Leveraging SUMO for Real-World Traffic Optimization

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Paper Target

Addressing real-world traffic challenges utilizing SUMO simulations

Importance of testing and validating traffic management solutions before deploying in the field.

Agenda

- **Terminology**
  - NoTraffic Technology
  - ATSPM
- **Realistic Micro-Simulation in SUMO**
  - SUMO Network
  - Simulation Scenario
  - Traffic Light Controllers
  - Calibration
- **Real-world application of SUMO**

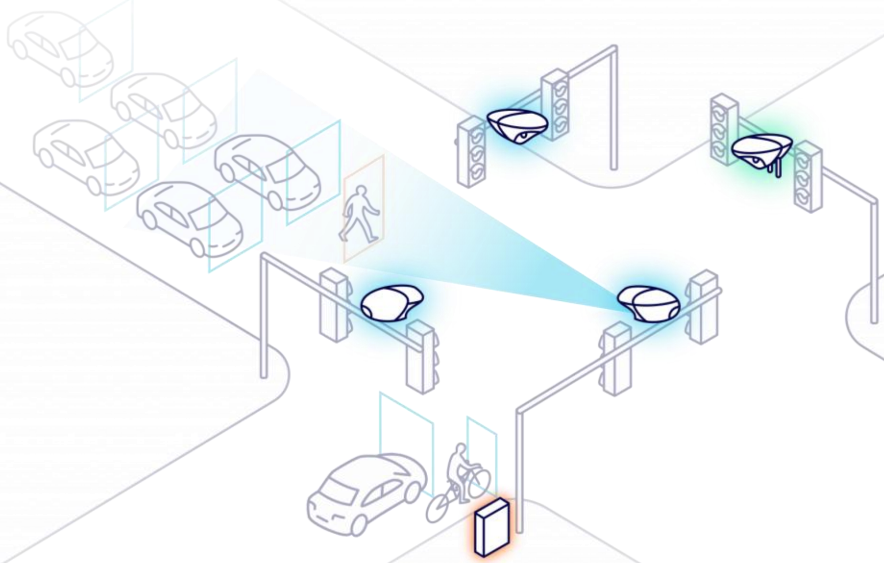
NoTraffic Overview

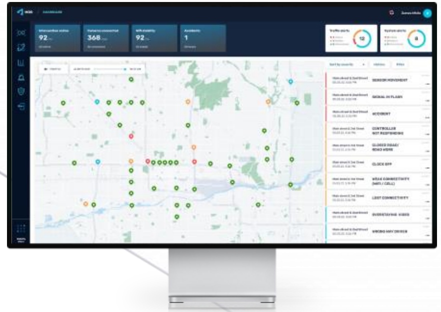
NoTraffic Smart & Connected Intersection

4x Sensor Units

3x Standard

1x V2X Ready





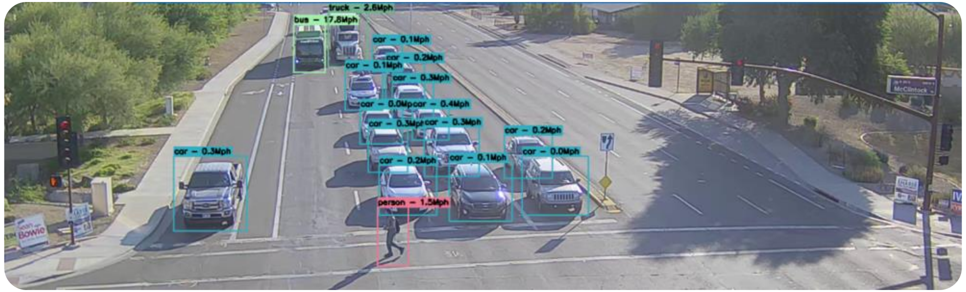
Cloud-Based Platform

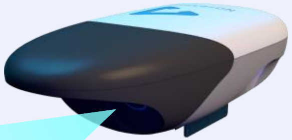
Nexus Unit

connected to the
traffic signal controller

Detection & Tracking

Powered by AI algorithms - Detecting Vehicles & Vulnerable Road Users

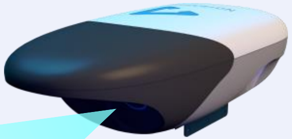




Sensor Units

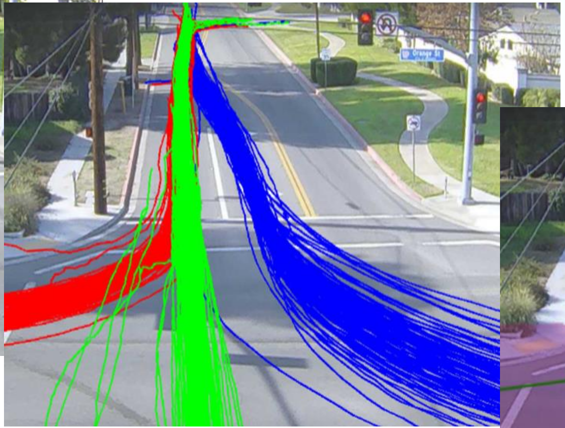
- Data sampled at f > 1 Hz
- Classification: car, bus, truck, pedestrian, bicycle and more
- Position: lane, distance from stop bar, direction, speed
- Yielding a robust and extensive dataset
- This dataset is used for real-time optimization and data analytics

Sensor Provides Trajectories Per Approach

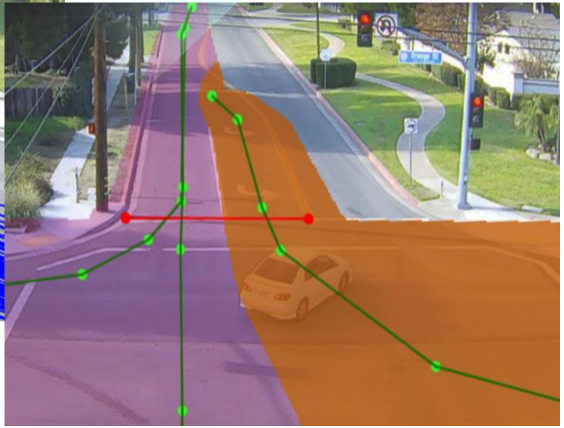


Sensor Units

Camera View



Trajectories from video

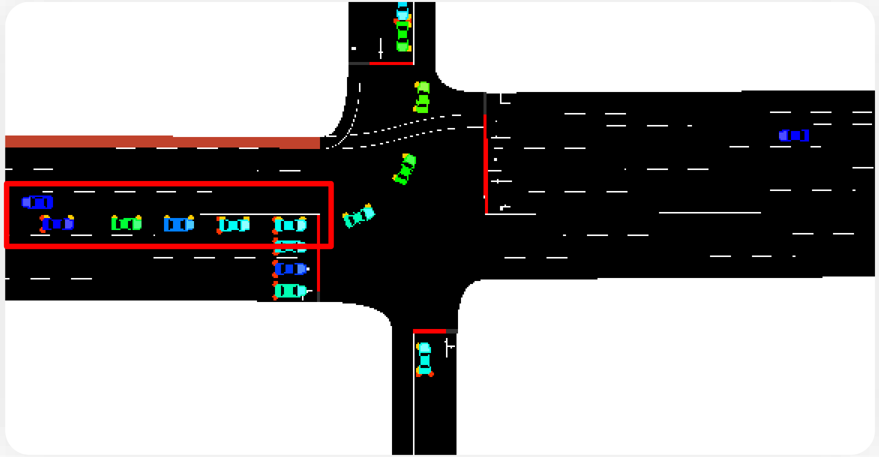


Lanes & connections

Automated Traffic Signal Performance Measures

- Traffic counts
- Average delay per vehicle
- Arrival on Green - AoG
- Split Failure

ATSPM



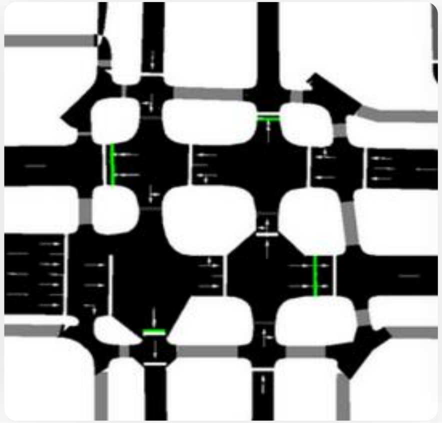
Realistic Micro-Simulation in SUMO

Key steps

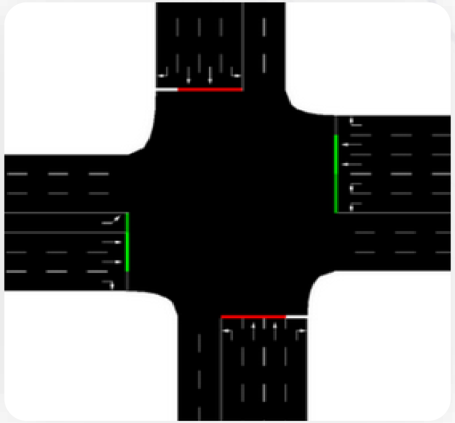
- SUMO Network
- Simulation Scenario
- Traffic Light Controllers
- Calibration

Network Layout Challenges

Real World



OSM



NoTraffic

SUMO Network Generation

Standard single intersection

Sensor view:

- Lanes
- Trajectories
- Intersections locations

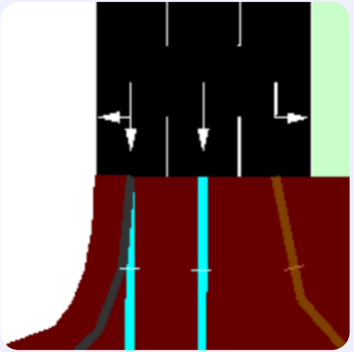
SUMO Network generation based on:

- Nodes, edges, connections

```
netconvert
--node-files=model.nod.xml
--edge-files=model.edg.xml
--connection-files=model.con.xml
 --output-file=model.net.xml
```

SUMO view:

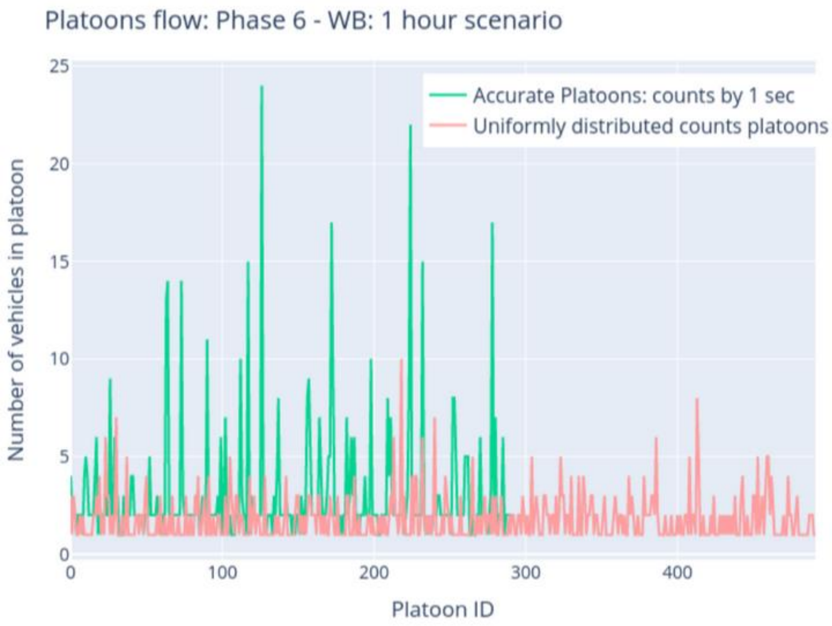
- Lanes
- Connections
- Nodes



Real-World Scenario

Counts distribution

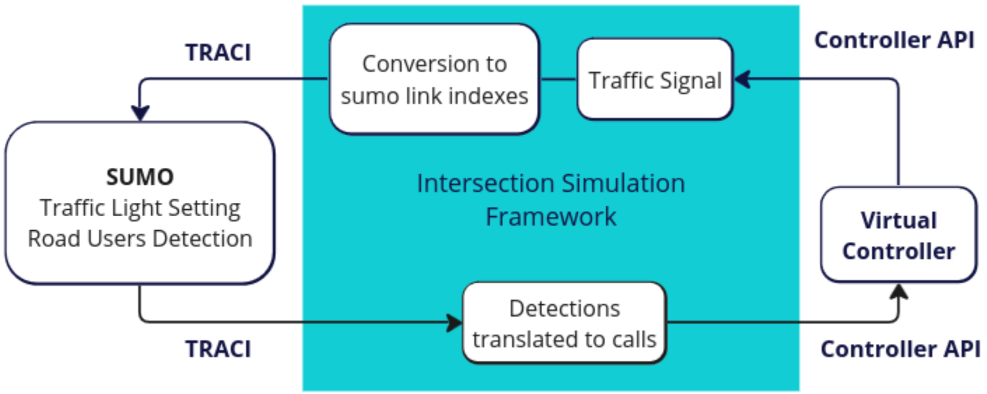
- **Counts by 1 min distributed uniformly:**
  - ~40-50% calibration success rate
- **Counts by 1 fps:**
  - ~70-80% calibration success rate



Software-in-the-loop (SIL)

Main components

- **SUMO:**
  - detected & crossed road users
- **Virtual Controller:**
  - Integrated controller configuration



Calibration Key Steps

- **Metrics for calibration:**
  - Average delay
  - Arrivals on Green
  - Counts
- **Car-Following model selection (**Weidemann 99 model**)**
- **Input parameters for calibration**
- **Calibration method**

Calibration – Input parameters

- **Standard parameters:**
  - Speed
  - Acceleration
  - Tau
- **Additional parameters:**
  - stratupDelay
  - jmDriveAfterYellowTime
  - CC2

Parameter	Default Value	Lower Bound	Upper Bound	Description
CC1 (tau)	1.2 s	0.5 s	2.5 s	Desired headway time between lead/prioritized and following vehicles.
CC2	8 m	1 m	10 m	Following variation distance.
CC8 (accel)	2.0 m/s^2	0.5 m/s^2	5.0 m/s^2	Standfill acceleration.
minGap	2.5 m	0.5 m	5 m	Empty space after leader.
desiredMaxSpeed	Varies by road user	1.39 m/s	50 m/s	Road user speed by type.
startupDelay	0 s	0 s	3 s	Delay time before starting to drive after having had to stop.
jmDriveAfterYellowTime	-1 s	-1 s	5s	Violation yellow light if the light had changed more recently than the given threshold.

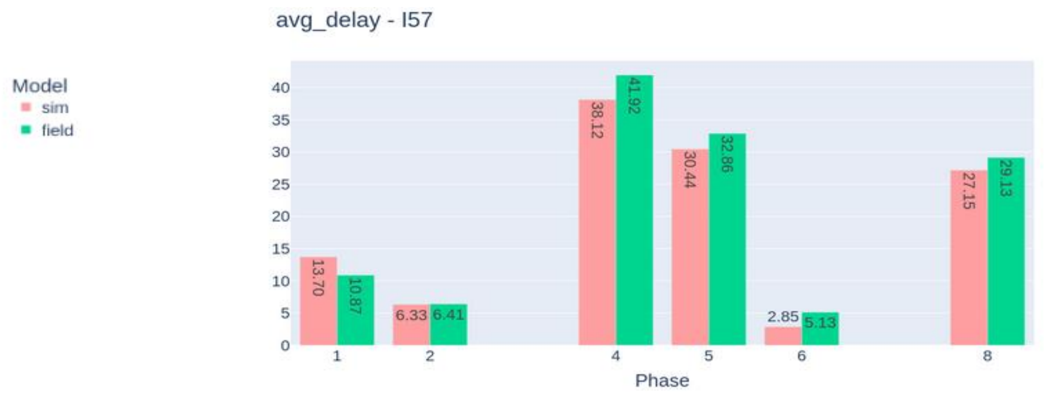
Calibration – Method

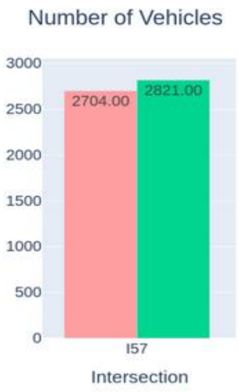
- Simple grid search on input parameters permutations.
- Error between simulation vs. field ATSPMs is calculated by following steps:

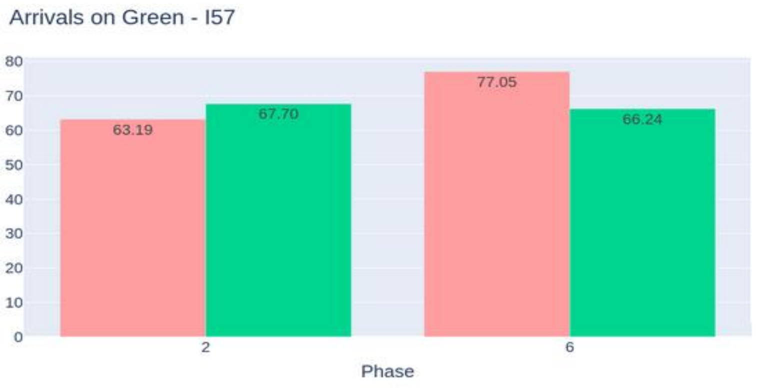
Step	Formula	Description
Values scaling	$$E_p = \frac{e_p}{M-m}, O_p = \frac{o_p}{M-m}$$	o_p = unscaled observed metric in simulation averaged over the entire scenario period per phase e_p = unscaled expected metric in field averaged over the entire scenario period per phase M = Maximum metric value per phase m = minimum metric value per phase
Metric error calculation per phase	$$\chi^2 = \sum_{p=1}^{n} \frac{(O_p - E_p)^2}{E_p}$$	O_p = scaled observed metric in simulation averaged over the entire scenario period per phase E_p = scaled expected metric in field averaged over the entire scenario period per phase
Total Error	$$error = \frac{1}{3} \cdot \sqrt{\chi^2_{total.count}} + \frac{1}{3} \cdot \sqrt{\sum_{p=1}^{n} \chi^2_{avg.delay(p)}} + \frac{1}{3} \cdot \sqrt{\sum_{p=1}^{n} \chi^2_{AoG(p)}}$$	

- **Input parameters that yield the minimum error and meet the specified thresholds are selected.**

Calibration – Results







Parameter	Value
CC1	1.2 s
CC2	4 m
CC8	2.5 m/s²
minGap	1.4 m
desiredMaxSpeed	17.89 m/s
startupDelay	0 s
jmDriveAfterYellowTime	1 s

Case Study

Steps to solve field issues

Reproduce the issue in simulation 🎯

Solve the issue in simulation ✌️

Verify the solution is stable 🤝

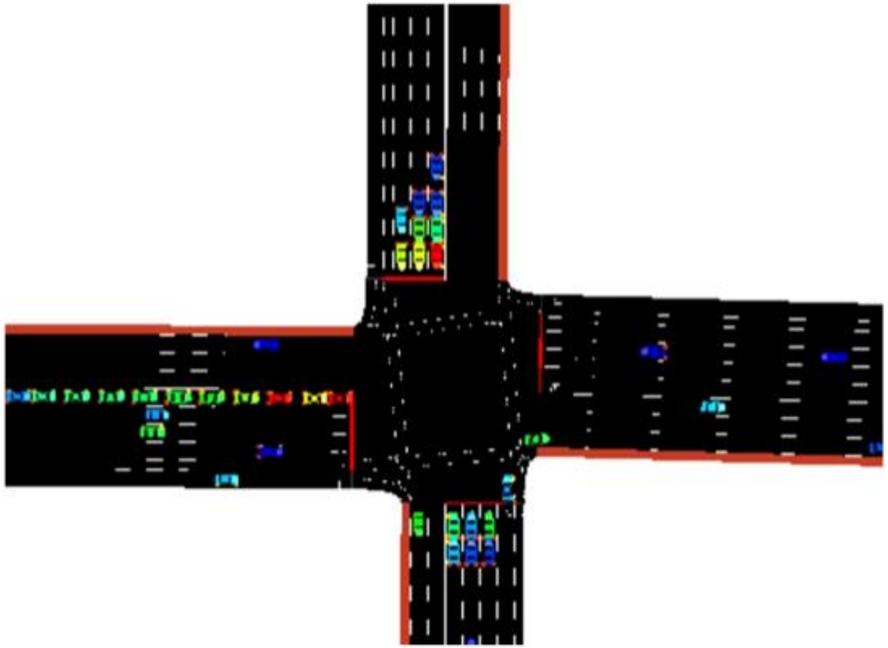
Deploy in the field with confidence 💪

Monitor 📈

Case Study: Arizona, USA - May 2023

Reproduce the issue

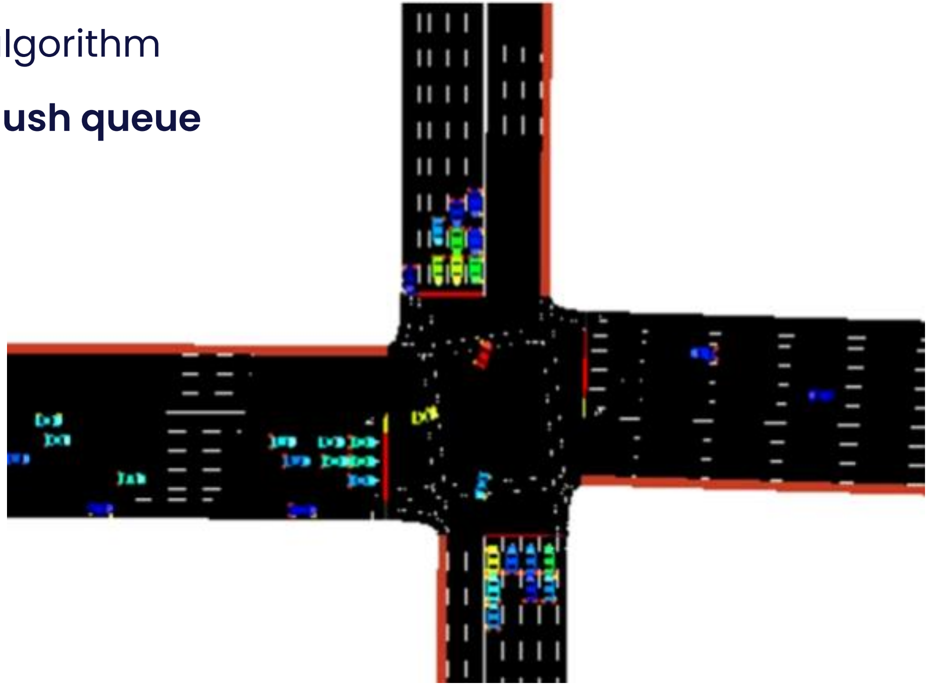
- Using the calibrated model and the scenario from the time of the incident



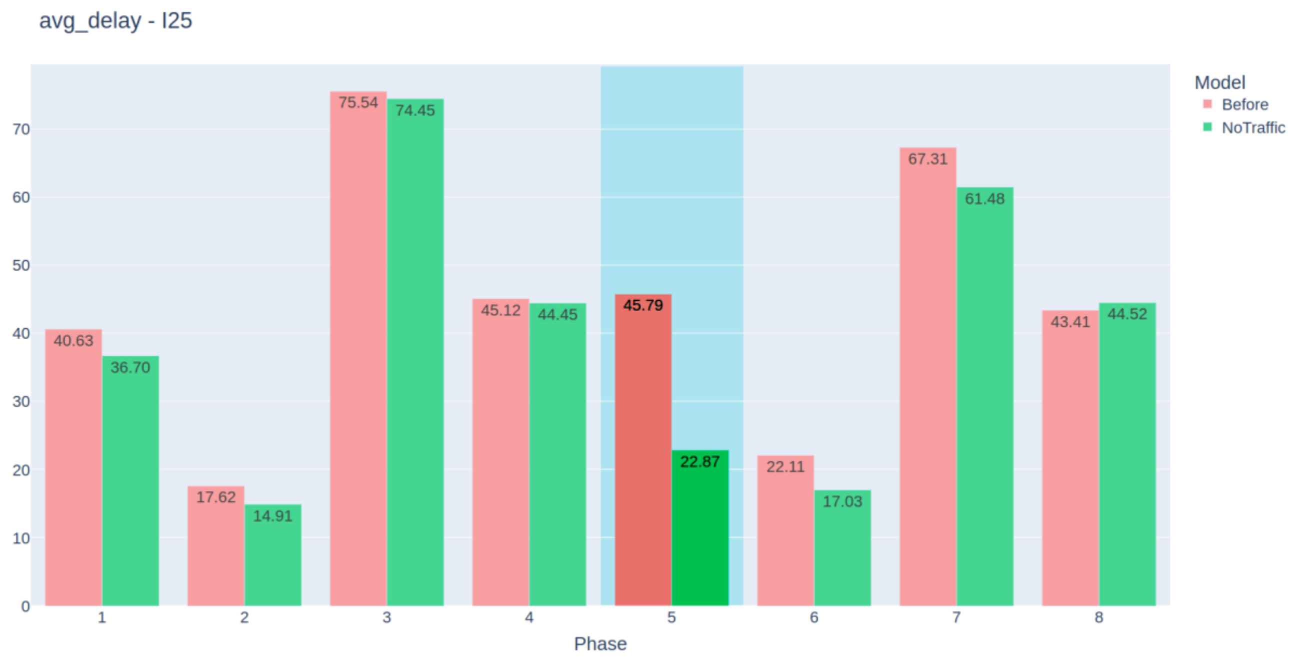
Solve the issue in simulation

Several strategies were tested in our optimization algorithm

The one we used is called **flush queue**



Verify the Solution is Stable



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Deploy & Monitor

Conclusion

- Quality In, Quality Out (QIQO)
- SUMO plays a vital role in our system and is integral to our business operations.
- Examples Await—Let's Watch!

Customer Case Studies

Thank You!

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