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Appendix A—Detailed Descriptions of Promising Greenhouse Gas Reduction Strategies

INTRODUCTION

This appendix provides details about each of the 24 strategies identified in Chapters 3 and 4 as being promising in their ability to reduce GHG emissions, beginning with the most effective. Each strategy includes the following details:

1. Long-Range Transportation Plan (LRTP) goals addressed by each strategy*
2. Description of the strategy
3. GHG reduction potential*
4. Cost and benefits*
5. Feasibility and timing*
6. Data needs associated with each strategy
7. MPO's role in implementing the strategy*

* More background information is provided in the following sections.

Long-Range Transportation Plan Goals

In addition to reducing GHG emissions, these strategies may address MPO goals that were established in the LRTP, *Charting Progress to 2040.* The goals addressed by each strategy are:

- Safety
- Capacity Management/Mobility
- Clean Air and Clean Communities
- Transportation Equity
- Economic Vitality
- System Preservation

Safety: Ensure that transportation by all modes will be safe by reducing the number of crashes and their severity, decreasing severe injuries and fatalities resulting from transportation, and protecting transportation users from other safety threats.

Capacity Management/Mobility: Use existing facilities' capacity more efficiently, and increase options for healthy transportation. This includes improving transit reliability, expanding and upgrading the bicycle and pedestrian network, increasing the percentages of population and places of employment within one-quarter mile of transit stations, eliminating bottlenecks on the freight network, and emphasizing capacity management through low-cost solutions.

Clean Air and Clean Communities: Reduce greenhouse gases generated in the Boston region by all transportation modes, as outlined in the Global Warming Solutions Act, and address other environmental impacts.

Transportation Equity: Provide comparable transportation access and service quality among communities, regardless of income level or minority population. This goal incorporates targeting investments to areas that would benefit a large percentage of low-income and minority populations, and minimizing any burdens associated with MPO-funded projects in these areas.

Economic Vitality: Ensure that our transportation network provides a strong foundation for economic vitality, such as by minimizing the burden of housing and transportation costs for residents in the region, and prioritizing transportation investments consistent with the compact-growth strategies of MetroFuture, the Boston region's 30-year land use plan.

System Preservation: Ensure that the transportation system is maintained—including bridges, pavement, and transit assets—at all times, prioritize projects that support emergency response capability during extreme conditions, and protect freight infrastructure that is vulnerable to climate change impacts. The strategies included in this report do not address the system preservation goal adopted by the MPO.

Strategies' Potential to Reduce GHG Emissions

For this report, a strategy's potential to reduce greenhouse gas emissions in the transportation sector is quantified by the percent reduction in greenhouse gas emissions in 2030. This year was chosen because the primary source of information in this report was the Transportation Research Board (TRB) document, *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*, which examined the potential of various strategies to reduce GHG emissions compared to a 2030 baseline. Emissions impacts in 2050 are discussed in some cases where they greatly differ from 2030 impacts. The percentages provided are based on a national level of implementation, since state-wide and regional data are not widely available. On occasion, GHG reductions are expressed in terms of million metric tons carbon dioxide equivalent (MMTCO_2e) in addition to percentages.[1]

[1] U.S. Environmental Protection Agency, 2015, Understanding Global Warming Potentials, http://www3.epa.gov/climatechange/ghgemissions/gwps.html.

The strategies listed in this literature review were selected because they have the potential to reduce national transportation GHG emissions by at least 0.2 percent compared to the 2030 baseline. Additional GHG reduction strategies exist but are excluded from this literature review if they do not have the potential to reduce national emissions by at least 0.2 percent. A strategy is considered to have

- High GHG reduction potential if it has a maximum potential to reduce GHG by at least 1 percent
- Medium GHG reduction potential if it has a maximum potential to reduce GHG by between 0.5 and 1 percent
- Low GHG reduction potential if it has a maximum potential to reduce GHG by less than one-half percent

Although MPO staff used national emissions data in this report because of the lack of state- or region-specific data for the strategies, we caution that the relative reductions that a strategy can achieve at the national level may differ significantly at the state and regional levels.

For instance, strategies such as bicycle and pedestrian improvements may yield the greatest emissions reductions in areas with relatively higher densities of land uses, where trips between origins and destinations are relatively short. Since Massachusetts and the Boston region generally have higher population and employment densities than the rest of the country, bicycle and pedestrian improvements may be able to achieve relatively high GHG emissions reductions compared to the country as a whole.

Congestion pricing is another example of a strategy that may have a relatively higher impact on GHG emissions in the Boston region than in the nation as a whole, as this strategy can be implemented only in certain congested locations. *Moving Cooler* states that, "in the context of the regions in which congestion pricing is implemented (versus this study's national perspective), the relative impact on GHGs will be greater".[2]

In order to understand the effects of implementing GHG reduction strategies in the Boston region, studies are needed to develop region-specific data for each strategy. In the meantime, national data is the best information available.

The pie charts included with each of the strategies show the relative national maximum GHG reduction potential of each of the strategies relative to the maximum national potential of each of the other 23 strategies. The strategies in each pie chart are categorized by MPO role in order to compare each strategy with other strategies that have the same MPO role. Strategies that the MPO can

[2] Cambridge Systematics Inc., 2009, *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, Urban Land Institute, p. 40.

fund are shown in light green; those that the MPO can publicize are in olive-green; and those that the MPO can only study or advocate are shown in dark green.

Cost and Benefits

Strategy Cost-Effectiveness

Each strategy's cost-effectiveness is quantified in terms of the direct cost to the implementing agency per $MTCO_2e$ reduced. This report discusses cost-effectiveness based on a national level of implementation. In addition, when available, a strategy's cost or savings to the public are also provided because many strategies have been found to save the public money.

For comparative purposes, we divided strategies into high, medium, and low cost-effectiveness:

- **High Cost-effectiveness**: Cost less than $250 per $MTCO_2e$ reduced
- **Medium Cost-effectiveness**: Cost between $250 and $500 per $MTCO_2e$ reduced
- **Low Cost-effectiveness**: Cost more than $500 per $MTCO_2e$ reduced

These categories were informed by the *Incorporating Greenhouse Gas Emissions* report by the Transportation Research Board, which quantifies direct implementation costs.[3]

There also is uncertainty surrounding the cost-effectiveness estimates of many strategies because of the limited studies on cost-effectiveness. Furthermore, the cost-effectiveness of an approach can differ considerably by location (e.g., rural versus urban) and context. The Transportation Research Board cautions against drawing blanket conclusions.[4] It recommends that strategies with substantial GHG reduction potential not be ruled out based on cost alone without analyzing the local region or by viewing them as part of a larger set of pricing strategies, some of which could provide revenue to support others that are more costly.

Other Strategy Benefits

In addition to emissions-reduction potential and cost-effectiveness, other considerations are important when selecting strategies for implementation. While cost-effectiveness is primarily discussed in this literature review in terms of direct implementation costs, the Transportation Research Board (and Cambridge

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[3] Transportation Research Board, *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*, 2013 Strategic Highway Research Program (SHRP 2), Report S2-C09-RR-1, p. 33.

[4] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.

Systematics) cautions against neglecting other perspectives and inaccurately representing full social costs and benefits,[5] such as:

- Travel time savings
- Other welfare gains or losses (because of accessibility and increased or decreased convenience)
- Equity (incidence of costs and benefits across population groups)

Resources such as *Moving Cooler* (Cambridge Systematics) and *Transportation's Role* (Cambridge Systematics and Eastern Research Group) quantify net costs (e.g., including vehicle operating savings) when discussing cost-effectiveness, demonstrating the prevalence of this methodology. However, they both highlight the need to consider further social costs and benefits. For example, while transit expansion and other major infrastructure improvements are not directly cost effective, they can be worthwhile for other purposes such as mobility, safety, and livability. They can also support a package of strategies that is collectively more cost effective, such as when transit is paired with compact development.[6]

Information about costs and benefits is included for each strategy. Equity impacts can vary from strategy to strategy. Disproportionate impacts (such as those related to pricing) on particular groups may need to be balanced or addressed. For example, lower-income groups already spend as much as four times more of their income on transportation compared to higher-income groups.[7] Social concerns, highlighted in FHWA's *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, considers public perception of strategies. Unique benefits and unique negative effects include impacts on livability, safety, and the environment.

Feasibility and Timing

The implementation feasibility rankings for technical, institutional, and political categories are listed as suggested in the Transportation Research Board's 2013 report, *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*. These ratings refer to the feasibility of implementation on a national scale, and may differ for Massachusetts or for the Boston region. Implementation concerns may include the need for inter-agency coordination. The U.S. Department of Transportation's Report to Congress, titled *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions* was a

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[5] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 32-33.

[6] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.

[7] Cambridge Systematics, *Moving Cooler*, p. 83.

central reference for information about timing of benefits (short, medium, or long), and asked the following questions for each strategy:

- **Technical Feasibility**: Is the technology well developed and proven in practice? What is the likelihood that the technology could be implemented in the near future at the deployment levels assumed in the analysis? Technological barriers can be low-tech as well as high-tech (for example, there may be right-of-way constraints to infrastructure expansion in urban areas).
- **Institutional Feasibility**: To what extent do the authority and resources exist for government agencies to implement the strategy? What is the administrative ease of running a program; and what are the levels of coordination required among various stakeholders?
- **Political Feasibility**: Is the strategy generally popular or unpopular with any interested stakeholders, elected officials, and the general public? What is the political influence of those supporting versus those opposed to the strategy?

Feasibility is assessed without respect to cost, which was evaluated as part of the cost-effectiveness measure.

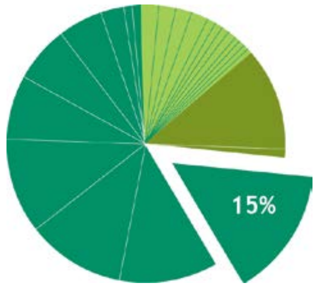
MPO Role in Implementing the Strategy

The strategies in each pie chart are categorized by MPO role to allow comparison of each strategy with other strategies that have the same MPO role:

- Light green – strategies that the MPO can fund
- Olive green – strategies that the MPO can publicize
- Dark green – strategies for which the MPO can only study or advocate

PROMISING STRATEGIES

1) Carbon Tax or Cap-and-Trade



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	NA
Technical Feasibility	M
Institutional Feasibility	M
Political Feasibility	L-M
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

A carbon tax or cap-and-trade policy, the most effective strategy for reducing GHG emissions, works by putting an economy-wide price on carbon (CO_2e). Pricing carbon is a market-based way to reflect the externalities, or greater social costs, of climate change. This strategy increases the cost of carbon-intensive decisions, providing businesses and consumers with the incentive to make less carbon-intensive transportation decisions. A carbon tax works by "rais[ing] the price of fossil fuels, with more taxes collected on fuels that generate more emissions."[8] Under a cap-and-trade program, the government sets a cap on the level of emissions, and creates allowances for emissions up to the level of the cap. Entities that are sources of carbon emissions can buy or sell these allowances.[9] Carbon pricing legislation could be adopted at the state or national level.

GHG Reduction:

Projections for national GHG emissions reductions range from 2.8 percent to 4.8 percent below the national transportation baseline in 2030.[10] This great potential for reductions assumes a substantial level of pricing with an allowance price of

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[8] The Editorial Board, The Case for a Carbon Tax, 2015, *The New York Times*, http://www.nytimes.com/2015/06/07/opinion/the-case-for-a-carbon-tax.html (accessed December 15, 2015).

[9] U.S. Environmental Protection Agency, Cap and Trade 101, 2015, http://www.epa.gov/capandtrade/captrade-101.html (accessed December 15, 2015).

[10] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 25.

\$30 to \$50 per $MTCO_2$ in 2030 or a similar carbon tax.[11] A carbon tax or cap-and-trade policy would achieve greater GHG cuts than other pricing strategies such as pay-as-you-drive (PAYD) and a vehicle miles traveled (VMT) fee, because directly pricing carbon encourages important improvements in fuel economy through utilizing more fuel-efficient vehicles and encouraging decreases in VMT.[12]

According to Cambridge Systematics and Eastern Research Group's 2010 report to Congress, one key difference between a cap-and-trade system and a carbon tax is that a carbon tax offers more certainty regarding energy prices, while a cap-and-trade system offers more certainty regarding overall GHG levels. Both policies are intended to shift activities to less GHG-intensive alternatives such as purchasing more fuel-efficient vehicles, using lower carbon fuels, taking public transportation, walking, biking, telecommuting, carpooling, and compact development.[13]

Costs and Benefits:

The Transportation Research Board (2013) analysis does not contain cost estimates. However, the estimates in *Moving Cooler* (2009) suggest relatively cost-effective implementation for carbon pricing compared to other pricing strategies—more than three times smaller than the cost of implementing a VMT fee, for instance.[14] Costs may be administrative in nature. A carbon tax may have an implementation advantage of a reduced administrative burden compared to a cap-and-trade program.[15]

Carbon pricing and other strategies that encourage a shift from single-occupancy vehicles to more efficient transportation modes also may help with the MPO's capacity management and mobility goal.

All pricing strategies, including carbon tax and cap-and-trade, would negatively affect lower-income groups unless mitigated. These groups "spend a higher proportion of their income on transportation, are less able to afford to pay higher fees, and may be priced off these services altogether."[16] Both a carbon tax and a

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[11] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 25.

[12] Cambridge Systematics Inc., *Moving Cooler*, p. 40.

[13] Cambridge Systematics, Inc. and Eastern Research Group, Inc., 2010. *Transportation's Role in Role in Reducing U.S. Greenhouse Gas Emissions*, Volume I, Report to Congress., U.S. Department of Transportation, Washington, D.C., pp. 4-28.

[14] Cambridge Systematics, *Moving Cooler*, p. 41.

[15] Cambridge Systematics, Inc. and Eastern Research Group, Inc., *Transportation's Role*, pp. 4-27.

[16] Cambridge Systematics Inc., *Moving Cooler*, p. 73.

cap-and-trade system could be made more socially equitable by providing rebates to low-income households for a carbon tax or compensating low-income households with some of the revenue generated through the cap-and-trade system. These policies could also create a new or alternative revenue source (depending on the amount of revenue distributed in rebates) that could be used to fund transportation infrastructure.[17] Investing in transportation services such as public transit may also help to mitigate adverse equity impacts.[18]

Feasibility and Timing:

The Transportation Research Board rates these policies' feasibility for nationwide implementation as medium technically and institutionally, and low to medium politically. Of all the taxation and pricing strategies examined in this literature review, cap-and-trade and carbon tax have the greatest technical feasibility. Carbon pricing is based on fuel/energy usage, which currently is well tracked. This is in contrast to distance traveled, upon which other pricing strategies are based, but which is not already systematically documented.[19]

Massachusetts is already part of a regional cap-and-trade initiative to reduce CO_2 emissions from power plants. The Regional Greenhouse Gas Initiative (RGGI) is a cooperative program among Connecticut, Delaware, Maine Maryland, New Hampshire, New York, Rhode Island, and Vermont that was implemented in 2008. To date, programs funded by cumulative RGGI investments have saved participating households $395 million and cut emissions by 1.2 $MMTCO_2$.[20]

A draft of bill S.1747, *An Act Combating Climate Change*, was introduced in fall 2015 that shows how Massachusetts could adopt a price on carbon. The act's purpose is to levy fees on fuels that emit CO_2, driving energy demand and emissions down. The act would distribute proceeds of the fee to residents equally via a rebate, thereby avoiding raising taxes. Residents who use more energy than average would pay more in fees than they receive in rebates. Most residents (the bottom 60 percent) are projected to receive rebates. A fee would be set at $10 per ton of CO_2 in the first year and increase by $5 per ton each year until it reaches $40 per ton seven years after adoption of the program.[21,22]

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[17] Cambridge Systematics, Inc. and Eastern Research Group, Inc., *Transportation's Role*, p. 4-28.

[18] Cambridge Systematics Inc., *Moving Cooler*, p. 73.

[19] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 25.

[20] RGGI Inc., *Regional Greenhouse Gas Initiative*, http://www.rggi.org/ (accessed December 15, 2015).

[21] Senator Mike Barrett, An Act Combating Climate Change: The Basics, 2015, http://senatormikebarrett.com/wp-content/uploads/2015/10/Carbon-Pricing-the-basics.pdf (accessed November 5, 2015).

The timing of this strategy's benefits extends over the short to long term, from within five years to more than twenty years.[23] This means that this strategy potentially could achieve strong immediate effects if sufficiently high pricing is in place, and even greater long-term effects as transportation system users, fuel providers, and vehicle manufacturers respond by making more structural adjustments.[24]

Data Needs:

No Massachusetts or Boston MPO-specific data is available for transportation sector GHG reductions or cost-effectiveness of various policies that support this strategy.

MPO Role:

The MPO does not have the authority to implement cap-and-trade or a carbon tax. If requested, the MPO could study the transportation benefits or advocate on behalf of this strategy. State agencies could, in turn, implement this policy at the state level (such as through Senate bill 1747) and/or seek implementation at the national level.

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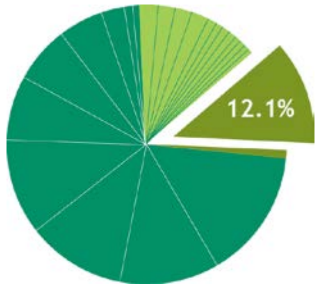
[22] The 189th General Court of Massachusetts, Bill S.1747, 2015, https://malegislature.gov/Bills/189/Senate/S1747 (accessed November 5, 2015).

[23] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-33.

[24] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-13.

2) Driver Education and Eco-Driving



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	L
Institutional Feasibility	L
Political Feasibility	H
MPO Role	Publicize

LRTP Goals Addressed:

- Safety
- Clean Air/Clean Communities
- Economic Vitality

Description:

Driver education, also known as eco-driving, consists of small changes in driving behavior—such as gentler braking and acceleration, slower driving, improved vehicle maintenance, and avoided idling—that collectively improve fuel economy. These practices can be encouraged through educational campaigns, in-vehicle training programs, and "dynamic eco-driving," where in-vehicle or road-based sensors provide drivers with feedback about their behaviors and emissions.[25] Driver education has the second-greatest potential to reduce GHG of the strategies studied in this literature review, along with potential cost-effectiveness.

GHG Reduction:

If driver education reaches 10 to 50 percent of the population, and in-vehicle instrumentation is provided, national transportation GHG emissions potentially could decrease by 0.8 to 3.7 percent. Specifically, Cambridge Systematics' analysis in *Moving Cooler* (2009) suggests potential reductions of 0.8 to 2.3 percent and the International Energy Agency (2005) predicts a 3.7 percent reduction.[26] According to *Moving Cooler*, implementing this strategy could

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[25] U.S. Department of Transportation, Federal Highway Administration, *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, 2012, by Rand Corporation and RSG, Inc., http://www.fhwa.dot.gov/environment/climate_change/mitigation/publications_and_tools/reference_sourcebook/referencesourcebook.pdf (accessed March 6, 2014), p. 201.

[26] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

generate results in the near term,[27] which would benefit cumulative savings over the long term as well.

Drivers who take in-vehicle eco-driving courses typically experience a 10 to 15 percent reduction in fuel consumption, and achieve better fuel economy than conventional drivers achieve, even two years after completing the course.[28]

A University of California study found that a 10 to 20 percent reduction in fuel use might be achieved through dynamic eco-driving technology, without much impact on travel time. (The researchers also noted that more savings were achieved in conditions with greater congestion.)[29] Some vehicles already include in-vehicle eco-driving instrumentation, and after-market instrumentation is available as well. Examples of vehicles with in-vehicle technologies include Ford's Fusion and Milan hybrid models, Honda's Insight model, Kia models with automatic transmission, and certain Toyota models. PLX Devices' Kiwi after-market miles-per-gallon meter is compatible with vehicles built in 1996 or later, and Hunter Research and Technology's inexpensive greenMeter application for iPhone and iPod Touch likewise could be used by drivers of vehicles without existing instrumentation.[30]

Costs and Benefits:

Cost estimates are not available for this strategy. However, it was included in *Moving Cooler's* "Low Cost" bundle of strategies, signifying low net costs when direct implementation costs are balanced with driver savings. One estimate cited by FHWA (2012) suggests costs for educational programs could be as low as \$14 per $MTCO_2$, signifying high cost-effectiveness: "In theory, eco-driving campaigns (e.g., formal public education and outreach on the nature and benefits of eco-driving) and programs may be among the more cost-effective ways to address GHG emissions." However, the cost-effectiveness of training only or dynamic technology is not currently known.[31]

Driver education and eco-driving may address the LRPT goals of safety, clean air and clean communities, and economic vitality. Potential safety benefits are

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[27] Cambridge Systematics, Moving Cooler, p. 42.

[28] Mineta Transportation Institute, *Ecodriving and Carbon Footprint: Understanding How Public Education Can Reduce Greenhouse Gas Emissions and Fuel Use*, 2012, by Susan A. Shaheen, Elliot W. Martin, and Rachel S. Finson, M.A., http://tsrc.berkeley.edu/sites/tsrc.berkeley.edu/files/ecodriving-greenhouse-gas-emissions-fuel-use-public-education.pdf (accessed March 24, 2014), p. 24.

[29] Mineta Transportation Institute, *Ecodriving and Carbon Footprint*, p. 15.

[30] Mineta Transportation Institute, *Ecodriving and Carbon Footprint*, pp. 21-22.

[31] USDOT, FHWA, *Reference Sourcebook*, p. 204.

associated with less aggressive driving.[32] Smoother driving patterns and improved vehicle maintenance reduce air pollution.[33] In addition, this strategy has one of the greatest positive impacts on vehicle costs, and saves drivers money.[34] The Michigan Action Council and Center for Climate Strategies estimate that an eco-driver program that trains 3 percent of Michigan's population annually will have a negative net cost-effectiveness of -$211 per MTCO$_2$e by 2030 because of drivers' fuel savings. The MPO's economic vitality goal is addressed by these cost savings for consumers.[35]

Feasibility and Timing:

Eco-driving voluntary training programs have been implemented in other countries such as Belgium, Iceland, Norway, Spain, and the United Kingdom.[36] In the US, a pilot eco-driving program is underway in the San Francisco Bay Area and some commercial fleet operators (e.g., United Parcel Service and Staples) include eco-driving in their employee training and equipment.[37]

The Transportation Research Board considers this strategy to have high political feasibility and FHWA reports "no significant barriers to implementing eco-driving…" and predicts high social acceptability.[38] Nevertheless, the TRB's low ratings for technical and institutional feasibility suggest that there may some challenges for national implementation.[39] The technical challenges are based on the strategy's assumptions regarding widespread adoption of in-vehicle instrumentation.[40] Promoting eco-driving is a MassDOT GreenDOT goal.[41]

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[32] USDOT, FHWA, *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, 2012, Rand Corporation and RSG, Inc., FHWA Project DTHF61-09-F-00117, pp. 201-205.

[33] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp.5-101.

[34] Cambridge Systematics, *Moving Cooler*, p. 42.

[35] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp.5-100.

[36] Cambridge Systematics, *Moving Cooler*, p. 42.

[37] Cambridge Systematics, n.d. What Are the Most Effective Things a State or Regional Transportation Agency Can Do to Reduce Greenhouse Gas Emissions, and Support Energy Independence, http://www.camsys.com/kb_experts_enviro.htm (accessed December 15, 2015).

[38] USDOT, FHWA, *Reference Sourcebook*, pp. 201-205.

[39] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[40] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

[41] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

Most eco-driving benefits could be realized in the short to mid-term, from within five years to less-than twenty years.[42]

Data Needs:

Unfortunately, the long-term effects of eco-driving campaigns and dynamic eco-driving are still largely unknown because "few [campaigns] have been studied rigorously, despite some evidence that [eco-driving] is one of the most cost-effective ways to reduce GHG."[43] The level of interest from Consumers interest in the strategy of eco-driving has not been determined.[44] In addition, air-pollutant-emission reductions have not been quantified.[45]

No Massachusetts or Boston MPO data is available for GHG reductions associated with eco-driving/driving education. Updated projections for the state and Boston region are not available. Limited data is available on the cost-effectiveness of this strategy.

MPO Role:

No campaigns or programs exist in Massachusetts to date, however MassRIDES includes eco-driving tips on their website as part of a *Drive Smart and Save* program. The MPO potentially could provide funding support for a program if one is established by another agency or organization. It could be funded through the MPO's Clean Air and Mobility program using Congestion Mitigation and Air Quality (CMAQ) funds, if approved by the Federal Highway Administration (as an innovative project). Alternatively, it could provide information about such a program through its public-information channels.

Eco-driving has the second-greatest potential to reduce GHG emissions of all the strategies, and the greatest potential for emissions reductions of the strategies that the MPO can fund (although the MPO is limited in funding only certain aspects of the program).

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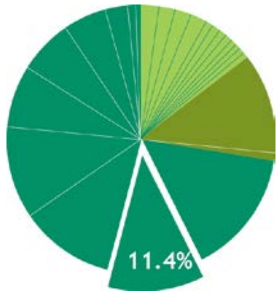
[42] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

[43] USDOT, FHWA, *Reference Sourcebook*, p. 201.

[44] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp.5-101.

[45] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp.5-101.

3) Pay-as-You-Drive Insurance



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	L-M
Institutional Feasibility	L-M
Political Feasibility	M
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

The third most-promising strategy in terms of the greatest potential to reduce GHGs is pay-as-you-drive insurance. This strategy charges drivers for vehicle insurance based on their vehicle-miles-traveled. Individuals' VMT data may be collected without compromising their privacy via audited odometer readings, advanced electronics, global positioning systems, and other telematics technologies. As users are informed of the insurance costs that they are paying on a per-mile basis, they are prompted to travel by vehicle less in order to reduce their costs. With PAYD, some of the fixed costs of owning a vehicle are changed to variable costs that may be managed by driving less.[46] PAYD would reduce costs for the majority of travelers and has high cost-effectiveness for the implementing agency.[47]

GHG Reduction:

PAYD is estimated to provide national GHG reductions of 1.1 to 3.5 percent annually. The low end of the reductions range may be achieved by requiring states to permit PAYD; and the high end of the range is possible by requiring motor vehicle insurance companies to offer PAYD.[48]

Costs and Benefits:

At a direct cost of \$30 to \$90 per $MTCO_2$, this strategy is highly cost-effective.

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[46] Cambridge Systematics, *Moving Cooler*, pp. 70-71.

[47] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-18.

[48] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 25.

PAYD could have beneficial transportation equity effects if implemented, addressing this LRTP goal. A Massachusetts Institute of Technology (MIT) study concluded that tying insurance rates to VMT would improve fairness among drivers because accident costs are related to miles driven. In addition, lower-income households drive less than higher-income households do; and a nationwide study by the Brookings Institute found that lower-income households generally would save money with PAYD, and that on average, higher-income households would pay more.[49]

Cost savings to consumers via this strategy may support the MPO's economic vitality goal. Large vehicle operating cost savings would result in a negative net cost-effectiveness of -$900 per $MTCO_2e$. Two-thirds of households are projected to see lower auto insurance premiums with PAYD (premiums would increase for the remaining one-third).[50]

PAYD also may help with the LRTP goals of capacity management/mobility and clean air/clean communities, as it encourages a decrease in VMT. In general, transportation demand-management strategies such as PAYD "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[51]

This pricing strategy would not promote fuel-efficiency gains unless the VMT fees also were tied to vehicles' GHG emission rates, fuel efficiency, or weights. PAYD (and VMT fee) technology also could be used to support congestion pricing, which would promote improved capacity management/mobility and reduced travel times.[52]

Feasibility and Timing:

In Massachusetts, PAYD was selected as a strategy to meet the Global Warming Solutions Acts goals, but has encountered considerable implementation challenges. The Massachusetts Executive Office of Energy and Environmental Affairs' December 2013 Global Warming Solutions Act progress report notes that this strategy has made "low" progress, and that a PAYD Auto Insurance Pilot funded by a FHWA grant is currently stalled: "The Commonwealth's plan to first initiate a pilot program, which could then be transitioned into a broader program,

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[49] Ian A. Bowles, *Massachusetts Clean Energy and Climate Plan for 2020* (2010), http://www.mass.gov/eea/docs/eea/energy/2020-clean-energy-plan.pdf (accessed February 25, 2015), p. 62.

[50] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-23.

[51] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[52] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-25.

is delayed due to potential legal challenges. Without a successful pilot program, it will be challenging to fine-tune and deploy a broader PAYD program that is effective at reducing VMT while also addressing the needs of insurers and consumers." Furthermore, the progress report questions the initial estimates of 0.4 to 2.1 percent statewide GHG reductions (from 1990 levels) achieved with full implementation. [53]

Nationally, the Transportation Research Board considers this strategy to have low-to-medium technical and institutional feasibility and medium political feasibility. This strategy has the highest political feasibility of the taxation and pricing-based strategies considered in this literature review.[54] PAYD has had consumer satisfaction rates as high as 87 percent when implemented, with the potential to save money compelling most people to reduce VMT. In addition, because signing is voluntary with this strategy, individuals who do not wish to have PAYD can simply choose not to.[55] PAYD insurance is currently offered in 35 states and is a MassDOT GreenDOT goal.[56, 57]

After implementation, the timing of benefits for PAYD is short term; the majority of GHG reductions can be achieved without delay.[58]

Data Needs:

The Massachusetts Executive Office of Energy and Environmental Affairs' Global Warming Solutions Act progress report cited above raised uncertainty about initial projections for GHG reductions attainable with this strategy in Massachusetts.[59] No updated Massachusetts or Boston MPO data is available about the GHG reductions associated with a PAYD Insurance strategy.

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[53] Massachusetts Executive Office of Energy & Environmental Affairs, Global Warming Solutions Act Implementation Subcommittees, *Global Warming Solutions Act: 5-Year Progress Report*, 2013, http://www.mass.gov/eea/docs/eea/gwsa/ma-gwsa-5yr-progress-report-1-6-14.pdf (accessed February 25, 2015), p. 56.

[54] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[55] USDOT, FHWA, *Reference Sourcebook*, pp. 64-65.

[56] http://www.lowmileagediscount.com/what-is-payg/lmd-states.asp.

[57] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

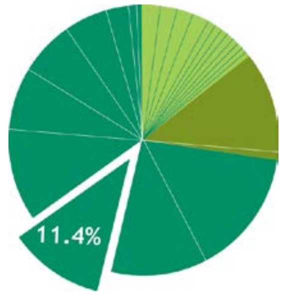
[58] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[59] Massachusetts Executive Office of Energy and Environmental Affairs, Global Warming Solutions Act Implementation Subcommittees, *Global Warming Solutions Act: 5-Year Progress Report*, p. 56.

MPO Role:

The MPO does not have the authority to implement PAYD Insurance. Depending on the outcomes of the Massachusetts PAYD pilot program legal challenges, this strategy may move forward in Massachusetts. If requested, the MPO could study or advocate for the transportation benefits of this strategy.

4) Compact Development



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	M
Institutional Feasibility	L
Political Feasibility	L
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Compact development can reduce the need for travel because destinations and activities are in close proximity. Utilizing land use codes, regulations and policies to attain compact development could have as great a potential impact on GHG emissions as a pay-as-you-drive insurance policy, and would be highly cost-effective.

GHG Reduction:

Cambridge Systematics estimates that between 0.2 to 1.8 percent GHG reductions are possible if 60 to 90 percent of new urban growth occurs in compact, walkable neighborhoods (+4,000 persons per square mile or +5 gross units per acre). Another analysis suggests cuts of between 0.4 to 3.5 percent if 25 to 75 percent of new urban growth occurs in compact, mixed-use developments.[60] The potential for high GHG reductions is backed by studies that have estimated that VMT can be cut by 5 to 12 percent if a region doubles its residential density and that GHG emissions can be reduced 7 to 10 percent in 2050 from current trends if 60 percent of new US residential growth follows compact patterns.[61] Overall, low-density development has been found to result in twice the GHG emissions per capita as high-density development.[62]

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[60] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[61] USDOT, FHWA, *Reference Sourcebook*, p. 25.

[62] U.S. Environmental Protection Agency, *Smart Growth: A Guide to Developing and Implementing Greenhouse Gas Reductions Programs*, 2011,

Costs and Benefits:

The estimated direct cost of this strategy for the implementing agency is only $10 per $MTCO_2$; compact development is highly cost-effective.[63] In addition, compact development saves municipalities money. A study by the Sacramento Area Council of Governments found that infrastructure costs an average of $20,000 less per housing unit for compact development than for low-density areas.[64]

According to *Moving Cooler*, land use and smart growth can provide an option to offset negative equity impacts of other GHG reduction strategies that cause increased transportation costs. By improving accessibility and mobility for individuals without access to automobiles and avoiding increased costs of automobile travel, compact development benefits multiple groups, addressing the transportation equity and capacity management/mobility LRTP goals. Other potential concerns regarding the effects of possible increases in property values may be mitigated by decreased transportation costs.[65] Nevertheless, policies to preserve housing affordability could ensure that the benefits of improved access are available equitably.

Feasibility and Timing:

Nationally, market and demographics trends are shifting towards more compact development patterns. The demand for compact development—attached and small-lot detached—was estimated at 46 percent of the national market in 2006 and could increase to 60 percent in 2025. Local zoning regulations that prevent higher density, mixed-use development have caused "an apparent undersupply" of this type of development. Other obstacles contributing to the undersupply include street designs that prioritize motorized travel at the expense of other modes and minimum parking requirements. As Cambridge Systematics and Eastern Research Group conclude, these trends may indicate that "some level of land use change likely would be supported by market factors; but more significant change approaching the more aggressive levels" such as those put forth in *Moving Cooler* "is likely to require stronger policy intervention."[66]

Perhaps because of this need for stronger policy intervention, the Transportation Research Board predicts future institutional and political challenges at the national level, ranking these areas low feasibility. Technical feasibility is ranked

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http://www.epa.gov/statelocalclimate/documents/pdf/sm_growth_guide.pdf (accessed March 20, 2015).

[63] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[64] Urban Land Institute, *Growing Cooler*, p. 147.

[65] Cambridge Systematics Inc., *Moving Cooler*, pp. 73-74.

[66] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-69–5-70.

medium.[67] As with all the strategies, feasibility may be different in Massachusetts than it is at the national scale. Massachusetts and the Boston region already are more densely settled than many areas of the country.[68]

Most of the benefits of compact development would not be realized within the first twenty years.[69] This strategy is best poised to help meet the statewide Global Warming Solutions Act limit for 2050.

Data Needs:

No Massachusetts or Boston-region-specific data quantifying GHG reductions achievable through compact development are available at this time.

MPO Role:

Growing Cooler provides examples of regional policy recommendations that can encourage compact development: regional transfer of development rights (TDR) programs, carbon impact fees for new development, and assistance to local governments with land development reforms. The MPO cannot directly fund land-use programs to encourage compact development. However, using its new land-use model, the MPO, in conjunction with MAPC, could study land-use policies that have direct links to transportation. For example, over the past several years, MAPC has conducted research and provided technical assistance to encourage transit-oriented development (TOD) near MBTA station areas.

The MPO also could advocate for particular types of land use policies that have benefits for the transportation system and for GHG reductions. For example, carbon impact fees for new development internalize carbon impacts into development costs, similar to more conventional impact fees that governments have charged to offset the costs of new development on transportation, schools, etc. This policy would reward best development practices, including compact, mixed-use development, and revenues could be put towards funding transit, bicycle, and pedestrian facilities. The San Joaquin Valley Air Pollution Control District in the Fresno, California area provides an example of an emissions-based development impact fee. In 2006-07, the district spent more than $9.5 million of nearly $13 million collected in emissions-reduction projects fees that reduced nitrogen oxide pollution by 824 tons and particulate matter (as much as 10 microns in diameter) by 34 tons.[70]

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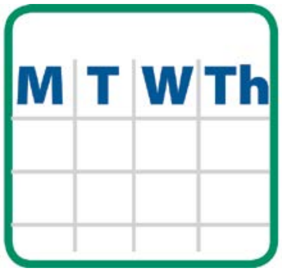
[67] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

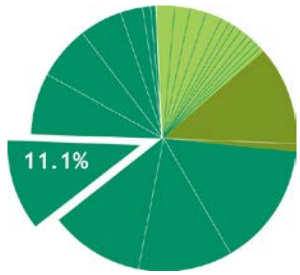
[68] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[69] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[70] Urban Land Institute, *Growing Cooler*, pp. 148-149.

5) Required Employer-Offered Compressed Work Week





Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	L
Political Feasibility	L-H
MPO Role	Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Compressed workweeks save GHG emissions by reducing the number of days that employees need to commute to their workplaces and the total weekly VMT. Examples of compressed workweeks include a four-day, 40-hour schedule (one less day of commuting per week) and a nine-day, 80-hour schedule (one less day of commuting per two weeks). As long as employees drive less on their day off than they would have done on a workday, there would be a reduction in VMT and GHG emissions.

GHG Reduction:

If employers were required to offer the option of working a compressed four-day, 40-hour work week to employees whose jobs are amenable, the International Energy Agency calculated that a sizable GHG emissions reduction of 2.4 percent could be achieved. In this scenario, employees choose whether they would like to adopt a compressed schedule; however, it is assumed that not all employees would choose to adopt a compressed schedule when offered.[71]

Costs and Benefits:

A requirement to offer a compressed work week would be extremely cost-effective, with less than $1 per $MTCO_2e$ in direct public sector costs.[72]

This strategy may support the Long-Rang Transportation Plan goals of capacity management/mobility and clean air/clean communities, as it decreases overall VMT, which in turn, would result in air quality benefits.

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[71] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[72] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

Data Needs:

No studies have been conducted about GHG reductions that might be achieved by implementing this strategy in Massachusetts or the Boston region.

Feasibility and Timing:

Nationally, the Transportation Research Board considers technical feasibility to be high, institutional feasibility to be low, and political feasibility to vary from high to low.[73]

The timing of this strategy's benefits is short; most benefits could be realized within five years.[74]

MPO Role:

The MPO could study the regional or statewide effects of a policy requiring employers to offer compressed work weeks. This strategy was not included in the list of MPO-fundable strategies because it cannot be implemented by the MPO.

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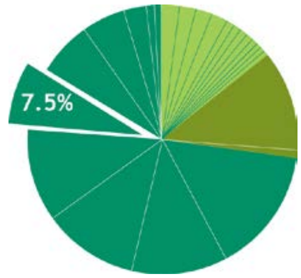
[73] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 26.

[74] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

6) Vehicle-Miles-Traveled Fee



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	L
Institutional Feasibility	H
Political Feasibility	L
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Charging drivers according to vehicle miles traveled, or VMT fees, is another pricing-based strategy with high potential to lower GHG emissions. This strategy works similar to pay-as-you-drive insurance in that motor vehicle drivers are encouraged to drive less through pricing distances driven. VMT could be tracked via the same mechanisms possible for implementing PAYD: audited odometer readings and advanced electronics, GPS, and other telematics technologies that can collect VMT data while not tracking location.[75] VMT and PAYD technology could also be used to support congestion pricing.[76]

GHG Reduction:

With a VMT fee of $0.02 to $0.05 per mile, GHG emissions can be reduced by 0.8 to 2.3 percent from the national transportation sector baseline in 2030. [77] A VMT fee of $0.02 to $0.05 is approximately equivalent (in terms of GHG reduction) to a gasoline tax of $0.40 to $1.00.[78] Note that *Moving Cooler* examined the effects of a VMT fee as high as $0.12 per mile for its maximum deployment scenario.

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[75] Cambridge Systematics Inc., *Moving Cooler*, pp. 70-71.

[76] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-25.

[77] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[78] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-18.

Costs and Benefits:

With a direct cost of \$60 to \$150 per $MTCO_2$, a VMT fee has high cost-effectiveness. The high cost-effectiveness and potential for large GHG emission reductions make this a promising strategy.[79]

This strategy may also support capacity management/mobility and clean air/clean communities benefits because it encourages a mode shift away from driving, therefore decreasing VMT and air pollution proportionally (there is also a potential for reduced crashes because of lower VMT).[80] In general, transportation demand-management strategies such as VMT fees “address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions.”[81]

The revenue generated through a VMT fee could be reinvested in transportation finance, which would help make this strategy’s effects more equitable. *Moving Cooler* found that this pricing strategy did create inequities for lower income groups, which could be mitigated through transportation programs, e.g., transit and ridesharing programs, to improve mobility. [82]

This pricing strategy would not promote fuel efficiency gains unless the VMT fees also were tied to vehicles’ GHG emission rates, fuel efficiency, or weight.[83]

Feasibility and Timing:

A VMT fee strategy faces feasibility challenges. For implementation at the national level, the Transportation Research Board ranks this strategy high in institutional feasibility, but low in technical and political feasibility.[84] In terms of social concerns, this road pricing strategy may be controversial, as it is a new fee and there may be privacy concerns despite technologies that delete locations traveled or offer anonymous accounts.[85] The Massachusetts Legislature has previously considered studying a VMT fee through a pilot study proposed in Bill

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[79] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[80] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, Volume 2, pp. 5-19.

[81] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[82] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 4-26–4-27.

[83] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 3-25.

[84] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[85] USDOT, FHWA, *Reference Sourcebook*, p. 41.

H.2660, *An Act Relative to Transportation Economic Development and Ridership*.[86]

This strategy's timing of benefits is short: Most benefits could be realized within five years.[87]

Data Needs:

No studies have been conducted on the effects of implementing a VMT fee in Massachusetts or the Boston region.

MPO Role:

The MPO does not have the authority to implement VMT fees; however, it could study or advocate for proposals for this strategy.

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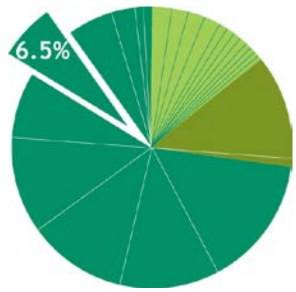
[86] The 189th General Court of Massachusetts, Bill H.2660: An Active Relative to Transportation Economic Development and Ridership, 2015, https://malegislature.gov/Bills/187/House/H2660.

[87] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

7) Reduced Speed Limits to 55 mph



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	M-H
Political Feasibility	L
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Clean Air/Clean Communities
- Safety
- Economic Vitality

Description:

Lowering the speed limit from the current 65 miles per hour (mph) to 55 mph is a promising GHG reduction strategy that requires relatively little expenditure to achieve. Because vehicles rapidly lose fuel economy as they increase speeds greater than 50 mph, setting the speed limit at 55 mph prevents wasted fuel by helping drivers achieve maximum efficiency.[88] The national maximum speed limit had been set at 50 to 55 mph in the past because of energy concerns: The Nixon Administration lowered the speed limit as an emergency response to the 1973 oil crisis. In Massachusetts, the 65 mph speed limit is established in the General Laws, Part I, Title XIV, Chapter 90, Section 17A.[89]

GHG Reduction:

Using the strategy of a lowered national speed limit, Gaffigan and Fleming (2008) calculated GHG reductions of 1.2 to 2.0 percent.[90]

Costs and Benefits:

Establishing a maximum speed limit of 55 mph would be a highly cost-effective means of achieving sizable GHG emissions. The International Energy Agency (2005) estimates a direct cost of only $10 per MTCO$_2$e for this strategy.[91]

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[88] U.S. Department of Energy, www.fueleconomy.gov, Driving More Efficiently, http://www.fueleconomy.gov/feg/driveHabits.jsp (accessed March 17, 2015).

[89] The 189th General Court of the Commonwealth of Massachusetts, *General* Laws, 2015, https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIV/Chapter90/Section17A

[90] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[91] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

Analyses for state climate action plans have found cost-effectiveness of $-200 (representing a net savings) to $55 per $MTCO_2e$; some of the analyses included vehicle operating cost savings in cost-effectiveness.[92] These cost-savings to drivers support the MPO's economic vitality goal.

Importantly, lower speeds also improve safety by reducing the number of crashes with fatalities and injuries, which addresses the LRTP safety goal.[93] According to a National Academy of Sciences analysis in 1984, an estimated 4,000 traffic fatalities per year were averted as a result of the previous national speed limit (55 mph).[94]

Moving Cooler notes that lower speed limits may increase travel times for multiple groups, and perhaps more for people living in rural areas.[95] Further, a speed-reduction program may have social concerns about increased travel times; however, one study of speed reduction from about 75 mph to 50 mph in Rotterdam, in the Netherlands, found that congestion actually improved downstream from the study area.[96,97] The effects on travel times could be positive or negative.

Setting lower speed limits is also associated with air quality benefits, addressing the MPO's clean air/clean communities goal. The Environmental Protection Agency (EPA) predicts that nitrogen oxide emissions are "about 10 percent lower at 60 mph compared to 65 mph, or 17 percent lower at 55 mph versus 65 mph."[98]

Feasibility and Timing:

The Transportation Research Board names potential implementation challenges, stating that although this strategy "can provide significant benefits at modest cost," it nevertheless is "not likely to be popular, and would require strong

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[92] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-39.

[93] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[94] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-39.

[95] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[96] USDOT, FHWA, *Reference Sourcebook*, pp. 136-137.

[97] European Environmental Agency, Success stories within the road transport sector on reducing greenhouse gas emission and producing ancillary benefits, 2008, Copenhagen, http://www.eea.europa.eu/publications/technical_report_2008_2 (accessed March 13, 2015).

[98] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-40.

enforcement to achieve these GHG benefits."[99] National political feasibility is ranked low, technical ranked high, and institutional ranked medium to high.[100]

Most of the benefits from reduced speed limits could be realized within the short-term (five years).[101]

Data Needs:

Studies have not yet been conducted on the effects of implementing a reduced speed limit in Massachusetts or the Boston region. Potential negative or positive effects on travel times in the region are unknown. Additionally, uncertainty exists regarding compliance rates and tolerance by law enforcement of speeding within 10 mph of the speed limit.[102]

MPO Role:

The MPO could advocate for proposals to set reduced speed limits, or it could study the estimated fuel savings and GHG reduction that could be achieved using this strategy.

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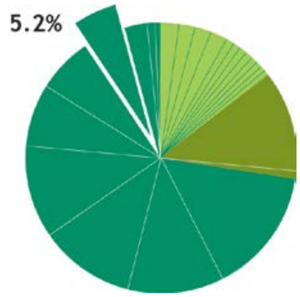
[99] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 34.

[100] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[101] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[102] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-37.

8) Congestion Pricing



Metrics Summary	Rating
GHG Reduction	H
Direct Cost-Effectiveness	M
Technical Feasibility	L
Institutional Feasibility	H
Political Feasibility	L
MPO Role	Study or Advocate

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Congestion pricing is another effective strategy that can be used to reduce greenhouse gas emissions. This concept involves charging a fee for travel during peak periods and/or in certain locations. People may respond by switching from driving to another mode, or by choosing not to drive in certain locations or at certain times to avoid costs associated with congestion pricing.

This strategy may be of particular interest in regional planning: *Cambridge Systematics* states that "of the regional measures evaluated [in *Moving Cooler*], congestion pricing results in the largest impact on reducing GHG emissions." This strategy applies to travel on congested major roads, where more than one-third of highway travel occurs nationally.[103]

London's congestion pricing system provides an example of this strategy in practice. Established in 2003, the London Congestion Zone includes most of Greater London (8.4 square miles) and charges vehicles entering the zone Monday to Friday between 7:00 AM and 6:00 PM about $17 (excluding holidays).[104] A report on London's congestion pricing found that the initiative shifted car occupants to public transportation. Traffic was reduced by about 20 to 30 percent. Bus passengers entering the congestion zone increased 37 percent during the congestion pricing hours in the first year of operation; as much as half of this growth is attributed to former car occupants dissuaded by the congestion charges (the remaining growth reflects the broader bus service improvements). By decreasing traffic volumes and increasing the efficiency of traffic circulation,

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[103] Cambridge Systematics Inc., *Moving Cooler*, p. 40.

[104] Mayor of London, Transport for London, Congestion Charge, http://www.tfl.gov.uk/modes/driving/congestion-charge (accessed March 19, 2015).

congestion pricing directly reduced carbon dioxide emissions from road traffic by 16 percent within the area subject to congestion pricing in the first year.[105] In addition, London has implemented a Low Emission Zone that also covers most of Greater London and uses daily fees to encourage the most polluting heavy diesel vehicles driving in London to become cleaner; it remains in effect 24 hours a day, every day of the year.[106]

In Stockholm, Sweden, a similar congestion pricing zone implemented in 2006 likewise has achieved numerous benefits. A $1.50 to $3 charge has cut traffic volumes by 22 percent, reduced greenhouse gases 14 percent, and increased transit ridership 5 percent. While public opinion was two-thirds against the pricing prior to implementation, understanding of the policy and its benefits has increased; now two-thirds of the public support the strategy. Businesses' sales have increased by 5 percent in the area subject to congestion pricing.[107]

GHG Reduction:

Cambridge Systematics calculated a 1.6 percent possible reduction in GHGs and Energy and Environmental Analysis calculated a 0.5 to 1.1 percent possible reduction through utilization of congestion pricing. Reductions are expressed in a percentage reduction from the national transportation sector baseline in 2030. Cambridge Systematics' high reduction assumes that a roadway level of service (LOS) D is maintained on all roads in the nation, which is equal to an average fee of $0.65 per mile applied to 29 percent of urban and 7 percent of rural roads. Environmental Analysis reductions assume area-wide systems of managed lanes.[108]

Congestion pricing is an example of a strategy that may have a relatively higher impact on GHG emissions in the Boston region than in the nation as a whole, as it is only able to be implemented in certain congested locations. *Moving Cooler* states that, "Of course, in the context of the regions in which congestion pricing is implemented (versus this study's national perspective), the relative impact on GHGs will be greater."[109]

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[105] Transport for London, Central London Congestion Charging, *Impacts monitoring: Fifth Annual Report*, July 2007, http://www.tfl.gov.uk/cdn/static/cms/documents/fifth-annual-impacts-monitoring-report-2007-07-07.pdf (accessed March 19, 2015), pp. 55-57.

[106] Mayor of London, Transport for London, About the LEZ, http://www.tfl.gov.uk/modes/driving/low-emission-zone/about-the-lez (accessed March 19, 2015).

[107] San Francisco County Transportation Authority, *Mobility, Access, and Pricing Study*, 2010, http://www.sfcta.org/sites/default/files/content/Planning/CongestionPricingFeasibilityStudy/PDFs/MAPS_study_final_lo_res.pdf (accessed March 20, 2015).

[108] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[109] Cambridge Systematics Inc., *Moving Cooler*, p. 40.

Costs and Benefits:

A medium direct cost-effectiveness of $340 per metric ton of CO_2e reduced is associated with national implementation of this strategy. No cost estimate is available for the Environmental Analysis calculations.[110]

This strategy potentially supports the Long-Range Transportation Plan goal of capacity management/mobility, depending on implementation, as well as the clean air/clean communities goal. In general, transportation demand-management strategies such as congestion pricing "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[111]

The main mobility concern with congestion pricing is that lower-income travelers might be priced off the roads without a high-quality alternative mode choice. While drivers who pay the congestion fees could experience a delay reduced by as much as 55 percent (estimated for Puget Sound) and enjoy improved reliability of arrival times, the needs of people for whom the pricing is an outsize burden must be met to support transportation equity.[112] Investing in transit, biking, and walking infrastructure can help address inequities for low-income travelers faced with pricing measures. To illustrate, before London implemented its congestion-pricing program, it first made large investments in the city's bus system.[113]

The Transportation Research Board suggests that congestion pricing, road pricing, and other strategies designed to encourage alternative modes would have a greater GHG reduction effect when implemented where better alternatives exist. Again, better alternatives could be brought about through more compact development or increased investment in transit, bicycling, and walking infrastructure.

Feasibility and Timing:

In order for successful implementation to occur, congestion pricing faces some challenges that need to be tackled. While the Transportation Research Board ranks this strategy high in terms of institutional feasibility, they rank it low in terms of technical and political feasibility for national implementation.[114] In terms of social concerns, public opinion surveys have found 70 percent opposition to

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[110] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[111] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[112] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-27–5-28.

[113] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 31.

[114] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

congestion pricing before implementation, but only 30 percent opposition afterwards; this seems to be because tolls are preferred to taxes when people feel that more funding is needed for transportation.[115] Major cities such as London and Stockholm have successfully implemented this strategy. In the US, San Francisco studied congestion pricing (and found it would have pedestrian safety benefits), but has not yet moved toward implementation.[116]

This strategy's timing of benefits is short, within five years.[117]

Data Needs:

GHG reduction estimates are a very rough approximation; "sophisticated regional models are needed to analyze more sensitively the necessary congestion fees and their impacts, which would vary substantially by facility and by time of day." Such models would need to account for "any increases in off-peak travel if people simply shift the time of their trip rather than forgoing it or choosing an alternative mode."[118]

No studies have been conducted about the effects of implementing congestion pricing in the Boston region or Massachusetts.

MPO Role:

The MPO could advocate for proposals to establish a congestion pricing program. It also could study the GHG reductions that could be reached through various levels of pricing.

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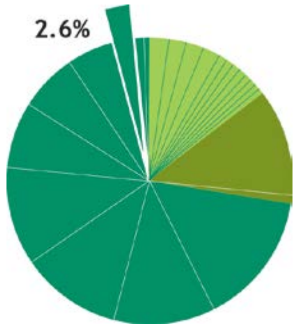
[115] USDOT, FHWA, *Congestion Pricing*, A Primer: Overview, 2008, Washington, D.C., http://www.ops.fhwa.dot.gov/publications/fhwahop08039/fhwahop08039.pdf (accessed March 13, 2014).

[116] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[117] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[118] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-25.

9) Alternative Road Construction Materials



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	L-H
Technical Feasibility	M-H
Institutional Feasibility	M
Political Feasibility	M-H
MPO Role	Advocate

LRTP Goals Addressed:

- Clean Air/Clean Communities

Description:

State and local highway departments and other transportation agencies can utilize less energy-intensive materials such as (recycled) fly-ash cement and warm-mix asphalt in their highway construction projects to cut their greenhouse gas emissions.[119]

GHG Reduction:

This strategy has the power to reduce national transportation sector GHG emissions by 0.7 to 0.8 percent.[120]

Fly ash substitutes for cement in concrete, currently at a rate of 9.8 percent across the US, with savings of 3.3 $MMTCO_2e$ annually. By increasing the substitution rate to 50 percent, 18.4 $MMTCO_2e$ could be cut each year.[121]

Warm-mix asphalt has the ability to cut GHG emissions from asphalt production by 30 to 40 percent, compared to hot mix asphalt. If it replaced hot-mix asphalt on all roadways, there would be a 2.9 $MMTCO_2e$ national GHG savings.[122]

Costs and Benefits:

Using alternative road construction materials can cost the same as conventional materials in some cases; cost-effectiveness ranges from \$0 to \$770 per $MTCO_2e$ reduced.[123]

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[119] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-6.

[120] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[121] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[122] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[123] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

This strategy addresses the MPO's clean air/clean communities goal through lowered air pollution and related environmental benefits as a result of using less energy-intensive technologies. Warm-mix asphalt lowers worker exposure to harmful aerosols and hydrocarbons. It also can reduce plant emissions by "30 to 40 percent for SO_2, 50 percent for VOC, 60 to 70 percent for NOx, and 20 to 25 percent for particulates."[124]

Warm-mix asphalt also provides some benefits for paving, including the ability to pave in cooler temperatures.[125]

Feasibility and Timing:

National adoption of alternative road construction materials has medium intuitional feasibility and medium-to-high technical and political feasibility.[126] Fly ash is a mature technology and practice, so benefits can be achieved in the very near term. However, warm-mix asphalt has not been widely adopted in the US, so benefits would take longer to realize.[127] If the alternative materials are not more costly than the conventional materials, social concerns are not anticipated.[128] In Massachusetts, MassDOT already has chosen warm-mix asphalt as the state standard specification and eliminated hot-mix asphalt.[129]

Once implemented, the timing of benefits for these technologies is short term.[130]

Data Needs:

It is unknown how widely warm-mix asphalt is used at the municipal level in Massachusetts and specifically in the Boston region, and how much further GHGs could be reduced through complete implementation.

MPO Role:

The MPO could advocate for the continued or expanded use of alternative road construction materials at the municipal level. Since the MPO does not directly implement projects, it has limited control over construction decision-making.

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[124] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-85.

[125] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 4-85.

[126] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

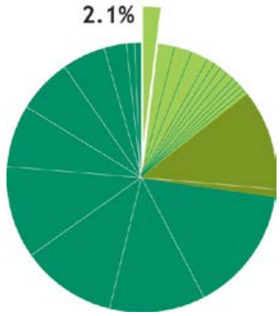
[127] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-84–4-85.

[128] USDOT, FHWA, *Reference Sourcebook*, p. 166.

[129] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

[130] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-35.

10) Expansion of Urban Fixed-Guideway Transit



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	L
Technical Feasibility	M
Institutional Feasibility	H
Political Feasibility	M
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Expansion of urban fixed-guideway transit has the potential to achieve medium GHG reductions, and has the largest potential of the directly MPO-fundable strategies. Many reports suggest that investment in transit could play a significant role in efforts to reduce GHG emissions by shifting travelers to more efficient modes of transportation. *Moving Cooler* makes this point: “Transit investments may be particularly critical if significant pricing strategies are in place, to provide travelers a viable, lower cost alternative to driving.”[131]

Expanding urban fixed-guideway transit in the Boston region would mean extending the Massachusetts Bay Transportation Authority’s (MBTA) existing rapid transit subway lines or adding new commuter rail or bus rapid transit lines. A project to extend the Green Line through Somerville is currently underway, and additional annual expansion would be needed to meet this strategy’s objectives. Large infrastructure projects (urban fixed-guideway transit projects) are capital intensive, but nevertheless this strategy has medium-to-high feasibility and could provide numerous societal benefits.

GHG Reduction:

Expanding urban fixed-guideway transit at a national rate of 2.4 to 4.7 percent annually would garner GHG reductions of 0.17 percent to 0.65 percent by 2030, the highest potential emissions reductions among the transportation

[131] Cambridge Systematics Inc., *Moving Cooler*, p. 42.

infrastructure strategies that the Boston Region MPO could potentially fund.[132] Importantly, transit also ties in to land-use strategies such as compact development. Transit-oriented development projects nationwide have been found to generate 44 percent fewer weekday vehicle trips, on average, than the amount of trips estimated by the Institute for Transportation Engineers.[133] In addition, GHG reductions from significantly expanded urban transit (together with land use changes and pedestrian and bicycle improvements) would continue to grow through 2050, and could be as much as one-third to twice as large in 2050 compared to 2030. [134] These characteristics make this strategy powerful for meeting the Global Warming Solution Act's statewide 2050 limit.

Costs and Benefits:

GHG reductions from expansion of urban fixed-guideway transit would be achieved at a low cost-effectiveness of $1,800 to $2,000 per $MTCO_2e$.[135] Although transit infrastructure and service improvements have low cost-effectiveness for the implementing agency, these strategies can yield net savings to users as a result of reduced personal vehicle operating costs. Ridership is an important factor in determining the cost-effectiveness and benefits of specific projects, which could be negative if ridership is low.[136] Transit is generally more cost-effective in areas of greater population density like the Boston region, so a region-specific analysis potentially could show improved cost-effectiveness.[137]

Transit has been linked to improved job access, access to educational opportunities (supporting increased employment), and access to preventative health care. Following the startup of new transit services, increased job opportunities have been found for low-wage workers, demonstrating the critical role transit can play in employment. Improved access to preventative health care can help individuals avoid the need for emergency care visits, resulting in cost savings.[138]

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[132] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[133] Transportation Research Board, Transit Cooperative Research Program, *Effects of TOD on Housing, Parking, and Travel*, 2008, Washington, D.C., http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_128.pdf (accessed March 20, 2015).

[134] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. ES-6.

[135] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[136] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 33-34.

[137] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 33.

[138] National Cooperative Highway Research Program, Selected Indirect Benefits of State Investment in Public Transportation, Research Results Digest 393, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_393.pdf.

Public transportation can provide transportation equity benefits in the Boston region by alleviating part of any mobility loss as a result of pricing measures, potentially helping to meet the LRTP transportation equity goal. Strategies that improve public transportation can provide a higher proportion of benefits to lower-income groups, as these groups rely on public transportation more than other groups. Similarly, this strategy would provide a higher proportion of benefits to other groups without other transportation mode choices, such as those who reside in rural areas and individuals without access to automobiles.[139] However, rising property values and rent increases associated with transit improvements potentially could result in displacement of lower-income residents; housing measures may be needed to ensure the most equitable outcomes.[140]

The strategic combination of significantly expanding urban transit while making land use changes and pedestrian and bicycle improvements also can "increase mobility, lower household transportation costs, strengthen local economies, and provide health benefits by increasing physical activity."[141] This strategy's importance to compact development means that implementation should explicitly consider the impact on land use to ensure favorable outcomes. If transit expansion is implemented in a way that fosters low-density suburban development, the goals of a compact development strategy may not be met, with adverse effects on other strategies that depend upon it. [142]

This strategy may also support the MPO's capacity management/mobility and clean air/clean communities goals since it increases the percentage of population and places of employment within one-quarter mile of transit stations and stops and encourages a mode shift away from driving, decreasing VMT and associated pollution. In general, transportation demand-management strategies such as new transit infrastructure "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[143]

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[139] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[140] Dukakis Center for Urban and Regional Policy, Northeastern University, Maintaining Diversity in America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change, http://www.northeastern.edu/dukakiscenter/transportation/transit-oriented-development/maintaining-diversity-in-americas-transit-rich-neighborhoods/ (accessed March 25, 2014).

[141] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. ES-6.

[142] USDOT, FHWA, *Reference Sourcebook*, p. 95.

[143] USDOT, FHWA, *Reference Sourcebook*, p. 31.

Feasibility and Timing:

The Transportation Research Board gives this strategy medium technical and political feasibility and high institutional feasibility.[144] Expanding transit service can be popular or controversial, depending on the location, cost, proposed fares, and proposed land uses.[145]

This strategy has medium timing of benefits; most benefits could be realized within five to twenty years.[146]

Data Needs:

Significant expansions to the MBTA's transit system at the scale proposed in this GHG reduction strategy have not been studied. MassDOT and the MBTA are currently developing their Program for Mass Transportation – Focus40, which will analyze and recommend transit improvements for future consideration.

Furthermore, non-fixed guideway transit (e.g., buses) was not studied in this literature review. The GHG reduction potential and cost-effectiveness of this alternative type of transit is unknown, but also is potentially promising. Federal Transit Administration data on average CO_2 emissions per passenger mile by mode show that the emission rate from private automobiles is higher than that from bus transit (although the bus transit rate is higher than the various rail rates). Bus transit emission rates also are projected to decrease by 50 percent by 2050 because of technological improvements.[147]

MPO Role:

If there is an opportunity to help fund a new or extended transit line, the MPO could flex highway funds to support construction of the project. The MPO previously contributed funds to construct the new Assembly Square Orange Line station and the MBTA's Green Line Extension to Medford. The MPO also could continue to study the feasibility, benefits, and challenges associated with implementing various types of transit infrastructure or service.

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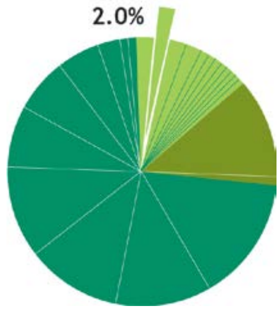
[144] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[145] USDOT, FHWA, *Reference Sourcebook*, pp. 94-95.

[146] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[147] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-35–5-38.

11) Teleworking



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	L
Technical Feasibility	M
Institutional Feasibility	L
Political Feasibility	M-H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Teleworking, or telecommuting, occurs when employees conduct their workday at home or otherwise outside their employer's office, using telecommunications and computer technology to overcome the distance. Most teleworkers across the country work from home, although a very small subset works from telecenters, or small offices that are closer to employees' homes than the main office. Public-sector programs can play a role in encouraging employers to adopt teleworking policies. Surveys indicate that between half and three-quarters of workers offered the option of telecommuting would be interested.[148]

Employers can support teleworking through both formal and informal policies. Potential technological investments also may be needed to support teleworking, although some employees may not need additional technological infrastructure in order to work from home.

GHG Reduction:

Teleworking as a GHG reduction strategy has the potential to cut national greenhouse gas emissions by 0.5 to 0.6 percent if current levels of teleworking are doubled.[149] Teleworking reduces GHG emissions because VMT decreases substantially as commute trips decrease. Although there can be a "rebound effect" where some of the decreased commute VMT is cancelled out by trips that the worker would have made on the way home from work and still needs to complete, it is estimated that this accounts for only one-quarter of daily VMT. This strategy's GHG-reduction estimates account for this rebound effect,

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[148] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-77–5-81.

[149] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

although they do not account for increased home energy use (perhaps 11 to 25 percent of travel energy savings) or the fact that individuals may choose to live further from their workplace when teleworking is an option, thereby increasing VMT on days when they do not telecommute.[150]

Costs and Benefits:

This strategy, at $1,200 to $2,300 per $MTCO_2e$ reduced, has low cost-effectiveness.[151] However, some research suggests that costs likely would decline in the future.[152]

Benefits of teleworking identified by EPA and Congress include “enhanced worker productivity and morale, improved employee attraction and retention, and reduced overhead expenses.” Telework can also enhance mobility and productivity of travel. [153]

This strategy may also support the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities, as it encourages decreased VMT; and can be considered to enhance mobility, as it allows workers to perform activities while eliminating the time and costs of travel.[154] In general, transportation demand-management strategies such as teleworking “address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions.”[155]

Feasibility and Timing:

This strategy generally is supported by private-sector trends. More and more US workers are choosing to work from home as the technology used in teleworking has improved and fuel prices have increased. Between 2001 and 2008 the number of workers employed by a company and teleworking has increased from approximately 8 million to 17 million. When self-employed and contract workers are included, the total number of workers teleworking was 17 million in 2001 and 34 million in 2008. Nearly three-quarters of employee teleworkers (24.2 million

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[150] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 5-77–5-81.

[151] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[152] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 5-77–5-81.

[153] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 5-77– 5-81.

[154] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, Volume 2, pp. 5-80.

[155] USDOT, FHWA, *Reference Sourcebook*, p. 31.

people) work from home at least once per week, representing 18 percent of the employed American workforce.[156]

The Transportation Research Board gives telework a range of feasibility rankings: medium technical, low institutional, and medium-to-high political.[157] There are few social concerns from the public or individual employees about teleworking. More often, employers may resist telework programs because of concerns about managing employees remotely, despite the identified benefits.[158] Increasing teleworking and meetings by web conference is a MassDOT GreenDOT goal.[159]

Most of the benefits of teleworking could be achieved within five years of implementation.[160]

Data Needs:

Information is not available about the percentage of the Boston region or Massachusetts workforce that could take advantage of teleworking. The GHG reduction potential of this strategy has not been studied on a regional or statewide scale.

MPO Role:

Although expansion of teleworking has been driven largely by the private sector, some public-sector programs have been influential as well. A study of teleworking in Washington, D.C. calculated that the Maryland and Virginia Telework Program was responsible for about 10 percent of the District's 0.5 $MMTCO_2$ GHG reductions. In order to encourage and support private businesses in adopting telework, government agencies can institute outreach programs, technical assistance, or incentives such as tax credits or recognition.[161]

MassRIDES advertises that it provides telework and flextime policy guidance to partner employers.[162] The MPO, in conjunction with MassRIDES, could support a telework outreach program through the Clean Air and Mobility Program using CMAQ funds. Teleworking could be included as a strategy in a Workplace

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[156] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-77 – 5-81.

[157] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

[158] USDOT, FHWA, *Reference Sourcebook*, p. 100.

[159] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

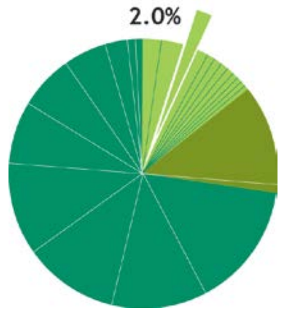
[160] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 3-36.

[161] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-77 – 5-81.

[162] Massachusetts Department of Transportation, MassRIDES, Partnership Program, 2015, http://www.commute.com/employer-options/partnership-program (accessed December 15,2015).

Transportation Demand Management package offered by employers (see Strategy 13 below for more information). Information about teleworking could be disseminated through the MPO's public information channels. The MPO also could study the impact of teleworking on transportation in Massachusetts.

12) Increased Transit Service



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	L
Technical Feasibility	H
Institutional Feasibility	H
Political Feasibility	H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Improving transit headways and level of service has the third-greatest potential to reduce greenhouse gas emissions of MPO-fundable strategies (that are not "publicize only"). As the quality and convenience of transit services increase, people are more inclined to switch from automobile trips to transit trips, reducing VMT and GHG emissions. Many reports suggest that investment in transit could play a significant role in efforts to reduce GHG emissions by shifting travelers to more efficient modes of transportation. *Moving Cooler* notes "Transit investments may be particularly critical if significant pricing strategies are in place, to provide travelers a viable, lower cost alternative to driving."[163] While this strategy is unfortunately one of the most costly means of GHG reductions, it has many other benefits in addition to GHG reductions and is considered one of the most feasible strategies.

GHG Reduction:

Nationally, if transit service is increased 1) by a minimum of 40 percent for off-peak service, and 2) as much as a maximum of 10 percent more for peak service, the International Energy Agency calculates that GHG emissions reductions of 0.2 to 0.6 percent could be realized.[164]

A study of transit agencies that saw rising ridership in the second half of the 1990s found that increased service levels caused growth in ridership. Transit

[163] Cambridge Systematics Inc., *Moving Cooler*, p. 42.

[164] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

agencies that increased their service hours (revenue vehicle hours) the least had the highest rates of return; an average of a 4.3 percent increase in service hours garnered an 8.5 percent rise in ridership. Despite declining rates of return, the agencies that increased their service hours the most saw the largest total ridership gains. On average, a 79 percent increase in service hours resulted in a 64.1 percent increase in ridership. However, the level of transit service provided is a function of demand, so there is no guarantee that increasing service will result in a corresponding ridership growth.[165].

Costs and Benefits:

The cost estimate of increasing transit service by a minimum of 40 percent more off-peak service and as much as a maximum of 10 percent more peak service would be $3,000 to $3,300 per MTCO$_2$e.[166] Although transit infrastructure and service improvements have low cost-effectiveness for the implementing agency, these strategies can yield net savings to users as a result of reduced personal vehicle operating costs.[167] In addition, while this range is at the low end of GHG reduction cost-effectiveness, it also includes many other benefits such as increased equity and economic vitality.

Transit has been linked to improved job access, access to educational opportunities (in this way supporting increased employment), and access to preventative health care. Following the startup of new transit services, increased job opportunities have been found for low-wage workers, demonstrating the critical role transit can play in employment. Improved access to preventative health care can help individuals avoid the need for emergency care visits, resulting in cost savings.[168]

Public transportation can provide transportation equity benefits in the Boston region by alleviating part of any mobility loss as a result of pricing measures, potentially helping to meet this LTRP goal. Strategies that improve public transportation can provide a higher proportion of benefits to lower-income populations since they rely on public transportation more than other populations. Similarly, this strategy will provide a higher proportion of benefits to populations without other transportation mode choices, such as those who reside in rural areas and individuals without access to automobiles.[169] However, rising property values and rent increases associated with transit improvements potentially could

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[165] USDOT, FHWA, *Reference Sourcebook*, pp. 91-92.

[166] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[167] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 33-34.

[168] National Cooperative Highway Research Program, Selected Indirect Benefits of State Investment in Public Transportation.

[169] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

result in displacement of lower-income residents; housing measures may be needed to ensure the most equitable outcomes.[170]

This strategy may also support the MPO's goals of capacity management/mobility and clean air/clean communities' benefits since it encourages a shift away from driving, decreasing VMT, and also may improve the reliability of transit. In general, transportation demand-management strategies such as increasing transit service "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[171]

Feasibility and Timing:

This strategy is considered to have high technical, institutional, and political feasibility at the national level, which makes it almost unique among the list of potential strategies for reducing GHG emissions.[172] Adding new transit service can be popular or controversial, depending on costs and other factors.[173]

Increased transit service has medium timing of benefits; most benefits could be realized within five to twenty years.[174]

Data Needs:

The MPO has conducted a number of studies for increased transit service in the Boston region, including late night transit service, South Station Expansion, and increased service as part of Green Line extension mitigation. However, these studies do not entirely capture the complete picture of full implementation of this strategy.

MPO Role:

The MPO could fund increased transit service to improve transit headways and level of service strategically, potentially through the Clean Air and Mobility program. The MPO can continue to study methods of improving transit service, and the potential impacts of these improvements, at various locations in the MPO region.

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[170] Dukakis Center for Urban and Regional Policy, Maintaining Diversity in America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change.

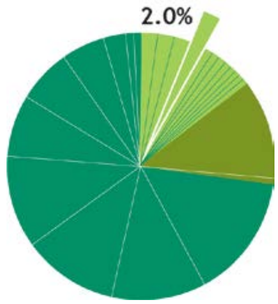
[171] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[172] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

[173] USDOT, FHWA, *Reference Sourcebook*, pp. 94-95.

[174] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

13) Workplace Transportation Demand Management (General)



Metrics Summary	Rating
GHG Reduction	M
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	L-H
Political Feasibility	H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

Transportation-demand management refers to strategies that improve capacity management and mobility by encouraging a shift from single-occupant vehicle (SOV) trips to non-SOV modes (such as to car pools).[175] The goal of workplace transportation demand management (TDM) is to reduce commuter trips by SOVs, and can take the form of requirements for employers to reduce SOV trips or outreach programs to encourage them to do so. During the 1970s energy crisis, transportation agencies were encouraged to develop workplace TDM programs; these programs continue to exist. Metropolitan planning agencies and State Departments of Transportation could implement this strategy and provide voluntary/outreach-based worksite trip-reduction programs.[176]

GHG Reduction:

Widespread employer outreach and alternative mode support can cut greenhouse gas emissions by 0.1 to 0.6 percent. Of the various tools for encouraging workplace TDM, financial incentives and disincentives such as discounted transit passes and parking pricing or cash-out have been found to have a greater effect than simply providing information or through coordination. Parking pricing or parking cash-out involves charging workers for parking or allowing them to “cash out” the value of unused parking. Employees’ willingness to shift modes is also affected by other factors, such as the quality of alternatives

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175 http://www.seattle.gov/transportation/docs/ump/07%20SEATTLE%20Best%20Practices%20in%20Transportation%20Demand%20Management.pdf.

176 Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 5-74–5-77.

to SOV driving and fuel pricing, which can be influenced through complementary strategies.[177]

As a local example, the City of Cambridge established requirements for some employers to reduce SOV trips. The City's Parking and Transportation Demand Management (PTDM) ordinance, originally adopted in 1998, serves as a national model for SOV reduction. The ordinance applies to non-residential properties where an owner proposes to increase parking, and requires owners of 20 or more parking spaces to submit a PTDM plan to ensure that the mode share of SOV drivers is less than 10 percent of 1990 levels. The ordinance gives the city the ability to fine and even close parking at workplaces that fail to meet the ordinance's standards; however, the city has never needed to put these tools into action to achieve compliance. The success of the PTDM ordinance is captured in Kendall Square, which in the past decade saw a 40 percent increase in commercial and institutional space, while automobile traffic decreased on major streets by as much as 14 percent. Less than half of the workers at some workplaces travel in SOVs.[178]

Costs and Benefits:

This strategy is highly cost-effective, at $30 to $180 per MTCO$_2$e.[179] The costs of demand-management strategies include administrative program coordination costs, which would be paid by local and regional agencies and employers. Large state and regional TDM programs usually employ five to ten full-time staff equivalents. Many TDM programs also involve transfer payments, such as transit fare subsidies provided by an employer or regional agency, or new revenue gathered through parking fees. This strategy has resulted in large vehicle cost savings for employees, addressing the MPO's economic vitality goal.[180]

According to MassRIDES, benefits to employers who implement workplace transportation demand-management strategies include improved employee productivity, easier recruitment and retention, reduced absenteeism and late arrivals, increased employee morale, reduced parking and office space needs

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[177] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-74 – 5-77.

[178] City of Cambridge, Community Development Department, Parking and Transportation Demand Management Ordinance, http://www.cambridgema.gov/CDD/Transportation/fordevelopers/ptdm.aspx (accessed March 13, 2015).

[179] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

[180] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-74 – 5-77.

and costs, easier access and traffic flow at the work place, tax savings, and enhanced corporate image.[181]

General workplace TDM may support the MPO's goals of capacity management/mobility and clean air/clean communities, as it encourages a mode shift away from single-occupancy vehicles, in turn decreasing VMT. Most workplace TDM programs "will result in additional mobility options for commuters."[182]

Feasibility and Timing:

In Massachusetts, MassDOT has established MassRIDES, a free program that works with employers and commuters to encourage them to help reduce traffic congestion and improve air quality and mobility. MassRIDES uses "hands-on worksite assistance, ride-matching services, marketing and outreach events" to reduce VMT by 23 million miles and air pollution by 10,000 tons annually.[183] The Boston region also contains eleven local transportation management associations (TMAs): A Better City TMA, Allston Brighton TMA, Charles River TMA, CommuteWorks/MASCO, Seaport TMA, TranSComm, 128 Business Council, The Junction TMO, MetroWest/495 TMA, Neponset Valley TMA, and North Shore TMA.[184]

Massachusetts has a rideshare regulation that requires businesses and educational institutions with 1,000 or more commuters and businesses with 250 or more commuters that are subject to the Massachusetts Air Operating Permit Program to develop plans and set goals for reducing commuter drive-alone trips by 25 percent.

The Transportation Research Board gives workplace transportation demand-management a high rating for technical and political feasibility, and a low-to-high rating for institutional feasibility.[185] Voluntary TDM measures such as ride sharing

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[181] MassRIDES, Partnership Program, Massachusetts Department of Transportation, http://www.commute.com/employer-options/partnership-program (accessed December 3, 2015).

[182] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-74.

[183] Massachusetts Department of Transportation, MassRIDES, "About MassRIDES," http://www.commute.com/about-massrides (accessed March 9, 2015).

[184] MassCommute, List of MA TMAs, http://www.masscommute.com/tma_directory/ (accessed March 25, 2015).

[185] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

are widely accepted, while mandatory TDM ordinances can be controversial.[186] Expanding TDM programs by 20 percent is a MassDOT GreenDOT goal.[187]

Most of this strategy's benefits could be realized in the short term, within five years.[188]

Data Needs:

MassRIDES and the eleven local transportation management associations in the Boston region already provide TDM services. The potential for additional GHG reductions through this strategy is unknown, and implementation of additional measures has not been studied.

MPO Role:

MassRIDES has been established for general workplace transportation demand-management in Massachusetts, and eleven TMAs serve various communities in the Boston region. The Massachusetts Department of Environmental Services administers the Commonwealth's rideshare regulation. The MPO could study the impacts of workplace TDM programs on travel and GHG emissions to see what types of services are most effective in changing travel behavior. It could also continue to provide technical support to the region's TMAs.

In order to see further cuts in GHG emissions, the MPO could consider contributing funding to MassRIDES or the TMAs through the Clean Air and Mobility program in order to expand their impact. In addition, the MPO could provide startup funding for TMA programs and provide information about the benefits of this strategy through its public outreach venues. Voluntary workplace TDM programs should involve financial incentives and disincentives for employees in order to reach maximum effectiveness.

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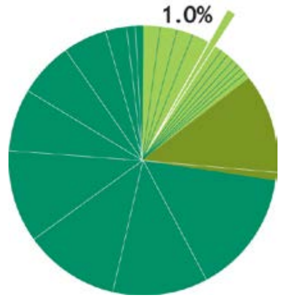
[186] USDOT, FHWA, *Reference Sourcebook*, p. 75.

[187] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

[188] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

14) Pedestrian Improvements



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	L-M
Political Feasibility	M
MPO Role	Fund or Study

LRTP Goals Addressed:

- Safety
- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Improved walking infrastructure can encourage people to choose walking instead of driving, thus reducing VMT and GHG emissions. This strategy assumes that pedestrian improvements are implemented near business districts, schools, and transit stations. Pedestrian improvements include adding or improving sidewalks, crosswalks, crossing signals, and shared-use paths, among others.

GHG Reduction:

If this strategy is implemented, a GHG reduction of 0.10 to 0.31 percent is possible.[189] Again, pedestrian improvements would have the greatest effect if compact, mixed-use development strategies are implemented simultaneously. Notwithstanding, where destinations already are relatively close together and pedestrian trips are discouraged by lack of sidewalks or safe crossings, this strategy can reduce VMT and GHG. To illustrate this at the national level, of the nearly 25 percent of all trips that are less than one mile, about three-quarters of them are made by automobile. Furthermore, less than one-third (fewer than 30 percent) of nationwide trips to school by children ages 5 to 15 are made by walking or bicycling.[190] There is great potential to shift automobile trips to walking trips.

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[189] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[190] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

Because the Boston region has greater population densities than much of the country, more trips may be suitable for walking than for national trips as a whole. This strategy could help achieve a larger share of regional emissions reductions than the national percentages suggest; see similar discussion regarding bicycle improvements.

Costs and Benefits:

Pedestrian improvements are highly cost-effective, as they can be implemented at $190 per MTCO$_2$e.[191] Some pedestrian improvements, such as incorporating enhanced pedestrian crossings into new or reconstructed roadways are low-cost, while more costly improvements include retrofitting suburban areas with sidewalks.[192]

The Long-Range Transportation Plan goal of capacity management/mobility may also be supported by this strategy as it creates a connected network of accessible sidewalk facilities by expanding existing facilities and closing gaps. It also encourages a mode shift away from driving, decreasing VMT.

Improvements to pedestrian (and bicycle) accommodations come with key public health and transportation equity benefits. *Moving Cooler* states that investment in pedestrian and bicycle modes "can have substantial positive equity effects by increasing mobility for lower income groups and all those without significant access to vehicles." Those without significant access to vehicles include youth, the elderly, disabled persons, lower income individuals, or other individuals without driver permits. Having walking and biking as newly available transportation options would enhance the ability of individuals in these groups to access needed services.[193]

The LRTP's economic vitality goal may be well supported by pedestrian and bicycle strategies. These modes offer substantial vehicle cost savings; when the costs of implementation are considered together with vehicle cost savings for users, there are net savings of $600 to $700 per MTCO$_2$.[194]

The safety benefits of pedestrian facilities are significant. Roadways with sidewalks on both sides of the street have half the likelihood of pedestrian crashes as sites without sidewalks. The presence of sidewalks "dramatically

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[191] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[192] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6.

[193] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[194] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

increases" how well people perceive that their needs are being met as they walk along a roadway.[195]

Pedestrian and bicycle facility improvement strategies also generate benefits in terms of increased physical activity and improved public health. Around 70 percent of American adults do not achieve recommended levels of physical activity, and sedentary lifestyles are associated with the rapid increase in the percentage of Americans that are overweight and obese. Environments that are unsafe for walking and biking influence decisions not to choose these transportation options. However, if these modes can be made safer, allowing more people to walk and bike, a great health benefit could be realized.[196, 197]

Pedestrian and bicycle improvements, like transit, benefit from the presence of compact development. These non-motorized modes support transit use by making connections to and from transit stops, and, like transit, are "much more effective" where destinations are close together in densely developed areas.[198]

Feasibility and Timing:

In *Growing Cooler: The Evidence on Urban Development and Climate Change*, adopting a statewide Complete Streets policy and funding program is named as a state policy recommendation for reducing greenhouse gases. Complete Streets policies could be used to implement the widespread pedestrian improvements needed for this strategy to succeed. *Growing Cooler* names three components of complete streets policies:

- A requirement that pedestrian and bicycle facilities be provided on all new and reconstructed streets and highways, and that pedestrians' and bicyclists' needs be considered in routine roadway operation and maintenance
- A mandate that new streets be interconnected and cul-de-sacs be discouraged so that travel distances for pedestrians and bicyclists are minimized
- Adequate state-level funding commensurate with actual and desired levels of biking and walking. If biking and walking trips make up ten percent of the mode split, then dedicating only one percent of state highway funds to

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[195] U.S. Department of Transportation, *Safety Benefits of Walkways, Sidewalks, and Paved Shoulders*, 2013, Federal Highway Administration, http://safety.fhwa.dot.gov/ped_bike/tools_solve/walkways_trifold/.

[196] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

[197] Centers for Disease Control and Prevention, "Obesity and Overweight," http://www.cdc.gov/nchs/fastats/obesity-overweight.htm (accessed March 6, 2015).

[198] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6.

> these trips would be insufficient. If the goal is to double or triple these types of trips, funding levels will "have to be commensurate" in order to "stand a chance of meeting this objective."[199]

Massachusetts incorporated Complete Streets principles into the 2006 MassDOT Highway Division Project Development and Design Guide, helping to ensure that pedestrian facilities are included in transportation projects. Featuring and prioritizing pedestrian facilities in designs rather than simply accommodating them is a MassDOT GreenDOT goal.[200] Furthermore, the Massachusetts Legislature recently implemented a Chapter 90-I Complete Streets Program that will provide $200 million in funding (12 percent of fiscal year 2016 capital investment) to communities in order to further "Complete Streets" goals such as increasing the safety and comfort of people walking and biking.[201, 202] This program could provide an important step towards achieving the comprehensive pedestrian improvements needed to meet the objectives of this strategy.

The Transportation Research Board ranks the pedestrian improvements GHG reduction strategy high for technical feasibility, low-to-medium for institutional feasibility, and medium for political feasibility.[203]

Most benefits could be realized within five to twenty years.[204]

Data Needs:

The potential for additional GHG reductions through this strategy in the Boston region and Massachusetts is unknown, and implementation of additional measures is not available at this time. However, the MPO recently adopted a work program to develop a method for calculating pedestrian levels of service in the region and provide guidance for its implementation. The program will help

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[199] Urban Land Institute, *Growing Cooler: The Evidence on Urban Development and Climate Change*, 2008, by Reid Ewing, et. al., Washington, D.C.

[200] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

[201] Massachusetts Department of Transportation, MassDOT Capital Investment Plan Fiscal Year 2016, 2015, https://www.massdot.state.ma.us/Portals/0/docs/infoCenter/docs_materials/FY16_FinalCapitalBudget.pdf (accessed December 2, 2015).

[202] The 189th General Court of Massachusetts, General Laws, Chapter 90I Complete Streets Program, 2015, https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIV/Chapter90I/Section1 (accessed December 2, 2015).

[203] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

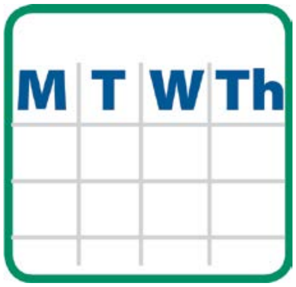
[204] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

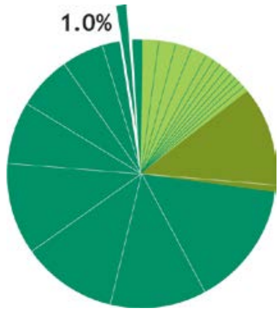
identify areas for improvement to pedestrian facilities in the region. It also will inventory data that is readily available for analyzing pedestrian facilities.

MPO Role:

Through its livability program and other bicycle and pedestrian planning activities, the MPO conducts ongoing pedestrian and bicycle planning activities such as studies and technical assistance. It then funds implementation of some of the small-scale roadway, intersection, bicycle, and pedestrian facilities that are recommended in these and other MPO evaluations and studies. The Congestion Mitigation and Air Quality Improvement program provides funding for implementing these small-scale projects and for constructing larger facilities such as a multi-use path in Somerville. In the MPO's recently adopted LRTP, *Charting Progress to 2040*, six percent of the LRTP's overall funding over the 25-year life of the plan was allocated to a bicycle and pedestrian program to fund these types of improvements. To match the aggressive levels of targeted improvements near business districts, schools, and transit stations called for in the GHG strategy, the MPO could increase funding dedicated to implementing pedestrian improvements.

15) Compressed Workweek: Mandatory Public and Voluntary Private





Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	NA
Technical Feasibility	H
Institutional Feasibility	L
Political Feasibility	L-H
MPO Role	Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

A compressed work schedule allows an employee to work a traditional 35-40 hour workweek in less than the traditional number of work days, which would reduce the number of days that employees would need to commute.[205] While a requirement for both public and private sector employers to offer a compressed work week would garner high GHG reductions, as discussed previously, this different compressed work week strategy is another viable option that would have a moderate effect on emissions. This strategy proposes implementing compressed work weeks for the public (government) sector and expanding voluntary private adoption of the strategy.

GHG Reduction:

If a minimum of 75 percent of government employees nationwide were required to work a four-day-40-hour work week, GHG emissions would be reduced at least 0.1 percent. If current private participation were doubled, in addition to the public sector efforts, the maximum 0.3 percent emissions reductions could be reached.

The public sector represents 14 percent of US employment. It may be easier to implement required compressed work weeks in the public sector than to double voluntary compressed work weeks in the private sector, although the private sector holds the potential for the largest GHG reductions.[206]

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[205] https://www.hr.cornell.edu/life/support/compressed_work_week.html

[206] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-81–5-84.

In order to understand a doubling of private sector participation, Cambridge Systematics and Eastern Research Group examined a number of studies of compressed work week participation. Current estimates put the number of private employers offering compressed work weeks at 33 to 44 percent nationwide. Assuming that employees in newly offering workplaces would elect to adopt compressed work weeks at the same rate, then 66 to 88 percent of private employees would need to offer this option in order to achieve twice the private sector participation. Doing so would reduce 14 billion VMT each year nationwide.[207]

Costs and Benefits:

No direct cost-effectiveness information is available.[208]

For three years beginning in 2008, Utah's state employees adopted a mandatory four-day work week, demonstrating implementation of this GHG reduction strategy. The compressed work week was estimated to cut 12,000 $MTCO_2$ and collectively save employees $5 million to $6 million annually through reduced commuting costs. The program was popular overall with both the employees and the public. A 2009 survey of state employees found that 82 percent wanted to continue the program. Twice as many state residents thought the program was a good idea (60 percent) as thought it was a bad idea (28 percent).[209] A program like this would address the LRTP's economic vitality goal. A few U.S. cities have also adopted four-day work weeks: Gainesville, FL, Huntington, WV, and El Paso, TX.[210]

Although compressed work weeks may be popular on the whole, "not all employees would prefer longer work days or have compatible personal schedules. Therefore, if compressed work weeks are made mandatory, it will benefit some employees and be a disadvantage to others."[211] The first compressed work-week strategy, required employer-offered compressed work week, would allow employees to choose their schedules, thereby addressing this potential negative effect.

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[207] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-81–5-84.

[208] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[209] Brook Vergakis, Associated Press, Utah gov keeps 4-day workweek, *Casper Star Tribune*,December 3, 2009, http://trib.com/news/state-and-regional/article_78cef17e-2897-5595-9e32-4c5e174e79da.html (accessed March 19, 2014).

[210] Jessica Mulholland, Is a Four-Day Workweek Desirable?, *Governing*, August 2011, http://www.governing.com/topics/public-workforce/Is-a-Four-Day-Workweek-Desirable.html (accessed March 19, 2014).

[211] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp. 5-83.

Benefits to capacity management/mobility also may be supported by compressed work weeks as they decrease VMT. This strategy can relieve peak-period congestion because "participating employees work longer hours than a traditional 9 to 5 schedule."[212]

Feasibility and Timing:

Nationwide technical feasibility is ranked high, institutional feasibility is ranked low, and political feasibility may vary from high to low.[213] The timing of benefits for compressed work weeks is short-term; most benefits can be attained within five years.[214]

Data Needs:

The GHG reduction potential of this strategy has not been studied at the regional or statewide scale.

MPO Role:

The MPO could study the impacts of governmental compressed work weeks along with its anticipated GHG reduction in the region. The MPO could conduct a study in conjunction with MassRIDES about the feasibility of increasing voluntary private-sector participation, including the benefits of offering compressed work weeks and its potential as part of a larger work-place TDM outreach program.

This strategy was not included in the list of MPO-fundable strategies, as the minimum assumption, a requirement for government employees, cannot be implemented by the MPO. Nevertheless, the MPO could fund outreach about compressed work weeks to help contribute to increased private-sector participation.

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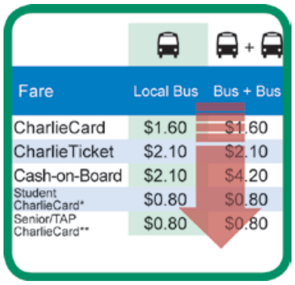
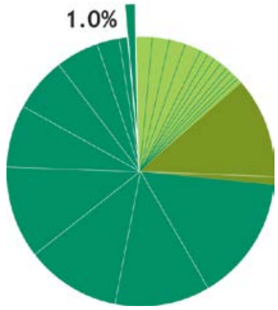
212 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, pp 5-83.

213 Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

214 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

16) Transit Fare Reduction





Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	L
Technical Feasibility	H
Institutional Feasibility	H
Political Feasibility	H
MPO Role	Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

The potential to save greenhouse gas emissions through a large fare reduction of 50 percent could be promising, but there appears to be uncertainty in the magnitude of potential reductions. This strategy could be studied by the Boston Region MPO.

GHG Reduction:

According to the International Energy Agency (IEA), a 50-percent fare reduction would save 0.3 percent of transportation-sector GHG emissions. However, Cambridge Systematics estimates that fare reductions as much as 50 percent can achieve only as much as 0.09 percent GHG emissions reductions.[215] Based mainly on studies in North America, IEA assumes a price elasticity of -0.3, which means that ridership increases three percent when price is reduced 10 percent; this varies according to peak and off-peak travel, as well as between bus and rail travel.[216] Cambridge Systematics' analysis assumes average vehicle occupancy of 1.43 and VMT per trip of 5.12 miles, also with -0.3 price elasticity.[217] It is unclear why the two analyses differ in their conclusions regarding GHG emissions reduced. FHWA separately notes that the effects of transit benefits on ridership can vary and external factors may be significant.[218]

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[215] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[216] International Energy Agency, *Saving Oil in a Hurry*, OECD, Paris, France, pp. 55.

[217] Cambridge Systematics, Inc., Technical Appendices, *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, 2009, p. C-24.

[218] USDOT, FHWA, *Reference Sourcebook*, pp.83-85.

Transit fare reduction cannot be implemented in areas without transit, and because Massachusetts and the Boston region have more transit service than the nation on average, this strategy may have an effect greater than the average 0.09 or 0.3 percent reduction where implemented.

Costs and Benefits:

IEA projects that this strategy would cost more than some others, at $1,300 per MTCO$_2$e in direct implementation costs.[219] Private vehicle operating cost savings would amount to about $900 per MTCO$_2$e, supporting the LRTP's economic vitality goal.[220]

Reducing the cost of transit fares may have beneficial equity impacts if the reductions allow low-income people who previously were unable to afford the fare to use transit, expanding their mobility options. A new 2015 fare-reduction program in Seattle that cut fares by more than half for low-income riders could benefit thousands of riders. Cincinnati has established a similar program that helps 35,000 residents each year.[221]

Transit incentives may help with the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities as it encourages decreasing VMT. In general, transportation demand-management strategies such as transit incentives "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[222]

Feasibility and Timing:

Fare reductions are considered to have high technical, institutional, and political feasibility nationally.[223] Transit fare-reduction programs are "generally well-accepted."[224]

Information on timing is not available.

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[219] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[220] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-40.

[221] National Public Radio, Seattle Cuts Public Transportation Fares For Low-Income Commuters, 2015, http://www.npr.org/sections/thetwo-way/2015/03/02/390279518/seattle-cuts-public-transportation-fares-for-low-income-commuters.

[222] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[223] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[224] USDOT, FHWA, *Reference Sourcebook*, p. 86.

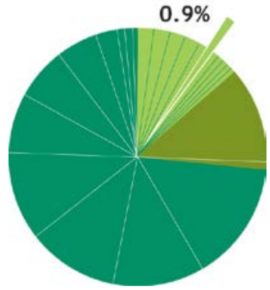
Data Needs:

There appears to be uncertainty about the magnitude of potential reductions with utilizing this strategy. Fare reductions of 50 percent have not been considered or studied for the Boston region or Massachusetts. The timing of benefits is unknown.

MPO Role:

The MPO could study the regional impacts of different levels of transit fare reduction, and recommend or support appropriate reductions. In the past, the Central Transportation Planning Staff of the MPO have studied proposed MBTA fare increases, so this is an area of MPO expertise. However, potential consideration of fare reduction (as opposed to fare increases) is dependent upon larger political decisions concerning funding of Massachusetts's public transportation system.

17) Individualized Marketing of Transportation Services



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	M
Institutional Feasibility	M
Political Feasibility	H
MPO Role	Fund

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

This GHG strategy, typically implemented at a neighborhood level, targets people who are open to alternative modes of transportation, then provides customized contact and transportation mode information. Individualized marketing is a relatively newer form of public information campaign that, in contrast to mass marketing, is tailored to specific individuals. While mass marketing can similarly achieve emissions reductions through travel behavior changes, individualized marketing has even greater GHG-cutting potential and is more cost-effective to implement.[225]

Individualized marketing programs use surveys to find individuals who are willing to consider alternative modes of transportation, and then supply "individualized contact and customized information" on transportation modes preferred by the selected respondents. According to Cambridge Systematics, the more thorough programs may provide "one-to-one personal interaction, such as travel planning advice," while more inexpensive programs "simply rely on survey responses to target print and web media information."[226] Selected neighborhoods in a number of US cities—including Cambridge, MA, Bellingham, WA, Cleveland, OH, Durham, NC, Portland, OR, and Sacramento, CA—have undertaken pilot projects.[227]

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[225] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[226] Cambridge Sytematics, Inc., Effects of Travel Reduction and Efficient Driving on Transportation: Energy Use and Greenhouse Gas Emissions , 2013, U.S. Department of Energy, http://www.camsys.com/pubs/TEF2.pdf (accessed December 2, 2015).

[227] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

GHG Reduction:

If individualized marketing reached 10 percent of the population, it would have the potential to cut emissions by 0.14 to 0.28 percent.[228] VMT reductions of 2 to 8 percent for targeted populations have been achieved by pilot individualized marketing programs that included work and non-work travel. The VMT reductions from these pilot programs suggest that if individualized marketing campaigns could effect a 5 percent VMT reduction in 5 to 10 percent of the US population, the net effect could be as high as a 0.25 to 0.5 percent reduction in VMT.[229]

Costs and Benefits:

This strategy is highly cost-effective, with a direct cost-effectiveness of $90 per MTCO$_2$e.[230] Analysis of Portland's SmartTrips individualized marketing program estimates a cost of $29 per household reached, while a Seattle program cost only $10 to $15 per participant.[231]

This strategy has a number of co-benefits. Public information campaigns increase welfare by helping people make more informed transportation choices, improving their mobility and reducing their travel costs, supporting the MPO's capacity management/mobility and economic vitality goals. Air quality improvements are another benefit of people switching to less GHG-intensive modes.[232]

This strategy would support the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities as it encourages decreased VMT.

Feasibility and Timing:

Individualized marketing does not face any significant feasibility constraints as public information campaigns have a history of implementation;[233] this strategy has medium technical and institutional feasibility and high political feasibility.[234] Pilot projects have been conducted in selected US neighborhoods (this strategy

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[228] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[229] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

[230] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[231] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-9 –5-95.

[232] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

[233] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

[234] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

was originally developed in Europe and Australia), including in Cambridge, Massachusetts.[235]

This strategy's timing of benefits is short term.[236]

Data Needs:

The GHG reduction potential of individualized marketing depends upon the proportion of the population that is: "1) willing to participate in individualized marketing programs, and 2) willing and able to make meaningful and permanent travel behavior shifts."[237] These parameters are unknown and this strategy has not been studied in Massachusetts or the Boston region.

MPO Role:

The MPO could provide funding support through its Clean Air and Mobility program for an existing or potentially new individualized marketing program to attain this strategy's greenhouse gas reductions. The MPO could also host elements of this program if it is web or internet-based, as well as support dissemination of information on the program through its standard outreach channels.

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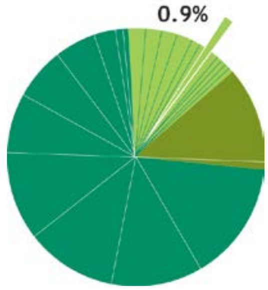
[235] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

[236] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

[237] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-93–5-95.

18) Truck Idling Reduction



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	M
Political Feasibility	M
MPO Role	Fund or Study

LRTP Goal Addressed:

- Clean Air/Clean Communities
- Economic Vitality

Description:

Addressing GHG emissions from freight is important because nationwide freight trucks produce 22.5 percent of transportation sector GHGs.[238] Truck idling reduction can cost-effectively make modest cuts to greenhouse gas emissions. Ways to reduce truck idling include education, laws, technology, and land use decisions. Of these, installing idle reduction equipment (i.e., auxiliary power units) on all sleeper cabs is the most effective way to reduce GHG emissions.[239] Implementation of on-board idle technology would need to coordinate with state regulations.[240]

GHG Reduction:

If 26 to 100 percent of truck sleeper cabs were outfitted with on-board idle reduction technology, GHGs could be cut by 0.09 to 0.28 percent.[241] In Massachusetts 87 percent of freight movement occurs by truck and the Massachusetts Freight Plan projects that trucks will continue to play the largest

[238] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, 2015, http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf (accessed December 2, 2015).

[239] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-41–4-45.

[240] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 34.

[241] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

role in freight movement in the future; GHG reduction strategies targeting truck emissions have significant potential depending on their scale.[242]

Costs and Benefits:

This strategy has a very high direct cost effectiveness of $20 per $MTCO_2e$.[243]

Truck idling reduction addresses the clean air/clean communities and economic vitality goals. The Transportation Research Board sums up the potentially "win-win" nature of this strategy— truck idling reduction "can provide modest total benefits with a low public investment cost while yielding net cost savings to truckers."[244] Similarly, this strategy supports the Massachusetts Freight Plan goal focused on environment and quality of life: "Ensure that the freight system preserves the environment and contributes to the quality of life in Massachusetts." [245] Diesel engines are a significant source of air pollutants such as nitrogen oxides (NOx) and particulate matter.

Feasibility and Timing:

Because only 26 percent of sleeper cab truck owners likely or very likely purchase idle reducing technologies, additional incentives are needed to attain full adoption of these technologies and reach the upper GHG benefits. Regulatory reforms, price incentives, and outreach programs can be used to reach widespread implementation. Examples of existing support for this strategy include EPA's SmartWay program which provides various financing programs for purchasing or leasing idle reduction technologies, and the Energy Improvement and Extension Act of 2008 removed the 12 percent excise tax on idle reduction devices for new trucks.

The feasibility of truck idling reduction is ranked high technically, low-to-medium institutionally, and medium-to-high politically.[246] The cost savings opportunities for truck operators make this strategy socially viable, and surveys on voluntary anti-idling campaigns for air quality purposes have found public support.[247, 248]

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242 Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

243 Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

244 Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 34.

245 Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

246 Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

247 USDOT, FHWA, *Reference Sourcebook*, p. 212.

248 USDOT, FHWA, *Reference Sourcebook*, p. 220.

The timing of benefits is short- to mid-term for this strategy.[249]

Data Needs:

Implementation of this strategy in the Boston region or Massachusetts has not been studied yet.

MPO Role:

The MPO could supply funding for the purchase of auxiliary power units (APU), as other MPOs seeking to reduce freight emissions have done. For example, the North Central Texas Council of Governments offers grant funding through the federal CMAQ program for projects that cut down on unnecessary truck idling. In 2008, $746,000 was split between four applicants, including $84,000 for two private companies to install APUs on the 18 trucks in their fleets (each company won separate grants). It is estimated that the APU would save about 9.8 tons of NOx during the life of the project.[250] The MPO could potentially use CMAQ funds to support such an initiative in the Boston area.

To reach the levels of implementation that match the ambitiousness of the strategy's national goals, the MPO would need to seek additional funding partners. Massachusetts currently has an Anti-Idling Law (MGL, Chapter 90, Section 16A, 310 CMR, Section 7.11 and MGL, Chapter 111, Sections 142A-142M) stating that no person should allow the unnecessary operation of the motor vehicle engine while the vehicle is stopped for a period in excess of five minutes. The regulation applies to all motor vehicles including trucks. Enforcement of this regulation is required for full compliance.

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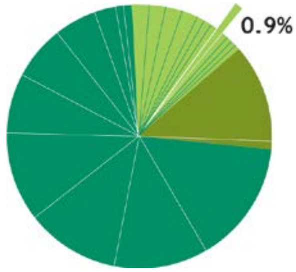
[249] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-35.

[250] Federal Highway Administration, U.S. Department of Transportation, Freight and Air Quality Handbook, Freight Management and Operations, http://www.ops.fhwa.dot.gov/publications/fhwahop10024/sect5.htm (accessed March 31, 2015).

19) Bicycle Improvements



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	M
Institutional Feasibility	L
Political Feasibility	M
MPO Role	Fund or Study

LRTP Goals Addressed:

- Safety
- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Transportation Equity
- Economic Vitality

Description:

Infrastructure investments such as bike lanes, protected bike lanes, and off-road paths are at the center of bicycle improvements. At the same time, bicycle improvements include not only robust networks of bicycle facilities, but also supporting elements such as parking and cyclist training.[251]

GHG Reduction:

If comprehensive bicycle infrastructure is implemented in moderate to high-density urban neighborhoods, GHG reductions of 0.09-0.28 percent could be realized nationally,[252] with much higher benefits possible for the Boston region. This range depends on the extent of improvements as captured by the density of the network and the extent of on-street versus protected or off-street routes. [253] Facilities will provide the most advantages when they are in key locations where the greatest numbers of people can utilize them. *Moving Cooler* describes bicycling strategies at three levels of deployment, as cited below. The intervals refer to the distance between facilities in a grid system of parallel and perpendicular lanes and paths.[254]

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[251] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

[252] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-6.

[253] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

[254] Cambridge Systematics, *Moving Cooler*, p. 24.

1. Expanded Current Practice: Bike lanes and paths at one-mile intervals in high-density areas (>2,000 persons per square mile)
2. More Aggressive: Bike lanes and paths at one-half-mile intervals in high-density areas
3. Maximum Effort: Bike lanes and paths at one-quarter-mile intervals in high-density areas

In the Boston region, more than half of the municipalities exceed 2,000 persons per square mile and would be considered high-density areas. Because the US, on average, has lower population densities that do not support bicycle infrastructure, bicycle improvements could play a much bigger role in the Boston region's emissions than in the nation's emissions as a whole, with regional reductions greater than the 0.09 to 0.28 percent projected nationally.

Costs and Benefits:

Like pedestrian improvements, bicycle improvements are a highly cost-effective strategy, with an estimated cost-effectiveness of $80 to $210 per $MTCO_2e$.[255] The costs of different bicycle infrastructure vary. To build bicycle lanes in new or reconstructed roadways can be inexpensive, while a more expensive example is building a shared-use path.[256] Note that a somewhat more costly facility still could be just as cost-effective per ton of GHG reduced, than a cheaper but less robust facility as not all bicycle facilities hold equal weight in terms of attracting people to bicycle travel. Just as the extent of GHG reductions is dependent upon the extent of on-street versus protected or off-street routes, so too is cost effectiveness. When protected bicycle lanes are built on streets that previously had bike lanes, bicycle ridership has been found to increase 21 to 126 percent, with some of the increase attributed to new riders who otherwise would have used a different mode for their trip.[257] Studies have shown that peoples' associations of safety and comfort increase exponentially in protected bike lanes compared to conventional bike lanes, and that women and people of color stand to benefit the most from protected bike lanes in terms of becoming interested in cycling.[258,259]

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[255] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[256] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6

[257] Portland State University and Alta Planning, *Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S.*, Executive Summary, 2014, National Institute for Transportation and Communities, http://ppms.otrec.us/media/project_files/NITC-RR-583_Executive_SummaryProtectedLanes.pdf (accessed March 25, 2015).

[258] Jennifer Dill, et. al., *Can Protected Bike Lanes Help Close the Gender Gap in Cycling?: Lessons from Five Cities*, 2014, http://docs.trb.org/prp/15-3481.pdf (accessed March 25, 2015).

Bike lanes and protected bike lanes in particular are associated with many safety advantages, not only for people biking but also for people walking. A review of 23 studies about bicycling injuries revealed that bicyclists are safest on bicycle facilities. Following the installation of many miles of new bike lanes in New York City, no increase in bike crashes resulted despite the increase in the number of cyclists. New York City's protected bike lanes reduced pedestrian injury rates by 12 to 52 percent. Another study found that protected bike lanes reduce bike-related intersection injuries by about 75 percent. [260]

Improvements to bicycle and pedestrian accommodations provide key public health and equity benefits. *Moving Cooler* states that investment in pedestrian and bicycle modes "can have substantial positive equity effects by increasing mobility for lower income groups and all those without significant access to vehicles." Those without significant access to vehicles include youth, the elderly, disabled persons, lower income individuals, or other individuals without driver permits. Having walking and biking as newly available transportation options would enhance the ability of individuals in these groups to access needed services.[261]

The Long-Range Transportation Plan goal of capacity management/mobility may also be supported by this strategy as it increases the percentage of population and places of employment with access to bicycle facilities and encourages a mode shift away from driving, decreasing VMT.

The LRTP's economic vitality goal may be well-supported by bicycle and pedestrian improvements. These modes offer substantial vehicle cost savings; when the costs of implementation are considered together with vehicle cost saving for users, there are net savings of $600 to $700 per $MTCO_2$.[262]

Bicycle and pedestrian facility improvement strategies also generate benefits in terms of increased physical activity and improved public health. Around 70 percent of American adults do not achieve recommended levels of physical activity, and sedentary lifestyles are associated with the rapid increase in the

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[259] PeopleForBikes and Alliance for Biking & Walking, *Building Equity*, Race, ethnicity, class, and protected bike lanes: An idea book for fairer cities, 2015, http://www.peopleforbikes.org/blog/entry/race-ethnicity-class-and-protected-bike-lanes-an-idea-book-for-fairer-citie (accessed March 25, 2015).

[260] People for Bikes, Statistics Library/Facilities Statistics, 2015, http://www.peopleforbikes.org/statistics/category/facilities-statistics (accessed December 2, 2015).

[261] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[262] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

percentage of Americans that are overweight and obese. Environments that are unsafe for walking and biking influence decisions not to choose these transportation options. However, if these modes can be made safer and allow more people to walk and bike, a great health benefit could be realized.[263,264]

Bicycle and pedestrian improvements, like transit, benefit from the presence of compact development. These non-motorized modes support transit use by making connections to and from transit stops, and, like transit, are "much more effective" where destinations are close together in densely developed areas.[265]

Feasibility and Timing:

Cities across the country have shown that high bicycle mode shares are possible where substantial investments in bicycle infrastructure are made, and not only where colleges and universities are located.[266] In the US, cities with the greatest share of bicycle commuters include Boulder, Colorado (11.1 percent) and Palo Alto, California (8.4 percent), which demonstrates that bicycling can represent significant mode share.[267] In Massachusetts, Somerville and Cambridge take the lead with more than 7 percent of residents commuting by bike.[268, 269] Abroad, countries that have built extensive cycling networks such as the Netherlands and Denmark have achieved bicycle mode shares of 27 and 18 percent, respectively.[270]

The trend in bicycling nationally and in Massachusetts has been one of rapid growth. Between 2005 and 2013, US states saw a 46 percent increase in the share of people commuting by bicycle; Massachusetts, with 0.8 percent of total commutes made by bicycle, was one of a handful of states that saw more than a 100-percent increase. In 2013, 1.9 percent of Boston's commuters biked to work,

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263 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

264 Centers for Disease Control and Prevention, "Obesity and Overweight," http://www.cdc.gov/nchs/fastats/obesity-overweight.htm (accessed March 6, 2015).

265 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6.

266 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

267 League of American Bicyclists, *Where We Ride: Analysis of bicycle commuting in American* cities, Report on 2013 American Community Survey Data by the League of American Bicyclists, http://bikeleague.org/content/updated-bike-commute-data-released (accessed March 6, 2015).

268 City of Somerville, "Somerville #1 in Northeast, #5 in Nation for Bike Commuting," November 5, 2014, http://www.somervillema.gov/news/somerville-1-ne-5-nation-bike-commuting (accessed March 6, 2015).

269 City of Cambridge Community Development Department, "Bicycle Trends," https://www.cambridgema.gov/CDD/Transportation/gettingaroundcambridge/bybike/biketrends.aspx (accessed March 6, 2015).

270 Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49–5-53.

more than double the statewide rate, representing a 100.7 percent increase in Boston between 2000 and 2013.[271]

Massachusetts incorporated Complete Streets principles in the 2006 MassDOT Highway Division Project Development and Design Guide, helping ensure that bicycle facilities are included in transportation projects. Featuring and prioritizing bicycle facilities in designs rather than simply accommodating them is a MassDOT GreenDOT goal.[272] Furthermore, the Massachusetts Legislature has recently implemented a Chapter 90-I Complete Streets Program that will provide $200 million in funding (12 percent of fiscal year 2016 capital investment) to communities to further Complete Streets goals such as increasing the safety and comfort of people walking and biking.[273, 274] This program could provide an important step towards achieving the comprehensive pedestrian improvements needed to meet the objectives of this strategy.

The feasibility of a bicycle improvement strategy at the national level is rated medium technically and politically and low institutionally.[275] This strategy's feasibility may be greater in Massachusetts than in other states as many Massachusetts cities are leaders in bicycle infrastructure. The League of American Bicyclists ranks Massachusetts as the tenth most bicycle-friendly state, with nine bicycle friendly communities: Cambridge, Somerville, Boston, Nantucket, Northampton, Arlington, Newton, Milton, and Lexington.[276] Furthermore, Hubway, one of a handful of bicycle share systems in the country, has been established in Boston, Brookline, Cambridge, and Somerville.

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[271] League of American Bicyclists, *Where We Ride: Analysis of bicycle commuting in American* cities, Report on 2013 American Community Survey Data by the League of American Bicyclists, http://bikeleague.org/content/updated-bike-commute-data-released (accessed March 6, 2015).

[272] Massachusetts Department of Transportation, *GreenDOT Implementation Plan*, 2012, https://www.massdot.state.ma.us/GreenDOT/GreenDOTReport/GreenDOTImplementationPlan.aspx (accessed December 15, 2015).

[273] Massachusetts Department of Transportation, MassDOT Capital Investment Plan Fiscal Year 2016, 2015, https://www.massdot.state.ma.us/Portals/0/docs/infoCenter/docs_materials/FY16_FinalCapitalBudget.pdf (accessed December 2, 2015).

[274] The 189th General Court of Massachusetts, General Laws, Chapter 90I Complete Streets Program, 2015, https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIV/Chapter90I/Section1 (accessed December 2, 2015).

[275] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[276] League of American Bicyclists, "Award Database," http://bikeleague.org/bfa/awards#community (accessed March 4, 2015).

Most benefits from bicycle improvements could be realized within five to 20 years.[277]

Data Needs:

The GHG reduction potential of this strategy in the Boston region or Massachusetts has not been studied yet.

MPO Role:

The MPO has funded Hubway bicycle shares in Boston, Brookline, and Cambridge, as well as multi-use path construction in Somerville, through its Clean Air and Mobility program. This program also serves as a funding source for implementing small-scale roadway, intersection, bicycle, and pedestrian facilities that are recommended in MPO evaluations and studies. Prioritizing bicycle improvements in multimodal studies/projects where limited resources or right-of-way result in perceived competition between different modes also could help achieve further GHG reductions.

In the Boston MPO's recently adopted LRTP, *Charting Progress to 2040*, six percent of the LRTP's overall funding during the 25-year life of the plan was set aside in a Bicycle and Pedestrian program to fund these types of improvements. In addition, 33 percent has been set aside in a Complete Streets program for the life of the LRTP. Fifty-eight other MPOs have created and adopted a Complete Streets policy to strengthen their bicycle work, including the Metropolitan Washington Council of Governments (Washington, D.C. area), Wilmington Area Planning Council (Wilmington, DE area), Winston-Salem Urban Area Metropolitan Planning Organization (Winston-Salem, NC area), and Lancaster County Transportation Coordinating Committee (Lancaster, PA area).[278]

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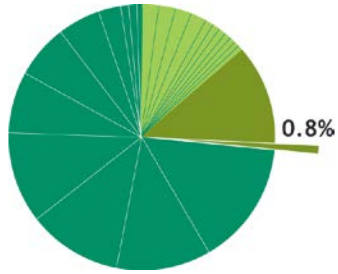
[277] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-36.

[278] Smart Growth America and National Complete Streets Coalition, *The Best Complete Streets Policies of* 2014, 2015, http://www.smartgrowthamerica.org/documents/best-complete-streets-policies-of-2014.pdf (accessed March 27, 2015).

20) Information on Vehicles Purchase



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	L-M
Technical Feasibility	H
Institutional Feasibility	H
Political Feasibility	H
MPO Role	Publicize

LRTP Goal Addressed:

- Clean Air/Clean Communities
- Economic Vitality

Description:

The information about vehicle purchase strategy relies upon expanding the US EPA's freight-oriented SmartWay program and consumer information. SmartWay Transport is the US Environmental Protection Agency's flagship program for improving fuel efficiency and reducing greenhouse gases and air pollution from the transportation supply chain industry.[279] SmartWay is a voluntary collaboration between EPA and the freight industry that assigns a special designation to vehicles that perform well in terms of reducing greenhouse gas emissions and air pollution. While non-freight vehicle purchasers can also benefit from emissions information, this GHG reduction strategy specifically focuses on information for freight vehicles. Examples of key resources for consumers include EPA's Green Vehicle Guide and the US Department of Energy's (DOE) website, www.fueleconomy.gov.

GHG Reduction:

Expanding the EPA's freight-oriented SmartWay program and consumer information could reduce the transportation sector's greenhouse gas emissions by 0.09 to 0.23 percent.[280]

EPA credits the SmartWay program with saving 120.7 million barrels in oil and 16.8 billion in fuel costs between 2004 and 2014.[281] Nitrous oxide and particulate matter have been reduced as well. More than 2,500 partners nationally have

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[279] http://www.epa.gov/smartway/about/documents/basics/420f15033.pdf.

[280] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[281] U.S. Environmental Protection Agency, "SmartWay Program Highlights," http://www.epa.gov/smartway/about/documents/basics/420f14003.pdf (accessed March 4, 2015).

entered the SmartWay program, including large companies such as Wal-Mart and Tyson Foods.[282]

The DOE's website, www.fueleconomy.gov, has also been found to offer information leading to significant emissions reductions. DOE attributes a savings of 200 million gallons and a GHG reduction of 2 $MMTCO_2$ to the program in 2006 alone.[283]

Costs and Benefits:

While the direct cost-effectiveness of this strategy has not been quantified, costs of providing information are expected to be modest relative to other strategies that involve investment in infrastructure or services.[284]

The improved information made available to consumers is expected to result in cost savings, addressing the MPO's Economic Vitality goal.[285] The clean air/clean communities goal also is addressed by this strategy. EPA's SmartWay program "has been credited with saving truckers money and reducing fuel consumption and air pollution. EPA estimates that in 2004–2005, SmartWay projects saved 298 million gallons of fuel per year, saving truckers $850 million in fuel costs, and reduced NOx emissions by 25,000 tons and PM by 841 tons."[286]

Feasibility and Timing:

This strategy is promising, with high technical, institutional, and political feasibility.[287]

Most of this strategy's benefits could be realized in the short- to mid-term.[288]

Data Needs:

The GHG reduction potential of this strategy in the Boston region or Massachusetts is unknown.

MPO Role:

The MPO could support dissemination of information about vehicle purchase through a CMAQ-funded outreach program or via its standard information channels.

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[282] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

[283] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

[284] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

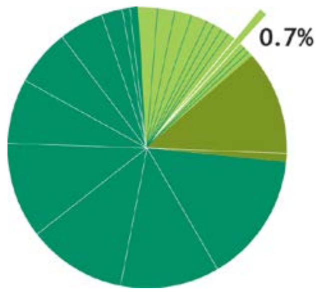
[285] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

[286] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-96–5-97.

[287] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[288] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.

21) Rail Freight Infrastructure



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	M
Institutional Feasibility	M
Political Feasibility	L-H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

Addressing GHG emissions from freight is important as nationwide trucks produce 22.5 percent of transportation sector GHGs.[289] Because moving goods by rail is more energy-efficient than moving goods by trucking, shifting or diverting freight from trucks to rail can reduce greenhouse gas emissions. Such a shift can be accomplished in several ways: infrastructure improvements that reduce the time and cost or increase the reliability of rail shipping, financial incentives or disincentives, and other policy and regulatory actions.[290] Currently 87 percent of all freight movement in Massachusetts is moved by truck, while only 5.0 percent is moved by rail.[291]

The elimination of rail system chokepoints has been compared to highway bottleneck improvements. Both can be accomplished with “infrastructure investments, operations strategies, or demand side improvements.” Rail delay chokepoints can be located at terminals (e.g., intermodal facilities and fueling stations), bridges, tunnels, at-grade crossings, single-track segments, and tracks with low-capacity signal systems.[292]

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[289] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, 2015, http://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf (accessed December 2, 2015).

[290] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 4-54–4-60.

[291] Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

[292] Cambridge Systematics and Eastern Research Group, *Transportation’s Role*, pp. 4-54–4-60.

GHG Reduction:

Rail infrastructure investments in particular hold promise to cut GHGs. With "aspirational estimates of potential truck-rail diversion resulting from [a] major program of rail infrastructure investments," a GHG reduction of 0.01 to 0.22 percent can be attained. Public-sector investments may be necessary to relieve the capacity constraints in the nation's rail network; a study for the American Association of Railroads projected that the private sector is unable to invest the necessary amount itself.[293]

Costs and Benefits:

The direct cost-effectiveness is \$80 to \$200 per $MTCO_2e$. [294] Cost-effectiveness can "vary widely," in part because infrastructure costs can differ greatly.[295]

The LRTP goals of capacity management/mobility, clean air/clean communities, and economic vitality may gain from improved rail freight infrastructure as it potentially involves eliminating bottlenecks on the freight network and decreases VMT. This strategy also supports the Massachusetts Freight Plan goal focused on environment and quality of life: "Ensure that the freight system preserves the environment and contributes to the quality of life in Massachusetts." [296]

Feasibility and Timing:

Nationally, technical and institutional feasibility are medium for this strategy; political feasibility ranges from low to high.[297] In Massachusetts, the Freight Plan projects that trucks will continue to carry the majority of freight movements in the state for the foreseeable future, as shifting freight from truck to rail would be challenging and expensive, and would require coordination across regions. (Potentially, broader concerns about climate change could provide the impetus for a shift in spite of these challenges.) Nevertheless, the Freight Plan did recommend rail improvements as one of several freight investment priorities, to help increase the long-term sustainability of the state's freight system. [298]

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[293] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-54–4-60.

[294] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[295] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 4-54–4-60.

[296] Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

[297] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[298] Massachusetts Department of Transportation, *Freight Plan*, 2010, https://www.massdot.state.ma.us/portals/17/docs/freightplan/MAFreightPlanSeptember2010v2.pdf (accessed December 2, 2015).

The timing of benefits for this strategy is medium-term, five-to-twenty years.[299]

Data Needs:

Implementation of a major program of rail infrastructure investments in the Boston region or Massachusetts has not been studied yet.

MPO Role:

The MPO could recommend or support increased rail freight infrastructure investments, and/or study the rail system to identify chokepoints. The MPO has previously studied freight movement in the region and provides funding annually for a freight-planning program.

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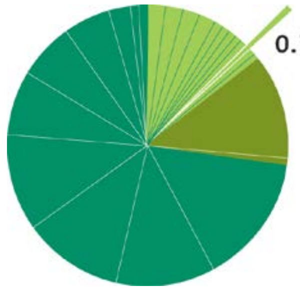
[299] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-35.

22) Parking Management



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	NA
Technical Feasibility	H
Institutional Feasibility	L
Political Feasibility	L
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities
- Economic Vitality

Description:

Changes to parking pricing, supply, and other management techniques that establish disincentives to driving are together called "parking management." Parking management can be used to encourage people to walk, bike, take transit, or use other non-SOV modes to reach their destinations, and it can reduce parking search time. Examples of parking-management techniques include:[300]

- Reducing parking requirements for new development
- Designing and locating parking to encourage pedestrian travel for short local trips
- Charging workers for parking or allowing them to "cash-out" the value of used parking
- "Unbundling" parking costs from the cost of a residential lease or purchase
- Pricing to encourage "park-once" behavior
- Pricing to maintain vacant spaces in order to reduce parking search time
- Reducing on-street parking to leave more right-of-way for facilities for people walking or biking
- Using technology that allows drivers to efficiently locate parking spaces

[300] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-70–5-73.

Parking polices, especially off-street parking for new developments, also may be discussed as part of land use decisions as they are created within the same local planning framework.[301]

GHG Reduction:

Parking management could offer a moderate contribution to a portfolio of combined strategies. Cambridge Systematics and Eastern Research Group (2010) calculated a GHG reduction of 0.2 percent if all downtown workers pay for parking, with a $5-per-day average cost for those not already paying. Both the cost and supply of parking significantly affect travel behavior. A San Francisco Bay Area study found that transit mode shares increased by 50 percent for employees that had to pay for parking, compared to employees with free parking.[302] A US DOT study found that single-occupancy vehicle driving declined 16 to 81 percent when employers raised the price of parking to market rates.[303] In addition, a study of eight firms with nearly 1,700 employees by UCLA professor Donald Shoup found that businesses' VMT declined from 5 to 24 percent, with 12 percent on average, when they offered "parking cash-out" to employees and paid those employees who do not use parking facilities.[304]

Costs and Benefits:

Cost-effectiveness information is not available. Cambridge Systematics includes it in *Moving Cooler's* Low Cost strategy bundle, suggesting that it is lower cost in terms of net cost-effectiveness (weighing direct implementation costs against traveler savings).[305] Parking management can result in lowered costs for new development through the cost savings of constructing fewer parking spaces.[306]

Parking management may help with the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities as it encourages decreased VMT. In general, transportation demand-management strategies such as parking management "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable

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[301] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-54.

[302] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-70–5-73.

[303] U.S. Department of Transportation, *Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources*, 1998, Washington, D.C.

[304] Donald C. Shoup, Evaluating the effects of cashing out employer-paid pashing: Eight case studies, 1997, *Transport* Policy, Vol. 4, No. 4, p. 201-216.

[305] Cambridge Systematics, *Moving Cooler*, p. 62.

[306] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-70–5-73.

communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[307]

Feasibility and Timing:

As a national strategy, technical feasibility is ranked high, but institutional and political feasibility is ranked low.[308] These practices have been implemented nonetheless; for example, California State Law requires certain employers who provide subsidized parking to offer parking cash-out.[309] Parking polices may be received differently in different locations, with more social acceptability in urban areas, where drivers have more transportation choices and already experience parking fees. According to FHWA, although this perception may not be borne out in reality, increased parking costs may be perceived as inequitable to low-income drivers.[310]

After implementation, most of the benefits of parking management could be realized within five to twenty years.[311] Techniques such as market-rate pricing or a parking cash-out option can be implemented within one or two years, while reduced parking requirements in zoning many take years to have widespread effect.[312]

Data Needs:

Implementation of comprehensive parking management in the Boston region or Massachusetts has not been studied yet.

MPO Role:

The MPO could recommend or support municipal, Metropolitan Area Planning Council (MAPC), and State parking management techniques with funding or studies. The MAPC already offers parking technical assistance to interested communities in the Boston region, and supports legislation to bring state laws up-to-date with parking technology and parking-management best practices.[313] The MPO could potentially study parking pricing or on-street parking pricing policy in MPO municipalities.

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[307] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[308] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

[309] Air Resources Board, California Environmental Protection Agency, California's Parking Cash-Out Law, http://www.arb.ca.gov/planning/tsaq/cashout/cashout.htm (accessed March 19, 2015).

[310] USDOT, FHWA, *Reference Sourcebook*, p. 49.

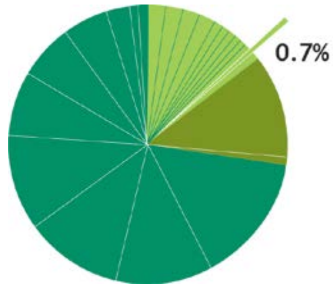
[311] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 3-36.

[312] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-70 – 5-73.

[313] Metropolitan Area Planning Council, Parking Resources, http://www.mapc.org/parking (accessed March 31, 2015).

The Boston Region MPO has the Community Transportation/Parking/Clean Air Mobility Program. Funding can be used to construct new parking spaces and it could fund new smart meters to manage existing parking spaces better through parking pricing. To increase private-sector adoption of parking management, the MPO also could conduct outreach about the benefits of parking management, potentially including this in a larger workplace TDM outreach program.

23) Carsharing



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	M
Political Feasibility	H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

Carsharing describes a system where members pay to rent vehicles as needed on a per-trip hourly basis, either from companies or through peer-to-peer sharing. People who use carsharing services can access cars without car ownership, and they may choose to forego owning their own vehicles. In Cambridge, 70 percent of Zipcar members do not own a car, and 47 percent of Zipcar members who owned a car gave it up after joining Zipcar.[314] Carsharing services already operating in Massachusetts include Zipcar (which offers cars in more than 10 Boston area municipalities), Hertz 24/7, Enterprise CarShare, and peer-to-peer RelayRides. There are more than a million carshare members nationally.

GHG Reduction:

Subsidies for carsharing start-up and operations would save 0.05 to 0.20 percent of transportation GHG emissions. Studies in the US and Canada have found that after accounting for carshare members who drive more often because they did not previously own vehicles, emissions still declined 0.8 to 1.2 $MTCO_2$ per member per year.[315]

Carsharing is dependent on land use strategies as its effectiveness increases with higher densities.[316] In addition, parking management is “synergistic with carsharing: parking polices may increase the incidence of car sharing, and car

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[314] City of Cambridge, Community Development Department, “Carsharing in Cambridge, 2014: The missing link in sustainable transportation,” 2014, http://www.cambridgema.gov/~/media/Files/CDD/Transportation/carpoolandcarshare/Carshare%20in%20Cambridge%20web_20141126.ashx (accessed March 11, 2014).

[315] USDOT, FHWA, *Reference Sourcebook*, p. 53-59.

[316] Cambridge Systematics, Technical Appendices, *Moving Cooler*, p. B-78.

sharing programs (especially with designated parking spaces) may make parking policies more acceptable."[317] Zoning changes also may benefit carsharing; the City of Cambridge Community Development Department suggests that a state Chapter 90 carshare definition be added, and that carsharing be considered in parking requirements and residential district regulations.[318]

Costs and Benefits:

This strategy has very high cost-effectiveness, with a direct cost of less than $10 per $MTCO_2e$ saved.[319] Carsharing is one of the most cost-effective ways to reduce GHG emissions, although ultimately its maximum reductions are limited. The public sector can support this strategy not only through subsidies, but also through publicity and parking spaces.[320]

Carsharing may help with the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities since it encourages decreased in VMT. In general, carsharing "addresses a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[321]

Drivers who drive fewer miles than the break-even point—at which the cost of carsharing equals the cost of car ownership—would save money with carsharing, and are strong potential car sharing candidates.[322] This strategy may support the MPO's economic vitality goal.

Feasibility and Timing:

The Transportation Research Board rates the technical and political feasibility of carsharing subsidies as high, and the institutional feasibility as medium.[323] Social acceptability of car sharing is typically high, and though there may be resistance to reserving public parking spots for carsharing, this has not been significant.[324]

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[317] USDOT, FHWA, *Reference Sourcebook*, p. 50.

[318] City of Cambridge, Community Development Department, "Carsharing in Cambridge, 2014: The missing link in sustainable transportation," 2014, http://www.cambridgema.gov/~/media/Files/CDD/Transportation/carpoolandcarshare/Carshare%20in%20Cambridge%20web_20141126.ashx (accessed March 11, 2014).

[319] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[320] USDOT, FHWA, *Reference Sourcebook*, pp. 53-59.

[321] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[322] USDOT, FHWA, *Reference Sourcebook*, pp. 53-59.

[323] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[324] USDOT, FHWA, *Reference Sourcebook*, p. 58.

Currently, Boston is launching a pilot program that would allow carsharing services to use 200 of the city's public parking spaces, and has collaborated with Zipcar to promote carsharing.

Information on timing is not available.

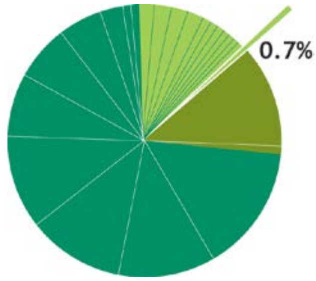
Data Needs:

The GHG reduction benefits of carsharing in the Boston region or Massachusetts have not been studied yet. In addition, information on this strategy's timing is not available.

MPO Role:

Expanding current public outreach programs such as MassRIDES to include carsharing more fully could be relatively simple. The MPO could fund carsharing outreach through existing programs, supported with CMAQ funds or coordinated with the MPO's other public involvement activities. The MPO also could study the role and use of carsharing in the MPO's transportation system, and how that role could be expanded.

24) Ridesharing



Metrics Summary	Rating
GHG Reduction	L
Direct Cost-Effectiveness	H
Technical Feasibility	H
Institutional Feasibility	L-H
Political Feasibility	H
MPO Role	Fund or Study

LRTP Goals Addressed:

- Capacity Mangement/Mobility
- Clean Air/Clean Communities

Description:

This strategy focuses on one type of workplace transportation-demand management—ridematching, carpooling, and vanpooling—which jointly may be called ridesharing. This strategy can reduce VMT by increasing vehicle occupancies for work trips. Carpooling is a formal or informal arrangement between at least two people to commute together in a private vehicle. Vanpooling typically involves five to fifteen people that choose to drive to work together in a van. Ridematching is a service that helps individuals find others with whom to carpool or vanpool. Dynamic ridesharing is a type of ridesharing that allows carpools to be formed on very short notice via internet technologies, mobile phones, etc. Another important piece of ridesharing is guaranteed ride home programs, in which employers reimburse employees for the costs of taxi rides or rental cars in the event of an emergency, or in a situation that requires them to leave work early or stay late.[325]

GHG Reduction:

Extensive rideshare outreach and support for ridematching, carpooling, and vanpooling has the potential to reduce GHG emissions by 0.0 to 0.2 percent.[326] One study of an early vanpool program in Massachusetts found a 66 percent average reduction in fuel use per participant. In Connecticut, a state vanpool program with more than 3,000 commuters in 2006, saved 2.8 million passenger miles and reduced GHG emissions by 1,250 $MTCO_2e$.[327]

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[325] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87–5-91.

[326] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[327] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87–5-91.

Costs and Benefits:

This strategy has a high estimated cost-effectiveness of $80 per $MTCO_2e$. [328] Carpool programs realize a net savings when private vehicle operating costs are included in cost-effectiveness. Vanpool programs can cover most, if not all, of their purchase, operating, and administrative costs through subscription fees, as individuals save on vehicle operating costs. Some state and regional agencies subsidize vanpools to increase viability and ridership; the Denver Regional Council of Governments' fiscal-year 2009 budget set aside $500,000 for vanpool subsidies.[329]

Ridesharing participants see lower travel costs and reduced stress, which are considered to more than offset the extra 10 to 12 minutes of travel time compared to driving alone.[330]

Ridesharing may help with the Long-Range Transportation Plan goals of capacity management/mobility and clean air/clean communities as it encourages decreased in VMT. In general, transportation demand-management strategies such as ridesharing "address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and GHG emissions."[331]

Feasibility and Timing:

MassRIDES has established a statewide ridematching program, NuRide, a free online tool that helps commuters find carpool matches and rewards them for greener trips.[332] This program is supported by the MassRIDES Emergency Ride Home Program that includes as many as four unexpected personal or family illness emergencies, or unexpected mandatory overtime events, per year. NuRide currently reduces GHG by 10,900 $MTCO_2e$.[333] The transportation management associations in the Boston region also offer ridesharing services; see "General Workplace TDM," above, for details.

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[328] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[329] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87–5-91.

[330] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87–5-91.

[331] USDOT, FHWA, *Reference Sourcebook*, p. 31.

[332] Massachusetts Department of Transportation, MassRIDES, "Ridematching & Travel Rewards," http://www.commute.com/commuter-options/nuride (accessed March 9, 2015).

[333] Massachusetts Department of Transportation, unpublished table of Transportation System GHG Reduction Strategies, n.d.

Ridesharing has high technical and political feasibility and low to medium institutional feasibility.[334] Ridesharing on a voluntary basis "is already a widely accepted strategy."[335]

The timing of this strategy's benefits is short, within five years.[336]

Data Needs:

Information about the current NuRide program is available through MassRIDES. The MPO could coordinate with MassRIDES and MassDOT to study further GHG reduction potential by offering additional services.

MPO Role:

MassRIDES and various TMAs in the Boston region currently provide ridesharing services. In order to gain further decreases in GHG emissions, the MPO could consider contributing publicity funding to MassRIDES or the TMAs through the Clean Air and Mobility program using CMAQ funds in order to expand their impact. If the MPO provided funding for a general workplace TDM program at the regional level, new ridesharing services could be provided. The MPO also could directly subsidize the costs of vanpools, as other regional (and state) agencies have done. The MPO could study the role and use of ridesharing in the MPO area, and how that role could be expanded.

Although not included as part of this literature review, transportation network companies should be mentioned as an important transportation alternative emerging in the region. Transportation network companies use online-enabled platforms to connect passengers with drivers using their personal, non-commercial vehicles. Some may refer to these services as ridesharing. Examples in the Boston area include Uber and Lyft. The MPO is currently studying the impacts of these types of services on the Boston Region's transportation system.

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[334] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

[335] USDOT, FHWA, *Reference Sourcebook*, p. 75.

[336] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 3-37.