Dual-Objective Transit Signal Priority for Improving Speed and Reliability of High-Frequency Lines: A Deep Reinforcement Learning Approach

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MOTIVATION

Transit Signal Priority (TSP)

• Effective in reducing signal delays

• Does not guarantee improvement in reliability

Transit Reliability and Speed

• Key performance indicators for transit agencies and users

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

• No strategies can adaptively optimize reliability and speed simultaneously

OBJECTIVE

Dual-Objective TSP

Adaptively optimize reliability (i.e., headway regularity) and reduce signal delays simultaneously

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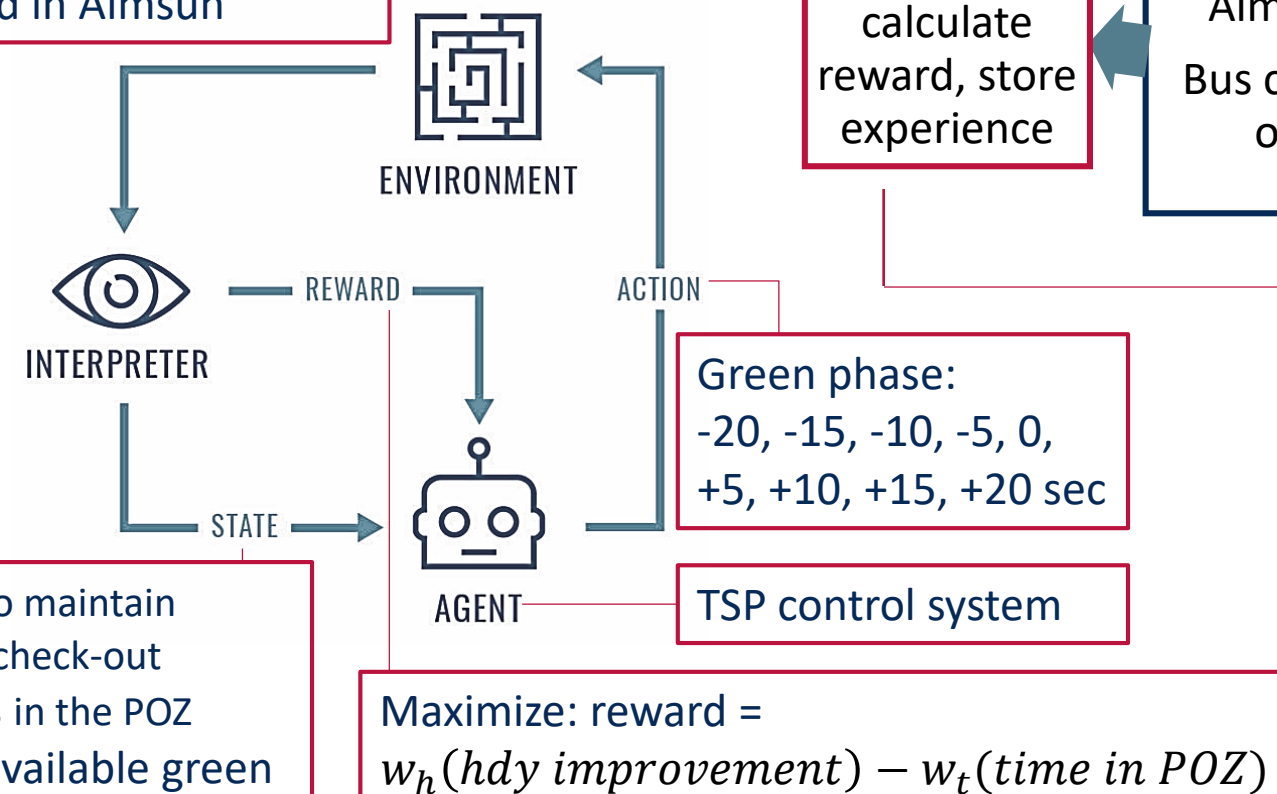### Two Objectives: Minimize Signal Delay vs. Minimize Headway Deviation

• Headway > scheduled headway: minimize signal delay reduces headway deviation

• Headway < scheduled headway: minimize signal delay aggregates headway deviation

MODEL FORMULATION

Deep Reinforcement Learning (DRL)

• Model free

• Efficient for large state space
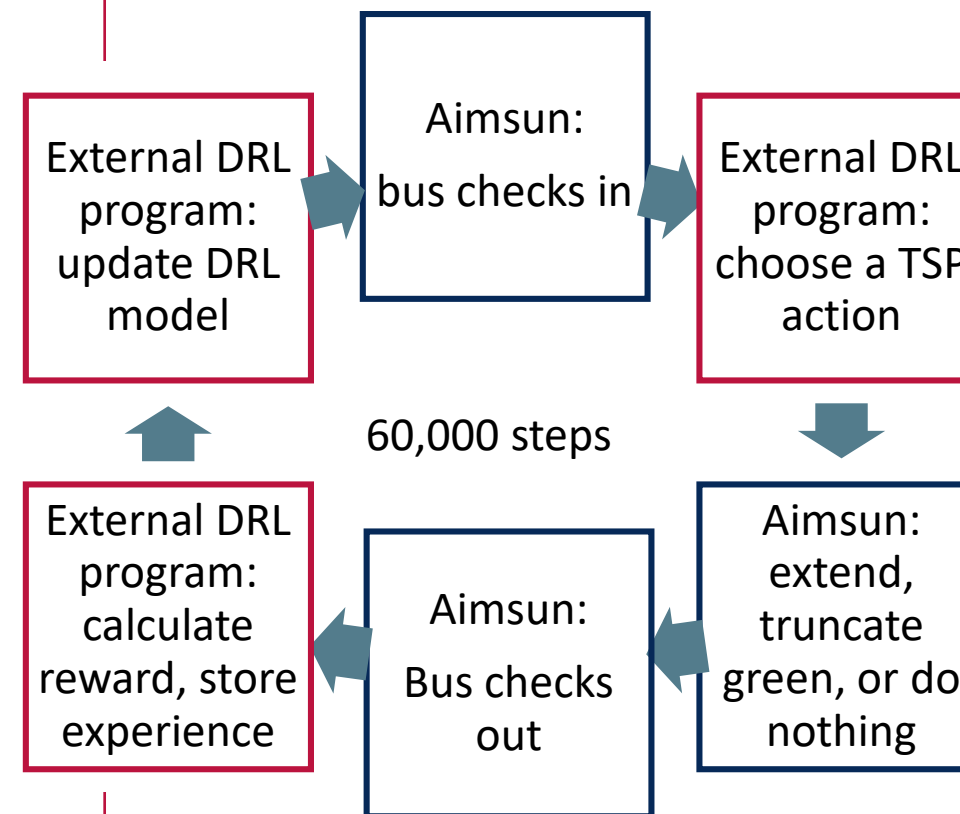

Transportation network simulated in Aimsun

ENVIRONMENT

REWARD — ACTION

INTERPRETER

STATE

AGENT

Green phase: -20, -15, -10, -5, 0, +5, +10, +15, +20 sec

TSP control system

• Target travel time to maintain scheduled headway at check-out
• Number of vehicles in the POZ
• Time to end of 1st available green

Maximize: reward = $w_h(hdy\ improvement) - w_t(time\ in\ POZ)$

SIMULATION

Training

• Microsimulation using Aimsun Next connected with external DRL program

External DRL program: update DRL model

Aimsun: bus checks in

External DRL program: choose a TSP action

60,000 steps

External DRL program: calculate reward, store experience

Aimsun: Bus checks out

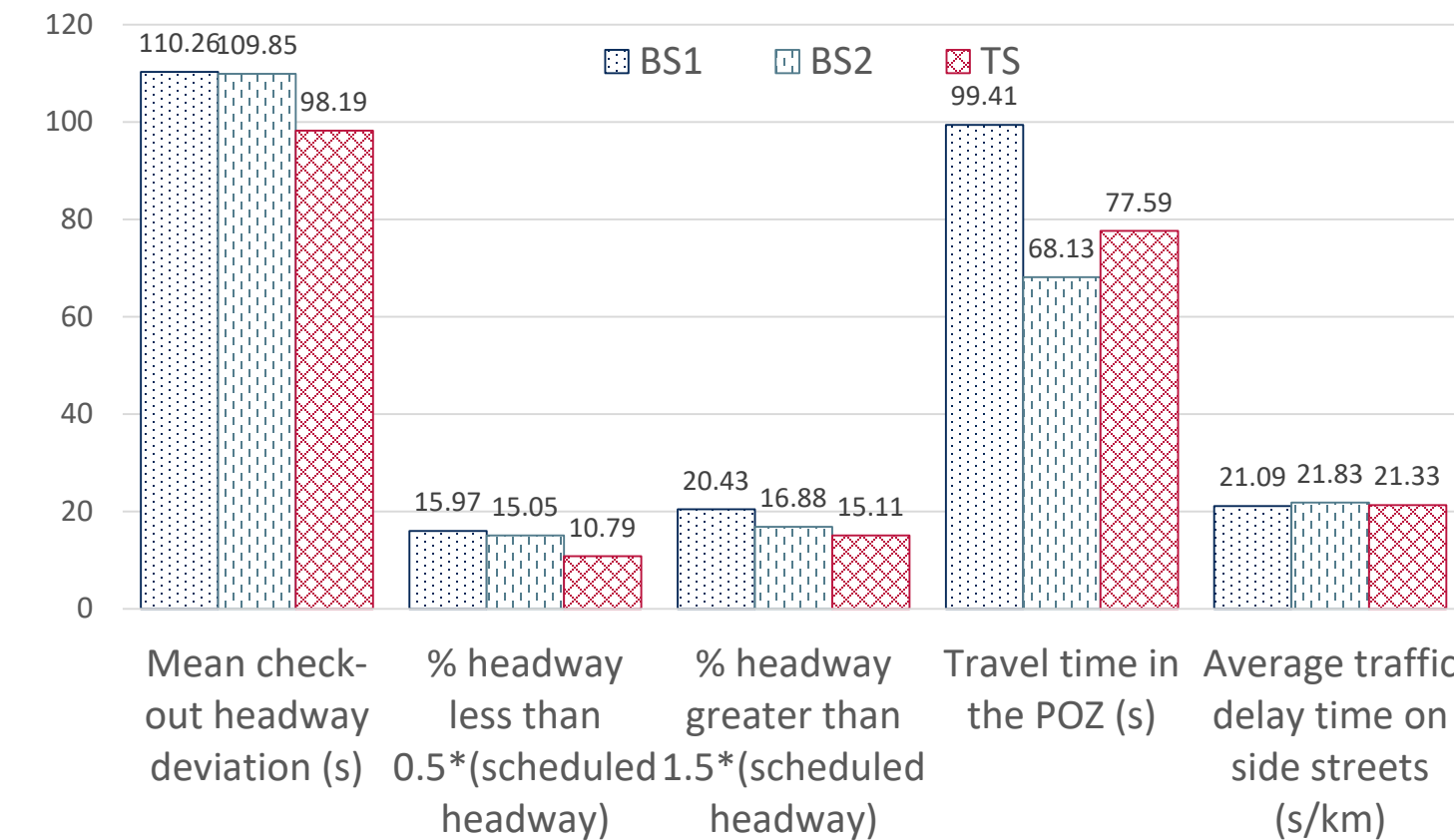Aimsun: extend, truncate green, or do nothing

Intersection

• Finch Ave West at Kipling Ave, Toronto

• A major intersection with TSP installed

• Existing TSP modeled: green extension up to 20 s

RESULTS

Base Scenarios

• No TSP (BS1) and Existing TSP (BS2)

Comparison of Performance

	BS1	BS2	TS
Mean check-out headway deviation (s)	110.26	109.85	98.19
% headway less than 0.5*(scheduled headway)	15.97	15.05	10.79
% headway greater than 1.5*(scheduled headway)	20.43	16.88	15.11
Travel time in the POZ (s)	99.41	68.13	77.59
Average traffic delay time on side streets (s/km)	21.09	21.83	21.33

• The DRL TSP (TS) has lower headway deviations compared with BS1 and BS2, and lower travel time (tt) in the POZ compared with BS1

• TS has longer tt compared with BS2. It may be worth trading 9 s of extra tt for 12 s of improvement in headway deviation, because passengers perceive one unit of out-of-vehicle tt longer than one unit of in-vehicle tt