

MBTA Incident Risk Zones

An Analysis of Trauma Center Proximity

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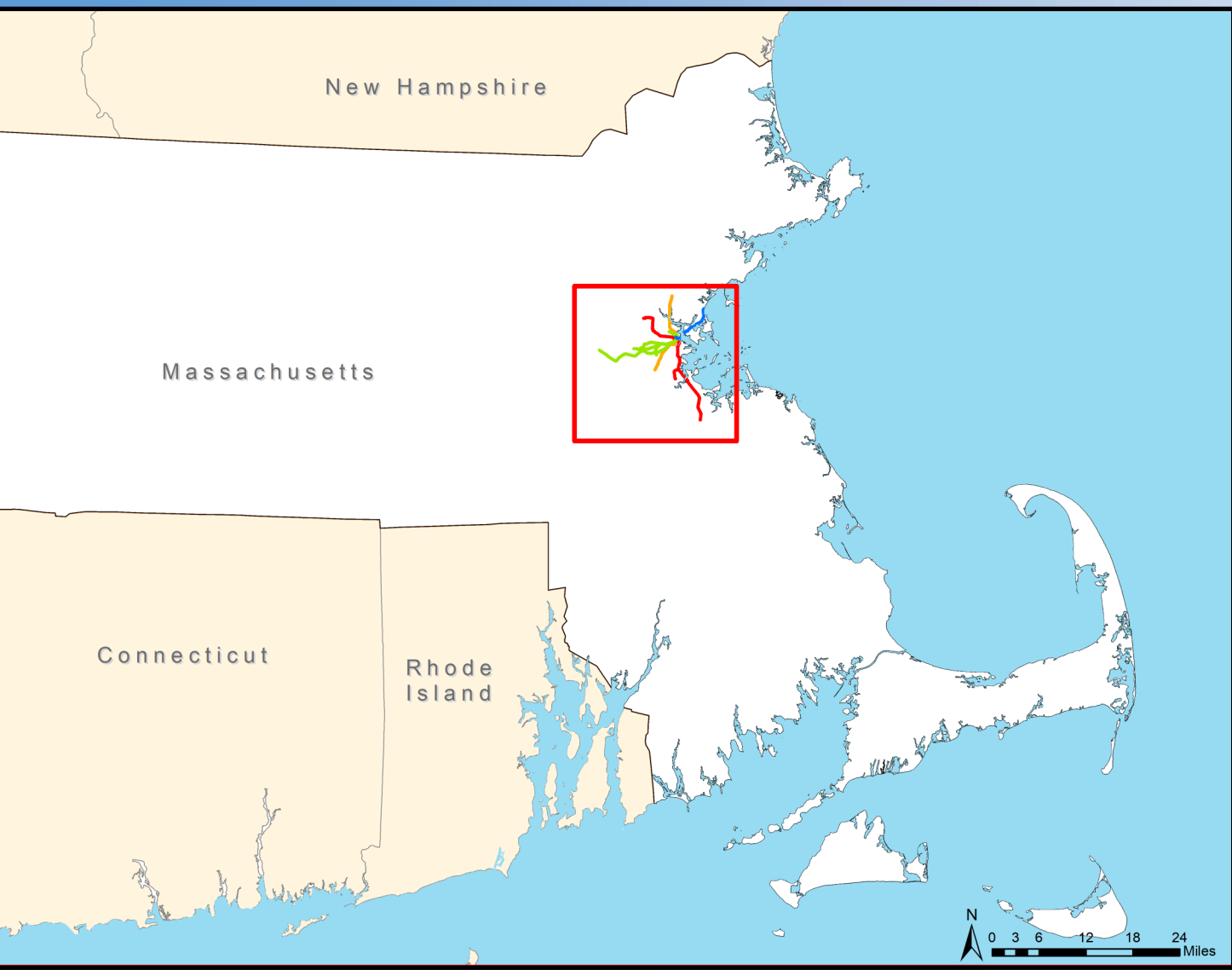
Background: The Massachusetts Bay Transit Authority (MBTA) rapid transit system serves the Boston metropolitan area and, as of 2019, provides an average of 641,000 trips per day (Massachusetts Bay Transit Authority, 2019) along four main lines, plus a bus rapid transit line. As a heavily trafficked, publicly accessible, transportation resource, the MBTA is an area of public health vulnerability as its thousands of daily riders are exposed to the risks of a coordinated terrorist attack, such as the 2004 Madrid train bombings or the 1995 Tokyo sarin gas subway attack, or a catastrophic accident or fire – the most common causes of subway fatalities (Yifan, 2018). The security of this infrastructure is a critical element of the MBTA’s status as an open and accessible resource to the public, and it is important to have a clear picture of the risks and vulnerabilities to riders within each region of the transit map. This analysis seeks to quantify “risk zones” by evaluating the availability of hospitals with trauma centers and total hospital bed capacity at said hospitals within five miles of each MBTA station. The five-mile Euclidian radius is based on previous literature showing that an incident distance of more than 5 miles from a trauma center was associated with increased fatalities and negative outcomes in Chicago, a comparably urban setting (Crandall, et al., 2013). In doing so, the analysis seeks to elaborate which regions of the MBTA might be most vulnerable in the event of an incident, in terms of lack of immediate access to necessary medical resources. The hospitals that might be engaged in the case of such an incident will also be identified.

Methods

All data used were sourced from the public MassGIS (Massachusetts Bureau of Geographic Information) data repository. The data used were location, capacity and trauma status data of Massachusetts acute care hospitals (vector data, 2019) and location of MBTA rapid transit stations and line routes (vector data, 2020).

The primary analysis, mapping of the risk zones along the extent of the MBTA, was done by mapping the locations of the trauma hospitals and MBTA stations in ArcMap and creating 5-mile buffer rings around each hospital. These buffers were used to assess which hospitals fall within 5 miles of each station in order to create a count for each station. Each station was then plotted on the map by category of hospital density within five miles, and the drawing tool was used to extend the relevant symbol color along the train line. Each zone along the line corresponding to a specific station extends to the approximate midpoint between that station and the next. The map produced, titled “MBTA Risk Zones,” visualizes zones along the MBTA route by total number of trauma centers within 5 miles of each station. For the secondary analysis, density of hospital beds within 5 miles of each station, trauma hospitals were mapped along with station maps of each line. 5-mile buffer rings were created around each station and a spatial join was used to assess the sum hospital capacity of trauma centers located within each ring. The data from each buffer ring was then joined to the corresponding station. This data was used to create four individual maps, corresponding to each of the major MBTA lines, visualizing total hospital bed capacity at trauma hospitals within 5 miles of each station.

The analysis of total stations closest to each hospital was performed using the near tool in ArcMap to determine the closest hospital to each station, and then summing the number of stations associated with each hospital identifier.

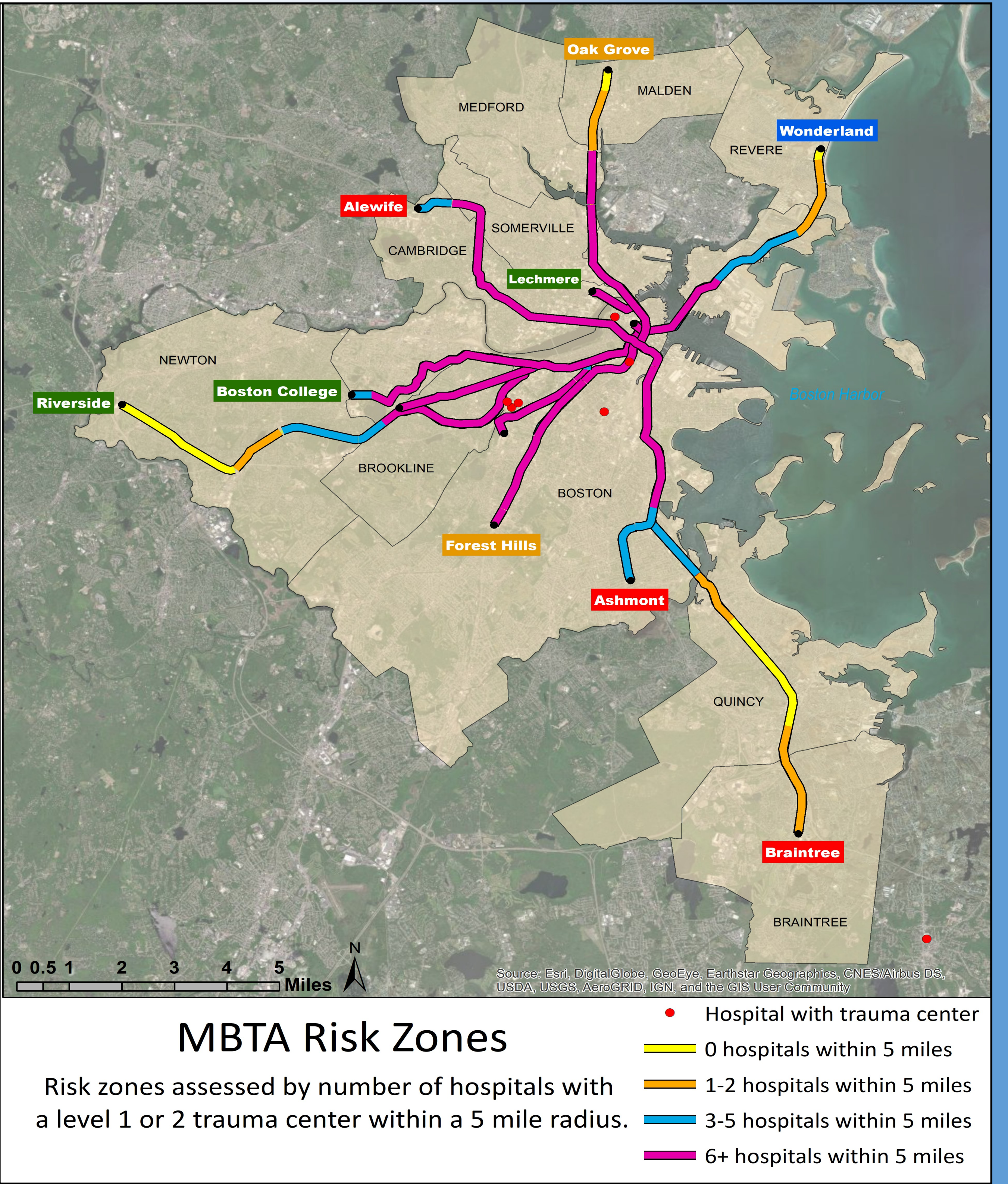


Results

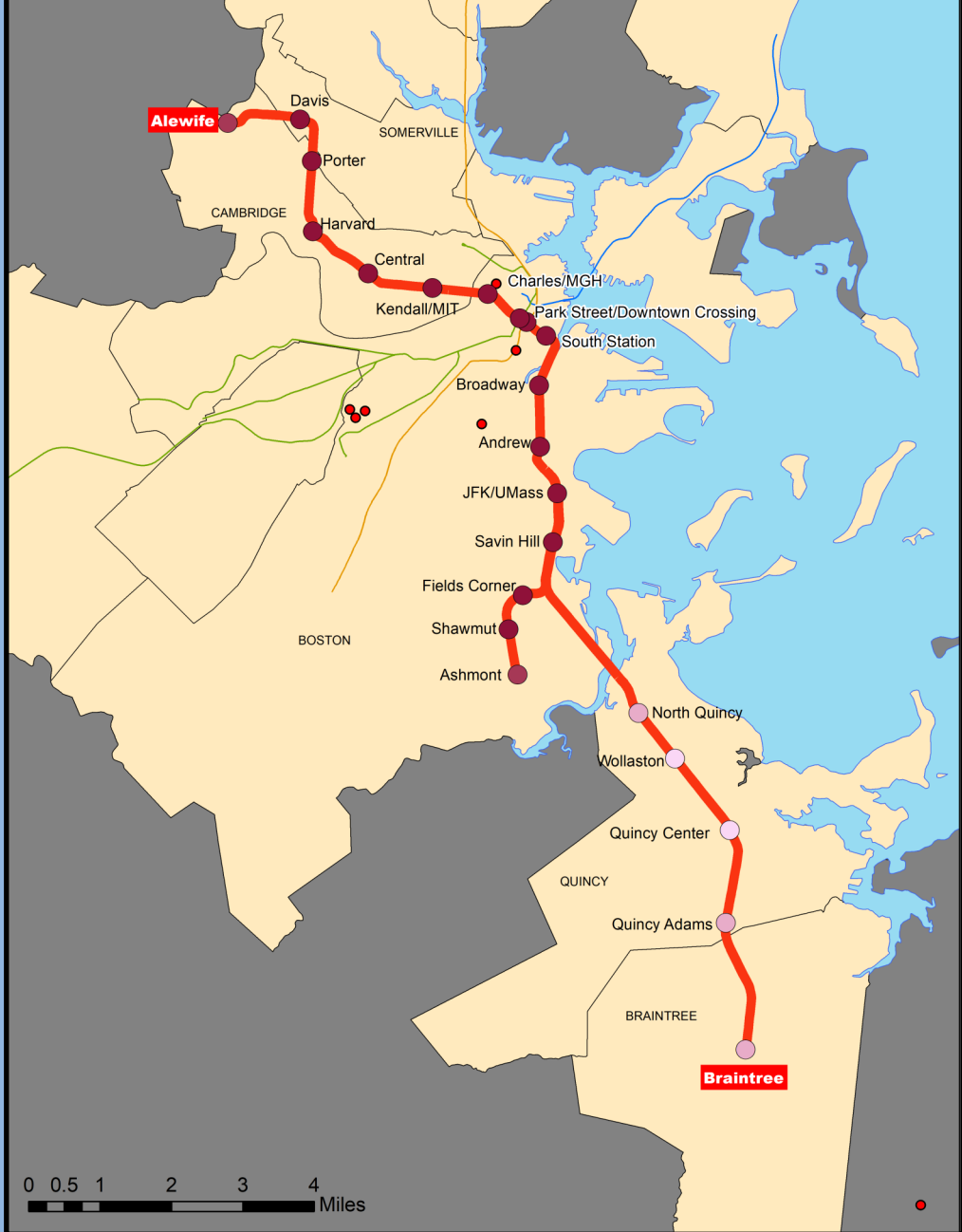
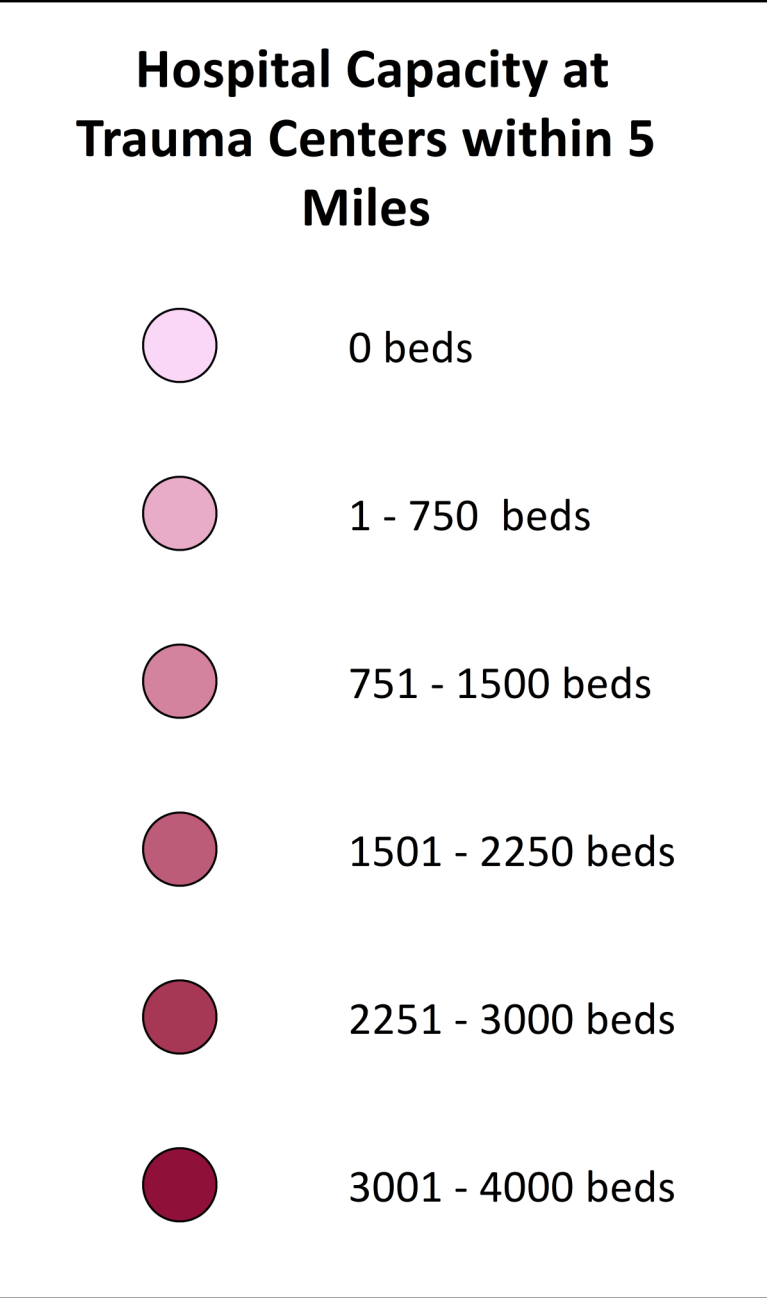
There are seven hospitals with trauma centers located within a five-mile radius of the MBTA rapid transit system: Beth Israel Deaconess Medical Center, Boston Medical Center, Boston Children’s Hospital, Brigham and Women’s Hospital, Massachusetts General Hospital, Tufts Medical Center, and South Shore Hospital. These resources are primarily clustered in the heart of Boston and the border of Boston and Brookline, and as a result, the entirety of the MBTA’s Boston and Brookline extent is maximally supported by six hospitals with trauma centers. More diversity among the zones is seen closer to the outbound termini of each line, with areas in Malden, Revere, Newton, Quincy and Braintree supported by 1-2 hospitals within 5 miles or none at all. The largest zones with zero hospital support are located at the west end of the Green Line D Branch, between Newton Highlands and Riverside stations, and in Quincy, between North Quincy and Quincy Adams. The overarching pattern of the data shows that as the MBTA route proceeds outbound, the total number of accessible trauma centers within 5 miles decreases steadily. The exception to this observation is the southbound terminus of the Red Line at Braintree Station, which within 5 miles of South Shore Hospital, the only trauma center involved in the analysis not located in Boston proper. Overall, the data suggest that the Orange and Green lines are most well-situated in the event of a catastrophe on the MBTA, along with swaths of the Red and Blue lines. The most vulnerable zone of the MBTA overall lies between North Quincy and Quincy Adams, a heavily used stretch of the line with zero hospital support within five miles. While the downtown stations are well-supported by trauma centers as assessed by Euclidean distance, their location in the congested heart of the city could be a drawback based on real-time traffic conditions. A future analysis using the same principles along with drive times could further stratify the zones and quantify the risk level of each station. Future work could also use the patterns identified in the below table to assess and create a disaster protocol around which hospitals would automatically be engaged in the event of an incident at a given station.

How frequently is each trauma center the nearest to a MBTA Station?		
Hospital Name	Number of closest stations	Capacity
Beth Israel Deaconess Medical Center	43	405
Tufts Medical Center	35	415
Massachusetts General Hospital	34	1035
Boston Medical Center	31	288
Boston Children’s Hospital	11	404
Brigham and Women’s Hospital	9	763
South Shore Hospital	3	370

Discussion: The findings show strong hospital support along much of the MBTA rapid transit map but reveal two main regions of vulnerability in Newton and Quincy. This suggests that, in the event of a major incident along these two stretches of the subway, location and local infrastructure may play a part in exacerbating the severity of the outcome or, at the very least, complicate the logistics of the emergency response. The study is an effective macro level view of how risk, as defined by trauma center availability and hospital bed capacity, is segmented spatially along the routes, but is limited in its practical application by a lack of relevant real-time variables, such as traffic patterns and average ridership by time and station. Incorporating these variables in future research would generate a more nuanced and detailed risk profile for each station and segment of the route. Future research on this topic should therefore go beyond Euclidian distance to explore how these variables interact with the hospital availability at each station to determine the extent to which station location in downtown Boston, here assessed as a low risk factor, works as a double-edged sword by pairing close proximity to hospitals with increased ridership and high traffic congestion, increasing drive time. This study also identified the trauma centers most frequently located closest to a train station; this is a good starting point for identifying which medical resources should be engaged as part of an emergency protocol, but a future analysis should explore the extent of medical resources availability locally, not only in trauma centers, to generate a fuller picture of the capacity of the surrounding medical infrastructure. While the current results show a clear need for an efficient response protocol in the vulnerable areas in Quincy and Newton, the suggested further analysis would provide a starting point for a station-by-station emergency response protocol identifying which hospitals would be engaged by region and for what purpose, as well as optimal and frequently engaged routes between medical resources and stations which could be repurposed as arteries for emergency vehicles.

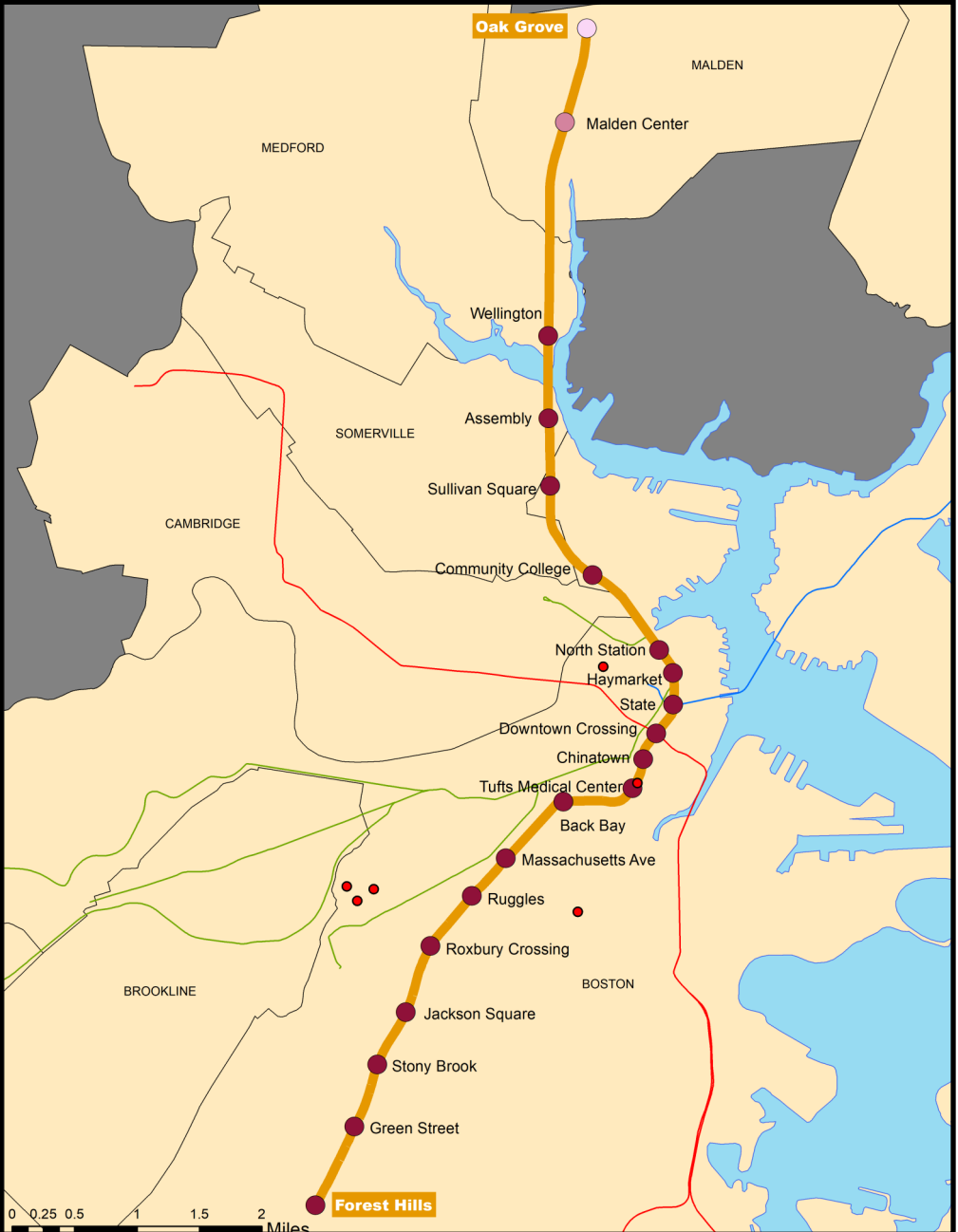


Aggregate Hospital Capacity within 5 miles, by Station



Red Line

Aggregate bed capacity is consistently above 3000 along much of the length of the red line, dipping at the terminus stations of Alewife and Ashmont. The North Quincy to Braintree stretch of the line sees a significantly lower aggregate bed count, ranging from 0 to 750. While the terminus stations by nature see the lowest average ridership along the lines, the vulnerable stretch between North Quincy and Quincy Adams is heavily used by commuters and trains may frequently reach capacity at rush hour.



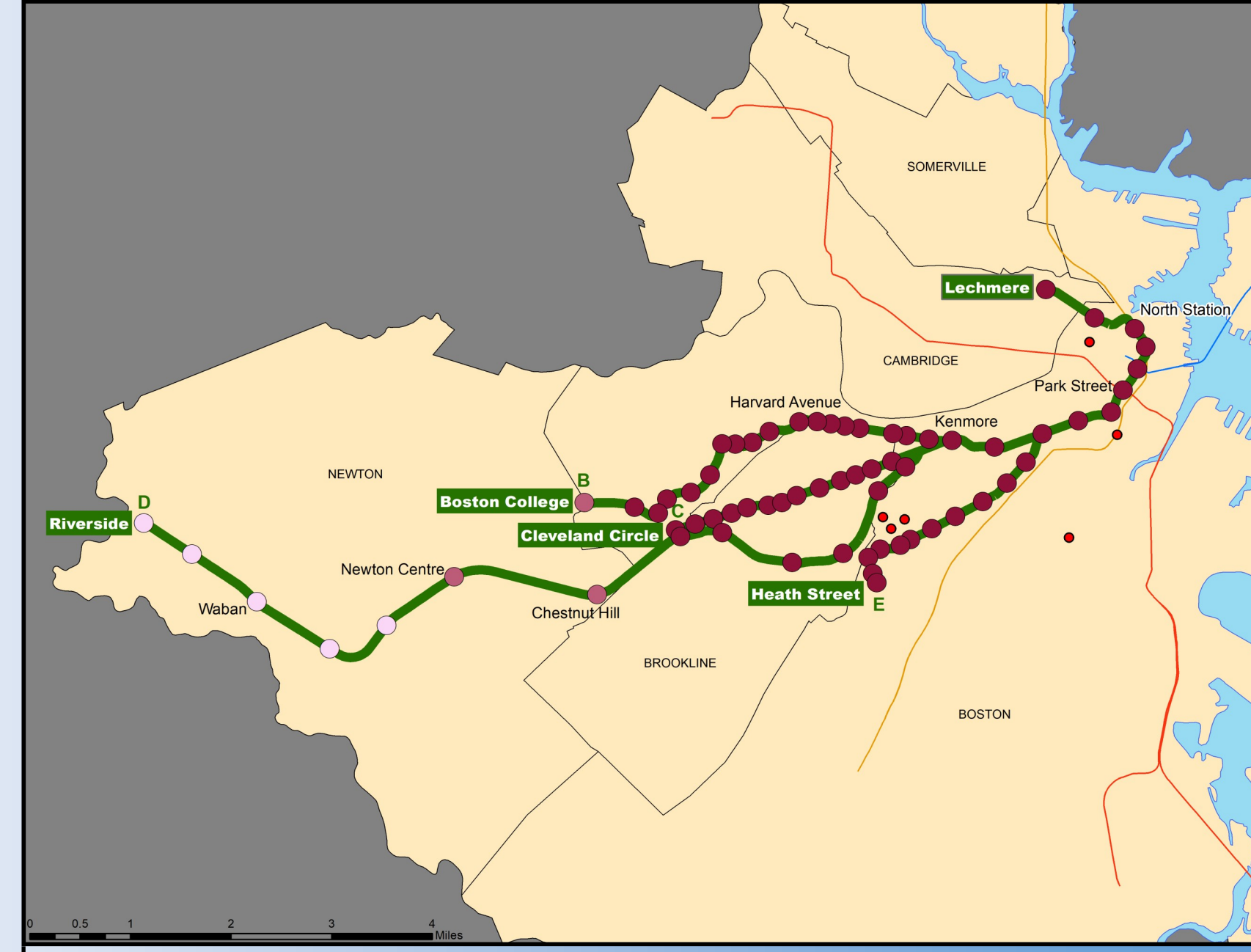
Orange Line

The majority of the orange line is within 5 miles of over 3000 beds in hospitals with trauma centers and is well supported. The exceptions are the two stations located in Malden – Oak Grove and Malden Center, with capacity falling to zero beds at the terminus station. As ridership is lowest at the terminus station, this is a fairly low risk area in terms of potential victims, offsetting the decreased capacity.



Blue Line

The Boston extent of the Blue Line, from Bowdoin to Airport Station is maximally supported by hospital beds. Bed capacity decreases steadily as the line travels outbound toward Wonderland station in Revere; however, this risk is offset by the Blue Line’s low ridership relative to the other three lines.



Green Line

The entirety of the Green Line’s downtown extent, as well as the B, C, and E branches are well supported by hospital beds at trauma centers. At west end of the D line, stretching from the terminus station at Riverside to Newton Highlands, capacity drops to zero, making this heavily commuted area vulnerable.