Real-Time Traffic Signal Safety Interventions in Bellevue

ITE Western District Conference

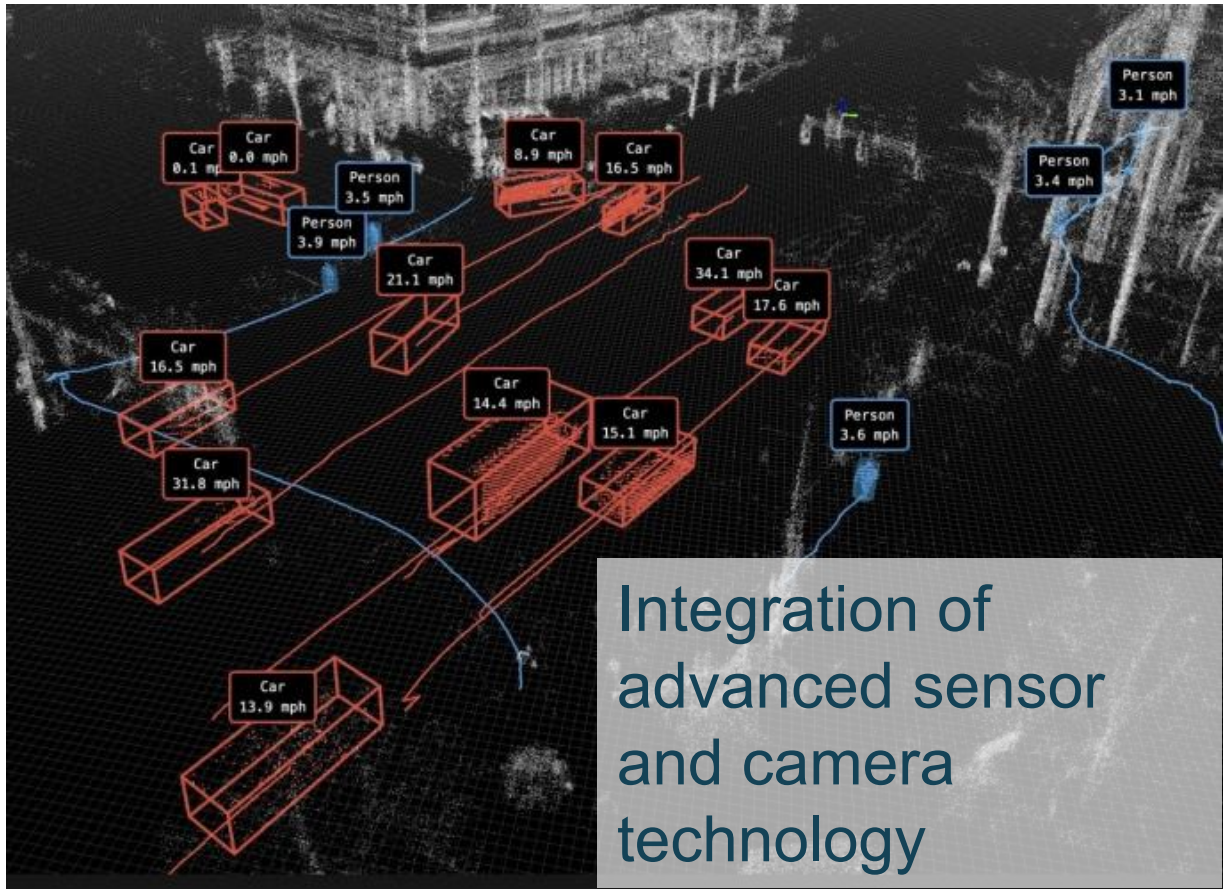
Bellevue – June 2026

Smart Mobility Vision

Use innovation and partnerships to deploy emerging technologies that enhance the safety, sustainability, efficiency, and accessibility of Bellevue's transportation system.

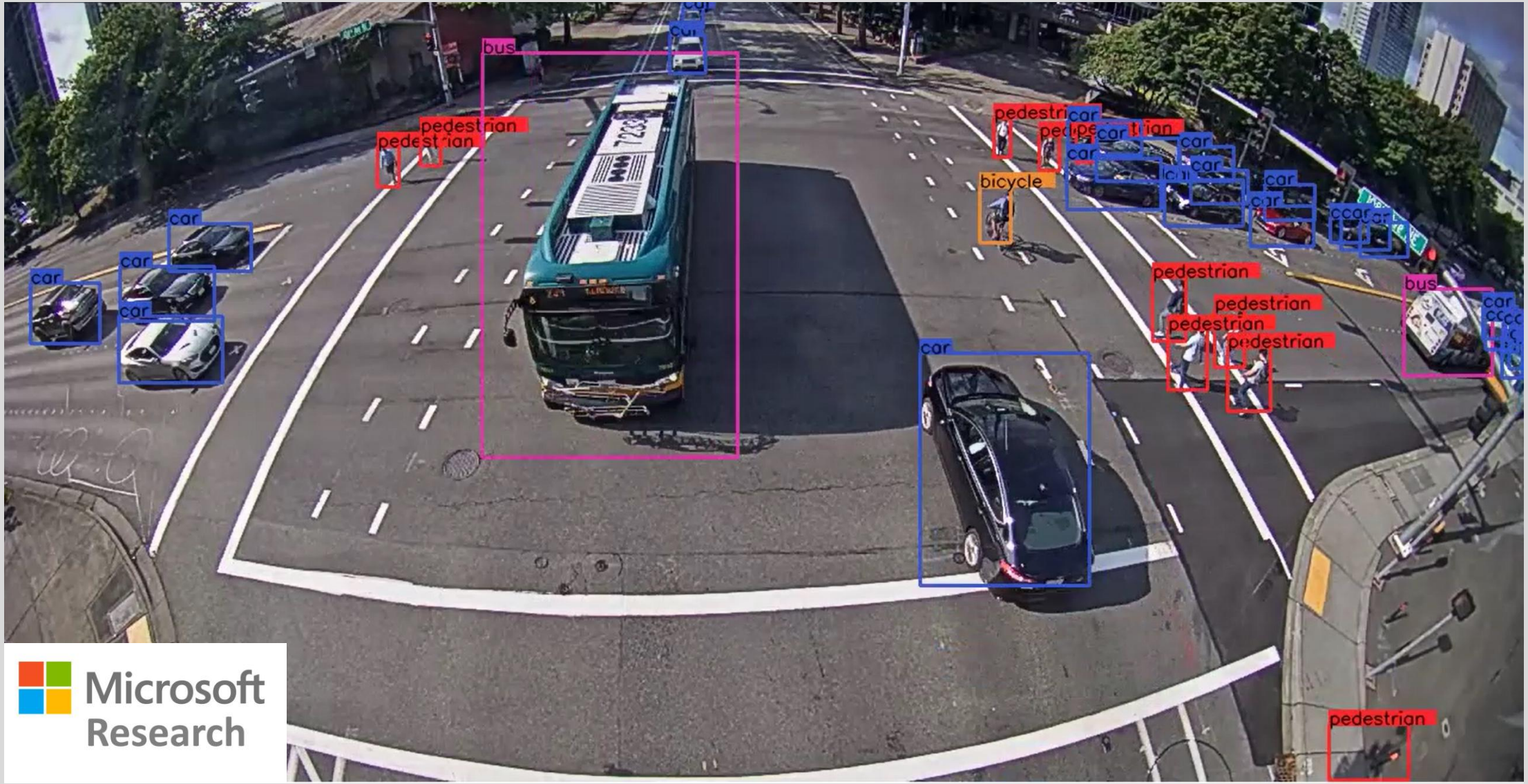
Traffic Signal Technologies

- Bellevue reached 100% adaptive signal control in 2016
- 10GB high speed network connectivity between traffic signals and city hall



Integration of advanced sensor and camera technology

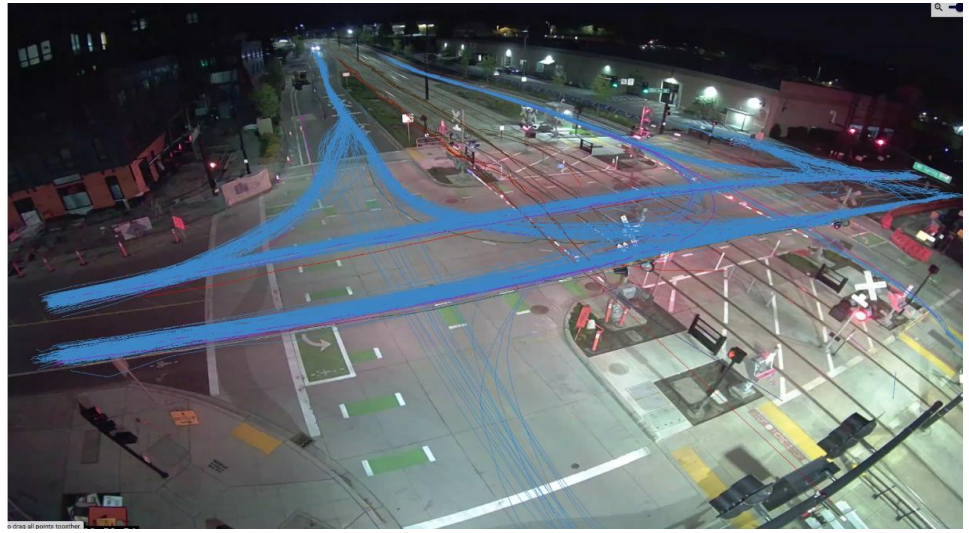
Cloud Computing + AI + Video Analytics

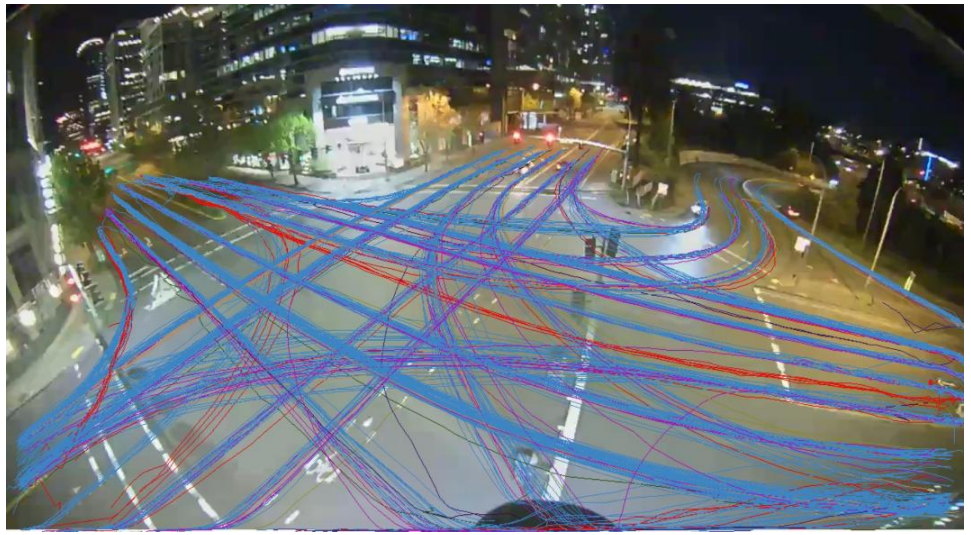


Microsoft Research

Safe System - Video Analytics

- Cloud-based video analytic solution
- Leverages Bellevue's traffic camera platform
- Automatically flags anomalous movements based on vehicle trajectory
- Provide video playback of events that constituted an anomalous movement
- Provides comprehensive insights on traffic operations and safety





SMART Operations

ALERTS | DANIEL LAI

Live Alerts

Map | List

Map | Satellite | NE 8th St / Bellevue-Way

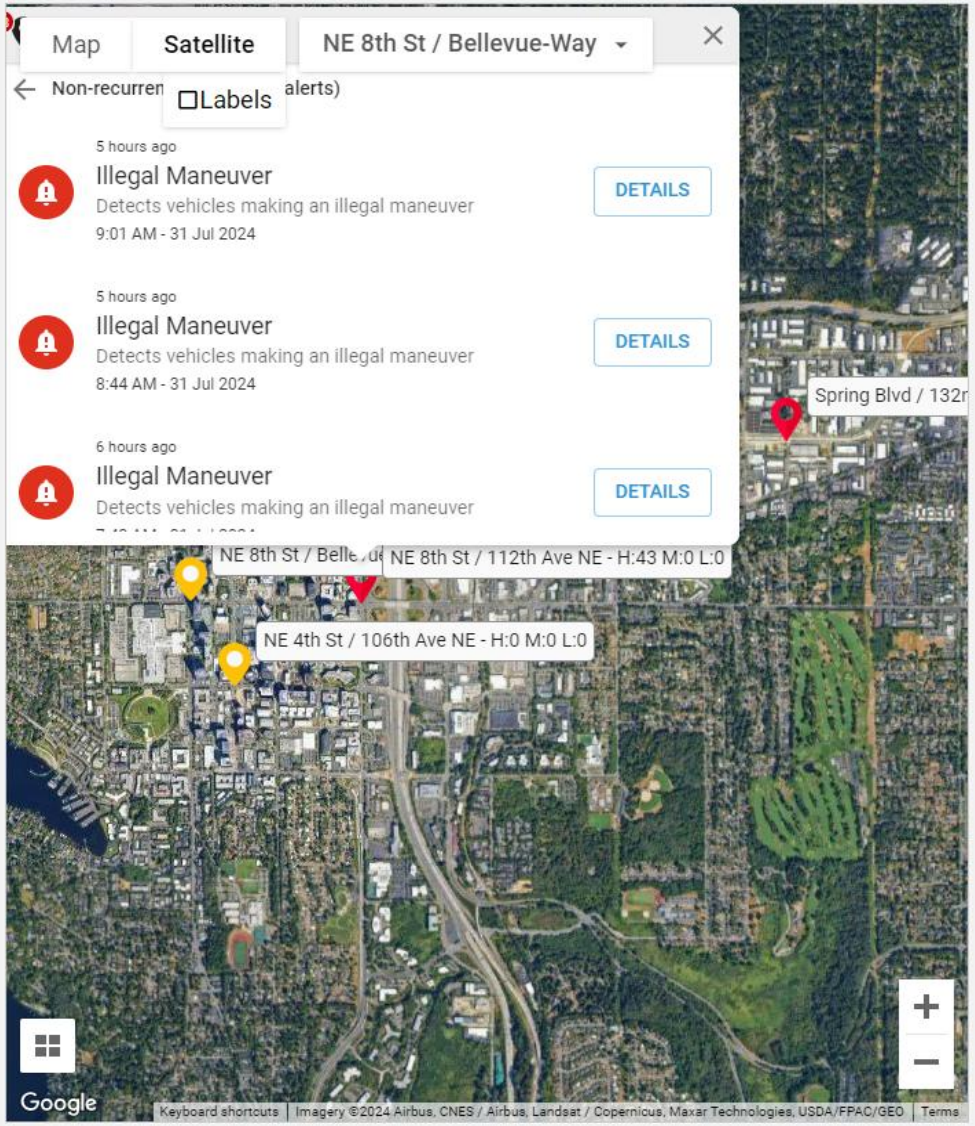
Non-recurren… alerts)

Labels

5 hours ago
Illegal Maneuver
Detects vehicles making an illegal maneuver
9:01 AM - 31 Jul 2024
DETAILS

5 hours ago
Illegal Maneuver
Detects vehicles making an illegal maneuver
8:44 AM - 31 Jul 2024
DETAILS

6 hours ago
Illegal Maneuver
Detects vehicles making an illegal maneuver
DETAILS



Illegal Maneuver

ALERT DETAILS | MANAGE ALERT | ACTION HISTORY

Configured for: NE 8th St / Bellevue-Way; NE 4th St / 106th Ave NE; NE 8th St / 112th Ave NE; Spring Blvd / 132nd Ave NE

SITE DETAILS

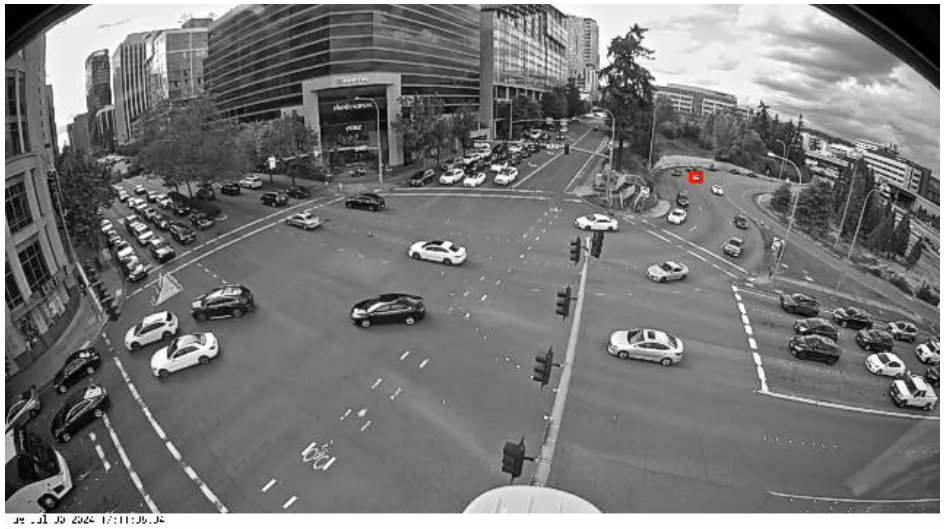
Site Name: NE 8th St / 112th Ave NE
Road User Type: Passenger Car
Camera Name: Test WWD 1

SYSTEM INFORMATION

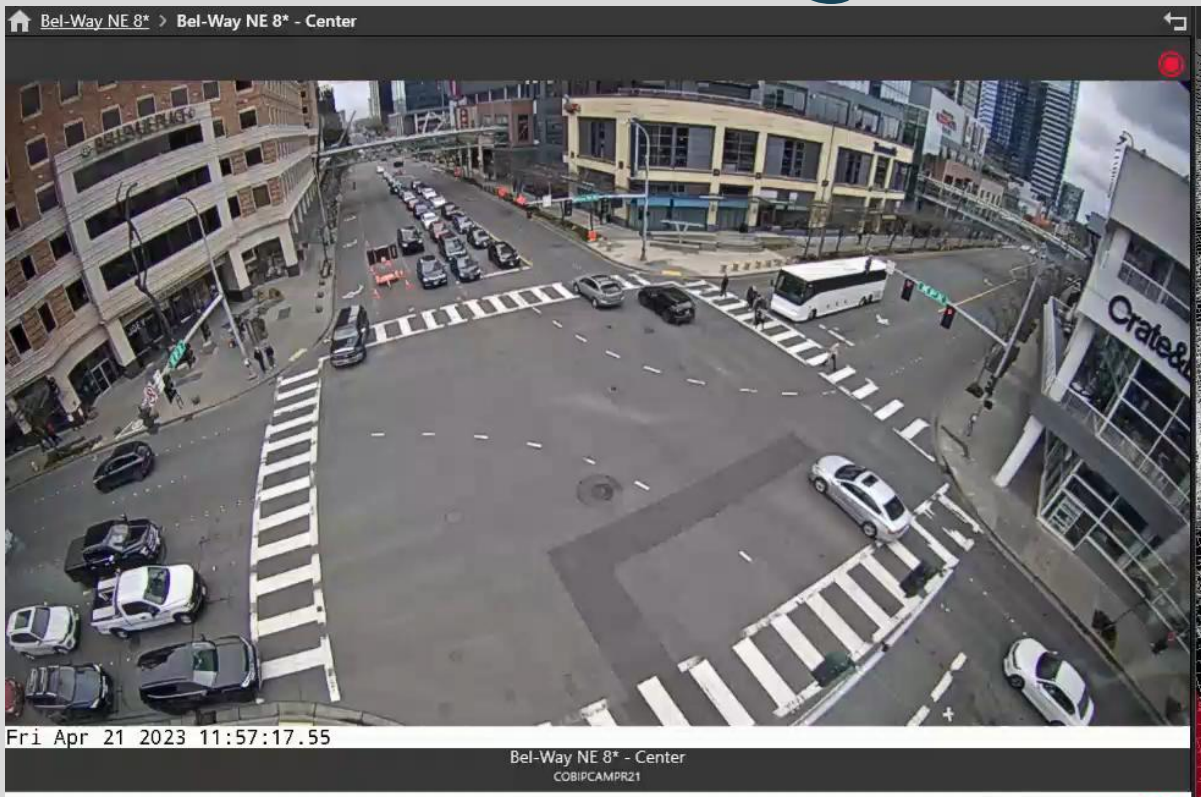
Alert PK: COB~1662
Alert SK: 1722384774114

ALERT CLIP

REPORT ERROR

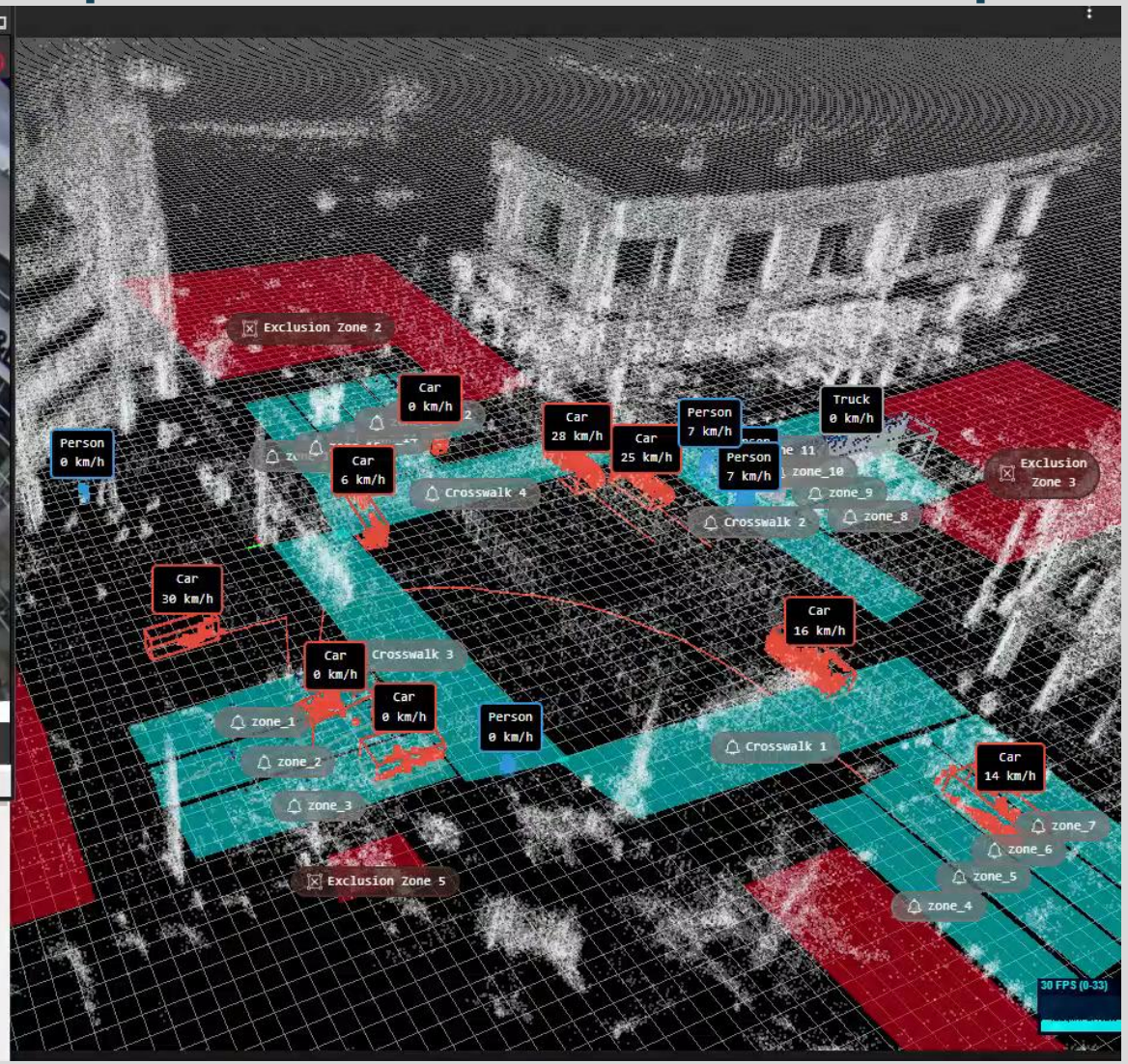


2023-2024 Edge Compute Partnership



Alarms and Tasks 100

ID	Name	State	Occupants
0	Crosswalk 1	VACANT	0
1	Crosswalk 2	OCCUPIED	3
2	Crosswalk 3	VACANT	0
3	Crosswalk 4	VACANT	0



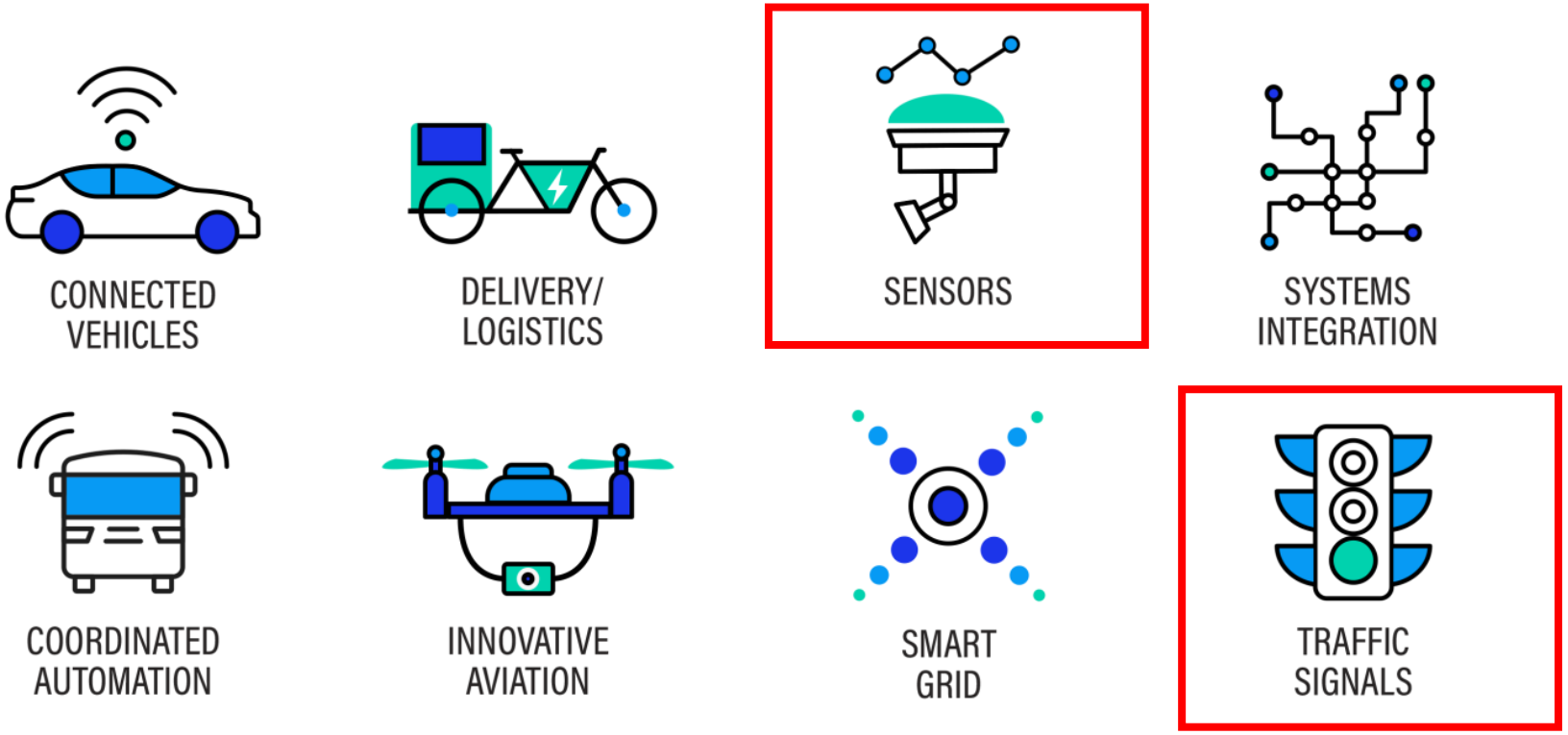
SMART Grant

- **What is SMART?**
  - Strengthening Mobility and Revolutionizing Transportation
  - Funding for innovative, technology-focused projects

- **Bellevue's Award**
  - Stage 1 grant: $1.43 million for planning and prototyping
  - Grant period: October 2024 – September 2026

- **RTSSI – From Grant to Project**
  - Development and live testing of five critical use cases
  - Launchpad for partnerships, technology integration, and future expansion

USDOT SMART Grant – FY23 Recipient



The Problem

52%

of fatal and serious injury crashes occur at signalized intersections.

51%

of fatal and serious injury crashes involve a vulnerable road user.

41%

of all pedestrian fatalities and serious injuries involve failure to yield.

13%

of fatal and serious injury crashes involve a bicyclist.

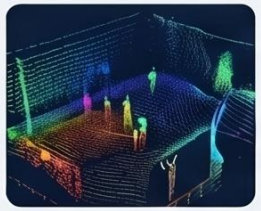
Traditional traffic signals optimize vehicular throughput and are not responsive to vulnerable road user risks

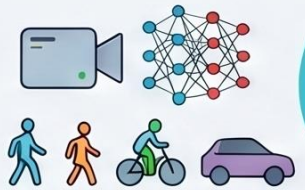
Bellevue RTSSI: Smarter Traffic Signals for Pedestrian Safety

Real-Time Traffic Signal Safety Interventions project moving toward Adaptive for All.

The Technology Backbone

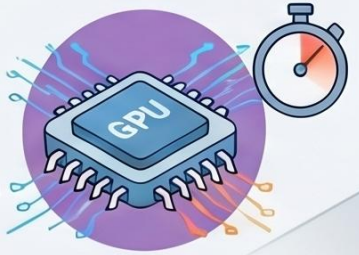
LiDAR & Video AI Analytics





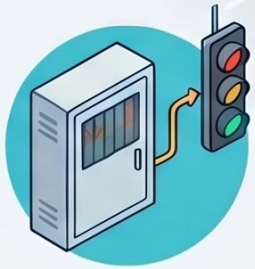
High-resolution 3D detection and AI-powered intent prediction classify pedestrians, cyclists, and vehicles.

GPU-Powered Edge Computing



Local processing at the intersection achieves sub-second latency for instant traffic signal responses.

SCATS Signal Integration



Sensors link directly to adaptive signal controllers to drive phase extensions and restrictions.

4 Pilot Safety Use Cases

Pedestrian & Walk Extensions

Automatically holds vehicle movements or extends "Walk" times for slow walkers and groups.

Dynamic No Right Turn on Red (NRTOR)

Activates digital "No Turn" signs only when pedestrians are waiting or crossing.

Dynamic Left-Turn Phasing

Switches between protected and permissive left-turn phases based on real-time vehicle gaps.

Pedestrian Clearance Extension

Extends the red light for vehicles if a pedestrian is still in the crosswalk after the walk phase ends.

SMART Grant

Sensors
- Video
- LiDAR

Signal Cabinet

Edge Computing Device

Detector Inputs

Traffic Controller

Data
-SPaT
(SAE J2735)

Identify type of road user, speed of road user, trajectory of road user, number of road user, etc ….
Determine if an "qualifying event" occurs and sends input to controller.

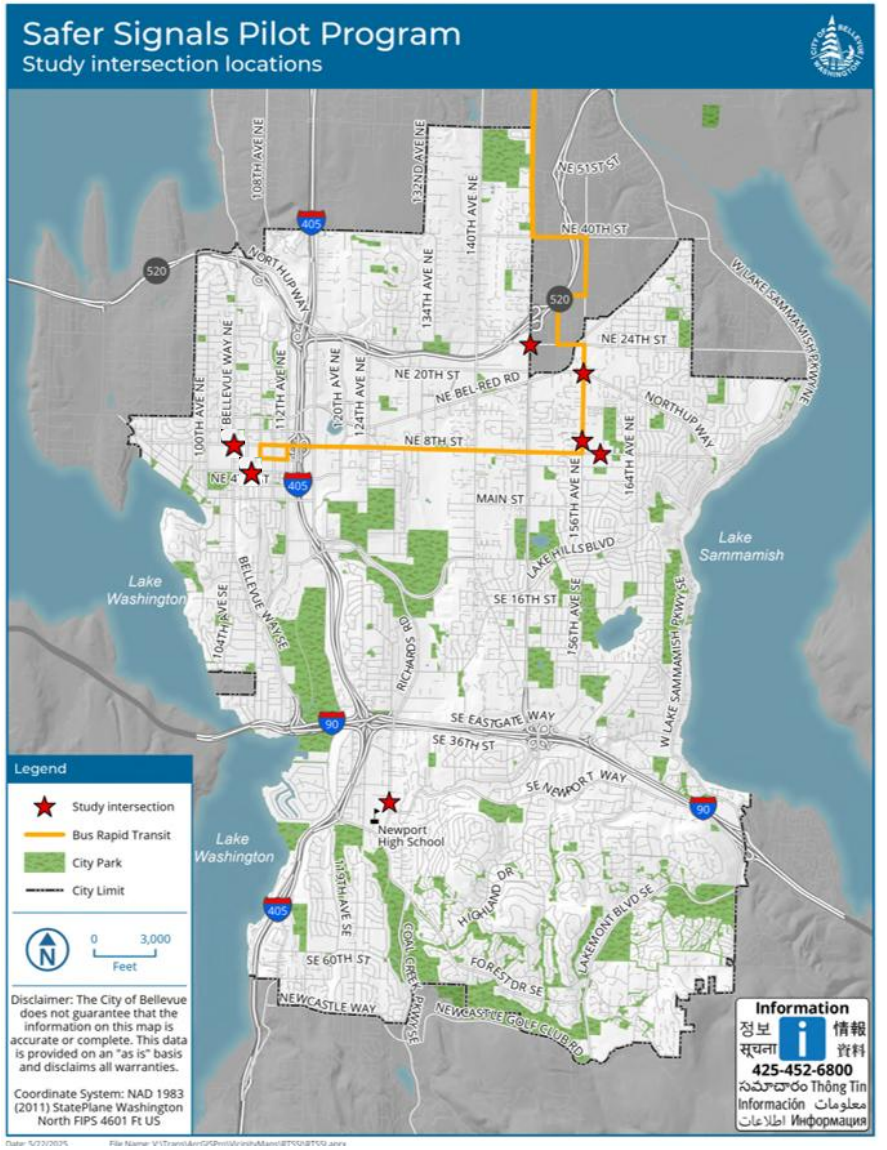
Receives input (on/off). The logic for what to do resides in the controller.
Triggers intervention if in correct signal phase

Smart Use Cases for Safer Intersections

- **Seven pilot intersections**
  - Crossroads - 4
  - Factoria - 1
  - Downtown Bellevue – 2*

- **Five pilot use cases**
  - Pedestrian Clearance
  - Dynamic Walk Extension
  - Dynamic No Right Turn on Red (NRTOR)
  - Dynamic Left-Turn Phasing
  - Dilemma Zone*

*not part of initial grant application, added later in project implementation



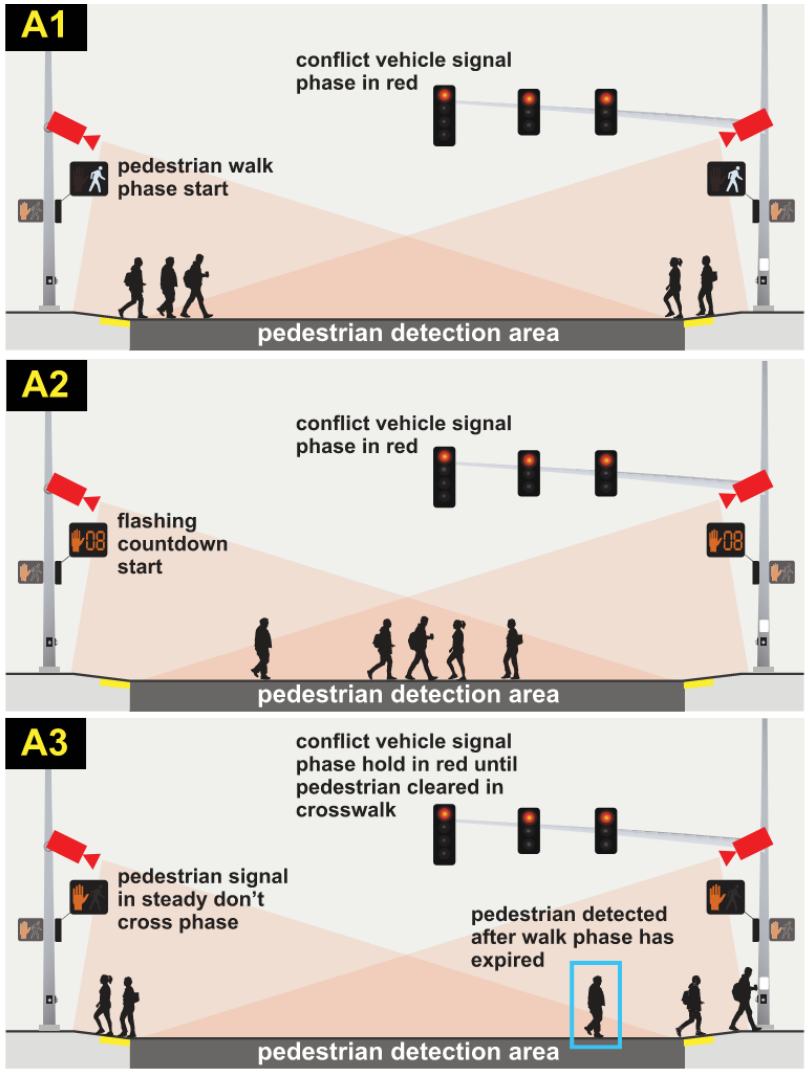
Use Case 1: Pedestrian Extension

What It Is

- Detects pedestrians still in the crosswalk when the orange “Hand” symbol begins to flash (clearance interval)
- Automatically holds vehicle movements and *extends the green phase after clearance* until the pedestrian fully exits the crosswalk.

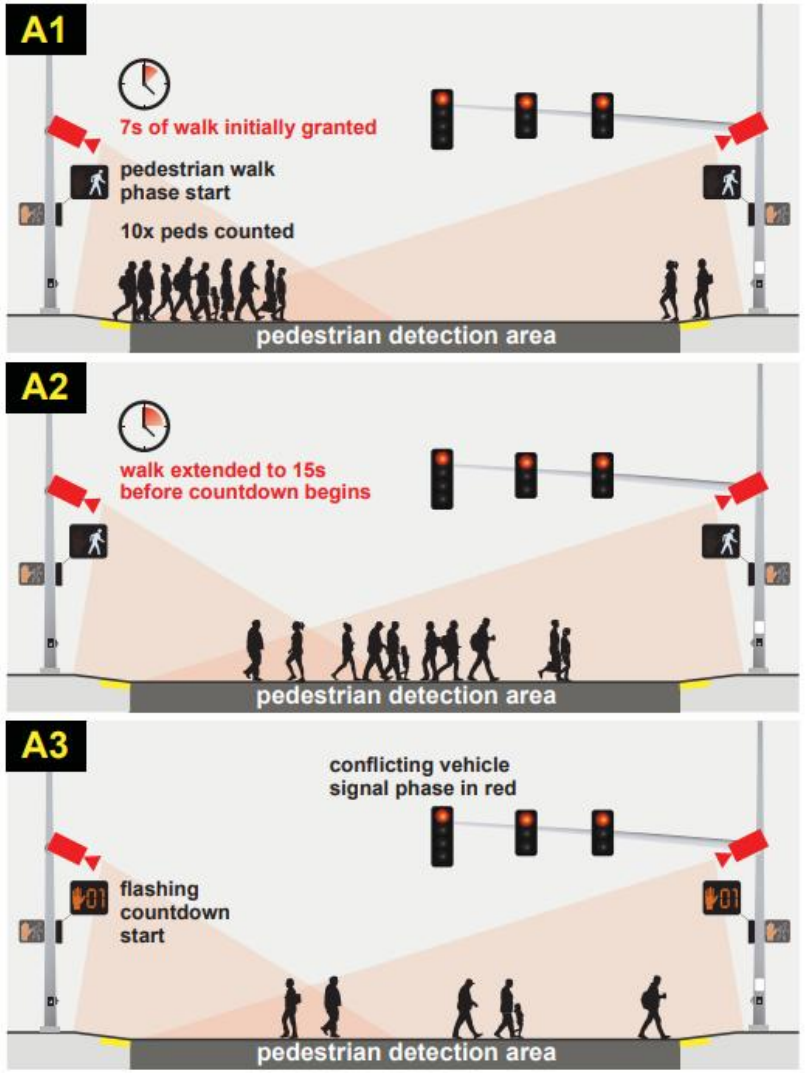
Why It Matters

- Directly addresses the top cause of pedestrian exposure in crosswalks: people being caught in the road as traffic moves
- Helps protect the most vulnerable users—seniors, people with disabilities, children, families, or anyone needing extra time.
- Proven safety practice that reduces risk of pedestrian-vehicle conflicts, especially at large or complex intersections.



Pedestrian Clearance

Use Case 2: Walk Extension



What It Is

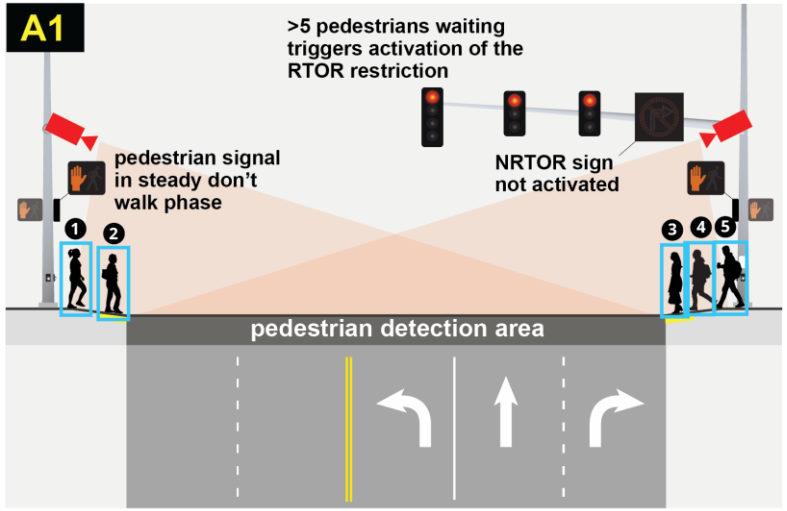
- The system detects slow walkers, people with mobility devices, or large groups waiting to cross—*as soon as the "Walk" signal starts*
- If needed, it automatically extends the "Walk" display (e.g., from 7 seconds up to 15–20 seconds), ensuring everyone has enough time to step into the crosswalk before the countdown or "Don't Walk" hand appears.

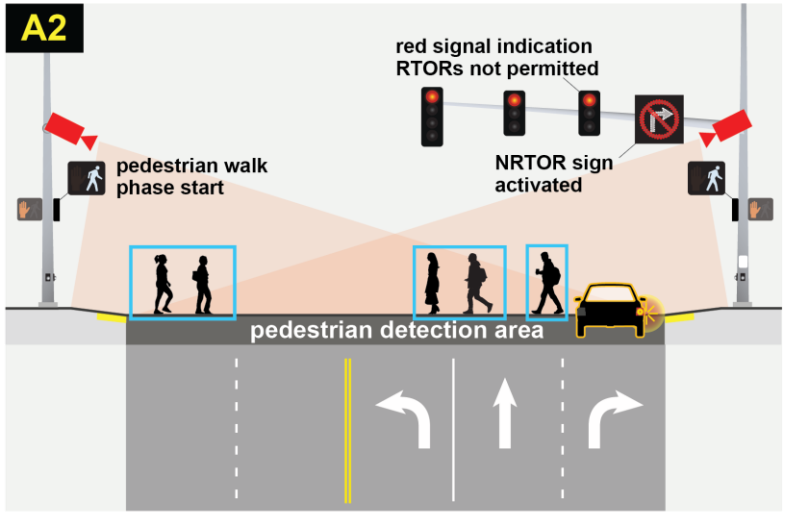
Why It Matters

- Ensures older adults, people with disabilities, children, and families aren't rushed or left behind at the start of their crossing.
- No button-pushing or extra steps required for pedestrians—*the process is fully automated and equitable*.
- Applies adaptive signal timing for pedestrians.

Use Case 2: Walk Extension

Use Case 3: Dynamic No-Right Turn on Red





What It Is

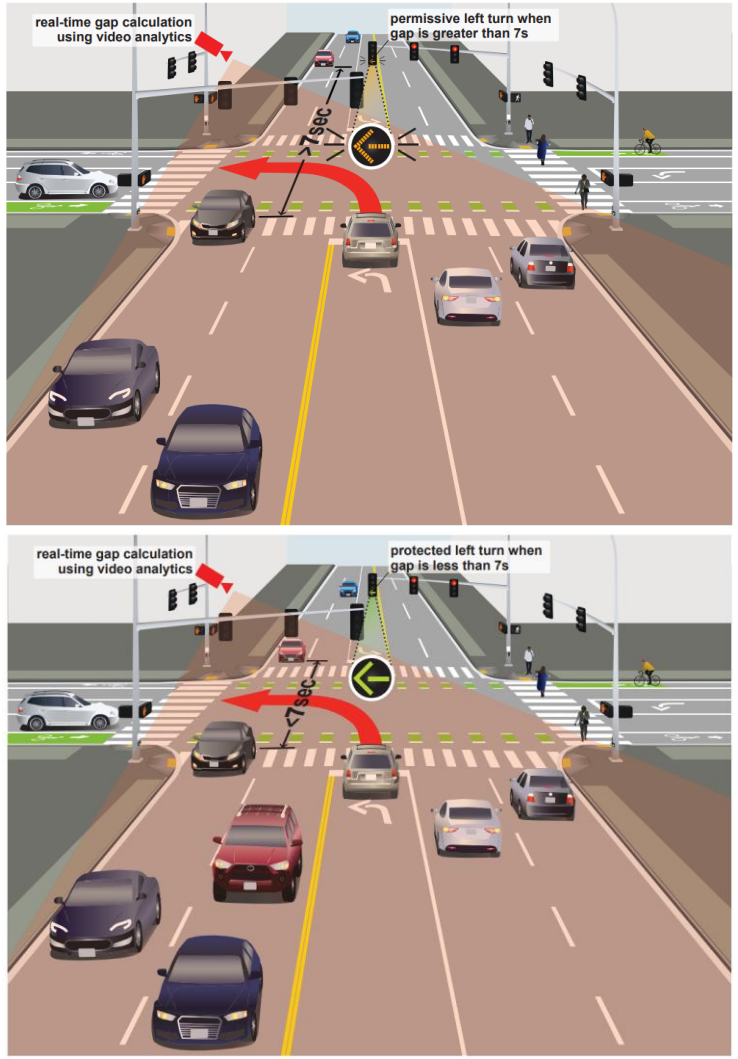
- Smart, real-time activation of "No Right Turn on Red" signals when pedestrians are detected crossing or waiting to cross, to eliminate vehicle-pedestrian conflicts during the red phase.
- The NRTOR sign is activated only when it matters—minimizing unnecessary driver delay and maximizing safety

Why It Matters

- Reduces risk while drivers are looking for gaps to enter traffic flow, while observing pedestrian conflicts simultaneously
- Applies NRTOR as a dynamic, data-driven safety intervention—building legitimacy for flexible, non-permanent restrictions that match live conditions

Use Case 3: Dynamic NRTOR

Use Case 4: Dynamic Left Turn Phasing



What It Is

- The system dynamically selects between protected (solid green arrow = left turn only, solid red arrow = left turn prohibited) and permissive (flashing yellow arrow = yield to oncoming traffic) phasing for left turns, based on real-time vehicle gaps
- When safe gaps are detected, the signal transitions to a *flashing yellow arrow*, allowing permissive (yielding) left turns

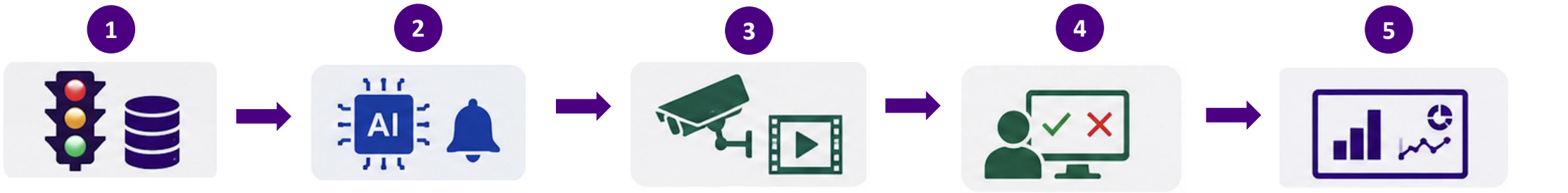
Why It Matters

- Reduces risky left turns during periods of heavy or unpredictable oncoming traffic
- Increases safety and operational flexibility, using protected phases when gaps are insufficient
- Maximizes throughput and driver satisfaction without compromising intersection safety

Validation Framework

Validation Framework

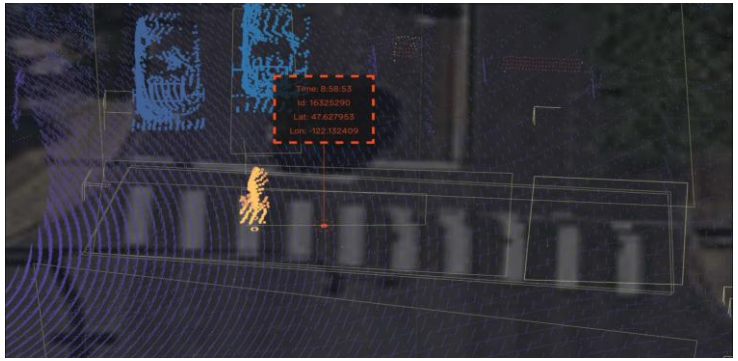
Multi-source real-world validation pipeline for AI traffic sensing systems

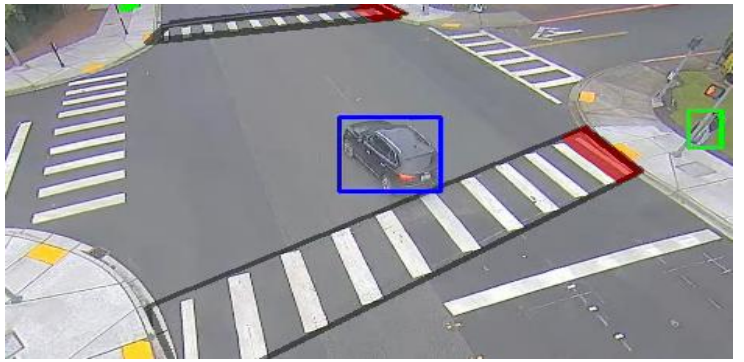


System Validation

Correct Trigger

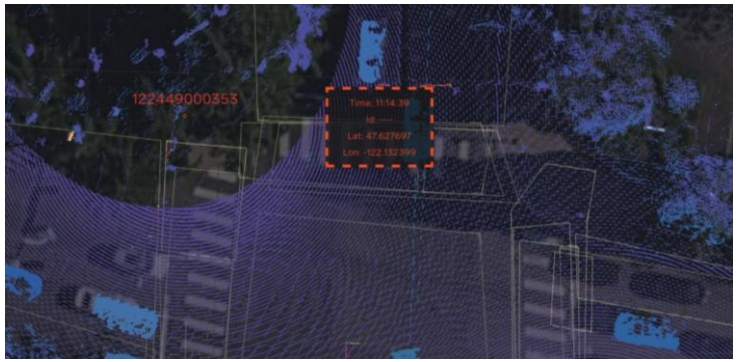
The pedestrian is in the crosswalk, and the system triggers appropriately.





False Trigger

System triggers, but no relevant pedestrian event is present.



Evaluation Metrics

We evaluate AI traffic sensing systems from two complementary perspectives

Detection Accuracy
"Did the system **SEE** correctly?"

Vehicle / VRU detection
Detect vehicles, pedestrians, and other VRUs

Detection zone performance
Evaluate performance within the intended zone

Focus: Perception (Sensing Performance)
How well the system detects and localizes objects

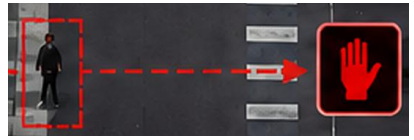
Activation Accuracy
"Did the system **ACT** correctly?"

Trigger validation
Verify triggers occur at the right time

TP / TN / FP / FN analysis
Evaluates system performance based on ML Metrics

✓ Correct Trigger
Pedestrian in a crosswalk → Phase Extension Triggered

✕ False Positive
Pedestrian on the curb → Unnecessary Trigger

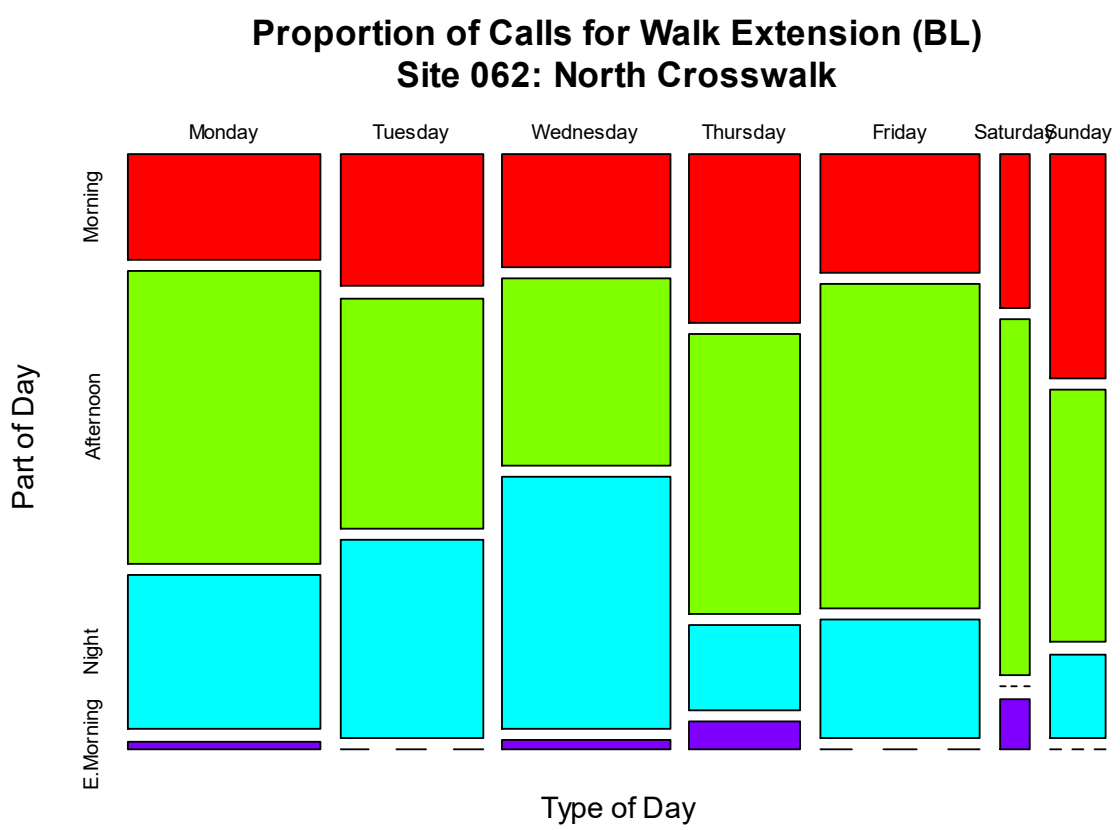


✕ False Negative
Pedestrian in a crosswalk, but isn't detected → Missed Trigger

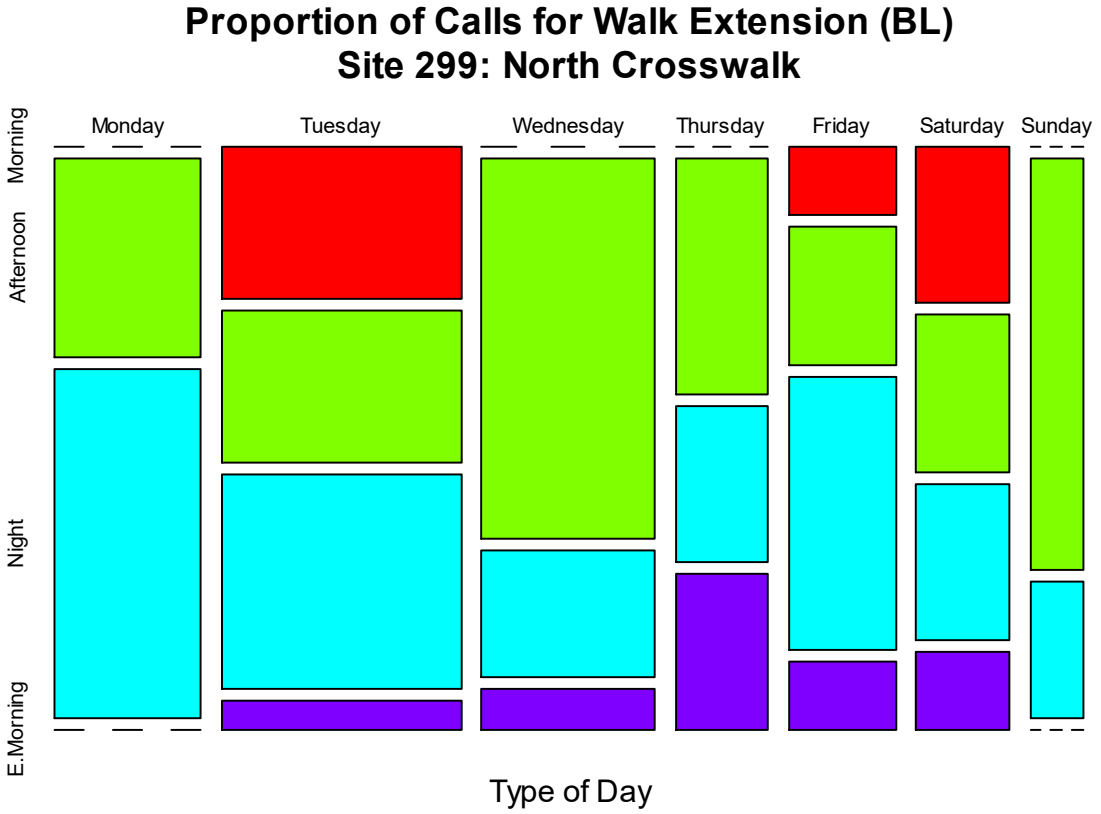
Focus: Operation (Signal Performance)
How well the system makes correct signal decisions

Day of Week – Mosaic Plot

Site 062

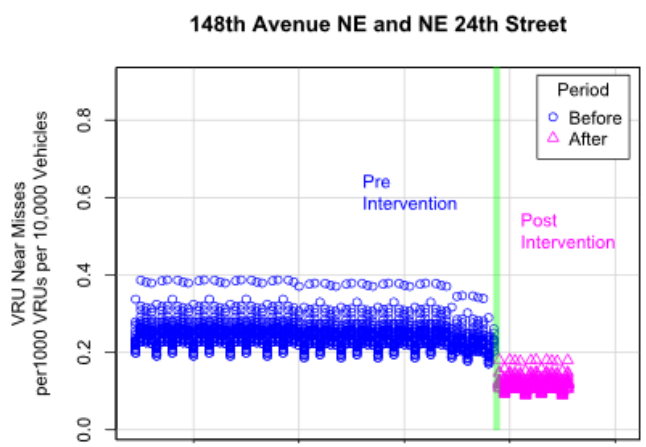


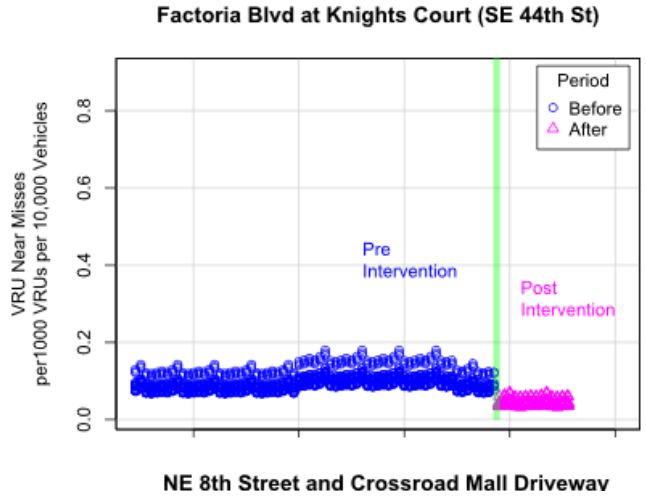
Site 299

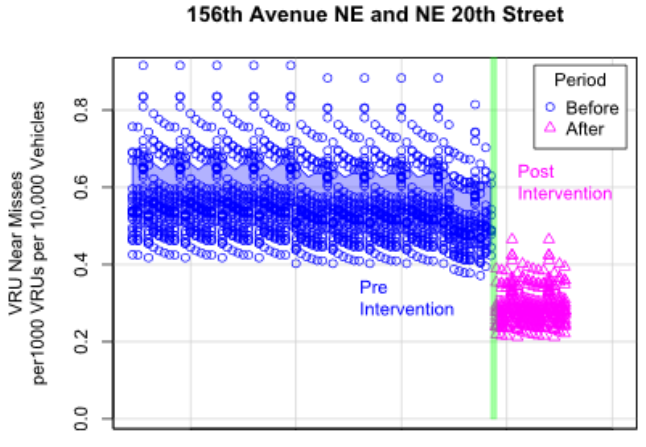


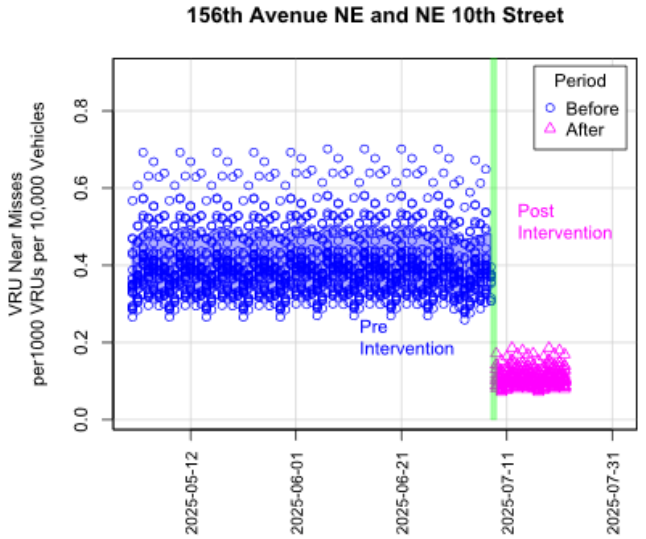
Preliminary Results

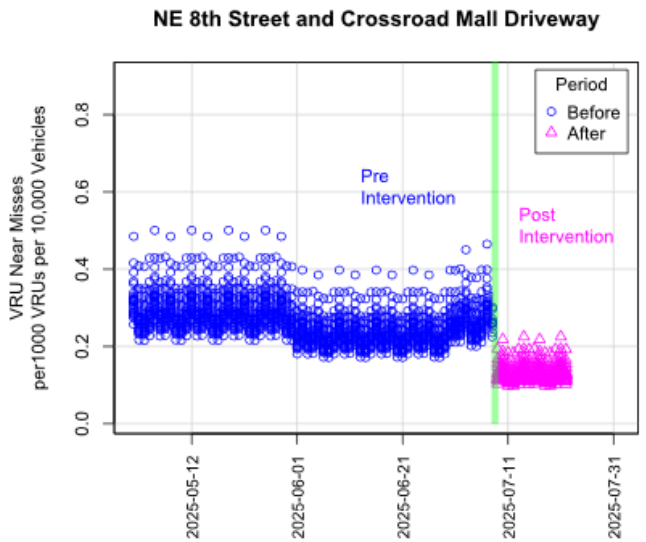
Effects on VRU Near-Misses after 2 weeks







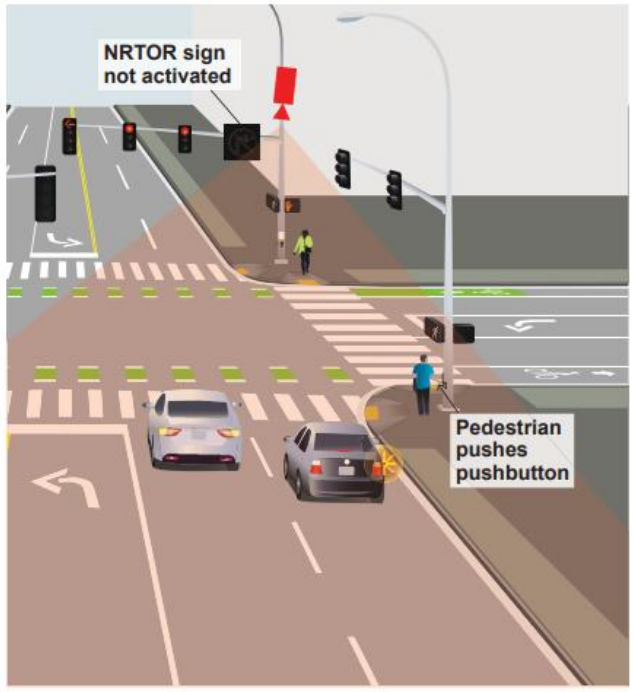


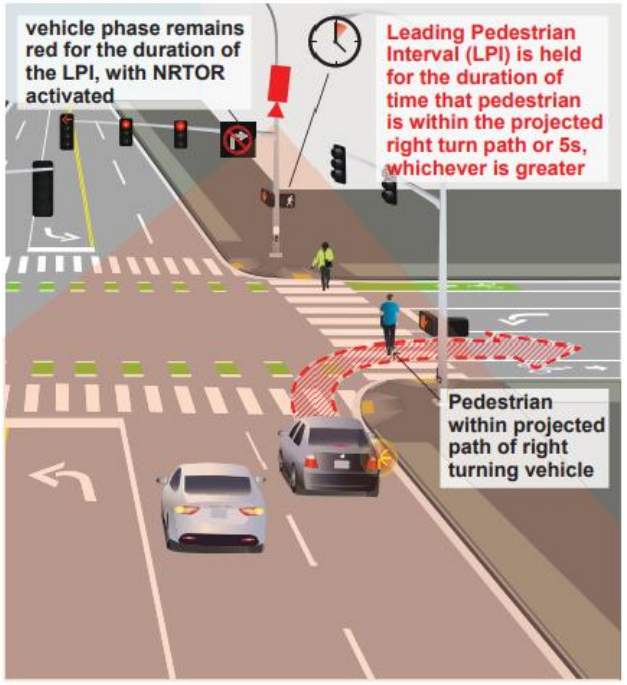


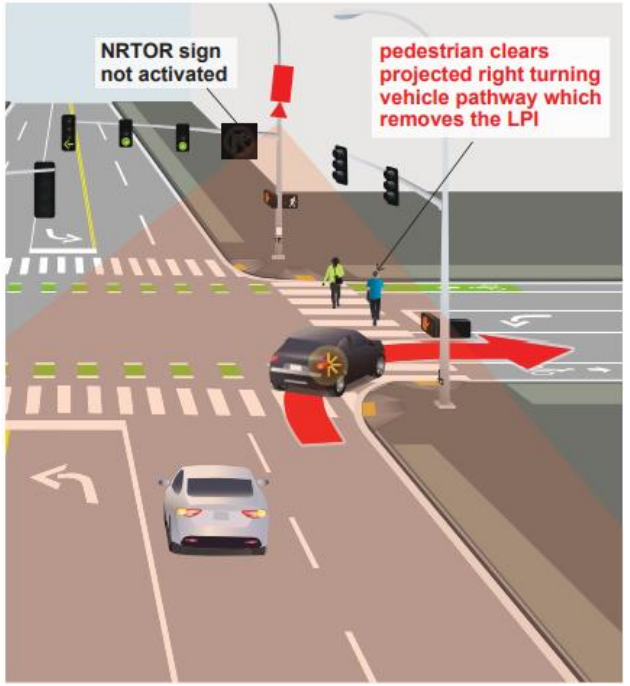
Dynamic NRTOR: **42.9% reduction**

Walk Extension: **51.5% reduction**

Future Use Case: Dynamic LPI







What It Is

- Actively detects location of pedestrian with respect to right turning movement trajectory
- Holds LPI until pedestrian clears projected trajectory of right turning vehicle

Why It Matters

- Reduces right turn vehicle vs. pedestrian conflicts
- Provides a dynamic approach towards what would otherwise be a static LPI operation (5s LPI in Bellevue)

Additional Future Use Cases:

- **Dynamic Walk Extension:** Dynamic walk extension will calculate an estimated time of arrival for each pedestrian during the walk phase. A walk phase extension may be granted based each pedestrians' anticipated time of arrival to the other side of the crosswalk.
- **Mid-phase Pedestrian Reservice:** The Mid-phase Pedestrian Reservice use case will detect for instances of downstream vehicular blocking and will reservice the perpendicular pedestrian movements before returning back to the prior phase, when sufficient time is available.
- **Dynamic Left Turn Split Allocation:** The Dynamic Left Turn Split Allocation use case will detect for heavy vehicles in the leading position of a left turn lane. If detected, more time will be dynamically granted for the left turn movement to compensate for heavy vehicle slow startup movements.

Best Practices for AI Use in Transportation

Engage cross-disciplinary partners early

- Involve all stakeholders from the outset: IT, traffic engineering, community members
- Cross-functional teams anticipate challenges, accelerate solutions, and boost both technical and public trust

Prioritize privacy and transparency

- Design data flows and system specs to ensure *no collection of PII* and proactively publish privacy policies
- Keep the public and city leadership informed with clear communications on what is (and isn't) collected

Test innovations with live demos and feedback loops

- Pilot new use cases in the real world—host live demonstrations for agency staff, policymakers, and community members
- Gather feedback before—and during—deployment to pivot quickly if problems or concerns arise

Document integration issues and share guidelines

- Rigorously track integration challenges: sensor placement, network connectivity, timing mismatches, data anomalies
- Create and publicly share "how-to" guides so peer agencies can benefit from lessons learned

Takeaway

- Future-ready traffic technology is as much about collaboration and transparency as it is about code and hardware. Agencies that share early, test openly, and document thoroughly set the standard for smart mobility innovation.

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