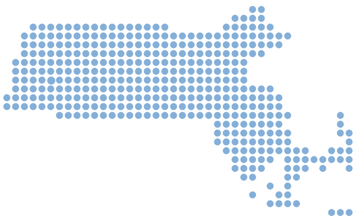
massDOT
Massachusetts Department of Transportation

CONGESTION IN THE COMMONWEALTH

REPORT TO THE GOVERNOR 2019



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LETTER FROM THE SECRETARY

Nobody likes being stuck in traffic. We all know the frustration that comes from sitting in a sea of taillights or watching a traffic signal repeatedly turn red as we creep toward an intersection. Congestion is nothing new in Massachusetts, but traffic data, anecdotal information, and our own daily experiences seem to be telling us that travel times are getting longer, becoming less predictable, or both. Congestion has become an unpleasant fact of life for too many Massachusetts drivers, who are finding that it takes longer than it used to in order to get where they are going.

People in Massachusetts don't need this study to confirm what they experience every day: congestion has gone from bad to worse, from occasional inconvenience and frustration to a constant and daily reality. Congestion is causing problems for far more than daily commutes; it chokes growing communities, reduces access and opportunity to jobs, affects people's choices about where to live and work and may undermine the Commonwealth's commitment to reduce greenhouse gases (GHGs), a primary cause of climate change.

That reality is clear. But as we at the Massachusetts Department of Transportation (MassDOT) dug into the data and research, it also became clear that this all-encompassing issue called "congestion" is much more complicated than it may seem, driven by a variety of different factors and tying together a wide range of related problems, including our persistent inability to produce sufficient amounts of reasonably priced housing, particularly in places where transit is or could be a real option. This study took longer to complete because we found that we needed to explore different kinds of data, and the more we examined each kind of data the more we realized the need to fundamentally reframe how we define, measure, and achieve success in relieving congestion. And if the problem of congestion is complicated, the solutions are even more vexing: there is no single, let alone simple, solution to congestion.

Key Findings

To some extent the data and analysis presented in this report confirm what Massachusetts drivers already know: that congestion exists in pockets all across the Commonwealth, but is generally worst on the roadways in and around Greater Boston. As presented in Chapter 4 of this report, the report's key findings are:

1. Congestion is bad because the economy is good.
2. The worst congestion in the Commonwealth occurs in Greater Boston.
3. Congestion can and does occur at various times and locations throughout the Commonwealth.
4. Many roadways are now congested outside of peak periods.
5. Congestion worsened between 2013 and 2018.
6. Changes in travel time on an average day do not capture the severity of the problem.
7. Massachusetts has reached a tipping point with respect to congestion.
8. Many commuting corridors have become unreliable, with lengthy trips on bad days.
9. Congestion has worsened to the point where it reduces access to jobs.
10. We should be worried about congestion on local roads, too.

The issue is reliability

Our current transportation system of rails and roads is carrying far more people going to and from many more jobs than the system was designed to handle. Congestion has gotten worse largely because the state and regional economy are doing so well and the population and labor force are growing.

As a result, in many places in Massachusetts, the roadway network is moving the maximum possible number of cars at many hours of the day: the system is full, if not overflowing. This is particularly true in Greater Boston within the I-95/128 corridor and, increasingly, out to I-495 and beyond. Under such congested conditions, comparatively small "insults" to the system—a crash during the morning rush hour, bad weather, a work zone—can have significant and cascading effects on surrounding roads. The problem of so-called "non-recurring" congestion due to these factors is exacerbated by the fact that the roads are so full in the first place.

As there is for everything, there is a tipping point for congestion. Many parts of our roadway system, particularly in eastern Massachusetts, are working as hard as possible every day and are therefore easily tipped into significant congestion by relatively minor occurrences. When this happens, travel times not only lengthen but become inconsistent and unreliable, making it difficult for motorists to plan their days and their lives. Congestion has become as much a quality of life problem as it is a transportation or economic problem.

People are upset with the length of their commutes, but what especially frustrates them is the daily uncertainty of just how long that commute might be. They may not be happy about it, but people can tolerate an average commute time that increased from, say, 29 minutes to 34 minutes. What really frustrates people is how that commute can occasionally spike to an hour or more due to accidents, weather, or seemingly for no reason at all.

The congestion measure that best captures this human dimension of congestion is reliability: what matters most to people is not how long it takes to get someplace on a typical day but how long it can take on a bad travel day. Once their commute is unreliable, people have to plan not around the average commute, but around the worst delays. That means arranging daycare and other work and family plans on the basis of that one in every 5- or 10-day spike, not the average daily commute.

Our goal as we tackle congestion must therefore be to eliminate as much of the variability as possible that now makes it so difficult for people to predict how long it will take them to get anywhere, for both transit and automobile users. By identifying and fixing the things that make the system so unreliable, we can make travel more consistent and predictable, even if not necessarily much faster or shorter.

What else are we trying to accomplish?

As important as it is to make commute times more reliable for both drivers and transit users, easing congestion must be carried out in a way that helps the Commonwealth achieve other important policy objectives. Congestion relief, for example, could focus on moving as many solo drivers in vehicles as quickly as possible. But such an approach could directly contradict the admonition of the Commission on the Future of Transportation—that the job of the transportation system is to move **people,** not vehicles.

As we tackle congestion, we cannot lose focus on Massachusetts' goal of reducing greenhouse gas emissions from the transportation sector. This congestion report and the recently filed bond bill reflect an integrated approach to dealing with the twin challenges of congestion and climate. So does the Commonwealth's participation in the Transportation and Climate Initiative (TCI), a "cap and invest" partnership of 12 states in the Northeast and mid-Atlantic similar to the Regional Greenhouse Gas Initiative (RGGI) model. When enacted, this initiative will be designed both encourage drivers to consider alternate means of transportation and to generate revenues to invest in other approaches to congestion mitigation, including better public transit.

Finally, we cannot lose sight of the need to incorporate considerations of equity—economic and racial equity but also regional equity and equity for both urban and rural residents—into our congestion relief strategy. Improved transportation system reliability and predictably is especially important for people who lack options such as traveling outside of peak periods or using public transit. Policies to make the Commonwealth's transportation system more reliable should also enhance social and economic equity by improving accessibility to jobs and other opportunities.

How can we improve reliability?

Congestion relief success means giving people more confidence that they can get to work or where they're going within a certain time frame. That means solutions that increase reliability, even if we cannot necessarily speed up every trip. By addressing the "bad day" problem, we can give people more confidence that their commute time will align with the average, not the extreme.

MassDOT must play a central role in improving reliability; we are the steward of the state's roads and multimodal transportation networks. But historically, MassDOT and other state transportation agencies have focused primarily on building and maintaining that network. We build the roads, we plow them, and fix the potholes. But if we are to make the overall system more reliable in the face of mounting congestion, we must expand this mindset. We must not only build and maintain the network, we must actively monitor and manage it every day.

What does active management look like? System constraints and demands may well limit our ability to significantly reduce average commute times. **But we can do something about the bad days, the spikes that now make commutes so unpredictable.** That means conducting root cause analyses of how to prevent such negative travel experiences. We can, for example, more systematically station tow trucks or create pull-out lanes in areas data show to have frequent accidents. MassDOT can work harder to get contractors off the roads well before peak travel times. We can make more widespread use of technology, from Waze to smart signals. And we can bring some fresh thinking to the problem. It has, for example, been 30 years since MassDOT has seriously looked at the utility of high-occupancy vehicle lanes or thought much about its role in providing park and ride lots. A comprehensive re-thinking is long overdue.

Recommendations for Next Steps

There is no single, let alone simple, solution to congestion. Nothing less than a coordinated and collaborative effort will make a difference. The recommendations for next steps presented in Chapters 4 and 5 of this report represent a portfolio of inter-dependent approaches that, taken together, can help us manage the congestion on Massachusetts roadways:

- Address local and regional bottlenecks where feasible
- Actively manage state and local roadway operations
- Reinvent bus transit at both the MBTA and Regional Transit Authorities
- Increase MBTA capacity and ridership
- Work with employers to give commuters more options
- Create infrastructure to support shared travel modes
- Increase remote work and telecommuting
- Produce more affordable housing, especially near transit
- Encourage growth in less congested Gateway Cities
- Investigate the feasibility of congestion pricing mechanisms that make sense for Massachusetts, particularly managed lanes

While MassDOT has an important role to play and a lot of work to do, we cannot make the Commonwealth's transportation system more reliable (and sustainable) by ourselves. As made clear in this report's recommendations, other state agencies, as well as local government and the private sector, must also take meaningful steps. Municipalities can create more dedicated bus lanes, with financial assistance from the Commonwealth. Employers can adopt policies to enable more work at home or off-peak work scheduling. Many players can work together to increase production of affordable housing and streamline the process of creating transit-oriented development.

A multitude of factors are responsible for our current congestion challenges. A multitude of actors, public and private, will need to work together to resolve them.

It can happen

People are understandably skeptical of the ability of different players to work together. But not that long ago, the public and private sectors demonstrated an ability to come together and work together to ensure that Boston would remain open for business through a looming transportation challenge: the Big Dig.

For years before and during the project itself, the traffic and congestion consequences of the Big Dig were treated like a necessity. We had to build this megaproject while still getting people in and out of Boston every day. The population was smaller then and the economy was not as strong, but the challenge was still great. During the Big Dig, we treated every day as one that required careful congestion management by MassDOT and lots of communication and collaboration among all stakeholders to minimize disruption.

Just as the Big Dig forced public and private sector players to transform what they do, today's levels of daily congestion demand similar smart thinking and management today.

This report lays a data-driven foundation for policy makers to begin a serious conversation about a coordinated set of policy options to restore reliability to our transportation system. We recognize that different people will look at the data and draw different conclusions and come up with different recommendations. That's appropriate. What's vital is that this important congestion conversation is built on a common understanding of what is happening and a shared commitment among the state, cities and towns, travelers, workers, and employers, and other stakeholders to make the necessary choices and recognize that rather than a "silver bullet" we will need to implement a comprehensive portfolio set of solutions to make a difference in the complicated, critical problem that is congestion in Massachusetts.

Stephanie Pollack
Secretary and CEO
Massachusetts Department of Transportation

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 ABOUT THIS REPORT

In August 2018, Governor Baker directed MassDOT to complete a comprehensive analysis of when, where, and why roadway congestion is getting worse in the state. This report is the product of that data-driven analysis. It includes a set of next steps for how to respond to congestion and the challenges that accompany it. A series of detailed appendices present the data, maps, and charts that underlie this report.

This chapter provides an overview of the report and includes definitions of key concepts as well as a review of our study area, scope, data sources, and methodological framework. Additional information about the roadways included and the data sources used is in Appendices A and B.

Chapter 2 starts by answering some basic questions, such as when and where congestion occurs in Massachusetts, using mostly quantitative techniques from a variety of sources. Using data collected from the Federal Highway Administration (FHWA), this chapter reviews the locations and severity of the congestion that drivers encounter on average weekdays. This first piece of analysis is a baseline and straightforward description of roadway conditions throughout the day. In addition to an hour-by-hour review, we also highlight the top five most severe occurrences of congestion and the most consistently congested corridors and describe congestion in Central and Western Massachusetts. A full set of maps that illustrate where congestion occurs and its severity by hour of the day is included as Appendix C.

Next, Chapter 2 reviews how congestion has changed over time. A set of charts that compare average travel times in 2013 to 2018 on select corridors is in Appendix D.

The timing and severity of congestion on discrete roadway segments is just one way to describe congestion. Chapter 2 also draws on data collected by the All Electronic Tolling (AET) gantries to describe the impact of traffic volumes on travel speeds at different spots along the Massachusetts Turnpike. Detailed volume and speed data collected from the gantries, including posted speed limits, are included as Appendix E.

These descriptions of how congestion affects traffic flow do not, however, fully capture how congestion impacts people's lives. That is why Chapter 2 concludes by looking at congestion through two important lenses. The first is reliability: how congestion affects the reliability of travel by examining the variability of travel times on popular commutes. The second is accessibility: the ability for people to use the transportation network to get where they need to go, within a reasonable amount of time. Specifically, we describe the effects of congestion on access to jobs and its impact on the quality of public transit service.

Chapter 3 focuses on "why" congestion has worsened. We break out congestion by its two types—recurring and non-recurring—and explore statewide trends in the factors that drive each type in order to explore why patterns of congestion may have changed.

Chapter 4 summarizes the key findings that frame a series of recommendations and next steps for how key actors and stakeholders in the state can respond to the burdens of congestion.

Congestion pricing is a strategy increasingly considered and implemented by cities and states across the U.S. Chapter 5 explores various approaches to congestion pricing as well as the applicability of congestion pricing in Massachusetts. Final conclusions are presented in Chapter 6.

Defining and Measuring Congestion

There are many ways to identify and measure vehicular congestion. Most simply, **congestion** is a way to describe traffic flow on a roadway, which reflects the number of cars on a given segment and the vehicular capacity of that segment. When the number of cars begins to exceed capacity, travel slows and congestion occurs. However, the severity, causes, and impacts of congestion vary widely by location, day, and time.

Transportation planners and engineers classify congestion as either non-recurring or recurring. **Non-recurring** congestion is the kind that drivers face because of a travel anomaly. It is often the result of what the FHWA calls "incidents,"[1] such as breakdowns, crashes, road work, special events, or intense weather.

Recurring congestion, on the other hand, is the congestion that drivers expect to face every day and associate with morning and evening commutes. Recurring congestion is driven largely by socioeconomic and demographic factors, such as economic activity, land use, and travel patterns and behaviors.

Reliability refers to the consistency or dependability in travel times. The most frustrating aspect of congestion—and a large part of why congestion is so problematic—is that people are often unsure of how long it takes to get certain places. A more complete discussion of reliability appears in Chapter 2.

Accessibility is the degree to which people can reach desired destinations via the transportation network, including the ease and convenience of travel. While transportation planning has traditionally focused on the condition of the network itself, it is more important to measure the utility of the transportation network to its users in terms of the number and types of destinations people can get to in a given amount of time from different starting points.

Peak travel periods are the times of day that most people either are or are expected to be traveling through the network, typically to and from work in the morning and evening. Peak period travel times vary with respect to when and how long they last across both different regions in the state, and different travel modes. For vehicular travel, this study relies on peak period definitions that are consistent with FHWA guidelines, which are the same across the state.

This Study's Area and Scope

This report takes a layered and mixed-methods approach to identify and investigate where, when, and why congestion occurs in Massachusetts. While not every question can be answered due to data limitations, this discussion relies on several different sources of information to be as thorough as possible and reflect all of the different ways to understand and describe congestion. See Appendix B for a full list of the data used in this report.

To describe where and when congestion occurs, this analysis primarily relies on **weekday travel times** recorded and averaged for each hour of the day over the course of calendar year **2018**. The analysis is focused on **major roadways** unless otherwise noted (see Appendix A).

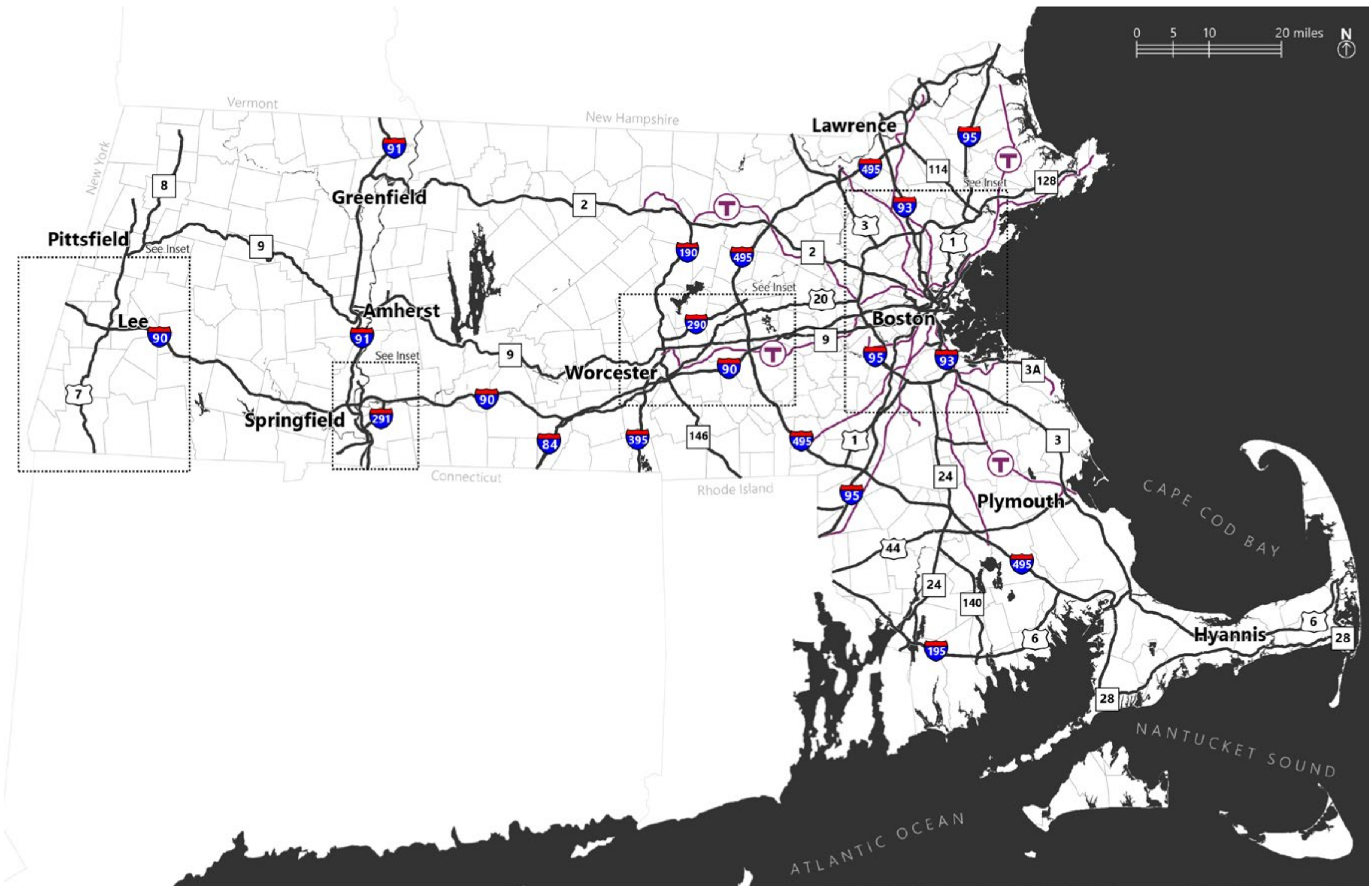
This report describes **typical** roadway conditions and, except where otherwise noted, relies on data that is aggregated and averaged for each hour of the day over two one-year periods (2018 and 2013) for comparison.

While travel times can of course vary on a day-to-day basis, **these findings are illustrative of truly average conditions;** the experiences of specific days or weeks are not reported.

This report is driven by data that reflect travel times that are averaged across one calendar year and only for certain roadway segments in the Massachusetts transportation network. While some of our approaches to understand congestion allow us to approximate how often drivers can expect to face varying travel

1 U.S. Department of Transportation, Federal Highway Administration (FHWA), January 2010. "2010 Traffic Incident Management Handbook Update." https://ops.fhwa.dot.gov/eto_tim_pse/publications/timhandbook/chap1.htm

Figure 1. Study Network



conditions, this report does not attempt to identify or capture any specific trips. As a result, the data-driven findings here may not fully reflect how people actually experience congestion.

Congestion is not a condition that affects some roadways and not others—it can happen anywhere at almost any time. However, this report almost exclusively provides information on a select network of large roadways in the state called the National Highway System (NHS), most of which are owned by MassDOT. This is because these are the only roads in the state where data is reliably and regularly collected and reported to the FHWA. While anecdotal and experiential information suggests that local roads are also significant sites of congestion, there is simply no authoritative data reported about them. That said, local roads are critical elements of the network and must be specifically considered for congestion management efforts as well.

2 CONGESTION IN MASSACHUSETTS

While congestion in general is a serious problem, what most frustrates people is the unreliability of their travel times. It's not just how much time people are spending stuck in traffic—it's the unpredictability of their commutes that shape how people feel about transportation: the difference between an "average" day and a "bad" day can be enormous in terms of how much time people spend in traffic, whether on cars, buses, or trains.

Massachusetts is a diverse state. So too are its local transportation conditions and experiences, including the occurrence of congestion. Congestion is simply not uniform with respect to when or where it occurs, or how severe it is when it does.

This chapter addresses a series of questions about congestion in Massachusetts on the major roadways that constitute the National Highway System, beginning with when it happens and where it happens.

Along with the straightforward "when" and the "where" of congestion, it is also important to understand the trends that surround it, including the impact of volumes on speeds, the relationship between congestion and reliability, and the burden of congestion on access to jobs and the quality of transit services.

This chapter discusses roadway conditions on different segments of the network at different times of day. Appendix C contains a catalog of maps that show roadway conditions throughout the day and across the state.

The Occurrence and Severity of Congestion

The first step to understanding congestion is to identify where it occurs and its severity. This first section includes an hour-by-hour review of the occurrence and severity of congestion throughout the state, descriptions of especially congested segments, and a discussion of congestion in Central and Western Massachusetts.

The analyses are each informed by data collected through the FHWA's National Performance Monitoring Research Data Set (NPMRDS) for calendar year 2018 and reflect average daily conditions.

Our approach describes the occurrence and severity of congestion by comparing hourly average travel times to "free-flow" travel times on different segments. We classify roadway conditions as:

- *Less congested:* average travel times are up to 50 percent longer than free-flow conditions;
- *Congested:* average travel times are up to twice as long as free-flow conditions; and
- *Highly congested:* average travel times are more than twice as long as free-flow conditions.[2]

[2] For more information on the methods and data sources used in this analysis, see Appendix B.

A full description of the approach used to classify roadway conditions appears in Appendix B.

CONGESTION THROUGHOUT THE DAY

Different roadways face different levels of congestion at different times. Greater Boston, particularly the area within the I-95/128 belt, sees the most severe congestion throughout an average day but other regions in the state also grapple with it.[3]

Table 1 shows the percentage of roadway miles[4] that are congested during different daytime hours in different regions throughout the state.

Table 1. Percent of Study Roadway miles Congested or Highly Congested, by Hour and Region, *4 a.m.–11 a.m. (2018)*

	Miles	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM
Greater Boston: Inside I-95/128	322	0%	4%	25%	48%	55%	37%	17%	18%
Greater Boston: Between I-95/128 and I-495	778	0%	0%	10%	18%	17%	3%	1%	2%
South Coast	344	0%	0%	0%	0%	0%	0%	0%	5%
Cape Cod	193	0%	0%	0%	1%	1%	0%	0%	21%
Central	451	0%	0%	0%	4%	5%	3%	3%	3%
Western	601	0%	0%	0%	0%	1%	2%	2%	2%

Table 2. Percent of Study Roadway miles Congested or Highly Congested, by Hour and Region, *1 p.m.–8 p.m. (2018)*

	Miles	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM
Greater Boston: Inside I-95/128	322	21%	35%	62%	64%	66%	44%	9%	1%
Greater Boston: between I-95/128 and I-495	778	5%	7%	15%	20%	26%	6%	0%	0%
South Coast	344	5%	11%	11%	14%	9%	0%	0%	0%
Cape Cod	193	21%	21%	21%	21%	21%	0%	0%	0%
Central	451	3%	3%	5%	8%	11%	3%	0%	0%
Western	601	10%	3%	3%	10%	10%	1%	0%	0%

3 Descriptions of congested conditions are not exhaustive and do not list conditions on every segment during every hour. For comprehensive maps on how congested different segments of the roadway network included in this study are at different times of the day, see Appendix B.

4 Centerline miles.

Figure 2. Roadways by Region

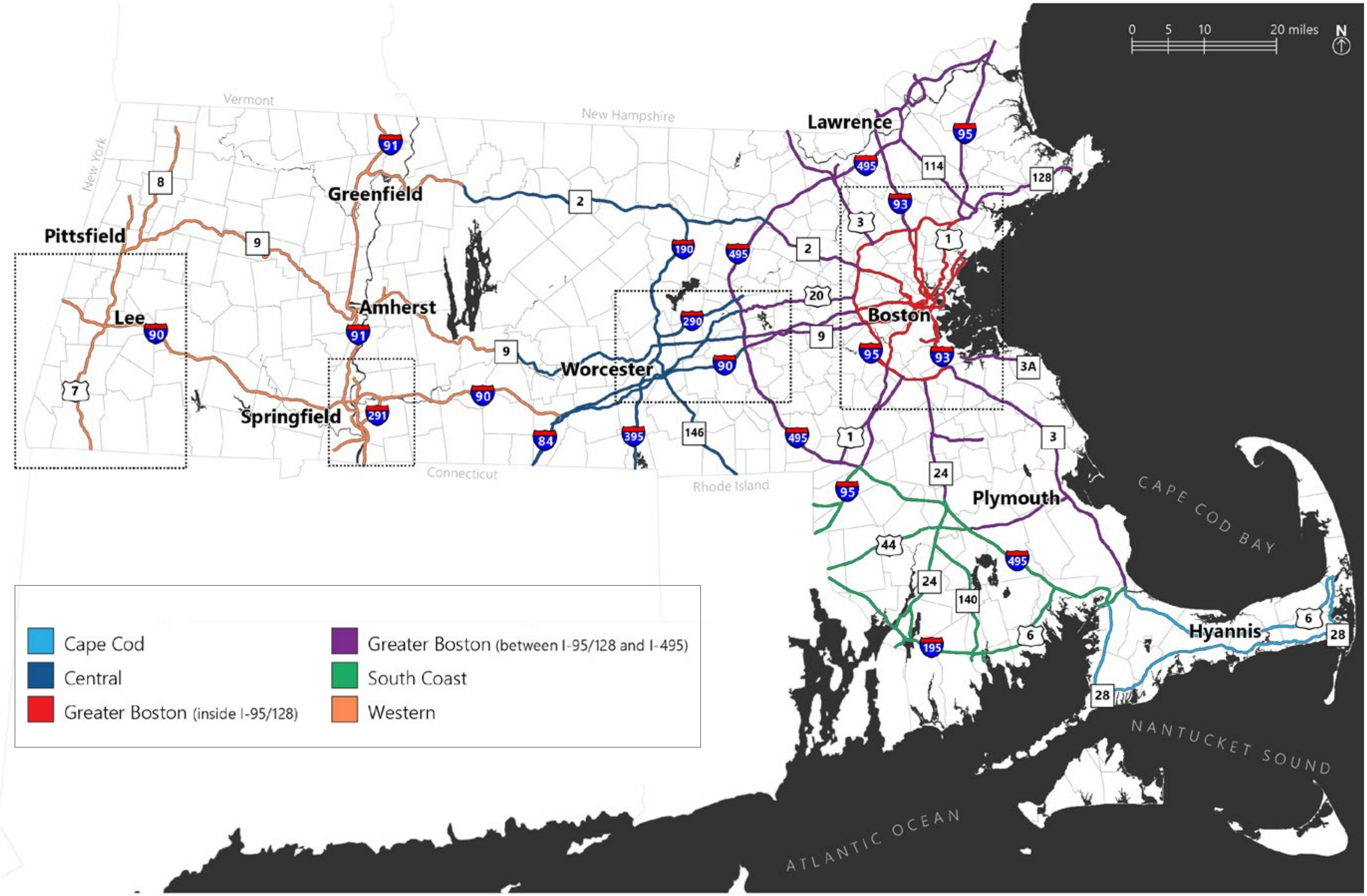


Figure 3. Percent of Congestion on Study Roadway miles, *Boston Region inside Route 128*

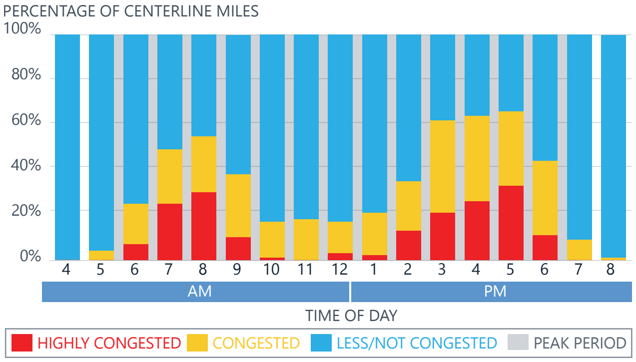


Figure 4. Percent of Congestion on Study Roadway miles, *Boston Region between Route 128 and I-495*

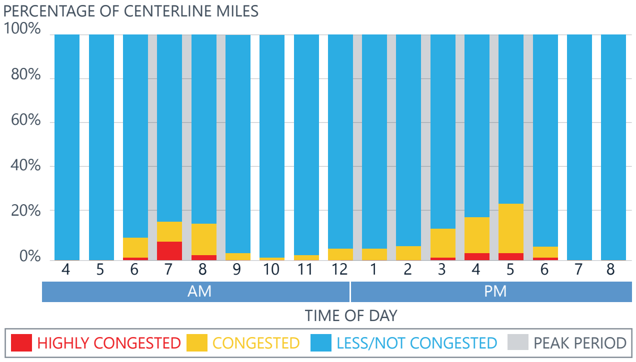


Figure 5. Percent of Congestion on Study Roadway miles, *South Coast Region*

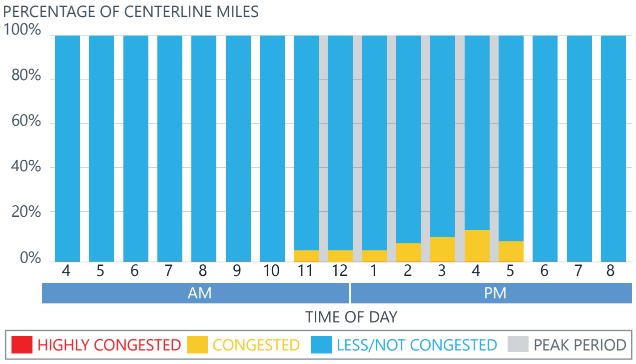


Figure 6. Percent of Congestion on Study Roadway miles, *Cape Cod Region*

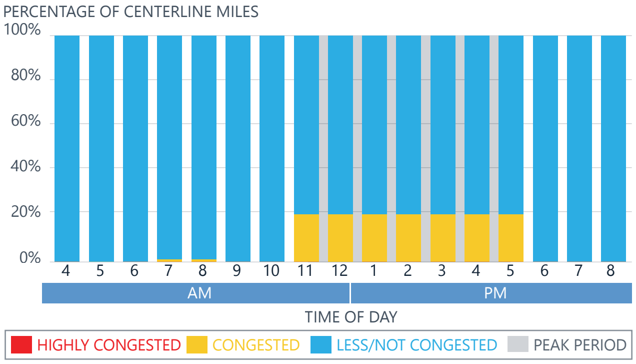


Figure 7. Percent of Congestion on Study Roadway miles, *Central Region*

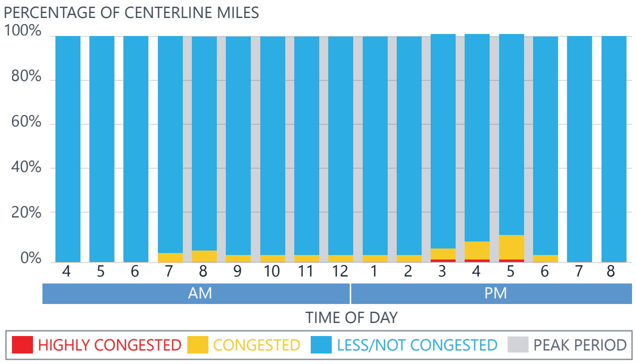


Figure 8. Percent of Congestion on Study Roadway miles, *Western Region*

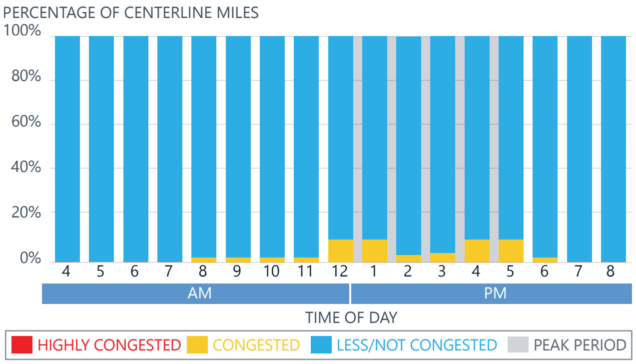
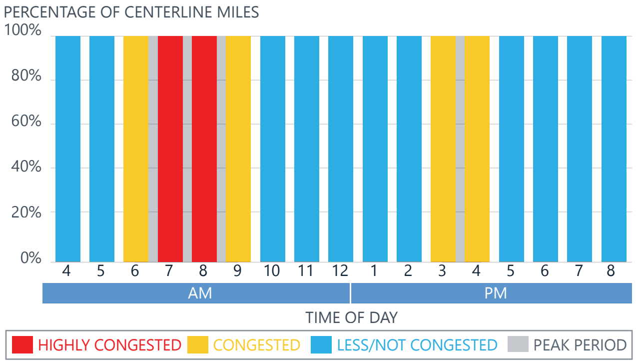


Figure 9. Percent of Congestion on Study Roadway miles, *Sumner Tunnel*



During the **4 a.m.** hour, all roadways in the state are less or uncongested, meaning drivers do not face any significant travel delays. Congestion first appears on roadways inside the I-95/128 belt in Greater Boston as early as the **5 a.m.** hour, specifically along I-93 northbound from Route 24 through the Braintree Split to Neponset Circle. The Leverett Connector, which links I-93 to Storrow Drive near the Museum of Science in Boston, also sees congestion in this hour.

In the **6 a.m.** hour, congestion begins to spread on roadways leading into Greater Boston as commuters make their way to work. Several more roadway segments within the I-95/128 belt become congested, including Route 28 between Stoneham and Boston (Main Street, Fellsway, McGrath Highway, and O'Brien Highway), and I-93 southbound from I-95/128 in Reading to the Fellsway in Medford. Route 1A southbound from Revere through the Sumner Tunnel into Boston starts to see congestion, as does the Riverway in Boston and Route 9 eastbound from Chestnut Hill to Brookline Village. The Southeast Expressway northbound from the Braintree Split to Neponset Circle is now highly congested, as is US-1 South from I-95/128 in Peabody across the Tobin Bridge to I-93 in Charlestown, right before the Leverett Connector.

In the **7 a.m.** hour, more roadway segments are highly congested within the I-95/128 belt, as are certain roadways that connect to it from outside the region. The segments of I-93 and Route 28 (Fellsway, McGrath, and O'Brien Highways) that connect I-95/128 in Reading to Boston are now highly congested, as is the majority of Route 1 between the same roadways. Route 1A southbound from Revere through the Sumner Tunnel into Boston is now highly congested as

Figure 10. Boston Area Inset, *6:00 a.m. hour*

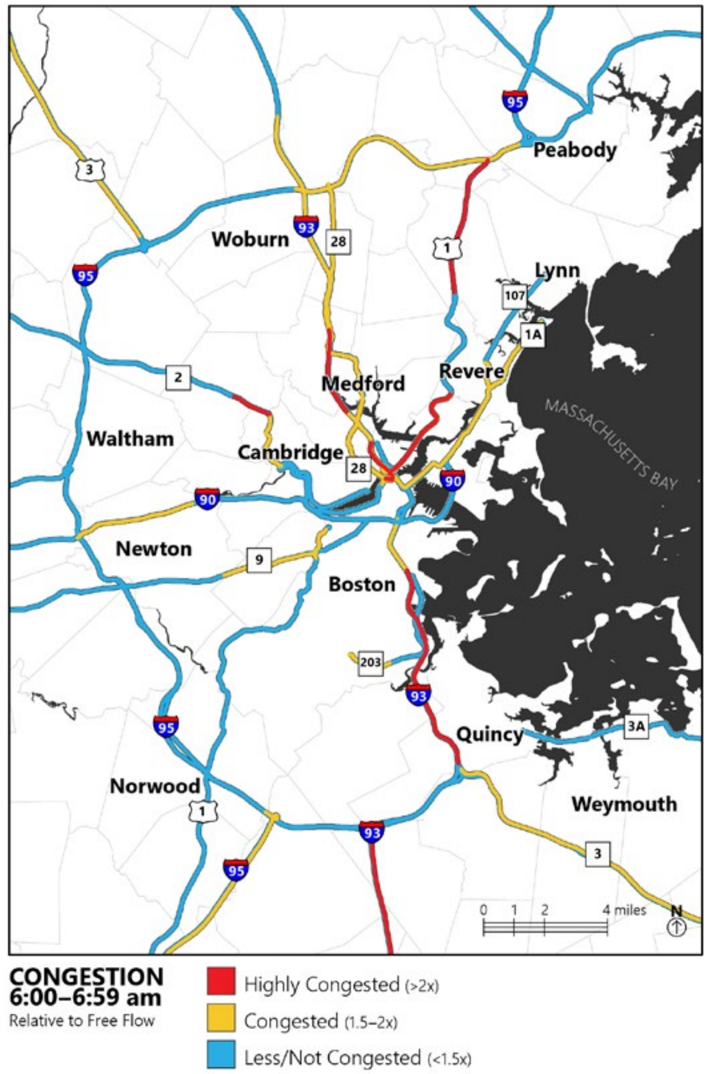
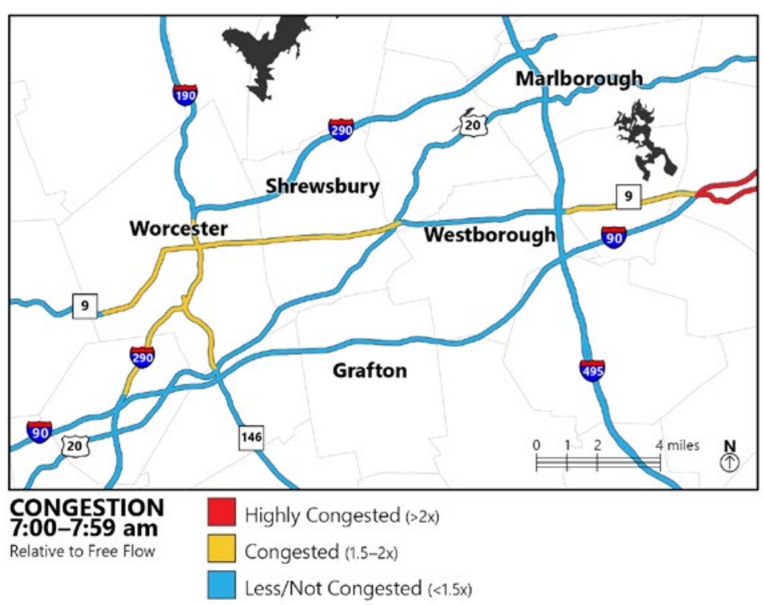


Figure 11. Worcester Area Inset, *7:00 a.m. hour*



well. Roads that approach Boston begin to face heavy congestion in this hour too, specifically I-95/128 southbound from I-93 in Stoneham to Route 1 in Peabody, Route 24 northbound from Route 27 in Brockton to I-93 in Randolph, and Route 9 eastbound from Route 27 in Natick to Route 16 in Wellesley.

Congestion also develops on roadways outside of the I-95/128 belt around 7 a.m. Route 125 and Industrial Avenue in Haverhill are usually congested during this hour, as is Route 114 southbound from I-495 in Lawrence to I-95 in Danvers.

The 7 a.m. hour also brings the first appearance of roadway congestion in Central Massachusetts. Route 9 east-bound from Worcester Regional Airport through downtown Worcester to Route 20 in Northborough is congested, as are I-290 from the Mass Pike in Auburn through downtown Worcester to I-190 and MA-146 from the Mass Pike in Millbury to I-290 at Brosnihan Square.

During the **8 a.m.** hour, highly congested conditions coming from the south into Boston slightly wane, while congestion approaching the city from the north worsens. Specifically, the Fellsway/ McGrath Highway segment of Route 28 from I-95/128 in Reading to Boston remains highly congested, as does the segment of I-93 southbound from I-95/128 in Reading to the Fellsway in Medford, and Route 1 southbound from Revere Beach Parkway across the Tobin Bridge to I-93.

Congested conditions appear on some Western Massachusetts roadways during the 8 a.m. hour as well. Specifically, Route 7 southbound from Great Barrington to Sheffield. This stretch is one of the most persistently congested roadway segments on an average day in the study network.

Figure 12. Boston Area Inset, *8:00 a.m. hour*

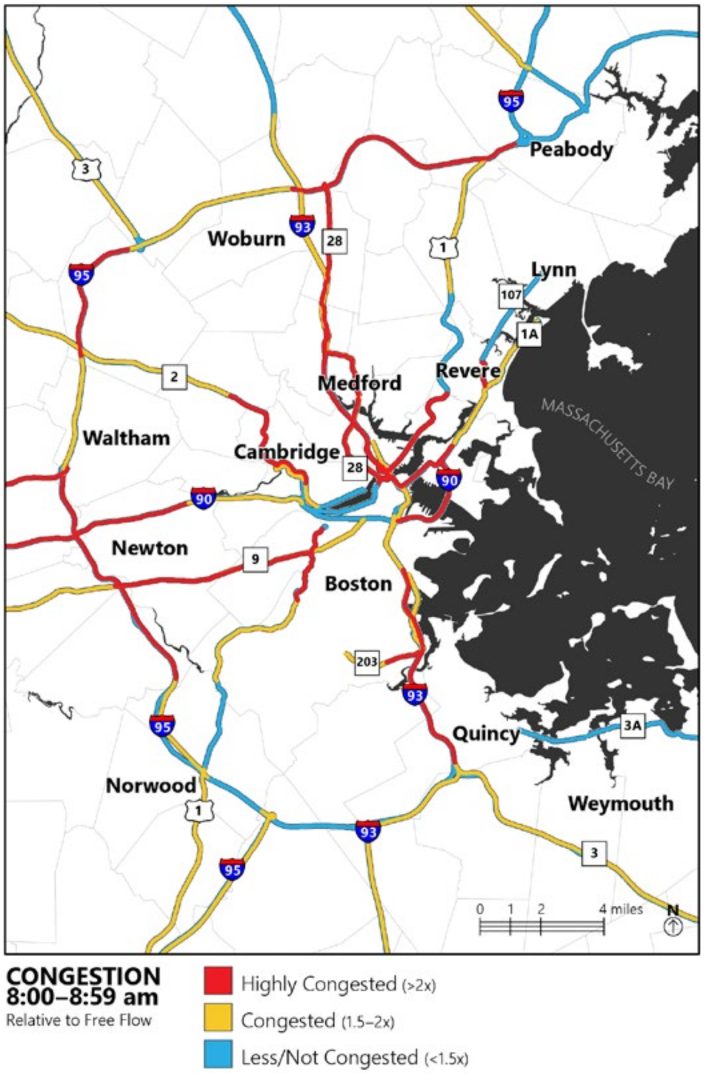
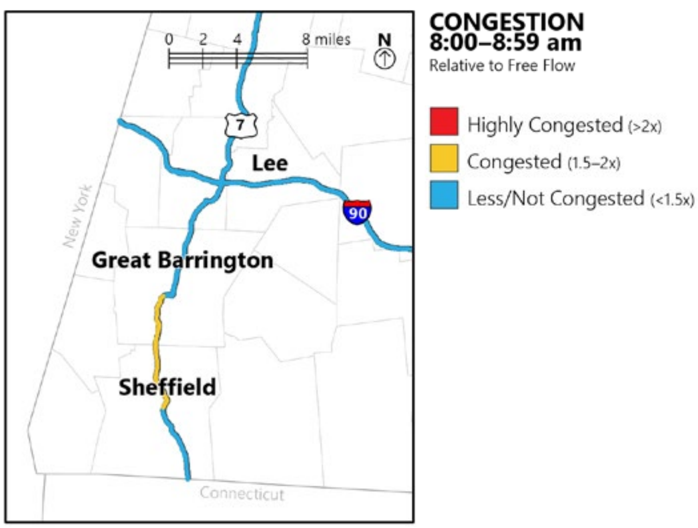


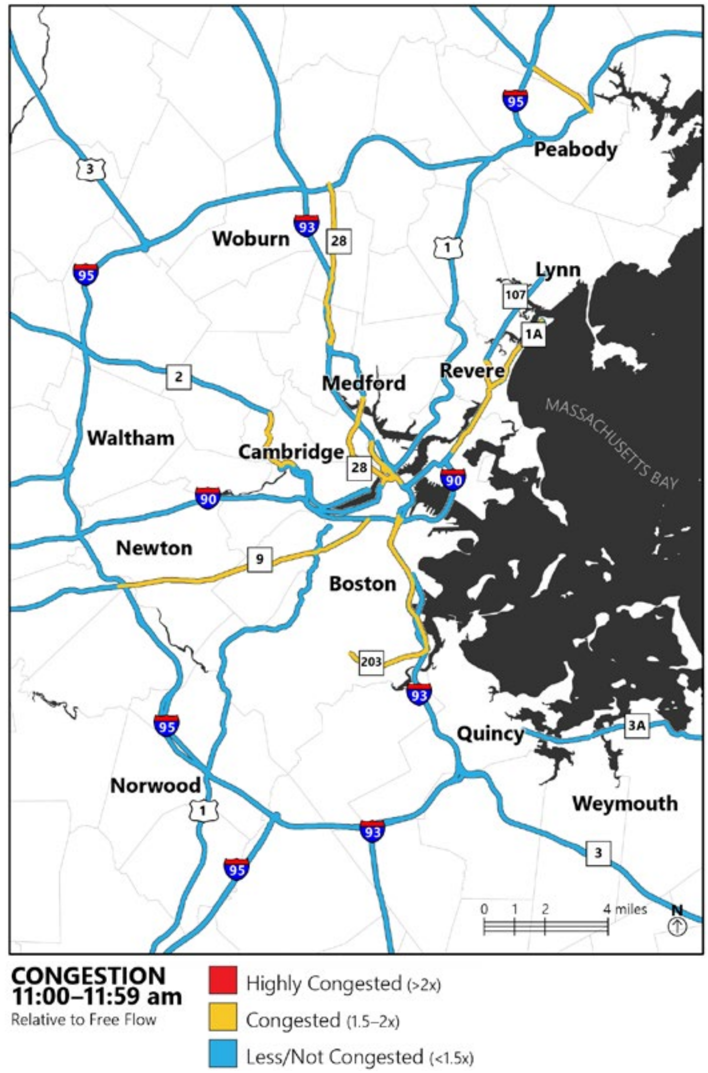
Figure 13. New York Border Inset, *8:00 a.m. hour*



Heavy congestion persists during the **9 a.m.** hour on several roadway stretches within the I-95/128 belt, including Route 9 eastbound from I-95/128 through Newton to Brookline Village, and then along the Riverway past Longwood to Fenway. The Southeast Expressway northbound from the Braintree Split to Neponset Circle remains highly congested as well. I-93 southbound from Mystic Valley Parkway in Medford to Charlestown and McGrath/O'Brien Highway in Somerville and Cambridge are also highly congested.

In the **10 a.m.** hour, the Southeast Expressway northbound in Dorchester remains highly congested. Although not highly congested, several roadways within the I-95/128 belt remain congested, including McGrath/O'Brien Highway and Route 9 between Newton and Brookline.

Figure 14. Boston Area Inset, *11:00 a.m. hour*



Individual road segments across the Commonwealth experience congestion at **11 a.m.** These include Main Street northbound in Stoneham and McGrath Highway southbound in Somerville. O'Brien/McGrath Highway remains highly congested the whole of the noontime hour. Near the New Hampshire border, Main Street in Haverhill grows congested in both directions around noon and remains congested until 3 p.m. Route 9 between Chestnut Hill and Brookline Village, the Southeast Expressway in both directions between Neponset Circle and South Bay, and Gallivan Boulevard in Dorchester all are congested as well by noon.

Even at **midday,** certain roadway segments across the state are congested. In Western Massachusetts, these include Route 7 in both directions and Route 9 westbound from Northampton to Pittsfield, and in Central Massachusetts on Route 9 eastbound from Worcester to Northborough. In Southeastern Massachusetts, congestion is especially persistent on US-44 westbound from Route 24 in Taunton to the Rhode Island border, on Pleasant Street in Brockton, in both directions on Route 28 between Woods Hole and Hyannis, and on the Sagamore Bridge.

Congestion worsens between 1 and 2 p.m., and in the **2 p.m.** hour, the whole Southeast Expressway is highly congested in both directions and I-93 southbound from Medford through the Central Artery is congested as well. In addition, I-93 northbound has become congested from Charlestown to Medford. Fresh Pond Parkway in Cambridge is congested in both directions and highly congested outbound toward Alewife. New pockets of congestion also appear, specifically along segments of Route 2 westbound in Concord and Route 9 westbound in Framingham, on I-95/128 southbound from Waltham to Wellesley.

Heavy congestion spreads out from Boston at **3 p.m.** For drivers heading southbound through Boston on I-93, congestion begins in Charlestown and continues through the Braintree Split to Route 24 in Randolph and is heavy in some segments. I-93 from Medford through Boston to Route 24 is congested or highly congested in both directions. Heavy congestion also appears on I-95/128 northbound from Burlington to Reading. Route 2 westbound in Concord is now highly congested. Outside of Boston, I-290 westbound from I-190 to Route 146 through downtown Worcester and the Mass Pike westbound from Stockbridge to New York are highly congested as well.

In the **4 p.m.** hour, heavy congestion tangles many roadways inside the I-95/128 belt, including the Mass Pike westbound from Allston to Weston, Route 9 in both directions inside I-95/128, I-93 and McGrath/O'Brien Highway between Boston and Medford, and the Southeast Expressway. Route 1 northbound from Charlestown to Peabody is also marred by congestion, which is heavy in some spots.

Figure 15. Boston Area Inset, *2:00 p.m. hour*

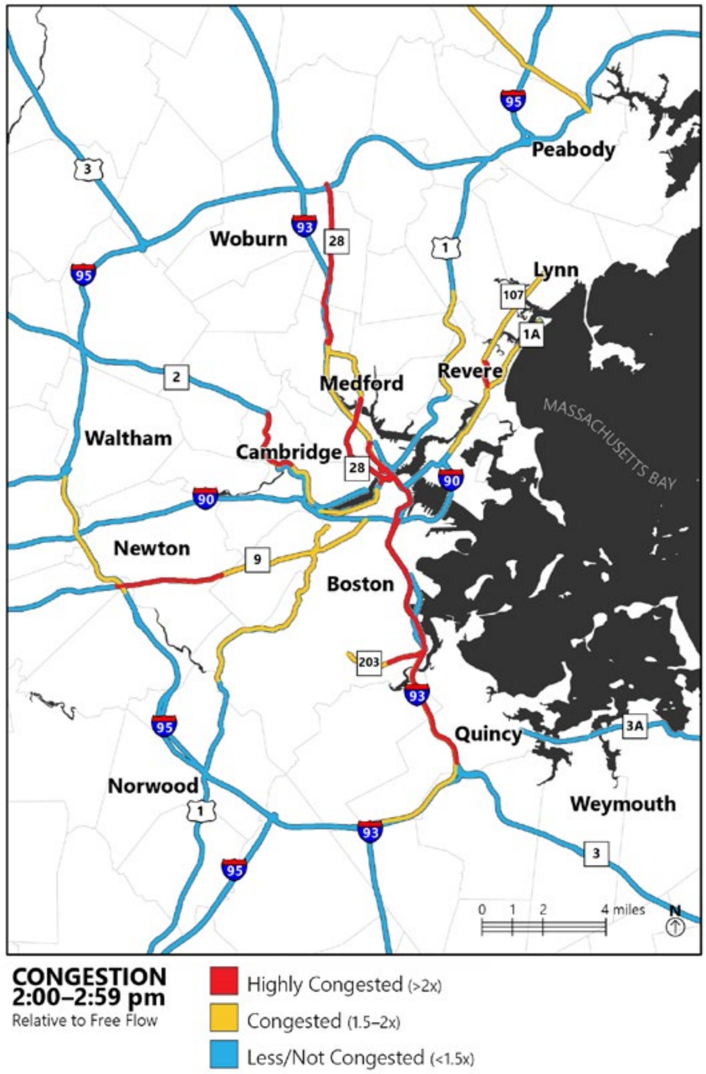


Figure 16. Worcester Area Inset, *4:00 p.m. hour*

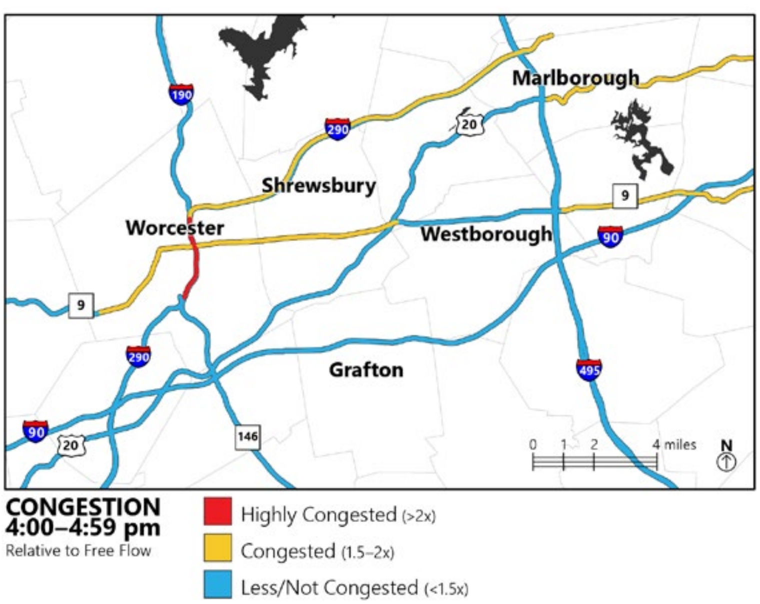
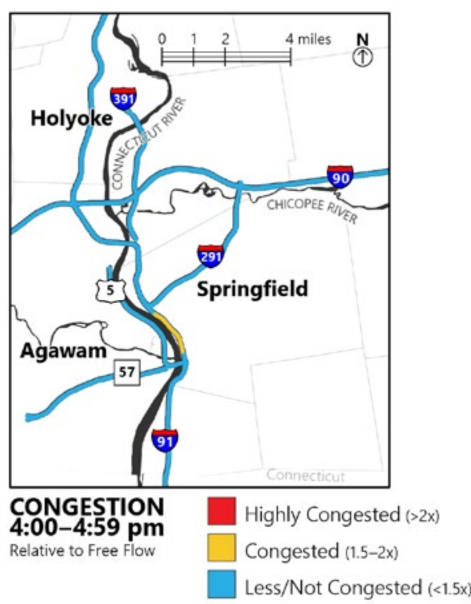


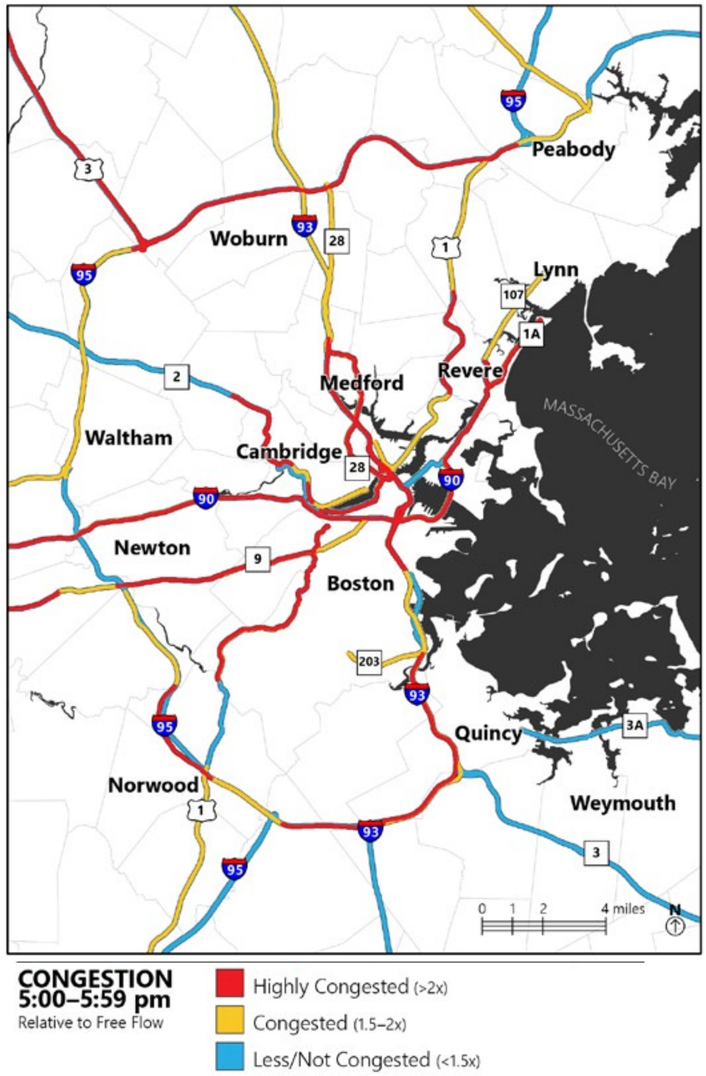
Figure 17. Springfield Area Inset, *4:00 p.m. hour*



I-290 in downtown Worcester remains highly congested. Route 9 westbound through the Berkshires becomes congested in this hour, as does I-91 southbound in downtown Springfield. Routes 44 in Bristol County and 28 on Cape Cod between Woods Hole and Hyannis remains congested.

Though **5 p.m.** is the typical "close of the business day" for many Boston-area workers, many of the roads leading out of Boston and the region are already heavily congested by then. It has become easier to identify road segments along and inside I-95/128 that are *not* congested: I-95/128 from Waltham to Newton, Route 2 from Arlington to Lexington, the Callahan Tunnel and Route 1A southbound in East Boston, and Storrow Drive in both directions west of Charles Circle, among some other small segments. For some commuters, this hour is a sort of point-of-no-return: there are few uncongested alternatives to take you out of the city. I-93 northbound is congested from Boston all the way to New Hampshire, as is Route 3 northbound from Burlington to Nashua—highly so between I-95/128 and I-495 in Chelmsford—and I-495 southbound between I-290 in Marlborough and I-90 in Westborough. I-95/128 northbound from Reading to Peabody is now highly congested as well.

Figure 18. Boston Area Inset, *5:00 p.m. hour*



Though the worst of the congestion outside of I-95/128 is gone by **6 p.m.**, several roadways inside that belt remain highly congested, including McGrath/O'Brien Highway, parts of I-93 from Reading to Braintree, Fresh Pond Parkway in both directions in Cambridge, and Route 9 in Newton and Brookline. I-95/128 northbound from Route 3 to I-93 and Route 2 westbound from Concord to Acton are highly congested as well. Route 20 westbound from I-95 to Wayland is congested, as is Route 9 westbound in Framingham and in both directions from Worcester to Northborough.

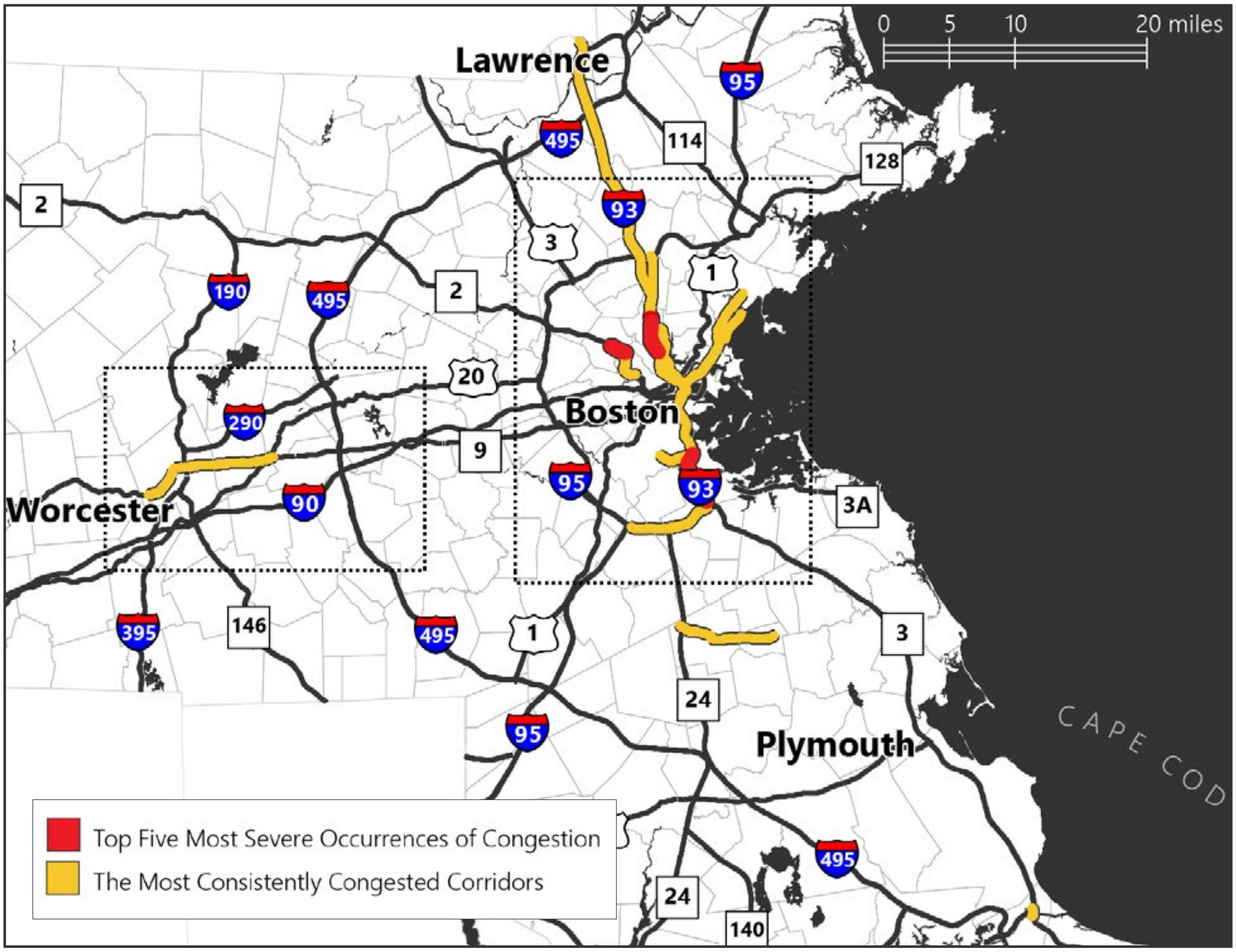
Some roadways still typically see congestion at **7 p.m.**, although no roadways typically see heavy congestion. Those roadways that are still congested are McGrath/O'Brien Highway, Fresh Pond Parkway, Huntington Avenue in Boston, Memorial Drive in Cambridge, the Southeast Expressway in both directions between the Mass Pike and Neponset Circle, and the Sagamore Bridge.

TOP FIVE MOST SEVERE OCCURRENCES OF CONGESTION

Like its location and duration, the severity of congestion also varies. The top five places and times where congestion on an average day is most severe, defined as where the ratio of average travel time to free-flow travel time is the highest, are:

1. I-93 southbound from Mystic Valley Parkway in Medford to the Fellsway in Medford at 7 in the morning. Free flow-travel on this segment is recorded at 4 a.m. as 2.7 minutes; by 7 a.m., travel time averages 10.5 minutes over 2.8 miles.
2. Route 2 eastbound approaching Alewife at 8 in the morning. Free-flow travel on this segment, which is recorded as 1.8 minutes at 4 a.m., is 6.8 minutes over 1.3 miles by 8 a.m.
3. The Southeast Expressway northbound from the Braintree Split to Neponset Circle. Free-flow travel on this segment at 4 a.m. averages 4.2 minutes, and at 7 a.m. averages 15.9 minutes over 4.2 miles.
4. Route 2 eastbound approaching Alewife at 7 a.m. Free-flow travel on this segment is recorded as 1.8 minutes at 4 a.m. and reaches 6.6 minutes at 7 a.m.
5. I-93 southbound from Mystic Valley Parkway in Medford to the Fellsway in Medford at 8 a.m. Free-flow travel on this segment is recorded at 4 a.m. as 2.7 minutes; travel time at 8 a.m. is 9.8 minutes.

Figure 19. Most Consistently Congested Corridors and Top Five Most Severe Occurrences of Congestion



THE MOST CONSISTENTLY CONGESTED CORRIDORS

Another way to identify notable sites of congestion is to count how many hours per day each roadway segment sees congested conditions. For example, several corridors in the state feature segments that are congested for more than 10 hours per day. While some roads, especially longer ones like Route 9 or I-93, feature numerous segments with congestion, others are consistently congested on small, discrete segments, like the Sagamore Bridge or Fresh Pond Parkway. The following nine roadway segments each see over 10 hours per day of congested or highly congested conditions.

Route 28 The most consistently congested corridor throughout the day is the sequence of roads north of Boston—O'Brien Highway in Cambridge, McGrath Highway in Somerville, the Fellsway in Medford, and Main Street in Stoneham—that carry the Route 28 designation from Boston to I-95/128. While at 2 a.m. the corridor takes 21 minutes to traverse southbound, by 8 a.m. the same corridor requires 47 minutes to traverse.

The data shows that segments of the corridor are congested between 7 and 16 hours on an average day:

- O'Brien and McGrath Highways northbound from Leverett Circle to Mystic Valley Parkway are congested 16 hours a day, from 6 a.m. to 10 p.m. Northbound is highly congested from noon until 7 p.m., with 5 p.m. being the worst hour. The southbound direction is congested 14 hours a day, from 6 a.m. to 8 p.m. It is highly congested from 7 to 10 a.m. and again from 1 to 3 p.m. Southbound congestion is worst during the 8 a.m. hour.
- The Fellsway and Main Street southbound from Reading to Medford are congested 14 hours a day, beginning at 6 a.m., and are highly congested between 7 and 9 a.m., noon and 1 p.m., and 2 to 3 p.m. Congestion is worst at 8 a.m.

Fresh Pond Parkway Fresh Pond Parkway connects Memorial Drive and Soldiers Field Road to Alewife Brook Parkway and cuts through residential neighborhoods in Cambridge. Fresh Pond Parkway carries the Route 2 designation for its full length and the Route 16 designation between Alewife and Huron Avenue. It features low posted speeds (relative to other roads in our study network), rotaries, and many four-way and five-way intersections, some of which are signalized. At free flow, an inbound trip takes 4.3 minutes at 3 a.m. and an outbound trip takes 5.5 minutes at 1 a.m. In their worst hours, an inbound trip at 8 a.m. takes 11.1 minutes while an outbound trip at 4 p.m. takes 15.2 minutes. Inbound, Fresh Pond Parkway is congested for 14 hours a day and is highly congested from 7 through 10 a.m. and again from 3 to 7 p.m. Headed outbound, the segment is congested for 12 hours a day and highly congested between 8 and 9 a.m. and from 2 until 7 p.m.

I-93 Interstate 93, one of the most congested corridors in Massachusetts, is effectively made up of four segments: the Northern Expressway (called I-93) from Boston to New Hampshire, the Central Artery in Downtown Boston, the Southeast Expressway from Boston to Braintree, and a segment of the ring roadway between the Braintree Split and I-95/128 in Canton. Congestion is severe on all of these segments, particularly within I-95/128. It is especially pronounced on the Southeast Expressway. Northbound from the Braintree Split to Morrissey Boulevard is congested for up to 12 hours on an average day; headed southbound, the two-mile segment from the Mass Pike to Morrissey Boulevard is congested for 11 hours a day.

Directionality of congestion exists on the I-93 segment north of Boston, with southbound congestion in the morning and northbound congestion in the evening. The Southeast Expressway, by contrast, is congested in both directions 11 hours each day. In other words, I-93 southbound, headed into Boston, is a regularly congested corridor—but only for between 4 and 7 hours a day, depending on the specific segment of roadway. However, when congestion on I-93 South is bad, it's very bad, as noted in the previous section. While the Southeast Expressway doesn't have the same severity of congestion, congested conditions persist for a longer period of time on an average day.

Most segments of I-93 recorded free-flow travel times at 4 a.m., when traveling the entire stretch of roadway southbound from New Hampshire to Canton takes 49 minutes total. At 4 p.m., when the most segments of I-93 South are under heavily congested conditions, travel time is 88 minutes.

Route 1A Route 1A southbound in Revere is congested for 12 hours a day, from 6 a.m. to 6 p.m. Revere Beach Boulevard features low posted speeds and several pedestrian crossings (both signalized and unsignalized).

South of Route 60 and the Revere Beach Parkway, the section of Route 1A southbound between the Mass Pike and I-93 in downtown Boston carries traffic from Revere, Lynn, Swampscott, Salem, and other North Shore communities to the city through the Sumner and Callahan tunnels. Free-flow speeds along this segment of 1A at 4 a.m. is 3.7 minutes, but on an average day at 7 a.m. it takes over 10 minutes to traverse this same short segment; this southbound segment of 1A is congested for 6 hours per day. The southbound segment from Point of Pines to I-93 in downtown Boston takes an average of 14 minutes at 11 p.m. but twice that—28 minutes—at 8 a.m.

American Legion Highway (Revere) American Legion Highway, which carries the Route 60 designation, connects the Salem Turnpike (Route 107) at Brown Circle to Route 1A, all in Revere. The southbound direction is congested for 11 hours per day, from 6 a.m. to 5 p.m. The northbound direction is congested for 9 hours per day, from 11 a.m. to 8 p.m. Free-flow conditions in both directions are recorded at 3 a.m. as 1.7 minutes heading south and 1.8 minutes heading north; at 8 a.m., headed southbound, travel time averages 4.2 minutes, and northbound it averages 5.6 minutes at 5 p.m.

Morton Street and Gallivan Boulevard (Dorchester) These roads carry the Route 203 designation from Blue Hill Avenue to Morrissey Boulevard and I-93, all within Dorchester. The stretch of roadway is 2.7 miles long. While the corridor is congested throughout the day, it is heavily congested between 8 and 9 a.m. and between 2 and 3 p.m. on Gallivan Boulevard eastbound from Dorchester Avenue to I-93.

Route 27 The segment of Route 27 on the study network begins as Temple Street in Whitman, continues as Crescent Street in Brockton, jogs through Downtown Brockton on Montello Street, and reaches Route 24 using Pleasant Street. The roadway has low posted speeds and is marked by several major intersections with local roads. In several places, it is two lanes wide. The westbound segment of Route 27 between Montello Street in Brockton and Route 24 is congested for 14 hours a day, between 7 a.m. and 9 p.m. In the Route 24 direction, it is congested for 11 hours, from 8 a.m. to 7 p.m. Under free-flow conditions, the stretch takes 5.1 minutes going toward Brockton at 4 a.m. and 5.6 minutes going toward Route 24 at 2 a.m. At 3 p.m., it takes 10.8 minutes going toward Brockton. At noon, it takes 10.5 minutes going toward Route 24.

Route 9 Running from Pittsfield to Boston, Route 9 is a major east-west route in Massachusetts. However, there are certain non-contiguous segments of Route 9 that are consistently congested throughout the day, including the segment through Worcester between Worcester Regional Airport and Shrewsbury (Route 20), the segment east of I-95/128 through Newton and Brookline, and Huntington Avenue in Boston.

Although never highly congested on an average day, the Worcester/Shrewsbury segment is congested in both directions for 12 hours per day under average conditions, between 7 a.m. and 7 p.m. Under free-flow conditions, this segment of Route 9 heading eastbound takes 20.1 minutes to travel, but at 3 p.m. it takes 37.3 minutes.

Route 9 westbound in Newton, Brookline, and Boston (as Huntington Avenue) is congested between 11 and 13 hours per day, with highly congested conditions between 7 and 10 a.m. eastbound and 8 a.m. westbound, and again between 5 and 7 p.m. eastbound between I-95/128 and Hammond Pond Parkway. At 4 a.m., drivers need an average of 18.3 minutes to traverse the entire westbound segment of Route 9 between I-90 in downtown Boston and I-95/128, but at 8 p.m., it typically takes 38.5 minutes. Eastbound heading into Boston, travel time at 4 a.m. is recorded as 17.6 minutes, but at 8 a.m., it averages 37.4 minutes to cross this segment.

The Sagamore Bridge The Sagamore Bridge connects Route 3 and Route 6 (the Mid-Cape Highway) on Cape Cod. Traffic on the bridge headed from Cape Cod is congested for 11 hours per day. While it takes 1.3 minutes to traverse the bridge at 4 a.m., between 7 and 10 a.m. and again between noon and 8 p.m., average travel times are longer than 2 minutes. While this may not sound like a significant amount of congestion, it does indicate that there is no excess roadway capacity for significant periods of time on an average day. As travel time over the bridge grows, delays accumulate, which is problematic on a typical day but especially so during the summer months when Cape Cod sees significant volumes of tourists and visitors.

CONGESTION BEYOND I-95/128

Although much of the most persistent and severe congestion seen on a daily basis is in and around Greater Boston, congestion is a very real issue for drivers across the entire state. The maps presented in this chapter and in Appendix C illustrate congestion hotspots at various times and in various locations throughout the Commonwealth. (In addition, as mentioned previously, this report focuses on major roadways and fails to capture similar congestion hotspots on local roadways.)

For example, of the nine corridors presented in the previous section which are congested or highly congested more than 10 hours per day, the **Sagamore Bridge** is in the Cape Cod region of the state. The congestion shown in that region in Figure 6 is entirely due to congestion on the bridges crossing the Cape Cod Canal. Another of those most congested corridors is the segment of Route 27 between Whitman and **Route 24**, is similarly outside of the Greater Boston area.

One concern raised by the data is the spread of congestion toward the outer reaches of the Boston metropolitan area, from the area inside I-95/128 to the area extending out to I-495. As illustrated in Figure 4, the region between Route 128 and I-495 shows the greatest congestion and most highly congested areas of all of the regions outside I-95/128. Three roadways that bring motorists from I-495 and beyond into Route 128 and the Boston core illustrate these congestion challenges: Route 3, Route 24, and the Massachusetts Turnpike.

The entire stretch of **Route 3** southbound from the New Hampshire border to I-95/128 in Burlington is congested between 6 and 9 a.m. The segment that runs between the border and I-495 is heavily congested during the 7 a.m. hour—free-flow travel time is 10 minutes, but during 7 a.m. it takes drivers 21 minutes, on average. In the afternoon, Route 3 northbound is congested between 3 p.m. and 6 p.m., highly so between Burlington and Chelmsford. At free flow, this segment takes 11.6 minutes to travel, but 26 minutes at 5 p.m.

Route 24 between Route 27 in Brockton and I-93 in Randolph is another roadway that sees heavy congestion, especially in the morning. Route 24 northbound is heavily congested beginning in the 6 a.m. hour, falls to simply congested during the 8 a.m. hour, and is less or uncongested during the 9 a.m. hour, on average. Although this stretch takes just over 6 minutes to cross at free flow, it takes over 13 minutes during the morning peak travel period.

The Massachusetts Turnpike also sees congestion outside of I-95/128, particularly inside I-495. Many segments of the Mass Pike have seen improvements in travel time since 2013 due to the installation of All Electronic Tolling (AET) gantries, but congestion still occurs during peak travel periods. At 6 a.m., the segment of the Mass Pike between I-495 and **Route 9** is congested; while the segment is categorized as less or uncongested at 7 a.m., the average travel time during this hour is recorded as 1.4 times free-flow speed. As will be reviewed, data collected from the gantries shows that vehicles traveling eastbound slow to roughly half of the posted speed limit during the morning peak travel period at gantries 9 and 10 in Framingham and Weston, and again headed westbound at the same locations in the afternoon.

In Central Massachusetts, as already noted, the stretch of Route 9 through Worcester and Shrewsbury is one of the most consistently congested corridors in the state. I-290 westbound through downtown Worcester (from I-190 to Route 146) is heavily congested on average every day, from 3 to 6 p.m. Free-flow travel time on this segment is 2.7 minutes, but during the period of heaviest congestion at 4 p.m., travel time is 7.4 minutes. I-290 eastbound is congested between 7 and 9 a.m. from the Mass Pike to I-190. Under free-flow conditions, travel time is 6.2 minutes, rising to 11 minutes at 7 a.m.

In Western Massachusetts, **I-91** southbound between I-291 and US-5 in the Springfield area is congested between 4 p.m. and 8 p.m. Beyond this segment, roadways in the Springfield region appear to be largely less or uncongested on an average day. On the Massachusetts Turnpike, I-90 westbound from Exit 1 in West Stockbridge to the New York border is heavily congested between 3 p.m. and 6 p.m. and congested from 6 p.m. to 7 p.m. At 5 p.m., the trip takes 6.6 minutes, compared to 2.9 minutes at free-flow time. Finally, Route 7 from Sheffield to Great Barrington is a major retail and commercial corridor in Berkshire County is congested for 10 hours per day—from 8 a.m. to 6 p.m. southbound and from 9 a.m. to 7 p.m. northbound. At 3 p.m., it takes 21 minutes to traverse the corridor southbound and 20 minutes northbound, against a free-flow time of approximately 11 minutes in either direction.

Traffic Volumes and Travel Speeds

The next question is the relationship between traffic volumes and travel speeds. To put it in traffic engineering terms, vehicular congestion is a function of traffic volumes and roadway capacity. Once volumes rise enough to slow speeds to a certain point, travel times begin to build. Simply put, as volumes increase, speeds decrease and people get frustrated. That is congestion.

The easiest place to examine the relationship between volumes and speeds is where the gantries have been installed for All Electronic Tolling (AET), because they collect data on both speed and traffic volume. AET along I-90, the Tobin Bridge, and in the Sumner and Callahan Tunnels enables us to analyze aggregate travel data[5] including the impact of volumes on speeds at specific points in the highway network, as well as how congestion occurs with respect to time of day, severity, and impacts on throughput. Data can indicate when and where traffic could be shifted to better accommodate volumes and keep traffic flowing. To supplement this report's study of congestion, AET data from May 15, 16, and 17, 2018[6] was reviewed.

Gantries can be classified according to the nature of the conditions beneath them: some gantries see consistently less congested conditions, some see continuously congested conditions, and other gantries are congested at peak periods only. Under some gantries, volumes never increase enough to bring speeds below posted speed limits while volumes so frequently exceed capacity at other gantries that average speeds rarely reach the posted limit. Some gantries see intense congestion during peak travel periods only. Gantry data can thus help identify when traffic volumes are at their heaviest and how volumes affect speeds in order to consider where and when—and if and how—traffic can be shifted to accommodate capacity issues.

At AET Gantry 4 in Ludlow, for example, capacity is not constrained to the point where traffic speeds will slow even when roadway volumes are at their highest on an average day. In fact, traffic continues at speeds above the posted limit of 65 miles per hour and never appears to fall below it. This is an example of a roadway segment that has enough capacity to accommodate all vehicles that might be on it at any given time.

In contrast, the gantries in and around the Boston metropolitan region begin to show evidence of roadways that are almost always at capacity. Traveling southbound on the Tobin Bridge, vehicles are regularly unable to travel at the posted speed limit except when traffic volumes are at their very lowest between 10 p.m. and 3 a.m.

Congestion plays out differently at AET Gantry 8 in Southborough: capacity appears to be constrained only during the morning and afternoon commutes. As volumes rise on I-90 eastbound between 4 and 5 a.m., speed begins to fall precipitously, increasing again to above the posted speed limit as volumes taper off. The same pattern appears headed westbound during the afternoon, starting around 3 p.m. and lasting until around 7 p.m.

Roadway segments that show flexibility and capacity with respect to the impact of road volumes on travel speeds may be the ones with the best potential for interventions that could incentivize drivers to travel at non-peak periods. Historically, peak travel periods have been between 6 and 8 a.m. during the morning commute and between 4 and 6 p.m. for evening commuters. However, precisely because of the heightened traffic volumes during these times, people appear to be changing their travel behavior to benefit from less congested travel conditions. This phenomenon, which is known as "peak spreading," is discussed more in the next chapter.

Charts showing speed and volume data at the other AET gantries are in Appendix E.

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5 This data does not contain any personally identifiable information (PII).

6 The month of May was chosen to take data samples because May is a non-summer month that consistently experiences higher than average traffic volumes compared to other months. Data samples were only taken from Tuesday, Wednesday and Thursday because these days represent consistent commuter patterns. The days of May 15, 16, and 17, 2018 were chosen because these days fall within the middle of the month and are not close to any holidays. Traffic anomalies or data outliers have been removed to show average conditions on these dates.

Figure 20. AET 4 Gantry Data, *Eastbound*

I-90 Eastbound at Gantry AET 4, Ludlow

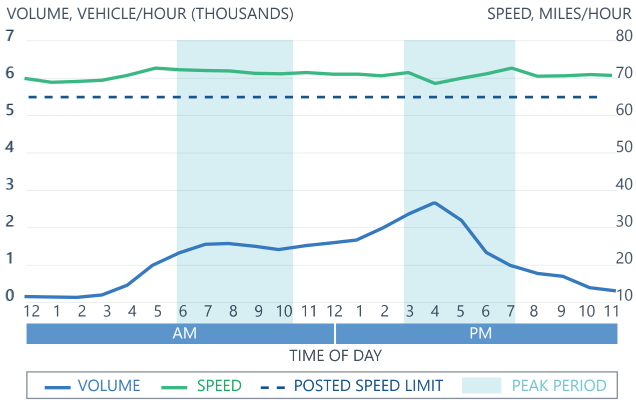


Figure 21. AET 4 Gantry Data, *Westbound*

I-90 Westbound at Gantry AET 4, Ludlow

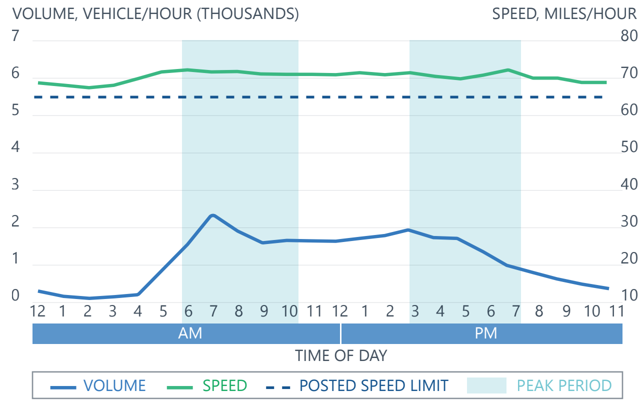


Figure 22. AET 8 Gantry Data, *Eastbound*

I-90 Eastbound at Gantry AET 8, Southborough

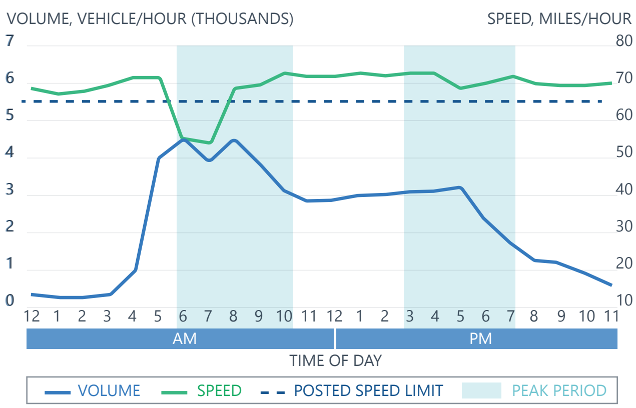


Figure 23. AET 8 Gantry Data, *Westbound*

I-90 Westbound at Gantry AET 8, Southborough

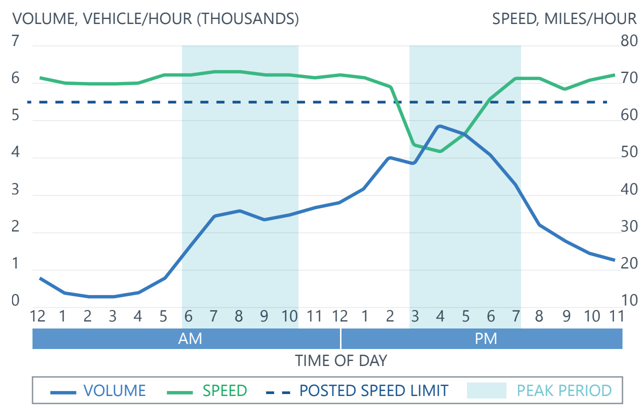


Figure 24. AET 15 Gantry Data, *Northbound*

Route 1 Northbound at Gantry AET 15, Boston *(Tobin Bridge)*

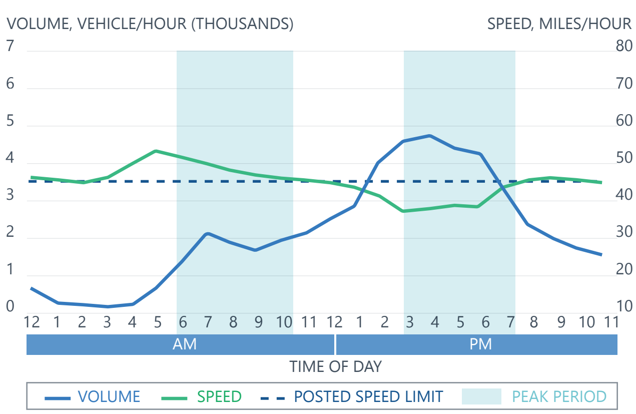


Figure 25. AET 15 Gantry Data, *Southbound*

Route 1 Southbound at Gantry AET 15, Boston *(Tobin Bridge)*

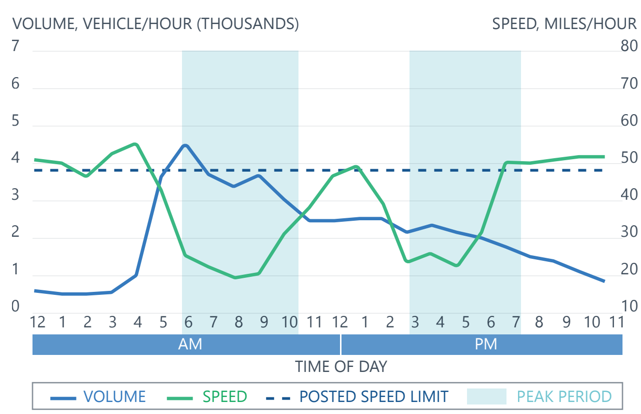


Figure 26. AET 11 Gantry Data, *Eastbound*

I-90 Eastbound at Gantry AET 11, Newton

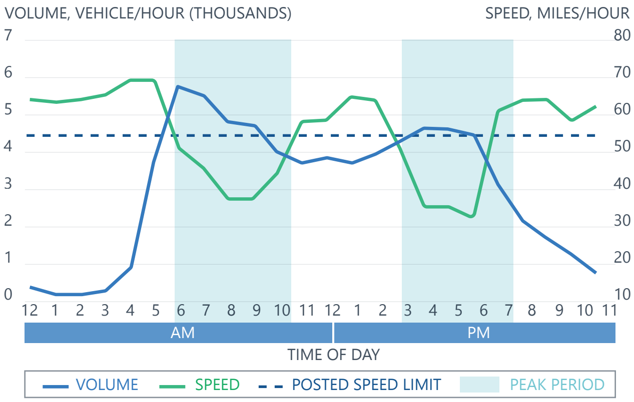


Figure 27. AET 11 Gantry Data, *Westbound*

I-90 Westbound at Gantry AET 11, Newton

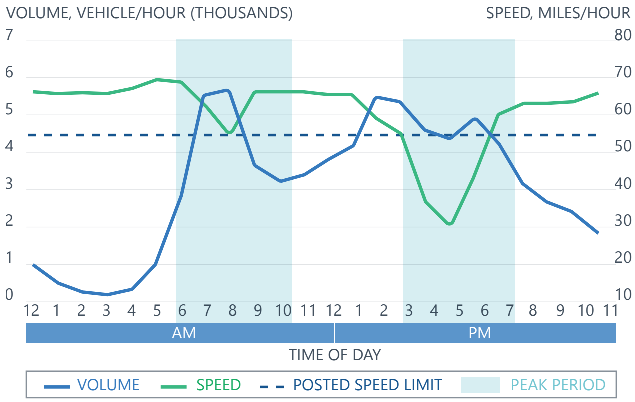


Figure 28. AET 16 Gantry Data, *Northbound*

Route 1A Northbound at Gantry AET 16, East Boston *(Callahan Tunnel)*

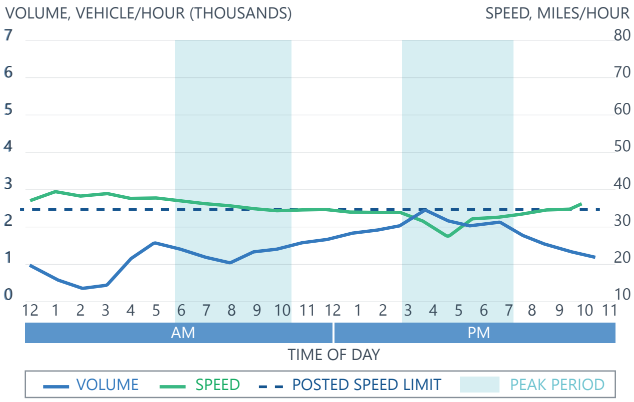
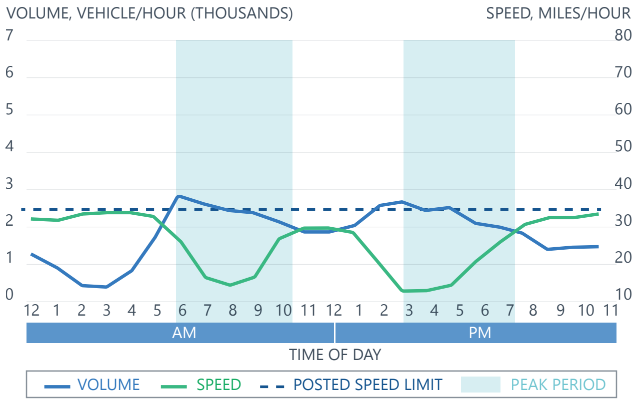


Figure 29. AET 16 Gantry Data, *Southbound*

Route 1A Southbound at Gantry AET 16, East Boston *(Callahan Tunnel)*



Congestion Trends Over Time

Beyond current roadways conditions, this analysis also explores how congestion in Massachusetts has changed over time, including how much longer it takes people to traverse certain segments of major corridors. Data that shows how travel times have changed from 2013 are consistent with commute time information that residents have personally relayed to the U.S. Census Bureau about their own travel, namely that travel times have grown gradually but moderately.

Table 3. Commute Time in Minutes as Reported to the U.S. Census Bureau, *2008–2017*

	Car		Transit	
Year	MA	Boston MSA[a]	MA	Boston MSA
2008	25.9	27	45.1	44.8
2009	26.1	27	43.9	43.4
2010	26.3	27.3	45.4	45.2
2011	26.7	27.7	45	44.7
2012	27	28	45.4	45.3
2013	27.1	28.4	46.2	45.6
2014	27.5	29.2	46.4	46.4
2015	28.2	29.7	48.7	48.4
2016	28.2	29.6	47.8	47
2017	28.4	29.7	47.7	47.7
Change over time	**9.7%**	**10.0%**	**5.8%**	**6.5%**

Note: [a] Metropolitan Statistical Area (MSA) name changed from Boston-Cambridge-Quincy MA-NH to Boston-Cambridge-Newton MA-NH starting in 2013; the geographic boundary remained consistent.

Source: U.S. Census Bureau, American Community Survey (ACS), 2008-2017, 1-year data. Table S0802.

CHANGES IN PEAK PERIOD TRAVEL TIME

Between 2013 and 2018, peak period[7] travel times have grown on most roadway segments for which we have data, but the most significant increases are overwhelmingly on the roads in and around Greater Boston. Congestion has not significantly grown over time in other parts of the state, except for stretches of I-290 in Central Massachusetts.

With the exception of the I-95/128 and I-93 ring that defines Greater Boston's southern edge (between I-90 and Route 3), it takes drivers longer to travel during the morning peak period than it did five years ago along nearly every roadway segment along the major corridors coming into Greater Boston. In the morning, the most significant worsening of congestion is on the southbound segment of Route 1A that includes the Sumner Tunnel and its approaches: in 2013, travel time during the morning peak took 1.2 times longer than free flow but in 2018 it jumped to 2.2 times free flow. This represents a near doubling of travel times on this segment over the five-year period.

Other places where travel time increased by more than 50 percent during the morning peak travel period include many of the most problematic segments in Greater Boston that have already been discussed: Route 2 eastbound approaching Alewife; the Mass Pike westbound from Logan Airport through the Ted Williams Tunnel and South Boston; Route 1 on the Tobin Bridge and Chelsea Curves in both directions; the Riverway headed inbound toward Fenway; the Fellsway from Mystic Valley Parkway to Assembly Square; American Legion Highway (Route 60) in Revere; and Main St. (Route 28) southbound through Stoneham. On many of these segments, travel times during the morning peak are now more than double travel times under free-flow conditions. And on Routes 1 and 2, travel times are three times free-flow travel.

[7] Every year, MassDOT reports performance data, including traffic counts and travel time reliability performance, to the FHWA; for this report, we chose a peak period consistent with Federal reporting requirements: 6:00 to 10:00 a.m. and 3:00 to 7:00 p.m. EST.

Table 4. Roadway Segments with Average Travel Time Increases of over 50%, *AM Peak*

Facility	Segment	Direction	Ratio of Average Travel Time over Free-Flow Travel Time, AM Peak, 2013	Ratio of Average Travel Time over Free-Flow Travel Time, AM Peak, 2018
MA-1A	I-93 to I-90	Southbound	1.2	2.2
MA-2	MA-60 to MA-16	Eastbound	2.1	3.0
I-90	I-93 to MA-1A	Westbound	1.1	2.0
US-1	I-93 to MA-16	Northbound	1.1	1.8
US-1	I-93 to MA-16	Southbound	2.2	3.0
DCR	Riverway	Northbound	1.7	2.4
MA-28	MA-16 to I-93	Southbound	1.3	1.9
MA-60	MA-1A to MA-107	Southbound	1.4	2.0
MA-28	I-93 to I-95	Southbound	1.5	2.0
I-95	US-1 to I-93	Northbound	1.3	1.8

In the afternoon peak, the most significant worsening of congestion is on the Southeast Expressway northbound from Morrissey Boulevard to the Mass Pike. In 2013, average travel time on this segment was 1.7 times peak free-flow time; in 2018, average travel time grew to 3.1 times free flow, an increase in average peak travel time of 143 percent in five years. Like the trends during the morning peak period, afternoon congestion in Massachusetts has worsened primarily in and around Greater Boston, most significantly on roadway segments that have already been identified as problematic: I-93, American Legion Highway, O'Brien and McGrath Highways, Routes 1, 1A, 2, and 3, and the Mass Pike.

Outside of Greater Boston, I-290 is the only roadway segment where peak period travel times have deteriorated to the same degree as roadways inside the I-95/128 belt. On the segment of I-290 westbound through down-town Worcester from I-190 to Route 146, travel times increased by approximately 60 percent between 2013 and 2018 during the afternoon peak period, from taking 1.6 times longer than free flow to 2.2 times free flow.

Table 5. Roadway Segments with Average Travel Time Increases of over 50%, *PM Peak*

Facility	Segment	Direction	Ratio of Average Travel Time over Free-Flow Travel Time, PM Peak, 2013	Ratio of Average Travel Time over Free-Flow Travel Time, PM Peak, 2018
I-93	Morrissey to I-90	Northbound	1.7	3.1
MA-60	MA-1A to MA-107	Northbound	1.6	2.8
I-93	US-1 to MA-16	Northbound	1.9	2.6
MA-28	Leverett to MA-16	Northbound	1.5	2.3
US-1	MA-16 to MA-99	Northbound	1.9	2.6
MA-2	W. Concord to MA-2A	Northbound	2.5	3.1
MA-1A	I-90 to MA-60	Northbound	1.7	2.3
I-290	MA-146 to I-190	Westbound	1.6	2.2
MA-9	I-95 to Hammond Pond Parkway	Eastbound	1.5	2.1
US-3	I-95 to I-495	Northbound	1.4	1.9
DCR	Riverway	Southbound	1.3	1.8
MA-9	I-95 to Hammond Pond Parkway	Westbound	2.1	2.6
I-90	Natick to I-95	Westbound	1.5	2.1
MA-28	MA-16 to I-93	Northbound	1.3	1.8

Figure 30. Change in Congestion in AM Peak Hour *(6:00–9:59 a.m.), 2013–2018, Statewide*

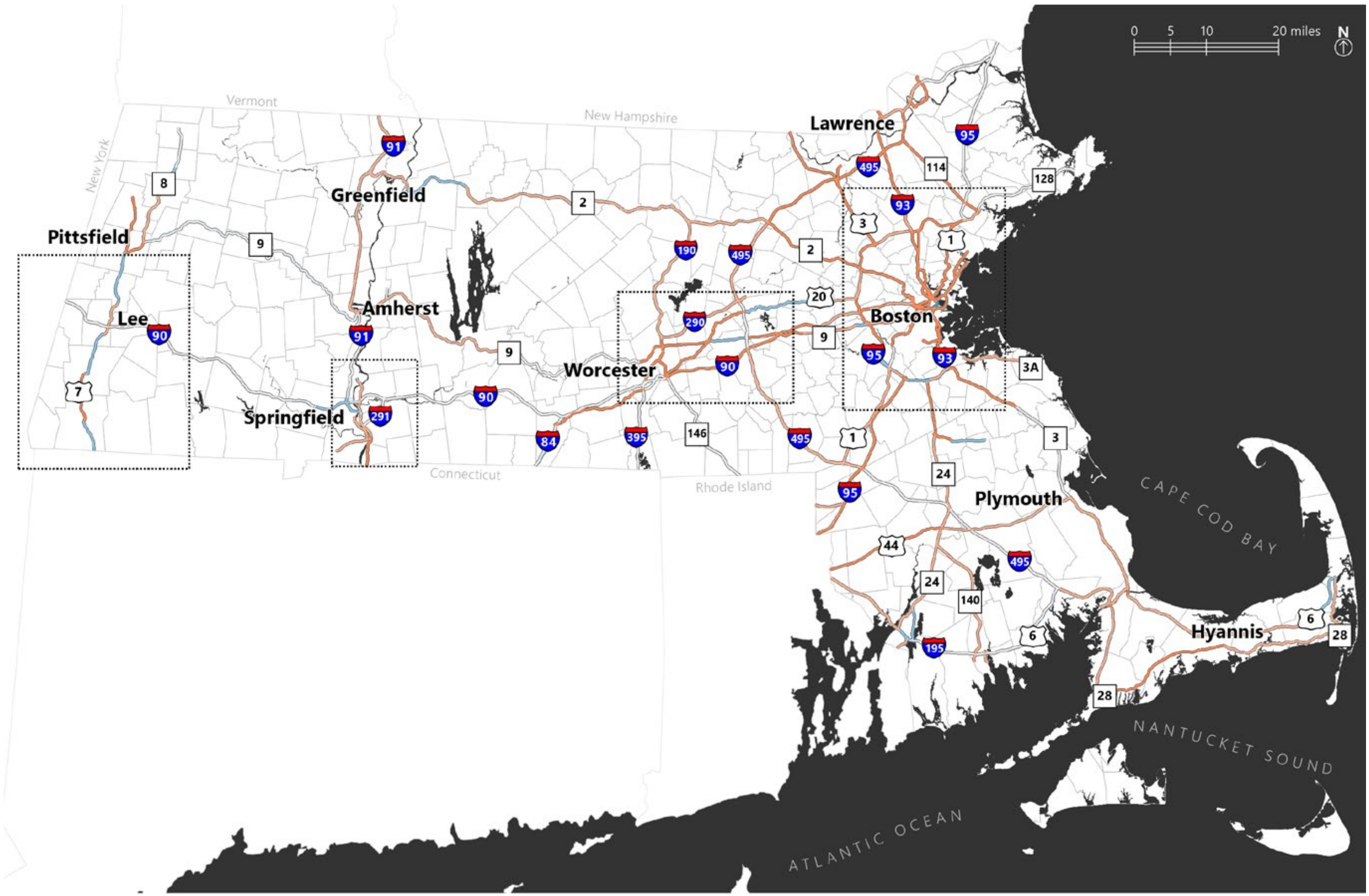
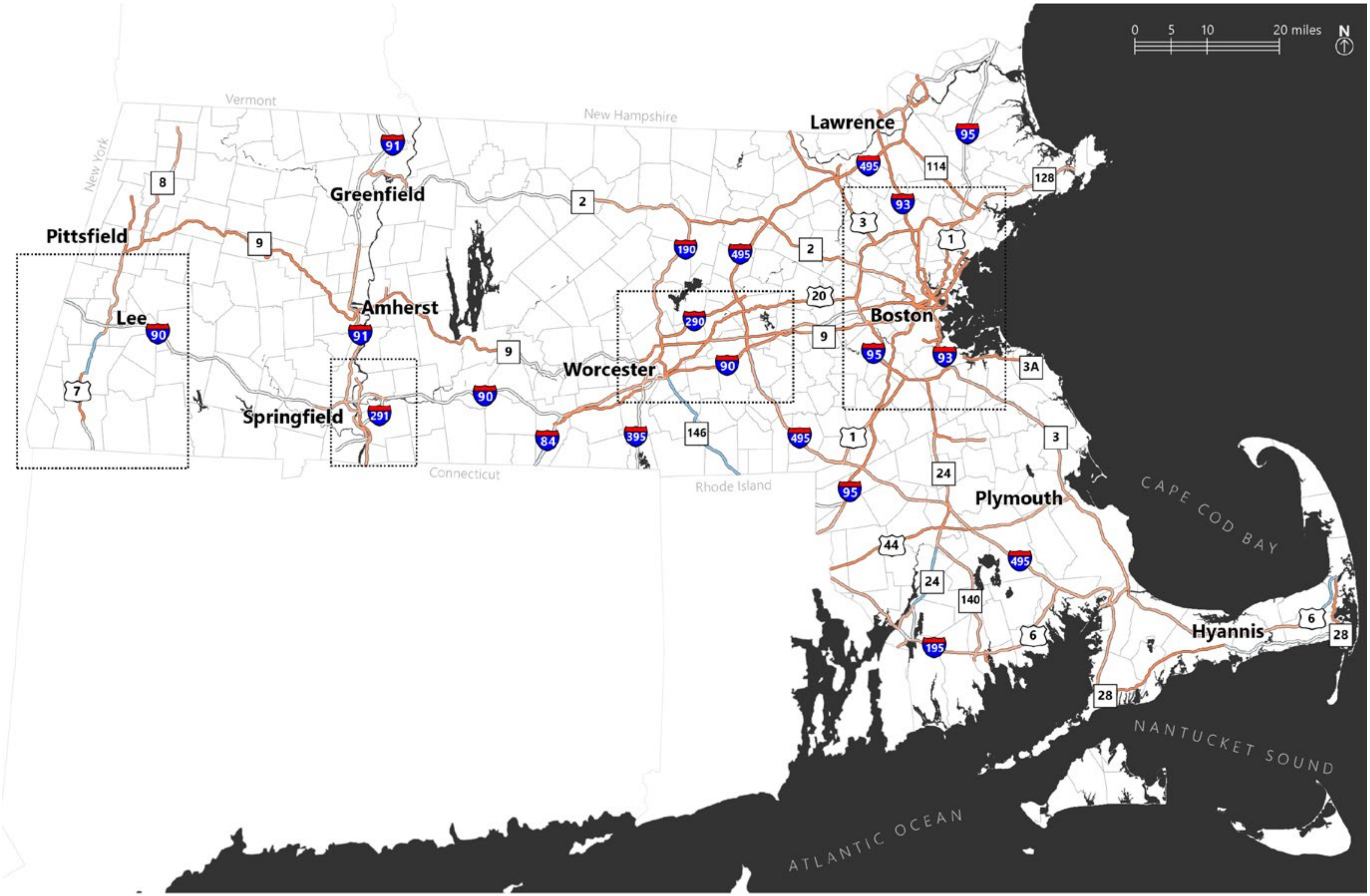


Figure 31. Change in Congestion in PM Peak Hour *(3:00–6:59 p.m.), 2013–2018, Statewide*



TRAVEL TIME CHANGES ON SELECT CORRIDORS

Another way to look at changes in travel time in recent years is to compare 2018 travel times to 2013 travel times (how many minutes it takes to traverse a given roadway segment) by time of day on a number of corridors in the state. While most of the charts show that the time spent on different roadways is increasing, the time increases are generally not as great as might be expected. The places where travel time has grown the most are on the roadways that are historically plagued by congestion: Route 3, Route 28 (the Fellsway/McGrath Highway), and I-93. But travel times have grown in low-density places outside of the Boston region as well: travel times during almost every hour of the day have risen on I-290 in both directions; they are especially longer headed west-bound during the afternoon peak period. Peak period travel times have also grown on I-91 in Springfield in both directions during both the morning and afternoon peak periods. Congestion may be at its worst in Greater Boston, but increased roadway volumes are slowing drivers down all over the state.

But not all congestion impacts are equal. On these road segments, travel time went up over the five-year period by no more than 10 minutes on US-3 northbound between I-95/128 in Burlington and I-495 in Chelmsford between 3 p.m. and 5 p.m., and on I-93 northbound between the Braintree Split and I-90 near South Bay. Every minute matters and small increases in travel time add up; because many trips require traversing several segments on different roadways, it is not difficult to see how adding one or two minutes on each roadway segment turns into significant additional travel time.

However, 10-minute increases are the exception rather than the rule. In fact, during most hours of the day and on most roadways this study includes, travel time has grown by just one or two minutes over five years. Given the level of frustration voiced by many motorists, these relatively modest increases in travel time by roadway seg-ment do not capture the entire experience of congestion in Massachusetts.

Another interesting finding is that on some segments, travel time is *decreasing,* especially for drivers on the Mass Pike, where drivers have seen travel time reductions of several minutes on certain segments at most times of day. However, there are exceptions, the most pronounced of which are I-90 headed westbound between Logan Airport and I-495 during the afternoon peak period. A likely reason for reduced travel times on the Mass Pike when and where they do occur is the installation of the AET gantries in October 2016. Without AET, travel times would likely have increased even more.

For a series of charts reflecting changes in travel times on selected roadways, see Appendix D.

Figure 32. Change in Congestion *(measured in travel time between 2013 and 2018) on I–91 Southbound*

I-91 | Southbound | I-391 (Chicopee) to Connecticut State Line

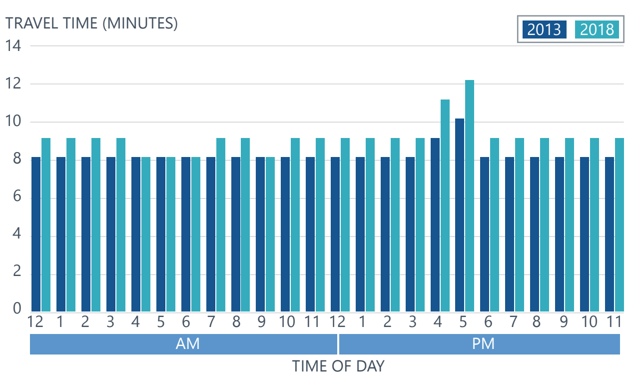


Figure 33. Change in Congestion *(measured in travel time between 2013 and 2018) on I–90 Eastbound*

I-90 | Eastbound | I-495 (Hopkinton) I-95/128 (Weston)

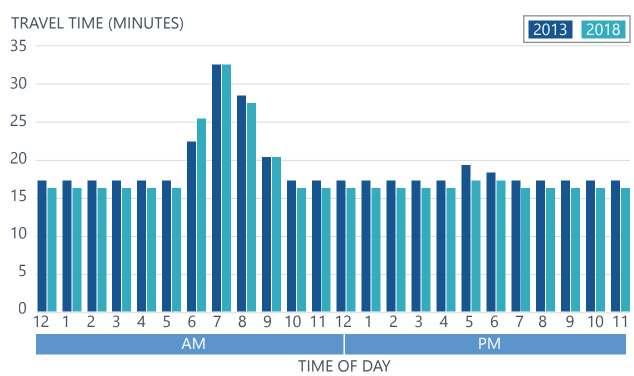


Figure 34. Change in Congestion *(measured in travel time between 2013 and 2018) on I-90 Eastbound*

I-90 | Eastbound | I-95/128 (Weston) to Logan Airport

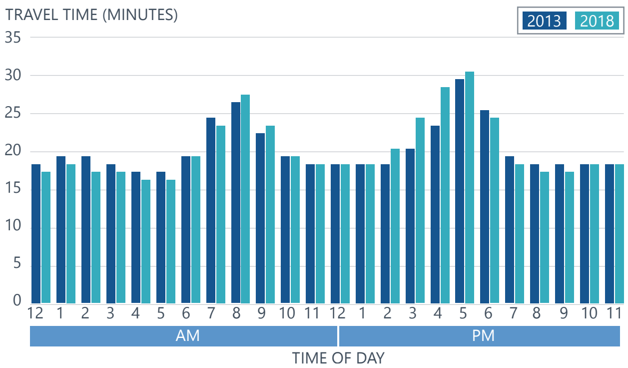


Figure 35. Change in Congestion *(measured in travel time between 2013 and 2018) on I-93 Northbound*

I-93 (SE Xway) | Northbound | Braintree Split to I-90

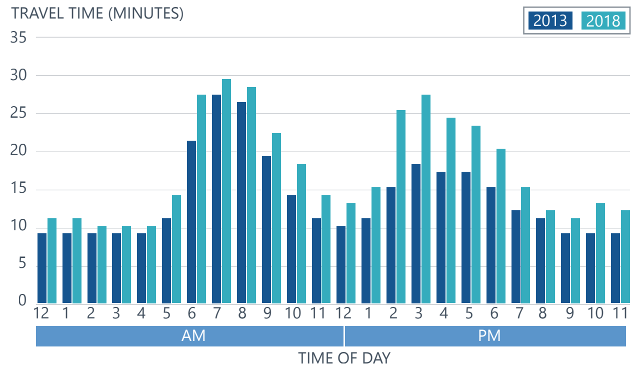


Figure 36. Change in Congestion *(measured in travel time between 2013 and 2018) on MA-28 Southbound*

MA-28 (Fellsway/McGrath) | Southbound | Middlesex Fells to Leverett Circle

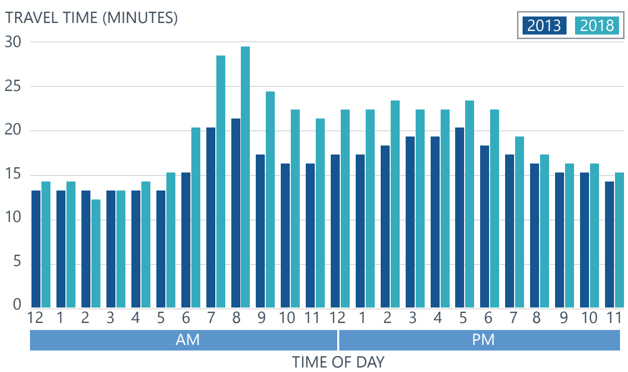
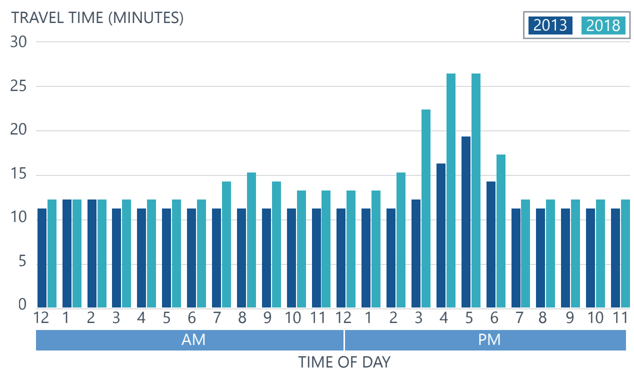


Figure 37. Change in Congestion *(measured in travel time between 2013 and 2018) on US-3 Northbound*

US-3 | Northbound | I-95/128 (Burlington) to I-495 (Chelmsford)



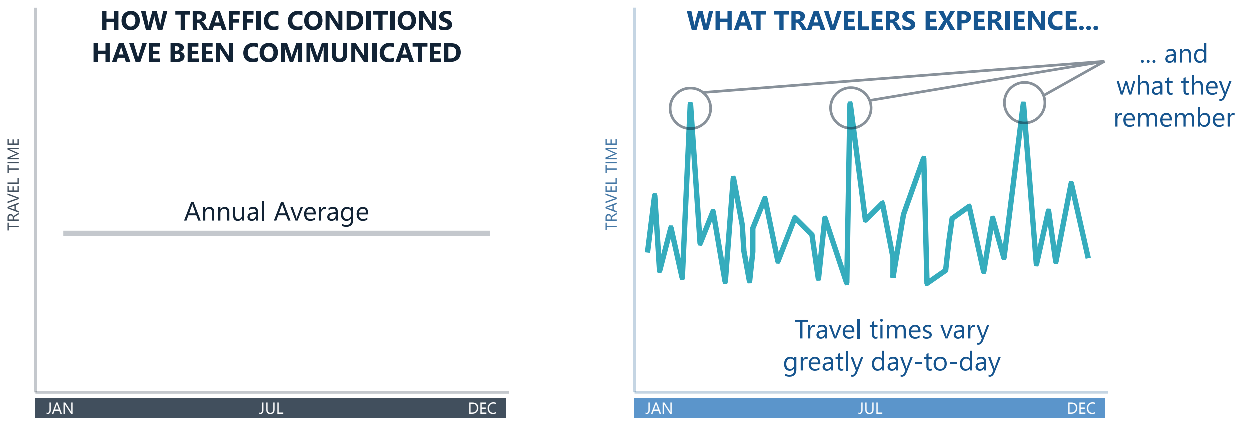
Congestion and Reliability

Sitting in congested traffic is frustrating. People do not like to needlessly waste time. But what is most problematic about congestion—why congestion really matters and drives people crazy—is that it leads to unreliability. For a trip that usually takes 30 minutes under already congested conditions to unexpectedly take 60 minutes is especially powerful, eating into the time people set aside for things like visiting with loved ones, participating in hobbies, working, or running errands.

As the FHWA's guidance on reliability succinctly notes: *Travelers want travel time reliability—a consistency or dependability in travel times, as measured from day to day or across different times of day. Drivers want to know that a trip will take a half-hour today, a half-hour tomorrow, and so on. Most travelers are less tolerant of unexpected delays because such delays have larger consequences than drivers face with everyday congestion. Travelers also tend to remember the few bad days they spent in traffic, rather than an average time for travel throughout the year.*[8]

8 U.S. Department of Transportation, Federal Highway Administration (FHWA), February 2017. "Travel Time Reliability Measures." https://ops.fhwa.dot.gov/perf_measurement/reliability_measures/index.htm

Figure 38. FHWA Reliability Infographic



Source: https://ops.fhwa.dot.gov/publications/tt_reliability/brochure/index.htm

This is a key driver of the mounting and understandable frustration with congestion. Of all the routine trips that most people take, the ones that stand out most are the extremes, those trips that are especially good or especially poor. This is because people end up having to plan for the worst days to make sure they are at a place when they need or want to be there. How often people experience especially good or poor days is what determines reliability.

Transportation reliability improvements are among the most impactful on people's lived experiences. The impacts of a transportation intervention may seem modest when looking at its effects on average travel times. But from a reliability perspective, if there is less variation in trip times—fewer days when travelers experience "especially poor" trips—then reliability has improved. If travelers can expect more consistency from day to day, the project is a success.

So while congestion is discouraging in its own right, what most angers travelers is the unpredictability of trips and the domino effects of this unpredictability on the daily round trip. Congestion impacts the reliability of travel in two ways:

1. As roadways grow congested, travel times tend to become more unreliable because any event of any impactful size (for example, a disabled vehicle in the shoulder) that affects travel on a segment that does not have extra space can have ripple effects that extend far beyond their initial impact. The more congested a roadway is, the more commuters have to anticipate unreliable trips day to day.

2. Non-recurring congestion, the congestion that occurs because of traffic anomalies like crashes, also factor into the reliability of trips. But even events that are difficult to plan for like collisions can be better addressed through safety improvements and traffic management solutions.

MassDOT measures reliability as part of its biannual FHWA reporting requirements.[9] However, this measure reports the percentage of roadway segments considered reliable, a summary measure at the system level that has limited ability to speak to the lived experiences of congestion and the impacts that congestion can have on daily trips.

Therefore, to evaluate the reliability of different trips, we looked at how travel times vary on some of Massachusetts' most "popular" commutes in 2018.[10] These "popular" commutes are the likely travel paths between

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9 Formally known as the Level of Travel Time Reliability (LOTTR).

10 Routes were selected based on data shared by the Longitudinal Employer-Household Dynamics (LEHD) program of the U.S. Census. For more information, see https://lehd.ces.census.gov/data/

the largest employment centers in the state and the cities or towns where significant numbers of people who work there live. To collect travel times on each hypothetical route, we used a traffic model software program to send an imaginary car in both directions of the sample commute (inbound and outbound) every five minutes between 8 a.m. and 5 p.m.

Figure 39. Travel Time Reliability, *Lynn/Boston Corridor*

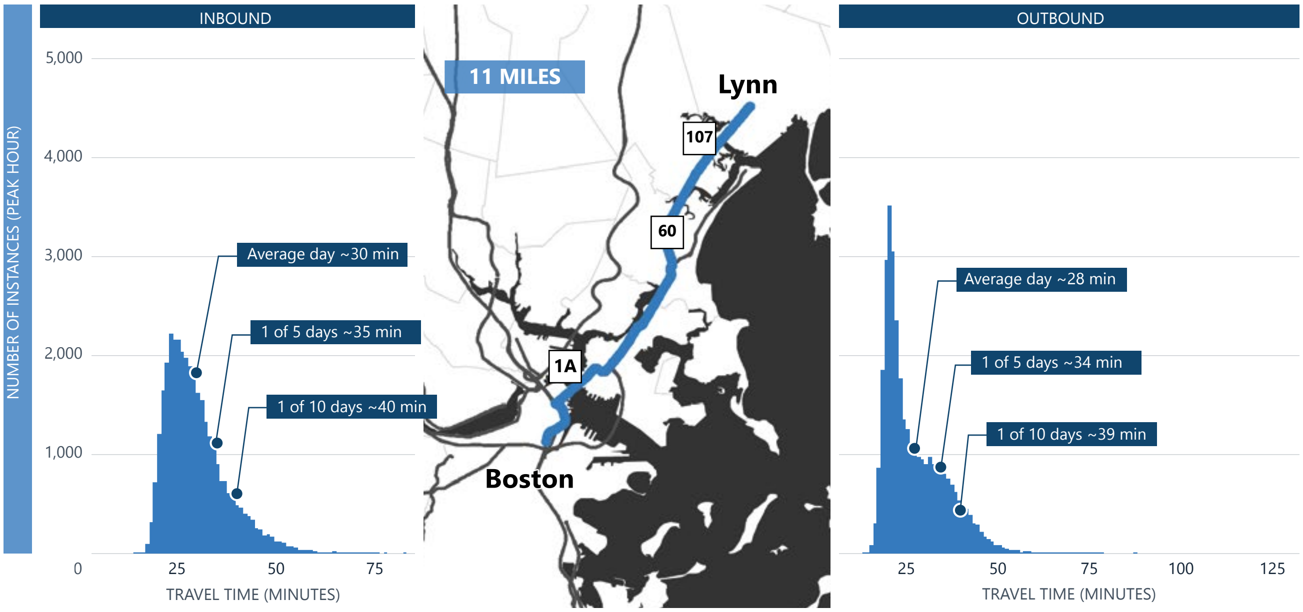


Figure 40. Travel Time Reliability, *Danvers/Back Bay Corridor*

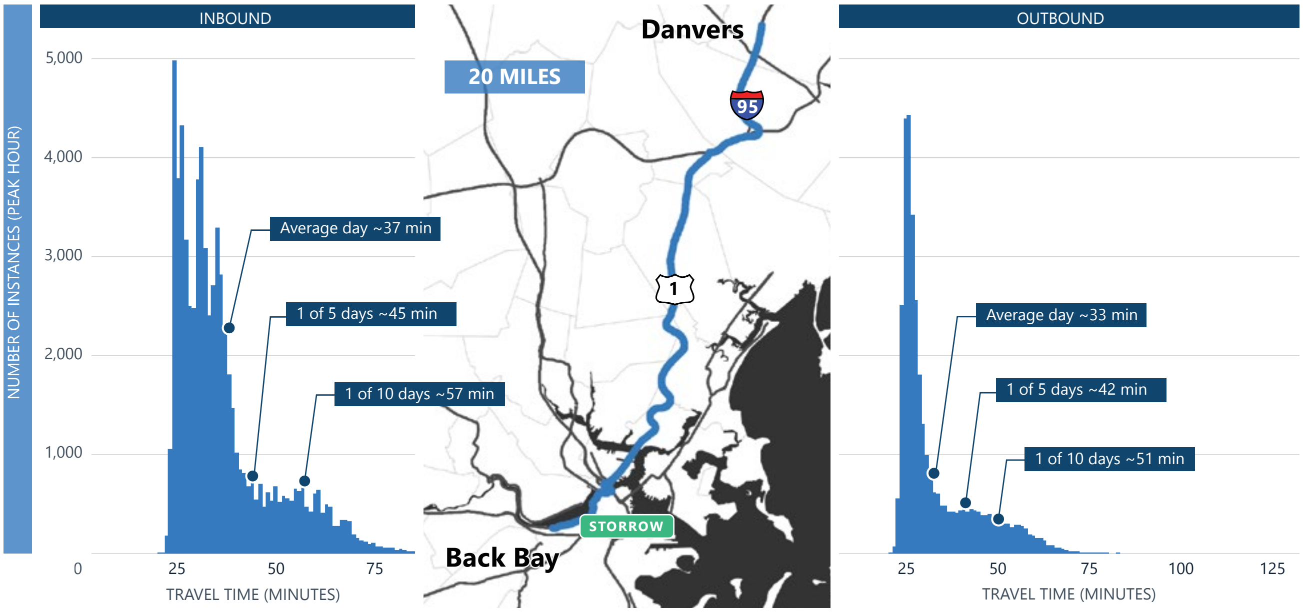


Figure 41. Travel Time Reliability, *Stoneham/Leverett Circle Corridor*

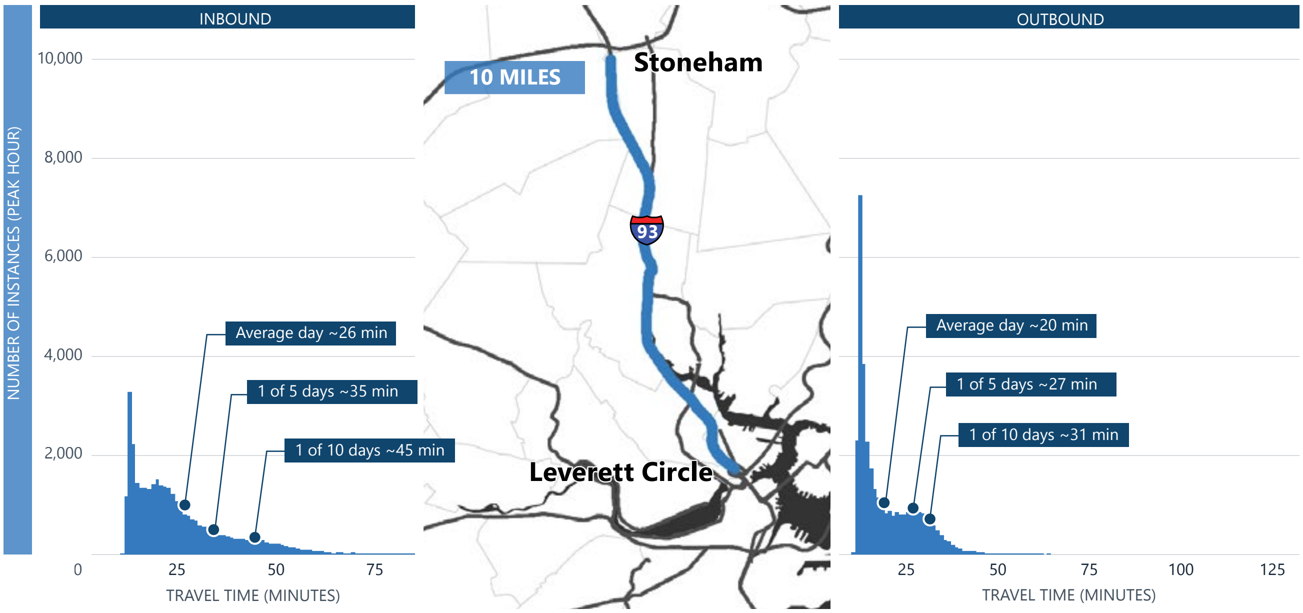


Figure 42. Travel Time Reliability, *Burlington/Kendall Square Corridor*

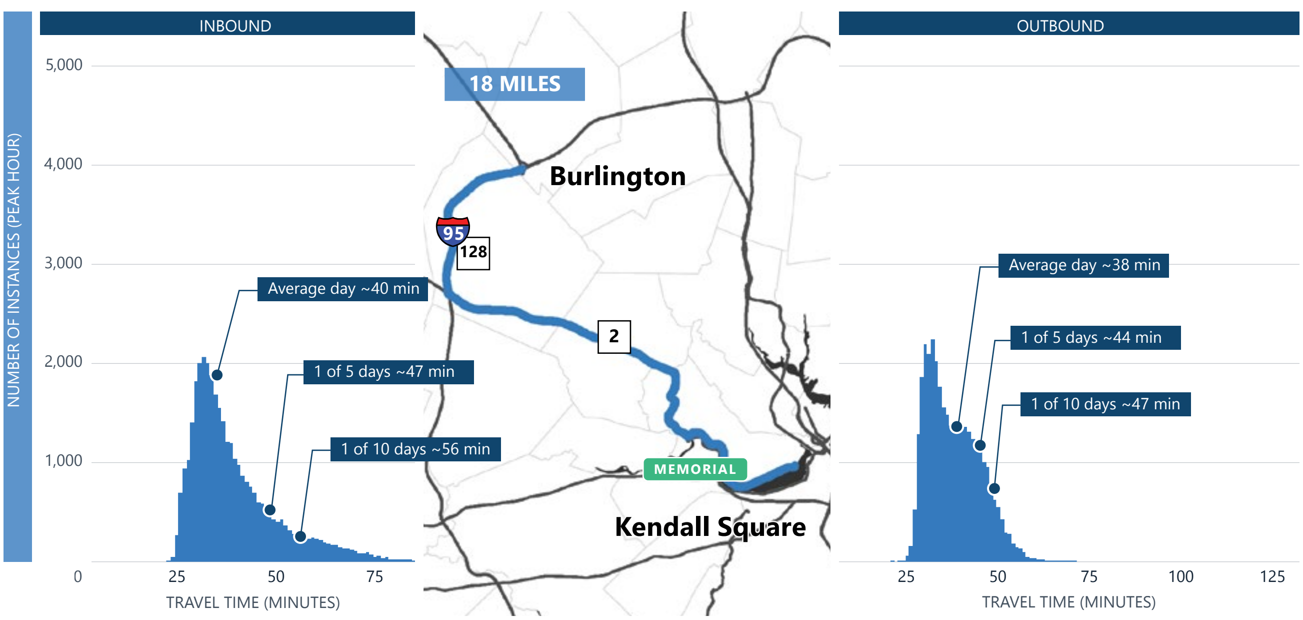


Figure 43. Travel Time Reliability, *Chelmsford/Waltham Corridor*

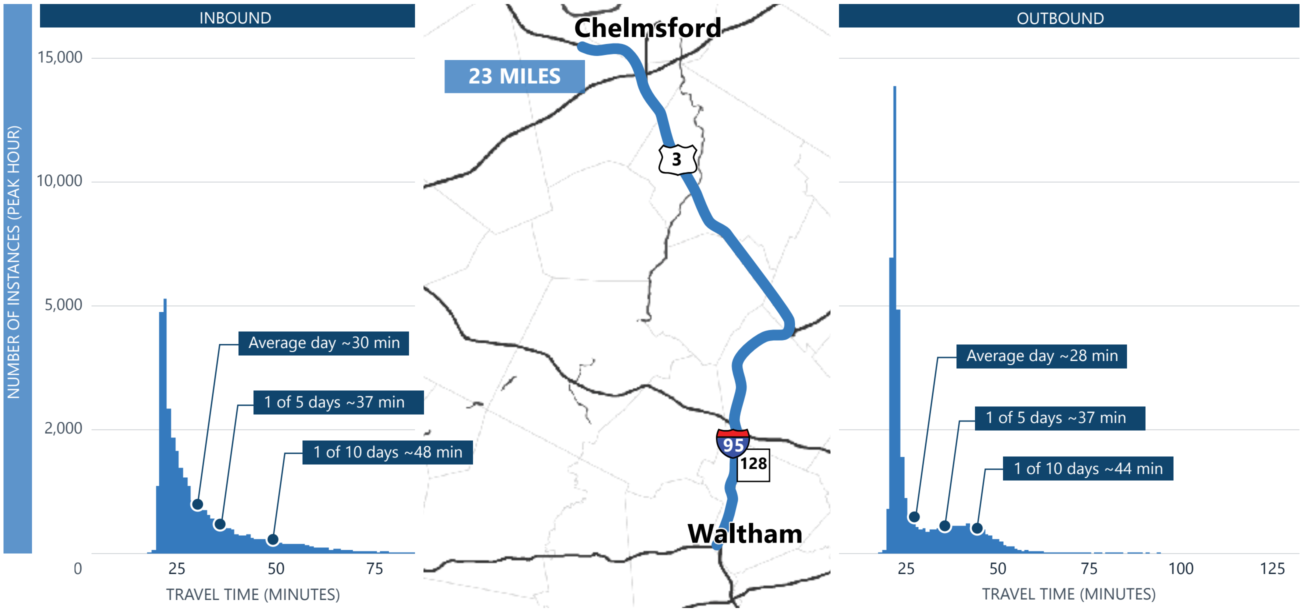


Figure 44. Travel Time Reliability, *Wayland/Logan Airport Corridor*

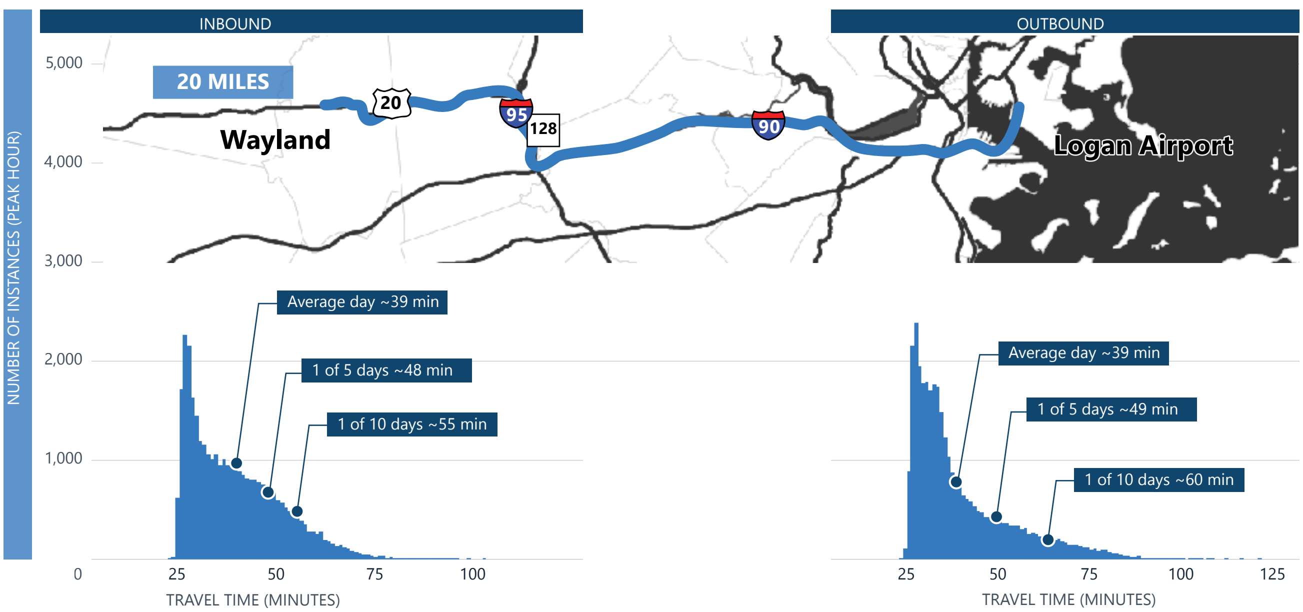


Figure 45. Travel Time Reliability, *Framingham/Northeastern University Corridor*

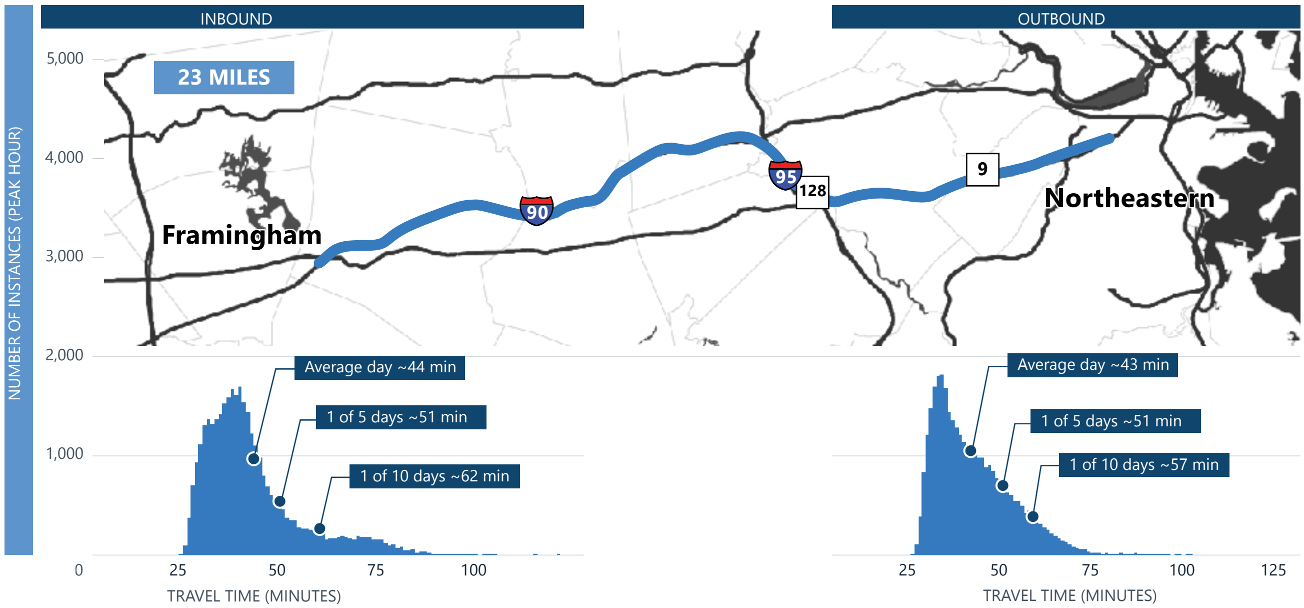


Figure 46. Travel Time Reliability, *Longwood/Dedham Corridor*

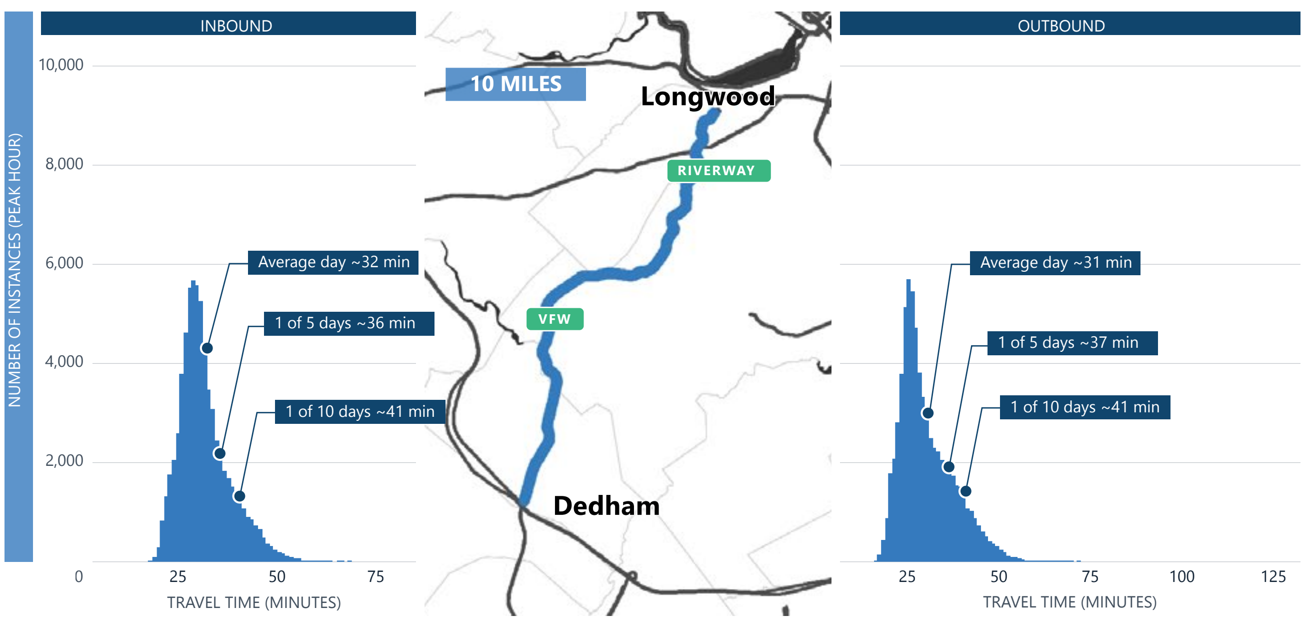


Figure 47. Travel Time Reliability, *Boston/Brockton Corridor*

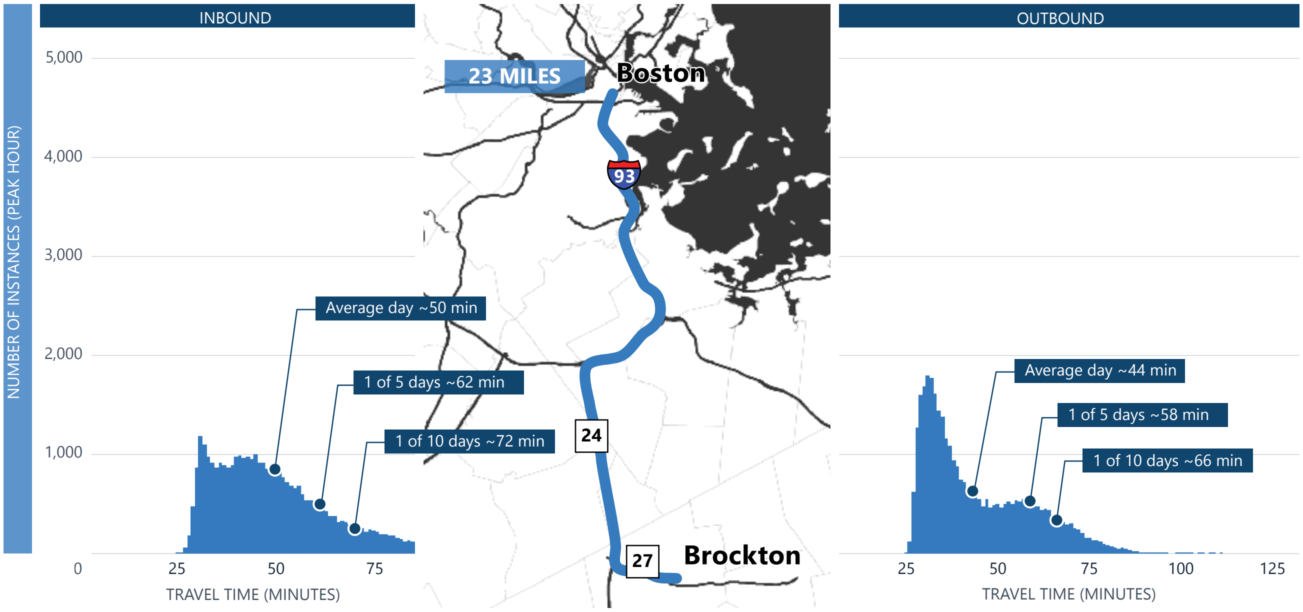


Figure 48. Travel Time Reliability, *Worcester/Webster Corridor*

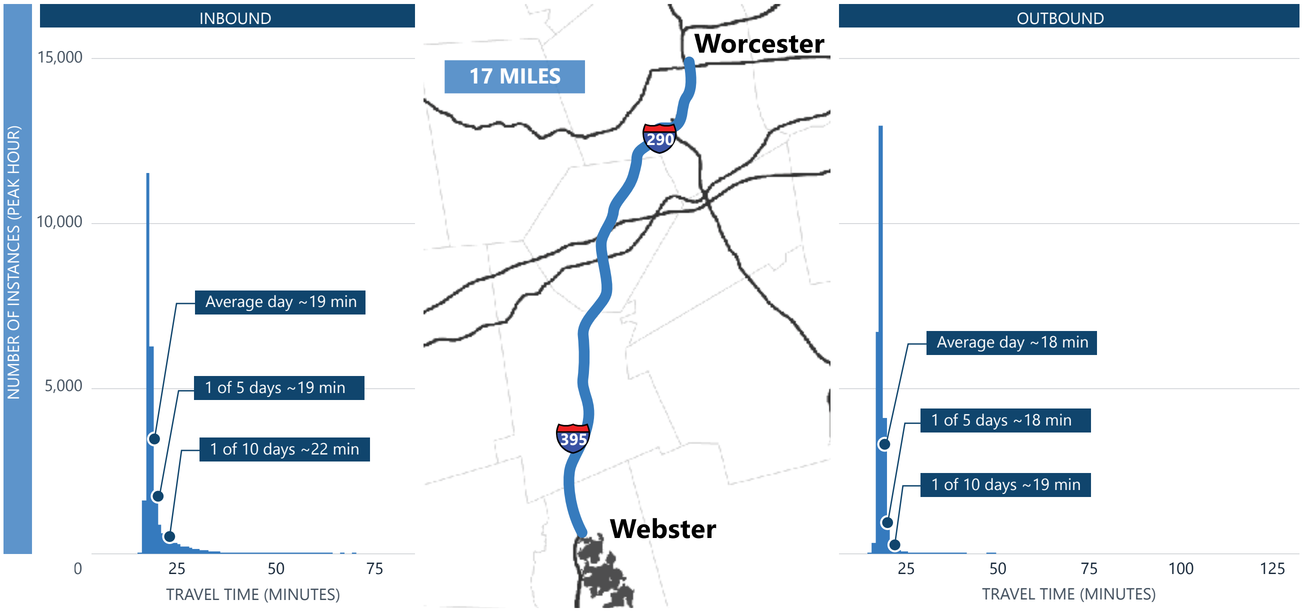
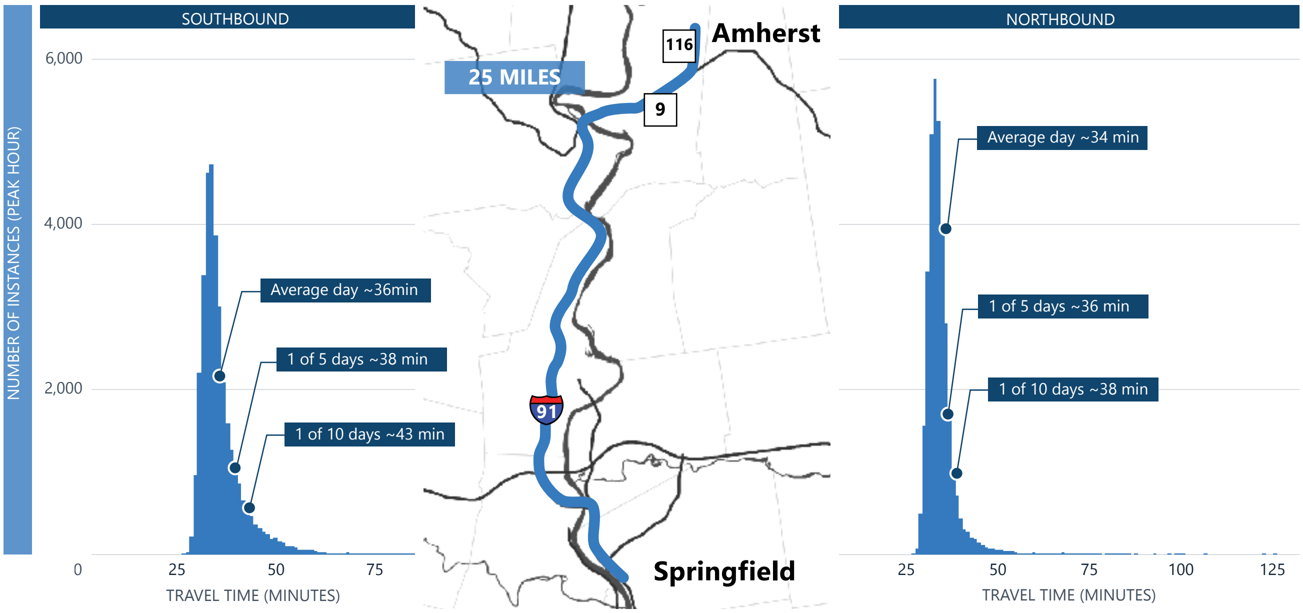


Figure 49. Travel Time Reliability, *Amherst/Springfield Corridor*



Histograms that show the travel times of different routes indicate which can be considered reliable and which are not. The histograms display the share of trips along the route that took different lengths of time to complete. If most trips took 30 minutes, then 30 minutes is the tallest bar in the chart. Histograms whose bars are close together and are compact are generally reliable since there is not much variation in how long a trip will take and times will cluster together around the average. On the other hand, those with long "tails" represent unreliable trips. There is more variation in the total amount of time a trip will take, which could range from below to far beyond the average length.

This reliability analysis gets to the core of what is so upsetting about congestion in Massachusetts, particularly during peak travel periods in Greater Boston. During an average commute period, roadway conditions are highly congested and trips will take longer than they would under free-flow conditions, even up to twice as long or more. But how often drivers experience "average" commute days is highly varied on most commutes in the Greater Boston region. Because of unreliability in commute times, there is no way of knowing which travel days will be of "average" congestion and which days will be especially bad.

Of all the trips we modeled, just one commute appears definitively reliable: from Webster to Worcester via I-395 and I-290. The histogram is highly clustered and the vast majority of trips take the exact same amount of time. Travel time is consistently about 18 minutes in both directions during the analysis period.

The commute between the Longwood Medical Area in Boston and Dedham, a trip of about 10 miles along the Riverway and the VFW Parkway, is also relatively reliable: the bars are relatively clustered and there is not an especially long tail on the chart. But while most trips take just over 31 minutes in either the inbound or outbound direction, some will take 40 minutes or more.

Likewise, the trip between Amherst and Springfield on I-91, Route 9, and Route 116 is generally reliable, especially headed northbound from Springfield: trips take about 35 minutes on average, and the longest observed trips were 50 minutes, though only occasionally. The southbound trip is a bit more unreliable.

Most other commutes appear to be unreliable. The travel time between Burlington and Kendall Square via I-95/128, Route 2, Fresh Pond Parkway, and Memorial Drive varies greatly over the course of a year, between about 25 and 50 minutes. But that trip can take up to 75 minutes headed inbound, which is about three times the average trip length. The outbound trip is slightly more reliable, but travel times can still vary greatly. The trip between Chelmsford and Waltham, along Route 3 and I-95/128, can be anywhere from 25 minutes to over 50 minutes, and the trip between Danvers and Back Bay along I-95, Route 1, and Storrow Drive can also take anywhere between 25 and 75 minutes headed inbound.

The trip between Worcester and Webster is a generally reliable trip. Heading inbound to Worcester in the morning on an average day, the trip will take a driver, on average, 17 minutes. But the histograms indicate that one of five weekday trips will take 19 minutes, and one of ten weekday trips will take 22 minutes—about a third longer than usual. The outbound evening trip is even more reliable: on an average day it will take 17 minutes, and at its worst, it will take about 19 minutes.

The histograms also indicate *how often* drivers should expect to experience unreliability in travel times. When travelers plan for their trips, they often budget for the most that a trip could possibly take in order to arrive at a destination when they want or need to be there. This becomes a default commute time, because travelers must be prepared for unexpected delays and account for potential unreliability in a trip.

Unreliable commutes mean the greater possibility of excessively long trips more often. While on an average day, the trip from Wayland to Logan Airport on Route 20, I-95/128, and I-90 takes about 39 minutes, on one of 5 weekday trips, that route will take 48 minutes, which is 12 minutes or 33 percent longer. And on one of 10 week-day trips (roughly once every two weeks), the trip will take 55 minutes—nearly 20 minutes longer, or an extra 53 percent longer than it does on average.

Trips between Lynn and Boston along Routes 1A, 60, and 107 are also unreliable heading in both directions. Going inbound in the morning on an average day, the trip will take 30 minutes, but one commute per week will take 35 minutes, and one commute every two work weeks will take 40 minutes. Drivers headed outbound can expect to experience the same conditions with roughly the same frequency.

The trip inbound from Brockton to Boston takes drivers along many of the corridors already noted for particularly congested conditions: Route 27 to Route 24 to I-93. This trip on weekday mornings is already a long drive on an average day: 50 minutes. But on one out of five commute days, drivers can expect this trip to take over an hour. On one out of every 10 commute days, this trip will take 72 minutes—nearly an hour and a half. The return trip in the evening is not much better in terms of reliability—in fact, this trip is the most unreliable that we have measured.

Impacts on Access to Jobs

Most measures of congestion and of transportation focus on mobility, the movement of people (or goods) from one place to another. But the most important "social good" produced by the transportation system is accessibility—the ability of people to get to desired destinations, by a specific mode, in a specific amount of time. People use the transportation system to reach opportunities and to connect with the people and places that are important to them.

While the transportation research community has made great strides in measuring accessibility, there can be no single measure of accessibility because the answer to "how accessible is Massachusetts?" or "how accessible is Greater Boston?" varies depending on three things: what is the study measuring access to (jobs, child care, health care, education, healthy food, recreational opportunities); what transportation mode is being used for access (driving, transit, walking or cycling); and what seems like a reasonable amount of time. One increasingly common measure of access is the ability of people to access jobs (or non-work destinations like supermarkets) within a certain amount of travel time by either driving or transit.

Congestion impedes accessibility by making it harder to travel and reach places in a reasonable amount of time. This means people have less access to jobs and the other things they want or need within a reasonable amount of time. This is true both for those in cars and for those on surface transit vehicles like buses.

Given their compact size and relative density, Massachusetts and the Boston region in particular have distinct advantages with respect to getting places: Boston ranks 16th among the 50 metropolitan areas studied in access to jobs by automobile and the 5th in access to jobs by transit.[11, 12] But it is precisely this accessibility advantage conferred by proximity—desired destinations being relatively close together—that exacerbates congestion, which increases the amount of time it takes to get to places that are relatively close to each other. When congestion increases the time it takes to go even a short distance, it erodes the advantages of being a compact region.

Because of the importance of accessibility and concern about congestion, MassDOT is participating with thirteen other state transportation departments in a study[13] designed to map and quantify how congestion affects access to jobs, measured as the number of jobs that can be accessed within a 45-minute drive. Data collected for this study demonstrate that congestion is now reducing access to jobs in Greater Boston, particularly within I-495: as of 2017, the Boston region ranked 6th of all U.S. metro areas in terms of the loss of access to jobs due to traffic congestion.[14]

The maps that follow illustrate how growing traffic congestion during the morning rush hour effectively shrinks the area in which residents have good access to jobs within a 45-minute commute. The first set of maps shows how many jobs are accessible by car from each Census tract across the state within 45 minutes throughout the morning peak travel period.[15] Unsurprisingly, access to jobs tends to go down as the morning peak progresses, particularly in Eastern Massachusetts.

The second set of maps shows how access to jobs changes during the morning peak period compared to accessibility levels at 2 a.m., when traffic tends to flow freely with few impediments. These maps show where congestion most limits access to jobs, and how and where the impacts of congestion multiply in scope and severity: as early as 6 a.m., job access is severely impeded along or near I-495 as commuters begin their journey to work and traffic picks up along this corridor. By 7 a.m., job access within the communities between I-495 and I-95/128 is severely impacted. Access is at its lowest during the 8 a.m. hour, when almost all communities between I-495 and I-95/128 and communities along the Massachusetts Turnpike between Worcester and Weston lose reasonable access (i.e., access within 45 minutes of travel time) to up to 1.25 million jobs.

Improving and maintaining good access to opportunities is not a matter that transportation agencies can take on alone. It is simultaneously a land use and housing issue—if people live closer to the places they need to go, such as job centers, they have better access to them. In the second set of maps, job access either does not change or remains relatively unchanged in one area: the inner core communities of Greater Boston. That's because even with heightened roadway volumes, people are very close to where most of the jobs are. Even if it takes them 45 minutes to drive two miles, they still maintain access to over one million jobs. In these close-in areas, access is not limited by congestion, but by the lack of sufficient quantities of affordable housing.

Traffic congestion effectively shrinks the number of communities with good automobile access to jobs and high housing costs limit who can afford to live in those high-access communities. For this reason, the quantity and location of housing is a big part of the

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11 Accessibility Observatory, October 2018. "Access Across America: Auto 2017". Note: Travel times and job access estimates reflect typical conditions for an 8 a.m. Wednesday morning departure. From the authors: "Rankings are determined by a weighted average of accessibility, with a higher weight given to closer, easier-to-access jobs. Jobs reachable within 10 minutes are weighted most heavily, and jobs are given decreasing weights as travel time increases up to 60 minutes." http://access.umn.edu/research/america/auto/2017/

12 Accessibility Observatory, June 2018. "Access Across America: Transit 2017". Note: Rankings are for access to jobs within 30 minutes travel time. http://access.umn.edu/research/america/transit/2017/maps/index.html

13 The study, entitled the "National Accessibility Evaluation," is being led by the Minnesota Department of Transportation in coordination with the Accessibility Observatory (AO) at the University of Minnesota. Through participation in this "pooled fund" study, MassDOT has received data that counts the number of jobs accessible at the Census block level. Unlike other accessibility metrics, the AO dataset allows MassDOT to understand travel times to jobs at different times of day, thereby gaining an understanding of how congestion impacts access to jobs statewide.

14 Accessibility Observatory, October 2018. "Access Across America: Auto 2017". http://access.umn.edu/research/america/auto/2017/

15 Consistent with FHWA reporting, the morning peak period is defined as 6:00–10:00 am; see footnote 15 for more information.

Figure 50. Access to Jobs within 45 minutes Travel Time, *AM Peak Period*

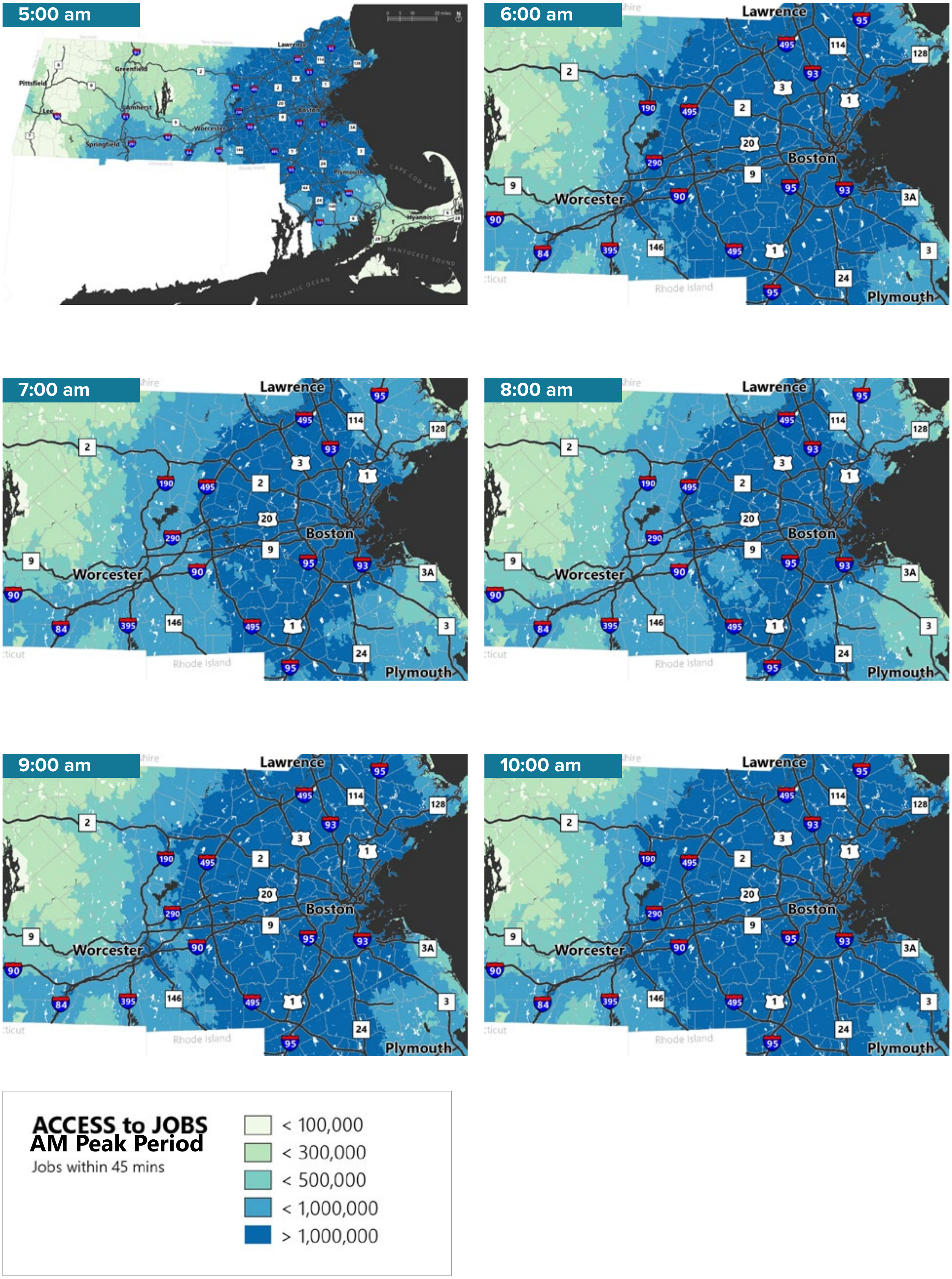
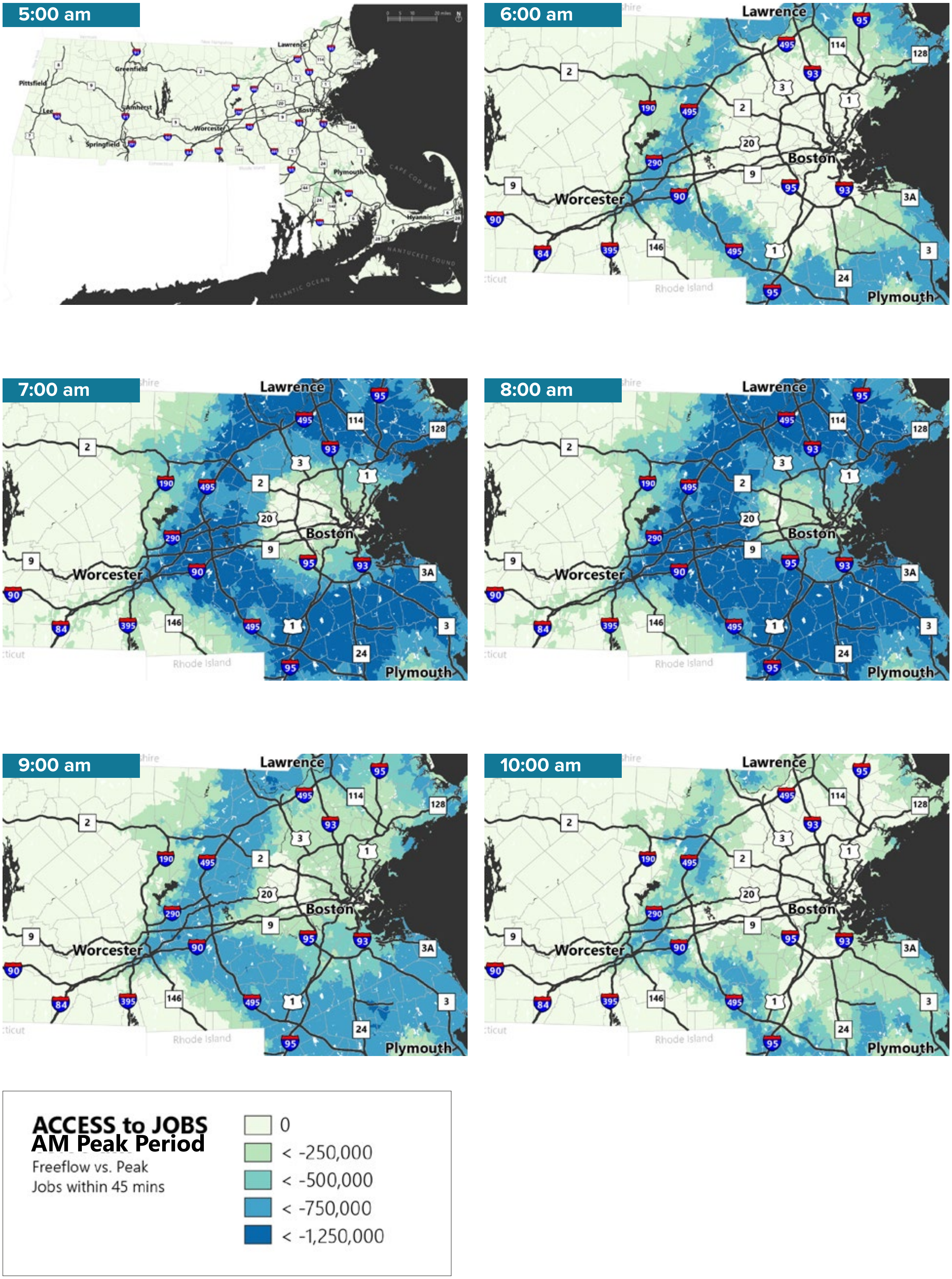


Figure 51. Changes in Access to Jobs within 45 minutes vs. Free Flow *(2AM)*



congestion equation. Increasing the availability and affordability of housing in high-access areas is a critical strategy if the Commonwealth wants to maximize reasonable and convenient access to jobs and other opportunities for its residents by either driving or transit.

Impacts of Congestion on Transit Services

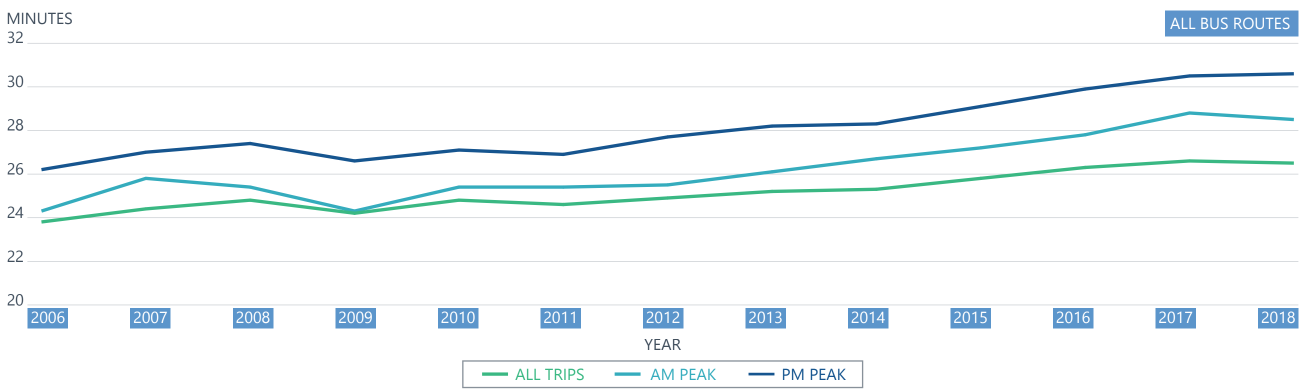
Transit riders, especially bus riders, are just as susceptible to the effects of congestion as drivers of single occupancy cars. With their frequent stops and need to be close to the curb to safely accommodate passengers, buses must maneuver around traffic more frequently in order to pull in and out of bus stops, a particular challenge during peak travel periods when roadways are clogged with traffic. When even a single bus is affected by congestion, this means that all of its passengers—up to 50 people or more—are simultaneously affected.

Although NPMRDS data does not include information on volumes or speeds on the local roads that most buses use, there is evidence that roadway congestion is increasingly hampering the performance and efficiency of transit services, especially buses. Trip time data collected by the MBTA shows the growth in run times on select bus routes from 2006 to 2018: while the length of all collective trips throughout the day has grown by 11 percent (or 2.7 minutes), trip times during the morning and afternoon peak have grown 17 percent during each period (4.2 minutes in the morning peak and 4.4 minutes in the afternoon peak).

As transit service planners make regular updates to schedules and operations, they must account for the impact of congestion and incorporate estimates of how much congestion affects run times. For example, the MBTA updates bus schedules based on how long buses actually take to travel the length of a route and make all scheduled stops. Using 2018 run time data, the MBTA is presently assuming that buses will travel at their slowest speeds since data has been available: on average, buses are assumed to travel at 11.5 miles per hour, down from 12.7 miles per hour in 2009.

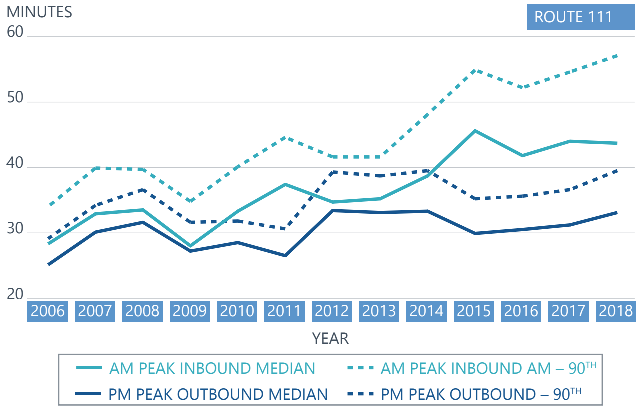
Congestion not only impacts the length of individual trips but the reliability of transit services as well. The size of the gap between its average (median) run time and its "90th percentile" run time represents the difference between an average trip and most—or 90 percent—of all trips. In other words, the difference between the median and the 90th percentile is like the difference between being on a bus that is traveling more or less at the speed a passenger would expect and being on a bus mired by frequent obstacles like roadway congestion, vehicles blocking bus stops, and inefficient signal timing. The charts in this section show how run times have changed over time as well as travel time variability on different routes.[16]

Figure 52. Median Weekday Trip Run Times, *All Day vs. Peak Periods, 2006–2018*



16 The routes were selected to show a variety of route types, destinations, and coverage areas. The additional charts show other MBTA bus routes and trends in average and 90th percentile run times. Route 215 runs between Quincy Center and Ashmont and makes connections to Fields Corner and North Quincy Commuter Rail Station; Route 245 connects Quincy Center with Mattapan Station via Milton; and Route 501, a peak period express bus, travels between Oak Square in Brighton and the Financial District in Downtown Boston via the Mass Pike.

Figure 53. Bus Route 111 Run Times, *Median and 90th Percentile, 2006–2018*



ROUTE 111, one of the Key Bus Routes, has one of the highest riderships in the MBTA system. The 111 begins in Revere, travels through Everett and Chelsea, and crosses the Tobin Bridge on its way to Haymarket station. Although inbound trips on the 111 during the morning peak travel period average under 45 minutes, it is very likely that this trip could last over 55 minutes.

ROUTE 7 is a "strictly Boston" bus: it starts at Otis and Summer Street in the Financial District, travels through the Seaport (on Summer Street), and runs through South Boston to end at the City Point Bus Terminal. On average during the morning peak period headed inbound, the route takes just over 25 minutes from end-to-end; in the opposite direction in the afternoon, it takes just over 20 minutes. But in the morning, on a particularly bad day, it can take this bus almost 35 minutes to go roughly 3 miles.

Figure 54. Bus Route 7 Run Times, *Median and 90th Percentile, 2006–2018*

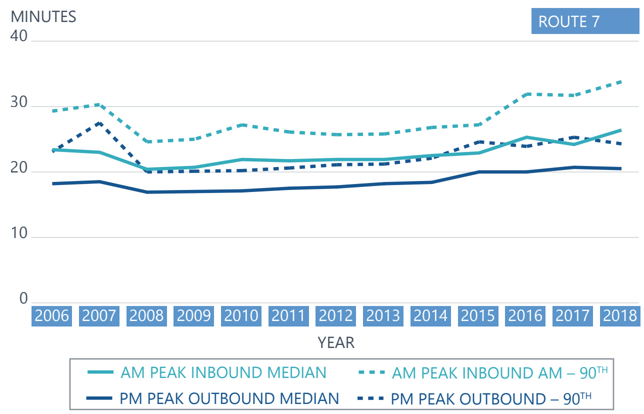
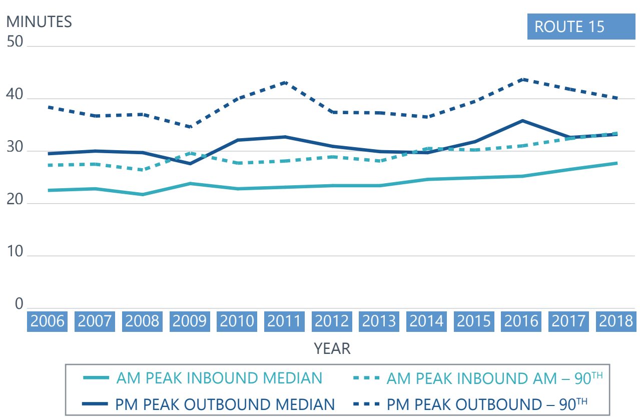
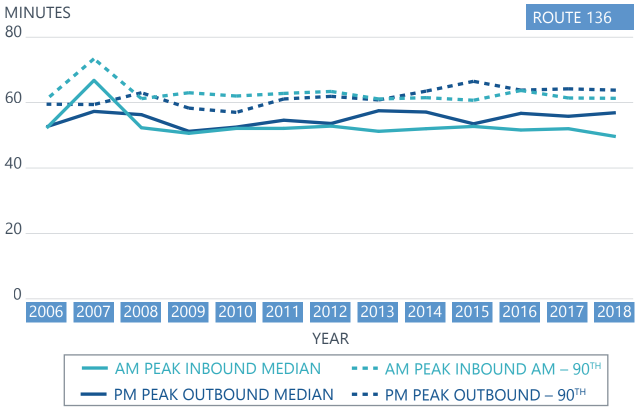


Figure 55. Bus Route 15 Run Times, *Median and 90th Percentile, 2006–2018*



Like Route 7, the **ROUTE 15** is a "strictly Boston" bus. There are four "variants" or sub-routes of the Route 15: it can go between Ruggles and Kane Square, Fields Corner, or St. Peters Square in Dorchester, or to Mattapan Square. On the Kane Square variant, average afternoon peak period travel time headed outbound improved between 2016 and 2018, falling from 35.8 to 33.2 minutes. But the reliability of the outbound trip has improved as well: the 90th percentile travel time fell almost 4 minutes, from 43.7 to 40.1 minutes.

Figure 56. Bus Route 136 Run Times, *Median and 90th Percentile, 2006–2018*



ROUTE 136 connects Malden Center to Reading Depot via Melrose and Wakefield, all on local roads. On average, the route takes between 50 minutes and an hour traveling in the peak direction at peak travel times. While the median and the 90th percentile travel times have been consistent and reliability has shown slight improvement recently, as the gap between median run times and the 90th percentile run times appears to be growing.

Figure 57. Bus Route 215 Run Times, *Median and 90th Percentile, 2006–2018*

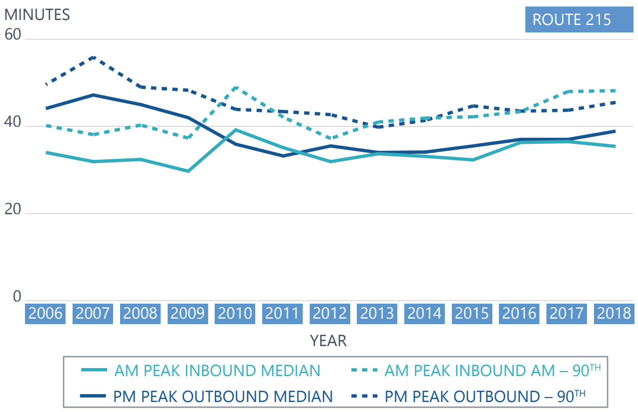
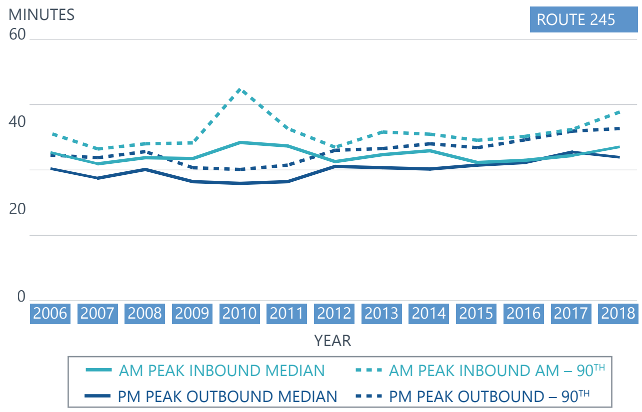
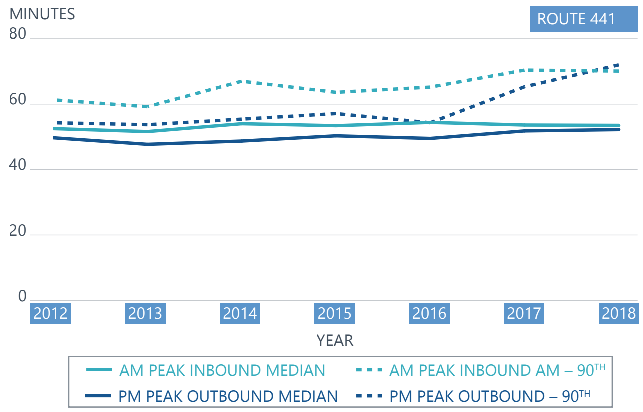


Figure 58. Bus Route 245 Run Times, *Median and 90th Percentile, 2006–2018*



ROUTE 441 travels from Marblehead to the Wonderland MBTA station in Revere via Swampscott and Lynn. Since 2012, median travel times on both inbound and outbound trips have remained steady at around 50 minutes. But as shown in the 90th percentile trend line, long trips have been getting even longer since 2016. It can take over 70 minutes to get from one end of the route to the other.

Figure 59. Bus Route 441 Run Times, *Median and 90th Percentile, 2012–2018*



Dedicated bus lanes are incredibly powerful tools that municipalities can wield to maintain traffic flow and move many people around efficiently.

Run time data on routes that benefit from dedicated bus lanes shows the effect that they have for commuters and other riders. In 2017, Cambridge and Watertown partnered together to pilot bus lane improvements on Mount Auburn Street, where the 71 and 73 buses run, including a dedicated bus lane. During the morning peak travel period, the 71 bus

Figure 60. Bus Route 501 Run Times, *Median and 90th Percentile, 2006–2018*

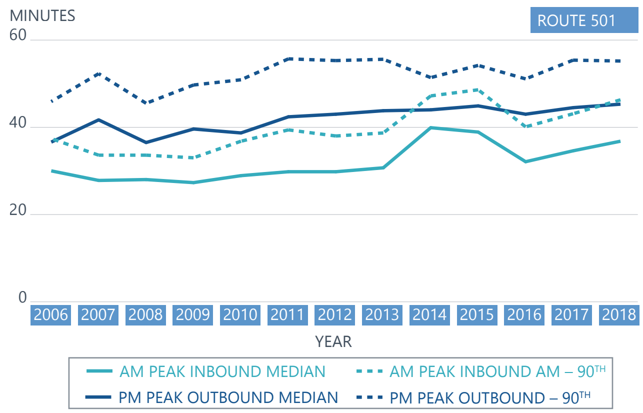


Figure 61. Route 71 Dedicated Bus Lane Run Times, *AM Peak 2009–2019*

Mt. Auburn at Belmont to Mt. Auburn Hospital

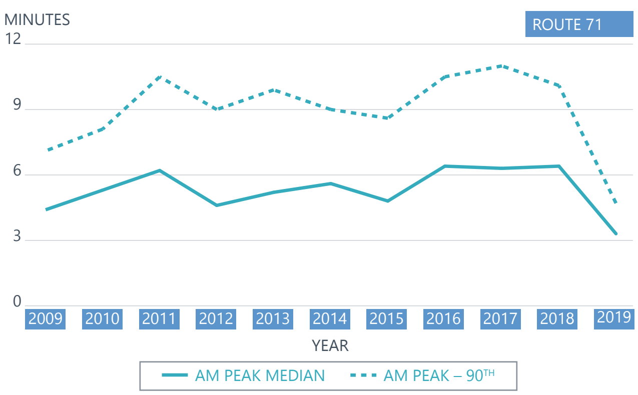


Figure 62. Route 73 Dedicated Bus Lane Run Times, *AM Peak 2009–2019*

Mt. Auburn at Belmont to Mt. Auburn Hospital

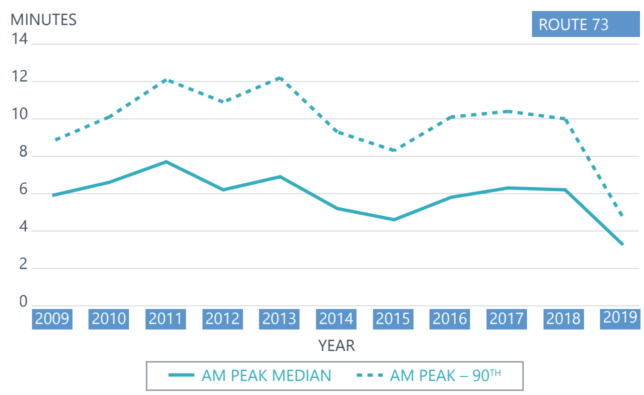


Figure 63. Route 109 Dedicated Bus Lane Run Times, *AM Peak 2007–2018*

Glendale Square to Sweetser Circle

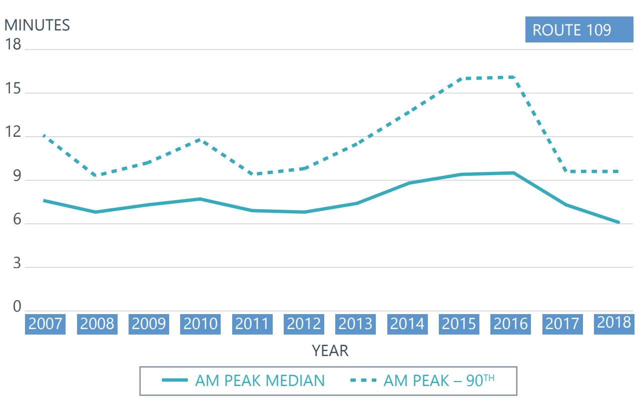
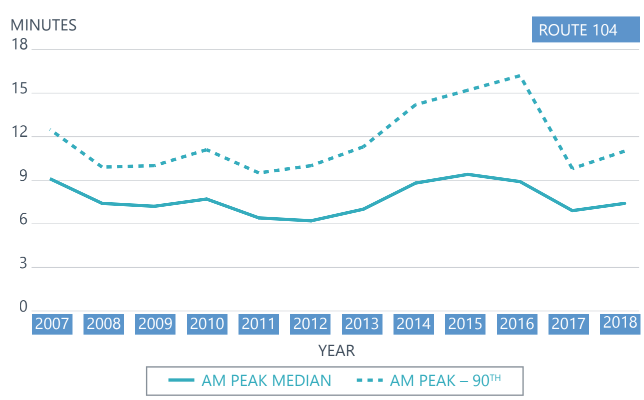


Figure 64. Route 104 Dedicated Bus Lane Run Times, *AM Peak 2007–2018*

Glendale Square to Sweetser Circle



run time between Mount Auburn at Belmont Street and Mount Auburn Hospital fell by over 3 minutes, and the 90th percentile fell by over 5 minutes—meaning that not only did run times fall between 2018 and 2019, but also there is far less variability in how long trips take. Not only did benefits accrue to bus riders, but following a comprehensive evaluation, the project team determined that total vehicle throughput remained virtually unchanged since before the bus lane was introduced. In short, car drivers and passengers' mobility were unchanged following the dedication of the bus lane.

The same effects are seen on Broadway in Everett where bus lanes have also been dedicated: Routes 104 and 109 have seen reductions in both average run times and in run times that exceed the average.

3 WHY CONGESTION OCCURS

Pinpointing where and when congestion occurs is a relatively straightforward exercise, especially given the public data that can highlight variations in travel times and speeds on roadways. But describing why congestion occurs and why it changes over time is much more complicated and far less certain. The root causes of vehicular congestion lie in both direct, micro-level factors, such as poor signal operations and crashes, as well as in indirect macro-level phenomena, such as population and income trends, land use patterns, and changing travel behaviors.

This chapter describes the factors, transportation-oriented or otherwise, that affect the occurrence and severity of congestion. We break congestion out into its two types—recurring and non-recurring—because the causes behind trends in each are not always the same. While many other forces likely impact trends in roadway volumes, those included here are recognized as among the most salient.

Recurring Congestion

Recurring congestion is traditionally associated with commuting patterns, but the regular increase of traffic volumes beyond available roadway capacity is the product of several and overlapping forces including population and employment growth, housing and land use development priorities, travel behavior, and elements of the roadway network itself.

POPULATION AND EMPLOYMENT GROWTH

More people living and working in Massachusetts directly translates to more regular daily trips across the state. In the case of labor force growth, many of these are work trips that occur during peak travel hours.

Population and Household Growth The population of the Commonwealth is growing. According to data posted by the University of Massachusetts Donahue Institute (UMDI), the state grew by more than 350,000 people between 2010 and 2018, from 6.5 million to 6.9 million residents. Between 2017 and 2018 alone, Massachusetts added nearly 39,000 people and the population is projected to grow to more than 7.3 million people by 2035. While a growing population is a positive trend and an indicator of a vibrant place, it also means that more trips are being made, the vast majority of which are by single-occupancy vehicle.

Except for large swaths of Western Massachusetts and Cape Cod, most regions of the Commonwealth are gaining population; the most concentrated pockets of population growth are near or within the I-495 corridor. Given trends in travel behaviors and established land use patterns, most of these new residents will do most of their travel by car.

Like population growth, household growth leads to greater demand for travel. The fact that household growth is consistent throughout the state and strong in low-density areas outside of Greater Boston is especially significant, because it means there are more people living in places where it is challenging to provide high frequency transit service. Residents thus usually rely on cars to get around. More people living in areas that encourage driving leads to growing roadway volumes and congestion.

Figure 65. Change in Population, *2012–2017*

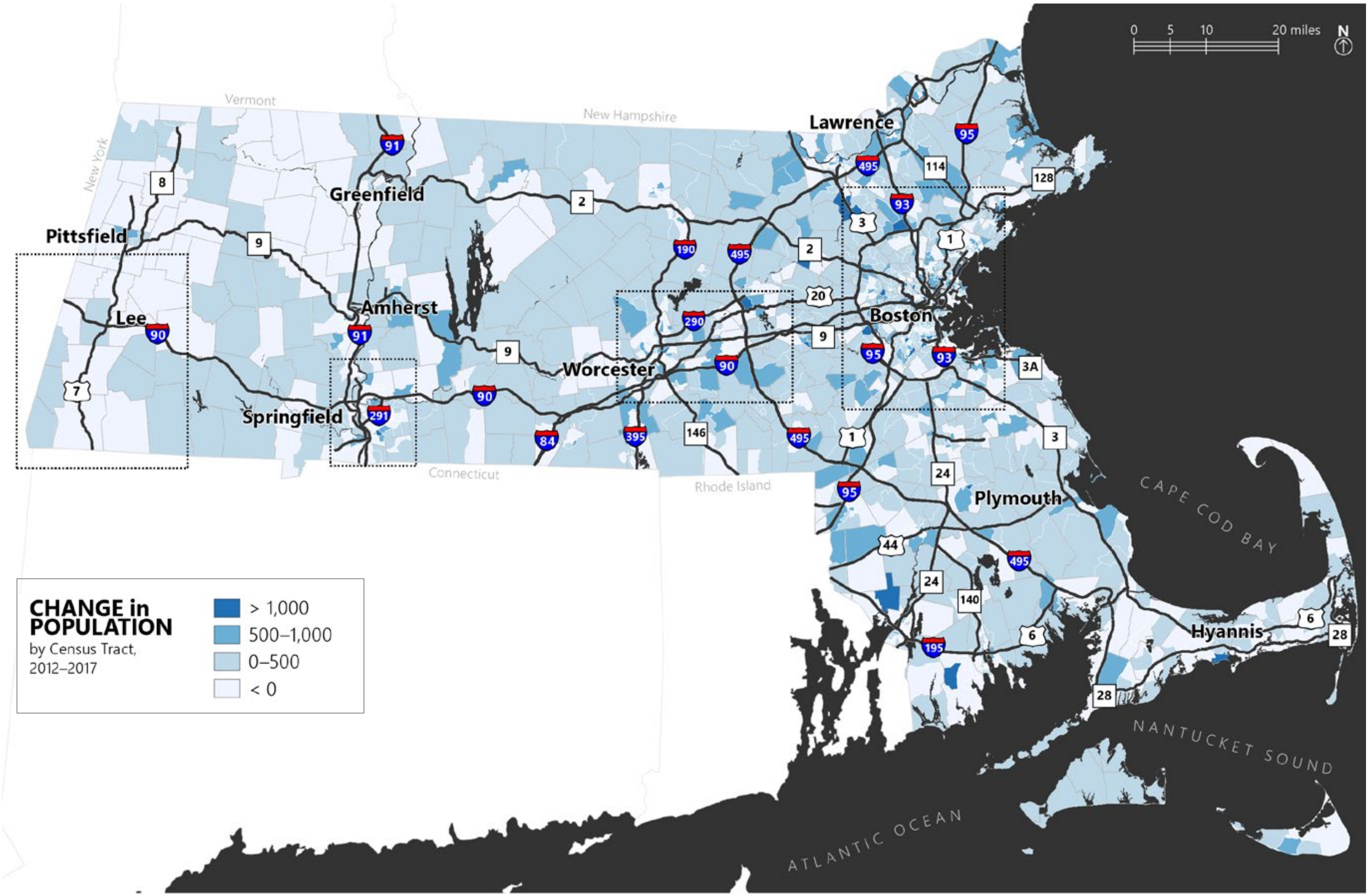
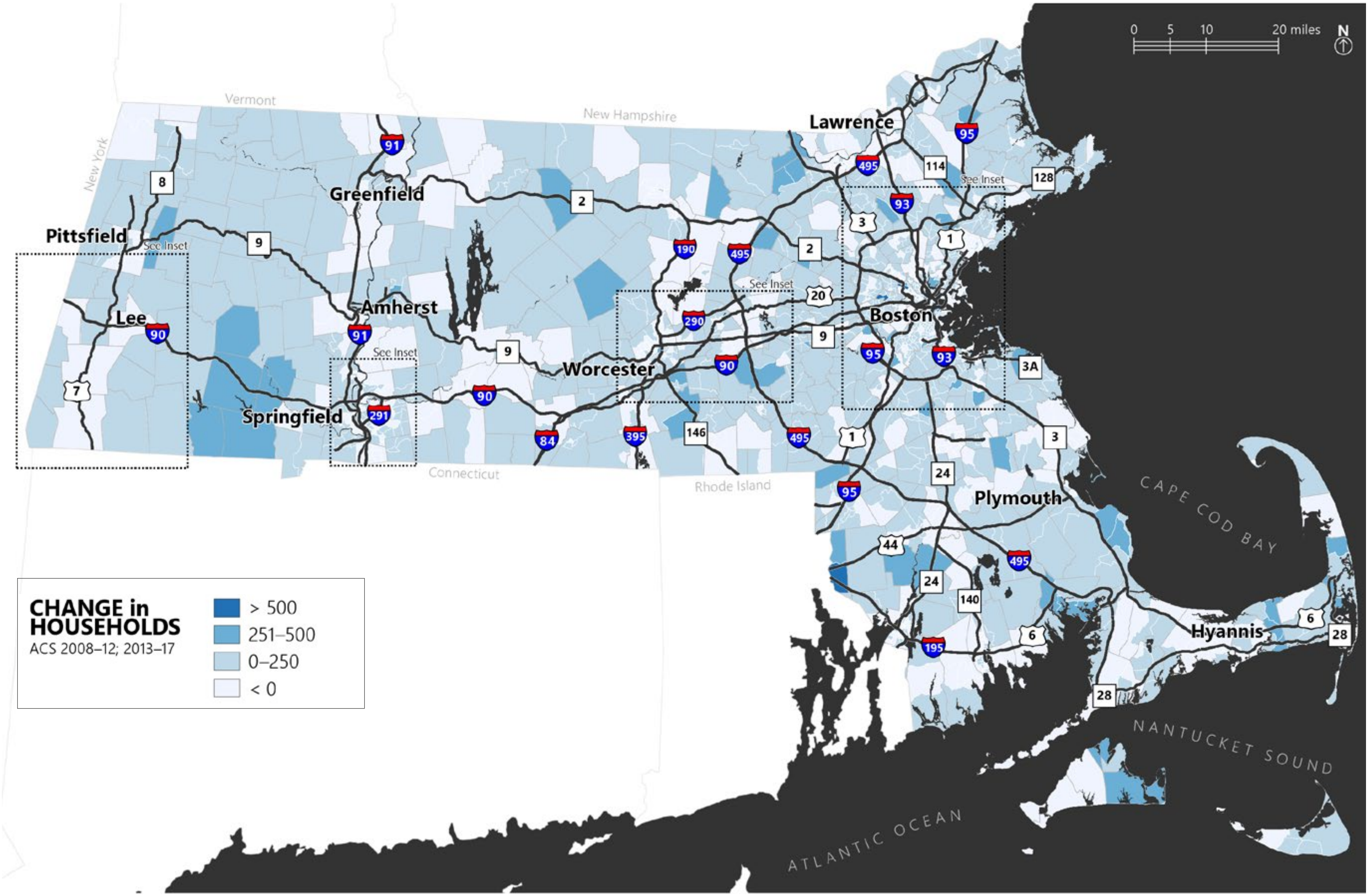


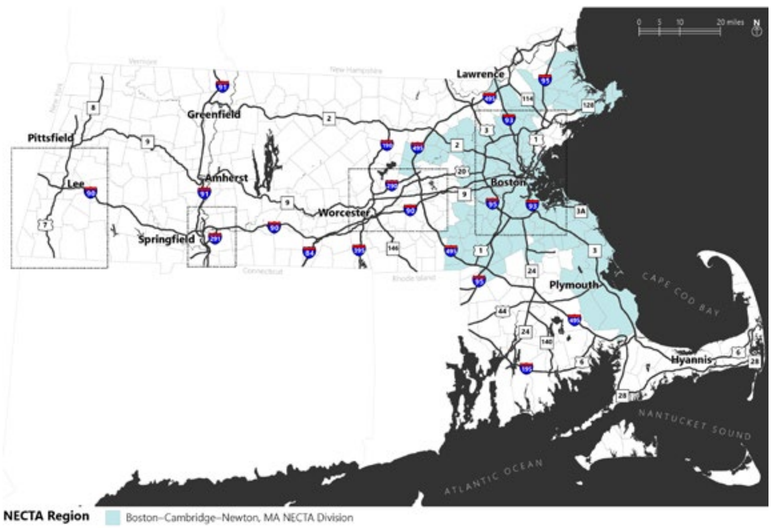
Figure 66. Change in Households, *2012–2017*



Labor Force and Labor Force Distribution Like population and household growth, job growth is a good thing for the Commonwealth. Greater Boston is one of the most important economic regions in the country and home to a thriving and expanding workforce. Data from the Bureau of Labor Statistics (BLS) shows that as of January 2019, the number of employed people in Massachusetts topped 3.7 million people, up 3 percent from January 2018. While jobs are being added in most parts of the Commonwealth, 44 percent of all jobs statewide are concentrated in the Boston region (as defined by the Census' New England City and Town Area boundaries). Since 2000, employment in the Boston NECTA region has grown by 19 percent, compared to 12 percent growth in the rest of the state. Year-over-year job gains are also greater in the Boston region than in the rest of the state, again underscoring the concentration of economic activity there.

As with trends in population and household growth, labor force growth usually leads to greater travel and more traffic in key locations. Where workers work, especially in relation to where they live, has direct impacts on average daily traffic conditions, especially during peak travel periods and on corridors that lead directly to employment centers. And as shown in Section 3.5, the patterns and proximities of job sites to home locations has significant consequences for the degree of access people have to employment opportunities.

Figure 67. Boston NECTA Map



Job growth between 2012 and 2017 was concentrated in a handful of places, mainly where employment hubs already existed, such as along the I-95/128 belt. Outside of Route 128 and Greater Boston, the most significant employment growth is happening along other major corridors or in places where major roadways meet, like Northampton, near the intersection of Route 9 and I-91, or Taunton, near the intersection of Route 24, I-495, and US-44.

Figure 68. Employment Growth, Boston NECTA vs. Rest of Massachusetts, *2000–2019 (January averages)*

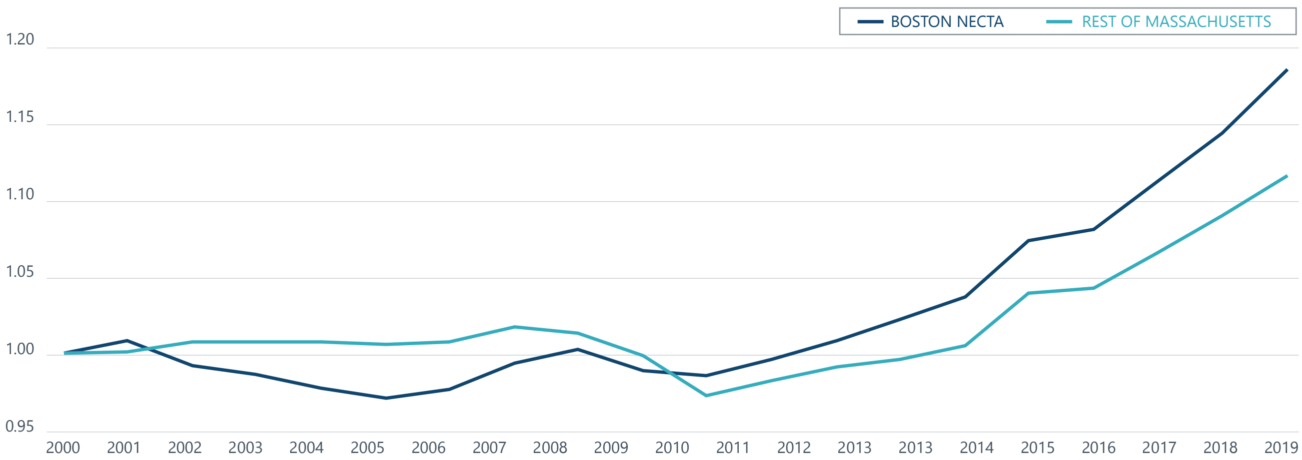
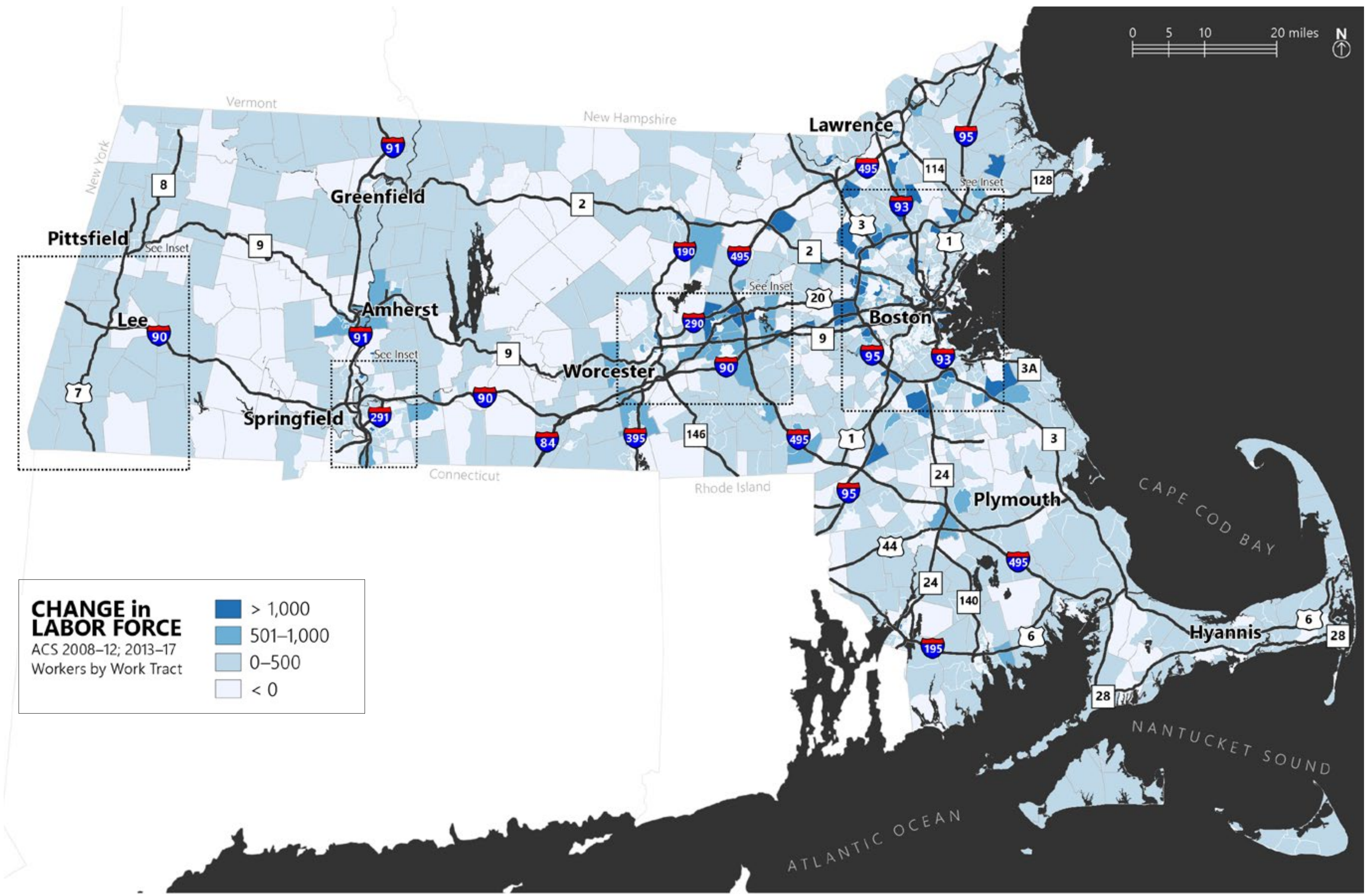


Figure 69. Change in Labor Force by Work Census Tract, *2012–2017*



HOUSING AND LAND USE

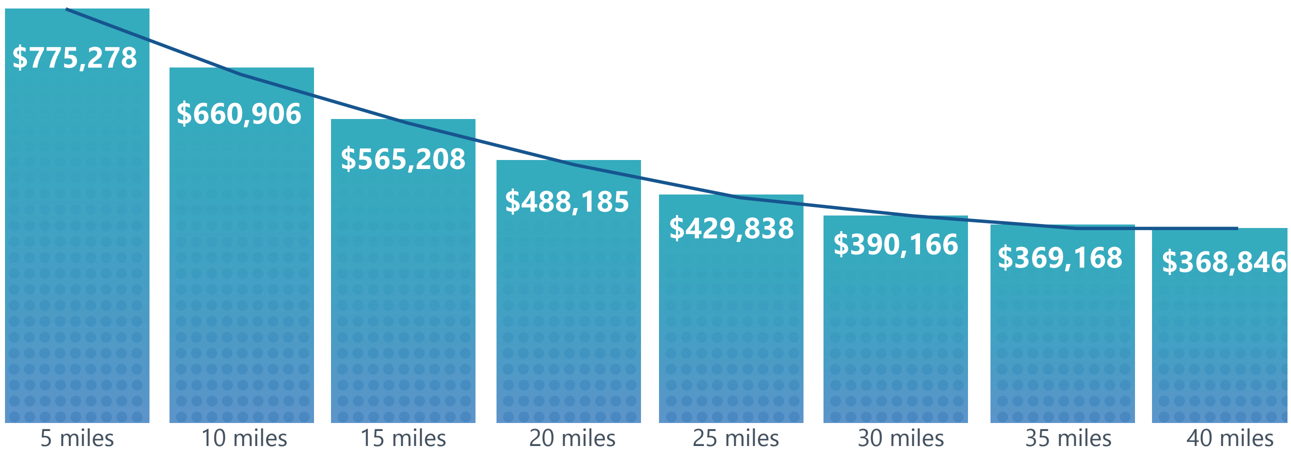
Housing Affordability Greater Boston's status as one of the most expensive housing markets in the country is well known. Rents have risen dramatically across the state and especially in the Boston metro area. Boston, Cambridge, and Somerville have seen rents almost double since 2000.[17] Massachusetts had the third highest median home value in 2017, only less than Hawaii and California.[18]

The relationship between high housing costs and transportation issues such as congestion may not be apparent to many residents, though most would recognize that the decrease in housing affordability is a relevant concern. Of respondents to a MassINC poll about transportation in the state who live within the I-95/128 corridor, 75 percent found that housing costs are considered a major priority for the state government to address, compared to 67 percent who felt that transportation was a major priority.[19]

Many households may be moving farther and farther away from areas in the Commonwealth with the greatest number of transportation options because of the increasing cost of housing in those areas. The transit-rich Boston metro area is experiencing the most acute increase in housing costs—though there may be an influx of residents moving into Boston, many households may also be moving to lower-density communities where housing costs less and driving is the primary mode of transportation used.

An analysis of home prices by distance from the center of Boston found clear trends in proximity and affordability: housing costs are significantly lower farther away from Boston. While the median price of single-family homes within a five-mile radius of Boston exceeded $775,000, the median price dropped $115,000 ten miles out, and by another $95,000 fifteen miles out. Thirty miles from Boston, the median home price fell below $400,000.[20] Households with more than one wage earner must find housing "in between" two different job locations. For example, in 2016, the 495/MetroWest area (from Westford to Foxborough) contained 9.2 percent of all jobs in Massachusetts.[21]

Figure 70. Greater Boston Housing Report Card,
Median Price vs. Distance from City of Boston in miles, 2017



Source: Warren Group Data; Authors' Analysis.

[17] U.S. Census Bureau, Decennial Census (2000), Table H063; U.S. Census Bureau, American Community Survey (ACS), 2013-2017 5-year data. Table B25064.

[18] U.S. Census Bureau, American Community Survey (ACS), 2013–2017 5-year data. Table B25077.

[19] MassINC Polling Group, April 2019. "Gridlock: Stopped in Traffic, Delayed on Transit." https://static1.squarespace.com/static/59a6d1d0e9bfdf582649f71a/t/5cc043534192025ff55e3892/1556104021235/Report+2019+03+Barr+Transpo+Issues.pdf

[20] The Boston Foundation, November 2017. "The Greater Boston Housing Report Card 2017." https://www.tbf.org/-/media/tbf/reports-and-covers/2017/2017-housingreportcard.pdf

[21] https://www.mass.gov/files/documents/2018/02/12/495MW%20Profile%20by%20UMass%20D%20PPC.pdf

The Massachusetts Housing Partnership's Center for Housing Data recommends in its February 2019 Housing Brief that "encouraging housing development around existing transit helps make the most of existing infrastructure and minimizes impacts on traffic congestion." Greater housing supply helps mitigate rent levels, and research has shown that rental apartment density is a predictor of transit use and reduced per capita vehicle miles traveled (VMT).[22] The failure to produce housing, including affordable housing, and other appropriate mixed-use development near transit may further contribute to congestion.

Some cities and towns are meeting the regional demand for housing production better than others. For example, Boston permitted 38 percent of all new housing units in MBTA-served communities (including bus and rail service) between 2013 and 2017 while representing 18 percent of the population in the service area.[23] Fifteen municipalities in Greater Boston are responsible for more than half of all building permits issued across the state between 2013 and 2017: Boston, Cambridge, Plymouth, Watertown, Everett, Weymouth, Somerville, Burlington, Chelsea, Framingham, Hopkinton, Middleborough, Quincy, Arlington, and Canton.[24] The failure of other communities to consistently build housing near transit routes reduces housing options for residents who want to use transit and increases congestion. Programs such as 40R offer incentives to build more density near transit, and the MBTA developed Transit Oriented Development (TOD) Policies and guidelines.[25]

In addition to increasing the overall housing stock near transit hubs as a means to decrease congestion, increasing affordable housing options near transit should also be considered as part of an approach to decreasing congestion. A recent study of almost 200 multi-family developments in 14 municipalities in Greater Boston found that in general, parking spaces had a 30 percent vacancy rate and that the percent of vacant parking spaces increased proportionately with the number of affordable units. The study recommends: "Because residents at affordable housing sites are demonstrated to have lower parking demand (and thus are more dependent on transit, we should not only build less parking at transit—oriented sites, but also including a larger share of affordable units in these projects."[26]

Housing costs can also be offset, to a degree, by savings in the daily work commute. The Center for Neighborhood Technology has devised a combined metric, the H+T Affordability Index. Rather than the traditional affordability benchmark, in which no more than 30 percent of household income is devoted to housing, the H+T benchmark is that no more than 45 percent is devoted to housing plus transportation costs. A neighborhood that a family might find unaffordable based on housing costs alone may be manageable if daily commuting costs—thanks to transit—are low.[27] In Greater Boston as a whole, automobile ownership and average household transportation costs are significantly higher than in the City of Boston and other "inner core" communities with concentrated MBTA service.

Land Use and Development Patterns When people live farther apart from each other and from the places that they need and want to go, they have to cover more ground to complete these trips. In this way, low-density development patterns and land use policies that separate places based on use types are a leading contributor to congestion. Such suburban land use patterns are reinforced by zoning adopted by local governments. Zoning can be very difficult to change because of the statutory requirement in Massachusetts to have a two-thirds majority vote of a legislative body to amend zoning.

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22 Stephanie Pollack, "How Can Equity in TOD Be Defined and Measured?" Rail~Volution, 2014.

23 Massachusetts Housing Partnership Center for Housing Data, February 2019. "Housing Brief."

24 The Boston Foundation, June 2019. "The Greater Boston Housing Report Card 2019: Supply, Demand and the Challenge of Local Control." https://www.tbf.org/-/media/tbf/reports-and-covers/2019/gbhrc2019.pdf?la=en&hash=6F5C3F0B829962B0F19680D8B9B4794158D6B4E9

25 MBTA/MassDOT TOD Policies and Guidelines DRAFT: Revised March 31, 2017.

26 Metropolitan Area Planning Council, July 2019. Metro Boston Metro Perfect Fit Parking Initiative, Phase II Report: The cost of Unused Parking."

27 Center for Neighborhood Technology; http://htaindex.cnt.org/map/; MAPC http://tstation.info/; MAPC, Metro Boston Regional Indicators; Transportation: Staying on Track (2017).

A recent study looked into the influence of the built environment on travel in Massachusetts and found that the distance between locations (e.g. home locations and retail) has among the largest impacts on vehicle miles traveled (VMT), a measure of mobility and how much people drive. A key finding of the analysis is that "increasing land use mix (i.e., reducing distance between home and retail) could reduce statewide passenger VMT by 4.3 percent by 2040."[28] Studies by other state transportation agencies have similarly found that households in high-density communities generate fewer vehicle miles and are more likely to use non-auto modes to get around.[29]

The decrease in congestion as well as the affordability benefit of living near transit is only realized if jobs are transit-accessible as well. TOD offers two strategies for enhancing job access. One is to consciously develop concentrations of jobs in high-capacity transit locations.[30] It is significant that Partners' HealthCare, the region's largest private employer, narrowed its search for a consolidated administrative headquarters site (for 4,500 workers) to two Orange Line stations in the region's Inner Core, selecting Assembly Square.

Reducing reliance on automobiles is an important strategy for congestion relief, but is not a task of the transportation industry alone: municipalities, regional planning organizations, developers and land owners are among the most important stakeholders for advancing land use policies that move away from the types of low-density development where uses are separated that leave areas and roadways vulnerable to congestion to ones that prioritize the ease of access for people to travel to and between destinations. The Governor's Housing Choice legislation makes changing zoning to increase housing production in transit areas and in town centers and downtowns easier for local governments to enact by reducing the voting threshold from two-thirds to a simple majority.

TRAVEL BEHAVIOR

Mode Choice What mode of transportation people choose also impacts congestion. The more people travel by car, the more traffic there is. But residents with limited or no access to transit options have little choice but to travel by car. Public transit is easier to provide in areas with greater population and land use densities, often limiting the amount of service available from Regional Transit Authorities in lower density areas of the Commonwealth which in turn limits the utility of transit as a viable commuting option beyond the Commonwealth's major urban areas. Similarly, while growing, infrastructure for walking and bicycling is still limited and relatively few of these off-road facilities offer direct connections to employment hubs. In the absence of reliable transit and other non-automobile options, single occupancy vehicles are the most convenient and reasonable travel option for most of the trips some residents make.

The degree of growth in car commuting is greater in some communities than others, with the most concentrated growth in car commuters primarily outside of Greater Boston. In many places across the state, the number of workers who drove alone to work grew between 2013 and 2018. However, many places have seen a decline in solo car commuting in the past five years, especially in broad swaths of Central and Western Massachusetts.

Car Ownership The relationship between car ownership and traffic volumes is also straightforward. People in households that own cars will drive to get to where they need to go. Car ownership is itself influenced by a number of factors, including home and work location, public transit accessibility, changes in income, and affordability, including fuel costs, which have been falling. Owning a car is a powerful incentive for using it: growth in vehicle ownership among low-income communities in Southern California is shown to be responsible for much of the decline in transit ridership among the system's most frequent riders.[31] Demographic

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28 Bill Holloway, Eric Sundquist, and Chris McCahill, 2016. "Built environment policies to reduce vehicle travel in Massachusetts." https://trid.trb.org/view/1437848

29 Arizona Department of Transportation Research Center, March 2012. "Land Use and Traffic Congestion." https://www.azdot.gov/docs/default-source/planning/az618.pdf

30 MBTA/MassDOT TOD Policies and Guidelines DRAFT: Revised March 31, 2017.

31 UCLA Institute of Transportation Studies (ITS), January 2018. "Falling Transit Ridership: California and Southern California." https://www.its.ucla.edu/2018/01/31/new-report-its-scholars-on-the-cause-of-californias-falling-transit-ridership/

Figure 71. Change in Labor Force Commuting by Driving Alone, *2012–2017*

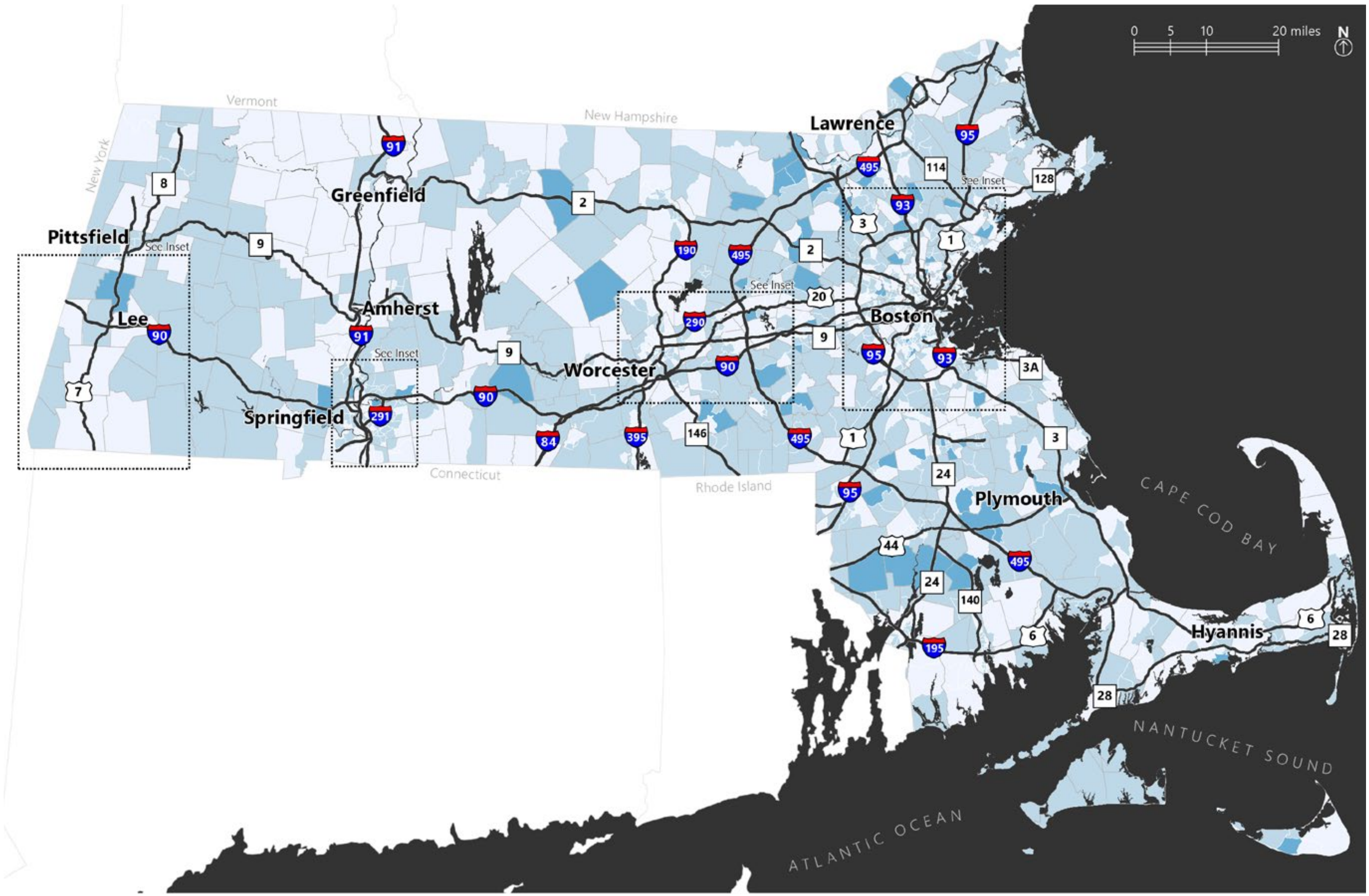
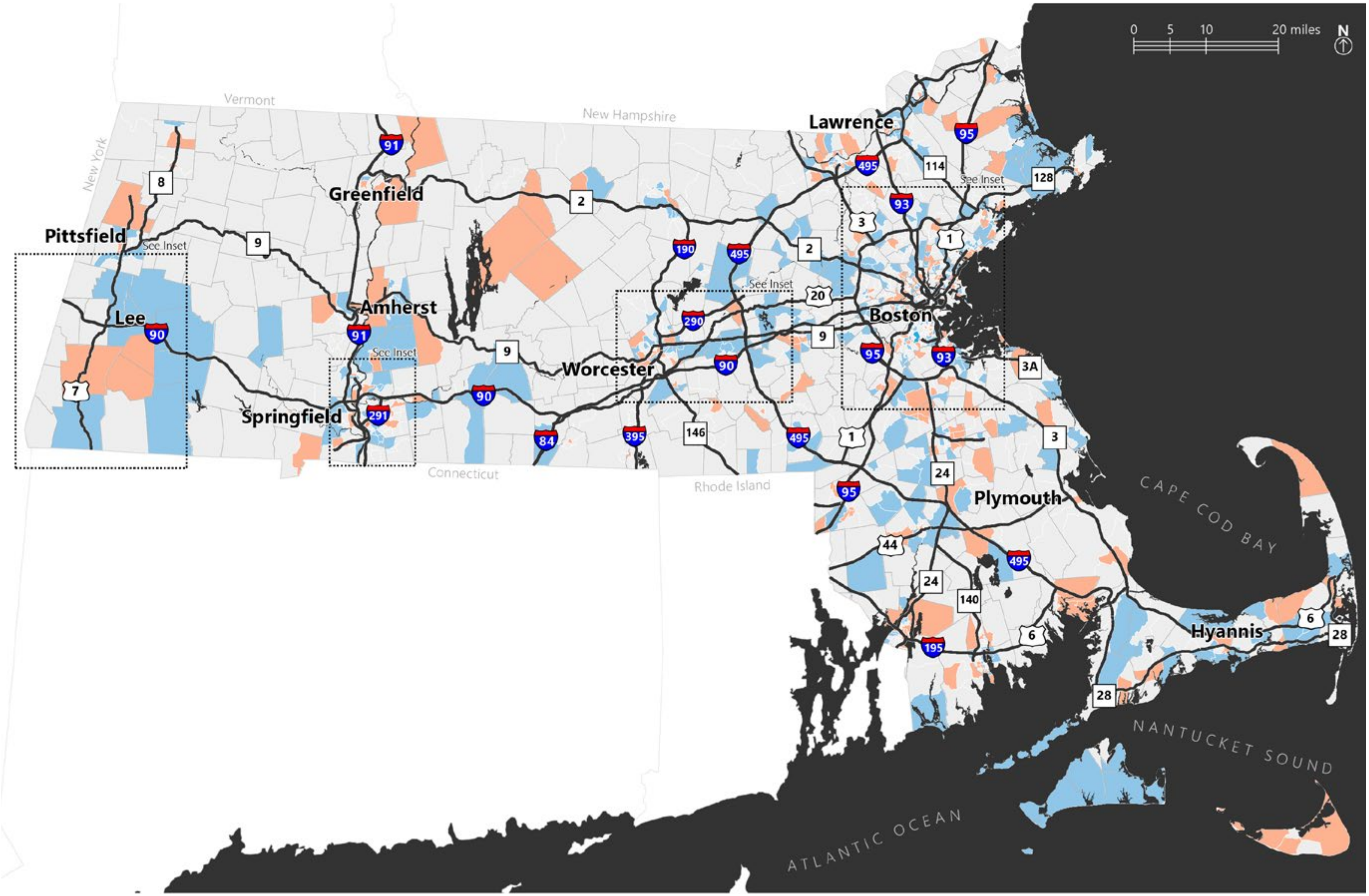


Figure 72. Change in Households Owning a Car, *2012–2017*



factors are also believed to drive ownership decisions, as younger generations have lower rates of car ownership than older generations at similar ages. However, debate continues about whether generational differences in ownership trends represent a legitimate shift in preferences or a short-term reaction to economic and social conditions.

Massachusetts shows no clear patterns or trends with respect to household car ownership. Statewide, the share of households that own a car remained steady at 88 percent in 2012 and 2017, though the number of registered vehicles rose by 8.3 percent between 2012 and 2018, from 5.0 million to 5.4 million vehicles.[32]

Fuel Costs The relationship between fuel costs and traffic volumes is also straightforward: people drive more regularly and over greater distances when it is cheaper to do so. Studies by the FHWA and others have shown that fuel costs and vehicle travel are negatively correlated: when fuel costs go up, vehicle travel goes down.[33]

This has been the case in Massachusetts: although per capita vehicle miles traveled remained relatively flat after fuel costs began to rise in 2009, when fuel costs dropped close to their 2009 levels in 2016, VMT rose as well.

Commuting Behaviors Congestion itself can change travel behavior, inducing people to change their commute times in order to avoid the worst congestion; this is called "peak spreading." In a recent MassINC poll on transportation issues, 67 percent of *all* respondents and 72 percent of respondents who work full-time stated that travel delays (on either roadways or on public transit services) have caused them to "leave earlier or later to avoid the busiest times of day."[34] With respect to full-time workers who exclusively drive, 71 percent of these respondents have adjusted their commuting routines.

Another notable shift in commuting behaviors is the rise of the reverse commute. As businesses develop or locate outside of the urban core, people living inside or around the urban core will commute in the opposite direction of peak period travel. While workers making such "reverse commutes" have historically had the benefit of relatively light traffic volumes, growth in the number of reverse commuters[35] means drivers are increasingly likely to face congestion no matter what direction they are headed in. Reverse commutes are also less served by public transit systems, making it harder for non-car owning reverse commuters to escape bad traffic.

The AET gantry data presented in the previous chapter not only clarifies the volume and speed relationship, but also informs questions about commuting trends and behaviors, including where there is evidence of peak spreading and reverse commuting.

AET gantry 4 captures commutes in the Springfield area. Data shows that traffic volumes begin to rise starting around 5 a.m. east and westbound. Volumes remain steady throughout the day, with cars passing under the gantries at a rate of over 1,000 vehicles per hour through 6 p.m. Headed westbound, traffic volumes are highest at 7 a.m. and eastbound at 4 p.m. The gradual increases in the early morning and afternoon periods and consistency of rising volumes in opposite directions at either end of the day suggest that Springfield area workers are not yet peak-spreading nor engaging in much reverse commuting. Even during the peak periods, traffic speeds remain above the posted speed limit, indicating that even when traffic volumes are heaviest, they are not high enough to induce congestion.

Speed and volume trends are not as consistent on the corridors leading into and around Greater Boston. At AET gantry 8 in Southborough headed eastbound towards the metropolitan region, traffic volumes jump from 1,000 vehicles per hour to 4,000 vehicles per hour between 4 and 5 a.m., and remain elevated until

[32] Registry of Motor Vehicles, Massachusetts Department of Transportation.

[33] Federal Highway Administration (FHWA), 2009. "Impacts of Higher Fuel Costs." https://www.fhwa.dot.gov/policy/otps/innovation/issue1/impacts.cfm; U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, January 2016. "Fact #906: January 4 2016 VMT and the Price of Gasoline Typically Move in Opposition." https://www.energy.gov/eere/vehicles/fact-906-january-4-2016-vmt-and-price-gasoline-typically-move-opposition

[34] MassINC Polling Group, April 2019. "Gridlock: Stopped in Traffic, Delayed on Transit." https://static1.squarespace.com/static/59a6d1d0e9bfdf582649f71a/t/5cc043534192025ff55e3892/1556104021235/Report+2019+03+Barr+Transpo+Issues.pdf

[35] In other words, the number of people who live in Boston and are employed outside of Boston, according to LEHD data for 2012 and 2015.

10 a.m. Speeds are correspondingly affected, although vehicles are able to travel above posted speed limits for most of the day. Headed westbound, traffic volumes are highest from 3 to 7 p.m. and speed falls below the posted speed limit of 65 miles per hour until about 6 p.m., when volumes begin to fall and speeds again increase.

At AET gantry 11 in Newton, however, traffic volumes headed both eastbound and westbound begin to precipitously rise at 5 a.m. and volumes are significantly elevated but inconsistent throughout the day. The spike in volumes at 5 a.m. and the elevated volumes in both directions throughout the day suggest peak spreading as well as reverse commuting. Given the location of AET gantry 11, this makes sense: it is between downtown Boston and the I-95/128 belt, two major employment centers in the region.

At AET gantry 15 on the Tobin Bridge, southbound traffic volumes spike between 4 and 5 a.m. and traffic speeds drop to below the posted limit. The early hour and the rapid rate of change in traffic volumes suggests peak spreading. And yet, while volumes are at their height at 6 a.m., speeds are not at their lowest (15 miles per hour) until 8 a.m. Although volumes decline throughout the day, speed varies greatly, particularly between 3 and 5 p.m., despite low traffic volumes. Other impediments beyond traffic volume could affect travel speeds.

Headed northbound on the Tobin, trends in traffic volumes throughout the day are more stable than volumes headed southbound, but there is a spike in traffic volumes as early as 2 p.m., which again suggests peak spreading. There is also again a clear relationship between traffic volumes and speeds: the time when volumes are highest headed northbound (between 2 p.m. and 6 p.m.) is the only period when travel speeds fall below posted limits.

Telecommuting One trend that can affect roadway congestion especially during peak travel periods is telecommuting, also known as telework or working from home. Nationally, there has been an increase in the proportion of workers who work from home. Indeed, as of 2017, a higher share of workers nationwide telecommute or work from home than use transit.[36]

In Massachusetts, however, a larger share of workers ride transit than work from home. Just 5.3 percent of workers across both Massachusetts and the Boston metropolitan statistical area worked from home or telecommuted in 2017, compared to 10.4 and 13.4 percent of workers who rode public transit.

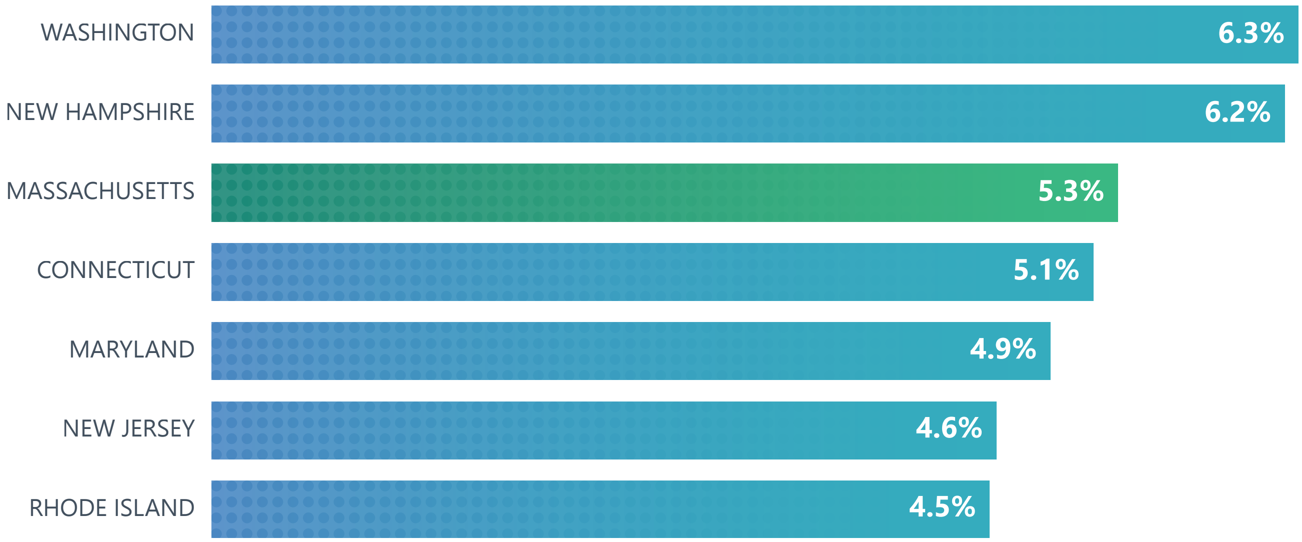
The number of companies that allow telecommuting grew 70 percent between 2010 and 2017 in New England.[37] But there is a markedly lower share of home-based workers in Massachusetts and the Boston region than in other states or metro areas: the

Figure 73. Percent of Workers Commuting via Transit and Working from Home, *2008–2017*

[36] The American Community Survey (ACS) asks respondents to indicate how they usually got to work last week; among the possible response options is "'Worked at home'." These figures do not exclude workers who are self-employed or part-time workers.

[37] Global Workforce Analytics & Flexjobs. (n.d.) 2017 State of Telecommuting in the U.S. Employee Workforce. https://www.flexjobs.com/2017-State-of-Telecommuting-US/

Figure 74. Percent of Workers who Work From Home, MA vs. Peer States



Seattle, Atlanta, San Francisco, and Raleigh metro areas have home-based work rates of 6.3, 7.25, 7.3, and 9.1 percent, respectively. Nationally, Massachusetts ranks 20th of all states and the District of Columbia with respect to workers who telecommute or work at home, lagging far behind Colorado, where 8.5 percent of workers were home-based in 2017. Compared to our peer states,[38] Massachusetts falls in the middle, lagging Washington State and New Hampshire but with a higher share than Connecticut, Maryland, New Jersey, and Rhode Island.

Studies show that telecommuting is associated with more positive work experiences[39] and improved job performance.[40] Some organizations, including Charles River Analytics and UMass Medical School have even started to advertise flexible work schedules as benefits or perks of employment, with telecommuting as one type of "flexibility" usually offered. With congestion in the state and in the Boston region in particular at its worst during the peak morning and afternoon travel periods, more people teleworking could have a significant impact on roadway volumes and congestion.

Of course, not all workers in all industries have the opportunity to telework. Nurses, retail and restaurant workers, and construction workers usually need to be on-site in specific places at specific times of day. But some industries and occupations are well-suited to telecommuting, including the medical research, technology, and financial sectors that are vital to the Massachusetts economy.

Vehicle Miles Traveled VMT is a measure of how much people travel. It is also a measure of how much roadways are being used.

National trends over time show pronounced VMT growth in most parts of the country in recent years and Massachusetts is no exception. According to data collected by MassDOT and reported to the FHWA's Highway Performance Monitoring System (HPMS), VMT on all roadways in the state grew by 13.8 percent between 2007 and 2017,[41] the most recent year with available data.

Growth in the amount of travel and the subsequent growth in roadway volumes that contribute to congested conditions are largely driven by eco-

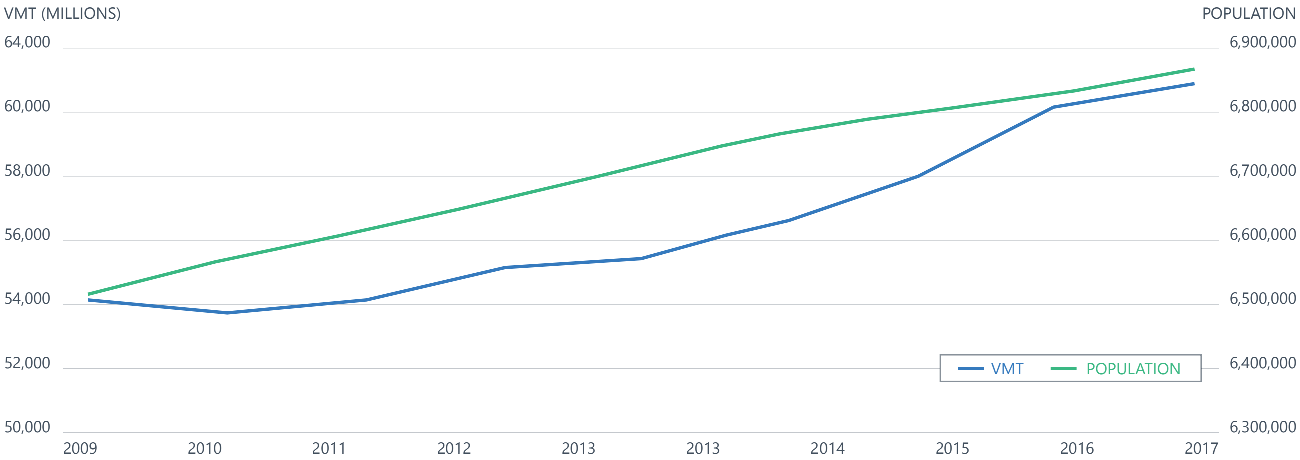
38 Hendren, P., & Niemeier, D. (2008). Identifying peer states for transportation system evaluation and policy analyses. Transportation, 35(4), 445-465.

39 Allen, T. D., Golden, T. D., & Shockley, K. M. (2015). How effective is telecommuting? Assessing the status of our scientific findings. *Psychological Science in the Public Interest,* 16(2), 40-68.

40 Golden, T. D., & Gajendran, R. S. (2018). Unpacking the role of a telecommuter's job in their performance: Examining job complexity, problem solving, interdependence, and social support. *Journal of Business and Psychology.*

41 Bob Frey, Office of Transportation Planning, MassDOT. Note: MassDOT's traffic counts contractor updated the methods by which they collect daily traffic data in 2017-2018.

Figure 75. Trends in VMT vs. Population, *2009–2017*



nomic and population growth. The Massachusetts economy has been growing steadily since 2010, which is when VMT also began to grow after slightly falling from 2009, and individuals are driving a little more. While the state's population grew by 5.4 percent between 2009 and 2017,[42] VMT per capita grew by 8.5 percent.

According to research commissioned by MassDOT, the vast majority—86 percent—of all VMT generated in Massachusetts can be attributed to vehicles that are garaged here, meaning most of the travel in the state is generated by state residents[43] rather than out-of-state workers or those driving through Massachusetts on their way elsewhere.

Transportation Network Companies (TNCs) The public's widespread adoption of ridesharing services such as Uber and Lyft has been swift. According to data recently released by the Department of Public Utilities, which oversees TNC activities in Massachusetts, rideshare use rose 25 percent from 2017 to 2018.

The use of TNCs varies greatly by region and community. TNC use is concentrated in Greater Boston and other large municipalities, but even there continues to account for a relatively small proportion of all trips. According to trip data calculated by the Metropolitan Area Planning Council, TNC trips accounted for just 4.4 percent of all trips that originated in Boston in 2018. In Cambridge, Somerville, and Brookline—the next top municipalities with respect to TNC use—TNC trips are 4, 3.8, and 3.2 percent of all trips originating in these towns, respectively.[44]

In fact, most of the growth in rideshare trips has been in communities outside of Greater Boston. Some of the smallest and least dense communities in the state saw the use of companies like Uber and Lyft double, including Palmer, Templeton, and Adams.

TNCs consider most data related to trips and services proprietary and as a result, transportation policymakers have little insight into the nature of and patterns about the services they provide. However, some evidence suggests that TNCs are adding to problems of local congestion rather than alleviating them. While rideshare services may get people to leave their car at home, these people are still traveling in vehicles and not making walking or bicycling or transit trips, thus contributing to already heavy traffic volumes on local roads. Rideshare services are also associated with a significant number of "deadhead" miles run up by drivers cruising around alone in between calls for rides.

[42] U.S. Census Bureau Population Division, Table 1. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2018 (NST-EST2018-01); U.S. Census Bureau, American Community Survey (ACS) 2005-2009 5-year data. Table B01003.

[43] Office of Transportation Planning, MassDOT. 2019. "MassDOT VMT by State Origin Analysis."

[44] Percentage of total TNC trips by municipality is available only for the communities MAPC services.

The lack of municipal regulation and enforcement with respect to how TNCs operate can also jam up roadways. In the absence of dedicated pickup and drop-off lanes or lots, for example, TNC drivers often pull over where it is most convenient to accommodate riders, including in active travel lanes or in ways that temporarily block other drivers. The effects of these seemingly minor diversions accumulate and can create dangerous situations for both drivers and passengers while contributing to and exacerbating roadway congestion.

ROADWAY NETWORK

Roadway geometry Another factor that influences recurring congestion is the physical layout of roadways. Although roadways are planned to allow for the most efficient flow of traffic, they can over time accumulate congestion-exacerbating features, such as lane reductions and sub-standard on- and off-ramps.

While lane reductions and ramps are necessary for various reasons, including safety, accessibility, and agreements with municipalities and other stakeholders, there are particular sites in the network where roadway geometry is known to impede traffic flow.

Not every feature of physical roadway geometry impedes traffic flow to the point where it becomes a "bottleneck" that causes recurring congestion. Figures 76 and 77 illustrate the location of geometric issues such as curves, ramps and lane drops throughout the National Highway System and demonstrates that many are not in locations that are congested or highly congested. In those cases, fixing roadway geometry is not an effective tool for addressing congestion, although geometric issues may warrant correction if a project is otherwise being implemented in that area to address asset condition or safety issues.

Regional Bottlenecks Some issues affecting the roadway network do rise to the level of a major regional bottleneck, where the size and/or geometry of an intersection is contributing in a significant way to recurring congestion (and, in some cases, safety issues). While there is no definitive definition of what constitutes a regional bottleneck, factors that MassDOT considers include:

- Current and future projected traffic volumes.
- Congestion at the bottleneck and its contribution to congestion on surrounding roadways.
- Roadway geometry issues and how difficult it would be to address them.
- Safety issues (e.g., number of serious crashes occurring at the intersection or on the roadway segment).
- Significance of the location not only for passenger travel but for regional economic development and/or freight transport.

One example of a regional bottleneck that MassDOT is focusing on is the interchange where the Mass Pike and I-495 meet. This project was chosen for inclusion in the Capital Investment Plan because the interchange contributes to congestion on the surrounding roadways, serves significant amounts of freight traffic and addresses issues of both safety and congestion.

Another example of a regional bottleneck that warrants attention, including increased capacity, involves the two bridges that connect Cape Cod to mainland Massachusetts. The Sagamore Bridge, for example, is congested for 11 hours per day. MassDOT has advocated for the Army Corps of Engineers to replace both of those bridges and to add an additional lane in each direction on both bridges. Traffic analysis done as part of the Cape Cod Canal Transportation Study indicates that additional bridge capacity will substantially improve travel conditions, although it will not eradicate all summertime traffic congestion.

One vexing question for transportation professionals is how best to address local and regional bottlenecks. In many cases, roadway expansion is not an effective way to alleviate congestion. Roadway expansions frequently lead to higher roadway volumes, a phenomenon known as "induced demand". State and local agencies who have experimented with expanding roadway capacity by adding more pavement and mileage have frequently found that any capacity that was added led to collateral increases in traffic that almost immediately

Route 128 Add-A-Lane Project

The Massachusetts Highway Department began construction of the "Route 128 Add-A-Lane" project in 2003. This project consisted of widening 13.7 miles of the Yankee Division Highway, the roadway segments where I-95, Route 128, and I-93 all run concurrently, from a six-lane highway to an eight-lane highway in between Route 9 in Wellesley and Route 24 in Randolph. Nineteen over- and under-passes along the 13.7 mile stretch of highway were rebuilt to accommodate the added lane. The project took about 16 years to complete, with the last phase completed in the Spring of 2019 to a cost of around $420 million.

Although the Route 128 Add-A-Lane project may have slightly increased capacity of I-95/I-93/128 by constructing a fourth lane in each direction, congestion management was not the rationale behind this project—rather, it primarily sought to eliminate travel on the shoulder, a practice that raises major safety concerns. Adding a lane widened the roadway to current Interstate standards, allowed for more emergency pull-off areas, and fixed some of the poor roadway geometry features at on- and off-ramps.

Although travel times have improved since the opening of the fourth lane in each direction between Route 9 in Wellesley and Route 24 in Randolph, the I-95/128/I-93 corridor still experiences congestion on most of its segments during the peak hours.

I-495/I-90 Interchange

The intersection of I-495 and I-90 in Westborough frequently sees congestion, not only on the on and off ramps, but often on the surrounding roadways as well. As the meeting of two of the major east-west and north-south roadways that traverse the state, this interchange is significant not only for residents of the Commonwealth traveling locally, but for interstate commerce and freight transport as well as interstate travelers.

Given this significance as well as the increasing concerns around traffic congestion, MassDOT is leading a modernization project to improve traffic flow on the interchange and on the roadway segments leading up to it. The design phase for the I-495/I-90 Interchange Improvements Project began in 2017 with the purpose of improving safety and operational efficiency of the system interchange. The goals of the project include reducing recurring congestion by improving queuing behavior and travel time through the interchange. The project is specifically exploring new roadway configurations that could alleviate backups due to inefficient lane change and merging behaviors.

eliminated any benefit that the expansion was supposed to introduce.[45] Unfortunately, it appears that the more roadway there is, the more people are incentivized to use it.

Another problem with trying to add capacity in order to alleviate regional congestion bottlenecks is the amount of time and money involved. At least part of the project to add a lane to Route 128 between Route 9 in Wellesley and Route 24 in Randolph has been under construction since 2003. The project, just now being completed, has cost an estimated $420 million.

[45] Houston, Texas (Katy Freeway): https://www.citylab.com/transportation/2018/09/citylab-university-induced-demand/569455/; LA Metropolitan Area (Interstate 405 between Interstate 10 and U.S. Route 101): https://usa.streetsblog.org/2019/05/08/l-a-really-is-a-great-big-freeway-thanks-to-induced-demand/; Denver, CO (Interstate 25): https://denver.streetsblog.org/2016/08/26/after-I-25-was-widened-it-filled-back-up-with-cars-in-less-than-5-years/; Portland, OR (Interstate 5):http://cityobservatory.org/backfire_wider_worse_traffic/

Figure 76. Roadway Geometry and Levels of Congestion, *Statewide*

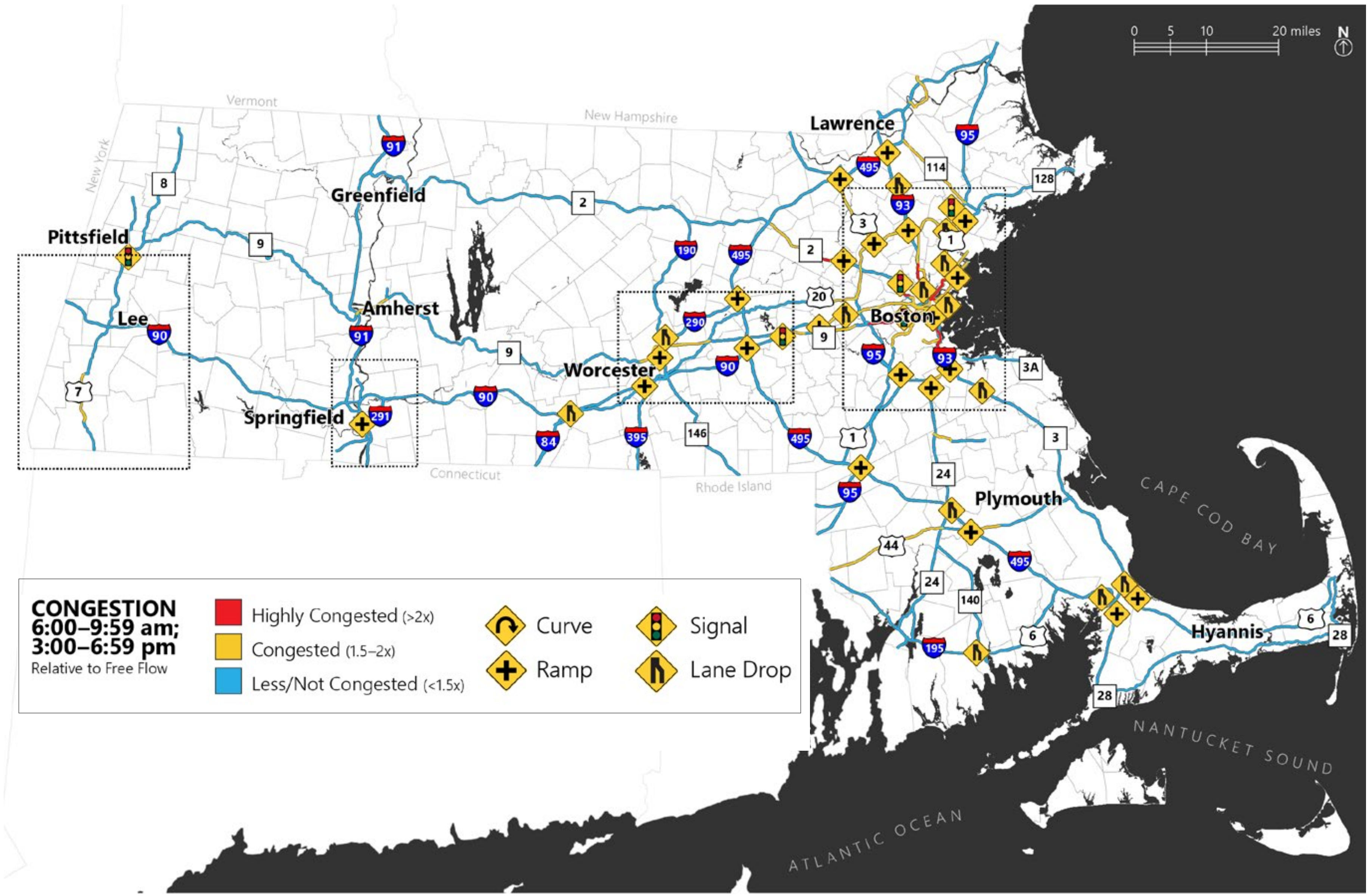
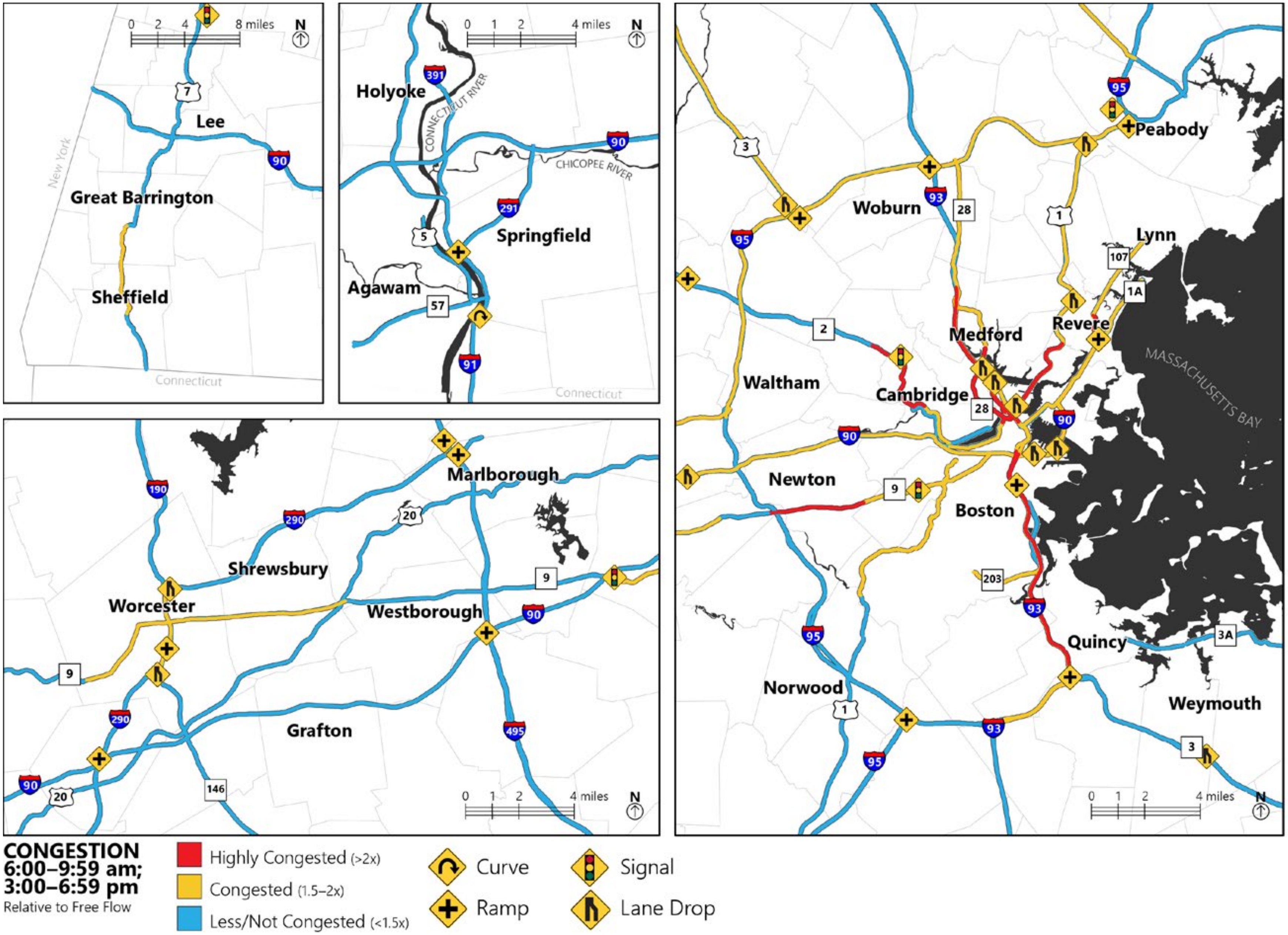


Figure 77. Roadway Geometry and Levels of Congestion, *Metro Area Insets*



Every regional bottleneck, however, needs to be evaluated on a case-by-case basis, and some will warrant the time and cost required for reconstruction.

In some cases, such bottlenecks can be addressed through less complicated and expensive interventions. A good example is the Middleborough Rotary. While awaiting 25 percent design on a proposed $80 million reconstruction of the rotary, MassDOT developed a traffic flow solution which was implemented in months rather than years and at a cost of $1.4 million. Completed in October 2018, the project has increased travel speeds even during the periods of heaviest traffic volumes.

Middleborough Rotary

The interchange known as the Middleborough Rotary, where five roads merge, including state highway Routes 44, 18, and 28, is just a few hundred feet from I-495 and has historically been a known site of local congestion. In addition to affecting daily commuting, the rotary has a high crash rate. MassDOT has been working to design a comprehensive revamp of the interchange's road geometry and grade changes which would cost an estimated $80 million and take years to design, permit, and construct.

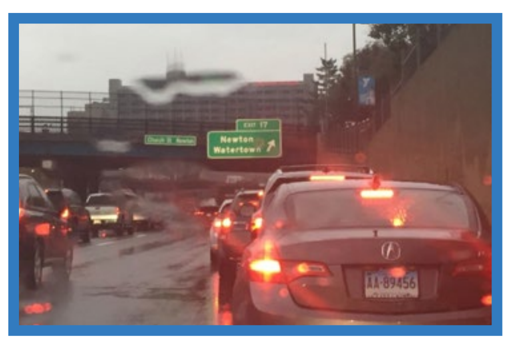
In order to provide more immediate relief, MassDOT worked with stakeholders and developed a solution that could be executed quickly while still introducing improved traffic flow to the rotary. Specific improvements included restriping and reconfiguring existing geometries within the rotary itself as well as on the roadway segments that approach it. Given the priority and significance of this project, MassDOT worked expeditiously to achieve improvements. The project was advertised in 2017 and completed by October 2018 at a final cost of $1.4 million.

The improvement has already made a significant difference in in reducing delay and congestion and enhancing overall mobility through the area. One public comment reads:

> I just wanted to congratulate you on the Hwy44/18 rotary reconfiguration project in Middleboro. I commute from Plymouth to Lakeville through that rotary every workday and have for the last 20 years. The improvements your dept. made to that rotary have resulted in an amazing increase in efficiency and probably safety. Before the reconfiguration, I would take alternate routes to avoid taking 44 directly to the rotary—this based on GPS directions for fastest route. Since completion, my GPS directs me straight to the rotary and I save 3-5 minutes on my commute time—not to mention all the frustration of sitting in traffic! THANK YO

Travel data collected since the rotary upgrades were made show that average hourly travel speeds during the periods of heaviest traffic volumes range between 22 and 35 miles per hour. Given a posted travel speed of 25 miles per hour through the rotary, there is enough capacity to accommodate demand during high-travel periods and keep traffic flowing at or near the speed limit.

Traffic Control and Local Bottlenecks Poor traffic control systems, such as traffic signals, also contribute to recurring congestion. While signals are primarily on local roads (which are not included in this study), their impact on traffic flows have domino effects that can impact traffic operations on other roads, such as highways. An example is exit 17 headed eastbound on the Mass Pike, which provides access to Newton Corner. This is a notorious off-ramp, where traffic backs up onto travel lanes on the interstate because of local roadway geometry and an antiquated traffic signal equipment that does not allow for optimized signal progression on the other side of the ramp.



Source: Photo courtesy Foursquare.com.

Although local roads are not the focus of this study, they are nonetheless significant sites of congestion. Local roads account for 81.1 percent of all roadway miles in the state,[46] and all traffic travels on local roads at some point in their trip. Many factors related to signal operations on local roads, including their timing and placement, has direct and meaningful impacts on the way that traffic flows through cities and towns and across the state.

Adaptive Signal Control Technologies and Retiming Initiatives

Over the last six years, MassDOT has been ambitiously advancing the implementation of Adaptive Signal Control Technologies (ASCT), an operations strategy that is far more dynamic than traditional signalization and incorporates real-time data collected from network system detection. This data is used to evaluate volume demand and adjust green times for optimal progression. ASCT is an important tool to combat congestion as it can react to and adjust for events (e.g., crashes, incidents and special events) that cannot be anticipated by traditional time-of-day timing plans. ASCT advancements are currently in the design phase, under construction, or in operation at close to 200 locations throughout the Commonwealth.

ASCT was introduced in Burlington in 2018. ASCT tools were installed at 27 signalized intersections along Burlington Mall Road, Cambridge Street, and the Middlesex Turnpike. The ASCT system along these corridors have led to more thorough and accurate data collection with respect to travel times and has introduced the capability to automatically evaluate traffic patterns and update signaling algorithms to accommodate and improve flow—a feature that has particular relevance for seasonal increases in traffic volumes around the Burlington Mall, in instances of traffic surges due to events on adjacent I-95, and the ability to manage the passage of emergency vehicles as they approach Lahey Clinic and nearby fire stations. The success of ASCT in Burlington has led to plans to expand the use of these technologies.

In early 2017, the MassDOT District 3 Highway Division studied a corridor of Route 20 in the Charlton area to determine if signal timing adjustments would improve throughput. A review of signal performance meausures noted that the Route 31 Northbound left turn movement needed more green time, particularly during the afternoon peak period, and that other conflicting signal phases had spare capacity. MassDOT traffic engineers then increased the time provided for the northbound left turn phase by five seconds. The signal performance measures allow the District to compare operations before and after the change, which show that the percentage of cycles with a split failure decreased from approximately 22 percent of cycles to approximately 9 percent of cycles, which would reduce the amount of delay experienced for this movement.

MassDOT Highway District traffic maintenance sections regularly evaluate the timing of signals at various intersections along critical routes and retime them as appropriate. For example, in District 3, traffic signals are retimed approximately every three-four years. In addition to optimizing signal timings, regular visits to different intersections allows MassDOT Highway planners and engineers to identify other roadway and signaling inefficiencies that lead to unnecessary travel delays.

While ASCT introduces many opportunities to improve and optimize traffic flow, there are potential challenges to implementing ASCT on corridors that have accommodations and facilities for several modes. For example, MassDOT is looking into understanding how to effectively implement transit signal priority (TSP) technologies on corridors that have ASCT.

[46] Centerline miles.

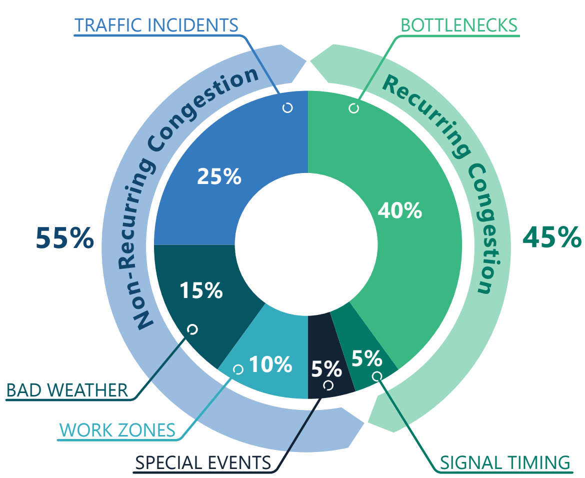
Non-Recurring Congestion

Non-recurring congestion is the congestion drivers face due to travel anomalies, or non-recurring incidents such as breakdowns, crashes, weather, and construction and maintenance projects that cause a reduction of roadway capacity or an abnormal increase in demand.[47]

Non-recurring congestion particularly impacts travel reliability, or the consistency or dependability of travel times. When a problem occurs during periods of heightened traffic volumes like peak commuting periods, the traffic delays associated with the incident accumulate on top of normally lengthened travel times and lead to severe disruptions in the system. Even when a problem occurs during periods of reduced volumes, congestion accrues according to the severity and nature of the incident. Figures 79 and 80 illustrate where all of the crashes in the state were in 2018 with levels of congestion during the AM and peak periods.

According to the FHWA, non-recurring congestion accounts for more than half of all congestion nationwide. While the sizes of each slice of this "congestion pie" may be slightly different in Massachusetts, non-recurring congestion is a significant source of traffic delay.

Figure 78. The Sources of Congestion: National Summary



TRAFFIC INCIDENTS

Events such as vehicular crashes, breakdowns, and debris in the roadway are the most common sources of non-recurring congestion. In addition to temporary physical reductions in capacity, traffic incidents can also distract drivers and decrease speeds through impacted areas.

An example is an early morning crash that occurred on Tuesday, March 27, 2018 on I-93 North in South Boston that caused long delays for commuters. The multi-vehicle crash resulted in the temporary closure of the left travel lane for almost two hours during emergency response. Although the crash was cleared by 6:30 a.m., drivers experienced cumulative and residual delays, leading to travel times up to double the average for the next three and a half hours. Normal travel times did not resume until almost 11 a.m.

The MassDOT Highway Operations Center actively pursues strategies to enhance incident detection, response, and recovery practices, including the use of intelligent transportation system technologies, media outlets, direct relationships with law enforcement and highway districts, and social media and crowdsourcing applications to monitor and report on roadway conditions and incidents in an accurate and timely manner.

47 U.S. Department of Transportation, Federal Highway Administration (FHWA), January 2010. "2010 Traffic Incident Management Handbook Update." https://ops.fhwa.dot.gov/eto_tim_pse/publications/timhandbook/chap1.htm

Traffic Incident Management (TIM): Emergency Service Patrols

MassDOT currently operates various service patrols to address incidents that contribute to non-recurring congestion:

- Emergency Service Patrol, covering I-90 from New York to Boston;
- Incident Response Operators, which provide towing service throughout the Metropolitan Highway System, including its tunnels; and
- Highway Assistance Patrol, covering 13 major state roadways and interstates.

These patrols provide a host of services along 34 high volume routes, including changing flat tires, charging batteries, removing debris from the roadway after a crash, providing gas, helping motorists contact AAA, coordination of towing assistance, and providing emergency medical assistance.

The Highway Assistance Patrol operates Monday to Friday during peak periods. During holidays, HAP extends the geographic scope of patrols to accommodate additional roadways. On the Mass Pike, ESPs provide assistance 24 hours a day, seven days a week, as do Incidence Response Operators working closer to the urban core. Collectively, these patrols had over 80,000 interactions with motorists in 2018.

Traffic Incident Management (TIM): Safe & Quick Clearance and the Unified Response Manual

While not a formal element of the Transportation Systems and Management Operations program, MassDOT has advanced policies, training, and capabilities regarding safe and quick clearance of traffic incidents, also known as Traffic Incident Management (TIM). Nationwide, according to the FHWA, TIM efforts are credited with reducing annual delay by 129.5 million hours, with an associated cost savings of $2.5 billion.

In 2014, MassDOT led the development of the Incident Management Task Force Committee. This committee created the Unified Response Manual (URM), a series of guidelines and best practices to follow in response to roadway traffic incidents. The URM—the development which itself was identified as a best practice for states to emulate by the FHWA—establishes a comprehensive statewide traffic management plan for use by all responders to all Massachusetts highway roadway incidents. The URM combines the essential elements of unified command, accepted standards of fire and life safety and emergency medical response, as well as the latest traffic management, incident management, and hazardous material mitigation standards.

As of July 1, 2019, MassDOT has trained over 6,500 first responders in the state on the concepts and principles associated with safe quick clearance and traffic incident management. With 55 percent of its training goal achieved, MassDOT was recently recognized by the FHWA as having one of the highest scoring TIM programs in the country.

Figure 79. Total Crashes and Level of Congestion in Peak Hours, 2017–2018, *Statewide*

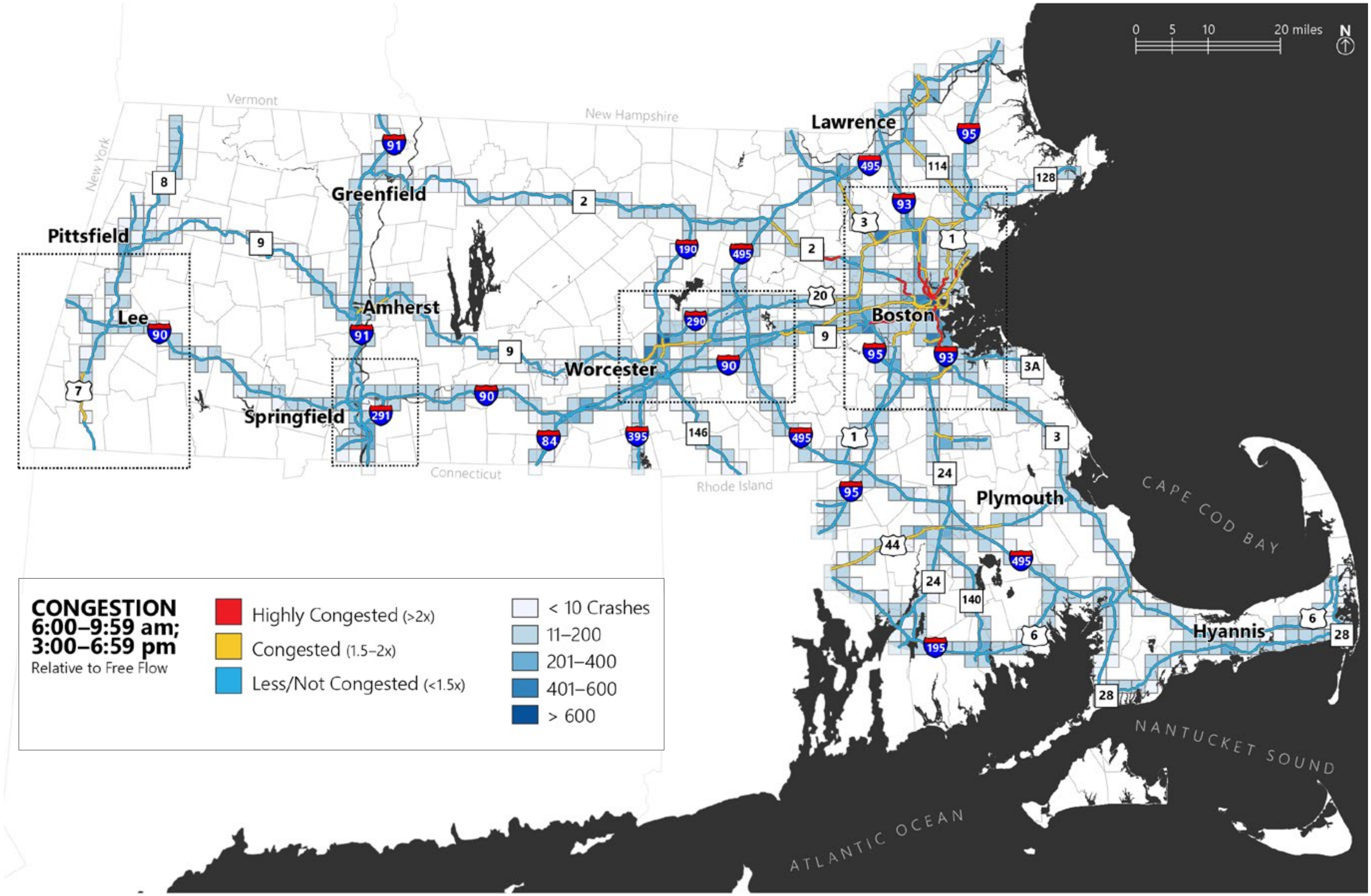
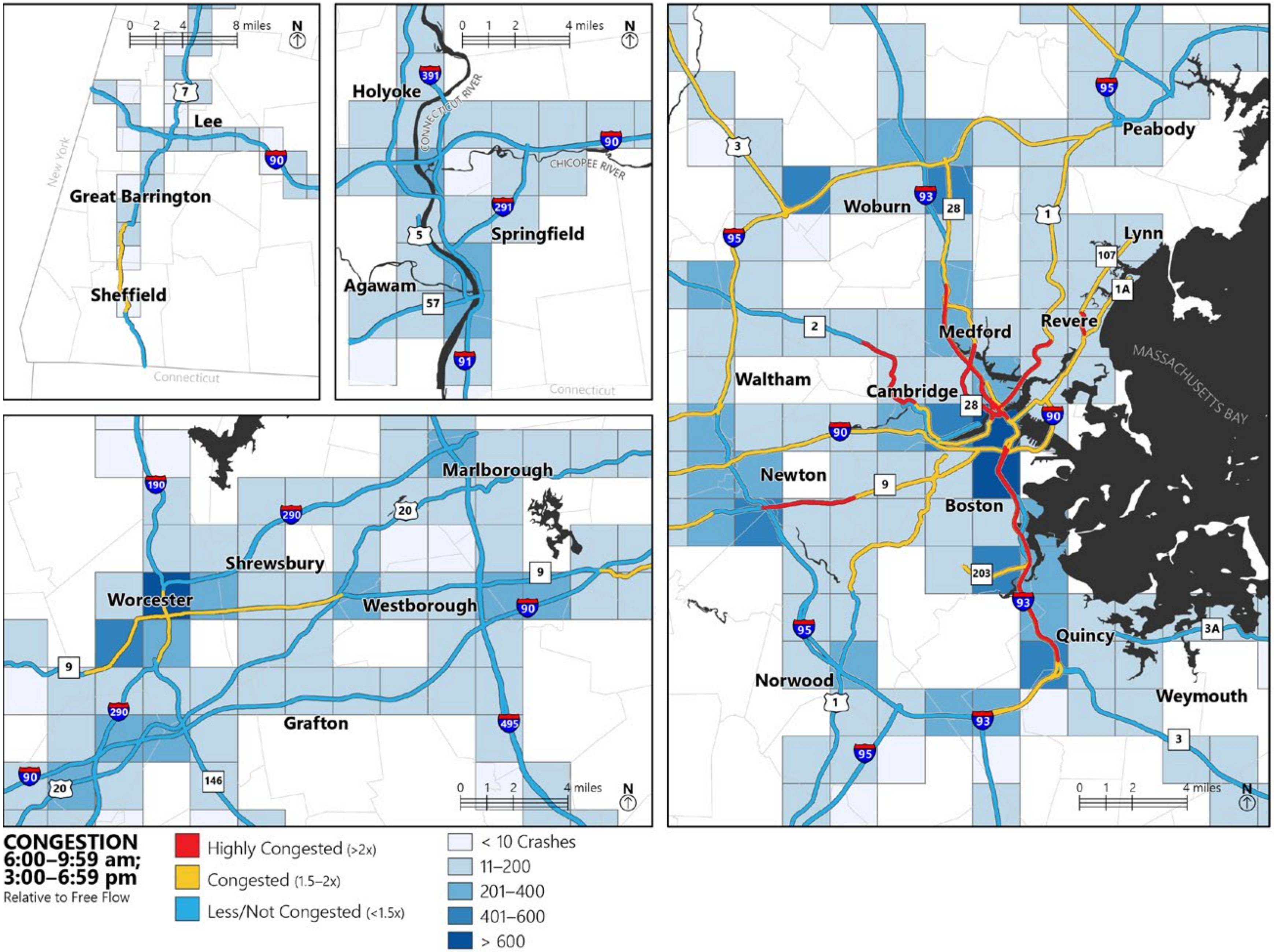


Figure 80. Total Crashes and Level of Congestion in Peak Hours, 2017–2018, *Metro Inset*



WEATHER

Environmental conditions can lead to changes in driver behavior that affect traffic flow. Massachusetts roadways are prone to significant rain, sleet, ice, and snow, as well as fog, wind, and solar glare (primarily on east-west roadways such as Routes 2 and 9). In many cases, these conditions reduce visibility or traction and drivers may reduce speed and/or increase the distance to the vehicle in front of them. These changes in behavior affect traffic flow, which in turn can lead to congestion.

MassDOT relies on public weather forecast services and 48 Road Weather Information Stations to monitor and respond to weather events. Detailed data on how weather conditions impact travel trip times suggests that for the most part, weather does not significantly increase congestion on the roadways included in this analysis. The histograms below show how weather impacted three example commutes—from Lynn to Boston, Webster to Worcester, and Amherst to Springfield. Each figure shows vehicle trip times through actual weather conditions (i.e., clear, visibility impaired, light precipitation, and heavy precipitation).

If the weather had a significant impact on the typical trip time, the histograms would have long tails. However, the shape of the bad weather charts follow a similar pattern as the overall trip times do, suggesting that other factors tend to impact trip times more than weather does.

See Appendix F for an explanation of how the histograms are developed.

Figure 81. Weather Map, *Lynn/Boston*

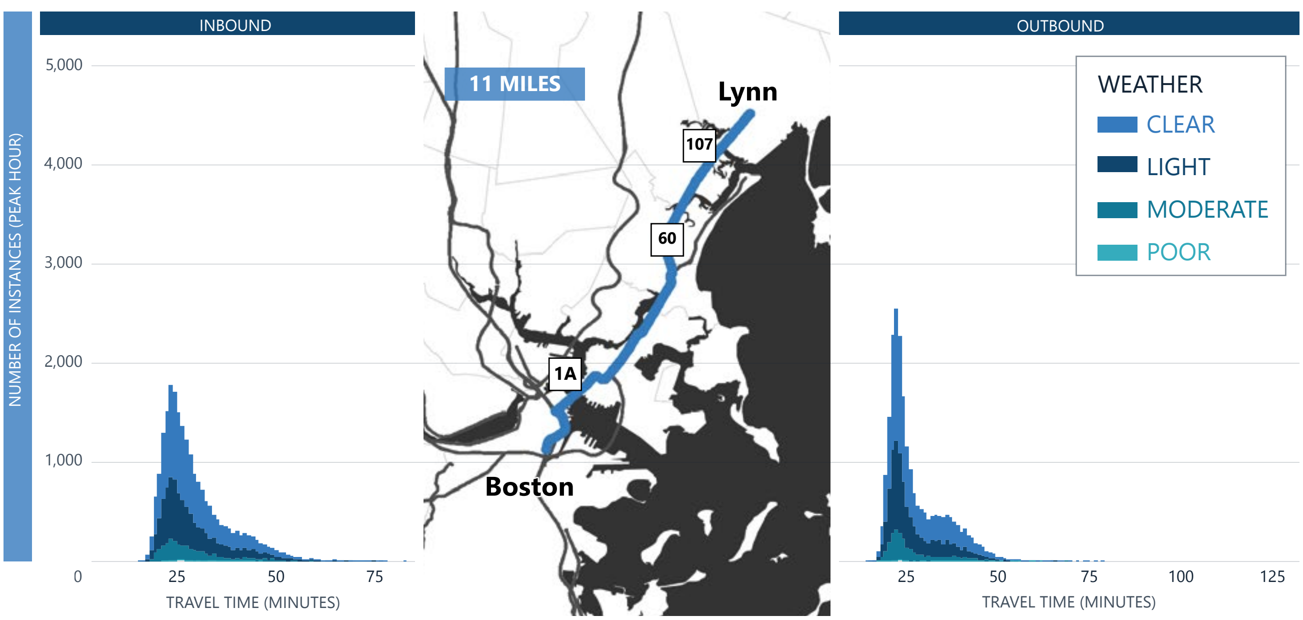


Figure 82. Weather Map, *Worcester/Webster*

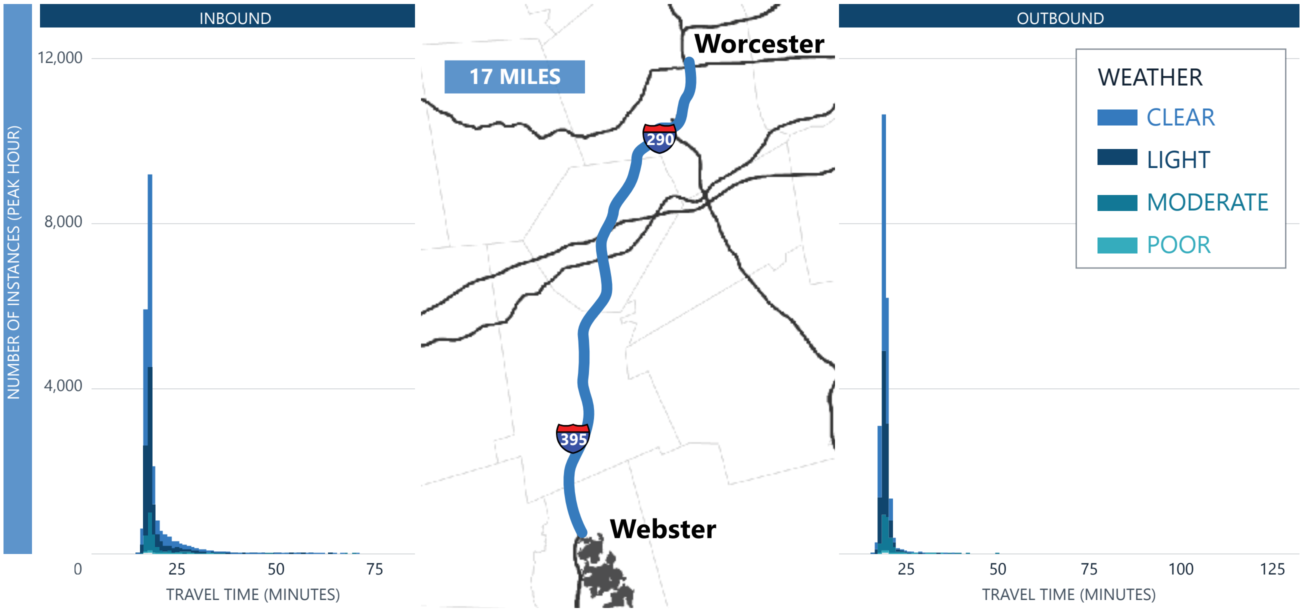
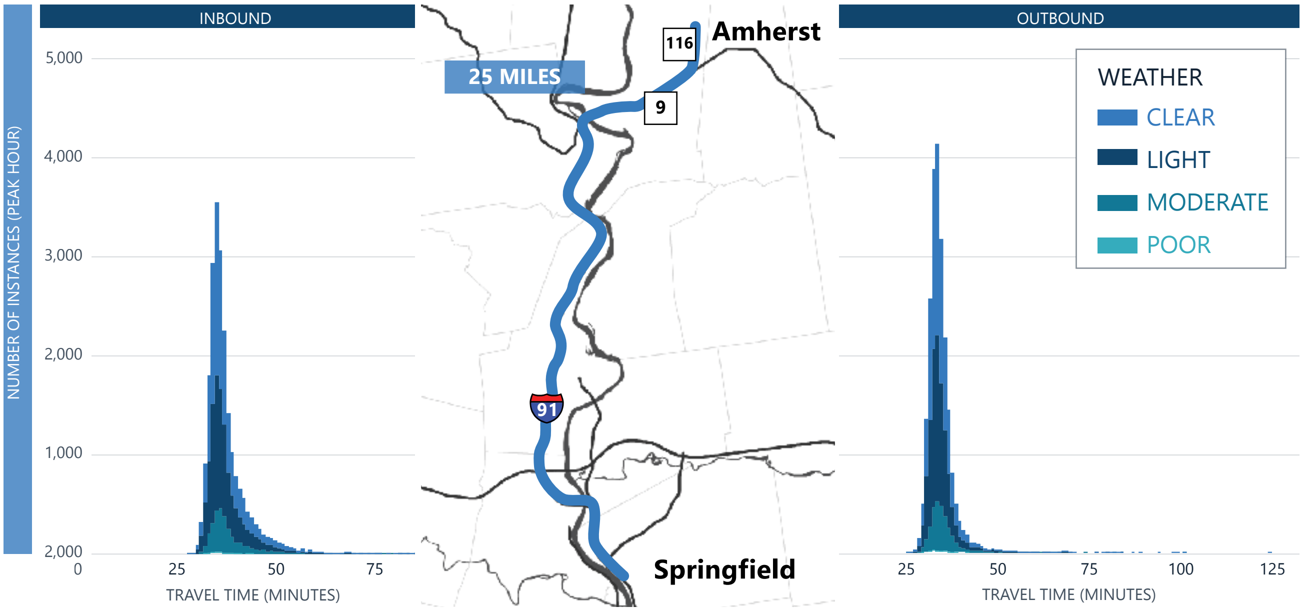


Figure 83. Weather Map, *Amherst/Springfield*



WORK ZONES

Work zones set up for road construction and maintenance activities could include a reduction in the number or width of travel lanes, lane shifts, lane diversions, reduction or elimination of shoulders, and even temporary roadway closures. The degree to which work zones contribute to congestion depends on the duration of construction and how much roadway capacity needs to be reduced. Many times, even when work zones do not physically impact the roadway, curiosity and “rubbernecking” negatively impact speeds. While some construction and maintenance activities can be completed quickly or outside of peak hours, many large-scale or long-term infrastructure projects often require lane or road closures during peak travel periods.

MassDOT has a robust construction program, with over $4 billion worth of investments in the highway system over the next five years. Figures 84 and 85 show major construction projects and congestion classifications in 2017 and 2018 that involved some degree of reduced roadway capacity. Many work zones were located on roadways that had less congested or uncongested road segments, so that even with work zones in place, demand for roadway

Commonwealth Avenue over I-90

MassDOT relied on advanced techniques associated with Accelerated Bridge Construction to expedite the replacement of the Commonwealth Avenue bridge over I-90 (Mass Turnpike) in Boston. Traffic was primarily impacted over two nine-day periods in July and August of 2017 and 2018, when I-90 was reduced to 50 percent or less of existing capacity and Commonwealth Avenue was closed to general traffic. Travel times into Boston on the Mass Pike between Newton and I-93 throughout the day increased by approximately 5 minutes, from 10 minutes under normal conditions to 15 minutes during construction. During the morning peak period, travel time essentially doubled to over 20 minutes. While a notable increase in congestion was associated with this approach, the impact was far less severe than would have been under a traditional construction approach, when construction would last for months if not years.

I-91 Viaduct Rehabilitation (Springfield)

MassDOT took a traditional approach to deck rehabilitation on the I-91 viaduct in downtown Springfield from 2015 through 2018. Over a period spanning more than two construction seasons, one lane out of three was permanently closed in both northbound and southbound directions.

One strategy that MassDOT used to alleviate work zone congestion is the dynamic zipper merge system. Zipper merge systems improve work zone traffic flow by instructing drivers when to merge for a lane closure based on real-time data. Portable electronic message signs are placed along the roadway of a work zone, and drivers are directed to an *early merge* or a *late merge* depending on traffic volumes. A late merge works best for high traffic volumes and slow average speeds because it utilizes the maximum capacity of the roadway by informing drivers to remain in their lanes until the merge point. An early merge works best for low traffic volumes and high average speeds by instructing divers to merge well ahead of the merge point to avoid slowing down traffic. The MassDOT Highway Division first implemented a zipper merge as a pilot during the viaduct rehabilitation. Dynamic zipper merge systems continue to be considered in current and upcoming MassDOT projects whenever appropriate.

While congestion on I-91 grew throughout the construction period, the use of innovative driver communication channels and availability of viable alternative routes (including East and West Columbus Avenues, and Route 5) led to reduced traffic volumes, and travel times increased by only a few minutes on average during peak periods: what is typically a 6-to-7 minute trip increased to approximately 10 minutes on average in the afternoon peak period, between 3:00 and 7:00 p.m.

Figure 84. Long-Term Work Zones 2017–18 and Level of Congestion in Peak Hours, *Statewide*

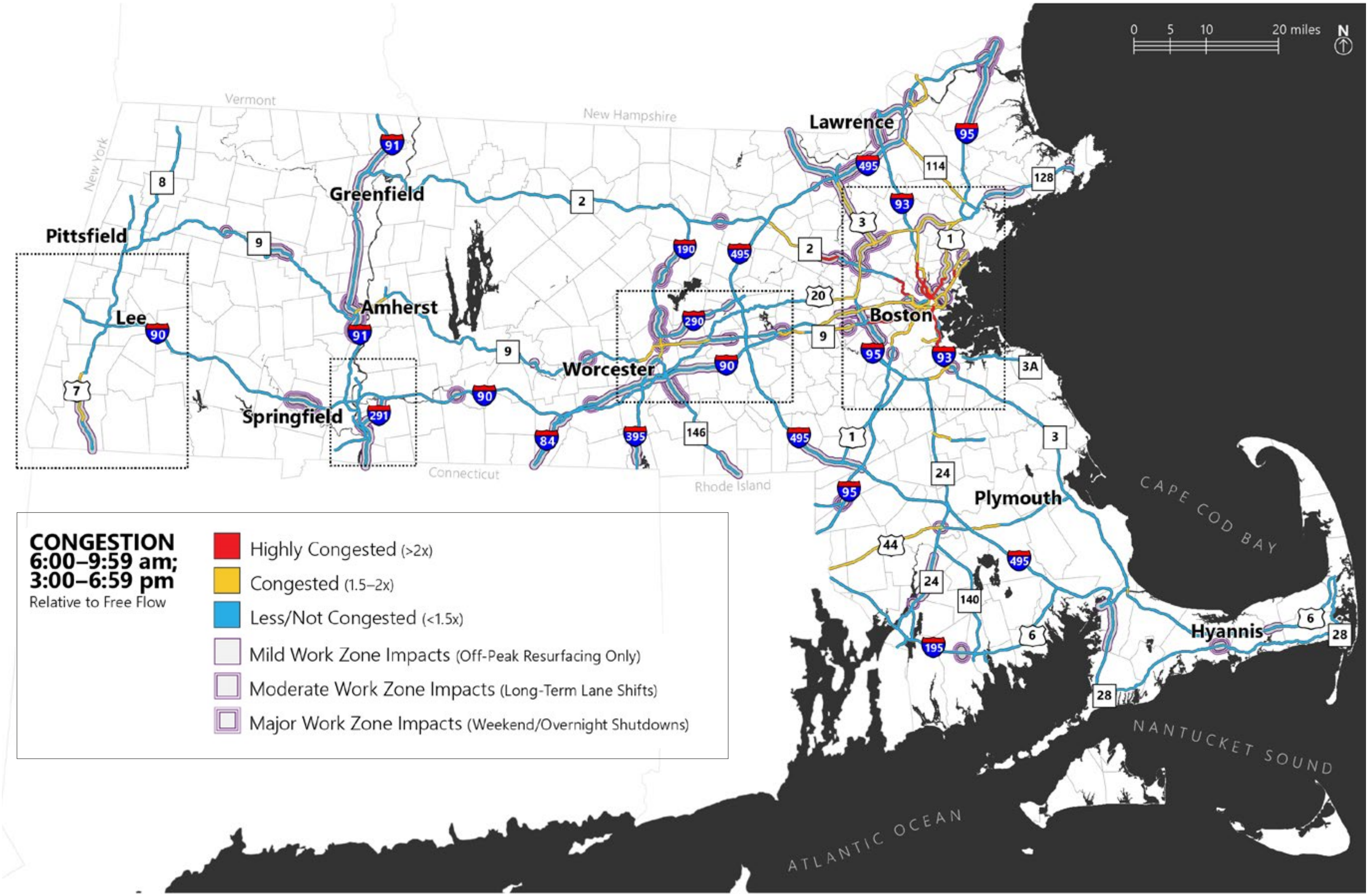
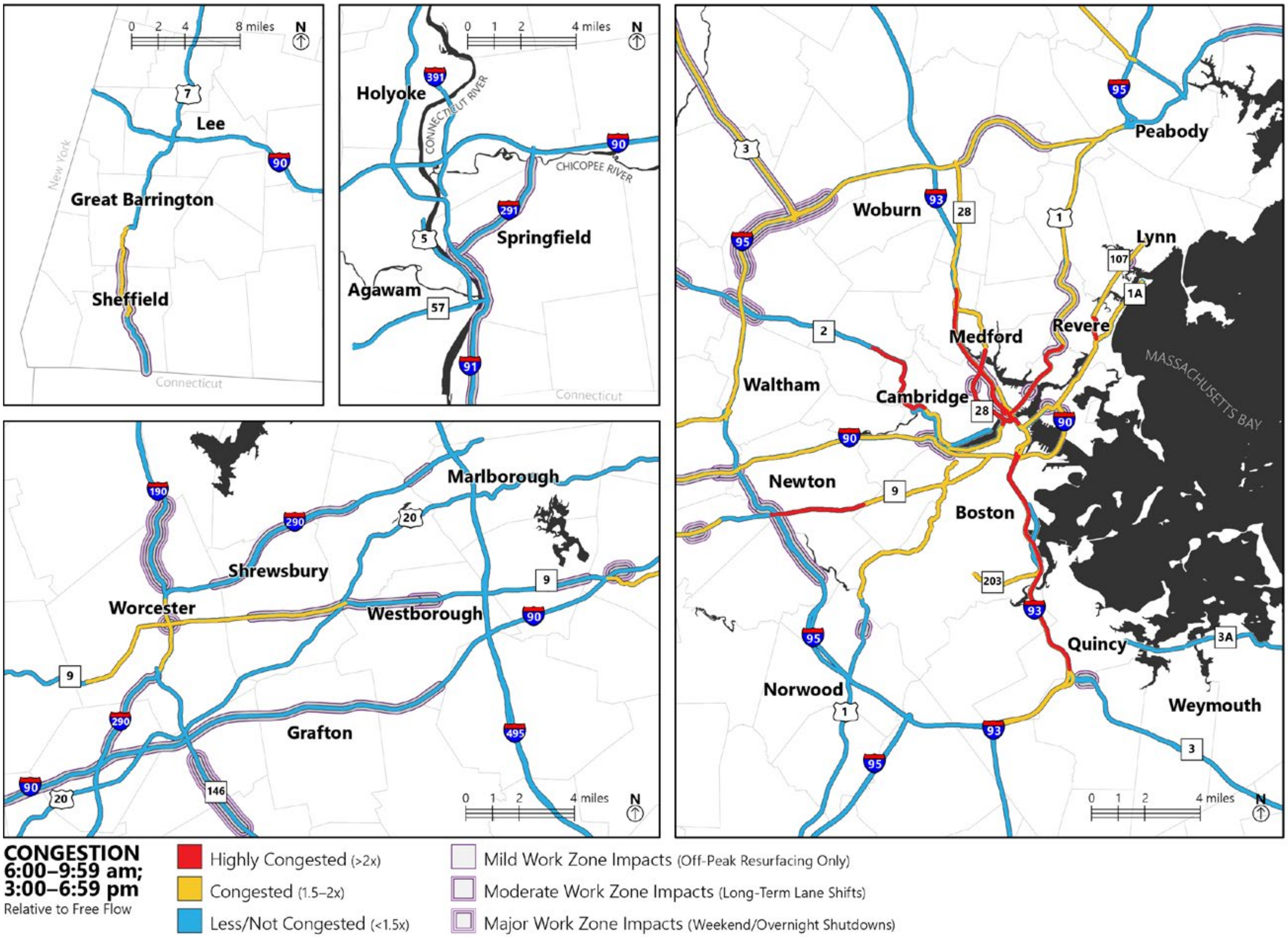


Figure 85. Long-Term Work Zones 2017–18 and Level of Congestion in Peak Hours, *Metro Areas*



space did not exceed capacity. The same cannot be said for all roadways and all construction projects: there are several work zones that overlap with congested and highly congested roadways.

MassDOT has launched a particularly aggressive construction schedule planned for major roadways, bridges and tunnels in and around Boston, one which will continue for a number of years. Many of the projects will affect the same travel corridors, particularly north and west of the city, as shown in Figure 86. MassDOT will use innovative and accelerated construction techniques, such as those used for the reconstruction of the Commonwealth Avenue bridge over the Massachusetts Turnpike, whenever possible but such major construction will undoubtedly impact travel to and from Boston during the next few years.

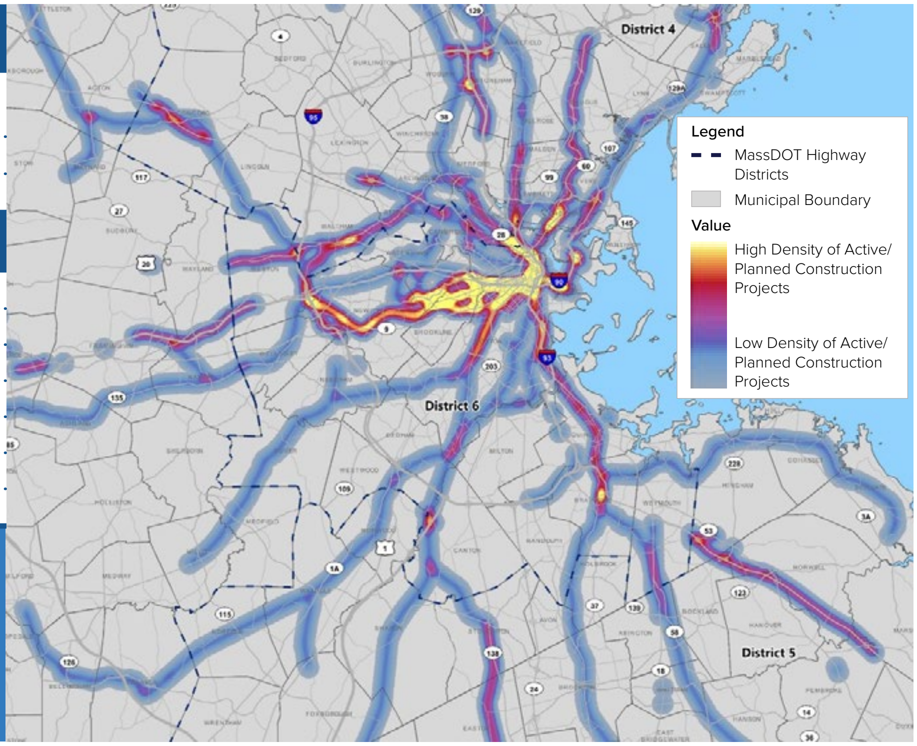
Figure 86. 2019 Project Density Heat Map

Owner/ Proponent	Number	Percent of Total
MassDOT Highway	87	70%
MBTA	32	25%
Other	6	5%

Owner/ Proponent	Number	Percent of Total
Roadway	64	51%
Bridge	17	14%
Transit	32	26%
Ped/Bike	4	3%
Utilities	4	3%
Development	1	1%
Other	3	2%

Highway & transit projects with roadway lane closures, transit service disruptions/ diversions, and/ or parking impacts during all time periods.

Not all projects have fixed work zones.



4 FINDINGS AND NEXT STEPS

By carefully analyzing data about how traffic congestion is being experienced throughout the Commonwealth, this report has laid a solid foundation from which to develop recommendations. To some extent, the data and analysis presented in Chapters 2 and 3 confirm what Massachusetts drivers already know: congestion exists in pockets all across the Commonwealth but is generally worst on the roadways in and around Greater Boston. But a more nuanced understanding of congestion is needed in order to understand what is happening and therefore what can most effectively be done about it. To help frame the recommendations that follow, the next section summarizes the key findings drawn from the data and analysis presented in this report.

Key Findings

First, a reminder: this report almost exclusively provides information on a select network of large roadways in the state called the National Highway System (NHS) because these are the roadways where data is reliably and regularly collected and reported to the federal government. While anecdotal and experiential information suggests that many local roads are also experiencing serious congestion, there is simply no authoritative data reported about them. With that constraint in mind, these are the key findings about congestion in Massachusetts:

1. Congestion is bad because the economy is good. Since 2010, Massachusetts has added 350,000 new residents, nearly 39,000 just from 2017 to 2018. During the same period, employment in Greater Boston (roughly along and within I-95/128) grew by 19 percent, while employment in the rest of the state grew by 12 percent. More people, more households, more workers and more jobs lead to more driving and more congestion.

2. The worst congestion in the Commonwealth occurs in Greater Boston. On an average workday, the worst congestion in the Commonwealth occurs primarily within the I-95/128 belt because this is where the jobs are. In many places along I-93 and Routes 1, 3, 9, 16, and 28, the system is at or beyond capacity at most times of the day. The places and times where congestion on major roadways is most severe are not necessarily in the City of Boston but on the roads leading to it.

3. Congestion can and does occur at various times and locations throughout the Commonwealth. Southeastern, Western, and Central Massachusetts are not free of traffic congestion, but the congestion observed there is generally on a different scale than it is in the Boston area. One concern is the spread of congestion toward the outer reaches of the Boston metropolitan area, from the area inside I-95/128 to the area extending out to I-495 including radial roadways such as Route 3, Route 24 and the Massachusetts Turnpike. While congestion is not as persistently severe outside of Greater Boston, it is nonetheless a source of frustration for drivers who travel along Route 9, Route 7, I-91, I-290, or some western portions of the Mass Pike during peak commuting periods.

Top Five Most Severe Occurrences of Congestion

The top five places and times where congestion on an average day is most severe, defined as where the ratio of average travel time to free-flow travel time is the highest, are:

1. I-93 southbound from Mystic Valley Parkway in Medford to McGrath Highway in Somerville at 7 in the morning
2. Route 2 eastbound approaching Alewife at 8 in the morning
3. The Southeast Expressway northbound from the Braintree Split to Neponset Circle at 7 in the morning
4. Route 2 eastbound approaching Alewife, at 7 in the morning
5. I-93 southbound from Mystic Valley Parkway in Medford to McGrath Highway in Somerville at 8 in the morning

4. Many roadways are now congested outside of peak periods. While the most severe congestion in the state occurs during the morning and afternoon peak travel periods, many roads are congested outside of those time periods, especially but not exclusively in Greater Boston. By 6 a.m., one-quarter of roadway miles inside the I-95/128 belt are already either congested or highly congested and at 10 a.m., 17 percent of those roads are still congested or highly congested. And the afternoon "rush hour" inside Route 128 has begun by 3 p.m., with 62 percent of roadway miles congested or highly congested.

Some people are getting up very early to begin their commutes ahead of the expanding morning rush hour: at the All Electronic Tolling gantries in Southborough and on the Tobin Bridge, traffic volumes spike between 4 and 5 in the morning; the same is true at 5 a.m. at the gantry in Newton.

5. Congestion worsened between 2013 and 2018, especially in Greater Boston. Between 2013 and 2018, peak period travel times increased on almost all roadway segments for which we have data. The most significant increases in travel time— by 50 percent or more in either the morning or afternoon peak or more—occurred on the roads in and around Greater Boston. Statewide, the most significant worsening of congestion is on the southbound segment of Route 1A that includes the Sumner Tunnel and its approaches, where travel times in the morning nearly doubled over the five-year period. Congestion did not grow as significantly over time in other parts of the state, with one notable exception: on the segment of I-290 westbound through downtown Worcester from I-190 to Route 146, travel times increased by approximately 60 percent between 2013 and 2018 during the afternoon peak period.

6. Changes in travel time on an average day do not capture the severity of the problem. Comparing the number of minutes it took Massachusetts drivers to traverse a given roadway segment in both 2013 and 2018, travel time had increased on most roadway segments—but not by much. Increases of 10 minutes or more over five years were the exception, not the rule. During most hours of the day and on most roadways that this study includes, travel time grew by just one or two minutes per roadway segment between 2013 and 2018. But given the level of concern voiced by many motorists, these relatively modest increases in travel time by roadway segment clearly do not capture the frustrating experience that is congestion in Massachusetts.

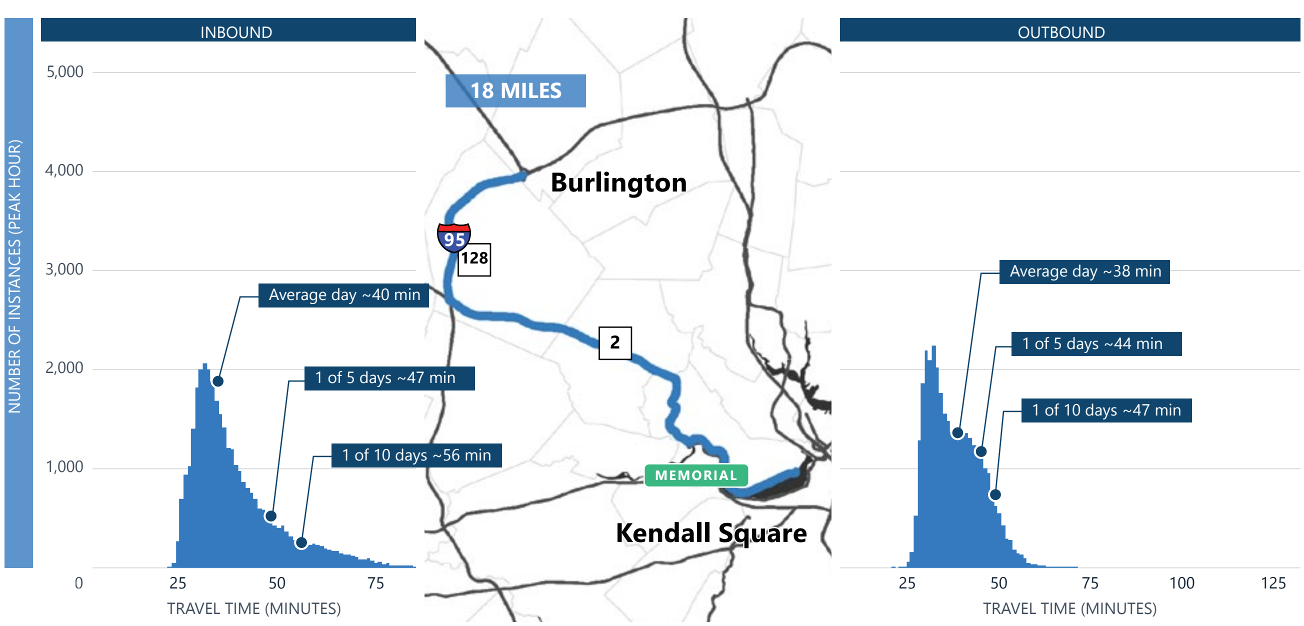
7. Massachusetts has reached a tipping point with respect to congestion. Particularly within the Route 128 corridor, Massachusetts's roadway network is moving the maximum possible number of cars at many hours of the day. The system is full, if not overflowing, with what traffic professionals call "recurring congestion" that occurs every working day. The relatively small size of the area and the connectivity of the road network inside the I-95/128 belt mean that traffic between different parts of the system is highly interdependent. In such a compact and congested roadway network, comparatively small insults to the system—such as a crash during rush hour—can cause rippling delays. The "non-recurring congestion" that results from such incidents is exacerbated by a roadway network already filled to capacity; the result is congestion, delay, and unreliability. It's not so much that travel times lengthen, but that they become inconsistent and unpredictable, making it difficult for motorists to plan their days and their lives.

8. Many key commuting corridors have become unreliable, with lengthy trips on bad days. To evaluate the reliability of different trips, we looked at how travel times vary on commutes between certain cities and towns and large employment centers where their residents likely work. To collect travel times on each hypothetical route, a traffic model software program was used to send an imaginary car in both directions of the sample commute (inbound and outbound) every five minutes between 8 a.m. and 5 p.m. This exercise demonstrated that in certain key commuting corridors, one trip every five days can take one and a half times as long as the average; one trip every ten days can take nearly twice as long. (Lacking historical data for this part of the analysis, we do not know if reliability has changed over time.) For example, we looked at the travel time between Burlington and Kendall Square via I-95/128, Route 2, Fresh Pond Parkway, and Memorial Drive. That commute time varies greatly, between 25 and 75 minutes, and takes 40 minutes on an average day but 56 minutes on one day in every ten.

9. Congestion has worsened to the point where it reduces access to jobs. Because people use the transportation system to reach opportunities and the people and places that are important to them, it is important to measure such "accessibility" and not just congestion. One increasingly common measure of access is the ability of people to access jobs within a certain amount of travel time (for example, 45 minutes) by either driving or transit. As measured by the Accessibility Observatory at the University of Minnesota, Boston ranks 5th among 50 metropolitan areas studied in access to jobs by transit and 16th in access to jobs by automobile. This report presents important new data on how congestion is reducing access to jobs in Massachusetts, generated by a study that MassDOT is participating in with 13 other states. Due to congestion, by 7 a.m., job access within 45 minutes is severely impeded for communities between I-495 and I-95/128; by 8 a.m., almost all communities between I-495 and 128 and those along the Massachusetts Turnpike between Worcester and Weston lose job access. And the few communities that still have access to hundreds of thousands of jobs at 8 a.m. are those where housing is very expensive.

10. Congestion on local roads is a problem, too. Although the data set used in this report does not include information on volumes or speeds on local roads, both anecdotal and experiential data suggest that congestion is also growing worse on local roads. MBTA data on trip times for its buses, presented in the report, confirms that roadway congestion is increasingly hampering the performance and efficiency of buses. Trip time data collected by the MBTA shows the growth in run times on select bus routes from 2006 to 2018: while the length of all collective trips throughout the day has grown by 11 percent, trip times during the morning and afternoon peak have grown 17 percent. In setting up schedules, the MBTA now assumes that its buses will travel at their slowest speeds since data has been available: on average, buses are assumed to travel at 11.5 miles per hour, down from 12.7 miles per hour in 2009.

Figure 87. Travel Time Reliability, *Burlington/Kendall Square Corridor*



Recommendations for Next Steps

These key findings confirm that congestion is taking its toll on Massachusetts' economy and environment and, perhaps most importantly, on the daily lives of Massachusetts residents, businesses, and communities.

But as important as it is to address bottlenecks and ease congestion, it is important that congestion relief efforts are carried out in a way that helps the Commonwealth achieve other policy objectives. The recommendations that follow were chosen because they contribute toward simultaneously addressing several important policy priorities:

- **Reliability:** The goal in tackling congestion must be to eliminate as much as possible the variability that now makes it so difficult for people to plan for how long it will take to get where they are going. Whether for transit users or drivers, commute times and trip times in general must be made more predictable and reliable, even if not necessarily much faster or shorter.
- **Accessibility:** People need to get from where they live to where they work within a reasonable period of time. There are many ways to improve such "accessibility" in addition to tackling the ways that congestion impedes driving. These include providing alternative means of access to jobs—such as transit—and producing housing and growing jobs in ways that improve access by increasing the number of Massachusetts residents who can afford to live closer to where they work.
- **Sustainability:** The challenges of congestion and climate change must be faced simultaneously. In Massachusetts, the transportation sector is both the largest and the fastest growing emitter of greenhouse gases. The Commonwealth cannot meet its goal of reducing overall GHG emissions 80 percent by 2050 without substantially reducing transportation sector carbon emissions.
- **Equity:** As did the Commission on the Future of Transportation in the Commonwealth, it is important to think about the impact of these recommendations on "people with low-incomes, disabilities, limited access to public transit and other transportation options, as well as communities of color." Key stakeholders must collaborate and think about regional equity, creating a portfolio of congestion solutions that work for residents of cities and of rural communities, workers who can stay home or shift their travel time and those who cannot, and travelers who would like to use transit or share a ride and those who need to drive.

Recommendations for Next Steps

- Address local and regional bottlenecks where feasible
- Actively manage state and local roadway operations
- Reinvent bus transit at both the MBTA and Regional Transit Authorities
- Increase MBTA capacity and ridership
- Work with employers to give commuters more options
- Create infrastructure to support shared travel modes
- Increase remote work and telecommuting
- Produce more affordable housing, especially near transit
- Encourage growth in less congested Gateway Cities
- Investigate the feasibility of congestion pricing mechanisms that make sense for Massachusetts, particularly managed lanes (addressed in Chapter 5)

The Administration has not waited to complete this report in order to begin implementing solutions to address congestion and the related issues of accessibility, sustainability, and equity: the recommendations that follow build on many initiatives already underway to tackle these inter-related challenges. MassDOT is addressing local and regional congestion bottlenecks, whether through construction projects or transportation systems management initiatives. The MBTA is working to accelerate its efforts to modernize and transform Greater Boston's transit system, while MassDOT and the Regional Transit Authorities are working together to implement the recommendations of the recent Task Force report to improve public transportation and grow ridership throughout the Commonwealth.

In addition, the Baker-Polito Administration's Housing Choice Initiative rewards municipalities that have produced certain rates or amounts of new housing units in the last five years and that adopted best practices related to housing production that will sustain a 21st Century workforce and increase access to opportunity for Massachusetts. The Administration has also expanded the Transformative Development Initiative, a Mass Development Program for Gateway Cities designed to accelerate economic growth within focused districts.

The Baker-Polito Administration has also filed three bills that further congestion relief and other objectives of this report and we look forward to working with our colleagues in the Legislature to advance this important legislation:

- Housing Choice legislation that would enable cities and towns to adopt certain zoning best practices related to housing development by a simple majority vote, rather than the current two-thirds supermajority. Without mandating cities and towns to make any zoning changes, the legislation will allow municipalities to more easily rezone for denser, transit- or downtown-oriented and other new housing development.
- An Act Relative to Public Safety and Transparency by Transportation Network Companies that would require companies such as Uber and Lyft to provide municipalities and the Commonwealth with more detailed data about their operations in Massachusetts, thereby empowering municipalities to better manage curbside and other types of congestion caused by these ride-sharing companies.
- An Act Authorizing and Accelerating Transportation Investment, an $18 billion transportation bond bill that would provide resources for MassDOT, the MBTA, RTAs and cities and towns to increase investment in ways that address many of the findings of this report. The $5.695 billion authorized for the MBTA supports efforts to transform the Red, Orange, and Green lines and the bus system while increasing capacity on and exploring new service models for commuter rail. Investments in sustainable transportation modes like walking, biking and water transportation will both help address local and regional congestion and move the needle on lowering transportation sector greenhouse gas emissions.

Three new programs funded by the bond bill directly address the issues of congestion identified in this report. The $50 million Transit Infrastructure Partnership Program is open to cities and towns served by the MBTA or RTAs, enabling transit authorities and municipalities to work together to provide bus lanes, transit signal priority and other infrastructure to keep buses moving. Another new $50 million grant program will help cities and towns tackle local "bottlenecks" with modestly-priced but proven interventions like smart traffic signals, better signage, re-striping roadways and making smaller configuration changes that can produce big results. In order to encourage employers to support telecommuting and remote working in the service of congestion reduction, the bill proposes a managed tax credit program, capped at $50 million annually, which provides a credit of $2,000 for every employee who no longer commutes.

But as can be seen in the recommendations for next steps that follow, much much more needs to be done. Many stakeholders must act and act with urgency, and they include MassDOT, which must play a central role in tackling the Commonwealth's congestion challenges. In addition to working to design and deliver construction projects and maintain the Commonwealth's roadway and multimodal networks, MassDOT needs to evolve into an agency that can actively monitor and manage congestion every day.

But MassDOT alone cannot make the Commonwealth's transportation system more reliable—or accessible or sustainable or equitable. Nothing less than a coordinated and collaborative effort will make a significant difference. The remainder of this chapter therefore outline roles that can be played not only by MassDOT but also by the MBTA and Regional Transit Authorities, by partners in cities and towns, and by private sector actors such as developers and employers.

As shown in the recommended next steps that follow, multiple and overlapping stakeholders, tools and strategies must respond urgently to the challenges of congestion.

ADDRESS LOCAL AND REGIONAL BOTTLENECKS WHERE FEASIBLE

The very design of roads, including elements such as geometry and signal timing, can lead to congestion. Many state and local roads would benefit from maintenance, upgrades to more modern design standards, new signals and more nuanced signal timing, and better enforcement of existing traffic laws. As previously explained, MassDOT identifies regional bottlenecks by looking at:

- Current and future projected traffic volumes
- Potential bottlenecks and their contributions to congestion on surrounding roadways
- Failures of roadway geometry and the ease or challenge of correcting them
- Safety issues, such as the number of serious crashes occurring at a particular intersection or on a particular roadway segment
- Significance of the location not only for passenger travel but for regional economic development and/or freight transport

Some regional or local bottlenecks will require reconstruction, while others can be treated with interventions that can be implemented more expeditiously and affordably with minimal disruption to travelers.

Better management of traffic signals is one good example of a reasonably low-cost improvement that can provide meaningful benefits. A number of MassDOT-operated signals have negative impacts on regional traffic flow, such as on Routes 2 and 9. To try to tackle this problem, MassDOT plans to replace all of the traditional traffic signal controllers with more advanced signals that will improve traffic and allow MassDOT to measure and evaluate their performance over time. MassDOT also recently launched a study of signal operations at the various intersections along Route 2 between Concord and Fitchburg in order to identify opportunities to enhance safety and mobility by optimizing timing plans based on traffic volumes.

Most cities and towns own the traffic signals on local roadways. Poor signal operations can be attributed to any number of issues, including less than optimal timing plans, outdated control technologies, and/or malfunctioning equipment, such as vehicle detection or pedestrian push-buttons. Preventative maintenance, updating signal equipment, and optimizing signal timing on a regular basis could have a notable impact on reducing recurring congestion.

While upgrading signal operations has significant potential to alleviate roadway congestion, it is not the only way to try to solve local and regional bottlenecks. Both MassDOT and municipalities should be working—and working together, whenever possible—to identify and address areas of problematic roadway configuration, faulty signal operations, and other impediments to the improved flow of traffic.

Recommended Next Steps:

- MassDOT will continue to identify, plan for, design, fund and construct targeted congestion-reducing improvements on the roadways it owns and operates. These efforts will focus on regional bottlenecks that can be redesigned and reconstructed in ways that address congestion and safety issues but that are also sensitive to the local context and carefully designed so as not to induce additional congestion or substantially increase greenhouse gas and other emissions. Projects underway include the reconstruction of the I-90/I-495 interchange and the reconstruction of approaches to the Cape Cod Canal bridges being undertaken in coordination with Army Corps' of Engineers.
- When addressing such regional bottlenecks, MassDOT will consistently consider alternatives to traditional, major reconstruction and evaluate the use of less complicated and expensive interventions that address the most serious safety and congestion impacts of the bottleneck. Such approaches may include reconfiguring existing geometries within the right of way and/or relevant approaches, restriping and improved signage and signal timing.
- MassDOT will support and provide technical assistance to municipalities in their efforts to tackle local bottlenecks. MassDOT will be ready to quickly implement the new $50 million grant

program proposed in the transportation bond bill to help cities and towns tackle local bottlenecks with modestly-priced but proven interventions like smart traffic signals, better signage, re-striping roadways and making smaller configuration changes that can produce big results.

- ☐ Cities and towns should take a parallel approach to identifying and addressing their local bottlenecks, considering a variety of interventions less expensive and intrusive than full reconstruction to address those bottlenecks and related safety issues.

ACTIVELY MANAGE STATE AND LOCAL ROADWAY OPERATIONS

Roads can't simply be built and then left to their own devices. In addition to regular maintenance, they require active intervention to operate as efficiently as possible and minimize congestion. They require monitoring, periodic modernization of systems such as traffic signals, and updating of lane striping.

Active roadway management also requires addressing the causes of non-recurring congestion described in Chapter 3, including traffic incidents and work zones. Congestion is dense enough and constant enough in parts of the Commonwealth that better and more active operation of the roadways has taken on new urgency. During intrusive construction projects like the replacement of the Commonwealth Avenue Bridge over the Mass Pike and the reconstruction of the I-91 viaduct in Springfield—and, of course, dating back to the Big Dig—MassDOT has worked hard to ensure careful congestion management. The roadway network is now so full that comparatively small insults to the system can cause rippling delays during any peak period anywhere on the network. So MassDOT, and our partners in cities and towns, need to actively manage the causes of non-recurring congestion every day with the same level of preparation and focus as when an important roadway is closed for repair.

Like many other state transportation agencies, Massachusetts has implemented Traffic Management and Systems Operations (TSMO) practices for years. TSMO provides a disciplined framework for managing roadways, including coordinating work zones, incident response, special events, traffic signals, the integration of multiple modes, and traveler information. Many Commonwealth municipalities also use elements of TSMO to manage their roads. For example, MassDOT consistently uses traffic management strategies, as well as work zone management programs. MassDOT has developed a unified response manual, which is considered to be a national best practice, and provides a number of emergency response services for motorists. MassDOT has also deployed over 1,000 CCTV cameras and 500 dynamic message signs, with more in the pipeline, to help manage traffic in real time. The Highway Operations Center in South Boston is a modern, 24/7 statewide traffic management center and is currently piloting an incident/anomaly detection system.

The accompanying tables provide a roadmap as to how MassDOT does and can use TSMO concepts to mitigate the various causes of congestion. The second table details a recent self-assessment conducted by MassDOT regarding the level of success and opportunities to expand on the use of TSMO solutions. Many of these practices can also be utilized by municipalities and other road-owning agencies.

Moving forward, however, actively managing roadways through a TSMO framework needs to be as much a part of MassDOT's DNA as fixing potholes and plowing snow. One model is Pennsylvania, where the Department of Transportation has adopted "a formalized and unified approach to ensure that all aspects" of a TSMO program are being implemented in order to "decrease congestion and increase reliability for the everyday driver."[48]

Advancing, expanding, and institutionalizing its current use of TSMO-type solutions should allow MassDOT to continue to reduce congestion by minimizing the number of crashes, as well as improving crash or incident detection and response times; maximizing the effectiveness of current roadway capacity and traffic control devices (i.e., signals); facilitating freight movement; enhancing the prediction, monitoring, and communication of weather events; improving operations and safety at work zones; and planning/managing for major special events.

48 Pennsylvania Department of Transportation, 2018. Transportation Systems Management and Operations Strategic Framework for Pennsylvania.

Table 6. Status of Current TSMO Solutions

TSMO SOLUTION	INFLUENCE OF CONGESTION					
	Recurring Congestion			Non-Recurring Congestion		
	Bottlenecks	Poor Signal Timing	Traffic Incidents	Inclement Weather	Work Zones	Special Events
Traffic Incident Management	■		■		■	■
Safe Quick Clearance	■		■		■	■
Incident Response (TIM) Teams	■		■		■	■
Move Over, Move It, Hold Harmless			■		■	■
Emergency Service Patrols			■		■	■
Towing Incentives			■		■	■
Enforcement Programs			■		■	■
Traffic Demand Management	■		■	■	■	■
Influence Time of Use	■				■	
Dynamic Rerouting	■		■		■	■
Flex Lanes	■		■		■	■
Managed Lanes	■					
Queue Warnings	■		■		■	■
Variable Speed Displays	■		■	■	■	
Ramp Metering	■		■			■
Freight Management			■	■		
Curve Warnings			■	■		
Permitting			■	■		
Parking			■			
Cargo/Structure Restrictions			■	■		
Systems Management	■	■	■	■	■	■
ITS Deployment Program	■	■	■	■	■	■
CCTV	■	■	■	■	■	■
VMS/DMS	■		■	■	■	■
Signal Optimization		■				
Operations Management	■	■	■	■	■	■
Traffic Management Centers	■	■	■	■	■	■
Incident/Anomaly Detection			■			
Traveler Information Systems	■		■	■	■	■

TSMO SOLUTION	INFLUENCE OF CONGESTION					
	Recurring Congestion			Non-Recurring Congestion		
	Bottlenecks	Poor Signal Timing	Traffic Incidents	Inclement Weather	Work Zones	Special Events
Work Zone Management					■	
Smart Work Zones					■	
Speed Awareness/Enforcement					■	
Advance Warning					■	
Weather Management				■		
Deicing and Snow Removal				■		
Road Weather Info. Systems (RWIS)				■		
Speed Restrictions				■		
Integrated Corridor Management	■	■	■	■	■	■
Influence/Incentivize Mode Choice	■		■	■	■	■
Dedicated Resources for Transit Use	■					■
Multimodal Applications	■		■	■	■	■
Transit Signal Priority		■				

Table 7. Status of Current TSMO Solutions

TSMO SOLUTION	COMMENTS
Traffic Incident Management	**STRONG**—URM, incident response, ESP and enforcement programs solid; hold harmless legislation would allow consideration for towing incentives.
Safe Quick Clearance	Unified response manual (URM) identified as best practice by FHWA.
Incident Response (TIM) Teams	Do not have TIM Teams per se, but Districts, MSP and Engineering function as teams. Providing TIM training to first responders Statewide.
Move Over, Move It, Hold Harmless	Move over law in place, do not have move it or hold harmless.
Emergency Service Patrols	HAP for surface roads, IRO for tunnels and ESP on I-90.
Towing Incentives	None to date—would be tied to hold harmless.
Enforcement Programs	Strong DUI, speeding, work zone, distracted driving and move over programs and stings with MSP.
Traffic Demand Management	**MODERATE**—a few flex and managed lanes, no variable speed or ramp metering to date.
Influence Time of Use	Have not seriously considered congestion pricing or other options to date.
Dynamic Rerouting	GoTime app developed—provides info for numerous roadways and work zone applications.
Flex Lanes	Currently used for I-93 southeast expressway HOV, and new installation at entrance to Sumner Tunnel.
Managed Lanes	HOV lanes in place from I-93 NB, surface streets to Logan, as well as on I-93 SB entering Boston from the north, no HOT or reversible lanes.
Queue Warnings	Currently for work zone applications only.
Variable Speed Displays	No implementation, but have conducted research and are considering.
Ramp Metering	No implementation, difficult and limited opportunities on MA roadways.
Freight Management	**MODERATE**—good processes in place re permitting, haz mat restrictions, could use additional freight parking and more technology driven curve warning devices.
Curve Warnings	Currently employing static with flashers, anticipate more dynamic signage on future projects.
Permitting	Handled through permits issued re: overheight/overweight with the Trucks Permit Office.
Parking	Some tandem lots provided, however recent freight study identified more freight parking as a need, especially along I-495.
Cargo/Structure Restrictions	Solid Haz Material restrictions in place, inclement weather policies in place for I-90 (re: restrictions).
Systems Management	**STRONG**— ITS revisited annually, numerous devices deployed, would prefer to do more re: signal optimization.
ITS Deployment Program	Strong program revisiting annually via systems engineering approach involving DOT-Boston, District Offices and HOC.
CCTV	1,035 cameras deployed throughout the system with additional in development.
VMS/DMS	521 DMS deployed on all major roadways—additional in development.
Signal Optimization	In process, limited somewhat by resources and funding—would prefer to do more.
Operations Management	**MODERATE TO STRONG**—strong HOC and traveler info systems, incident detection pilot initialized.
Traffic Management Centers	HOC centralizes statewide operations 24/7 with recent software and hardware upgrades.
Incident/Anomaly Detection	Incident/anomaly detection pilot underway—peds/bikes in tunnels, crowd sourcing for portions of pilot, video analytics being tested on Route 2, I-495, and I-290.
Traveler Information Systems	Multiple options, including 511 and MA 511 website, GoTime system and MassDOT (Highway) website.

Level	TSMO SOLUTION	COMMENTS
Strong	**Work Zone Management**	**STRONG—** implementing smart work zones more and more, programs in place for speed awareness/enforcement, solid advance warning signage.
Strong	Smart Work Zones	Smart work zones utilized on most, if not all major construction projects. Anticipate use of more dynamic merge and queue warning systems in the future. Plan to do more smart work zone lite applications.
Moderate	Speed Awareness/ Enforcement	Programs in place.
Strong	Advance Warning	Included on all projects.
Moderate	**Weather Management**	**MODERATE TO STRONG—**strong deicing and snow removal programs, need more RWIS, speed restrictions related to weather only on I-90.
Strong	Deicing and Snow Removal	Strong deicing and snow removal programs.
Moderate	Road Weather Information Systems (RWIS)	48 RWIS deployed around the state, with additional in development—would prefer additional installations.
Moderate	Speed Restrictions	Only implemented on I-90.
Limited	**Integrated Corridor Management**	**LIMITED—**little to no implementation, some research and study on alternatives and options has been conducted.
Initiated*	Influence/Incentivize Mode Choice	Considering Route 3 south for pilot.
Initiated*	Dedicated Resources for Transit Use	Studied I-93 N/S, nothing on major interstates to date.
Limited	Multimodal Applications	Nothing to date.
Moderate	Transit Signal Priority	Implemented in limited locations such as Springfield, capabilities will be developed along Route 9 (as part of SPaT pilot) and South Boston as part of Adaptive Signal System.

Level of MassDOT Implementation/Adoptions

Strong | Moderate | Initiated* | Limited — *initial research conducted, but no firm plans for implementation.

TSMO is not a strategy that is exclusive to state agencies. Like MassDOT, municipalities are not only the owners of roads and pavement but also the managers of them as well. In Pennsylvania Metropolitan Planning Organizations and rural planning agencies are collaborative partners with PennDOT in planning and coordinating road management strategies.

Cities and towns also have almost exclusive jurisdiction of perhaps the most overlooked and undervalued element of surface transportation: the curb. Parking and curb management are critical for maintaining the flow of people and vehicles through networks and especially intersections.[49] Active management of curbs also means that municipalities must respond to the challenges and opportunities presented by the introduction of TNCs, which can obstruct the flow of traffic due to frequent stopping.

Recommended Next Steps:

- ☐ MassDOT will develop and implement a comprehensive, strategic framework for Transportation Systems Management and Operations. Advancing and expanding its current use of TSMO-type solutions will enable MassDOT to reduce and better manage the level of congestion.

- ☐ MassDOT will work with our colleagues in the Legislature to enact legislation that can improve roadway operations by promoting faster clearance of crashes. The Move It Legislation, filed as part of the Transportation Bond Bill, would require motorists to move their vehicles to a safe location in the event of a minor incident if they are able to do so, to avoid creating congestion and potentially causing secondary incidents

49 Up to 30 percent of all congestion on local roadways is due to people looking for parking. Shoup, Donald, July 2016. "Cruising for Parking." http://www.accessmagazine.org/wp-content/uploads/sites/7/2016/02/Access-30-04-Crusing-for-Parking.pdf

on an active roadway. Hold Harmless Legislation would seek to hold Towing Entities harmless in the event they are directed by a law enforcement official to move a vehicle or cargo from the roadway and some damage was sustained to that vehicle or cargo as it was being moved.

- MassDOT should collaborate with and support municipalities to make more use of TSMO techniques, if on a smaller scale.

REINVENT BUS TRANSIT AT BOTH THE MBTA AND REGIONAL TRANSIT AUTHORITIES

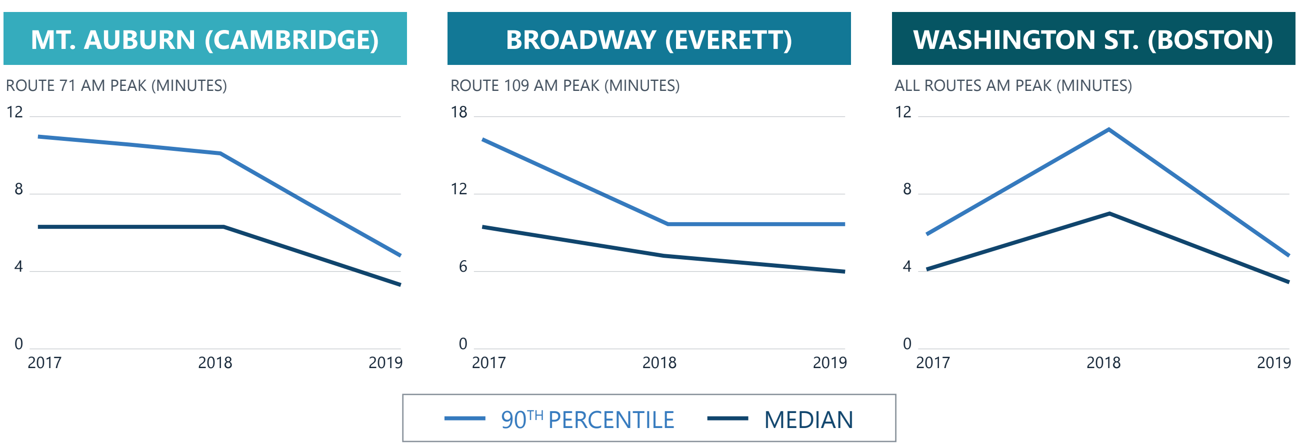
Public transportation is a critically important option for tackling congestion and simultaneously addressing issues of accessibility, sustainability and equity. Transit provides an alternative connection between home and work for commuters, increasing employment access particularly for those who may have fewer options about where to live and/or work. Creating a robust and reliable transit option for more Massachusetts residents is therefore a central strategy for addressing congestion here.

The Commission on the Future of Transportation began its report with recommendations on improving transit, explaining that "Future public transit in Massachusetts, whether provided by the MBTA or RTAs, has to be frequent, reliable, and convenient enough to compete in a 2040 world that includes a mix of autonomous vehicles, conventional vehicles, micro-mobility options, and different forms of [mobility as a service]. Bus service, in particular, needs to be reinvented—the future can and must be more than 40-foot buses following fixed routes and schedules and mired in the same traffic as personal vehicles."[50]

The Commission was right to focus on buses. One-third of MBTA riders depend on its bus service. Every day in Massachusetts, transit users make roughly a half million bus trips, just under 400,000 on the MBTA and the rest on buses provided by the state's 15 Regional Transit Authorities (RTAs). As many trips are made on buses daily, across the state, as are on the MBTA's Orange and Green Lines and all of the commuter rail lines combined.

But the congestion that is the subject of this report is affecting the attractiveness and reliability of buses. As noted in Chapter 2, the MBTA now assumes that buses will travel at 11.5 miles per hour on average, the slowest speeds since data has been made available. The reinvention of bus transit by the MBTA and RTAs will therefore need to address both service changes to ensure that bus routes meet the needs of commuters and other travelers and infrastructure changes to allow buses to operate reliably.

Figure 88. Impact of Bus Lanes on Run Times



Up to **5 MINUTES SAVED PER TRIP** versus 2017

50% REDUCTION in variability versus 2017

Up to **7 MINUTES SAVED PER TRIP** versus 2016

40% REDUCTION in variability versus 2017

Up to **2-3 MINUTES SAVED** per trip versus 2016

10% REDUCTION in variability versus 2016

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[50] Commission on the Future of Transportation in the Commonwealth, 2018. "Choices for Stewardship: Recommendations to Meet the Transportation Future." https://www.mass.gov/orgs/commission-on-the-future-of-transportation

Of course, approaches taken by the MBTA and the RTAs might look very different from each other and could differ within the same service area. Upgrading and enhancing bus services could mean adopting transit signal priority systems (TSP), dedicating roadway miles for the exclusive use of buses, purchasing new vehicles, upgrading fare collection systems, or updating service delivery policies, including routes and stops.

The MBTA's Better Bus Project has been at work for several years to improve bus service. Following an extensive process first of data analysis and then of public outreach, service changes will be to more than two dozen bus routes in September, consolidating duplicate routes, improving the space available at bus stops, and streamlining route variants to better serve the majority of passengers. These updates will make the MBTA bus system more reliable, improve frequency and make routes easier for riders to understand.

The Better Bus Project has also begun reimagining the bus network through its Network Redesign initiative. This effort will take a holistic look at all bus service in the MBTA service area using data to understand the travel patterns not well served by the current network. The redesign effort will ultimately develop recommendations for a new version of the bus system that will better serve the region's changing travel needs, establishing a regional vision for how the bus network can be competitive in today's changing mobility marketplace.

Reinventing bus transit is also critical for the RTAs. Following the 2019 task force report on RTA performance and funding, MassDOT is working with the RTAs to reinvigorate the RTA Council, a forum in which the RTAS, Mass-DOT, and other stakeholders come together to discuss new techniques to reach potential transit riders and the analytical tools that the RTAs can use to better understand and serve their markets, including those that best support a variety of mobility programs in their service areas. The RTA Council is an ideal mechanism from which the RTAs can explore a reinvention of transit services with resources and reinforcement from MassDOT.

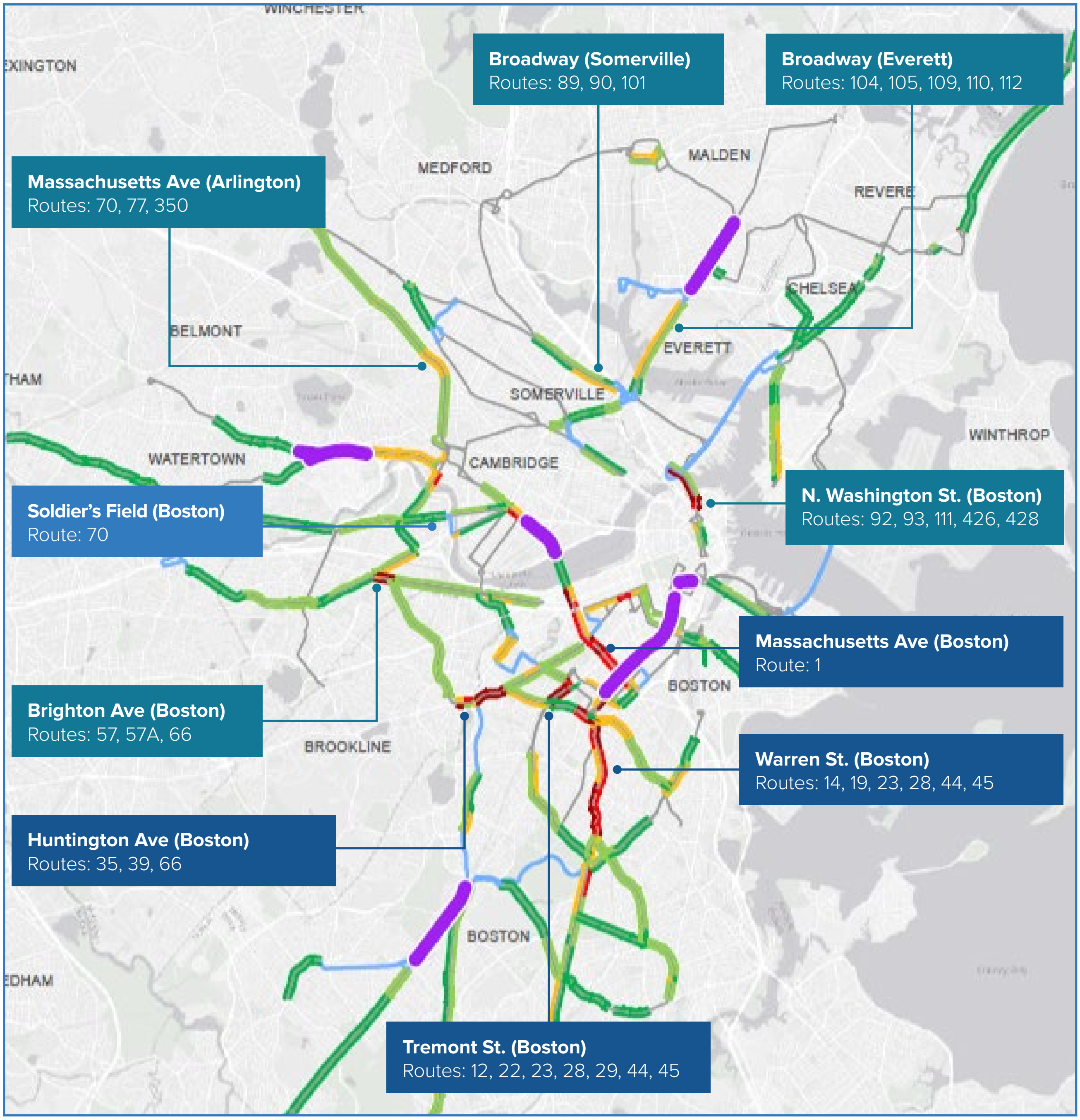
In order to ensure that bus service is reliable enough to keep and attract passengers, such service planning efforts at the MBTA and RTAs need to be accompanied by investment in infrastructure that will help buses travel reliably on increasingly congested streets. Bus infrastructure can include bus lanes, transit signal priority and fare collection to support all-door boarding. The $50 million Transit Infrastructure Partnership Program proposed in the Transportation Bond Bill would be open to cities and towns served by the MBTA or RTAs, enabling transit authorities and municipalities to work together to provide bus lanes, transit signal priority and other infrastructure to keep buses moving. While the Commonwealth should take the lead in funding the needed investments, however, the cities and towns that host MBTA and RTA bus routes have a critical role to play as partners in improving bus service, working with the MBTA or RTA to identify opportunities for bus infrastructure and ensure its prompt implementation and maintenance.

In the past few years the MBTA has developed effective bus infrastructure partnerships with a number of the communities that it serves. In Everett, Mayor DiMaria directed the Department of Public Works to use traffic cones to designate the dedicated bus lane on Broadway for a pilot program in 2016; the cones have since been replaced with paint and the bus lane is now permanent. The City of Boston has created a Transit Team within the Boston Transportation Department dedicated to working with the MBTA on establishing additional bus lanes and improving service to advance the city's ambitious goal of goal of increasing the percent of commuters using public transportation by a third over the next 15 years. The cities of Cambridge and Watertown teamed up to install a bus lane on Mount Auburn Street, where studies found that buses traveling between Brattle Street and Coolidge Avenue accounted for just three percent of all traffic during the morning peak travel period but carried 56 percent of all people using the corridor. A recent evaluation of the bus lane and transit signal priority project found that "travel times improved in all hours of the day on a typical day and especially on the worst days. During the AM rush hour, bus riders saved 4-5 minutes on an average trip. At the same time, riders felt that time savings were even more significant with more than half surveyed reporting they saved 7-10 minutes."[51]

RTAs can also benefit from bus infrastructure investments. In one ongoing project, MassDOT is working with the Pioneer Valley Transit Authority on an adaptive signal control and transit signal priority project along Route 9 in

[51] Cambridge Watertown BRT, June 2019. "Mount Auburn Street Bus Priority Pilot Evaluation Summary." https://www.cambridgema.gov/CDD/Projects/Transportation/~/media/972CE961CDFC4AA9A2BBB41F986BBD5F.ashx

Figure 89. Investment Plan for Up to 14 High-Priority Miles



Already planned for FY20:

2.3–3.5 miles

NEXT STEPS: Design and implement

High priority, requested CIP funding, target FY20 + FY21:

Up to 11 miles *(examples shown are not exhaustive)*

NEXT STEPS: Identify best suite of investments, design, and implement

Also planned in FY20, but moderate priority:

0.2 miles

Northampton, Hadley, and Amherst, and also along the entire B43 route. The project includes the replacement of almost 30 signal controllers along the B43 route to enable medium-to-high Transit Signal Priority along a very high-volume bus route.

The MBTA has identified 14 miles of corridors that serve its bus routes on which bus lanes and/or other forms of transit prioritization infrastructure are needed, with a goal of completing such infrastructure within two years.

Recommended Next Steps:

- The MBTA will work with municipalities (and MassDOT, where appropriate) to complete the buildout of the 14-mile bus prioritization network as rapidly as possible.
- MassDOT will work through the RTA Council to provide conceptual and logistical resources to the Regional Transit Authorities to upgrade and enhance their bus services and ensure that the Council serves as a clearinghouse for best practices and innovative approaches to service planning. The fiscal year 2020 Memoranda of Understanding with the RTAs will all include ridership targets and MassDOT will work with the RTAs to support efforts to increase ridership.
- MassDOT, the MBTA and the RTAs should work together to identify opportunities for bus services that can directly address the congestion issues identified in this report, for example by expanding existing commuter bus service to employment centers and by providing connections between to and from the MBTA Commuter Rail system for residents.

INCREASE MBTA CAPACITY AND RIDERSHIP

In some areas of the Commonwealth—particularly the areas in and near Boston with high levels of vehicular congestion—there is a dense public transit network which should be able to offer many people a competitive alternative to driving. Just as with growing bus ridership, increasing rapid transit and commuter rail ridership is a critically important strategy for addressing congestion in the Boston core and in the commuter-rail served area. Much of this vital work has already launched, but more can and should be done to provide the region with the MBTA that it needs to help manage congestion, reduce emissions, and give the residents and workers of eastern Massachusetts a balanced and comprehensive transportation system.

Over the past several years, the MBTA has significantly ramped up its investment in improved service and upgraded assets. This work is being done to retain and grow MBTA ridership. The T's ongoing $8 billion, 5-year capital investment plan supports renovating stations; modernizing fare collection systems; upgrading services on buses, subways, and ferries; and improving the accessibility of the entire system. But to continue to play its role in the overall transportation system, and to provide broad-based mobility that provides more options for commuters and motorists, the MBTA needs to be able to carry more people than it currently does. Expanded capacity is not derived solely from more spacious trains and buses. For example, more frequent trains that are more reliable and less prone to delays mean that more trains can run each hour, allowing more people to be moved faster and with greater reliability. These kinds of investments benefit current and future riders while simultaneously addressing maintenance and state of good repair needs.

Importantly, investments already planned and paid for will significantly expand the capacity of the system to support future ridership growth:

- By the end of 2021, the Orange Line Improvement Program, including signal upgrades and an all-new, expanded Orange Line fleet of 152 modern, spacious vehicles, will enable an additional 30,000 riders per day to take the Orange Line.
- By the end of 2022, the Red Line Improvement Program, including signal upgrades and an all-new, expanded Red Line fleet of 252 modern, spacious vehicles, will enable an additional 65,000 riders per day to take the Red Line.

- By the end of 2021, the Green Line Extension project will have relocated Lechmere Station and built six new Green Line stations along two branches in Somerville and Medford. The Green Line Extension is predicted to carry 37,900 trips per day, providing substantially new and better transit capacity.
- By 2023, the South Coast Rail project will restore rail service between Boston and Fall River and New Bedford, bringing a long-awaited transit connection and anticipated daily riders of 2,700, with capacity for growth as land use and travel patterns shift in response to the new and much better access to and from Boston.

Recent growth in Commuter Rail ridership is an important trend to which the MBTA needs to respond with additional capacity, both to serve today's growth and attract additional new riders. Between 2012 and 2018, daily Commuter Rail ridership increased from 104,574 in 2012 to 126,754, a gain of 21.2 percent. To meet this need, the MBTA is actively exploring options to add capacity to its current fleet of Commuter Rail vehicles, such as purchasing additional bi-level coaches, electric multiple units, or diesel multiple units.

In addition, MassDOT is currently developing a series of potential future scenarios for reimagining the existing Commuter Rail network, even the most modest of which—essentially a continuation of current trends without meaningful change—predicts an increase of 24,000 new daily trips by 2040. The Commonwealth's rail network is a tremendous asset that has the potential to provide much more and much better transit service, thereby helping with the congestion, climate, and general mobility problems facing Massachusetts. To do so, the system needs to expand its capacity to carry more passengers through additions to its fleet, changes and upgrades to its infrastructure, and different service models that can attract and retain riders.

The Commuter Rail network is part of the overall transportation system that allows commuters to travel from residential communities across Massachusetts to the employments hubs of central Boston. Another part of that system is the highway network, which provides essentially the same kind of access along routes that run—in some locations and corridors—parallel to certain Commuter Rail lines. In the absence of public transit, traffic volumes on roadways would be even higher than they are today.

The Table 8 shows the relative usage of these two parts of the system, and how they work together, symbiotically, to move people every day. This table shows where demand for both roadway and ridership has increased as well as where there is potential capacity to accommodate new demand. While the commuter rail volumes are generally well below the traffic counts, the transit ridership does meaningfully help take commuters out of the peak. On the Mass Pike, for example, there could have been another 5,000 drivers in addition to the increase of 15,000 experienced between 2012 and 2018 if those commuters had not instead taken the Worcester line. And South Coast Rail's thousands of new riders can help some of the pressure off of traffic growth on Route 24.

The Southeast Expressway is another example, a section of I-93 that is one of the most persistently and most severely congested corridors in the entire study network. In some places, especially closer into Boston, the path of I-93 is very close to that of several commuter rail lines, including the Middleborough/Lakeville Line, the Kingston/Plymouth Line, and the Greenbush Line. Between 2012 and 2018, annual average daily traffic grew by nearly 9,000 vehicles on this roadway while ridership on the parallel commuter rail lines grew by only approximately 5,000 passengers. While roadway capacity on corridors like the Southeast Expressway is beyond full, transit alternatives can add crucial capacity given the right investments and solid service.

Table 8. Annual Average Daily Traffic on Select Corridors and Parallel Commuter Rail Line Ridership, *2012 vs. 2018*

Study Network Corridor[52]	Count Station Number	2012 AADT	2018 AADT	*Change over Time*	Parallel Commuter Rail Line	2012 Ridership	2018 Ridership	*Change over Time*
Fellsway/ McGrath Highway	8,089	32,092[a]	30,951[c]	-1,141	Haverhill Line + Lowell Line	16,664	17,893	1,229
Interstate 90 (inside I-495)	9,018	132,304[b]	147,853[c]	15,549	Worcester Line	12,207	18,057	5,850
I-93 Northeast Corridor	82	177,776[a]	189,716[a]	11,940	Haverhill Line + Lowell Line	16,664	17,893	1,229
I-93 Southeast Expressway	691	189,125[a]	198,038[a]	8,913	Middleborough/Lakeville Line + Kingston/Plymouth Line + Greenbush Line	14,120	19,034	4,914
Interstate 95 Southeast Corridor	6,328	109,234[a]	123,784[c]	14,550	Newburyport Line	14,003	14,972	969
Interstate 95 Northeast Corridor	595	121,657[a]	131,926[c]	10,269	Providence Line	20,416	24,647	4,231
MA Route 1A	8,087	56,677[a]	60,846[a]	4,169	Newburyport Line	14,003	14,972	969
MA Route 2	403	43,615[a]	45,632[a]	2,017	Fitchburg Line	7,507	8,885	1,378
MA Route 24	6,072	64,911[a]	68,257[c]	3,346	Middleborough/Lakeville Line	5,503	7,360	1,857
MA Route 3	6,255	132,053[a]	133,238[a]	1,185	Kingston/Plymouth Line	5,422	5,998	576
MA Route 3A	7,073	11,058[b]	13,348[c]	2,290	Greenbush Line	3,915	5,676	1,761
MA Route 9	307	49,008[a]	51,675[c]	2,667	Worcester Line	12,207	18,057	5,850
US Route 1	550	47,372[a]	46,284[c]	-1,088	Newburyport Line	14,003	14,972	969
US Route 3	4,073	94,163[b]	112,793[c]	18,630	Lowell Line	9,817	10,925	1,108

Note: [a] Actual, [b] Estimate, and [c] Grown.

Recommended Next Steps:

- ☐ In order to attract and retain riders—to effectively compete with driving—the MBTA must continue the work that is already underway to invest in the improvement and modernization of transit infrastructure, fleets, and technology to increase capacity. Like the Red Line and Orange Line programs already planned,

[52] AADT numbers are taken from unique (single spot) locations on identified network corridors, represented by the Count Stations identified.

funded and underway, the Green Line Transformation program needs to combine signal and power upgrades with procurement of new Type 10 Green Line cars to produce a quantifiable increase in capacity.

- The MBTA should advance procurement of bi-level commuter rail coaches to help accommodate recent ridership growth and support future ridership growth.
- The MBTA and the cities and towns served by commuter rail should collaborate to identify opportunities to increase commuter rail ridership by expanding the availability of parking proximate to stations as well as first mile/last mile connections to bring more commuters to existing transit.
- Employers can support and encourage employees to commute via public transit wherever possible by locating offices in transit-dense areas, subsidizing transit passes for employees, charging market-rate prices for onsite parking, and providing shuttles to make connections between transit stations and job centers. Employers can also be effective advocates for increasing local transit facilities and can work with transit providers and cities to ensure that transit service is an option for their workers.

WORK WITH EMPLOYERS TO GIVE COMMUTERS MORE OPTIONS

While transit—whether buses or MBTA rapid transit and commuter rail—is an important way to provide employment access without exacerbating traffic congestion, there are others. The more options commuters have for getting to work, the better.

Many employers invest in either "transportation demand management" programs or "commute options" programs to help attract and retain a skilled workforce by easing their commute. Employers may participate in Transportation Management Associations, subsidize transit passes and even provide shuttles for so-called first and last mile connections to transit stops and stations. Enlisting more employers as partners in creating more commute options presents real opportunities for reducing roadway volumes, especially during peak periods.

While MassDOT has supported transportation demand management programs using federal Congestion Mitigation and Air Quality funds, we do not have a comprehensive program to work with employers to reduce commute trips. One model for an expanded MassDOT effort on commute options in Washington State, where the DOT provides technical assistance to employers implementing the Commute Trip Reduction Law which is designed to shift commuter behavior in order to relieve congestion and reduce greenhouse gas emissions. That program has produced quantifiable reductions in peak hour trips and congestion.[53] Massachusetts has a rideshare regulation, overseen by the Department of Environmental Protection. That regulation (310 CMR 7.16) requires many businesses with 250 or more employees and educational facilities with 1,000 or more students and employees combined to develop plans and set goals for reducing by 25 percent the number of commuters driving alone to work or school. Given the growing concern about congestion, it could be beneficial for MassDOT and MassDEP to conduct outreach to businesses and educational facilities about how this program could be strengthened and improved.

With or without a formal state commute trip reduction program, there is a lot that employers can do to help employees avoid peak hour traffic congestion. Specific employer approaches include offering and subsidizing pre-tax transit benefits; securing fewer employer-sponsored parking spaces via lease or purchase; charging market-rate prices for any employer-sponsored parking; offering cash incentives to employees that forego employer parking benefits for telework, transit or walk/bike commutes; siting in transit-accessible site locations; providing secure bike parking; supporting carpools/vanpools, including with priority parking; supporting corporate carshare and rideshare accounts; providing shuttle, bike and scooter share services; and offering commuting planning assistance. A *Better City,* a business association in Boston, has compiled a list of successful strategies.[54]

[53] Washington State Commute Trip Reduction Board, December 2017. Commute Trip Reduction Partnerships Help People and the Transportation System.

[54] A Better City, 2014. "Establishing an Effective Commute Trip Reduction Policy in Massachusetts." https://www.abettercity.org/docs/Effective%20TRO%20Final.pdf

Ultimately, what is needed is more commuting options: more transit, more employer shuttles, more "first mile last mile" services to connect transit to workplaces, more vanpools and carpools. MassDOT recently completed a "listening tour" on the need for more employee commute options, holding eight sessions across the state attended by nearly 300 people. Based on this input, MassDOT will be launching a new grant program for Workforce Transportation.

Recommended Next Steps:

- ☐ MassDOT will provide up to $4.5 million in funding (in grants of roughly $100,000–$250,000) to support Workforce Transportation commute options services provided by employers, municipalities, Transportation Management Associations, Regional Transit Authorities and others who are willing and able to provide workforce transit options to employees. The request for applications will be issued in August and applications will be due in late September.
- ☐ Employers, especially those in industries whose workers must be on-site during traditional work hours, should develop strategies to alleviate the burden of commuting on workers, adopting best practices to support the development, adoption, and success of employee commute options and transportation demand management strategies.
- ☐ The MBTA and employers in Greater Boston should work together to substantially increase participation in the MBTA's Perq corporate pass program.

CREATE INFRASTRUCTURE TO SUPPORT SHARED TRAVEL MODES

The Commission on the Future of Transportation in the Commonwealth challenged MassDOT to adopt a paradigm shift when it comes to transportation: to focus on moving people instead of vehicles, noting that such an approach "is not only a new way of understanding and responding to the challenges we face today, but well-prepares us for any number of possible futures." Meeting the Commission's challenge will require finding ways to encourage the use of more shared travel modes ranging from transit to carpools.

Currently, most trips both to work and non-work destinations are made in vehicles in which the driver is the only occupant. This trend not only exacerbates congestion but contributes to greenhouse gas emissions. Changing travel behavior, however, requires providing commuters and other travelers with better options for shared travel modes ranging from transit to carpools, vanpools, employer shuttles and so-called "first mile last mile" connections to transit.

As has already been discussed, many actors—Regional Transit Authorities, Transportation Management Associations, municipalities, employers and others—can help provide such services. Another way of encouraging shared travel and thereby moving more people in fewer vehicles is to provide infrastructure that will provide speedier and/or more reliable travel for those who choose to use shared travel modes.

Greater Boston has relatively few travel lanes dedicated to transit and shared travel modes. As far as we could determine, there has been no comprehensive effort to look at the potential for adding new High Occupancy Vehicle (HOV) lanes since the 1990s, when planning for the Big Dig was underway. The existing HOV lanes on I-93 south and north of the city cover relatively short distances and do not necessarily provide sufficient travel time savings to achieve their objectives. Enforcement appears to be an issue, at least for the HOV lane on the north side of Boston.

In addition, the few HOV lanes that exist are not connected to a network either of high occupancy vehicle lanes or parking facilities that could support transfers from personal vehicles to shared travel modes. Greater Boston has no network of infrastructure for commuters who might want to drive part of the way but avoid the worst of the congestion inside I-95/128 by parking in a park and ride lot and then taking shared travel modes (buses, shuttles, vanpools or carpools) for the rest of their commute, travelling in dedicated lanes for vehicles with two or more occupants. MassDOT does own park and ride lots but many are full and there is no organized system for assessing where additional commuter parking might be valuable or for ensuring that bus and other shared travel services are available to those who would use the parking facilities.

MassDOT needs to take a comprehensive look at opportunities for creating more high occupancy vehicle lanes on major highways and arterials around Greater Boston, connected to additional commuter parking and bus or shuttle services. Such a network of parking, travel lanes and shared travel services could – unlike the few modest and disjointed HOV lanes now in existence – could allow commuters to avoid traffic congestion inside I-95/128 by parking and shifting to shared travel modes and/or by using high occupancy vehicle lanes to bypass congested general travel lanes. It may be difficult to identify options for creating new high occupancy vehicle lanes around Greater Boston, as well as new commuter parking facilities that can be connected to those lanes. But given the levels of congestion identified in this report, it is time to try. The success of the Logan Express system that provides airport-bound employees and travelers with places to park and buses to ride can serve as a model or at least an inspiration.

One opportunity worth evaluating is the use of shoulders not so much as general travel lanes but as potential travel lanes for buses. While the Federal Highway Administration has rules for using shoulders as travel lanes, any effort to identify potential locations for additional high occupancy vehicle and bus facilities in Greater Boston should also consider whether there are locations where at least transit use of shoulders may be possible. Route 128, for example, is one of several highways that might benefit from a bus on shoulder system. Given the density of employment along the highway, a bus on shoulder option might attract many of the employees who now suffer from and contribute to daily congestion. If this service could be paired with strategically sited park and ride lots and feeder bus networks, a bus on shoulder alternative could offer a transit option as an alternative.

This effort can also support the feasibility work on managed lanes described in Chapter 5.

Recommended Next Steps:

- ☐ MassDOT will launch a year-long effort to identify potential locations for HOV lanes, commuter park-and-ride lots and "bus on shoulder" operations throughout Greater Boston. The focus will be on identifying potential networks that would support substantially increased use of buses, shuttles and other shared travel modes by commuters who would transfer out of cars they are driving alone and shift to shared travel modes before reaching the worst of the traffic congestion in and around Greater Boston.
- ☐ MassDOT will explore existing locations in the network of roads that it owns where they may be a need for bus priority facilities to serve existing MBTA or RTA bus services, including examining whether there is any feasible way to provide MBTA buses with 'queue-jump' options getting on or off the Tobin Bridge (for implementation after completion of current construction on the bridge and Chelsea curves).

INCREASE REMOTE WORK AND TELECOMMUTING

Employers have a significant amount of influence on the commutes of their employees, including allowing for flexible commuting options that could impact roadway volumes, especially at peak travel periods. But Massachusetts lags behind other states in its share of workers who telecommute. While remote work is not be appropriate or even possible for all employees in all industries, many unrealized opportunities exist to offer alternative work arrangements like telecommuting or flexible work schedules. Some of the sectors with the largest share of telecommuters are also among the state's largest employers, including the health care and social assistance as well as professional and technical services.

Of course, not all workers in all industries have the opportunity to telework. Nurses, retail and restaurant workers, and construction workers usually need to be on-site in specific places at specific times of day. But as technology improves and teleworking becomes an increasingly viable option for a wide range of workers, telecommuting and remote work arrangements could make a meaningful difference in vehicular congestion during peak travel hours.

As noted in Chapter 3, there is a markedly lower share of home-based workers in Massachusetts and the Boston region than in other states or metro areas. Just 5.3 percent of workers across both Massachusetts and the Boston metropolitan statistical area worked from home or telecommuted in 2017. Nationally, Massachusetts ranks 20th of all states and the District of Columbia with respect to workers who telecommute or work at home, lagging far behind Colorado, where 8.5 percent of workers were home-based in 2017. At the metropolitan area level, the Seattle, Atlanta, San Francisco, and Raleigh metro areas have home-based work rates greater than those in Boston. Simply bringing telecommute rates up to those in similar metro areas and states could take tens of thousands of commuters off congested roadways at peak travel times.

Recommended Next Steps:

- MassDOT will conduct additional research on how employers are running successful telecommuting and work-from-home and identify best practice models. This research can help support future implementation of a managed tax credit program, proposed in the transportation bond bill and capped at $50 million annually that would provide a credit of $2,000 for every employee who no longer commutes.
- State agencies, including but not limited to MassDOT, can lead by example by reviewing existing flexible hours and telecommuting policies and making adjustments as appropriate to provide at least some employees with options for avoid congested peak hour travel conditions.
- Public and private employers can incorporate remote work sites, telecommuting and work from home options, as well as flexible work options, in their employee commute options and transportation demand management programs. Employers should consider investing in technologies that facilitate telework and creating a work culture that supports flexible and alternative working arrangements.

PRODUCE MORE AFFORDABLE HOUSING, ESPECIALLY NEAR TRANSIT

This strategy is perhaps the most fundamental: producing more housing in order to make it possible for more people to live closer to their jobs, thereby shortening commutes and reducing the overall need for driving. With housing affordability and availability already a major topic of discussion, the Commonwealth is facing a profound dilemma as the numbers of residents and households are far outstripping the supply of housing, particularly in areas with good access to public transit, employment centers, and other destinations.

Housing is being constructed unevenly across the region, often only at the high end of the cost spectrum, and in much smaller numbers than is needed. More and more residents of the region are paying as much as half of their monthly income for housing, reducing economic security, contributing to inequality, and making Massachusetts a difficult place for people to settle. As analyzed by the Metropolitan Area Planning Council, the 15 municipalities that surround and include the City of Boston – home to 1.5 million people – have added 148,000 new jobs since 2010, while only permitting 32,500 units of housing. It is in the interests of the Commonwealth as a whole, as well as individual municipalities, to fill those jobs with people who can live within reasonable commuting distance of their work, contribute to their communities, and afford homes for families. Otherwise, greater volumes of congestion and increased residential and spatial economic segregation will continue.

Some municipalities that receive MBTA service are working hard to produce more housing. The Metro Mayors Coalition has set a collective target for production of 185,000 housing units by 2030 and agreed on a set of ten principles to guide future housing development and preservation. The cities and towns in the coalition include Arlington, Boston, Braintree, Brookline, Cambridge, Chelsea, Everett, Malden, Medford, Melrose, Newton, Quincy, Revere, Somerville, and Winthrop – many of the communities that are served by MBTA rapid transit.

Other cities and towns, including some served by MBTA commuter rail, effectively limit the construction of new housing, thereby reducing the benefits of public transit while also contributing to regional congestion and housing unaffordability. MBTA service should be used to attract and concentrate residential and employment density and to attract new riders and reduce the number of vehicle trips. More opportunities to affordably live in communities in and around employment centers, especially in those places that are served by reliable transit service, provides many regional benefits, including helping to mitigate roadway congestion.

Recommended Next Steps:

- ☐ The Commonwealth should continue to pursue state-level policies that encourage cities and towns to produce more housing, especially in those areas that are best positioned to enable good non-vehicular access to destinations by residents.
- ☐ Cities and towns, particularly those served by the MBTA, should consider changing their land use, zoning, housing, and transportation policies as needed to avoid limiting housing production or exacerbating existing congestion with further low-density, automobile-oriented housing and commercial development.

ENCOURAGE GROWTH IN LESS CONGESTED GATEWAY CITIES

Municipalities and regions – local decision-makers as well as Metropolitan Planning Organizations and Regional Planning Agencies – wield significant control over many of the decisions about where homes and jobs are located and therefore influence where and how badly congestion occurs. Land use and zoning decisions that drive the siting and placement of everything from retail stores to office buildings to the size and nature of housing directly affect how much people need to travel to complete their daily rounds.

The growing number of people who live and work in Massachusetts must be able to get to places and access opportunities conveniently and in a reasonable amount of time. The major employment hubs in the Commonwealth are primarily located in Greater Boston and are concentrated along I-495 and the I-95/128 belt. This means that a large share of all existing and future workers in the state are and will be commuting to roughly the same places at roughly the same times or are at least taking the same roadways to get between home and work. This pattern has been true for decades and has only intensified as the Commonwealth has gained jobs and residents.

Municipalities have a powerful opportunity to reduce congestion by encouraging new housing, especially higher-density housing, next to or close to transit services. This would help Massachusetts residents get to the places they need and want to go without having to rely as much on a car, contribute to roadway volumes and pollution, or get stuck in traffic. Several Gateway Cities, including Attleboro, Brockton, Haverhill, Lowell, and Lynn, are served by the MBTA's Commuter Rail system. Permitting and developing housing near transit services, as some of these communities are doing, is a clear way to not only encourage transit use but incentivize people to move to these places from either more expensive areas of Greater Boston or from low-density areas far away from employment centers.

As long as most employment growth continues in the same places in or near Boston's urban core, roadway volumes in those areas during peak travel periods will worsen. Companies control their siting decisions, and where they decide to locate affects not only their access to the other companies with which they collaborate but the access that workers have to them. Too often, individual siting decisions by employers lead to calls for new transportation investments as congestion worsens. Better coordination at the outset could help break this pattern.

Communities and municipalities also benefit from high degrees of economic and other activity. But the persistent concentration of employment growth in the same locations along corridors that already see some of the worst congestion in the state during peak travel periods further exacerbates challenges to drivers. While myriad considerations factor into where a company decides to establish itself, the effects of location on the transportation network must be more prominently considered. Redistributing economic activity to parts of the state that are already well-prepared to anchor regional economies, including Gateway Cities, is one strategy to not only reduce traffic volumes on corridors that are frequently stressed but to encourage more growth in and around these cities, many of which already have infrastructure that can support employers and help to transport employees.

Recommended Next Steps:

- ☐ Employers should consider, and state policy should encourage, locating jobs and commercial growth in Gateway Cities or other communities with strong transit ties to residential areas and other activity centers.
- ☐ Gateway cities should encourage the development of high density and affordable housing near commuter rail stations and other transit, especially transit services that connect to major existing or planned employment centers.

5 CONGESTION PRICING IN MASSACHUSETTS

Many U.S. states and cities are currently exploring the use of congestion pricing and, to date, at least forty congestion pricing projects have been implemented in the United States. A number of recent reports have cataloged both the benefits and challenges of congestion pricing.[55] As one part of its recommendation on managing traffic congestion, the Commission on the Future of Transportation in the Commonwealth recommended that MassDOT "consider various congestion pricing strategies that compel changes in default transportation behaviors on corridors that are or could be served by transit and/or new mobility options."

Following up on the Commission's recommendation and as part of undertaking this congestion study, MassDOT has explored different types of congestion pricing. We have focused on those that could work in Massachusetts, given the specifics of our existing tolling infrastructure, our state statutory context, and the geography of Greater Boston's roadway network, including where congestion is worst.

Studies and experience in the United States and abroad have shown that congestion pricing, properly designed and implemented, can be effective—but it is not a silver bullet solution. Congestion pricing could be one tool in the Commonwealth's congestion toolkit, a tool worth investigating and implementing while also undertaking the recommended next steps presented in the previous chapter. We also stress that implementing any type of congestion pricing, even as a pilot, will involve potentially difficult policy choices and likely require state statutory changes.

To help inform a robust and useful conversation among the stakeholders discussing congestion pricing as a potential strategy for congestion management, we propose the use of a common vocabulary that makes the critical distinction between tolling and congestion pricing. For purposes of this report, we make the following distinctions:

Tolling involves drivers paying a fixed fee to use specific pieces of infrastructure. The Mass Pike has tolls on its entire expanse from the New York State border to Boston. The primary and sometimes exclusive purpose of tolling is to generate revenue to maintain the infrastructure on which it is collected. That is the case in Massachusetts, as MassDOT's enabling act requires that all revenue received from tolls be applied exclusively to the costs of owning, maintaining and operating tolled roads.[56]

Smart tolling or variable tolling is a smarter way to meet the revenue-raising objective of tolling, one that generates revenue and also has the potential to change travel behavior and thereby relieve congestion. With smart tolling, the level of tolls along a specific roadway or throughout an area varies between peak and off-peak periods or changes

[55] Cambridge Systematics, Inc., 2017. Tolling and Congestion Pricing Research and Policy Support: Congestion Pricing White Paper. Prepared for Oregon Department of Transportation; Seattle Department of Transportation, 2019. Seattle Congestion Pricing Study Phase 1 Summary Report.

[56] Massachusetts General Laws Chapter 6C, Section 13(c).

based on congestion levels, roadway volumes, or location. This type of smart tolling, while still producing revenue to cover roadway costs, thus also serves as a form of congestion pricing.

Congestion pricing, while it generates revenue, is primarily a mechanism for changing travel behavior and relieving congestion. Congestion pricing is often designed to provide congestion relief in two ways: by sending price signals to drivers and by investing the resulting revenue in transit or other attractive alternatives to driving alone, particularly during peak travel periods. Congestion pricing, as discussed below, can take different forms. If Massachusetts wants to congestion price roadways and invest the proceeds in public transportation or other mobility options, changes will have to be made to state law, which restricts the use of toll proceeds to investments in operating and maintaining the tolled facility.

This report recommends some next steps relative to congestion pricing. But first, it is important to discuss what is *not* being recommended with respect to congestion pricing—and why.

Problems with Smart Tolling

This report does not recommend using the existing toll network as the basis for any smart tolling or congestion pricing efforts—especially if those efforts involve discounting existing tolls. Massachusetts' All Electronic Tolling system certainly has the capacity to be used as a collection mechanism for congestion pricing. But the current system of toll gantries, in their current locations, cannot effectively be used to implement a congestion pricing system. Simply converting existing tolls into behavior change mechanisms for congestion will not address the worst areas of congestion, will not work to shift travel times where no off-peak capacity exists, is unlikely to change travel behavior at current toll rates (especially if discounts are used) and raises serious equity issues.

If Massachusetts is going to experiment with or adopt congestion pricing, that effort should focus on the areas where congestion is most severe. Yet none of the locations of the five most severe occurrences of congestion identified in Chapter 2—portions of I-93, Route 2 and the Southeast Expressway—are currently tolled. Similarly, as illustrated in Figure 90 the most consistently congested corridors identified in Chapter 2 are not currently tolled.[57]

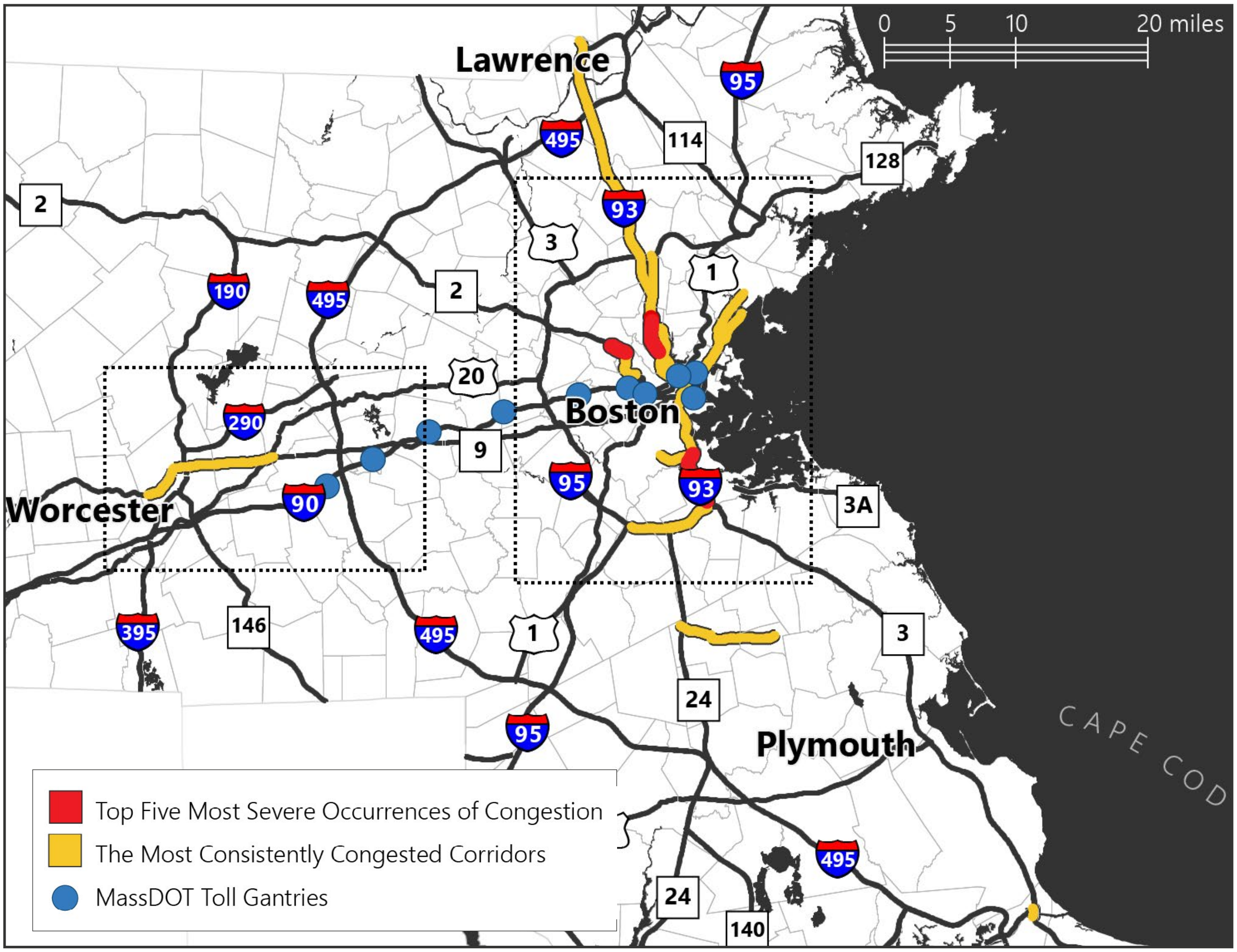
There is almost no overlap between current gantry locations and where the Commonwealth's most severe congestion occurs; gantries are located where they are due to history and revenue-raising needs. And current law limits MassDOT's abilities to put up additional gantries: MassDOT is statutorily authorized to impose tolls only on the Turnpike and the Metropolitan Highway System, a limitation that effectively prohibits border tolls, for example. If Massachusetts were to build a congestion pricing system using toll gantries, the number and location, and maybe type of gantries must change first, which would require changes to state law. (Even changing the toll structure to implement time-of-day or other smart tolling would require holding hearings and publishing a report documenting that other fiscal alternatives were examined for raising the required revenue and were found not to be viable,[58] another statutory provision confirming that the current system has been established as a tolling system to collect revenue, not as a congestion pricing platform.)

Using smart tolling to shift drivers to off-peak periods can work only if there is off-peak capacity to be had, but the data presented in Chapter 2 demonstrates that such off-peak capacity is not available at all current gantry locations. Time-of-day discounts are designed to shift drivers into less congested "shoulder" time periods earlier or later than the traditional peak. For such a smart tolling program to make sense, two things need to be true: the roadway needs to be congested enough during the peak to warrant such intervention and there needs to be

57 An exception is the Sumner Tunnel, included in the Route 1A corridor identified as one of the state's most consistently congested corridors. But congestion pricing there is not possible unless the General Court is willing to change the statute that guarantees low tolls rates for the Sumner, Callahan and Ted Williams tunnels for residents of East Boston, South Boston and the North End (see Massachusetts General Laws Chapter 6C, Section 13(b)). If the tunnels are congestion priced—even as a pilot -- but resident discounts are left in place, any congestion relief provided by higher tolls will be ineffective as any resulting capacity will be filled by vehicles with resident discounts paying 20 cent tolls.

58 Massachusetts General Laws, Chapter 6C, Section 3(18).

Figure 90. Most Consistently Congested Corridors and Top Five Most Severe Occurrences of Congestion with Gantries



capacity to spread the peak traffic into other time periods. The charts showing speed and volume data in Chapter 2 (Figures 20 through 29) and Appendix E illustrate that many current toll locations do not have both characteristics. At the gantry on the Mass Pike in Southborough (shown in Figures 22), for example, travel speeds on a typical day never fall below 50 miles per hour traveling eastbound in the morning peak; no peak shifting is needed. On the other hand, traveling into Boston southbound on the Tobin Bridge (Figure 25) volumes rise and speed drops as early as 4 a.m., and speeds remain at or under 30 miles per hour until 10 a.m. In such locations there is no less congested "shoulder period" into which to move the peak hour traffic, likely because drivers have already spread out the peak in response to the congestion itself, without the need for an additional price signal.

A third problem is that any smart tolling scheme can only be effective in Greater Boston if the price signal is significant enough to change travel behavior. Prices need to be meaningful, to incentivize drivers to either travel at a different time or on a different road. We do not recommend even piloting an off-peak toll discount program because discounting existing toll rates is unlikely to produce the desired change in travel behavior. Massachusetts already has among the lowest per-mile toll rates of all roadways in the E-ZPass network.[59] Discounting already modest tolls is unlikely to induce peak period travelers to shift their schedules. And while toll rates are modest, they provide important revenue. Changing the toll structure by providing off-peak discounts would result in a loss of revenue needed to keep the Metropolitan Highway System and Turnpike in a state of good repair.

Since discounts from existing toll rates are unlikely to change anyone's behavior, an effective smart tolling program for Massachusetts would presumably need to increase toll rates during peak hour. But such a system

59 MassDOT analysis, based on information gathered from websites for each state agency with E-ZPass roads.

would raise serious equity issues for drivers who cannot change the time that they commute or switch to other modes. With managed lanes, as discussed below, commuters have the option of using untolled roadways; with smart tolling, all drivers would have to pay. Peak hour premium tolling could not change such commuters' travel behavior; instead, they would be penalized for driving at peak times when they have no option.

If Massachusetts is going to explore congestion pricing, we must move beyond the notion that we can use the existing tolling system or convert it to smart tolling. Instead, the focus should be on congestion pricing mechanisms that address severe congestion where it occurs, not where there happen to be toll gantries today.

Congestion Pricing Mechanisms

There are many ways to categorize congestion pricing mechanisms, as is evident from a review of recent studies and conferences (including the National Congestion Pricing Conference held at the U.S. Department of Transportation Headquarters in Washington, D.C. in 2018).[60] Given that this congestion study is being conducted by a state department of transportation and focuses on major state and regional roadways, we categorize congestion pricing mechanisms based on whether they are generally implemented by cities, states, or both:

- *Urban congestion pricing mechanisms* have been implemented in a number of cities around the world and are being explored by several U.S. cities. The most common of these is usually referred to as "cordon pricing," under which vehicles must pay a fee in order to be allowed to drive into, typically, the densest and most congested areas within a city. The recent Seattle congestion report further distinguishes cordon pricing, which imposes fees for traveling to or from a priced zone, from "area pricing" which also involves fees for traveling within the defined area.
- *Mileage or usage charges* can be assessed at the city or state level. The Seattle congestion study further distinguishes between "fleet pricing," which imposes fees on specific types of vehicles such as trucks or Transportation Network Companies and "road usage charges" which impose fees tied to road use. Sometimes referred to as mileage-based pricing or Vehicle Miles Traveled (VMT) fees, these are sometimes seen as revenue-raising mechanisms but could be used to implement congestion pricing if the per-mile charge changes based on time of day and/or travel location.
- *Managed lanes* are rapidly becoming the congestion pricing mechanism of choice for state transportation departments, with 40 projects spread across interstates and major state roadways in at least 15 metropolitan areas including Atlanta, Seattle, San Francisco, Los Angeles and Tampa. Managed lanes involve a system of parallel lanes on a highway, with one or more lanes for drivers that are not priced (in other words, that remain free) while one or more lanes require drivers traveling alone to pay a toll or drive free, which may be constant or vary depending on congestion levels.

With respect to urban congestion pricing, perhaps the most well-known example is in London, where drivers are assessed a fee of roughly $16 per day if they want to travel into or park in London's central business district. Interest in cordon or area pricing has grown in the United States, with New York State enacting legislation that authorizes New York City to assess a fee on drivers traveling below 60th Street in Manhattan starting no earlier than December 31, 2020. This additional congestion pricing mechanism would supplement New York City's existing smart tolling rates, which already provide off-peak discounts on weekdays between 10 a.m. and 4 p.m. for both personal vehicles ($2 off the $12.50 peak hour E-ZPass toll rate) and trucks ($2-$6 off the peak hour rates for trucks of varying sizes).

Cordon or area pricing is generally implemented by cities, not states: we know of no instance in which a state or country has imposed cordon or area pricing in a city which did not support that strategy. In Massachusetts, an urban cordon model would require the strong support of the City of Boston and might require statutory or policy changes to authorize the city to implement such pricing. At this time, the City of Boston does not appear to have an interest in pursuing cordon pricing. While MassDOT has the responsibility for addressing regional congestion issues on state-owned and controlled roadways

60 https://www.fhwa.dot.gov/ipd/tolling_and_pricing/resources/webinars/congestion_pricing_2011.aspx

leading to Boston, the city must control any decision about the use of urban congestion pricing within its borders. Therefore, we do not propose further exploration of cordon or area pricing for the City of Boston at this time.

Mileage or usage charges can be imposed at either the state or municipal level. Rhode Island, for example, has instituted truck tolls, taking advantage of authority under federal law that permits tolling of currently non-tolled bridges and tunnels. The so-called "Rhode Island model" cannot, however, be used for congestion pricing if one of the goals of congestion pricing is to invest in alternatives for drivers who want to avoid the charge: the use of the toll revenue is limited to the reconstruction, maintenance and operation of the tolled facility or of other bridges on the National Highway System.

London Congestion Charge Zone

London is one of the most congested cities in the world. The same Inrix ratings[61] which rank Boston as the most congested city in the United States classify London as more congested than Boston, with London as the 6th most congested city in the world (with 227 hours annually lost to traffic delay) and Boston as the 8th (with 164 hours annually lost to traffic delay).

Traffic congestion had long been a defining characteristic of London's streets when London's cordon charge first went into effect in 2003. The city's Congestion Charge Zone (CCZ) is an area that surrounds central London and covers an area of about 13 square miles.[62] Cars entering the CCZ between the hours of 7 a.m. and 6 p.m. on weekdays (excluding holidays) are charged £11.50 per day[63] – roughly $16.20 – regardless of how much time they spend there. As of April 2019, vehicles entering the CCZ that do not meet certain emissions standards pay an additional surcharge.[64]

The effects of the congestion charge were initially positive but have been more mixed over time. According to data released by Transport for London, the number of personal cars entering central London fell by 39 percent between 2002 and 2014.[65] Traffic volumes have changed little following the initial impact of the charge: even raising the cost of the toll in 2005 failed to deter many additional drivers from entering the zone than it did in its first days. Travel times within central London have not markedly improved since the CCZ was enacted and vehicle miles travelled within the zone have remained essentially flat.[66]

An August 2017 report on bus transportation in London by the Transport Committee of the London Assembly found that bus ridership – like that in Boston and many U.S. cities – was declining and that "the primary reason for the fall in usage appears to be the rise in traffic congestion on London's roads", noting that "after a long period of stability, traffic congestion had been increasing for a number of years" in London.[67]

Some argue that congestion levels remained the same because of the influx of hired cars like taxi services as well as Uber and Lyft, who were initially exempt from the charge. Data shows a significant increase in the number of "private for hire" vehicles registered between 2010 and 2018.[68] However, beginning in spring 2019, Uber and Lyft will also be required to pay the congestion charge. And the current mayor has proposed expanding the surcharge for vehicles not meeting emissions standards—which is levied in addition to the congestion charge—to cover a much broader area of the city beginning in 2020.

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61 http://inrix.com/scorecard/

62 Tang, Cheng Keat, 2017. "The Cost of Traffic: Evidence from the London Congestion Charge". https://www.aeaweb.org/conference/2018/preliminary/paper/bnGtSeif

63 Ibid; Metz, David, 2018. "Tackling urban traffic congestion: The experience of London, Stockholm, and Singapore". Case Studies on Transport Policy 6, 494-498; Badstuber, Nicole. 2018. "London's Congestion Charge is Showing Its Age." CityLab, https://www.citylab.com/transportation/2018/04/londons-congestion-charge-needs-updating/557699/

64 https://www.london.gov.uk/press-releases/mayoral/ulez-will-start-in-2019-to-tackle-toxic-air

65 London Assembly, 2017. "London stalling: reducing traffic congestion in London." https://www.london.gov.uk/sites/default/files/london_stalling_-_reducing_traffic_congestion_in_london.pdf

66 Metz, David, 2018. "Tackling urban traffic congestion: The experience of London, Stockholm, and Singapore". Case Studies on Transport Policy 6, 494-498.

67 London Assembly, 2017. "London's bus network." https://www.london.gov.uk/sites/default/files/bus_network_report_final.pdf

68 Badstuber, Nicole, 2019. "London congestion charge: what worked, what didn't, what next." https://theconversation.com/london-congestion-charge-what-worked-what-didnt-what-next-92478

Congestion Pricing Mechanisms for Further Consideration

So what types of congestion pricing might be appropriate for Massachusetts to explore further? With a focus on proven methods that can be wielded to address congestion where it is most severe while also not unfairly burdening those with the fewest options, two potential pricing strategies are most appropriate for further consideration: usage charges focused on Transportation Network Company (TNC) trips and managed lanes.

While this congestion study did not examine the congestion impacts of TNCs in detail—largely because the study does not look at the local roads most used by TNCs—a growing body of evidence indicates that TNCs contribute to local traffic congestion. While touted as reducing traffic, even shared ride services such as UberPOOL, Uber Express POOL and Lyft Shared Rides add mileage to city streets and do not appear to offset the traffic-clogging impacts of private ride TNC services like UberX and Lyft."[69] Here in Massachusetts, the Metropolitan Area Planning Council has prepared a series of research briefs that support concerns that TNCs are contributing to localized congestion and potentially to increased greenhouse gas emissions.

TNC taxes or fees have become the most popular form of "usage fee" or "fleet pricing" in recent years. A recent research paper by the Eno Center for Transportation found that seven major cities and 12 states had imposed some type of fee or tax on such trips.[70] Massachusetts is one of those states but several legislators and stakeholders have suggested that the time has come for the Commonwealth to reconsider both its existing fee structure and the uses of the revenue generated by those fees. We look forward to collaborating with our colleagues in the Legislature as they consider various bills that have been filed on TNCs including the Administration's Act Relative to Public Safety and Transparency by Transportation Network Companies.

The second type of congestion pricing worthy of further study is the use of managed lanes. A growing body of evidence suggests that dynamically priced lanes, in locations with parallel and free general travel lanes, can provide a real option for those willing and able to pay more to avoid congestion while simultaneously improving the performance of the entire corridor including the non-tolled lanes. The Washington State Department of Transportation (WSDOT) published a report on the efficacy of three years of operations for express toll lanes on I-405, for which drivers paid an average toll rate of $3.17 during peak periods. WSDOT found that the highway is carrying up to 23 percent more vehicles each weekday during peak periods, average speeds in the express toll lanes have increased by as much as 27 miles per hour and general purpose lanes have improved by as much as six miles per hour. Both drivers and buses using the lanes save up to 11 minutes per trip compared to before the express toll lanes opened.[71]

The Georgia State Road and Tollway Authority has reported similarly positive results for its 67 mile network of toll lanes on I-85 northeast of Atlanta, I-75 to the south of the city and I-75 and I-575 northwest of the city. The Authority reported recent statistics to the Atlanta Journal-Constitution: speeds have increased in both the toll lanes and general lanes as drivers choosing to pay the toll have freed up space in the untolled lanes. Rush hour traffic on the I-85 and I-75 South Metro express lanes averaged around 10 miles per hour faster than in the adjacent free lanes, with the average toll paid in April 2019 of $3.44. One study by the Authority found that one-quarter of those using the I-85 toll lanes were riding in buses.[72]

As the Commission on the Future of Transportation cautioned when it recommended consideration of congestion pricing strategies, "Price signals can change travel behavior to alleviate congestion, but only if drivers can change their time of travel or switch to transit or other multi-passenger modes. Pilots should therefore focus on corridors where commuters have alternatives and/or off-peak capacity exists. How the burden of congestion fees may fall more heavily on people with lower incomes should be a specific consideration." A number of issues will need to be addressed before Massachusetts can decide to implement managed lanes here.

69 Schaller Associates, 2018. The New Automobility: Lyft, Uber and the Future of American Cities.

70 Eno Center for Transportation, 2018. Taxing New Mobility Services: What's Right? What's Next?

71 Washington State Department of Transportation, 2018. I-405 Express Toll Lanes: 36 Months of Operations.

72 Wickert, David, 2019. "Are Toll Lanes Really the Answer to Atlanta's Traffic Mess"?, Atlanta Journal-Constitution.

Managed Lanes on I-66 in Virginia

In December 2017, a dynamic pricing approach to traffic management went live on a nine-mile stretch of I-66 between the I-495 beltway in Virginia and Washington, DC.[73] These managed lanes have attracted national attention because tolls are uncapped—there is no limit to the price that solo drivers can be charged in order to manage speeds in the tolled lanes and daily one-way tolls have exceeded $40 at times.[74]

The tolls are limited to single-occupancy vehicles, which were previously barred from using the High Occupancy Vehicle Lane on this stretch of roadway during rush hour periods. Tolls are also only in effect during the peak period (5:00 to 9:30 a.m. and 3:00 to 7:00pm) and only in peak directions. Tolls are adjusted every six minutes based on existing traffic volumes. After one year, the average morning weekday toll is close to $8.[75]

Because the program is relatively new and a substantive data report has yet to be released by the Virginia Department of Transportation, outcomes of the dynamic pricing approach are unclear. Data shows that not only are traffic volumes on I-66 lower during the peak period after the tolling began, but more commuters are carpooling than before the tolls were enforced and transit ridership increased over the previous year.[76] Anecdotal evidence, however, suggests that the scheme has done more to shift the peak and extend rush hour past the time the toll ends than impact actual traffic volumes. Local, formerly uncongested roads have also seen an uptick in traffic, as drivers are deterred from taking the toll road and are seeking alternate routes. While traffic speeds have risen slightly, one analysis found that "the expanded HOV hours, rather than the tolls, appeared to have the most significant impact on increasing speeds on Interstate 66".[77]

73 Virginia Department of Transportation, 2016. http://inside.transform66.org/meetings/asset_upload_file542_90544.pdf

74 Lazo, Luc and John D. Harden. 2018. "Year-old 66 Express Lanes have caused shifts in commuter behavior, but not necessarily in ways officials have hoped". Washington Post. https://www.washingtonpost.com/local/trafficandcommuting/year-old-66-express-lanes-have-caused-shifts-in-commuter-behavior-but-not-necessarily-in-ways-officials-hoped/2018/12/08/6e78d944-e832-11e8-a939-9469f1166f9d_story.html

75 Smith, Max, 2019. "I-66 Tolls turn 1 year old – Are they working?" WTOP. https://wtop.com/dc-transit/2019/01/average-i-66-price-speeds-from-first-year-of-tolls-and-extended-hov-hours/

76 Lazo, Luc and John D. Harden. 2018. "Year-old 66 Express Lanes have caused shifts in commuter behavior, but not necessarily in ways officials have hoped". Washington Post. https://www.washingtonpost.com/local/trafficandcommuting/year-old-66-express-lanes-have-caused-shifts-in-commuter-behavior-but-not-necessarily-in-ways-officials-hoped/2018/12/08/6e78d944-e832-11e8-a939-9469f1166f9d_story.html

77 Smith, Max, 2019. "I-66 Tolls turn 1 year old – Are they working?" WTOP. https://wtop.com/dc-transit/2019/01/average-i-66-price-speeds-from-first-year-of-tolls-and-extended-hov-hours/

One such issue is the need to comply with federal law when adding tolls to roadways that are currently not tolled. Federal law controls the use of High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) lanes on all Federal-aid highways, including but not limited to Interstate highways. Under the so-called Section 129 program, states can put tolls on such highways in order to pay for rehabilitation or reconstruction activities but only as long as the overall number of toll-free lanes is not reduced.[78] Many managed lane projects therefore involve adding an additional lane and tolling that lane, while leaving the same number of untolled lanes. (There is also a way to convert HOV lanes to HOT lanes, but as noted previously, Massachusetts currently has very few HOV lanes.)

Under the so-called Section 166 program for High Occupancy Vehicle and High Occupancy Toll lanes, states can permit solo drivers into HOV lanes for a fee but must prove that they will enforce all HOV and other restrictions and that the tolled lanes will meet performance standards (generally that the tolled lanes will maintain speeds of 45 miles per hour or more at least 90 percent of the time).[79] Many states have found that they need to increase toll rates in order to meet those operational requirements. In 2018, for example, Utah had to double the maximum toll to $2 per segment of its 7-zone Express Lanes system because speeds in parts of the system dropped to as low as 31 miles per hour during peak

78 23 United States Code Section 129.

79 23 United States Code Section 166.

periods. Georgia similarly had to eliminate its cap or maximum toll on I-85 in 2018 and since then tolls have topped $15 at times. Washington DOT has reported that in recent periods its $10 maximum toll rate was reached during almost two-thirds of peak weekday periods.

The federal requirements are not the only reason that congestion prices on managed lanes might need to be set at high levels. Congestion tolls need to be set at a rate that will compel behavior change, at least some of the time for some peak-hour commute trips. Current toll rates in Massachusetts are nowhere near high enough to cause most drivers to think twice about driving into congested areas.

As part of investigating the potential of managed lanes to address congestion, we will need to have a civic discussion about whether to impose fees of $2-3 per one-way commute “segment”—a minimum of $20 to $30 weekly—on commuters who want to use the managed lanes rather than the slower general purpose lanes.

Whatever type of congestion pricing Massachusetts chooses to explore must ensure that low-income workers and those without commute alternatives are not effectively priced out of travel to certain locations or limited in their access to jobs and other opportunities. One potential advantage of managed lanes as a congestion pricing mechanism is that they pose fewer equity concerns than other types of congestion pricing, for three reasons. First, motorists can still choose to travel in the parallel, untolled general lanes on the same roadway. Second, as noted above, experience in other states demonstrates that there are lesser but meaningful increases in travel speeds even on those untolled lanes. Finally, if carpools, vanpools and private and public transit buses are allowed to use managed lanes for free, many commuters will have the ability to take advantage of the faster travel speeds in the managed lanes without paying the congestion fees.

As with any type of congestion pricing, investigating and implementing managed lanes will require extensive dialogue among all affected stakeholders and collaboration with our colleagues in the Legislature. There are many thoughtful models for Massachusetts to consider as we begin to investigate the potential for using managed lanes to price and address congestion in Greater Boston. In Oregon, for example, the Keep Oregon Moving Act established a clear process and timetable for tackling issues such as diversion of traffic onto local roads to avoid the toll charges and impacts on low-income and other populations that could be unduly burdened by the congestion fee.

Recommended Next Steps:

- ☐ MassDOT will investigate the feasibility of implementing managed lanes on one or more highways in Greater Boston, assessing options for the addition of High Occupancy Toll lanes or other managed lanes on highways north, south and west of Boston. While this feasibility analysis will consider a variety of options for managed lanes, one location that has been considered in the past for a managed lane and will be included in this feasibility analysis is the Southeast Expressway. The Southeast Expressway is one of the most congested corridors identified in this report and is one of the only locations in Massachusetts with an existing High Occupancy Vehicle lane. Over the next year, this feasibility analysis will assess the travel, congestion relief and revenue impacts of different types of congestion fees, the likelihood of traffic diversion to local roads, equity impacts and the need for changes to state and/or federal law to support implementation of managed lanes in Massachusetts.
- ☐ MassDOT and the Department of Public Utilities (which regulates Transportation Network Companies) should collaborate with other stakeholders who have proposed changes to current TNC fee legislation and explore whether a consensus can be developed both on how to change the fee structure to act as a form of congestion pricing for the fleet of TNC vehicles and on how best to invest the resulting revenue.

The Keep Oregon Moving Act

Between 2013 and 2015, Portland, Oregon drivers experienced a 14 percent increase in the number of hours that state roadways were congested and a 23 percent increase in travel times stemming from congested conditions. In order to mitigate and respond to occurrences of congestion, the Oregon legislature approved the Keep Oregon Moving act (HB2017), a measure that increased investments in transportation infrastructure.[80]

With this Act, the Oregon legislature took the lead on deciding where congestion pricing should be implemented and how it wanted the Oregon Transportation Commission (OTC) to work through the many issues that would entail. The legislation required OTC to conduct a feasibility study, develop a proposal and submit that proposal to the Federal Highway Administration by December 31, 2018 to implement congestion pricing along I-5 and I-205 in the Portland metropolitan area.[81]

OTC then convened a Policy Advisory Committee consisting of 24 representatives from local government as well as stakeholders from environmental, business, social justice and equity organizations.[82] That committee worked with OTC to address issues such as what type of congestion pricing should be implemented, the locations on the designated highways best suited to congestion pricing and mitigation strategies to reduce the equity impacts of the recommended congestion pricing scheme.

The proposal submitted to the FHWA for approval and to access to federal funds recommends implementing a variable toll pricing scheme along segments of I-5 and I-205 in the Portland metro area. The proposal also described possible mitigation strategies to address impacts on low-income and other populations that could be unduly burdened by the toll, as well as concerns related to the diversion of traffic onto local roads to avoid the toll charges. While the OTC proposal does not describe specific actions or policies, it does note that these are priorities that need to be addressed as the policy moves through the development process.[83]

The FHWA responded positively to the OTC on January 8, 2019, clearing the way for OTC to move forward with the next stage of traffic, environmental and revenue analyses.[84]

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80 Oregon Department of Transportation, n.d. "Portland Metro Area I-5 and I-205 Tolling Project Frequently Asked Questions", https://www.oregon.gov/ODOT/KOM/VP_FAQs.pdf

81 Oregon Department of Transportation, n.d., "Congestion Pricing Overview", https://www.oregon.gov/ODOT/Pages/VP-Feasibility-Analysis.aspx

82 Ibid.

83 Oregon Department of Transportation, 2018. "Oregon Application to the FHWA: Value Pricing Feasibility Analysis and Proposed Implementation, Traffic Congestion Relief Program." https://www.oregon.gov/ODOT/KOM/VP%20Final_FHWAApplication_Draft.pdf

84 https://www.oregon.gov/ODOT/KOM/19-01-08%20Oregon%20Tolling%20Letter.pdf

6 CONCLUSIONS

Congestion is, from one perspective, a symptom of success: the Commonwealth is currently benefiting from substantial economic and population growth, and dynamic and flourishing places draw a crowd. Paradoxically, congestion can also be seen as a sign of failure, if we as a Commonwealth are unable to provide Massachusetts residents and travelers with options that enable them to reliably get where they need to go, particularly from homes they can afford to jobs they want and need. Action is needed now to ensure that congestion does not erode the positive qualities that attract people and businesses to a place like Massachusetts.

The unpredictability of travel times caused by congestion is fueling frustration, particularly in Greater Boston but increasingly in communities small and large across the Commonwealth. Residents are tired of being late to work, of missing appointments, of never knowing how much time to leave to drive somewhere. It is this problem of variability or “reliability” of the system that has made congestion as much a quality of life problem as it is a transportation or economic problem.

For those who drive in Massachusetts, the data provided in this report likely provide few surprises. Traffic is getting worse in places where it has always been bad—particularly around Greater Boston—and the problem is no longer limited to traditional morning and evening commuting hours. Travel times are becoming less consistent and more unreliable as the road network as a whole comes under greater strain from a growing population and a vibrant economy. Transit buses are increasingly slowed by traffic on local streets, making congestion a problem that affects public transportation as well as driving. While Greater Boston and the roads leading into it are the most frequent locations of sometimes day-long congestion, congested and highly congested roadways can be found throughout the Commonwealth.

Defining the problem may seem relatively straightforward. Finding solutions is not. There is no single, let alone simple, solution to congestion. Many stakeholders need to tackle congestion in partnership, using a portfolio of tools, new and old: relieving bottlenecks, actively managing roadways, encouraging employers to provide their employees with more options for commuting and working from home, implementing policies that produce more housing and connecting those homes to jobs and other opportunities with frequent and reliable transit and other shared mobility options. MassDOT must work in partnership with others to double down on initiatives already underway and investigate solutions not yet tried, including “managed lanes” that may allow Massachusetts to use congestion pricing in a manner that addresses the serious equity issues that can arise when trying to control congestion by making drivers pay more.

A range of factors created today’s growing congestion problem. Only an equally wide range of actions by public and private players alike can fix it.

APPENDIX A

TABLE OF ROADWAYS IN STUDY NETWORK

Roadway Name	South or West Endpoint	North or East Endpoint
Boston-Providence Turnpike	I-95/MA-128, Dedham	Bridge Street, Boston
Centre Street	VFW Parkway, Boston	Arborway, Boston
I-190	I-290, Worcester	MA-2, Leominster
I-195	Rhode Island State Line, Seekonk	I-495, Wareham
I-290	I-395, Auburn	Washington Street, Hudson
I-291	I-90, Chicopee	I-91, Springfield
I-295	RI State Line, North Attleborough	I-95, Attleboro
I-391	I-91, Chicopee	South Street, Holyoke
I-395	Connecticut State Line, Webster	I-290, Auburn
I-495	MA-25, Wareham	I-95, Salisbury
I-84	Connecticut State Line, Holland	I-90, Sturbridge
I-90	NY State Line, West Stockbridge	MA-1A, Boston
I-91	CT State Line, Longmeadow	VT State Line, Bernardston
I-93	I-95/MA-128, Canton	NH State Line, Methuen
Industrial Avenue	I-495, Haverhill	MA-125, Haverhill
Jamaicaway	Arborway, Boston	MA-9, Boston
Lowell Connector	US-3, Chelmsford	Gorham Street, Lowell
MA-107	Bell Circle, Revere	Summer Street, Lynn
MA-114	I-495, Lawrence	MA-128, Peabody
MA-116	MA-9, Hadley	North Hadley Road, Hadley
MA-125	Industrial Avenue, Haverhill	I-495 Haverhill
MA-128	I-95, Peabody	MA-127, Gloucester
MA-146	Rhode Island State Line, Millville	MA-290, Worcester

Roadway Name	South or West Endpoint	North or East Endpoint
MA-1A	I-93, Boston	MA-60, Revere
MA-2	Moore Street, Erving	Memorial Drive, Cambridge
MA-203	Blue Hill Avenue, Boston	I-93, Boston
MA-213	I-93, Methuen	I-495, Methuen
MA-24	I-93, Randolph	Rhode Island State Line, Fall River
MA-25	MA-28, Bourne	I-495, Wareham
MA-27	MA-24, Brockton	West Street, Whitman
MA-28	Leverett Circle, Boston	I-95/MA-128, Reading
MA-28	Bourne Bridge, Bourne	MA-6A, Orleans
MA-57	South Westfield Street, Agawam	US-5, Agawam
MA-6	MA-3, Bourne	Cranberry Highway, Eastham
MA-60	MA-1A, Revere	Bell Circle, Revere
MA-79	MA-24, Fall River	I-195, Fall River
MA-9	US-7, Pittsfield	Copley Square, Boston
Memorial Drive	Eliot Bridge, Cambridge	Main Street, Cambridge
Morrissey Boulevard	I-93, Boston	Day Boulevard, Boston
Soldiers Field Road	Eliot Bridge, Boston	BU Bridge, Boston
Storrow Drive	BU Bridge, Boston	I-93, Boston
Riverway	MA-9, Boston	Park Drive, Boston
US-1	I-95/MA-128, Dedham	I-495, Plainville
US-20	I-84, Sturbridge	I-95, Waltham
US-3	I-95/MA-128, Burlington	NH State Line, Tyngsborough
US-44	Rhode Island State Line, Seekonk	MA-3, Plymouth
US-5	I-91, Springfield	Morgan Road, West Springfield
US-6	US-6 BYP, Wareham	MA-6A, Orleans
US-7	Connecticut State Line, Sheffield	Brodie Mountain Road, Pittsfield
VFW Parkway	Bridge Street, Boston	Centre Street, Boston

APPENDIX B

METHODS, ANALYTICAL APPROACH AND DATA SOURCES

The analysis described in this report, specifically in Chapter 2, relies on several different ways to measure, understand, and describe vehicular congestion on roadways.

Much of our analysis, including the review of roadway conditions throughout an average day detailed in Chapter 2 relies on data collected through the National Performance Management and Research Database (NPMRDS) and a measure that classifies the severity of congestion in terms of travel time and relative to free flow.

The fastest average travel time along a roadway segment represents so-called **free-flow** travel time, in which drivers are to get from origin to destination without being held up by obstructions, including congestion from other cars. To identify free-flow travel times, one years' worth of weekday travel time data was segmented into individual hour-long periods, travel times were averaged across each hour, and the "fastest" hours were highlighted. This "fastest average" time is thus used as the travel time that represents "free-flow" conditions.

Next, free-flow travel times are compared to the average travel time along each roadway segment during each hour-long period throughout the day. These average hourly travel times indicate the "typical" conditions that drivers normally face during these periods.

For example, the fastest average travel time on US-3 North between Burlington and Chelmsford is 11.6 minutes and occurs during the 9 p.m. hour—so in this analysis, free-flow travel time on this segment is 11.6 minutes. But it usually takes drivers 15 minutes during the 8 a.m. hour and 26 minutes in the 5 p.m. hour to traverse this stretch—1.3 times longer in the morning, and 2.2 times longer in the evening.

The severity of roadway congestion on different segments of the roadway network during each hour of the day is calculated as the ratio of average hourly travel time to free-flow travel time, and is classified as:

- *Less congested,* where average travel times are up to 50 percent longer than free-flow conditions;
- *Congested,* where average travel times are up to 100 percent longer than, or up to twice as long as, free-flow conditions; and
- *Highly congested,* where average travel times are over 100 percent longer than, or over twice as long as, free-flow conditions.

In other words, for a trip that normally takes 30 minutes in free-flow conditions, a "less congested" trip is one that takes between 30 and 45 minutes; a "congested" trip is one that takes between 45 and 60 minutes; and a "highly" congested trip is one that takes more than 60 minutes.

While our approach to identifying and measuring congestion uses free-flow travel times as the baseline from which the severity of roadway conditions are gauged, free-flow conditions should not be interpreted to represent the conditions under which drivers should expect to travel on roadways at any or all times of day. We recognize that congestion analyses that rely on free flow to approximate the most "ideal" travel can be misleading: for example, most Massachusetts drivers don't expect to be able to drive from the Braintree Split clear into downtown Boston at 6 p.m. in five minutes, but our approach would classify a 10-minute drive on this corridor as highly congested. In this way, using free flow as a baseline tends to "favor" regions that have low population and low employment, because there is less overall demand for travel, fewer drivers on those roads, and thus fewer instances in which they can slow each other down.

Data Sources

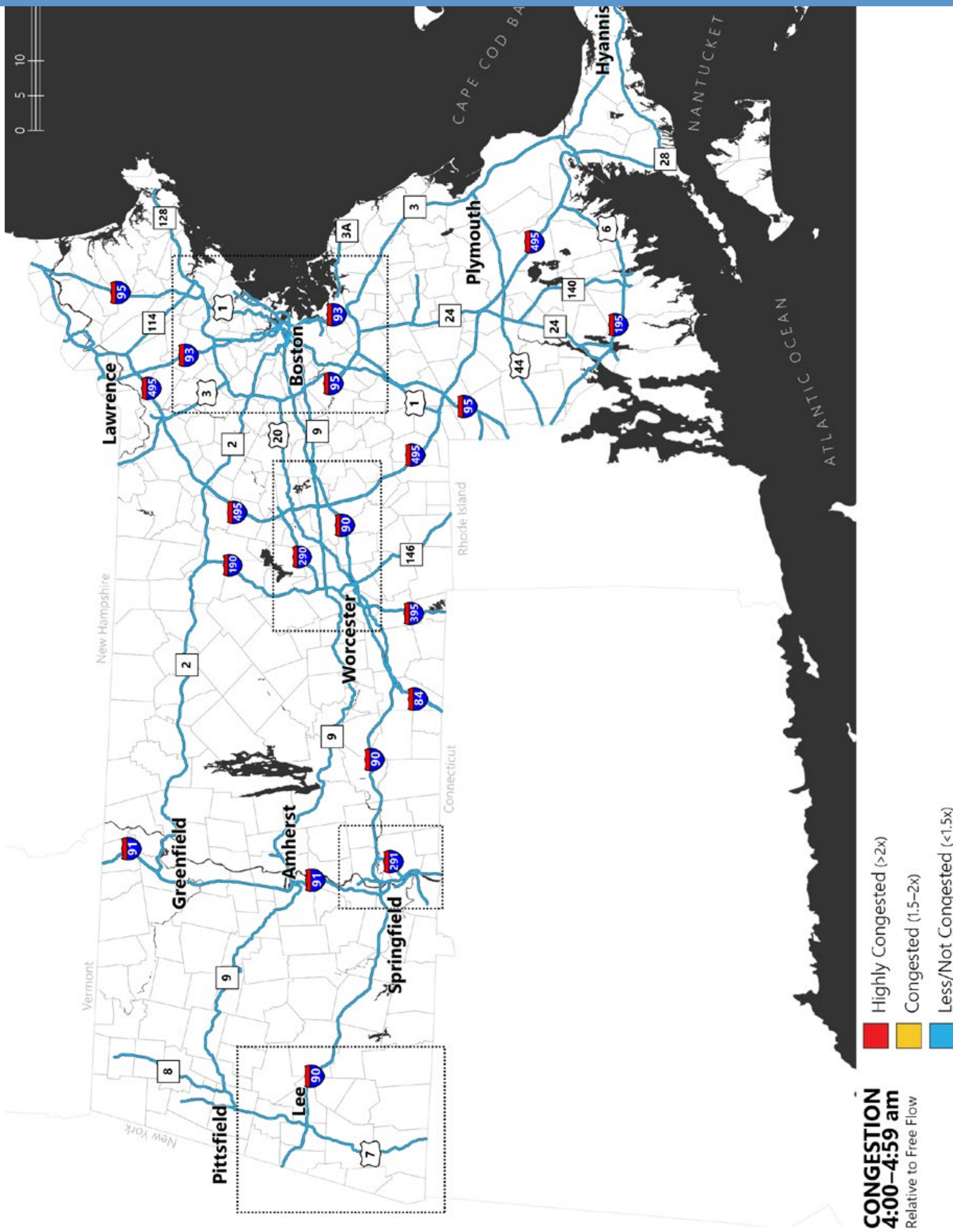
This analysis relies on data made available from a variety of regional, state, and national sources:

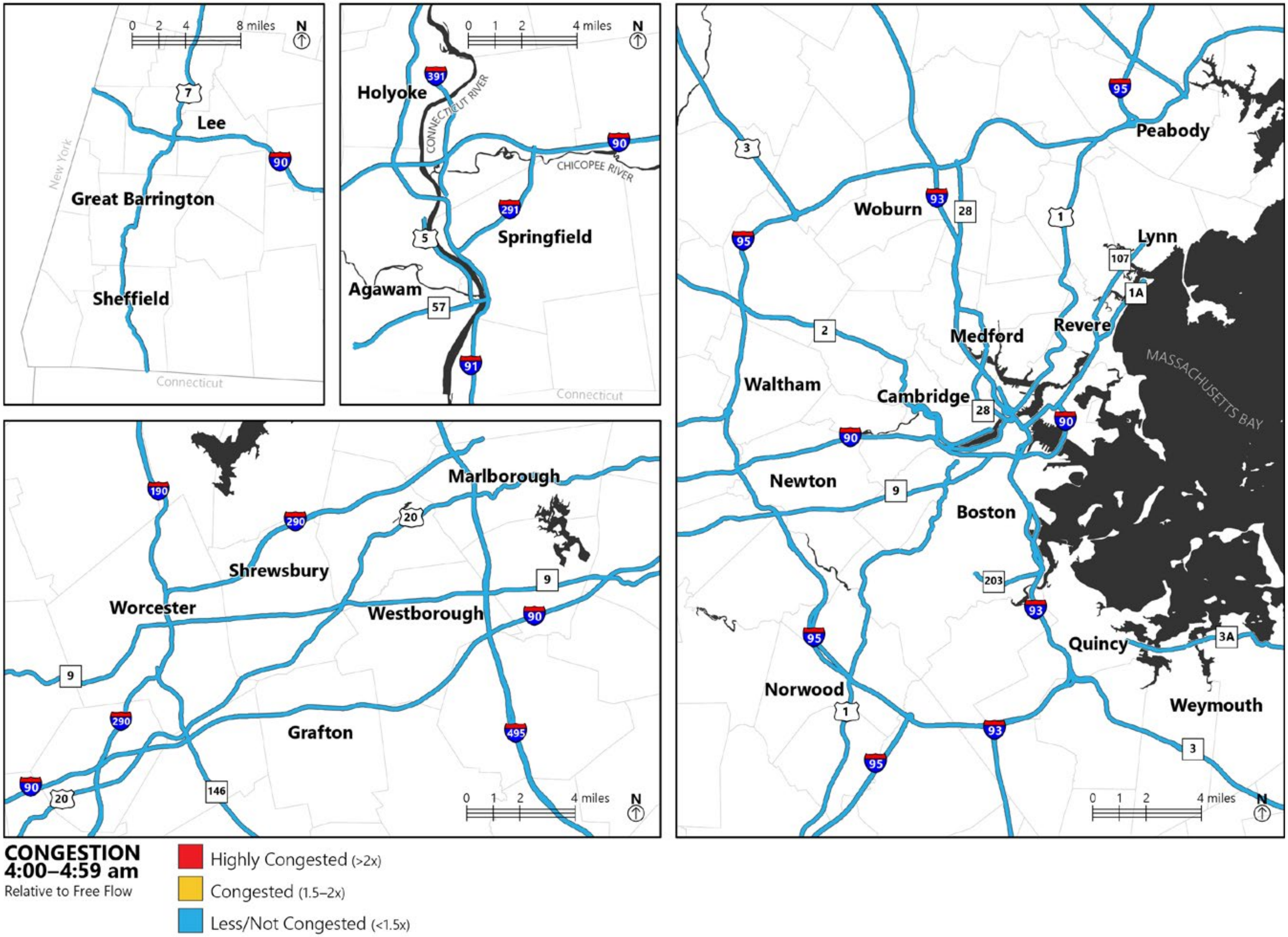
Data Type	Segment	Direction
Chapter 2		
Travel time and speed by roadway segment	The time and speed at which drivers traverse a road segment	National Performance Management Research Dataset (NPM-RDS), Federal Highway Administration (FHWA) https://ops.fhwa.dot.gov/perf_measurement/index.htm
Lane miles of public road	The number of miles along each lane of a state- or municipally owned road	Highway Performance Monitoring System (HPMS), FHWA https://www.fhwa.dot.gov/policyinformation/hpms.cfm
Roadway volume and speeds at AET gantries	The number of cars and the average speed at which they are traveling	All Electronic Tolling (AET) Gantries, MassDOT Highway Division
Access to jobs	The total number of jobs accessible from Census blocks by hour of day	Accessibility Observatory, University of Minnesota
MBTA bus run times	The total time it takes for an MBTA bus to complete its route; data includes 50^{th} (median) and 90^{th} percentile	Service Planning Division, MBTA
Average annual daily traffic (AADT)	The total volume of vehicle traffic on roadways in one year divided by 365 days	All Electronic Tolling (AET) Gantries and Continuous Count Stations, MassDOT Highway Division
Commute time	Self-reported commute time information published by the U.S. Census Bureau	U.S. Census Bureau, American Community Survey (ACS), 2008-2017 1-year data. Table S0802
Chapter 3		
Households	The number of households; Census tract level	U.S. Census Bureau, American Community Survey (ACS), 2008-2012 & 2013-2017 5-year data. Table DP05
Population	The number of persons; Census tract level	U.S. Census Bureau, American Community Survey (ACS), 2008-2012 & 2013-2017 5-year data. Table DP05
Employment growth	Number of workers in Massachusetts and the Boston NECTA	Bureau of Labor Statistics (BLS), Local Area Unemployment Statistics, Series ID LAUDV257165400000005 (Boston NECTA) & LASST250000000000005 (Massachusetts)
Labor force by work Census Tract	Number of workers aged 16 and over; Census tract level	U.S. Census Bureau, American Community Survey (ACS), 2008-2012 & 2013-2017 5-year data. Table B08406

Data Type	Segment	Direction
Commute mode	Number of workers commuting by different modes (Transit and Telecommuting), Census tract level	U.S. Census Bureau, American Community Survey (ACS), 2008 & 2017 1year data. Table S0801
Commute mode	Number of workers commuting by different modes (Driving Alone), Census tract level	U.S. Census Bureau, American Community Survey (ACS), 2008-2012 & 2013-2017 5-year data. Table S0802
Household vehicle ownership	Car ownership by household (including number of vehicles), Census tract level	U.S. Census Bureau, American Community Survey (ACS), 2008-2012 & 2013-2017 5-year data. Table B08141
Annual population estimates	Number of persons, statewide	U.S. Census Bureau, American Community Survey (ACS), 2005-2009 5-year data. Table B01003 U.S. Census Bureau, Table 1. Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2018 (NST-EST2018-01)
Vehicle miles Traveled (VMT)	Total number of miles traveled on Massachusetts state-owned roadways	Bob Frey, Office of Transportation Planning (OTP), MassDOT
Road geometry	The shape and/or configuration of a roadway (i.e., tight curves, number of lanes, road steepness)	Office of Transportation Planning (OTP), MassDOT
Total crashes	The number and location of crashes on state owned roadways	MassDOT Highway Division
Weather events	Data includes information on the dates, location, and nature of weather events	Dark Sky
Work zones	Areas where construction or maintenance work is occurring on or near a roadway	MassDOT, MBTA, and private construction schedules
Chapter 5		
Annual Average Daily Traffic (AADT)	Average daily traffic volumes on select corridors	MassDOT Highway Division, https://mhd.ms2soft.com/tcds/tsearch.asp?loc=Mhd&mod=
Annual Commuter Rail Ridership	Ridership on MBTA commuter rail lines	Central Transportation Planning Staff (CTPS)

APPENDIX C

ANNUAL AVERAGE DAILY CONGESTION ON MASSACHUSETTS LIMITED ACCESS HIGHWAYS




Lee
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Sheffield
New York
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Holyoke
Springfield
Agawam
CONNECTICUT RIVER
CHICOPEE RIVER
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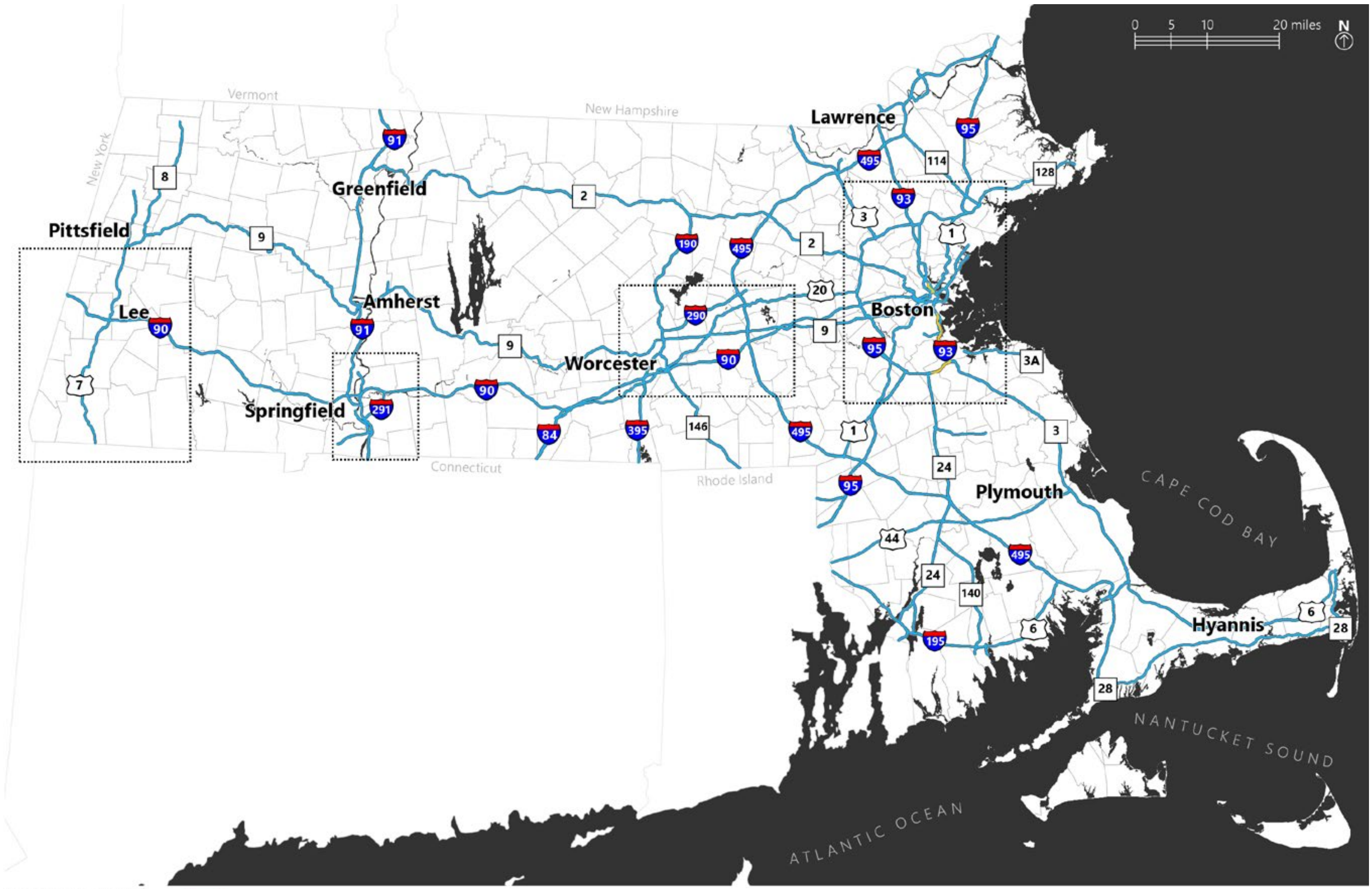
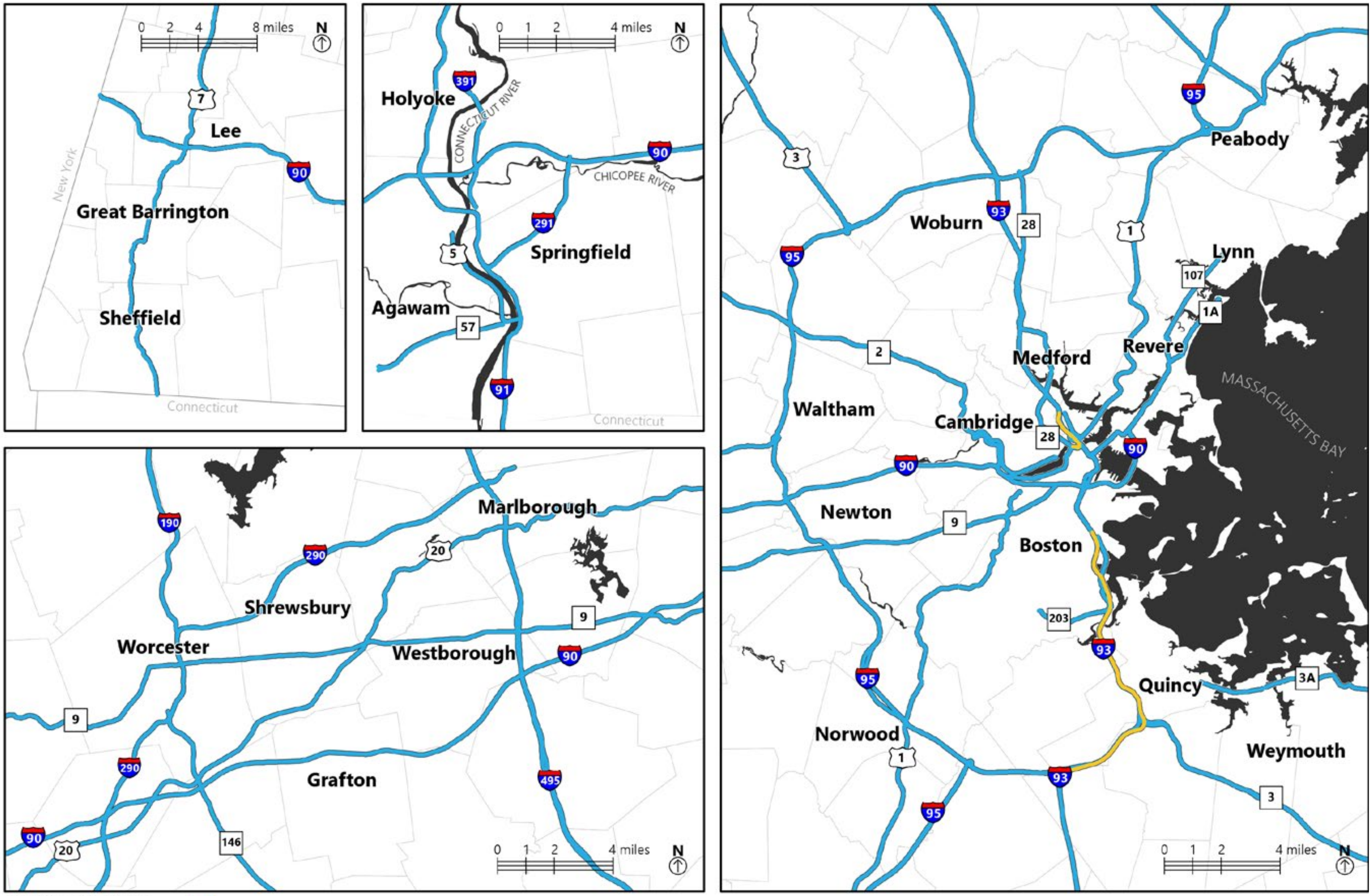
Worcester
Shrewsbury
Westborough
Marlborough
Grafton
0 1 2 4 miles
N
Woburn
Peabody
Lynn
Medford
Revere
Waltham
Cambridge
Newton
Boston
Norwood
Quincy
Weymouth
MASSACHUSETTS BAY
0 1 2 4 miles
N
CONGESTION
4:00–4:59 am
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)



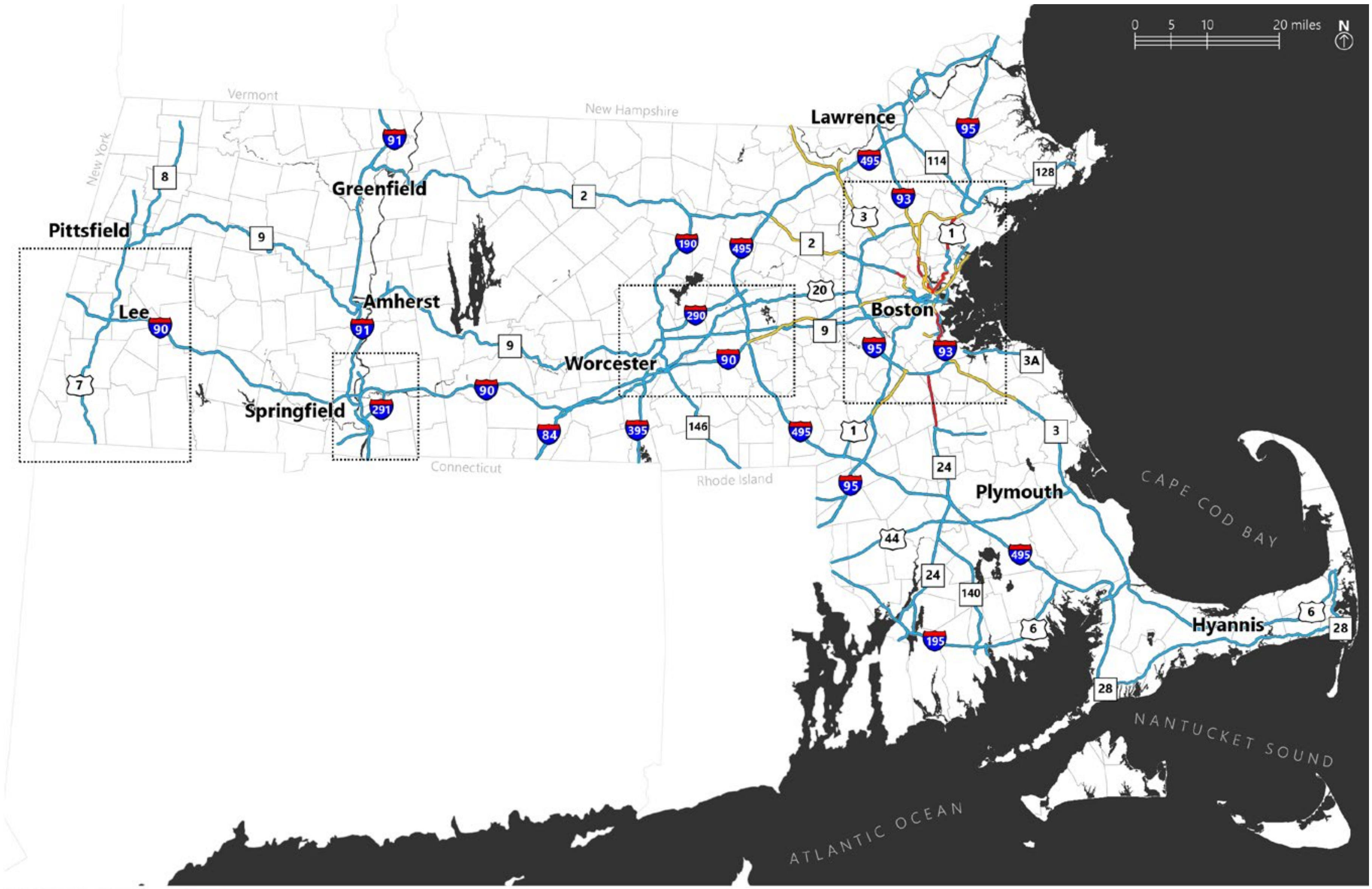
CONGESTION
5:00–5:59 am
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



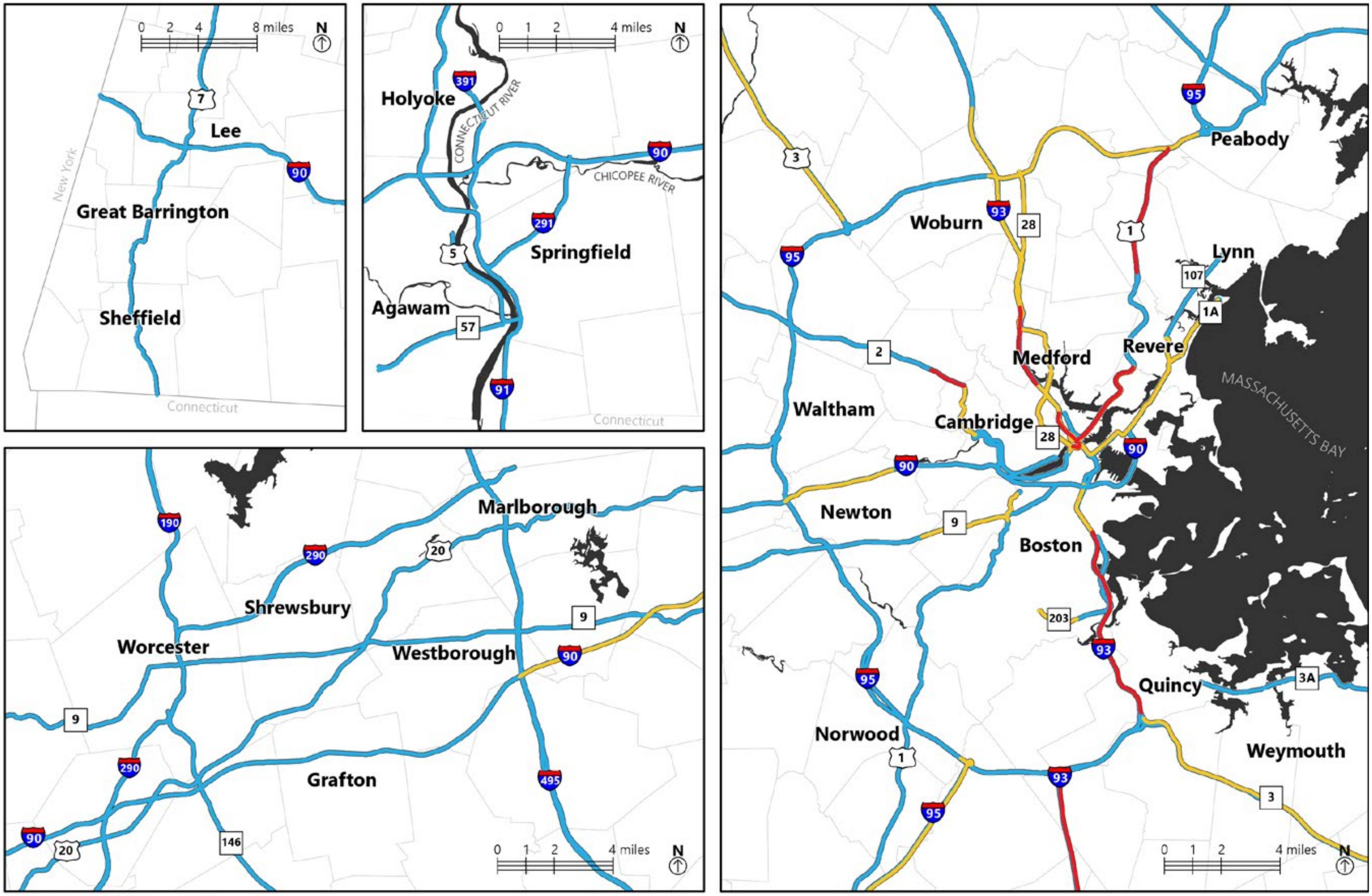
CONGESTION
5:00–5:59 am
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



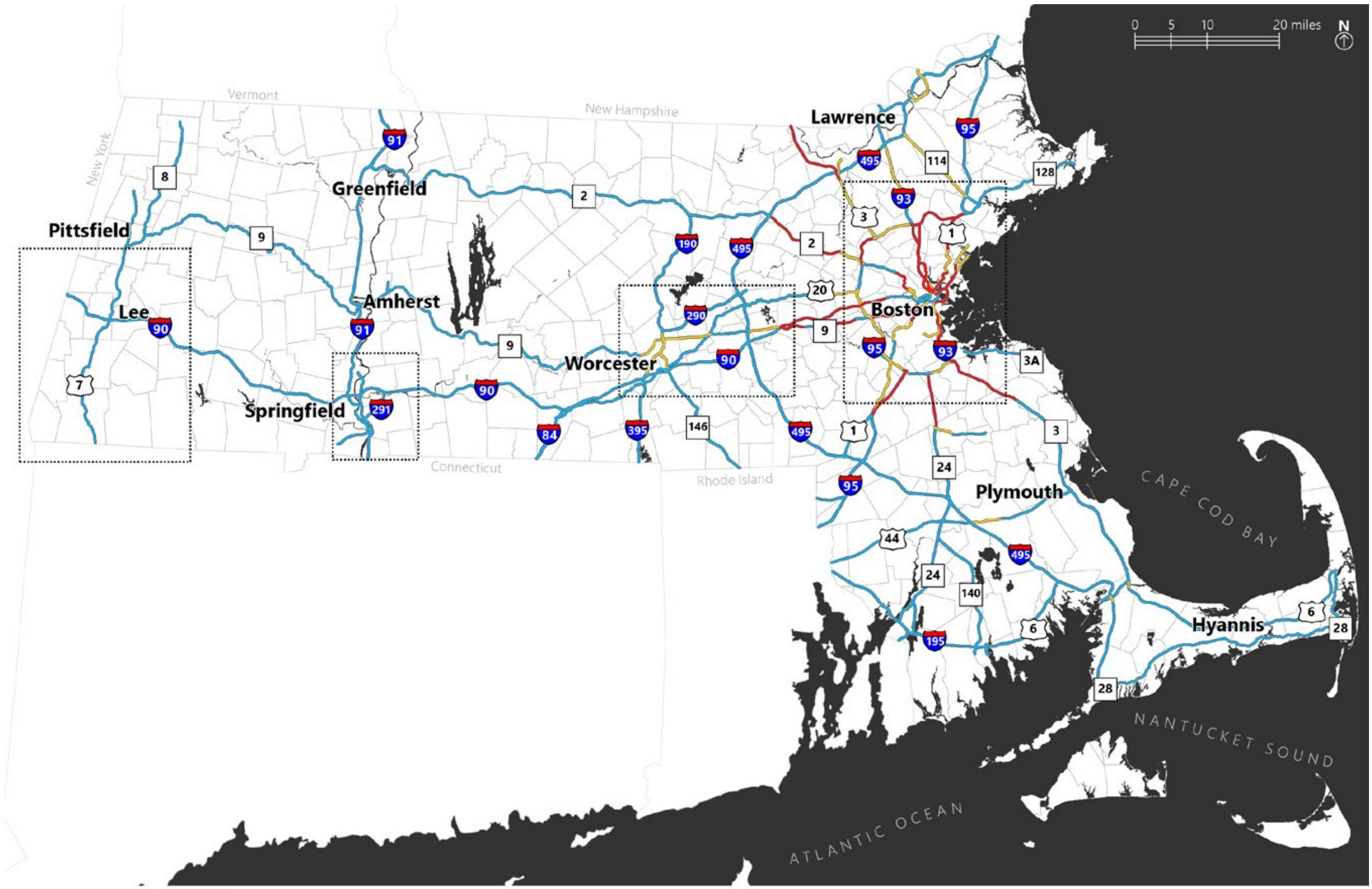
CONGESTION 6:00–6:59 am
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



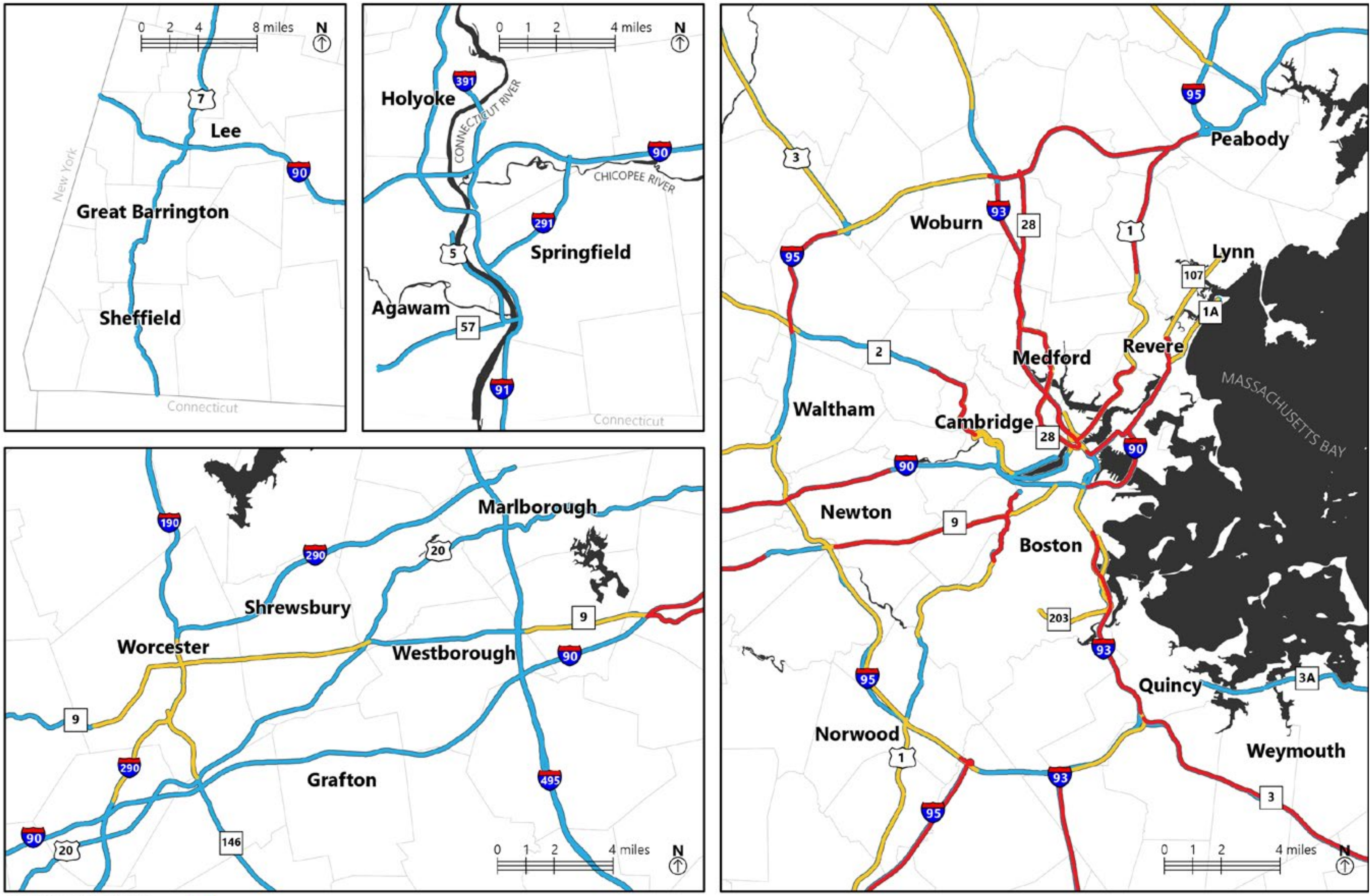
CONGESTION
6:00–6:59 am
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



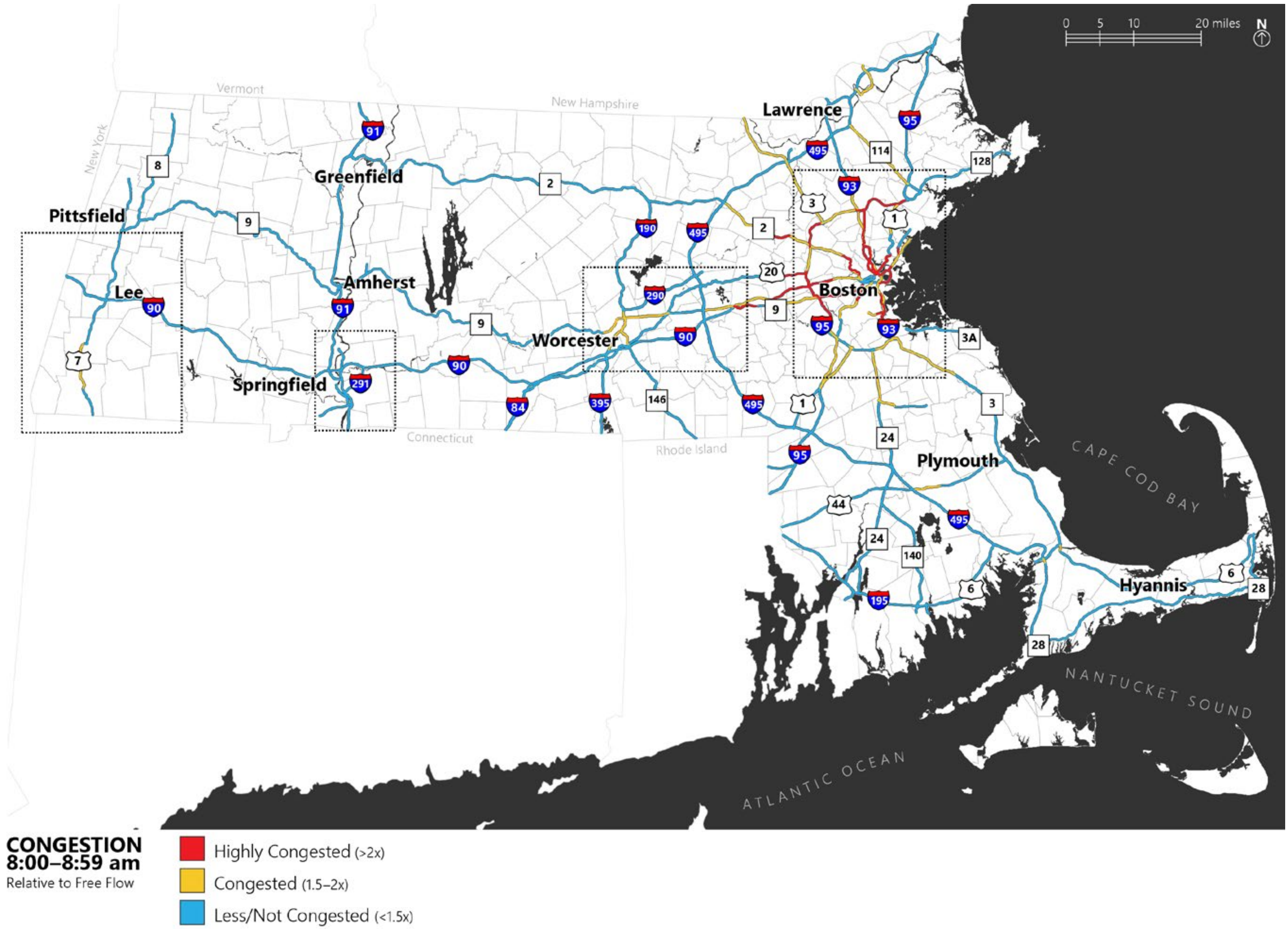
CONGESTION 7:00–7:59 am
Relative to Free Flow

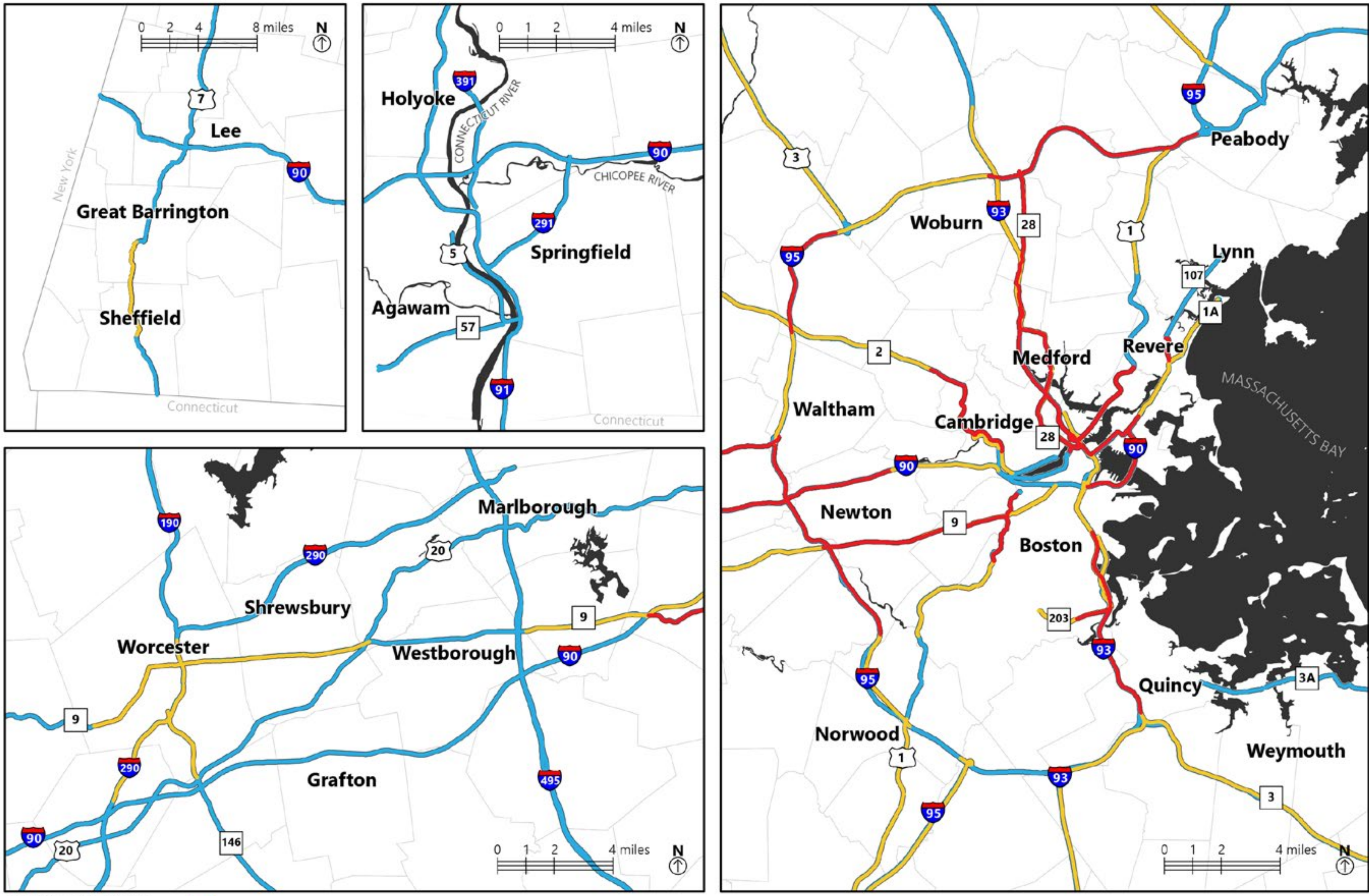
- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



CONGESTION
7:00–7:59 am
Relative to Free Flow

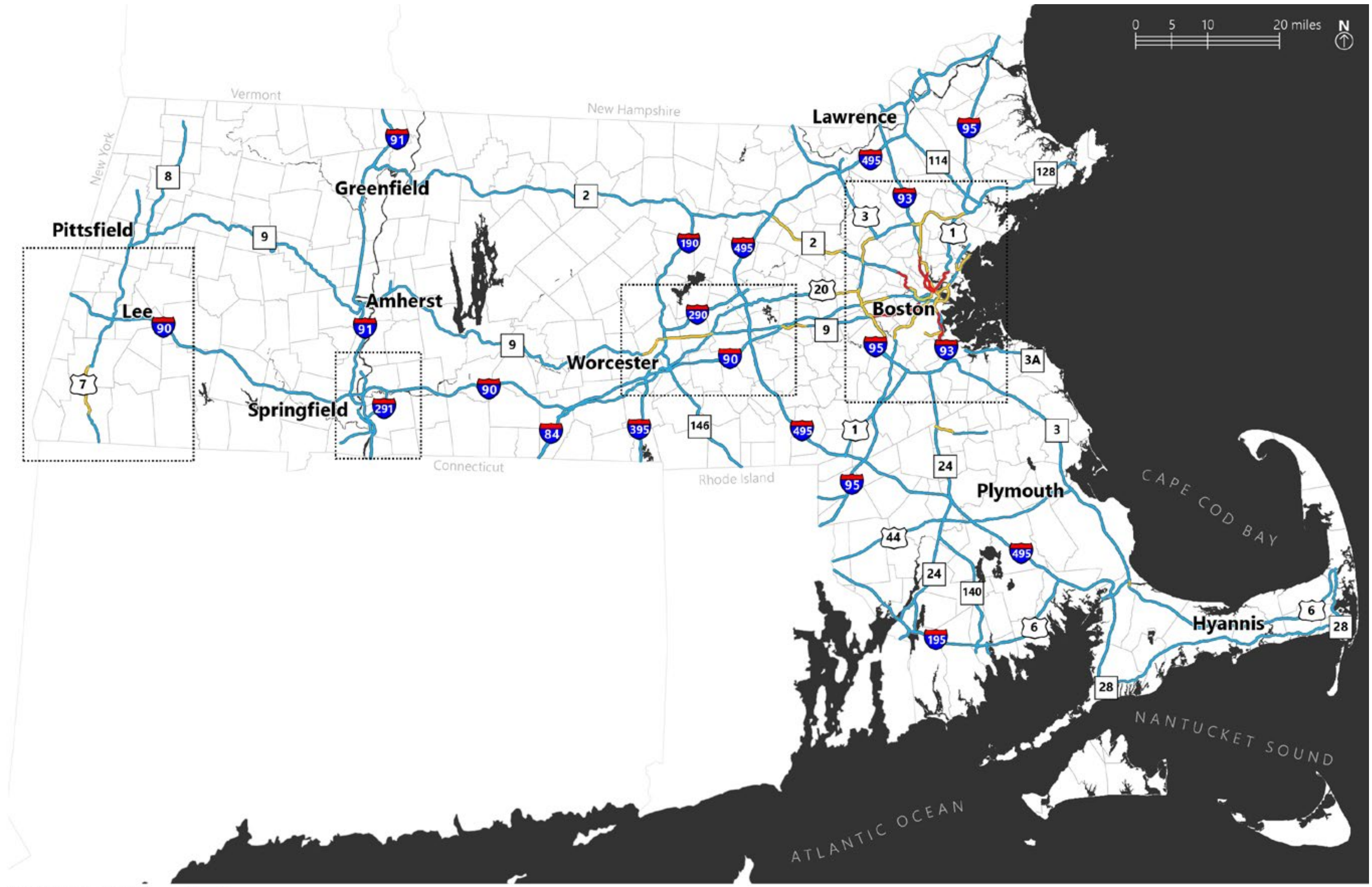
- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)


0 5 10 20 miles
N
Vermont
New Hampshire
New York
Connecticut
Rhode Island
Pittsfield
Lee
Greenfield
Amherst
Springfield
Worcester
Lawrence
Boston
Plymouth
Hyannis
CAPE COD BAY
NANTUCKET SOUND
ATLANTIC OCEAN
CONGESTION
8:00–8:59 am
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)



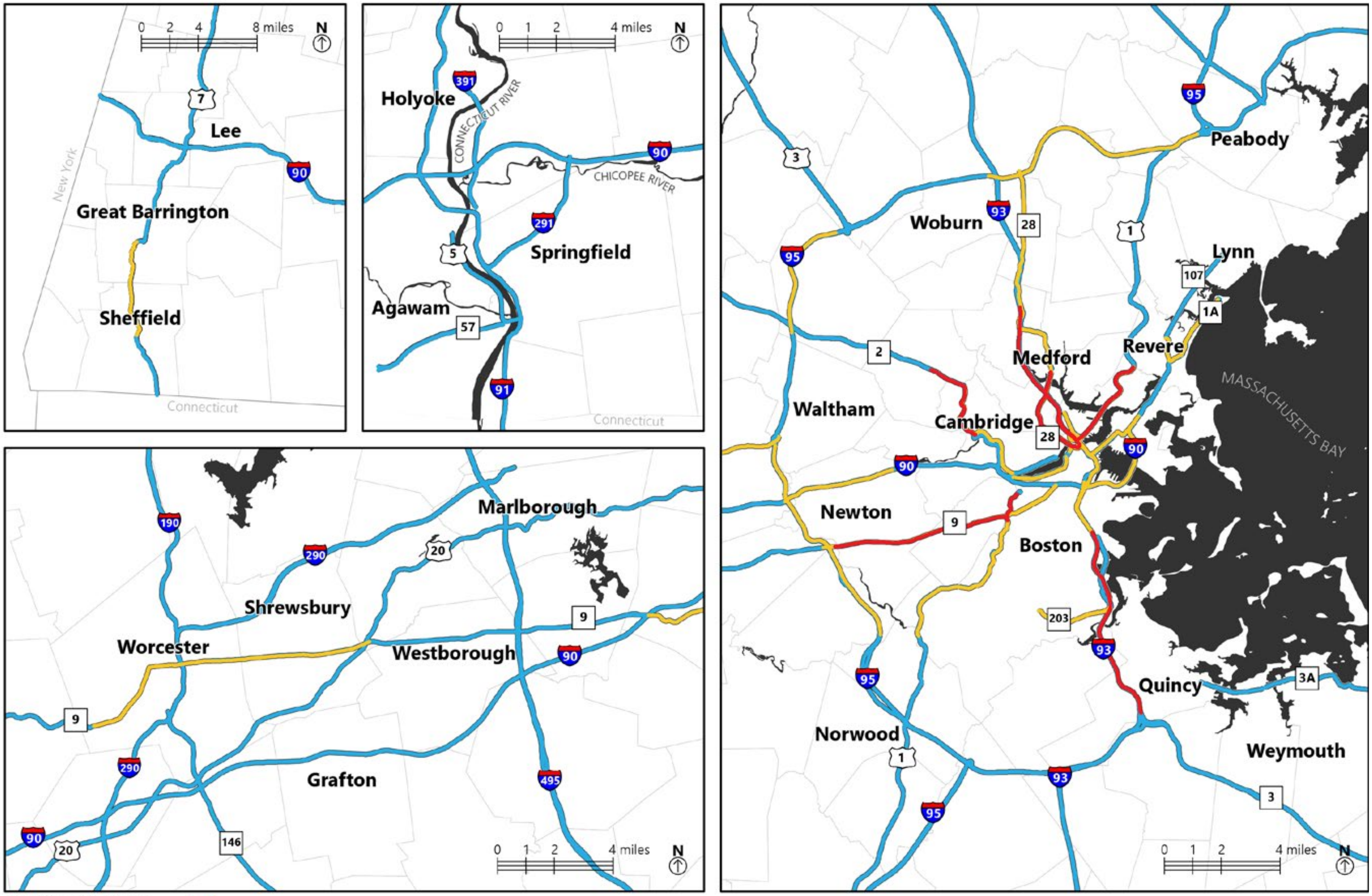
CONGESTION
8:00–8:59 am
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



CONGESTION
9:00–9:59 am
Relative to Free Flow

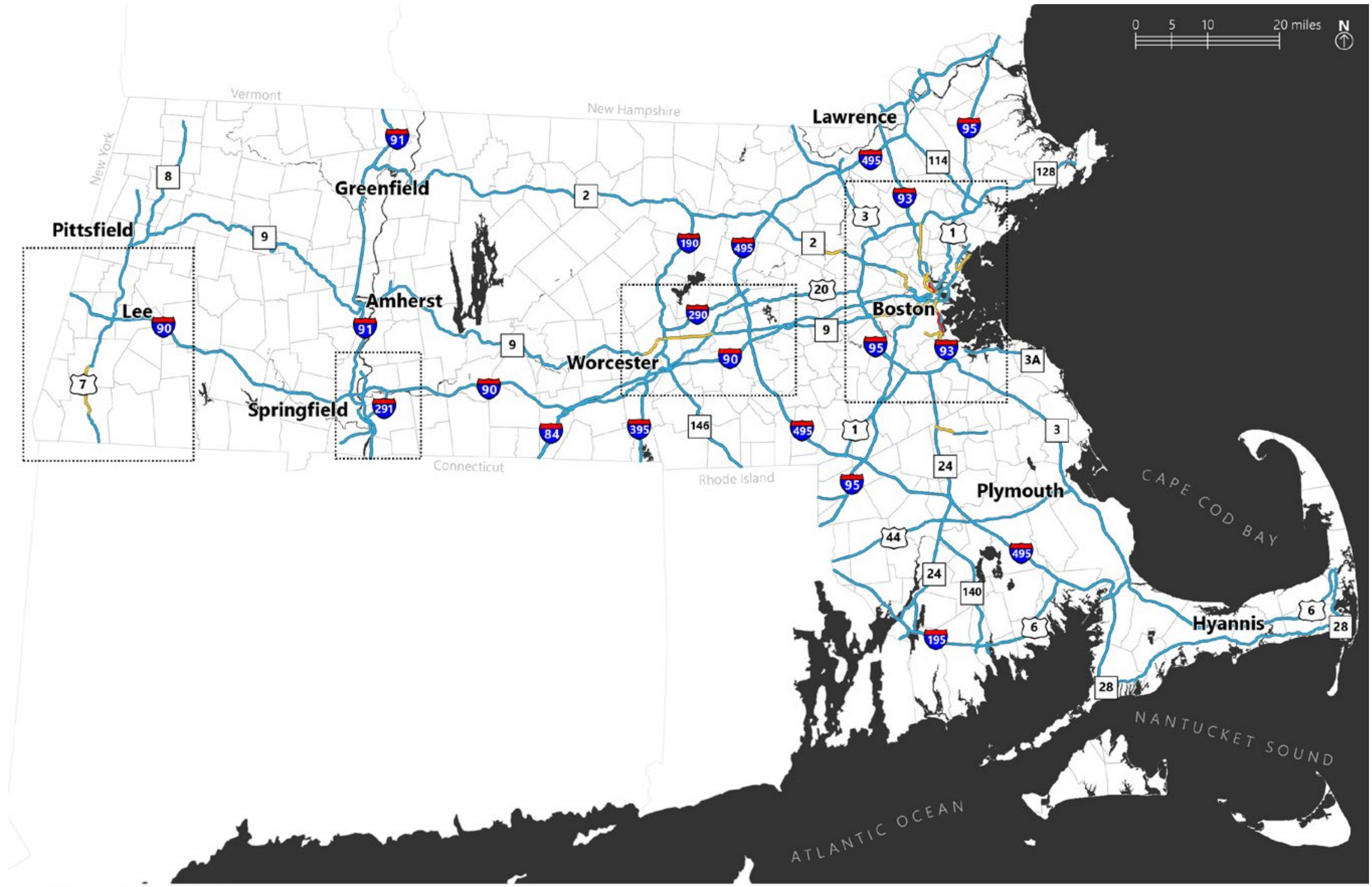
- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



CONGESTION 9:00–9:59 am

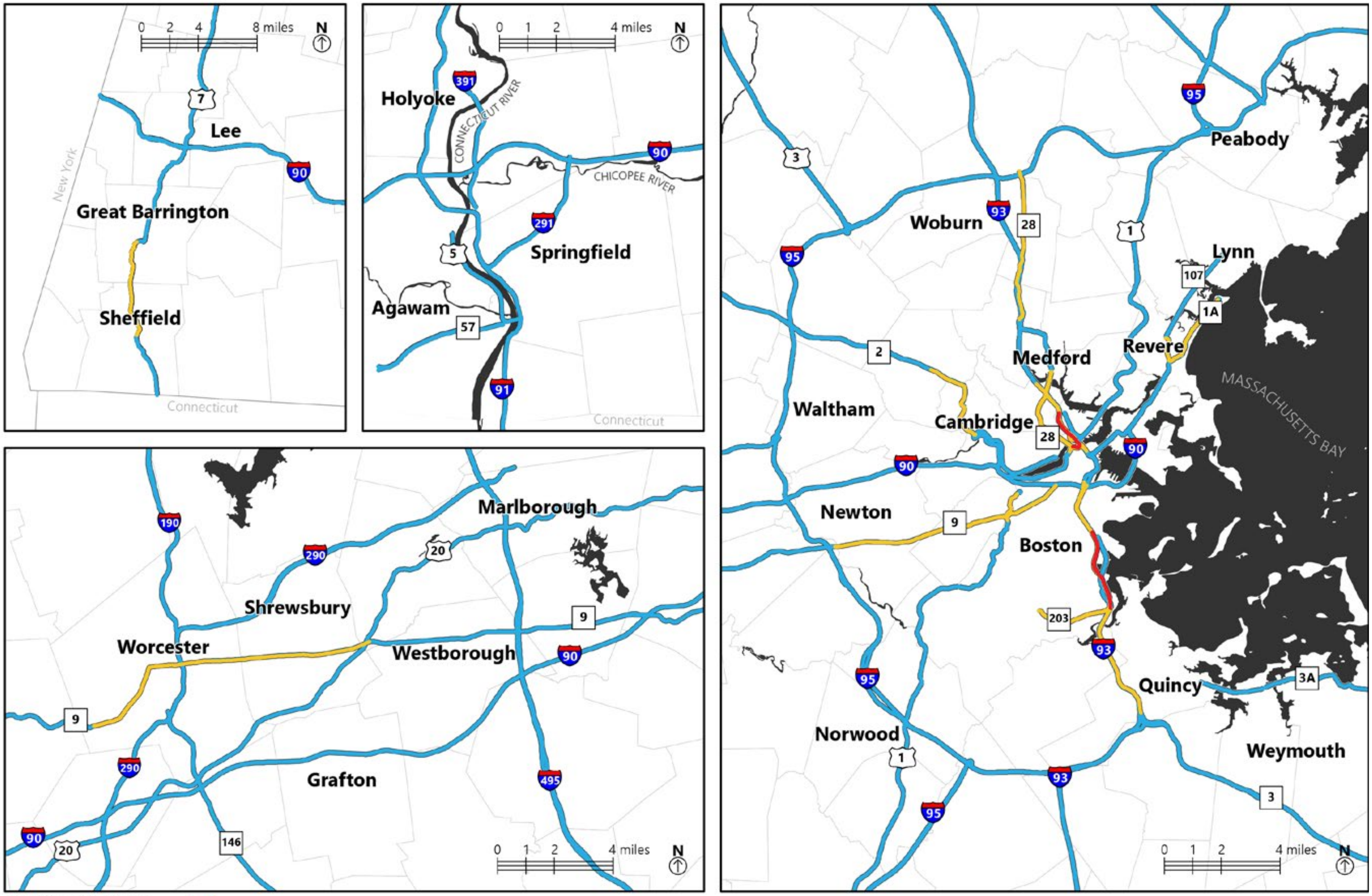
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



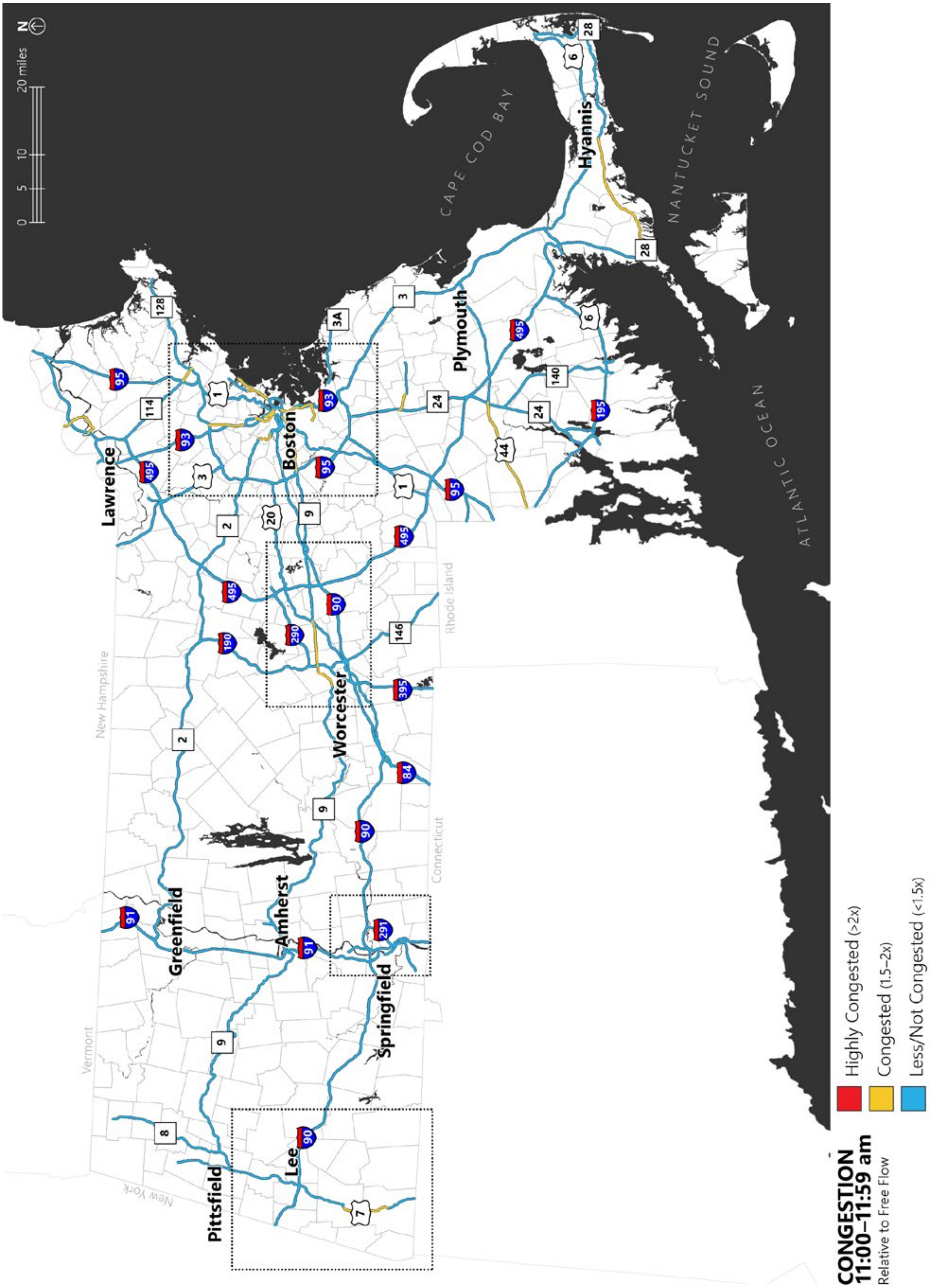
CONGESTION
10:00–10:59 am
Relative to Free Flow

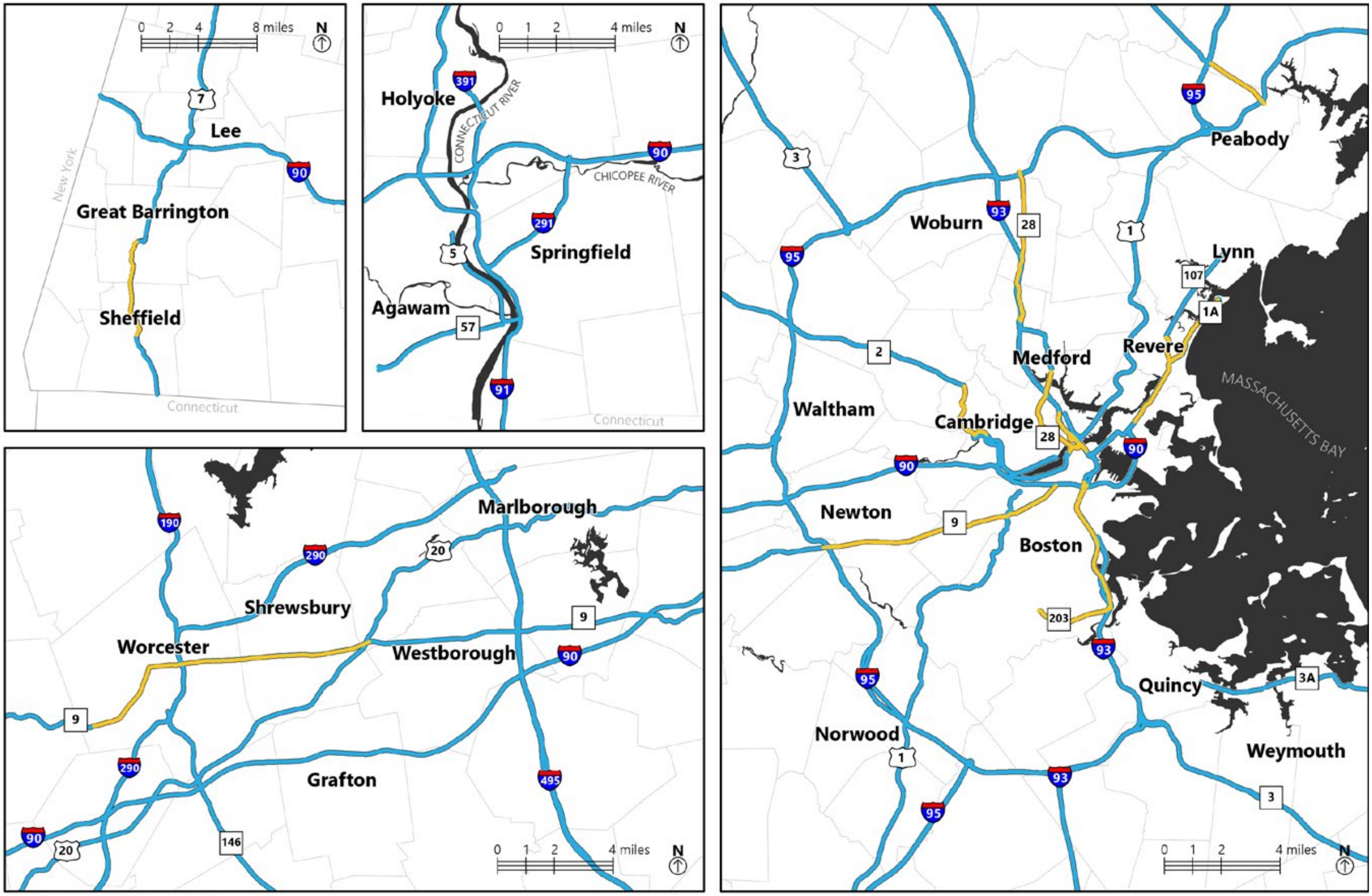
- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



CONGESTION
10:00–10:59 am
Relative to Free Flow

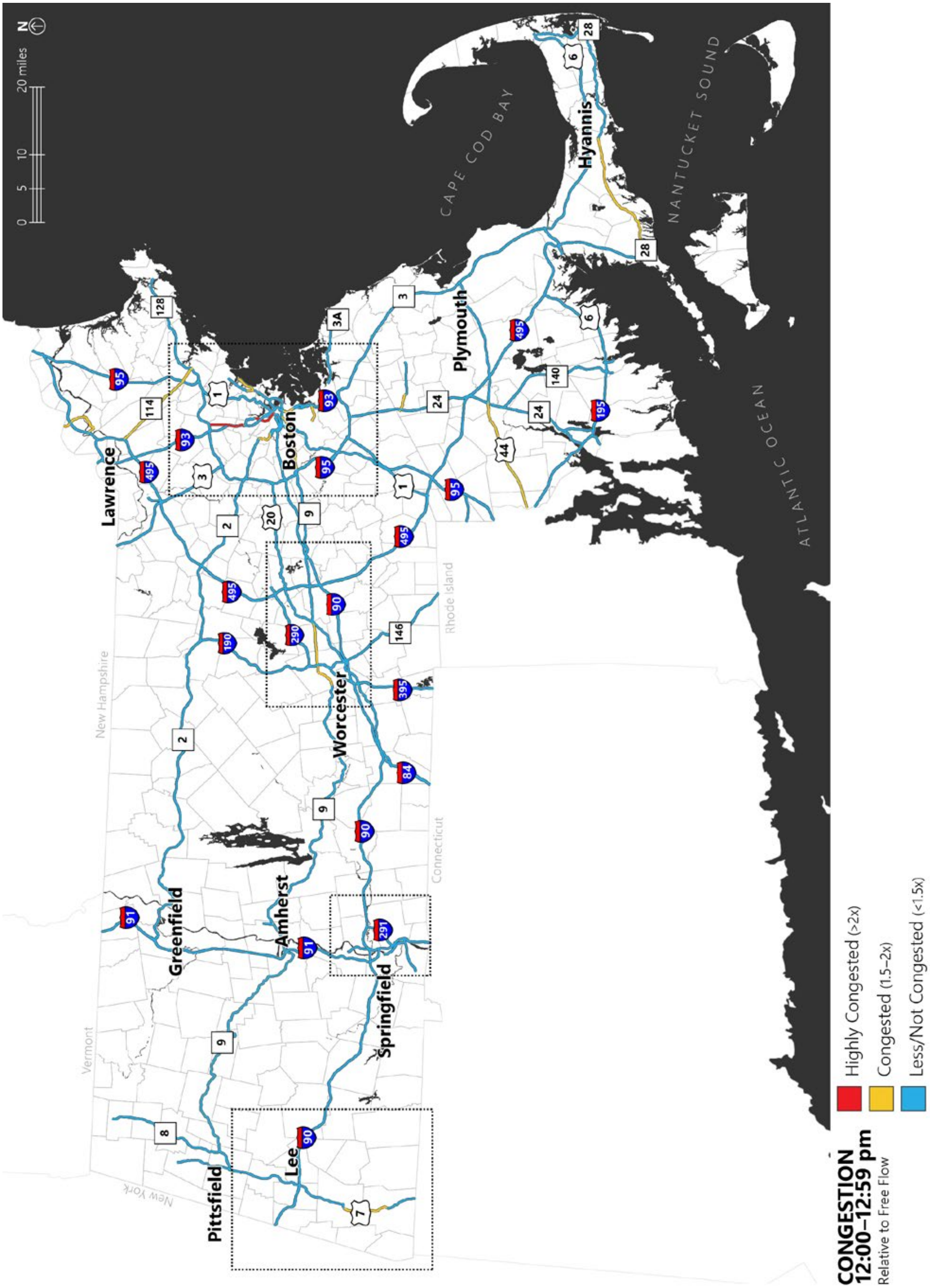
- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)

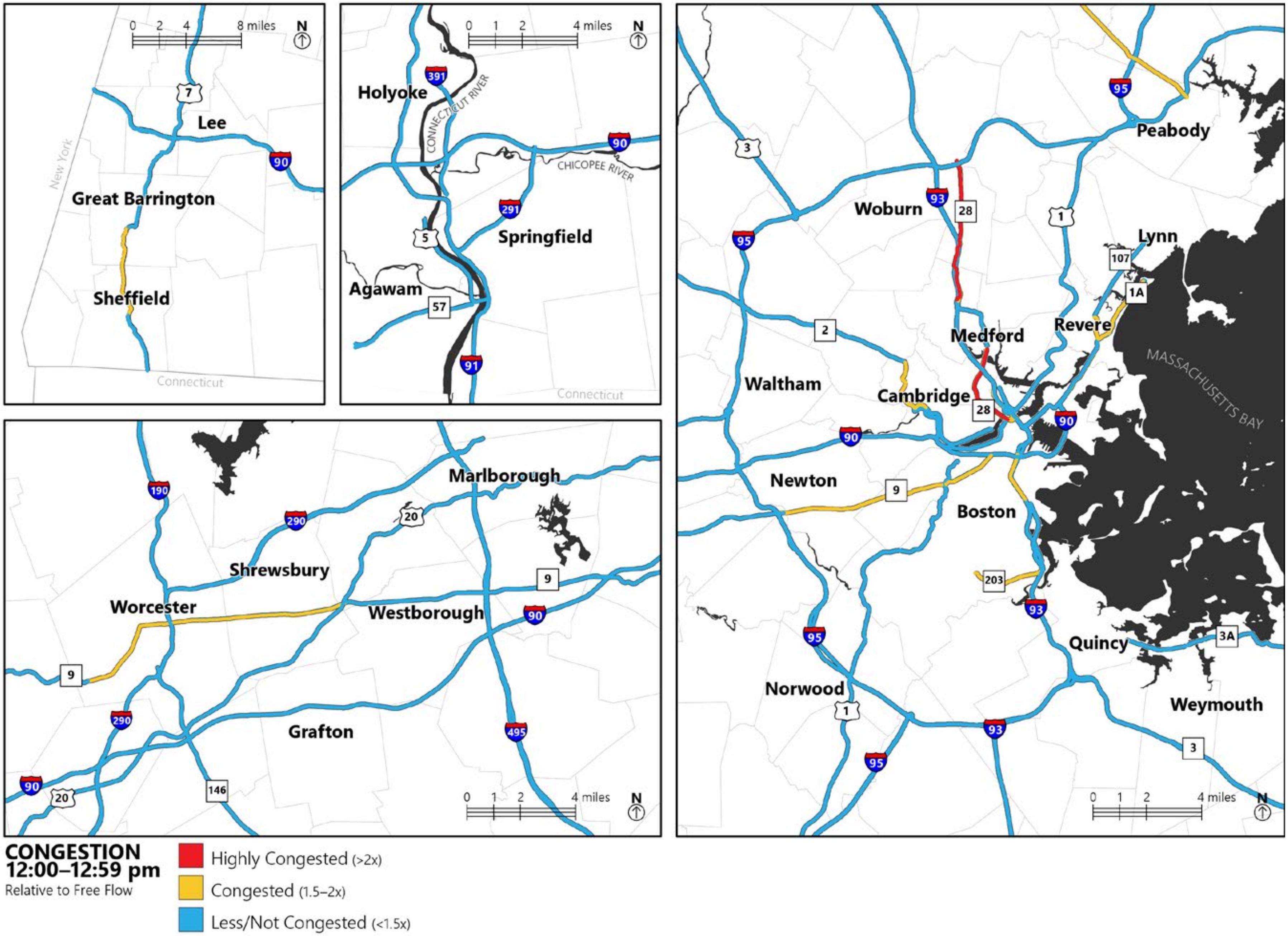

CONGESTION
11:00–11:59 am
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)
0 5 10 20 miles
N
CAPE COD BAY
NANTUCKET SOUND
ATLANTIC OCEAN
Vermont
New Hampshire
New York
Connecticut
Rhode Island
Pittsfield
Lee
Greenfield
Amherst
Springfield
Worcester
Lawrence
Boston
Plymouth
Hyannis

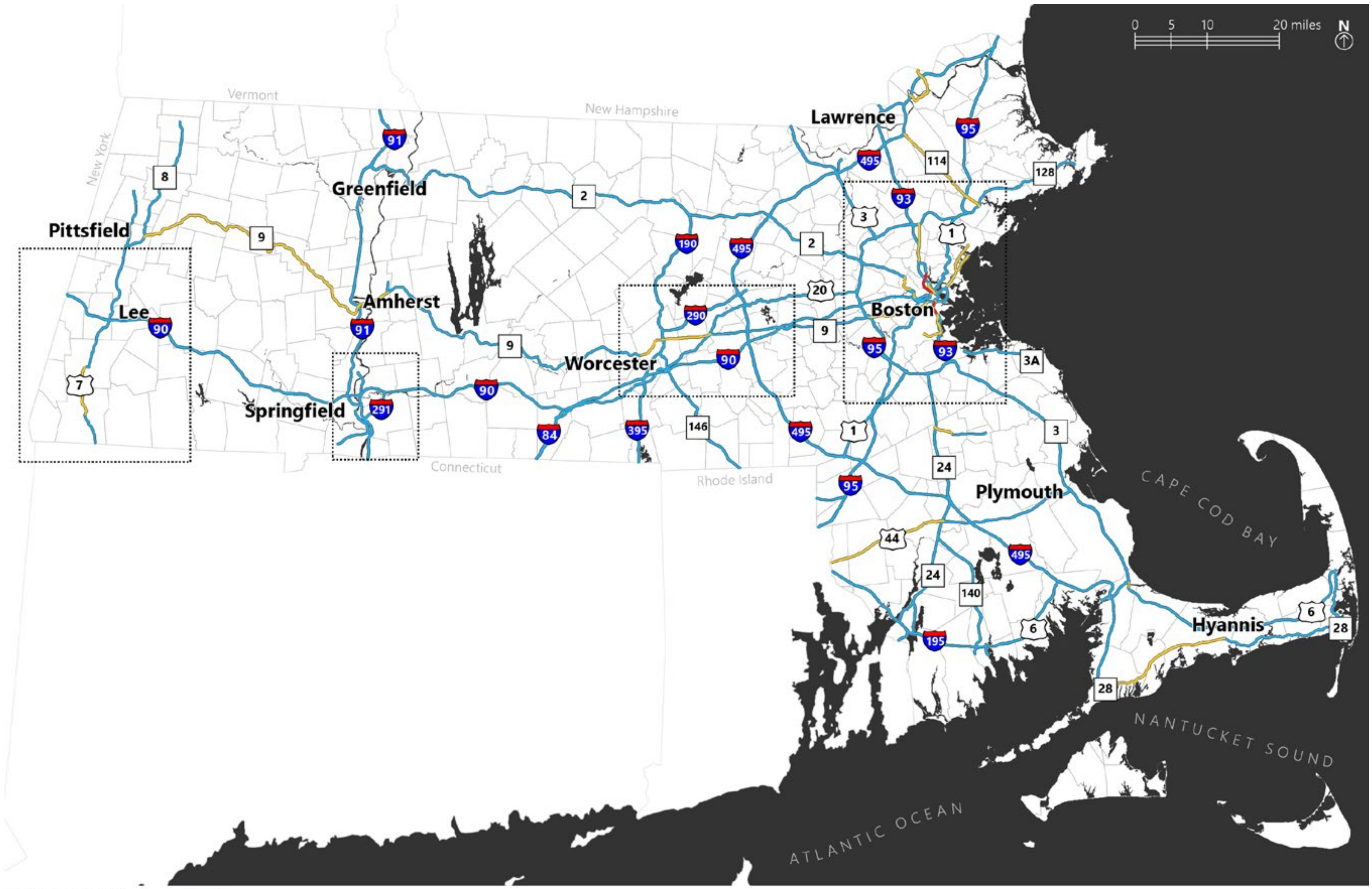


CONGESTION
11:00–11:59 am
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)

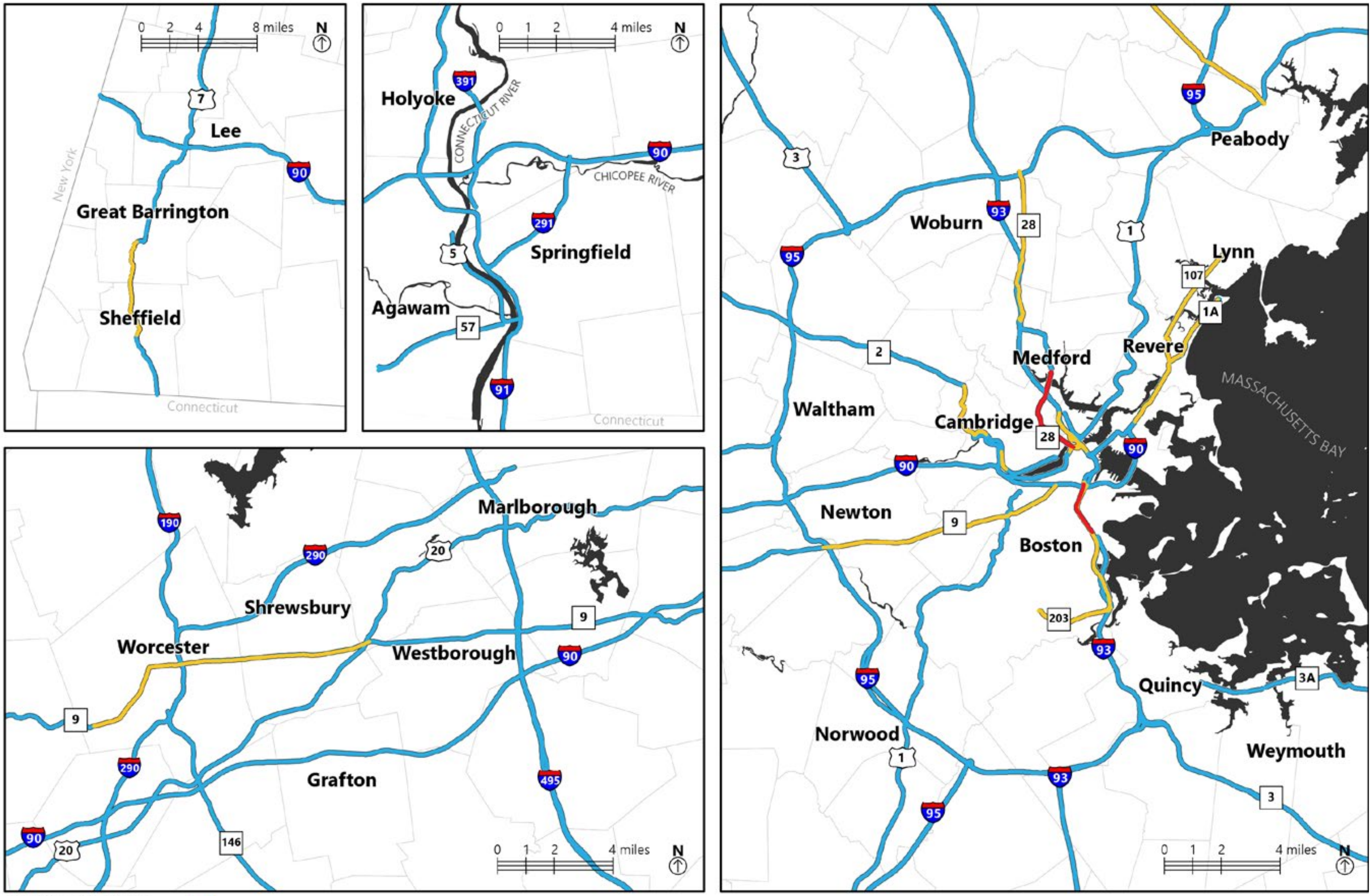

CONGESTION
12:00–12:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)
0 5 10 20 miles
N
Pittsfield
Lee
Springfield
Amherst
Greenfield
Worcester
Lawrence
Boston
Plymouth
Hyannis
New York
Vermont
New Hampshire
Connecticut
Rhode Island
CAPE COD BAY
NANTUCKET SOUND
ATLANTIC OCEAN


Lee
Great Barrington
Sheffield
New York
Connecticut
0 2 4 8 miles
N
Holyoke
Springfield
Agawam
CONNECTICUT RIVER
CHICOPEE RIVER
Connecticut
0 1 2 4 miles
Worcester
Shrewsbury
Westborough
Marlborough
Grafton
Woburn
Peabody
Lynn
Medford
Revere
Waltham
Cambridge
Newton
Boston
Quincy
Norwood
Weymouth
MASSACHUSETTS BAY
CONGESTION
12:00–12:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)



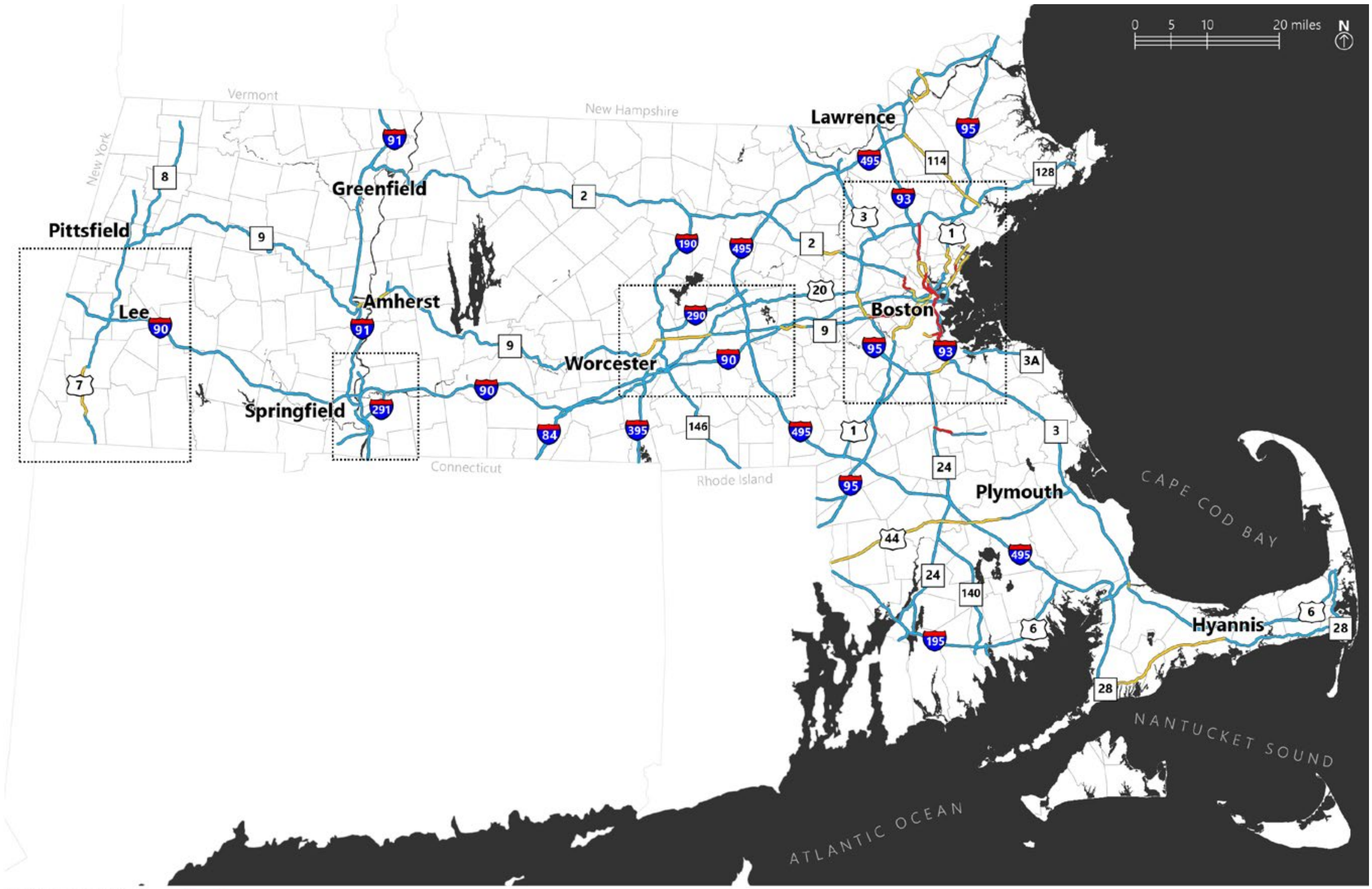
CONGESTION
1:00–1:59 pm
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



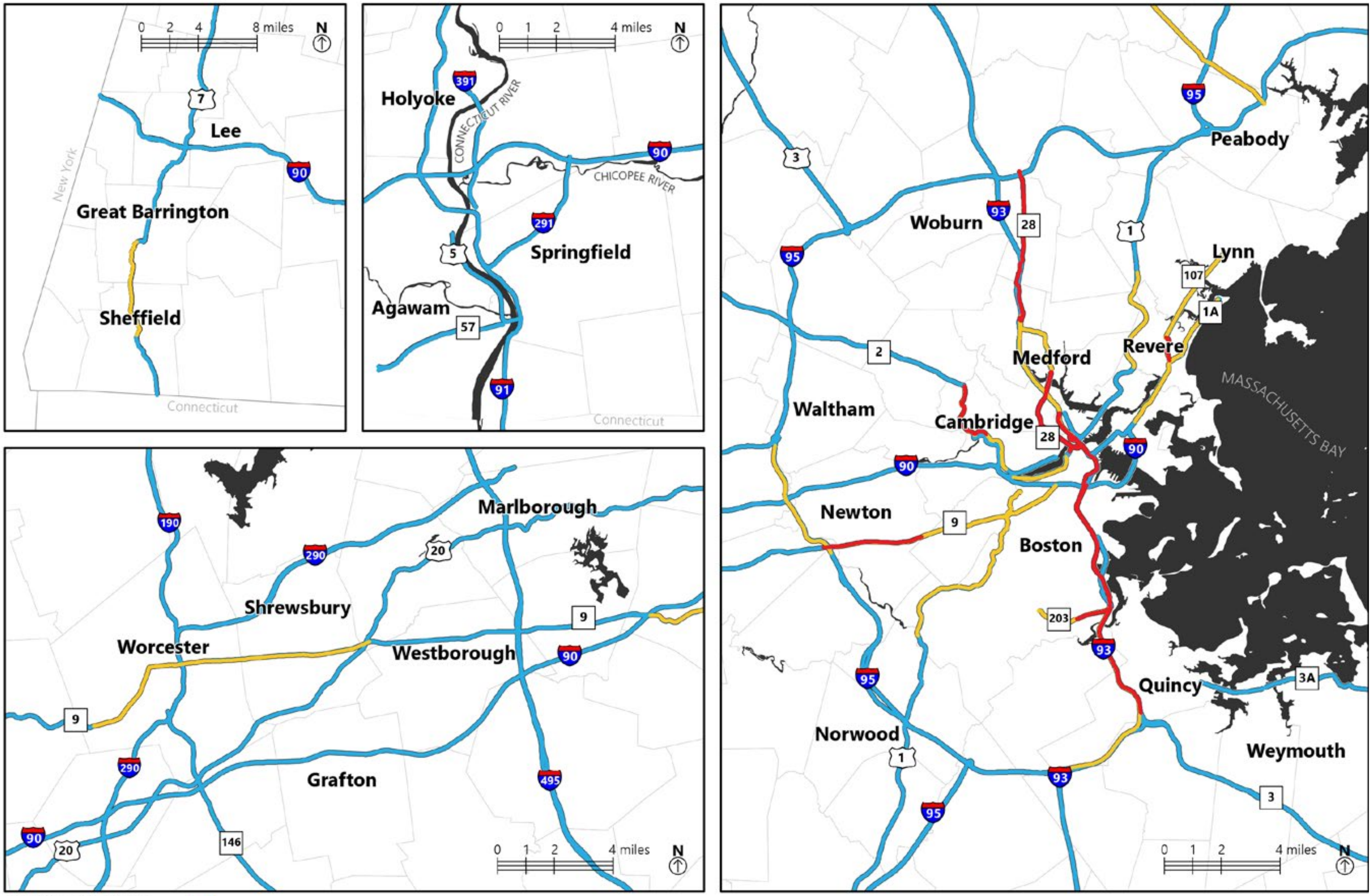
CONGESTION 1:00–1:59 pm
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



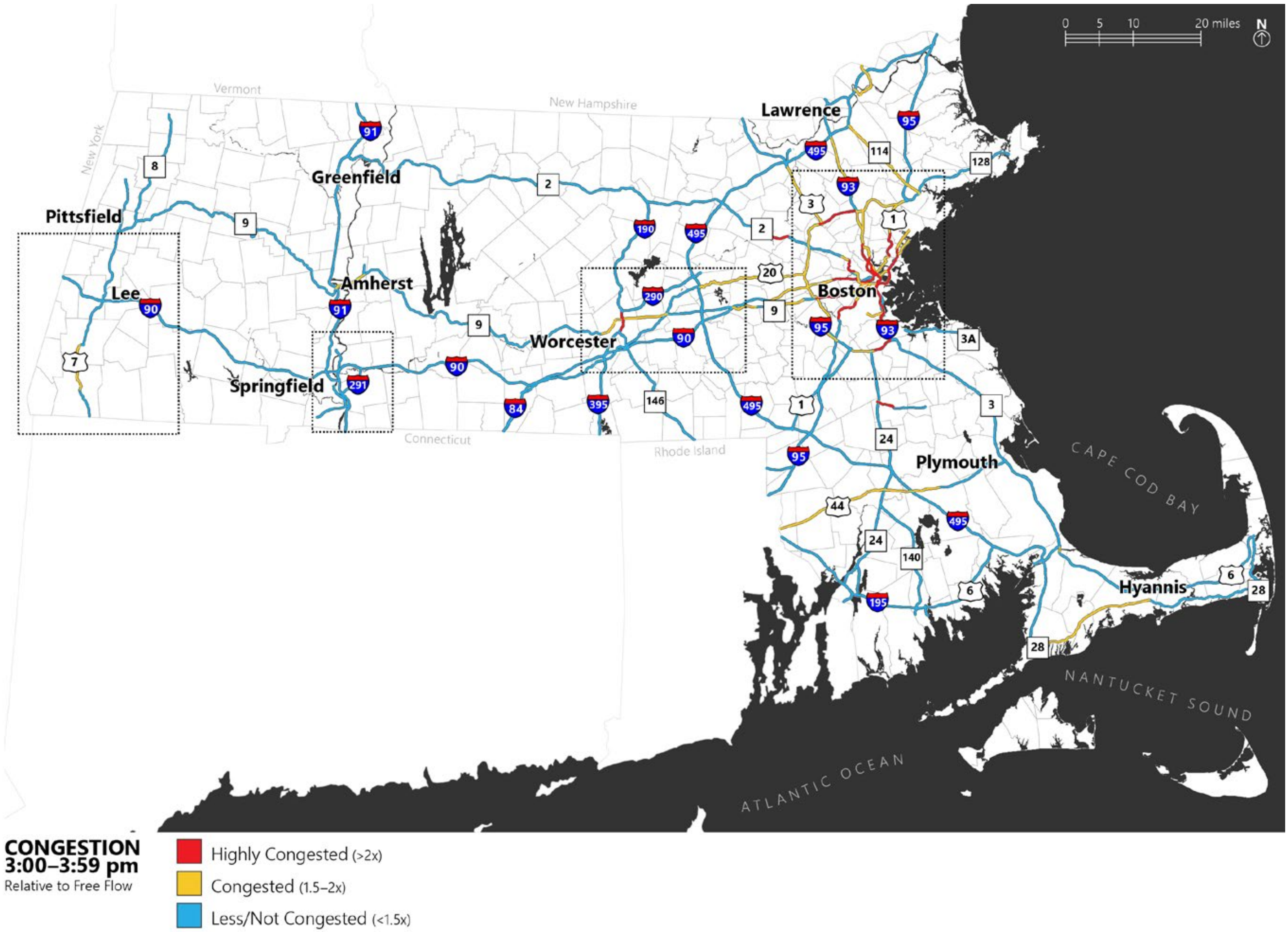
CONGESTION
2:00–2:59 pm
Relative to Free Flow

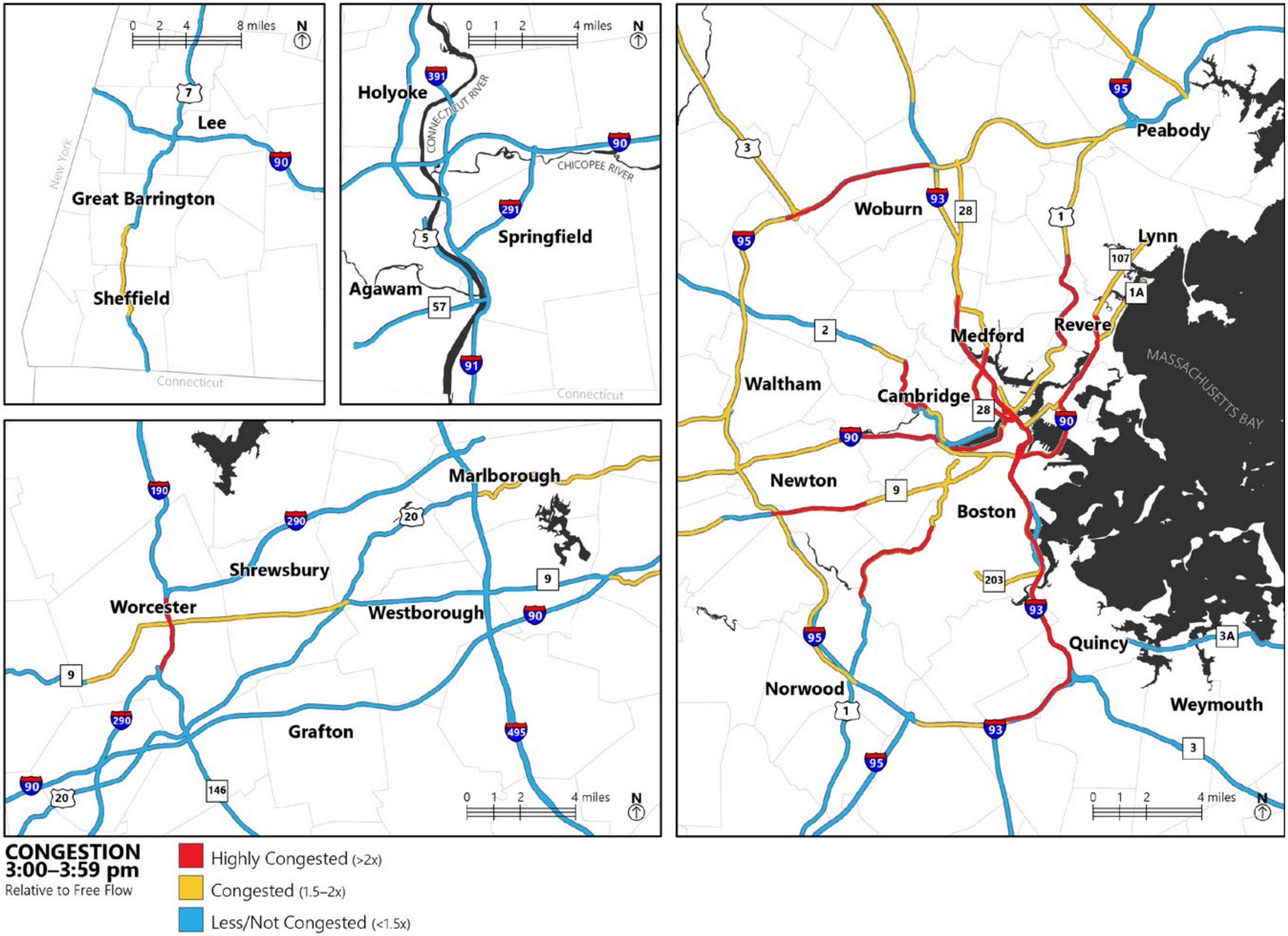
- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)

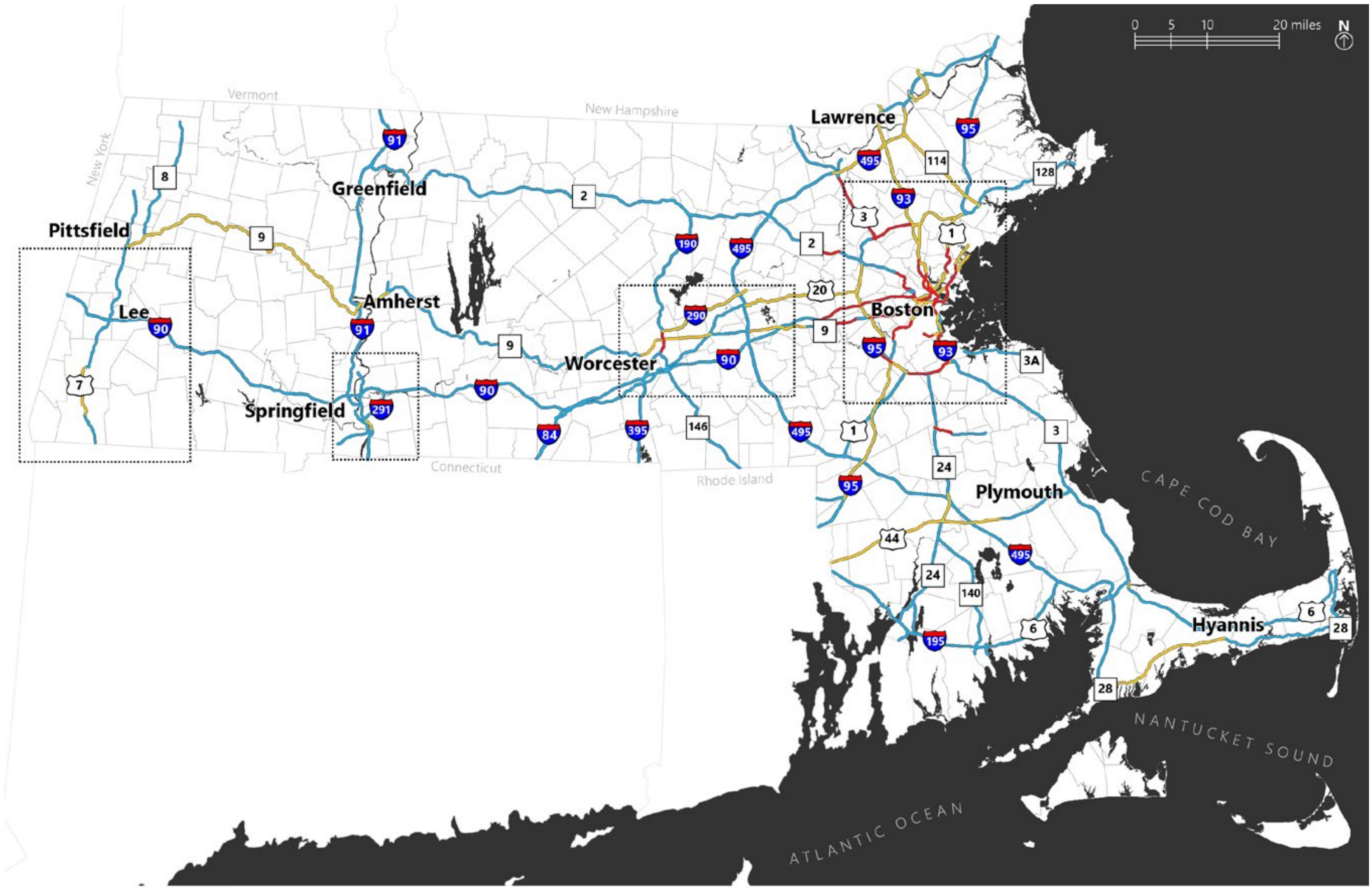


CONGESTION
2:00–2:59 pm
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)

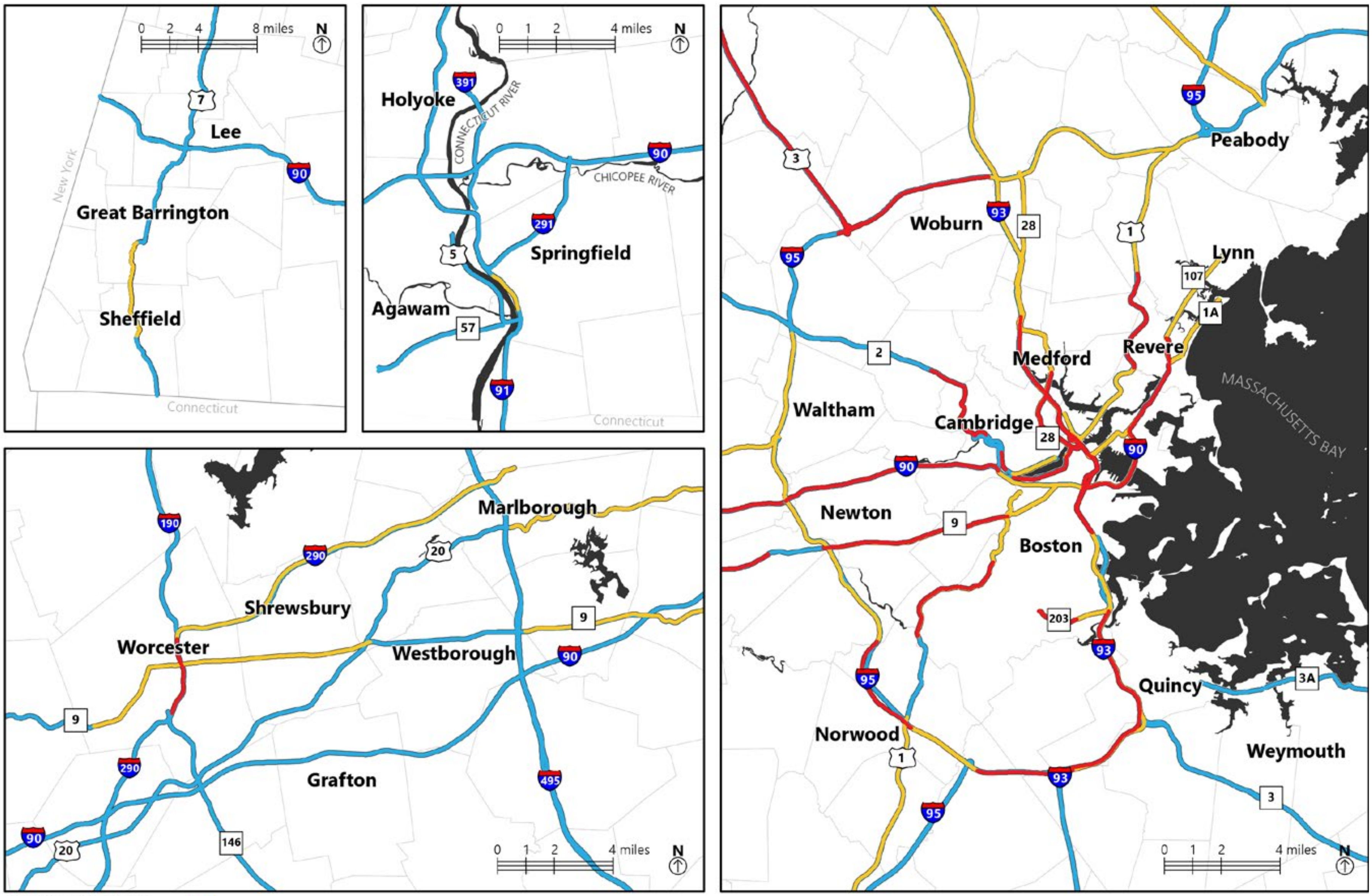

0 5 10 20 miles
N
Vermont
New Hampshire
New York
Connecticut
Rhode Island
Pittsfield
Lee
Greenfield
Amherst
Springfield
Worcester
Lawrence
Boston
Plymouth
Hyannis
CAPE COD BAY
NANTUCKET SOUND
ATLANTIC OCEAN
CONGESTION
3:00–3:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)


Lee
Great Barrington
Sheffield
New York
Connecticut
0 2 4 8 miles
N
Holyoke
Springfield
Agawam
CONNECTICUT RIVER
CHICOPEE RIVER
Connecticut
0 1 2 4 miles
N
Worcester
Shrewsbury
Westborough
Marlborough
Grafton
0 1 2 4 miles
N
Woburn
Peabody
Lynn
Medford
Revere
Waltham
Cambridge
Newton
Boston
Quincy
Norwood
Weymouth
MASSACHUSETTS BAY
0 1 2 4 miles
N
CONGESTION
3:00–3:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)



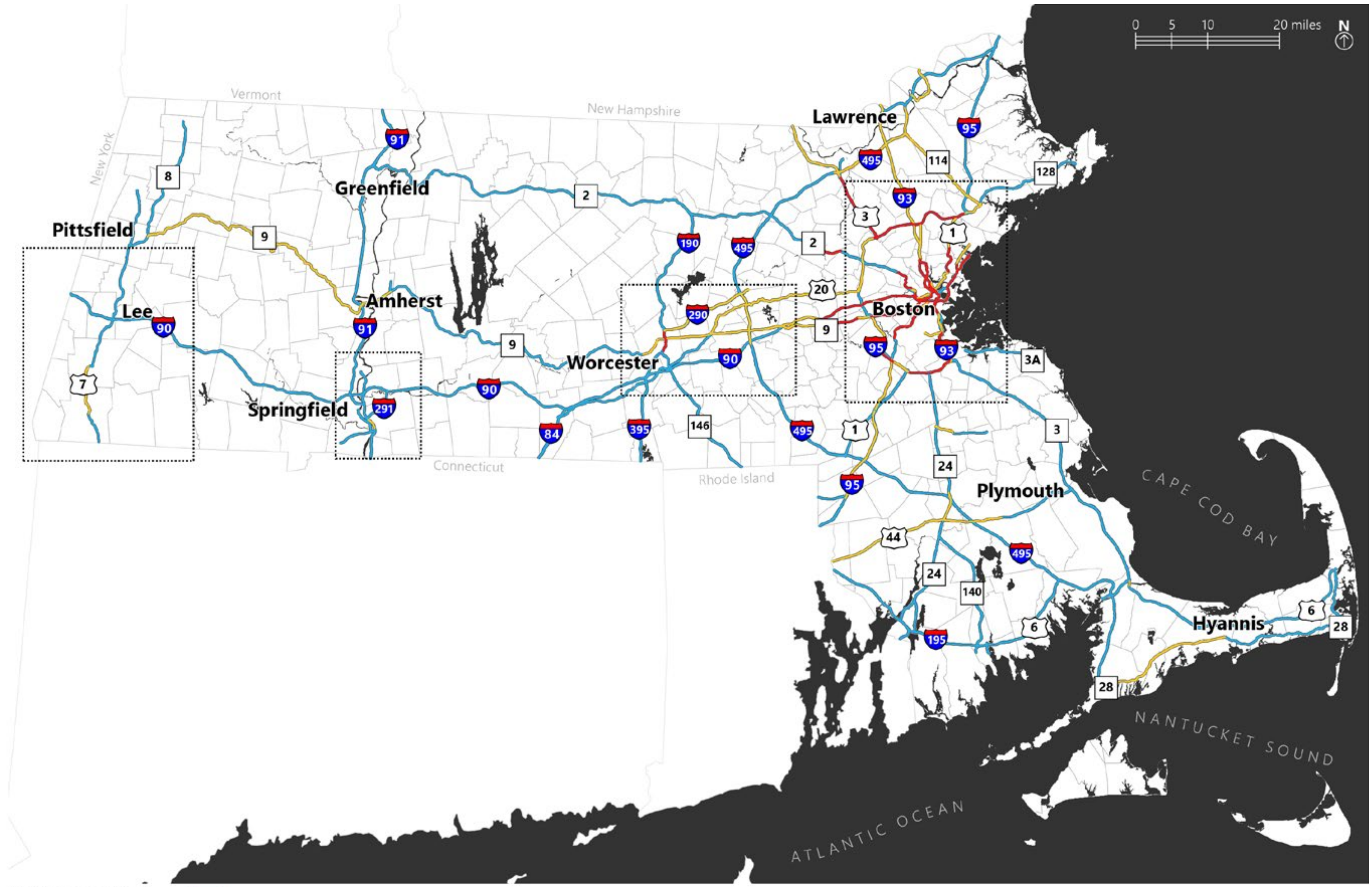
CONGESTION
4:00–4:59 pm
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



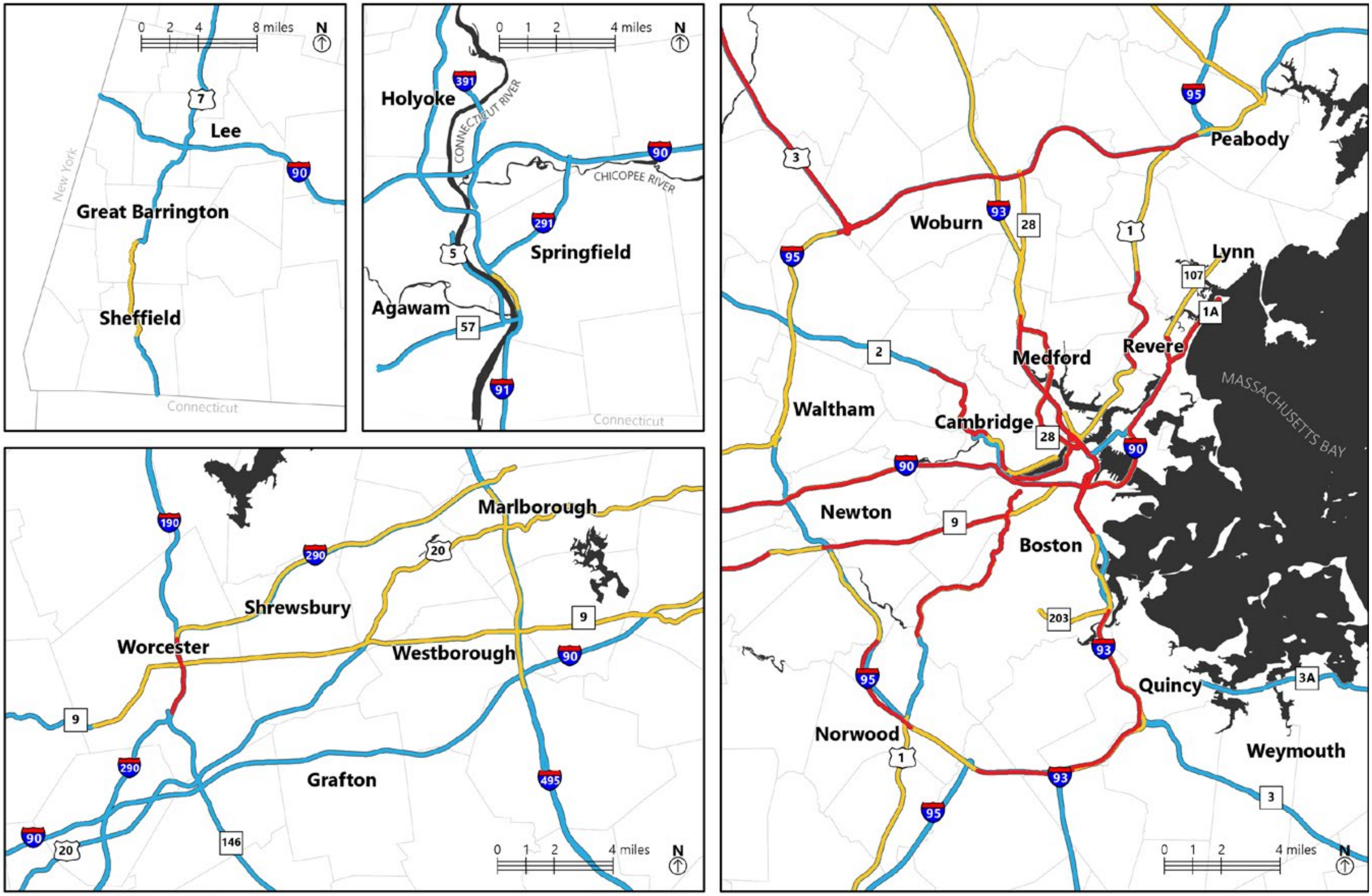
CONGESTION
4:00–4:59 pm
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)



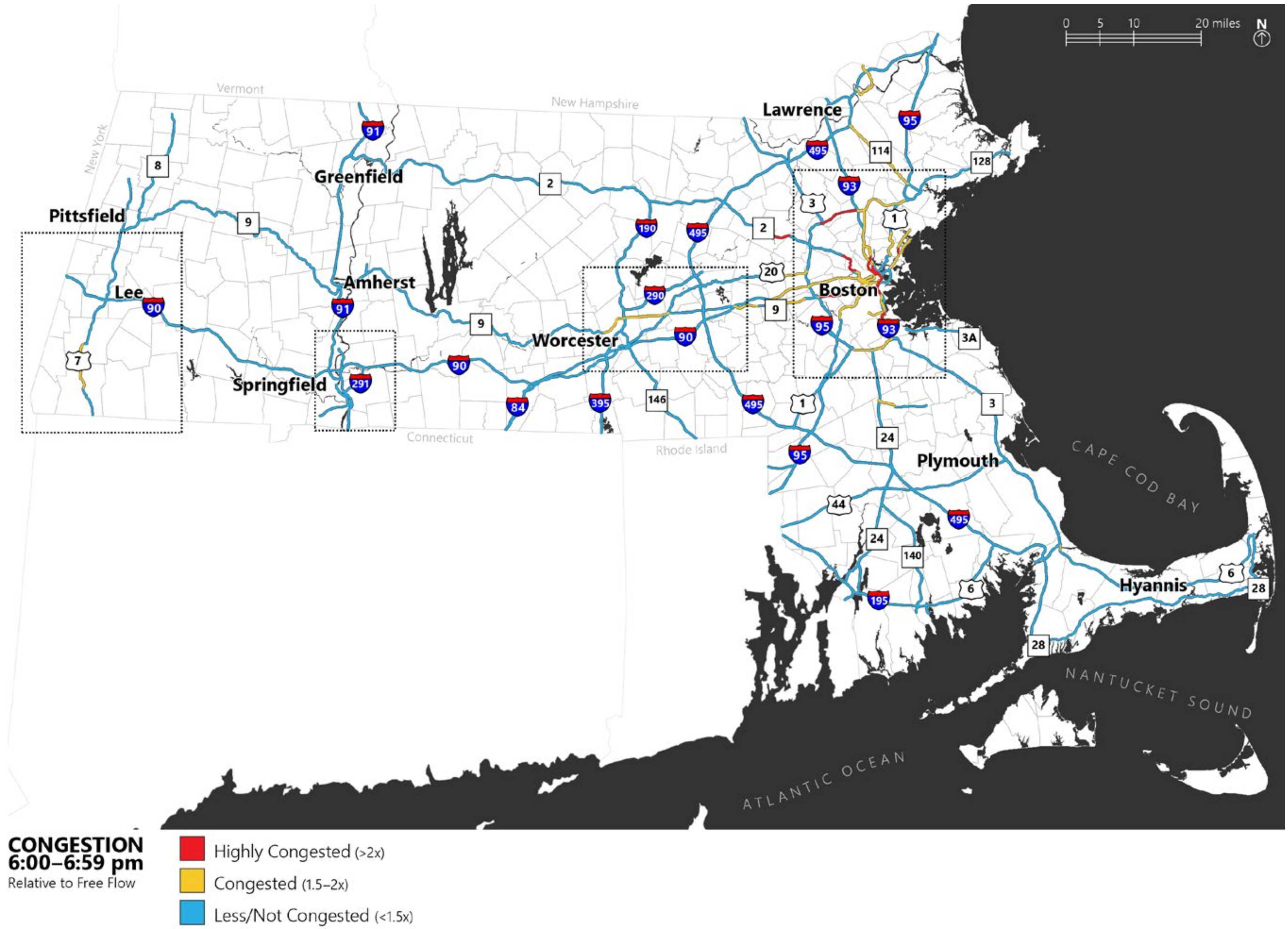
CONGESTION
5:00–5:59 pm
Relative to Free Flow

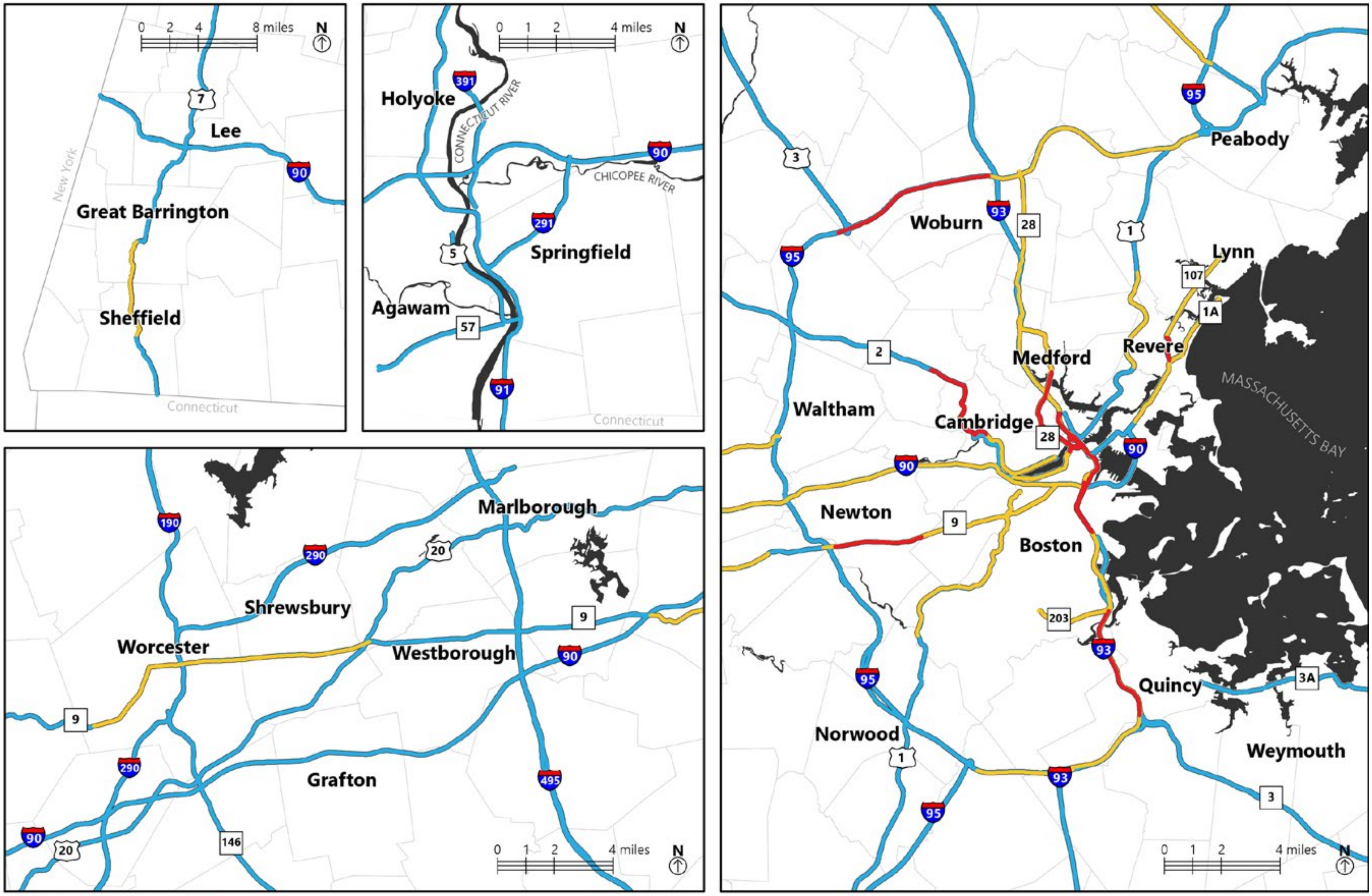
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)



CONGESTION
5:00–5:59 pm
Relative to Free Flow

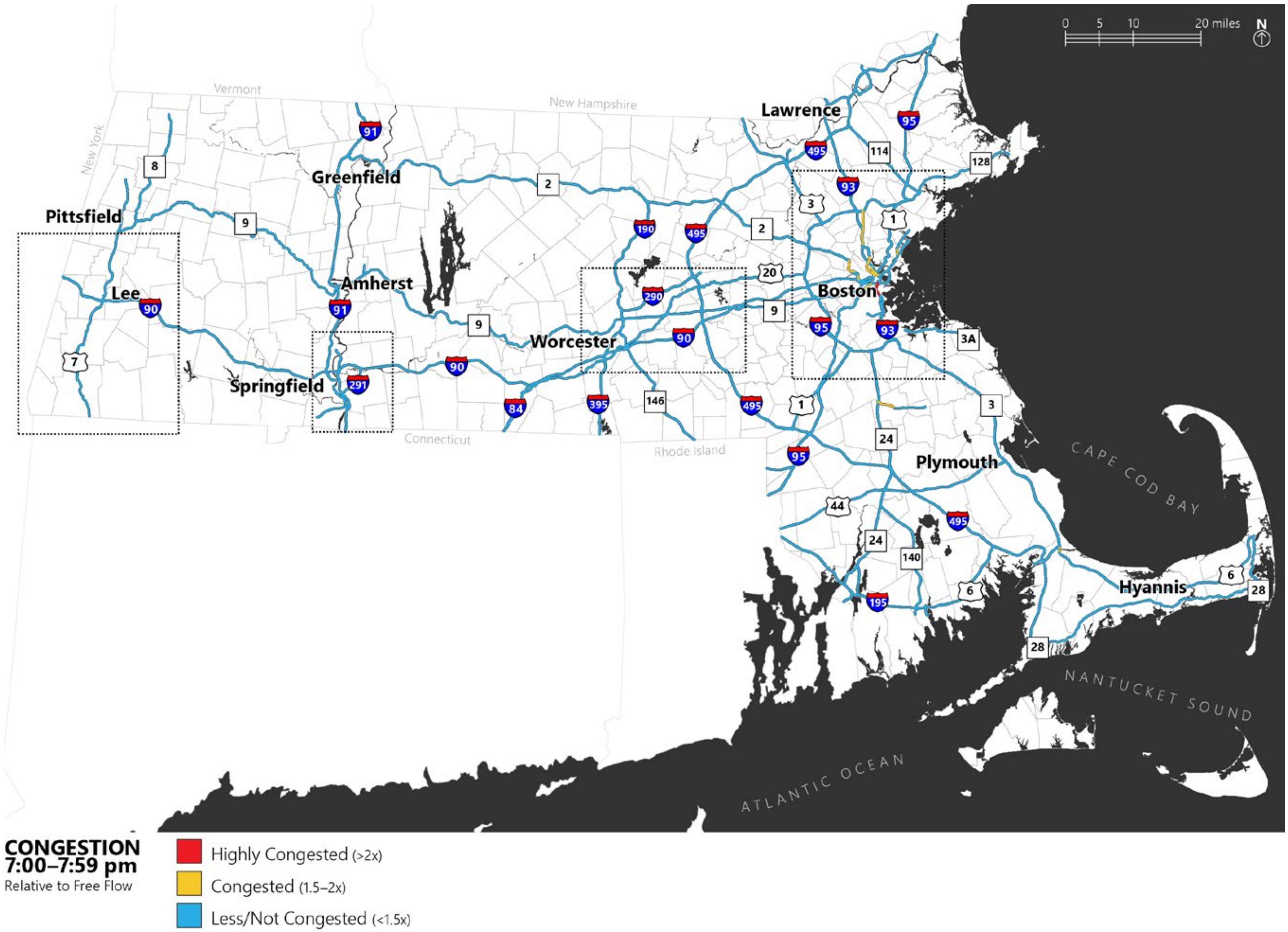
- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)

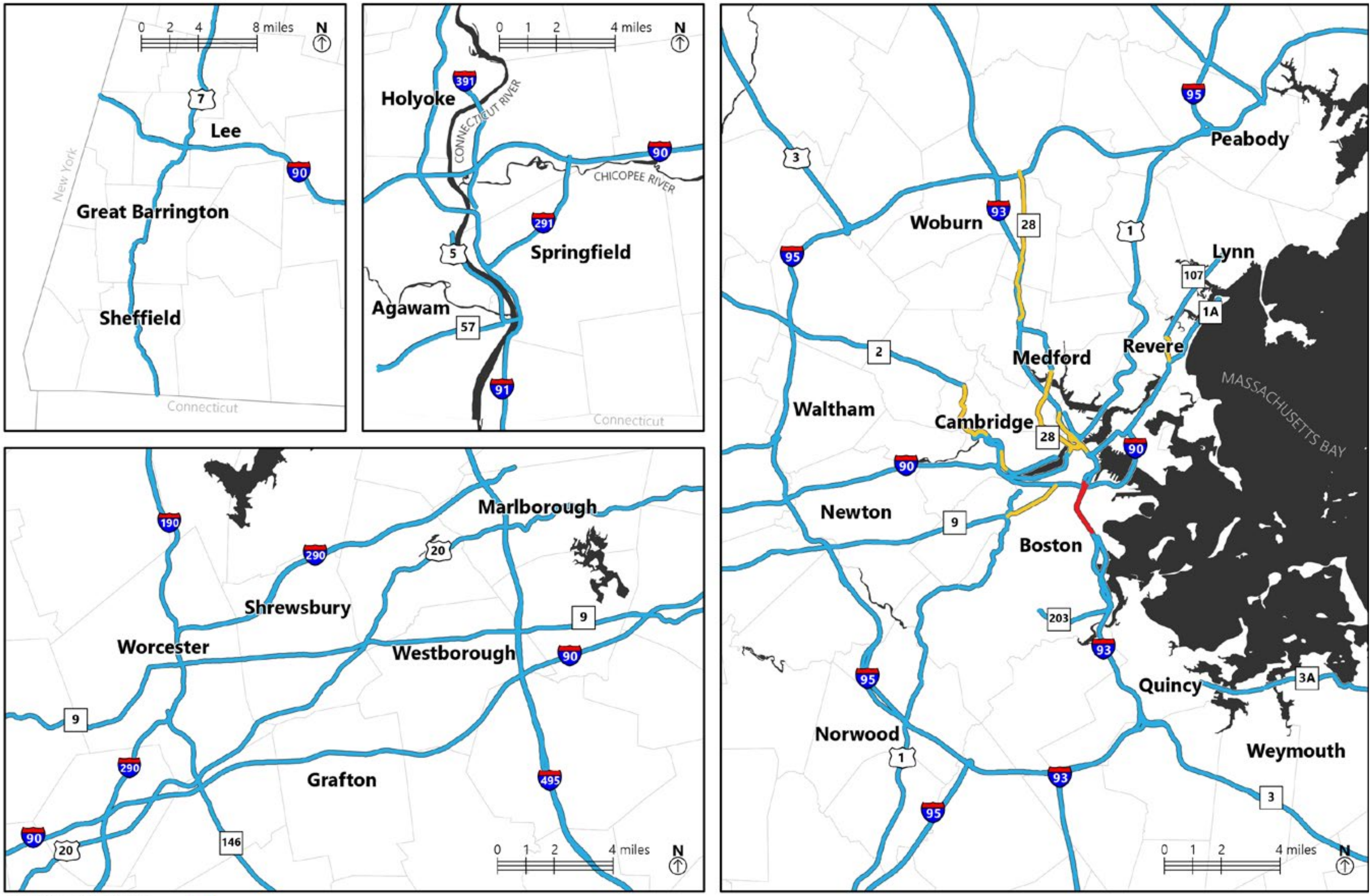

0 5 10 20 miles
N
Vermont
New Hampshire
New York
Connecticut
Rhode Island
Pittsfield
Lee
Greenfield
Amherst
Springfield
Worcester
Lawrence
Boston
Plymouth
Hyannis
CAPE COD BAY
NANTUCKET SOUND
ATLANTIC OCEAN
CONGESTION
6:00–6:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)



CONGESTION
6:00–6:59 pm
Relative to Free Flow

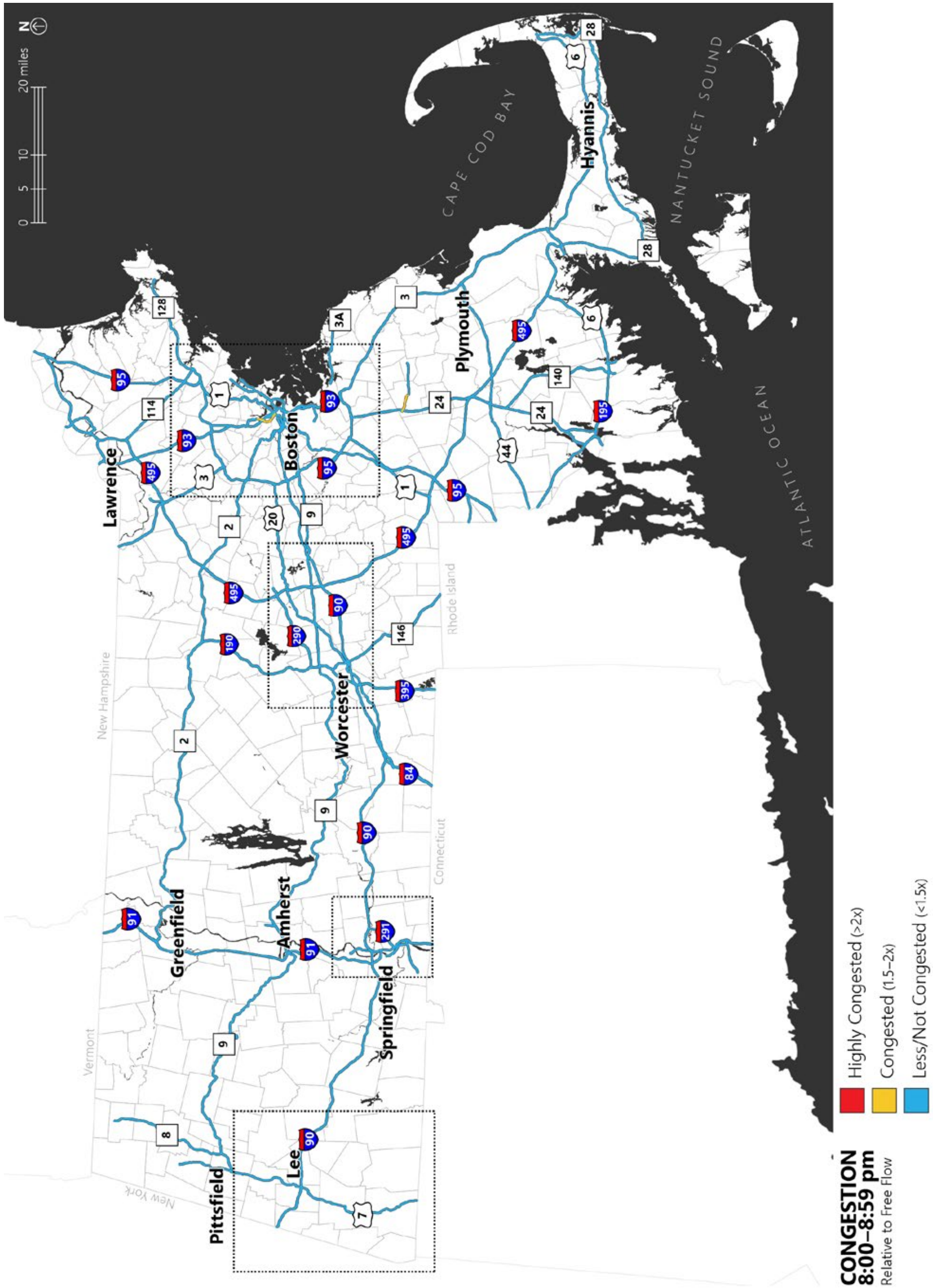
- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)

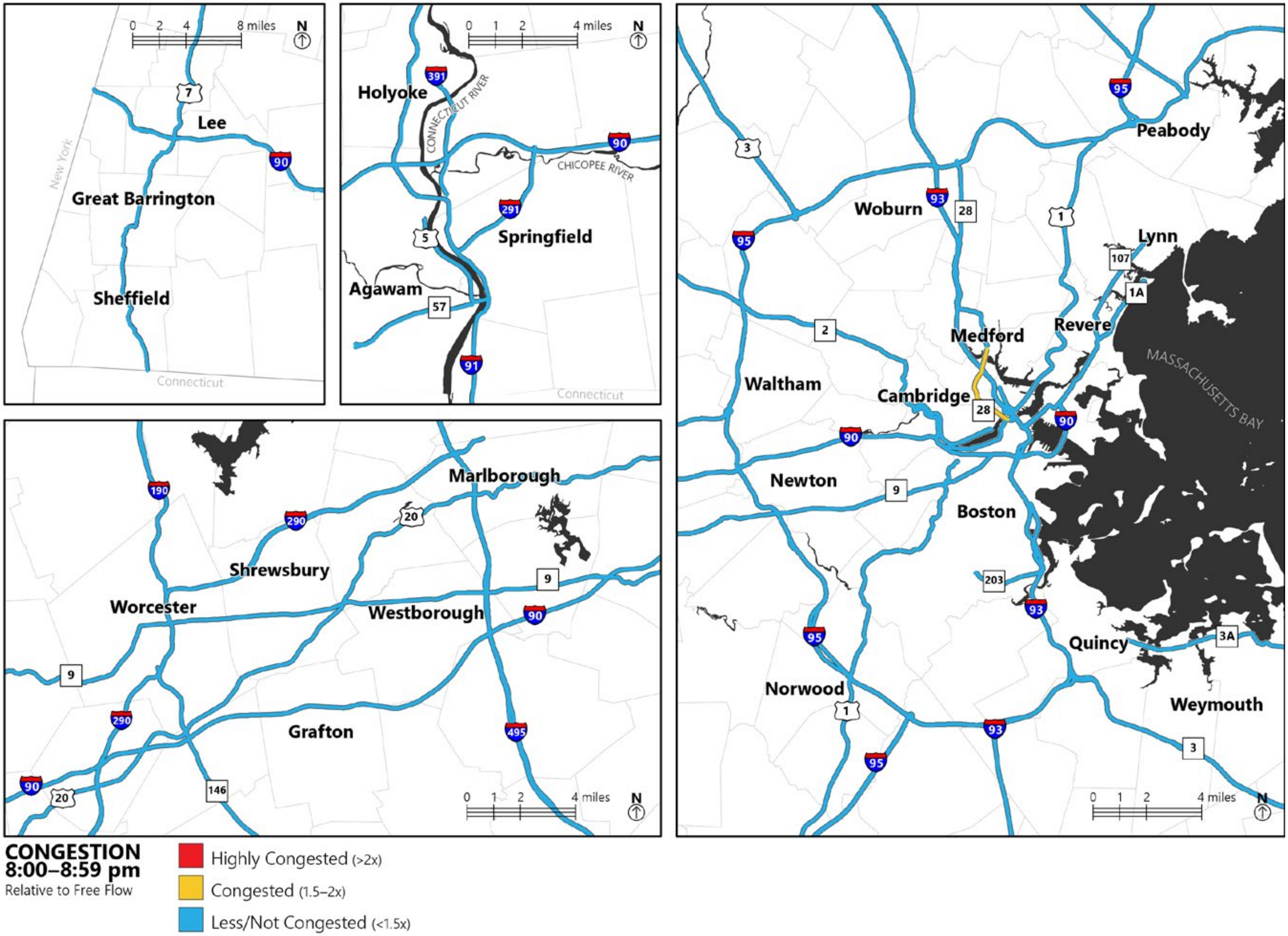

0 5 10 20 miles
N
Vermont
New Hampshire
New York
Connecticut
Rhode Island
Lawrence
Greenfield
Pittsfield
Amherst
Lee
Worcester
Boston
Springfield
Plymouth
Hyannis
CAPE COD BAY
NANTUCKET SOUND
ATLANTIC OCEAN
CONGESTION
7:00–7:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)

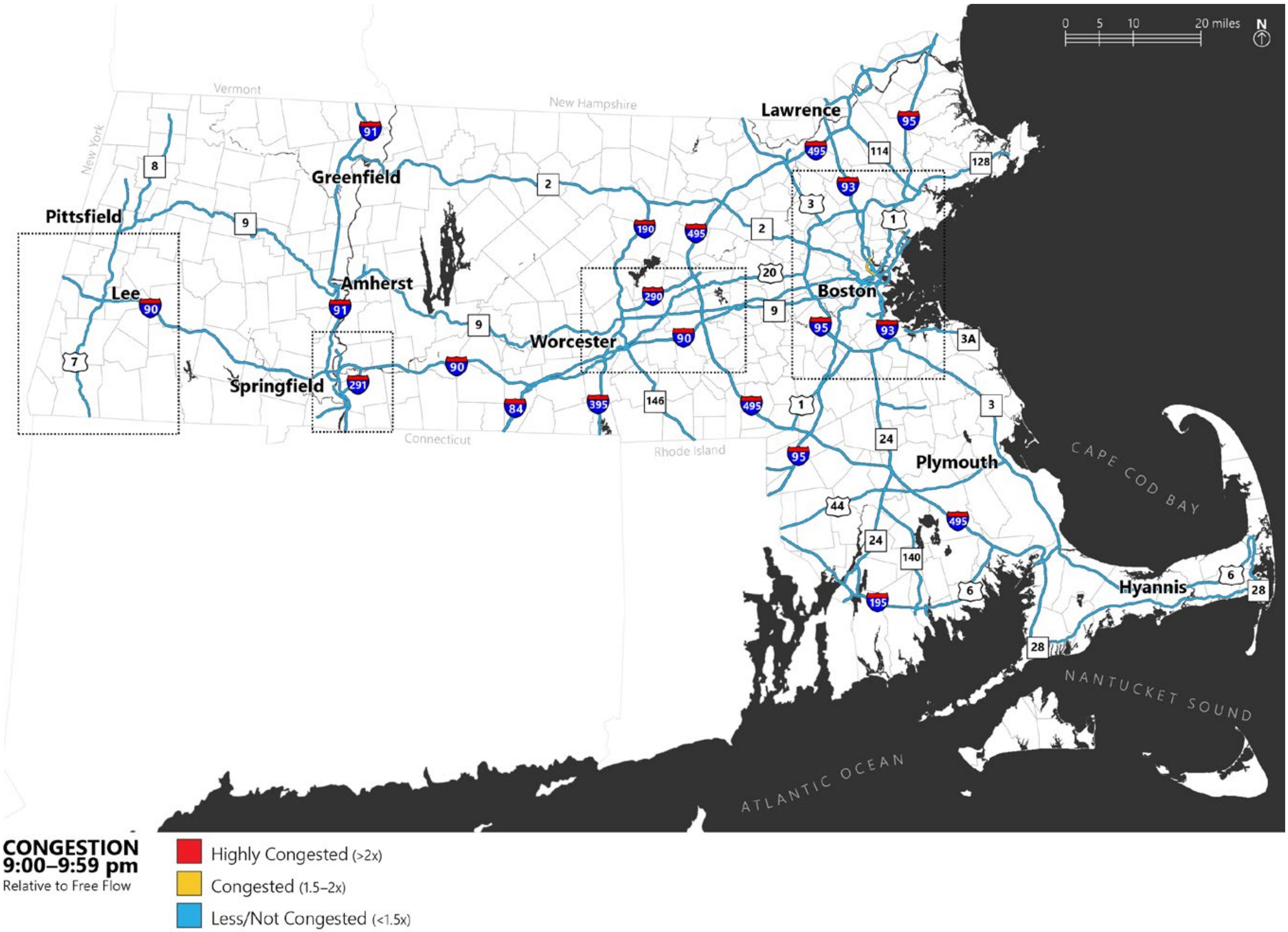


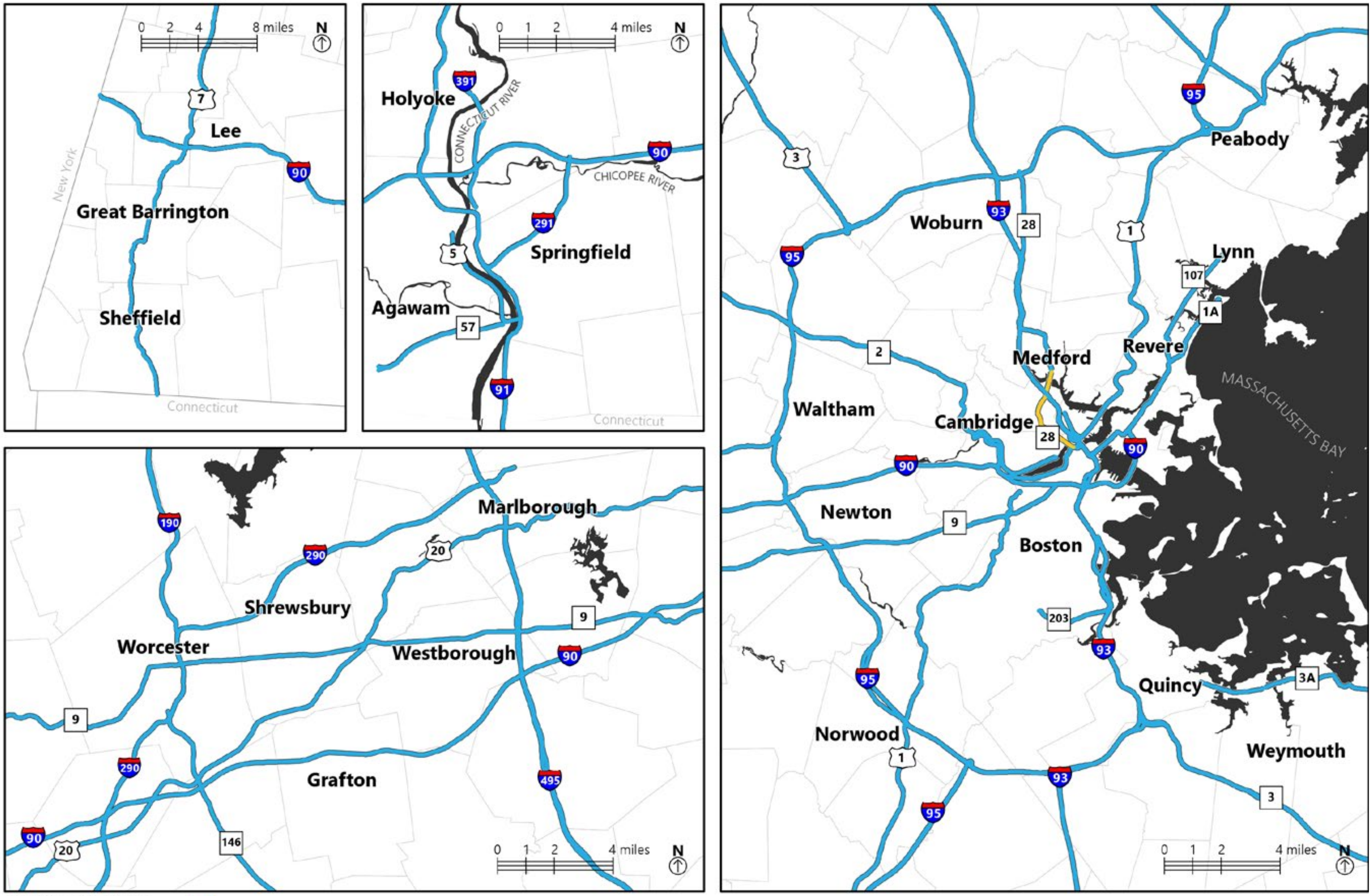
CONGESTION
7:00–7:59 pm
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)


CONGESTION
8:00–8:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)
0 5 10 20 miles
N
Pittsfield
Lee
Springfield
Amherst
Greenfield
Worcester
Lawrence
Boston
Plymouth
Hyannis
CAPE COD BAY
NANTUCKET SOUND
ATLANTIC OCEAN
New York
Vermont
New Hampshire
Rhode Island
Connecticut


Lee
Great Barrington
Sheffield
New York
Connecticut
Holyoke
CONNECTICUT RIVER
CHICOPEE RIVER
Springfield
Agawam
Worcester
Shrewsbury
Marlborough
Westborough
Grafton
Woburn
Peabody
Lynn
Medford
Revere
Waltham
Cambridge
Newton
Boston
Quincy
Norwood
Weymouth
MASSACHUSETTS BAY
CONGESTION
8:00–8:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)


0 5 10 20 miles
N
Vermont
New Hampshire
New York
Connecticut
Rhode Island
Lawrence
Greenfield
Pittsfield
Lee
Amherst
Worcester
Springfield
Boston
Plymouth
Hyannis
CAPE COD BAY
NANTUCKET SOUND
ATLANTIC OCEAN
CONGESTION
9:00–9:59 pm
Relative to Free Flow
Highly Congested (>2x)
Congested (1.5–2x)
Less/Not Congested (<1.5x)



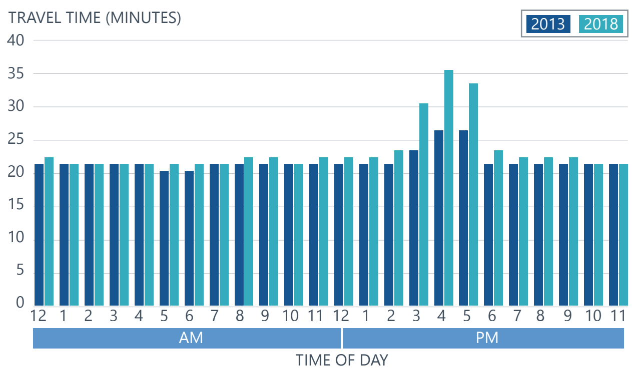
CONGESTION
9:00–9:59 pm
Relative to Free Flow

- Highly Congested (>2x)
- Congested (1.5–2x)
- Less/Not Congested (<1.5x)

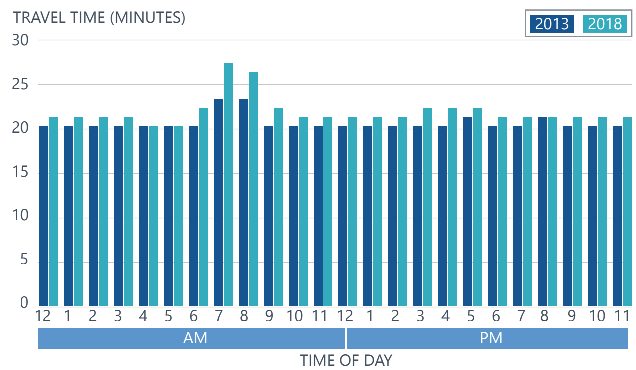
APPENDIX D

TRAVEL TIME ON SELECT CORRIDORS, 2013 AND 2018

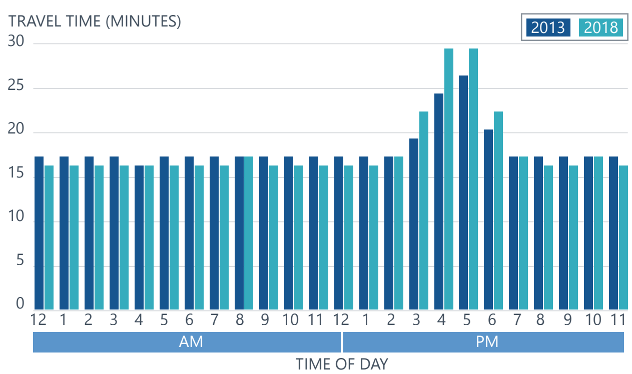
I-290 | Westbound | I-495 (Marlborough) to I-90 (Auburn)



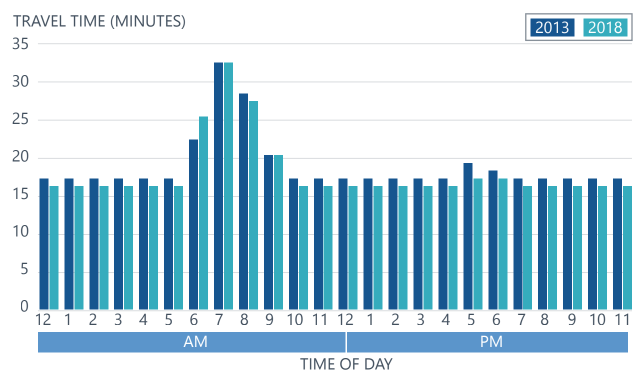
I-290 | Eastbound | I-495 (Marlborough) to I-90 (Auburn)



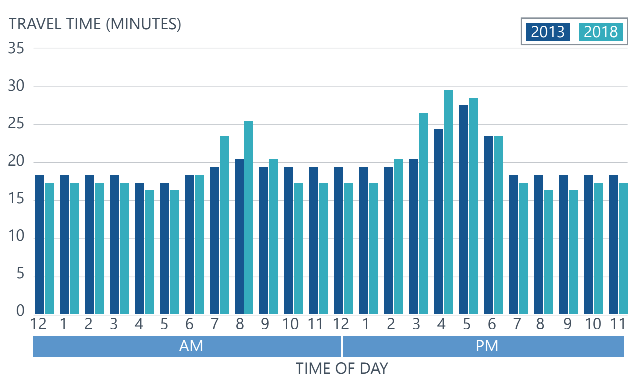
I-90 | Westbound | I-95/128 (Weston) to I-495 (Hopkinton)



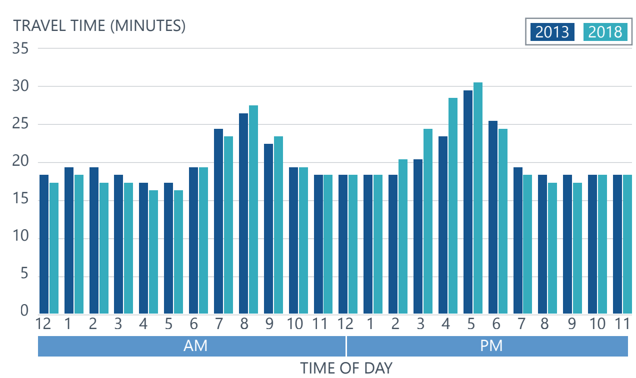
I-90 | Eastbound | I-495 (Hopkinton) I-95/128 (Weston)



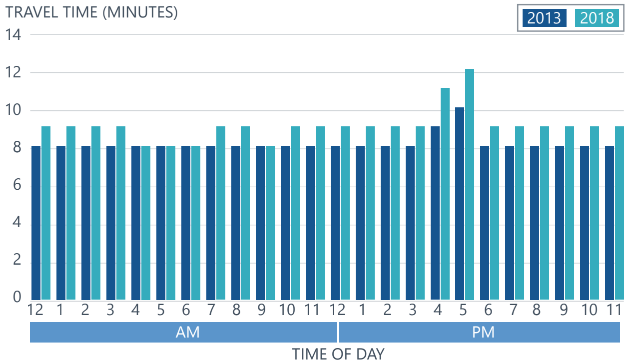
I-90 | Westbound | Logan Airport to I-95/128 (Weston)



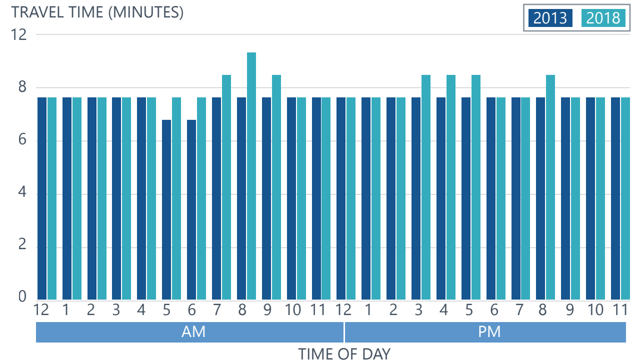
I-90 | Eastbound | I-95/128 (Weston) to Logan Airport



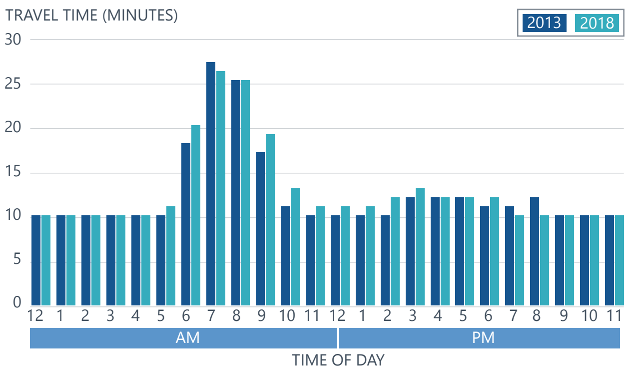
I-9I | Southbound | I-391 (Chicopee) to Connecticut State Line



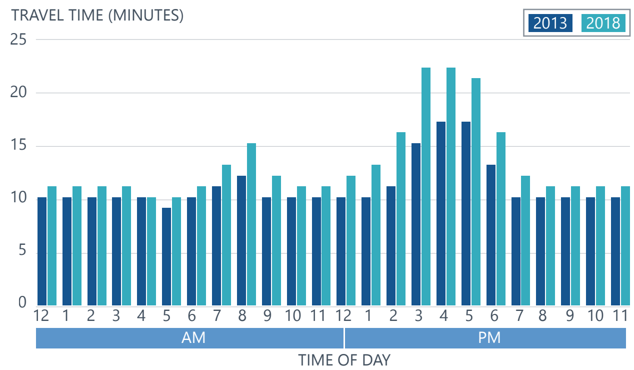
I-9I | Northbound | Connecticut State Line to I-391 (Chicopee)



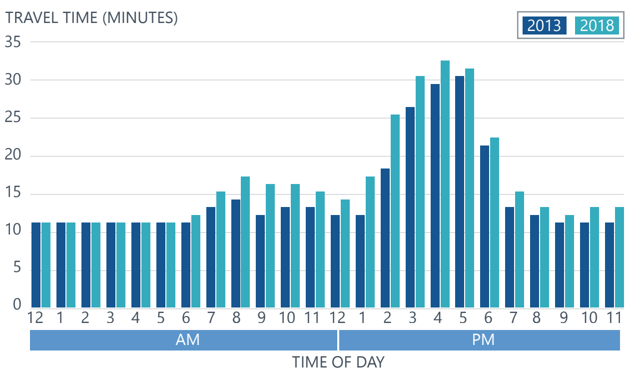
I-93 (Northern Expressway) | Southbound | I-95/128 (Woburn) to Zakim Bridge



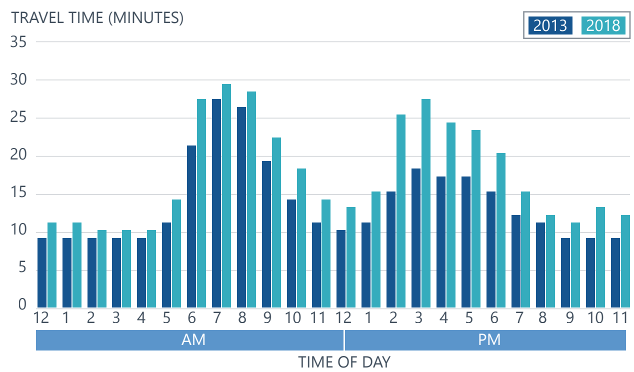
I-93 (Northern Expressway) | Northbound | Zakim Bridge to I-95/128 (Woburn)



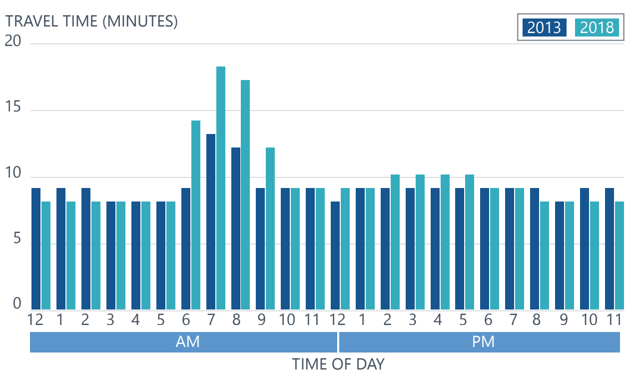
I-93 (SE Xway) | Southbound | I-90 (South Bay) to Braintree Split



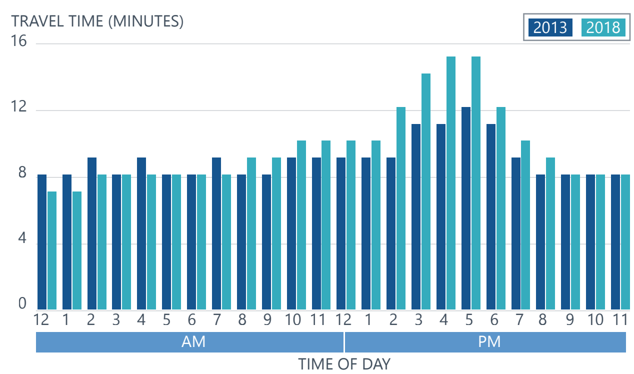
I-93 (SE Xway) | Northbound | Braintree Split to I-90



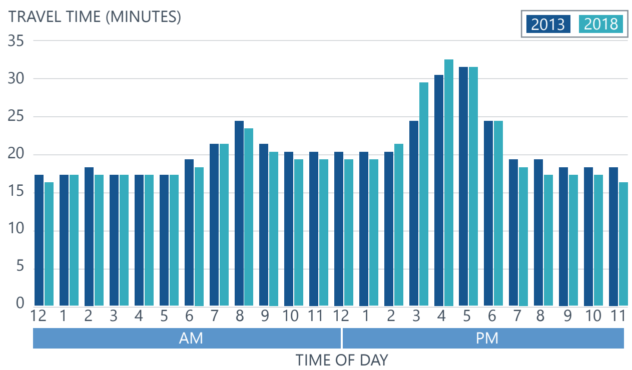
MA-1A | Southbound | Bell Circle to Sumner Tunnel



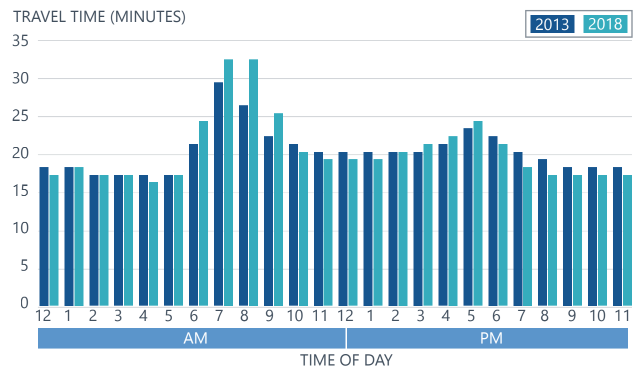
MA-1A | Northbound | Callahan Tunnel to Bell Circle



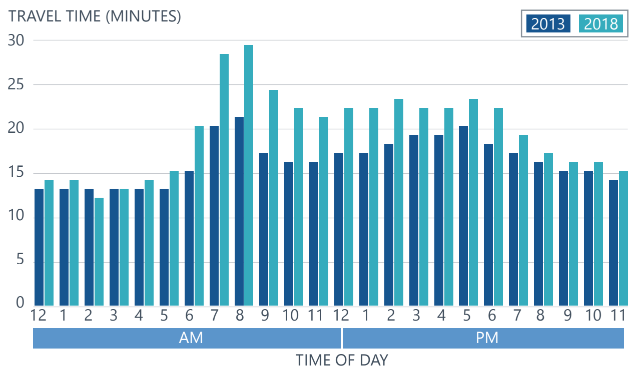
MA-2 | Westbound | Alewife to West Concord



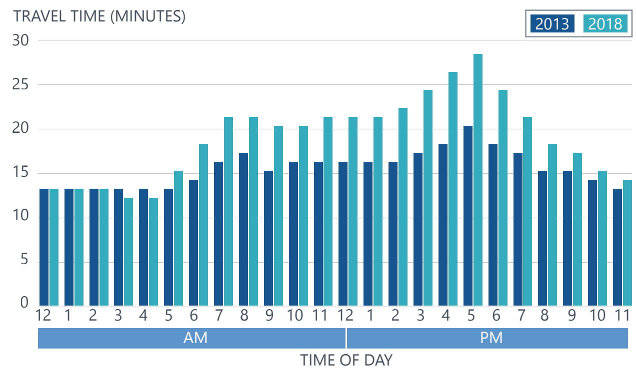
MA-2 | Eastbound | West Concord to Alewife



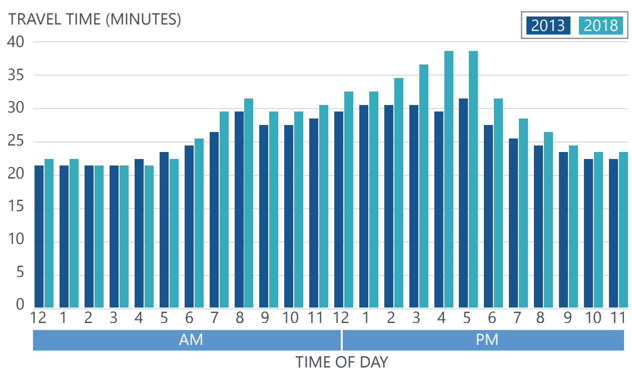
MA-28 (Fellsway/McGrath) | Southbound | Middlesex Fells to Leverett Circle



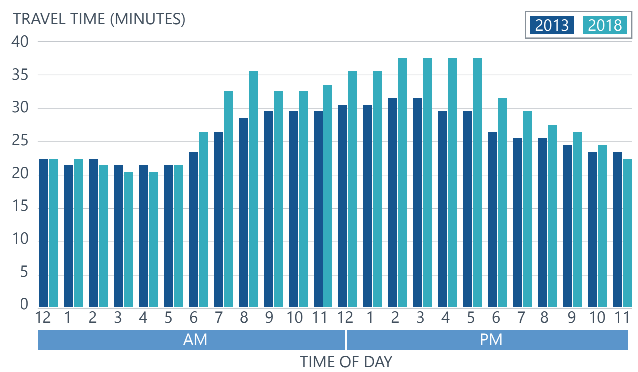
MA-28 (Fellsway/McGrath) | Northbound | Leverett Circle to Middlesex Fells



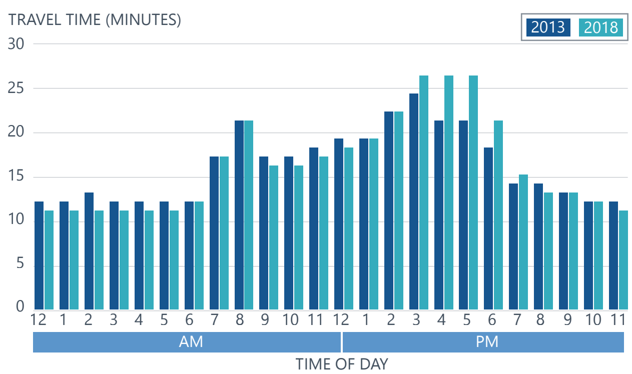
MA-9 | Westbound | US-20 (Northborough) to Worcester Airport



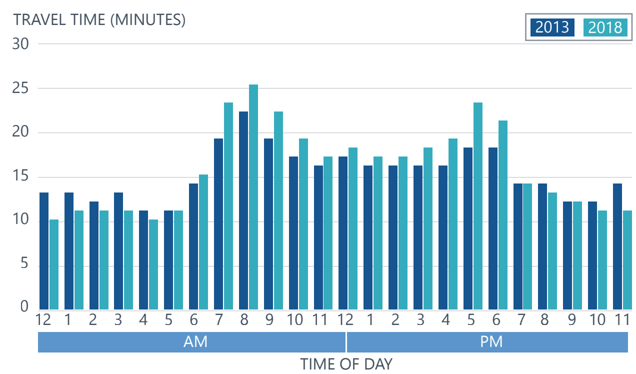
MA-9 | Eastbound | Worcester Airport to US-20 (Northborough)



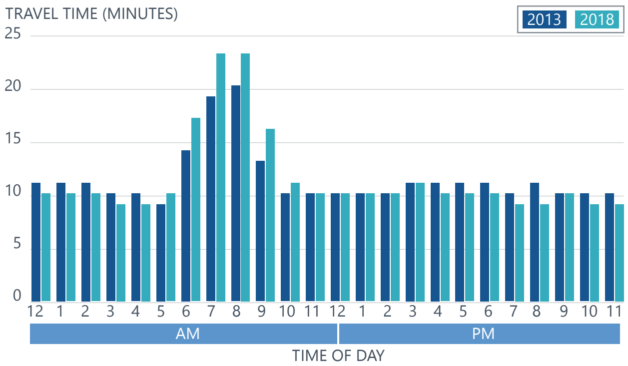
MA-9 | Westbound | Brookline Village to I-95/128



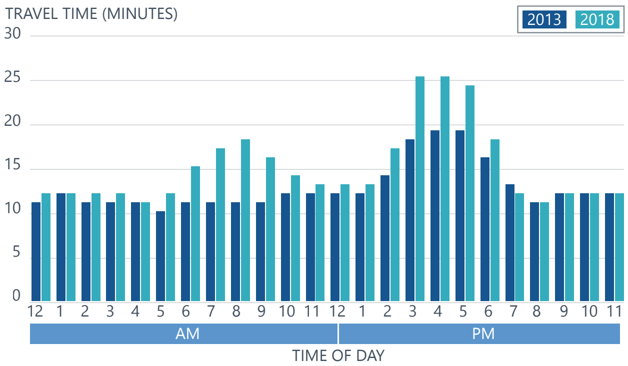
MA-9 | Eastbound | I-95/128 (Wellesley) to Brookline Village



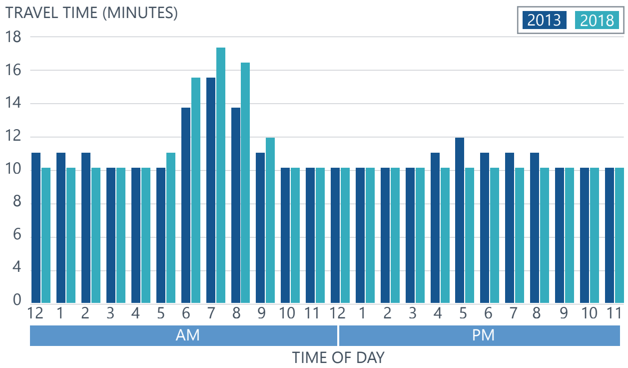
US-1 | Southbound | MA-99 (Saugus) to Tobin Bridge



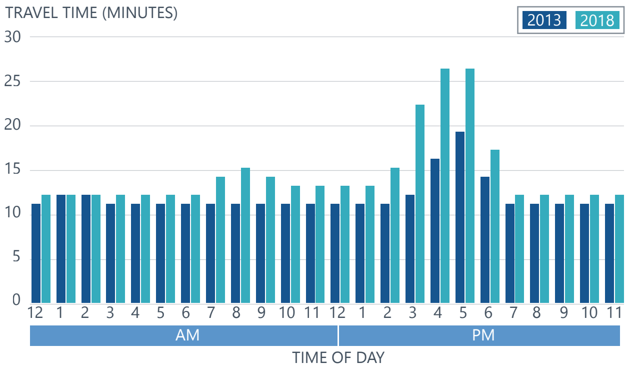
US-4 | Northbound | Tobin Bridge to MA-99 (Saugus)



US-3 | Southbound | I-495 (Chelmsford) to I-95/128 (Burlington)



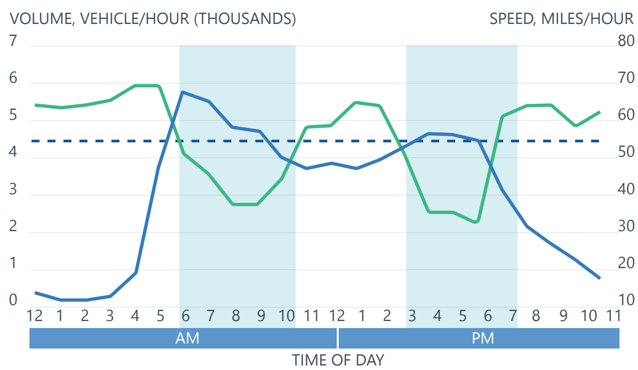
US-3 | Northbound | I-95/128 (Burlington) to I-495 (Chelmsford)



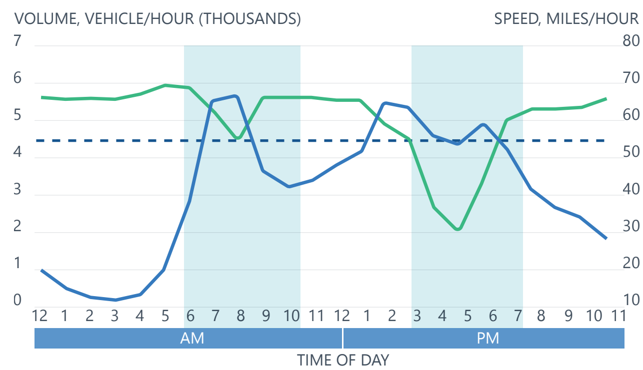
APPENDIX E

ALL ELECTRONIC TOLLING (AET) GANTRY DATA, ROADWAY VOLUMES AND SPEEDS

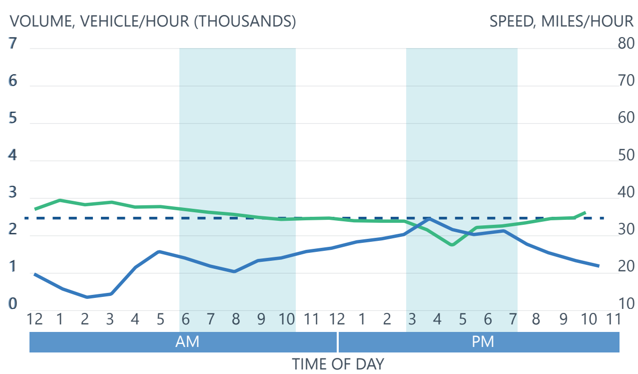
I-90 Eastbound at Gantry AET 11, Newton



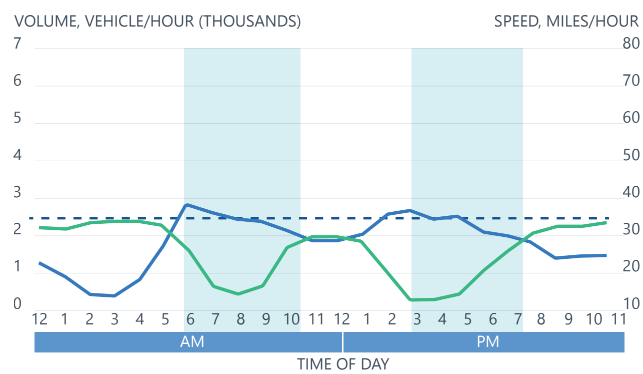
I-90 Westbound at Gantry AET 11, Newton



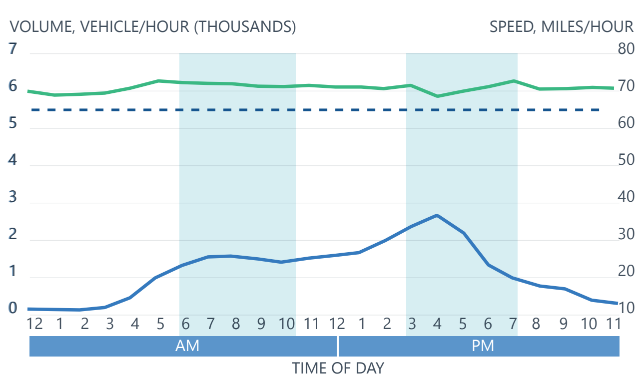
Route 1A Northbound at Gantry AET 16, East Boston *(Callahan Tunnel)*



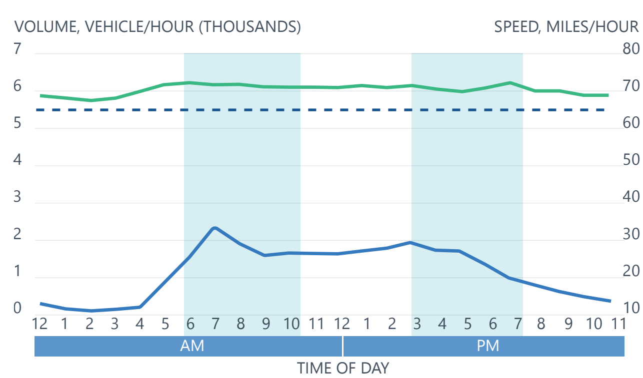
Route 1A Southbound at Gantry AET 16, East Boston *(Callahan Tunnel)*



I-90 Eastbound at Gantry AET 4, Ludlow

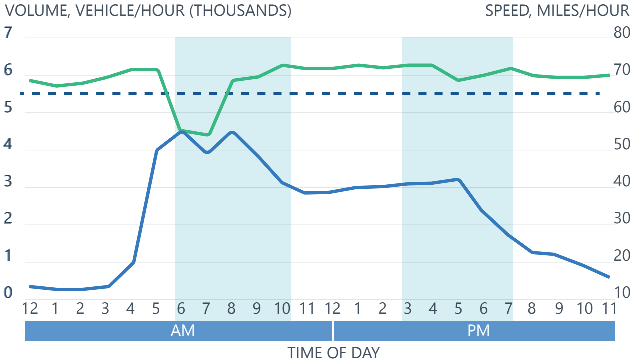


I-90 Westbound at Gantry AET 4, Ludlow

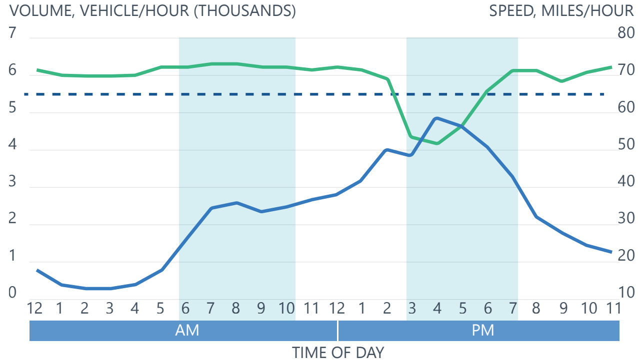


VOLUME — SPEED — POSTED SPEED LIMIT — PEAK PERIOD

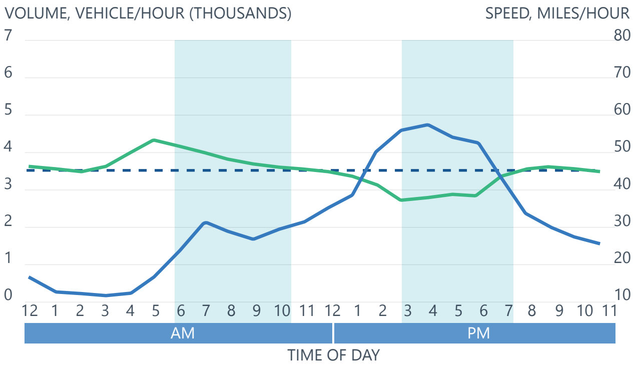
I-90 Eastbound at Gantry AET 8, Southborough



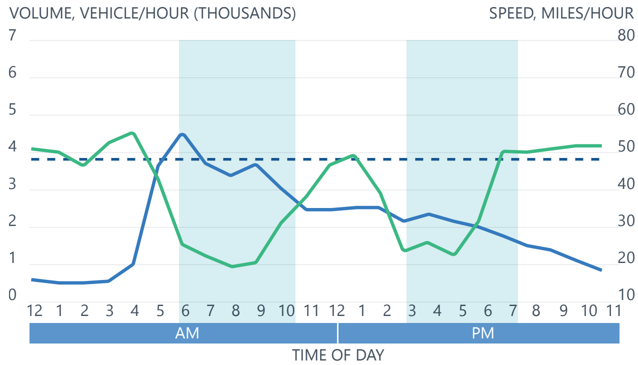
I-90 Westbound at Gantry AET 8, Southborough



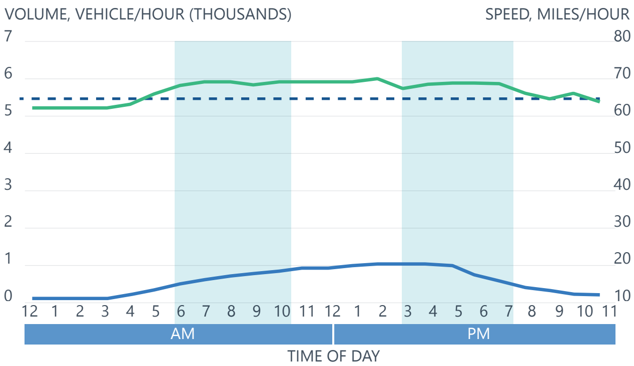
Route 1 Northbound at Gantry AET 15, Boston *(Tobin Bridge)*



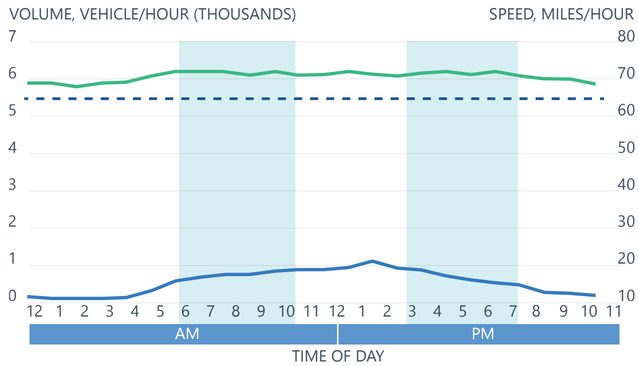
Route 1 Southbound at Gantry AET 15, Boston *(Tobin Bridge)*



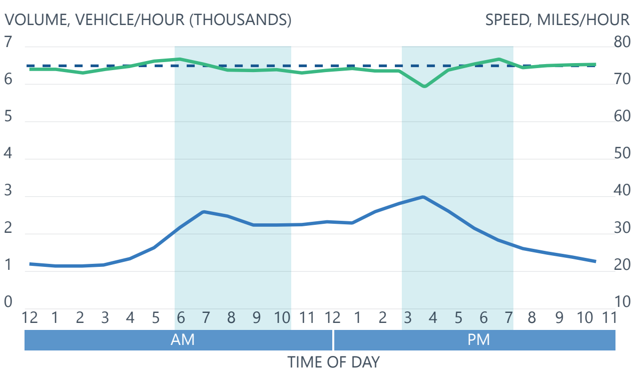
I-90 Eastbound at Gantry AET 2, Blanford



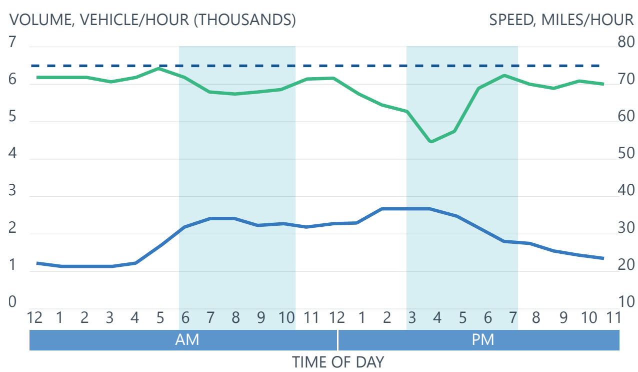
I-90 Westbound at Gantry AET 2, Blanford



I-90 Eastbound at Gantry AET 3, Westfield

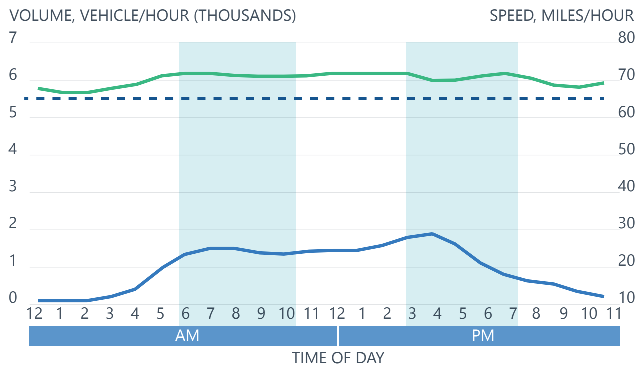


I-90 Westbound at Gantry AET 3, Westfield

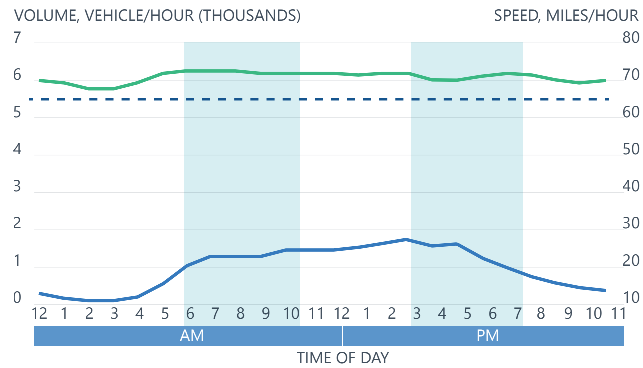


VOLUME — SPEED — POSTED SPEED LIMIT — PEAK PERIOD

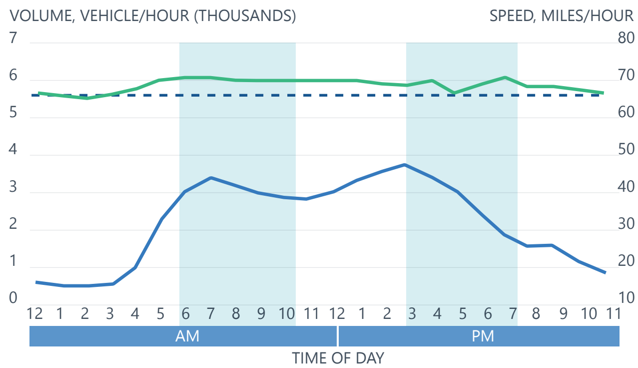
I-90 Eastbound at Gantry AET 5, West Brookfield



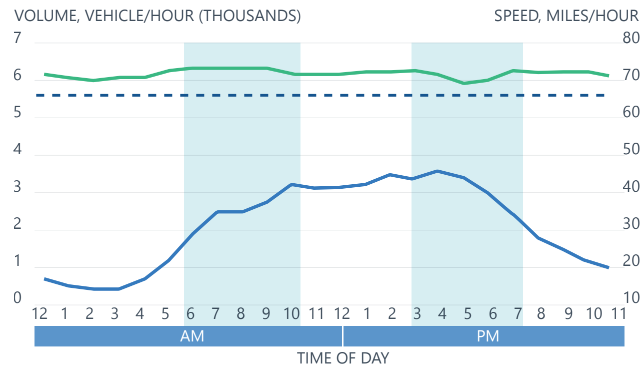
I-90 Westbound at Gantry AET 5, West Brookfield



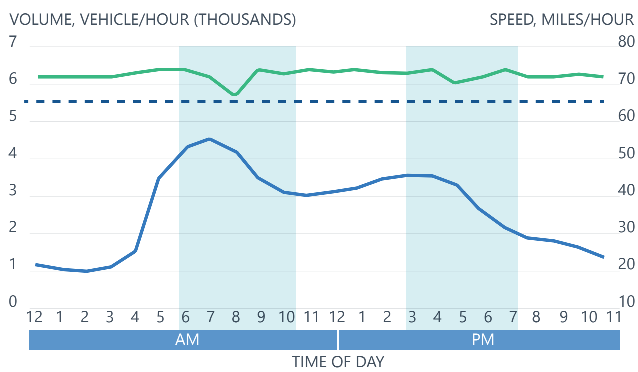
I-90 Eastbound at Gantry AET 6, Charlton



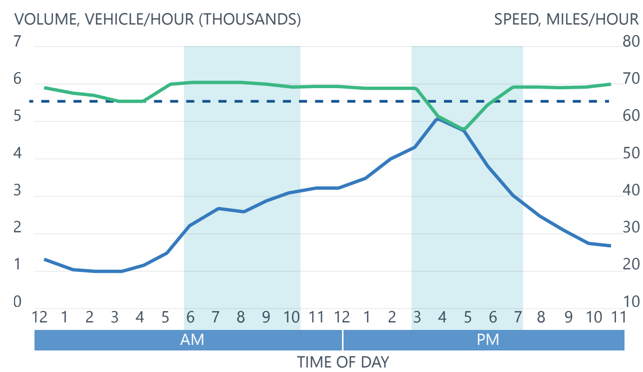
I-90 Westbound at Gantry AET 6, Charlton



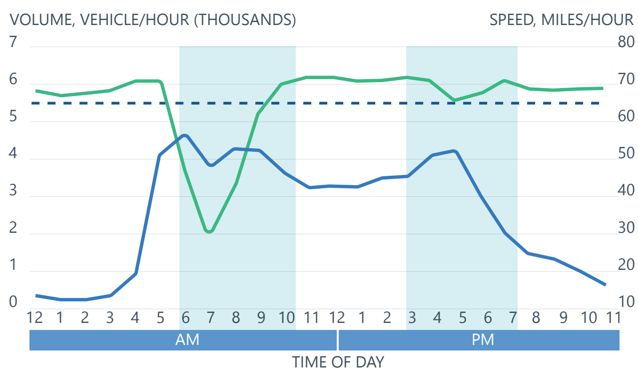
I-90 Eastbound at Gantry AET 7, Hopkinton



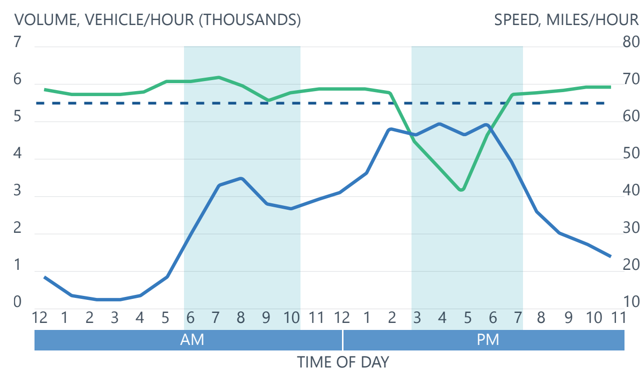
I-90 Westbound at Gantry AET 7, Hopkinton



I-90 Eastbound at Gantry AET 9, Framingham

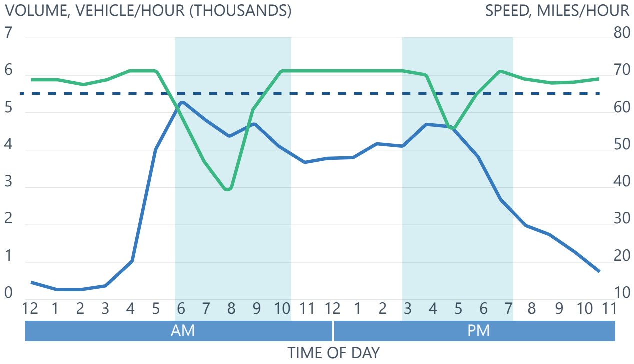


I-90 Westbound at Gantry AET 9, Framingham

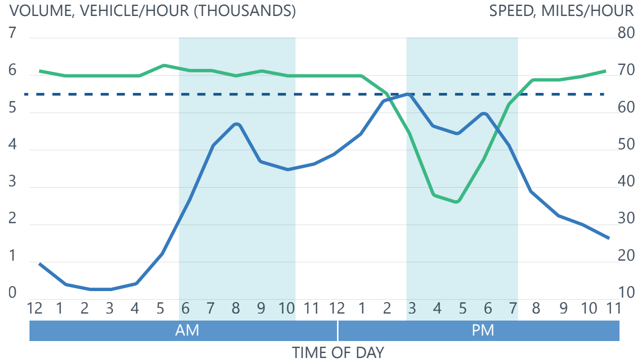


VOLUME — SPEED — POSTED SPEED LIMIT — PEAK PERIOD

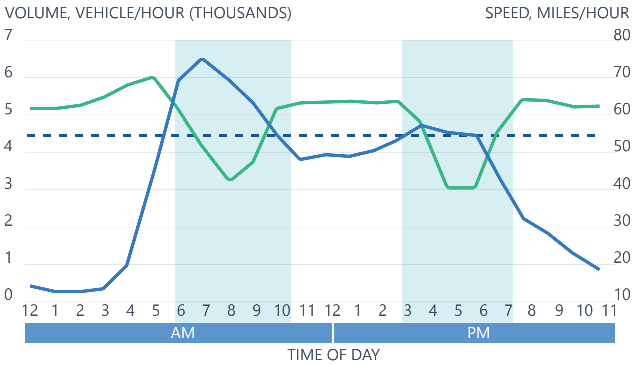
I-90 Eastbound at Gantry AET 10, Weston



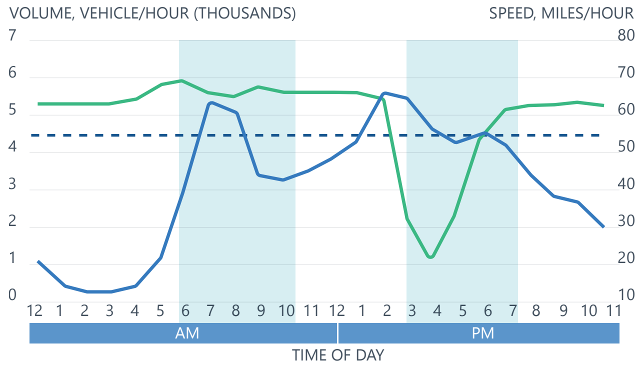
I-90 Westbound at Gantry AET 10, Weston



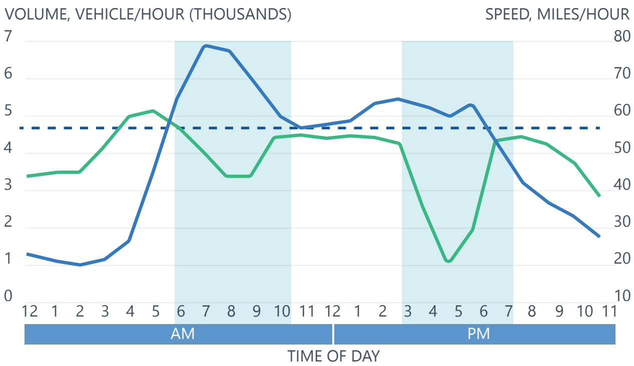
I-90 Eastbound at Gantry AET 12, Allston



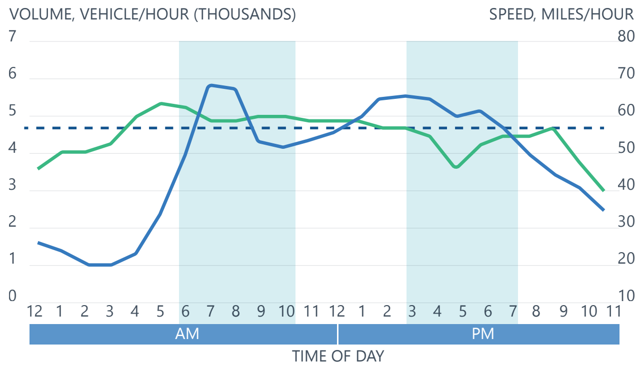
I-90 Westbound at Gantry AET 12, Allston



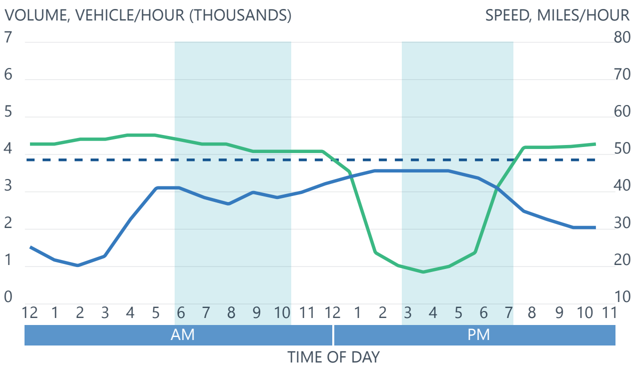
I-90 Eastbound at Gantry AET 13, Boston University



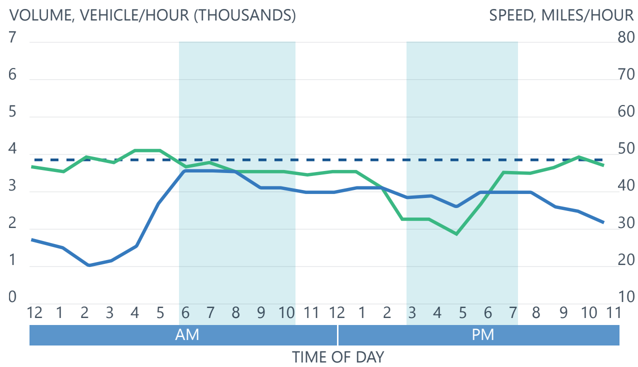
I-90 Westbound at Gantry AET 13, Boston University



I-90 Eastbound at Gantry AET 14, Ted Williams Tunnel



I-90 Westbound at Gantry AET 14, Ted Williams Tunnel



VOLUME — SPEED — POSTED SPEED LIMIT — PEAK PERIOD

APPENDIX F
WEATHER ANALYSIS DETAILS

An online weather database (https://darksky.net) was used to identify any correlation between observed weather and congestion patterns. Eleven origin-destination pairs were selected for analysis; National Performance Management Research Data Set (NPMRDS) travel time data (available at five-minute resolution throughout 2018) was used to estimate mean travel time between origin-destination pairs in both the inbound and outbound directions.

For each origin-destination pair of interest, a single geographic coordinate (corresponding to the approximate midpoint between origin and destination) was identified. Weather conditions at this coordinate for both the morning and evening commute (8:00 a.m. and 5:00pm, respectively) were paired with travel times across a three-hour period in the morning (6:00am-9:00am) and four-hour period in the evening (4:00-8:00pm). The weather-tagged travel times were then binned into one-minute increments and shown as histograms.

CONGESTION IN THE COMMONWEALTH

REPORT TO THE GOVERNOR 2019

Massachusetts Department of Transportation
10 Park PlazaSuite 4160,
Boston, MA 02116

www.mass.gov/orgs/massachusetts-department-of-transportation

massDOT
Massachusetts Department of Transportation