Urban Mobility: Comparing government funding's impact on public transportation systems, bus and rail, throughout the Bay Area

Climate change is the largest continuous threat to humanity's survival and ability to maintain or improve our quality of life. The root cause is fossil fuels and global warming. Fossil fuels have a large presence in our energy grid and transportation – two institutional frameworks deeply ingrained in human life. In California, 40% of all the emissions come from transportation, the largest single source of pollution in the state. While electric vehicles are becoming more popular, they do not change the car-dependent culture that causes congestion, emissions, and traffic-related dangers.

According to a recent study by the Washington Post, the annual GHG emission from the average U.S. commute is 1,814.82 kg of CO2e. Compare this to other activities like annual personal digital activities (193.72 kg of CO2e) or eating 1kg of beef (60kg of CO2e). While driving is ridiculously bad for the environment and expensive for the consumer, current public transportation systems aren't much better. Public transit trips almost always take more than twice as long as driving and can be quite costly, especially if for daily commuting and spanning longer distances.

This study will examine whether there is a relationship between transit funding and ridership. Specifically, if there is a positive effect of funding on ridership, and if there is a difference between buses and rail in the Bay Area. After collecting ridership data from the American Public Transportation Association (APTA) and fiscal funding information from the agency's annual reports and standardizing for population changes and inflation, regressions on Stata show a small but significant positive effect for buses but no significant effect for rail.

Context

California is pushing a mandate to have all cars sold by 2035 be electric vehicles. While that addresses carbon emission concerns, it doesn't reduce congestion or VMTs (vehicle miles traveled, number of cars times distance traveled), the standard way of measuring driving quantity. A solution to this problem is getting drivers to take public transit instead of a car when possible. Unfortunately, there is a perception of public transit being dangerous or for "poor" people, which discourages riders. Public transit often takes much longer than driving, and can be expensive. However, other countries in Europe, China, Japan, and Singapore have successfully developed their public transportation infrastructure to be many people's primary mode of transportation. A key difference between these places and the United States is land use and city density. The dense geography of their city, combined with land use planning that puts stores and schools nearby, allows people to capitalize on public transportation as the most time and cost-efficient mode of transportation.

In California, SB 375 “requires the integration of land use and transportation planning to reduce GHGs from VMTs”, a key step in creating sustainable cities. But with large suburbs already established in California, cities will need large scale infrastructure changes to model this. This includes transportation infrastructure, with improvements to route expansion, facilities’ quality, safety, and speed to motivate drivers to switch to public transit.

Unfortunately, public transportation improvement projects are very costly – requiring millions of dollars to purchase new equipment, construct subways and stops, and hire additional transit operators. To keep fares inexpensive, very little of transit agencies' revenue comes from fares; most comes from taxes and government grants. However, money that comes from the federal government can only be used for “capital projects”, meaning purchasing equipment or construction projects. Federal money cannot be used for operating costs and safety measures like law enforcement presence, violence monitoring systems, and criminal activity response, making a large gap in available funding for equipment, but having insufficient funds to operate it. This year, Congressman Mike Lawler (R-NY 17) introduced the Transit Funding Flexibility Act

(H.R. 5024) of 2025 to give the transit agencies free use of federal dollars. This bipartisan bill would also unlock more funding to address common safety concerns that drivers cite as a deterrent to public transportation.

Literature Review

A key piece of information on understanding how to reduce driving is measuring VMTs and what impacts VMTs. In the 2000s, researchers studied how public transportation influences VMTs. Sabouri et.al use a mathematical model and household database surveys to conduct complex analysis using equations for direct effect and indirect effect on VMTs. This shows that to achieve transit, cities must provide an alternative transportation option (bus or train), and/or promote efficient land use patterns that encourage active modes of transportation. An example of this is city density that increases walkability and other modes of active transportation (Sabouri et.al 2024). This is the main assumption my paper uses: public transit usage is directly related to a reduction in VMTs.

Holtzclaw researched something similar when he researched the Bay Area’s metropolitan cities and compared VMTs to their suburban counterparts. By comparing transit passenger miles (passenger times miles traveled) with VMTs across cities with different densities, he established that land use and density changes are the most effective means to reduce driving. Holtzclaw suggests mixed reforms to transit systems and zoning to allow pedestrian-friendly developments in communities. Aside from the temporal scope being vastly different from my study, he compares transit passenger miles to VMTs, while this study compares funding to ridership. By looking at funding's impact on ridership, knowing ridership's impact on VMTs, we can draw a connection between funding and VMTs. Therefore, we can make policy recommendations to provide funding to or unlock funding (H.R. 5024) for transit agencies to reduce transportation-related carbon emissions.

From a broader research perspective, this aligns with findings that unstable or insufficient operating funding directly reduces ridership through lower quality service and increasing fare costs. Brookings and the Hamilton Project similarly argue that this relationship reduces ridership and allows driving to consistently outcompete public transit (Turner 2019). Knowing what discourages public transportation is also crucial to improving it. California transit agencies experience many budget concerns, the largest being the state budget deficit. According to Calmatters, around 50% of agency funding comes from the state, but the state's budget constantly changes, sometimes forcing transit agencies to increase fares. This primarily impacts lower income people, making budget shifts at the state level disproportionately impact already disadvantaged populations. Unfortunately, raising fares is a way to combat this, but unpopular and discourages some riders (Calmatters 2023).

Sabouri et. al and Holtzclaw address how land use is important in predicting transit ridership, while others address challenges agencies face in increasing ridership. But few studies examine the direct effect of funding on ridership in Bay Area agencies, highlighting an information gap.

Theory and Hypothesis

Existing theory suggests public transit ridership is heavily influenced by factors like accessibility, service area, safety, quality, population density, and infrastructure. In particular, buses have simpler infrastructure and the flexibility to reach more places. Buses also have a larger service area, with the ability to serve more neighborhoods and adapt to changes in demand. This means a more effective public service system. Rail has fixed infrastructure and less ability to service certain geographic areas due to construction limitations. For these reasons, funding will have a greater impact on ridership compared to rail. The Public Policy Institute of California also says buses are more successful at increasing ridership because bus riders are former bus drivers, while rail riders are former bus riders – so there's no decrease in VMT from the group that shifts from buses to rail.

I hypothesize that increased funding for bus transit systems will result in a larger increase in ridership compared to equivalent funding increases in rail systems. Specifically, hypothesizing that an increase in funding will result in a greater percent change in ridership for buses compared to rail, because the funding will allow for the expansion of routes, more frequent service, and more accessibility in a more economically efficient fashion.

Research Design

To analyze the impact of funding on ridership for buses and rail, data was collected from the Bay Area transit agencies because of their extensive overlapping systems with an abundance of online recorded information. The unit of analysis is the transit agencies (seven in total), over the span of fiscal year 2009-2010 to fiscal year 2023-2024, making the full design a panel design.

Bus Agencies:

- Alameda Contra Costa Transit District (AC Transit)
- Eastern Contra Costa Transit Authority (Tridelta Transit)
- Central Contra Costa Transit Authority (County Connection)
- San Mateo County Transit District (Samtrans)
- San Francisco Municipal Transit Authority – Bus (SFMTA).

Rail Agencies:

- Bay Area Rapid Transit District (BART)
- San Francisco Municipal Transit Authority – light rail (SFMTA)

The San Francisco light rail was included with rail since the San Francisco light rail infrastructure includes subway tunnels and underground platforms for light rail. The complexity of underground infrastructure is a key aspect of the causal mechanism. However, since the data included five bus agencies and two rail agencies, the smaller n of rail data will affect the regression results.

When collecting data, the independent variable is funding in thousands of dollars. The annual funding reports included many line items of operational costs, assets, cash flow, and revenue. For all agencies, the study looks at forms of revenue, including operating revenue (fares), operating assistance (all tax income), non-operating revenue (interest and sale of equipment revenue), and capital contributions (federal grants). SFMTA did not differentiate between these categories and had different titles for their categories, so sources of revenue for the local, state, and federal levels were added. Since the method was consistent throughout all fiscal years, the percent change should remain accurate and a consistent measurement when comparing different agencies. To control for inflation, the design standardized the dollar amounts using CPI-U 2024. Without taking inflation into account, the percent change from year to year can be overstated.

Controlling for inflation makes the dependent variable more accurate. Percent change over time accounts for the different raw amounts of funding and ridership each agency has– whether due to agencies being in a wealthier area (higher tax revenue), or having higher ridership (higher fare revenue), more riders (higher populous), or any other differing structural factors between agencies. For this reason, the percent change over time of funding is the independent variable.

The dependent variable is ridership as reported by the transit agency. All agencies except for Samtrans reported their ridership numbers to APTA, which separates their ridership reports by transit mode, month, quarter, and year. Because the fiscal reports are organized by fiscal year, but APTA reports in calendar years, quarterly ridership data were combined to align with each fiscal year. Specifically, quarters 3 and 4 of year 1 were combined with quarters 1 and 2 of year 2 to provide an accurate ridership total for the corresponding fiscal year. This ensured consistency between financial and ridership datasets. To account for variations in ridership due to population size, county level population data for the areas served by each agency were obtained from Neilsburg, and annual ridership was normalized on a per-capita basis. My final independent variable is fiscal year ridership per capita. The model included lagged ridership by one and two years in case there is a delayed effect of funding on ridership due to the time it takes to implement changes.

Research Methods

A bivariate regression analysis on Stata showed the multiple possible relationships between my variables. Specifically, the study looks at R^2, P-value, and slope coefficient. This will show the correlational relationship between funding and ridership, controlling for population changes and inflation. In the model, K represents years lagged.

$$ln(ridership) = \beta_0 + \beta_1 ln(funding_{t-k}) + \epsilon$$

The model did not include years affected by COVID (FY2020-2022) to control for the decrease in ridership during those years. First, the regression examines the relationship between unadjusted percent changes in ridership and funding to assess whether a basic association exists before accounting for potential confounding factors or adjustments. This analysis could reveal potential gaps in how agencies allocate funding and the need to account for additional factors influencing ridership. To capture the delayed effect of funding, data is shifted one and two years and regressed. Funding increases take time to affect ridership – construction projects, purchase and order of equipment, hiring of new staff, etc. A summary of the regressions and results is displayed below.

Figure 1: Regression Table

Type of Regression (excluding years 2020-2022)	coef	R^2	P value	Interpretation
Unadjusted funding on ridership for bus, nonlagged	.1149389	0.0616	0.100	Weak effect and fit
Unadjusted funding on ridership for rail, nonlagged	.056495	0.0085	0.754	Weak effect and fit
Unadjusted funding on ridership for both, nonlagged	.1008338	0.0396	0.127	Weak effect and fit
Adjusted funding on adjusted ridership for bus, nonlagged	.1994839	0.1228	0.018	Weak positive effect and fit
Adjusted funding on ridership for rail, nonlagged	.144794	0.0430	0.477	Weak positive effect and fit
Adjusted funding on adjusted ridership for both, nonlagged	.185404	0.0928	0.018	Weak positive effect and fit
Adjusted funding on adjusted ridership for bus, lagged 1 year	.4534271	0.1494	0.014	Moderate positive effect, weak fit
Adjusted funding on adjusted ridership for rail, lagged 1 year	.6732158	0.0250	0.606	Moderate positive effect and weak fit
Adjusted funding on ridership for both, lagged 1 year	.4536493	0.0493	0.110	Moderate positive effect and weak fit
Adjusted funding on ridership for bus, lagged 2 year	-.641538	0.1403	0.027	Moderate negative effect and weak fit
Adjusted funding on ridership for rail, lagged	-.6111257	0.0097	0.773	Moderate negative effect and weak fit

2 years				
Adjusted funding on ridership for both, lagged 2 years	-.6476546	0.0559	0.114	Moderate negative effect and weak fit

Data Sources: APTA, NTD, BART, Tridelta Transit, CCTA, Samtrans (2009-2024)

The coefficient column describes the slope of the best fit line when scattered. This means that 1% increase in funding is correlated with a (coefficient)% increase in ridership for the specific variables included (bus or rail, adjusted or not, time lags).

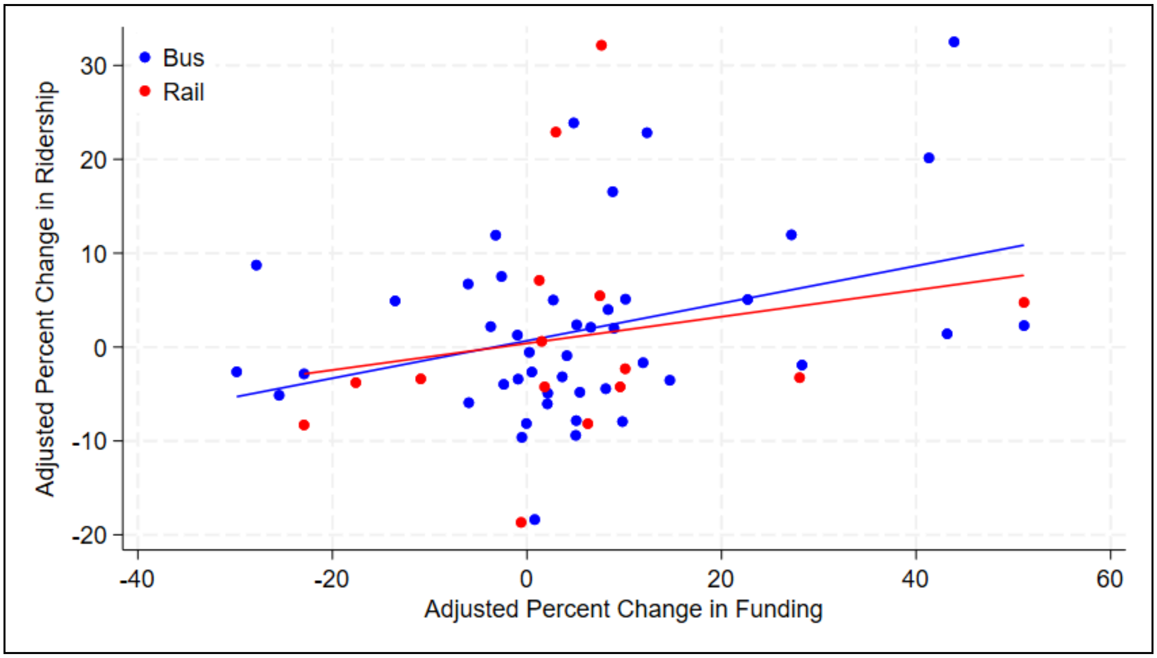
The R^2 column describes how close to the line of best fit the points are. The closer to 1 the R^2 is, the proportion of variance in the ridership that is explained by changes in funding. For all the statistically significant results, the R^2 is low, meaning the model is not the best fit, and funding isn't a strong indicator of ridership.

The P value column determines statistical significance – only rows with a P value under 0.05 can be considered statistically significant. This means that the study can reasonably assume that the error is unlikely to be due to random chance.

Overall, none of the rail regressions were statistically significant, so the paper can't compare rail and bus directly. However, for buses with a one year lag, a 1% increase in funding is correlated to a 0.45% increase in ridership. With no lag, it is about 0.19%.

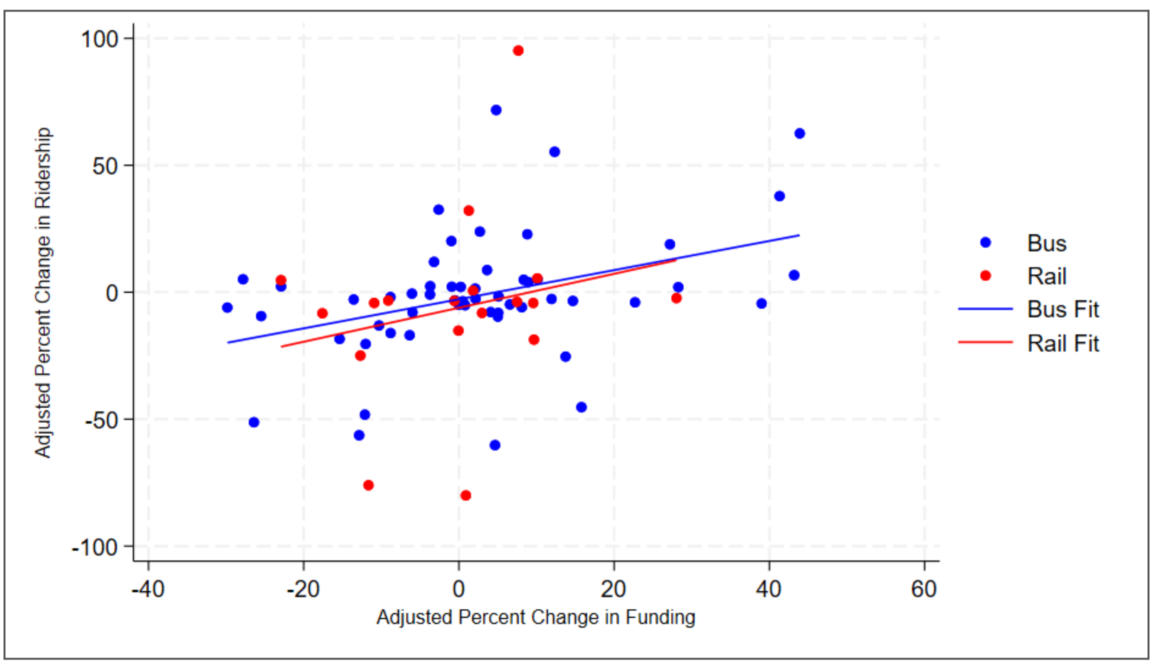
However, the low R^2 of 0.15 and 0.12, respectively, means the model is a weak fit and therefore only explains a small portion of variation in ridership, limiting the reliability of the estimates.

Figure 2: Adjusted ridership vs adjusted funding (no lag)



Data sources (Figures 2 and 3): APTA, NTD, BART, Tridelta Transit, CCTA, Samtrans (2009-2024)

Figure 3: Adjusted ridership and adjusted funding (1 year lag)



The two graphs visually show the low correlation between ridership and funding – many points are removed from the line of best fit.

Discussion

Is there a relationship between the amount of funding a transit agency receives and its ridership? Is it different for buses and rail? Since none of the rail regressions were significant, bus and rail can't be directly compared. However, the bus regressions showed statistically significant results, showing there is a relationship between funding and ridership for buses.

The results partially support the hypothesis. Even though the model couldn't compare bus and rail, buses showed a small relationship between funding and ridership. The small R^2 and weak fit are likely because of several outlying data points. Across multiple years and agencies, large one-time grants were awarded at irregular intervals. As a result, the year to year percent change sharply rose, then dropped just as sharply for the following year. The inconsistent swings in funding caused the data points to be more scattered, contributing to the smaller R^2.

These irregular funding spikes can temporarily decrease ridership during construction phases, as seen with the -0.64 coefficient for a 2 year lag for buses. It's also possible that the time lag should've included more years (3-10 years) for large capital grants and subsequent projects, but data availability limited long-term time scaling.

The moderate strength coefficient means that funding is not the only variable that impacts ridership. The model did not include fare prices, changing routes, safety, or housing development placement compared to routes. With more time and resources, conducting a multivariate analysis would provide a more complete picture of changing ridership numbers.

Transit safety is one of the largest ways funding can have an impact on ridership. The perception of transit being unsafe is a large deterrent for potential riders who can afford other alternative transportation modes. In South Africa, perceived insecurity and poor safety is highly associated with lower transit ridership, more so for older people than younger (Noleen et.al 2023). In Chicago, lower income is related to higher crime rates, which is associated with a higher perception of perceived safety because of desensitization to crime. On the other hand, higher income people reported a lower perception of safety (Yavuz et.al 2007). 71% of Bay Area transit riders have a household income of less than $99,999, and 65% of riders don't have access to a private alternative vehicle. So, there is a large untapped market of transit riders from the wealthier population in the Bay Area. Funding can be used to improve incident reporting and response, upgrade facilities, improve lighting, hire cleaning and security staff, etc.

Limitations

The annual financial reports did not distinguish the distinct uses of the funding. Thus, the model included total revenue to include all dollars that could be applied toward the transit agency. In hindsight, the costs/expenditures may have been a better metric to show the relationship between transit spending and ridership, but the intention was to include a policy recommendation that would give more funding to agencies so they could apply it towards improving operational efficiency.

There were also a lot fewer data points for rail because there were not 2 compared to the five bus agencies. The data was unavailable for a few of the earlier years for BRST, and the SFMTA funding and ridership data were gathered through NTD. While the 3rd party site is reliable, it's unclear if that affected the results since it wasn't a direct report. Especially after scaling for time lags, it eliminated some of the data points the model could use because the earlier and later years no longer had matching ridership and funding data.

The model also did not include the fare increases as a variable; it didn't really have a place within the model since it looked at percent change and didn't differentiate between agencies during analysis. The fare changes are between agencies, and it would need to be chronological, something the analysis eliminated.

With more time, and requesting more years of data from these agencies to get a more complete picture. Als,o comparing the data over time across different regions, to see if there is a plateau in ridership growth after a certain amount of time. Comparing a region like NYC (dense, plentiful transit) to an area like LA (sprawling and sparse transit) would offer a view of how density and city layout shape the development of transit, not just ridership.

Conclusion

In conclusion, this study contributes to existing research that shows the multifaceted operating complexity of public transit. Funding, in conjunction with strategic city planning, making transit safer, and tailoring a region's transit system to its geography, can be an effective way to increase bus ridership and decrease driving related emissions.

Although the results did not provide a complete picture to compare the impact on bus vs rail, it showed a small but significant relationship between funding and ridership for buses. While funding alone does not explain ridership changes, evaluating other indicators is crucial for shaping policies that can improve how effectively transit agencies operate. The intention of public transportation is to serve the public – something that requires deep analysis into the operation styles of transit agencies, and the communities they operate within. At its core, transportation is about people, and improving transit means improving people's experiences. The findings of this study highlight room for improvement in how transit strategies are designed and implemented to better support ridership growth. Funding is not enough – a more cohesive and future oriented attempt to revitalize public transit, especially after COVID, is necessary.

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