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A Bridge Too Far: Sagging Investment Leaves 644 Massachusetts Bridges Structurally Deficient

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Every bridge in our Commonwealth should be safe, well maintained, and open for travel. Well maintained bridges provide connection among towns and between regions. Public buses also use bridges, as does passenger and freight rail. Bridges link goods to markets, workers to jobs, and families to essential services.

The Massachusetts Department of Transportation (MassDOT) maintains a database tracking 7,880 bridges across the Commonwealth. This paper examines the condition of these bridges and the impact of bridge disrepair on communities. It analyzes how some regions and populations are harmed more than others, and how these problems could be helped by investing more public resources in transportation.[1]

Key Takeaways

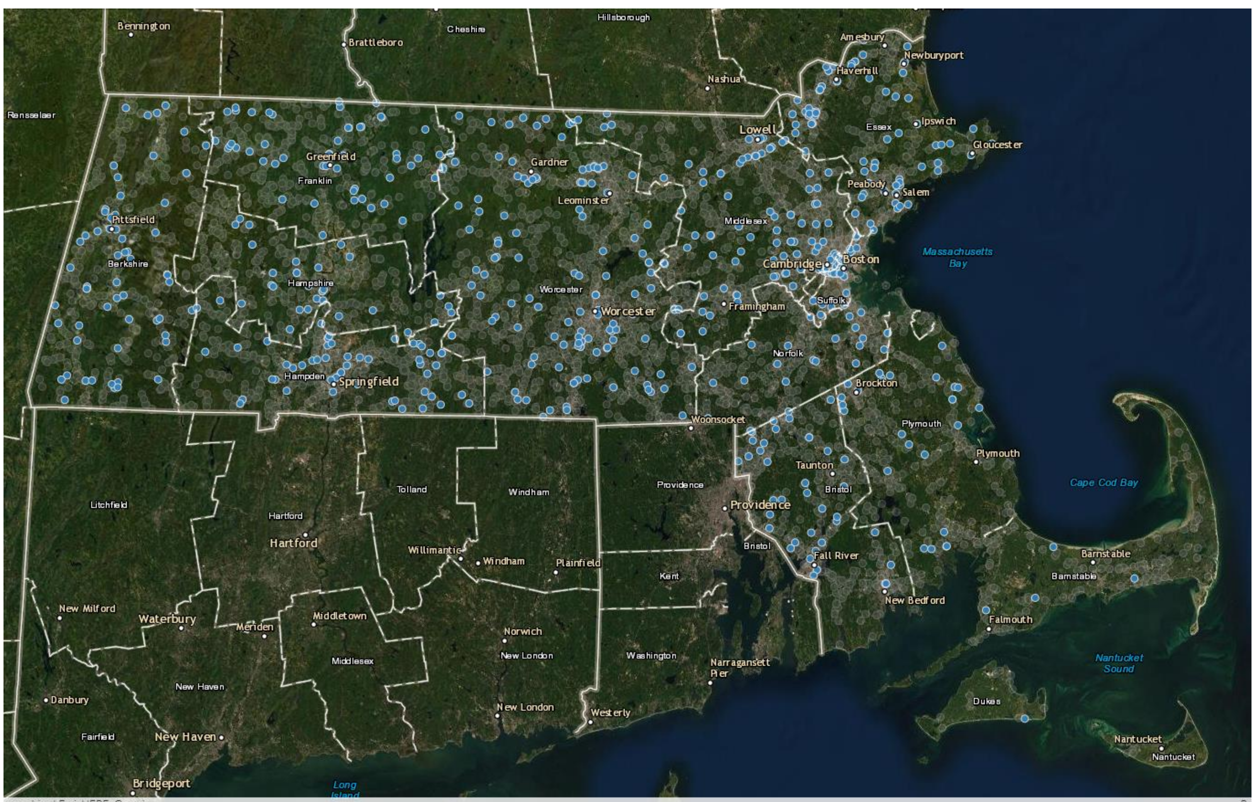
- About one in nine bridge crossings in Massachusetts occur on a structurally deficient bridge. Bridges with more traffic volume are more likely to be structurally deficient.
- Structurally deficient bridges are more likely to become closed or to restrict heavy vehicles from passage, leading to a variety of potential traffic, safety, and other problems.
- There are significant differences among regions in the prevalence and proximity of bridges in disrepair as well as of closed bridges.
- The average Massachusetts resident lives 1.7 miles from a structurally deficient bridge. Residents classified as a racial or ethnic "minority" live an average of 1. 3 miles from a structurally deficient bridge. On average a limited English speaking household lives 1.2 miles from such bridges.
- Climate change, heavier vehicles, and an aging stock of bridges present heightened challenges for the future.
- Increased investment has improved the state of bridge repair in the past. Current lack of long-term funding makes it more likely that bridges will fall into worse disrepair.

Structurally Deficient Bridges are a Widespread Problem

According to the state's most comprehensive database of nearly eight thousand bridges compiled by the state's Department of Transportation (MassDOT), there are **644 structurally deficient bridges in Massachusetts**, and another 218 for which the condition is listed as "unknown." The MassDOT database is the broadest dataset, including bridges across the state, as well as smaller and municipally-managed bridges.[2] It shows 1-in-12 bridges are structurally deficient.[3] The designation as "structurally deficient" means that at least one major weight-bearing component of these structures has serious problems and is in need of repair or replacement.[4]

At the end of last year, the MassDOT's Performance and Asset Management Advisory Council reported to the Legislature that with the depletion of the $3 billion in one-time funds raised by the state's Accelerated Bridge Program last decade, Massachusetts can expect further deterioration of our bridges. They found, "**Massachusetts is 4th worst in the nation for the percentage of poor bridges** (by area) . . . . Additional bridge investment is needed to address the clear needs to core transportation infrastructure . . . [I]nvestment is necessary to preserve our current infrastructure so that it may continue to serve the Commonwealth in a resilient and sustainable future."[5]

Structurally deficient bridges tend to be larger and carry more traffic. On average **11 percent of daily vehicle bridge crossings are over structurally deficient bridges.** Of the nearly 127 million average daily bridge crossings in Massachusetts, 14.3 million daily crossings occur across bridges that are structurally deficient. An additional 1.9 million daily trips occur across bridges with "unknown" conditions. [6] Cars and trucks aren't the only type of travel threatened by the disrepair of bridges. Of the twenty structurally deficient bridges with the highest traffic volume in Massachusetts, seven carry MBTA rail and two carry Amtrak service.



Massachusetts Department of Transportation shows the location of the 644 structurally deficient bridges across the state

Another measure of the scope of the problem is the average distance a Massachusetts resident lives from a structurally deficient bridge. On average, Massachusetts residents live 1.7 miles away from the nearest structurally deficient bridge.

National data show that Massachusetts bridges are in a worse state of disrepair relative to bridges across the rest of the nation. According to a 2021 report on National Highway System (NHS) bridges, only a quarter of Massachusetts NHS bridges were graded in "good" condition, compared with 45 percent nationally. Meanwhile, nearly two-thirds of such Massachusetts bridges were in "fair" condition. This is a troubling sign for the future because it means that while still structurally sound, the condition of most bridges has deteriorated or they suffer from minor defects. By comparison, less than half of NHS bridges nationwide are in this degraded condition.[7]

The poor condition of Massachusetts' bridges has triggered federal rules that reduce discretion for states with particularly high levels of deterioration by forcing them to focus predetermined minimum amounts on bridge repair. States with more than 10 percent bridge deck area of National Highway System bridges in poor (structurally-deficient) condition are subject to this restriction. Massachusetts is over 12 percent, about three times the national average.[8]

A few factors make Massachusetts bridges particularly susceptible to falling into disrepair. Our harsh winters mean that roadways contract each year and that salt is placed on surfaces, accelerating the aging of infrastructure. Massachusetts bridges also tend to be quite old. On average, a Massachusetts bridge was built or most recently reconstructed 56 years ago. By comparison, the average bridge age nationally is 44 years old. Like cars or houses, bridges become more difficult and costly to maintain as they become older. The average structurally deficient bridge in Massachusetts is 73 years old.[9]

The Cost of Bridges in Disrepair

Several kinds of harm can result from a bridge being structurally deficient. A catastrophic bridge collapse, such as in Minnesota, or more recently near Pittsburgh, is extremely rare. Massachusetts travelers are highly unlikely to ever risk such a tragedy crossing a bridge. Even so, bridges in disrepair can cause other significant harms.

Structurally deficient bridges are more likely to require closure or restrictions for safety reasons. Of the 64 Massachusetts bridges that are currently closed, more than half are listed as structurally deficient.[10] Other bridges may be closed because they are in the process of repairs or reconstruction or their structural soundness may be unknown.

For bridges that are not safe to carry heavy trucks, closure can be avoided by restricting access by weight. In fact, more than one in five structurally deficient bridges in Massachusetts have restrictions on what kinds of vehicles can pass, mostly weight limitations.[11] This creates problems for communities as well as for truck drivers. When heavy trucks can't pass on the most direct route over a river, for instance, they must drive a longer, less direct route. As a result, commerce is slowed, time is wasted in traffic congestion, additional fuel is burned, and trucks sometimes end up driving through residential areas they would otherwise avoid. Especially in rural areas, weight posted bridges can also delay the response time of rescue vehicles such as fire trucks. About 1 in 13 of all bridges in the state are posted with restrictions.

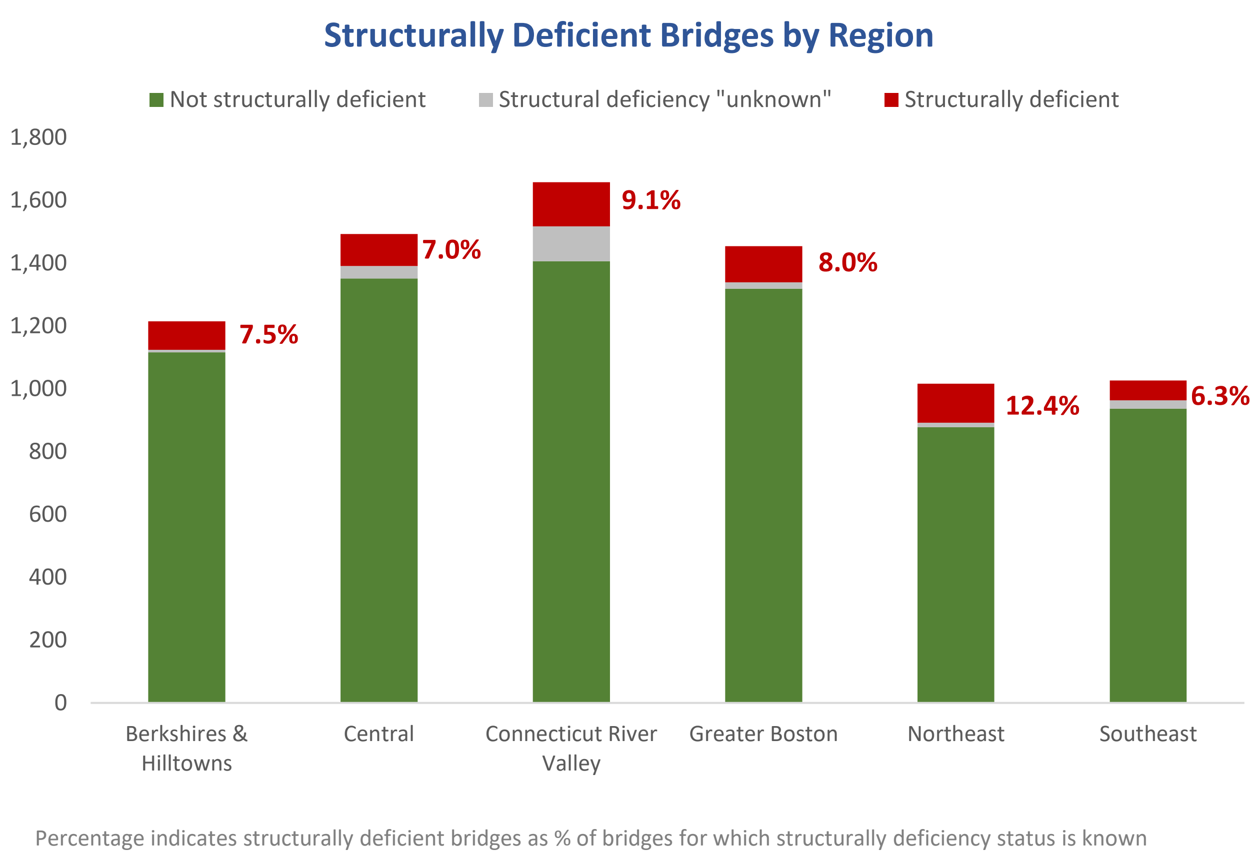
The State of Disrepair is Worse in Some Regions than Others

Every region in the Commonwealth has bridges in disrepair, though some regions have bigger problems than others. Both urban and rural bridges have approximately the same percent of bridges that are structurally deficient. Three quarters of bridges in Massachusetts are in urban areas while one-quarter are in rural areas. Urban bridges may face greater stress from a larger volume of traffic and may affect more people when they are in disrepair. Rural bridges may face particular challenges when they are managed by cash-strapped rural towns with declining populations.[12] The impact of closing or weight limiting rural bridges may be magnified by the longer distances people are required to travel for alternative routes.

Nonetheless, there are distinct regional patterns evident by subdividing the Commonwealth into six state-defined regions.[13]

- The Berkshires & Hill Towns contains 1,116 bridges, of which 91 (7.5 percent) are structurally deficient. On average residents in the region live 1.6 miles from the nearest structurally deficient bridge. The region's 16 closed bridges are the highest percent of closures in the state. Similarly, the 123 bridges posted for limited load or capacity represent the highest percent (10 percent) for any region.
- The Greater Connecticut River Valley contains 1,658 bridges, the most of any region. The 141 structurally deficient bridges are also the highest total in any region. Among bridges with a known status, 9.1 percent are structurally deficient. The region contains 111 bridges for which structural deficiency is listed as "unknown," just over half the total number of unknown-status bridges in the entire state.[14] The region shares the highest count of closed bridges (16). The 131 bridges that are restricted for large load or capacity are more than in any other region. On average residents live 1.5 miles from the nearest structurally deficient bridge.
- The Central region contains 1,493 bridges, 102 of which (7 percent) are structurally deficient. On average residents live 1.6 miles from the nearest structurally deficient bridge. Three bridges are closed and 79 are posted for limited weight or capacity – both the lowest percent of any region.

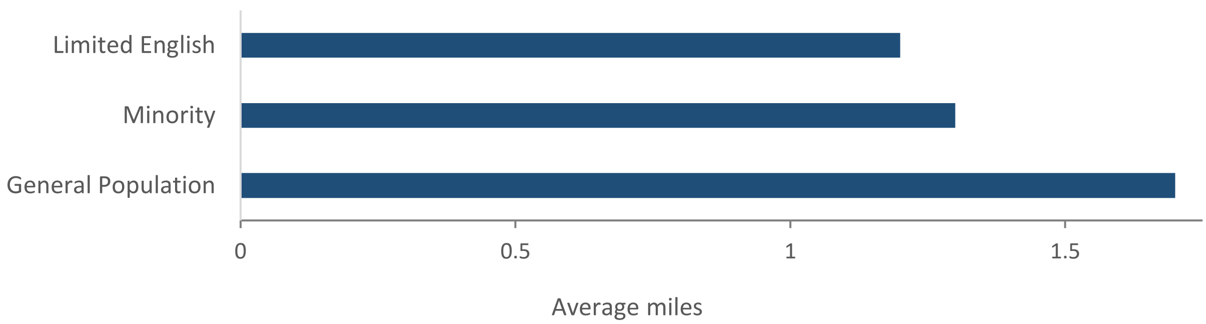
- **The Northeast region** contains the fewest number of total bridges (1,016) among the six regions, but the highest percentage of them (12.4 percent) are structurally deficient, a total of 124. On average residents live 1.5 miles from the nearest structurally deficient bridge. Eight bridges are closed and 60 limit the load or capacity that can pass.
- **Greater Boston** contains 1,454 bridges, 115 of which (8 percent) are known to be structurally deficient. On average residents live 1.2 miles from a structurally deficient bridge. Seven bridges are closed and 125 are limited for load or capacity.
- **The Southeast region** contains 1,026 bridges, 63 of which (6.3 percent) are structurally deficient, the lowest percentage of any region. On average residents live 3.2 miles from the nearest structurally deficient bridge. Seven bridges are closed and 78 are posted for load or capacity.



Likelihood of Living Near a Structurally Deficient Bridge Varies by Ethnicity and Race

In Massachusetts, racial and ethnic minorities and limited-English proficient households tend to live nearer a structurally bridge than others. "Minority" residents – those who self-identify to Census as a category other than non-Hispanic white – live closer on average to a structurally deficient bridge than the general population.[15] This disparity is even greater for limited English-speaking households.[16] The disparities exist even when each region is viewed separately or when looking only at urban areas.[17] It's not clear why there are such pronounced differences between racial and language groups in their proximity to structurally deficient bridges.[18]

Some Groups Live Closer to Structurally Deficient Bridges than Others



Bigger Challenges Ahead

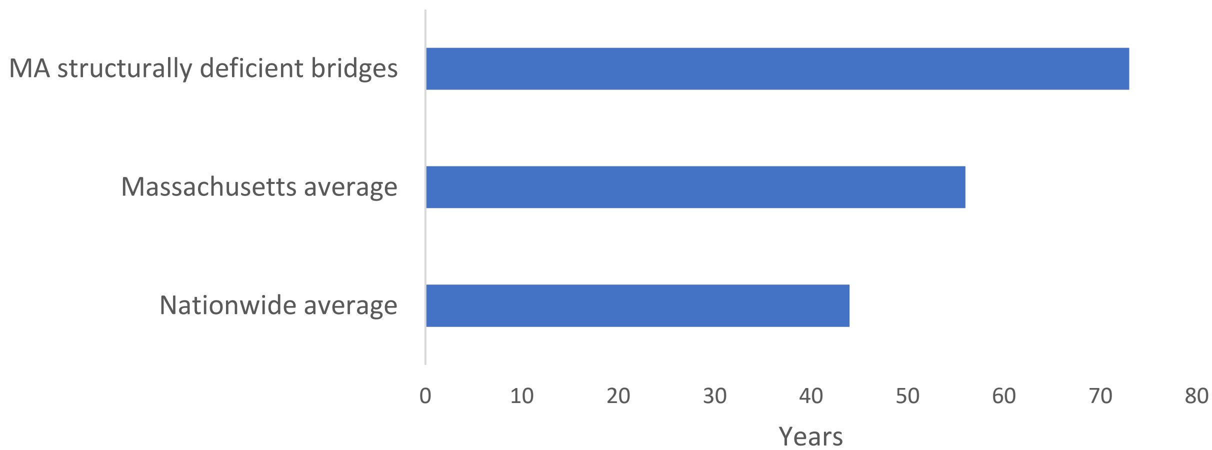
In the coming years, several factors are likely to accelerate the deterioration of Massachusetts bridges. Each on its own threatens to worsen the state of repair of our bridges and without significant new investment, together they could have far greater impact.

- **Climate change** – All infrastructure is vulnerable to climate change, but bridges can be particularly vulnerable. Bridges are often built crossing water which exposes them to flooding and erosion. Climate scientists expect climate change in New England to bring steep increases in precipitation.[19] Bridges are typically designed to meet criteria based on historical weather patterns, but these patterns are being replaced with more extreme and uncertain conditions. Climate change will bring stronger storm surges, flood flows, and thermal stresses on building materials that will worsen the decay and decline of bridges.[20]

- **Heavier vehicles** -- Trucks and emergency vehicles keep getting heavier. Heavy vehicles inflict a disproportionate amount of damage on roadways. Most bridges were designed for much lighter vehicles and based on older standards.[21]

- **Old, deteriorated stock** -- Compared to other states, Massachusetts bridges are exceptionally old. Nationwide, the average age of bridges in the National Highway System is 44 years old.[22] But in Massachusetts, the average age of bridges is 56 years old. The Commonwealth's structurally deficient bridges are not surprisingly even older: an average of 73 years old, according to MassDOT's bridge data. The problem isn't just a few historic covered bridges pulling up the state average. A total of 778 bridges in Massachusetts exceed 100 years old since they were first built or most recently reconstructed. According to National Bridge Inventory data, 14 percent of bridges exceed 90 years of age in Massachusetts, almost three times the prevalence of such old bridges nationwide.[23] All 20 of Massachusetts' structurally deficient bridges with the greatest traffic volume were constructed before 1966, and none of the handful that were reconstructed have been since 1993.

Massachusetts Bridges are Older ...and it Shows



Investing to Improve Our Bridges

Repairing and replacing bridges requires significant public investment. The good news is that additional investment has a clear track record in making a difference to improve the condition of bridges. Unfortunately, the Commonwealth hasn't dedicated the resources to make an overall improvement to the state of bridge repair. Without such investments, several factors make it more likely that bridge conditions will further deteriorate.

Back in 2008 the Commonwealth identified that the already-large number of structurally deficient bridges was on a trajectory to spike upwards in coming years. Spurred by a high-profile 2009 bridge collapse in Minneapolis, the administration dedicated $3 billion in additional funds through the Accelerated Bridge Program to fix its growing repair backlog. The effort paid off with major improvements to the overall condition of bridges across the Commonwealth. No similar commitment has been made since. Bond bills that could provide resources to fix large numbers of bridges would still need funds put aside to pay back these borrowed funds and might not even be enough to keep up with the aging and wear of bridges across the state.

The Massachusetts Department of Transportation Performance and Asset Management Advisory Council made reference to this experience and the need for additional current investment in introducing its 2022 report,

> "Today's conditions reflect the $3 billion investment of the Accelerated Bridge Program (2008-2018), which rehabilitated or replaced nearly 300 bridges and forestalled a further decline of condition. However, **a significant investment is needed to rehabilitate or replace legacy infrastructure and sufficiently fund maintenance and preservation**."[24]

The MassDOT report notes these additional funds are needed, despite increased federal funding from the Infrastructure Act, recent bond bills, and a state program to help municipalities with small bridges.

Without additional funding, our bridges are likely to fall into worse disrepair. But the good news is that timely additional investments in bridges can end up saving money over the longer term. Repair of a bridge is cheaper than waiting to replace it once the problem gets worse.[25] A state of good repair provides further savings in time and safety for drivers, and environmental benefits from avoiding a full tear down.

The integrity of our bridges for the decades ahead depends greatly on the decisions we make in the next few years. The problem of structurally deficient bridges is serious and widespread, but it is a problem we can choose to fix.

Acknowledgements: This project would not have been possible without Marcos Luna, Professor of Geography and Sustainability and Graduate Program Coordinator for the Geo-Information Sciences program at Salem State University, who provided essential guidance to the data analysis behind this study. Thanks also to officials at the Massachusetts Department of Transportation for answering questions: Tom Prendergast, Bridge Inspector IV; Carrie Lavallee Acting Chief Engineer and Deputy Administrator of MassDOT's Highway Division; Alexander Bardow, State Bridge Engineer; Jose Simo, GIS Outreach Coordinator; and Jack Moran, Deputy Chief of Performance and Asset Management.

Appendix 1: Data and Methodology

Unless otherwise indicated, all bridge data was downloaded for analysis in January 2022 from the Massachusetts Department of Transportation (MassDOT) Highway Division Bridge Inspection Management System (BIMS). It includes MassDOT and municipally-owned structures with spans greater than 20 feet. These are categorized as National Bridge Inventory (NBI) and inspected by MassDOT on a biannual basis. MassDOT Highway and municipally-owned bridges between 10 to 20 feet are also included, but the first short bridge inventory remains incomplete. Finally, the database includes an incomplete inventory of shorter MassDOT Highway and municipally owned spans between 4 to 10 feet. Federally owned spans or those owned by other state entities or owned privately are not included. Bicycle and pedestrian overpasses are not included.

Bridges are categorized into three different types of structural conditions: no structural deficiency; structural deficiency; and unknown structural deficiency. According to the 2021 Report Card for America's Infrastructure: Bridges, structural deficiency is defined as a key structural element of a bridge, which includes the deck, superstructure, substructure, or culvert, having a rating of "poor" or worse. While a confirmed absence or presence of structural deficiency for a bridge is clear for our analysis, a bridge condition of 'unknown' structural deficiency is unclear; the MassDOT database provides no detail or explanation for 'unknown' status, and no follow up information was provided in response to our request for information about clusters of bridges with "unknown" status.

Additionally, two operational categories of bridges were selected for analysis—closed and load/capacity restriction. A "closed" operational condition indicates a bridge is closed to all traffic; the duration of its closure is unspecified in the MassDOT database on bridges. "Load/capacity restriction" combines two separate categories in the database: posted for load and posted for other load-capacity restriction. This operational condition indicates a bridge has a restriction on its use which may include, but is not limited to, number of vehicles, speed, and weight. Operational categories are independent of their structural category. For instance, a bridge can be closed without being structurally deficient.

Traffic volume for each bridge was calculated by identifying the closest road and attributing to the bridge its Annual Average Daily Traffic (AADT) data as acquired from the MassDOT Road Inventory 2020 dataset. AADT is the total volume of vehicle traffic of a highway or road for a year divided by 365 days. Calculations for averages for each structural category of bridge did not include null and zero values for AADT.

Population data comes from the Census Bureau American Community Survey 5-year estimates for 2016-2020 at the geographic unit of the block group came from the Census Bureau. A block group generally contains between 600 and 3,000 people and is the smallest unit for which the Census Bureau reports a full range of demographic statistics. The census tables used are: B02001 Race and C16002 Household Language by Household Limited English Speaking Status. *Minority* corresponds to people who do not identify as non-Hispanic White. It does include people who are designated as multiracial. A household with limited English proficiency is a household in which all members age 14 years and over speak a non-English language and also speak English less than "very well" (have difficulty with English).

Calculations on data used to derive population statistics on minorities and households with limited English proficiency are adopted from the Environmental Protection Agency's EJSCREEN Technical Documentation. This report matches the definitional qualities used to determine the subsets of the population under examination with that of the Environmental Justice Mapping and Screening Tool. Further analysis to parse data by a specific racial identity, as an example, can be conducted to offer more nuance. For our initial review, however, we focus on these three high-level subsets of the population. Demographic data was apportioned to areas within a block group that contained residential parcels. This method offers greater accuracy when calculating average distances to bridges because it considers where people reside within a block group. Residential parcels were identified using the Metropolitan Area Planning Council's Land Parcel Database.

Proximity to bridges was calculated based on three different geographic scales: Massachusetts (MA) state; municipal vulnerability preparedness (MVP) regions; and urban areas. We selected the MVP regions, as used for the Massachusetts Vulnerability Preparedness program by the Massachusetts Office of Energy and Environmental Affairs, to provide the basis for dividing the state into six exclusive areas for our analysis. Urban areas, designated by the Census Bureau, represent densely developed territory, and encompass residential, commercial, and other non-residential urban land uses. Rural areas encompass all population, housing, and territory not included within an urban area.

We use population-weighted averages to calculate distances to a bridge. Weighted averages are used to give different groups proportional representation; it removes biased overrepresentation of large groups and underrepresentation of small groups. To do this, each data point value is multiplied by the assigned weight, which is then divided by the number of data points. For our analysis, the calculation is (population*average distance to bridge)/population.

Data comparing Massachusetts bridge ages to the nationwide stock of bridges is acquired from 2021 National Bridge Inventory state data on good, fair, and poor rated bridges by year was downloaded from the Federal Highway Administration.

Appendix 2: Examples of Structurally Deficient Bridges with High Traffic Volume, by County

The table below represents the three greatest values representing most trafficked open bridges by county (including those posted for load) with a structural deficiency. Dukes county has one entry which the only open bridge with a structural deficiency and Nantucket county has zero such bridges.

To generate this table, the data layer containing bridge with Average Annual Daily Traffic (AADT) values were filtered to contain only structurally deficient bridges that are open or posted for load. This layer was joined to the Massachusetts county layer—so that every bridge was assigned a home county. Within each county, the 3 largest AADT values were selected (Suffolk County has 9 records in this table due to multiple bridges having the same AADT value).

Examples of Structurally Deficient Bridges by County

County	Municipality	Year	Age	Street Name	Average Annual Daily Traffic	Latitude	Longitude
BARNSTABLE	Sandwich	1926	96	CRANBERRY HIGHWAY	5,239	41.73645900	-70.42577500
BARNSTABLE	Falmouth	1959	63	BRICK KILN ROAD	3,999	41.59441000	-70.62830597
BARNSTABLE	Dennis	1935	87	MAIN STREET	10,836	41.66582300	-70.18202700
BERKSHIRE	Pittsfield	1993	29	PONTOOSUC AVENUE	8,534	42.46653700	-73.25189000
BERKSHIRE	North Adams	1958	64	STATE ROAD	15,081	42.69817597	-73.14811797
BERKSHIRE	Pittsfield	1932	90	LEBANON MOUNTAIN RD	8,665	42.43150900	-73.33535700
BRISTOL	Attleboro	1959	63	INTERSTATE 95	89,690	41.93405200	-71.31982600
BRISTOL	Attleboro	1969	53	INTERSTATE 95	114,648	41.95241000	-71.30660000
BRISTOL	Fall River	1963	59	INTERSTATE 195	92,423	41.68506397	-71.13646400
DUKES	Edgartown	1850	172	KATAMA ROAD	350	41.34963889	-70.51167222
ESSEX	Andover	1975	47	INTERSTATE 93	131,347	42.70063600	-71.20986000
ESSEX	Andover	1959	63	INTERSTATE 93	134,835	42.67731111	-71.20030278
ESSEX	Lynnfield	1963	59	YANKEE DIVISION HIGHWY	137,341	42.51651600	-71.00157000
FRANKLIN	Greenfield	1966	56	INTERSTATE 91	31,409	42.58609200	-72.62095897
FRANKLIN	Greenfield	1962	60	INTERSTATE 91	31,085	42.61151397	-72.60342797
FRANKLIN	Whately	1962	60	INTERSTATE 91	29,984	42.43225497	-72.62202700
HAMPDEN	Springfield	1969	53	SPRINGFIELD EXPRESSWAY	74,816	42.12690700	-72.56700397
HAMPDEN	Springfield	1970	52	SPRINGFIELD EXPRESSWAY	74,816	42.12767000	-72.56540497
HAMPDEN	Palmer	1984	38	MASS TURNPIKE	53,504	42.16997400	-72.26449597
HAMPDEN	Palmer	1957	65	MASS TURNPIKE	55,729	42.17052197	-72.29966600
HAMPSHIRE	Northampton	1965	57	INTERSTATE 91	49,564	42.30790900	-72.62291700
HAMPSHIRE	Northampton	1965	57	INTERSTATE 91	49,564	42.31166000	-72.61943300
HAMPSHIRE	Northampton	1965	57	INTERSTATE 91	45,276	42.31186600	-72.61966997

HAMPSHIRE	**Ware**	**1937**	**85**	**PALMER ROAD**	**11,918**	**42.23874897**	**-72.28587100**
MIDDLESEX	Waltham	1960	62	YANKEE DIVISION HIGHWY	175,232	42.41529100	-71.25729200
MIDDLESEX	Burlington	1962	60	YANKEE DIVISION HIGHWY	179,109	42.47775833	-71.21508056
MIDDLESEX	**Lexington**	**1961**	**61**	**YANKEE DIVISION HIGHWY**	**182,647**	**42.44316500**	**-71.25730500**
NORFOLK	Quincy	1954	68	INTERSTATE 93	172,438	42.25184997	-71.03816797
NORFOLK	Braintree	1978	44	INTERSTATE 93	228,768	42.22696400	-71.02041800
NORFOLK	Randolph	1958	64	INTERSTATE 93	210,559	42.20241300	-71.08087197
PLYMOUTH	Middleborough	1963	59	ROUTE 44	30,379	41.90676200	-70.92440297
PLYMOUTH	Norwell	1961	61	PILGRIM HIGHWAY	69,956	42.11620400	-70.77809800
PLYMOUTH	Brockton	1939	83	OAK STREET	22,537	42.10143800	-71.04330500
SUFFOLK	Boston	1964	58	MASS TURNPIKE	150,719	42.34755500	-71.08545900
SUFFOLK	Boston	1965	57	MASS TURNPIKE	156,916	42.34735200	-71.06577000
SUFFOLK	Boston	1965	57	MASS TURNPIKE	150,719	42.35325997	-71.11618597
SUFFOLK	Boston	1993	29	MASS TURNPIKE	150,719	42.34788000	-71.10056400
SUFFOLK	Boston	1965	57	MASS TURNPIKE	150,719	42.34768300	-71.08791100
SUFFOLK	Boston	1965	57	MASS TURNPIKE	150,719	42.34755700	-71.08668783
SUFFOLK	Boston	1965	57	MASS TURNPIKE	148,803	42.34782200	-71.07874300
SUFFOLK	Boston	1965	57	MASS TURNPIKE	156,916	42.34774097	-71.06891500
SUFFOLK	Boston	1965	57	MASS TURNPIKE	156,916	42.34769697	-71.06842197
WORCESTER	**Auburn**	**1994**	**28**	**MASS TURNPIKE**	**104,513**	**42.20263083**	**-71.82375600**
WORCESTER	Auburn	1980	42	MASS TURNPIKE	104,513	42.19612083	-71.84404000
WORCESTER	Auburn	1980	42	MASS TURNPIKE	104,513	42.19639000	-71.84391600
WORCESTER	Auburn	1978	44	MASS TURNPIKE	104,513	42.19251783	-71.85309200
WORCESTER	Worcester	1958	64	INTERSTATE 290	138,816	42.26571100	-71.79331703
WORCESTER	Worcester	1958	64	INTERSTATE 290	138,816	42.26585583	-71.79351483
WORCESTER	Worcester	1958	64	INTERSTATE 290	144,751	42.25589083	-71.79518000

Bridges in **bold** have been posted for limited load or capacity. Year refers to the date built or most recently reconstructed.

Endnotes

[1] GIS analysis is drawn from Hallah Elbeleidy, "Massachusetts Residents' Proximity to Bridges," Salem State University. Geo-Information Science capstone project report to the Massachusetts Budget and Policy Center (June 2022).

[2] Some bridges are state owned and others are municipally owned. "MassDOT is responsible for the inspection, prioritization, and funding of capital projects on all state and municipally-owned bridges. Municipal owners are responsible for operation and maintenance of bridges within their jurisdiction." See MassDOT Transportation Asset Management Plan 2019, p. 8. MassDOT owns more – and generally bigger – bridges than municipalities. The remainder of bridges are owned and operated by the MBTA, MASSPORT, or DCR with a few operated by other state agencies.

[3] Based on August 9, 2022 tally from the database indicating 644 structurally deficient bridges, and excluding the 218 bridges with unknown condition from the 7,880 total, as listed on the MassDOT Bridge Inspection Management System (BIMS) database. By this measure, 8.4 percent of bridges are structurally deficient.

[4] "The definition for structurally deficient bridge is a bridge with any component (Deck, Superstructure, Substructure, or Culverts) in Poor condition" Federal Highway Administration, "Frequently Asked Questions: Pavement and Bridge Conditions Performance Measures Final Rule." A structurally deficient bridge is not inherently unsafe, but it is at greater risk of structural failure, and for future closure or weight restrictions.

[5] Cover letter from the Massachusetts Department of Transportation's Performance and Asset Management Advisory Council (December 2020) at : https://malegislature.gov/Reports/10580/SD3149_pamacCvrLetter2020.pdf

[6] According to MassDOT officials bridges with an "unknown" status often were recently added to the inventory and have not yet been inspected.

[7] 2021 National Bridge Inventory state data on good, fair, and poor rated bridges by year downloaded from from the Federal Highway Administration. Forty eight percent of Massachusetts bridges were rated "Fair."

[8] 2022-performance-and-asset-management-advisory-council-annual-report, p. 8. https://www.mass.gov/doc/2022-performance-and-asset-management-advisory-council-annual-report/download

[9] National data are from the National Bridge Inventory of National Highway System bridges. Massachusetts data from MassDOT database.

[10] Data downloaded from MassDOT on July 10th. Of the 64 closed bridges, 36 are listed as structurally deficient and another two are listed as "unknown" with regard to structural deficiency. See https://geo-massdot.opendata.arcgis.com/datasets/bridges/explore?filters=eyJTdHJ1Y3R1cmFsbHlfRGVmaWNpZW50IjpbIlFUyJdLCJQb3N0ZWQiOlsiQ2xvc2VkIl19&location=42.050554%2C-71.726950%2C8.00

[11] Data downloaded from MassDOT on July 10th at https://geo-massdot.opendata.arcgis.com/datasets/bridges/explore?filters=eyJTdHJ1Y3R1cmFsbHlfRGVmaWNpZW50IjpbIlFUyJdLCJQb3N0ZWQiOlsiUG9zdGVkKExvYWQvQ2FwYWNpdHkgUmVzdHJpY3Rpb24pIiwiUG9zdGVkIEZvciBMb2FkIl19&location=42.050554%2C-71.726950%2C8.00 . For more on standards and procedures for weight limits on bridges, see MassDOT, Bridge Inspection Handbook (April 2019), chapter 6, "Rating, Posting, and Closing of Bridges."

[12] Auditor's report, https://www.mass.gov/info-details/findings-public-infrastructure-in-western-massachusetts#1.-transportation-infrastructure-such-as-roadways,-bridges,-and-culverts-are-an-area-of-primary-conc-

[13] There are multiple ways to subdivide territory in Massachusetts with no single standard method. These six regions are, for instance, used by the Commonwealth's Municipal Vulnerability Preparedness program. The analysis of these regions is based on MassDOT data downloaded in January 2022. Unless otherwise noted, the percent of structurally deficient bridges includes only those bridges for which structural deficiency is not listed by MassDOT as "unknown." When noting the percent of closed or posted bridges, all bridges in the region are counted.

[14] Statewide, there are 218 bridges for which public authorities do not know whether or not they are structurally deficient or not. Some of these could be smaller bridges that were recently added to the state database and haven't yet been inspected as part of that protocol. Many of the bridges in unknown condition are located in three distinct clusters of bridges in the middle of the state: West of Springfield, around Worcester, and between the towns of North Brookfield and Gilberville.

[15] On average a "minority" lives 1.3 miles from a structurally deficient bridge, as opposed to 1.7 miles for the general population. The Commonwealth uses this definition of "minority" in designating Environmental Justice communities,

noting that "minorities comprise 40 per cent or more of the population" at https://www.mass.gov/info-details/environmental-justice-populations-in-massachusetts .

[16] On average a household with a limited English speaking household lives 1.2 miles from the nearest structurally deficient bridge. A limited English-speaking households is one where no member over 14 years of age speaks English well The Commonwealth uses this definition of language isolation as part of its methodology for designating Environmental Justice communities, noting that "25 per cent or more of households lack English language proficiency" at https://www.mass.gov/info-details/environmental-justice-populations-in-massachusetts.

[17] Thus, the disparities do not appear to derive simply from patterns of people of color and households with limited English residing more in certain regions or in urban areas where there are more bridges. Curiously, the relatively small number of minorities and limited-English households in rural areas live further away from a structurally deficient bridge on average than the general population in these areas.

[18] To our knowledge, there have not been previous studies of disparities between different groups' proximity to structurally deficient bridges. People of color and households with limited English proficiency also tend to live in denser, more urban settings and thus also live closer to more bridges. Results may also reflect residential patterns around old industrial areas that tend to be near rivers and highways. However, the disparity in the ratio of proximity to *structurally deficient* bridges is steeper than the disparity of proximity in the ratio of bridges in general. Thus, the disparity appears in part to be specifically linked to the disrepair of infrastructure. A potential source of structural racism could be that municipalities with more people of color have fewer resources for investment in locally owned bridges. A recent academic study also suggests that communities with a greater proportion of people of color face greater public borrowing costs as a result of racial bias. See, A. Eldemire, K; Luchtenberg, and M. Wynter, "Black Tax: Evidence of Racial Discrimination" (May 2022 at https://www.brookings.edu/wp-content/uploads/2022/06/Ashleigh-et-al_Black-Tax_27-May-2022.pdf).

[19] U.S. Global Change Research Program, Fourth National Climate Assessment (2018), pages 117-118. Already in 2016 the Environmental Protection Agency noted that the Northeast saw by far the greatest increase of any region – a 71 percent jump between 1958 and 2012 -- in the volume of precipitation falling during the heaviest weather events. See EPA, "Adapting to Climate Change: Northeast" (2016).

[20] See for example, U.S. AID, "Bridges: Incorporating Climate Change Adaptation in Infrastructure Planning and Design" (2015).

[21] Society of Engineers 2021 Infrastructure Report Card: Bridges, p. 23.

[22] 2021 Report Card for America's Infrastructure for bridges Note that the report card examines only bridges on the national highway system, whereas the more complete and up to date calculation of average bridge age in Massachusetts is taken from downloaded MassDOT data.

[23] MassDOT presents a similar analysis of its National Highway System bridges in the most recent (2019) Performance Asset Management report, noting that a majority of its bridge deck area was built in the four decades between 1940 and 1980, and only a quarter built during the subsequent forty years (p.12).

[24] 2022 Performance and Asset Management Advisory Council Annual Report page 6. MassDOT's 2019 Performance and Asset Management Plan similarly reflected on the success of past increases to investment in the now-completed Accelerated Bridge Program (ABP) and connected a current anticipation of deteriorating bridge conditions with a lack of investment: "the ABP had a positive effect on the count of poor bridges. Between the years 2008 and 2016, the program was the primary driver behind a 20 percent reduction in the number of poor bridges. These gains are not sustainable at the current investment level, and pre-ABP condition is expected to be reached by 2025. See https://www.mass.gov/doc/2019-transportation-asset-management-plan/download (p.20)

[25] "Quantifying the Impact of Bridge Maintenance Activities on Deterioration: A Survey of Practice and Related Resources," Transportation Research Synthesis 1509, Minnesota Department of Transportation, January 2016. A Life Cycle Cost Analysis by the Minnesota Department of Transportation similarly found that simply repairing pavement facilities in the worst condition costs one and a half times as much over time as preventative maintenance. MnDOT - Minnesota Department of Transportation, "Technical Report: Assessing Return on Investment in Minnesota's State Highway Program," (2013). As the U.S. Society of Civil Engineers states in the 2021 Infrastructure Report Card that, "bridges categorized as fair are a concern and an opportunity, as they are potentially one inspection away from being downgraded in classification, but they can also be preserved at a fraction of the cost required to address a structurally deficient bridge." (2021), p. 19.