massDOT
Massachusetts Department of Transportation

CONGESTION IN THE COMMONWEALTH

MANAGED LANES SCREENING STUDY 2020

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Abbreviations

- CTPS Central Transportation Planning Staff
- DBFOM design-build, finance, operate and maintain
- DOT Department of Transportation
- FHWA Federal Highway Administration
- HCTRA Harris County Toll Road Authority
- ISRRPP Interstate System Reconstruction and Rehabilitation Pilot Program
- ITS intelligent transportation system
- MassDOT Massachusetts Department of Transportation
- MBTA Massachusetts Bay Transportation Authority
- MEPA Massachusetts Environmental Policy Act
- MPO metropolitan planning organization
- mph miles per hour
- NEPA National Environmental Policy Act
- NHS National Highway System
- HOT high occupancy toll
- HOV high occupancy vehicle
- SOV single occupant vehicle
- TAC Technical Advisory Committee
- TDM transportation demand management
- TRB Transportation Research Board
- VDOT Virginia Department of Transportation
- vphpl vehicles per hour per lane
- VPPP Value Pricing Pilot Program

1. Introduction/Background

Massachusetts has been experiencing increased levels of vehicle congestion throughout the region for the past several years. To address this transportation issue, the Massachusetts Department of Transportation (MassDOT) is seeking and implementing strategies to address and manage travelers' needs throughout the state. An important starting point was the release of a comprehensive report to the governor in August 2019. That report quantifies several variables related to congestion on major roadways in the state and highlights the frustrations that residents, workers, and visitors can experience when moving about the Commonwealth. The report identified recommendations to ease congestion and improve reliability, one of which was to investigate the feasibility of implementing managed lanes treatments on especially congested corridors in Greater Boston.

Managed lanes are defined by the FHWA as highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions. MassDOT commissioned HDR, Inc. to complete a screening study for managed lanes implementation on major National Highway System (NHS) roadways within the I-495 beltway to determine which of four different managed lanes treatments may be feasible and beneficial: high occupancy vehicle (HOV) to high occupancy toll (HOT) lane conversion, repurposing existing roadway shoulders for managed lanes, converting a general purpose lane to a managed lane, or building additional capacity for a managed lane corridor.

This report summarizes the findings of the study and lays the foundation for further analysis on selected corridors on which there is potential for successfully improving congestion or reliability through the implementation of managed lanes treatments.

The objectives of the study were three-fold:

- Develop a list of "Success Factors" through both a literature review of relevant national guidelines for implementing managed lanes and from discussions with other state DOTs who have implemented similar projects.
- Perform an initial screening of the roadways within the I-495 beltway to assess which corridors warrant further evaluation for a managed lanes treatment.
- Evaluate those identified corridors to determine which managed lanes treatment is most appropriate and determine analysis requirements for future detailed study.

Implementing managed lanes in and around a dense, physically constrained, and economically thriving region with highly engaged citizens requires not only technical expertise, but thoughtful policy approaches and well-planned, diverse public outreach. Many success factors discussed in this report are deeply interrelated; they should not be seen as a checklist, but rather as a collection of themes that interact in many complex ways, as one may impact the effectiveness of another. The objective of this report is to find the initial balance of implementation factors that complement this unique region in order to justify the investment of further design and research on a specific corridor. However, stakeholders must consider many more factors before decisions are made on any of these corridors.

It is also important to note that identifying corridors for potential managed lanes treatments as part of this study is only one element of congestion relief that the Baker – Polito Administration is pursuing. Additional initiatives that are being explored include bus-on-shoulder pilot initiatives, a shared travel network study, and other transportation demand management (TDM) strategies. Because these initiatives are in the development stage and are not fully implemented or adopted at the time of writing, they will not be considered as fully implemented during the evaluation phase of this study. As they become accepted policy initiatives, their benefits and impacts to the overlapping managed lanes corridors will be incorporated into future implementation projects.

2. Existing Managed Lanes Initiatives

MassDOT currently has several HOV and express lanes throughout the metropolitan Boston region, as well as some bus-on-shoulder pilot programs in the initial stages of implementation. Corridors evaluated herein likely would build on the successes of the initiatives summarized in the following subsections.

2.1. I-93 SB HOV Lane (North of Boston)

There is an existing 2.6-mile-long buffer separated HOV lane on I-93 southbound from Somerville to the Zakim Bridge in Boston as shown in Figure 1 through Figure 3. Prior to May 2019 vehicles were required to have two or more passengers to legally access the HOV lane between 6 AM and 10 AM, Monday through Friday. In coordination with the major rehabilitation of the Tobin Bridge and adjacent construction improvements along portions of the US 1 corridor through Chelsea, that occupancy requirement was lifted on a temporary basis.

Figure 1 - I-93 SB HOV Lane Location (North of Boston)

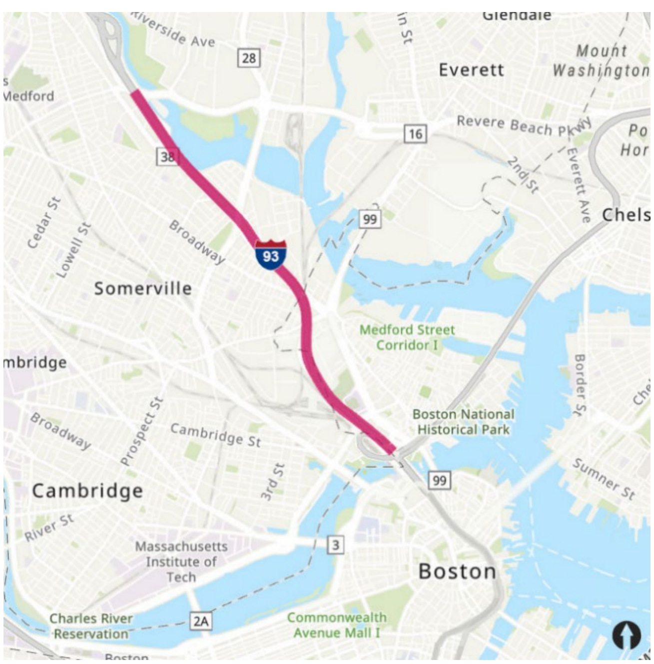


Figure 2 - I-93 SB HOV Lane entrance (North of Boston)

Figure 3 - I-93 SB Carpool Lane terminus at Zakim Bridge

According to the reporting requirements outlined in Department of Environmental Protection CMR 310 7.37 MB High Occupancy Vehicle Lanes, prior to May of 2019, this HOV lane was operating within the required travel time savings of 1 minute per mile length of HOV lane over the general purpose lane travel times.

2.2. I-93 SB HOV Lane from Kneeland Street/Lincoln Street to the Airport and I-93 SB

There are several shorter segments of HOV lanes that provide direct access from local streets to Logan Airport and I-93 that were designed and opened as part of the Central Artery/Tunnel Project. Figure 4 and Figure 5 highlight the access from Kneeland and Lincoln Streets to I-93 and ultimate connections to I-90.

Figure 4 - I-93 SB HOV Lane at Kneeland Street to Logan Airport

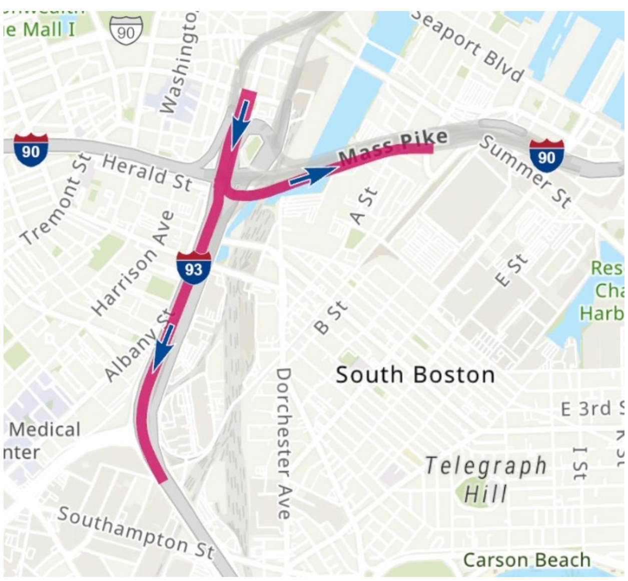


Figure 5 - I-93 SB HOV Lane at Kneeland Street

2.3. I-93 HOV Zipper Lanes (NB and SB) (South of Boston)

There is a system of reversible HOV lanes on the 5.5-mile section of the Southeast Expressway (I-93) between Boston near Morrissey Boulevard and Quincy near the Braintree Split (see Figure 6) utilizing a “zipper type” barrier system. The high speed lanes in the off-peak general purpose direction are utilized for an additional lane in the peak period direction by deploying a string of moveable barriers (see Figure 7 and Figure 8). This system was installed in 1992 and has been operating within the Department of Environmental Protection travel time saving requirements mentioned in 2.1.

Figure 6 - I-93 NB/SB HOV Zipper Lane Location

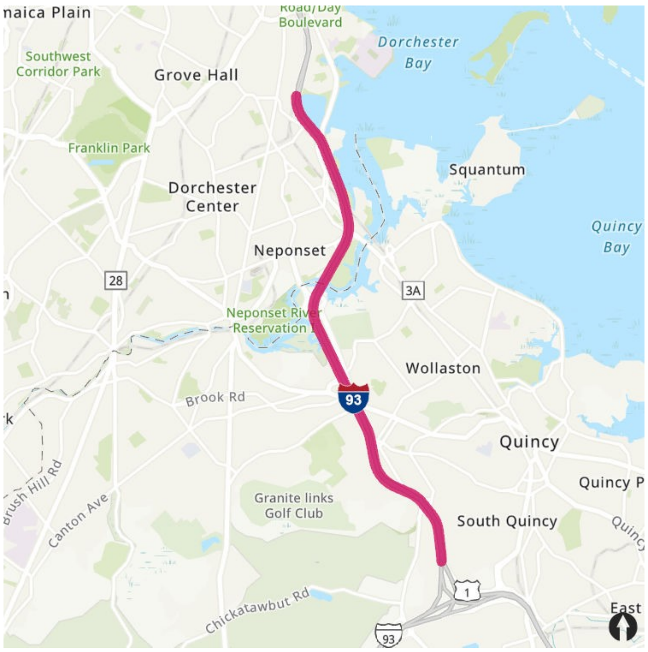


Figure 8 - I-93 Southeast Expressway HOV Zipper Lanes

Figure 7 - Southeast Expressway HOV Zipper Barrier Deployed

2.4. I-93 NB HOV/Express Lane from Southeast Expressway to TWT

Developed as part of the Central Artery/Tunnel Project, an approximately 1.5-mile HOV/express lane to Logan Airport originates just north of the Massachusetts Avenue Connector and connects with I-90 eastbound at the Ted Williams Tunnel as well as Kneeland Street (see Figure 9 and Figure 10). It was originally opened and signed as an HOV lane but has since been converted to a general purpose express lane because of available capacity.

Figure 9 - I-93 HOV/Express Lane from Southeast Expressway to TWT Location

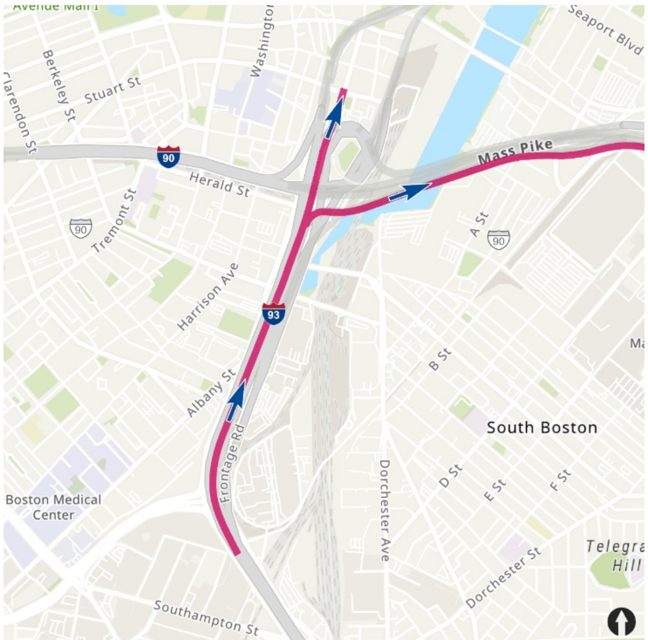
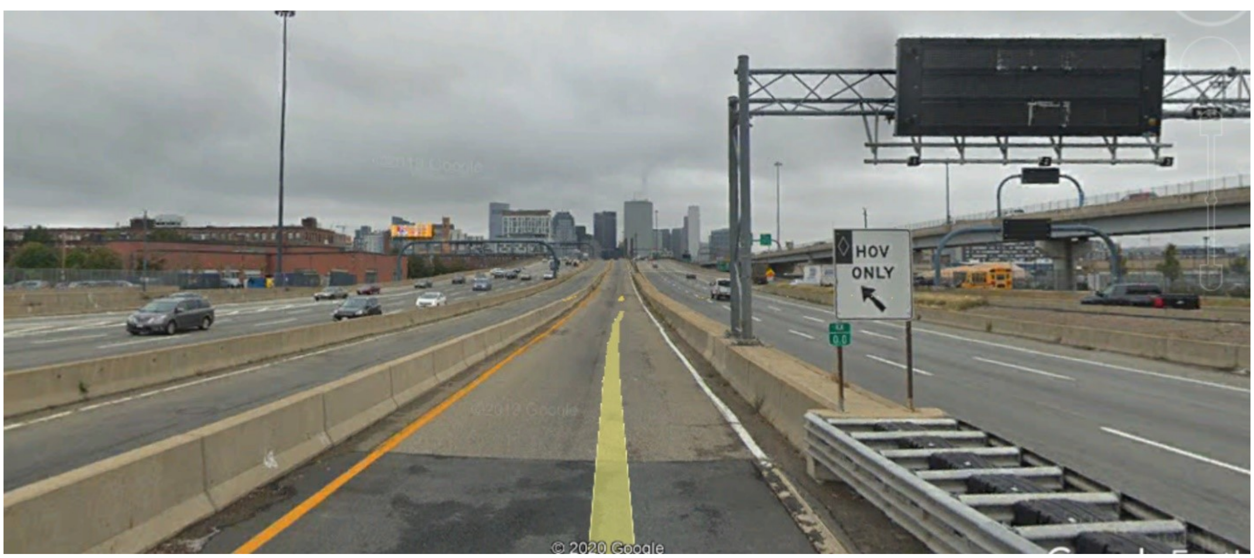


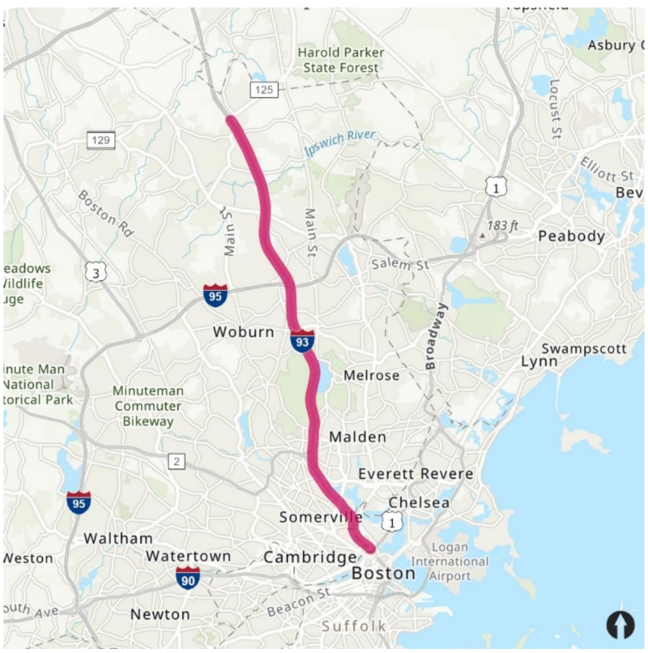
Figure 10 - I-93 NB HOV/Express to Logan Airport



2.5. Bus on Shoulder Pilot(s)

In March 2020, MassDOT completed a Bus-on-Shoulder Screening Study that identified candidate corridors throughout the state where a bus-on-shoulder pilot program could be initiated. Through a multi-tiered screening process that evaluated shoulder width, congestion levels, and the location and volume of interchange ramps, I-90, I-93 and US 1 were identified as potential candidate corridors. Based on further review and evaluation of the candidate corridors, the I-93 segment between US 1 and I-95/MA 128 (See Figure 11) showed the greatest potential for a pilot installation based on the available shoulder width, high number of Massachusetts Bay Transportation Authority (MBTA) and regional buses, and recurring levels of congestion. MassDOT is currently coordinating with FHWA to gain approval for a pilot installation along both directions of I-93 between US 1 and I-95/MA 128.

Figure 11 - I-93 Bus-on-Shoulder Pilot Corridor Limits



3. Important Factors for Implementing Managed Lanes

In order to support the success in planning, designing and operating managed lanes facilities within Massachusetts, a review of available studies and guidance was performed. Through this review and subsequent interviews with managed lane operators around the country, a list of key planning, design, and operating consideration along with key success factors were documented and are summarized within the following section.

3.1. Literature Review

One of the first tasks for this study is a review of existing studies and guidelines related to the planning, development, and operation of managed lane facilities. The HDR team identified the most relevant recent literature that would provide insight for evaluating the need and appropriateness of a proposed managed lane system in the metro Boston area. The review materials are summarized in Table 1.

Table 1 - Managed Lanes Literature Reviewed

Author	Title	Year	Topic	Description
MassDOT	Congestion in the Commonwealth: Report to the Governor 2019	2019	Congestion	Summary of existing congestion within the Commonwealth of Massachusetts
USDOT	Managed Lanes Best Practices	2017	Case Studies	MN, LA County and WSDOT examples
NCHRP	Guidelines for Implementing Managed Lanes	2016	Guidelines	Guidelines for designing and implementing managed lanes
USDOT	Priced Managed Lane Guide	2012	Guidelines	Guidelines for dynamic and fixed pricing for managed lanes
USDOT	HOV to HOT Screening Checklist	2012	Checklist	Decision flow chart and checklist
NCHRP	Assessing the Environmental Justice Effects of Toll Implementation or Rate Changes: Guidebook and Toolbox	2018	Equity	Discussion of EJ effects on priced managed lanes
TRB	Continuous Access Priced Managed Lanes	2018	Case Studies	Recent presentation covering projects without barrier separation that implement pricing
TRB	Ensuring Equity With Priced Managed Lanes	2018	Case Studies	Recent presentation from how three states dealt with Equity in the designs of their systems.

3.2. DOT Interviews/Case Studies

Much can be learned from other state DOTs or concessionaires with existing managed lanes facilities that operate in similar contexts. In cooperation with MassDOT, a series of questions were developed and used to guide conversations with others regarding how facilities were planned, designed, and implemented, including any special considerations that they could offer MassDOT for a more streamlined and successful implementation strategy. Table 2 lists the agencies interviewed and Table 3 provides a summary of associated managed lanes projects. Included within Table 3 is a summary of the key operating characteristics of each corridor along with additional background of how it was developed.

Table 2 - DOT Interviews Conducted

#	Owner	Project	Location	State	Type
1	**CDOT**	I-25 US 36; I-70 Express Lanes	Denver	CO	Reversible Managed: HOV 3+ - Free, Buses/SOV - Toll, Trucks - Surcharge
2	**WSDOT**	SR-167 HOT Conversion	Seattle	WA	HOV to HOT, HOV Lane Free
3	**MnDOT**	I-394 HOT Lanes	Minneapolis	MN	HOT Lanes
4	**HCTRA**	IH-10 Katy Tollway	Houston	TX	Managed lanes - SOV Toll, HOV free
5	**VDOT**	I-395/I-95 Express Lanes	Dulles	VA	HOV Express Lanes free, HOT/SOV Tolled during Peak direction only
6	**FDOT D4**	I-75/I-95 Express in Broward County	Miami	FL	Managed Lanes with Congestion pricing, HOV to HOT
7	**FDOT D6**	I-75/SR 826 Express in Miami-Dade	Miami Dade	FL	Managed Lanes with Congestion pricing, HOV to HOT
8	**Riverside County Transportation Commission (RCTC)**	SR-91 Express Lanes	Riverside County	CA	HOV to Express Lane
9	**UDOT**	I-15 Express Lanes	Statewide	UT	HOV/HOT Lane
10	**GDOT/SRTA**	I-85	Atlanta NE	GA	HOV to HOT conversion
11	**MDTA**	I-95 Express Lanes	Baltimore	MD	HOT Lanes

Table 3 - DOT Interviews Facility Summary

Agency	Corridor	Length (mi)	Cross-Section[1]	Separation Type	Toll Rate Type	Conversion	Transit Present	Enforcement Type
CDOT	US 36	16	6 lanes: 4 GPL, 2 EL	Striped/ Concrete Barrier	Dynamic Pricing	HOV to HOT	Bus	Manual
CDOT	I-25	5	10 lanes: 4 GPL, 2 REL	Concrete Barrier	Time of Day	HOV to HOT	Bus	Manual
CDOT	I-70 Mountain	13	6 lanes: 4 GPL, 2 EL	Striping	Dynamic Pricing	Shoulder to Express Lane	No	Manual
WSDOT	SR-167	21	6 lanes: 4 GPL, 2 EL	Barrier Separated	Dynamic Pricing	HOV to HOT	Bus	Manual
WSDOT	I-405	30	6 lanes: 4 GPL, 2 EL	Barrier Separated	Dynamic Pricing	HOV to HOT	Bus	Manual
MnDOT	I-394	9.8	6 lanes: 4 GPL, 2 EL and 8 lanes: 6 GPL, 2 REL	Striping	Dynamic Pricing	HOV to HOT	Bus	Manual
HCTRA	I-10	1	12 lanes: 10 GPL, 2 EL and 14 lanes: 10 GPL, 4 EL	Striping/ Pylon Separated	Time of Day	HOV to HOT	Bus	Manual
VDOT	I-395/I-95	35	8 lanes: 6 GPL, 2 REL and 11 lanes: 8 GPL, 3REL	Barrier Separated	Dynamic Pricing	HOV to HOT	Bus	Manual
FDOT	I-95	21	12 lanes: 8 GPL, 4 EL	Stripping/ Pylon Separated	Dynamic Pricing	HOV to HOT	Bus	Manual
FDOT	I-75	22	12 lanes: 8 GPL, 4 EL	Striping/ Pylon Separated	Dynamic Pricing	HOV to HOT	Bus	Manual
RCTC	SR-91	18	12 lanes: 8 GPL, 4 EL 14 lanes: 10 GPL, 4 EL	Stripping/ Pylon Separated	Time of Day	New Construction HOV to HOT	Bus	Automated Manual
UDOT	I-15	17	12 lanes: 10 GPL, 2 EL	Striping	Time of Day	HOV to HOT	Bus	Manual
GDOT/ SRTA	I-85	10	14 lanes: 12 GPL, 2 EL	Striping	Dynamic Pricing	HOV to HOT	Bus	Manual
GDOT/ SRTA	NW Corridor (I-75/I-575)	29.7	10 lanes: 4 GPL, 2 REL	Barrier Separated	Dynamic Pricing	HOV to HOT	Bus	Manual
GDOT/ SRTA	I-75	12	12 lanes: 8 GPL, 4 REL and 10 lanes: 8 GPL, 2 REL	Barrier Separated	Dynamic Pricing	HOV to HOT	Bus	Manual

[1] GPL – General Purpose Lanes, EL – Express Lanes, REL – Reversible Express Lanes

Agency	Corridor	Length (mi)	Cross-Section[1]	Separation Type	Toll Rate Type	Conversion	Transit Present	Enforcement Type
GDOT/ SRTA	I-85 Extension	10	10 lanes: 8 GPL, 2 EL	Striping	Dynamic Pricing	New Construction	Bus	Manual
MDTA	I-95	8.1	12 lanes: 8 GPL, 4 EL	Barrier Separated	Time of Day	New Construction	Bus	Manual

[1] GPL – General Purpose Lanes, EL – Express Lanes, REL – Reversible Express Lanes

Ultimately, the result of the literature reviews and the DOT interviews yielded a compilation of topics that MassDOT can consider when implementing managed lanes and, based on other DOT experiences, specific areas to pay special attention to drive the successful implementation and operation of these facilities. These topics are summarized in three major areas—planning, design and operations/maintenance.

3.3. Planning Considerations for Managed Lanes

It is evident from the literature review and from speaking with other state DOTs that every state has different goals and objectives for implementing managed lanes projects. Identifying the goals of the program from the very beginning was paramount to the successful implementation of managed lanes systems.

> *Massachusetts needs to establish its own vision and set of goals for implementing managed lanes.*

Design guidance and other sources highlight goal setting as an important early planning step that helps to build agreement between stakeholders and the broad array of agencies, departments and municipalities involved.

As cited in ***NCHRP 835, "Guidelines for Implementing Managed Lanes"*** – the objectives for implementing managed lane projects throughout the country was compiled; all cited adding capacity, increasing vehicle throughput, and improving reliability as an objective; generating revenue was an objective for 10 projects; promoting transit services was a goal for four and promoting bus rapid transit was a goal for only one.[2]

The following list of planning considerations for managed lanes was created based on existing federal guidelines but also augmented by reports from, and interviews with, agencies who have successfully implemented new managed lanes projects around the country.

3.3.1. Maximizing Person and Vehicle Throughput

An important goal of a new managed lane facility is to provide a reliable and consistent corridor that a motorist can use to get to a destination—either by carpooling, utilizing buses or shuttles on the facility, or paying a toll as a single occupant vehicle (SOV). A combination of these three opportunities can result in a corridor that is maximizing person and vehicle throughput along the corridor.

Managed lanes introduce a new travel option for people who drive or ride in motor vehicles or take transit that uses highways. Maintaining a reliable travel speed can be achieved through monitoring and adjusting price, which in turn influences the behavior of single-occupancy drivers who must decide whether to pay a toll or to change the time in which they travel. When managed lanes are priced in a way that maintains higher vehicle speeds than can be achieved in nearby general purpose lanes, higher numbers of vehicles and people are able to be processed overall.

[2] Table 3, NCHRP 835, "Guidelines for Implementing Managed Lanes" p. 11

3.3.2. Generating and Sharing Revenue

As confirmed through the DOT interview process, the intent of most managed lane facilities is to maximize vehicle and person throughput, but the facility may, by design, collect revenue. While DOTs warn that generating revenue on its own is not a compelling reason to implement a managed lane, how the toll revenue is collected and allocated on the facility can help win the project public support. For example, several DOTs revealed that the revenue generated in their managed lanes facility was allocated in a distinct and predetermined way:

- Revenue was pledged to pay back capital costs required to build the lane.
- Revenue was then allocated to cover operations and maintenance costs for the lane.
- There may be a partial pledge to support transit improvements in their area.

While no pre-determined formula will work for all agencies, MassDOT can consider areas for revenue allocation that would best serve the whole region through the support of transit or other TDM techniques.

3.3.3. Improving Transit and Increasing Ridership

Greater Boston has robust commuter rail, subway, and bus networks. Many bus routes and shuttles use existing highways and a network of park-and-ride facilities and could benefit from the implementation of managed lanes, including reducing travel times, improving reliability, and adding ridership. Colorado's US-36 Express Lanes, which hosts the Flatiron Flyer express bus and other local routes, have incorporated dedicated Bus Rapid Transit projects into newly constructed managed lanes. Other DOTs, such as Virginia's I-66 and RCTC in California, have focused on generating revenue for transit, biking and walking improvements near the corridor.

With MassDOT's currently programmed transit and rail improvements such as the Green Line Extension and South Coast Rail, there may be slight improvements to current congestion levels in some of the corridors identified in this study, but additional opportunities for transit improvements like bus rapid transit on a newly constructed managed lane facility will have additional benefits. For example, creating a new bus rapid transit opportunity prior to an ingress point of a managed lane and/or developing additional park-and-ride lots to support these types of improvements can be part of the holistic approach for congestion relief and would support the ongoing efforts from MassDOT with respect to identifying and enhancing shared travel network opportunities in the region.

3.3.4. Increasing the Use of Carpooling, Vanpooling, and Ride Sharing

Managed lanes that allow carpools (otherwise referred to as HOVs) of two or three riders to use them for free often lead to increased carpool use, and carpoolers often make up the majority of people moved by a managed lane. The Minnesota Department of Transportation (MnDOT) stated that their MnPASS managed lanes typically have approximately 10 percent more carpools than a roadway without MnPASS lanes. Projects have also increased ride sharing by pairing the new lanes with outreach from Transportation Management Associations and other organizations that work directly with employers. Florida DOT worked with South Florida Commuter Services to create a dedicated website for incentivizing carpooling and the Washington State Department of Transportation (WSDOT) regularly engages with employers and carpool advocacy groups. The Virginia Department of Transportation (VDOT) has included carpooling “slug lines” in their design of park-and-ride lots by adding direct on and off ramps to them and special pick up areas with signage that helps organize potential riders into carpools according to their destinations.

Consideration for improving these carpooling outreach initiatives (once a reliable and consistent commuting experience can be offered) may contribute to drawing single occupant drivers into multiple occupant vehicle options.

3.3.5. Vehicle Eligibility to Use Managed Lane

Factors relating to what vehicles will be eligible to use the managed lane depend on the goals set for the project. If the only goal is to increase vehicle capacity of the lane (which also increases person throughput), dynamic pricing can control speeds under any vehicle eligibility rules as long as prices are not capped. There are, however, many environmental and economic benefits to encouraging carpooling and transit use by allowing those vehicles to use the managed lanes for free. Conversely, increasing the number of free users of the lane may require higher toll prices for single occupant vehicles or additional capacity in order to maintain desired travel speeds and reliability. All the DOTs interviewed allowed buses to use their managed lanes at no cost. Many reported ridership increases directly related to their project and identified improvements to public transportation as one of their top three success factors as it helped address equity demands.

The Harris County Toll Road Authority (HCTRA) expressed regret that HOV-2 vehicles were allowed in many of its express lanes where performance had “degraded” in the six to eight years since opening. HCTRA tolls are only allowed to be raised through legislative means, which has limited their ability to respond to increased traffic congestion in recent years. If they were not limited in their ability to adjust their toll rate schedules, extra capacity could be attained by changing from HOV-2+ to HOV-3+. Practitioners from VDOT in Northern Virginia cited another benefit of HOV-3+—thousands of people use “slug lines” to achieve HOV-3 by picking additional people up at park-and-rides near the highway. In Washington State, WSDOT has built in the ability to switch from HOV-2 to HOV-3 at varying times (peak periods and off-peak periods) helping to keep their lanes moving.

Other vehicles eligible for toll free use of managed lanes varied from state to state and sometimes included motorcycles, hybrids, super ultralow-emission vehicles, partial zero-emission vehicles, alternative fuel vehicles, electric vehicles, plug-in electric vehicles, or inherently low-emission vehicles. Under the 2015 FAST Act, states had the ability to offer low-emission vehicles an exemption from tolls in HOV lanes, but this ability expired in September 2019 and its future is uncertain. A new transportation act is being considered by the United States Congress.

Several iterations of modeling various vehicle eligibility requirements will be part of the RFP requirements for the detailed study (future phase of work) for any corridors determined to have potential for further development.

3.3.6. Pricing Algorithms

Vehicle eligibility for a managed lane facility controls large volumes of vehicles (i.e., HOV 2+ vs. HOV 3+), but pricing algorithms (i.e., HOT toll rates for SOVs) can help "fine tune" the capacity of a lane when used dynamically and in real time.

Dynamic pricing allows for fine tuning of traffic volumes to meet the FHWA requirement Title 23, Section 166 - to operate a managed lane at speeds faster than 45 mph for at least 90 percent of the time.

Facilities around the country have had various levels of success for maintaining speed and reliability, with the key success factor appearing to be implementing dynamic priced tolling without a price cap. Many practitioners we interviewed look to the dynamic toll pricing example set by MnDOT, where the toll price is controlled by an algorithm that uses speed and volume data collected by detectors in the lanes. When vehicle speeds in the managed lanes slow down, prices go up, thereby deterring more SOVs from entering. When ongoing toll increases depend on lengthy and onerous legislative approval, it is difficult for DOTs and operators to manage the traffic in the lanes based on demand. Some facilities have pointed to this restriction as a reason for the lane operating over capacity and/or breaking down.

3.3.7. Supporting Community Land Use Goals

Land use concerns often enter the community conversation around managed lanes projects. A 2013 Urban Land Institute study concluded that HOV to HOT conversions that prioritize reliability or improved travel times are likely to "encourage sprawl" unless the lanes prioritize transit, specifically as part of a bus rapid transit network, and their toll revenue supports transit improvements.[3] Examples of managed lanes that incorporate transit are Florida's I-95 Express Lanes, San Diego's I-15 Express Lanes, and Colorado's U.S. 36 Bus Rapid Transit/Managed-Lanes Project. In this region, managed lanes and their resulting generated revenue can help improve the performance of parallel-running transit options along with the potential to contribute to more walkable, denser land use.

3.3.8. Equity

Transportation infrastructure provides or impedes access to opportunity. People use it to access work, school, commerce, healthcare and other activities that they use to survive and thrive. When discussing charging a price or raising a price for a method of transportation, concerns for those who most need or want access to opportunity will arise. A recent study on environmental justice and tolling[4] identified three types of equity—income, geographic, and modal—that typically are identified in managed lanes projects and were confirmed in some of the interviews of DOT staff that were conducted for this report. While typical equity considerations are summarized in the following paragraphs, MassDOT will identify equity characteristics for full

[3] 2013"When the Road Price is Right," Urban Land Institute

[4] 2018 "Environmental Justice Analyses When Considering Toll Implementation for Rate Changes Final Report" NCHRP Web-Only Document 237 p.41

consideration in future analysis once specific corridors are identified as having potential for implementation for a managed lane treatment.

INCOME EQUITY

Any time a managed lane is considered on a roadway, there should be consideration for motorists who may have limited resources or opportunities to either carpool or pay the required toll. Some agencies expressed an intent to experiment with discounts for low-income individuals, but others indicated that outreach in low-income communities near managed lanes indicated that those communities seemed to take advantage of the opportunities for improved transit operations offered through the managed lanes projects. These improvements included improved travel times, new express bus routes, and more frequent service. In all these projects, the agency could show data that traffic flow in general purpose lanes also had been improved because of the project. To predict impact and uncover potential mitigation strategies, an equity analysis could seek to identify how many low-income users currently use any facility being considered for managed lanes treatments, and in what way (transit, single occupant vehicle, carpool, etc.).[5]

GEOGRAPHIC EQUITY

Geographic equity, which relates to the idea that managed lanes might benefit or harm one geographic location more than another, also has become an important consideration in managed lanes projects. In Florida DOT's Palmetto Express Lanes project, one community's access to a newly implemented managed lanes facility was limited to a transit hub that allowed only bus access to the facility, leaving a neighborhood without the same access for vehicles that was provided to other communities along the corridor. The disparity angered residents who engaged their elected officials in an effort to derail the project entirely, until project owners changed the design.[6] A very careful consideration of ingress and egress to any new managed lane facility using origin and destination data and significant public outreach and participation along the project lifecycle should help avoid equity issues of this type.

MODAL EQUITY

Concerns about modal equity can arise when benefits to SOV drivers raise concerns among carpoolers and/or transit riders that their benefits might be reduced. This concern was cited most often among those interviewed in cases when HOV-2+ lanes were changed to HOV-3+ lanes in order to increase the efficiency of HOT lanes (thus allowing more toll-paying single occupant drivers in it). One interviewee noted opposition to such a change among retirees, and another among a much broader segment of users. This challenge also could occur among transit advocates if the speeds in a managed lane were degraded enough to affect bus schedules and reliability.

Equity concerns overall should be highlighted and addressed in all phases of the project, particularly in the data collection and outreach stages, so that a shared understanding of potential issues can be created during the public process. It is also critically important to

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[5] Ibid. p.49
[6] FDOT D4 Interview

understand equity issues with clarity to avoid their use by others to mask their own special interest in avoiding tolls or preventing them from being implemented.[7]

3.3.9. Project Champions and Public Support

Projects on heavily congested roadways can also be more likely to cause controversy when priced correctly, since the price needed to maintain the level of reliability and travel speeds can be high, such as has been the case with Northern Virginia's I-66 Express Lanes.

Many interviewees cited achieving public support as one of their top three success factors and had broad sophisticated public outreach efforts including permanent communications staff for their managed lanes facilities. Gaining public support was seen as less of a challenge when managed lanes were part of a general highway widening project that adds capacity, and more of a challenge for HOV to HOT conversions where the improvements to general purpose lanes were less visible, or where additional SOVs had the potential to impact the existing performance of traditional HOV lanes.

The I-66 Express Lane Project in Virginia's uncapped tolls gained national notoriety for soaring over $40 per trip for single-occupant drivers; however, VDOT staff interviewed noted the controversy has died down after continuing public outreach efforts, despite tolls remaining high. This project and others have highlighted the importance of strong data and transparency to show members of the public the benefits of the managed lane. In I-66's case, these benefits have included a 25 percent increase in carpooling use, 5 percent and 6 percent increases in rail and bus use, and millions in funding generated by toll revenue for capital, maintenance, TDM and significant transit improvements including new express bus routes.[8]

DOTs facing the more challenging public conversations employed traditional meetings and stakeholder groups as well as focused advertising such as billboards, radio, television advertisements and professional media outreach—taking advantage of "every radio interview we could get," as one interviewee phrased it.

In Minnesota, MnDOT collaborated with the Humphrey School of Public Affairs at the University of Minnesota to create a stakeholder group consisting of the state's transportation leadership, including elected officials who were not all in support when the meetings began. They produced a Policy Report that MnDOT cited as essential in shifting public opinion. The report recommended a prioritization of managing congestion, adding bus rapid transit routes on MnPASS lanes and funding transit. It offered various ways to fund the project, supported variable price tolling in perpetuity, and called for including managed lanes in comprehensive transportation plans. "Toll lanes are a good tool to manage congestion, but they are not

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[7] Taylor, Brian and Kalauskas, Rebecca. (2010). Addressing Equity in Political Debates over Road Pricing. Transportation Research Record: Journal of the Transportation Research Board. 2187. 44-52. 10.3141/2187-07.

[8] 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

enough," the plan quoted Minnesota Senator Sharon Marko as saying. "There must be substantial new funding to meet critical transportation needs."[9]

Interviewees and the literature provided several key talking points that helped reveal the need for and scope of the public engagement process, as well as highlighting what the design may need to accomplish to win public support:

- A managed toll lane is a new option, and people have a choice whether to use it or not.
- People may use the toll lane for free if they or their vehicle meet certain requirements (e.g., carpool, transit, low-emissions vehicle (if applicable).
- This project also will improve transit (e.g., travel times, new services, funding).
- Travel times in the general purpose lanes will not be degraded, and may even be improved.

KEY PUBLIC ENGAGEMENT METHODS

- *Engage key stakeholders early*
- *Traditional public hearings*
- *Focus groups*
- *Present strong data and performance expectations*
- *Media outreach*
- *Social media*

They also cited several potential situations that can arise and significantly impact public support:

- Unexpected "bottlenecks" that occur near egress points due to insufficient capacity in the receiving lanes or due to weaving shortly after egress
- Degraded speeds or increased congestion in general purpose lanes that can be attributed to the managed lanes project
- Extreme speed differential between express and general purpose lanes
- Significant hurdles towards toll increases (approved dynamic toll variances controlled by algorithms were not reported as controversial).

A general theme of these comments was to reinforce that public perception and support will ebb and flow based on the user experience, but if the overall outcome of the managed lane implementation improves reliability and travel time savings, then the support will follow.

[9] "MnPASS: A System for Managing Congestion" MnPASS System Study Steering Committee Policy Report, April 2005

3.4. Design Considerations for Managed Lanes

3.4.1. Traffic Modeling

There are several types of modeling options available in the industry to simulate and forecast demand on managed lanes. Depending on the level of detail needed, certain types of modeling methods may be more suitable than the others. For example, if the focus is on conceptual feasibility of managed lanes, a sketch planning approach that draws upon empirical data from peer cities may be a cost-effective option. For preliminary feasibility analysis, a network-based modeling approach with a robust choice component may be required. To analyze regional pricing strategies, a Trip Based or Activity Based modeling system with a sophisticated traffic assignment component may be needed. For investment grade type of toll and revenue studies, extremely detailed network-based models may be required with highly sophisticated choice structure that can assess the managed lane sensitivity with respect to corridor speeds, toll diversions, peak hour conditions, and traffic management.

3.4.2. Civil Design Features

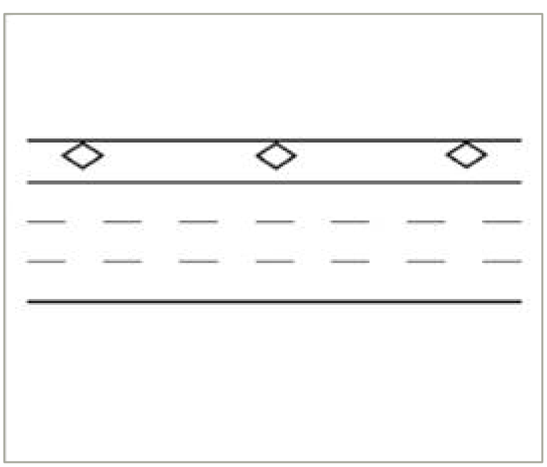
There are several different ways to implement a managed lane from a highway design perspective. The level of ingress and egress is variable depending on the implementation approach adopted by the facility owner. A summary of advantages and disadvantages for the various types of managed lane design is provided in subsections 3.4.3 through 3.4.7.

3.4.3. Continuous Access Lane(s)

A continuous access managed lane allows vehicles to enter or exit at any point. The general purpose and managed lane facilities run in parallel, and movement between the two facilities is unrestricted as is illustrated within Figure 12.

This type of lane provides access to all travelers throughout the corridor. The challenges to this type of facility lies with enforcement as it is very difficult and costly to enforce either HOV or SOV “violators.” These facilities also require additional toll collection and enforcement zones which translate to increased capital investment compared to a more physical separation which limits the ingress/egress of the facility.

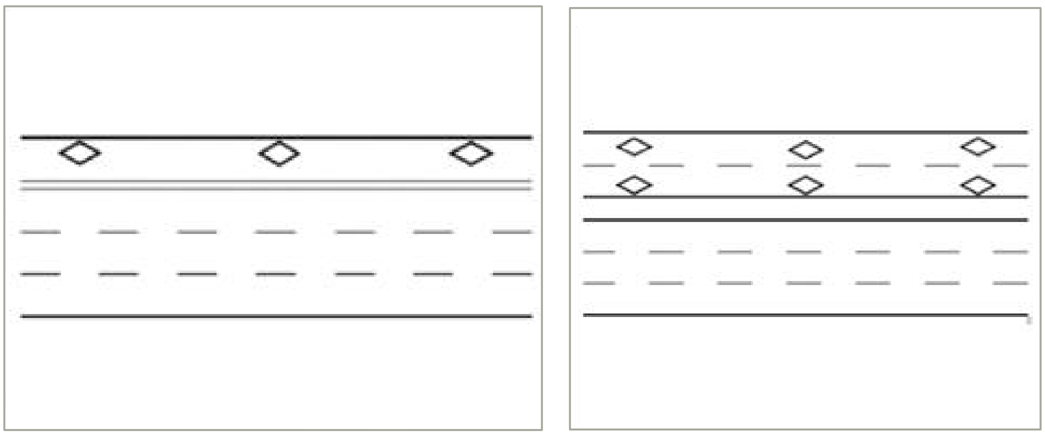
Figure 12 - Single Managed Lane with Continuous Access



3.4.4. Buffer Separated Lane(s)

A managed lanes facility with buffer separation offers intermittent access to the general purpose lanes. As is shown in Figure 13, the buffer usually deploys striping techniques, such as a solid white line or double white lines, or other at-grade separation such as tubular channelizing devices spaced at variable distances. The occasional buffer opening areas are designated by dashed lines.

Figure 13 - Managed Lanes with Buffer Separation

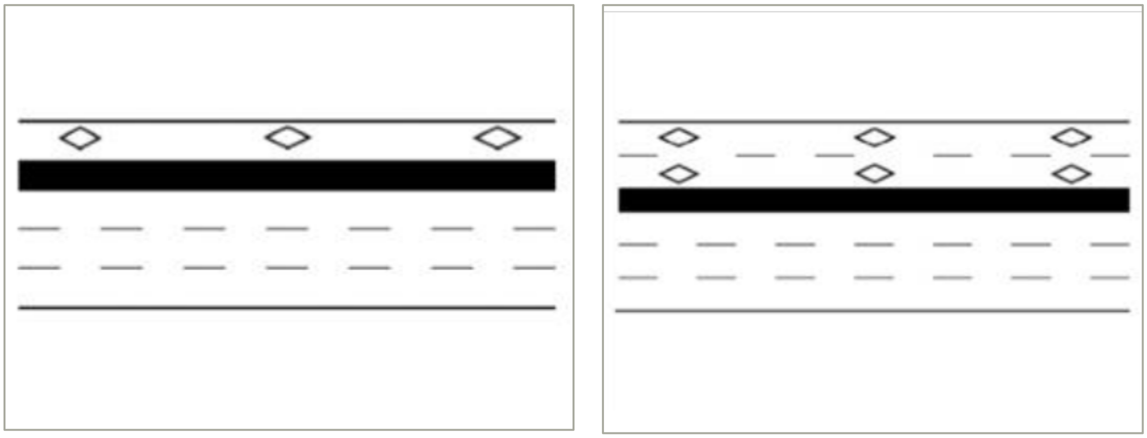


This type of design was more prominent in the DOT interviews that were conducted, as it allows intermittent access and egress from the lane(s) but provides a greater level of enforcement capability than the unlimited access option. Several agencies noted that the spacing of the tubular channelizing devices was critical in allowing access for emergency vehicles, tow trucks and other maintenance equipment to effectively manage incidents while promoting compliance with eligibility requirements. MnDOT noted that future installations of managed lanes in their state would be of this type.

3.4.5. Barrier Separated

Barrier-separated managed lanes would have discontinuous access and are typically found with dedicated express lane-type facilities as is shown in Figure 14. Separation is achieved through barrier walls, berms, landscaping, or any other physical separation schemes to prevent vehicles from entering or exiting the managed lane except at designated ingress and egress locations.

Figure 14 - Managed Lanes with Barrier Separation



This type of lane allows more control for ingress, egress, and operational parameters like speed and travel time maintenance. However, this application does not allow for intermediate egress for adjacent highway off ramps and on ramp access and needs to be carefully applied with consideration of specific origin and destination pairs.

3.4.6. Ingress and Egress

During the evaluation and selection of ingress and egress points, including the beginning and ending treatments, consideration must include an evaluation of the additional roadway width required to facilitate the ingress and egress into the managed lane facilities. The following figures taken from the Florida Department of Transportation (FDOT) are meant to provide example layouts for various managed lane ingress and egress configurations to better understand the potential implications on the roadway typical sections and physical space constraints. The reference to these examples is strictly for informational purposes only and by no means documents the support for these layouts by MassDOT's Highway Design Section. As part of future manage lanes planning phases, MassDOT Highway Design staff should look to develop their own specific ingress and egress typical configurations to aid in locating access points and further their understanding of potential project impacts.

As is shown in the following figures, the additional width required to facilitate these transitions between the managed and general purpose lanes can range from 0 to 12 feet. Figures 15 through Figure 18 illustrate standards that have been published by FDOT within their 2020 Design Manual Part 2, Chapter 211. Figure 15 and Figure 16 provide examples of how to begin and end the managed lanes by either transitioning general purpose lanes to express lanes, or by creating a new entrance lane for the managed lanes. Figure 17 provides examples for creating independent ingress and egress slip ramps which adds at least an extra 12 feet to the typical section. Figure 18 shows an option to combine the ingress and egress points in a weaving segment, reducing the additional width required to 8 feet if creating a weaving lane; or reducing it to zero if creating a weaving zone. Applicability, feasibility and variations of these treatments may impact the desired location to provide access to and from the managed lanes and will be considered early when developing a corridor-wide ingress/egress master plan.

FDOT Design Manual is available online at: https://www.fdot.gov/roadway/FDM/Default.shtm

Figure 15 - Example Begin Managed Lanes Treatment from FDOT Design Manual

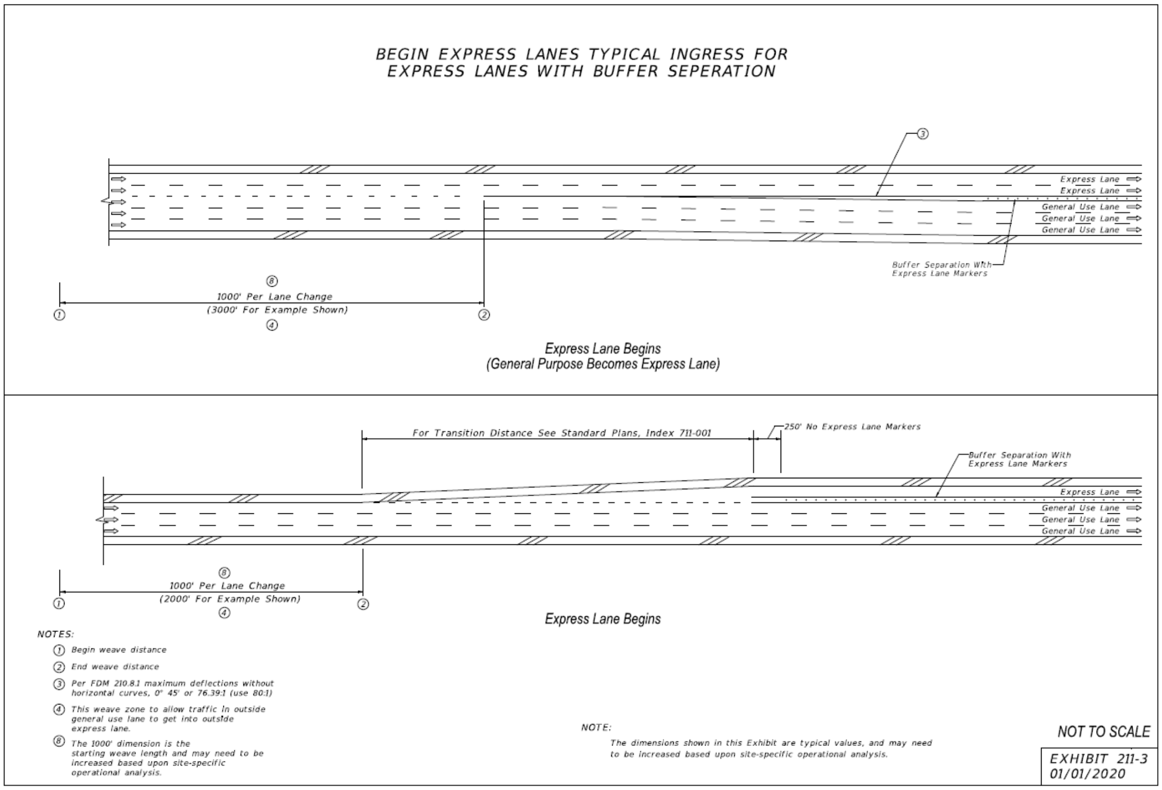


Figure 16 - Example End Managed Lanes Treatment from FDOT Design Manual

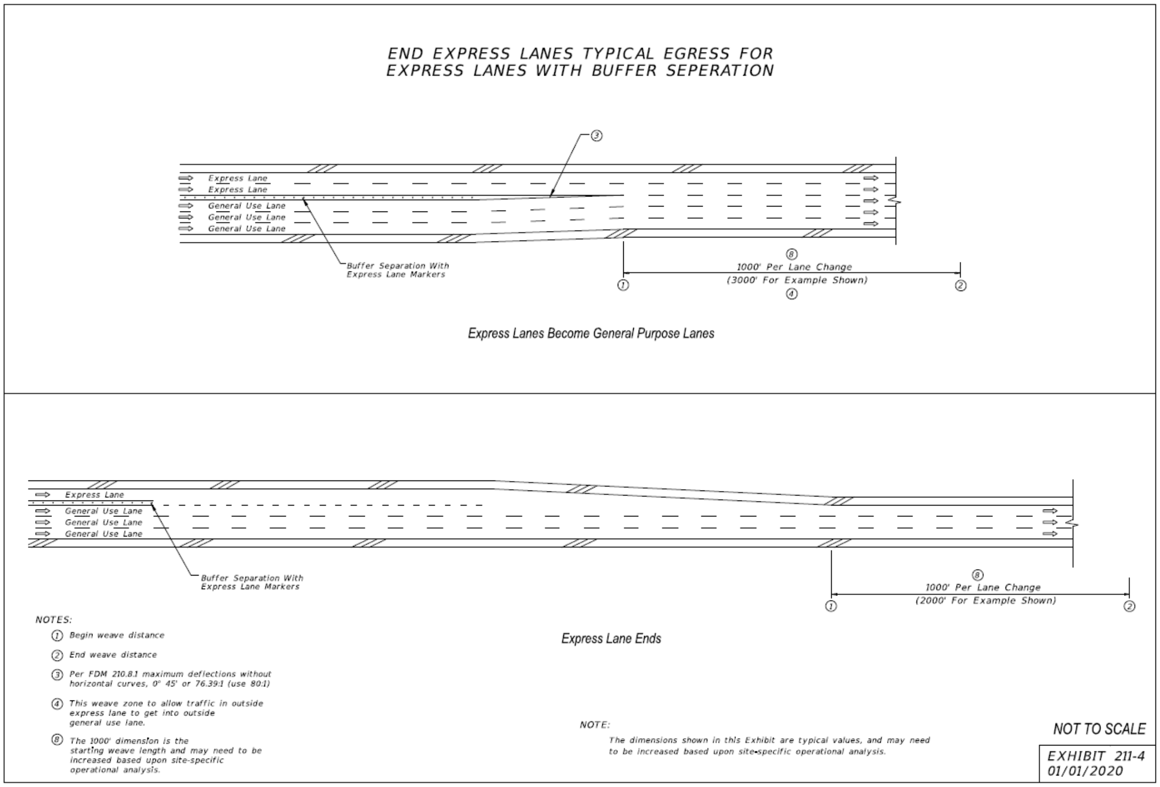


Figure 17 - Example Typical Managed Lanes Ingress & Egress Slip Ramp from FDOT Design Manual

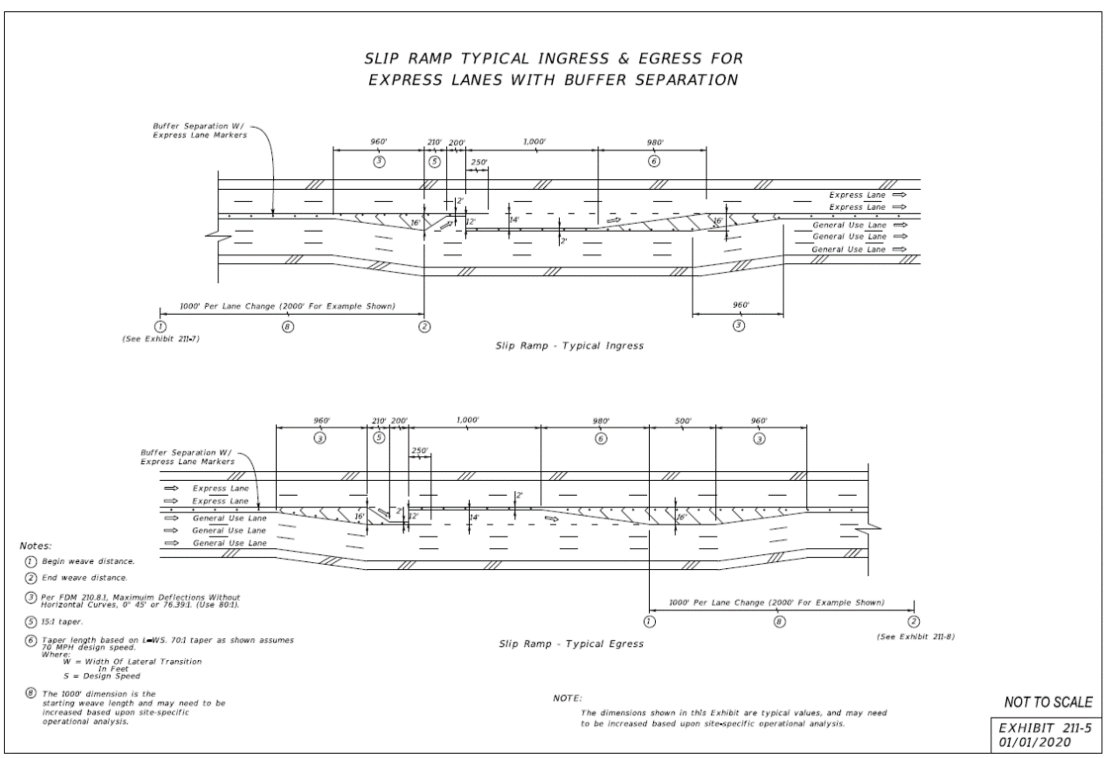
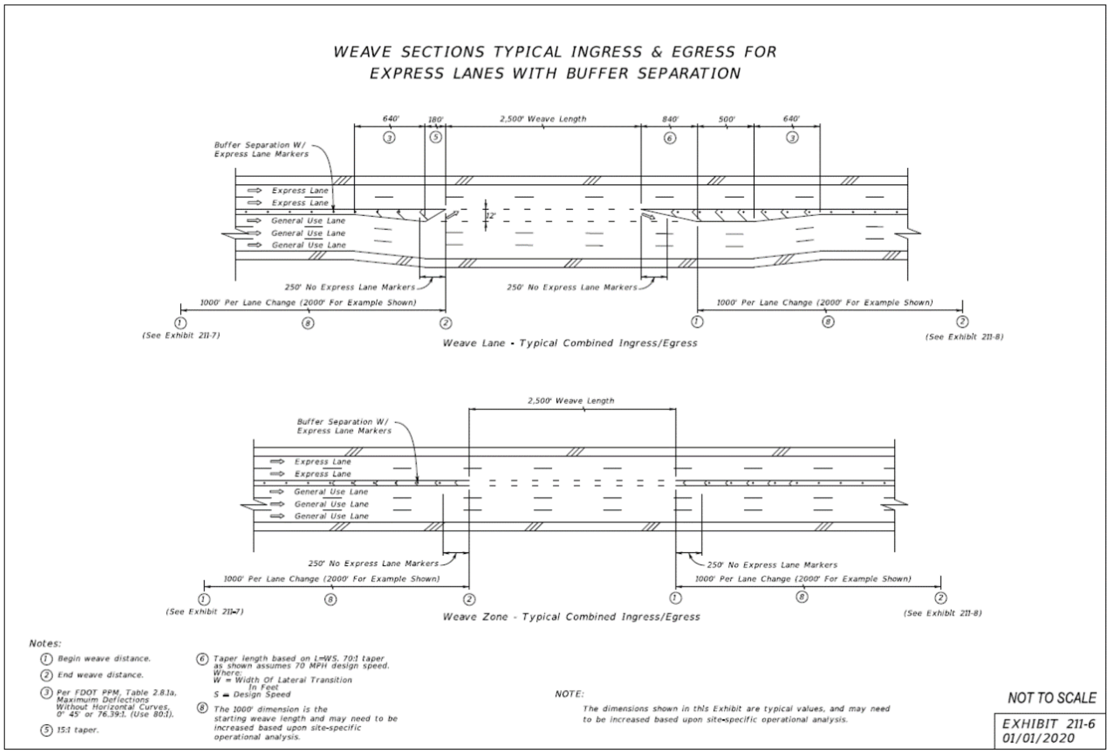


Figure 18 - Example Typical Managed Lanes Ingress & Egress Weaving Section from FDOT Design Manual



3.5. Operations & Maintenance Considerations for Managed Lanes

The operation and maintenance of managed lane facilities tends to be similar to that of traditional and limited access facilities. A common theme that emerged from the various DOT interviews is the concept of providing high levels of customer service and maintaining system reliability so that customers of the facility can experience measurable improvements in mobility such as safety, reduction in travel time, and increase in speeds during peak periods.

3.5.1. Back Office Establishment

DOTs interviewed described three types of back office approaches to address the tolling operations associated with any tolling aspect of managed lanes.

The first approach involves the use of pre-existing toll road systems like the Florida's Turnpike Enterprise which is the Florida Department of Transportation's (FDOT's) tolling agency. Since MassDOT currently has tolling on the Massachusetts Turnpike, Tobin Bridge, Sumner/Callahan Tunnels, and the Ted Williams Tunnel, the incorporation of any new managed lanes facilities should be relatively seamless. Implementation of a new managed lane facility would not have to employ the same roadway equipment as in use today, but could open the market for the most innovative and state of the art tolling equipment and enforcement strategies available today. However, because of the interoperability with the existing systems, utilizing the same transponder technology (EZPass) would be recommended. Many of the customers utilizing the roadways as part of this study already have existing transponders—either because they drive through an existing MassDOT toll facility or they travel within the New England region to states like New Hampshire, Maine and Rhode Island, where EZPass is required.

A second type of back office approach involves the creation of a new quasi-public entity like Colorado's High Performance Transportation Enterprise, which is business enterprise owned by the Colorado Department of Transportation (CDOT) that financed and delivered Colorado's first innovative and accelerated express lanes projects and now continues to manage the systems, collects toll revenue, bonds, loans, and concessions to raise money to increase capacity on congested corridors.

The last type of back office approach involves the use of a concessionaire like Transurban for VDOT in Northern Virginia. If a concessionaire is the method of choice, it is important to establish key performance measures with oversight of the local agency to regulate how the third party is to monitor and operate the back office operations.

The Federal Highway Administration (FHWA) Priced Managed Lanes Guide indicates that "regardless of the chosen processing entity, it should be well understood and codified under operational documentation that priced managed lanes must account for assembled toll trips, not single point toll transactions, and do so without incurring cumulative transaction costs for the assembly."[10]

[10] USDOT FHWA Priced Managed Lane Guide 2012

3.5.2. Managed Lanes Enforcement

Violations continue to be a significant hurdle in the operations of managed lanes. Besides the enforcement of speeding, moving violations, and lane crossings along the managed lanes facility, agencies also need to enforce the use of lanes based on the eligibility criteria that is adopted. Toll violations and occupancy verification must be continuously monitored and enforced to maintain the integrity of the system. Violations can be categorized as HOV violators, or drivers who illegally access the managed lane by weaving in or out at unauthorized locations. The point at which a user is considered a violator depends on the policies and business rules established by the agency, the laws established by the legislature or the actions of the courts. Pursuing violators creates equity and fairness by ensuring all users of the facility pay the toll. Effective enforcement also reduces overall system revenue loss.

Violators not only reduce the operating efficiency of the managed lane facility, but they also may create unsafe conditions for other drivers and law enforcement officials. If not enforced, the perception of inequities in enforcement and operations could lead to public pushback.

As managed lane operators, agencies must be fiscally responsible with all assets and as trustees of managed lanes, which are revenue-generating assets, there is a public expectation of fiscal responsibility. Tolerance of violations perpetuates more violations and may significantly reduce revenue generation capacity. Violations threaten reliability of service to toll-paying customers and can reduce overall levels of service and performance. Studies in Colorado and California show that HOV violations are on the rise and reach 30 percent of the self-declared HOV traffic.

All the DOTs interviewed confirm they partnered with state police, state troopers or local law enforcement to patrol the managed lanes for enforcement purposes.

3.5.3. Automated Toll Enforcement

Agencies like FDOT, CDOT, HCRTA, WSDOT, MDTA and VDOT indicated they use cameras in the managed lanes for toll by plate or to capture vehicles traveling in the managed lanes without a valid transponder. It should be noted that this automated enforcement only captures vehicles that do not have a transponder where required. However, this technology does not have the ability to enforce HOV occupancy.

3.5.4. HOV Enforcement

So far, DOTs confirmed that HOV enforcement is done primarily through visual and manual verification of occupancy requirements—HOV2+ or HOV 3+. Currently, none of the DOTs interviewed use technology to confirm or verify vehicle occupancy for HOV compliance, and they rely solely on visual confirmation by law enforcement.

However, one agency noted that an audit of their manual HOV enforcement has proven to be less than 100 percent accurate—even as high as 50 percent error rate, i.e., law enforcement pulling over a vehicle suspected of having less than the minimum HOV required only to determine there were occupants in the rear of the vehicle.

Many states are conducting pilot tests of technology focused enforcement systems such as infrared cameras, but none are ready for implementation. MnDOT is testing beacons and other technology to help identify whether a valid MnPASS tag is in the vehicle. VDOT is working on a pilot program that uses the vendor 3M to do photo enforcement; however, it is in trial phases. Some agencies like CDOT described challenges with visitors and tourists and enforcing and collecting tolls.

For speeding or moving violations enforcement within the managed lanes, all the interviewed DOTs use the physical presence of law enforcement to monitor, stop and issue citations, at varying operational levels. Like Massachusetts, states like Florida do not have legislation that allows them to use digital enforcement for moving or speeding violations. One of the main challenges for any type of manual enforcement is the ability to safely pull drivers over on a managed lane facility where there is limited right-of-way. A design strategy for enforcement would include the creation of regular enforcement/emergency pull-off areas to minimize long stretches without safe enforcement zones.

With the increase in managed lanes facilities across the country, associations like the Transportation Research Board (TRB) are researching best practices for enforcement. To date, there have been a few “self-declaring” applications (i.e., where a customer is required to set either HOV or SOV on their switchable transponder) and infrared camera technology pilots tested, but industry leaders caution that these are not yet proven and work is still needed to provide a solution for enforcement.

3.5.5. Incident Management

Incident management in any managed lane facility should be of utmost importance. Quick identification, response and clearance of disabled vehicles is required in order to maintain the integrity and reliability of the facility. Users of a facility, especially motorists paying a toll to use the system, expect that all means and methods available will be utilized by an agency.

While incident response is always an important factor in facility design, the complexity of the incident response plan and the required capital investment required can vary depending on the design of the facility. For instance, a sufficiently wide managed lane with a dedicated breakdown lane or pull off areas will translate to a higher tolerance for incident response scenarios because one disabled vehicle in the managed lane will not effectively stop the lane. Facilities with limited areas for disabled vehicles will rely on rapid and efficient incident response programs and will require more complex incident response systems.

FDOT described a very robust incident management plan and protocols that includes dedicated resources and law enforcement, supported by revenues collected from the managed lanes tolls. Additional resources included Road Rangers to assist disabled vehicles, cones, and equipment to support lane closure operations, towing and flatbed trucks to quickly evacuate vehicles, and dedicated law enforcement to respond and assist. Because of reduced shoulder width in some locations, the managed lane along with the adjacent general purpose lane may need to be closed at times depending on the severity of the incident and the safety and mobilization needs of first responders. Alternately, some DOTs do not routinely open up the managed lanes to general purpose traffic to bypass an incident, but they may allow it if the incident is determined to be significant or if they are directed by public safety officials.

The goal for FDOT is to clear the incidents within the managed lanes in 30 minutes or less in order to keep the system open. Based on prior experience, if it takes longer than 30 minutes to clear, the system will likely not recover and result in congestion for an extended period of time. During the interview with MnDOT, it was stated that they use different policies for handling incidents. In most cases, MnDOT disallows using MnPASS lanes for incident management, but it can and has been used in severe incidents to keep traffic moving. If there is an incident in the HOT lanes, the price does not change (uses same algorithm); however, refunds can be provided to users, if requested. In the case of emergency situations or MnDOT construction, there is consideration for potential refunds to customers. For facilities operated by a concessionaire such as Transurban, VDOT works closely with the concessionaire to respond to and clear incidents.

3.5.6. Operations and Maintenance

One common theme between all the interviewed DOTs is the use of a portion of tolling revenues for operations and maintenance. In some cases, DOTs have specific teams whose efforts are focused on the managed lane corridors, independent from maintenance teams for the other freeways and state roadways. Maintenance items include Intelligent Transportation Systems structure management (technical issues), pavement rehabilitation, damage restoration (due to crashes), restriping and clearing of debris.

One major advantage to managed lane facilities is that the maintenance is factored into the roadway lifecycle. This combined with revenue management allows the facility owner more flexibility in planning for maintenance events. In addition, should reconstruction or major activities be required, these can be scheduled in advance with dedicated revenue from tolling.

3.5.7. Additional Infrastructure/Toll Equipment Considerations

Most managed lane facilities utilize electronic toll collection as well as traffic information systems which make variable, real-time toll pricing of vehicles possible. While MassDOT has an existing toll system, there are several areas where capital investment would be needed to manage and operate a manage lane facility. They include the following:

- **Advance Changeable Message Signs** – Information on price levels and travel conditions is normally communicated to motorists via changeable message signs well upstream of the ingress point to the managed lane. They provide potential users with the information they need to decide whether or not to use the managed lanes or the adjacent general purpose lanes that may be congested during peak periods. The active toll rates would need to be conveyed to the motorists via variable message signs well upstream of the ingress point of the managed lane.
- **Volume and Speed Detection** – Depending on the pricing structure of the managed lane, volume and/or speed data would be required at various points along the corridor, both in the managed lane and for the general purpose lanes. Federal reporting requirements may warrant additional traffic data collection and traffic information

systems along the whole corridor. Power and communications to the devices would be required.

- **New Toll Gantries/Equipment** – Depending on the number of ingress and egress points of the managed Lane, one or more toll gantries would be required. In some managed lane facilities including HOT lanes, FHWA requires that electronic toll collection is utilized so only motorists with transponders are using the lane. This transponder also allows for drivers to self-indicate whether they are carrying additional passengers to meet the occupancy requirements to ride in the lane for free. Enforcement decisions will dictate the need for additional equipment (i.e., infrared cameras, etc.). Relative to the existing I-93 HOV lane, only ingress and egress point are provided along each corridor and thus only one toll gantry would be needed. If the I-93 SB HOV/Carpool lane north of Boston is extended in a northerly direction, and additional ingress/egress points are introduced, the number the tolling points would also increase.

3.5.8. Toll Pricing and Revenue

In order to maintain reliable travel conditions within new managed lane facilities, toll levels need to be set to limit the number of users by willingness to pay. Per federal guidelines, a managed lane facility fee structure may be fixed, varying by time of day or dynamic, varying in response to real-time traffic conditions. In either case, higher tolls are charged during peak demand periods with information on toll rates being conveyed to motorists through variable message signs located near entry points. It should be noted that if the real time adjustment of toll rates and required occupancy rates is needed on MassDOT managed lane facilities, a capital investment would be required to procure a new managed lane tolling software platform to provide this capability. It is envisioned that this new managed lane tolling module could build upon the existing AET tolling system that MassDOT currently uses but additional development and integration would be required to implement a managed lane scenario. MassDOT has historically had a strong market share in the metro-Boston region, with EZPass penetration rates between 85 and 90 percent. This market penetration and the acceptance of electronic tolling in the Northeast Region as a whole, can prove to be an advantage for public acceptance.

FDOT, MnDOT, VDOT, CDOT, UDOT, GDOT/SRTA and WSDOT use dynamic pricing in their facilities to manage congestion by using an algorithm that analyzes (in real time) parameters like speed and volume to adjust the pricing up or down in order to maintain a minimum average speed of 45 miles per hour (mph). MnDOT indicated that they strive for a minimum of 50 to 55 mph. Several other states, including HCTRA, FDOT, MDTA and CDOT, utilize time of day variable pricing –where dynamic pricing is either not applicable or the facility is not ready for implementation yet. Pricing strategies like this are easier to implement/design, as the pricing is programmed into the system based on time of day—i.e., peak periods from 5 a.m. to 9 a.m. are priced higher than off peak periods. The pricing does not rely on facility traffic data sensors and does not change based on real-time traffic conditions.

Another strategy discussed is the combination of fixed variable pricing and dynamic pricing within the same managed lanes system. FDOT described this hybrid approach when opening and operating a facility with a fixed variable pricing scheme for a period of time while customers get accustomed to using the managed lanes, and the variable pricing algorithm is being tested and fined-tuned in the background until the system is ready to be implemented.

The minimum and maximum cost of the tolls charged by agencies varied from system to system. As noted previously, some DOTs described full autonomy in allowing the algorithm to dictate how high the tolls could be based on the congestion, while others were more restrictive due to political or community opposition to tolls.

Typically, as a condition of the federal approval process, pricing algorithms need to be designed to achieve an approximate travel speed of 45 mph speed in the lanes for 90 percent of the time. The algorithms to meet this threshold are based on the existing capacity of the lane and the expectation of a certain percentage of single occupant vehicles switching to the lane based on the toll rates established. States submit annual reporting on these metrics.

Again, distribution and use of the revenues received from tolls collected also varied from agency to agency. Predominantly, the tolls were first allocated to pay for the capital cost of the managed lanes, then operations and maintenance, and finally towards improvements to transit corridors or express bus transit service that uses the managed lanes. It is important to note that one installation pledged a fixed dollar amount towards transit improvements at the outset of the project. MassDOT may not be limited to revenue allocations prescribed by other agencies, but could, in conjunction with federal and local partners, formulate an approach that works for them.

Similar to the former Massachusetts Turnpike, where toll revenue collected on the roadway must stay on the roadway, HCTRA indicated that funds must stay in the county. This consideration should be remembered if the Massachusetts Turnpike is considered for a managed lane treatment, as the Western Turnpike funds must currently be pledged for the WT roadway, the MHS toll revenue for the MHS, etc. unless legislation is changed.

3.6. Top Three Key Success Factors to Consider from Sister Agencies

In addition to the planning, design and operations considerations listed above, the sister facility owners were asked what they would consider as their top three factors for success. The results were varied, indicating that each region has its own set of priorities and objectives. The results are summarized in Table 4.

Table 4 - Top Three Success Factors for Managed Lanes – per DOT Interviews

ML Owner and Project	Early Stakeholder Support	Extensive Planning/ Traffic Analysis	Coordinate w/ Transit	Carefully Consider Ingress/ Egress	Good Public Outreach	Be Ready to Adjust	Ensure GPL Operation
CDOT *I-25 US 36; I-70 Express Lanes*	●	●	●				
WSDOT *SR-167 HOT*	●	●			●		
MnDOT *I-394 HOT Lanes*	●	●	●				
HCTRA *IH-10 Katy Tollway*	●		●		●		
VDOT *I-395/ I-95 Express Lanes*	●	●	●				
FDOT D6 *I-95 Express*	●	●	●				
FDOT D4 I-75/I-595 Express				●		●	●
RCTC, CA *I-15 Express*	●			●	●		
UDOT *I-15 Express*		●		●		●	
GDOT *I-85 HOT*	●	●		●			
MDTA *I-95 Express Lanes*	●	●		●	●		

4. Initial Assessment of Candidate Corridors

This chapter describes the approach to identifying which corridors or roadways are the most worthwhile to consider for a managed lane based on the severity and persistence of recurring congestion, as well as other factors such as overall implementability and person-carrying capacity. The list of corridors that were considered included all the corridors analyzed in the Congestion Report, specifically ones with an NHS designation and located largely within the I-495 beltway around Greater Boston as are shown in Figure 19. There are 26 such facilities, but many of them are not suitable for a managed lanes application, either because they do not meet the basic congestion thresholds or do not have the physical characteristics to support a successful managed lane operation. Therefore, a two-stage screening process was developed to eliminate those roadways that are not suitable for managed lanes deployment and to evaluate the suitability of the remaining potential candidates for a managed lane treatment.

Figure 19 - Study Network

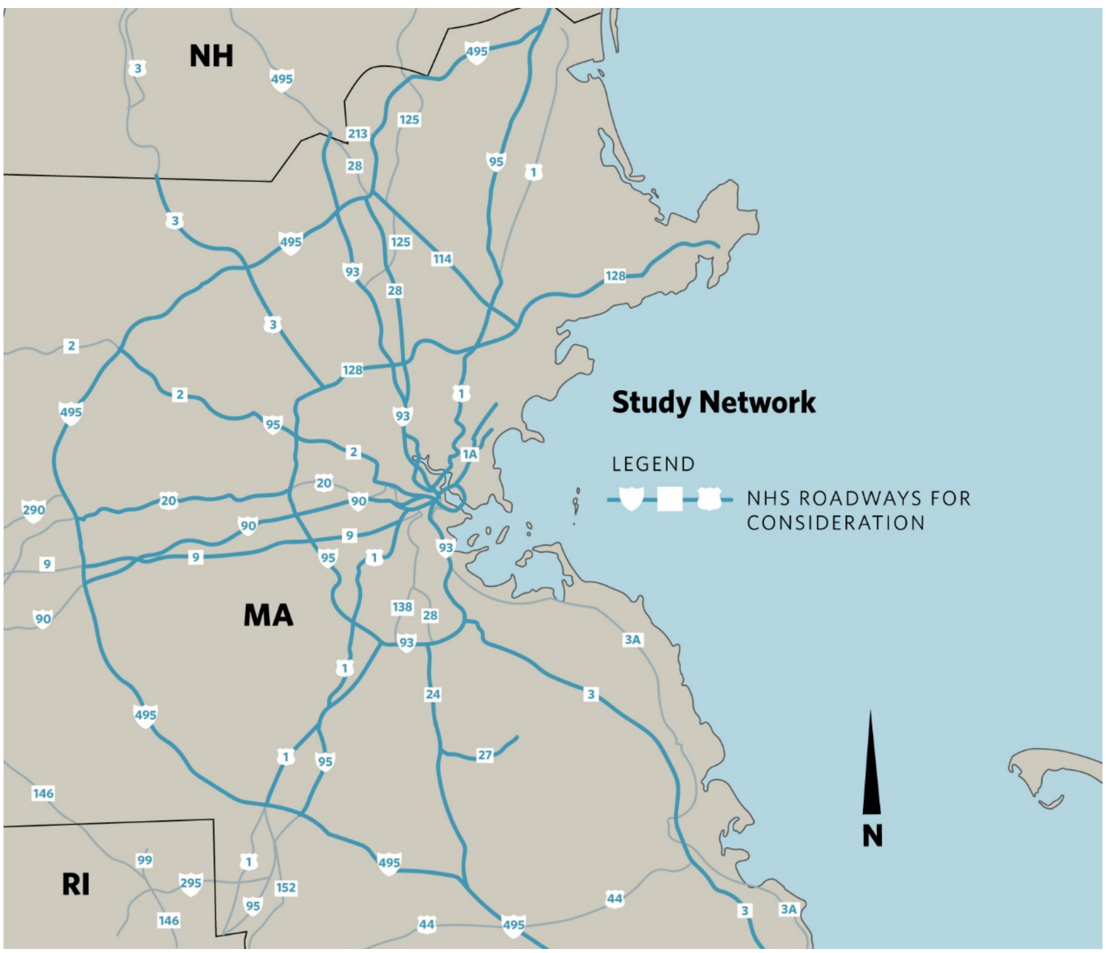
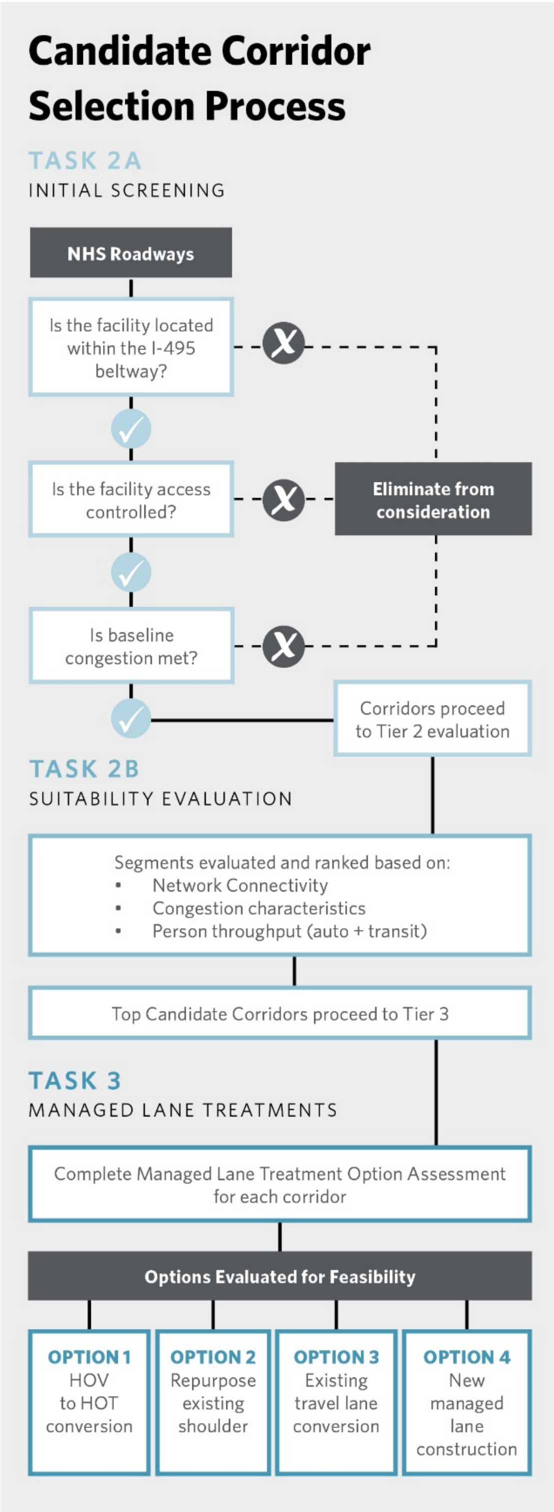


Figure 20 - Candidate Corridor Selection Process



HDR's screening methodology uses a three-level filtering process. The first level of screening (Tier 1) relies on a high level "Fatal Flaw" approach using qualitative, rather than quantitative, screening factors. Those travel corridors that did not meet the thresholds set forth in Tier 1 were eliminated from further analysis.

Tier 2 evaluates and ranks the remaining corridors using a combination of available qualitative and quantitative criteria as well as an overall score. The corridors that emerge as viable candidates within the Tier 2 screening will be further assessed in Tier 3 (Study Task 3) to determine which type of managed lane treatment is most appropriate.

Figure 20 outlines the multi-tiered screening process.

4.1. Tier 1 Screening

Two initial criteria were used to eliminate unviable corridors within the study network of NHS roadways within the I-495 beltway: Access Control and Baseline Congestion.

4.1.1. Access Control

In managed lanes operations, limiting access traditionally has been applied as a means of reducing the number of entry and exit conflict points and to minimize turbulence in traffic flow. Roadways with unlimited access, traffic signals, multiple curb cuts, and lane-drops are therefore considered unsuitable for managed lanes treatment. Since the main purpose of a managed lane is to consistently offer a prescribed level of operating service with a high degree of reliability, only access-controlled facilities of higher functional classification are typically suitable for managed lane applications. The first level screening involved eliminating all facilities that do not have adequate access control. This resulted in 11 corridors being carried forward.

4.1.2. Baseline Congestion

The presence of recurring traffic congestion is a fundamental prerequisite for considering managed lanes as a congestion management strategy. According to NCHRP Report 835 titled “Guidelines for Implementing Managed Lanes,” recurring congestion (level of service D or worse, or average travel speeds below 30 to 35 mph) within a corridor for a significant period of time is one of the most important attributes that is critical to the success of managed lanes.

A baseline congestion threshold was used as a requirement for a corridor to be considered for managed lane deployment. If the average travel times during peak periods are at least 50 percent longer than free flow travel times, that corridor was designated as a congested corridor and considered to have met the basic requirement for managed lanes strategy. Of the 12 access-controlled corridors, 3 of them did not meet the threshold for Baseline Congestion and were therefore eliminated. MA-128 north of Peabody, the Lowell Connector, as well as MA-213 did not meet the minimum congestion criteria over an adequate length of the corridor, as the congestion experienced on these facilities is largely related to terminus interchange or intersection operations that would not benefit directly from a managed lane along its length.

As a result of the initial screening process, 9 corridors emerged out of Tier 1 screening and were advanced to Tier 2 for further detailed analysis. These corridors are presented in Table 5. The table also includes all 52 corridors that were included within the Congestion Report and summarizes which corridors were eliminated for each screening criteria.

Table 5 - Initial Screening Results

Roadway Name	South or West Endpoint	North or East Endpoint	Inside I-495?	NHS Facility?	Access Controlled?	Baseline Congestion?
I-495	MA-25, Wareham	I-95, Salisbury	Yes	Yes	Yes	Yes
I-95/MA-128	I-495, Mansfield	I-495, Amesbury	Yes	Yes	Yes	Yes
I-93	I-95/MA-128, Canton	NH State Line, Methuen	Yes	Yes	Yes	Yes
I-90	NY State Line, West Stockbridge	MA-1A, Boston	Yes	Yes	Yes	Yes
US-1	I-495, Plainville	I-95/MA-128, Lynnfield	Yes	Yes	Yes	Yes
MA-2	Moore Street, Erving	Memorial Drive, Cambridge	Yes	Yes	Yes	Yes
MA-24	Rhode Island State Line, Fall River	I-93, Randolph	Yes	Yes	Yes	Yes
MA-3	US-6	I-93, Braintree/Quincy	Yes	Yes	Yes	Yes
US-3	I-95/MA-128, Burlington	NH State Line, Tyngsborough	Yes	Yes	Yes	Yes
MA-128	I-95, Peabody	MA-127, Gloucester	Yes	Yes	Yes	NO
MA-213	I-93, Methuen	I-495, Methuen	Yes	Yes	Yes	NO
Lowell Connector	US-3, Chelmsford	Gorham Street, Lowell	Yes	Yes	Yes	NO
MA-1A	I-93, Boston	MA-60, Revere	Yes	Yes	NO	
MA-9	US-7, Pittsfield	Copley Square, Boston	Yes	Yes	NO	
US-20	I-84, Sturbridge	I-95, Waltham	Yes	Yes	NO	
MA-114	I-495, Lawrence	MA-128, Peabody	Yes	Yes	NO	
US-44	Rhode Island State Line, Seekonk	MA-3, Plymouth	Yes	Yes	NO	
MA-28	Leverett Circle, Boston	I-95/MA-128, Reading	Yes	Yes	NO	
MA-125	Industrial Avenue, Haverhill	I-495 Haverhill	Yes	Yes	NO	
MA-107	Bell Circle, Revere	Summer Street, Lynn	Yes	Yes	NO	
Memorial Drive	Eliot Bridge, Cambridge	Main Street, Cambridge	Yes	Yes	NO	
MA-27	MA-24, Brockton	West Street, Whitman	Yes	Yes	NO	
Boston-Providence Turnpike	I-95/MA-128, Dedham	Bridge Street, Boston	Yes	Yes	NO	
MA-203	Blue Hill Avenue, Boston	I-93, Boston	Yes	Yes	NO	
Storrow Drive	BU Bridge, Boston	I-93, Boston	Yes	Yes	NO	
MA-60	MA-1A, Revere	Bell Circle, Revere	Yes	Yes	NO	
Soldiers Field Road	Eliot Bridge, Boston	BU Bridge, Boston	Yes	NO		
Centre Street	VFW Parkway, Boston	Arborway, Boston	Yes	NO		
Industrial Avenue	I-495, Haverhill	MA-125, Haverhill	Yes	NO		
Jamaicaway	Arborway, Boston	MA-9, Boston	Yes	NO		
Morrissey Boulevard	I-93, Boston	Day Boulevard, Boston	Yes	NO		
Riverway	MA-9, Boston	Park Drive, Boston	Yes	NO		
VFW Parkway	Bridge Street, Boston	Centre Street, Boston	Yes	NO		
I-190	I-290, Worcester	MA-2, Leominster	NO			
I-195	Rhode Island State Line, Seekonk	I-495, Wareham	NO			
I-290	I-395, Auburn	Washington Street, Hudson	NO			
I-291	I-90, Chicopee	I-91, Springfield	NO			
I-295	RI State Line, North Attleborough	I-95, Attleboro	NO			
I-391	I-91, Chicopee	South Street, Holyoke	NO			
I-395	Connecticut State Line, Webster	I-290, Auburn	NO			
I-84	Connecticut State Line, Holland	I-90, Sturbridge	NO			
I-91	CT State Line, Longmeadow	VT State Line, Bernardston	NO			
MA-116	MA-9, Hadley	North Hadley Road, Hadley	NO			
MA-146	Rhode Island State Line, Millville	MA-290, Worcester	NO			
MA-25	MA-28, Bourne	I-495, Wareham	NO			
MA-28	Bourne Bridge, Bourne	MA-6A, Orleans	NO			
MA-57	South Westfield Street, Agawam	US-5, Agawam	NO			
MA-6	MA-3, Bourne	Cranberry Highway, Eastham	NO			
MA-79	MA-24, Fall River	I-195, Fall River	NO			
US-5	I-91, Springfield	Morgan Road, West Springfield	NO			
US-6	US-6 BYP, Wareham	MA-6A, Orleans	NO			
US-7	Connecticut State Line, Sheffield	Brodie Mountain Road, Pittsfield	NO			

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The remaining 9 corridors were divided into multiple segments based on roadway characteristics and major interchange points. For example, if a facility provided access into Boston from the north and from the south as I-93 does, then the two segments were analyzed separately. Similarly, if the level of congestion between two segments differed, then these segments also were separated for the analysis. In some cases, such as I-495 and I-95 north of Peabody, portions of the overall corridor were removed based on it not meeting baseline congestion criteria. Within the subsequent stage of evaluation in Task 3, some segment limits also were adjusted based on other geometric, operational, or environmental considerations, or to fill a potential gap in a network of managed lanes. For Tier 2 screening, 13 corridor segments were developed.

Figure 21 and Table 6 summarize the corridor segments that were analyzed in the Tier 2 Suitability Evaluation.

Figure 21 - Corridor Segments for Further Analysis

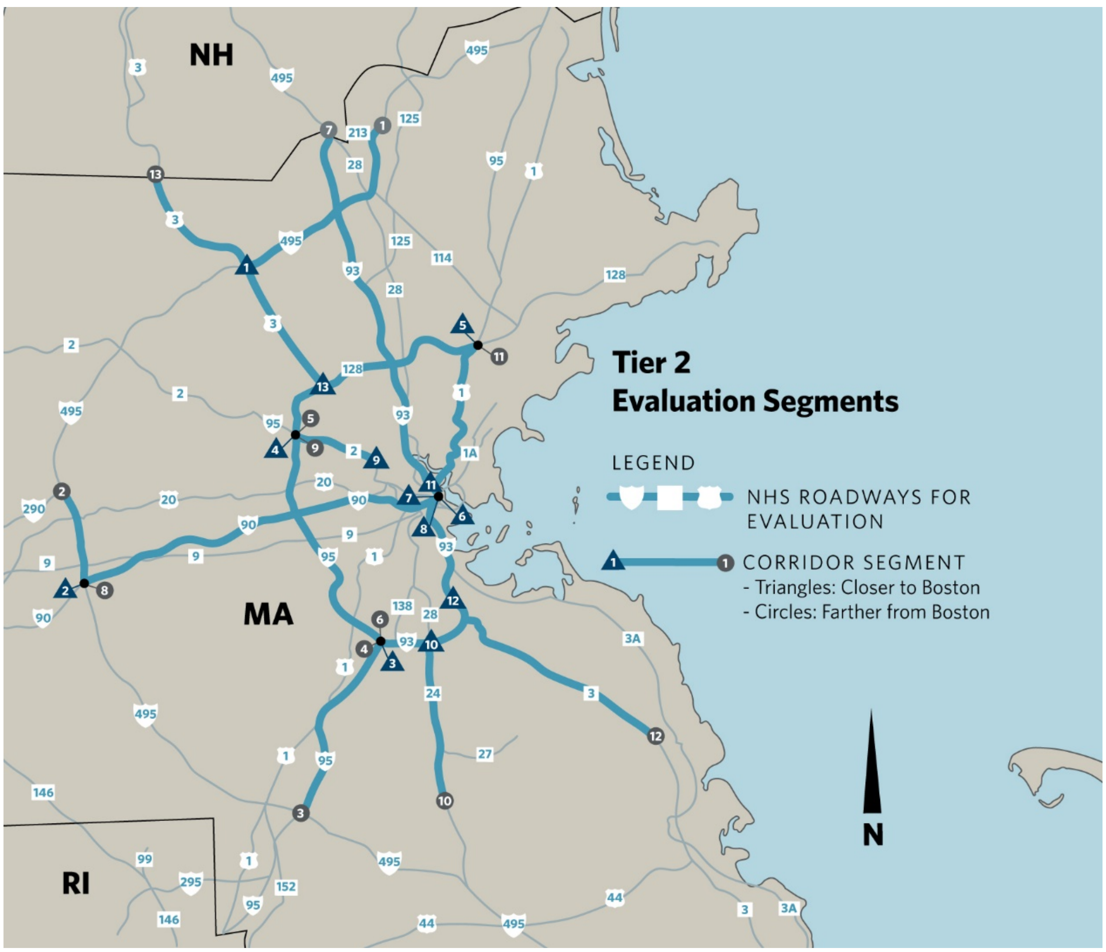


Table 6 - Corridor Segment Limits

Roadway Name/Segment	South or West Endpoint	North or East Endpoint
I-495	MA-25 (Wareham)	I-95 (Salisbury)
1	US-3 (Lowell)	MA-213 (Methuen)
2	I-290 (Marlborough)	I-90 (Westborough)
I-95	I-495 (Mansfield)	I-93/I-95 (Canton)
3	I-495 (Mansfield)	I-93/I-95 (Canton)
I-95/MA-128	I-93/I-95, (Canton)	I-95/MA-128 (Peabody)
4	I-93/I-95 (Canton)	MA-2 (Lexington)
5	MA-2 (Lexington)	I-95/MA-128 (Peabody)
I-93	I-95/MA-128 (Canton)	NH State Line (Methuen)
6	I-95/MA-128 (Canton)	I-90 (Boston)
7	US-1 (Boston)	NH State Line (Methuen)
I-90	I-495 (Westborough)	MA-1A (Boston)
8	I-495 (Westborough)	MA-1A (Boston)
MA-2	I-495 (Boxborough)	Alewife Brook Pkwy (Cambridge)
9	I-95 (Lexington)	Alewife Brook Pkwy (Cambridge)
MA-24	MA-27 (Brockton)	I-93 (Randolph)
10	MA-27 (Brockton)	I-93 (Randolph)
US-1	I-495 (Plainville)	I-95/MA-128 (Peabody)
11	I-93 (Boston)	I-95/MA-128 (Peabody)
MA-3	MA-139 (Pembroke)	I-93 (Braintree)
12	MA-139 (Pembroke)	I-93 (Braintree)
US-3	I-95/MA-128 (Burlington)	NH State Line (Tyngsborough)
13	I-95/MA-128 (Burlington)	NH State Line (Tyngsborough)

Corridors that were not considered viable for a managed lane treatments may be suitable for other congestion relief strategies outlined in the Congestion Report, including addressing local and regional bottlenecks, actively managing traffic operations through signal operations enhancements, enhancing transit service access and reliability, and investing in infrastructure that diversifies transportation options available for existing single occupant vehicle drivers. Several corridors that were not advanced have ongoing or completed congestion mitigation initiatives which are further discussed within Section 5.6.

4.2. Tier 2 Screening

Using a combination of qualitative and quantitative criteria, the 13 corridor segments that emerged from Tier 1 were evaluated and scored in terms of their suitability for managed lanes.

Several data sources were reviewed to analyze the existing traffic conditions along corridor segments and apply relative scoring as part of the evaluation:

- Traffic and travel time data used in the Congestion Report
- Long Range Transportation Plan and Needs Analysis (CTPS)
- Regional Integrated Transportation Information System
- MassDOT Transportation Data Management System
- Ridership Data from MBTA

The following six evaluation criteria were selected for Tier 2 screening.

4.2.1. Network Connectivity

For managed lanes to be successful, the proposed corridor will either need to link major origins and destinations directly or provide good connectivity to other facilities that offer such linkages. Segments that end in a bottleneck or carry trips that do not have common destinations usually do not perform well as managed lanes. Bottlenecks were identified using congestion information as well as a review of lane geometry at the end of each segment; end points with high congestion or pinch points generally scored lower than corridors that end in more free-flow conditions. Origin-destination information from the Regional Integrated Transportation Information System database was used to understand where users of a corridor may have common destinations; if a large percentage of vehicles at the origin of a segment were still travelling through the corridor at the mid-point, then the corridor scored higher.

4.2.2. Level of Congestion

The level of congestion in the corridor, among other attributes, provides a good indication of how well a managed lane strategy might work in addressing the recurring congestion problems. The congestion level can be quantified using an index called the travel time index. This index is a measure of average conditions that tells one how much longer, on average, travel times are during congestion compared to during light traffic. However, it should be noted that priced managed lane treatments may not be as successful in changing travel behavior on corridors with consistently high levels of congestion for prolonged periods, and therefore, other aspects of the congestion on each corridor were also reviewed, including travel time variability. Corridors with higher and more variable levels of congestion provide a greater potential to achieve travel time savings through a managed lanes installation.

4.2.3. Travel Time Variability

The Congestion Report recognizes the most frustrating aspect of traffic congestion is that people are often unsure of how long it will take to get to their destinations day after day. The lack of consistency and dependability in travel times can be measured in terms of reliability. Corridors where travel times vary significantly may be potential candidates for managed lane application. The reliability factor is measured using an index called the Planning Time Index, which is a ratio of the 95th percentile travel time during peak periods to the free flow travel time. This index represents how much total time a traveler should allow to ensure on-time arrival.

4.2.4. Person Throughput

Person throughput is an indication of the overall productivity of the corridor. In addition to improving travel time reliability, managed lanes have the potential to incentivize shared rides, increase transit usage and offer some relief on parallel corridors, thereby optimizing the overall benefits for all users of the facility. Person throughput was estimated by applying average auto occupancies to vehicular traffic across all lanes and adding projected transit ridership resulting from a potential managed lane application.

4.2.5. Traffic Growth

Future traffic levels on candidate corridors must be considered in evaluating the suitability of managed lanes. Traffic on different corridors may grow at different rates based on where the population and employment densities are projected to grow. A corridor that is at capacity today but is projected to grow significantly in the future and lead to severe congestion would be an ideal candidate for a managed lane application. Historical average daily traffic volumes were reviewed for each corridor segment between 2010 and 2018 to determine whether the average annual growth rate was increasing faster along certain corridors as compared to others.

4.2.6. Bus Service

Managed lanes can be used to significantly improve transit level of service by offering faster and more reliable travel times as well as more frequent bus service. Improved transit service has the potential to increase ridership both within the corridor and along adjacent transit routes, which in turn, can increase total person throughput. Therefore, the level of current bus service, including MBTA routes, private regional coaches, and shuttle services, was considered in the evaluation process. Future bus service could be added to any managed lane facility; however, routes with existing service and ridership were considered more suitable at this stage.

4.3. Scoring Methodology and Results

Each corridor segment was evaluated for managed lanes suitability on the basis of each of the six criteria discussed above. Table 7 presents a summary of the criteria and scoring metrics. A score of 0 (less suitable), 1 (adequate), or 2 (more suitable) was assigned to each criterion based on a quantitative analysis as well as a qualitative assessment. The total score for each corridor was also computed to determine which corridors to move forward to the next stage of analysis. Table 8 presents the results of the scoring analysis.

Table 7 - Corridor Evaluation Scoring Criteria

No.	Criteria	Considerations	Scores 0 if	Scores 1 if	Scores 2 if
1	**Network Connectivity**	Links popular/common origins and destinations. Does the segment end in a bottleneck?	Segment ends in a bottleneck or no clear origin-destination pair	Strong origin-destination pair at beginning and end of segment. Potential bottleneck at terminus	Strong origin-destination pair at beginning and end of segment. No major bottleneck at terminus
2	**Level of Congestion**	Based on Congestion Report metrics	If Travel Time Index is <1.5	If Travel Time Index is >1.5 and < 2.0	If Travel Time Index is >2.0
3	**Travel Time Variability**	Potential to improve reliability. Are day-to-day travel times inconsistent?	If Planning Time Index is <1.25	If Planning Time Index is >1.25 and < 3.0	If Planning Time Index is >3.0
4	**Person Throughput**	Potential for increasing person throughput, including auto and transit users	If the estimated increase in person throughput is under 5 %	If the estimated increase in person throughput is >5% but <=15%	If the estimated increase in person throughput is >15%
5	**Traffic Growth**	Is the traffic on this corridor growing based on past trends (2010-2018)?	Annual growth rate in traffic less than 1%	Annual growth rate in traffic between 1 and 2%	Annual growth rate in traffic greater than 2%
6	**Bus Service**	Routes that existing bus service utilizes.	Existing bus trips <20 per day	Existing bus trips >20 and <100 per day	Existing bus trips >100 bus trips per day

Table 8 - Summary of Scores for Corridor Segments

	Segment Limits												
	I-495		I-95	I-95 / MA-128		I-93		I-90	MA-2	MA-24	US-1	MA-3	US-3
Criteria	US-3 and MA-213 (Segment 1)	I-290 and I-90 (Segment 2)	I-495 and I-93/I-95 (Segment 3)	I-95/I-93 and MA-2 (Segment 4)	MA-2 and US-1 (Segment 5)	I-95/MA-128 and I-90 (Segment 6)	US-1 and NH State Line (Segment 7)	I-495 and MA-1A (Segment 8)	I-95 to Alewife Brook Pkwy (Segment 9)	MA-27 and I-93 (Segment 10)	I-93 and I-95/MA-128 (Segment 11)	MA-139 and I-93 (Segment 12)	I-95/MA-128 and NH SL (Segment 13)
Network Connectivity	1	2	1	2	2	1	1	1	1	2	1	2	1
Level of Congestion	1	1	2	2	2	2	2	2	2	2	2	2	2
Travel Time Variability	1	1	1	1	2	2	1	1	1	1	1	1	1
Person Throughput	1	1	1	1	1	2	2	2	1	1	2	2	2
Projected Traffic Growth	0	0	2	2	1	1	2	1	1	1	0	0	2
Transit	0	0	0	1	1	2	2	2	2	1	2	1	1
TOTAL SCORE	4	5	7	9	9	10	10	9	8	8	8	8	9

Scoring

More Suitable	2
Adequate	1
Less Suitable	0

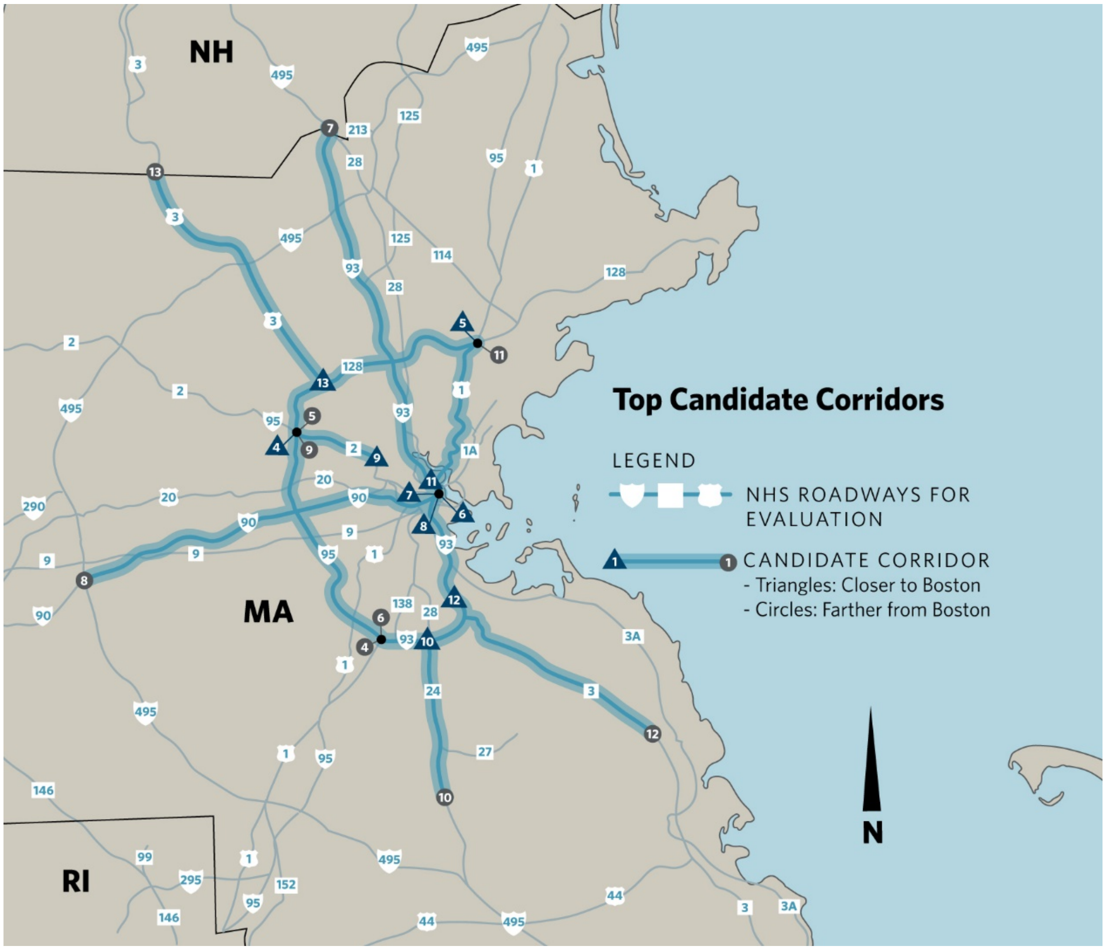
From the evaluation, several corridors have been deemed more feasible to move on to further study for the implementation of one or more managed lane treatments. The resulting candidate corridors will be carried forward in the analysis to determine which managed lane treatment types are possible for each: HOV to HOT conversion, repurposing of existing shoulders, conversion of existing travel lanes, or construction of new managed lanes. In the next stage of analysis, segment limits may be adjusted.

A score of 8 or above was identified as adequate to consider managed lanes treatments on the corridor, while a score of less than 6 removed a corridor from further consideration. Corridors with a score of 6 or 7 could be suitable for managed lanes treatments or other congestion management strategies in the future but are not recommended to advance at this time. Additional strategies include the evaluation and design of interchange bottleneck reductions treatments like the planned improvements to the I-90/I-495 interchange in Hopkinton (MassDOT Project 607977, advertisement date 10/31/2021) and recently completed ones at the I-495 and US 3 interchange in Chelmsford. In addition the regional Shared Travel Network Study will also be identifying opportunities to enhance multi-modal connections throughout the regional roadway network to existing and proposed Park and Rides.

The resulting candidate corridors for managed lanes are shown in Figure 22 and include the following:

- I-95/MA-128, between I-95/I-93 and MA-2 (Segment 4)
- I-95/MA-128, between MA-2 and US-1 (Segment 5)
- I-93, between I-95/I-93 and I-90 (Segment 6)
- I-93, between US-1 and NH State Line (Segment 7)
- I-90, between I-495 and MA-1A (Segment 8)
- MA-2, between I-95 to Alewife Brook Parkway (Segment 9)
- MA-24, between MA-27 and I-93 (Segment 10)
- US-1, between I-93 and I-95/MA-128 (Segment 11)
- MA-3, between MA-139 and I-93 (Segment 12)
- US-3, between I-95/MA-128 and NH State Line (Segment 13)

Figure 22 - Top Candidate Corridors



5. Managed Lane Treatment Options for Candidate Corridors

The top ten candidate corridors selected in Chapter 4 were evaluated for the likely success or failure of the four managed lane treatment types: the conversion of existing HOV lanes into HOT lanes, the repurposing of existing roadway shoulders into managed lanes, the conversion of existing travel lanes into managed lanes and the construction of new managed lanes along existing roadways. For the purpose of the analysis, some of the corridors were split into shorter segments based on logical demarcation points such as major interchanges or significant changes in corridor characteristics. The corridor sub-segment limits and general roadway characteristics are summarized in Table 9. This allows for the possibility to install managed lanes on segments of the corridor, even if full corridor installation is not feasible at the same time.

In order to assess the corridor sub-segments a desktop review using ArcGIS compiled background open source data including parcel/right-of-way mapping, corridor mile posts, bridge identification and aerial measured roadway dimensions was performed.

Table 9 - Top Candidate Corridors Segmentation

Corridor	Sub-Segment	South or West Endpoint	North or East Endpoint	Existing Typical Section
I-95/MA-128 *(Southwest)*	**4A**	I-95 (Canton)	MA-9 (Wellesley)	4- 12' GPLs in each direction with 10-12' shoulders with a median jersey barrier. Approximately 3.5 mi of separate NB and SB corridors between US 1 and Great Plain Ave, and at the Highland Ave interchange.
	4B	MA-9 (Wellesley)	MA-2 (Lexington)	4- 12' GPLs in each direction with 10-12' shoulders with a median jersey barrier. There is a 1 mi segment through the I-90 interchange with 3 GPLs with offset limits for NB and SB.
I-95/MA-128 *(Northwest)*	**5A**	MA-2 (Lexington)	I-93 (Woburn)	4- 12' GPLs in each direction with 10-12' shoulders with a median jersey barrier.
	5B	I-93 (Woburn)	US-1 (Peabody)	3- 12' GPLs in each direction with 2-12' shoulders with median jersey barrier. It includes approximately 2,500 feet of independent NB and SB corridors between MA-28 and Parker Rd.

Corridor	Sub-Segment	South or West Endpoint	North or East Endpoint	Existing Typical Section
I-93 *(South)*	**6A**	MA-3/I-93 (Braintree)	I-90 (Boston)	4- 11-13’ GPLs with approx. 2’ shoulders in each direction. Between southern terminus and just north of Morrissey Blvd. a zipper lane operates to provide additional HOV thru lane in peak hour direction. The HOV lanes are 12’ and are separated by 2’-9” movable barriers with a 3’ to 6’-6” fixed concrete barrier separating the north and southbound directions.
	6B	I-95 (Canton)	MA-3/I-93 (Braintree)	4-12-foot travel lanes in each direction with 10-12-foot outside and 2-foot inside paved shoulders. It includes independent NB and SB corridors. There is approximately 2.5 miles with median separation of jersey barriers from I-95 to east of Ponkapoag Trail with 10-11 foot inside paved shoulders.
I-93 *(North)*	**7A**	I-495 (Andover)	New Hampshire SL (Methuen)	3-12’ GPLs in each direction with 10-12’ outside and 4-6’ inside shoulders with approximately 20-30’ grassed median. Peak hour shoulder use is permitted between Wilmington/ Tewksbury and Andover/Methuen town lines.
	7B	I-95/MA-128 (Woburn)	I-495 (Andover)	3-12’ GPLs in each direction with 10-12’ outside and 4-6’ inside shoulders with approximately 20-30’ grassed median north of MA 125. From north of MA 125 it transitions to 4-12 GPLs. Peak hour shoulder use is permitted between MA 125 and I-495. It includes independent NB and SB corridors through the MA 125 interchange.
	7C	US-1 (Boston)	I-95/MA-128 (Woburn)	4-12’ GPLs in each direction with 10-12’ outside and 4-6’ inside shoulders with approximate 20 to 30’ grassed/asphalt/ concrete median width north of MA 28 in Somerville. From MA 28 in Somerville to the south it reduces to 3 GPLs NB with 6-7’ inside shoulders; and 2 GPL and 1 HOV SB with a 4’ buffer and 1’ inside shoulder with median jersey barrier. Tobin Bridge section extends from south of Cambridge St. to the Zakim Bridge.
I-90	**8A**	I-495 (Hopkinton)	I-95/MA-128 (Newton)	3-12’ GPLs in each direction with 10-12’ shoulders with median jersey barrier. There is a 0.75 mi segment through the I-95 interchange with 2 GPLs.

Corridor	Sub-Segment	South or West Endpoint	North or East Endpoint	Existing Typical Section
	8B	I-95/MA-128 (Newton)	MA-1A (Boston)	3-12’ GPLs in each direction with 2-4’ shoulders and median jersey barrier west of Newton Corner. East of Newton Corner it transitions to 4-12’ GPLs.
MA-2	**9**	I-95/MA-128 (Lexington)	Alewife Brook Pkwy (Cambridge)	3-12' GPLs in each direction with a 10-12’ outside shoulder and 2-4’ inside paved shoulder and approximately 50' grassed median west of MA-4. East of MA-4 the roadway transitions to 4-12' travel lanes in each direction with 10-12’ outside shoulder and 2-4’ inside shoulders with a narrow asphalt/concrete median and double-faced guardrail. East of Lake Street in Arlington, the road transitions to 2-12' travel lanes in each direction on the approach to Alewife Brook Parkway.
MA-24	**10**	MA-27 (Brockton)	I-93 (Randolph)	3-12’ GPLs in each direction with 10-12' outside and 2-5' inside shoulders with approximately 30-37' grassed median north of Harrison Blvd. South of Harrison Blvd there is a median jersey barrier separation. At the northern limits it includes separate NB and SB system to system interchange ramps with I-93 for 0.67 mi.
US-1	**11A**	MA-60 (Revere)	I-95/MA-128 (Peabody)	2 to 3-12’ GPLs in each direction with 1-10’ outside shoulder and 1-5’ inside shoulder. The median varies from jersey barrier, wide grassed median, and narrow asphalt/grassed with double faced guardrail median. Except through the MA-129 interchange, 3 GPLs are provided between I-95/MA 128 and MA-99, and 2 GPLs from MA-99 to MA-60. There is an independent NB and SB corridor south of MA-128 for 0.5 miles and within the MA-99 interchange. Only 2 GPLs are provided through the MA-129 interchange. This segment is not limited access and it has intermittent side streets and driveway connections along with sidewalks.
	11B	I-93 (Boston)	MA-60 (Revere)	3-12' GPLs in each direction with 2'-10' shoulders with median jersey barrier. Approximately 2 miles of the corridor is on Tobin Bridge from south of the MBTA Silver Line in Chelsea to the City Square Tunnel in Boston. At the southern limits it includes separate NB and SB system to system interchange ramps with I-93 through the City Square Tunnel.

Corridor	Sub-Segment	South or West Endpoint	North or East Endpoint	Existing Typical Section
MA-3	**12A**	MA 139 (Pembroke)	MA-18 (Weymouth)	2-12’ GPLs in each direction with a 10-12’ outside and 4’ inside shoulders with an approximate 35’-100’ wide grassed median. Peak hour shoulder use is permitted in this section. From Oak St in Hingham to Main St/MA-18 in Weymouth there are 3 SB GPLs. It includes independent NB and SB corridors for approximately 1.25 miles south of Main St/MA-18
	12B	MA-18 (Weymouth)	I-93 (Braintree)	3-12’ GPLs in each direction with 12’ outside shoulders and 6’-10’ inside shoulders with median jersey barriers. At the northern limits it includes separate NB and SB system to system interchange ramps with I-93 for approximately 1 mile.
US-3	**13A**	I-95/MA-128 (Burlington)	MA-129 (Chelmsford)	3-12’ GPLs in each direction with 10'-15’ outside shoulders and 12’-20' inside shoulders with an approximately 30'-55' wide grassed median separation. Corridor appears to be built with bridges and overpasses that can accommodate future widening.
	13B	MA-129 (Chelmsford)	MA-4 (Chelmsford)	3-12’ GPLs in each direction with 10'-15’ outside shoulders and 12’-20' inside shoulders with median jersey barriers. Corridor appears to be built with bridges and overpasses that can accommodate future widening.
	13C	MA-4 (Chelmsford)	New Hampshire SL (Tyngsborough)	3-12’ GPLs in each direction with 10'-15’ outside shoulders and 12’-20' inside shoulders with an approximately 30'-55' wide grassed median separation. Corridor appears to be built with bridges and overpasses that can accommodate future widening.

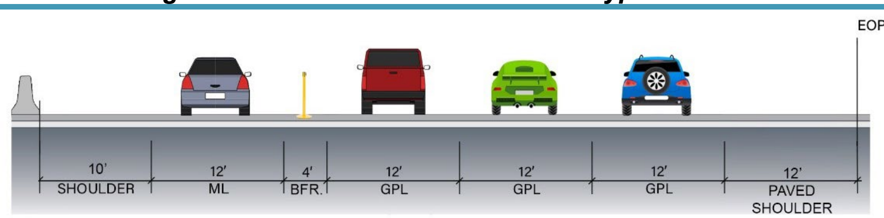
5.1. Managed Lane Typical Section Considerations

In order to assess a corridors overall feasibility for implementing new managed lane facilities, several roadway cross sections were developed to illustrate typical elements such as lane widths and shoulder widths based on a review of operating managed lanes facilities in other states. These sections were further refined based on direct conversations with other state DOT’s regarding lessons learned and best practices they have experienced on similar facilities. These conversations were supplemented with input from MassDOT’s Highway Design section to reflect local standards and context. MassDOT recognizes that each corridor where managed lanes are being considered is unique and will require a great deal of design flexibility that balances the various site constraints and operational and safety goals of the organization and project stakeholders. Therefore, the typical roadway cross sections shown below include options with reduced cross section dimensions to account for locations along each corridor where constraints may exist and design flexibility is needed to construct a managed lane facility.

Recognizing that each typical section needed to be evaluated to help determine a corridors overall feasibility for implementing specific manage lane types, rankings for each typical section were designated based on their overall desirability. For example, wider shoulders and buffer widths received a higher score over other sections that utilize narrow dimensions for those roadway elements. The following typical sections shown in Figure 23 generally maintain a standard 12-foot travel lane width for both the general purpose and manage lane facility but differ in the width of the inside managed lane shoulder and buffer separating the general purpose lane. The first typical establishes a preferred typical section with standard 10-foot wide inside and 12-foot wide outside shoulders and a 4-foot buffer width separating the managed lane and general purpose. It's important to note that depending on enforcement needs along each corridor, the inside shoulder will likely need to increase in width for short segments to allow for enforcement vehicles to safely perform their duties.

The next two typical sections reflect potential roadway configurations that might be considered in constrained locations based on input and approval from MassDOT Highway Design section. The last typical section shows a managed lane with no buffer separation from the general purpose lanes and should only be considered with careful consideration of occupancy detection technology, enforcement capabilities and availability of enforcement zones. If enforcement zones are implemented for any of the typical sections shown, then a wider inside shoulder with a barrier bulb-out should be considered and coordinated with Massachusetts State Police and local law enforcement agencies to confirm it meets their needs.

Figure 23 - Typical Section for Concurrent Flow Priced Managed Lane

<table>
<tr><th>Managed Lane Corridorwide Desirable Typical Sections</th><th>Desirability</th></tr>
<tr><td>
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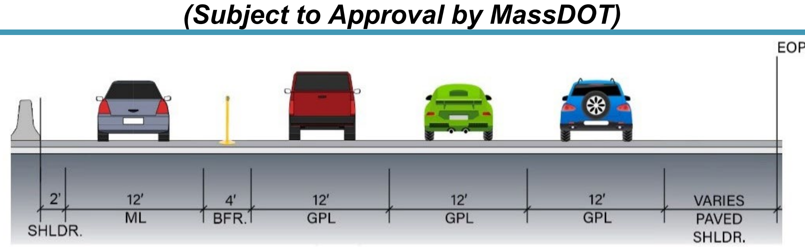
<tr><th>Managed Lane Constrained Typical Sections
(Subject to Approval by MassDOT)</th><th>Desirability</th></tr>
<tr><td>
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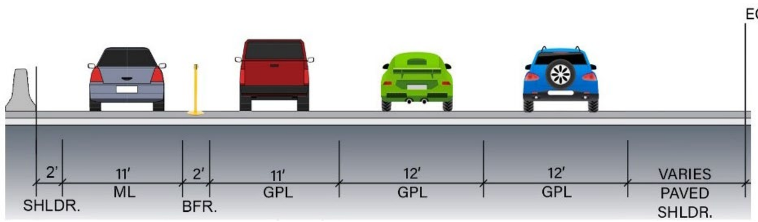
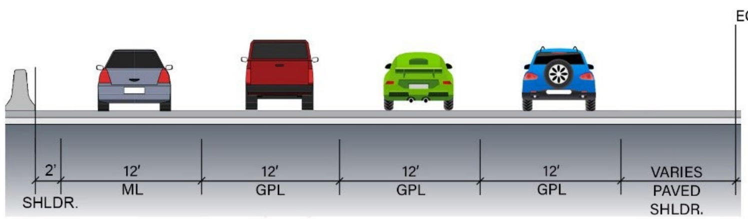
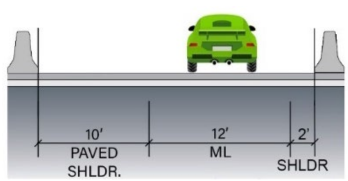
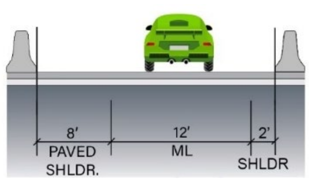
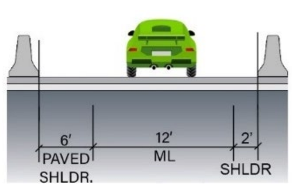
	●
	❍*

❍* - Managed Lanes with pricing and HOV components with no buffer may be considered with careful consideration of occupancy detection technology and enforcement and availability of enforcement zones

In addition to the typical sections discussed above, several other typical sections shown in Figure 24 were developed to address more unique managed lane configurations including the use of reversible lanes. The reversible managed lane scenario may have limited application but highlights the ability to fit a managed lane segment where otherwise typical bi-directional managed lanes may not be feasible. The following details potential typical sections within those managed lane contexts. In addition, typical sections for bus-on-shoulder use are highlighted within Section 5.3.

Figure 24 - MassDOT Desirable Cross Section for Bi-direction Priced Managed Lanes

Bi-directional Cross Section




5.2. HOV to HOT Lane Conversion

As described in Chapter 2, there are currently four existing HOV lanes operating within Massachusetts. For the purposes of this study, two of the existing HOV lanes were considered for HOT conversion based on their longer overall length of the facility and the potential to have a greater impact on travel time reliability and congestion as described in the Congestion in the Commonwealth Report to the Governor. They include the 2.6-mile section of HOV lane on I-93 southbound north of Boston and the 5.6-mile length of reversible HOV zipper lanes on the I-93 Southeast Expressway south of Boston.

The other two HOV corridors noted in Section 2.2 and 2.4 are located along the I-93 corridor south of Boston. One corridor operates in the southbound direction and generally extends from Lincoln and Kneeland Streets south along I-93 to approximately the interchange with the Massachusetts Avenue Connector. The second corridor mirrors the southbound facility in the northbound direction along I-93 extending from the Massachusetts Avenue Connector to Lincoln and Kneeland Streets. Both corridors have short spurs that provide direct access between the I-93 and I-90 (Massachusetts Pike) corridor east of I-93. Currently both of these corridors exhibit little congestion and little overall demand for managed lanes treatments as was demonstrated when the northbound HOV lane was recently opened to all general purpose traffic and experienced little increase in traffic volumes.

HOT lanes combine HOV and pricing strategies by allowing vehicles that do not meet passenger occupancy requirements to gain access to HOV lanes by paying a toll. The lanes are "managed" by using price and occupancy restrictions to manage the number of vehicles traveling in them. HOT lanes are typically designed and managed to maintain volumes consistent with uncongested levels of service even during peak travel periods. HOT lanes can fulfill the following functions:

- Expand mobility options in congested urban areas by providing an opportunity for reliable travel times to users willing to pay a premium for this service.
- Utilize excess capacity to increase vehicle throughput while maintaining the required performance requirements of HOV facilities.
- Generate a source of revenue which can be used to pay for transportation improvements, including enhanced transit service.

For a HOV to HOT lane conversion to be feasible, an existing HOV lane must either have existing excess capacity, or existing access restrictions must be increased, such as a change from HOV2+ (two or more vehicle occupants required) to HOV3+ (three or more vehicle occupants required) to create additional capacity. Corridors that exhibit lower overall HOV or general traffic demand, similar to the short segments along I-93 immediately south of downtown Boston, are not viable candidates for HOV to HOT lane conversions. The primary key to the success of this strategy is to actively manage how many vehicles can use the excess capacity—using dynamic and variable priced toll collection, with tolls set by level of congestion, time of day, as well as vehicle class. This keeps a congestion-free incentive for carpool and transit vehicles (HOV) while fully utilizing the lane capacity provided within the facility. Motorists have the option of paying to access a congestion-free restricted freeway lane or traveling for free on a more congested general purpose freeway lane.

5.2.1. Existing and Available Capacity

The traffic volumes for the existing HOV lanes were obtained from MassDOT Office of Transportation Planning and CTPS and are shown in Table 10. The hourly freeway capacity of 1,600 vehicles per hour per lane (vphpl) is consistent with FHWA's "Guide for Highway Capacity and Operations Analysis of Active Transportation and Demand Management Strategies."

Table 10 - Existing and Available HOV Capacity

HOV facility	**Eligibility**	**Hourly HOV volume (vphpl)**	**Hourly freeway capacity (vphpl)**	**Available capacity on HOV lane (vphpl)**	**% of 2 person cars in HOV facility**	**% of 3+ cars in HOV facility**	**% of 3+ cars in General Purpose lane**
I-93 SB HOV *(North of Boston)*	2+ only	760[1]	1,600	840	55.0%	5.8%	0.6%
I-93 NB/SB HOV, Zipper Lane *(South of Boston)*	2+ only	1,250	1,600	350	75.2%	6.1%	0.7%

Source: HOV count data on I-93 SB HOV (North of Boston) was collected by CTPS In November 2017
HOV count data on Zipper Lane was collected by CTPS on June 21, 2017,

[1] As part of the Tobin Bridge reconstruction mitigation, MassDOT started allowing all traffic to use the I-93 N HOV in May 2019. Therefore, the most up to date HOV data available is from the November 2017 counts only.

The Peak Hour HOV volumes shown in Table 10 reflect the average hourly volume between 7 a.m. and 9 a.m., provided by CTPS. They were collected in 2017 between June and November 2017. More detailed data obtained from ATR counts taken in May 2018 indicate the HOV volumes reach a peak of 1,400 vehicles for a short duration between 5 a.m. and 6 a.m. and drop back to around 800 between 7 a.m. and 9 a.m.

These data show that there is excess capacity available in both HOV facilities, with a larger availability in the southbound direction (north of Boston). It also highlights that a large proportion of the HOV users are currently vehicles with two occupants and thus a change in vehicle eligibility rules could potentially increase the available capacity in these lanes even further.

5.2.2. Permitting

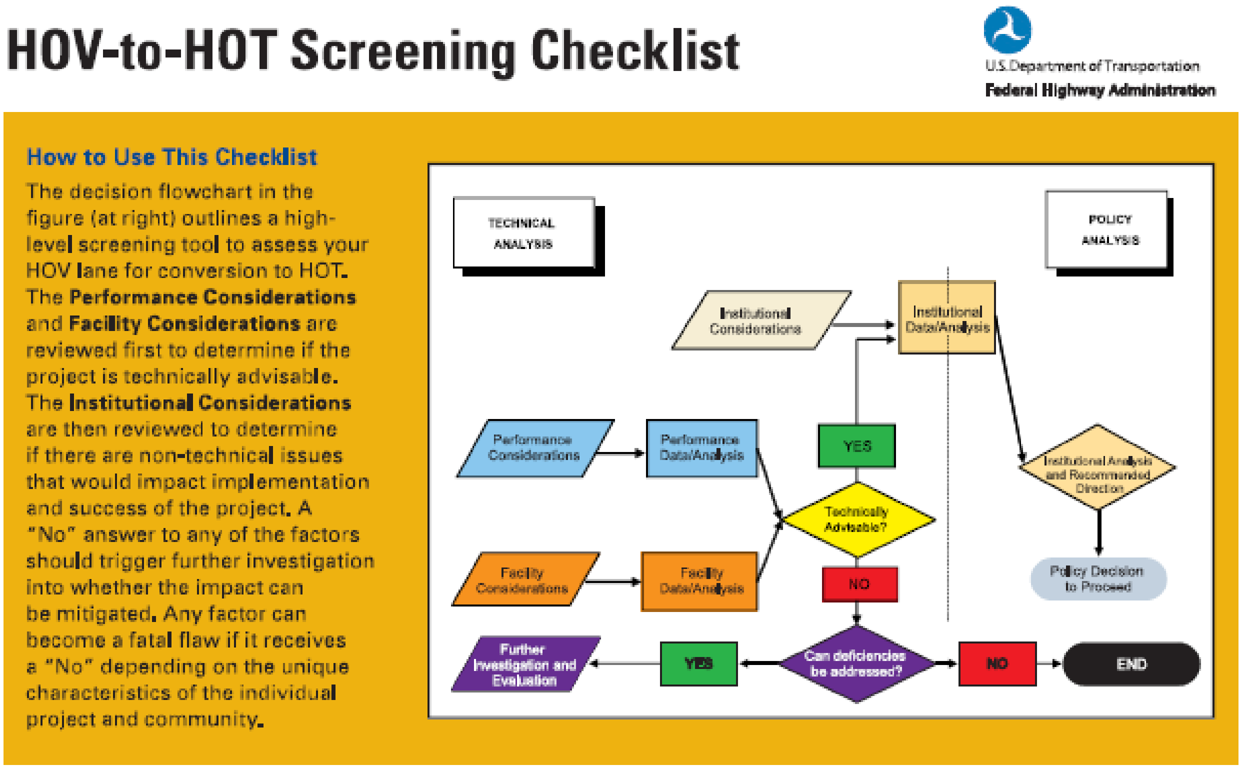
Under Section 166 of Title 23 of the United States Code, existing HOV lanes may be converted to tolled operation provided that the local metropolitan planning organization (MPO) endorses the use and price of tolls on the converted lanes. All tolls on new lanes must be variably priced and collected electronically in order to manage travel demand. To implement tolls on an existing HOV lane, project sponsors must demonstrate two primary elements including that conditions on the facility are not already degraded as is defined by vehicles operating on the facility are failing to maintain a minimum average operating speed 90 percent of the time over a consecutive 180-day period during morning or evening weekday peak hour periods (or both). Secondly that the presence of paying vehicles will not cause conditions on facility to become degraded as described above. Ongoing annual reporting documenting conditions on the converted lanes also is required, and if the HOV facility becomes degraded, the sponsor must bring the facility into compliance either by increasing HOV occupancy requirements, increasing tolls, increasing capacity, or eliminating access to paying motorists.

The following certification provisions apply whenever an HOV lane is converted to HOT operations under Section 166:

- States must certify annually to FHWA that they meet the operational requirements stipulated in Section 166, including vehicle eligibility; enforcement, and operational performance monitoring, evaluation and reporting. The annual certifications must demonstrate that the presence of paying vehicles in the HOT lane has not caused traffic service to become degraded.
- States must demonstrate that programs are in place to inform motorists how they may enroll and use the managed lane, either in a non-paying HOV vehicle or a paying HOT vehicle.
- States must indicate that they have or will have an automated electronic toll collection system in place on the managed lanes.

FHWA publishes an HOV to HOT screening checklist to help agencies facilitate the decision-making process when considering whether to convert from HOV Lane to HOT operation. A summary of that checklist is shown in Figure 25. Portions of the checklists that could be completed at this early stage of the planning process were completed as part of this screening study. Because MassDOT has an existing and well-established toll collection practice, albeit on different roadways, many of the checklist items can be checked and will facilitate discussions between FHWA and MassDOT for any future HOV to HOT conversion initiatives.

Figure 25 - FHWA HOV to HOT Screening Checklist Flowchart



5.2.3. Feasibility

Based on the initial constraint analysis, both existing HOV corridors along I-93 (zipper lane on the Southeast Expressway and the segment between Boston and Somerville) appear to provide opportunities to be converted to HOT lanes. Further analysis is required to document the operational and technological performance metrics along with the many other environmental aspects that are needed to determine each facilities true feasibility. It should be noted that based on the shorter segment lengths and constrained geometrics along each corridor, the existing configuration of a single access and egress point at each corridors terminus will likely need to be maintained. This is especially true along the I-93 South (Southeast Expressway) segment where the logistics of providing a break in the movable barrier system would be extremely challenging. Table 11 below provides a high level overview of each corridors feasibility.

Table 11 - HOV to HOT Conversion Feasibility

Corridor	Sub-Segment	S or W Endpoint	N or E Endpoint	Feasible	Comments
I-93 *(South)*	**6A**	MA-3/I-93 (Braintree)	Morrissey Blvd (Boston)	✓	• Access and egress likely limited to existing termini • Technological and operational elements in zipper lane need to be evaluated for feasibility • FHWA approval and monitoring required
I-93 *(North)*	**7C**	US-1 (Boston)	Mystic Valley Pkwy (Somerville)	✓	• Access and egress likely limited to existing termini based on shorter length • FHWA approval and monitoring required

5.3. Repurposing Existing Shoulder

Massachusetts was one of the early adopters of part-time shoulder use for general purpose traffic to alleviate recurring congestion along I-95 and MA-3 in 1985. While the applications on Massachusetts highways with part time shoulder use has been reduced as roadway widening and additional capacity has been added, several corridors including the I-93 corridor north of Boston and MA Route 3 south of Boston continue to use this treatment. The I-93 north segment extends from the Wilmington/Tewksbury town line to the Andover/Methuen town line. The MA Route 3 segment extends from the communities of Weymouth to Pembroke. It should be noted that in the future if either the I-93 north segment or MA Route 3 segment are considered for bus-on-shoulder applications, active use of the breakdown lane for general purpose traffic will need to be terminated and existing agreements with the FHWA will need to be updated.

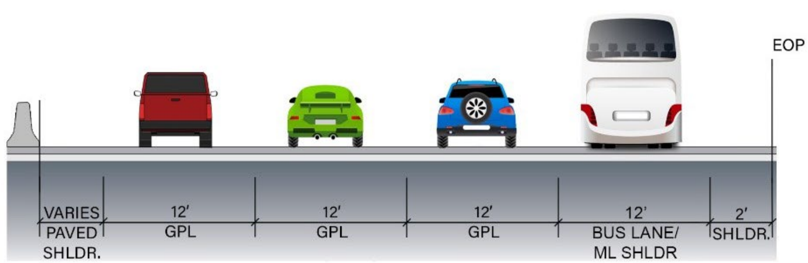
Many other state DOTs interviewed are currently managing both their left and right shoulders through dynamic lane assignments to help improve travel time reliability for general traffic during peak hours. While the application to manage the shoulder use shows good potential, in the near term MassDOT is focusing on enhancing person throughput and improving transit service reliability through bus-on-shoulder applications. In coordination with several bus operators, MassDOT has performed an evaluation to determine the feasibility and potential corridors to pilot and implement bus-on-shoulder applications. Bus-on-shoulder is a low-cost solution that allows buses to travel on the shoulder and bypass congested areas of freeway systems, thereby improving transit efficiency and person throughput. When considering the options for implementing bus-on-shoulder, the corridors were evaluated for adequate existing shoulder width or potential for minor widening to develop a usable shoulder. This high-level evaluation was performed using a GIS review of available aerial mapping and parcel data.

MassDOT provided bus-on-shoulder cross sections when evaluating the corridors as shown in Figure 26 below. While these cross sections illustrate a bus-on-shoulder being provided on the right shoulder, there is the potential to consider a left side shoulder application if existing roadway characteristics would support it. Regardless of the side of the road that is used, further evaluation of each corridor's potential feasibility needs to be evaluated to confirm constraints and mitigation to address such issues as:

- Environmental resource impacts
- Bridge clearance restrictions (future electric bus fleet and roof mounted battery packs may result in an increase in bus height)
- Shoulder counterslope
- Pavement widening
- Right-of-way impacts
- Inlet and utility locations
- Pavement sub-base and wheel path loading
- Utility post and sign structure conflicts
- Setback from barrier or guard rail

Depending on these constraints, a 10- to 11-foot-wide shoulder may be able to provide adequate safety and operations for both MassDOT and transit operators. As part of this evaluation, it is recommended that MassDOT and local transit operators perform a functional operation test with bus operators to better understand driver experience and overall feasibility of the facility in relation to the factors listed above.

Figure 26 - Bus-on-Shoulder Cross Section

<table>
<tr><th>Bus-on-Shoulder Cross Section</th><th>Score</th></tr>
<tr><td>
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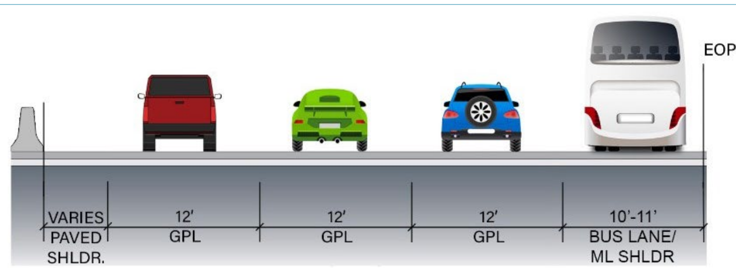
<tr><td>
</td><td>●</td></tr>
</table>

Based on the initial feasibility analysis, 9 of the 10 corridors have sections where bus-on-shoulder could potentially be implemented. For the analysis, some of the corridors were split in segments based on logical demarcation points such as major interchanges and are shown in

Table 9. This allows for the possibility to implement bus-on-shoulder along segments of the corridor, even if full corridor utilization is not feasible based on identified constraints. The constraints could include reduced width or no shoulders, which would result in high capital costs from bridge widening or replacement along with right-of-way impacts to local properties. The sections of the corridors within the Boston urban area are particularly susceptible to these limitations as is summarized in Table 12 below.

Table 12 - Repurpose Shoulder Feasibility

Corridor	Sub-Segment	S or W Endpoint	N or E Endpoint	Feasible	Typical Section	Comments
I-95/MA-128 *(Southwest)*	**4A**	I-93/I-95 (Canton)	MA-9 (Wellesley)	✓	●	• May require minor widening or restriping to accommodate 11' or 12' shoulders • Vertical Clearance at overpasses needs to be confirmed
	4B	MA-9 (Wellesley)	MA-2 (Lexington)	✓	●	• May require minor widening or restriping to accommodate 11' or 12' shoulders • Vertical Clearance at overpasses needs to be confirmed
I-95/MA-128 *(Northwest)*	**5A**	MA-2 (Lexington)	I-93 (Woburn)	✓	●	• Possible between Lexington Rd (Lexington) and Middlesex Turnpike (Burlington) • Some constricted overpasses north of Middlesex Turnpike (Burlington) that would likely need to be widened.
	5B	I-93 (Woburn)	US-1 (Peabody)	✓	●	• Possible between I-93 (Woburn) and Walnut St (Lynnfield), and between Summer St (Lynnfield) and US-1 • Some constricted overpasses at Walnut St (Lynnfield) and Summer St (Lynnfield) that would likely need to be widened.
I-93 *(South)*	**6A**	MA-3/I-93 (Braintree)	I-90 (Boston)	X	N/A	• Much of the corridor is near Boston and extremely constrained with infrastructure and little to no right-of-way opportunities
	6B	I-93/I-95 (Canton)	MA-3/I-93 (Braintree)	✓	●	• May require minor widening or restriping to accommodate 11' or 12' shoulders
I-93 *(North)*	**7A**	I-495 (Andover)	NH SL (Methuen)	✓	●	• Bus-on-shoulder application will require the elimination of the active breakdown lane use and will require modifications to the existing FHWA agreements
	7B	I-95/MA-128 (Woburn)	I-495 (Andover)	✓	●	• Bus-on-shoulder application will require the elimination of the active breakdown lane use and will require modifications to the existing FHWA agreements

Corridor	Sub-Segment	S or W Endpoint	N or E Endpoint	Feasible	Typical Section	Comments
	7C	US-1 (Boston)	I-95/MA-128 (Woburn)	✓	●	• Current bus-on-shoulder pilot in the SB direction north of Exit 28 – Sullivan Square (Boston)
I-90	8A	I-495 (Hopkinton)	I-95/MA-128 (Newton)	✓	●●	• Feasible from I-495 (Hopkinton) to MA-30 (Auburndale)
	8B	I-95/MA-128 (Newton)	MA-1A (Boston)	X	N/A	• Much of the corridor is near Boston and extremely constrained with infrastructure and little to no right-of-way opportunities
MA-2	9	I-95/MA-128 (Lexington)	Alewife Brook Pkwy (Cambridge)	✓	●●	• Last 0.75 miles has minimal shoulder width and a constrained right-of-way leading to likely challenges to implement a bus-on-shoulder application for the entirety of the corridor
MA-24	10	MA-27 (Brockton)	I-93 (Randolph)	✓	●	• Possible to have bus on shoulder on outside shoulder
US-1	11A	MA-60 (Revere)	I-95/MA-128 (Peabody)	X	N/A	• Large sections with no shoulder, reduced shoulder, or unpaved shoulder
	11B	I-93 (Boston)	MA-60 (Revere)	X	N/A	• Large sections with reduced shoulder • Much of the corridor at the south end near Boston is on structure, making widening costly.
MA-3	12A	MA 139 (Pembroke)	MA-18 (Weymouth)	✓	●	• Bus-on-shoulder application will require the elimination of the active breakdown lane use and will require modifications to the existing FHWA agreements
	12B	MA-18 (Weymouth)	I-93 (Braintree)	✓	●	• Bus-on-shoulder application will require the elimination of the active breakdown lane use and will require modifications to the existing FHWA agreements
US-3	13A	I-95/MA-128 (Burlington)	MA-129 (Chelmsford)	✓	●●	• Bus on shoulder on outside shoulder can be accommodated
	13B	MA-129 (Chelmsford)	MA-4 (Chelmsford)	✓	●●	• Bus on shoulder on outside shoulder can be accommodated
	13C	MA-4 (Chelmsford)	NH State Line (Tyngsborough)	✓	●●	• Bus on shoulder on outside shoulder can be accommodated

● Refers to typical section desirability illustrated in Figure 26.

Each of the full and partial corridors listed above as feasible appear to have at least an approximate 10-foot shoulder within the limits based. Minor widening or re-striping may be needed along various sections of these corridors to accommodate the required 10-foot minimum shoulder width provided by MassDOT. In addition, any potential conflict points with the on and off ramps and auxiliary lanes would need to be carefully considered and adequately signed.

If acceptable to MassDOT, bus-on-shoulder could be implemented on a combination of the high speed and low speed shoulders depending on the corridor and limitations. If implemented on the high speed shoulder, there are some constrained sections surrounding bridges, bridge piers, and median sign structures where the shoulders would need to be reduced or require adjustments to the general purpose travel lanes to provide adequate shoulder width. These areas will have to be evaluated to determine if restriping or minor widening could eliminate some of these constraints.

5.4. Conversion of General Purpose Lane to Managed Lane

In determining the feasibility of converting a general purpose lane to a managed lane, the objective was to screen for feasibility using the MassDOT recommended highway typical sections and a review of available aerial mapping and measurement tools found within ArcGIS and Google Earth to understand physical constraints. A general evaluation of potential corridor typical sections is summarized in Figure 23.

It is important to note that while a typical section's overall constructability is an important aspect when considering a general purpose lane to managed lane conversion, there are several other equally important aspects that need to be considered including:

- **resulting traffic operations in the adjacent travel lanes**
- **trip diversion impacts to other corridors**
- **potential ingress and egress locations and configuration**
- **available right-of-way**
- **stakeholder support**

These aspects are not included within this analysis but should be evaluated as part of future planning phases of this managed lane effort.

Based on the initial feasibility analysis all corridors with three or more lanes could potentially convert one general purpose lane to a managed lane, assuming reduced typical sections with no buffer separation and/or reduced shoulders being applied. It should be noted that this assessment does not account for the other factors noted above that will need to be evaluated as part of future planning phases. The following Table 13 summarizes each corridor's sub-segments feasibility based on an achievable typical section and provides an overview of the identified physical constraints.

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Table 13 - General Purpose Lane to Managed Lane Feasibility

Corridor	Sub-Segment	S or W Endpoint	N or E Endpoint	Feasible	Typical Section	Comments
I-95/MA-128 *(Southwest)*	**4A**	I-93/I-95 (Canton)	MA-9 (Wellesley)	✓*	●●●	• 6 bridges to widen and 2 bridges to replace to provide standard buffer and shoulder widths
	4B	MA-9 (Wellesley)	MA-2 (Lexington)	✓*	●●	• 4 bridges to widen and 4 bridges to replace to provide standard buffer and shoulder widths
I-95/MA-128 *(Northwest)*	**5A**	MA-2 (Lexington)	I-93 (Woburn)	✓*	●●	• 6 bridges to widen and 3 bridges to replace to provide standard buffer and shoulder widths
	5B	I-93 (Woburn)	US-1 (Peabody)	✓*	●●	• The number of GPL would be reduced to two through the I-90 interchange
I-93 *(South)*	**6A**	MA-3/I-93 (Braintree)	I-90 (Boston)	✓*	●	• Much of the corridor is near Boston and extremely constrained with infrastructure and little to no right-of-way opportunities
	6B	I-93/I-95 (Canton)	MA-3/I-93 (Braintree)	✓*	●●	• 2 bridges to widen to provide standard buffer and shoulder widths
I-93 *(North)*	**7A**	I-495 (Andover)	NH SL (Methuen)	✓*	●●	• Various locations where minor widening may be required to provide buffer and shoulder widths
	7B	I-95/MA-128 (Woburn)	I-495 (Andover)	✓*	●●	• 1 bridge to replace to provide standard buffer and shoulder widths
	7C	US-1 (Boston)	I-95/MA-128 (Woburn)	✓*	●●	• South of MA-28 between Somerville and Boston will be challenging but feasible if constrained typical section is utilized • North of MA-28, 4 bridges to widen and 1 bridge to replace to provide standard buffer and shoulder widths.
I-90	**8A**	I-495 (Hopkinton)	I-95/MA-128 (Newton)	✓*	●●	• 4 bridges to widen and 2 bridges to replace to provide standard buffer and shoulder widths
	8B	I-95/MA-128 (Newton)	MA-1A (Boston)	✓*	○*	• Much of the corridor is extremely constrained with infrastructure and little to no right-of-way opportunities. • Air-Rights projects near the Allston Landing interchange will be creating multi-year lane reduction in both directions of I-90, thus influencing traffic operations and lane configuration through that area. Managed lane treatment could serve as part of traffic mitigation/control plan.

Corridor	Sub-Segment	S or W Endpoint	N or E Endpoint	Feasible	Typical Section	Comments
MA-2	**9**	I-95/MA-128 (Lexington)	Alewife Brook Pkwy (Cambridge)	✓*	●●	• 1 bridge over Minuteman Commuter Bikeway (Lexington) may need to be widened to provide standard buffer and shoulder widths. • Two GPLs available east of Lake Street (Arlington). Major widening would likely be needed to accommodate a managed lane in this area.
MA-24	**10**	MA-27 (Brockton)	I-93 (Randolph)	✓*	●●	• 1 bridge to widen and 1 bridge to replace to provide standard buffer and shoulder widths.
US-1	**11A**	MA-60 (Revere)	I-95/MA-128 (Peabody)	X	N/A	• Corridor contains sections with only two travel lanes
	11B	I-93 (Boston)	MA-60 (Revere)	✓*	❍*	• Feasible for conversion to transit only lane with no additional widening. GPL to managed lane conversion is not feasible due to inability to widen Tobin Bridge
MA-3	**12A**	MA 139 (Pembroke)	MA-18 (Weymouth)	X	N/A	• Corridor contains sections with only two GPLs
	12B	MA-18 (Weymouth)	I-93 (Braintree)	✓*	●●	• 1 bridge to replace to provide standard buffer and shoulder widths • The number of GPL would be reduced to two through the I-90 interchange
US-3	**13A**	I-95/MA-128 (Burlington)	MA-129 (Chelmsford)	✓*	●●●	• All bridges and overpasses were built to accommodate additional width
	13B	MA-129 (Chelmsford)	MA-4 (Chelmsford)	✓*	●●●	• All bridges and overpasses were built to accommodate additional width
	13C	MA-4 (Chelmsford)	NH State Line (Tyngs-borough)	✓*	●●●	• All bridges and overpasses were built to accommodate additional width

● Refers to typical section desirability illustrated in Figure 23.

✓* - Further analysis required to confirm feasibility

5.5. Major Widening for Additional Managed Lane

Each corridor was also evaluated based on its feasibility of widening to add an entirely new managed lane which could be comprised of a directional lane or a reversible express lane. This option provides the advantage of providing motorists a managed lane without reducing the current capacity of the general purpose lanes.

In determining the feasibility of adding a managed lane, the objective was to screen for feasibility to implement at least the “desirable” typical shown in Figure 23. The desirable typical section provides the advantage of a standard 10-foot inside shoulder to reduce the chance that stopped vehicles or minor crashes fully block the managed lane.

Based on the initial feasibility analysis, 9 out of the 10 corridors have sections where the roadway could be widened to accommodate a managed lane. Similar to other managed lane treatment options, for the purpose of the analysis some of the corridors were split in segments based on logical demarcation points such as major interchanges. This allows for the possibility to install managed lanes on segments of the corridor, even if full corridor installation is not feasible.

The following Table 14 summarizes each corridor’s sub-segments feasibility based on an achievable typical section and provides an overview of the identified physical constraints. Some corridors are identified as feasible but may require bridge replacement or widenings or use of a constrained typical section to minimize impacts. Locations deemed as not feasible generally involve locations where substantial infrastructure investments and/or extensive environmental mitigation would be needed to mitigate identifiable constraints. The sections of the corridors within the Boston area are particularly susceptible to these limitations.

Table 14 - Roadway Widening to Accommodate Managed Lane Feasibility

Corridor	Sub-Segment	S or W Endpoint	N or E Endpoint	Feasible	Typical Section	Comments
I-95/MA-128 *(Southwest)*	**4A**	I-93/I-95 (Canton)	MA-9 (Wellesley)	✓*	●●●	• 10 bridges to widen and 8 bridges to replace to provide the desired typical section. • May require extending existing, replacing or adding new sound barrier walls. • May require reduced section in some segments such as Kendrick St interchange (Needham), Highland Ave interchange (Needham Heights) and MA-9 (Wellesley).
	4B	MA-9 (Wellesley)	MA-2 (Lexington)	✓*	●●●	• 4 bridges to widen and 10 bridges to replace to provide the desired typical section. • Segment between MA-9 (Wellesley) and MA 16 (Newton) may not be feasible due to Charles River. Southbound segment between Winter St (Waltham) and Trapelo Rd (Waltham) may not be feasible due to the Cambridge Reservoir. • May require extending existing, replacing or adding new sound barrier walls. • May require reduced typical section in some segments north of Main St.
I-95/MA-128 *(Northwest)*	**5A**	MA-2 (Lexington)	I-93 (Woburn)	✓*	●●●	• 10 bridges to widen and 6 bridges to replace to provide the desired typical section. • May require extending existing, replacing or adding new sound barrier walls.
	5B	I-93 (Woburn)	US-1 (Peabody)	✓*	●●●	• 5 bridges to widen and 2 bridges to replace to provide the desired typical section. • May require extending existing, replacing or adding new sound barrier walls.
I-93 *(South)*	**6A**	MA-3/I-93 (Braintree)	I-90 (Boston)	X	N/A	• Much of the corridor is near Boston and extremely constrained with infrastructure and little to no right-of-way opportunities
	6B	I-93/I-95 (Canton)	MA-3/I-93 (Braintree)	✓	●●	• 6 bridges to widen and 2 bridges to replace to provide the desired typical section.
I-93 *(North)*	**7A**	I-495 (Andover)	NH SL (Methuen)	✓*	●●●	• 7 bridges to widen and 2 bridges to replace and to provide the desired typical section.

Corridor	Sub-Segment	S or W Endpoint	N or E Endpoint	Feasible	Typical Section	Comments
	7B	I-95/MA-128 (Woburn)	I-495 (Andover)	✓	●●●	• 17 bridges to widen and 5 bridges to replace and to provide the desired typical section.
	7C	US-1 (Boston)	I-95/MA-128 (Woburn)	✓* *(North of MA-28)*	●●●	• Not feasible south of MA-28 (Somerville) going into Boston due to major bridge impacts and major commercial right-of-way impacts. • North of MA-28 (Somerville), 7 bridges to replace and 18 to widen. • Right-of-way impacts near Marble Street (Stoneham), Spot Pond (Medford), and Wright's Pond (Medford).
I-90	8A	I-495 (Hopkinton)	I-95/MA-128 (Newton)	✓*	●●●	• 30 bridges to widen and 16 bridges to replace and to provide the desired typical section.
	8B	I-95/MA-128 (Newton)	MA-1A (Boston)	X	N/A	• Much of the corridor is extremely constrained with infrastructure and little to no right-of-way opportunities.
MA-2	9	I-95/MA-128 (Lexington)	Alewife Brook Pkwy (Cambridge)	✓*	●●●	• 2 bridges to widen and 2 bridges to replace and to provide the desired typical section. • Residential right-of-way impacts near Spring Street (Arlington), Park Avenue (Arlington), and Pleasant Street (Arlington). Commercial right-of-way impacts near Acorn Park Drive (Cambridge).
MA-24	10	MA-27 (Brockton)	I-93 (Randolph)	✓	●●●	• 7 bridges to widen and 3 bridges to replace and to provide the desired typical section. • 4 New Braided Ramps may be required for direct connection to Corridor 6 - I-95/MA-128
US-1	11A	MA-60 (Revere)	I-95/MA-128 (Peabody)	X	N/A	• Multiple commercial right-of-way and driveway impacts along its lengths including north of Salem Street (Lynnfield), near Carpenter Road (Lynnfield), and south of Hawkes Pond (Saugus).
	11B	I-93 (Boston)	MA-60 (Revere)	X	N/A	• Majority of corridor is along Tobin Bridge (Boston) and raised viaduct through Chelsea.
MA-3	12A	MA 139 (Pembroke)	MA-18 (Weymouth)	✓	●●●	• 11 bridges to widen and 4 bridges to replace and to provide the desired typical section. • Commercial right-of-way impacts near Webster Street (Hanover).

Corridor	Sub-Segment	S or W Endpoint	N or E Endpoint	Feasible	Typical Section	Comments
	12B	MA-18 (Weymouth)	I-93 (Braintree)	✓*	●●●	• 7 bridges to widen and 2 bridges to replace and to provide the desired typical section. • Residential right-of-way impacts near Washington St (Braintree) and commercial right-of-way impacts near Elm Street (Braintree).
US-3	13A	I-95/MA-128 (Burlington)	MA-129 (Chelmsford)	✓	●●●	• 1 bridge will need to be widened to provide the desired typical section.
	13B	MA-129 (Chelmsford)	MA-4 (Chelmsford)	✓	●●●	• 1 bridge to widen and 2 bridges to replace and to provide the desired typical section.
	13C	MA-4 (Chelmsford)	NH State Line (Tyngsborough)	✓	●●●	• 1 bridge to widen to provide the desired typical section

● Refers to typical section desirability illustrated in Figure 23.

✓* - Significant constraints identified; further analysis required

5.6. Corridor Treatment Feasibility Summary

In order to aid in further development and refinement of managed lane alternatives within subsequent planning studies, the following table was developed to summarize each corridor and sub-segment's feasibility for implementing the four managed lane types. Where applicable each managed lane treatment type was assigned a feasibility value based on the analysis discussed earlier in this study. Generally these feasibility values correspond to the corridors overall constructability. For example the US 3 north corridor was reconstructed recently to facilitate a future roadway expansion with widened bridges and thus segments 13 A-C were assigned a feasible rating with no significant constraints under a new managed lane scenario. Whereas MA 3 – segment 12A was deemed to be potentially feasible with significant constraints identified based on the narrower median and tighter overall right of way in locations that may make it more challenging to support a major roadway widening.

While this table is not meant to prioritize potential corridors or sub-segments for future planning efforts, integrated within left hand column of the table is a blue color coding that was applied from Table 9 and refers to each corridor's scoring results following the Tier 2 screening. This reference can be used to aid in understanding which corridors exhibited a greater number of characteristics that might lend to a potential manage lane treatment being more successful.

This analysis was based on a desktop review of the ArcGIS aerial mapping and open source data. As noted in prior sections, this analysis generally applies a preferred or constrained managed lane typical section and does not account for additional design elements including but not limited to managed lane ingress and egress points, environmental impacts, traffic operations and stakeholder support. In order to truly assess each corridor's overall feasibility, a more detailed review of existing and potential proposed conditions should be undertaken within subsequent planning efforts discussed within Section 6.0.

The results of the managed lanes treatment type feasibility analysis are summarized in Table 15.

Table 15 - Managed Lane Feasibility Summary

Corridor	Sub-Segment	South or West Endpoint	North or East Endpoint	HOV to HOT	Repurpose Shoulder	GPL Conversion	New ML Construction
I-95/MA-128 *(Southwest)*	4A	I-93/I-95 (Canton)	MA-9 (Wellesley)		●	◐	◐
	4B	MA-9 (Wellesley)	MA-2 (Lexington)		●	◐	◐
I-95/MA-128 *(Northwest)*	5A	MA-2 (Lexington)	I-93 (Woburn)		●	◐	◐
	5B	I-93 (Woburn)	US-1 (Peabody)		●	◐	◐
I-93 *(South)*	6A	MA-3/I-93 (Braintree)	I-90 (Boston)	●		◐	
	6B	I-93/I-95 (Canton)	MA-3/I-93 (Braintree)		●	◐	●
I-93 *(North)*	7A	I-495 (Andover)	NH SL (Methuen)		●	◐	◐
	7B	I-95/MA-128 (Woburn)	I-495 (Andover)		●	◐	●
	7C	US-1 (Boston)	I-95/MA-128 (Woburn)	●	●	◐	◐
I-90	8A	I-495 (Hopkinton)	I-95/MA-128 (Newton)		●	◐	◐
	8B	I-95/MA-128 (Newton)	MA-1A (Boston)			◐	
MA-2	9	I-95/MA-128 (Lexington)	Alewife Brook Pkwy (Cambridge)		●	◐	◐
MA-24	10	MA-27 (Brockton)	I-93 (Randolph)		●	◐	●
US-1	11A	MA-16 (Revere)	I-95/MA-128 (Peabody)				
	11B	I-93 (Boston)	MA-16 (Revere)			◐	
MA-3	12A	MA 139 (Pembroke)	MA-18 (Weymouth)		●		●
	12B	MA-18 (Weymouth)	I-93 (Braintree)		●	◐	◐
US-3	13A	I-95/MA-128 (Burlington)	MA-129 (Chelmsford)		●	◐	●
	13B	MA-129 (Chelmsford)	MA-4 (Chelmsford)		●	◐	●
	13C	MA-4 (Chelmsford)	NH State Line (Tyngborough)		●	◐	●

LEGEND

● Feasible - No significant constraints identified; further analysis still required

◐ Potentially Feasible - Significant constraints identified; further analysis required

Suitability Evaluation Scores (Tier 2 – See Table 9)

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9
8

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As noted in Section 4, corridors that were not considered viable for a managed lane treatment may be suitable for other congestion relief strategies outlined in the Congestion Report, including addressing local and regional bottlenecks, actively managing traffic operations through signal operations enhancements, enhancing transit service access and reliability, and investing in infrastructure that diversifies transportation options available for existing single occupant vehicle drivers. Congestion initiatives that were underway for corridors eliminated from this screening study at the time of this report writing are summarized in Table 16.

Table 16 - Other Congestion Initiatives

Corridor	**Rationale to Remove from Study**	**Other Congestion Initiatives**	**Project Status**
MA-1A *(Sumner/Callahan Tunnels and Bell Circle)*	Access management, signals, constrained cross section	Suffolk Downs mitigation	Permitting and Design
MA-1A *(north of Bell Circle)*	Access management, signals, at-grade intersections	Lynnway Bus Priority Lane	Potential component of Lynn Transit Action Plan
Route 2 *(west of Lexington)*	Access management, signals	Route 2 Corridor Study	In progress
Route 1 *(north of Peabody)*	Access management, limited recurring congestion		
I-95 *(north of Peabody)*	Limited recurring congestion		
MA-128 *(east of Peabody)*	Limited recurring congestion		
MA-213	Limited reoccurring congestion		
Lowell Connector	Signal at terminus	Redesigning Lowell Connector and Gorham St Intersection	Conceptual Design
MA-9	Access management, signals	Route 9 Connected Corridor SPaT Project	Pre-Construction
I-495	Scored less than a 6 in the Tier 2 Screening (see Section 4.3)	I-495/I-90 Interchange Reconstruction	Design
		I-495/I-290 Interchange Improvements	Conceptual Design
		I-495 at Rt 3/Lowell Connector Pavement Marking Improvements	Complete

6. Conclusions and Next Steps

The Managed Lanes Screening Study has identified several corridors within the I-495 beltway that show potential promise to implement various managed lane treatments. This report has served as the initial step in the screening and refinement of this list of candidate corridors. Further evaluation and due diligence is necessary to fully understand a corridor's feasibility, managed lane treatment type, operating characteristics, environmental and socioeconomic impacts, stakeholder support and implementation strategies. In addition, ongoing legislative discussions surrounding managed lanes at the state and federal levels will also need to be considered as the development of corridors and managed lane treatment types are advanced.

CONGESTION IN THE **COMMONWEALTH**

MANAGED LANES SCREENING STUDY **2020**

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