

RWR 4013

# Digital Twins for Smart Cities

Dr. Ahmad Mohammadi

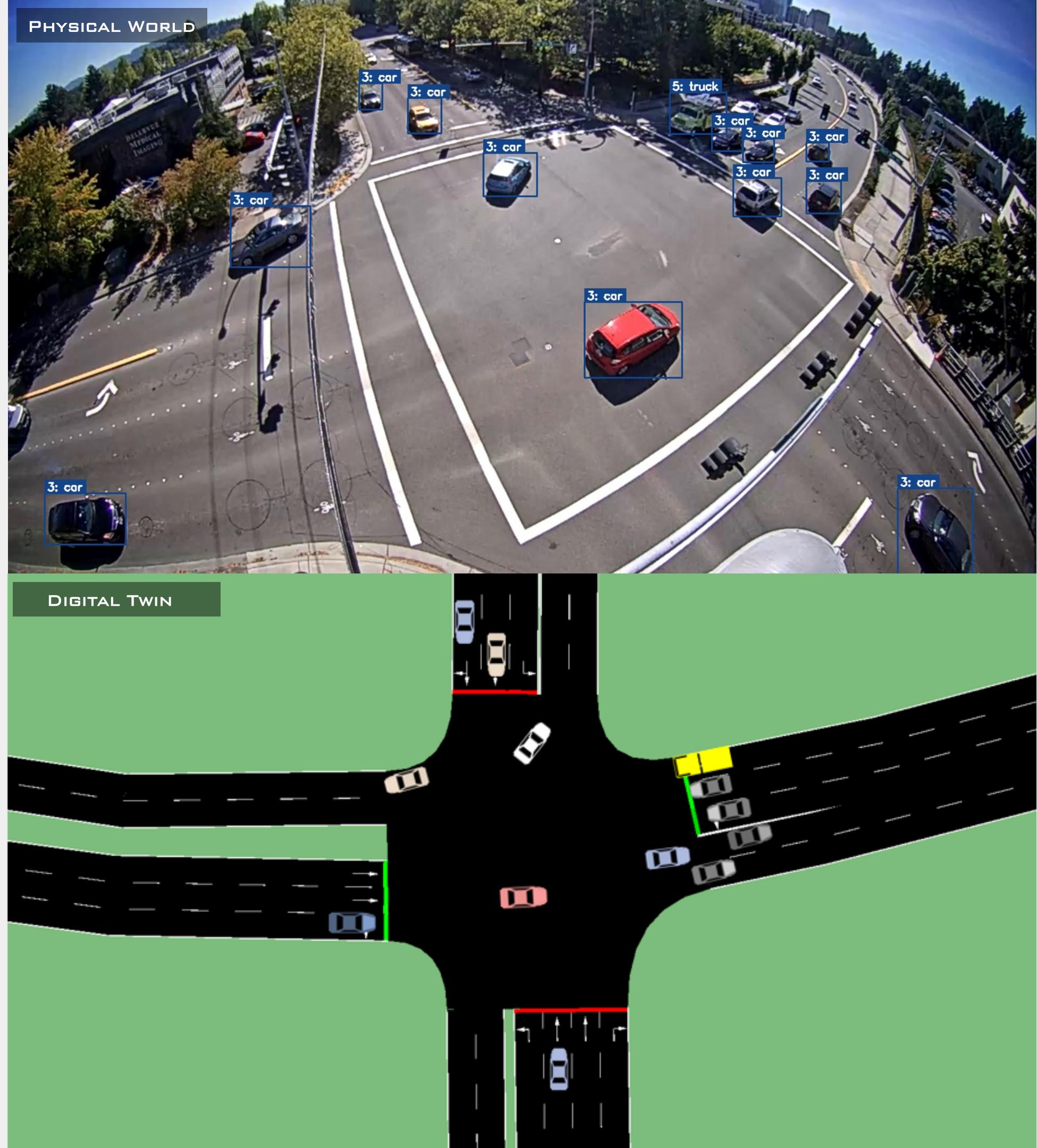
Week 4 | Session 1:  
Introduction to Traffic Simulation

Fall 2026

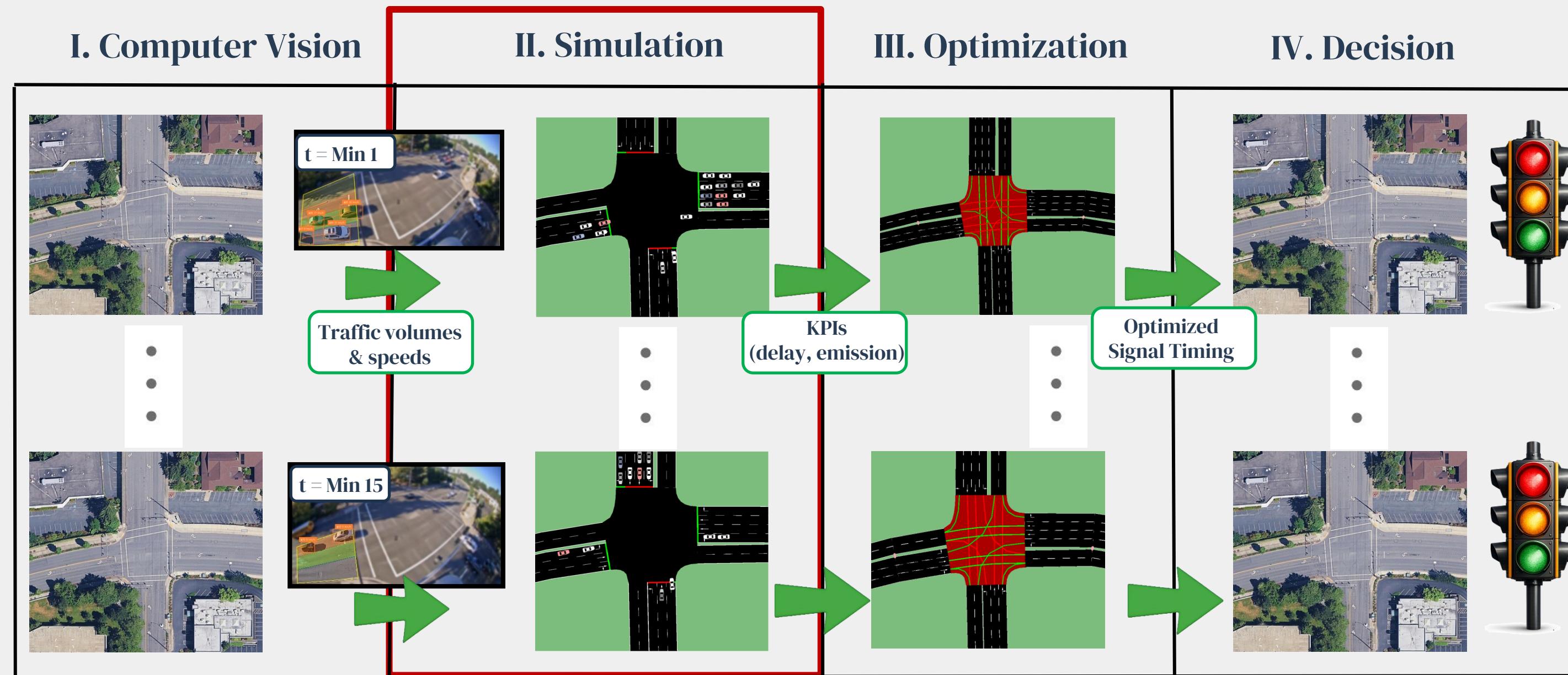
RoadwayVR



[roadwayvr.github.io/DigitalTwinsforSmartCities](https://roadwayvr.github.io/DigitalTwinsforSmartCities)

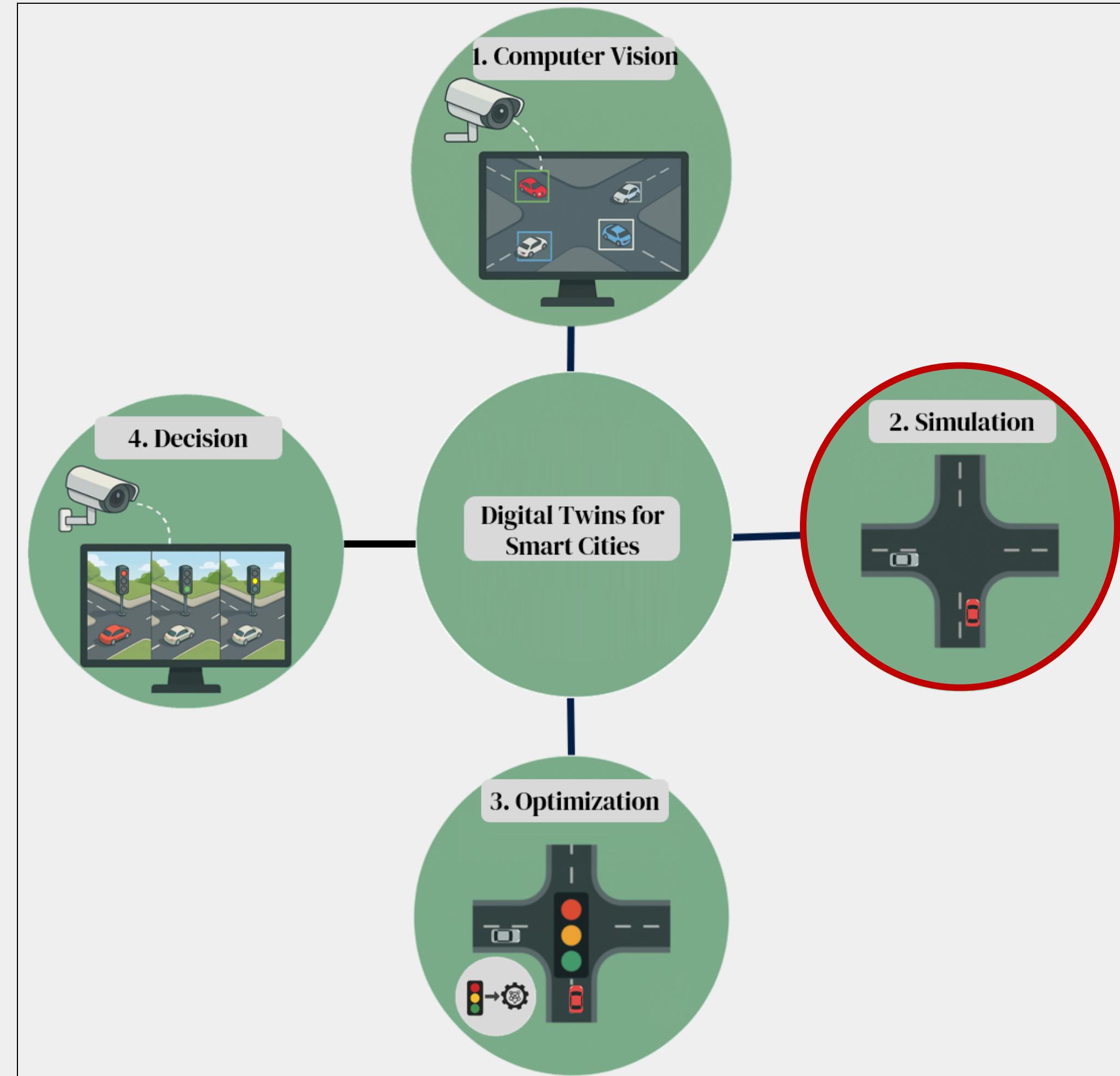


# Overview of Course Syllabus in One Shot



# Agenda

- ❑ What is Traffic Simulation?
- ❑ Purpose of Traffic Simulation
- ❑ Examples of Traffic Simulation Studies
- ❑ Simulation of Urban Mobility (SUMO)
- ❑ Road Network Development
- ❑ Vehicles Characteristics
- ❑ Vehicle Dynamics
- ❑ Car Following and Lane Changing Models



# Traffic in Different Cities

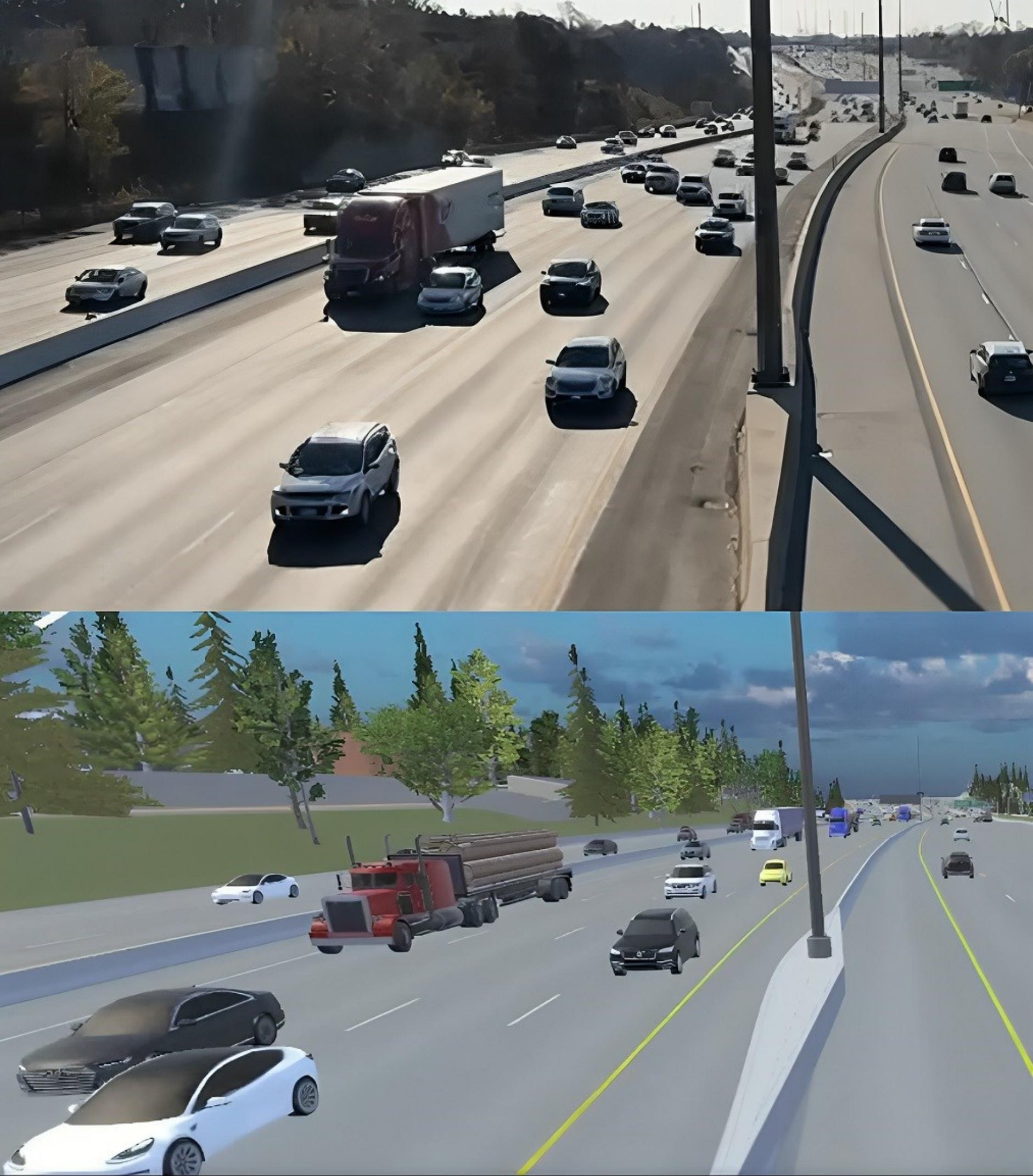
2024 Impact Rank (2023 Rank)	Urban Area	Country	2024 Delay per Driver (hours)	2023 Delay per Driver (hours)	Change from 2023	Downtown Speed (mph)
1 (6)	Istanbul	TUR	105	91	15%	15
2 (1)	New York City NY	USA	102	101	1%	13
3 (5)	Chicago IL	USA	102	96	6%	14
4 (2)	Mexico City	MEX	97	96	1%	13
5 (3)	London	GBR	101	99	2%	13
6 (4)	Paris	FRA	97	97	0%	13
7 (10)	Jakarta	IDN	89	65	37%	13
8 (7)	Los Angeles CA	USA	88	89	-1%	22
9 (9)	Cape Town	ZAF	94	83	13%	14
10 (12)	Brisbane	AUS	84	74	14%	21
11 (14)	Bangkok	THA	74	63	17%	16
12 (8)	Boston MA	USA	79	88	-10%	13
13 (13)	Philadelphia PA	USA	77	69	12%	14
14 (11)	Miami FL	USA	74	70	6%	20
15 (16)	Dublin	IRL	81	72	13%	15
16 (15)	Rome	ITA	71	69	3%	15
17 (19)	Houston TX	USA	66	62	6%	17
18 (20)	Brussels	BEL	74	68	9%	12
19 (21)	Atlanta GA	USA	65	61	7%	18
20 (28)	Warsaw	POL	70	61	15%	17
21 (22)	Melbourne	AUS	65	62	5%	18
22 (18)	Washington DC	USA	62	63	-2%	12
23 (27)	Seattle WA	USA	63	58	9%	18
24 (25)	Milan	ITA	64	60	7%	18
25 (17)	Toronto ON	CAN	61	63	-3%	13

# What is Traffic Simulation?

- A computer-based model that imitates how traffic moves and interacts on a road network over time, allowing “what-if” testing of changes (signals, lanes, demand) without affecting real traffic.

Watch the Video

<https://youtu.be/CQV4e2ZA8h0>



# Why Traffic Simulation?



# WHY TRAFFIC SIMULATION?

01

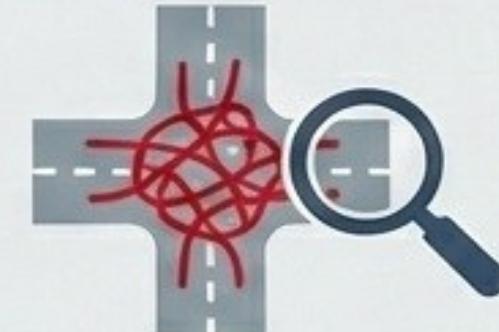
## UNDERSTAND SYSTEM PERFORMANCE



Analyze current & future network performance, including potential improvements.

02

## MODEL COMPLEX CONGESTION



Analyze complex systems under congested conditions where analytical methods fail.

03

## CAPTURE DETAILED INTERACTIONS



Evaluate interactions like queue spillback, weaving, and merging behaviors.

04

## VISUALIZATION FOR COMMUNICATION



Use animated flows for public outreach and stakeholder presentations.

05

## CONSIDER ALL MODES



Assess impacts on general traffic, transit, and pedestrians for multimodal effects.

06

## SUPPORT PLANNING & INVESTMENT



Inform decisions on signals, freeway operations, ITS strategies, and more.

# Purpose of Traffic Simulation

**Traffic simulation helps us to:**

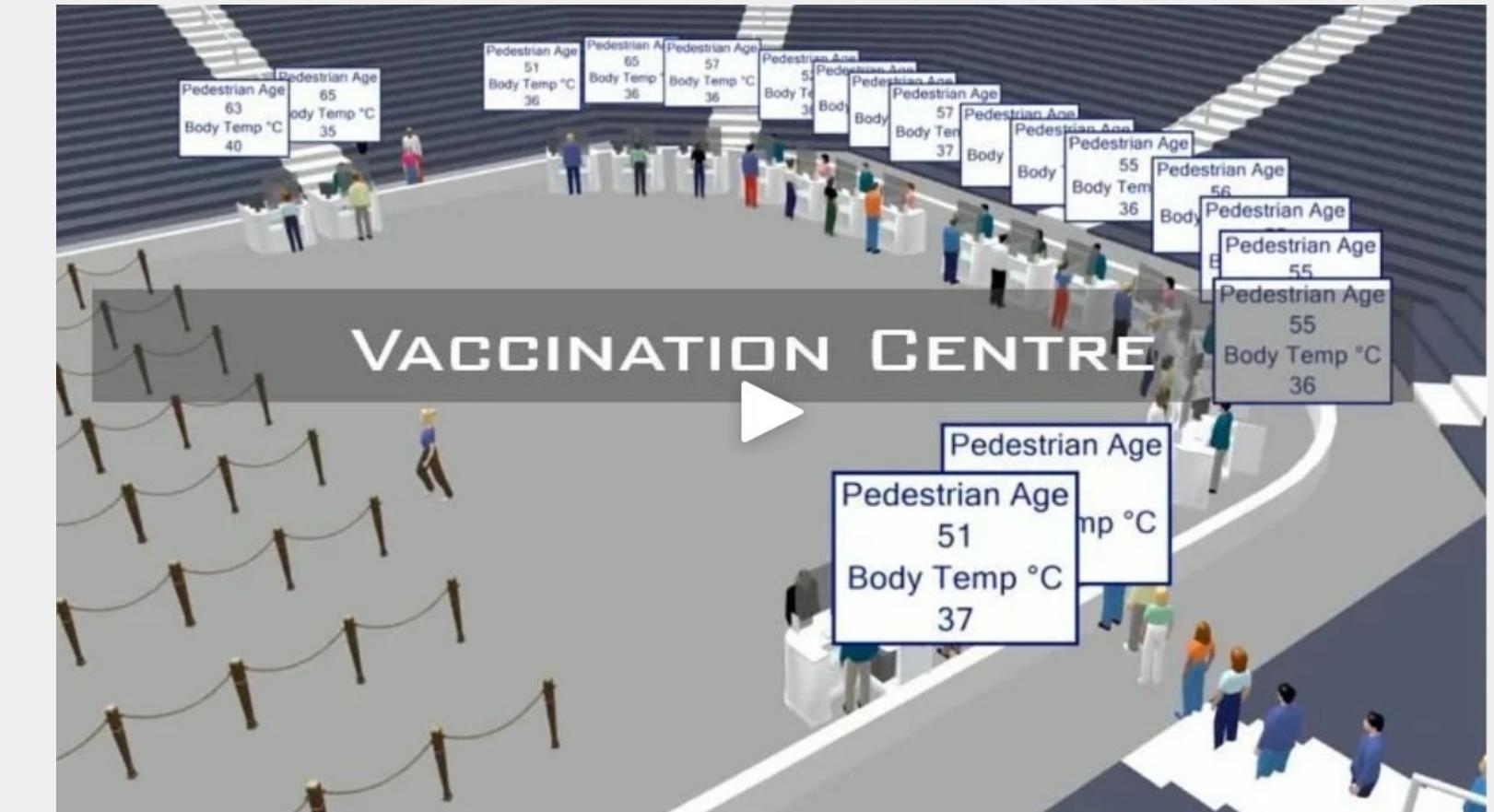
- 1. Design and compare alternatives (lanes, geometry, signal plans) before real-world changes**
- 2. Understand traffic dynamics (queues, spillback, bottlenecks, merging/weaving) over time**
- 3. Assess new strategies and technologies (ITS, transit priority, CAV concepts, work zones) safely**
- 4. Optimize operations (signal timing, coordination, ramp metering, lane management) to improve performance**

# Examples of Traffic Simulation Studies

# I. Design and Compare Alternatives?



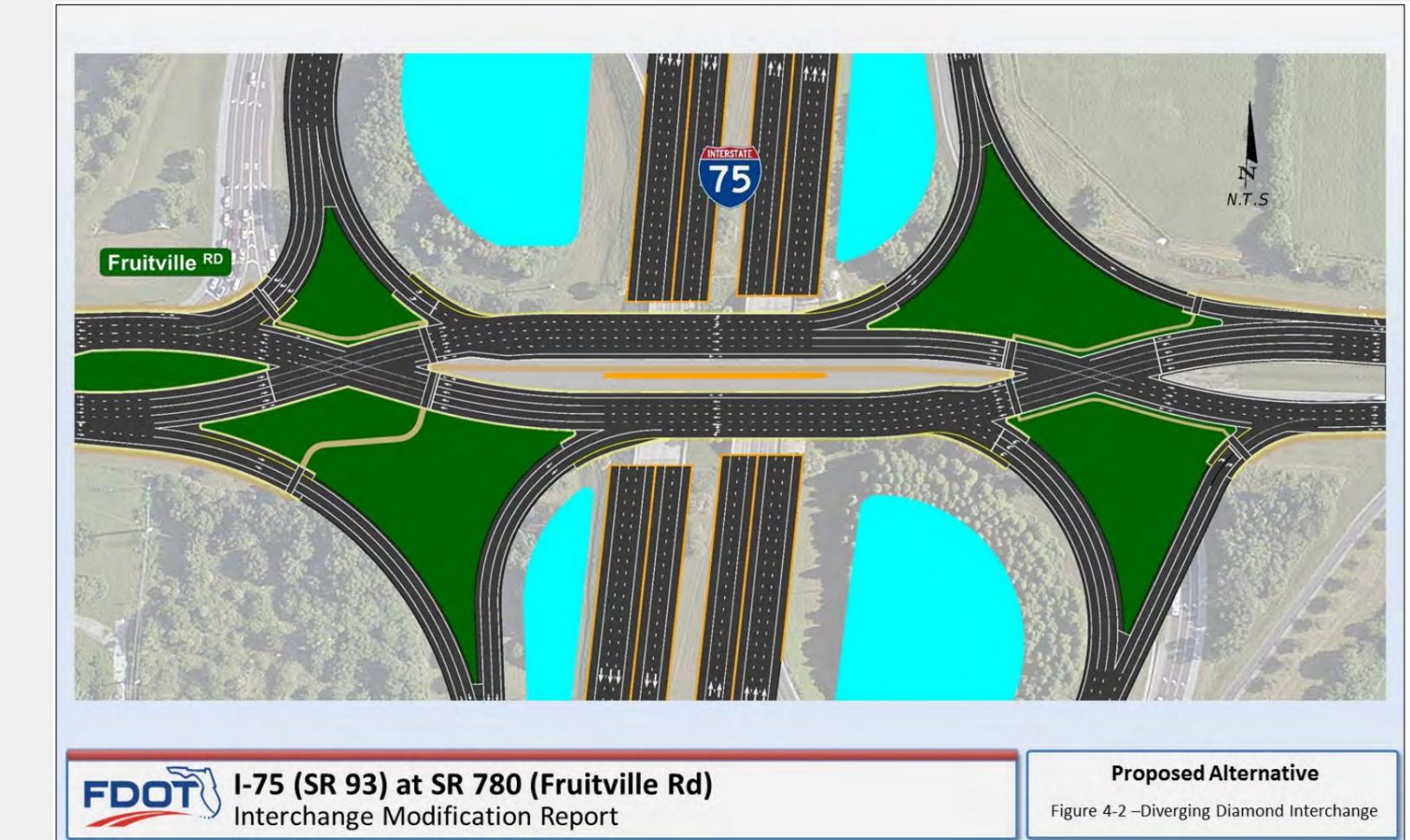
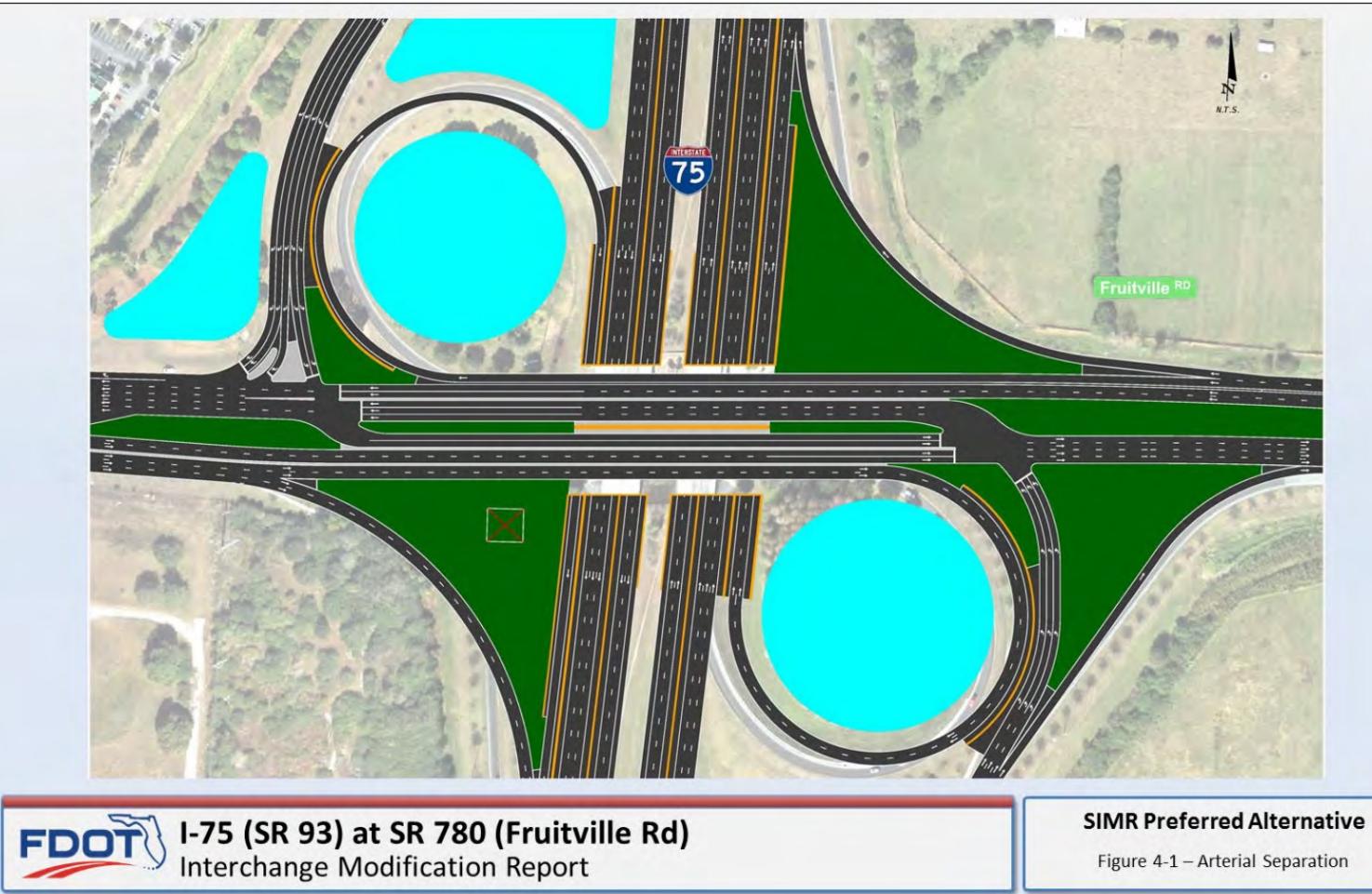
<https://www.youtube.com/watch?v=rEOmc2tJ9WY>



<https://www.youtube.com/watch?v=Z5ep9H5cPZE>

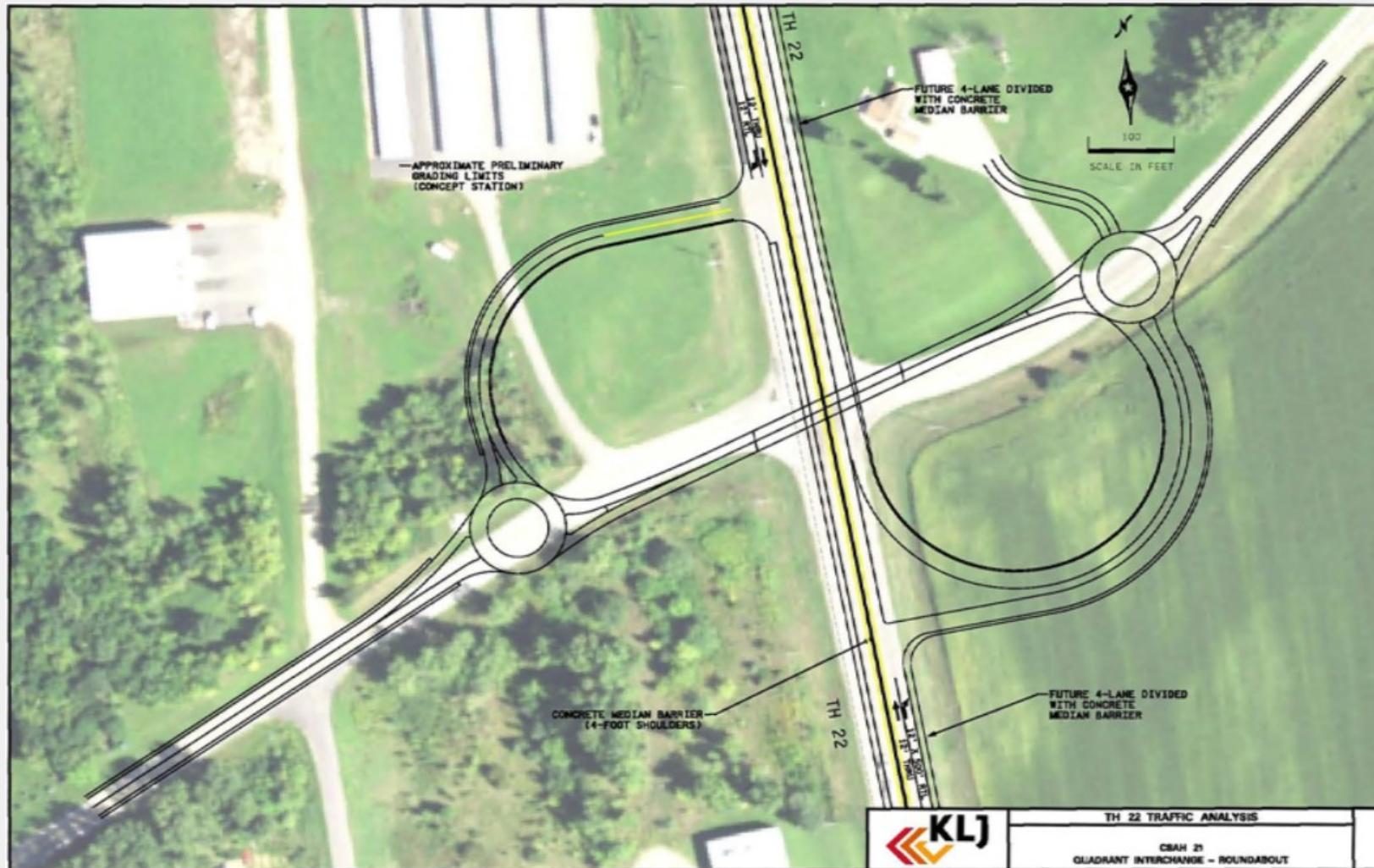
# I. Design and Compare Alternatives?

- Which design layout is the best for less congestion in now and 20 years later?

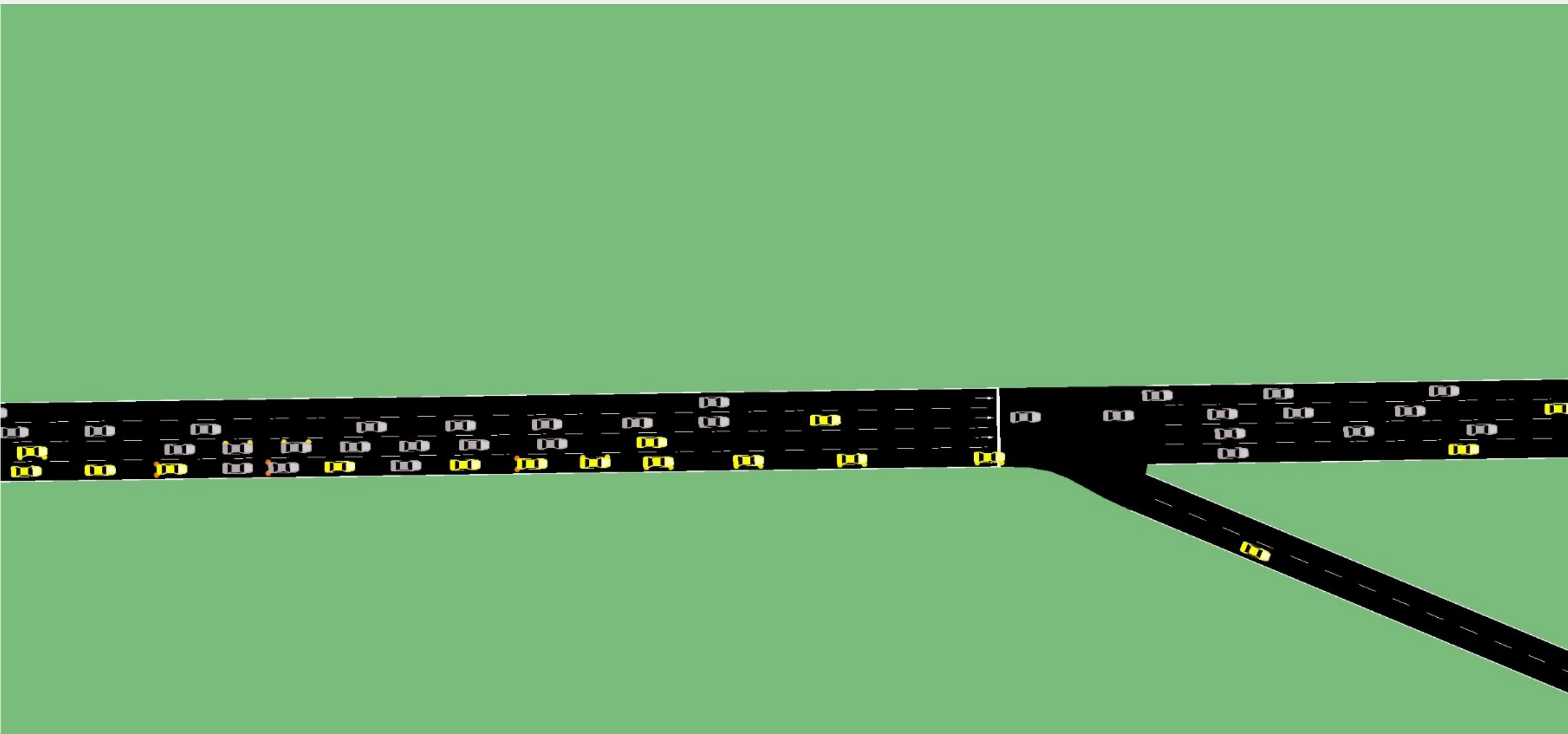


# I. Design and Compare Alternatives?

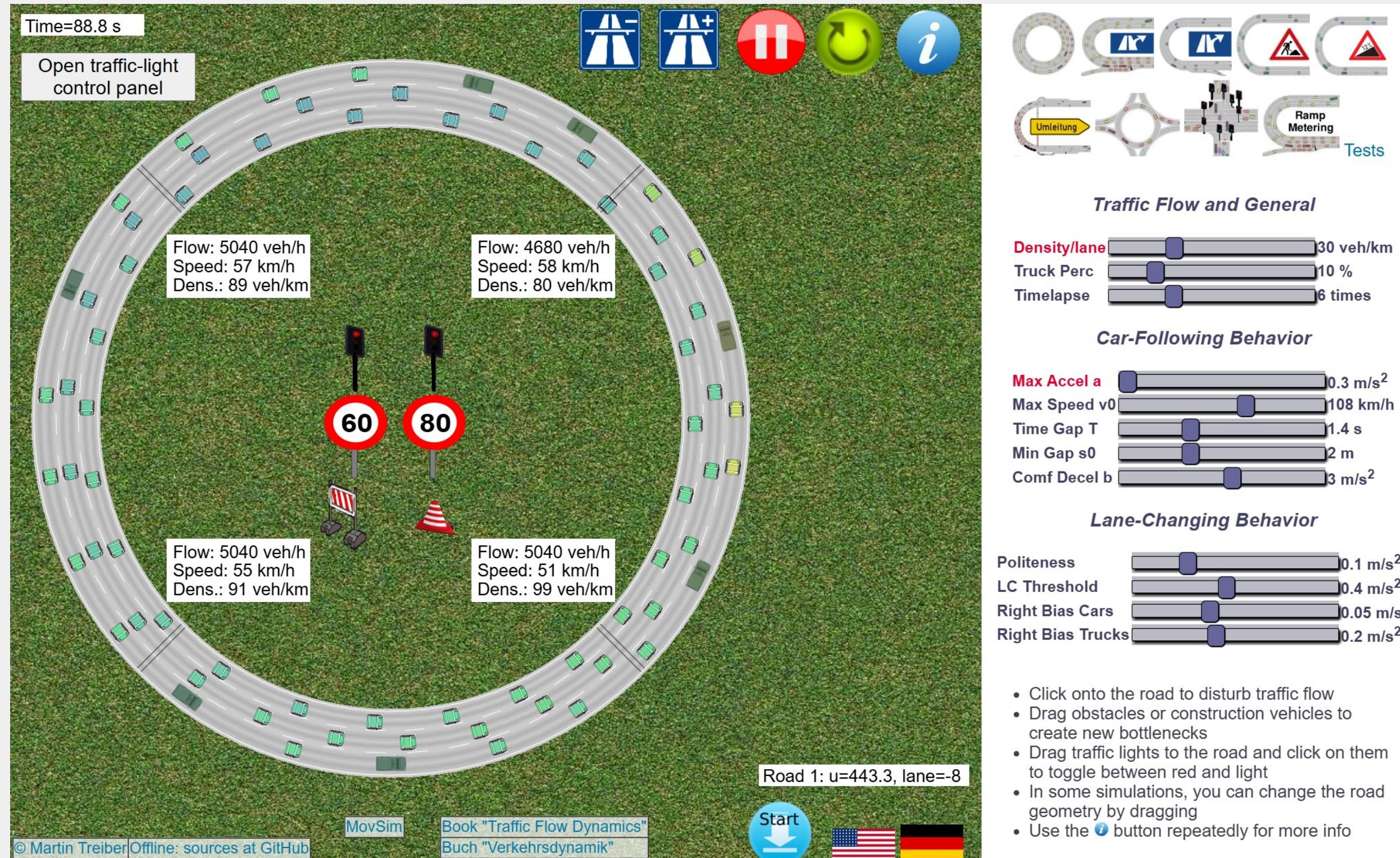
- Which design layout is the best for less congestion in now and 20 years later?



## II. Understand Traffic Dynamic?



# II. Understand Traffic Dynamic?



<https://traffic-simulation.de/ring.html>

# Cities Developed Traffic Simulation Guidelines



Reference link:

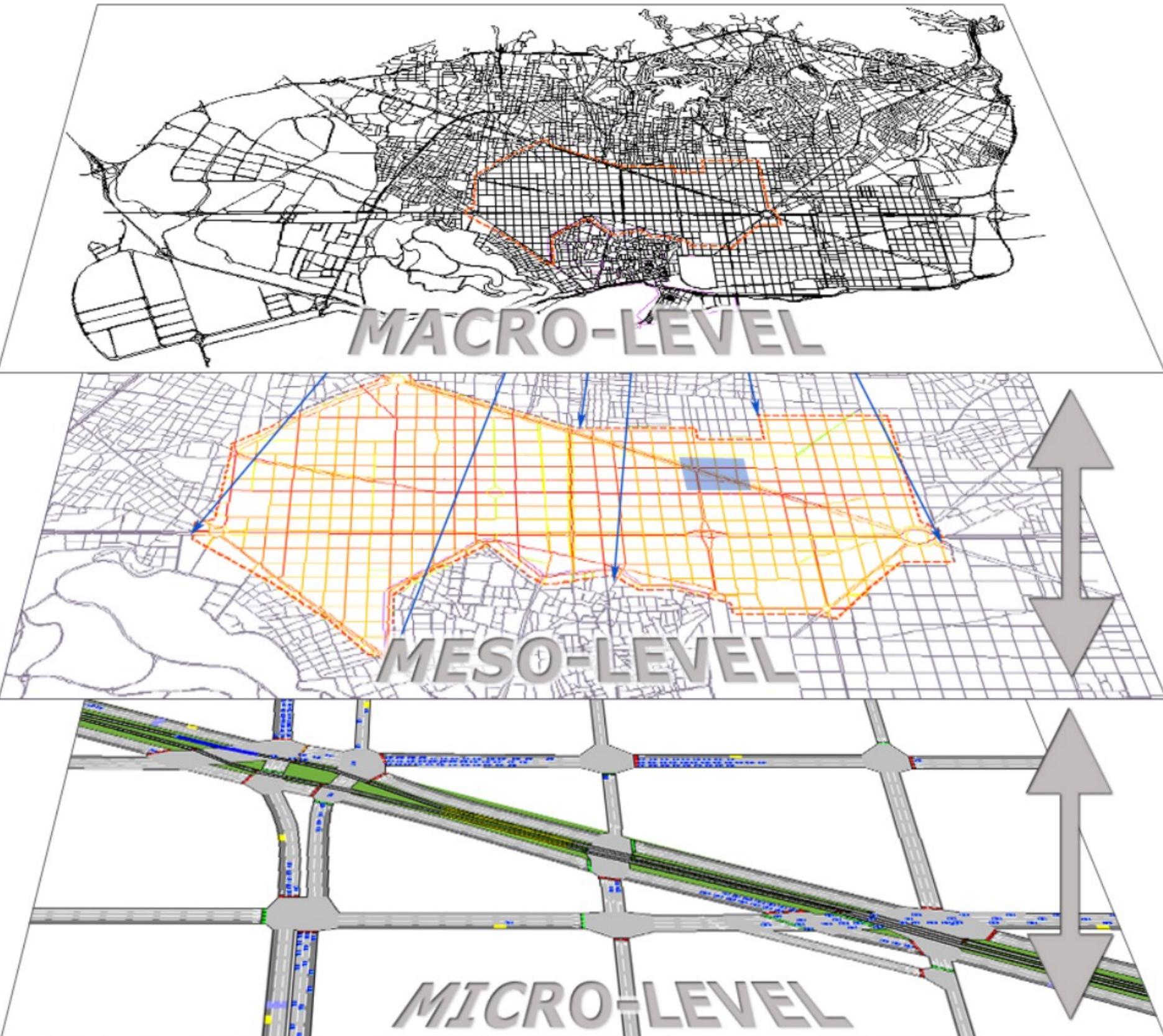
<https://ops.fhwa.dot.gov/publications/fhwahop18036/fhwahop18036.pdf>

# Traffic Modelling

**Macroscopic:** Traffic as aggregate flow

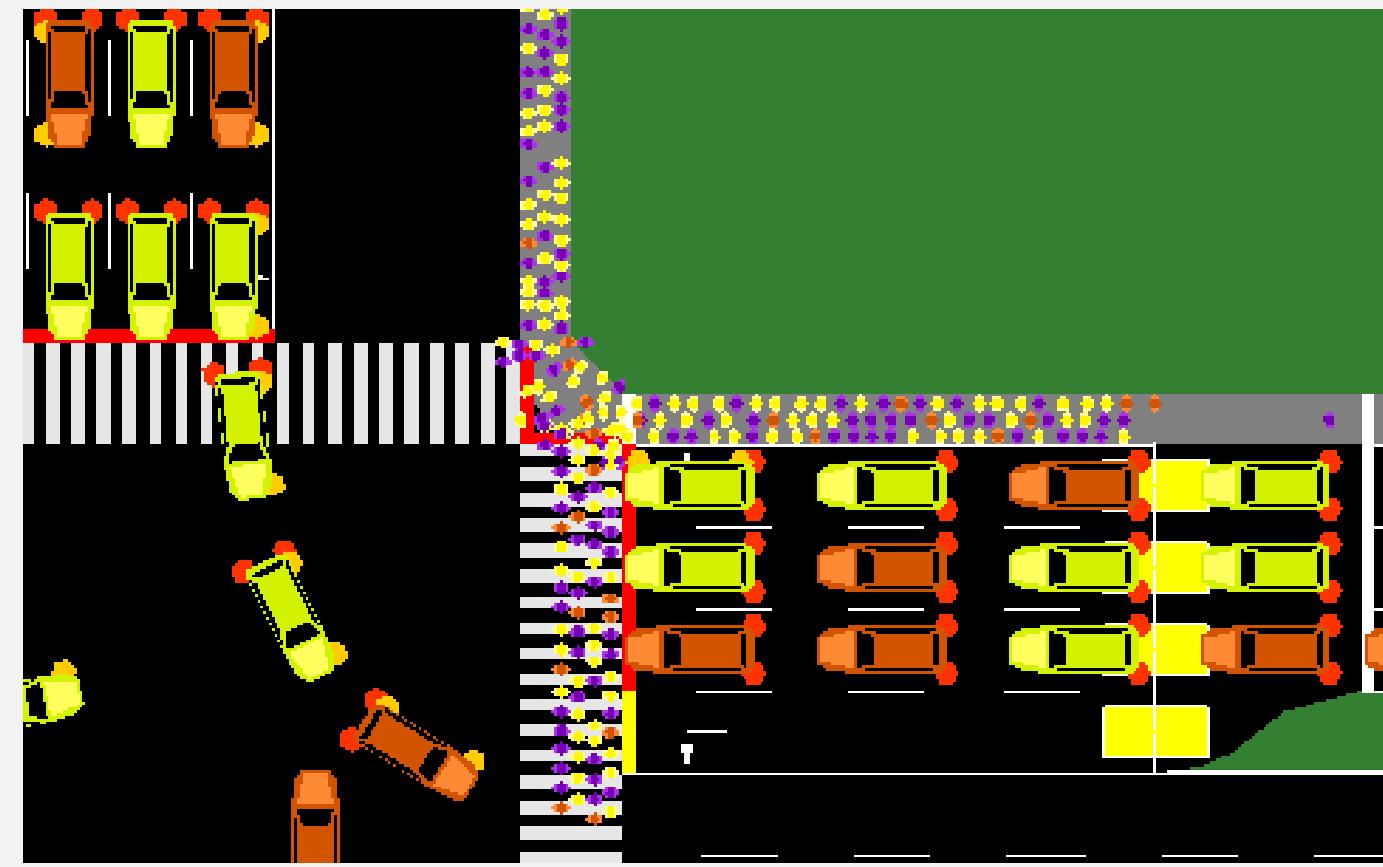
**Mesoscopic:** Groups/packets

**Microscopic:** Individual vehicles



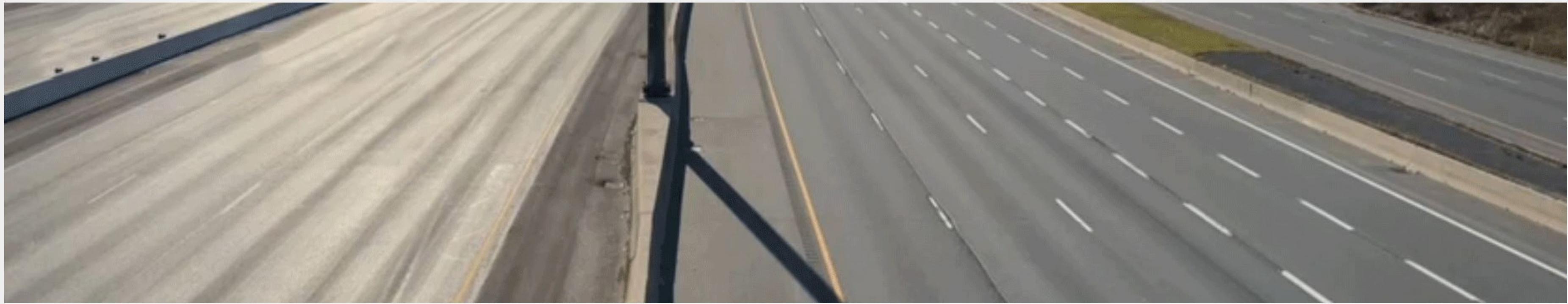
# Simulation of Urban Mobility (SUMO)

- SUMO: Traffic Simulation
- Open Source and Free to Everyone
- Designed Vehicle Characteristics, Car Following Model, Lane Changing Model
- Includes Passenger Cars, Trucks, Public Transport, Bicycle, and Train
- Include Traffic Signal Scheduling



# Road Network Development

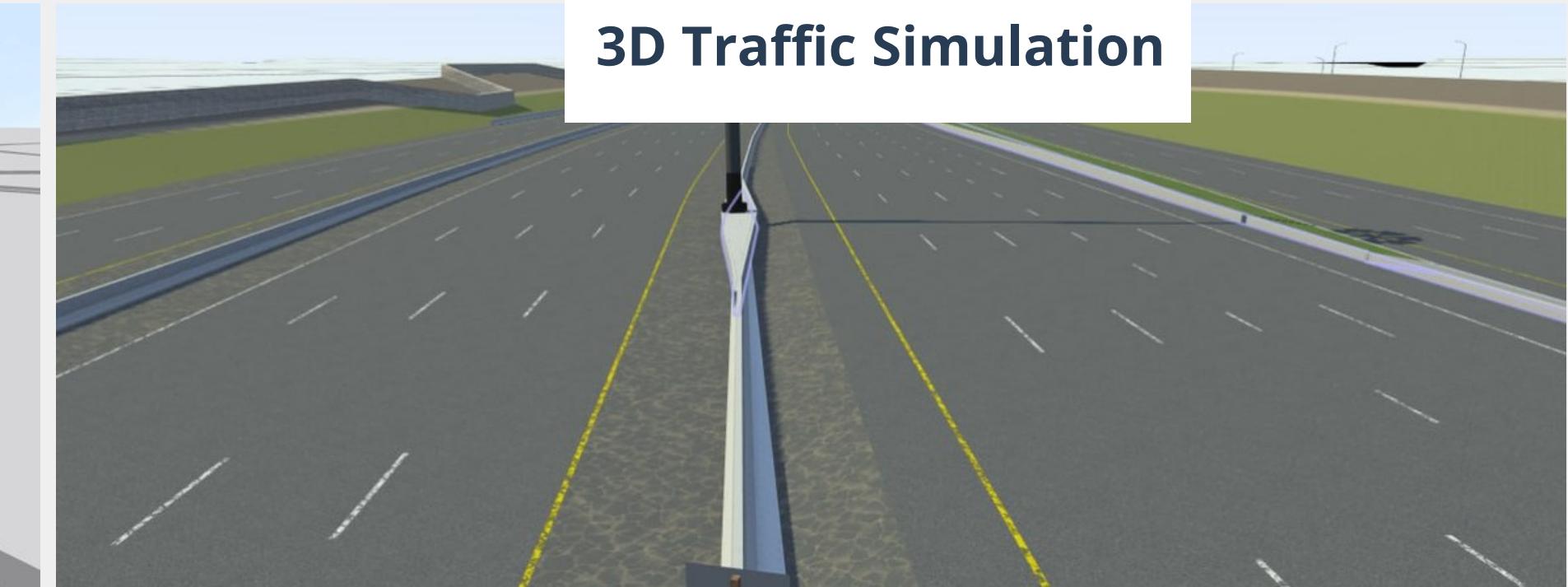
Real-World



2D Traffic Simulation

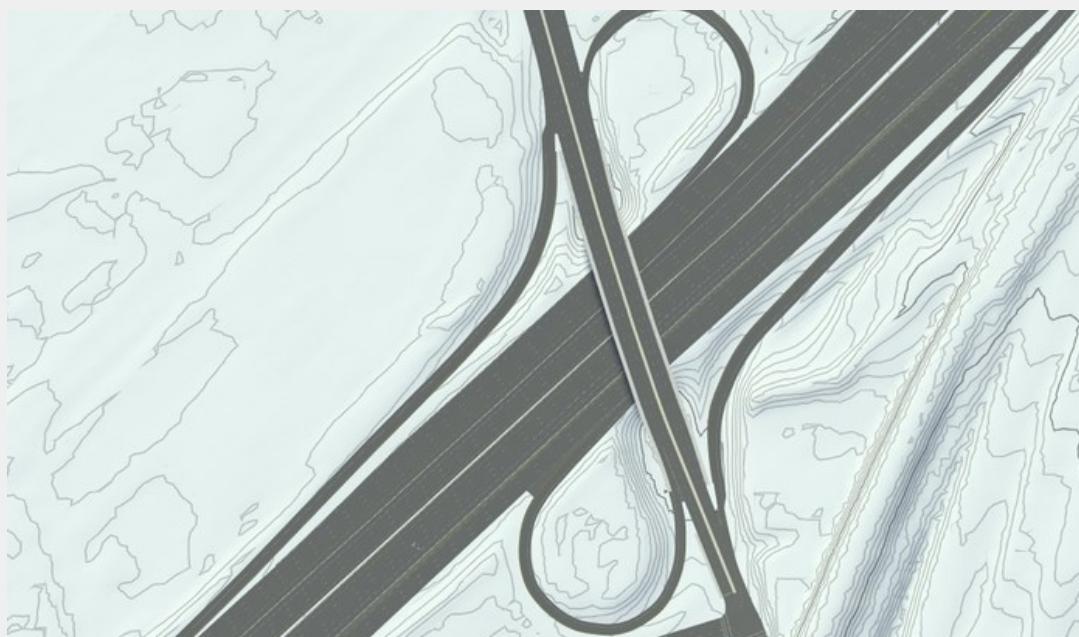


3D Traffic Simulation

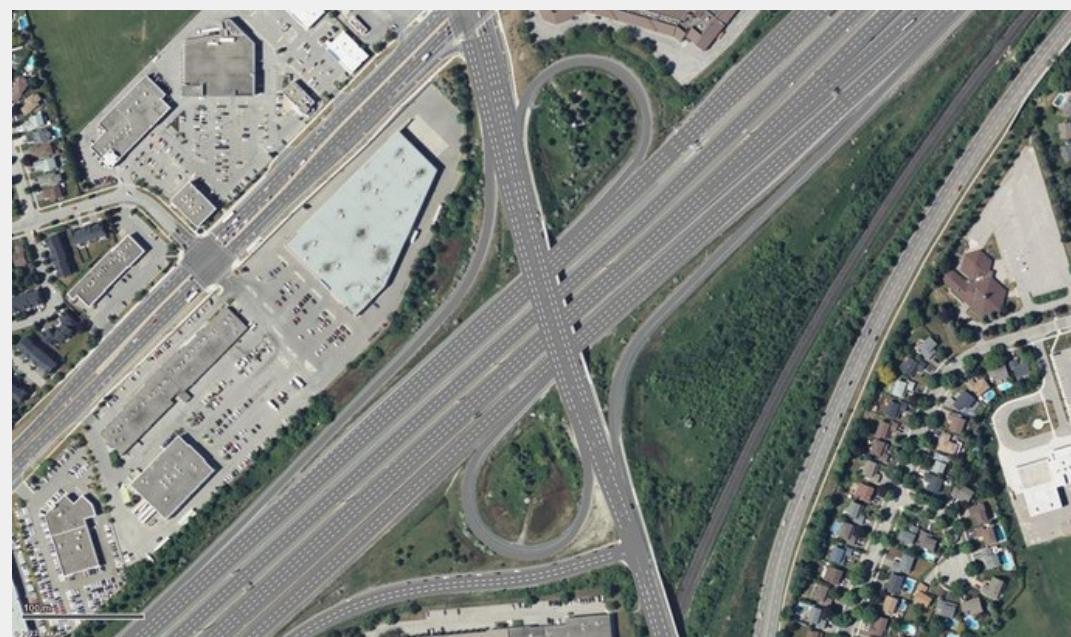


# Road Network Development

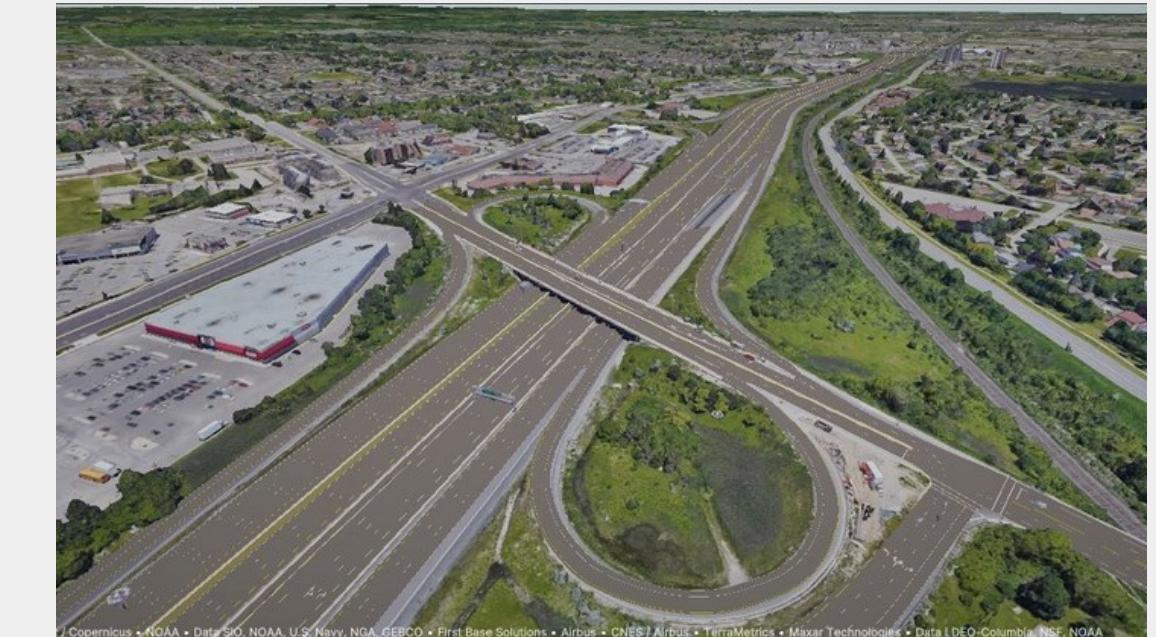
**Step 1:**  
**The Developed Network**



**Step 2:**  
**The Network in  
2D Traffic Simulation**

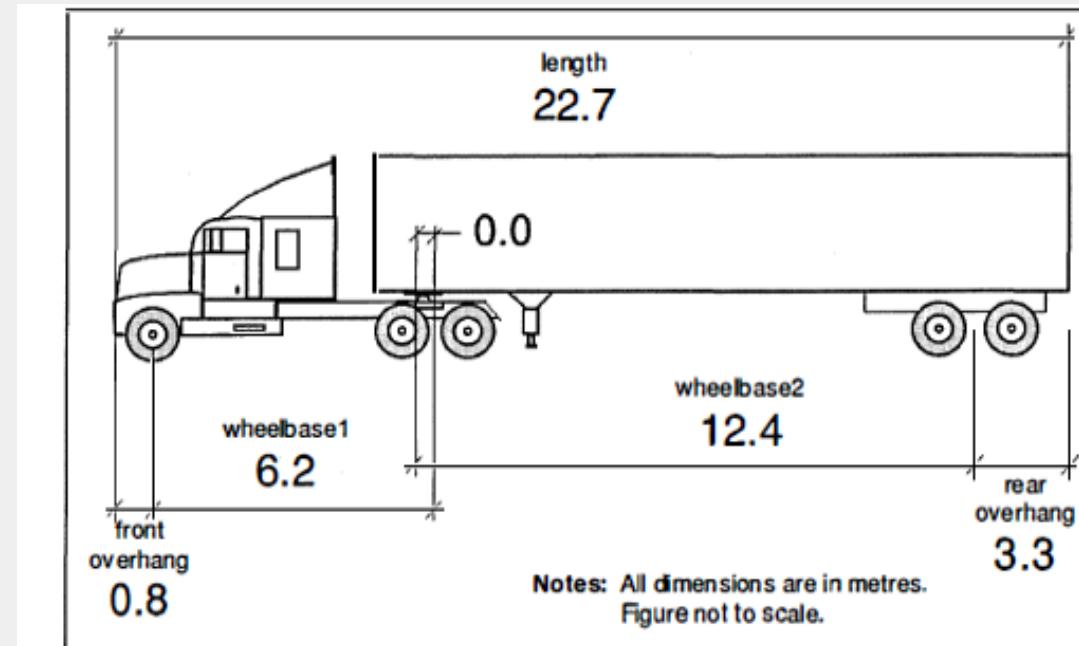


**Step 3:**  
**The Network in  
3D Traffic Simulation**

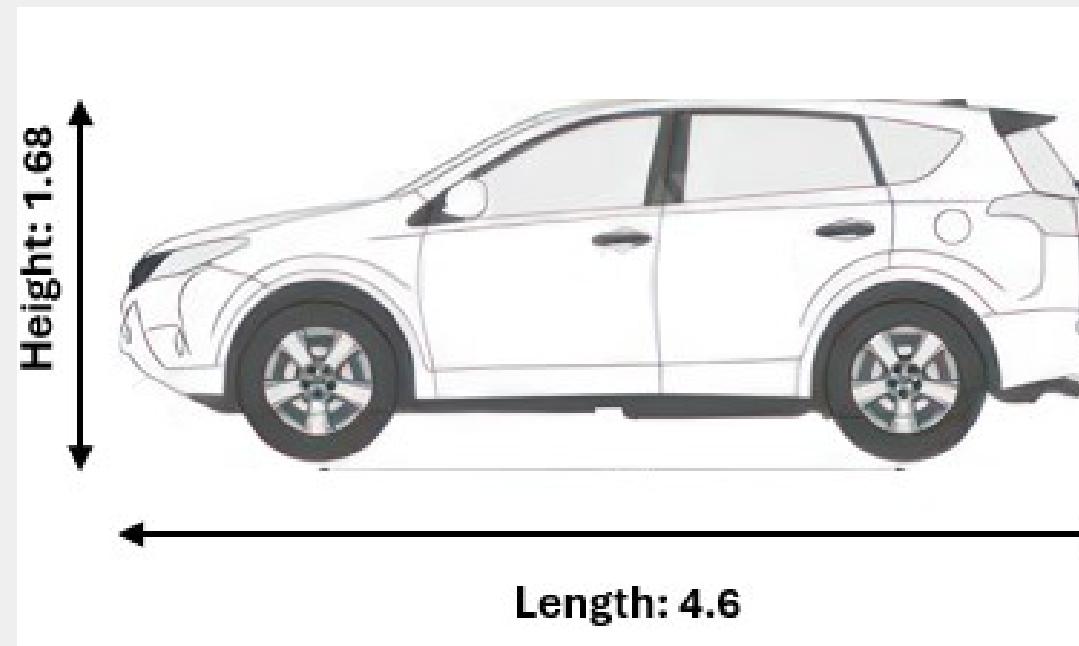
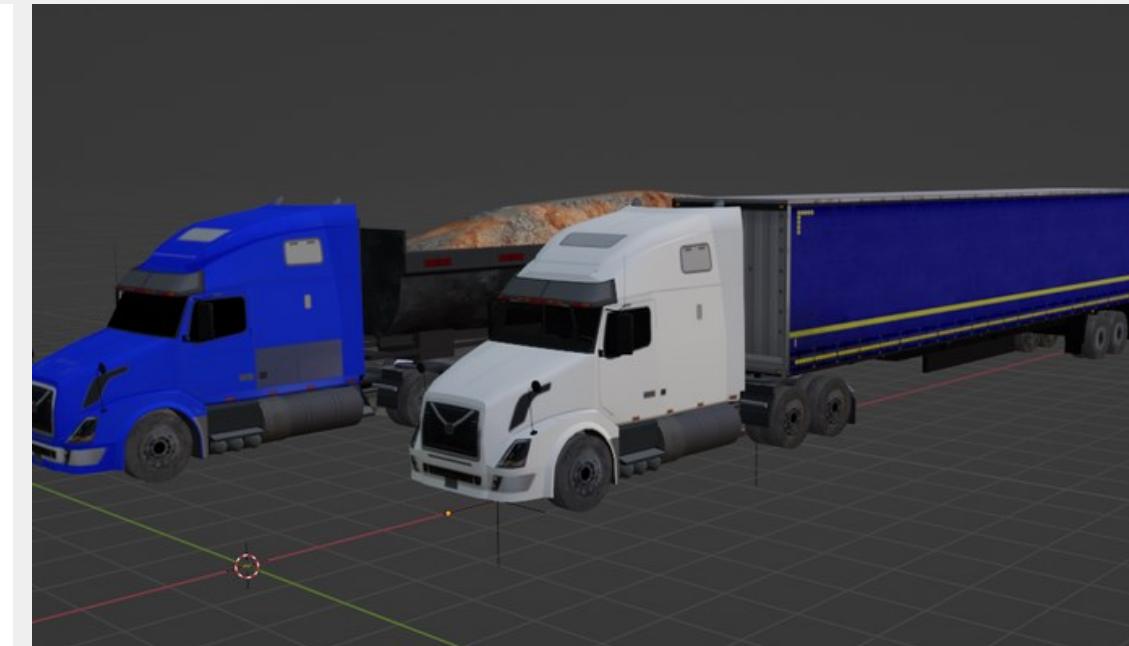


# Vehicles Characteristics

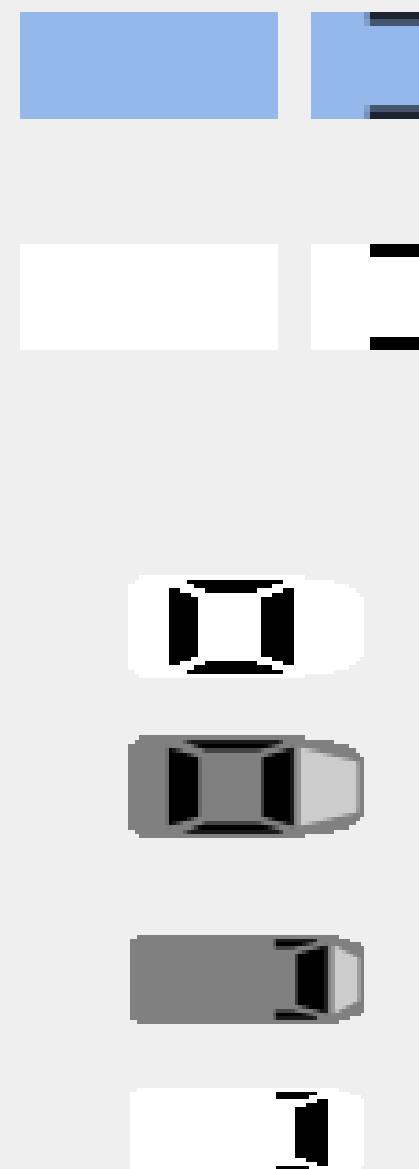
## Real-World Dimension



## 3D Traffic Simulation



## 2D Traffic Simulation



# Vehicles Dynamics

Modelling the Behavior

Real-World



Steering



Braking/Acceleration

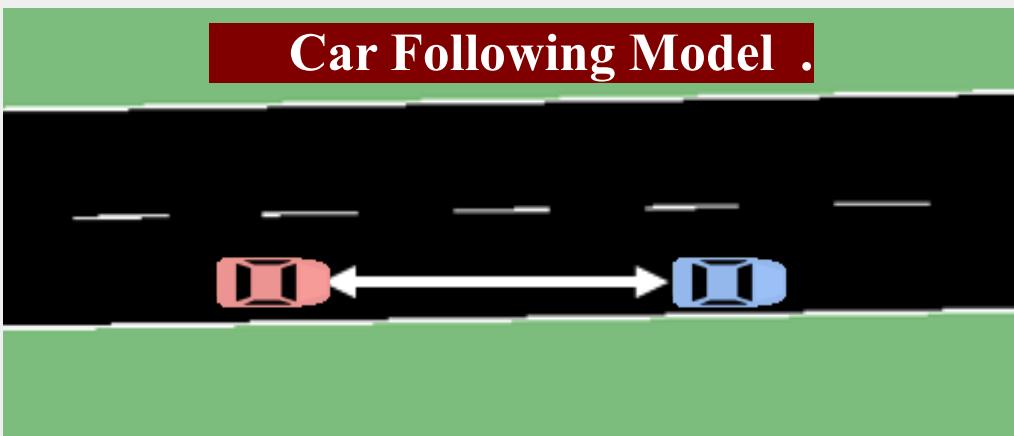


Simulation

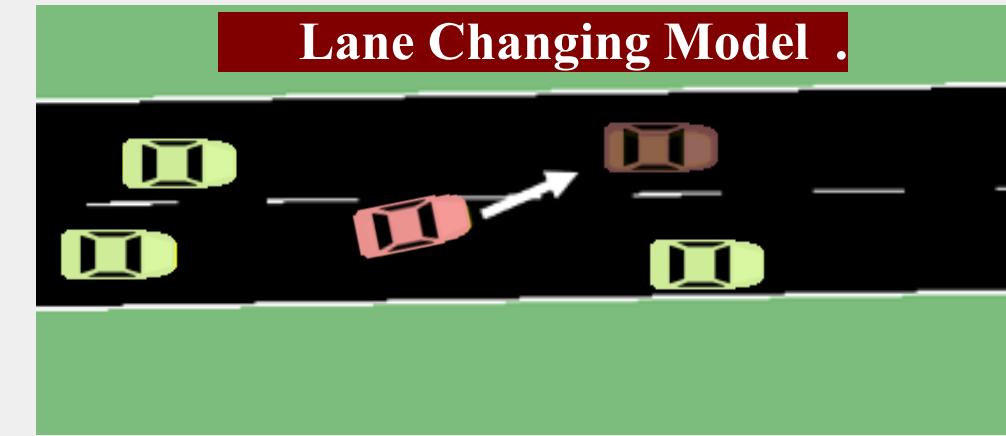


# Car Following and Lane Changing Model

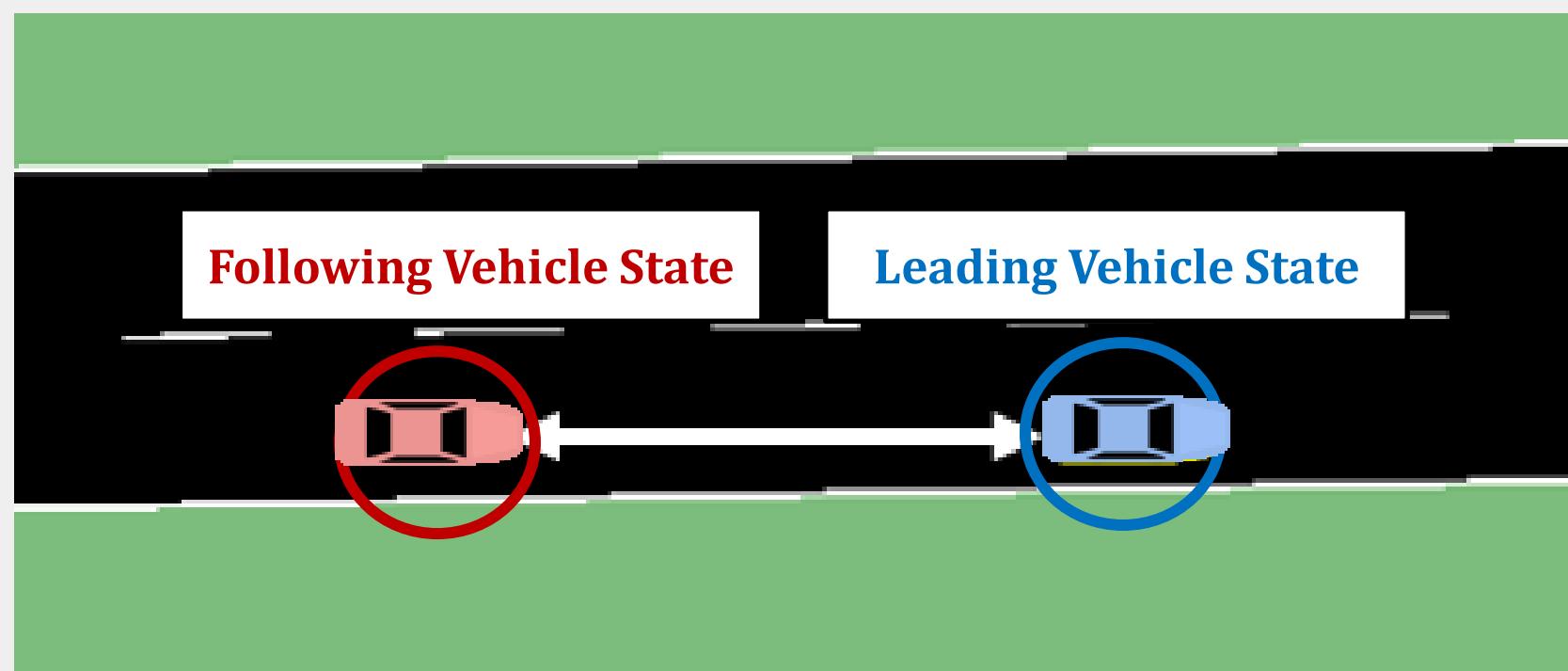
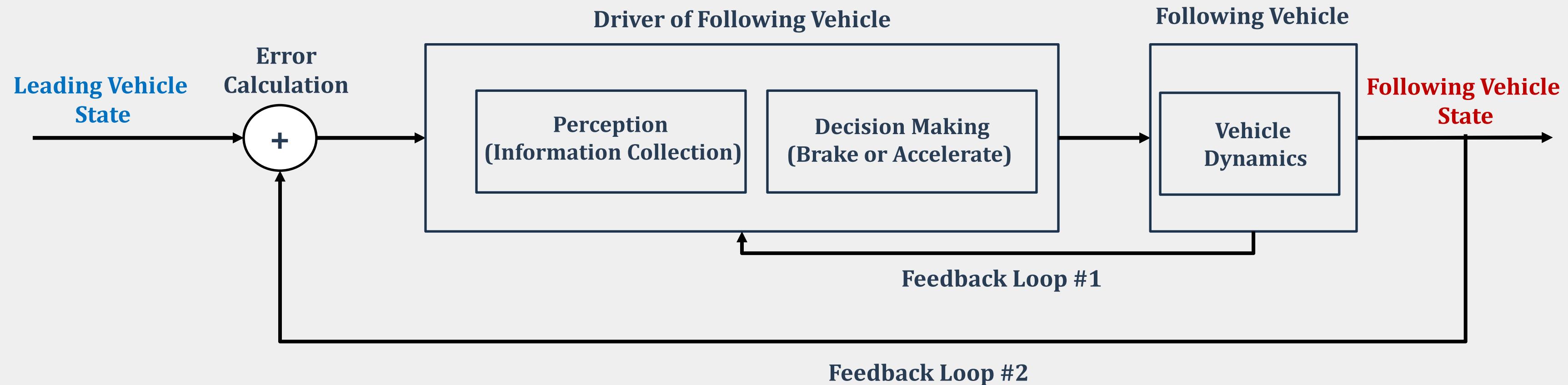
**Longitudinal Movement**



**Lateral Movement**



# Car Following Model Flow Chart

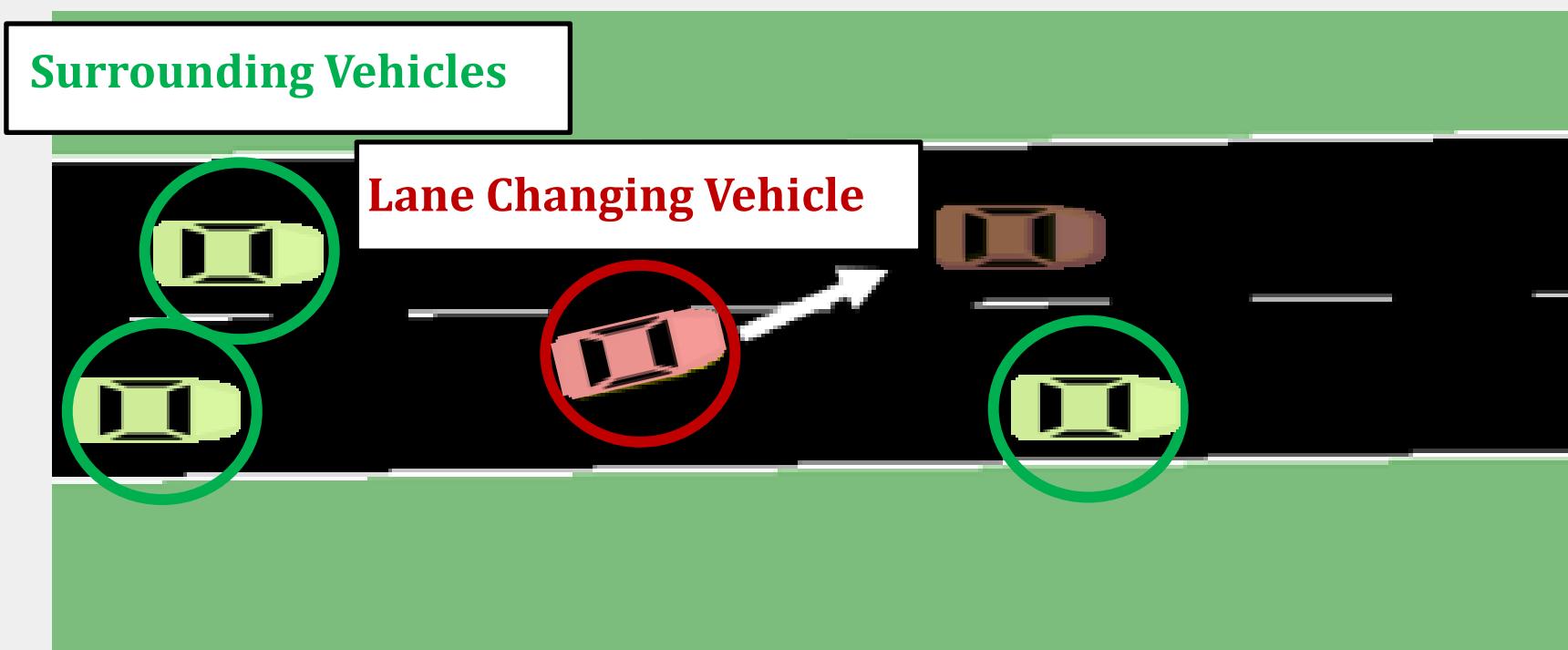
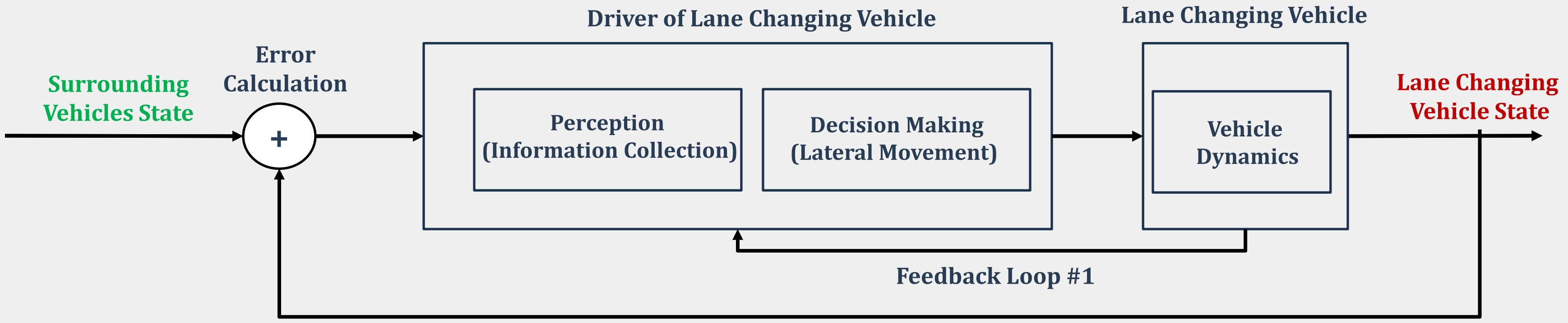


Reference:

Decision Making Flow in Car Following and Lane Changing Model, Rothery (2001)



# Lane Changing Model Flow Chart



Reference:

Decision Making Flow in Car Following and Lane Changing Model, Rothery (2001)