

RWR 4015

Traffic Simulation for Planning Applications

Dr. Ahmad Mohammadi

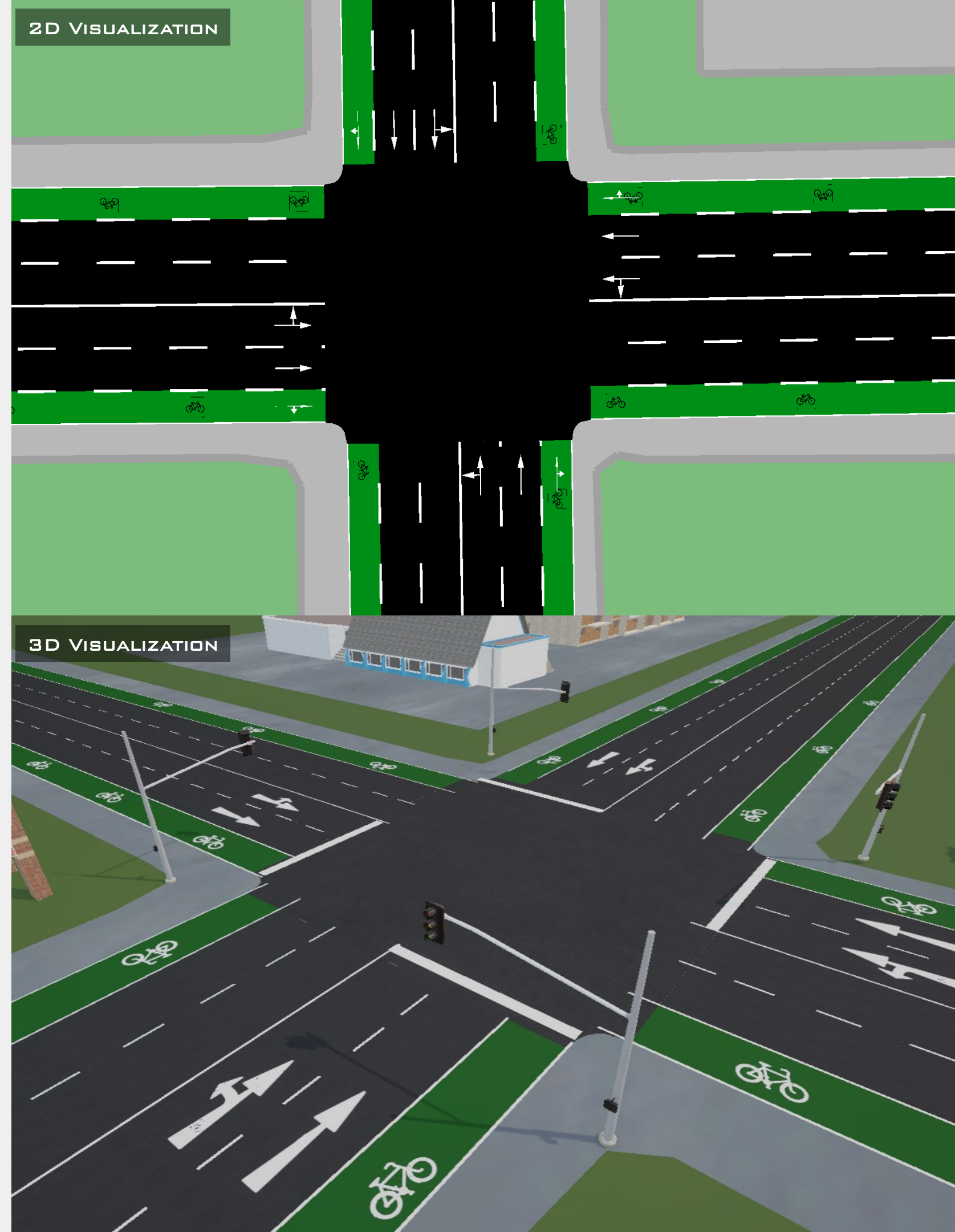
Week 7 | Hands-on:
Environmental Analysis in Simulation
(Energy, Emissions, EVs)

Fall 2026

RoadwayVR



roadwayvr.github.io/TrafficSimulationforPlanningApplications



Agenda

- ❑ **Energy Consumption and Emission Model (HBEFA Model)**
- ❑ **Emission Models in Simulation**
- ❑ **Environmental Analysis in Simulation**
- ❑ **Develop Mixed Traffic Planning Strategies of EVs and ICE in Simulation**
- ❑ **Analyze Environmental Impacts of Different Scenarios**



HBEFA Model

- ❑ Includes a wide range of vehicle categories (passenger cars, light-duty vehicles, heavy duty vehicles, buses, motorcycles),
- ❑ Different fuel types, and pollutants (CO₂, NO_x, HC, PM, etc.)



The Handbook of Emission Factors for Road Transport

GET THE HANDBOOK



Emission Models in Simulation

Emissions

Introduction

SUMO includes the following emission models:

- **HBEFA v2.1-based**: A continuous reformulation of the [HBEFA](#) v2.1 emissions data base (open source);
- **HBEFA v3.1-based**: A continuous reformulation of the [HBEFA](#) v3.1 emissions data base (open source);
- **HBEFA v4.2-based**: A continuous reformulation of the [HBEFA](#) v4.2 emissions data base (open source);
- **PHEMlight**, a derivation of the original [PHEM](#) emission model (model is open source, but full data sets are only commercially available);
- **PHEMlight5**, the V5 version of PHEMlight supporting deterioration emission model (model is open source, but full data sets are only commercially available);
- **Electric Vehicle Model**: an electricity-consumption model by Kurczveil, T., López, P.A., Schnieder.
- **MMP Electric Vehicle Model**: an electricity-consumption model by Kevin Badalian from Teaching and Research Area Mechatronics in Mobile Propulsion (MMP), RWTH Aachen University.

Literature on the Models and their implementation can be found at [the DLR electronic library \(https://elib.dlr.de/89398/\)](https://elib.dlr.de/89398/).



HBEFA Model in Simulation

Good news is → We only Assign Emission Class in SUMO → It Automatically calculate energy and Emission based on:

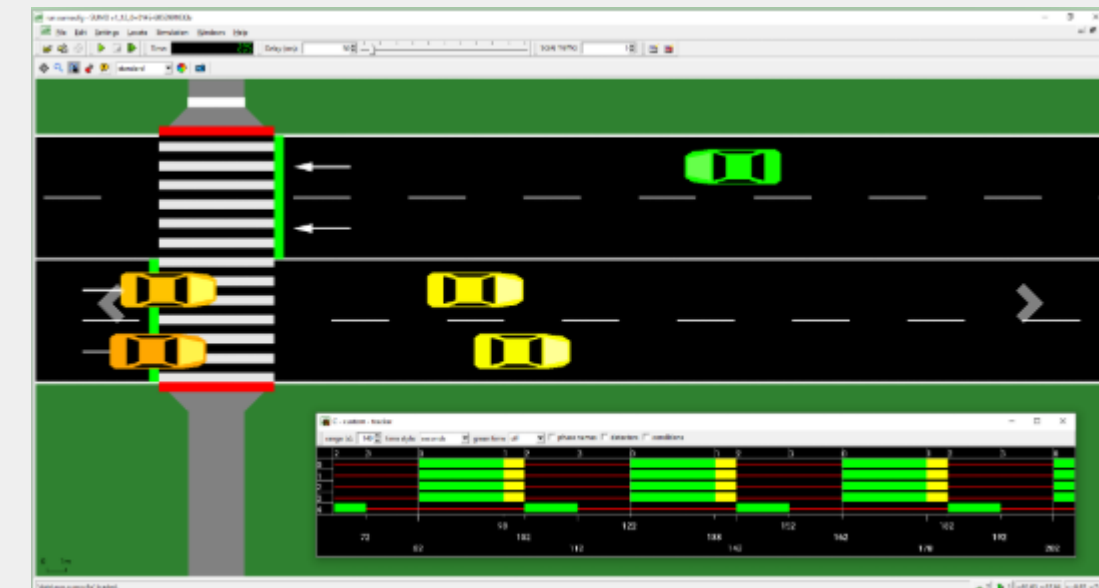
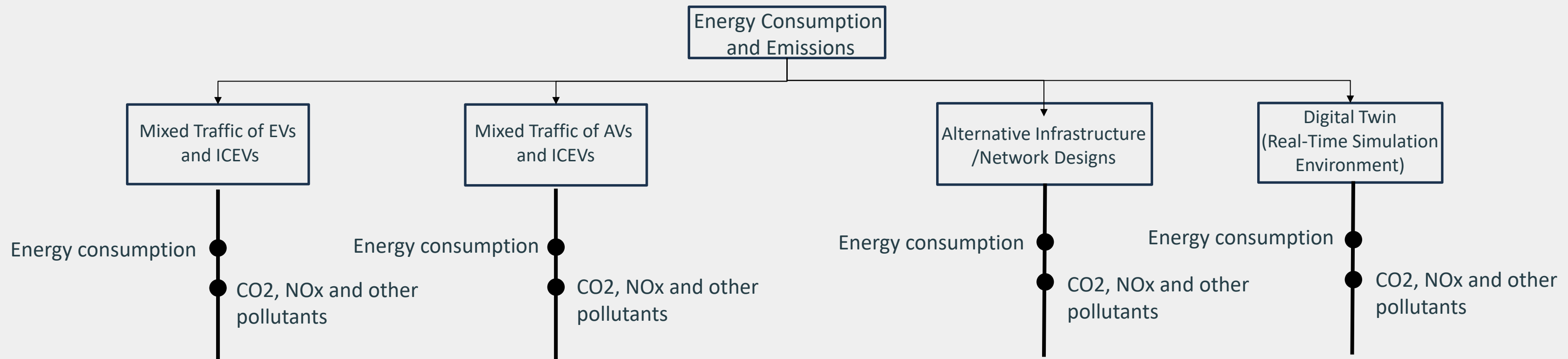
Parameter	Description	Influence
Speed	Instantaneous vehicle speed	Major factor — emission curves are speed-dependent
Acceleration / Deceleration	Rate of speed change	Impacts NO _x , HC, CO, and fuel use heavily
Vehicle Weight / Mass	From <code>weight</code> or <code>mass</code> parameter (optional override)	Affects energy demand, fuel consumption, uphill power
Road Gradient (slope)	Optional if elevation data is provided in the network	Increases or decreases energy/fuel use
Traffic dynamics	Stop-go cycles, queueing, idling, etc.	Affects emissions indirectly through speed profiles

HBEFA Model in SUMO Simulation

What each string encodes

- `HBEFA3/PC_G_EU4`
 - **Dataset/version:** HBEFA 3.x (what SUMO calls “HBEFA3.1”)
 - **Vehicle:** Passenger Car (**PC**), **Gasoline**
 - **Standard:** **EU4** (Euro 4 \approx mid-2000s tech)
- `HBEFA4/PC_petro1_Euro-6d`
 - **Dataset/version:** HBEFA 4.x (e.g., 4.1/4.2)
 - **Vehicle:** Passenger Car (**PC**), **petrol**
 - **Standard:** **Euro-6d** (latest Euro 6 stage with RDE/PEMS compliance, \approx 2020s tech)

Environmental Analysis in Simulation




Develop Mixed Traffic Planning Strategies of EVs and ICE in Simulation

Vehicle Type	Powertrain	Driving Type	Included in Study?	Notes
ICEV	Gasoline	Human-driven	✓	Baseline reference
BEV	Electric	Human-driven	✓	Present-day EVs
BEAV	Electric	Autonomous	✓	Future autonomous EVs



Goal: How they reduce energy consumption and emissions at a complex intersection


Transportation Research Part D 136 (2024) 104403




Contents lists available at [ScienceDirect](#)

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd





Energy savings and emissions reduction of BEVs at an isolated complex intersection[☆]

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ARTICLE INFO

Keywords:

Intersection management
Battery electric vehicles
Internal combustion engine
Human-driver control
Autonomous control
Energy savings
Emissions reduction

ABSTRACT

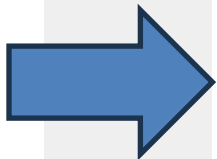
Improving urban dwellers quality of life requires mitigating traffic congestion, minimizing waiting delays, and reducing fuel wastage and associated toxic air pollutants. Battery-electric vehicles (BEVs) are envisioned as the best option, thanks to zero exhaust emissions and regenerative braking. BEVs can be human-driven or autonomous and will co-exist with internal combustion engine vehicles (ICEVs) for years. BEVs can help at complex intersections where traffic is saturated. However, their benefits can be reduced by poor intersection management (IM) strategies that coordinate mixed traffic configurations inefficiently. This paper studies energy savings and emissions reduction using BEVs mixed with human-driven ICEVs under

Reddy, R., Almeida, L., Santos, P. M., Kurunathan, H., & Tovar, E. (2024). Energy savings and emissions reduction of BEVs at an isolated complex intersection. Transportation Research Part D: Transport and Environment, 136, 104403.

Develop Mixed Traffic Planning Strategies of EVs and ICE in Simulation

Table 3
Parameters specific for BEVs/BEAVs.

Parameters	Values
Max. battery capacity	64 kWh
Max. power	150 kW
Constant power intake	100 W
Internal moment of inertia	0.01 Kg m ²
Air drag coefficient	0.35
Radial drag coefficient	0.5
Roll drag coefficient	0.01
Propulsion efficiency	0.98
Recuperation efficiency	0.96
Stopping threshold	0.1 km/h



key	Value Type	Default	Description
device.battery.capacity	float	35000 (Wh)	Maximum battery capacity E_{max}
maximumPower	float	150000 (W)	Maximum power which the vehicle can reach (unused)
vehicleMass	float	1830 (kg)	Vehicle mass m_{veh} (deprecated)
loading	float	0 (kg)	Additional mass (to be defined in the vehicle type)
frontSurfaceArea	float	2.6 (m ²)	Front surface area A_{veh}
airDragCoefficient	float	0.35	Air drag coefficient c_w
rotatingMass	float	40 (kg)	(Equivalent) mass of internal rotating elements
radialDragCoefficient	float	0.1	Radial drag coefficient c_{rad}
rollDragCoefficient	float	0.01	Rolling resistance coefficient c_{roll}
constantPowerIntake	float	100 (W)	Avg. (constant) power of consumers P_{const}
propulsionEfficiency	float	0.98	Drive efficiency η_{prop}
recuperationEfficiency	float	0.96	Recuperation efficiency η_{recup}
stoppingThreshold	float	0.1 (m/s)	Maximum velocity to start charging
device.battery.maximumChargeRate	float	150000 (W)	Maximum charging rate of the battery
device.battery.chargeLevelTable	float list		Ordered list of state of charge values (from 0 to 1) for which maximum charge rates are defined in <code>device.battery.chargeCurveTable</code>
device.battery.chargeCurveTable	float list		Corresponding maximum charge rates to each state of charge value in <code>device.battery.chargeLevelTable</code>

https://sumo.dlr.de/docs/Models/Electric.html#emission_output

Develop Mixed Traffic Planning Strategies of EVs and ICE in Simulation

“has.battery.device” value=“true”

“device.battery.capacity” value=“64000”

“maximumPower” value=“150000”

constantPowerIntake” value=“100”

airDragCoefficient” value=“0.35”

rollDragCoefficient” value=“0.01”

propulsionEfficiency” value=“0.98”

recuperationEfficiency” value=“0.96”

Develop Mixed Traffic Planning Strategies of EVs and ICE in Simulation

Types

Type Editor

Create Type

Delete Type

Copy Type

Current Type

EV

Attributes

id	EV
typeDist.	
vClass	evehicle
color	
length	5.00
minGap	2.50
maxSpeed	55.56
desiredMaxSpeed	2777.78
parkingBadges	
accel	2.60
decel	4.50
sigma	0.50
tau	1.00

Help

Extended attributes

Edit extended attributes

Edit vType

Vehicle Type attributes

vClass	evehicle	guiShape	
id	EV	probability	1.00
color		personCapacity	4
length	5.00	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	Zero/default	maxSpeedLat	1.00
width	1.80	actionStepLength	0.00
height	1.50	carriageLength	-1.00
imgFile		propulsiveLength	-1.00
osgFile	car-normal-citrus.obj	carriageGap	1
laneChangeModel	default		

2 Edit parameters

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

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	
epRightAcceptanceTime	
overtakeDeltaSpeedFactor	

Car Following Model attributes

Algorithm	Krauss
accel	2.60
decel	4.50
apparentDecel	4.50
emergencyDecel	9.00
sigma	0.50
tau	1.00

3 Edit parameters

key	value
has.battery.device	true

Operations

Sort

Clear

Load

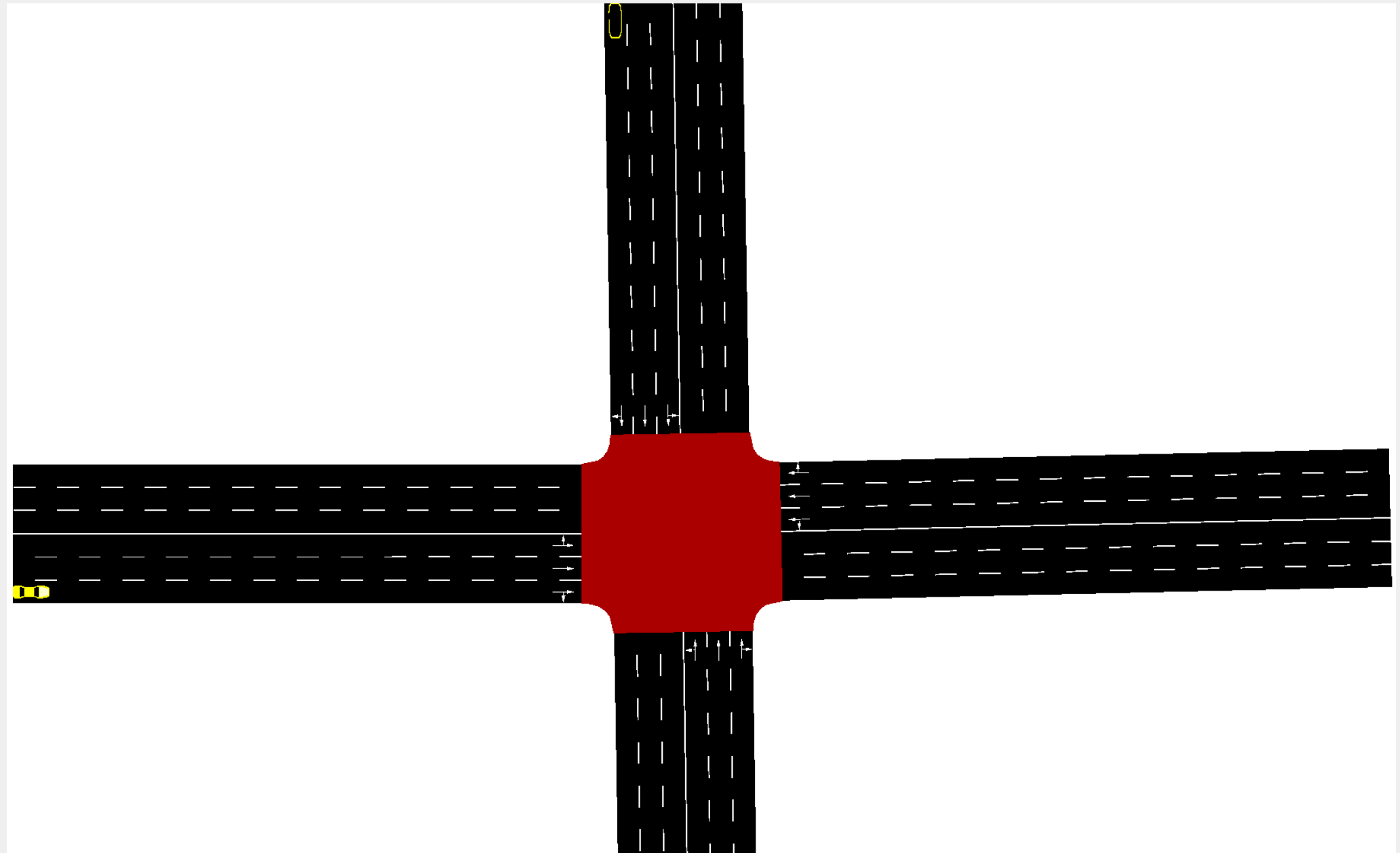
Save

Help

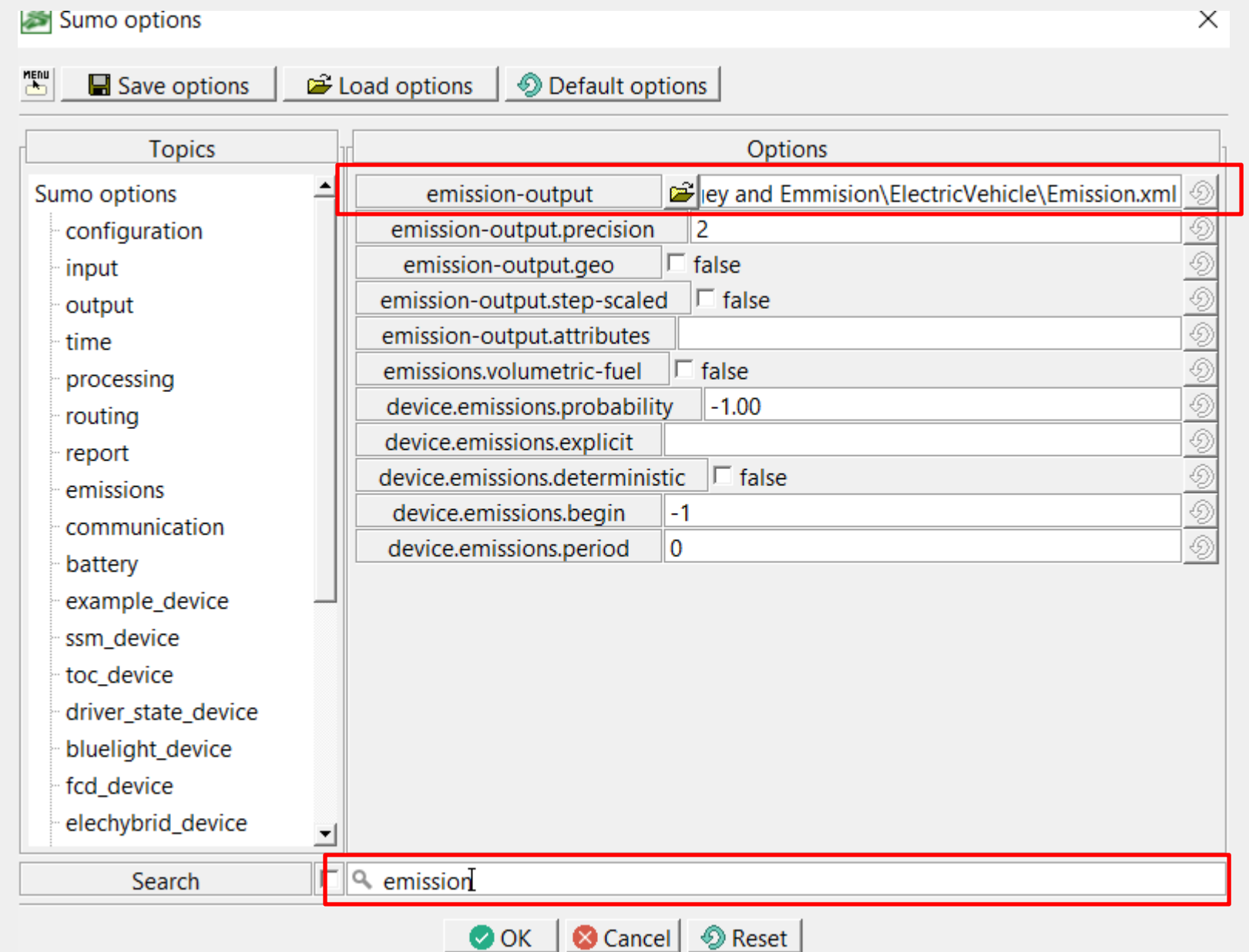
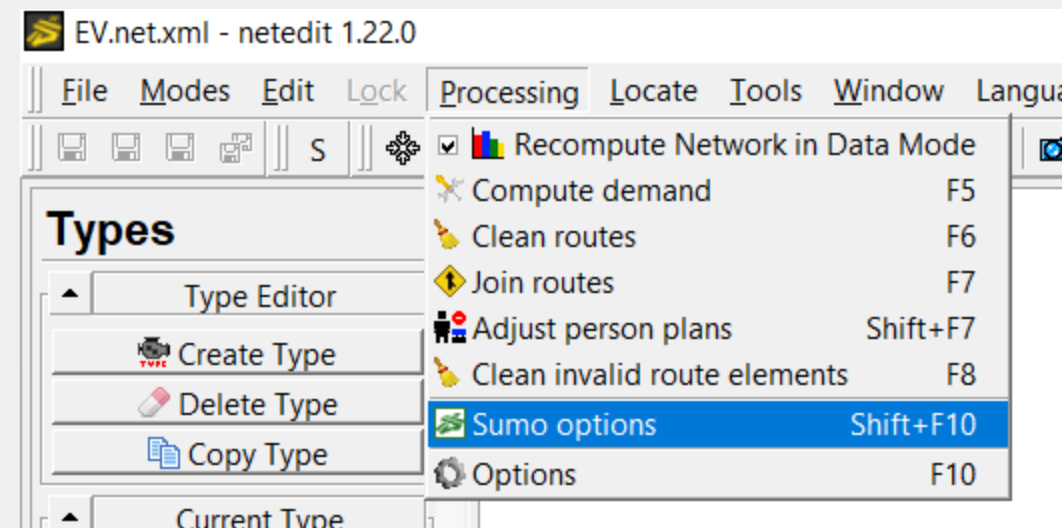
accept cancel reset

Develop Mixed Traffic Planning Strategies of EVs and ICE in Simulation

- ☐ Create an Intersection
- ☐ Add one Combustion Vehicle
- ☐ Add one Electric Vehicle
- ☐ Save SUMO Files



Analyze Environmental Impacts



Analyze Environmental Impacts

t_0 is Combustion Engine Vehicle
t_1 is Electric Vehicle

mg of CO2/CO/HC/NOx/PMx produced in
this 1-second step

mg of fuel consumed in this 1-second step

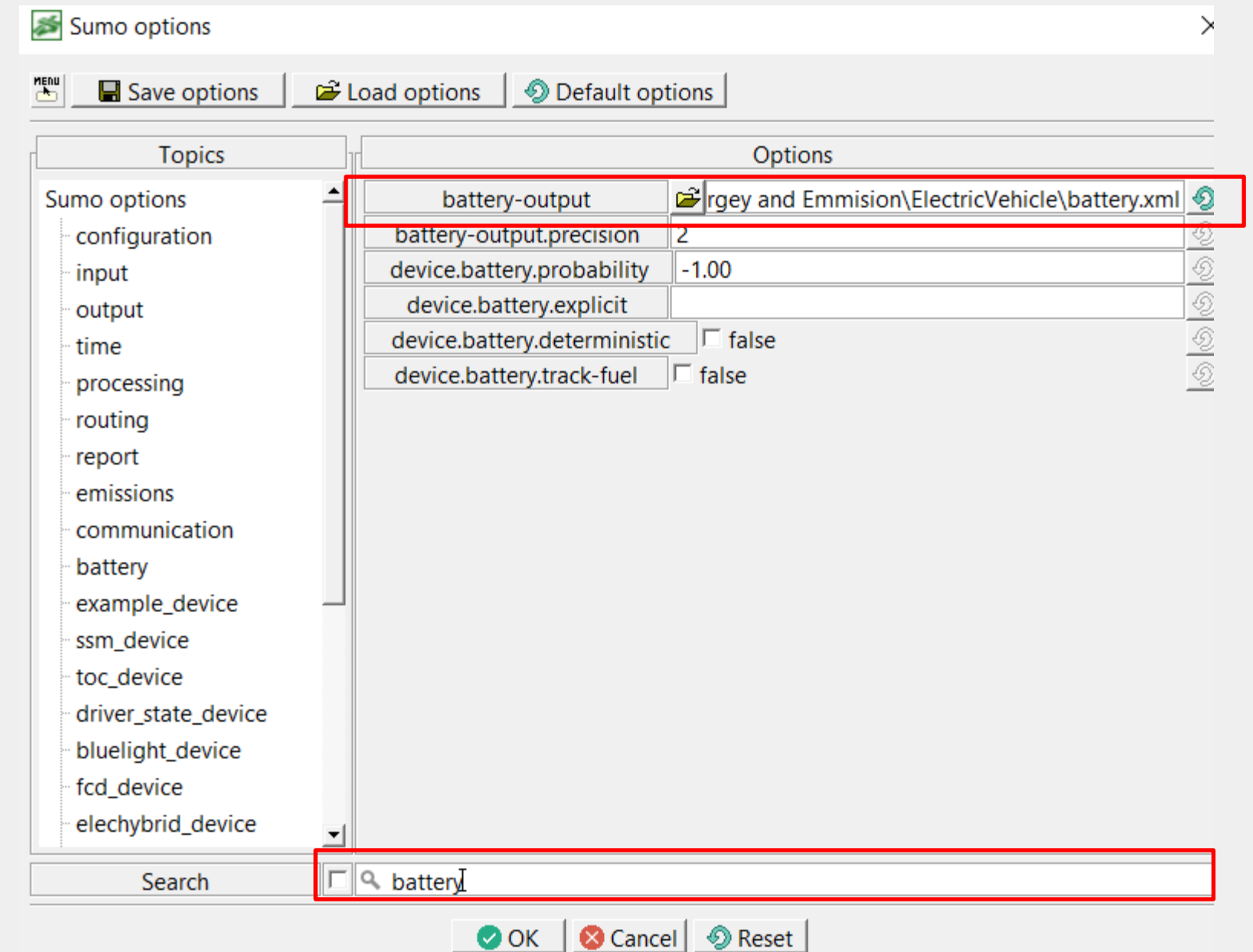
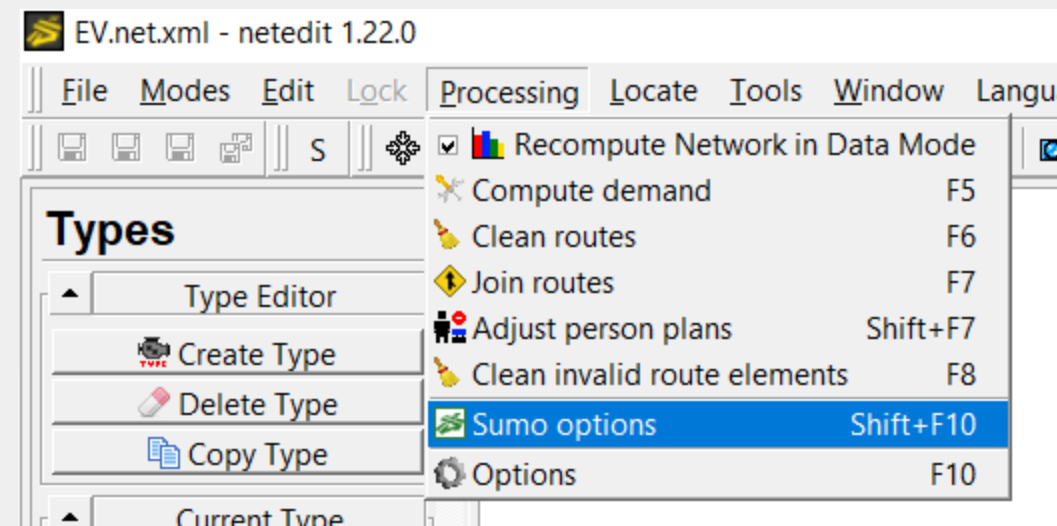


```
<timestep time="1.00">
  <vehicle id="t_0" eclass="HBEFA3/PC_G_EU4" CO2="3089.80" CO="147.47" HC="0.74" NOx="1.38" PMx="0.07" fuel="985.55"
  <vehicle id="t_1" eclass="Energy/default" CO2="0.00" CO="0.00" HC="0.00" NOx="0.00" PMx="0.00" fuel="0.00" electric
</timestep>
```

```
<vehicle id="t_0" electricity="0.00" noise="63.49" route="!t_0" type="DEFAULT_VEHTYPE" waiting="0.00"
<vehicle id="t_1" electricity="1.40" noise="66.38" route="!t_1" type="EV" waiting="0.00" lane="-E6_0"
```

Wh consumed in this 1-second step.

Analyze Environmental Impacts



Analyze Environmental Impacts

```
<battery-export xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/battery_file.xsd">
  <timestep time="0.00">
    <vehicle id="t_1" energyConsumed="0.00" totalEnergyConsumed="0.00" totalEnergyRegenerated="0.00" actualBatteryCapacity="17500.00" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
  <timestep time="1.00">
    <vehicle id="t_1" energyConsumed="1.40" totalEnergyConsumed="1.40" totalEnergyRegenerated="0.00" actualBatteryCapacity="17498.60" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
  <timestep time="2.00">
    <vehicle id="t_1" energyConsumed="4.68" totalEnergyConsumed="6.08" totalEnergyRegenerated="0.00" actualBatteryCapacity="17493.92" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
  <timestep time="3.00">
    <vehicle id="t_1" energyConsumed="7.00" totalEnergyConsumed="13.09" totalEnergyRegenerated="0.00" actualBatteryCapacity="17486.91" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
  <timestep time="4.00">
    <vehicle id="t_1" energyConsumed="6.07" totalEnergyConsumed="19.16" totalEnergyRegenerated="0.00" actualBatteryCapacity="17480.84" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
  <timestep time="5.00">
    <vehicle id="t_1" energyConsumed="7.22" totalEnergyConsumed="26.38" totalEnergyRegenerated="0.00" actualBatteryCapacity="17473.62" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
  <timestep time="6.00">
    <vehicle id="t_1" energyConsumed="10.02" totalEnergyConsumed="36.40" totalEnergyRegenerated="0.00" actualBatteryCapacity="17463.60" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
  <timestep time="7.00">
    <vehicle id="t_1" energyConsumed="-18.29" totalEnergyConsumed="36.40" totalEnergyRegenerated="18.29" actualBatteryCapacity="17481.89" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
  <timestep time="8.00">
    <vehicle id="t_1" energyConsumed="-10.45" totalEnergyConsumed="36.40" totalEnergyRegenerated="28.74" actualBatteryCapacity="17492.34" maximumBatteryCapacity="35000.00" charging="0.00" />
  </timestep>
</battery-export>
```

Charging Stations

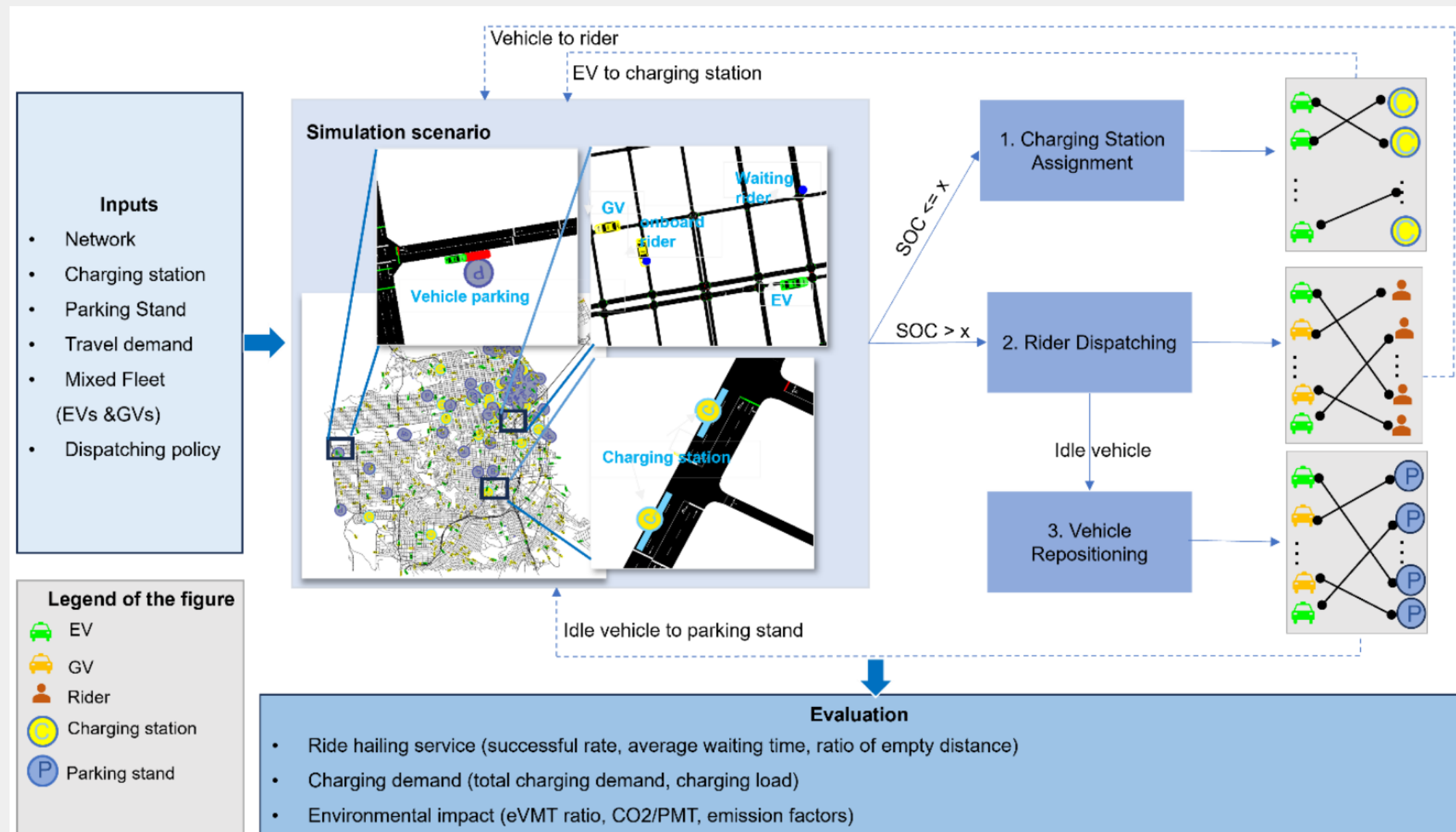


Figure 1. TNC mixed fleet management framework

Evaluating the Impact of Clean Miles Standard on the Transportation system: A Microscopic Simulation in San Francisco

April 2024

A Research Report from the Pacific Southwest Region University Transportation Center

Peng Hao
Haishan Liu
Guoyuan Wu
Matthew Barth