a face-to-face interview using tablet personal computers (PCs) and printed surveys. Tablet PCs were the primary method and paper surveys, which were printed on heavy card stock for easy distribution and completion, were only used on some express route buses.

The tablet PCs were the preferred method as they have an on-screen mapping feature that allows for real-time geocoding of addresses and places based on either an address, intersection or place provided by the bus rider. The respondents can then confirm the geocoded location based on the on-screen map that shows the searched address/location via a Google Map indicator icon. In addition to using the mapping feature to collect the GPS coordinates of origin, destination, boarding and alighting, major survey locations a General Transit Feed Specification (GTFS) feed was used for transit system's scheduled operations as visible to riders. This included: routes, stop locations, and scheduled arrival/departure time.

The tablet PC allowed the surveyor to walk through each question with the respondent to answer any questions as well as to ensure the quality of the data collected. The respondent can also press the answers to the questions directly on the tablet PC during the demographic section in order to allow for more privacy. The Tablet Version Survey can be found in Appendix B.

For express routes, the respondent generally had a longer ride time, thus to capture the maximum number of participants, paper surveys were distributed to willing passengers. This often led to a much higher percentage of survey responses than would have been possible by using tablet PCs alone

Each paper survey contained a serial number that was used by the ETC Institute to track the route and sequence in which surveys were completed. The paper version of the survey is provided in Appendix A.

Respondents who did not have time to complete the survey during their bus trip were also given the option of providing their phone numbers for follow-up. Those who provided their phone numbers were then contacted by ETC Institute's call center within three days of the original attempt to survey the rider to gather the remaining information needed to create a complete survey record.

Bilingual interviewers were also hired to administer the surveys on tablet PCs in Spanish. ETC Institute's Call Center was also able to follow-up in Spanish.

3. SAMPLING PROCEDURES

In order to ensure that the distribution of completed surveys mirrored the actual distribution of riders, ETC Institute developed a sampling plan that would ensure the completion of the On-to-Off survey with at least 6,800 of the system's riders, and 5,700 surveys of the full origin and destination based on Tuesday – Thursday average ridership.

On-to-Off Sampling Goals

An on-to-off survey is meant to capture the ridership flow of the bus route. In other words, the On-to-Off Survey captures where the individual rider boarded the bus and the corresponding location where the rider alighted. This allows for a more comprehensive understanding of the true ridership flow of the route, which then allows the main survey data to be more accurately expanded. The on-to-off survey was conducted on routes that had a daily ridership of 1,000 or more passengers. For all other routes, boarding and alighting location information collected during the main full intercept survey data collection process was used in place of the on-to-off surveys. During the collection, the survey team collected samples from 25% of the bus runs. The goal was to collect over 6,500 completed on-to-off surveys, with goals of collecting 20% of the estimated weekday ridership by time period and direction for each route. Table 1 series shows the original sampling goals and the actual number of completed on-to-off surveys that were obtained by route and direction.

Main Intercept Survey Sampling Goals

In order to ensure that the distribution of completed surveys mirrored the actual distribution of riders who use the region's transit system, CT*transit* provided 2014 and 2015 ridership reports. Transystems along with CT*transit* and ETC developed sampling goals for each route by direction, and time of day and route type. The sampling goals for the survey were set by applying the sampling rates average weekday ridership for each bus route. During the collection, the survey team collected samples from 15% of the bus runs to reach their goals. The goals and the actual number of "complete and useable surveys" are also provided in Table 2, Table 3, and Table 4 for each route.

Table 1: Sampling Goals and On-to-Off Survey

Route ID	Route Name	Direction	2015 Average Weekday Boardings	20% Sampling Goal	Collected Sample	Percent Sampled
31-33	Park St	Inbound	2,619	524	614	23%
		Outbound	1,930	386	535	28%
37-39	New Britain Ave	Inbound	1,377	275	301	22%
		Outbound	1,243	249	366	29%
40-42	N. Main St	Inbound	1,771	354	450	25%
		Outbound	1,440	288	332	23%
46	Vine St	Inbound	1,115	223	329	30%
		Outbound	918	184	336	37%
47	Franklin St	Inbound	1,619	324	392	24%
		Outbound	1,451	290	361	25%
50-54	Blue Hills Ave	Inbound	2,640	528	820	31%
		Outbound	2,459	492	758	31%
60-66	Farmington Ave	Inbound	2,877	575	635	22%
		Outbound	2,627	525	815	31%
83	Silver Ln	Inbound	1,002	200	286	29%
		Outbound	1,223	245	319	26%
86-88	Burnside Ave	Inbound	1,204	241	362	30%
		Outbound	1,256	251	395	31%
101	CT*fastrak*	North	1,696	339	443	26%
		South	1,646	329	395	24%

Table 2: Sampling Goals and Main Intercept Survey Completed for Local Buses:

Route ID	Route Name	Route Type	2015 Average Weekday Ridership	Collected Sample	Percent Sampled
30	Bradley Flyer	Local	635	93	15%
31-33	Park St	Local	4,549	466	10%
32-36	Windsor Ave	Local	2,287	210	9%
37-39	New Britain Ave.	Local	2,620	328	13%
38	Weston St	Local	584	60	10%
40-42	N. Main St - Barbour St	Local	3,211	370	12%
41	New Britain - Hartford	Local	1,181	129	11%
43	Campfield Ave	Local	781	84	11%
44	Garden St	Local	347	44	13%
45	Berlin Tpke Flyer	Local	45	7	16%
46	Vine St	Local	2,033	185	9%
47	Franklin Ave	Local	3,070	352	11%
50-54	Blue Hills Ave	Local	5,099	498	10%
53-55	Wethersfield Ave	Local	1,872	202	11%
56-58	Albany Ave	Local	1,390	157	11%
59	Locus St	Local	473	63	13%
60-66	Farmington Ave	Local	5,504	624	11%
61	Broad St	Local	838	137	16%
63	Hillside Ave	Local	976	119	12%
69	Capitol Ave	Local	563	55	10%
72	Asylum Ave	Local	923	128	14%
74	Granby St	Local	1,095	105	10%
76	Ashley St	Local	1,722	147	9%
82-84	Buckland Hills	Local	2,101	248	12%
83	Silver Ln	Local	2,225	213	10%
86-88	Burnside Ave	Local	2,460	259	11%
87	Brewer St	Local	322	56	17%
91	Forbes St	Local	384	43	11%
92	Tower Ave	Local	364	52	14%
94-96	Park Ave	Local	562	83	15%
95	Glastonbury	Local	1,256	122	10%

Table 3: Sampling Goals and Main Intercept Survey Completed for CTfastrak Buses:

Route ID	Route Name	Route Type	2015 Average Weekday Ridership	Collected Sample	Percent Sampled
101	Hartford - New Britain	BRT	3,342	406	12%
102	Hartford - New Britain - Bristol	BRT	921	115	12%
121	MCC- UConn Health	BRT	1,312	204	16%
128	Hartford - Westfarms - New Britain	BRT	1,549	171	11%
140	CCSU Shuttle	BRT	157	13	8%
144	Wethersfield - Westfarms	BRT	184	16	9%
153	Flatbush - Copaco	BRT	193	20	10%
161	St. Francis & Hartford Hospital	BRT	394	36	9%

Overall, the total number of surveys exceeded the contractual requirements by more than 2,400 bus surveys. More information on the main intercept survey procedures and QA/QC process can be found Chapter 4 and Chapter 6.

Table 4: Sampling Goals and Main Intercept Survey Completed for Express Buses:

Route ID	Route Name	Route Type	2015 Average Weekday Ridership	Collected Sample	Percent Sampled
903	Manchester - Buckland Exp.	Express	697	77	11%
904	Glastonbury Exp.	Express	258	46	18%
906	Cromwell Exp.	Express	215	23	11%
85	MCC Flyer	Express	137	29	21%
901	Avon-Canton Exp.	Express	243	24	10%
902	Corbins Exp.	Express	63	7	10%
905	Enfield- Windsor Locks Exp.	Express	858	65	8%
907	Newington Exp.	Express	30	3	10%
909	Farmington- Unionville Exp.	Express	32	4	25%
910	Rocky Hill Exp.	Express	244	27	22%
912	Simsbury-Granby Exp.	Express	212	12	6%
914	Colchester Exp.	Express	381	27	7%
917	Tolland- Vernon Exp.	Express	77	7	9%
918	Willimantic - Coventry Exp.	Express	53	6	11%
919	Meriden Exp.	Express	25	5	20%
921	Middletown - Old Saybrook Exp.	Express	57	6	11%
923	Bristol Exp.	Express	67	6	9%
924	Southington- Cheshire Exp.	Express	53	6	11%
925	Cheshire-Waterbury Exp.	Express	32	3	9%
926	Winsted Exp.	Express	23	2	9%
927	Torrington Exp.	Express	19	2	11%
928	Southington- Cheshire - Waterbury Exp.	Express	41	24	59%
950	New Haven - Hartford Exp.	Express	107	16	15%

Note: Although route 85 MCC Flyer is considered a local route, for survey efforts since the route is intercity and on interstate, it was determined to be grouped with express routes.

METHODS FOR SELECTING MAIN INTERCEPT SURVEY PARTICIPANTS

On bus routes, a random number generator was used to determine which passengers were asked to participate in the survey after boarding a bus at a particular stop. If four or more people boarded the bus, the surveyor would enter the number four into the tablet and the tablet PC randomly generated a number from one to four. If the answer was two, the second person who boarded the bus was asked to participate in the survey. If the answer was one, the first person was asked to participate in the survey, and so forth. The selection was limited to the first four people who boarded a bus at any given stop to ensure the interviewer could keep track of the passengers as they boarded. There was also a contingency plan such that the interviewer would proceed sequentially through the boarders he tracked if a refusal occurred. For example, if four people boarded the route, and the random number generator specified two, and if the second passenger refused to be interviewed, then the surveyor would approach the third passenger.

TIMING OF THE MAIN SURVEY ADMINISTRATION

Most of the surveys were administered between the hours of 5 a.m. and 8 p.m. This was to ensure that the administration of the survey began prior to peak ridership levels in the morning and continued after peak ridership levels in the evening.

The bulk of the main survey was administered during weekdays (Tuesday through Thursday) with the exception of national holidays, and school breaks observed by local colleges/schools from late March to late May 2016. Additional clean-up was conducted during June 2016. The data collected in June was only 2% of the total database. (123/7027 records)

OTHER TECHNIQUES THAT WERE USED TO MANAGE THE SAMPLE

Daily Reviews of Interviewer Performance

During each day, the research team evaluated the performance of each interviewer. This included a review of the characteristics of the passengers who were interviewed with regard to age, gender, race, the number of reported transfers, the number of required data fields that were completed, the number of desired data fields that were completed, and the average length of each interview. These reviews were completed while the surveyor was on the bus and the findings were discussed with that surveyor when they checked-in. This allowed the research team to provide immediate feedback to the interviewers to improve their overall performance. It also allowed the research team to quickly identify and remove interviewers who were not conducting the survey properly.

Management of the Sample by Time of Day

In addition to managing the total number of surveys that were completed for each route/station, ETC Institute also managed the number of surveys that were completed during each of the following four time periods: 6:00 a.m. to 9:00 a.m.; 9:00 a.m. to

3:00 p.m.; 3:00 p.m. to 6:00 p.m.; and 6:00 p.m. to 6:00 a.m. These four time periods correspond to time periods that are used for regional travel demand forecasting. This was done to ensure that the number of completed surveys for each time period would adequately support data expansion requirements for travel demand modeling. The data expansion process is described in Chapter 7 of this report.

4. SURVEY ADMINISTRATION

The following sections describe the survey administration methodology used for the 2016 on-board study. This methodology includes recruiting and training of interviewers, organization of the survey teams, and procedures used for the surveys

Recruiting and Training Interviewers

Assembling a team of high-quality surveyors was one of the most important steps in the administration process. For this project, ETC Institute complemented its team of supervisors with temporary surveyors who were local to the area. Surveyors recruited by a staffing agency were required to have a familiarity with the service areas, a solid work history, ability to work with the public, a professional attitude and appearance, an ability to operate a tablet PC, and become proficient with both ETC Institute's software program and procedures.

Each surveyor was required to attend ETC Institute's training session for both the on-to-off survey and main intercept survey. During this training session, surveyors were taught how to operate the tablet PCs and the suitable software, execute the suitable surveying procedures, and deal with various situations that could be encountered during their surveying period. The surveyor training was conducted in a classroom style setting at a local hotel meeting room. The training content included:

- Overview of the on-board survey objectives
- Either main intercept or on-to-off equipment / software overview and training
- Either main intercept or on-to-off barcode administrating procedures
- One-on-one tutoring / mock interview with an ETC Institute supervisor
- Overview of rules and procedures and a code of conduct to be followed while representing CT*transit* and ETC in the field.

Once an ETC Institute supervisor approved of each surveyor's abilities in the classroom, the surveyors then spent several days in the field under the supervision of an ETC field supervisor who assessed each surveyor's ability to properly conduct the surveying procedures. Surveyors who did not demonstrate proficiency in all of the required tasks were released.

Organization of the Survey Team

The organizational structure of each type of survey is described in the following sections:

ORGANIZATION OF THE ON-TO-OFF SURVEY TEAM

The on-to-off survey was administered by teams that were directly managed by an ETC Institute supervisor. The supervisors were responsible for reviewing the performance of each team and ensuring that all parts of the on-to-off procedure were being followed and the sampling goals for each route were met. The supervisors operated from centralized locations, such as downtown New Britain CT*fastrak* station, Central Row Area in Hartford, Union Station, and Hartford Public Library area, for on-the-go performance evaluation of all teams.

The on-to-off survey team sizes for buses were determined by route ridership levels and bus size (articulated [3+ doors] or standard [1-2 doors]). A typical team consisted of two members, based on a medium to high-ridership level and a standard size bus. On-to-off teams were typically deployed on at least two buses running in opposite directions. For high-volume routes, teams may have been deployed on up to four buses on a route. On lower-volume routes, teams may have been deployed on just one bus serving the route.

The responsibilities of each of the positions on the on-to-off teams are described:

- The team leader was responsible for route and direction selection for on-to-off software, offering riders an opportunity to participate in the survey, scanning barcode cards for boarding riders, answering rider questions, and overseeing on-to-off operations of his/her bus.
- The support surveyor was responsible for collecting and scanning barcode cards for alighting riders, reminding riders to keep their cards ready to hand in to a surveyor when they exited at their bus stop, and answering rider questions.

ORGANIZATION OF THE MAIN INTERCEPT SURVEY TEAM

The main survey was administered by teams who were directly supervised by an ETC Institute supervisor. The supervisors were responsible for reviewing the performance of each interviewer ensuring that all parts of the surveying procedure were being followed and the sampling goals for each route were met. The supervisors operated from centralized locations with Wi-Fi, such as Hartford Public Library, Union Station, New Britain Downtown CT*fastrak* station so that the performance of all interviewers could be evaluated instantaneously.

Interviewers were typically deployed on at least two buses of the same route running in opposite directions. On high-volume routes, interviewers may have been deployed on up to six buses on a route. On lower-volume routes, interviewers may have been deployed on just one bus serving the route.

The responsibilities for each of the positions on the Main Survey team are the following:

- The Field Supervisor was responsible for ensuring that interviewers were properly trained, equipping interviewers to conduct surveys, scheduling interviewers, inspecting work, and reviewing the data collected.
- The Main Intercept Surveyor was responsible for administering surveys while following surveying procedures.

Survey Administration Procedures

The Administration Procedures of each type of survey is described in the following sections:

On-to-Off Program Procedure

The purpose of the on-to-off survey is to identify ridership patterns based on an individual's boarding and alighting locations which are used to develop the sampling plan for the Main Survey.

The on-to-off bus surveying team used the on-to-off software with a GPS-equipped tablet PC to record the rider's boarding latitude/longitude, alighting latitude/longitude, time of usage, route used, and inbound/outbound direction. The on-to-off software was complemented with a barcode scanning system method as described:

- Riders were asked to participate in the on-to-off ridership pattern survey as they entered the bus.
- Riders who agreed to participate were handed a barcode card which was scanned by a surveyor.
- Riders were told to keep the barcode card for the duration of their trip.
- Riders were reminded to hand their cards back to the surveyor as they exited the bus.
- When riders' bus stops were approached, the surveyor took their barcode cards before they exited. The surveyor scanned riders' barcode cards as they departed the bus.
- The software then paired the boarding and the alighting location of each rider based on the unique barcode card each was handed.

A screen shot of the interface of the on-to-off boarding/alighting software that was used to record the information and a picture of a barcode card is shown in Figure 1.

Figure 1: On-to-Off Survey Scan Card Screenshot

Main Intercept Survey Administration Procedure

Local bus routes were surveyed using the tablet PCs. Since local routes have more frequent stops than express routes and shorter ride times for the passenger, an interviewer conducting the survey via tablet PC was deemed necessary in order to achieve the desired response rates.

Once an interviewer had selected a person for the survey, the interviewer did the following:

- Approached the person who was selected and asked him or her to participate in the survey.
- If the person refused, the interviewer ended the survey.
- If the person agreed to participate, the interviewer asked the respondent if he/she had at least five minutes to complete the survey.
- If the person did not have at least five minutes on the bus, the interviewer asked the person to provide his/her home address, boarding location, alighting location, name, and phone number. Within 24 hours, a phone interviewer from ETC Institute's call center contacted the respondent and asked him/her to provide the information by phone. This methodology ensured that people who completed "short-trips" on public transit were well represented.
- If the person had at least five minutes on the bus, the interviewer began administering the survey to the respondent as a face-to-face interview using a tablet PC.

An express bus service is a service type that is intended to run faster than normal bus services between the same destination points. This type of bus service usually runs with limited stops and during peak hours only. The surveyed bus routes classified as express service routes were the CT*transit* 900 series and CT*fastrak* Rapid Bus routes (100 series). Routes that were classified as express routes were surveyed by interviewers using the self-administered, printed questionnaires, as described in Chapter 2. Interviewers distributed the printed surveys and pencils to boarding riders. The CT*fastrak* routes were surveyed using both tablet PCs and printed surveys.

Once a rider finished a survey, an interviewer conducted a short-version interview with the rider to ensure that all questions were answered properly and then made corrections/additions to the survey as necessary. After corrections/additions were made, the interviewer initialed the printed survey for submittal.

Surveys submitted with tablet PCs went under a pre-approval phase by an ETC Supervisor in real-time using ETC Institute's survey program's on-line database to ensure that the following information was provided:

- Origin address
- Destination address
- Boarding location
- Alighting location
- Home address
- Access mode
- Egress mode
- Trip purpose/type of place at the origin
- Trip purpose/type of place at the destination
- Number of transfers
- Transfer routes
- Time of Day Trip was completed
- Access location to transit
- Egress location from transit
- Number of vehicles available to the household
- Number of household occupants
- Student status /Employment status
- Driver's license(s) status
- Age
- Income

If any information was missing or incomplete, the supervisor flagged the record for reviewing. ETC Institute's Project Manager then forwarded all flagged survey records and the corresponding name and phone number to ETC Institute's call center. Interviewers working in ETC Institute's call center then called respondents who had provided their names and phone numbers to retrieve the missing information by phone.

Express route paper surveys were physically reviewed by an ETC manager to ensure that the same information had been provided. The printed surveys were then sent to ETC Institute's data entry department to be entered. Those surveyed on express routes were sometimes called by ETC Institute's call center to retrieve any missing information by phone.

Once survey records were classified as complete, meaning all of the required information had been collected, the records were forwarded to ETC Institute's geocoding manager, who then finalized the home, origin, boarding, alighting, and destination geocoded locations. Afterwards, ETC Managers and SRRT (Survey Records Review Team) were also able to check survey trip logic by being able to review the main survey's origin-boarding-alighting-destination on a single screen to begin the quality control data review process. See Chapter 5 and Chapter 6 for more information about SRRT and the quality control process.

5. GEOCODING PROCESS OF SURVEY

Process for Geocoding Address Records

Each transit survey record conveys information about five physical locations: trip origin, trip destination, boarding stop (where the transit user boarded the transit vehicle on which he/she was surveyed), alighting stop (where the transit user exited the transit vehicle on which he/she was surveyed), and the home/residence location of the transit user. Because the vast majority of the data collection occurred on the tablets using real time geocoding, converting the data into a consistent format for street names, street numbers, zip codes, and landmarks was an automated process.

BOARDING AND ALIGHTING GEOCODING

Effective route geocoding depends mainly on the initial quality of the stop data. These pre-configured lists contained bus route numbers, and bus stop names. Figure 2 and Figure 3 shows a screen shot from the tablet PC that allowed interviewers to precisely record boarding and alighting locations while the survey was being administered.

Figure 2: Tablet PC Boarding and Alighting locations

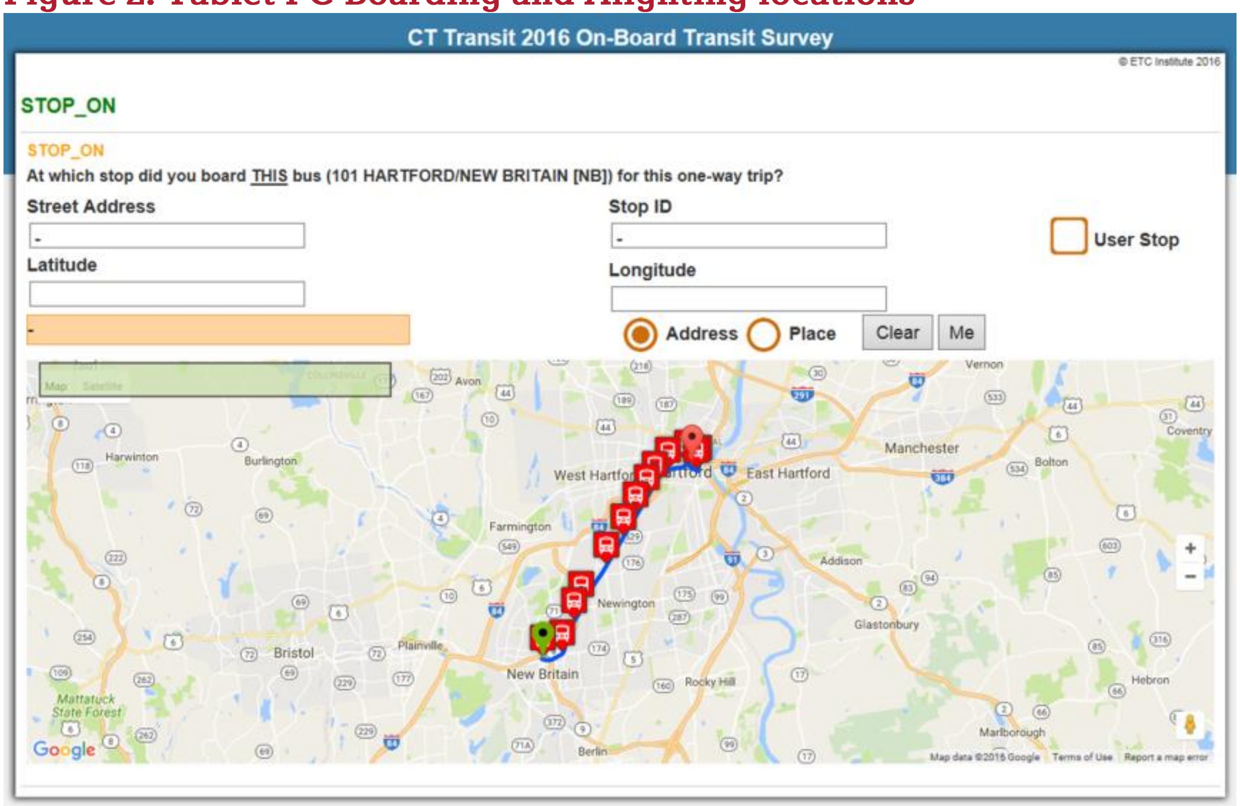
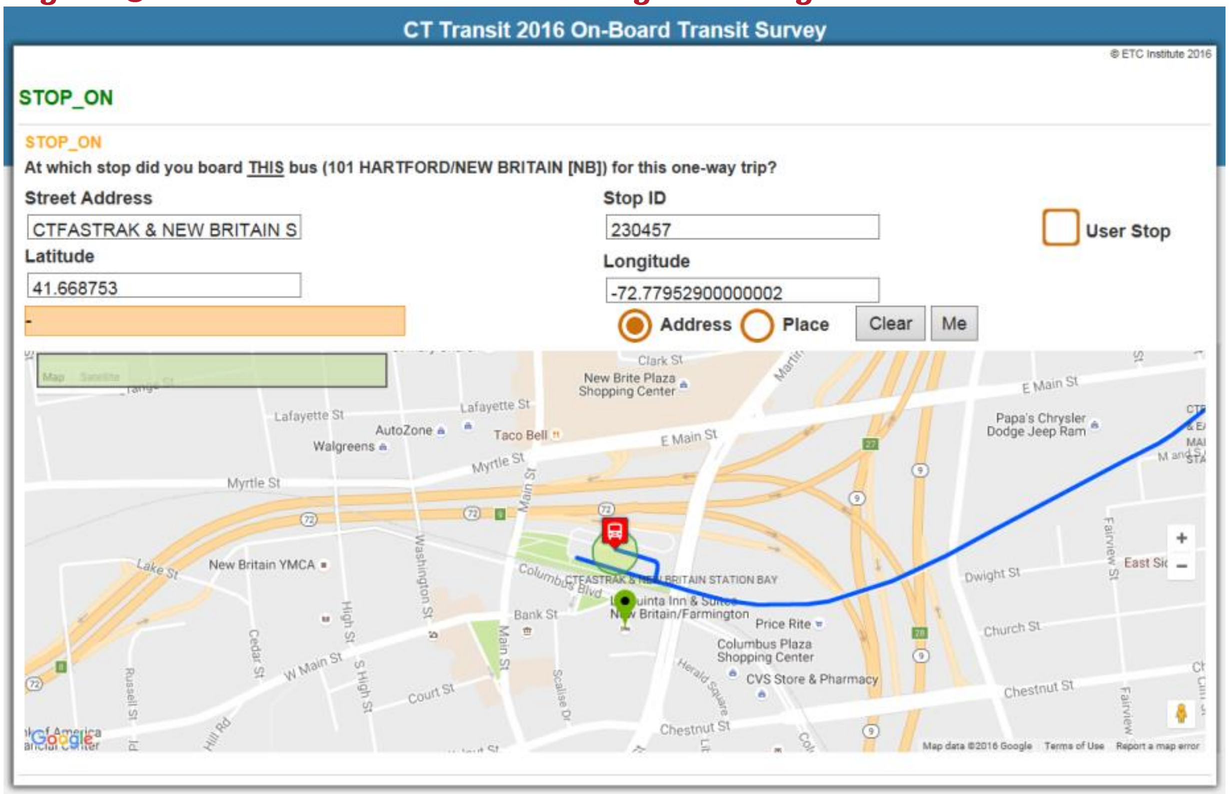


Figure 3: Tablet PC Zoom to Boarding and Origin Location.



All geocoded results were checked for errors recursively, until all five locations (origin location, boarding location, alighting location, destination location, transfer location(s) if any, and survey administration location) within a record were completely geocoded or until a record was declared unfit for further processing. Error checks included comparing attributes derived from the geocoded coordinates to those recorded during the field survey, e.g. city name. Quality checks also comprised proximity tests between the geocoded boarding or alighting locations and the known bus stop locations or line segment representing the bus route. Some of the proximity tests and corrections were performed within TransCAD using custom scripts developed for this project in Geographic Information System Developer's Kit (GISDK). Distances between each consecutive pair of trip points were also computed as a basis of logic checks used to flag records for further (typically manual) verification and correction.

6. DATA REVIEW PROCESS (QA/QC)

Many of the processes described in the first five chapters of this report were essential elements of the overall quality assurance/quality control (QA/QC) process that was implemented throughout the survey administration process. The establishment of specific sampling goals and procedures for managing the goals ensured that a representative sample was obtained from each bus route. Training of interviewers and the high levels of oversight provided by team leaders and the project manager ensured that the survey was administered properly. Also, the use of the latest geocoding tools contributed to the high quality of geocoding accuracy that was achieved. The following sections describe the QA/QC processes that were implemented after the data was collected.

Process for Identifying Completed Records

To classify a survey as being completed, the record must contain all required data. Required data involved questions for which a response from a respondent was required in order for the survey to be considered complete. At a minimum, the full intercept survey was designed to gather the following information:

- Origin / Destination address
- Boarding / Alighting location
- Home address
- Access / Egress mode
- Trip purpose/type of place at the origin
- Trip purpose/type of place at the destination
- Number of transfers
- Transfer routes
- Time of Day Trip was completed
- Direction of travel
- Distance walked from the origin to the transit system (if applicable)
- Distance walked to the destination from transit system (if applicable)

- Access / Egress location to transit
- Method of payment
- Trip frequency
- Number of vehicles available to the household
- Number of household occupants
- Student status /Employment status
- Driver's license(s) status
- Age
- Disability status
- Race/Ethnicity
- Gender
- Income
- English language ability & primary language spoken at home.

Once a survey had been classified as complete, the next phase of the QA/QC process was to determine the usability of each survey record. The term 'useable' was used to identify records that passed all of the QA/QC tests after it was classified as complete. In this section, the QA/QC tests conducted are described.

PRE-PROCESSING TESTS

The first step in this process involved the application of a series of QA/QC tests that were conducted before the address fields were processed for geocoding. Some of the specific checks that were conducted during the pre-processing phase included the following:

- Checking that home street names, city names, and zip codes can be geocoded;
- Checking that origin street names, city names, and zip codes can be geocoded;
- Checking that destination street names, city names, and zip codes can be geocoded;
- Checking for origin place names that could be matched to a pre-existing list of major destinations that had been previously geocoded;
- Checking for destination place names that could be matched to a pre-existing list of major destinations that had been previously geocoded;
- Ensuring the number of household occupants was greater than or equal to the number of employed members of the household;
- Ensuring the respondents who indicated that they were employed also reported that at least one member of their household was employed;
- Ensuring that bus route names were consistently spelled and coded correctly;
- Ensuring that transfers to a bus route were possible;
- Ensuring that transfers from a bus route were possible;
- Ensuring that the number of vehicles available to a respondent's household were consistent with the respondent's reported annual household income. Low income families who reported owning many vehicles and high income families that reported no vehicles were flagged;
- Ensuring the time of day a survey was completed was reasonable given the published operating schedule for the route;
- Ensuring the origin type of place code matched the type of place reported by the respondent; and,
- Ensuring the destination type of place code matched the type of place reported by the respondent.

Records that did not pass all of the tests were sent to ETC Institute's Survey Records Review Team (SRRT) for further review. Based on the type of issues found with the record, the SRRT members then took one of the following actions.

- They corrected the deficiency in the record.
- They directed ETC Institute's Call Center to contact the respondent by phone (if a phone number was available) to retrieve additional information or to confirm whether or not their responses were correct.
- They reclassified the record as incomplete by assigning a value of "3" for the record's quality control flag. This assignment removed the record from further inclusion in the final survey database.

Records that passed all the pre-processing QA/QC tests were forwarded to ETC Institute's geocoding team. See Chapter 5 for Geocoding Process.

POST-PROCESSING TESTS

After all five addresses were successfully geocoded; the next step in this process involved the application of a series of QA/QC tests:

- Ensuring the origin and destination addresses were not the same;
- Ensuring the boarding and alighting addresses were not the same;
- Ensuring that the respondent did not list the same route as both a "transfer from" and a "transfer to" during their one-way trip;

- Checking to be sure the access mode was appropriate given the distance of travel from the trip origin to the place where the respondent initially accessed transit. For example, if a rider reported that he/she accessed transit by car but the distance from his/her origin to the entry point for transit was less than 0.25 mile, the record would have been flagged for further review. Similarly, if a respondent reported that he/she walked to transit but the distance from the origin to transit was more than two miles, the record would have been flagged to check for a missing transfer since two miles or more is well beyond typical walk distance;
- Checking to ensure that the egress mode was appropriate given the distance of travel from place where the respondent exited the transit system to his/her destination;
- Reviewing the total distance the respondent traveled on transit compared to the distance the respondent traveled from the origin to the destination for his/her trip. For example, if a respondent reported traveling six miles on transit in order to travel 0.5 mile from the origin to the destination for his/her trip, the record would have been flagged for further review. Similarly, if a respondent reported traveling just one mile on transit to complete a 10-mile trip, the records would have been flagged to check for a missing transfer;

Records that were flagged for further review were forwarded to the appropriate section based on the nature of the flag.

- Issues that involved address geocoding assignments were referred to ETC Institute's geocoding team.
- Issues that needed clarification of data were directed to ETC Institute's Call Center (if a phone number was available). The Call Center then contacted the respondent to retrieve additional information as needed. If respondent was unable to be contacted, final assessment of the records were approved by Senior Management.
- All other issues were directed to ETC Institute's SRRT.

Records that passed all the post-processing QA/QC tests or that were corrected were then forwarded to ETC Institute's SRRT for a final visual inspection of the trip using the Visual Survey Editor Program (VSEP), which is described in the following section.

Records that were complete but could have problems with the trip logic or other attributes of the trip were reclassified as problematic by assigning a value of "2" as the record's Quality Control Flag. This assignment removed the record from further consideration for the final survey database.

VISUAL INSPECTION

The final step of the QA/QC data review process involved a visual inspection of the trip record using the VSEP. The key tasks that were conducted as part of this visual inspection included the sensibility of results for the following areas:

- Key variables of survey trips with very short distances (less than one mile for local bus trips and less than four miles for express trips). The key variables reviewed were the four major geocoded points (origin, destination, boarding, alighting) of the trip. If the review of the trip indicated an illogical pattern, it wasn't included in the final expanded database;

- Trips with zero transfers given location of boarding and alighting locations relative to the origin and destination;
- Trips that reported three or more transfers;
- Drive access/egress trips given the distance traveled by car relative to the distance traveled by bus ;
- Drive access/egress trips with more than one transfer;
- Looking at the origin-to-destination to ensure that it was appropriate for the survey route that was used for the trip;
- Finalize trip logic by reviewing the origin-boarding-alighting-destination locations on a single screen.

If a record passed all the visual checks listed, the record was classified as useable and tagged for inclusion in the final survey database by assigning a value of "1" as the record's Quality Control Flag.

If a record did not pass all the visual checks, the record was sent back to the SRRT for further review. If the SRRT was not able to resolve the problem that was identified, the record was reclassified as problematic by assigning a value of "2" as the record's Quality Control Flag. This assignment removed the record from further consideration for the final survey database.

SUMMARY OF DATA REVIEW QA/QC PROCESS

Overall, 10,489 individuals (17% of riders) were approached to participate in the main intercept survey, and 14% of the bus riders initially said "yes." Table 5 highlights the response rates reasons for refusal or non-participation. The 9,132 initial participants, the total survey response number further dropped to 7,935 records.

Among the 9,132 surveys that were originally administered, 7,047 met the contractual requirements for completeness. Of those that were classified as "complete", 7,027 passed all of the QA/QC tests and were subsequently classified as "useable" records. (Table 6)

Only the "useable" records were included in the final survey database that was expanded and used for the analysis in this report. The results of the QA/QC review are shown in Table 6 below.

Table 5: Response Rate

Description	Number of Surveys	Percent of All Surveys Administered
Yes I can participate in the survey (have 5 min+)	9,132	87.1%
No (refused)	615	5.9%
No (already did this survey)	288	2.8%
Do not speak the interviewer's language (Spanish)	236	2.3%
Yes (but no time for full survey)	161	1.5%
Do not speak the interviewer's language (other)	34	0.3%
Disabled (not able to communicate with rider)	23	0.2%
Total	**10,489**	**100%**

Note: 7,935 of the 9,132 surveys were completed.

Table 6: Data Review QA/QC Summary

Classification	Quality Control Flag Value	Description	Number of Surveys	Percent of All Surveys Administered
Not usable	3	Missing one or more of pieces of required data.	888	11.19%
Problematic	2	All required data was provided but there was a problem with the trip logic or other attribute of the trip	20	0.25%
Usable	1	Record Passed all QA/QC tests	7,027	88.56%
Total			**7,935**	**100%**

7. DATA EXPANSION PROCESS

This section describes the process for developing the weighting factors that were used to expand the survey database to the total transit ridership in the region. Two types of expansion factors were developed.

- **Unlinked trip weighting factors** were developed to expand the total number of completed surveys to the actual number of transit boardings in the region.
- **Linked trip weighting factors** were developed to adjust the total number of boardings to one-way trips. The linked trip weighting factor accounts for multiple boardings that would occur when a passenger transfers during his/her one-way trip.

The CT*transit* On-Board Transit Surveys were generally expanded by route, direction, time of day, and by the boarding and corresponding alighting location of the rider. Ridership data from CT*transit* was used at the start of the project in order to set goals for the field data collection. The ridership data used to conduct the expansion was from 2015 and supplemented with 2014 data.

From a finite population sampling theory perspective, analytic weights are needed to develop estimates of population parameters and, more generally, to draw inferences about the population that was sampled. Without the use of analytic weights, estimates are subject to biases of unknown, possibly large, magnitude.

In on-board surveys, the universe of trips operated by transit routes cannot be sampled. At the same time, all the riders who board the sampled routes cannot be surveyed because the survey is voluntary. All these factors lead to biases in the survey data. Consequently, sample weighting and expansion is critical to account for and correct these biases. In particular, sample weighting adjusts for nonresponse at the bus stop level and accounts for sampling trips at the route, time, and direction level (RTD). Sample expansion, on the other hand, expands the weighted sample to reflect the population ridership at the system-wide level. The next section describes the sample weighting procedures for unlinked and linked trips.

Unlinked Trip Weighting Factors for All Records

A total of 7,027 surveys were completed with bus passengers. The number of completed bus surveys represented 11.1% of the average weekday boardings on the bus system in 2015 (63,445 boardings). In order to ensure that the survey data accurately represented the travel patterns of the 63,445 passengers who use bus service in the region on a typical weekday, unlinked trip weighting factors were prepared for each bus survey record in one of the following two ways:

- **High Volume Routes.** Local bus routes, CT*fastrak*, and express routes with average weekday boardings of 100 passengers or more were expanded by direction, time of day, and boarding location. There were a total of 31 local routes, all 8 CT*fastrak* routes and 12 express routes in this category.

- **All Other Routes**. Bus routes with average weekday boardings of less than 100 passengers were expanded by direction and time of day. There were a total of

11 routes in this category. The total boardings on these routes was less than a thousand, which was less than 1% of the region's average weekday bus ridership. Each of these two methods is described in more detail on the following pages.

UNLINKED TRIP WEIGHTING FACTORS FOR HIGH VOLUME BUS ROUTES

The process for calculating unlinked trip weighting factors for high volume bus routes involved several activities that are described below:

- **Collecting Boarding/Alighting Counts** - Although CT*transit* collects daily boarding and alighting data by stop, data on the boarding and alighting pairs along routes was not available. While the number of passengers that board and alight at each stop is important, the next step is learning where a passenger boards and then correspondingly where that same passenger alights. In order to estimate actual ridership between stops and segments along each route, an on-to-off survey was administered to approximately 20% of the passengers on preselected routes with daily ridership higher than 1,000.

- **Segmenting Routes Based on the Observed Distribution of Boardings and Alightings** – in addition to on-to-off, the boarding and alighting data from the on-board counts were reviewed in GIS to assess the general distribution of ridership along each route by time of day. Based on the observed distribution, the research team divided each route into at least three segments. The purpose of the segmentation was to control the expansion of the sample with regard to the location of boardings along a route. The number of segments per route was related to the number of completed surveys along the route and the presence of major ridership generators, such as park and ride lots. Since the sample size was limited to approximately 10% of the total ridership on each route, the number of segments was limited to ensure that most expansion factors would have a value of 40 or less, which was double the value of the average weighting factor. (Note the average weighting factor was 10 since 1 in 10 (or 10%) of the ridership was surveyed. Only one outlier was found with route 43 where unlinked weight factor was 136.

- **Estimating the Total Number of Boardings for Each Segment.** Once each route had been segmented, the percentage of all boardings that were observed in each segment (based on the results of the boarding/alighting counts) was multiplied by the total number of boardings on the route in each direction for each of four time periods:
  - AM Peak (6:00am-9:00am)
  - Midday (9:00am-3:00pm)
  - PM Peak (3:00pm-6:00pm)
  - Off Peak (6pm-6:00am)

  The result of this process was an estimate for the total number of boardings within each segment by direction and time of day.

- **Calculating the Weighting Factors.** Once the total boardings for each segment had been estimated by time of day and direction, weighting factors for each segment were calculated by dividing the estimated number of boardings on each segment by the total number of completed surveys for each segment. A unique set of weighting factors was created for each segment on a route for each of the following types of trips.
    - Inbound / Northbound/ North/ East/or Eastbound trips during the AM Peak (6:00am-9:00am)
    - Inbound / Northbound/ North/ East/or Eastbound trips during the during the Midday (9:00am-3:00pm))
    - Inbound / Northbound/ North/ East/or Eastbound trips during the PM Peak (3:00pm-6:00pm)
    - Inbound / Northbound/ North/ East/or Eastbound trips during the Off Peak (6pm-6:00am)

    - Outbound / Southbound/ South/ West/or Westbound trips during the AM Peak (6:00am-9:00am)
    - Outbound / Southbound/ South/ West/or Westbound trips during the during the Midday (9:00am-3:00pm))
    - Outbound / Southbound/ South/ West/or Westbound trips during the PM Peak (3:00pm-6:00pm)
    - Outbound / Southbound/ South/ West/or Westbound trips during the Off Peak (6pm-6:00am)

A one direction route with three segments would have had up to 36 unique weighting factors. Table 7 illustrates a sample of unlinked weight factors for route 31-33. Appendix C provides unlinked factors for all routes.

Table 7: Sample of Unlinked Trip Weighting Factors by Route, Segment, and Time

Route by Direction	Alighting Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
31-33 IB	1	2.9	4.4	11.9	12.8								
	2	2.9	7.6	15.8	9.0		19.8	15.8					
	3	13.2	3.6	10.5	12.5	13.2	19.8	10.5	12.5	13.2	24.1	10.5	12.5
31-33 OB	2		22.8										
	3	6.1	7.3	8.8	2.9	8.4	4.6	4.1	2.9	12.3	10.6	11.6	16.8

UNLINKED TRIP WEIGHTING FACTORS FOR ALL OTHER BUS ROUTES

The process for calculating unlinked trip weighting factors for other bus routes simply involved dividing the number of boardings in each direction by time of day on each route by the number of surveys that were completed. For most routes, expansion factors were developed for the following eight types of trips. An example of the calculation from Route 917 is shown in Table 8 below:

- Inbound / Northbound/ North/ East/or Eastbound trips during the AM Peak (6:00am-9:00am)
- Inbound / Northbound/ North/ East/or Eastbound trips during the during the Midday (9:00am-3:00pm)
- Inbound / Northbound/ North/ East/or Eastbound trips during the PM Peak (3:00pm-6:00pm)
- Inbound / Northbound/ North/ East/or Eastbound trips during the Off Peak (6:00pm-6:00am)

- Outbound / Southbound/ South/ West/or Westbound trips during the AM Peak (6:00am-9:00am)
- Outbound / Southbound/ South/ West/or Westbound trips during the during the Midday (9:00am-3:00pm)
- Outbound / Southbound/ South/ West/or Westbound trips during the PM Peak (3:00pm-6:00pm)
- Outbound / Southbound/ South/ West/or Westbound trips during the Off Peak (6:00pm-6:00am)

Table 8: Unlinked Trip Weighting Factors for Route 917

Concatenate of Route Code and Time Period	Direction	Time of Day	Actual Boarding (2015 Ridership)	Number of Completed Surveys	Expansion Factor
CTT917IB_1	Inbound	AM Peak (6am-9am)	25	2	12.5
CTT917OB_2	Outbound	Midday (9am-3pm)	18	2	9
CTT917OB_3	Outbound	PM Peak (3pm-6pm)	25	2	12.5
CTT917OB_4	Outbound	Off Peak (6pm-6am)	9	1	9

Note: Column 1 is the chained value of route number, direction, and time period.

In Appendix C, Table 35 provides unlinked expansion factors for express routes without segmentation.

Linked Trip Weighting Factors for All Records

The linked trip weighting factor adjusts the total number of boardings to one-way trips by accounting for the number of transfers that were completed by each passenger.

The equation that was used to calculate the linked trip weighting factor is shown below:

Linked Trip Weighting Factor = [1 / (1 + # of transfers)]

If a passenger did not make a transfer, the linked trip weighting factor would be 1.0 because the person would have only boarded one vehicle. If a person made two transfers, the linked trip weighting factor would be 0.33 because the person would have boarded three transit vehicle during his/her one-way trip. An example of how the linked trip weighting were calculated is provided in Table 9 below.

Table 9: Sample Calculations of Linked Trips Weighting Factors

Number of Transfers	Calculation	Linked Trip Weighting Factor
None	[1 / (1+0)]	1
One	[1 / (1+1)]	0.5
Two	[1 / (1+2)]	0.33
Three	[1 / (1+3)]	0.25

The linked trip factor was calculated for every rider who completed the survey. This weight is provided as a stand-alone factor. Following the application of this factor to the weighted data (i.e. data weighted by the expansion weight), the information can be expressed as 'linked' trips instead of individual boardings. In Appendix C,Table 35 thru Table 39 provides linked and weighted expansion factors for local, CT*fastrak* and express routes.

Weighting is used to adjust a dataset so it better represents a known population. When done correctly, weighting a dataset can make the overall results more accurate and representative of what is really occurring on your transit system.

The next step after creating the weighting factors was to give each record in the OD survey database a weight factor name based on route, direction, time period, boarding segment, and alighting segment. For example, the weight factor name of "15LEB_2_1_2" indicates that the record is from example route going eastbound (15LEB), during the "Midday" Time Period (2), the rider boarded at Segment-1 (1), and the rider alighted at Segment-2 (2).

Validating the Expansion

After all the expansion factors were added into the OD survey database, the weighting factors were summed up by route, direction and time period. Those summed weighting factors were then compared to the overall ridership numbers in order to make sure they were the same.

8. SELECTED FINDINGS

Demographics

This section highlights selected demographic findings from the survey. The database used for the tables in this chapter and all chapters were expanded based on weekday linked weight factors created during the data expansion process.

HOUSEHOLD SIZE

The household size results (Figure 4 and Table 10) indicate that 86% of riders have a household size of four or fewer individuals. In particular, about 49% of riders live in one- or two-person households, while 38% live in three- or four- person households. The remaining 14% have a household size of five or more individuals.

Figure 4: Distribution of Household Size

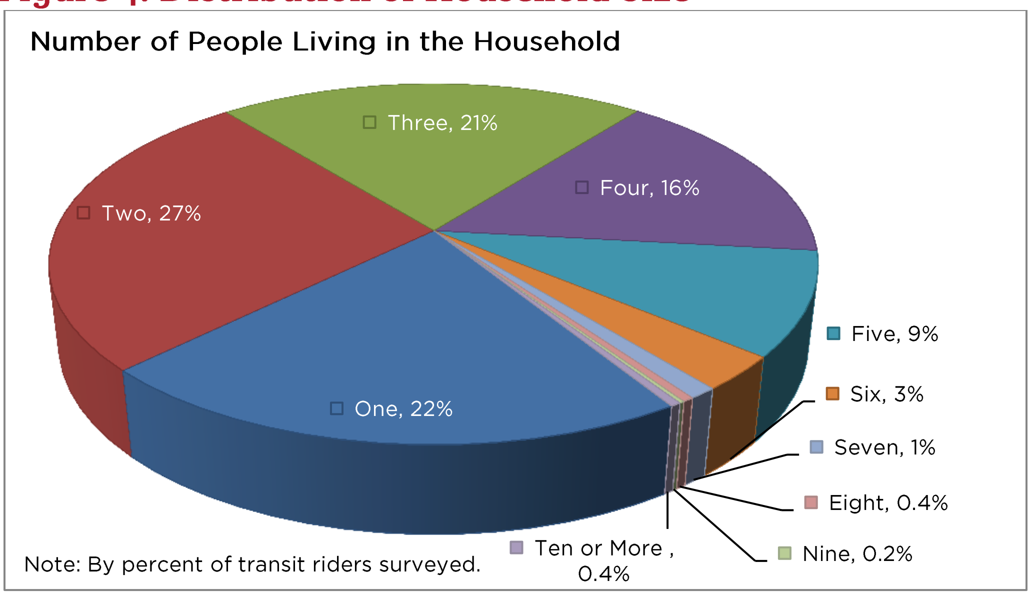


Table 10: Distribution of Household Size

Mode	Number of People Living in the Household				
	One (1)	Two (2)	Three (3)	Four (4)	Five or More
Local	22%	26%	22%	16%	15%
BRT	26%	25%	19%	14%	16%
Express	11%	35%	23%	20%	10%
Total	**22%**	**27%**	**21%**	**16%**	**14%**

HOUSEHOLD INCOME

The distribution of annual household income (Figure 5 and Table 11) shows that 50% of rider households have an annual income of less than $35,000, with 6% earning less than $10,000. About 40% of rider households have an income in the middle range between $35,000 and $75,000, while 10% have an income of $75,000 or higher. 9% of riders didn't know or refused to answer the question.

Transit riders are more likely to be from low-income households as compared to the general population. According to 2015 Census ACS 1-year survey, the median household income for the Hartford-West/Hartford-East/Hartford Connecticut metro area was $72,275, well above the average income of transit riders.

Figure 5: Annual Household Income

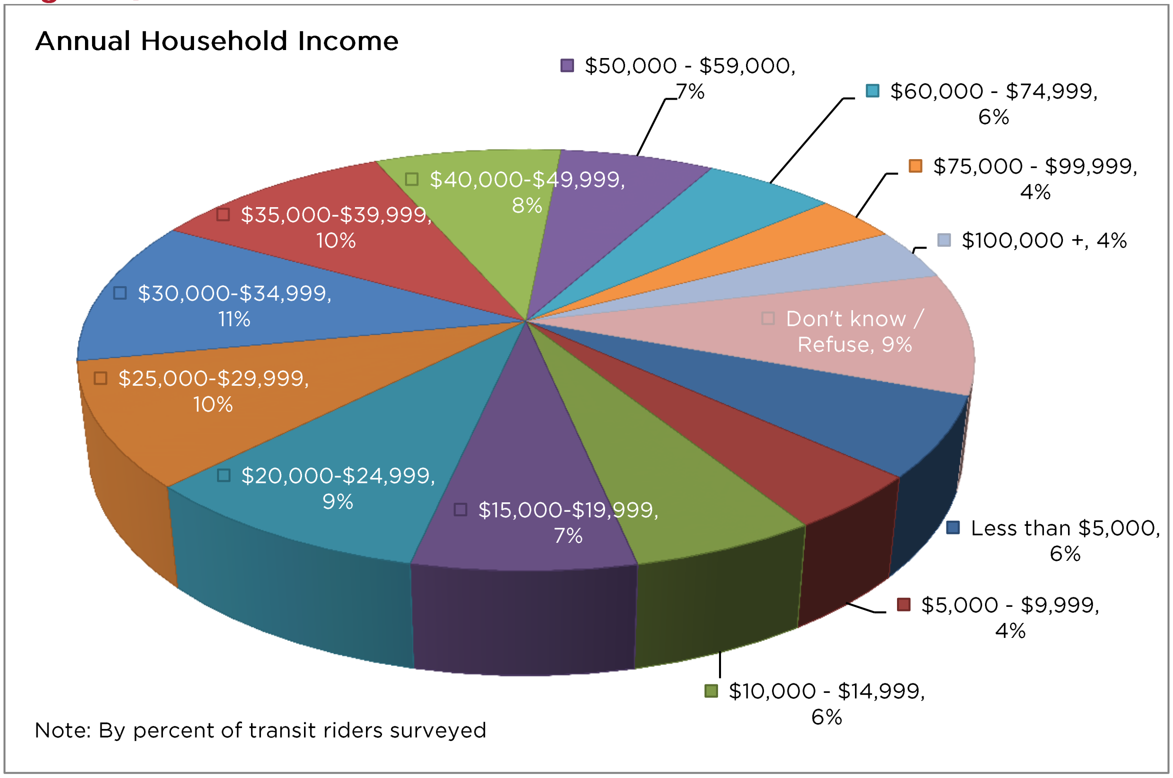


Table 11: Distribution of Household Income

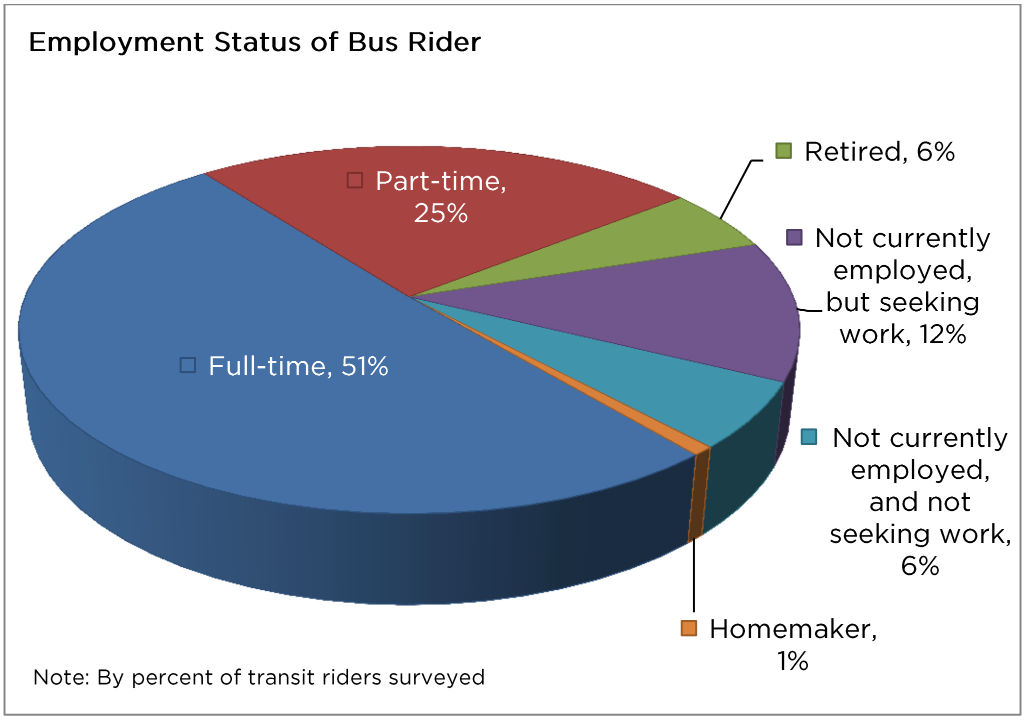
Household Income	Mode			
	Local	BRT	Express	Total
Less than $5,000	7%	6%	0%	6%
$5,000-$9,999	5%	4%	0%	4%
$10,000-$14,999	6%	5%	0%	6%
$15,000-$19,999	7%	7%	1%	7%
$20,000-$24,999	10%	8%	1%	9%
$25,000-$29,999	10%	11%	2%	10%
$30,000-$34,999	11%	13%	5%	11%
$35,000-$39,999	11%	8%	8%	10%
$40,000-$49,999	8%	7%	8%	8%
$50,000-$59,000	6%	8%	12%	7%
$60,000-$74,999	4%	8%	15%	6%
$75,000-$99,999	2%	5%	16%	4%
$100,000+	2%	4%	29%	4%
Don't know/Refuse	10%	6%	3%	9%

EMPLOYED PERSONS PER HOUSEHOLD / EMPLOYMENT STATUS OF RIDER

Seventy-six percent (76%) of transit passengers indicated that they were employed full time or part-time. Retired and homemaker percentages are in line with national averages of 6% and 1% respectively. Also, 18% of bus passengers were unemployed; however 66% of those individuals are currently seeking work.

When looking at respondents' household members' employment status 70% observed are with one or two household individuals employed, 18% with three or more employed individuals, and only 12% households were households with non-employed members. Figure 6 and Table 12 illustrate these findings.

Figure 6: Employment Status and Number of Employed Individuals in Household



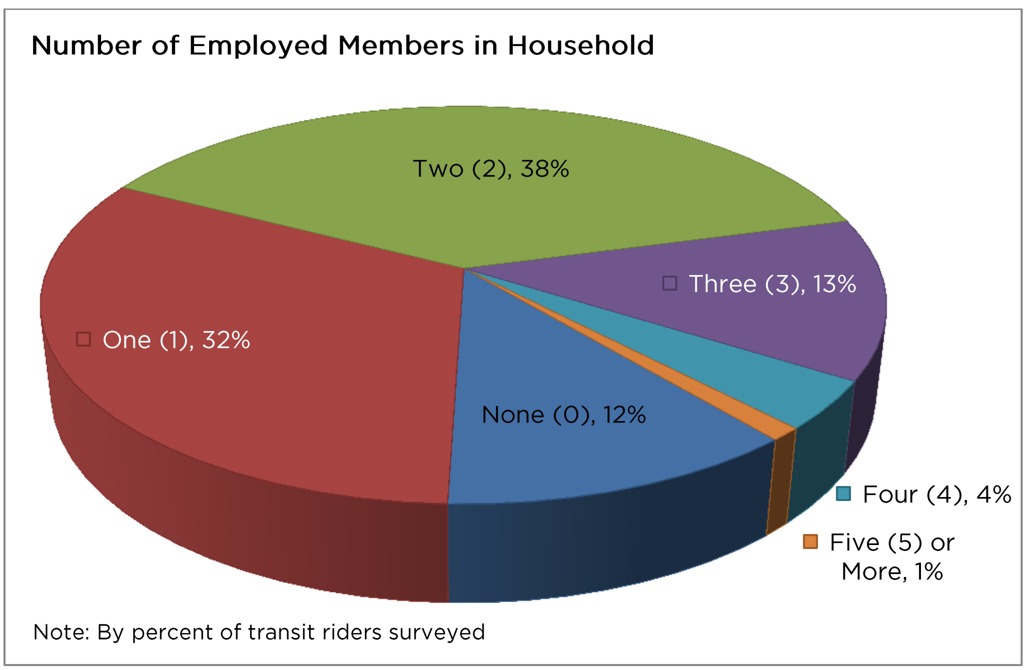


Table 12: Employment Status and Number of Employed Individuals in Household

Mode	Employment Status of Respondent					
	Employed Full-time	Employed Part-time	Retired	Not currently employed, but seeking work	Not currently employed, and not seeking work	Homemaker
Local	47%	26%	6%	13%	7%	1%
BRT	48%	30%	6%	11%	4%	1%
Express	93%	5%	1%	1%	0%	0%
Total	**51%**	**25%**	**6%**	**12%**	**6%**	**1%**

Mode	Number of employed household members in respondents house					
	None (0)	One (1)	Two (2)	Three (3)	Four (4)	Five (5)
Local	13%	32%	37%	13%	4%	1.2%
BRT	11%	35%	37%	13%	3%	0.4%
Express	0%	23%	56%	11%	9%	0.4%
Total	**12%**	**32%**	**38%**	**13%**	**4%**	**1%**

STUDENT STATUS

Twenty-one percent (21%) of all transit passengers indicated they were students with 14% enrolled full-time for college, trade school and or K-12 and Seven percent (7%) of riders' part-time students.

Fourteen percent (14%) of respondents who are employed full and/or part-time were enrolled in a school program. Table 13 illustrates the correlation.

Figure 7: Student Status

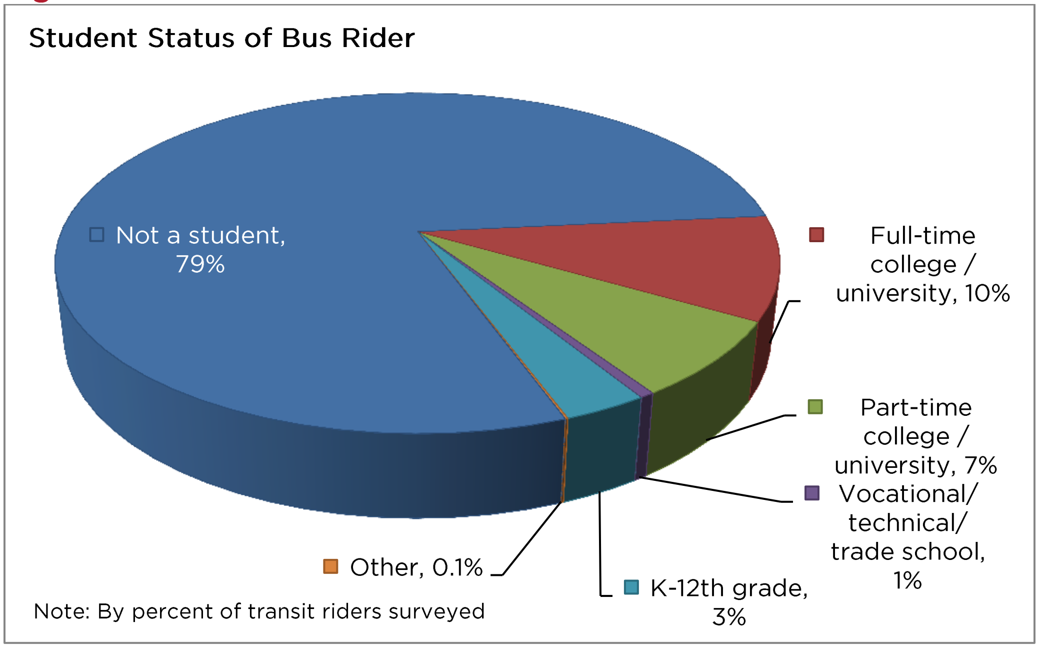


Table 13: Employment Status and Number of Employed Individuals in Household

Respondent student status	Employment Status of respondent					
	Employed Full-time	Employed Part-time	Retired	Not employed, but seeking work	Not employed, and NOT seeking work	Homemaker
Not a student	45.6%	15.7%	5.5%	8.3%	3.2%	0.7%
Yes - Full-time college /university	2.2%	4.7%	0.0%	2.1%	0.8%	0.0%
Yes - Part-time college /university	2.6%	3.6%	0.1%	0.6%	0.4%	0.0%
Yes – Vocational / trade school	0.2%	0.2%		0.1%	0.0%	0.0%
Yes - K-12th grade	0.1%	0.6%		1.1%	1.4%	0.0%
Yes - Other	0.1%	0.0%		0.0%		
Percent of Total	**51%**	**25%**	**6%**	**12%**	**6%**	**1%**

DRIVER LICENSE STATUS

More than half of bus riders do not have a driver's license, however, when viewed from the type of bus service used, the ratio changes. Ninety-three percent (93%) of express bus riders have a driver's license suggesting that their boarding location may require driving. (Table 14)

Table 14: Driver License Status

Has Driving License	Yes	No
Local	38%	62%
BRT	48%	52%
Express	93%	7%
Total	**43%**	**57%**

VEHICLE OWNERSHIP AND AVAILABILITY

Half of the transit rider household owns one or more vehicle. Figure 8 and Table 15 illustrates detail percentages. Forty-eight (48.3%) of all bus riders household do not own a vehicle and solely rely on transit.

Figure 8: Vehicle Ownership

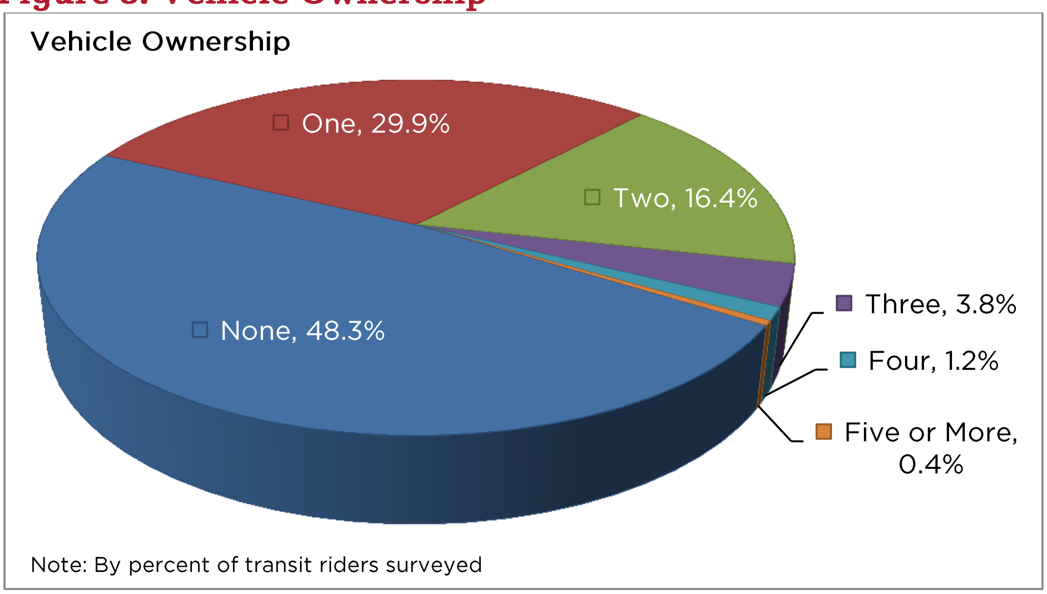


Table 15: Vehicle Ownership

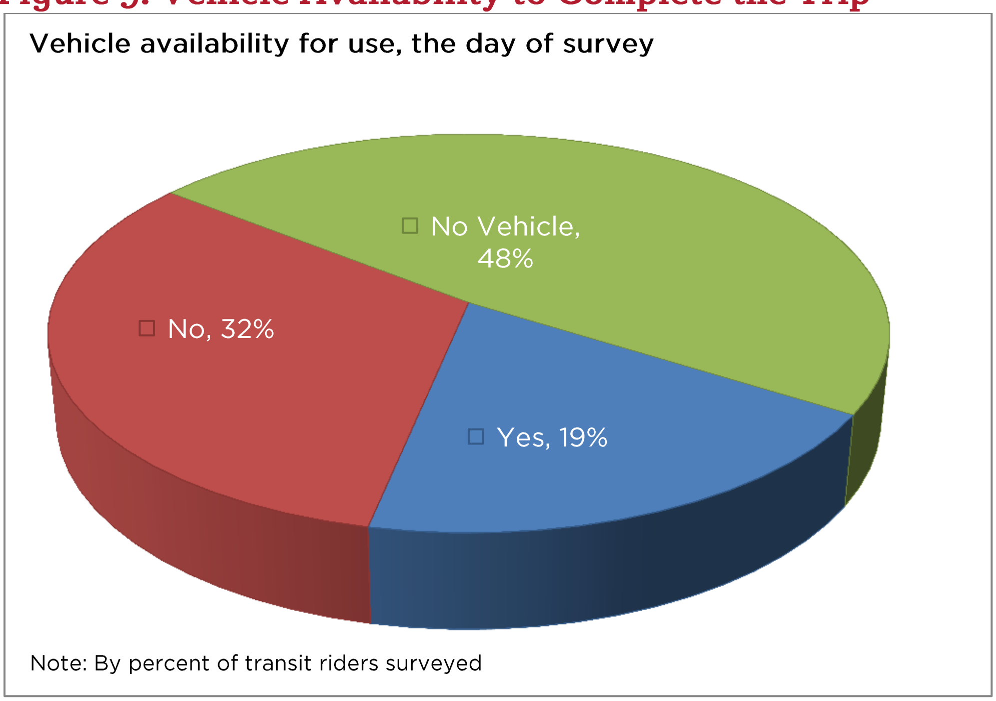
Mode	None (0)	One (1)	Two (2)	Three (3)	Four (4)	Five or More
Local	52%	30%	14%	3%	1%	0%
BRT	45%	31%	16%	5%	2%	1%
Express	10%	28%	43%	14%	4%	1%
Total	**48.3%**	**29.9%**	**16.4%**	**3.8%**	**1.2%**	**0.4%**

Less than twenty percent (19%) of bus riders could have used their own vehicles to complete the trip; 32% of riders with at least one vehicle in the household did not have access to vehicle for this trip, 77% of long distance transit riders, did have a vehicle to complete the trip if needed. Table 16 and Figure 9 show the percent breakout.

Table 16: Vehicle Availability to Complete the Trip

Mode	Yes	No	(No household Vehicle)
Local	13%	34%	52%
BRT	23%	32%	45%
Express	77%	13%	10%
Total	**19%**	**32%**	**48%**

Figure 9: Vehicle Availability to Complete the Trip



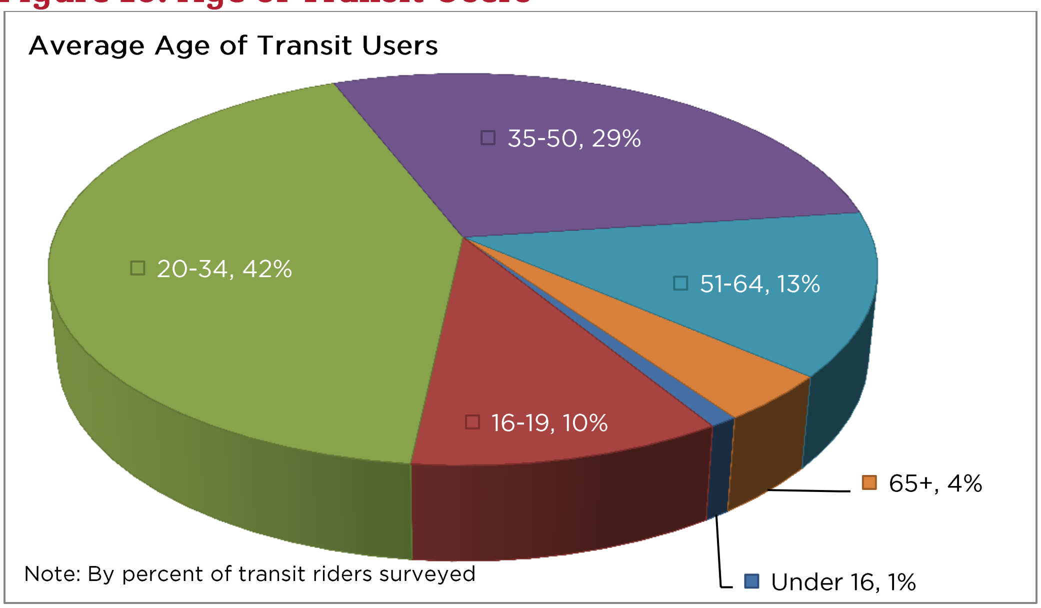
AGE

Table 17 shows the age of transit rider by service type. Seventy-one percent (71%) of all transit riders indicated that they were between the ages of 20 and 50; 11% were 19 and younger, and 17% were age 50 or older. Mode of transit had no impact on the age distribution of riders. Figure 10 illustrates total percentages by age group.

Table 17: Age of Transit Riders

Mode	Age Group					
	Under 16	16-19	20-34	35-50	51-64	65+
Local	1%	11%	42%	29%	13%	4%
BRT	1%	13%	45%	26%	12%	4%
Express	0%	2%	46%	31%	20%	1%
Total	**1%**	**10%**	**42%**	**29%**	**13%**	**4%**

Figure 10: Age of Transit Users



GENDER

Fifty-two percent (52%) of all transit passengers were female; 48% were male. There were no significant differences with regard to gender based on the mode of travel as shown in Table 18 below.

Table 18: Gender of Transit Riders

Mode	Gender		
	Male	Female	Don't Know / Refused
Local	47%	52%	0.3%
BRT	49%	51%	0.1%
Express	46%	54%	0.0%
Total	**48%**	**52%**	**0.2%**

RACE/ETHNICITY

Forty one percent (41%) of transit riders identified themselves as Black or African American; 27% identified themselves as Hispanic or Latino, and 25% identified themselves as White or Caucasian. Express bus passengers were more likely to be White or Caucasian than local bus passengers (21% local bus only vs. 58% express bus only) as shown in Table 19 and Figure 11 below.

Figure 11: Race and/or Ethnicity of Transit Users

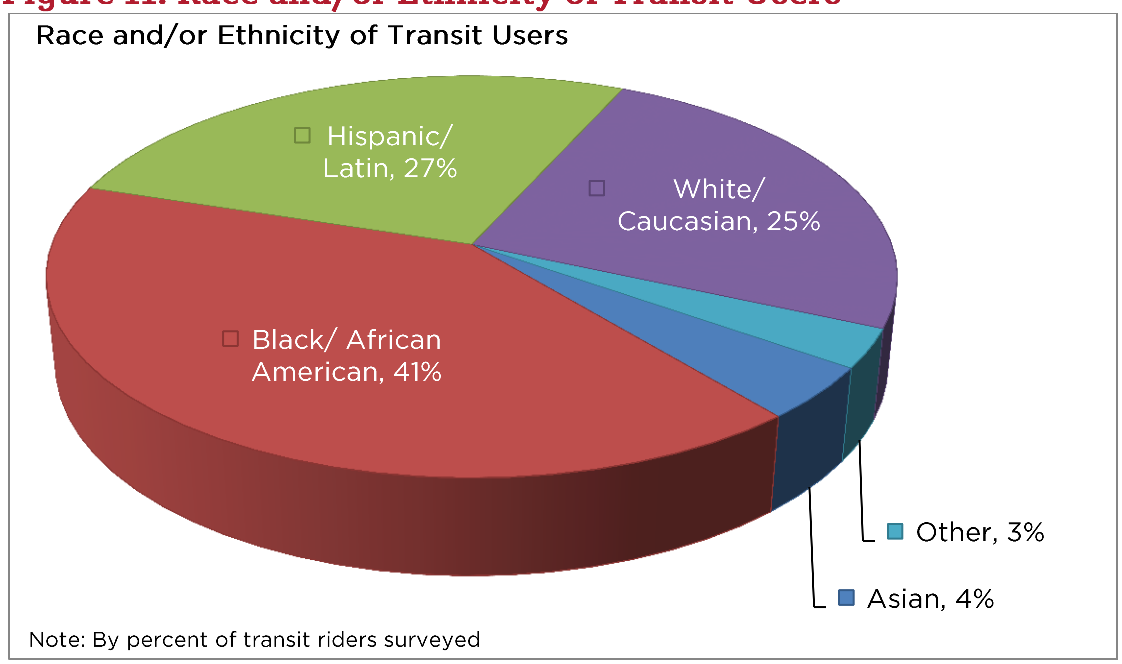


Table 19: Race and/or Ethnicity of Transit Users

Mode	Race / Ethnicity				
	Asian	Black/ African American	Hispanic/ Latin	White/ Caucasian	Other
Local	3%	44%	28.7%	21%	3%
BRT	5%	34%	26.5%	30%	4%
Express	12%	22%	7.2%	58%	1%
Total	**4%**	**41%**	**27%**	**25%**	**3%**

Travel Characteristics

This section highlights selected trip-related findings from the survey. The database used for the tables in this chapter and all chapters were expanded based on weekday linked weight factors created during the data expansion process.

LENGTH OF TIME USING PUBLIC TRANSIT

Eighty five percent (85%) of all transit passengers indicated that they have been using public transit in the Hartford area for at least one year. CT*fastrak* (BRT) users' show 19% new ridership in 2015 since it's opening, and since 41% of BRT riders stated they have been using transit for more than 4 years, it can be assumed they shifted from either local or express bus routes. Figure 12 and Table 20 support these findings.

Figure 12: Length of Time Using Public Transit

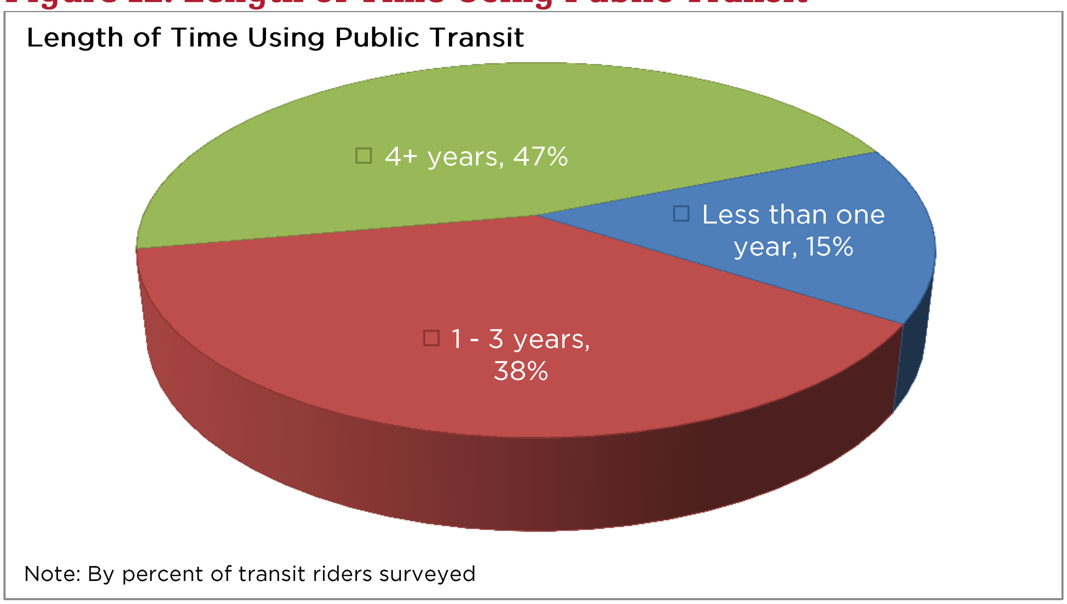


Table 20: Length of Time Using Public Transit

Mode	Length of Time Using Public Transit		
	Less than one year	1 - 3 years	4+ years
Local	15%	36%	49%
BRT	19%	40%	41%
Express	16%	53%	31%
Total	**15%**	**38%**	**47%**

FREQUENCY OF USING PUBLIC TRANSIT

Almost half (46%) of the surveyed riders use CT*transit* 5 days or more a week. Express bus routes show a higher percentage with 65% using public transit 5 days a week. One can assume these riders are commuting to / from work. Figure 13 and Table 21 illustrate the remaining 54% of rider's frequency distribution.

Figure 13: Frequency of Using Public Transit

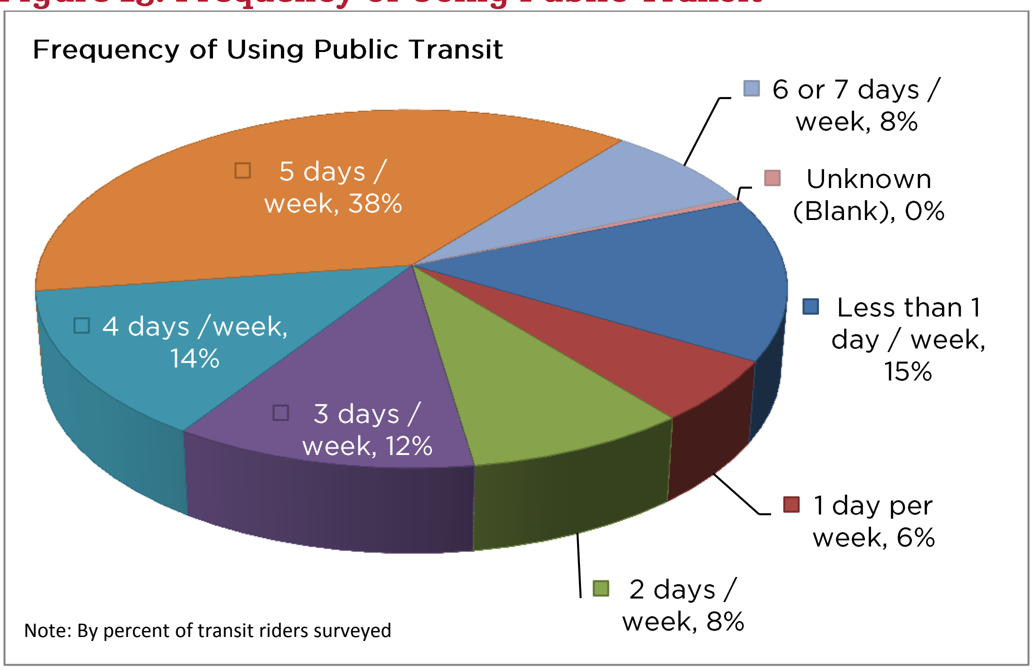


Table 21: Frequency of Using Public Transit

Mode	Frequency of Using Public Transit							
	Less than 1 day / week	1 day per week	2 days / week	3 days / week	4 days /week	5 days / week	6 or 7 days / week	Unknown (Blank)
Local	16%	6%	9%	12%	13%	36%	9%	
BRT	14%	5%	10%	14%	19%	33%	5%	1%
Express	6%	3%	6%	7%	13%	65%	1%	
Total	**15%**	**6%**	**8%**	**12%**	**14%**	**38%**	**8%**	**0%**

PAYMENT METHOD

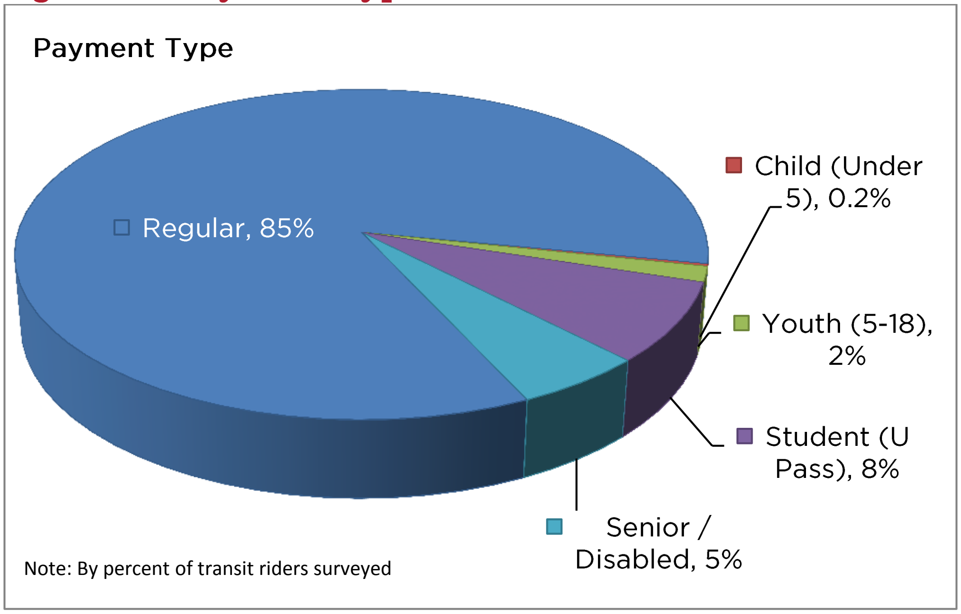
Almost forty percent (39%) of all transit riders still use cash as means to purchase a single ride ticket. Fifty-four percent (54%) utilize a pre-paid payment method (7 types) such as a day pass, 10 ride ticket or monthly pass. Seven percent (7%) of all riders utilize student discount, U Pass. Table 22 illustrates payment method based on the mode of travel.

Table 22: Payment Method

Mode	Payment Method								
	Cash	Day Pass	5 Day Pass	31 Day Pass	2 Hour Pass	3 Day Pass	7 Day Pass	10 Ride Ticket	U Pass (Student discount)
Local	41%	14%	3%	22%	3%	0%	1%	9%	7%
BRT	37%	14%	2%	22%	2%	0%	2%	11%	9%
Express	13%	7%	5%	53%	0%	-	1%	17%	3%
Total	**39%**	**14%**	**3%**	**24%**	**3%**	**0%**	**1%**	**10%**	**7%**

The vast majority of transit riders pay the regular price for a transit ticket(s). Youth, students, and seniors make up only 15% of discounted ticket holders. Children (under 4 years old) that travel for free accounted for minor value of less than one percent. Figure 14 shows the discount breakdown.

Figure 14: Payment Type



NUMBER OF TRANSFERS

Almost three quarters (72%) of public transit users made zero transfers during their trip. Twenty eight percent (28%) made one or more transfers. Passengers who used express buses were least likely to make any transfers. Table 23 illustrates the number of transfers by mode.

Table 23: Number of Transfers

Mode	Number of Transfers			
	0	1	2	3 or more
Local	70%	29%	1%	0.0%
BRT	75%	22%	2%	0.1%
Express	93%	7%	0%	0.1%
Total	**72%**	**27%**	**1%**	**0%**

LENGTH OF TRIP

Express bus routes had the highest percentage of longest trips at 61% for 9 miles or more. The distance was measured from boarding to alighting location and categorized into four categories to obtain a summary, which is shown in Table 24: The longest trip recorded was by a rider from Old Saybrook traveling to Hartford; this individual rode route 921 the entire 40 plus miles. The shortest trip length was 0.1 mile a distance between two stops on one route.

Table 24: Average Trip Length

Mode	Average Trip length (Boarding-Alighting)			
	0 - 3	3 - 6	6 - 9	9 or more
Local	61%	27%	9%	3%
BRT	34%	28%	32%	6%
Express	1%	9%	29%	61%
Total	**53%**	**26%**	**13%**	**7%**

It should be noted that the distance calculated was using a "Great Circle Distance formula" where coordinates (latitude & longitude) of boarding and alighting was used to obtain a straight line distance.

TRIP ORIGIN

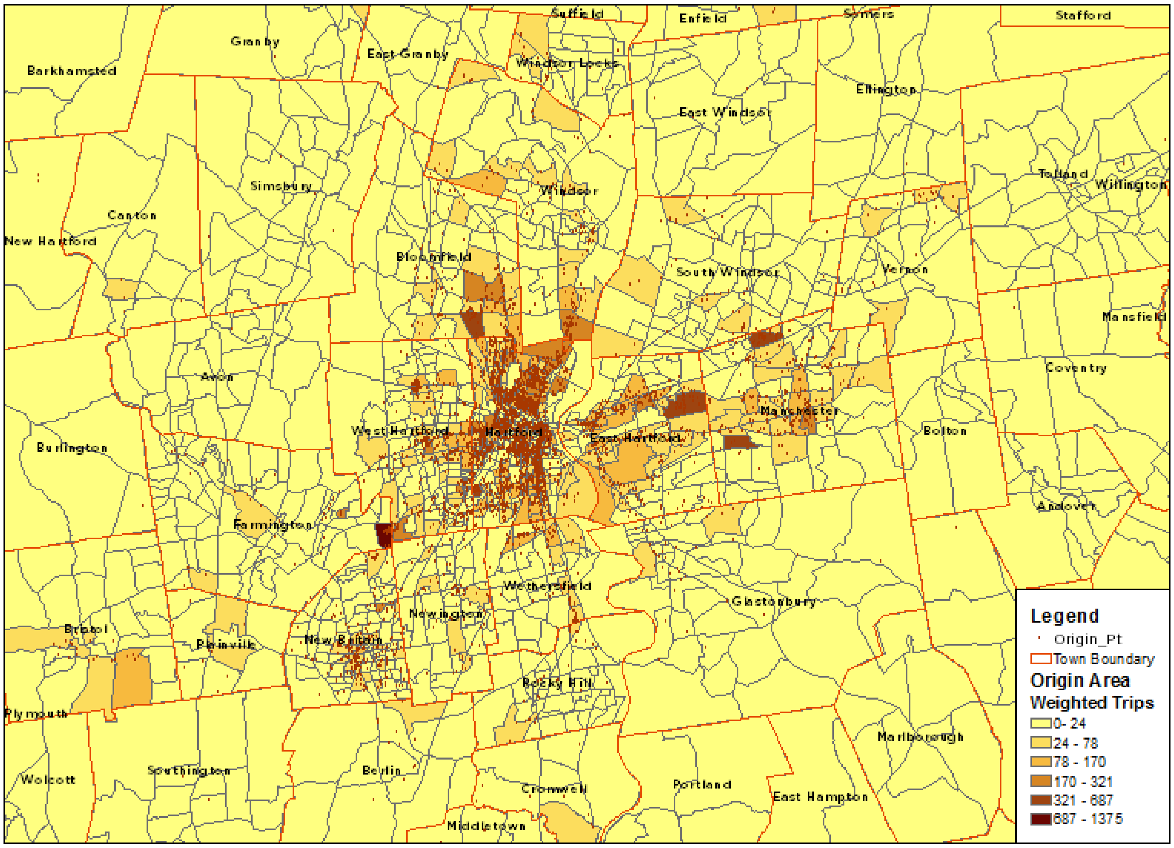
Approximately fifty-four percent (54%) of riders begin their trips from home and another 22% begin their trips from work or a work-related location. This indicates that most riders' (76%) bus trips are to and from home or work. Four percent (4%) of riders had their trip originate at school. Table 25 shows percentage breakdown by mode and five location types.

Table 25: Type of Place Respondent is Coming From:

Mode	Type of place respondent is coming from				
	Home	Work	School	Other	Airport
Local	54%	20%	4%	21%	0.2%
BRT	53%	22%	6%	19%	0.1%
Express	51%	46%	1%	2%	0.1%
Total	**54%**	**22%**	**4%**	**20%**	0.2%

In addition, Figure 15 graphically illustrates the density of trip origins. Since town boundaries were too generic, a Traffic Analysis Zone (TAZ - towns divided into relatively similar areas of land use and land activity) was used to illustrate which areas are hot spots. The darker the color the more trips originate from the area. The dots on this map show the origin address of respondents to the survey.

Figure 15: Location of Trip Origins



TRIP DESTINATION

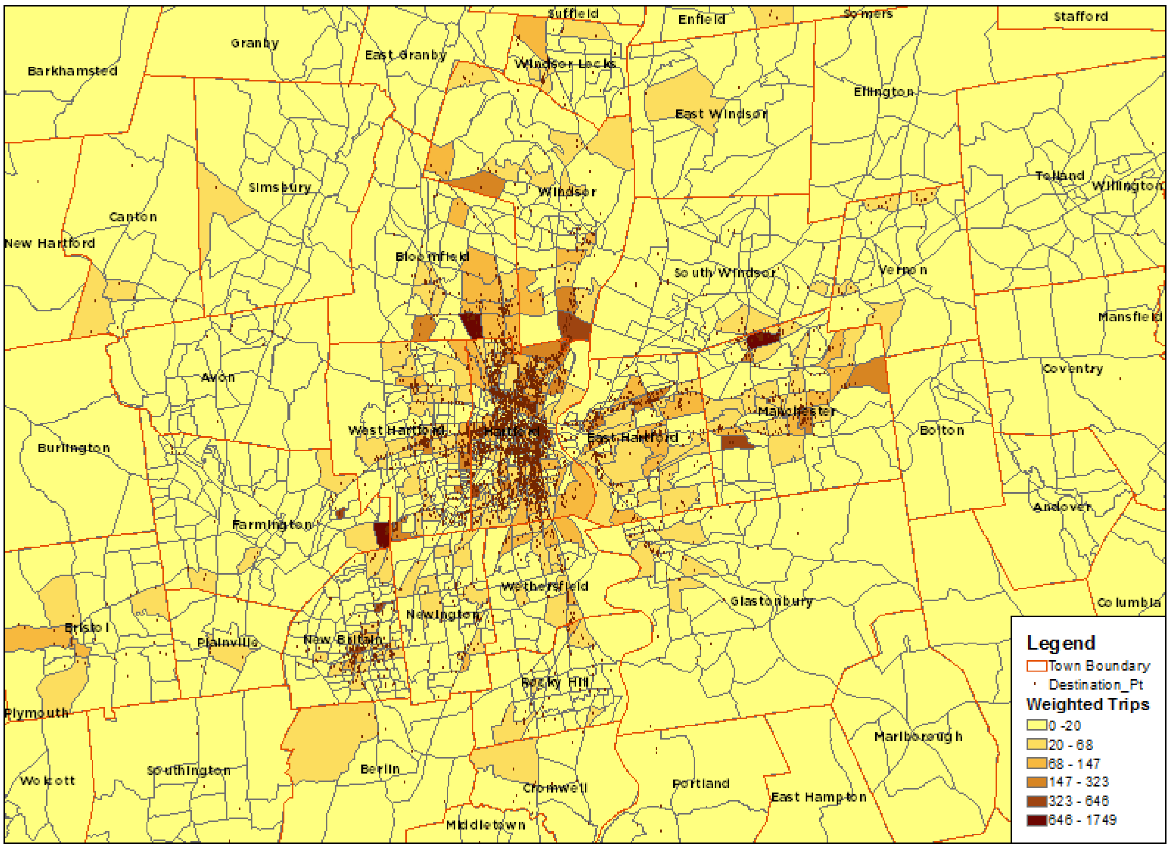
Similarly to the origins, most transit rider's trips are either to home or work (69%) with thirty-seven percent (37%) home destination. School trips account for 5 % of total trips and airport trips account for only small percentage of trips (0.2%). Other trip purposes such as: medical appointment, shopping, dining out, recreational, and etc., account for a quarter of all trips. Table 26 shows percentage breakdown by mode and five location types.

Table 26: Type of Place Respondent is Going to Now:

Mode	Type of place respondent is going to now				
	Home	Work	School	Other	Airport
Local	36%	32%	5%	27%	0.2%
BRT	37%	26%	9%	28%	0.0%
Express	44%	51%	2%	4%	
Total	**37%**	**32%**	**5%**	**25%**	**0.2%**

Graphically (Figure 16) the trip destination shows heavy concentrations in Harford (dark brown areas) and a few other generators, such as malls in Farmington and Manchester, medical centers, social services, etc. The dots on the map pin-point the exact locations of the trip destination.

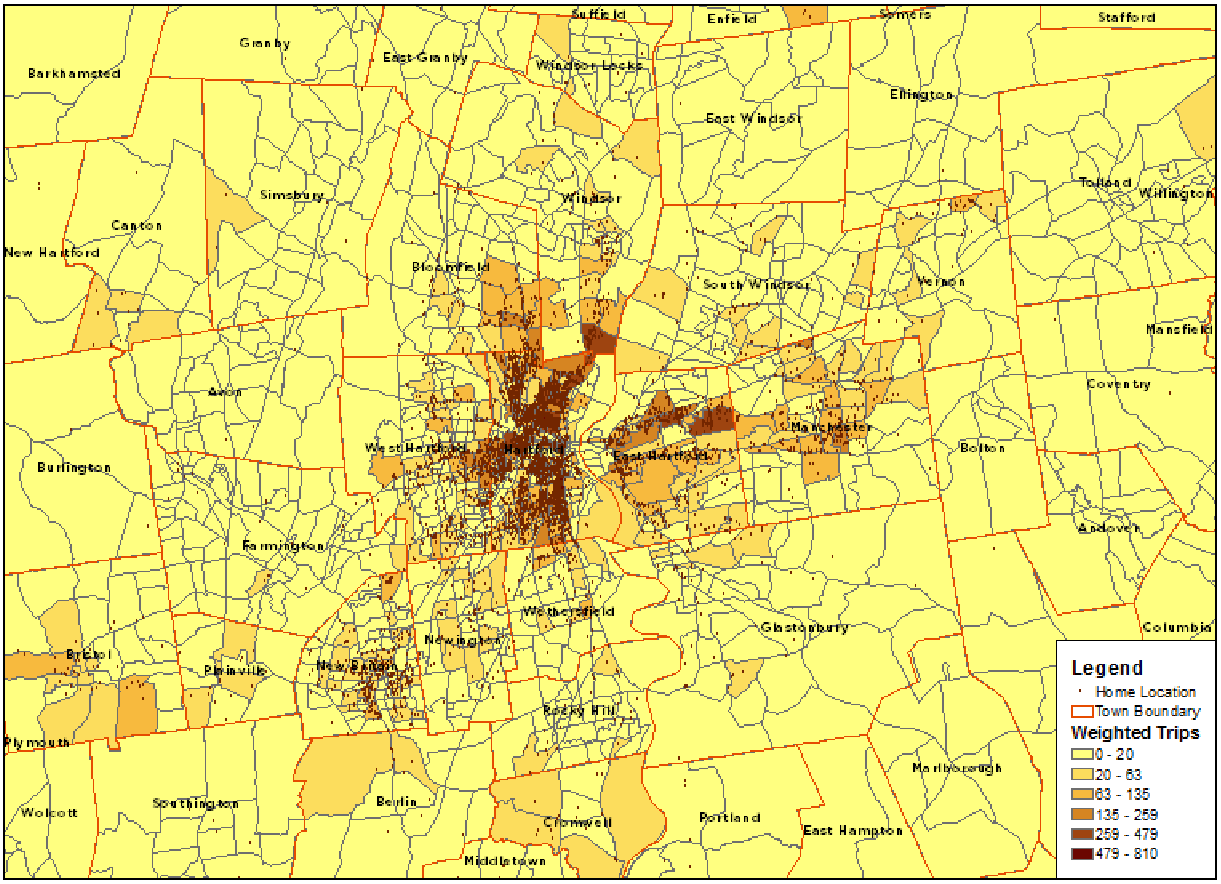
Figure 16: Location of Trip Destinations



WHERE TRANSIT USERS LIVE

Another graphic metric is to compare the location of trip origin or destination to a home address. Figure 17 illustrates home locations of transit riders in the region. Overlaying this information with bus routes can show the distance a rider must traverse to or from the bus stop.

Figure 17: Home Location of Bus Riders



Harford and East Harford are the primary transit users. Riders that reside in Windsor live along the bus routes or Route 159, similarly in Manchester along Route 44 and Route 83.

ACCESS MODE

How passengers first access public transit for their one-way trip by service type is shown in Table 27. Most (94%) of transit passengers indicated that they accessed public transit by walking all the way. Local and CT*fastrak* riders were significantly more likely to report walking to public transit than express bus riders (97% and 90% for local and CT*fastrak* vs. 59% for express). Express bus passengers were more likely to access public transit by driving alone and parking (28%). Express bus passengers were also significantly more likely to access public transit by being dropped off by someone else (7% express vs. 1% local bus and CT*fastrak*).

Table 27: Access Mode to Transit System

Mode	Access Mode			
	Walk	Bike	Drove alone and parked	Other
Local	97%	1%	0%	1%
BRT	90%	2%	5%	2%
Express	59%	3%	28%	10%
Total	**94%**	**1%**	**3%**	**2%**

EGRESS MODE

The vast majority of the riders (94%) walk to their desired destination once they egress transit. (Table 28) Only express bus riders showed variation in their egress mode, for example, twenty percent drove alone after to reach their destination.

Table 28: Egress Mode from Transit System

Mode	Egress Mode			
	Walk	Bike	Drove alone and parked	Other
Local	97%	1%	0%	2%
BRT	93%	2%	1%	4%
Express	63%	3%	20%	14%
Total	**94%**	**1%**	**2%**	**3%**

When paired with the calculated distance between alighting stop and destination, 80% of riders walk less than one mile. Ten percent (10%) of individuals walk anywhere between one to two miles, and the remaining are individuals who walked more than 2 miles. (Table 29)

Table 29: Distance walked between Alighting and Destination

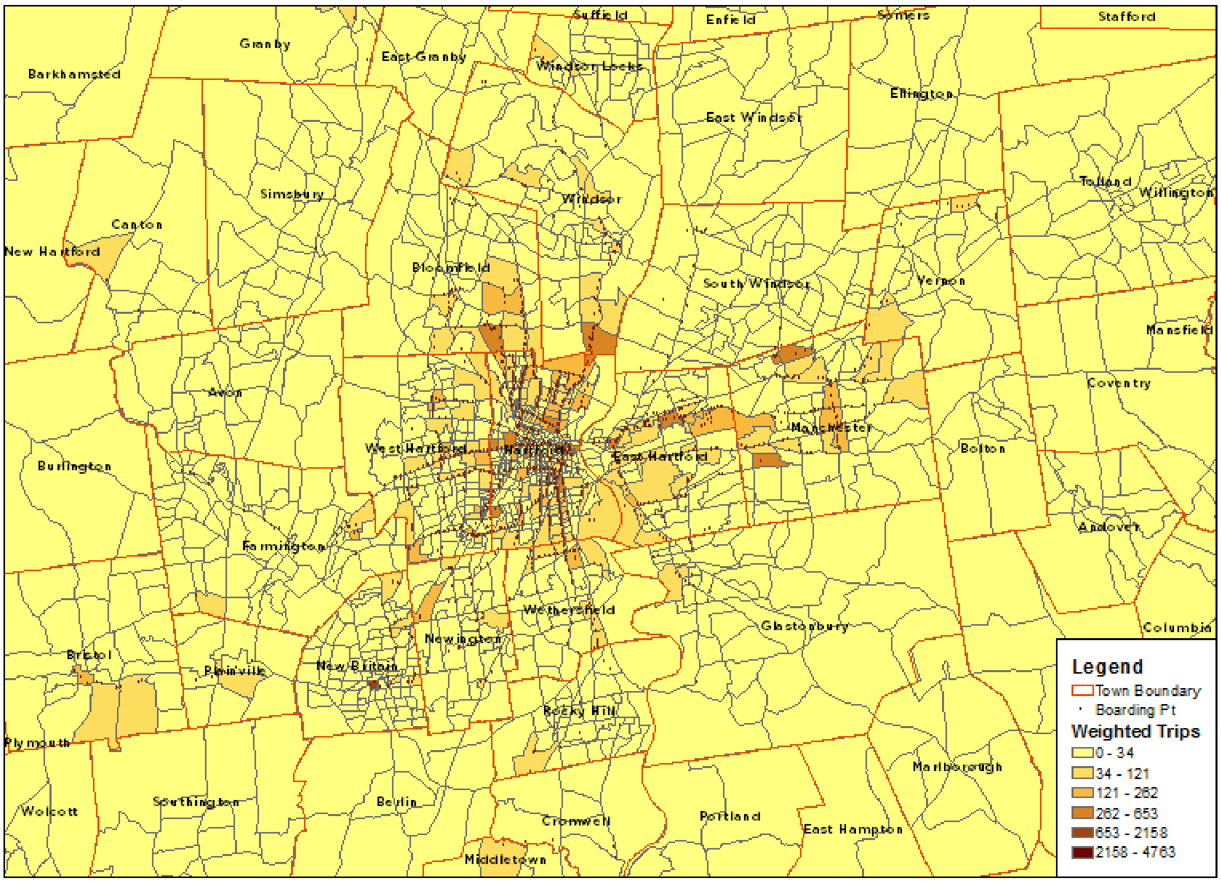
Mode	Distance Walked between Alighting & Destination			
	0 - 1	1-2	2-5	5 or more
Local	80%	11%	6%	4%
BRT	78%	12%	6%	4%
Express	90%	4%	4%	2%
Total	**80%**	**10%**	**6%**	**4%**

Note: Data filtered to just walk mode

TRANSIT BOARDING AND ALIGHTING

Figure 18 illustrates where transit riders boarded the bus. Since the travel distance between origin and boarding is less than 1 mile for 78% of riders, the graphic between origin of trip location (Figure 15) and boarding (Figure 18) will be similar. The point layer will have all the access locations aligned with bus stop locations, whereas the origin map has the points at various locations within in TAZ.

Figure 18: Location Where Bus Riders Boarded the Bus

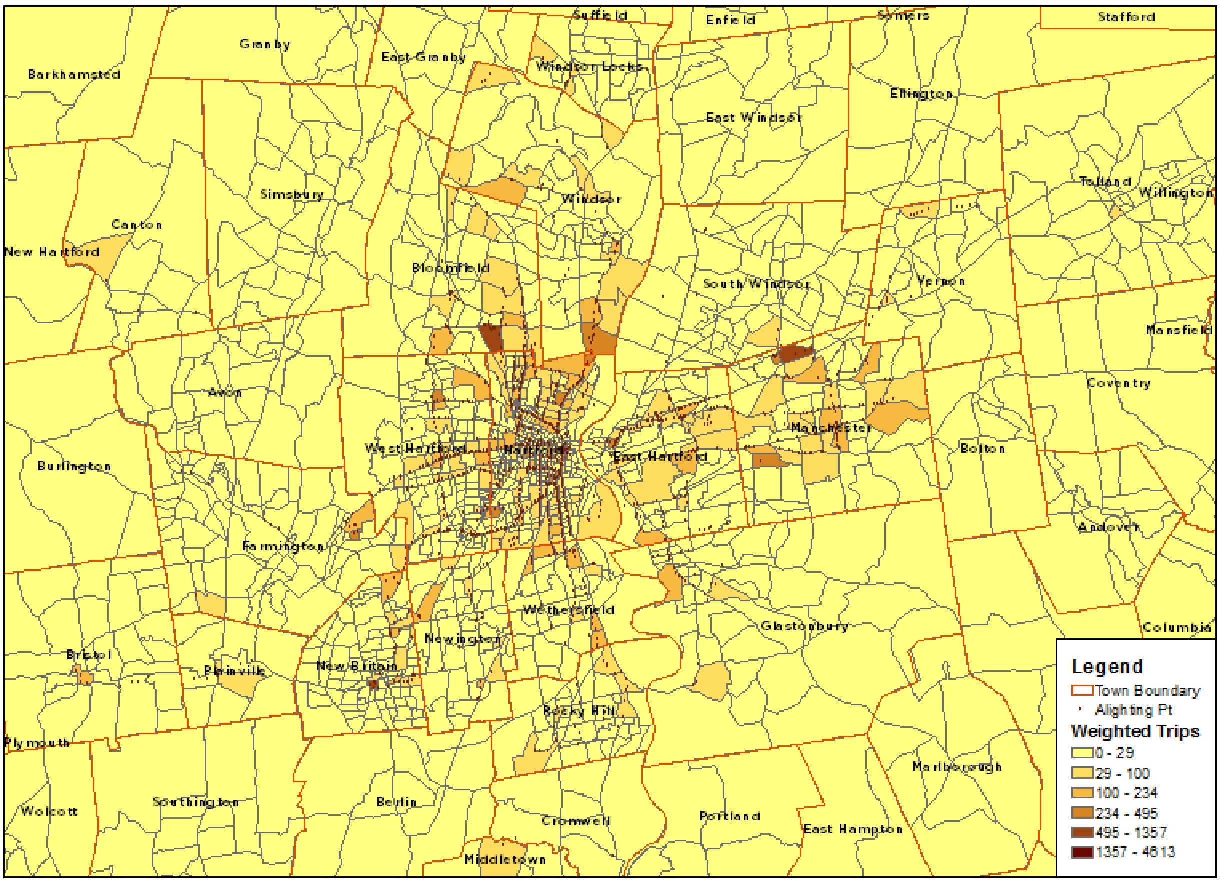


The alighting location map (Figure 19) will be similar to trip destination map (Figure 16). This is because the majority of transit riders (78%) traverse less than 1 mile between alighting and trip destination (Table 30). Furthermore, when paired with walk as the only access mode to transit the percentages remain similar with 0-1 mile range increase from 78% to 80% (Table 29).

Table 30: Distance between Alighting and Destination

Mode	Distance between Alighting & Destination			
	0 - 1	1-2	2-5	5 or more
Local	78%	11%	6%	4%
BRT	76%	12%	7%	4%
Express	69%	10%	16%	5%
Total	**78%**	**11%**	**7%**	**4%**

Figure 19: Location Where Bus Riders Alighted the Bus



SUMMARY

This chapter presented the demographic and travel behavior characteristics of Hartford division transit riders.

Below are some important findings about these riders:

- The demographics indicate that riders are more likely to be from low-income households; 53% of riders have an annual household income less than $35,000.
- About 25% of riders are transit dependent, i.e., they are from households that do not own any vehicles and 81% of riders reported they did not have a vehicle available for the trip they were making while being surveyed. Of these transit dependent riders, 60% are from households with an annual income less than $35,000.
- 75% riders are employed, with more than half (51%) employed full-time.
- The majority of riders are between 20 and 50 years of age. Transit riders are more likely to be from larger, low-income, and zero-vehicle households.
- The travel behavior characteristics of riders indicate that home and work are the most common trip origins and destinations; 76% of riders make home or work trips using transit.
- Walking is the dominant access and egress mode for all riders.
- 72% of riders make zero transfers to complete their one-way trip.

9. DECOMPOSITION ANALYSIS

The decomposition analysis reviews all transit routes used by survey respondents and looks to see how many riders transferred to each route and from each route. This allows us to determine whether the total ridership estimated from the linked trip weight using all the routes adds up to the total boardings on a particular route as well as the total boardings for the entire system.

Decomposition Summary for All Records

A very small overall difference of 0.9% between linked and unlinked trips was found. It was determined that the asymmetry between linked and unlinked trips was largely due to the inclusion of 21 additional transfer options in the linked trip weighting scheme which were not included in route sampling, such as New Britain routes 501 Arch Street, 512 Berlin Turnpike, and others. Analysis by route type shows that weights are very close for local and express routes while there is a slightly larger difference for CT*fastrak* routes, where many of these non-surveyed route transfers occur. The differences seen on CT*fastrak* are still very small and well within the acceptable range. Table 31 provides a summary of decomposition analysis and Appendix D provides a more detailed look by route.

Table 31: Decomposition Summary

	Segment	Linked Trips	Unlinked Trips	Absolute Difference	Percent Difference
Route Type	Local	51,202	51,471	269	-0.5%
	BRT	7,808	8,053	244	-3.1%
	Express	3,886	3,922	35	-0.9%
Overall	**Total**	**62,896**	**63,445**	**549**	**-0.9%**

10. LESSONS LEARNED AND OPPORTUNITIES FOR IMPROVEMENT

Although the number of completed surveys and the quality of the survey data exceeded the contractual requirements for the project, the research team identified a few opportunities for improvement to enhance the quality of future surveys based on lessons learned from the 2016 Hartford On-Board Transit Survey. The opportunities are briefly described below.

- **Availability of Automatic Passenger Counting (APC) data** – APC data would have provided an additional means of verifying the manual ridership counts performed annually. At the time of data collection, APC equipment was being installed on local Hartford transit buses. Only CT*fastrak* buses had APC equipment already installed, but a partial dataset was not deemed useful. Manual ridership checks from 2014 and 2015 were used to develop a sampling plan for the survey.

- **Additional focus on stop list:** Since this issue was not identified until after the administration of the survey began, manual geocoding of some bus stops was required on routes for which the stop inventory was not completed prior to the start of survey. If a stop inventory had been completed before the survey began, the location of all bus stops on each route could have been included in the tablet PC survey program, which would have minimized the number of boarding and alighting locations that had to be manually geocoded after the survey was administered. In addition, we also encountered several stop locations that could have been considered as one.

- **Availability of Previous Surveys** – while most the survey questions were similar to previous on-board survey efforts, there were differences in sample size, survey administration methodology, timing of survey administration, and details in title VI and trip information questions. These differences made it impossible to develop trend analysis.

- **Additional Title VI Question - Dependency on Transit** – While we took care of asking all standard title VI questions, after survey development we discovered that our survey does not ask "How Transit Users Would Complete Their Trip If Transit Were Not Available". This could have been a question with preselected categories such as: I could not make this trip, Drive with someone else, Walk or Bike, Taxi / Uber, Drive Myself, and Other.

LIMITATIONS OF THE DATA

Although the sampling and completeness goals for this survey were met or exceeded in all areas, the survey database does have limitations. The limitations listed below are intended to provide guidance to persons who will use data from this survey to conduct analysis in the future. The list is not all inclusive, and anyone using the database should consider other limitations that are common to databases that area obtained from random or stratified random sampling.

- **Weekend:** Weekend travel patterns are not represented in this database. This survey did not include weekend trips. Although weekend trips may have similar characteristics to trips completed during weekdays, this survey only included trips that were completed Monday through Friday.

- **Special Event:** Special event travel patterns are not represented in this database. This sampling plan was desired to capture data from transit users on a typical weekday. In order to ensure the data reflected a "typical" weekday, routes were not surveyed on days that special events were conducted along the route.

- **Low volume:** Lower volume route data may not be statistically representative of individual lower volume routes. Since many lower volume routes have unique characteristics, the data for lower volume routes may not be representative of the routes that were not included in the sample. Every effort was made to select a representative cross-section of lower volume routes, but caution should be used for any routes that have fewer than 50 completed surveys.

APPENDIX A

Survey Instrument

Paper Survey

Figure 20: On-Board Transit Survey (Paper): Trip Information: PG1

I-84 On-Board Transit Survey

(for office use only) Route Code: ______ Dir: N S E W Time: ______ am / pm Interviewer: ______ Serial #: ______

Please take a few moments to help plan for your transit needs by filling out this survey.

All personal information will be kept strictly confidential and WILL NOT be shared or sold.

What is your **HOME ADDRESS?** (please be specific, ex: 123 W. Main St):
(If you are visiting the Hartford area, please list the ***hotel name*** *or address where you are staying)*

Street Address ______ City ______ State ______ Zip Code ______

COMING FROM?

1. What type of place are you **COMING FROM NOW?** (the starting place for your one-way trip)
   - O Your usual WORKPLACE
   - O Other business related
   - O College / University (students only)
   - O Airport (as an air passenger)
   - O Recreation / sightseeing
   - O Medical appointment / doctor's visit
   - O Social visits (friends/relatives)
   - O Personal business (bank, post office)
   - O Pick up/drop off someone (daycare, school)
   - O Your HOME
   - O Shopping
   - O Eating/Dining Out
   - O School (K-12) (students only)
   - O Hotel/motel
   - O Sporting event
   - O Other: ______
2. What is the **NAME** of the place you are coming from now?

   ______
3. What is the **EXACT ADDRESS** of this place? (**OR** nearest intersection/ business if you do not know the exact address:)

   ______

   City: ______ State: ______ Zip: ______
4. How did you **GET FROM** the place in Questions #1-3 TO THE VERY **FIRST** bus / Amtrak you used for this one-way trip?
   - O Walk O Bike O Wheelchair
   - O Drove alone and parked (answer 4A)
   - O Was dropped off by someone going somewhere else (answer 4A)
   - O Drove or rode with others and parked (answer 4A)
   - O Car share (e.g. ZipCar, etc.) (answer 4A)
   - O Taxi, Uber, Lyft, etc. (answer 4A)
   - O Other: ______

   4A. Where did you board the FIRST bus / Amtrak you used for this one-way trip? (Nearest intersection / Park-n-Ride lot):

   ______

GOING TO?

5. What type of place are you **GOING TO NOW?** (the ending place for your one-way trip)
   - O Your usual WORKPLACE
   - O Other business related
   - O College / University (students only)
   - O Airport (as an air passenger)
   - O Recreation / sightseeing
   - O Medical appointment / doctor's visit
   - O Social visits (friends/relatives)
   - O Personal business (bank, post office)
   - O Pick up/drop off someone (daycare, school)
   - O Your HOME?
   - O Shopping
   - O Eating/Dining Out
   - O School (K-12) (students only)
   - O Hotel/motel
   - O Sporting event
   - O Other: ______
6. What is the **NAME** of the place you are going to now?

   ______
7. What is the **EXACT ADDRESS** of this place? (**OR** nearest intersection/ business if you do not know the exact address:)

   ______

   City: ______ State: ______ Zip: ______
8. How will you **GET TO** your destination (listed in Qs #5-7) after you get off the **LAST** bus / Amtrak you will use for this one-way trip?
   - O Walk O Bike O Wheelchair
   - O Drove alone and parked (answer 8A)
   - O Was dropped off by someone going somewhere else (answer 8A)
   - O Drove or rode with others and parked (answer 8A)
   - O Car share (e.g. ZipCar, etc.) (answer 8A)
   - O Taxi, Uber, Lyft, etc. (answer 8A)
   - O Other: ______

   8A. Where will you get off the LAST bus / Amtrak you are using for this one-way trip? (Nearest intersection / Park-n-Ride lot):

   ______

9. Did you transfer FROM another bus/train BEFORE getting on this bus? O Yes O No
10. Where did you GET ON THIS bus? Please provide the nearest intersection / station name / Park-n-Ride lot: ______
11. Where will you GET OFF THIS bus? Please provide the nearest intersection / station name / Park-n-Ride lot: ______
12. Will you transfer TO another bus/train AFTER getting off this bus? O Yes O No
13. *(a) How many transfers will you make for this one-way trip?* ______
    (b) Please list the BUS / TRAIN ROUTES in the exact order you use them for this one-way trip (Including the Amtrak, CTfastrak, CTtransit, DASH, Greyhound, Peter Pan, Megabus, etc.)

START → ______ → ______ → ______ → ______ → **END**

1st Route | 2nd Route | 3rd Route | 4th Route

Continue

Figure 21: On-Board Transit Survey (Paper): Demographic Information: PG2

OTHER INFORMATION ABOUT THIS TRIP

14. What time did you BOARD this bus? ______ : ______ am / pm (circle one)

15a. What fare payment methods were used for this one-way trip? (Select all that apply) (Zone 1 prices)
O Cash ($1.50) O Day Pass ($3) O 5 Day Pass($12) O 31 Day Pass ($54)
O 2 Hr Pass ($1.50) O 3 Day Pass($7.50) O 7 Day Pass($16.50) O 10 Ride Ticket($13.50)
O Free (4-Yrs Old & younger) O U Pass (Student discount) O Other (Transfer-Free) ______________

15b. What type of fare was this? *(choose only one answer)*
O Regular O Child (Under 5) O Youth (5-18) O Student (U Pass) O Senior / Disabled

16a. Will you (or did you) make this same trip using the same transit routes in exactly the opposite direction today? ONo OYes

16b. (If 16a = Yes) At what time did/will you leave for this trip in the opposite direction? _____:_____ am/pm (circle one)

17. How often do you usually make this trip by bus?
O Less than 1 day / week O 1 day per week O 2 days / week O 3 days / week
O 4 days /week O 5 days / week O 6 or 7 days / week

18. How many years have you been riding CT*transit* / CT*fastrak*? O Less than 1 year O 1-3 years O 4 or more

ABOUT YOU AND YOUR HOUSEHOLD

19. How many WORKING vehicles (cars, pick-up trucks, SUVs) are available to your household? ____ vehicles.

19a. [If #19 is more than NONE] Could you have used one of these vehicles for this trip? OYes ONo

20. Including YOU, how many people live in your household? _______ people.

21. What is your employment status? *(check the one response that BEST describes you)*
O Employed full-time O Employed part-time
O Not currently employed O Disabled and unable to work
O Retired O Homemaker

22. Including YOU, how many people (over age 15) in your household are employed full/part-time? ___ people

23. Are you a student? *(check the one response that BEST describes you)* O No, I am not a student
O Yes – Fulltime College/University O Yes – Part-time College/University O Yes – K - 12th grade
O Yes – Other: ____________________

24. Are you a licensed driver? OYes ONo

25. How many licensed drivers are in the household? ____

26. What is your AGE? O Under 16 O 16-19 O 20-34 O 35-50 O 51-64 O 65+

27. What is your Race and/or Ethnicity? *(check all that apply)*
O American Indian / Alaska Native O Asian O Black/African American
O Native Hawaiian / Pacific Islander O White / Caucasian O Other: ______________
O Hispanic / Latino / Spanish *(includes: Mexican/Mexican American, Puerto Rican, Cuban/Cuban American, Columbian, Nicaraguan, etc.)*

28. What is your gender? O Male O Female

29. Which of the following BEST describes your TOTAL ANNUAL HOUSEHOLD INCOME in 2015 before taxes?
O Less than $5,000 O $15,000 - $19,999 O $30,000 - $34,999 O $50,000 - $59,999
O $5,000 - $9,999 O $20,000 - $24,999 O $35,000 - $39,999 O $60,000 - $74,999
O $10,000 - $14,999 O $25,000 - $29,999 O $40,000 - $49,999 O $75,000 - $99,999
O $100,000 or more

30. Do you speak a language other than English at home? O No OYes - Which language? ___________

30a. [If #30 is Yes] How well do you speak English? O Very well O Well O Less than well O Not at all

REGISTER TO WIN $100

People who submit an accurately completed survey will be entered in a random drawing for one of Five $100 Visa gift cards. You must provide your home address at the beginning of the survey to be eligible.

Your Name: ______________________

Phone Number: (____) ______________

Thank you for your help!

If you completed this survey before getting off the bus, please return this survey to the survey staff.

APPENDIX B

Survey Instrument

Tablet version

Figure 22: On-Board Transit Survey (tablet): Start-up Page

Figure 23: On-Board Transit Survey (tablet): Interviewer initials/ Identification

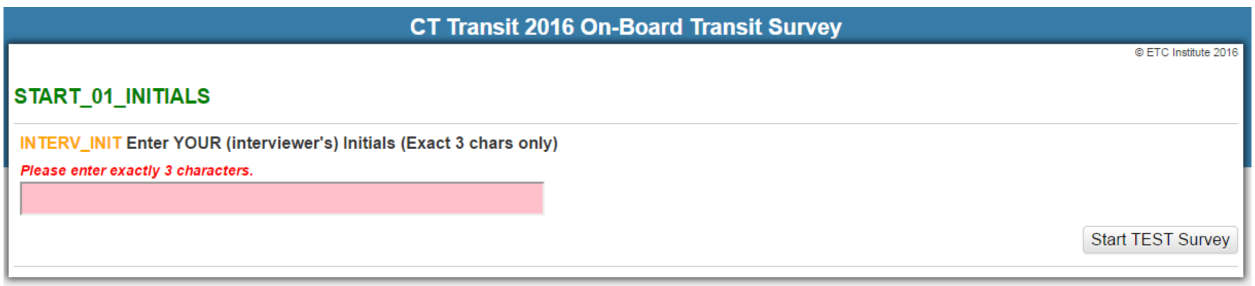


Figure 24: On-Board Transit Survey (tablet): Select Route the Surveyor is on

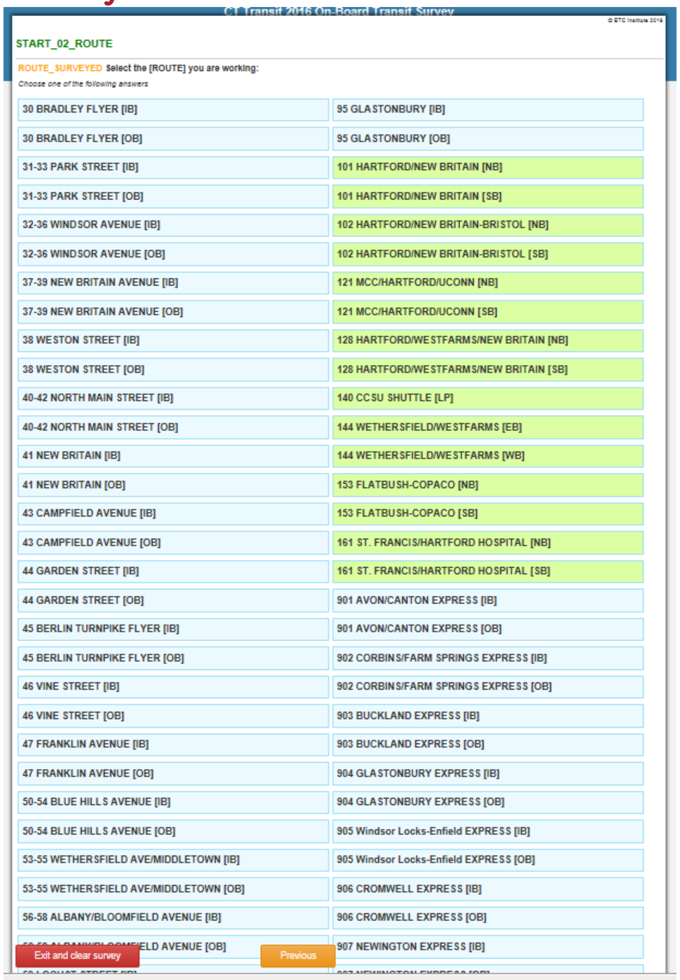


Figure 25: On-Board Transit Survey (tablet): Random Surveyor Selection

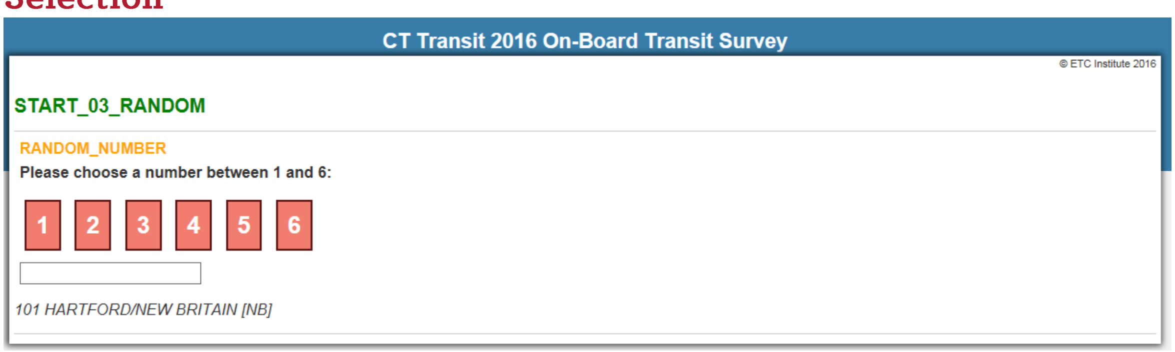


Figure 26: On-Board Transit Survey (tablet): Survey Opening Page

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START_04_HAVE5MIN

HAVE_5_MIN_FOR_SURVE

Hello. My name is PTP

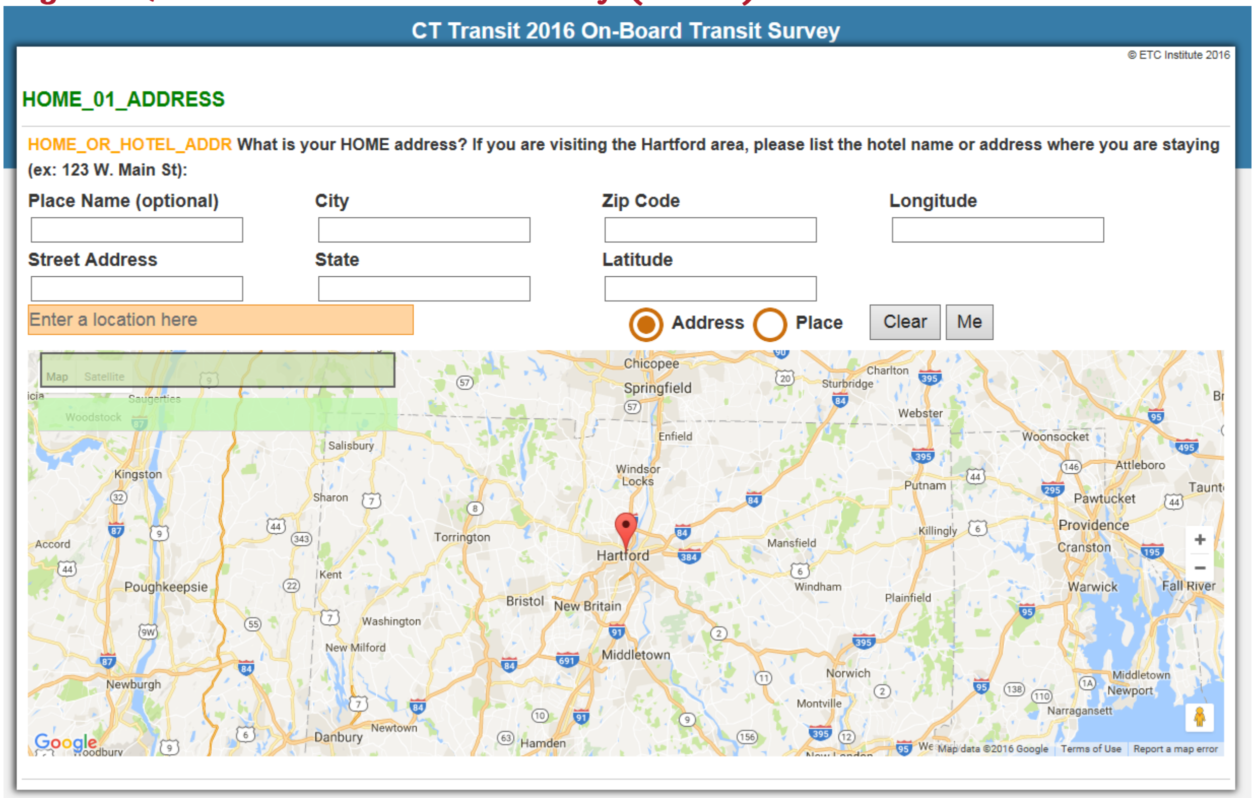
We're doing a quick survey on bus services in the City of Hartford, CT. Would you mind answering questions about your trip today?

Choose one of the following answers

- **Yes I can participate in the survey (have 5 min+)**
- **Yes (but no time for full survey)**
- **No (refused)**
- **No (already did this survey)**
- **Do not speak the interviewer's language (Spanish)**
- **Do not speak the interviewer's language (other)**
- **Disabled (not able to communicate with rider)**

101 HARTFORD/NEW BRITAIN [NB]

Figure 27: On-Board Transit Survey (tablet): Home Address



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HOME_01_ADDRESS

HOME_OR_HOTEL_ADDR What is your HOME address? If you are visiting the Hartford area, please list the hotel name or address where you are staying (ex: 123 W. Main St):

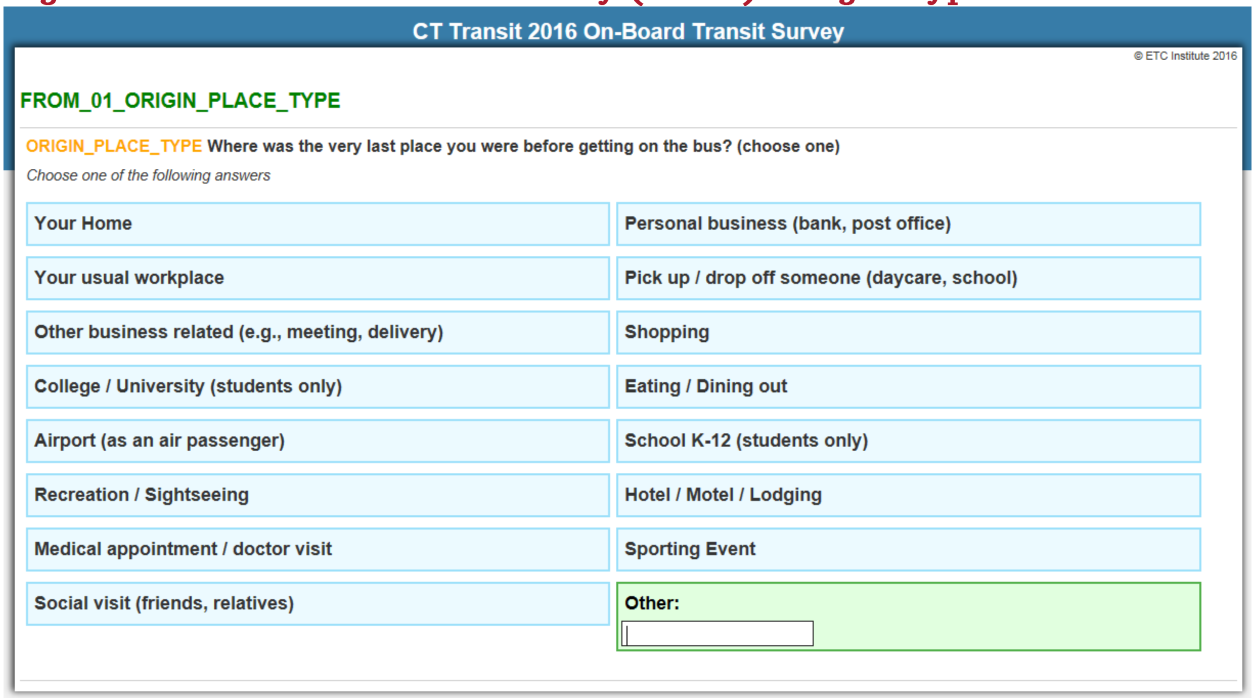
Place Name (optional) | City | Zip Code | Longitude

Street Address | State | Latitude

Enter a location here

Address Place Clear Me

Figure 28: On-Board Transit Survey (tablet): Origin Type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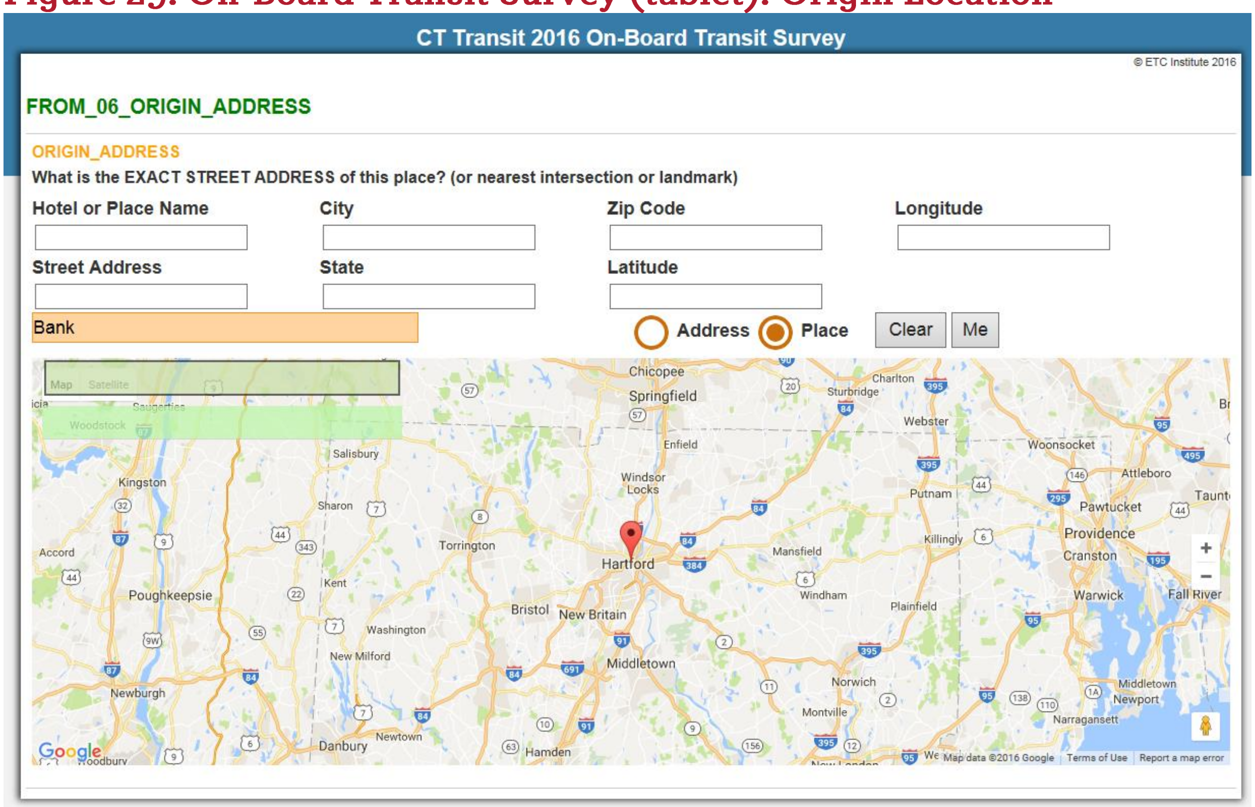
FROM_01_ORIGIN_PLACE_TYPE

ORIGIN_PLACE_TYPE Where was the very last place you were before getting on the bus? (choose one)

Choose one of the following answers

Your Home	Personal business (bank, post office)
Your usual workplace	Pick up / drop off someone (daycare, school)
Other business related (e.g., meeting, delivery)	Shopping
College / University (students only)	Eating / Dining out
Airport (as an air passenger)	School K-12 (students only)
Recreation / Sightseeing	Hotel / Motel / Lodging
Medical appointment / doctor visit	Sporting Event
Social visit (friends, relatives)	Other:

Figure 29: On-Board Transit Survey (tablet): Origin Location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FROM_06_ORIGIN_ADDRESS

ORIGIN_ADDRESS

What is the EXACT STREET ADDRESS of this place? (or nearest intersection or landmark)

Hotel or Place Name | City | Zip Code | Longitude

Street Address | State | Latitude

Bank

Address Place Clear Me

Figure 30: On-Board Transit Survey (tablet): Access Mode

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FROM_07_ORIGIN_TRANSPORT

ORIGIN_TRANSPORT **How did you get from Other business related (e.g., meeting, delivery) - Bank to the first bus you took on this one-way trip?**

Choose one of the following answers

Walk	Drove or rode with others and parked
Bike	Car share (e.g. RideShare, etc.)
Wheelchair	Taxi, Uber, Lyft, etc.
Drove alone and parked	Other:
Was dropped off by someone	

Figure 31: On-Board Transit Survey (tablet): Destination Type

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TO_01_DESTIN_PLACE_TYPE

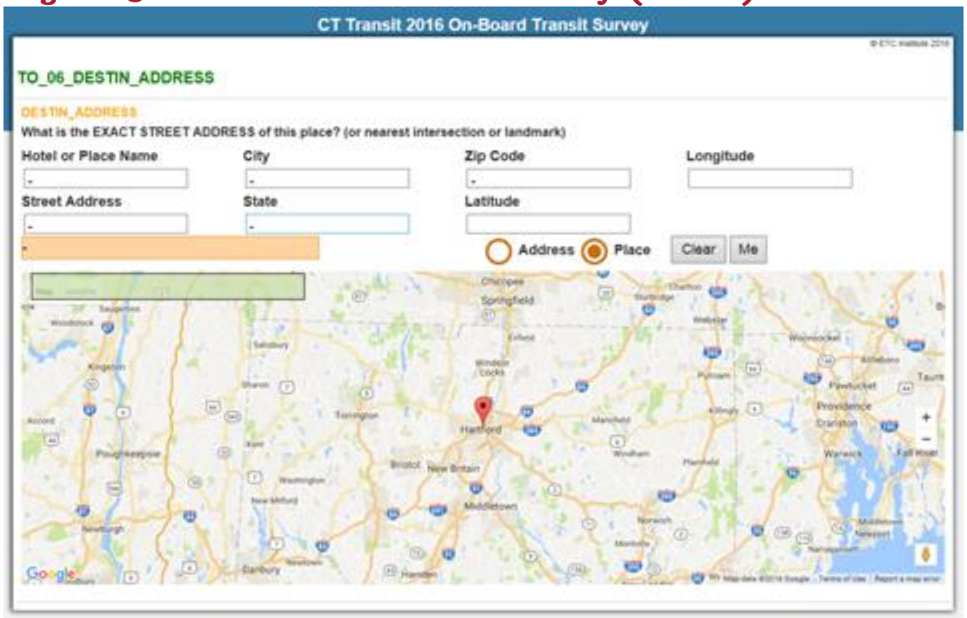
DESTIN_PLACE_TYPE

Where are you going once you get off your last bus on this one-way trip?

Choose one of the following answers

Your Home	Personal business (bank, post office)
Your usual workplace	Pick up / drop off someone (daycare, school)
Other business related (e.g., meeting, delivery)	Shopping
College / University (students only)	School K-12 (students only)
Airport (as an air passenger)	Eating / Dining out
Recreation / Sightseeing	Hotel / Motel / Lodging
Medical appointment / doctor's visit	Sporting Event
Social visit (friends, relatives)	Other:

Figure 32: On-Board Transit Survey (tablet): Destination Address


CT Transit 2016 On-Board Transit Survey

TO_06_DESTIN_ADDRESS

DESTIN_ADDRESS

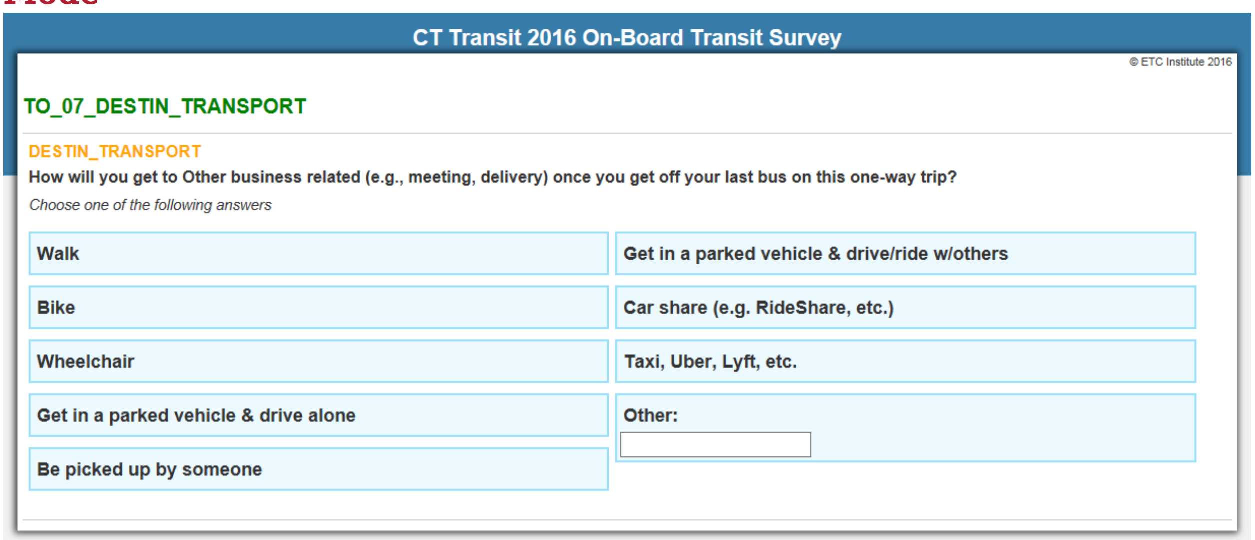
What is the EXACT STREET ADDRESS of this place? (or nearest intersection or landmark)

Hotel or Place Name | City | Zip Code | Longitude

Street Address | State | Latitude

Address / Place | Clear | Me

Figure 33: On-Board Transit Survey (tablet): Destination Egress Mode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TO_07_DESTIN_TRANSPORT

DESTIN_TRANSPORT

How will you get to Other business related (e.g., meeting, delivery) once you get off your last bus on this one-way trip?

Choose one of the following answers

Walk	Get in a parked vehicle & drive/ride w/others
Bike	Car share (e.g. RideShare, etc.)
Wheelchair	Taxi, Uber, Lyft, etc.
Get in a parked vehicle & drive alone	Other:
Be picked up by someone	

Figure 34: On-Board Transit Survey (tablet): Boarding Location (1st Stop)

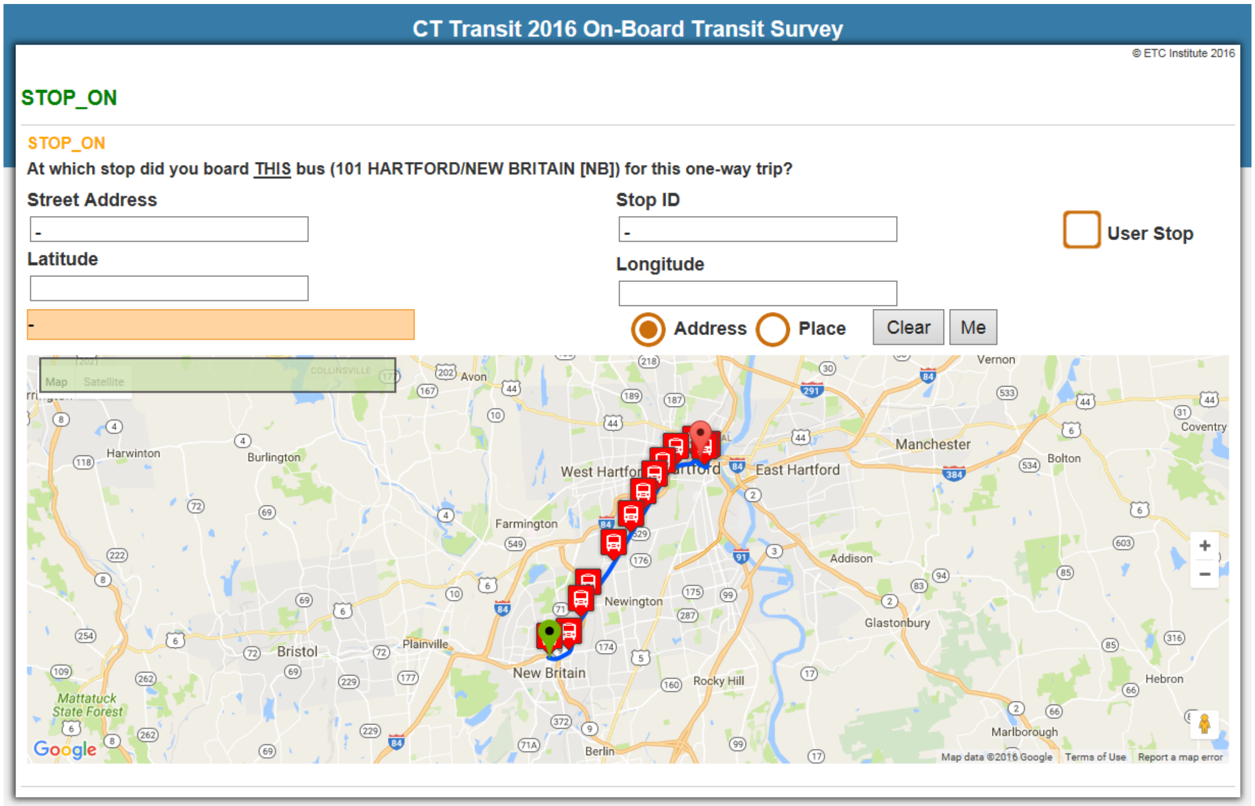
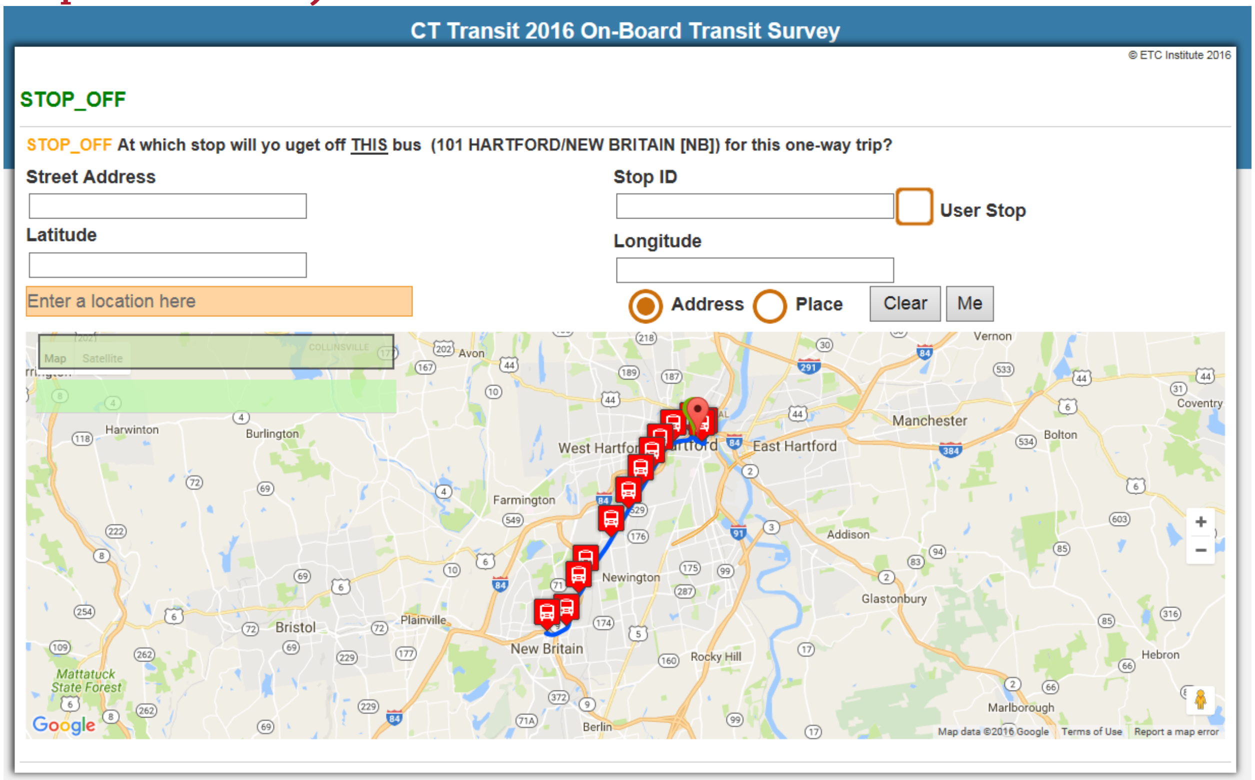


Figure 35: On-Board Transit Survey (tablet): Alighting Location (Last Stop on this route)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STOP_OFF

STOP_OFF At which stop will yo uget off THIS bus (101 HARTFORD/NEW BRITAIN [NB]) for this one-way trip?

Street Address

Stop ID

User Stop

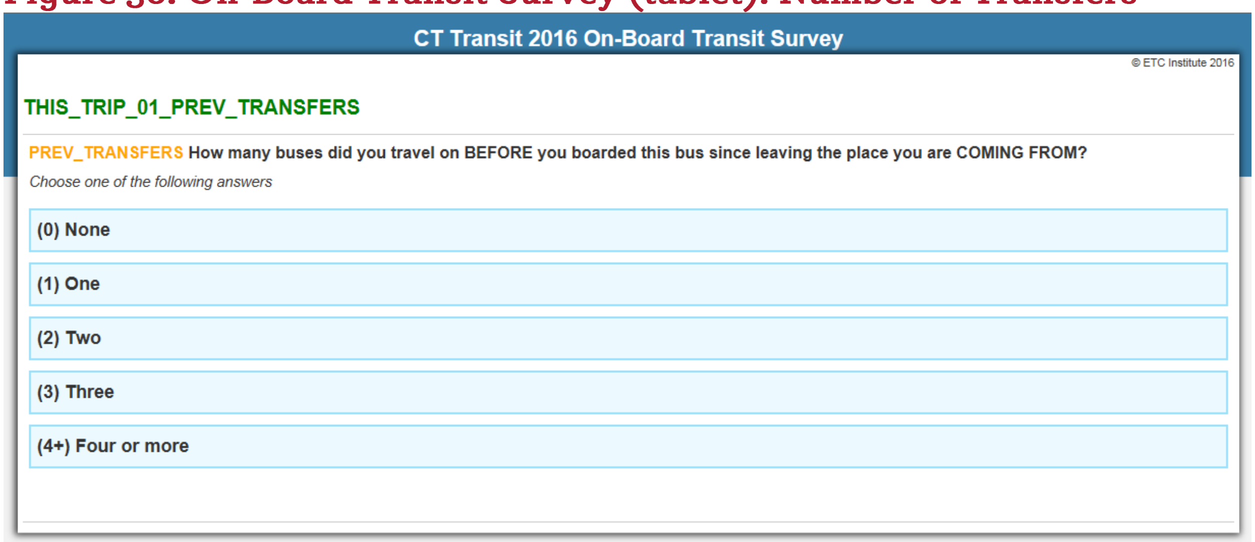
Latitude

Longitude

Enter a location here

Address Place Clear Me

Figure 36: On-Board Transit Survey (tablet): Number of Transfers


CT Transit 2016 On-Board Transit Survey

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THIS_TRIP_01_PREV_TRANSFERS

PREV_TRANSFERS How many buses did you travel on BEFORE you boarded this bus since leaving the place you are COMING FROM?

Choose one of the following answers

(0) None

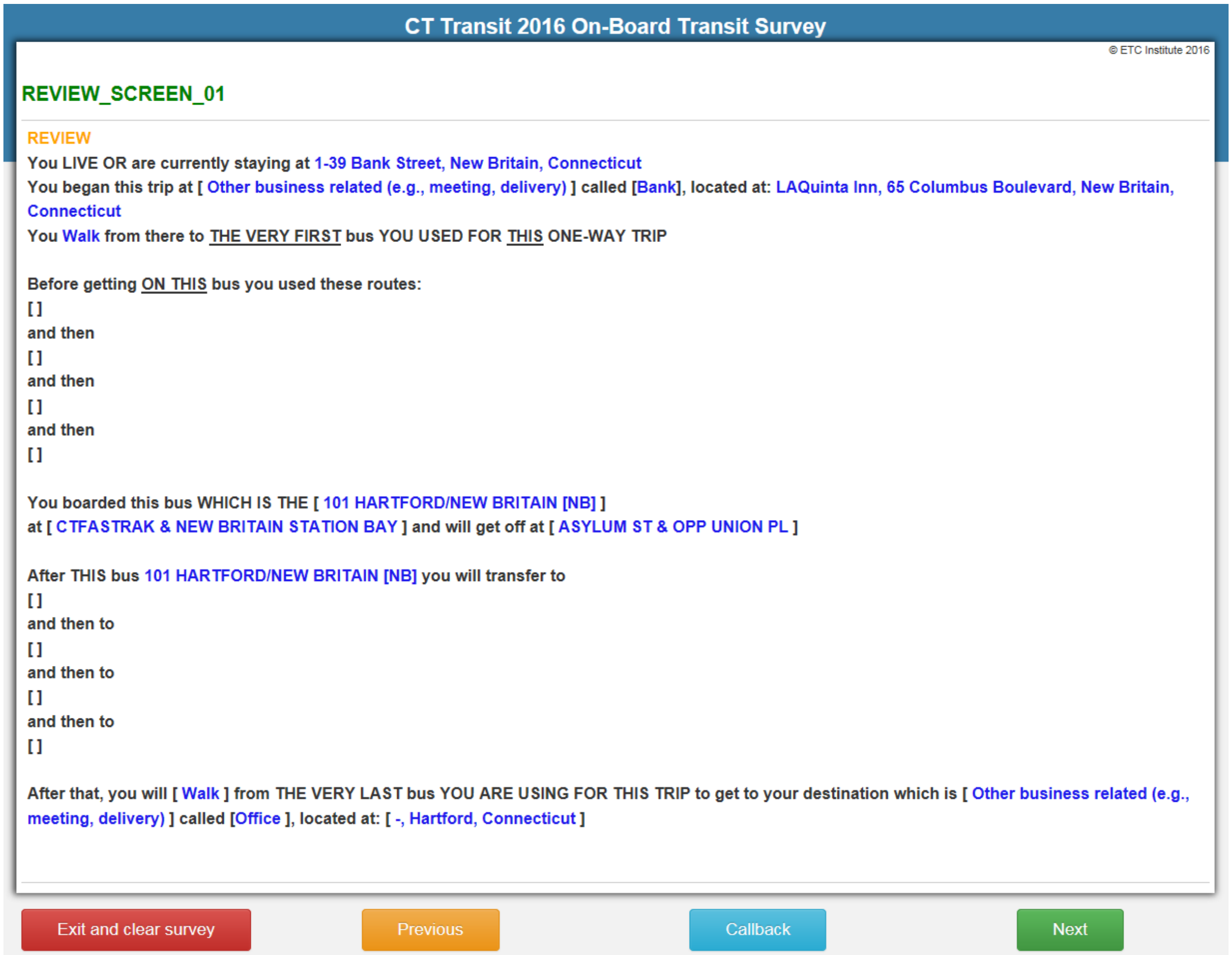
(1) One

(2) Two

(3) Three

(4+) Four or more

Figure 37: On-Board Transit Survey (tablet): Overview of Trip Information



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REVIEW_SCREEN_01

REVIEW

You LIVE OR are currently staying at 1-39 Bank Street, New Britain, Connecticut

You began this trip at [Other business related (e.g., meeting, delivery)] called [Bank], located at: LAQuinta Inn, 65 Columbus Boulevard, New Britain, Connecticut

You Walk from there to THE VERY FIRST bus YOU USED FOR THIS ONE-WAY TRIP

Before getting ON THIS bus you used these routes:
[ ]
and then
[ ]
and then
[ ]
and then
[ ]

You boarded this bus WHICH IS THE [101 HARTFORD/NEW BRITAIN [NB]]
at [CTFASTRAK & NEW BRITAIN STATION BAY] and will get off at [ASYLUM ST & OPP UNION PL]

After THIS bus 101 HARTFORD/NEW BRITAIN [NB] you will transfer to
[ ]
and then to
[ ]
and then to
[ ]
and then to
[ ]

After that, you will [Walk] from THE VERY LAST bus YOU ARE USING FOR THIS TRIP to get to your destination which is [Other business related (e.g., meeting, delivery)] called [Office], located at: [-, Hartford, Connecticut]

Exit and clear survey | Previous | Callback | Next

Figure 38: On-Board Transit Survey (tablet): Time Boarding the Bus

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OTHER_01_TIME_ON

TIME_ON **What time did you BOARD this bus?**

Choose one of the following answers

Before 5:30 am	9:30 - 10:30 am	2:30 - 3:30 pm	7:30 - 8:30 pm
5:30 - 6:30 am	10:30 - 11:30 am	3:30 - 4:30 pm	8:30 - 9:30 pm
6:30 - 7:30 am	11:30 am - 12:30 pm	4:30 - 5:30 pm	After 9:30 pm
7:30 - 8:30 am	12:30 - 1:30 pm	5:30 - 6:30 pm	
8:30 - 9:30 am	1:30 - 2:30 pm	6:30 - 7:30 pm	

Figure 39: On-Board Transit Survey (tablet): Trip in Opposite Direction

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OTHER_02_TRIP_IN_OPP_DIR

Trip_in_Opposite_Dir **Will you (or did you) make this same trip using the same transit routes in exactly the opposite direction today?**

Choose one of the following answers

- No
- Yes, I will make a return trip in exactly the opposite direction today
- Yes, I will make the exact return trip but not on the same bus(ses)

Current trip from Other business related (e.g., meeting, delivery) (origin) to Other business related (e.g., meeting, delivery) (destination)

Figure 40: On-Board Transit Survey (tablet): Approximate Time Boarding Return Trip

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OTHER_03_OPP_DIR_TIME

Opp_Dir_Trip_Time **At what time did/will you leave for this trip in the opposite direction?**

Choose one of the following answers

Before 5:30 am	9:30 - 10:30 am	2:30 - 3:30 pm	7:30 - 8:30 pm
5:30 - 6:30 am	10:30 - 11:30 am	3:30 - 4:30 pm	8:30 - 9:30 pm
6:30 - 7:30 am	11:30 am - 12:30 pm	4:30 - 5:30 pm	After 9:30 pm
7:30 - 8:30 am	12:30 - 1:30 pm	5:30 - 6:30 pm	
8:30 - 9:30 am	1:30 - 2:30 pm	6:30 - 7:30 pm	

Current trip from Other business related (e.g., meeting, delivery) (origin) to Other business related (e.g., meeting, delivery) (destination)

Figure 41: On-Board Transit Survey (tablet): Payment Method

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OTHER_04_PAYMENT_METHOD

PAYMENT_METHOD **What fare payment methods were used for this one-way trip?** ***(select all that apply)***

Cash	7 Day Pass
Day Pass	10 Ride Ticket
5 Day Pass	Free (4-Yrs Old & younger)
31 Day Pass	U Pass (Student discount)
2 Hr Pass	Other (Transfer-Free)
3 Day Pass	

Figure 42: On-Board Transit Survey (tablet): Fare Type

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OTHER_05_FARE_TYPE

FARE_TYPE What type of fare was this?

Choose one of the following answers

Regular	Student (U Pass)
Child (Under 5)	Senior / Disabled
Youth (5-18)	

Figure 43: On-Board Transit Survey (tablet): Years Riding CTtransit

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OTHER_06_USING_CT_YEARS

USING_CT_YEARS How many years have you been riding CT Transit?

Choose one of the following answers

- Less than one year
- 1 - 3 years
- 4+ years

Figure 44: On-Board Transit Survey (tablet): Trip Frequency

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OTHER_07_TRIP_FREQ

TRIP_FREQ

How often do you usually make this trip by bus?

Choose one of the following answers

- Less than 1 day / week
- 1 day per week
- 2 days / week
- 3 days / week
- 4 days /week
- 5 days / week
- 6 or 7 days / week

Figure 45: On-Board Transit Survey (tablet): Number of Vehicles in Household

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OTHER_08_COUNT_VH_HH

COUNT_VH_HH **How many WORKING vehicles (cars, pick-up trucks, SUVs) are available to your household?**

Choose one of the following answers

None (0)	Three (3)	Six (6)	Nine (9)
One (1)	Four (4)	Seven (7)	Ten or more (10+)
Two (2)	Five (5)	Eight (8)	

Figure 46: On-Board Transit Survey (tablet): Availability of Vehicle to complete the trip

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OTHER_09_CAN_USE_VEH_TRIP

CAN_USE_VEH_TRIP **Could you have used one of these vehicles to make this trip?**

Choose one of the following answers

Yes	No

Figure 47: On-Board Transit Survey (tablet): Household Size

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OTHER_10_COUNT_MEMBER_HH

COUNT_MEMBER_HH Including YOU, how many people live in your household?

Choose one of the following answers

One (1)	Four (4)	Seven (7)	Ten or More (10+)
Two (2)	Five (5)	Eight (8)	
Three (3)	Six (6)	Nine (9)	

Figure 48: On-Board Transit Survey (tablet): Rider's Employment Status

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OTHER_11_STATUS_EMPLOYMENT

STATUS_EMPLOYMENT What is your employment status?

Choose one of the following answers

Employed Full-time	Retired	Not currently employed, and not seeking work
Employed Part-time	Not currently employed, but seeking work	Homemaker

(select the one response that BEST describes you)

Figure 49: On-Board Transit Survey (tablet): Rider's Student Status

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OTHER_13_STUDENT_STATUS

STUDENT_STATUS What is your student status?

Choose one of the following answers

Not a student	Yes – Vocational/technical/trade school
Yes – Full-time college/university	Yes – K-12th grade
Yes – Part-time college/university	Yes - Other

(Check the one response that BEST describes you)

Figure 50: On-Board Transit Survey (tablet): Rider's Driving License Status

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OTHER_16_HAS_DRIVE_LICENSE

HAS_DRIVE_LICENSE **Do you have a valid driver's license?**

Choose one of the following answers

- Yes
- No

Figure 51: On-Board Transit Survey (tablet): Number of Drivers in Household

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OTHER_17_DRIVE_LICENSE_HH_COUNT

HH_LICENCE_COUNT **How many licensed drivers are in the household?**

Choose one of the following answers

- One (1)

Figure 52: On-Board Transit Survey (tablet): Age of Rider

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OTHER_18_AGE

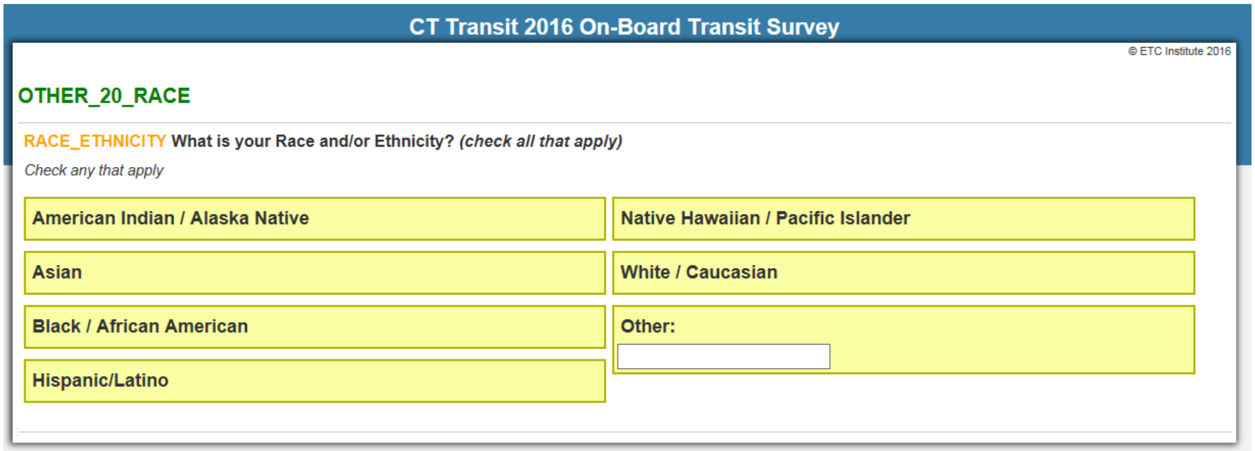
AGE

What is your AGE?

Choose one of the following answers

Under 16	20-34	51-64
16-19	35-50	65+

Figure 53: On-Board Transit Survey (tablet): Race and/or Ethnicity of Rider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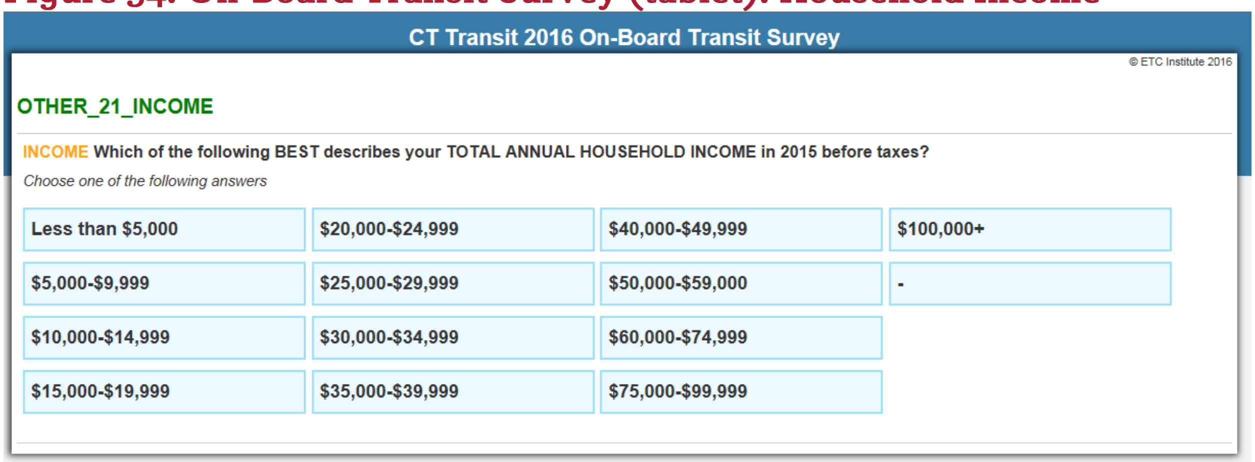
OTHER_20_RACE

RACE_ETHNICITY What is your Race and/or Ethnicity? *(check all that apply)*

Check any that apply

American Indian / Alaska Native	Native Hawaiian / Pacific Islander
Asian	White / Caucasian
Black / African American	Other:
Hispanic/Latino	

Figure 54: On-Board Transit Survey (tablet): Household Income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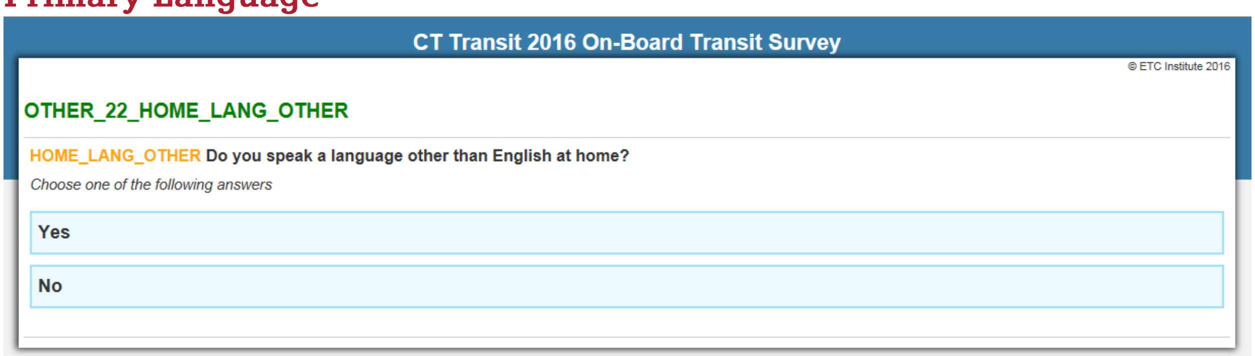
OTHER_21_INCOME

INCOME Which of the following BEST describes your TOTAL ANNUAL HOUSEHOLD INCOME in 2015 before taxes?

Choose one of the following answers

Less than $5,000	$20,000-$24,999	$40,000-$49,999	$100,000+
$5,000-$9,999	$25,000-$29,999	$50,000-$59,000	-
$10,000-$14,999	$30,000-$34,999	$60,000-$74,999	
$15,000-$19,999	$35,000-$39,999	$75,000-$99,999	

Figure 55: On-Board Transit Survey (tablet): English as Household Primary Language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OTHER_22_HOME_LANG_OTHER

HOME_LANG_OTHER Do you speak a language other than English at home?

Choose one of the following answers

Yes

No

Figure 56: On-Board Transit Survey (tablet): Household Primary Language other than English

CT Transit 2016 On-Board Transit Survey

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OTHER_23_HOME_OTHER_LANG

HOME_OTHER_LANG **Which language?**

Choose one of the following answers

Other Recorded Value:

Figure 57: On-Board Transit Survey (tablet): Rider's English Ability

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OTHER_24_ENGLISH_ABILITY

ENGLISH_ABILITY **How well do you speak English?**

Choose one of the following answers

- Very well
- Well
- Less than well
- Not at all

Figure 58: On-Board Transit Survey (tablet): Sweepstake Participation

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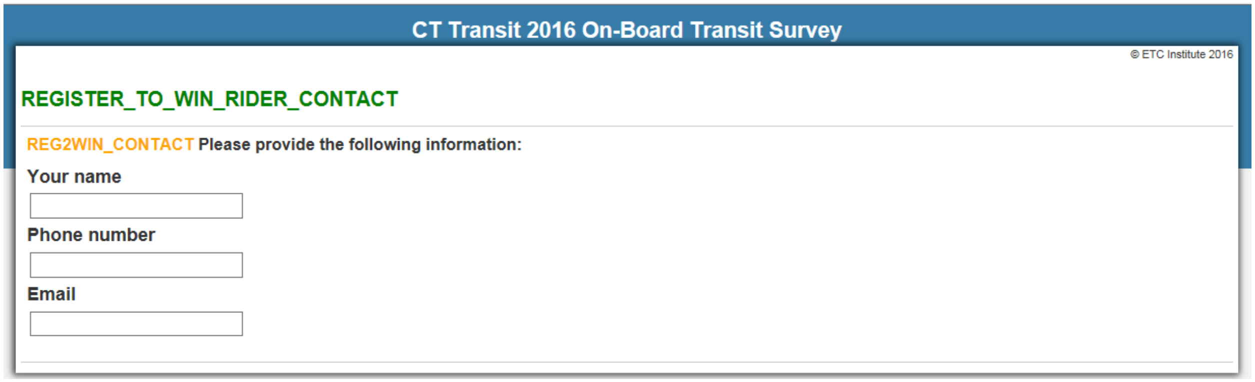
REGISTER_TO_WIN

REGISTER_TO_WIN_Y_N **People who submit an accurately completed survey will have the option of being entered in a random drawing for one of five $100 Gift Cards. Would you like me to enter you into the drawing?**

Choose one of the following answers

- Yes
- No
- Not interested in contest but will provide contact info

Figure 59: On-Board Transit Survey (tablet): Sweepstake Contact Information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REGISTER_TO_WIN_RIDER_CONTACT

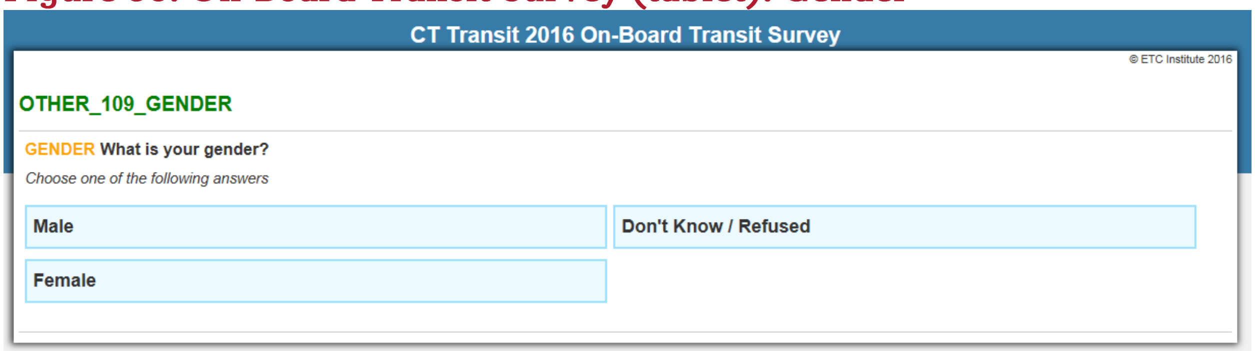
REG2WIN_CONTACT Please provide the following information:

Your name

Phone number

Email

Figure 60: On-Board Transit Survey (tablet): Gender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OTHER_109_GENDER

GENDER What is your gender?

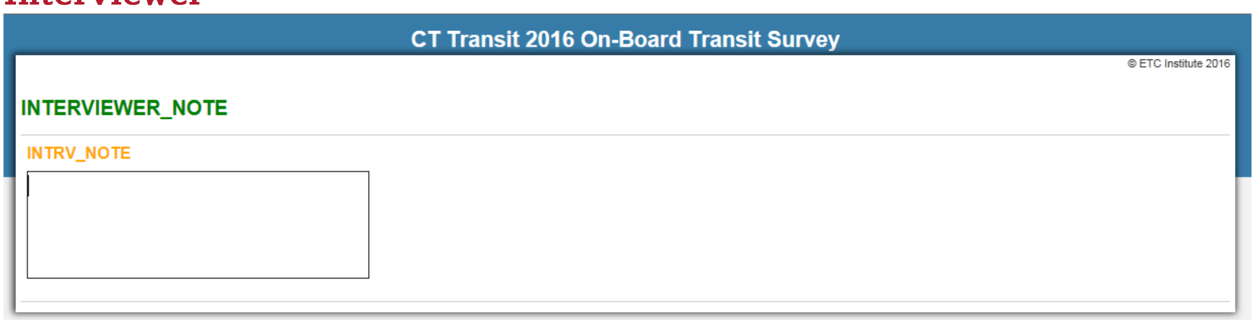
Choose one of the following answers

Male

Don't Know / Refused

Female

Figure 61: On-Board Transit Survey (tablet): Comments/Notes by Interviewer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INTERVIEWER_NOTE

INTRV_NOTE

APPENDIX C

Unlinked Weight Factors

Table 32: Unlinked Trip Weighting Factors by Route, Segment, and Time for Local Routes

Route by Direction	Alight Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
30 IB	3	3.0	5.5	7.8		1.1	2.6	3.5	32.0	1.1	6.2	5.4	12.0
30 OB	3	8.0	2.9	1.5		4.5	9.1	8.3	32.0	4.5	4.7	9.0	
31-33 IB	1	2.9	4.4	11.9	12.8								
	2	2.9	7.6	15.8	9.0		19.8	15.8					
	3	13.2	3.6	10.5	12.5	13.2	19.8	10.5	12.5	13.2	24.1	10.5	12.5
31-33 OB	2		22.8										
	3	6.1	7.3	8.8	2.9	8.4	4.6	4.1	2.9	12.3	10.6	11.6	16.8
32-36 IB	1		32.4	6.5	26.8								
	2	11.9	32.4	6.5				7.2					
	3	11.9	3.6	6.5	3.0	11.9	7.0	18.4	21.0	11.9	12.7	18.4	
32-36 OB	2	20.0	24.3	10.7									
	3	20.0	1.6	2.7	12.2	20.0	29.0	24.8	12.2	20.0	29.0	24.8	8.4
37-39 IB	1	3.8	12.7		20.6								
	2	3.4	5.9	4.5	15.2	10.7	21.0		15.2				
	3	2.5	3.6	4.5	15.2	10.7	24.7	14.2		26.7	24.7	14.2	
37-39 OB	2		4.5				21.7						
	3	3.5	4.5	8.7	6.7	24.0	5.8	9.9	6.7	24.0	7.2	9.9	9.2
38 IB	3	2.0	2.8	7.0	13.3	20.0	8.1	19.5			26.3		
38 OB	3	14.1	6.0	4.7	14.0	14.1	6.0			1.3		5.0	
40-42 IB	1	11.0	11.7										
	2		17.5			6.3							
	3	4.0	4.3	5.5	4.0	31.5	21.1	12.3	11.7	31.5	21.1	32.4	11.7
40-42 OB	3	1.9	6.4	6.6	4.3					13.9	9.2	13.2	8.0
41 IB	1		1.1	6.1									
	2	0.8	5.8	10.5	49.5	0.5	9.0						
	3	10.7	2.9	10.5	49.5	6.1	13.5	11.3		21.0	13.5		49.5
41 OB	2				9.0								
	3	7.3	6.0	6.8	9.0		12.4	9.3	27.0	5.6	8.7	12.0	6.0
43 IB	1		4.1										
	3	136.0	4.1	2.3			7.2	15.5			10.5		
43 OB	3	3.8	3.6	7.4	4.7	11.5	3.0	5.6		11.5	23.6	7.9	

Route by Direction	Alight Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
44 IB	3	5.0	5.3	3.0		5.0	8.7	8.1		15.0	18.0	18.8	
44 OB	3	5.5	6.1	15.6	17.5		5.1		1.1	9.8	5.4	5.0	
45 IB	3											16.0	
45 OB	2	4.8											
	3	4.8											
46 IB	1		2.2										
	2	11.2	6.5	13.1	17.3								
	3	11.2	6.5	13.5	4.4	11.2	26.2	13.5	18.2		26.2	13.5	
46 OB	3	10.9	7.3	12.4	9.5	10.9	7.3	12.4	13.4	15.3	5.5	12.4	21.0
47 IB	1		4.5	7.1									
	2	11.4	1.3	4.9	9.1								
	3	11.4	4.7	4.1	15.9	33.1	17.6	28.0	29.5	33.1	28.9	28.0	
47 OB	3	3.0	3.5	9.3	22.8	3.0	3.2	9.1		21.0	8.2	15.2	22.8
50-54 IB	1	9.1	14.4		4.3								
	2	9.1	14.4	11.5	14.2	9.1		11.5					
	3	3.9	2.5	9.0	14.1	18.0	22.1	9.0	14.1	18.0	29.4	21.3	
50-54 OB	2		4.2				23.2	13.1					
	3	8.0	4.2	8.5	21.2	13.3	9.8	11.6	21.2	11.1	9.7	25.2	14.7
53-55 IB	1		7.1	29.9									
	2	17.7	7.1		8.9								
	3	12.7	7.1	5.8	8.9	12.7	20.6	15.5	13.3	12.7	20.6	15.5	
53-55 OB	3	6.7	4.4	12.8	4.3	6.7	4.5			12.0	19.5	12.8	
56-58 IB	1		1.3	21.8									
	2	5.2	4.6	8.9	3.6								
	3	5.2	5.6	8.9	3.6	30.8	10.4	8.9	33.0		27.4		
56-58 OB	3	6.0	20.8	6.4	5.4	7.2	3.3	18.0		10.4	6.5	4.5	
59 IB	2	3.0					12.8						
	3	3.0	4.2	16.3		3.0	12.8		3.0	3.0			
59 OB	3	16.0	18.8	4.3			1.4	3.3		3.6	2.2	3.3	
60-66 IB	1	6.2	9.2	4.6	10.8								
	2	6.2	7.8	9.4	13.0	15.1	15.5						
	3	2.6	2.3	12.6	2.3	15.1	17.0	12.6	29.0	29.9	17.0	12.6	29.0

Route by Direction	Alight Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
60-66 OB	2	2.1											
	3	8.1	7.3	7.9	9.0	8.5	4.0	5.3	15.8	12.4	8.6	13.0	13.3
61 IB	1		7.9										
	2		7.0										
	3	4.7	4.8	16.8	1.5		13.0	4.2	19.5	16.5	10.4	8.0	13.5
61 OB	2	2.0					5.0						
	3	2.4	4.0	9.6	4.2	0.3	2.9	17.6	13.2	1.4	8.3	12.8	
63 IB	1			28.1									
	2							28.1					
	3	8.0	2.8	23.1		30.0	19.7			32.0	26.4	23.1	
63 OB	3	3.8	9.0	4.9	13.5	5.3	1.8	5.3	8.0	14.0	3.3	6.0	
69 IB	1			10.0									
	2			10.0									
	3	2.0	9.6	4.0		12.0	18.7			18.0	18.7	21.0	39.0
69 OB	2	2.4						10.8					
	3	2.4	6.2	24.1		11.7	12.0	10.8			21.0		
72 IB	2			7.9									
	3		5.2	7.9	1.7	8.8	9.1	20.3	7.0	18.2	17.9		
72 OB	3	8.8	4.0	7.5	6.2	10.5	1.8	18.0			24.0		
74 IB	2	6.5	9.1	0.6			17.2	2.2	6.0				
	3	6.5	3.2	4.9		12.7	10.9	24.9	10.5		10.9	24.9	4.5
74 OB	2			6.2			17.6						
	3	16.5	6.4	6.2	9.2		11.2			6.9	14.6	26.0	10.0
76 IB	1			3.1									
	2	5.1	10.8	4.5	18.1	6.1							
	3	7.2	4.3	4.5	18.1	21.4	14.0	18.7	18.1	21.4	40.0		
76 OB	2	7.4	16.8	11.1	25.9		17.0						
	3	7.0	16.8	7.3	13.0	13.7	17.0	6.4		5.1		12.1	15.7
82-84 IB	1		17.4	3.3	8.4								
	2	33.0	16.1	13.2			13.7	6.7	8.4				
	3	33.0	4.7	7.9	8.4	6.0	4.0	10.2	8.4	32.0	7.5	10.2	8.4
82-84 OB	2	6.1	28.7		18.2								
	3	4.7	3.9	8.9	18.2	19.4	5.8	7.3	18.2	19.4	14.7	28.0	18.2

Route by Direction	Alight Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
83 IB	2	2.6	8.5	6.7			17.6						
	3	2.6	8.5	6.7	20.0	23.4	14.9	19.0		11.3	8.7	10.5	24.9
83 OB	2		8.1	20.1	25.0		2.4	20.1					
	3	10.2	2.3	12.0	12.0	10.2	7.7	12.0	12.0	10.2	19.3	12.0	
86-88 IB	1	5.0	15.1	8.1	6.0								
	2	5.0	18.6	8.3	6.0								
	3	5.0	4.6	4.1	6.0	15.0	19.4	26.5	12.2	15.0	19.4	26.5	12.2
86-88 OB	2		2.8	20.2									
	3	13.1	9.1	7.3	9.4	1.8	4.1	7.3	5.4	32.7	8.0	24.5	29.7
87 IB	3	3.8		17.5	4.0	2.5		10.0		13.3	9.6	10.0	3.0
87 OB	2	3.1	4.3	7.7			3.6						
	3	3.1		7.7	15.0								
91NB	1			2.6									
	2		3.0	2.6				2.6					
	3	4.7				4.7	7.2	3.0	8.8		15.0	21.0	8.8
91SB	1		6.7										
	2			5.0									
	3		13.4	5.0		27.0	13.4	27.2		4.5	13.4		20.0
92EB	2		14.3	10.9									
	3	13.1	3.7	4.2	10.5		5.2	11.9	6.0		7.0	12.5	15.0
92WB	2	0.3	0.8	3.5	11.3		5.8						
	3	0.3	2.8	3.5	11.3		33.2			2.4	33.2	9.0	
94-96 IB	3	4.8	4.3	15.7	4.0	4.8	3.1	4.9	6.0	24.0	22.7	3.3	6.0
94-96 OB	2		12.5	6.8									
	3	3.6	12.5	6.8	16.0			6.8		3.6			
95 IB	1		10.1	3.3									
	2							2.2					
	3	6.1	4.4	9.8	29.8	16.8	11.0	3.8		16.8	23.0	17.7	29.8
95 OB	2	10.3											
	3	10.3	6.0	10.2	11.7		14.2		11.7	10.3	14.2	10.2	

Note: the route direction codes are: IB-inbound, OB-outbound, WB-Westbound, and EB-eastbound

Table 33: Unlinked Trip Weighting Factors by Route, Segment, and Time for CT*fastrak*

Route by Direction	Alighting Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
101NB	2	7.6			17.3								
	3	5.7	5.6	4.8	9.0	10.8	5.2	6.3	8.4	26.0	22.3	19.2	15.0
101SB	3	3.5	5.8	8.9	6.8	20.0	5.5	12.5	21.0	9.1	19.6	18.0	5.6
102NB	2		10.9						7.5				
	3	28.7	12.7	21.0			7.7	27.0	7.5	2.8	6.1	4.3	7.5
102SB	2	2.5	30.8	8.1	9.9			7.1					
	3	3.1	2.0	6.2	1.3	1.8	11.3	5.4	25.0	18.8	24.7	24.2	25.0
121NB	1	3.0	10.6	6.2	3.7								
	2	3.2	4.8	4.4			8.7	7.1					
	3	4.6	1.6	1.5	3.7	6.4	2.9	2.4	12.1	18.0	6.2	7.5	12.1
121SB	2		20.0	4.3	20.8			12.2					
	3	2.1	13.9	20.3		2.1	10.5	20.3	20.8	4.4	5.7	6.9	20.8
128NB	1		8.5		12.0								
	2		17.0	14.0	12.0								
	3	5.4	2.6	4.2	7.6	10.3	17.0	6.6	5.0	25.1	11.9	7.6	18.6
128SB	2	5.3	5.2	12.6		12.6	12.6	11.0					
	3	5.3	3.0	7.1	10.8	12.6	7.4	6.2			30.7	31.7	10.8
140LP	2		5.0			19.0		21.3			17.5	21.3	
	3			4.0		2.0	24.0	22.7		6.0	7.5		
144EB	2			12.0									
	3		15.4				10.5				6.1	18.0	
144WB	2						15.6		7.0				
	3		6.8	16.5			15.6						
153NB	2				28.0								
	3	15.0	6.3	19.0							22.0	9.0	
153SB	2		6.0	7.0									
	3	7.0	4.0	7.0			8.4			1.0	19.2	7.0	
161NB	2		1.6	7.5									
	3	7.3	1.6	4.4			15.3	15.3	15.0			28.4	
161SB	3		28.0	11.0	10.0	12.0	28.0		18.0		14.7		

Table 34: Unlinked Trip Weighting Factors by Route, Segment, and Time for Express Bus Routes

Route by Direction	Alighting Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
903IB	3	10.3	4.2			10.3	4.2						
903OB	3			15.1	1.2								
904IB	3	8.4								8.4			
904OB	3			3.6				3.9	4.0				
906IB	3	6.0				12.0					1.0		
906OB	3	0.7	1.0			0.7	4.0	30.0					
85IB	3		3.9	59.5									
85OB	2		2.4										
	3	2.4	2.4			2.4							
901IB	3	22.2		3.3		2.4				2.4		3.3	
901OB	3			11.2	3.0	14.0							
902IB	3	11.5		9.0									
902OB	3							5.0				5.0	
905IB	3	11.0	39.2			11.0							
905OB	3			14.7						54.0	15.0	14.7	
907IB	3	2.0											
907OB	3											26.0	
909IB	1	8.0											
909OB	3							8.0				8.0	
910IB	3	10.3		4.5				4.5		11.0		4.5	
910OB	3			10.6		9.0		10.6					
912IB	3	17.6				17.6				17.6			
914IB	3	10.8				10.8							
914OB	3			15.4		6.0	7.0	25.5				25.5	

Table 35: Expansion Factor for Express Routes without segmentation

Route by Direction	Route by Direction	AM	MD	PM	OP
917 IB	Inbound	12.5			
917 OB	Outbound		9.0	12.5	9.0
918 IB	Inbound	10.0	5.0		
918 OB	Outbound			11.0	6.0
919 IB	Inbound	6.5			
919 OB	Outbound			4.0	
921 IB	Inbound	11.0			
921 OB	Outbound		7.0	10.5	
923 IB	Inbound	10.5			
923 OB	Outbound		14.0	10.0	12.0
924 IB	Inbound	8.7			
924 OB	Outbound			9.0	
925 IB	Inbound	12.0			
925 OB	Outbound			14.0	6.0
926 IB	Inbound	12.0			
926 OB	Outbound			11.0	
927 IB	Inbound	10.0			
927 OB	Outbound			9.0	
928 IB	Inbound	2.0	1.7	2.0	
928 OB	Outbound	3.0	2.0	0.8	3.0

Table 36: Linked and Weighted Trip Factors by Route, Segment, and Time for Local Routes

Route by Direction	Alight Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
30 IB	3	1.5	4.8	6.8		0.7	2.3	2.6	24.0	1.0	4.3	2.7	6.0
30 OB	3	7.2	2.3	1.5		2.5	6.3	4.1	24.0	4.5	3.9	9.0	
31-33 IB	1	2.2	4.2	11.9	12.8								
	2	2.9	6.7	13.5	8.2		19.8	15.8					
	3	10.3	2.7	7.4	9.4	8.3	14.1	6.3	10.4	9.9	17.6	6.5	6.2
31-33 OB	2		11.4										
	3	4.6	4.5	7.2	2.1	7.0	3.8	3.8	1.9	12.3	9.8	11.2	15.6
32-36 IB	1		10.8	6.5	26.8								
	2	11.9	32.4	6.5				7.2					
	3	9.5	2.3	3.7	1.7	9.4	4.3	12.2	10.5	8.9	8.0	9.2	
32-36 OB	2	8.9	18.2	8.0									
	3	11.5	0.9	1.6	7.6	18.0	29.0	18.6	11.0	20.0	29.0	24.8	8.4
37-39 IB	1	2.8	12.7		20.6								
	2	3.4	5.9	3.4	11.2	10.7	21.0		14.0				
	3	1.6	2.6	3.8	10.5	8.7	14.8	8.7		16.0	20.9	10.6	
37-39 OB	2		2.3				21.7						
	3	1.9	2.8	5.4	4.5	9.6	4.1	8.8	5.1	19.2	7.0	9.1	9.2
38 IB	3	1.0	1.8	3.5	13.3	13.3	6.6	9.8			21.9		
38 OB	3	9.2	4.0	2.3	7.0	14.1	3.0			1.1		2.5	
40-42 IB	1	11.0	11.7										
	2		17.5			6.3							
	3	2.7	3.2	3.9	2.4	22.5	16.8	7.5	7.6	31.5	15.9	25.9	8.8
40-42 OB	3	1.1	4.2	4.5	2.7					11.8	8.7	11.5	8.0
41 IB	1		1.1	6.1									
	2	0.7	4.7	10.5	24.8	0.5	9.0						
	3	8.0	2.4	7.9	16.5	4.6	10.1	7.6		21.0	6.7		24.8
41 OB	2				9.0								
	3	4.3	4.3	5.7	9.0		12.4	9.3	27.0	4.9	7.1	12.0	5.0
43 IB	1		4.1										
	3	68.0	3.4	1.0			4.8	13.6			7.0		
43 OB	3	2.6	2.2	4.9	3.3	8.6	2.6	2.8		11.5	23.6	3.9	

Route by Direction	Alight Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
44 IB	3	4.2	5.3	2.3		2.5	8.7	6.1		7.5	13.5	18.8	
44 OB	3	2.7	4.9	11.1	8.7		4.2		1.1	9.8	5.4	5.0	
45 IB	3											8.0	
45 OB	2	4.0											
	3	3.2											
46 IB	1		1.8										
	2	11.2	6.5	10.9	8.7								
	3	6.9	4.9	8.4	2.2	7.8	19.7	10.1	9.1		15.3	10.1	
46 OB	3	6.0	4.8	9.7	7.5	10.9	7.3	12.4	11.2	13.8	5.2	8.3	21.0
47 IB	1		4.5	7.1									
	2	11.4	1.1	4.9	4.5								
	3	9.3	3.5	2.7	15.9	29.0	12.4	22.4	14.8	27.6	25.0	23.4	
47 OB	3	2.0	2.2	6.3	16.0	2.7	2.9	6.8		15.8	7.1	14.1	11.4
50-54 IB	1	4.6	14.4		4.3								
	2	7.8	13.4	10.2	14.2	9.1		11.5					
	3	3.0	1.8	6.4	10.9	12.9	18.7	5.1	11.8	13.5	19.3	14.7	
50-54 OB	2		4.2				23.2	13.1					
	3	5.6	2.8	5.6	14.9	13.3	7.8	9.2	10.6	10.7	9.3	25.2	14.7
53-55 IB	1		7.1	29.9									
	2	17.7	7.1		8.9								
	3	7.8	5.0	3.7	4.4	8.9	16.0	10.9	6.7	6.3	12.9	7.8	
53-55 OB	3	4.3	2.5	7.5	2.4	6.7	4.5			9.0	19.5	12.2	
56-58 IB	1		1.3	10.9									
	2	3.9	4.1	7.2	2.7								
	3	4.4	4.9	6.1	3.0	30.8	8.8	6.7	16.5		24.0		
56-58 OB	3	3.3	14.6	4.9	4.1	6.5	3.0	15.8		10.4	6.3	4.3	
59 IB	2	3.0					12.8						
	3	1.5	2.1	10.2		2.3	7.7		1.5	1.5			
59 OB	3	8.0	15.7	2.4			0.7	2.8		3.2	1.9	1.7	
60-66 IB	1	4.2	8.5	4.1	5.4								
	2	5.3	7.8	9.0	12.3	15.1	15.5						
	3	2.0	1.7	8.9	1.9	14.2	13.6	9.9	25.4	23.5	13.5	9.5	29.0

Route by Direction	Alight Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
60-66 OB	2	1.1											
	3	5.1	4.6	6.1	6.9	7.4	2.7	4.8	13.2	12.0	8.3	10.7	12.6
61 IB	1		7.9										
	2		7.0										
	3	3.9	3.1	12.6	0.9		10.4	3.3	9.8	16.5	5.2	5.3	11.3
61 OB	2	1.0					3.7						
	3	1.2	2.5	7.2	3.2	0.3	2.7	8.8	6.6	1.4	8.3	12.8	
63 IB	1			28.1									
	2							28.1					
	3	6.0	2.1	17.7		22.5	13.2			16.0	23.1	11.6	
63 OB	3	2.8	5.6	4.3	13.5	3.3	1.6	5.3	8.0	14.0	3.3	5.6	
69 IB	1			5.0									
	2			5.0									
	3	1.7	5.6	2.5		9.0	16.3			9.0	9.3	10.5	19.5
69 OB	2	1.6						8.1					
	3	1.2	3.8	24.1		7.8	9.0	7.2			15.8		
72 IB	2			7.9									
	3		3.1	6.2	1.5	5.4	6.4	10.2	3.5	18.2	13.4		
72 OB	3	5.3	2.3	5.8	4.1	6.6	1.2	13.5			24.0		
74 IB	2	6.5	9.1	0.4			8.6	2.2	6.0				
	3	6.5	2.4	2.5		8.9	9.8	14.5	5.2		10.9	12.5	4.5
74 OB	2			6.2			17.6						
	3	8.2	4.1	4.6	6.4		11.2			6.2	14.6	26.0	10.0
76 IB	1			3.1									
	2	5.1	10.8	3.5	9.0	4.5							
	3	5.4	3.5	3.4	12.1	17.1	9.0	13.4	9.0	10.7	20.0		
76 OB	2	3.7	8.4	6.3	16.2		8.5						
	3	4.2	10.5	5.2	9.1	13.7	15.3	5.1		5.1		12.1	15.7
82-84 IB	1		17.4	3.3	8.4								
	2	16.5	8.0	13.2			13.7	6.7	8.4				
	3	16.5	4.4	5.5	6.3	4.3	3.4	6.5	5.4	21.3	5.7	9.6	8.4
82-84 OB	2	3.0	8.4		9.1								
	3	3.3	2.2	6.6	10.6	16.1	4.4	4.3	18.2	19.4	13.4	24.5	13.7

Route by Direction	Alight Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	AM	AM	MD	AM	OP	AM	AM	PM	OP
83 IB	2	2.6	8.5	6.7			17.6						
	3	2.1	8.1	5.8	15.0	14.0	11.5	15.8		7.0	6.7	7.0	12.4
83 OB	2		5.7	11.7	12.5		2.3	16.8					
	3	5.1	1.8	9.0	7.5	9.5	6.5	11.3	12.0	10.2	19.3	12.0	
86-88 IB	1	5.0	15.1	7.1	6.0								
	2	5.0	18.6	8.3	6.0								
	3	3.9	3.1	2.3	5.2	12.8	14.6	23.9	9.7	12.5	19.4	13.3	6.1
86-88 OB	2		1.8	20.2									
	3	8.1	5.6	5.7	7.0	1.2	2.6	5.0	2.7	32.7	7.4	24.5	29.7
87 IB	3	1.9		17.5	4.0	1.3		5.0		6.7	7.2	8.0	1.5
87 OB	2	1.7	3.7	4.8			3.6						
	3	1.9		7.7	15.0								
91NB	1			2.6									
	2		2.3	2.6				2.6					
	3	4.7				4.7	6.5	3.0	8.8		15.0	10.5	8.8
91SB	1		2.8										
	2			5.0									
	3		13.4	1.7		13.5	13.4	27.2		3.4	13.4		15.6
92EB	2		14.3	10.9									
	3	9.8	3.7	4.2	10.5		4.7	9.0	6.0		7.0	12.5	7.5
92WB	2	0.1	0.8	3.5	11.3		4.4						
	3	0.2	2.8	3.1	11.3		33.2			1.2	33.2	9.0	
94-96 IB	3	2.6	2.1	10.4	4.0	2.1	1.6	3.0	6.0	18.0	4.7	2.2	6.0
94-96 OB	2		4.2	2.3									
	3	2.5	7.3	4.7	16.0			6.0		2.4			
95 IB	1		10.1	3.3									
	2							2.2					
	3	5.6	3.2	6.5	29.8	16.8	9.2	3.8		15.1	14.4	7.8	29.8
95 OB	2	4.3											
	3	6.4	3.8	6.9	9.3		13.0		5.8	10.3	14.2	5.1	

Table 37: Linked and Weighted Trip Factors by Route, Segment, and Time for CTfastrak Routes

Route by Direction	Alighting Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
101NB	2	1.9			17.3								
	3	3.4	4.5	3.6	6.8	7.4	2.9	4.1	5.2	23.8	16.1	13.7	9.4
101SB	3	2.4	3.9	6.3	4.5	6.7	4.4	11.7	21.0	6.1	17.6	16.2	4.1
102NB	2		10.9						7.5				
	3	28.7	12.7	21.0			5.8	27.0	7.5	2.1	4.8	3.7	5.4
102SB	2	1.9	30.8	6.1	6.6			7.1					
	3	1.6	1.5	4.1	1.0	0.8	8.4	5.0	25.0	18.8	16.4	24.2	25.0
121NB	1	1.0	7.9	4.6	3.7								
	2	2.5	4.3	2.8			8.7	3.5					
	3	3.3	1.5	1.5	2.8	3.6	2.0	1.8	9.3	18.0	5.8	7.5	6.1
121SB	2		10.0	3.6	20.8			12.2					
	3	2.1	9.7	15.2		2.1	8.3	6.8	20.8	3.6	4.8	4.0	17.3
128NB	1		6.6		12.0								
	2		14.2	14.0	12.0								
	3	3.2	2.3	3.8	5.0	10.3	14.2	6.6	3.1	12.5	8.4	5.3	14.0
128SB	2	2.6	4.7	10.5		12.6	10.5	11.0					
	3	3.9	1.7	4.2	6.2	11.0	7.0	5.9			23.9	31.7	10.8
140LP	2		1.7			19.0		21.3			8.8	21.3	
	3			2.0		1.5	12.0	22.7		6.0	3.7		
144EB	2			6.0									
	3		15.4				5.3				4.0	9.0	
144WB	2						13.0		7.0				
	3		6.8	16.5			15.6						
153NB	2				28.0								
	3	15.0	4.7	19.0							11.0	9.0	
153SB	2		6.0	7.0									
	3	7.0	2.4	7.0			8.4			1.0	19.2	7.0	
161NB	2		1.6	7.5									
	3	7.3	1.3	4.4			15.3	15.3	15.0			14.2	
161SB	3		28.0	7.8	10.0	12.0	28.0		18.0		14.7		

Table 38: Linked and Weighted Trip Factors by Route, Segment, and Time for Express Routes

Route by Direction	Alighting Segment	Boarding Segment											
		Segment 1				Segment 2				Segment 3			
		AM	MD	PM	OP	AM	MD	PM	OP	AM	MD	PM	OP
903IB	3	10.3	4.2			9.9	4.2						
903OB	3			15.1	1.2								
904IB	3	8.4								8.4			
904OB	3			3.6				3.9	4.0				
906IB	3	6.0				12.0					0.3		
906OB	3	0.7	1.0			0.5	2.0	30.0					
85IB	3		1.9	29.8									
85OB	2		1.2										
	3	1.2	1.4			1.2							
901IB	3	22.2		3.3		2.4				2.4		3.3	
901OB	3			11.2	3.0	7.0							
902IB	3	9.6		3.4									
902OB	3							5.0				5.0	
905IB	3	11.0	19.6			11.0							
905OB	3			14.7						27.0	7.5	14.4	
907IB	3	1.5											
907OB	3											26.0	
909IB	1	8.0											
909OB	3							8.0				8.0	
910IB	3	8.5		2.3				4.5		11.0		3.4	
910OB	3			9.2		4.0		10.6					
912IB	3	17.6				17.6				17.6			
914IB	3	10.1				10.8							
914OB	3			15.4		3.0	7.0	25.5				25.5	

Table 39: Weighted Expansion Factor for Express Routes without segmentation

Route by Direction	Route by Direction	AM	MD	PM	OP
917 IB	Inbound	12.5			
917 OB	Outbound		9.0	12.5	9.0
918 IB	Inbound	10.0			
918 OB	Outbound		5.0	11.0	6.0
919 IB	Inbound	4.9			
919 OB	Outbound			3.3	
921 IB	Inbound	11.0			
921 OB	Outbound		7.0	10.5	
923 IB	Inbound	7.9			
923 OB	Outbound		14.0	10.0	12.0
924 IB	Inbound	8.7			
924 OB	Outbound			9.0	
925 IB	Inbound	12.0			
925 OB	Outbound			14.0	6.0
926 IB	Inbound	12.0			
926 OB	Outbound			11.0	
927 IB	Inbound	10.0			
927 OB	Outbound			9.0	
928 IB	Inbound	2.0	1.1	1.4	
928 OB	Outbound	1.5	1.2	0.8	1.5
917 IB	Inbound	6.5			6.0
917 OB	Outbound	5.2		5.2	

APPENDIX D

Decomposition Analysis

By Route Type

By Route Number

Table 40: Summary of Decomposition Analysis

Mode	Linked Trips			Unlinked Trips			Percent Difference
	Boardings on Surveyed Routes*	Transfers FROM Route*	Transfers TO Route*	Estimated Boardings (Linked Trips + Transfers)*	Actual Boardings (Unlinked Trips)**	Absolute Difference	
Local	39,108	5,625	6,469	51,202	51,471	269	-0.5%
CT*fastrak*	6,334	693	781	7,808	8,053	244	-3.1%
Express	3,640	142	104	3,886	3,922	35	-0.9%
Total	**49,083**	**6,461**	**7,353**	**62,896**	**63,445**	**549**	**-0.9%**

Table 41: Decomposition Analysis by Route Type

Route ID	Route Name	Route Type	Linked Trips			Unlinked Trips			
			Boardings on Surveyed Routes*	Transfers FROM Route*	Transfers TO Route*	Estimated Boardings (Linked Trips + Transfers)*	Actual Boardings (Unlinked Trips)**	Absolute Difference	Percent Difference
30	Bradley Flyer	Local	466	46	66	578	635	(57)	-10%
31-33	Park St	Local	3,572	491	709	4,772	4,549	224	5%
32-36	Windsor Ave	Local	1,629	118	234	1,981	2,287	(306)	-15%
37-39	New Britain Ave.	Local	1,940	304	378	2,622	2,620	2	0%
38	Weston St	Local	405	57	132	593	584	9	2%
40-42	N. Main St - Barbour St	Local	2,490	392	394	3,275	3,211	64	2%
41	New Britain - Hartford	Local	914	58	49	1,021	1,181	(160)	-16%
43	Campfield Ave	Local	517	73	91	681	781	(100)	-15%
44	Garden St	Local	281	103	74	458	347	110	24%
45	Berlin Tpke Flyer	Local	29	3	3	36	45	(9)	-25%
46	Vine St	Local	1,433	226	293	1,952	2,033	(81)	-4%
47	Franklin Ave	Local	2,348	493	485	3,326	3,070	256	8%
50-54	Blue Hills Ave	Local	4,052	495	586	5,133	5,099	34	1%
53-55	Wethersfield Ave	Local	1,298	251	344	1,893	1,872	20	1%

Route ID	Route Name	Route Type	Linked Trips			Unlinked Trips			
			Boardings on Surveyed Routes*	Transfers FROM Route*	Transfers TO Route*	Estimated Boardings (Linked Trips + Transfers)*	Actual Boardings (Unlinked Trips)**	Absolute Difference	Percent Difference
56-58	Albany Ave	Local	1,136	192	232	1,559	1,390	169	11%
59	Locus St	Local	306	47	76	428	473	(45)	-10%
60-66	Farmington Ave	Local	4,423	529	579	5,531	5,504	26	0%
61	Broad St	Local	645	107	86	837	838	(1)	0%
63	Hillside Ave	Local	766	162	58	986	976	9	1%
69	Capitol Ave	Local	387	150	188	725	563	163	22%
72	Asylum Ave	Local	642	143	185	970	923	47	5%
74	Granby St	Local	826	90	62	978	1,095	(117)	-12%
76	Ashley St	Local	1,197	164	222	1,583	1,722	(140)	-9%
82-84	Buckland Hills	Local	1,521	232	168	1,921	2,101	(179)	-9%
83	Silver Ln	Local	1,756	246	316	2,318	2,225	93	4%
86-88	Burnside Ave	Local	1,969	164	195	2,328	2,460	(132)	-6%
87	Brewer St	Local	234	45	44	324	322	2	1%
91	Forbes St	Local	328	9	21	358	384	(26)	-7%
92	Tower Ave	Local	333	44	48	425	364	62	15%

Route ID	Route Name	Route Type	Linked Trips			Unlinked Trips			
			Boardings on Surveyed Routes*	Transfers FROM Route*	Transfers TO Route*	Estimated Boardings (Linked Trips + Transfers)*	Actual Boardings (Unlinked Trips)**	Absolute Difference	Percent Difference
94-96	Park Ave	Local	354	73	20	447	562	(115)	-26%
95	Glastonbury	Local	911	121	133	1,164	1,256	(91)	-8%
101	Hartford - New Britain	BRT/ CT*fastrak*	2,488	245	259	2,993	3,342	(349)	-12%
102	Hartford - N.B. - Bristol	BRT/ CT*fastrak*	789	32	44	865	921	(56)	-6%
121	UConn Health	BRT/ CT*fastrak*	1,033	120	121	1,275	1,312	(38)	-3%
128	Westfarms	BRT/ CT*fastrak*	1,220	159	198	1,578	1,549	29	2%
140	CCSU Shuttle	BRT/ CT*fastrak*	123	45	24	193	157	35	18%
144	Wethersfield - Westfarms	BRT/ CT*fastrak*	145	33	55	233	184	49	21%
153	Flatbush - Copaco	BRT/ CT*fastrak*	171	23	15	209	193	16	8%
161	Hartford Hospitals	BRT/ CT*fastrak*	364	36	63	463	394	69	15%
903	Manchester - Buckland Exp.	Express	686	7	8	701	697	4	1%
904	Glastonbury Exp.	Express	258	-	-	258	258	-	0%
906	Cromwell Exp.	Express	211	6	4	222	215	7	3%
85	MCC Flyer	Express	71	26	2	99	137	(37)	-38%
901	Avon-Canton Exp	Express	229	9	16	254	243	11	4%

Route ID	Route Name	Route Type	Linked Trips			Unlinked Trips			
			Boardings on Surveyed Routes*	Transfers FROM Route*	Transfers TO Route*	Estimated Boardings (Linked Trips + Transfers)*	Actual Boardings (Unlinked Trips)**	Absolute Difference	Percent Difference
902	Corbins Exp.	Express	46	-	-	46	63	(17)	-37%
905	Enfield- Windsor Locks Exp.	Express	786	27	19	832	858	(25)	-3%
907	Newington Exp.	Express	29	-	6	35	30	5	13%
909	Farmington- Unionville Exp.	Express	32	-	-	32	32	-	0%
910	Rocky Hill Exp.	Express	206	-	8	215	244	(29)	-14%
912	Simsbury-Granby Exp.	Express	212	4	2	218	212	6	3%
914	Colchester Exp.	Express	367	1	-	369	381	(12)	-3%
917	Tolland- Vernon Exp.	Express	77	8	6	92	77	15	16%
918	Willimantic - Coventry Exp.	Express	53	-	10	63	53	10	16%
919	Meriden Exp.	Express	20	-	-	20	25	(5)	-27%
921	Middletown - Old Saybrook Exp.	Express	57	-	1	58	57	1	2%
923	Bristol Exp.	Express/ CT*fastrak*	62	-	-	62	67	(5)	-9%
924	Southington- Cheshire Exp.	Express/ CT*fastrak*	53	4	-	57	53	4	6%
925	Cheshire-Waterbury Exp.	Express/ CT*fastrak*	32	5	7	44	32	12	27%
926	Winsted Exp.	Express/ CT*fastrak*	23	2	7	32	23	9	28%

Route ID	Route Name	Route Type	Linked Trips			Unlinked Trips			
			Boardings on Surveyed Routes*	Transfers FROM Route*	Transfers TO Route*	Estimated Boardings (Linked Trips + Transfers)*	Actual Boardings (Unlinked Trips)**	Absolute Difference	Percent Difference
927	Torrington Exp.	Express/ CT*fastrak*	19	2	-	21	19	2	9%
928	Southington- Cheshire - Waterbury Exp.	Express/ CT*fastrak*	29	13	-	41	41	0	1%
950	New Haven - Hartford Exp.	Express/ CT*fastrak*	84	28	6	118	107	11	9%
Local			**39,108**	**5,625**	**6,469**	**51,202**	**51,471**	**(269)**	**-1%**
CT*fastrak*			**6,334**	**693**	**781**	**7,808**	**8,053**	**(244)**	**-3%**
Express			**3,640**	**142**	**104**	**3,886**	**3,922**	**(35)**	**-1%**
Total			**49,083**	**6,461**	**7,353**	**62,896**	**63,445**	**(549)**	**-1%**

Technical Memo #4

Trip Generation Model Development

March 12, 2018

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff

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1. INTRODUCTION

This report describes the Trip Generation Model developed as a part of the CRCOG Model Update. Trip generation is the first step in the conventional four-step transportation forecasting process. The model predicts the number of trips produced by a geographic area, also known as a traffic analysis zone (TAZ). Trip generation models typically utilize socioeconomic data (SED), including number of households and employment, to understand the trip generation potential associated with a given TAZ. Other models rely upon land use information, such as square feet of commercial space, to estimate trips. The CRCOG model is SED based.

A comparison of the model specifications for the existing CRCOG model and the updated CRCOG model is presented in Table 1.

Table 1: CRCOG Model Enhancements to Trip Generation

No.	Model Component	Existing Specification	Revised Specification
1	Household Segmentation	HHs by 0, 1, 2+ autos and by 7 income categories	HHs by 0, 1, 2, 3+ autos, by 4 income categories, by size 1, 2, 3, 4+ and by 0, 1, 2, 3+ workers.
2	HBW and HBO Productions	HBW trip production rates by 0, 1, 2+ cars HBO trip production rates are not segmented	Trip production rates by auto sufficiency with the following market segments: **Zero**: zero auto households; **Low Insufficient**: low income and workers > autos: **Low Sufficient**: low income and workers >= autos; **High Insufficient**: high income and workers > autos; and, **High Sufficient**: high income and autos >= workers.
3	NHB Trip Productions	Rates not segmented	No change
4	External and Truck Trips	Separate modules for these trips	No change
5	Trip Attractions	Trip attraction rates by purpose	Destination Choice model will have size terms that eliminate the need for calculating trip attraction rates

2. GEOGRAPHIC MODIFICATIONS

Traffic Analysis zones

Traffic Analysis Zones (TAZ) 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 a means to organize model inputs and outputs throughout the modeling process.

TAZ boundaries are typically based on census geography and 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. TAZs should also be consistent with the underlying transportation networks and be bounded by roadways. The TAZ structure normally remains constant in the base and future years.

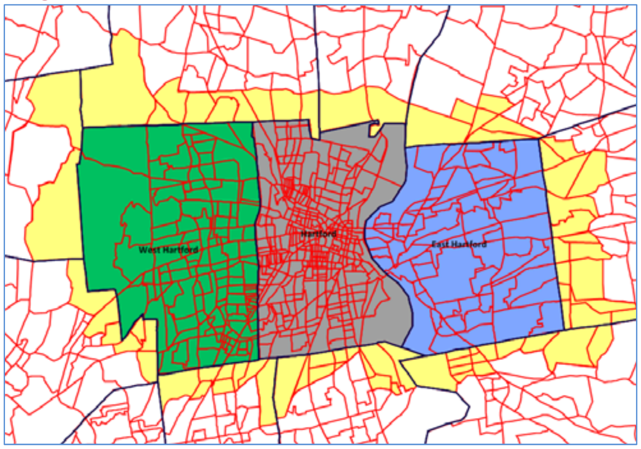
TAZs are linked to the model network by means of centroids and centroid connectors. A centroid is a special class of node that represents the starting point and ending point for all trips generated by a TAZ. Each centroid is connected to the network by means of a centroid connector. Centroid connectors represent local streets, within a TAZ, and permit trip movement from a centroid to the model roadway network.

Travel demand models also include a special type of TAZ known as an external station. Because the model cannot stretch on endlessly, external stations are used to help represent the boundary of the model area and the physical locations at which vehicles can enter or exit the region. Rather than land-use and socioeconomic data, these externals are coded with trip ends categorized to be consistent with the model structure.

The focus of the TAZ review was the area in and around the I-84 Hartford Project area; specifically the towns of Hartford, East Hartford, and West Hartford (See Figure 1). Each TAZ within these towns, as well as a ring of TAZs surrounding these towns, was examined with the possibility of future subdivision. The decision to modify any TAZ was based on the following considerations:

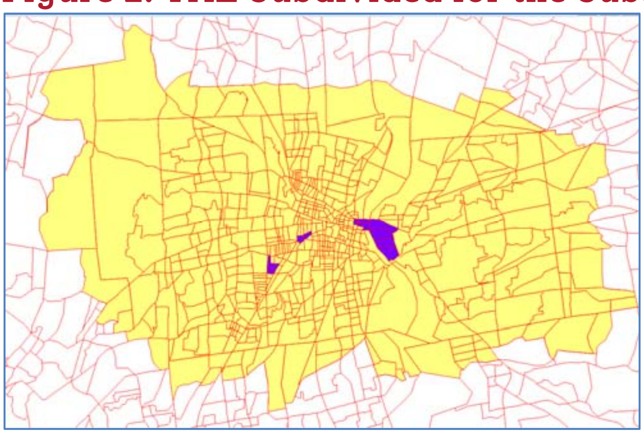
- Maintain consistency with the previously developed I-84 Hartford Project Subarea Model.
- Recognize the alignment of probable I-84 alternatives. TAZ boundaries were modified so as to limit the possibility of a TAZ being split by the alignment of an alternative being considered for project.
- Accommodate major developments within the project area, e.g., the DoNo Development
- Add greater detail in the towns of Hartford, East Hartford, and West Hartford.
- Increase consistency with the roadway network and minimize situations where a TAZ was divided by a roadway.

Figure 1: The Towns of East Hartford, Hartford, and West Harford



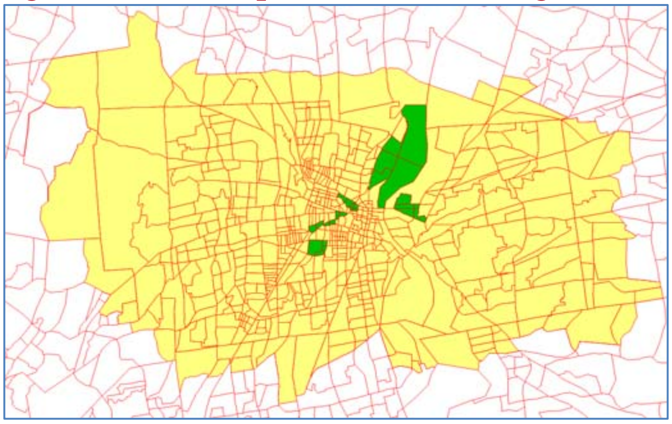
The subarea model was used extensively for the analysis of literally hundreds of alternatives during earlier stages of the project. This model, originally developed by an independent consultant, was based on a version of the 2014 regional CRCOG model. During the development of the subarea model the following regional TAZs were subdivided: 375, 2111, 2112, 2042, and 2059 (See Figure 2).

Figure 2: TAZ Subdivided for the Subarea Model



The TAZs highlighted in Figure 3 were subdivided to accommodate alternative ramp locations as well as various alignment options. The TAZ subdivided for this purpose are: 86, 87, 374, 2018, 2024, 2033, 2042, 2074, 2036, and 2135.

Figure 3: TAZ Split to Avoid Alignment Conflicts



DoNo (Downtown North) Hartford development area (Figure 4) is bounded by Chapel Street and Morgan Street to the south, Market Street to the east, Pleasant Street to the north, and High Street to the west. The center of the redevelopment will include a minor league baseball stadium in the area bounded by Main Street, Trumbull Street, Pleasant Street, and Windsor Street. The mixed-use development will also include residential, retail, and restaurant components. Regional TAZs 88 and 275 were subdivided to accommodate the new development (See Figure 5).

Figure 4: DoNo Development Plan

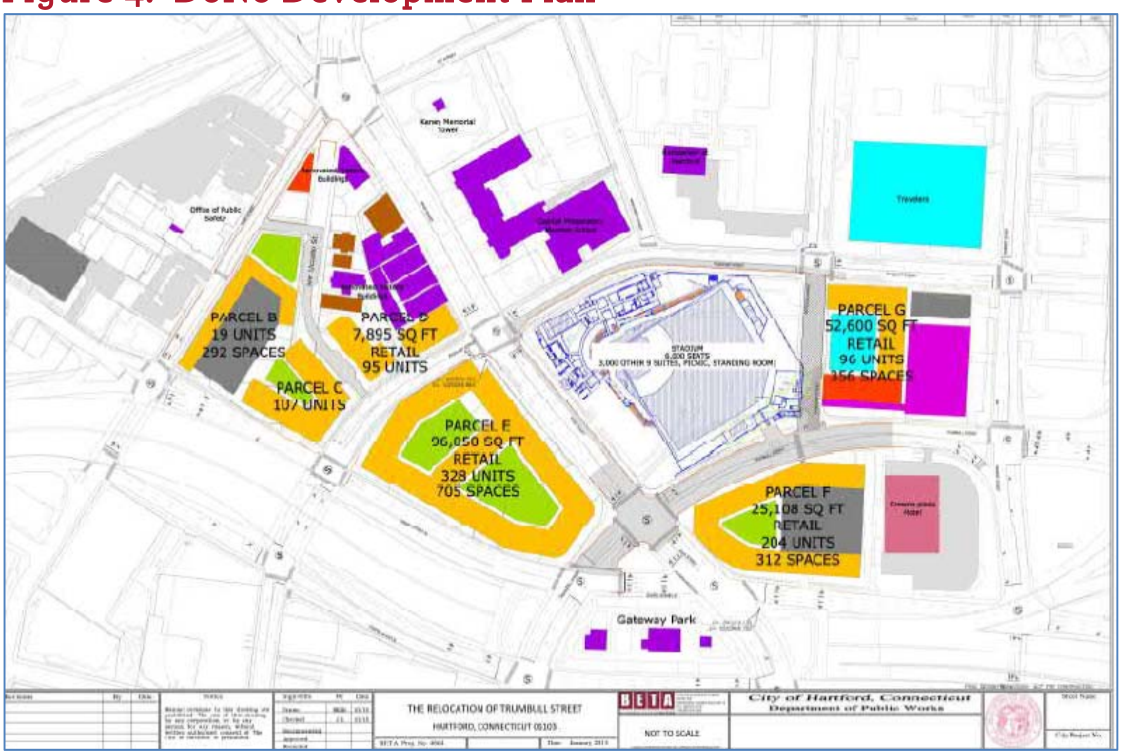
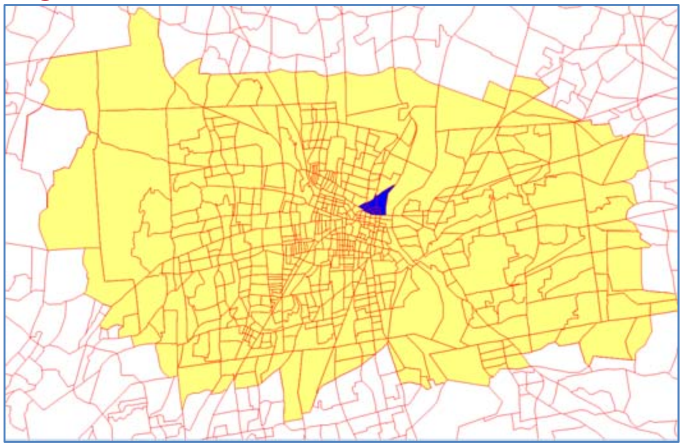
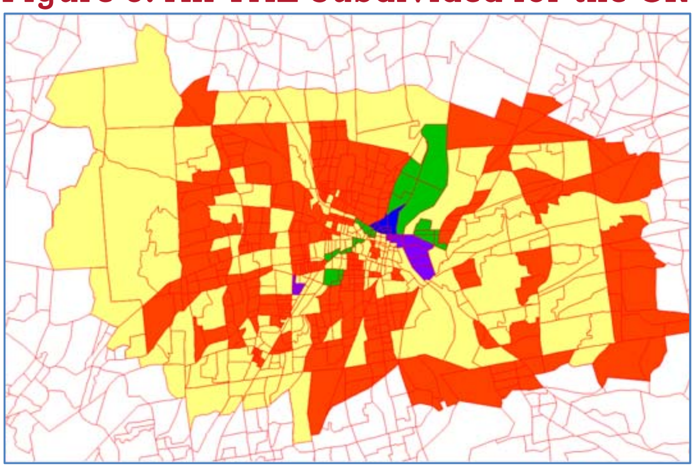


Figure 5: TAZ Subdivided for the DoNo Development



As noted above, all of the TAZs within the towns of East Hartford, Hartford, and West Hartford, along with a ring of TAZs around these towns, were considered for possible subdivision. Figure 6 illustrates all of the TAZs that were subdivided for the purposes of the CRCOG Model Update.

Figure 6: All TAZ Subdivided for the CRCOG Model Update



For any TAZ modified, socioeconomic data were distributed among the parent and children TAZs based on size of the resulting TAZ, Census data, and/or visual inspection. Original population, household, and employment data were held constant.

Table 1Table 2 summarizes the changes made to the TAZ structure by town. A total of 244 TAZs were added to the area covered by the review. The largest number, 144 of TAZ were added in the city of Hartford, f 53 TAZ were added in town of West Hartford, 30 TAZ outside perimeter of the three towns (Ring Area), and 19 in the town of East Hartford. Within the area reviewed the average TAZ area decreased from 0.27 to 0.14 square miles. As a result of the model update and TAZ review there are now 2,028 TAZ in the CRCOG model. This includes 1,991 internal TAZ and 37 external stations.

Table 2: TAZ Review and Modification Summary

Area	Number of TAZ		Average Area	
	Old	New	Old	New
East Hartford	56	75	0.33	0.25
Hartford	194	336	0.09	0.05
West Hartford	90	143	0.43	0.16
Ring	46	75	0.69	0.41
Totals	386	629	0.27	0.14

District modifications

In addition to the TAZ modifications, the District system used in the CRCOG model was also revised. The primary objective behind these revisions was to reduce the number of Districts from 40 (as in the previous model) to a number felt to be more manageable. The revised system has 27 districts. A summary of the revised Districts appears in Table 3.

Table 3: District Summary

District	Description	Old District	Notes
101	Hartford CBD East	10, 11	Consistent with the CBD as defined by CBD_IND
102	Hartford CBD West	34,891,415	TAZ identified as HFD_CBD by the attribute AREA_IND except for those TAZ defined as CBD by CBD_IND and, thereby, made part of DISTRICT 101.
103	Hartford North	12,367	Remainder of the TOWN of Hartford north of the CBD (DISTRICTS 101 AND 102) and north of Capitol Avenue.
104	Hartford South	121,314,151,617	Remainder of the TOWN of Hartford south of the CBD (DISTRICTS 101 AND 102) and south of Capitol Avenue.
201	West Hartford North	27	TOWN of West Hartford north of Farmington Avenue
202	West Hartford South	28	TOWN of West Hartford south of Farmington Avenue
301	East Hartford	36	TOWNs of Bolton, East Hartford, Manchester, South Windsor, Vernon
401	Other CT West Border	0	TOWNs of Barkhamstead, Colebrook, Hartland, Harwinton, New Hartford, Plymouth, Prospect, Southington, Thomaston, Torrington, Waterbury, Winchester, Wolcott

402	Other CT	31	TOWNs of Barkhamstead, Canton, Granby, New Hartford, Simsbury
403	Other CT	32	TOWNs of East Granby, East Windsor, Enfield, Somers, Suffield, Windsor, Windsor Locks
404	Other CT	34	TOWNs of Coventry, Ellington, Mansfield, Stafford, Tolland. Willington
405	Other CT East Border	0	TOWNs of Ashford, Chaplin, Colchester, Columbia, Durham, East Haddam, East Hampton, Haddam, Lebanon, Mansfield, Salem, Union, Windham
406	Other CT	33	TOWNs of Bloomfield, Windsor
407	Other CT	30	TOWN of Avon
408	Other CT	29	TOWNs of Burlington, Farmington
409	Other CT	21	TOWNs of Bristol, Plainville, Southington
410	Other CT	23	TOWN of New Britain
411	Other CT	24	TOWN of Newington
412	Other CT	25	TOWN of Newington
413	Other CT	26	TOWNs of Rocky Hill, Wethersfield
414	Other CT	35	TOWN of Glastonbury
415	Other CT	20	TOWNs of Andover, Columbia, Hebron, Marlborough, Portland
416	Other CT	19	TOWNs of Cromwell, Meriden, Middlefield, Middletown, Wallingford
417	Other CT	22	TOWN of Berlin
418	Other CT	18	TOWN of Cheshire
501	Other MA	38	TOWNs of Blandford, Granville, Montgomery, Russell, Southampton, Southwick, Tolland MA, Westfield
502	Other MA	39	TOWNs of Agawam, Chicopee, East Longmeadow, Easthampton, Granby MA, Hampden, Holyoke, Longmeadow, Ludlow, South Hadley, Springfield, West Springfield, Wilbraham
503	Other MA	37	TOWNs of Wales, Holland, Monson
601	CT and MA Externals	Included with DISTRICTS 19, 20, 21, 29, 31, 34, 37,38, 39	External TAZ

3. SOCIOECONOMIC DATA

Statewide socioeconomic data for 2010, 2025, and 2040 data was provided by the Connecticut Department of Transportation, Bureau of Policy & Planning. Information was extracted from this data for the CRCOG model area. Socioeconomic data for that part of the CRCOG model area in Massachusetts was carried over from the previous CRCOG model. Table 4 is a summary of these data.

Table 4: Socioeconomic Data

SED	2010	2025	2010 - 2025 Change		2040	2025 - 2040 Change	
			Number	Percent		Number	Percent
Households	802,832	866,736	63,904	7.96%	924,595	57,859	6.68%
Population	2,067,580	2,188,838	121,258	5.86%	2,289,137	100,299	4.58%
Retail Employment	141,888	149,983	8,094	5.70%	157,319	7,336	4.89%
Non-Retail Employment	767,693	817,728	50,035	6.52%	859,257	41,528	5.08%

Validation of the socioeconomic data was accomplished by means of a comparison between model socioeconomic data and the same data from the U.S. Census Bureau Transportation Planning Program (CTPP) and Longitudinal Employer-Household Dynamics (LEHD) program. The following CTPP tables were referenced for the comparison to population and household data:

- A101100 – Population (1) (All persons),
- A112107 – Population in Households (1) (Population in households),
- A112100 – Total Households (1) (Households), and
- A103100 – Total Workers in Households (1) (Workers 16 years and over in households).

Data for comparison of employment totals came from the LEHD program. For Connecticut, 2010 estimates of all jobs was used. Massachusetts did not start to participate in the program until 2011, therefore, the employment data was estimated as follows:

2010 MA Employment = 2010 CT Employment * (2011 MA Employment / 2011 CT Employment)

A comparison, between model and census data, of population, population in households, households, workers, and employment is presented in Table 5. For the most part, differences between the two data sets are relatively small (< 1.0 percent difference). The only exceptions being the number of workers in Massachusetts (8.29 percent), Connecticut employment (2.62 percent), and Massachusetts employment (1.12 percent). Overall, however, the results were deemed to be acceptable and within reason.

Table 5: Socioeconomic Data Validation

SED	Model	CTPP / LEHD	Difference	
			Number	Percent
CT Population	1,575,577	1,565,960	9,617	0.61%
MA Population	492,003	490,745	1,258	0.26%

Total Population	**2,067,580**	**2,056,705**	**10,875**	**0.53%**
CT Population in HH	1,516,043	1,508,110	7,933	0.52%
MA Population in HH	475,019	471,770	3,249	0.68%
Total Pop in HH	**1,991,062**	**1,979,880**	**11,182**	**0.56%**
CT Households	611,336	607,350	3,986	0.65%
MA Households	191,496	189,675	1,821	0.95%
Total HH	**802,832**	**797,025**	**5,807**	**0.72%**
CT Number of Workers	745,356	750,945	-5,589	-0.75%
MA Number of Workers	233,520	214,150	19,370	8.29%
Total Workers	**978,877**	**965,095**	**13,782**	**1.41%**
CT Employment	711,073	729,733	-18,660	-2.62%
MA Employment	198,508	196,279	2,230	1.12%
Total Employment	**909,581**	**926,012**	**-16,430**	**-1.81%**

4. HOUSEHOLD CLASSIFICATION MODELS

The 2016 "Let's Go CT" Household Travel Survey (HTS) collected information about the daily household travel activities from residents across the state to understand how they travel, where they go, why they travel, and how long it takes. These data provide an overview of daily travel patterns for all travel modes and primary trip purposes (home-based-work, home-based-other, non-home-based). A sample set of data from the HTS was supplemented and compared to U.S. Census American Community Survey (ACS) data applicable to Connecticut and Hartford region. The ACS data provides detailed demographic characteristics along with journey-to work data.

A cross-classification approach to trip production models requires the use of household sub-models to disaggregate the household attribute data into the proper format required by the cross-classification model. Auxiliary submodels were developed to forecast household distributions based upon average household size, number of workers, and income. A regression model was used to estimate the total workers per TAZ using average household size as the independent variable. Auto ownership per TAZ was estimated using Public Use Microsample (PUMS) data. Trip rates are derived for household cross classified by number of workers, number of vehicles, and income category. The following ACS tabulations were used in the development of the Household Classification models:

- Table: A103100: Total Workers in household
- Table: A112100: Total Households
- Table: A112107: Population in Households
- Table: A112209: Household size (5) by Number of workers in household (6) (Households)
- Table: A112214: Vehicles available (6) by Household income in the past 12 months (2010$) (26) (Households)

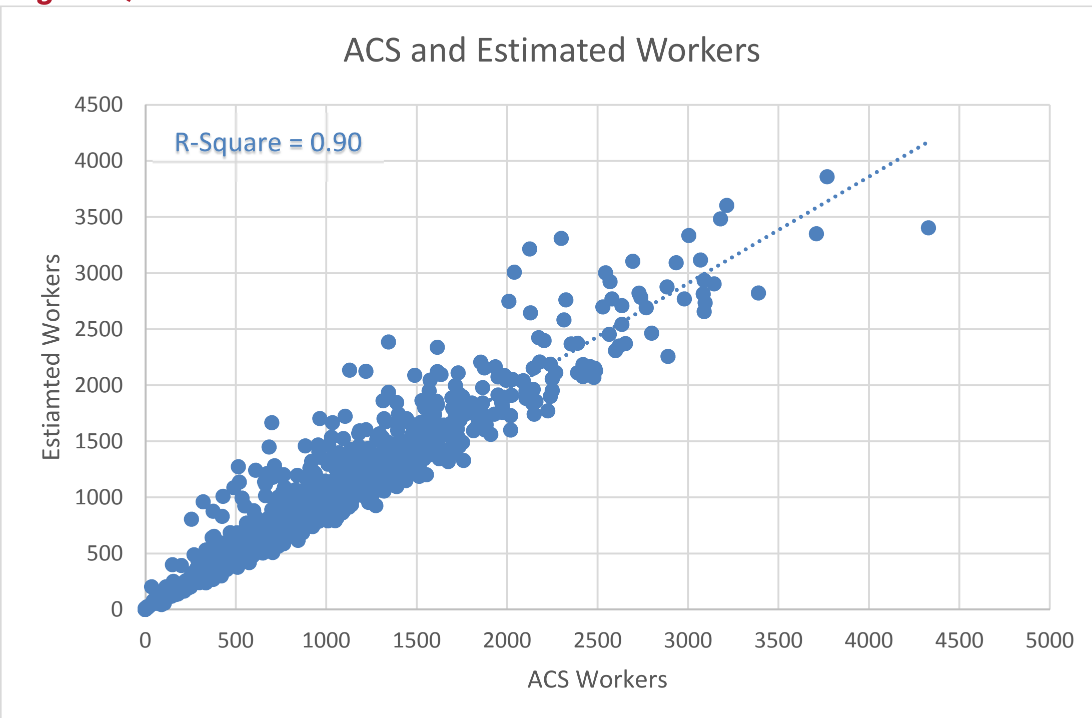
Number of Workers

Ideally the number of workers per TAZ is an input to the travel demand model and can be used to calculate the number of workers per household in order to estimate the number of 0, 1, 2, and 3+ worker households using the household worker submodel. Application of this approach for the CRCOG model involved an additional step to estimate the number of workers by TAZ. A regression model was used to forecast workers by TAZ using various combinations of household size, density, and population as the independent variables. Several models were tested with the final selected model using average household size. Table 6 summarizes the resulting worker model and the associated R2 statistics. Figure 1 demonstrates the fit of the number of workers estimated by the model against ACS data.

Table 6: Worker Model

Term	Coefficient	t.Stat	R Square
Intercept	0.18	4.70	0.44
HH Size	0.42	27.04	

Figure 7: ACS Workers and Estimated Workers



To develop the workers per household curves, the workers per household size marginals were set up for 0, 1, 2, and 3+ worker households. Household classification was also developed using the 5-year ACS dataset. A customized spreadsheet was set up to process the raw records, pivot the results into an average number of workers per household lookup format, interpolate the results to set up step increments of 0.1 and create a text lookup file for percentage of households in each of the four worker categories given the average workers per household in the TAZ. The zonal average was plotted against percentage of households by category. Table 7 shows a sample of the workers per household output lookup table and Figure 8 shows the raw ACS data for the household shares by workers per household. Mathematical relationships were then estimated for each category using the trend line analysis available in Microsoft Excel. The trend line analysis presents an equation for each size category that relates the attribute average to the percentage of households in that size category. Figure 9 shows the smoothed workers per household curves for CRCOG region along with equations.

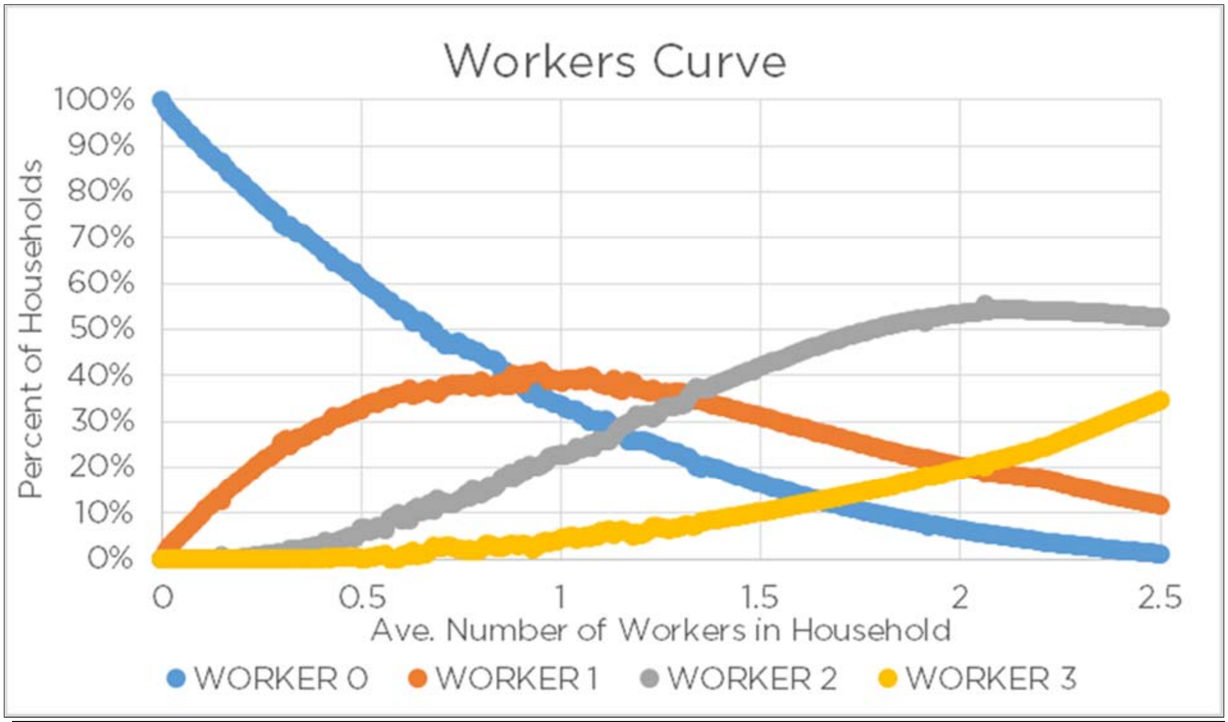
Table 7: Workers per Household Lookup table (sample)

Workers per Household	Worker 0	Worker 1	Worker 2	Worker 3
0.60	0.5429	0.3626	0.0848	0.0097
0.61	0.5368	0.3651	0.0878	0.0103
0.62	0.5317	0.3722	0.0861	0.0100

0.63	0.5149	0.3589	0.1058	0.0204
0.64	0.5145	0.3621	0.1155	0.0079
0.65	0.5183	0.3656	0.1047	0.0114

Figure 8: ACS Data – Household Shares by Workers per Household:

Figure 9: Workers per Household Classification Curves:



Variable	Equation	Root Square (R^2)
Worker 0	$y = -0.0271x^3 + 0.2656x^2 - 0.8799x + 0.9762$	$R^2 = 0.9998$
Worker 1	$y = 0.0961x^3 - 0.548x^2 + 0.789x + 0.0501$	$R^2 = 0.9853$
Worker 2	$y = -0.0774x^3 + 0.2489x^2 + 0.0895x - 0.0244$	$R^2 = 0.9951$
Worker 3	$y = 0.0085x^3 + 0.0332x^2 + 0.0006x - 0.0019$	$R^2 = 0.9992$

Income and auto ownership

Included in the SED file for the CRCOG model is the distribution of households by income and auto ownership for each TAZ. These estimates were developed using public-use micro-sample (PUMS) data. The distribution uses four auto categories (0, 1, 2, 3+) and four income quartiles and replaces the previous distribution which had three auto categories (0, 1, 2+) and 7 income groups. Household income quartiles were identified based on data from the U. S. Census Bureau, American Community Survey 2006 – 2010 Five-year Period Estimates available through the Census Transportation Planning Program. The household income classifications used in this model update appear in Table 8.

Table 8: Household Income Classification

Income Quartile	Household Income
1	Less than $29,999
2	$30,000 - $59,999
3	$60,000 - $99,999
4	$100,000 or more

Each TAZ was assigned to a specific PUMS zone if the geographic center of the TAZ fell within the PUMS zone boundary. The CRCOG model area was covered by 19 PUMS Zones. The number of households in each PUMS Zones ranged from 10,084 to 65,021 with a median number of households per PUMS Zones of 44,372. The distribution of households by autos by income for any TAZ was determined by applying the same characteristics of the PUMS Zone to which that TAZ was assigned. A summary of number of households by auto and income category is provided in Table 9.

Table 9: Households by Auto Ownership and Income Quartile

Auto	Income Quartile	Households
0	1	62,199
	2	13,150
	3	4,468
	4	3,179
1	1	100,183
	2	98,803
	3	54,915
	4	23,114
2	1	23,877
	2	62,486
	3	89,764
	4	121,983
3+	1	5,107
	2	16,140
	3	34,838
	4	88,628

Household SEED Submodel

The proportion of regional households was estimated from HTS and PUMS data and cross classified by number of workers in household, number of vehicles in the household, and income quartile. A regression model was used to estimate the total workers per TAZ using average household size as the independent variable. A multinomial logit model was estimated for forecasting auto ownership using variables describing household characteristics along with other predictive variables including accessibility. The data set was developed using the ACS five year data.

These resulting distribution curves must sum to 100% and for the household size model, the results are consistent with the input value when averaged. Hand-fitted curves were adjusted to fit the observed data points, sum to 100%, and produce the appropriate average. A summary of each market segment (number of workers, auto ownership, and income group) and the proportion of regional households in that segment is illustrated in Table 10.

Table 10: Household Seed Submodel

Autos	Income Quartile	Workers			
		0	1	2	3+
0	1	1.317	1.109	0.146	0.015
	2	0.168	0.336	0.259	0.022
	3	0.069	0.128	0.161	0.040
	4	0.033	0.040	0.223	0.066
1	1	2.138	2.674	0.565	0.018
	2	1.820	3.152	1.116	0.131
	3	0.569	1.901	1.105	0.201
	4	0.266	0.617	0.799	0.175
2	1	1.321	1.262	0.649	0.040
	2	2.481	3.670	3.462	0.295
	3	1.729	4.480	7.967	0.843
	4	0.959	4.254	14.406	1.197
3+	1	0.244	0.270	0.168	0.047
	2	0.492	1.113	1.218	0.445
	3	0.390	1.591	3.714	2.036
	4	0.288	2.036	7.836	7.719

5. TRIP PRODUCTION MODEL

This section describes the development and validation of the trip production model. In terms of model sequence, this model represents the first step in the traditional 4-step process. The trip production model uses the results from the household classification submodels to estimate trip production for households in each TAZ. The outputs from the trip production model are fed into the destination choice models.

Model Structure

The model maintained the primary trip purposes from previous CRCOG model generating trips for the following trip purposes:

- Home-based work (HBW)
- Home-based other (HBO)
- Non-home-based (NHB)

The rates for the HBW and the HBO purposes are segmented based on household income and the relationship between the number of vehicles the household has and the number of workers (auto sufficiency). This replaces the market segmentation used in the previous CRCOG model, which had three auto and seven income categories. Auto sufficiency compares the number of vehicles available with the number of workers in the household (or a proxy variable). The household market segmentation used for the updated CRCOG model is as follows:

- Zero-car households, all income groups
- Households with fewer autos than workers, low income
- Households with fewer autos than workers, high income
- Households with autos greater than or equal to workers, low income
- Households with autos greater than or equal to workers, high income

Thus, in an auto "sufficient" household, each worker has a car that they can drive whereas in an auto "insufficient" household there are more workers than cars. Households with no cars are a special type of "insufficient" household and are therefore treated as a separate category. Households that have zero cars, less cars than workers, or a car for each worker have distinct travel generation and mode choice patterns, especially when it comes to transit ridership.

The NHB trip rates are not segmented. Trip production procedures for trucks, internal/external trips, and airport trips were kept as in the previous model.

Trip attractions, called size terms in the context of a destination choice model, are incorporated directly into the destination choice model during the calculation of the utility equation and will be discussed in following tech memos.

Trip Production Rates

Initial trip production rates for resident trip purposes (HBW, HBO, and NHB) were asserted from the French Broad River Metropolitan Planning Organization (Asheville, NC, 2015) trip production model. These rates were used to generate trips for the CRCOG model area which were then compared to the trip totals from the previous CRCOG model. Without the final HTS results it was decided that the trip totals from the previous model represented reasonable target values. These original asserted rates were then applied and adjusted until the resulting trip totals were a reasonable match to the target values.

The trip production rates were also checked for logical variable relationships. Cells with more workers and higher income should have higher trip rates than cells with fewer workers and lower income. In several cases the trip production rates did not follow logical variable relationships so they were adjusted to create a final set of rates. The iterative adjustment process was carried out until the trip totals were a reasonable approximation of the target values. The process continued until total trip productions from the revised rates reasonable matched those of the prior model totals. Table 11 presents a comparison of current trip production totals with those from previous CRCOG model.

Table 11: Trip Production Totals

Previous CRCOG Model		CRCOG Model Update	
Purpose	**Productions**	**Purpose**	**Productions**
HBW_0Car	68,062	HBW_zero	73,650
SubTotal	68,062		73,650
HBW_1Car	295,720	HBW_low_insufficient	59,116
HBW_2Car	820,955	HBW_low_sufficient	254,436
		HBW_high_insufficient	85,954
		HBW_high_sufficient	850,089
SubTotal	1,116,675		1,249,594
HBW_IX	109,120	HBWP_IX	109,120
HBW_XI	118,902	HBWP_XI	118,902
Sub Total	228,022		228,022
		HBO_zero	344,394
		HBO_low_insufficient	127,827
		HBO_low_sufficient	1,292,225
		HBO_high_insufficient	156,910
		HBO_high_sufficient	1,945,788
HBO Sub Total	3,867,144		3,867,144
NHB Sub Total	1,646,763		1,646,763
NWIX	275,463	NWIXP	275,463
NWXI	325,790	NWXIP	325,790
BIA_Airport	6,153	BIAP	6,153
TII	496,949	TIIP	497,141
TIX	36,820	TIXP	36,722
TXI	37,943	TXIP	37,849
Truck Sub Total	571,712		571,712
TOTAL TRIP PRODUCTION	8,105,783		8,244,292

Table 12 – Table 14 illustrate the original and final trip rates for HBW, HBO, and NHB trips used in the CRCOG regional trip production model.

Table 12: Home-Based Work Trip Production Rates (HBW)

Autos	Income Quartile	Original Rates				Final Rates			
		Workers				Workers			
		0	1	2	3+	0	1	2	3+
0	1	0	0.72	2.21	1.77	0	1.38	1.93	2.61
	2	0	0.72	2.21	1.77	0	1.38	1.93	2.61
	3	0	0.63	1.92	1.55	0	1.44	2.35	2.98
	4	0	0.63	1.92	1.55	0	1.44	2.35	2.98
1	1	0	1.37	2.33	2.95	0	1.38	1.93	2.61
	2	0	1.37	2.33	2.95	0	1.38	1.93	2.61
	3	0	1.42	1.86	2.59	0	1.44	2.35	2.98
	4	0	1.42	1.86	2.59	0	1.44	2.35	2.98
2	1	0	1.37	3.37	3.13	0	1.38	2.34	3.15
	2	0	1.37	3.37	3.13	0	1.38	2.34	3.15
	3	0	1.42	2.32	3.13	0	1.44	3.16	3.40
	4	0	1.42	2.32	3.13	0	1.44	3.16	3.40
3+	1	0	1.37	3.37	3.39	0	1.38	2.34	3.42
	2	0	1.37	3.37	3.39	0	1.38	2.34	3.42
	3	0	1.42	2.32	3.57	0	1.44	3.40	3.60
	4	0	1.42	2.32	3.57	0	1.44	3.40	3.60

Table 13: Home-Based Other Trip Production Rates (HBO)

Autos	Income Quartile	Original Rates				Final Rates			
		Workers				Workers			
		0	1	2	3+	0	1	2	3+
0	1	1.40	1.40	1.40	1.40	4.14	4.14	4.14	4.14
	2	1.40	1.40	1.40	1.40	4.14	4.14	4.14	4.14
	3	1.45	1.45	1.45	1.45	4.28	4.28	4.28	4.28
	4	1.45	1.45	1.45	1.45	4.28	4.28	4.28	4.28
1	1	1.50	1.50	1.50	1.50	4.42	4.42	4.42	4.42
	2	1.50	1.50	1.50	1.50	4.42	4.42	4.42	4.42
	3	1.64	1.64	1.64	1.64	4.85	4.85	4.85	4.85
	4	1.64	1.64	1.64	1.64	4.85	4.85	4.85	4.85
2	1	1.70	1.70	1.70	1.70	5.02	5.02	5.02	5.02
	2	1.70	1.70	1.70	1.70	5.02	5.02	5.02	5.02
	3	1.71	1.71	1.71	1.71	5.07	5.07	5.07	5.07
	4	1.71	1.71	1.71	1.71	5.07	5.07	5.07	5.07
3+	1	1.70	1.70	1.70	1.70	5.02	5.02	5.02	5.02
	2	1.70	1.70	1.70	1.70	5.02	5.02	5.02	5.02
	3	1.78	1.78	1.78	1.78	5.26	5.26	5.26	5.26
	4	1.78	1.78	1.78	1.78	5.26	5.26	5.26	5.26

Table 14: Non-Home Based Trip Production Rates (NHB)

Autos	Income Quartile	Original Rates Workers 0	1	2	3+	Final Rates Workers 0	1	2	3+
0	1	1.11	1.11	1.11	1.11	1.30	1.30	1.30	1.30
	2	1.11	1.11	1.11	1.11	1.30	1.30	1.30	1.30
	3	1.11	1.11	1.11	1.11	1.30	1.30	1.30	1.30
	4	1.11	1.11	1.11	1.11	1.30	1.30	1.30	1.30
1	1	1.60	1.60	1.60	1.60	1.77	1.77	1.77	1.77
	2	1.60	1.60	1.60	1.60	1.77	1.77	1.77	1.77
	3	1.89	1.89	1.89	1.89	2.21	2.21	2.21	2.21
	4	1.89	1.89	1.89	1.89	2.21	2.21	2.21	2.21
2	1	1.52	1.52	1.52	1.52	1.87	1.87	1.87	1.87
	2	1.52	1.52	1.52	1.52	1.87	1.87	1.87	1.87
	3	2.05	2.05	2.05	2.05	2.39	2.39	2.39	2.39
	4	2.05	2.05	2.05	2.05	2.39	2.39	2.39	2.39
3+	1	1.73	1.73	1.73	1.73	2.02	2.02	2.02	2.02
	2	1.73	1.73	1.73	1.73	2.02	2.02	2.02	2.02
	3	2.11	2.11	2.11	2.11	2.46	2.46	2.46	2.46
	4	2.11	2.11	2.11	2.11	2.46	2.46	2.46	2.46

Validation of the trip generation model included a check of common ratios based on person trip totals and socioeconomic data to those seen in other modeling efforts. As shown in Table 15 below, the trips produced by the CRCOG model compare reasonably well with the observed values.

Table 15: Validation Ratio Checks

Ratio Checks	Model	Reasonable or Observed Rates
Workers to Employment	1.08	1.04
Persons to Households	2.48	2.48
Workers to Households	1.22	1.21
HBW Productions per Worker	1.35	~2 per worker
HBW Productions per Household	1.65	1.55
Total Productions by HH	10.3	8 to 18
Total Productions by Person	4.1	3.5 to 4.0
HBW Productions per HH	1.6	1.7 to 2.3
HBO Productions per HH	4.8	3.5 to 4.8
NHB Productions per HH	2.1	1.7 to 2.9

Technical Memo #5

Mode Choice Model Development

April 2, 2018

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff

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1. INTRODUCTION

This technical memorandum describes the development of the mode choice models for the Capital Region Council of Governments (CRCOG). The mode choice models were developed with information from the 2016 'Let's Go CT' Household Travel Survey, 2016 CRCOG On-Board Transit Survey, and U.S. Census American Community Survey (ACS) and Census Transportation Planning Program (CTPP) data. The model formulation is a nested logit model. Based upon the proposed structure and asserted coefficient values, calibration target values were constructed from the observed data.

The mode choice models are calibrated using market-stratified person trip tables from the trip distribution model. Calibration includes the calibration of alternative specific constants while reviewing trips by market stratification, mode, and transit access mode. Mode choice calibration is an iterative process that builds upon previous model steps that addressed the transportation networks, trip generation, and trip distribution. This technical memorandum will discuss the following:

- Calibration Target Preparation
- Mode Choice Model Description
- Mode Choice Calibration and Results

2. CALIBRATION TARGET PREPARATION

In order for the mode choice model to accurately reflect observed travel patterns, the model must be calibrated to observed conditions. These observed conditions typically come from a household travel survey, on-board transit survey, or ideally a combination of the two. The calibration process consists of adjusting the terms in the mode choice utility equations to match observed data in the form of calibration targets. For the CRCOG mode choice calibration process, calibration targets were needed by mode, market segment, and trip purpose. The preparation of the calibration targets relied primarily upon the outputs from the CRCOG trip generation model, the 2016 CRCOG transit on-board survey, and the 2016 'Let's Go CT' Household Travel Survey. Other data considered during this process included the National Household Travel Survey and ACS data available through the CTPP.

The aggregate trip totals by purpose were taken from the CRCOG trip generation model. As shown in Table 1, the total number of Home Based Work (HBW) trips is 1,184,737, Home Based Other (HBO) trips is 3,867,144, and Non-Home Based trips is 1,646,763. These data served as the overall model control totals for trips by trip purpose.

Table 1: Trips by Mode for Mode Choice

Mode	HBW		HBO		NHB		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Drive Alone (DA)	985,133	83.15%	1,505,407	38.93%	818,013	49.67%	3,308,553	49.39%
Shared Ride 2 (SR2)	75,424	6.37%	823,706	21.30%	316,520	19.22%	1,215,650	18.15%
Shared Ride 3+ (SR3+)	40,212	3.39%	981,919	25.39%	338,427	20.55%	1,360,557	20.31%
Local Bus	16,973	1.43%	18,434	0.48%	3,701	0.22%	39,108	0.58%
Express Bus	3,247	0.27%	212	0.01%	192	0.01%	3,651	0.05%
Bus Rapid Transit (BRT)	2,474	0.21%	3,212	0.08%	648	0.04%	6,334	0.09%
Walk	52,150	4.40%	494,931	12.80%	157,251	9.55%	704,332	10.51%
Bike	9,126	0.77%	39,323	1.02%	12,010	0.73%	60,458	0.90%
Total	1,184,738	100.00%	3,867,144	100.00%	1,646,762	100.00%	6,698,644	100.00%

To begin creating mode choice targets, a count of trips was developed for each market stratification generated by the CRCOG trip generation model as shown in Table 2. As noted in the table, the Home Based Work (HBW) and Home Based Other (HBO) purposes are split into five markets based on household income and the relationship between auto ownership and household workers (auto sufficiency). The Non-Home Based (HNB) purpose is not market stratified.

Table 2: CRCOG Model Trips by Market Segment

Purpose	Household Income	Auto Sufficiency *	Trips
Home-Based Work (HBW)	All Incomes	Zero Auto	68,062
	<= $59,999	Insufficient (Autos < Workers)	52,828
	<= $59,999	Sufficient (Autos >= Workers)	76,811
	>= $60,000	Insufficient (Autos < Workers)	227,372
	>= $60,000	Sufficient (Autos >= Workers)	759,665
Home-Based Other (HBO)	All Incomes	Zero Auto	344,394
	<= $59,999	Insufficient (Autos < Workers)	127,827
	<= $59,999	Sufficient (Autos >= Workers)	156,910
	>= $60,000	Insufficient (Autos < Workers)	1,292,225
	>= $60,000	Sufficient (Autos >= Workers)	1,945,788
Non-Home Based (NHB)	No Market Stratification		1,646,763

*Auto sufficiency is market segmentation by income, number of works and autos. The auto "sufficient" household are defined where each worker has a car that they can drive whereas in an auto "insufficient" household there are more workers than cars.

Transit Trip Targets / On-Board Transit Survey

The on-board transit survey captured weekday travel between March and June 2016. This survey provides an understanding of transit travel on the CT*transit* Hartford District. The survey, which included over 100 local bus, express bus, and BRT (CTfastrak) routes, was the largest and most comprehensive origin and destination survey conducted by CRCOG. The goal of the survey effort was to obtain useable surveys from approximately 8-10% of transit riders. The actual number of usable surveys collected was 7,027. The expanded on-board survey is taken as the total number of transit trips for the region because of a sampling plan that was developed by route, direction, and time of day, and weighted and expanded to represent the universe of transit users in the Hartford District. Based on the expanded linked trips from the survey, daily transit trips on the CT*transit* Hartford District total 22,694 HBW trips, 21,857 HBO trips, and 4,542 NHB trips. These trips are used as the control total for all transit trips in the Hartford District. Table 3 provides a summary of the expanded transit trips for the three transit modes.

Table 3: Expanded on Board Survey Transit Trips by Mode

Transit Mode	Transit Trips	
	Number	Percent
Local Bus	39,108	79.7%
Bus Rapid Transit	6,334	12.9%
Express Bus	3,651	7.4%
Total	49,093	100.0%

The On-Board Survey included questions on trip purpose, household income, and auto ownership. This allowed the transit trips to be allocated by transit mode to CRCOG Model market stratification. Table 4 shows the expanded On-Board transit trips by trip purpose, mode, and market stratification.

Table 4: Expanded on Board Survey Transit Trips by Trip Purpose, Mode, and Market Stratification

Purpose	Mode	Total Trips	Trips by Market Segment				
			Zero	Low-Insufficient	High-Insufficient	Low-Sufficient	High-Sufficient
HBW	Local Bus	16,973	7,896	4,907	660	2,481	1,028
	Express Bus	3,247	253	244	476	747	1,528
	BRT	2,474	894	522	138	449	470
	Total	22,694	9,043	5,673	1,274	3,677	3,026
HBO	Local Bus	18,434	10,236	3,768	362	3,651	416
	Express Bus	212	51	70	43	12	35
	BRT	3,212	1,628	623	89	715	156
	Total	21,857	11,915	4,462	495	4,378	608
NHB	Local Bus	3,701	NHB Trips are not Market Segmented				
	Express Bus	192					
	BRT	648					
	Total	4,542					

The On-Board Transit Survey also gathered information on how riders access the transit system. Table 5 shows how Hartford District riders access each transit mode (BRT, express bus, and local bus) in the system. Table 6 shows a further breakdown of the access data by transit mode, trip purpose, mode of access, and market segment. These data represent the calibration targets for transit and transit access mode in the mode choice model.

Note that the transit access mode data presented in Table 5 and Table 6 is presented in Production-Attraction (PA) format. The trip tables input into mode choice model are in PA format as dictated by the trip distribution / destination choice model. Further, as is standard practice, transit person trips are assigned in PA format in order to maintain consistency with the transit networks used to inform the mode choice model (AM conditions for peak trips and mid-day conditions for off-peak trips).

In PA format, the home end of a trip is considered the production end so the choice of mode is based on the travel impedances that the trip sees from the production zone to the attraction zone. For highway trips this is not an issue, there is not a concern that a PA trip, when converted to an OD trip, won't be able to find a return path – there will always be links to drive on. However, for transit, this is a concern because a PA trip, when converted to an OD trip, might not be able to find a return path. This is because the PM and Evening networks might be inconsistent with the AM and Mid-day networks that the PA trip saw when making its choice of mode. As a result, those trips would be unassigned. As further explanation, consider the following example.

Assume a rider takes Bus A to and from work. This would result in two 2 PA bus trips assigned to Bus A. Further, assume that the bus taken is an East-West route which in the TransCAD model network is coded as two separate routes: Bus A East and Bus A West. The PA trips will both be assigned to Bus A East assuming the work location is east of the home location. Thus, in this example, Bus A West does not get assigned any trips. However, in OD format Bus A East would be assigned a trip in the morning and Bus A West would be assigned a trip in the afternoon. How is this reconciled?

What is typically done to report transit boardings by route is to add up the boardings from the eastbound route and the westbound route and report the total for Bus A (instead of separately by East and West). So while Bus A East had 2 trips and Bus A West had 0, in total Bus A had two trips, which is the correct answer. Similarly, for stop-level analysis, the boardings and alightings are added up at each stop and divide by 2 to get-ons and -offs at that stop. It is also important to note, that this is standard practice and accepted by the Federal Transit Administration (FTA).

Table 5: Expanded on Board Survey Transit Survey Mode of Access (PA Format)

Mode of Access	BRT		Express Bus		Local Bus		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Walk	5,457	86.1%	926	25.4%	38,224	97.7%	44,607	90.9%
Bike	160	2.5%	156	4.3%	345	0.9%	661	1.3%
PnR	505	8.0%	1,994	54.6%	186	0.5%	2,685	5.5%
KnR	213	3.4%	575	15.8%	353	0.9%	1,141	2.3%
Total	6,334	100.0%	3,651	100.0%	39,108	100.0%	49,093	100.0%

Note: Common Acronyms: PnR – Park and Ride, KnR – Kiss and Ride

Table 6: Expanded Transit Mode of Access Targets (PA Format)

Mode	Purpose	Access	Market Segmentation				
			Zero	Low Insufficient	High Insufficient	Low Sufficient	High Sufficient
BRT	HBO	Walk	1,557	638	47	633	116
		Bike	64				
		PnR	4				
		KnR	3	22	24	48	32
	HBW	Walk	836	496	105	326	94
		Bike	44			6	22
		PnR		9	11	121	334
		KnR		22	23		25
	NHB	Walk	290	128	16	100	74
		Bike				5	19
		PnR			2		
		KnR	12	2			
Express	HBO	Walk	41	69	12	11	16
		Bike					2
		PnR			15		18
		KnR	11		16		
	HBW	Walk	146	88	109	171	121
		Bike	51	21	11	42	11
		PnR	16	76	306	307	1,227
		KnR	48	60	53	223	160
	NHB	Walk	58	43	2	2	37
		Bike	18				
		PnR				11	18
		KnR	2				1
Local	HBO	Walk	9,696	3,890	378	3,712	388
		Bike	106	68		21	
		PnR	2			17	
		KnR	55	22	6	45	27
	HBW	Walk	7,652	4,970	672	2,351	910
		Bike	39	40		32	4
		PnR		13	5	41	94
		KnR	53	61	12	19	7
	NHB	Walk	2,118	543	78	688	180
		Bike	36				
		PnR	15				
		KnR	37	4		4	

Auto and Non-Motorized Trip Targets

The number of non-transit trips was determined by subtracting the number of transit trips from the trip generation control totals for each trip purpose. This resulted in 1,162,043 HBW, 3,845,287 HBO, and 1,642,221 NHB auto and non-motorized trips. These trips totals were assumed to represent the number of daily trips by drive alone (DA), shared ride 2 person (SR2), shared ride 3+ person (SR3+), walk, and bike modes of travel.

For each trip purpose the proportion of trips by each non-transit mode was determined based on the 2016 Let's Go CT Household Travel Survey results for the CRCOG Metropolitan Planning Organization (MPO) area. The mode choice targets for auto and non-motorized modes are shown in Table 7 and Table 8.

Table 7: Expanded on Board Survey Transit Trips by Mode

Purpose	Mode	Total	Zero	Low-Insufficient	High Insufficient	Low Sufficient	High Sufficient
HBW	DA	1,029,208	1,097	27,712	36,705	211,695	751,999
	SR2	60,036	4,525	1,001	4,815	22,808	26,888
	SR3+	35,023	558	7,847	6,120	6,823	13,675
	Total	1,124,267	6,181	36,560	47,641	241,325	792,562
HBO	DA	1,608,053	10,417	33,396	31,276	514,827	1,018,137
	SR2	871,270	19,541	22,714	15,395	242,044	571,577
	SR3+	948,631	10,286	35,145	26,263	225,293	651,645
	Total	3,427,954	40,244	91,255	72,934	982,163	2,241,358
NHB	DA	861,238	NHB Trips are not Market Segmented				
	SR2	333,245					
	SR3+	269,533					
	Total	1,464,016					

Table 8: Non-Motorized – Mode Choice Targets

Purpose	Mode	Total	Zero	Low Insufficient	High Insufficient	Low Sufficient	High Sufficient
HBW	Walk	29,989	6,093	8,034	747	1,742	13,373
	Bike	7,787	363	0	914	1,347	5,163
	Total	37,776	6,456	8,034	1,661	3,089	18,536
HBO	Walk	384,835	104,678	5,892	5,733	106,133	162,399
	Bike	32,498	6,977	961	211	8,505	15,843
	Total	417,333	111,655	6,853	5,944	114,638	178,243
NHB	Walk	165,561	NHB Trips are not Market Segmented				
	Bike	12,644					
	Total	178,205					

3. MODE CHOICE MODEL DESCRIPTION

Mode choice models are mathematical expressions which are used to estimate the modal shares of the travel market given the time and cost characteristics of the various competing modes, the demographic and socio-economic characteristics of the travelers, and the excluded attributes of the modes represented in the model. Mode choice models are designed to be an integral link in the travel demand chain, with possible feedback mechanisms to a number of related model components such as trip generation, trip distribution, and (modal) trip assignment.

The CRCOG mode choice 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, and non-motorized (walk and bike) forms of travel. Access to and egress from transit also reflects a range of available options including park and ride, kiss and ride, walk, and bike. The mode choice model was calibrated using data from the 2016 'Let's Go CT' Household Travel Survey, 2016 CRCOG On-Board Transit Survey, and the U.S. Census ACS / CTPP data.

The variables included in the utility equation include cost, in-vehicle time, transit wait time, and an intrazonal shares variable. With the exception of the nesting coefficients, the model parameters will be segmented by income and auto sufficiency for HBW and HBO but will not be segmented for NHB trips. Finally, each mode will have an alternative-specific constant that represents the effect of mode attributes that are not included in the mode choice utility function. Examples of excluded 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, among others.

Basic Logit Model Mathematics

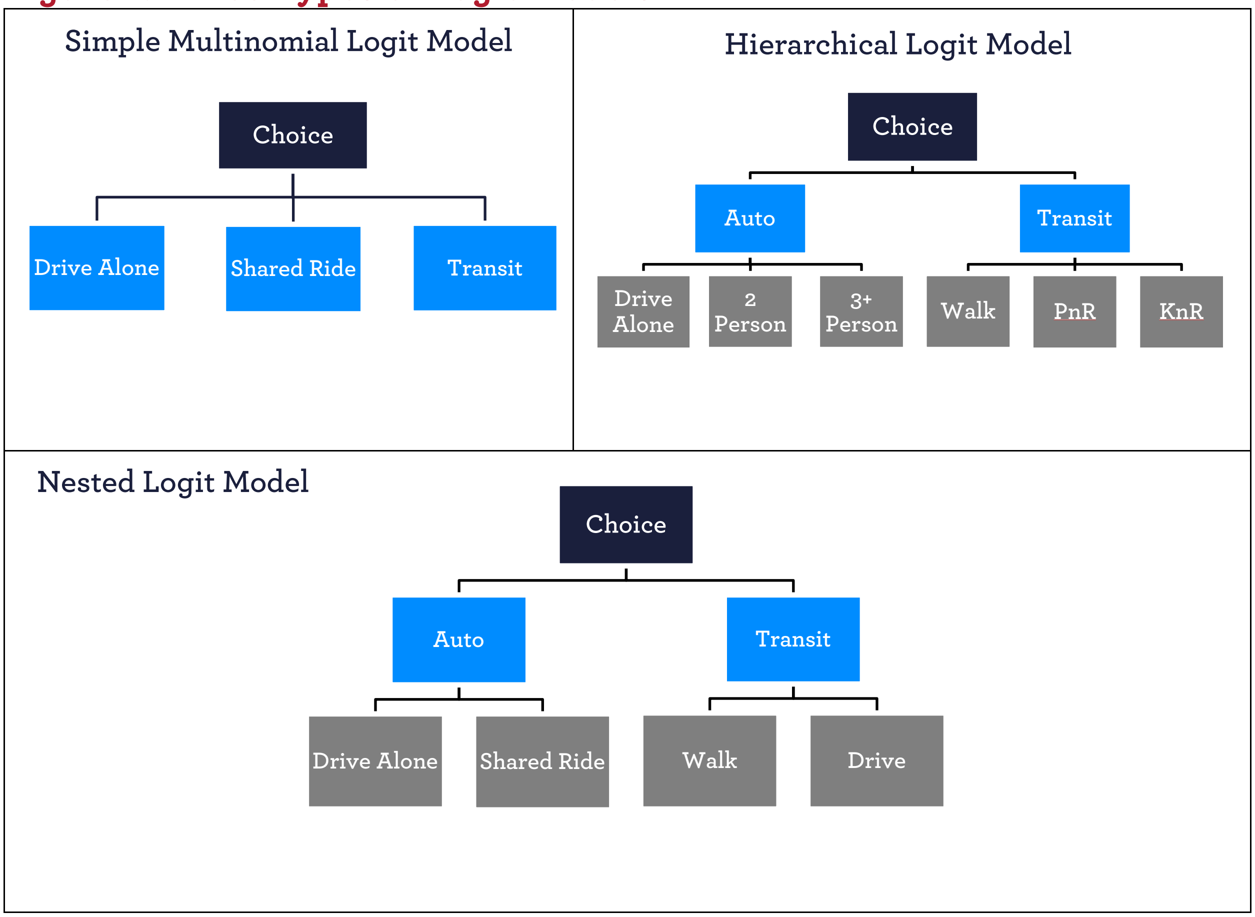
There are three types of Logit models: multinomial logit, hierarchical logit, and nested logit. The mode choice model structure used for the CRCOG mode choice model is a nested logit structure.

The multinomial logit model assumes that there is equal competition among alternatives. This allows for the "shifting" of trips to and from other modes in proportion to the initial estimates of these modes. A common problem typically associated with the multinomial structure is the potential for violation of the Independence of Irrelevant Alternatives (IIA) axiom.

The hierarchical logit model is a variation of the multinomial model that allows for the subsequent splitting (or allocation) of trips to a set of sub-modes. In most structures of this type a LogSum variable (or the denominator of the lower level choice) is used in the upper level choice together with other (typically socio-economic) explanatory variables. In this manner, the lower level sub-modes are reflected in the upper level choice, but as if they were equally competing modes with the other primary mode(s) (i.e., with a LogSum coefficient of 1.0).

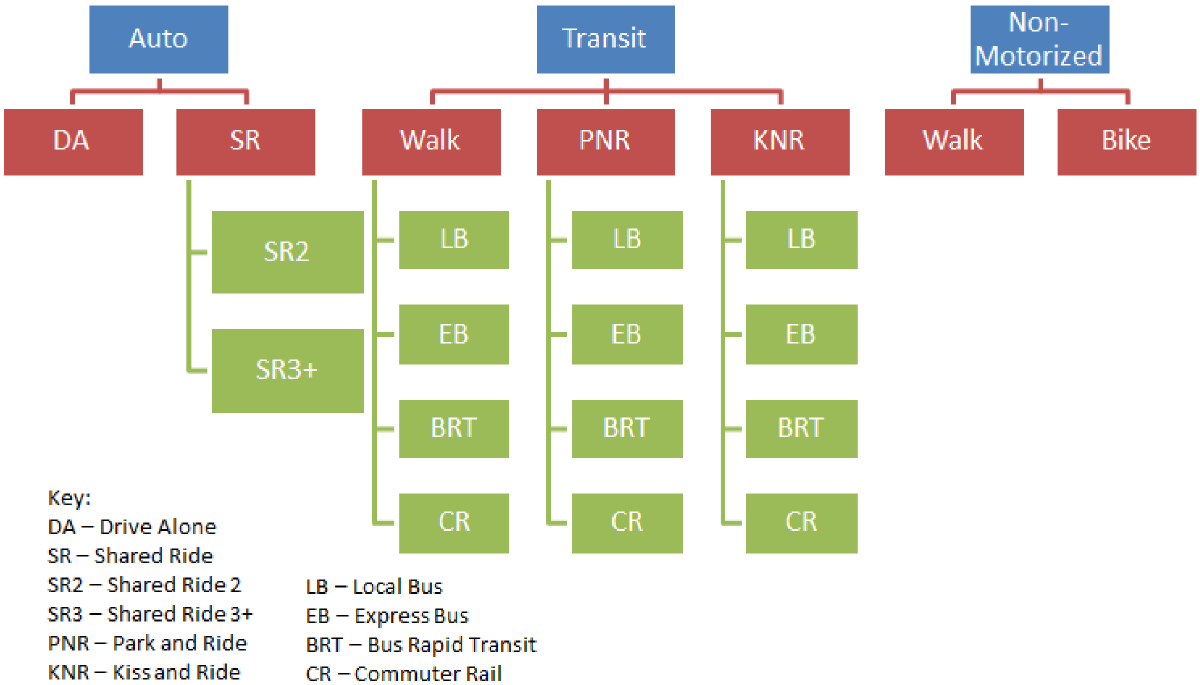
A nested logit model, as used in the CRCOG mode choice model, recognizes the potential for something other than equal competition among modes. This structure assumes that modes, sub-modes, and access modes are distinctly different types of alternatives that present distinct choices to travelers. Its most important departure from the multinomial structure is that the lower level choices are more elastic than they would be in the multinomial or hierarchical structures. Thus, an improvement in walk access to transit would alter the existing diversions between walk and drive access to transit the most. This same improvement in walk access would also shift travelers from auto to transit, but with elasticities that are equal to the elasticities found in the multinomial logit models; therefore, the elasticities for access choice are higher. This increased sensitivity is reasonable if the modes included in a single level of the nest are reasonably related. It seems intuitive that a person who has already decided to use transit would be more sensitive to a change in transit travel time or cost, than would be a person who is deciding to use transit or not. Figure 1 illustrates the differences between the various mode choice model structures.

Figure 1: Three Types of Logit Models



The final mode choice model structure applied in the CRCOG model is graphically displayed in Figure 2.

Figure 2: CRCOG Nested Logit Model Choice Model Structure



At the upper level of the nesting structure are non-motorized modes, highway modes (auto) and transit. In the non-motorized nest, bicycle and direct walk are represented. The auto mode nest addresses the auto occupancy choice including drive alone, shared ride 2, (two person carpools) and shared ride 3+ (3+ person carpools).

In the transit nest walk, park-and-ride, and kiss-and-ride are represented. In the lower level nest are local bus (LB), express bus (EB), and bus rapid transit (BRT). This design recognizes that, in many instances, the various transit modes offer travelers a competitive choice. It also allows the model to reflect the important differences in un-included attributes offered by each of the primary transit modes. An access choice nest differentiates primarily between walk and drive access to each primary transit mode. As discussed in Section 3.2 the mode choice model also represents commuter rail in anticipation of this service coming on-line in the near future. As the model currently stands, however, the commuter rail service is not operational.

Mathematical Formulation for Logit Models

The standard logit formulation can be expressed as:

$$P_i = \frac{e^{U_i}}{\sum_k e^{U_i}}$$

Where:

P_i = is the probability of a traveler choosing mode i

U_i = is a linear function of the attributes of mode i that describe its attractiveness

$\sum e^{Ui}$ = is the summation of the linear functions of the attributes over all the i

k = alternatives (k) for which a choice is feasible

The utility expression for each available mode (i) is specified as a linear function which incorporates a range of variable types, including time, cost, locational measures, and the socio-economic characteristics of the traveler. For example:

$$U_i = \beta_1 * Time_i + \beta_2 * Cost_i + \beta_3 * Location_{Var} + \beta_4 * SE + \beta_0$$

Where:

U_i is the utility for mode i

β_0 is a constant specific to mode i that captures the overall effect of any significant variables that are missing or unexplained in the expression which may include, for example, comfort, convenience, and safety

β_1 is a set of coefficients describing the level-of-service (in travel time) provided by mode i such as in-vehicle time, wait time, and walk time

β_2 is a set of coefficients describing travel cost which may include, for example, transit fare, automobile operating cost, and parking costs

β_3 is a set of coefficients describing the specific attributes of the trip interchange such as a Central Business District (CBD) destination or park and ride lot use

β_4 is a set of coefficients describing the influence of each socio-economic characteristic of the traveler such as income group and auto ownership

The travel time variables are typically disaggregated into in-vehicle and out-of-vehicle time at a minimum. Out-of-vehicle time is further stratified into walk time, initial wait, and transfer wait time – the latter two categories being applicable to the transit modes only. Similarly, travel cost is often disaggregated into the more general out-of-pocket cost, which may include for example, automobile operating cost, transit fare, and destination parking cost.

Locational variables in utility expressions are used to reflect a set of unique geographically based characteristics, such as a CBD. Alternatively, these geographic attributes may be represented in the form of land use variables such as employment or population density. A wide variety of variables are possible in the socio-economic category (SE) including variables that measure the relative wealth of the trip maker, such as income or auto sufficiency, or reflect other household characteristics such as workers per household. Finally, an alternative specific constant reflects the unexplained behavior, or the un-included attributes of that mode. The individual coefficients associated with each variable reflect the relative importance of each attribute.

In the simple example nested model structure shown in Figure 2 the formulation employs three multinomial logit models, one for the primary choice of mode among auto and transit, a second level choice among auto sub-modes (drive-alone and shared-ride) and another second level choice among transit access modes (walk and drive access). In application, the model independently addresses auto sub-mode and transit access choice first. This is expressed as:

$$P_{DA} = \frac{e^{U_{DA}}}{e^{U_{DA}} + e^{U_{SR}}} \quad \text{and} \quad P_{W} = \frac{e^{U_{W}}}{e^{U_{W}} + e^{U_{D}}}$$

A composite of the utilities of the auto sub-mode and transit access choices then represent auto and transit respectively in the upper tier of the model structure. This composite measure is the natural logarithm of the denominator of the logit model, often termed the "LogSum". The LogSum term is effectively the total utility provided by the sub-modes of a particular primary mode. A LogSum is calculated for each of the second level nests as:

$$LogSum_{A} = -\ln[e^{U_{DA}} + e^{U_{SR}}] \quad \text{and} \quad LogSum_{T} = -\ln[e^{U_{W}} + e^{U_{D}}]$$

The LogSum terms for the auto sub-modes and transit access choice then appear in the utility expression for the primary mode level as:

$$P_{T} = \frac{e^{\beta_{T}*LogSum_{T}}}{e^{\beta_{T}*LogSum_{T}} + e^{\beta_{A}*LogSum_{A}}}$$

The value of the LogSum coefficients in the upper tier of the model (auto versus transit), is an indicator of the degree to which the lower level choices form a sub-choice that is distinct from the primary mode alternatives. A value of 1.0 indicates that the lower level modes are not a sub-choice but rather are full options equally competitive with the primary modes. In this instance, these lower level choices can be simplified or included directly in the upper level. A value of 0.0 would indicate that the lower level choices are perfect substitutes for each other. Values between 0.0 and 1.0 indicate the extent to which the lower level choices represent a sub-choice.

The mode choice model structure includes commuter rail as a transit choice. At the time of this technical memorandum, however, there was no commuter rail service operating in the CRCOG model area. It was included in the model to accommodate the New Haven Hartford commuter rail service that was in development at the time of the CRCOG model update and is expected to start operations in May of 2018.

Since there currently no service, there is no data available that can be used to inform the model calibration process for commuter rail and, therefore, this choice is not operational. One way to address calibration for commuter rail is to wait for the service to come on-line and then collect the required data once regional travel patterns have had an opportunity to adjust to the new service and demand has stabilized. A second alternative would be to utilize the FTA's Simplified Trips on Projects Software (STOPS) and derive calibration targets from the STOPS model. In essence, STOPS would be used to create a base year forecast in order to assess commuter rail demand under existing conditions. STOPS was designed by the FTA to provide all travel forecasting information required of project sponsors seeking funding from the FTA's Capital Investment Grant program. The STOPS is a limited application of the traditional four step travel demand model geared to transit analysis. It was developed and calibrated using national data from cities with a variety of transit modes, including commuter rail, and relies upon readily available local data, such as the CTPP and on-board transit surveys, to allow the software to understand local travel patterns. The STOPS has a fixed guideway focus but also provides a detailed system-wide representation of transit ridership. STOPS was designed to be easier to implement that a typical 4-step model and may be set up and calibrated in approximately six to eight weeks. Calibration targets developed from STOPS forecasts may provide a useful placeholder until such time as data is available to further calibrate the CRCOG mode choice model.

Market Segmentation Considerations

There are three basic trip purposes for mode choice modeling - Home-Based Work, Home-Based-Other, and Non-Home Based. This simplification stems from the notion that household and individual travel behavior properties, as translated into elasticities, are relatively similar when considering the choice of mode.

Another element often used for market segmentation is the stratification of alternative specific constants by an indicator of wealth or socio-economic status. Historically, either auto ownership or income has been used for this purpose. The design of the CRCOG mode choice model utilizes a method of stratification called auto sufficiency. The HBW and HBO purposes are segmented based on household income and the relationship between the number of vehicles the household has and the number of workers (auto sufficiency) as shown below:

- Zero-car households, all income groups;
- Low income households with fewer autos than workers;
- High income households with fewer autos than workers;
- Low income households with autos greater than or equal to workers; and
- High income households with autos greater than or equal to workers.

Thus, in an auto "sufficient" household the number of autos is equal to or greater than the number of workers whereas in an auto "insufficient" household there are more workers than autos. Households with no autos are a special type of "insufficient" household and are therefore treated as a separate category. More than just auto ownership, households that have zero autos, less autos than workers, or an auto for each worker have distinct mode choice patterns, especially when it comes to transit ridership.

Lastly, the NHB purpose is not segmented.

Asserted Model Coefficients

Table 9 presents the recommended set of mode choice coefficients for the three trip purposes in the CRCOG model. Logical and consistent nesting coefficients are applied at each level of the nest. Auto operating costs were established at 16.8 cents per mile for all purposes.

Table 9: Mode Choice Model Coefficients

Variable Description	HBW	HBO	NHB
In-Vehicle Travel Time	-0.02500	-0.01500	-0.02000
Initial Transit Wait Time < 5.0 minutes	-0.05625	-0.03375	-0.04300
Initial Transit Wait Time >= 5.0 minutes	-0.02500	-0.01500	-0.02000
Transit Transfer Wait Time	-0.06250	-0.03750	-0.05000
Drive to transit in-vehicle time	-0.05625	-0.03375	-0.04300
Intrazonal shares for drive alone	0.67725	0.38614	0.26094
Intrazonal shares for share ride 2	0.20152	0.12414	0.25977
Intrazonal shares for share ride 3P	0.02812	0.20961	0.26777
Intrazonal shares for walk trips	0.09311	0.28011	0.21152

4. Mode Choice Calibration

Calibration Process

Model calibration is the process of establishing proper values for the alternative specific constants. The calibration of the mode choice model was done manually. The process would start with all alternative specific constants set to zero. Then the trip distribution and mode choice model steps would be run. The number of trips produced by the model for each mode and market segments were compared to the identified targets, the values of the alternative specific constants were adjusted accordingly, and the trip distribution and mode choice steps rerun. The process continued until model results matched the mode target values reasonably well. Table 10 shows key calibrated values for the mode choice models. Note that the market stratifications are active for both HBW and HBO. Non-Home Based trips were estimated for all market segments as one.

Table 10: Mode Split Constants by Trip Purpose and Market Segmentation

Market Segment	Constants for Shared Ride										
	HBW					HBO					NHB
	Zero	Low - I	Low - S	High - I	High - S	Zero	Low - I	Low - S	High - I	High - S	
SR2	2.97	-0.41	-1.69	-1.20	-2.48	0.29	0.06	-0.51	11.09	-0.29	-0.62
SR3	3.81	-1.19	-2.11	-1.29	-2.31	0.56	-0.08	-0.43	9.87	-0.29	-0.58
Market Segment	**Constants for Walk and Bike**										
	HBW					HBO					NHB
	Zero	Low - I	Low - S	High - I	High - S	Zero	Low - I	Low - S	High - I	High - S	
Walk	2.42	-2.73	-13.00	-5.00	-3.96	1.69	-3.29	-2.00	5.88	-2.25	-2.05
Bike	0.68	-8.55	-7.17	-3.66	-4.55	-0.17	-3.86	-3.75	3.67	-3.88	-3.83
Market Segment	**Constants for Local Bus**										
	HBW					HBO					NHB
	Zero	Low - I	Low - S	High - I	High - S	Zero	Low - I	Low - S	High - I	High - S	
Walk	8.17	4.73	-0.59	-0.41	-2.24	3.40	1.41	-1.06	7.94	-3.46	-1.32
PnR	-0.87	-2.90	-3.69	-4.24	-4.25	-4.40	-6.31	-6.54	3.30	-9.10	-7.09
KnR	0.78	-3.36	-7.96	-4.48	-6.80	-2.48	-4.45	-5.83	3.96	-6.86	-6.42
Market Segment	**Constants for Express Bus**										
	HBW					HBO					NHB
	Zero	Low - I	Low - S	High - I	High - S	Zero	Low - I	Low - S	High - I	High - S	
Walk	7.03	3.24	0.06	0.91	-2.08	3.38	2.52	-1.81	9.61	-1.93	0.67
PnR	2.87	0.27	-0.34	0.17	-0.89	2.34	-0.62	-3.65	10.84	-1.59	-0.21
KnR	2.68	-1.71	-5.04	-2.07	-3.66	4.01	-0.62	-3.64	10.88	-3.61	-1.79
Market Segment	**Constants for Bus Rapid Transit**										
	HBW					HBO					NHB
	Zero	Low - I	Low - S	High - I	High - S	Zero	Low - I	Low - S	High - I	High - S	
Walk	7.67	4.11	-0.87	-0.65	-2.74	3.52	1.47	-1.03	7.84	-3.06	-1.33
PnR	-0.67	-2.70	-2.56	-3.45	-3.22	-3.82	-5.94	-7.14	5.39	-8.54	-7.57
KnR	-0.46	-3.53	-7.59	-4.01	-5.92	-3.42	-4.23	-5.41	5.19	-6.30	-6.62

Note: Market Segmentation: **Zero** are zero auto households; **Low – I** are households with low income and fewer autos than workers; **Low – S** are households with low income and with autos greater than or equal to workers; **High – I** are households with high income and with fewer autos than workers; and **High - S** are households with high income and with autos greater than or equal to workers.

Calibration Results

A set of tables were prepared to show the performance of the mode choice models. The first, Table 11, provides an overview. This table shows a reasonably good fit of observed trips to the calibrated mode choice estimated trips. Approximately 49% of daily trips are conducted using the drive alone mode. Non-motorized travel (bike and walk) makes up about 11% of the region's average weekday travel. Transit is represented by linked trips, not boardings, and represents less than one percent of the region's average weekday travel.

Table 11: Top Level Mode Choice Validation

Mode		Trips	Percent of Total
Drive Alone	Observed	3,308,553	49.4%
	Estimated	3,277,806	48.6%
Shared Ride 2	Observed	1,215,650	18.1%
	Estimated	1,253,500	18.6%
Shared Ride 3+	Observed	1,360,557	20.3%
	Estimated	1,407,148	20.9%
Bike	Observed	60,459	0.9%
	Estimated	59,779	0.9%
Walk	Observed	704,332	10.5%
	Estimated	696,641	10.3%
Local Bus	Observed	39,115	0.6%
	Estimated	35,821	0.5%
Express Bus	Observed	3,656	0.1%
	Estimated	3,493	0.1%
Bus Rapid Transit	Observed	6,339	0.1%
	Estimated	6,027	0.1%
Total	Observed	6,698,662	100%
	Estimated	6,740,215	100%

Table 12 shows the same information by trip purpose. In this table it can be seen that HBO (which includes trips to and from home for reasons such as shopping, recreation, personal business) makes up 58% of daily travel. The next largest contributor to daily trips is the NHB purpose. Transit trips are almost equally associated with HBW and HBO trips and to a much lesser extent with NHB trips. This table also shows that the percentages of observed trips by trip purpose are closely replicated by the mode choice model.

Table 12: Top Level Mode Choice Validation by Purpose

Mode		HBW	HBO	NHB
Drive Alone	Observed	985,133	1,505,407	818,013
	Estimated	972,541	1,485,786	819,479
Shared Ride 2	Observed	75,424	823,706	316,520
	Estimated	62,114	906,571	284,814
Shared Ride 3+	Observed	40,212	981,919	338,427
	Estimated	91,080	943,002	373,066
Bike	Observed	9,127	39,323	12,010
	Estimated	8,557	39,210	12,012
Walk	Observed	52,150	494,931	157,251
	Estimated	47,136	492,221	157,283
Local Bus	Observed	16,976	18,436	3,703
	Estimated	13,916	18,200	3,705
Express Bus	Observed	3,247	217	192
	Estimated	3,111	190	192
Bus Rapid Transit	Observed	2,477	3,214	648
	Estimated	2,222	3,157	648
Total	Observed	1,184,745	3,867,153	1,646,764
	Estimated	1,200,676	3,888,338	1,651,200
Percent	Observed	18%	58%	25%
	Estimated	18%	58%	24%

The detailed versions of the same mode choice output by trip purpose and income group are shown in the following tables. HBW and HBO are displayed with the two income groups tabulated. The other purposes were not stratified by income and are displayed as a single stratification.

- Table 13: Home-Based Work Mode Choice Validation
- Table 14: Home-Based Other Mode Choice Validation
- Table 15: Non-Home Based Mode Choice Validation

Table 13 shows the mode choice results for the Home-Based Work trips:

- **Overall:** Overall the model seems to perform fairly well. There is room for improvement in representing the auto modes in Zero Auto and Low income market stratifications. Further investigation of the Home Interview Survey is also warranted to understand the drive alone trips made by zero auto households.
- **Drive**: As expected, the Drive Alone mode dominates drive nest, with high income showing the highest share of Drive Alone trips.
- **Transit**: There are three transit modes currently operating in the Harford District: Local Bus, Express Bus, and Bust Rapid Transit (CTfastrak). Most transit trips occur on the local bus network. The share of bus trips is higher for low income households.

- **Non-Motorized**: The model is doing a good job of capturing non-motorized travel. The share of non-motorized trips for the region is much higher than the share of transit trips. Walk trips are dominated by zero auto households. The highest proportion of bike trips are in higher income households.

Table 13: HBW Mode Choice Validation

Mode		Zero	Low Insufficient	Low Sufficient	High Insufficient	High Sufficient
Drive Alone	Observed	5,125	29,303	193,749	55,448	701,508
	Estimated	128	25,444	194,462	56,058	696,450
Shared Ride 2	Observed	21,135	1,058	20,874	7,274	25,082
	Estimated	5,284	14,525	17,205	8,879	16,220
Shared Ride 3+	Observed	2,606	8,298	6,244	10,307	12,757
	Estimated	39,549	3,719	10,844	8,971	27,997
Bike	Observed	1,697	1	1,233	1,380	4,816
	Estimated	1,277	1	1,108	1,384	4,787
Walk	Observed	28,457	8,495	1,594	1,128	12,475
	Estimated	21,732	8,883	3,045	1,106	12,370
Local Bus	Observed	7,745	5,084	2,443	689	1,015
	Estimated	5,518	4,166	2,536	692	1,004
Express Bus	Observed	261	245	743	479	1,519
	Estimated	188	236	725	477	1,484
Bus Rapid Transit	Observed	882	527	454	139	475
	Estimated	628	458	492	145	498
Total	Observed	67,907	53,011	227,334	76,844	759,648
	Estimated	74,305	57,432	230,416	77,713	760,810

Table 14 shows the mode choice results for the Home-Based Other trips.

- **Overall:** For the most part the model is representing HBO trips fairly well but there is an issue with auto trips in the high income insufficient auto ownership stratifications.
- **Drive**: Drive Alone trips dominate in the auto sufficient market stratifications for both low and high income households.
- **Transit**: The largest share of transit ridership comes from zero auto households. As with the work trips, the share of bus trips is higher for low income households than high income households.
- **Non-Motorized**: Walk trips dominate non-motorized trips. The largest proportion of these trips occur in zero auto households.

Table 14: HBO Mode Choice Validation

Mode		Zero	Low Insufficient	Low Sufficient	High Insufficient	High Sufficient
Drive Alone	Observed	22,801	41,994	604,502	17,603	818,507
	Estimated	22,800	43,295	600,744	0	818,948
Shared Ride 2	Observed	42,771	28,561	284,204	8,665	459,505
	Estimated	26,155	40,983	238,896	142,400	458,137
Shared Ride 3+	Observed	22,515	44,193	264,535	126,802	523,874
	Estimated	51,738	34,823	317,944	13,183	525,314
Bike	Observed	15,272	1,208	9,987	119	12,737
	Estimated	15,226	1,220	9,981	46	12,737
Walk	Observed	229,119	7,409	124,620	3,227	130,557
	Estimated	228,397	7,457	124,547	1,247	130,573
Local Bus	Observed	9,859	3,981	3,795	385	416
	Estimated	9,843	3,991	3,796	153	417
Express Bus	Observed	53	71	13	43	37
	Estimated	53	71	13	16	37
Bus Rapid Transit	Observed	1,628	661	682	94	149
	Estimated	1,627	663	680	39	148
Total	Observed	344,019	128,078	1,292,337	156,937	1,945,782
	Estimated	355,840	132,503	1,296,601	157,085	1,946,310

Table 15 summarizes the Non-Home Based trips purposes. No income categories were established for this purposes.

- **Overall:** The model performs reasonably well for this trip purpose.
- **Non-Home-Based** – This purpose has a high number of walking trips.

Table 15: NHB Mode Choice Validation

Mode		NHB
Drive Alone	Observed	818,013
	Estimated	819,479
Shared Ride 2	Observed	316,520
	Estimated	284,814
Shared Ride 3+	Observed	338,427
	Estimated	373,066
Bike	Observed	12,010
	Estimated	12,012
Walk	Observed	157,251
	Estimated	157,283
Local Bus	Observed	3,703
	Estimated	3,705
Express Bus	Observed	192
	Estimated	192
Bus Rapid Transit	Observed	648
	Estimated	648
Total	Observed	1,646,764
	Estimated	1,651,200

Summary of Mode Choice

Following the calibration of the destination choice models, the mode choice model was calibrated based upon the observed market-stratified person trip behavior based on the 2016 Let's Go CT Household Travel Survey and the 2016 CRCOG On-Board Transit Survey. The calibration process revealed the need for further refinement to the mode choice estimation. It is likely that additional changes and improvements will be made to the mode choice model during the final step of highway and transit assignment validation and overall model calibration. These final results will be reported in the final model development report.

Technical Memo #6

Destination Choice Model Development

April 18, 2018

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff

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1. INTRODUCTION

This technical memorandum describes the development of the destination choice model for the Capital Region Council of Governments (CRCOG). The destination choice model replaces the gravity model commonly used in trip based models. 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. Unlike the gravity model, the destination choice 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 (end of a trip). The destination choice model is preceded by the trip production models, which forecast the number of trip productions by zone for different market segments, primarily identified by purpose and income. As shown in Table 1, the destination choice model is applied for eleven combinations of trip purpose and market segments.

Table 1: CRCOG Market Segmentation

Purpose	Household Income	Household Auto Sufficiency
Home-Based Work	All Incomes	Zero Auto
Home-Based Work	<= $59,999	Auto Insufficient (autos less than workers)
Home-Based Work	<= $59,999	Auto Sufficient (autos greater than or equal to workers)
Home-Based Work	>= $60,000	Auto Insufficient (autos less than workers)
Home-Based Work	>= $60,000	Auto Sufficient (autos greater than or equal to workers)
Home-Based Other	All Incomes	Zero Auto
Home-Based Other	<= $59,999	Auto Insufficient (autos less than workers)
Home-Based Other	<= $59,999	Auto Sufficient (autos greater than or equal to workers)
Home-Based Other	>= $60,000	Auto Insufficient (autos less than workers)
Home-Based Other	>= $60,000	Auto Sufficient (autos greater than or equal to workers)
Non-Home Based	No Market Segmentation	

2. SUPORTING DATA

The 2016 'Let's Go CT' Household Travel Survey (HTS) was key to the development of the target values that are the core of the estimation data used for calibration of the destination choice model. Information regarding trip characteristics obtained from the HTS includes trip purpose, household income, number of workers, and auto ownership. The HTS also provided the observed trip length frequency distributions necessary for model calibration.

Based on the HTS, for the CRCOG area trip length distributions, in one mile segments, by trip purpose and market segment were determined. These distributions were assumed to represent the entire CRCOG model area. Then, for each trip purpose and market segment, the proportion of trips by distance was applied to the total trips by purpose and market segment generated by the trip production model. The resulting distribution represented the target values used in the calibration of the destination choice model.

Required network impedance information came from the mode choice logsums and distance skims from the CRCOG model. In addition, Census Transportation Planning Products (CTPP) data based on the 2006-2010 5-year American Community Survey (ACS) were used to assess the Home Based Work (HBW) trip distribution.

3. MODEL STRUCTURE

The utility (U_{ij}) of choosing a trip attraction destination (j) for a trip produced in zone (i) is a function of mode choice logsums, distance between zone *i* and zone *j*, distance factors, and an indicator variable for intrazonal production-attraction (PA) pairs. This is expressed as:

$$U_{ij} = \beta_{LS} * logsum + \beta_d * distance + \sum_{d=1}^{7} \beta_{DF_d} * (1\ if\ i\ and\ j\ \epsilon\ d) + \beta_{IZ} * (1\ if\ i = j)$$

In the utility equation above, β_{DF_d} is the coefficient for distance factor *d*. Other distance terms such as distance squared or distance cubed, if included, enter the utility equation in exactly the same way as the distance term. For brevity those terms are not shown in the utility equations above. Also note that the beta coefficients are unique to each trip purposes.

Once the utility for each PA pair is obtained from the utility equation above, they are used to construct the probability using a multinomial logit model (MNL). The MNL probability expression is given by:

$$P_{ij} = \frac{\exp(U_{ij})}{\sum_k U_{ik}}$$

In the above expression, the index *k* takes all the available attraction zones in the region.

The destination choice utilities are a function of mode choice logsums, and they are applied consistently, in the sense that the same coefficients and constants that are used for mode split are also used for calculating the logsums. Shadow prices are used to constrain the HBW attractions to a given zone to be proportional to the employment in that zone. This means that after the location probabilities are calculated on the basis of the utility functions, a shadow price is added to the utility of each destination with the objective of matching a pre-specified number of trip attractions to the zone. Employment is usually a standard input to travel models and is considered largely independent of the household travel survey. The shadow price addition is shown below:

$$U'_{ijm} = U_{ijm} + sp_j$$

In the equation above U_{ijm} is the base utility from production zone *i* to attraction zone *j* for purpose *m* and sp_j is the shadow price for attraction zone *j*. U'_{ijm} is the final utility.

The mode choice logsum coefficients were asserted based on experience with the estimation of other destination choice model, and typical values used in other metropolitan area. All other coefficients in the destination choice model were calibrated to obtain good fit with the calibration targets. The distance factors are constant terms added to the utility if the distance between production and attraction falls within a particular distance band. The seven distance factors, for the first seven one mile distance bands were used in the calibration.

Model Calibration

The calibration of the destination choice model involves making small incremental adjustments to the distance coefficients to better match observed trip patterns. The models are first calibrated to match first-order calibration targets for trip length frequency and average trip lengths by trip purpose. Segmented distance terms are often needed to match the short distance portion of the observed trip length frequency curve. The distance cap is also often adjusted during model calibration to ensure that the model reproduces the tail (longer trips) of the trip length frequency distribution. The CRCOOG model also included intrazonal coefficients.

The CRCOG destination choice models were calibrated to reproduce observed trip patterns, including trip length frequency distributions and average travel times based on the HTS, and intrazonal percentages from the previous CRCOG model.

CALIBRATION TARGETS

The following calibration targets were developed for this effort:

- Intrazonal percentage by trip purpose
- Average trip lengths by trip purpose and market segmentation
- Trip length distributions by trip purpose and market segmentation

Table 2 provides a summary of the destination choice model calibration by trip purpose. The coincidence ratio is a measure of the goodness-of-fit of the calibrated trip length distribution compared to the observed (target) trip length distribution. Anything above 0.75 is usually considered a good fit to the observed distribution. The coincidence ratio shows a good fit for all three trips purposes with a ratio of 0.84 for Home Based Work (HBW), 0.89 for Home Based Other (HBO), and 0.80 for Non Home Based (NHB) trips.

The percentage of total trips that are attracted to the production zone (intrazonal trips) is also compared between the model and the target data in Table 2. For each trip purpose the match between the target proportion of intrazonal trips and model results is reasonably good. For all three trip purposes the model results are with 0.30 percent of the target percentage.

The model predicted average trip length (miles) is within one-tenth of a mile of the target value for HBW trips and approximately five-tenths of a mile for HBO and NHB trips. For travel time, the model predicted average travel time is within a minute of the target value for HBW and NHB trips and 1.7 minutes greater for HBO trips.

Table 2: Goodness of Fit Measures

Purpose	Coincidence Ratio	%Intrazonal trips		Average trip length (miles)		Average trip length (min)	
		Target	Model	Target	Model	Target	Model
HBW	0.84	7.50	7.76	11.84	11.94	18.40	19.09
HBO	0.89	8.70	8.80	5.09	5.62	10.21	11.91
NHB	0.80	8.20	8.32	7.70	7.23	12.71	13.46

A comparison between the average trip distances for the HBW and HBO by market segment is shown in Table 3. For the most part, the model average trip lengths are longer than the target lengths with the only exception being HBW trips from zero auto households. Among the other markets, the differences range from 0.04 miles for HBW trips from high income, auto sufficient households to 2.06 miles for HBW trips from high income, auto insufficient households. For the remaining eight market segments, seven have model trip lengths within 0.65 miles of the target value.

Table 3: Average Trip Length by Market Segment

Market Segment	Average trip length (miles)	
	Target	Model
HBW – zero	7.14	6.94
HBW – low income, insufficient	6.51	6.95
HBW – low income, sufficient	9.84	10.06
HBW – high income, insufficient	12.36	14.42
HBW – high income, sufficient	13.01	13.05
HBO – zero	3.20	4.28
HBO – low income, insufficient	3.95	4.51
HBO – low income, sufficient	4.98	5.48
HBO – high income, insufficient	4.23	4.48
HBO – high income, sufficient	5.47	6.11

Trip Length Frequency Distribution Calibration

Household survey data was processed into trip length frequency distributions and prepared as targets to be compared to the destination choice output. The trip length frequency curves were visually analyzed and compared using a normalized coincidence index. The calibrated destination choice model coefficients are shown in Table 4.

The match between the model calibrated trip length profile and the target trip length profile for HBW, HBO, and NHB trips can be observed in Figure 1 thru Figure 3.

Table 4: Calibrated Coefficients

Market Segmentation		Distance Coefficients		Intrazonal Term	Distance K-Factors						
		c_dist	c_dist²	c_iz	c_KF01	c_KF12	c_KF23	c_KF34	c_KF45	c_KF56	c_KF67+
HBW	Zero	-0.197	0.000	1.143	0.975	-2.293	-1.807	0.134	-1.550	0.476	0.342
	Low insufficient	-0.134	0.000	-0.855	3.826	1.226	-1.294	0.944	-0.025	1.024	-3.654
	Low sufficient	-0.089	0.000	1.254	1.083	-0.095	0.266	1.693	0.759	0.724	0.487
	High insufficient	-0.020	0.000	1.267	1.308	2.189	0.817	2.450	0.949	0.556	2.055
	High sufficient	-0.082	0.000	1.498	1.314	-0.234	0.166	-0.103	0.286	0.379	0.490
HBO	Zero	-0.120	0.000	-2.007	5.447	2.902	1.417	1.653	-0.421	0.750	-0.374
	Low insufficient	-0.161	0.000	-1.766	3.332	3.085	1.718	-0.516	-0.113	1.109	0.052
	Low sufficient	-0.106	0.000	-1.698	5.391	3.299	2.379	1.840	1.043	0.577	0.770
	High insufficient	-0.279	0.000	-0.989	2.439	1.355	1.332	-0.024	0.270	0.087	-0.225
	High sufficient	-0.134	0.000	-0.988	4.128	2.677	1.875	1.914	1.405	1.040	0.342
NHB		0.076	0.000	-1.572	6.344	4.237	2.892	2.641	2.067	2.032	1.299

Note: Data in Distance K-Factors cells, are grouped and organized in 1-mile increments, thus "c_KF01" provides coefficients for 0-1 mile, "c_KF12" provides coefficients for 1-2 mile, with seven defined distance bins. Intrazonal trips have separate coefficient.

Figure 1: HBW Trip Length Frequency Distribution

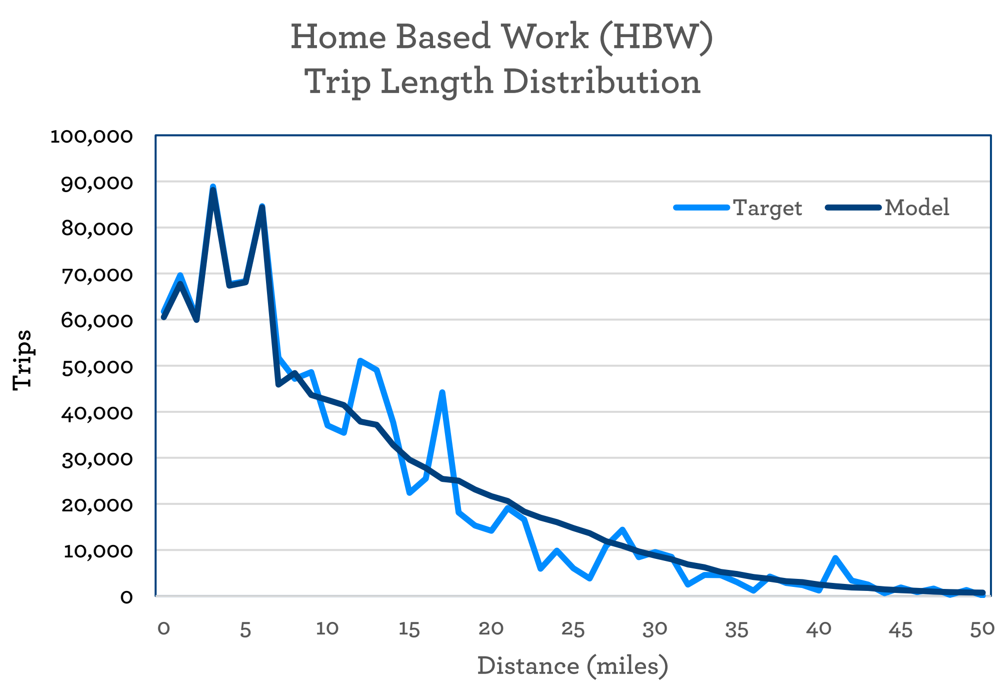


Figure 2: HBO Trip Length Frequency Distribution

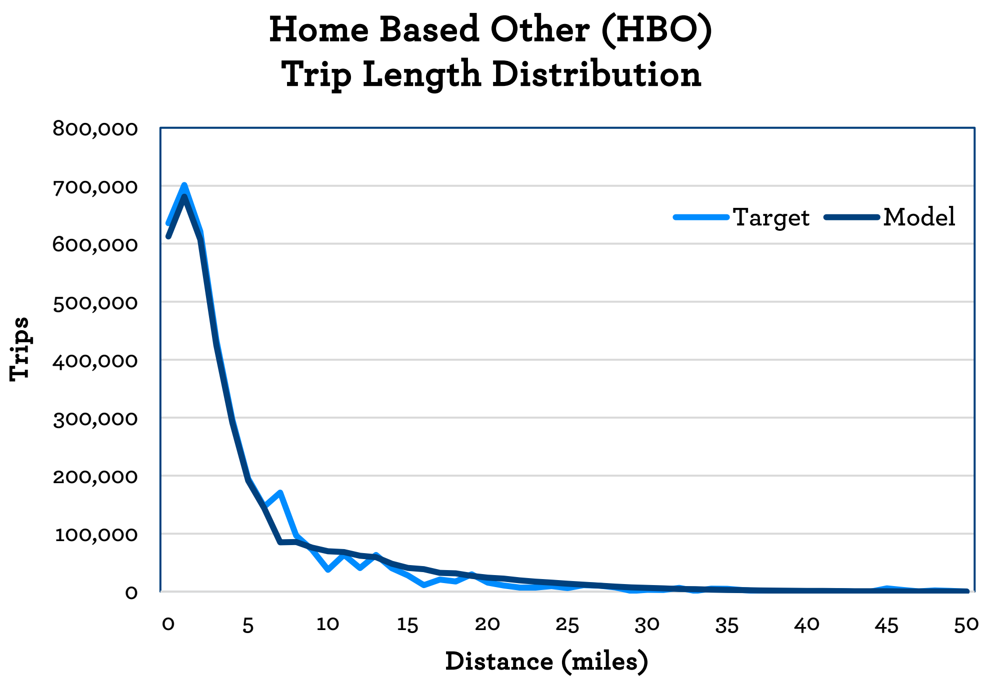
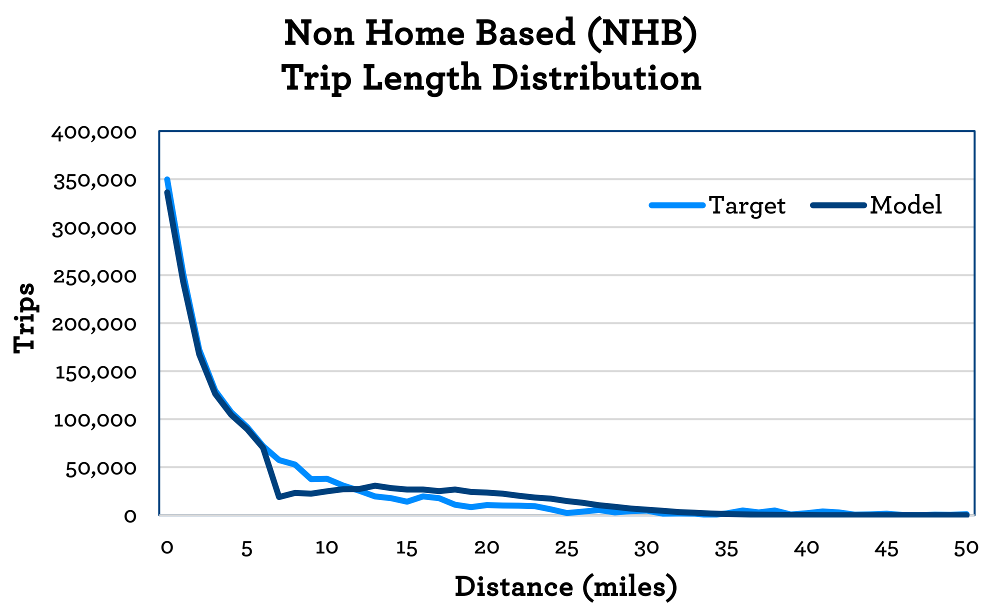


Figure 3: NHB Trip Length Frequency Distribution

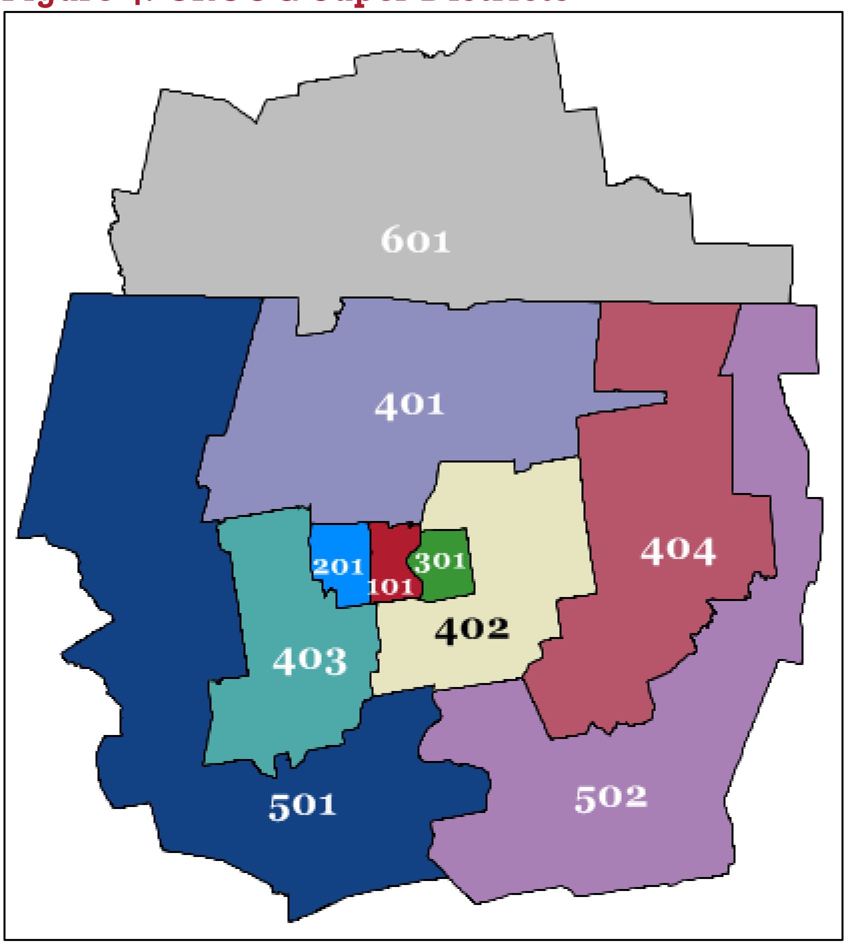


District to District Flow Comparison

District to district flows were also compared as part of the destination choice calibration. The goal of this exercise is to compare person movements between the study districts using the trip tables output from destination choice calibration. For the purposes of this exercise, the CRCOG Districts were aggregated into 10 Super Districts shown in Figure 4. A list of the Districts is presented in Table 5.

Limited geocoding information was available from the HTS for the purposes of the CRCOG model update. A district-to-district flow comparison was only completed, therefore, for HBW trips using CTPP data. The CTPP has multiple geographic layers available for data analysis. These include Traffic Analysis Zones which represent the basic unit of geography in travel demand modeling and can be readily aggregated into larger geographies such as Districts. The geographic information made available with the HTS included only County and MPO layers. Neither of these was felt suitable for a flow analysis.

Figure 4: CRCOG Super Districts



Note: Super Districts 501, 502 and 601 fall outside of CRCOG area.

Table 5: CRCOG Super Districts

Super District	Name
101	Hartford
201	West Hartford
301	East Hartford
401	Northern CRCOG
402	Southeastern CRCOG
403	Southwestern CRCOG
404	Eastern CRCOG
501	West Buffer
502	East Buffer
601	Massachusetts

HBW Flow Analysis

Table 6shows flows obtained from the CTPP normalized to the row totals from the calibrated model HBW trip table. Table 7 presents the HBW trip flows from the calibrated model.

Table 6: CTPP Work Flow by Super District

CTPP		Attraction Districts										
		101	201	301	401	402	403	404	501	502	601	Total
Production Districts	101	28,573	5,390	2,832	8,015	7,188	6,228	416	1,611	87	173	60,514
	201	11,126	10,595	849	4,090	2,552	5,718	0	2,272	206	394	37,802
	301	6,459	1,359	5,457	3,839	7,517	2,972	416	1,328	214	23	29,583
	401	18,492	4,632	3,879	61,432	10,535	9,381	2,077	4,376	291	7,477	122,574
	402	22,095	3,587	9,340	13,840	48,187	9,040	4,942	6,910	1,028	1,011	119,979
	403	15,608	6,488	2,988	9,635	8,398	68,379	733	20,950	369	429	133,977
	404	5,491	754	2,617	4,557	9,096	2,148	20,390	1,605	3,756	571	50,983
	501	15,239	4,120	4,137	11,814	9,225	37,867	1,186	208,018	1,974	474	294,054
	502	5,177	855	2,135	2,047	5,709	3,638	6,756	9,221	22,937	111	58,586
	601	3,952	396	1,106	18,976	2,414	1,447	799	1,074	173	246,347	276,684
Total		132,211	38,176	35,340	138,244	110,821	146,818	37,715	257,365	31,035	257,011	1,184,737

Note: the values are normalized by model row totals

Table 7: Model Work Flow by Super District

HBW Trips		Attraction Districts										
		101	201	301	401	402	403	404	501	502	601	Total
Production Districts	101	30,384	5,082	4,269	5,746	5,775	5,602	329	2,253	221	854	60,514
	201	11,623	4,490	2,007	5,133	3,330	7,197	294	2,707	200	822	37,802
	301	9,759	1,155	3,891	2,928	6,539	2,285	437	1,668	258	663	29,583
	401	15,707	4,017	3,978	47,365	12,311	9,502	2,750	5,919	716	20,309	122,574
	402	23,172	3,955	8,828	14,201	38,001	11,761	4,439	9,238	2,022	4,363	119,979
	403	16,396	6,671	3,534	10,052	10,710	54,153	701	29,043	874	1,842	133,977
	404	5,297	1,013	2,068	5,813	9,209	2,433	13,688	2,305	5,245	3,912	50,983
	501	18,108	5,829	4,601	14,365	15,102	50,169	1,063	178,847	2,333	3,638	294,054
	502	5,371	1,043	1,948	3,254	7,315	4,144	7,027	9,124	18,075	1,286	58,586
	601	6,084	1,384	1,734	30,979	6,110	3,178	2,960	2,750	609	220,897	276,684
Total		141,900	34,639	36,857	139,836	114,404	150,423	33,689	243,853	30,552	258,585	1,184,737

The comparison of district interchanges focused on those interchanges where the absolute difference between model and CTPP interchange trip totals was greater than 0.50 percent of the total number of HBW trips (5,924) and the percent difference between the model and CTPP interchange trip totals was more than 50 percent. For the most part, the comparison between the modeled trip flows and the CTPP trip flows is reasonable. The exceptions involve trips within Super District 201 (West Hartford) and interchanges between Super District 401 (Northern CRCOG) and Super District 601 (Massachusetts). These district interchanges have been flagged in Table 8. Particular attention will be paid to these areas during the system wide model calibration and validation steps to determine if further measures can be taken to address these discrepancies.

The calibration process is still on going, and further refinement to the destination choice model calibration will be pursued. It is likely that additional changes and improvements will be made to the destination choice model during the final step of highway and transit assignment validation and overall model calibration. The result of these efforts will be reported in the final model development report.

Table 8: Estimated Vs. CTPP Work Trips – Flagged Super District Interchanges

Interchange Flags		Attraction Districts									
		101	201	301	401	402	403	404	501	502	601
Production Districts	101	-	-	-	-	-	-	-	-	-	-
	201	-	Review	-	-	-	-	-	-	-	-
	301	-	-	-	-	-	-	-	-	-	-
	401	-	-	-	-	-	-	-	-	-	Review
	402	-	-	-	-	-	-	-	-	-	-
	403	-	-	-	-	-	-	-	-	-	-
	404	-	-	-	-	-	-	-	-	-	-
	501	-	-	-	-	-	-	-	-	-	-
	502	-	-	-	-	-	-	-	-	-	-
	601	-	-	-	Review	-	-	-	-	-	-

Technical Memo #7

Parking Lot Choice Model

March 15, 2017

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff

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1. INTRODUCTION

The supply of parking is considered to be a major factor in determining travel patterns within urban areas, as shown by the high number of policy interventions that focus on parking. These include parking meters, workplace parking surcharges and/or workplace incentives for using transit, and many others. However, the behavioral mechanisms involved in determining individual parking choice are complex and difficult to translate into standard highway assignment programs.

Because data necessary for the development of a parking choice model was not available, this Technical Memorandum discusses an approach to the development of such a model that may be applied in the future. This document outlines available data, additional data needs, and sample future modelling steps leading to the development of a parking lot choice model subroutine.

2. DATA COLLECTION

For parking demand to be modelled realistically, a parking model needs to represent several key attributes. These may include: general parking lot/garage information such as: facility type (on-street, parking lot, or garage), number of spaces (capacity), accommodation type (handicap spaces, cars, motorcycles or larger vehicles exceeding low clearance limits), cost to park (hourly, daily, weekly or monthly), utilization by time of day (e.g. residential, events, workplace, etc.), and parking supply type (privately owned with exclusive usage or shared space.) The cost function associated with parking in a particular location should also include a means of understanding not only the fee charged, but also the time associated with searching for a parking space and with travelling from the parking structure to the desired destination.

Available Data

As part of the I-84 Hartford Project's *Analysis, Needs and Deficiencies Report*, the project team compiled and evaluated existing parking conditions for the study area (see Figure 1). Within this area both on-street and off-street parking were evaluated.

The study area contains approximately 22,826 off-street and on-street parking spaces. The vast majority of the total parking capacity, however, is made up of private (employee) off-street parking lots and garages. A summary of Study Area parking is presented in Table 1.

Figure 1: I-84 Hartford Parking Study Area.

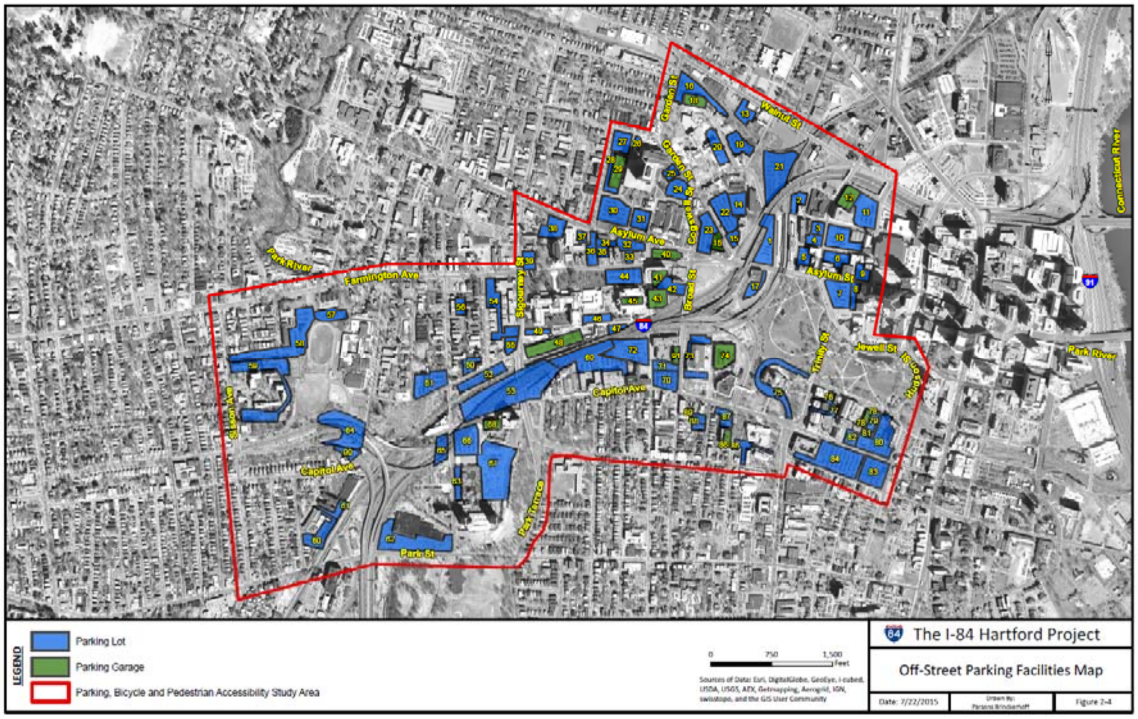


Table 1: Existing Parking within I-84 Hartford Parking Study Area

Off-Street Parking	
Public Parking	
Type	*# of Spaces*
Surface Lots	1,522
Structures	1,504
Total Public	3,026
Private Parking	
Type	*# of Spaces*
Surface Lots	12,154
Structures	6,480
Total Private	18,634
Total Off-Street Parking:	21,660
On-Street Parking	
Type	*# of Spaces*
Metered- Coin	56
Metered- Pay-to-Park	192
Unmetered	970
Total On-Street Parking:	**1,218**
Total Parking	**22,826**

The City of Hartford also undertook a parking study in 2013/2014 to review existing parking conditions and determine future parking needs within the downtown neighborhood. Similar to the I-84 Hartford Project's *Analysis, Needs and Deficiencies Report*, this study area was limited to part of Central Business District (CBD) and not the entire city of Hartford (see Figure 2). The study looked at challenges and opportunities at city-owned parking sites and infrastructure as well as recommendations for changes to parking, pricing, and transportation policies. The available report provided summaries, such as Table 2, of parking capacity at city-owned off-street parking facilities. However, the information collected, as well as that shared with the project team, was limited and lacks the detail necessary to support development of a parking lot choice model.

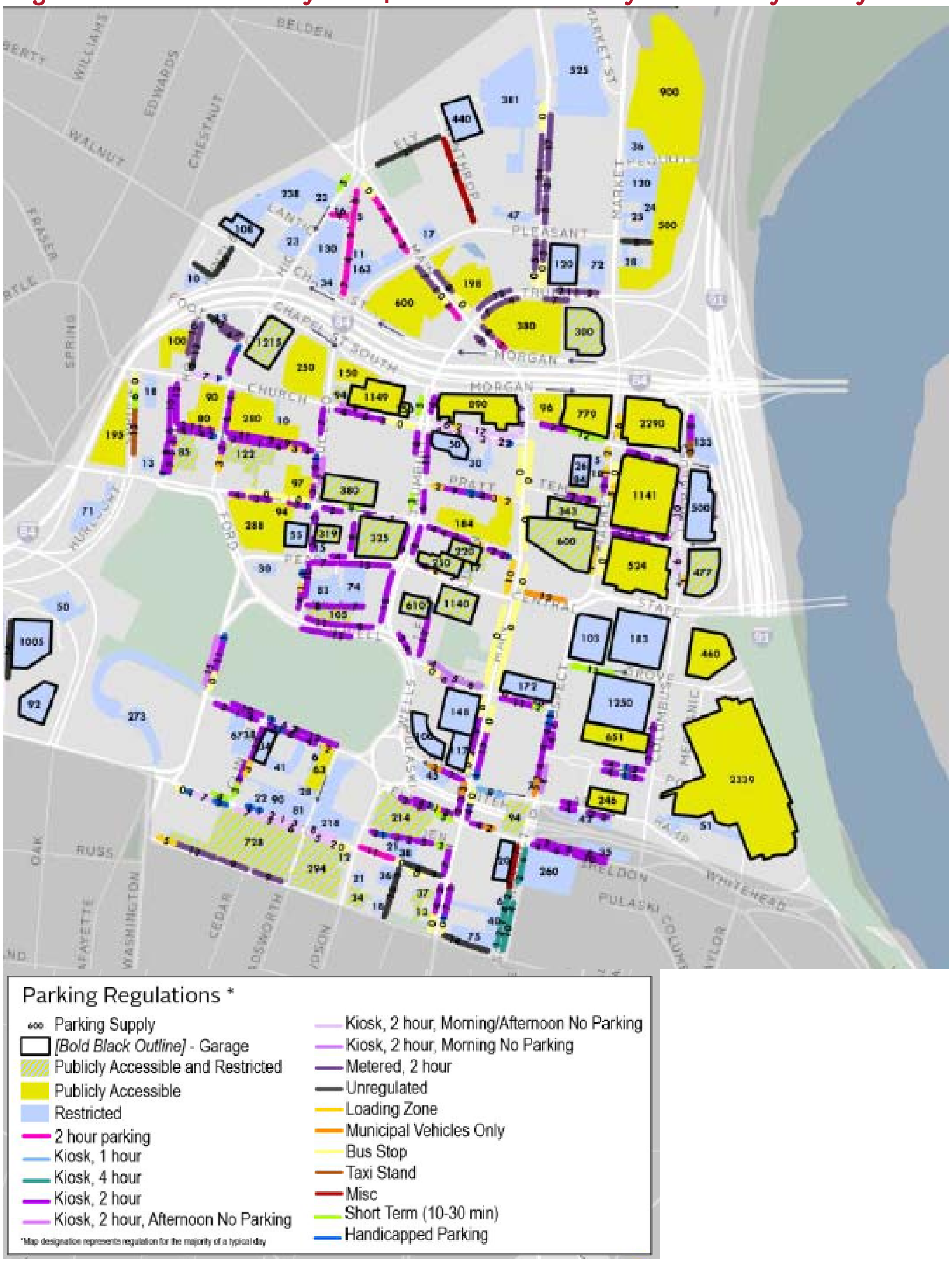
Table 2: Hartford City 2014 off-street facility inventory

	Total	Public	Mixed *	Restricted **
Garage	21,862	10,619	6,617	4,626
Lot	10,723	4,545	1,839	4,339

* Represents inventory that is available for public use during a portion of the day or the entire day, but has some specific spaces dedicated to permit holders/certain user groups only.

** Category includes facilities that were completely closed on the day of data collection and data is based using other sources.

Figure 2 Hartford City 2014 off-street facility inventory study area



Data Needs

In order to adequately support the development of a parking choice model, data are necessary to represent as fully as possible the parking supply and demand with the study area. Toward this end, consideration should be given to collecting the following data in order to undertake a parking choice modeling effort.

Parking Capacity and Utilization

Although both previous studies gathered information to describe on-street and off-street (parking lot or garage) parking capacity, they were limited in their geographic scope and there were some inconsistencies in the data collected between them. For example, at the Union Station Spruce Parking Lot one study estimated the number of spaces at 197 while the other had the capacity at 300. Further, the two studies did not collect the same information. For example, The Hartford City Inventory Data did not collect information on EV charging stations or the number of ADA compliant parking spaces. Finally, neither study collected information necessary to sufficiently describe on-street parking capacity and utilization. Capacity and utilization data needed to support the development of a parking choice model should include, but not necessarily be limited to, the following:

- Number of spaces by type, e.g., paid short term, paid long term, free short, or free long term
- Parking restrictions / regulations
- Parking utilization, i.e., percentage of spaces filled by time of day
- Entering / exiting traffic by time of day

Parking Ownership

Both studies identified the ownership of parking facilities. This is important because private parking facilities may be reluctant to share information or allow access to their facilities. Ownership may explain why in some cases utilization or capacity for a facility are unknown. Both studies identified the ownership of parking facilities and any reasons why utilization is unknown at some structures. Private facilities with exclusive usage, as opposed to shared public use, did not yield utilization rates. Access to these facilities was limited or prohibited. Many sites were only field checked once without confirming utilization by time of day. Strategies need to be developed to encourage owner participation and/or data collection methods developed that do not require entering a facility, e.g., GPS based OD studies.

Parking Costs

Similar to parking capacity, data on cost were not collected by time of day or in a manner adequate to inform a parking choice model of the cost paid to park. For example, facility inventory for the City's study provided ranges of cost during hourly event pricing, daily maximums, and monthly cost but no information that can be used to determine the normal cost paid by customers. In addition, the data lacks time of day detail that might allow determination of an average cost paid by peak and off-peak period. The information on private facilities was again limited and was missing information on specific facility cost structure, availability, and time of day detail. Cost data needed to support the development of a parking choice model should include, but not necessarily be limited to, the following:

- Facility cost structure
- Number of customers paying hourly, daily, weekly, or monthly fees

- Number of customers parking for free
- Time of day information
- Employee incentives to persuade mode switch

Parking OD Survey

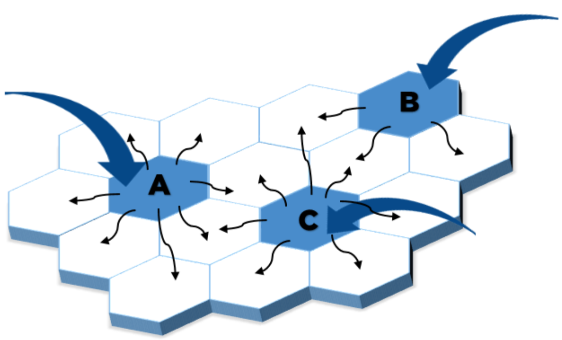
Similar to a Household Travel Survey or On-board Transit Survey, a Parking Survey could help to understand the characteristics and behavior of travelers that drive and park downtown. Information gathered by such a survey could include, but not necessarily be limited to, the following for study area parkers:

- Origin location
- Vehicle occupancy
- Parking location
- Cost for parking
- Method of payment
- Length of stay
- Ultimate destination location
- Mode to ultimate destination
- Trip Purpose
- Demographic characteristics

A particularly interesting aspect of parking behavior is the relationship between a traveler's parking location and their ultimate destination.

Figure 3 illustrates this relationship and shows demand being distributed among parking zones in overlapping parking areas. Zones A, B and C represent desired destinations to which demand would be allocated by the model, however desired destination may not be available and thus vehicle would be parked in nearest neighboring zone. Understanding these relationships will help a parking choice model to better represent parking behavior.

Figure 3 Travel Demand being distributed Among Parking Zones



Parking at Transit Stations

Special attention should be given to transit station parking facilities. As with other parking facilities, stations should be viewed as an intermediate destination and not the final desired destination. The data collected during a transit station parking survey would provide greater insight to travel behavior at specific stations than an on-board transit survey. The survey could collect station specific information on mode of access as well as parking capacity, length of stay, and parking utilization.

3. CBD PARKING MODEL

This section provides an overview of a possible methodology for the development of a CBD (Central Business District) Parking Model. This methodology develops a CBD parking model which has three components. The first is a parking cost forecasting model to determine the average cost of parking in each CBD zone. The second is a free parking eligibility model (also called parking payment model), which determines if a driver with a CBD destination will face parking costs. The third is a parking location choice model.

Parking costs are important factors in travel demand modeling. They not only affect parking location choice but also mode choice, destination choice and, potentially, even trip generation. They are especially important in the choice between transit and auto modes. Empirical data shows that parking costs vary with size and density characteristics of CBDs. Parking costs (and supply) can also be an instrument of demand management with supply held down and costs pushed up to encourage greater transit use and, thereby, reduce traffic congestion. The parking cost model is designed to forecast parking costs for desired forecast years and also includes the ability to reflect policy options. However, a certain proportion of the driving population has access to free parking, even for CBD locations, and their mode and destination choices should not be influenced by parking costs. Thus, the free parking eligibility model identifies these individuals and suppresses the parking cost component of their travel utilities.

The parking location choice model is designed to improve the assignment of private vehicle trips by simulating actual parking locations. Without such a model component, all trips destined for each TAZ are assumed to park in the destination TAZ. For some TAZs this may be appropriate, but in the Hartford CBD it is not uncommon to park in a TAZ different from the final destination. This practice is influenced both by the lack of parking supply in the destination TAZ relative to demand and the desire to reduce parking costs by parking in a less expensive facility. The parking location choice model reflects both parking capacity restraints and the tradeoff between the monetary costs of parking and the time costs of walking.

Parking Cost Model

The parking cost model is designed to forecast average parking costs by TAZ for a given forecast year. The purpose of the parking cost model is to provide parking costs that will be taken into account during the model-destination choice component (MDC). It is likely that parking costs will not be relevant everywhere in the model area. For example, within the CRCOG Model area parking costs will certainly be relevant to decision making for TAZ within the Hartford CDB but less relevant outside of the CBD.

Data for the Parking Cost Model may come from several sources. These include Household Travel Surveys, the travel demand model's socioeconomic data, e.g., population, households, and employment, network skims, Parking Facility Surveys, and Parking OD studies.

Parking cost models are often formulated as a simple relationship between parking cost in a TAZ and the employment density in that same TAZ. Such an approach, however, ignores the effect of changes in supply and also the competitive effect of surrounding TAZ's. Alternatively, the change in average parking costs may be assumed to be a function of the ratio of demand over supply. Indirect measures of demand have been analyzed, including:

- The number of employees within a given walking time of each zone, perhaps by employment type and for multiple walk time thresholds, or

- Walk accessibility to employment for each zone calculated in a manner similar to the denominator in the gravity model formulation, using walk time as the travel time.

Other independent variables related to demand have been considered as potentially significant including:

- The average income of workers in the zone,
- Income-weighted measures of employment accessibility,
- CBD Area Type,
- Walk to work skims,
- Employment density,
- Long Term Parking Supply,
- Long Term Paid Parking Supply,
- 75 percent of parking in a TAZ free (binary), and
- 51 percent of parking in a TAZ free (binary)

Linear and non-linear regression techniques have been used to test alternative formulations in an attempt to best explain observed variations in parking costs by facility type and duration.

Free Parking Eligibility Model

The Free Parking Eligibility Model, also known as the Parking Payment Model, assumes that people who park for free downtown are aware of the availability of this free space before they begin any trips. This is likely to be the case for workers who are guaranteed free parking downtown by their employer, but less true for drivers undertaking non-mandatory trips. Some may be aware of free parking offered by particular retail stores and take this into consideration at the beginning of their trip; others may well encounter free parking while driving through the fringes of downtown. This later type of free parking situation, however, will not be captured by the free parking eligibility model.

Due to the placement in the model chain, household characteristics, including household origin, and total trips are known prior to determining free parking eligibility. Trip destinations and mode are unknown. This placement in the model chain is due to the assumption that a person's awareness, prior to making a trip, that they will not pay for parking will influence their mode and destination choice.

It is possible to independently model access to free long-term parking (work trips) and short term parking (shopping). Independently modeling the two cases means the model would recognize the possibility that individuals may have free parking downtown for work but then have to pay to park for a subsequent shopping trip. While this is possible, it is an unlikely scenario. A simplified model determines if the driver pays for any downtown parking or not.

Data for the Free Parking Eligibility Models come from the same sources as the Parking Cost Model. The basic framework of the model uses household characteristics to determine free parking status for individual adults, not the entire household. Households with 0 autos are not modeled, since it is assumed they cannot make SOV trips. The choice predicted is between 0 (no free parking) and 1 (free parking in CBD zones for all purposes). Independent variables which may be considered as potentially significant include:

- Household Income,
- 1 auto households,
- Origin District, e.g., high income areas,
- Total workers in households,
- Children in Household,
- Driving age child in household,
- University student in household,
- Non-worker in household,
- Household Size,
- Total household mandatory trips, (trips to work or school), and
- Total household non-mandatory trips, (flexible travel such as: shopping or social activities).

Parking Location Choice Model

The Parking Location Choice Model is intended to work in conjunction with the assignment process and improve the realism of the auto component of assigned vehicle traffic. It is applied after destination and mode choice have been completed. The destination end of auto-vehicle trips destined for the CBD are reallocated to parking location TAZs in accordance with model results for input to the assignment process. Two separate models are developed; one for work trips and one for non-work trips.

An additional segmentation is involved because the free parkers and paid parkers have somewhat different characteristics. On the supply side, the stock of free parking and paid parking are established as a model input. On the demand side, the free parking eligibility model will already have determined which potential drivers will not pay to park downtown.

The parking location choice is made at the traffic analysis zone (TAZ) level of detail, with each zone described in terms of parking cost and parking capacity. The model has a multinomial logit form and the utility equation for each parking zone will be of the general form shown below:

$$U_k = \beta_1 \cdot (\text{parking cost}_{k}) + \beta_2 \cdot (\text{walk distance}_{k\text{-}j}) + \beta_3 \cdot (\ln(\text{parking capacity}_{k})) + \beta_4 \cdot (\text{auto travel time}_{i\text{-}k})$$

where	U_k	= Parking location utility of zone k
	$\beta_{1\text{-}4}$	= Model coefficients
	parking cost_k	= Parking Cost of parking location k (cents)
	walk $\text{distance}_{k\text{-}j}$	= Walking distance from parking zone k to final destination zone j (miles)
	parking capacity_k	= Parking capacity of zone k (spaces)

auto travel time$_{i\text{-}k}$	= Auto travel time from origin zone i to parking zone k (minutes)

The subscripts in the utility equation follow the convention in which the origin zone is labeled with an "i", the final destination zone is labeled with a "j", and the parking zone is labeled with a "k". Thus, U_k refers to the utility for parking in zone k as considered by a traveler coming from home zone i and going to a final destination zone j. Note that while income is generally an important variable, it can only be included in the model if it is collected as part of a parking survey.

The parking costs employed are the average zonal parking rates that come out of the parking cost model. Even though the costs are different for short and long-term purposes, short-term parking costs are a fixed factor of the long-term costs.

The walk distance variable represents the walk distance (in miles) from the parking location k to the final destination j. The parking capacity term is included to give a higher utility to larger parking lots, which may have a higher visibility, or awareness level, than smaller lots. Auto travel time measures the time to travel from the home location to the parking location and is expressed in minutes.

The probability calculations are performed using the standard logit form:

$$P_k = \frac{e^{U_k}}{\sum_m e^{U_m}}$$

where	P_k	= Probability of selecting parking location k
	U_k	= Parking location utility of zone k
	m	= Available parking locations (the destination zone and 10 randomly selected CBD zones)

The parking location choice model is estimated using data collected during CBD parking surveys. The parking survey data is augmented with zone-to-zone network-based travel times and zonal socioeconomic data. An estimation file is then created in which each parking survey record is augmented with the additional data. The estimation file can include variables such as those shown in Table 3.

Table 3: Parking Location Choice Model Estimation File Variables

Label	Description	Source
ID	Identification Number	Parking O-D Survey
CODE	Survey Station Code	Parking O-D Survey
PZN	Parking TAZ	Parking O-D Survey
ATYPE	Area Type of parking zone	Parking O-D Survey
OZN	Origin TAZ	Parking O-D Survey
DZN	Destination TAZ	Parking O-D Survey
Q1	Purpose at Destination TAZ	Parking O-D Survey
Q3	Purpose at Origin TAZ	Parking O-D Survey
PTY	Parking Type	Parking O-D Survey
PCST	Parking Cost (Cents)	Parking O-D Survey
PDUR	Parking Duration	Parking O-D Survey
PTMA	Time Parking Began	Parking O-D Survey
PTMB	Time Parking Ended	Parking O-D Survey
STENT	Street On Which CBD Entered	Parking O-D Survey
VTY	Vehicle Type	Parking O-D Survey
AUOCC	Number of Persons in Vehicle	Parking O-D Survey
Pct$0Wrk	Average Percent Free - Work Trips	Parking O-D Survey
Pct$0NWrk	Average Percent Free - Non-Work Trips	Parking O-D Survey
LTSpace	Number of Long-Term Spaces	Parking Inventory
STSpace	Number of Short-Term Spaces	Parking Inventory
LTCost	Average Parking Cost - Long Term	Parking Inventory
STCost	Average Parking Cost - Short Term	Parking Inventory
ATimeIJ	Auto time - Origin Zone to Work Zone	Road Network
ATimeIK	Auto time -Origin Zone to Parking Zone	Road Network
WalkKJ	Walk time - Parking Zone to Destination	Road Network
HHINC	Average Household Income at Origin Zone	Zonal Variables
WKRINC	Average Worker Income at Destination Zone	Zonal Variables

4. CONCLUSIONS

The supply of parking is considered to be a major factor in determining travel patterns within urban areas, as shown by the high number of policy changes that focus on parking. A parking lot subroutine within a travel demand model would assist in accessing the behavioral mechanisms involved in determining individual parking choice and thus better inform the trip distribution and mode choice assignment components of travel demand model. It would provide a robust determination of likely relationships between parking zones and destination zones. Further, the model could be used to assess "what if" scenarios covering policy options such as change to parking type, parking supply control, and changes to parking cost.

Technical Memo #8

Time of Day and Peak Spreading in Model Development

June 2, 2017

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff

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1. INTRODUCTION

In recent years, there has been increasing interest in the ability of travel demand models to estimate travel not only for the average weekday, but for different time periods within the day. Travel demand models are increasingly required to be analysis tools for a broad range of issues on transportation policy and project alternatives. These issues often require detailed analysis, not only spatially, but temporally as well.

The previous CRCOG Model was an auto only daily model. While a transit network was created, application of the model did not result in the creation of transit trip tables or transit assignments being carried out. Time-of-day was recognized in the slicing of the daily auto trip table into AM Peak, Midday, PM Peak, and Nighttime components. The AM and PM peak periods were two and three hours in length while the midday and nighttime periods were six and 13 hours in length.

During the update of the CRCOG regional travel demand model TSC and CRCOG staff considered revisions to this approach. This included the possibility of developing a choice model for forecasting peak spreading. Such a model, similar in approach to a mode choice model, would seek to capture the behavioral response of drivers to increasing congestion through a shift in their departure time. In the end, it was determined that a choice model was not necessary based on observed travel patterns nor the best option given CRCOG's traditional four step model. A simple modification to the time period definitions would be sufficient to meet the CRCOG's modeling needs.

This technical memorandum presents a brief overview of time of day modeling in travel demand forecasting, discusses how time of day is considered in the updated CRCOG model structure, and reviews the traffic count and other data that supports the current time of day approach.

2. APPROACHES TO TIME OF DAY MODELING

The approach used in the Capital Region Council of Governments (CRCOG) model is typical of methods used to address time of day in four-step travel demand forecast models. There are, however, other approaches. These all have the same objective which is to take the trips generated by the trip generation model and allocate them appropriately to different times of the day. Traditionally, in the context of a four-step travel demand model such as the CRCOG regional model, this involves the use of factors derived from traffic counts or survey data.

Discussions regarding time-of-day modeling have been published in several readily available reports. The Second Edition (2010) of the *Travel Model Validation and Reasonableness Checking Manual*, published by the Federal Highway Administration (FHWA) Travel Model Improvement Program (TMIP) contains a chapter on time of day. It includes an overview of various methods (including choice models), as well as sources of data and guidelines for the development and checking of time-of-day model components. Among Fixed Factor Methods, the most common method, the Manual lists several ways in which time-of-day factors may be applied:

- Pre-distribution: daily trips are factored between the trip generation and the trip distribution steps;
- Post-distribution: factors are applied after trip distribution and before mode choice;
- Post-mode choice: factors are applied after mode choice and before assignment; and
- Post-assignment: factors are applied after assignment.

Time of Day Modeling Procedures Report (FHWA)[1] published in 1997 presents a discussion of the standard factoring approaches to time of day modeling. The report also covers several innovative approaches that go beyond factoring to address peak spreading and approaches that attempt to model time choice in the same manner as mode choice. Table 1, from the report summarizes the approach, advantages, and disadvantages of each method.

Travel Demand Forecasting: Parameters and Techniques NCHRP 716 (2012) includes a discussion of time of day modeling within the context of the four step model. This report states that, while many analysts prefer to perform the daily to TOD conversion prior to mode choice, there is no consensus as to the best point in the modeling process to carry out this conversion.

The *Travel Model Validation and Reasonableness Checking Manual* also discusses time-of-day choice models noting that a shortcoming of the fixed factoring methods is that time-of-day choice is insensitive to transportation level of service. While there has been research into incorporating variables that represent level of service it has had limited success when used with a four-step model. The time-of-day choice model approach appears better suited to tour and activity based models.

The National Cooperative Highway Research Program (NCHRP) Report 765 (2014) *Analytical Travel Forecasting Approaches for Project-Level Planning and Design,* updates NCHRP 255, and contains a chapter on improving the temporal accuracy of traffic forecasts. This report includes discussion on the development of activity based models incorporating time-of-day choice models, the use of dynamic traffic assignment to analyze the temporal nature of travel, approaches to evaluating peak spreading, as well as factoring approaches to time-of-day.

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[1] *Time-of-Day Modeling Procedures Report*, Prepared for: Federal Highway Administration – Travel Model Improvement Program. Prepared by: Cambridge Systematics, Inc. Final Report: February 1997.

Table 1: Assignment Types for Time of Day and Peak Spreading

Method	Approach	Advantages	Disadvantages
TIME OF DAY (TOD) Approaches			
TOD Assignment after Trip Assignment	Run daily 4-step model, factor daily volume outputs to obtain hour/period values	• Simple, quickest method to apply. (ex. Use K and D factors) • Accounts for different peaking /directional characteristics by subregions/roadways. • Allows for the possibility of link-based peak spreading but not trip based peak spreading or time of day choice	• Daily equilibrium assignments are performed for period that is not homogenous- speeds vary greatly over an average weekday (i.e. assignments are based on daily speeds, which are not every meaningful.) • Insensitive to future changes in land use or composition of traffic (through vs. local) • Peaking is unrelated to congestion levels – application of fixed factors to forecast year daily volumes may results in unrealistically high peak volumes.
TOD Assignment Between Mode Choice and Trip Assignment	Run trip generation, distribution, and mode choice on a daily basis, factor trip tables by purpose and mode to obtain peak hour / period trips tables, assign trip tables for each period to appropriate networks.	• Simple method to apply – trip table manipulation functions, factors derived from surveys, calibrated to time of day counts. • Assignments can be done for relatively homogenous periods (speeds within a peak or off-peaks periods vary much less than daily speeds.) • Mode can be considered in time of day factoring – transit could have explicitly different peaking characteristics than auto. • Allow for the possibility of trip based or link-based peak spreading, or time of day choice.	• Mode choice and trip distribution are still performed using daily speeds. • Applying a single set of regional factors causes inaccuracies due to different peaking characteristics across the region, but it's difficult to derive sub regional factors. • Peaking is not directly related to congestion levels – assigning trips tables based on the application of fixed factors to forecast year daily trip tables could results in unrealistically high peak volumes. This problem could be mitigated by using feedback; however, the feedback process is complicated when assignment travel time outputs are peak/off-peak but distribution/mode choice travel time inputs are daily.
TOD Assignment Between Trip Distribution and Mode Choice	Run trip generation, distribution on daily basis, factor person trip tables by purpose to obtain peak hour / period trips tables, perform mode choice and assignment for each period using appropriate networks	• Assignments can be done for relatively homogenous periods (speeds within a peak or off-peaks periods vary much less than daily speeds.) • Mode choice (but not distribution) is performed for the peak/off-peak periods using appropriate networks. • Allows for the possibility of trips-based or link-based peak spreading, or time of day choice (this assumes factors are not fixed).	• Trip distribution still using performed using daily speeds. • Applying a single set of regional factors causes inaccuracies due to different peaking characteristics across the region, but it's difficult to derive sub regional factors. • Difficult to justify using inconsistent procedures between trip distribution and mode choice procedures – distribution uses daily speeds, mode choice uses peak/off-peak speeds. • Peaking is not directly related to congestion levels – assigning trips tables based on the application of fixed factors to forecast year daily trip tables could results in unrealistically high peak volumes. This problem could be mitigated by using feedback; however, the feedback process is complicated when assignment travel time outputs are peak/off-peak but distribution/mode choice travel time inputs are daily.
TOD Assignment Between Trip Generation and Trip Distribution	Run trip generation on a daily basis, factor person trip tables by purpose to obtain peak hour / period trips tables, perform trip distribution, mode choice, and assignment for each period using appropriate networks.	• Assignments can be done for relatively homogenous periods (speeds within a peak or off-peaks periods vary much less than daily speeds.) • Mode choice and trip distribution are performed for the peak/off-peak periods using appropriate networks, consistent with the trip assignment approach. • Allows for the possibility of trips-based or link-based peak spreading, or time of day choice (this assumes factors are not fixed). • The use of feedback is facilitated since assignments travel time outputs and inputs to trip distribution and mode choice are all for the same peak/off-peak periods.	• Applying a single set of regional factors causes inaccuracies due to different peaking characteristics across the region, but it's difficult to derive sub regional factors. • Peaking is not directly related to congestion levels – assigning trip tables based on the application of fixed factors to forecast year daily trip tables could results in unrealistically high peak volumes. This problem could be mitigated by using feedback. • If time of the day choice is used, zone-to-zone measures of congestion cannot be considered since factors are applied to trip ends, not trip tables.

Peak Spreading Approaches			
Spreading within the Peak Period: Linked based Approach	Obtain peak period assignments, estimate relationships between V/C ratios and ratio of peak hour / peak period percentages, apply to peak period link volumes from assignment.	• Simple method to apply (spreadsheet or simple program); peaking-congestion relationships can be estimated from time of day count information. • Accounts for congestion at the link level and diverts trips to the "shoulder" hours on either side of the peak	• Procedure is insensitive to many factors effecting peak spreading, including trip purpose and length. • Resulting peak hour volumes among links may not be consistent (i.e. volume entering a node may not equal the volume leaving the node) • Addresses neither spreading of trips outside the peak period nor the redefinition of peak periods over time. • Applying a single set of regional factors causes inaccuracies due to different peaking characteristics across the region, but it's difficult to derive sub regional factors. • Peaking is not directly related to congestion levels – assignment trip tables based on the application of fixed factors to forecast year daily trip tables could results in unrealistically high peak volumes. This problem could be mitigated by using feedback. • If time of the day choice is used, zone-to-zone measures of congestion cannot be considered since factors are applied to trip ends, not trip tables.
Trip-Based Peak Spreading based Approach	Obtain peak period trip tables, estimate relationships between ratio of peak hour/peak period percentages and other variables such as trip purpose and length, apply to peak period trip tables prior to peak hour assignments.	• Simple method to apply (spreadsheet or simple program); peaking-congestion relationships can be estimated from time of day count information. • Good foundation for approach; relationship between peak spreading and other variables is well documented.	• Procedure has not been tested using congestion as a variable. • Addresses neither spreading of trips outside the peak period nor the redefinition of peak periods over time • Does not account for changes in traveler behavior due to congestion. • Not sensitive to traffic congestion on specific links or specific origin-destination flows as well as to different trip purposes.
System-Wide Peak Spreading	Apply a model that relates the percentage of trips in the peak period to variable such as congestion, trip length geography, and socioeconomic variables. Apply the resulting percentages on a zone-to-zone basis to the person trip tables by purpose and mode that are outputs from mode choice, and run assignments for peak and off peak periods. Considers the system-wide excess travel demand and delay and distributes excess travel demand between the individual travel hours that comprise the peak period	• The effects of congestion on peak spreading can be explicitly considered. • Assignments can be done for relatively homogenous periods (speeds within a peak or off-peak period vary much less than daily speeds) • Mode can be considered in time of day factoring; transit could have explicitly different peaking characteristics than auto.	• Not sensitive to different trip purposes • Not sensitive to traffic congestion on specific links or specific origin-destination flows • Data required include TOD factors that describe the distribution of trips in each of the three analysis hours that comprise the peak period. Also a set of v/c limits (by facility type) that differentiates between temporal and spatial diversion • Mode choice and trips distribution are still performed using daily speeds. • Feedback process is complicated when assignments travel time outputs are peak /off-peak but distribution/ mode choice travel time inputs are daily. • Has not been developed for non-work trips.

3. TRAFFIC DATA ANALYSIS

The first objective of the traffic data analysis was to determine if there was evidence of peak spreading in the Hartford area. Evidence of peak spreading would help to inform the discussion regarding consideration of developing a peak spreading model either now or in the future. A second objective of the analysis was to determine if there had been a shift in the peak period that might necessitate the need for adjusting the time of day definitions currently used in the CRCOG model. The analysis was based on continuous count and traffic monitoring data available from the Connecticut Department of Transportation (CTDOT). Appendix B, contains some definitions and figures pertinent to the traffic analysis.

Continuous Traffic Counts

CTDOT maintains 40 continuous traffic count sites throughout the state. Eight of these sites are within the CRCOG Metropolitan Planning Organization (MPO) region and an additional eight are in the in the CRCOG model "buffer zone" as shown in Figure 1 and Table 2.

Figure 1: Continuous Traffic Counts Locations

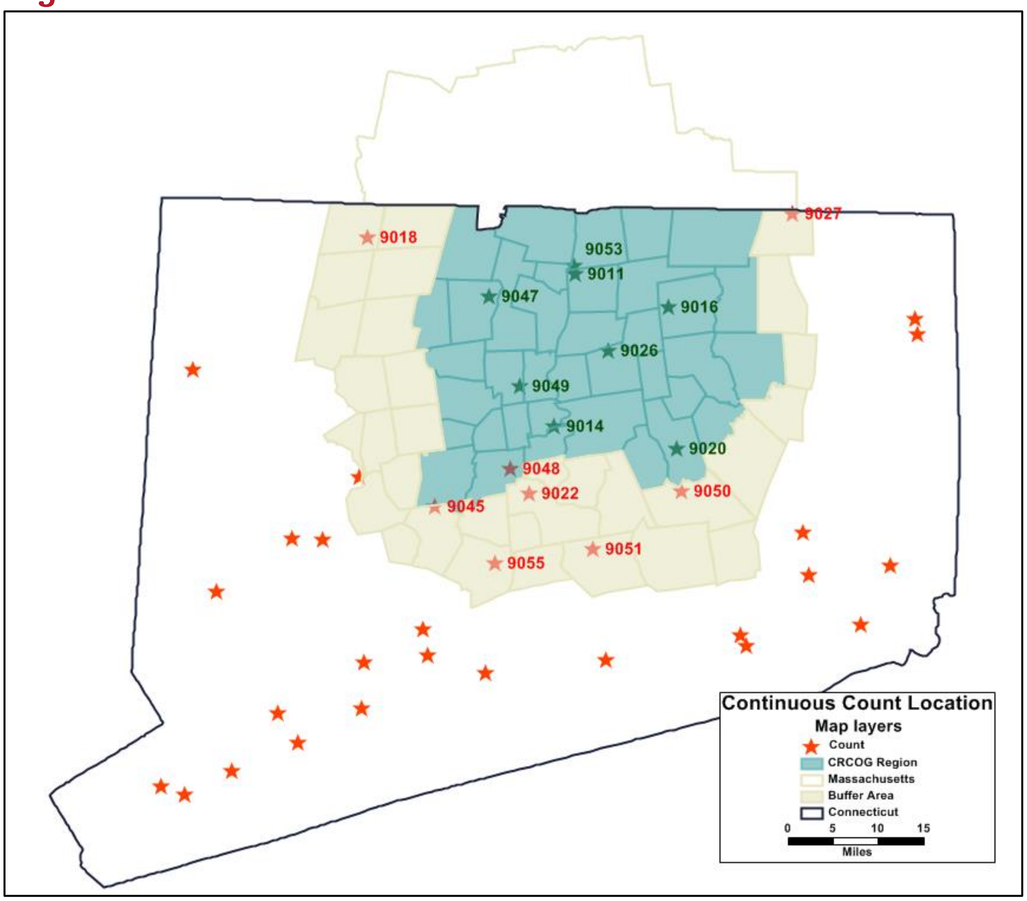


Figure 2 and Figure 3 show hourly counts from the continuous count site in West Harford (Count ID 9049), the site closest to the I-84 project area, for 2011 and 2015. These data display expected temporal profiles. Morning demand increases from a very low level to a pronounced peak about mid-morning, heavily influenced by the travel-to-work trip purpose. Demand then drops during the late morning and early afternoon until another peak occurs when individuals return home from work, school, or other activities. Subsequent to the evening peak, demand again drops to a relatively low level until morning.

In the eastbound direction, in 2011 and 2015, similar predominant peaks are evident at 8:00 AM with smaller peaks visible at 3:00 PM in the afternoon and 7:00 PM in the evening. In the westbound direction, the prominent peak occurred during the evening at 6:00 PM in 2011 and 5:00 PM in 2015. A smaller peak also occurred during the morning in the westbound direction at 10:00 AM in 2011 and 9:00 AM in 2015.

Table 2: Continuous Traffic Counts Locations

Count ID	Direction	Route No.	Road Type	Functional Class	Town	CRCOG Model Area
9011	North / South	Rt-5	Urban	Principal Arterial (Other)	East Windsor	MPO Region
9014	North / South	I-91	Urban	Principal Arterial (Interstate)	Wethersfield	MPO Region
9026	East / West	I-84	Urban	Principal Arterial (Interstate)	Manchester	MPO Region
9047	North / South	Rt-10	Urban	Principal Arterial (Other)	Simsbury	MPO Region
9049	East / West	I-84	Urban	Principal Arterial (Interstate)	West Hartford	MPO Region
9053	North / South	I-91	Urban	Principal Arterial (Interstate)	Enfield	MPO Region
9016	North / South	Rt-30	Urban	Collector	Tolland	MPO Region
9020	East / West	Rt-66	Rural	Principal Arterial (Other)	Hebron	MPO Region
9048	North / South	Rt-15	Urban	Principal Arterial (Other Expressway)	Berlin	Buffer Zone
9018	North / South	Rt-8	Rural	Minor Arterial	Colebrook	Buffer Zone
9023	North / South	Rt-8	Urban	Principal Arterial (Other Expressway)	Watertown	Buffer Zone
9022	North / South	Rt-217	Urban	Minor Arterial	Middletown	Buffer Zone
9051	North / South	Rt-9	Urban	Principal Arterial (Other Expressway)	Haddam	Buffer Zone
9045	East / West	I-691	Urban	Principal Arterial (Interstate)	Cheshire	Buffer Zone
9055	North / South	I-91	Urban	Principal Arterial (Interstate)	Wallingford	Buffer Zone
9050	East / West	Rt-2	Urban	Principal Arterial (Other Expressway)	Colchester	Buffer Zone
9027	East / West	I-84	Rural	Principal Arterial (Interstate)	Union	Buffer Zone

ADT at this site declined by 800 vehicles (0.61%) between 2011 and 2015. This is evident in the relative position of the curves for the two years. In addition, there appears to have been a slight shift in travel times to earlier time periods most likely in response to congestion on I-84. Peak spreading results in the expansion of peak period of traffic, from original peak period to include additional shoulder-hours, in response to traffic levels that exceed capacity. Hence, the peaks in the demand profile would appear flatter and include more time periods. Given that the 2011 and 2015 curves have approximately the same shape there does not appear to be evidence of peak spreading.

Figure 2: West Hartford Continuous Traffic Count Data (I-84 East)

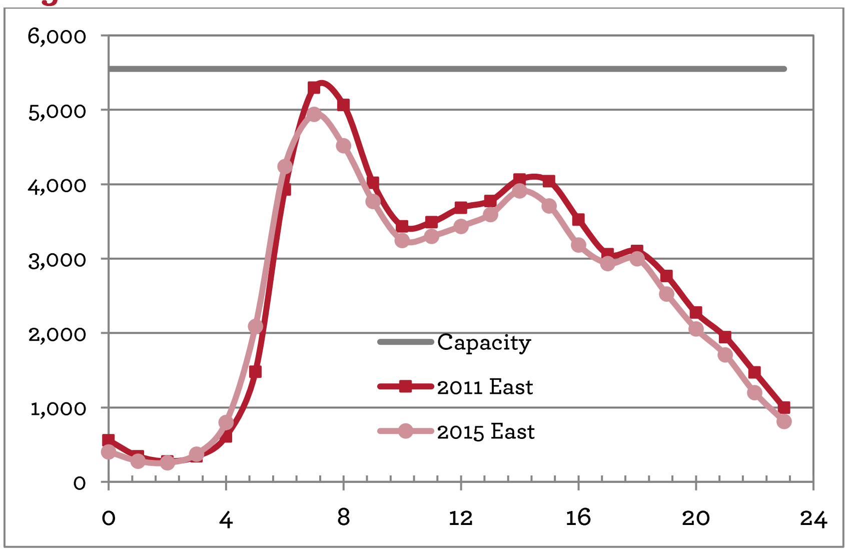
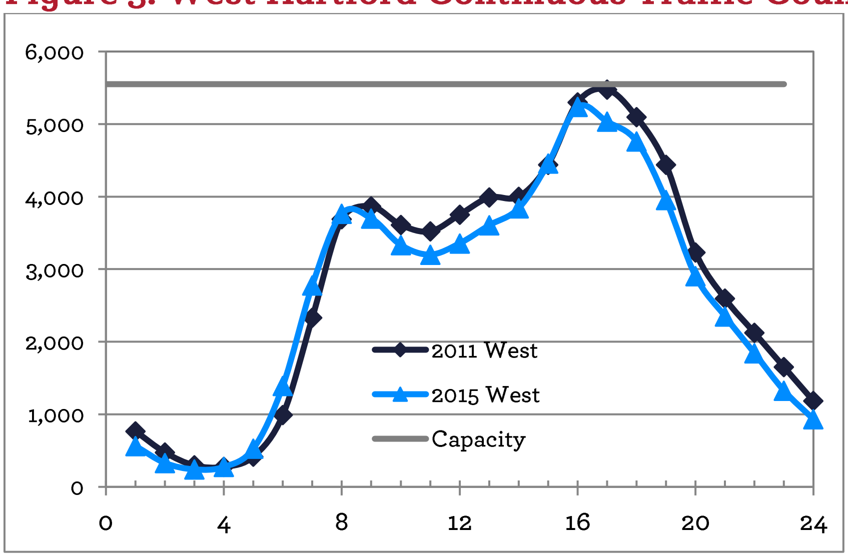


Figure 3: West Hartford Continuous Traffic Count Data (I-84 West)



Count profiles for all of the continuous counts sites in the CRCOG model area are in Appendix A. Across all the sites there is modest growth over the last five years with 1 percent or less of

Average Annual Percent Change (AAPC) on interstates and 1 to 3 percent of AAPC on principal arterials. The Table 3 illustrates the change in traffic volumes in the I-84 corridor between 2001 and 2015.

Traffic Monitoring Data

In addition to the continuous count stations (CCS) data, historical average daily traffic (ADT) for I-84 and I-91 was collected from CTDOT's Traffic Monitoring Volume Information Traffic Count Data. Table 3, following, displays 15 years of ADT data, from 2001 to 2015.

Table 3: Historical Average Daily Traffic Volumes

Year	I-84: Bulkeley Bridge	I-91		I-84				
		Between Exits 33 and 34	South HOV Ln Between Exits 33 and 34	WB: Off-Ramp to I-91 NB (Exit 51)	EB: Off-Ramp to I-91 SB (Exit 52)	EB: On Ramp from I-91 SB	WB: On Ramp from I-91 NB	EB: Off Ramp to I-91 NB (Exit 51)
2001	141,800			10,200	14,500	21,900	-	
2002			7,000				23,300	11,200
2003							-	
2004	141,400			11,300	15,500	23,600	-	
2005			9,400				23,100	12,400
2006			8,100				-	
2007	141,400			9,400	13,100	20,500	-	
2008					14,500		21,300	11,900
2009		129,900	8,000				21,900	12,500
2010	141,100	135,400	8,600	10,900	14,500	22,000	23,000	
2011							23,100	11,800
2012		133,200	9,600	11,300	14,500	22,900	-	
2013	141,700			10,800	14,900	22,100	22,900	
2014								
2015		144,000	6,200		14,800			
CHANGE FROM FIRST TO LAST YEAR IN EACH SERIES								
Number	-100	14,100	-800	600	300	200	-400	600
Percent	-0.07%	10.85%	-11.43%	5.88%	2.07%	0.91%	-1.72%	5.36%
CAGR	-0.01%	1.48%	-0.86%	0.44%	0.14%	0.07%	-0.14%	0.58%

Note: CAGR is the Compound Annual Growth Rate, calculated as: = ((End Value / Start Value) ^ (1/Periods) -1

Overall, the table shows an irregular pattern of change in ADT volumes across the years and at the locations listed. Daily traffic volumes on I-84 over the Bulkeley Bridge have remained fairly constant over time with ADTs between 141,100 and 141,800 vehicles per day. This is likely due to the recurring congestion throughout Hartford. Most of the city's freeways have operated at or near capacity for decades, leaving little room for growth. While the peak periods have shifted into traditionally off-peak hours, the overall daily volumes have not increased substantially, reflecting the time-sensitive nature of commuter traffic. In addition to this mainline location, another mainline location and a High Occupancy Vehicle (HOV) connector location plus five ramps connecting I-91 and I-84 are shown. The other mainline location has seen growth in traffic increasing by 10.85 percent between 2009 and 2015. Most of the ramps have seen little or no growth during the 15 years. The largest growth, 5.36 percent, was on the I-84 eastbound off-ramp to I-91 northbound (Exit 51) while the I-84 westbound on-ramp from I-91 northbound saw a decline in traffic of 1.72 percent.

Conclusion

The phenomenon of peak spreading is the result of a shift in travel demand away from a critical peak hour to earlier or later times (the peak shoulders) resulting in a longer peak period. In the CRCOG region, while there is certainly congestion, there does not appear to a peak spreading response to this congestion. What does seemed to have happened is a shift of some peak period traffic to non-traditional peak hours. In addition, there has also been for the most part, little or no growth in traffic during the recent past.

Figure 2, illustrates typical traffic patterns found in the Hartford area with a shift in peak hour traffic to earlier times but no evidence of peak spreading. A review of the daily and peak hour traffic profiles found in Appendix A from CTDOT's continuous count program would also seem to support this observation. Finally, little or no growth in traffic volumes over the last several years leads to the conclusion that peak spreading will not be a significant response to congestion in the near future.

These observations led to the conclusion that the expansion of the AM peak period time slice from two hours to three hours and a corresponding reduction in the Off-Peak period from 13 to 12 hours, while maintaining the other time slices, would suffice to depict time of day throughout the region. As a result of these changes the CRCOG Model now utilizes the following four time periods:

- AM Period: 6:00AM- 9:00AM (3 hours)
- MD Period: 9:00AM- 3:00PM (6 hours)
- PM Period: 3:00PM- 6:00PM (3 hours)
- OP Period: 6:00PM- 6:00AM (12 hours)

4. CRCOG TIME-OF-DAY METHODOLOGY

The CRCOG regional model remains essentially a daily model. In addition, the approach to the temporal distribution of daily trips is unchanged from the previous model. However, while the approach is unchanged, there has been a modification to the definition of the time periods used to divide the daily auto trip table. The time of day factors used to in this process are based on observed traffic counts, transit on-board survey data, and household survey data. Further, the development of a mode choice model with a working transit component brings something of another time-of-day element into the model structure.

After the mode choice model is run, the auto trip matrices are converted from PA to OD format and divided into time periods. There are four time periods: AM Peak (three hours), Midday (six hours), PM Peak (three hours), and Nighttime (12 hours). Note that the modification from the previous CRCOG Model was an increase in the AM Peak from two to three hours and a reduction in the nighttime period from 13 to 12 hours.

For the transit assignment the trip tables input into mode choice model are in PA format as dictated by the trip distribution / destination choice model. Further, as is standard practice, transit person trips are assigned in PA format in order to maintain consistency with the transit networks used to inform the mode choice model (AM conditions for peak trips and mid-day conditions for off-peak trips). In addition, peak trips are assumed to be HBW trips and off-peak trips are assumed to be HBO and NHB trips.

In PA format, the home end of a trip is considered the production end so the choice of mode is based on the travel impedances that the trip sees from the production zone to the attraction zone. For highway trips this is not an issue, there is not a concern that a PA trip, when converted to an OD trip, won't be able to find a return path – there will always be links to drive on. However, for transit, this is a concern because a PA trip, when converted to an OD trip, might not be able to find a return path. This is because the PM and Evening networks might be inconsistent with the AM and Mid-day networks that the PA trip saw when making its choice of mode. As a result, those trips would be unassigned. As further explanation, consider the following example.

Assume a rider takes Bus A to and from work. This would result in two 2 PA bus trips assigned to Bus A. Further, assume that the bus taken is an East-West route which in the TransCAD model network is coded as two separate routes: Bus A East and Bus A West. The PA trips will both be assigned to Bus A East assuming the work location is east of the home location. Thus, in this example, Bus A West does not get assigned any trips. However, in OD format Bus A East would be assigned a trip in the morning and Bus A West would be assigned a trip in the afternoon. How is this reconciled?

What is typically done to report transit boardings by route is to add up the boardings from the eastbound route and the westbound route and report the total for Bus A (instead of separately by East and West). So while Bus A East had 2 trips and Bus A West had 0, in total Bus A had two trips which is in fact the correct answer. Similarly, for stop-level analysis, the boardings and alightings are added up at each stop and divide by 2 to get ons and offs at that stop. It is also important to note, that this is standard practice and accepted by the Federal Transit Administration (FTA).

Diurnal Factors by Trip Purpose

The diurnal factors for each trip purpose were estimated using the 2016 Let's Go CT Household Travel Survey. Each individual trip record was segmented into one of the following trip purposes using origin and destination responses:

- Home-Based Work (HBW)
- Home-Based Other (HBO)
- Non-Home-Based (NHB)

Each trip record was assigned one of two directions: PA or AP. Home-based trips, with home as the destination, were designated as AP trips, home-based trips with home as the origin were assigned as PA trips. All non-home-based trips were nominally designated as PA trips, and the PA/AP split was set at 0.5/0.5 for each time period.

The Resident time of day factors are shown in Table 4. These factors are based on information from the CT DOT Household Travel Survey. Only a limited set of geographic identifiers were provided with the home interview survey data. As a result, the CRCOG MPO area was used to represent the entire model region which includes the MPO area, the Buffer Area in Connecticut, and TAZ's in Massachusetts.

TOD factors for the non-resident trip purposes are shown in Table 5. Non-resident trips include the following purposes:

- Home Base Work Internal – External and External – Internal trips (HBW-IX/XI)
- Non-Work Internal – External and External – Internal trips (NW-IX/XI)
- Truck trips including Internal – Internal, Internal - External, and External – Internal trips (TRUCK-II/IX/XI)
- Thru trips.

Since no data were available on which to base estimation of the TOD factors for the non-resident trip purposes. Therefore, HBW-IX/XI trips are assumed to have the same TOD distribution as HBW resident trips. In similar fashion, NW—IX/XI trips are assumed to have the same TOD distribution as HBO trips.

For Bradley International Airport (BIA) trips the TOD splits were based on the previous CRCOG Model TOD splits (see Tech Memo #1, Table 15). To be used in the updated model TOD structure, this value (0.03) was adjusted to reflect a three rather than a two hour time period. This was accomplished by applying the equation 0.03 + ((0.03/2)*.5). This equation assumes that the new AM Peak TOD split for BIA is the previous value (0.03) plus 50 Percent of the average hourly value reflected in the previous TOD split. Finally, TOD splits for Truck and Thru trips were borrowed from the model developed for the French Broad River Metropolitan Planning Organization as reported in their Model Development documentation.

Table 4: Resident Time of Day Factors

Resident Time of Day Assignment						
Purpose	Direction	AM	MD	NT	PM	Daily
HBW	AP	0.01	0.07	0.12	0.25	0.44
HBW	PA	0.40	0.09	0.05	0.02	0.56
HBO	AP	0.03	0.14	0.18	0.16	0.51
HBO	PA	0.17	0.14	0.09	0.09	0.49
NHB	AP	0.06	0.22	0.07	0.15	0.50
NHB	PA	0.06	0.22	0.07	0.15	0.50

Table 5: Non-Resident Time of Day Factors

Non-Resident Time of Day Assignment						
Purpose	Direction	AM	MD	NT	PM	Daily
HBW_IX	OD	0.67	0.12	0.20	0.02	1.00
HBW_XI	OD	0.03	0.23	0.19	0.55	1.00
NW_IX	OD	0.04	0.23	0.12	0.11	0.50
NW_XI	OD	0.04	0.23	0.12	0.11	0.50
BIA	AP	0.06	0.56	0.22	0.16	1.00
BIA	PA	0.32	0.40	0.22	0.06	1.00
TII	AP	0.07	0.23	0.12	0.08	0.50
TII	PA	0.07	0.23	0.12	0.08	0.50
TIX	OD	0.67	0.12	0.20	0.02	1.00
TXI	OD	0.10	0.30	0.39	0.21	1.00
THRU	AP	0.04	0.23	0.12	0.11	0.50
THRU	PA	0.04	0.23	0.12	0.11	0.50

APPENDIX A

Continuous Traffic Counts

Graphics

Figure 4: Traffic Count 9049: West Hartford

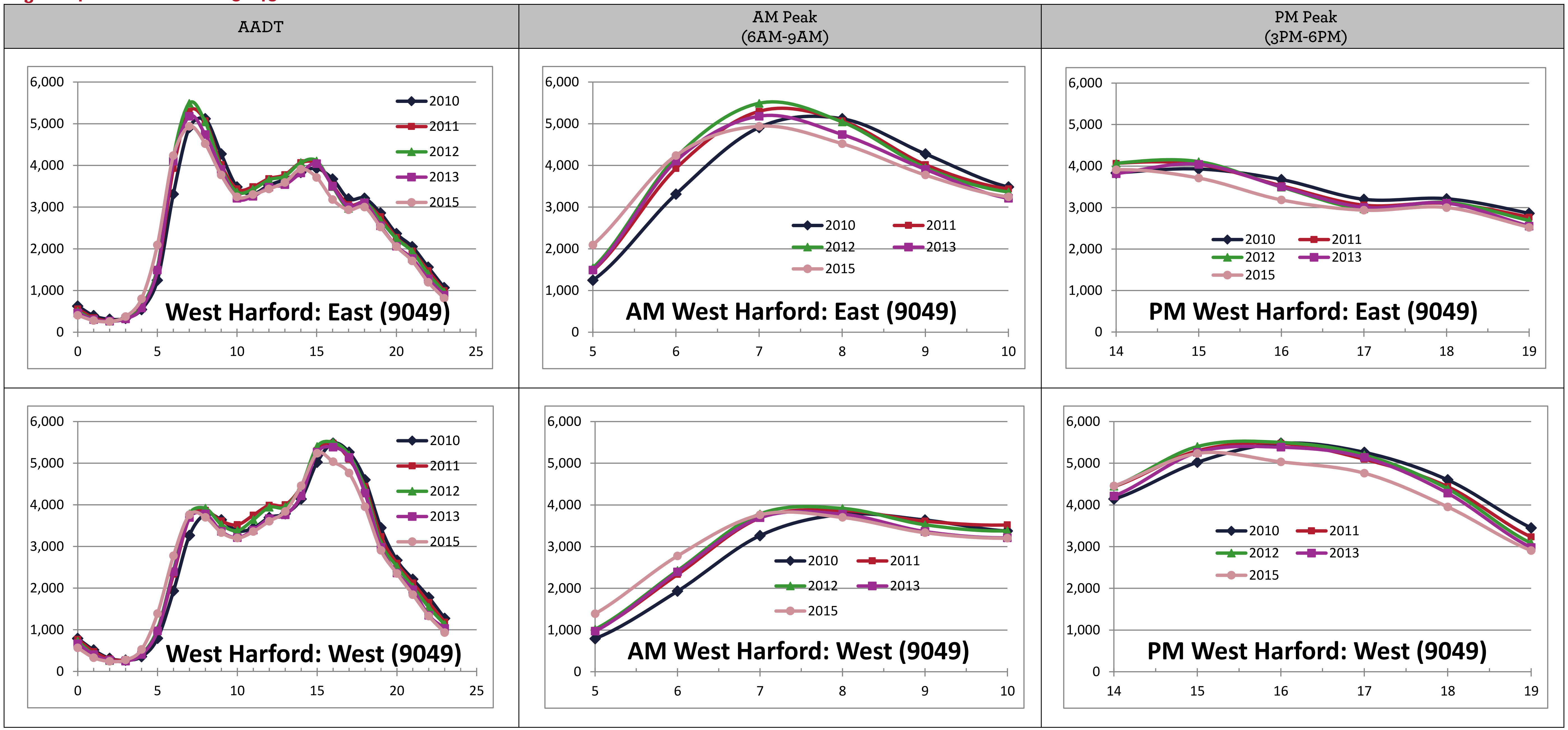


Figure 5: Traffic Count 9011: East Windsor

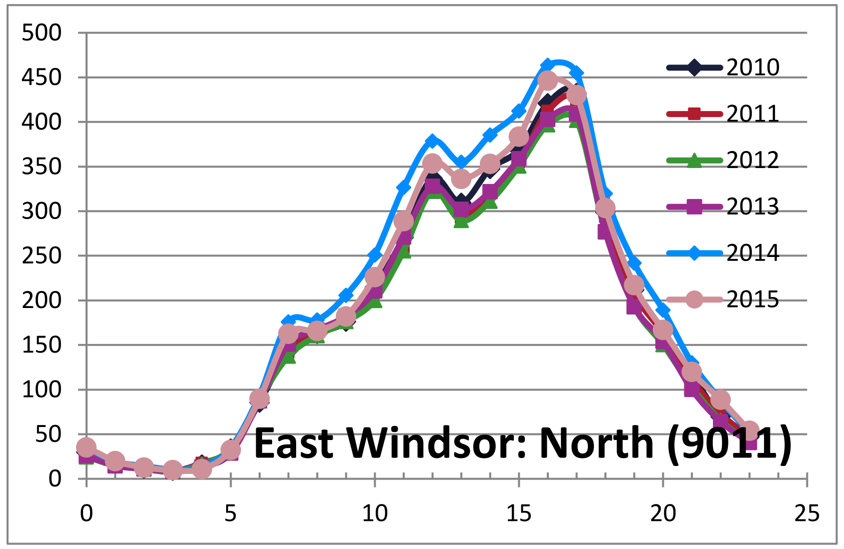
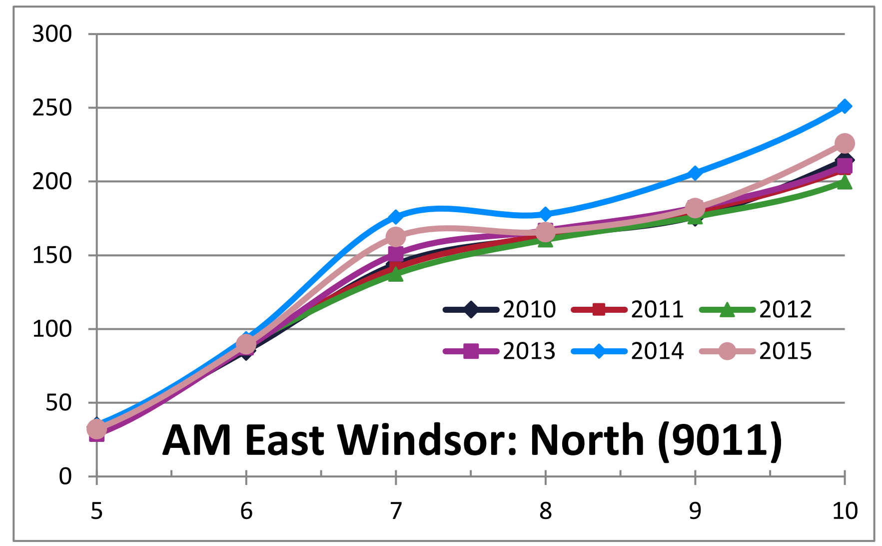
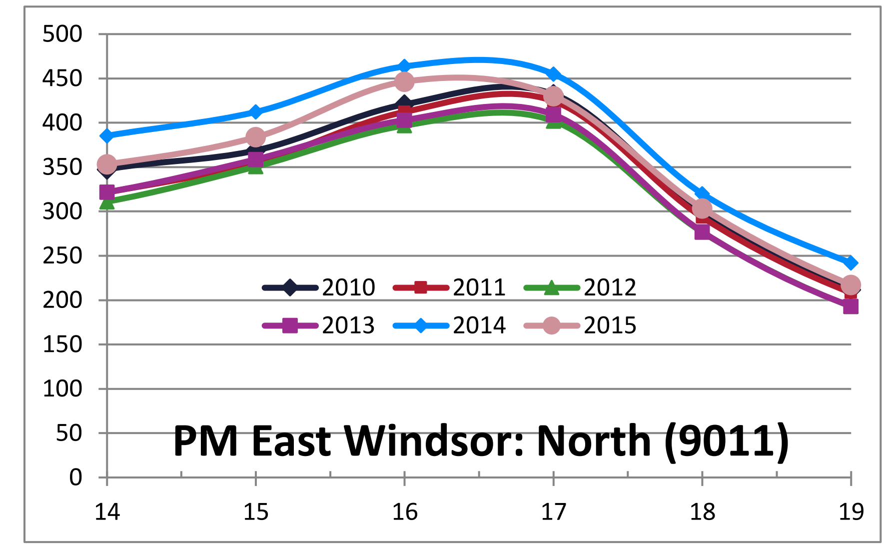
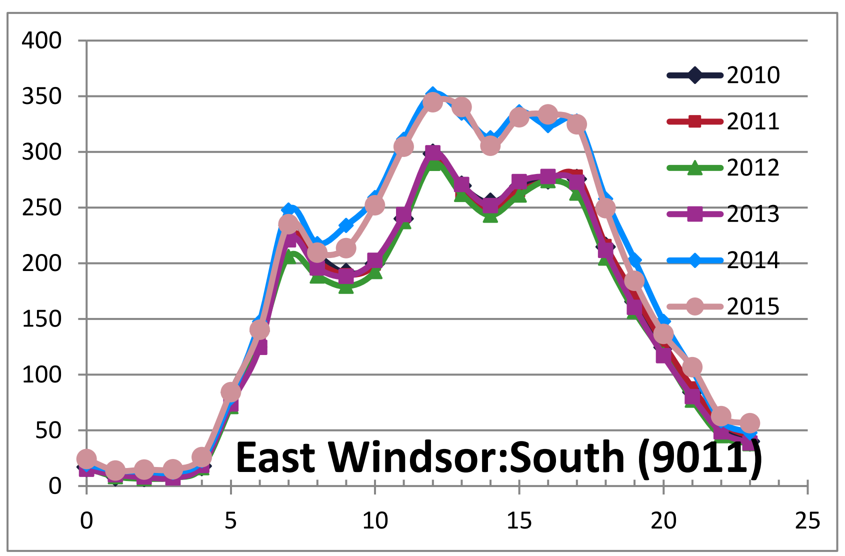
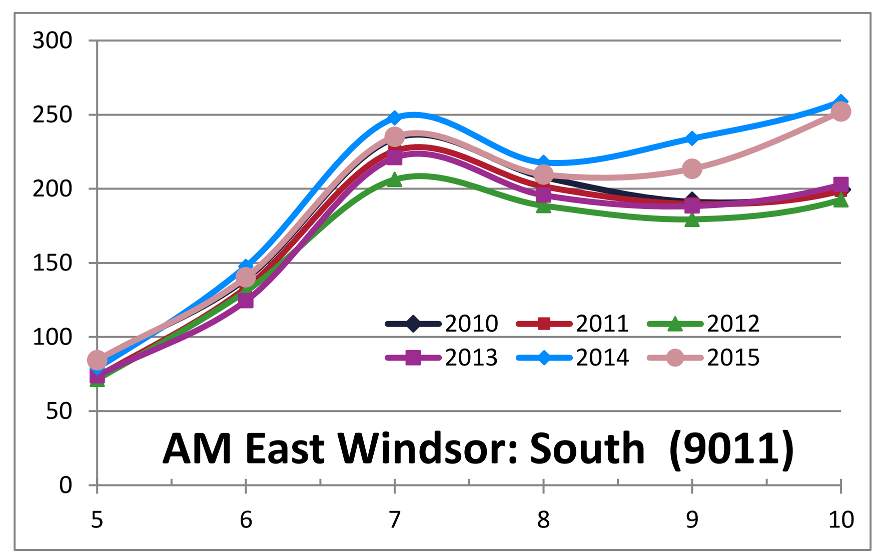
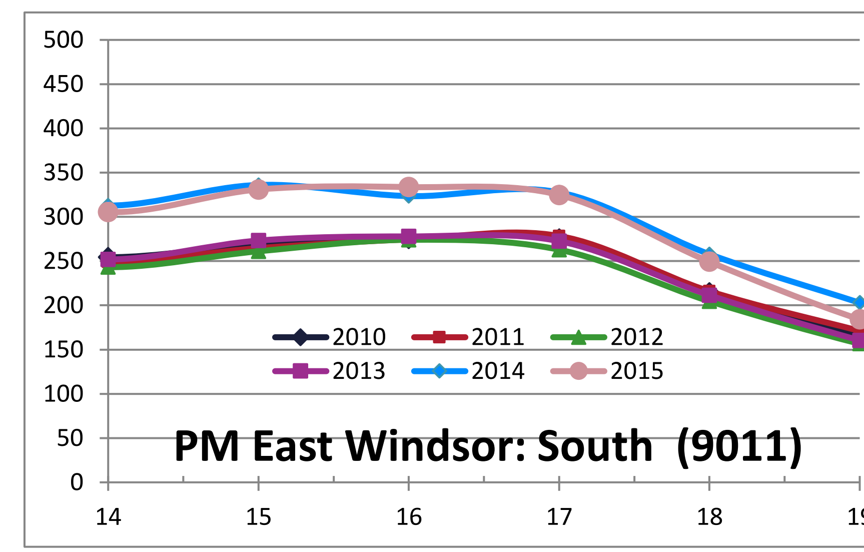
AADT	AM Peak (6AM-9AM)	PM Peak (3PM-6PM)
		
		

Figure 6: Traffic Count 9047: Simsbury

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(3PM-6PM)</th></tr>
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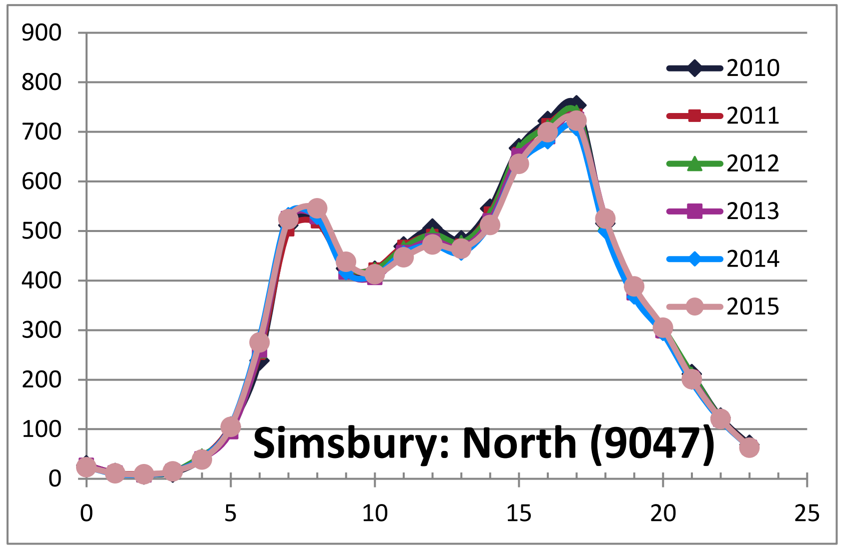
<td>
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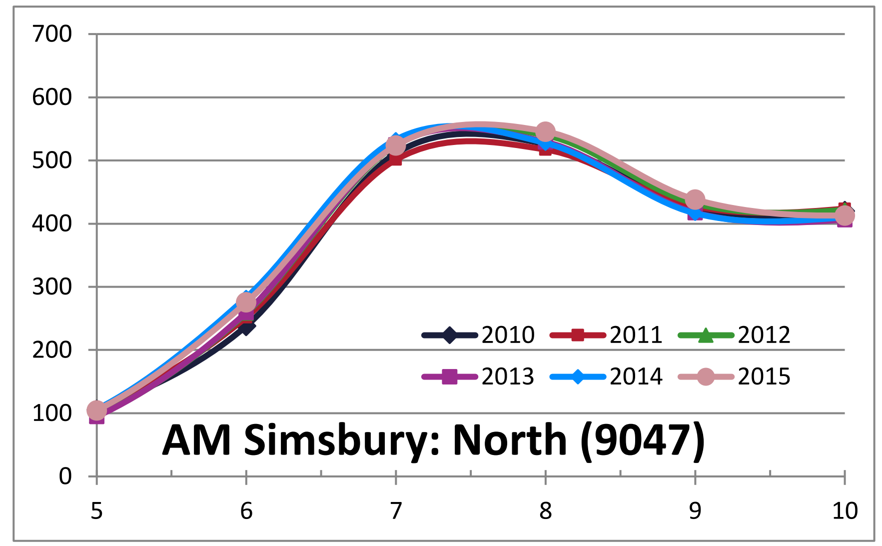
<td>
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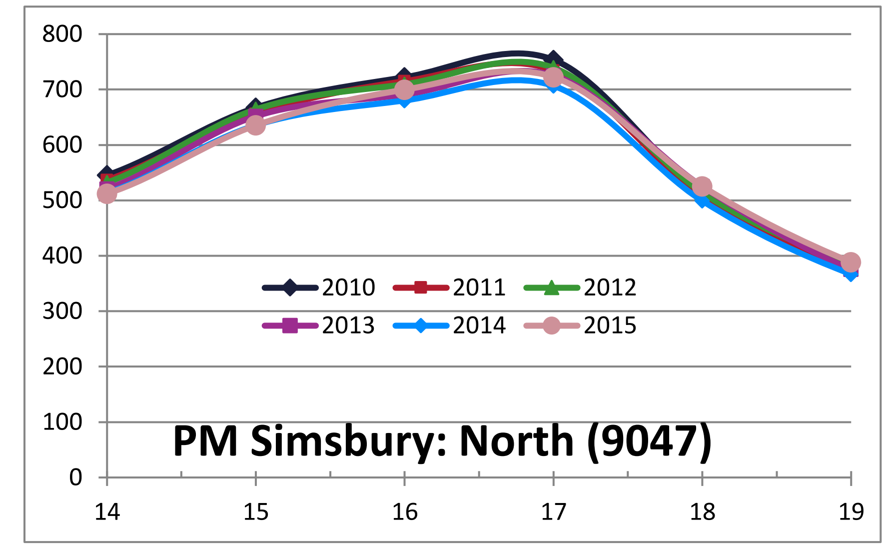
<td>
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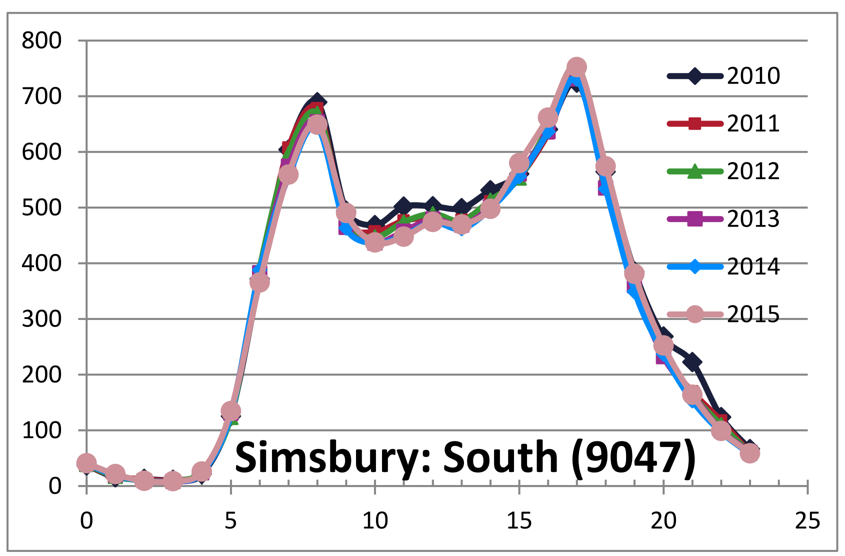
<td>
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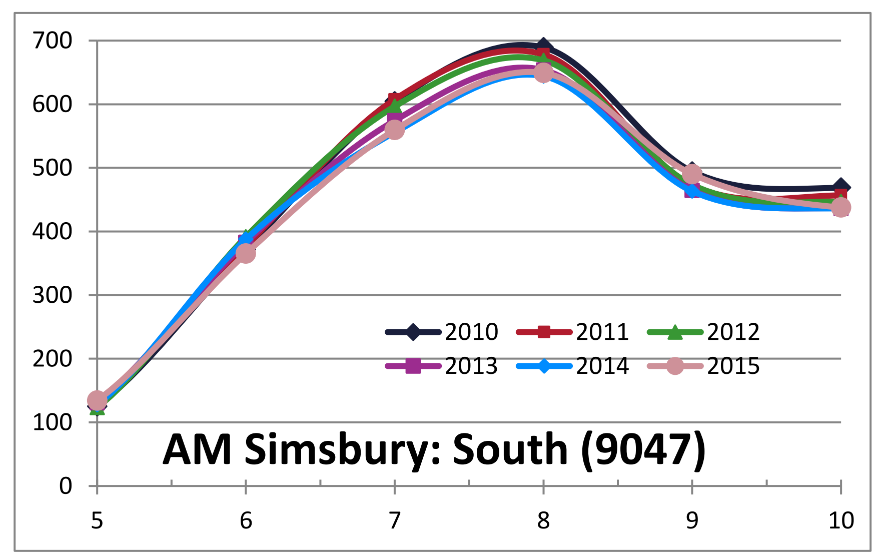
<td>
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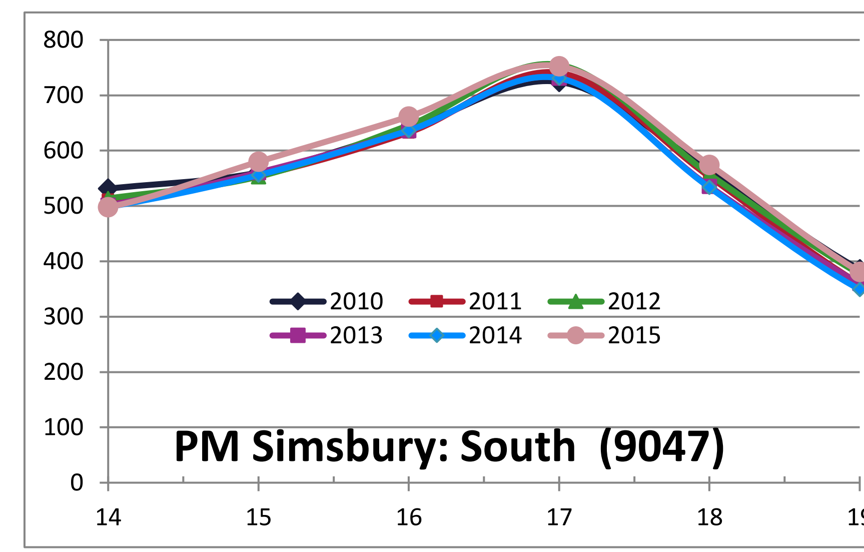
<td>
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Figure 7: Traffic Count 9022: Middletown

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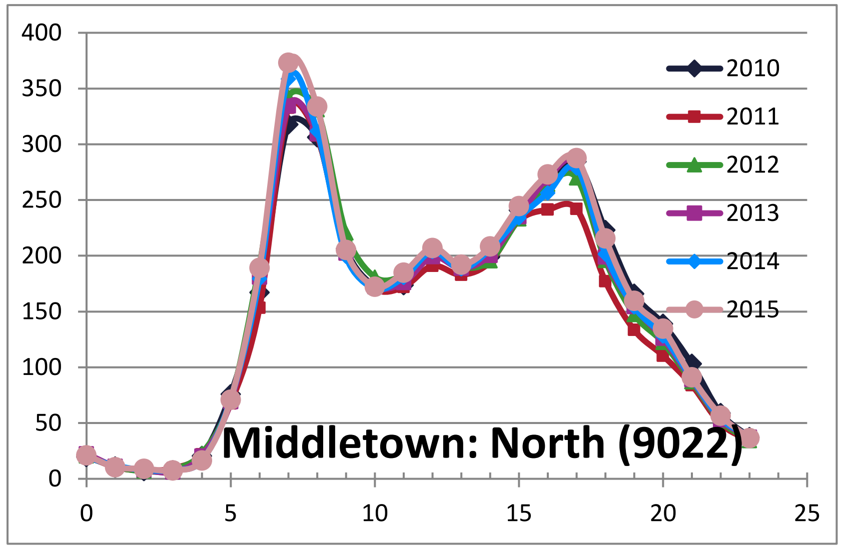
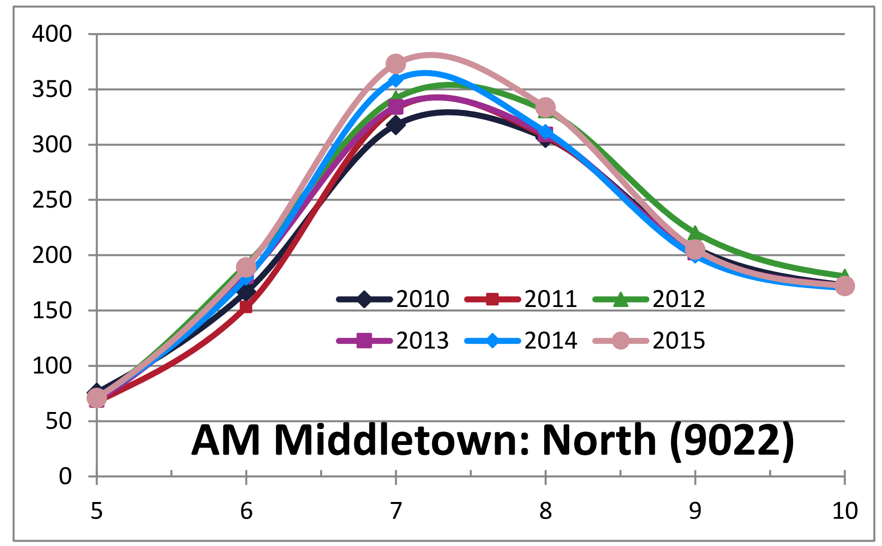
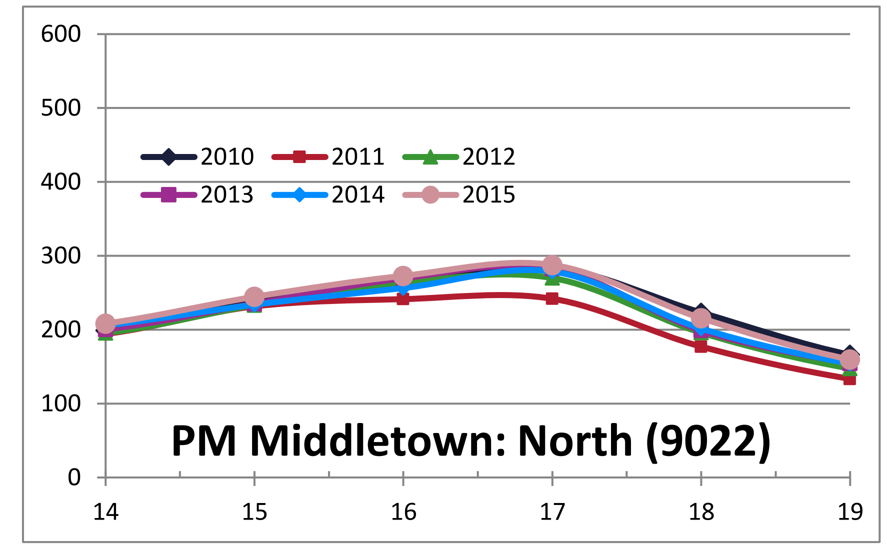
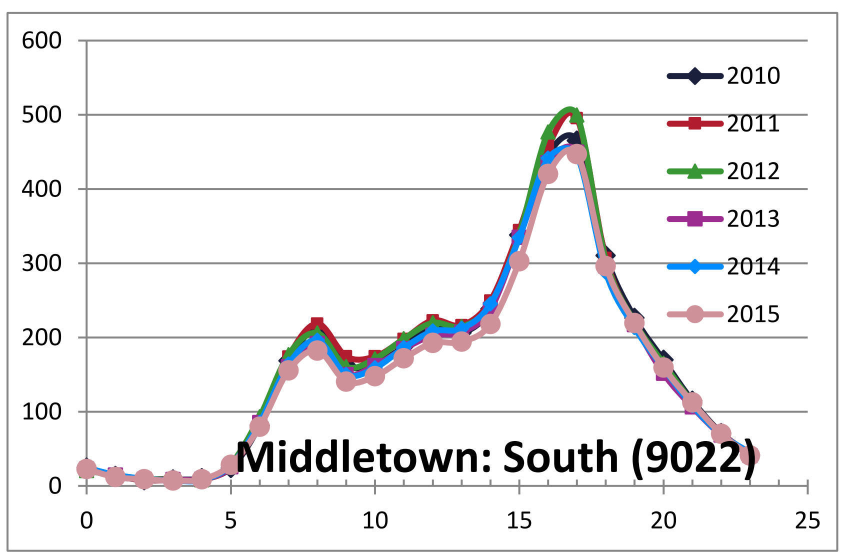
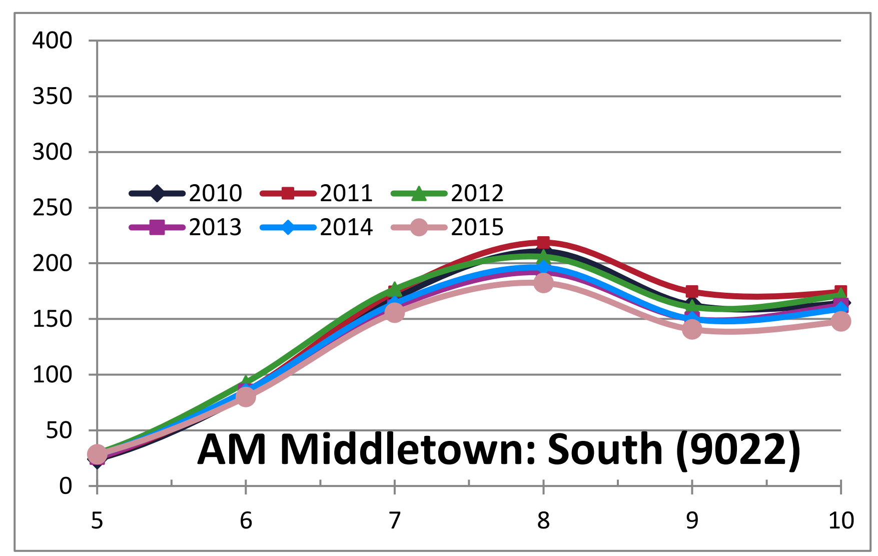
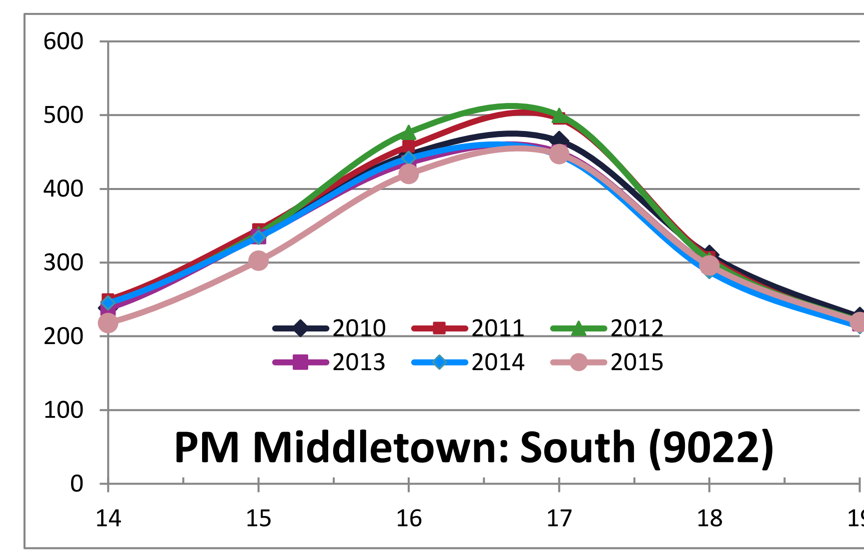
		
		

Figure 8: Traffic Count 9016: Tolland

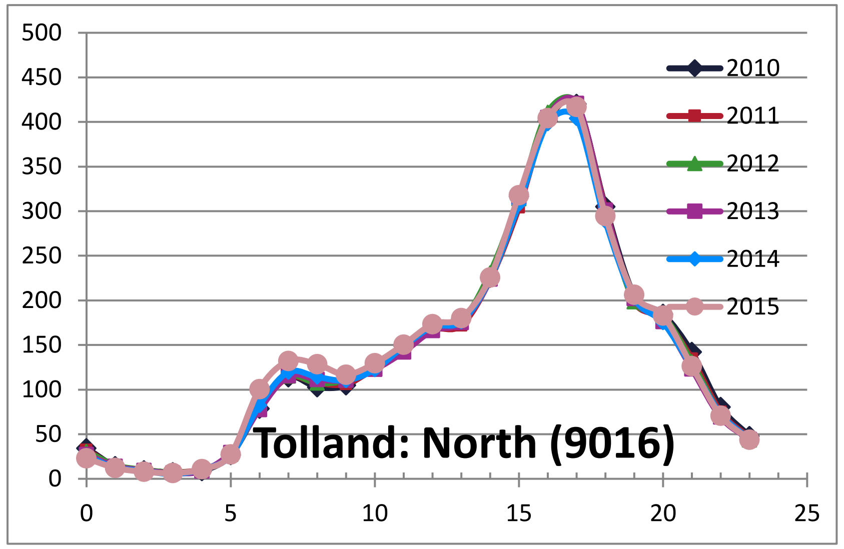
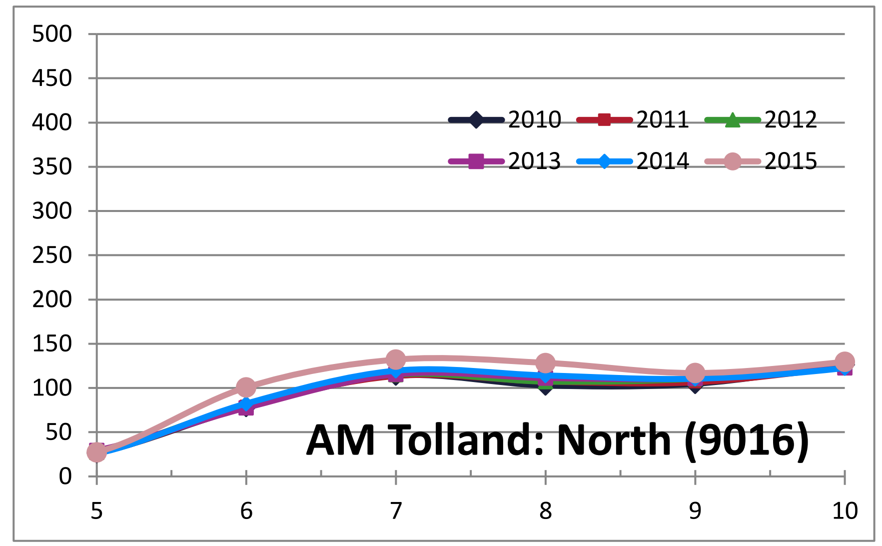
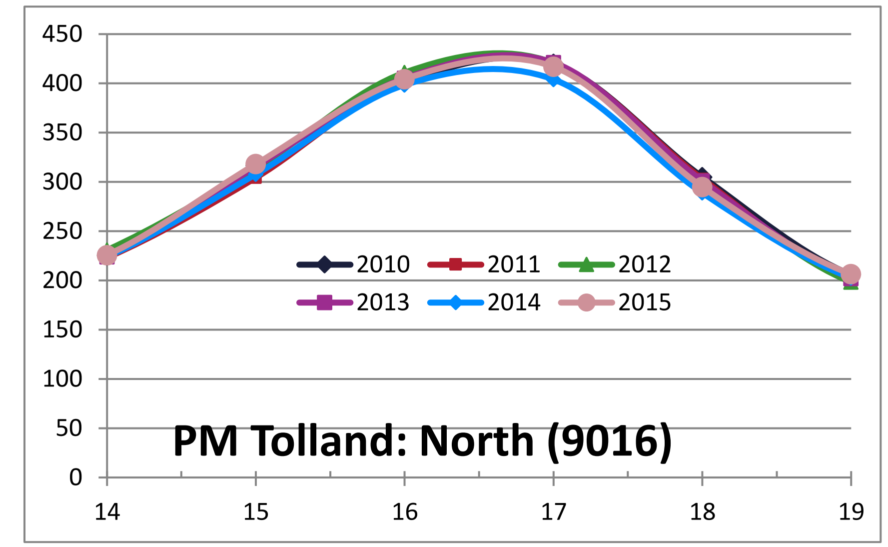
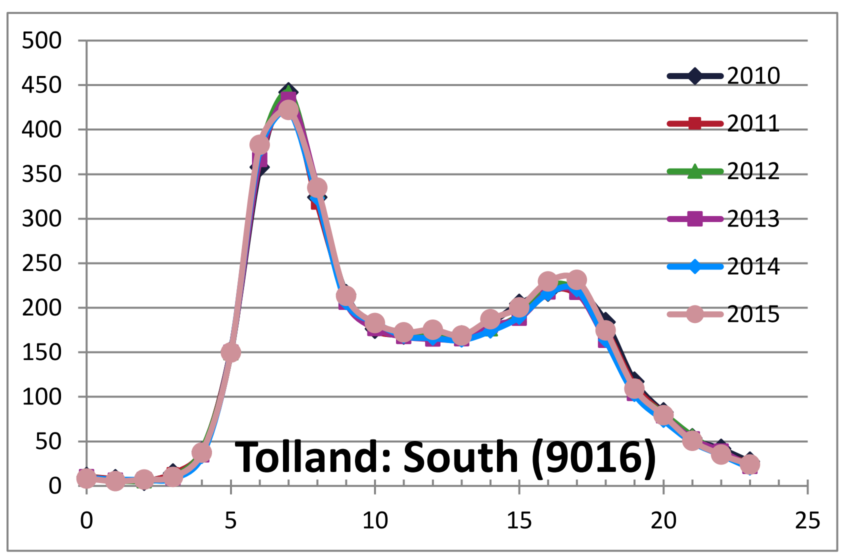
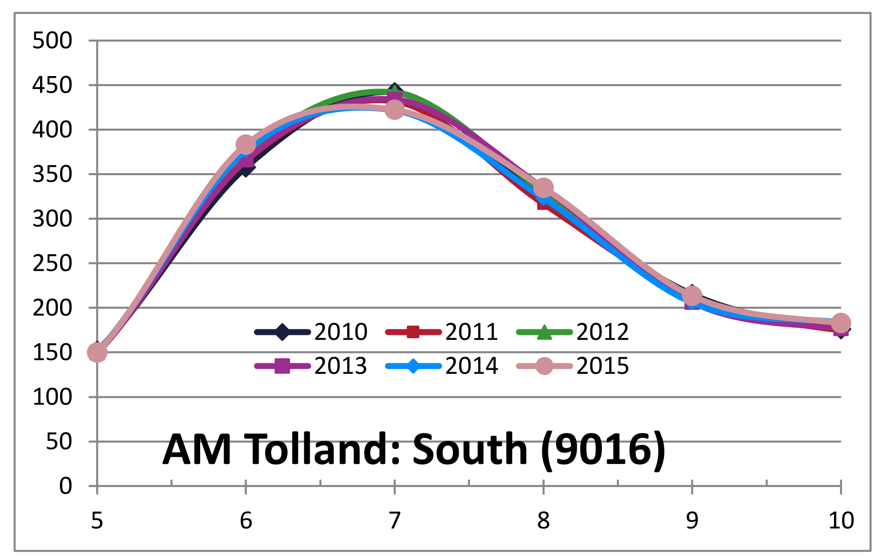
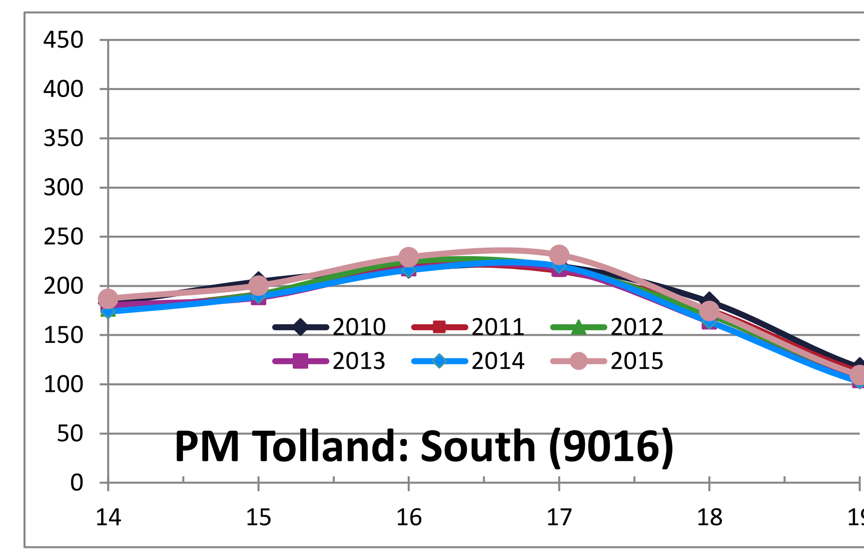
AADT	AM Peak (6AM-9AM)	PM Peak (3PM-6PM)
		
		

Figure 9: Traffic Count 9053: Enfield

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(3PM-6PM)</th></tr>
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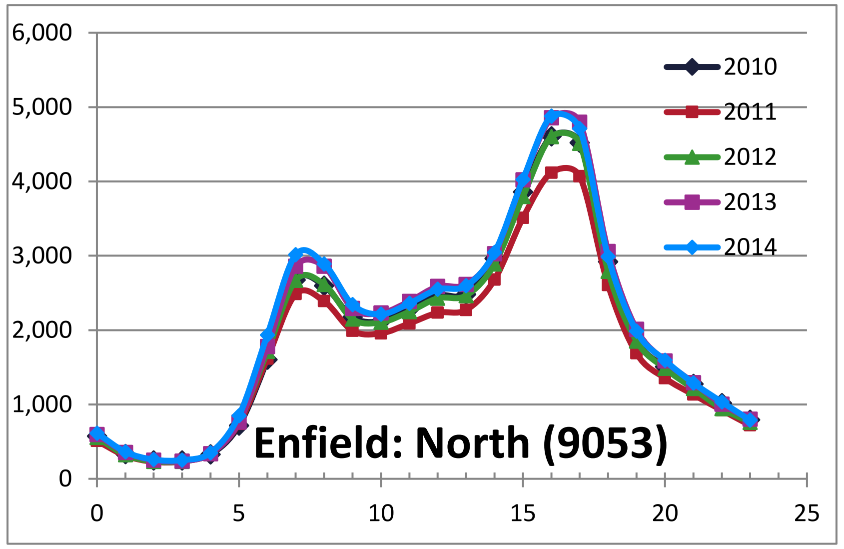
<td>
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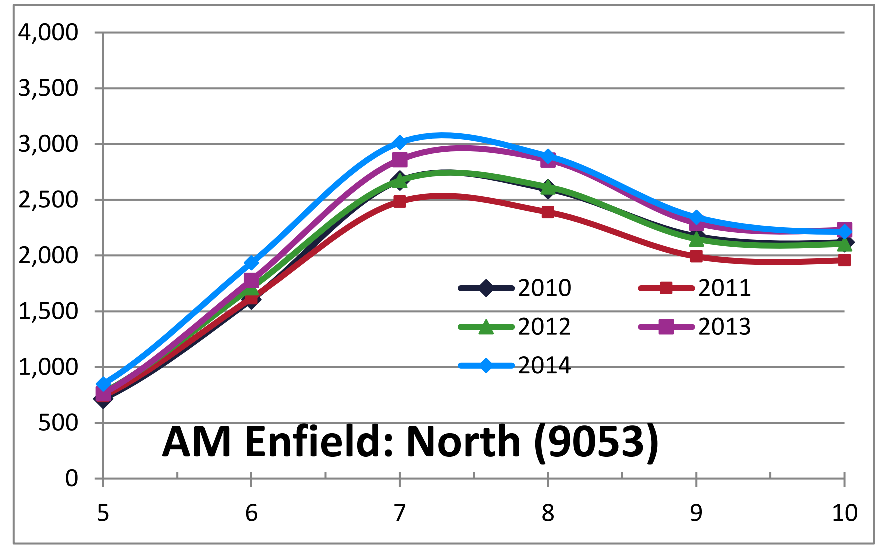
<td>
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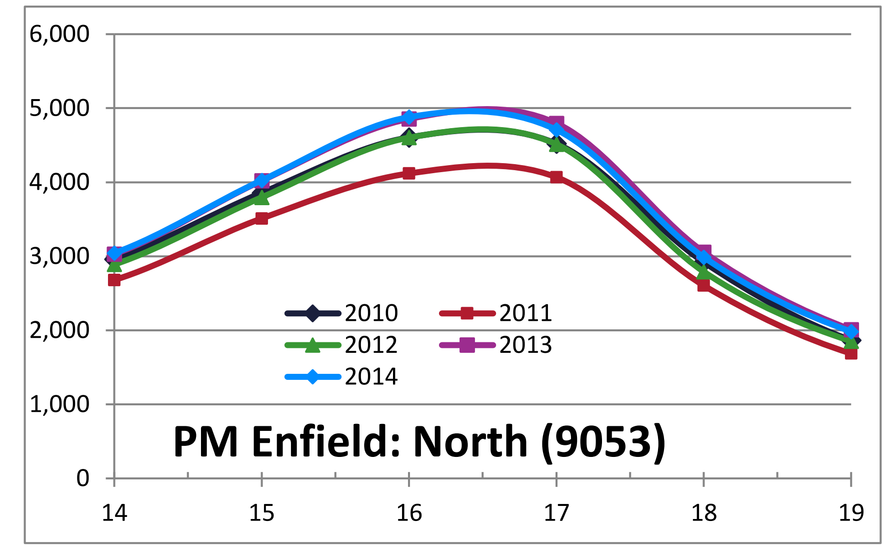
<td>
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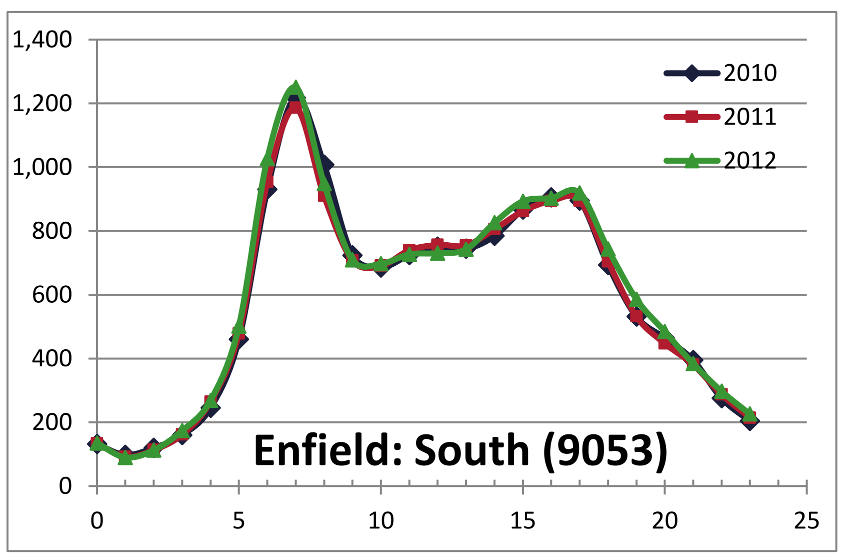
<td>
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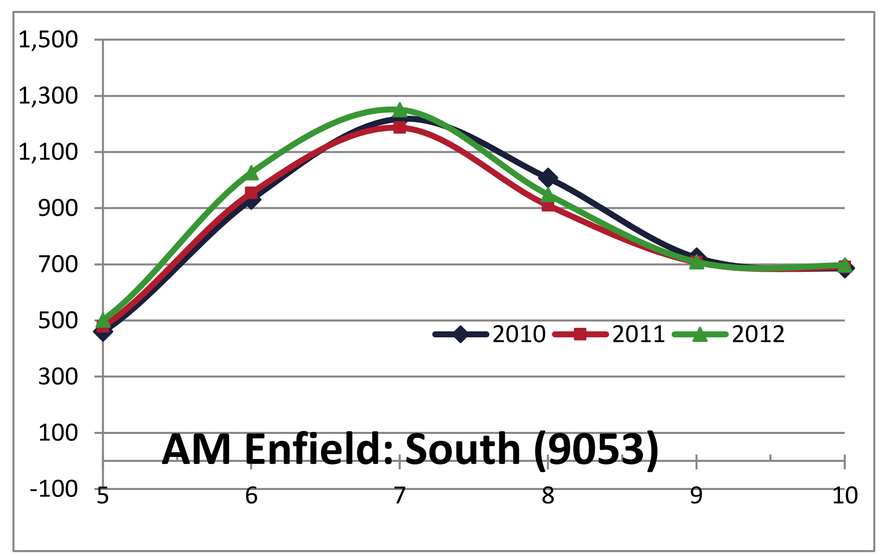
<td>
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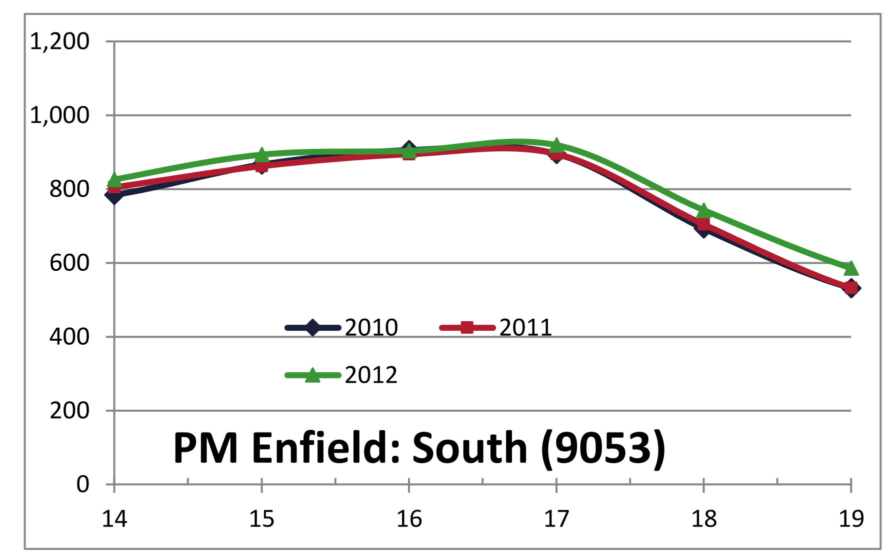
<td>
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Figure 10: Traffic Count 9026: Manchester

AADT	AM Peak (6AM-9AM)	PM Peak (3PM-6PM)

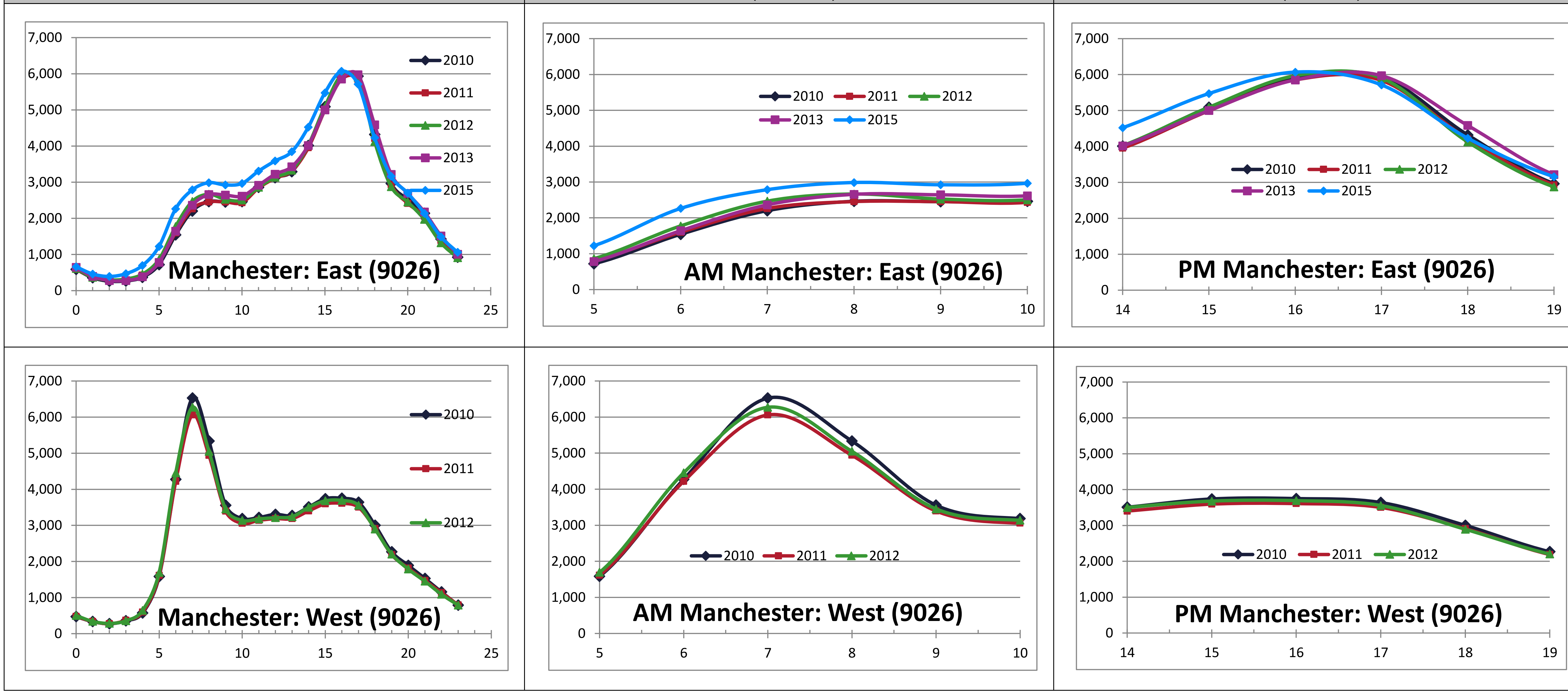


Figure 11: Traffic Count 9014: Wethersfield

AADT	AM Peak (6AM-9AM)	PM Peak (3PM-6PM)

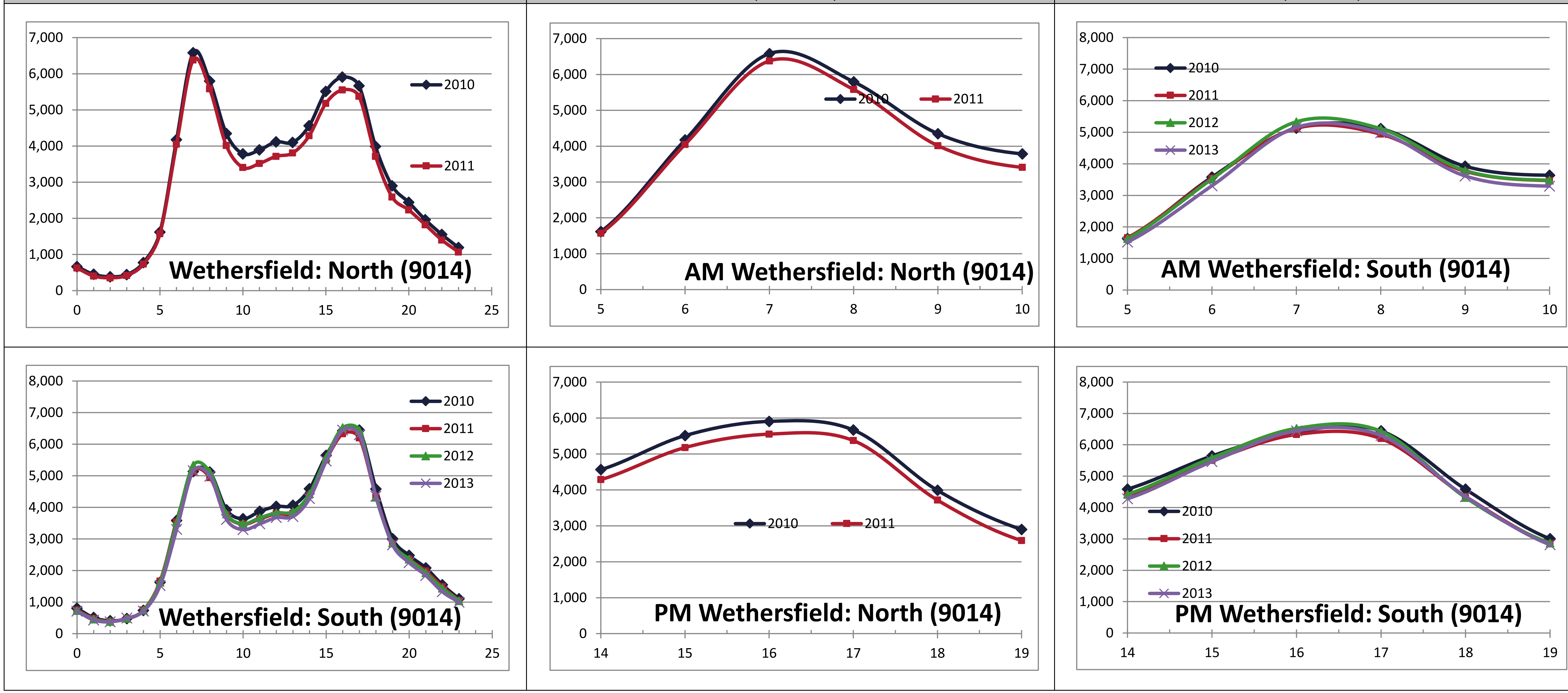
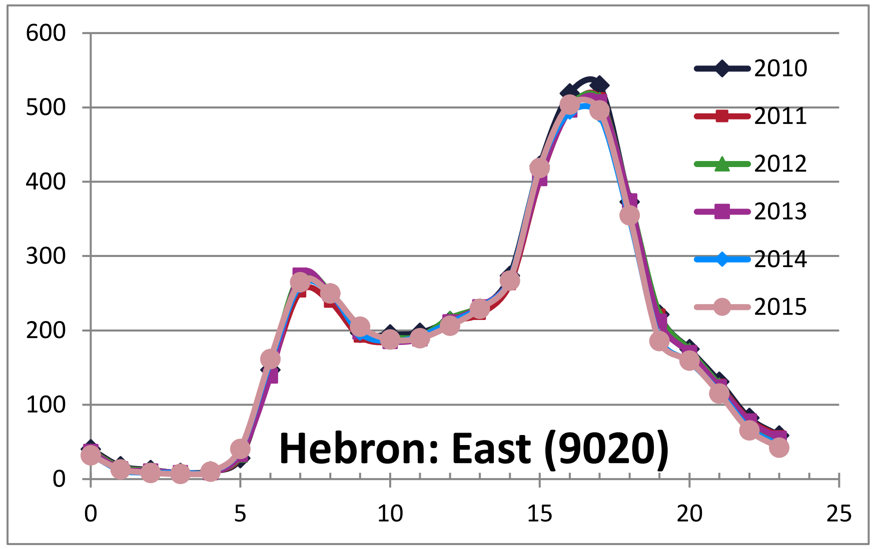
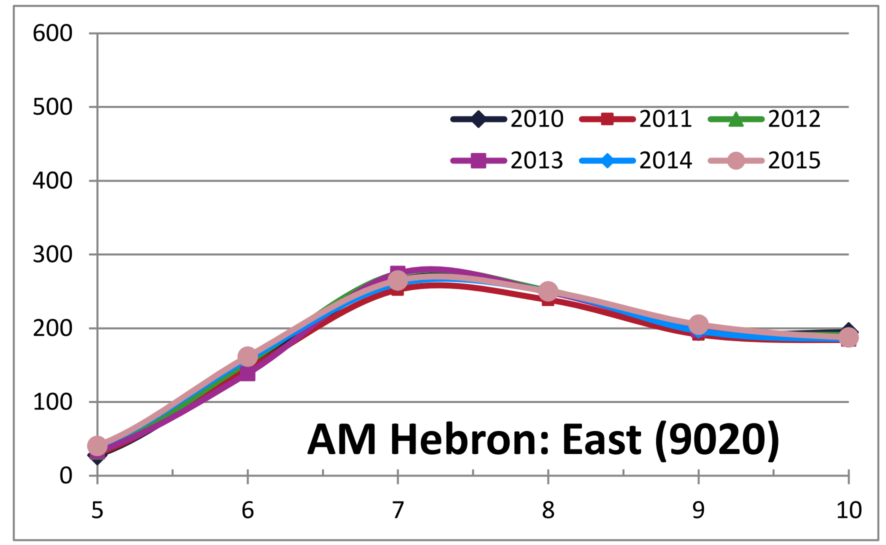
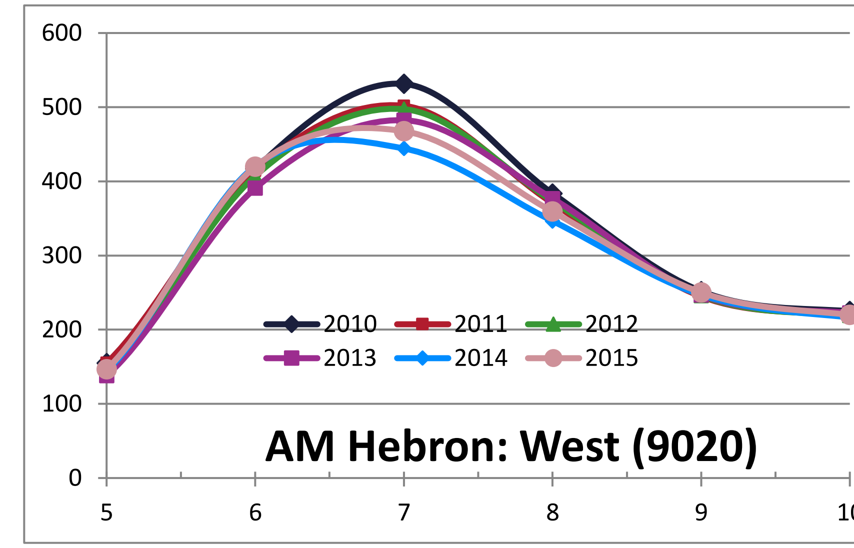
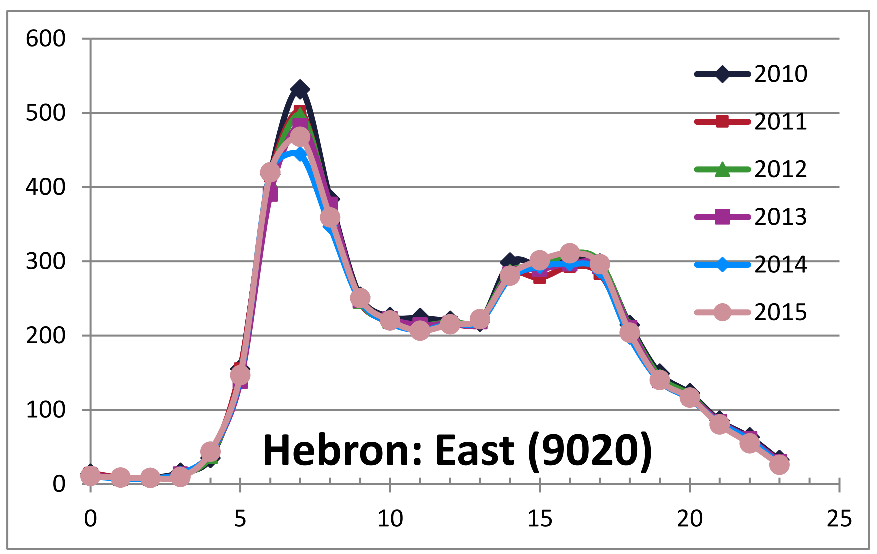
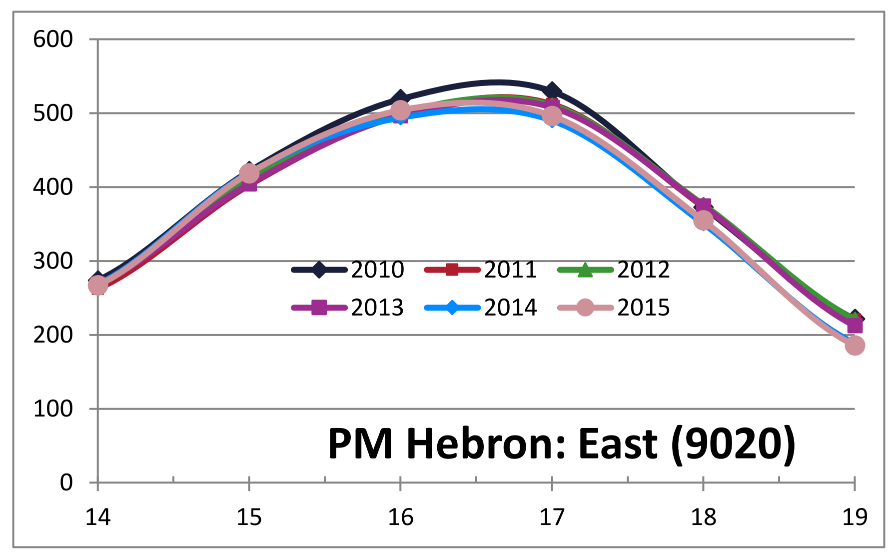
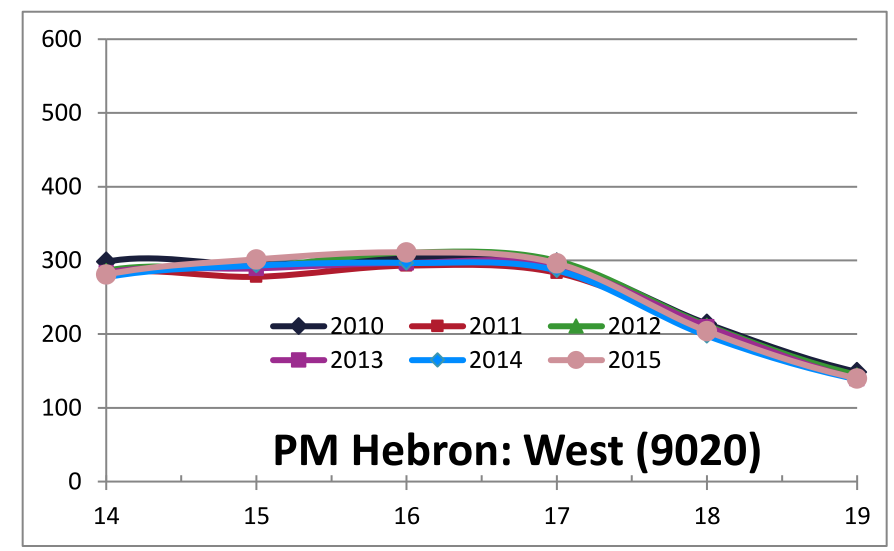


Figure 12: Traffic Count 9020: Hebron

AADT	AM Peak (6AM-9AM)	PM Peak (3PM-6PM)
		
		

APPENDIX B

Relevant Traffic Definitions

For vehicular traffic information, such as observed traffic counts for model validation and justification of four time slices, few definitions with graphics are outlined below:

AADT (Annual Average Daily Traffic) – the total volume of traffic passing a point or segment of a roadway for one year divided by the number of days in the year. **Error! Reference source not found.** illustrates typical 24 – hour count profile with AM high volumes indicating peak direction.

(Roadway) Capacity - the maximum number of vehicles that can reasonably be expected to pass over a given roadway during a given time period without delay.

Continuous Count – a location where sensors are permanently embedded into a road and traffic data is measured all 365 days a year. It provides historical trends as well as seasonal, day-of-week, weekday vs weekend variations.

Peak Period - AM or PM time frame when traffic volumes are at their highest – also referred to as "rush hour" but can be more than 60 minutes in length. **Error! Reference source not found.** illustrates AM, PM and Mid-day peaks.

Traffic Oversaturation - situations where the traffic demand exceeds the capacity of the system for an extended period of time. Vehicles will experience congestion and possible delays. **Error! Reference source not found.** illustrates the condition.

Traffic Saturation – Refers to traffic operating conditions in which the traffic demand is equal to or exceeds the capacity of a facility for short period of time.

Peak Spreading - The expansion of peak period of traffic, from original peak period to include additional shoulder-hours, as the demand to use the facility surpasses capacity. Vehicular peak traffic ranges across more hours, but the saturation remains at or just exceeds capacity. (**Error! Reference source not found.**)

Figure 13: Average Annual Daily Traffic Profile

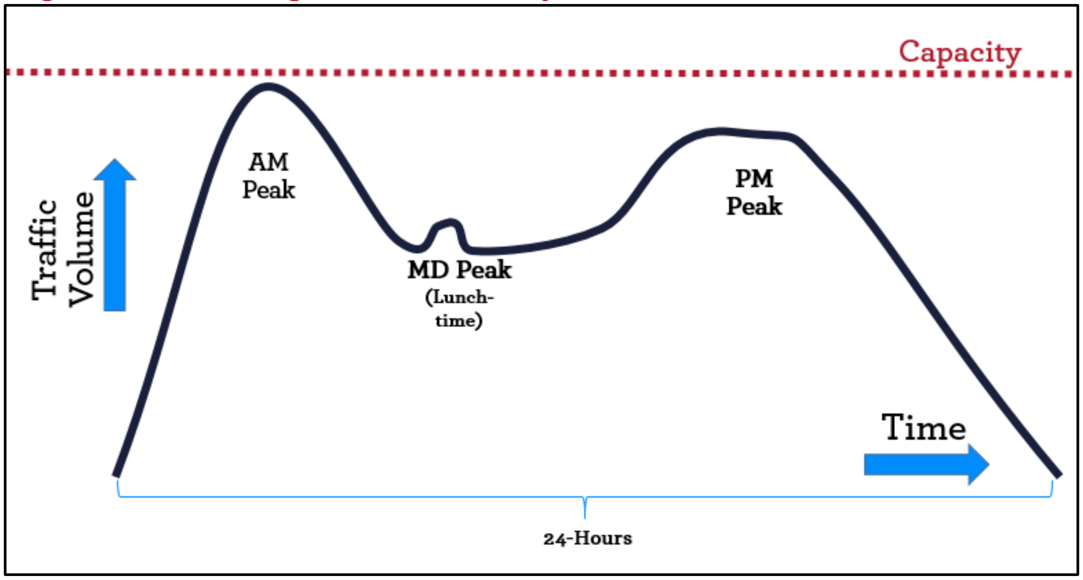


Figure 14: Illustration of Traffic Saturated / Oversaturated Conditions

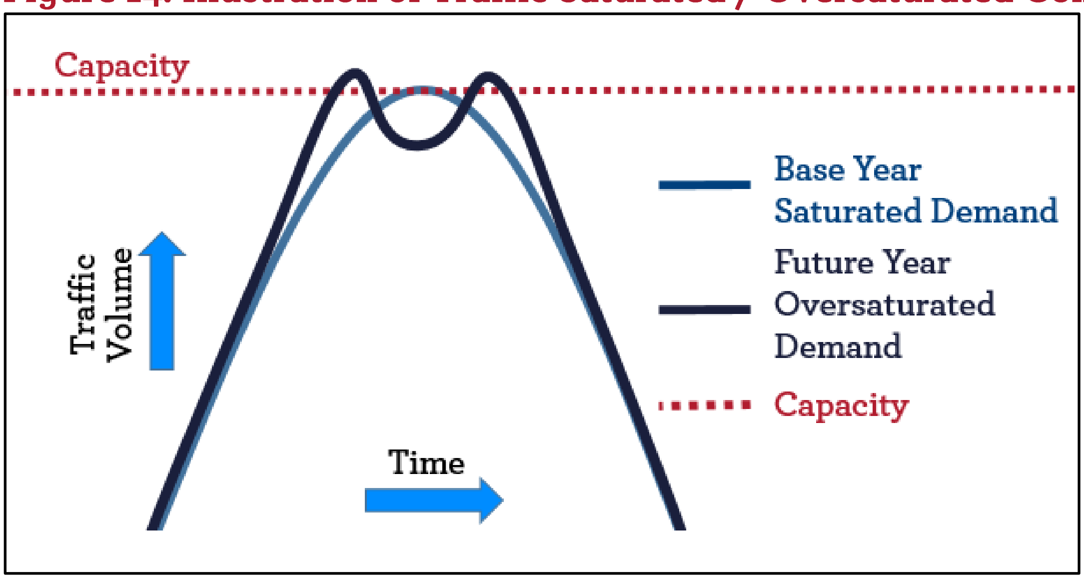
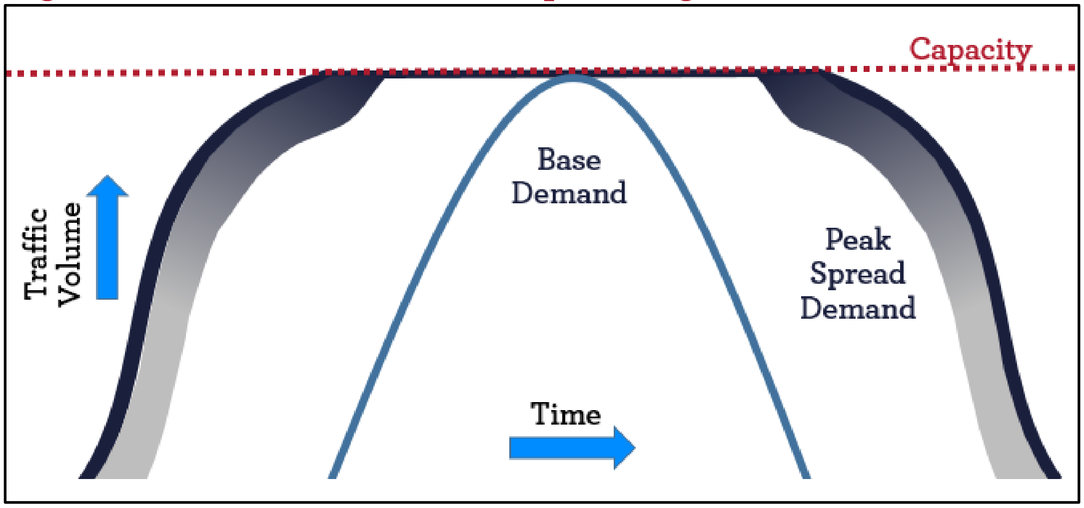


Figure 15: Illustration of Peak Spreading



Technical Memo #9

Special Event Model

July 20, 2018

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENT

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP

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1. INTRODUCTION

Travel by residents and visitors to events such as baseball games, festivals, convention centers and other similar venues falls under the umbrella of special event travel. Historically the focus of regional travel demand models has been on daily weekday travel for trip purposes such as Home Based Work (HBW), Home Based Other (HBO) and Non-Home Based (NHB). As a result, these models do not directly address travel to and from special events.

This Technical Memorandum documents the development of a Special Events Model (SEM) which was incorporated into the CRCOG regional model structure. The impetus for this effort comes from the successful introduction of CTfastrak in the Hartford region where special event patrons constitute a significant portion of transit ridership.

The special event sub-model was added to the CRCOG model to generate trips to and from a special event location, i.e. zone. The special event model step occurs just prior to the assignment step in the model. The special event trips are added to the existing trip tables for residents and non-residents by time of day and mode. The details of the model implementation are discussed in the following sections.

2. SPECIAL EVENT VENUES

Special events in the Hartford region range from weekend festivals that attract local residents to large sporting events, which bring thousands of visitors into the region. Given the large number of special events that occur each year, it is not practical to collect data and create models for each individual event. Therefore, the special events in the region were reviewed in light of the following characteristics:

- Predicted Attendance
- Event Frequency
- Regular versus Periodic Event
- Venue Type
- Event Start and End Time
- Single versus Multiple Days
- Day of Week
- Event Market Area
- Local versus Regional Attendance.

As a result of the initial review, and the large number of events that occur in a single year, it was decided to focus on special event venues that attract at least 6,000 patrons. In addition, the following criteria were considered in bringing the list down to six venues where data collection was necessary (and conducted):

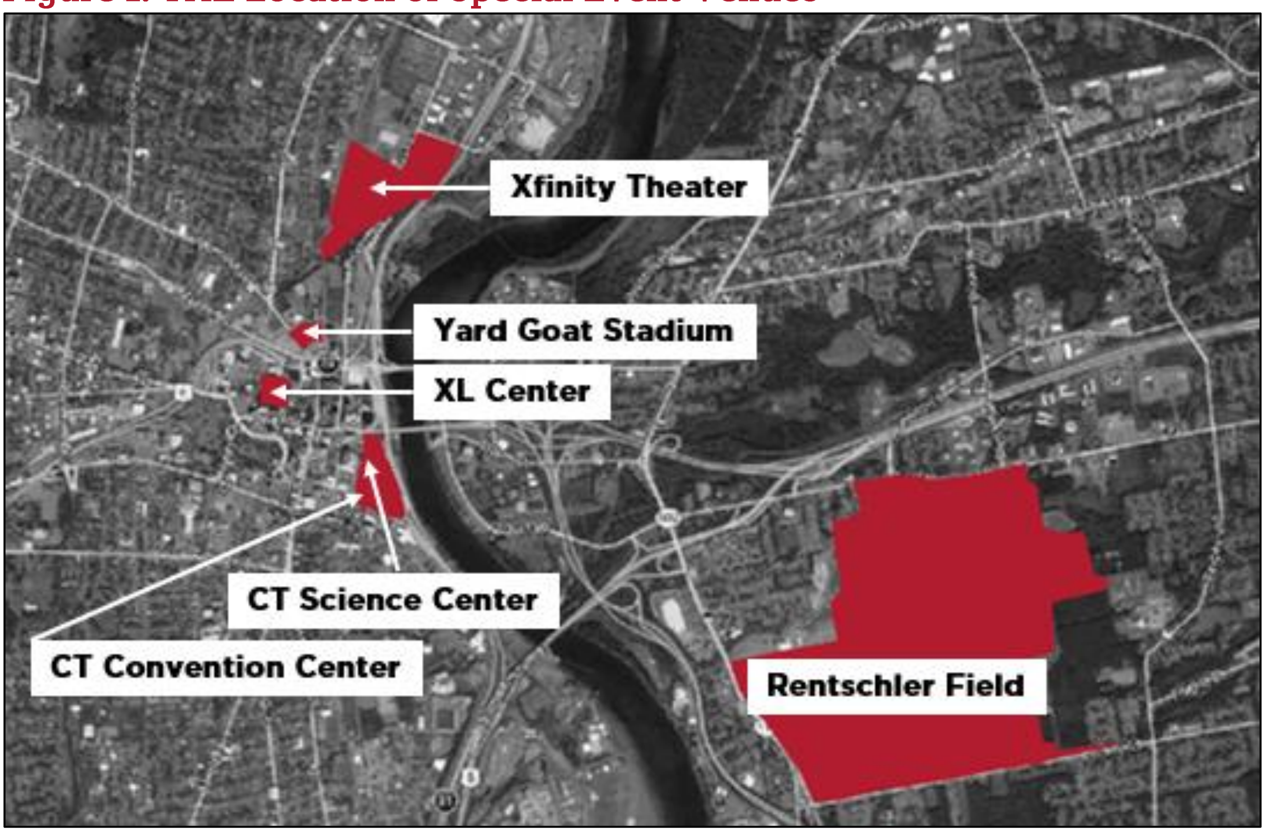
- Importance of capturing impacts of special events on the transit system;
- High attendance events at several large stadiums and sports complexes;
- Good representation within each of the nine classifications;
- Importance of seasonality of special events.

The Table 1 illustrates the venues, capacity or size, and assumed event attendance for the six venues considered by the CRCOG SEM. Figure 1 shows the TAZ in which each of the venues is located.

Table 1: Venue, TAZ, Capacity and Assumed Attendance

Venue	TAZ	Venue Capacity or Venue Size	Assumed Venue Attendance
XL Center	2014	16,600 people	16,600
Yard Goat Stadium	27501	6,050 people	6,050
Xfinity Theatre	8602	30,000 people	30,000
Rentschler Field	178	40,600 people	40,600
CT Science Center	2107	154,000 Sq. Ft.	2,000
CT Convention Center	2106	540,000 Sq. Ft.	12,800

Figure 1: TAZ Location of Special Event Venues



3. METHODOLOGY

The special event sub-model uses the daily attendance (SE_ATTEND) field from the model's socio-economic data file. SE_ATTEND is the estimated or expected number of people participating in a specific special event within a specific traffic analysis zone (TAZ). To create a set of trips that can be assigned to the network, the following attributes need to be computed:

- Location:
    - Origin location for participants coming to the special event.
    - Destination location from special event after the event is over.
- Mode:
    - Modes for trips to the special event
    - Modes for trips from the special event
- Time-of-day periods:
    - For trips to the special event
    - For trips from the special event

The total number of trips generated by each special event is twice the number of SE_ATTEND as every participant makes two trips: 1) a trip to the special event, and 2) a trip from the special event. In this model, the trips to the special event are outbound trips and trips from the special event are inbound trips. Due to unavailability of a special event survey, reasonable coefficients were asserted for the choice models which may require updates during final model validation.

Location

The origin location for outbound trips is determined using a reverse destination choice model and inbound trips are determined using a standard destination choice model. Typical to any location choice model, the origin choice for outbound trips and destination choice for inbound trips is determined based on the size term and the impedance term.

The size term captures the supply side of travel behavior. The size term for the special event origin and destination choice model is a combination of the number of households by income level, the amount of retail employment, and the amount of non-retail employment. The size term for the origin location for outbound trips was different than the destination location size term for inbound. This was based on the rationale that the share of participants coming from their workplace to the special event would be different than the share of participants going back to their workplace after the special event. In particular, it is assumed that there is a greater share of one end of the trip to be home for trips from special events thus demanding a larger coefficient on number of households by income level for inbound trips. The coefficients on different components of the size term are listed in Table 2.

The impedance term captures the impact of level-of-service on location choice. Special event trips typically have a fixed schedule/location and thus are not particularly sensitive to travel conditions/distances. Due to such unique properties of these trips, only highway distance with a relatively small coefficient was used as an impedance term in the location choice model. The coefficient (c_dist) was set to be -0.1.

Table 2: Size Term Components for Location Choice Model

Size Term Component (socio-economic variable)	Outbound (trips to special events)	Inbound (trips from special events)
nHHInc1	0.2	0.3
nHHInc2	0.2	0.3
nHHInc3	0.3	0.5
nHHInc4	0.3	0.5
RET_EMP	0.5	0.1
NR_EMP	0.5	0.1

("...\CRCOG\Base\inputs\td\destchoice_parameters.bin")

The output of this step is two daily person trip tables:

- Outbound trip table ("...\CRCOG\Base\outputs\specialevent\Trip_SE_out.mtx") and
- Inbound trip tables ("...\CRCOG\Base\outputs\specialevent\Trip_SE_in.mtx").

Time-of-day

The next step is to split the daily trip table into four time-of-day periods: 1) AM, 2) MD, 3) PM, and 4) NT. Logical time-of-day factors for outbound and inbound were used to split the trip tables by time-of-day periods. Similar to the location choice model logic, these factors were set to be different by direction due to inherent chronology associated with these trips. Since inbound trips are always after outbound trips, the time-of-day factors for late periods for inbound trips is set to be higher than that of outbound trips. The time-of-day factors are listed in Table 3.

Table 3: Time-of-Day Factors by Direction

Time of Day	Outbound (trips to special events)	Inbound (trips from special events)
AM Period: 6:00AM- 9:00AM	0.1	0.05
MD Period: 9:00AM- 3:00PM	0.1	0.05
PM Period: 3:00PM- 6:00PM	0.5	0.4
NT Period: 6:00PM- 6:00AM	0.3	0.5

("...\CRCOG\Base\inputs\SpecialEvent\SE_param.bin")

Mode

After splitting the person trip tables by time-of-day, the next step is to split by trip modes. For simplicity and due to lack of special event mode share data, the person trip tables are assumed to be auto trips; however, this model can be enhanced in a future effort if a significant share of participants is expected to travel by transit.

The mode share factors were asserted such that the auto occupancy is higher for trips from special events which is consistent with the assumption in location choice model that the share of trips to home would be higher for inbound trips, and thus more likely to be carpooled with a household member. These mode share factors are listed in Table 4.

Table 4: Mode Share Factors by Direction

Mode	Outbound (trips to special events)	Inbound (trips from special events)
SOV	0.3	0.2
HOV2	0.45	0.5
HOV3	0.25	0.3
NT Period: 6:00PM- 6:00AM	0.3	0.5

("...\CRCOG\Base\inputs\SpecialEvent\SE_param.bin")

The final output of the special event model is eight time-of-day specific person trip tables with cores specific to the person trip modes:

- Trip_AM_SE_in.mtx and Trip_AM_SE_out,
- Trip_MD_SE_in.mtx and Trip_MD_SE_out,
- Trip_PM_SE_in.mtx and Trip_PM_SE_out,
- Trip_NT_SE_in.mtx and Trip_NT_SE_out.

These trip tables are then added to trip tables generated by the core demand model before assigning to the highway network.

4. VALIDATION AND CALIBRATION

As mentioned earlier, the coefficients in the CRCOG special event sub-model were asserted based on logical assumptions. Due to unavailability of a special event survey, this model cannot be directly validated. However, some of the components in this model can be indirectly calibrated if there are highway counts available near special event locations. There are two main steps in adjusting the time-of-day and mode share factors:

- If the daily auto volumes near a special event location do not match counts, then the asserted mode shares should be adjusted. If model volume is greater than counts then increase the share of HOV2 and HOV3+ (and decrease SOV – making sure sum of shares equals 1.0). Conversely, if the model volume is less than the counts then increase the SOV share (and decrease the HOV2 and HOV3 shares respectively).

- If the daily auto volume near a special event location is similar to the counts but time-of-day distribution is off, then the time-of-day factors should be revised.

I-84 Hartford Stated Preference
Appendix A

Survey Screen Captures

September 8, 2017

PREPARED BY:

RSG
TranSystems Corporation

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1. INTRODUCTION AND QUALIFICATION QUESTIONS

Figure 1-1: Survey Introduction and Instructions

I-84 HARTFORD PROJECT

Thank you for participating in the Hartford I-84 Travel Study!

The answers you provide in this survey will help the Connecticut Department of Transportation plan the best possible strategies to manage upcoming construction on I-84 in Hartford.

Your survey answers will not be linked to any personal information and will be analyzed together with many other survey responses.

Use the "Next" and "Previous" buttons below to navigate the survey. Do **NOT** use your browser's "forward" and "back" buttons because your answers will **NOT** be recorded.

Answering all of the questions will take about 10-15 minutes.

Please click "Next" to begin.

Next »

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Questions or comments? Contact us at ct184@rsginc.com

5%

Figure 1-2: Trip Qualification Question #1

I-84 HARTFORD PROJECT

Were you the driver for a recent trip that...

- **Traveled on I-84 in Hartford** between I-91 and Flatbush Avenue/Exit 45 (shown at right) in the past month (30 days)
- Was made on a weekday (Monday – Friday)
- Was made in a personal vehicle (e.g. car, pickup truck, minivan, etc.)

○ Yes, I have made a recent trip that meets all of these conditions

○ No, I have not made a recent trip that meets all of these conditions

click to enlarge

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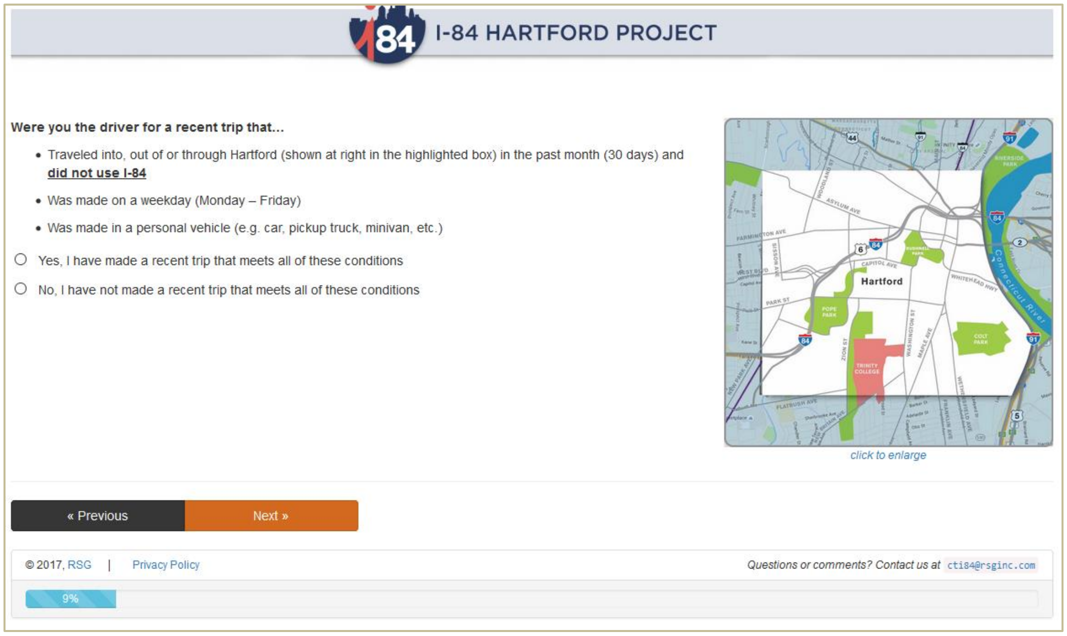
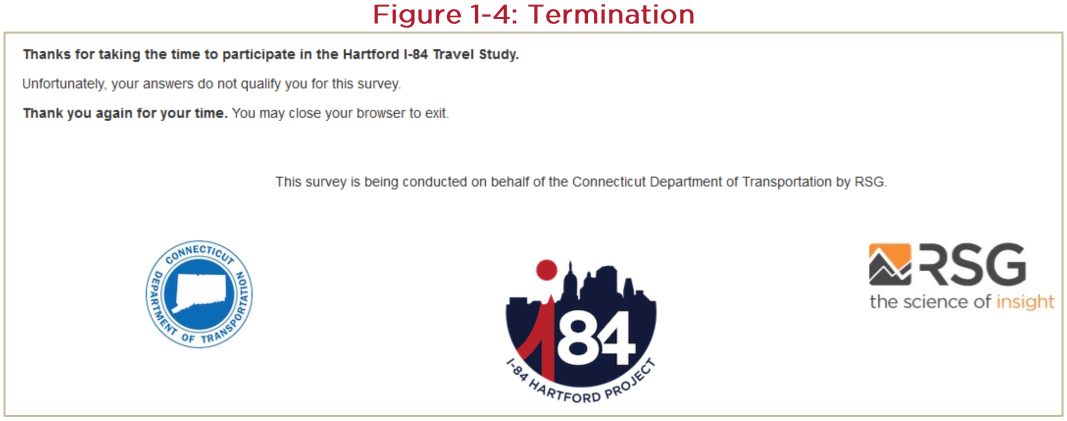
7%

Figure 1-3: Trip Qualification Question #2



If respondent did not make a recent trip on I-84 in Hartford

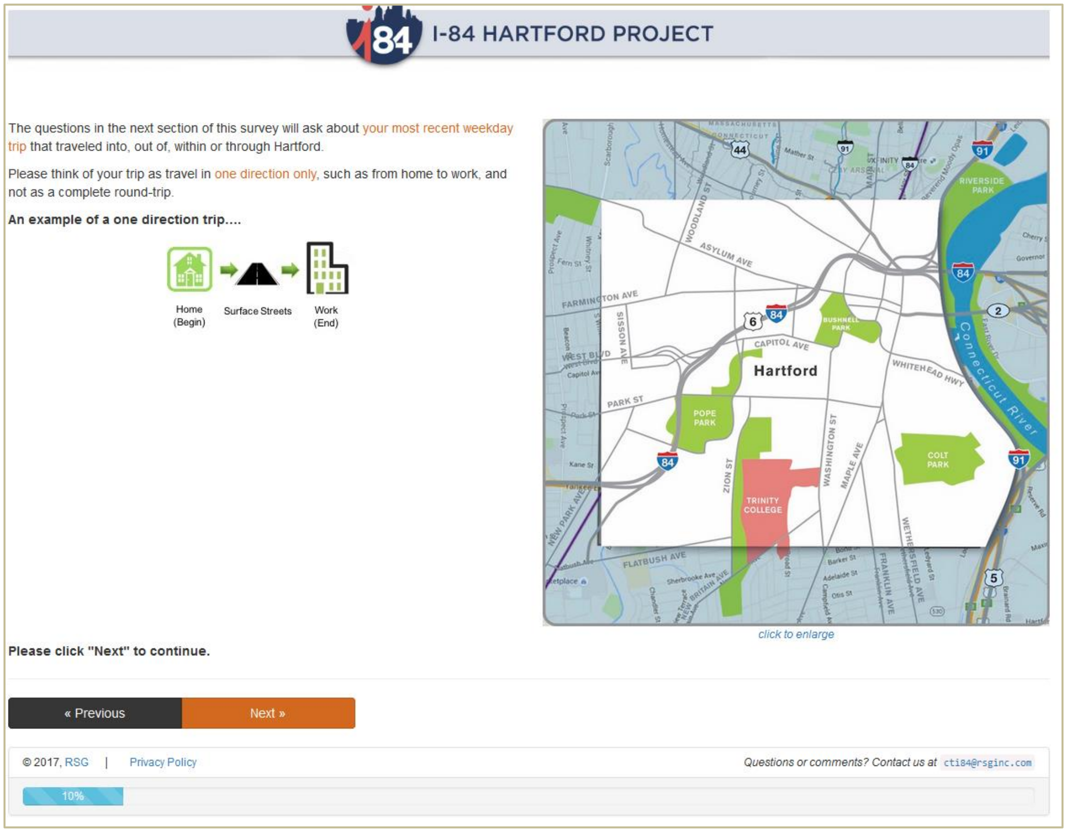
Figure 1-4: Termination



If respondent did not make a qualifying trip

2. TRIP CHARACTERISTICS QUESTIONS

Figure 2-1: Definition of a Qualifying One-Way Trip


I-84 HARTFORD PROJECT

The questions in the next section of this survey will ask about your most recent weekday trip that traveled into, out of, within or through Hartford.

Please think of your trip as travel in one direction only, such as from home to work, and not as a complete round-trip.

An example of a one direction trip....

Home (Begin) → Surface Streets → Work (End)

click to enlarge

Please click "Next" to continue.

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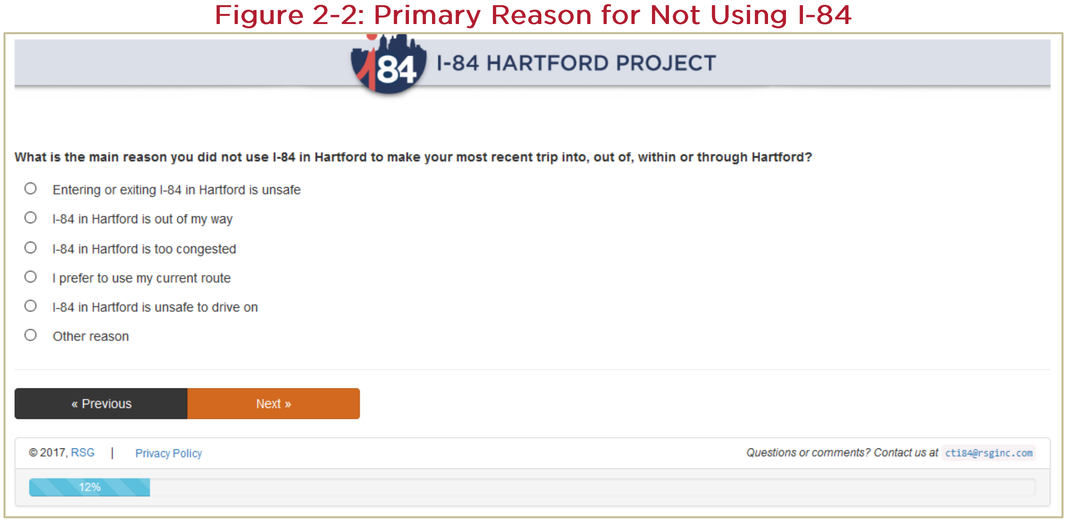
10%

Figure 2-2: Primary Reason for Not Using I-84


I-84 HARTFORD PROJECT

What is the main reason you did not use I-84 in Hartford to make your most recent trip into, out of, within or through Hartford?

- Entering or exiting I-84 in Hartford is unsafe
- I-84 in Hartford is out of my way
- I-84 in Hartford is too congested
- I prefer to use my current route
- I-84 in Hartford is unsafe to drive on
- Other reason

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12%

If respondent did not make their recent trip on I-84

Figure 2-3: Day of Week


I-84 HARTFORD PROJECT

Please think about your most recent trip that traveled into, out of, within or through Hartford.

On what weekday did you make your most recent trip?

- Monday
- Tuesday
- Wednesday
- Thursday
- Friday

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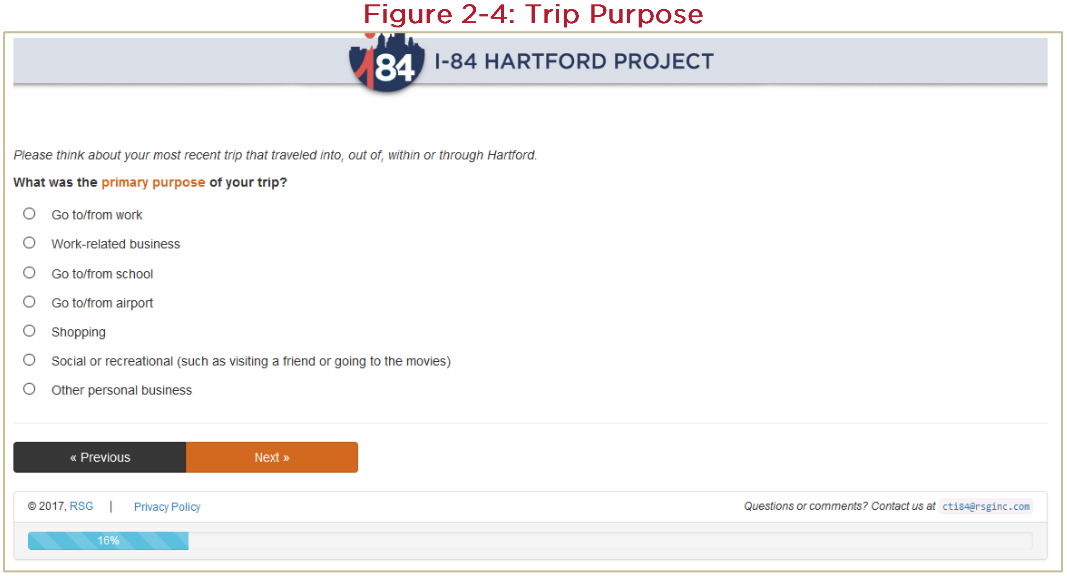
14%

Figure 2-4: Trip Purpose


I-84 HARTFORD PROJECT

Please think about your most recent trip that traveled into, out of, within or through Hartford.

What was the primary purpose of your trip?

- Go to/from work
- Work-related business
- Go to/from school
- Go to/from airport
- Shopping
- Social or recreational (such as visiting a friend or going to the movies)
- Other personal business

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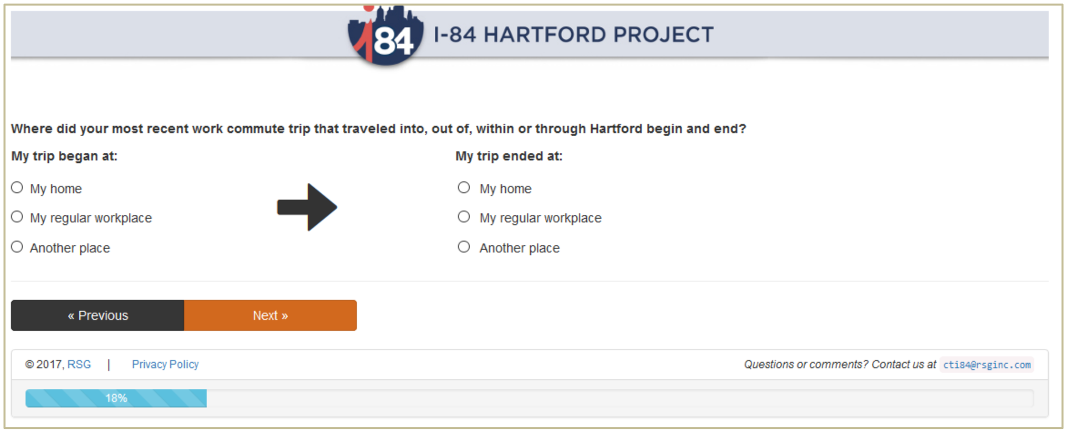
16%

Figure 2-5: Trip Beginning and Ending Locations


I-84 HARTFORD PROJECT

Where did your most recent work commute trip that traveled into, out of, within or through Hartford begin and end?

My trip began at:
- My home
- My regular workplace
- Another place

My trip ended at:
- My home
- My regular workplace
- Another place

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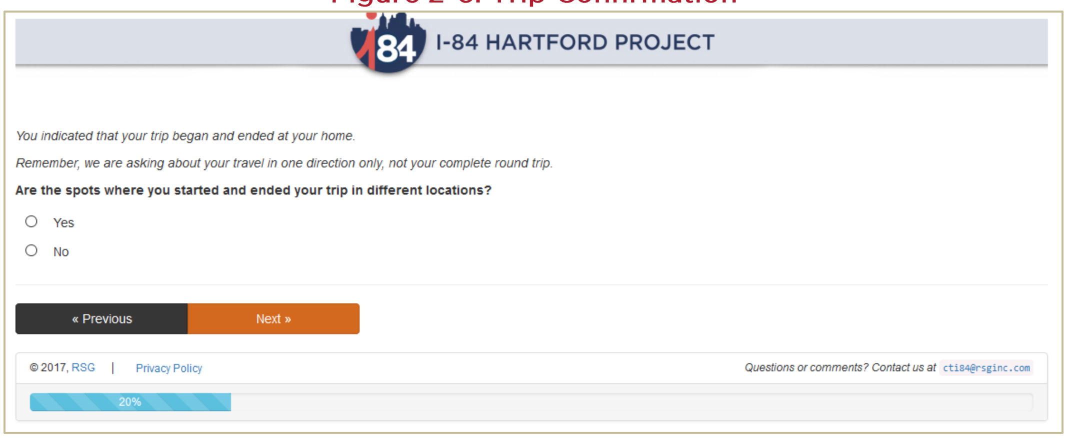
18%

Figure 2-6: Trip Confirmation


I-84 HARTFORD PROJECT

You indicated that your trip began and ended at your home.

Remember, we are asking about your travel in one direction only, not your complete round trip.

Are the spots where you started and ended your trip in different locations?
- Yes
- No

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20%

If respondent's beginning and ending locations are both home or both work

Figure 2-7: Origin Location

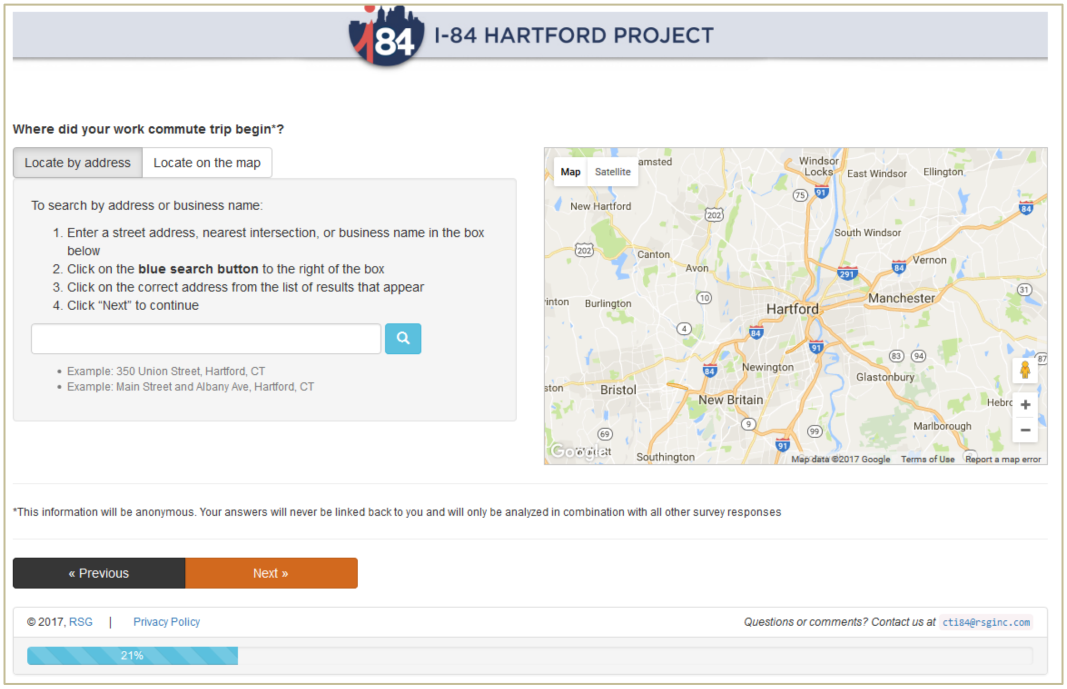


Figure 2-8: Destination Location

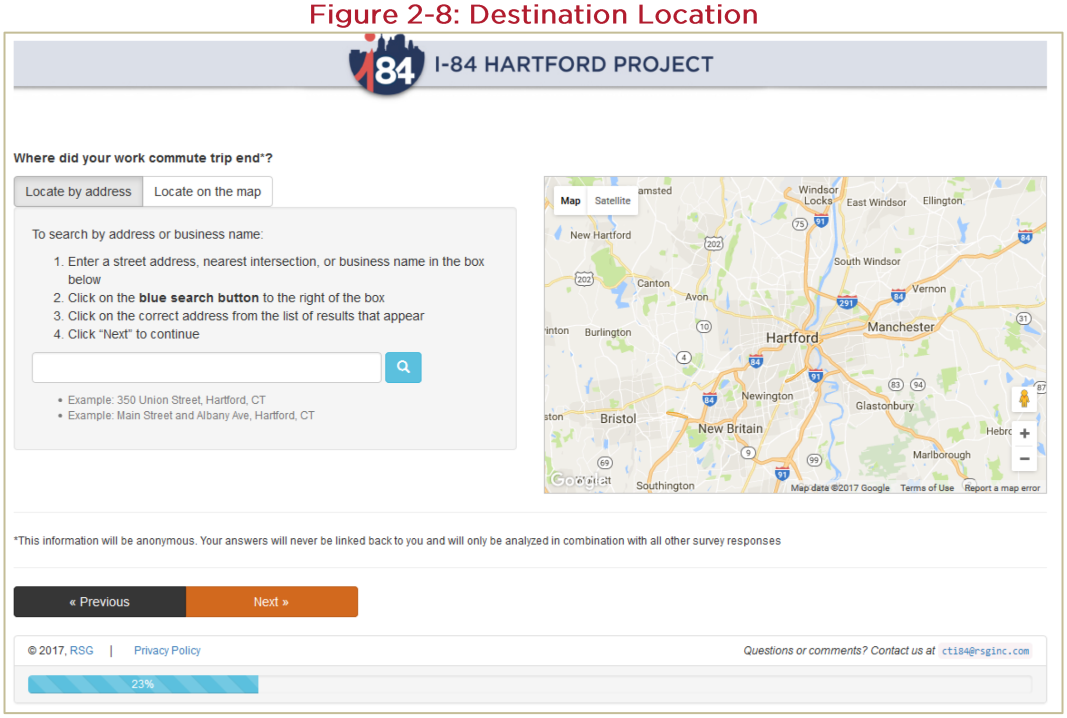
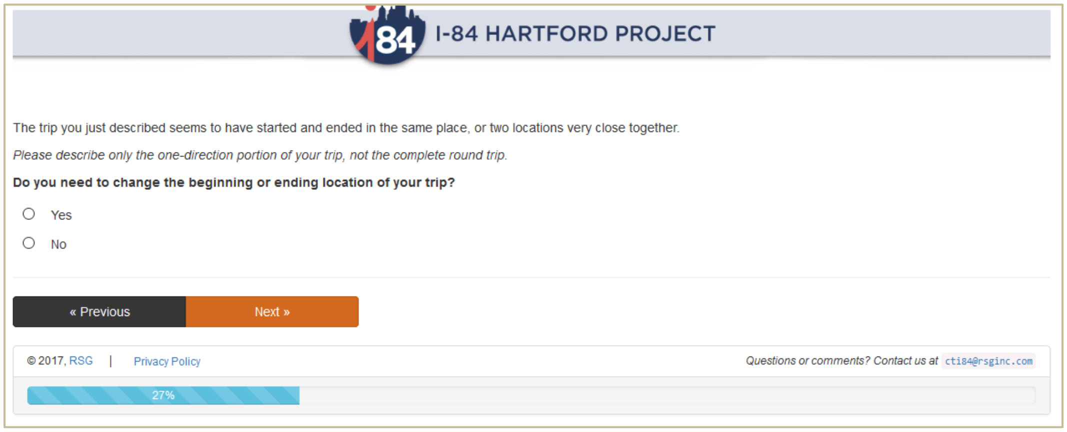


Figure 2-9: Invalid Trip



If respondent's origin and destination indicate an invalid trip

Figure 2-10: Origin and Destination Confirmation

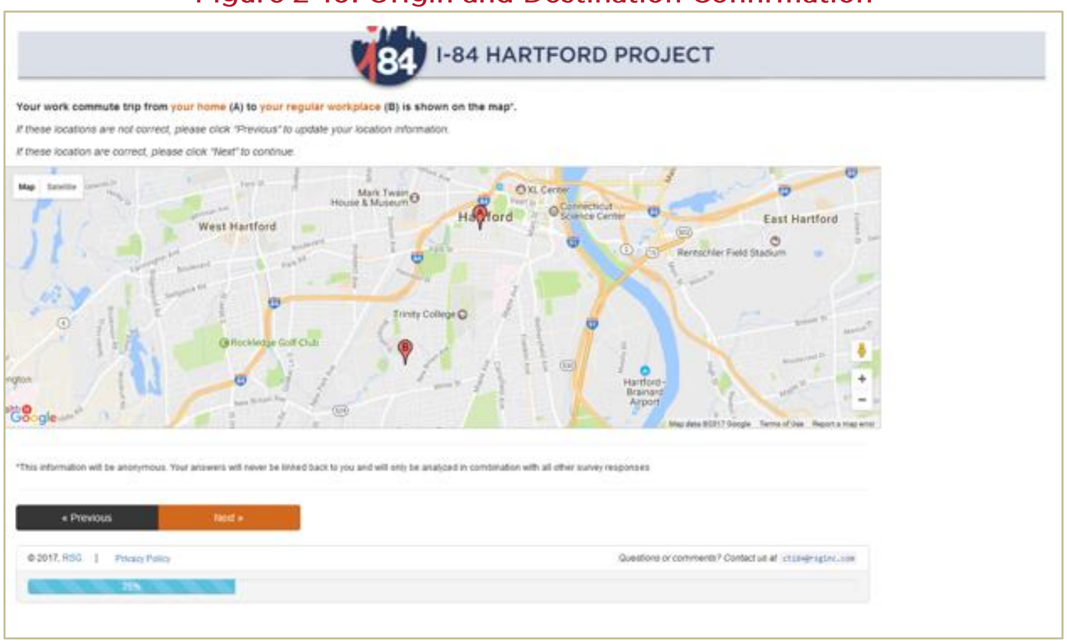


Figure 2-11: Departure Time

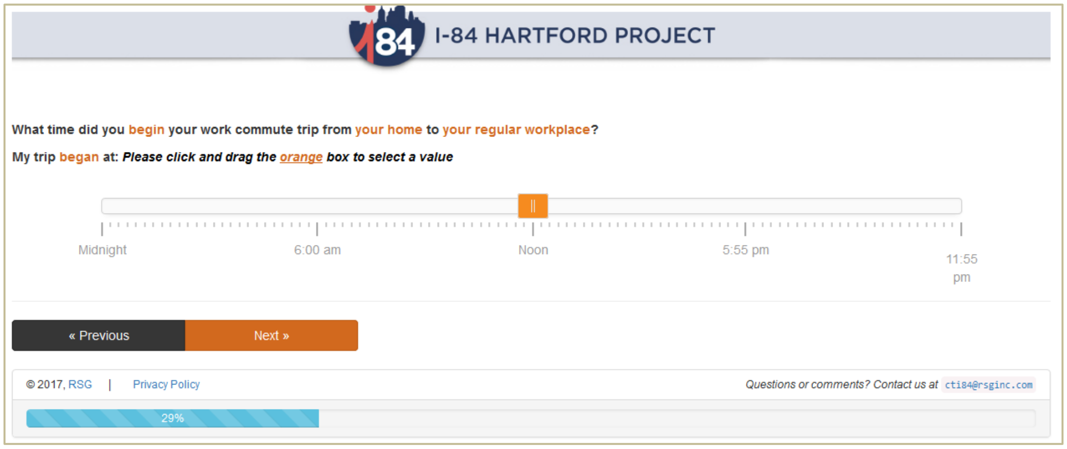


Figure 2-12: Travel Time

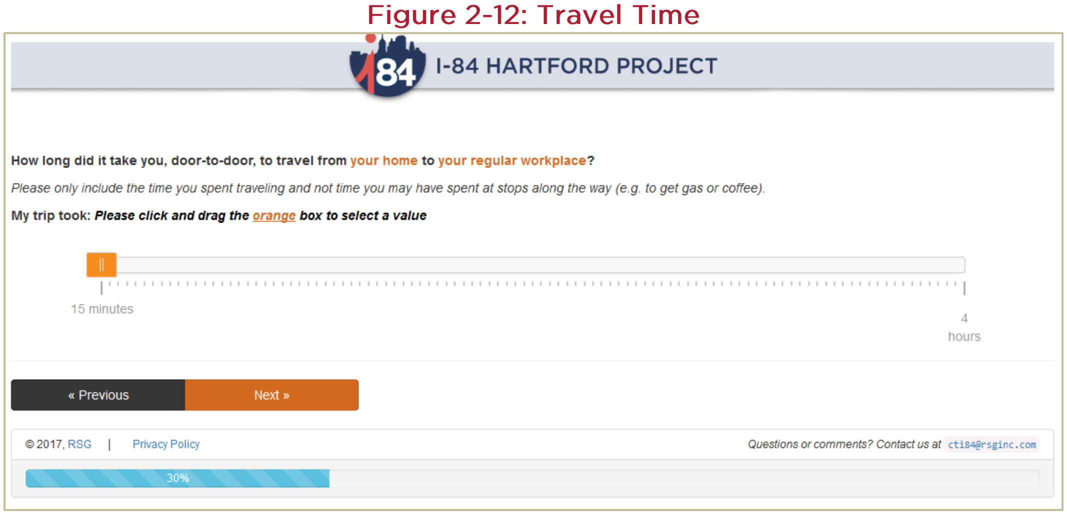
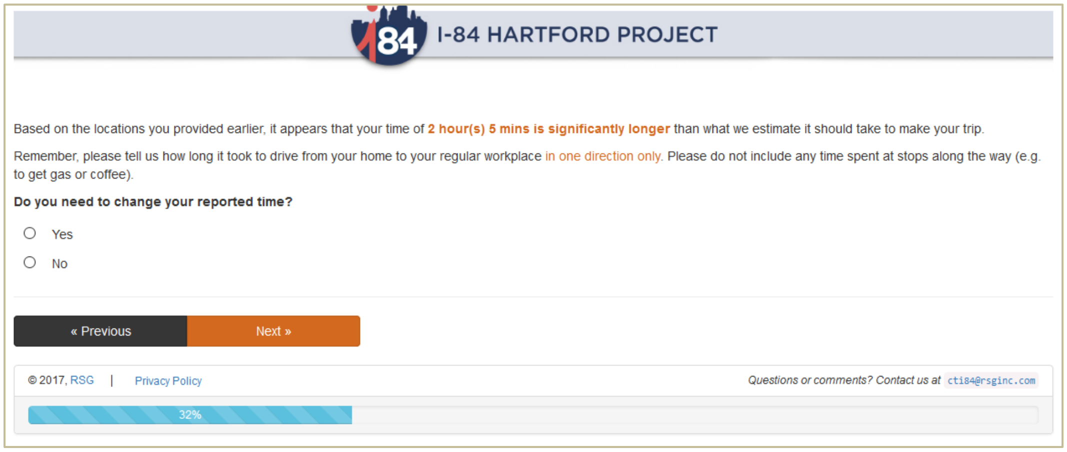


Figure 2-13: Travel Time Confirmation



I-84 HARTFORD PROJECT

Based on the locations you provided earlier, it appears that your time of **2 hour(s) 5 mins is significantly longer** than what we estimate it should take to make your trip.

Remember, please tell us how long it took to drive from your home to your regular workplace in one direction only. Please do not include any time spent at stops along the way (e.g. to get gas or coffee).

Do you need to change your reported time?

- Yes
- No

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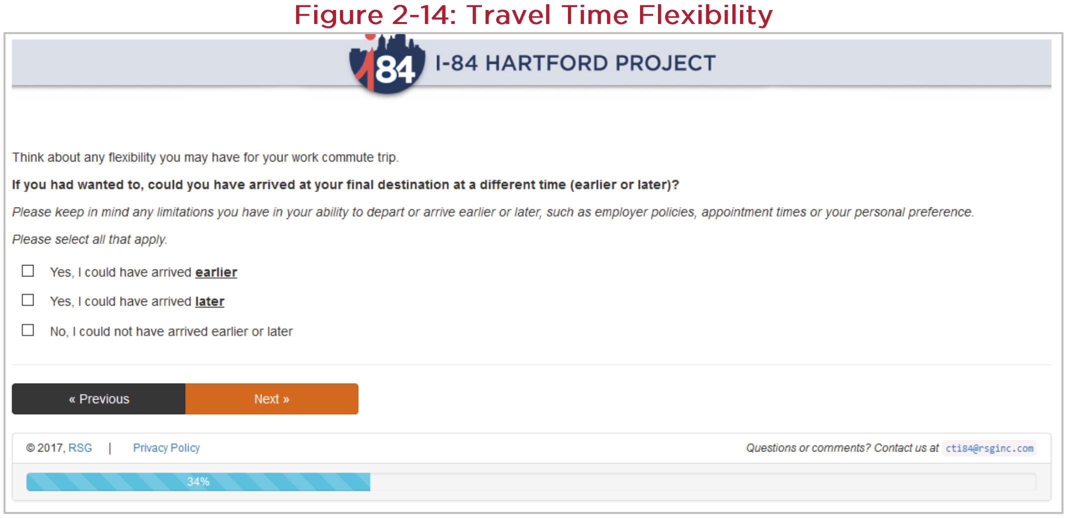
32%

If reported travel time is less than 0.75 or greater than 2.5 times Google-calculated trip time

Figure 2-14: Travel Time Flexibility



I-84 HARTFORD PROJECT

Think about any flexibility you may have for your work commute trip.

If you had wanted to, could you have arrived at your final destination at a different time (earlier or later)?

Please keep in mind any limitations you have in your ability to depart or arrive earlier or later, such as employer policies, appointment times or your personal preference.

Please select all that apply.

- Yes, I could have arrived **earlier**
- Yes, I could have arrived **later**
- No, I could not have arrived earlier or later

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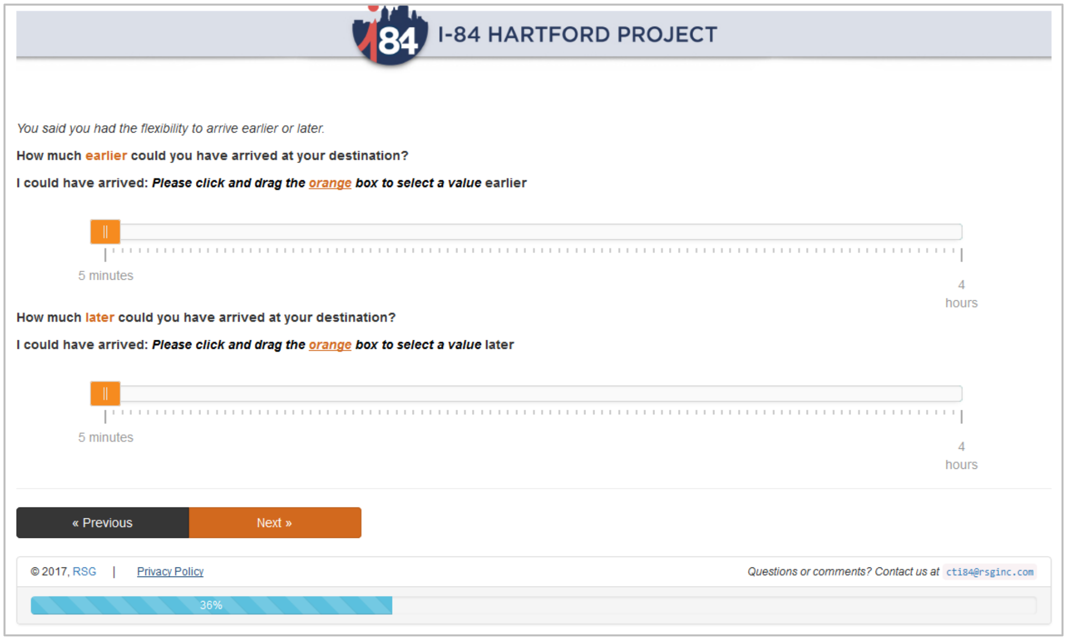
34%

If respondent traveled during morning or evening peak period

Figure 2-15: Amount of Travel Time Flexibility



If respondent traveled during morning or evening peak period and could have arrived earlier or later

Figure 2-16: Delay due to Congestion

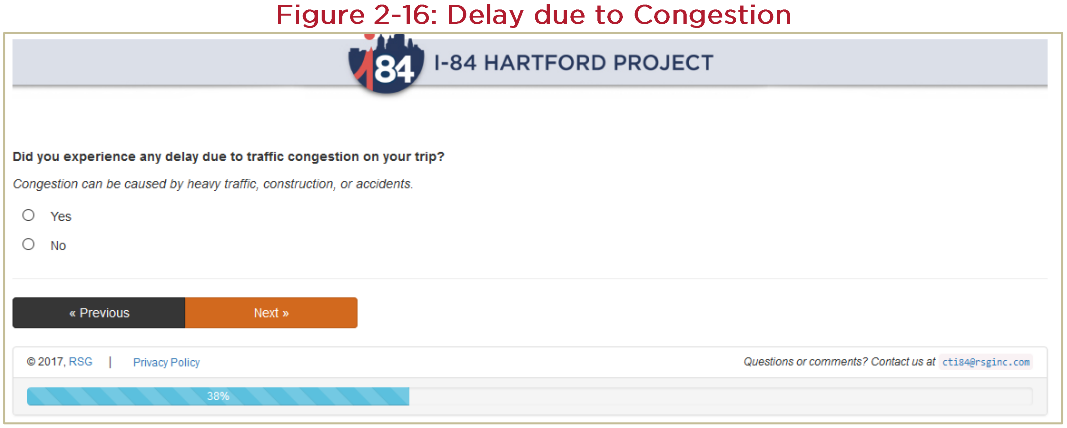
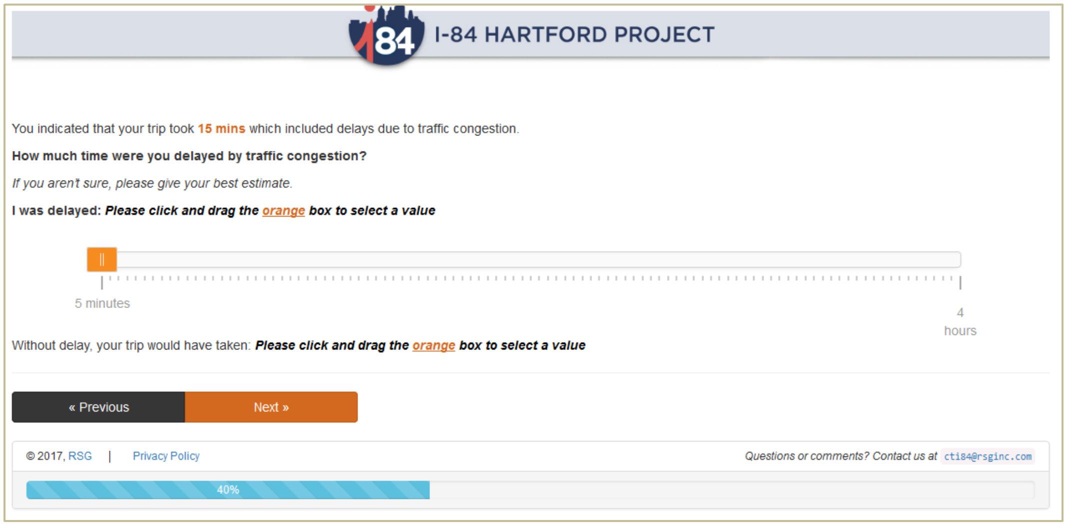


Figure 2-17: Amount of Delay due to Congestion



If respondent experienced delay on their reference trip

Figure 2-18: Vehicle Occupancy

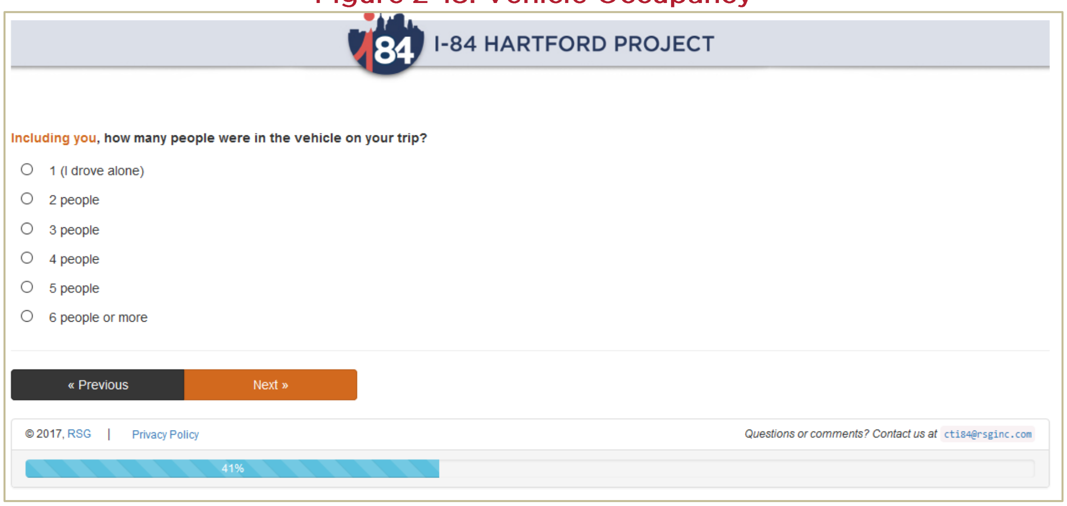


Figure 2-19: Trip Frequency

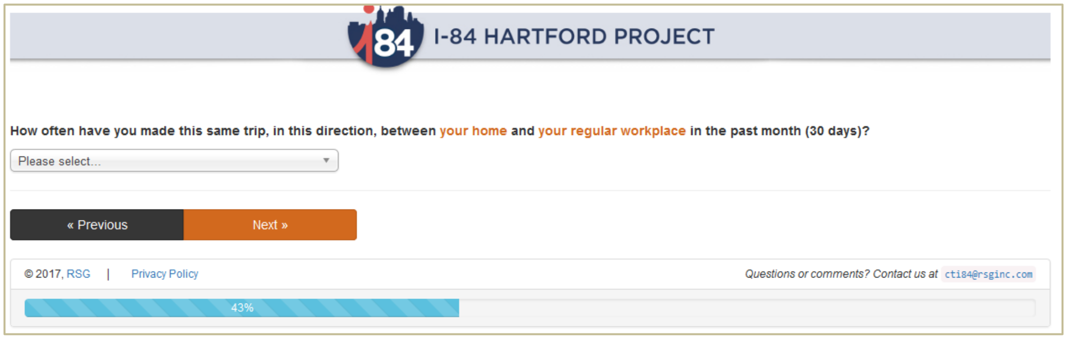


Figure 2-20: Paid Parking

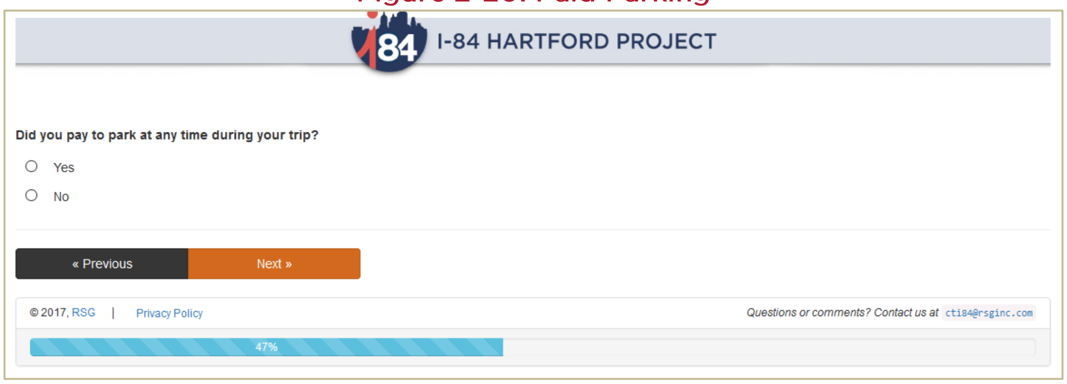
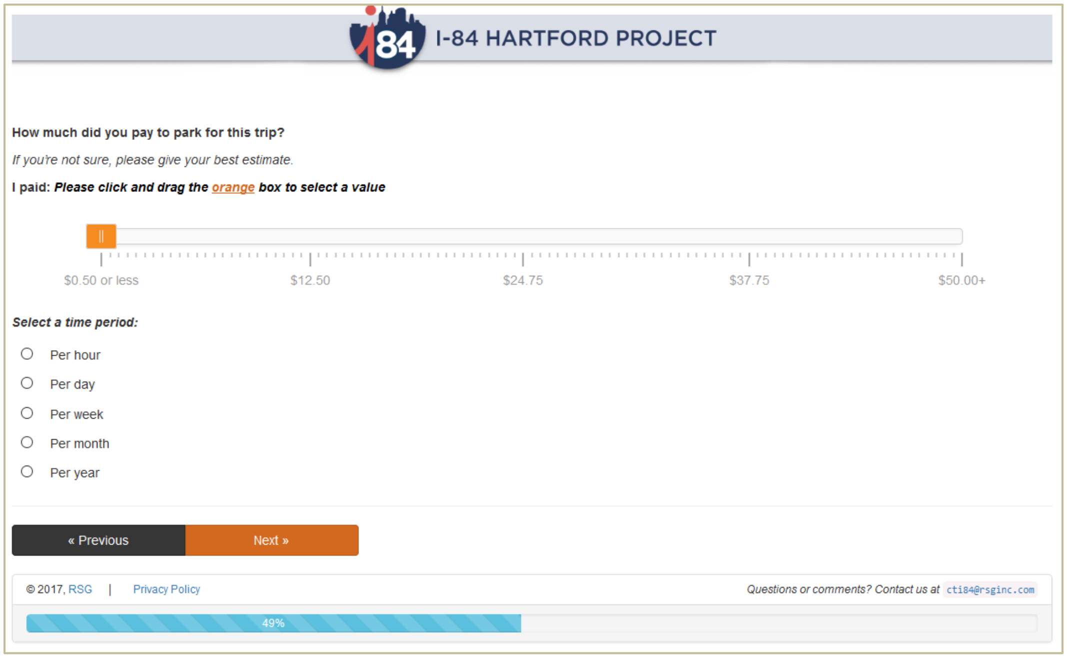


Figure 2-21: Parking Cost


I-84 HARTFORD PROJECT

How much did you pay to park for this trip?

If you're not sure, please give your best estimate.

I paid: ***Please click and drag the orange box to select a value***

$0.50 or less | $12.50 | $24.75 | $37.75 | $50.00+

Select a time period:

- Per hour
- Per day
- Per week
- Per month
- Per year

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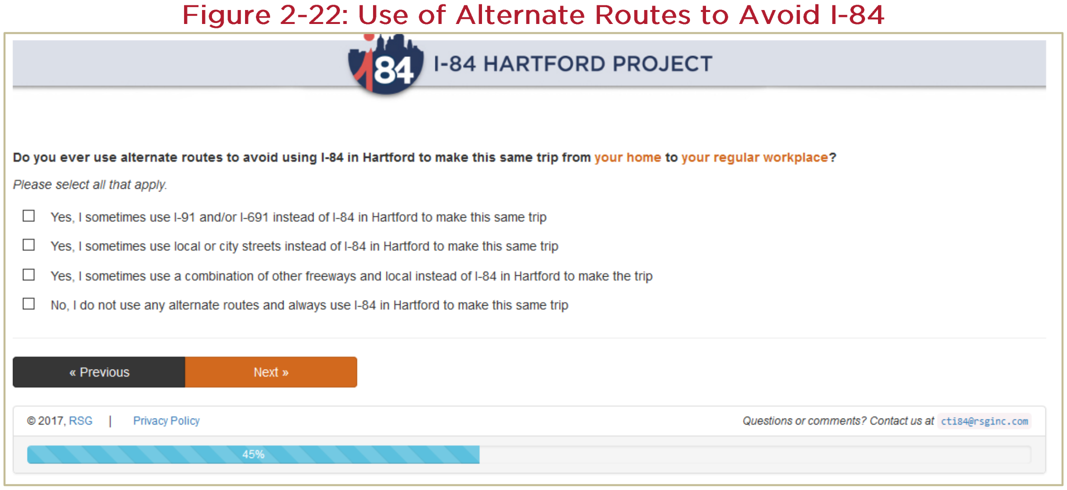
49%

If respondent paid to park during their reference trip

Figure 2-22: Use of Alternate Routes to Avoid I-84


I-84 HARTFORD PROJECT

Do you ever use alternate routes to avoid using I-84 in Hartford to make this same trip from your home to your regular workplace?

Please select all that apply.

- Yes, I sometimes use I-91 and/or I-691 instead of I-84 in Hartford to make this same trip
- Yes, I sometimes use local or city streets instead of I-84 in Hartford to make this same trip
- Yes, I sometimes use a combination of other freeways and local instead of I-84 in Hartford to make the trip
- No, I do not use any alternate routes and always use I-84 in Hartford to make this same trip

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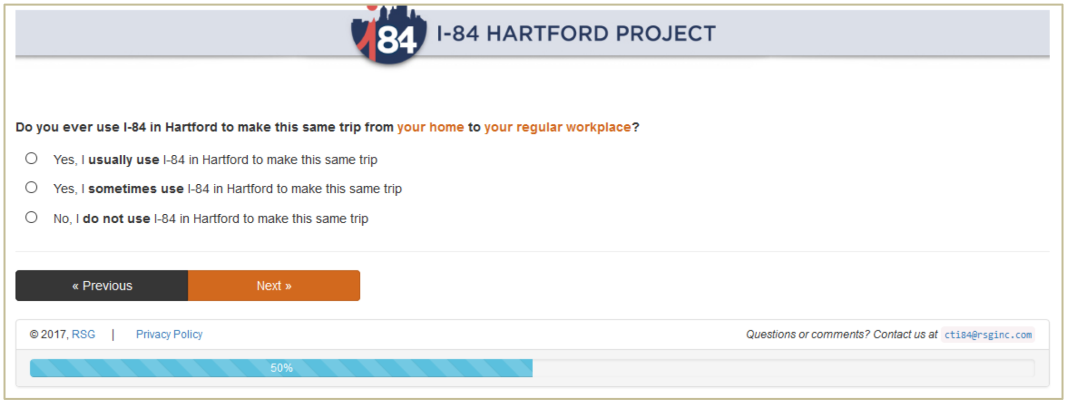
45%

If respondent made their reference trip on I-84

Figure 2-23: Use of I-84


I-84 HARTFORD PROJECT

Do you ever use I-84 in Hartford to make this same trip from your home to your regular workplace?

- ○ Yes, I **usually use** I-84 in Hartford to make this same trip
- ○ Yes, I **sometimes use** I-84 in Hartford to make this same trip
- ○ No, I **do not use** I-84 in Hartford to make this same trip

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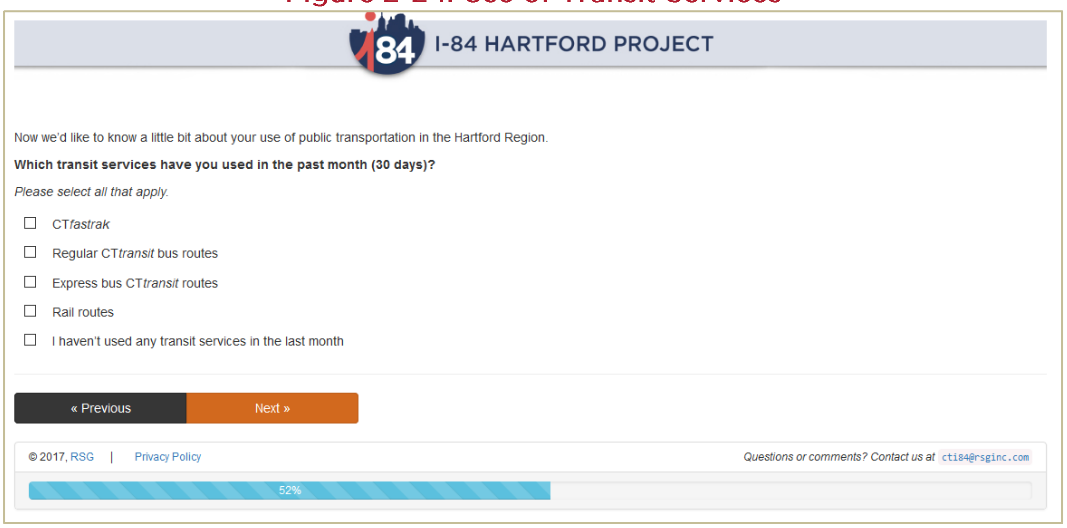
50%

If respondent did not make their reference trip on I-84

Figure 2-24: Use of Transit Services


I-84 HARTFORD PROJECT

Now we'd like to know a little bit about your use of public transportation in the Hartford Region.

Which transit services have you used in the past month (30 days)?

Please select all that apply.

- ☐ CT*fastrak*
- ☐ Regular CT*transit* bus routes
- ☐ Express bus CT*transit* routes
- ☐ Rail routes
- ☐ I haven't used any transit services in the last month

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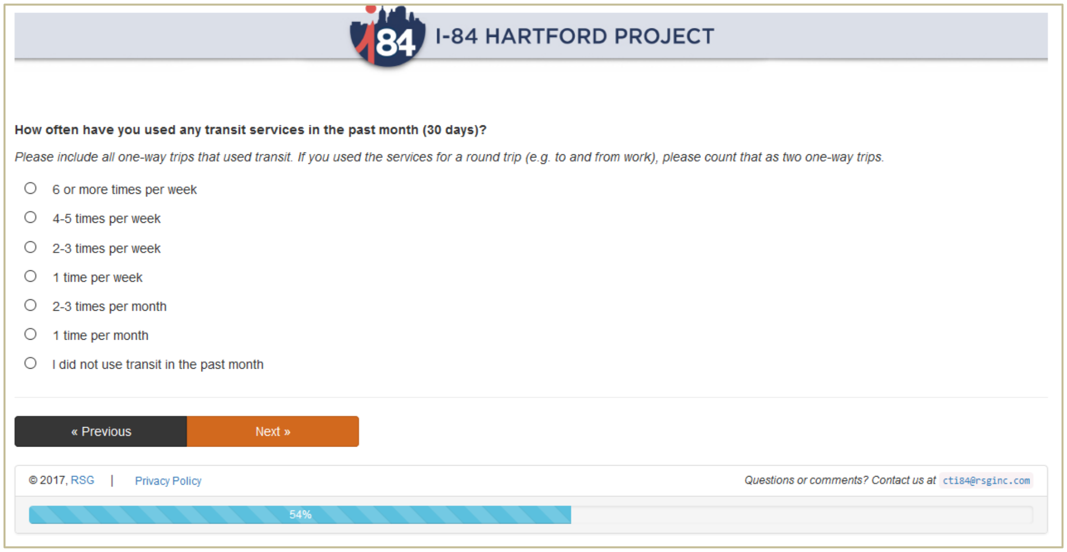
52%

Figure 2-25: Frequency of Transit Use



I-84 HARTFORD PROJECT

How often have you used any transit services in the past month (30 days)?

Please include all one-way trips that used transit. If you used the services for a round trip (e.g. to and from work), please count that as two one-way trips.

- ○ 6 or more times per week
- ○ 4-5 times per week
- ○ 2-3 times per week
- ○ 1 time per week
- ○ 2-3 times per month
- ○ 1 time per month
- ○ I did not use transit in the past month

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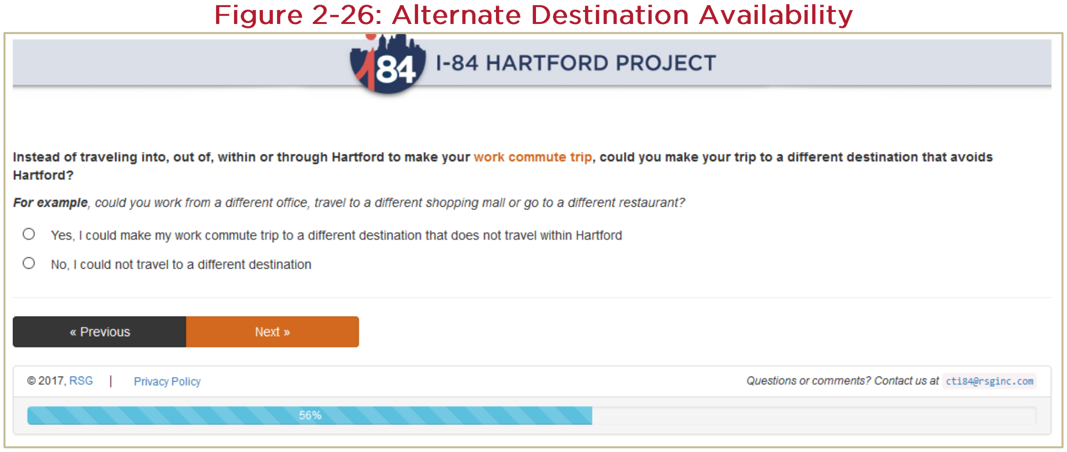
54%

If respondent used transit in the past month

Figure 2-26: Alternate Destination Availability



I-84 HARTFORD PROJECT

Instead of traveling into, out of, within or through Hartford to make your work commute trip, could you make your trip to a different destination that avoids Hartford?

***For example**, could you work from a different office, travel to a different shopping mall or go to a different restaurant?*

- ○ Yes, I could make my work commute trip to a different destination that does not travel within Hartford
- ○ No, I could not travel to a different destination

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56%

3. STATED PREFERENCE QUESTIONS

Figure 3-1: I-84 Improvement Information

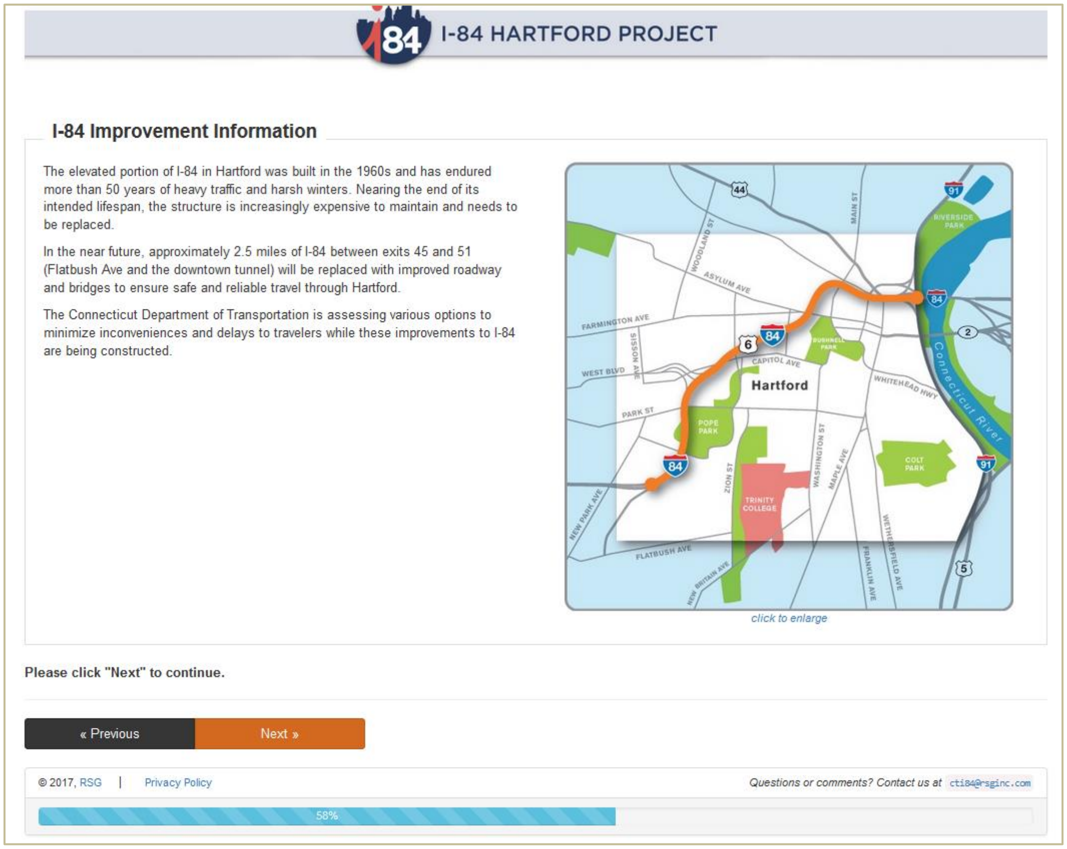
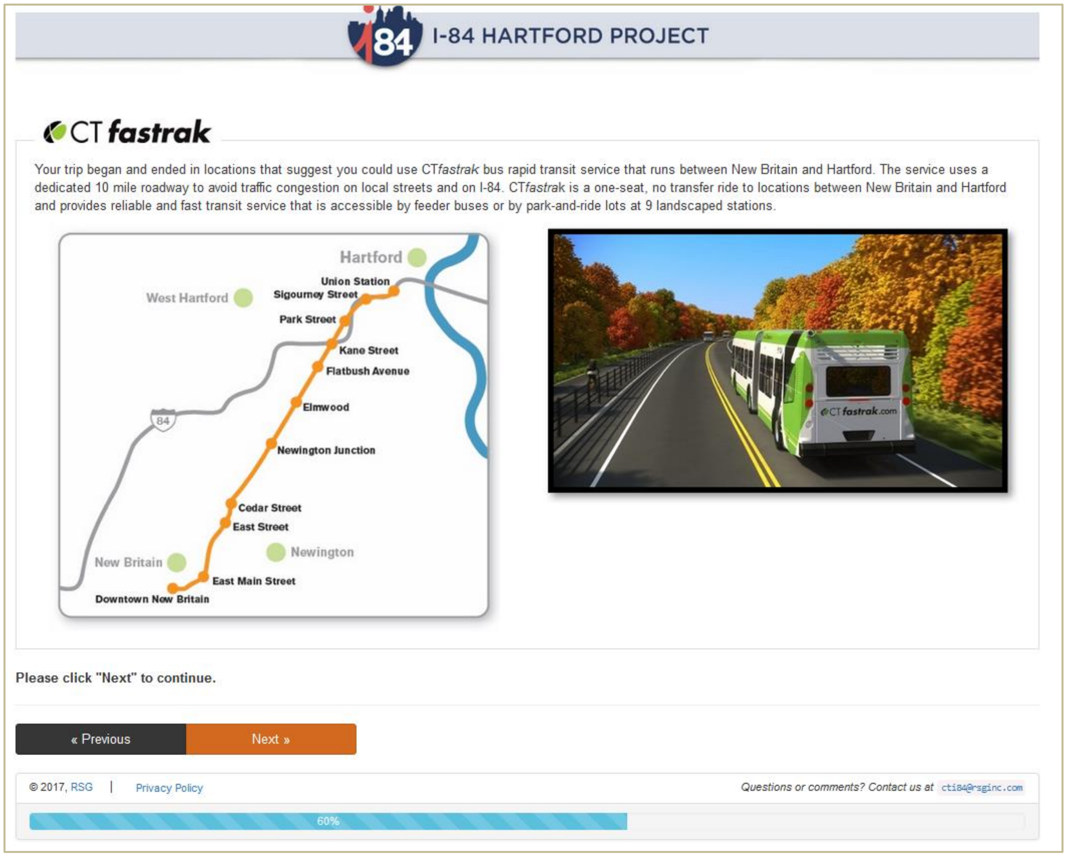
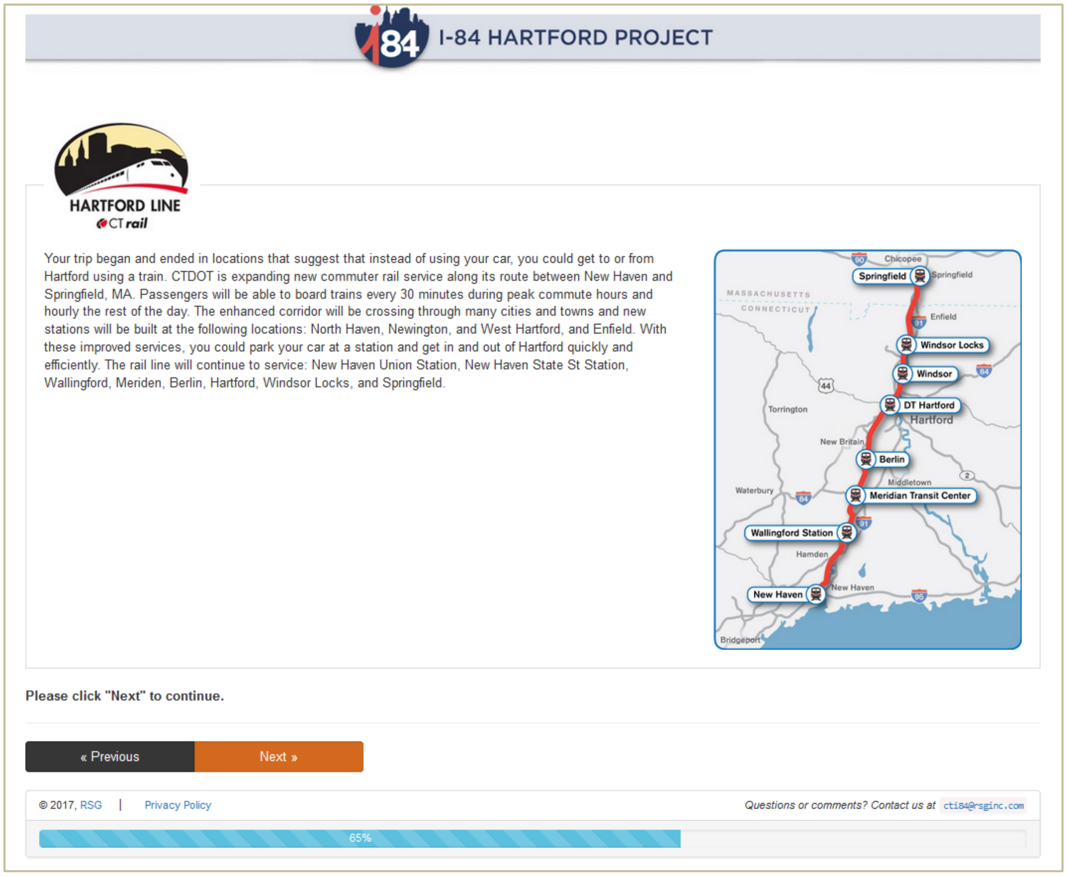


Figure 3-2: CTFastrak Information



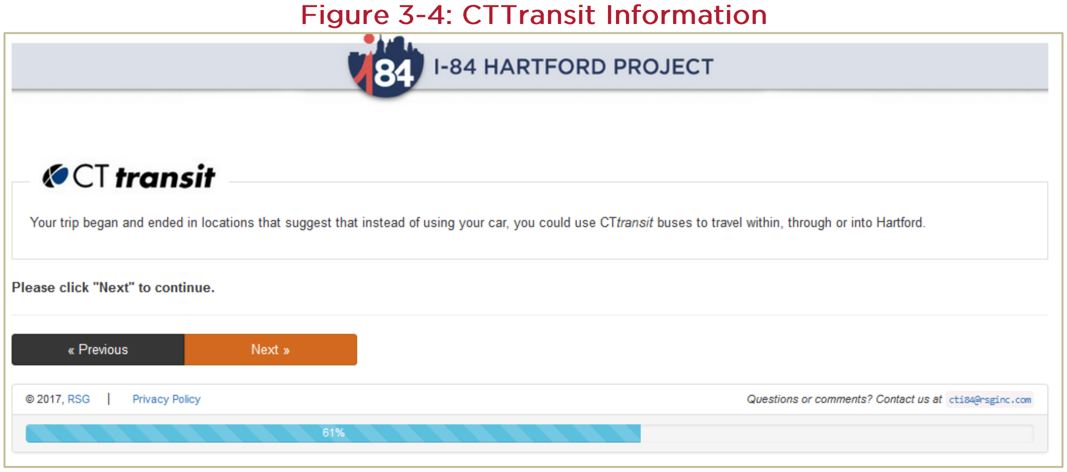
If respondent was assigned to CTfastrak for the SP questions

Figure 3-3: CTrail Information



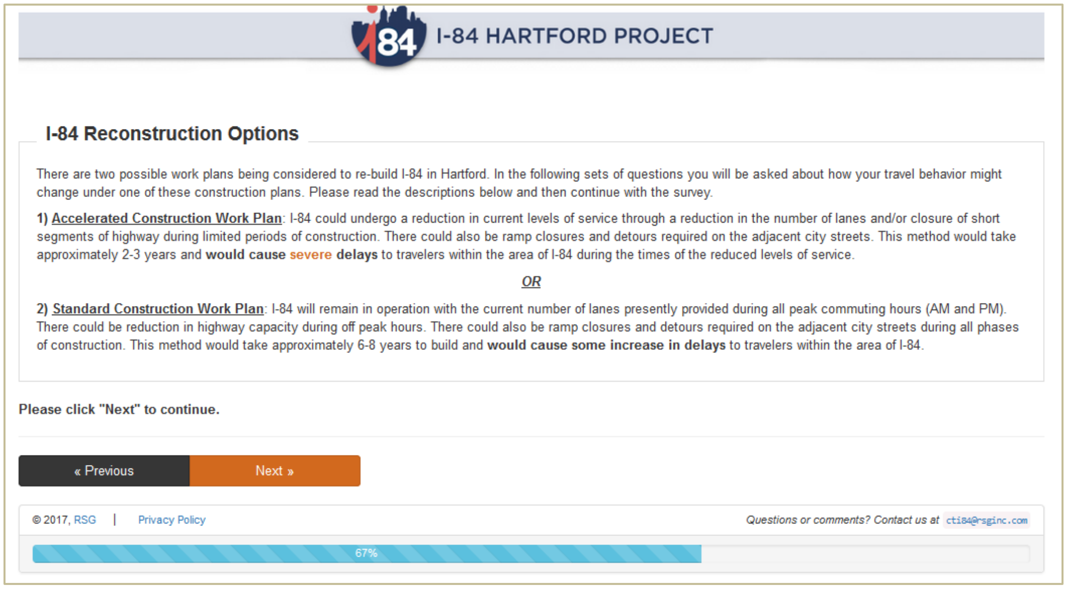
If respondent was assigned to CTrail for the SP questions

Figure 3-4: CTTransit Information



If respondent was assigned to CTtransit for the SP questions

Figure 3-5: I-84 Reconstruction Options



I-84 HARTFORD PROJECT

I-84 Reconstruction Options

There are two possible work plans being considered to re-build I-84 in Hartford. In the following sets of questions you will be asked about how your travel behavior might change under one of these construction plans. Please read the descriptions below and then continue with the survey.

1) Accelerated Construction Work Plan: I-84 could undergo a reduction in current levels of service through a reduction in the number of lanes and/or closure of short segments of highway during limited periods of construction. There could also be ramp closures and detours required on the adjacent city streets. This method would take approximately 2-3 years and **would cause severe delays** to travelers within the area of I-84 during the times of the reduced levels of service.

OR

2) Standard Construction Work Plan: I-84 will remain in operation with the current number of lanes presently provided during all peak commuting hours (AM and PM). There could be reduction in highway capacity during off peak hours. There could also be ramp closures and detours required on the adjacent city streets during all phases of construction. This method would take approximately 6-8 years to build and **would cause some increase in delays** to travelers within the area of I-84.

Please click "Next" to continue.

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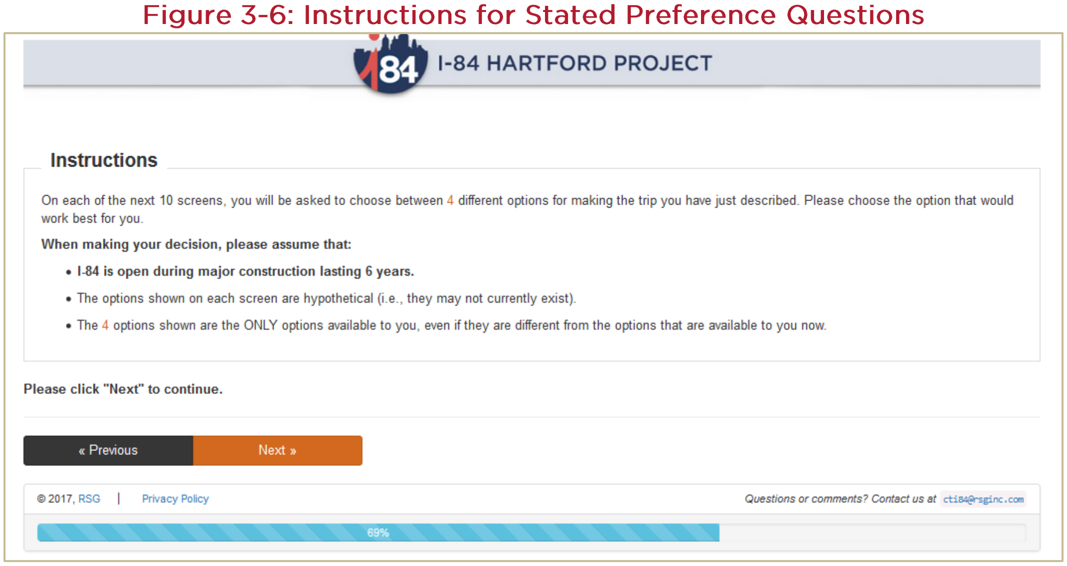
67%

Figure 3-6: Instructions for Stated Preference Questions



I-84 HARTFORD PROJECT

Instructions

On each of the next 10 screens, you will be asked to choose between 4 different options for making the trip you have just described. Please choose the option that would work best for you.

When making your decision, please assume that:

- **I-84 is open during major construction lasting 6 years.**
- The options shown on each screen are hypothetical (i.e., they may not currently exist).
- The 4 options shown are the ONLY options available to you, even if they are different from the options that are available to you now.

Please click "Next" to continue.

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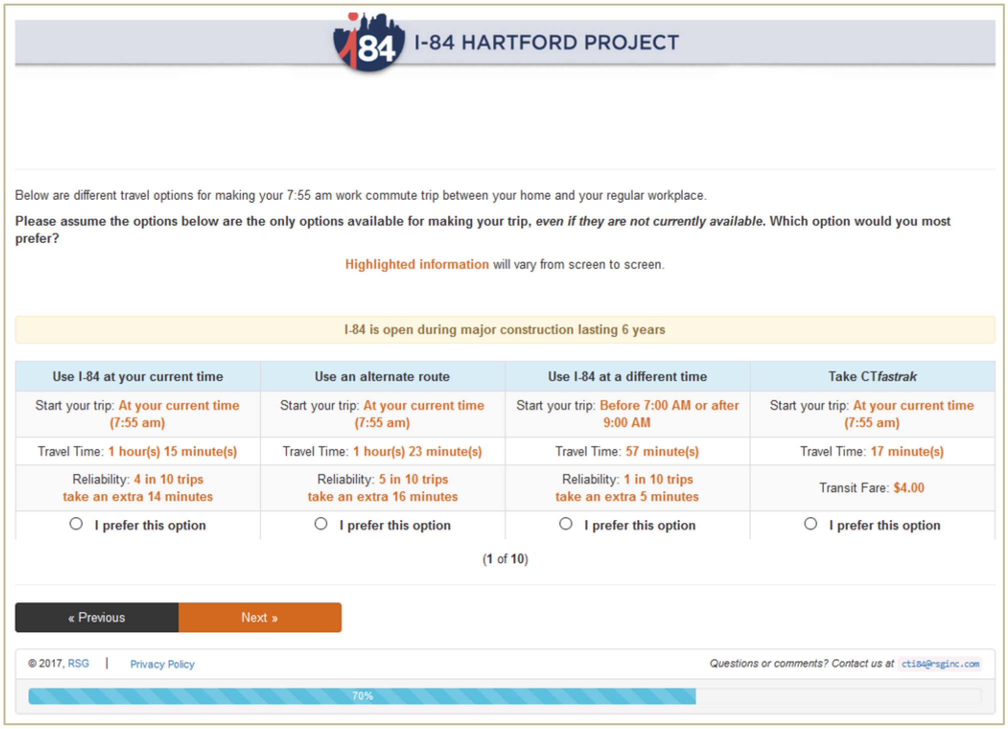
69%

Figure 3-7: Stated Preference Scenario #1


I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available*. Which option would you most prefer?

Highlighted information will vary from screen to screen.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: **At your current time (7:55 am)**	Start your trip: **At your current time (7:55 am)**	Start your trip: **Before 7:00 AM or after 9:00 AM**	Start your trip: **At your current time (7:55 am)**
Travel Time: **1 hour(s) 15 minute(s)**	Travel Time: **1 hour(s) 23 minute(s)**	Travel Time: **57 minute(s)**	Travel Time: **17 minute(s)**
Reliability: **4 in 10 trips take an extra 14 minutes**	Reliability: **5 in 10 trips take an extra 16 minutes**	Reliability: **1 in 10 trips take an extra 5 minutes**	Transit Fare: **$4.00**
○ **I prefer this option**	○ **I prefer this option**	○ **I prefer this option**	○ **I prefer this option**

(**1** of **10**)

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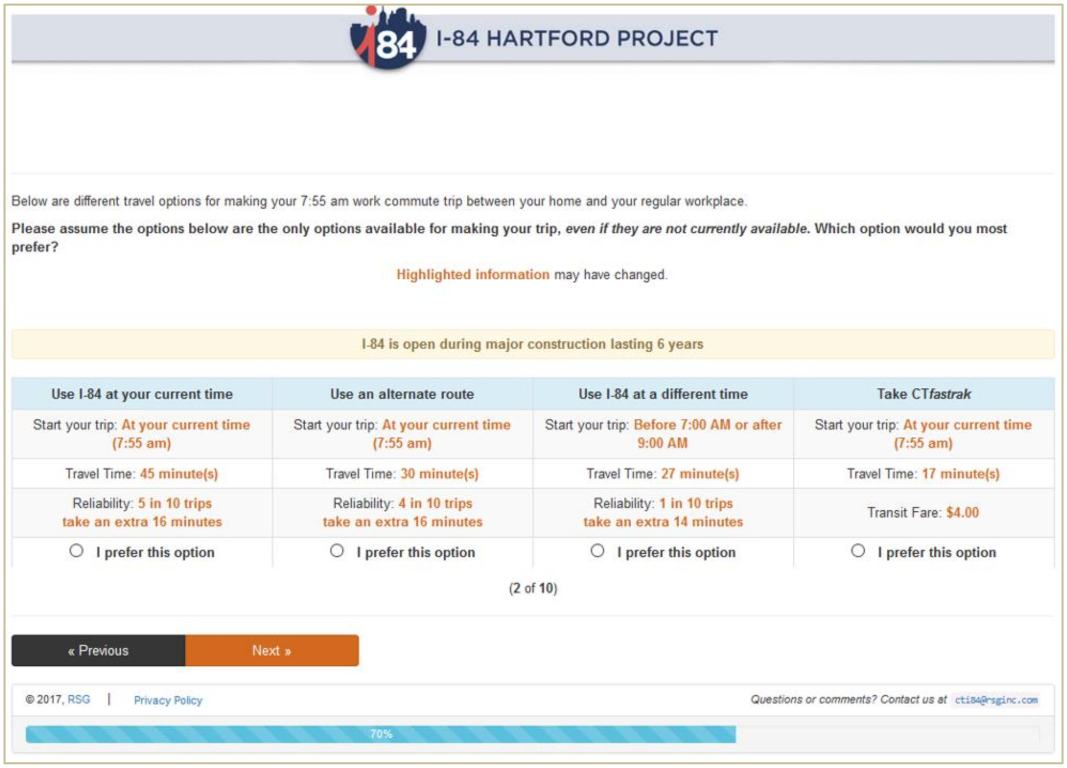
70%

Figure 3-8: Stated Preference Scenario #2



I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available.* Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: At your current time (7:55 am)	Start your trip: At your current time (7:55 am)	Start your trip: Before 7:00 AM or after 9:00 AM	Start your trip: At your current time (7:55 am)
Travel Time: 45 minute(s)	Travel Time: 30 minute(s)	Travel Time: 27 minute(s)	Travel Time: 17 minute(s)
Reliability: 5 in 10 trips take an extra 16 minutes	Reliability: 4 in 10 trips take an extra 16 minutes	Reliability: 1 in 10 trips take an extra 14 minutes	Transit Fare: $4.00
○ I prefer this option	○ I prefer this option	○ I prefer this option	○ I prefer this option

(2 of 10)

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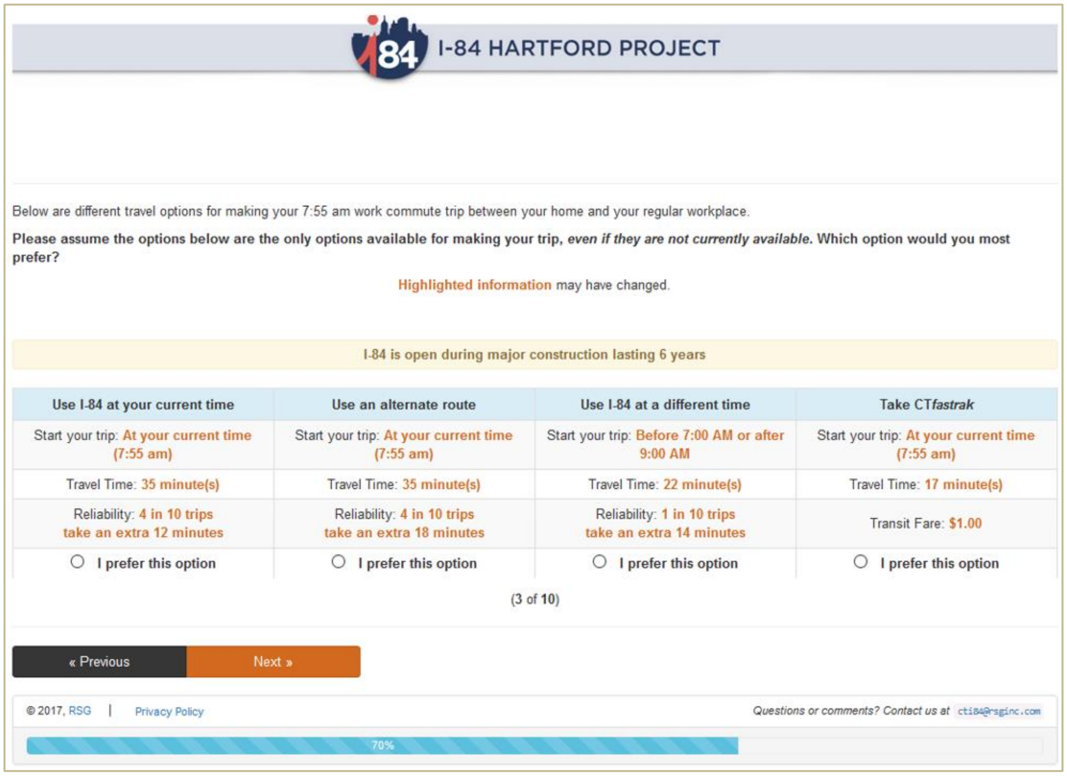
70%

Figure 3-9: Stated Preference Scenario #3



I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available*. Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: At your current time (7:55 am)	Start your trip: At your current time (7:55 am)	Start your trip: Before 7:00 AM or after 9:00 AM	Start your trip: At your current time (7:55 am)
Travel Time: 35 minute(s)	Travel Time: 35 minute(s)	Travel Time: 22 minute(s)	Travel Time: 17 minute(s)
Reliability: 4 in 10 trips take an extra 12 minutes	Reliability: 4 in 10 trips take an extra 18 minutes	Reliability: 1 in 10 trips take an extra 14 minutes	Transit Fare: $1.00
○ I prefer this option	○ I prefer this option	○ I prefer this option	○ I prefer this option

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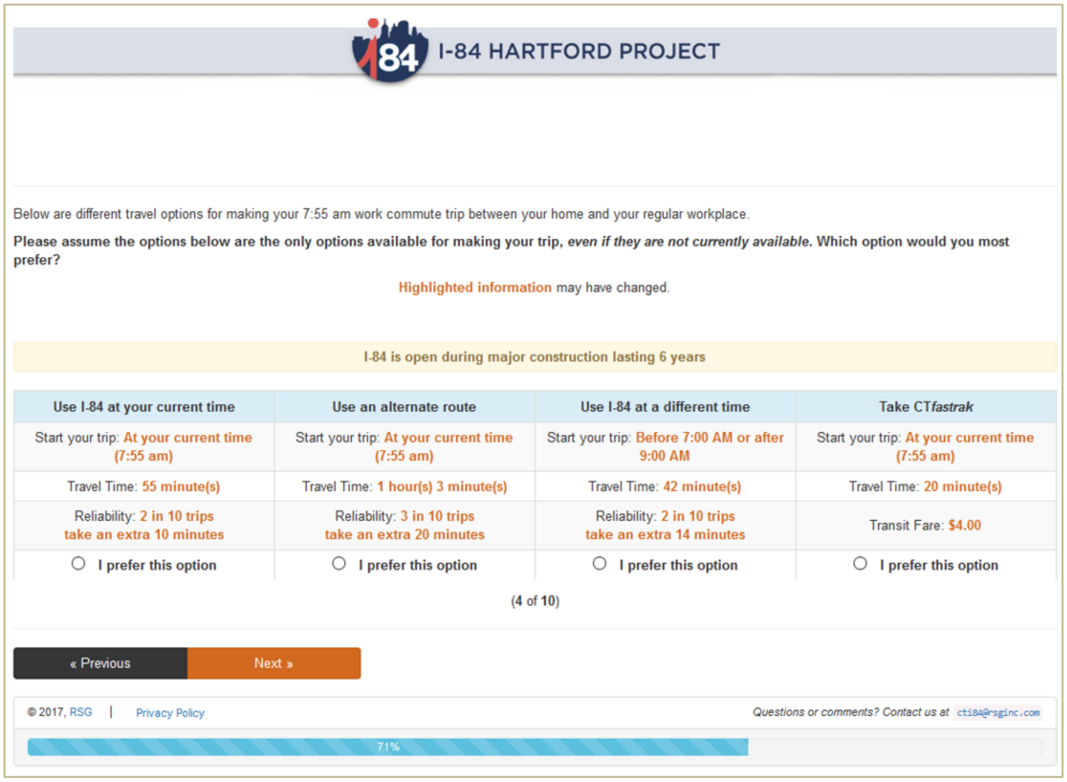
70%

Figure 3-10: Stated Preference Scenario #4



I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available*. Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: **At your current time (7:55 am)**	Start your trip: **At your current time (7:55 am)**	Start your trip: **Before 7:00 AM or after 9:00 AM**	Start your trip: **At your current time (7:55 am)**
Travel Time: **55 minute(s)**	Travel Time: **1 hour(s) 3 minute(s)**	Travel Time: **42 minute(s)**	Travel Time: **20 minute(s)**
Reliability: **2 in 10 trips take an extra 10 minutes**	Reliability: **3 in 10 trips take an extra 20 minutes**	Reliability: **2 in 10 trips take an extra 14 minutes**	Transit Fare: **$4.00**
○ I prefer this option	○ I prefer this option	○ I prefer this option	○ I prefer this option

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71%

Figure 3-11: Stated Preference Scenario #5

I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available*. Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: At your current time (7:55 am)	Start your trip: At your current time (7:55 am)	Start your trip: Before 7:00 AM or after 9:00 AM	Start your trip: At your current time (7:55 am)
Travel Time: 1 hour(s) 15 minute(s)	Travel Time: 1 hour(s) 0 minute(s)	Travel Time: 57 minute(s)	Travel Time: 15 minute(s)
Reliability: 3 in 10 trips take an extra 12 minutes	Reliability: 5 in 10 trips take an extra 12 minutes	Reliability: 2 in 10 trips take an extra 12 minutes	Transit Fare: $3.00
I prefer this option	I prefer this option	I prefer this option	I prefer this option

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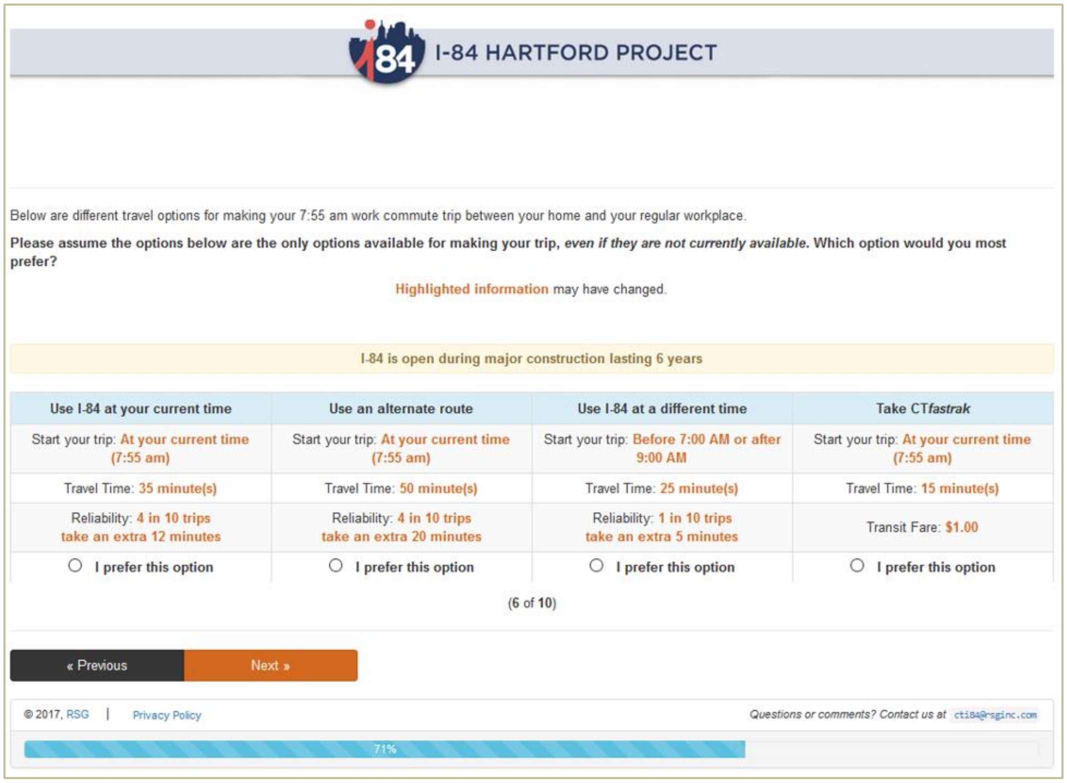
71%

Figure 3-12: Stated Preference Scenario #6



I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available.* Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: At your current time (7:55 am)	Start your trip: At your current time (7:55 am)	Start your trip: Before 7:00 AM or after 9:00 AM	Start your trip: At your current time (7:55 am)
Travel Time: 35 minute(s)	Travel Time: 50 minute(s)	Travel Time: 25 minute(s)	Travel Time: 15 minute(s)
Reliability: 4 in 10 trips take an extra 12 minutes	Reliability: 4 in 10 trips take an extra 20 minutes	Reliability: 1 in 10 trips take an extra 5 minutes	Transit Fare: $1.00
I prefer this option	I prefer this option	I prefer this option	I prefer this option

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71%

Figure 3-13: Stated Preference Scenario #7

I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available*. Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: **At your current time (7:55 am)**	Start your trip: **At your current time (7:55 am)**	Start your trip: **Before 7:00 AM or after 9:00 AM**	Start your trip: **At your current time (7:55 am)**
Travel Time: **1 hour(s) 5 minute(s)**	Travel Time: **1 hour(s) 20 minute(s)**	Travel Time: **1 hour(s) 0 minute(s)**	Travel Time: **20 minute(s)**
Reliability: **4 in 10 trips take an extra 18 minutes**	Reliability: **5 in 10 trips take an extra 12 minutes**	Reliability: **1 in 10 trips take an extra 14 minutes**	Transit Fare: **$1.00**
○ **I prefer this option**	○ **I prefer this option**	○ **I prefer this option**	○ **I prefer this option**

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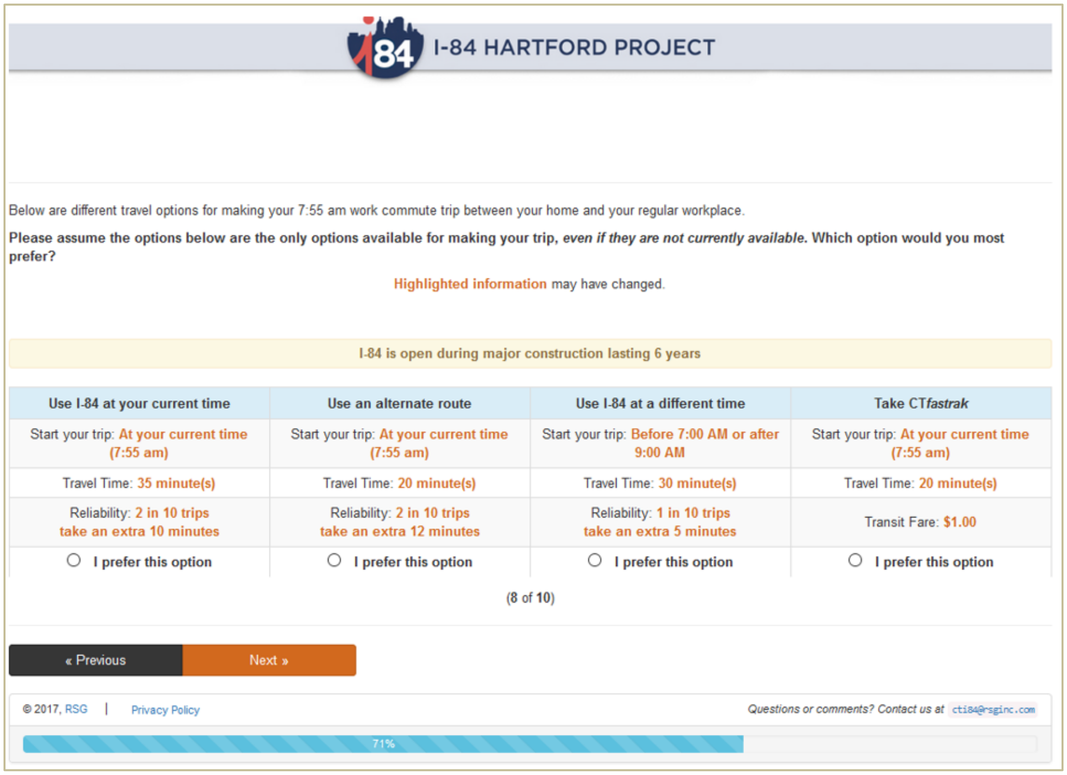
71%

Figure 3-14: Stated Preference Scenario #8



I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available*. Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: At your current time (7:55 am)	Start your trip: At your current time (7:55 am)	Start your trip: Before 7:00 AM or after 9:00 AM	Start your trip: At your current time (7:55 am)
Travel Time: 35 minute(s)	Travel Time: 20 minute(s)	Travel Time: 30 minute(s)	Travel Time: 20 minute(s)
Reliability: 2 in 10 trips take an extra 10 minutes	Reliability: 2 in 10 trips take an extra 12 minutes	Reliability: 1 in 10 trips take an extra 5 minutes	Transit Fare: $1.00
○ I prefer this option	○ I prefer this option	○ I prefer this option	○ I prefer this option

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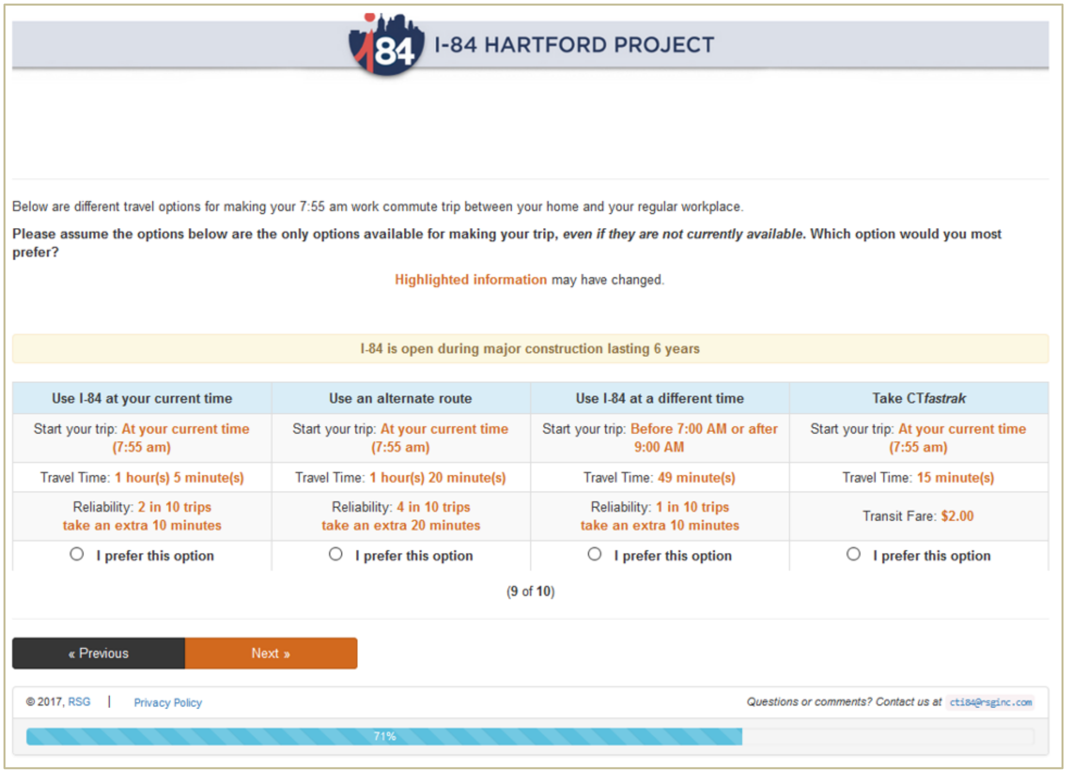
71%

Figure 3-15: Stated Preference Scenario #9



I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available*. Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: **At your current time (7:55 am)**	Start your trip: **At your current time (7:55 am)**	Start your trip: **Before 7:00 AM or after 9:00 AM**	Start your trip: **At your current time (7:55 am)**
Travel Time: **1 hour(s) 5 minute(s)**	Travel Time: **1 hour(s) 20 minute(s)**	Travel Time: **49 minute(s)**	Travel Time: **15 minute(s)**
Reliability: **2 in 10 trips take an extra 10 minutes**	Reliability: **4 in 10 trips take an extra 20 minutes**	Reliability: **1 in 10 trips take an extra 10 minutes**	Transit Fare: **$2.00**
○ I prefer this option	○ I prefer this option	○ I prefer this option	○ I prefer this option

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71%

Figure 3-16: Stated Preference Scenario #10

I-84 HARTFORD PROJECT

Below are different travel options for making your 7:55 am work commute trip between your home and your regular workplace.

Please assume the options below are the only options available for making your trip, *even if they are not currently available*. Which option would you most prefer?

Highlighted information may have changed.

I-84 is open during major construction lasting 6 years

Use I-84 at your current time	Use an alternate route	Use I-84 at a different time	Take CT*fastrak*
Start your trip: **At your current time (7:55 am)**	Start your trip: **At your current time (7:55 am)**	Start your trip: **Before 7:00 AM or after 9:00 AM**	Start your trip: **At your current time (7:55 am)**
Travel Time: **1 hour(s) 5 minute(s)**	Travel Time: **1 hour(s) 20 minute(s)**	Travel Time: **52 minute(s)**	Travel Time: **17 minute(s)**
Reliability: **4 in 10 trips take an extra 14 minutes**	Reliability: **3 in 10 trips take an extra 18 minutes**	Reliability: **2 in 10 trips take an extra 12 minutes**	Transit Fare: **$1.00**
○ **I prefer this option**	○ **I prefer this option**	○ **I prefer this option**	○ **I prefer this option**

(**10** of **10**)

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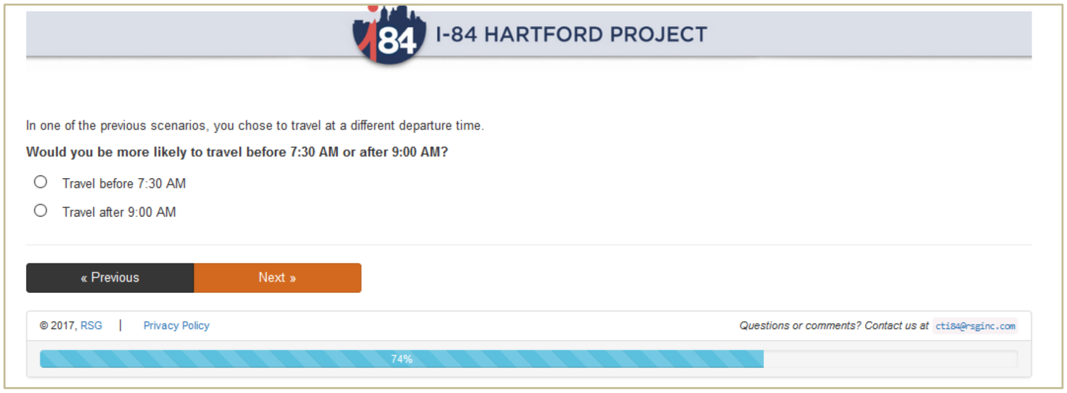
71%

4. DEBRIEF AND OPINION QUESTIONS

Figure 4-1: Departure Time Shift



I-84 HARTFORD PROJECT

In one of the previous scenarios, you chose to travel at a different departure time.

Would you be more likely to travel before 7:30 AM or after 9:00 AM?

- Travel before 7:30 AM
- Travel after 9:00 AM

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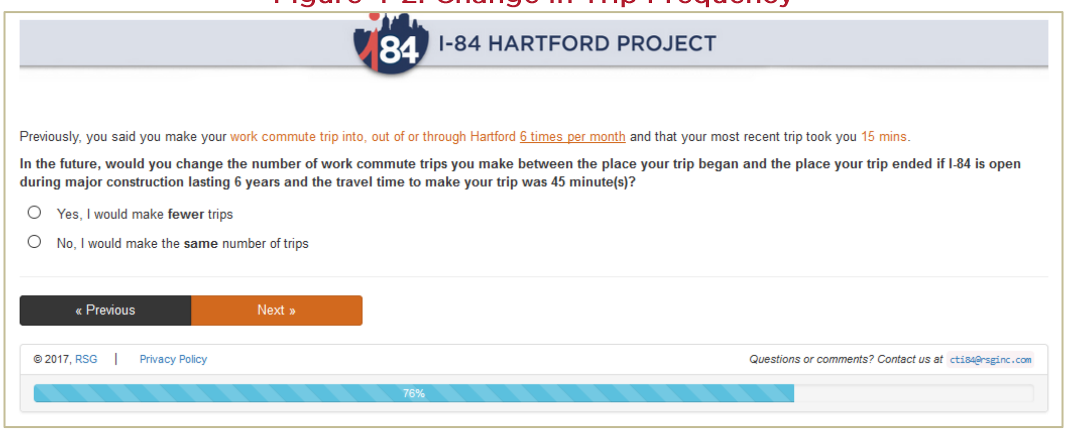
74%

If reference trip was in a peak period and respondent chose at least one alternative to travel at a different departure time

Figure 4-2: Change in Trip Frequency



I-84 HARTFORD PROJECT

Previously, you said you make your work commute trip into, out of or through Hartford 6 times per month and that your most recent trip took you 15 mins.

In the future, would you change the number of work commute trips you make between the place your trip began and the place your trip ended if I-84 is open during major construction lasting 6 years and the travel time to make your trip was 45 minute(s)?

- Yes, I would make **fewer** trips
- No, I would make the **same** number of trips

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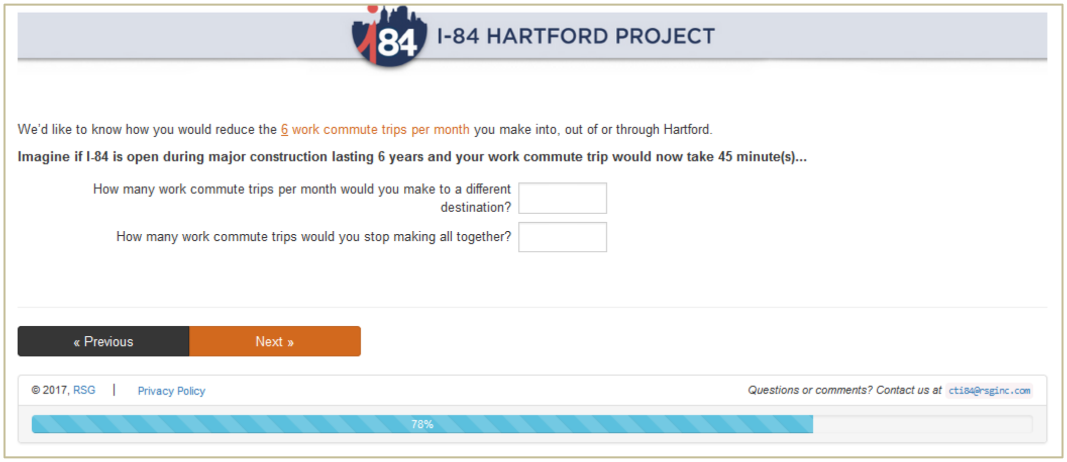
76%

If respondent made their reference trip more than once per month

Figure 4-3: Trip Suppression


I-84 HARTFORD PROJECT

We'd like to know how you would reduce the 6 work commute trips per month you make into, out of or through Hartford.

Imagine if I-84 is open during major construction lasting 6 years and your work commute trip would now take 45 minute(s)...

How many work commute trips per month would you make to a different destination? [ ]

How many work commute trips would you stop making all together? [ ]

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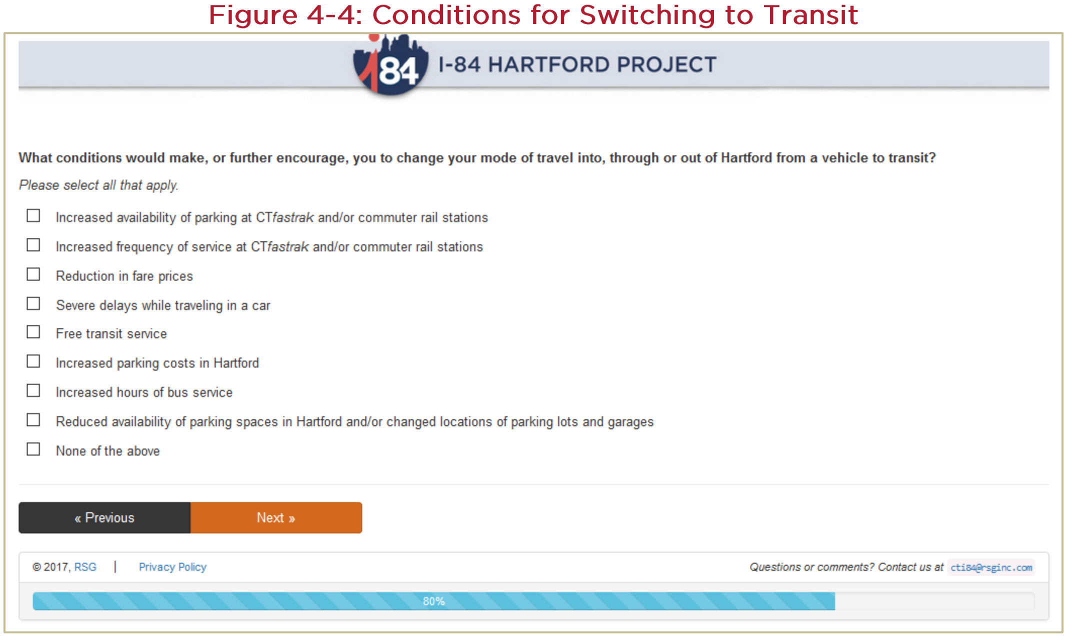
78%

If respondent indicated they would make their reference trip less frequently during construction

Figure 4-4: Conditions for Switching to Transit


I-84 HARTFORD PROJECT

What conditions would make, or further encourage, you to change your mode of travel into, through or out of Hartford from a vehicle to transit?

Please select all that apply.

- ☐ Increased availability of parking at CT*fastrak* and/or commuter rail stations
- ☐ Increased frequency of service at CT*fastrak* and/or commuter rail stations
- ☐ Reduction in fare prices
- ☐ Severe delays while traveling in a car
- ☐ Free transit service
- ☐ Increased parking costs in Hartford
- ☐ Increased hours of bus service
- ☐ Reduced availability of parking spaces in Hartford and/or changed locations of parking lots and garages
- ☐ None of the above

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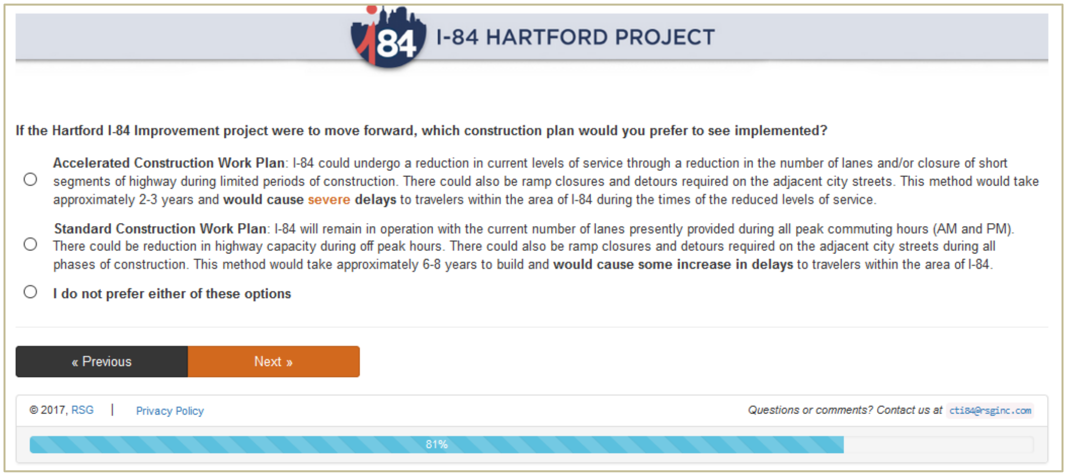
80%

Figure 4-5: Construction Plan Preference



I-84 HARTFORD PROJECT

If the Hartford I-84 Improvement project were to move forward, which construction plan would you prefer to see implemented?

- **Accelerated Construction Work Plan**: I-84 could undergo a reduction in current levels of service through a reduction in the number of lanes and/or closure of short segments of highway during limited periods of construction. There could also be ramp closures and detours required on the adjacent city streets. This method would take approximately 2-3 years and **would cause severe delays** to travelers within the area of I-84 during the times of the reduced levels of service.
- **Standard Construction Work Plan**: I-84 will remain in operation with the current number of lanes presently provided during all peak commuting hours (AM and PM). There could be reduction in highway capacity during off peak hours. There could also be ramp closures and detours required on the adjacent city streets during all phases of construction. This method would take approximately 6-8 years to build and **would cause some increase in delays** to travelers within the area of I-84.
- **I do not prefer either of these options**

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81%

5. DEMOGRAPHIC QUESTIONS

Figure 5-1: ZIP Code

Figure 5-2: Gender

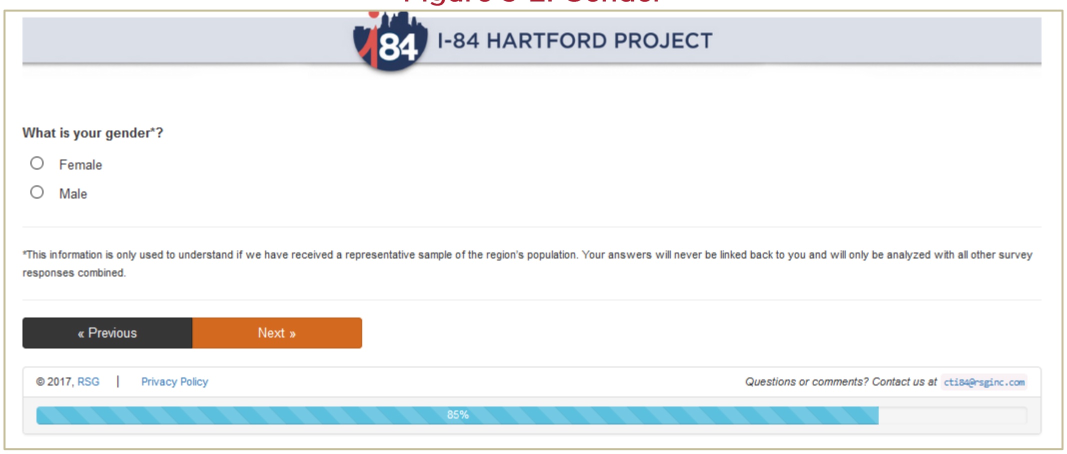
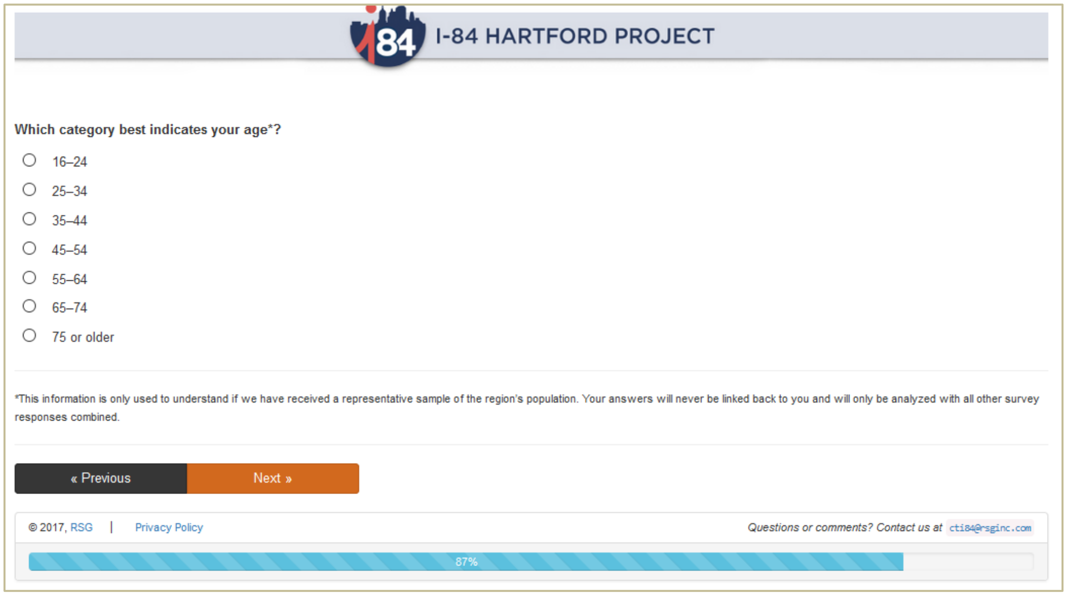


Figure 5-3: Age


I-84 HARTFORD PROJECT

Which category best indicates your age*?

- 16–24
- 25–34
- 35–44
- 45–54
- 55–64
- 65–74
- 75 or older

*This information is only used to understand if we have received a representative sample of the region's population. Your answers will never be linked back to you and will only be analyzed with all other survey responses combined.

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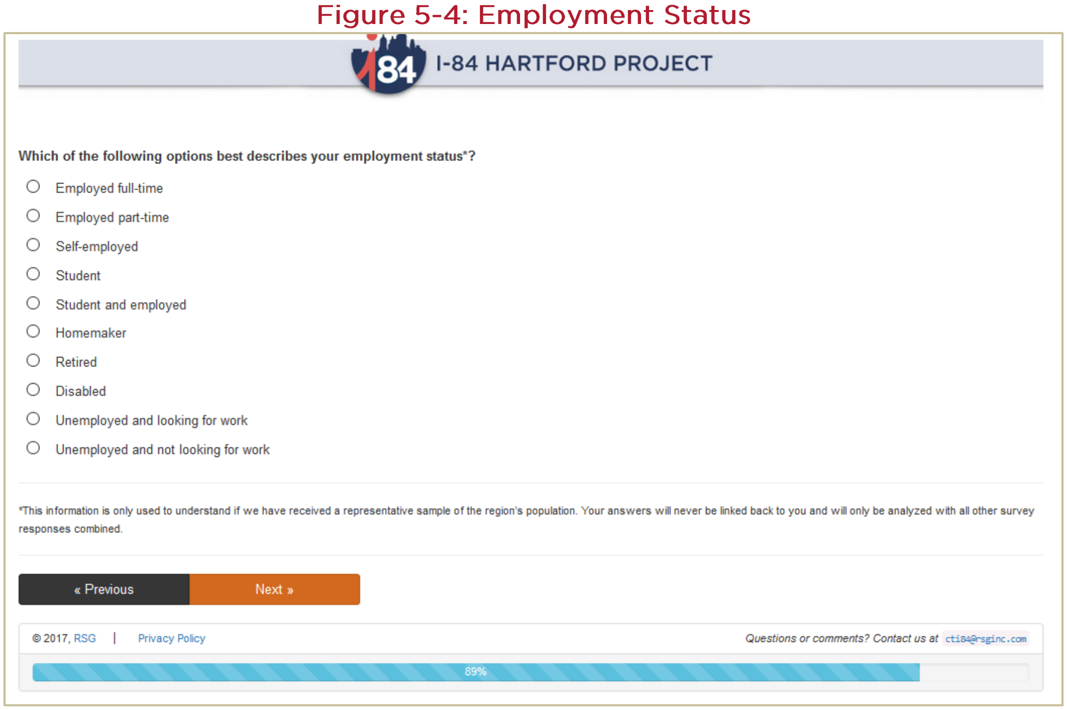
87%

Figure 5-4: Employment Status


I-84 HARTFORD PROJECT

Which of the following options best describes your employment status*?

- Employed full-time
- Employed part-time
- Self-employed
- Student
- Student and employed
- Homemaker
- Retired
- Disabled
- Unemployed and looking for work
- Unemployed and not looking for work

*This information is only used to understand if we have received a representative sample of the region's population. Your answers will never be linked back to you and will only be analyzed with all other survey responses combined.

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89%

Figure 5-5: Household Size

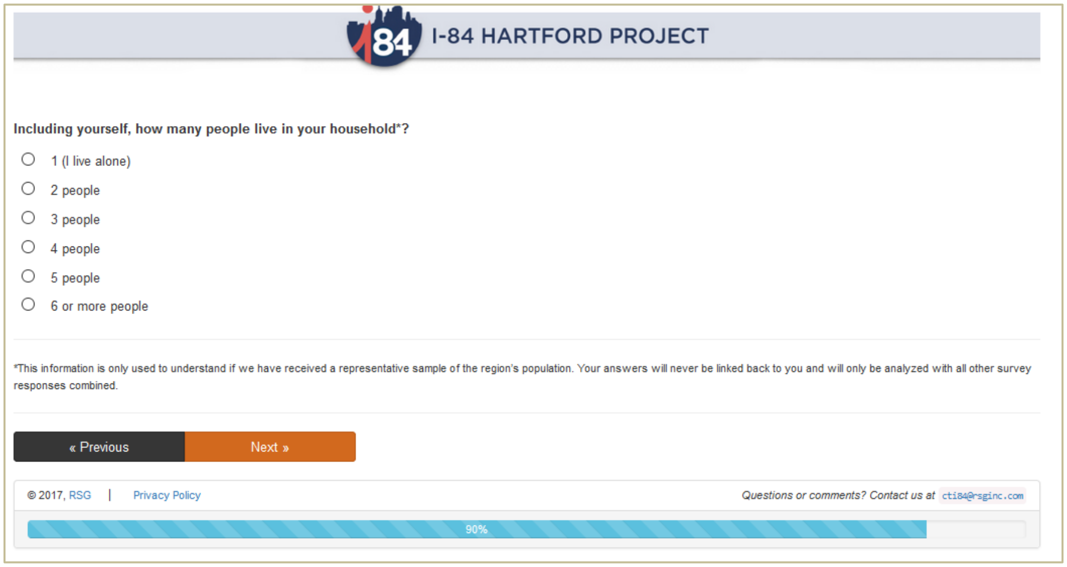
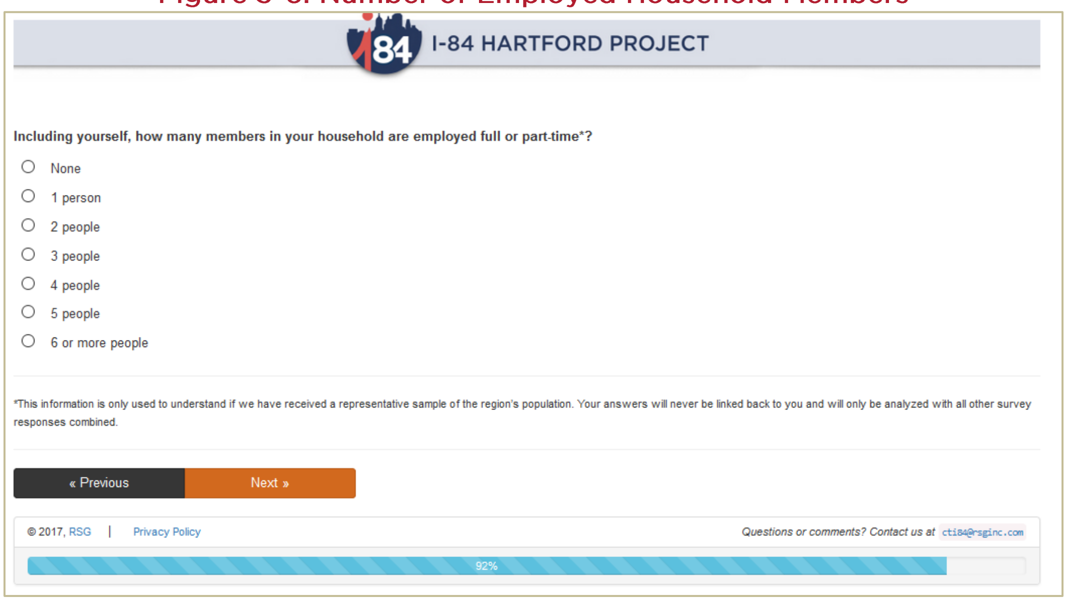
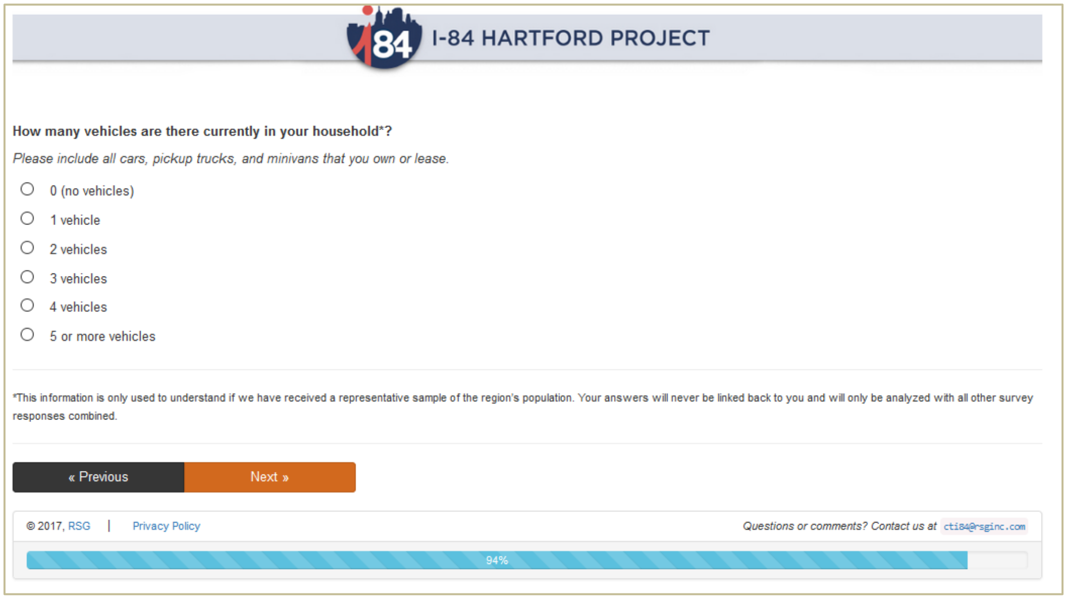


Figure 5-6: Number of Employed Household Members



If two or more people live in household

Figure 5-7: Number of Household Vehicles



I-84 HARTFORD PROJECT

How many vehicles are there currently in your household*?

Please include all cars, pickup trucks, and minivans that you own or lease.

- 0 (no vehicles)
- 1 vehicle
- 2 vehicles
- 3 vehicles
- 4 vehicles
- 5 or more vehicles

*This information is only used to understand if we have received a representative sample of the region's population. Your answers will never be linked back to you and will only be analyzed with all other survey responses combined.

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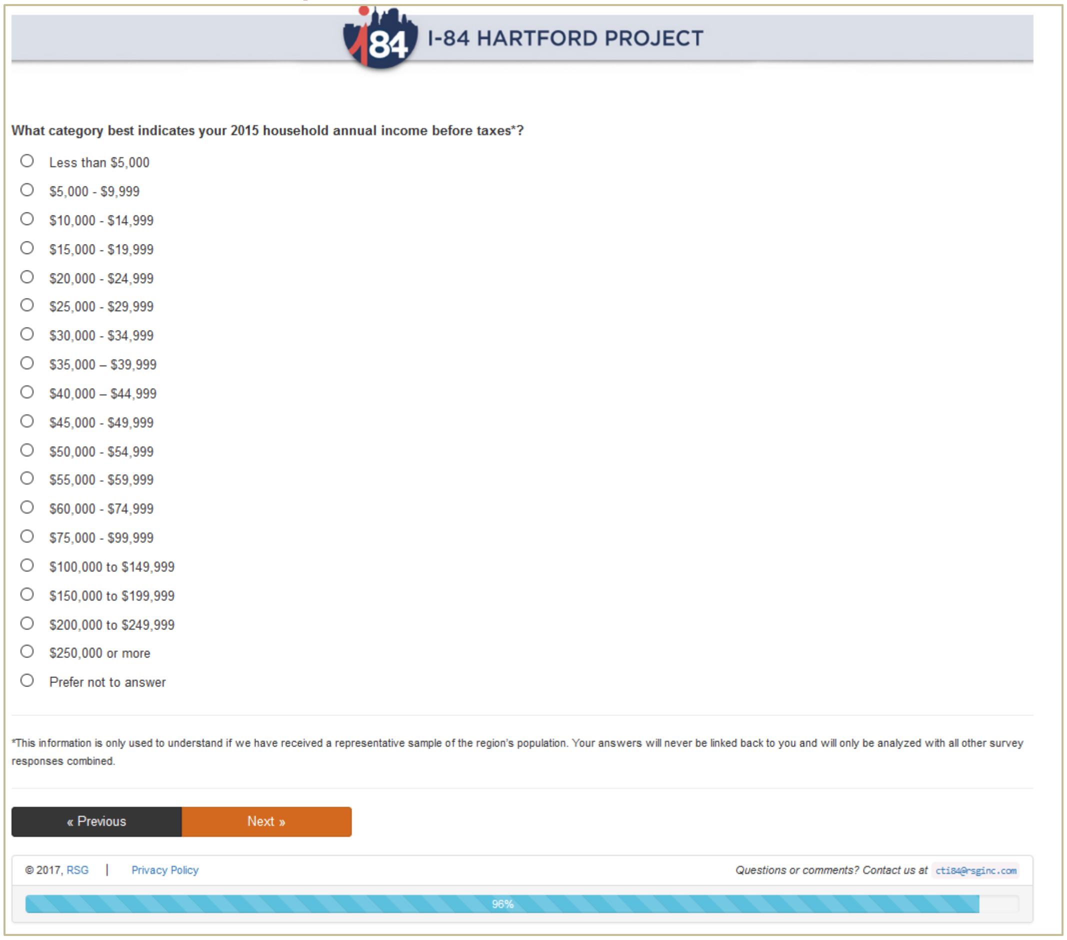
94%

Figure 5-8: Annual Household Income


I-84 HARTFORD PROJECT

What category best indicates your 2015 household annual income before taxes*?

- Less than $5,000
- $5,000 - $9,999
- $10,000 - $14,999
- $15,000 - $19,999
- $20,000 - $24,999
- $25,000 - $29,999
- $30,000 - $34,999
- $35,000 – $39,999
- $40,000 – $44,999
- $45,000 - $49,999
- $50,000 - $54,999
- $55,000 - $59,999
- $60,000 - $74,999
- $75,000 - $99,999
- $100,000 to $149,999
- $150,000 to $199,999
- $200,000 to $249,999
- $250,000 or more
- Prefer not to answer

*This information is only used to understand if we have received a representative sample of the region's population. Your answers will never be linked back to you and will only be analyzed with all other survey responses combined.

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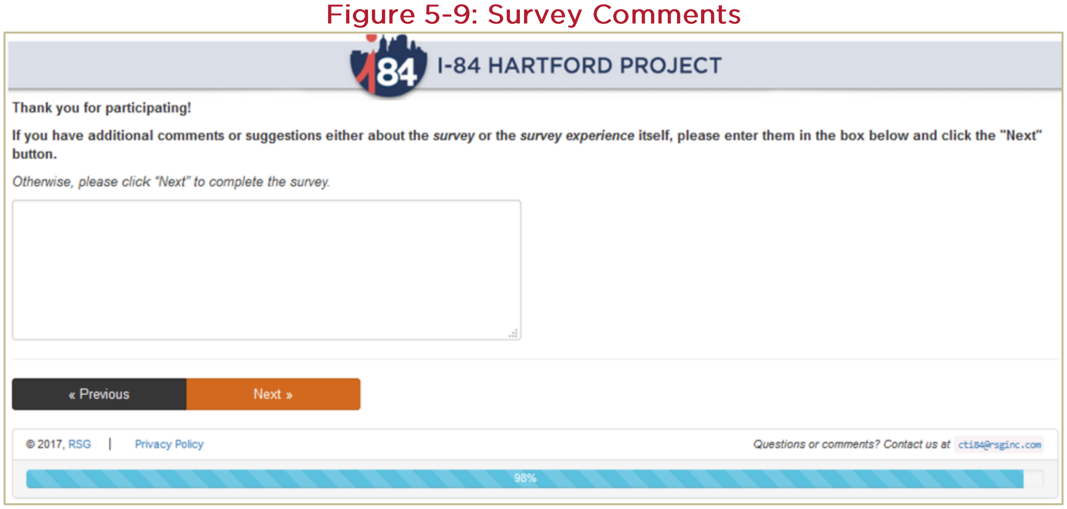
96%

Figure 5-9: Survey Comments


I-84 HARTFORD PROJECT

Thank you for participating!

If you have additional comments or suggestions either about the *survey* or the *survey experience* itself, please enter them in the box below and click the "Next" button.

Otherwise, please click "Next" to complete the survey.

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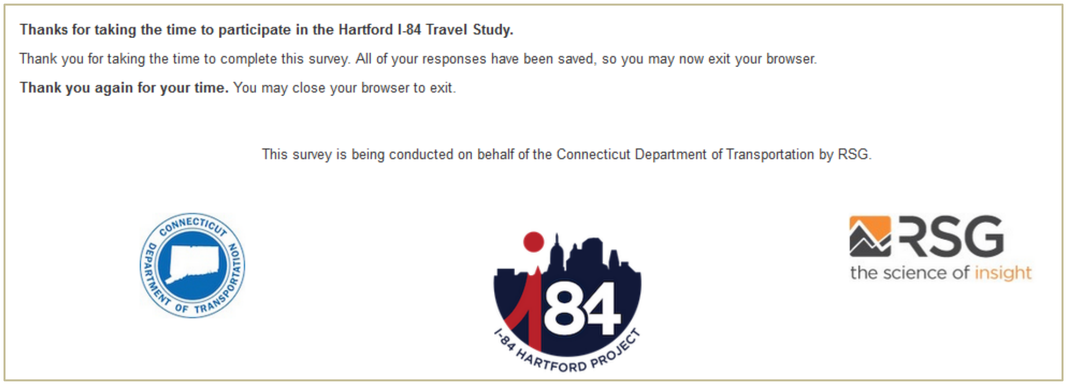
98%

Figure 5-10: Survey End


Thanks for taking the time to participate in the Hartford I-84 Travel Study.

Thank you for taking the time to complete this survey. All of your responses have been saved, so you may now exit your browser.

Thank you again for your time. You may close your browser to exit.

This survey is being conducted on behalf of the Connecticut Department of Transportation by RSG.

I-84 Hartford Stated Preference
Appendix B

Tabulations

September 7, 2017

PREPARED BY:

RSG
TranSystems Corporation

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LIST OF TABLES

1. QUALIFICATION AND TRIP CHARACTERISTIC QUESTIONS

Table 1-1: Trip Qualification

Use of I-84 (between I-91 and Flatbush Avenue/Exit 45) during reference trip

	Count	Percent
Used I-84 to drive in, through or out of Hartford	2157	91.9%
Used other streets to drive in, through or out of Hartford (not I-84)	189	8.1%
Total	2346	100.0%

Table 1-2: Primary Reason for Not Using I-84

[If did not use I-84] What is the main reason you did not use I-84 in Hartford to make your most recent trip into, out of, within or through Hartford?

	Count	Percent
I-84 in Hartford is out of my way	55	29.1%
I-84 in Hartford is too congested	49	25.9%
Entering or exiting I-84 in Hartford is unsafe	8	4.2%
I-84 in Hartford is unsafe to drive on	4	2.1%
I prefer to use my current route	47	24.9%
Other reason	26	13.8%
Total	189	100.0%

Table 1-3: Day of Week

On what weekday did you make your most recent trip?

	Count	Percent
Monday	666	28.4%
Tuesday	325	13.9%
Wednesday	398	17.0%
Thursday	443	18.9%
Friday	514	21.9%
Total	2346	100.0%

Table 1-4: Trip Purpose

What was the primary purpose of your trip?

	Count	Percent
Go to/from work	1406	59.9%
Work-related business	193	8.2%
Go to/from school	37	1.6%
Go to/from airport	57	2.4%
Shopping	153	6.5%
Social or recreational (such as visiting a friend or going to the movies)	246	10.5%
Other personal business	254	10.8%
Total	**2346**	**100.0%**

Table 1-5: Trip Beginning Location

Where did your most recent trip that traveled into, out of, within or through Hartford begin?

	Count	Percent
My home	1938	82.6%
My regular workplace	276	11.8%
Another place	132	5.6%
Total	**2346**	**100.0%**

Table 1-6: Trip Ending Location

Where did your most recent trip that traveled into, out of, within or through Hartford end?

	Count	Percent
My home	285	12.1%
My regular workplace	1259	53.7%
Another place	802	34.2%
Total	**2346**	**100.0%**

Table 1-7: Departure Time

What time did you begin your trip?

	Count	Percent
12AM - 12:59AM	0	0.0%
1AM - 1:59AM	1	.0%
2AM - 2:59AM	1	.0%
3AM - 3:59AM	5	.2%
4AM - 4:59AM	21	.9%
5AM - 5:59AM	72	3.1%
6AM - 6:59AM	311	13.3%
7AM - 7:59AM	557	23.7%
8AM - 8:59AM	378	16.1%
9AM - 9:59AM	148	6.3%
10AM - 10:59AM	111	4.7%
11AM - 11:59AM	68	2.9%
12PM - 12:59PM	62	2.6%
1PM - 1:59PM	72	3.1%
2PM - 2:59PM	67	2.9%
3PM - 3:59PM	87	3.7%
4PM - 4:59PM	134	5.7%
5PM - 5:59PM	132	5.6%
6PM - 6:59PM	62	2.6%
7PM - 7:59PM	30	1.3%
8PM - 8:59PM	14	.6%
9PM - 9:59PM	7	.3%
10PM - 10:59PM	3	.1%
11PM - 11:59PM	3	.1%
Total	2346	100.0%

Table 1-8: Travel Time

How long did it take you, door-to-door, to travel from your beginning location to your destination?

	Count	Percent
Less than 30 minutes	796	33.9%
30 to 44 minutes	764	32.6%
45 to 59 minutes	440	18.8%
60 to 74 minutes	172	7.3%
75 to 89 minutes	77	3.3%
90 to 119 minutes	44	1.9%
2 hours or more	53	2.3%
Total	**2346**	**100.0%**

Table 1-9: Travel Time Flexibility

[If respondent traveled during morning or evening peak period[1]] If you had wanted to, could you have arrived at your final destination at a different time? (Select all that apply)

	Count	Percent
Yes, I could have arrived earlier	735	49.0%
Yes, I could have arrived later	465	31.0%
No, I could not have arrived earlier or later	608	40.5%
Total	**1501**	**100.0%**

Table 1-10: Amount of Travel Time Flexibility – Earlier

[If could have arrived at final destination earlier]
How much earlier could you have arrived at your destination?

	Count	Percent
Less than 15 minutes	170	23.1%
15 to 29 minutes	195	26.5%
30 to 44 minutes	177	24.1%
45 to 59 minutes	31	4.2%
60 to 89 minutes	103	14.0%
90 to 119 minutes	18	2.4%
2 hours or more	41	5.6%
Total	**735**	**100.0%**

[1] This question (and follow-up questions about amount of travel time flexibility, when applicable) was asked of respondents whose trips began between 6:15–8:45 a.m. or between 3:15-6:45 p.m.

Table 1-11: Amount of Travel Time Flexibility – Later

[If could have arrived at final destination later]
How much later could you have arrived at your destination?

	Count	Percent
Less than 15 minutes	53	11.4%
15 to 29 minutes	103	22.2%
30 to 44 minutes	144	31.0%
45 to 59 minutes	21	4.5%
60 to 89 minutes	88	18.9%
90 to 119 minutes	23	4.9%
2 hours or more	33	7.1%
Total	**465**	**100.0%**

Table 1-12: Delay due to Congestion

Did you experience any delay due to traffic congestion on your trip?

	Count	Percent
Yes	1522	64.9%
No	824	35.1%
Total	**2346**	**100.0%**

Table 1-13: Amount of Delay due to Congestion

[If experienced delay] How much time were you delayed by traffic congestion?

	Count	Percent
Less than 15 minutes	715	47.0%
15 to 29 minutes	642	42.2%
30 to 44 minutes	117	7.7%
45 to 59 minutes	29	1.9%
One hour or more	19	1.2%
Total	**1522**	**100.0%**

Table 1-14: Travel Time with No Delay due to Congestion

[If experienced delay] Travel time with no delay

	Count	Percent
Less than 30 minutes	955	62.7%
30 to 44 minutes	376	24.7%
45 to 59 minutes	119	7.8%
60 to 89 minutes	47	3.1%
90 to 119 minutes	13	.9%
Two hours or more	12	.8%
Total	1522	100.0%

Table 1-15: Vehicle Occupancy

Including you, how many people were in the vehicle on your trip?

	Count	Percent
1 (I drove alone)	1790	76.3%
2 people	414	17.6%
3 people	74	3.2%
4 people	39	1.7%
5 people	9	.4%
6 people or more	20	.9%
Total	2346	100.0%

Table 1-16: Trip Frequency

How often have you made this same trip, in this direction, between your beginning location to your destination in the past month (30 days)?

	Count	Percent
Less than 5 times	888	37.9%
5-9 times	296	12.6%
10-19 times	405	17.3%
20 or more times	757	32.3%
Total	2346	100.0%

Table 1-17: Trip Frequency by Market Segments

How often have you made this same trip, in this direction, between your beginning location to your destination in the past month (30 days)? BY Trip Purpose

	Home-based Work Trips		Home-based Nonwork Trips		Not Home-based Trips		Total	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Less than 5 times	222	14.9%	537	79.9%	129	70.1%	888	37.9%
5-9 times	193	13.0%	77	11.5%	26	14.1%	296	12.6%
10-19 times	360	24.2%	35	5.2%	10	5.4%	405	17.3%
20 or more times	715	48.0%	23	3.4%	19	10.3%	757	32.3%
Total	**1490**	**100.0%**	**672**	**100.0%**	**184**	**100.0%**	**2346**	**100.0%**

Table 1-18: Paid Parking

Did you pay to park at any time during your trip?

	Count	Percent
Yes	996	42.5%
No	1350	57.5%
Total	**2346**	**100.0%**

Table 1-19: Parking Cost (Hourly)

[If paid to park and paid by hour] How much did you pay to park, by hour?

	Count	Percent
Less than $5	93	86.1%
$5-$9.99	9	8.3%
$10-$14.99	4	3.7%
$15-$19.99	0	0.0%
$20 or more	2	1.9%
Total	**108**	**100.0%**

Table 1-20: Parking Cost (Daily)

[If paid to park and paid by day] How much did you pay to park, by day?

	Count	Percent
Less than $5	81	27.5%
$5-$9.99	95	32.2%
$10-$14.99	49	16.6%
$15-$19.99	54	18.3%
$20 or more	16	5.4%
Total	295	100.0%

Table 1-21: Parking Cost (Weekly)

[If paid to park and paid by week] How much did you pay to park, by week?

	Count	Percent
Less than $10	5	6.6%
$10-$19.99	25	32.9%
$20-$29.99	25	32.9%
$30-$39.99	12	15.8%
$40-$49.99	2	2.6%
$50 or more	7	9.2%
Total	76	100.0%

Table 1-22: Parking Cost (Monthly)

[If paid to park and paid by month] How much did you pay to park, by month?

	Count	Percent
Less than $10	6	1.2%
$10-$19.99	27	5.4%
$20-$29.99	47	9.3%
$30-$39.99	43	8.5%
$40-$49.99	75	14.9%
$50 or more	306	60.7%
Total	504	100.0%

Table 1-23: Parking Cost (Yearly)

[If paid to park and paid by year] How much did you pay to park, by year?

	Count	Percent
$40-$49.99	1	7.7%
$50 or more	12	92.3%
Total	13	100.0%

Table 1-24: Use of Alternate Routes to Avoid I-84

[If used I-84] Do you ever use alternate routes to avoid using I-84 in Hartford to make this same trip? (Select all that apply)

	Count	Percent
Yes, I sometimes use I-91 and/or I-691 instead of I-84 in Hartford to make this same trip	349	16.2%
Yes, I sometimes use local or city streets instead of I-84 in Hartford to make this same trip	760	35.2%
Yes, I sometimes use a combination of other freeways and local streets instead of I-84 in Hartford to make the trip	454	21.0%
No, I do not use any alternate routes and always use I-84 in Hartford to make this same trip	928	43.0%
Total	2157	

Table 1-25: Use of I-84

[If did not use I-84] Do you ever use I-84 in Hartford to make this same trip from your beginning location to your destination?

	Count	Percent
Yes, I usually use I-84 in Hartford to make this same trip	25	13.2%
Yes, I sometimes use I-84 in Hartford to make this same trip	42	22.2%
No, I do not use I-84 in Hartford to make this same trip	122	64.6%
Total	189	100.0%

Table 1-26: Use of Transit Services

Which transit services have you used in the past 30 days? (Select all that apply)	Count	Percent
CTfastrak	162	6.9%
Regular CTtransit bus routes	131	5.6%
Express bus CTtransit routes	72	3.1%
Rail routes	47	2.0%
I haven't used any transit services in the last month	2014	85.8%
Total	**2346**	

Table 1-27: Frequency of Transit Use

[If previously indicated using transit in the past month] How often have you used any transit services in the past month (30 days)?	Count	Percent
6 or more times per week	52	15.7%
4-5 times per week	40	12.0%
2-3 times per week	49	14.8%
1 time per week	34	10.2%
2-3 times per month	71	21.4%
1 time per month	78	23.5%
Total	**324**	**100.0%**

Table 1-28: Alternate Destination Availability

Instead of traveling into, out of, within or through Hartford to make your trip, could you make your trip to a different destination that avoids Hartford?	Count	Percent
Yes, I could make my trip to a different destination that does not travel within Hartford	401	17.1%
No, I could not travel to a different destination	1945	82.9%
Total	**2346**	**100.0%**

2. DEBRIEF AND OPTION QUESTIONS

Table 2-1: Departure Time Shift

[If reference trip was in a peak period and respondent chose at least one alternative to travel at a different departure time] Would you be more likely to travel before or after the peak times?

	Count	Percent
Travel before peak times	476	53.1%
Travel after peak times	421	46.9%
Total	897	100.0%

Table 2-2: Change in Trip Frequency

[If made reference trip more than once per month] In the future, would you change the number of trips you make to this destination, given the I-84 construction plans outlined here?

	Count	Percent
Yes, I would make fewer trips	864	43.4%
No, I would make the same number of trips	1128	56.6%
Total	1992	100.0%

Table 2-3: Trips to an Alternate Destination

[If would make their reference trip less frequently during construction] How many trips per month would you make to a different destination?

	Count	Percent
Wouldn't make trips to a different destination	1517	76.2%
1 to 4 trips	321	16.1%
5 to 9 trips	66	3.3%
10 to 14 trips	53	2.7%
15 or more trips	35	1.8%
Total	1992	100.0%

Table 2-4: Trips Eliminated Entirely

[If would make their reference trip less frequently during construction] How many trips per month would you stop making all together?

	Count	Percent
Would make same number of trips	1282	64.4%
1 to 4 trips	385	19.3%
5 to 9 trips	191	9.6%
10 to 14 trips	91	4.6%
15 or more trips	43	2.2%
Total	1992	

Table 2-5: Conditions for Switching to Transit

What conditions would make, or further encourage, you to change your mode of travel into, through or out of Hartford from a vehicle to transit? (Select all that apply)

	Count	Percent
Increased parking costs in Hartford	304	13.0%
Reduced availability of parking spaces in Hartford and/or changed locations of parking lots and garages	266	11.3%
Increased availability of parking at CTfastrak and/or commuter rail stations	632	26.9%
Increased frequency of service at CTfastrak and/or commuter rail stations	756	32.2%
Increased hours of bus service	600	25.6%
Reduction in fare prices	673	28.7%
Severe delays while traveling in a car	1108	47.2%
Free transit service	910	38.8%
None of the above	664	28.3%
Total	2346	

Table 2-6: Construction Plan Preference

If the Hartford I-84 Improvement project were to move forward, which construction plan would you prefer to see implemented?

	Count	Percent
Accelerated Construction Work Plan	1024	43.6%
Standard Construction Work Plan	930	39.6%
I do not prefer either of these options	392	16.7%
Total	2346	100.0%

3. DEMOGRAPHIC QUESTIONS

Table 3-1: Gender

What is your gender?

	Count	Percent
Female	1270	54.1%
Male	1076	45.9%
Total	**2346**	**100.0%**

Table 3-2: Age

Which category best indicates your age?

	Count	Percent
16-24	114	4.9%
25-34	488	20.8%
35-44	455	19.4%
45-54	602	25.7%
55-64	513	21.9%
65-74	150	6.4%
75 or older	24	1.0%
Total	**2346**	**100.0%**

Table 3-3: Employment Status

Which of the following options best describes your employment status?

	Count	Percent
Employed full-time	1787	76.2%
Employed part-time	150	6.4%
Self-employed	83	3.5%
Student	17	.7%
Student and employed	44	1.9%
Homemaker	35	1.5%
Retired	164	7.0%
Disabled	31	1.3%
Unemployed and looking for work	33	1.4%
Unemployed and not looking for work	2	.1%
Total	**2346**	**100.0%**

Table 3-4: Household Size

Including yourself, how many people live in your household?

	Count	Percent
1 (I live alone)	343	14.6%
2 people	861	36.7%
3 people	463	19.7%
4 people	460	19.6%
5 people	165	7.0%
6 or more people	54	2.3%
Total	2346	100.0%

Table 3-5: Number of Employed Household Members

[If two or more people in household] Including yourself, how many members in your household are employed full or part-time?

	Count	Percent
None	130	6.5%
1 person	467	23.3%
2 people	1138	56.8%
3 people	194	9.7%
4 people	61	3.0%
5 people	11	.5%
6 or more people	2	.1%
Total	2003	100.0%

Table 3-6: Number of Household Vehicles

How many vehicles are there currently in your household?

	Count	Percent
0 (no vehicles)	29	1.2%
1 vehicle	514	21.9%
2 vehicles	1139	48.6%
3 vehicles	450	19.2%
4 vehicles	156	6.6%
5 or more vehicles	58	2.5%
Total	2346	100.0%

Table 3-7: Annual Household Income

What category best indicates your 2015 household annual income before taxes?	Count	Percent
Less than $5,000	21	.9%
$5,000-$9,999	12	.5%
$10,000-$14,999	23	1.0%
$15,000-$19,999	27	1.2%
$20,000-$24,999	33	1.4%
$25,000-$29,999	46	2.0%
$30,000-$34,999	46	2.0%
$35,000-$39,999	34	1.4%
$40,000-$44,999	42	1.8%
$45,000-$49,999	57	2.4%
$50,000-$54,999	58	2.5%
$55,000-$59,999	66	2.8%
$60,000-$74,999	168	7.2%
$75,000-$99,999	283	12.1%
$100,000-$149,999	470	20.0%
$150,000-$199,999	307	13.1%
$200,000-$249,999	121	5.2%
$250,000 or more	122	5.2%
Prefer not to answer	410	17.5%
Total	2346	100.0%

4. TRIP SUPPRESSION RESULTS

Table 4-2: Multinomial Logit (MNL) Coefficients:

Coefficient	Alt 1: Current Route	Alt 2: Alternative Route	Alt 3-1: Early Shift	Alt 3-2: Late Shift	Alt 4-1: CT*transit* Bus	Alt 4-2: CT*fastrak*	Alt 4-3: CT*rail*	Units	Value	Rob. T-stat
Vehicle Travel Time										
Travel time	X	X	X	X				Min.	-0.0346	-27.84
Vehicle Departure Time Shift										
Shift time before peak period			X					Min.	-0.0141	-6.77
Shift after peak period				X				Min.	-0.0138	-6.41
Transit Travel Time										
CT*rail*					X			Min.	-0.0416	-18.03
CT*fastrak*						X		Min.	-0.043	-16.36
CT*transit* bus							X	Min.	-0.0331	-9.2
Transit Fare										
CT*rail*					X			$	-0.0992	-8.43
CT*fastrak*						X		$	-0.155	-7.87
CT*transit* bus							X	$	-0.707	-3.49
Reliability										
Expected reliability	X	X	X	X				Min.	-0.0487	-7.41
Dummy Variables										
Transit user					X	X	X	1,0	1.01	9.31
Alternative-Specific Constants										
Accelerated plan—current route	--Fixed--							1,0	--Fixed--	--
Accelerated plan—alternative route		X						1,0	0.0148	0.24
Accelerated plan—early shift			X					1,0	0.0647	0.44
Accelerated plan—late shift				X				1,0	-0.157	-0.99
Accelerated plan—public transit					X	X	X	1,0	-1.1	-8.59
Standard plan—current route	--Fixed--							1,0	--Fixed--	--
Standard plan—alternative route		X						1,0	-0.195	-3.64
Standard plan—early shift			X					1,0	-0.153	-1.03
Standard plan—late shift				X				1,0	-0.241	-1.58
Standard plan—transit					X	X	X	1,0	-0.873	-7.4

Table 3-1A: Multinomial Logit (MNL) Statistics

Model Statistics	
Number of parameters	19
Number of observations	23,460
Number of individuals	2,346
Initial log-likelihood	-33441
Final log-likelihood	-31083
Rho-square	0.071
Adjusted rho-square	0.07

Table 4-3: Suppression Models Non-Stratified

Model	Number of Observations	Coefficient	Standard Error	T-Stat	P-Value	Adjusted R
All respondents	1992	0.0033427	0.0001352	24.72	0	0.2345
Work trips	1514	0.0030437	0.0001435	21.21	0	0.2286
Non-work trips	478	0.004472	0.0003381	13.23	0	0.2668
Standard work plan	991	0.0036711	0.0002178	16.86	0	0.2223
Accelerated work plan	1001	0.0031494	0.0001735	18.16	0	0.2472

Table 4-4A: Suppression Models Non-Stratified Statistics

Time Penalty (min.)	Percent Reduction of Trips				
	All Respondents	Work Trips	Non-work Trips	Standard Construction Plan	Accelerated Construction Plan
0	0.00%	0.00%	0.00%	0.00%	0.00%
5	1.67%	1.52%	2.24%	1.84%	1.57%
10	3.34%	3.04%	4.47%	3.67%	3.15%
15	5.01%	4.57%	6.71%	5.51%	4.72%
20	6.69%	6.09%	8.94%	7.34%	6.30%
25	8.36%	7.61%	11.18%	9.18%	7.87%
30	10.03%	9.13%	13.42%	11.01%	9.45%
35	11.70%	10.65%	15.65%	12.85%	11.02%
40	13.37%	12.17%	17.89%	14.68%	12.60%
45	15.04%	13.70%	20.12%	16.52%	14.17%
50	16.71%	15.22%	22.36%	18.36%	15.75%

Table 4-5: Suppression Models Stratified

Construction Plan	Location and Purpose	Number of Observations	Coefficient	Standard Error	T-Stat	P-Value	Adjusted R
All respondents	All respondents	1992	0.0033427	0.0001352	24.72	<0.001	0.2345
Standard	Home based work	725	0.003218	0.000234	13.76	<0.001	0.2059
Standard	Home based other	212	0.0051068	0.0005806	8.796	<0.001	0.2639
Standard	Non-home based	51	0.005298	0.001023	5.181	<0.001	0.332
Accelerated	Home based work	706	0.002898	0.00019	15.25	<0.001	0.2468
Accelerated	Home based other	230	0.0041918	0.0004461	9.397	<0.001	0.2743
Accelerated	Non-home based	62	0.0028239	0.0007065	3.997	<0.001	0.1921

Table 4-6A: Suppression Models Stratified Statistics

Time Penalty (min.)	Percent Reduction of Trips					
	Standard Construction Plan			Accelerated Construction Plan		
	Home based work	Home based other	Non-home based	Home based work	Home based other	Non-home-based
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5	1.61%	2.55%	2.65%	1.45%	2.10%	1.41%
10	3.22%	5.11%	5.30%	2.90%	4.19%	2.82%
15	4.83%	7.66%	7.95%	4.35%	6.29%	4.24%
20	6.44%	10.21%	10.60%	5.80%	8.38%	5.65%
25	8.05%	12.77%	13.25%	7.25%	10.48%	7.06%
30	9.65%	15.32%	15.89%	8.69%	12.58%	8.47%
35	11.26%	17.87%	18.54%	10.14%	14.67%	9.88%
40	12.87%	20.43%	21.19%	11.59%	16.77%	11.30%
45	14.48%	22.98%	23.84%	13.04%	18.86%	12.71%
50	16.09%	25.53%	26.49%	14.49%	20.96%	14.12%

I-84 Hartford Stated Preference
Appendix C

Survey Comments

September 8, 2017

PREPARED BY:

RSG
TranSystems Corporation

TABLE OF CONTENTS

SURVEY COMMENTS:

On the last page of the survey, respondents had the opportunity to leave open-ended comments. These comments about the project and the survey itself are presented below, edited only for profanity.

- # of trips to and from work vary in my particular job. I have provided the average. Also, in the years to come, work at home options may change further reducing trips to and from work. Also, due to my age and financial situation, I may not be commuting beyond a few more years.
- 10 scenarios is a bit too much. I live in simsbury and share a car with my wife. We both work in downtown, so taking a bus is unlikely. That being said, delaying a project to 6-8 years is just stupid and costing too much. With Trump in place, it would be better get it done fast and live with the pain shortly, and that is the right way to go.
- 1-84 should be re-designed and modernized to follow a beltway style loop around the city - allowing ease of future expansion, while at the same time keeping the current highway as is. Once the beltway is done - it would allow a bypass,for those not needing to go to Hartford. Both highways working together would greatly reduce strain on the road and flow of traffic.
- 2 long
- 6-8 years without closing traffic is better
- 84 currently causes so much back up onto 91 that I now take back roads from home into Hartford and avoid the highway. Construction cannot make the backup worse which is dangerous with folks switching lanes last minute to get in the 84 entrance lane; or just stopping short because no one will let them in. CT Transit for me is not an option because I need to stay longer some days to get the work done.
- 84 is already a mess and it's tough to get to this location any other way. The public transportation coming from east of the river is basically non existent or lousy. I would rather drive than drive to a bus just to get on a bus. I would say leave 84 as is if possible and focus more on bring a professional hockey team back with the money
- 84 needs to reconstructed around Hartford area.
- a light rail &/or a more direct & cost effective train service to fairfield county will be much appreciated...thank you very much...
- A plan to complete work faster exploring how to reroute traffic across the river and connecting travelers to i 91 from 1 84 would help reduce some of the problem.
- A rail system is great, but if you cannot get to where you need from the train station it does not matter.
- A tunnel appears to me to be a better option than either a new viaduct or street-level roadway.

- Accelerate the project as quickly as possible (2 years or less); the added cost for completing the cost quickly will be acceptable to minimize the duration of the increased traffic congestion.
- Accessibility to and availability of bus service in Glastonbury is not good.
- Accessible, reliable, public transportation is the key.
- Actually, I think it would take a lot more time and information to meaningfully weigh the travel options you outline.
- Aetna has asked its Hartford-based employee to return to the office and be in the office at least 15 days a month. This is bad timing given the highway project and will increase traffic from what we currently see.
- Aetna has now mandated work at home employees to come back into work. The DOT should work with employers such as Aetna, Travelers and the Hartford to encourage them to allow a more flexible work arrangement and work at home employees to reduce the amount of traffic in and out of Hartford. This would alleviate some of the congestion in and around Hartford during construction.
- Aetna just changed all our work at home policy requiring full time work at home to come into the office, partial work at home to be in full time and those that would work at home 1 day a week to be in the office 5 days a week. Unfortunately, because of this new policy there will be more cars coming into the office each day with less opportunity to be able to work from home. While I understand the need to update the highway, it will create many issues working in Hartford. Hopefully some of the businesses in Hartford will be willing to let their staff work more from home to help alleviate the drive times.
- Aetna will be requiring employees to work in the office vs at home so commuting from eastern Ct to Hartford is necessary. there are no trains near my commute and I get sick on a bus.
- All they have to do is an alternative way from 84 w to route 2 that is what creates the congestion. Also make a direct connection of route 4 with Route 9. Synchronize well Traffic lights along Cottage Grove so people can quickly flow into I-91 (This latter should be cheaper and easier to do than built another fast track)
- Although likely more expensive, I would prefer the I-84 project in Hartford to be placed underground similar to the Boston big dig. This would allow the city of Hartford to have more green and open space and allow communities to better develop rather than currently being separated by the highway.
- although my work commute was correct on the map, the site indicated I'm on the CTfastak route. I checked and I do not see anything for East of the River commutes. Perhaps it saw that I live on Cedar Ridge drive in Glastonbury and thought it was Newington? I think you have an error in your questionnaire

- "As a taxpayer and motorist I would prefer to see CLOSURE and CONSTRUCTION (C&C) rather than trying to maintain traffic through the viaduct replacement project. I understand the build time and therefore the overall cost savings would be substantial. The initial push back of public opinion to C&C would be replaced by new or continued criticism to the expected traffic jams caused by allowing live traffic though the construction zone(s). An extended build time also carries with it the safety risk to all involved at the work areas. Conversely a well published notice of the impending road closure (not unlike the I84 / Marion Avenue success) would give ample time to commercial and private through-traffic to plan ahead and avoid this route.
- I believe we the public would learn to live with alternate routes for a shorter period of time than sitting in traffic for years and paying increased costs for the privilege."
- As an older adult , I find that taking Fastrack to the mall in no way appealing. I cannot imagine carrying several shopping bags on a bus trip and walking between stores and malls. In order to make several stops at stores I would be walking across the intersection carrying numerous bags. It is easier for me to go 91 south to Rt. 9 and avoid the 84 corridor. Thus saving hassle, time and stress. The bus is a great idea, but for casual shopping I find it unusable.
- bad
- Because of my job I do not have the option of taking public transportation. Sometimes equipment needs to be hauled/delivered to different buildings and I need to provide on site support at multiple locations at any given time.
- Before DOT undertakes any action to reconstruct I-84, they should ensure that other viable transit options are in place and operating efficiently. For example, beginning construction on I-84 before commuter rail service is operating would prove disastrous for traffic, and (more importantly) would miss a very big opportunity to steer people towards transit. Secondly, DOT should take a closer look at existing bus routes, express and local, to see what could be improved from a frequency and service perspective. Providing frequent, reliable service will be the key to acquiring and maintaining transit riders during this transition, and will prove to be less important than using scant public resources to build elaborate stations, parking lots, or access roads.
- Better bike options, please!
- Better traffic control East Hartford through Newington to Rte 9 for I84W
- Both I and my spouse work in Hartford and I take classes in Hartford. There is no way to avoid traveling to Hartford. The CT Fastrack does not travel close enough to my house to make it worth using (I live 3 miles from work, nearest fastrack station is 2 miles in opposite direction).
- build a sub-way system.
- build an express highway around hartford and leave 84 alone

- Bulldoze Hartford and turn it into a Big Parking Lot with a McDonalds there. Your public transit options are useless. Public transit is nt reliable and does not run close to my house in a timely manner.
- Businesses should be encouraged to allow more Work At Home options doing this time period of construction.
- businesses should increase working from home to accommodate less travel
- Close down that stretch of 84 COMPLETELY. Work on as many sections of it as possible, 24/7, 7 days a week. Free parking garages from all 4 directions into Hartford, where you can park and take a free shuttle to the downtown area where there are also free or low cost circulator bus routes. Encourage most through traffic to use alternate routes (691/91, etc). If can't use any of those, then can use local streets. Coordinate traffic signals. Where possible ADD lanes, DON'T SUBTRACT them! Use premade sections where possible to speed things along. GO FULL TILT AND FINISH THIS THING ASAP. Make sure to PLOW the local streets much better than normal during storms, so they won't bog down. By the way, I would prefer to see all options for one section Previewed, so I can make more informed choices rather than guess what is coming next. The different costs for "CTrail" were presented kind of haphazardly, for example. Just list the choices, from 0-$8.
- Close sections at night for extensive work. If they can complete build a highway butterfly interchange in NJ in a few months due to incentives for quick completion I am sure you can come up with an incentive to complete this in one year or less!!! Ultimately it saves the state and our businesses money. Don't be foolish and push even more businesses out of CT.
- Concerns over driving from East Hartford to UCONN medical center in Farmington for appts. Your survey did not consider time to take bus to Hartford and then switch to another bus and maybe another change in New Haven to get to the VA medical center. Could be a lot of waiting time in all kinds of weather. As a senior I have the 1/2 price ID card for bus transit.
- Connect CT Rail to Boston via Springfield and to Montreal!
- connect Meriden to the CT Fast track!!!
- Connect to other interstates by going around Hartford, not thru it.
- Connecticut roadways are the worst in the country…everyone who travels through this state confirms this to be true. Construction seems unending no matter what interstate you travel on. And we live in the better part of the state…I have family living in Fairfield County where not only is there ongoing roadwork but the traffic is obscene no matter when you travel in that area. It's obvious the condition of the roads as well as the traffic needs to be addressed…but it will not be painless for any of us living here.

- Contrary to a point made somewhere in the survey, there is NOT easy access to rail from Tolland to Hartford that would shorten trip. Windsor Locks is OUT of the way. So rail is not an option despite you listing it as such in the survey.
- Convenience and perceived time would drive my decisions about using rail and/or bus routes. I count the time it takes to find parking, waiting for transit, and walking to my end destination in the calculus. If the sum of time is sometimes (1 out of 3, or 1 out of 4 times) greater than drive time, I'll drive. If the total is consistently less than drive time I could see using transit instead.
- cost of the project should have been included in the survey as this would have help in the decision making process.
- Could you have some one besides our state government run this project, their track record for completing projects on time and on budget is abysmal.
- CT Fastrack would be great, but it doesn't go anywhere NEAR me. My commute would take more than double if I drove all the way out to New Britain just to get on a bus. Middletown/Cromwell is a major suburban Hub - Put a station off of I-91!
- CTFastrak and CTTransit need to add more stops in more parts of Hartford as well as make more buses available between towns.
- Current average traffic time is over 40 minutes, construction in this area should be accelerated plan considering winter weather affects construction productivity and may be one of many factors delaying the construction projects.
- Currently interviewing for a position in New Britain and the # of commuting days would increase from 2 to 20 if I get the position. Problem with public transportation is that it doesn't stop at the place I would be going or within walking distance.
- Dear Governor Malloy: stop doing this bulls***. just leave the roads alone. you made this half a billion dollar disaster of a transit system that very few people are using but we're all paying for. now you want to gut the highway and re-do the whole thing? You have no idea what you are doing, you idiot. every time you try to do something with the roads, you just end up spending MY tax money frivolously. You're going down next election, please believe, you loser.
- Dig a fricken tunnel, or extend rail lines to Norwich for god sakes. A rail system from new Britain to Hartford is a good start but I need to get to Manchester from west Hartford, or to Norwich. How about a high speed rail?
- Dig a tunnel!!!
- Do a good job on the highway construction
- do the travel times in the various scenarios include my commute time to CT transit locations from the starting point of my trip and the finishing point of my trip. If that is not included, it would likely change my responses.

- Do what Detroit did and shut it down for two years. http://michiganradio.org/post/what-expect-southbound-i-75-closes-next-two-years
- Do what is best for the long term, not just for immediate convenience. Support public transportation....it supports equality.
- Don't spend any more money on CT Fast-track, it is not used enough and runs where most commuters are not living.
- Doubling the time of ones commute should not be an option.
- Each of 10 alternate scenarios listed CT/Fastrak as an option for me even though my trip begins in Massachusetts. As such, getting to either the Elmwood or Cedar Street Fastrak stations would require that I continue South on I91 past Hartford to either route 5 or New Britten Ave. Google tells me either option would add 14 minutes to my trip under optimum circumstances. So, with no traffic at all, trip would require at least 50 minutes to get South of Hartford on I9I plus another 14 minutes to get to a Fastrack station. Add 20 minutes to park the car, wait for the bus and then travel to my place of employment at Sigourney Street and the whole trip would take an hour and 24 minutes – under the BEST of circumstances. However, your survey says that trip takes a maximum 70 minutes – really – ridiculous. So this survey is quite badly flawed by alternatives that any commuter will immediately recognize as being nonsense. You shouldn't expect anyone to take this survey seriously.

  But there are other problems as well. We all know that the DOT is enamored with Fastrak. It is, truly, a tremendous success. But really, can you think of nothing but that or a car? The train was given short shrift and not even listed as one of my options. However, the trip from Windsor to Union Station on Amtrak is short, affordable, and could get me within a couple of blocks of my place of employment. I would be using the train right now if it wasn't for its very unfriendly schedule. But, once you rip up I84, I will deal with that schedule and take the train in favor of any of your ludicrous alternatives.

  Also, have you ever heard of telecommuting? If so, there is no evidence of it in the survey. Why can't the DOT work with the governor's office to twist some arms among the larger Hartford area employers to get them to PUSH that option? There are a lot of people, like me, who can perform all of their duties from home but drive to Hartford each day only because that what their employer demands. Get rid of those cars and leave the roads to those who really need to go to Hartford.

  To answer another of your questions: What would it take to persuade me to use mass transit? How about putting charging stations in the park-and-ride lots? I drive an electric car which I can easily charge for free in my employer's parking garage. Why doesn't the Fastrak and express bus lots have charging stations? Also, I took the express bus from Enfield for 15 years when I worked for Travelers. The service to that destination was great. However, I had to give up the bus when I moved to Aetna because the very poor service to that location. My car became cheaper, faster and much more convenient. However, if the service on that route improved I would be back on the bus in a minute.

- Easier access to train stations and transport from those stations to major places in the city would be very helpful. Train is much more reliable
- employers would need to offer work at home. Transit system is too costly.
- encourage teleworking for companies impacted during the construction process
- Extend Metro North to Hartford! It is that simple, Malloy is Blind!
- Fast Track buses are a colossal waste of taxpayer money. Shame on you.
- Fast Track wouldn't work for me b/c I need to bring my son to private school prior to heading to work.
- Fast TRak from New Britain and is not convenient service at all. It would take 20 minutes just to get to the station. Makes no sense. The frequency of public transportation to the town is not accommodating. Used to take a bus but very inconvenient when plans change to get out of Hartford. I-84 is so inconvenient to get to having to drive through the awful Farmington Route 4.- that takes longer than driving through the city.
- Fastrack is a nice idea with terrible locations! the fact that you have to go to new Britain to get on the bus and get on and off at certain locations makes it a very undesirable mode of transportation. so even if you add more times and parking (which there is none), I can't use it. I would be going to New Britain to travel to Hartford. so I don't see how it would be less time. Fastrack was ill-designed.
- Fasttrac options should have notes that this is the bus time only and does not include the time required to get to the bus and from the bus to the location one is going..the survey could be biased if people do not realize this. And the downtown New Britain fast trac would increase the amount of time one needed considerably since it is not commuter friendly.
- FastTrack is not a realistic option East of the River. Your survey does not recognize this. Boo!
- FastTrak is a huge waste of taxpayer money. The state revenues wasted on FastTrak could have been better invested I-84 and I-91 Hartford exchange traffic improvements.
- For commuting by train to be practical my employer would have to provide shuttle service from the train station to the office and back. Shuttle service would have to be offered into the evening as I often work fairly late. Have a great weekend.
- For specific this trip, we went to vet for our dog. We cannot take the public transportation with my dog such a long way. The car is the only option.
- For the choices, I always picked the one that was the shortest travel time. In your examples, that was often FastTrack which is not available in my area of the state. I can't avoid 84 (or a

bridge) to travel from my home in Vernon to my job in downtown Hartford. I am a state employee with a set schedule who cannot telecommute. I am not fond of any of those options as I cannot change my work hours and cannot work from another location.

- FYI on my travel - home to west farms to airport. On alternates - predictability is best to meet work requirements, pick up children from school (attend magnet school in Hartford), manage time.
- generally I do not use the highway for commuting. I live in West Hartford and fasttrack parking stations are not convenient so I drive using city streets. I use the highway often on non-commuting trips and on weekends. The quick and painful option has an appeal but only if the very severe impacts can be limited (a couple of months). otherwise I would prefer the more extended construction option which would allow for life to continue more easily
- Get 'er done! Connecticut needs better mass transit; trains, buses, fastTrack! Let's get more connected within Connecticut and the surrounding region.
- Get good engineering consultants, and if you let the general public influence this project too much it will be doomed to failure or ultimate delay.
- get it done fast.
- Good
- Good luck
- Good luck!!!
- Good work! This is very savvy and I'm glad you're looking into this. In terms of disruption to the existing highway, it view it like removing a band-aid: I'd rather it be quicker and more painful than slower and less painful.
- Great survey instrument!
- Great to be asked. Thank you.
- Have to take my senior parent to the doctor - cannot make the train take me to West Hartford and pick him up and then take both of us to the doctor.
- How about allowing a bicycle lane on the busway shoulder? Work is 2 miles from Travelers Fastrak and home is 1 mile from Rt 4 / Knollwood intersection in Farmington. Google Maps says public transport will take 1.5 hours, so biking to work is much more practical.
- How is the state pay for this project when where in a hugh defecit
- How would rail service get me to 2012 Albann Ave, West Hartford?
- I always use I 84 when traveling out of state. I prefer I 84 than I 95!

- I am a catering and food delivery driver I need to drive on 84 to get to my customers. This would greatly affect my job
- I am a police officer in the city, and due to the nature of my job, with frequent mandated holdovers, I cannot count on catching FASTRAK or CTrail at 3:00 AM if I stay late. If I were working in the private sector, I would be much more inclined to use public transportation.
- I am hoping FastTrack will extend its service
- I am in favor of (and would use) public transportation to Hartford and its surrounds, including Bradley Airport, provided access from my home were available.
- I am unable to use CT transit services due to the fact that I need my vehicle for work. I transport students and therefore cannot use the bus or train system.
- I answered related to a pleasure trip because may daily commute which ends at exit 46 did not meet the criteria, but I expect I84 project will significantly impact me.
- I answered that I would prefer an alternative route to Hartford - honestly, I would prefer the CT fast track but I live north of Hartford. I believe that fixing 84 and reconnecting Asylum Hill to Hartford is a top priority for the health of our capital city. I would support any option that made that happen more quickly.
- i avoided this area in question on this survey, and drove through the city to get t0 84 east
- I believe these improvements to I-84 are necessary and, not just for the purpose of creating jobs, but improving the traffic flow to improve travel conditions and reduce travel times. The supplement of a bus-way/transit is a good compliment to the stated improvements. I do not believe anything is free, so I would prefer to see a fare for transit as a public buyer option. At the same time, free fares should be provided to those "workers" who need to use the transit as work transportation. Public users would still be required to pay the transit fee.
- I believe this would be a nice thing to do for our highways opening a new lane and it wouldnt b so congested and might just save lives cause everyone wouldnt be so cramed from triing to enter on or getting off the highway. Thank you
- I cannot take public transportation because I have little children who have emergencies and I may need to leave work unexpectedly during the day. My friend tried to us the emergency ride once and had major issues with it--she had to end up taking the bus anyway. I also prefer not to take an alternate route to my job at 151 Farmington Avenue because the neighborhoods which I would need to pass through are very sketchy. I just wanted to share with you the reasoning behind my choices.
- I can't take public transportation like Fast Trak due to being a single parent with a child that is in school and may need to be picked up during the day due to illness, etc. Fast Trak does not provide me with flexibility and I have no help with transportation. I currently work from home

full time but my employer is eliminating that option so I will need to commute full time on 84. Seems like bad timing due to the construction.

- I choose to NOT use the transit option due to Safety concerns
- I chose the quicker plan for construction because I'm hoping that it would be less likely to go over budget during that time and incur less delays.
- I commute on I-84 every day but only for a part of the distance (get on/off at Sission Ave.) Did not use that trip as it didn't cover the whole study distance (perhaps that was a mistake). I chose transit over each other option when presented with choices because they were attractive in terms of time and cost, however I do not believe that CT Transit properly covers the locations I listed (Tolland, CT) or the times I would need to make the trip I gave as an example (8PM- with 11PM return).
- I considered taking the fast track and did a couple of times, but I do not feel safe on the bus. Some of the drivers are reckless and some of the passengers are obviously not on there due to working commuting reasons.
- I could work from home if my company would let me.
- I currently have access to the Hartford Express (Middletown/Old Saybrook Route) bus service through CT Transit. It would be extremely helpful to have both later morning and evening options, 1-2 maximum. The service is great, but added options would make it even better.
- I currently use the Express Bus from Cheshire to Hartford which does use 84 to 72 to the busway in New Britain. However, the reliability of the pick up time in the afternoon causes me to drive in because the afternoon busses are never on time and if I need to be somewhere at a certain time I have to eat the cost of parking at my employers. The bus routes would have to become more efficient and consistent during the construction in addition, I can foresee more people taking the bus due to the delays in 84, we will need more busses running to accommodate the volume, is the fast trak prepared to handle the increased volume?
- I didn't like that this survey was based on your most recent trip into Hartford as that might not be your typical trip. This also did not allow for when your schedule will increase the number of trips into Hartford in the future. I am full time work at home now but will be driving into Hartford 5 days a week in the coming months.
- I didn't understand the variants of the 10 questions - couldn't see what was being changed to determine what answer to put - I chose the $2 transit because I would love to see CT expand its transit system, I would use my car less if I had more options for public transit
- I do military funeral honors, using 84 for west of the river cemeteries. Have to drive own vehicle, transporting special equipment. Public transit is never in the equation. I would use 291 or 9 to go around Hartford. Also, the current design of 84/91 intersections [all ways] suggests that the state planning and execution will be a clust-f, as usual.

- I don not see how the CT FastTRak that runs between New Britain and Hartford would help me since I live in Colchester/Hebron area which is Eastern CT; not near the New Britain line in any way shape or form. Our buses from Colchester are limited.
- I don't know if it is obvious from my answers, but I take the Glastonbury commuter bus everyday EXCEPT when I have a reason to need to drive. I have no reason to want to change that.
- I don't like the idea of delays for 2-3 or even 6-8 years, but I support the initiative. I think it has to happen.
- I don't take public transportation due to personal safety concerns, the cost and time associated are irrelevant.
- I don't understand why Connecticut rebuilds roads only to shoot themselves in the foot. Ex: Rebuild (and widen) I-95 Bridgeport then restrict traffic flow with wider than normal breakdown lanes on both sides. Same thing possibly in New Haven area but they are not completed yet. Another beneficial way would be 1/2 loops. As an example - build a connecting highway looping I-95 Milford to I-91 North Haven and then another loop I-91 North Haven to i-95 Branford. Works everywhere else.
- I don't view the bus as a viable option when I'd have to take one into Hartford then transfer out to the Manchester location I used as an example. I will probably view FastTrak as more viable going to the XL Center and Dunkin Donuts Park once construction begins. I already try to avoid I-84 in Hartford at all costs and use I-91 to the Charter Oak Bridge and I-84 E as well as going through New Britain on I-84W trips. Both construction options bring pain to the citizens, difficult to choose between more severe but less duration vs. less severe but still painful but for a longer duration. Neither are very desirable. How about Larson's idea and get all the through traffic off I-84 from Sisson Ave to I-91 before tackling the Viaduct? (That's as close to the initial intent of the Interstate Highway system as we can probably get today. Yes, expensive but how would it compare to some other I-84 rerouting that bypassed Hartford altogether?) How about fixing the I-91 ramps to/from the Charter Oak Bridge first so more traffic can be routed via I-691 and I-91 to again reduce traffic flow in the Viaduct area? How about not delaying the commuter rail implementation if a budget cut occurs so you can get some people out of their cars NOW? How about you devise dedicated, frequent bus service from Union Station to major employers in Downtown Hartford, Hartford Hospital, St. Francis Hospital and Pratt & Whitney to entice more to use rail and get more people out of their cars?
- I drive my children to and from magnet high school, so the boondoggle busway is not an option.
- I drive to Waterbury to see family and if this construction is like that construction … please think thru it carefully. Maybe chunk it out. I did say to myself regarding the repair of Rte 2 ramp into Hartford when it was done … wow … that was fast. Use that as a model. Chunk it out into small

sprints. And I know you tried to give options in the survey, but the only answer anyone wants is … as few slow downs as possible in the shortest time frame as possible.

- I feel I84 does need improvements for smoother travel into the city
- I feel it would be very enticing and beneficial if the state of CT could offer a train line West of Hartford to surrounding towns such as Bristol, New Britain, and Farmington.
- I feel that with the money spent on CT FasTrak and the proposed New Haven-Springfield rail line -- which, by the way, duplicates an existing Amtrak route -- those of us who prefer to drive are being pushed into using public transportation, probably out of concern for climate change which is supposedly man-made, though this has never been conclusively proven.
- I felt as though the premise of these questions was unrealistic as there is nothing that would cause me to stop commuting to work. Even if travel times increase significantly due to construction, it is not as if my employer would allow me to work from home or work during non-standard business hours.
- I go to west hartford a lot for dinner and social reasons.
- I have a child in school/daycare and cannot leave at an alternate time or take public transportation that runs on a set schedule. I need to put my child up at various times if I receive a call from the school/daycare.
- I have almost never used mass transit in my life except in city subways (this includes most of the people that I know as well) and the primary reason for that is most of the transit options in Hartford County are not as quick and convenient as a car. If this were to change you would see a dramatic increase in public transportation use (assuming reasonable cost). I really hope that someday in the future that there are high speed rail options (outside of heavy traffic areas, I see this as really the only mass transit option for faster then a car service).
- I have alternatives on local streets that I wouldn't anticipate would add the amount of time to my trip that your choices indicated.
- I have an option to work from home at my current job. If there is significant traffic delay due to construction, I'd explore the option of working from home more often, and avoiding the commute to Hartford. Many businesses in Hartford may offer this option for employees.
- I have taken the bus into Hartford in the past. The additional time to travel due to transfers and infrequency of buses made me say I'd never do it again.
- I have to commute in to Hartford for work. Unless they allow us to telecommute during the heavy construction, I will be expected to commute to and from Hartford 5 days a week. If I had permission from my employer to work from home I would not commute to Hartford and thus reduce the amount of people on 84.

- I have to commute through Waterbury, almost every day there is a back up. Please do not start the Hartford project, until Waterbury is finished, otherwise I will have to deal with 2 traffic jams every day I commute into Hartford. Also I thought the State was broke, How can they justify the expense of this project.
- I hope all considerations are thought of when asking these Questions.(Security at Commuter lots, traffic conditions when going and coming from work, etc.)
- I hope this helps!
- I know and understand that 84 has to be revamped. That being said, I live in Newington, where traffic during rush hour is heavy and backs up on major routes. I dread this rebuild as it will force vehicles off the highway onto local streets. Luckily, my spouse and I are retired. We can avoid traveling at these times. We also have the option to avoid I84 in Hartford, which I choose to do now...can't stand the traffic.
- I know there is a commuter bus parking lot conveniently located near my home, but I don't think there is a bus which will take me to & from my office in Farmington.
- i know this wasn't one of the survey options, but I sort of like the tunnel option! Thanks!
- I leave my house in East Haven at 4:15am to get to Hartford. I do this to avoid any morning traffic issues and so I can leave work at 2:00 pm to get home in the afternoon. On my afternoon trip I frequently use Capitol Ave to get to Trinity St and on to Elm (then under the library) to I91 south. I'm not a big fan of traffic and I avoid getting on 84E by the Courant because there are too many idiots changing lanes in that area (my afternoon trip home). I'd take the train from New Haven on the expanded line to Hartford if the trains would run at the same time I'm coming in (4:15am to 5:00am say) and there is free parking in New Haven to do this. I've been a van driver for Aetna in the past driving from Tolland to Windsor for (12 years) and I also car pooled with other people from Coventry to Middletown (8 years). I have also taken the Coach bus from Bolton to Hartford (7 years) and that's a great way to travel. I've been at Aetna for 34 years, so I've done ALOT of rides to and from work on most of the major state roads and from all of Aetna's major locations in CT. Good luck with the Aetna viaduct project, this has to be one of the most engineering intensive projects the DOT will ever face as well as another lane on 95.
- I like the idea of a commuter rail service coming to Enfield, CT. As long as the cost is low. I think rates more than $4 round trip will become cost prohibitive.
- I like the idea of mass transit. It is important that I can park easily near a station and get to my locations in Hartford easily too. I've never paid much attention to FasTrack but believe it is our future especially having commuted in and through Hartford over the last four years. I would offer DOT should do what is best for the long-term goals of the residents and now be concerned with short-term blowback.

- I like WestFarms mall - I sometimes go to Evergreen in South WIndsor. if West Farms became a hassle to get to I would shop online more. Also bus service seems severely limited in non-rush hour situations, and there does not seem to be much service from the suburbs to anywhere but downtown Hartford, To go other places requires a lot of waiting and transfers, I love public transportation, I grew up in NYC, and travel often to Wash DC and use the metro, The options in Northern CT are lackluster. With the demise of the Enfield Mall approaching, maybe a transportation hub should be built there and not a casino...
- I live 8 miles from my workplace so Fast track is not a viable option
- I live by UConn health ctr in Farmington, CT. By main route to travel is 84. My elderly parents live in Dover, NH and I visit them a few times per month or if they are ill weekly. This construction may necessitate my renting an apartment in NH to stay there when necessary. I mostly travel during daylight. This will be an extreme inconvenience
- I live east of Hartford, in Manchester. There is NO LOCAL ROAD OR ALTERNATE ROUTE that one can take to get into the city ... even if we take local roads, EVENTUALLY WE HAVE TO TAKE I-84 to cross the river. People who live North, South and West have the luxury of having numerous alternate routes, we do not! I hope this is kept in mind during your planning stages. We who live east are sitting ducks for commuting disaster. Thank you.
- I live in a town where not everyone has access to a computer to complete a survey such as this one. I am concerned that the survey results will be skewed to reflect only those drivers with internet and computer access. It will not be a fair representation of the sentiments and opinions of those in my town of East Hartford, or those in the City of Hartford. Thank you for listening.
- I live in Avon. The Fast track from New Britain is useless to me. I commute on city streets. Virtually all the delays are on Asylum Avenue in Hartford. Those could be SUBSTANTIALLY reduced with very little effort: 1) enforce the parking ban in rush hour, 2) plow to the curbs when it snows, 3) re-schedule the HARC businesses to a time other than rush hour. If you are going to force more traffic on city streets you should fix the current congestion problems now. You should also build a decent Hartford by-pass for I-84 through traffic before taking down the current roadway. The interstate should never have been routed through the city in the first place.
- I live in Cromwell, work in Hartford, had to go to West Hartford. Why would I take the bus from Hartford to West Hartford only to take the bus back to Hartford and then drive back to Cromwell?
- I live in East Hampton, CT, yet the survey indicated that CT Fast track, which runs between New Britain and Hartford, is available to me, but it isn't, so your survey is flawed. Some options to take CT transit during construction would not save any time because the bus would have to take the same route as I would in my car.

- I live in Hartford and work 3 jobs, look after my mom, and go to school - so I travel from Hartford north on 91, then east on 84, then west on 84, and back and forth again every day. Transit is not easy for me. But I applaud it for everyone who can use it!
- I live in Simsbury which is inconvenient to either 84 or 91. I travel and city streets from West Hartford to Hartford routinely.
- i love CT Transit and FastTrak
- I love mass transit. I wish we had more trains, especially from hartford to new haven trains. They are way too expensive and take longer than driving. not helpful.
- I love the transit service & have used it in the past for about 2 years. I do not use it now because I work at home. I would recommend the transit service to others.
- I need to have my car at work for occasional work use, so I can't take mass transit even if I wanted to. You need to ask that which would narrow the (too) many choices that are presented. Also, the travel times for the C-rail are impossibly short and apparently don't take into account the drive to and parking and waiting times at the station.
- I often travel from New Haven or Stamford to New York and use Metro north as an alternate to driving in and I'm not opposed to public transportation; however, I think that the CT Fasttrack was poorly planned and therefore, I choose not to use it. I live in New Britain and the Downtown New Britain station was poorly designed with a commuter parking lot which is a very far walk from the station. The closest parking facility is the Municipal Garage behind City Hall on Washington Street. It's a good hike from the garage to the station. If you are not a municipal employee working at City Hall, don't even think of parking on the first 3 floors of the garage. The added hassle of a far walk from the station is a deterrent from taking the CT Fasttrack because, in the end driving is more convenient - and I'd still have to pay for parking. The Newington as well as West Hartford stations have very limited parking (30-50 spaces). I hope parking is taken into consideration in the planning process - particularly if there's an expected increase in the number of people taking the CT Fasttrack as a result of the upcoming construction.
- I only make 2 trips per month to that particular location, but I probably make about 20 trips per month to Hartford. I would drive to Hartford via Route 10 and Farmington Ave if I-84 were slower. I would prefer to travel to Hartford by rail or bus, but there is no rail service in my town and the nearest bus stop is a 25 minute walk. I love the city of Hartford and I would like to move there as soon as I save up enough money and find a job there; however, I would not choose to move to Hartford if I-84 were to be down for 5-10 years. I would probably choose New Haven, Stamford, or New York City instead. I hope construction can be accomplished on a timeframe closer to 2-4 years. I am willing to put up with hassles or delays for a few years if it will result in significant improvements to CT's transit systems. As far as parking and then taking oublic transit - that is far too much effort to be worthwhile. I only want public transit or car transit - not both. I

would love to have public transit to Hartford, because then I could have drinks and come home by myself, but as of now the public transportation is far too scarce where I live. I would need to get a ride to and from a park and ride, which is more difficult then just driving. Having to use a car and buses makes the trip not worth the effort.

- I plan to kill myself if you make my commute 1 hr each day. Wasn't on your option list. The only reason I am on 84 is because you closed Flower street making it easier to take 84 to 91 rather than city streets to 91. Fastrack is useless for the eastern side of Newington because we have to travel 15 minutes in the wrong way to get to it. I already go in to work at 5am to avoid rush hour.
- I really hope there are other options for the construction!! :)
- I ride a bike to work every day.
- I ride CT Transit from Middletown to Hartford. Fasttrack is not an option for me.
- I seriously doubt that CT Transit could deliver me to my sister-in-law's house that is out in the middle of nowhere, over narrow winding roads.
- I stopped taking the bus due to it could not get me at work at the time I needed, my wife was driving me in. I need to be at work at 5:00am at Aetna, driving was much more cost effective. I would love to start taking the bus again both ways.
- I think a good idea would be to provide free transit service through Hartford during the constuction project. Particularly if the highway is closed.
- i think free ct transit would be great
- I think i-84 should be built out around the city of Hartford first to allow through traffic to go around the city. Then once that is built, deal with the Aetna viaduct. Keeping through traffic on an interstate that goes around the city would lower daily traffic going into the city. It'd be great to either bury i84 as it goes through Hartford to reunite the city.
- i think if you let people know of the delays and provide alternate routes to make things smoother it should be handled better
- I think it is unreasonable to suggest a project that will take 3 years and cause severe delays. We need to see a project that is 1-2 years if it will cause severe delays versus dragging our the project like the stadium. Rails being offered do not go to my portion of the state so the 4th scenario of a rail line is inaccurate because the commute times do not take into the account that I would need to drive to new haven first to get to Hartford which is completely crazy to do. My commute should take 40 minutes. I can handle up to an hour when there is an accident and up to 1.5 hours for severe weather. Anything over 1 hour on a regular basis is not reasonable. Cutting off access to Hartford is not good for business. I would want to see what these plans would improve before we commit to changes.

- i think it would be stupid to close down the highway completely . People need to get to work and to other places. They need to do the construction at night after 6 or 7 to 4 am in the morning, makes sense less people on road.
- I think it's a little ridiculous that there is a suggestion I take the CT Fast Track. I live in Colchester. It would take me 40 minutes, without traffic, to get to New Britain. Then another 45 minutes riding the bus to get into Hartford/my place of work. That is not at all a reasonable option.
- I think that you should have pointed out that the project will not address congestion which is predicted to be as bad after the project is done as it is now. This project must improve throughput to have any real value to the people most affected.
- I think the CT Fast Trak estimates were way off. First to get from Cromwell/Rocky Hill after having my granddaughter catch her school bus (which is why it's 8:15AM) the commute to get to the Fast Trak in New Britain itself is 20 minutes not 20 minutes for me to get to my work office. The exit off of Rt. 9 is bad. Just like I84 which is the worse part of the commute. The Asylum St. Exit is horrible as too much traffic getting off between, HIG, Aetna, and State Workers. If anything I could look at a local or Express bus but those routes are limited and will have the same issues.
- I think the current availability of CT public transit is very poor. I never use it for the greater Hartford area. If I had access to the bus/shuttle/subway systems in the greater Boston area or the greater Portland, OR area, I wouldn't hesitate to commit to using public transit more frequently. As things are if traffic delays get so bad (trip time doubled or tripled!) I will be forced to rely on alternate routes and/or going somewhere else instead.
- I think there should more service in the Windsor area.
- I think this survery was very well done! I usually get bored, but this was about soemthing I actually cared for. Thanks!
- I took the CT Fast Track five times. I feared for my safety while taking CT Fast Track and am very concerned that this is going to be my only option for commuting to work to provide for my family (me and 3 kids). It greatly saddens and worries me that my options are going to be adding 2-4 hours of commute time to my daily travel because this would limit my time with my children, would hinder me getting them to after school activities, would put a financial burden on me to provide additional child care and an emotional impact on being physically unavailable to assist them with homework and cook a healthy meal for them.
- I travel the route from 06107 to 06033 to bring my child to a gymnastics studio. There is no mass transit service for this trip. The trip requires vehicle transit. I do work in Hartford and take CTFastrack which is great!

- I tried using CT transit. The closest commuter lot is 15 minutes in the opposite direction and with going to the commuter lot, waiting and taking the bus and the stops through Hartford my trip was over an hour. This meant getting up earlier and getting home later and this was inconvenient.
- I use 84 a lot for personal reasons and FastTrack would NOT be an option for me to get to places east of Hartford, where I frequent.
- I use my car at the office to do volunteer work at lunchtime and after work. I could not carry the items on the bus that I need daily. I deliver items from the volunteer council to shelters and hospitals, including left over food.
- I used to be able to work from home which would have eliminated the need for me to travel during construction times but the company I work for has determined management needs to work more from the office.
- I used to use i-84 more frequently when my parents lived in Waterbury. The construction project in Waterbury took forever and had to be redone. Surely, we could do a better job in the Hartford project. My other preference would be to complete a ring road around Hartford.
- I very strongly support the shortest construction time-frame option available to the DOT.
- I want to see CT Fastrak succeed! However, there needs to be one or more dedicated "stations" in downtown Hartford. For example, the new transportation center, near the stadiums, downtown east/Front Street. Also, with the east of the river routes there needs to be a stop near Rentschler Field with large available parking availabliity.
- I was told that this survey would take 2 minute -- what a lie! Unless the person taking it is unemployed, I can't imagine that she or he would be willing to spend this amount of time to do it.
- I wish I could flex my work hours or location (i.e., work from home), but it really isn't possible. I can get to the office early/stay late, but this would add a lot of extra hours to my day. However, I also understand this construction project is needed and will cause significant hassle for everyone no matter how/when it was done. Very curious to hear how it will end up being paid for
- I wish I could use public transport, but as a licensed massage therapist, I have multiple bags of linens that I need to transport to and from work daily, and public transport makes that VERY challenging!
- I wish I had bus service from the shoreline here in Guilford to Hartford. I would take it three days a week and it would make my life much easier. Now, I have to drive to Middletown to get the CT bus to Hartford. It is a tough commute. I could drive to Old Saybrook, but then my commute starts at 5 AM, that is not an option.

- I wish the construction would include flattening and straightening I-84 through West Hartford, and a fly over/around for vehicles that are just passing by Hartford and not into Hartford. Unless that happens I don't see traffic improving in and out of Hartford at all.
- I wish the survey wasn't so generic and would involve more specific travel routes and directions. Everyone doesn't use the Fast Track and if it were a feasible option for me, there isn't a place to park my vehicle for free so that I can take advantage of the transportation between New Britain and Hartford. There needs to be better consideration for those of us who have vehicles and would like to take advantage of the public transportation system.
- I work at St. Francis Hospital. I don't mind the idea of taking public transportation. I can easily take an Express bus from Manchester into Hartford. But once I get into Hartford, I need to transfer to a local bus in order to get to St. Francis. Because of the additional time this transition can add to my compute is why I drive in rather than use the bus. If some of the Express bus routes could be adjusted to include such locations as St. Francis (as is done with Aetna & State Offices), I would be willing to consider riding CT Transit more frequently. Also, more companies need to encourage their employees to use public transportation. Currently employees can buy bus passes at St. Francis, but the hospital really does not encourage ridership. There are no incentives to do so especially as they offer free parking.
- I work in East Haddam, CT at the Goodspeed Opera House. There are no public transportation options that would get me to East Haddam so your questions asking me to consider public transit as an option were not relevant. I would take public transit to the Goodspeed Opera House if it were available. And so would our patrons!
- I would be able to commute less but my employer is reducing telework
- I would be against a rail system from east of the river into Hartford. Huge cost and I don't believe it would be utilized. Adults with children need the flexibility, and more employers are offering work at home. If employees continue to have this flexibility with their employers they will travel off peak to have the flexibility to get to where they need to get after work without having to go to a commuter lot which will extend drive time to their final destination.
- I would be extremely interested in a commuter rail service between Springfield MA and Hartford.
- I would be willing to do more work at home which had been widely encouraged by my Hartford employer but is now requesting employees to come into the office 3-5 days/week.
- i would consider that most people are not just taking a one way trip. most people have lots of things to do. so having my vehicle allows me freedom to go anywhere. i would pay for an express lane. for quicker access to the hartford area if i needed to go that way.. having my vehicle is most important part of ,my travels

- I would find any solution that turns my commute to anything more that 20 minutes from home to Hartford absolutely unacceptable. Seems like the state should have been planning this years ago in order to avoid severely inconveniencing it's working residents that commute to the state capital city to work.
- i would have the option of a different route eg; 91
- i would like for the traffic could be managed more and drivers be more careful on the road.
- i would like free bus ride tickets sometimes
- I would like to see whatever construction project is the cheapest completed, and completed right. Stick to a budget and timeline and fire the workers if they are falling behind. Tax payers do not want their money spent on highways.
- I would like to take the Express bus that picks up on Silver Street Park and ride in Middletown more often, but the bus's last pickup in the morning from Middletown is too early for me. If there were more pickups after the 7:50, I could commute that way no problem. Ideally an 8:50 and/or 8:30 could make a difference for me and some others that I know work in Hartford but live in Middletown.
- I would love to take a ctfastrak or CT transit bus from West Hartford center that continues on to Pratt and Whitney without need to transfer.
- I would love to take fasttrak daily but with daycare location not on the fast track line it makes it almost impossible to change driving to public transportation without adding hours to my day.
- I would love to take mass transit or the Fastrack but both are cumbersome for where I go. I am in North West Hartford on the Bloomfield line and when I go into Hartford for business it's to the southside of downtown (Hartford Hospital). There is not a fastrack station near me or that makes sense to use. The closest is Elmwood with is the absolute opposite side of town from me. This survey seemed to think that because I am in West Hartford I was near the Fastrack or 84 and I'm not close to either. I am on a bus route but would have to change buses at the old State house and I've never quite figured out which bus is where there. And it makes my current trip about twice as long or more. So it would make any of your proposed route times even longer. I am really looking forward to the redone 84 and would love more mass transit options and ease.
- I would love to use public transportation but child care responsibilities require that I have a car at work.
- I would much rather see the construction done during the evening hours - 7PM to 7AM then during the day. Traffic is horrible enough as it is without any closures.
- I would need to go to the same destination in Hartford area but would try and find an alternate route or take a bus if it were easy for me to do so.

- I would not pick the rail options until I know how I would get from the rail station to work. currently I park in a garage at my work location. the options you provided for rail, gave me no info (including associated cost) on how I would get from the rail station to my work location. I would consider using rail service if I knew that travel from the rail station to my work location was readily available and at a minimal cost.
- I would not recommend increasing parking prices or decreasing parking options in Hartford just to deter drivers from going to the city - that will only piss people off, especially those that need to go into the city every day for work.
- I would opt for the Fast Track but it seems to me that you are planning to use the construction to the benefit the state by raising transit fares, I could not get off the page without making a selection but I will NOT pay $3.00 or more each way to leave my care in an unsecured area and doesn't have enough parking.
- I would personally rather deal with worse traffic for a shorter amount of time, knowing that a better solution is only 3 years away, instead of dealing with traffic for 6-8 years.
- I would possibly use the rail option if it went between downtown, MCC , malls and I could take my trained, hypoallergenic dog
- I would prefer a total shutdown of I-84 to speed up construction. I heard at one meeting that plan would mean construction might take 6-9 months. I'd rather be totally hassled for 9 months than drag it out for 2-3 years. Further, if there was greater hartford train service; subway, metro-north type I'd take it and pay for it. Besides Fast-trak local buses are too slow and just stuck with the regular cattle.
- I would prefer that you build a loop around Hartford for people who do not work in the city or do not have business here. I work in Hartford 6 days a week, so this is not an option. I do not like the restrictions of taking a bus, because of obligations or errands I always need to get done. I would probably take city streets into the city if the highway is detoured. please make sure the signs are CLEAR about the areas closed or detoured. thank you. If you need any other suggestion feel free to ask.
- I would prefer to use a multimodal transit strategy with a combination bike/car (ride my bike from EH to Farmington after driving from Bolton to EH with the reverse upon my return home). I currently do this but would appreciate safer bike riding conditions in Hartford. I can ride a bike faster from Farmington to EH than I can drive on most days. I would also consider taking the Fasttrack with my bike if I could guarantee that my bike could have a place on the bus. There are currently 2 spots. If the fast track route extends with more routes east of the CT river, I would use this service more often with my bike.
- I would probably consider biking as a more viable option to get to and from downtown

- I would probably use side streets thru the Arigoni bridge, Portland and Glastonbury to get to 84 east in East Hartford area. This takes about 45 - 55 minutes.
- I would really like to see some better plans that require less delays for drivers and less emphasis on this CTrail idea.
- I would really like to see the CTFastTrak service expanded to make travel around the metro area and surrounding towns more efficient.
- I would take a local bus or ride a bike or walk before I would use most of your suggested alternatives.
- I would take CT bus transit if there was a bus that left Hartford around 3:00/3:30 and traveling to the Bristol/Southington avenue (express). I work 7 - 3 and the only bus available to me to get home is at 3:50 which will get me home too late for my evening activities.
- I would take public transit if it dropped me off right in front of work.
- I would take the Express bus route in Unionville, if additional routes were added to give me more than just two chances to catch it.
- I would use public transit, there are no good options from Rocky Hill. It's easier to get on the highway for me than drive to anyone of the stations in New Britain or Newington.
- I would use the CT FastTrack but I'm concerned that there is not enough parking at my nearest station. Also, my child is in daycare and worry about not having a vehicle at my worksite in the event of an emergency.
- I would work from home more often to avoid the traffic delays and would have chosen and accelerated plan, but my employer is now cutting back on work at home options.
- I84 - I91 bypass loop. What happened to that?
- I-84 aND I-91 are already congested highways. To have construction that will last 2-6 years would have a great impact on life. United States should really learn about constructing highways aND engineering from Japan. Please, consult them. They really know how to fix a road in the least possible time.
- I-84 in Hartford has been outdated for many years. It is in need of serious updating. I understanding it will be messy during the updating process, but the quicker it can be accomplished the better.
- I-84 should have 4 through lanes for travel from Exit 39A at Route 9 through exit 59 at route 384. The Bulkley Bridge should be widened to 12 total lanes and 84 through East Hartford should also be rebuilt to build the additional travel lanes. The current project will not add any additional travel lanes thus the same traffic load and delays through Hartford will occur unless additional lanes are added.

- If CT 902 Express has more frequency and its drop off points in Hartford are increased, then I would prefer to take 902 Express over CTFastrack, as it will save me more time in commuting from home to CTFastTrack station.
- If I felt safer to walk around the train station, I would walk to work instead of driving to work.
- If I took CT Fasttrack, the closest station is in chesire / Waterbury line. I would still have to drive through Waterbury construction to get to the station. I cannot predict traffic in Waterbury each day so I don't have the ability to arrive at the station by a certain time.
- if i worked in hartford, I would take a bus. mostly i go to hartford for the theater. if I can (depends on weather) I park in east hartford and walk over the bridge
- If it takes me more than an hour to get to Hartford every day for 4-6 years I will look to relocate out of State. It already takes too long to get in and out of the city during rush hour. I am also not happy about proposed tolls. Tolls were removed and replaced by the gas tax. Now you want to reinstate tolls and keep the gas tax.
- If it were possible, I would prefer to maintain the existing viaduct. We don't need more expensive highway projects. We need more viable transit options. Frequent service inter-city bus lines would be a good place to start.
- If my dog could accompany me on transit, I would consider that option.
- If somehow that bike lane adjacent to the fast track were extended from New Britain into Hartford, I'd ride my bike on days where weather was fine and take the bus on poor weather days! The bike lanes from my location in West Hartford to downtown are not very safe, nor direct.
- If the closest rail service is 40-45 minutes away (Rockville to Windsor) and then you sit on a train for 40 minutes - that is not a faster commute. Check your math.
- If there are increased coverage of CTFasttrack to Rocky Hill, or increased frequency of CTTransit buses from & to Rocky Hill, I would consider switching to public transport.
- If there was an inexpensive ($1) uber-style pickup service that brought folks within 1 mile to the FasTrak station, I would definitely use it.
- IF there was security at Fast Track locations- Live web cameras or other security measures...I would consider it
- If there were buses from Windsor early enough, I would consider using them. Your FastTrack suggestion has me driving 10 miles to pick up a bus to drive 1 mile to work. Kinda silly.
- If there were more convenient rail or bus options along 84, that would be a better option than expecting people in this area to drive to a train station along 91 - once you factor in the time to get to the station, travel time and then a bus from the train station to work, it's not that

appealing of an option at all. My employer allows telework, so I would hope that they would be more flexible about how many days we could work from home during the construction.

- If this major construction is going to happen I hope my employer Aetna will be even more flexible with work at home situations to help with the traffic.
- If this project goes through I would consider leaving the State of Connecticut
- If you are going to ask my starting point and destination, why on earth would you think that FastTrak is an option I would consider? It takes me 10-15 minutes to get to the nearest station, and it dumps me in Hartford where I would have to transfer to another bus to get to East Hartford where I am left almost a mile from my destination??? They the hell would I pay for that? I take the route 66 bus when I have to go into my office in Hartford because 84 is a pain, but if I have to get east of the river, it makes no sense to take the buses because by the time you're done transferring and having the bus stuck in traffic, it's faster and costs less to drive.
- If you do go cover the highway with a sort of park (please do), you should have Dunkin Donuts chip in for some goats and a goat landscaper. Goats on the greens would be a great tourist opportunity. And it's not as ridiculous as it sounds. Portland's done it. Boston. Brooklyn. And none of them have a goat-themed baseball team. Goats. Think about it.
- If you offered personal security (i.e. bodyguard) to accompany me to and from the transit station to my place of employment, then maybe I would consider choosing an alternative method of transportation.
- If you were to create this reconstruction my concern would be living in east hartford, hypothetically, where would i take the train? There's no train service out here. Would i have to take the bus? Would the buses also get stuck in this traffic or would you be creating alternate routes for these buses? These are just some of the many of my concerns.
- Ignorant people driving with no licenses and no insurance disobeying US driving laws cause problems on I 84. The highway is just fine.
- I'm a mom of 2small kids. I would be surprised if you found other parents with young children willing to give up their personal vehicles for mass transit, while trying to travel into/through Hartford and West Hartford. I would think that's a pretty big demographic of travelers.
- I'm concerned in the lack of attention placed on all the accidents caused by the very curvy areas of I84 in the WestHartford area.
- I'm glad there will be an effort to improve the highway system into Hartford. I think I84, I91, and Rt2 are all poorly constructed and not very good highways for today and the future. There are not enough lanes. Merging between highways and exiting the highways is actually very dangerous.

- I'm not sure what assumptions this survey had. For example, does the travel time include the mix master work tear down work that hasn't started yet..
- I'm not sure why you suggested fasttrack as an option for me as it's not at all on my route. Route 2 travel is very much not convenient for getting over to the fast track route.
- I'm sure you have done this but you should reach out to major employers in the Hartford area and ask them to push Work At Home arrangements with their employees if you do an accelerated build. Even adding one WAH day to a regular office employee's schedule should help reduce traffic.
- In addition to the length of commute time, a big concern for me is the total estimated cost for both of the reconstruction options, which was not addressed or mentioned at any point in this survey. I think any taxpayer that is taking this survey should also be informed as to what the total estimated cost would be for both of these options, as that would weigh into what their responses would be.
- In most cases like mine the suggestions of this survey are not applicable as I need to get my child to daycare which requires a specific timeframe as well as being forced to no longer work from home but commute into the office everyday by my employers after having been full-time work from home for 9 years. I would rather not have to deal with this traffic at all but it is not an option.
- Increase and make our bus services more effective, efficient, and actually meet the needs of the community (more bus offerings at later times and on weekends, better transfer connections, separate bus lanes and separate green light signals so buses are actually faster than cars), increase paid parking in the cities and popular towns. Get more people on buses--let's be more like Seattle!!!
- Increase availability of fasttrak or rail stations; have it reach further south than just New Britain. it would be nice to have a line that goes from New Haven to Hartford.
- increase fas trak to areas south of Hartford.
- Increase fast track routes to include more cross town connections to all parts of Hartford and inner suburbs ,add safer bike only lanes to make it easier to get around ,run service til 2am,in other words make it enticing for people to get out of there cars to commute
- Increased feeder buses to Fastrak stations would be awesome. I would have to walk a mile to the bus stop which isn't an issue in the summer/fall but is a problem in winter/spring.
- Interesting survey especially for an advocate of public transport such as I am. However, you do have to make it more affordable for those who have no other choice and don't want to or can't get another car.

- Interesting survey. This is the first I've heard of the different plans being considered for the I-84 construction.Thank you!
- Investing in the accessibility and frequency of alternative transportation options along with aggressive market of these options may help to increase awareness and use during an accelerated construction plan. Much like what the internet had done with retail it is all about convenience. There needs to be clear features and benefits onthe commuter. This in turn may have the ancillary consequences of reducing traffic once the project is complete by turning more commuters into permentant alternative transportation users.
- Is there a plan to inform commuters of the status of lane closures daily as the will be changing? Could it be put on a web page?
- Is there a way of shutting down the entire highway and getting the work done even faster than 2-3 years as was done in Knoxville, TN with Interstate 40 ("SmartFix 40")? I wonder why this was not presented as an option. Yes it would require a significant increase in transit options along the I-84 corridor on both sides of the Connecticut River, but the faster we can replace this dangerous eyesore of a highway, the better for the region. (Also, why not ask for the most traveled departure and destination points using I-84 through Hartford, rather than the most recent trip?)
- It currently is not easy to take the fastrak from Southington or other suburban areas. Increase frequency of express bus options into hartford.
- It is good this kind of survey because the community can expresse their needs and like this the competences authorities could focus in the problem community.
- It never asked about my trip home. I generally take city streets home rather than 1-84 and usually take 1-84 in the morning to work.
- It seems like the data in this survey is going to be very biased by the responses of those that are most often car commuters. Designing a transit system around the responses of those that don't currently use transit could be problematic. Also curious how CTfastrak could ever be viable for the rural / suburban (East Granby) address that I selected as an example personal car trip.
- It would be nice to have information for fun family things families could do at the end of the fast track. Think about musiums, parks, and events; like parades.
- it would be wonderful if the bus service goes all the way to New Haven.
- It's a complete joke to suggest to someone who lives in Waterbury that they can drive to Newington or New Britain to take a train or bus into Hartford. Tracks exist between Waterbury and Hartford already. Revamp them, and connect the Metro North from Waterbury to Hartford and offer commuters from West Central CT a REAL option to take the train to Hartford. You can have stations in Waterbury, Terryville, Bristol, Plainville, Berlin, etc.

- It's a little odd that it suggested I take the CT Fastrack considering my starting location. I'd have to take it from... Newington, I guess, and that's pretty far out of my way. I get the point that transit is a viable option when talking about THOSE kinds of delays, though.
- its best to keep i84 open due to causing more traffic for the local trafficers to pass
- ive indicated that I might be willing to start using the mass transit including the rail service provided it is completed on time. from Bristol there are no good options other than commuter bus so travelling to a mass transit station takes additional time in the commute that probably is not factored into the questionnaire. also, the 2-3 years appears optimistic considering the major impact to the city and knowing how construction is frequently delayed and costs are underestimated. finally, 1-91 and the exits into hartford are going to take a major hit to the increased traffic volume and in my opinion are not adequate to handle the increased volume during peak times (commutes, events at xl center, meadows performances, yard goat games, etc).
- Just build a tunnel for 84 and 91. Maybe people will want to go to hartford for once.
- Just get on with it before Hartford dies!
- Lack of free parking options at CT/FastTrak stations makes me less likely to use the bus. I used it more often when it first opened, but ridership grew and now you need to be at the bus station I use (by Stop n Shop in Newington/New Britain near CCSU campus) before 7 AM to get parking - I don't want to leave for work that early. Living in Berlin, I am very close to the train station. If a commuter rail option becomes available for a similar low cost (i.e. $3.00 for 1 day round trip like CT FastTrak), I will definitely start using that option as I would ride my bike less than 1 mile from home to rail station in Berlin and less than 1/2 mile from station to Aetna (151 Farmington Avenue). Could be closer if the rumored location change of Union Station in Hartford has to happen to accommodate the work on I-84. Thank you for doing these surveys. Please continue to ask us these questions, and think about doing focus groups that are specific to folks who live in certain towns. The more information you get, the better decisions you can make.
- leave the roads alone taxes are high enough
- less delays is better repair done over time will impact the public less
- Let's just get it over with. Have alternate routes posted. Delays are going to be awful either way so just get it done as quick as possible.
- Lets really solve the problem. Connect Metro North New Haven Line to Hartford and get that done quickly (or other high speed rails). Lets not let a few towns that object ruin progress for everyone else.
- loads slowly

- Make FastTrak go to more destinations. Build the highway to make truck lanes.
- Make the survey more user friendly and easier to understand
- Make things as safe and quick as possible
- Malloy has to go!
- Many families have children that can not leave any earlier or later than their current time. that is my situation so would I like to leave my house at 630 AM - yes but due to school and daycare that is not an option.
- many of the questions were unclear and not worded in ways that made sense.
- Many people rely on this stretch of highway to commute to work. I would caution against shutting down major portions of the highway during peak commuting hours.
- Mass transit doesn't work because I need to utilize the impacted section of I-84 to get to the transit stops and/or the bus will still need to travel through areas impacted by the traffic that takes to the local streets. This project is going to be a significant inconvenience to everyone; that said quit dithering and get something started. I have travelled a lot, I-84 through Hartford is one of the worst stretches of road I have experienced.
- Most of your questions I don't have a choice on. Public transportation worksfor some - but with 2 full-time working parents (one travels to Manhattan), and 2 kids under the age of 4... not being readily available to pick them up in an emergency would be an issue. I need my car at all times and can't be on the public transportation schedule. I also don't have a choice with work times (going in earlier because of the kids), and I can't just stay home with Aetna's new "no telework" policy.
- My ability to use public transportation is limited due to need to drop and pick up child at school.
- My answers were mainly chosen based on the fact that I need to pick up my daughter from day care and she is in the car with me, making it difficult to use fasttrack.
- My company is deciding to bring the workforce back into the office full time where I have flexibility currently to work both at home and the office. If that occurs with the delays in traffic work life balance will become nonexistent for me and will force me to move closer or find employment closer to my residence.
- My current understanding is that the Fastrack would need to be shut down during the I-84 construction project, so I don't see how it could be a substitute means of transportation. Frankly, I think the Fastrack is a waste of time and money and should be used as a dedicated carpool work commuter route instead of a bus route.
- My employer in Hartford has thousands of Teleworkers (full time Work from Home) in CT. In the past they were closing huge offices (Middletown and Windsor Locks) and moving thousands to

Work from Home. Now, for no good reason, they are forcing all those thousands to go back to working from an office. Considering that they just closed Middletown and Windsor Locks they are adding tremendously to this problem by forcing the thousands of teleworkers to come back into the office in Hartford. I will be one of those that only makes occasional trips now, but will be making daily trips in the future.

- My employer is kind enough to offer me the privilege to work from home so I would have no problem with the I-84 Hartford Project Accelerated strategy.
- my flexibility for when I can arrive and leave the office is up to my employer, not my choice.
- My kids go to a magnet school in Hartford. How would this impact their commute from Portland to the campus of UHART? Not sure if you are including the impact to all of the buses that come from suburbs to the magnet schools.
- My preferred mode of transportation to and from work is biking, but due to recently being ill and hospitalized, I have been driving in with my husband who works at the same place I do. I bike on the back roads and avoid 91 and 84 altogether. I am in favor of construction on 84 if it reduces traffic back-ups in the long run. Thanks
- My problem is that when I need to cross the bridge and I don't really have options other than using 84. Outside of the bridge I can go without the highway.
- my trip on I84 is approx. 8 minutes from home to Aetna parking lot on a good traffic day. I have tried both i84 and through downtown and either one can take 35-45 minutes from route 2 exit 5A to exit 47. that's just crazy.
- My trips usually require carrying large objects in my SUV thus precluding bus trips.
- nice job
- nice survey thanks!
- night construction is best
- No construction work during "rush hour" commute times please.
- No. It was good.
- None of these options are a solution to our highway and infrastructure problems. You should scrap the plan and come up with a real solution.
- Not sure why rail was listed as an option for my commute. There is no train station close by. There is a fast track station that is MUCH closer and more convenient. Even more convenient yet is the local bus stop across the street from where I live, however it is only a one direction bus stop/I can not use it because the return trip from Hartford appears to take me through the entire City of New Britain route before I would get back to the same bus stop. There is another bus stop maybe a half mile away but there are no absolutely no sidewalks or even a shoulder on

the road making it unusable during the rush hour commutes. I would be interested in exploring fast track however the lack of free parking at the fast track station prevents me from using it.

- Offer fast track or better rail service to the Enfield area. Currently I ride a commuter van and would love other options.
- option one gives the idea of improvement at a cost in money while option two doesn't really improve much at a cost of time. I am very confident that the DOT engineer staff can come up with something a lot more efficient and not as time consuming. merry Christmas and happy new year.
- Other items to consider: 1) Travel time to commuter lot for bus or rail (FastTrack) service. Driving to a FastTrack station is not in the same direction as the current commute. 2) Commuter bus requires transfers. There is not a direct bus line to or near place of employment. 3) Need additional commuter options for individuals traveling 91N to Hartford
- Out of safety concerns, I would rather the entire section be shut and traffic re-routed through or around the city. I think the highways condition is too poor to allow it to remain open while it's worked on. I know logistics would be a nightmare, but safety is paramount and I am willing to seek alternative solutions.
- People often congest traffic owing to not following the zipper rule when entering from ramps/exits and coming onto Highway. This cause major delays near Exit 44-51 and also near Exit 60-64/65. This alone if followed could help alleviate the situation that keeps building through out AM and late afternoon (4-6PM) duration.
- Pienso que un buen servicio de transporte publico debe ser ofrecido independientemente de que s ehagan mejoras a las autopistas. Apoyo la iniciativa de ampliar el servicio de transporte publico y que se fomente su uso
- Please allow the commuter lane from 91 South to go directly to 84. It is very difficult to cross 3 lanes on 91 to get to 84 west. Thank you.
- Please consider major employers in Hartford and seek their opinions.
- Please do the bulk of construction at night.
- Please don't waste tax payer dollars on this project. The busway was a complete waste of money. There isn't enough parking to support the use of buses and the location of lots is terrible. Commuting 30 minutes to train station and then having a 45 min train commute makes absolutely no sense. Fire whoever came up with this idea.
- Please encourage employers to offer more work at home
- please encourage the large employers in the area to retain their telecommute policies and in anticipation of the I-84 project allow their employees to use this benefit instead of requiring employees to travel and add to the I-84 congestion during construction.

- Please find a way to construct without adding to the burden of traffic that is already plaguing I-84.
- Please fix traffic congestion, taking public transit won't work as Rocky Hill does not have good hours.
- Please get it done as fast as possible! 6 years is much too long!
- please get the train from Wallingford to Hartford done and please get the train from Wallingford to Stamford done so it is fast and safe.
- Please keep other options open. I can't take fast track bc I have to pick the kids up from schools after care program. This would severly impact my ability to pick them up on time.
- Please note when answering some of the scenarios there was no box to say - none of the answers. I would take local back roads before having to commute an hour for that trip. there are other ways to go besides the highway from where I live.
- Please provide free bus services from other location to hartford or at least reduce the cost of the bus fare
- Please provide more smite gems. These surveys are incredibly tedious
- Please share results of this survey.
- please take a train?!! once I get to Hartford on the train am I supposed to walk to Farmington
- Please wait 5 years before starting this mess because I will have retired by then.
- Poorly written survey. Very confusing to someone not as familiar with the options as writer(s) of survey. Also, was not given the opportunity to explain why I would not take public transportation, but I guess you don't really care, as long as I wouldn't do so.
- Provide tax incentives to Hartford companies for allowing more of their employees to work from home, keeping the employees off of I-84 during the construction period.
- Public transportation or lite rail from Glastonbury through Hartford and on to new Britain at a reasonable fare would be ideal. 84 is a colossal mess with curves, heavy merges and overburdened exits. Perhaps an expressway over or under w a no exit zone would help? Let the Hartford workers go local and everyone else skip by completely.
- public transportation regardless of the price would not work for me as I usually am going into Hartford from work to pick up an employee who is having their vehicle serviced
- Put i-84 on the ground and have the side roads done with bridges.
- Put more cops on i-81 and i-91 to keep people who are speeding and cutting you off so that the roadways can be safer for everyone. Don't make a tunnel, there is not a good reason to go underground.

- Put the highway underground; remove/reduce number of exits off highway in Hartford; remove/reduce parking in downtown Hartford; increase parking and transit hubs on edges of city; this is an opportunity to greatly improve the quality of our capital city
- Rail and bus services/quality would have to be increased significantly (more frequent trains, buses to/from destination ALL DAY and run much later than 6 p.m. to allow flexibility for days when I have to be in early, later leave work early stay much later than normal business hours. Also, should be comfortable, (clean, air conditioning in summer, heat in winter plenty of seating, Internet access.
- Rail is great idea, but unless implemented appropriately you are trading a roadway problem for a railway problem. Given the taxes that I pay, none of the options described are desirable and I would like consider relocating to another state should my commute be disrupted for 6-8 years.
- Rip out the whole highway at once and install the replacement in ONE (1) year. increase the manpower and equipment on site. work both ends at same time and work to meet in middle.
- Sadly, our suburban network does not lend itself easily to mass transit options: If commuting from suburb to Hartford, all is well. Suburb to suburb leaves me unable to get to work. Unfortunately, these areas were more accessible in the days of the trolley!
- Safety comes first. Make I-84 safe. The speed of the project comes second. People will always find alternate routes, carpool options, alternative modes of transportation, etc. Safety and quickness to completion of the project is paramount. People can and will adapt for brief times. The sooner it is over, the sooner the memory of inconvenience will fade.
- Se que es necesario los trabajos a realizar pero hay que pensar en lo que causara al pueblo dicha remocdelacion. Se que se necesitan hacer eso areglos pues despues de tantoss anos de uso hay que remplazar los puentes y las carreteras. Esa es mim opinion pero se que haran lo que tienen qyue hacer.
- Seeing that I have to cross the CT river, I do not have the luxury of alternate routes. The majority of traffic occurs because of the bridge and tunnel. Creating multiple ways over the river may increase commute time and decrease accidents.
- Seguridad para las vias de acceso a la i-84 capitol y prospect, asi mismo mejoras de accesos para ingresar a la autopista en hora punta.
- Senior citizens seem to have more time to attend your events but I hope you take the opinion of people working and driving through Hartford daily as a priority over the opinions of those who are no longer working.
- Shut down the highway completely during construction!!! Keep the busway running and detour the rest of the traffic to I-91/Rt.9/I-691. This will be a great opportunity for the Hartford workforce (those who don't already use the busway) to realize the benefit of having it. You may have to add additional routes, build more bus stops, etc.... but when taking the bus becomes the

best option, people will realize how convenient and easy it is and it will be more successful. Thank you for including ideas from the public in your design.

- Single mom, my commuting hours are dictated by the time my children get on the bus, otherwise I would prefer to travel thru Hartford earlier than 7:15am
- Some areas of Bristol are in serious need of transit options. Living where I do makes it extremely difficult to get around without a vehicle, despite the fact that there are transit stops at many of the surrounding areas.
- Some of these questions were very confusing.
- Staff was very polite
- start work at night not so much traffic at night 7 pm to 430 am
- steps must be taken to speed travel through city streets to reduce travel times during construction. The one-hour times for trips is much too long. The option of just not making the trip will become the preferred one.
- Straighten the curves and add another lane on 84East from Farmington to Hartford. That is most of the delay reason.
- Suggest making an option for increased viability of public transit into Hartford from the west. There are not enough good options for people traveling from/through the Waterbury area.
- Suggest that Overhead automated EZ pass type Highway toll locations be installed on the East and West side of Hartford. Tolls would encourage people to use public transit, car pools, bicycle trails to enter Hartford. The effect goes beyond actual $ amount but is also psychological because of natural desire to avoid taxes/fees/tolls.
- Suggest to keep all lanes open during peak hours of the work week. Have construction take place after 10:00pm at night until 5:00am in the morning during the week and possibly weekend. Try to avoid construction during working hours Mon-Fri. Thank you.
- Suggest you ask if employer would consider work at home options. That would mean that I would not travel into Hartford 5 days a week. Also, I take my daughter to school everyday so cannot take public transportation to work. You might consider asking if one of the reasons for not switching to public transit is to due childcare responsibilities.
- Suggesting that using the fasttrack option would only take 20-27 minutes on all of those screens completely ignores the time required to also drive to those locations and the potential increased congestion to get to those locations. This is careless at best and purposely deceptive at worst.
- Survey does not address any options from East of the river but assumes congregating commuters east of the river to I91 north or south. Providing short-duration bus service just east

and north of the river (within a couple of miles), with parking, and linking to Hartford's CT Fastrack stations at the railroad station and nearby locations could ease a lot of traffic problems. At present, traffic congestion eases up right after the Asylum exit, which suggests many commuters end their journey within a mile of the river.

- Survey experience was great
- Survey gives impression certain decisions have already been made. Also seems like a deliberate effort to expand Fasttrak program which isn't always an option based on the hours I work. I also find it difficult to believe that an hour would be added to my commute when today I encounter zero congestion on the roads. I feel like there are better investments the state could make like 1) move 84 around majority of downtown so the city feels like a city and 2) take 91 off of the river and create an actual riverfront attraction for people to visit. The highway is eating up incredibly valuable real estate that would draw many visitors and improve overall economy of downtown Hartford. or 3) add overhead tolls like Massachusetts but also manage the state's budget in a more disciplined fashion
- Survey indicated the proposed improved train route would be useful to me based on my noted commute, however, it didn't appear to run anywhere near my commute, It appeared I would have to drive to West Hartford (more than 3/4 of my commute) and it was unclear if there would be a rail connection on the north west side of West Hartford that I could use for the last few miles of my commute. I don't see the value of being able to use rail for the last 4 or 5 miles of my commute if I have already drive 25 miles. If for instance there were a train route that ran frequently out the route 44 corridor to at least Canton, I might take advantage of that.
- survey is too long and detailed
- Survey questions about travel options were not relevant for a city resident who uses I-84 to commute downtown. My trip door to door is less than 15 minutes. Fasttrak is not an option because no station is located close to me. No option to bike or walk as an alternative was provided. Both are viable alternatives. If the highway is too slow to travel I would just take the city bus or walk as I sometimes do presently - even in the winter.
- survey said I could take fasttrack, but that's not the case; I go between Marlborough & Hartford
- Survey seemed broken. Alternatives were either 1+ hours in vehicle to travel on I-84 between Storrs and Hartford, versus 35 minutes to magically appear there via CTfastrak. Obviously I picked CTfastrak in all cases.
- survey was too long
- taking CT Bus would be an option except that there are only 2 morning departure times and I would have to transfer busses in downtown Hartford - requiring a fairly substantial distance between points which is difficult given my difficulty walking. taking the commuter bus requires

going 5 miles in the opposite direction to also have limited times. Mass transit in the Hartford area is virtually non-existent.

- Taking public transportation would be an option for me, depending on how close my Hartford work location is to the transit dropoff. If I got off the train and had to then wait for a bus to my work location, it really increases the time/complexity to get to work.
- Talk to Aetna about allowing their employees to work from home. This option was just taken away adding to the traffic congestion on the highway.
- thank you
- thank you :)
- Thank you for asking the drivers of the section of I84 their opinion about the impending improvements. Your survey did not ask or take into account for the CT Fastrack option that the nearest terminal to me is approx. 15 minutes from my home-which add to the proposed times you listed. In addition, if I were to take a regular transit bus to the CTFastrack terminal, that would also add approx. 15 minutes to my travel time to Hartford. In addition, once I arrived in Hartford at the Sigourney St. Fastrack station, I would have to add 10 minutes to walk to my place of employment-sometimes on icy streets. This time was also not reflected in the CT Fastrack option.
- Thank you for the opportunity. Although an interesting survey the estimated travel time for my stated trip using the Hartford Line alternatives did not seem feasible given I would have to take the train then transfer to a CT TRANSIT bus route to reach my destination.
- Thank you for the survey .. but ..here are some suggestions: 1- It [survey] is too cumbersome & confusing. I got well into the survey before I realized that the to & from were from my home to a Dr's appointment. Yes it was explained in the instructions but is still a bit confusing. 2- If & when this is done please do not detour traffic or encourage more traffic down Farmington Ave, Asylum Ave, Albany or Capital Ave .. my condo is on Woodland St. between Farmington and Asylum Avenues and I don't need the headache. 3- Please lobby for John Larson's idea of a tunnel from the Flatbush area to US-91. Pres. Trump wants to rebuild the infrastructure this is a good chance to get this done. It is certainly better that building Afghanistan's and Iraq's. 4-I use my car as infrequently as possible basically for out of the way Dr. Appt.s. I welcome taking the bus every chance I get but sometimes I have to resort to my personal vehicle and deal with all of the texting morons out on the roadways. 5-Maybe have employers to partially subsidize cabs & Uber? Thanks again & have a great day.
- Thank you for this survey. I really appreciate the opportunity. The questions were great, easy to read and understand and I could tell they were very thought out. One thing I wanted to add was that I'm not opposed to taking the bus to and from work. It'll same money on my car insurance/wear+tear on my car/be so much easier. BUT I don't have the luxury in my job to be

held to the bus schedule. I wish it was, but it's just not the case. I would already be taking the bus, if I could. Being a salaried employee, I can't plan my job around the schedule. If there's some other way/method I should be thinking of and that the public should consider, please let me and everyone else know. We're all concerned about I-84 and what this construction will mean.

- thanks
- The 10 questions in the middle of the survey were very confusing. No idea how accurate the answers are. Not even sure what you were asking. Poorly explained!
- The best solution is to develop a tunnel under the current I 84 roadway with exits and entrances along the route that merge into existing traffic.
- The best solution is to provide FREE bus service between the commuter parking lots and downtown Hartford, as well as continuing the shuttle within the downtown area, from 6 a.m. to 10 a.m. and again from 3 p.m. to 7 p.m. weekdays. I understand that about 80 % of the traffic on I-84 in Hartford is commuter driving, often with just one person in the car. Getting these people to use buses in work-related driving would allow much less upkeep of the highway. (Also, use of min-buses on bus routes during less-utilized hours would save money.)
- The biggest nightmare during any of my commutes are school buses. Get them off the highways (where they are doing 55 in a 65 zone) during rush hour (7-9 a.m. and (4-6 p.m.). Second biggest nightmare are state workers. The difference between leaving at 3:55 versus 4:05 is horrific!!
- The CTFasttrak option shown to me was from New Britain to Hartford, CT. While I commute from Springfield, MA to Hartford, CT. I think your system may only be working for starting points in CT.
- The discrete-choice section was a bit confusing, but otherwise a great survey. I'm a full-time bus commuter and think it would be great for the environment if more people chose to travel that way (we might need a few more buses, to be sure). I'd also love to have a commuter rail option to get to New Haven for work trips, a lot of people have to get to NY for different meetings all the time.
- The elevated highway did not work well FOR THE CITY. The surface level road will work less well. The only option the City should allow is a tunnel!!!
- The examples only included CTfastrak for commuting rather than regular bus service. During the summer, I use the regular bus service to Hartford 3 days per week. An additional opportunity would be to provide for a limited bus lane on Farmington Ave during peak hours.
- the express buses don't run to Vernon yet for Fast Track & there is no current direct route to Aetna for a bus that runs during my work hours

- The Fast Track should have been a train similar to Denver's light rail. If future additions are added to the Fast Track and you want people to actually ride the system, use a train or light rail as opposed to a bus. There are different physiological effects between the two. Also, for the new 84, spend the money to do something that will benefit the city. The highway cuts it in half right now which is why no one lives downtown. It's a 9-5 city. To change that and have a better impact on the living conditions downtown (i.e. more parks, less obstructive infrastructure, more real estate...) put in the tunnel, not surface or elevated.
- The fastrack was a large waste and we will never step foot in any vehicle related to it. CT is in dire need of overhaul.
- The fasttrack locations are inadequate. You need more locations from point south of Hartford, the completion of the rail system from Wallingford to Hartford would significant ease the issue. Additionally fast track should have pickup locations off of I91 and I691 from New haven north, and they need to be frequent, every half hour
- The highway geometry is the problem. If it's possible within budget, you should focus on reducing curves and eliminating entrances and exits on the left side of the roadway. This is what makes the traffic so awful.
- The highway is always congested, especially exit 48, which is the worst exit if you'd ask me. If there was one thing that I liked from San Antonio, Texas highway was the length going and coming from the exit. It was its own proper lane which made it easier for vehicles to go in and out without the congestion. Maybe that would be an option to see how other state highways work. I-84 automatically has to be taken from E. Hartford to Hartford and vice versa because vehicles need to cross over the river. If there were smaller bridges to cross over without hitting the highway I would most certainly take that route. But taking the highway is a must for me because of where I'm coming from. I appreciate this survey and I will forward on.
- The introduction of CT FastTrack actually created more traffic congestion in the Hartford area with the closure of Flower St to Capital Ave. Re-opening Flower St would provide additional alternate route options for surface traffic to leave Hartford. Currently all Aetna traffic is funneled to Farmington Ave to reach the Asylum St on ramp, which runs straight into all The Hartford traffic trying to enter the same street as situation created by CT FastTrack.
- The issue I have with taking the train into work, is that I still have to get to and from the train station in all forms of weather. Adding a 20-30 min to and from work through Hartford (which is not a safe place to walk) makes this option take just as long and is far more inconvenient than driving myself.
- The New Britain bus station is not an option - it is not safe for me or my parked car, there is no parking and it would take considerable time to drive from my house to that location. The question about altering my days traveling to work would be dependent on my employers policy for additional flexibility.

- The numerous options were onerous and difficult to quickly review, and understand. I more often than not avoid I-91 and I-84 at all costs within 1-1.5 hours from rush hours. At those times I take back roads.
- The only intelligent option you have, even though the costs would be very expensive, is to build a tunnel. If you consider all the productivity losses caused by accidents, people being late to work, commercial trucks & buses coming into Hartford or on their way to Massachusetts, Vermont, New Hampshire, Maine & Rhode Island these delays would cause losses to be in the billions of dollars. When you add the inconvenience and aggravation to everyone that travels on 84, of which many of us are local taxpayers, it makes no sense monetarily or in any way especially when you think about the hate and misery that it's going to generate towards the DOT. It becomes a leave it alone and continue the high maintenance costs and do it the intelligent way when you have the funding, or cause years of grief and loss of productivity, Resulting in a huge loss of respect for the DOT a far more costly price for all of us in & out of the state. nvcp@sbcglobal.net thank yot Perfito
- The only option given to me was the Train and that is a terrible alternate option for me as I would have to drive half an hour to a station to then try to take the train in... this is stupid I would not do that. There are express buses that make way more sense but were excluded from this survey for some god forsaken reason which make way more sense than either the bus way or a train.. also I think I would just try to work at home atleast a day a week to try to make commuting in easier on myself if I can but that was not considered at all in the survey. A road like this should not have ever gone through Hartford to begin with to make this whole thing easier down the road (pun intended) all in all this survey was dumb for me as the train is a stupid way for me to commute in and did not give other factors to the questions such as non-busway buses that have been running for a long time and I hope the 2-3 year estimate goes much quicker than that but knowing the state it will take way longer than that...
- The only reason I wouldn't use CT transit is because I work a part time job after working my full time job and cant get there on time using public transportation.
- The only thing more is GET RID OF THE LEFTHAND ON RAMPS AND EXITS, it causes confusion because people drive slower than regular fast lane traffic. And causes road rage!!!
- The press and politicians complain that 84 splits up Hartford and that it was a bad thing. Then they split of Hartford between Aetna and the Courant to build the busway. The other observation is that the busway usage numbers are terrifically overstated as most buses have few or no people on them.
- The problem is that I need my vehicle to attend meetings in various locations throughout the day, so mass transit for commuting is not an option on most days. Also, your map regarding using the train made no sense to me. The closest train stop to where I live is where I would

disembark (Hartford), so unless you added stops in Rocky Hill or Wethersfield, that would not be an option.

- The project I'd like to see move forward is: (1) take 84 under Hartford altogether, replacing the current route, (2) restoring the Park River and the look of Hartford before I-84, and (3) overall improvement of light rail as a solution for work / leisure travel from Danbury to Storrs, from Hartford to Springfield, from New London to Hartford, and along the I-95 corridor. All CT universities and colleges and all state parks should be accessible via public transportation. I would also support tolls along the CT, MA, and RI borders for interstate traffic in order to underwrite infrastructure projects, with reduced easypass rates for CT residents.
- The project is necessary, the highway now is a nightmare!
- The project team is doing a great job! Keep up the good work. I prefer the buried tunnel solution as it will best reunite the city, create the most economic development, reduce noise, and improve aesthetics. I love the creative thinking and support accelerated construction. This will make Hartford the great city it can be! Keep it up!
- The proposed plan to spend $10B putting I91 and I84 underground seems very ill advised - see Boston's Big Dig!
- The public transportation options as they currently exist would not be sufficient to make me choose an alternative commuting method. I do not keep regular hours, frequently working late (7:00 pm or later), and there are certain nights that I go to other destinations than my home directly from work. Driving my personal car gives me flexibility that public transportation does not offer unless there are substantial changes to hours and destinations.
- The question about reducing trips into Hartford is wrong. I said I would reduce my trips and then it asked me how many out of 15 I would reduce. I said 5 and it gave me an error saying I needed to pick a number under 15. I changed my response to continue, so I would suggest fixing the checks on that question
- The question of how many times to reduce travel to Hartford doesn't present itself accurately. I would only be able to work from home on Friday's for example so reduction of 5 days per month. But the question requires the full 20 days to be reduced. Just FYI
- The reason I cannot take public transportation is i travel using my vehicle for work.
- The reason I would not be able to take transit is that although I typically travel into Hartford each day, most days I travel out of Hartford during the day to meetings with clients, etc. Therefore, I need my car each day as there are days I find out at the last minute that I need to travel. Although, I believe the CT FastTrak is a great service, I would be extremely limited due to my work commitments outside of the office. I have traveled in and out of Hartford for the past 14 years and have developed alternative ways to get in and out when there are accidents on I-84. My best option would be to take an alternative route, or in some cases, I can work from

home if feasible. Althought there would be severe delays in 84 with the advanced track schedule, I would rather deal with the delays for 2-3 years rather than 6.

- The RIGHT thing to do is build the tunnel . Congressman Larson is 100% right. A true and honest long-term cost benefit analysis would tell you the same. No traffic disruption, true reunification of the city. Reclaiming valuable developable land and open space, no additional property taken by eminent domain, no need to relocate rails or abandon historic Union Station. This HAS to be fully vetted, or we lose a once in a lifetime opportunity. It doesn't have to include crossing the river but imagine accessing the riverfront from the city for the first time in 60 years!
- The sooner it gets done the better. I84 is a nightmare and the combination terrible drivers make unbearable at times. My fear is even with the reconstruction, aggressive drivers are a MAJOR problem!!!
- The state highway department should include bike lanes in all its plans. the I-84 route should include a separate , protected bike pathway
- The state should also be evaluating adding routes across the river...in addition to the current condition of 84 through Hartford, another source of congestion is the fact that there is essentially only one bridge over the river into/out of Hartford, meaning anyone traveling east of Hartford has to travel over the same 4-lane bridge (which reduces to 2 lanes for those staying on 84).
- the suggestion that I could use the FastTrack service out of New Britain is ludicrous. I do not live anywhere near New Britain. I use Rt 2W to I-84W to Asylum St exit. Suggesting I could use FastTrack and the commute times noted in the survey were totally wrong. It is NOT an option. Stop pushing that as an option-its not!
- The survey assumes we are in agreement with the construction. I don't think the Federal or the State can afford this "nice to have" at this time. We need to fiscally prioritize with obligations such as deleting debt and stop spending more than we have.
- the survey did not ask, but related to the # of days travelled, I am transitioning from telework to having to go into Hartford office everyday, so # of days traveling will significantly increase.
- The survey didn't really touch on the reasons why some may not be able to take other routes or change travel times, etc; I think it's important to account for that to have a better idea. Different route or times could be impacted by stops or drop-offs along the way or can't switch time at work or even have a telecommuting option. All of this matters and makes a huge difference in these type of decisions.
- The survey didn't seem to account for traffic leading up to I-84 and my answers reflect my ability to use the commuter lane but I only do so 3 times a week. The congestion on I-91 just before 35 A and B and the merging traffic from the commuter lane into Hartford, causes delays.

When driving alone I start my commute at 7:00 am in hopes I arrive at 8:45 am. I'm foreseeing a future commute that begins at 6:00 am

- The survey inaccurately reported that my work location was close to the I-91 corridor and that mass transit was an option. I work off 84.
- the survey incorrectly presented the option to take a train to Hartford. there are no trains from Simsbury to Manchester.
- The survey indicated CTRail would be available to me in the future, but the map did not show me any locations where it would be convenient to get to from South Glastonbury. Berlin? That is back tracking. If it truly is an option for me to get to a station that won't add to my commute I would consider it. Thank you.
- The survey indicated that I commute on I84 11 times per month. I actually travel on it more often; On every business day excluding vacation, holidays, and 1 day/wk I telecommute.
- The survey was a little confusing to understand and I wasn't sure how to answer some questions.
- The survey was a little confusing when offering the options of drive time and then reliability that is could increase even more.
- The survey was really easy and quick to take. The survey was really informational.
- The times indicated on the "take transit" options are completely inaccurate and misleading. There is no way that I can leave my house in Manchester travel to a transit parking lot (when none are located anywhere near my home), park my car, wait for a bus, get on the bus, drive to Hartford with multiple stops, get off the bus in Hartford and then walk from the bus terminal to my job. There is no way that is not happening in 20 to 27 minutes as indicated in the survey. That is going to take at least 45 minutes.
- The times provided for Fast Track are too optimistic. I live in Middletown and would have to drive out to New Britain to catch the bus. Route 9 experiences delays in Berlin consistently as I used to work out that way. So its more like 30 minutes plus to the bus station, park, wait, then ride into Hartford. I think improvements to Capitol Avenue would help with some of the issue. Eliminate parking and bike path and make it two lanes through in each direction.
- the traffic on i84 is outrageous, but i would still want to drive my own car, and i still have to make the same number of trips!!
- The traffic within the area is already very heavy during rush hours in the am and pm. I can't imagine how bad it will be with construction. A real nightmare!
- The transit bus is a great idea, however, once you get to Hartford you have to take another bus to get to your destination. You have to drive to the area to park your car to take the bus. All of these factors enter in to exactly how long you would spend making the same trip.

- The travel commute time to/from work or events in Hartford is unbearable! In addition, our state highways are a mess! I agree with the constructions plans to improve my commute to/from work! CT should install Tolls to defer the cost of the construction expense.
- The trip I answered questions about could not have been made using FasTrak as it was at the end of the day after meeting a friend for dinner after work east of the River. The options I was offered were therefore nonsensical. I don't think my survey responses will be very useful to you.
- There are certainly alt routes to avoid 84 if traveling from Wethersfield to west Hartford.
- There are very limited alternative options for those commuters on the east side of the river. Increasing these options will help travel overall.
- There is no fast track in Glastonbury, and I believe it is a waste of money to put one in- Please fix the roads you already have before building new ones. I am not willing to take buses due to demands of my job and personal life. Traffic is already bad on the way home from work and you need to figure out a way to fix this issue without inconveniencing us for a short amount of time over a long period or a long amount of time for a short period. Sorry we pay enough - please find a solution that fits the taxpayers budgets and respects their time.
- There is no fastrack east of the river. It would need to run more 30 minutes all day
- There is no fastrack or rail near Glastonbury, CT. What I would not do is drive more than ten minutes to public transportation. Right now I believe the closest stop to Glastonbury is over 20 minutes away. So all of my hypothetical responses to preferring a short ride into Hartford on public transportation only apply if it is available in Glastonbury.
- There is NO rail service from Farmington to East Hartford. There is no easy bus service either. The survey was irrelevant.
- There needs to be more options for crossing the Connecticut River then highways. For example, 4 Lane 30 mph Bridge from East Hartford to Hartford. Or Glastonbury to Wethersfield. It is simply baffling to me that this river city is so severely limited in ways to cross from one side to the other without getting on a highway. As someone who grew up in the Minneapolis - Saint Paul Metro area, we have multiple options for crossing the Mississippi River to accommodate all modes of transportation. If Hartford wants to grow and thrive, I84 can not be the only efficient way to transit the river.
- There needs to some viable transit service from Western CT to Hartford, preferably rail as it is not subject to the traffic jams on 84.
- There should be an alternate way for DOT to accelerate the project , but yet still minimize the delays, so as to make it fair and appropriate for everyone.
- There should've been an option listing "Shop/Travel to another destination to avoid I-84 construction."

- There was no option to indicate that my travel plans will change to more frequent trips from my home to my work. I am currently full time work-at-home but that will be changing in the Spring to full time in the office which would mean I would travel into Hartford 5 days a week at an earlier time in the morning.
- There would also have to be plans to improve commuting from Massachusetts through back roads. Currently the backlog once you get close to Hartford is just as bad in the morning and I anticipate it getting worse during construction as more people choose back roads.
- There would need to be consideration for work from home policies by Aetna during this construction time, otherwise this will be a colossal waste of production time spent commuting to and from the office.
- They should leave 84 the way it is... save the money and do something more productive!!!
- This construction will have a huge impact on drivers coming into Hartford. It is my hope this construction project finally gets it right. Asking people to endure won't be acceptable if the driving problems we currently experience are not addressed. How is the project being paid for?
- this gave my anxiety
- This is a flawed survey, it really is impractical considering my return home to plainville from BDL this past Fri. Mass transit is just not possible or practical from my point A to point B. It is flawed as it doesn't address travelers who happen to be passing through the 84 corridor focused in this survey, who are no/will not ever use CT fasttrac or any other mass transit. There are tons of travelers M-F who are not heading into work in Hartford or approximate locals to this 84 construction project. And forget about Fr-Su travel from May to Oct-Disaster-I assume construction will be suspended for evenings on Fr until Sun at night...DISASTER now, what a mess when this all begins
- This is a horrible plan. It is not up to me on whether or not I can limit the number of days that I can come into the office, its up to my employer. If you are suggesting that everyone take the CT-Rail or CT-Transit they are going to be just as packed.
- This is such a good long-term idea for the city
- this is the kind of s*** that causes people move out of this state
- THis is the worst driving experience I have ever been through. I drove through LA before...
- This may not fully apply to me, as I work in Avon. If I were to take a train service to Hartford, I'd need a way to get to work from there.
- This project will greatly affect my work schedule. I'm an educator who travels to teach.

- This survey doesn't account for people who don't have options - ie are required to be at their work in (or beyond) hartford at a certain time, and also need their vehicle for either child care or other issues.
- This survey has a flaw. I reported that I live east of the river and commute into Hartford. Then it showed me fasttrak for WEST of the river (new Britain to Hartford) was an option. That is not true. Additionally, it kept asking me 10 times if I would choose fasttrak. I can't. it's not an option. I feel this survey was misleading and inaccurate.
- This survey is confusing. I pick my son up on the way home. Is the commute considered to end where I pick him up, or when we get home? This was unclear. Also, the choice sections were too long and tediously boring. Because I need to pick up a child on the way home from work, and because the bus service is so infrequent, there is nothing that will get me out of my car. Bus service would have to be drastically improve, but it never will. What Hartford really needs is a bypass highway.
- This survey is flawed - told me CTfastrak is an option - which is odd because I live in Hebron and driving to any current CTfastrak station would take me longer than my current drive. And then add in the time to ride CTfastrak from station to Aetna. Since I drive to work early in the morning, I currently experience little traffic. When I leave work at 4:00PM traffic is starting to get congested on I-84 - still not too bad. However, once construction delays begins, I will probably ride the commuter bus from Marlborough.
- This survey is very poorly designed.
- This survey looked liked it was slanted toward a 6 year process. Also - CT fast track does not go to Glastonbury - so it was stupid to say that I would be served taking it from New Britain. I do primarily take the express bus to work - but I needed to make these trips separately last month and could not time them differently.
- This survey or a future survey should include questions relevant to bicycle and pedestrian travel, particularly in mind to last-mile CTfastrak trips.
- This survey said i could take fast track. I come from ma and cannot take fast track. Further, there is no good bus option going from the enfield ct commuter lot to aetna on farmington ave. Because of this i take a ct vride commuter van. The rates are expensive.
- This trip in not my regular commute. My regular commute is very different from this one, but my opinion still stands.
- This was a great survey thank you for the opportunity.
- This was a great survey. I was pleased to take part in it. It's such an important topic that affects so many people.

- This will probably kill Hartford from an Employer standpoint and the State of Connecticut from a commerce standpoint. Hartford based companies have already started to reallocate their workforce out of Connecticut due to traffic congestion and the cost of doing business in the State. I know you see the population numbers (no growth), employed numbers (no growth), companies numbers (no growth) and the retirees who move out of state for at least 183 days per year Hopefully once the I-84 viaduct is completed Hartford will be able to attract new business to the city. But with the technology changes and other states offering economic incentives Hartford will no longer support the workforce and employers it once did. And with the reallocation of the workforce also comes a lot of the demographic shift where retirees will move out of Connecticut for the same reasons that employers are reallocating their workforce - traffic congestion, cost of living and other states providing a perceived better quality of life (at least for 183 resident days a year). I-84 and I-91 really did change the Hartford and Connecticut landscape but the attempts to address traffic (like the HOV lanes that don't get used) and the CT FastTrack that does get some ridership but doesn't come anywhere near to paying for itself - continues to show the challenges of moving people and product through the state. And while relocating the UConn branch to downtown Hartford and the new Yard Goats stadium, these two projects will be challenged with the traffic congestion and construction. No matter when the reconstruction occurs, it will affect traffic both from the commuter and the multi-modal transportation companies that bring their tandem trailers through Hartford every day.
- Tinted windows to stop sun glare!!! Stop going up on prices! Covered sit down bus stops! Posted bus schedules at bus stops!!
- Trains would have to be VERY frequent for me to consider public transportation. every 1/2 hour wouldn't cut it on weekdays. If trains were available every 15 minutes I'd consider sacrificing flexibility of using my personal vehicle and relying on public transportation.
- transit is not an option due to the need to transport child to school before I drive to work
- Transit is the future but requires affordable fairs and high frequency include late night services.
- Transit is unappealing if you live East of river from Hartford. I have to drive too far to pick up transit and it doesn't seem like it saves me time or $$, just increases hassle.
- Try to keep construction to off-peak hours and weekends - tired of construction starting at 7:30 or 8:00am - you're asking for congestion!
- Tunnel option not given.
- Two years of chaos is much, much better than 6-8 years of minor chaos and the cost will only go up a lot, if the construction is done over more years. Representative Larsons concept of tunnels under the Ct River is the best if money is no object. Defintely do not like the 6-8 year concept.

- Unfortunately, fast-build option sounds intolerable. As to the survey, those number bars were very hard to move on my tablet. Simple number entry would be much easier.
- Use of public transportation into Hartford would only be viable if the CTfastrak schedule, express rides, etc. were expanded and the trip length was reduced… if there is a way to maintain a dedicated lane for CTfastrak to prevent the same increase in 84 traffic that I would experience driving it would be more attractive as an option
- Use the 91/95 reconstruction in New Haven as an example, they did a great job, straighten 84 out, use commonsense when creating the exit/entrance ramp, one lane to 84 west to from 91 is ridiculous, think this through, maybe make 84 underground??
- Very clever.....use a survey to promote an agenda to push everyone to the busses. If I wanted to ride busses, I certainly wouldn't live here.Time to leave Hartford. by the time this project gets completed there won't be anyone here to use the roads. I would be interested in seeing how much of the traffic is just passing through, without a stop. probably way more than anyone want's to admit.
- very interested in the commuter line that will extend from new haven to springfield and go through hartford.
- Waaay too many options listed
- We get this! I-84 needs to be replaced. It needs to be straighter and flow better. Just replacing the road is not going to fix the problem. Also, spend the money by funding alternative transportation, so people will get off the highway. I car pool, so I take cards off the road, but even better would be free express buses. Also, pay attention to how terrible the current express bus service is for people leaving form downtown. I am fortunate to get on at Sigourney, so I don't have the same problems. Also, employers need to kick up the contribution to public transportation. 17% fare increases are hard to swallow. People are upset, so do something first, then start the construction.
- We need a subway and tolls in Connecticut
- We need more Fast-track busses and more pick up areas.
- We need public transit from UConn health center > west hartford> hartford> UConn main campus in Storrs. A train would be awesome, but a bus would do. A lot of graduate students want to live in the city but the commute is awful. I put in long days already to avoid going in on other days and having to drive. At least if there were a transit option, even if it were a but longer than my commute by car, that time could be used to do work.
- We should have finnished RT291 loop before now, should finish rt 6 to providence also both would have reduced trafic issues in CT. That said you have to get CT people used to using the rail, historically it was not an option so you some sort of incentive/event to get people to try it,

once they see how it works it becomes a viable option, otherwise people will continue to clog our roads and highways while rail is hardly used. good luck

- We will prefer additional frequent bus service with minimum fares that will serve the purpose.
- Well just forget about updating the roads and bridges and do the underground tonal Idea. We would be spending less money and less frudtration
- what accomodations will be made if alternate routes (91 to 691) were chosen?
- What ever plan you decide to implement this, please keep the travel time predictable for daily commute.
- whatever needs to be done for safety on the highway
- When it said $10 transit fare, was that per day, per trip, per month? It was unclear to me.
- when there is any kind of minor or major accident traveling in either direction the traffic in either direction in delayed because of nosey rubberneckers and that causes a domino effectfor miles in both directions if they the police or service people were dedicated spaciffically for the hoghway in that area it would get the problem off the highway faster and them keep traffic flowing PLEASE PLEASE do something this is insane !!!
- when traveling to downtown hartford, and having to park for numerous eventxs in same day or night, have one laz parkinge . not 2, 3 or more.example , dinner, then xl center, then dancing. i never go to hartford events as laz is too greedy.pay 10 once, not 10, the n 10 the n 10 again for visiti ng hartford 5pm to say 12. will visit for 10 not 30.
- Where is the State going to get the money to pay for this project. I will not support a increase in the state gas tax or a increase of any tax to pay for this.
- Which do I prefer section was confusing, and seemed like it just wanted me to choose the bus option.
- While I have a young child, I need flexibility to be able to leave on moment's notice (ex/call from school nurse), or run important errands (like pick up medicine) if needed on way home. When child is older, mass transit may be a more feasible option for me,
- While I have access to bus service (Peter Pan), it would follow the same route as I do so there's no advantage...and FastTrack is nowhere near Windham.
- While my current residence is in Hartford (and I would like to continue living in Hartford) there is a chance that I will need to move to the suburbs in the next year. If this was to occur, I would be looking at moving to a location close to a station on the anticipated Hartford Rail line.
- While somewhat comprehensive, this survey does not account for the reality that in most situations my using of the commuter rail is just not realistic. I would have to drive five minutes to the rail station, spend 20 minutes on the train, then walk 25 minutes to my office, and this is

assuming no delays at all. Unless the construction delays my car trip to well over an hour long, paying a commuter rail system to get to my destination at the same time or longer than it would take in a car is not going to happen.

- whiy did i have to pick a sex?
- why does it take soooo long to build a road... Waterbury is already a nightmare i can't imagine having 2 of our biggest cities clogged. 84 is a nightmare from Danbury to Hartford. I work in Danbury, live in Waterbury, shop in Hartford and my life is seriously negatively impacted by the amount of traffic I endure on a daily basis. Very Unhappy!!!
- Why would you suggest that CTrail would be an option for me, but you did not mention CTfastrak?? Also, you did not give me the option to select walking or biking or standard bus to get to work. Those are the options that I would very seriously consider. From where I live, with the potential delays you mention, I would not use I84 or the parallel route that is also under construction. I could bike or walk or take a farmington ave bus and get to Hartford much more quickly.
- widen highway building for years ahead and not 20 years behind by etending lanes and extra lanes to build ahead
- With the new baseball field it will be virtually impossible to commute home. Who will be doing the construction on I-84
- With the upcoming project, I strongly recommend that Aetna keep their telework arrangement to decrease the amount of traffic on I-84, as some of us have obligations and can't take public transportation.
- Within the survey, there was feedback given that said there were transit options available for my trip. I don't agree that there are rail or Fastrak options currently available to go from East Hartford to Aquaturf in Southington that would get me there at all, and certainly not in 45 minutes.
- Would hope that the bulk of the construction be completed after hours 8pm-6pm.
- Wow! Was your survey confusing. And I am a civil engineer. You should seriously consider redesigning the survey questions. I am not sure you can gather useful info with the way the information is presented. Were you really saying that a 35 minute drive from Glastonbury to Hartford to see a movie would take 1 hour and 40 minutes ? People with optional travel are going to simply avoid doing anything in Hartford. I probably go into Hartford 5-10 times a month right now. And will probably stop if the delays are as presented. And your survey question about trips elsewhere vs reduced trips to Hartford - I almost gave up on the survey, it would not accept the numbers I desired to enter. So again, could not give you a clear picture. Definitely not a well designed survey.

- Yes. I definitely have additional comments. First of all, thank you for making this survey available to all of us. Second, even though I did choose to drive, I would definitely be open to FasTrack service. I told you I work in Southington and yet you suggested to me that I would benefit from taking FasTrack from my home to New Britain. However, I would then need to get to Southington. Even if I took the express bus to Southington Commuter lot, I would then have a 5-6 mile trek to my work. Could I leave my car there? um...maybe. There is no security there. If that changed, i would be open to taking the bus during the week and leaving my car in Southington. I hope these comments help. I know this is a BIG JOB and very difficult to decide on. I will be good with whatever you decide. Lee McLeanHoule....and yes, I signed my name. :)
- You asked the wrong question . I make this trip because I am picking up my daughter at UCONN after I get out of work, so the transit option really doesn't suit me. Neither is truly my final destination
- You did not indicate the cost differential between the two options. As a taxpayer that would be just as important to me as the inconvenience in determining which option I would prefer.
- you forgot option 4, don't make the trip, being that this was a discretionary trip I would not take it
- You happened to ask about a voluntary and occasional drive. My answers might have been different if it were a longer drive, or required, or more frequent.
- You have surveyed me only about one of the trips that I take on I-84 per week - at many different times of day and into the evening/night. Answers at other times of day could be different. Many of the times that I use I-84 are for meetings, events, appointments that by their nature - are outside of my control - and are always going to be in Hartford. Accessing CTFastrak from my starting point requires very long walks from my starting point (which I am no longer able to do) or multiple transfers on CTTransit Buses. There are also no sidewalks on a portion of the walkway to the nearest CTFastrak station.
- You need to ask if there is bus transportation in the eastern part of the state.. there are no buses that run at 4-4:30 AM to Hartford from the Lebanon area.
- You never questioned why someone would NOT use FastTrack. Sure it gets you to the train station--and MAYBE on time, but what happens to get you to the airport AND your times may not be the desired time to get to the aiport on time. Bus transportation in and out of Hartford has never been dependable and waits for connections are sometimes VERY time consuming. And what about return from the airport???
- You seem to have left off the bike to work option. Also, the survey seemed to suggest I could get to LL Bean on the new commuter rail. The rail won't be going anywhere near Evergreen Walk.

- You should ask WHY a person would not use the transit option even though it appears faster and less expensive. in my case I need my car throughout the day for client visits. Otherwise I would love to take CT Fastrak. It might help you to know how many people are in that situation and can't use it no matter how attractive you make it. Also, you might ask if people would do something else to avoid a much longer commute. I will move or change jobs, for instance, and that wasn't an option on your survey. Thank you for the opportunity to participate.
- You suggest CTFastrak as an option. You only indicate travel time in your time estimates. I would need to drive out of my way to the New Britain station, park my car, wait for a bus, and then walk to a longer distance to the office. This has a high probability of making my commute longer than waiting in traffic and I would probably use local Hartford streets to get to the office.
- You would need to the transit system available in places outside of downtown hartford without requiring transfers (e.g., hospitals, Aetna, the Hartford)
- Your algorithm that indicates that I could utilize the CT Rail system does not take into account that I live in NY state off of I-84. To utilize the CT Rail system I would have to travel into NYC (1.5 hrs) and then travel out of NYC then get on CT Rail, OR drive to some other location in CT to pick up the rail or bus systems. Either add considerable cost and time to my travel into Hartford. I have already reduced my travel to minimum due to the construction mess that is Waterbury. I leave for Hartford at 0430 to avoid the Waterbury and Hartford traffic in the morning. The return trip home results in traffic no matter what time I leave. During I84 construction in Hartford on top of the Waterbury effort will drive commutation time to probably 4 hours return trip. I suggest finding solution to through traffic (I-84 or I-91) around Hartford as best option to reduce congestion in Hartford at all hours plus will allow construction in Hartford to progress at accelerated pace. Buenos suerte and vios con dios.
- Your estimates for travel time are delusional using CTFastTrack. It would take almost the same time to drive to a bus stop in New Britain as it would to make my commute into Hartford. Then, I have to find parking, since there will no longer be enough. I have to tack on the added cost of the bus, the added time waiting for the next bus, the time the bus takes stopping along the way, and the added time walking from the bus stop to my office. Then, I have to repeat that going home. With all of that, I still have the cost of a car, gas, and insurance to get to the bus stop. CTFastTrack is only useful and cost effective for people that live within walking distance to a bus stop. Hence, this is why we have near empty buses running. Sorry, not going to be a bus rider.
- Your survey is incorrect. I put in my location and there is no fast track running East from Hartford. Buses don't run enough runs throughout the day and it becomes a problem when having to leave work to get somewhere for a child living in that area, especially being a single mother. If there was a bus that ran every hour on the hour, that would be different and I would think about it.

Travel Demand Model
User Guide

March 8, 2018

PREPARED FOR:

THE CONNECTICUT DEPARTMENT OF TRANSPORTATION

CAPITOL REGION COUNCIL OF GOVERNMENTS

PREPARED BY:

THE I-84 HARTFORD PROGRAM MANAGEMENT TEAM

TranSystems Corporation
WSP | Parsons Brinckerhoff

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1. INTRODUCTION

This User's Guide provides instructions on the operation of the Capitol Region Council of Governments (CRCOG) Travel Demand Model (TDM). It provides relevant information necessary to understand how the model is applied through a Graphical User Interface (GUI), including creating scenarios, setting parameters, executing a model run, and reviewing output summaries and performance measures.

This document should be viewed as living document. Thus, it is hoped that the document will evolve over time. Collaboration and cooperation among all involved in the development and application of the CRCOG model is a key component of this evolution. To help in this process, it is encouraged that a modeling users group be established and meet regularly to exchange information, solve problems, and provide training. This group could include technical staff from local jurisdictions and state agencies, consultants, and others involved in the day-to-day application of the tools.

The model is run from the TransCAD software platform through a customized user interface. This interface provides access to custom calculations developed specifically for CRCOG. A basic understanding of the TransCAD software program is required to get the most out of the model. Users unfamiliar with the software, however, should be able to perform some modeling tasks with the assistance of this guide.

Some of the travel model data is stored in a Comma-Separated Values (CSV) data file. The file contains tabular information such as trip rates, socioeconomic data, and other TAZ-specific data. The file feeds this information to the TransCAD based travel model. Guidance on use and maintenance of the database is also included in this User's Guide.

2. SYSTEM REQUIREMENTS

The model must be run on a computer running Windows XP, Windows 7, or higher and the TransCAD software program. Specific system requirements are shown in Table 1.

The listed requirements are suggested minimums; a computer that does not meet these requirements may still succeed in running the model. Increased processor speeds, multiple processor cores, and additional memory will reduce the amount of time required to run the model. The required disk space for installation must be available on the drive where TransCAD has been installed. The required disk space for additional scenarios can be on a local or network drive and must be available before attempting to run the model. However, model run times will be considerably longer if the model is run from a network drive instead of a local drive.

Table 1: System Requirements

Operating System	Windows XP or Windows 7 or higher A 64-bit operating system is recommended, 32-bit works fine.
Processor	Intel Core 2 processor or later Note: Multiple cores will significantly improve model run times.
Memory	4GB – 12 GB Note: At least 8 GB of memory is recommended.
TransCAD Software	Version 6.0 r2 Build 9025 32-bit
Microsoft Office	Version 2007 or later
Disk Space (Installation and input data)	50MB
Disk Space (Scenario output)	10-20 GB for each scenario / year (depends on number of selected queries)

3. INSTALLING THE MODEL

Before running the model, it is very important to ensure that all the model files have been installed correctly. Any errors in the user interface files (ex. CRCOG.dbd), Add-ins.txt file, or path (e.g. CRCOG.ini) file may prevent the model from loading. If the model is installed properly, the model user interface can be activated for a run.

All files are organized in a "CRCOG" folder with subfolders that designate the following:

- \\CRCOG\Base\inputs\ - Base year scenario input and output files.
- \\CRCOG\Scripts\ - Source code

Next, the user should compile the 0_CRCOG.lst file located at \\CRCOG\Scripts\ and save the crcog.dbd interface at \\CRCOG\Scripts\UI\. Model UI setup should be as shown in the Figure 1 below.

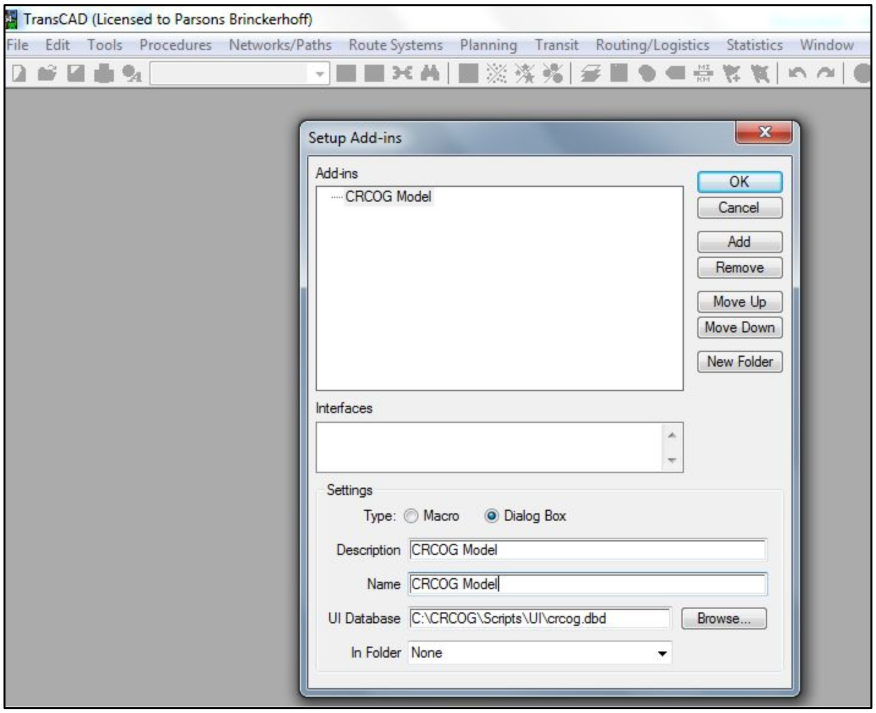


Figure 1: CRCOG Model Setup

The model setup file is named "CRCOGModel.bin" and is located at \\CRCOG\Scripts\UI\. This model file has information on scenarios and parameters necessary for the model to run. Note that every time the source code is modified, the user needs to compile it and replace the existing pre-compiled with the latest compiled code.

Accessing the CRCOG Model from TransCAD

The newly added plug-in is accessed via Tool > Add-Ins > CRCOG Model as shown in Figure 2. When clicked, this opens CRCOG Model GUI.

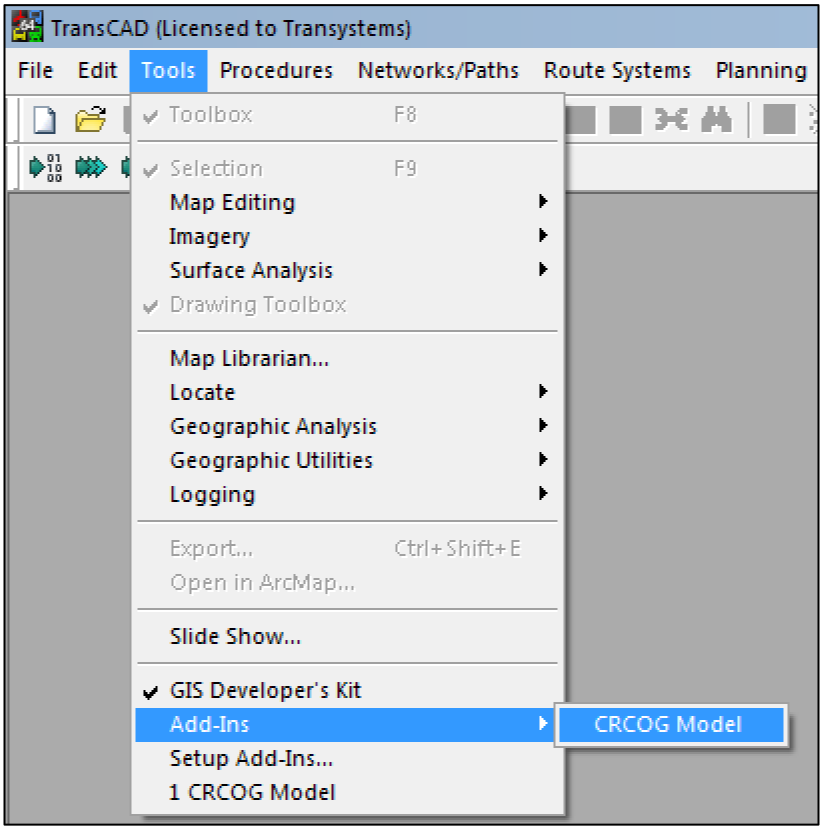


Figure 2: Accessing CRCOG Model in TransCAD

4. COMPONENTS OF THE MODEL

This chapter describes the CRCOG Model GUI and all the steps under each stage. Broadly, the GUI is broken down into five parts as shown in Figure 3. The first and last parts are only information items where the user is informed about the model name and version.

1. Banner Section
2. Scenario Setup
3. Run Setup
4. Model Stages
5. Version Tracking

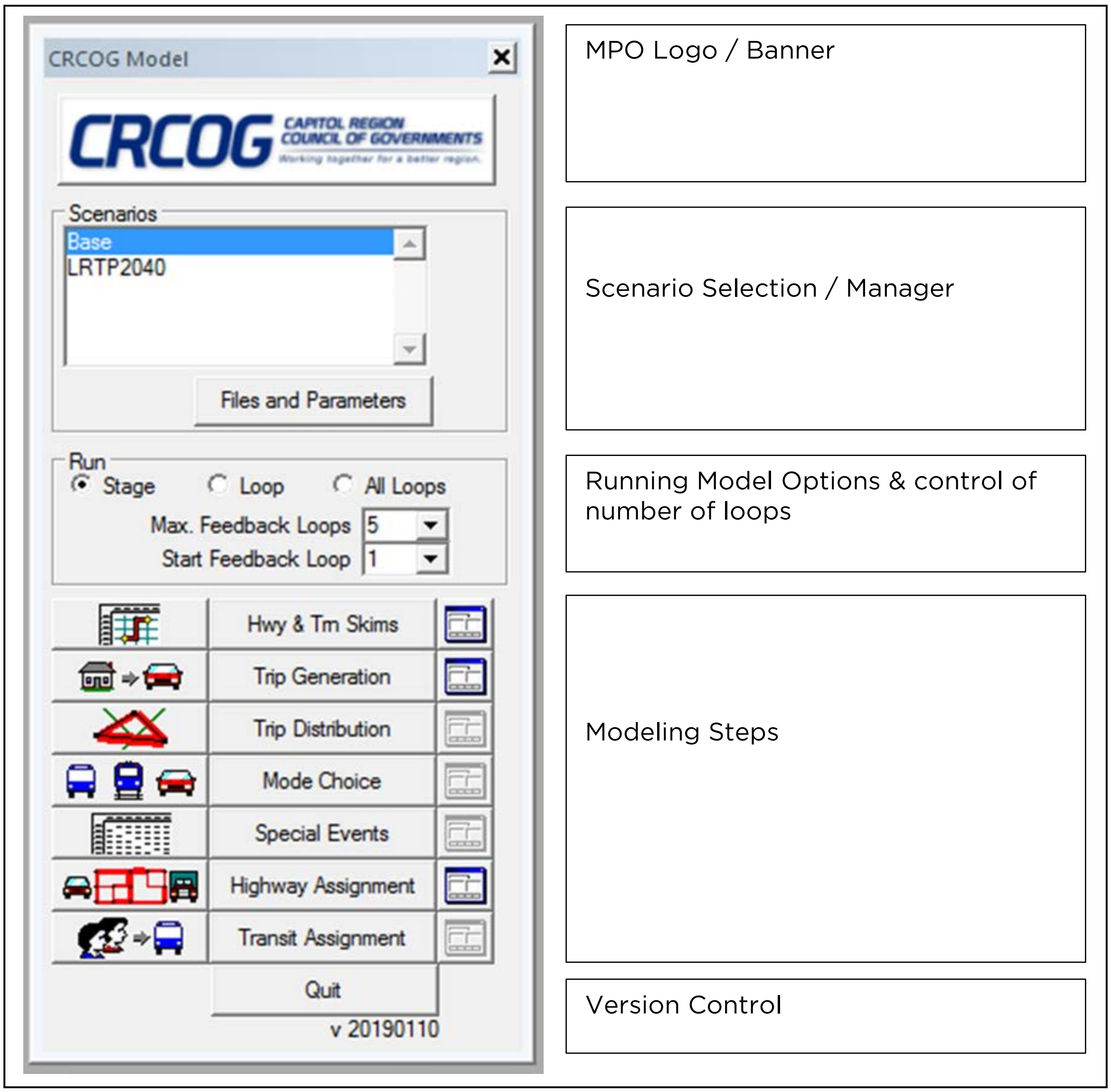


Figure 3: CRCOG Model Interface

Scenario Setup

This component lists modeling scenarios associated with the model. By selecting one scenario listed and clicking on the “Files and Parameters” shown in Figure 4, the user will be able to access input files as well as designate location of output files associated with the run.

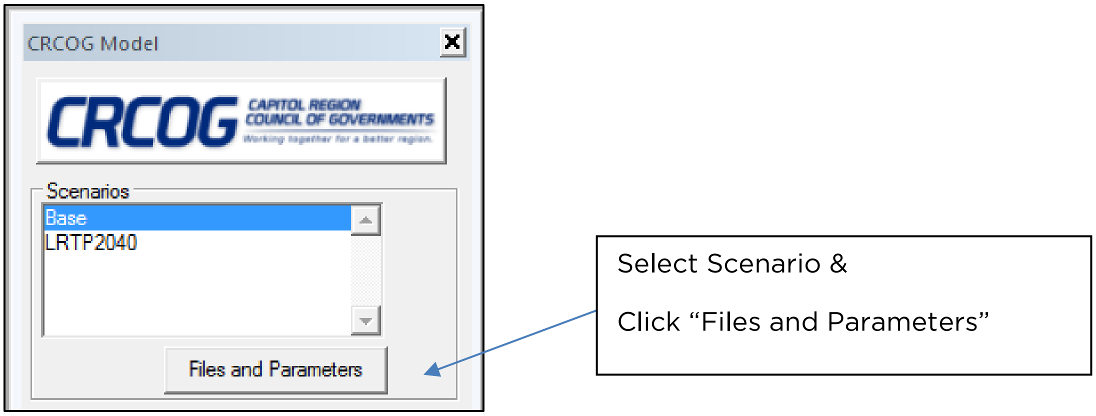


Figure 4: Scenario Selection

Figure 5 shows the Scenario Manager, which lists all the existing scenarios in the Model, the location directory of the scenarios, and the last saved date. Users can edit the scenario location by double clicking on the Folder location (see higlighted) and also can rename the scenaros by editing the name of the scenario. Users can also see the list of input and output files specified for each scenario by each step.

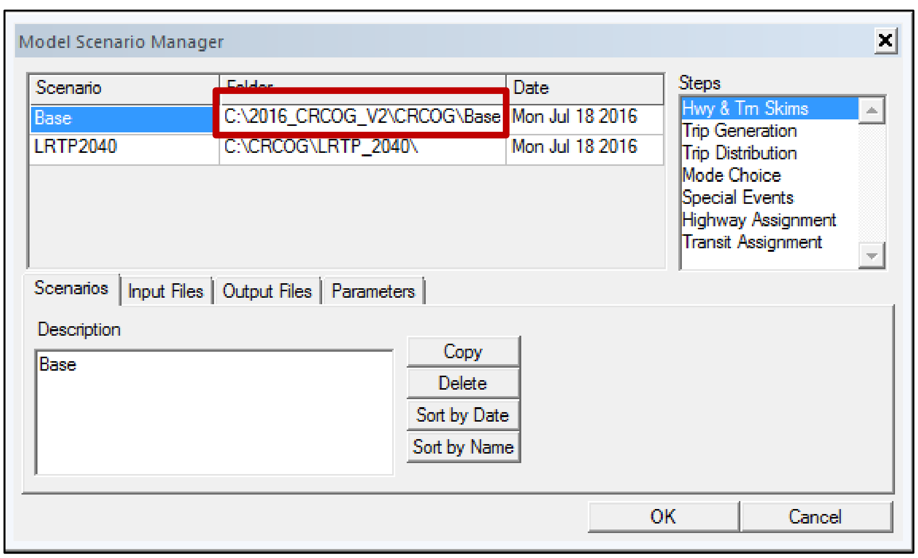
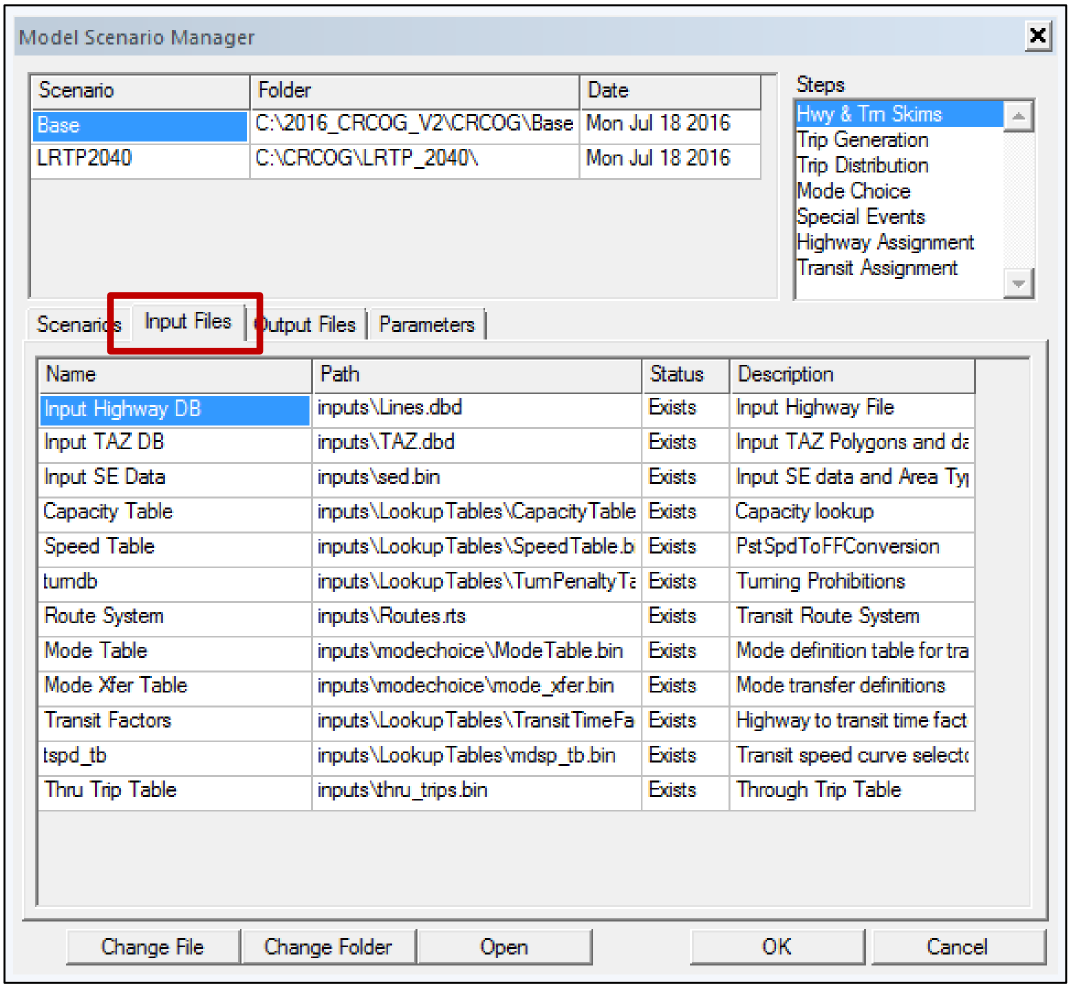


Figure 5: Scenario: Files and Parameters

Figure 6 and Figure 7 show the input and output files for the Base Scenario and Hwy & Trn Skims Step. Users can edit the location of the files by selecting and clicking on the "Change File" button. Users can also open the files by simply double clicking on the name of the file, as shown in Figure 8.



Scenario	Folder	Date
Base	C:\2016_CRCOG_V2\CRCOG\Base	Mon Jul 18 2016
LRTP2040	C:\CRCOG\LRTP_2040\	Mon Jul 18 2016

Name	Path	Status	Description
Input Highway DB	inputs\Lines.dbd	Exists	Input Highway File
Input TAZ DB	inputs\TAZ.dbd	Exists	Input TAZ Polygons and da
Input SE Data	inputs\sed.bin	Exists	Input SE data and Area Ty
Capacity Table	inputs\LookupTables\CapacityTable	Exists	Capacity lookup
Speed Table	inputs\LookupTables\SpeedTable.b	Exists	PstSpdToFFConversion
turndb	inputs\LookupTables\TurnPenaltyTa	Exists	Turning Prohibitions
Route System	inputs\Routes.rts	Exists	Transit Route System
Mode Table	inputs\modechoice\ModeTable.bin	Exists	Mode definition table for tra
Mode Xfer Table	inputs\modechoice\mode_xfer.bin	Exists	Mode transfer definitions
Transit Factors	inputs\LookupTables\TransitTimeFa	Exists	Highway to transit time fact
tspd_tb	inputs\LookupTables\mdsp_tb.bin	Exists	Transit speed curve select
Thru Trip Table	inputs\thru_trips.bin	Exists	Through Trip Table

Figure 6: Scenario: Inputs Files

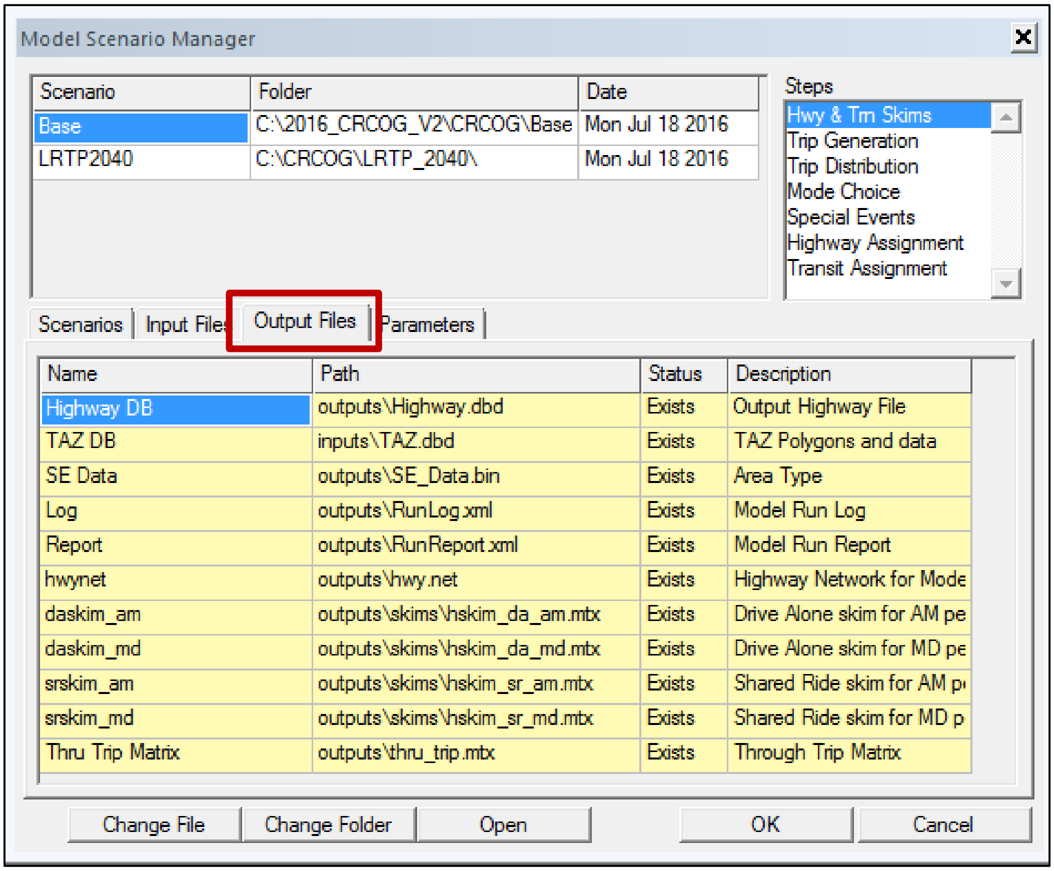


Figure 7: Scenario: Output Files

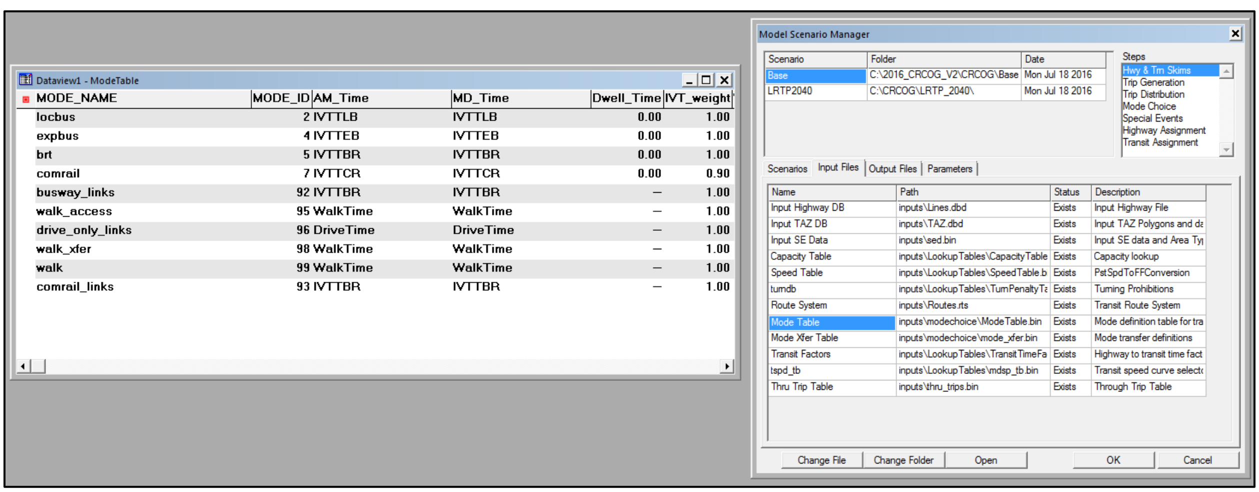


Figure 8: Scenario: Bin File Selection

Run Settings

The CRCOG model interface is shown in Figure 9. The user can run the model in three different ways.

1. Stage: The user can run the model one step at a time by clicking on any stage with the Stage radio button selected. Please note that there are multiple procedures within each stage that may be selected or unselected to meet the user's needs.

2. Loop: This option lets the user run the model one full loop from start to finish. Click on the "Hwy & Trn Skims" button to start the run.

3. All Loops: This options runs the full CRCOG model with a maximum of five feedback loops. Click on the "Hwy & Trn Skims" button to start the run.

   With the "Start Feedback Loop" selector, the user may select which feedback loop to start the current run. With the "Max. Feedback Loops" selector, the user may specify on which loop the model should stop. For example, a user may start a run on Loop 1 and have the model continue for 3 Feedback Loops. Then, if the results are satisfactory, the run can be resumed by selecting Start Feedback Loop 4 and Max Feedback Loops 5.

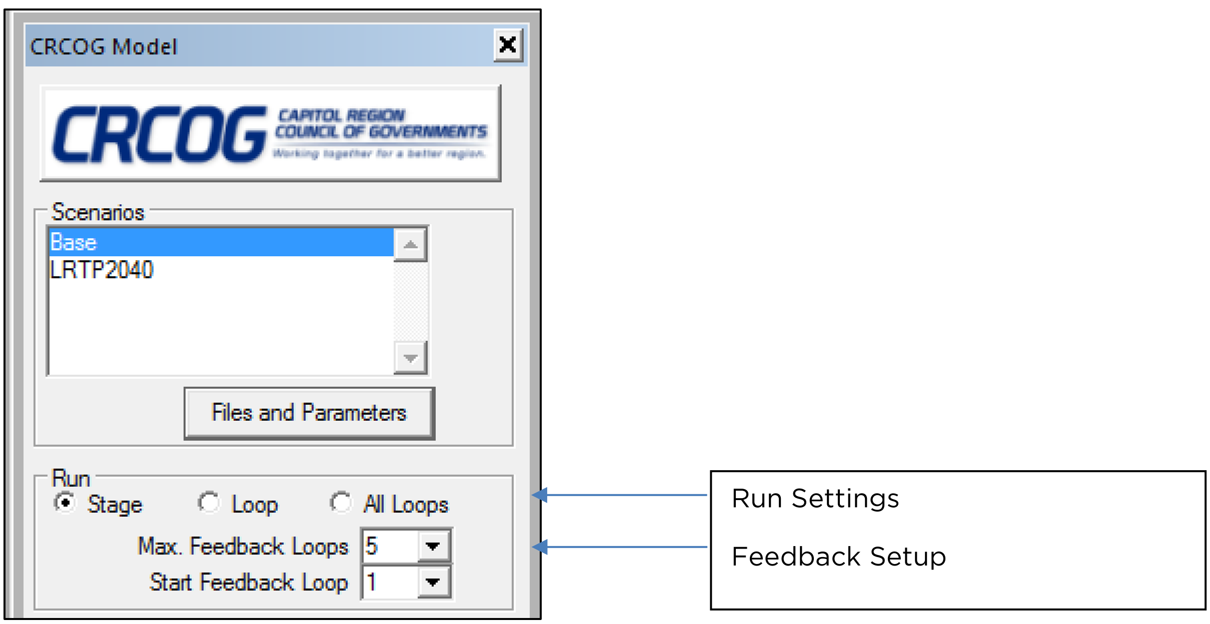


Figure 9: Run Type Settings

Model Stages

The model stages are designed to represent the different individual modules of the model. Each stage consists of a variety of processes and routines to perform different computational aspects of the model. For example, the "Hwy & Trn Skims" stage consists of eight sub-processes. Within each sub-process there are numerous subroutines that interact with other macros to produce outputs for a specific need. For instance, there is only one process to build transit skims; however, within this process there is one subroutine to check the number of transit modes and another routine to build skims by walk and drive access to all transit modes.

Model Stage GUI Buttons

Each model stage GUI has three parts, as shown in

Figure 10. These include buttons for:

1. Procedures and Macros
2. Model Stage
3. Quick View Results

Procedures and Marcos

This button displays all the sub process under the stage. The user can check or uncheck individual processes to run under the stage. Figure 11 shows the list of sub processes under Trip Generation Stage; all processes are turned on.

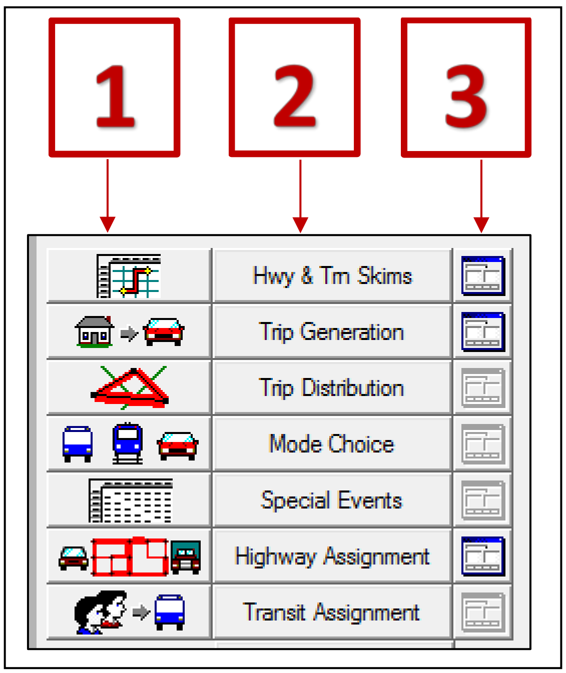


Figure 10: Model Stage GUI Buttons

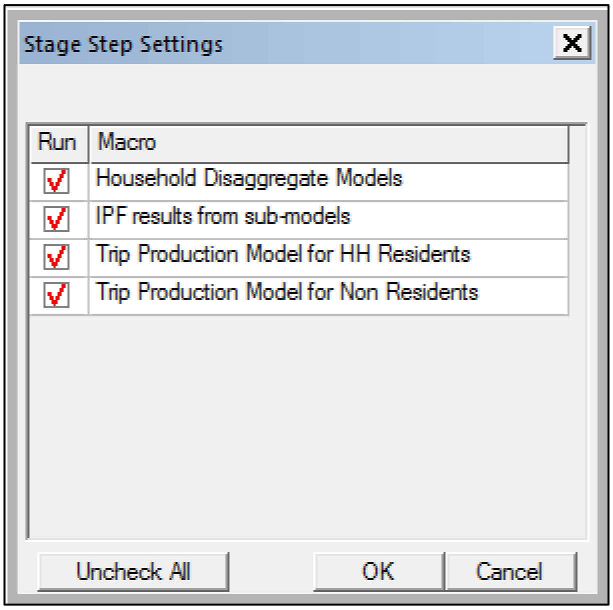


Figure 11: Procedures and Macros (1): List of Sub Processes

Model Stage

By clicking on the button, the user:

- Runs the stage for a Stage run type (selected modeling step)
- Runs from this stage for a Loop run type
- Runs from this stage for the current loop and runs all stages for the next loop under All Loops run type.

More detail on individual stages is provided in the Model Stage section.

Quick View Results

After running a model stage, users can quickly view results using the Quick View buttons. A Quick View button exists after every step except for Network Skimming, and is used to view results for that stage.

Model Stages

There is a total of seven modeling stages in the CRCOG model as shown in

Figure 10. Each Stage is described below:

Stage: Hwy & Trn Skims:

In this stage highway and transit skims are produced. The detailed processes for this stage are displayed in Figure 12. This is the first stage of the model where several highway attributes are calculated and the highway network file is built. After the highway network is built, highway skims are created and accessibility measures are calculated. The transit network and transit skims are also generated during this step.

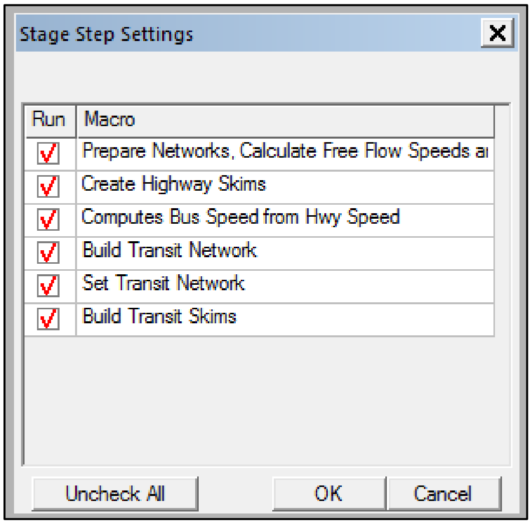


Figure 12: Hwy & Trn Stage: Skims Processes

Stage: Trip Generation:

In this stage households are disaggregated by size, income, worker and auto types and the trip attractions are produced by applying trip rates by each category. Details are provided in Figure 13.

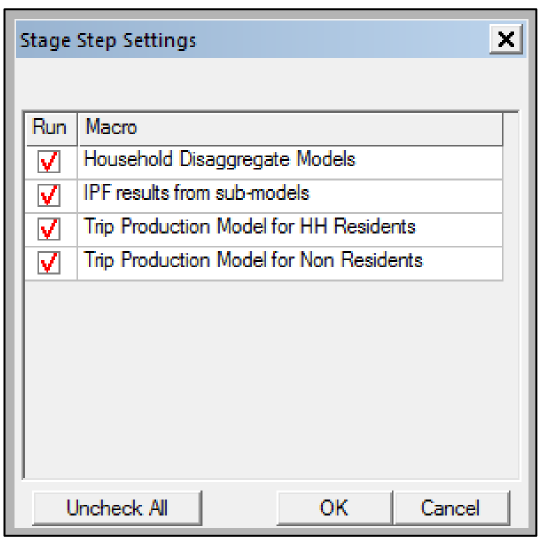


Figure 13: Trip Generation Stage Steps

Stage: Trip Distribution:

The disaggregated trip attractions by size, income, worker and auto types produced in earlier step are associated with trip productions (distribution) are produced by applying trip rates by each category. Details are provided in Figure 14. This stage computes mode choice logsums and destination choice model trips for all trip purposes.

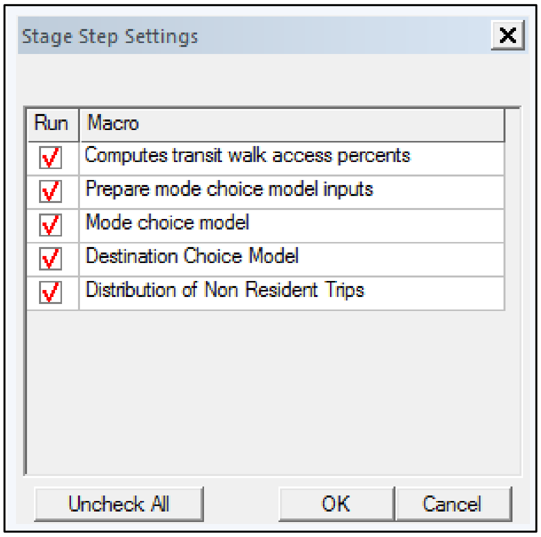


Figure 14: Trip Distribution Stage Steps

Stage: Mode Choice:

This stage computes a mode choice model. There is only two process under this stage: calculate the mode choice trips and write out summary output file.

Non-motorized share and long walk and bike distance skims are computed. The trips by purpose and income markets from the destination choice model are then pre-processed for each walk market and used as input into the mode choice model. The mode choice model is run and produces trips by mode for each of the specified markets. A post processor is then run to aggregate trips by mode across the markets.

Stage: Special Events:

This stage computes a special event model. There is only one process under this stage.

Stage: Highway Assignment:

This stage runs PA to OD trip conversion, time of day model, vehicle occupancy and highway assignment steps, as shown in Figure 15.

All combined vehicle trips by time period are assigned to the highway network and link volumes, link paths and intersection volumes are generated in this stage.

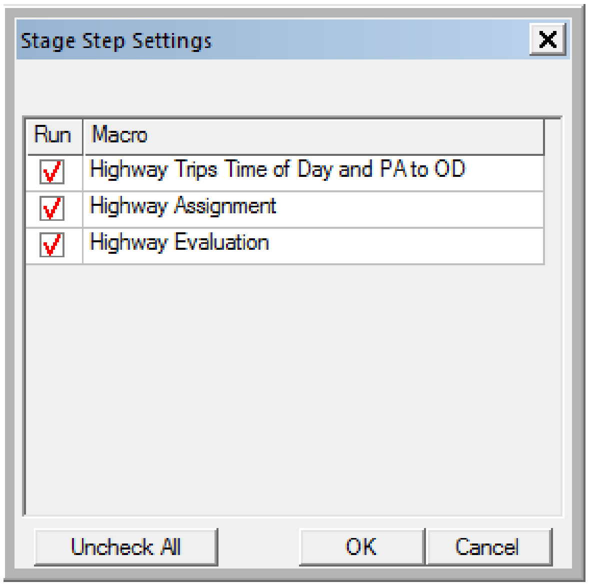


Figure 15: Highway Assignment Steps

Stage: Transit Assignment

This stage, as shown in in Figure 16, computes transit trip tables from the mode choice model and runs transit assignment.

Similarly to highway assignment stage, the mode choice output is processed and assigned to the transit network.

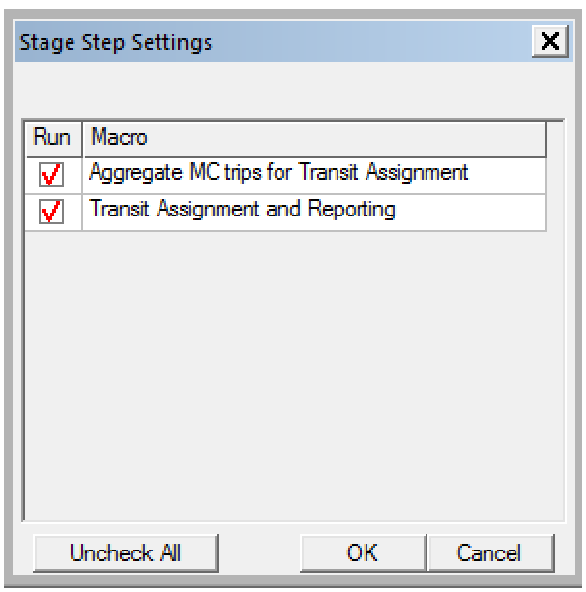


Figure 16: Transit Assignment Steps

Model Input Files

The CRCOG TDM relies on a large amount of data and numerous parameters and lookup tables. The TransCAD software provides a table format that can be used to store this type of information. The TransCAD table format is relatively efficient and very stable. It allows for sufficient precision in storage of decimal numbers using Fixed Format Binary (BIN) format that has been used to store all appropriate data output from the travel model in table format. However, a Comma-Separated Values (CSV) database has also been used to store data that is input to the model.

The list of input and output files can be easily accessed and modified from the scenario manager, as illustrated in Figure 6. However, only the files that are specified in the CRCOGModelTable.bin are displayed in the scenario manager. This section of the User's Manual will define the inputs and outputs for each stage of the model.

Table 2 contains a list of the input files, a description of the data contents, the file format, and the step in which it is used.

Table 2: Input Database files

Input Files	Modeling Step	Format	Input Description
Input SE Data	Hwy & Trn Skims	BIN	Input SE data and Area Type File
Capacity Table	Hwy & Trn Skims	BIN	Capacity lookup
Speed Table	Hwy & Trn Skims	BIN	Posted Speed to Free Flow Conversion
Turndb	Hwy & Trn Skims	BIN	Turning Prohibitions
Route System	Hwy & Trn Skims	BIN	Transit Route System
Mode Table	Hwy & Trn Skims	BIN	Mode definition table for transit skims
Mode Xfer Table	Hwy & Trn Skims	BIN	Mode transfer definitions
Transit Factors	Hwy & Trn Skims	BIN	Highway to transit time factors
tspd_tb	Hwy & Trn Skims	BIN	Transit speed curve selector by AT/FT/Mode
Thru Trip Table	Hwy & Trn Skims	BIN	Through Trip Table
Work Curve	Trip Generation	CSV	Household Worker Disaggregate Curve
IPFseed	Trip Generation	CSV	IPF based on PUMS Seed (0,1,2)
TripRates	Trip Generation	CSV	Resident Model Trip Generation Rates
Coeff_DC_Size	Trip Distribution	BIN	Destination Choice Model Size Term Coefficient
res_tod	Highway Assignment	CSV	Time-of-day Factors - Resident
nonres_tod	Highway Assignment	CSV	Time-of-day Factors - Non Resident

Model Output Files

The TransCAD modeling software contains mapping and reporting utilities that can be used to produce model outputs and summary data. These tools, described below, are used by modelers to validate the simulation and check the calibration or success of the run. These utilities usually operate on one scenario at a time.

All output files generated by each modeling step can be accessed using the CRCOG model add-in interface. As shown in Figure 7, select the scenario run, and click "Files and Parameters" to access the "Model Scenario Manager" that provides means to access input and output files. Select the modeling Step on the top right and "output files" tab on the bottom half of the interface.

Table 3 thru Table 8 contain a list of data outputs, file format, a description of the data contents, and the modeling step in which it is produced.

Table 3: Output files from Highway and Transit Skims

Input Files	Modeling Step	Format	Input Description
Highway DB	Hwy & Trn Skims	DBD	Output Highway File
TAZ DB	Hwy & Trn Skims	DBD	TAZ Polygons and data
SE Data	Hwy & Trn Skims	BIN	Area Type
Log	Hwy & Trn Skims	XML	Model Run Log
Report	Hwy & Trn Skims	XML	Model Run Report
hwynet	Hwy & Trn Skims	Net	Highway Network for Mode Choice & Assignment
daskim_am	Hwy & Trn Skims	MTX	Drive Alone skim for AM period
daskim_md	Hwy & Trn Skims	MTX	Drive Alone skim for MD period
srskim_am	Hwy & Trn Skims	MTX	Shared Ride skim for AM period
srskim_md	Hwy & Trn Skims	MTX	Shared Ride skim for MD period
Thru Trip Matrix	Hwy & Trn Skims	MTX	Through Trip Matrix

Table 4: Output files from Trip Generation and Trip Distribution Model

Input Files	Modeling Step	Format	Input Description
IPF_trace	Trip Generation	RPT	Reports IPF output
res_productions	Trip Generation	BIN	Resident trip productions
nonres_productions	Trip Generation	BIN	Non resident productions
nonres_tripgen_report	Trip Generation	TXT	Non resident trip generation report file
friction_factors	Trip Generation	BIN	Friction factors for trip distribution
k_factor_matrix	Trip Distribution	MTX	K factor matrix in trip distribution
nonres_trips	Trip Distribution	MTX	Trip distribution output for non residents
dummy	Trip Distribution	MTX	Blank zonal matrix file

Table 5: Output files from Mode Choice

Input Files	Modeling Step	Format	Input Description
AM Walk Percent	Mode Choice	MTX	AM walk percents (logsums)
MD Walk Percent	Mode Choice	MTX	MD walk percents (logsums)
mcsum	Mode Choice	CVS	Mode Choice Summary Report

Table 6: Output files from Special Events

Input Files	Modeling Step	Format	Input Description
specialevent_trips_in	Special Events	MTX	Inbound special event trip table
specialevent_trips_out	Special Events	MTX	Outbound special event trip table

Table 7: Output files from Highway Assignment

Input Files	Modeling Step	Format	Input Description
outam	Highway Assignment (HA)	MTX	AM HWY vehicles for Assignment
outmd	HA	MTX	MD HWY vehicles for Assignment
outnt	HA	MTX	NT HWY vehicles for Assignment
outpm	HA	MTX	PM HWY vehicles for Assignment
hwyam	HA	BIN	AM Peak flow from Highway Assignment
hwymd	HA	BIN	MD flow from Highway Assignment
hwynt	HA	BIN	NT flow from Highway Assignment
hwypm	HA	BIN	PM Peak flow from Highway Assignment
hwydaily	HA	BIN	Daily flow for Final Highway Assignment

Table 8: Output files from Transit Assignment

Input Files	Modeling Step	Format	Input Description
outpktrn	Transit Assignment (TA)	mtx	Peak transit trips for Assignment
outoptrn	TA	mtx	Off peak transit trips for Assignment
pk_transit_flw_wlb	TA	bin	Peak Transit Flow walk-local bus
pk_transit_flw_dlb	TA	bin	Peak Transit Flow drive-local bus
op_transit_flw_wlb	TA	bin	Off-peak Transit Flow walk-local bus
op_transit_flw_dlb	TA	bin	Off peak Transit Flow drive-local bus
pk_walk_flow_wlb	TA	bin	Peak Walk Flow walk-local bus
pk_walk_flow_dlb	TA	bin	Peak Walk Flow drive-local bus
op_walk_flow_wlb	TA	bin	Off peak Walk Flow walk-local bus
op_walk_flow_dlb	TA	bin	Off peak Walk Flow drive-local bus
pk_transit_onoff_wlb	TA	bin	Peak Transit OnOff walk-local bus
pk_transit_onoff_dlb	TA	bin	Peak Transit OnOff drive-local bus
op_transit_onoff_wlb	TA	bin	Off peak Transit OnOff walk-local bus
op_transit_onoff_dlb	TA	bin	Off peak Transit OnOff drive-local bus
pk_transit_flw_web	TA	bin	Peak Transit Flow walk-express bus
pk_transit_flw_deb	TA	bin	Peak Transit Flow drive-express bus
op_transit_flw_web	TA	bin	Off-peak Transit Flow walk-express bus
op_transit_flw_deb	TA	bin	Off peak Transit Flow drive-express bus

Input Files	Modeling Step	Format	Input Description
pk_walk_flow_web	TA	bin	Peak Walk Flow walk-express bus
pk_walk_flow_deb	TA	bin	Peak Walk Flow drive-express bus
op_walk_flow_web	TA	bin	Off peak Walk Flow walk-express bus
op_walk_flow_deb	TA	bin	Off peak Walk Flow drive-express bus
pk_transit_onoff_web	TA	bin	Peak Transit OnOff walk-express bus
pk_transit_onoff_deb	TA	bin	Peak Transit OnOff drive-express bus
op_transit_onoff_web	TA	bin	Off peak Transit OnOff walk-express bus
op_transit_onoff_deb	TA	bin	Off peak Transit OnOff drive-express bus
pk_transit_flw_wbr	TA	bin	Peak Transit Flow walk-brt
pk_transit_flw_dbr	TA	bin	Peak Transit Flow drive-brt
op_transit_flw_wbr	TA	bin	Off-peak Transit Flow walk-brt
op_transit_flw_dbr	TA	bin	Off peak Transit Flow drive-brt
pk_walk_flow_wbr	TA	bin	Peak Walk Flow walk-brt
pk_walk_flow_dbr	TA	bin	Peak Walk Flow drive-brt
op_walk_flow_wbr	TA	bin	Off peak Walk Flow walk-brt
op_walk_flow_dbr	TA	bin	Off peak Walk Flow drive-brt
pk_transit_onoff_wbr	TA	bin	Peak Transit OnOff walk-brt
pk_transit_onoff_dbr	TA	bin	Peak Transit OnOff drive-brt
op_transit_onoff_wbr	TA	bin	Off peak Transit OnOff walk-brt
op_transit_onoff_dbr	TA	bin	Off peak Transit OnOff drive-brt
pk_transit_flw_wcr	TA	bin	Peak Transit Flow walk-commuter rail
pk_transit_flw_dcr	TA	bin	Peak Transit Flow drive-commuter rail
op_transit_flw_wcr	TA	bin	Off-peak Transit Flow walk-commuter rail
op_transit_flw_dcr	TA	bin	Off peak Transit Flow drive-commuter rail
pk_walk_flow_wcr	TA	bin	Peak Walk Flow walk-commuter rail
pk_walk_flow_dcr	TA	bin	Peak Walk Flow drive-commuter rail
op_walk_flow_wcr	TA	bin	Off peak Walk Flow walk-commuter rail
op_walk_flow_dcr	TA	bin	Off peak Walk Flow drive-commuter rail
pk_transit_onoff_wcr	TA	bin	Peak Transit OnOff walk-commuter rail
pk_transit_onoff_dcr	TA	bin	Peak Transit OnOff drive-commuter rail
op_transit_onoff_wcr	TA	bin	Off peak Transit OnOff walk-commuter rail
op_transit_onoff_dcr	TA	bin	Off peak Transit OnOff drive-commuter rail
pk_trn_summary_flow	TA	bin	Peak transit flow summary
op_trn_summary_flow	TA	bin	Off peak transit flow summary
pk_trn_summary_onoff	TA	bin	Peak transit OnOff summary
op_trn_summary_onoff	TA	bin	Off peak transit OnOff summary
pk_transit_summary_rpt	TA	bin	Peak transit summary report
op_transit_summary_rpt	TA	bin	Off peak transit summary report

Performance Report / Performance Log

This utility creates an HTML performance report that summarizes model results. The user may choose to create various reports outlining the performance of the model and calibration parameters for various modeling steps. To access the performance reporting in TransCAD, select Tools > Logging > View Report or View Log.