BICYCLE INFRASTRUCTURE AND ACCESSIBILITY IN BOSTON'S ENVIRONMENTAL JUSTICE COMMUNITIES

Honors Thesis

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By

Laura Swindell

Dr. Keith Ratner

Faculty Advisor

With additional assistance from

Dr. Nicholas Geron

Department of Geography & Sustainability

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Abstract

This project focused on bicycle infrastructure in Boston, including the city's count of bicycle infrastructure and cycling accessibility. Infrastructure included Bluebike stations from November 1st, 2023, and bicycle trails from the 2020 MassDOT Bike Inventory. Accessibility explored the gaps in Boston's bicycle infrastructure in environmental justice (EJ) 2020 census block groups. As of the 2020 Census, 460 of the 581 census block groups in Boston are EJ designated, meaning that approximately 79.17% of census block groups are EJ designated. 2020 EJ designated census block groups' count of bicycle infrastructure and their accessibility to bicycle infrastructure in Boston, MA were analyzed in ArcGIS Pro using spatial joins, distance accumulation, and a suitability modeler. The average number of bicycle trails in a 2020 EJ census block group was 4.22, while the average number of Bluebike stations in a 2020 EJ census block group was less than 1 (0.465). Bicycle lanes were the most common bicycle trail type across the EJ designated census block groups, but 139 (30.22%) of the EJ 2020 census block groups had zero bicycle trails, showcasing a need for bicycle trail connection in these areas. More than the majority, or 302 (65.65%), of EJ designated census block groups had 0 Bluebike stations as of November 1st, 2023. Accessibility to bicycle infrastructure was highest in the neighborhoods surrounding Downtown, such as the North End, West End, Beacon Hill, Back Bay, Fenway, South End, Chinatown, and the South Boston Waterfront. Accessibility was more varied elsewhere, particularly in the West Roxbury, Hyde Park, Brighton, Dorchester, Roxbury, Jamaica Plain, Mattapan, and Roslindale neighborhoods. Bicycling is an essential aspect of multimodal transport and should be constantly evolving and improving.

Keywords: ArcGIS Pro, Geographic Information Systems (GIS), cyclists, Boston, Massachusetts, transportation, infrastructure, bicycle infrastructure, bicycle lanes, bicycle shares, accessibility, environmental justice, census block groups

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Introduction

Bicycling is a sustainable transportation mode and an alternative to automobiles. Benefits of bicycling include decreased air pollution, decreased noise pollution, decreased traffic congestion, decreased dependence on motor vehicles, and increased physical activity (Branion-Calles et al. 2019; Karpinski 2021). When bicyclists travel together in groups, it can act as a social activity (Frank, Hong, and Ngo 2021; MassDOT 2019). Electric bikes, or “e-bikes,” extend travel distances and aid riders that have physical difficulties cycling without electric assistance (Davis 2023). Bicycles require less materials to build, and environmentally damaging materials like palladium and platinum, which are typically used in automobile manufacturing, are not usually used in bicycle manufacturing (European Cyclists’ Federation 2018). Bicycles also have a smaller carbon footprint, which makes bicycling a desirable transport mode for reducing greenhouse gas emissions; motorized transportation collectively emitted 29% of the United States’s greenhouse gas emissions in 2021 (EPA 2023).

As a transport mode, bicycles take up significantly less space and weight on roadways than automobiles, which places less strain on road systems. In the European Union in 2017, the average car weighed 14,000 kg (15.4 tons), while a bicycle weighed usually less than 20 kg (44 lbs). In a single driver’s parking space, 15 bicycles can be stored (European Cyclists’ Federation 2018). Significant amounts of tax dollars go towards road maintenance; in August 2023, Massachusetts Governor Maura Healey signed a $375 million dollar bill devoted to roads, bridges, and multi-modal transportation, of which more than $200 million was set aside for bridge and road maintenance (Healey, Driscoll, and MassDOT 2023). Bicycles are smaller and weigh less, resulting in less strain on both pavements and wallets.

In addition, bicycles are an essential aspect of multimodality in cities. Frank, Hong, and Ngo define multimodality “as the use of more than one transport mode” (Frank, Hong, and Ngo 2021, 1). In the COVID-19 pandemic, bicycling, along with walking, was a way to travel without a need to interact with potentially disease-carrying passengers (Frank, Hong, and Ngo 2021). Bicycles, including rental bicycles offered through bicycle-sharing services like the Bluebike bicycle share in the Greater Boston area, pictured in Figure 1, connect people between public transit and their destinations (Karpinski 2021). Bicycles allow people to travel between a bus stop, home, or workplace in what Davis calls the “last-few-feet connection,” or the “gap in the transportation network” connecting residents between their homes and transit stops. In addition, Davis hails bicycling as “freedom.” She states, “for me, biking is freedom—the freedom to come and go when you want and the financial savings from not having to own a vehicle” (Davis 2023, 35 and 28).

Figure 1. In Boston and several cities in the Greater Boston Metro area, the Bluebikes bicycle-sharing service is an alternative transportation option. Users can rent bicycles from docks and then return them at any other Bluebikes docks. This is the author's own image of the Bluebikes docks at Loring Avenue across from the Central Campus of Salem State University in Salem, Massachusetts.

In Boston, bicycling is a sustainable way to reach jobs, green spaces, businesses, and other transport modes. It is an alternative to walking, using the public transport system, or it can act as a supplemental transport mode. Over the course of three years from 2022 to 2025, Boston aims to expand its bicycle network, including its bicycle trails and Bluebike bicycle-share capacity. By 2025, the City of Boston (2022) hopes that at least half of the city's residents will be within a "3-minute walk" (541 feet or approximately 165 meters) to the joined bicycle network (1). A continuous problem outlined in the publication is the disconnect between bicycle routes and the need to expand the network. By increasing the bicycle network, Boston can increase its bicycle accessibility.

Environmental justice (EJ) populations benefit from expansions to the bicycle network. EJ population groups are susceptible to "environmental burdens," or "any destruction, damage, or impairment of natural resources that is not insignificant, resulting from intentional or reasonably foreseeable causes" (Executive Office of Energy and Environmental Affairs 2021, 4). Burdens can be caused by climate change, natural disasters, water contamination, air pollution, noise pollution, damage to green spaces, and anything that limits access to green spaces. Considering many environmental burdens are either directly or indirectly related to motorist use (e.g. noise and air pollution, and lack of walkability), burdens could be mitigated by bicycle usage and bicycle network expansion. Bicycle usage could also improve access to green spaces. EJ populations fall in the following categories: "(i) the annual median household income is not more than 65 per cent of the statewide annual median household income; (ii) minorities comprise 40 per cent or more of the population; (iii) 25 per cent or more of households lack English language proficiency; or (iv) minorities comprise 25 per cent or more of the population and the annual median household income of the municipality in which the neighborhood is located does not exceed 150 per cent of the statewide annual median household income" (Executive Office of Energy and Environmental Affairs 2021, 4). According to the Bureau of Geographic Information (2022b), EJ criteria include low income (I), minority population (M), and English non-proficiency or isolation (E). Intersectional categories include low income and minority (MI); English non-proficiency/isolation and low income (IE); minority and lack of English proficiency (ME); and minority, lack of English proficiency, and low income (MIE). The Bureau of Geographic Information (2022b) provides publicly available statewide data of EJ population groups assigned to census blocks.

Using spatial joins, distance accumulation, and accessibility maps within ArcGIS Pro version 3.1.3, this paper studies Boston's count of bicycle infrastructure and accessibility within EJ communities. Bicycle infrastructure includes the Bluebike stations as of November 1st, 2023 and bicycle trails from the 2020 MassDOT Inventory (Analyze Boston 2024; Bureau of Geographic Information 2023a). Using existing literature, I explore definitions of "accessibility" and "justice" in the context of transportation. I investigate the following questions: how much cycling infrastructure is in Boston? Where is the cycling infrastructure in Boston, especially within EJ designated census block groups? Where is the disconnect of bicycle infrastructure in EJ designated census block groups?

Literature: "Justice" and "Access" In the Context of Transportation

Past researchers have investigated the relationship between "justice" in the context of transportation. Forms of justice often include the word "accessibility" or "access" to define whether something is just or unjust. Imani, Miller, and Saxe (2019) define accessibility as "the ability to reach destinations where opportunities, activities and individuals are located" (1). To be able to "access" something is to get where you need to go.

The amount of infrastructure, distance, and stress affects whether people choose to bicycle. To McNeil (2011), a city is more "bikeable" when cyclists can travel throughout most of it with ease using existing bicycle infrastructure, though he mentions he merely looks at infrastructure and "does not take into account other factors such as slope, stops and signals per mile, turns and intersection maneuvers per mile, and bridge facilities" (62). Furth, Mekuria, and Nixon (2016) are highly critical of lack of connectivity between infrastructure, claiming that it results in only accessibility by the most confident bicyclists. Frank, Hong, and Ngo (2021) found that the construction of a new separated bike lane resulted in more bicycling amongst residents living in a 300-meter radius. Karpinski (2021), meanwhile, found that other infrastructure types such as bikeshares influence accessibility; the presence of Bluebike bicycle shares in Boston, MA alone increased ridership, though especially when combined with bike lanes.

Forms of justice are diverse and expansive, but several types that are helpful for this paper include distributive justice, procedural justice, interactional justice, transportation justice, and environmental justice. All are concerned with accessibility and can be applied to transportation, including bicycling. Davis (2023), using research from the City University of New York, looks at distributive, procedural, and interactional justices. Distributive justice is the ability to easily and freely access spaces that are open to the entire public, which means that people without cars or with physical limitations must also have access. Once this access is given, interactional justice is concerned with being comfortable in these places. Procedural justice, meanwhile, is the ability to freely impact policy, which includes decisions, transportation policy, and planning. Davis summarizes that all three of these justices relate to "fairness and communities having what they need," including what they need for transportation (42-43). While Davis (2023) connects three forms of justice to transportation (distributive, procedural, and interactional), Karner et al. (2020) outright defines transportation justice as being "a normative condition in which no person or group is disadvantaged by a lack of access to the opportunities they need to lead a meaningful and dignified life" (440). In other words, in transportation justice anyone can get anywhere without hindrance and can do so in a fulfilling, accessible way.

Another form of frequently quoted "justice" in literature is the environmental justice (EJ), which bridges the spheres of the environment and society and encompasses the other forms of justice. EJ is the right to a healthy, comfortable environment. According to Wagner (2020), EJ arose in the 1980s to describe the environmental problems experienced by marginalized individuals, as well as their lack of access to the decision-making intended to solve environmental issues. This marginalization can be related to a diverse range of physical and social characteristics, including but not limited to race, income, and ethnicity. In environmental justice, marginalized groups, called EJ populations, are more likely to experience a lack of access to a healthy environment and experience a lack of input in decision-making (Executive Office of Energy and Environmental Affairs 2021; Mass.gov 2022). Wagner's (2020) definition of environmental justice overlaps with Davis's summary of other justices (2023). Disadvantaged groups could experience noise and air pollution, congestion, and discomfort while bicycling or walking due to motorists, leading to distributive and interactional injustices. In addition, the inability to change these environmental conditions would be procedural injustice. When applied specifically to the context of transportation, environmental justice also becomes intertwined with transportation justice. A violation of environmental justice, therefore, also violates other forms of justice.

Data and Materials

2020 MassDOT Bicycle Trails

I use the bicycle trail data provided by the Commonwealth of Massachusetts Bureau of Geographic Information, Executive Office of Technology and Security Services, also known as MassGIS. The Bureau of Geographic Information (2023a) lists “bicycle trails” as being “shared use path[s], bicycle lane[s], separated bicycle lane[s], or bicycle/pedestrian priority roadway[s].” Bicycle trails, sometimes called “bikeways” (MassDOT 2019), are either incorporated into the streets also used by motor vehicles, located alongside streets with or without physical dividers, or are fully separated. Table 1 uses information from MassDOT (2019) to define the different types of bicycle trails, and it also lists the count of each bicycle trail type. Bicycle trails were from the 2020 MassDOT Bike Inventory (Bureau of Geographic Information 2023a). In addition, Figure 2 visualizes the percentage of each bicycle trail type in Boston. Most bicycle trails are bicycle lanes. Bicycle trails in Boston are mapped in Figure 3.

Bicycle Trail Type (Bureau of Geographic Information 2023a)	Bicycle Lanes	Separated Bicycle Lanes	Shared Use Paths	Bicycle/ Pedestrian Roadways
Description (MassDOT 2019)	Within roadways. They have single or multiple white lines painted on the road indicating a division from motorists. Includes buffered bicycle lanes. Motor vehicles can physically move into bicycle lanes without impediment.	Within roadways. These bicycle lanes have poles or other barriers, though they are still within streets. The physical barriers prevent travel from motor vehicles.	Off-road, separated paths that permit both bicyclist and pedestrian traffic. Examples include small road-like paths adjacent to streets, trails within parks, and former railroad lines that are converted into mixed used recreational paths.	These are roads in which bicycles and pedestrians are prioritized. Also called bicycle boulevards. Bicyclists travel in the middle of low-speed streets where they have the right of way and are guided by signs and bike symbols
Count of Bicycle Trails in Boston as of 2020 **(**Bureau of Geographic Information 2023a)	1,069 (56.56%)	191 (10.11%)	613 (32.43%)	17 (0.90%)

Table 1.

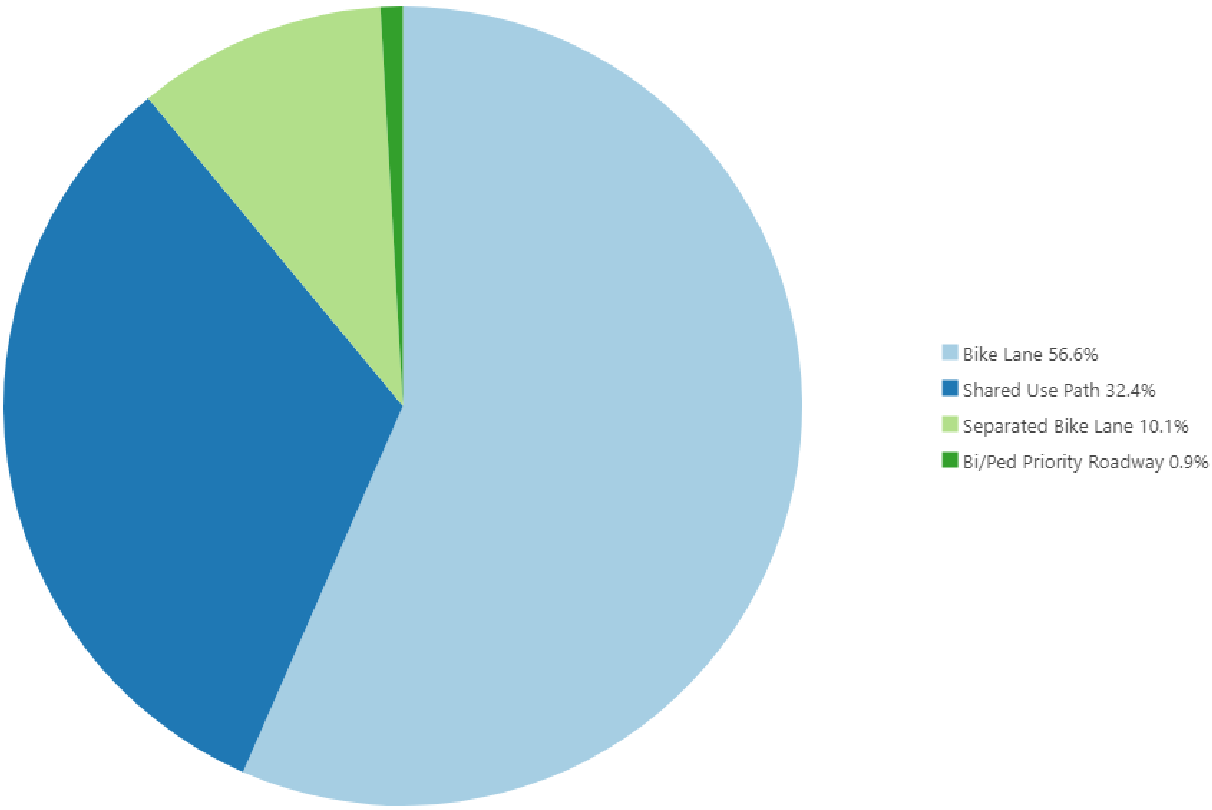

Figure 2. This pie graph depicts the percentages of the types of existing bicycle trails as of 2020 in all of Boston. As of 2020, there are 1,890 existing individual bicycle trails in Boston, with a majority being bicycle lanes (56.56%). This is followed by shared use paths (32.4%), separated bike lanes (10.1%), and bike/pedestrian priority roadways (0.9%). This pie graph was calculated in ArcGIS Pro 3.1.3 using bicycle trail data from the 2020 MassDOT Bike Inventory clipped within the Boston boundary (Bureau of Geographic Information 2022a; Bureau of Geographic Information 2023a).

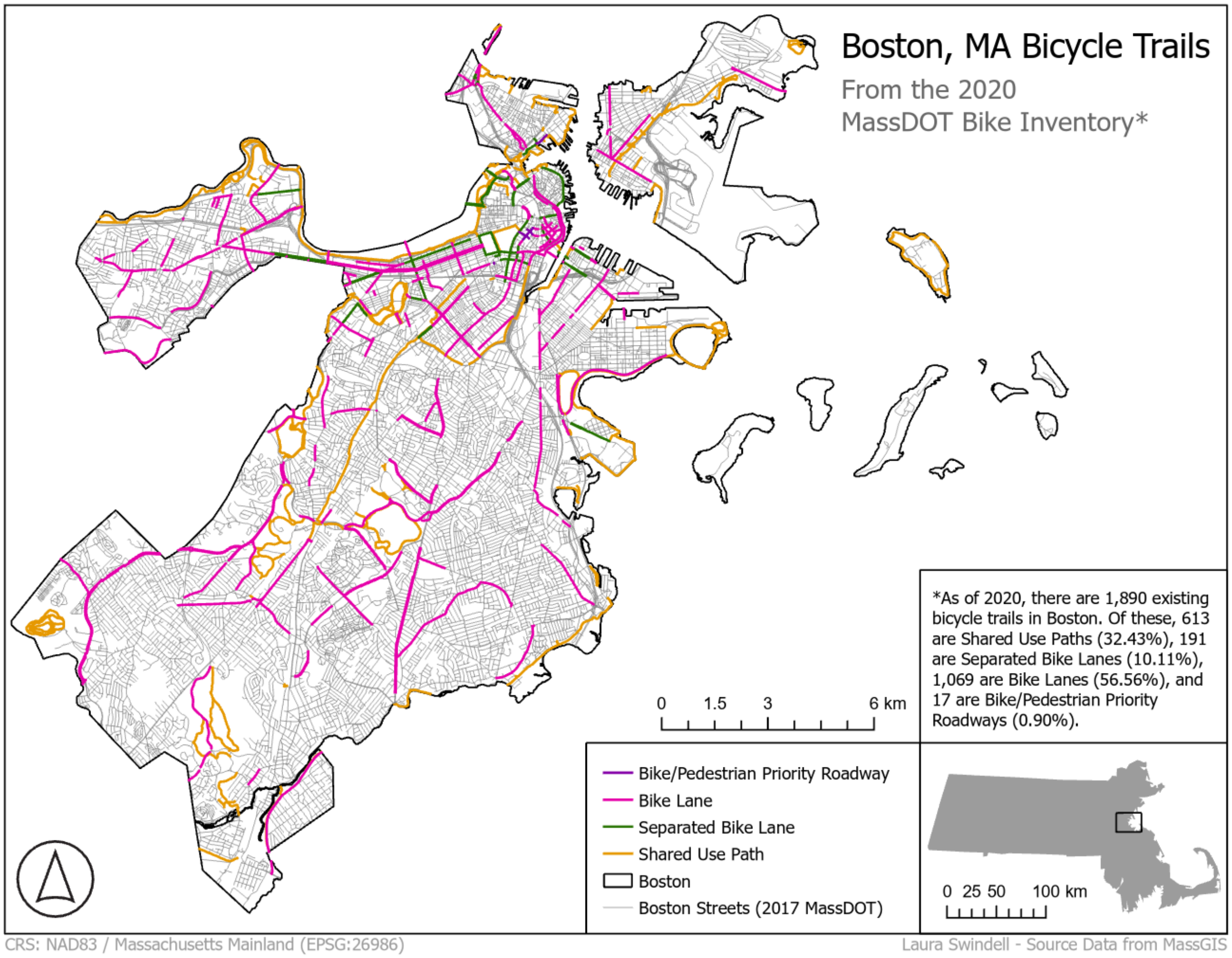

Figure 3. Bicycle trails as of 2020 within the Boston city boundary. Author's own map, created in ArcGIS Pro 3.1.3. Bicycle trail, Boston boundary, and Massachusetts inset data layers are from the Bureau of Geographic Information (2007; 2022a; 2023a; 2023c). CRS: NAD83 / Massachusetts Mainland (EPSG:26986).

Bluebike Dock Stations

Bluebikes are another important aspect of bicycle infrastructure in Boston. Bluebikes are Greater Boston's bicycle-share network. A rider locates a Bluebike dock station, rents a Bluebike for their desired amount of time at the station's kiosk or in the Bluebikes app, and returns their Bluebike at any other Bluebikes dock station. In 2020, Bluebikes was in 10 municipalities, and there were collectively at least 4,000 bicycles and 400 stations. It is sponsored by the non-profit health insurance company Blue Cross Blue Shield of Massachusetts, and it "is jointly owned and managed by Boston, Brookline, Cambridge, Everett, and Somerville." Bluebikes calls itself "public transportation by bike" (Bluebikes 2021).

I acquired Bluebike dock location data from Analyze Boston (2024), the City of Boston's open data hub, on November 1st, 2023 and March 15th, 2024. However, when calculating count and accessibility, I focused on the early November 2023 data to better reflect the summer operations, which at the time had only just concluded in October (Bluebikes 2023). It is important to note Bluebike stations are not permanent and may be added, removed, or relocated over a short period of time, especially in the "winter-riding season" or because of construction (Bluebikes n.d.; Bluebikes 2023). For instance, both the November 1st, 2023 and March 15th, 2024 time frames had different counts of Bluebikes; the latter had 40 less Bluebike stations. This rapid change is a potential limitation to consider when analyzing Bluebike count and accessibility.

The November 1st, 2023 Bluebike station locations are depicted in Figure 4, and the March 2024 locations are depicted in Figure 5. In addition, the October and March stations are overlaid in Figure 6 to better illustrate the differences in locations and counts.

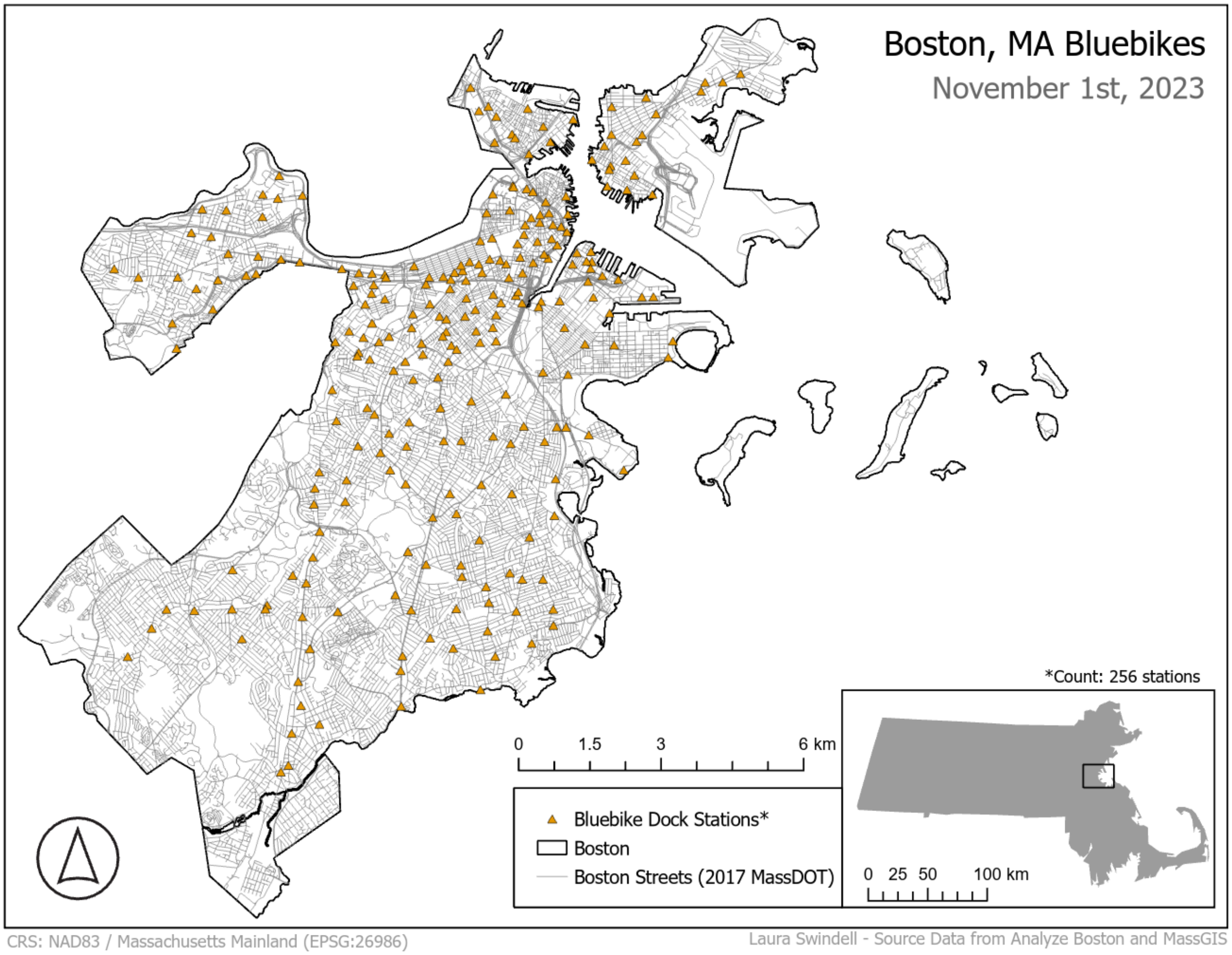

Figure 4. Bluebike dock stations on November 1st, 2023, within the Boston city boundary. There were 256 Bluebike stations throughout Boston, which was 40 more stations than on March 15th, 2024. Author's own map, created in ArcGIS Pro 3.1.3. Boston boundary, Massachusetts inset data layer, and streets are from the Bureau of Geographic Information (2007; 2022a; 2023c). Bluebikes data is from Analyze Boston (2024). CRS: NAD83 / Massachusetts Mainland (EPSG:26986).

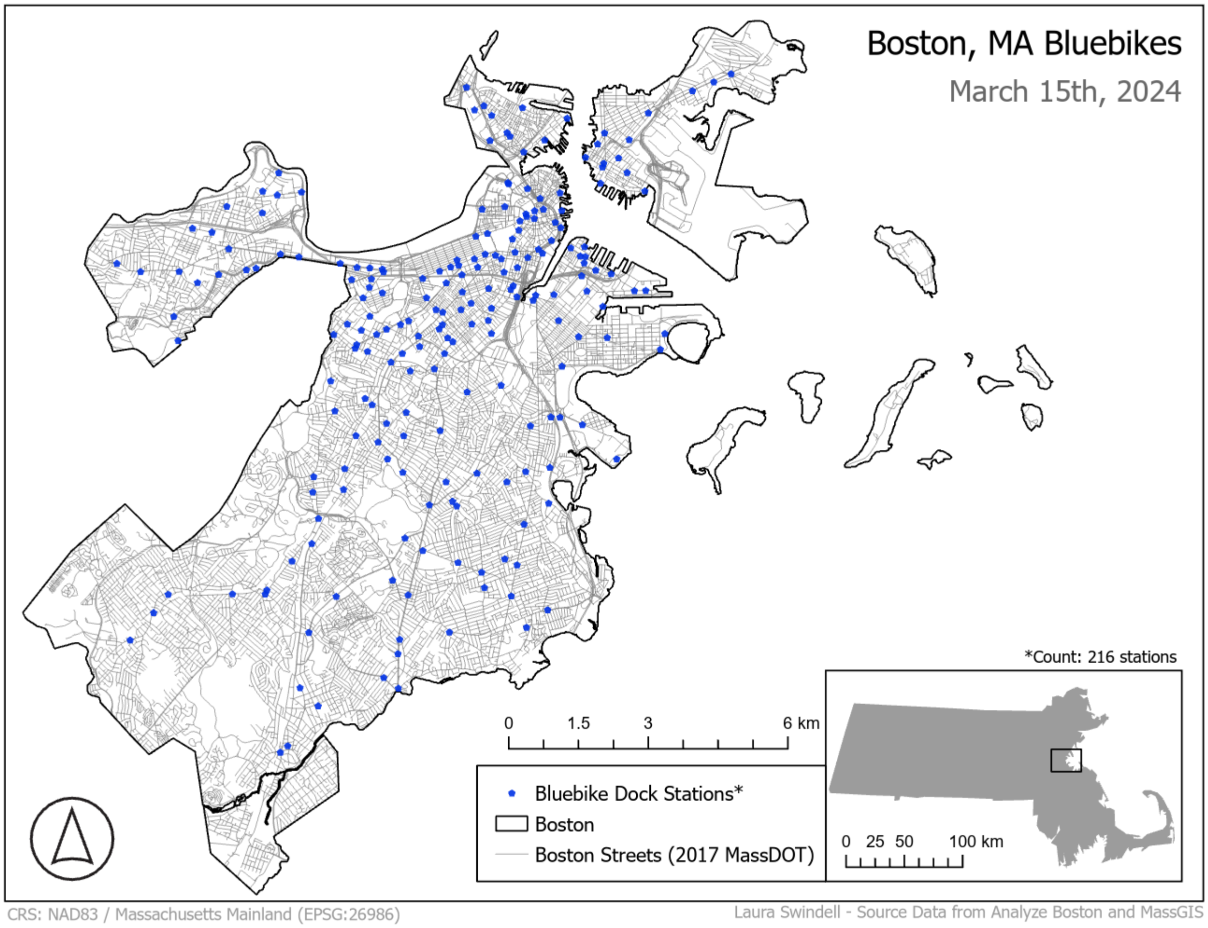

Figure 5. Bluebike dock stations as of March 15th, 2024, within the Boston city boundary. There were 216 Bluebike stations throughout Boston, which was 40 less stations than in November 2023. Author's own map, created in ArcGIS Pro 3.1.3. Boston boundary, Massachusetts inset data layer, and streets are from the Bureau of Geographic Information (2007; 2022a; 2023c). Bluebikes data is from Analyze Boston (2024). CRS: NAD83 / Massachusetts Mainland (EPSG:26986).

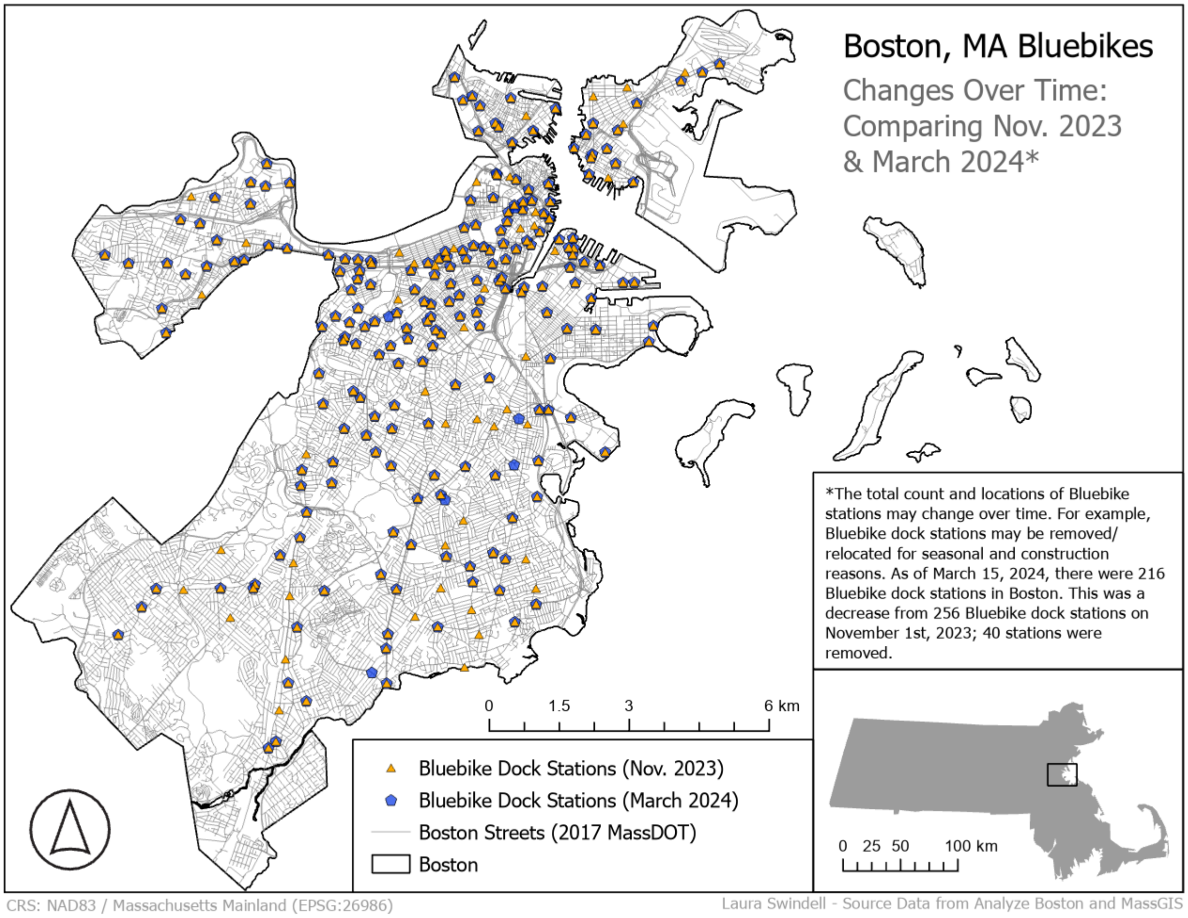

Figure 6. Bluebike dock stations on both November 1st, 2023 and March 15th, 2024 within the Boston city boundary. By overlaying data from both time frames, one can visually see the differences. Author's own map, created in ArcGIS Pro 3.1.3. Boston boundary, Massachusetts inset data layer, and streets are from the Bureau of Geographic Information (2007; 2022a; 2023c). Bluebikes data is from Analyze Boston (2024). CRS: NAD83 / Massachusetts Mainland (EPSG:26986).

Environmental Justice (EJ) and Census Block Group Data Sources

I looked at the bicycle infrastructure and accessibility of 2020 U.S. census block groups and 2020 EJ designated census block groups. EJ communities, which were previously defined in the introduction and are assigned to census block groups, are more likely to experience environmental burdens, including a lack of access to healthy natural environments. Figure 7 depicts all the EJ designated census block groups in Boston. These include Minority (M), Income (I), English isolation (E), Minority and Income (MI); Minority and English Isolation (ME);

Income and English Isolation (IE); and Minority, Income, and English isolation (MIE). EJ data and US census block group data were acquired from the Bureau of Geographic Information (2022b; 2022c).

As of the 2020 Census, 460 of the 581 census block groups in Boston are EJ designated, meaning that approximately 79.17% of census block groups are EJ designated. The IE designation is not present in Boston, while there are 272 M census block groups (59.1%), 115 MI census block groups (25%), 44 MIE census block groups (9.6%), 27 ME census block groups (5.9%), 1 I census block group (0.2%), and 1 E census block group (0.2%). The majority of EJ designated census block groups in Boston have the minority designation. The percentages of each EJ type in Boston are depicted in Figure 8.

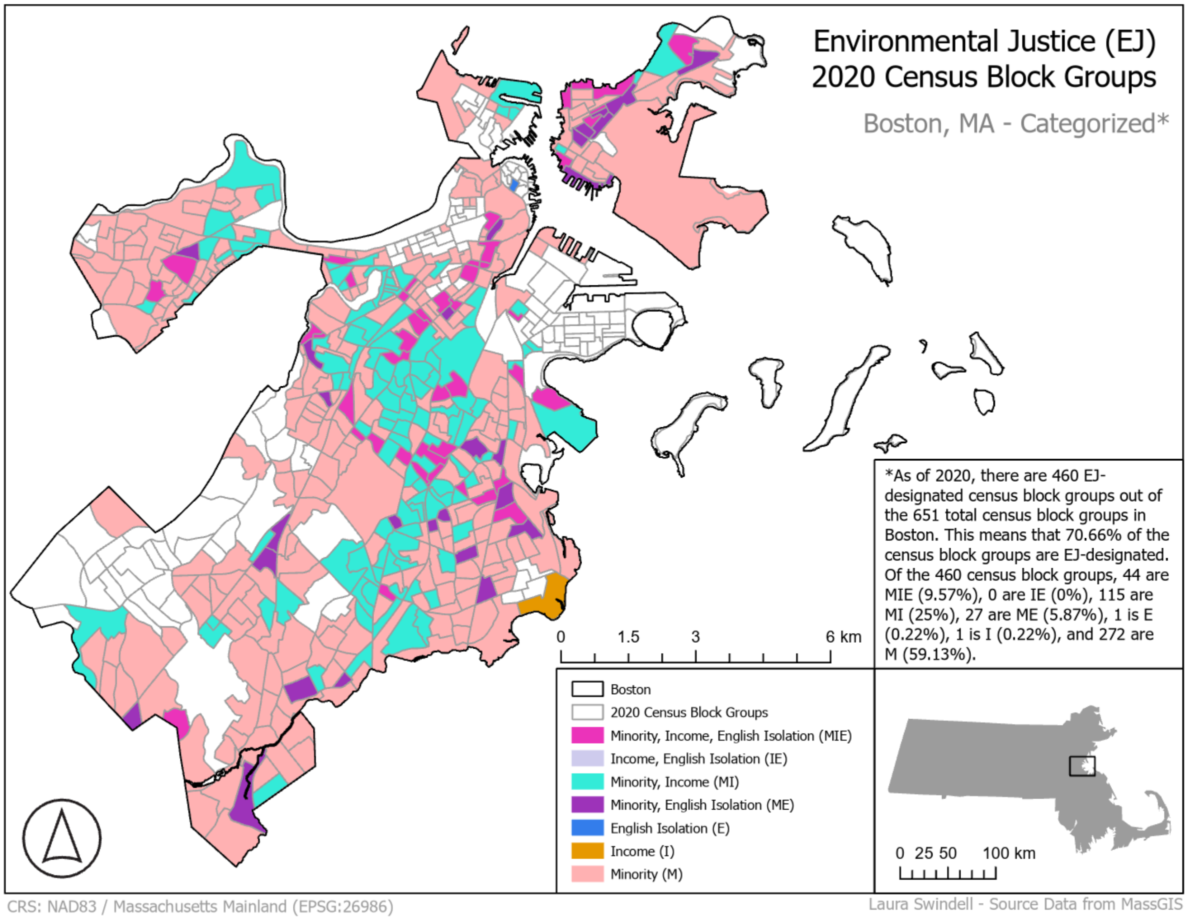

Figure 7. This map shows all EJ designated 2020 census block groups, divided by type, as well as the total 2020 census block groups in Boston. Author's own map, created in ArcGIS Pro 3.1.3. The majority (70.66%) of 2020 census block groups are EJ designated. The EJ, Boston boundary, census block groups, and the Massachusetts inset data layers are from the Bureau of Geographic Information (2007; 2022b; 2022a). CRS: NAD83 / Massachusetts Mainland (EPSG:26986). Note that IE is not present in Boston.

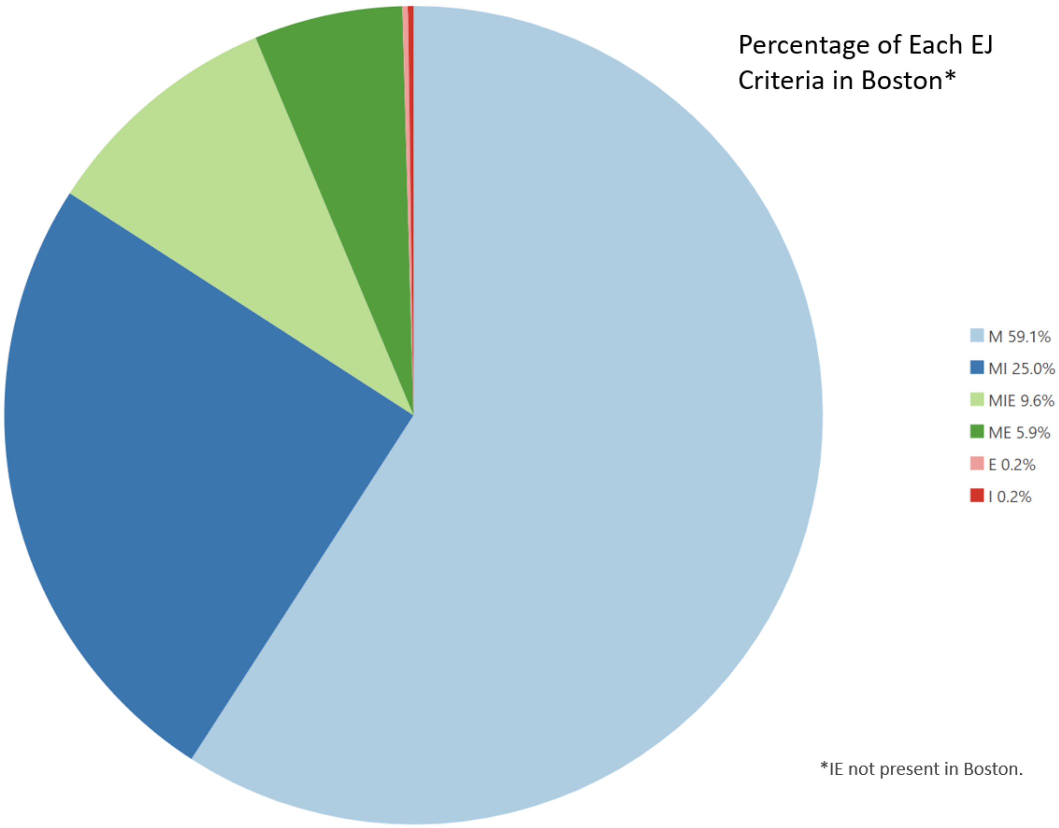

Figure 8. This pie graph depicts the percentage of each 2020 EJ census block group in Boston. Note that IE is absent due to not being present in Boston. M holds the highest percentage, followed by MI, MIE, ME, I, and E. I and E are tied with one census block group each. Calculated in ArcGIS Pro 3.1.3 using the EJ census block group data clipped within the Boston Boundary (Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b).

Digital Elevation Models

Mapping accessibility requires the use of Digital Elevation Models (DEMs). DEMs are derived from Light Detection and Ranging (LiDAR) technologies. LiDAR components include "laser, a scanner, and a specialized GPS receiver" that are attached to either a plane or helicopter rather than a satellite (NOAA 2023). LiDAR can be used for either topographical or bathymetric purposes. When used for topography, LiDAR emits pulsed near-infrared lasers to scan the bare Earth, resulting in a 3D point cloud used to generate DEMs. DEMs do not take into account objects on the Earth's surface like shrubs, trees, or buildings; they merely look at the surface of the Earth itself (NOAA 2023).

The Bureau of Geographic Information (2023b) provides LiDAR DEM data, including DEMs in 31 regional mosaics encompassing Massachusetts. Of these 31 regional mosaics, regions 15 and 16 encompass the extent of Boston and were generated in 2021. DEMs representing regions 15 and 16 were imported into ArcGIS Pro. They were then mosaiced together to create one cohesive layer using the Mosaic tool. This single mosaic was clipped to match the extent of Boston using Clip Raster. Finally, the clipped and mosaiced DEM was resampled with the Resample tool, converting the resolution from 0.5-meter pixels to 5-meter pixels. This resampled Boston DEM, pictured in Figure 9, was used to measure the distances of bicycle trails (Bureau of Geographic Information 2023a) and Bluebike dock stations (Analyze Boston 2024).

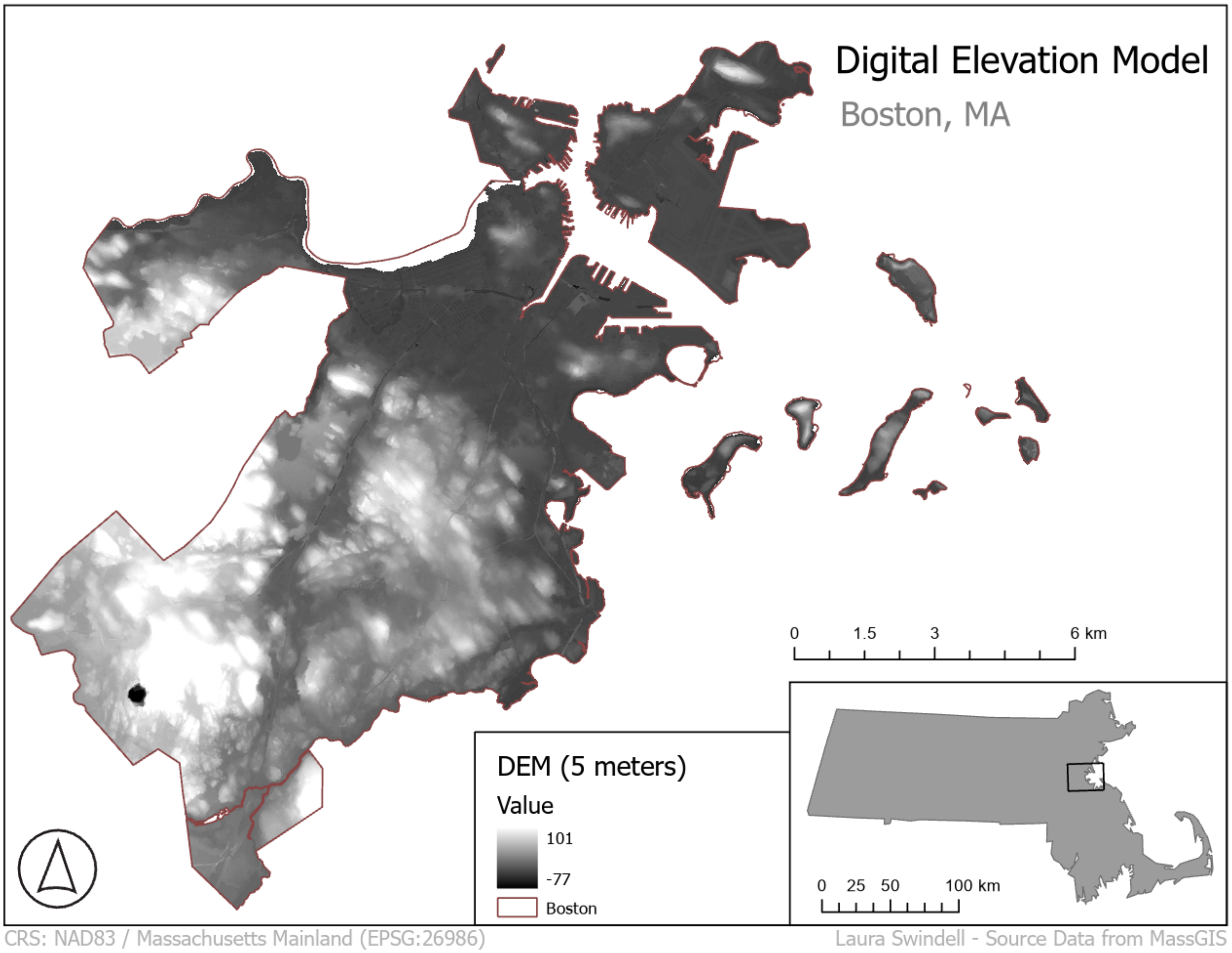

Figure 9. This map depicts a 5-meter pixel DEM in the extent of Boston. Author's own map, created in ArcGIS Pro 3.1.3. DEM, Boston boundary, and Massachusetts inset data layers are from the Bureau of Geographic Information (2007; 2022a; 2023b). CRS: NAD83 / Massachusetts Mainland (EPSG:26986).

Boston Neighborhoods

When a Boston "neighborhood" is named, this refers to the neighborhoods defined by Analyze Boston (2021). While the U.S. Census does not officially determine neighborhoods, "census block groups can be aggregated to approximate Boston neighborhood boundaries to allow for reporting and visualization of Census data at the neighborhood level" (Analyze Boston 2021). The city's defined neighborhood boundaries aid in comparing neighborhoods' bicycle accessibility. Figure 10 visualizes the Boston neighborhoods. In my results, the Boston neighborhood layer is overlaid over the distance and accessibility maps to look at whether some neighborhoods experience a disconnect to bicycle infrastructure.

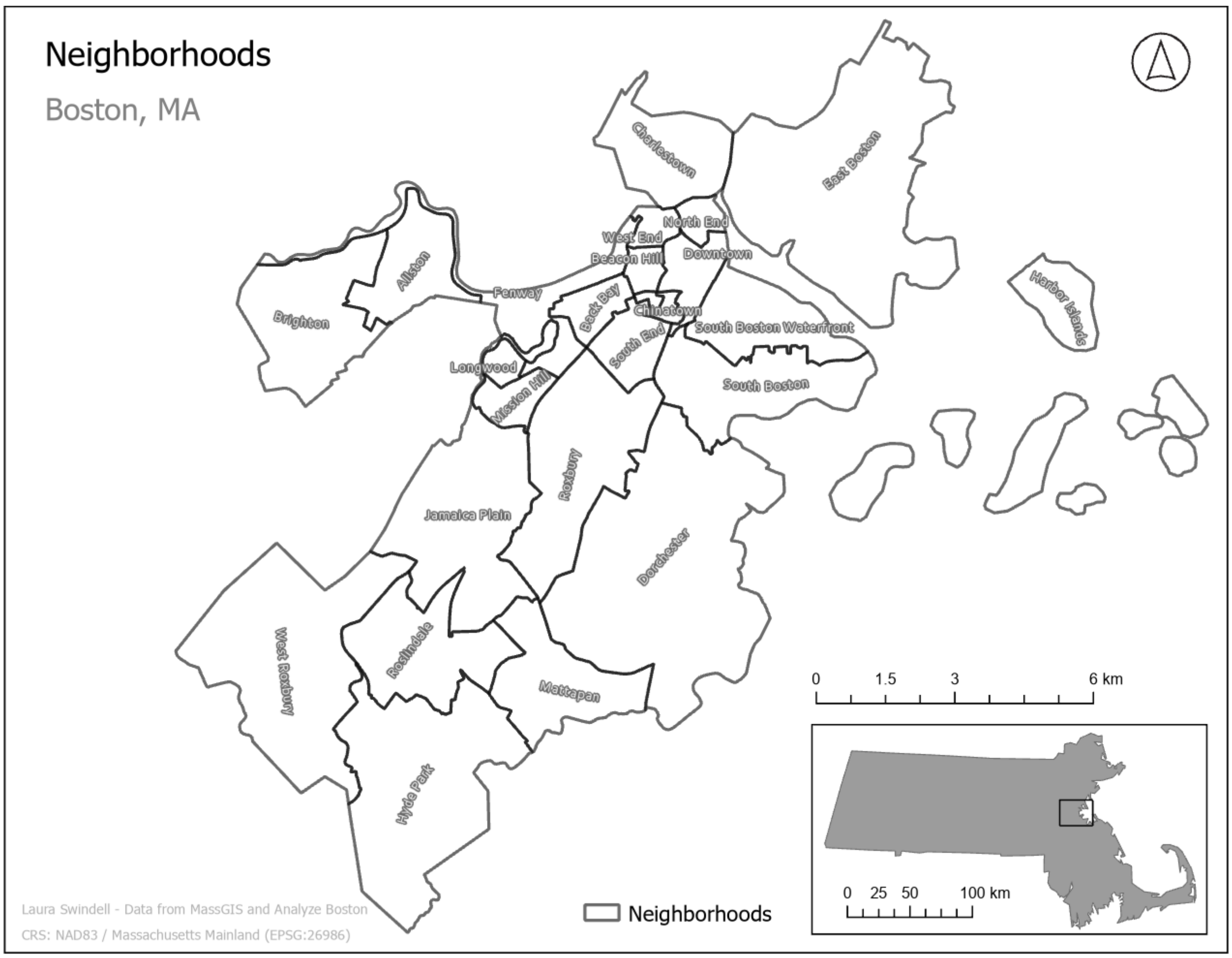

Figure 10. This map splits up Boston into neighborhoods based on 2020 census block group data. Created in ArcGIS Pro 3.1.3. Boston boundary and Massachusetts inset data layers are from the Bureau of Geographic Information (2007; 2022a). Neighborhood data is from Analyze Boston (2021). CRS: NAD83 / Massachusetts Mainland (EPSG:26986).

Methodology

Bicycle Trail and Bluebike Station Spatial Join Maps

Spatial joins can show count, which is important for determining the amount of bicycle infrastructure in a geographic area. In ArcGIS Pro version 3.1.3, a desktop software by Esri cited at the end of this document, I generated two spatial join maps: one for Boston Bluebike dock stations in each 2020 EJ designated Boston census block group for November 1st, 2023, and one for the total bicycle trails in each 2020 EJ designated Boston census block group. In the Spatial Joins (Analysis Tools), “target features” were the EJ criteria census block groups in Boston. “Join features” were the type of bicycle infrastructure: Bluebike stations or bicycle trails. The “join operation” was join one to one, and all target features were kept. Figure 11 outlines the spatial join methodology.

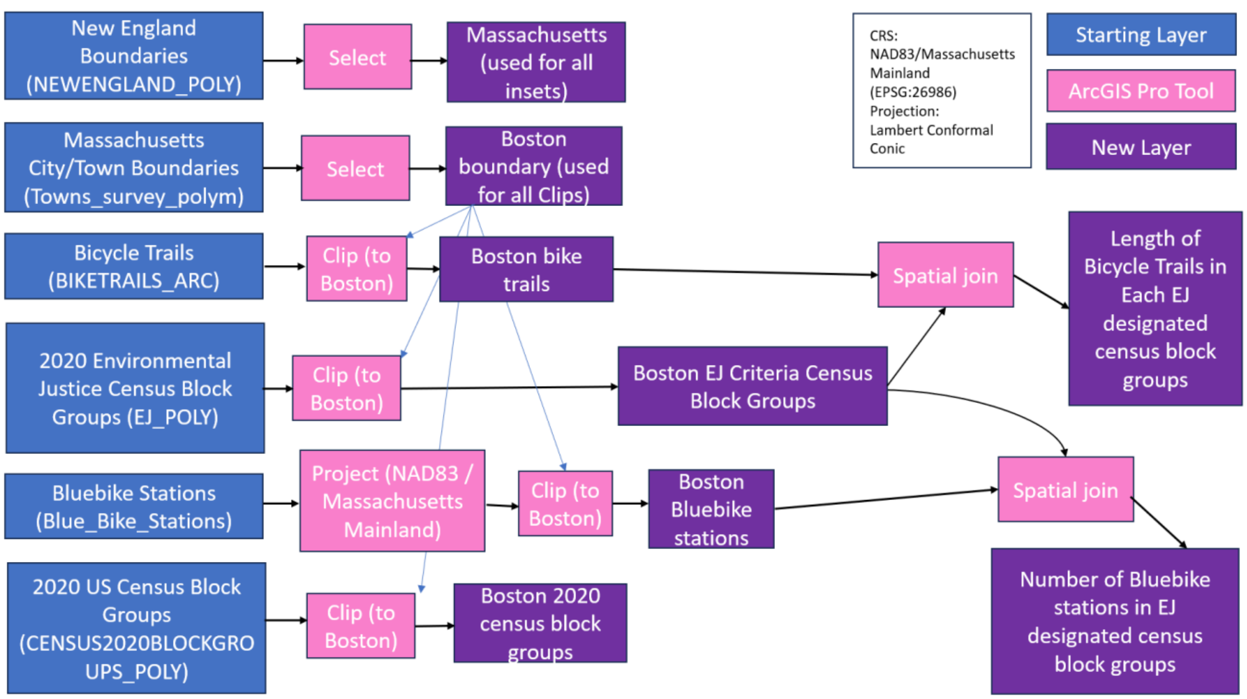

Figure 11. This chart depicts input layers, the ArcGIS Pro tools used to transform them, and the resulting layers for the two spatial join maps. Two spatial join maps were created: one for November 1st, 2023 Bluebikes (Analyze Boston 2024), and one for the bicycle trails from the 2020 MassDOT Bike Inventory (Bureau of Geographic Information 2023a). The 2020 census block groups, 2020 EJ criteria, Boston boundary, and Massachusetts inset from the Bureau of Geographic Information (2007; 2022a; 2022b; 2022c).

Bicycle Infrastructure Accessibility Maps

An accessibility map is important for investigating whether different parts of Boston have different levels of bicycle infrastructure accessibility. The smaller a person's distance to infrastructure, the better. Through a suitability model using a 5-meter pixel DEM of Boston and two distance rasters (in meters) for bicycle trails and November 2023 Bluebike dock stations, I generated an accessibility map for bicycle infrastructure in Boston, MA.

Distance rasters were created in Distance Accumulation, a geoprocessing tool in ArcGIS Pro 3.1.3. The "input rasters" for this tool were the November 2023 Bluebike station layer and the Boston bicycle trails. Since each of these rasters use meters for their units, the resulting distance layers were in meters. No "input barrier raster or feature data" was set for each distance accumulation. Originally, I had intended to set water bodies, particularly the ocean, as barriers. However, I found that clipping the DEM to the Boston extent effectively omitted major water bodies, so setting barrier features was no longer necessary. The "travel direction" was set to be "from source" for both distance accumulations. The "input surface raster" was set to be the Boston Digital Elevation Model (DEM) I produced, depicted previously in the data section.

After each distance raster was created, the default symbologies were changed to classify and manually altered so that they match increments of the "3-minute walk" (165 m) according to the City of Boston (2022). The first and best class was based on a 3-minute walk (165 m), the second class was based on a 6-minute walk (330 m), the third a 9-minute walk (495 m), the fourth a 12-minute walk (660 m), and the fifth class being anything more than a 12-minute walk.

Following manual classification for both distance rasters, each distance raster was applied to the Reclassify (Spatial Analysis) tool. Values were assigned scores from 1 to 5, with 5 being the best (3-minute walk or less to infrastructure), and 1 being the worst (more than 12-minute walk to infrastructure).

- 2020 Bicycle trail reclassification (5 classes):
  0.001 - 165 meters → 5 (best)
  165.001 - 330 → 4
  330.001 - 495 → 3
  495.001 - 660 → 2
  660.001 - 3327.935 → 1 (worst)
- November 1st, 2023 Bluebike dock stations reclassification (5 classes):
  0.001 - 165 meters → 5 (best)
  165.001 - 330 → 4
  330.001 - 495 → 3
  495.001 - 660 → 2
  660.001 - 3670.085 → 1 (worst)

The individual distance maps for Bluebike stations and bicycle trails were compared side-by-side with the spatial join maps for Bluebike stations and bicycle trails respectively.

The reclassified distance layers for Boston's November 2023 Bluebike stations and bicycle trails were put through ArcGIS Pro's Suitability Modeler. Like the reclassified layers, in the suitability modeler, a pixel can have a minimum total score of 2 (low/least suitable/worst biking conditions) and the maximum total score of 10 (high/most suitable/best biking conditions). After the distance rasters were combined in the Suitability Modeler, a pixel could have a minimum total score of 2 (low/least accessible for both bicycle trails and Bluebikes) and a maximum total score of 10 (high/most accessible for both bicycle trails and Bluebikes).

- Applied suitability modeler settings:
  - Unique categories transformation method
  - Model input type: Criteria
  - Suitability scale: 1-5
  - Weight by multiplier
  - The two rasters (distance to Bluebikes and bike trails) were both transformed and given equal weight (1).

The Suitability Model results were applied to a map showing accessibility to November 1st, 2023 Bluebike stations and 2020 bicycle trails based on location in Boston. The distance rasters for Bluebike stations and bicycle trails were compared with the spatial joins for Bluebike stations and bicycle trails featuring the 2020 EJ census block groups. The Boston neighborhood layer was applied on top of the resulting accessibility map to visualize whether certain neighborhoods experience accessibility or a lack thereof.

The web below (Figure 12) thoroughly outlines the process to create the initial distance layers, reclassification, and the accessibility map from the Suitability Modeler. The individual distance maps for Bluebike stations and bicycle trails are compared side-by-side with the spatial join maps for Bluebike stations and bicycle trails respectively; the processes for spatial joins were more thoroughly described in Figure 11.

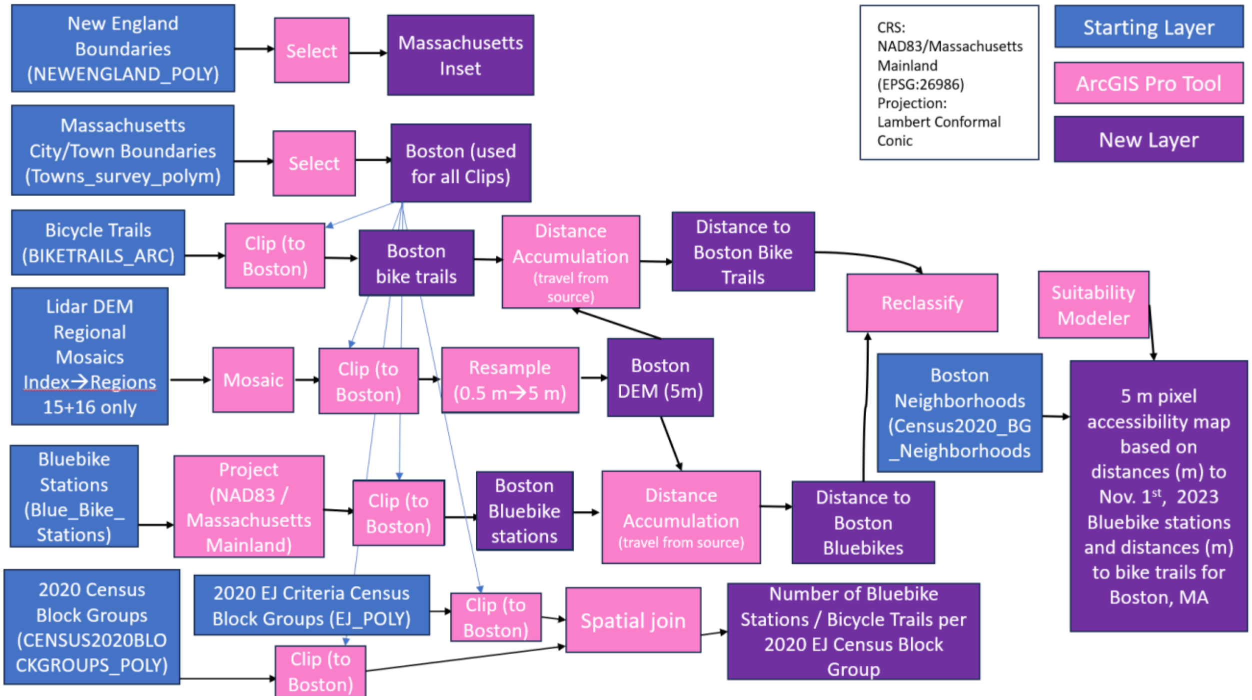

Figure 12. This chart depicts input layers, the ArcGIS Pro 3.1.3 tools used to transform them, and the resulting layers for the distance and accessibility maps for the November 1st, 2023 Bluebike stations (Analyze Boston 2024) and the bicycle trails from the 2020 MassDOT Bike Inventory (Bureau of Geographic Information 2023a). The 2020 census block groups, 2020 EJ criteria, Boston boundary, Massachusetts inset, and DEM data layers are from the Bureau of Geographic Information (2007; 2022a; 2022b; 2022c; 2023b). Boston neighborhoods data is from Analyze Boston (2021).

Results and Discussion

Spatial Join: Bicycle Trails

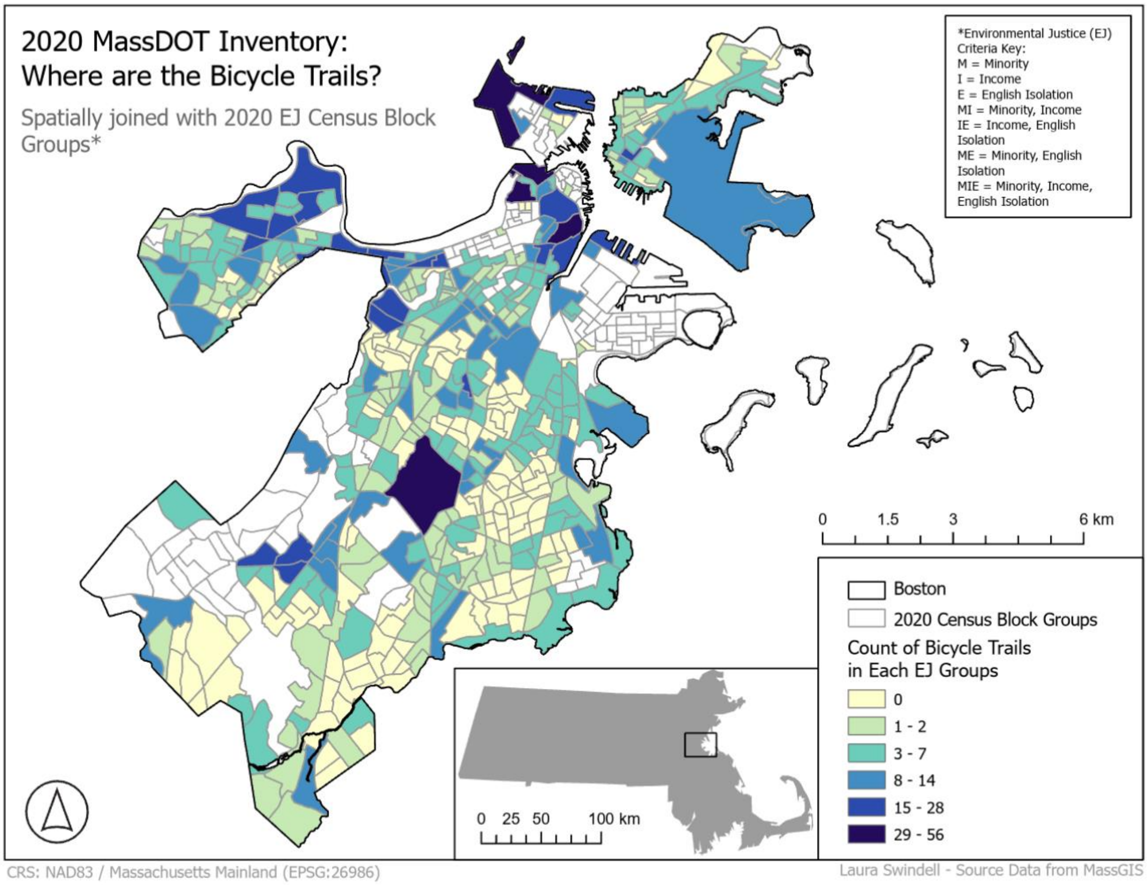

Figure 13. This map is a spatial join of 2020 EJ designated census block groups and bicycle trails as of the 2020 MassDOT Inventory. Author's own map, created in ArcGIS Pro 3.1.3. The 2020 census block groups, 2020 EJ criteria, Boston boundary, Massachusetts inset data layers, and bicycle trails from the 2020 MassDOT Inventory are from the Bureau of Geographic Information (2007; 2022a; 2022b; 2022c; 2023a). CRS: NAD83 / Massachusetts Mainland (EPSG:26986).

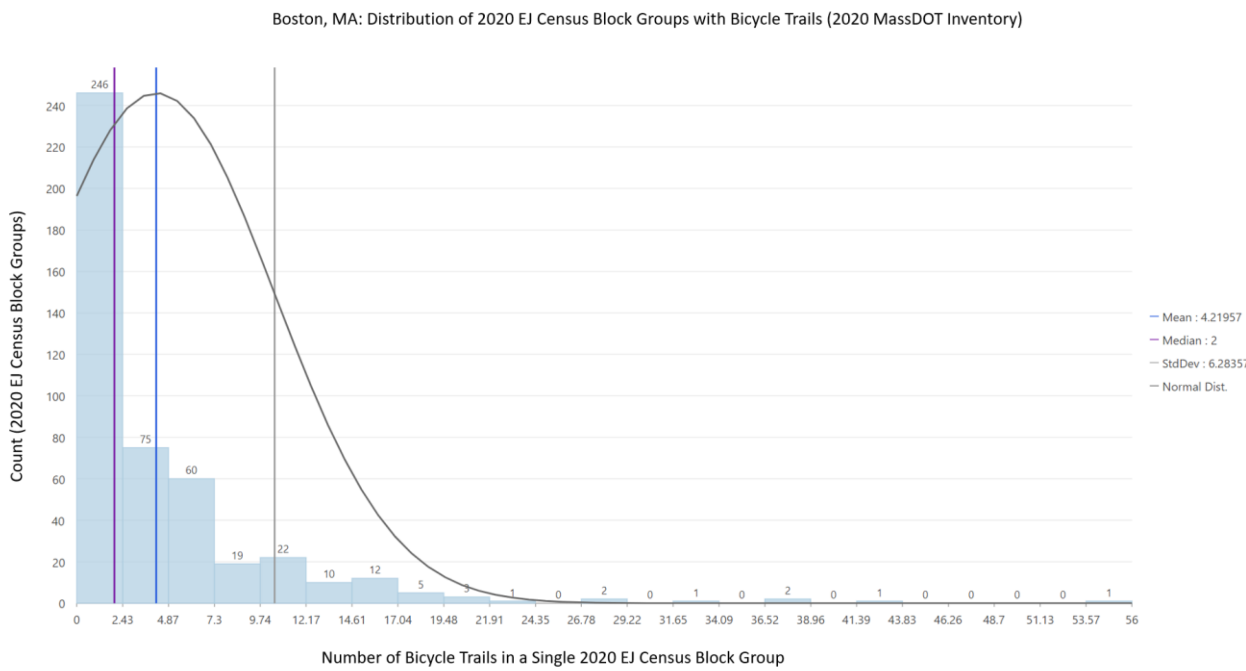

Figure 14. This is a histogram and statistical information for Where Are the Bicycle Trails? (Figure 13). Calculated in ArcGIS Pro 3.1.3 using the spatial join of the 2020 EJ census block groups with the bicycle trails from the 2020 MassDOT Bike Inventory within the Boston boundary (Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b; Bureau of Geographic Information 2023a).

Figure 13 is the spatial join map for 2020 bicycle trails in Boston's 2020 EJ census block groups. As depicted in the above histogram (Figure 14), the average number of bicycle trails in a single EJ designated 2020 census block group was approximately 4.22, while the median number of bicycle trails was 2. The standard deviation was approximately 6.28. 139 (30.22%) of the EJ 2020 census block groups had zero bicycle trails, showcasing a need for bicycle trail connection in these areas. Neighborhoods such as Dorchester, Hyde Park, Mission Hill, Roxbury, and Mattapan contain clusters of EJ designated 2020 census block groups with zero bicycle trails. Meanwhile, the majority, or 321 (69.78%), of all EJ designated 2020 census block groups contained at least one bicycle trail of any type. The most bicycle trails of any type that a single EJ designated 2020 census block group had was 56. The only EJ designated 2020 census block group with 56 bicycle trails was Block Group 2, Census Tract 701.04 in the Downtown neighborhood. Counts for bicycle trails in each EJ 2020 census block group are visualized in Figure 15.

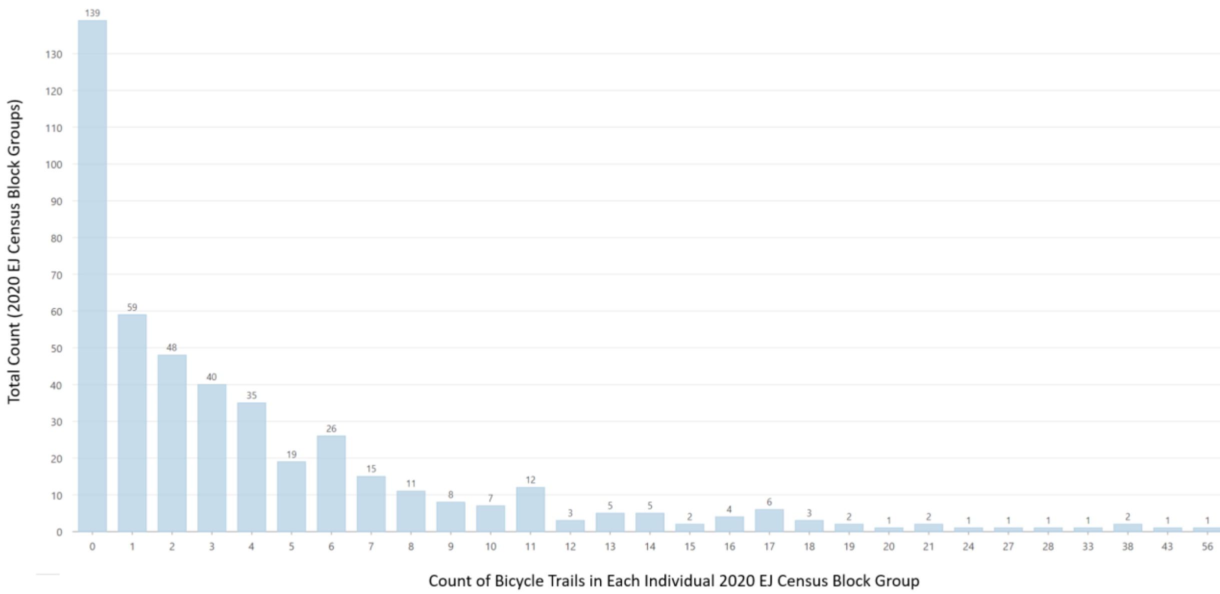

Figure 15. While one 2020 EJ census block group had 56 bicycle trails, each of the other EJ census block groups had fewer bicycle trails. For example, 139 EJ census block groups had zero bicycle trails, 59 EJ census block groups had 1 bicycle trail, 48 EJ census block groups had 2 bicycle trails, etc. Generated in ArcGIS Pro 3.1.3 using the 2020 EJ criteria data and bicycle trails within the Boston boundary (Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b; Bureau of Geographic Information 2023a).

Of the four bicycle trail types, bicycle lanes are the most common across the EJ designated 2020 census block groups. Bicycle lanes are 76.0% of all the EJ designated 2020 census block groups, making them the majority. This is followed by shared use paths (16.8%), separated bike lanes (6.5%), and bicycle/pedestrian roadways (0.6%). These percentages are depicted in the pie graph in Figure 16. For each individual EJ criterion in Boston (Table 2 and Figure 17), bicycle lanes are at least 50% of the total, except for the Income designation which has at least one shared use path 100% of the time in its only census block group.

After bicycle lanes, the second largest ratio for each individual criterion except for Income and English Isolation is 0 bicycle trails. Income and English Isolation are exceptions because each only has 1 census block group, and each of these census block groups for Income and English Isolation has at least one shared use path and bicycle lane respectively.

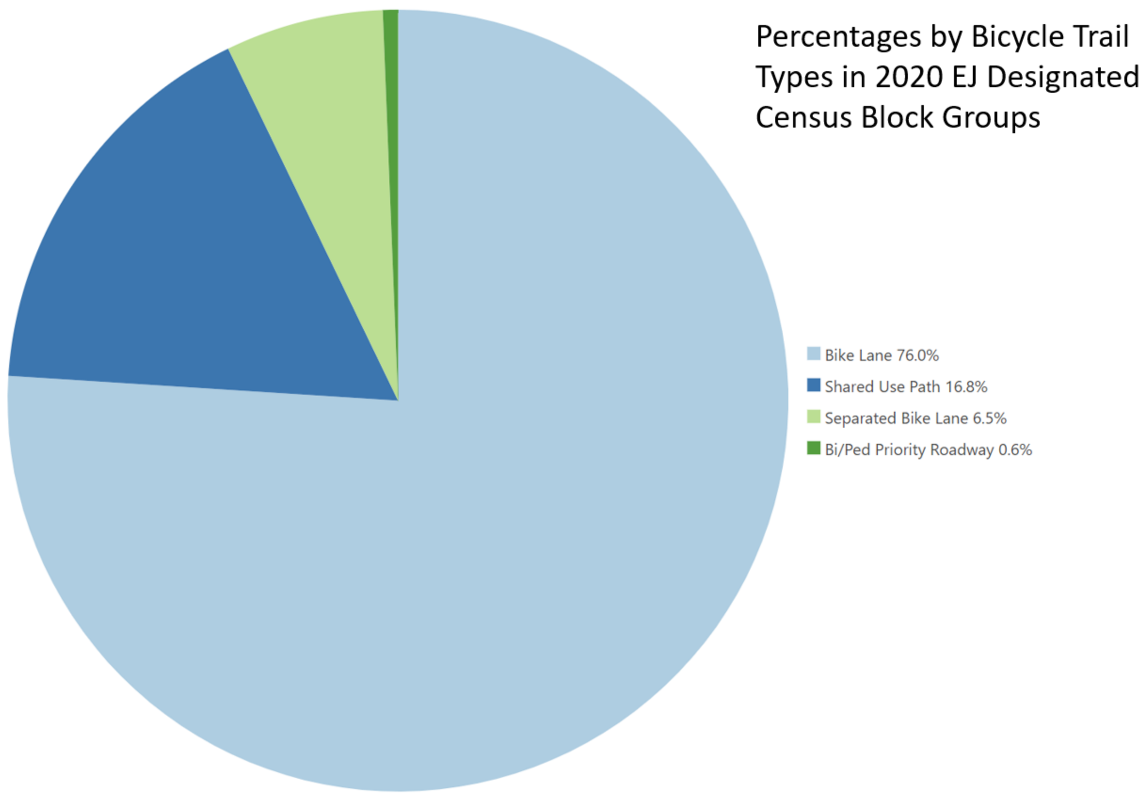

Figure 16. This pie graph depicts the percentages of bicycle trail types across all the 2020 EJ designated census block groups. Generated in ArcGIS Pro 3.1.3 using the 2020 EJ criteria data and bicycle trails within the Boston boundary (Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b; Bureau of Geographic Information 2023a).

2020 EJ Designated Census Block Groups in Boston	**M (272)**	**MI (115)**	**MIE (44)**	**ME (27)**	**I (1)**	**E (1)**
Count of EJ Criterion with Zero Bicycle Trails	82 [30.15%]	41 [35.65%]	10 [22.73%]	6 [22.22%]	0	0
Count of EJ Criterion with At least One Bicycle Lane	138 [50.74%]	58 [50.43%]	27 [61.36%]	20 [74.07%]	0	1 [100%]
Count of EJ Criterion with At least One Bicycle/Pedestrian Roadway	1 [0.37%]	0	1 [2.27%]	0	0	0
Count of EJ Criterion with At least One Separated Bicycle Lane	10 [3.68%]	7 [6.09%]	4 [9.09%]	0	0	0
Count of EJ Criterion with At Least One Shared Use Path	41 [15.07%]	9 [7.83%]	2 [4.55%]	1 [3.70%]	1 [100%]	0

Table 2. Note that the IE designation is not present in Boston. Created using the 2020 EJ criteria data, 2020 bicycle trails, and Boston boundary (Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b; Bureau of Geographic Information 2023a).

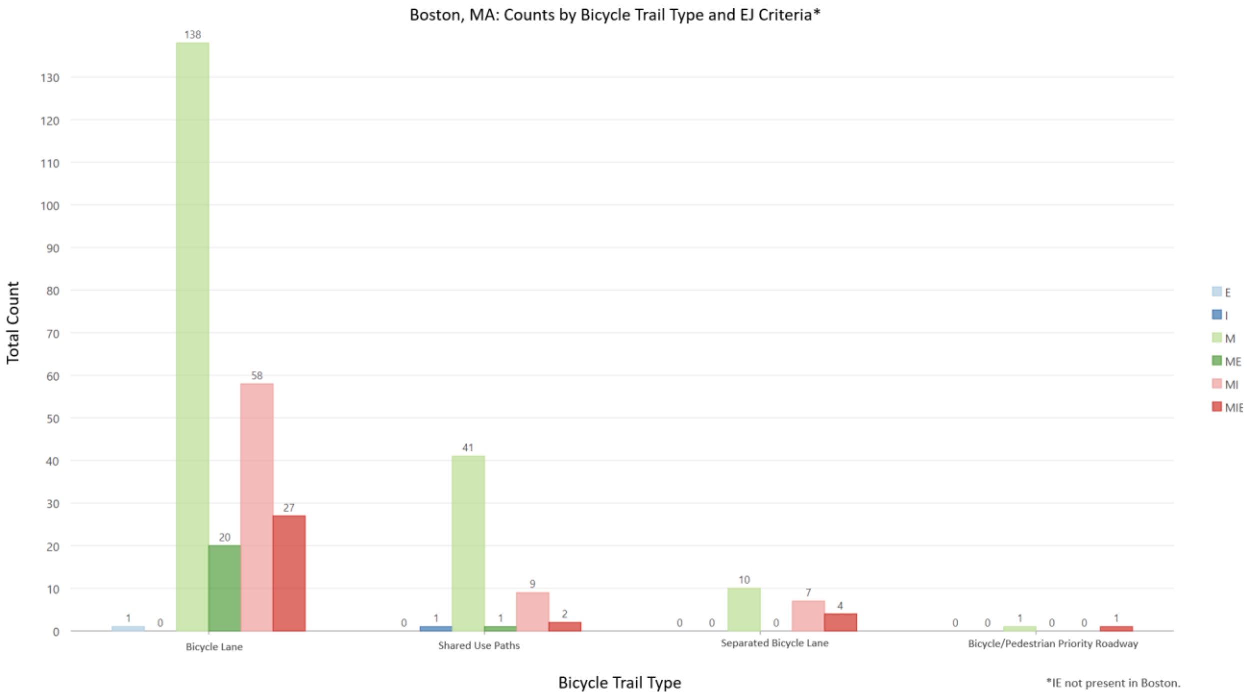

Figure 17. Bicycle lanes dominate the bicycle trails in the different EJ criteria. Generated in ArcGIS Pro 3.1.3 using the 2020 EJ criteria data, 2020 bicycle trails, and Boston boundary (Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b; Bureau of Geographic Information 2023a).

Spatial Join: Bluebike Dock Stations on November 1st, 2023

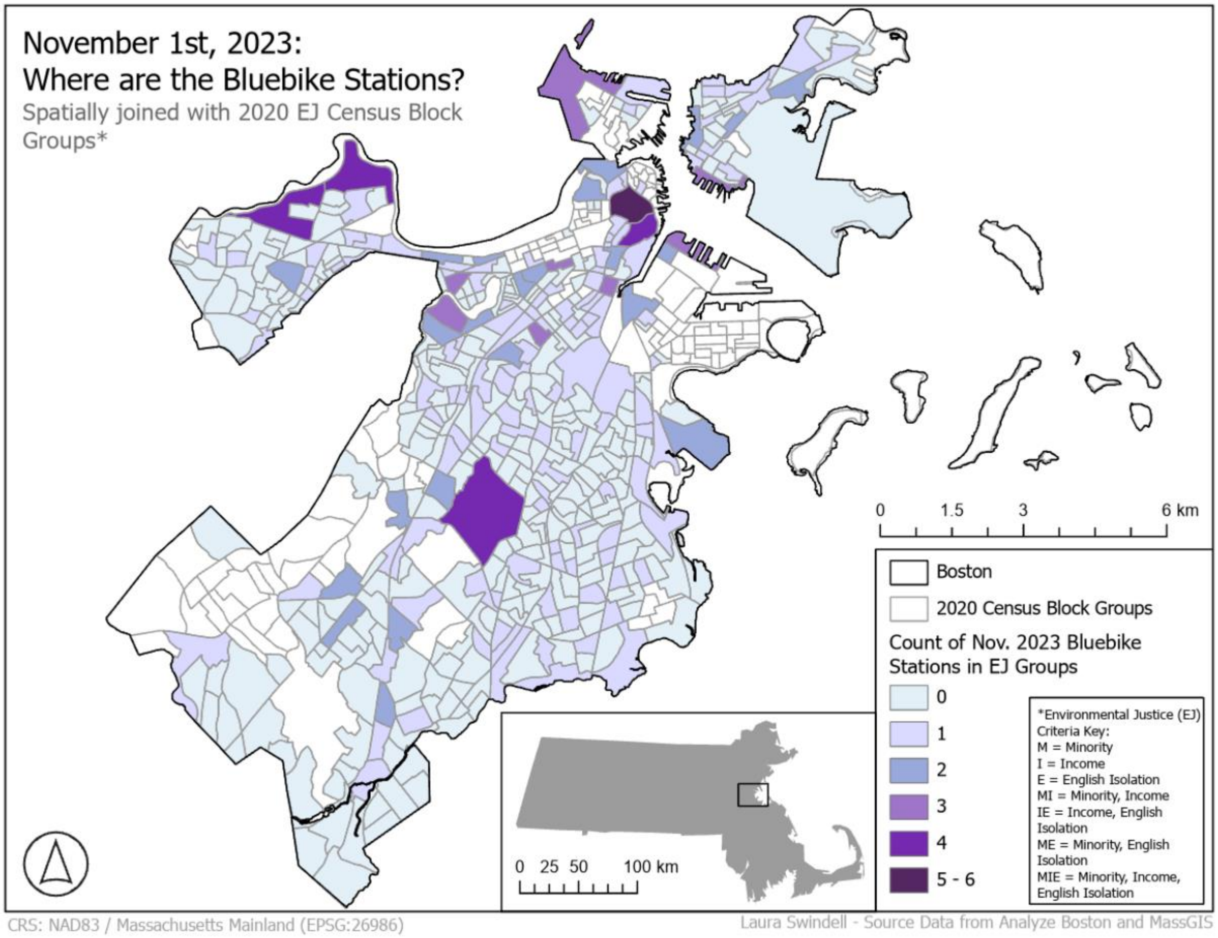

Figure 18. This map depicts 2020 EJ census block groups and their count of Bluebike dock stations on November 1st, 2023. Manual classification with no normalization and 6 classes. Author's own map, created in ArcGIS Pro 3.1.3. 2020 census block groups, 2020 EJ criteria, Boston boundary, and Massachusetts inset data layer are from the Bureau of Geographic Information (2007; 2022a; 2022b; 2022c). Bluebike information from Analyze Boston (2023). CRS: NAD83 / Massachusetts Mainland (EPSG:26986).

Figure 18 is the spatial join map for November 1st, 2023 Bluebike stations in Boston's 2020 EJ census block groups. The histogram (Figure 19) for November 2023 Bluebike stations in intersectional EJ designated census block groups counted all 460 of the EJ designated 2020 census block groups in Boston: M, I, E, MI, ME, and MIE. IE was not present in Boston as of 2020. The mean number of Bluebike stations for each census block group was very low: there were less than 1 Bluebike station in each individual intersectional EJ designated census block group on average (0.47). The standard deviation was 0.79. The highest number of Bluebike stations found in an EJ designated census block group was 6. There was no EJ designated census block group with 5 Bluebike stations in November 2023, and there was no EJ designated census block group with more than 6 Bluebike stations.

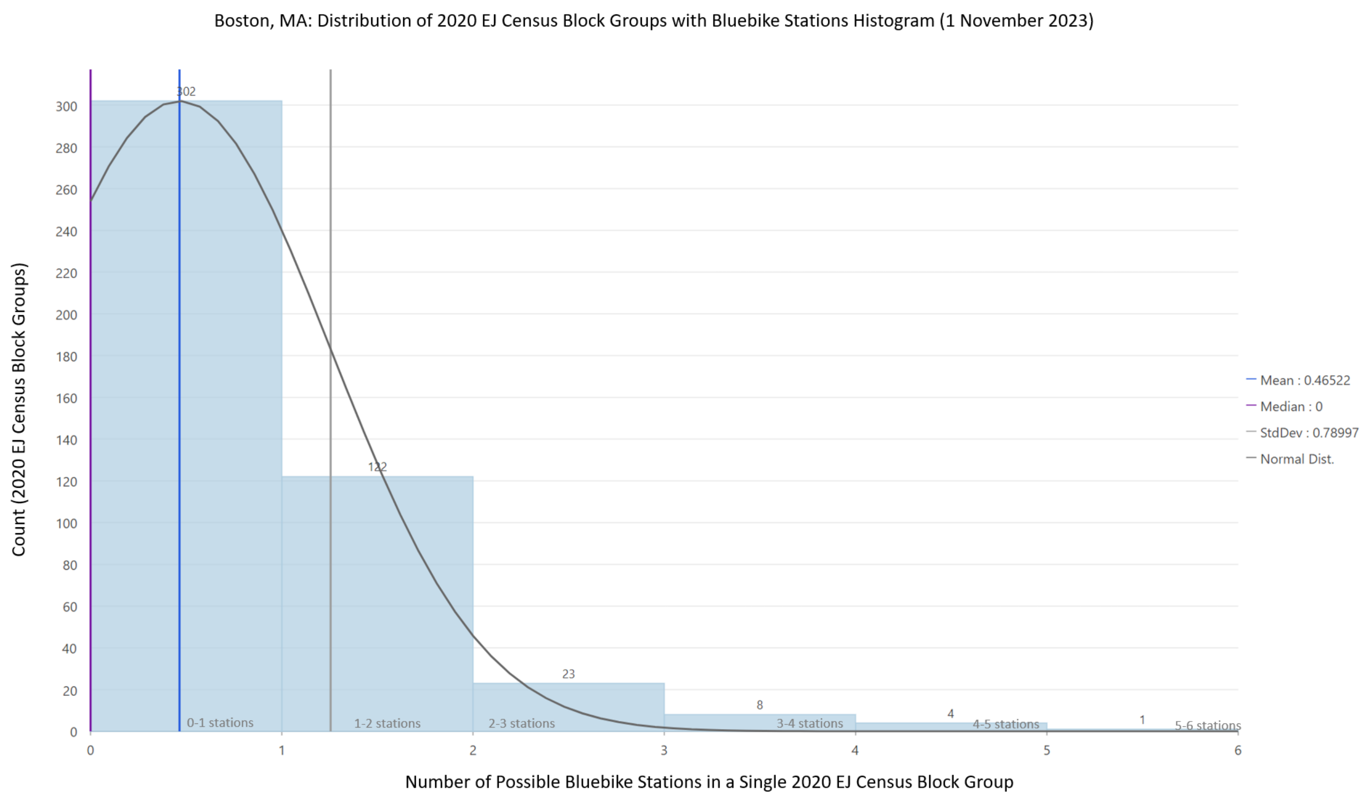

Figure 19. 6-bin histogram and statistics for the November 1st, 2023 Bluebike station spatial join map (Figure 18). Generated in ArcGIS Pro 3.1.3 with the 2020 EJ criteria data, the November 1st, 2023 Bluebike station data, and Boston boundary (Analyze Boston 2024; Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b).

As shown in Table 3 and Figure 20, more than the majority, or 302 (65.7%), of EJ census block groups had 0 Bluebike stations on November 1st, 2023. In addition, 122 (26.5%) EJ census block groups had 1 Bluebike station, 23 (5.0%) EJ census block groups had 2 Bluebike stations, 8 (1.7%) EJ census block groups had 3 Bluebike stations, 4 (0.9%) EJ census block groups had 4 Bluebike stations, and finally 1 (0.2%) EJ census block group had 6 Bluebike stations. Since the majority (65.7%) of the census block groups lacked a Bluebike station on November, 1st 2023, which is a situation that did not improve by March 15th, 2024, there is an ongoing disconnect of Bluebike infrastructure for the people living in the 2020 EJ designated census block groups.

Possible Count of Bluebike Stations per EJ Census Block Group (0-4, 6):	**0**	**1**	**2**	**3**	**4**	**6**
Total count of EJ Census Block Group in Boston with this number of Bluebike stations:	302	122	23	8	4	1
Total percentage of EJ Census Block Group in Boston with this number of stations:	65.7%	26.5%	5.0%	1.7%	0.9%	0.2%

Table 3. On November 1st, 2023, EJ designated 2020 census block groups in Boston had either 0, 1, 2, 3, 4, or 6 total Bluebike stations. This table contains the total count and percentages of EJ designated census block groups with 0, 1, 2, 3, 4, or 6 Bluebike stations. As of 2020, there are 460 total EJ designated census block groups in Boston. Created with the 2020 EJ criteria data, the November 1st, 2023 Bluebike station data, and the Boston boundary (Analyze Boston 2024; Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b).

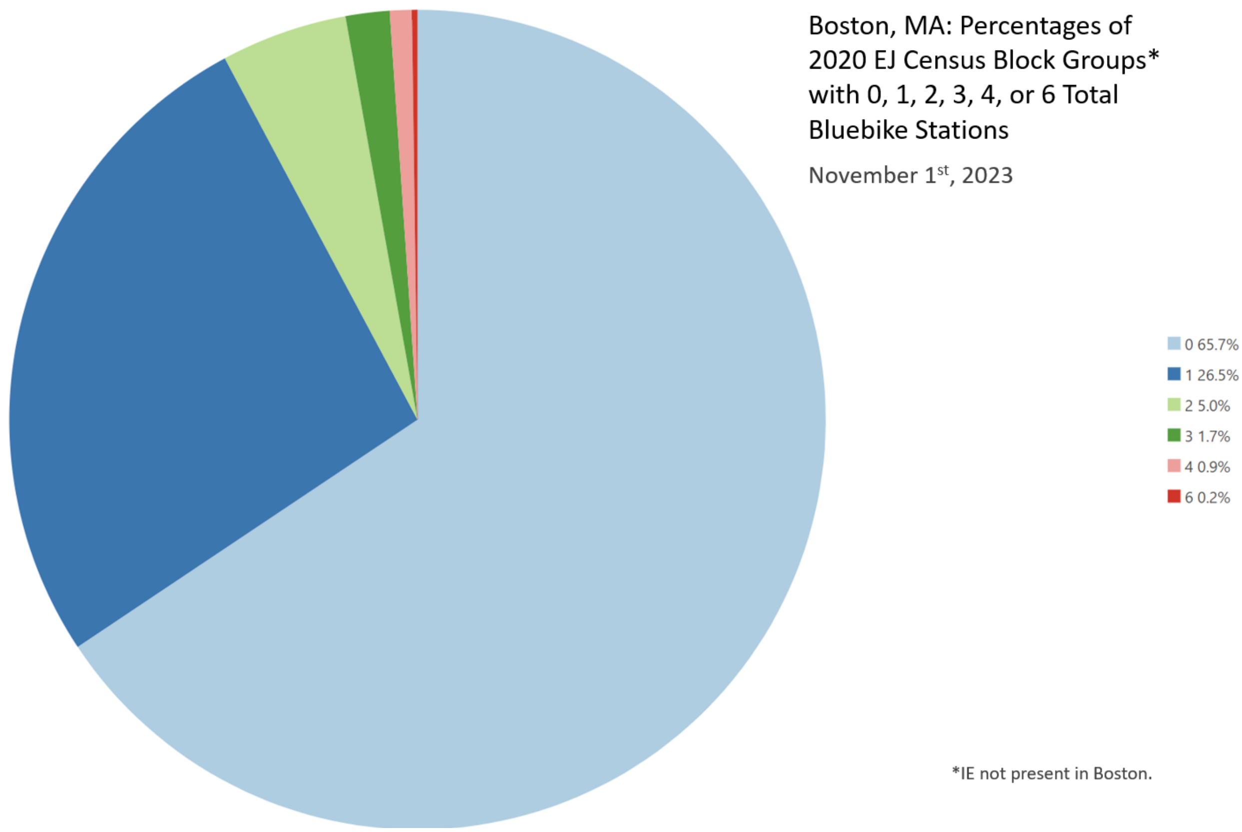

Figure 20. In November 2023, the EJ designated census block groups in Boston, MA had either 0, 1, 2, 3, 4, or 6 total Bluebike stations. This pie graph depicts the percentages of EJ designated census block groups with 0, 1, 2, 3, and 4 Bluebike stations. Generated in ArcGIS Pro 3.1.3 with the 2020 EJ criteria data, the November 1st, 2023 Bluebike station data, and the Boston boundary (Analyze Boston 2024; Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b).

For each EJ type, I counted how many census block groups each had 0 Bluebike stations, 1 Bluebike station, 2 Bluebike stations, 3 Bluebike stations, 4 Bluebike stations, and 6 Bluebike stations. In ArcGIS Pro 3.1.3, this was generated in a bar graph (Figure 21) in which aggregation was "count," the category was EJ_CRITERI, and the data was split by Join_Count. The results are also outlined in Table 3, including percentages for each classification rounded to the nearest hundredth. For each EJ type in Boston, most census block groups had 0 Bluebike stations.

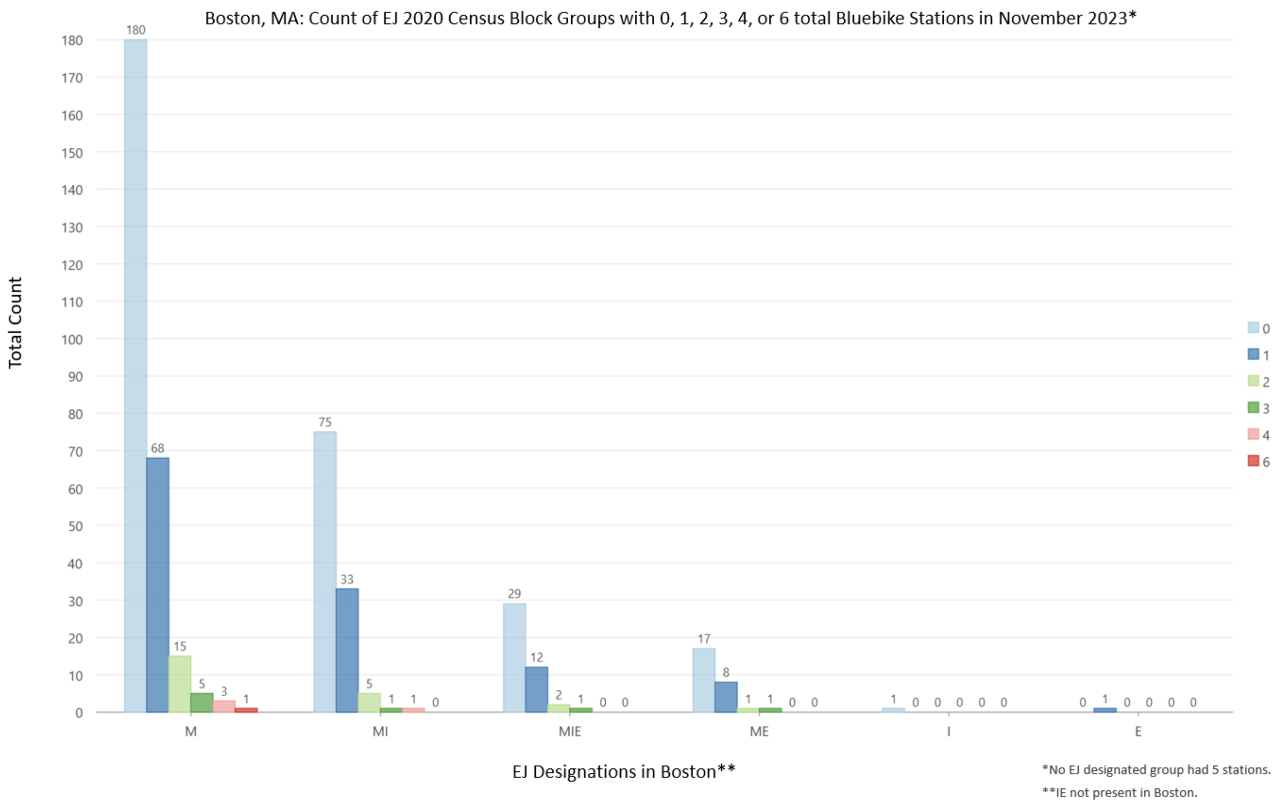

Figure 21. This bar graph depicts the count of EJ designated 2020 census block groups with 0, 1, 2, 3, 4, or 6 Bluebike stations on November 1st, 2023. EJ designated census block groups include M, I, E, MI, ME, MIE, and IE. IE was found to not be in Boston. For each EJ criteria in Boston, most census block groups had 0 Bluebike stations. Generated in ArcGIS Pro 3.1.3 with the 2020 EJ criteria data, the November 1st, 2023 Bluebike station data, and the Boston boundary (Analyze Boston 2024; Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b).

EJ Census Block Groups in Boston	M (272)	MI (115)	MIE (44)	ME (27)	I (1)	E (1)
Count of EJ Designation with 0 Bluebike Stations	180 [66.18%]	75 [65.22%]	29 [65.91%]	17 [62.96%]	1 [100%]	0
Count of EJ Designation with 1 Bluebike Station	68 [25%]	33 [28.70%]	12 [27.27%]	8 [29.63%]	0	1 [100%]
Count of EJ Designation with 2 Bluebike Stations	15 [5.51%]	5 [4.35%]	2 [4.55%]	1 [3.70%]	0	0
Count of EJ Designation with 3 Bluebike Stations	5 [1.84%]	1 [0.87%]	1 [2.27%]	1 [3.70%]	0	0
Count of EJ Designation with 4 Bluebike Stations	3 [1.10%]	1 [0.87%]	0	0	0	0
Count of EJ Designation with 6 Bluebike Stations	1 [0.37%]	0	0	0	0	0

Table 4. Created with the 2020 EJ criteria data, the November 1st, 2023 Bluebike station data, and the Boston boundary (Analyze Boston 2024; Bureau of Geographic Information 2022a; Bureau of Geographic Information 2022b).

As seen in Table 4 above, for the M, MI, MIE, and ME designations in Boston, the percentage of census block groups with 0 Bluebikes were all in the 60-70% range. The Income and English Isolation groups stand out since each criterion has only 1 census block group in Boston. Consequently, the Income designated group had no Bluebike stations 100% of the time, and the English Isolation designation group had 1 Bluebike station 100% of the time. These percentages illustrate that, overall, all the different EJ classifications present in Boston (M, I, E, MI, MIE, and ME) need Bluebike dock stations, considering most EJ groups have 0 stations.

Bicycle Infrastructure Accessibility

First, I individually focused on the distance results of bicycle trails and Bluebikes as of November 1st, 2023 (Figure 22). Bicycle trails had a distribution like a negative (left) skew with a mean score of approximately 3.8, a median of 4, and a standard deviation of approximately 1.37 (Figure 20). Count represents the count of points, or pixels. The bicycle trail accessibility score of 5 (best) had the highest number of points, while the accessibility score of 2 had the least number of points. One limitation is clear in all distance and accessibility results: the large amount of score 1 pixels that are in East Boston are at the location of the Logan International Airport. It is reasonable to assume that there is a lack of infrastructure on airport runways, which would not permit bicycle trails or Bluebike stations.

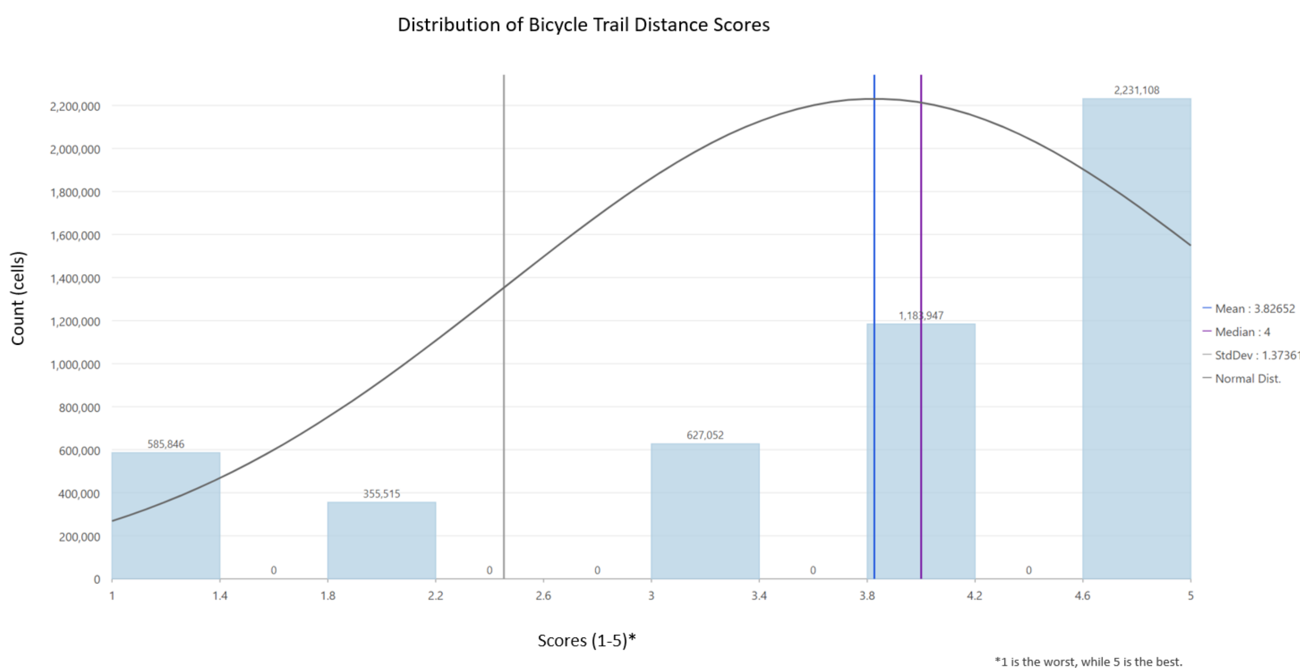

Figure 22. A histogram of bicycle trail distance scoring across Boston using the individual bicycle trail distance layer that was used for the Suitability Modeler accessibility map (Figure 23). Calculated in ArcGIS Pro 3.1.3 with the 2020 bicycle trails, Boston boundary, and Boston DEM (Bureau of Geographic Information 2022a; Bureau of Geographic Information 2023a; Bureau of Geographic Information 2023b).

When looking at the individual distance raster for all bicycle trails in Boston as of 2020 (Figure 23), it is evident that the pockets of areas with the worst accessibility score (score 1) are in southern Boston in the West Roxbury, Hyde Park, Mattapan, Roxbury, Jamaica Plain, and East Boston neighborhoods. East Boston, however, is deceiving. Again, though it is true that East Boston has a lack of accessibility in its northernmost tip, the large amount of score 1 pixels that are in East Boston are where the Logan International Airport is located; it is reasonable to assume that there is a lack of bicycle infrastructure on airport runways. Neighborhoods surrounding Downtown (i.e. North End, West End, Chinatown, South End, Back Bay) almost entirely consist of the scores 4 and 5, showing high concentrations of bicycle trail accessibility in these neighborhoods.

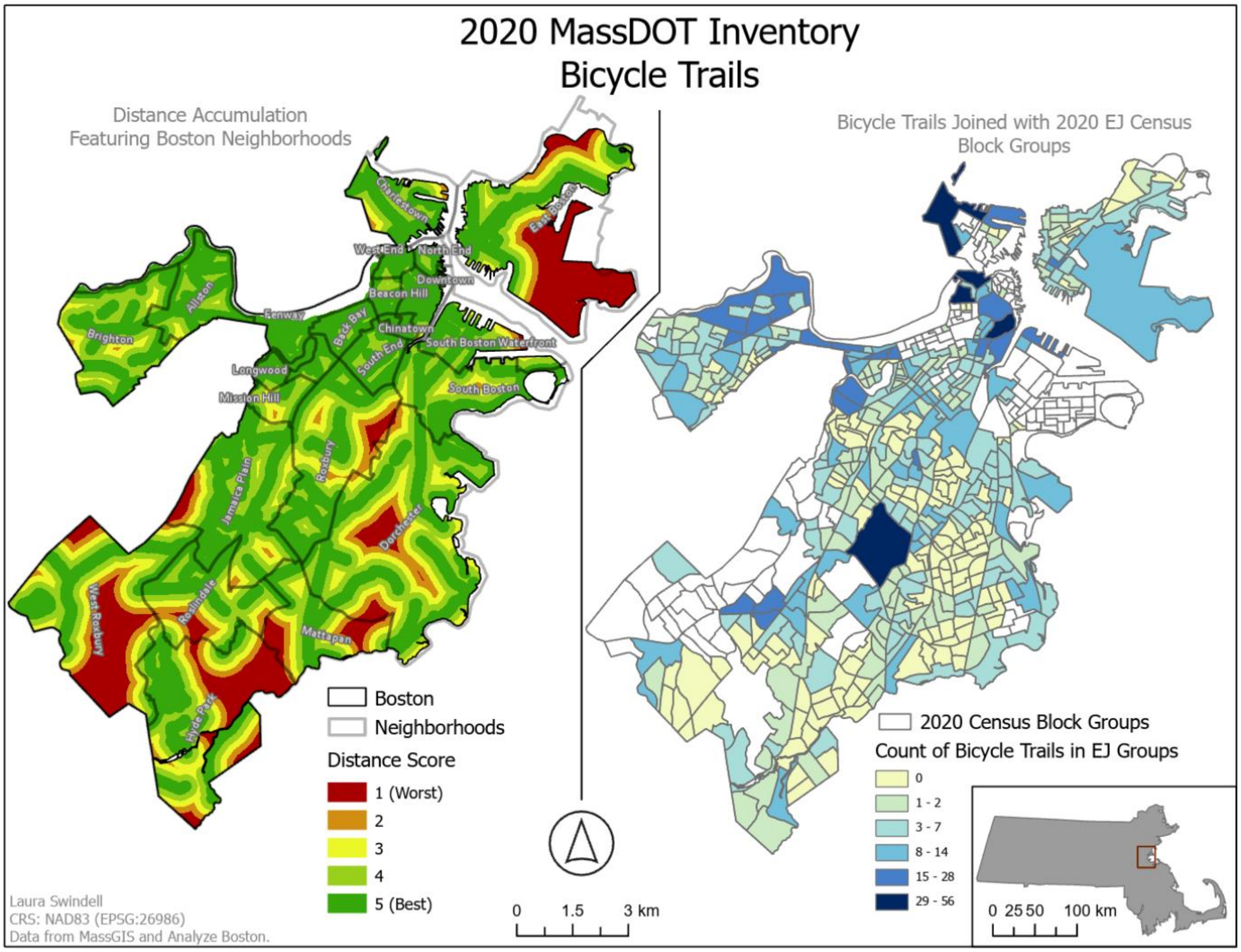

Figure 23. Left depicts the distance raster for the 2020 MassDOT Inventory bicycle trails created with the ArcGIS Pro 3.1.3 tool Distance Accumulation. The neighborhood layer is placed over the distance raster. Right depicts the spatial join map for bicycle trail counts in EJ designated census block groups. Bicycle trails, 2020 census block groups, EJ criteria, Boston boundary, Boston DEM, and Massachusetts inset data layer are from the Bureau of Geographic Information (2007; 2022a; 2022b; 2022c; 2023a; 2023b).

As seen in its histogram (Figure 24), most pixels in the November 1st, 2023 Bluebike station distance raster fell under either score 1 or score 4. In other words, it usually took between 3 to 6 minutes (score 4) to reach the nearest Bluebike dock station on November 1st, 2023, or it took 12 minutes or more (score 1) to reach a station. Score 5, or a 3 minute or less walk, was only the second smallest group. The mean score for Bluebike station accessibility was approximately 2.97, and the median was a score of 3. The standard deviation of Bluebike accessibility was about 1.44. These statistics suggest that increased Bluebike accessibility is needed across Boston, particularly in the areas with a distance score of 1.

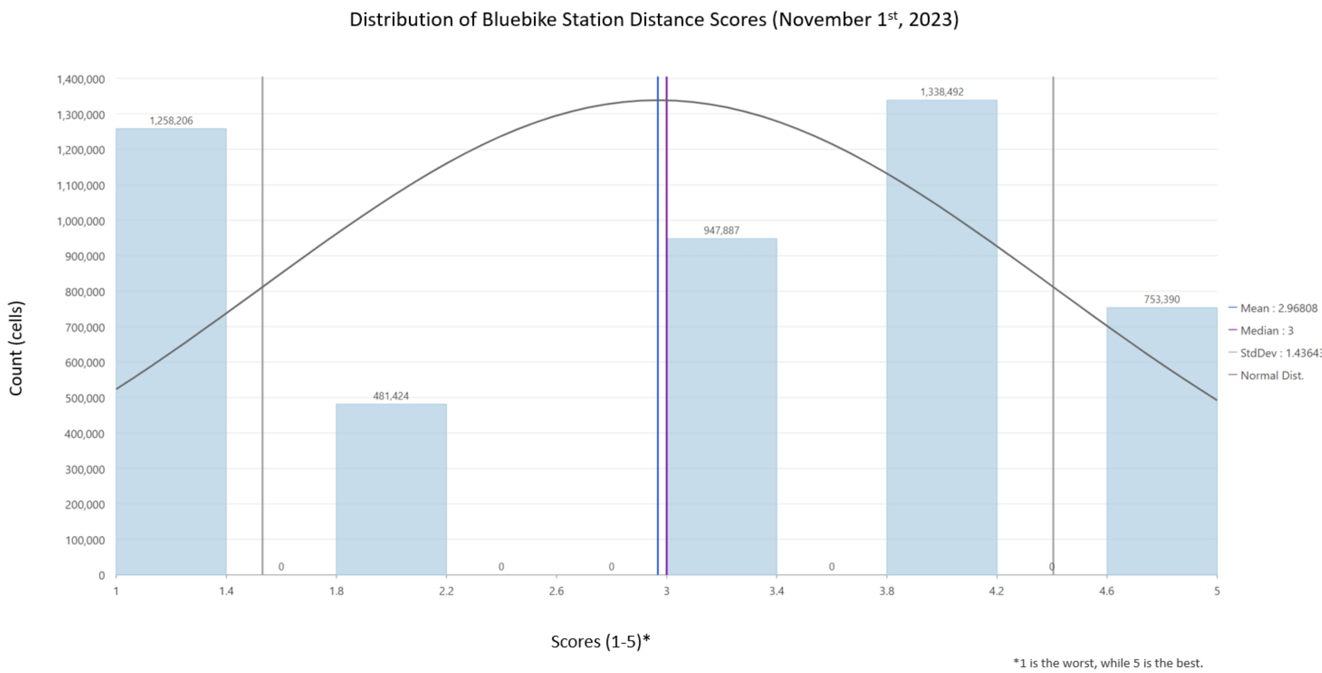

Figure 24. A histogram of Bluebike station accessibility scoring across Boston as of November 1st, 2023. Calculated in ArcGIS Pro 3.1.3 with the individual November 2023 Bluebike station (Analyze Boston 2024) distance layer that was used for the Suitability Modeler accessibility map (Figure 25). Calculated in ArcGIS Pro 3.1.3 with the November 1st, 2023 Bluebike stations data, Boston boundary, and Boston DEM (Analyze Boston 2024; Bureau of Geographic Information 2022a; Bureau of Geographic Information 2023b).

Based on the distance raster of Bluebikes alone (Figure 25), most Bluebike stations are in the central part of the city surrounding the neighborhood of Downtown (i.e. Beacon Hill, Back Bay, Fenway, South End, Chinatown). Southern Boston, particularly West Roxbury, Hyde Park, Jamaica Plain, parts of Dorchester, parts of Mattapan, and parts of Roslindale experience a notable disconnect with pockets of dark red representing score 1.

As with the bicycle trails, it is important to note that much of East Boston is deceiving due to the airport; no Bluebike station is in the middle of the airport, which makes much of the lower parts of East Boston a misleading deep red (score 1). In addition, while the Harbor Islands do not have data for Bluebikes, which is unsurprising due to the disconnect from the rest of the city network, there is a noticeable chunk of Hyde Park missing data by the Neponset River. This makes it difficult to conclude whether there was a disconnect of Bluebikes in Hyde Park as of November 2023. This may be an error by the source (Analyze Boston 2024), since the data should not have been altered in any way during processing that would result in missing data in the Hyde Park neighborhood.

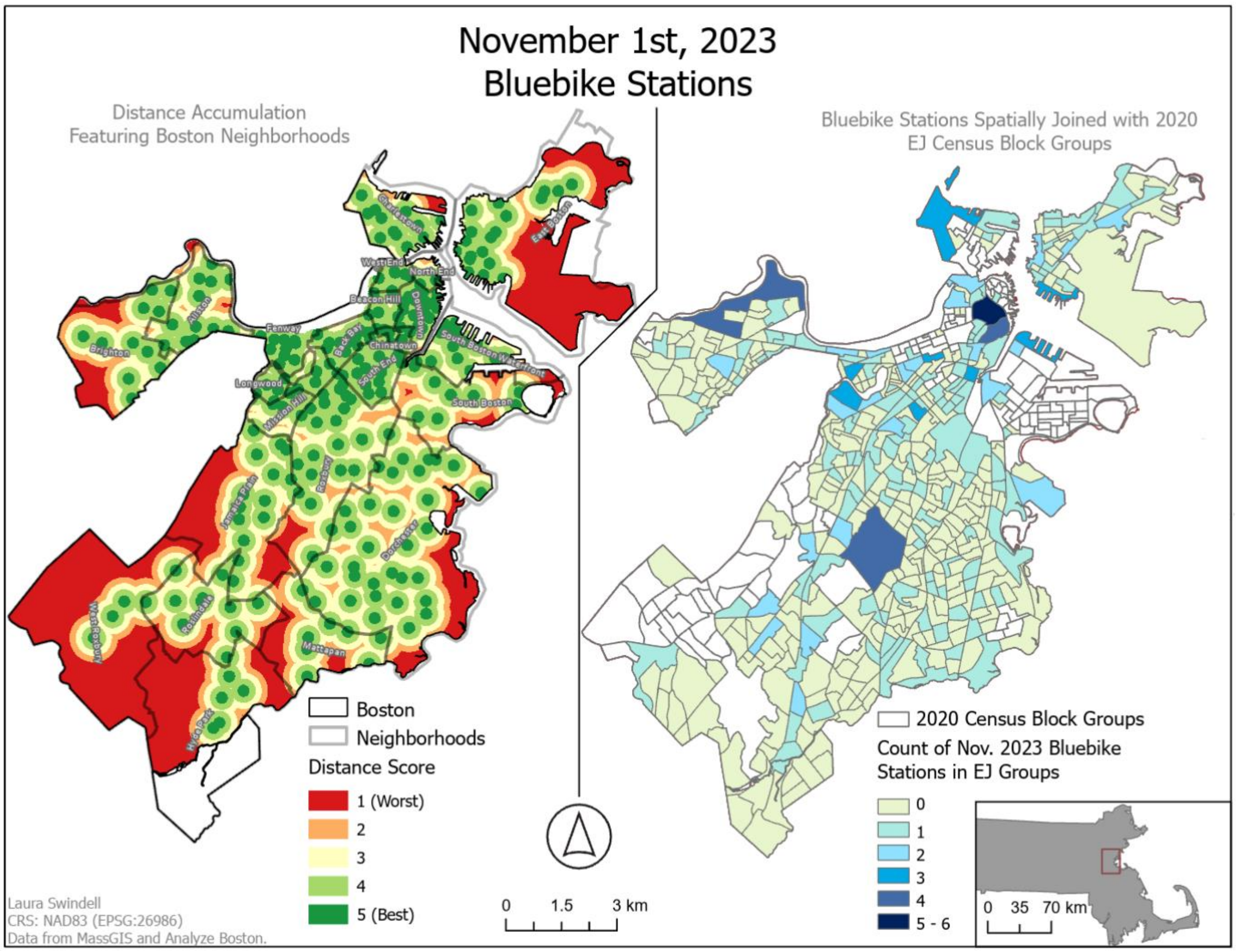

Figure 25. Left depicts the distance raster for November 1st, 2023 Bluebike stations created with the ArcGIS Pro 3.1.3 tool Distance Accumulation. The neighborhood layer is placed over the distance raster. Right depicts the spatial join map for November 1st, 2023 Bluebike station counts in EJ designated census block groups. Boston DEM, 2020 census block groups, EJ criteria, Boston boundary, and Massachusetts inset data layer are from the Bureau of Geographic Information (2007; 2022a; 2022b; 2022c; 2023b). Boston neighborhoods and Bluebikes data are from Analyze Boston (2021; 2024).

By combining the distance rasters for bicycle trails and Bluebike stations in a suitability modeler, the sections of Boston that have poor accessibility to both bicycle trials and Bluebikes can be visualized (Figure 26). Scores for Bluebike stations and bicycle trails are combined, creating a scale between 2 (worst) and 10 (best). A score of 10 means that a location has no more than a 3-minute walk (≤ 165 m) to both bicycle trails and at least one Bluebike station. In contrast, a score of 2 means there is a 12-minute walk or more (≥ 660 m) to both bicycle trails and a Bluebike station. The average accessibility score was 6.8 out of 10, and the median accessibility score was 7 out of 10 (Figure 27). Accessibility was highest in the neighborhoods surrounding Downtown, such as the North End, West End, Beacon Hill, Back Bay, Fenway, South End, Chinatown, and the South Boston Waterfront. Accessibility was varied elsewhere, particularly in the West Roxbury, Hyde Park, Brighton, Dorchester, Roxbury, Jamaica Plain, Mattapan, and Roslindale neighborhoods. Accessibility should be improved in the areas with lower scores, such as where scores are 5 and under. Notably, East Boston continues to be deceiving due to the airport, and part of Hyde Park continues to experience missing data; only the bicycle trail data is included in the area by the Neponset River.

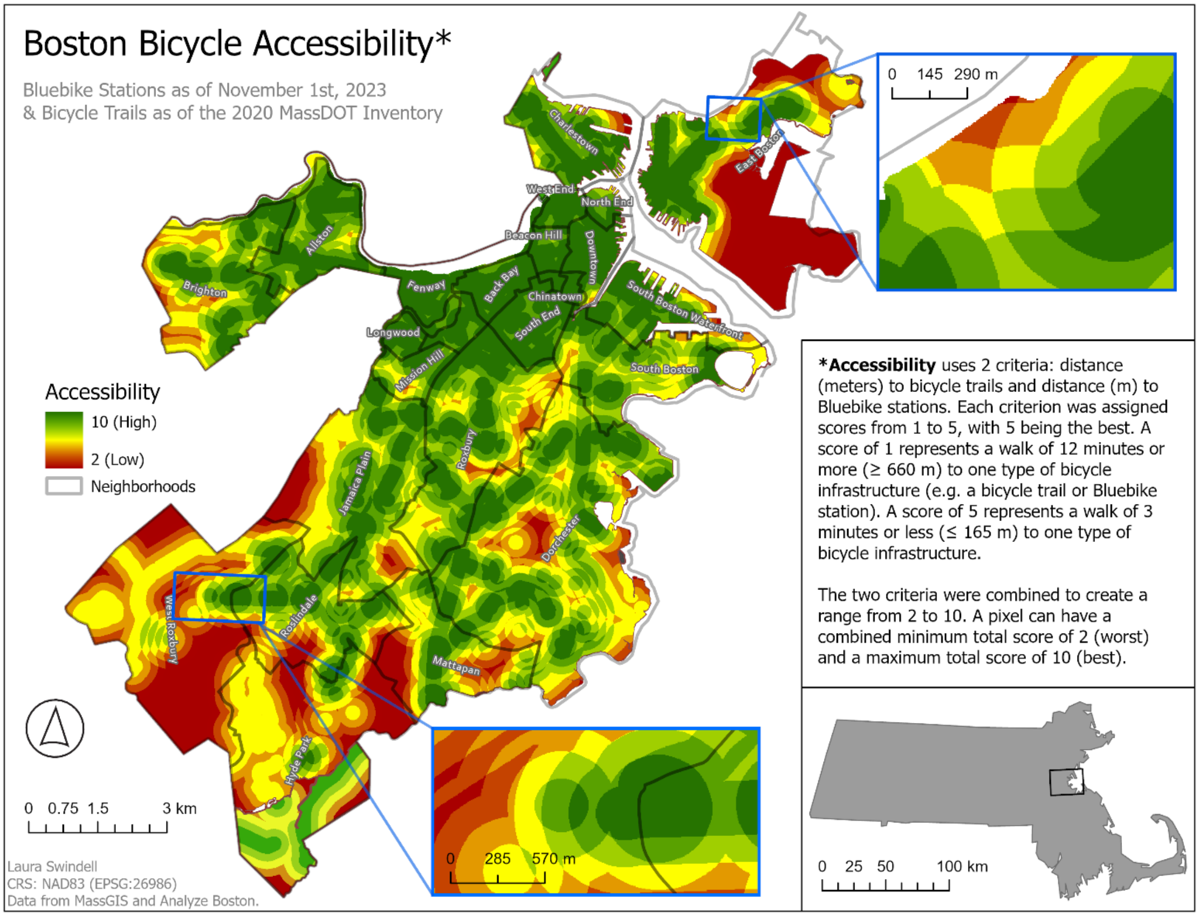

Figure 26. In this map depicting Boston, the Boston neighborhood layer is overlaid to visualize the accessibility to Bluebike stations and bicycle trails at the neighborhood scale. The Suitability Model combines the two distance rasters for bicycle trails and Bluebike stations (Figures 25 and 26). Boston DEM, 2020 census block groups, 2020 EJ criteria, Boston boundary, and Massachusetts inset data layer are from the Bureau of Geographic Information (2007; 2022a; 2022b; 2022c; 2023b). Boston neighborhoods and Bluebikes data are from Analyze Boston (2021; 2024).

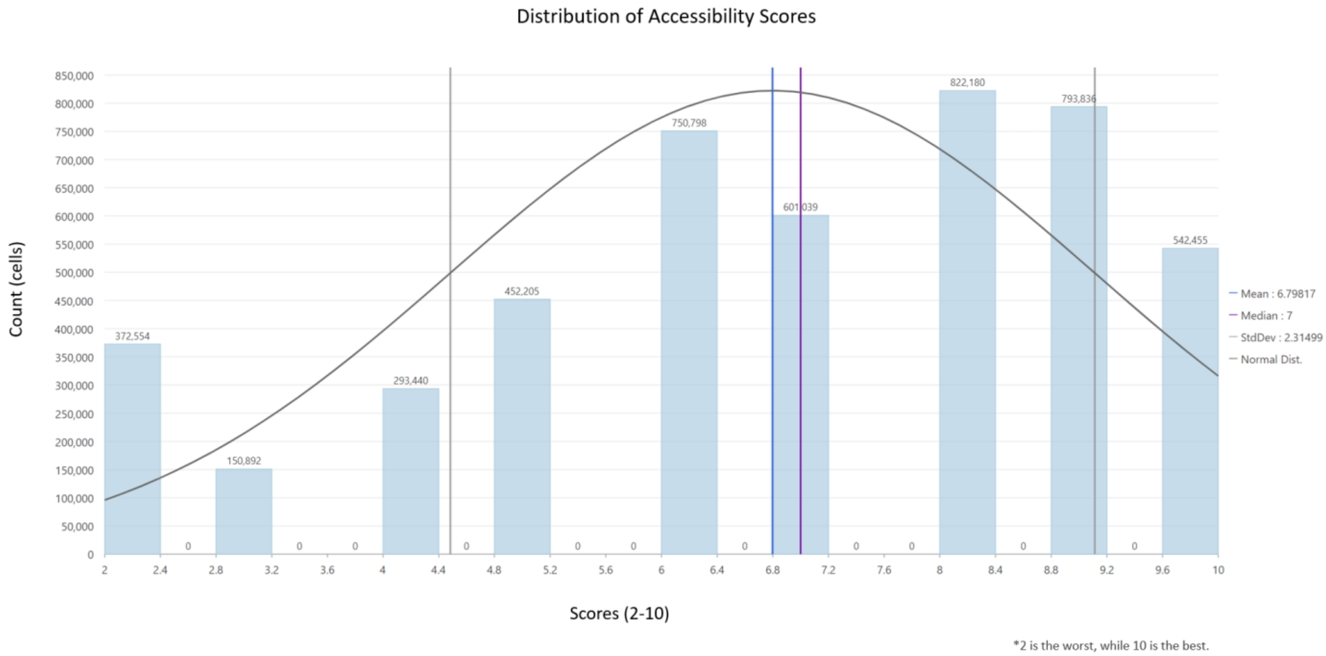

Figure 27. A histogram of accessibility scoring across Boston generated in ArcGIS Pro 3.1.3 from the Suitability Model results and data (Figure 26). Calculated in ArcGIS Pro 3.1.3 with the November 1st, 2023 Bluebike stations data, 2020 bicycle trails, Boston boundary, and Boston DEM (Analyze Boston 2024; Bureau of Geographic Information 2022a; Bureau of Geographic Information 2023a; Bureau of Geographic Information 2023b).

Limitations

This paper primarily focused on only two types of bicycle infrastructure: official bicycle trails according to the 2020 MassDOT inventory (Bureau of Geographic Information 2023a), and Bluebike stations as of November 1st, 2023 (Analyze Boston 2024). Future studies could also incorporate other variables, such as access to green space, slope, and access to bicycle shops. My results do not consider road type, zoning, land use, or population distribution or density which could potentially impact accessibility and decide where bicycle infrastructure is built. An obvious effect of land use was the Logan International Airport in East Boston. A lack of bicycle infrastructure is present in the airport, which skews pixels' accessibility scores.

Time is a also major limitation. Changes in land use in Boston or new development, such as in the South Boston Waterfront, would logically result in rapid changes in bicycle infrastructure accessibility or even changes in EJ designation as populations change. Likewise, the removal of infrastructure, such as the removal of 40 Bluebike stations between November 1st, 2023 and March 17th, 2024 could also affect accessibility (Analyze Boston 2024). I am only using infrastructure data provided by the state and City of Boston (Analyze Boston 2024; Bureau of Geographic Information 2023a).

It is important to acknowledge data limitations in the Bluebike station and bicycle trail data. In addition to Bluebike station counts and locations changing over time, the Bluebike data contains a gap in data in the Hyde Park neighborhood by the Neponset River. Additionally, the Bureau of Geographic Information (2023a) acquired its bicycle trail data from the Massachusetts Department of Transportation (MassDOT) 2020 data inventory. Since transportation infrastructure rapidly evolves, the most recent bicycle trail construction since 2020 was not represented. Future research should use more recent bicycle trail inventory data once available. This data uses only officially counted bicycle trails and does not count other potential infrastructure like minimally trafficked streets that could be low stress for bicyclists.

Conclusion

Bicycling is a sustainable form of transportation. Bicycling has a small carbon footprint; places less strain on roads compared to motor vehicles, resulting in less costly maintenance; and connects people to nodes of public transportation (Davis 2023; European Cyclists' Federation 2018). In Boston, Massachusetts, examples of bicycle infrastructure include bicycle trails and rentable bicycle-shares from the bicycle-share network Bluebikes. Bicycle trail types include shared use paths, separated bike lanes, bike lanes, and priority roadway) (Analyze Boston 2024; Bureau of Geographic Information 2023a; City of Boston 2022).

Accessibility to bicycle routes and Bluebike dock stations as well as amount of infrastructure varies depending on one's geographic location within the city. The problem is that there is disconnection in the city's bicycle network (City of Boston 2022). Bicyclists find that a bicycle route suddenly ends, that a Bluebike dock station is far away, or that there is no infrastructure nearby. By increasing infrastructure, bicycle ridership also increases (Karpinski 2021). I specifically focused on bicycling in EJ designated 2020 census block groups, or census block groups designated as either M, I, E, MI, ME, MIE, or IE. My research looked at the following questions: where is the disconnect of bicycle infrastructure? Where is improvement in accessibility needed, especially among EJ criteria census block groups?

This paper looked at the count of Bluebike stations in each EJ census block group, the total length of bicycle trails in each EJ census block group, distance to Bluebike stations, and distance to bicycle trails. Distance was based on the idea from the City of Boston (2022) that a 3-minute walk, or 165 m (541 ft), is ideal. Distances were calculated using regional Digital Elevation Models (DEMs) and bicycle trail and Bluebike data (Analyze Boston 2024; Bureau of Geographic Information 2023a and 2023b).

The count of bicycle infrastructure was represented by spatial joins of EJ designated 2020 census block groups with bicycle trails from the 2020 MassDOT Inventory and Bluebike station locations as of November 1st, 2023 (Analyze Boston 2024; Bureau of Geographic Information 2022b; Bureau of Geographic Information 2023a). The IE designation was found to not be in Boston, rendering it irrelevant. Bicycle lanes were the most common bicycle trail type across the EJ designated census block groups. 139 (30.22%) of the EJ 2020 census block groups had zero bicycle trails, showcasing a need for bicycle trail connection in these areas. More than the majority, or 302 (65.7%), of EJ designated census block groups had 0 Bluebike stations as of November 1st, 2023; there is a need to improve the count of Bluebike stations in these 2020 EJ designated census block groups.

Accessibility was based on distances to Bluebike stations and bicycle trails. Two distance rasters were produced with the Bluebike stations data (Analyze Boston 2024), bicycle trail data (Bureau of Geographic Information 2023a), and regional DEMs (Bureau of Geographic Information 2023b). In the distance rasters, default symbologies were manually altered so that they match the increments of the "3-minute walk" (165 m). The first and best class was based on a 3-minute walk (165 m), the second class was based on a 6-minute walk (330 m), the third a 9-minute walk (495 m), the fourth a 12-minute walk (660 m), and the fifth class being anything more than a 12-minute walk. Values were assigned scores from 1 to 5, with 5 being the best (3-minute walk or less to infrastructure), and 1 being the worst (more than 12-minute walk to infrastructure). After combining the two distance rasters in a suitability modeler, a pixel can have a minimum total score of 2 (low/least accessible for both bicycle trails and Bluebikes) and a maximum total score of 10 (high/most accessible for both bicycle trails and Bluebikes). Accessibility to bicycle infrastructure was highest in the neighborhoods surrounding Downtown, such as the North End, West End, Beacon Hill, Back Bay, Fenway, South End, Chinatown, and the South Boston Waterfront. Accessibility was varied elsewhere, particularly in the West Roxbury, Hyde Park, Brighton, Dorchester, Roxbury, Jamaica Plain, Mattapan, and Roslindale neighborhoods. Issues included a lack of data for Bluebikes in the southern part of Hyde Park, as well as the airport making it seem like East Boston has very limited bicycle infrastructure and accessibility. The passage of time and the rapid development of bicycle trails and Bluebike station locations was another limitation.

Bicycling is a physical, low-carbon way to reach a destination. All 2020 census block groups, including those EJ designated whether intersectional or not, should contain bicycle infrastructure and experience accessibility to this infrastructure. I hope that by evaluating counts, distances, and accessibility to bicycle infrastructure, gaps in bicycle infrastructure in Boston can be addressed. As an essential aspect of city multimodality, bicycle infrastructure should be constantly evolving and improving.

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