Mapping Transportation Accessibility in Boston

Cleo Hein, Gabrielle Walczak, Jack Minella, Kushagra Srivastava, Yi Ding

Background/Abstract

In order to initiate a transition to greener transportation within the greater Boston area, a more comprehensive understanding of public transportation is needed. It is critical to understand the extent to which communities are served by public transport systems, specifically Boston's MBTA. Communities that are well served by public transportation do not necessarily have better access to public transportation. If public transportation is more easily accessible, it becomes more convenient for the residents and commuters of Boston to reduce their transportation footprint by relying on shared transportation infrastructure (e.g., buses, subways, trains) rather than individual modes of transportation (namely cars).

To ensure it is possible for commuters to rely on public transportation, the accessibility of the current system must be better understood. If more people are expected to utilize public transportation in Boston as time goes on, the system must be convenient and easily accessible. Conducting research on the relative distances between subway stations reveals which communities have comparatively better access to public transportation. This data can then be used in conjunction with other iCons 2 Renewable Energy research data to propose methods to improve public transportation accessibility. In addition, the research will work to broaden the use of public transportation throughout Boston and the surrounding suburbs served by the MBTA.

Knowns

The transit layout of the MBTA is already known, along with the number and location of different stations. The V3 Application Programming Interface (API) provided by the MBTA will be used to gather data on the same in JSON format (MBTA). This API gives details on the location of stops, as well as other data such as real-time transit alerts, facilities, etc.

Unknowns

Although the locations of subway stations are published by the MBTA, and the distance between stops is also known, the relative area served by a given stop is not yet known. This research seeks to determine the area that each stop covers by determining the closest subway station to any given location in the city.

Additionally, it is unknown how this accessibility map will overlap with demographic data. For example, census data could be overlaid with the maps created by this research to find correlations between demographics and areas that are well served or underserved. Examples of currently unknown demographic correlations include median household income, racial background, etc. Other qualitative, non-census data could be overlaid with accessibility data in the form of surveys asking people about their general attitudes toward public transportation.

Data Collection, Methods and Tools

The data used were made available by the Metropolitan Bay Transportation Authority via their V3 API. MBTA subway station data in Boston will be analyzed using R and displayed in GIS and Leaflet, a package for R.

To analyze accessibility, first a diagram is created displaying the area around each subway stop using the Voronoi Technique (Weisstein). The Voronoi technique takes a finite set of points, called nodes, on a plane and expands their boundaries radially outward until all boundaries meet. This creates a series of polygons such that every point in a given polygon is closer to that polygon’s node than to any other node on the plane. In terms of the map of Boston, there will be a series of polygons, herein referred to as blobs, created around each subway station in Boston. Any location in a blob is closer to that blob’s station than to any other station on the map.

Once this blob map is created, GIS and R are used in combination to find the land area represented by each blob. Finally, the diagram generated will be posted on an interactive website which will display the accessibility data discussed below.

Using GIS and R, the area of each blob is calculated and stored in a spreadsheet for analysis. Each area is then normalized so that the polygon area values are on a scale of 0-100. They are normalized using the formula $z_i = 100 - (x_i – min(x)) / (max(x) – min(x)) * 100$, where z_i is the i-th normalized value in the dataset, x_i is the i-th value in the dataset, and min(x) and max(x) is the minimum and maximum value in the dataset. (Zach).

Sample Size

In total, the sample size incorporates every station from all of the MBTA's subway lines, which is 164 subway stations.

Data Restrictions and Permissions

The research data on transit stop locations come from the MBTA and are publicly available. There are no restrictions on sharing the data and no additional permissions are required to share them.

Data Analysis

The accessibility score previously mentioned will be described as the "blob score." Blobs with smaller areas receive higher scores, whereas blobs with larger areas receive lower scores. Blobs with small areas have easily accessible subway stations; there are no locations within a blob that are very far away from its subway station, thus yielding a high score for accessibility. Conversely, blobs with large areas have more inaccessible subway stations; there are many locations within a blob that are very far away from its subway station, thus yielding a low score for accessibility.

Methodology Justification

The MBTA subway network was selected for its intensive usage and geographical extensivity. Additionally, it was selected due to the partnership between the Boston Museum of Science and the iCONS program. However, it should be noted that this research can be applied to other cities and metropolitan areas around the United States or even internationally.

The Voronoi technique was selected as a naive means of analyzing which stations are more or less accessible. These findings should not be viewed as an absolute ranking, but a general order of which sets of stations are accessible or inaccessible in a broad sense.

The 0-100 scale makes it easier for viewers of the interactive map to gauge subway network accessibility.

Conclusions

It was found that blobs close to the center of the city had higher accessibility scores, and that blobs on the outskirts of the city and in the suburbs had lower accessibility scores. These findings match initial expectations. The Hyde Park station had the lowest accessibility score, and the Chinatown station had the highest accessibility score. The accessibility map, along with the source code, can be viewed on the interactive website created by this research [1].

Possible Improvements

This research calculates land area around a stop using the Voronoi Technique, which finds the smallest straight line distance from any given location in a blob to a subway station. As it stands, the naive approach used in this research illustrates an idealized travel distance in which a commuter is able to take a straight line path from their location within a blob to that blob’s station. However, as previously mentioned, this is a somewhat naive approach, and it could be improved by factoring in the arrangement of streets and buildings and/or terrain data to more accurately reflect the path that a commuter would have to take to access a subway station. For example, a stop may be 100 feet away on a map, but there could be a large obstacle like a building in the way that would make the travel distance it takes to reach the station much longer. While a blob may indicate the shortest possible route from a given area to a subway station, this route is almost never actually usable due to densely packed buildings and other city obstacles. This research could be improved by making the blobs include the factors listed above, thus making the accessibility map more representative of the current state of the subway system in Boston.

Social Value

This research is useful as a visualization of subway accessibility in Boston. It allows commuters and other users of public transit in Boston to have a better knowledge of their surrounding subway stations, further allowing them to make more informed decisions about how to travel within the city in a less carbon intensive manner. This study is also beneficial to people who do not own personal vehicles and travelers from other cities because the map created from these data allows them to know which areas in Boston have more or less accessible subway stations based on the accessibility scores.

Additionally, this research reveals which areas are particularly underserved by public transit and enables people to petition for the wider adoption of public transit in these underserved areas. Since public transit is a critical component of decarbonizing the transportation sector, informing commuters in Boston about the usability of the MBTA will allow them to have a better understanding of the system, where its inequities exist, and how to address them.

Scientific Value

The findings of this research act as a stepping stone on the path to reducing transportation sector carbon emissions. If more people start to use public transportation, it would reduce the amount of cars on the road, and therefore reduce carbon emissions from individual passenger vehicles in Boston. It is crucial to reduce carbon emissions to mitigate the effects of global climate change. Decreased presence of passenger vehicles in the city would also improve air quality, which would improve public health of city residents.

Additionally, the findings of this research could act as a primer for further studies, especially in the fields of transport optimization and city planning. Specifically, the MBTA could take into account this data and analyze the efficacy of their routes in their pursuit to lower Boston's carbon footprint. For example, in the suburbs where the T is less accessible and it may also be infeasible to expand the subway network, a further study of the bus networks of Boston could be carried out to get a better understanding of transportation accessibility as a whole.

Benefited Populations

Commuters in Boston, as well as other users of the MBTA, will benefit greatly from this research. The data can be used by the city of Boston to assess which areas of the city are best and worst served by different transit methods offered by the MBTA. Knowing which areas are poorly served is critical to make improvements to the accessibility of public transit within the city. People who might have less access to public transportation, based on location and potentially demographics, would benefit from this research because more attention can be brought toward regions that have less access to the subway system. This would raise awareness about the accessibility of subway systems and provide an opportunity for change so that public transportation can soon be more accessible.

This research also provides benefits to members of the audience of the Museum of Science, which attracts many families and younger individuals, including children. They could benefit from seeing this exhibit because it would provide them with knowledge about what areas have more accessible transportation, and they could in turn act to effect change in policy around transportation to make public transit more widely accessible. Additionally, young children, who may not have the ability to participate in policy making or activism would still learn the benefit of reducing carbon emissions from transportation in an engaging and interactive environment. This could potentially encourage those visiting the Museum of Science to use public transit more often.

It should be noted that members of underprivileged communities may not be as able to change their transportation methods due to cost, accessibility, availability, or a variety of other limiting factors. This is a critical reason that increasing accessibility is essential to decreasing transportation emissions. The city of Boston must ensure that the MBTA is accessible to everyone equitably if they truly want to reduce transportation sector carbon emissions.

Finally, with the addition of future research, the accessibility of the MBTA can be correlated with demographic data to determine what factors affect accessibility. This research can also be overlaid with map data from other iCons groups' projects to determine potential trends in accessibility and use of public transit. Increasing the understanding of public transit accessibility throughout Boston will help the city achieve its ambitious carbon neutrality goal.

Generalization to Other Contexts

These findings could be applied to other cities with similar public transportation networks across the US and international metropolitan areas. Public transport serves as critical infrastructure which allows residents and travelers in cities to commute without relying on individual vehicles, reducing carbon emissions and air pollution associated with transportation. By analyzing public transportation accessibility in different cities throughout the world, there will be a better understanding of which cities are best served by public transit, and which cities need to invest more in public transit infrastructure. Introducing a comprehensive public transit model can assist urban city residents to choose sustainable transportation methods over individual vehicles.

Future Implications

It is important to study the accessibility of public transit because not only can this knowledge be used to reduce the carbon emissions caused by transportation in Boston, but it can also provide data that will allow for the optimization of the transit system. The accessibility map created by this research allows for the accessibility of public transportation in the city of Boston to be better understood. In areas where accessibility is lacking, improvements can be discussed and these proposals can be better informed with data from this research. Improving the accessibility, and thereafter the use, of public transportation will lead the city of Boston to reduce its transportation sector carbon emissions, since individual reliance on cars would decrease, and vehicle emissions would decrease, too.

Works Cited

Geospatial - Analyze Boston. Welcome - Analyze Boston. *https://data.boston.gov/group/geospatial*

MassGIS (Bureau of Geographic Information). 2021, December. MassGIS Data: MBTA Rapid Transit. Mass.gov. https://www.mass.gov/info-details/massgis-data-mbta-rapid-transit

MBTA. *V3 API | Developers Massachusetts Bay Transportation Authority*. https://www.mbta.com/developers/v3-api

Weisstein, E. *Voronoi Diagram.* Wolfram MathWorld: The Web's Most Extensive Mathematics Resource. https://mathworld.wolfram.com/VoronoiDiagram.html

Zach. *How to Normalize Data Between 0 and 100 - Statology*. 2020, November 30. https://www.statology.org/normalize-data-between-0-and-100/

Appendix

[1] Interactive Map: https://suobset.github.io/iCons/iCons2-MoS/index.html which has been Open Sourced at https://github.com/suobset/iCons2-MoS