Improved Transit Route Operations through Signal Priority and Bus Bridging Decision Support

Alaa Itani (alaa.itani@mail.utoronto.ca)
Wenxun Hu (wenxun.hu@mail.utoronto.ca)
Siva Srikukenthiran (siva.srikukenthiran@utoronto.ca)
Amer Shalaby (amer@ecf.utoronto.ca)

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
Transportation Research Institute

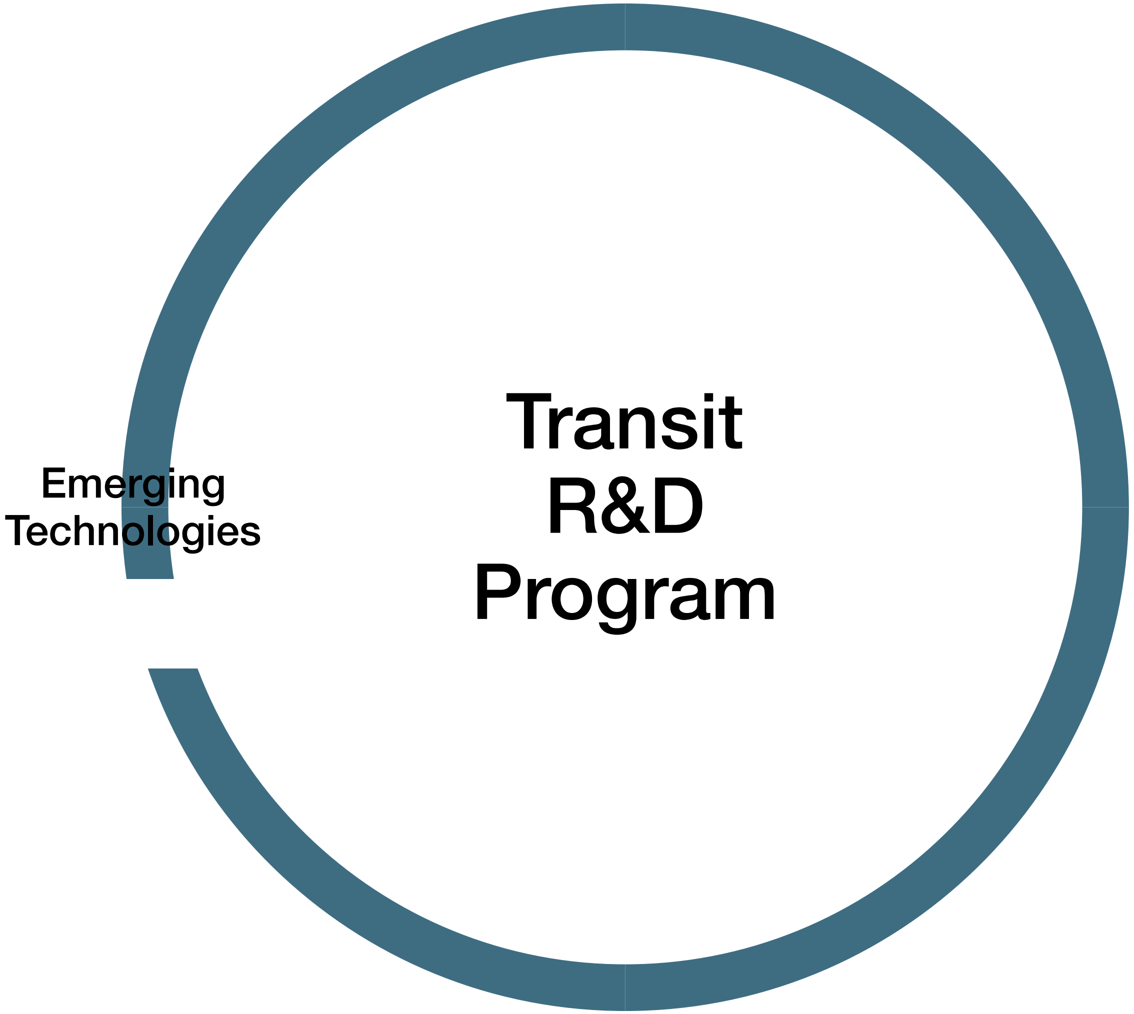
UTTRI

Outline

Transit Research Program Overview

Improved Transit Route Operations through Signal Priority

Bus Bridging Decision Support


Transit
R&D
Program
Emerging
Technologies

Past & Ongoing Research

- iCity: Urban Informatics for Sustainable Metropolitan Growth (IBM, City of Toronto, ESRI) – Transit Management Projects
- Nexus: Connected Simulation Platform for Operational Management and Planning of Transit Networks (Arup)
- Joint Optimization of Route Design and Schedules for Fixed Route Transit Systems (Trapeze)
- Canadian Ridership Trends Analysis (CUTA)

Improved Transit Route Operations through Signal Priority

Wenxun Hu (wenxun.hu@mail.utoronto.ca)

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
Transportation Research Institute

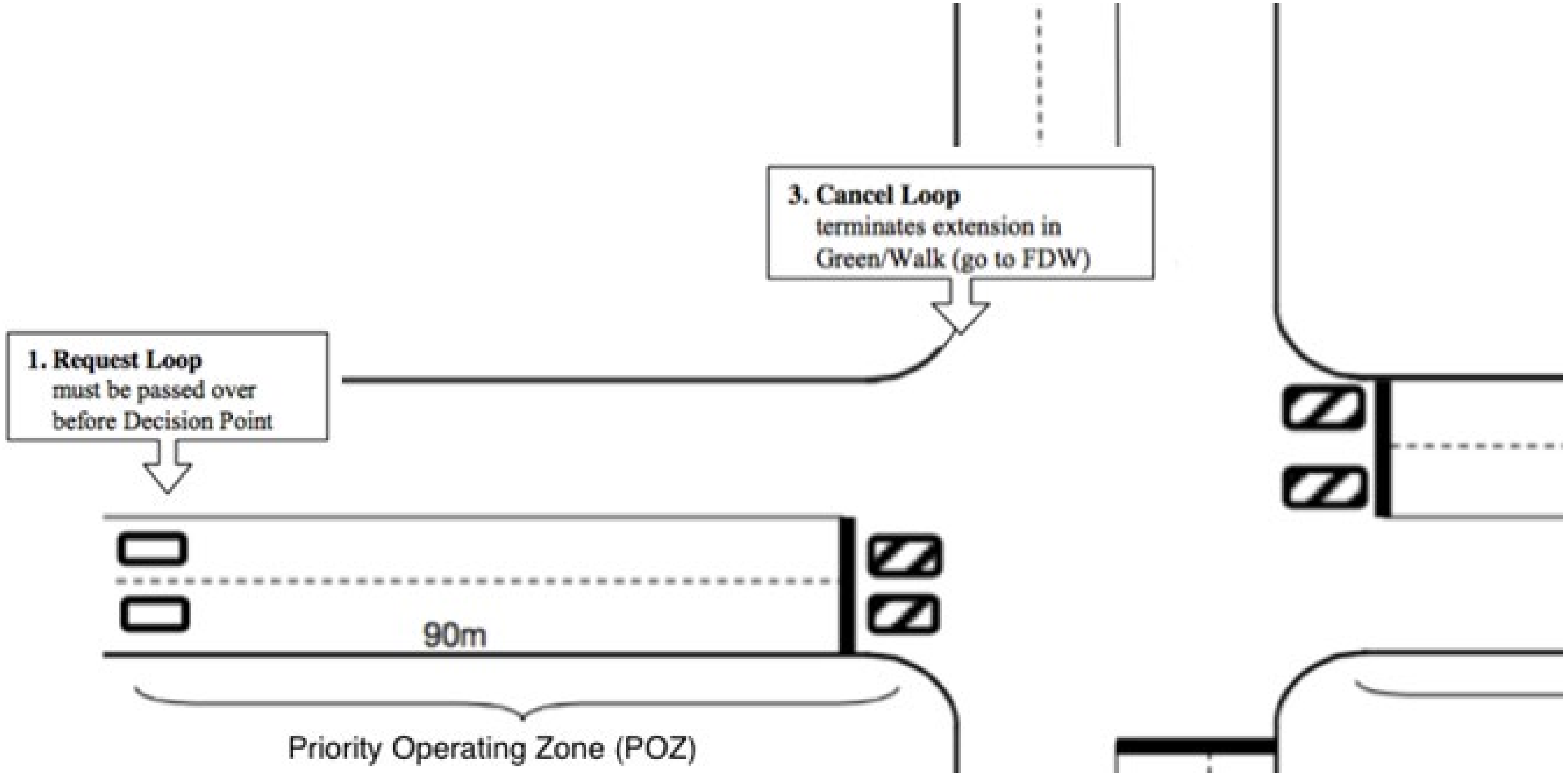
UTTRI

Transit Signal Priority (TSP)

A set of operational improvements that use technology to reduce dwell time at traffic signals for transit vehicles

Methods include holding green lights longer or shortening red lights

TSP in Toronto



Motivation

Reliability and speed are performance indicators important for both transit agencies and passengers

Transit services are vulnerable to variability and delays, especially in busy networks

The conventional TSP only aims at reducing delays

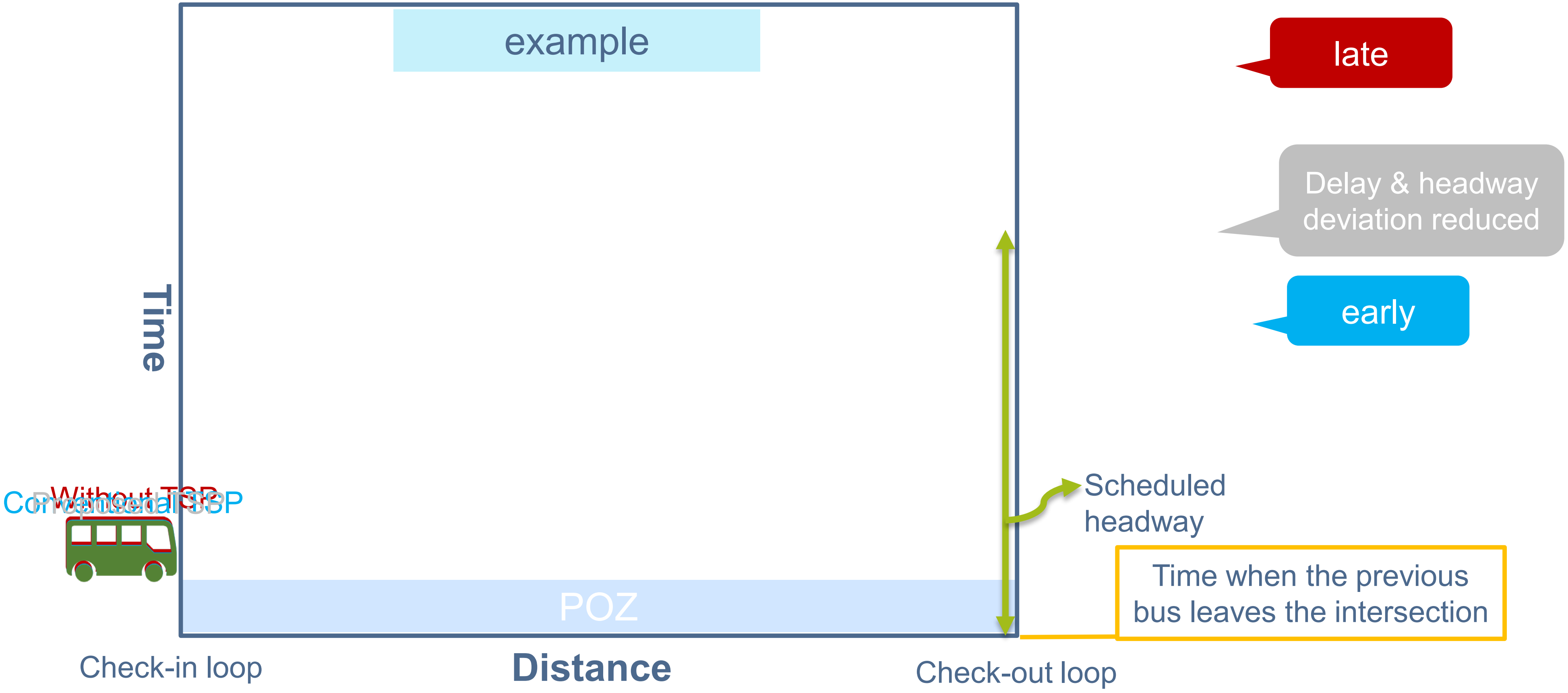
No strategies can adaptively improve headway regularity and reduce signal delays simultaneously

Goals

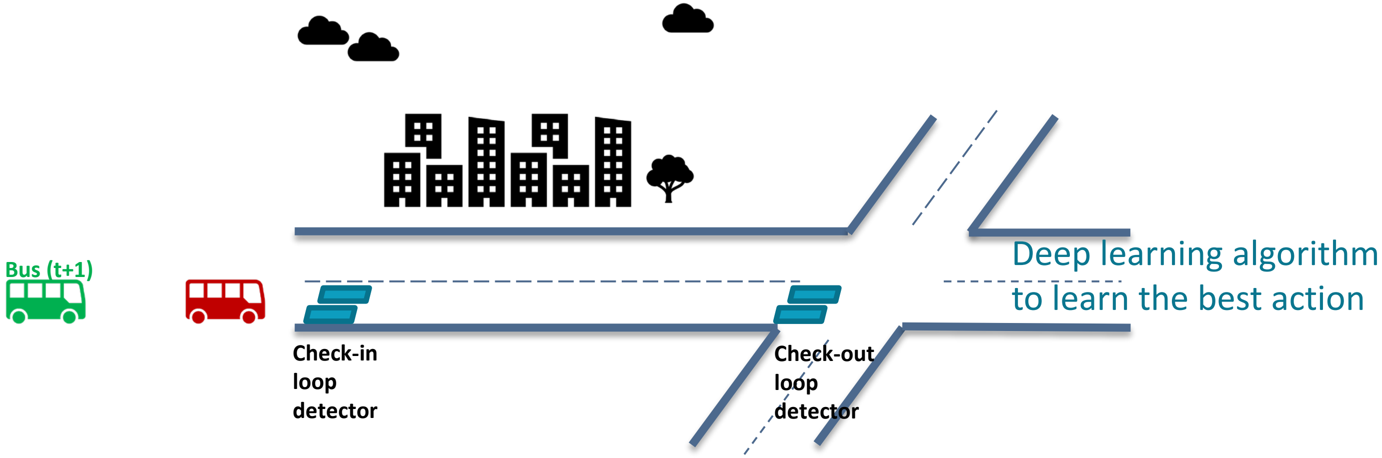
Develop adaptive TSP for improved reliability (regular headways) and speed

Validate the proposed TSP algorithm in the micro-simulation environment using an intersection in Toronto as a case study

Goals


example
late
Delay & headway deviation reduced
early
Time
Scheduled headway
Time when the previous bus leaves the intersection
POZ
Check-in loop
Distance
Check-out loop

Method – Deep Learning



APPROACH

Bus checks in: collect data of the environment state, including information on traffic flow, bus headways, and traffic signal timing

Information sent to the learning agent: traffic signal control system

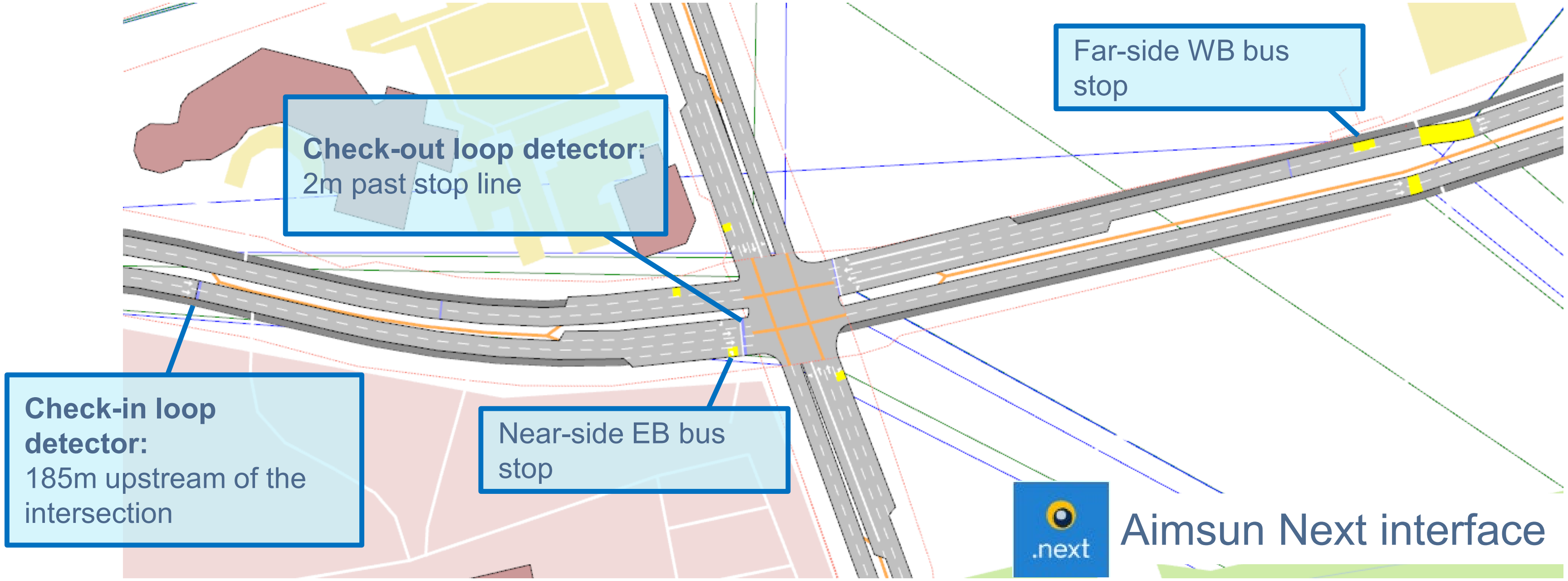
Take an action: decide on the length of green phase extension

Bus checks out: calculate headway to prior bus

Next bus checks in: collect data of the new state, calculate reward of action At, update the action-value function

Case Study

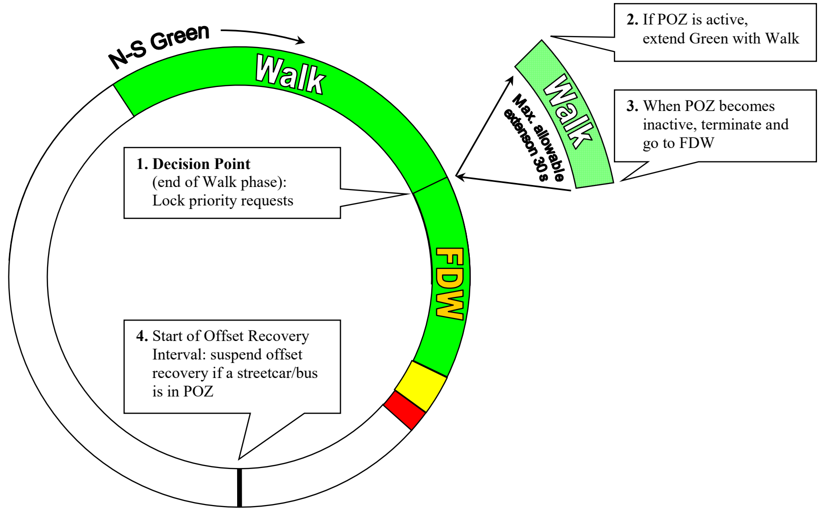
- Finch Ave West & Kipling Ave
  - TSP installed
- Bus line: 36 Finch West
  - poor reliability



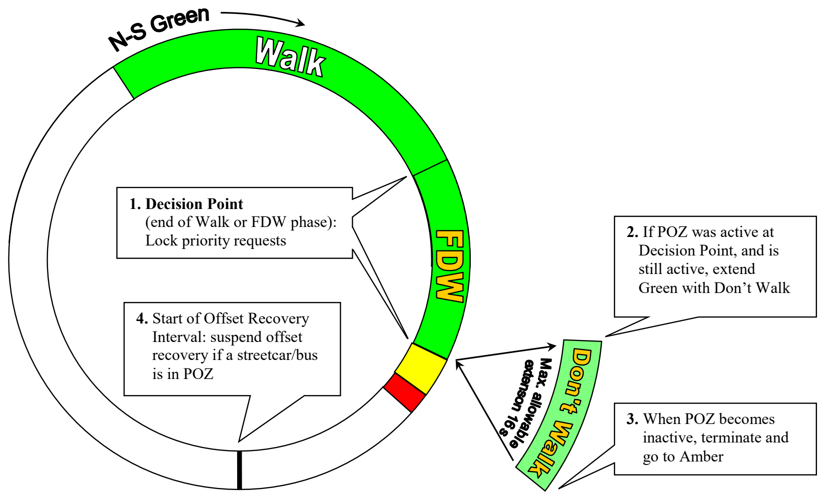
Case Study

- Base cases
  - No TSP
  - Existing TSP algorithms used in Toronto
    - Algorithm A and B
    - Simulation shows
      - no improvement in headway regularity
      - Time spent in POZ
        - Algorithm A: 78 sec （45% shorter than No TSP)
        - Algorithm B: 114 sec (19% shorter than No TSP)

Example A. Standard Algorithm:
Extensions during Walk (up to 30 s)

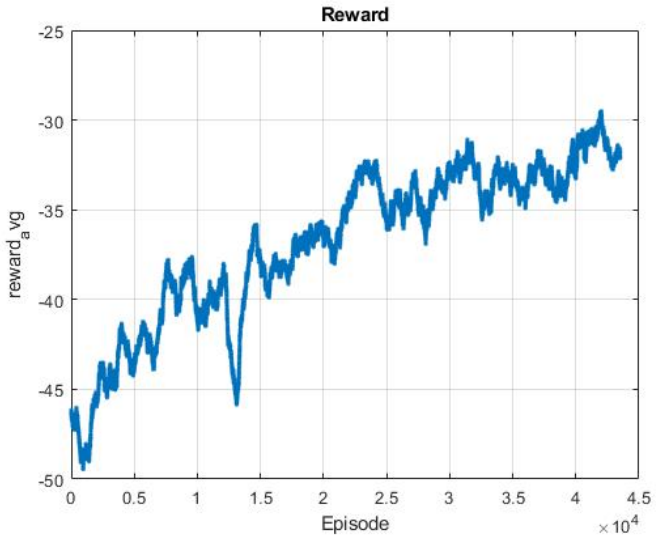


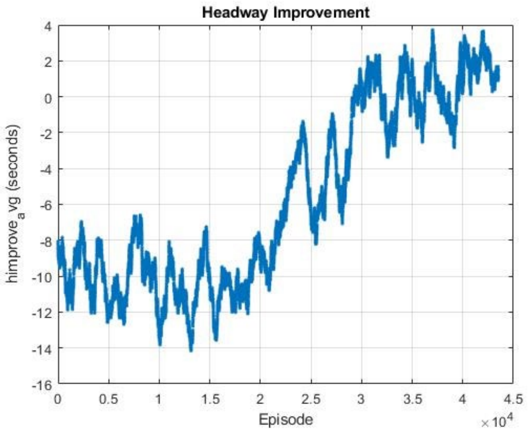
Example B. Standard Algorithm:
Extensions during Solid Don't Walk (up to 16 s)

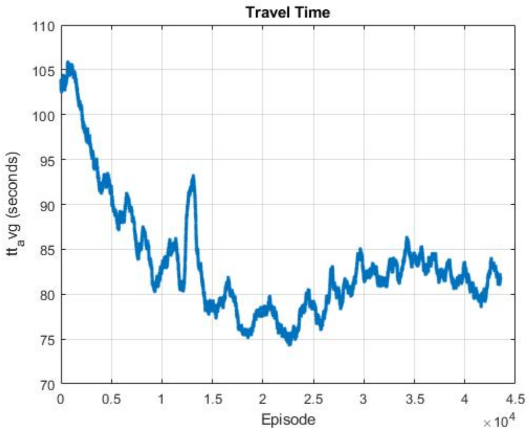


Case Study

- Proposed adaptive TSP (still in training)
  - Reward
    - Maximize $r = w_1(|h_{in} - h_{sc}| - |h_{out} - h_{sc}|) - w_2 tt$
    - 1st term: headway improvement, absolute value of check-in headway deviation minus check-out deviation
    - 2nd term: time spent in the POZ (tt)
    - Ws: weights







Summary

	No TSP	TSP Algm. A	TSP Algm. B	Proposed TSP
Average headway improvement per bus	/	/	/	10s
Average time in POZ per bus	141s	78s	114s	~80s

- Algorithm A and B provide green extension to buses when the POZ is active at predetermined decision point(s) in regardless of the headway
- No headway/reliability improvement using TSP algorithm A or B
- The proposed TSP
  - improves headway
  - Time spent in POZ is comparable to algorithm A

Next Step

- Test the effectiveness of the proposed TSP algorithm in scenarios with near- and far-side bus stops
- Develop coordinated route-based TSP

Bus Bridging Decision Support

Alaa Itani (alaa.itani@mail.utoronto.ca)

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
Transportation Research Institute

UTTRI

Motivation

Major unexpected rail disruptions occur frequently

Often, a simplistic approach is followed for selecting shuttle buses

Can lead to extensive delays for passengers and buildup at stations

Result in degraded service and potential loss of loyal passengers

Bus Bridging Assessment Tool

Main Goals

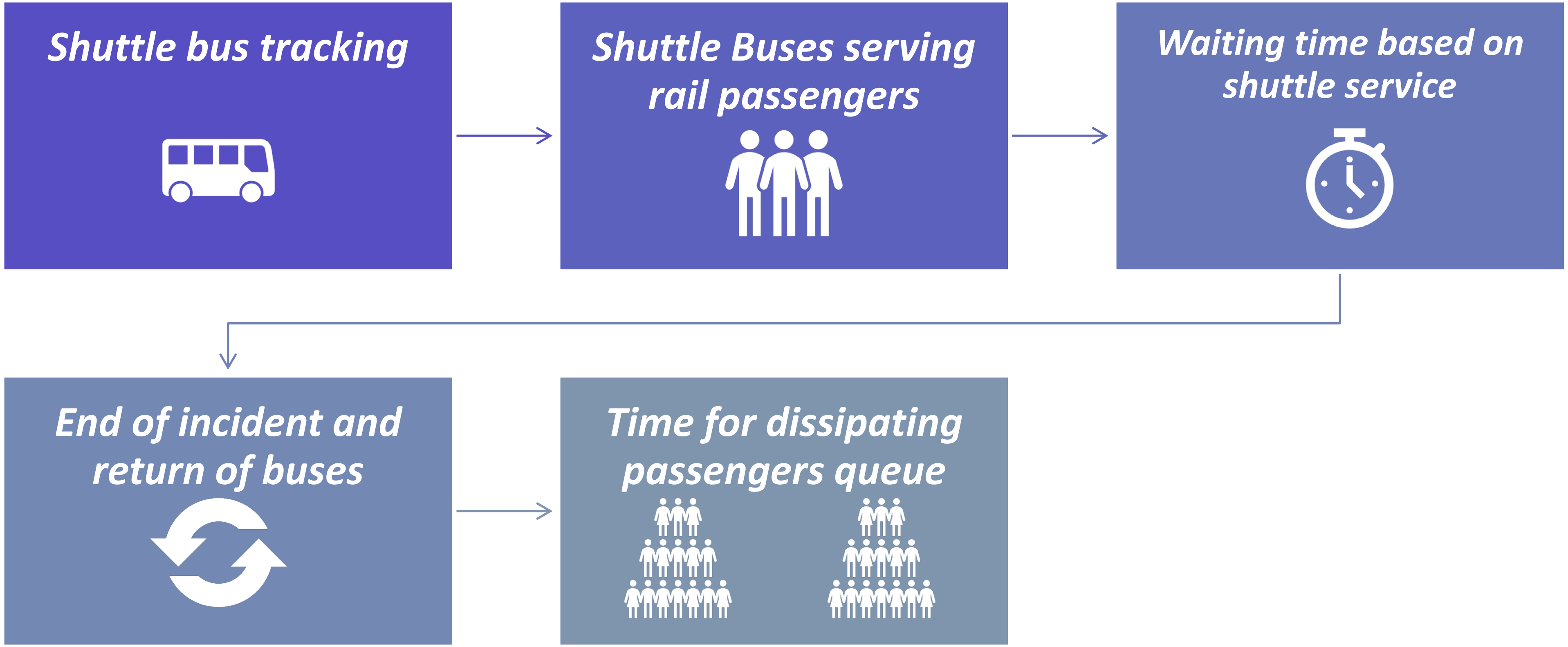
Develop a tool to help agencies evaluate potential bus bridging plans

Provide measures of the impact on train and bus passengers

Provide measure of how well shuttle buses are used

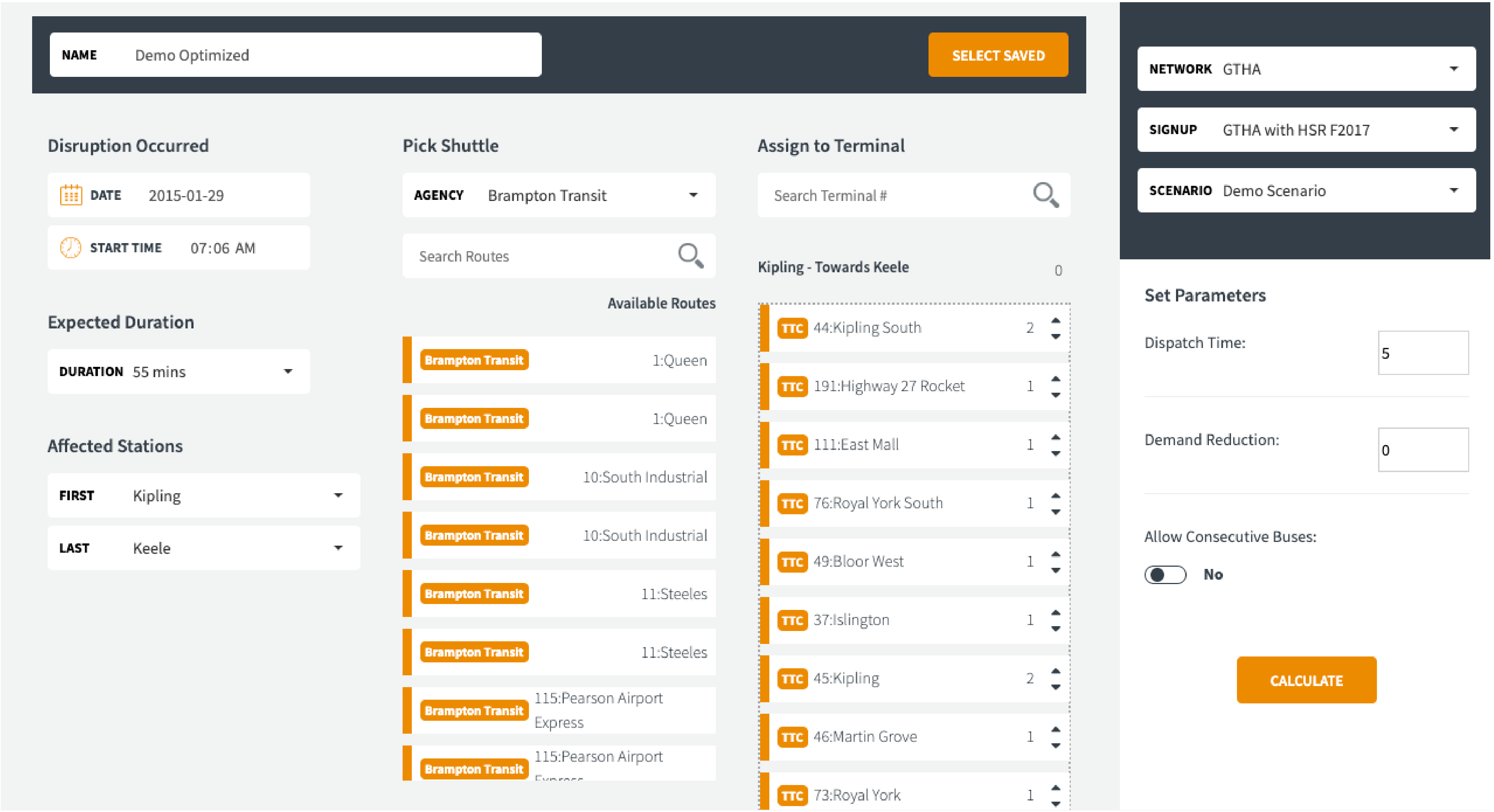
Bus Bridging Assessment Tool

Overview of the Methodology



Demo of the Bus Bridging Assessment Tool

Subway Disruption between Kipling and Keele Station (Line 2)



Demo of the Bus Bridging Assessment Tool

Subway Disruption between Kipling and Keele Station (Line 2)

Effectiveness Summary

TOTAL DELAYS

2227.5 hours
For **Subway Riders**

98.3 hours
For **Bus Riders**

MAP VIEW

NETWORK GTHA

SIGNUP GTHA with HSR F2017

SCENARIO Demo Scenario

DELAYS PER STATION

Station Name	No Riders Affected	RidersDelays (h)	Queue at End (p)	To Clear Queue (min)	Extra Wait
Old Mill Station - Westbound Platform	59.8	7.73	13.31	14.91	4.44
Keele Station - Westbound Platform	1,892.9	197.4	731.67	0	6.26
Jane Station - Westbound Platform	136.9	16.67	36.22	13.31	3.78
Runnymede Station - Westbound Platform	103.2	11.06	30.59	9.54	3.6
High Park Station - Westbound Platform	42.8	3.07	14.76	1.62	3.74
High Park Station - Eastbound Platform	231.5	153.95	224.88	15.95	25.18
Kipling Station - Eastbound Platform	1,851.6	403.65	1,318.03	0	13.08
Jane Station - Eastbound Platform	507.2	294.64	485.93	11.25	24.64
Old Mill Station - Eastbound Platform	261.7	151.82	256.17	10.03	25.27
Royal York Station - Eastbound Platform	793.8	403.72	766.85	8.6	24.73
Islington Station - Eastbound Platform	1,136.1	287.64	752.95	4.37	12.59
Royal York Station - Westbound Platform	81.4	11.14	13.33	16.05	5.58
Runnymede Station - Eastbound Platform	459.7	278.68	439.88	14.99	24.68

SAVE

MODIFY

Demo of the Bus Bridging Assessment Tool

Subway Disruption between Kipling and Keele Station (Line 2)

Effectiveness Summary

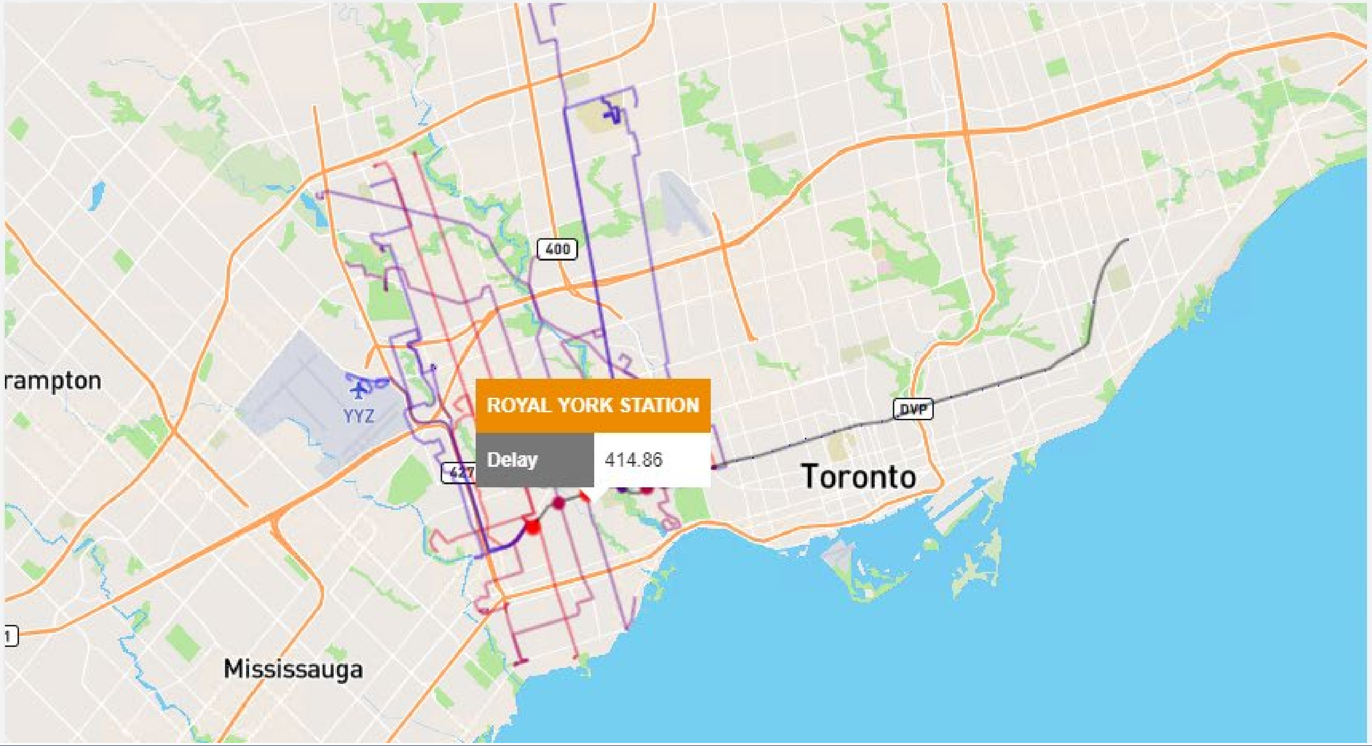
TOTAL DELAYS

2227.5 hours
For **Subway Riders**

98.3 hours
For **Bus Riders**

TABLE VIEW

Map View



NETWORK GTHA

SIGNUP GTHA with HSR F2017

SCENARIO Demo Scenario

SAVE

MODIFY

Beyond the Assessment Tool

1) Determine the maximum number of shuttle buses that could be deployed to serve a disrupted segment

2) Optimization (*Work in progress)*
   – Minimize the inconvenience of transit users due to disruption
   – Ensure passenger safety by minimizing passenger build-up at stations

Maximum Allowable Number of Shuttle Buses

Loading Areas

- Number of bus loading areas at each station

Station-Bus Capacity

- Allowable bus capacity at each station

Utilized Capacity

- Used space, per hour, by connecting buses at each station (Frequency)

Remaining capacity

- Available capacity for shuttle buses at each station

Maximum Number of shuttle buses

- The station of least remaining capacity controls the maximum number of shuttle buses

The following procedure is taken from Chapter 6 (Bus Transit Capacity) of the Transit Capacity and Quality of Service Manual (TCQM).

Bus Bridging Optimization Tool

Main Goal

Develop an algorithm that generates an efficient bus bridging plan

Minimize the impact on train and bus passengers

Maximize the utilization of shuttle buses

Genetic algorithms *are optimization methods that imitate the same mechanisms as those found in nature say inheritance, mutation, selection and crossover*.

Bus Bridging Optimization Tool

Objectives and Assumptions

Minimizing Transit User Inconvenience

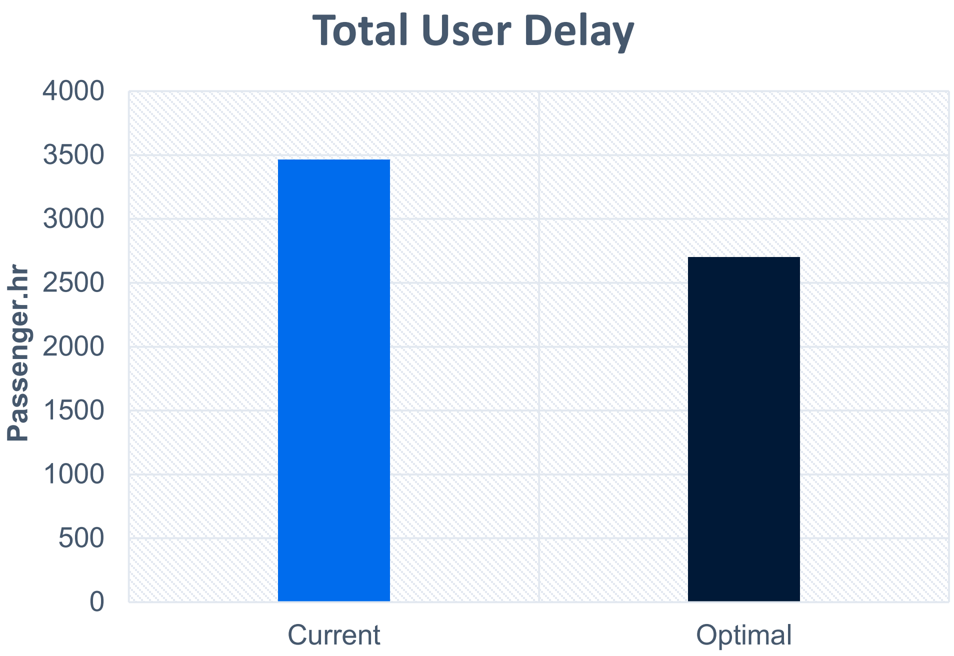
- Minimize subway passenger delays
- Minimize bus rider delays during disruption

Ensuring Passenger Safety

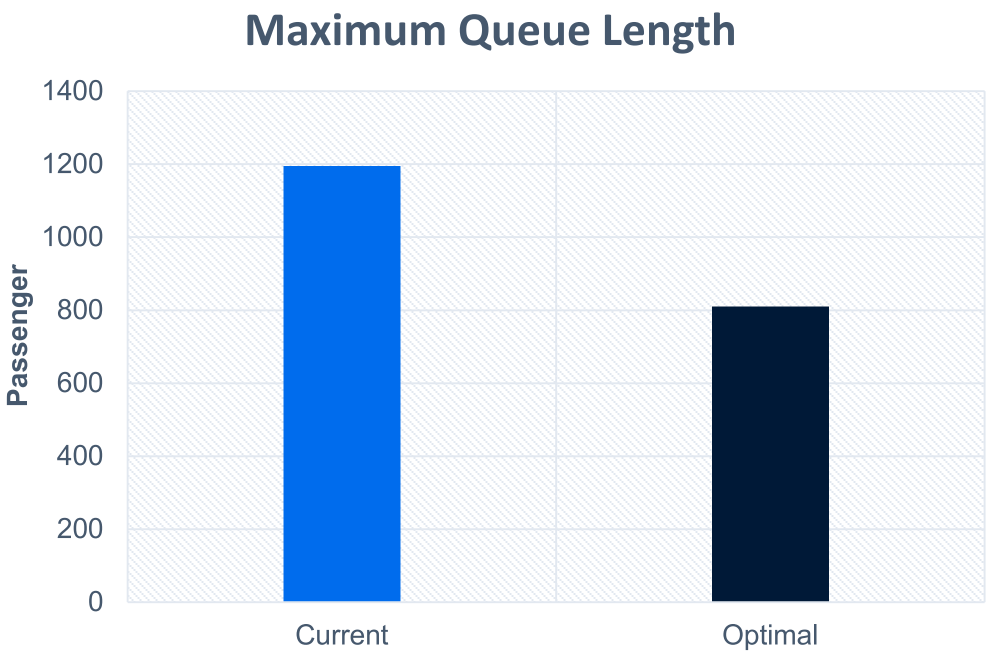
- Minimize the maximum queue at disrupted stations

Comparison of Outcomes

Current Practice vs. Optimal Plan



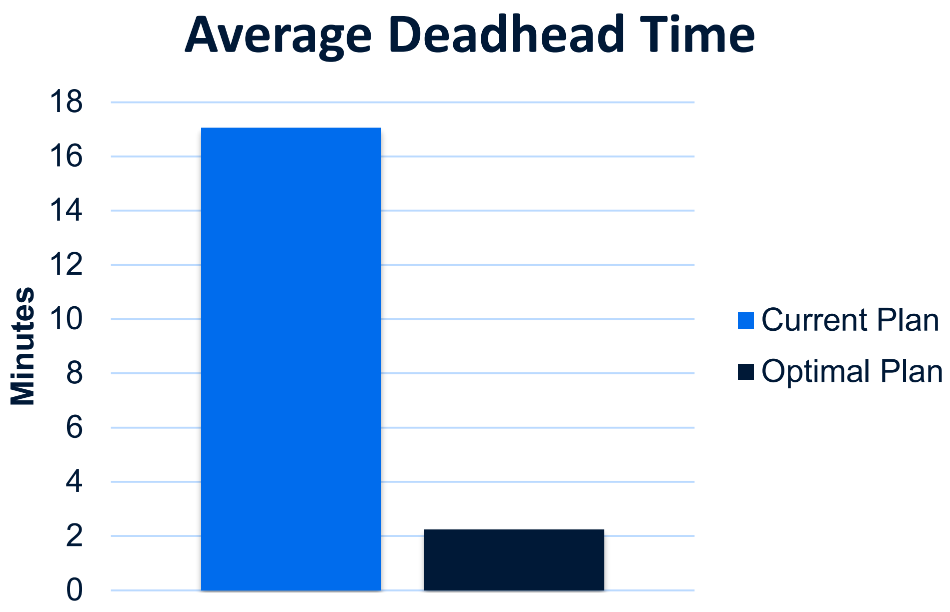
Net Savings = 765 passenger.hr
(Total reduction in waiting time for all affected passengers)

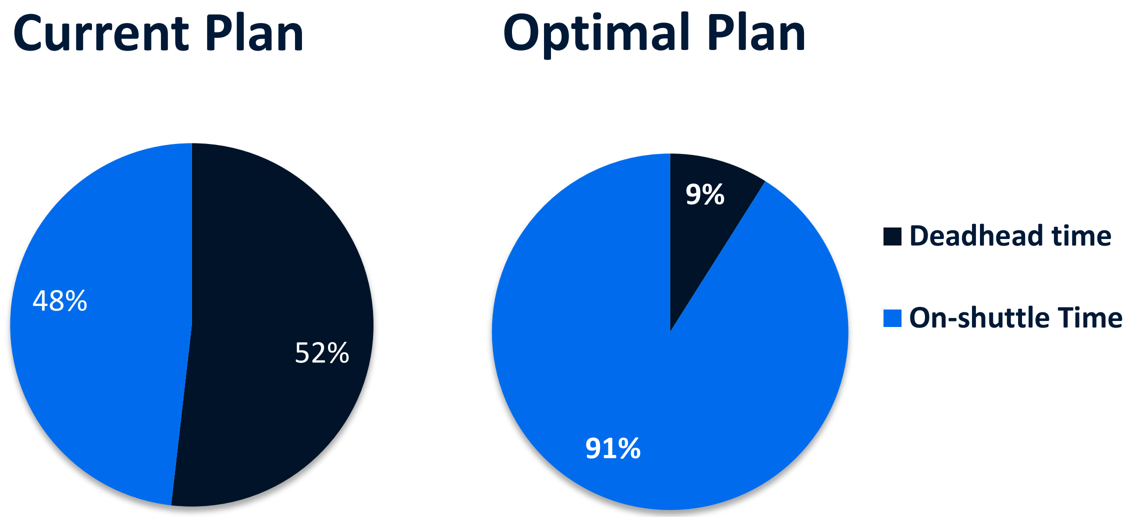


Reduced the queue at Kipling station by 400 passengers

Comparison of Outcomes (Cont.)

Current practice vs. Optimal Plan





15 mins, on average, is saved in deadhead time of each shuttle bus

Optimal plan shows a better utilization of shuttle buses along the disrupted segment

Benefits

Fast execution time, allowing for the evaluation of multiple plans rapidly

Enable the assessment and refinement of bus bridging policies and guidelines

Training tool for staff dealing with disruption management

Determine the most efficient bus bridging plan