Transit Equity Team 2
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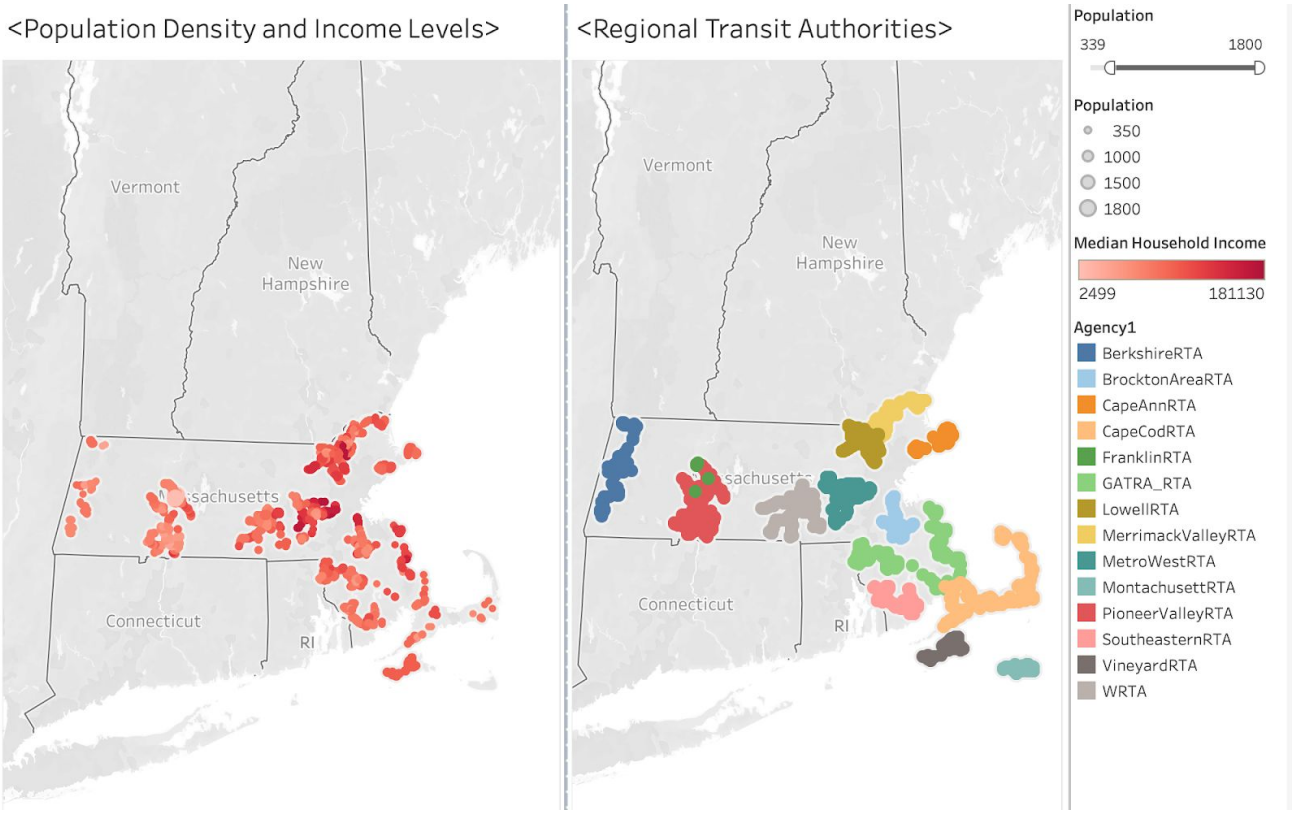
Deliverable 2

**Bus routes/stops with highest number of low income riders**

Our first strategic question focuses on finding which bus routes and stops, if made free, would most benefit low income rides in Massachusetts.

As per the client's request, we generated a map of bus stops/routes for all RTAs with dot population density and a color gradient representative of median household income. Both the population and median household income are at the level of a census tract, and were retrieved from the American Community Survey (ACS) 2018 Census data that can be found here.




Based on the generated visualization, we can see which RTAs have a relatively dense population coupled with low median household income. Initial RTAs that stand out are PionnerValleyRTA and BerkshireRTA. We take a closer look at these RTAs through calculations in our code.

| RTA | Bus Route | Bus Route Name | Median Household Income |
|---|---|---|---|
| PioneerValleyRTA | 36 | Olympia Dr / Atkins Corner | 10934.92 |
| PioneerValleyRTA | B4 | Plainfield Street | 17313.0 |
| PioneerValleyRTA | G3 | Spfld Plaza via Liberty/King-Westford | 27971.98 |
| PioneerValleyRTA | 30 | North Amherst / Old Belchertown Rd | 30293.61 |
| LowellRTA | 6 | Broadway/UMass Lowell | 30809.36 |
| PioneerValleyRTA | 46 | Whately via S. Deerfield Center/ UMass | 30908.76 |
| LowellRTA | 18 | Downtown Shuttle | 31194 |
| WRTA | 7 | Washington Heights Apt | 32129.8 |
| LowellRTA | 9 | Lowell Circulator | 32315.56 |
| BerkshireRTA | 34 | North Adams Loop | 33586.11 |

These are the top ten bus routes, if made free, would benefit people of the lowest income in Massachusetts. The median household income of a route is calculated by doing the following: $\frac{\sum p * m}{\sum p}$, where p is the population census count of some bus stop and m is the median household income of some bus stop. We essentially normalize the median household income of a route based on the stops along that route.

Our calculations parallel our observations from the map visualization. We can see that five routes from PioneerValleyRTA are in the top ten bus routes, with lowest median household income. Note that our median household income is only based on income from tracts along the bus route. As a next step, we would like to “draw” a buffer around a stop/route to incorporate income and population data from census tracts within a certain amount of distance from a stop/route.

**Impact of fare policy change on each RTA**

Our next goal is to determine how each region would benefit by a policy change to the fare change for their bus routes.

We calculated the original cost per unlinked passenger trip for each RTA by dividing the annual operating expenses by the number of unlinked passenger trips. One goal of transit equity is to minimize cost per passenger because this would mean that each passenger trip costs the RTA less to maintain, resulting in higher efficiency.

As a result of rendering fares free, the number of passengers in each RTA would be expected to increase by 30%. This expected increase is based off of an often cited guideline, the Simpson-Curtin Rule. According to the “The Implications of a Fare-Free WRTA” research paper, the guideline states “a 100 percent reduction in fare prices would theoretically result in a 30 percent rise in ridership.” With this new passenger trips number, we are able to calculate the new cost per unlinked passenger trip. The RTA with the greatest percentage decrease in cost per unlinked passenger trips would benefit the most from fare policy changes.

We defined the following formulas, where C is the total operating cost, T is the total number of unlinked trips, and F is the total fares in a fiscal year:

$$\text{Average cost} = \frac{C}{T}$$

$$\text{Free estimated average cost per trip} = \frac{C + F}{T * 1.3}$$

Additionally, we prove that average cost per trip will always decrease when the amount of revenue you generate is less than 3 tenths of the total operational cost, with the assumption that we have a 30% increase of ridership when we remove 100% of fares via the simpson curtson rule.

$$g(x) = \frac{(\frac{c+x}{t*1.3}) - \frac{c}{t}}{\frac{c}{t}}$$

Notice this function will be strictly increasing when C and T are positive numbers.

Now to solve for when y=0:

$$0 = \frac{(\frac{c+x}{t*1.3}) - \frac{c}{t}}{\frac{c}{t}}$$

$$0 = \frac{c+x}{t*1.3} - \frac{c}{t}$$

$$\frac{c}{t} = \frac{c+x}{t*1.3}$$

$$c*1.3 = c+x$$

$$c*1.3 - c = x$$

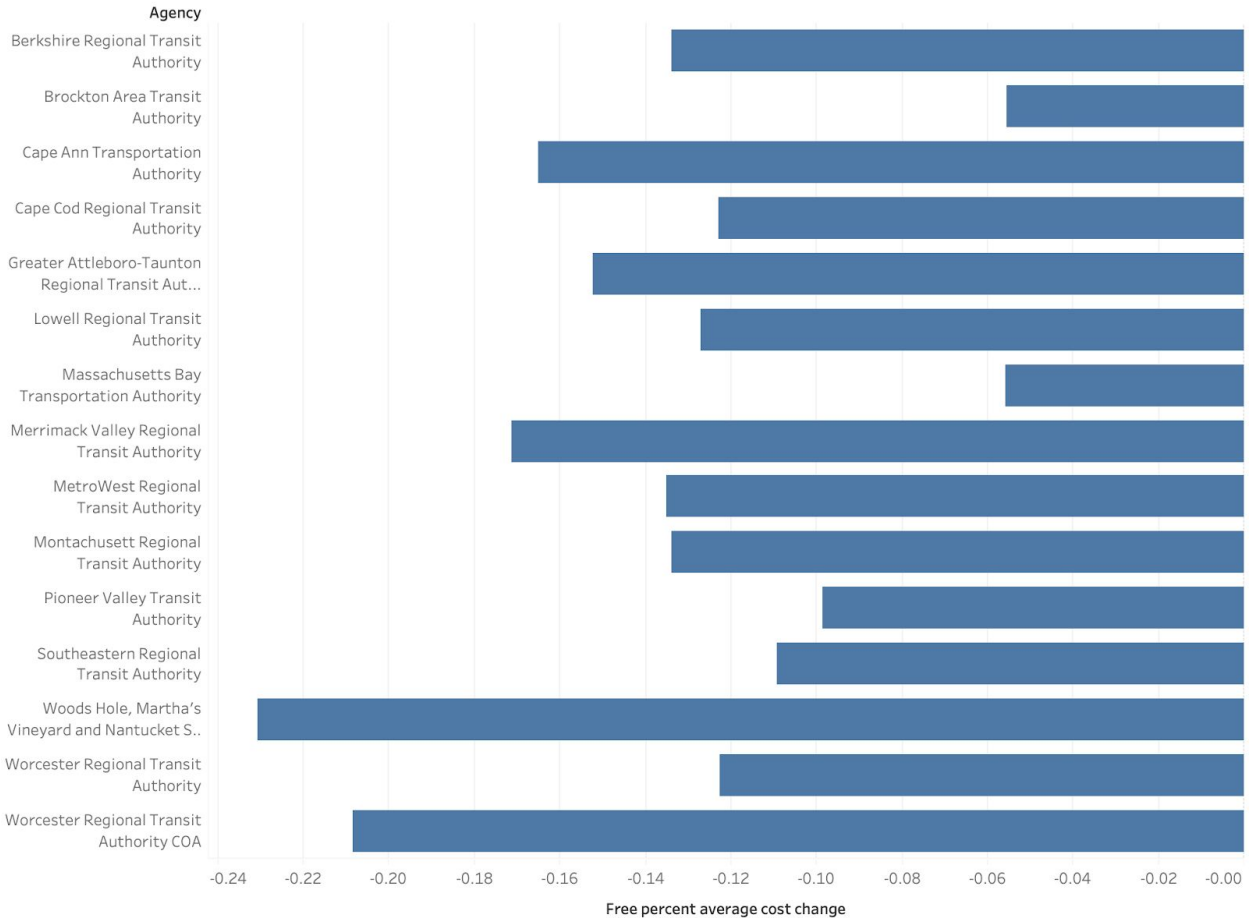
$$.3*c = x$$

We performed the average cost and free estimated average cost per trip formulas for each RTA and found that the average cost per trip decreases for all RTAs if we assume that there is a 30% increase in ridership from making bus fares free. This means that RTAs have a higher efficiency and utilization due to increased ridership and no change in operating expenses. The results for each RTA is shown in the table below.

| | Estimated Num Passengers | Free Estimated Average Cost Per Trip | Average Cost per Trip FY | Free percent average cost change | Agency |
|---|---|---|---|---|---|
| **270** | 8.575441e+05 | 5.843595 | 7.5967 | -0.230772 | Woods Hole, Martha's Vineyard and Nantucket St... |
| **152** | 9.516940e+05 | 4.565229 | 5.8452 | -0.218978 | Massachusetts Bay Transportation Authority |
| **261** | 3.869998e+02 | 38.680183 | 48.8760 | -0.208606 | Worcester Regional Transit Authority COA |
| **170** | 1.952899e+06 | 6.272620 | 7.5696 | -0.171341 | Merrimack Valley Regional Transit Authority |
| **201** | 2.059997e+05 | 7.516318 | 9.0034 | -0.165169 | Cape Ann Transportation Authority |
| **217** | 7.166826e+05 | 9.408694 | 11.1007 | -0.152423 | Greater Attleboro-Taunton Regional Transit Aut... |
| **257** | 5.921663e+05 | 7.948441 | 9.1898 | -0.135080 | MetroWest Regional Transit Authority |
| **210** | 5.373832e+05 | 9.334594 | 10.7798 | -0.134066 | Montachusett Regional Transit Authority |
| **165** | 4.974989e+05 | 9.223292 | 10.6482 | -0.133817 | Berkshire Regional Transit Authority |
| **160** | 1.370682e+06 | 6.260449 | 7.1723 | -0.127135 | Lowell Regional Transit Authority |
| **247** | 6.101734e+05 | 9.986896 | 11.3875 | -0.122995 | Cape Cod Regional Transit Authority |
| **174** | 3.013265e+06 | 5.896456 | 6.7203 | -0.122590 | Worcester Regional Transit Authority |
| **162** | 2.666555e+06 | 4.799070 | 5.3885 | -0.109387 | Southeastern Regional Transit Authority |
| **167** | 1.012028e+07 | 3.492483 | 3.8750 | -0.098714 | Pioneer Valley Transit Authority |
| **151** | 9.930234e+07 | 4.036709 | 4.2757 | -0.055895 | Massachusetts Bay Transportation Authority |
| **156** | 2.636712e+06 | 4.193935 | 4.4399 | -0.055399 | Brockton Area Transit Authority |

We also graph the percent change of cost per passenger for each RTA, which is shown below:

<RTA Free Percent Average Cost Change>



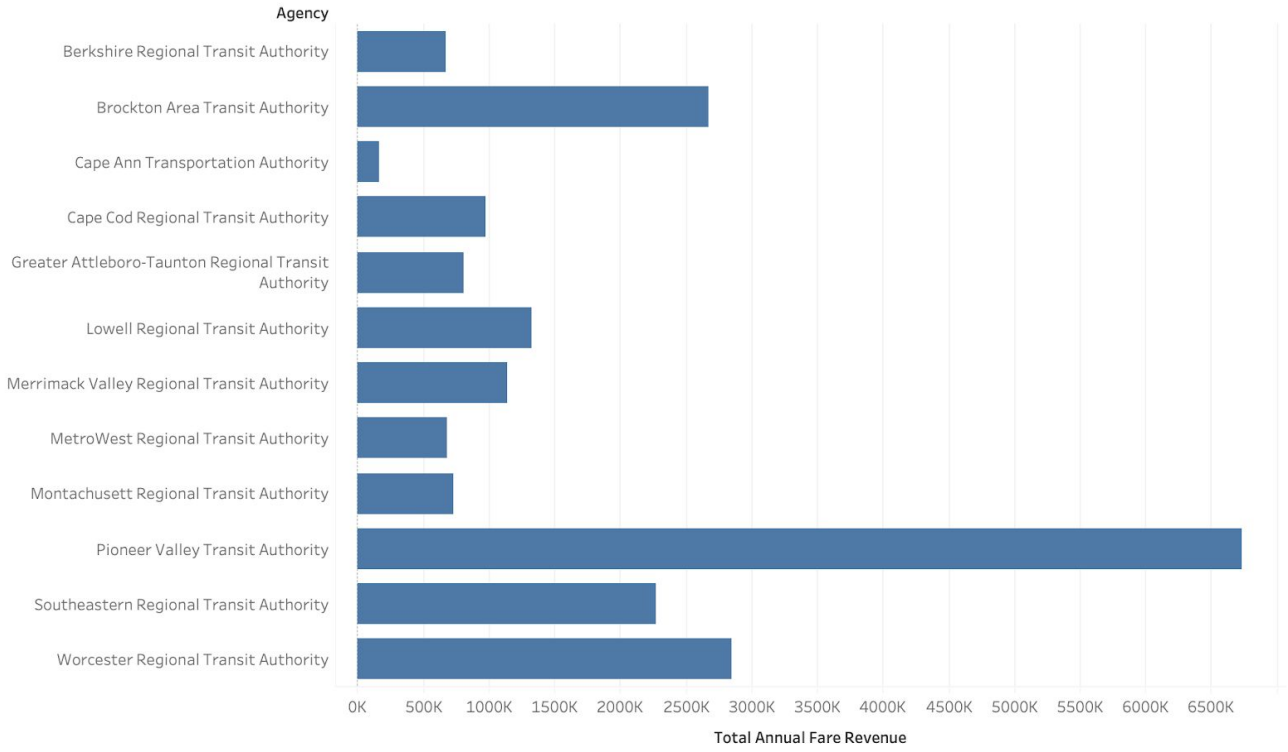

By combining impact of fare policy change on each RTA with the bus routes serving the 10 lowest median income areas (from the earlier section), we can conclude that the agencies that would benefit the most from these route policy changes would be Berkshire Regional Transit Authority, Lowell Regional Transit Authority, Worcester Regional Transit Authority, and Pioneer Valley Transit Authority, in that order.

## **Cost impact of free bus routes to the regional transit authorities**

We would like to further expand our data and investigate the impact of cost and ridership by making individual bus routes free. However we were unable to access any datasets providing ridership and cost per bus stop/route. Without this data, we can move forward with a more holistic approach which is to multiply the operating costs plus fare revenue loss from making an entire regional transit area free by the ratio of the population serviced by a specific route divided by the population of the town.

## Cost impact of free regional transit area

We define cost to be the fare revenue loss from making an entire regional transit area free. The cost to make each RTA free is specified in the graph below:




Although there will be a revenue loss from fares, making an entire transit authority free would eliminate the cost needed for fare management (which includes farebox maintenance, farebox purchase, and staff to process revenue). For example, according to the Worcester Regional Research Bureau, Inc. the estimated annual WRTA cost for fare management is approximately $850,000 (Worcester Regional Research Bureau, Inc.). If we take this to account, we would have a 28% cost decrease for the WRTA. A relatively safe assumption is that this would be the general case for all other RTAs.

Notes

- We filtered out data by mode (MB = bus), so the fare revenue only considers revenue from buses.