VALUE PRICING IN CONNECTICUT

September 2008

Norman Garrick (PI)
Wesley Marshall, P.E.
Eric Jackson

JHR 08-313 Project 05-6

This research was sponsored by the Joint Highway Research Advisory Council (JHRAC) of the University of Connecticut and the Connecticut Department of Transportation and was performed through the Connecticut Transportation Institute of the University of Connecticut.

Technical Report Documentation Page

1. Report No.
JHR 08-313

2. Government Accession No.
N/A

3. Recipient's Catalog No.

4. Title and Subtitle
VALUE PRICING IN CONNECTICUT

5. Report Date
September 2008

6. Performing Organization Code
N/A

7. Author(s)
Norman Garrick (PI), Wesley Marshall, P.E. and
Eric Jackson

8. Performing Organization Report No.
JHR 08-313

9. Performing Organization Name and Address
University of Connecticut
Connecticut Transportation Institute
Storrs, CT 06269-5202

10. Work Unit No. (TRAIS)
N/A

11. Contract or Grant No.
N/A

12. Sponsoring Agency Name and Address
Connecticut Department of Transportation
280 West Street
Rocky Hill, CT 06067-0207

13. Type of Report and Period Covered
FINAL

14. Sponsoring Agency Code
N/A

15. Supplementary Notes

This study was conducted under the Connecticut Cooperative Highway Research Program (CCHRP, http://www.cti.uconn.edu/chwrp/index.php).

16. Abstract

This report documents a comprehensive research effort, funded by the Connecticut Cooperative Highway Research Program, to determine which roadways and/or regions in Connecticut were candidates for congestion pricing and to evaluate the impacts of pricing in these areas. Congestion is a problem on major arterials in the larger metropolitan regions in Connecticut. Two routes (I-95 and Route 15) in Connecticut were identified as candidates for congestion pricing. Multiple congestion pricing scenarios were simulated in TransCAD during the AM peak hour to investigate the impact on mode choice and congestion. The results of this analysis indicate that when pricing only one of these routes, the other route (which runs parallel) experiences a significant increase in congestion. The results suggest that the biggest and most positive outcome in terms of reducing traffic and decreasing congestion in the region would come from pricing both routes simultaneously. However, this strategy would require a significant increase in rail capacity and level of service in the region since the resultant shift to rail travel would tax the existing rail service. Our preliminary assessment of income suggests that this pricing scheme could generate some of the income needed for upgrading the rail system.

17. Key Words
Value, Congestion, and Road Pricing
Transportation and Scenario Planning
Four-Step Model
Mode Choice

18. Distribution Statement
No restrictions. This document is
available to the public through the
National Technical Information Service
Springfield, Virginia 22161

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
67

22. Price
N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^{o}C	Celsius	1.8C+32	Fahrenheit	^{o}F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

TABLE OF CONTENTS

List of Figures

List of Tables

1 Introduction

This report documents a comprehensive research effort, funded by the Connecticut Cooperative Highway Research Program, to determine which roadways and/or regions in Connecticut were candidates for congestion pricing and to evaluate the impacts of pricing in these areas.

1.1 Background

Congestion is sometimes a problem on major arterials in the larger metropolitan regions in Connecticut. Academic, professional, and journalistic evidence not only confirms this fact, but attempts to describe some of its negative consequences (Schrank and Lomax, 2005; Weisbrod, et al., 2001; Howard, 2003; Ambrosini, 2000; ConnDOT, 2004). Lost time and additional fuel costs are sometimes used to quantify impacts, but the true costs of congestion are likely much greater. Congestion acts as a tax on economic activity that, over the long term, raises costs for businesses, reduces productivity, and corrodes quality of life.

Remedies prove evasive, however, as Connecticut's landscape provides unique challenges to reducing congestion. Expanding highway capacity, whether through additional lanes on existing roads, or by building entirely new highways, is expensive and provides only short-term benefits (Ewing and Lichtenstein, 2002; Cervero, 2002) and in itself, often has a significant negative impact on quality of life and on economic, social and environmental sustainability. Demand management, in contrast, is attractive for a number of reasons including its cost-effectiveness. Connecticut has long promoted carpooling, bus transit, rail, telecommuting and van pooling with the hope of slowing the growth of single-occupant vehicles. These efforts have not had much success. The primary reason is that the current land use pattern, along with the configuration and design of the transportation network, limits choices and makes driving the most practical alternative for the vast majority of trips made by Connecticut residents.

Demand management is most effective when it encompasses a wide range of supportive strategies that affect both land use and mobility patterns. Road pricing is one tool that has become part of this demand management strategy[1]. The process of selecting routes where congestion pricing would most effectively reduce traffic congestion has been widely investigated (Ferrari, 1995; Yang and Lam 1996; Bergendorff et al. 1997; Lawphongpanich and Hearn 2004; Yildirim and Hearn 2005). The team drew upon these previous studies in an effort to select and design the pricing projects with the best chance of success.

Road pricing, also known as congestion pricing or value pricing, succeeds where some other congestion-reducing strategies fail; this is because it specifically confronts the

---

[1] Existing pricing projects can be found in California, Florida, Texas, Minnesota, and New York/New Jersey. A variety of other states have proposed or are developing pricing policies. For a catalog of these projects, see http://www.hhh.umn.edu/centers/slp/projects/conpric/index.htm.

economic landscape that incentivizes congestion. By creating a "market" for fixed highway capacity, road pricing invites drivers to consider more carefully their transportation decisions, including where to travel, when to travel, what mode to choose, or whether to make a trip at all. This "consumer response" provides facility managers with an effective tool to manage demand, thus providing them with the ability to improve travel time, reliability, and vehicle throughput on existing transportation infrastructure.

However, despite its theoretical attractiveness, there are many challenges to implementing road pricing. These challenges include the perception that pricing a roadway favors the wealthy. Another challenge is to not overwhelm city or local streets by removing a disproportionate of traffic from the major arterials. However, the primary challenge among these is the fundamental shift required in how the public perceives automobile travel. The majority of State and Federal highways were promoted and built as "public goods," financed collectively through the fuel tax under the perceived premise of unrestricted use for everyone. Road pricing, by contrast, makes highway travel a private good on those facilities or lanes where it is applied; one vehicle "buys" uncongested passage from start point to end point on the facility. This conceptual shift makes implementing road pricing difficult. But priced facilities in California and elsewhere have been largely successful in winning public acceptance and support (Harrington et al., 1998; Podgorski and Kockelman, 2004). Drawing on these early successes, states such as Minnesota, Florida, Texas, and Virginia were recently able to garner public and political support for similar projects.

The multiple success stories are reassuring to policymakers who are considering pricing as a congestion-reduction strategy, but they do not take the risk out of such projects, either politically or financially. Transportation networks and traffic problems vary in nature and intensity from one metropolitan region to the next, making strategies successful in one city possibly inappropriate for another's geographic, social, or political landscape. Thus, a great deal of uncertainty remains regarding the potential success of pricing for a specific facility.

Recognizing that modern tools such as transportation computer models can, to some extent, reduce the uncertainty of applying specific road pricing tools to specific highways through simulation and forecasting, this report documents our attempt to apply these with the goal of better understanding how road pricing would affect Connecticut.

1.2 Research Objectives

The overall research goal was to understand how road pricing will impact travel in Connecticut. The analysis was limited to modeling short term changes; the intent was to model how travelers would respond to road pricing if it were in place today. More specifically, the model was built to quantify both mode shift and road use in response to pricing. Unlike many transportation planning models, the road use analysis was not limited to just the priced roads or even the limited access highways and arterials; rather, the analysis included all roads in the transportation network for the region in question.

This enabled the model to reveal how pricing certain roads affected the rest of the transportation network.

Quantifying long-term changes was not undertaken in this study because to do so with any confidence would require modeling changes in land use patterns in response to pricing the transportation network. This is an extremely important issue for understanding the longer term impacts of pricing but is beyond the scope of this current project.

The road pricing scenarios were developed based on current network characteristics and the perceived need for congestion management. The simulation of current traffic conditions and various congestion pricing scenarios resulted in an analysis of how road pricing affects the transportation network (in the short term) and the transportation choices people will make. The study had three main objectives:

1) Determine realistic road value pricing scenarios in Connecticut;
2) Model these scenarios and determine the short-term impact on automobile travel; and
3) Determine the mode shift and the traffic impacts as a result of each pricing scenario

The subsequent sections outline the processes used to select a viable study area and to accomplish these objectives.

2 Scenario Development

The process of developing congestion pricing scenarios for Connecticut involved two general steps: *selection* and *design*. The first step involved the search for a location within the state where congestion pricing was hypothesized to be most beneficial. Data characterizing the current operation of the statewide transportation network were obtained to identify highway segments likely to be good candidates for road pricing. The second step was to focus on a region and develop pricing scenarios to address the problems identified in that region. These two steps are outlined in detail below.

2.1 Selection

The overall goal in selecting sites for road pricing scenarios is to isolate highway segments where pricing may be viable or desirable. This process began by identifying, understanding, and quantifying what characteristics impacted the viability of congestion pricing. Then, an algorithm was developed to identify which road segments were the best candidates for congestion pricing.

2.1.1 Identifying Factors

Two general factors were used to initially identify roads where pricing showed potential. First, and most critically, a highway or segment must be congested for road pricing to be implemented successfully. There are several reasons for this. First, pricing fundamentally draws its success from creating a market for limited highway capacity. If a particular highway is below design capacity, then flow capacity on that segment is unconstrained until capacity is reached. Therefore, more cars can be added to the facility with no new or additional cost to the users. Under this circumstance, pricing solely based on congestion would result in a toll of $0. As congestion worsens, the benefits to the user become more substantial and more visible. Under heavily congested conditions, drivers perceive pricing as "buying" higher travel speeds and increased travel time reliability. Routes with higher congestion levels often gain public support for road pricing due to these perceived gains in travel. Of course this all depends on successful project selection, design, and outcome.

The second factor impacting the viability of pricing is the physical layout of the road. There are certain existing lane configurations that readily facilitate pricing. More specifically, existing HOV lanes provide an excellent opportunity to implement pricing in the form of a High Occupancy/Toll (HOT) lane. HOV lanes are usually located in corridors that already have considerable congestion as a means to promote carpooling and reduce the number of single occupancy vehicles in the regular travel lanes. However, these HOV lanes are typically under-utilized, thus leaving extra capacity that can be "sold" to single occupancy vehicles. The primary advantage from converting HOV lanes to HOT lanes is that the public already views the existing lane or lanes as distinct from general purpose lanes. Furthermore, much of the infrastructure necessary for pricing, such as limited access points, a separated lane, and sign gantries, already exists for HOV lanes. Thus, HOV-HOT conversions provide an opportunity to initiate pricing with low capital costs and limited public and political opposition.

Therefore, highway segments with congestion or existing HOV lanes were initially considered good candidates for road pricing.

2.1.2 Characterizing Connecticut's Highways

To select highways where pricing may be viable, data was collected in an effort to characterize Connecticut's entire network of limited access highways. The Connecticut Department of Transportation (ConnDOT) provided a comprehensive dataset of all state and federally maintained limited access roads. Each road is described in short segments (or links) usually less than ¼ mile long. Each link contained metrics of traffic, level of service (LOS), alignment characteristics, truck traffic, and future traffic conditions. Furthermore, the 2004 Congestion Screening and Monitoring Report (also published by ConnDOT) was used to supplement the original dataset. This report provided more detail for each of the links based on congestion and truck demand for each of ConnDOT's sixteen transportation planning regions. Despite the lower resolution, the Congestion Monitoring Report provides useful information such as the percent of VMT subject to congestion, delay rates, and additional truck demand characteristics, both current and as a 20-year forecast.

Data reduction began by eliminating all numbered roads shorter than 2.5 miles long. Most of these are short State Routes distant from congested highways. Their short lengths and (typically) rural locations make them poor candidates for road pricing. This process left the set of state and interstate highways shown in Table 2.1.

Table 2.1: Connecticut Limited Access Highways Considered for Pricing

Highway	Location	Length (mi.)
Rt. 2	From Hartford to Norwich	38.15
Rt. 2A	From Rt. 395 to Casinos (Montville)	3.39
Rt. 3	I-91 to Rt. 2 Connector (Glastonbury)	3.09
Rt. 6	From Columbia to Windham	14.13
Rt. 7	I-95 to Rt. 15 Connector (Norwalk)	3.96
Rt. 7	From Rt. 84 to Brookfield	11.12
Rt. 8	From Bridgeport to Winsted	58.49
Rt. 9	From New Britain to Old Saybrook	40.89
Rt. 11	From Rt. 2 to Salem	7.42
Rt. 15 (Merritt Pkwy)	From NY State Line to I-91 (Meriden)	66.89
Rt. 15	I-91 to I-84 Connector (E. Hartford)	5.59
Rt. 20	From I-91 to Bradley Airport	3.84
Rt. 25	From Bridgeport to Trumbull	6.28
Rt. 40	Rt. 15 to I-91 Connector (Hamden)	3.08
Rt. 72	I-84 to Rt. 9 Connector (New Britain)	7.9
I - 84	From New York To Massachusetts	97.9
I - 91	From I-95 (New Haven) to Mass.	58
I - 95	From New York To Rhode Island	111.57
I - 291	I-84 to I-91 Connector (S. Windsor)	6.4
I - 384	From I-84 to Bolton	8.53
I - 395	From I-95 (Waterford) to Mass.	54.69
I - 691	I-91 to I-84 Connector (Meriden)	8.92
I - 695	From I-95 (Killingly) to Rhode Island	4.49
Rt. 796 (Milford Pkwy.)	I-95 to Rt. 15 Connector (Milford)	2.88

The remaining routes were then aggregated into roadways of manageable lengths. This step was necessary because the highly segmented nature of the original dataset made characterization of a whole route difficult. Segments were aggregated in such a way that the resulting dataset was homogeneous in operating and congestion characteristics. For example, by defining segment endpoints at major interchanges, traffic demand along the group of links remained relatively constant. The resulting links had average lengths of less than five miles in urban areas (where congestion is dynamic), but more than twenty miles in relatively uncongested rural areas. Short highways, for example Rt. 40 in Hamden, are defined as a single link.

Drawing from the two data sources, each of the resulting 62 links were classified based on level of congestion and presence of HOV lanes. Congestion may be measured a number of ways. Peak-hour volume to capacity (V/C) ratio is a common metric since it reflects conditions when demand is highest and thus congestion is at its worst. This statistic, however, does not reflect other important characteristics. For instance, two highways with similar peak-period V/C ratios may have different peak structures. If road A maintains a high V/C for four hours, where Road B does so for only a single hour, Road A could be considered more heavily congested than Road B. Furthermore, the geographic scope of congestion along the length of a link also contributes to the overall traffic picture. If two links have the same average peak hour V/C, but one experiences congestion along 75% of its length as compared to only 25% for the other, traffic may be considered worse on the first. Finally, expected traffic growth is an important facet to the overall congestion picture. Other things being equal, highways with high growth rates pose a greater problem than those with slow growth rates. Following these arguments, five criteria were used to characterize congestion: (1) average peak hour V/C ratio, (2) average percent of VMT on link experiencing V/C greater than 0.85, (3) percent of link with peak hour V/C greater than 0.85, (4) forecasted (20-year) average peak hour V/C, and (5) forecasted (20-year) average percent of VMT subject to V/C greater than 0.85. Table 2.2 displays each link with congestion and HOV properties.

Table 2.2: Congestion & HOV Properties of Connecticut's Limited Access Highways

Highway Segment	Length (mi.)	Description	Avg. peak-hour volume/ capacity ratio	Avg. % of VMT subject to congestion	% of segment subject to peak hour congestion	Future avg. peak hour vol./cap. ratio	Future avg. % of VMT subject to congestion	Existing HOV lanes?
2	5.6	Jct. 84 to Jct. 17	0.97	1.7	71.3	1.31	8.8	-
2	19.7	Jct. 17 to Jct. 11	0.67	1.3	34.0	0.93	7.3	-
2	12.9	Jct. 11 to Jct. 395	0.32	0.2	0.0	0.45	3.1	-
2A	3.4	Jct. 395 to Norwich	0.44	0.2	2.1	0.61	3.9	-
3	3.1	Jct. 91 to Jct. 84	0.74	0.8	51.1	0.98	2.9	-
6	14.1	Columbia to Windham	0.09	6.5	0.0	0.34	11.8	-
7	4.0	Jct. 95 to Wilton	0.44	17.2	0.0	0.58	28.6	-
7	11.1	Jct. 84 to Brookfield	0.24	0.0	0.0	0.44	29.4	-
8	5.5	Jct. 95 to Jct. 15	0.62	1.6	7.8	0.72	4.8	-
8	7.1	Jct. 15 to Jct. 34	0.77	0.6	46.0	0.98	5.3	-
8	12.9	Jct. 34 to Jct. 63 (Naug)	0.74	0.2	18.4	0.96	3.4	-
8	3.6	Jct. 63 (Naug) to Jct. I-84	0.68	0.1	0.0	0.84	0.9	-
8	9.6	Jct. I-84 to Jct. 6	0.54	0.1	0.3	0.67	0.9	-
8	19.8	Jct. 6 to Winchester	0.23	0.0	0.0	0.30	0.1	-
9	29.4	Old Saybrook to Jct. 91	0.60	0.7	10.7	0.78	3.7	-
9	6.6	Jct. 91 to Jct. 72	0.89	2.7	43.2	1.10	11.1	-
9	5.0	Jct. 72 to Jct. 84	0.69	1.5	13.7	0.85	6.0	-
11	7.4	Jct. 2 to Salem	0.13	0.0	0.0	0.23	0.0	-
15	17.3	New York to Jct. 7	1.09	14.1	99.4	1.40	33.8	-
15	14.9	Jct. 7 to Jct. 25	1.15	18.6	100.0	1.42	34.8	-
15	2.2	Jct. 25 to Jct. 8	0.99	21.9	70.9	1.21	35.6	-
15	3.3	Jct. 8 to Jct. 796	1.05	21.0	95.4	1.24	34.7	-
15	5.1	Jct. 796 to Jct. 34	0.86	5.9	86.0	1.08	19.8	-
15	10.5	Jct. 34 to Jct. 40	0.98	5.9	96.7	1.21	19.8	-
15	13.6	Jct. 40 to Jct. 91	0.78	5.9	42.4	1.00	19.8	-
15	5.6	Jct. 91 to Jct. 84	0.89	4.7	64.6	1.13	16.9	-
20	3.8	Jct. 91 to Bradley Airport	0.65	1.4	0.0	0.84	5.2	-
25	6.3	Jct. 8 to Trumbull	0.34	18.5	0.0	0.42	22.8	-
40	3.1	Jct. 91 to Hamden	0.39	0.0	0.0	0.48	0.0	-
72	7.9	Jct. 84 to Jct. 9	0.41	0.5	3.4	0.59	1.7	-
84	3.8	New York to Jct. 7 SB	0.80	13.8	18.3	0.78	37.0	-
84	3.6	Jct. 7 SB to Jct. 7 NB	0.98	13.8	91.9	1.28	37.0	-
84	7.8	Jct. 7 NB to Jct. 6	1.02	13.8	95.9	0.90	37.0	-
84	9.8	Jct. 6 to Jct. 188	0.92	18.2	87.5	0.81	37.4	-
84	7.2	Jct. 188 to Jct. 8	0.91	20.5	86.6	0.81	37.6	-
84	8.9	Jct. 8 to Jct. 691	1.12	19.3	95.5	0.95	35.6	-
84	8.0	Jct. 691 to Jct 72	0.89	3.6	58.8	1.02	9.5	-
84	6.0	Jct 72 to Jct. 9	0.86	3.5	48.2	0.96	9.4	-
84	7.1	Jct. 9 to Jct. 91	0.98	3.4	95.5	1.19	9.3	-
84	4.4	Jct. 91 to Jct. 384	0.84	3.4	30.7	1.10	9.3	Yes
84	6.9	Jct. 384 to End HOV	0.69	3.4	43.5	0.92	9.3	Yes
84	24.6	Vernon to Mass.	0.61	1.6	0.0	0.76	4.3	-
91	6.3	Jct. 95 to Jct. 40/15	0.74	2.0	14.9	0.91	5.9	-
91	14.2	Jct. 40/15 to Jct. 691	0.60	2.0	0.0	0.77	5.9	-
91	6.3	Jct. 691 to Jct. 9	0.87	4.6	59.3	1.09	12.1	-
91	6.7	Jct. 9 to Jct. 3	0.92	3.8	88.1	1.16	10.9	-
91	5.2	Jct. 3 to Jct. 84	0.94	3.6	76.0	1.18	10.5	-
91	3.8	Jct. 84 to Jct. 291	0.77	3.6	0.0	0.96	10.5	Yes
91	6.1	Jct. 291 to Jct. 20	0.78	3.6	23.9	1.01	10.5	Yes
91	9.5	Jct. 20 to Mass.	0.79	3.6	25.4	0.97	10.5	-
95	15.2	New York to Jct. 7	0.96	17.0	87.4	1.25	55.4	-
95	13.8	Jct. 7 to Jct. 8	0.97	15.4	100.0	1.16	45.3	-
95	8.6	Jct. 8 to Jct. 796	0.94	14.0	84.2	1.11	35.4	-
95	9.9	Jct. 796 to Jct. 91	0.90	14.8	82.8	1.05	37.0	-
95	7.9	Jct. 91 to Jct. 1	0.96	14.8	96.3	0.88	37.0	-
95	56.1	Jct. 1 to Rhode Island	0.74	7.6	27.8	0.93	25.6	-
291	6.4	Jct. 91 to Jct 84	0.79	0.0	35.5	1.02	4.2	-
384	8.5	Jct. 84 to Bolton	0.51	0.0	0.0	0.68	0.1	-
395	54.7	Jct. 95 to Mass.	0.48	0.1	6.0	0.67	5.6	-
691	8.9	Jct. 84 to Jct. 91	0.66	0.5	7.5	0.86	2.8	-
695	4.5	Jct 395 to Rhode Island	0.04	0.0	0.0	0.06	0.0	-
796	2.9	Jct. 95 to Jct. 15	0.66	0.0	34.4	0.77	1.2	-

2.1.3 Selection

The link data shown in Table 2.2 was used to select candidates for pricing. For the reasons discussed in Section 2.1.1, all highway segments with existing HOV lanes were selected as candidates for road pricing. Because congestion can be measured in a variety of ways, an algorithm was used to calculate an overall "congestion factor." This congestion factor was then used to narrow the search for select highways where road pricing may be viable.

The congestion factor was generated by first considering what values within each category represent high or low levels of congestion. Using these cut-off values, routes were assigned to one three weight categories: 0, 0.5, or 1. Doing so normalizes each variable so that they can be weighted and then summed for a final score. For example, a road segment with peak hour V/C greater than 0.9 was assigned a value of 1; a peak hour V/C less than 0.8 yields a value of zero for the road; if between 0.8 and 0.9, the road is assigned the value 0.5. Cutoff values for all factors are shown in Table 2.3.

Table 2.3: Category Breaks Used to Construct Overall Congestion Factor

Variable	Variable weight	Factor equal zero if	Factor Equals 0.5 if	Factor equals 1 if
Avg. peak-hour volume/capacity ratio	30%	< 0.80	> = 0.80 and < 0.9	> = 0.9
Avg. % of VMT subject to congestion	30%	< 5.00	> = 5.00 and < 12	> = 12
% of segment subject to peak hour congestion	10%	< 50.0	> = 50.0 and < 70	> = 70
Future avg. peak hour vol./cap. ratio	15%	< 0.85	> = 0.85 and < 1.0	> = 1.0
Future avg. % of VMT subject to congestion	15%	< 8.00	> = 8.00 and <15	> = 15

The overall congestion score was calculated for each link as the weighted sum of the category factors. Weights are assigned based on perception of which variables are more or less important. Generally, current congestion characteristics were weighted as 70% of the overall score, with the remaining 30% attributed to forecasted congestion. More detailed weightings are shown in Table 2.3. One reason for giving greater weight to the existing congestion variables is that the focus of the study was on using existing traffic volumes and land use patterns to determine how pricing would affect current travel habits in Connecticut. Also, existing congestion factors are more reliable than future congestion estimates. Future congestion variables are typically determined using a number of different assumptions and conditions, some of which will be changed with the institution of road pricing in Connecticut.

This algorithm was applied to all highway links using the characteristics shown in Table 2.2. The resulting congestion scores range between a minimum of zero and a maximum of one, as shown in Table 2.4.

The congestion scores in Table 2.4 provide a general picture of how congestion affects Connecticut across its highway network, now and into the future. To provide further insight into this overall picture and to give it geographic meaning, the results were mapped to display Connecticut's congestion severity. In Figure 2.1, roads designated as "Heavy Congestion" are those with an overall congestion score greater than 0.75. "Moderate Congestion" is defined by a score between 0.5 and 0.75, and roads with scores less than 0.5 are described as "Little Congestion." The map also indicates which highway segments have existing HOV lanes.

Table 2.4: Link Congestion Scores

State Route Segment	Length (mi.)	Description	Congestion Score	Interstate Highway Segment	Length (mi.)	Description	Congestion Score
2	5.6	Jct. 84 to Jct. 17	0.625	84	3.8	New York to Jct. 7 SB	0.600
2	19.7	Jct. 17 to Jct. 11	0.075	84	3.6	Jct. 7 SB to Jct. 7 NB	1.000
2	12.9	Jct. 11 to Jct. 395	0.000	84	7.8	Jct. 7 NB to Jct. 6	0.925
2A	3.4	Jct. 395 to Norwich	0.000	84	9.8	Jct. 6 to Jct. 188	0.850
3	3.1	Jct. 91 to Jct. 84	0.125	84	7.2	Jct. 188 to Jct. 8	0.850
6	14.1	Columbia to Windham	0.225	84	8.9	Jct. 8 to Jct. 691	0.925
7	4.0	Jct. 95 to Wilton	0.450	84	8.0	Jct. 691 to Jct 72	0.425
7	11.1	Jct. 84 to Brookfield	0.150	84	6.0	Jct 72 to Jct. 9	0.300
8	5.5	Jct. 95 to Jct. 15	0.000	84	7.1	Jct. 9 to Jct. 91	0.625
8	7.1	Jct. 15 to Jct. 34	0.075	84	4.4	Jct. 91 to Jct. 384	0.375
8	12.9	Jct. 34 to Jct. 63 (Nau	0.075	84	6.9	Jct. 384 to End HOV	0.150
8	3.6	Jct. 63 (Naug) to Jct. I-	0.000	84	24.6	Vernon to Mass.	0.000
8	9.6	Jct. I-84 to Jct. 6	0.000	91	6.3	Jct. 95 to Jct. 40/15	0.075
8	19.8	Jct. 6 to Winchester	0.000	91	14.2	Jct. 40/15 to Jct. 691	0.000
9	29.4	Old Saybrook to Jct. 91	0.000	91	6.3	Jct. 691 to Jct. 9	0.425
9	6.6	Jct. 91 to Jct. 72	0.375	91	6.7	Jct. 9 to Jct. 3	0.625
9	5.0	Jct. 72 to Jct. 84	0.075	91	5.2	Jct. 3 to Jct. 84	0.625
11	7.4	Jct. 2 to Salem	0.000	91	3.8	Jct. 84 to Jct. 291	0.150
15	17.3	New York to Jct. 7	1.000	91	6.1	Jct. 291 to Jct. 20	0.225
15	14.9	Jct. 7 to Jct. 25	1.000	91	9.5	Jct. 20 to Mass.	0.150
15	2.2	Jct. 25 to Jct. 8	1.000	95	15.2	New York to Jct. 7	1.000
15	3.3	Jct. 8 to Jct. 796	1.000	95	13.8	Jct. 7 to Jct. 8	1.000
15	5.1	Jct. 796 to Jct. 34	0.700	95	8.6	Jct. 8 to Jct. 796	1.000
15	10.5	Jct. 34 to Jct. 40	0.850	95	9.9	Jct. 796 to Jct. 91	1.000
15	13.6	Jct. 40 to Jct. 91	0.450	95	7.9	Jct. 91 to Jct. 1	0.925
15	5.6	Jct. 91 to Jct. 84	0.500	95	56.1	Jct. 1 to Rhode Island	0.375
20	3.8	Jct. 91 to Bradley Airpo	0.000	291	6.4	Jct. 91 to Jct 84	0.150
25	6.3	Jct. 8 to Trumbull	0.450	384	8.5	Jct. 84 to Bolton	0.000
40	3.1	Jct. 91 to Hamden	0.000	395	54.7	Jct. 95 to Mass.	0.000
72	7.9	Jct. 84 to Jct. 9	0.000	691	8.9	Jct. 84 to Jct. 91	0.075
796	2.9	Jct. 95 to Jct. 15	0.000	695	4.5	Jct 395 to Rhode Island	0.000

Figure 2.1 reveals an overall congestion picture that closely mirrors anecdotal evidence. Connecticut's southwest corner suffers the worst congestion in the state because only two primary highways accommodate the strong demand to and From New York City in addition to local traffic. The Hartford region also experiences congestion but not at the same magnitude of congestion in Fairfield County. One key difference between the Hartford region and the southwest corner is that although there are some pockets of high congestion in the Hartford region, this congestion does not persist over extended lengths of highway. Interstate 84 between Danbury and Cheshire currently experiences traffic congestion on the same scale as Interstate 95 and the Merritt Parkway. However, the analysis of this road is complicated by recent construction to widen the road from two to three lanes in certain areas. This capacity expansion is intended to mitigate traffic congestion.

Unlike corridor widening, road pricing is a transportation demand management strategy. Such strategies are typically intended to maximize efficiency of the existing transportation network. On the other hand, rather than simply accommodating existing demand, the additional capacity created by widening highways has been shown in most of the existing literature to actually induce additional demand. In other words, the short-term gains found with more road capacity are quickly lost with more people choosing to use these highways. In the southwest Connecticut region, this would likely include a mode shift away from transit in favor of highway use in order to use the newly created capacity.

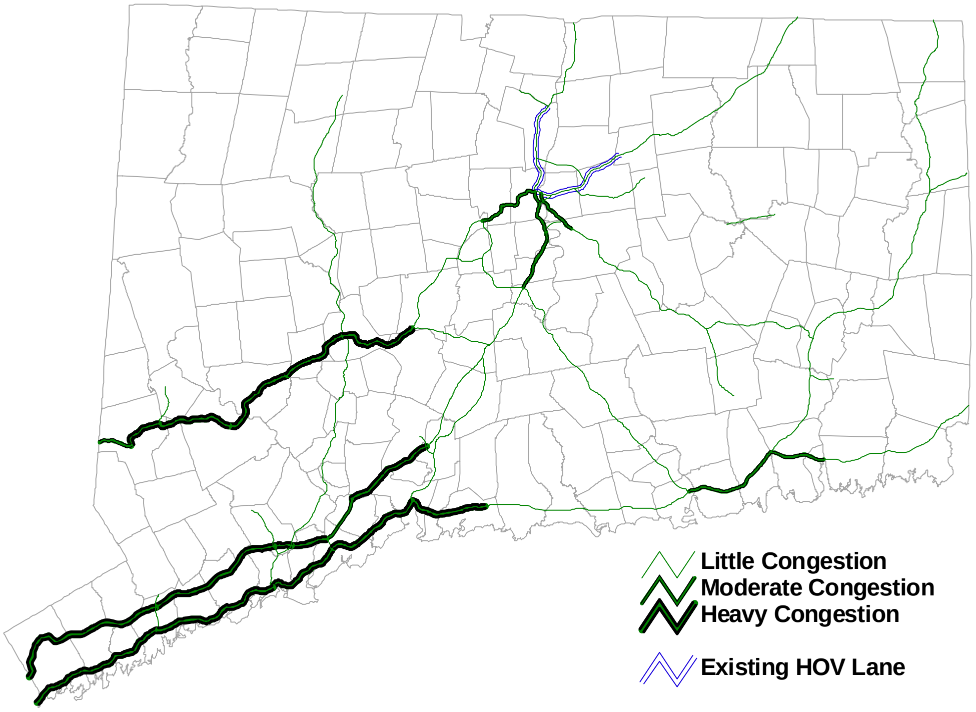


Figure 2.1: Link Congestion and HOV Properties

One link where the congestion data does not reflect anecdotal evidence is Interstate 95 east of New Haven. The reason is that this highway segment experiences demand cycles much different than others in the state. The corridor serves as the primary link between New York and Southern Connecticut and Rhode Island. As such, I-95 accommodates tourists traveling to Providence, Newport, and other coastal areas such as Cape Cod. This seasonal demand generates considerable congestion on I-95 during the summer months, particularly between Thursdays and Mondays (Clough, Harbour & Associates 2004). The stretch of highway between Rt. 9 and Rt. 395 is particularly subject to congestion because it is only two lanes and transverses hilly terrain. Due to the seasonal nature of demand, the corridor is primarily uncongested for most of the year.

Because of its unusual demand characteristics, and because it has no HOV facility, our selection methodology does not highlight I-95 between New Haven and Rhode Island on Figure 2.1. However, the segment provides a unique opportunity for pricing because summer demand is constituted primarily of out-of-state drivers.

Through this analysis, the Hartford and southwest regions of Connecticut were identified as candidates for congestion pricing. However, New Haven and Fairfield counties were the optimal choice for the investigation of the impacts of congestion pricing primarily due to the number of route options commuters have in the region with the Merritt Parkway and I-95 running parallel with each other. In addition, the southwest region of Connecticut is serviced by Metro North. Metro North is a rail line that runs from New Haven to New York City and also contains several spur lines that run north/south to connect inland commuters to mainline. Rail travel in the southwest region is a convenient transit alternative for many travelers and commuters; transit in the rest of the state is a less attractive option.

The Hartford region was the second choice for congestion pricing scenarios. The level of congestion in the Hartford area is much lower than the congestion levels in the southwest corridor of Connecticut. Furthermore, the pricing of roads often entices drivers to seek out alternate modes of transportation. Although there is an extensive bus network for the Hartford region, the system is not configured in a way that would make it an attractive option for travelers looking for an alternative to highway travel. To properly explore congestion charging in the Hartford region one would also have to consider how the transit system would be re-configured to meet the needs of those travels that would want to switch from the highway to transit. Given the complexity of this analysis, we felt that it was beyond the scope of this study; as a result, the Hartford region was not selected in this study for scenario pricing. However, future research of this area is warranted according to the criteria established above. With more predictable transportation alternatives to driving in the southwest corridor, the decision was made to concentrate the scenario analysis on I-95 and Route 15.

Thus, based on the proceeding discussion and analysis the following roadways were selected for further study:

- I-95 between New York and New Haven
- Merritt Parkway and Wilbur Cross Highway (Rt. 15) between New York and Hamden

2.2 Road Pricing Scenario Design

This section further characterizes the two roads selected for potential pricing: I-95 and Route 15 in Southwestern Connecticut. In addition, a description of the land use and employment trends provides context to better understand the specific demand patterns on each link. Then, each selected link is analyzed based on truck volumes, current and future traffic, and alignment characteristics. The goal of this analysis is to help in designing the best combination of possible pricing scenarios.

The data used to characterize the corridors and links provides a context in which to understand the road pricing tools that may be applicable to specific roads. It is important to keep in mind that the consequences of road pricing critically depend on the political and economic context in which projects are designed. Generally, the desired outcomes of a road pricing project depend on whether the designing agency is public or private, whether the motivation is to raise revenues or reduce congestion, and even how revenues are to be used. Because the planning and economic context is so critical to what road pricing tools are used, the following section outlines the assumptions made prior to developing road pricing scenarios.

2.2.1 The Southwestern Connecticut Corridor

The selection process reveals that Connecticut's southwest corridor from New York to New Haven suffers the worst congestion in the state. Fundamentally, Southwest Connecticut's congestion arises partly because it is home to much economic activity, dispersed and segregated land uses, and limited transit options for travel between destinations in the region. Nearly one-quarter of Connecticut's daily work trips are destined for one of eight urban centers between Greenwich and New Haven (ConnDOT 2004). These eight towns, including the two just mentioned along with Stamford, Bridgeport, Norwalk, Milford, Fairfield, and Stratford, were the combined destination of 358,000 daily work trips in 2000. Figure 2.2 displays where aggregate work trips destined for Stamford, Norwalk, Bridgeport, and New Haven and Manhattan originated.

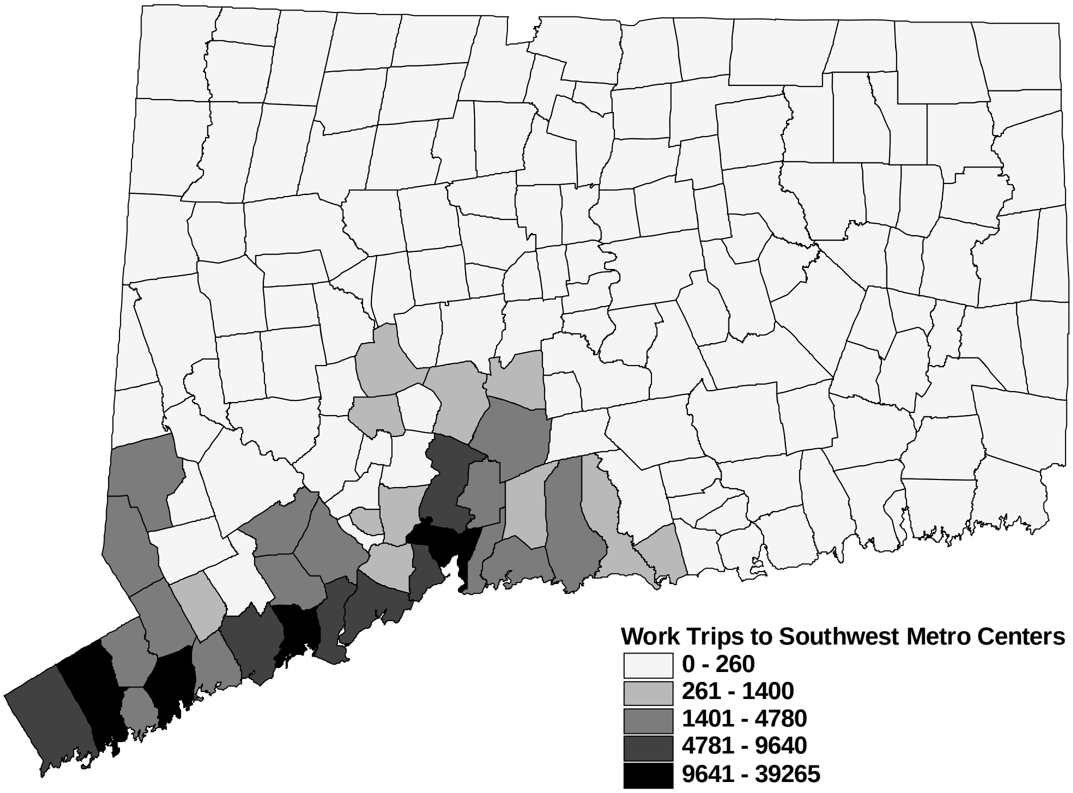


Figure 2.2: Origin of Work Trips in Southwest Connecticut

Figure 2.2 gives an indication of part of the reason for the strong east-west travel that is accommodated by I-95 and Rt. 15. As such, the Rt. 15 and Interstate 95 are good candidates for road pricing. Figure 2.1 shows severe congestion on all I-95 links between New York and Branford. Rt. 15 has equally bad congestion for all segments except the five miles between the Milford Expressway and the Orange/Woodbridge town line. Road pricing scenarios were developed for these two roads based on the general characteristics of the region as well as specific features of each road separately.

The fact that these two facilities run parallel makes them substitutes to some extent. As such, they work in unison to carry the bulk of automobile traffic in the region, and changes affecting demand for one will affect the other. However, important differences limit their effectiveness as substitutes. Most critically, most types of trucks are prohibited on the Merritt Parkway, forcing truck traffic to either I-95 or I-84. Furthermore, I-95 is typically six lanes as compared to four on Rt. 15, giving it higher capacity. Finally, Rt. 15 is located a few miles north of I-95 through most of the corridor. This puts the alignment outside of most commercial areas into more residential land uses. Generally, Rt. 15 has more local traffic and services urban centers to a lesser extent that I-95.

In terms of choosing our potential pricing scenarios for the southwest Connecticut corridor, it helps to list the scenarios in terms of economic efficiency beyond the base case of existing conditions with no pricing. The optimal solution in terms of economic efficiency, or the first best solution, is congestion pricing all lanes of both Rt. 15 and I-95. This is the first best solution because it optimizes highway usage; if the road is being underutilized, the price is lowered and if the road begins to slow due to congestion, the price is increased to keep traffic moving freely. The second best solution in terms of economic efficiency is therefore optimal toll pricing either Rt. 15 or I-95 while leaving the other untolled. Although in practice it is more difficult to manage than a simpler congestion based toll, the key here would be to try and optimize the toll in order to attract enough traffic from the untolled route to prevent congestion on either highway. The third best solution is a congestion toll on either Rt. 15 or I-95 leaving the other untolled. The difference between the second and third best scenarios is that the toll in the third best solution is really only based upon congestion related to that road specifically; it does not take into account or try to minimize congestion on the parallel road. The fourth best solution and beyond start to look at pricing individual lanes of these roads.

In most situations, whether due to structural impracticalities or political realities, pricing individual existing general lanes is usually a difficult proposition. As a result, the projects that have successfully implemented pricing on individual lanes have either converted existing HOV lanes to HOT lanes or built new lanes altogether. Rt. 15 presents a unique challenge to designing pricing scenarios. Most of these challenges are due to alignment characteristics. Rt. 15 is two lanes in each direction for its entire length from New York to Interstate 91. Since Rt. 15 is strung with overpasses, underpasses, and bridges that would have to be widened or replaced at great expense and loss of historic integrity, adding new lanes is a virtual impossibility. To add further complication, the Merritt has, on average, an exit every 1.5 miles. In some spots for example, as the road passes north of Bridgeport, exits occur at much greater densities. As a result, any reasonable pricing policies are constrained to the existing lanes. For Route 15, for much of its length, widening is constrained by the historic status of the road and the bridges which would make widening prohibitively expensive and, perhaps, politically infeasible.

In the case of I-95, the right-of-way passes through highly built-up areas and offers little room for expansion. It would also be an extremely difficult proposition to convert one of the existing general lanes into a priced lane. This conversion would be problematic in terms of the physical changes to the roadway that would be necessary to safely separate one lane from the others while still maintaining on-ramp and off-ramp access to all the lanes. It would also be challenging to sell the idea of this conversion and use it as a model for future pricing. HOV to HOT conversions typically work because the idea is that existing unused capacity is being sold in order to maximize efficiency on the HOT lane and in turn, reduce congestion on the general lanes. Converting a general lane into a priced lane would indeed reduce congestion on the now priced lane, but it would also inevitably increase congestion on the remaining unpriced general lanes. Overall congestion and delays on the roadway would likely increase in such a scenario, and the resulting situation would be worse than what exists today.

Consequently, the models developed focus on pricing Rt. 15 only, pricing I-95 only and pricing both I-95 and Rt. 15 simultaneously. Furthermore, a range of toll prices will be investigated for each of these route pricing scenarios to evaluate the pros and cons of congestion pricing in the southwest region of the state.

3 Methodology for Analysis of Pricing Impacts

The first step in evaluating the impact of congestion pricing in the southwest Connecticut region began with collecting the background data necessary to simulate current traffic and travel conditions. These datasets included:

- Detailed transportation network in TransCAD (version 4.8) from the New York Metropolitan Transportation Council (NYMTC),
- Statewide mosaic of the 2004 black and white digital orthophotos from the University of Connecticut's Center for Land Use Education and Research (CLEAR),
- Travel and mode choice data obtained from the Census Transportation Planning Package (CTPP), and
- Current traffic and operations data from the Connecticut Department of Transportation (ConnDOT).

3.1 Data

The following sections outline how these datasets were used to obtain the information necessary to simulate travel conditions and road pricing scenarios in the southwest region of the state.

3.1.1 Transportation Network

The TransCAD network provided by NYMTC contained road and intersections (link and nodes) for Fairfield and New Haven counties in Connecticut (as well as the majority of southern New York). The NYMTC road network showed a single line for each Connecticut road, including the highways. In order to increase model accuracy, the representation of the road network needed to be improved. This meant that each highway needed be dualized into two lines representing one for each direction of travel. NYMTC had already completed this process for the New York state portion of their network, but this level of detail was not carried over beyond the Connecticut border. One example of a limitation of the dataset from NYMTC is that the number of lanes in each direction was not included in the link attributes. To correct this, the orthophotos were imported into TransCad and the road networks were overlaid on these photos to obtain the correct number of lanes for each link. Using the aerial photographs as a reference, the on-ramps and off-ramps were added to the divided highways so that the dualized highway links connected to the rest of the network appropriately. This was completed for every highway interchange.

To simplify the analysis, early in the development process the road network was reduced only to those the roads within Connecticut. (This decision later proved to be slightly problematic as it precluded better modeling of the effect of charging on the immediately adjacent highway network in New York State. Future iterations of this work should include the surrounding network.) The resulting network was examined and modified to ensure the network was accurate and ready for use in the TransCAD model. This involved checking link capacities and speeds, number of travel lanes, ramp locations along I-95 and the Merritt Parkway (Route 15) and coded restrictions on link travel directions for one way travel on divided highways. The resulting network can be seen in Figure 3.1.

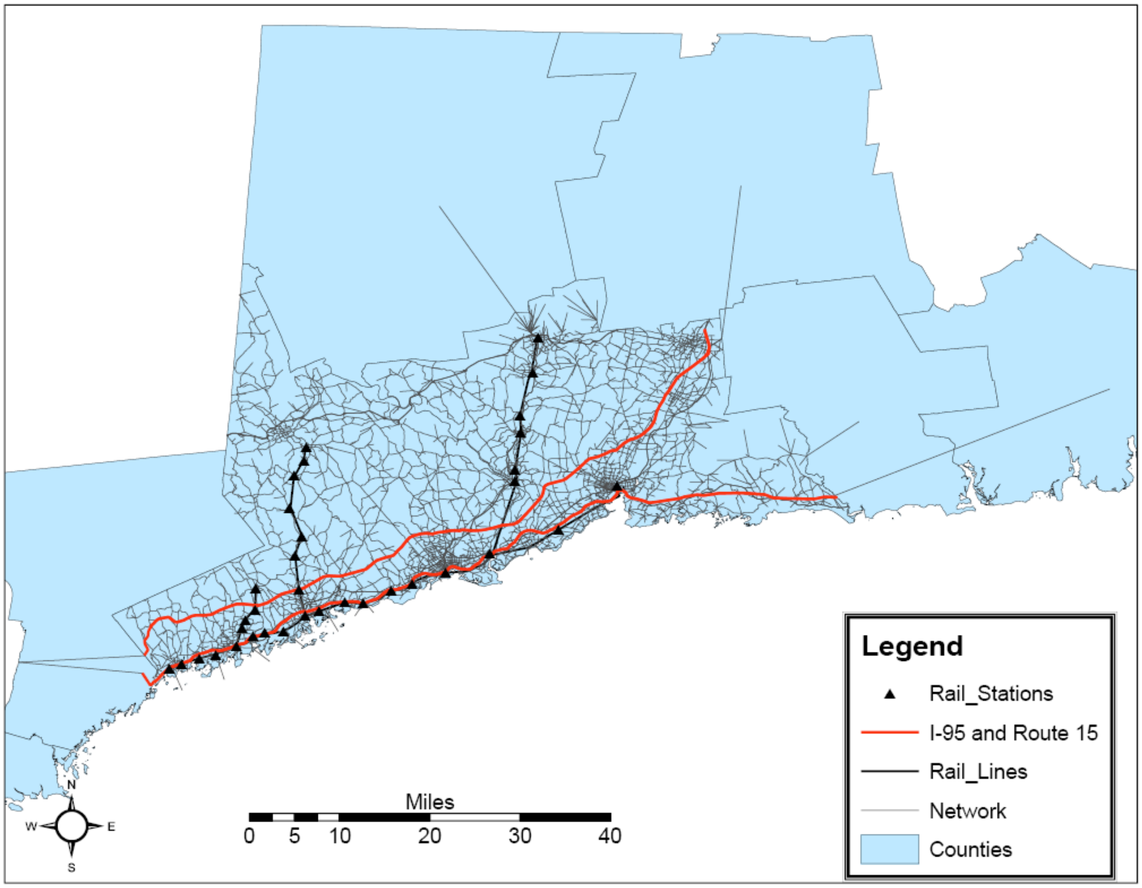


Figure 3.1: Transportation Network

3.1.2 CTPP Data

The CTPP contains data tabulations from the U.S. census designed specifically for transportation planners. The data are tabulated from answers contained in the long form questionnaire, mailed to one in six U.S. households. Because of the large sample size, the data are considered to be relatively accurate. The 2000 CTPP data for Connecticut were obtained and used for analysis in this project. Data pertaining to travel, household size, transportation mode and employment statistics were obtained for each of Connecticut's Traffic Analysis Zones (TAZ) in Fairfield and New Haven counties. There are 1,024 TAZs in southern Connecticut; these were used as productions and attractions zones for the Trip Generation step of the model. There were a total of five external zones used in the analysis; Hartford, Litchfield, Middlesex, and New London counties (in Connecticut) and New York. Figure 3.2 contains a map of TAZs for this region.

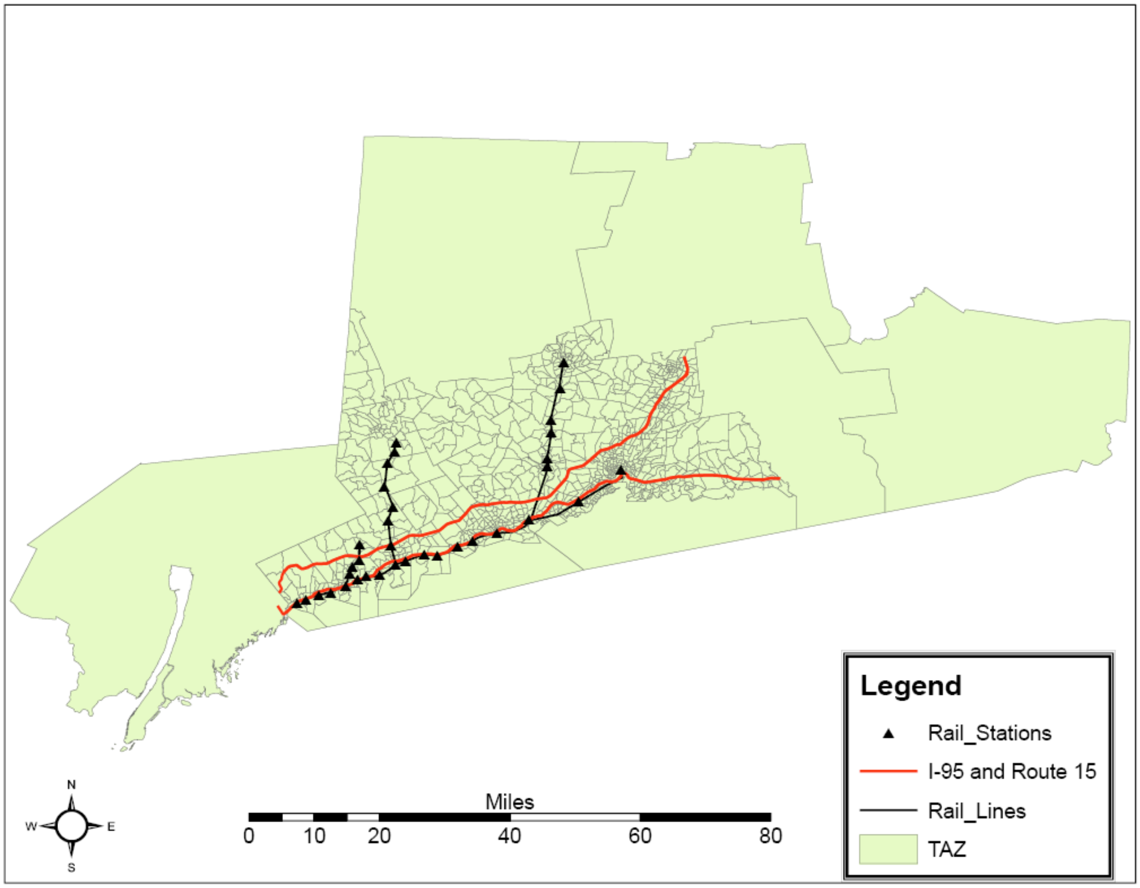


Figure 3.2: TAZ Map of Region

3.1.3 Traffic and Operations Data

Data were obtained from the 2006 ConnDOT's Traffic Count Locator Program (TCLP) was used to provide a manual check of traffic volumes once the TransCAD simulation was run. This provided an assurance that the output was consistent with current traffic conditions.

3.2 Four-Step Planning Model

The data obtained above were used to develop a transportation planning model using the four step process of Trip Generation, Trip Distribution, Mode Choice, and Trip Assignment.

The goal of Trip Generation is to predict the total number of trips that start and end in each TAZ by trip purpose. Trip purpose refers to the type of trip taken (i.e. whether the trip is a work trip or a non-work trip combined with whether the trip begins at home or someplace else). This process typically uses socioeconomic data such as household size, income, and the number of vehicles available to predict the number of trips produced in each TAZ and land use data such as the amount of office, industrial, and retail space to predict the numbers of trips attracted to each TAZ. The result is columns of trip productions and trip attractions by trip purpose. Since home based work (HBW) trips are predicted most accurately and because they comprise a vast majority of peak period trips, most planning models focus on predicting these HBW trips.

Trip Distribution distributes the trips from the Trip Generation step amongst all the TAZs. Most simply, the number of trip interchanges between certain TAZs is a function of the number of productions, the number of attractions, and the cost of travel between those places. The result is a matrix with every TAZ listed along two axis that shows the number of trip interchanges between each and every TAZ.

Mode Choice takes the matrix of trip interchanges created in Trip Distribution and determines how many of those trips are made by each mode of transportation. Typically this is a function of transportation system "cost" in terms of variables such as time, convenience, parking, comfort, level of service, and actual costs. Other considerations sometimes include attributes about the trip maker, what time of day the trip is being taken, or the trip purpose itself. Variables such as time of day and trip purpose are less of a concern in our model since the focus of this study is on work trips during the peak hour of the morning commute when all transit options are fully operational. The outputs of the Mode Choice step are multiple trip interchange matrices, one for each mode.

The goal of the Trip Assignment step is to allocate the trip interchanges found in Mode Choice to the transportation network. Trips are assigned to the network based upon the connectivity of the network in terms of the paths available to certain destinations as well as the time and money it would take to accomplish the trip. With Trip Assignment, the traffic flows on every link of the network are generated as well as the ridership on the transit lines. This information allows us to compare and contrast various scenarios, in our case, pricing scenarios.

Since the four-step model is essentially an iterative process, the updated link travel times from the Trip Assignment were then used as input for a second iteration of the Trip Distribution step. The updated Trip Distribution matrix was then used for Mode Choice and Traffic Assignment. This iterative process effectively enabled the simulated travelers to make travel decisions based upon updated congested conditions rather than the uncongested conditions that figure into the first run. Thus, the congestion found in Trip Assignment impacts the trip interchange matrix developed in the Trip Distribution step in terms of people having the potential to select different destinations and different modes.

The "cost" functions calculated in mode choice also grant people the ability and opportunity to select different modes. The following sections discuss each of these four steps in more detail specific to this project.

3.2.1 Trip Generation

Trip Generation in this project was completed using the Quick Response Method (QRM) in TransCAD. TransCAD uses a trip rate table from NCHRP 187 (Sosslau et al., 1978) to calculate productions for a TAZ. The trip table is a cross-classification table, segmented by the size of the urban area, household (HH) income, and auto-ownership, and includes trip rates for three trip purposes: home-based work, home-based other, and non-home-based. The output of the model is the number of person-trips produced per zone for each of the three trip purposes. Data obtained from the CTPP were used to generate the number of person trips produced and attracted to each TAZ. The inputs for production in the QRM were total number of households, mean household income, and the auto ownership split for homes with 0, 1, 2 and 3+ vehicles. The inputs for the attractions portion of the QRM were the number of dwelling units, the number of retail employees, and the number of non-retail employees. The model was then balanced by productions to give the number of person trips attracted to and produced by each TAZ. These production and attraction values were then compared to the Trip Generation rates obtained from the CTPP dataset to ensure TransCAD was generating appropriate values. The Trip Generation portion in the model for this project is done independently of the transportation network. Therefore, once a satisfactory Trip Generation table was constructed, it was used for all pricing scenarios. The assumption is that the number of trips generated is independent of the characteristics of the available transportation. In reality, this assumption is likely to induce some error into the model.

3.2.2 Trip Distribution

To conduct the Trip Distribution portion of this analysis, the TAZ centroids were connected to the transportation network using centroid connectors. This process involves first finding the geographic centroid for each TAZ; this point becomes the origin and destination point for all trips to and from that TAZ. The next step is to bring vehicles from this theoretical point in space to the actual road network with centroid connectors. The centroid connector serves as a new link in the transportation network that allows the trips produced and attracted by each TAZ to enter or exit the transportation system. Each centroid was connected to the nearest two local road or arterial intersections, and the centroid connectors were coded to prevent through traffic. This ensured they would not serve as a shortcut in the transportation network as they do not exist in reality. Routes with limited access (I-84, I-91, I-95 and Rt. 15) were precluded from having a centroid connected to them directly.

Once the TAZs were connected to the transportation network, the gravity model application in TransCAD was used to generate a production-attraction (PA) matrix based on the shortest path impedance from TAZ to TAZ. The PA matrix was converted to an origin-destination (OD) matrix where the total number of trips were divided into hourly volumes. Furthermore, the PA matrix reported the number of person trips between TAZs. Then, the OD matrix was converted to vehicle trips using the assumption that 1.5 person trips were equal to one vehicle trip.

This portion of the four-step process relies on link by link travel times to distribute trips. Trip Distribution is therefore sensitive to link travel times and travel conditions. However, the Trip Distribution step was not repeated for each scenario because there is the assumption that the proposed changes to the transportation system will not have a significant short term impact on where people reside and work. In the long term, this assumption will not be valid.

3.2.3 Mode Choice

The Mode Choice portion of this analysis was the most involved and required the development of a model specific to the transportation network in the region. The development of a Mode Choice model began with a review of the literature on similar regions with congestion pricing and transit options. The selected model incorporated the following mode choices; single occupancy car, carpooling, and transit. Through an exhaustive search, only a few study regions have had significant transit along with road with tolls or pricing of any kind. A model developed by Murray et al. (2001) using data collected in the metro-region Boston area during April of 1991 was identified as a suitable base model to modify for this application.

Rossi and Outwater (2002) discuss the potential transferability of mode choice models and parameters. They found that a model transferred from a different location can provide very reasonable results, and in some cases, better results than developing a new model. They stress that a transferred model needs to follow certain protocols in order to work properly. For instance, the relative size and level of service of the regions should be similar. A model developed from data collected in the Boston metro-region was selected as the base mode choice model, which best matches the geographic scale of the southwest Connecticut corridor out of all the mode choice models reviewed. Rossi and Outwater found that estimating mode choice for HBW trips to be the most consistent in transfer. As a result, the peak morning commute was modeled where HBW trips are dominant. They also advocate transferring the complete model rather than select coefficients since variables are often correlated with each other and not taking one into account could negatively impact the overall model.

The base utility functions for the multinomial logit model can be found in equations 1- 3.

$V_{SOV} = - 0.04722 * \text{Generalized cost}$ [Equation 1]
$V_{HOV} = - 2.169 - (0.04722 * \text{Generalized cost})$ [Equation 2]
$V_{Rail} = - 0.598 - (0.04722 * \text{Generalized cost})$ [Equation 3]

HOV= Shared Ride
SOV= Drive Alone
Rail= Rail Transit
Generalized cost expressed in a unit of time (minutes)

The base utility functions of the generalized cost portion of the formula needed to be defined and calibrated to best match mode splits for each TAZ obtained from the CTPP dataset. The generalized cost portions of the utility functions are represented below for each of the three mode choices. Any monetary costs (i.e. fare, fuel cost and parking) were converted to time (minutes) based on the value of time (VOT). VOT refers to an individual's value judgment of how much their time is worth. The literature indicates that VOT varies from $9/hr to $36/hr. Several prominent studies on mode choice and transportation-related research use $22/hr for commuters. Following this precedence, a value of $22/hr was selected for this study.

For HOV: Generalized cost = *f* (Travel Time, Fuel Cost, Parking, Toll cost)
For SOV: Generalized cost = *f* (Travel Time, Fuel Cost, Parking, Toll cost)
For Rail: Generalized cost = *f* (Travel Time, Fare, Parking, Wait time, Rail Impedance)

Travel time for the HOV and SOV are the length of the link multiplied by the speed of travel along that link summed by all links from origin to destination. For travel time, a shortest path matrix between each TAZ was developed and used for both HOV and SOV. Travel time for Rail is comprised of travel time to and from the station (link length * link speed) plus the travel time between stations on the train schedules obtained from Metro North. The transportation network can be found in Figure 3.1 and the rail network with TAZ links can be found in Figure 3.3.

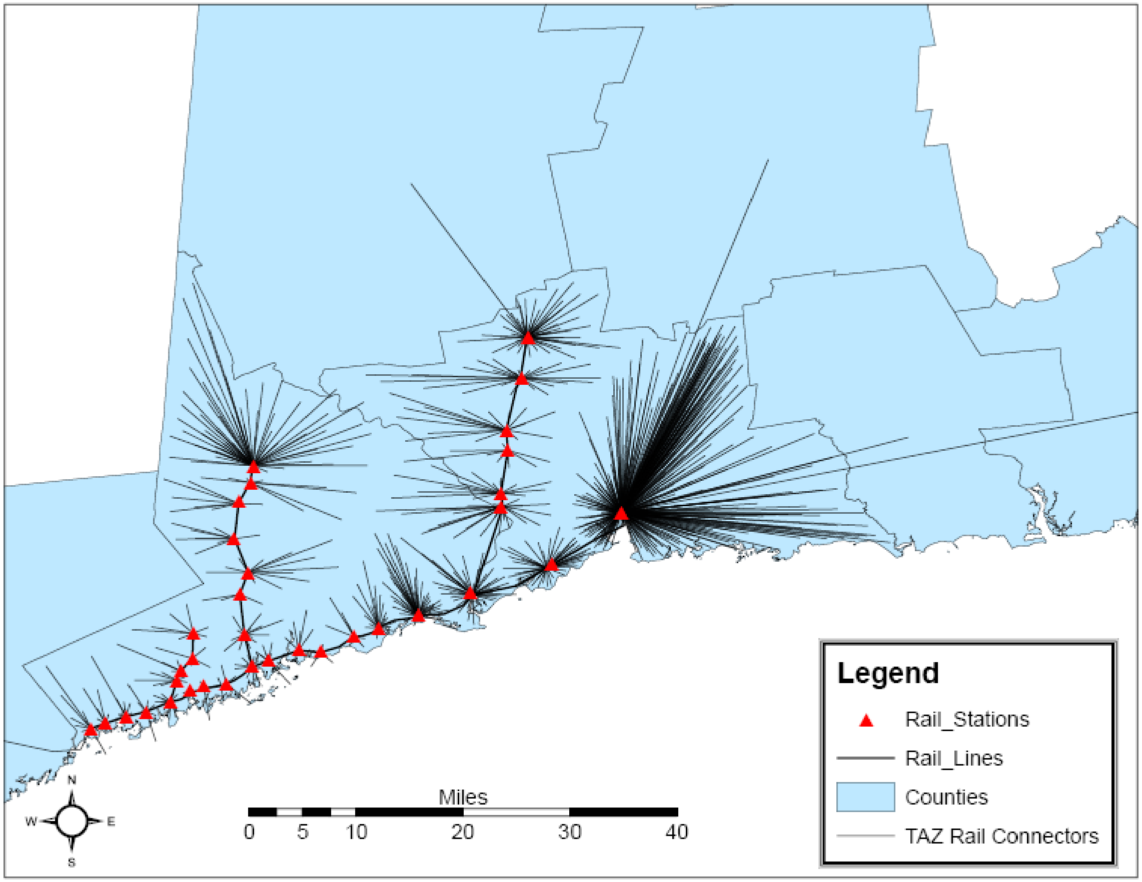


Figure 3.3: Rail Network and TAZ Connectors

Fuel costs are determined by estimating a cost per mile of fuel and then multiplying by the shortest distance between TAZs. Fuel estimates were generated by assuming an average fuel efficiency of 20 mpg and an average fuel cost of $3.30 per gallon. This produces a cost of 16.5 cents per mile. Converted to time using the VOT selected corresponds to 0.45 minutes per mile. This value was multiplied by the shortest distance matrix to estimate "generalized time" cost of fuel consumed.

Parking costs for HOV, SOV and Rail were determined based on TAZ destination attributes. Parking data for each TAZ was not readily available. Therefore, parking costs were assumed to be zero in rural TAZs and in major metropolitan areas were assumed to be $5. However for HOV, the parking cost was assumed to be half of the SOV and Rail cost due to carpooling. Therefore, a constant $5 was used to estimate parking costs for Rail and SOV in metropolitan TAZs and $2.5 was used for HOV parking costs.

Toll costs vary based on the scenario being evaluated. These costs were calculated on a per mile basis and varied in magnitude to allow for an investigation into the impact of road pricing on traffic volumes and elasticity of mode choice. When a road was selected for pricing, the total monetary cost for traveling along that link was calculated by multiplying the per mile cost by the length (i.e. 5 cents per mile multiplied by a fifteenmile long link would result in a toll of \$0.75). That cost was then converted to a time using VOT. In our case, \$0.75 toll with a VOT of \$22/hr would result in time of approximately two minutes.

For the rail choice, additional parameters considered included wait time and rail impedance. Wait time was simply calculated by taking the time between trains during the peak hour (obtained from Metro North's train schedule). This gave the maximum wait time that an individual would experience at each station if they arrived as the train was pulling out of the station. The mean wait time for each station was calculated by dividing the maximum wait time for that station by 2. This approximates the time an individual would wait if they arrived at the station between trains and is a compromise between individuals who miss the train and those that arrive at the platform "on time".

Rail impedance is a value assigned to each TAZ based on the distance the TAZ is from the station. This rail impedance was assigned as a destination attribute as many users of rail transit do not have a vehicle parked at the destination station to drive to work. Conversely, many people do drive to the station of origin then walk (or take a bus) to their final destination. Therefore, as the distance of the destination TAZ increases from a station, there is a decrease in the use of rail transit.

The utility functions are input for the multinomial logit model used to determine the probability an individual would select a certain mode. The model form can be seen in Equation 4.

$$\Pr_n(i) = \frac{\exp(V_{in})}{\sum_{J=1}^{J} \exp(V_{jn})} \qquad \text{[Equation 4]}$$

Where:
$\Pr_n$(i)=Probability of individual n choosing mode i
V_{in}=utility for alternative i
V_{jn}=utility for alterative j and
J = all sets of possible alternatives

The Mode Choice model outputs the percent of trips for each TAZ by mode based on the origin-destination matrix generated in the Trip Distribution step. These percentages were checked against the percentage obtained from the CTPP dataset. The coefficient of generalized cost was changed by trial and error until the difference in modeled mode split and reported mode split was minimized.

Once an acceptable mode split model was developed, a new OD table was generated to reflect the number of SOV, HOV and rail trips that were made to and from each TAZ. The development of the Mode Choice model was only done once and then the resulting Mode Choice model was re-run for each scenario with the network attributes being updated to reflect the pricing changes.

3.2.4 Traffic Assignment

The final stage of the process is to assign vehicles to the transportation network and obtain link flows and link speeds. Traffic was assigned using the user equilibrium method. Traffic assignment was only completed for the automotive portion of the route since it was assumed the rail capacity could be expanded and would be able to accommodate higher demands as needed. The results of the traffic assignment are link flows and speeds which allow for an analysis of system functionality and traffic conditions. The volumes from the traffic assignment stage were checked against volumes recorded by ConnDOT to ensure the model results were realistic.

The resulting speeds and travel times were then used to start over at the Trip Distribution stage of the process to ensure the model is calibrated to current traffic conditions. Iterations continue until a solution is reached for each scenario and pricing scheme.

4 Results

Analysis of the impact of congestion pricing on the southwestern portion of Connecticut involved simulating the current conditions and three different pricing scenarios. The first step was to simulate current conditions with no pricing in place. This first scenario was used to obtain the base conditions in the region and to calibrate the Mode Choice and Traffic Assignment models. The results portion of this section is divided into three scenarios. These three scenarios involved adding road pricing (at varying levels) to two major roadways in the region (I-95 and Rt. 15), which are known to be heavily congested. The first pricing scenario involved adding pricing only to Rt. 15, the second scenario involved adding pricing only to I-95, and the third scenario involved adding pricing to both routes. The shift in number of trips for each mode (single occupancy vehicles, high occupancy vehicles, and rail) will be evaluated along with the shift in traffic volumes throughout the region. The subsequent sections will present the results for each of these scenarios followed by a discussion of how pricing could impact travel in the area, what pricing levels would be necessary to have an impact, and how pricing would impact the use of transit.

4.1 Calibration for Current Conditions

Using the methods outlined above, the model was calibrated to reflect current conditions in Connecticut. Trip Generation and Distribution values generated by TransCAD were checked against home based work (HBW) trip data for the region aggregated by county. Table 4.1 contains summary statistics for the Trip Generation data from TransCAD output and trip count data obtained from the CTPP tables. The last column in the table shows the TransCAD sum of trips for each county divided by the CTPP census data. The number of HBW produced trips generated by TransCAD are higher than the number of trips reported by the Census data. Therefore, the numbers of trips reported by TransCAD were reduced by the factor in the last column of Table 4.1 to ensure the Trip Generation rates are accurate for current conditions. The trips were then distributed and origin-destination matrixes were generated for each hour of the day. The Trip Distribution step was carried out in TransCAD using the gravity model application and a matrix of shortest travel times between TAZs.

Table 4.1: Trip Generation Results

	Census (CTPP)			TransCAD			TransCAD/
County	Sum	Mean	Stdev	Sum	Mean	Stdev	Census
New London Co. CT	125,479	15,685	37,069	155,594	19,449	45,966	1.24
New Haven Co. CT	381,827	47,728	99,388	481,102	60,137	125,229	1.26
Middlesex Co. CT	79,453	9,932	14,618	97,727	12,216	17,980	1.23
Litchfield Co. CT	89,947	11,243	17,401	107,936	13,492	20,881	1.20
Hartford Co. CT	395,170	49,396	121,904	493,963	61,745	152,380	1.25
Fairfield Co. CT	363,383	45,423	117,392	428,792	53,599	138,523	1.18

It was also necessary to calibrate the Mode Choice model to reflect the current mode splits reported by the CTPP. Therefore, the base Mode Choice model was constructed and run through multiple iterations. After each iteration the resulting mode splits for each TAZ were compared to the CTPP dataset. Changing the coefficient of the “General Cost” variable in Equations 1, 2, and 3 resulted in a shift in mode split between the three modes. The coefficient was varied until the difference in mode split reported by TransCAD and the CTPP data set was minimized. The resulting coefficient for the generalized cost portion of the Mode Choice model was 0.04650 rather than 0.04722 in the original model. This result produced a mode split where the maximum discrepancy between simulated and actual mode split was 5 percentage points for any given TAZ (i.e. if TAZ X has a CTPP rail split of 10%, TransCAD predicted at most, a 15% rail share). Overall, the generated model was a good fit to the current modal split values and was implemented in TransCAD using the Logit model application. The resulting splits were multiplied by the hourly OD matrices to generate the rail, high occupancy and single occupancy vehicle trip OD matrices for the current conditions.

The results of this analysis enabled us to apply congestion pricing schemes to the major roads in the southwest portion of the state and observe how mode splits shifted in response. The results of this analysis are presented in section 4.2.

Finally, the Trip Assignment stage of the model was run to distribute the trips in the OD matrix across the network. Figure 4.1 shows the volume to capacity (V/C) ratios for every link of the network generated at this step. The V/C ratios for select links were then manually checked against ratios for I-95, Rt. 15, and I-91 reported in the September 2004 Congestion Management System report by ConnDOT. Overall the V/C ratios reported by TransCAD were slightly larger (< 5%) than those reported by ConnDOT in 2003. An error of less than 5% was felt to be suitable for this analysis.

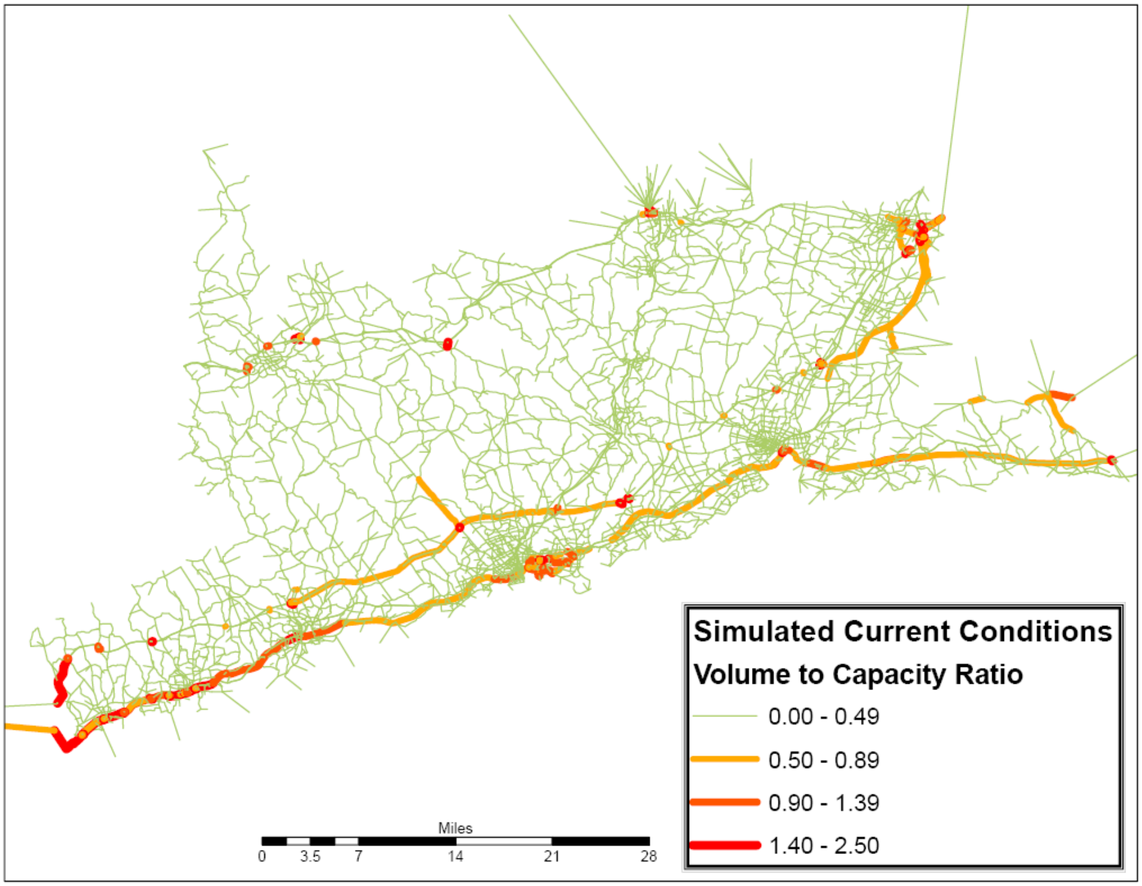


Figure 4.1: Volume to Capacity Ratios for Current Conditions

There are however areas where the V/C is notably smaller (or larger) than noted in the real-world. For instance, for the Merritt Parkway in the southwest corner, V/C's are reported to be approximately 1 (in 2003) where TransCAD is reporting them to be 0.48. The low V/C ratios are hypothesized to be due to the exclusion of the transportation network and TAZs in the southeastern portion of New York State which is adjacent to this part of the Merritt.

4.2 Mode Split Results

The first scenario was the simulation of current conditions with no pricing in order to obtain the base conditions for the region. This scenario was used to calibrate the Mode Choice model and verify that TransCAD was producing realistic and reliable results as presented in the previous section. The number of trips for the current conditions is reported as the total number of home based work trips for the region made during the AM peak period (7 am to 8 am). All trips produced by each TAZ were summed, resulting in a total 242,336 HBW trips. These trips were then split into mode shares using the mode split model described above. As a result, the base condition had 149,697 trips in SOV, 73,449 trips in HOV, and 19,190 rail trips during the peak hour. These total trips were then used to evaluate mode shift for the entire region based on the pricing scheme and pricing rate schedule.

4.2.1 Pricing Only Rt. 15

When pricing only Rt. 15, there is little reduction in SOV travel, effectively no change in carpooling, and only a marginal increase in rail ridership (Figure 4.2). The base case refers to current conditions; subsequent values along the X-axis represent the pricing level per mile for the given route. At the highest price of 25 cents per mile, only 1,461 SOV trips were eliminated for the AM peak hour for the entire region. Notably, there is very limited SOV trip reduction (< 200 trips) as the price of Rt. 15 increases from 3 cents to 25 cents per mile.

This lack of modal shift is hypothesized to be due to the lack of access to transit in the TAZs around Rt. 15. Overall, the percentage of HOV trips remained constant throughout the study area. In terms of rail usage when pricing only Rt. 15, there is an initial jump to use rail transit. However, as the rates increase, the subsequent shift to rail is negligible. The initial jump was thought to be for those living close to transit stations, and as price increases, poor access to the stations may play a role in limiting gains in rail ridership at higher levels of pricing.

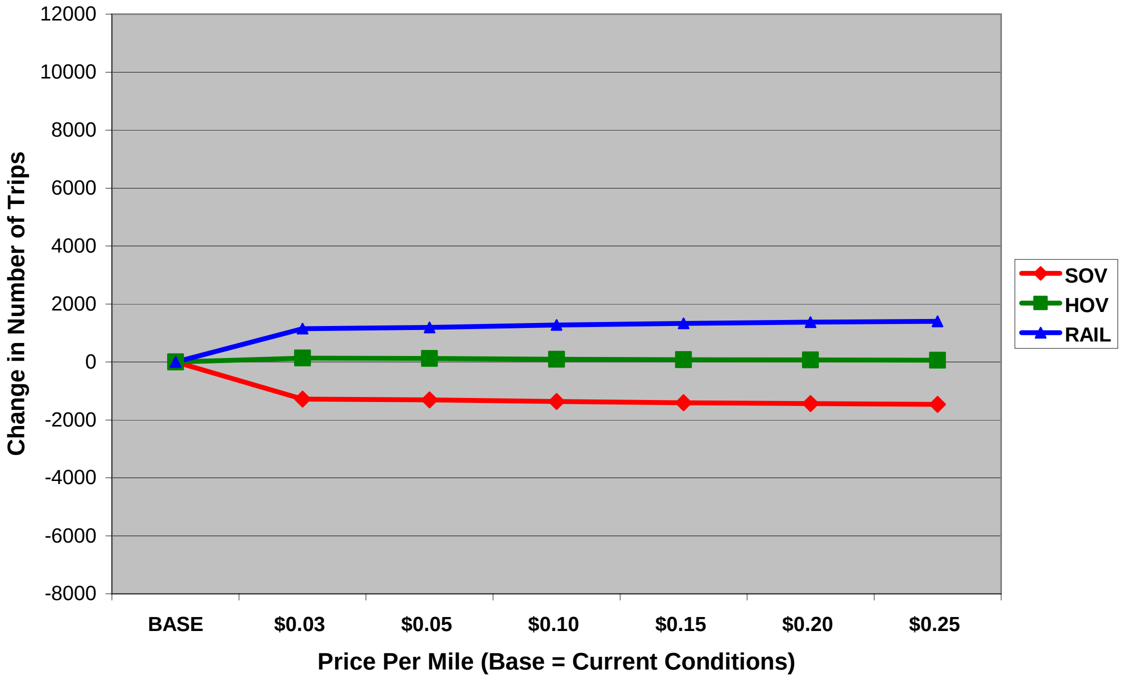


Figure 4.2: Mode Shift for Pricing Rt. 15 Only

4.2.2 Pricing Only I-95

The second scenario was to only price I-95, which runs along the coast line of southern Connecticut. Figure 4.3 contains the mode shift results if pricing were added only to I-95. At 25 cents a mile, a trip from New Haven to Greenwich on I-95 would cost $11.25, one-way. To give some perspective, a train ticket on Metro North from New Haven is Greenwich is as high as $13.00 one-way (bought on the train) and as low as $3.45 one-way (using a monthly ticket bought online as most commuters would do).

When comparing the trip rates, there is an overall reduction of 3,637 SOV trips at 25 cents per mile. For HOV trips, there gain of almost 1,200 HOV trips at the lowest price of 3 cents per mile. This is thought to be due to people shifting from SOV to HOV. However as the price per mile increases, there is a decrease in HOV trips that follows the pattern for SOV trips. For rail trips in the region under this pricing scenario the initial move to transit is small at 3 cents per mile. Then as the price increases to 5 cents a mile, there is a rapid jump in rail ridership. As pricing continues to rise, the rate at which rail ridership increases begins to taper off.

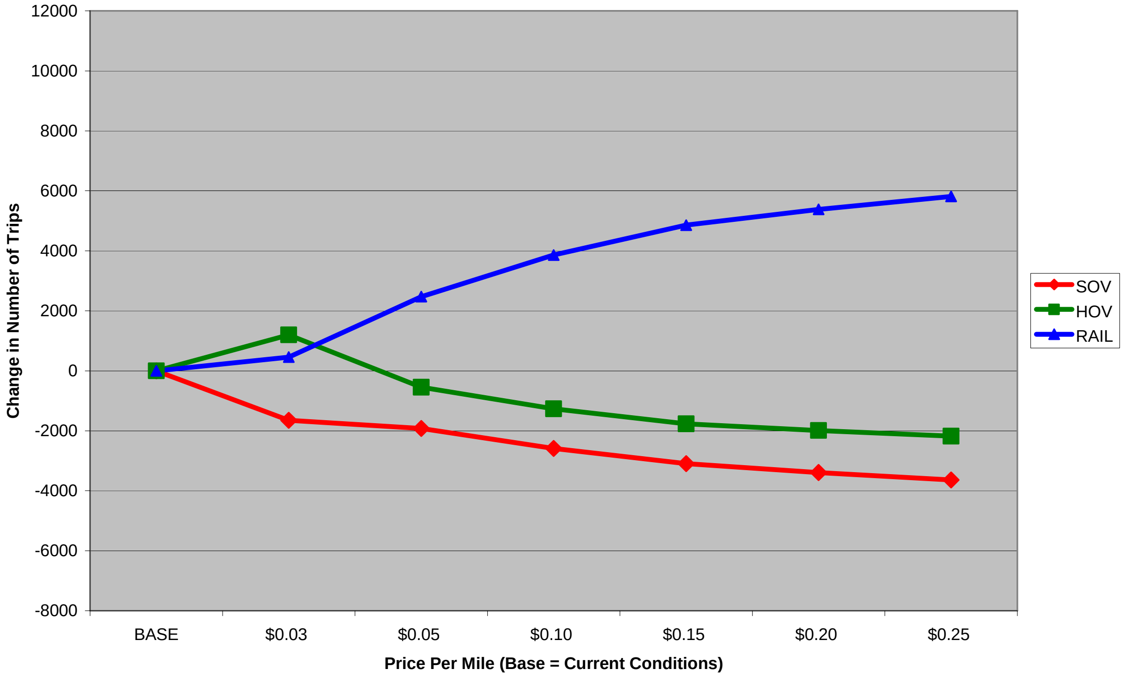
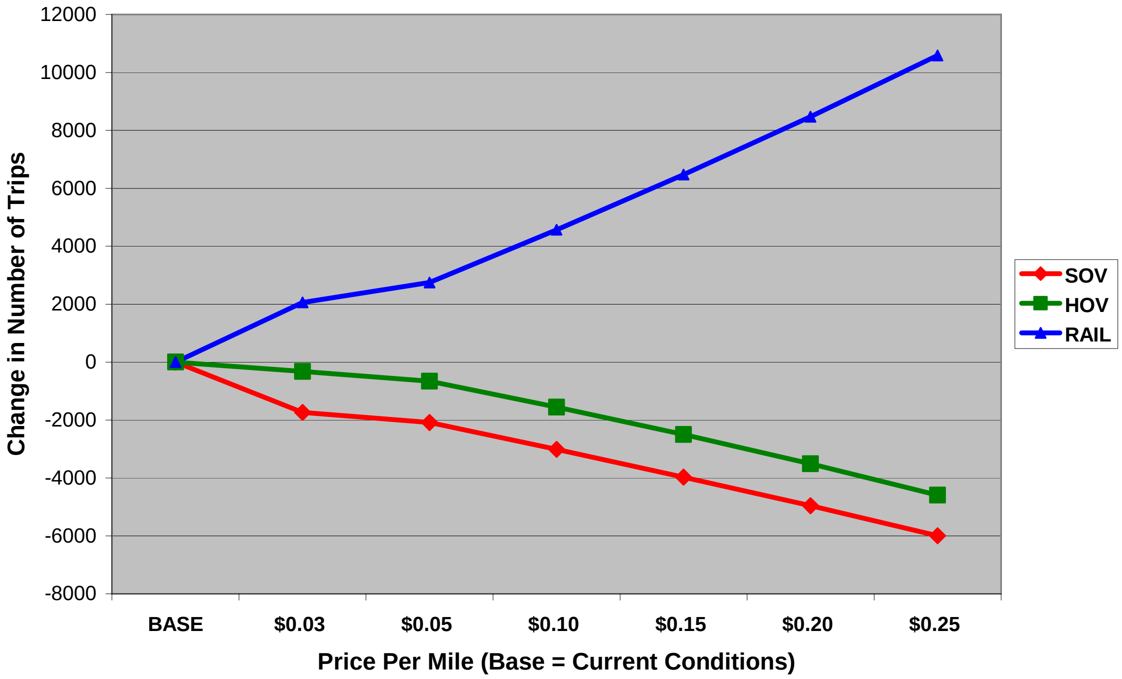


Figure 4.3: Mode Shift for Pricing I-95 Only

4.2.3 Pricing Both Rt. 15 and I-95

The final scenario was to add pricing to both routes and observe how trips were redistributed across modes in the region (Figure 4.4). With this option, at the highest pricing rate investigated, almost 6,000 single occupancy vehicles were removed from the highway network. This shift in SOV trips is more than if you simply combine the mode shift numbers for SOV from the previous two scenarios. This implies that pricing both routes at a low level will have a more significant impact on SOV use than applying a large charge to only one route. Similar to SOV, there is a large drop in HOV traffic right from the first pricing scenario. At the most restrictive pricing scheme, there are almost

4,600 HOV trips and almost 6,000 SOV trips removed from the network. However, these 10,586 trips were added to the rail system during the peak hour, an increase of over 55% when compared to the base trip rates. Such a large shift to rail would severely tax existing rail capacity and would require a significant upgrade of rail service in the region.



<u>**Figure 4.4: Mode Shift for Pricing both Rt. 15 and I-95**</u>

The mode shift analysis suggests that pricing only Rt. 15 will have limited impact on SOV and HOV trips but these small changes in trips over the region will increase rail trips during the peak hour by 6 to 7 percent. The pricing of I-95 will have a marginal impact on SOV and HOV trips while significantly increasing rail trips by up to 30%. The pricing of both routes will have the greatest impact on SOV and HOV trips and significantly increase the rail mode share. Under all three scenarios and at every pricing level, there was a shift to rail use. Therefore, rail level of service and improvements to the rail system is needed before any kind of pricing is implemented.

4.3 Rail Shift Spatial Analysis

To better understand how the pricing scenarios will impact rail use in the region; a spatial analysis was conducted to determine which TAZs would be most affected. Figures 4.5-5.7 contain spatial plots indicating the change in the origin of rail trips by TAZ once pricing was enacted. Figure 4.5 represents pricing only Rt. 15 at $0.25 per mile. Figure 4.6 represents pricing only I-95 at $0.25 per mile and Figure 4.7 represents the shift to rail once both routes were priced at $0.25 per mile. Figure 4.5 indicates that once Rt. 15

is priced, more rail trips will originate from TAZs along Rt. 15 and north of Rt. 15. However, the magnitude of this change is small. The darkest shade on this figure only represents 5 to 6 new rail trip origins.

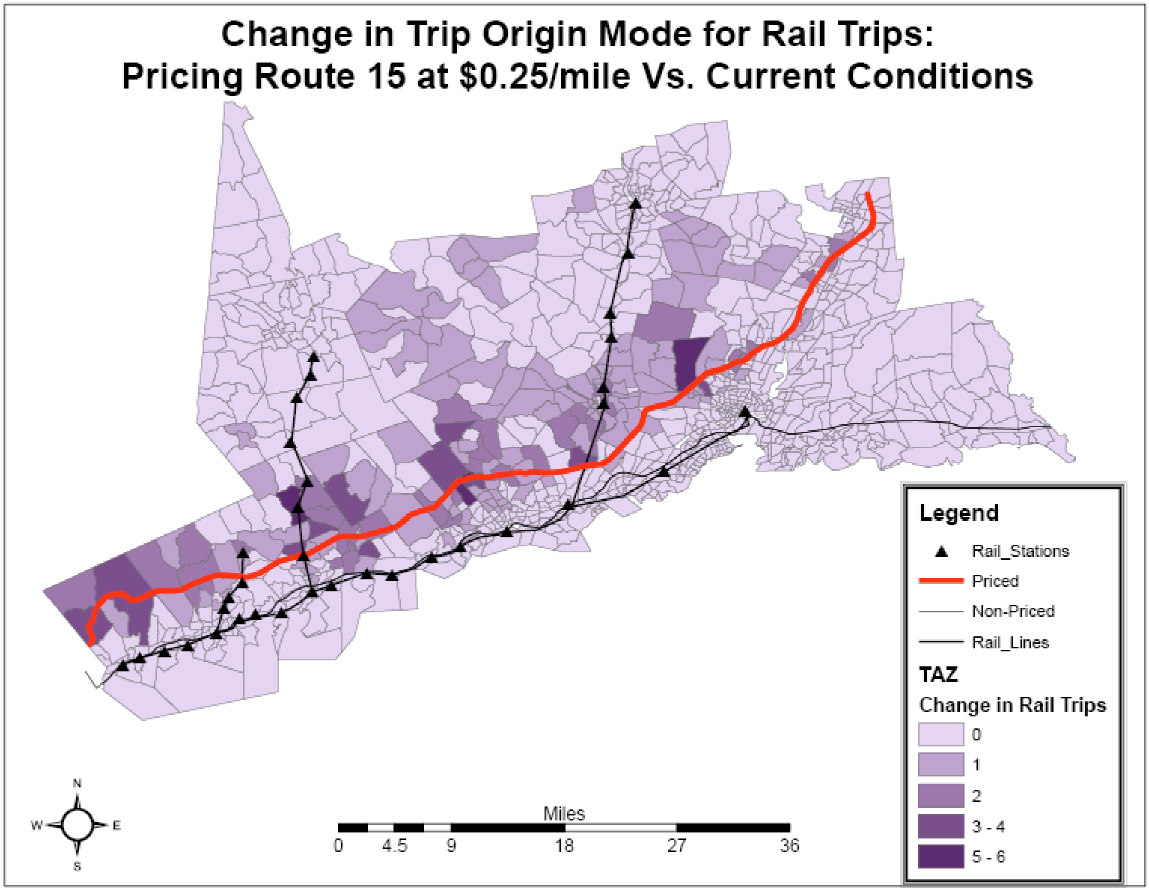


Figure 4.5: Rail Shift from Current Conditions, Only Rt. 15 Priced $0.25/mile

In Figure 4.6, pricing only I-95 causes there to be a shift to rail transit for TAZs located along the coast (and rail stations) and along the spur lines that travel north and south. In addition, the magnitude of the shift is much larger than just pricing Rt. 15. Here, the darkest shade corresponds to 20-27 new rail trips from a TAZ.

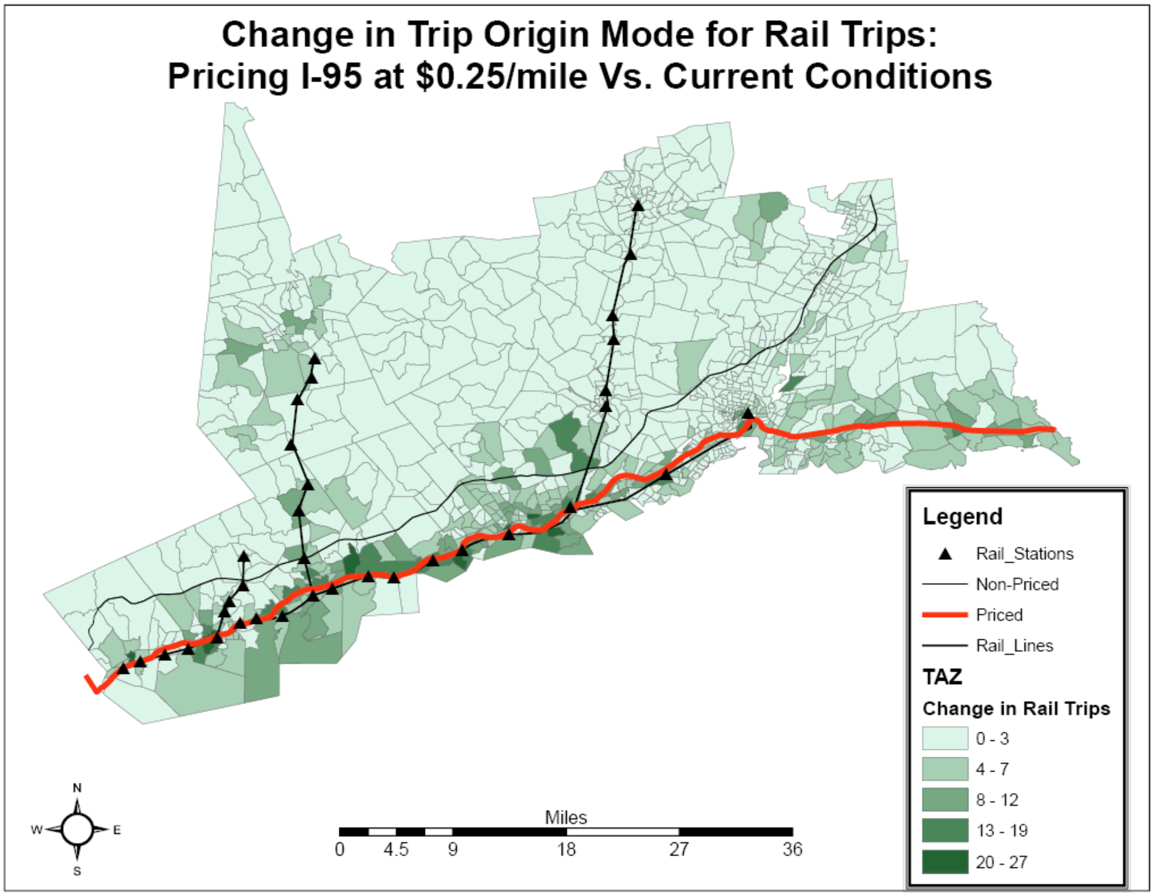


Figure 4.6: Rail Shift from Current Conditions, Only I-95 Priced $0.25/mile

When pricing both routes (Figure 4.7) the rail shift is more dramatic and spread throughout the southwest portion of the state. However, the majority of new rail trips are generated from TAZs located close to transit stations, showing the importance of the rail system for affecting congestion. In this figure, the darkest shade now represents 35 to 60 new rail trips originating from a TAZ. Since the increase in rail trips are comprised of SOV and HOV trips lost, the spatial patterns for reductions in SOV and HOV trips are the same as the increased trips for rail. The results for the most extreme pricing scenarios were depicted in order to allow for easy identification of TAZs where the mode shift would be most dramatic. The other pricing levels have similar patterns in mode shift, just at a reduced scale.

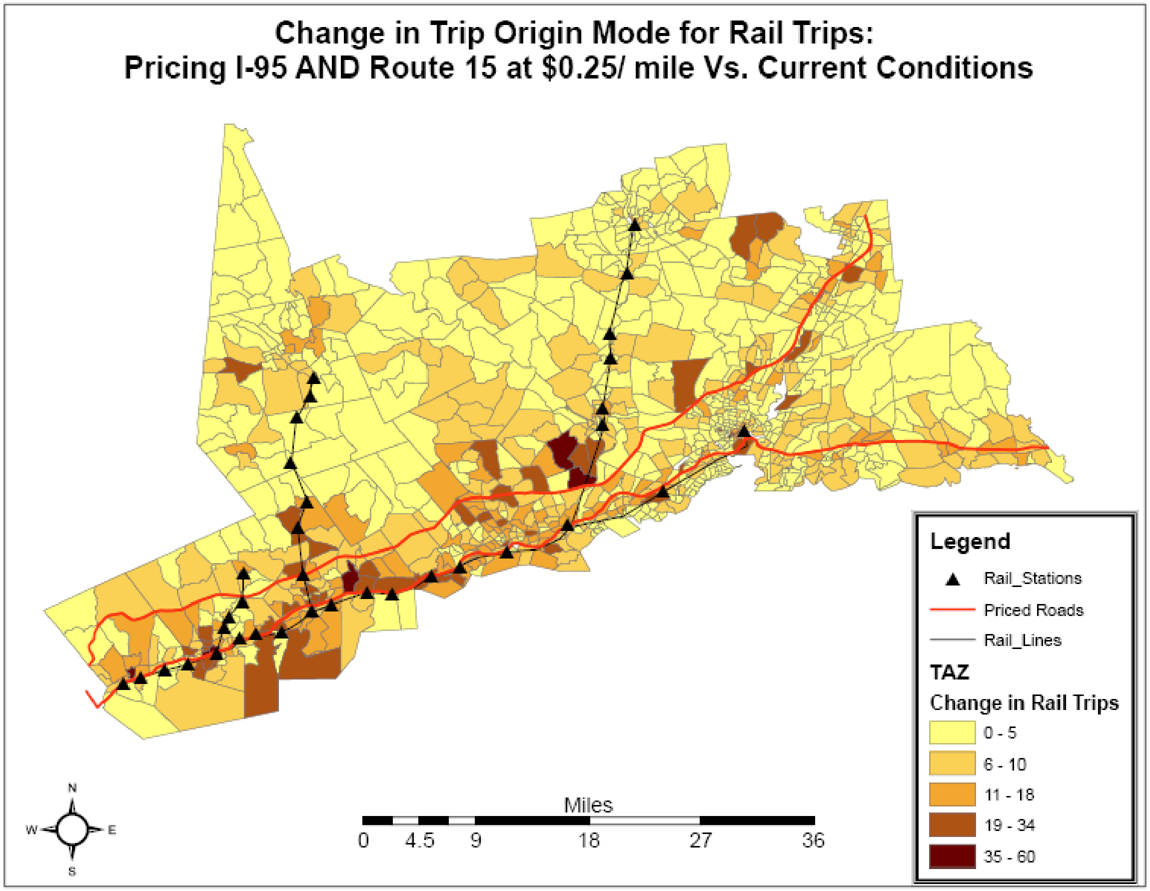


Figure 4.7: Rail shift from Current Conditions, Rt. 15 and I-95 Priced $0.25/mile

4.4 Effect of Pricing on Congestion

The mode shift analysis indicated that there is a reduction in the number of automobile trips (SOV and HOV). This should correspond to a reduction in traffic flow in the area and ease of congestion during the peak hours. The results of the traffic assignment response to the three road pricing scenarios are presented here with a discussion of how changes could impact travel on the priced roads as well as local routes. Due the large number of figures generated for this analysis, all the plots discussed in this section can be found in Appendix A. Volume to capacity (V/C) ratios for each link (as reported by TransCAD) under current traffic conditions were presented in Figure 4.1. These figures show the link-by-link V/C ratio for each pricing scenario and allow for an analysis of the shift in V/C ratios as pricing levels increase. In the following sections these shifts in V/C ratios by pricing scenario are discussed.

4.4.1 Pricing Rt. 15 Only

The results from pricing Rt. 15 indicate the congestion problems on I-95 will increase as shown by the increase in V/C ratios along I-95. For example, the addition of a 3 cent per mile charge on Rt. 15 increases the V/C ratios on all links of I-95 south of Bridgeport to a level greater than 1. Pricing at 3 and 5 cents per mile were effective at reducing the V/C ratio to levels on Rt. 15 to below 0.5. However, there are still links near intersections where the V/C is high and could cause delay, especially in the southwest corner of the state.

Figures 5.8-5.10 contain plots showing how the traffic volumes increase or decrease in response to pricing. In the top plots, the Y-axis shows the percent change in the number of vehicles gained or lost while the X-axis indicates the pricing level for each scenario. For the bottom plot, the Y-axis indicates the percent change in number of **person trips** (not vehicle trips) added to the rail network. To obtain the percent change in volumes, as a result of pricing, the average traffic volume was calculated for Rt. 15 and I-95 for each pricing scenario and pricing level. The average volume for each scenario was then subtracted by the mean traffic volume of the base conditions. The result is a value which indicates the mean amount of traffic that will be added to or removed from each of the routes by pricing scenario. That mean was then divided by the amount of traffic in the base scenario and multiplied by 100 to generate a percent change in traffic volume.

As a result of pricing only Rt. 15, Figure 4.8 indicates that as the price per mile was increased, there was a steady increase in traffic volume on I-95 and a steady decrease in traffic volume on Rt. 15. This scenario has the most significant impact on reducing traffic on Rt. 15. At a price level of 5 cents a mile, on average 27 percent of the traffic was removed from Rt. 15. The increase in traffic on I-95 is not desired since the majority of I-95 in the western portion of the state is already operating at capacity (V/C ≥1). In terms of rail ridership, there are only marginal increases in ridership. This can be attributed to limited access to rail stations surrounding Rt. 15. Furthermore, drivers might be limited in using the rail due to the lack of stations close to their desired destination.

Figure 4.2 graphs the change in mode of travelers due to increasing the cost of driving on Route 15 while Figure 4.8 graphs the change in volume of traffic on Route 15 due to these same price increases. These graphics results are different because Figure 4.8 takes into account all those that continue to drive but choose an alternate route that is not necessarily I-95. The small mode shift shown in Figure 4.2 is likely a result of limited transit access in the Route 15 area. Nevertheless, the results of Figure 4.8 are as expected. Steadily increasing costs on Route 15 should lead drivers to either seek alternate modes or alternate routes. In the case of pricing only Route 15, our results suggest that most drivers will continue to drive but seek alternate routes.

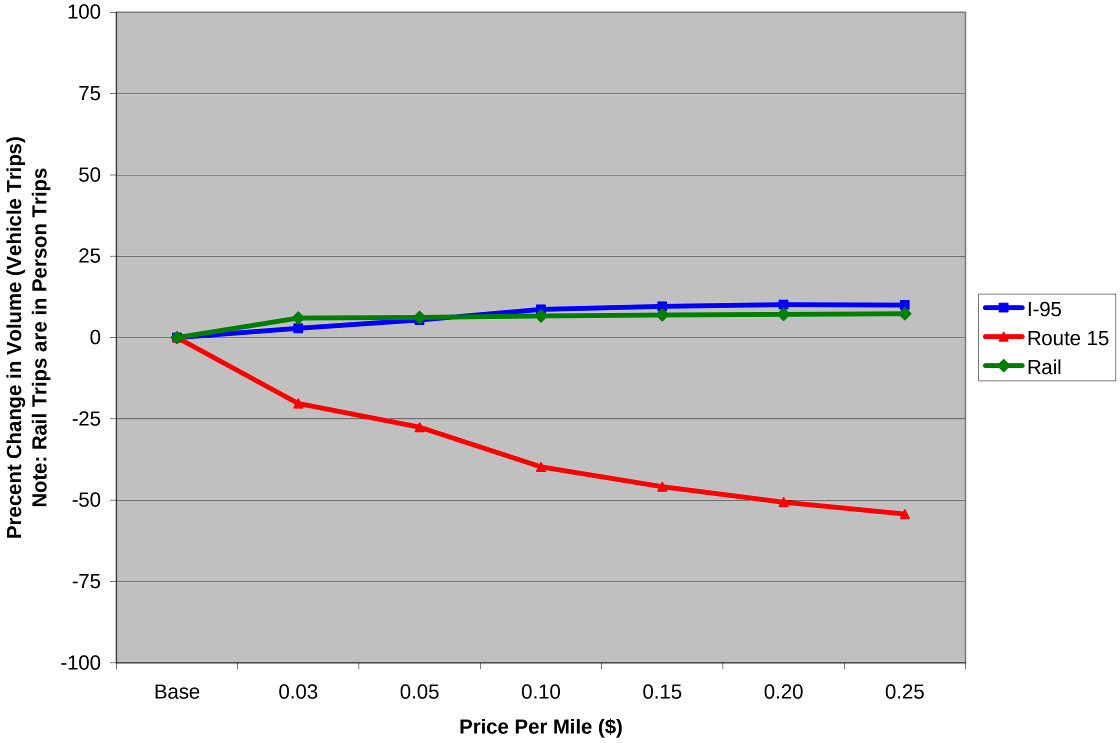


Figure 4.8: Volume Change When Pricing Only Rt. 15

4.4.2 Pricing I-95 Only

Figures A.7-A.13 contain the V/C plots for the various pricing levels when pricing only I-95. As expected, there is an overall shift away from I-95 and an increase in the V/C ratios along Rt. 15. At a modest pricing level of 5 cents per mile, the majority of Rt. 15 approaches a V/C of 1. However, there is an interesting situation that occurs in the southwest corner of the state where V/C ratios along roads that connect I-95 and Rt. 15 are now increased. This is hypothesized to be a result of people traveling along Rt. 15 (without being charged) then shifting over to I-95 for the last few exits in CT. This is most noticeable at the 25 cent per mile pricing rate. As a result, the pricing of I-95 has impacted the local roads in southwest Connecticut by increasing traffic volumes and congestion in the area, without alleviating congestion on I-95.

The impact on traffic volumes when pricing I-95 exclusively can be seen in Figure 4.9. This pricing scenario had a dramatic impact on traffic volumes on each of the two major east-west routes. Pricing I-95 exclusively increases congestion on Rt. 15 while alleviating congestion on I-95. However, in contrast to the previous scenario, there is a significant increase in traffic volume on Rt. 15 with only a modest decrease in volume on I-95. At a pricing level of 5 cents a mile, there is a 6 percent decrease in traffic on I-95 but a 13 percent increase in traffic on Rt. 15. In this scenario, rail ridership increase to a greater extent than when pricing only Rt. 15. This is due to the greater access to rail stations for the areas close to I-95 – therefore, travelers from these TAZs have an attractive transit option to which they can shift.

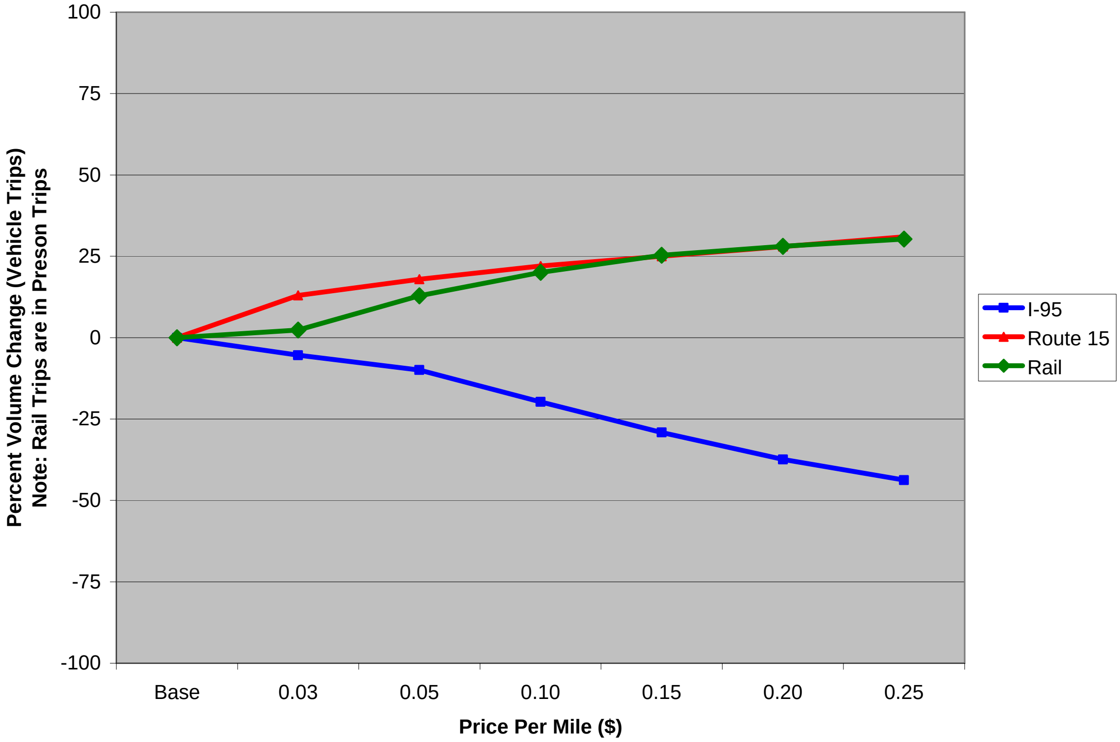


Figure 4.9: Volume Change When Pricing Only I-95

4.4.3 Pricing Both Rt. 15 and I-95

The most restrictive case in which both Rt. 15 and I-95 were priced had the most widespread impact on reducing congestion (Figures A.14-A.18) and traffic volumes (Figure 4.10). Figures A.14-A.18 indicate the V/C ratios along I-95 remained relatively unchanged while V/C ratios on Rt. 15 began to decline once pricing reached 15 cents per mile. However, there are more local arterials experiencing an increase in V/C ratios. For example, Routes 53 and 137 both increase in V/C; this would result from people now traveling further down I-84 or using I-84 (instead of Rt. 15) and then using these north/south routes to get to their destinations, limiting their travel on Rt. 15.

When pricing both routes, there is an overall decrease in traffic on I-95 and Rt. 15 throughout the region (Figure 4.10) but the impacts is seen most dramatically for rail ridership. Pricing both routes forces users to consider alternate forms of transportation. At the 5 cent per mile pricing level, there is a 1.5 % reduction in volume on I-95, 16 % reduction in traffic on Rt. 15, and a 16% increase in traffic on rail trips. In reality, the limitations of the rail network may cause less of a shift to rail, increase congestion on local roads and limit the volume reductions on Rt. 15 and I-95. In order to see the full impact, the capacity of the rail would have to be increased.

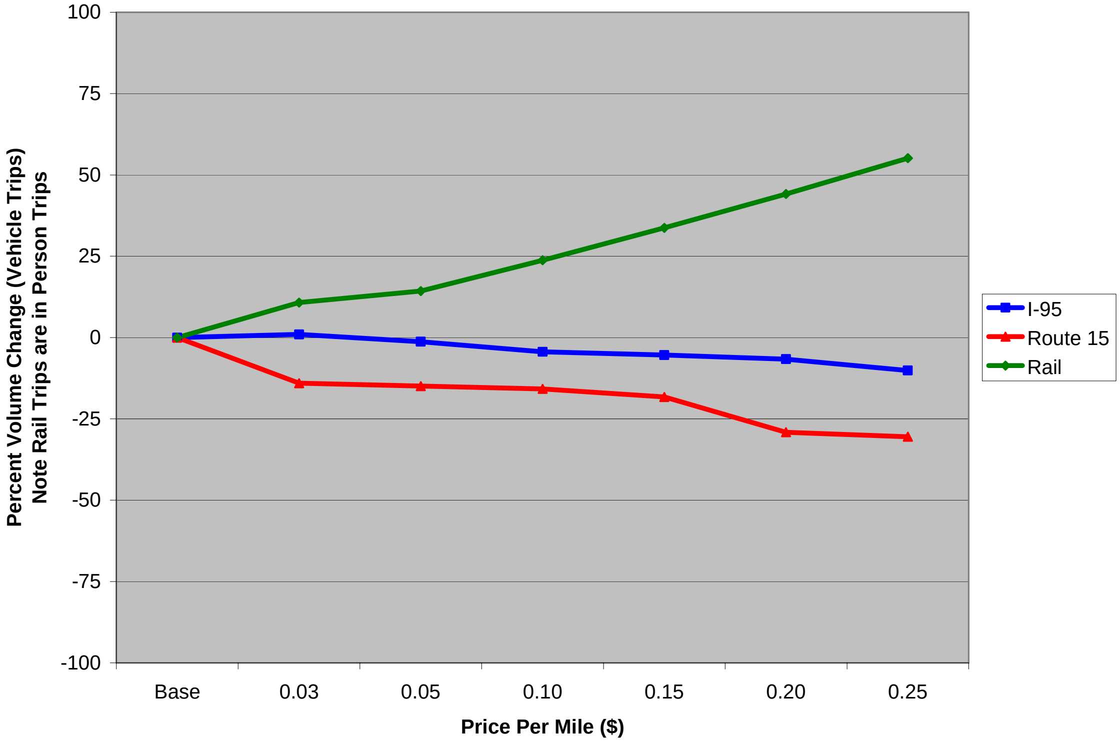


Figure 4.10: Volume Change When Pricing Both I-95 and Rt. 15

4.5 Revenue Analysis Results

The amount of revenue generated from each scenario was calculated for each of the three priced scenarios Table 4.2. The revenues were estimated for the peak hour by multiplying the traffic volume on that link by the length of the link. This produced a link-based vehicle miles traveled (VMT) output for the peak hour investigated. Then the link VMT was multiplied by the cost-per-mile of travel on that link and revenue estimates were generated for the AM peak hour. The hourly revenue ranges from $13,537 to $179,382. Keep in mind that pricing rates above 15 cents per mile have only been used on very short routes (<5 miles) and may not be realistic for a roadways of this length. The last column of Table 4.2 gives an estimate of the potential revenue generated by the pricing scenarios on a weekly basis. This is a very conservative estimate based on the following assumptions:

- The routes would be priced only during the peak period. This would result in three hours of pricing for the AM Peak and three hours of pricing the PM peak.
- All vehicles pay the same per mile fee regardless of vehicle type or number of passengers
- Pricing would not be implemented on the weekends
- The peak hour volumes generated by TransCAD would not vary greatly for the three peak period hours.

Any additional changes to the assumptions above (regarding the pricing structure) such as, pricing non-peak hours at a reduced rate, pricing 24 hours a day 7 days a week, or only pricing heavily congested areas at non-peak times would likely increase these revenue figures. Therefore, the estimates in the last column can be thought of as baseline weekly revenue numbers. Of course there are going to be considerable costs associated with adding pricing to the roadways that will vary greatly depending on the toll collection methods used. These costs are not considered in these estimates; these are estimates of revenue, not profit. At a modest pricing scheme of 5 cents a mile, pricing both routes, the baseline revenue for the year would be approximately 60 million dollars.

Table 4.2: Revenue Generated from Pricing Scenarios

	Price Per Mile	Peak Hour Revenue	Weekly Revenue (6 hours of pricing per day weekdays only)
Pricing I-95	0.03	13,537	406,123
	0.05	22,562	676,872
	0.10	45,125	1,353,744
	0.15	67,687	2,030,616
	0.20	90,250	2,707,488
	0.25	112,812	3,384,360
Pricing the Rt. 15	0.03	9,398	281,945
	0.05	15,664	469,908
	0.10	31,327	939,816
	0.15	46,991	1,409,724
	0.20	62,654	1,879,632
	0.25	78,318	2,349,540
Pricing Both	0.03	21,526	645,776
	0.05	35,876	1,076,294
	0.10	71,753	2,152,588
	0.15	107,629	3,228,881
	0.20	143,506	4,305,175
	0.25	179,382	5,381,469

5 Summary and Conclusions

The purpose of this study was to determine which roadways and/or regions in Connecticut were candidates for congestion pricing and to evaluate the impacts of pricing in these areas. Two routes (I-95 and Route 15) in southwestern Connecticut were identified as candidates for congestion pricing and evaluated. Multiple congestion pricing scenarios were simulated in TranCAD during the AM peak hour to investigate the impact on mode choice and congestion in this region.

Analysis of the impact of congestion pricing on the southwestern portion of Connecticut involved simulating the current conditions and three different pricing scenarios. The first step was to simulate current conditions with no pricing in place. This first scenario was used to obtain the base conditions in the region and to calibrate the Mode Choice and Traffic Assignment models.

The three pricing scenarios investigated including i) adding pricing only to Rt. 15, ii) adding pricing only to I-95, and the third scenario, and iii) adding pricing to both routes. The shift in number of trips for each mode (single occupancy vehicles, high occupancy vehicles, and rail) was evaluated along with the shift in traffic volumes throughout the region.

When pricing Rt. 15 alone, our model showed that there was only a small impact on mode choice. The most significant shift came from simply introducing a small price on Rt. 15 while subsequent increases in price made little additional impact on mode choice. This shift from auto to rail occurred for trips originating close to Rt. 15 and had little impact on trip origins along I-95. Traffic volumes along Rt. 15 did in fact decrease, but congestion along I-95 got worse.

Our model suggest that implementing pricing on I-95 alone, would result in an increase in HOV and rail trips at lower levels of pricing levels. At higher pricing levels, both the SOV and HOV trips decreased and rail trips increased. When comparing shifts in mode by trip origin, the majority of new rail trip were generated from TAZs along the coast. This pricing scenario had little impact on mode choice for trips originating north of Rt. 15. The pricing of I-95 had the most substantial impact on traffic volumes and reducing congestion and traffic on I-95. However, congestion along Rt. 15 deteriorated significantly.

The last scenario of pricing both routes indicates an immediate shift from auto to rail and as the price increased, the shift to rail continues to grow. Due to the pricing of both routes, the distribution of rail trip origins is spread throughout the region and not localized as with the previous two scenarios. Overall, there is a decrease in traffic on the two routes as vehicles move to local roads, alternate routes, and the transit system to make it to their destination.

The results of this analysis indicate that pricing only one route through the region will have a significant negative impact on the other route. Therefore, our results suggest that if pricing is enacted, both routes should be priced to avoid severe congestion on the route that is not priced and elsewhere in the region.

Some potential impacts and benefits of pricing that were not explicitly modeled include peak spreading and trip reductions. Peak spreading refers to the temporal redistribution of trips from the peak times to lesser traveled times. Flexible work schedules and expanded operating hours help facilitate peak spreading. In this regard, variable pricing, where the toll travel during the peak period is higher than the surrounding time periods, can really be a catalyst. Some existing toll projects vary the tolls every 15-minutes or so based upon a pre-planned schedule while others use real-time traffic information and adjust the toll accordingly to keep traffic moving.

The idea behind our analysis was to model how people adjusted their mode and route based on different pricing scenarios. This model did not address potential for people choosing to make fewer trips in the first place, which is most certainly a feasible outcome of pricing. This does not necessarily mean that the trip is never taken but rather that some people perform multiple tasks with one trip.

Pricing the highways will also have an impact on land use. These changes, especially if spurred by more favorable transit-oriented development zoning regulations would have a large impact on travel patterns favoring transit over car travel. Since our model focused on what would happen to today's traffic if pricing were implemented, these impacts were not modeled. However, several toll projects have found that pricing their highways has resulted in people having a greater desire to live in closer proximity to transit stations.

Mode shift in our analysis largely occurred in those TAZs that were more accessible to rail. In other words, pricing was most effective for reducing car travel in those TAZs where people had a viable choice for travel. These results show the important role that rail could play in helping to reduce congestion in Connecticut. To optimize the potential benefits from congestion charging, we would also need to shift our land use practices to more transit-oriented developments. This would not only result in more efficient land consumption but also more walking and biking trips, modes not normally captured in a traditional four-step transportation planning model. Greater densities of people living and working in close proximity to transit stations would create many advantages in terms of transportation efficiency and the ability to reduce traffic congestion in Connecticut. The next stage of this study should focus on looking at the synergistic effects of beneficial land use changes and congesting pricing on travel over the longer term in southwestern Connecticut.

6 Acknowledgments

The authors would like to acknowledge the efforts of Brian Baird and Stan McMillen who were involved in writing the proposal and selecting the regions in Connecticut that could benefit the most from congestion pricing. The authors also extend their thanks to the New York Metropolitan Transportation Council (NYMTC) and the Capital Region Council of Governments (CRCOG) for supplying transportation network files necessary to conduct this research.

7 References

Ambrosini, Dana (2000). Financial Jam: Traffic Congestion a Threat to Commerce. The Connecticut Post, Wednesday, November 1st, 2000.

Bergendorff, P., D.W. Hearn, M.V. Ramana, (1997). Congestion toll pricing of traffic networks, in: P.M. Pardalos, D.W. Hearn, W.W. Hager (Eds.), Network Optimization, Lecture Notes in Economics and Mathematical Systems, vol. 450, Springer-Verlag, Berlin, pp. 51–71.

Cervero, Robert (2002). Induced Travel Demand: Research Design, Empirical Evidence, and Normative Policies. Journal of Planning Literature, Vol. 17 (1), pp. 3-20.

Clough, Harbour & Associates, LLP (2004). I-95 Corridor Feasibility Study: Branford to Rhode Island. December.

Connecticut Department of Transportation (2004). Long-range Transportation Plan for the State of Connecticut, 2004-2030. (www.ct.gov/dot) July.

Ewing, Reid and Lichtenstein, Allan (2002). Induced Traffic and Induced Development: A Literature Review. Prepared for the Chester County Planning Commission. Available at http://dsf.chesco.org/.

Ferrari, P. (1995) Road pricing and network equilibrium, Transportation Research B 29 357–372.

Golob, J., Golob, T., and Supernak, J. (2001). I-15 Congestion Pricing Project Monitoring and Evaluation Services Task 8: Phase II Year Three Attitudinal Panel Study. San Diego State University Foundation.

Lawphongpanich, P., D.W. Hearn, (2004) An MPEC approach to second-best toll pricing, Mathematical Programming 101 33–55.

Murray et al. 2001. “Methodology for Assessing High-Occupancy Toll-Lane Usage and Network Performance.” TRR 1765: Paper No. 01-3002. Pg. 8-19.

Rossi, Thomas and Maren Outwater. (2002). “How Valid is it to Transfer Model Choice Model Parameters?” Proceedings of the TRB Conference on the Application of Transportation Planning Methods,.

Schrank, David and Lomax, Tim (2005). The 2005 Urban Mobility Report. Texas Transportation Institute

Yang H., W.H.K. Lam, (1996). Optimal road tolls under conditions of queuing and congestion, Transportation Research A 30 319–332.

Yildirim, M.B., D.W. Hearn, (2005). A first best toll pricing framework for variable demand traffic assignment problems, Transportation Research B 39 659–678.

8 Appendix A: Volume to Capacity Ratio Plots by Pricing Scenario

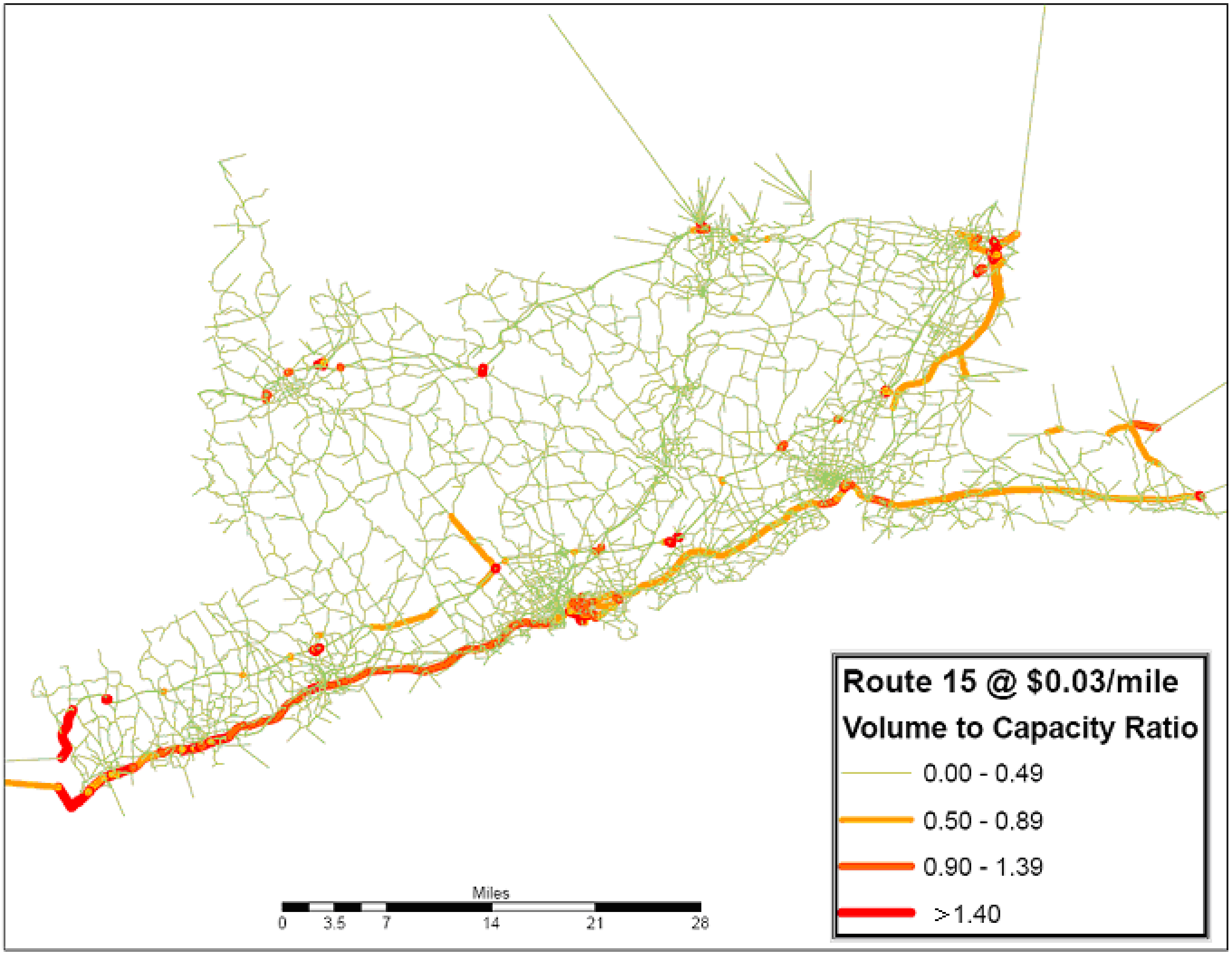


Figure A.1: Rt. 15 Priced at $0.03 per mile

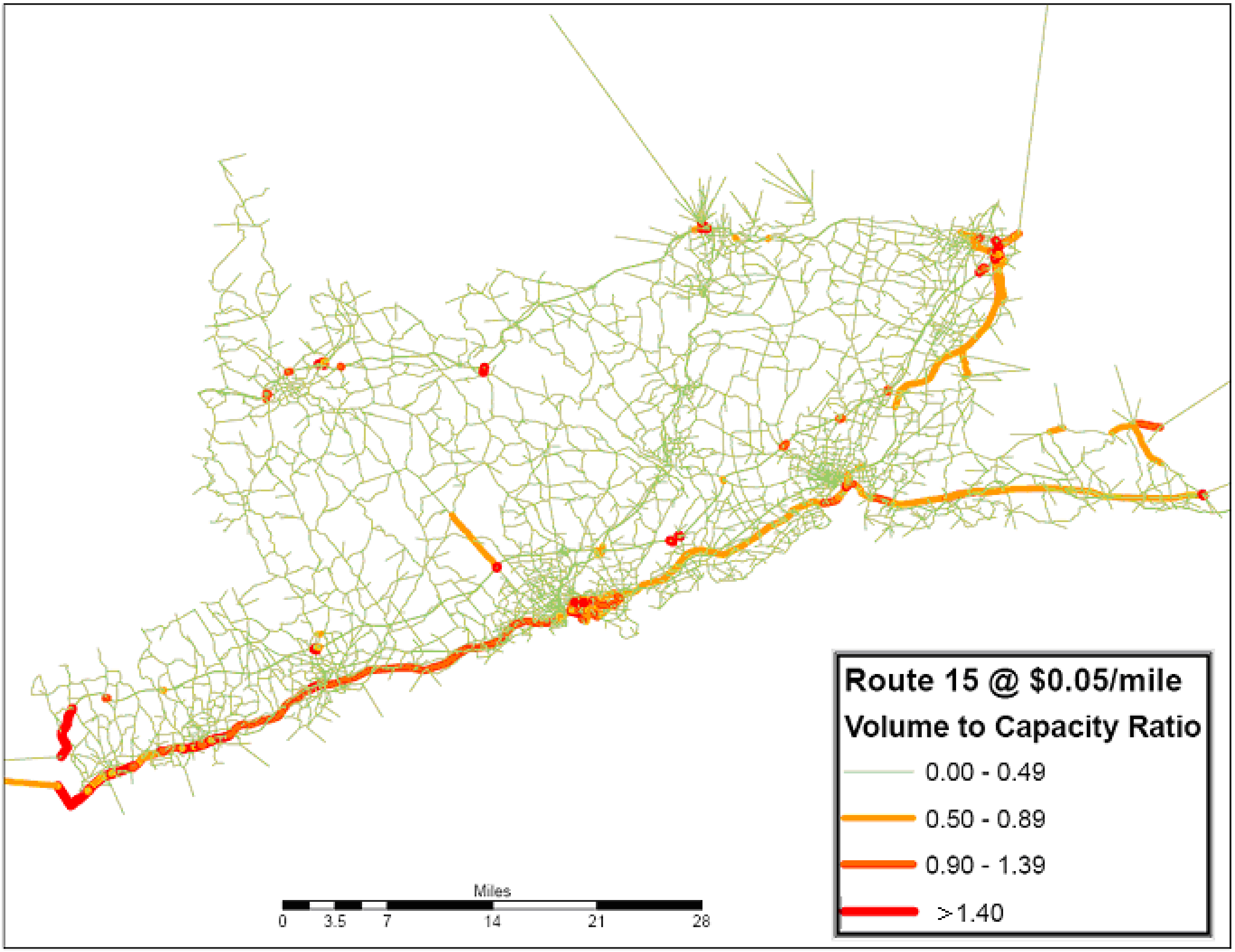


Figure A.2: Rt. 15 Priced at $0.05 per mile

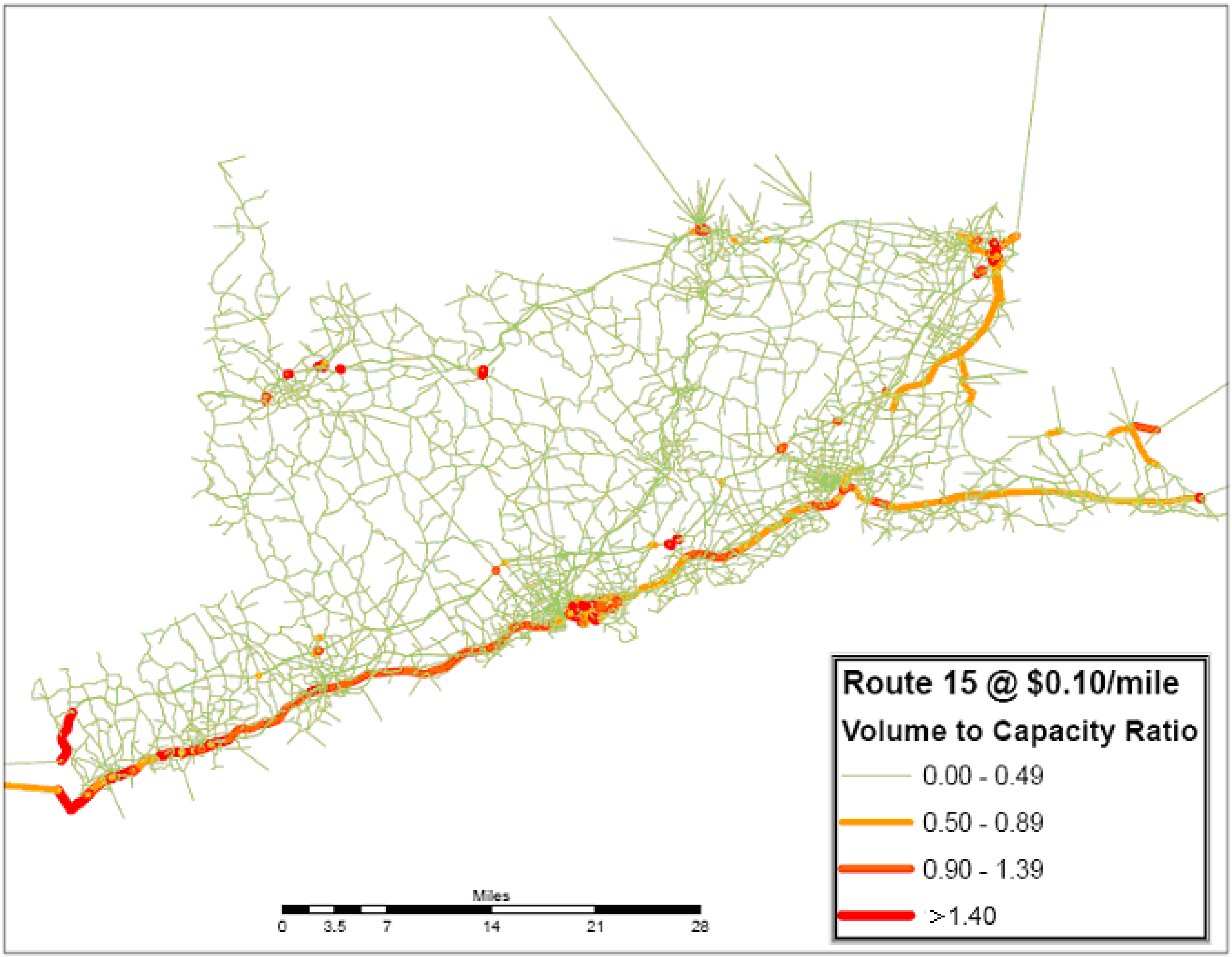


Figure A.3: Rt. 15 Priced at $0.10 per mile

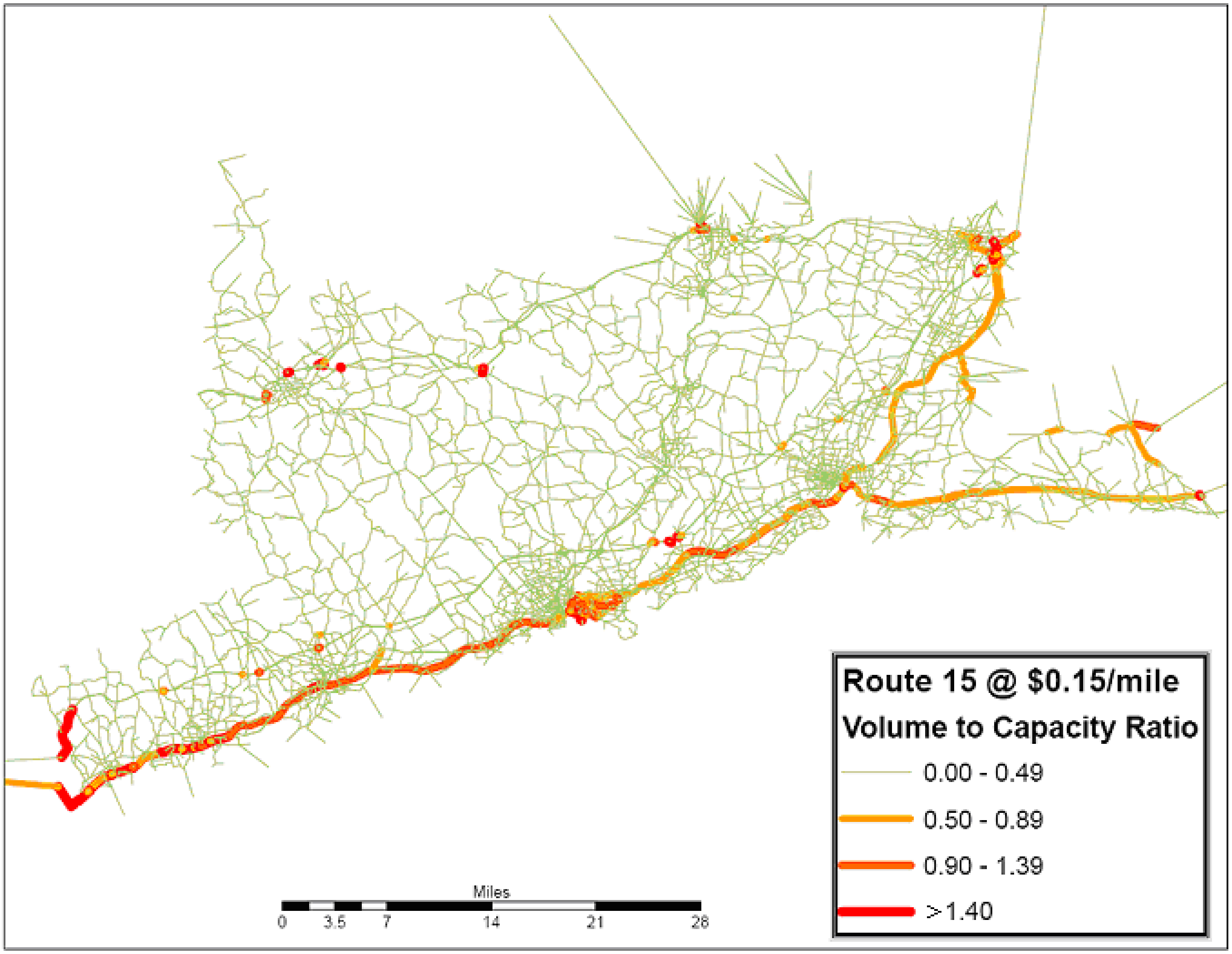


Figure A.4: Rt. 15 Priced at $0.15 per mile

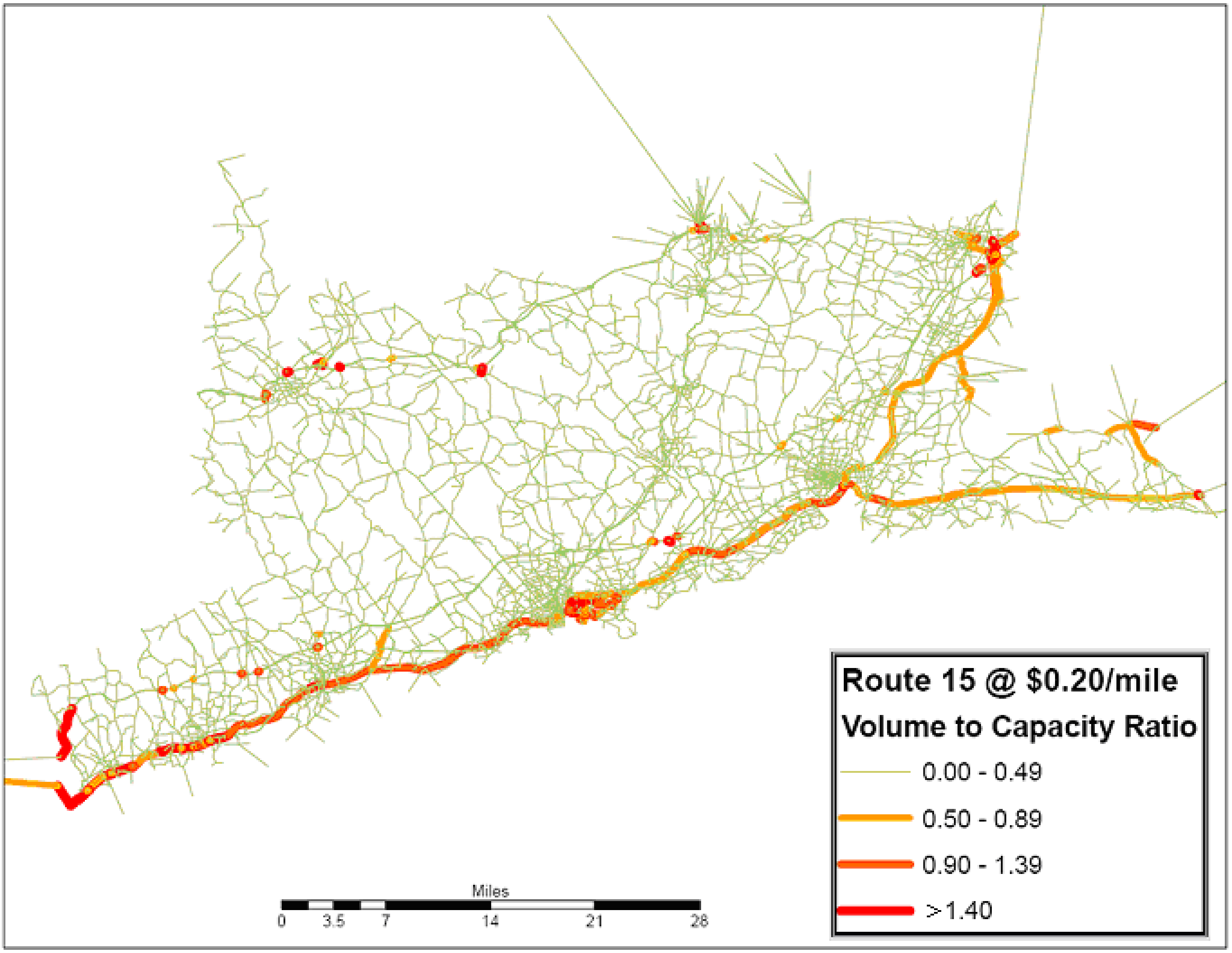


Figure A.5: Rt. 15 Priced at $0.20 per mile

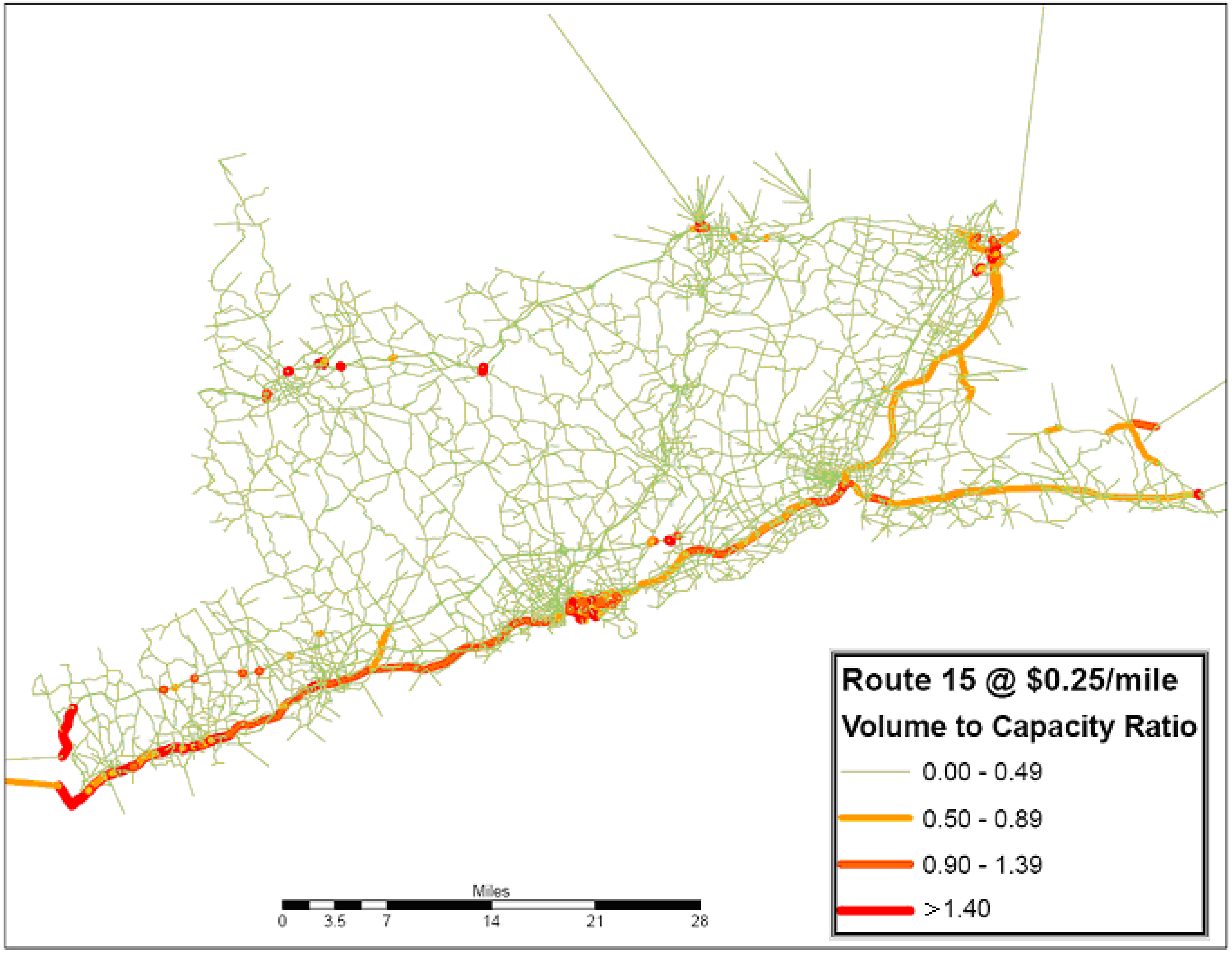


Figure A.6: Rt. 15 Priced at $0.25 per mile

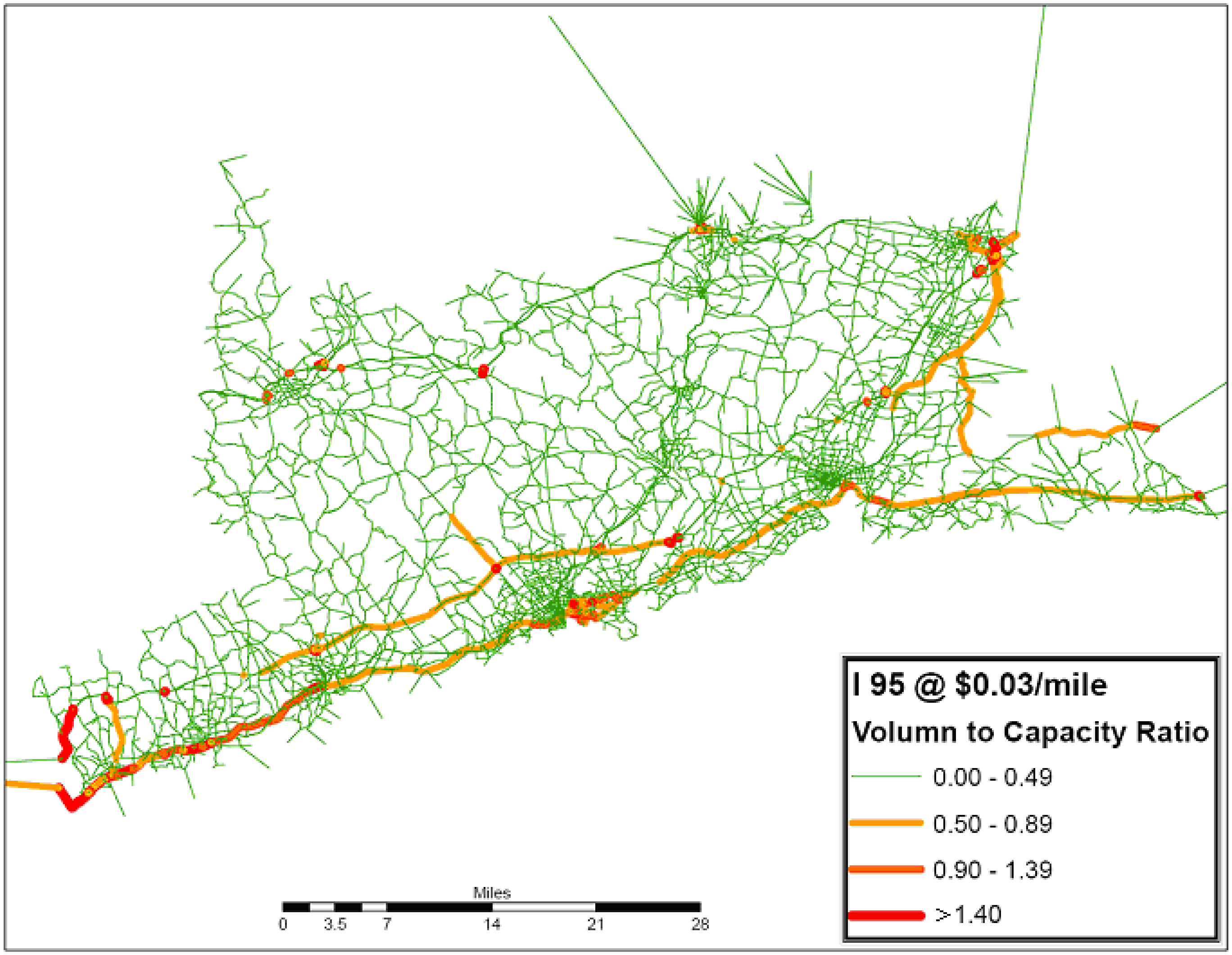


Figure A.7: I-95 Priced at $0.03 per mile

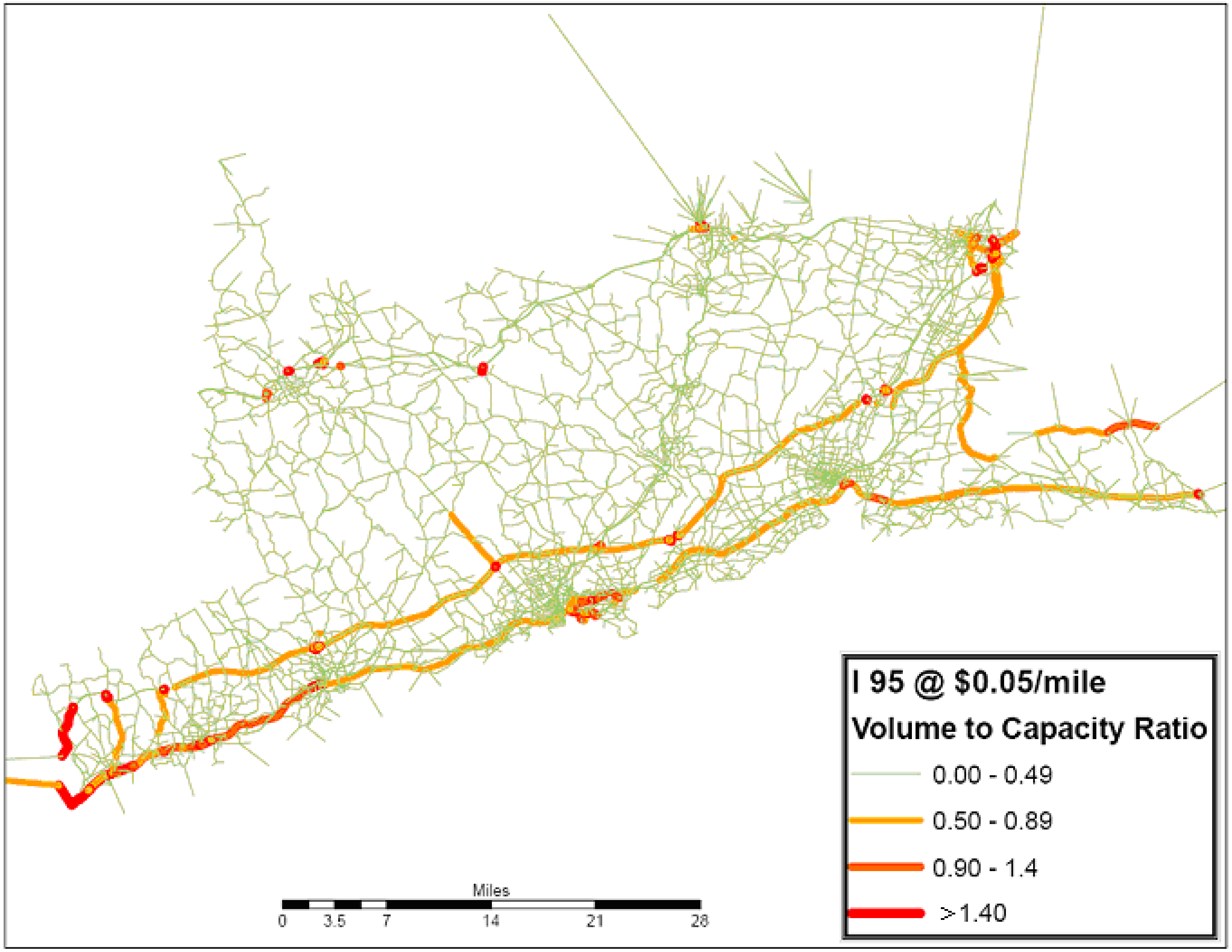


Figure A.8: I-95 Priced at $0.05 per mile

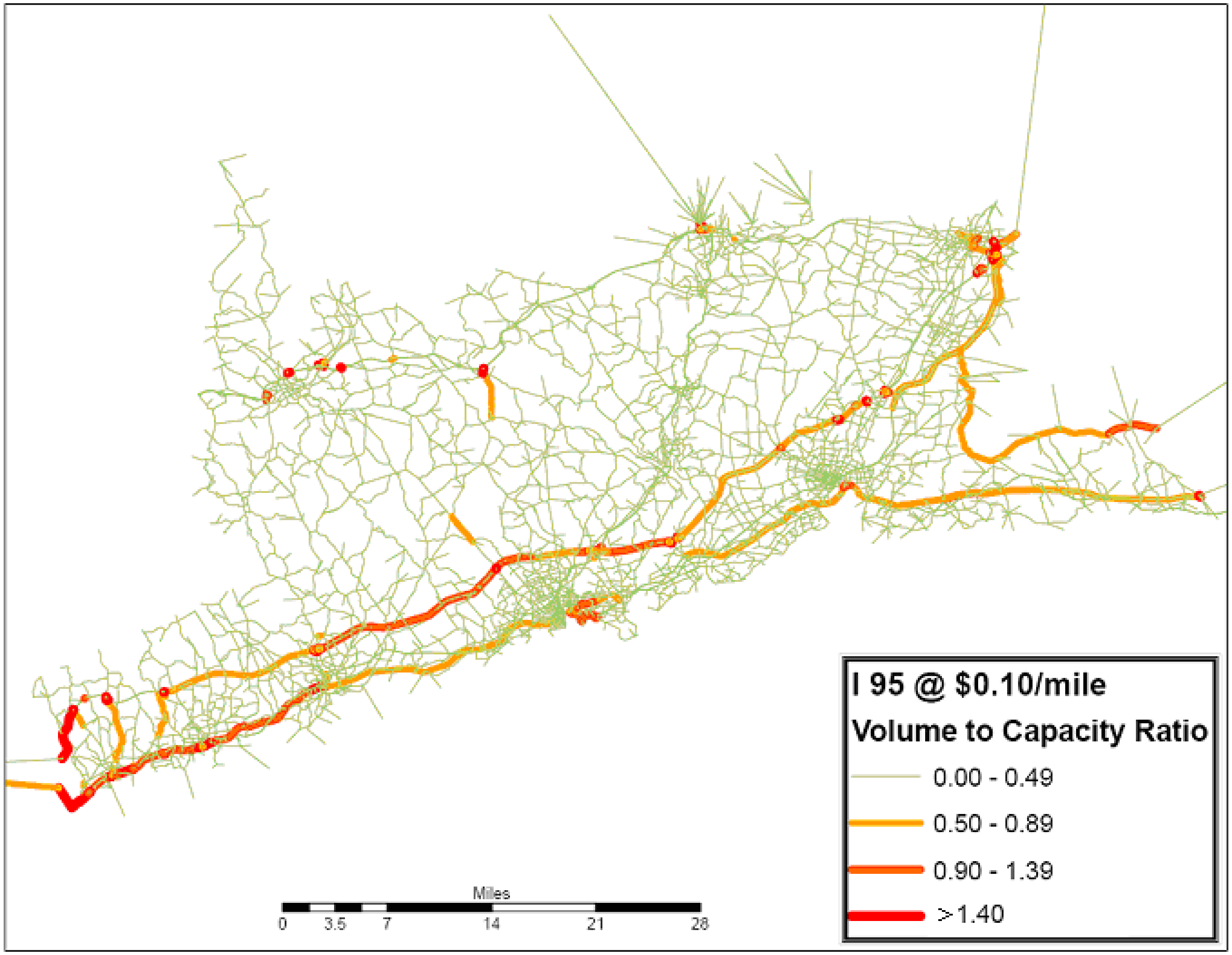


Figure A.9: I-95 Priced at $0.10 per mile

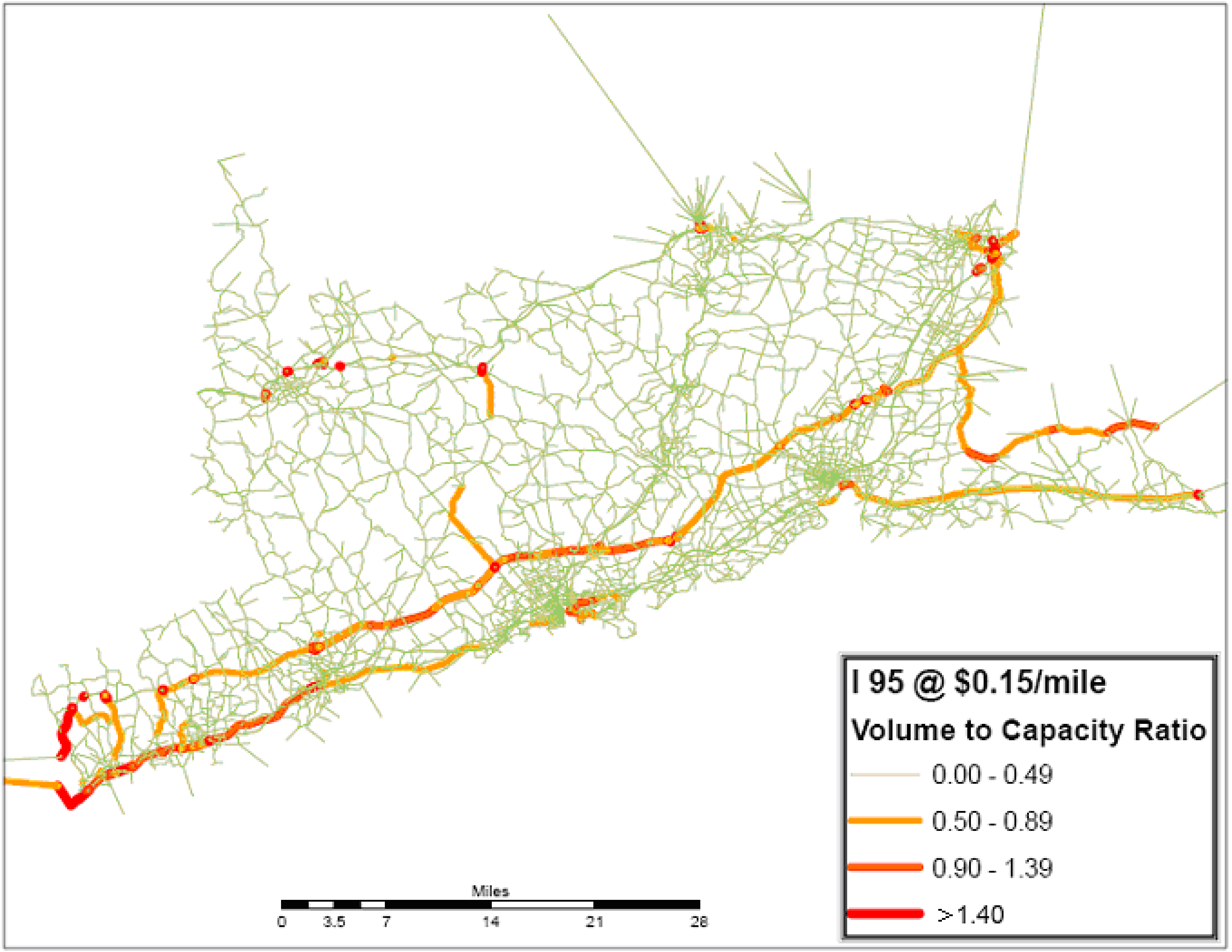


Figure A.10: I-95 Priced at $0.15 per mile

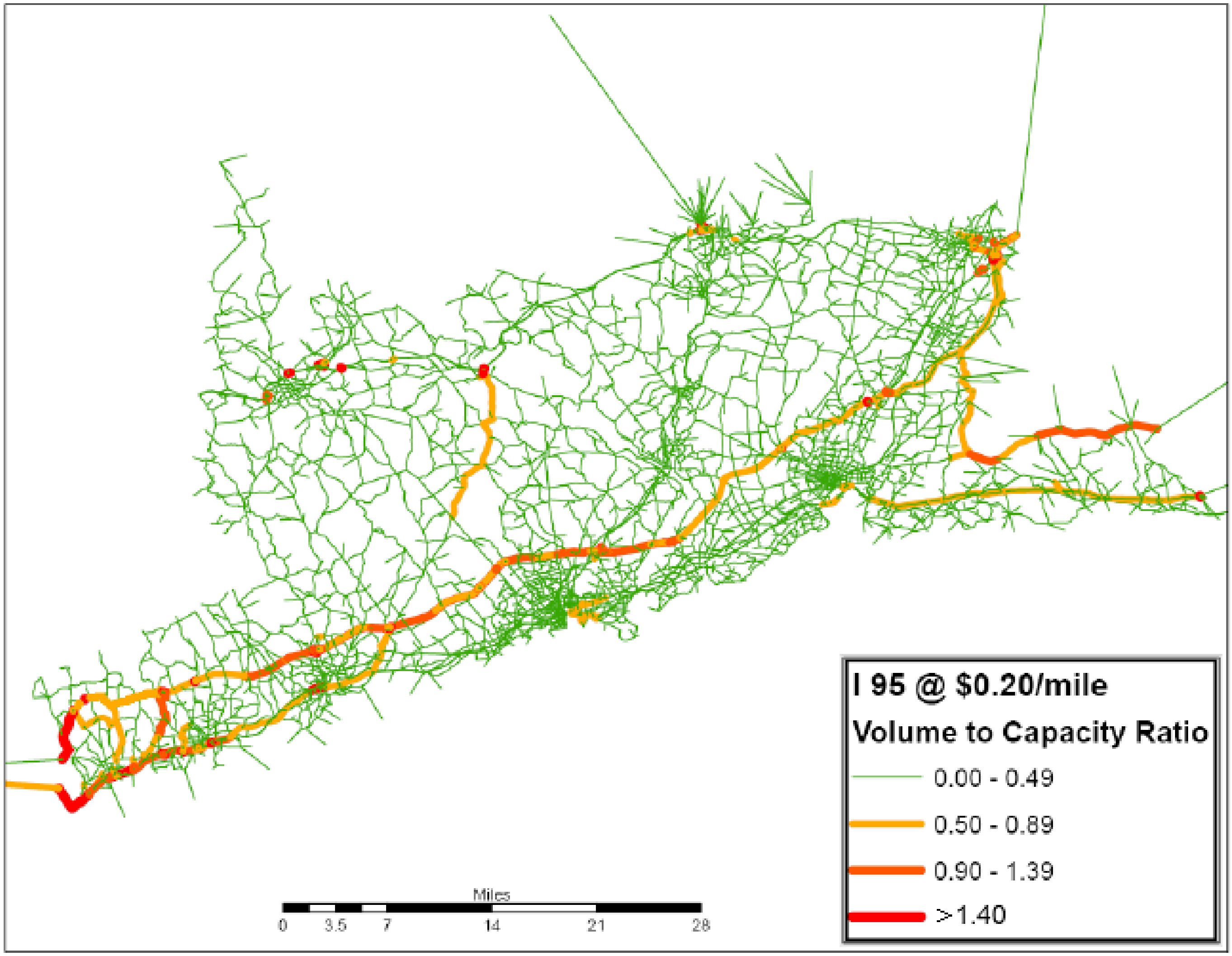


Figure A.11: I-95 Priced at $0.20 per mile

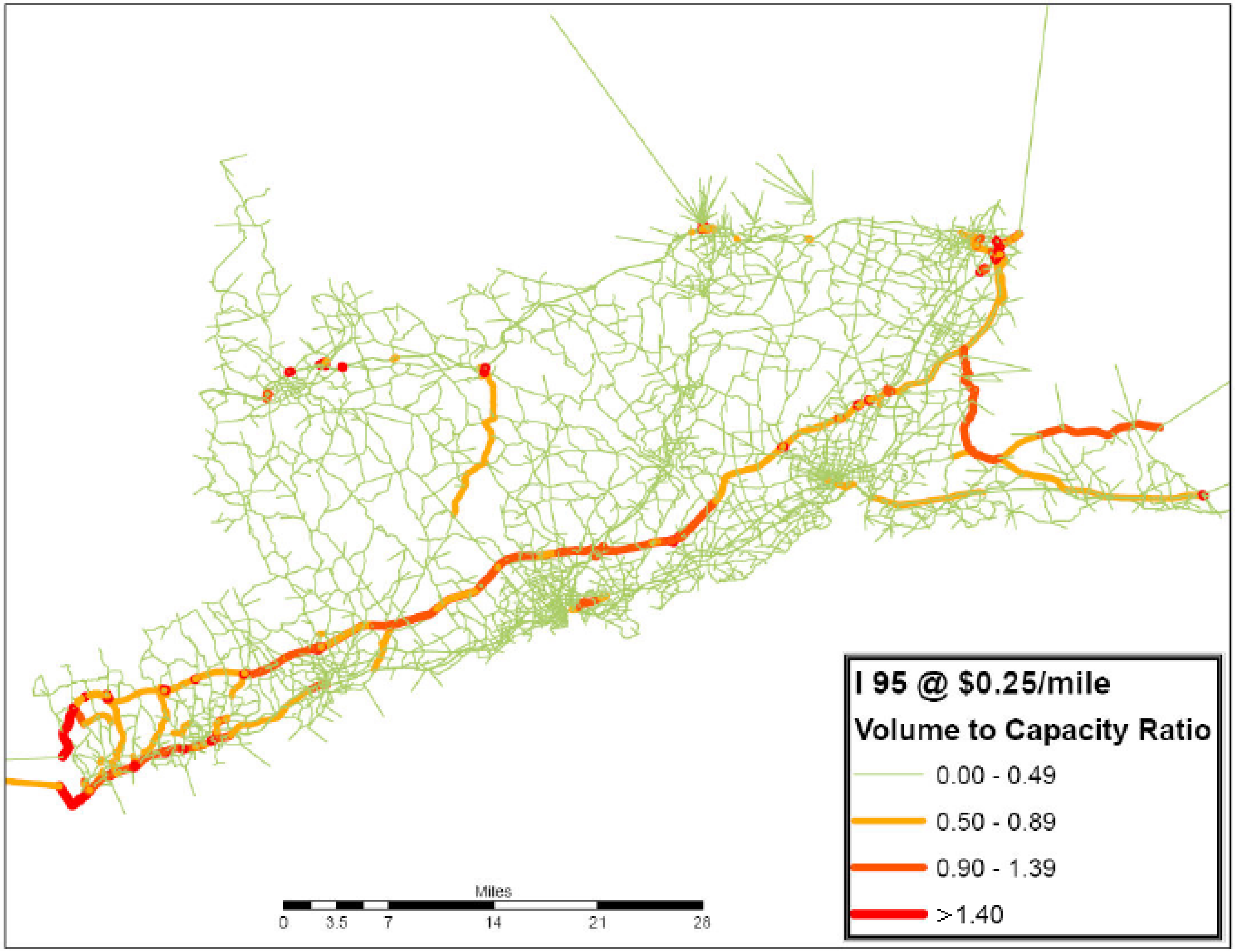


Figure A.12: I-95 Priced at $0.25 per mile

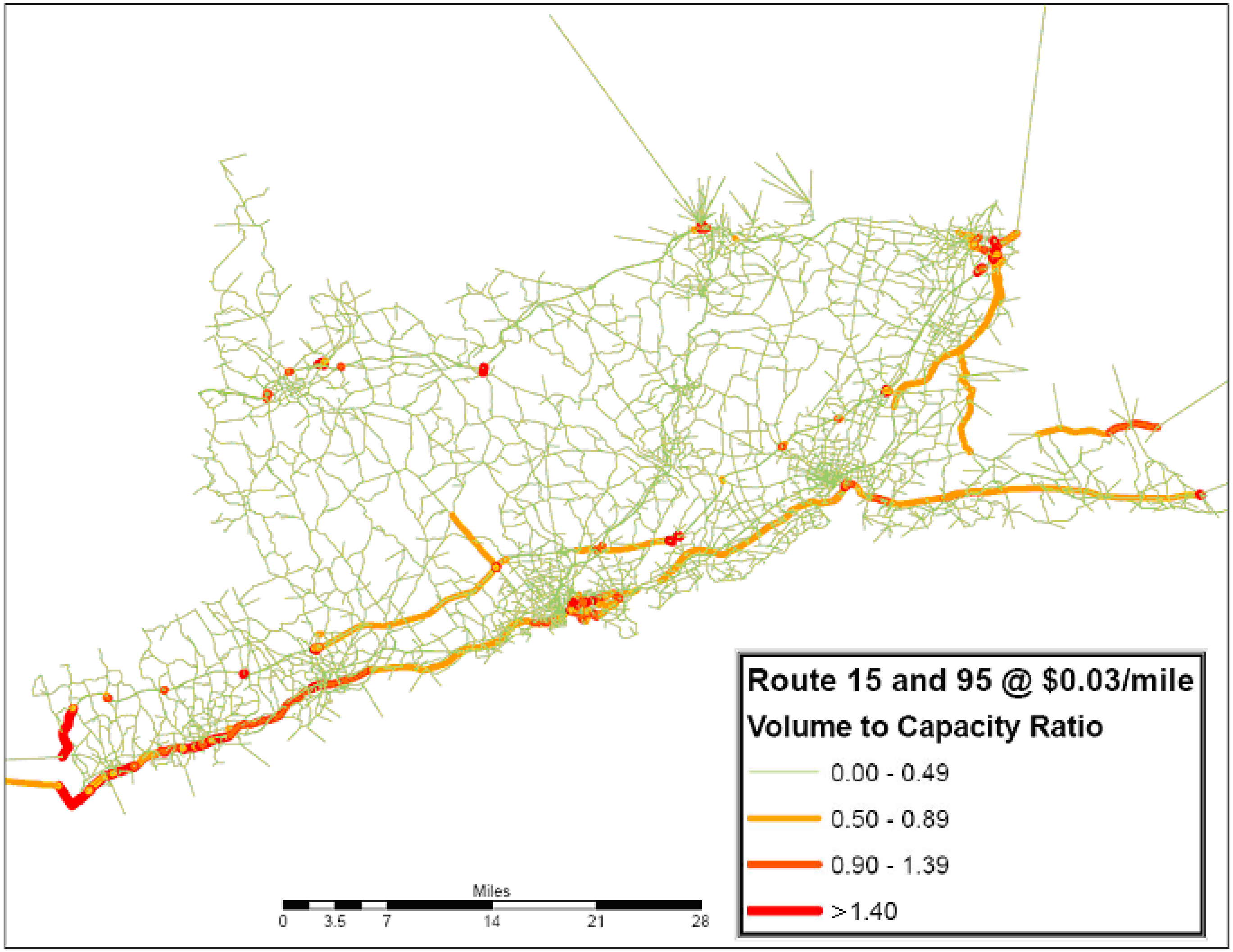


Figure A.13: I-95 and Rt. 15 Priced at $0.03 per mile

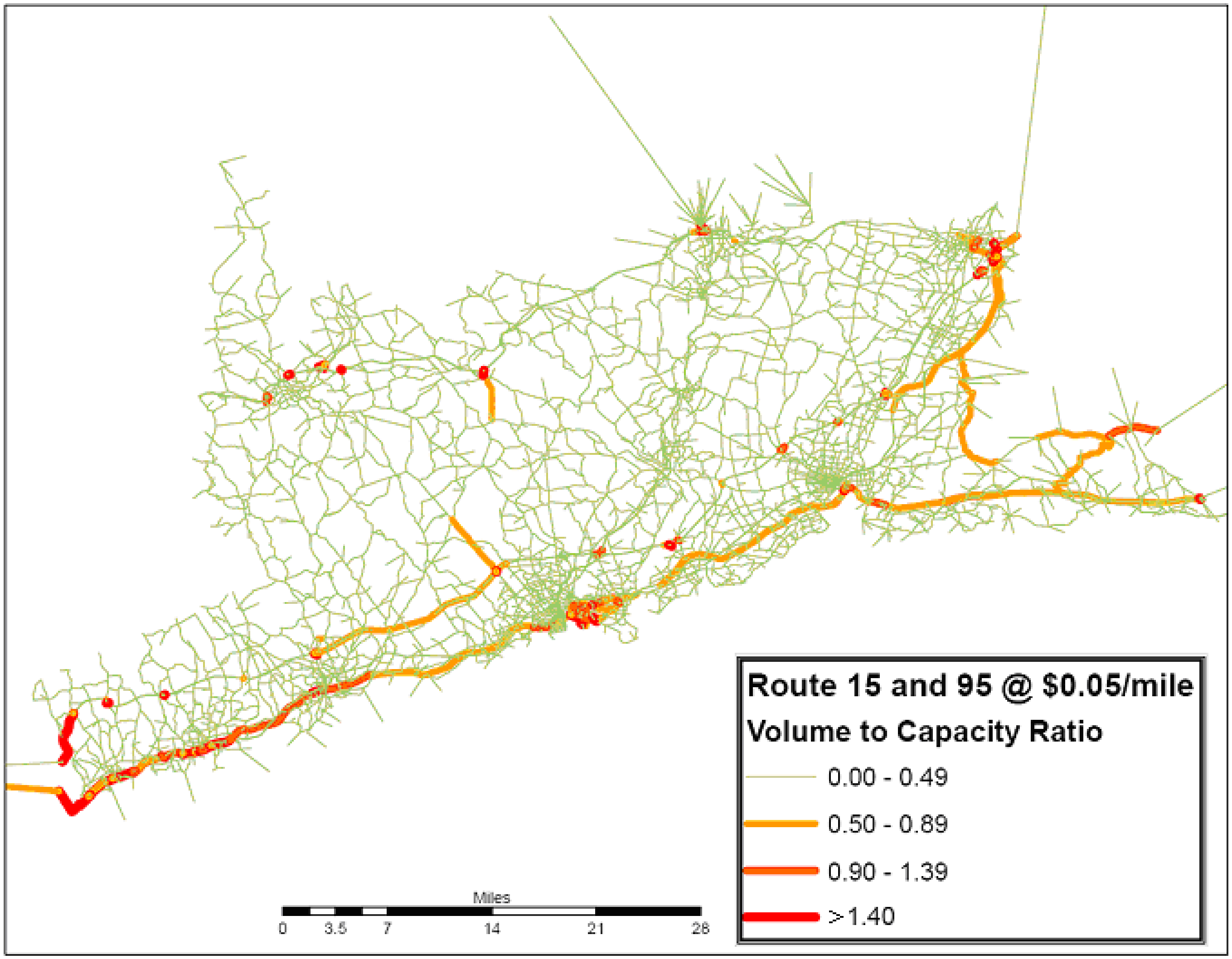


Figure A.14: I-95 and Rt. 15 Priced at $0.05 per mile

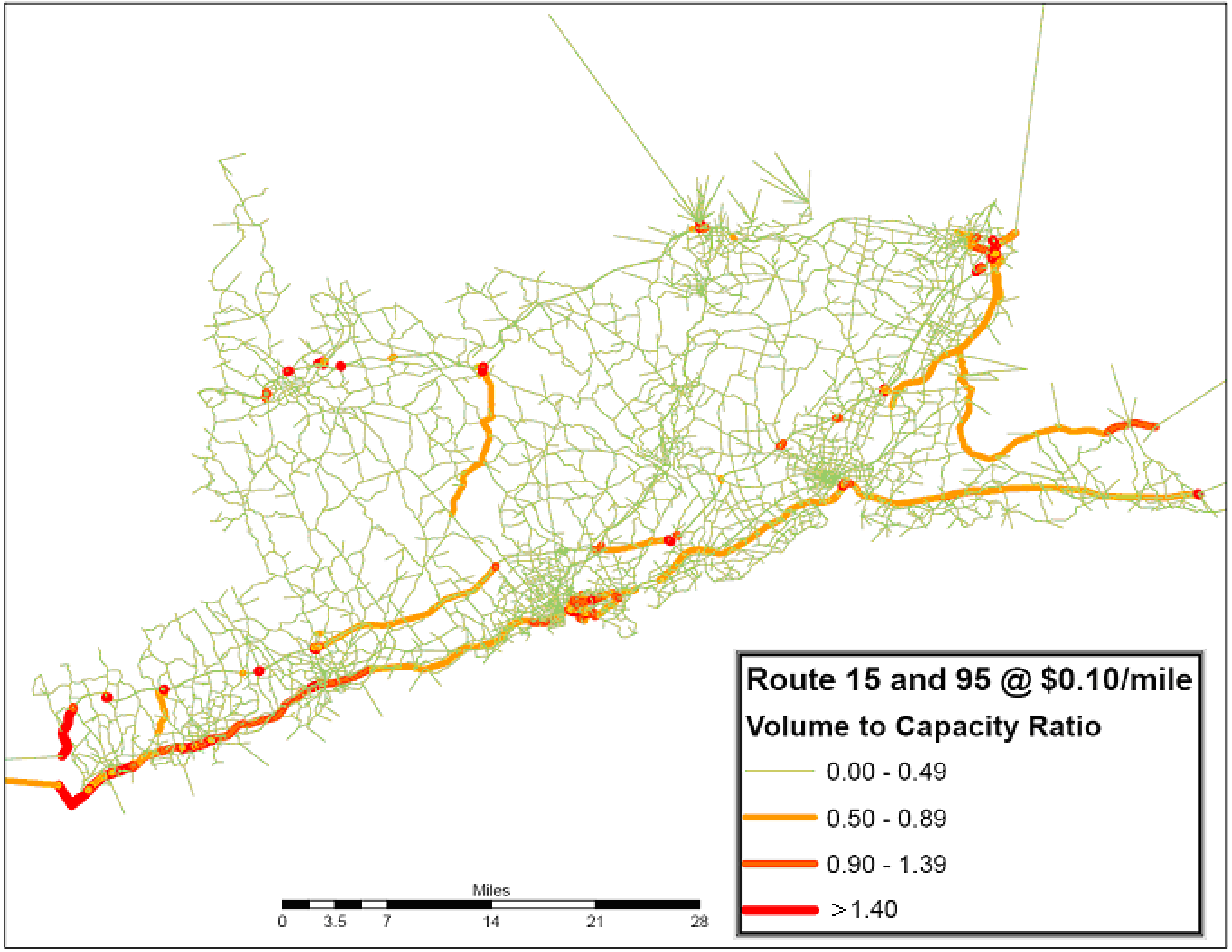


Figure A.15: I-95 and Rt. 15 Priced at $0.10 per mile

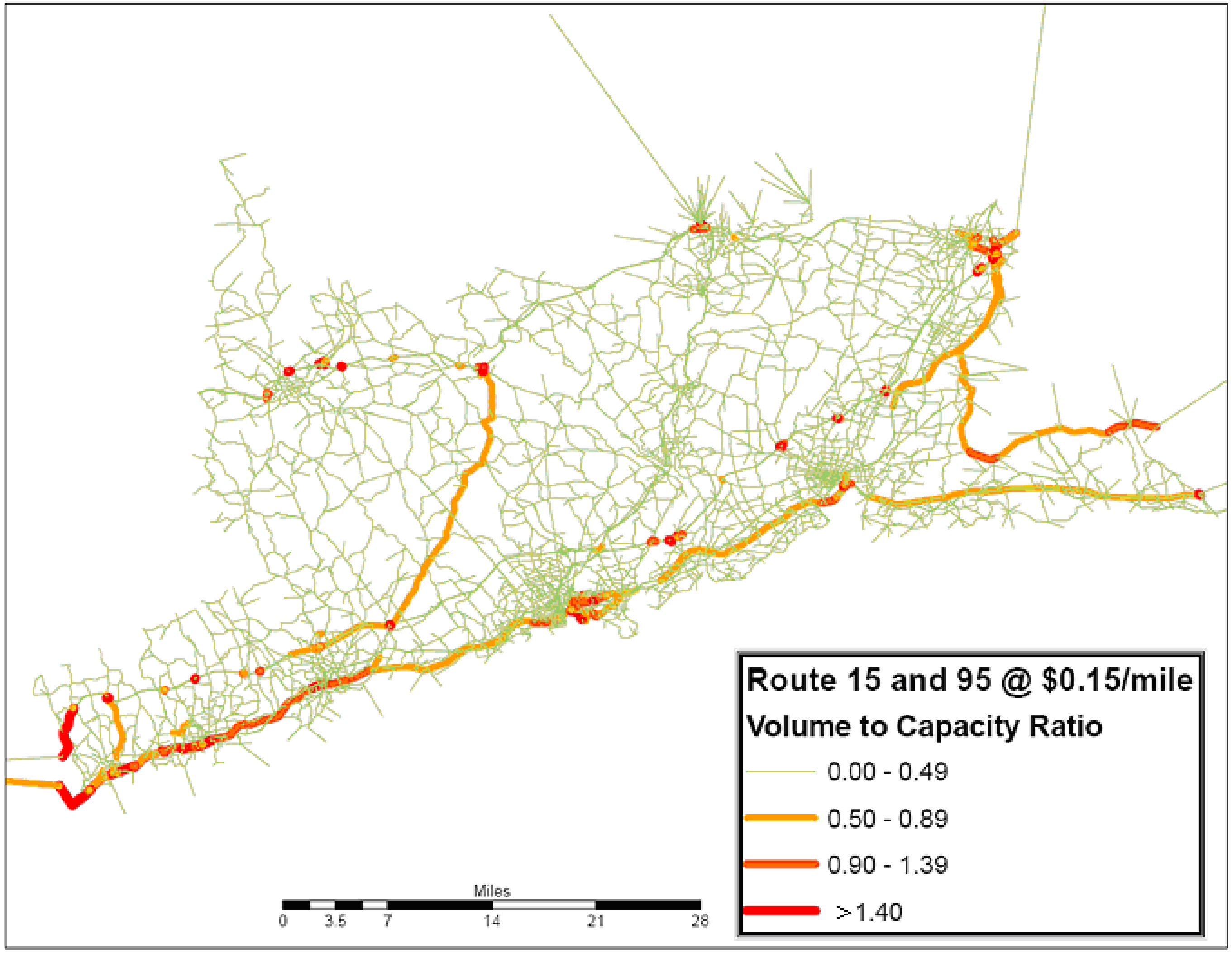


Figure A.16: I-95 and Rt. 15 Priced at $0.15 per mile

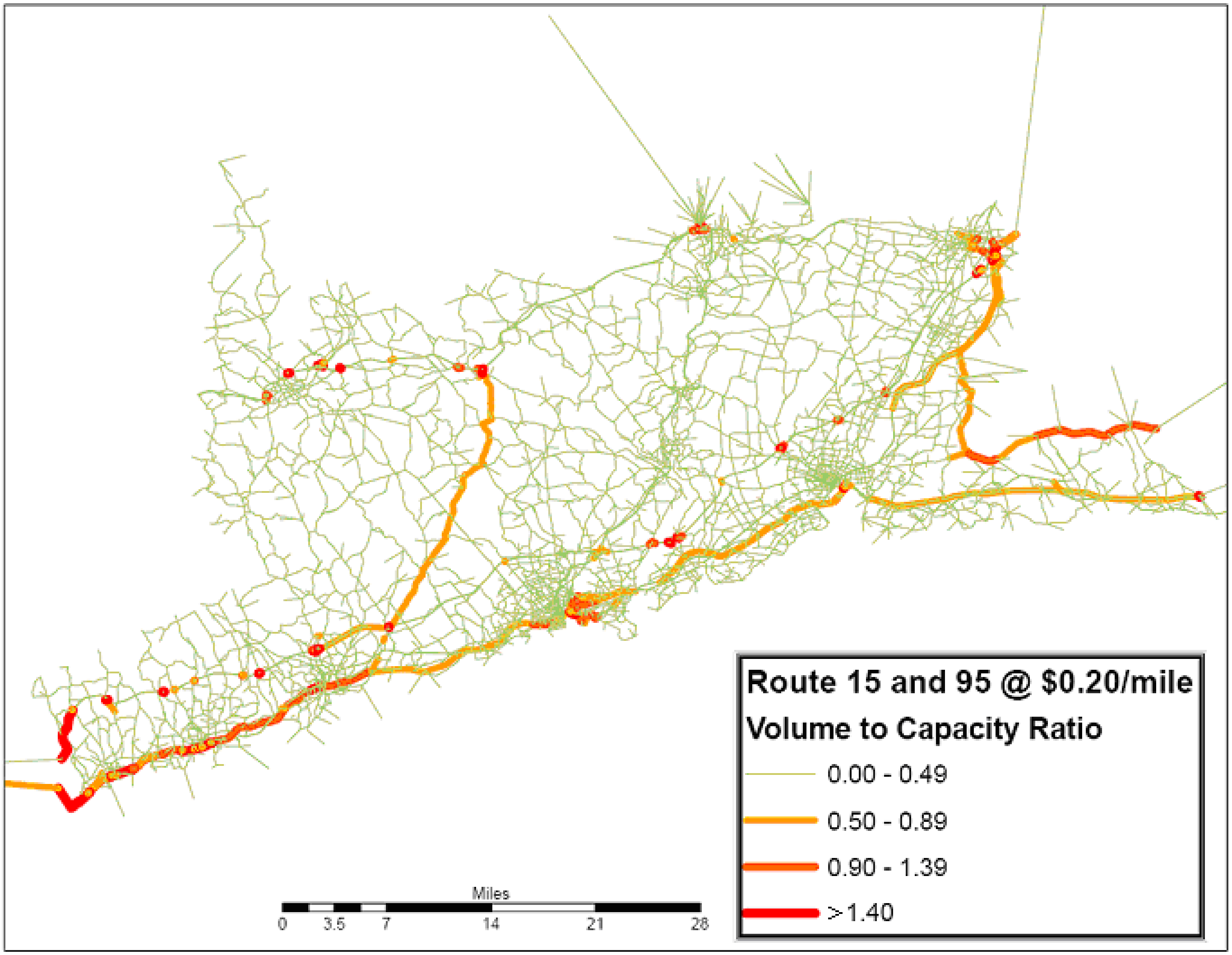


Figure A.17: I-95 and Rt. 15 Priced at $0.20 per mile

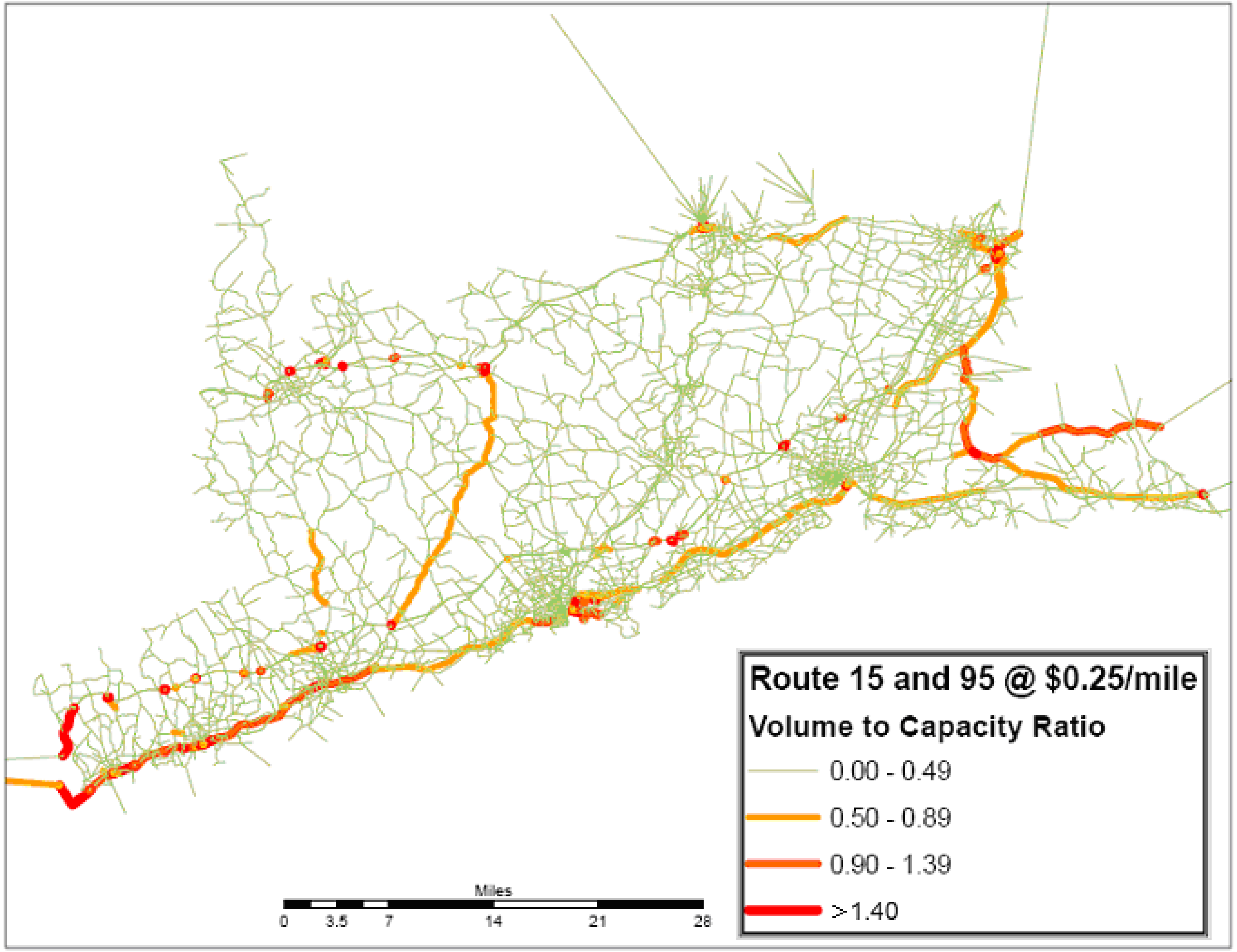


Figure A.18: I-95 and Rt. 15 Priced at $0.25 per mile