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## How can we make public transportation more efficient in the United States for workers over 16?

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### Abstract

There is a long history of American transport, for the most significant parts of history, such as the transcontinental railroad, marks an important change that would change society forever. Railroads and public transport have aided civilians to travel, trade, and spread religions, contributing to continual advanced and revolutionary changes regarding modern technology. After collecting data from two cities in each of the fifty states, we utilized an equation to derive the efficiency of a city's transportation system by examining the variables of a number of passengers transported daily, total working population, and the median commute time. The budget per capita for each city's transportation system and the annual snowfall was also examined, and all data was collected from the United States Census and public transit authority records. Throughout the data, the researched variables have proven their significance to the efficiency of transit systems across the country. The research shows that there is little correlation to total working population and budget of transit systems. Another variable that does not affect the efficiency is average snowfall per city. However, there are proven effects of spending per person and efficiency; the research shows a large correlation. There are several different correlations that the variables have with one another. These relationships play a major part in the efficiency of the public transportation system of these cities.

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Categories: Public transportation, MTA, Economy

Key Words: MTA, Economy, Optimization

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## Background/Literature Review

American transportation was revolutionized by the invention of the steam-powered locomotive, allowing Americans to build massive railroad networks. These American steam powered locomotives were pioneered by John Stevens, who received the first charter for a railroad in North America in 1815. Initial railroad systems were no more than horse drawn cars running on tracks that transported freight for short distances. It was not until 1830 that the first mechanical passenger train was completed, setting off a period of rapid railroad expansion that transformed the transportation industry in the United States. By 1850, over 9,000 miles of track had been laid across the United States, and companies adapted a standardized locomotive model and track that allowed railroads to be connected easily. As the railroad industry boomed in conjunction with the steel and oil industries, many smaller railroad companies began to conglomerate into large corporations that dominated the industry. Railroads played an essential role during the Civil War as well, helping to shuttle supplies and reinforcements to faraway armies. After the war was over and the country was united, at the very least in name, again, the need for a railroad system that spanned the country was readily apparent. The Transcontinental Railroad, completed in 1869, was not only a symbol of the newly united nation, but an enabler of trade that allowed goods and passengers to be moved across the country faster than ever before. This ushered in a new age of industrialization that fundamentally altered the American economy. With every new decade, new technological advances made railroad systems more advanced, and labor unions and corporations grappled with terms of employment and new regulations. In 1897, the Tremont Street Subway opened in Boston, making it the first subway system in North America. An effective solution to congestion on the streets, cities across the United States began building subways of their own, slowly replacing the above ground railroads until the modern-day subway systems in use today were developed.

### *History of the MTA*

The MTA is the leading public transport system in the state of New York. Up until the early 1950s, New York was facing an economic crisis that took a toll on its public transportation system, as they had to manage a system with a annual budget of \$50 million, which would be \$500 million today. With no legislation on the public transport system, many conflicts arose in the industry, with independent subway lines competing with private companies. All in all, until the formation of an official transit authority, the state of public transport was in disarray (Gelinas, 2019). The original New York City Transit Authority, referred to as the NYCTA, or the TA for short), was founded in 1953. A public corporation, the TA took full responsibility for public travel in New York City, including all city-owned buses, trains, and trolleys in use at the time (Cook, 2016). However, the modern-day Metropolitan Transit Authority did not emerge for another decade and a half. Within this fifteen-year period, many advancements were made to improve the New York public transportation structure, including new track connections in the subway,

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discontinuation of trolley cars, air conditioning in trains and buses, and extensions for both the subway and city buses (Cook, 2016). Despite these accomplishments, the fiscal deficit had hardly improved. The TA was able to borrow against future revenues and purchase any needed equipment for public transit. The TA's independence was intended to introduce a sense of "fiscal discipline" to create a fare rate that would be self-sustaining for the subway. Despite these measures, this authoritative structure of the TA ultimately failed. With maintenance costs rapidly escalating, the fare that the TA originally hoped to be "self-sustaining" was unable to cover the costs of running the system. In fact, the significant gap between the costs and the profits continued to grow. In order to salvage the situation, the New York state government needed to step in (Gelinas, 2019). In 1968, the MTA was finally created by Governor Nelson Rockefeller and the New York Legislature. This newly created organization oversaw twelve New York counties, and was identified as the parent agency to the New York City Transit Authority (Cook, 2016).

Although the MTA was created to help the New York transportation system reach financial stability, public transportation ridership decreased drastically when the MTA was first introduced. The initial plan of action was to increase the fare from twenty cents to thirty cents, as the previous "self-sustaining" fare plan was deemed ineffective. Immediately after the fare increase, the MTA saw a drop in public transport ridership. The fare increase was designed to help shrink the large financial gap between the MTA's expenditures and revenue. . . However, the increase did not have the effects its proprietors hoped for. The fare discouraged ridership, and New York public transport hit its darkest point. The subway in the 1970s was underfunded and under maintained, as it was very dirty, covered in graffiti, and had a high crime rate. Many upgrades and maintenance arrangements that were established in the 1960s under the TA were suspended during the 1970s. In 1979, persuaded by the high rate of crime in the New York City subways, Mayor Ed Koch organized a panel to discuss solutions to the rapidly worsening transit crisis. In the coming decade, the MTA was able to make drastic improvements. The corporation was able to create graffiti-free, stainless steel train cars, an improved lighting system, and a new force of police officers to ensure fewer crimes on the subway. As a result of these improvements, ridership began to increase. In the 1990s, the MetroCard was introduced, discontinuing the subway tokens that had been used up to the point; this made riding the subway and other transportation services more efficient. Many further improvements were made to MTA t services, with new technological improvements, more attentive law enforcement, safety measures, subway line expansions, and new subway routes created (Ormsbee, 2004). Today, the MTA has evolved to be the leading state-wide transit system, carrying an average of 5.5 million New Yorkers every weekday.

### **MTA Budget in the Past**

In the past, the MTA budget has been severely criticized, with increased spending correlating to increased debt. Back in 2007, a projected \$800 million deficit was on course to reach \$1.1 billion in total losses by 2010. Yet, after the economic crash of 2008, this "expected-dent" in financial planning skyrocketed. Since then, many efforts have been made to restore the workforce and transport system. In 2008, plans were made to increase the retirement age, allowing for less MTA workers to be employed.

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Similarly, over \$200 million in pension payments were given out as soon as possible, with risks of inflation looming. While pre-purchase agreements for fuel and metallic parts were able to save over \$300 million that year alone, the situation only got worse by 2010. Two years later, the MTA budget began taking more hits alongside revenue losses. To compensate for this, EZ created fines, bus subsidy reductions and utilized Inter-Agency loans.

However, no improvements were made. By 2017, national federal aid to the MTA reached over \$4 billion, yet layoffs alongside severe service cuts were made. In 2019, Long Island RailRoad President Phil Eng even defended service cuts, which saved only \$15 million yet offended all 4 counties. In the last 2 decades, what has become most intriguing though is the supply chain of the MTA's money. Now, dedicated taxes make up approximately 40% of the budget, when they only accounted for 31% in 2013. The same goes for local and state subsidies, which have greatly risen since farebox revenue has lessened. Over 15% of the MTA's total budget, or \$675 million, went into debt payroll as of 2020. The developing issue of paying off this debt is a persistent issue in any MTA financial decision, hence the impractical and delays of multiple vehicles across New York City. While more money goes to overtime wages and pension plans, it seems as if labor and production is on the decline.

### **Present Day Situation/Present Day Budget**

Currently, the MTA system, like all businesses, follows COVID-19 regulations to keep citizens nationwide healthy. The MTA schedule remains the same, but following the coronavirus regulations, the MTA suggests that riders should keep their mask on at all times, use hand sanitizer frequently, social distance from other riders, and, if possible, travel during less busy times. Additionally, New Yorkers and public transportation users in North America can find what the MTA does to follow coronavirus regulations on their side from reading the MTA service website. The website states that the MTA continues to deep clean all stations and vehicles, reminds riders to be precautionary towards the pandemic, and has available masks and hand sanitizers at each station to ensure all passengers are healthy and safe (*MTA Service during the Coronavirus Pandemic*, 2021). When the pandemic hit, the MTA suffered many losses and had to change the system, budget, and policies altogether. From the beginning, some of the most significant problems were a lack of precaution for the coronavirus and an increase in delays. For instance, a New York Times article from April 2020 discusses a vast number of MTA workers who died or got sick due to the virus. Specifically, due to the pandemic's sudden hit, 41 transit workers died, and at least 6,000 fell ill. This led to an unexpected crew shortage for the MTA. That same month, there were over 800 subway delays, and over 40 percent of train trips were canceled in a single day (Goldbaum, 2020). Now, the delays have decreased since last year, and there are many more precautions and safety regulations that followed, unlike the previous year. However, one major conflict currently discussed is the MTA's interchanging and conflicting budget that has been contested for many years. For the past year, the MTA was set on increasing the fee for passengers to ride trains and buses from \$2.75 to \$3.00, as well as hiking up the price for purchasing a MetroCard from \$1.00 to up to \$3.00 (Chung, 2021).

As mentioned previously, there currently exists massive budgetary and cost inefficiencies within the MTA. First, we see these massive inefficiencies when looking at the lack of adaptability for adjusting to various situations. We saw this firsthand for 2020 and the impacts of coronavirus on ridership in the MTA. The average daily ridership for the MTA in 2019 was at around 5.8 million

passengers per day. However, in 2020, the average daily ridership for the public transport system had plummeted to only around 1.5 million daily passengers (MTA Info, 2021). Despite this massive fall, the MTA budget did not decrease at all to account for this. In 2019, the budget for the MTA was \$16.7 billion. In 2020, the budget was \$16.9 billion. In 2021, the proposed budget is \$18.4 billion. We see that even through a nearly 70% decline in ridership, the actual cost of the MTA has only increased (MTA Budget, 2021). Decreased ridership would indicate decreased maintenance costs, as less people would be using the public transportation system. However, we did not see a decrease in non-labor related expenses, although they were not the main factor that contributed to a rise in MTA cost. The 10% increase in MTA expenditures from 2019 to 2021 were due to a nearly \$1.5 billion increase in labor costs. Overtime costs experienced an increase of nearly 50 percent, while payroll costs had only seen a 3.5 percent increase. Health related costs saw a ten percent increase, and other labor related costs saw a 50% increase as well. This massive upsurge in labor costs and lack of ability to adjust to outside events has played a large role in the many inefficiencies of the New York City Public Transit system.

### **Labor Situation**

Issues of labor and maximizing the efficiency of MTA workers has also become a prevalent issue. The Transport Workers Union is responsible for ensuring that the rights of urban transit workers are protected across the country, but the Local 100 is specifically responsible for ensuring that MTA workers are fairly compensated for their work. Under pressure of the Local 100, the MTA often hires many more workers than is needed for certain maintenance jobs, causing the costs of labor to skyrocket. In addition, the MTA's train system still relies on an Automatic Block Signaling (ABS) system, which essentially divides the train tracks into "blocks". When a train is in a "block", no other train can be in the same one, slowing down trains significantly. Opting into a Communications Based Train Control (CBTC) system, which makes use of telecommunications between the train and track equipment to allow trains to move faster, would greatly improve the efficiency of the MTA system. Looking into semi-automated train systems, which would allow the MTA to hire less workers and therefore cut down on exorbitant labor costs, may also be a solution to the MTA's massive debt problem.

### **Modern Day Problems**

Among many economic issues, the MTA system in New York City suffers from pollution and unintentionally provides shelter for the homeless population. Intensified by the coronavirus pandemic, these problems affect the everyday lives of commuters in the city. Littered trash contributes to about 700 fire-related incidents every year on the tracks. The trash also causes flooding in the water system, where water flows because of the sewer system. The water build-up can affect train signals and can even impair the electrical system used to keep trains running. These problems cause major delays and can even stop an entire line for up to days at a time for repairs. This does not include the lack of sanitation in the cars and between. The cold temperatures force many homeless into the ventilated subway cars as a place to sleep and even ride endlessly. Not only do people sleep on the trains, but some use the tracks in place of a toilet. This is dangerous not only for passengers but MTA workers as well. As of October 25th, 2020, 126 MTA workers have died from the coronavirus. Rats have also been forced to seek a new

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food source in the subway stations because of the closed restaurants. According to ABC7NY, New York City is the “3rd rattiest city”. This lack of hygiene and close proximity is not only dangerous but affects the number of people who want to use public transportation over other modes.

The MTA also deals with financial problems within the system. They have required emergency funding and need billions of more dollars to keep running, which includes major changes to the existing schedules. In order to keep the system running, an estimated 7200 people would lose their jobs amid the pandemic. Bus service would need to be cut by up to 40% and wait times for subways could drastically rise. This economic crisis also stands to affect commuters from outside the city. Specific routes would need to close entirely. The pandemic has not helped the transit system, as the number of people needing to commute plummeted leading to a loss in fare dollars. A whopping 93% of usual riders stopped using the subways at the beginning of the pandemic. As of September 2020, only a quarter of riders are back; however, riders are hesitant about even going back to the subways after the pandemic. Violence and crime have risen, and dozens of MTA workers have been harassed. Murders have taken place on ordinary train lines like the A train that stretches between 2 boroughs. Hundreds of more police officers are said to facilitate everyday travel, but many still do not feel safe. These modern-day problems only pose more need for change in the question of “How can we make public transportation more efficient in the United States?”

### **Comparison to other US transit systems**

Past research has often focused on supply-side efficiency when measuring the efficiency of a system like the MTA or other worldwide and U.S. public transits. However, by focusing on the demand-side efficiency, researchers can produce more accurate results for multiple reasons. For example, the United States Bureau of Labor Statistics gives an illustrating example by saying “an outside observer would likely consider a bus full of passengers to be producing more output than an empty bus. However, a measure of output based on vehicle hours in service would count them the same (Chansky, 2018). New York City may have the largest transit system, but that does not necessarily mean it has the most efficient system. A worldwide comparison of efficiency that compared overarching urban mobility using five measures of success found that only two U.S. cities made the top ten list. In a measure of “Availability, Affordability, Efficiency, Convenience and Sustainability”, the researchers found that Chicago and New York make the worldwide top ten with Chicago edging New York out by 1.1% (Knupfer 2018). This study showed that New York’s system is lacking in efficiency in comparison to the rest of the world and is not even the most efficient in the United States.

A study by the Mineta Transportation Institute triangulated New York’s public transit system to a ranking in comparison with other states. A transport system is present in almost every densely populated city in America, and each one has differences in its operating technique. Public transport systems around the United States have different amounts of privatization, different operating budgets, and different goals. Privatization has been heavily suggested as an improvement in many public transport systems, and the subject of many research studies and debates, but there has not been a significant correlation between the amount privatized and

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efficiency. Other factors that go into a public transport system's efficiency are if the system is state-owned or city-owned, the types of transportation vehicles it uses, and the size of its workforce. McKinsey approached their experiment by finding a value for the Super Efficiency of each state. "Super Efficiency" was calculated by dividing the Technical Efficiency of the public transport system by the Pure Technical Efficiency. New Hampshire had the highest by far, with 1.875. The scores slump down after with Wyoming having 1.225, Mississippi having 1.009, and then finally New York having a score of 1.003. The results showed that mass transit systems that made use of van-pooling services or Ride-Share programs tended to perform better, whereas mass transit systems that used light-rail heavily tended to perform poorly (Hokey, 2017). All of the top performers also tended to be open to partnerships with private enterprises. Commuter rail and demand response taxis tended to create greater efficiencies than other modes of public transportation such as trolley bus and light rail. The study further showed that privatization of mass transit systems did not necessarily improve efficiency. The study showed that the efficiency of a public transport system is often attributed to the vehicle types used.

The MTA is the leading public transport system in the state of New York. Founded in 1965 by Nelson Rockefeller, the MTA continues to carry an average of 5.5 million New Yorkers every weekday, helping them commute to their homes, school, work, or anywhere else (Zhang, 2015). Despite the accolade of being the top transit authority in one of the most densely populated cities in the world, the MTA is still very far from reaching its potential for maximum efficiency. The average commute time in New York City averages 53 minutes, taking the place as the city with the longest average commute time, while San Diego has the shortest average commute time in the United States, with an average of 26 minutes (Metro Magazine Staff, 2019). New York is also identified as the least reachable city in the United States, with only 4% of commuters being able to reach the city in less than thirty minutes due to the incredible traffic from regulars and tourists and 6% of public transportation riders being able to reach the city in under thirty minutes (Metro Magazine Staff, 2019). Compared to Minneapolis, identified as the most reachable city in the United States with 31% of public transport riders being able to reach the city in under thirty minutes, New York seemingly can improve significantly. The costs of building and maintaining this transit system are staggeringly high compared to other major cities around the world. The Second Avenue Subway took \$1.7 billion per kilometer to build, while the MetroSur line in Madrid, Spain, took \$58 million per kilometer, a much lower cost than the construction of the Second Avenue Subway (Sisson, 2017). With these various other large cities being able to incorporate their public transport array so efficiently, it raises the question: How can the MTA learn from this and make public transportation more efficient?

### **Material & Methods**

We will collect data from two cities in each of the fifty states in the United States. In order to determine the efficiency of a city's public transportation system, the number of passengers transported daily by the system will be divided by the overall number of commuters. This number will then be divided by the median commute time in that city in order to determine an efficiency rating for that city. We will also collect data on average snowfall, total budget, and average spending per capita in order to determine whether weather conditions and a city's funding have an effect on that transportation system's efficiency. All data will be compiled using

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records from the United States census, as well as records from each city's transportation authority and weather data from each region.

**Efficiency= (number of passengers transported daily/total working population)/median commute time**

**$E=(P/W)/M$**

P=Number of passengers transported daily

W=Working population

M= Median commute time

New York City is only one of many cities across the world that use public transportation systems. This research study will choose other cities to compare to base on similar population sizes. New York City has a population of about 8.5 million across the 5 boroughs, which is significantly more than most cities with public transportation in the US. The cities with the closest consumer usage to New York, which is 56 percent, are Jersey City, Washington, Boston, and San Francisco. Out of these 19 cities, only some are useful for accurate testing because some have spent more on public transportation than others, and typically those that spend more are better. These cities must be close to or less than that 15 billion dollars per year that the MTA spends on transportation.

Public transportation has been around for a very long time and is very beneficial to millions of Americans to the point where it has become a lifeline for them. With public transportation, civilians from all over the world are able to connect with people and places. As well as bringing connections and transporting individuals to their desired destinations, public transportation eases traffic congestion and promotes a cleaner environment, according to a publication made by the American Public Transportation Association. However, since transport systems are so important to society, how many commuters are there that use public transportation such as trolleys, trains, buses, cable cars, etc? Statistics show that in 2019, 9.9 billion trips were made by Americans, using public transportation. Additionally, since there are many ways, we can utilize public transportation in our lives, our statistics will show the main transit systems used by American workers, students, and others. For instance, according to a Bloomberg CityLab report, only five percent of American commuters use transit daily to get to work. There are many statistics shown on a vast range of websites, reports, and publications, this will help us conduct our survey as well as ask around how beneficial public transportation is for you.

In order to compare the efficiencies of cities around the country, there are many factors we need to consider. One of these factors is the distribution of public transportation throughout a given city. For example, New York City consists of 5 boroughs and reaches out further into the tri-state area. However, the availability of stations is much larger in Manhattan. This inequality between areas is not uncommon when considering major cities. The layout of stations also affects minority communities directly. Because of this, we will be using maps of bus, train, subways, and other modes of public transportation in different cities to evaluate the number of passengers that need more resources in order to get from place to place. This will include the lines and stops and the percentage of land that is covered in the specific city. Across the United States, different transit systems have countless variables that influence efficiency and differentiate their systems

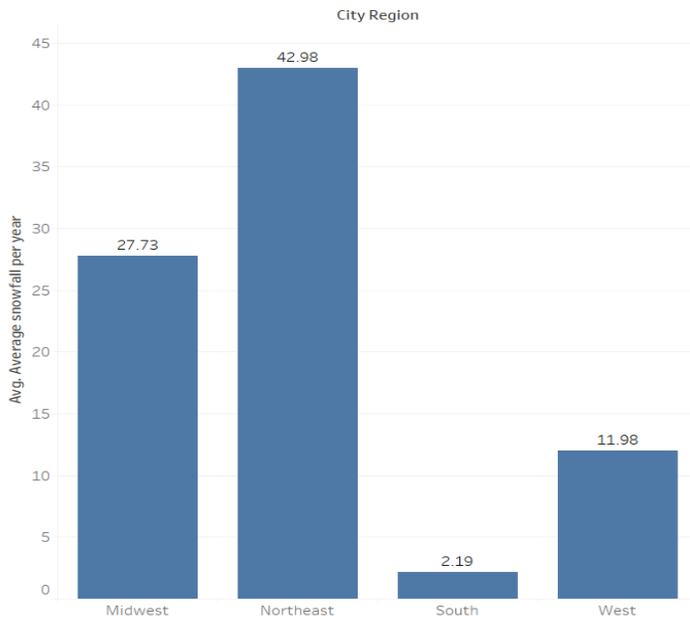
from others. A transit system has the choice of using countless different modes of transport. New York City, for example, has buses, railroads, subways, e-bikes, and ferries. Other systems like San Francisco and Boston have light-rail trolley or tram systems. The combination of choices of different modes of transport is a vital variable in changing the efficiency of a transit system. Light-Rail has been shown to have a strong correlation with lowering the efficiency of a transport system. This can be attributed to their low speed and low capacity. Railroads and subways, in comparison, are considerably faster and make less stops while transporting more people. Light-Rail also brings risks and setbacks, as there is always a risk of a pedestrian being in the way of or hit by a tram or trolley. This risk is much greater in trolleys/trams than in railroads and subways, as they are incorporated into pedestrian walkways. This directly brings a higher risk in delay time, thus lowering efficiency. Meanwhile, ridesharing means of public transport has been shown to correlate with increased efficiency. While the public bus is the most common ride-sharing method, there are other methods such as vanpooling that has been incorporated in cities across the world. Measuring the most common mode of transport of a transit system produces valuable, usable data. We can compare our measured efficiency with the most common mode of transport and see if we find patterns across different cities. If the least efficient transit systems all have the same primary mode of transport, we can suggest increases based on this data.

We must take the average snowfall of a given city, in order to see if this could be a cause of their extensive delays. We will go city by city, finding the average snowfall for each. Certain cities, such as those in the Northeast for example, experience much more snow than hotter cities, like those in the Midwest. Finding a statistically significant correlation between average snowfall and efficiency will show if snowfall is a factor that we must consider when comparing efficiencies across different cities. If there is no statistical significance between average snowfall and efficiency, then we can compare efficiencies without considering their respective snowfalls.

We will be using the various data derived and discussed in the above paragraphs to find our E value, the efficiency of various public transit systems. Having this value as just one value, yet a concrete one allows us to have a simple platform that compares the various public transit systems. Through relying on only one value, our data will be much easier to examine, understand, and also replicate. The higher the efficiency value for each city, the more efficient its public transit system is according to our study. If the New York City Public Transit System has a higher E value than Chicago's public transit system, this means New York City has a more efficient system. If a city has a higher E value when compared to the other evaluated cities, we will then focus on which of the individual variables discussed above has caused the city in question to have a higher E value. Through a further dissection of this individual variable, we will then be able to produce an explanation for why each city had a higher, or lower, E value than another city. Through this method, we will be able to pinpoint the exact reasons for why one public transit system is more efficient than another public transit system.

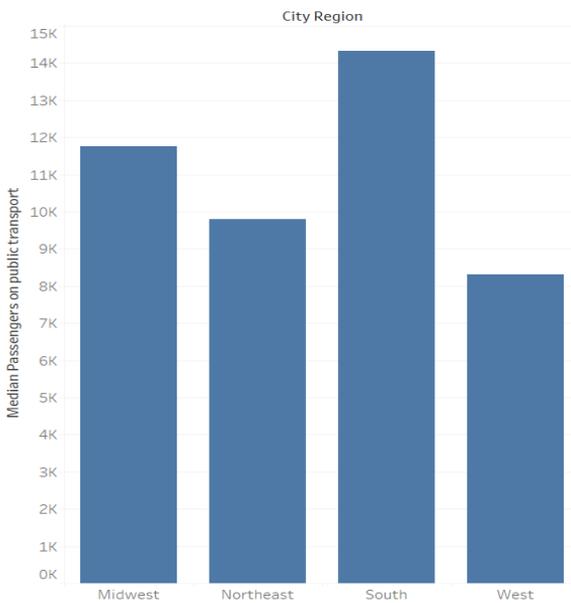
## Results

Region and Average Snowfall



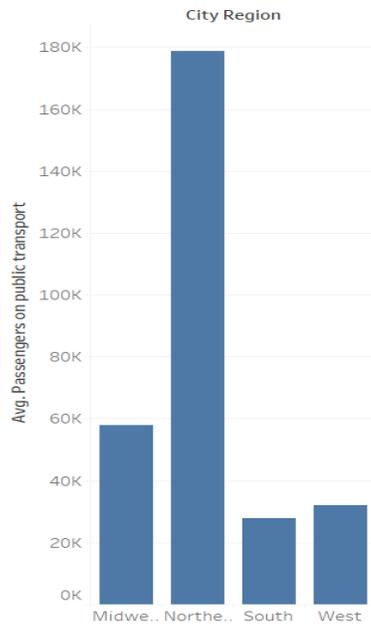
*Average snowfall per region according to our data*

Region and Passengers on Public Transportation



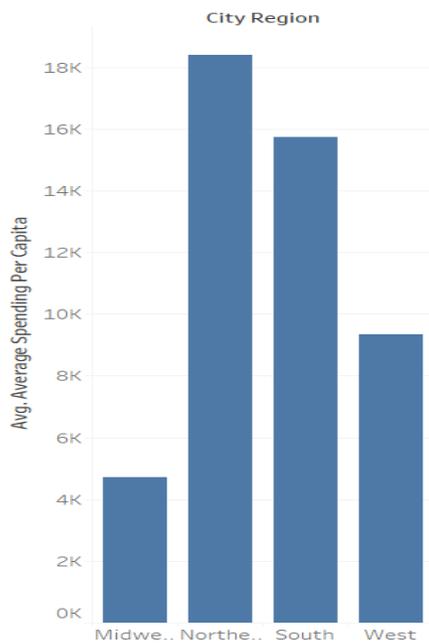
*Median Number of passengers on public transit*

### Region and Passengers on Public Transportation

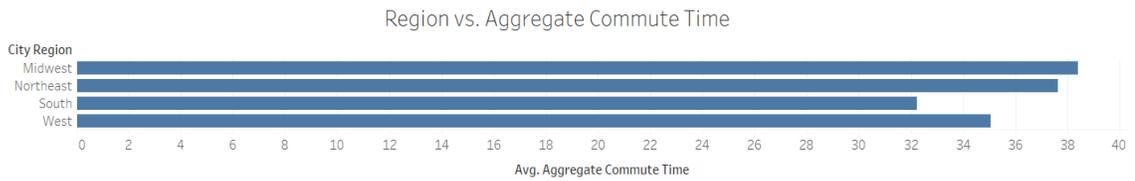


*Average number of passengers on public transport by region. Compared to the previous graph, the Northeast has much more commuters due to large outliers like NYC. However, we saw in the previous graph that when excluding outliers by looking at medians, the south has more commuters in its cities.*

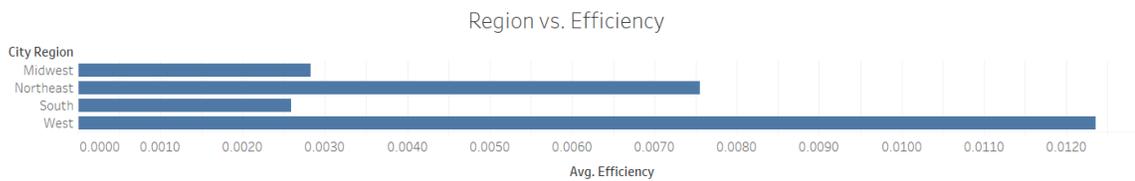
### Region and Spending Per Person



*Spending per person for public transport by region.*



*Regions by average aggregate commute time. The Midwest has the highest times, followed by the Northeast, West, and South*



*Efficiency levels by Region.*

**ANOVA**

ANOVA - Aggregate Commute Time

Cases	Sum of Squares	df	Mean Square	F	p
City Region	1902.917	3	634.306	6.799	< .001
Residuals	33772.513	362	93.294		

Note. Type III Sum of Squares

In this figure, we can see that the City region has a significant correlation with average commute time, as our p-value is less than 0.05, which allows us to reject our null hypothesis.

## Descriptive Statistics

### Descriptive Statistics

	Average snowfall per year				Aggregate Commute Time			
	Midwest	Northeast	South	West	Midwest	Northeast	South	West
Valid	81	100	70	100	96	100	70	100
Missing	19	0	0	0	4	0	0	0
Mean	28.839	42.805	2.010	14.490	38.390	37.625	32.214	35.050
Std. Deviation	17.789	26.799	3.969	21.800	9.406	9.817	3.529	12.296
Minimum	0.000	4.800	0.000	0.000	27.000	22.000	27.000	17.500
Maximum	92.760	151.800	22.200	72.800	60.000	52.000	39.500	60.000

Note. Excluded 1 rows from the analysis that correspond to the missing values of the split-by variable City Region

We see in this figure the average snowfall and commute time per region. The regions in order of most snowfall to least was Northeast, Midwest, West, and South. The regions by order of average commute time from greatest to least were Midwest, Northeast, West, and South.

### Descriptive Statistics

### Descriptive Statistics

	Efficiency				Total Working Population			
	Midwest	Northeast	South	West	Midwest	Northeast	South	West
Valid	96	100	70	96	100	100	70	100
Missing	4	0	0	4	0	0	0	0
Mean	0.003	0.008	0.003	0.012	267930.190	342681.850	455132.529	377412.210
Std. Deviation	0.005	0.010	0.009	0.014	296291.482	867079.412	234026.429	433569.451
Minimum	3.409e-5	5.640e-4	1.720e-4	1.087e-4	95227.000	23851.000	130216.000	55403.000
Maximum	0.025	0.050	0.074	0.080	1.586e+6	4.073e+6	1.128e+6	2.021e+6

Note. Excluded 1 rows from the analysis that correspond to the missing values of the split-by variable City Region

The regions by most Efficient to least are the West, Northeast, and South tied with Midwest. Regions with highest average working population in cities from greatest to least are South, West, Northeast, and Midwest.

### Descriptive Statistics

### Descriptive Statistics

	Average Spending Per Capita				Passengers on public transport			
	Midwest	Northeast	South	West	Midwest	Northeast	South	West
Valid	93	99	64	42	100	100	70	100
Missing	7	1	6	58	0	0	0	0
Mean	4714.283	7929.497	14752.291	9336.403	54057.460	179218.720	27578.286	148259.720
Std. Deviation	6229.485	12117.508	13566.318	8442.919	131841.651	602688.180	51334.302	192350.534
Minimum	3.000	647.930	1140.860	30.420	179.000	1592.000	1486.000	303.000
Maximum	33837.600	96757.470	90927.260	32152.140	530573.000	2.788e+6	378255.000	834179.000

Note. Excluded 1 rows from the analysis that correspond to the missing values of the split-by variable City Region

Regions from greatest to least spending per public transportation use were South, West, Northeast, and Midwest. By public transportation mean users from greatest to least, the regions are West, Northeast, Midwest, South (the Northeast and West are much larger here due mainly to large outliers such as Los Angeles and New York City).

### Data Analysis

*Formula:*

$$\text{Efficiency} = \text{Passengers on Public Transport} / \text{Total Working Population} / \text{Median Commute Time}$$

In order to interpret the effects of numbered variables, we utilized a linear regression test on all data values of all years on efficiency values. We see that the correlation for number of passengers on public transport ( $p < 0.001$ ), total working population ( $p < 0.001$ ), average spending per capita ( $p = 0.018$ ), and city region all have a significant correlation with efficiency. However, average snowfall per year was found to not be significantly correlated with the efficiency. More evaluation on every variable will be given in the following paragraphs. Interestingly, we found that as spending per capita increased, efficiency decreased. All the appropriate correlation values can be seen in the following chart with the unstandardized values.

Model Summary - Efficiency ▼

Model	R	R <sup>2</sup>	Adjusted R <sup>2</sup>	RMSE
H <sub>0</sub>	0.000	0.000	0.000	0.013
H <sub>1</sub>	0.422	0.178	0.166	0.011

ANOVA

Model		Sum of Squares	df	Mean Square	F	p
H <sub>1</sub>	Regression	0.008	4	0.002	15.465	< .001
	Residual	0.037	286	1.305e-4		
	Total	0.045	290			

Note: The intercept model is omitted, as no meaningful information can be shown.

Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
H <sub>0</sub>	(Intercept)	0.005	7.334e-4		7.415	< .001
H <sub>1</sub>	(Intercept)	0.008	0.001		6.468	< .001
	Passengers on public transport	2.612e-8	3.719e-9	0.776	7.024	< .001
	Total Working Population	-1.372e-8	2.377e-9	-0.651	-5.775	< .001
	Average snowfall per year	1.388e-5	2.768e-5	0.029	0.502	0.616
	Average Spending Per Capita	-7.234e-9	3.036e-9	-0.129	-2.382	0.018

### Total working population compared to those who take public transportation

It is important to know if the percentage of people who take public transportation is the majority of the population. If it is, the system is probably efficient and if it is not the public transportation system is not as good as it could be. In this data, the p value is always less than .001, which is less than .005, so it is significant. This means that the system is efficient.

### Population effect on spending per capita (p=0.051)

This section examines if a larger working population means a higher spending per capita. This essentially asks if larger cities spend more per person. For all years and values, we found that there is no significance (p=0.051). For 2019, there still is no significant correlation (p=0.352). For 2018, the correlation was insignificant (p=0.396). For 2017 it was also insignificant (p=0.284). For 2016, it was insignificant (p=0.385). For 2015, it was insignificant as well (p=0.298). This proves that larger cities do not always spend more money per person for public transportation.

Coefficients						
Model		Unstandardized	Standard Error	Standardized	t	p
H <sub>0</sub>	(Intercept)	75399.228	12175.781		6.193	< .001
H <sub>1</sub>	(Intercept)	90202.655	14278.252		6.317	< .001
	Total Working Population	-0.041	0.021	-0.111	-1.961	0.051

### ANOVA ▼

Model		Sum of Squares	df	Mean Square	F	p
H <sub>1</sub>	Regression	7.290e +7	1	7.290e +7	0.595	0.441
	Residual	3.630e +10	296	1.226e +8		
	Total	3.637e +10	297			

Note. The intercept model is omitted, as no meaningful information can be shown.

### Correlation by region

We found that there is a significant correlation between the region of the city being examined and the efficiency of the public transportation system within that city (p < 0.001). We also found a significant correlation between the city region and average commute time (p < 0.001). Average spending per capita also had a significant difference by region (p < 0.001).

ANOVA - Efficiency

Cases	Sum of Squares	df	Mean Square	F	p
City Region	0.019	3	0.006	24.291	< .001
Residuals	0.094	362	2.585e -4		

Note. Type III Sum of Squares

**Snowfall effects on Average Commute Time, Budget, Efficiency**

The effect of snowfall on multiple transit factors is quite clear, as it surely does not affect budget, commute time, or efficiency entirely. First analyzing the snowfall’s p value, it remains greater than 0.05 in all years from 2015 to 2019. Based on this, the success and practicality of transit systems is not impacted by snowfall. Seeing how this relates to budget, the p value for budgets also remains above 0.05 in the majority of years of collected data. In order, it follows with 0.085, 0.084, 0.083, 0.420, 0.032. As 2019 is the only year where snowfall influenced the budget, this outlier concludes that there is some relation to increased budget as well as increased snowfall. Finally, the average commute time on a national basis remains over 0.05 in terms of the p value. For all years 2015-2019, this is depicted. Overall, snowfall does not influence anything in terms of average commute time or efficiency but has recently shown effects on budget plus spending.

The number of passengers has shown to consistently not impact efficiency. In the context of efficiency, there is no shown significance which correlates to the number of passengers. Analyzing the given data, such can be proven consistently. In 2015, a p value of 0.118 can be noted. From 2016-2019 in order, the p value follows with 0.065, 0.075, 0.124, 0.070. In every given year, a p value greater than 0.05 can be noted. All in all, it is evident that the number of passengers does not impact efficiency. No matter how many people board transit, the success of the ride is influenced by other factors.

**How median time travel affects efficiency**

Model Summary

Model	R	R <sup>2</sup>	Adjusted R <sup>2</sup>	RMSE
1	0.010	0.000	-0.003	0.011

ANOVA ▼

Model		Sum of Squares	df	Mean Square	F	p
1	Regression	4.435e -6	1	4.435e -6	0.037	0.848
	Residual	0.043	360	1.200e -4		
	Total	0.043	361			

Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
1	(Intercept)	0.006	0.002		2.822	0.005
	Aggregate Commute Time	1.130e -5	5.879e -5	0.010	0.192	0.848

As seen by the chart above, the correlation between aggregate commute times within cities and efficiency is not significant. We conclude this information because the P value is larger than 0.05. This information includes all of the years collectively. For the individual years, all but 2017 and 2016 show that the correlation is also insignificant. For the year 2019, the P value was 0.054. For the year 2018, the P value was 0.053. The P value of 2017 was shown to be 0.032. This significance was represented in 2016 as well where the P value was equal to 0.008. Finally, for the year 2015, 0.324 was equal to the P value.

**How the number of passengers affects the median commute time**

All Years (p= <0.001)

ANOVA ▼

Model		Sum of Squares	df	Mean Square	F	p
H <sub>1</sub>	Regression	1854.913	1	1854.913	19.964	< .001
	Residual	33820.517	364	92.914		
	Total	35675.430	365			

Based on the chart above, there seems to be a significant relationship between the dependent variable of median commute time and the total amount of passengers. The overall p-value between all the years is shown to be less than 0.001, deeming this correlation very significant. Despite only 2019 and 2015 having p-values that are less than 0.05 (with 2019 having a p-value of 0.027 and 2015 having a p-value of 0.048), this was enough to make the overall p-value be significant. Therefore, it can be concluded that having a larger number of passengers does equate to longer commute times.

**The effect of spending per person on efficiency (p=0.026)**

All Years

ANOVA ▼

Model		Sum of Squares	df	Mean Square	F	p
H <sub>1</sub>	Regression	7.515e -4	1	7.515e -4	4.972	0.026
	Residual	0.046	307	1.512e -4		
	Total	0.047	308			

From the graph above, we determined that the effect of spending per person on efficiency is significant because the P-values of the charts following were all less than 0.05. It is shown that in the years 2016, 2017, 2018, and 2019, the relationship between spending per person and efficiency is significant, which greatly contributed to the P-value in our chart which depicted all the years. In 2015, the data was significant. However, the P-value was 0.024 which is much greater than the P-values in the other graphs that were reported to be less than 0.001.

When comparing the total working population to the dependent variable of average spending per capita, we see a p-value of above .05. Although this number is very close to confirming the two as statistically significant, it is not enough. As a result, we can conclude there is no statistical correlation between total working population and average spending per capita. More research can be done to see if cities with higher population spend more per person, but our research shows there is no correlation.

**Spending per capita compared to median commute time**

When comparing spending per capita to median commute time, we see an R2value of 0.124, suggesting that the two variables have very little correlation. The p value is 0.005, which indicates that this lack of correlation is not statistically significant. Therefore, we can conclude that there is no relation between spending per capita to median commute time, though logically spending more on improving and maintaining a transport system should correlate with shorter commute times, as this would indicate that the improvements made are ones that benefit the customer by decreasing their commute time.

## Linear Regression

Model Summary – Aggregate Commute Time

Model	R	R <sup>2</sup>	Adjusted R <sup>2</sup>	RMSE
H <sub>0</sub>	0.000	0.000	0.000	8.228
H <sub>1</sub>	0.353	0.124	0.110	7.763

ANOVA

Model		Sum of Squares	df	Mean Square	F	p
H <sub>1</sub>	Regression	521.921	1	521.921	8.661	0.005
	Residual	3675.856	61	60.260		
	Total	4197.777	62			

Note. The intercept model is omitted, as no meaningful information can be shown.

Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
H <sub>0</sub>	(Intercept)	35.748	1.037		34.483	< .001
H <sub>1</sub>	(Intercept)	34.831	1.026		33.937	< .001
	Average Spending Per Capita	1.445e –5	4.911e –6	0.353	2.943	0.005

The above linear regressions show the relationship between the aggregate commute time and the average spending per capita

## Discussion

Snowfall affects public transportation budgets and efficiency in several ways. For instance, it affects efficiency because of the delays that snowfall causes. For example, in many cities that don't typically go through snowstorms, even minor snow can cause serious problems. The infrastructure and transportation mechanisms might not be suited to endure these conditions, and most of the time they break down. This can occur in a train system, adding 20-30 minutes to commute time. Secondly, snowfall forces transportation agencies to cancel some routes due to safety. Many above ground vehicles, such as buses, become less frequent. This is due to either the company shutting down the routes for safety because of low visibility and bad traction, or the snow stopping the drivers from getting anywhere. Thirdly, snow has many indirect effects. In places with both frequent and infrequent snowfall, the roads get closed, forcing any available drivers to find new ways to get to the right destinations and making travel time a lot longer. In many cases, these problems or the possibility of these problems stops riders from attempting to take public transportation, decreasing ridership. The second problem with snowfall is that it causes major costs for the companies. Snowstorms make public transportation companies lose money through the loss of fares with lower ridership, having to pay workers even if they aren't

able to work properly or at all, as well as with repairs to any damage to vehicles or machines used in the transportation. Even with the chance of them accounted for, snowstorms cost a lot of money. For example, in New York City, snow is not an uncommon thing in the winter. However, in 2011 a major snowstorm took place, shutting down almost all parts of the MTA, costing them over 30 million dollars, not including repairs. However, it is even worse in places that don't typically get snow, such as cities in Texas and California. Because they do not have the necessary preparations for these light snow falls that occur every few years, it costs them more in reparations than their budgets can handle.

Using our data, we were able to calculate average spending per capita. This was done by dividing the budget by the passengers on public transport. We ran a linear regression and an anova to see if there was a correlation between the number of passengers and the amount the city spends per person on public transport. There was no statistical significance between passengers on public transport and average spending per person. However, we did notice some patterns in the average spending per person when looking region by region. The Northeastern region spent an average of \$27,913.01 per person using their public transport system. The South region spent an average of \$24,152.34, and the West region had an average spending of \$13,454.31. The Midwest region stands out immensely with an average spending per capita of \$123,012.61. This is most likely due to the Midwest having the lowest ridership out of the regions. Areas like New York and Boston in the Northeast have a much higher percentage on average of the total working population riding on public transport than a city in the Midwest, like Lincoln, Nebraska. The same can be said for Southern cities like Washington D.C. which has over  $\frac{1}{3}$  people in their working population using public transport! Another factor to consider is that some regions are willing to spend more on their transport system. Different systems have different levels of efficiency. Light-Rail systems have been shown in previous studies to be the least efficient mode of transport, while subways are considerably more efficient. It is entirely plausible that cities in the Midwest have a much smaller need for more efficient transport systems like subways because their cities are considerably less dense than areas like New York. Subways can provide exponentially more rides and passengers than a tram or trolley system but could be impractical due to the lack of density in midwestern cities. Light-Rail systems have the benefit of being easier to construct and stretch to long distance but carry sizably less passengers. For less dense cities that are found in the Midwest, it makes sense to build a light-rail system instead of a subway, even if it is more efficient and costs more per person. A New Yorker can take the subway many times in a day, as they traverse the city and stop by different sight-seeing locations. Meanwhile, a light-rail system makes more sense for a small midwestern city, who's occupants only rely on public transport to get to work and home. Subways will provide considerably more rides, but the Midwest does not have the density to support running as many lines and stops if they build a subway in the first place. With more riders comes more money spent. New York is willing to spend billions because their citizens will take many more subway rides than a person trying to traverse through his hometown in the Midwest. This institution of less efficient systems is the most plausible cause for the high spending-per-capita of the Midwest region.

In the United States of America, there are many different types of cities ranging from more urban areas to rural. Because of this diversity, there are different population numbers such as New York City which currently has a population of about 8.5 million people (not including the people who commute in and out of the state every day) to 680,000 people in El Paso, Texas. This range in

population however does not necessarily correlate with the spread of people in the city. As New York City is a very dense community it also lies in the Northeastern region. The Northeastern part of the nation contains 11 states. There are 162,257 square miles of land in the northeast. This can be compared to another region, the Midwest. The Midwest has 12 states, and it is 821,000 square miles. The landmass makes the Midwest compared to the size of Mexico. This comparison can also be shown by population. The Northeast contains around 55,982,803 people while the Midwest has 65,000,000. When you divide the population by the square miles for the Midwest, you get the number 80246.9135802. When you use this equation for the Northeast, the number is much smaller: 345.025502752. These numbers represent the disproportional relationships between the population and amount of land throughout the country's regions. This pertains to transit systems as well because some cities will have to account for more areas and more passengers, or vice versa. New York City, for example, takes into account 665 miles of subway lines with countless stops, while the Metro of Washington DC has 117 miles. The population of these respective cities is very different since New York City has around 5.6 million riders daily and Washington DC has 626,000. If we divide the number of daily riders by miles covered by the transit systems, we, once again, will see the disproportional relationship between daily riders and mileage by their underground railroad systems. New York City's quotient to that equation is 8421.05263158 while Washington DC's metro's quotient is 5350.42735043. The difference of over 3000 highlights the disparity between cities across the nation in terms of population, land, and coverage of transit lines.

The use and spending of public transportation are unequally dispersed throughout the entire nation. Reports conclude that New York City/New York spends the most money on public transportation also known as the MTA. The same reports display that 56.5% of New York residents exploit public transportation on a daily basis, "with Jersey City in New Jersey where 47.6% of the residents use public transportation instead of commuting by car being a close runner-up." Now, it is no surprise that New York City has the most people who use public transport because New York City has one of the greatest populations in the nation with a whopping 18,823,000 people occupying the city. Compared to other cities, New York City has a massive population which significantly contributes to the high percentage of public transportation users. In New Orleans, Louisiana, for instance, there is only 7.8% of the population that utilizes public transport daily. This should not be seen as a really low percentage considering its population (998,000, which is almost 18 times smaller than the New York City population) Additionally, the population and the percentage of people who use public transport directly affects the budget and how much each city pays for their public transportation. For example, New Orleans spends \$109 million to run its public transit system as of 2020, compared to New York City which spends so much that the MTA faces an \$8 billion deficit through 2024. Additionally, in comparison, New Jersey, which holds the second greatest percentage of public transport users went from spending \$2 billion to \$2.6 billion for public transport, as of 2020. Another large public transit system to consider is in California. In California, sources display that San Francisco Bay Area, which has a 7.75 million population, has the most effective system in California. California, due to its high population and expenses, has paid \$12 billion in expenses for its public transport system.

The efficiency in this formula of the public transportation of a city is determined by the number of people taking public transport divided by the total working population divided by the median

aggregate commute time. All these factors are affected by how much of the total budget is dedicated to a city's public transport system. Taking into consideration the total budget of some select cities that have a low efficiency can help determine how exactly the total budget might not always increase efficiency. One example of this is the city of Stamford, Connecticut. With a total budget of \$42700058 in 2019, the public transportation efficiency is still at a mere 0.2227085157, despite only 7,997 people taking public transit as their form of transportation. Oddly, this trend continues for the previous five years in Stamford. In 2018, the budget was \$34573016 and had only 8663 people taking public transit, yet still had an efficiency of only 0.2037256147. In 2017, there were 7,278 people taking public transportation and the city had a total budget of \$32389867, but the efficiency was only 0.2415361363. The years 2016 and 2015 had a rather higher amount of people taking public transport, with 10,351 in 2016 and 9,558 in 2015. However, the budget was still in the same range for 2016 and 2015, with \$34278859.00 and 36059530.00, respectively. As a result, despite the slight increase in ridership, the efficiency value still remains quite low, with 0.2222611342 in 2016 and 0.2288397154 in 2015. Other cities, such as New York City, have low efficiency even with a higher number of people taking public transit every day and a higher budget. The efficiency in 2019 is 0.02782031303 despite the total budget being \$3,999,859,000.00. Additionally, the total amount of people taking public transportation is shown to be 2,787,582 people, which is a relatively high number. This same pattern for New York City continues for all five years. 2018 has an efficiency of 0.0277161487 and a budget of \$3999859000. The year 2017 has an efficiency of 0.02809671804 and a total budget of \$2938292071. 2016 has an efficiency of 0.02777412663 and a total budget of \$2,733,958,550.00. Lastly, the public transit efficiency of New York City in 2015 was 0.02786707166, while the total budget was \$2,972,675,796. There is seemingly a trend of low efficiency due to having a high quantity of people despite a large budget dedicated to the public transit system.

When analyzing transport efficiency, data has shown that the number of passengers does not impact the efficiency of these systems. However, the question remains; Why don't certain cities have as many public transportation users? Looking for answers, city population and land area can be referred to. Using recent 2019 statistics, Boston, Massachusetts has a reported 272,835 annual users on public transit. Ranking quite high, this number is accompanied by Boston's total estimated population of 692,600. In 2 the land area, Boston however ranks very little, with only 89.63 mi. On the other end of the spectrum, 2019 statistics for Fort Worth, Texas tell a different story. With a reported 3,022 annual users of public transport, this total comes as a shock. With a general population of 909,585 and a land area of 355.6 mi<sup>2</sup>, Fort Worth in whole is much larger. Yet, its public transport usage is over 90x less than Boston's. Explaining this, a variety of reasons can be noted. To begin with, Vox's article, "*Why US public transportation is so bad — and why Americans don't care*" by Aditi Shirkant addresses the safety issues brought alongside these transit forms. Mentioning uprisings in passenger violence and broken-down train lines all over San Francisco since 2016, she depicts the unreliability of these systems, even prior, a 2014 article by Ecolane titled, "*7 REASONS WHY PEOPLE STOP USING PUBLIC TRANSIT*" addressed some concerns on the end of hesitant passengers. Citing delays due to traffic, overcrowding, and delays due to mechanical failure, this group expressed the variety of difficulties faced by riders. Comparing Fort Worth and Boston once again, the answer to the question presented earlier can be simplified in two ways. First, the compactness and urbanization of major, dense cities like Boston, Washington D.C., and New York City makes public transit

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more practical. In locations like Fort Worth, more rural surrounding and greater distances between locations makes cars the transport of choice. Additionally, the financial surroundings of these two locations varies greatly, with Boston surrounded by major banks, corporations, and higher-priced institutions. Such makes the need for funding less difficult with increased taxes and allows construction to fit growing communication needs. All in all, city population and land area does not impact public transport usage, whereas budgeting, stop-distances, and communication needs all do.

In New York City, the Metropolitan Transportation Authority spends an exorbitant amount of money and spent \$1434.88 per capita in 2019. One would assume that such a large budget would help improve the commute time of the average New Yorker. However, it seems that the variables of spending 2 per capita and median commute time are not correlated. With a p value of 0.124, this indicates that spending per capita does not significantly affect the median commute time in a city. These results are not statistically significant with a p value of 0.005. This lack of a correlation suggests that the budgets of many cities in the United States are not being adequately utilized to improve the customer experience for a passenger on a transportation system. Ideally, the budget per capita should be used to improve transportation by investing in repairs, new train lines, cleaner and new stations, and other improvements that help shorten commute times. Especially in New York City, where the MTA is heavily relied upon by millions of people, this linear regression suggests that the MTA needs to reevaluate its budget and what it is spending money on. Unnecessary repairs and improvements, high labor costs, and other expenditures may be causing this lack of correlation between spending per capita and median commute time. Though it is important to note that some cities will inherently have larger commute times due to the “suburban sprawl” in the region or distance of certain neighborhoods from the city center, working to improve the relationship between spending per capita and median commute time is a surefire way to improve the efficiency of a city’s transportation system. More research must be done on the individual budgets of the transportation systems of cities across the cities in order to evaluate what adjustments can be made in order to achieve this goal.

### **Limitations**

In this conducted data collection study, it is possible that the budget records for some of the smaller cities are not fully up to date, affecting the analysis of the budget per capita. A lot of smaller cities fall into a larger public transportation system. The MBTA, for example, does not only service Boston. Cities like Cambridge are also a part of the MBTA, and this led to no official budget for the city of Cambridge. Estimates were made based on publicly available information. Although websites like the Census were used in order to solidify accurate values for the working population and aggregate commute time, there is no common database for budgets of all of the various transportation authorities in the United States, which may potentially cause disparities in the ways the budgets were reported. Certain budgets had to be recorded based on pdfs of a city’s budget plan, while others were listed on websites and information guides specifically posted by the transit system. The MTA makes their budget available, and so does Albany, but cities in between the two had no information on their transit system’s budget. This limited our choice in cities, affecting the creation of our list of cities for each region, and the development of the average spending per capita variable. In addition, the total working population often did not account for out-of-state travelers or even out of city travelers. Cities like Newark had a median commute time of 39.50, as many of their citizens travel long distances to

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New York City for work. There is no statistic on how many people travel out-of-city to work, only a statistic on the working population living in a city. In a similar vein, median commute times do not necessarily indicate that a city's transportation system is inefficient, as geographic factors also play a role. In cities with more "suburban sprawl", such as Los Angeles, commute times will naturally be longer, as it will take more time for commuters to cover longer distances. The United States Census records used to collect data on the total working population and on public transportation users only accounted for those over the age of 16; however, many children under the age of 16 use public transportation and are not accounted for with these statistics. Although one website was used to recover data for each city in this study, some cities did not have readily available information for each year. Because of this, some cities may have recorded the annual snowfall average rather than the total for each year individually. It is important to address these limitations when considering this investigation; however, this does not undermine the overall conclusion of the data recorded.

Although, according to this investigation, the train systems of the Northeast contained the most efficient transit systems in the country, this does not directly correlate with rider satisfaction. There are still countless issues with the MTA, including cleanliness, delay times, and overall infrastructure of the underground train system. Studying transportation systems in depth across the country will allow New York City to replicate the benefits that are found in the transportation systems of various cities. The MTA has no shortage of problems, and it is important to recognize that solving these problems requires a multifaceted approach to address different parts of the MTA's shortcomings. Ensuring that all reforms made focus on helping the commuter, from shortening commute times to increasing the quality of subway cars and trains. Reallocating parts of the MTA's budget to address these important issues will help increase ridership. Raising the fare is not the answer, as this will only deter New Yorkers from using MTA services. It is essential that the government and the MTA reevaluate their expenditures in order to ensure that the system can continue to run more efficiently in the years to come.

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