Transit Equity Team 2
Curtis Mason, Justin Ching, Kelly Ruan

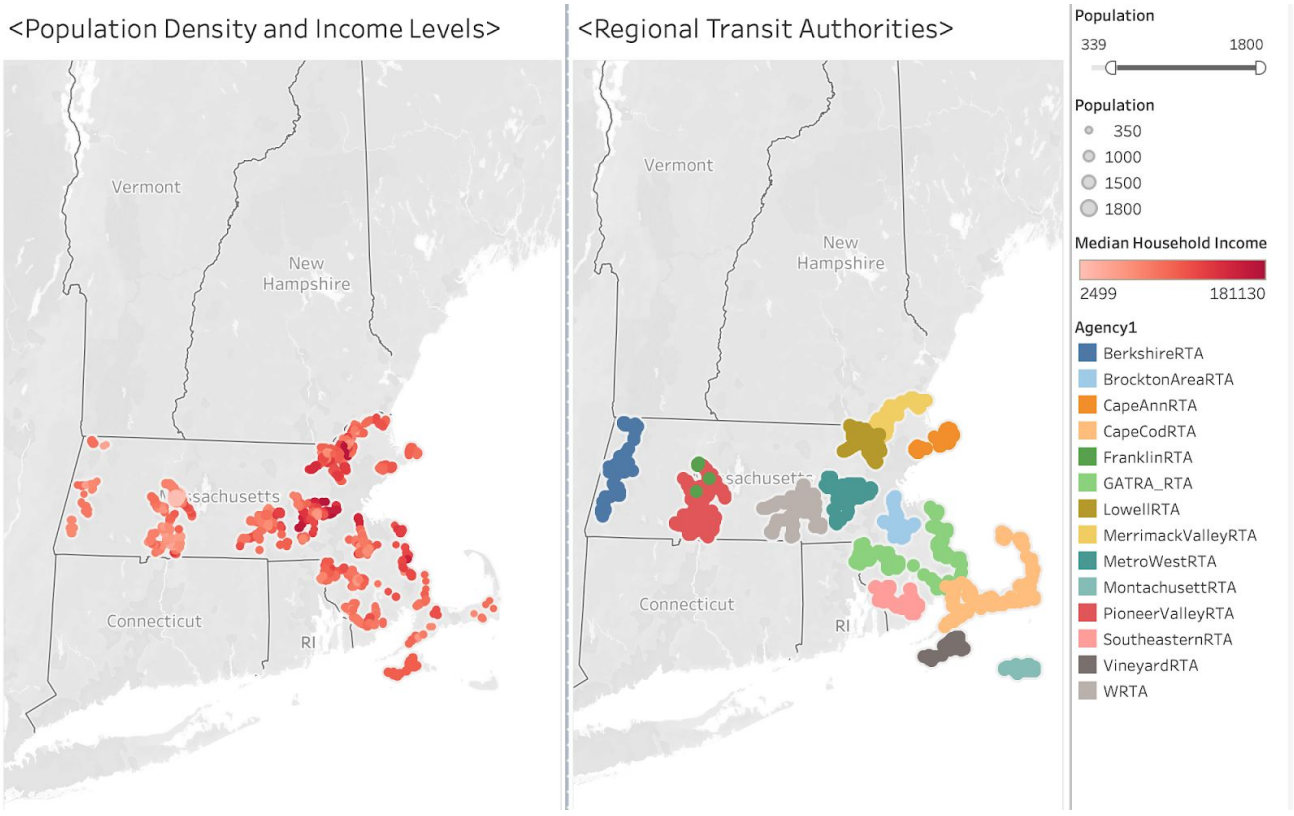
Deliverable 3

Free public transportation has been a significant achievement for many cities, states, and even countries around the world. With Luxembourg becoming the first country to make all public transportation free in March 2020, the precedent has been set for other countries or smaller regional transit authorities to research the costs and benefits of creating a free public transit system.

More relevant to Massachusetts, the Worcester Regional Transit Authority (WRTA) research on creating a free transit system acts as precedent for other Massachusetts RTA and the MBTA. By observing the median household income data spread of Massachusetts, it is clear that there are many low income areas with inefficient bus routes that are very costly for both the towns or Regional Transit Authority (RTA) and residents that live near the bus stops. After aggregating different datasets together, we were able to determine which bus routes had the highest potential low income riders, the cost benefits that the RTA would receive, and the costs of removing fares for certain bus routes and the entire RTA.

Bus routes and stops with highest number of low income riders

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



As per the client's request, we generated a map (figure above) of bus stops and routes for all RTAs with dot population density and a color gradient representative of median household income. Both the population and median household income data are displayed at the census tract level of granularity, 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 ten bus routes that would most benefit people of the lowest income in Massachusetts. The median household income of a route is calculated by performing 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 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 and three routes from LowellRTA 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. To gain a more accurate representation on the income level along a bus route, we could potentially look at a buffer around a bus route to incorporate income and population data from census tracts within a certain radius from the route.

Impact of fare policy change on each RTA

Our next goal was to determine how each RTA would benefit from a fare policy change to their bus routes.

We calculated the cost per unlinked passenger trip for each RTA by dividing the annual operating expenses by the number of unlinked passenger trips. An unlinked passenger trip counts the number of boardings a rider may take from his/her origin to destination. One goal of transit equity is to minimize cost per passenger because this means 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. In *"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 a new cost per unlinked passenger trip (free estimated average cost per 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 generated is less than 3 tenths of the total operational cost, with the

Simpson-Curtin Rule assumption that there is a 30% increase of ridership when 100% of fares are removed.

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

Notice this function will be strictly increasing when c and t are positive numbers. Now, solve for x when y = 0.

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

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

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

$$c * 1.3 = c + x$$

$$c * 1.3 - x = c$$

$$x = .3 * c$$

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.

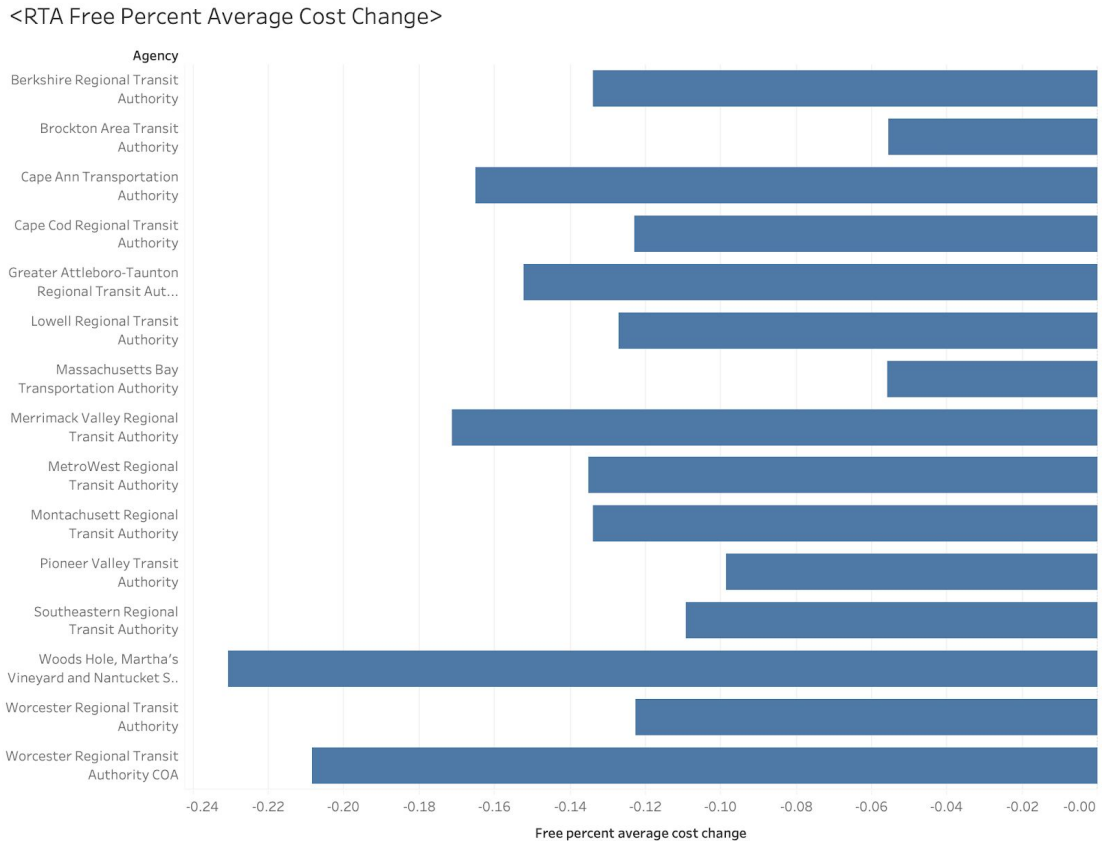
The results for each RTA is shown in the table below.

Agency	**Estimated Number of Passengers**	**Average Cost per Trip in $**	**Free Estimated Average Cost per Trip in $**	**Percent Change of Average Cost**
Woods Hole, Martha's Vineyard and Nantucket Steamship	857544	7.5967	5.843595	-23.08%

Authority				
Worcester Regional Transit Authority COA	387	48.876	38.680183	-20.86%
Merrimack Valley Regional Transit Authority	1952899	7.5696	6.27262	-17.13%
Cape Ann Transportation Authority	206000	9.0034	7.516318	-16.52%
Greater Attleboro-Taunton Regional Transit Authority	716683	11.1007	9.408694	-15.24%
MetroWest Regional Transit Authority	592166	9.1898	7.948441	-13.51%
Montachusett Regional Transit Authority	537383	10.7798	9.334594	-13.41%
Berkshire Regional Transit Authority	497499	10.6482	9.223292	-13.38%
Lowell Regional Transit Authority	1370682	7.1723	6.260449	-12.71%
Cape Cod Regional Transit Authority	610173	11.3875	9.986896	-12.30%

Worcester Regional Transit Authority	3013265	6.7203	5.896456	-12.26%
Southeastern Regional Transit Authority	2666555	5.3885	4.79907	-10.94%
Pioneer Valley Transit Authority	10120280	3.875	3.492483	-9.87%
Brockton Area Transit Authority	2636712	4.4399	4.193935	-5.54%

We then graphed the percent change of cost per passenger for each RTA:



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 conclude that the

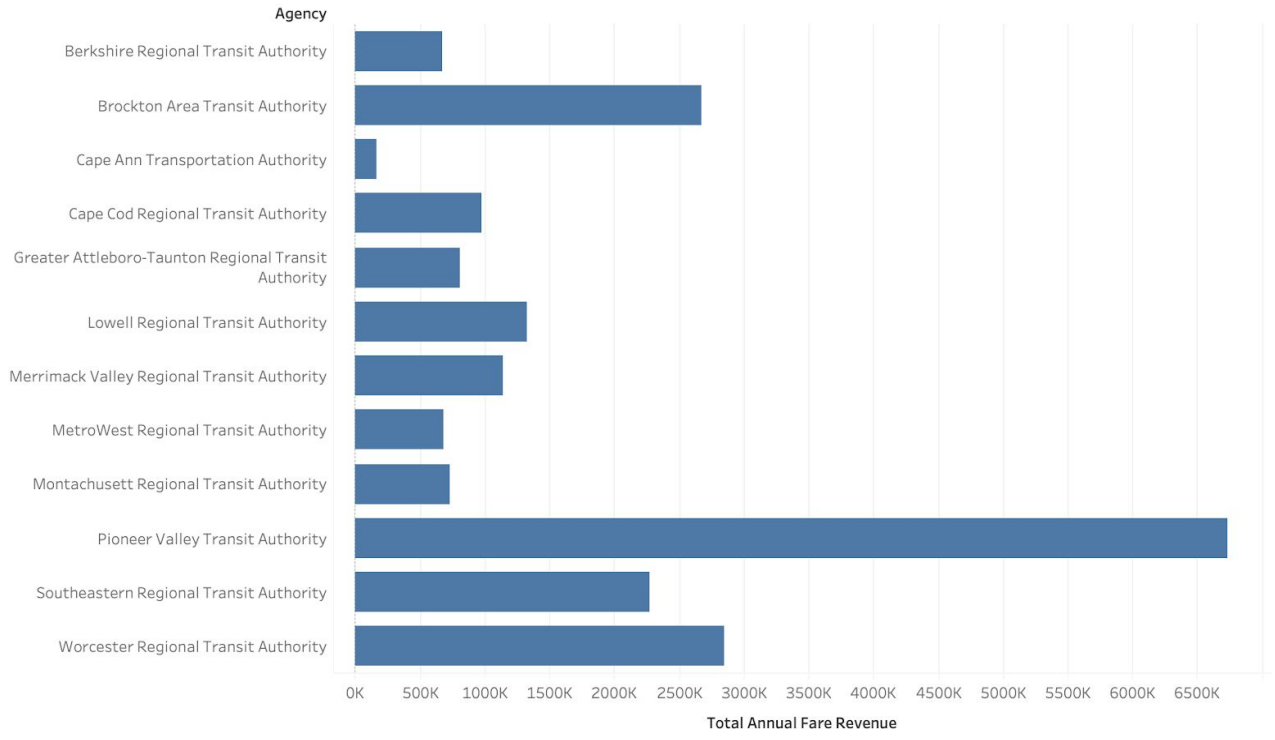
agencies that would benefit the most from these route policy changes would be Berkshire Regional Transit Authority, Lowell Regional Transit Authority, Worcester Regional Transit Authority, and Pioneer Valley Transit Authority, in that order.

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 and route. Without this data, it is difficult to analyze the cost impact of making certain bus routes free, without making huge assumptions. A very generalized approach would be 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 the entire bus system in the regional transit area free. The cost to make each RTA free is specified in the graph below:



From the graph, we observe that it would cost the most to make the entire bus system free for Pioneer Valley Transit Authority, followed by Worcester Regional Transit Authority and then Brockton Area Transit Authority. Although free transit would cause

RTAs to lose revenue from fares, we saw in the previous section that it would result in making systems more cost-efficient due to increased ridership and no change in operating costs.

It is also important to point out that 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. According to the Worcester Regional Research Bureau, Inc. the estimated annual WRTA cost for fare management is approximately $850,000. If we take this into consideration, we would have a 28% cost decrease for the WRTA. We can expect to observe a similar cost reduction in the other RTAs as well.

Conclusion

There are many potential candidates to create a free bus system. Berkshire Regional Transit Authority, Lowell Regional Transit Authority, Worcester Regional Transit Authority, and Pioneer Valley Transit Authority are the transit authorities that serve the lowest income areas in Massachusetts. The existing transit systems all have very low fare recovery ratios, as most of the transit systems are subsidized by alternate sources and not bus fares. Free bus routes or free public transit systems would not only improve the lives of many people but also increase the efficiency of transit systems. Increased ridership from transit equity would lead to many advantages such as fewer traffic congestion, increased mobility, a decrease in unemployment rates and an increase in tourism. To conclude, a quote from *The Implications of a Fare-Free WRTA* resonated deeply with us: “Making the WRTA [or any RTA] fare-free is not charity. It is a way to increase the efficiency of a key government service in a creative and compassionate way”.

All data, code, and visualizations can be found in this github repository.