Leuven, 31 May 2022

MATSim User Meeting 2022

Simulation of e-bike and e-scooter trips using MATSim

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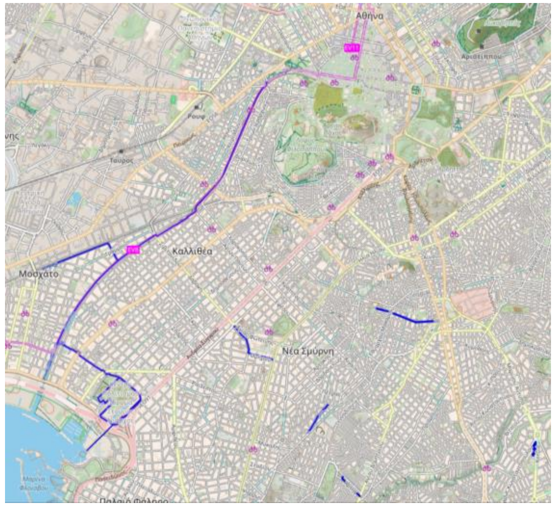
Research Project: Simulation tool for Micromobility to improve Urban Transportation Planning – SIM4MTRAN (project code: T2EDK – 02494, NSRF 2014 -2020)

Modeling problem

Delft, NL

Athens, GR



CyclOSM maps - https://www.openstreetmap.org

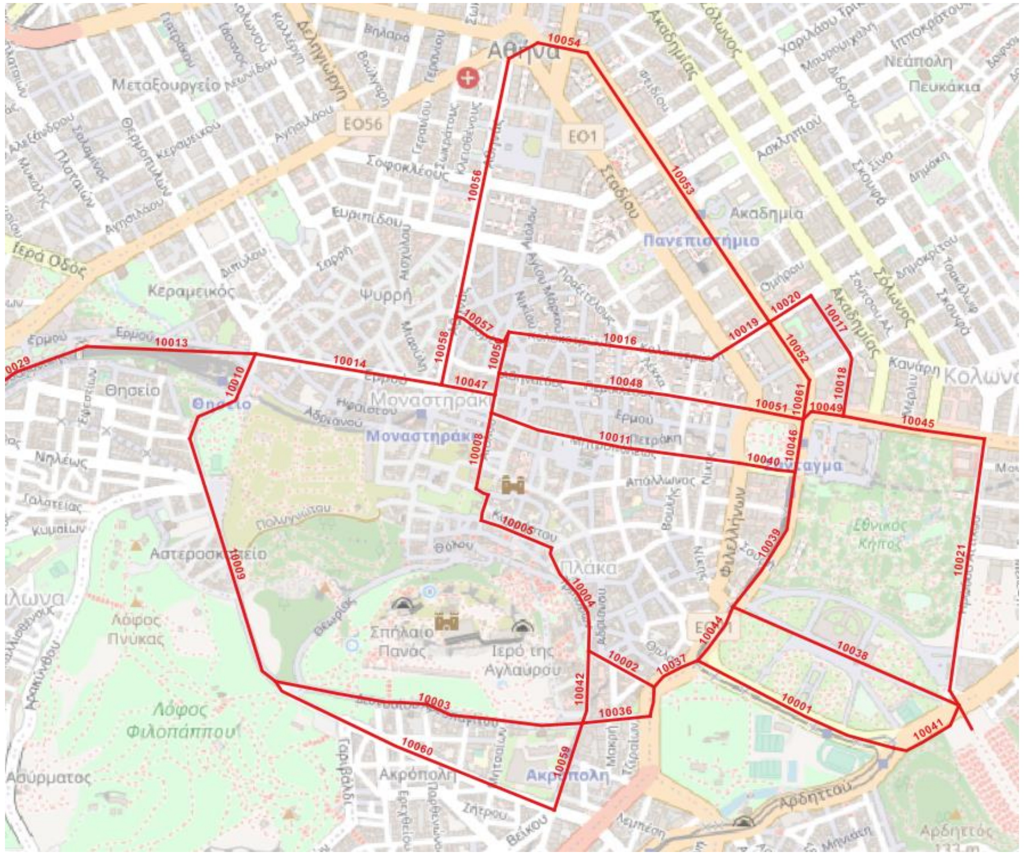
Micromobility modes

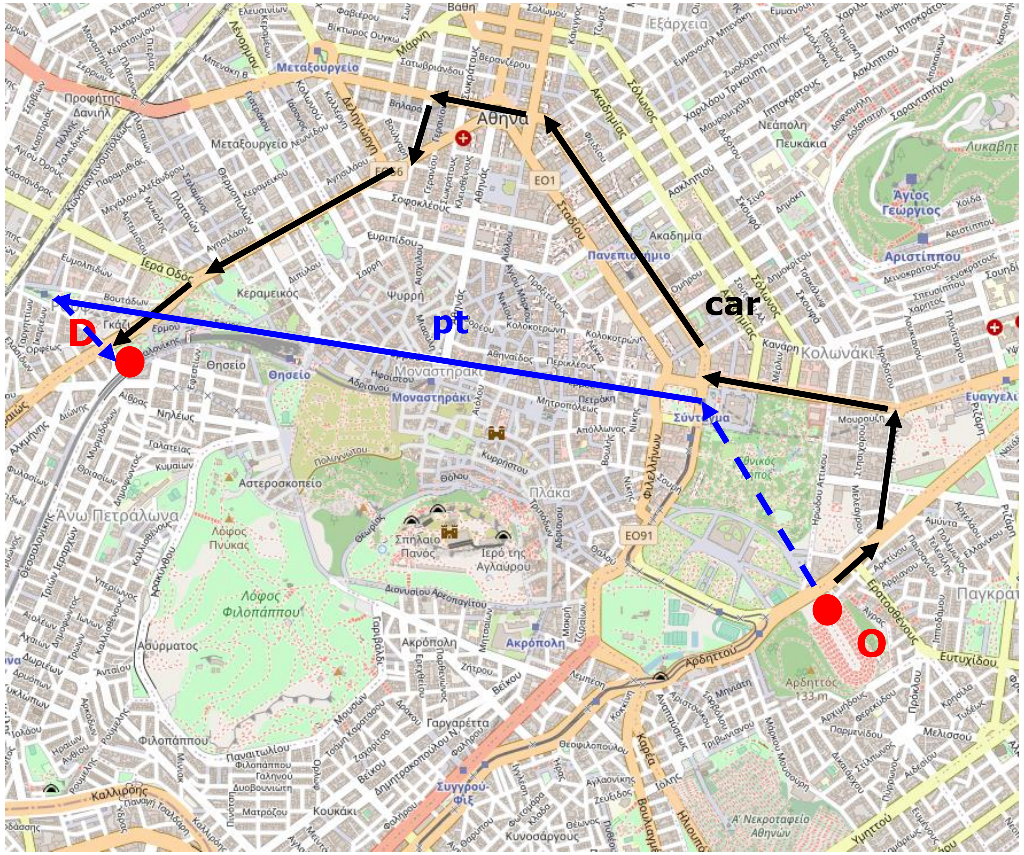
	Powered Bicycle	Powered Standing Scooter	Powered Seated Scooter	Powered Self-Balancing Board	Powered Non-Self-Balancing Board	Powered Skates
Center column	Y	Y	Y	Possible	N	N
Seat	Y	N	Y	N	N	N
Operable pedals	Y	N	N	N	N	N
Floorboard / foot peg	Possible	Y	Y	Y	Y	Y
Self-balancing[2]	N	N	N	Y	N	Possible

SAE International, 2019b

"Dual behavior" of e-scooter: from vehicle to pedestrian and vice versa

Routing problem



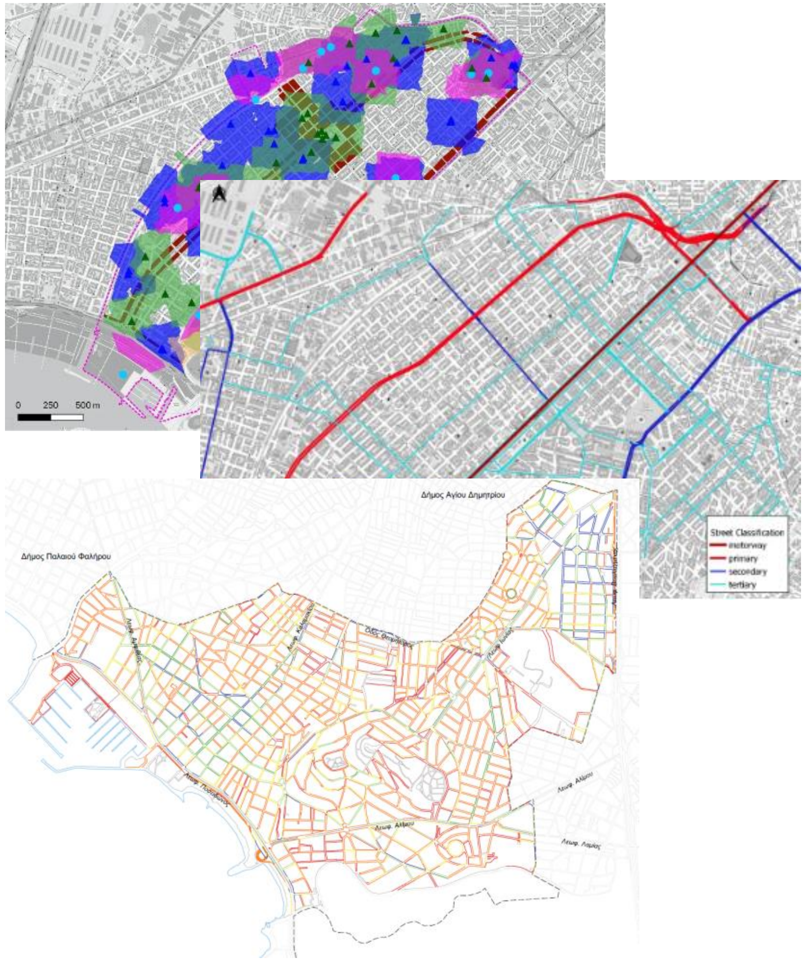


Number of alternative routes:
Public transport < car < e-bike < e-scooter < walk

so: simulation -> MATSim
Multi-Agent Transport Simulation

Spatial data

- Sustainable Urban Mobility Plans (SUMPs) turned out to be a great chance to collect (at least) spatial data in Greek cities.
- Land uses, road or sidewalk width, pavement condition etc. are some of the available spatial data.
- These datasets can become a significant input in simulations to describe supply.
- Greek Transport Planners are very familiar with these datasets, i.e., shapefiles, as they have been widely used in plans since then.

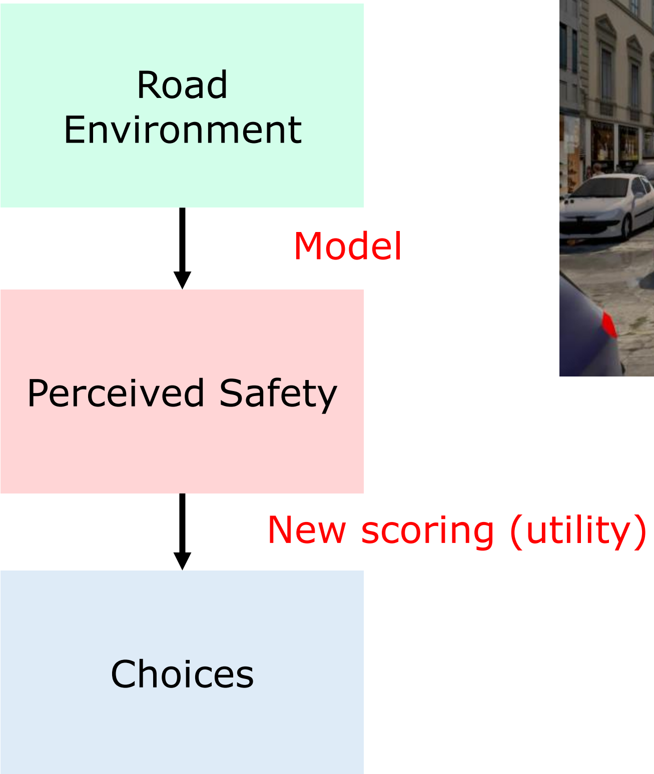


SIM4MTRAN project aims to construct useful tools for Transport Planners !!

so: **GIS** ✚ **ABM**

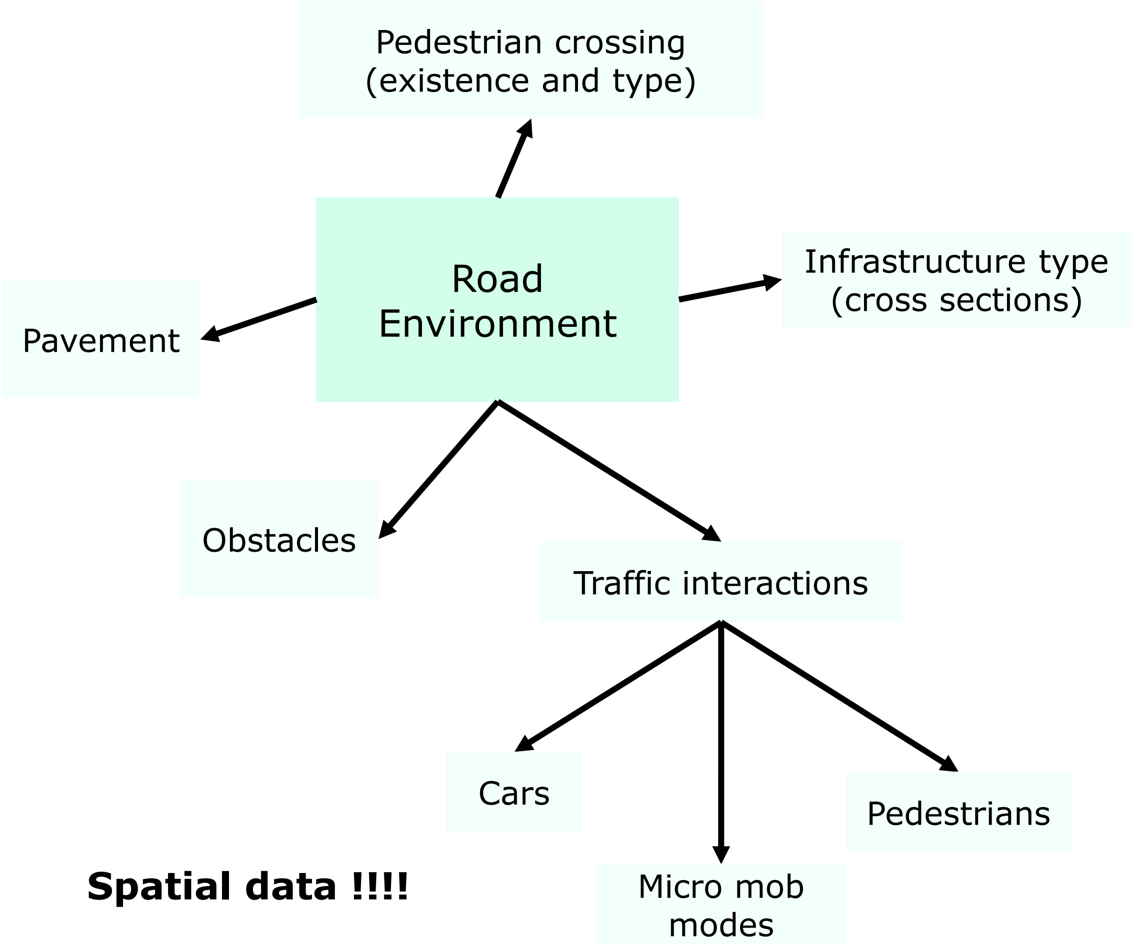
Approach (1)

Main assumption: Perceived safety as an additional factor that is related to the road environment and affect (route or even mode) choices.



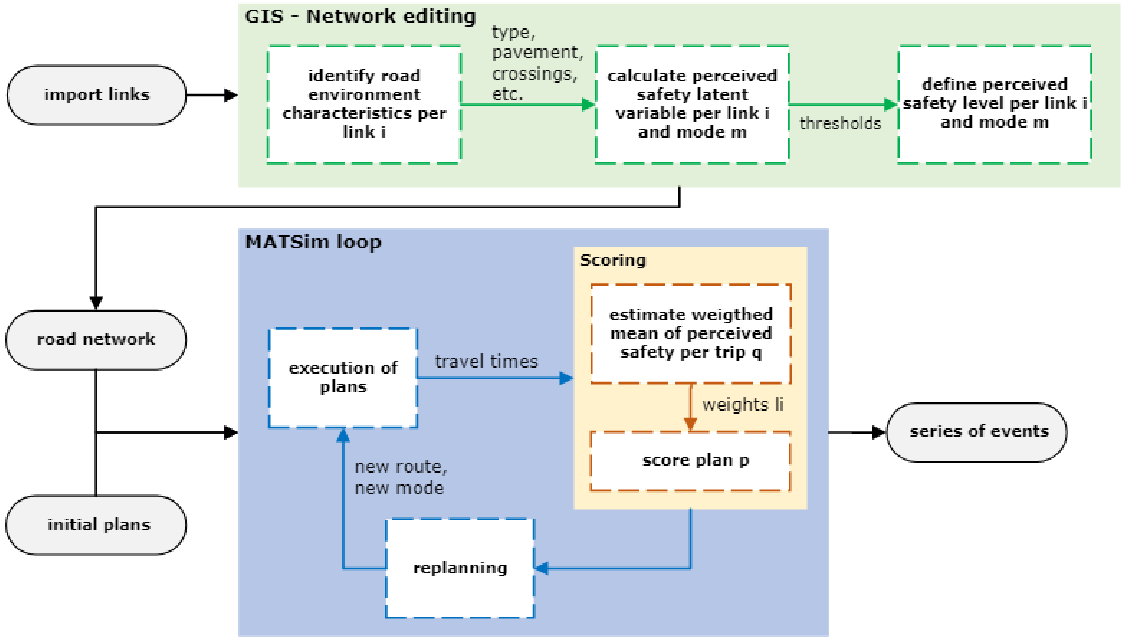
How safe would you feel? To drive a car?
To ride an e-bike? Or an e-scooter? To walk?

Approach (2)



Spatial data !!!!

no traffic interactions flow diagram



a new scoring function based on time + distance + safety

Equations (1)

$$psafe^{*}_{i,\mathrm{m}} = \beta_{\mathrm{inf1,m}} * inf1_i + \beta_{\mathrm{inf2,m}} * inf2_i + \beta_{\mathrm{inf3,m}} * inf3_i + \beta_{\mathrm{cross,m}} * \mathrm{cross_i} + \beta_{\mathrm{pav,m}} * pav_i + \beta_{\mathrm{obst,m}} * obst_i$$

<u>where:</u>

$psafe^{*}_{i,\mathrm{m}}$: perceived safety of using mode m in link i (latent variable);

$\beta_{\mathrm{inf1,m}}, \beta_{\mathrm{inf2,m}} \ldots, \beta_{\mathrm{obst,m}}$: beta parameters; they differ per mode;

$inf_{1,i}$: 1, if there is an urban road with sidewalks less than 1.5 m wide and without a cycle lane (type 1) in link i;

$inf_{2,i}$: 1, if there is an urban road with sidewalks more than 1.5 m wide and without a cycle lane (type 2) in link i;

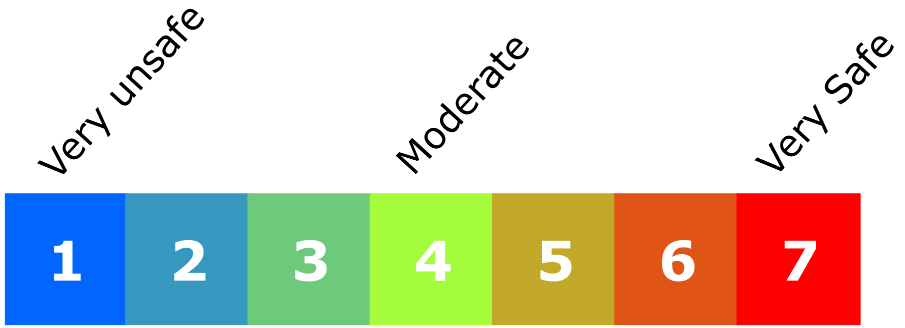
$inf_{3,i}$: 1, if there is an urban road with a cycle lane (type 3) in link i. All infrastructure type variables are equal to 0 in case of a shared space road environment (type 4);

$cross_{\,i}$: 1, if there is a pedestrian crossing not protected with traffic lights in link i;

$pav_{\,i}$: 1, if the pavement of the urban road is in a good condition in link i;

$obst_{\,i}$: 1, if there are obstacles on the sidewalk of the urban road in link i.

$$psafe_{i,m} = \begin{cases} 1, & -\infty < psafe^{*}_{i,m} \le k_{1,m}, \quad very\ unsafe \\ 2, & k_{1,m} \le psafe^{*}_{i,m} \le k_{2,m} \\ 3, & k_{2,m} \le psafe^{*}_{i,m} \le k_{3,m} \\ 4, & k_{3,m} \le psafe^{*}_{i,m} \le k_{4,m} \\ 5, & k_{4,m} \le psafe^{*}_{i,m} \le k_{5,m} \\ 6, & k_{5,m} \le psafe^{*}_{i,m} \le k_{6}, m \\ 7, & k_{6,m} \le psafe^{*}_{i,m} < +\infty, \quad very\ safe \end{cases}$$



Equations (2)

$$S_{trav,q} = C_{m(q)} + \beta_{trav,m(q)} * t_{trav,q} + \left(\beta_{d,m(q)} + \beta_{cost,m(q)} * \gamma_{d,m(q)}\right) * \sum l_i + \boldsymbol{\beta_{psafe,m(q)}} \frac{\sum \boldsymbol{psafe_{i,m(q)}} * \boldsymbol{l_i}}{\sum \boldsymbol{l_i}}$$

where:
$S_{trav,q}$: sum of all travel (dis)utilities of trip q;
l_i: length of link i;
$psafe_i$: perceived safety of link i;

min psafe vs: **mean psafe**

Or: $+\boldsymbol{\beta_{psafe,m(q)}} * \boldsymbol{min(psafe_{i,m(q)})}$

3/7 L

1/7 L

3/7 L

Source: Google StreetView

Would you "cycle" this route?

Problem of discontinuities….

Parameters

E-bike

```
elif mode=='ebike': # parameters for ebike perceived safety
    ch=2 # if ebike, ch is 2
    # kappa thresholds of ordinal model
    c = 1.897269
    k1 = -c
    k2 = 1.393254 - c
    k3 = 2.306729 - c
    k4 = 3.449309 - c
    k5 = 4.438222 - c
    k6 = 5.783248 - c
    # beta parameters related to road environment
    b_inf1 = -1.022189
    b_inf2 = -0.524563
    b_inf3 = 2.595236
    b_pav = 0.595346
    b_obst = 0.292934
    # b_sl=0.25
    b_cross = -0.235141
```

$$\begin{cases} \beta_t = -6.0000\ utils/h \\ \beta_c = -0.8377 \text{ utils/euros} \\ \gamma h = 4.0 \text{ euros}/h \\ v = 18 \text{ km}/h \\ \gamma d = 0.2222 \text{ euros}/km \\ \beta_d = -0.00019 \text{ utlis}/m \\ \beta saf = 1.22447 \text{ utils}/Level \end{cases}$$

pre-calibration…

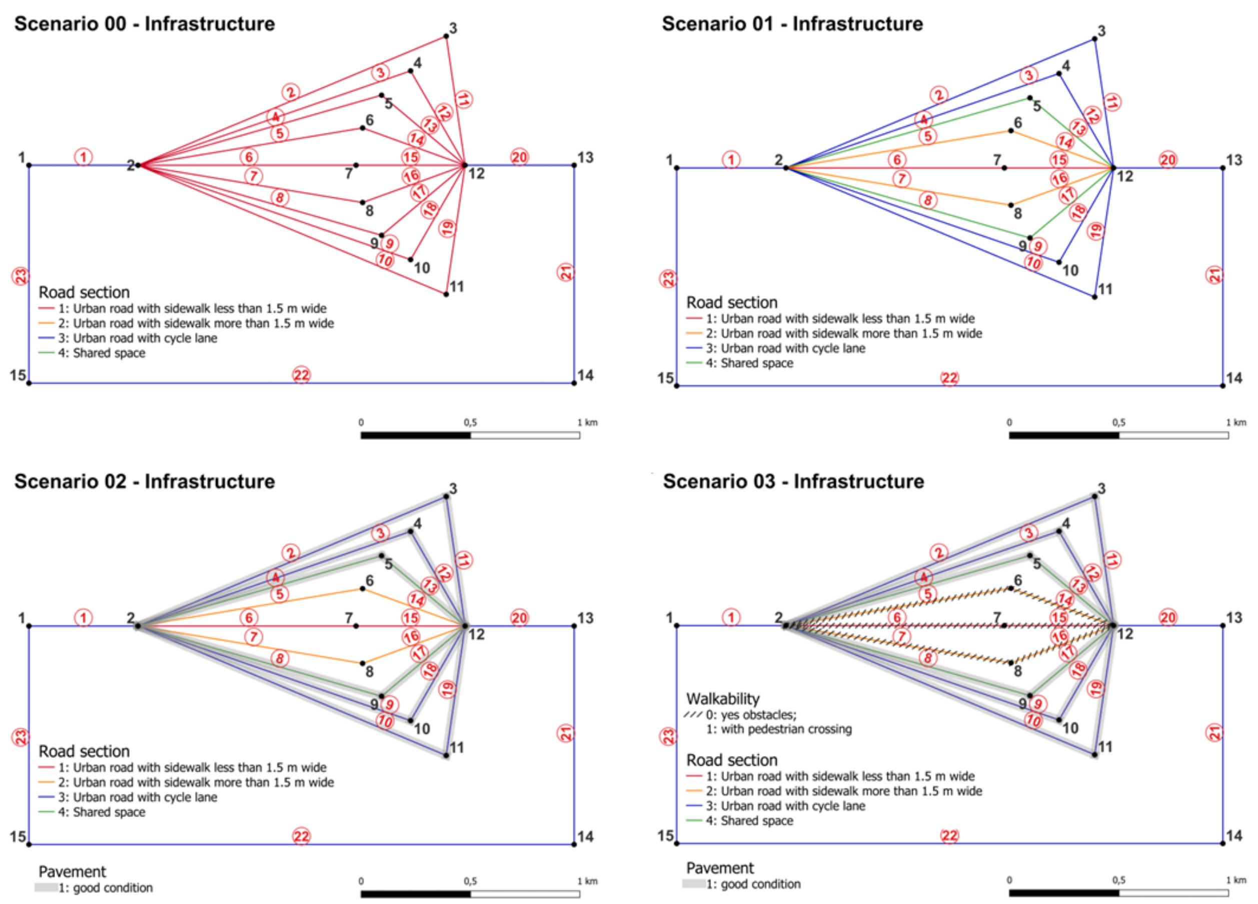
E-scooter

```
elif mode=='escooter': # parameters for escooter perceived safety
    ch=3 # if escooter, ch is 3
    # kappa thresholds of ordinal model
    c = 1.494295
    k1 = -c
    k2 = 1.473174 - c
    k3 = 2.223765 - c
    k4 = 3.175898 - c
    k5 = 4.115999 - c
    k6 = 5.240571 - c
    # beta parameters related to road environment
    b_inf1 = -1.118602
    b_inf2 = -0.430227
    b_inf3 = 1.897135
    b_pav = 0.690822
    b_obst = 0.368650
    # b_sl=0.25
    b_cross = -0.311438
```

$$\begin{cases} \beta_t = -6.0000\ utils/h \\ \beta_c = -0.4307 \text{ utils/euros} \\ \gamma h = 3.5 \text{ euros}/h \\ v = 15 \text{ km}/h \\ \gamma d = 0.2333 \text{ euros}/km \\ \beta_d = -0.00010 \text{ utlis}/m \\ \beta saf = 0.45307 \text{ utils}/Level \end{cases}$$

Traffic interactions are not considered in these models

Example 1 - Scenarios



Scaling factor: 1/10

Network xml file

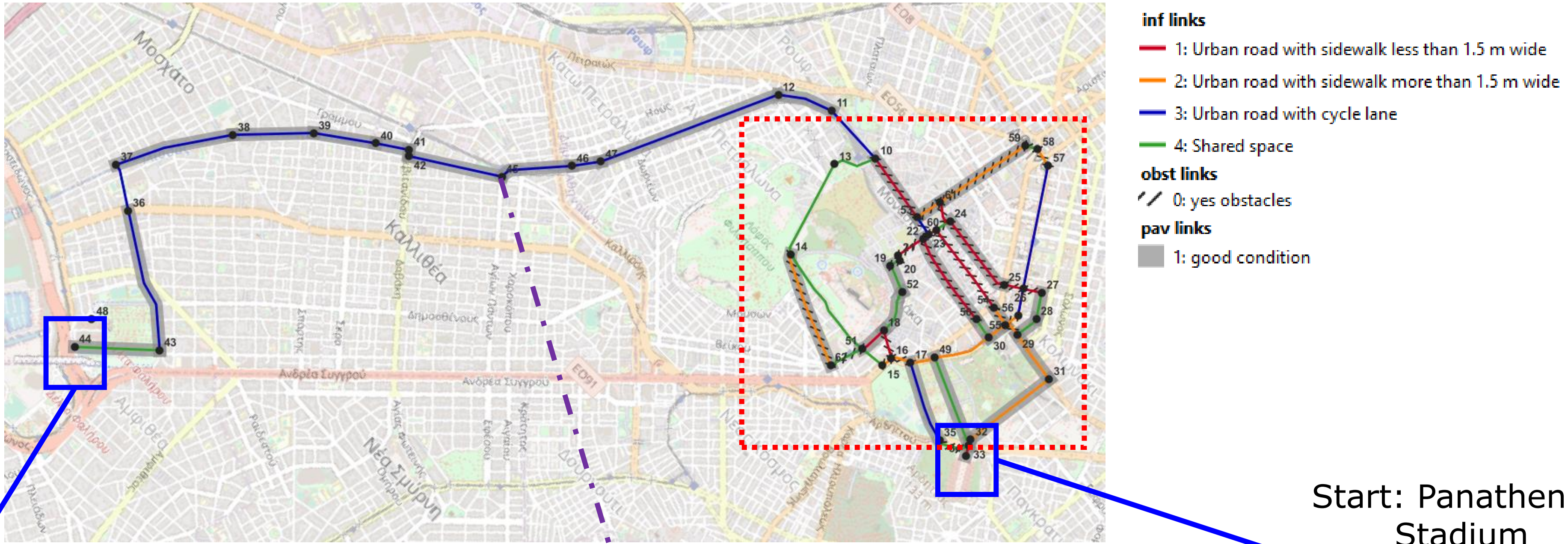
```
<link id="10002" from="16" to="18" length="175.205" capacity="1200.0" freespeed="13.889"
permlanes="1" oneway="1" modes="ebike,escoot" origid="">
  <attributes>
    <attribute name="ebikepsafe" class="java.lang.Integer">2</attribute>
    <attribute name="escootpsafe" class="java.lang.Integer">2</attribute>
    <attribute name="type" class="java.lang.String">primary</attribute>
  </attributes>
</link>
```

Additional attributes

Example 1 - Results

		Via node 3 link 2 and link 11	Via node 4 link 3 and link 12	Via node 5 link 4 and link 13	Via node 6 link 5 and link 14	Via node 7 link 6 and link 15	Via node 8 link 7 and link 16	Via node 9 link 8 and link 17	Via node 10 link 9 and link 18	Via node 11 link 10 and link 19
Additional Distance (m)		300	200	100	50	0	50	100	200	300
Additional Time (s)		72	48	24	12	0	12	24	48	72
Scenario 0	**design**	Urban road with sidewalk less than 1.5 m wide	Urban road with sidewalk less than 1.5 m wide	Urban road with sidewalk less than 1.5 m wide	Urban road with sidewalk less than 1.5 m wide	Urban road with sidewalk less than 1.5 m wide	Urban road with sidewalk less than 1.5 m wide	Urban road with sidewalk less than 1.5 m wide	Urban road with sidewalk less than 1.5 m wide	Urban road with sidewalk less than 1.5 m wide
	psafe	level 2	level 2	level 2	level 2	level 2	level 2	level 2	level 2	level 2
	no. agents	0	1	10	41	1091	47	10	0	0
	perc (%)	0.00%	0.08%	0.83%	3.42%	90.92%	3.92%	0.83%	0.00%	0.00%
Scenario 1	**design**	Urban road with cycle lane	Urban road with cycle lane	Shared Space	Urban road with sidewalk more than 1.5 m wide	as in scenario 0	Urban road with sidewalk more than 1.5 m wide	Shared Space	Urban road with cycle lane	Urban road with cycle lane
	psafe	level 5	level 5	level 3	level 3	level 2	level 3	level 3	level 5	level 5
	no. agents	0	1	10	536	122	521	10	0	0
	perc (%)	0.00%	0.08%	0.83%	44.67%	10.17%	43.42%	0.83%	0.00%	0.00%
Scenario 2	**design**	+ pavement in good condition	+ pavement in good condition	+ pavement in good condition	as in scenario 1	as in scenario 0	as in scenario 1	+ pavement in good condition	+ pavement in good condition	+ pavement in good condition
	psafe	level 6	level 6	level 4	level 3	level 2	level 3	level 4	level 6	level 6
	no. agents	0	31	406	96	119	114	401	33	0
	perc (%)	0.00%	2.58%	33.83%	8.00%	9.92%	9.50%	33.42%	2.75%	0.00%
Scenario 3	**design**	as in scenario 2	as in scenario 2	as in scenario 2	+ pedestrian crossing + obstacles on the sidewalk	+ pedestrian crossing + obstacles on the sidewalk	+ pedestrian crossing + obstacles on the sidewalk	as in scenario 2	as in scenario 2	as in scenario 2
	psafe	level 6	level 6	level 4	level 2	level 2	level 2	level 4	level 6	level 6
	no. agents	0	25	406	41	281	47	370	30	0
	perc (%)	0.00%	2.08%	33.83%	3.42%	23.42%	3.92%	30.83%	2.50%	0.00%

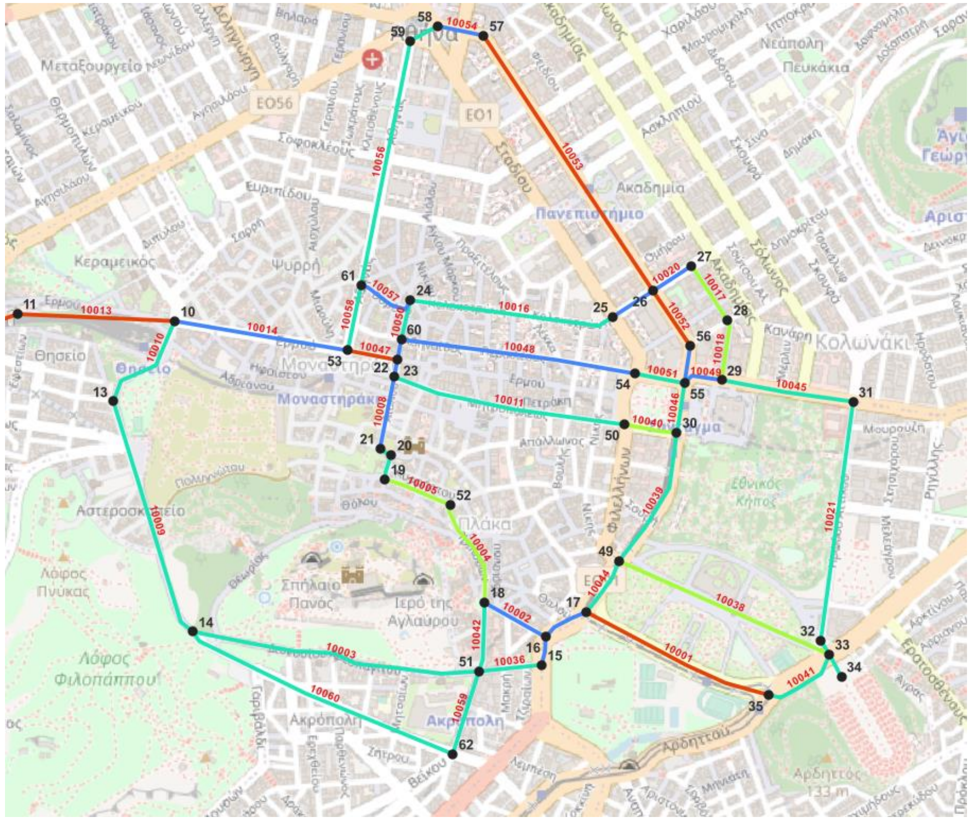
Example 2 – The study case



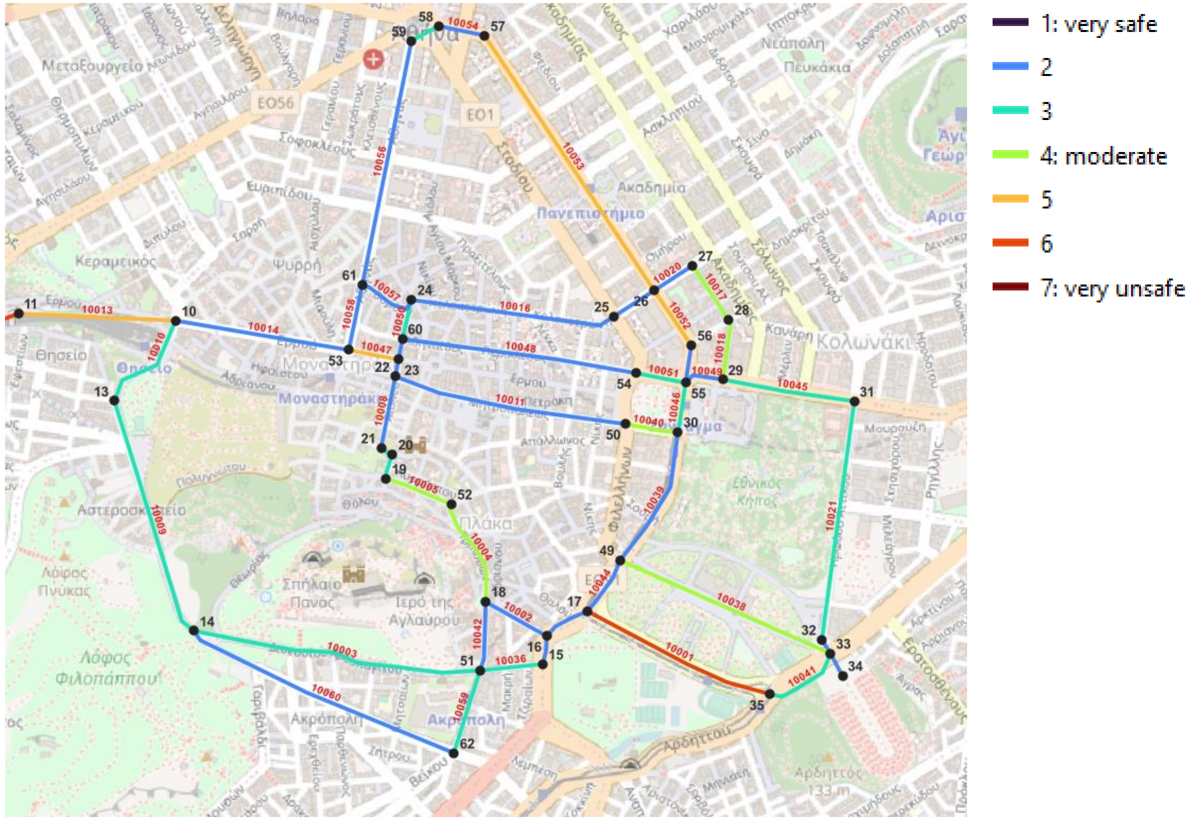
Finish: SNF Cultural Center

Start: Panathenaic Stadium

Example 2 – Perceived Safety

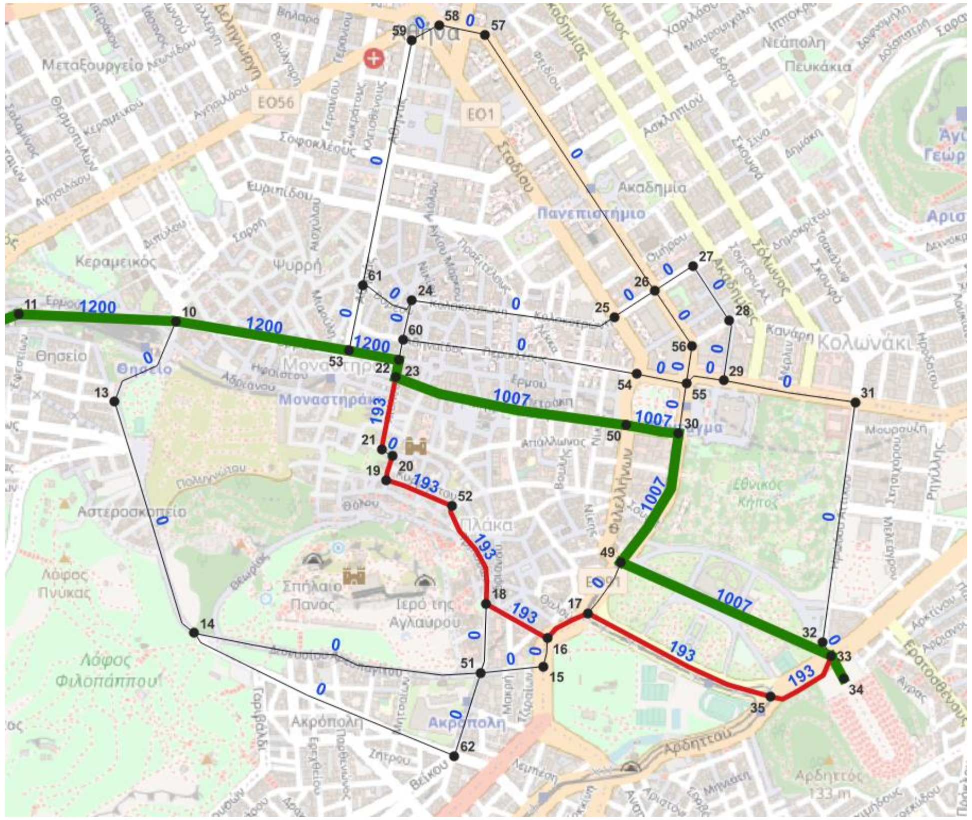


E-Bike

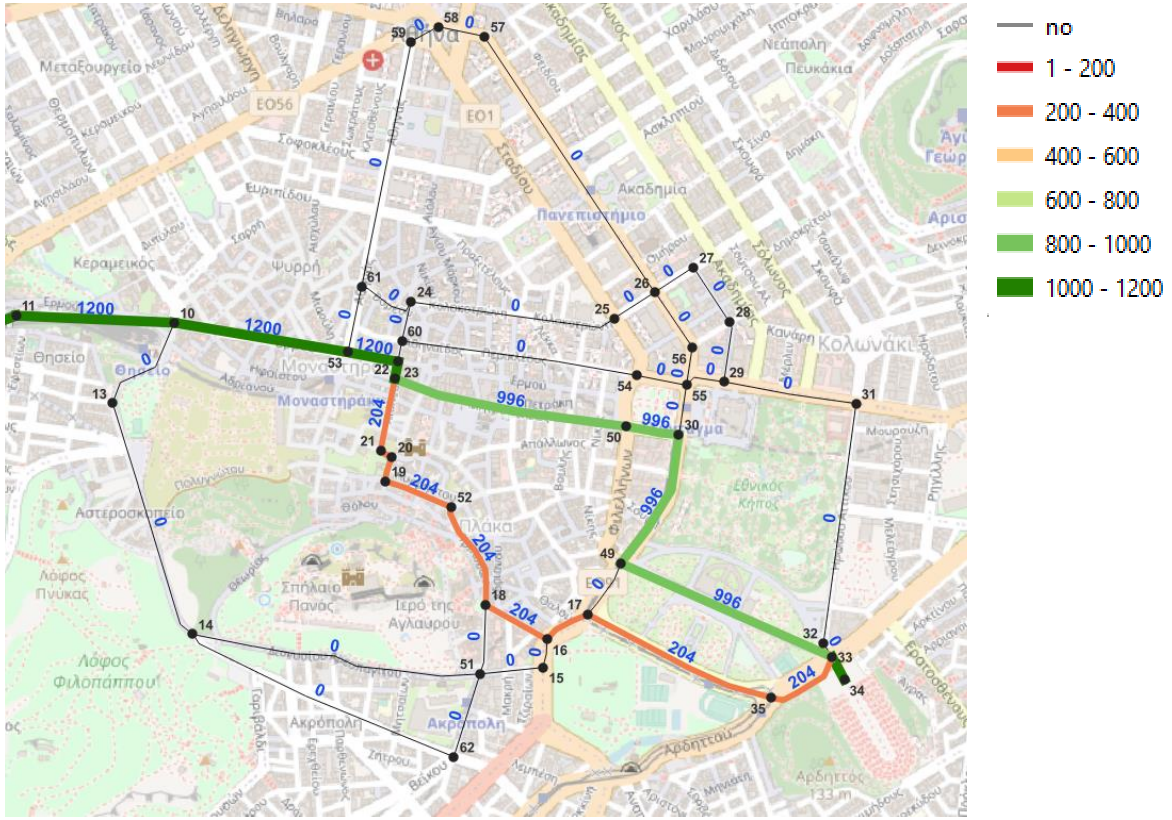


E-Scooter

Example 2 – Flows



E-Bike



E-Scooter

Conclusions

- By definition, perceived safety is a subjective notion; it differs not only per mode but per individual. Yet, it seems to be more "objective" compared to other factors used in simulations, i.e. comfort.
- Speaking about (the "unsafe") micromobility modes, perceived safety can be used to model these trips especially in cities or areas with no specialized infrastructure.
- By integrating perceived safety in MATSim, we can examine the impact of the road environment (i.e., road design and traffic interactions) on simulation outputs, as it determines supply.
- In general, there are some distance-thresholds for which e-scooter users are not willing to travel longer, even if safety levels for such routes are higher.
- These simulation tools can contribute to the planning process that aims to create car-independent cities by increasing the attractiveness of sustainable modes, like e-bike and e-scooter.

Next steps…

- Update speeds based on the infrastructure; speeds were fixed (e-bike = 20 km/h and e-scooter = 15 km/h).
- Integrate traffic interactions in the simulation framework; this means an internal loop + new scoring factors.
- A real-experiment in the case shown in the previous slides.
- Re-calibration of scoring function to increase the validity of the simulation outputs.
- Add car option in the simulation scenario.
- Examine modal shifts based on changes in the infrastructure; therefore perceived safety.
- Publish results, models and tools…

Thank your for your attention