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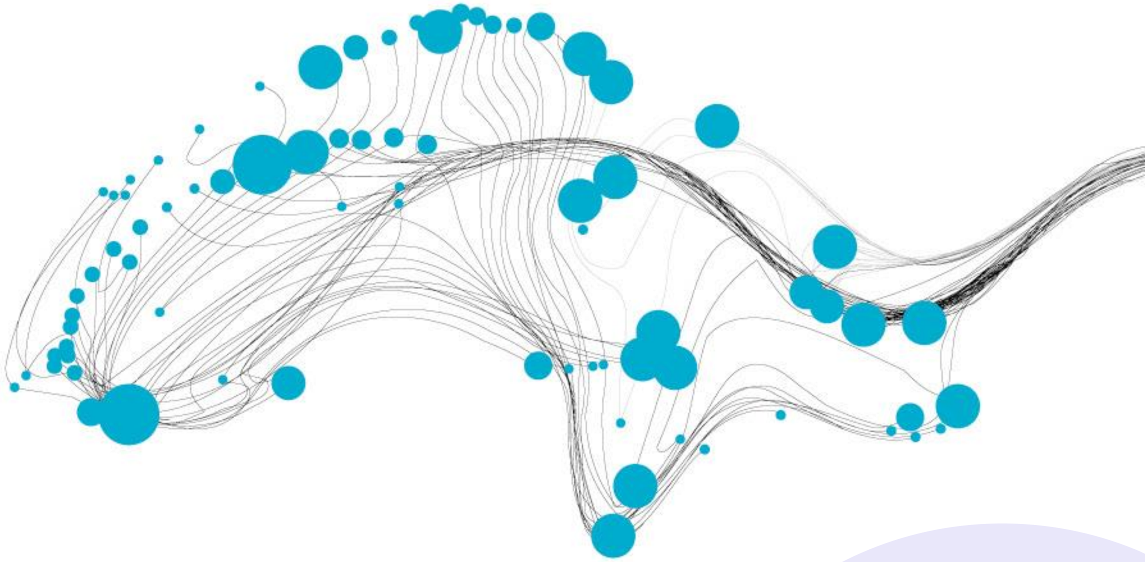
TRB

OPTIMAL BUS REASSIGNMENT CONSIDERING IN-VEHICLE OVERCROWDING



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NATIONAL TECHNICAL UNIVERSITY OF ATHENS

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DISRUPTIONS IN PUBLIC TRANSPORT

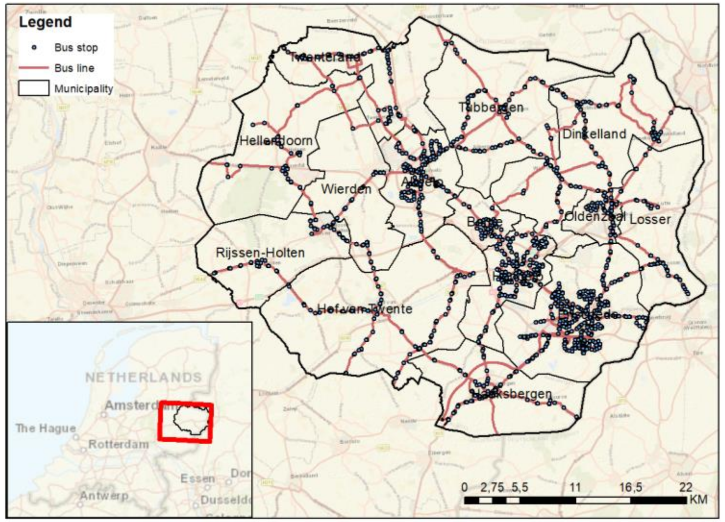
Disruptions and consequences

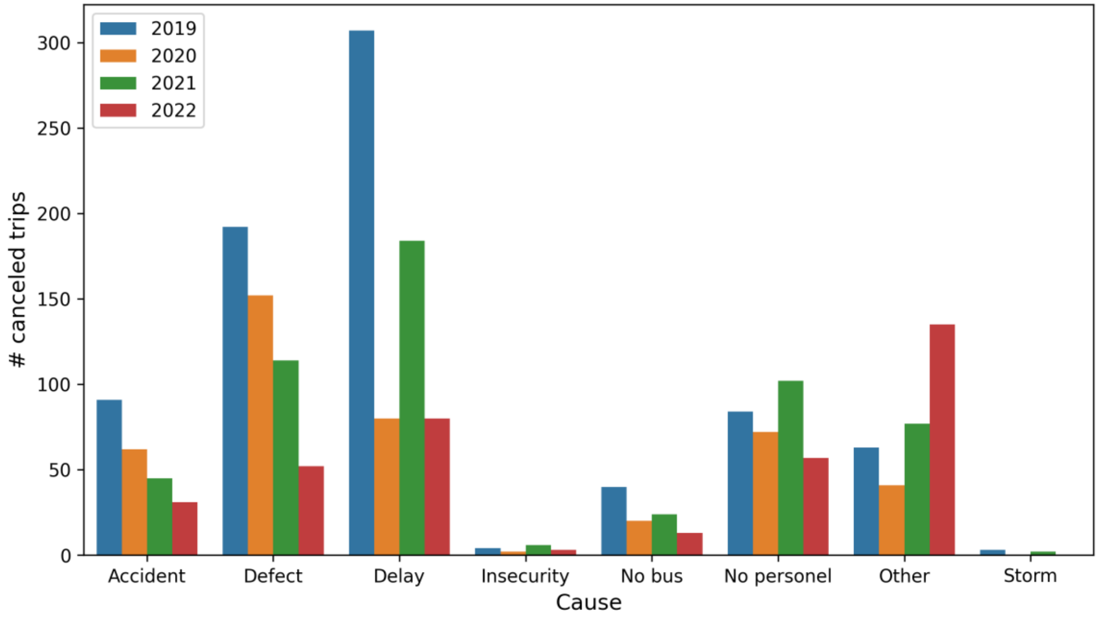
- Disruptions are inevitable for public transport
- Sources:
  - Weather
  - Road works
  - Technical failures
  - Events, etc.
- Potential consequences:
  - Direct: rescheduling, trip cancelations, delays, punctuality fines
  - Indirect: unpleasant travel experience, revenue loss, company’s image

DISRUPTIONS IN PUBLIC TRANSPORT

Twente network, the Netherlands

- Around 800 bus trips have been cancelled annually in the Twente bus network
- Primary/Secondary reasons:
  - Delays
  - Accidents
  - Vehicle defects
  - Shortage of drivers or vehicles
- Bus operation remains inflexible when facing such disruptions





WEATHER AND BUS RIDERSHIP

Impacts of extreme weather conditions

- Previous studies: weather influences travel mode choice behavior.
- In the Netherlands – frequent modal shifts between public transport (buses) and cycling
- Weather disruptions often result in crowded buses. In some cases the crowd exceeds the vehicles' maximum capacity

OPTIMAL BUS REASSIGNMENT

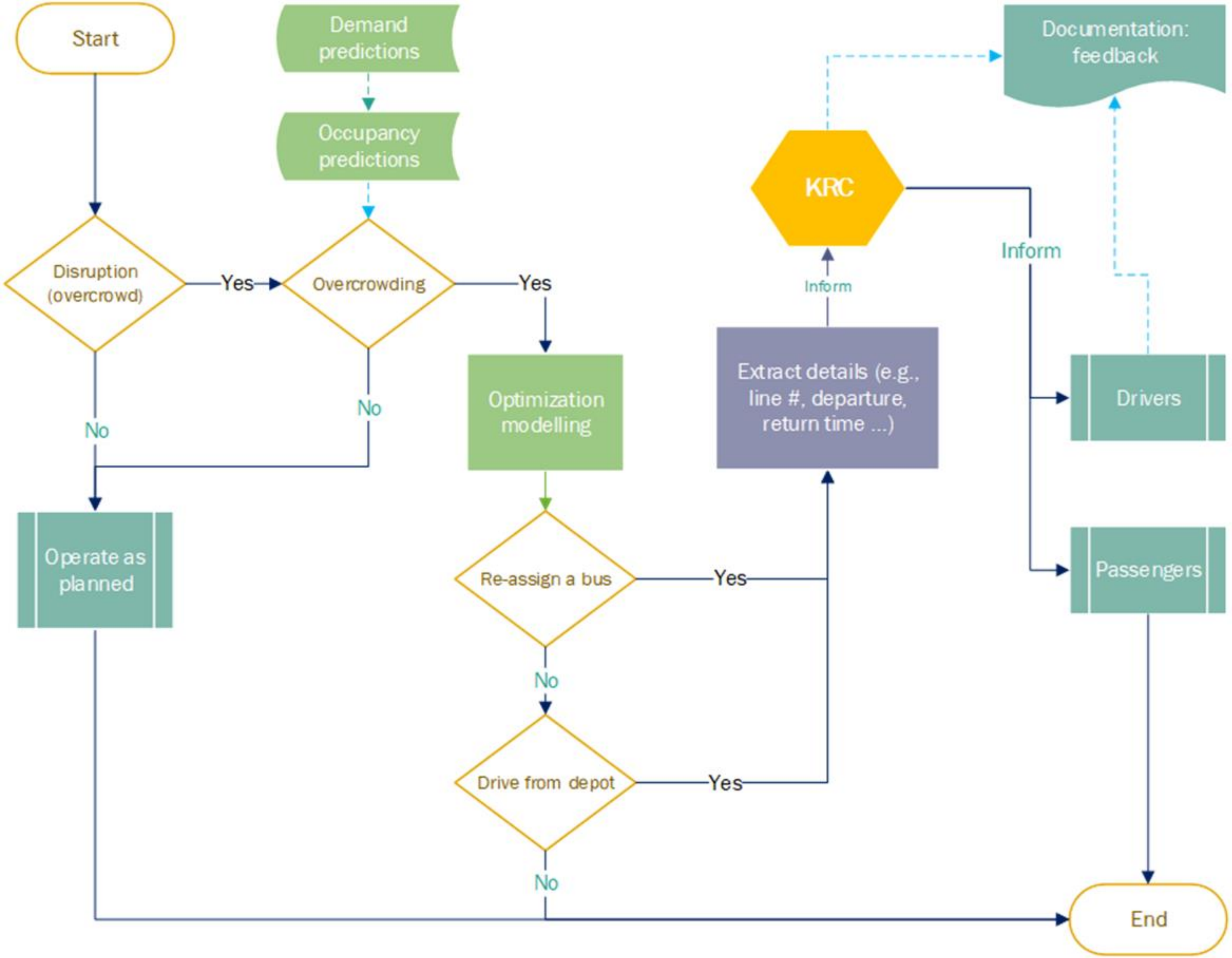
Current state-of-practice

- Run additional buses from the depot
- Disadvantages:
  - Require reserved capacity (drivers and vehicles)
  - Additional operating costs for the company

Alternative solution

- Bus reassignment from low-demand lines to overcrowded lines
- Advantages:
  - Efficient capacity allocation
  - Low cost for operators

REASSIGNMENT FRAMEWORK



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PROBLEM FORMULATION

Problem Formulation

Minimize waiting time of stranded passengers at bus stops under disrupted conditions

- Two-folded problem:
  - More passengers will be served with reassignment to overcrowded lines
  - Trip cancelation will cause discomfort for people whose bus got canceled.

$$\min f(x,y) = \sum_{(i,j)\in L}\sum_{s\in S_j}\zeta_s^j \cdot w_s^j \cdot x_{i,j} + \sum_{(i,j)\in L}\sum_{s\in S_j} 3\zeta_s^j \cdot w_s^j \cdot (1-x_{i,j})$$
$$+\sum_{(i,j)\in L}\sum_{s\in S_i} 2\vartheta_s^i \cdot w_s^i \cdot x_{i,j} + \sum_{(i,j)\in L}\sum_{k_i\in F_i}\sum_{s\in S_{k_i}} 2\vartheta_s^{k_i} \cdot w_s^{k_i} \cdot y_{k_i,j}$$

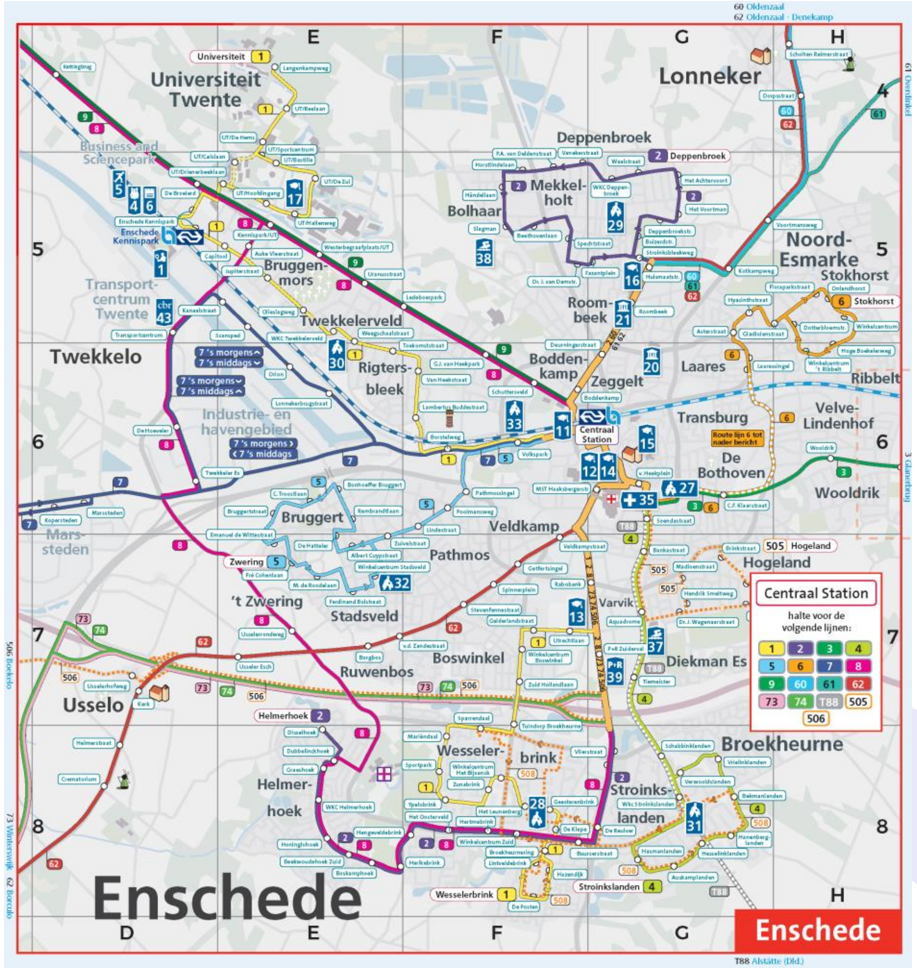
Subject to:

$$d_i + \delta_{i,j} \le d_{f_j}, \forall (i,j)\in L$$
$$-(d_i + \delta_{i,j}) \le -d_{p_j}, \forall (i,j)\in L$$
$$d_i + \delta_{i,j} \le d_j + T, \forall (i,j)\in L$$
$$-(d_i + \delta_{i,j}) \le -(d_j - T), \forall (i,j)\in L$$
$$\sum_{i\in L} x_{i,j} \le 1, \forall i \in T^r$$
$$\sum_{j\in L} x_{i,j} \le 1, \forall j \in T^a$$
$$d_i + (\delta_{i,j} + \lambda_j + \delta_{j,k_i}) x_{i,j} - M y_{k_i,j} \le d_{k_i}, \forall (i,j)\in L, \forall k_i \in F_i$$
$$\sum_{k_i\in F_i} y_{k_i,j} \le 2, \forall (i,j)\in L$$
$$x_{i,j} \le y_{k_i,j}, \forall (i,j)\in L, \forall k_i \in F_i$$
$$\delta_{i,j} \le \alpha, \forall (i,j)\in L$$
$$\delta_{j,k_i} \le \alpha, \forall k_i \in F_i$$
$$x_{i,j} \in \{0,1\}, \forall (i,j)\in L$$
$$y_{k_i,j} \in \{0,1\}, \forall k_i \in F_i$$

EXPERIMENT SETUP

Input data

Smart-card	• In-vehicle occupancy data • 2019 and September 2022
Timetable	• Departure, arrival, direction, vehicle number
Bus network	• Directed graph G=(N,A) • Nodes= stops, edges= segments
Deadhead time	• GoogleMaps API (distance matrix)
Weather	• KNMI (historical data) • Buienalarm (weather warning)



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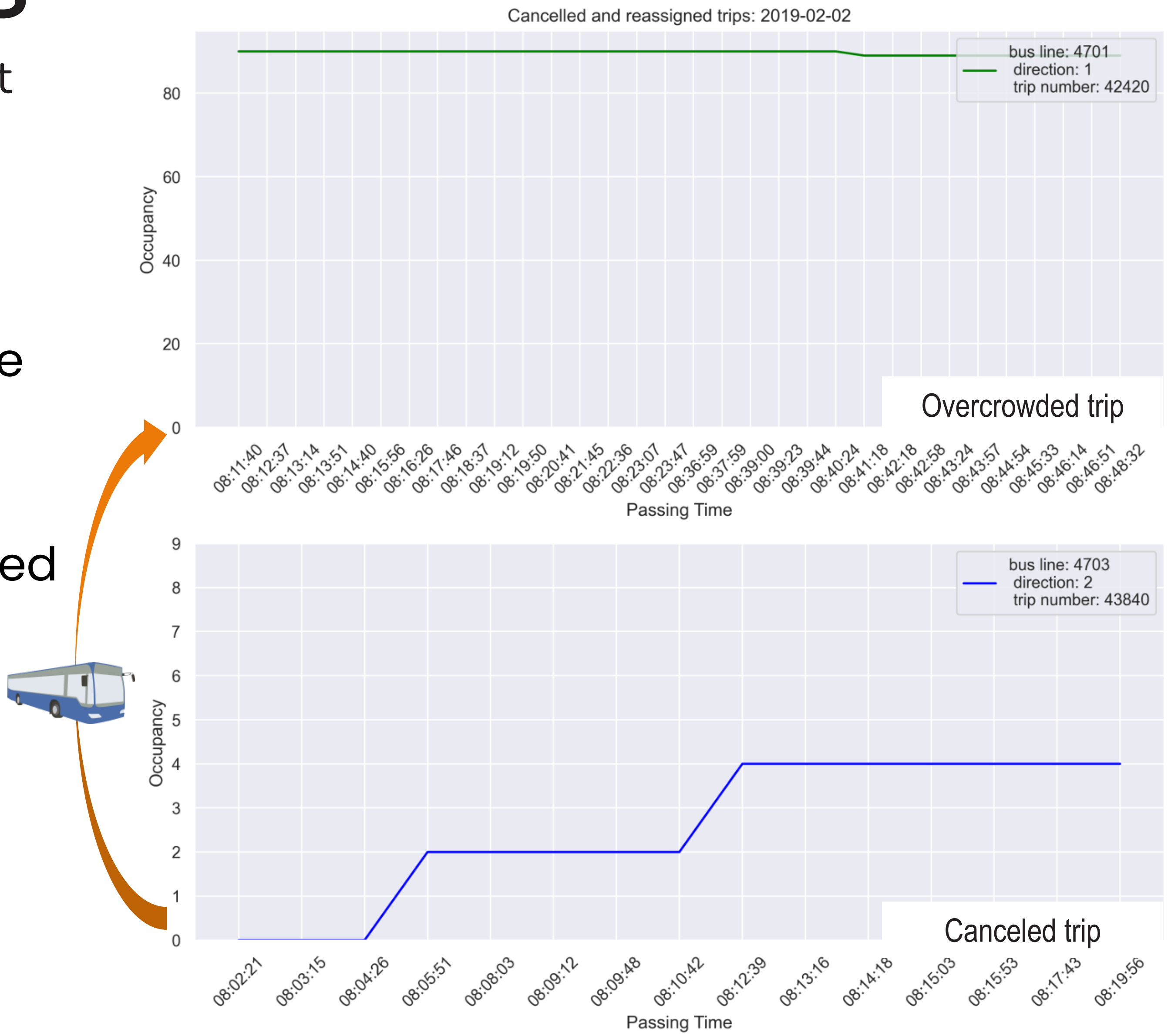
EXPERIMENT RESULTS

Overcrowding cases with bus reassignment

- Bus line 1: around 85 people boarded during the morning peak ➔ no more passengers picked up
- Bus line 3: max 4 people in the vehicle throughout the entire trip

- So, the bus from line 3 can be assigned to line 1 without significant negative impacts on passengers in line 3

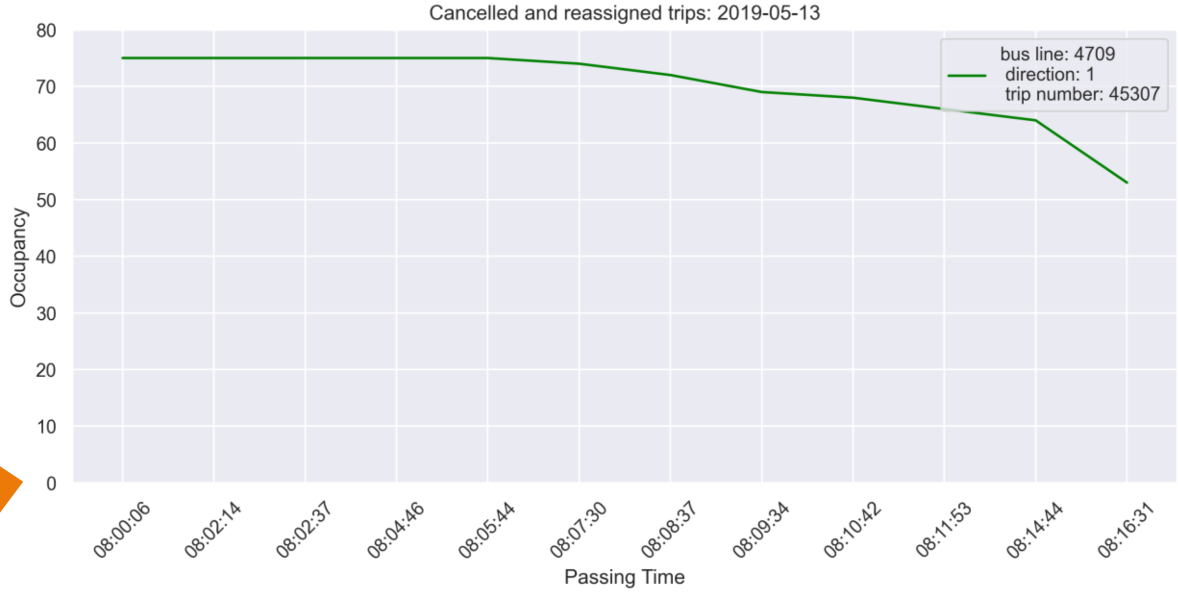


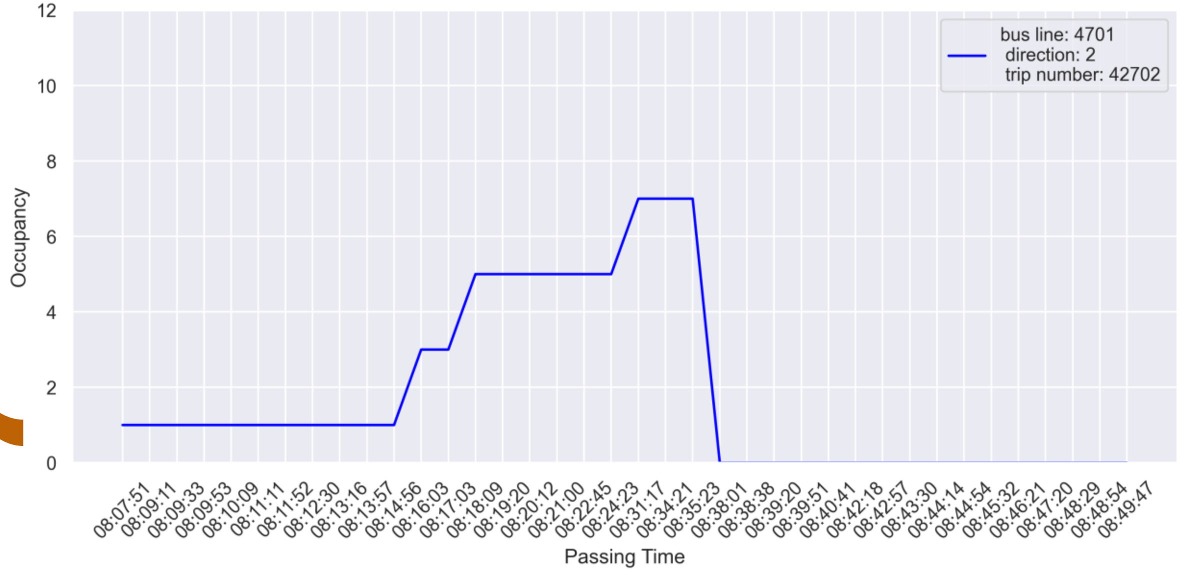
EXPERIMENT RESULTS

Overcrowding cases with bus reassignment

- Bus line 9: around 75 people boarded during the morning peak
- Bus line 1: max 7 people in the vehicle for a few segments

- So, the bus from line 1 can be assigned to line 9 without significant negative impacts on passengers in line 1



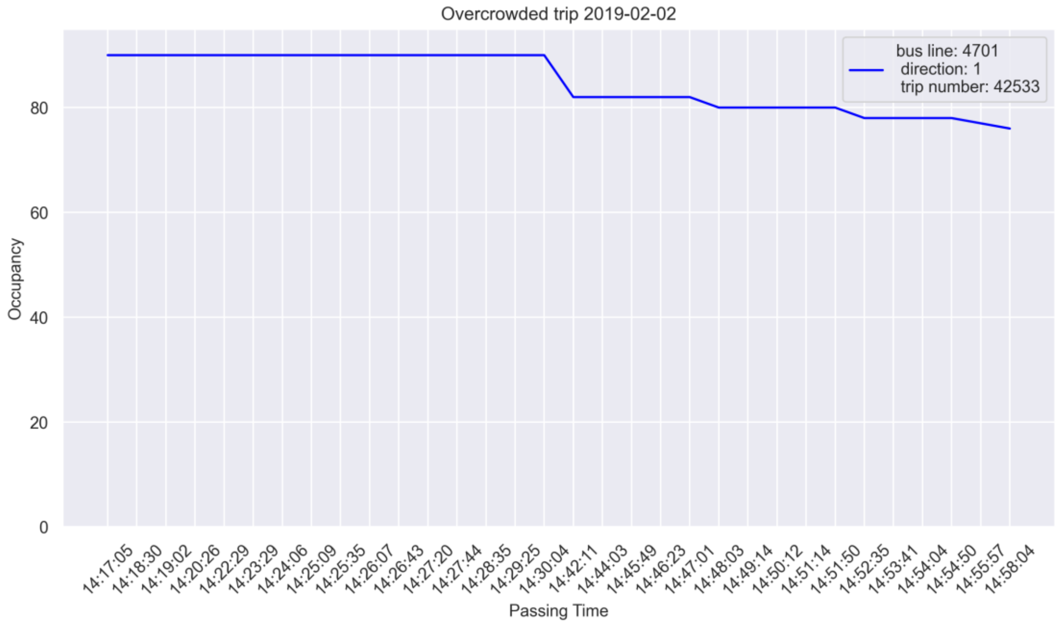


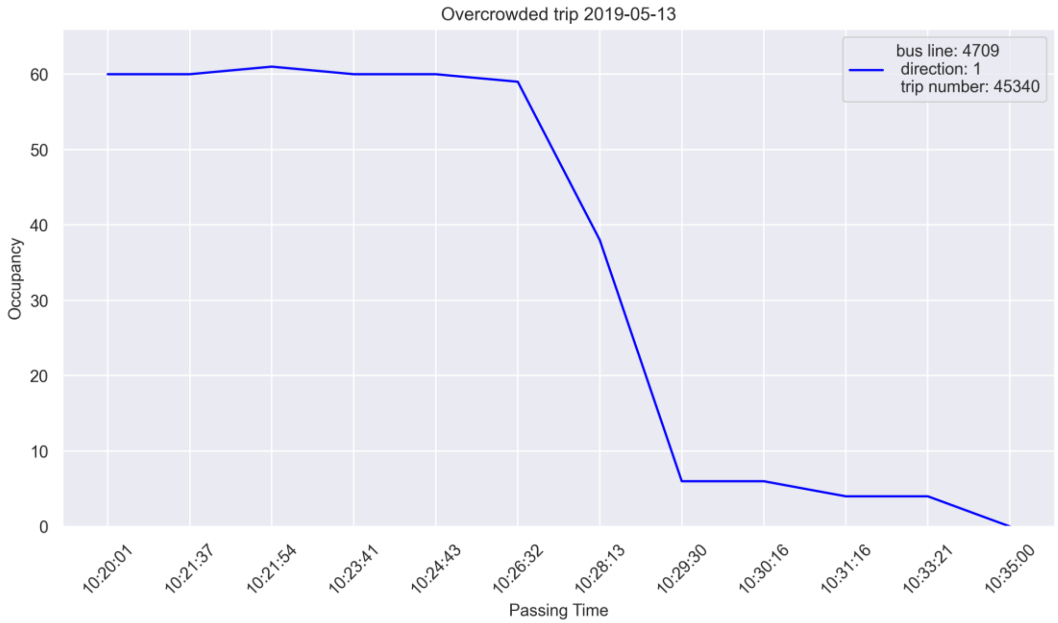
EXPERIMENT RESULTS

Overcrowding cases without bus reassignment

- Bus line 1: around 85 people boarded the bus in the afternoon ➔ no more passengers picked up
- Bus line 9: around 60 people boarded the bus

- In Both cases, no other trips could be canceled to reassign their buses.





CONCLUSIONS AND FUTURE RESEARCH

1. Efficient allocation of existing capacity under disrupted conditions
2. Solve overcrowding issues, as well as the shortage of bus drivers
3. Reduce reserved capacity to a minimum level

1. Test the model for other disruptions, e.g., large events, accidents, drivers' sickness
2. Implement the model in a network with higher passenger demand
3. Upgrade to multi-objective optimization (waiting time, operating cost)

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Q&A

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THANKS FOR YOUR ATTENTION!

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