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Managing Traffic in Massachusetts: Assessing the Potential Income Equity Impacts of Congestion Pricing in Greater Boston

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Assessing the Potential Income Equity Impacts of Congestion Pricing in Greater Boston

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LIST OF ABBREVIATIONS

BTA	Balanced Transportation Analyzer
CBD	Central Business District
CPTC	California Private Transportation Company
CTPS	Central Transportation Planning Staff (Boston MPO)
FDR Drive	Franklin D. Roosevelt East River Drive (Manhattan)
FHWA	Federal Highway Administration (U.S. Department of Transportation)
HOT	High-Occupancy Toll Lane
HOV	High-Occupancy Vehicle Lane
I-495	Interstate 495 (Massachusetts) / Outer Beltway
I-90	Interstate 90 / Massachusetts Turnpike (Mass Pike)
I-93	Interstate 93 / Southeast Expressway / Central Artery / Northern Expressway
I-95	Interstate 95 / Route 128 (Yankee Division Highway)
ITF	International Transport Forum
MassDOT	Massachusetts Department of Transportation
MBTA	Massachusetts Bay Transportation Authority
MPO	Metropolitan Planning Organization
MTA	Metropolitan Transit Authority (New York)
MTS	Massachusetts Travel Survey
MTTF	Massachusetts Transportation Trust Fund
SR-91	State Route 91 (California)
T4MA	Transportation for Massachusetts
TNC	Transportation Network Company (e.g. Uber, Lyft)
USDOT	United States Department of Transportation
VMT	Vehicle Miles Traveled

EXECUTIVE SUMMARY

Boston has long grappled with traffic. The city's investment in the Big Dig—then the nation's largest highway construction project—helped ease road congestion after opening in 2006. Yet the persistence of high traffic levels in the city and region reveals the limits of roadway construction. News roads are expensive, spur induced demand, and harm the environment. Despite Boston's recent and substantial investments, the city in 2018 earned the spot of worst-congested city in the United States.[1]

Rather than increasing the supply of roadways, congestion pricing offers a mechanism to manage the demand for these roads. By charging for road access during peak demand periods, congestion pricing attempts to shift demand from peak to non-peak periods, incentivize trip bundling, and/or induce people to shift to alternative travel modes. Congestion pricing has been implemented in a variety of forms globally and across the United States.

Any congestion pricing scheme must address questions of equity, particularly those related to a driver's income and an ability to pay. However, congestion pricing helps address many outstanding equity concerns associated with private vehicle use. For example, Boston's primary source of emissions come from driving trips into or out of the city. Meanwhile, vehicle usage by typically higher income households places health burdens on lower-income areas that drive significantly less. Of those people in the Boston urban area living immediately adjacent to a highway, nearly a quarter are in poverty and more than a third are nonwhite, significantly higher than the Boston area in general.[2]

Case studies of Stockholm, California's SR-91, and New York City reveal the possible equity implications associated with congestion pricing and policy implementation strategies. Several themes emerge from these locations. First, that public acceptance of these policies can be difficult and requires some form of urgency—typically excessive traffic or funding needs—to precipitate action. Second, that any pricing system must provide a clear benefit-cost tradeoff to the public. Typically, that has meant substantial transit improvements prior to the launch of congestion pricing. And third, congestion pricing can prove its worth and overcome public skepticism, although it requires substantial price differentials to shift demand. Indeed, all income groups can benefit from flexibility and time-savings associated with a congestion scheme.

Analysis of the 2011 Massachusetts Travel Survey (MTS) reveals the extent to which commuters driving into Boston come from higher income households. Boston's geographic and socioeconomic distribution in 2011 indicate that a small share—approximately 2%—of commuters from Boston's surrounding communities drive into the region's central zone and are from below median household incomes. And of just those commuters who travel into the central zone from a surrounding town, only about 11% fit this profile. This report estimates that only about 3% of Massachusetts Department of Transportation (MassDOT) toll revenue came from that commuter group. That few radial commuters are lower income drivers points to the feasibility of

[1] INRIX, "INRIX 2018 Global Traffic Scorecard."
[2] Manville and Goldman, "Would Congestion Pricing Harm the Poor?," 8.

providing discounts, waivers, or other equity mitigation strategies while maintaining the pricing scheme's effectiveness to reduce congestion and/or raise revenue.

The preponderance of higher income commuters who drive into Boston presents a strong fit for a congestion pricing scheme. Implementation of this pricing should follow a three-phase time horizon: a near-term pilot, a medium-term permanent policy, and long-term comprehensive policy for the region. A pilot should focus on gauging user responsiveness via discounts on existing MassDOT tolls, which enables short-term testing without a costly transit service change or large equity adjustments. A permanent policy as envisioned in this document would involve expanding some form of tolling to the major roadways into Boston. MassDOT could utilize geography and means testing to mitigate impacts on lower income drivers, while also retaining the policy's effectiveness. Over the long term, the region can consider congestion pricing as an alternative to the motor fuel tax ("gas tax") to more tightly align the burden of highway costs with those who use those roads.

Greater Boston already indirectly bears the costs of congestion, through lost time, higher driving costs, and worse health. In an era of persistently clogged roadways, already-expanded highways, and a surge in ride-hailing apps, congestion pricing acts as mechanism to direct the costs of overused roads to those who create these burdens.

INTRODUCTION

The case for reducing congestion is clear. In 2018, Boston reigned as the most congested city in the United States, with the typical driver losing one week to traffic every year.[3] Attempts to build additional roadway capacity in Boston to address the imbalance are costly, environmentally unfriendly, and lack efficacy. Congestion pricing is a mechanism to impact the demand for roadway usage and has been used in other parts of the United States and around the world. This paper analyzes the potential equity impacts of congestion pricing in Greater Boston and how these impacts could be ameliorated.

Case studies of Stockholm, California's SR-91, and New York City provide insight into congestion pricing's policy construction, delivery, and impacts. Overall, they reveal that congestion pricing is effective, but must be paired with trade-offs (like improved transit service) and quickly demonstrate their effectiveness. Meanwhile, analyzing granular household travel data from the 2011 Massachusetts Travel Survey (MTS) reveals how few people from Boston's surrounding communities both drive into the region's central zone and come from a below-median income household.[4] Of adult workers and students across 155 municipalities surrounding the central zone, only 2.3% of them fit this income and travel profile.

The prevalence of higher income drivers as a share of those who drive into the central zone (approximately 75%) suggests that the economic burden of congestion pricing for those living outside of Boston would largely avoid lower income households.[5] Additionally, mitigating the burden of congestion pricing on impacted lower income households would likely have minimal dilutive and lost-revenue impacts. These equity indicators support experimentation with congestion pricing in greater Boston, given the policy's potential to address the region's intractable traffic levels.

BACKGROUND

History of Boston & Traffic Congestion

As long as there have been vehicles in Boston, there has been traffic. Boston's planning commission noted in 1922 how cars were "strangling the city."[6] Decades later, traffic congestion was a sensitive and relevant political topic in mayoral elections in the 1950s.[7] Despite large investments in highway infrastructure in the 1950s and 1960s, traffic woes continued over the next

[3] INRIX, "INRIX 2018 Global Traffic Scorecard."
[4] Note: Central zone defined by CTPS as Boston, Brookline, Cambridge, Somerville, Medford, Malden, Everett, Revere, and Winthrop.
[5] See Figure 11, Appendix D.
[6] Gellerman, "Why Greater Boston Keeps Getting Stuck In Traffic."
[7] Vaccaro, "Can Traffic Woes Drive Votes?"

several decades. Further proposed highway projects like the Inner Belt and the Southwest Expressway were controversial, and ultimately rejected by residents.[8]

In the 1980s, facing rising congestion levels, Boston began planning an ambitious highway submersion and construction project later called the "Big Dig." By the time construction started in 1991, Boston's main through highway—the Central Artery (I-93)—carried 200,000 vehicles a day, more than twice its original capacity. The project did prove ambitious: when Big Dig construction ended in 2006, costs had ballooned to $24 billion (including interest). As the most expensive highway project in U.S. history, it provided some congestion relief for downtown Boston. But over time, that congestion has returned, and other areas saw congestion continue to worsen.[9] Boston's experience has been consistent with that of other cities: construction of new roadway infrastructure provides short-term relief, but does not solve a region's traffic congestion challenges.

Current trends point to continued higher traffic: Boston's ongoing population rebound (after peaking in the 1950s), the proliferation of rideshare apps (100,000 rides daily within Boston city limits alone), and rising housing costs (pushing workers farther away from downtown).[10] Unwieldy and frustrating traffic levels have been part of metro Boston for decades, with little sign that demand for roadways will slacken without changes to the management of these roads.

Boston's Current Highway System & Access Points

Boston's metropolitan area highway system features two beltways and several radiating roadways. The two beltways sit across the eastern half of Massachusetts. The outer beltway, Interstate 495, runs 120 miles and sits about thirty miles from the center of Boston. This highway was constructed largely wholesale starting in the 1950s and the following decades. Closer to Boston sits Interstate 95 (also better known as Route 128), which acts as the area's inner belt and sits fifteen miles out from downtown Boston. Running perpendicular to these beltways are several major, limited-access roadways that constitute the primary highway entrances into Boston. The endpoints of these radiating roadways in downtown Boston are the focus of this report.

First, the I-93 northern access point runs across the iconic Zakim Bridge. Traffic is untolled, but a 1.6-mile HOV (high occupancy vehicle) lane exists for southbound traffic into the city. During peak travel periods (weekdays 6am-10am), cars with two or more occupants can use the lane. Outside of those restricted hours, traffic can use the lane just like any other. Route 1

[8] Flint, "10 Years Later, Did the Big Dig Deliver?"
[9] Flint.
[10] Acitelli, "Boston Traffic."

Figure 1

Schedule of Selected MassDOT Tolls (Jan 2019)

Route	Toll	Annual Cost*
Tobin Bridge	$ 1.25	$ 625
Sumner / Callahan Tunnels	1.50	750
Ted Williams Tunnel	1.50	750
Mass Pike from S. Station to…		
Newton Corner (Allston)	1.35	675
I-495 (Westborough)	2.45	1,225
Northern Expressway (I-93)	-	-
Southeast Expressway (I-93)	-	-

*Assumes 250 work days with two daily toll events
Source: EZ Drive MA

traffic feeds across the Tobin Bridge and into either the Leverett Circle Connector Bridge ("Leverett Connector") or the Zakim Bridge. Drivers on the Tobin pay a $1.25 flat rate toll.[11] Thus, traffic on the same or adjacent access point into Boston (the Zakim / Leverett Bridges) is a mix of tolled and untolled traffic, despite traveling from similar areas north of Boston.

Second, the Sumner and Callahan tunnels (each hold two lanes of one-way traffic for Route 1A). This tunnel system was the primary access point for decades (until 2003) to get across the harbor from Boston's central business district to East Boston and Boston Logan Airport. This access point is tolled, with electronic tolling gantries installed in 2016. Drivers (with a transponder) pay a $1.50 flat fee to use either tunnel, with local qualified residents paying a small fraction of that toll.[12]

Third, the eight-lane Ted Williams Tunnel runs underneath Boston Harbor between Boston Logan and the Seaport District. Built in 1995 as an extension of the Massachusetts Turnpike (I-90), users with transponders pay a $1.50 flat charge to use the tunnel. Both the Ted Williams and Callahan / Sumner Tunnels feed traffic from Boston to Logan, and vice versa.

Fourth, the Southeast Expressway (I-93) runs from South Station—at the end of the Tip O'Neill Tunnel—serving areas south and southeast of the city. The Southeast Expressway has a 5.4-mile HOV zipper lane: concrete barriers are moved each weekday morning and afternoon to create a separated lane. The HOV lane inbound to Boston operates from 5am-10am and is available for cars with two or more occupants. For outbound traffic in the afternoon, the southbound HOV lane operates from 3pm-8pm.[13] Only about 5% of expressway traffic uses the HOV lane, and it generally has not successfully spurred additional carpooling as originally intended.[14]

Finally, the Mass Pike represents the entry point into Boston for Metro West. Users pay static, distance-based tolls to use the road on any portion between the New York-Massachusetts border and Logan Airport. Traveling from South Station to Worcester, for example, would cost $2.90.[15] Tolling is entirely electronic.

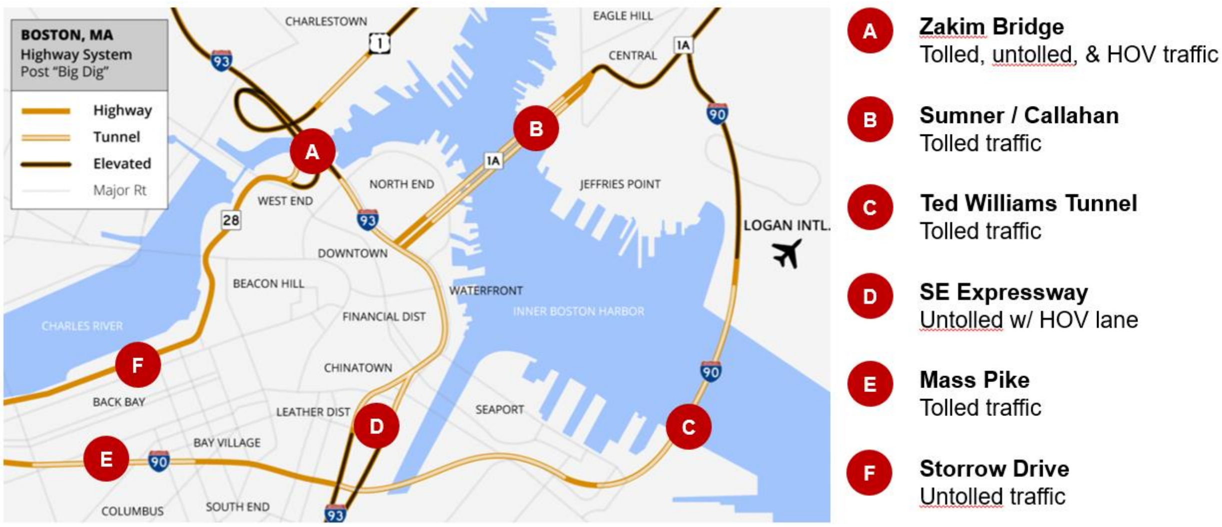
Together, these five primary conduits reflect the current, uneven nature of roadway access into Boston. Part of this variation reflects U.S. law, which has generally prohibited tolls on

[11] MassDOT, "Toll Calculator."
[12] Dumcius, "New All-Electronic Tolling."
[13] "Southeast Expressway HOV Lane."
[14] Adams, "HOV Lane into Boston Gets Little Use."
[15] MassDOT, "Toll Calculator."

federally funded roads (like I-93).[16] In contrast, the Mass Pike came into existence as a tolled facility prior to the expansion of the Federal interstate highway system in the late 1950s.[17] Some drivers in the region pay tolls or have access to HOV lanes, but no form of congestion pricing currently exists. Examples of congestion pricing would be dynamic tolls based off demand (e.g. higher tolls during rush hour) or conversion of HOV lanes to HOT (high occupancy toll) lanes.

MassDOT does offer a carpooling transponder option on the Mass Pike and the Sumner / Callahan tunnels, effectively acting as an overlaying HOT3+ lane policy. A driver must apply in person at one of the seven EZ Drive MA Customer Service Centers with a valid license, registration, transponder, and credit or debit card. Drivers pay a fixed, zone-based annual fee, resulting in discounts of 95% on the Tobin and Boston Harbor tunnels, for example (see Appendix C). The popularity of these programs is not readily available.

Figure 2
Map of Downtown Boston and Major Highways



Credit: Jesse Andrew/Wikimedia Commons; author analysis.

Complementing this road network is the Massachusetts Bay Transportation Authority (MBTA), the fourth-largest public transit system in the United States.[18] Funding comes primarily from external sources: in 2019 fares represent 33% of revenues, while a dedicated sales tax accounts for 51% of revenues.[19] The MBTA generally provides strong transit coverage, with the Boston MPO (Metropolitan Planning Organization) region ranked as having the sixth-best transit access in the United States.[20] However, service is not always reliable and offers patchwork

[16] Deakin et al., "Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy. And Equity Impacts," 2–6.
[17] EDR, "Economic Impacts of the MA Turnpike Authority," p-i.
[18] APTA, "2018 APTA Factbook," 24.
[19] MBTA, "FY19 Itemized Budget."
[20] AllTransit, "AllTransit Rankings."

coverage in certain, often low-income areas. One of the region's worst winters in 2015 crippled the public transit system, leading to a management overhaul and an effort to eliminate the system's State of Good Repair backlog. The MBTA is currently in the process of a five-year, $8 billion capital improvement plan. Around Boston, inner core communities most lacking rapid transit access—thus reliant on bus service, impacted by congestion—are also lower-income areas, like Roxbury, Mattapan, and Everett.[21]

Transit is an alternative to driving, and transit users (particularly bus riders) can benefit from reduced congestion levels that improve the speed and reliability of their routes. Congestion pricing can also generate revenue to improve transit service. As Greater Boston considers congestion pricing, it is important to note that transit coverage and quality dictates the impact of these policies.

Managing Congestion: Supply versus Demand

Jammed roadways act as an indicator of a supply and demand imbalance. Mitigating congestion thus requires addressing either the supply of, or the demand for, roadways. Congestion pricing acts as a mechanism to manage the demand for roadways and presents a more sustainable alternative than simply building new road capacity.

Relieving this imbalance is imperative for policymakers beyond simply alleviating the frustration of drivers. Congestion eats up economic activity: the United States lost $160 billion in 2014 from clogged roads, due to wasted time and extra fuel costs. Meanwhile, chronic traffic backups slow employment growth in cities and reduce economic output.[22] Finally, slow-moving traffic leads to higher emissions, harming public health.

Congestion relief through roadbuilding presents three problems for a city like Boston: price, induced demand, and the environment. First, new roadways are expensive: widening or outright new construction often requires the destruction of existing businesses, homes, or public spaces. Second, as witnessed in the years after the Big Dig, increasing roadway supply causes induced demand: more roadways pull more drivers onto the roads, minimizing the potential reduction in traffic and travel time.[23] Boston is not alone in trying to build its way out of high traffic levels. For decades, roadway construction has been the primary lever to alleviate congestion challenges within the United States.[24] The Boston metro is unique in that its high-ticket roadway projects reveal the limit to which roadway expansion is feasible and efficacious. Third, environmental regulation has tightened over the past several decades to address the emissions generated by vehicle traffic.[25] Building additional roadway capacity is more challenging from a regulatory perspective than previously. In Boston, for example, a lawsuit compelled the state to

[21] Focus40, "Focus40: The 2040 Investment Plan for the MBTA," 16.
[22] Krol, "Tolling the Freeway," 6.
[23] Flint, "10 Years Later, Did the Big Dig Deliver?"
[24] Ecola and Light, "Equity and Congestion Pricing," 2.
[25] Harrington, Krupnick, and Alberini, "Overcoming Public Aversion to Congestion Pricing," 2.

provide significant public transit funding (e.g. the multi-billion-dollar Green Line extension project) to offset the increase in traffic and pollution tied to the Big Dig.[26]

If supply-side mechanisms are costly or ineffective, demand-side mechanisms offer a potentially more compelling opportunity. Congestion pricing attempts to do three things: (1) shift demand from peak to non-peak periods, (2) reduce demand by incentivizing people to bundle trips, or (3) induce people to shift travel modes (e.g. ride the commuter rail instead of driving). That many peak period trips are not work-related suggests an opportunity to shift or bundle discretionary trips.[27]

By pricing roadway use to reflect externalities, Liisa Ecola and Thomas Light of RAND note that this "encourages motorists to behave in ways that more closely reflect the interests of others in society."[28] In other words, congestion pricing corrects a negative externality – the cost that driving imposes on other people trying to use the same road at the same time.[29] This solution provides several benefits: efficiency, and the opportunity for those who value speed to pay and make that tradeoff. Meanwhile, bus riders enjoy more reliable service. And because of the increasing marginal impact of drivers on congestion, reducing traffic by only 5-10% is enough to alleviate congestion by 20% or more.[30] Roadway fees can improve public transit service, warranted because public transit takes drivers off the road. A survey of public transit strikes estimated that a third of public transit users would shift to driving if they lacked an alternative.[31] Congestion pricing presents one primary issue: while offering theoretical net benefits, the fees do hurt low-income drivers who cannot adjust their schedule. In fact, low-income drivers are most likely to suffer from a transition to congestion-based pricing.[32] Assessing equity impacts requires first understanding the income make-up of drivers in Boston, explored in the following sections of this report.

Managing driver demand for roadways provides a better alternative than simply building new roadways, but does require assessing important questions around which groups bear the burden of changing their behavior and incurring costs.

Background on Congestion Pricing as Policy

Congestion pricing has existed for decades in various forms. There are three primary forms of congestion pricing (see Figure 3). First, cordon-based schemes. Under this system, cars pay a fee to enter or exit a specific area. This type of scheme most benefits residents of the charge zone, as they can move freely throughout the zone and take advantage of reduced congestion from outside car traffic. Second, area-based schemes. Similar to cordon-based schemes, users must pay

[26] "Mass. Settles Transit Lawsuit with CLF."
[27] Lee and Gordon, "The US Context for Highway Congestion Pricing," 332.
[28] Ecola and Light, "Equity and Congestion Pricing," 2.
[29] Krol, "Tolling the Freeway," 7.
[30] Deakin et al., "Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy. And Equity Impacts," 2–2; see case studies below.
[31] Aftabuzzaman, Currie, and Sarvi, "Evaluating the Congestion Relief Impacts of Public Transport in Monetary Terms," 20.
[32] Ecola and Light, "Equity and Congestion Pricing," 16.

to be on a roadway inside a specific area. However, they are charged based on whether they are inside the cordon, rather than a fee for entering or exit. London uses this scheme, for example, which encourages users to spend less time downtown. Finally, and most common in the United States are access-point-based pricing schemes. A user pays a fee to pass through a specific roadway point or set of points (corridor). Cordon-based schemes can be thought of as simply a network of coordinated point-based fees. Within the United States, point-based systems exist in a variety of different forms, with highways having some or all lanes tolled at a given tolling point. More than forty jurisdictions across eleven states in 2017 had some form of variable or time-based pricing on busy toll roads.[33]

The United States has generally eschewed congestion pricing in favor of roadway expansion, but traffic volumes and delays grow ever higher. Through the 1970s up to the 1990s, a variety of pilot programs supported by the Federal government foundered, due to their political undesirability.[34] Only recently have demand-based schemes begun to proliferate.

Boston effectively has a flat-rate, point-based system with several major access points and corridors to the city's peninsula requiring a fee to use (e.g. Mass Pike, Tobin Bridge). Users pay regardless of both the time period and level of demand on the highway, as the objective of tolls in Boston is simply to raise revenue for maintenance, not manage demand.

Figure 3

Comparison of Basic Congestion Pricing Policies & Examples

	Congestion Pricing Schemes		
	Cordon	**Area**	**Point**
Concept	Charge for individual or daily trips into and/or out of a specific area	Charge for being in a specific area during a given time	Charge for passing through a certain road point or corridor
Example	Stockholm (2006)	London (2003)	California's SR-91 (1995)
Implementation	Tolls placed on 18 key access points into city center, with prices varying based on demand	Daily flat rate, charged if vehicle identified by cameras within downtown area	Express corridor, with hourly toll schedule adjusted twice a year in response to demand

Source: Economist Intelligence Unit; author analysis

Pricing roadway usage to reduce congestion as an actual, rather than theoretical, policy first emerged in the 1970s. This followed a theoretical breakthrough by William Vickrey in 1969, who identified how optimal tolling can eliminate the social costs of travel delays.[35] Singapore implemented the first comprehensive form of congestion pricing in 1975, relying for decades on

[33] Jansen, "'Dynamic Tolls.'"
[34] Harrington, Krupnick, and Alberini, "Overcoming Public Aversion to Congestion Pricing," 91.
[35] Santos and Verhoef, "Road Congestion Pricing," 564; See Vickrey, "Congestion Theory and Transport Investment."

manual and then later electronic record keeping.[36] Hong Kong was also an early innovator, launching a pilot program in 1985 that ultimately failed to persist amid the tumult of the British transfer.[37] Yet Singapore's system persisted, as city traffic fell by a quarter and the city upgraded the system with newer technology.[38] The policy was not without growing pains: technocrats throughout the 1980s and 1990s needed to implement policy tweaks to resolve negative unintended consequences.[39] Singapore today remains the most extensive form of congestion pricing in operation today, and highly effective at achieving target travel speeds within the city.[40]

London launched congestion pricing in 2003 after decades of studies, using a system of cameras to monitor a downtown cordon area. The city invested in hundreds of new buses before implementing the charges.[41] The first year after implementation saw a sustained 30% reduction in congestion in London's CBD, with no major demand spillover observed onto adjacent areas. Meanwhile, bus ridership into the cordon area rose 37%, even as average bus loads remained stable due to the expanded capacity.[42] Over time, however, the efficacy of London's pricing scheme has weakened. Policy dilution has come from a lack of charges on for-hire and low-emission vehicles. With the advent of ride-hailing and electric vehicles, the growth of these exempt vehicles over the last decade has undermined the policy's impact on congestion levels.[43] Despite the high flat daily rate in London, fewer vehicles incur the full fee compared to when the program launched in 2003.

Congestion pricing exists in a variety of forms globally, with few examples in the United States beyond point-based corridor pricing. Dynamic pricing has recently begun to expand in the United States, albeit with some growing pains as policy makers become more familiar with these schemes. In 2017, Virginia began pricing a HOT lane and briefly saw peak period prices on a segment of Interstate 66 jump to nearly $50. Although prices—and public outrage—eventually stabilized, the episode highlighted the potential challenges of transitioning to priced roadways. Ultimately, however, pricing schemes have continued and evolved even among high-profile cities, reflecting the leverage these schemes can have on downtown traffic levels.

Managing Emissions: Health Equity & Climate

Beyond the economic efficiencies of correctly pricing roadway use, reducing congestion leads to a corollary drop in emissions. These reductions provide substantive health and climate benefits. Moreover, they help address existing inequities on the distribution of harms and benefits from vehicle usage.

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[36] "How and Why Road-Pricing Will Happen."
[37] Harrington, Krupnick, and Alberini, "Overcoming Public Aversion to Congestion Pricing," 2.
Small and Gomez-Ibañez, "Road Pricing for Congestion Management," 219.
[38] "Fix NYC Report," 12.
[39] "Where Economics Stops Short."
[40] Santos and Verhoef, "Road Congestion Pricing," 572.
[41] "Fix NYC Report," 12.
[42] Richards, *Congestion Charging in London*, 187–88.
[43] "The Right Way to Handle Congestion."

Stop-and-go traffic generates substantially more pollution than free-flowing traffic. And in contrast to emission sources that spew particulates high into the air, vehicle emissions are harmful because of their proximity to neighboring residential areas.[44] Highway-adjacent residents thus bear much higher harm from car pollution than other residential areas. Analysis of New Jersey's replacement of toll booths with EZ Pass electronic transponders in the late 1990s, for example, highlights the health benefits of reduced congestion. Electronic tolling eliminated much of the congestion caused by toll booth plazas. In turn, premature and low-weight births each fell roughly 10% for mothers living within two kilometers of the highway.[45]

Pollution raises equity issues of not only geography, but also of income and race. Within the United States, highway-adjacent communities are lower income and have more people of color than highway-free neighborhoods. Of those people in the Boston urban area living immediately adjacent to a highway, nearly a quarter are in poverty and more than a third are nonwhite, significantly higher than the Boston area in general.[46] Those households within 1,250 feet (0.24 miles) of a highway had a poverty rate twice as high than households outside of that zone.[47] Reducing congestion alleviates existing equity concerns about the disproportionate impacts of vehicle-based emissions.

As the health burden of vehicle usage falls more heavily on vulnerable communities, the benefits of vehicle usage accrue mainly to other communities. Low-income households drive less than their more affluent counterparts. In Boston, 40% of households living immediately adjacent to a highway lacked a vehicle, a rate three times higher than the Boston area overall.[48] Reducing congestion eliminates a potent source of emissions, a harm created by more affluent drivers which largely falls on non-driving, lower income, and nonwhite households.

Finally, reducing congestion tackles macro-scale impacts of emissions, namely climate change. Private vehicle emissions accounted for nearly 70% of Boston's transportation-related greenhouse gas emissions in 2016. Three quarters of those emissions come from radial trips starting or ending outside of Boston, which are predominantly private vehicles, versus inter-Boston trips which favor transit, walking, or bike.[49] Congestion pricing can therefore mitigate two contributors of greenhouse gases. First, it reduces the volume of driving, which raises traffic speeds. Incremental speed changes matter: researchers in the 1990s found that a four mile-per-hour drop in average rush hour speed led to a 30% increase in hydrocarbon emissions.[50] Second, the volume of driving decreases from peak period, radial private vehicles, the primary emitters.

Congestion emissions thus exacerbate the existing inequities regarding who benefits and bears the harms from vehicle usage. Vehicle emissions in the Boston area often come from higher income drivers who reside outside of the city. Those emissions then generate the bulk of the city's

[44] Manville and Goldman, "Would Congestion Pricing Harm the Poor?," 4.
[45] Currie and Walker, "Traffic Congestion and Infant Health," 67.
[46] Manville and Goldman, "Would Congestion Pricing Harm the Poor?," 8.
[47] Manville and Goldman, 11.
[48] Manville and Goldman, 10.
[49] Cleveland et al., "Carbon Free Boston," 51–52.
[50] Harrington, Krupnick, and Alberini, "Overcoming Public Aversion to Congestion Pricing," 89.

transportation-related greenhouse gases and harm the health of highway-adjacent communities which are predominantly nonwhite, lower income, and non-driving. Congestion pricing, while raising other equity considerations, can act as a policy instrument to address non-economic equity issues tied to vehicle emissions.

Congestion Pricing Equity Implications

The equity implications of congestion pricing exist prima facie, but an exact definition of what equity entails remains elusive. As Ecola and Light explain, "no accepted and widely used manual exists for assessing equity for transportation project evaluations, let alone congestion pricing."[51] Their RAND research report identifies two major ways to evaluate equity, reflected in the literature: vertical equity and horizontal equity. Vertical equity evaluates the impact of congestion pricing across different groups. Typically, vertical equity refers to income / an ability to pay, and this is the paradigm of highest visibility: how does congestion pricing impact low-income individuals? Questions of vertical equity are highly relevant to congestion pricing because congestion fees implicitly favor users with a willingness to pay. This often, though not always, aligns with the user's income.[52] Horizontal equity then considers how congestion policy impacts members within a group. This axis asks us to consider not how well-off the policy makes the average low-income household, for example, but to look directly into the distribution of those benefits across all low-income households.[53]

Researchers point to tolls as having generally neutral-to-positive equity implications. There are two primary reasons why this positive ambiguity exists.

First, the equity implications of tolls depend heavily on context. Geography matters, and so do the ultimate destinations of toll revenues. In fact, the mechanisms through which toll revenues can ameliorate financial hardship of vulnerable populations largely dictate the policy's equitability.[54] Congestion pricing schemes are progressive to the extent that they have the flexibility to offset impact to the most vulnerable groups.[55]

Second, tolls likely represent an incremental improvement in overall equity, versus current funding and tax schemes. In the United States, the primary funding mechanism for roads is the fuel tax – drivers essentially pay road usage fees based off how much fuel they use. This funding mechanism is fundamentally income regressive, noted as early as 1990 by the CBO.[56] Moreover, fuel and car ownership taxes overlook the high marginal costs imposed by those who use roadways in peak travel times, such as pollution, additional congestion, and lost productivity.[57] As noted

[51] Ecola and Light, "Equity and Congestion Pricing," 5.
[52] Deakin et al., "Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy. And Equity Impacts," 2–3.
[53] Ecola and Light, "Equity and Congestion Pricing," 6–7.
[54] Karlström and Franklin, "Behavioral Adjustments and Equity Effects of Congestion Pricing," 284.
[55] Ecola and Light, "Equity and Congestion Pricing," x.
[56] DeCorla-Souza, "Income-Based Equity Impacts of Congestion Pricing," 6.
[57] "How and Why Road-Pricing Will Happen."

above, congestion emits the highest levels of air pollutions from vehicle traffic, which disproportionately impacts highway-adjacent, often low-income communities.[58]

For Boston, vertical equity involves the distribution of those who drive into the city: how able is this group to bear the burden of congestion fees? Horizontal equity then asks us to consider among those income groups bearing the burden, how could travel alternatives and mitigating strategies ensure a balanced policy impact? The case studies of Stockholm, California's SR-91, and New York illuminate some of the potential equity impacts in Boston, while the 2011 MTS analysis provides a more granular assessment of a congestion price policy.

METHODOLOGY

This report relied on a mix of primary and secondary research sources. Assessing the literature and analyzing the case studies came from analysis of secondary sources, including a mix of news articles, scholarly articles, and policy reports. Analyzing the income equity impacts of a potential congestion scheme around Boston relied on analysis of the 2011 Massachusetts Travel Survey (MTS), administered by the Massachusetts Department of Transportation. The basis for the MTS analysis was a mixture of the raw final survey results, along with an extended dataset created by the staff at the Central Transportation Planning Staff (CTPS), housed within the Boston MPO. Unless explicitly referencing an official MassDOT publication, the 2011 MTS data analysis in this report represents calculations by the author.

CASE STUDIES

Stockholm

Stockholm presents a valuable case study of cordon-based pricing. It is highly relevant for Greater Boston because it represented a successful "trial effort" by policy makers. In 2006, Stockholm had 1.8 million residents with a central business district largely surrounded by water and demarcated by bridge access points.[59] Moreover, researchers conducted extensive, if stuttered surveying of users. Researchers conducted two waves of travel diary surveys before and during the pilot, producing some 40,000 responses.[60]

Congestion pricing in Stockholm did not have a preordained success story. Initially, the government conceived congestion pricing in the mid-1990s as a funding source for new ring road

[58] Ecola and Light, "Equity and Congestion Pricing," ix.
[59] Provonsha and Sifuentes, "Road Pricing in London, Stockholm, & Singapore: A Way Forward for New York City," 10.
[60] Eliasson, Brundell-Freij, and Hugosson, "Stockholm Congestion Charging System," 300.
"Currency Converter: Foreign Exchange Rates."
"CPI Inflation Calculator."

construction. Shifting political priorities and public pushback ultimately halted the effort. Several years later, pricing resurfaced as an environmental mitigation effort.[61]

Approved in 2004 as a permanent policy, Stockholm's congestion pricing suffered early setbacks. First, because of its novelty, the policy had to wrestle with legal issues. Sorting out the legal jurisdiction of the tolls delayed the program by a year. Second, mounting negative public opinion caused lawmakers to curtail the program to only a half-year pilot.[62]

The system eventually went live in January 2006 and ran for seven months. The new policy placed tolls on eighteen access points into downtown Stockholm. The price to pass into or out of the cordon area ranged from €1.50 – €$3.00 (approximately $2.25 – $4.50 in 2019 U.S. dollars), with pricing set dynamically throughout weekdays to target peak travel periods.[63] 30% of traffic entering the zone did not have to pay the pricing scheme, as policymakers exempted specific use-cases like buses and taxis from the tolls. A major north-south highway through the zone—already highly congested prior to 2006—remained untolled throughout the period.[64] The system utilized redundant and affordable technology. The system remained active 99.9% of the time, and had a gross cost-to-revenue ratio of 20% (i.e. twenty-cent cost to get one euro of revenue), in comparison to London which had a ratio of up to 60%.[65]

Despite the program's early setbacks and its limited run, researchers pointed to Stockholm as a success story for several reasons. Most notably, the trial showed a clear, sustained drop in traffic levels within the cordon area. Indeed, proponents and critics of the policy alike had wondered if a short trial would be enough to change behavior. Instead, traffic fell 20-25% throughout the trial period, and quickly rebounded after the trial ended.[66]

The seven-month pilot also revealed other positives. Roadways neighboring the cordon area saw only negligible traffic increases, rather than the spillover congestion feared by many. Commuters also engaged in a slight mode shift, with public transit usage rising by 6% over the period.[67] As drivers made more efficient trips and curtailed the volume of discretionary travel, downtown businesses meanwhile reported no discernable change in business.[68]

Vehicle-related pollution fell concomitantly with congestion. Stockholm's particulate matter (PM10), for example, decreased 15-20%.[69] This reduction in emissions has delivered long-run health benefits. A study in 2018—comparing Stockholm's pre- and post-implementation health records—associated the pricing scheme with a nearly 50% reduction in asthma-related hospitalizations for children under the age of six.[70] Moreover, these asthma rates steadily declined after congestion pricing began—even between the end of the 2006 trial and the permanent policy

[61] Richards, *Congestion Charging in London*, 73.
[62] Shinkman and Buchanan, "Driving Change," 12, 17.
[63] Shinkman and Buchanan, 12.
[64] Eliasson, Brundell-Freij, and Hugosson, "Stockholm Congestion Charging System," 295.
[65] Shinkman and Buchanan, "Driving Change," 2.
[66] Eliasson, Brundell-Freij, and Hugosson, "Stockholm Congestion Charging System," 297.
[67] Eliasson, Brundell-Freij, and Hugosson, 298, 300.
[68] Eliasson, Brundell-Freij, and Hugosson, 300; Shinkman and Buchanan, "Driving Change," 12.
[69] Simeonova et al., "Congestion Pricing, Air Pollution and Children's Health," 3.
[70] Simeonova et al., 16.

launch in 2007—highlighting the increasing long-run health benefits of reduced vehicle emissions.[71]

One key feature of the Stockholm trial was a major upfront investment in public transit in the year prior to implementation of congestion pricing. Tying these investments to the implementation of congestion pricing was meant to both (a) win over a skeptical public and (b) help mitigate potential equity concerns. The investment was substantial: Stockholm's transit system purchased nearly 200 new buses, launched sixteen new bus routes, and bulked up departure frequency on bus, subway, and commuter lines. Simultaneously, the city built 2,800 new park-and-ride spaces (a 25% increase) on the edge of the cordon area, to enable mode shifting as commuters entered the central business district.[72]

Yet despite these significant upfront investments, the evidence does not suggest that these expanded transit facilities in fact drove increased ridership.[73] Indeed, grade-separated riders like subway and commuter rail users don't necessarily experience travel time changes as congestion falls. Of those who maintained the same home and work address from before and after the pilot, few people changed their travel behavior.[74]

The Stockholm case holds several lessons. From a theoretical perspective, it reveals the efficacy of congestion pricing, in cordon-based form. Traffic levels dropped significantly throughout the trial period. Moreover, the city's use of dynamic time-of-day pricing—rather than London's flat daily rate—allowed the city to use lower tolls while still achieving the same reduction in congestion.[75]

Second, from an implementation perspective, Stockholm reveals the importance of a policy "ramp-up" period. In the case of Stockholm, this involved using a trial period to overcome public wariness of new road use fees. Additionally, the city's ex ante investment in public transit reveal how pairing new fees with improved public services delivers clear, understandable trade-offs. This investment might be considered a start-up cost, given that the services themselves did not lead to meaningful public transit use change. The importance of a ramp-up period should not be understated. Sweden's second largest city, Gothenburg, attempted a referendum on congestion pricing in 2013. Without any form of trial, even despite the success of nearby Stockholm, the referendum failed.[76]

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[71] Simeonova et al., 15.
[72] Provonsha and Sifuentes, "Road Pricing in London, Stockholm, & Singapore: A Way Forward for New York City," 4–5.
Eliasson, Brundell-Freij, and Hugosson, "Stockholm Congestion Charging System," 295.
[73] Eliasson, Brundell-Freij, and Hugosson, "Stockholm Congestion Charging System," 303.
[74] Karlström and Franklin, "Behavioral Adjustments and Equity Effects of Congestion Pricing," 291, 295.
[75] "Fix NYC Report," 13.
[76] Davis and Olsson, "Congestion Charging in Stockholm," 187–88.

Finally, public opinion improved throughout the trial as drivers experienced meaningful changes in congestion. In the months prior to the trial, 55% believed the trial was a "rather/very bad decision." By the end of the trial, that opinion share fell to 41%. Ultimately, 51% of Stockholm voters supported the tolls and voted to make the pilot permanent later that year.[77] That support also had key geographic segmentations. Respondents who lived in city center enjoyed the pilot, whereas all the surrounding counties viewed the charges negatively.[78] Yet five years later, the tolls enjoyed nearly 70% support, suggesting that plans that can deliver consistent results can prove their worth.[79]

Figure 4

Change in Attitudes towards Congestion Pricing in Stockholm

Period	Program Status	Public Opinion
Late 2005	Immediately prior to launch of congestion pricing trial	55% believe trial is "rather/very bad decision"
July 2006	End of congestion pricing trial	41% believe trial is "rather/very bad decision"
September 2006	Referendum on permanent congestion pricing policy	51% of Stockholm residents support referendum
2011	Five-year anniversary of congestion pricing policy	70% of Stockholm residents support policy

Source: Bhatt & Higgins, Economist.

Ultimately, the success of Stockholm's pricing scheme linked closely to the decisions of policy makers in how they crafted and executed the policy. Officials made improvements: the city used London's scheme as a foundation, but tweaked it, achieving similar results at lower cost to drivers and government budgets. The city packaged it as a pilot and paired it with transit, to win initial acceptance. And then finally, policy makers let the results speak for themselves. The policy used its easily-verifiable efficacy (commute length change) to shift public acceptance. Stockholm provides policy makers with useful signposts on how to construct and deliver congestion pricing, even in the face of initial skepticism.

California's SR-91

The California legislature in 1989 enabled the launch of the SR-91 express lanes, which opened in 1995 to connect Riverside and Orange Counties. The original ten-mile, four-lane segment ran through the middle of the existing highway, using transponder technology (FasTrak) to charge motorists. The highway represents the first instance of dynamic pricing in the United

[77] Bhatt and Higgins, "Lessons Learned from International Experience in Congestion Pricing," 2–24.
[78] Shinkman and Buchanan, "Driving Change," 13.
[79] "How and Why Road-Pricing Will Happen."

States and an early demonstration of entirely electronic toll collection.[80] Two decades later, in 2017, the express lane corridor would double in length with an expansion into Riverside County.

The corridor operated as a HOT lane: vehicles with three or more passengers could use it free of charge, while others could pay a fee for access. Tolled lanes were priced to ensure 65-mph free-flow traffic, with a single entry and exit point on each end, with no intermediate access points to the express lanes.[81] Later, after 1998, three-passenger vehicles could access the lane with a 50% discount during peak weekday periods, and then use the lanes free during other periods.[82]

At the time of the tolled lane expansion, SR-91 was experiencing five hours of severe congestion each day, with travel patterns shifting to take advantage of shoulder periods of demand.[83] Southern California's packed roadways reflected state-wide trends. California's vehicle traffic (specifically VMT) had doubled between 1973 and 1990, yet its roadways had expanded only 6.8% during that time.[84] Meanwhile, only 5% of commuters in Southern California used public transit, despite substantial investment in transit over the preceding years.[85] Commuters had few travel alternatives to driving, even as traffic conditions deteriorated.

Even in the face of this worsening traffic, congestion management was not the initial impetus for the project. Instead, congestion pricing acted as an alternative funding method for the construction of additional highway lanes: a traditional highway bond financing effort had failed.[86] High congestion levels and a lack of financing alternatives facilitated public acceptance of the proposed toll lanes.[87]

A consortium of highway construction firms, the California Private Transportation Company (CPTC), successfully pitched the thirty-five-year franchise to regional officials in 1990. Beyond caps on the project's rate of return and meeting performance targets, the firm had wide latitude in how it built the roadway and priced the tolls.[88] The highway's launch in December 1995 and its subsequent performance over the following two years proved successful. The public supported the trade-off of tolls for new highway capacity, and CPTC met its performance goals.[89]

SR-91 had a wide range of impacts. In the five years after the lanes opened, parallel routes saw little to no traffic diversion. Attempts to tweak hourly pricing to manage demand produced middling results, with evidence suggesting that toll differentials in peak and non-peak periods were insufficiently large.[90] The tolled lanes delivered value for a wide spectrum of users: all income groups utilized the toll lanes, not just those from high-income groups.[91] In fact, focus groups of

[80] Boarnet and Dimento, "The Private Sector's Role in Highway Finance: Lessons from SR91," 27.
[81] Richardson et al., "Case Study of SR91," 342–43; "SR-91 Express Lanes."
[82] Sullivan, "Continuation Study to Evaluation the Impacts of the SR 91 Value-Priced Express Lanes Final Report"; "SR-91 Express Lanes."
[83] Fielding, "Acceptability of Congestion Pricing in Southern California," 392.
[84] Fielding, 385.
[85] Fielding, 387.
[86] Fielding, 393.
[87] Fielding, 402.
[88] Boarnet and Dimento, "The Private Sector's Role in Highway Finance: Lessons from SR91," 26–27.
[89] Boarnet and Dimento, 27–28.
[90] Sullivan, "Continuation Study to Evaluation the Impacts of the SR 91 Value-Priced Express Lanes Final Report."
[91] Richards, *Congestion Charging in London*, 69.

moderate and lower income households revealed that they valued the option of time savings.[92] SR-91 highlighted the willingness of drivers to pay for reliable travel times.[93]

Drivers using even the untolled lanes experienced a sharp improvement, with travel times more than halving.[94] In the years after construction, the preexisting untolled lanes of SR-91 experienced rising congestion as driver demand for the roadway continued to grow, even as the tolled lanes remained free-flowing. To allow adjacent roadway construction near SR-91, state officials in 2001 purchased the express lane operations from CPTC. The express lanes have continued to be free-flowing, and reveal the extent to which a state agency can operate these tolled facilities.[95]

Tolls vary significantly on SR-91 today. The Orange County Transportation Authority (OCTA) publishes a table of these hourly rates, allowing users to know the toll for any given time of use. Off-peak prices are set annually and adjusted for inflation, while peak period prices are reevaluated every six months.[96] As of January 2019, tolls ranged from $1.65 to $9.65 each way depending on day of week and time of day, with the typical rush hour commuter paying $5-$6 each way.[97] The price spread could be even larger—via cheaper pricing during off-peak times—without the road's requirements to cover operating costs.[98] The range of pricing highlights the need for substantial differences in toll rates in order to shift demand.

As the first instance of demand-based pricing in the United States, SR-91 holds several lessons for other potential value-based roadways. First, similar to Stockholm, congestion pricing was a mechanism to meet other critical policy goals, namely paying for new roadways. As a highway expansion project, the tolls fueled positive public perception. All highway drivers benefited from the additional capacity, but only tolled drivers would have to pay for it. Second, the project revealed the efficacy and relative ease of using tolls to maintain highway speeds. Toll levels are transparent and adjusted on a regular six-month basis, and have been effectively implemented by a public agency. The successful execution of variable pricing by a state agency suggests that MassDOT could administer similarly transparent toll mechanisms. Finally, the project reveals the limits of highway expansion as a long-term strategy to solve congestion. Contrary to California's transit-sparse urban landscape, Boston enjoys a much stronger transit network. Yet even California, oriented towards roadbuilding, soon faced congestion challenges again on the untolled lanes of SR-91.

The success of the SR-91 express lanes stems from their status as new lane construction. The expressway's variable tolls helped pay for construction and maintenance of the road, meaning users benefitted from new lanes. In Boston, congestion pricing would likely overlay existing roadways rather than expand them, although some HOV lanes might experience greater usage if

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[92] Richardson and Bae, "The Equity Impacts of Road Congestion Pricing," 258.
[93] Richards, *Congestion Charging in London*, 23.
[94] Boarnet and Dimento, "The Private Sector's Role in Highway Finance: Lessons from SR91," 28.
[95] Poole, "Useful Lessons from California's Tests with Congestion Pricing."
[96] 91 Express Lanes, "Toll Policies."
[97] 91 Express Lanes, "Orange County Toll Schedules."
[98] Manville and Goldman, "Would Congestion Pricing Harm the Poor?," 14.

transformed to HOT lanes (see policy recommendations below). Nonetheless, the persistence of the SR-91 express lanes and their recent doubling in length in 2017 speak to the viability of demand-based pricing on roadways in the United States.

New York City

New York City remains the most recent and high-profile congestion pricing effort in the United States. As of March 2019, Governor Cuomo and Mayor de Blasio had thrown their support behind congestion pricing, to relieve dual crises of vehicle traffic and critical subway repairs.[99] Experts expect the latest proposed congestion price scheme to fund $15 billion in new bond issuances.[100] This discussion followed other legislative changes in the city. In October 2018, legislators had approved a surcharge on for-hire vehicles (e.g. taxis, Ubers).[101] This recent policy activity and ongoing discussion highlights the extent to which extraordinary, recent circumstances have facilitated the path for congestion pricing as a serious policy consideration.

Since the 1970s, New York City has flirted with the possibility of a pricing scheme to manage traffic demand.[102] The first serious proposal happened during Mayor Bloomberg's administration in 2009, in the wake of London's high-profile congestion scheme in the early 2000s.[103] Despite approval by New York City Council, the effort ultimately failed when the state legislature refused to bring the proposal to vote.

Congestion pricing remained legislatively untouched throughout the following decade. A handful of supporters kept the proposal alive via a grassroots organization, Move NY. Despite a dedicated information campaign, even that simmering effort seemed to stall in 2016 as legislation was unable to move forward. The policy became politically relevant in 2017 when, facing a burgeoning transit crisis, Governor Cuomo identified the scheme as a potential funding mechanism.[104] The Governor convened "Fix NYC," a fifteen-person panel from across the region.

Between 2009 and 2017, the state of New York City's transportation above- and below-ground network had changed substantially for the worse. Part of the change stemmed from long-running trends. The city's population in 2017, for example, had grown by 500,000 since 2000 (approximately the population of Boston in 2000). Other developments, however, were more recent. Tourism had swelled 25%, to 60 million, since 2010.[105] Ride-sharing apps like Uber and Lyft led to a spike in downtown traffic. For-hire vehicle trips in the Manhattan CBD increased 24% in only a five-year period leading up to 2017.[106] Meanwhile, policies to enhance livability—like bike lanes and pedestrian plazas—had (deliberately) reduced the supply of roadways in the

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99 Fitzsimmons and McKinley, "Boost for Congestion Pricing in Manhattan as de Blasio Supports Cuomo Plan."
100 Fitzsimmons and McKinley.
101 Berger and Vielkind, "Congestion Pricing in NYC Gains Traction as Cost of Subway Turnaround Looms; Charging Motorists to Drive into Certain Parts of Manhattan Is the 'only Realistic Option,' Cuomo Says."
102 Fitzsimmons and McKinley, "Boost for Congestion Pricing in Manhattan as de Blasio Supports Cuomo Plan."
103 Schaller, "New York City's Congestion Pricing Experience and Implications for Road Pricing Acceptance in the United States," 2.
104 Hu, "New York's Tilt Toward Congestion Pricing Was Years in the Making."
105 Dwyer and Hu, "Driving a Car in Manhattan Could Cost $11.52 Under Congestion Plan."
106 "Fix NYC Report," 8.

city.[107] This resulted in a nearly 30% drop in central Manhattan traffic speeds within five years, to 4.7 miles per hour.[108] Simultaneously, public transit faced operational and funding crises. Transit challenges stemmed not only from keeping up with city growth, but also long-standing infrastructure decay exacerbated by Hurricane Sandy in 2012. The Metropolitan Transit Authority (MTA) in 2018 estimated that repairing the system would require a ten-year, $40-billion modernization program.[109]

Although the exact details of the city's congestion plan remain in flux as of late March 2019, the plan supported by Governor Cuomo and Mayor de Blasio has several key features. The city would charge a fee to enter Manhattan's central business district, between Battery Park on the city's southern tip to 60th street as the northern boundary. Drivers who entered from a preexisting tolled tunnel would pay only the difference between the congestion fee and their initial toll. Meanwhile, FDR Drive along the eastern side of Manhattan would remain untolled, with drivers arriving from the Brooklyn Bridge able to use FDR to drive north past the congestion zone free of charge.[110] The Fix NYC panel recommendation calls for a flat fee of $11.52 on auto drivers, approximately $25 for trucks, and an exemption for all buses and taxis.[111] However, the exact pricing scheme remains in flux, as the panel also considered variable pricing as a viable policy alternative.

Unsurprisingly, the plan has been accompanied by debate on the equity implications. Suburban politicians and groups have voiced the loudest objections, given the lower density of public transit options outside the city.[112] Support, meanwhile, has come from poverty-oriented advocates, given the volume of transit usage by the working poor. One advocacy group, for example, identified that the congestion fee would hurt a minimal number of outer-borough residents: only 4% of outer-borough residents commuted to Manhattan via car, and less than half of those were from low-income groups.[113] Meanwhile, observers noted that subway delays caused by the MTA's lack of funding and aging infrastructure disproportionately impacted low-income communities, who typically lack affordable alternatives.[114]

Even as New York City's congestion policy remains pending, the process so far has revealed several key implications. First, like California, the policy became viable only in the face of crisis. The specter of crawling traffic and a 30% MTA fare increase enabled a willingness to experiment. And although congestion pricing floundered in 2018, the effort did lead to the $400

[107] "Fix NYC Report," 4.
[108] "Fix NYC Report," 7.
[109] Berger and Vielkind, "Congestion Pricing in NYC Gains Traction as Cost of Subway Turnaround Looms; Charging Motorists to Drive into Certain Parts of Manhattan Is the 'only Realistic Option,' Cuomo Says."
[110] McKinley and Hu, "Congestion Pricing in Manhattan, First Such Plan in U.S., Is Close to Approval."
[111] "Fix NYC Report," 22.
[112] McKinley and Hu, "Congestion Pricing in Manhattan, First Such Plan in U.S., Is Close to Approval."
[113] "Congestion Pricing: CSS Analysis," 2–3.
[114] Fitzsimmons and Blint-Welsh, "Low-Income Riders Suffer Most When Subway Melts Down, Report Says."

million annual surcharge on for-hire vehicles noted earlier. Observers point with optimism to 2019, without a looming election.[115]

Second, the dedication of a small group of advocates led to the creation of an extensive policy analysis tool. This openly-available tool, the Balanced Transportation Analyzer (BTA) created by Charles Komanoff, became the basis for the governor's Fix NYC panel. Other groups could then use the same tool to test their own possible scenarios. For example, one nonprofit group identified that bus riders would save an hour or two each week, just from faster traffic speeds in and around the congestion zone.[116] An openly available tool provided common ground about the facts and projected equity outcomes of congestion pricing, allowing resulting debate to then focus on how policy makers should distribute and ameliorate those impacts.

Third, the extended policy debate—the lag between proposal and potential implementation—has spurred a variety of equity discussions to understand the tradeoffs associated with implementing a fee. For example, vocal opponents of congestion pricing came from specific 'transit deserts' who relied disproportionately on non-transit travel options and would be hit hardest by congestion fees.[117] Engaging with these groups strengthened the ultimate policy proposal, by diverting revenues to roadway improvement, not just public transit.[118]

No less than four different congestion pricing proposals had surfaced between 2006 and 2017, prior to the Fix NYC panel.[119] The seriousness of the current proposal reflects the city's urgent needs to fund infrastructure and alleviate traffic backups. Boston's challenges may currently be less acute, but the city faces the same trends that caused New York's road speeds to quickly drop.

Figure 5

Current Congestion Pricing Rates (January 2019)

		Price Range ($USD)		
	Access	Low	High	Spread
London	Daily	$ 14.50	$ 14.50	1.0x
Stockholm	Entry/Exit	1.70	3.90	2.3x
Milan	Entry/Exit	2.26	5.65	2.5x
Singapore	Entry/Exit	1.45	11.00	7.6x
SR91*	Corridor	1.65	9.65	5.8x
New York City (proposed)**	Daily	11.52	11.52	1.0x

*Original 10-mile segment in Orange County
**Fix NYC Panel recommendation, auto vehicle rate
Source: Carbon Free Boston (2019), OCTA, Fix NYC (2018)

[115] Berger and Vielkind, "Congestion Pricing in NYC Gains Traction as Cost of Subway Turnaround Looms; Charging Motorists to Drive into Certain Parts of Manhattan Is the 'only Realistic Option,' Cuomo Says."
[116] Riders Alliance, "Congestion Pricing Would Save Queens/Brooklyn Express Bus Riders 1 to 2 Hours Per Week!"
[117] Fitzsimmons and McKinley, "Boost for Congestion Pricing in Manhattan as de Blasio Supports Cuomo Plan."
[118] Hu, "New York's Tilt Toward Congestion Pricing Was Years in the Making."
[119] "Fix NYC Report," 29.

Findings

Overview of 2011 Massachusetts Travel Survey

Any consideration of congestion fees in Greater Boston requires understanding the income makeup and travel patterns of residents. Analyzing the 2010-2011 Massachusetts Travel Survey (MTS) allows policy makers an insight into these key questions. Overall, as outlined in this section below, few workers and students from lower income households commute into Boston.

MassDOT organized and administered the 2011 MTS over a period of six months, with respondents providing detailed trip information on a randomly selected day. Students, workers, and non-workers were all part of the survey, which reached 15,000 households via stratified random sampling using addresses and phone numbers.[120] Of the 37,000 individual respondents, some 40% were workers or students above age sixteen who provided information on their mode of travel. The MTS provides a robust, customized picture of household trip patterns of Massachusetts residents.

The 2011 MTS offers advantages over alternative data sources which lack granularity or have conflicting area definitions, such as the American Community Survey and the 2009 National Household Travel Survey.[121] The 2011 MTS, a follow-up to the original 1991 MTS, provides granular data on household travel patterns within the Boston metro region. Survey results included all of a person’s trips within a given day, providing insight on trip patterns beyond respondents’ origin and destination. For example, on a given workday, commuters devote about three-quarters of their trips in a day towards their commute, with other errands and trips accounting for the remaining quarter.[122] The subsequent analysis uses weighted survey responses to account for oversampling of certain household types and expand the survey results to Greater Boston at large.

Characteristics of Commuters into Boston

Of primary interest are those “radial” commuters who live in the suburbs and then travel into the city center for their work via car. The Central Transportation Planning Staff (CTPS), part of the Boston Region Metropolitan Planning Organization (Boston MPO), analyzed the 2011 MTS data and categorized respondents based upon their commute patterns within the eastern half of Massachusetts (approximately the I-495 ring).[123] Of the 37,000 survey respondents, 40% commuted within this 164-muncipality zone. CTPS categorized 2,400 respondents as falling into this “radial” commuting pattern, representing approximately 356,000 Massachusetts residents. The CTPS defined these types of commuters as those who lived outside of the central Boston zone, but worked within the zone. The central zone consists of Boston, Brookline, Cambridge, Somerville, Medford, Malden, Everett, Revere, and Winthrop. CTPS also used raw trip data to identify the

[120] See MassDOT, “2011 MTS Dataset,” 10–11.
[121] See Manville and Goldman, “Would Congestion Pricing Harm the Poor?,” 11.
[122] CTPS, “Focus on Journeys to Work,” 17.
[123] CTPS, 10–11.

primary work commute method, with slight adjustments made by the author in cases of un-coded, but text-based responses. Additionally, only commuters above the age of 18 were included in the analysis below.

Why focus primarily on radial commuters? Existing tolling mechanisms in Massachusetts center around several key highway access points that become congested for on-direction, peak travel times. Radial drivers account for a greater share of downtown traffic than those who both live and work in the central zone, or those who live in the central zone and work elsewhere. Given the nature of suburban communities and the distance inherent with radial commutes, radial commuters skew richer and more educated than other commuters in Massachusetts. Radial commuters are about twice as likely (30% vs. 16%) to have at least a college or technical degree as their highest educational attainment, and a little under half (44%) of radial commuters hold graduate degrees (see Figure 13 in Appendix D).

Central commuters (those who live and work in downtown Boston and thus bear the primary impact of congestion from suburban traffic in the center zone) differ substantially from their radial counterparts. Transit, rather than driving, is the most popular commute mode across all income groups. Meanwhile, households making less than $50,000 (in 2009 dollars) account for 30% of all commuters, a share three times greater than that of radial commuters.

Figure 6

Comparison of Radial Commuters v. All Commuters Residing in Radial Zones

		Share of Radial Resident		
Radial Commuting Group	**Group Size**	Population	Commuters	Radial Commuters
All Incomes	356,084	7.1%	20.7%	100.0%
Drivers	181,274	3.6%	10.5%	50.9%
Below Median Household Income	87,516	1.8%	5.1%	24.6%
Drivers	40,374	0.8%	2.3%	11.3%
Below $50K Household Income	32,676	0.7%	1.9%	9.2%
Drivers	14,162	0.3%	0.8%	4.0%

Note: Income in 2009 dollars, median household income of MPO region ~$75K
Source: 2010 Census, 2011 MTS analysis (weighted responses)

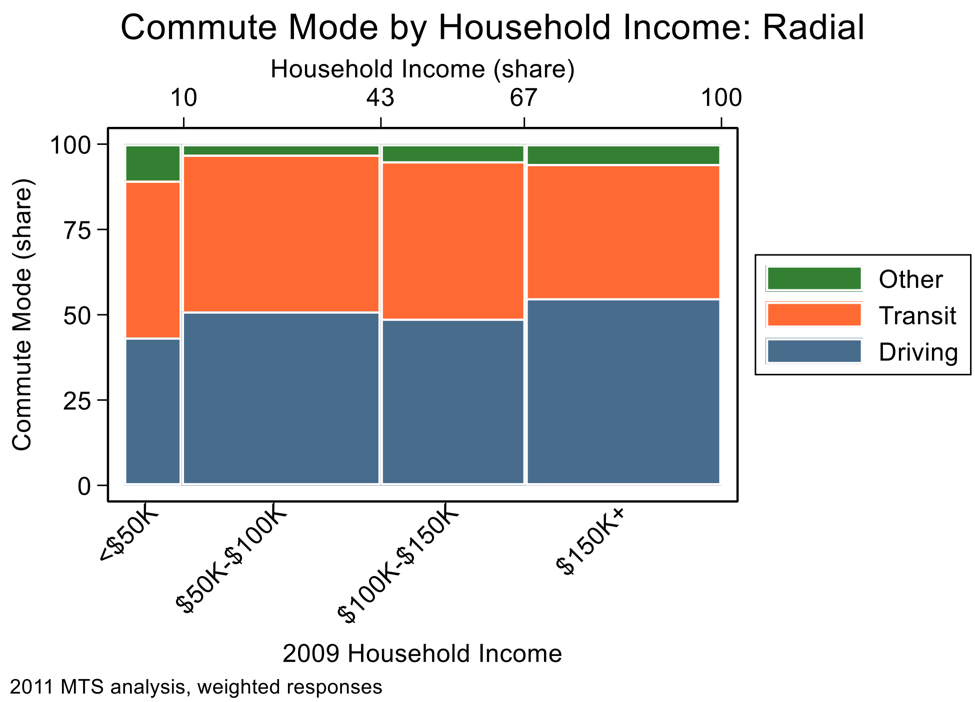
At the time, the median household income for the Boston MPO region was slightly below $75,000.[124] Based on calculations from the 2011 MTS and 2010 Census data, 10.5% of all commuters living in the radial zone around Boston drive alone into the central zone. Of those workers with that radial commuting pattern, only about 11% drive and are also below median household income. Thus, for every hundred people living in a radial zone who commute, approximately two of them will drive alone and come from below median household income. Considering only drivers from households at two-thirds of the median income ($50K)—or roughly the United States median household income at the time—that 11% share of radial commuters drops to 4%, evident in the income-commute mode mekko chart below. In other words, a congestion

[124] CTPS, “MA Median Household Income.”

policy that tolled only solo drivers with above median household income would capture more than 75% of the single-occupancy, radial vehicle traffic into the central zone (see Figure 11 in Appendix D).

Figure 7

Note: Breakdown of radial pattern commuters by income and travel mode. Only 10% of all radial commuters come from households making less than $50K annually, and less than half of those choose to drive.



Radial commute patterns are consistent, with workers from all income groups typically working five days a week, even if they drive. Meanwhile, drivers from higher income groups ($100,000+ in 2009 dollars) would be less likely to bear the dual cost of peak-hour congestion pricing. Drivers from these income groups reported the highest likelihood of working ten hours or more a day, a time period long enough to miss at least one of the peak roadway periods. Conversely, drivers from lower income households reported the highest incidence of standard work periods (between seven and nine hours each day), suggesting a greater likelihood of incurring peak period pricing on both inbound and outbound commutes (see Figure 15 in Appendix D).

Driving is the most popular form of travel, which has important implications for the tradeoffs associated with the burden of congestion fees. In New York and Stockholm, revenues from congestion pricing supported improvements in public transit. If Boston were to impose such a scheme, the trade-off would mean benefitting 2.2 transit users for every driver into Boston (a 2.2x ratio): 181,000 people drove alone into the central zone, while 400,000 people use public transit as their primary commute mode. Looking only at households below the median income, the tradeoff doubles in impact. Because transit is more popular and driving less so with lower income households, congestion pricing revenues would have a 4.5x ratio. Only 40,000 drivers from below-median income households travel into the central zone, whereas 182,000 users from the same income levels utilize public transit within the model region.

Figure 8
Note: see appendix E for additional comparisons

Radial Driver Group Size Comparison

Commuter Group	Group Size	*v. Radial Driver Income Group* All	<$75K[a]	<$50K
Drivers				
Radial	181,274	1.0x	4.5x	12.8x
Central Intersecting[b]	401,233	2.2x	9.9x	28.3x
Transit Users				
Radial Commuters	157,190	0.9x	3.9x	11.1x
<$75K Commuters[a]	181,700	1.0x	4.5x	12.8x
All Commuters	400,415	2.2x	9.9x	28.3x

[a] Approximate median household income in 2009 of Boston MPO region
[b] Indicates commuter who lives, work, and/or attends school in central zone
Source: 2011 MTS analysis (weighted responses)

Overall, analysis of the MTS data reveals the low incidence of both radial commutes and lower income radial drivers. 21% of workers living in the radial, surrounding communities commute into downtown Boston. Only 11% of those radial commuters drive and are from households making less than the Massachusetts median income (~$75,000 in 2009), or only 2.3% of all radial resident commuters. That small minority also differs substantially on other characteristics besides income, such as educational attainment and their potential likelihood of incurring a peak period toll.

Figure 9
Note: See appendix G for full revenue model

Revenue Analysis of Radial Drivers in 2011

	Radial Driver Income Group All	<$75K
In $ millions		
Estimated Toll Revenue	$ 41	$ 9
MassDOT 2011 Toll Revenues	$ 329	$ 329
Driver Group Share of Tolls	**12.5%**	**2.8%**

Source: 2011 MTS analysis (weighted responses), MassDOT, BLS

Comparing the 2011 MTS analysis above with MassDOT revenue numbers from that time period suggests that radial drivers represent a small share of toll revenues. Using a simple model with data from current traffic patterns (as a rough proxy for 2011), we can estimate the revenue share of these radial drivers. Approximately 40% of trips into central Boston on any given day use tolled roadways.[125] We can then apply that share to radial drivers, assume two daily tolled trips, calculate the number of commuting days, and then retroject the average toll paid (from 2018 price points and road usage). These data allow us to ignore tolled leisure trips (e.g. weekends or after returning home) and focus solely on revenue from trips which commuters have less flexibility to change. These assumptions

[125] Author analysis; MassDOT, "MassDOT TDMS."

suggest that less than 13% of all MassDOT toll revenues come from radial drivers during their work commute, and less than 3% comes from below-median income households with that commute. The 3% revenue share is likely an overestimate, given a hypothesis that lower income drivers use tolled roadways less often than other drivers (i.e. below 40%).

The 2011 MTS analysis highlights how few drivers into Boston come from lower income households. A congestion scheme with a fee waiver or discount using even this conservative benchmark (median household income) would still impact more than three-fourths of radial drivers. Meanwhile, the simple revenue model identifies the minor revenue impact from charging or discounting lower income drivers.

Adjustments & Further Analysis

Analysis here has focused on radial commuters as defined by CTPS, which excludes workers from outside of city center. A congestion scheme would likely focus on just the Boston CBD, which would exclude many parts of the central zone. Nonetheless, the central zone is a useful proxy for that traffic, and provides a common geographic frame given its use by the Boston MPO and other planning agencies. A more targeted analysis could focus only on specific zipcodes within Boston.

Because the MTS occurred in 2011 and did not count the unemployed as workers (even if part of the workforce), this survey likely underestimates the current volume of commuters, particularly those choosing to use higher-cost transport forms like solo auto driving.[126] Indeed, the state unemployment rate in 2019 was less than half that of 2011.[127] Some commuters who travel through the central zone (from one radial zone to another) may be omitted from this radial consideration. Yet commuters with that radial-to-radial travel pattern accounted for less than 5% of the weighted responses, and relatively few respondents within that group had travel patterns that would justify crossing the central zone.

This analysis considered household income without making explicit adjustments for the size of the households. Of all commuting respondents considered here, less than 3% came from households making less than $50K annually and with more than four people. Thus, nearly all households made at least twice the federal poverty threshold in 2009, with many households earning several multiples more than this threshold.[128] A more sophisticated analysis could perform detailed income and household size consideration to assess the burden of potential tolls of households within a given income bracket. Given the low volume of lower income radial commuters, however, the analysis would likely be incremental to this initial analysis.

A major travel change, as noted earlier in this report, is the rise of ride-hailing apps (TNCs): 100,000 daily trips occur within Boston city limits alone. Given the travel distance and direction (on-peak) of radial commutes, solo passenger travel likely remains a minor component, given the prohibitive costs. These costs stem from demand and time-based pricing, echoing the goal of

[126] CTPS, “Focus on Journeys to Work,” 17.
[127] BLS, “Massachusetts Statewide Unemployment Statistics.”
[128] Census Bureau, “Poverty Thresholds.”

congestion fees themselves. Travel within the central zone may have experienced modal shifts, given the convenience of short-distance trips in comparison to public transit.

Further analysis would enable a zipcode-by-zipcode study of homes and workplaces. This analysis considered only those who travel into the central ring, which includes places like Medford and Brookline. Given that these would likely fall outside of congestion pricing points given their distance to city center, these commuters could be treated differently than those commuters who drive directly into downtown Boston. Additionally, further analysis could involve analyzing the characteristics of those who use toll gantry points today. This raw data exists within the MTS database, but would require detailed trip matching. That analysis would enable a more granular look at the households impacted by a change in tolls, particularly to check the volume of low-income households that rely on tolled access points.

Overall, these findings point to only one type of users, albeit the group of primary equity concern: personal travel of Massachusetts residents. Personal travel of out-state visitors (e.g. vacation travel) is not included in this analysis. Commercial users, like trucks and for-hire-vehicles, are another major group of road users largely not considered. Some commercial trips of Massachusetts residents are included in the survey. But out-of-state drivers and residents are not in this data. The impact of congestion fees on businesses is a valid concern, yet of lower priority than the equity concerns of vulnerable and low-income communities for the purposes of this report.

POLICY RECOMMENDATIONS

Tolling has proven successful as a mechanism to manage roadway demand. Reducing congestion is beneficial from the lens of both economic efficiency and quality of life. For Greater Boston, as in other locations, congestion pricing's primary equity issue involves the burden imposed on lower income households who lack feasible transportation alternatives and/or the flexibility to travel outside of congested times.

Boston's vertical equity breakdown—namely income distribution—provides a strong fit for a congestion pricing scheme. Few lower income drivers in fact travel into city center. Using even median income household as a conservative test of means, over three fourths of drivers into Boston exceed this threshold.

Massachusetts has three different time horizons as it considers congestion pricing: the near-term ("pilot"), medium-term ("permanent policy"), and long-run ("comprehensive pricing"). The sections below outline the policy recommendations for each time horizon, guided by the findings from the case studies and 2011 MTS analysis.

Figure 10

Congestion Pricing Time Horizon

	Near-Term	Medium-Term	Long-Term
Goal	Gauge driver responsiveness and technology feasibility	Reduce congestion in downtown Boston	Region-level congestion management
Pricing Mechanism	Flat percentage discount during off-peak periods	Variable toll rates for peak and off-peak periods	Variable toll rates for peak and off-peak periods
Equity Mitigation	• None	• Geography- and income-based discounts • HOV to HOT • Active equity monitoring • Transponder availability • Use of revenue for transit	• Reduction of gas tax • Discount program • Regional price-setting commission
Execution Strategy	• Discounts as sole pricing tool • Defined time period	• Pre-launch transit improvement • Common analysis tool • MassDOT funding commission	• Transit improvement • Reduction of gas tax

Near-term: Pilot

Massachusetts should seek to first test some form of variable pricing. Current policy debates in 2018 and 2019 have centered around the feasibility of a discount on MassDOT tolls outside of peak period hours. A discount pilot toll program would be possible along the existing tolled routes into downtown Boston: the Tobin Bridge, the Sumner / Callahan & Ted Williams Tunnels, and the Mass Pike. These tolls are all ~$1.25-$1.50 each way.

Using tolls discounts for a pilot offers the advantage of limited equity impacts. Residents near MassDOT's toll gantries already qualify for ~85% discounts on tolling. These discounts could remain in place, while other lower income drivers could then take advantage of lower prices by shifting their schedule, or potentially enjoy the benefits of more reliable traffic time during their typical rush hour commute. Current users of MassDOT's carpooling transponder program would experience little change, given their already low roadway tolls.

From a policy execution perspective, a discount pilot program provides a testing mechanism without the need for an expensive and challenging transit service buildup. Implementing congestion pricing has nearly always been paired with a transit "sweetener," to provide capacity for new public transit users shifting away from vehicles and to simply provide political feasibility.

Goals for the pilot should be to monitor shifts in traffic levels on primary and secondary access points into city center. Reducing tolls may encourage new demand in off-peak periods, as drivers currently using public transit may be induced by lower travel costs, but the relatively low current toll levels suggest this is a minor risk.

A pilot program would ideally experiment with increasing fees upward, simply because the relatively low pricing levels (versus, for example, SR-91) place a cap on the price differential possible between peak and off-peak pricing. Discounting from current price levels would likely require a significant discount of at least 50% (~$0.75 or more). Stockholm and California highlight that meaningful toll differentials, even if more challenging politically upfront, enable long-term policy success because larger differentials prove their efficacy to the public.

A pilot using price increases rather than discounts would be challenging to implement without a policy trade-off established ahead of time. Stockholm, London, and the ongoing debate in New York City highlight the importance of providing a benefit to the public, rather than merely incremental fees. An option to make public transit free, for example, would lead to a surge in usage and likely not attract many drivers on their commute. One trade-off would be to increase tolls, and pair it with a 'gas tax' holiday. Another could be to raise tolls on targeted peak period times, but then make them free during other times. Neither would resolve the fundamental equity concern of hurting low-income commuters who lack other travel options.

Ultimately, the ideal outcome for a pilot entails drivers on the edge of peak period travel shifting their demand into adjacent shoulder periods, benefitting from reduced tolls, accompanied by little price-induced demand from users of alternative modes. The pilot would (a) test how responsive drivers might be to variable tolling, (b) provide insight into how traffic patterns might change, and (c) test the implementation of dynamic pricing within the existing MassDOT toll gantry technology.

Medium-term: Permanent Policy

Establishing a permanent tolling program, after the deployment of a pilot, will likely require raising rates to achieve a targeted reduction in congestion. Whereas the pilot would simply provide a gauge of how responsive driving patterns might be to variable tolling, current tolling schemes suggest that reaching targeted congestion levels will require increasing toll fees in order to properly price roadway usage for drivers.

A permanent tolling scheme would implement variable pricing on all major access points into Boston. Expanding tolls to I-93 north and south of the city, and Storrow Drive, would mean nearly 90% of traffic into Boston on a major access point would be on a roadway with at least some form of tolled lane (see Appendix F).[129]

Boston currently relies on a set of HOV lanes on I-93. Although I-93 is an interstate highway, Federal code allows tolls for HOT vehicles within existing HOV facilities.[130] Massachusetts should consider installing toll gantries over the HOV / zipper lanes on the Northern and Southeast Expressways. This would allow MassDOT to charge single occupancy vehicles for use of the carpool lanes. At the same time, increasing the HOV occupancy requirement from two to three would preserve lane space for tolled vehicles while encouraging more structural carpooling arrangements. In fact, the HOV lane on the Southeast Expressway originally launched with a three-person carpool requirement which MassDOT later dropped to two because of low usage, a phenomenon that has persisted.[131]

Switching from an HOV to HOT approach fits with larger theoretical assessments of HOVs, which finds them consistently underused in the United States.[132] Even a one-lane toll addition on I-93 north and south of Boston could be effective. Research indicates a mix of tolled and untolled lanes is enough to gain three-quarters of the theoretical benefits from pricing all lanes of a highway[133]

Some horizontal equity concerns would still persist under such a scheme. Imposing dynamic pricing on the Mass Pike but leaving some lanes free on I-93 would magnify the existing price differential on drivers from different geographies (e.g. Metro West versus the North Shore). Adding a HOT lane to I-93 would ameliorate some of this horizontal equity variation, but likely not enough to overcome the added differential from dynamic prices.

Because of the potential for fee increases during peak period times, Massachusetts can offer a discounted pass program, relying on a mix of geography and means-testing. With MassDOT having switched to all-electronic tolling gantries in 2016, the agency faces fewer implementation barriers. Like how resident discount rates are set at the zipcode level for the Tobin Bridge and Sumner / Callahan tunnels, the agency can exclude from higher congestion fees those transponders registered to any of the corresponding central zone zipcodes.

[129] Author analysis; MassDOT, "MassDOT TDMS."
[130] FHWA, "Guidance on HOV Lanes," 10.
[131] Adams, "HOV Lane into Boston Gets Little Use."
[132] Lee and Gordon, "The US Context for Highway Congestion Pricing," 338.
[133] Krol, "Tolling the Freeway," 22.

To accommodate lower income drivers from the radial zones who travel into downtown Boston for work, MassDOT could perform a geography and means test. Geography could similarly be based on the zipcode associated with a transponder. Meanwhile, MassDOT could either (a) use existing government program participation to means test and / or (b) applicants could potentially submit a tax stub or fee waiver form in person or online to qualify them for discounted rates. Because these groups may also lack access to transponders or linked financial institutions, MassDOT could distribute transponders to these groups free of charge, enabling faster processing of toll discounts.

A discount or rebate specifically for low-income drivers impacted by a congestion fee is ideal because it offsets those directly harmed by the fee with those who benefit (high-income drivers).[134] Simultaneously, discounts for low-income users are unlikely to induce incremental demand from that income group. Driving and its complements (e.g. fuel, maintenance, registration, parking, insurance) are expensive, and discounted tolls would not impact these other barriers to vehicle ownership and usage. An annual renewal process and linking of a discounted transponder to a specific vehicle would help prevent fraudulent use.

Stockholm, California's SR-91, London, and the current New York City policy debate all highlight the importance of packaging higher roadway fees with improvements in public transit. These improvements should occur before an increase in fees, in part to address potential mode shifts from cars to public transit, and also to demonstrate a clear benefit-fee trade-off for the public. Based off analysis of the 2011 MTS, radial commuters in Boston who do not drive rely most on the commuter rail. Improvements in the reliability and service levels of the commuter rail may be the most important transit priority, beyond that of existing MBTA capital programs. Cheaper alternatives may be to enhance the service quality of park-and-ride services, or the launch of new express bus routes that provide service across congestion-priced access points.

Dedicating any form of congestion fees towards public transit service improvement will likely require reorganizing the flow of funds through MassDOT and the MBTA. Toll revenues are currently 'owned' by MassDOT, in that they do not require legislative appropriation (versus gas tax revenues) as they flow directly into the Massachusetts Transportation Trust Fund (MTTF). MassDOT thus sets its annual operating budget based off the size of the MTTF. Toll revenues today can only be directed towards toll road operations (first) and capital projects (second).[135] An expansive congestion toll scheme would require adjusting the scope of approved toll revenues. In New York, for example, Governor Cuomo has proposed a new commission to allocate congestion revenue between roads and public transit. A similar joint highway / transit team within MassDOT may also be necessary. For example, rather than have toll revenues flow directly into the MTTF (which does not fund the MBTA), a new toll fund may be necessary, to direct toll revenues between the MTTF and the MBTA.[136]

[134] Manville and Goldman, "Would Congestion Pricing Harm the Poor?," 3.
[135] "MassDOT: FY19 Operating Budget Presentation," 6.
[136] "MassDOT: FY19 Operating Budget Presentation," 4.

MassDOT would presumably need to build capacity for ongoing toll policy assessment. California's SR-91 demonstrated that a predetermined toll adjustment policy can be carried out within the confines of a state agency. The complexity of different highway points with varying peak travel windows would require some form of dedicated oversight and management. The cost of this capacity expansion would be justified by the significant revenue potential and economic benefits of implementing congestion pricing.

Finally, Massachusetts should formally integrate equity impact mitigation into the planning process. The planning process should outline key equity monitoring metrics, engage with advocacy groups, and identify a continuous process to identify and alleviate equity concerns. The use of the BTA in New York, for example, has provided a common basis for policy makers and advocates to analyze the equity tradeoffs associated with different policy settings during the planning process. Key metrics for Massachusetts to monitor include the geographic distribution of tolled users, and the incidence of tolls on lower income users. An ideal evaluation process would begin, like in Stockholm, with a pre-implementation survey. A post-implementation survey could then track changes in commuting and travel behavior, to enable detailed equity analysis like that performed in Stockholm after the city implemented congestion pricing. Smaller follow-on surveys could then support continuous equity monitoring.

Long-term: Comprehensive Pricing

A long-term vision of congestion pricing would expand its use beyond that of the central zone of Boston. This would serve two purposes. First, it would allow a more comprehensive congestion management program. The risks of possible demand spillover due to area-based pricing could be mitigated with a larger congestion fee 'net.' For example, Route 128 sits well outside of downtown Boston, but regularly becomes congested. Second, an expanded congestion program could reduce or eliminate a need for the motor fuel tax or sales tax in Massachusetts. Massachusetts had $771 million in fuel tax revenue in 2017, a little less than half of MassDOT toll revenues that year.[137] A congestion pricing scheme could likely replace a significant portion of these revenues. This would more tightly align the burden of highway costs in proportion to those who use them.

Any form of widespread, regional congestion pricing raises important mobility concerns. Addressing vertical equity concerns around income would likely require high degrees of coordination, in comparison to a smaller CBD congestion zone. For example, users could receive graduated resident discounts on tolling points based on the toll's proximity to a user's residence. Traveling on a tolled highway point close to home, for example, might be substantially discounted, while traveling on distant points elsewhere in the state would cost the full toll. Meanwhile, regionwide congestion pricing would entail facilitating discussion with a disparate, diverse group of towns and communities. MassDOT could remain the overseeing agency, but would likely need a specific congestion-pricing overseeing committee comprised of representatives from impacted towns.

[137] Poole, "Toll Revenue, Gas Taxes, and Gas Prices in Selected States," 2, 4.

A region-based congestion pricing scheme could be predicated on the elimination or substantial reduction of the motor fuel tax, which would improve the distribution of costs and reduce the net economic burden of congestion fees. However, such a complex policy scheme would require high degrees of policy analysis, real-time measurement, and coordination with diverse political communities. A plan of this scope has also yet to be implemented elsewhere. Similar to the success of a policy trial in Stockholm, greater Boston should first aim to achieve policy success within the highly congested central business district. Later, if deemed necessary, the region can experiment with gradually expanding the congestion zone over time to better manage regional traffic patterns.

CONCLUSION

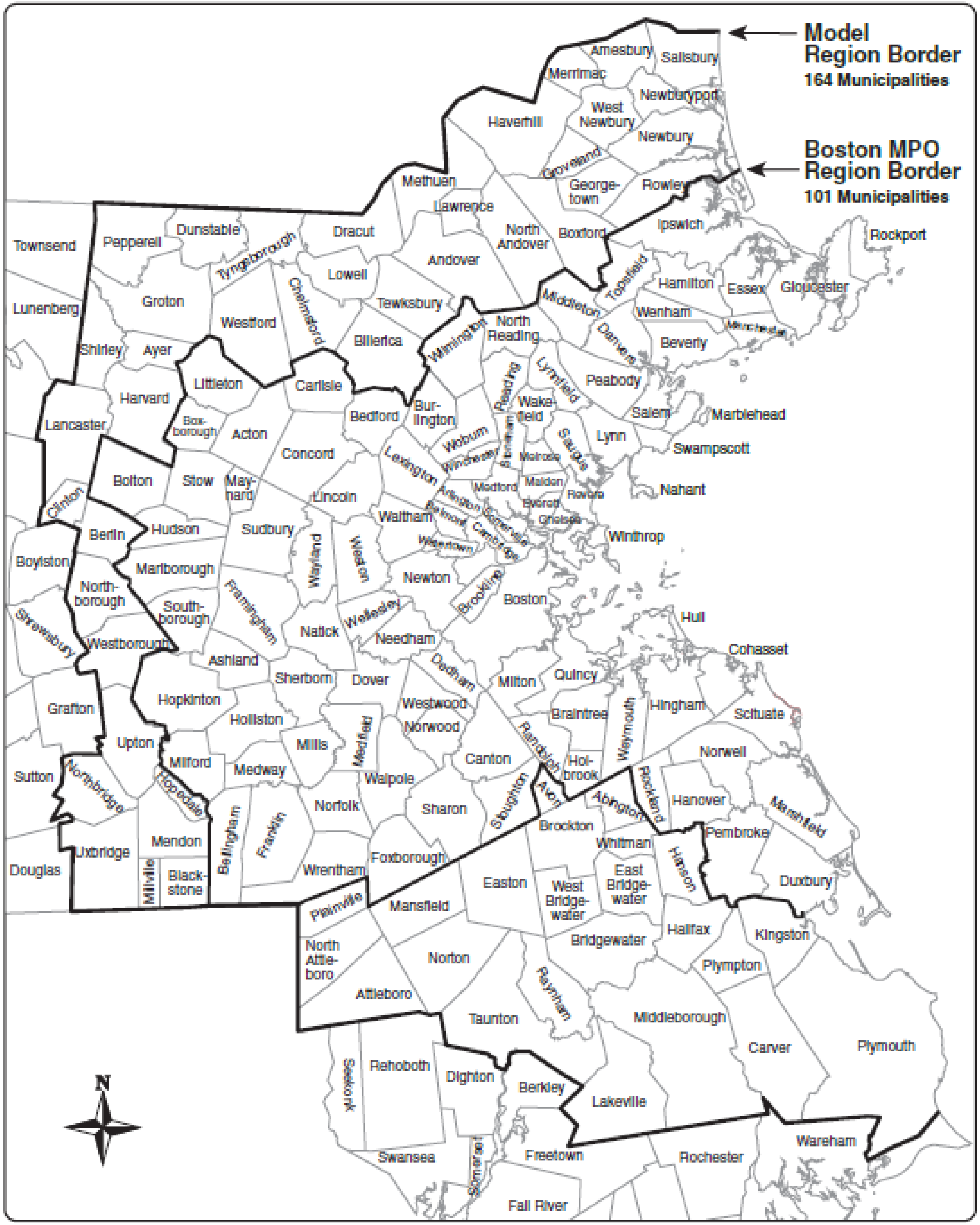
Traffic takes time from drivers. Congestion pricing examples from the United States and globally have demonstrated the effectiveness of these schemes to reduce traffic and its associated costs. Indeed, these costs will inevitably be borne by Greater Boston, regardless of whether congestion pricing policy exists. Today, the costs of congestion are evident in Boston, given the private and public burden of worse health, lost travel time, and additional driving costs. Congestion pricing acts as a mechanism to direct the costs of overused roads to those who create those costs.

The primary equity consideration for a fee-based policy like congestion pricing is the burden it places on lower income households. Boston's geographic and socioeconomic distribution in 2011 indicates that a small share—approximately 2%—of commuters from Boston's surrounding communities drive into Boston and come from below median household incomes. And of just those who travel into the city from a surrounding town, only about 11% exhibit these characteristics. That few radial commuters are low-income drivers point to the feasibility of providing discounts, waivers, or other equity mitigation strategies while maintaining the pricing scheme's effectiveness.

Other cities like Stockholm and London have successfully experimented with these schemes. The recent adoption of a congestion scheme by New York City in March 2019 represents a shift in policymaking within the United States. Boston and its Big Dig became synonymous with construction and traffic. Now, more than a decade after that highway construction project ended, Greater Boston can use congestion pricing to ease the area's persistently clogged roadways. To be sure, any congestion policy will need to quickly prove its worth and monitor for unintended consequences. Congestion pricing can enable policy makers to shift costs to those most able to afford it, protect lower income groups, and give drivers the opportunity to put their time elsewhere than on a road.

APPENDICES

Appendix A: Boston MPO Region and Travel Demand Model Region



Source: CTPS

Appendix B: CTPS Analysis Sectors

Source: CTPS

Appendix C: Current MassDOT Carpooling Fees

Schedule of MassDOT Carpooling Fees (Jan 2019)

Carpooling Fee	**Cost**	**Daily Cost***	**Daily / Person***
From Mass Pike Exit 1 to…			
Palmer	$ 50	$ 0.20	$ 0.07
Route 128	95	0.38	0.13
South Station	145	0.58	0.19
Ted Williams	195	0.78	0.26
Tobin Bridge	50	0.20	0.07
Sumner/Callahan	50	0.20	0.07

*Assumes 250 annual work days and minimum passenger requirement (3)
Source: EZ Drive MA

Appendix D: 2011 MTS Analysis

Figure 11

Note: Travel mode choice of radial commuters by income group. Of all radial drivers into the central zone, less than a quarter come from households below median household income.

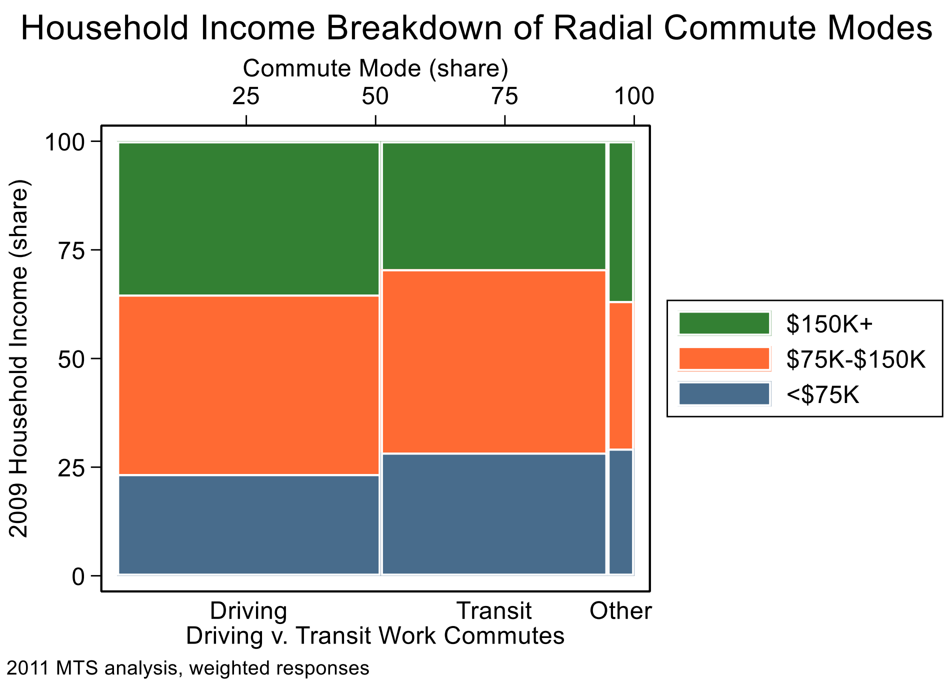


Figure 12
Note: Travel mode choice by household income of central pattern commuters (live and work in central zone). Transit is much more popular across all income groups, with other travel modes (like walking or biking) more popular than driving.

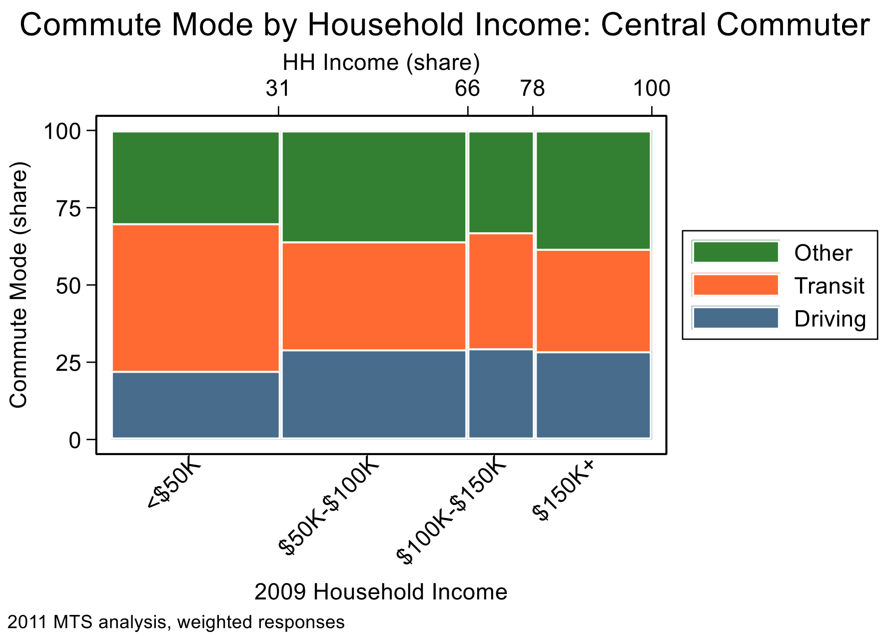


Figure 13
Note: Educational comparison of radial versus non-radial commuters. Those who travel into the central zone have substantially higher educational attainment than other commuters in the region.

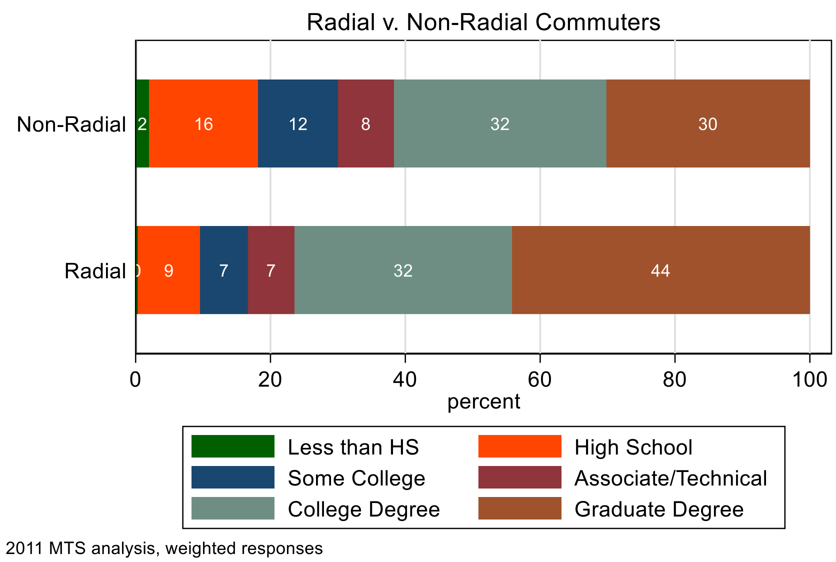


Figure 14
Note: Breakdown of workdays per week, by income. Consistent number of workdays across all income groups, with lower income households (<$50K) exhibiting a wider range of workdays per week.

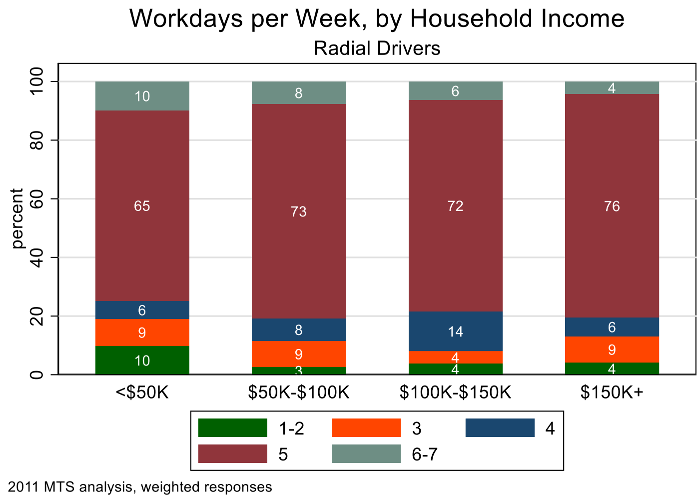


Figure 15
Note: Hours per week by household income group. Higher income radial drivers have the greatest propensity to work longer hours, suggesting lower exposure to peak period congestion charges.

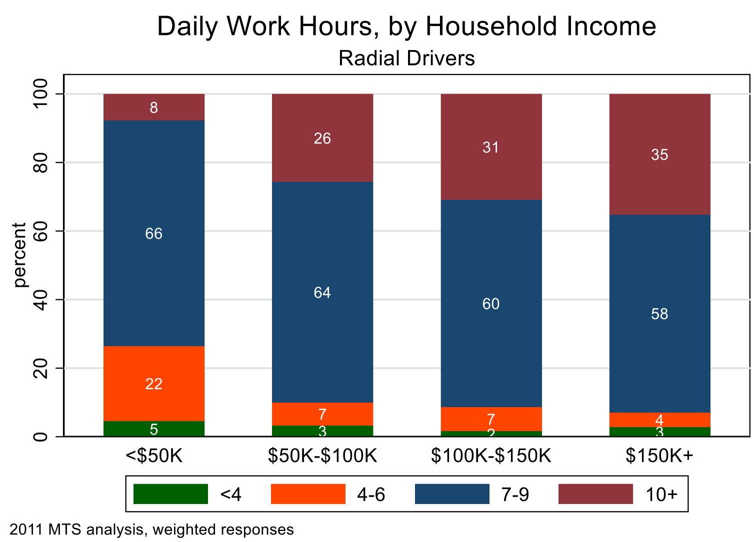
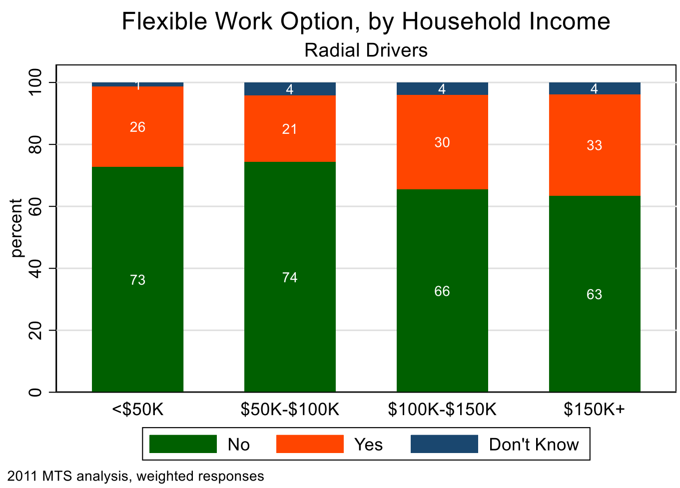


Figure 16
Note: Among radial drivers, higher income households report greater flexibility with their work schedule.



Appendix E: Comparison of Group Sizes

Radial Driver Group Size Comparison

		v. Radial Driver Income Group		
Commuter Group	**Group Size**	All	<$75K[a]	<$50K
Radial Pattern				
Drivers	181,274	1.0x	4.5x	12.8x
Transit	157,190	0.9x	3.9x	11.1x
<$75K Transit	42,506	0.2x	1.1x	3.0x
Central Intersecting[b]				
Drivers	401,233	2.2x	9.9x	28.3x
Transit	355,558	2.0x	8.8x	25.1x
<$75K Transit	150,473	0.8x	3.7x	10.6x
All Commuters				
Drivers	2,092,866	11.5x	51.8x	147.8x
Transit	400,415	2.2x	9.9x	28.3x
<$75K Transit	181,700	1.0x	4.5x	12.8x

[a] Approximate Massachusetts median household income in 2009

[b] Indicates commuter who lives, work, and/or attends school in central zone

Source: 2011 MTS analysis (weighted responses)

Appendix F: Traffic Volumes on Major Roadways into Boston

Selected Traffic Volumes into Boston City Center (2018)

Location	AADT*	Share	Tolled
Southeast Expressway (I-93)	189,202	20%	No
Mass Pike	160,803	17%	Yes
Storrow Drive	120,358	13%	No
Northern Expressway (I-93)	108,770	12%	No
Tobin Bridge	83,902	9%	Yes
Ted Williams Tunnel	73,097	8%	Yes
Washington St. Bridge	43,562	5%	No
Leverett Connector	42,993	5%	No
Callahan / Sumner Tunnels**	39,676	4%	Yes
Charles River Dam Bridge	38,025	4%	No
Longfellow Bridge	25,279	3%	No
Total Daily Traffic	925,667	100%	
Tolled Traffic	357,478	39%	

*AADT: Annual Average Daily Traffic

**Only data for Callahan tunnel, doubled as proxy for two-way traffic

Source: MassDOT TDMS; author analysis

Appendix G: Revenue Model of MassDOT Tolls from Radial Commuters

Revenue Analysis of Radial Drivers in 2011

		Radial Driver Income Group	
		All	**<$75K**
Line	***Volume***		
A	Number of Drivers	181,274	40,374
B	% Tolled	40%	40%
C	Tolled Drivers [A*B]	72,510	16,150
D	Daily Trips	2.0	2.0
E	Daily Toll Events [C*D]	145,019	32,299
F	Workdays / Week	4.71	4.75
G	Workweeks / Year	50.0	50.0
H	Workdays / Year [F*G]	236	237
I	Annual Toll Events [E*H]	34,167,630	7,666,098
	Price		
J	Avg. Toll Paid	$ 1.20	$ 1.20
	Revenue		
K	Annual Revenue [I*J]	$ 41,001,156	$ 9,199,318
L	MassDOT 2011 Toll Revenues	$ 329,000,000	$ 329,000,000
M	**Group Share [K/L]**	**12.5%**	**2.8%**

Source: 2011 MTS analysis (weighted responses), MassDOT, BLS

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