Effect of stop skipping on passenger travel time on the Washington Metro

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Elements of design

Problem Statement

What is the effect of AB stop skipping on total travel time of passengers on a single line on the Washington Metro? An AB skip stop pattern consists of two types of trains: an A train and a B train. There are also three types of stations: A, B, and AB. Each train stops at its corresponding letter station in addition to the AB stations. Presently, the Washington Metro does not utilize stop skipping under normal operation, so it is of interest to see if there would be a benefit to riders by using such a system, particularly because it requires a low investment (Vuchic, 1976).

Hypothesis

If a continuous approximation model is used to calculate the effect of stop skipping on total travel time of passengers on the Washington Metro, then that model will show a decrease in passenger travel time after stop skipping is implemented.

Independent Variable

The independent variable for this project is the AB station density, which will be optimized to minimize the total passenger travel time.

Dependent Variable

The dependent variable for this project is the total waiting time for passengers, which will be calculated using the cost function in the model.

Constants

The primary constants for this project are the parameters for the model, which include the length of the track, number of trains operating, number of passengers per unit of time, station density, dwell time in every station, acceleration and deceleration rate of the train, the GDP per capita of the country (used to determine travel cost in monetary terms), and the subway cruising speed.

Assumptions

For this project, it is assumed that each train has an unlimited capacity and that dwell times are identical in each station are identical regardless of the number of passengers. It is also assumed that trains will run all the time and that passenger demand is equally distributed across all the stations to simplify calculations. The effect of these assumptions is that it makes the skip stop model's waiting time less realistic. However, the author of the model has stated that this assumption tends to overestimate the number of trips requiring a transfer, which would increase the cost for skip stop operation. Thus, it can be expected that the skip stop operation would work slightly better than what the model will predict.

Materials

- Python Anaconda package- which includes the Python IDE Spyder to edit python files (https://pythonhosted.org/spyder/)
- Computer
- PyOpt Python optimization package (http://www.pyopt.org/)
- Washington Metro ridership dataset (https://planitmetro.com/2016/03/14/metrorail-ridership-data-download-october-2015/)

Note: This is all the materials that are required at this stage of the project; as I add more elements to the model, this list will expand.

Procedure

1. Utilize ridership data from the Washington Metro to identify the approximate number of passengers usually leaving from a given station on a line. The initial focus of this project will be on the Silver Line, but it will eventually broaden to include other lines as well.
    a. Along with the publicly available ridership data, the Washington Metro will be contacted to ask for acceleration/deceleration information about the trains along with their cruising speed. If this information cannot be acquired in a timely manner, it will be excluded from the model because they are not as important as the other parameters (Freyss, et. al, 2013).

2. Excluding the parameters about energy, program the various functions of the continuous approximation model into Python Spyder (Freyss, et. al, 2013).
    a. This includes the functions to estimate normal and skip stop operation wait times. Both of these are functions of AB station density, which is the number of AB stations per meter of track. The AB station density is also what will be optimized.
    b. In addition to the wait time estimation functions, a transfer cost function will be included to account for the time spent transferring between stations, which is required for certain routes on a line with skip stop. This would not be required for a normal operation because the train would stop at all stations.
    c. The normal operation cost function does not need to be minimized because it is not a function of AB station density. The cost can be calculated by inputting the constants previously outlined into the function.
3. Minimize the cost function skip stop operation using the PyOpt library.
    a. While the initial cost function is only a single input (AB station density), the model will likely be expanded to include other factors as well, which is why an optimization package is being used.
4. After identifying the optimal AB station density, find the cost of the skip stop operation at that density and compare it with the calculated normal operation cost to see if there is any improvement.
5. Future objective: integrate new variables into the model such as energy costs, passenger behavior, or collision probability to make the cost function more realistic.

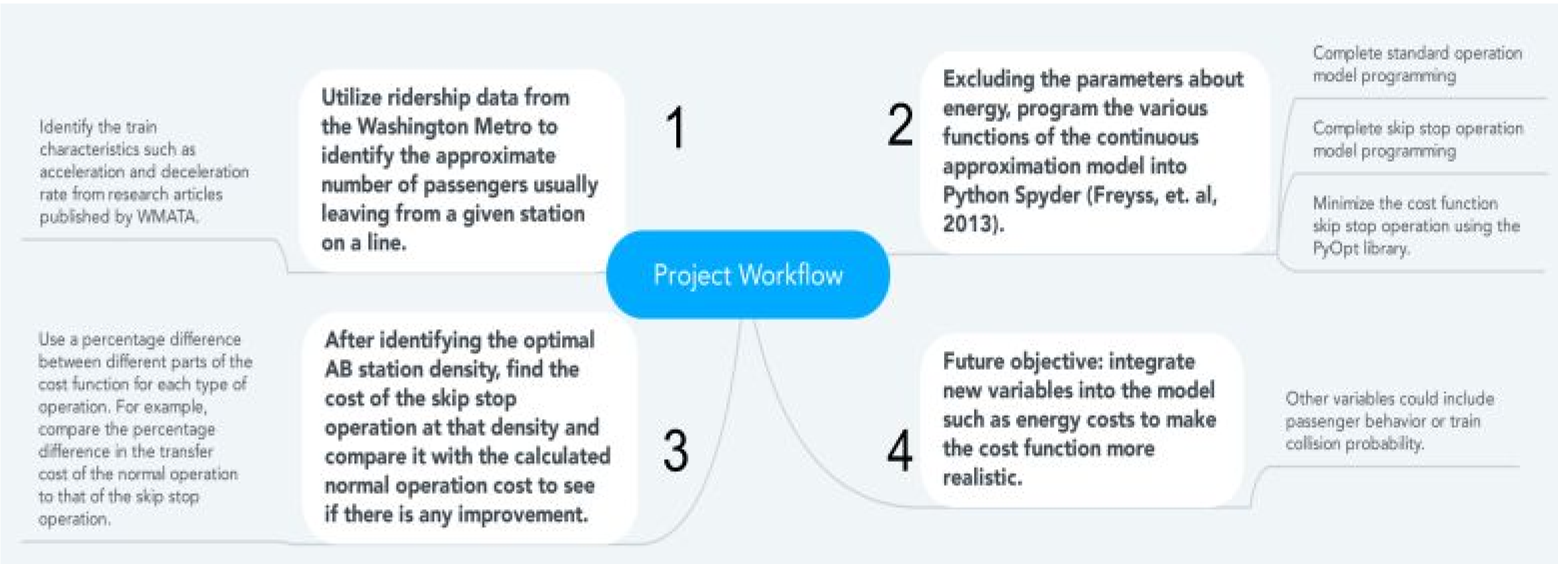

Figure 1: Diagram of Project Workflow

Rationale for using models

A continuous approximation model is being used for this project because it is a simplified way to identify the costs and benefits of using a skip stop system for a particular line before conducting an extensive study using detailed ridership data. This model has been tested on data from the Santiago Metro in Chile, which currently uses a skip stop operation system (Freyss et. al, 2013). Another benefit of using this type of model as a base is that it is relatively simple to optimize because the only input variable is the AB stations density. This allows for quick changes to the functions without lengthy optimization times that could occur with gradient descent (for multivariate functions).

Statistics

The type of modeling in this project does not require statistical tests because of the non-random data used and the lack of multiple trials. A percentage difference is likely the best choice to compare the cost of the skip stop operation to that of the normal operation. Since cost in this context is a sum of various other costs, it could also be useful to determine the percentage difference between these costs for both types of train operation. For example, while the total cost may be lower for the skip stop operation, its transfer cost may be higher than that of the normal operation. Thus, it would be valuable to compare these "sub costs" as well so the specific disadvantages and advantages of the skip stop system over the normal system can be seen.

References

Freyss, M., Giesen, R., & Muñoz, J. C. (2013). Continuous approximation for skip-stop operation in rail transit. Transportation Research Part C: Emerging Technologies, 36, 419-433.

Vuchic, V. R. (1976). Skip-stop operation: High speed with good area coverage. UITP Revue, 114.