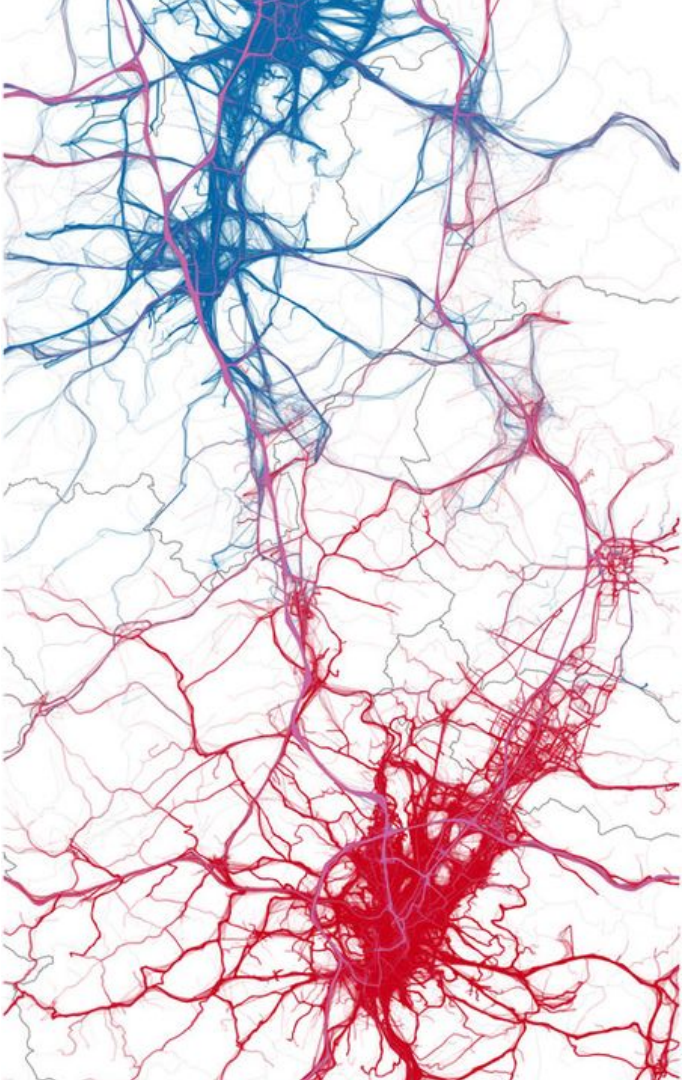


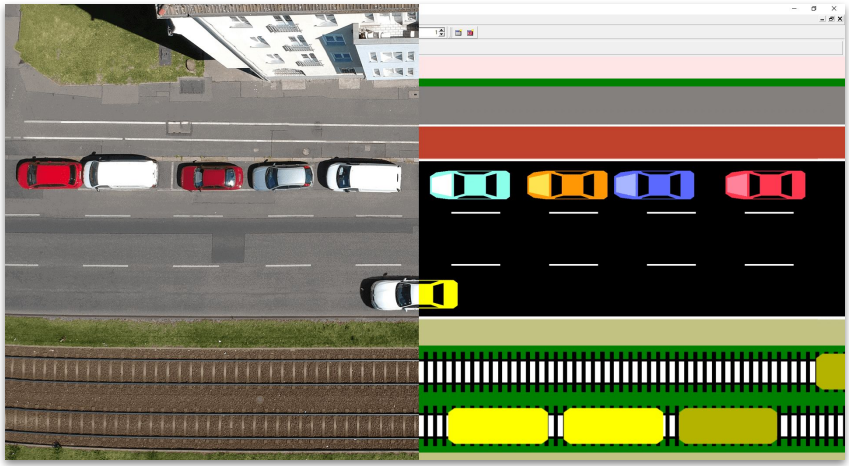
Consiglio Nazionale
delle Ricerche

Traffic simulation with SUMO

Traffic Simulation

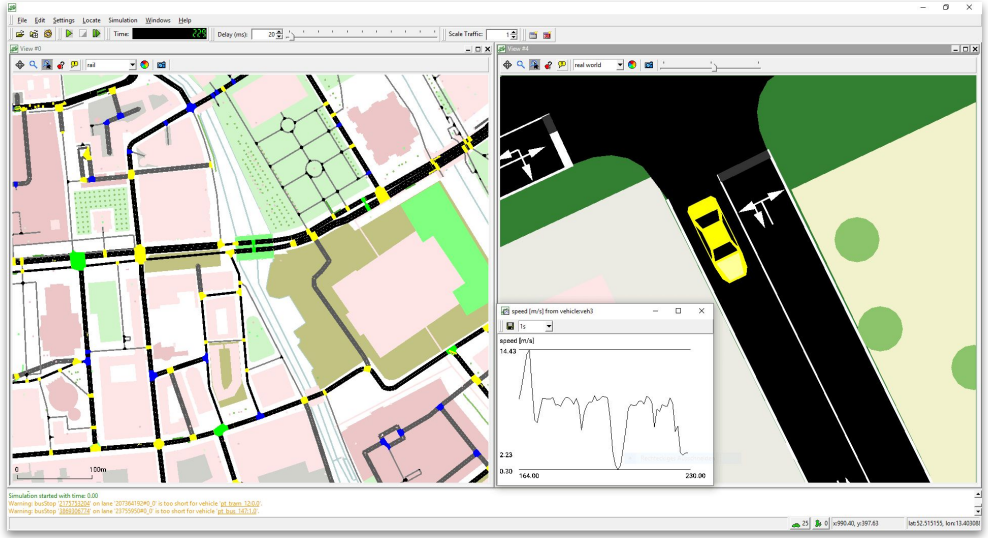
Traffic simulation is of fundamental in many areas:

- What-if analysis;
- Traffic and road optimization;
- Traffic forecasting;
- Data collection and augmentation;
- Traffic lights optimization.



SUMO (Simulation of Urban MObility)

SUMO (Simulation of Urban MObility) is an **open source**, highly portable, **microscopic** and continuous multi-modal **traffic simulation system** designed to handle large networks.



SUMO: inputs

SUMO: inputs

Road Network

File extension: **.net.xml**

SUMO: inputs

Road Network

File extension: **.net.xml**

Traffic Demand

File extension: **.rou.xml**

SUMO: inputs

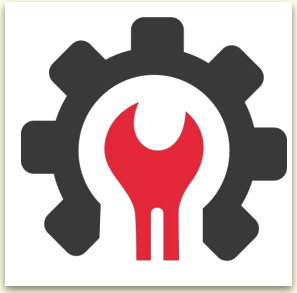
Road Network

File extension: **.net.xml**

Traffic Demand

File extension: **.rou.xml**

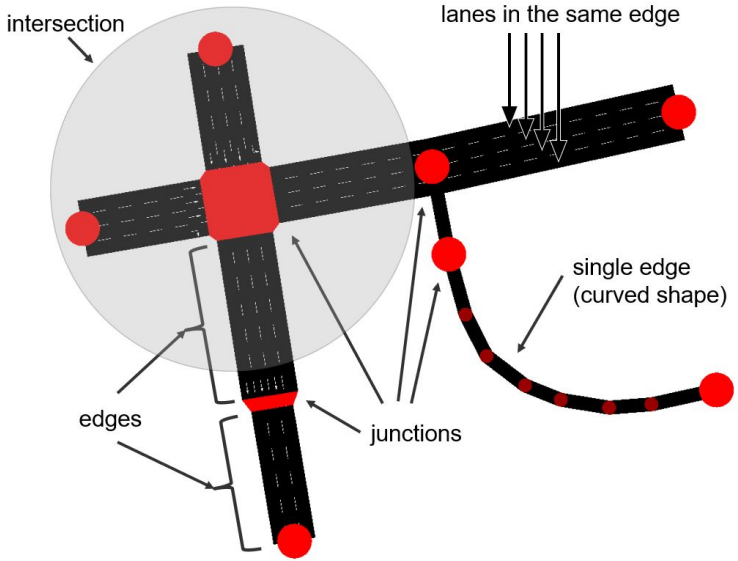
Configuration File



File extension: **.sumocfg**

Road Network

A SUMO **road network** describes the traffic-related **roads** and **intersections** the simulated vehicles run along or across.

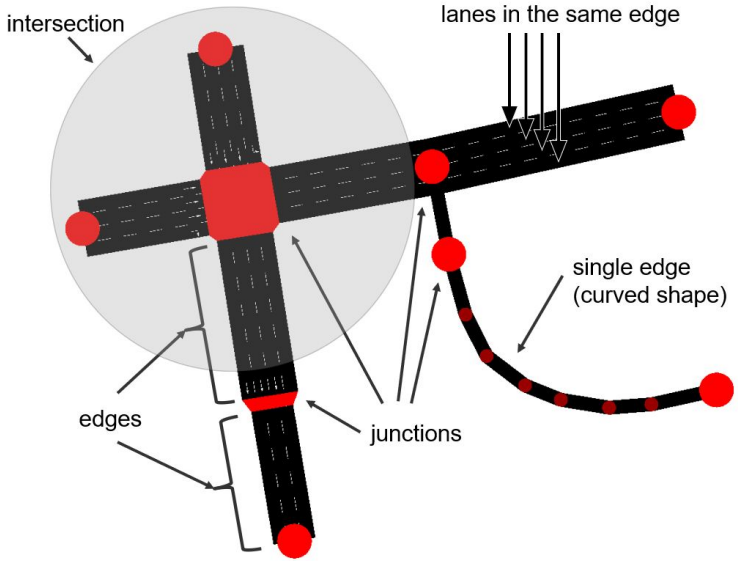


Road Network

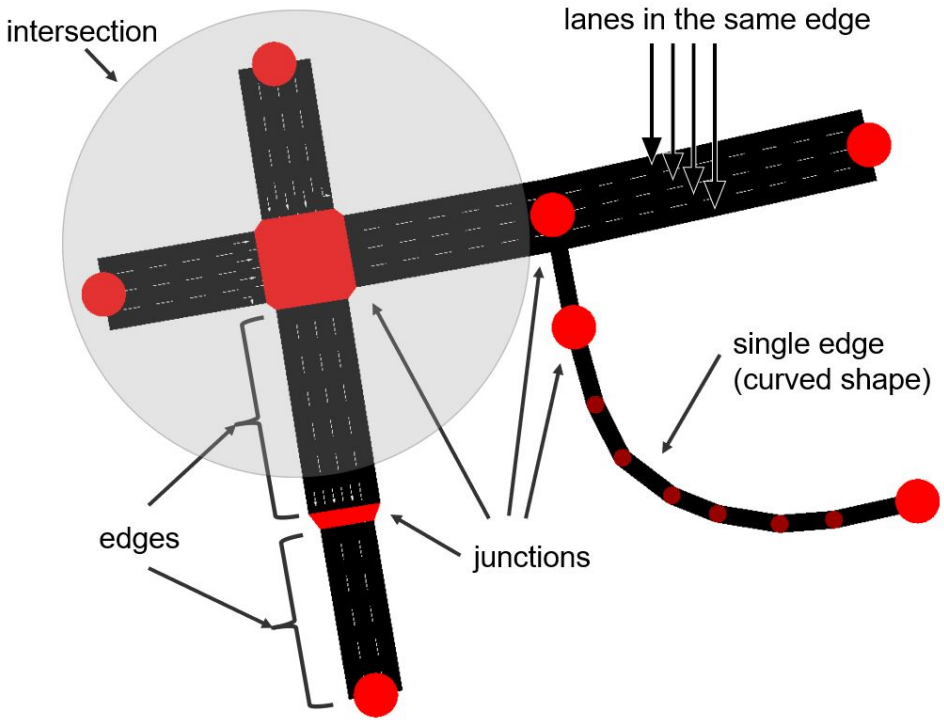
A SUMO **road network** describes the traffic-related **roads** and **intersections** the simulated vehicles run along or across.

In SUMO road networks are **directed** graphs in which

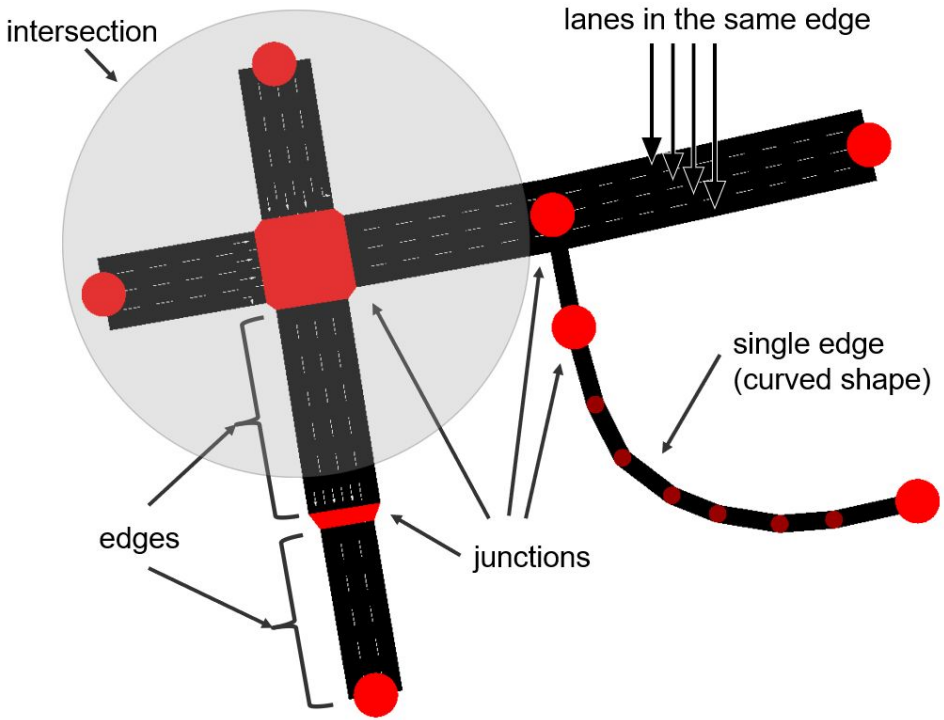
- **nodes** represent intersections/junctions;
- **edges** represent roads/streets.



Road Network

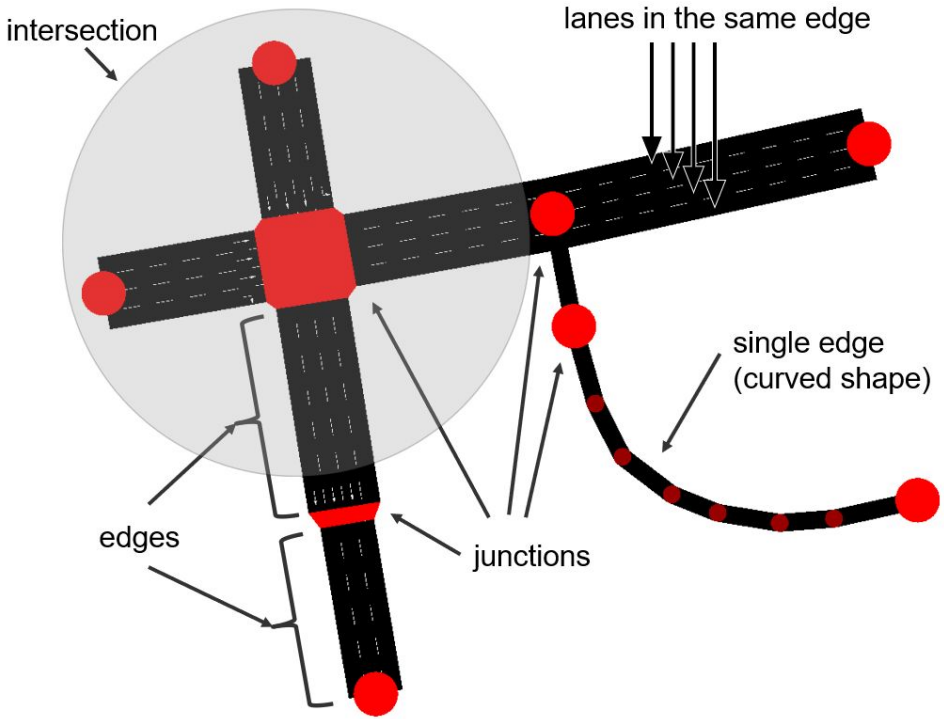


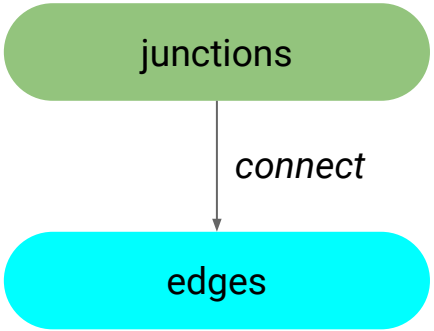
Road Network



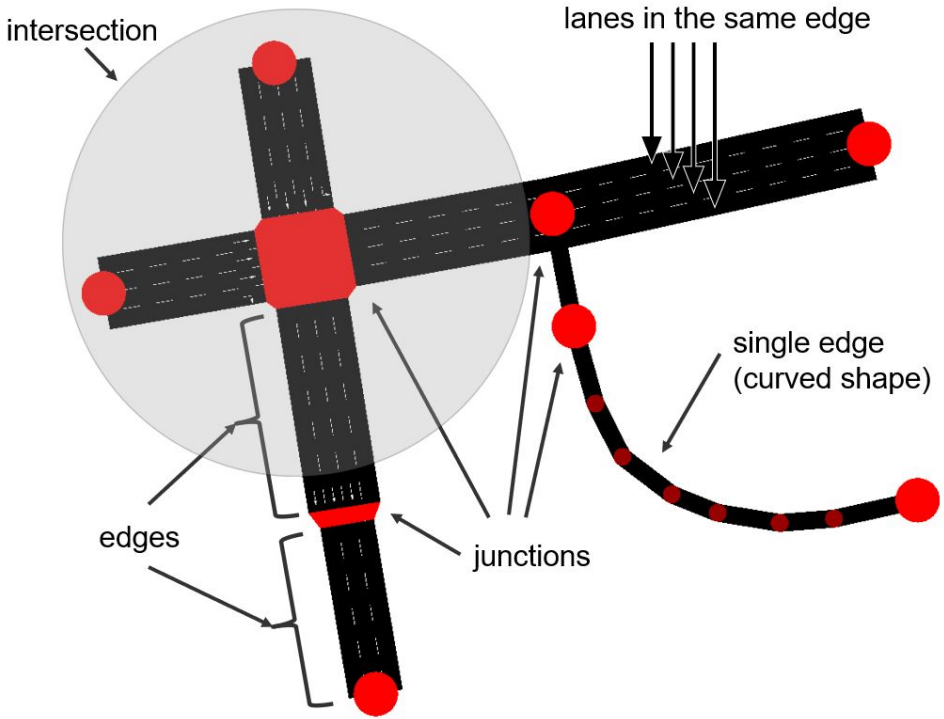
junctions

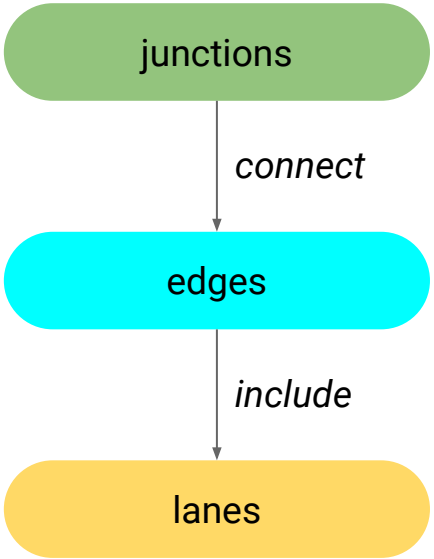
Road Network





Road Network





Road Network: Edges

- An **edge** is a connection between two nodes (junctions);

Road Network: Edges

- The **attributes** of an **edge** are:

Name	Type	Description
id	id (string)	The id of the edge
from	id (string)	The id of the node it starts at
to	id (string)	The id of the node it ends at
priority	integer	Indicates how important the road is (optional)
function	enum ("normal", "internal", "connector", "crossing", "walkingarea")	An abstract edge purpose (optional with default "normal")

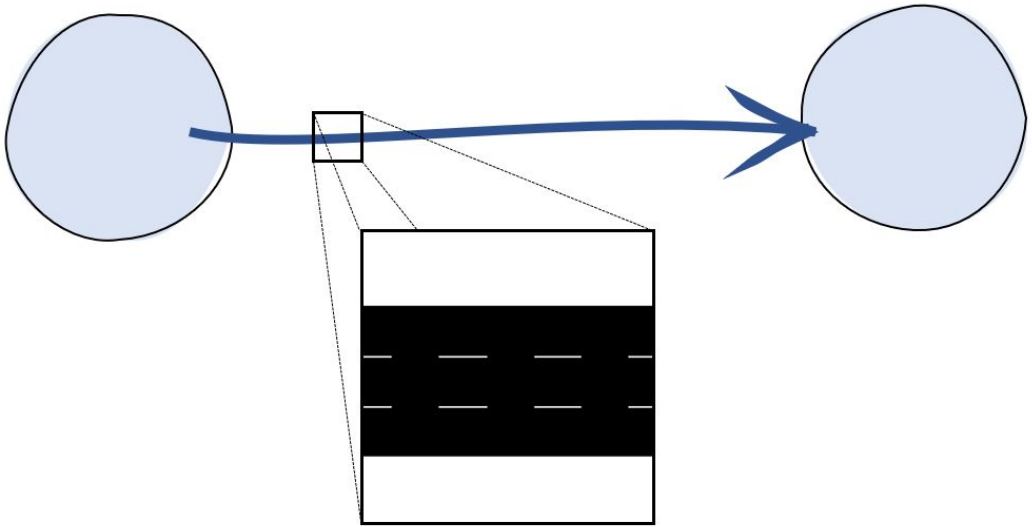
Road Network: Edges

- In the *xml* file, an **edge** is represented as:

```
<edge id="<ID>" from="<FROM_NODE_ID>" to="<TO_NODE_ID>"
priority="<PRIORITY>">
    ... one or more lanes ...
</edge>
```

Road Network: Lanes

- Each edge includes the definitions of **lanes** it consists of. Generally, an edge consists of at least one lane.



Road Network: Lanes

- The **attributes** of a lane are:

Name	Type	Description
id	id (string)	The id of the lane
index	running number (unsigned int)	A running number, starting with zero at the right-most lane
speed	float	The maximum speed allowed on this lane [m/s]
length	float	The length of this lane [m]
shape	position vector	The geometry of the lane, given by a polyline that describes the lane's center line

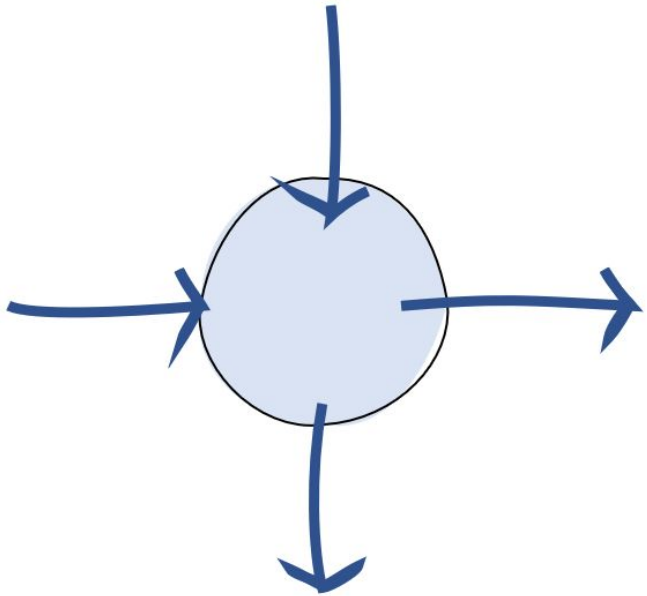
Road Network: Lanes

- In the xml file, a **lane** is represented as:

```
<lane id="<ID>" index="<INDEX>" speed="<SPEED>"
length="<LENGTH>" shape="<SHAPE>"/>
```

Road Network: Junctions

- Junctions represent the area where different streams (edges) cross; they include the right-of-way rules vehicles have to follow when crossing the intersection.



Road Network: Junctions

- The **attributes** of a junction are:

Name	Type	Description
id	id (string)	The id of the junction
x	x-position (real)	The x-coordinate of the intersection
y	y-position (real)	The y-coordinate of the intersection
incLanes	id list	The ids of the lanes that end at the intersection.
intLanes	id list	The IDs of the lanes within the intersection
shape	position vector	The geometry of the lane, given by a polyline that describes the lane's center line.

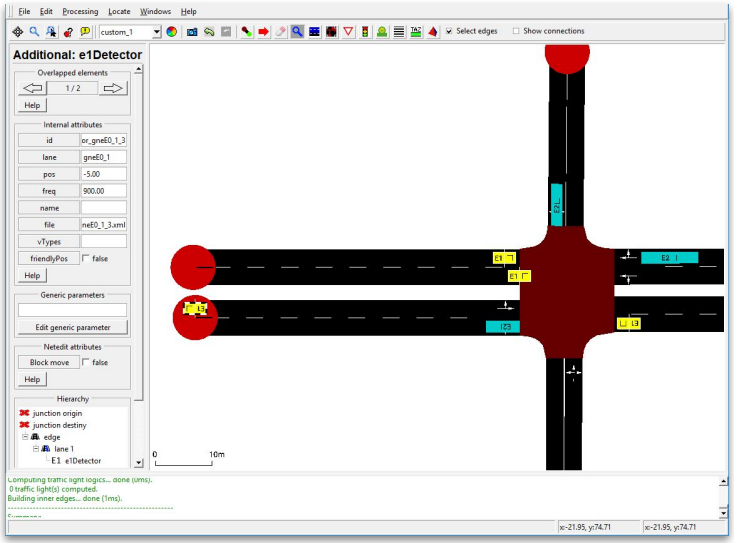
Road Network: Junctions

- In the xml file, a **junction** is represented as:

```
<junction id="<ID>" type="<JUNCTION_TYPE>" x="<X-POSITION>"
y="<Y-POSITION>" incLanes="<INCOMING_LANES>" intLanes="<INTERNAL_LANES>"
shape="<SHAPE>">
    ... requests ...
</junction>
```

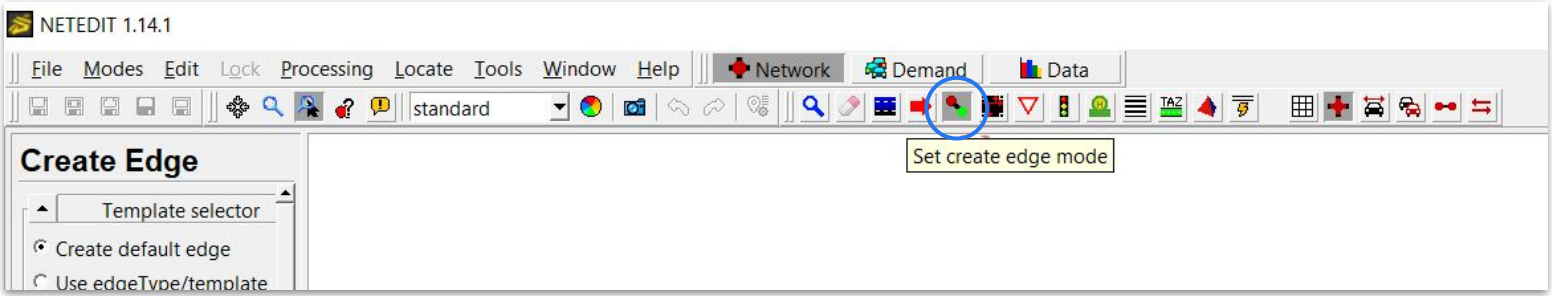
Netedit

- Netedit is a **graphical network editor** included in SUMO;
- Netedit can be used to **create** and **edit** SUMO networks.



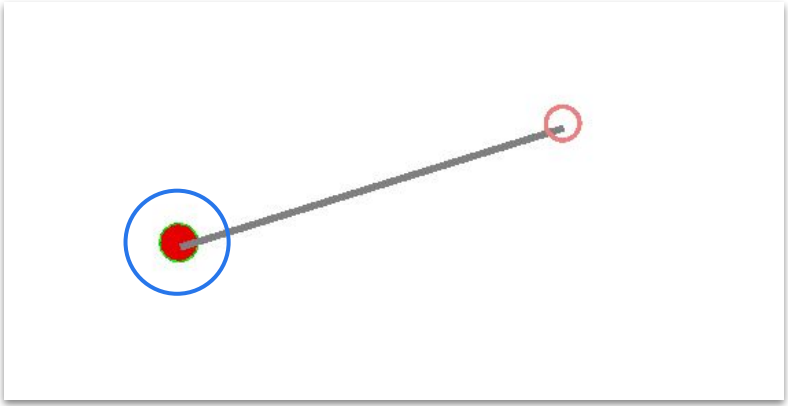
Netedit: create a simple network

Step 1: Open netedit and select the option “**Set create edge mode**” to create an edge.



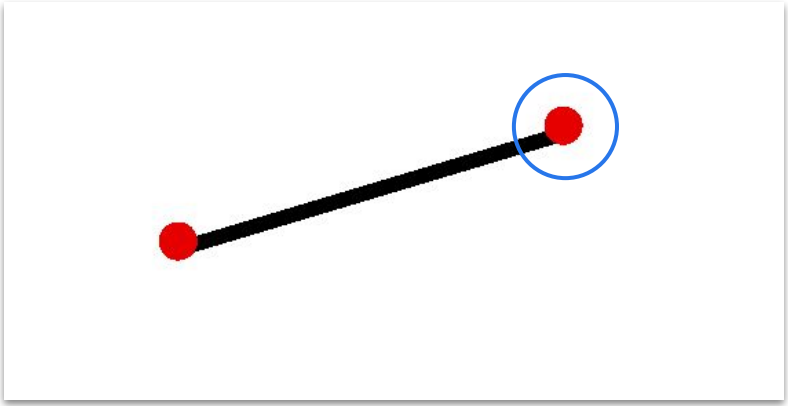
Netedit: create a simple network

Step 2: Left click to create the **from** node of the edge.



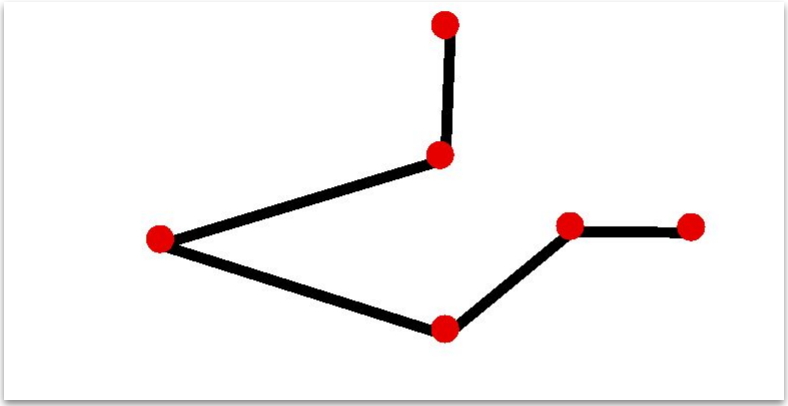
Netedit: create a simple network

Step 3: Left click to create the **end** node of the edge.



Netedit: create a simple network

Step 4: Re-iterate Steps 1-3 to create more edges in the road network and save it.



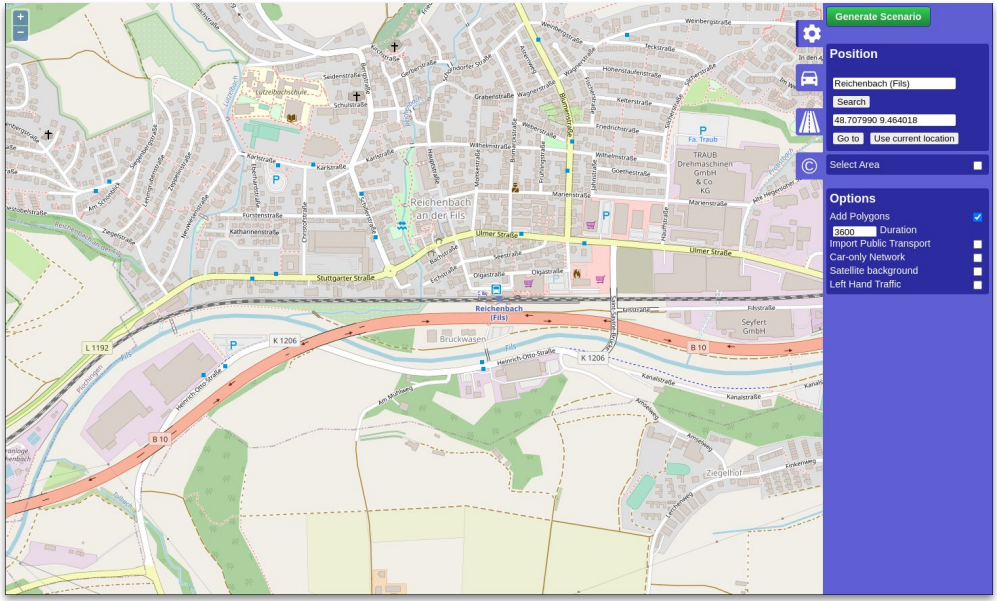
OSMWebWizard

What about **real-world** road networks?

OSMWebWizard

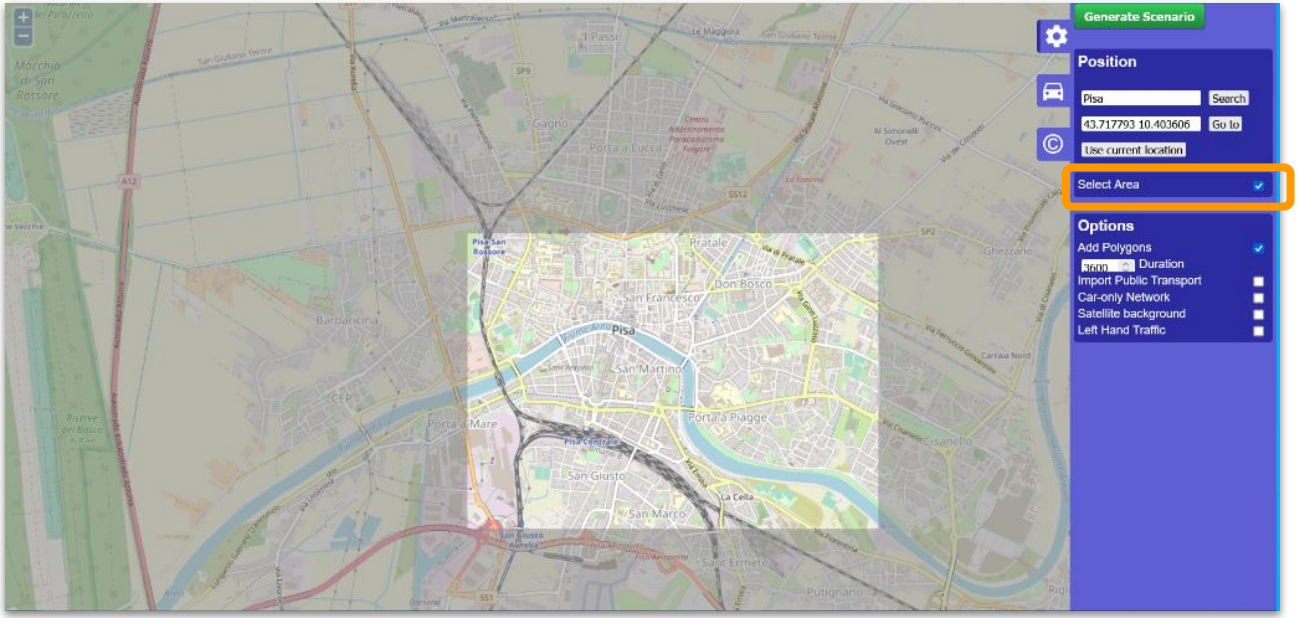
What about **real-world** road networks?

You can download **real-world** road networks in a SUMO-friendly format by using OSMWebWizard.



OSMWebWizard: download a real-world network

Step 1: Open OSMWebWizard and select your area of interest (e.g., Pisa).
The area selection will be activated by clicking the checkbox **“Select Area”** at the blue area selection panel on the right side of the map.



OSMWebWizard: download a real-world network

Step 2: Set the following options:

OSMWebWizard: download a real-world network

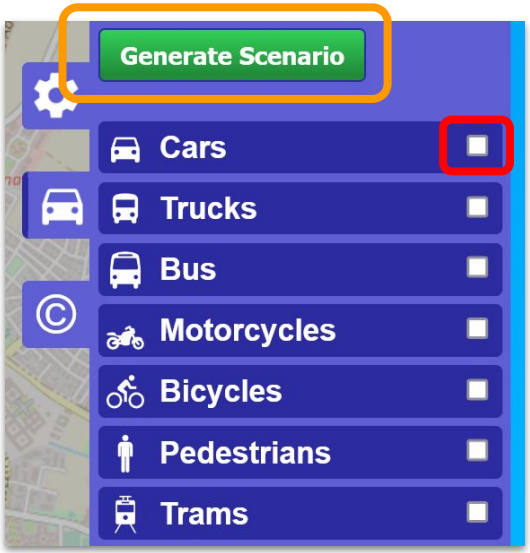
Step 2: Set the following options:

If enabled, only roads that permit passenger car traffic will be included.

If enabled, the network will be built with left hand traffic rules.

OSMWebWizard: download a real-world network

Step 3: uncheck “Cars” and click on “Generate Scenario”. The road network will be downloaded and ready to be used in SUMO.



Traffic Demand

A SUMO **traffic demand** describes the traffic that will circulate on the **road network** during the simulation.

Traffic Demand

A SUMO **traffic demand** describes the traffic that will circulate on the **road network** during the simulation.

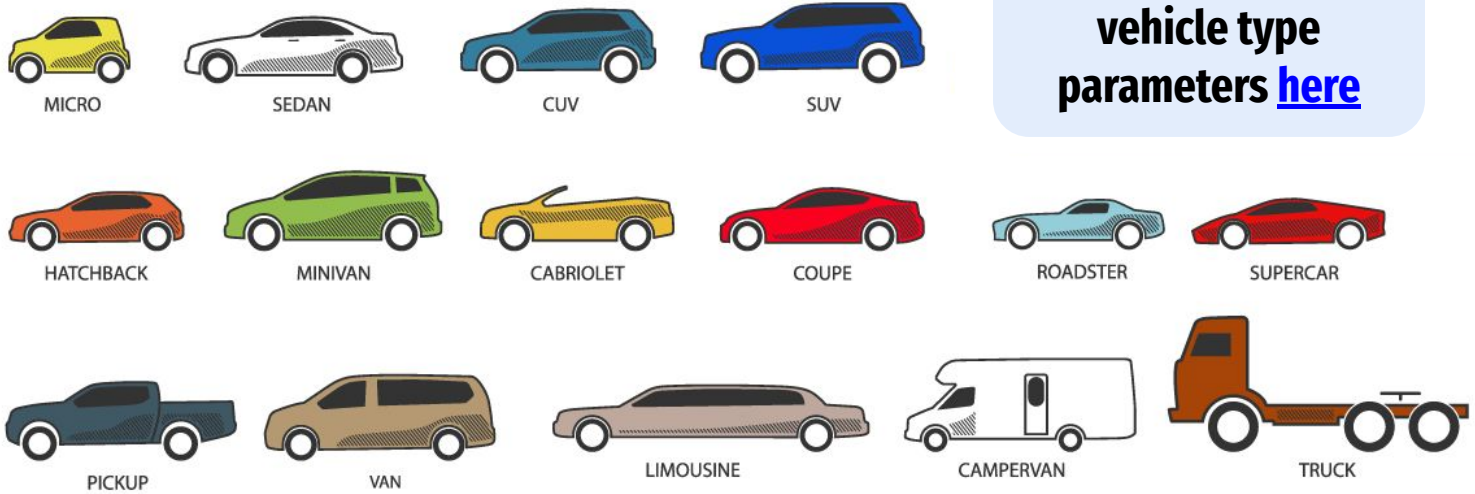
In SUMO there are two ways to define a vehicle movement:

- **Routes;**
- Incomplete Routes (**trips** and **flows**).

The traffic demand file **must** be sorted by departure time!

Vehicle Types

SUMO allows to define **vehicle types** to describe the vehicle's **physical features**.



See default SUMO vehicle type parameters here

Vehicle Types

The most important attributes of a **vehicle type** are:

Name	Type	Default	Description
id	id (string)	-	The name of the vehicle type
accel	float	2.6	The acceleration ability of vehicles of this type (in m/s^2)
decel	float	4.5	The deceleration ability of vehicles of this type (in m/s^2)
maxSpeed	float	55.55 (200 km/h)	The vehicle's (technical) maximum velocity (in m/s)
length	float	5.0	The vehicle's netto-length (length) (in m)
sigma	float	0.5	Driver imperfection

Vehicle Types

- In the xml file, a **vehicle type** is represented as:

```
<vType id="<ID>" accel="<ACCEL>" decel="<DECEL>" sigma="<SIGMA>"
length="<LENGTH>" maxSpeed="<MAX-SPEED"/>
```

Vehicle Types

- In the xml file, a **vehicle type** is represented as:

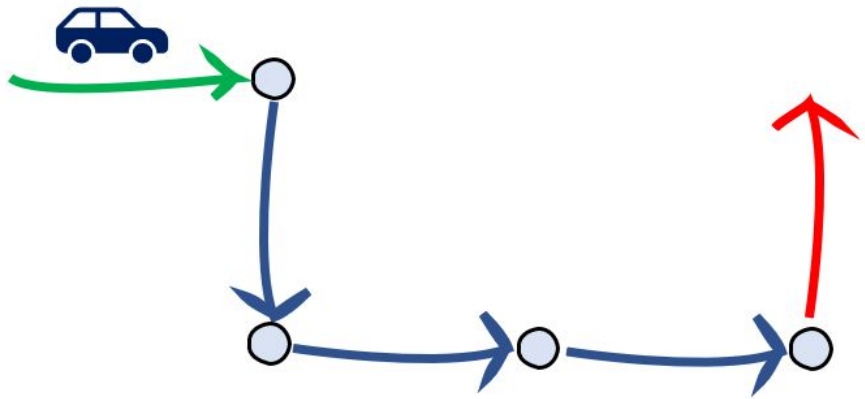
```
<vType id="<ID>" accel="<ACCEL>" decel="<DECEL>" sigma="<SIGMA>"
length="<LENGTH>" maxSpeed="<MAX-SPEED"/>
```

- In the xml file, a **default vehicle type** is represented as:

```
<vType id="<ID>" vClass="<DEF_VEHICLE_CLASS>"/>
```

Traffic Demand: Routes

- A **route** is a vehicle movement defined by all the **edges** the vehicle will pass and the **departure time**.
- The sequence of edges defined in a route has to be **connected**!



Traffic Demand: Routes

- In the xml file, a **vehicle** which follows a **route** is represented as:

```
<vehicle id="v0" type="type1" depart="0">
   <route edges="START E1 E2 E3 END"/>
</vehicle>
```

Traffic Demand: Routes

- In the xml file, a **vehicle** which follows a **route** is represented as:

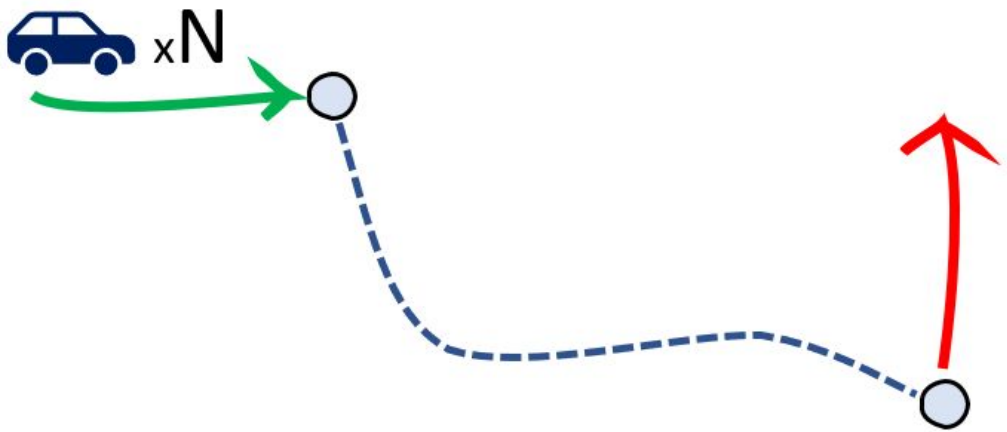
```
<vehicle id="v0" type="type1" depart="0">
   <route edges="START E1 E2 E3 END"/>
</vehicle>
```

- A vehicle of type “**type1**” with id “**v0**” departing at time “**0**” with the route **“START E1 E2 E3 END”** will be created;

- **“START E1 E2 E3 END”** must be a sequence of **connected edges** on the Road Network.

Traffic Demand: Flows

- A **flow** is a set of repeated vehicles defined by:
  - **number of vehicles**, **starting edge**, **destination edge**, **first vehicle departure time** and the **end of departure interval**



Traffic Demand: Flows

- In the xml file a **flow** represented as:

```
<flow id="f0" begin="0" end="100" number="50" type="type1"
from="START" to="END" via="Ex Ey">
</flow>
```

Traffic Demand: Flows

- In the xml file a **flow** represented as:

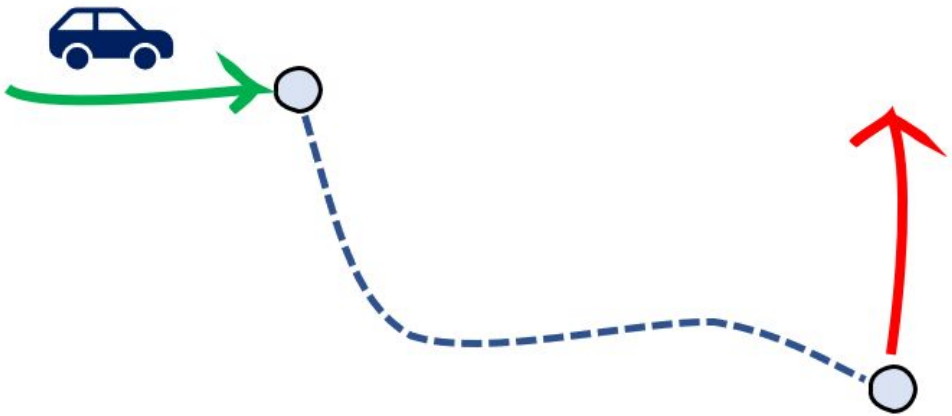
```
<flow id="f0" begin="0" end="100" number="50" type="type1"
from="START" to="END" via="Ex Ey">
</flow>
```

- **50** vehicles of type “**type1**” will be created departing between timesteps “**0**” and “**100**” (at regular intervals) starting from edge **“START”** and ending at edge **“END”**;

- The (optional) attribute `via` specifies a sequence of **intermediate** edges that will be traveled by vehicles to reach the destination.

Traffic Demand: Trips

- A **trip** is a vehicle movement defined by the **starting edge**, the **destination edge**, and the **departure time**.



Traffic Demand: Trips

- In SUMO, vehicles **cannot** be associated with trips. You can use duarouter (next. lecture) to translate **trips** into **routes**.

Traffic Demand: Trips

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How can we describe the movement of a vehicle specifying **only** the **starting** and **ending** edges?

(we can't use trips in SUMO)

Traffic Demand: Trips

- In SUMO, vehicles **cannot** be associated with trips. You can use duarouter (next. lecture) to translate **trips** into **routes**.

How can we describe the movement of a vehicle specifying **only** the **starting** and **ending** edges?

(we can't use trips in SUMO)

By using a "trick".
We can describe it using a **flow** for a **single vehicle**!
I.e., number="1"

Configuration File

- The configuration file specifies which **Road Network** and **Traffic Demand** to use in the SUMO **simulation** and the simulation **time interval.**

Configuration File

```
<?xml version="1.0" encoding="UTF-8"?>
<configuration xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/sumoConfiguration.xsd">
    <input>
        <net-file value="<ROAD-NETWORK_PATH>"/>
        <route-files value="<TRAFFIC-DEMAND_PATH>"/>
    </input>
    <time>
        <begin value="<START_TIMESTEP>"/>
        <end value="<END_TIMESTEP>"/>
    </time>
</configuration>
```

Configuration File

```
<?xml version="1.0" encoding="UTF-8"?>
<configuration xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
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        <begin value="<START_TIMESTEP>"/>
        <end value="<END_TIMESTEP>"/>
    </time>
</configuration>
```

XML schema info

Configuration File

```
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        <net-file value="<ROAD-NETWORK_PATH>"/>
        <route-files value="<TRAFFIC-DEMAND_PATH>"/>
    </input>
    <time>
        <begin value="<START_TIMESTEP>"/>
        <end value="<END_TIMESTEP>"/>
    </time>
</configuration>
```

Paths of the road network and traffic demand to simulate

Configuration File

```
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<configuration xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
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        <route-files value="<TRAFFIC-DEMAND_PATH>"/>
    </input>
    <time>
        <begin value="<START_TIMESTEP>"/>
        <end value="<END_TIMESTEP>"/>
    </time>
</configuration>
```

Time interval of the simulation (optional)

Configuration File

```
<?xml version="1.0" encoding="UTF-8"?>
<configuration xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
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    <input>
        <net-file value="<ROAD-NETWORK_PATH>"/>
        <route-files value="<TRAFFIC-DEMAND_PATH>"/>
    </input>
    <time>
        <begin value="<START_TIMESTEP>"/>
        <end value="<END_TIMESTEP>"/>
    </time>
</configuration>
```

Tip

Use this configuration file template for your simulations!

“Hello SUMO”

In this slides you can find the material to download a “Hello SUMO” simulation.

In the material you will find:

- A **road network** with 14 nodes and 21 edges;
- A **traffic demand** describing the **routes** of **two vehicles** and and **two flows** (one with the via parameter);
- The **configuration file** to run the simulation.

Download the material here

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Download the material here

Tip

Use these files as a starting point for the exercises!

“Hello SUMO”

- There are **two** ways to start the SUMO simulation:

“Hello SUMO”

- There are **two** ways to start the SUMO simulation:

From the SUMO application

_ □ X

1. Open sumo-gui;
2. File → Open Simulation;
3. Select the configuration file;
4. Run the simulation.

or

From Command Line

_ □ X

```
>> sumo-gui -c <PATH_CONFIG>
or
>> sumo -c <PATH_CONFIG>
```

Resources

- Useful resources:
  - How to install SUMO
  - SUMO documentation
  - SUMO FAQ
  - SUMO official tutorials

- For any question contact me at giuliano.cornacchia@phd.unipi.it

Homeworks

to be delivered by Thursday, November 25th 2022

Homework 10.1

Download the road network of La Spezia (Italy) from OSMWebWizard:
(i) *Create a python function that, given a list of tuples in the form (type, n_vehicles, edge_list, departure_time) creates an xml file describing the corresponding traffic demand; use the script to compute the traffic demand for the following points. Type can be route or flow.*
(ii) *Create a traffic demand of 1,000 vehicles moving through a random origin and destination edges. Ensure that origin and destination are connected. Departure time is chosen uniformly at random in [0, 600].*
(iii) *Apply duarouter to the mobility demand for w=1, 5, 10, 15, 20. Compute, for each value of w, the total distance traveled, the difference with respect to the shortest path, and the total CO2 emissions.*

- Submit a (well commented) python notebook and the SUMO files.

Homework 10.2

Download the road network of La Spezia (Italy) from OSMWebWizard:
(i) *Create a python function that, given a list of tuples in the form (type, n_vehicles, edge_list, departure_time) create an xml file describing the corresponding traffic demand; use the script to compute the mobility demands for the following points. Type can be route or flow.*
(ii) *Create a traffic demand of 500 vehicles moving through a random origin and destination edges. Ensure that origin and destination are connected. Departure time is chosen uniformly at random in [0, 200].*
(iii) *Use OpenStreetMap to compute the suggested paths for the 500 vehicles and create a traffic demand to describe them.*
(iv) *Compare the total emissions and distance traveled for the routed (ii) and non-routed (iii) traffic demands.*

- Submit a (well commented) python notebook and the SUMO files.