

1) Estimate the average of the following indicators for the nation's light rail (LR), heavy rail (HR), commuter rail (CR), and bus (MB) systems in 2019 (be careful to exclude systems that do not operate the modes in question or that report zero PMT):

a. Passenger miles (PMT) per unlinked passenger trip (UPT)

Analysis Method: Firstly, filter the data for the year 2019, considering only four modes: Light Rail (LR), Heavy Rail (HR), Commuter Rail (CR), and Bus (MB). Then, calculate the ratio of Passenger Miles (PMT) to Unlinked Passenger Trips (UPT) for each non-linked passenger journey. This ratio reflects the average length of each passenger trip.

Results: The average PMT/UPT ratio is 6.286304. This means that in 2019, across these four modes, the average Passenger Miles per Unlinked Passenger Trip is approximately 6.29 miles.

b. Passenger miles per directional route mile (DRM)

Analysis Method: Similarly, filter the data for the year 2019 and the four modes, then calculate the ratio of Passenger Miles (PMT) to Directional Route Miles (DRM). This ratio reveals the average Passenger Miles served per mile of directional route.

Results: The average PMT/DRM ratio is 340,612.1. This indicates that, on average, there are approximately 340,612.1 Passenger Miles served per Directional Route Mile across these modes.

c. Fare revenue per passenger mile

Analysis Method: Continuing with the 2019 data and the four modes, calculate the fare revenue per Passenger Mile. This ratio reflects the average fare revenue per mile of travel.

Results: The average Fare Revenue per Passenger Mile ratio is 0.405065. This means that, on average, for each mile of a passenger journey, the revenue for the transit system is approximately \$0.41.

1) Estimate the average of the following indicators for the nation's light rail (LR), heavy rail (HR), commuter rail (CR), and bus (MB) systems in 2019 (be careful to exclude systems that do not operate the modes in question or that report zero PMT):

d. Fare recovery ratio (total fare revenue divided by total operating costs)

Analysis Method: Once again, utilizing the 2019 data and the four modes, calculate the ratio of total fare revenue to total operating costs. This ratio is a crucial indicator for evaluating the economic efficiency of the transit system.

Results: The average Fare Recovery Ratio is 0.1867362. This implies that, on average, approximately 18.67% of the operating costs are covered by fare revenue.

e. Average speed (vehicle revenue miles divided by vehicle revenue hours)

Analysis Method: Choose the data for the year 2019 and the four modes. Calculate the ratio of Vehicle Revenue Miles (VRM) to Vehicle Revenue Hours (VRH), representing the average speed.

Results: The average speed is 15.5818 miles per hour. This indicates that, on average across these modes, the speed of the vehicles is approximately 15.58 miles per hour.

2) Calculate the fare recovery ratio for all nation's light rail, heavy rail, commuter rail, and bus systems in 2019. Compare this figure to the fare recovery ratios estimated in question 1. Discuss any differences.

In this analysis, our focus is on the Fare Recovery Ratio (FRR) of the national Light Rail (LR), Heavy Rail (HR), Commuter Rail (CR), and Bus (MB) systems for the year 2019. FRR is a crucial financial performance indicator for public transportation systems, representing the proportion of operating costs recovered through fare revenue.

Methodology:

Data Filtering: Firstly, we filtered the data from the NTD dataset for the year 2019, conducting separate filtering for each transportation mode (Light Rail, Heavy Rail, Commuter Rail, Bus).

FRR Calculation: For each mode, we calculated the ratio of total fare revenue to total operating costs, i.e., FRR. Specifically, this was done by summing the total fare revenue for all entities within each mode and then dividing it by the corresponding total operating costs.

Results:

- Light Rail (LR): FRR is 0.2046
- Heavy Rail (HR): FRR is 0.6085
- Commuter Rail (CR): FRR is 0.5049
- Bus (MB): FRR is 0.20854

2) Calculate the fare recovery ratio for all nation's light rail, heavy rail, commuter rail, and bus systems in 2019. Compare this figure to the fare recovery ratios estimated in question 1. Discuss any differences.

Comparison and Discussion:

When compared with the results from Question 1 (FRR averaged by agency), these numbers reflect the differences in calculation methods. FRR in Question 1 is based on the average FRR of each agency, while Question 2 is based on the ratio of total fare revenue and total operating costs for each mode.

For example, assuming three Heavy Rail systems A, B, and C with FRR values of $\frac{1}{2}$, $\frac{1}{5}$, and $\frac{1}{3}$, respectively. The answer to Question 1 would be $(\frac{1}{2} + \frac{1}{5} + \frac{1}{3}) / 3$, i.e., the average of individual system FRRs. Whereas, the answer to Question 2 would be $(5 + 100 + 1000) / (10 + 500 + 3000)$, i.e., the ratio of total fare revenue and total operating costs for all systems.

This difference often indicates that large or more efficient systems may have a greater impact on the overall FRR calculation. For instance, a high FRR in a large system could elevate the overall average, even though other smaller or less efficient systems might have lower FRRs.

Conclusion:

By comparing these two calculation methods, we gain a more comprehensive understanding of the financial performance of different public transportation modes. This analysis helps reveal which modes are more effective in covering their operating costs through fare revenue and highlights performance differences among different modes.

3) The Los Angeles Metropolitan Area has multiple providers of public transportation. Plot the fare recovery ratio for the Los Angeles MTA (TRS ID 90154) and the Southern California Regional Rail Authority (TRS ID 90151) for light rail, heavy rail, commuter rail, and bus from 2002 to 2021.

- **Time Range Selection: 2002 to 2021.**
- **Consider specific operating agencies (NTD.ID 90154 and 90151).**
- **Limit transportation modes (Light Rail, Heavy Rail, Commuter Rail, Bus).**
- **Exclude records with zero or missing fare (FARES) or total operating cost (OPEXP_TOTAL).**

Handling Bus Mode Data:

Segment Bus mode (Mode == "MB") based on service type into Directly Operated ("DO") and Privately Provided ("PT"), labeled as "MB_DO" and "MB_PT" respectively. This step aims to differentiate different types of bus services in the analysis, reflecting fare recovery efficiency under different operational modes.

Data Aggregation:

Summarize the filtered dataset annually and by mode, calculating total fare revenue and total operating costs for each mode each year.

Calculate Fare Recovery Ratio:

Utilize the summarized data to calculate Fare Recovery Ratio (FRR), i.e., the total fare revenue divided by total operating costs for each mode each year.

3) The Los Angeles Metropolitan Area has multiple providers of public transportation. Plot the fare recovery ratio for the Los Angeles MTA (TRS ID 90154) and the Southern California Regional Rail Authority (TRS ID 90151) for light rail, heavy rail, commuter rail, and bus from 2002 to 2021.

Plot Trend Graph:

Use ggplot2 to draw a time series line graph, showcasing the trend of fare recovery ratios for each mode from 2002 to 2021. Assign specific colors to different modes to ensure clarity and facilitate the distinction of different modes in the chart.

