August 2021

SHARED TRAVEL NETWORK STUDY

TECHNICAL MEMORANDUM 2
EXISTING CONDITIONS



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1 INTRODUCTION

Objective

The objective of this memorandum is to evaluate the landscape for shared travel in Greater Boston by cataloging existing shared travel infrastructure and service models; identifying significant origin/destination markets; analyzing the potential of different shared travel service models to serve these top markets; and assessing the potential of different infrastructure improvements to make shared travel services in top markets competitive with single-occupancy vehicles (SOV). This memorandum is a deliverable for Task 3 (of four) of the *Shared Travel Network Study*: Existing Conditions analysis.

Purpose of the Study

In 2018, Governor Baker signed HB4833, which included language that directed Massachusetts Department of Transportation (MassDOT) to conduct a study of vehicular congestion on Massachusetts roadways. Specifically, the mandate called for MassDOT to "design and execute a study that provides a detailed analysis of practical pathways by which the Commonwealth could reduce motor vehicle congestion and make appropriate recommendations for further study or pilot programs, if warranted." This report, *Congestion in the Commonwealth 2019*, was released on August 8, 2019. [1]

MassDOT is conducting several follow-on studies and initiatives to respond to *Congestion in the Commonwealth 2019*'s findings, one of which was a recommendation to serve commuters who might otherwise utilize single-occupancy vehicles (SOV) through park-and-ride lots and bus or shuttle services.

The *Shared Travel Network Study* is intended to assess the potential for new or enhanced services to connect origin locations (e.g., park-and-ride lots) with destinations in Greater Boston, primarily via physical and operational improvements to the surface transportation network. Specifically, the project asks how MassDOT can serve two types of trips through shared travel options:

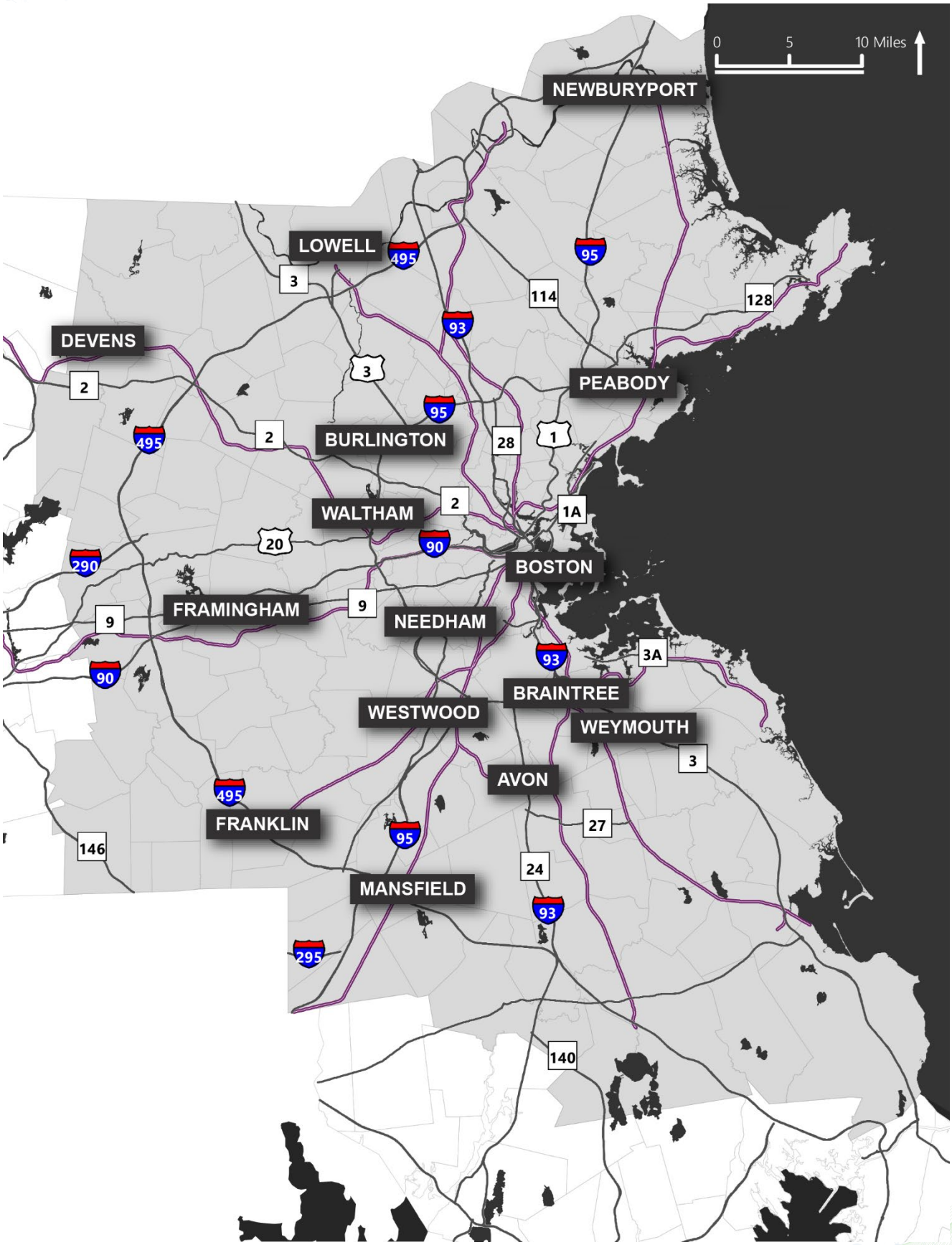
- Trips that can be routed through a park-and-ride facility along the I-95/MA-128 or I-495 corridors to a destination hub along or between them.
- Trips that can be routed through park-and-ride facilities to destinations in the urban core (i.e., Boston, Cambridge, Somerville, and neighboring dense areas). [2]

This study intentionally focuses on the Greater Boston region within the I-495 corridor, so the origin and destination points, or 'desire lines' identified through this analysis, are constrained to the area inside this beltway (as shown in Figure 1 on the next page).

[1] "Congestion in the Commonwealth". Massachusetts Department of Transportation, 2019. https://www.mass.gov/service-details/congestion-in-the-commonwealth

[2] The *Shared Travel Network Study* is meant to "fill gaps' in the existing transit network, so preference will be given to routes not currently served by the Massachusetts Bay Transportation Authority (MBTA) bus or commuter rail.

FIGURE 1 | MAP OF THE SHARED TRAVEL NETWORK STUDY AREA



Principles of Shared Travel Network Design

Case studies from the US and abroad have supported the argument that suburban locations are well-suited to freeway-based transit services that link jobs and housing across a region.[3,4] The *Shared Travel Network Study* conducted a review of national best practices – summarized in Technical Memorandum 1 (TM1) – that supported this same conclusion.

Shared travel is any mode for which members of more than one household share a vehicle. This includes all forms of transit, demand-responsive transportation, and carpooling, but does not include a single household all in one car. Ideally, a unified shared travel network consists of:[5]

- An integrated network of all public transport modes and different types of operations, with easy and comfortable transfer opportunities at several places in the city or region, allowing users to benefit from a "network effect".
- A simple network with a clear structure that is easy to learn and remember.
- Direct routes that operates at the fastest possible speed and highest possible reliability.
- High frequency services when and where the demand is reasonably high.
- Coordinated pulse timetables where demand is weaker (i.e., timetables that concentrate service when demand is the highest).
- Effective supporting measures such as fare structure, ticketing systems, information, and marketing.

Greater Boston's existing transportation system already features many of the elements of an integrated shared travel network – rapid transit and commuter rail lines are clearly delineated and culturally potent, and transit routes are sometimes direct and are relatively reliable (according to MassDOT's *Tracker* metrics). Outside I-95/MA-128, however, the network exhibits fewer "unified" characteristics. For example, transferring between Regional Transit Authorities (RTAs), business coalitions, and private curbside bus operators is often not possible, and few of these providers use unified, powerful branding and marketing to advertise and attract riders to services. Indeed, many residents and employees in the area may be completely unaware that a shared travel option exists when considering a trip, much less how much it costs, how it will be paid for, or whether the schedule is convenient and reliable.

TM1 identified takeaways for MassDOT's future shared travel efforts from its review of national best practices:

- **Marketing and Branding |** In order to establish a shared travel service as a "missing piece" of the Greater Boston transportation system, MassDOT should consider a unified marketing and branding approach. The brand may include a name, a logo, and/or a common vehicle livery (signage at stops, directional signage on

[3] "Employment Density". *EnviroAtlas*, US Environmental Protection Agency, 2014. https://enviroatlas.epa.gov/enviroatlas/DataFactSheets/pdf/Supplemental/EmploymentDensity.pdf
[4] Christopher Ferrell, "TCRP Report 145: Reinventing the Urban Interstate: A New Paradigm for Multimodal Corridors". *Transit Cooperative Research Program*, 2011. https://www.researchgate.net/publication/283491962_TCRP_Report_145_Reinventing_the_Urban_Interstate_A_New_Paradigm_for_Multimodal_Corridors
[5] Gustav Nielsen et al, "HiTrans Best Practice Guide 2: Public Transport – Planning the Networks". European Commission Interreg IIIB North Sea Programme, 2005. http://www.civitas.no/assets/hitrans2publictransportplanningthe-networks.pdf

highways and access roads, etc.). Marketing may include the service's website, a smartphone app, digital signage on the MBTA, Logan Airport, etc., billboards, online advertising, print advertising, and pop-up stands on streets or at festivals and events, etc.

- **Cooperation and Coordination Among Agencies |** In order to ensure that the new shared travel network integrates seamlessly and effectively into the Greater Boston transportation system, MassDOT should ensure coordination with and among RTAs, the MBTA, and other operators and stakeholders. MassDOT should consider existing RTA commuter shuttle services as well as those operated by business consortia when locating park-and-ride lots and designing services. Co-location of stops with these services and with local bus services may allow for transfers and a more efficient network generally.

- **Consideration of Unique Markets |** Houston's METRO shuttles demonstrate the flexibility of the coach bus-based shared travel concept and the many types of markets it can serve. METRO uses shuttles to ensure equitable access to its judicial functions (courthouses and auctions). MassDOT may wish to consider which events or specific demand centers might be uniquely well-served by shared travel services, drawing from location-based services and local insight.

- **Focus on Reliability |** Users of the transportation system must be confident in a particular service to use it, making reliability a crucial component of service provision. The Flatiron Flyer, a suburban transit service that uses motor coaches to connect Denver and Boulder, Colorado, overcame issues of unreliability by introducing managed lanes, which allow buses to stay on an established schedule. MassDOT may wish to consider integrating bus services into any potential future managed lane projects.

- **Operational Concerns |** The case studies and review of relevant literature identify some common operational challenges alongside potential infrastructure improvements and service patterns. MassDOT must also ensure equitable access to any of its solutions for people of varying levels of mobility – high-floor vehicles without wheelchair access may present challenges for some users, for example.

- **Performance Measures |** The case studies revealed that the performance of each service we reviewed is measured with operational data on at least an annual basis through common metrics such as boardings, revenues, and costs. MassDOT should provide for performance measurement and reporting at the outset of any plan for service, building on the MBTA Performance Dashboard, the MassDOT Tracker, and other internal performance reporting systems.

- **Pricing for Competitiveness |** In order to make shared travel more financially competitive with driving, Massachusetts could either lower the price of the former or increase the price of the latter through priced lanes or congestion pricing and access restrictions for SOVs. As Massport's Logan Express has demonstrated, incentives - both monetary and otherwise - can be very effective in driving higher patronage for shared travel services.

- **Land Use Policy |** MassDOT could partner with cities and towns to pursue transit-oriented development (TOD) opportunities adjacent to park-and-ride lots or curbside locations.

Regulatory Requirements for Shared Travel

While shared travel may be operationally and logistically feasible, regulatory requirements must be considered. Many of these regulations differ between the Federal, State and local levels:

- Federal regulations apply only if the carriers cross state lines, and are enforced by the Surface Transportation Board (STB).
- State regulations in Massachusetts are enforced by the Department of Public Utilities (DPU) under Title 220 CMR.[6]
- Local regulations in Massachusetts are limited to curbside access, including the boarding and discharging of passengers.
- Current shared travel operators in Massachusetts (the MBTA and RTAs) have their own specific enabling legislation (Chapters 161A[7] and 161B[8] respectively) which enforce the locations they serve and types of services they can provide.
- There are Federal and State laws regarding levels of insurance, financial capability, and vehicle safety that are broadly applicable to all operators.

In Massachusetts, services to be provided by an entity that is not already covered by a specific enabling legislation must have the approval of DPU to be activated. Before approving such an operator, the DPU will look for information on proposed tariffs (fares) and routes, accessibility, safety, and financial capacity.[9] Bus and taxi operators are regulated under the same statutes, and there are over 500 regulated entities currently in Massachusetts.[10] To meet DPU and Federal requirements, these services must be non-discriminatory, able to take all potential users, and operate according to their filed tariffs and routes.

For private operators, these stipulations are a relatively low barrier to entry in the shared travel marketplace. Filing with the DPU can be completed online followed by a hearing, with an application fee of $100 for the entity, plus $60 per vehicle.[11] Transportation Network Companies (TNCs) are exempt from regulation unless regulators define the ridesharing as being commercial (e.g., Uber and Lyft) and not occasional (e.g., neighbors sharing a car). TNCs include companies where rides are provided through a digital network. TNCs cannot provide rides through street hails, cruising, or street solicitations. Massachusetts regulates TNCs through the DPU.[12]

MassDOT may subsidize transit providers when it is in the public interest (e.g., when it will reduce capital needs through mode shift from SOV to transit), either by buying equipment and providing it to operators or by contracting with private companies to provide turnkey services (i.e., equipment, maintenance, and operations).

Beyond service providers, state and federal law permits infrastructure owners like MassDOT or DCR to charge a toll or fee for the use of their facility/infrastructure. This most commonly applies to roadway tolls but may also apply to roadside infrastructure. For example, MassDOT (infrastructure owner) can charge a bus operator for using their Park and Ride location (the infrastructure). The process for charging the fees must be the same for each user type (i.e., scheduled van, scheduled bus, charter bus etc.) and these fees must be posted and made public.

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[6] https://www.mass.gov/info-details/220-cmr-department-of-public-utilities
[7] https://malegislature.gov/laws/generallaws/parti/titlexxii/chapter161a
[8] https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXXII/Chapter161B
[9] https://www.mass.gov/files/220_cmr_155.00_final_8_7_09.pdf
[10] https://www.mass.gov/info-details/dpu-regulated-motor-bus-companies
[11] https://www.mass.gov/how-to/apply-to-be-a-passenger-carrier-in-massachusetts
[12] https://www.mass.gov/files/220_cmr_274_00_final_9-22-17_1.pdf

Structure of the Analysis

This memorandum is divided into two sections:

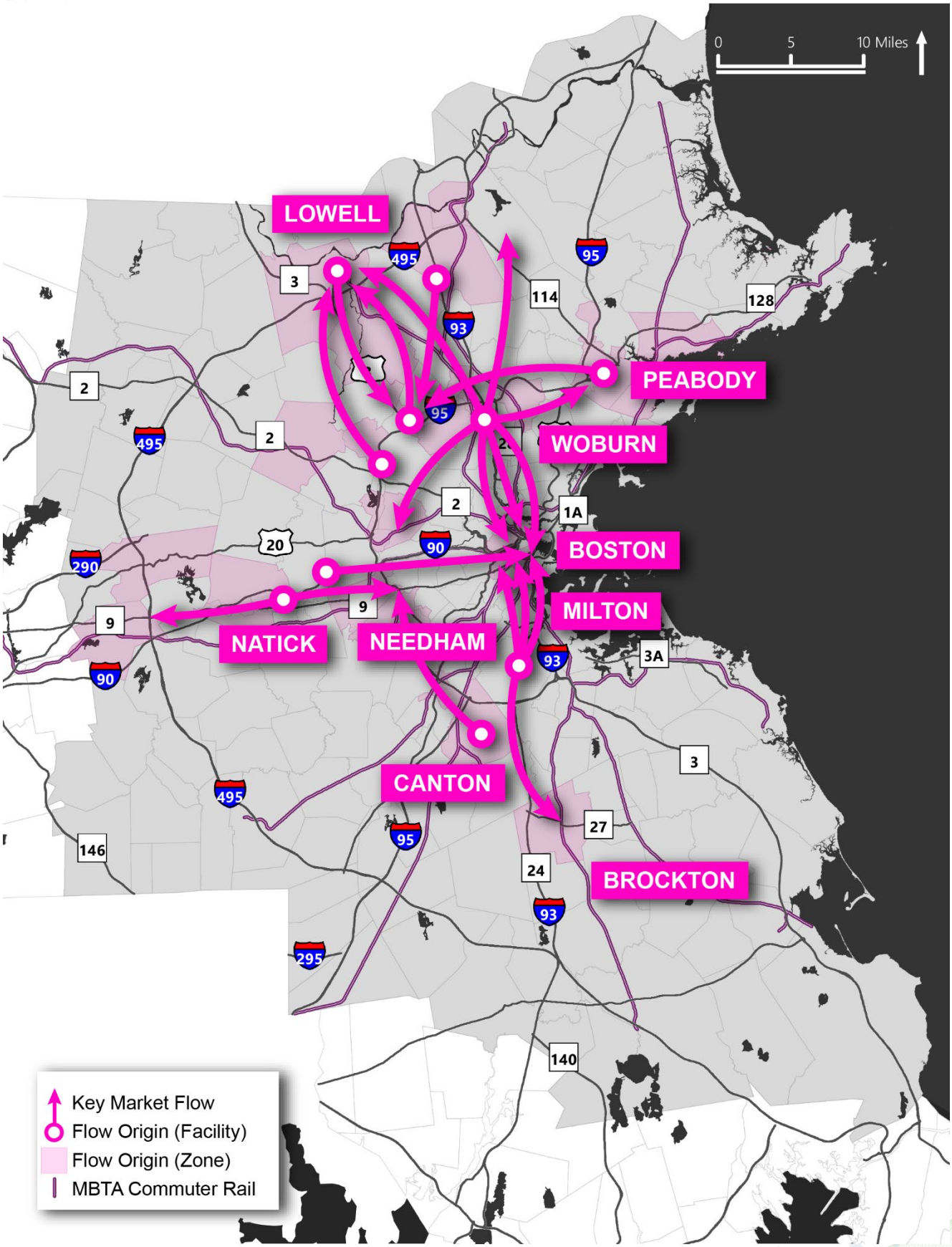
- **Existing Network (Chapter 2) |** This chapter presents the shared travel network in Greater Boston as it exists today. The network includes shared travel services (e.g., curbside bus, transit bus, and Transportation Management Associations (TMAs)) and park-and-ride lots. The chapter also discusses potential infrastructure improvements to improve the efficiency and competitiveness of shared travel services: freeway bus-on-shoulder (FBOS); freeway managed lanes; and arterial queue jumps and transit signal priority.

- **Analysis of Markets (Chapter 3) |** This chapter presents an exploration of the largest origin-destination markets in Greater Boston, as measured by miles traveled between them. Specifically, it describes:

  - How destination areas were identified based on clusters of trip endpoints in 2019.
  - How origin areas were identified based on clusters of trip stating points in 2019.
  - How the flows from origin to destination were measured and ranked by size.
  - How those flows compare to the hypothetical capacity of different shared travel service models.
  - How shared travel mode share in the markets with the largest flows could respond to network improvements.

Chapter 2 references at several points the highest-flow markets identified in Chapter 3. To ensure clarity of this memorandum when read end-to-end, they are illustrated in Figure 2 (next page).

FIGURE 2 | MAP OF TOP-20 MARKETS FROM O/D ANALYSIS



2 EXISTING NETWORK

This chapter introduces and reviews the shared travel network in Greater Boston as it exists today. This network includes shared travel services (e.g., curbside bus, transit bus, and Transportation Management Associations (TMAs)) and park-and-ride lots. The chapter also discusses potential infrastructure improvements to improve the efficiency and competitiveness of shared travel services, including freeway bus-on-shoulder (FBOS), freeway managed lanes, and arterial queue jumps and transit signal priority.

TAKEAWAYS FROM THIS CHAPTER

- Curbside services (including TMA shuttles and private coach carriers) are centered on Downtown Boston and do not serve suburban destinations and large markets identified by this study.
- Several transit services overlap with large suburban travel markets, but may not currently have service levels (e.g., frequency and vehicle size) to fully serve those markets.
- TMAs primarily provide reverse commuting services from inside I-95/MA-128 to that beltway.
- In general, the markets where both origins and destinations are outside I-95/MA-128 remain unserved by existing shared travel.
- MassDOT park-and-ride lots are often full of cars, but most of them are unserved by shared travel, implying a potential for future service, an argument for investment in the lots, and a need for more information about why the people parking in the lots are doing so, to be satisfied by a survey.
- Several park-and-ride lots could benefit from improved/additional striping, trash cans, lighting, and waiting areas.
- Several park-and-ride lots could benefit from improved pedestrian and bicycle access.
- MassDOT's scoping studies on FBOS and Managed Lanes defensibly establish stretches of highway where these improvements could be implemented, allowing this analysis to discuss the potential benefits of those improvements.

Services: Existing Shared Travel Services

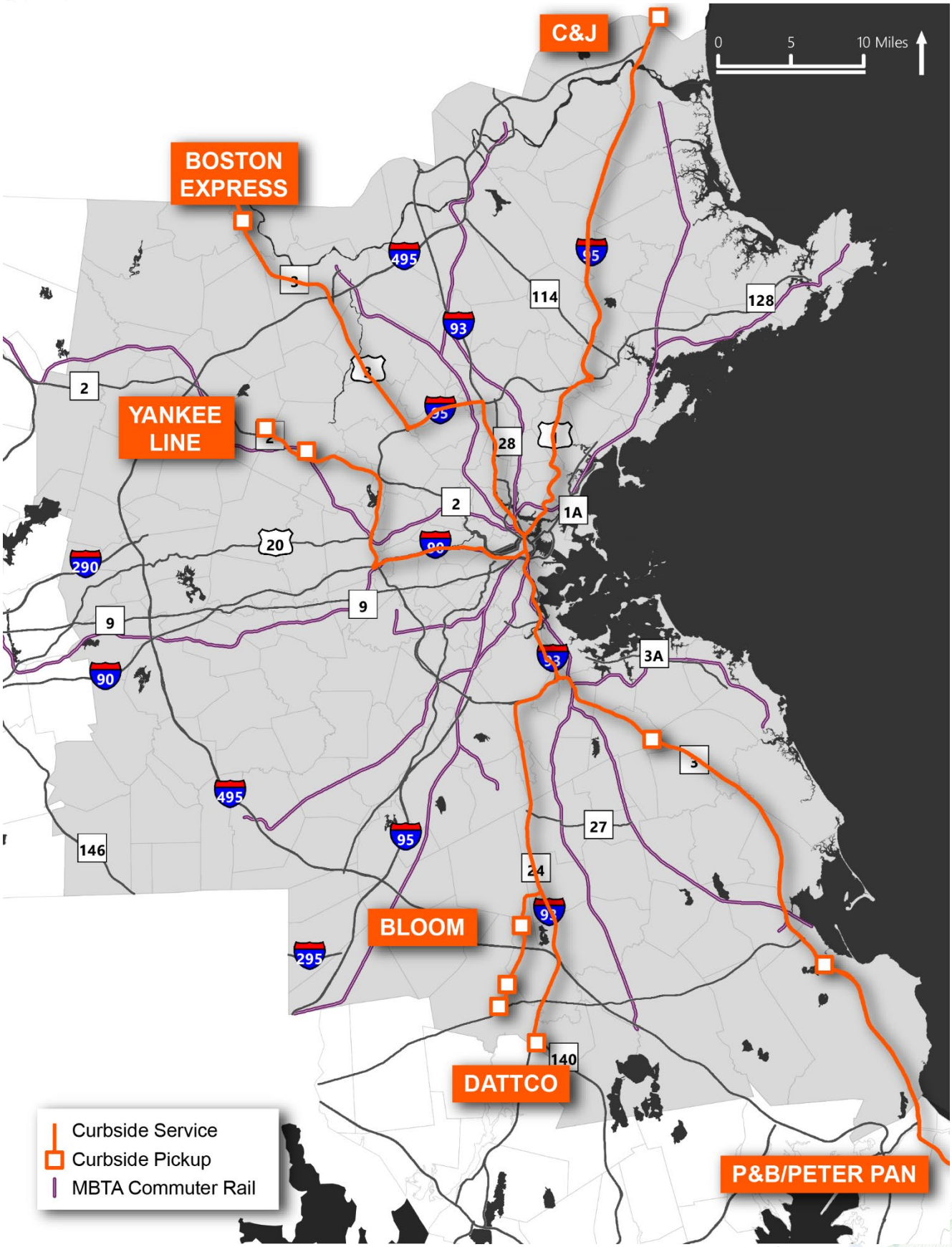
Curbside Bus

Prior to the COVID-19 pandemic, several private motor coach companies served Greater Boston with scheduled services throughout the region and beyond. However, some of these services have been suspended or shifted to on-demand since 2020.

Historically, several of these services have been supported by MassDOT's "BusPlus" public-private partnership program, which purchased 30 over-the-road coaches with FTA grant funds to provide to operators under a no-cost fixed-term lease. According to the program's managers, effectiveness has been limited by the lack of operational and marketing support for services that are provided – and as an agency without operational capacity on its own, MassDOT also lacks the capacity to replace, maintain, or store the buses ourselves. This means that as it currently stands, the program will sunset by 2030 as the buses reach the end of their service lifespan.

Curbside bus services in Greater Boston are illustrated in Figure 3 (next page).

FIGURE 3 | CURBSIDE BUS SERVICES IN GREATER BOSTON



Massachusetts curbside bus operators whose services are depicted in Figure 3 include:

- **Boston Express |** Provides seven weekday and five weekend round trips from MassDOT's Tyngsborough park-and-ride to South Station and Logan Airport.[13]
- **Bloom Bus Line |** Provides commuter services to Boston from Taunton, Raynham, Easton, and West Bridgewater. Commuter service connects to South Station and to Park Square in Boston. Services operate on weekdays.[14]
- **C&J Bus Lines |** Provides hourly service from Seabrook, NH to South Station in in the AM and PM peak hours. Service was based at the Newburyport Park-and-Ride until 2020, when the operator built a larger dedicated facility just across the border – C&J cited a lack of public investment to expand the Newburyport facility as a justification to move.
- **DATTCO |** Provides three weekday round trips from the Silver City Galleria Mall in Taunton to South Station and Copley Square (reduced schedule for COVID-19).[15]
- **Logan Express |** Provides shuttle services from dedicated remote terminals in Peabody, Framingham, and Braintree to Logan Airport. Buses are privately owned and operated under contract with Massport.[16]
- **Peter Pan |** Provides service from the Plymouth and Rockland park-and-ride lots to Boston (South Station and Logan Airport) as stops on a route to Hyannis (began April 2020).
- **Plymouth & Brockton (P&B) |** Provides service from the Plymouth and Rockland park-and-ride lots to Boston (South Station and Logan Airport) as stops on a route to Hyannis.
- **Yankee Line |** Provides three morning inbound trips and three afternoon outbound trips on weekdays between retail parking lots in Acton and Concord and Copley Square.[17]

Public Transit Agencies

The Greater Boston study area is served by the MBTA and seven regional transit authorities (RTAs): Brockton Area Transit Authority (BAT); Cape Ann Transit Authority (CATA); Greater Attleboro Taunton Regional Transit Authority (GATRA); Lowell Regional Transit Authority (LRTA); Merrimack Valley Regional Transit Authority (MVRTA); MetroWest Regional Transit Authority (MWRTA); and Montachusett Regional Transit Authority (MART).

While the MBTA and RTAs account for hundreds of services, the research team identified 17 routes that provide service over approximately 10-15 miles and serve the largest markets as identified in this analysis (e.g., they make stops in the drivesheds and destinations). These are mapped in Figure 4 and listed in Table 2.

[13] https://www.bostonexpressbus.com/stop/tyngsboro-ma-exit-35/
[14] https://www.bloombus.com/commuter-services/
[15] https://www.dattco.com/bus-schedules/boston-commuter-schedules/
[16] https://www.massport.com/logan-airport/to-from-logan/transportation-options/logan-express/
[17] https://yankeeline.us/scheduled-services/actonconcord/

FIGURE 4 | TRANSIT BUS SERVICES FOLLOWING TOP O/D MARKETS

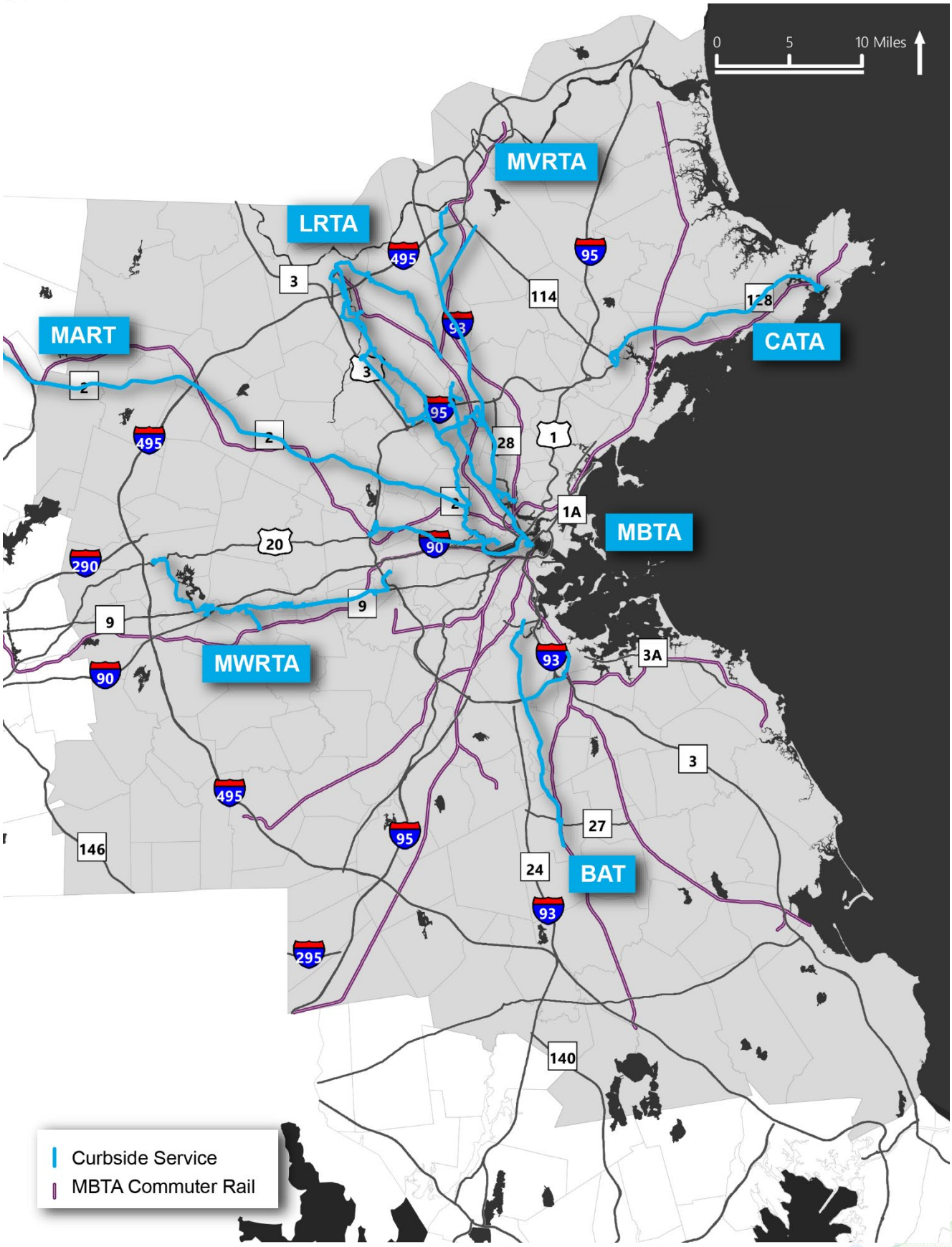


TABLE 1 | TRANSIT BUS SERVICES FOLLOWING TOP O/D MARKETS

Agency	Route # or Name	Market Served
BAT	12	Brockton to Ashmont MBTA Station
CATA	Yellow	Gloucester to Danvers and Peabody (malls)
LRTA	12	Lowell to Wilmington MBTA Station
LTRA	13	Lowell to Burlington Common
LRTA	14	Lowell to Burlington Mall
MART	Boston Shuttle	Fitchburg/Leominster to Alewife/Longwood/West Roxbury
MBTA	62/76	Bedford/Lexington to Alewife MBTA Station
MBTA	70	Waltham to Cambridge (Central Square)
MBTA	134	Woburn to Wellington MBTA Station
MBTA	240	Avon to Ashmont MBTA Station
MBTA	350	Burlington Mall to Alewife MBTA Station
MBTA	354	Burlington Mall to Boston
MVRTA	98	North Andover to Boston
MVRTA	99	Andover to Boston
MWRTA	1	Natick to Woodland MBTA Station
MWRTA	7	Framingham to Marlborough
MWRTA	9	Framingham to Natick

Bus Service Provided by Transit Management Associations

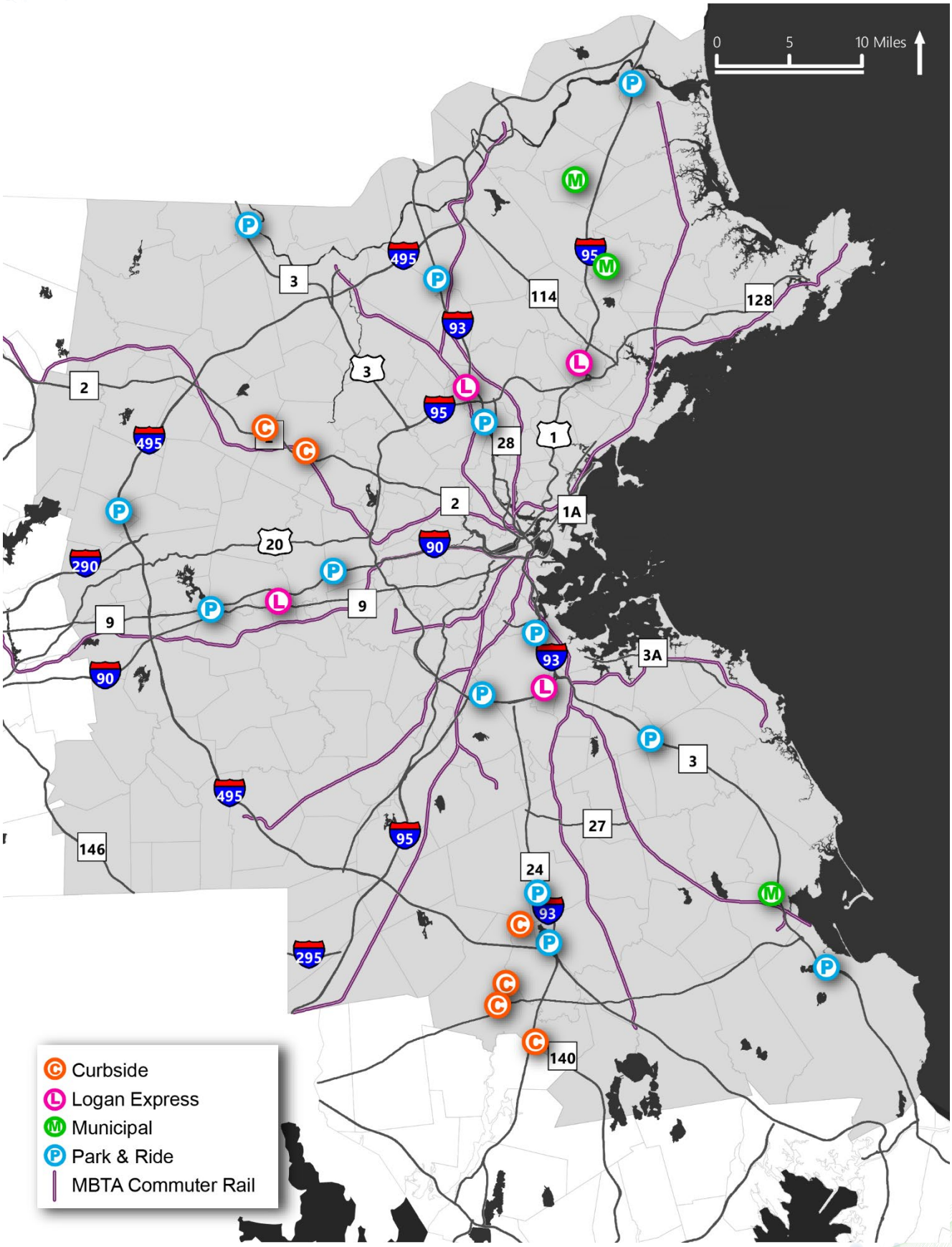
Two large-scale bus shuttle services from Transit Management Associations (TMAs, which are partnerships among employers to provide shared travel services for commuters and customers) operate in the Greater Boston region. The larger of these is the **128 Business Council**, which provides shuttle services to Lexington, Waltham, and Needham from MBTA rail stations (80% of the 2019 ridership was served from Alewife, 10% from Newton Highlands, and 6% from Waltham Center).[18] The smaller network belongs to **CommuteWorks/MASCO**, which serves the Longwood Medical Area with shuttle service from neighborhoods of Boston, Cambridge, and Newton.[19]

Infrastructure: Existing Park-and-Ride Lots

Figure 5 (next page) is a map of existing facilities that can accommodate shared travel in Greater Boston, which are entirely comprised of park and ride lots. This includes lots owned by MassDOT; lots owned by municipalities; pickup locations for curbside bus operators; and terminal facilities for Massport's Logan Express service to Logan International Airport.

[18] https://128bc.org/
[19] https://www.masco.org/lma-shuttles/shuttle-routes

FIGURE 5 | SHARED TRAVEL POINT FACILITIES IN GREATER BOSTON



MassDOT owns or operates 13 park-and-ride lots in the study area, and a complete lot-by-lot assessment of the park-and-ride facilities is provided in **Appendix B**.

Responsibility for these facilities is shared between the Highway Division, which executes operational contracts and coordinates development activities for the facilities, and the Office of Real Estate and Asset Development (OREAD), which directs site development and sales. Additionally, Highway Districts are responsible for maintenance of the lots in their jurisdiction, including pavement striping, waste management, and signage.

General observations about the condition of the lots in the study area include:

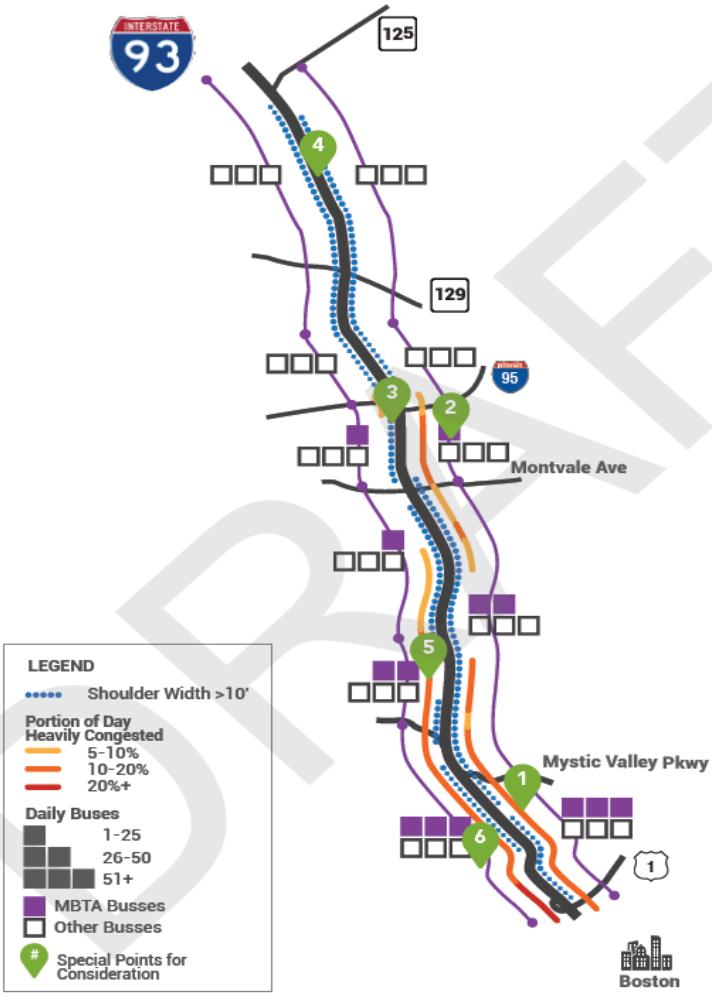
- The lots range from smaller facilities with lighting to larger ones with central buildings, benches, bike racks, and garbage receptacles.
    - Several lots could benefit from restriping of pavement or other physical repairs.
        - MassDOT might benefit from developing a system to monitor the maintenance of lots.
    - Some lots may benefit from investment in passenger amenities to improve comfort and perception of safety.
    - Many lots would benefit from improved signage and wayfinding to advertise their existence and what services are available.
- Some lots appear to be reaching their capacity or already exceed it at times. It might be useful to consider restriping or expanding these lots. Several lots utilize spots at the perimeter or adjacent to the lot itself and could benefit from better striping and signage. Specific recommendations for expansion would need to be made after a study of local conditions and lot usage patterns.
- Many lots are not served by shared travel but are nonetheless well-utilized, suggesting that people use them as assembly points for carpooling. MassDOT could facilitate this behavior with lot amenities and encourage it through marketing.
- Many lots would benefit from pedestrian and bicycle access improvements, including crosswalks, sidewalks, and signals.
- An opportunity exists to find a new curbside operator for the Newburyport Park-and-Ride, a large facility with substantial amenities which is currently underutilized after C&J moved to a location in New Hampshire.
- In addition to signage and wayfinding, lot usage could be promoted through variable message signs (VMS) on adjacent highways. These signs are best paired with transit priority investments and could include dynamic travel times for SOV and shared travel modes and live parking availability.

Infrastructure: Network Characteristics

To implement the recommendations of *Congestion in the Commonwealth 2019*, MassDOT conducted screening studies on the suitability of freeway bus-on-shoulder (FBOS) and managed lanes on freeways in Greater Boston.

Freeway Bus-on-Shoulder

FIGURE 6 | I-93 CORRIDOR FROM THE *BUS ON SHOULDER SCREENING STUDY*



The Federal Highway Administration (FHWA) considers part-time shoulder use as part of an effective Transportation System Management and Operations (TSMO) strategy. MassDOT has considered the possibility of FBOS for part-time transit use on the right shoulder of freeways and other expressways. Based on the *Bus on Shoulder Screening Study*[20] conducted by MassDOT in March 2020, the first pilot project deployment will be on I-93 South between Woburn and Somerville, as illustrated in Figure 6 (taken from that document).

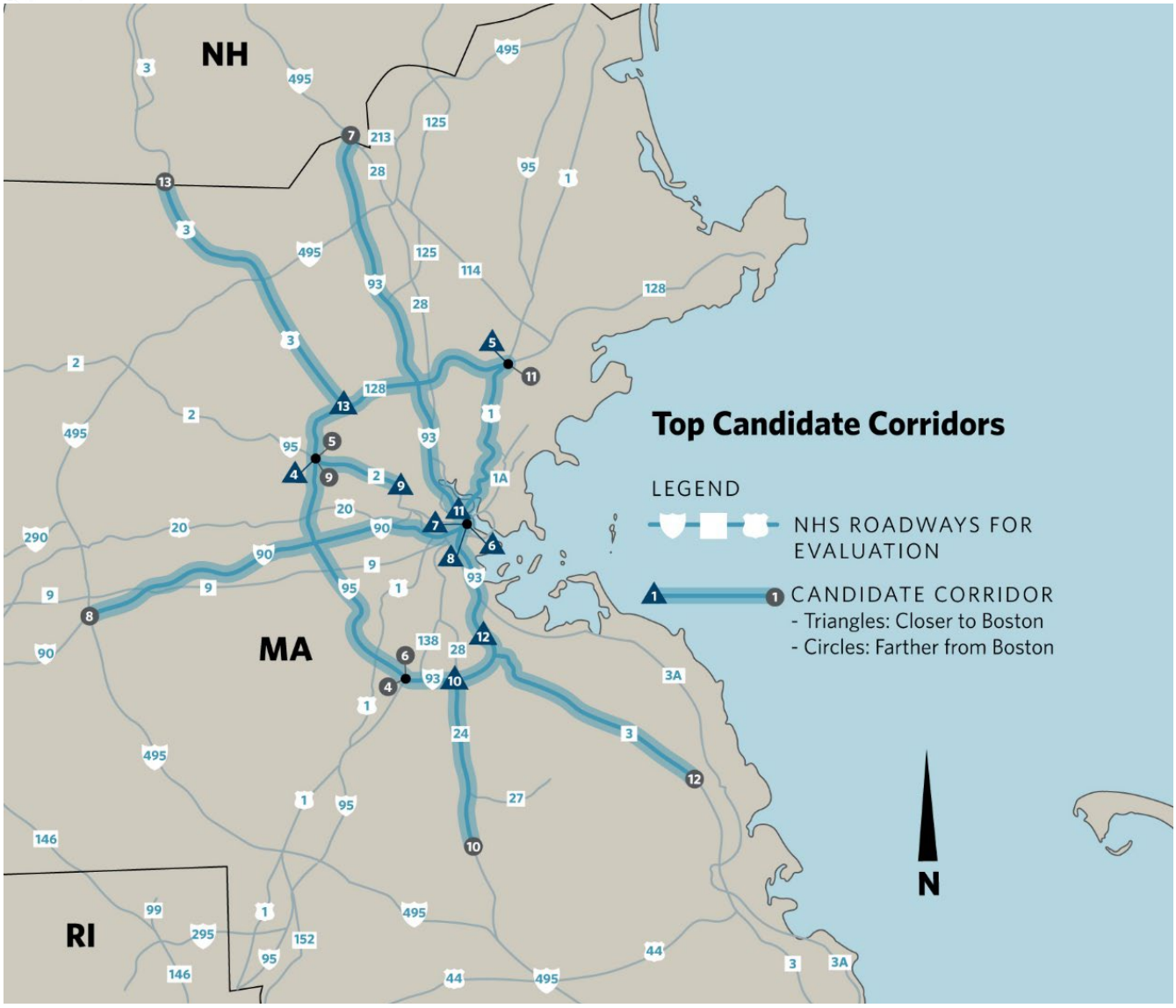
MassDOT currently allows part-time use of the shoulder for all vehicles on sections of I-93, and formerly did so on I-95 to manage peak demand. If implemented, an I-93 FBOS pilot project would be the first use of the shoulder for any purpose inside of Route 128.

Freeway Managed Lanes

MassDOT's *Managed Lanes Screening Study* identified the corridors shown in Figure 7 as top candidates for managed lane treatments.

[20] "Bus on Shoulder Screening Study". Massachusetts Department of Transportation, March 2020, Fig 13, p.15.

FIGURE 7 | TOP CANDIDATE CORRIDORS FROM THE *MANAGED LANES SCREENING STUDY*[21]



The study evaluated four different treatment options to create managed lanes on these corridors:

1. Converting an existing Highway Occupancy Vehicle (HOV) lane to a High Occupancy Toll (HOT) lane.
2. Re-purpose existing shoulder (such as for transit and shared travel use).
3. Convert an existing travel lane to a managed lane (as MassDOT is currently piloting on the Tobin Bridge).
4. Construct a new managed lane.

The *Managed Lanes Screening Study* identified several highways within the Boston region as having the potential for managed lane deployment. Each highway was assigned a score in terms of suitability of implementation for each of the above four options.

[21] "Managed Lanes Screening Study". Massachusetts Department of Transportation, 2020, Fig 22, p.43.

I-93 segments north and south of Boston were the only two identified under Option 1 for the conversion of existing HOV lane to HOT lane. Most of the highways considered in the study would have existing shoulders converted to either managed lanes or general travel lanes, with significant impacts to roadway operations. These highway segments included I-93 (Canton-Braintree), I-93 (Woburn-Andover), MA-24 (Brockton-Randolph), MA-3 (Pembroke-Weymouth), and US-3 (Burlington-Tyngsboro).

Arterial Bus Transit Priority Improvements

Even shared travel services that mostly travel on the freeway typically need to use arterial roadways (that are primarily under local jurisdiction) to access it. Infrastructure improvements that can support shared travel on arterials include:

- **Bus Lanes |** An existing arterial travel lane (or sometimes a parking lane) can be converted into a dedicated bus lane, as was recently built on Massachusetts Avenue in Cambridge. Sometimes, the bus lane is shared with bicycles, as is the case of Mt. Auburn Street in Cambridge and Watertown.

- **Queue Jump Lanes |** In some cases, traffic congestion is restricted to major intersections, and transit service can be significantly improved by enabling the transit vehicle to bypass the localized congestion. Queue jump lanes are short lengths of dedicated bus lanes at the intersection approaches. They are mostly created by converting an existing parking lane. They are usually combined with a far-side bus stop. Through modified signal phasing, the bus in a queue jump lane is allowed to proceed into the intersection prior to general traffic that is in the queue on the same approach.

- **Transit Signal Priority (TSP) |** Most traffic signal controllers have built-in TSP capability, which prioritizes the signal phase that will benefit an approaching transit vehicle. Integrating the signal controllers with a GPS-based automated vehicle locator (AVL) system allows buses to report their approach to the signal. TSP/AVL implementations are relatively inexpensive.

3 ANALYSIS OF MARKETS

This chapter presents an exploration of the largest origin-destination markets in Greater Boston, as measured by miles traveled between them. Specifically, it describes:

- How destination areas were identified based on clusters of trip endpoints in 2019.
- How origin areas were identified based on clusters of trip stating points in 2019.
- How the flows from origin to destination were measured and ranked by size.
- How those flows compare to the hypothetical capacity of different shared travel service models.
- How shared travel mode share in the markets with the largest flows could respond to network improvements.

TAKEAWAYS FROM THIS CHAPTER

- In 2019, the largest suburban travel markets in Greater Boston were located to the north of the city, extending from Woburn and Burlington along I-95/MA-128 in the south to Lowell and Lawrence along I-495 in the north.
- These were not the only large markets identified. Others in the suburbs included travel to Needham and Newton from Natick and Canton, Natick to Marlborough and Westborough, Peabody to Burlington and Woburn, and Milton to Brockton.
- Downtown Boston was by far the most prominent destination in the region in 2019. Large suburban markets were identified to Downtown Boston from the north (Woburn), west (Weston), and south (Canton). Large markets also linked Woburn and Milton to other destination areas in the urban core.
- The largest identified markets have demand that could hypothetically support a transit-style service using buses (some of these are already served by RTAs). They include Woburn to Lowell, Lawrence, Salem/Peabody, Waltham, and Kendall Square; Burlington to Lowell (and reverse); and Andover to Burlington and Woburn. Slightly smaller markets could support hypothetical curbside or demand-responsive services.
- When existing congestion is considered, markets with destinations in the urban core – Downtown Boston, North Station, and Kendall Square – improve their outlook for potential shared travel service. Note that this finding is from 2019 data, prior to COVID-19.
- While MassDOT has observed 2021 congestion in Greater Boston returning to 2019 levels, travel demand to Downtown Boston, the Seaport, and Kendall is still significantly down from 2019. This suggests that congestion may soon worsen beyond the pre-pandemic state, creating a problem that shared travel can help to solve.
- COVID-19 drastically reduced travel to Downtown Boston and Kendall Square and substantially reduced travel in all markets, though travel to the Longwood Medical Area, Back Bay, and the area around North Station has rebounded faster. In the suburbs, travel to Waltham has rebounded more slowly than travel in other markets.

Methodology

This analysis first identified the largest suburban travel markets in Greater Boston as measured by the mileage traveled between origins and destinations. It then assessed which of them were hypothetically appropriate for different models of shared travel service, as well as which of them would hypothetically benefit most from the infrastructure improvements included in MassDOT scoping studies on FBOS and Managed Lanes.

Origin/Destination Analysis

Travel in markets was measured using the StreetLight location-based services (LBS) dataset, which consists of "pings" that anonymously track GPS-enabled devices such as smartphones several times per minute (regardless of mode of travel). StreetLight cleans these reports into trips and normalizes the number of trips by the population of the Census blockgroup in which they originate, creating a modeled dataset of all travel in Massachusetts.[22] Each trip in this dataset is reported as a starting point, an endpoint, a travel time, and a travel distance.

This analysis generalized the individual trips in several steps:

- **Destinations** were drawn around groups of endpoints. The prominence of these destinations was assessed in terms of volume of travel (the number of trips with endpoints in the destination area) and mileage (the sum of the distance traveled for all trips with endpoints in the destination area).

- **Origins** were drawn around groups of starting points. For the destinations with the most volume and mileage, the starting points were mapped. Where clusters existed, origins were drawn, centered on an anchor point such as a MassDOT park-and-ride lot, a key freeway interchange, or a major multimodal facility.

- **Markets** were assessed for every pair of origin and destination (940 in total) using the mileage traveled between them.

Technical details on this methodology are provided in **Appendix C**.

The initial run of the origin/destination analysis covered travel in March, April, September, and October 2019, Monday to Thursday in the AM peak period (StreetLight's technical definition of a year). Additional runs were conducted for several periods in 2020 and 2021 to track the evolution of travel in Greater Boston through COVID-19. These runs are discussed in a later section.

The largest travel markets in 2019 are listed in Table 2 and mapped in Figure 8. Several observations can be made:

- Many of the largest destination markets have their origin in the area around Anderson Regional Transportation Center (RTC) in Woburn. MassDOT operates a separate park-and-ride lot in this area as well.

- Many of the largest markets link the Burlington-Woburn stretch of I-95/MA-128 with the Lowell-Lawrence stretch of I-495.

[22] "Our Methodology and Data Sources". *StreetLight*, October 2018. https://www.StreetLightdata.com/wp-content/uploads/StreetLight-Data_Methodology-and-Data-Sources_181008.pdf

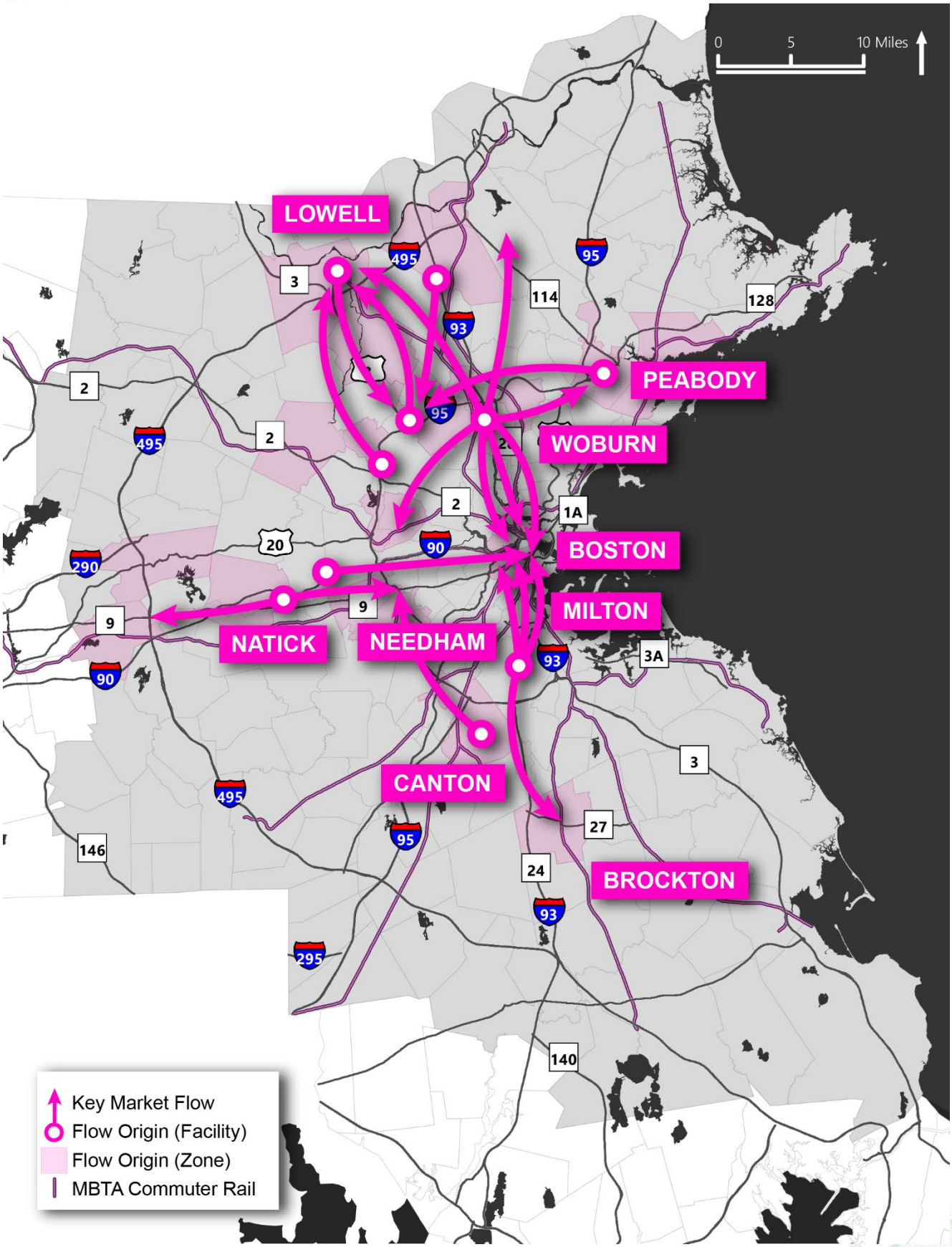
- Several of the largest markets follow MA-128. These connect Peabody with Burlington/Woburn, Canton with Newton/Needham/Wellesley, and Woburn with Waltham.
- Several of the largest markets serve Downtown Boston (represented here by the area around South Station). These approach Downtown from the north (Woburn), west (Weston), and south (Milton). Large markets also exist connecting Woburn and Milton with other job centers in the urban core.
- Several of the largest markets include Gateway Cities, such as Lowell, Lawrence, and Brockton as an origin or as a destination.
- As noted in Chapter 2, none of these markets are effectively served by existing curbside bus service. Several RTA and MBTA bus routes coincide with the markets, but not all of these have service patterns (stop locations, frequency, operating hours) designed to effectively address suburban commute travel.

Table 2 includes the largest markets, defined as those that scored a 20 or above on a 0-100 metric defined through mileage and accounting for the geographic size of the origin and destination areas.

TABLE 2 | LIST OF LARGEST MARKETS IDENTIFIED BY THE ORIGIN/DESTINATION ANALYSIS

Origin (location of anchor point)	Destination	Score
Woburn (Anderson RTC)	Lowell/Billerica/Chelmsford	100
Chelmsford (495/3)	Burlington/Woburn	78
Andover (park-and-ride)	Burlington/Woburn	75
Burlington (mall)	Lowell/Billerica/Chelmsford	74
Milton (park-and-ride)	South Station	69
Woburn (Anderson RTC)	Salem/Beverly/Peabody	52
Woburn (Anderson RTC)	Kendall Square	50
Milton (park-and-ride)	Longwood/Fenway	40
Canton (park-and-ride)	Newton/Needham/Wellesley	38
Milton (park-and-ride)	Back Bay/South End	36
Woburn (Anderson RTC)	Lawrence/Andover	35
Woburn (Anderson RTC)	South Station	31
Woburn (Anderson RTC)	North Station	30
Peabody (95/1/128)	Burlington/Woburn	29
Weston (park-and-ride)	South Station	29
Natick (90/30)	Newton/Needham/Wellesley	27
Milton (park-and-ride)	Newton/Needham/Wellesley	27
Woburn (Anderson RTC)	Lawrence/Andover	27
Framingham (park-and-ride)	Newton/Needham/Wellesley	24
Milton (park-and-ride)	Brockton	20

FIGURE 8 | MAP OF TOP-20 MARKETS FROM O/D ANALYSIS



Sizing Markets against Hypothetical Service Models

One way to assess the size or demand of the markets developed in the origin/destination analysis is to compare them to the capacity of hypothetical shared travel service models via the vehicles used to serve them. These might include:

- **Bus Services |** These could include new or improved curbside or transit services with a variety of vehicles.
- **Demand-Responsive Transportation (DRT) |** DRT is defined as any form of transport where day-to-day service provision is influenced by the demand of the users. With qualities of buses and taxis, the term covers a wide range of vehicular transport solutions; from traditional 'dial-a-ride' services that provide social transport booked by phone, to new services that allow journeys to be booked through a mobile app. i.e. Vanpooling networks. Examples in Boston include Flight Line (serving Logan Airport), UberPool, Lyft Line, and Bridj (2014-2017).[23]
- **Large-Scale Carpool |** This is similar to DRT but not organized by a central app or algorithm. Carpools could be organized to be a regular, daily occurrence or organized ad hoc at park-and-ride lots as in the Washington DC area's "slug lines".[24]

Table 3 presents the capacity of these services when hypothetically implemented with common shared travel vehicles. A full list of shared travel vehicle types, potential legal issues in Massachusetts, and applicability to the Massachusetts context, is provided in **Appendix D**. The hypothetical capacities assume a four-hour peak period.

TABLE 3 | COMPUTATION OF PEAK HOUR DEMAND FOR HYPOTHETICAL SERVICES

Service Model	Vehicle	Trips/Peak Hour, single direction	Vehicle capacity per peak
Transit	Double-decked bus	4	1,280
Transit	Articulated bus	4	960
Transit	40-foot bus	4	672
Curbside	Motor coach	4	640
Transit	35-foot bus	4	480
Curbside	Van	8	384
DRT	Van	8	384
Car Share	Van	8	384
Curbside	Cutaway	8	96
DRT	Car	8	96

[23] Curt Woodward, Adam Vaccarro, and Felicia Gans, "Bridj, local on-demand bus service, is shutting down". *The Boston Globe,* April 30, 2017. https://www.bostonglobe.com/business/2017/04/30/bridj-local-demand-bus-service-shutting-down/56xoGs674wYgyUWdrD9EuO/story.html

[24] http://www.slug-lines.com/

Table 4 compares the observed AM Peak Period volume in the large markets[25] to the capacities in Table 3. The eight shaded markets produce enough trips per peak period to be hypothetically sized for transit-type service: Woburn to Lowell, Kendall Square, Salem/Peabody, and Waltham; Burlington to Lowell; Chelmsford to Burlington/Woburn; and Andover to Burlington/Woburn. Except for Woburn to Kendall Square, all of these markets are located in the same area north of Boston, following I-93 and US-3.

It should also be noted that the markets connecting Woburn and Burlington with Lowell/Billerica/Chelmsford saw significantly higher traffic volume in 2019 than all the other markets – one sized comparably to transit services with large vehicles.

TABLE 4: HYPOTHETICAL SERVICE CONCEPTS MATCHED TO TOP SHARED TRAVEL MARKETS

Origin Driveshed	Destination	Parallel Rail	Shared Travel Share of AM Peak Period Volume	Hypothetical Services
Woburn	Lowell/Billerica/Chelmsford	Yes	3,245	Transit: Double-decked bus; Transit: Articulated Bus; Transit: 40-foot bus
Burlington	Lowell/Billerica/Chelmsford	No	2,751	Transit: Double-decked bus; Transit: Articulated Bus; Transit: 40-foot bus
Woburn	Kendall Square	Yes	889	Curbside: Motorcoach; Transit: 35-foot bus; Curbside/DRT/Carshare: Van
Woburn	Lawrence/Andover	Yes	602	Transit: 35-foot bus; Curbside/DRT/Carshare: Van
Woburn	Salem/Beverly/Peabody	No	553	Transit: 35-foot bus; Curbside/DRT/Carshare: Van
Chelmsford	Burlington/Woburn	Yes	542	Transit: 35-foot bus; Curbside/DRT/Carshare: Van
Woburn	Waltham	No	503	Transit: 35-foot bus; Curbside/DRT/Carshare: Van
Andover	Burlington/Woburn	Yes	482	Transit: 35-foot bus; Curbside/DRT/Carshare: Van
Milton	South Station	Yes	475	Curbside/DRT/Carshare: Van
Milton	Longwood/Fenway	Yes	451	Curbside/DRT/Carshare: Van
Milton	Back Bay/South End	Yes	421	Curbside/DRT/Carshare: Van

[25] Derived from the 2019 StreetLight dataset, multiplied by a base shared travel mode share of 5%

Origin Driveshed	Destination	Parallel Rail	Shared Travel Share of AM Peak Period Volume	Hypothetical Services
Woburn	North Station	Yes	413	Curbside/DRT/Carshare: Van
Milton	Brockton	Yes	407	Curbside/DRT/Carshare: Van
Woburn	South Station	Yes	398	Curbside/DRT/Carshare: Van
Canton	Newton/Needham/Wellesley	No	285	Curbside/DRT/Carshare: Van
Natick	Newton/Needham/Wellesley	No	221	Curbside/DRT/Carshare: Van; Transit/Curbside; Cutaway; DRT/Car share: Car
Framingham	Newton/Needham/Wellesley	No	221	Curbside/DRT/Carshare: Van; Transit/Curbside; Cutaway; DRT/Car share: Car
Peabody	Burlington/Woburn	No	218	Curbside/DRT/Carshare: Van; Transit/Curbside; Cutaway; DRT/Car share: Car
Weston	South Station	Yes	213	Curbside/DRT/Carshare: Van; Transit/Curbside; Cutaway; DRT/Car share: Car
Milton	Newton/Needham/Wellesley	No	170	Transit/Curbside; Cutaway; DRT/Car share: Car

Benefit to Markets from Infrastructure Improvements

The analysis in the prior section assumed a flat 5% transit mode share, meaning it assumed at least 5% of total travel between markets would be not in SOVs, but in shared travel vehicles. This initial analysis did not consider either the competitiveness of shared travel relative to SOV, or how that competitiveness could be improved using infrastructure improvements.

As an additional step, a ranking of large origin/destination markets that incorporated 'competitiveness' (of shared travel to SOV) was estimated using the 2019 INRIX dataset of vehicle travel times on roadway segments[26]:

- Each of the largest markets was redefined as one or several routes from the anchor point of the origin (the park-and-ride lot or other point-of-interest at the core of the origin area) to a logical point or set of points within the destination area.

[26] INRIX data relies on a different set of probes than Streetlight data.

- The average travel time in 2019 along this route for general traffic was estimated from the INRIX dataset for every minute between 6:00 am and 8:00 pm.
- The travel time was recomputed for shared travel services assuming that they would benefit from all the infrastructure improvements identified in MassDOT scoping studies on FBOS and Managed Lanes.
- A logit probability curve was used to compare the travel times for shared travel and general traffic at each minute of the day and estimate the transit mode share.
- The transit share and the StreetLight volume in the AM peak period were multiplied into a hypothetical ridership estimate. As this estimate is not meant to be a prediction of the performance of an actual service, it was normalized on a 0-100 scale to generate a score.

Details on this methodology are provided in **Appendix E**. A market-by-market summary of the findings is provided in **Appendix F**.

Table 5 ranks the major O/D markets by the 0-100 score computed from the ridership estimate. It builds on the ranking in Table 4 by incorporating the existing congestion (in 2019) in the market and enhancing the prior assumption of 5% transit mode share. Markets serving destinations in the urban core (e.g., South Station, North Station, and Kendall Square) score higher when congestion and infrastructure improvements to make shared travel competitive are considered.

Given the ridership scores generated through the competitiveness analysis, shared travel markets with origin points along the I-93 corridor are particularly competitive with SOV, even when destination points are outside of Downtown Boston. Given the presence of multiple facility and infrastructure elements along adjoining corridors that would potentially reduce the impact of congestion on shared vehicles, Woburn emerges as an especially strong origin point for the introduction of shared travel services to a variety of destinations, including Lowell, Kendall Square, Downtown Boston, and Beverly.

TABLE 5 | LARGE ORIGIN/DESTINATION MARKETS RANKED BY BENEFIT FROM INFRASTRUCTURE

Shared Travel Market	Network Improvements[1]	Ridership Score
Woburn – Lowell	ML (US-3); FBOS (I-93, I-95); TSP	100
Woburn – Kendall Square	FBOS (I-93); TSP	61
Burlington – Lowell	ML (US-3); FBOS (I-95); TSP	54
Woburn – North Station	FBOS (I-93); TSP	39
Woburn – South Station	ML (I-93); FBOS (I-93); TSP	31
Chelmsford – Woburn	ML (US-3); FBOS (I-93, I-95); TSP	28
Woburn – Beverly	FBOS (I-93, I-95); TSP	20
Weston – South Station	FBOS (I-90); TSP	20
Andover – Burlington	FBOS (I-93, I-95); TSP	19
Woburn – Waltham	FBOS (I-93, I-95); TSP	18

Shared Travel Market	Network Improvements[1]	Ridership Score
Natick – Marlborough via I-90	FBOS (I-90); TSP	15
Woburn – Lawrence	FBOS (I-93); TSP	15
Lexington – Lowell	ML (US-3); FBOS (I-95); TSP	13
Natick – Needham via I-90	FBOS (I-90, I-95); TSP	9
Peabody – Burlington	FBOS (I-95); TSP	8
Natick – Marlborough via MA-9	TSP; TSP w/QJ Lane	7
Canton – Needham	FBOS (I-95); TSP	7
Natick – Needham via MA-9	TSP; TSP w/QJ Lane	5

1: ML – Managed Lane; BOS – Bus On Shoulder; TSP – Transit Signal Priority; TSP w/QJ Lane – TSP with Queue Jump Lane

Impacts of COVID-19 on Market Size

To observe the impact of COVID-19 on demand between markets, the origin/destination analysis was rerun for additional periods in 2020 and 2021. Table 6 shows how the prominence of some key destinations around Greater Boston changed during the pandemic period. Note that destinations such as the Back Bay, Longwood Medical Area, Brockton, and Salem/Beverly/Peabody have recovered significantly more than either Downtown Boston (i.e., the area around South Station is seeing only 32% of the travel it did in 2019), the Seaport (also 32%), or Kendall Square (43%).

These data lead to two major findings:

- First, MassDOT has found that 2021 congestion in Greater Boston has essentially returned to 2019 levels, while travel demand to Downtown Boston still sits below 40% of pre-pandemic levels. Even if telework continues to suppress demand, the need exists for shared travel to relieve congestion which may exceed 2019 levels in 2021 or 2022.

- Second, given the slow recovery of Downtown Boston and Kendall, MassDOT may wish to focus new attention on destinations that have recovered faster.

TABLE 6 | TRAVEL DEMAND PER SQUARE MILE IN AVERAGE AM PEAK HOUR IN ALL 2019-2021 ANALYSIS PERIODS, RANKED BY 2019 VALUE

Destination	2019	Q1 2020	Q2 2020	Q3 2020	Q1 2021	2021 as % of 2019
South Station	936,792	161,092	192,079	294,557	298,929	32%
North Station	385,836	109,987	140,813	202,404	185,259	48%
Back Bay/South End	326,260	116,112	170,626	229,749	233,258	71%
Seaport	271,247	53,218	70,489	102,288	86,858	32%

Destination	2019	Q1 2020	Q2 2020	Q3 2020	Q1 2021	2021 as % of 2019
Kendall Square/Central Square	213,742	41,062	57,373	88,222	90,914	43%
Longwood Medical Area/Fenway	210,639	101,426	126,318	159,087	159,075	76%
Waltham	49,149	13,982	16,700	19,732	19,679	40%
Burlington/Woburn	48,309	17,536	20,620	24,072	23,399	48%
Newton/Needham/Wellesley	32,692	9,462	11,915	15,286	15,718	48%
Salem/Beverly/Peabody	24,826	10,711	12,928	16,827	17,875	72%
Brockton	23,235	10,632	12,478	15,294	15,965	69%
Framingham/Natick	22,122	7,430	9,244	10,894	11,092	50%
Dedham/Westwood/Canton	21,345	8,148	9,753	12,290	11,590	54%
Lawrence/Andover	15,503	4,855	5,652	7,413	7,661	49%
Lowell/Chelmsford/Billerica	14,603	5,803	6,853	8,008	7,990	55%
Marlborough/Westborough	11,381	3,650	4,535	5,764	5,473	48%