RWR 4013

Digital Twins for Smart Cities

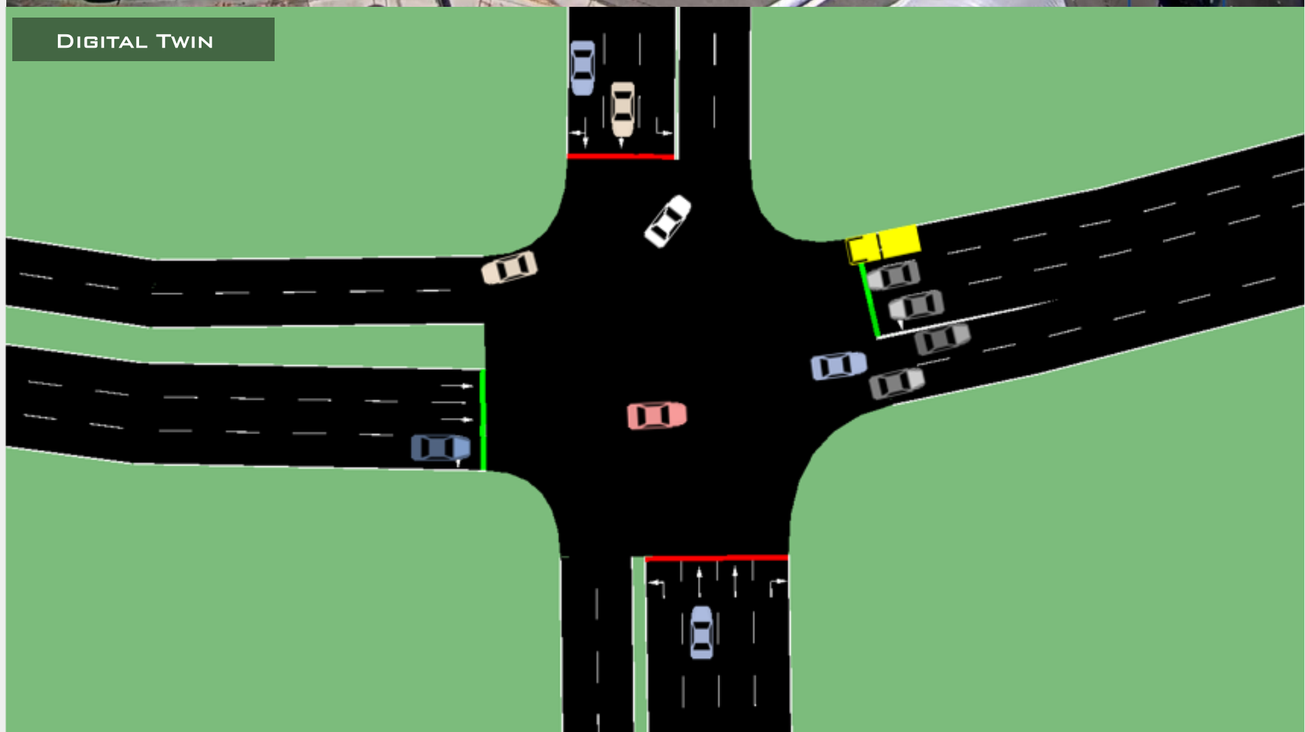
Dr. Ahmad Mohammadi

Week 6 | Session 1:
Simulation Calibration

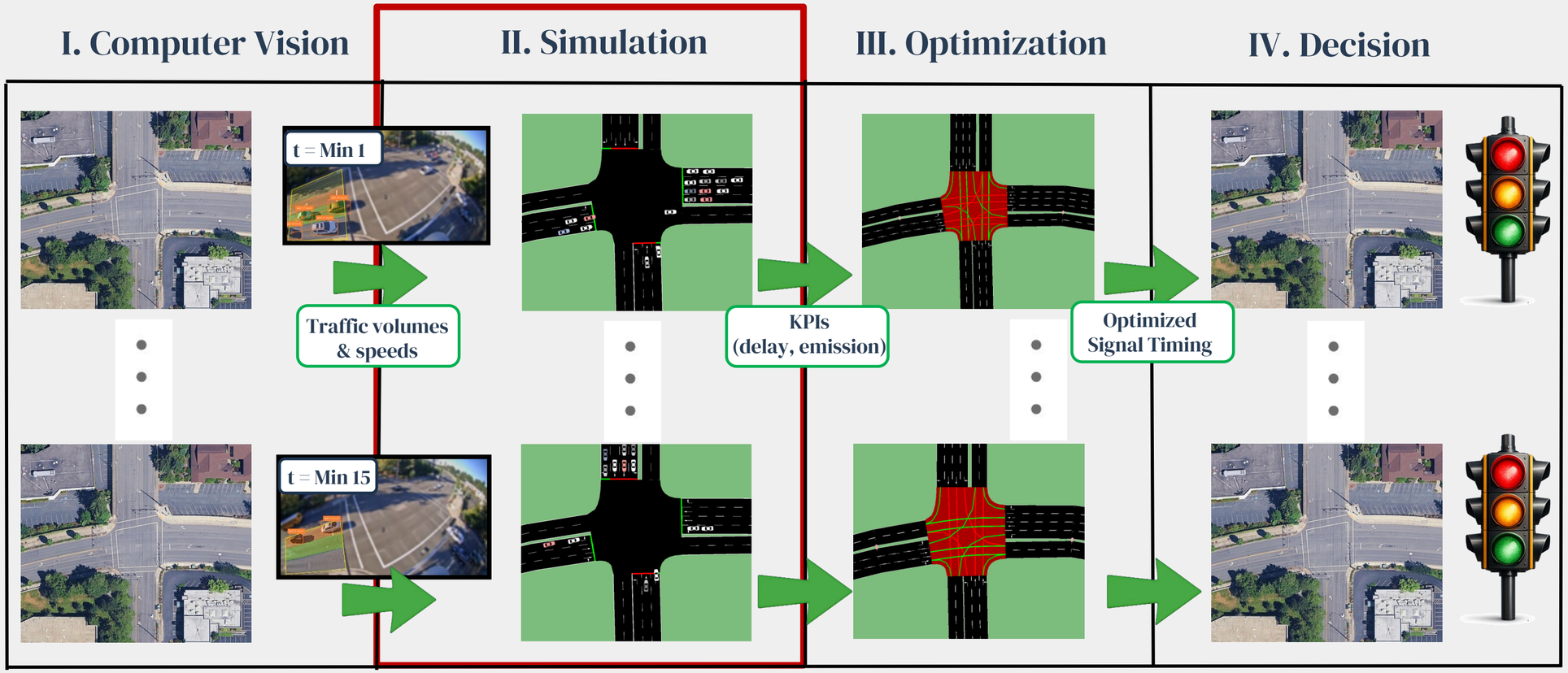
Fall 2026

RoadwayVR

roadwayvr.github.io/DigitalTwinsforSmartCities



Overview of Course Syllabus in One Shot



Agenda

❑ Simulation Calibration

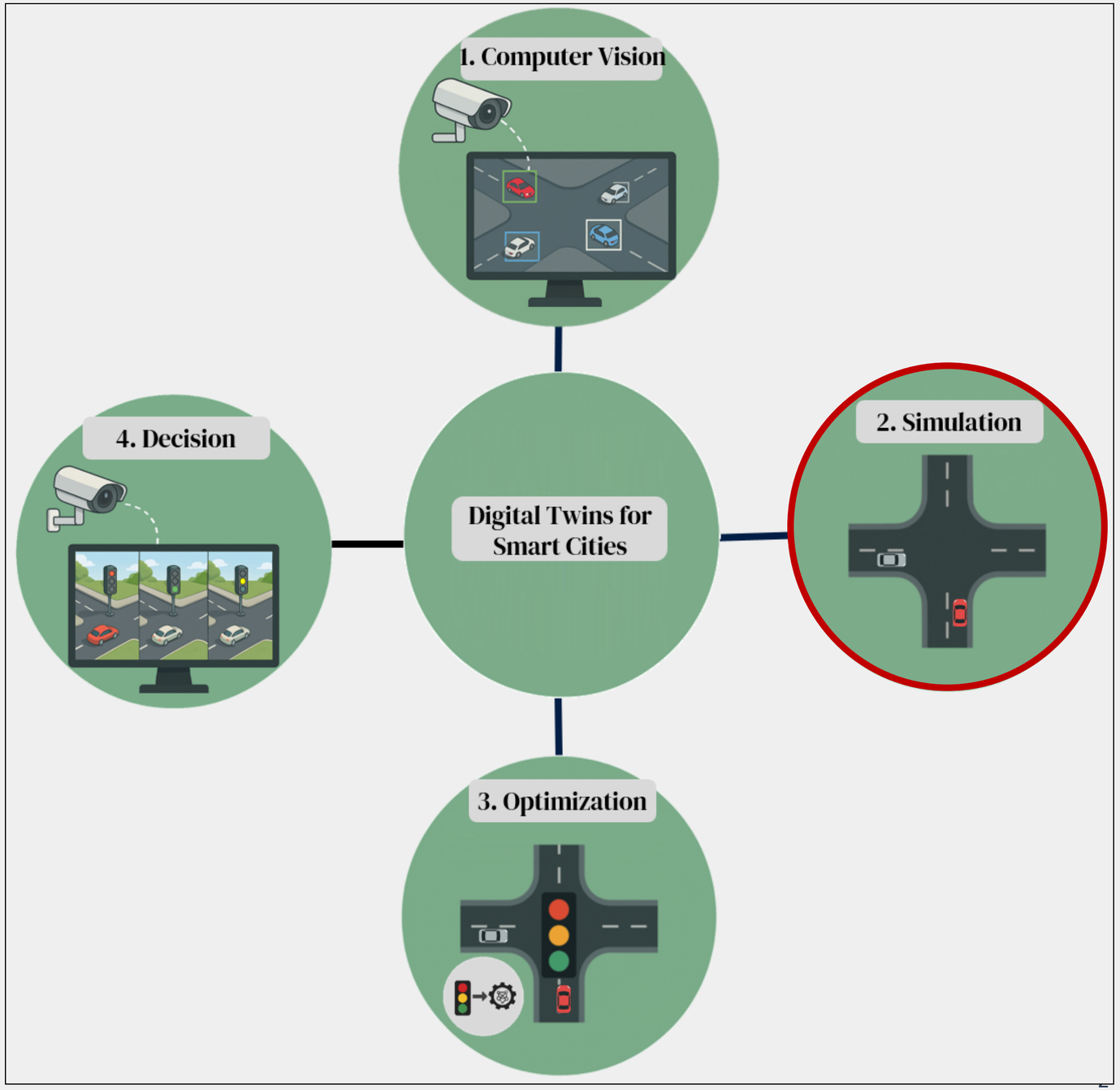
1. Accurate Road Network Development

2. Accurate Traffic Signal Timing

3. Traffic Movement Calibration

4. Traffic Volume Calibration

5. Traffic Speed Calibration

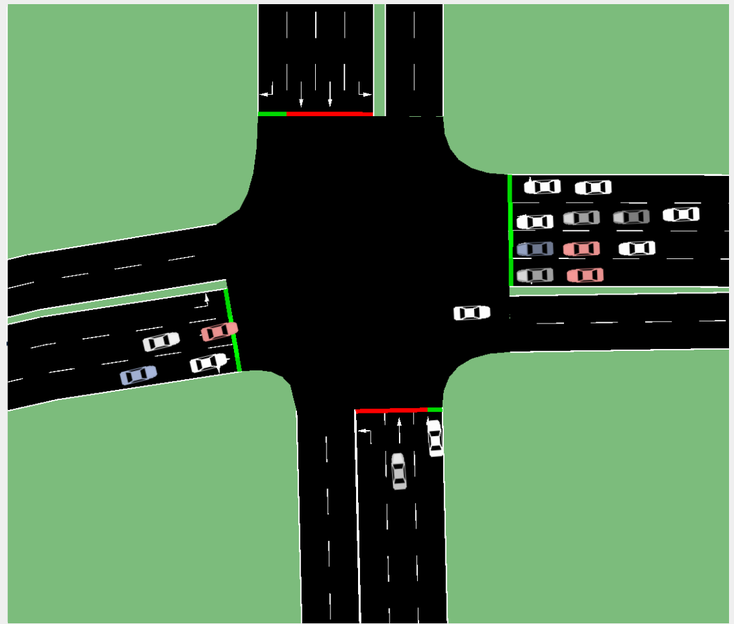


Simulation Calibration

1. Road Network Development: build an accurate road geometry and lane/connectivity model in the simulation.

2. Traffic Signal Timing: observed signal phases and timings into the simulation.

- ❑ In previous sessions, we already implemented Steps 1–2.
- ❑ This session, we will focus on Steps 3&4&5 (traffic movements, volumes, speeds).



Simulation Calibration

3-5. Traffic Movement, Volume & Speed

- **Traffic movement = the direction/turn (e.g., NBL, EBT, etc.)**
- **Traffic volume = the amount (e.g., 200 veh/h)**
- **Traffic Speed = the average speed of vehicles (e.g., 50 km/h)**

3. Traffic Movement

3&4. Traffic Movement & Volume

3&4&5. Traffic Movement & Volume & Speed

Quiz

- WBT has two through lanes.
- What are the traffic volume and speed for each lane?

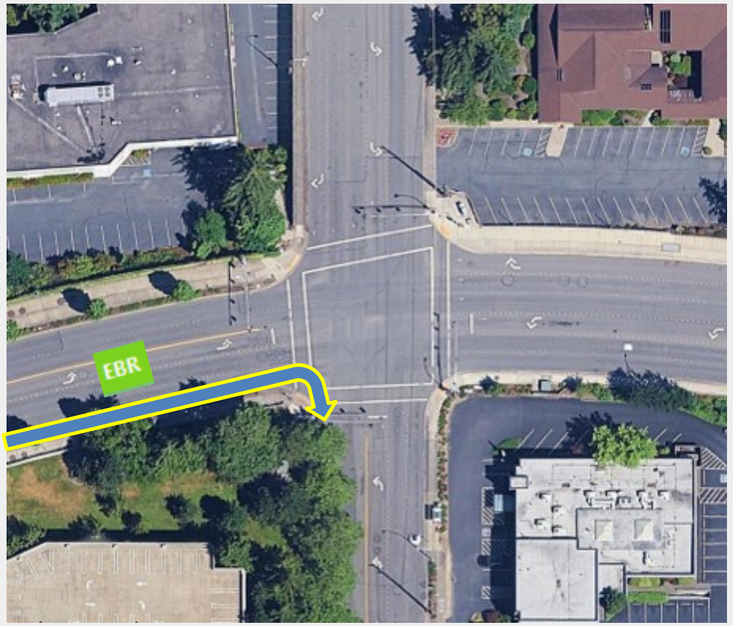
Quiz

- In the NB approach, the rightmost lane allows both through and right-turn movements.
- For the rightmost lane, what are the through-movement volume and speed?

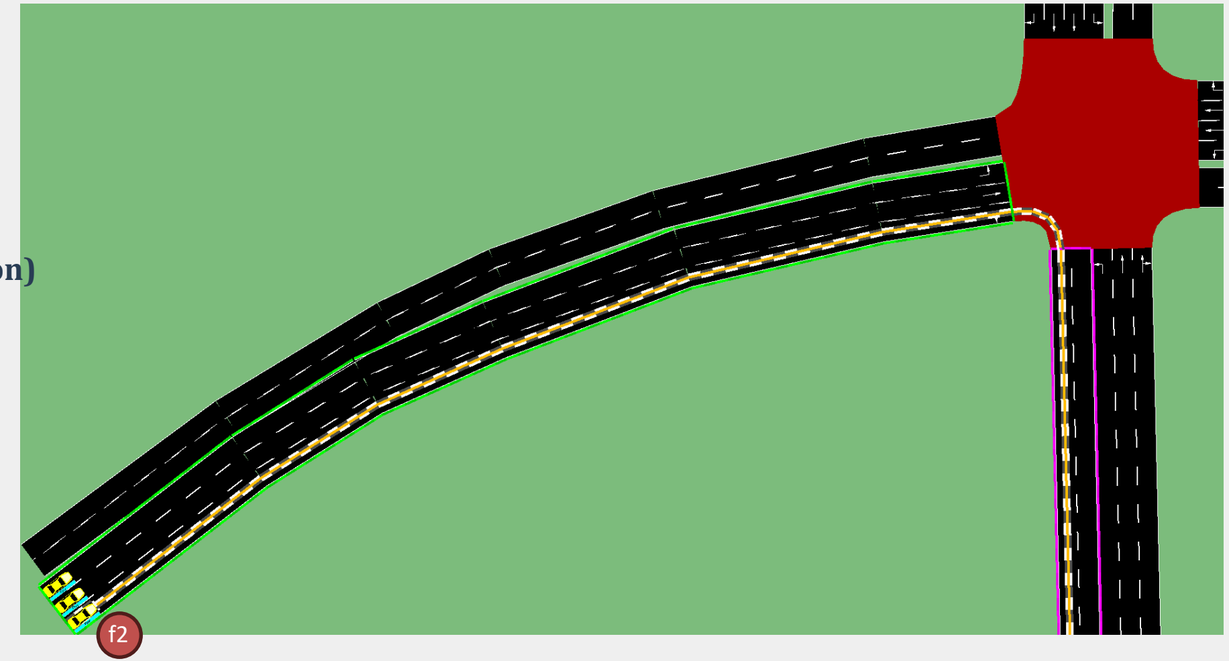
3. Traffic Movement Calibration

- In the real-world (video), each traffic demand is assigned to a specific movement by naming (e.g., NBL, NBT, NBR … WBR).
- In Simulation, each traffic demand is assigned to a specific movement by naming (f_0…f_{11})
- **Traffic Movement Calibration:** real-world (e.g., NBL, NBT, NBR … WBR) and simulation (f_0…f_{11}) traffic movements must be matched - this is Traffic Movement Alignment.

Traffic Movement Calibration Example for one Traffic demand (EBR) - (repeat for all movements).



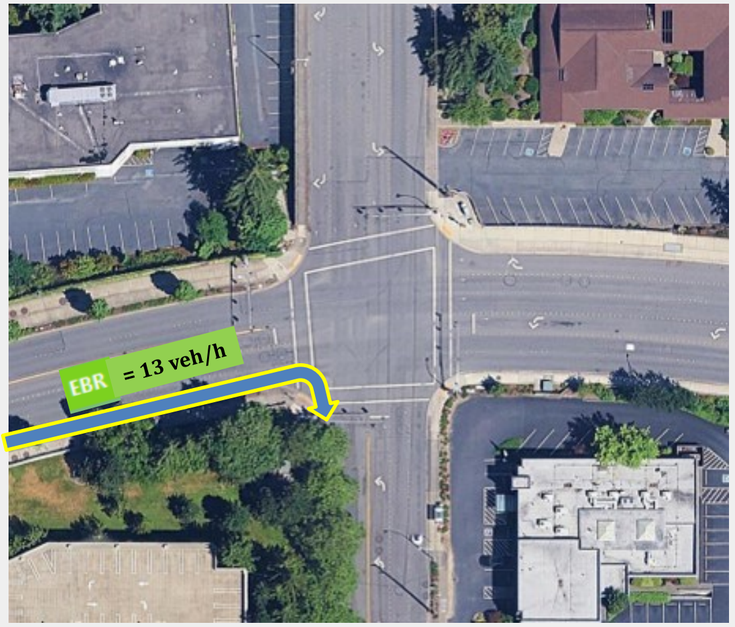
EBR (real-world) = f2 (Simulation)



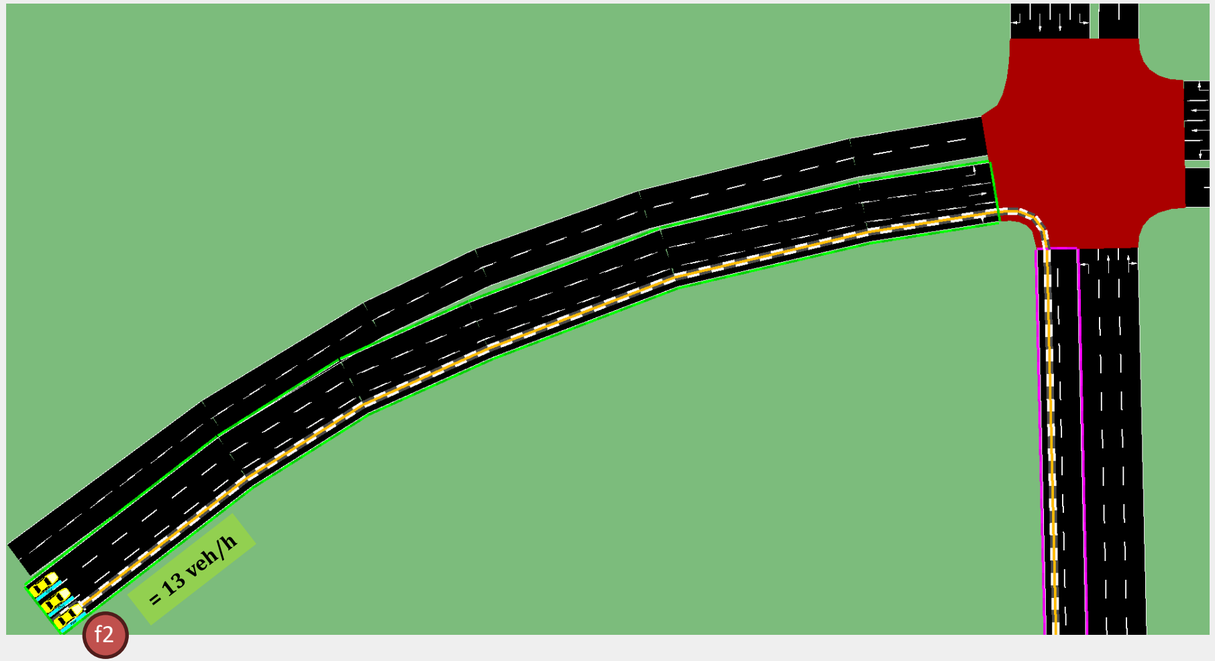
4. Traffic Volume Calibration

- ❑ In the real world(video), we observe traffic volumes for each movement (e.g., EBR = 13 (veh/h) …)
- ❑ In simulation, we set traffic volumes for each movement (e.g., f2=13 (veh/h)…)
- ❑ **Traffic Volume Calibration:** set simulated traffic volumes to the observed traffic volumes for each traffic movement

Traffic Movement & Traffic Volume Calibration Example for one Traffic Demand (EBR) - (repeat for all movements).

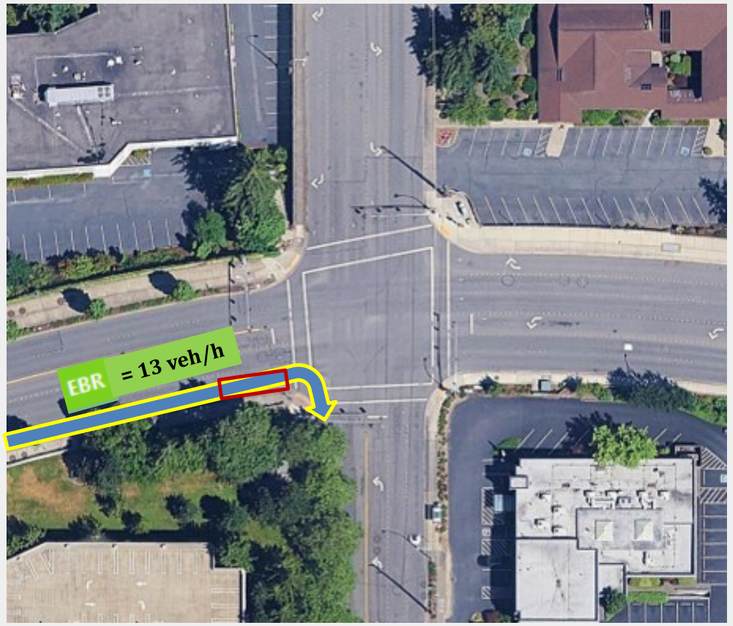


EBR (13 veh/h) = f2 (13 veh/h)

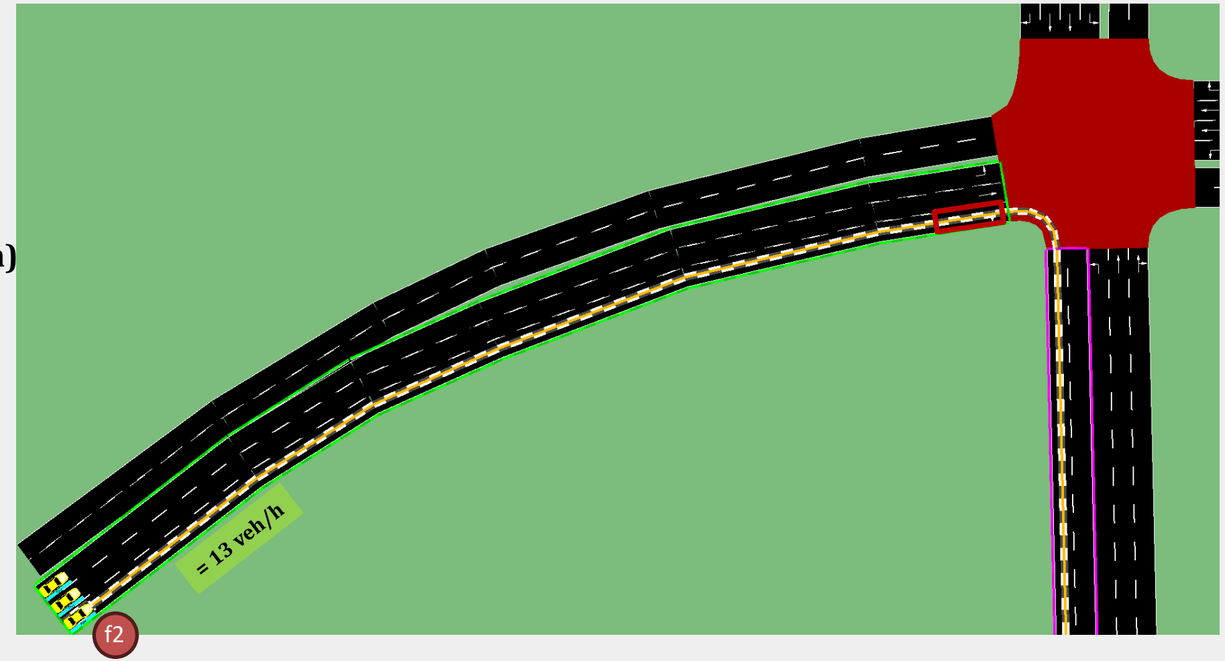


4. Traffic Volume Calibration (using GEH)

- In the real world (video), we observe traffic volumes for each movement at a measurement point (camera/detector near the intersection, red box).
- In simulation, we measure traffic volumes for each movement at the same location (virtual detector in the same red box).
- **Calibration goal:** adjust the simulation inputs so the simulated traffic volumes (red box) match the observed traffic volumes for each movement.
- We quantify the match using the GEH statistic (lower GEH = better).



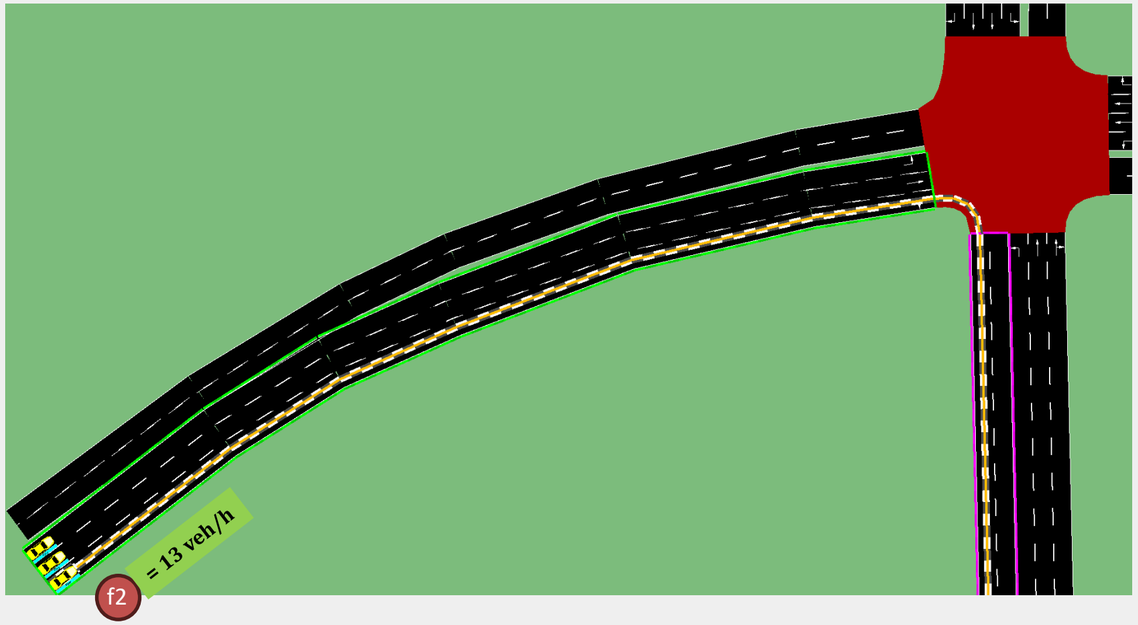
EBR (13 veh/h) = f2 (13 veh/h)



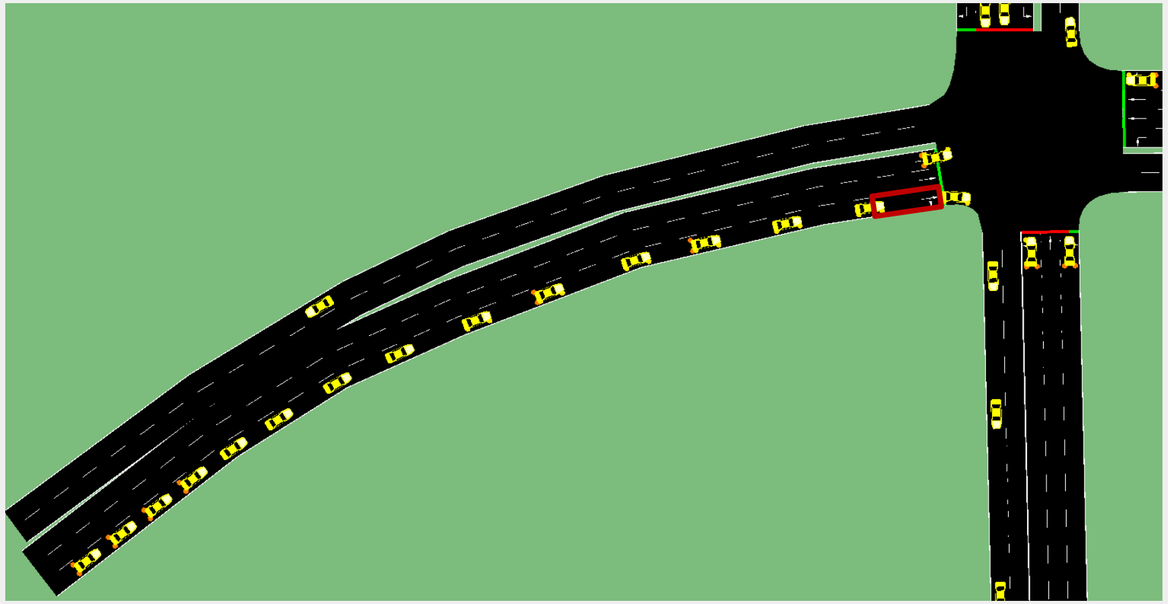
4. Traffic Volume Calibration (using GEH)

- ❑ The input traffic demand is not always the same as the traffic demand that actually reaches the intersection.
- ❑ **Reason:** Congestion and queues can block vehicles, so the requested demand ≠ the observed demand at the intersection.

Input Traffic Demand: We set f2 = 13 veh/h in SUMO.



Measured Traffic Demand (Red Box): Only 9 veh/h is observed at the measurement point because queues limit how many vehicles can enter and reach the intersection.



4. Traffic Volume Calibration (using GEH)

❑ **We do not expect simulated and real-world traffic volumes for each movement to match exactly.**

GEH Formula: $$GEH = \sqrt{\frac{2(M-C)}{M+C}}$$

$M = Simulated\ Traffic\ Volume\ (veh/h)$

$C = Observed\ Traffic\ Volume\ (veh/h)$

Interpretation:

$GEH < 5$	$Good\ match$
$5 \leq GEH < 10$	$Needs\ investigation$
$10 \leq GEH$	$Likely\ mismatch\ (check\ data, mapping, or\ model\ settings)$

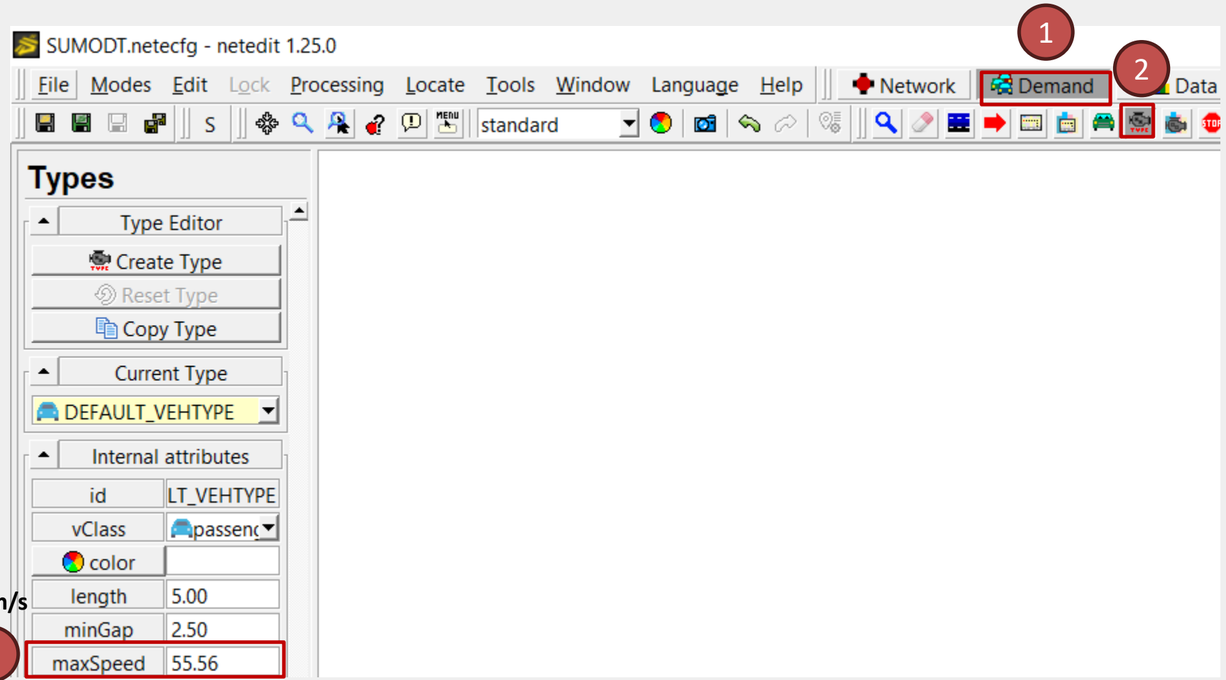
❑ **Compute GEH for each traffic movement separately.**

❑ **Aim for GEH < 5 for at least ~ 85% of traffic movements**

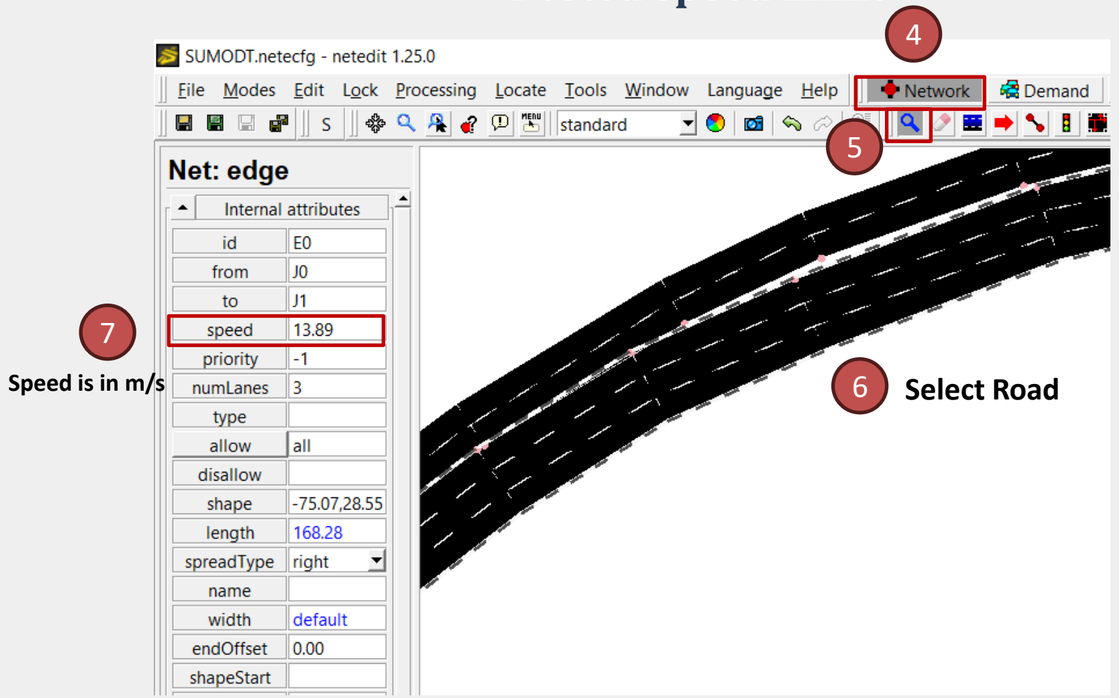
5. Traffic Speed Calibration

- ❑ In SUMO, traffic speed is defined by vehicle type and the posted speed limit on each road.
- ❑ Check the real-world posted speed limit and update the posted speed limit value in SUMO.
- ❑ If we have observed speeds for the entire link (not just near the intersection), we can also adjust the vehicle-type speed parameters.

Vehicle Type



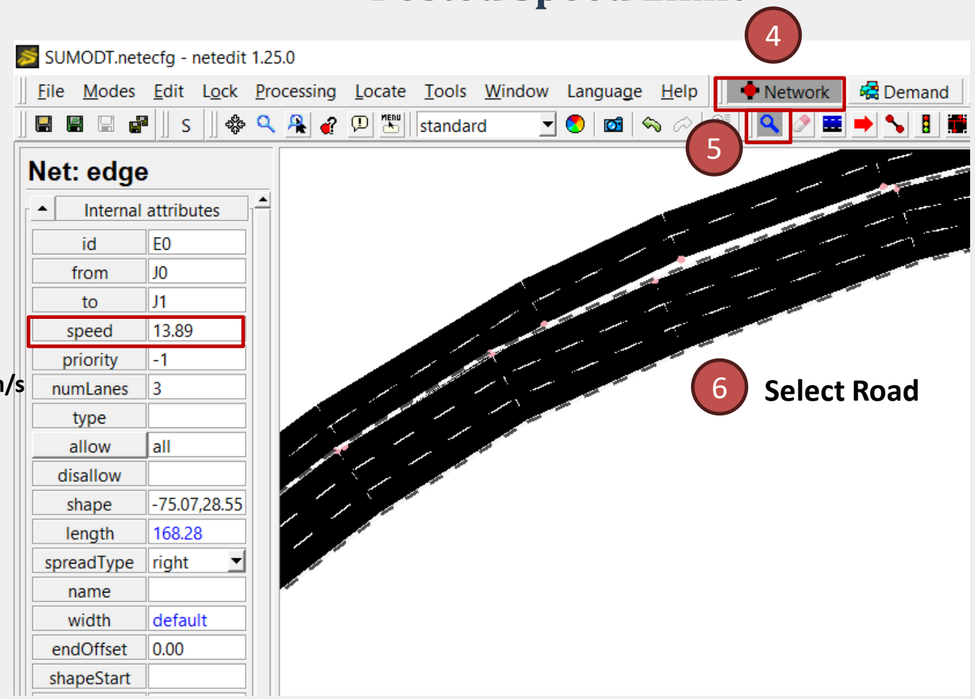
Posted Speed Limit



5. Traffic Speed Calibration

❑ For this course, we only adjust posted speed limits because we do not have speed data for the entire road.

Posted Speed Limit



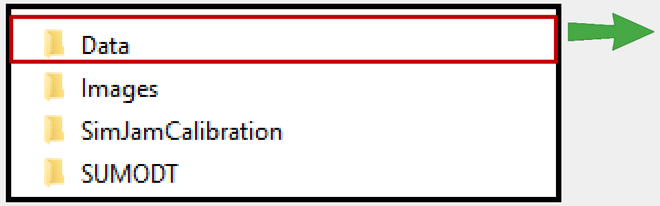
In-Class Deliverable

Download Required Materials

1. Download Week7a.Material.zip

2. Extract the Zip File

3. It has below structure:



Collected Through Weeks 1-3

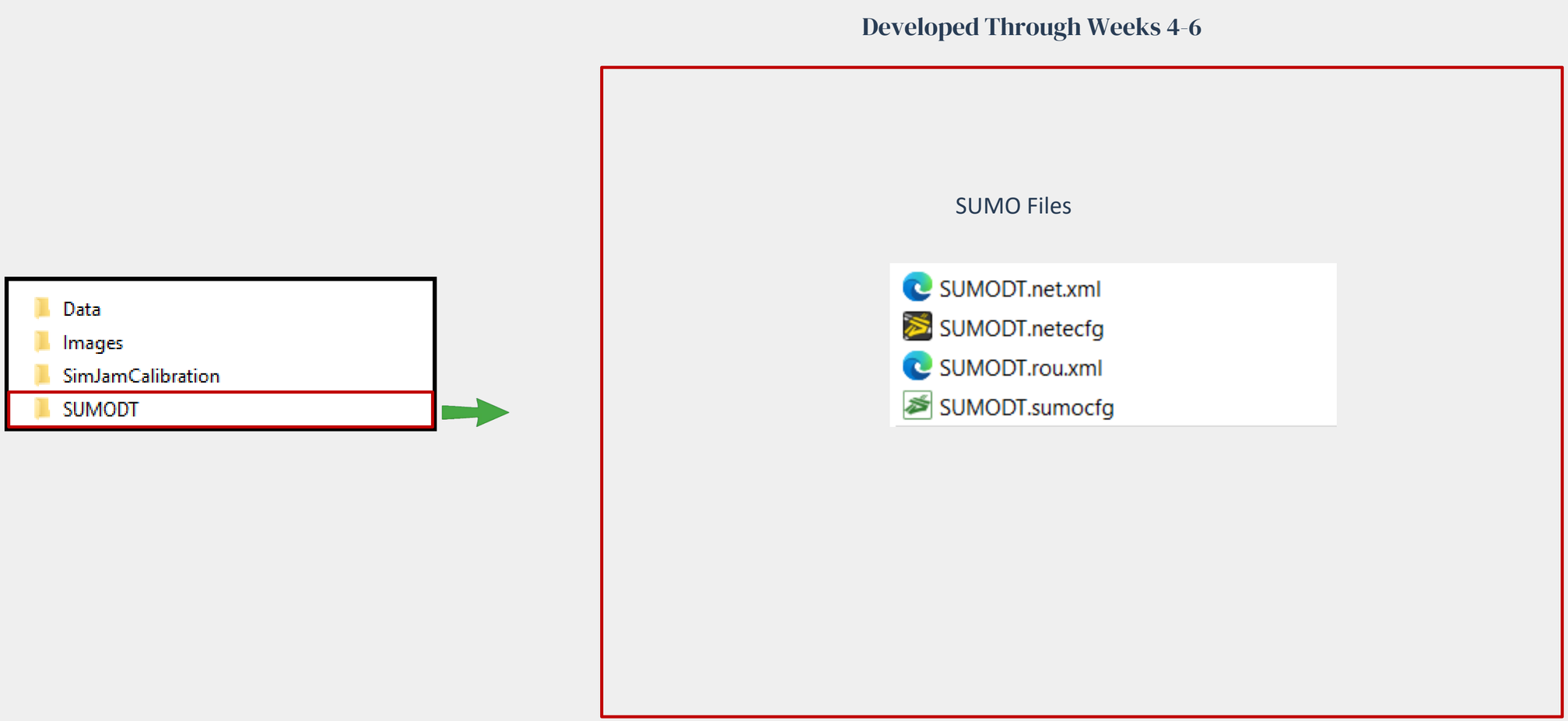
15-Min Observed Data.csv

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Minute	NBL	NBT	NBR	SBL	SBT	SBR	EBL	EBT	EBR	WBL	WBT	WBR
2	All	30	143	19	22	154	24	20	100	21	24	129	25

Interval Observed Data.csv

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Minute	NBL	NBT	NBR	SBL	SBT	SBR	EBL	EBT	EBR	WBL	WBT	WBR
2	1	2	15	1	1	10	2	1	6	1	1	6	1
3	2	3	16	1	1	11	2	1	4	1	1	7	2
4	3	1	9	1	2	9	1	1	5	3	2	8	1
5	4	2	4	1	3	8	2	1	4	1	3	8	2
6	5	3	13	1	1	10	1	2	7	3	2	6	2
7	6	1	12	2	2	12	2	2	10	1	1	12	2
8	7	2	7	1	2	13	1	1	8	1	2	8	2
9	8	3	9	1	1	11	2	2	8	1	1	5	1
10	9	2	5	2	1	10	2	1	6	1	2	10	2
11	10	1	1	2	1	11	2	1	8	1	2	11	1
12	11	2	10	2	1	9	1	2	6	1	1	8	3
13	12	2	11	1	1	12	2	1	8	1	1	12	2
14	13	3	5	1	1	10	1	2	6	3	2	10	2
15	14	1	14	1	2	8	2	1	7	1	1	9	1
16	15	2	12	1	2	10	1	1	7	1	2	9	1

Download Required Materials



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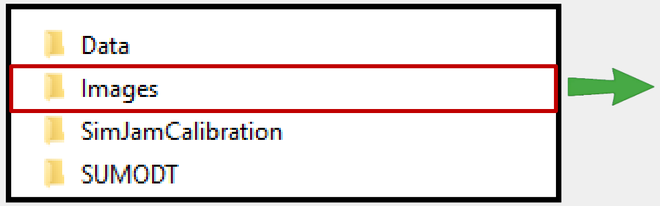
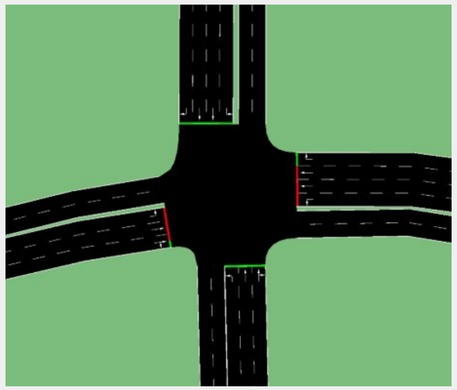


Real-World.jpg

SUMO.jpg



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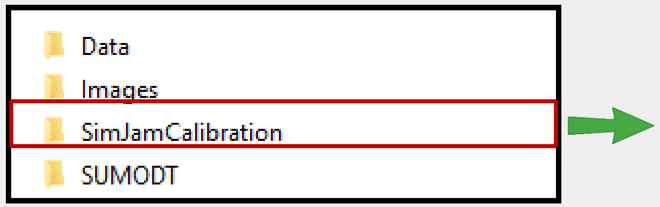


Application

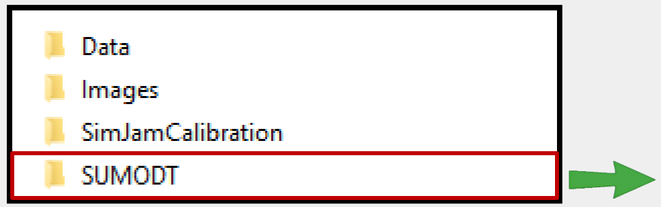
- CalibrationGUI15Min.py
- Calibrator15Min.py
- FlowMovementDetector.py
- ImageTaggerCanvas.py
- ModernDetectionTab.py

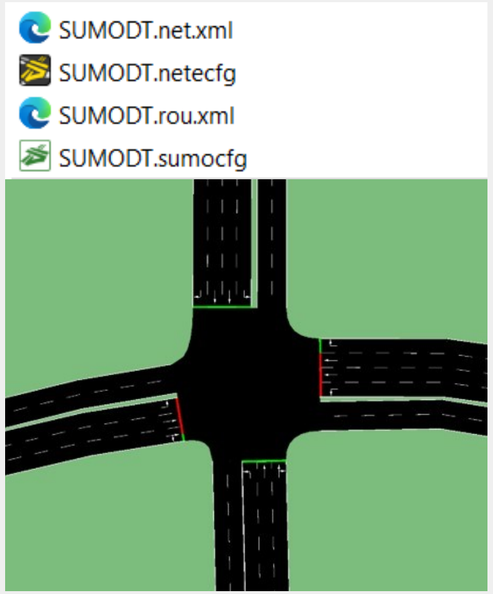
Step 1. Road Network Development & Traffic Signal Timing

1. Open Folder “SUMODT”

2. For this course, we already created this in previous tutorials

3. It includes Road Network Development & Traffic Signal Timing





Step 2. Traffic Movement & Volume Calibration

1. Data folder → Open 15-min Observed Data.csv

2. Find EBR and label it on the real-world image with the observed 15-min traffic volume (do this in PowerPoint).

See next slide for an example.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Minute	NBL	NBT	NBR	SBL	SBT	SBR	EBL	EBT	EBR	WBL	WBT	WBR
2	All	30	143	19	22	154	24	20	100	21	24	129	25
3													
4													
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16													

Step 2. Traffic Movement and Volume Calibration

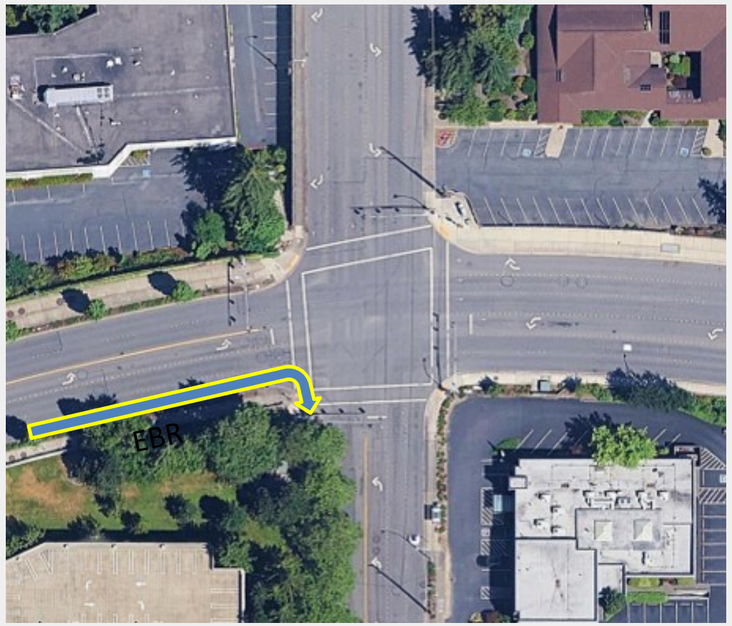
Example:

3. Open the “Images” folder → Copy and paste the real-world image into a PowerPoint slide.

4. In PowerPoint: Home → Drawing

5. Use the arrows below to draw each traffic movement and label its volume.

Draw arrow for each traffic movement



Step 2. Traffic Movement & Volume Calibration

6. Open the “Data” folder → Open 15-Min Observed Data.csv

7. Find EBR and add it to the real-world image with the 15-min observed traffic volume using a text box.

8. Use “Fill Shape” to add a background color to the text box.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Minute	NBL	NBT	NBR	SBL	SBT	SBR	EBL	EBT	EBR	WBL	WBT	WBR
2	All	30	143	19	22	154	24	20	100	21	24	129	25
3													
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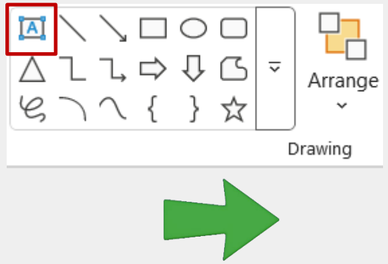

Step 2. Traffic Movement and Volume Calibration

9. Repeat the same process for all other traffic movements and volumes.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Minute	NBL	NBT	NBR	SBL	SBT	SBR	EBL	EBT	EBR	WBL	WBT	WBR
2	All	30	143	19	22	154	24	20	100	21	24	129	25
3													
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Step 2. Traffic Movement and Volume Calibration

10. Submit the deliverables to course website