RWR 4015

Traffic Simulation for Planning Applications

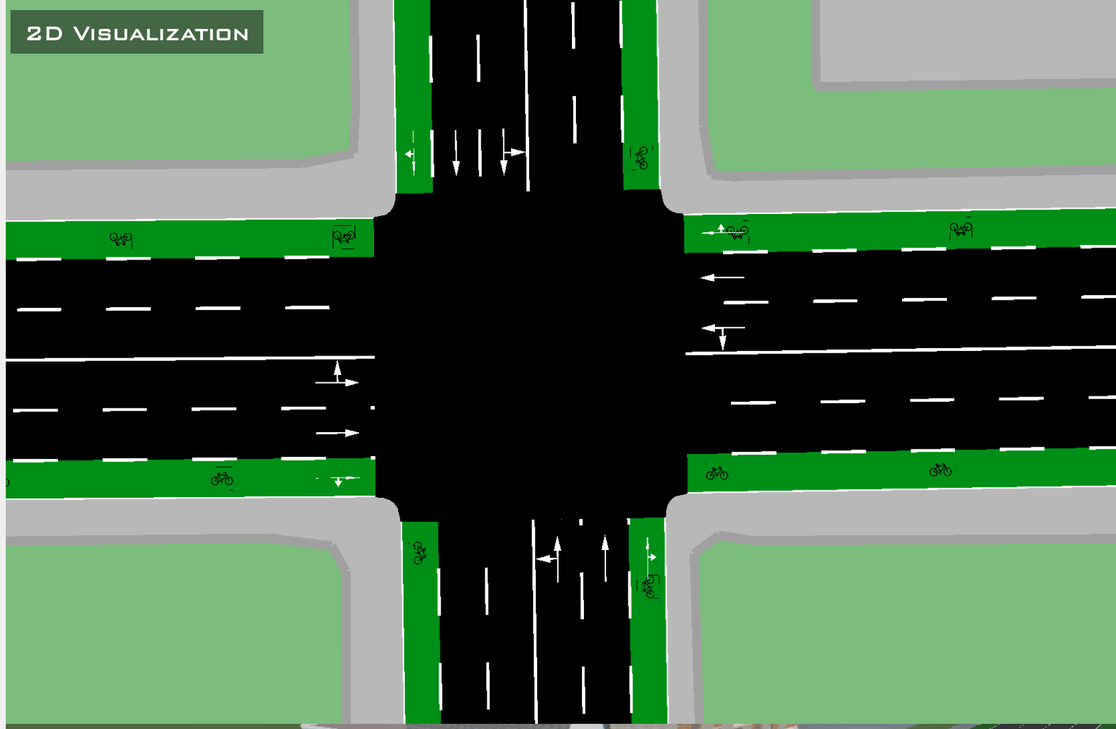
Dr. Ahmad Mohammadi

Week 2 | Hands-on:
Fundamentals of Traffic Simulation

Fall 2026

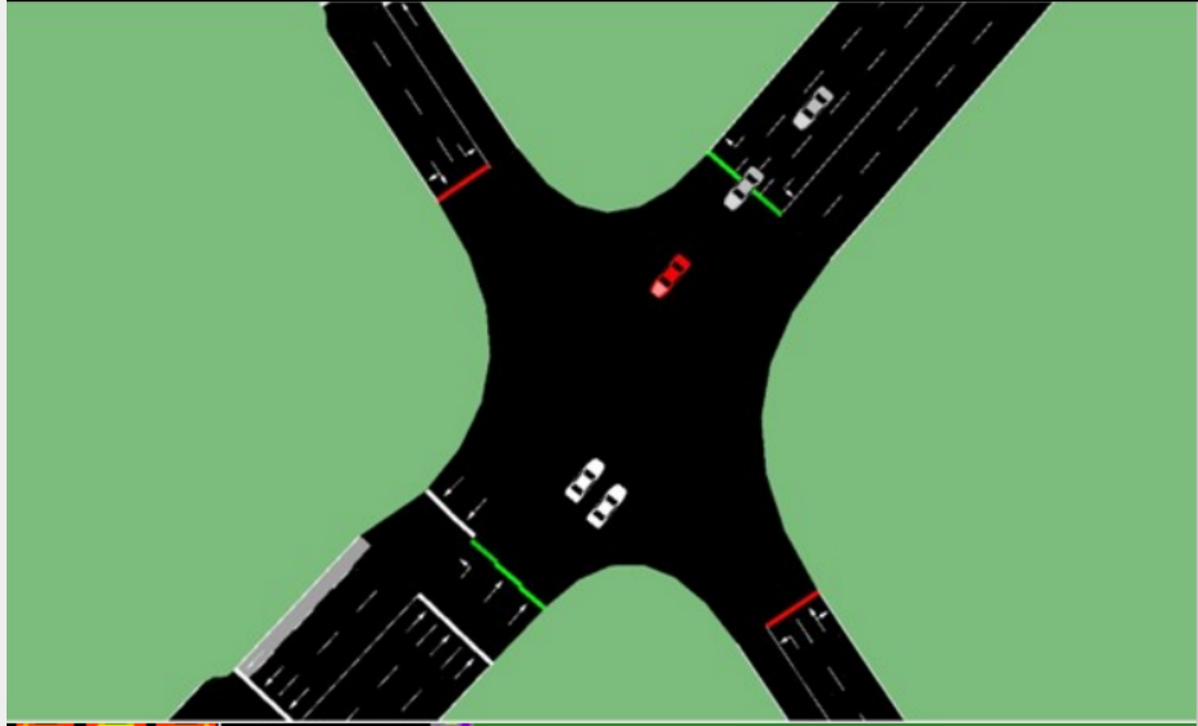
RoadwayVR

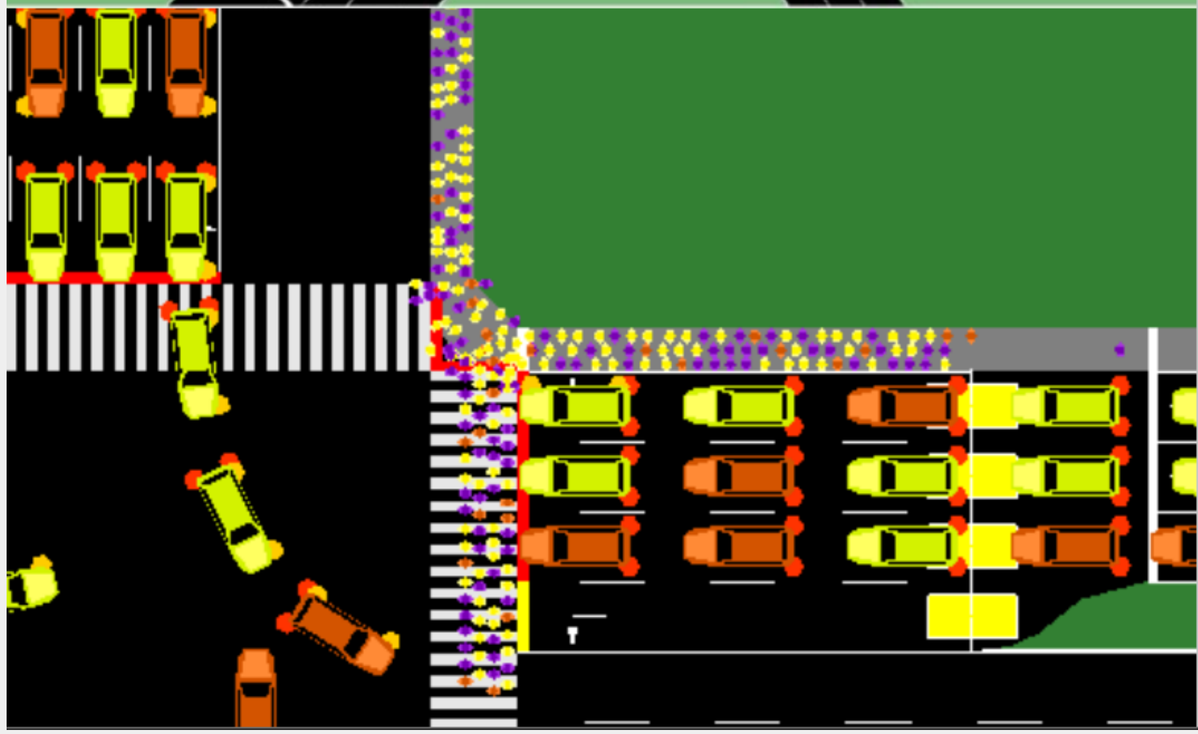
roadwayvr.github.io/TrafficSimulationforPlanningApplications



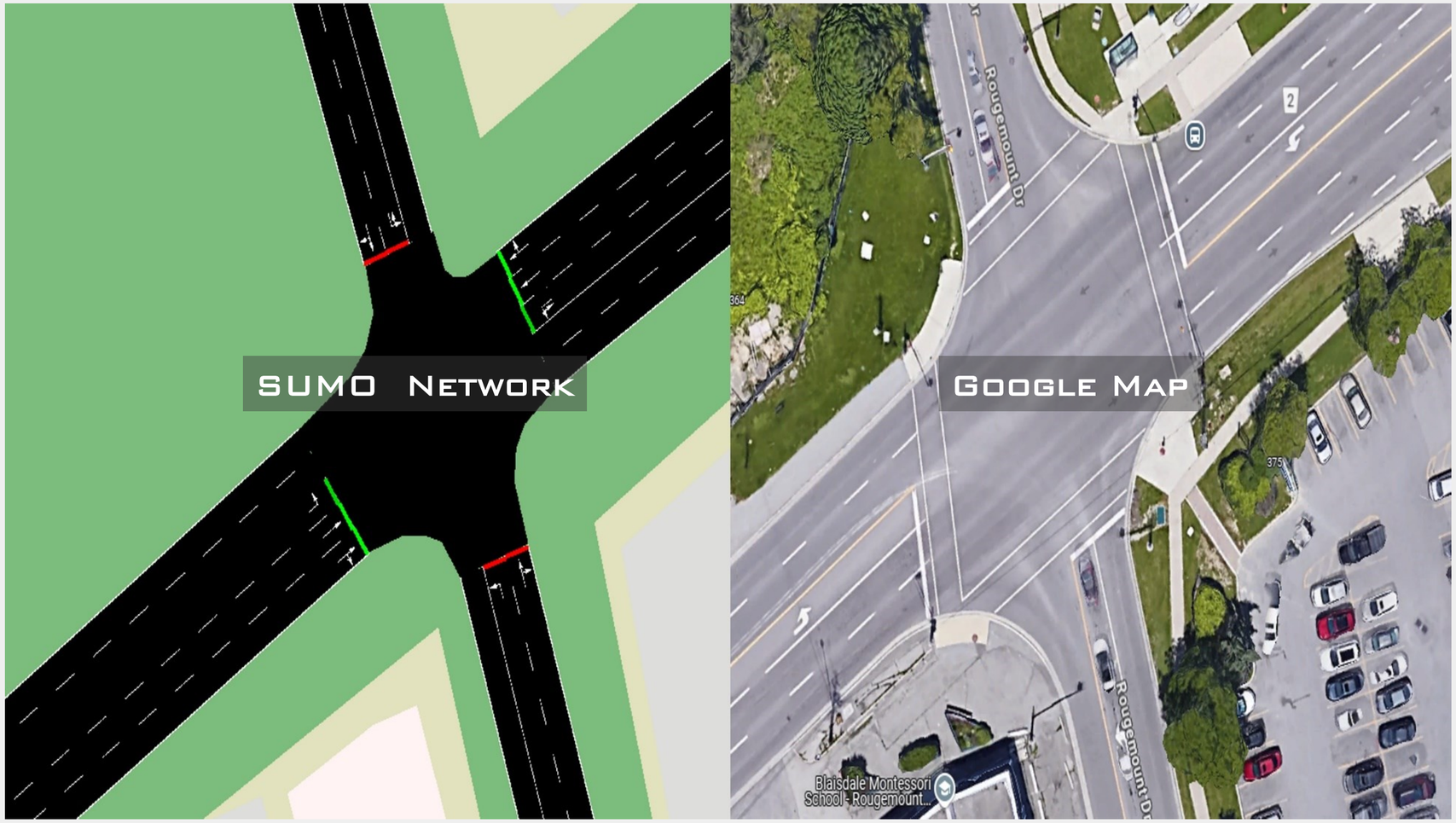
Agenda

- ❑ Road Network Development in Traffic Simulation
- ❑ Car Following and Lane Changing Models in Traffic Simulation

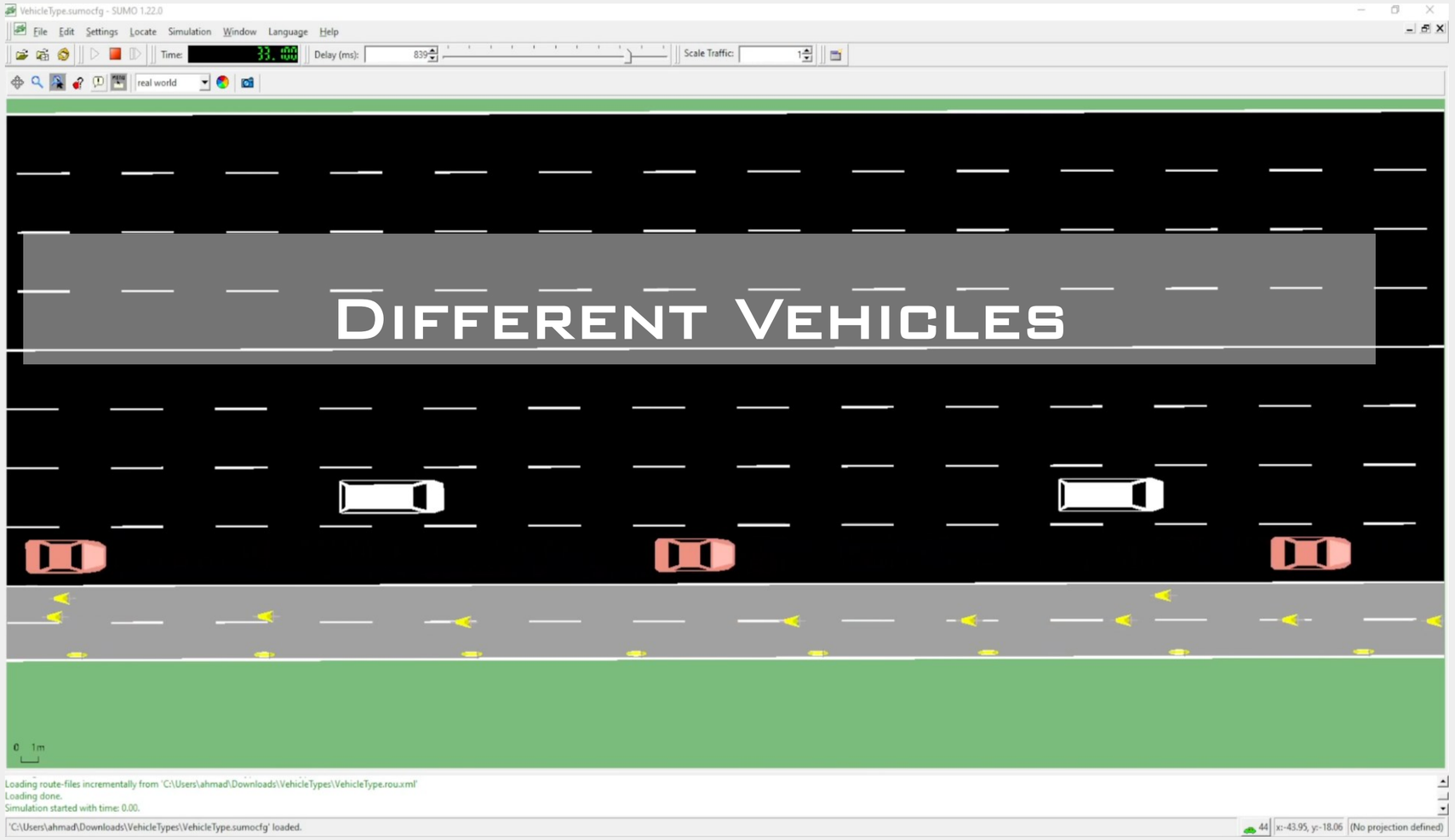




Objective 1: Road Network Development



Objective 2: Car Following and Lane Changing Models

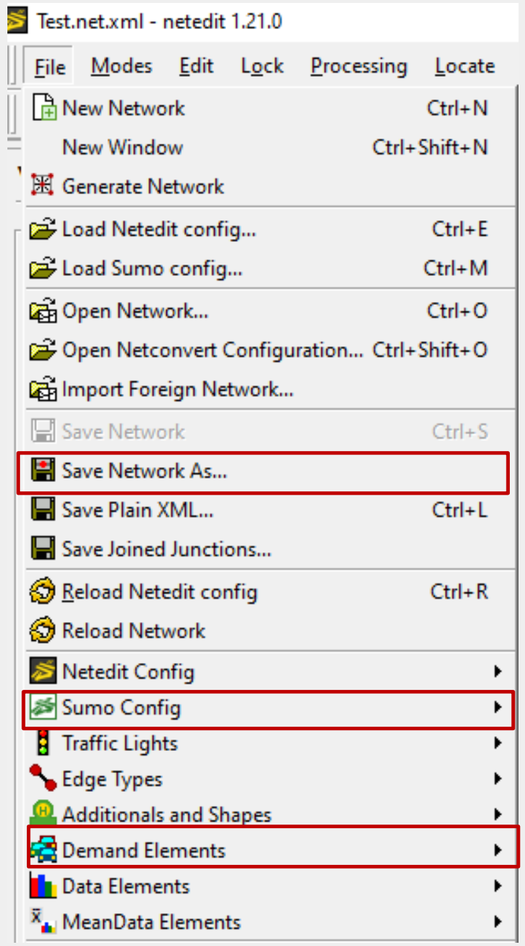


1. Road Network Development

- SUMO Files and Configuration
- Edge and Junction
- Element of Edge (Street including number of lanes)
- Elements of Junction (including traffic light, connections, right of way)
- File of *.net.xml
- NetEdit Modules (Inspect, Target Lane, Create Sidewalk, Bus Lane, HOV lane)
- NetEdit Modules (Compute Junctions, Reset junction shape, Change Width)

1. Road Network Development

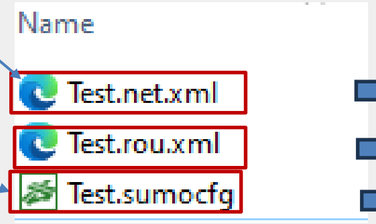
SUMO Files and Configuration



Network

Gui

Demand



Junction, edge

Vehicle Type and Volume

Gui Setting

*.rou.xml

*.dat.xml

...

You can edit by

- ❑ 1. Notepad
- ❑ 2. NetEdit
- ❑ 3. External python (traci)

*.net.xml

Do not edit

- ❑ It should be automatically created

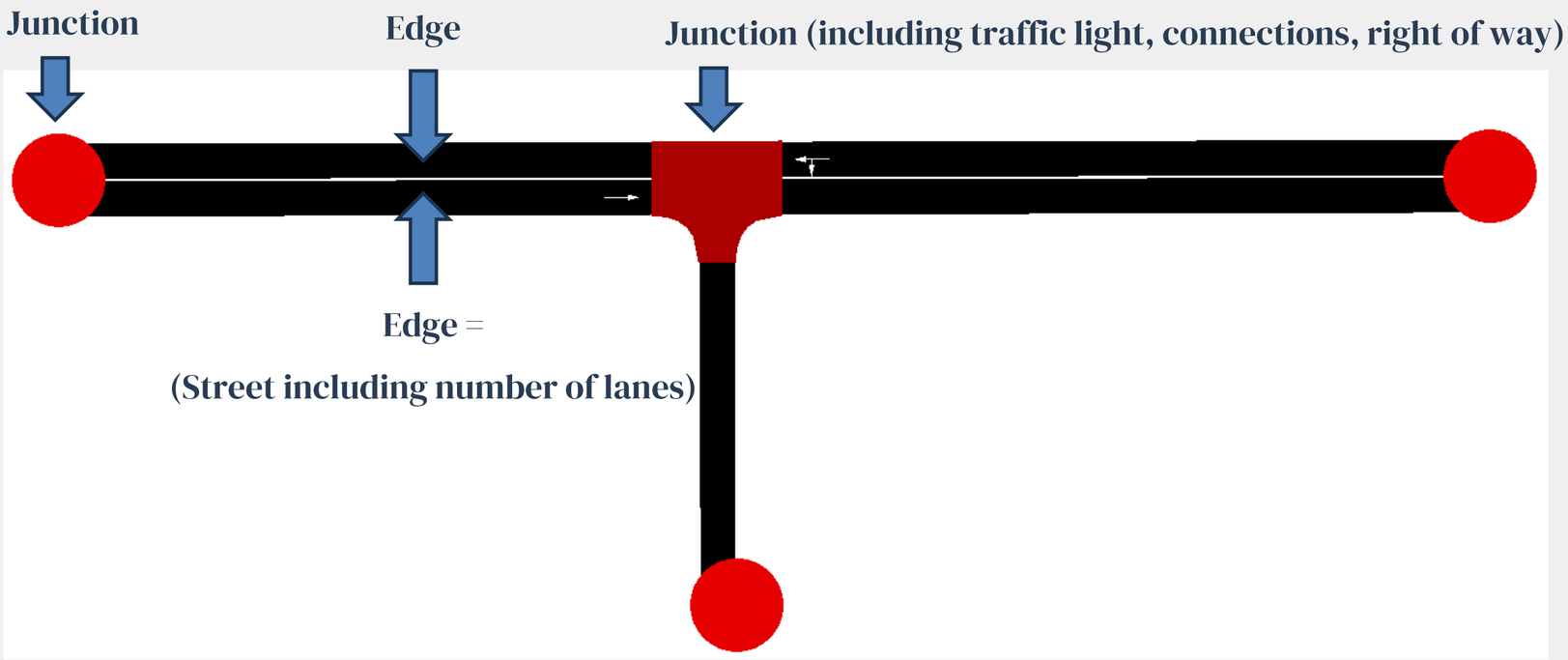
*.sumocfg.xml

You can edit by

- ❑ 1. Notepad
- ❑ 2. NetEdit
- ❑ 3. External python (traci)

1. Road Network Development

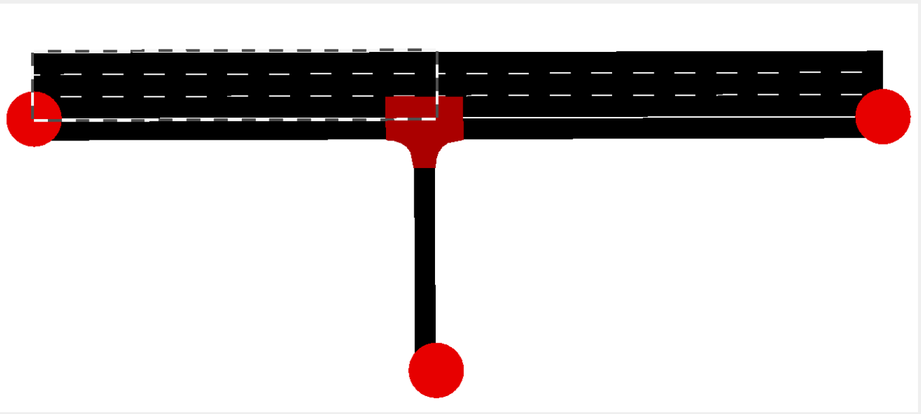
Edge vs Junction



1. Road Network Development

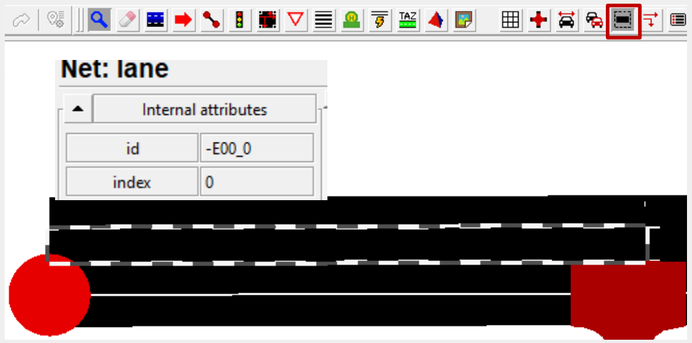
Element of Edge (Street including number of lanes)

Edge with 3 Lanes



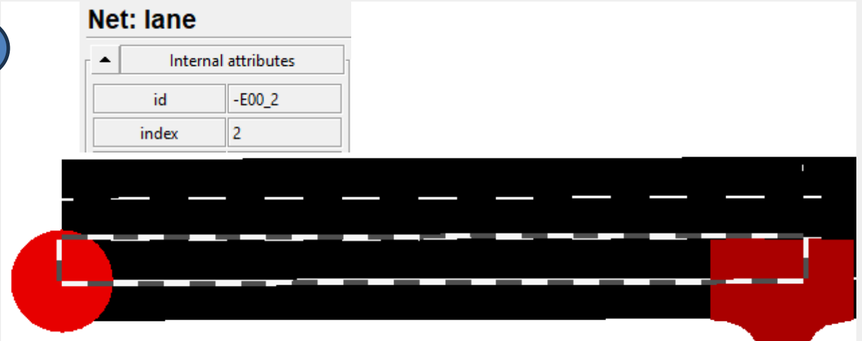
Select Lane

1



2

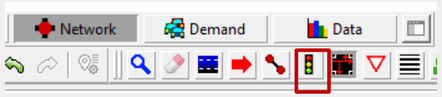
3

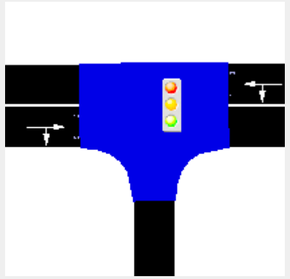


1. Road Network Development

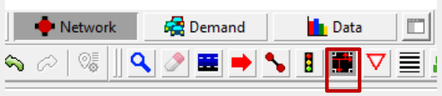
Elements of Junction (including traffic light, connections, right of way)

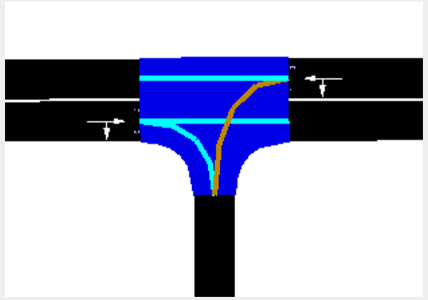
Traffic light



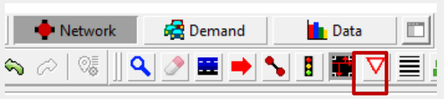


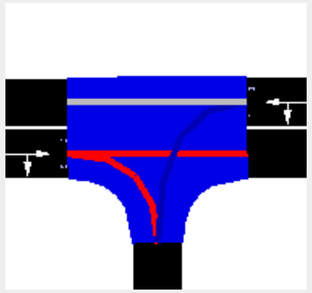
Connections





Right of way



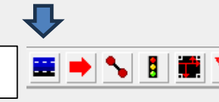


1. Road Network Development

Heart of SUMO (file of *.net.xml)

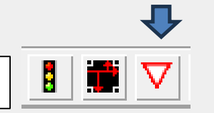
```
<net version="1.20" junctionCornerDetail="5" limitTurnSpeed="5.50" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/net_file.xsd">

    <location netOffset="0.00,0.00" convBoundary="-70.66,-24.21,51.69,12.40" origBoundary="-10000000000.00,-10000000000.00,10000000000.00,10000000000.00" projParameter="!"/>

    <edge id="-E0" from="J1" to="J2" priority="-1">
        <lane id="-E0_0" index="0" speed="13.89" length="64.48" shape="51.69,14.00 -8.79,13.83"/>
    </edge>
    <edge id="-E00" from="J2" to="J0" priority="-1">
        <lane id="-E00_0" index="0" speed="13.89" length="57.87" shape="-20.00,13.80 -70.66,13.65"/>
    </edge>
    <edge id="E0" from="J0" to="J2" priority="-1">
        <lane id="E0_0" index="0" speed="13.89" length="57.87" shape="-70.66,10.45 -19.99,10.60"/>
    </edge>
    <edge id="E0.57" from="J2" to="J1" priority="-1">
        <lane id="E0.57_0" index="0" speed="13.89" length="64.48" shape="-8.79,10.63 51.69,10.80"/>
    </edge>
    <edge id="E1" from="J2" to="J3" priority="-1">
        <lane id="E1_0" index="0" speed="13.89" length="36.43" shape="-14.37,5.02 -14.29,-24.21"/>
    </edge>

    <tlLogic id="J2" type="static" programID="0" offset="0">
        <phase duration="82" state="GgGGr"/>
        <phase duration="3"  state="yyyyr"/>
        <phase duration="5"  state="rrrrr"/>
    </tlLogic>

    <junction id="J0" type="dead_end" x="-70.66" y="12.05" incLanes="-E00_0" intLanes="" shape="-70.66,12.05 -70.67,15.25 -70.66,12.05"/>
    <junction id="J1" type="dead_end" x="51.69" y="12.40" incLanes="E0.57_0" intLanes="" shape="51.69,12.40 51.70,9.20 51.69,12.40"/>
    <junction id="J2" type="traffic_light" x="-12.79" y="12.22" incLanes="-E0_0 E0_0" intLanes="" shape="-8.80,15.43 -8.78,9.03 -11.00,8.58 -11.78,8.02 -12.33,7.24 -12.66,6.24 -12.77,5.02 -
        <request index="0" response="0000" foes="0000"/>
        <request index="1" response="1100" foes="1100"/>
        <request index="2" response="0000" foes="0010"/>
        <request index="3" response="0000" foes="0010"/>
    </junction>
    <junction id="J3" type="dead_end" x="-12.69" y="-24.21" incLanes="E1_0" intLanes="" shape="-15.89,-24.22 -12.69,-24.21"/>

    <connection from="-E0" to="-E00" fromLane="0" toLane="0" tl="J2" linkIndex="0" dir="s" state="O"/>
    <connection from="-E0" to="E1" fromLane="0" toLane="0" tl="J2" linkIndex="1" dir="l" state="o"/>
    <connection from="E0" to="E1" fromLane="0" toLane="0" tl="J2" linkIndex="2" dir="r" state="O"/>
    <connection from="E0" to="E0.57" fromLane="0" toLane="0" tl="J2" linkIndex="3" dir="s" state="O"/>

</net>
```

Edge

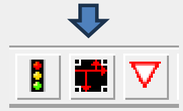


Traffic light

Right of way



Connections between lanes



https://sumo.dlr.de/docs/Networks/SUMO_Road_Networks.html

1. Road Network Development

Define Vehicle Type

Type Distributions

- Distribution Editor
  - New
  - Delete
- Distribution selector
  - td_0
- Internal attributes

id	td_0

Help

- Distribution values

Truck	0.50	✖
Cars	0.50	✖
Σ	1.00	

Types

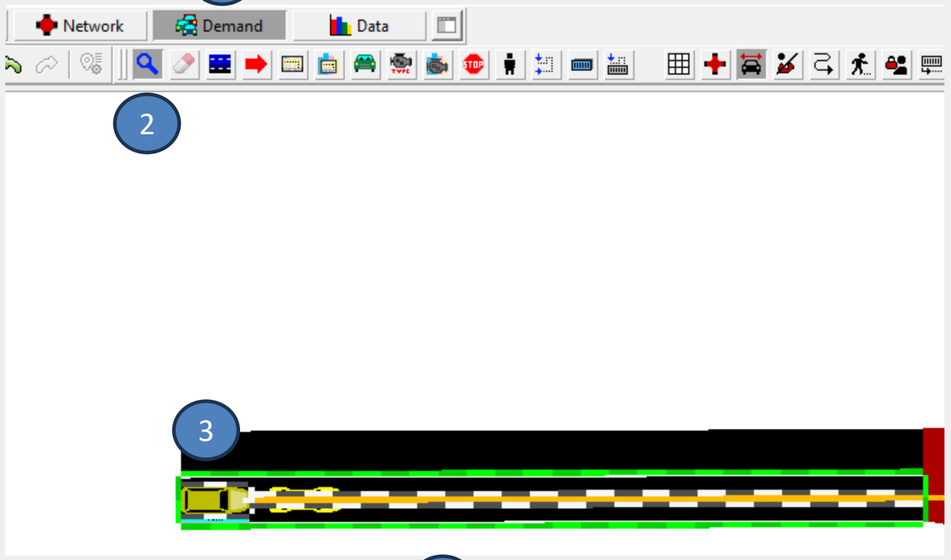
- Type Editor
  - Create Type
  - Delete Type
  - Copy Type
- Current Type
  - Truck
- Internal attributes

id	Truck
typeDist.	td_0
vClass	truck
color	220,219,222
length	7.10
minGap	2.50
maxSpeed	36.11
desiredMaxSpeed	2777.78
parkingBadges	
accel	2.60
decel	4.50
sigma	0.50
tau	1.00

Help

- Extended attributes
  - Open attributes editor

1



4

Vehicle: flow

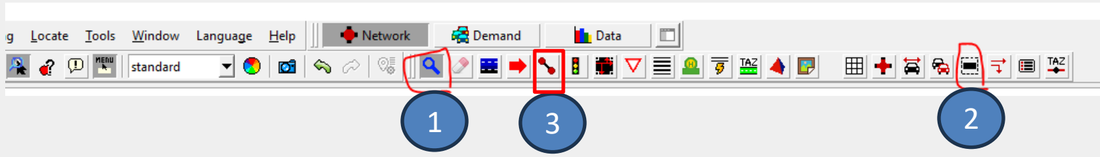
- Internal attributes

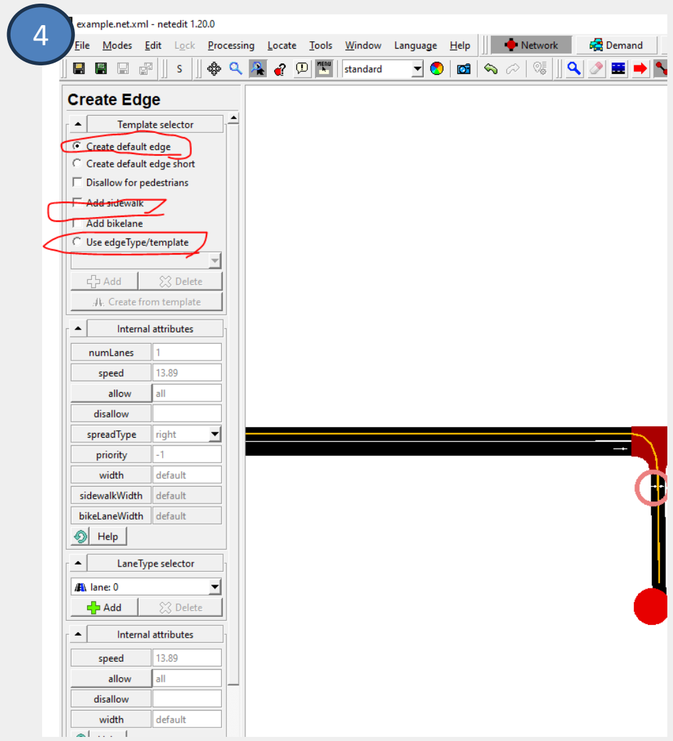
id	f_0
type	td_0
from	E0
to	E0.57
via	

1. Road Network Development

NetEdit Modules (Inspect, Target Lane, Create Sidewalk, Bus Lane, HOV lane)

- ❑ Inspect is very important to edit (1)
- ❑ Target lane is very important (2)
- ❑ In edge mode, you can add edge (another lane), or create template for roads (two lanes highway). (3)
- ❑ In edge mode, you can also create/add Sidewalk, Bus Lane, HOV lane etc. (4)





1. Road Network Development

NetEdit Modules (Compute Junctions, Reset junction shape, Change Width)

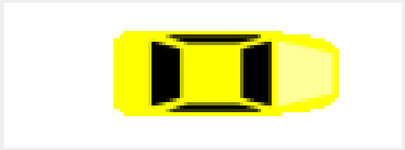
- ❑ Compute Junction = F5
- ❑ Reset Junction Shape
- ❑ Change of Width: Inspect → Target lane → change of width → F5

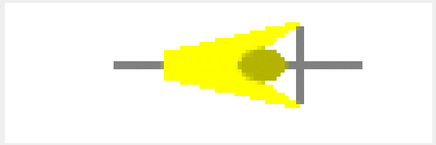
2. Car Following and Lane Changing Models

- Vehicle Characteristics
- Car Following Model Flow Chart
- Vehicle Dynamics
- Vehicle Dynamics Parameter
- Perception and Decision Making Parameters
- Lane Changing Model Flow Chart
- Bicycle Dynamics Parameter
- Scooter Dynamics Parameter

Passenger Car, Bicycle, Scooter

Vehicle Characteristics

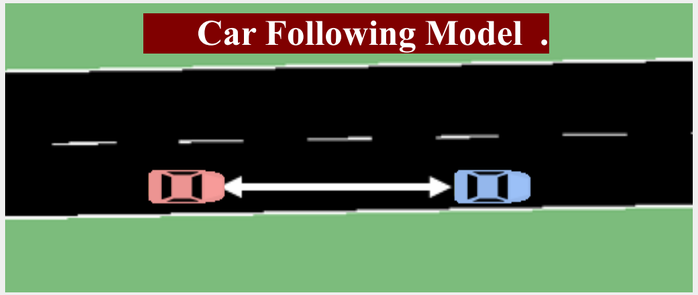




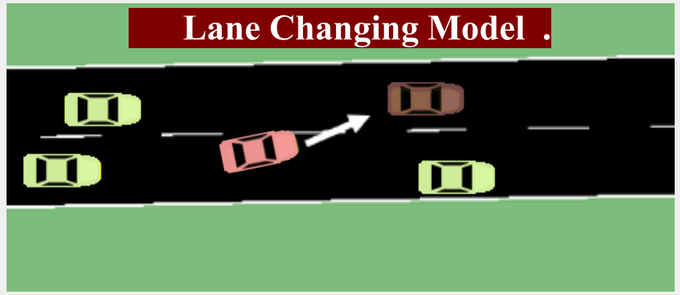
Images found: C:\Program Files (x86)\Eclipse\Sumo\doc\userdoc\images

Car Following and Lane Changing Model

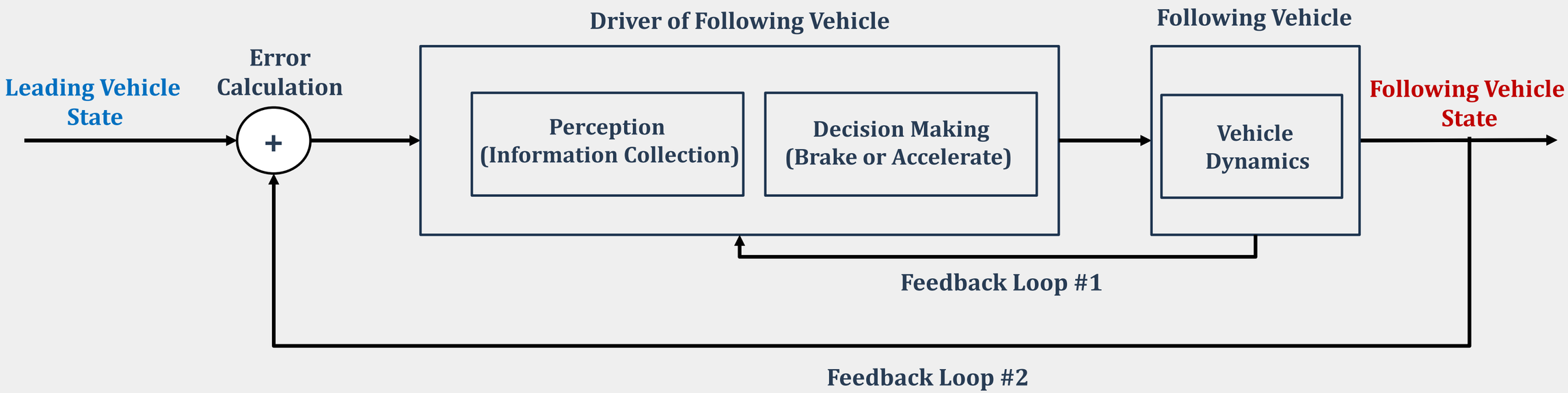
Longitudinal Movement

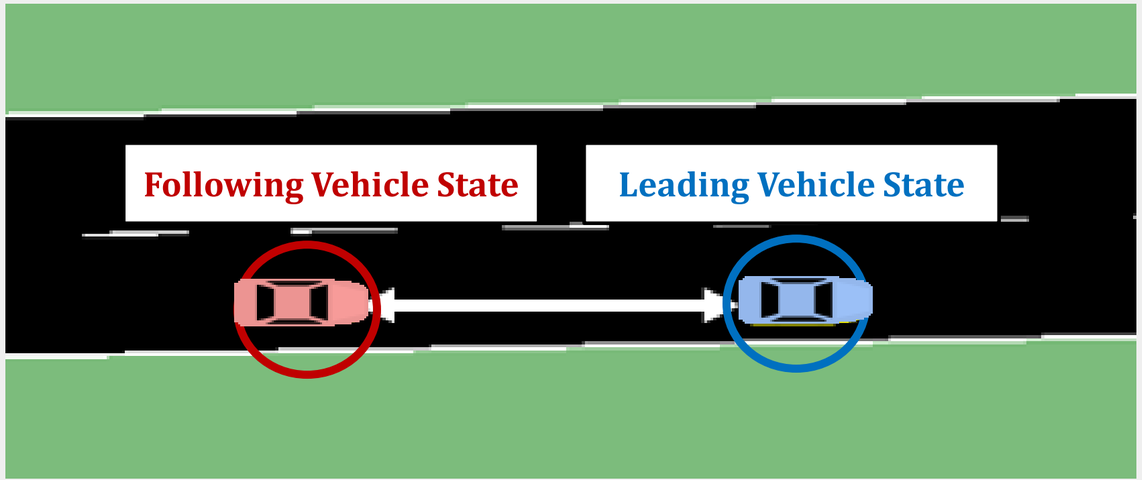


Lateral Movement



Car Following Model Flow Chart





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

Vehicle Dynamics

Vehicle Type attributes

vClass		guiShape	
passenger		passenger	
id	DEFAULT_VEHTYPE	probability	1.00
color	240,236,236,0	personCapacity	4
length	4.60	containerCapacity	0
minGap	2.50	boardingDuration	0.50
maxSpeed	55.56	loadingDuration	90.00
desiredMaxSpeed	2777.78	latAlignment	center
speedFactor	normc(1.00,0.10,0.20,2.00)	minGapLat	0.12
emissionClass	HBEFA3/PC_G_EU4	maxSpeedLat	1.00
width	1.80	actionStepLength	0.00
height	1.60	carriageLength	-1.00
imgFile		locomotiveLength	-1.00
osgFile	car-normal-citrus.obj	carriageGap	1
laneChangeModel	default	Edit parameters	

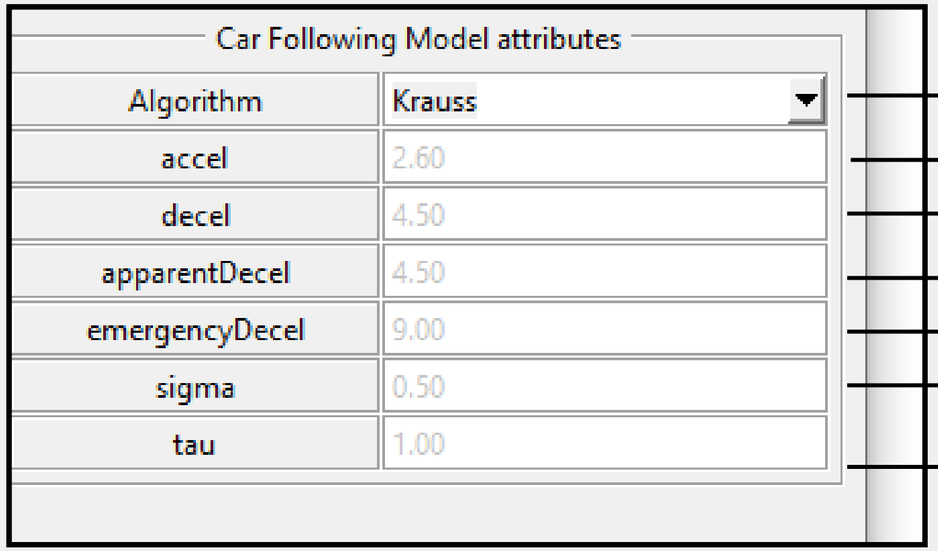
Vehicle Dynamics Parameter

Passenger Cars and Light Delivery

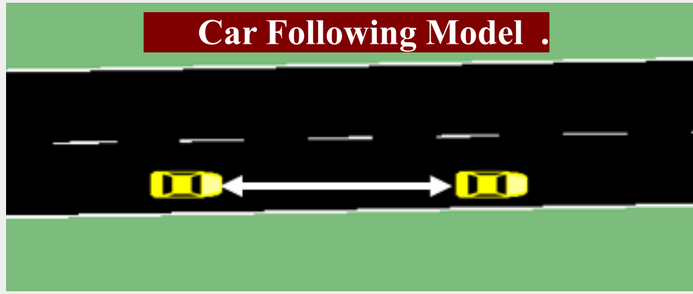
vClass	example	guiShape	length width height	mass	minGap	accel	decel	emergency Decel	maxSpeed	desired MaxSpeed	person Capacity	emission Class HBEFA3	speed Dev
passenger		passenger	5[29] 1.8m[29] 1.5m[29]	1500kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	4	PC_G_EU4	0.1
taxi		taxi	5[29] 1.8m[29] 1.5m[29]	1500kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	4	PC_G_EU4	0.05
evehicle		evehicle	5[29] 1.8m[29] 1.5m[29]	1500kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	4	zero	0.1
emergency		emergency	6.5m[37] 2.16m[37] 2.86m[37]	5000kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	3	LDV	0
delivery		delivery	6.5m[37] 2.16m[37] 2.86m[37]	5000kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	3	LDV	0.05

https://sumo.dlr.de/docs/Vehicle_Type_Parameter_Defaults.html

Perception and Decision Making Parameters



- **Algorithm Type**
- **The maximum acceleration a vehicle can apply (in m/s^2)**
- **The maximum deceleration a vehicle can apply (in m/s^2).**
- **The braking deceleration (in m/s^2) of leading vehicle perceived by following vehicles**
- **The maximum deceleration ability of vehicles of this type in case of emergency (in m/s^2)**
- **The driver imperfection (0 denotes perfect driving, 0.5 human like reaction, 0.7-1 aggressive driving))**
- **The driver's desired (minimum) time headway.**



https://sumo.dlr.de/docs/Definition_of_Vehicles%2C_Vehicle_Types%2C_and_Routes.html#car-following_model_parameters

Car Following Model Equation

1. **Safe Speed Calculation**

$$v_{\text{safe}}(t) = v_1(t) + \frac{g(t) - g_{\text{des}}(t)}{\tau_b + \tau}$$

- Computes the **safe speed** based on the lead vehicle's speed $v_1(t)$, the gap $g(t)$, and the desired gap $g_{\text{des}}(t)$.
- The denominator $\tau_b + \tau$ includes:
  - $\tau_b = \frac{\bar{v}}{b}$: Braking time scale.
  - τ: Driver reaction time.

2. **Desired Speed Calculation**

$$v_{\text{des}}(t) = \min[v_{\max}, v(t) + a(v)\Delta t, v_{\text{safe}}(t)]$$

- The desired speed at time t is the **minimum** of:
  - $v_{\max}$ (maximum speed limit).
  - $v(t) + a(v)\Delta t$ (current speed plus acceleration over time step Δt).
  - $v_{\text{safe}}(t)$ (computed safe speed).

3. **Final Speed Update**

$$v(t + \Delta t) = \max[0, v_{\text{des}}(t) - \eta]$$

- The new speed at the next time step is **desired speed minus random fluctuation** η (which accounts for human driving imperfections).
- Ensures the speed is **never negative**.

4. **Position Update**

$$x(t + \Delta t) = x(t) + v\Delta t$$

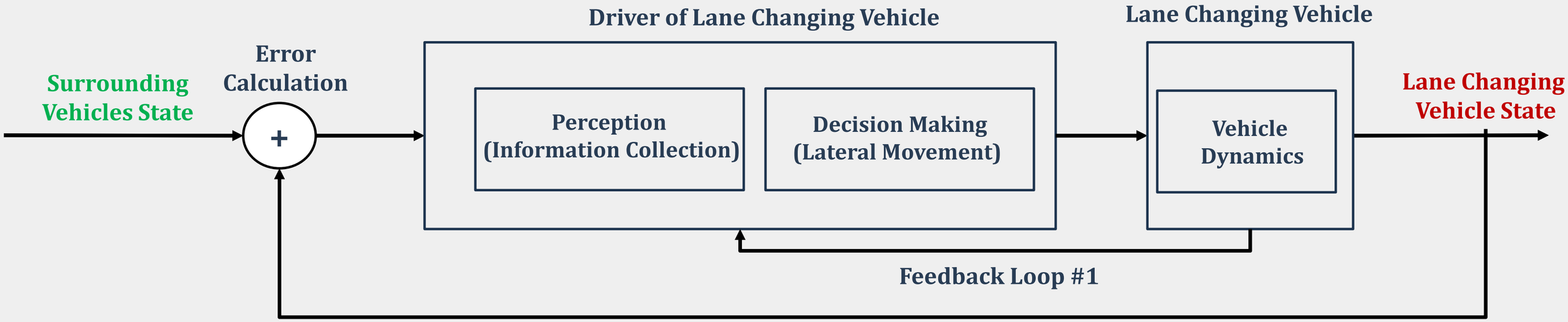
- The vehicle's **new position** is updated using **the new speed**.

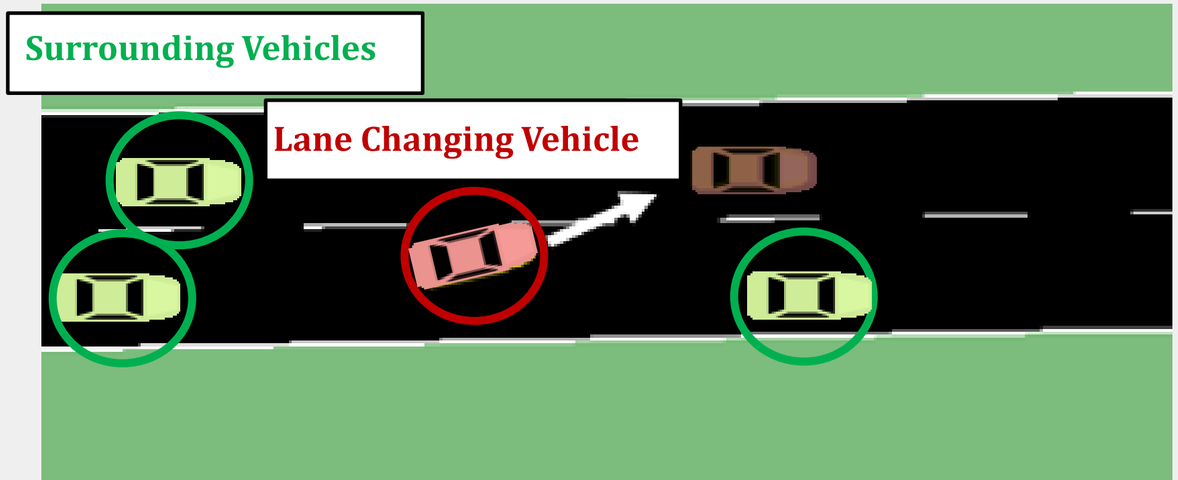
Table of Parameters in the Krauss Model

Parameter	Symbol	Description
Current speed	$v(t)$	Speed of the vehicle at time t.
Safe speed	$v_{\text{safe}}(t)$	Speed ensuring no collision with the lead vehicle.
Desired speed	$v_{\text{des}}(t)$	Speed constrained by acceleration, max speed, and safety.
Lead vehicle speed	$v_1(t)$	Speed of the vehicle in front.
Acceleration function	$a(v)$	Function defining acceleration behavior.
Maximum speed	$v_{\max}$	The vehicle's maximum allowed speed.
Time step	Δt	Simulation step size.
Gap	$g(t)$	Distance between the following and leading vehicles.
Desired gap	$g_{\text{des}}(t)$	Preferred safe following distance.
Reaction time	τ	Driver's reaction time.
Braking time scale	τ_b	Defined as $\tau_b = \frac{\bar{v}}{b}$, where $\bar{v}$ is average speed and b is braking deceleration.
Random perturbation	η	A noise term to simulate random driving behavior (imperfections, delays, etc.).

Reference:
Krauß, S. (1998). Microscopic modeling of traffic flow: Investigation of collision free vehicle dynamics. https://sumo.dlr.de/pdf/KraussDiss.pdf

Lane Changing Model Flow Chart





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

Vehicle Dynamics Parameter

Passenger Cars and Light Delivery

vClass	example	guiShape	length width height	mass	minGap	accel	decel	emergency Decel	maxSpeed	desired MaxSpeed	person Capacity	emission Class HBEFA3	speed Dev
passenger		passenger	5[29] 1.8m[29] 1.5m[29]	1500kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	4	PC_G_EU4	0.1
taxi		taxi	5[29] 1.8m[29] 1.5m[29]	1500kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	4	PC_G_EU4	0.05
evehicle		evehicle	5[29] 1.8m[29] 1.5m[29]	1500kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	4	zero	0.1
emergency		emergency	6.5m[37] 2.16m[37] 2.86m[37]	5000kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	3	LDV	0
delivery		delivery	6.5m[37] 2.16m[37] 2.86m[37]	5000kg	2.5m	2.6m/s²[29]	4.5m/s²[27]	9m/s²	200km/h[29]	-	3	LDV	0.05

https://sumo.dlr.de/docs/Vehicle_Type_Parameter_Defaults.html

Perception and Decision Making Parameters

Lane Change Model attributes

strategic	1.0
cooperative	1.0
speedGain	1.0
keepRight	1.0
sublane	1.0
opposite	1.0
pushy	0.00
pushyGap	0.00
assertive	1.0
impatience	0.00
timeToImpatience	infinity
accelLat	1.0
lookaheadLeft	2.0
speedGainRight	0.1
maxSpeedLatStanding	0.00
maxSpeedLatFactor	1.00
turnAlignDistance	0.00
overtakeRight	0.00
keepRightAcceptanceTime	-1
overtakeDeltaSpeedFactor	0.00

→ **The eagerness for performing strategic lane changing. Higher values result in earlier lane-changing**

→ **The willingness for performing cooperative lane changing. Lower values result in reduced cooperation**

→ **The eagerness for performing lane changing to gain speed. Higher values result in more lane-changing.**

→ **The eagerness for following the obligation to keep right. Higher values result in earlier lane-changing**

For Complete Definition: :
https://sumo.dlr.de/docs/Definition_of_Vehicles%2C_Vehicle_Types%2C_and_Routes.html#car-following_model_parameters

Seven Steps in Microsimulation Modeling

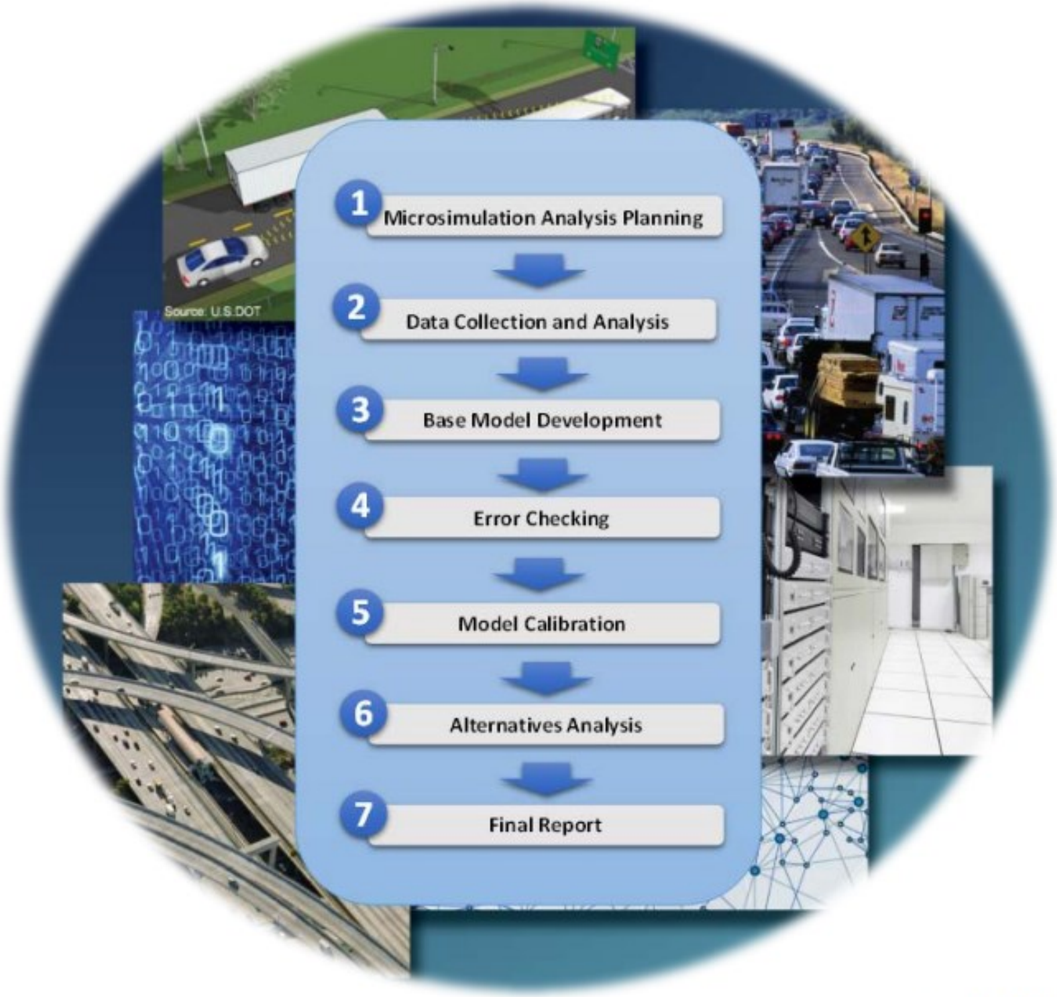
Step2 Data Collection requires:

- ❑ Vehicle Characteristics Data – Vehicle Dynamics
- ❑ Driver Characteristics Data – Car Following and Lane Changing Models

Reference link:
https://ops.fhwa.dot.gov/publications/fhwahop18036/fhwahop18036.pdf

Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software

2019 Update to the 2004 Version



April 2019

U.S. Department of Transportation
Federal Highway Administration

Seven Steps in Microsimulation Modeling

Junction Model attributes

crossingGap	10	ignoreFoeProb	0.0
ignoreKeepClearTime	-1	ignoreFoeSpeed	0.0
driveAfterYellowTime	-1	sigmaMinor	0.0
driveAfterRedTime	-1	timegapMinor	1
driveRedSpeed	0.0	impatience	0.0

SUMO's Road Intersection Model

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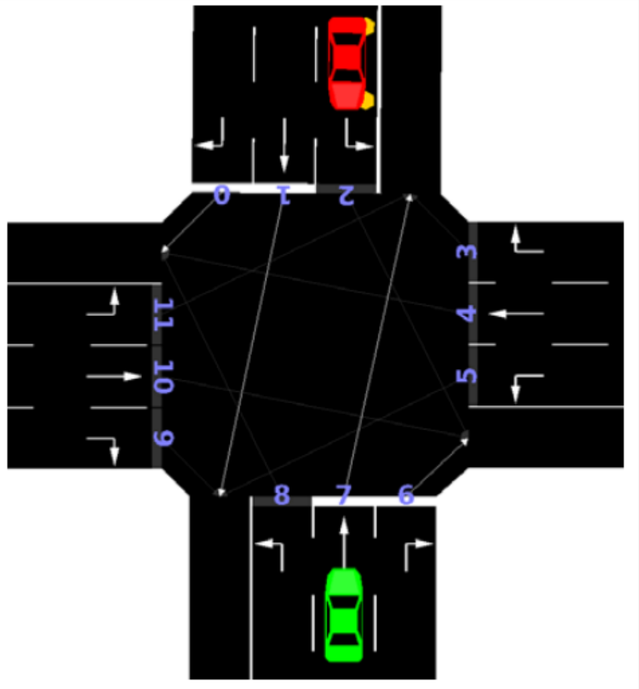
Abstract. Besides basic models for longitudinal and lateral movement, a traffic simulation needs also models and algorithms for right-of-way rules. This publication describes how passing an intersection is modeled within SUMO, including a description of an earlier and the currently used model.

Keywords: Road Traffic Simulation, Intersection Model.



Reference link:

https://sumo.dlr.de/docs/Definition_of_Vehicles%2C_Vehicle_Types%2C_and_Routes.html#junction_model_parameters

https://elib.dlr.de/93669/1/LNCS_SUMOIntersections.pdf
https://sumo.dlr.de/docs/Simulation/Intersections.html

References

Erdmann, J. (2015). SUMO's lane-changing model. In *Modeling Mobility with Open Data: 2nd SUMO Conference 2014 Berlin, Germany, May 15-16, 2014* (pp. 105-123). Springer International Publishing.

Krauß, S. (1998). Microscopic modeling of traffic flow: Investigation of collision free vehicle dynamics.

Krajzewicz, D., & Erdmann, J. (2013, May). Road intersection model in SUMO. In *1st SUMO User Conference-SUMO 2013* (Vol. 21, pp. 212-220). DLR.

Salles, D., Kaufmann, S., & Reuss, H. C. (2020). Extending the intelligent driver model in SUMO and verifying the drive off trajectories with aerial measurements. In *SUMO Conference Proceedings* (Vol. 1, pp. 1-25).

→ Lane Changing Model – LC2013

→ Car Following Model - Krauss

→ Junction Model

→ Intelligent Lane Model

Bicycle Dynamics Parameter

Pedestrians and Two-Wheelers

vClass	example	guiShape	length width height	mass	minGap	accel	decel	emergency Decel	maxSpeed	desired MaxSpeed	person Capacity	emission Class HBEFA3	speed Dev
pedestrian		pedestrian	0.215m[1] 0.478m[1] 1.719m[1]	70kg	0.25m	1.5m/s²[23]	2m/s²[23]	5m/s²	37.58km/h[41]	5km/h[23]	0	zero	0.1
bicycle		bicycle	1.6m[17] 0.65m[17] 1.7m[*]	10kg	0.5m	1.2m/s²[19]	3m/s²[19]	7m/s²	50km/h	20km/h[19]	1	zero	0.1
moped		moped	2.1m[43] 0.8m[43] 1.7m[*]	80kg	2.5m	1.1m/s²[25]	7m/s²[26]	10m/s²	45km/h[24]	-	2	LDV_G_EU6	0.1
motorcycle		motorcycle	2.2m[28] 0.9m[28] 1.5m[28]	200kg	2.5m	6m/s²[19]	10m/s²[27]	10m/s²	200km/h[28]	-	2	LDV_G_EU6	0.1
scooter		scooter	1.2m[*] 0.5m[*] 1.7m[*]	10kg[*]	0.5m[39]	1.2m/s²[39]	3m/s²[39]	7m/s²[*]	25km/h[39]	20km/h	1	zero	0.1

https://sumo.dlr.de/docs/Vehicle_Type_Parameter_Defaults.html

Bicycle Dynamics Parameter

Useful Model Parameters

Once the vClass "bicycle" is chosen, the following parameters, which can still be customized, are set for bicycle:

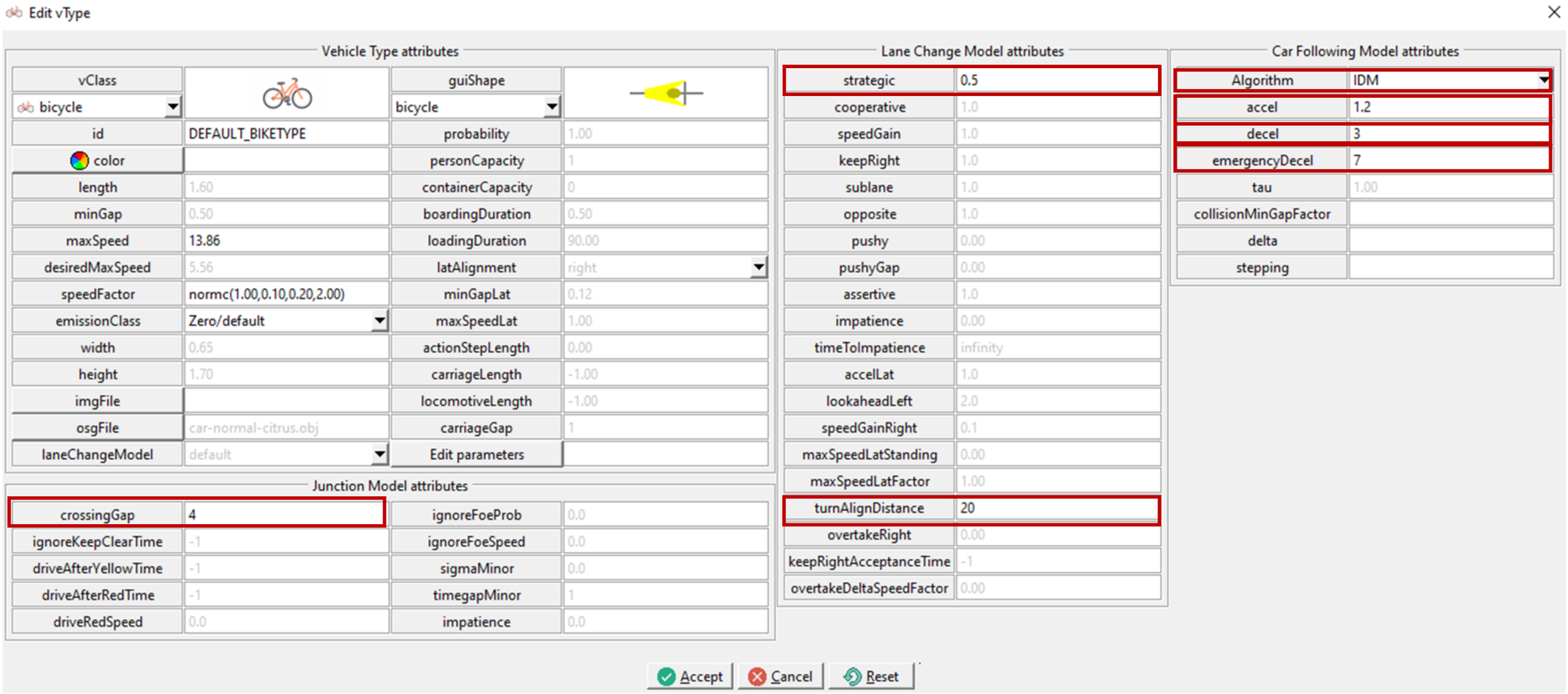
- minGap = 0.5 m
- max. acceleration = 1.2 m/s^2
- max. deceleration = 3 m/s^2
- emergency deceleration = 7 m/s^2
- Length = 1.6 m
- max speed = 20 kmh where you can modify it by defining vClass specific speed limit (see the point in the Problems and workarounds below)

The values of some other parameters for bicycles are different from those for vehicles apparently. If no real data for the respective calibrations is available, some intuitive suggestions are listed below for reference.

- latAlignment = "right" (cyclists ride on the right side of their lane)
- carFollowModel = IDM (if smoothed acceleration is desired)
- lcStrategic = 0.5 (in comparison to the default value (1) this setting makes bicycles to perform strategic lane changing later)
- lcCooperativeRoundabout = 0. (cyclists keep on the right lane in a multi-lane roundabout)
- lcTurnAlignmentDistance = 20. (distance to a location where bicycles start to keeping right/left of their lane for preparing to make turns)
- jmCrossingGap = 4 (Minimum distance to pedestrians that are walking towards the conflict point with a bike - lower than the default of 10 for cars)
- jmSigmaMinor = 0. (no imperfection while passing a minor link)
- jmStoplineGap = 0.5 (Stopping distance in front of prioritary / TL-controlled stop line)

https://sumo.dlr.de/docs/Simulation/Bicycles.html

Perception and Decision-Making Parameters



Scooter Dynamics Parameter

Pedestrians and Two-Wheelers

vClass	example	guiShape	length width height	mass	minGap	accel	decel	emergency Decel	maxSpeed	desired MaxSpeed	person Capacity	emission Class HBEFA3	speed Dev
pedestrian		pedestrian	0.215m(1) 0.478m(1) 1.719m(1)	70kg	0.25m	1.5m/s²(23)	2m/s²(23)	5m/s²	37.58km/h(41)	5km/h(23)	0	zero	0.1
bicycle		bicycle	1.6m(17) 0.65m(17) 1.7m(*)	10kg	0.5m	1.2m/s²(19)	3m/s²(19)	7m/s²	50km/h	20km/h(19)	1	zero	0.1
moped		moped	2.1m(43) 0.8m(43) 1.7m(*)	80kg	2.5m	1.1m/s²(25)	7m/s²(26)	10m/s²	45km/h(24)	-	2	LDV_G_EU6	0.1
motorcycle		motorcycle	2.2m(28) 0.9m(28) 1.5m(28)	200kg	2.5m	6m/s²(19)	10m/s²(27)	10m/s²	200km/h(28)	-	2	LDV_G_EU6	0.1
scooter		scooter	1.2m(*) 0.5m(*) 1.7m(*)	10kg(*)	0.5m(39)	1.2m/s²(39)	3m/s²(39)	7m/s²(*)	25km/h(39)	20km/h	1	zero	0.1

https://sumo.dlr.de/docs/Vehicle_Type_Parameter_Defaults.html

Perception and Decision-Making Parameters