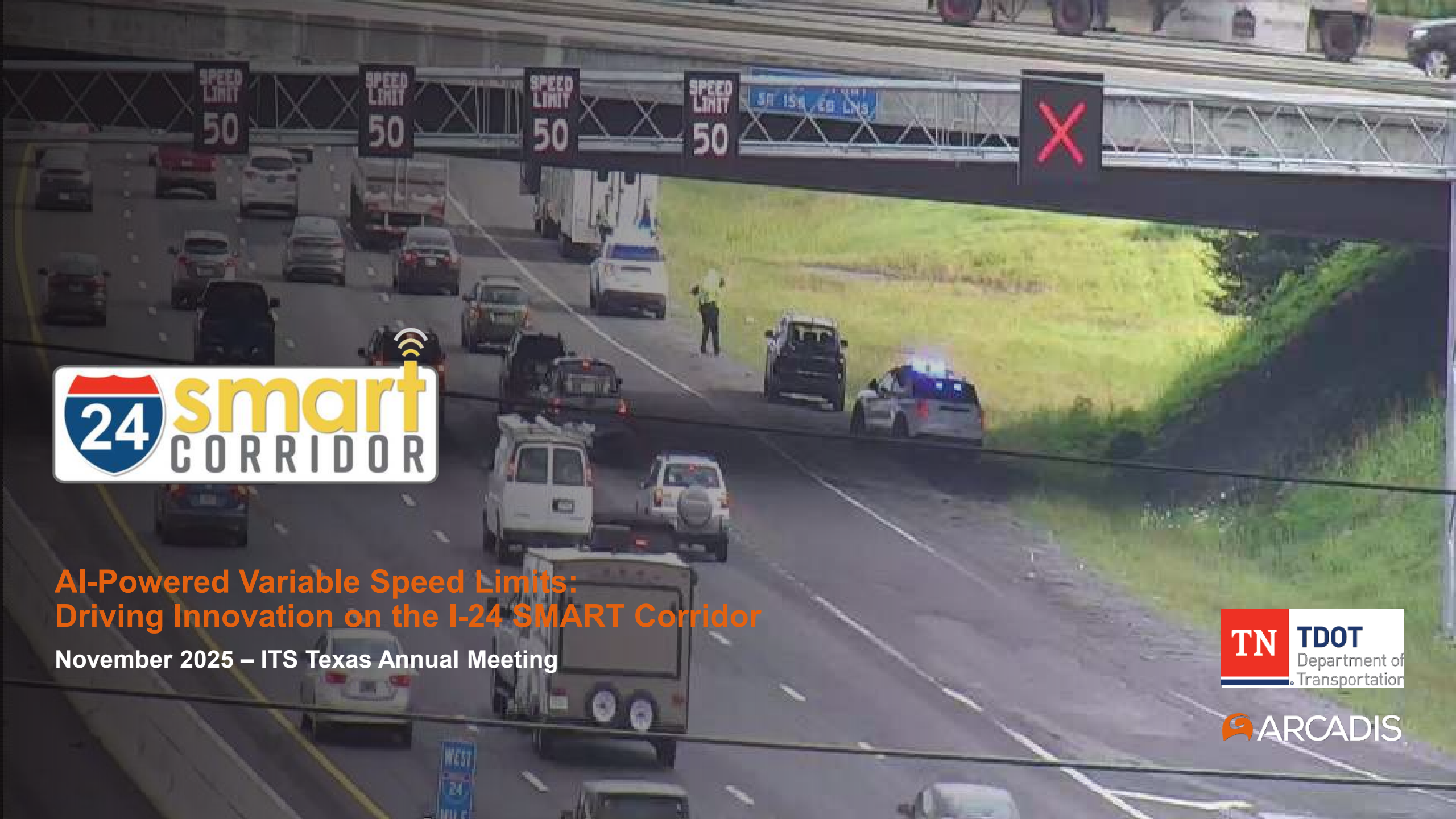



# AI-Powered Variable Speed Limits: Driving Innovation on the I-24 SMART Corridor

**November 2025 – ITS Texas Annual Meeting**

TN TDOT Department of Transportation

ARCADIS

# Project Location

**Integrated Corridor Limits:**

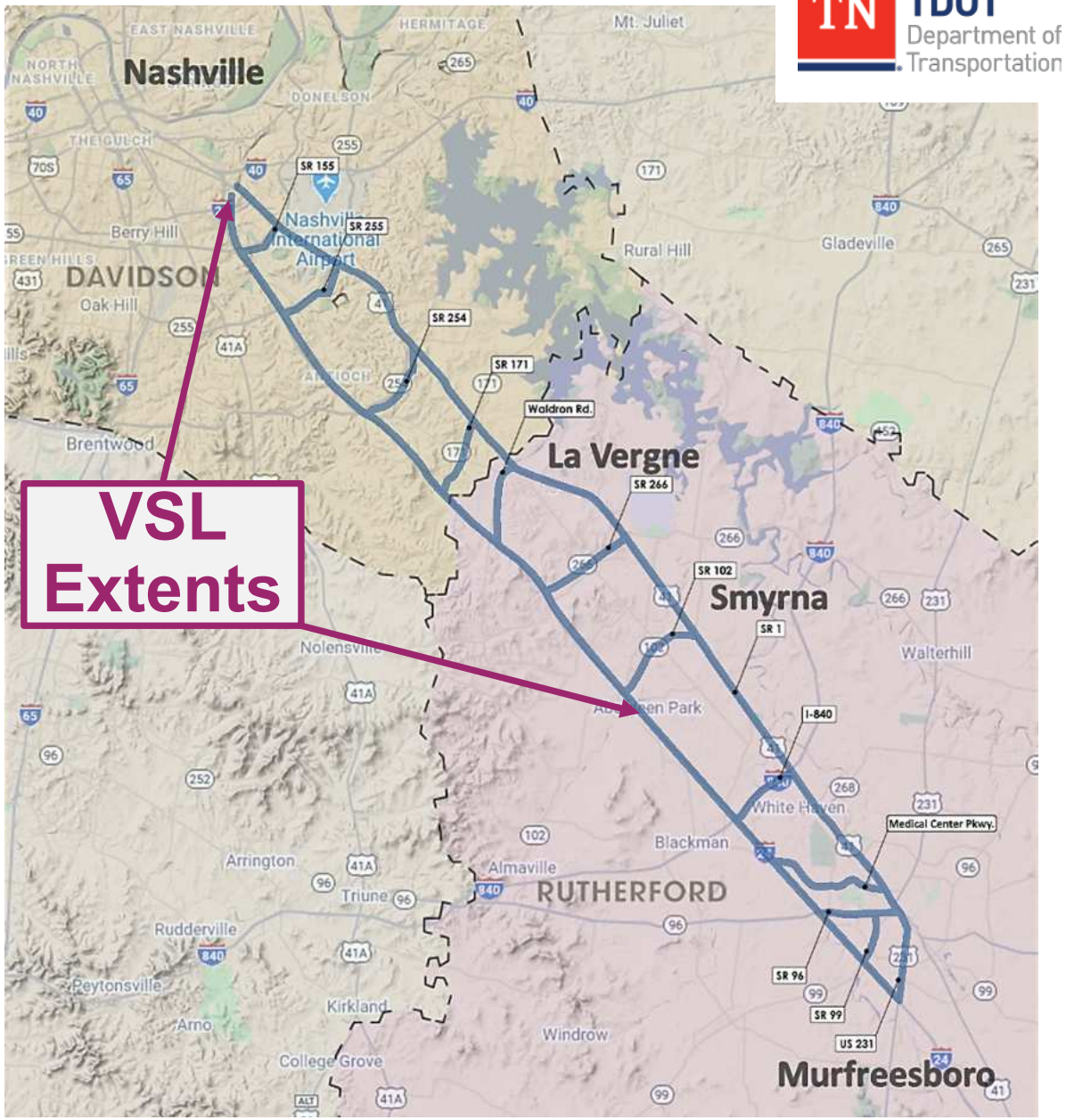
I-24: Exit 52 (I-440) to Exit 81 (US-231/Church St)

SR-1/US-41: Spence Ln to Church St

12 Connector Routes between I-24 to SR-1

**Lane Control with Variable Speed Limit Extents:**

I-24: Exit 52 (I-440) to Beyond Exit 70 (Lee Victory Pkwy)



# Advanced TMC Operations for Integrated Corridor Management

TN TDOT Department of Transportation

**I-24 SMART Corridor Physical Improvements:**

- Extended Ramp Lengths
- Emergency Pull-Off Locations w/ Video Detection
- Lane Control System
- Variable Speed Limits
- Additional CCTV Cameras
- Fiber Optic Communications
- Traffic Signal Optimization and Control
- Diversion Traffic Signal Operations

**Current TMC Strategies and Tools:**

- Video Analytics / Incident Detection
- Center-to-Center Connectivity with Local Agencies
- AI-Integrated Decision Support System


24 smart CORRIDOR

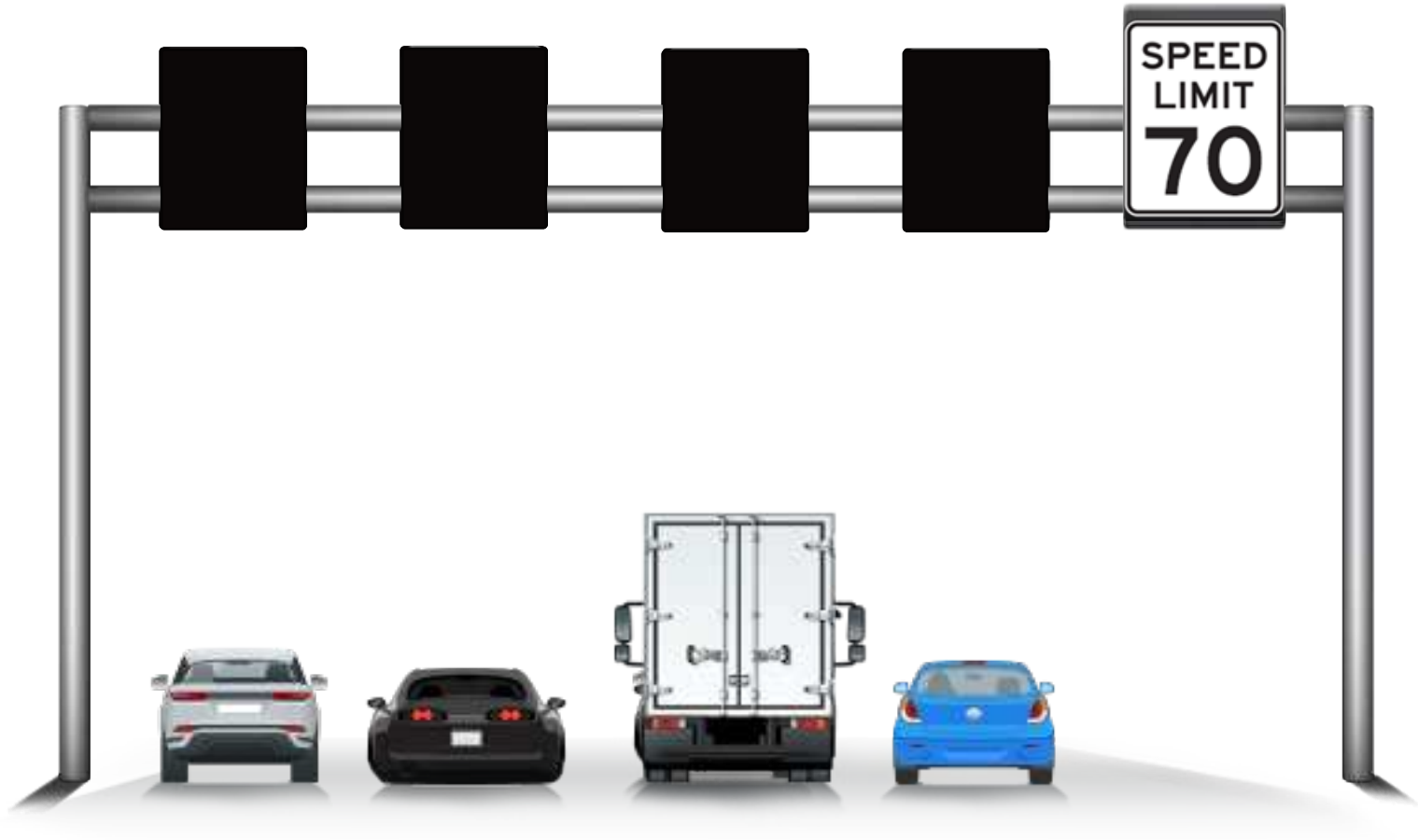
ARCADIS

# Gantry Basic Operations

What you see as you approach an event.

Includes Variable Speed Limits (VSL) and Lane Control System (LCS) signs.

LCS Gantries are spaced at approximately ½ Mile

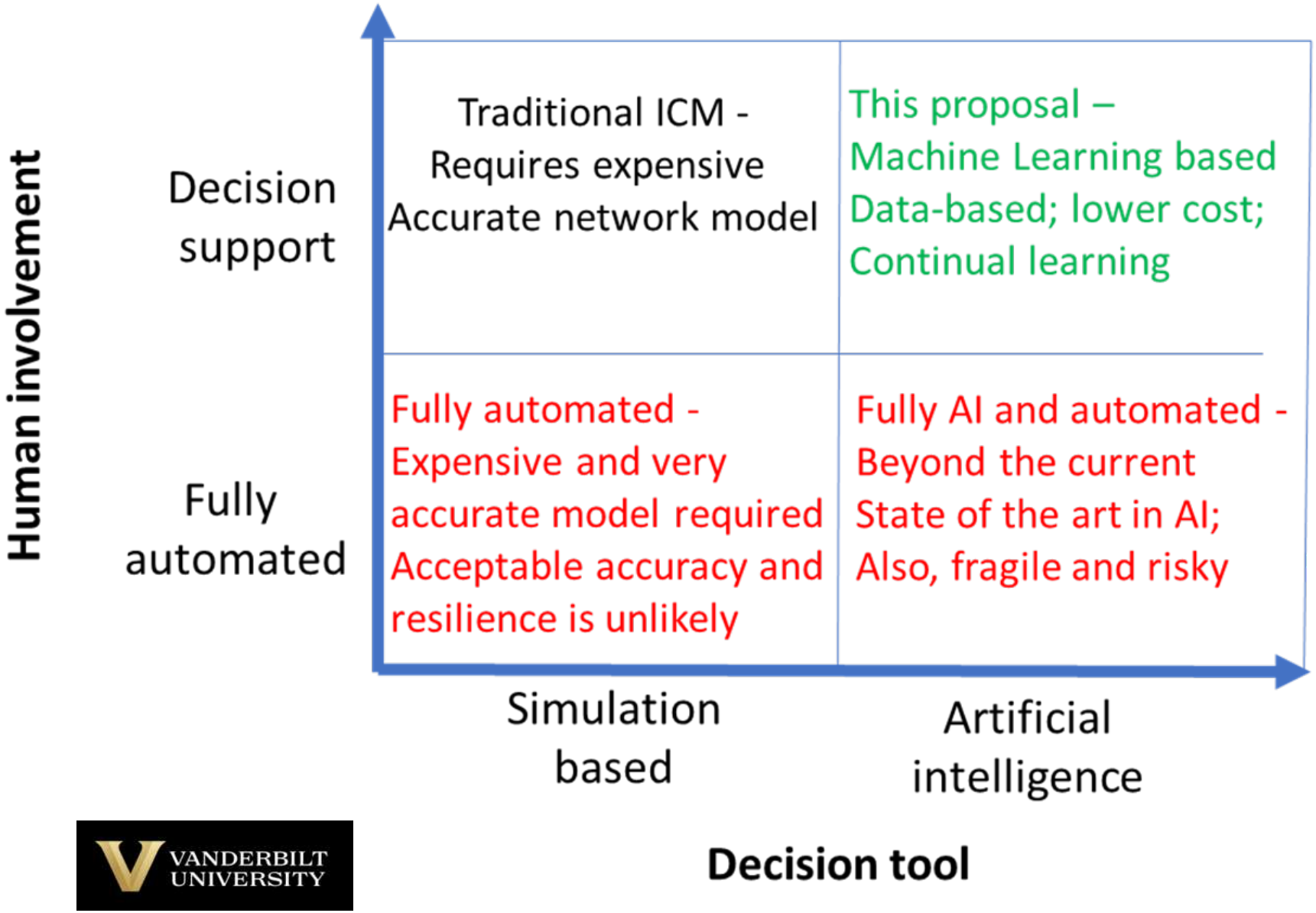


# Why AI?

AI-Decision Support System provides adaptive control based on real-time I-24 data.

The AI can receive, process, and respond to changing conditions almost instantly.

AI-VSL: The AI receives radar speed data every 30 seconds and can update every 30 seconds based on a rolling 90 second average.

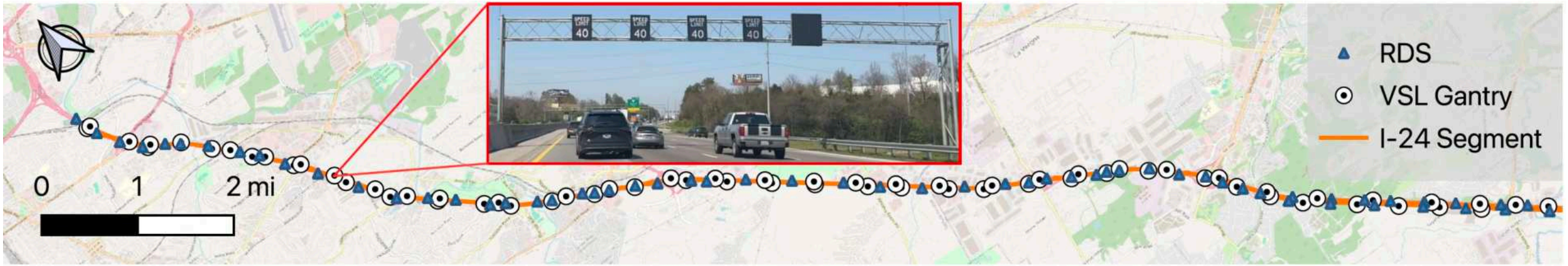


# TDOT AI-DSS

## Why TDOT selected AI-DSS for I-24 SMART Corridor

- The addition of hundreds of new devices significantly increases operational complexity for TMC operators.
- ICM strategies are being implemented for the first time at TDOT, requiring advanced coordination.
- A scalable software solution is needed to keep pace with the evolving needs of the Traffic Management Center.
- AI-DSS proactively recommends ICM response plans to operators for review and approval.
- The system continuously improves by learning from operator feedback, manual adjustments, and historical data.
- AI capabilities enhance the processing and analysis of data to support VSL operations.

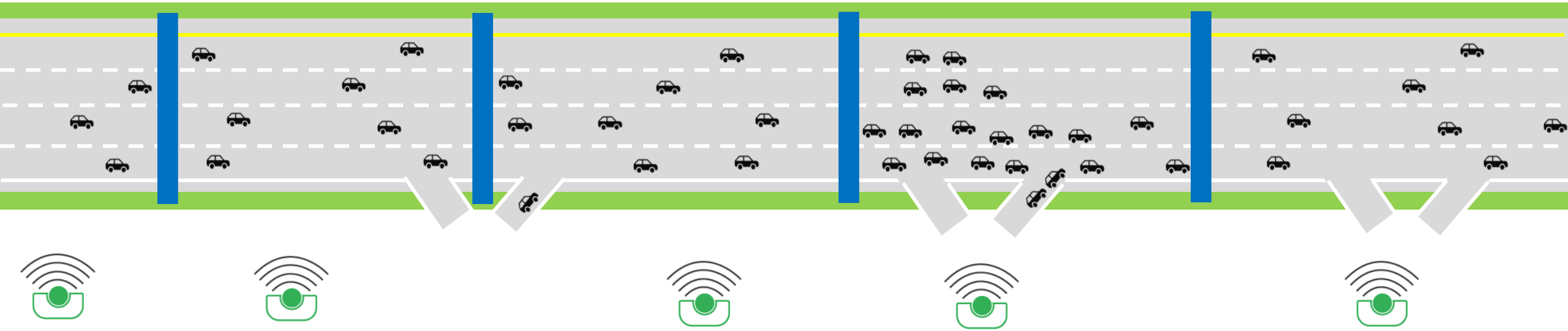
# Multi-Agent Reinforcement Learning (MARL) Design




- **Agents:** One per gantry. For scalability, all agents are homogeneous
- **State Space:** Downstream speed & occupancy, upstream speed and occupancy, downstream gantry speed limit.
- **Action Space:** Valid speed limits (with action masking to enforce step-down constraints)
- **Reward:** A weighted balance of performance goals
  - **Safety:** post a valid slowdown profile near the congestion tail
  - **Mobility:** Post higher speeds when traffic allows
  - **Adaptability:** Penalize large deviations between measured speeds and posted speed limits

[design details in Y. Zhang, M. Quiñones-Grueiro, Z. Zhang, Y. Wang, W. Barbour, G. Biswas, D. Work, 2023]

# Multi-agent reinforcement learning for VSL control

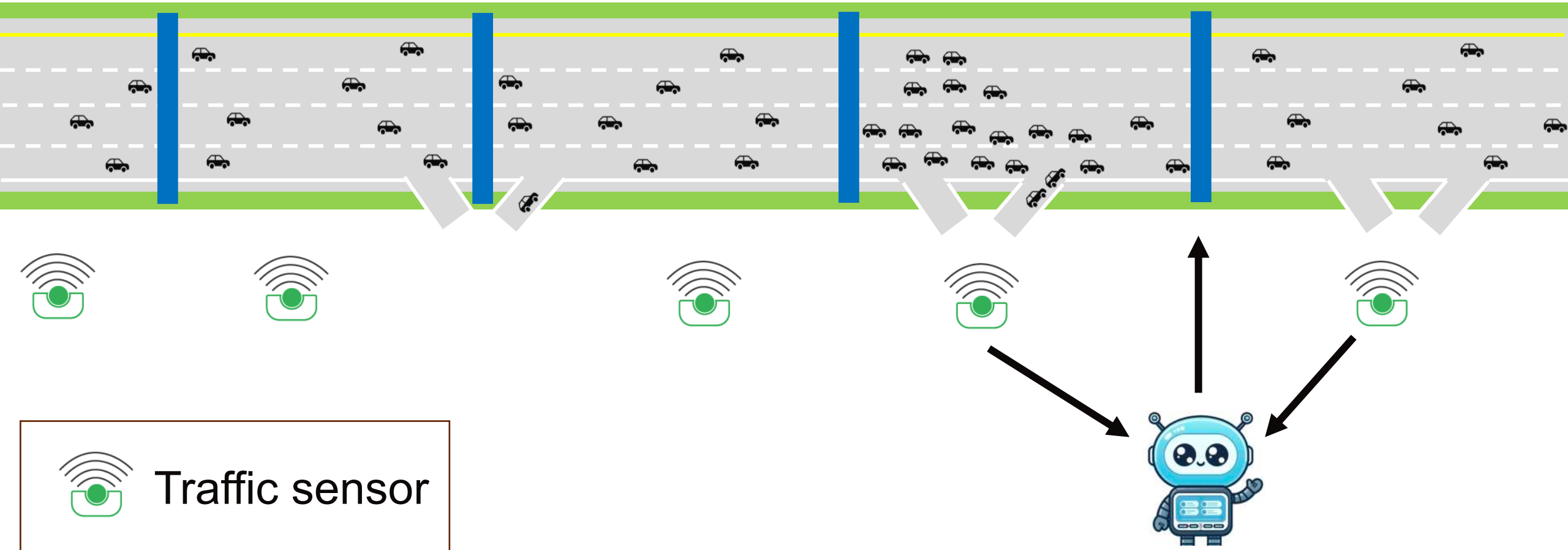


Traffic sensor

VSL Gantry

[design details in Y. Zhang, M. Quiñones-Grueiro, Z. Zhang, Y. Wang, W. Barbour, G. Biswas, D. Work, 2023]

# Multi-agent reinforcement learning for VSL control



Traffic sensor

VSL Gantry

[design details in Y. Zhang, M. Quiñones-Grueiro, Z. Zhang, Y. Wang, W. Barbour, G. Biswas, D. Work, 2023]

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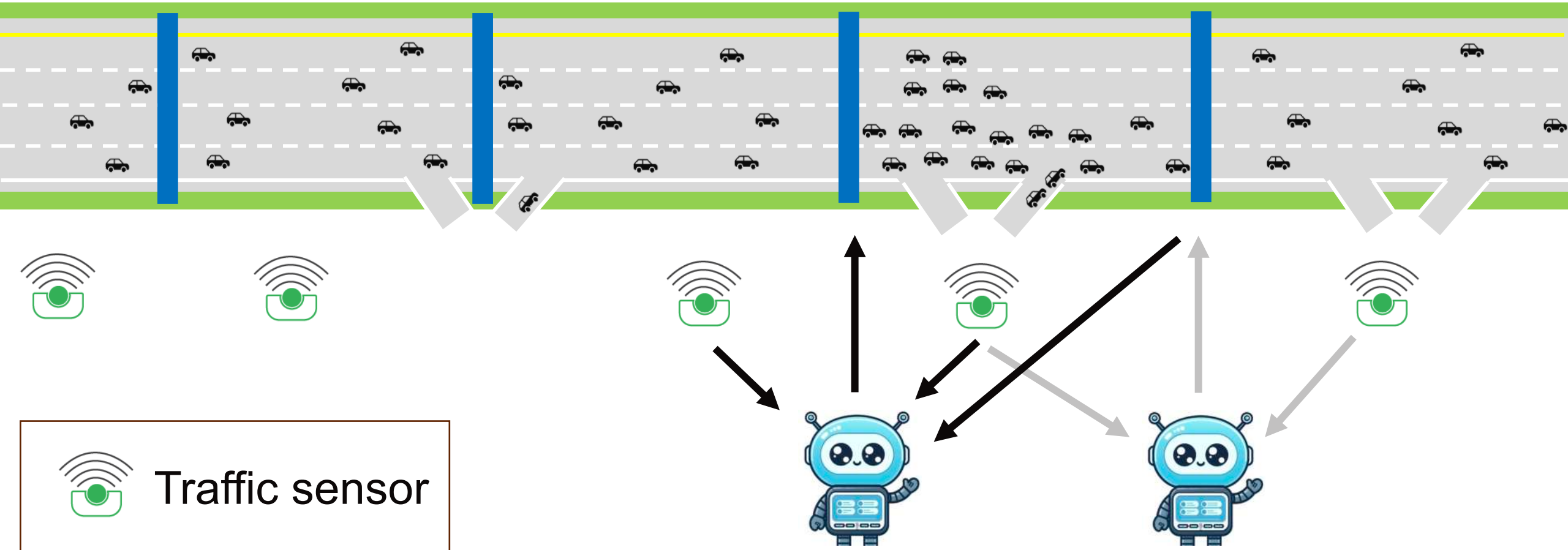

Traffic sensor

VSL Gantry

[design details in Y. Zhang, M. Quiñones-Grueiro, Z. Zhang, Y. Wang, W. Barbour, G. Biswas, D. Work, 2023]

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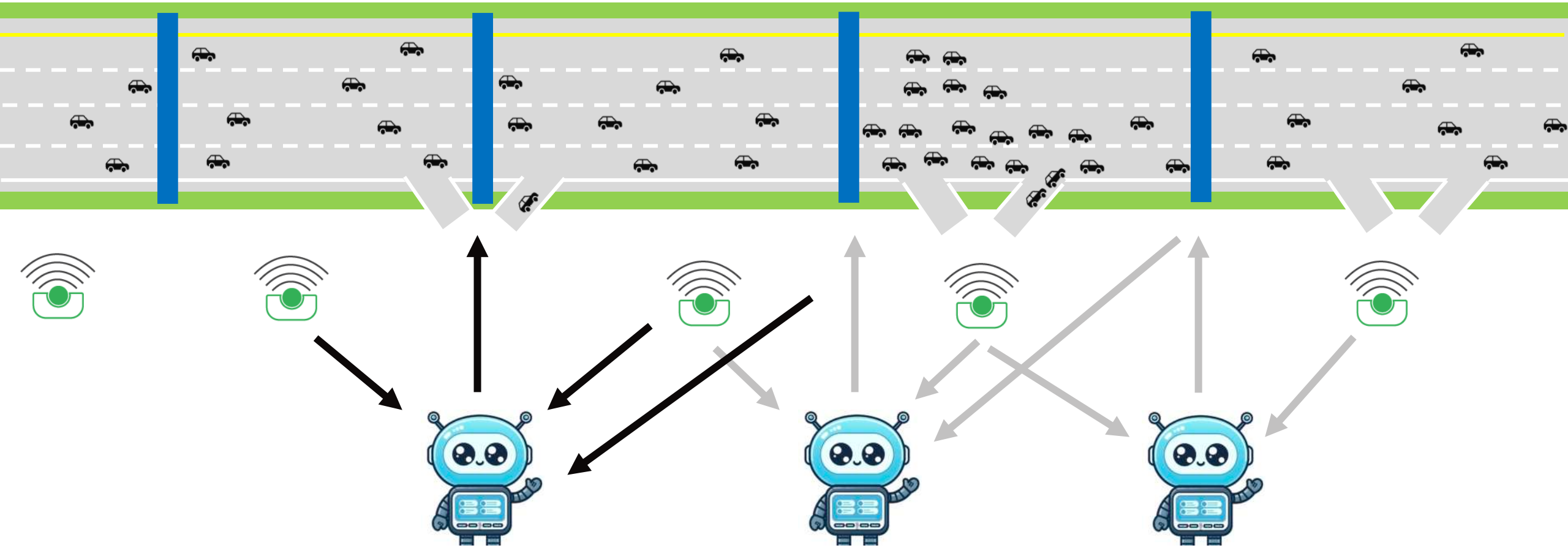
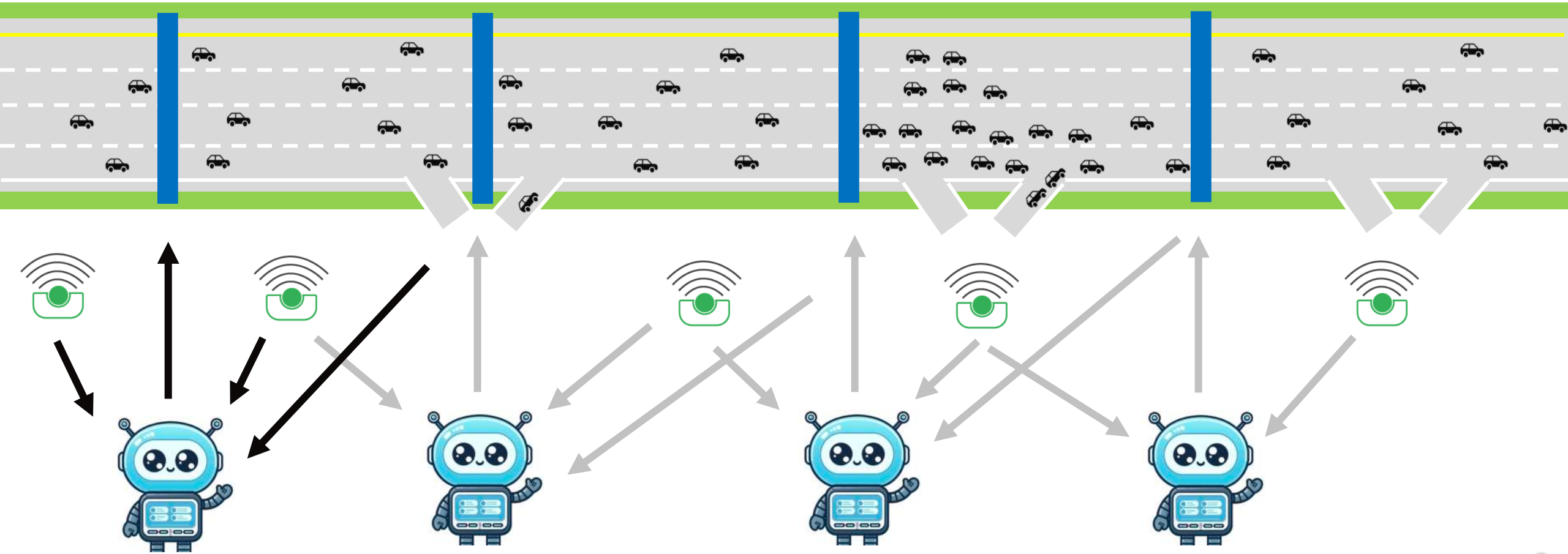
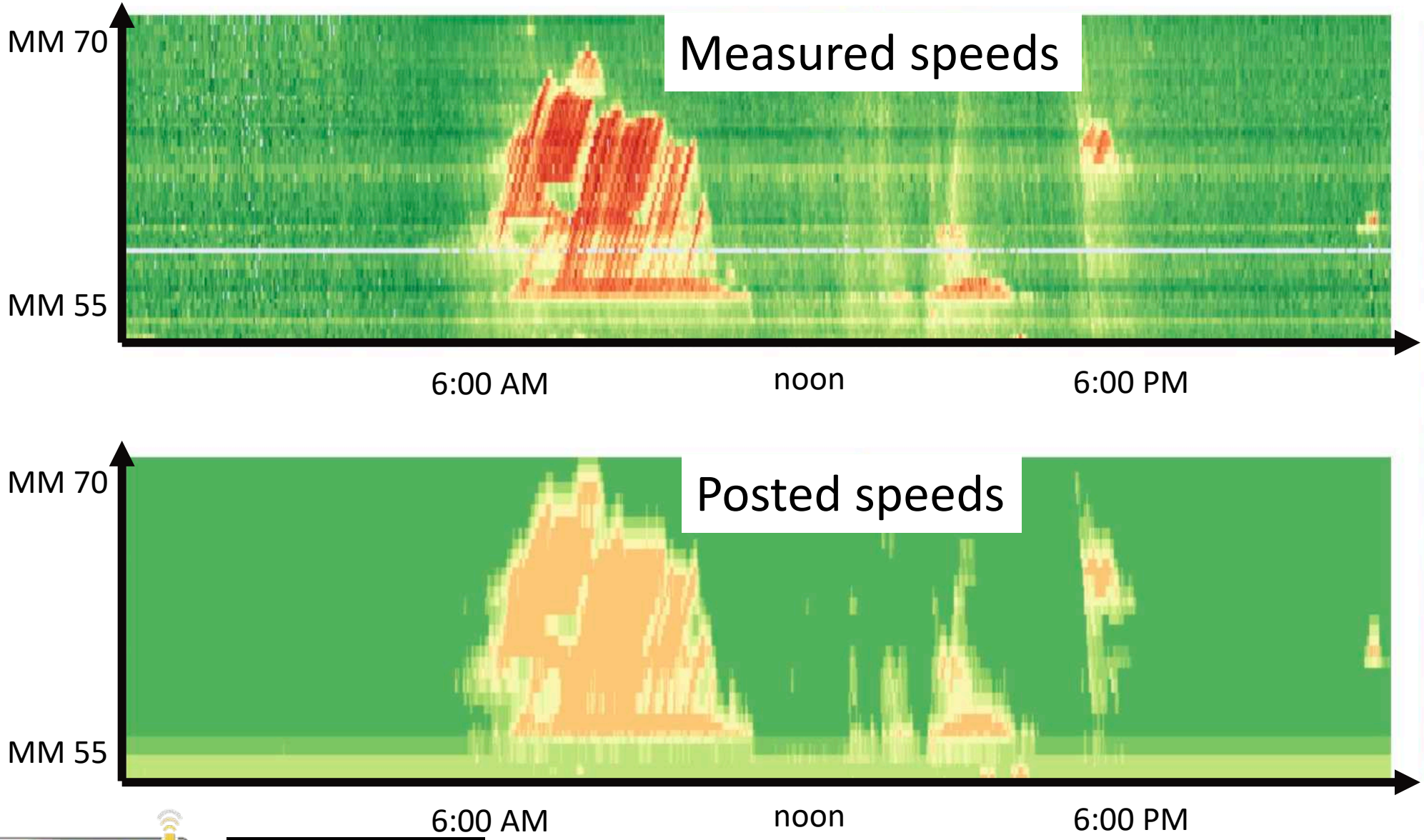


[design details in Y. Zhang, M. Quiñones-Grueiro, Z. Zhang, Y. Wang, W. Barbour, G. Biswas, D. Work, 2023]

# Multi-Agent Reinforcement Learning for VSL Control



[design details in Y. Zhang, M. Quiñones-Grueiro, Z. Zhang, Y. Wang, W. Barbour, G. Biswas, D. Work, 2023]


Measured speeds
MM 70
MM 55
6:00 AM
noon
6:00 PM
Posted speeds
MM 70
MM 55
6:00 AM
noon
6:00 PM
80 mph
0 mph

# Challenges & Successes

**Challenges:**

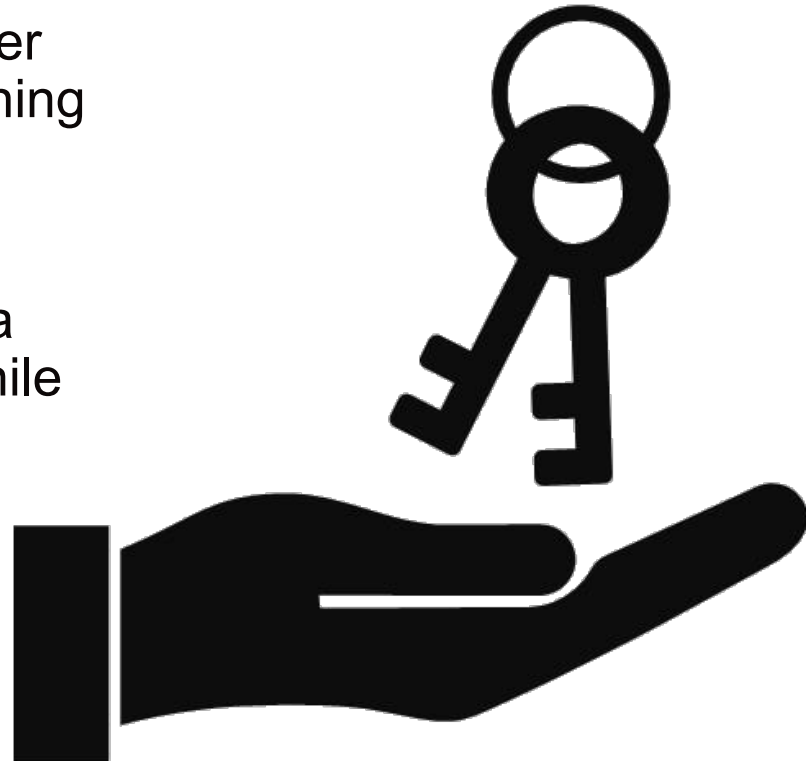
- Sychronized Updates and robust testing between the AI-DSS and the ATMS Platform.
- Fine-tuning to adjust the VSL response.
- Coordination with IT for the AI Virtual Machines to have access to the ATMS and make changes.
- TMC and ICM Operator trust of the AI suggestions and processes.
- Public Outreach and Education.

**Successes:**

- Reduced variability in measured speeds and posted speeds vs a non-AI algorithm VSL.
- 14% Reduction in Total Crashes when VSL was in an active state (reducing speeds)
- Drivers are noticeably driving slower in the approach to congested areas likely leading to fewer rear-end crashes.
- Overall travel times are holding steady despite the increase in traffic volumes each year.

# Key Takeaways

- While not a capacity project, I-24 SMART Corridor is realizing **safety benefits** while providing **improved throughput** at a fraction of the cost of building new lanes.
- TDOT encouraged partnering of the ICM Team (**Arcadis**) with the ATCMTD Grant team (**Vanderbilt**) and the ATMS software provider (**SwRI**) to work together in an agile way to produce a fully functioning system. The “Team” worked together to overcome obstacles and perform robust testing before the system went live.
- The AI-Driven Decision Support System enables the **benefits** of a SMART Corridor **without overwhelming the TMC Operators** while saving money and time on implementation.
- TMC Operations are **evolving**, AI-DSS is there to meet the **challenge**.
- Ability to **scale** and **expand**.



# Identification of an Incident – Left Shoulder Stranded Motorist


223E
I-24 E/O OLD FRANKLIN RD MM 61.2
222E
I-24 E/O HICKORY HOLLOW PKWY MM 60.5
220E
I-24 E/O BELL RD MM 59.6
221W
I-24 E/O HICKORY HOLLOW PKWY MM 60.2
TDOT
smartway


(223) R3A-00I24-061.2E (223)
Streams
223E
TDOT
smartway
I-24 E/O OLD FRANKLIN RD MM 61.2


223E
TDOT
smartway
LOWE'S
I-24 E/O OLD FRANKLIN RD MM 61.2


223E
I-24 E/O OLD FRANKLIN RD MM 61.2
219W
TDOT
smartway
I-24 W/O BELL RD MM 59.1
217W
I-24 E/O HAYWOOD LN MM 57.7
218W
I-24 W/O BLUE HOLE RD MM 58.3


223E
I-24 E/O OLD FRANKLIN RD MM 61.2
222E
I-24 E/O HICKORY HOLLOW PKWY MM 60.5
220E
I-24 E/O BELL RD MM 59.6
221W
TDOT
smartway
I-24 E/O HICKORY HOLLOW PKWY MM 60.2


223E
I-24 E/O OLD FRANKLIN RD MM 61.2
222E
I-24 E/O HICKORY HOLLOW PKWY MM 60.5
220E
I-24 E/O BELL RD MM 59.6
221W
TDOT
smartway
I-24 E/O HICKORY HOLLOW PKWY MM 60.2


223E
I-24 E/O OLD FRANKLIN RD MM 61.2
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I-24 E/O HICKORY HOLLOW PKWY MM 60.5
220E
I-24 E/O BELL RD MM 59.6
221W
I-24 E/O HICKORY HOLLOW PKWY MM 60.2
TDOT
smartway

# Thank You!

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