MBTA Optimized Bus Stops

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Problem Description

Our project addresses a pressing transportation issue: optimizing bus stop selection for the Massachusetts Bay Transportation Authority (MBTA). The primary goal is to strategically determine where buses should stop to maximize profit and minimize CO_2 emissions simultaneously. We aim to achieve this by refining the existing bus stop network under specific constraints.

Data

We are using two datasets from the MBTA for this project, a bus stops dataset and a ridership dataset. The bus stops dataset contains information about the exact location of each bus stop and the routes that stop at each bus stop. The ridership dataset contains information about average boarding, unloading, and ridership for each bus route at each bus stop, for every service time period (e.g. AM rush hour or mid-day), and for each quarter in the last five years. These two datasets provide plenty of data for this project.

Methods

Initially, we will focus on a single route within the broader MBTA system. We will then use optimization to review this route's stops, to see whether stops can be removed from the route based on a tradeoff between ticket revenue and CO_2 emissions. As an example, if a bus stop is never used, it might make sense to remove the stop from the route under certain conditions.

For our formulation, we encode the decisions to remove bus stops from the route with a binary decision variable, z_j, where $z_j = 0$ if stop j is removed from the bus route. We also define new variables for the load and the number of people going off the bus: these need to be adjusted from the data when one stop is removed. Our objective function combines profit and CO_2 reduction, balancing the two quantities, and we aim to solve the following Mixed Integer Optimization problem:

$$\text{Maximize } \lambda \times Revenue - (1 - \lambda) \times CO_2$$

The revenue component considers passenger loads and ticket prices, while CO2 emissions depend on passenger loads and the number of selected stops.

Key constraints include ensuring that passenger loads after each stop don't exceed the bus's capacity, calculating passenger loads at each selected stop j (this is determined by the load at stop $j - 1$ and the number of people going off and on at stop j), and limiting the number of removed stops within predefined groups G_k: $\sum_{j \in G_k} z_j \geq c_k$. For instance, for some busy neighborhoods in Boston, it might be better not to remove too many stops. Our method will allow us to easily customize the constraints depending on the routes and neighborhoods considered.

We also foresee several extensions to this methodology, including evaluating several routes at once and evaluating routes across several different daily time periods, like AM rush hour and mid-day. We plan to conduct a sensitivity analysis across all constraints and values of λ in each model in order to determine, and explain, the best approach to optimized bus stop selection that we find.

Expected results

Through this project, we expect to discover a strategy MBTA could use to review the bus stops and routes within its network, removing stops that are unnecessary and thereby reducing CO_2 emissions. We anticipate a reduction in the number of bus stops, striking a balance between lower emissions and increased profits. The parameter λ will play a crucial role in achieving this equilibrium. Furthermore, we expect that our sensitivity analysis will help us understand which constraints most impact bus routing stop decisions.

Practical implications

Reducing the number of stops is essential for minimizing CO_2 emissions, particularly in high-density urban areas like Boston. If implemented, the optimal bus stop selection strategy we hope to produce through this project could translate into substantial emission reductions. To that end, our solution seeks to improve citizens' quality of life by optimizing bus routes without compromising on service. Furthermore, we believe that our approach to this problem will be generalizable, and that our findings in Boston could be applied to improve transportation networks in other cities as well.