MBTA Incident Risk Zones
An Analysis of Trauma Center Proximity
Jonathan Chau

Background: The Massachusetts Bay Transit Authority (MBTA) rapid transit system serves the Boston metropolitan area and, as of 2019, provides an average of 841,000 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 2001 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 evaluate 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 suggesting that an incident distance of more than 5 miles from a trauma center was associated with increased fatalities and negative outcomes in Chicago, a comparable 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

As 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 stations of MBTA rapid transit stations and lines (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 centers in MBMap and creating 5-mile buffer rings around each hospital. These buffers were used to access 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 symbols along the train line. Each line 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 access the 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. This analysis of total stations closest to each hospital was performed using the open tool in ArcMap to determine the closest hospital to each station, and then summing the number of stations associated with each hospital identified.

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 Broadway extent is maximal—supported by six hospitals with trauma centers. More diversity among the zones is seen closer to the outbound terminals of each line, with areas in Malden, Revere, Newton, Quincy and Braintree supported by 2-3 hospitals within 5 miles of each or not at all. The largest zones with zero hospital support are located along the east and west of the Green Line D Branch, between Newton Highlands and Waverley stations, and in Quincy, between North Quincy and Quincy Adams. The overarching pattern of the data shows that as the MBTA route proceeds outward, the total number of trauma center within 5 miles decreases steadily. The exception to this observation is the southbound terminal of the Red Line at Government Station, which is 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 vulnerable 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 area stations are well supported by trauma centers as assessed by Euclidian distance, their location in the congested heart of the city could be a drawback based on real time traffic conditions. A future analysis using some 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.

<table>
<thead>
<tr>
<th>MBTA Line</th>
<th>Hospital with trauma center</th>
<th>0 hospitals within 5 miles</th>
<th>1-2 hospitals within 5 miles</th>
<th>3-5 hospitals within 5 miles</th>
<th>6+ hospitals within 5 miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Line</td>
<td>Hospital with trauma center</td>
<td>0 hospitals within 5 miles</td>
<td>1-2 hospitals within 5 miles</td>
<td>3-5 hospitals within 5 miles</td>
<td>6+ hospitals within 5 miles</td>
</tr>
<tr>
<td>Orange Line</td>
<td>Hospital with trauma center</td>
<td>0 hospitals within 5 miles</td>
<td>1-2 hospitals within 5 miles</td>
<td>3-5 hospitals within 5 miles</td>
<td>6+ hospitals within 5 miles</td>
</tr>
<tr>
<td>Blue Line</td>
<td>Hospital with trauma center</td>
<td>0 hospitals within 5 miles</td>
<td>1-2 hospitals within 5 miles</td>
<td>3-5 hospitals within 5 miles</td>
<td>6+ hospitals within 5 miles</td>
</tr>
<tr>
<td>Green Line</td>
<td>Hospital with trauma center</td>
<td>0 hospitals within 5 miles</td>
<td>1-2 hospitals within 5 miles</td>
<td>3-5 hospitals within 5 miles</td>
<td>6+ hospitals within 5 miles</td>
</tr>
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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 portions of the subway, riders may be at increased risk in exacerbating the severity of the outcome, at the very least, complicating 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 representational 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 riding time by line 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, as assessed by a low risk factor, works as a double-edged sword by providing close proximity to hospitals with increased demand and high traffic congestion, increasing drive time. This study also identified the trauma centers most frequently located closest to a MBTA 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 availability of medical and emergency services in the event of a catastrophe on the MBTA.

Aggregate Hospital Capacity within 5 miles, by Station

<table>
<thead>
<tr>
<th>Hospital Capacity at Trauma Centers within 5 Miles</th>
<th>0 beds</th>
<th>1-750 beds</th>
<th>751-1500 beds</th>
<th>1501-2500 beds</th>
<th>2501-3000 beds</th>
<th>3001-4000 beds</th>
</tr>
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</table>

Red Line

Orange Line

Blue Line

Green Line

The majority of the orange line is within 5 miles of over 3000 beds in hospitals within 5 miles of each MBTA station, with the highest density of hospital beds between Boston and Braintree. The majority of the Blue Line is within 5 miles of approximately 4000 beds in hospitals within 5 miles of each MBTA station, with the highest density of hospital beds between Ocean and Braintree. The majority of the Green Line is within 5 miles of over 2000 beds in hospitals within 5 miles of each MBTA station, with the highest density of hospital beds between Chelsea and Malden. The majority of the Red Line is within 5 miles of approximately 3000 beds in hospitals within 5 miles of each MBTA station, with the highest density of hospital beds between Government and North Station.

References:


