RWR 4015

Traffic Simulation for Planning Applications

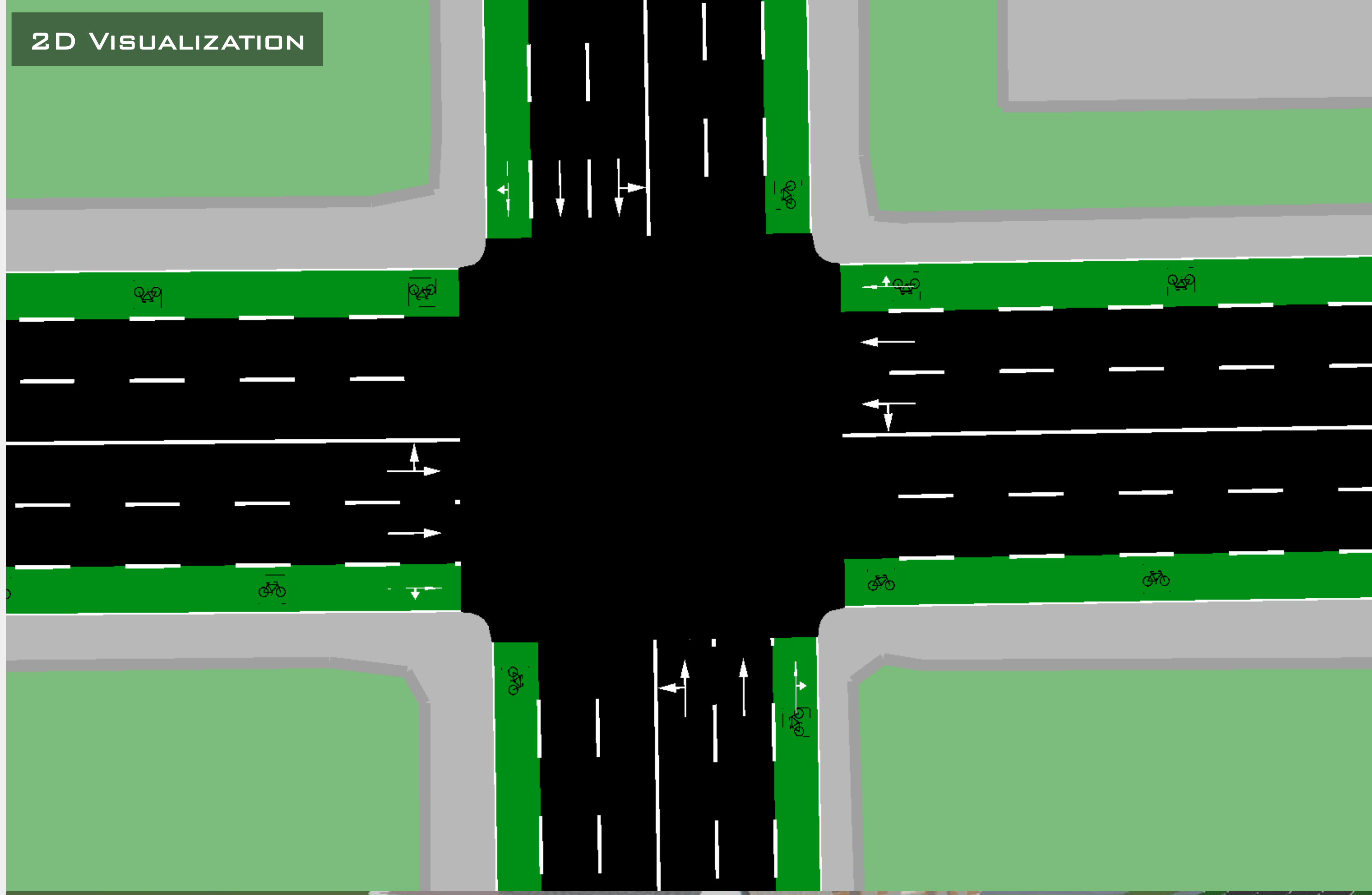
Dr. Ahmad Mohammadi

Week 4 | Lecture:
Traffic Signal Planning in Simulation

Fall 2026

RoadwayVR

roadwayvr.github.io/TrafficSimulationforPlanningApplications



Agenda

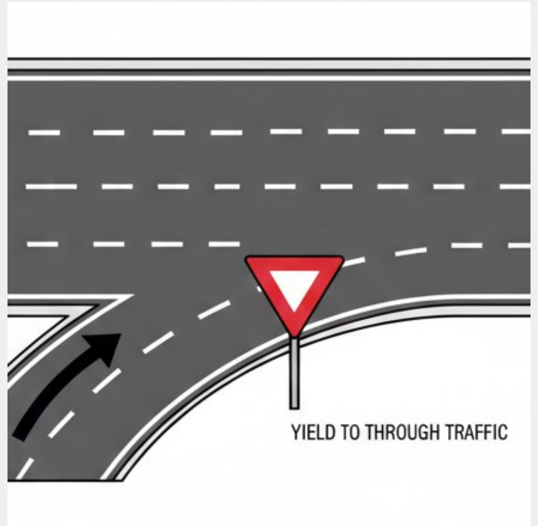
- ❑ Common Types of Intersection Control
- ❑ Identify the Types of Intersection Control
- ❑ Traffic Light History
- ❑ Traffic Signal Technology
- ❑ Traffic Signal Planning
- ❑ Type of Signal Control
- ❑ Signal Phasing
- ❑ Case Studies in Traffic Signal Planning

Traffic Light Tree in London, UK

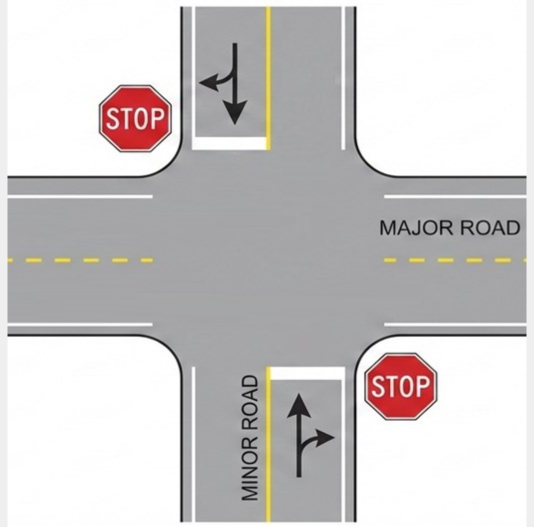
Common Types of Intersection Control

Unsignalized

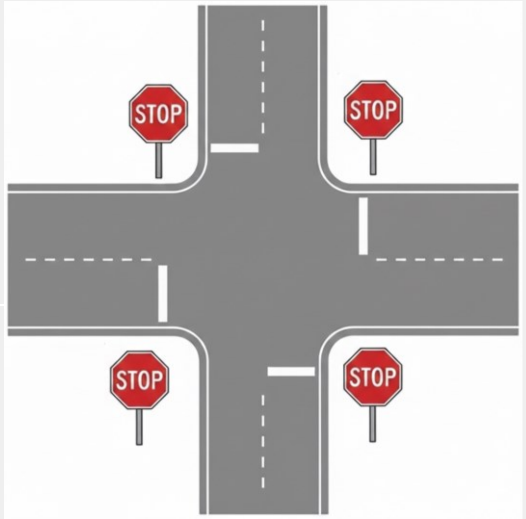
Unsignalized (YIELD Sign)



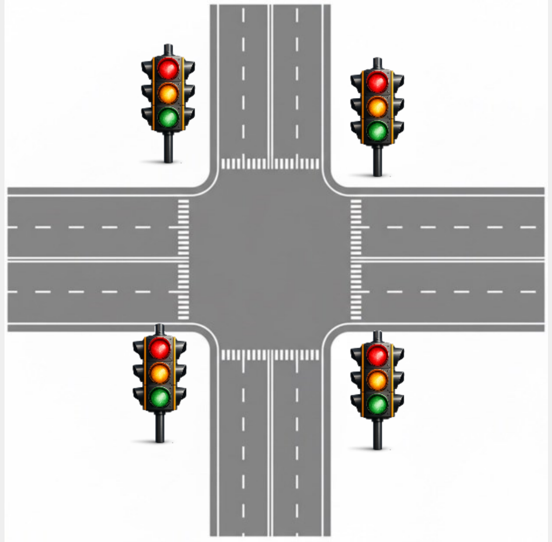
Unsignalized (two-way STOP control)



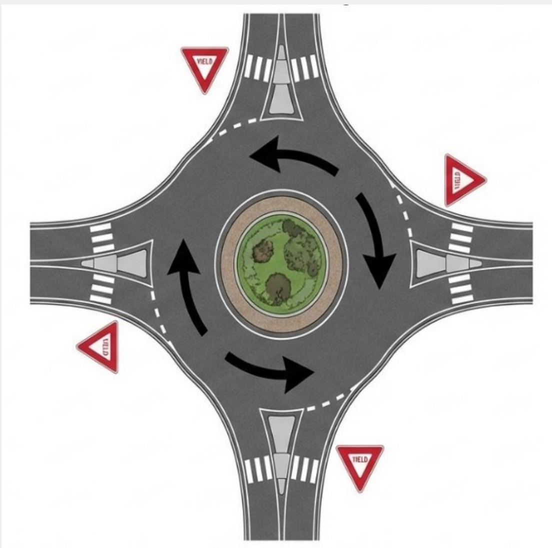
All-way STOP control



Signalized Intersections

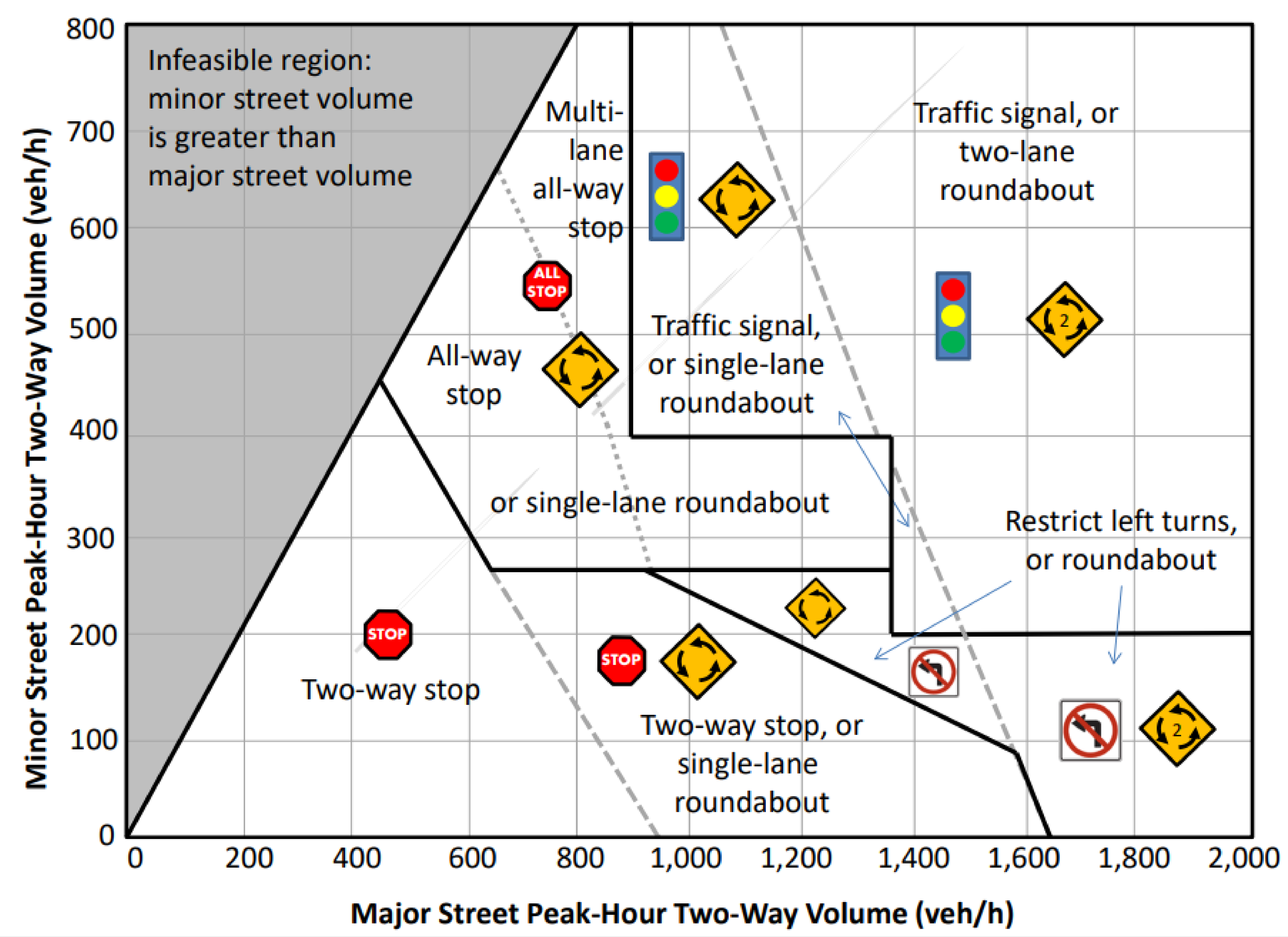


Roundabouts



Source: Transportation Research Board (TRB), Highway Capacity Manual 7th Edition (2022)

Identify the Types of Intersection Control



Florida Department of Transportation (FDOT), *Intersection Control Evaluation Procedure* (**Topic No. 750-010-003**, Sept 2017; **Revised: Nov 2020**), **Appendix A, Figure A1: "Intersection Control Type by Peak Hour Volume Thresholds"** (page **A-7**)

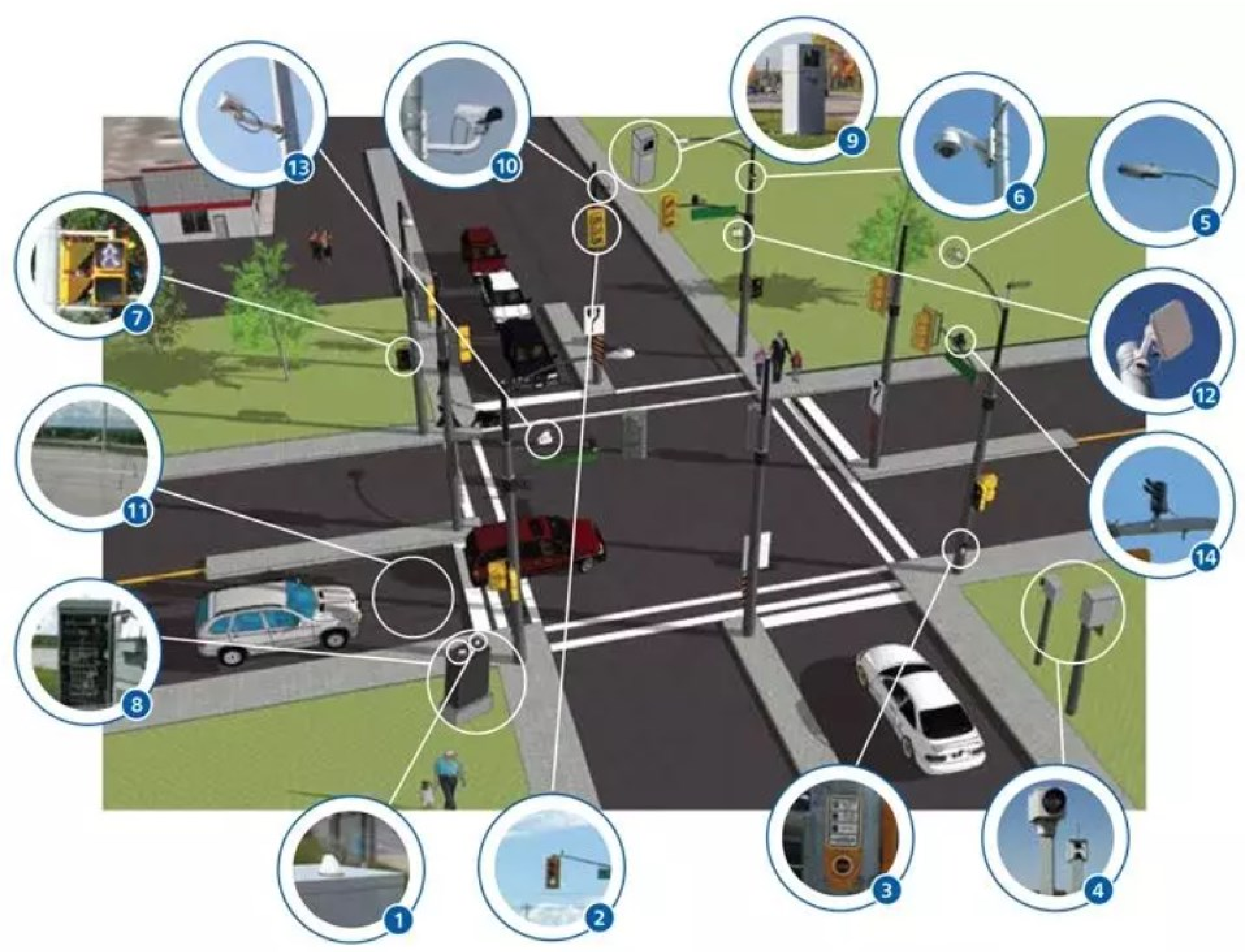
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/traffic/trafficservices/studies/mice/fdot-ice-manual_january-2021_v7.pdf?sfvrsn=178f93f1_0

Traffic Light History

- In 1868: First traffic signal outside the Houses of Parliament in London
- Manually operated by a police officer who controlled it based on traffic flow
- Using gas-lit; it exploded about a month later, injuring the operator

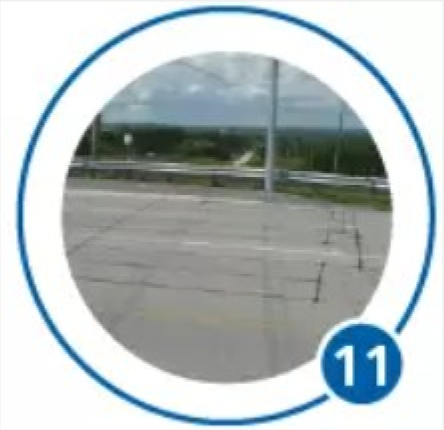
- In 1912: an advanced traffic signal in Salt Lake City in Utah (USA)
- Manually operated by a police officer who controlled it based on traffic flow
- Using electricity instead of gas

Traffic Signal Technology



https://www.york.ca/newsroom/campaigns-projects/traffic-technology-intersections

Vehicle Detectors



Underground Detection Loops

Video Detection

Underground Detection Loops

- ❑ Detects vehicles passing or arriving at a certain point (at the intersection)
- ❑ Wire loops buried in pavement carry electrical current
- ❑ When a vehicle drives over the loop, it changes the magnetic field, alerting the signal controller

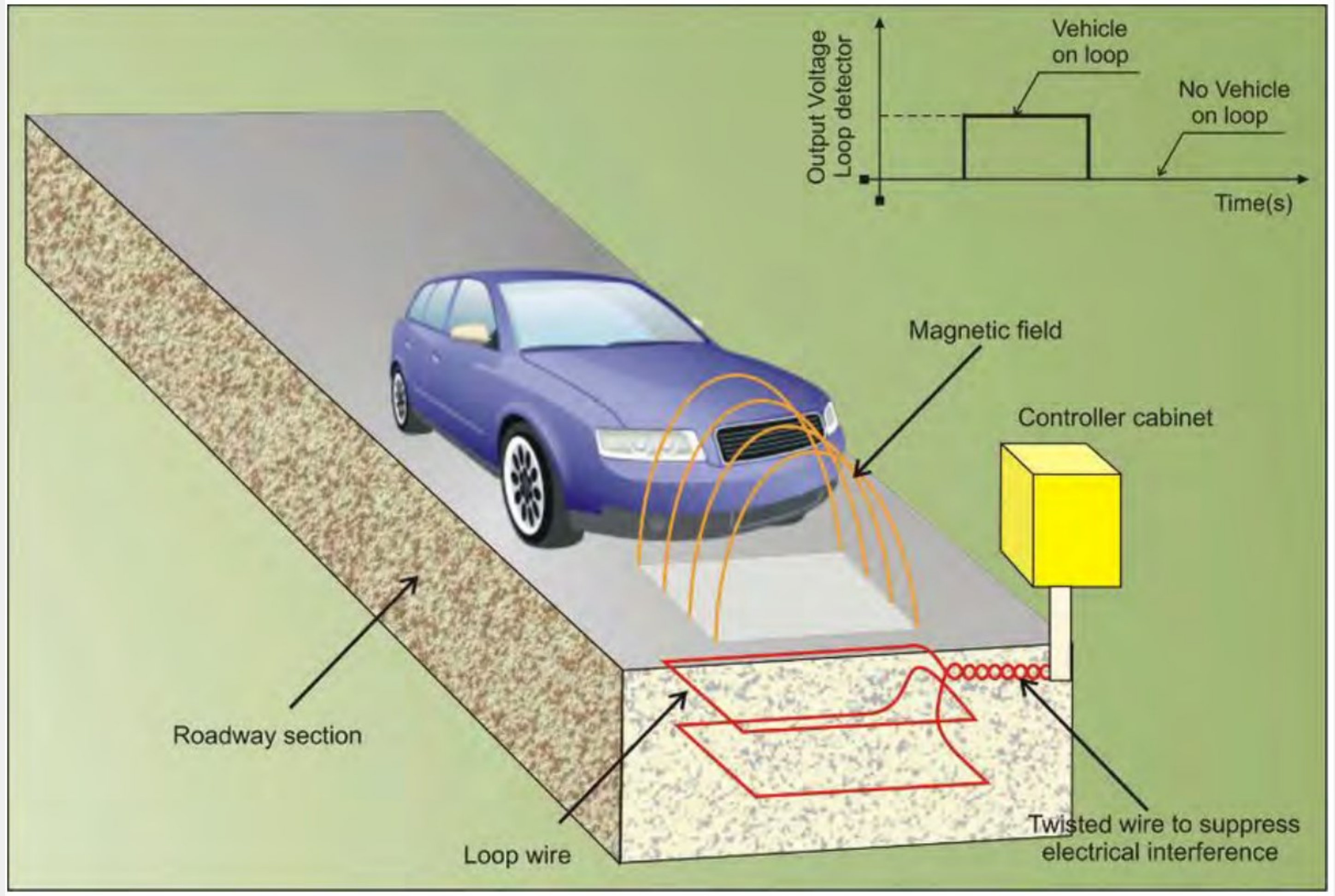
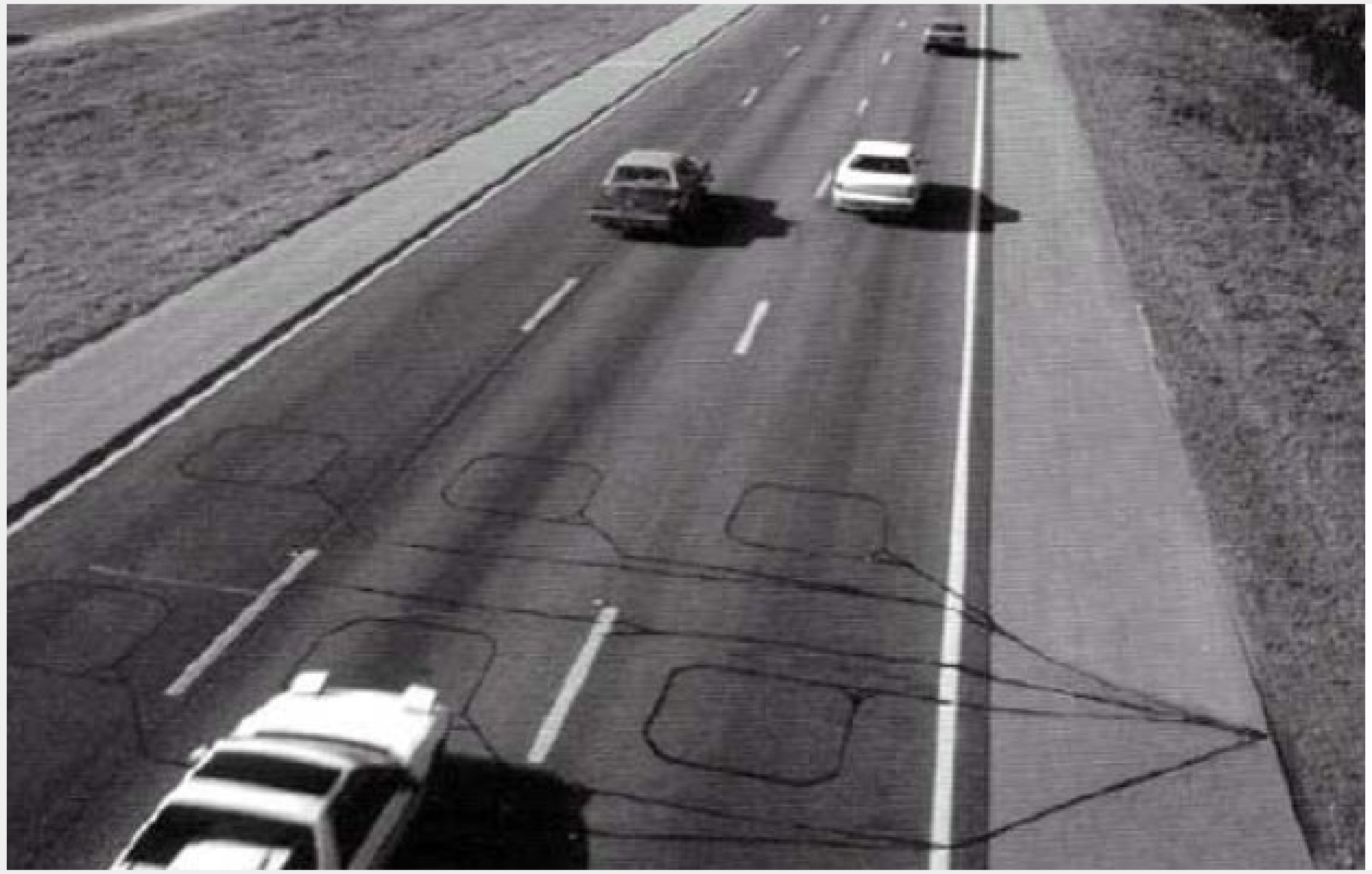
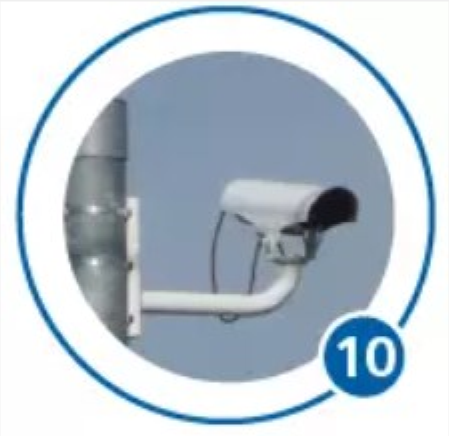


Figure 2. Loop Detector principle.



Video Detection

- ❑ Pole mounted cameras to detect the presence of vehicles
- ❑ Uses computer vision to detect object type, count and speed



Traffic Signal Planning

Definition: The systematic process of determining WHERE, WHAT, and HOW traffic signals should be implemented to optimize intersection performance while ensuring safety.

Key Questions:

- ❑ Where we need to implement Traffic Signal? (Warrant analysis)
- ❑ What type of signal control? (Fixed-time vs. actuated)
- ❑ How many phases are needed? (Movement accommodation)
- ❑ How long should each phase be? (Timing optimization)
- ❑ How do we coordinate multiple signals? (Network-level)

Sources: FHWA Traffic Signal Timing Manual (2008);
MUTCD (2009); ITE Traffic Engineering Handbook (2016)

What is a Signal Warrant?

Definition: A WARRANT is a threshold condition that JUSTIFIES installing a traffic signal.

Think of it like a prescription:

- ❑ A doctor needs symptoms (warrants) before prescribing medicine (signals)
- ❑ We need evidence (traffic data) before installing expensive signals

Key Principle:

Signals are NOT always the answer!

- Unnecessary signals create delay and pollution
- Signals cost $250,000-500,000 to install

The Question:

Does the BENEFIT of a signal outweigh the COST?

Source: MUTCD (2009), Section 4C.01: https://mutcd.fhwa.dot.gov/htm/2009/part4/part4c.htm

Warrant Analysis

Nine Warrants, Three Categories

Category 1: VOLUME-BASED (Most Common)

✓ Warrant 1: Eight-Hour Vehicular Volume

✓ Warrant 2: Four-Hour Vehicular Volume

✓ Warrant 3: Peak Hour

When to use: High traffic volumes justify signal

Category 2: SAFETY-BASED

✓ Warrant 4: Pedestrian Volume
✓ Warrant 5: School Crossing
✓ Warrant 7: Crash Experience

When to use: Safety concerns justify signal

Category 3: SYSTEM-BASED

✓ Warrant 6: Coordinated Signal System
✓ Warrant 8: Roadway Network
✓ Warrant 9: Intersection Near Grade Crossing

When to use: Network efficiency or special conditions justify signal

Warrant Analysis

Warrant 1: Eight-Hour Vehicular Volume (This is the most commonly used warrant)

The Logic: If an intersection is BUSY for most of the day, it needs a signal.

The Test: For ANY 8 hours of an AVERAGE day:

Major Street (higher volume road): - Must have ≥ 600 vehicles/hour (both directions combined)

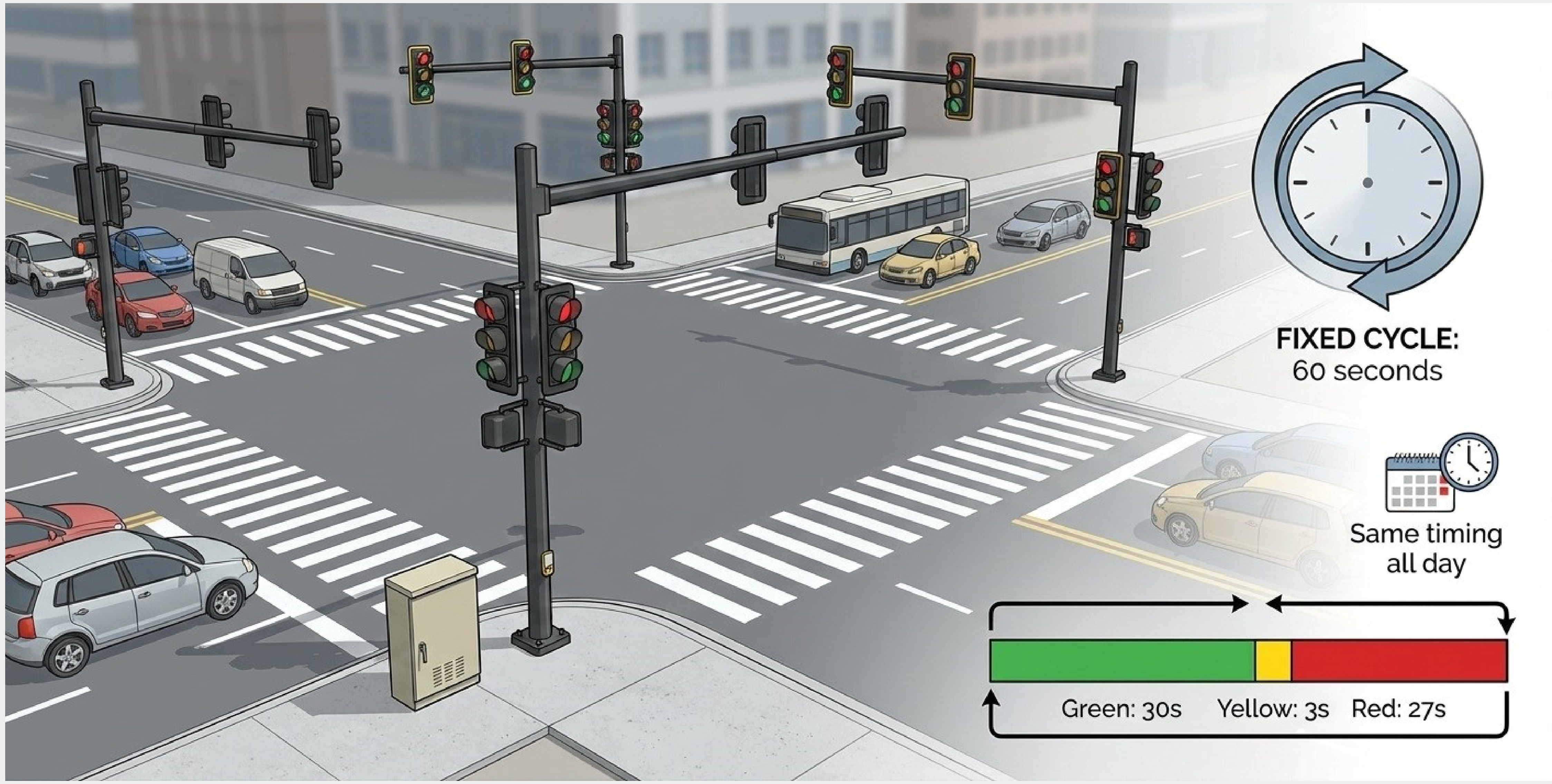
AND Minor Street (lower volume road): - Must have ≥ 150 vehicles/hour (highest volume approach)

Example

Time Period	Major (Yonge)	Minor (Side St)	Met?
7-8 AM	850 veh/hr	200 veh/hr	✓
8-9 AM	920 veh/hr	180 veh/hr	✓
9-10 AM	750 veh/hr	160 veh/hr	✓
…			
…			

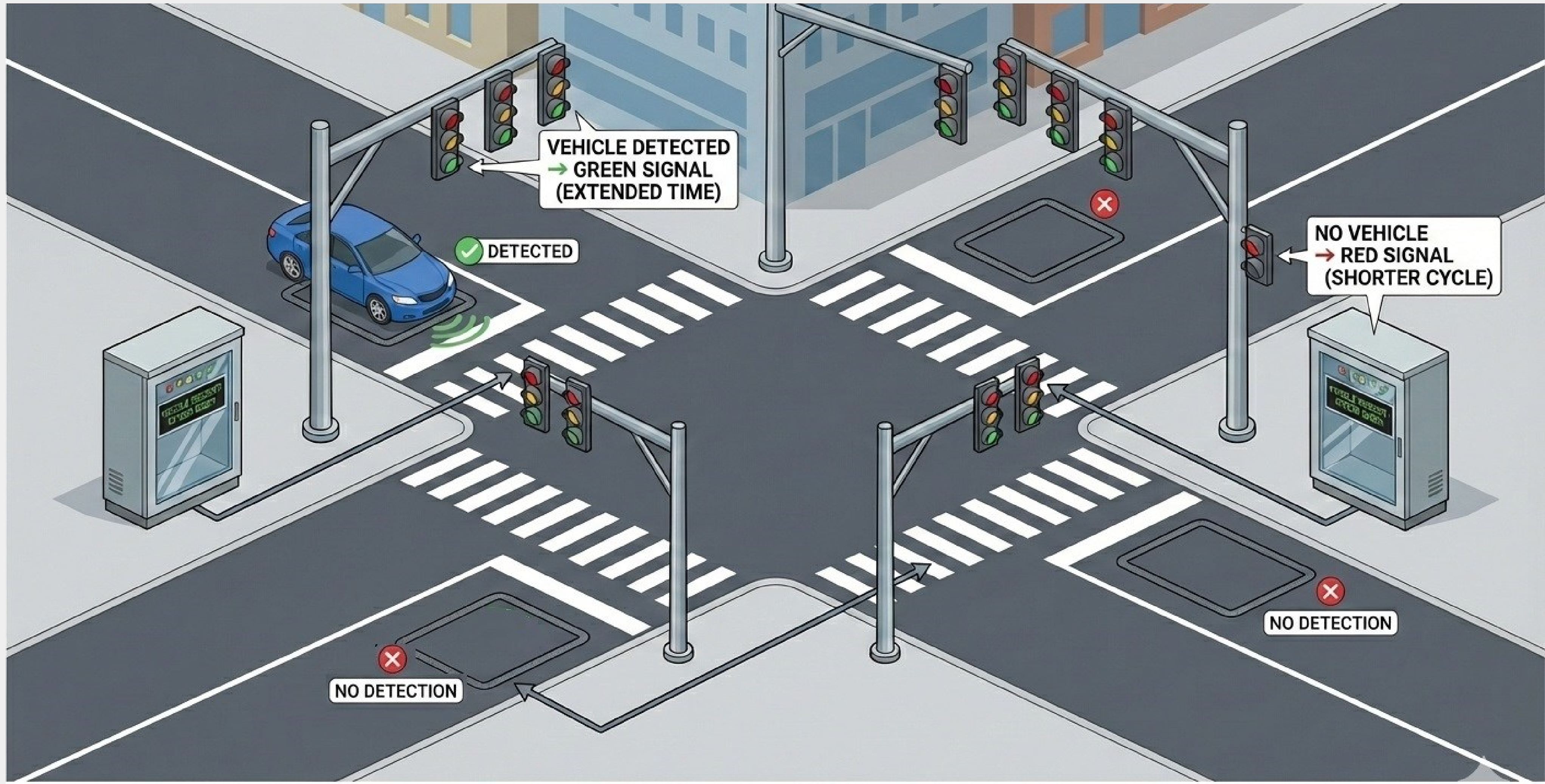
Types of Signal Control (Fixed-Time vs. Actuated)

- Fixed-time: Repeat a preset constant cycle and signal plan



Types of Signal Control (Fixed-Time vs. Actuated)

- ✓ Actuated: Respond to the presence of vehicles
- ✓ Semi-actuated: Detectors placed only on the minor approach
- ✓ Fully actuated: Detectors are installed at all approaches
- ✓ Green time are allocated based on the incoming traffic on each approach



Types of Signal Control (Fixed-Time vs. Actuated)

Fixed-Time

Advantage:

Simple Construction

Inexpensive to install and maintain

Disadvantage:

Inflexible to traffic conditions

Causes avoidable delay during low-traffic periods

Actuated

Advantage:

Flexible – adjusts according to traffic demand

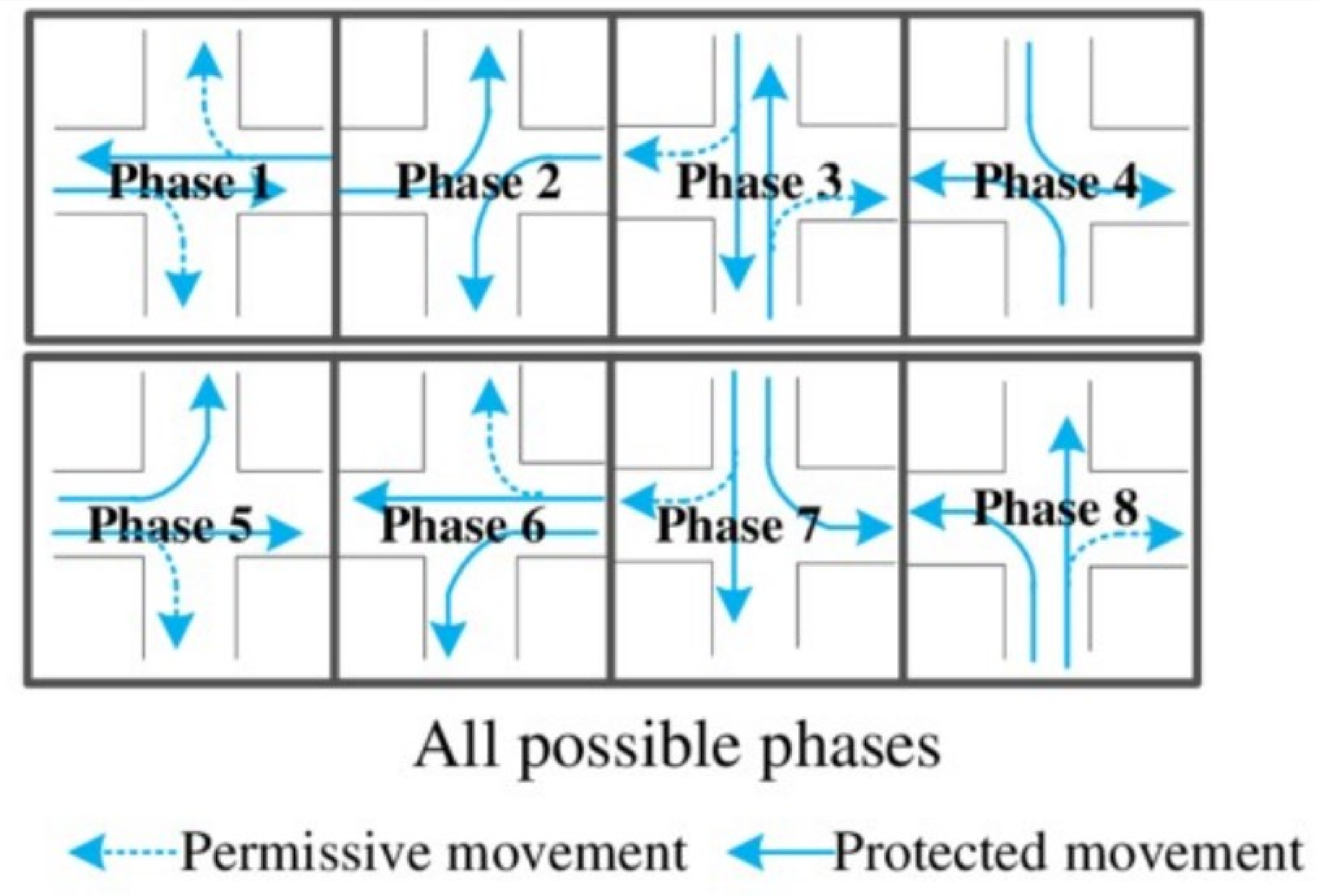
Minimizes delay to attain maximum capacity

Disadvantage:

Requires costly equipment including detectors

More complex maintenance

Signal Phasing



Signal Phasing

Cycle length: Total time for a signal to complete all phases and return to the start

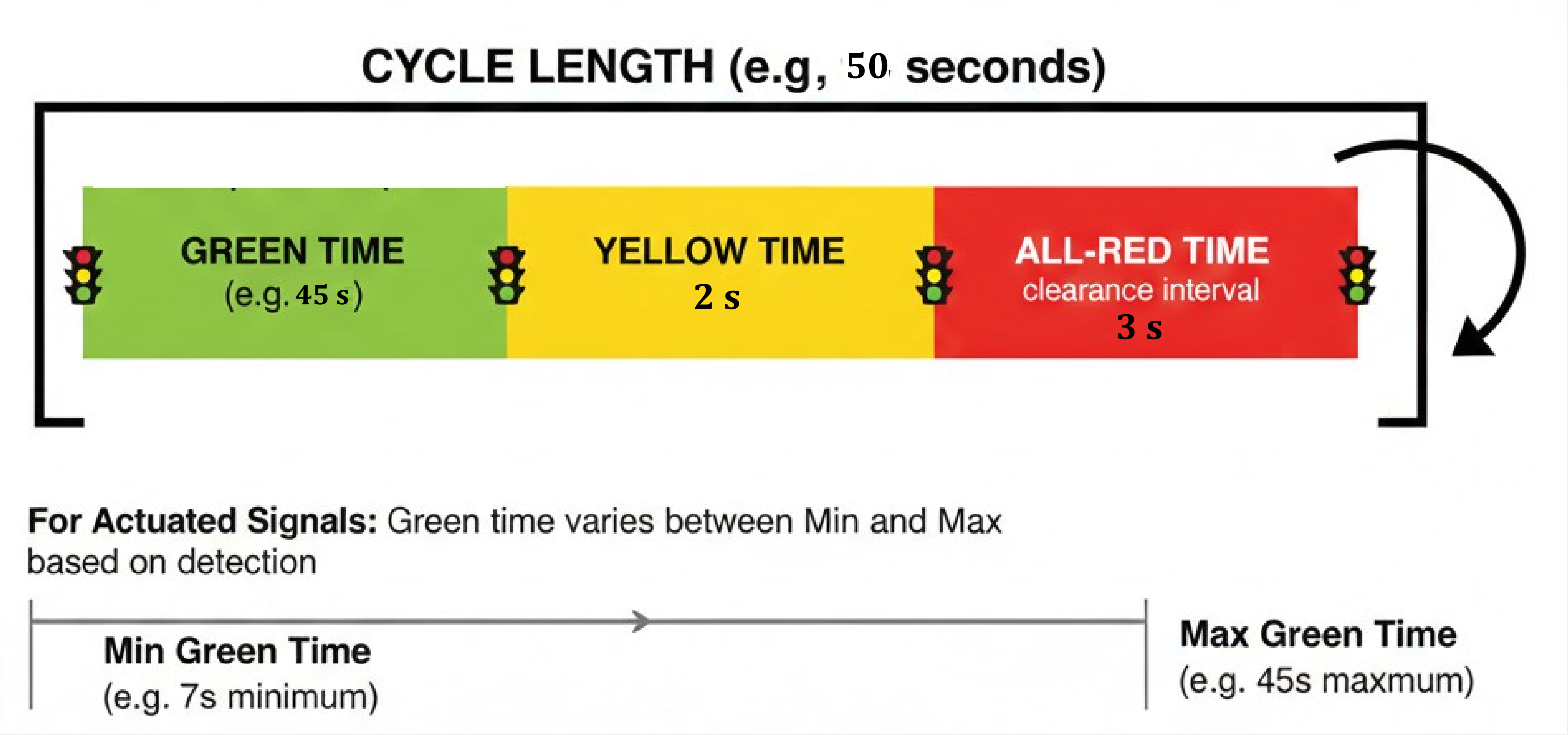
Green Time: Duration of green indication for vehicle movement

Yellow Time: Transition period warning drivers the signal is about to turn red

All Red Time: Brief period when all approaches show red to clear the intersection

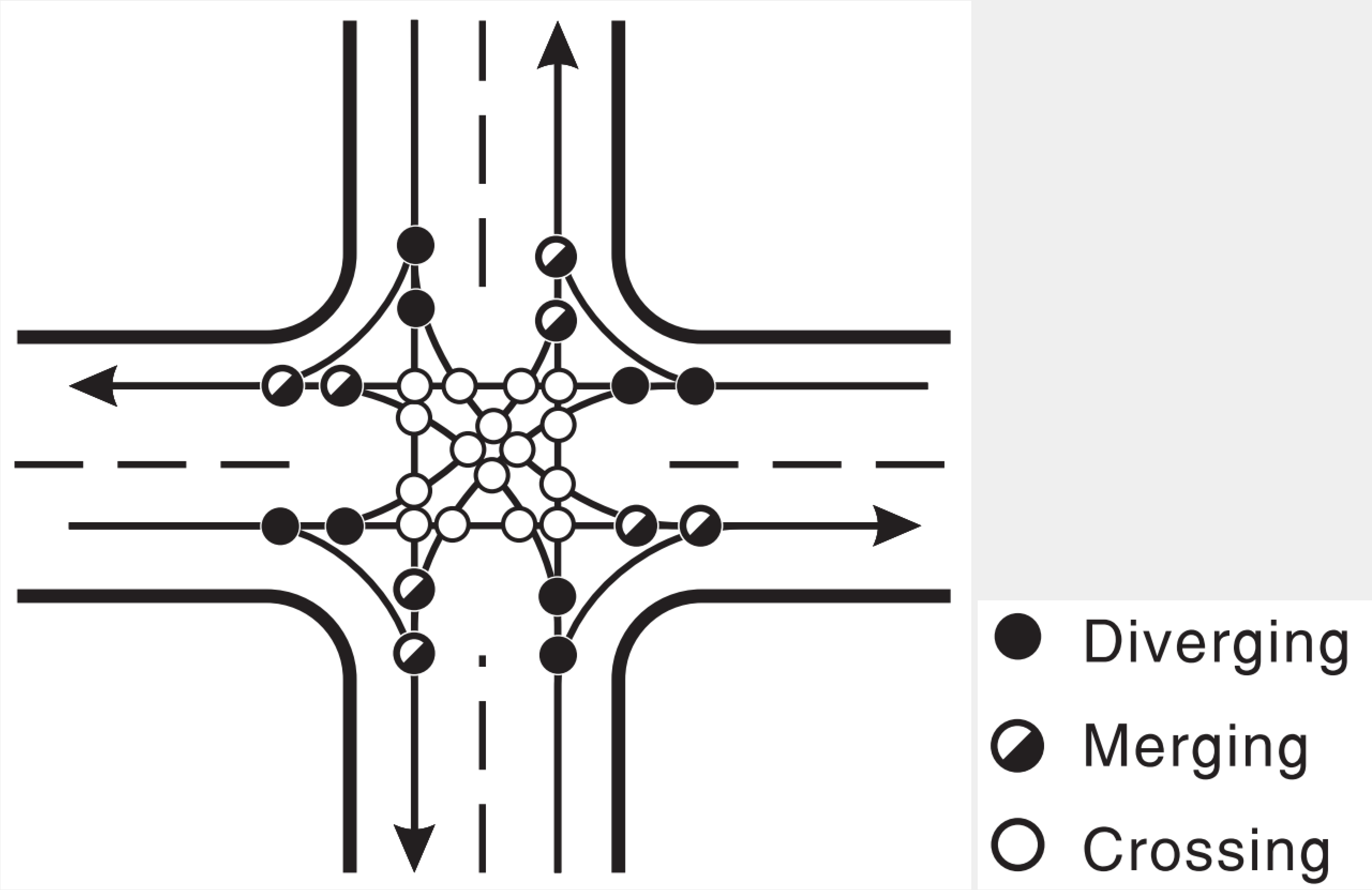
Min green Time: Shortest green duration allowed (ensures safety for detected vehicles)

Max green Time: Longest green duration allowed (prevents excessive delay on other approaches)



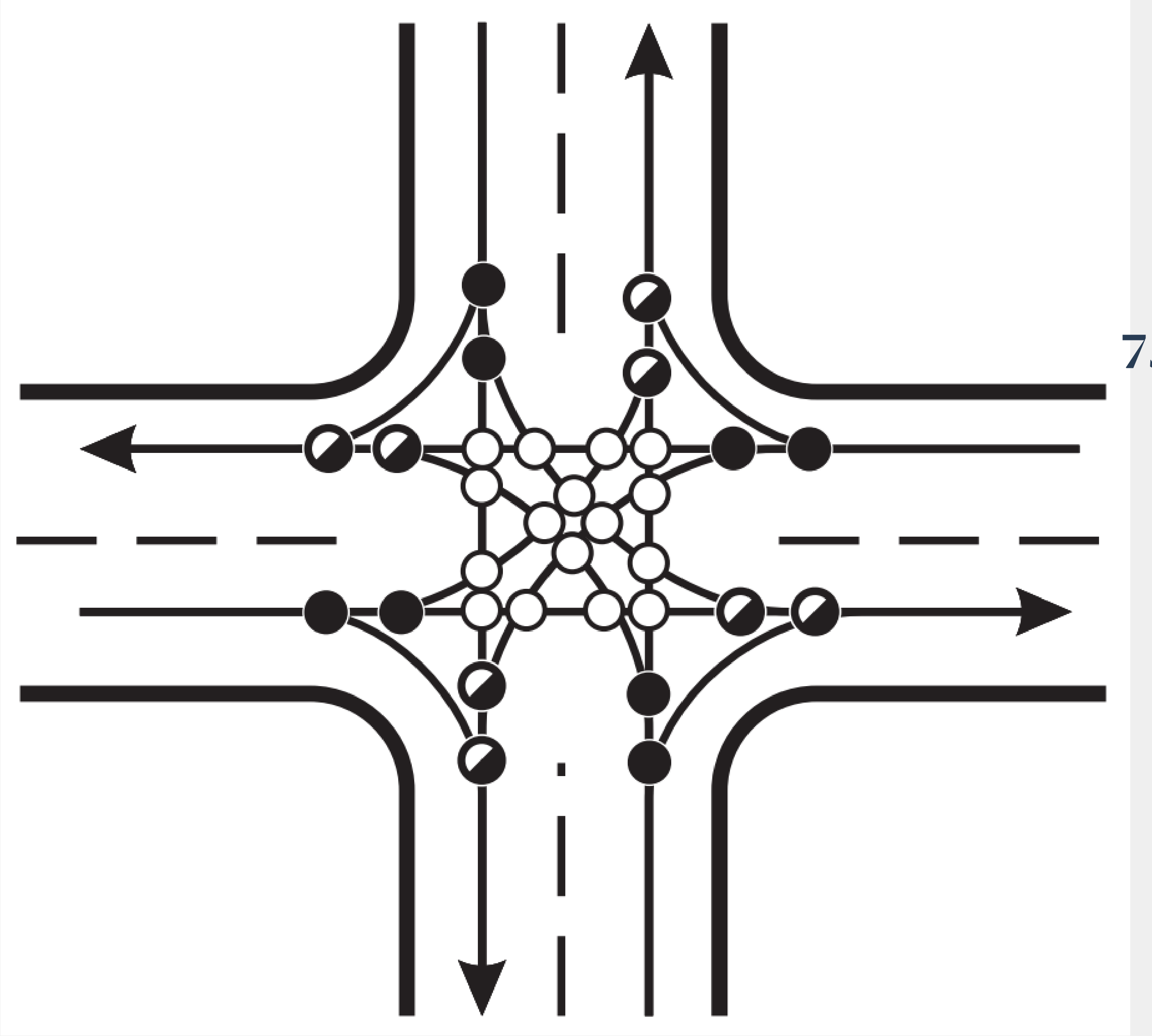
Overview of Intersections

- ➢ **In a 4-approach intersection:**

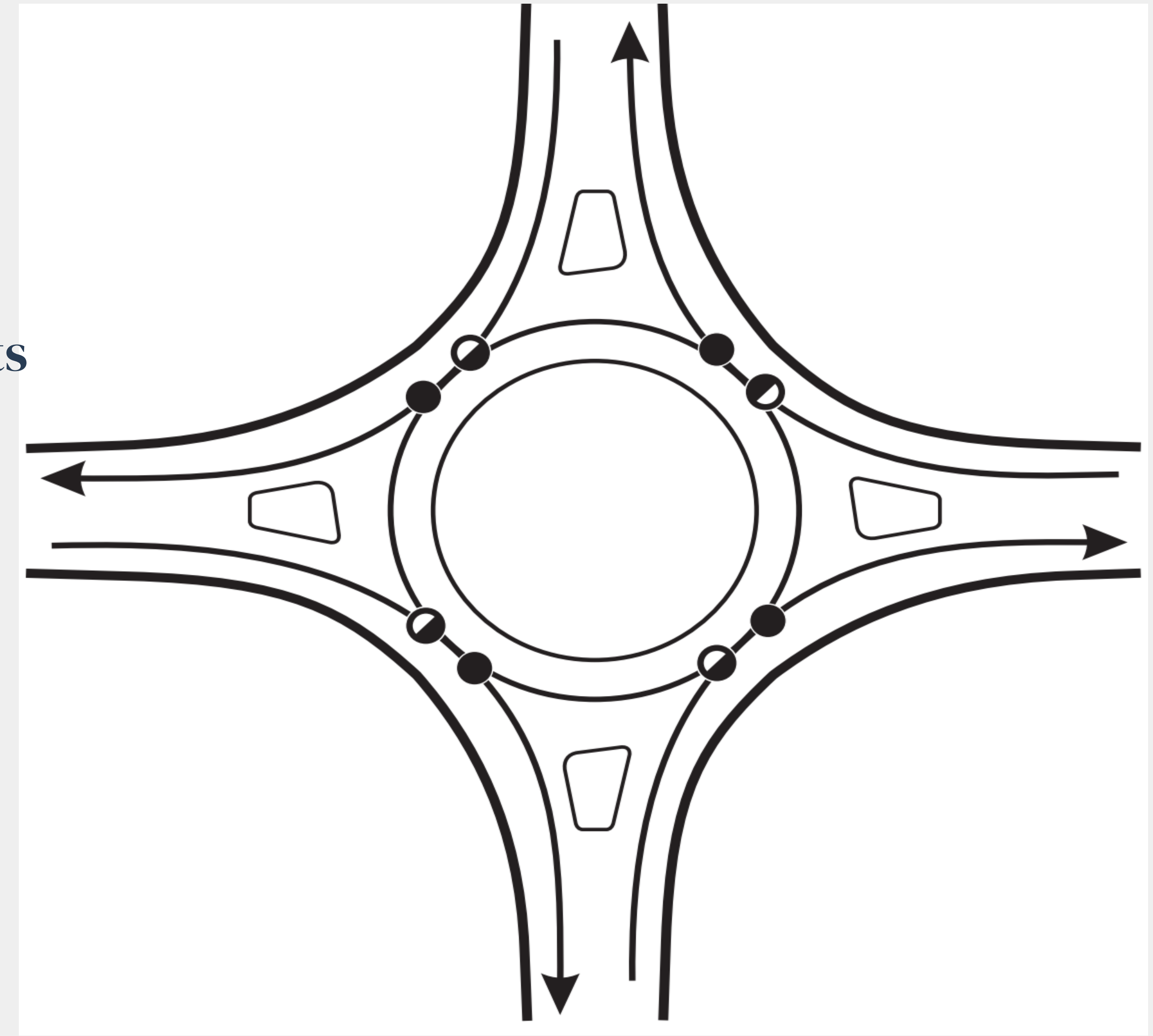


Federal Highway Administration (FHWA). *Roundabouts: An Informational Guide* (FHWA-RD-00-067), 2000. Exhibit 5-2: "Vehicle conflict point comparison for intersections with single-lane approaches."
https://www.fhwa.dot.gov/publications/research/safety/00067/00067.pdf

Overview of Intersections



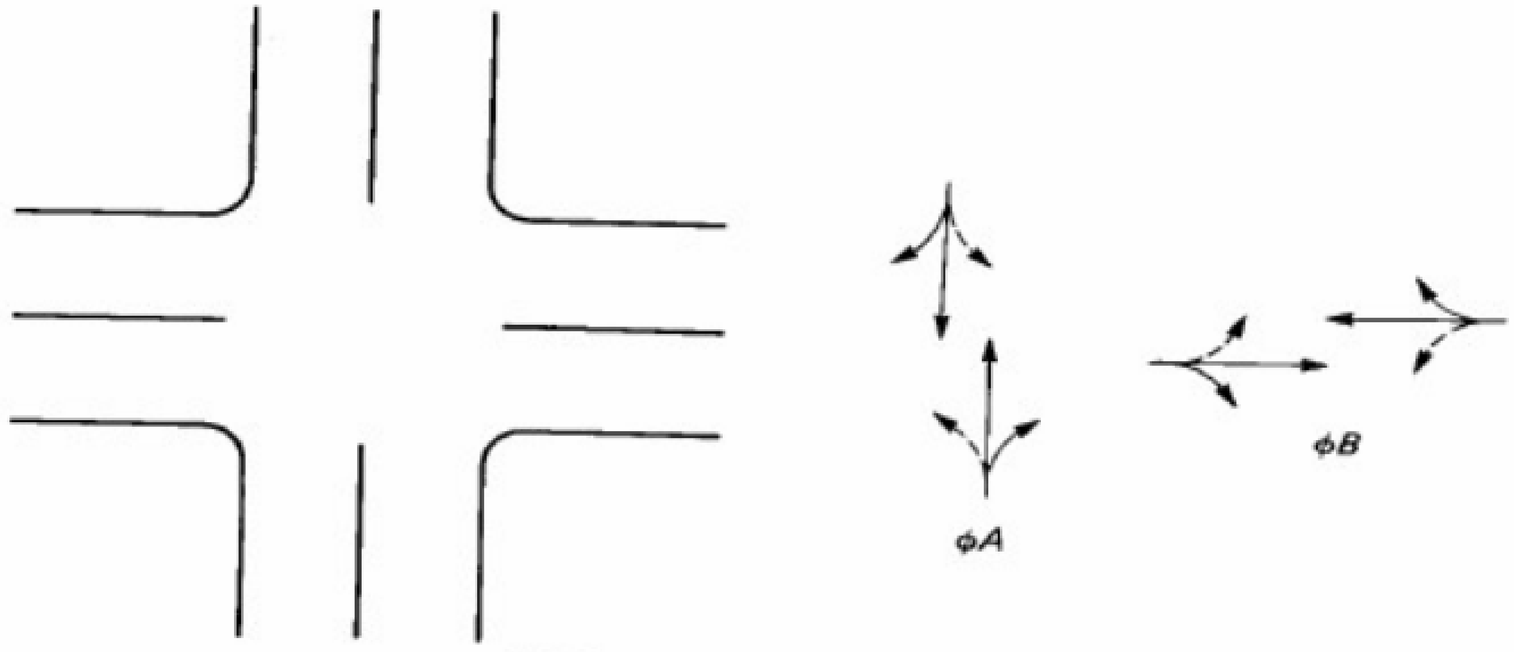
75% fewer vehicle conflict points



- Diverging
- Merging
- Crossing

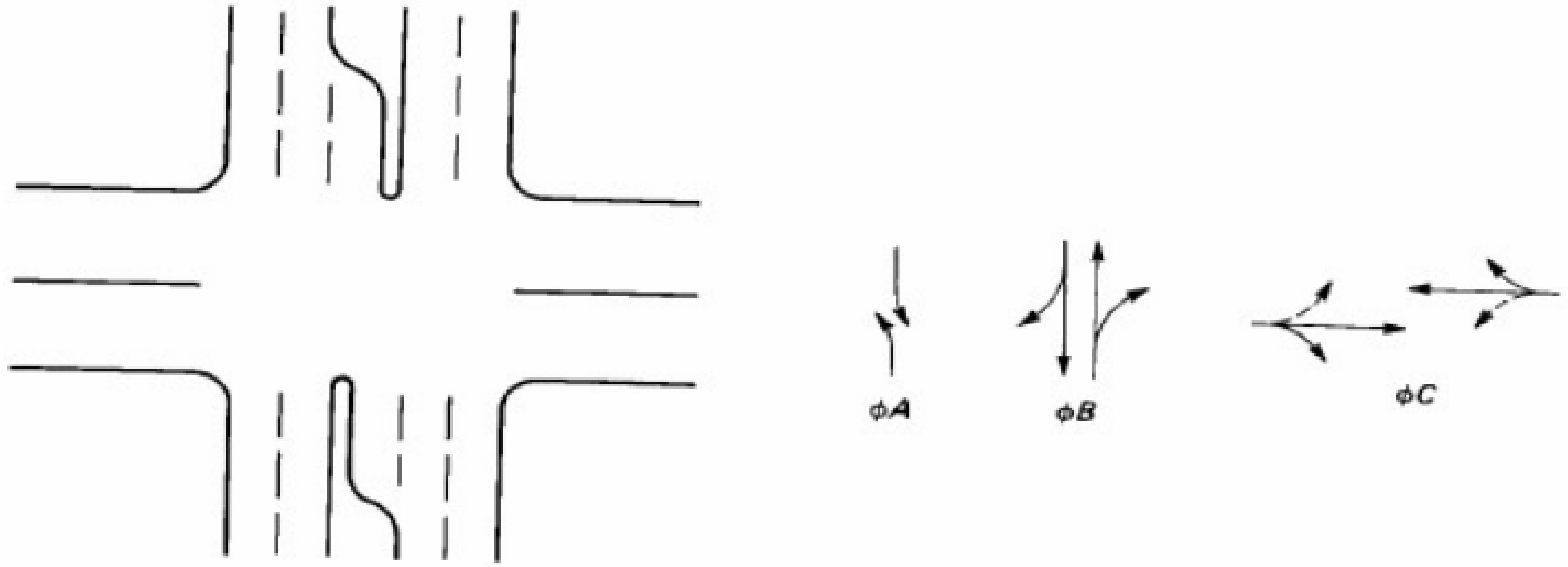
Signal Phasing

Two phases



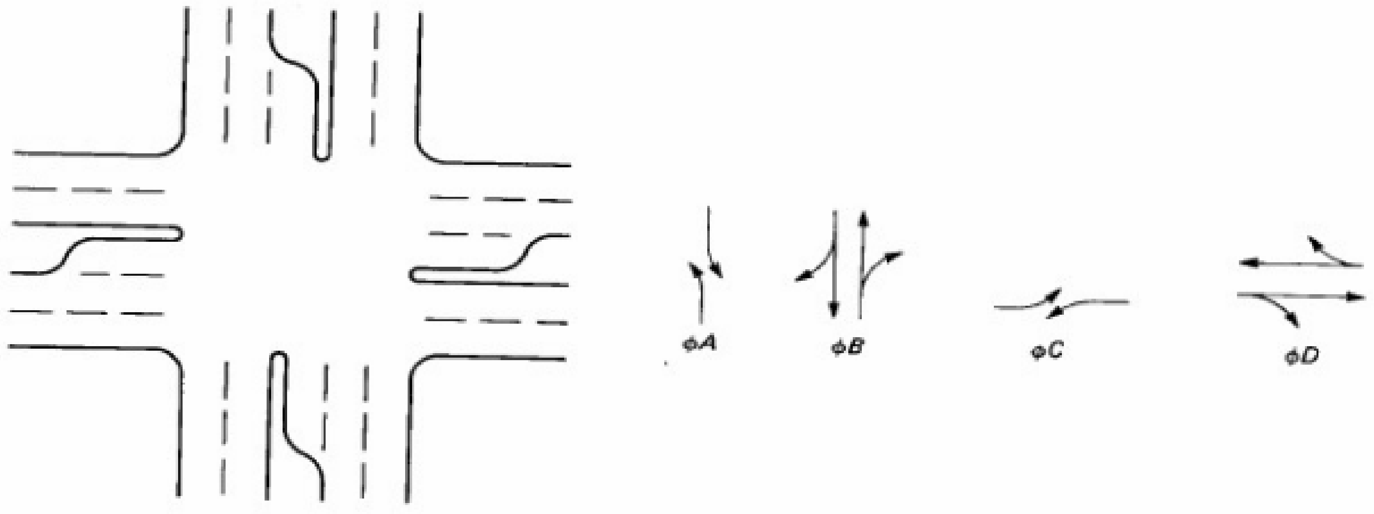
(a) Simple two-phase operation

Three phases



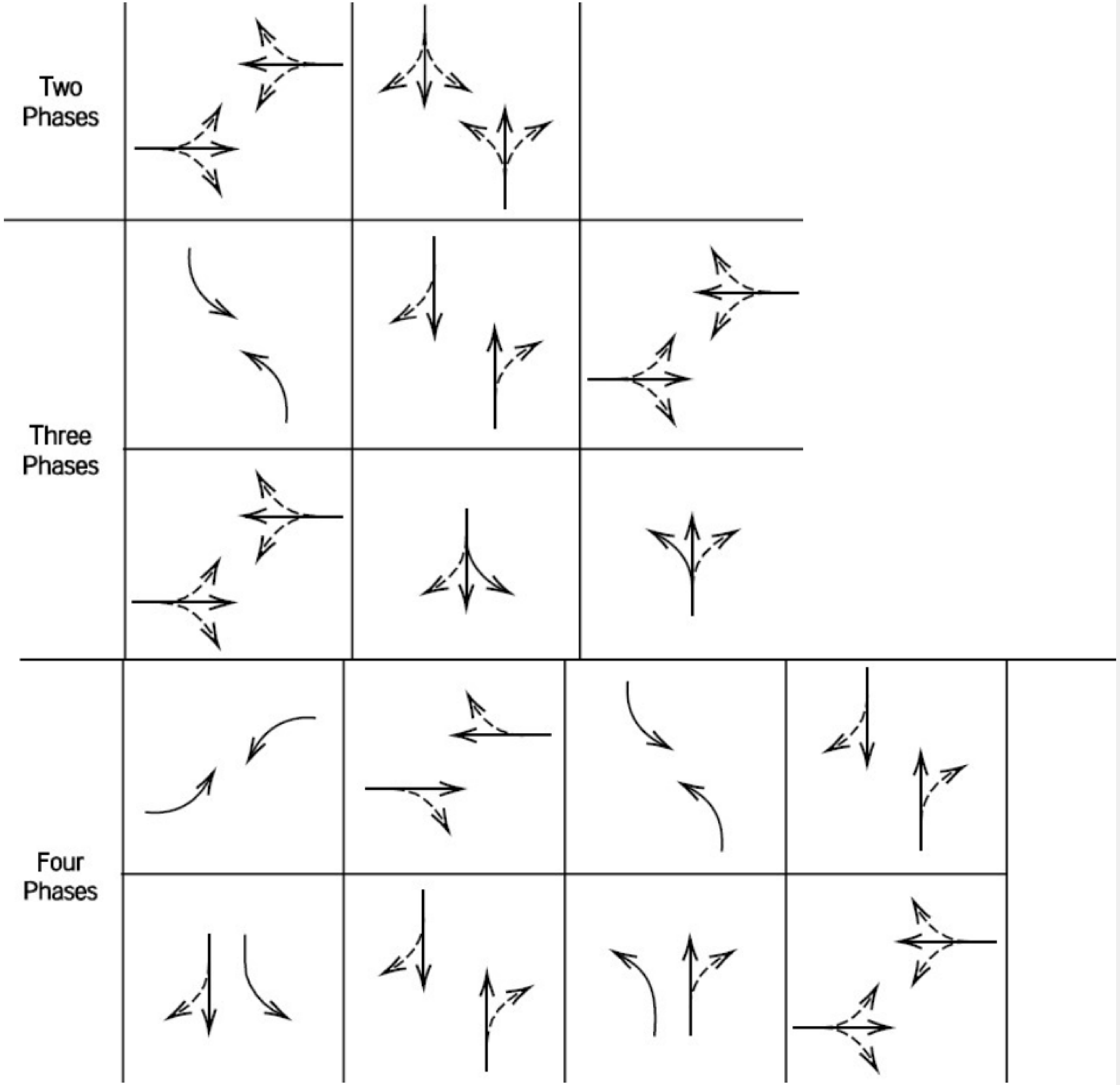
(b) Simple three-phase operation, protected turns on one street

Four phases

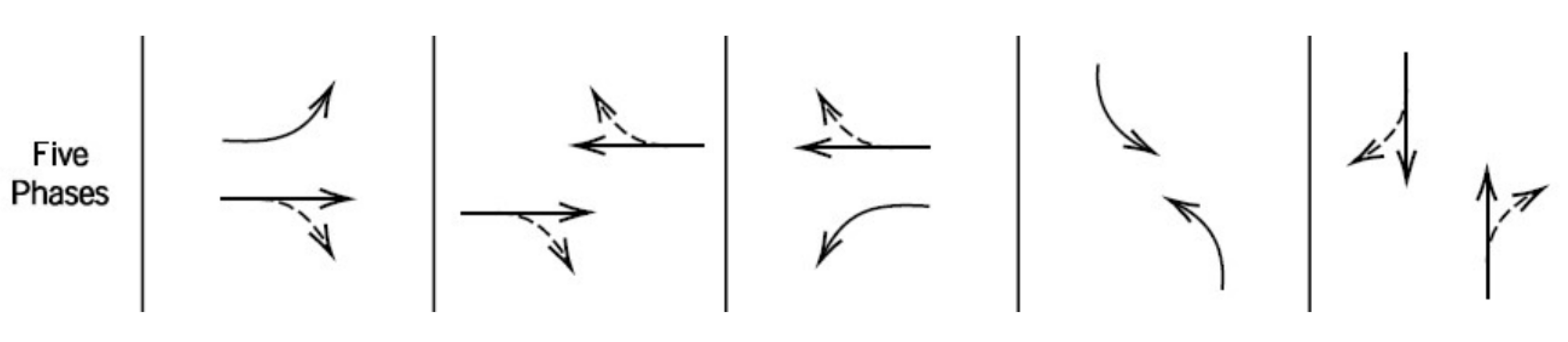


(c) Simple four-phase operation, protected turns on two streets

Signal Phasing



Signal Phasing

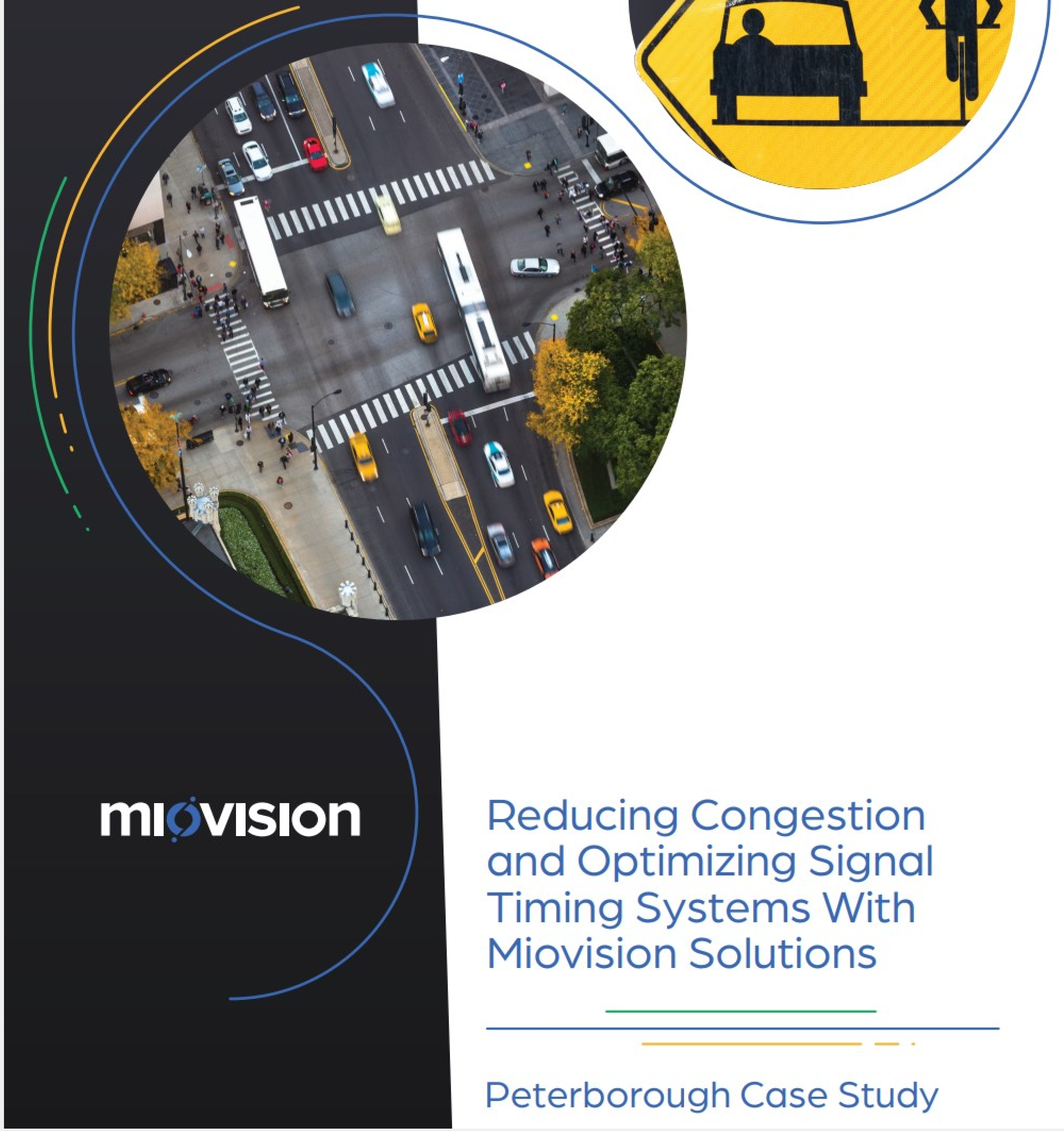


Case Study 1: MioVision

Company Type: Private (Canadian)

Product: Miovision TrafficLink + Surtrac Adaptive Control System

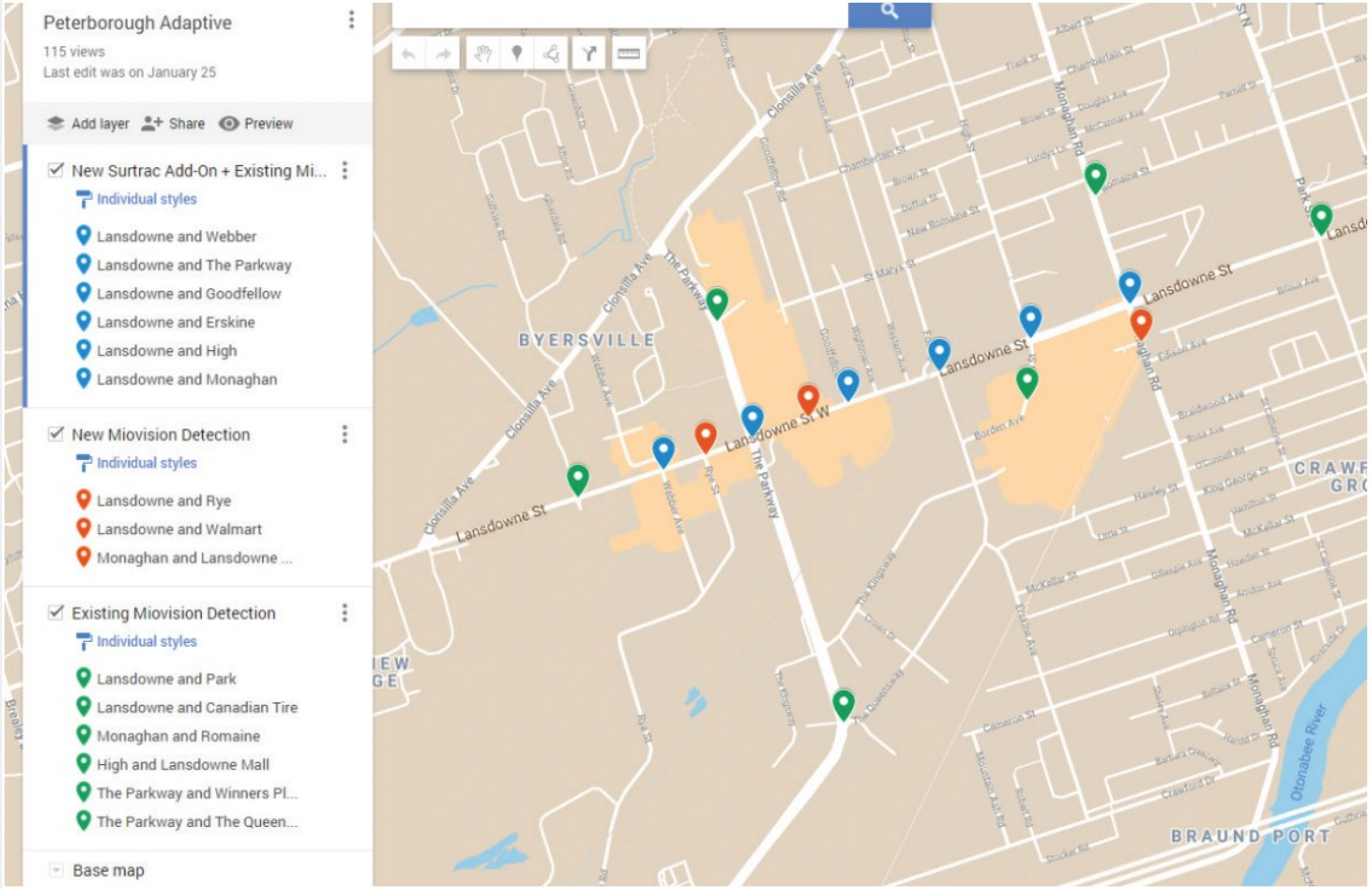
Study Area: Lansdowne Street Corridor, Peterborough, Ontario, Canada - 6 signalized intersections



https://miovision.com/wp-content/uploads/2023/11/Miovision_RapidFlow___Surtrac_Peterborough_CaseStudy.pdf

Case Study 1: MioVision

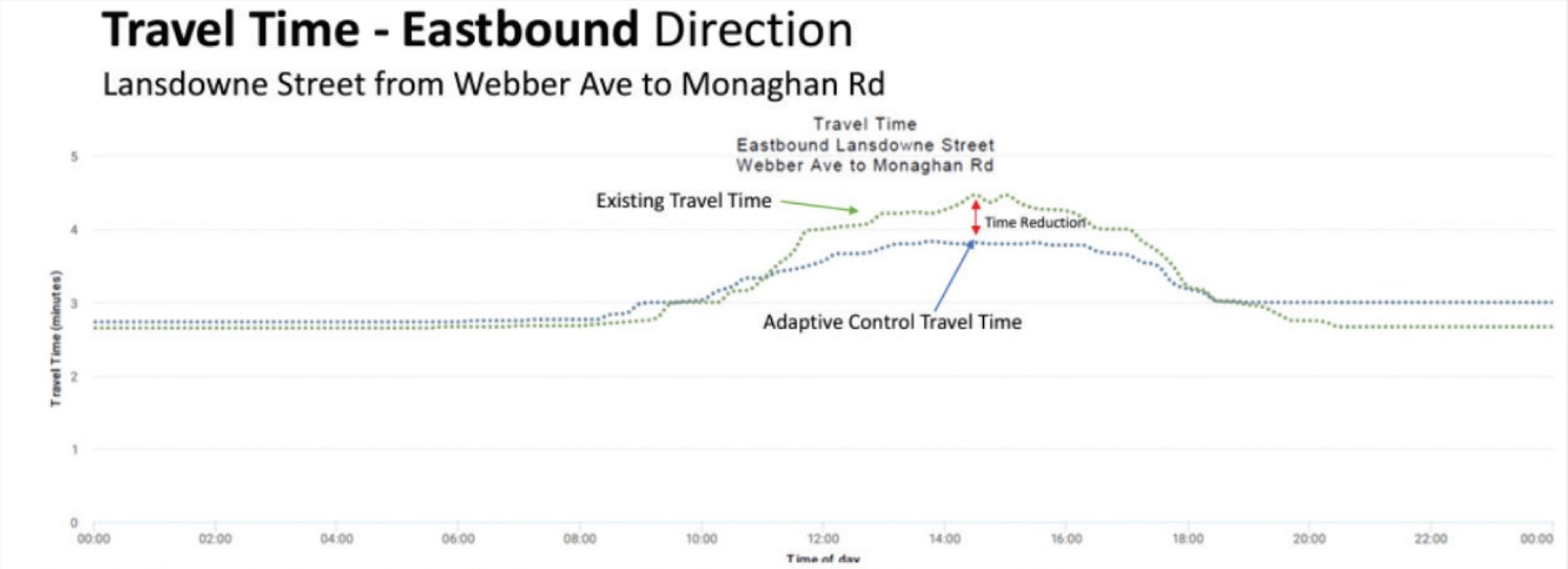
- 1.75 km corridor from Webber Avenue to Monaghan Road
- 6 signalized intersections
- August 2021
- **Input:** Traffic detection sensors (Traffic volumes/speeds etc)
- **Optimization:** Miovision Surtrac Adaptive Traffic Signal Control vs Traditional Fixed timing
- **Output:** Travel Time Reduction; Corridor Stops Reduction; Emissions



The selected corridor, with intersections included, the Surtrac deployment (blue), the additional Miovision detection locations (red) and the existing Miovision detection deployment locations (green) located near the corridor.

Case Study 1: MioVision

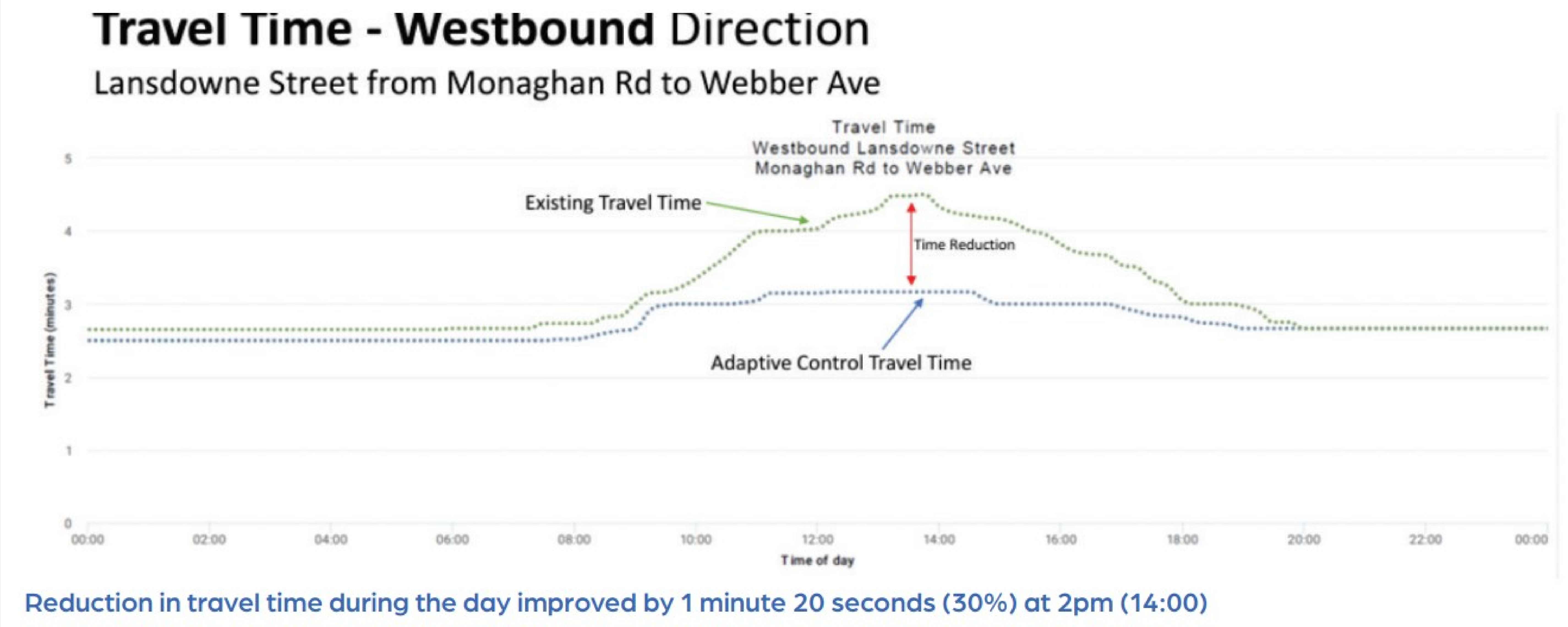
- **Eastbound direction:** showing 28-second reduction



Reduction in travel time during the day improved by 28 seconds (11%) at 3pm (15:00)

Case Study 1: MioVision

- **Westbound direction:** showing 80-second reduction



Results

- **Travel time reduction:** 11% eastbound, 30% westbound
- **Corridor stops reduction:** 37% eastbound, 53% westbound
- **Emissions:** 20% reduction (273 tons CO2/year)
- **User cost savings:** $977,000/year
- **Fuel savings:** 106,700 liters/year ($213,000/year)
- **Level of Service:** Improved from D to C (6% capacity increase)

Case Study 2: City of Toronto

- ❑ Signal Optimization Program: 2012-2024
- ❑ Traditional Way of Controlling Signal (Fixed Timing)
- ❑ Smart Control of Traffic Signals (SCATS)

https://www.toronto.ca/services-payments/streets-parking-transportation/traffic-management/traffic
signals-street-signs/signal-optimization-coordination-program/signal-coordination-study-map-2/#location=&lat=43.584975&lng=-79.370332&zoom=12

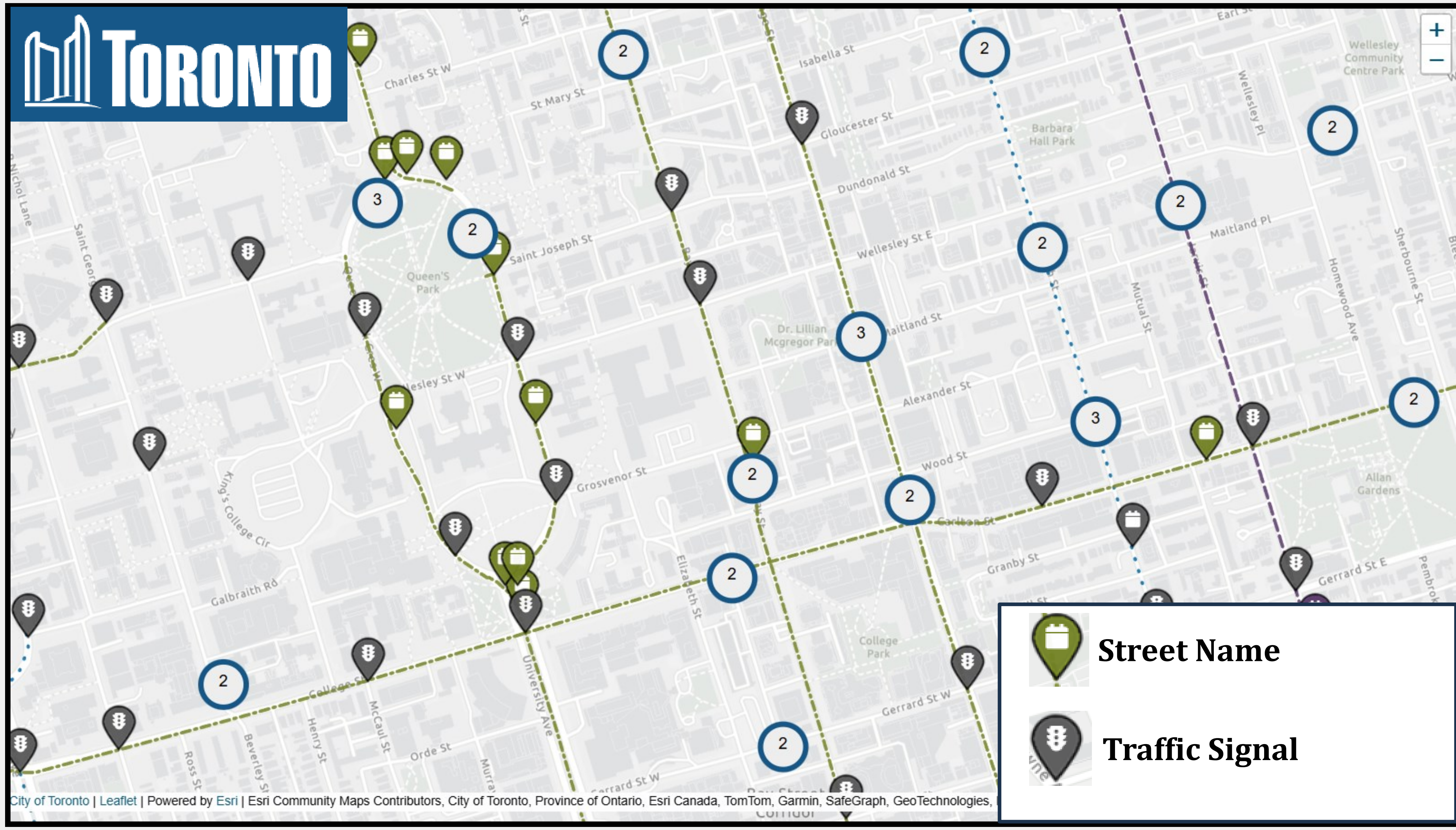
Traditional Way of Traffic Signal Control

- ❑ The City of Toronto’s Signal Optimization (Coordination) Program enhances the efficiency of over 2,500 traffic signals across the city.

- ❑ Fixed-time coordinated signal timing → Simulation

- ❑ "Uses Synchro® software for optimization“
"6 time-of-day periods: AM peak, day off-peak, PM peak, evening off-peak, night, weekend"

Map showing optimized corridors (2014-2024)



https://www.toronto.ca/services-payments/streets-parking-transportation/traffic-management/traffic-signals-street-signs/signal-optimization-coordination-program/signal-coordination-study-map-2/#location=&lat=43.584975&lng=-79.370332&zoom=12

Smart Way of Traffic Signal Control

- ❑ Sydney Coordinated Adaptive Traffic System (SCATS)
- ❑ Unlike fixed-time plans, SCATS adapts in real-time based on actual traffic conditions
- ❑ 89 signals use SCATS

Inductive loop detector embedded in pavement detects vehicles via magnetic field changes

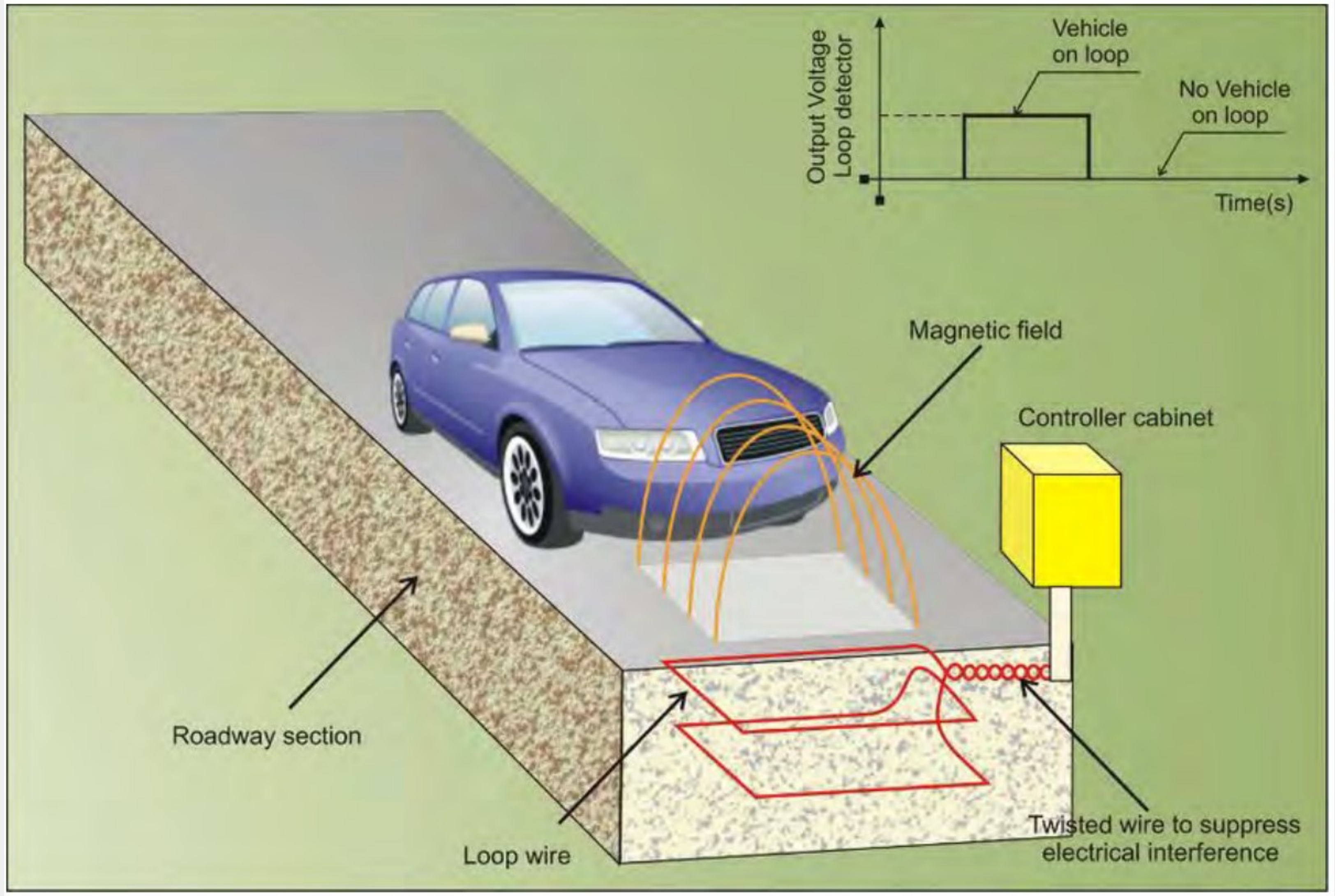


Figure 2. Loop Detector principle.

https://www.toronto.ca/services-payments/streets-parking-transportation/traffic-management/traffic-signals-street-signs/traffic-signals-in-toronto/types-of-traffic-signal-systems/

https://appliedtechnology.humber.ca/assets/files/civil-engineering-show/2024/SmartSolutionsForTorontoTrafficAdvancementsInATMS.pdf

SCATS Deployment in Toronto (2019-2023)

- ❑ Focus on major corridors: Queensway, Lake Shore Blvd, Kingston Rd
- ❑ These are mostly in western/central Toronto

TORONTO

Route	From	To	No. of Signals	Year
Lake Shore Blvd.	Windermere Ave.	Yonge St.	28	2023
Spadina Ave.	Front St.	Bremner Blvd / Fort York Blvd	2	2023
The Queensway	Kipling Ave.	Colborne Lodge Dr	19	2022
Kingston Rd.	Cliffside Dr/Claremore Rd.	Fenwood Hts	11	2022
Kingston Rd.	Bellamy Rd.	Beechgrove Dr.	17	2021
Morningside Ave.	Casebridge Crt.	Milner Ave.	2	2019
Sheppard Ave. E.	Neilson Rd.	Meadowvale Rd	10	2019
Total			89	

Benefits of Signal Optimization Program in City of Toronto (Primarily Fixed-Time Coordination, 2012-2016)

- Overall benefit/cost ratio: 53:1 (for every $1 invested, $53 saved to public)
- Total cumulative saving over 3-year lifecycle: $271.1 million
- Fuel consumption reduction equivalent to:
  - CO_2 emissions from 6,458 homes' electricity use for one year
  - Carbon sequestered by 41,395 acres of forest in one year
- **Annual Investment:** $850,000/year (2012-2015)

TORONTO

Benefits of SCATS in Toronto (Sheppard Avenue, 2018-2019)

- Travel time reduction: 2.6% (peak hours)
- Benefit-cost ratio: 3:1
- Improvements above already-optimized baseline

TORONTO https://www.toronto.ca/legdocs/mmis/2020/ie/bgrd/backgroundfile-157804.pdf