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Forecasting and Mitigating Disruptions in Public Bus Transit Services

Chaeeun Han[1], Jose Paolo Talusan[2], Dan Freudberg[3], Ayan Mukhopadhyay[2], Abhishek Dubey[2], Aron Laszka[1]

[1]Pennsylvania State University, University Park, PA, USA
[2]Vanderbilt University, Nashville, TN, USA
[3]WeGo Public Transit, Nashville, TN, USA

PennState
College of Information Sciences and Technology

Background

1. Infrastructure and Demand Imbalance

2. Congestion and Commute Delays

3. Need for Proactive Strategies

Background

Trips

A single journey along a designated route at a designated time
e.g., For Route 7 on January Mondays at 4am

Disruptions

Unplanned cancellation or suspension of service
e.g., Mechanical problems, Accidents, etc.

Objectives

1 **Forecasting Problem**

Predict disruptions in space and time

2 **Stationing Problem**

Optimize the stationing of substitute

buses to promptly respond to disruptions

Data

Dataset	Features	Date
General Transit Feed Specification (GTFS)	33 Routes, 1619 Stops	2020-2023
Automated Passenger Count (APC)	Ridership, Stops	2020-2023
Disruption	Location, Datetime, Stops	2020-2023
Weather	Location, Temperature, Precipitation	2020-2023

Data

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General Transit Feed Specification (GTFS)	33 Routes, 1619 Stops	2020-2023
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5096 disruptions out of about 90,000 trips

=> Imbalance in data

Disruption Forecasting

Trip

- Route + Direction
- Passenger Capacity
- Service Time
- Year
- Month
- Day of Week
- Precipitation
- Temperature

→

0: No Disruption

1: Disruption

Probability of Disruption

Disruption Forecasting

Categorical

Trip

- Route + Direction
- Passenger Capacity
- Service Time
- Year
- Month
- Day of Week
- Precipitation
- Temperature

4AM - 6AM: Early
6AM - 9AM: Morning
9AM - 2PM: Mid-day
2PM - 6PM: Afternoon
6PM - 0AM: Evening

0: No Disruption

1: Disruption

Probability of Disruption

Disruption Forecasting

Route + Direction

Passenger Capacity

Service Time

Year

Month

Day of Week

Precipitation

Temperature

VS

Negative Log Likelihood

Categorical

Route + Direction

~~Passenger Capacity~~

Service Time

Year

Month

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Disruption Forecasting

Route + Direction

Passenger Capacity

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VS

Negative Log Likelihood

Categorical

Route + Direction

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Disruption Forecasting

Route + Direction

Passenger Capacity

Service Time

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Temperature

VS

Negative Log Likelihood

Categorical

Route + Direction

~~Passenger Capacity~~

Service Time

~~Year~~

Month

Day of Week

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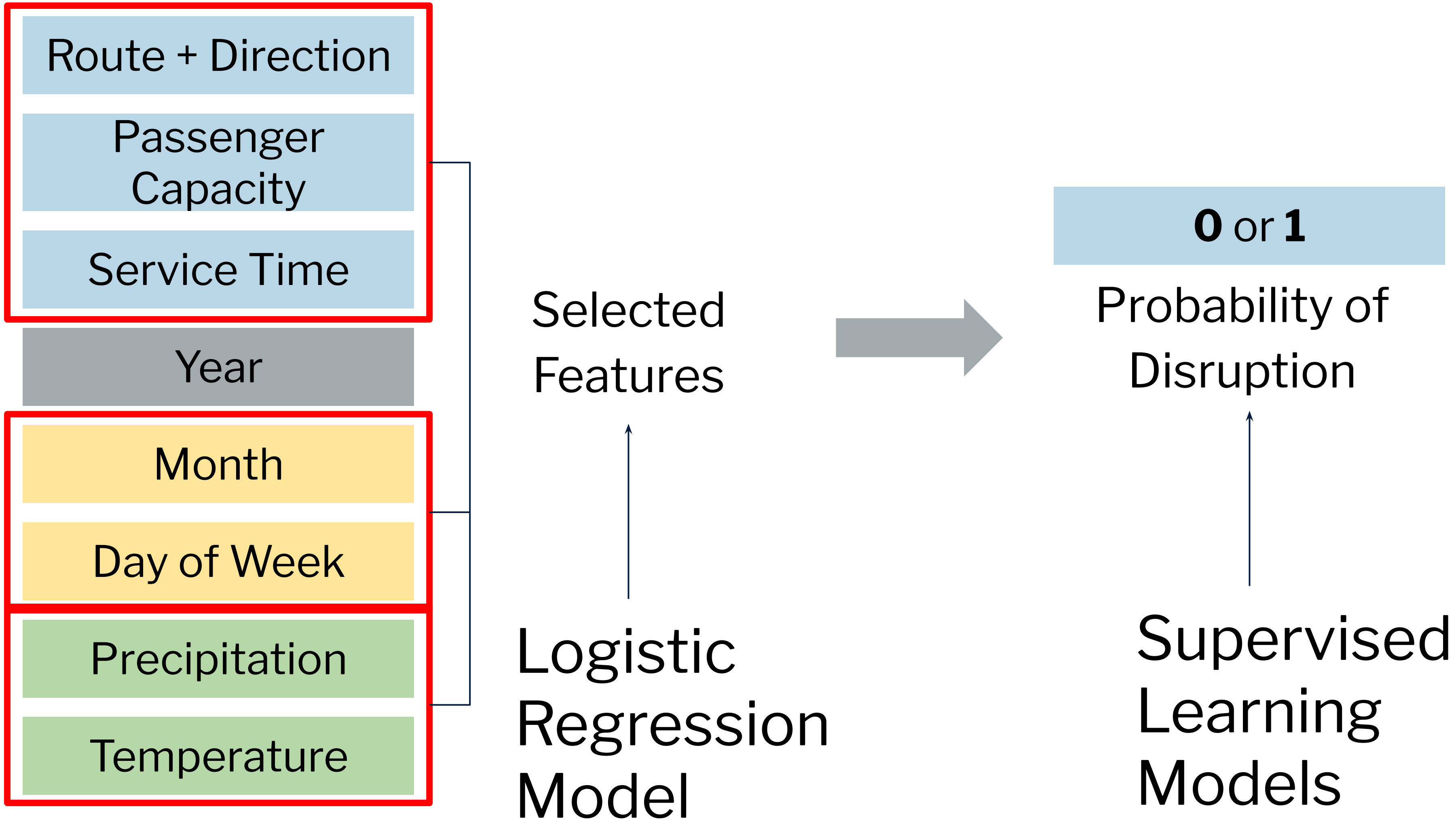
Temperature

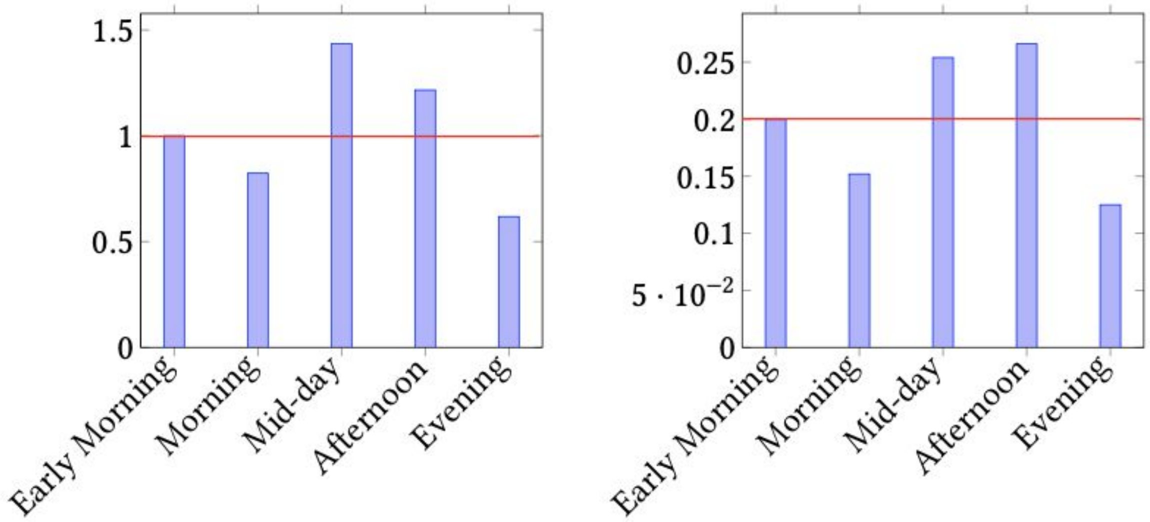
Disruption Forecasting

		Categorical
Route + Direction		Route + Direction
Passenger Capacity		~~Passenger Capacity~~
Service Time	VS	Service Time
Year	Negative Log Likelihood	~~Year~~
Month		~~Month~~
Day of Week		Day of Week
Precipitation		Precipitation
Temperature		Temperature

Disruption Forecasting



Disruption Forecasting



(a) Log-Odds **(b) Probability**

0 or **1**

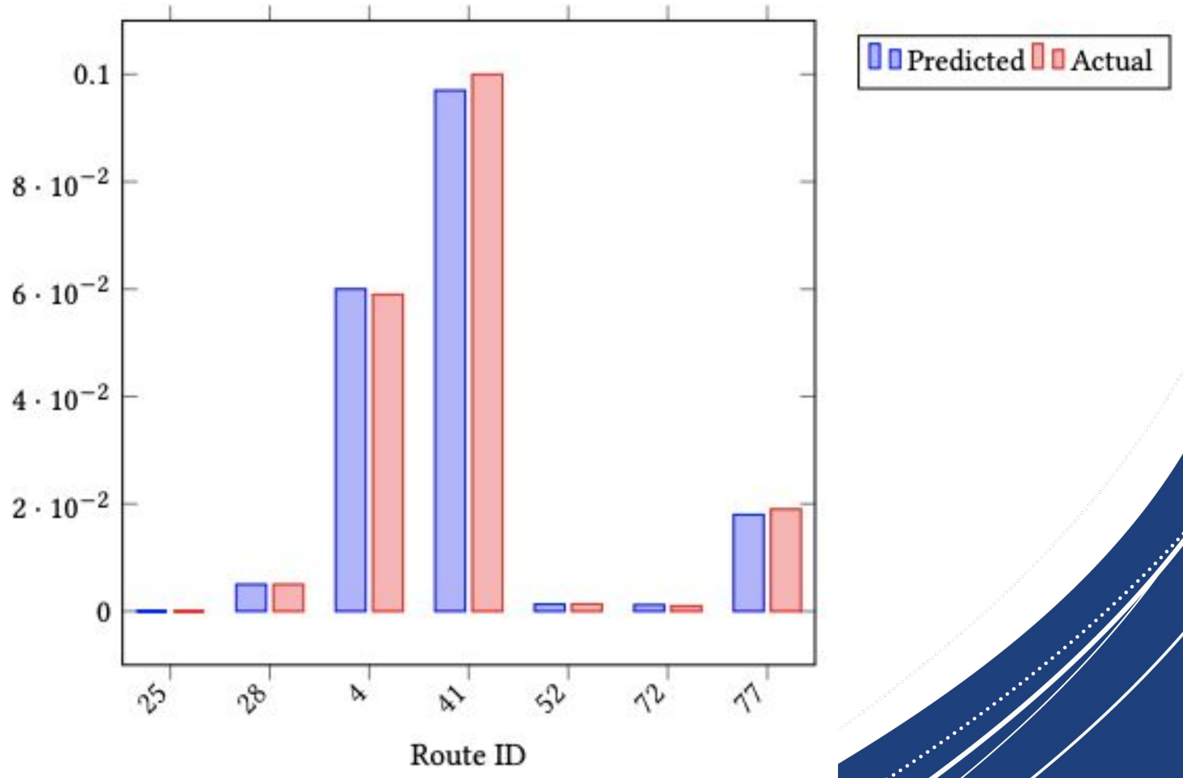
Probability of Disruption

Disruption Forecasting

Calibration

Transform classifier scores into class probabilities
i.e., probabilities of trips having disruptions or not

Model	Test Cross Entropy
Logistic Regression	0.0903
XGBoost	0.0872
XGBoost + Calibration	0.0870



Vehicle Stationing

Regular Buses

Normal buses start and end from main depot

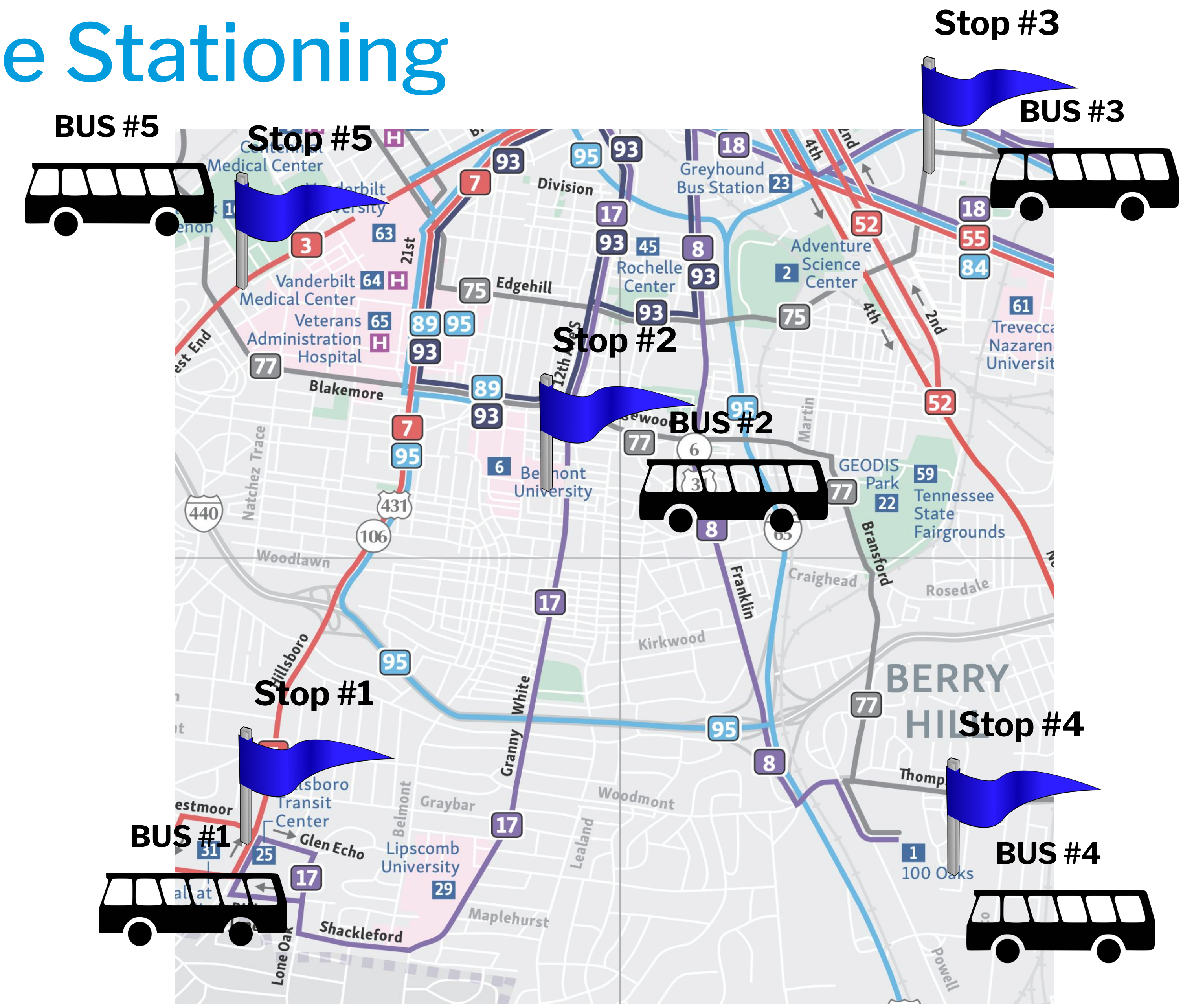
Substitute Buses

<u>Extra buses</u> waiting at <u>predetermined stop</u> for when regular buses are <u>overcrowd</u>ed or face <u>disruptions</u>

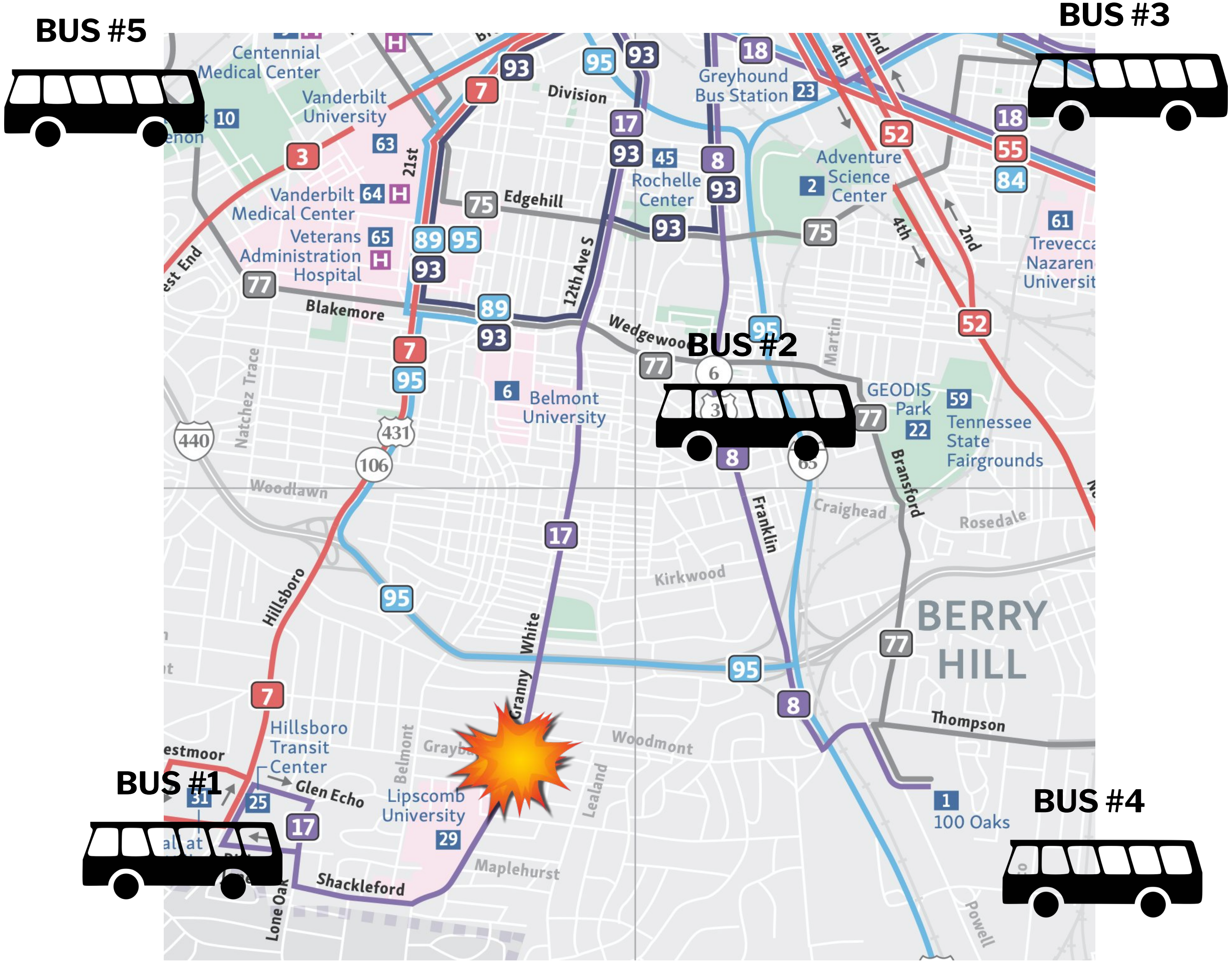
<u>Nearest</u> substitute bus provides service

Passengers

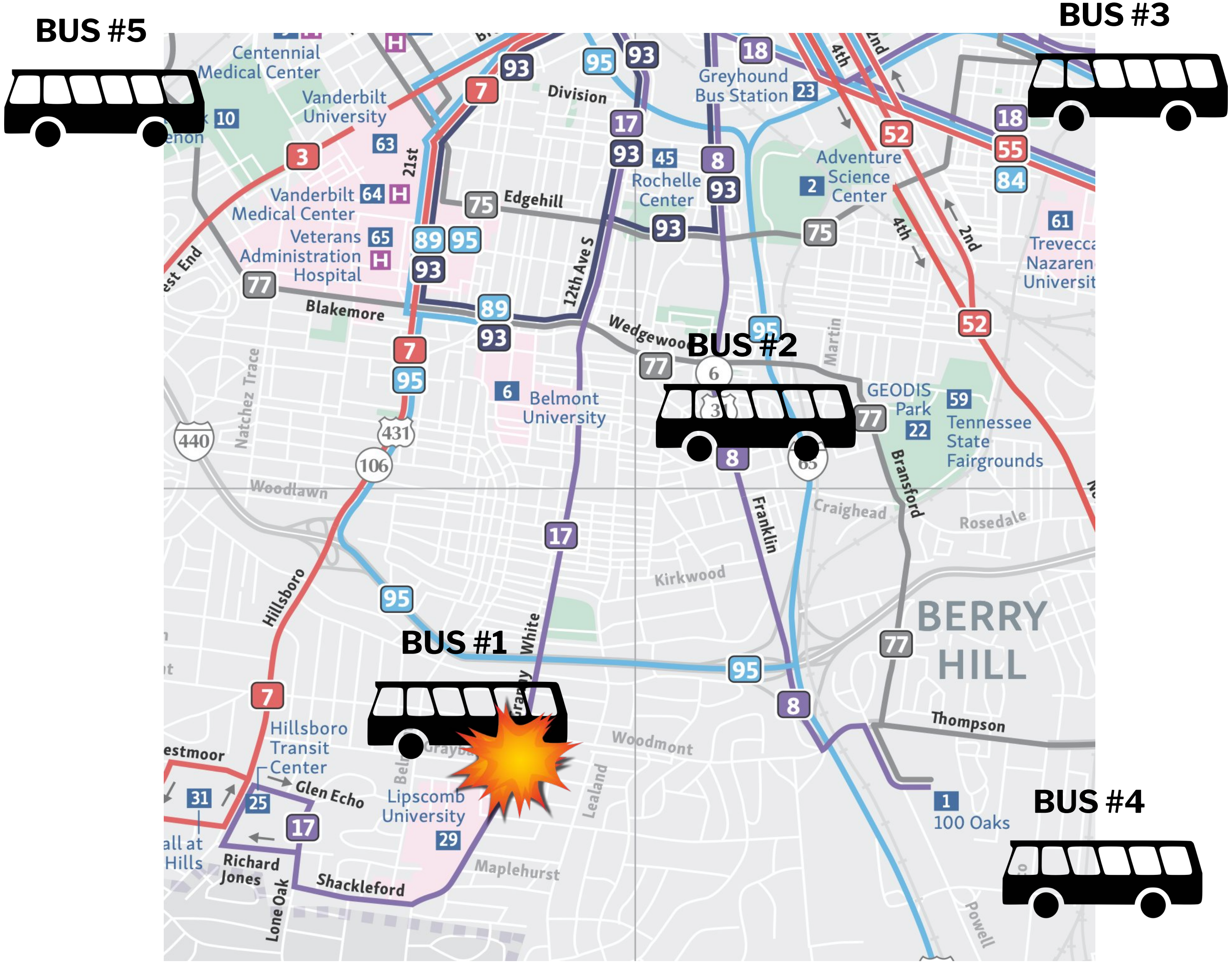
Vehicle Stationing



Vehicle Stationing



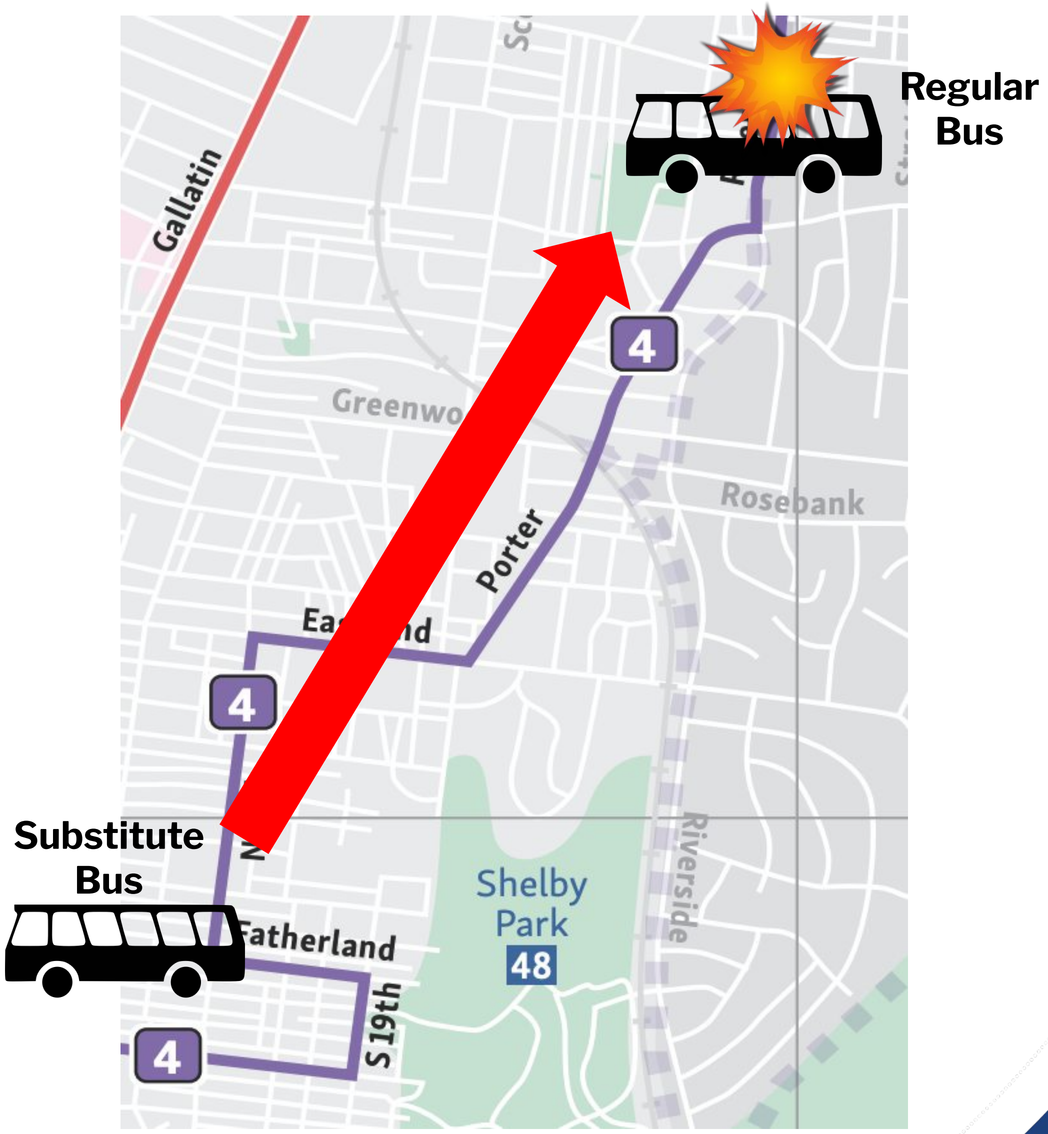
Vehicle Stationing



Vehicle Stationing

Objectives

1. How far? (Deadhead Miles)
2. How long it takes? (Deadhead Times)
3. How many passengers are left behind?



Vehicle Stationing

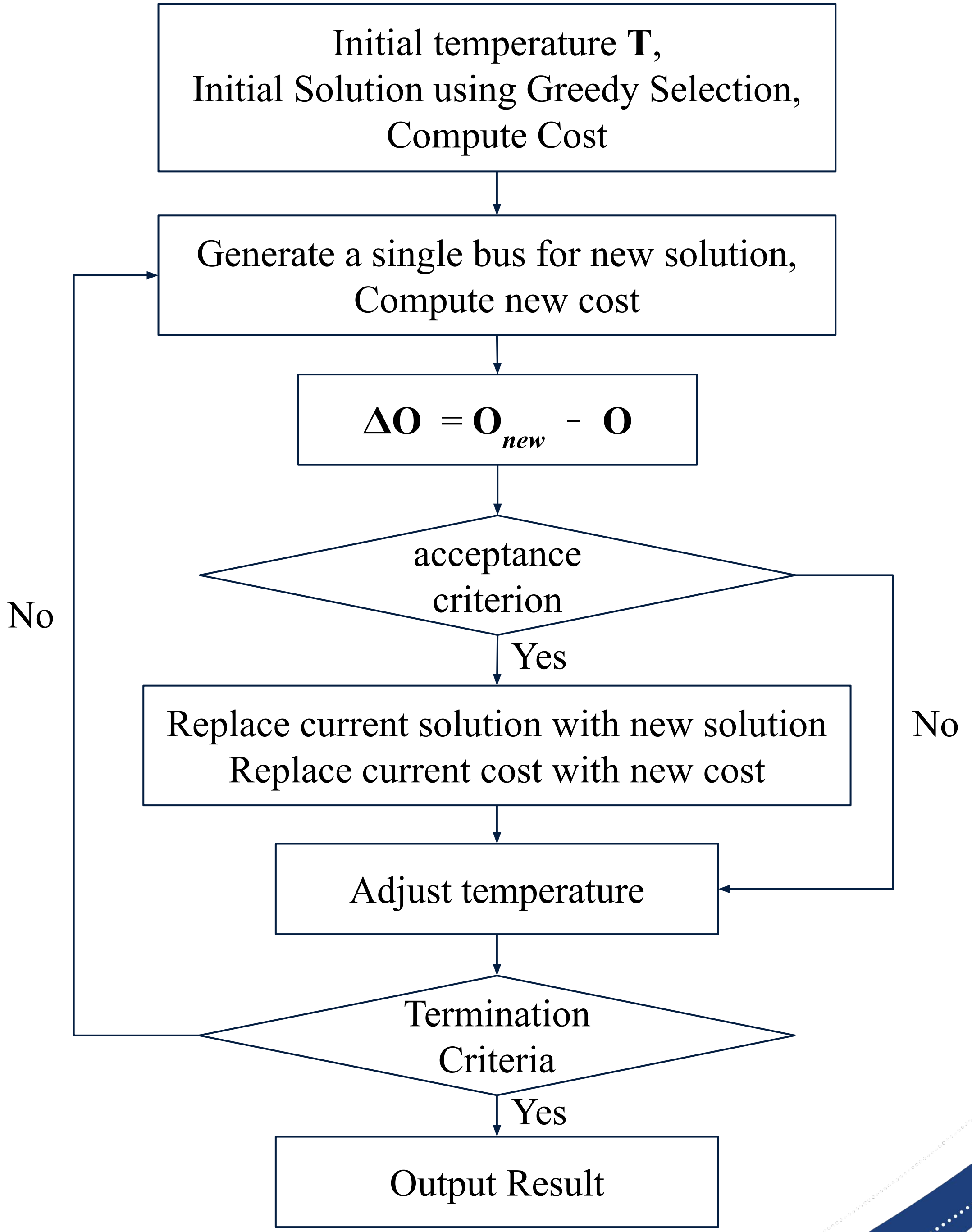
1. Deadhead Miles
2. Deadhead Times
3. Left behind passengers

$S_{Station}$:	Subset of stops
k:	Budget of substitute buses
D:	Deadhead Miles
T:	Deadhead Times
L:	Left behind passengers
P:	Occurrence of disruptions

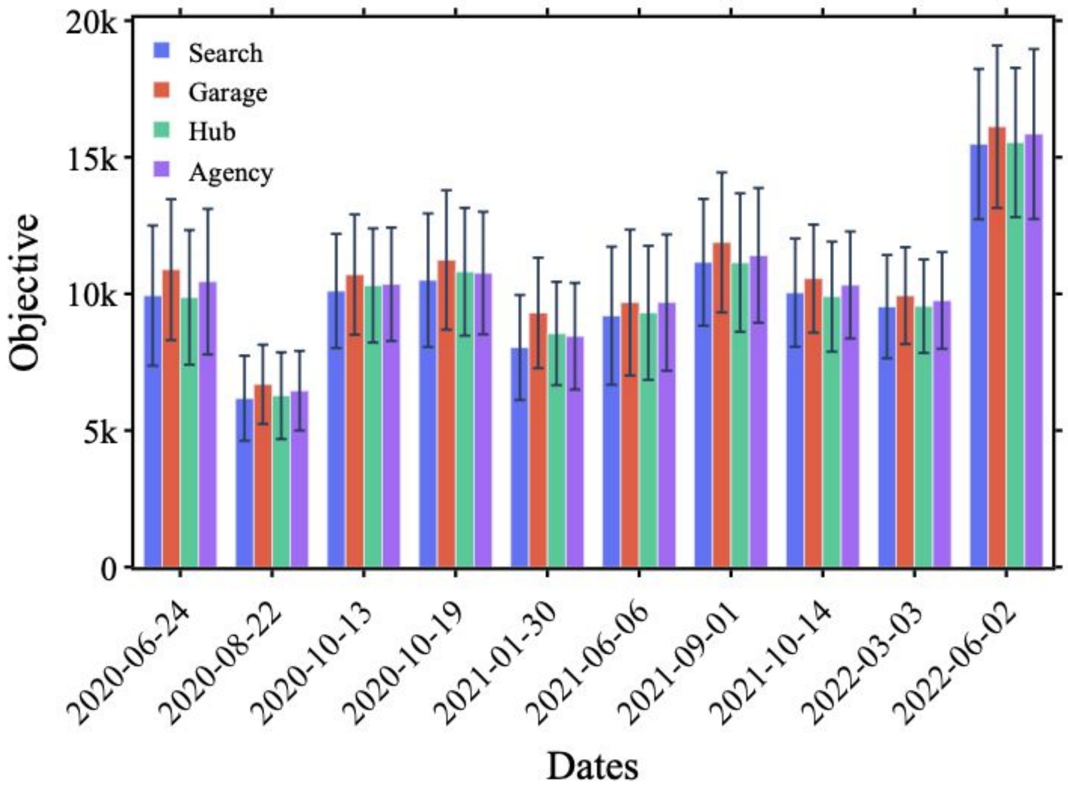
$$\text{argmin}_{x \subseteq S_{station} : |x| = k} \mathbb{E}_P \left[\overset{1}{D(x; P)} + \overset{2}{T(x; P)} + \sum_{j=1}^{J} \overset{3}{L(j, x; P)} \right]$$

Vehicle Stationing

Simulated Annealing Optimizer



Vehicle Stationing



Search

Our Proposed method

Garage

When all substitute buses are waiting at <u>garage</u>

Hub

When all substitute buses are waiting at <u>hub</u>

Agency

When following the current <u>agency policy</u>

Contribution

1. Predict rare incidents like disruptions
2. Reduce delays and crowding
3. Find optimal set of stops by simulation
4. Increase efficiency of transit operations and enhance the passenger experience

Thank you

Chaeeun Han (cfh5554@psu.edu)

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