

Ottimizzazione Semaforica e di Infrastruttura. Ottimizzazione del Trasporto Collettivo



Prof. Paolo Nesi, UNIFI DISIT



Decongestion



Safety



Accessibility



Cost Reduction



Decarbonization



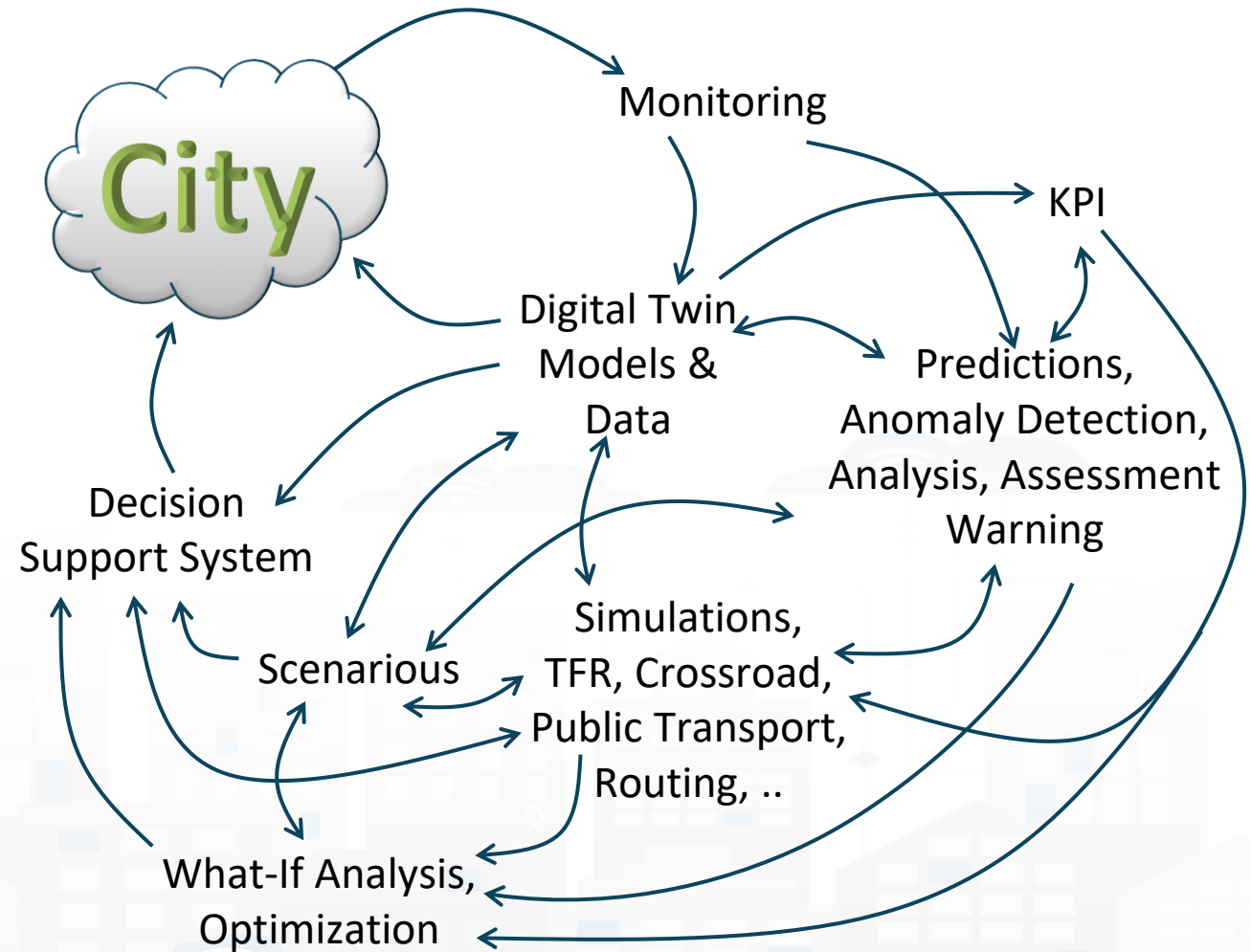
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INGEGNERIA
DELL'INFORMAZIONE

DISIT
DISTRIBUTED SYSTEMS
AND INTERNET
TECHNOLOGIES LAB

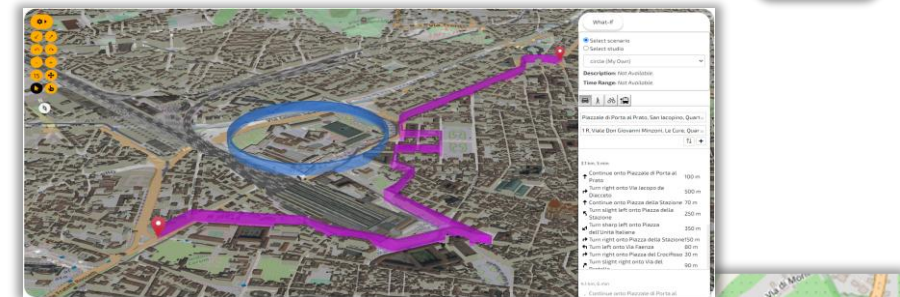


- **Controlling Status: management, and operational**
 - Monitoring via KPI
 - Predictions vs KPI
 - Anomaly detection
 - Neuro-Symbolic analysis
 - Risk assessment
 - Early warning on critical conditions
 - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
 - Simulation & optimization
 - Generative AI Prescriptions, scenarios
 - Resilience to Unexpected unknowns
 - What-if analysis wrt scenarios
 - Collaboration with stakeholders

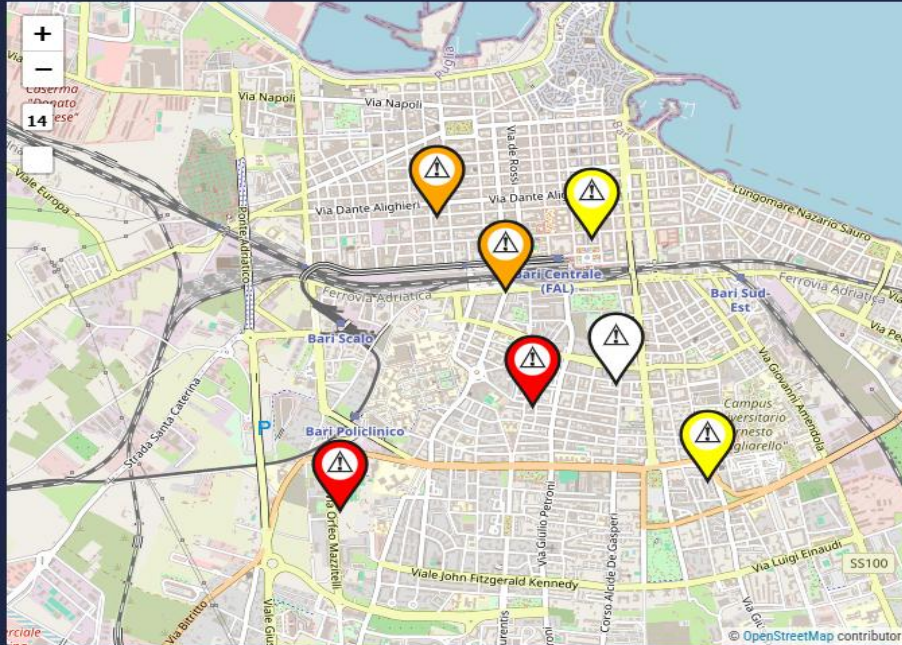


Mobility & Transport

- **Goals:**
 - Decongestion, Decarbonization, costs reductions
 - Improve Accessibility to services
 - Improve Security/Safety of city users
- **Operation and Plan:**
 - Traffic monitoring, prediction, reconstruction, identification of critical conditions (early warning), fleet management, dynamic routing, multimodal routing, city user behaviour analysis
- **Optimization and what-if analysis traffic light plans, infrastructure**
 - **Reduction:** travel time, waiting time, # stops, CO2 emissions, consume fuel, travel time for tramways and busses
- **Public Transport:** analysis of Mobility Demand vs Offer of Transportation
- **Parking Management:** monitoring, prediction, any payments, on/off-road
- **Sharing / Pooling Management:** eShare and mobile app, bikesharing, smart bike, fleet management
- **KPI:** SUMI/SUMP, travel time, emissions, traffic status, accessibility, ..
- **Mobile App:** final users and operators
 - Info Mobility, traffic reconstruction, charging, participation,
 - Parking, payments, overparking, fine reporting, ..
- **Participatory:** problem reporting, ticketing, etc.
- **Data Integration of any kind:** env, weather. Tickets, presences, POI, sat, etc.



- Home
- Traffic Monitoring
- Smart Parking
- 15 minuti index
- Urban Security



Road Monitoring

Media congestioniC	Nr. congestioniC	Picco congestioniC	Riduzione Co2 ZTLC	Emissioni medie CO2 C	Emissioni totali CO2 C
28.4	17	18:27	-5.2	282	846
%	-	-	%	ppm	ppm

Traffico in ingresso



Tot. veicoli in ingresso C	Velocità media C
12105	27
Veicoli	km/h

Traffico in uscita



Tot. veicoli in uscita C	Veicoli totali C
11703	7825
Veicoli	-

Pannello Rischi Meteo

MINIMO	BASSO	MEDIO	ALTO
Rischio Idraulico	MINIMO	Rischio Idrogeologico	MINIMO
Rischio Temporali	MINIMO	Rischio Neve	MINIMO
Rischio Ghiaccio	MINIMO	Rischio Vento	MINIMO

Viabilità

INCIDENTI	3
Chiusura Traffico	2
Chiusura Lavori	0
Limitazioni Traffico	4
Limitazioni Lavori	0
SEGNALAZIONI	7

Trasporto Pubblico

Tempo medio di attesa C	
5.9 sec	
Ritardo autobus C	
0 %	

Attesa Media Fermate

Linea 50	12 sec
Linea 11	10 sec
Linea 33	6 sec
Linea 02/	5 sec
Linea E	5 sec
Linea 19	4 sec

Sensori

15	3
Semafori	
22	0
Videocamere	
4	1
Sensori	

What-if on TFR

☰

SNAP4CITY

Scenario Editor

Some Points of Interest

Traffic Sensors

Air Quality Sensors

Weather Sensors (OW)

Bus Stops

Tram Stops

+

-

19

View

Edit

Show Road graph

Show Traffic Sensors

Filter by road types

Load Scenario:

Init

Acc

Scenarios waiting to be processed:

enrico909

Scenario version:

2024-09-23 11:58:27

Load Scenario

Clean

Free street

Fluid traffic

Heavy traffic

Very heavy

Sensor position

orionUNIFI_DISIT_deviceNameenrico909_2024-09-23T10-06-03

Traffic Heatmap Controls:

24H

Max Opacity:

<

>

1

< Prev

2024-09-23 15:00:00+02:00

INIT to ACC

Compute TFRS

Compute KPI

Show TFR

Data Update

enrico909 2024-09-23 12:06:03 (tfr)

2024-09-23T15:00:00+02:00

Calculate KPI

KPI	Value
Total CO2 emissions [ug/m^3]	13,979.071
Total fuel consumed [l]	0.249
Traffic state objective function [#]	3.935
number of vehicles [#]	51.394
total kilometers [km]	3.886
total travel time [s]	314.575

DISIT:OrionUNIFI:METRO1098 - VehicleFlow

8m

Time Series

3m

My Profile

Snap4City (C), Sett. 2025

6



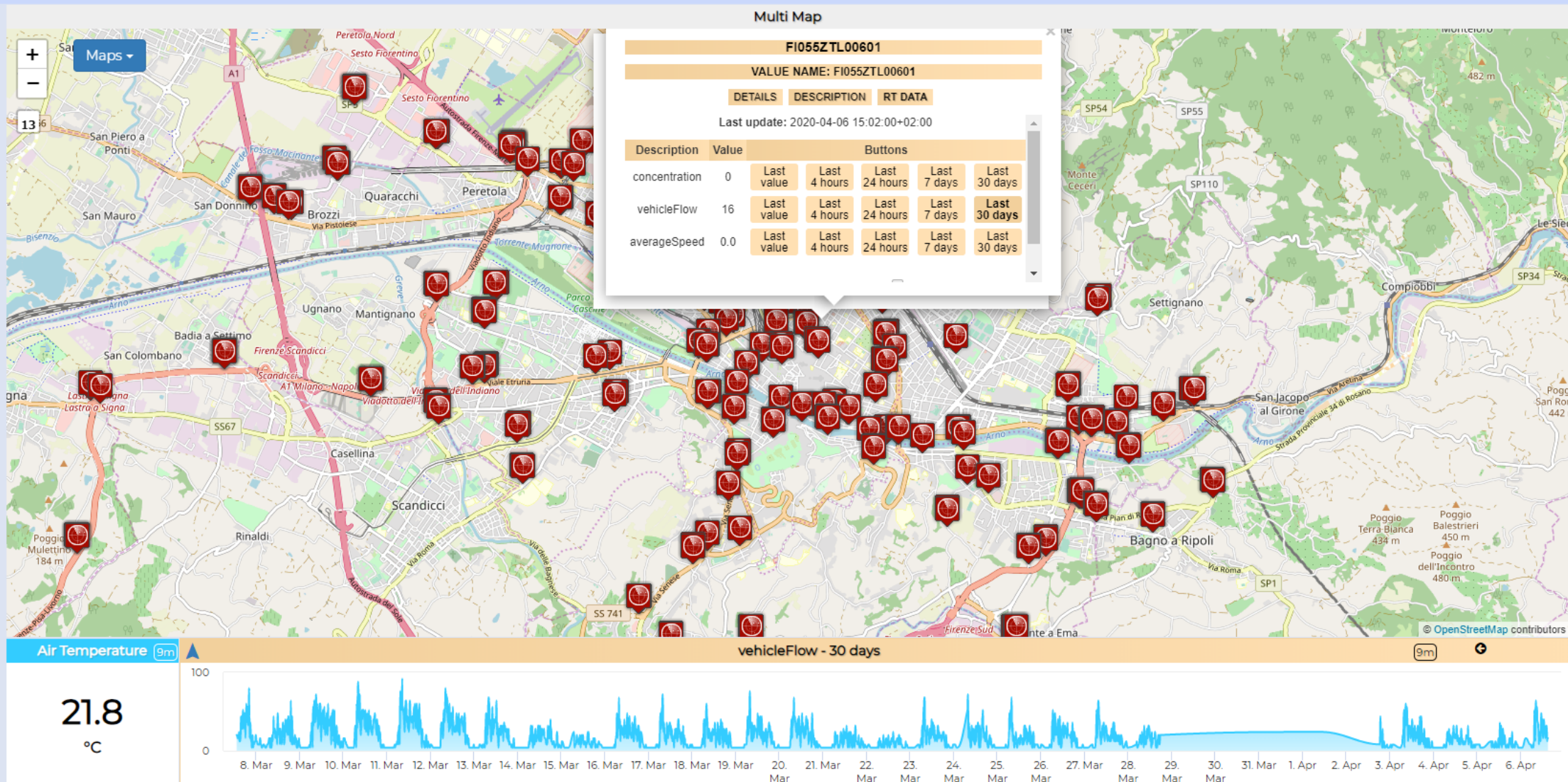
Firenze - Trafair - AirQuality Heatmaps



This dashboard contains data derived from actual sensors and predictive values under validation

Mon 6 Apr 15:12:27

- ▲ Air Quality Sensors
- ▲ Weather Sensors
- ▲ PM10 Heatmap
- ▲ PM2.5 Heatmap
- ▲ CO Heatmap
- ▲ CO2 Heatmap
- ▲ O3 Heatmap
- ▲ NO2 Heatmap
- ▲ Europ. AQI Heatmap
- ▲ Air Humidity Heatmap
- ▲ Air Temp. Heatmap
- ▲ Wind Speed Heatmap
- ▲ Gral Pred. HM NOX (3m)
- ▲ Gral Pred. HM NOX (6m)
- ▲ Traffic Sensors
- ▲ Traffic Flow
- ▲ Cycling Paths
- ▲ Accident Heatmap
- ▲ Accident Heatmap 2
- ▲ Only HRes Anym. Gral
- ▲ Green Areas
- ▲ Schools



Air quality trends

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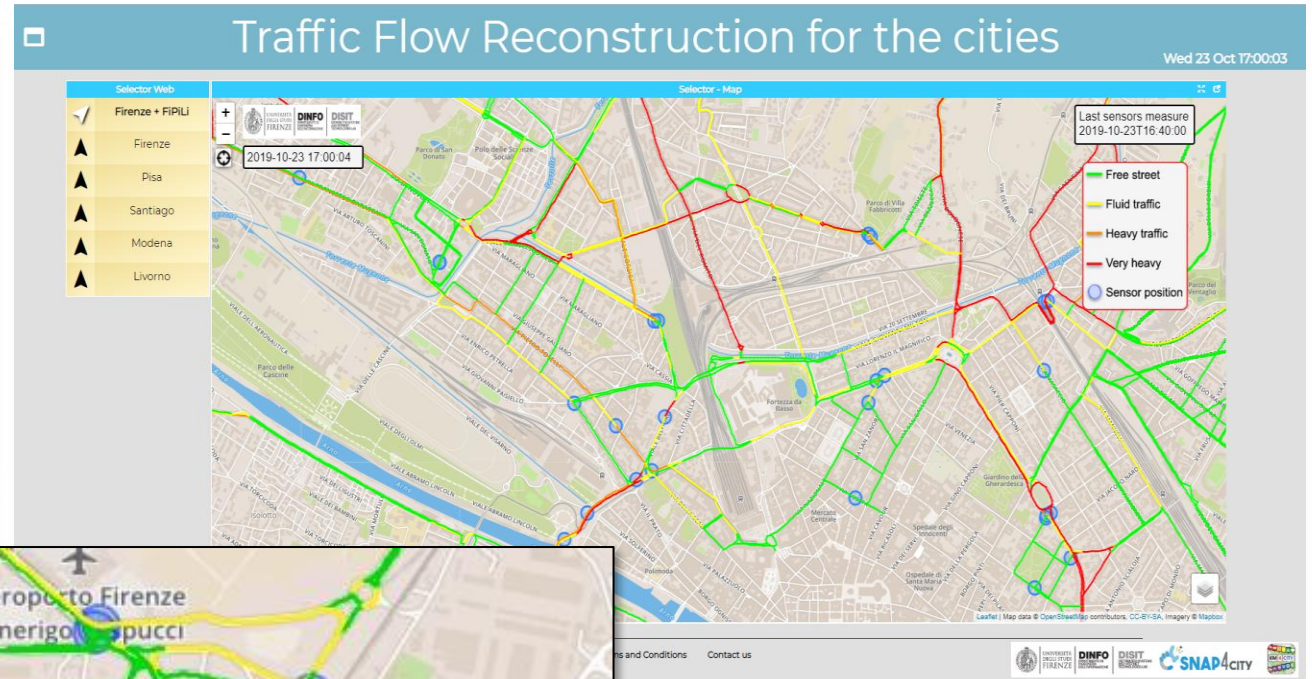


<https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTUzMg==>

Snap4City (C), Sett. 2025

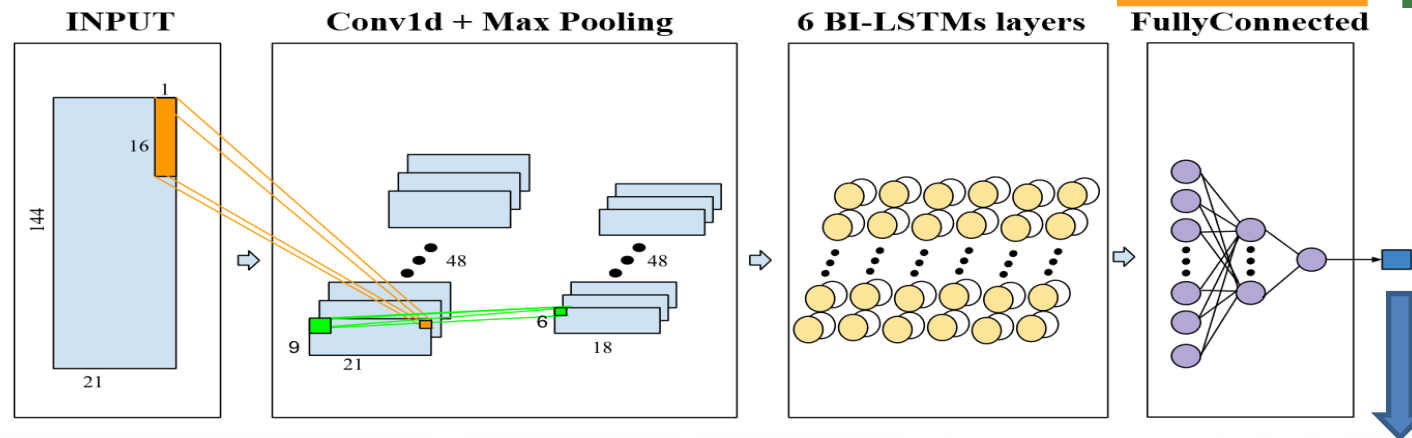
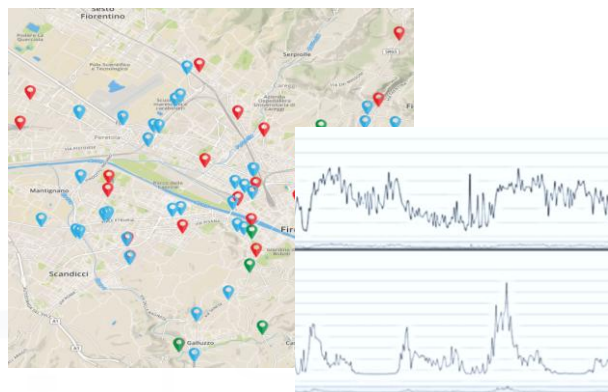
Why Dense Traffic Flow Reconstruction ?

- Making decision on mobility and transport solutions → what if analysis
- Controlling pollution
- Dynamic Routing for Firebrigade, Ambulances, general public
- Planning Public Transportation routing



<https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTc5NQ==>

Short-Term Prediction of City Traffic Flow via Convolutional Deep Learning



Urban data:

- Date-time
- Traffic
- Temporal
- Seasonality
- Pollution
- Weather

RF

XGBOOST

DNN

LSTM

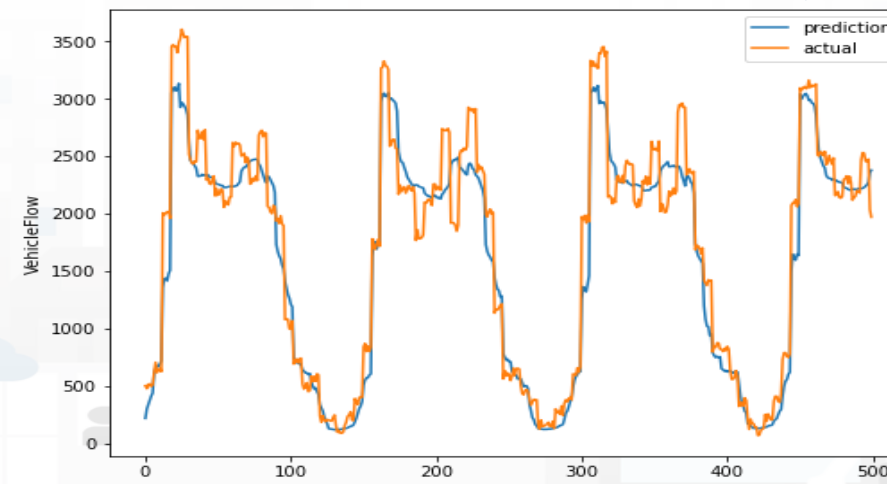
BI-LSTM

Autoencoder BI-LSTM

Attention CONV-LSTM

CONV-BI-LSTM

CONV-BI-LSTM



Routing Optimization

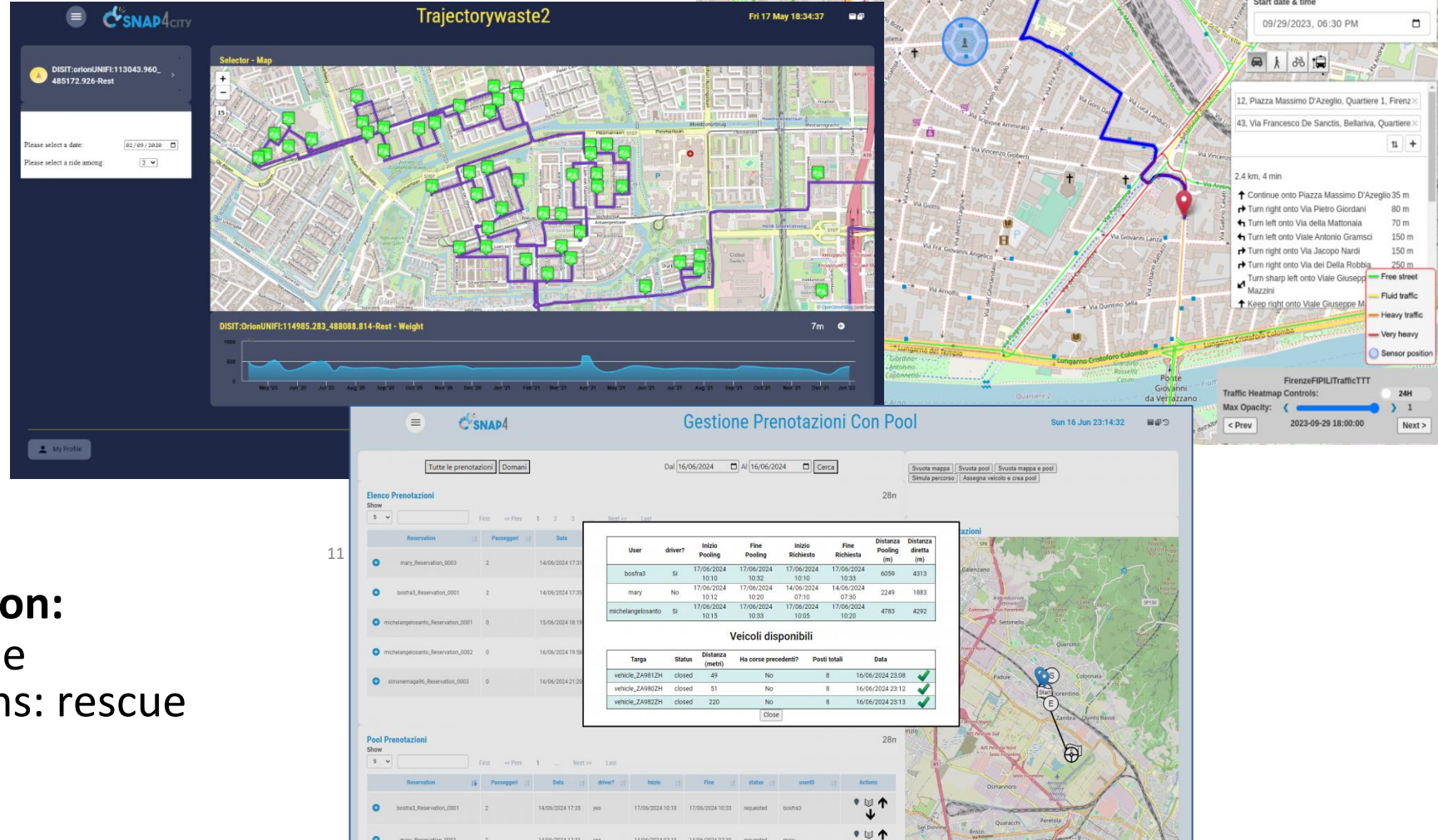
Goals on planning:

- Reduction of costs on plan
- **waste collection** optimization, Reduction of Km
- **car pooling trajectories** optimization for maximize the pool usage
- **delivering optimization**, reduction of travel time, reduction of Km
- etc.

Snap4City (C), Sett. 2025

Dynamic Routing on operation:

- React in operation to define immediate routing solutions: rescue teams, ambulance, etc.
- Recovery from failure



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DISTRIBUTED DATA INTELLIGENCE
AND TECHNOLOGIES LAB



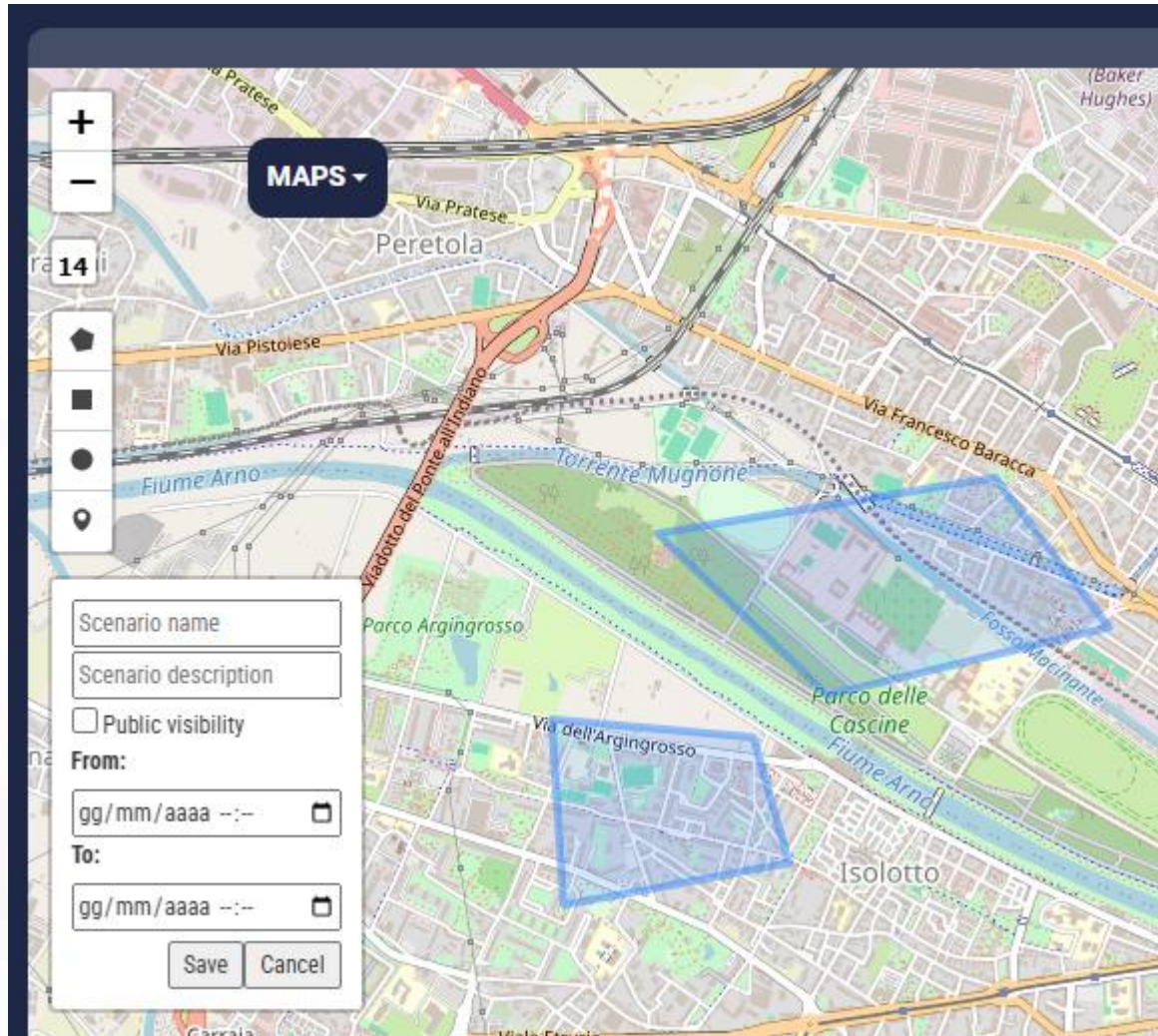
Routing Facilities

- **modal routing: private vehicles, bikes, pedestrian**
 - with start, end and multiple intermediate points
 - selecting: shorter, faster, quitter, etc..
 - dynamic conditional routing taking into account the effective traffic flow status, or typical traffic flow status
 - dynamic conditional routing taking into account eventual blocked areas (by scenario) for example for street working, restoring, etc. (what-if cases and analysis)
- **multimodal routing** for the city users to walk and take the public collective transport
- **modal routing for public administrations** (ambulance, fire brigade, police, busses, etc.) exploiting the reserved lanes, etc.
- **a combination of cases.**
- **Full API for exploitation from your applications**

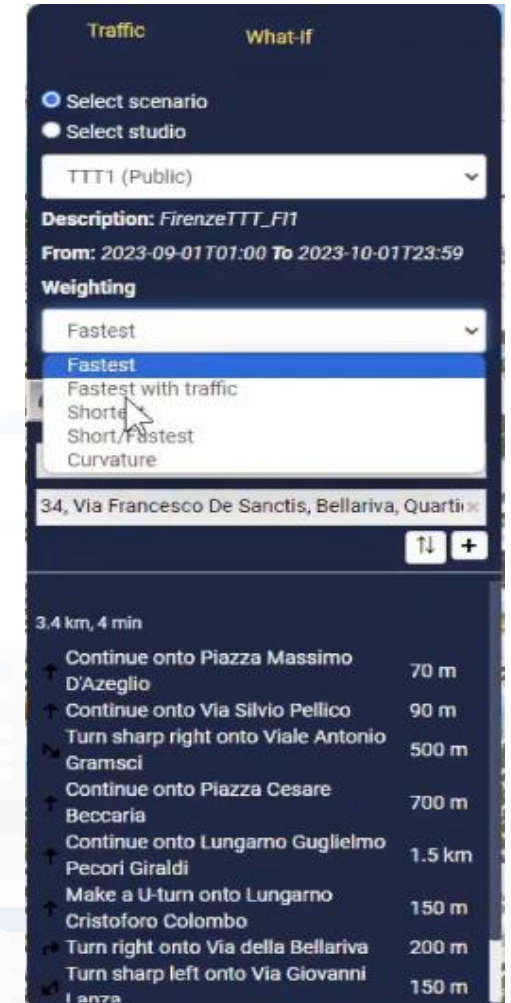
Routing Modal And Multimodal With What-If

 My Profile

What you can do with advanced tools



- **Basic Scenario editor**
 - Single and multiple blocked areas, which can be shared among users
- **What-if analysis tool**
 - Ready to use tools for exploiting Basic Scenarios as blocked areas and simulating/
 - computing in real time routing, in different traffic conditions

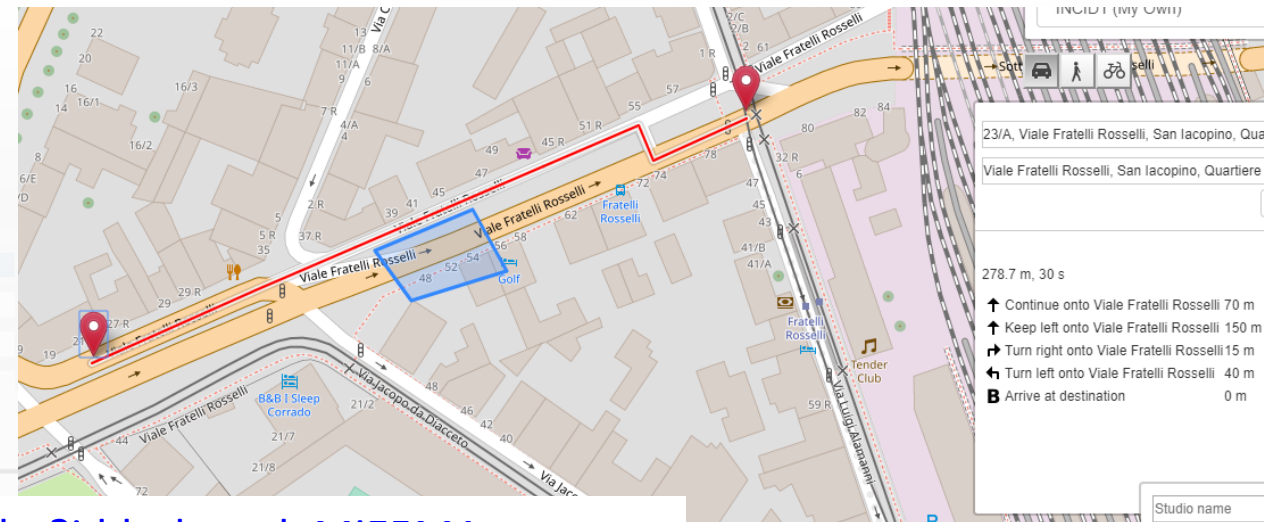
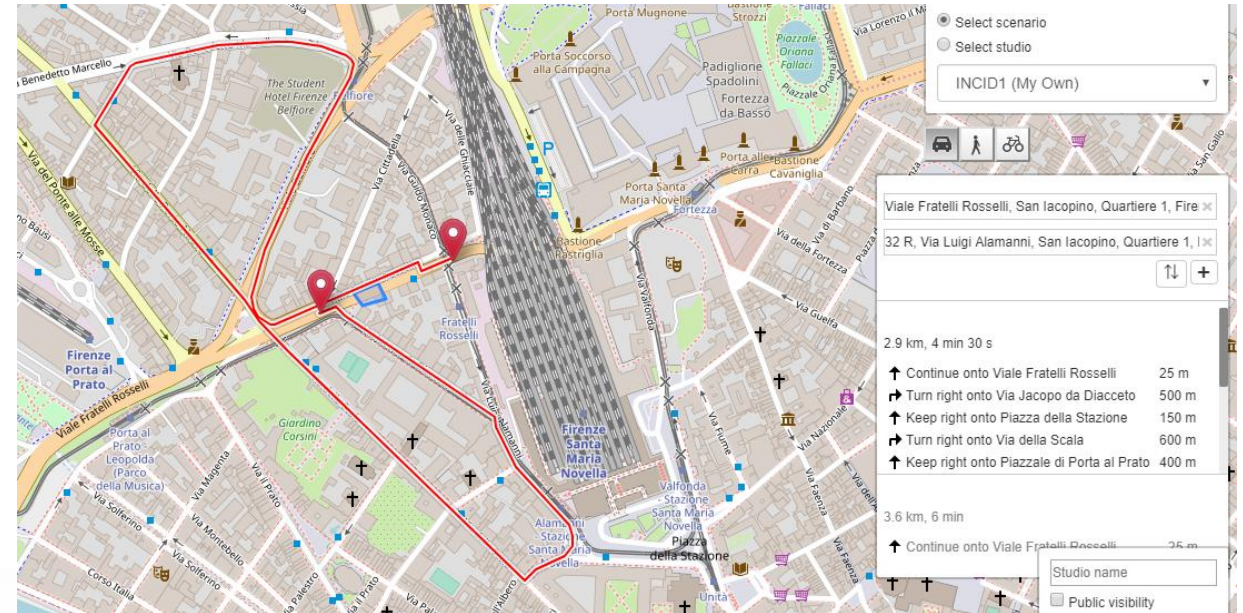


Accidents and elements blocking Points and Shapes taken into account for:

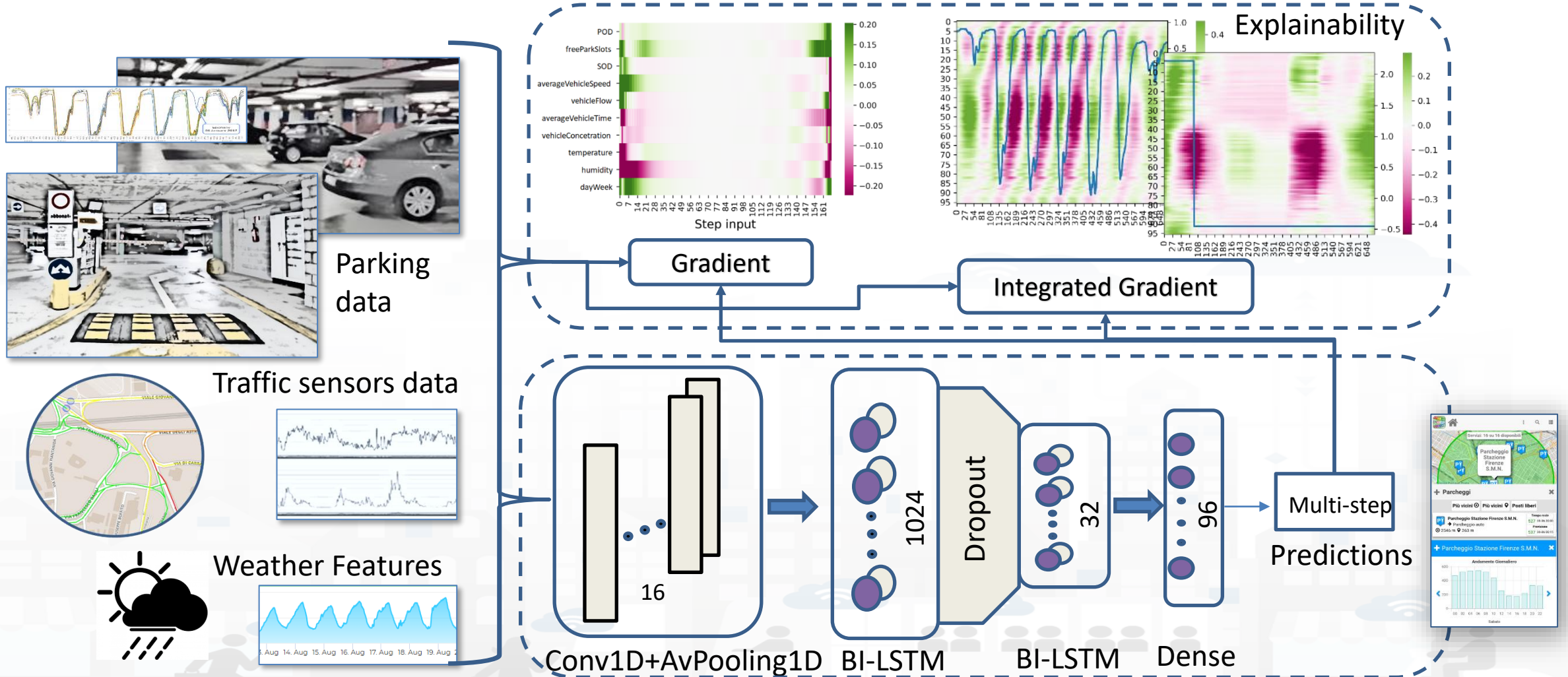
- Routing
- Traffic Flow reconstruction
- Evacuation paths
- Rescue team paths

Assessment on the basis of changes:

- Mobility demand assessment
- Mobility Offer assessment

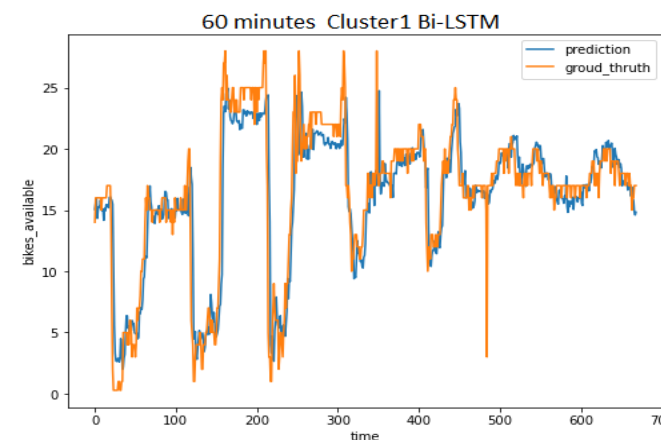
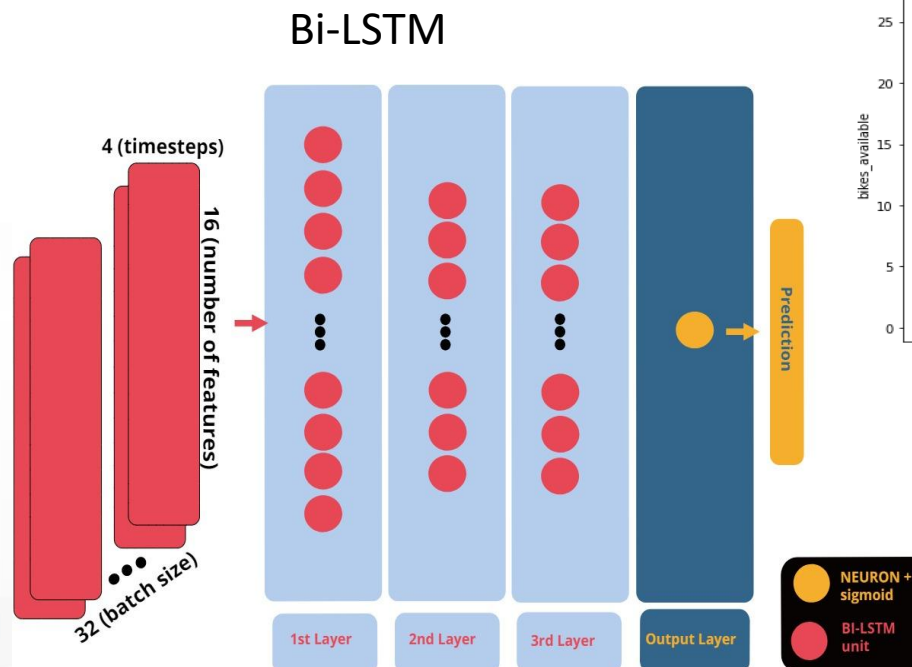
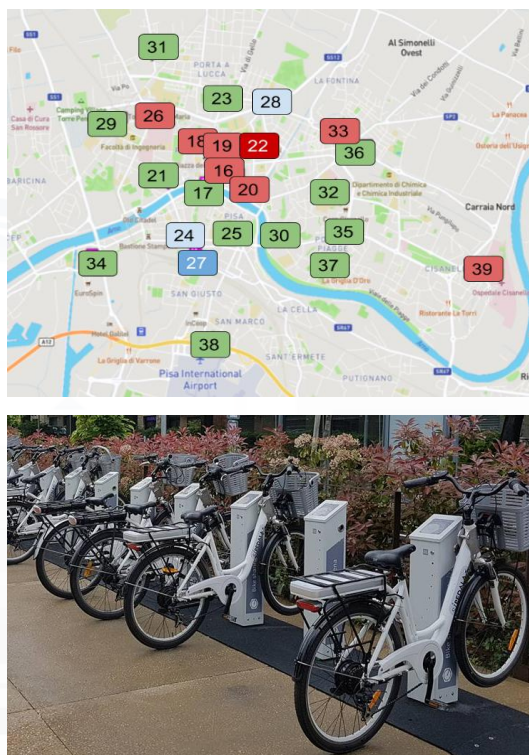


Deep Learning AI to surely Park!



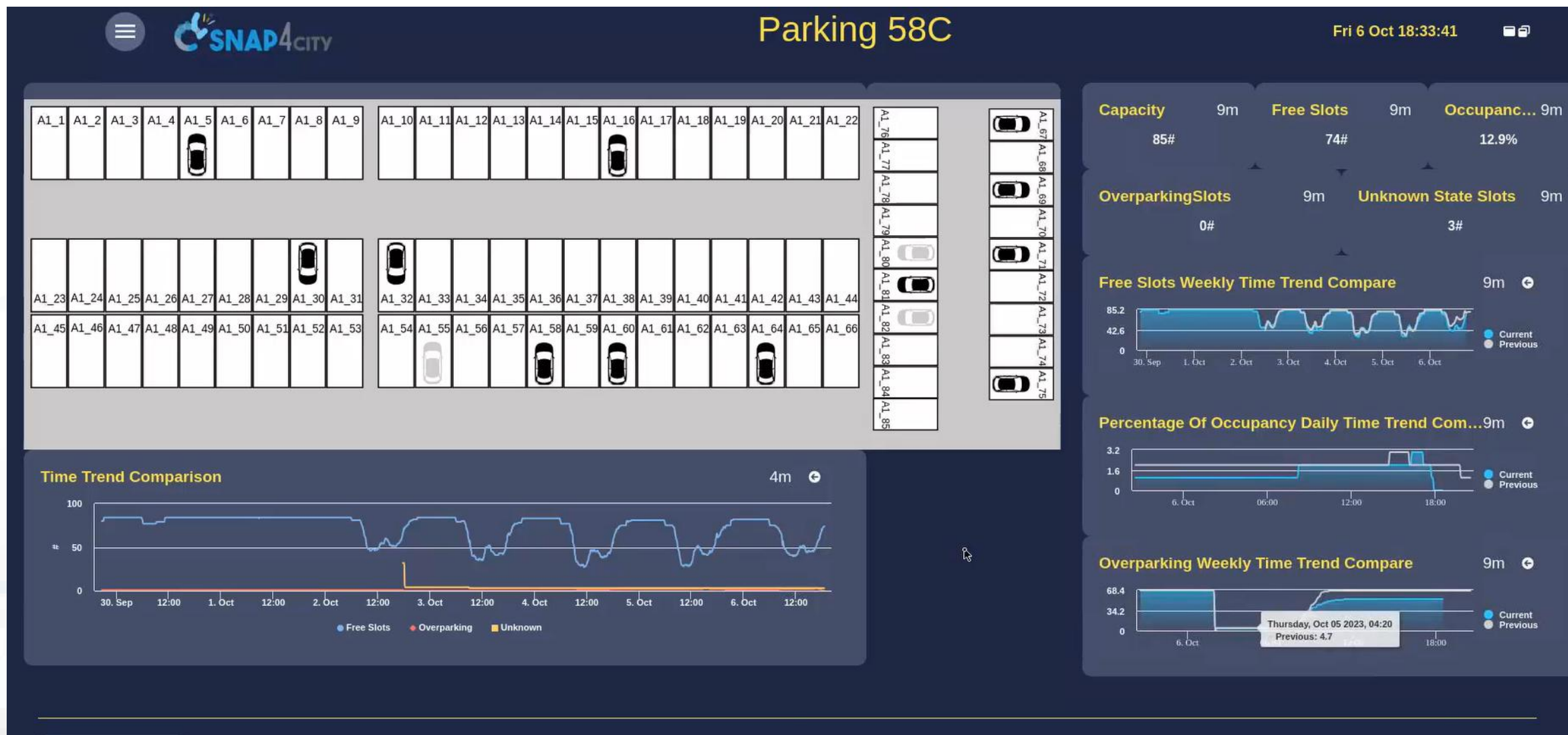


Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations



E. Collini, P. Nesi and G. Pantaleo, "Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations," in *IEEE Access*, vol. 9, pp. 124337-124347, 2021, doi: 10.1109/ACCESS.2021.3110794.
<https://ieeexplore.ieee.org/abstract/document/9530580>

Snap4ISPRA Parking: ISPRA JRC



- Home
- Traffic Monitoring
- Smart Parking
- 15 minuti index
- Urban Security

- Posto auto
- Posto auto per tipologia parcheggio
- Posto auto per tipologia veicolo



Disponibilità parcheggi

Liberi

20

stalli

Occupati

26

stalli

Non disponibili

0

stalli

Tipologia parcheggio

Gratuiti

3

stalli

A pagamento

35

stalli

Residenti

0

stalli

Prioritari

4

stalli

Disabili

4

stalli

Carico/Scarico

0

stalli

Tipologia veicolo

Auto

46

stalli

Moto

0

stalli

Bici

0

stalli

Camion

0

stalli

Camper

0

stalli

eSharing and Pooling

FROM CITY
DASHBOARD TO
APPLICATIONS

DATA
AND C
KNOW
MANA

TWITTER
VIGILANCE SOCIAL
MEDIA ANALYSIS

SNAP4CITY
AND KM4CITY
PROJECTS

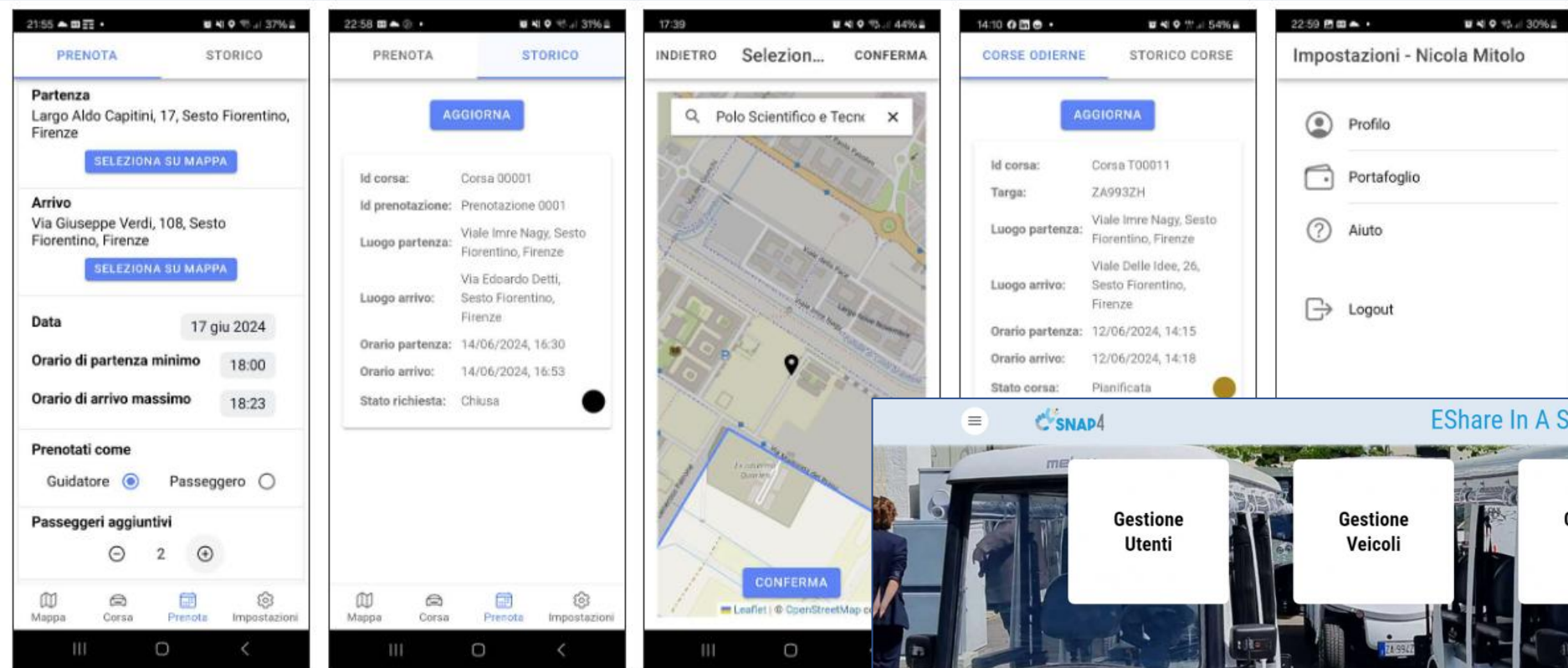
HOW TO ADOPT
SNAP4CITY, AND
ROADMAP

SNAP4CITY THE
VIEW OF THE
ADMINISTRATORS

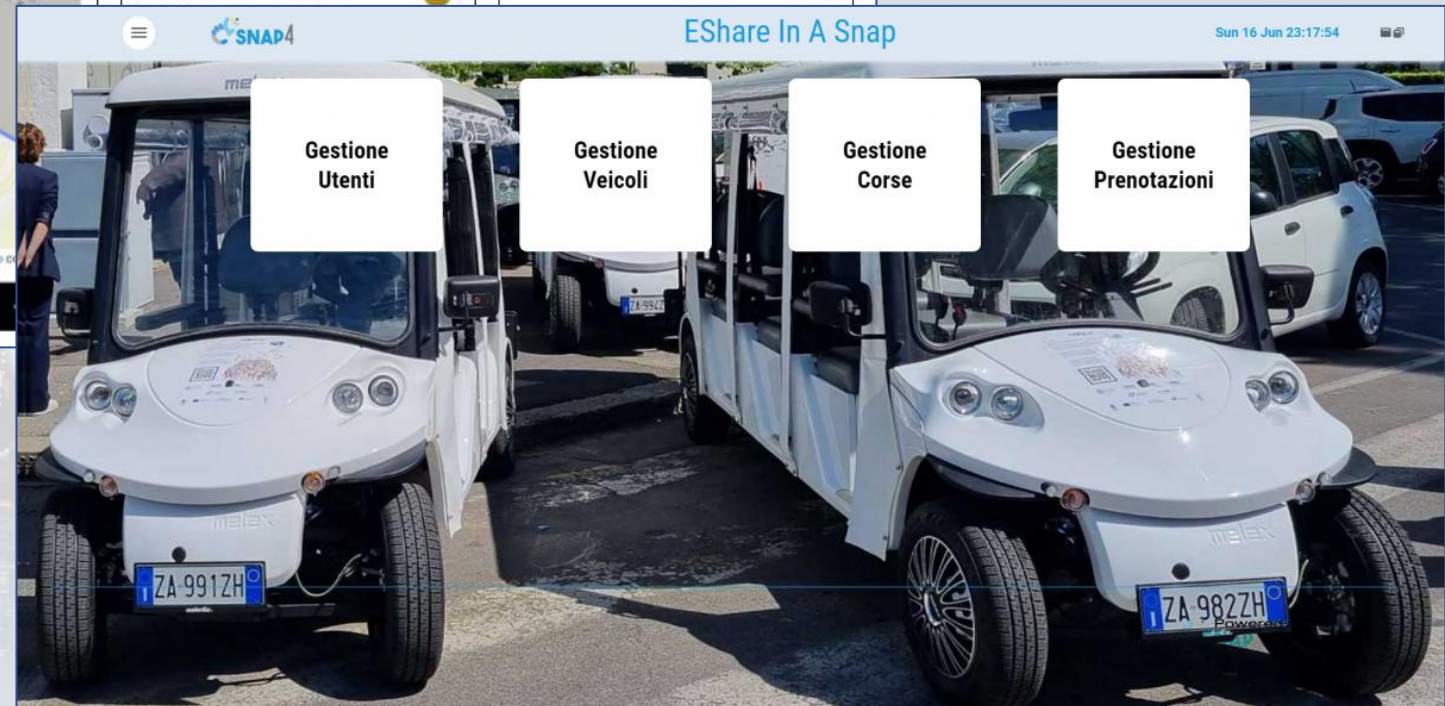


eShare in a Snap, by Snap4 s.r.l.

eShare in a Snap, by Snap4



Integrated car sharing and pooling
Multiple drivers on the same means
Dynamic pooling and e-sharing



eShare in a Snap, by Snap4



SNAP4

Gestione Veicoli

Sun 16 Jun 23:09:13

VehiclesDeviceTable

Show

5

First

<< Prev

1

2

Next >>

Last

Vehicle	Batteria	candition	Data	Blocco	Targa	status	Km/h	Actions
vehicle_ZA994ZH	97.75	Ok	16/06/2024 04:36	On	ZA994ZH	closed	0	
vehicle_ZA993ZH	98.67	Ok	16/06/2024 21:44	On	ZA993ZH	closed	0	
vehicle_ZA991ZH	92.64	Ok	16/06/2024 21:13	On	ZA991ZH	closed	0	
vehicle_ZA992ZH	88.76	Ok	16/06/2024 22:09	On	ZA992ZH	closed	0	
vehicle_ZA983ZH	87.33	Ok	16/06/2024 23:06	On	ZA983ZH	closed	0	

Time Trend Batteria

3m

11. Jun 12. Jun 13. Jun 14. Jun 15. Jun 16. Jun

vehicle_ZA993ZH - batteryLevel

Time Trend Velocità

11. Jun

Ricerca tutti i veicoli

show area

Selector - Map



Integrated car sharing and pooling
Multiple drivers on the same means
Dynamic pooling and e-sharing

SNAP4

Gestione Prenotazioni Con Pool

Sun 16 Jun 23:14:32

Tutte le prenotazioni

Domani

Dal 16/06/2024 Al 16/06/2024 Cerca

Svuota mappa | Svuota pool | Svuota mappa e pool

Simula percorso | Assegna veicolo e crea pool

Elenco Prenotazioni

Show

5

First

<< Prev

1

2

3

Next >>

Last

Reservation	Passeggeri	Data
mary_Reservatio_0003	2	14/06/2024 17:31
bosfra3_Reservatio_0001	2	14/06/2024 17:35
michelangelosanto_Reservatio_0001	0	15/06/2024 18:19
michelangelosanto_Reservatio_0002	0	16/06/2024 19:58
simonemaga96_Reservatio_0003	0	16/06/2024 21:20

Veicoli disponibili

User	driver?	Inizio Pooling	Fine Pooling	Inizio Richiesto	Fine Richiesta	Distanza Pooling (m)	Distanza diretta (m)
bosfra3	Si	17/06/2024 10:10	17/06/2024 10:32	17/06/2024 10:10	17/06/2024 10:33	6059	4313
mary	No	17/06/2024 10:12	17/06/2024 10:20	14/06/2024 07:10	14/06/2024 07:30	2249	1883
michelangelosanto	Si	17/06/2024 10:15	17/06/2024 10:33	17/06/2024 10:05	17/06/2024 10:20	4783	4292

Close

Pool Prenotazioni

Show

5

First

<< Prev

1

Next >>

Last

Reservation	Passeggeri	Data	driver?	Inizio	Fine	status	userID	Actions
bosfra3_Reservatio_0001	2	14/06/2024 17:35	yes	17/06/2024 10:10	17/06/2024 10:33	requested	bosfra3	
mary_Reservatio_0003	2	14/06/2024 17:31	yes	14/06/2024 07:10	14/06/2024 07:30	requested	mary	

Map

Trucks' Plates and Container ID Recognition



- **Managing Gates to Salerno Port**
- Gates: in/out
- **Recognition and decoding**
 - BIC code: TSSU 204006
 - ISO code: 22G1
 - Seal status: on/off
 - Multi-national Plates: 74-0771

SNAP4CITY GATE07 - Out Fri 5 Sep 15:36:52

Qcr

Immagine originale container

Targa truck

Codice Container

Container gate

HH4B123	05/09/2025, 10:22:17
BF C456	05/09/2025, 11:45:22
EX398AE	05/09/2025, 13:16:43

EX398AE
05/09/2025, 13:16:43
Orario: 05/09/2025, 13:16:43
Durata OCR (s): 2.3
Truck - Accuratezza: 97.9

Targa: EX398AE
Nazione: IT

Container - Accuratezza: 98.2

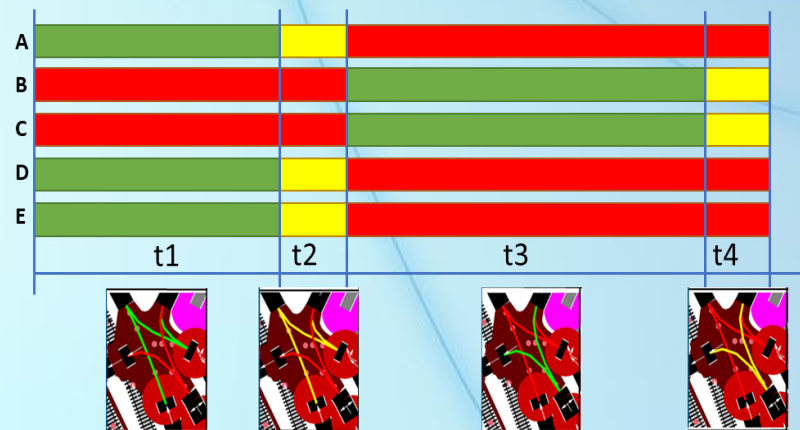
Codice: FCIU9644848
Codice ISO: 45G1
Nazione: Hong Kong

Rimorchio

Modifica Annulla Invia Scarica

My Profile

Powered by SNAP4Tech



IL FUTURO DELLA MOBILITA'
INTELLIGENTE E SOSTENIBILE



Ottimizzazione Semaforica

Prof. Paolo Nesi, UNIFI DISIT

<https://www.snap4city.org/1015>



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Traffic Light Optimisation

- **Traffic Light Plan:**

- General construction of Traffic Light Plans for the area
- TLP are loaded on the basis of the expected conditions: football game, ferial and festive, school period, morning and afternoon, etc.
- Single Junction TLP can be:
 - adjusted exploiting local data, on demand signals, etc.
 - Actuated on the basis of the measures of traffic

- **Issues:**

- Making multijunction synchronization to keep under control of quality of Service for TRAMWAYS and/or Busses Rapid Transit, BRT/HRB



Select map

Zoom

New Scenario

Editing

Drag & drop

Split & Join

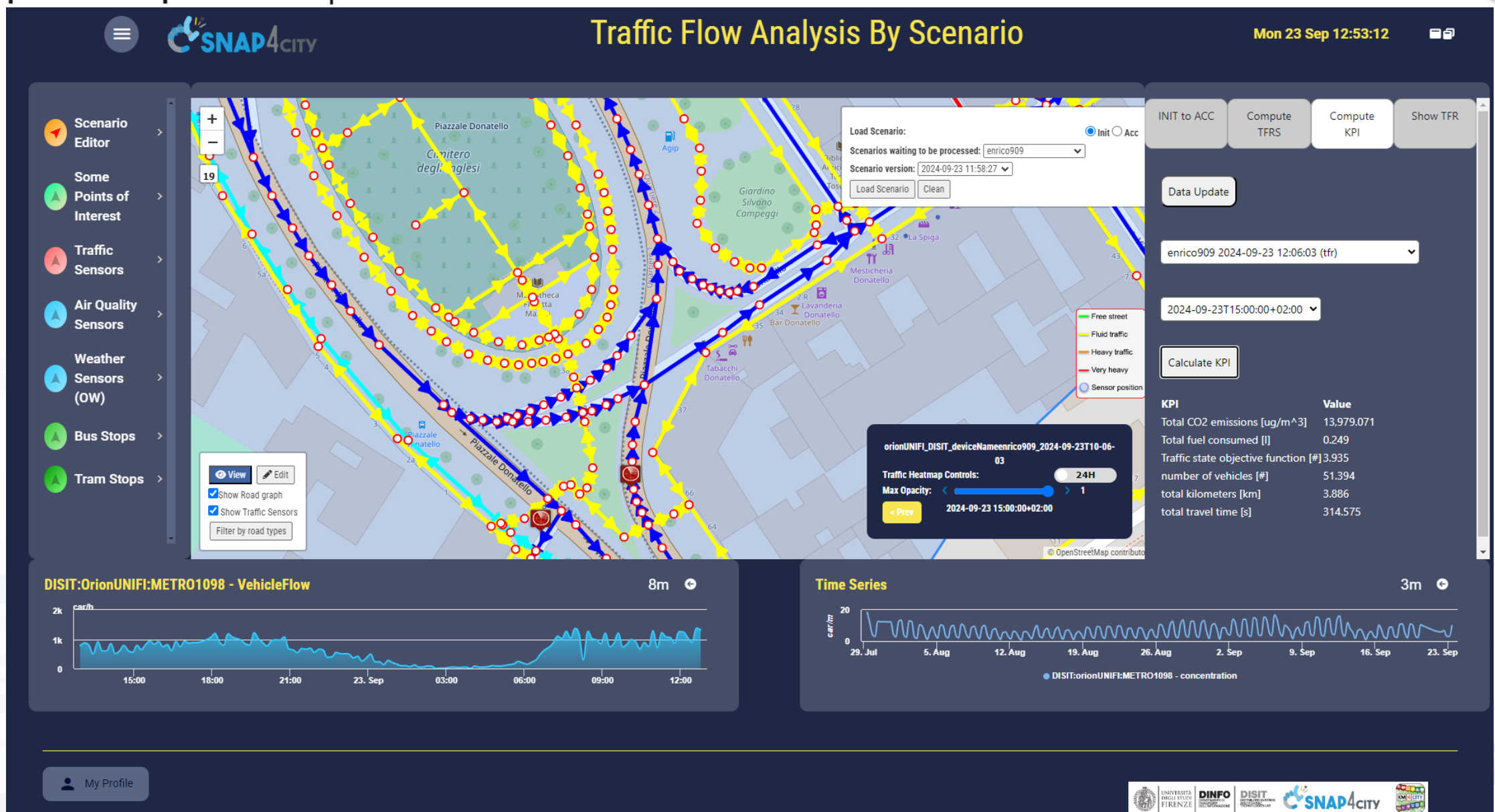
Delete

Do and Undo

Edit Road
Segment

identifier
composition
elemLocation
elementClass
elementType
length
operatingStatus
speedLimit
trafficDir
width
highwayType
route

What-if on TFR



Traffic Light Plan Optimisation, Digital Twin

- **Match Multiple Objectives and Synchronization:**

- public and private traffic, tramway priority
- Micro and Macro Scales

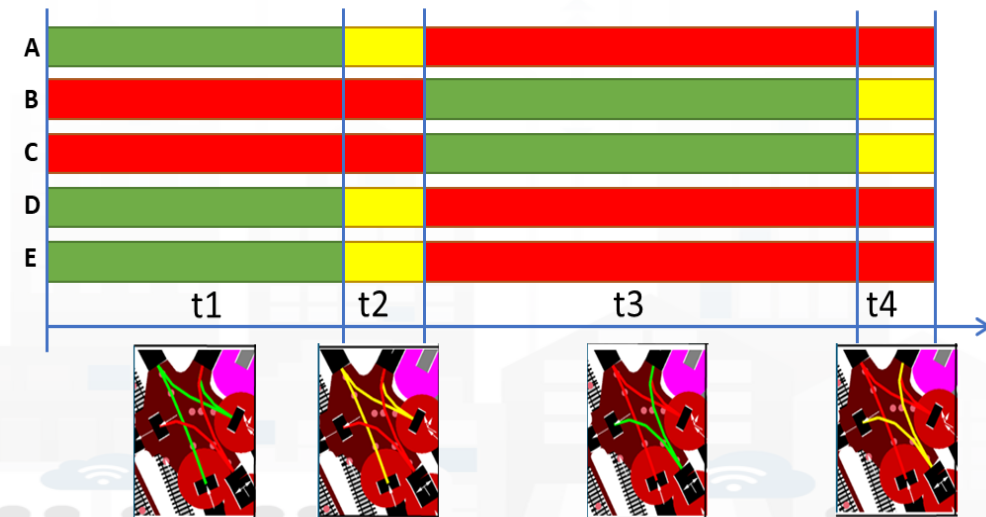
- **AI: Genetic Algorithms, Deep Reinforced Learning**

- Fixed and Actuated Cycles
- Adjusted on Demand

- **Validation/integ.** with *SUMO* simulation

- Travel Time, waiting time, waiting count
- Specific travel time on directions
- CO2 emissions, etc.

- **Reductions from 5% to 15%**



Traffic Light Plan Editor

Traffic Light Plan Generator

Wed 23 Oct 18:50:03

Traffic Light Plan Editor

Query radius:

Semaphore name:

Directions:

Time cycle:

Save Traffic Light

debug

Clear

View
Edit

Mode
☐
Mode

	Via Ve...	Via Fr...	Via Ve...
Via Ve...	1	0	0
Via Fr...	2	0	3
Via Le...	0	4	5

1 : Via Venti Settembre - Via Venti Settembre

2 : Via Francesco Crispi - Via Venti Settembre

3 : Via Francesco Crispi - Via Venti Settembre

4 : Via Leone Decimo - Via Francesco Crispi

5 : Via Leone Decimo - Via Venti Settembre

Selector - Map

19

Drill

MAPS

Load Scenario: ☒ Init ☐ Acc
Scenarios waiting to be processed: dbologna_scenario2
Scenario version: 2024-02-21 17:20:42

Load Scenario

Clean

View

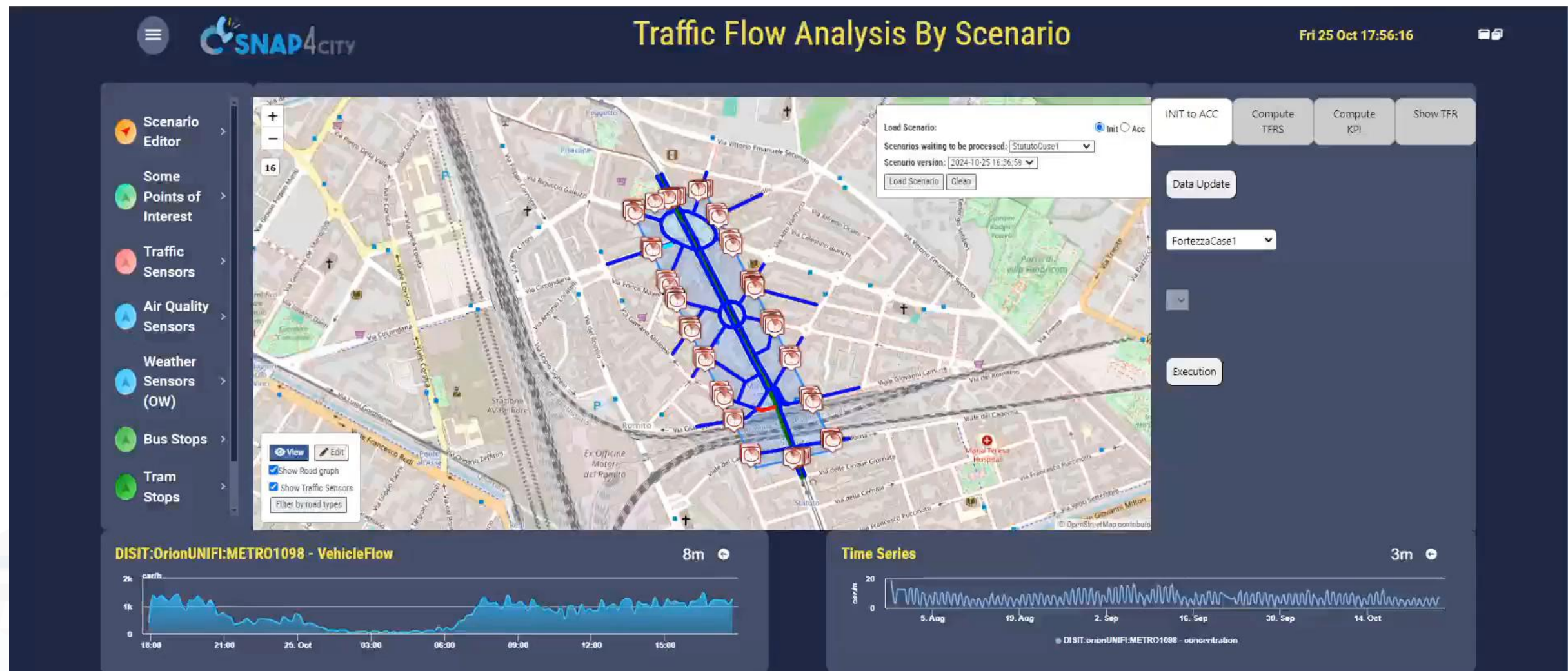
Edit

☒ Show Road graph

☒ Show Traffic Sensors

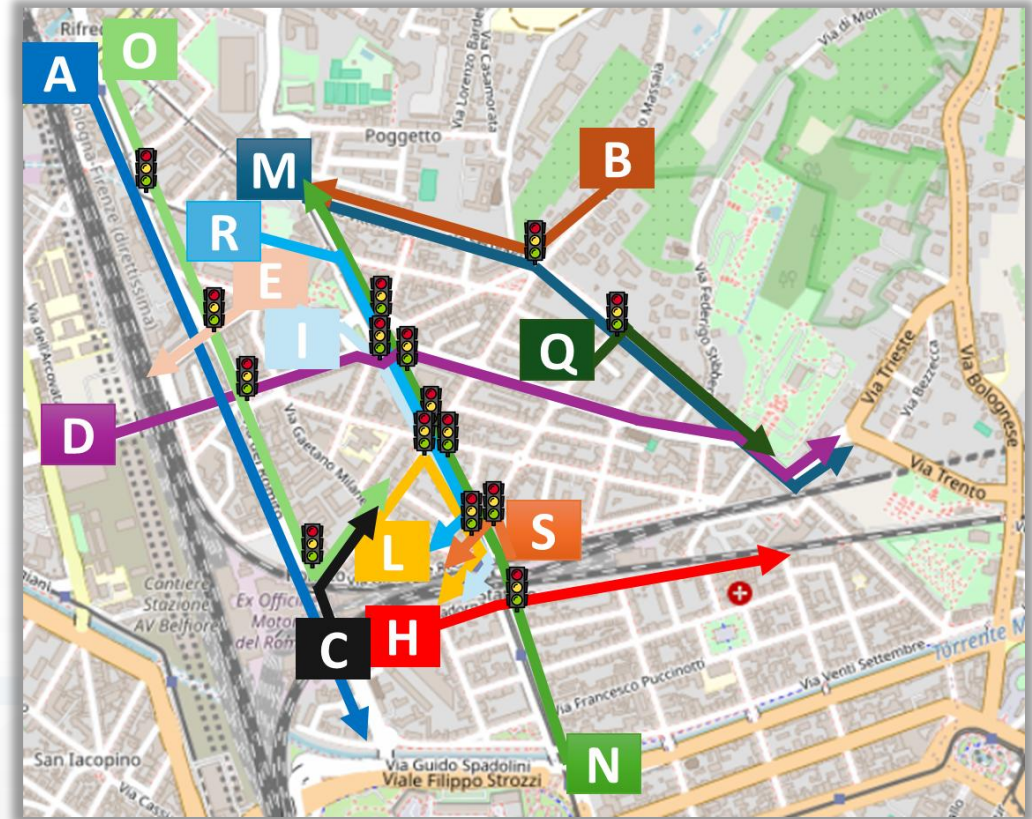
Filter by road types

Optimization of Traffic Light Plan



Optimization Drivers

- **MTT, Mean Travel Time** on
 - Multiple Directions or globally
 - For specific service
- **MWT, Mean Waiting Time** on
 - specific direction or globally
 - For specific service
- **MNS, Mean Number of Stops** on
 - specific direction or globally
 - For specific service



GA based: Mean Travel Time

	Traffic Load	MTTall	MTT dir_N	MTT dir_M	MTT dir_A	MTT TW Careggi	MTT TW Costanza
4TW-NTNS-MWD-P	1.5	3542.50	198.90	242.14	197.64	436.00	427.00
4TW-NTNS-MWD-A	1.5	3242.71	178.33	243.28	195.79	436.00	427.00
4TW-NTNS-MWD-P-A	1.5	3242.71	178.33	243.28	195.79	436.00	427.00
2TW-NTNS-MWD-P	1.5	4538.02	207.40	456.14	615.00	436.00	427.00
2TW-NTNS-MWD-A	1.5	3940.07	179.30	428.67	481.53	436.00	429.75
2TW-NTNS-MWD-P-A	1.5	4380.63	182.05	456.59	654.21	436.00	427.00
SUMO Actuated	1.5	3409.13	280.09	515.34	200.66	497.54	499.81
Webster	1.5	6474.95	465.45	441.93	210.50	1379.25	493.87
WebsterAdjusted	1.5	4035.08	195.82	441.09	205.66	463.87	447.06

-5%

-8%

-45%

-3%

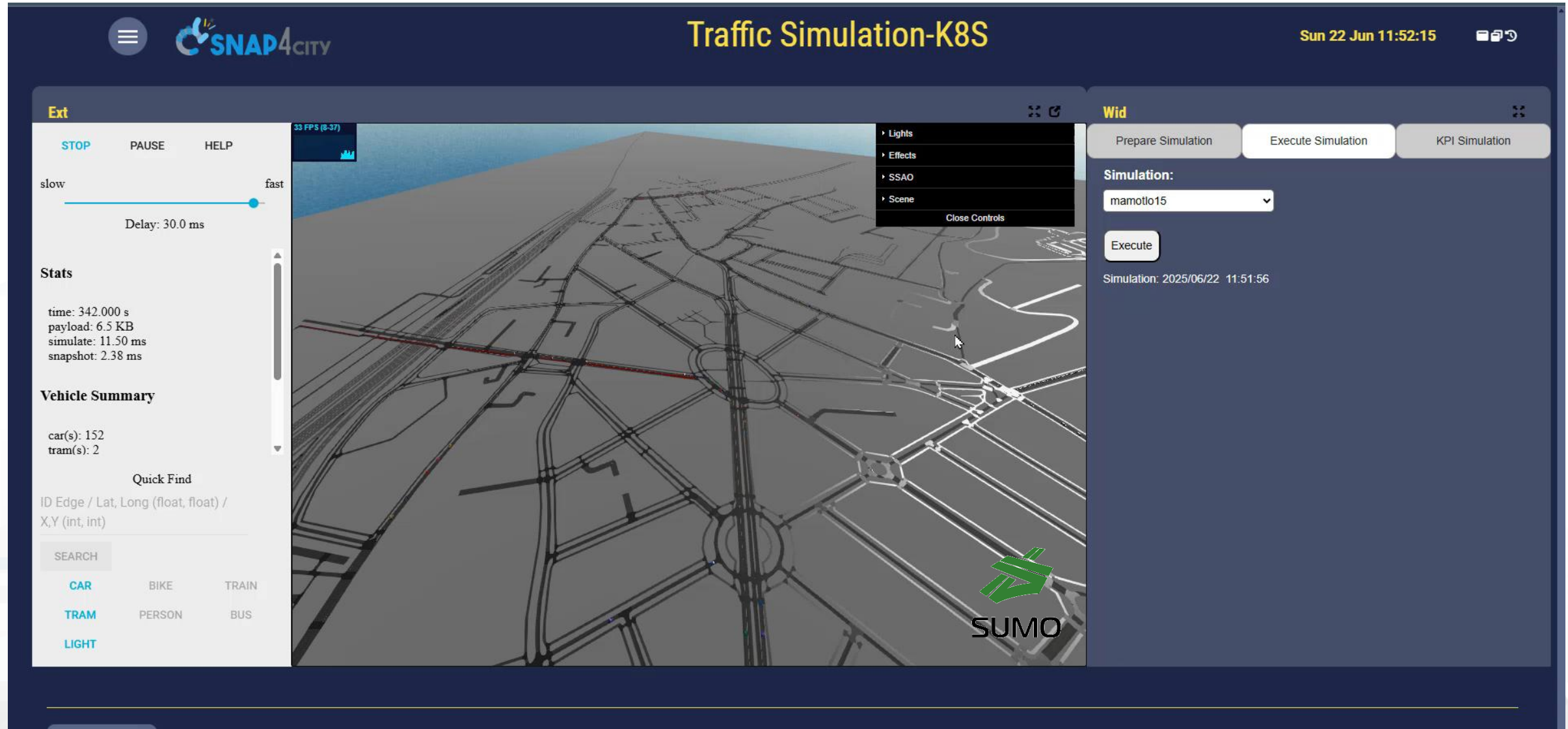
-6%

-4.5%

Reductions of Travel time of 3-45% and elimination of the #stops for the tramways

4TWD-NTNS-MWD-P-A: optimization by prioritizing traffic **directions**, the normalized number of **vehicles stops**, **NTNS**, the **mean waiting delay MWD**, for all traffic lights, and post synchronization, with Penalty and Adjust dynamically performed

S. Bilotta, Z. Fereidooni, L.A. Ipsaro Palesi, P. Nesi, "Macroscopic GA-based Multi-Objective Traffic Light Optimization Prioritizing Tramways", Applied Soft Comp. Journal, Elsevier, 2025.

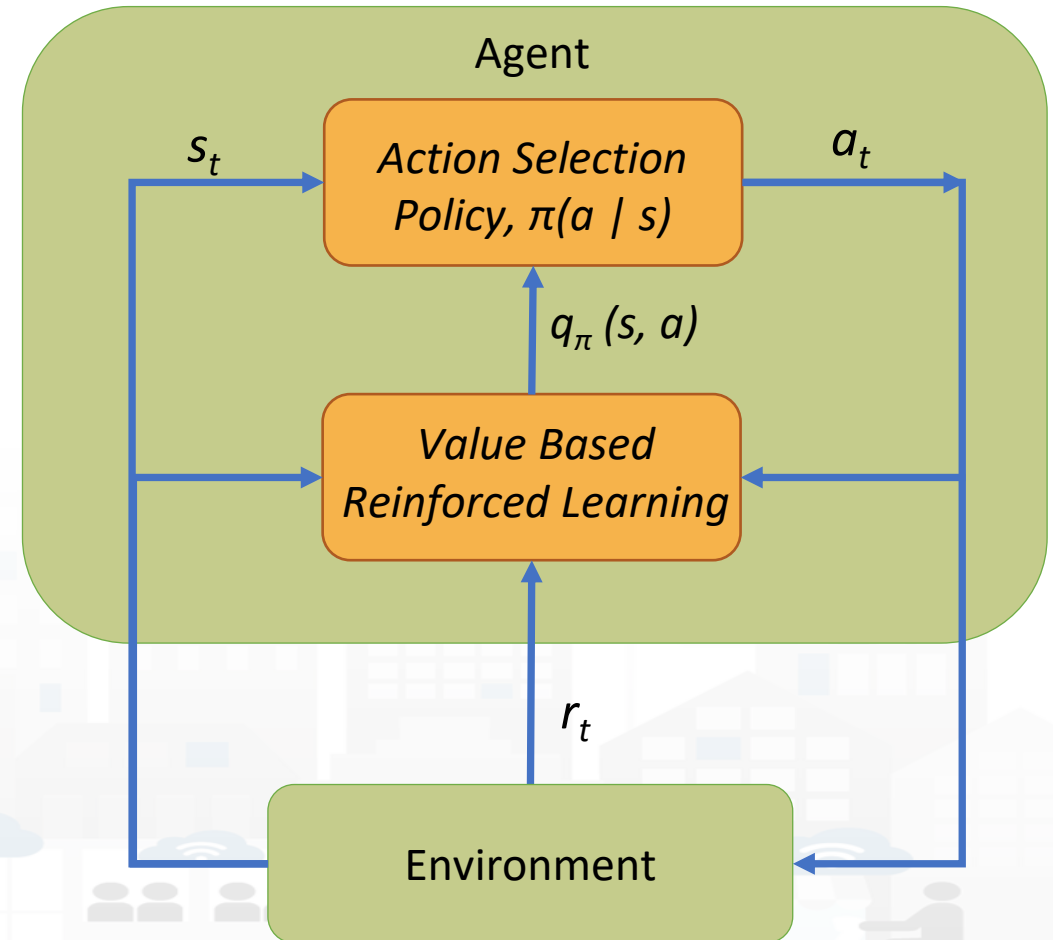


The screenshot displays the SNAP4CITY Traffic Simulation-K8S interface. The main window shows a 3D perspective view of a complex urban road network with a tram line highlighted in red. The interface is divided into several panels:

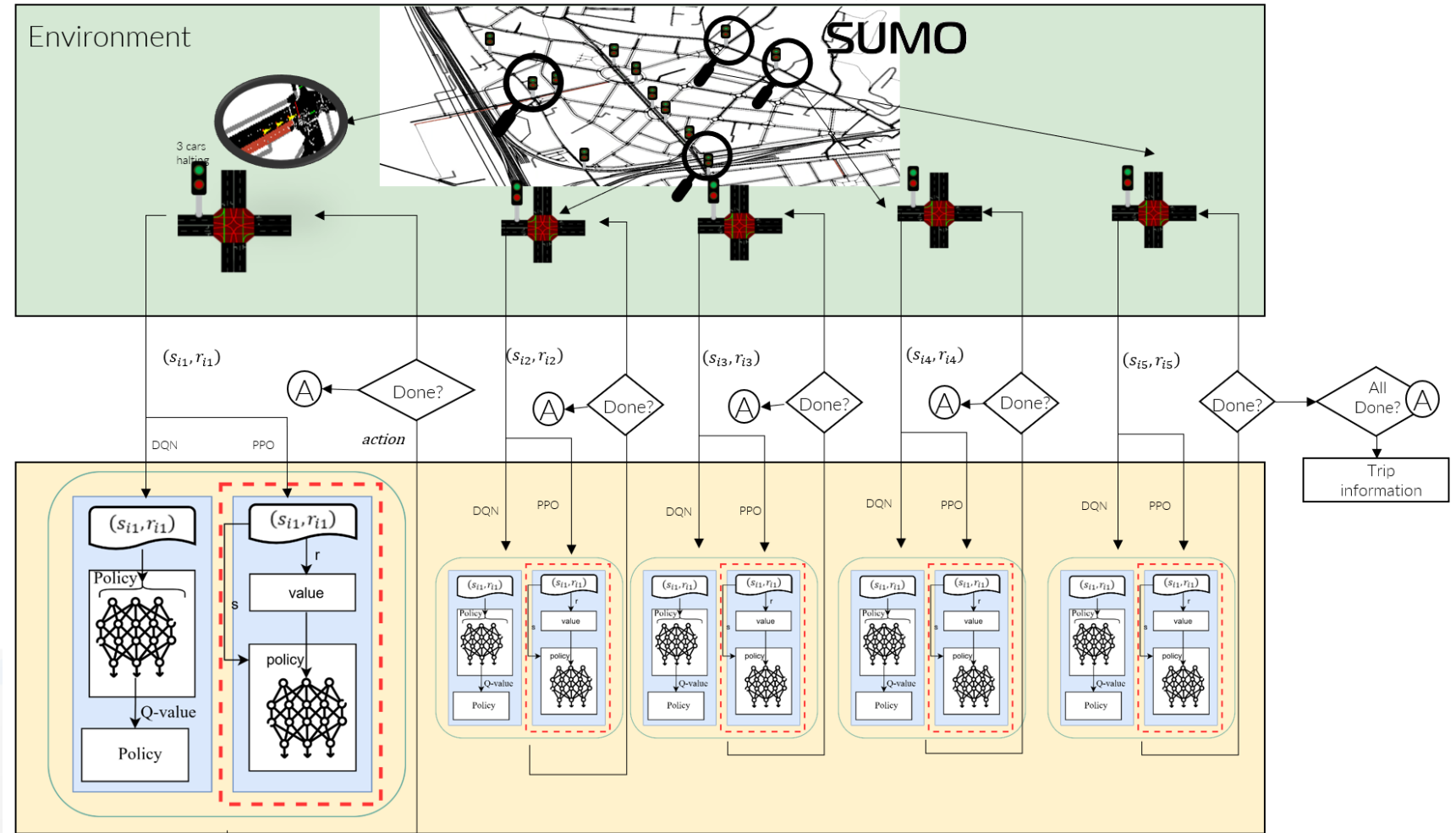
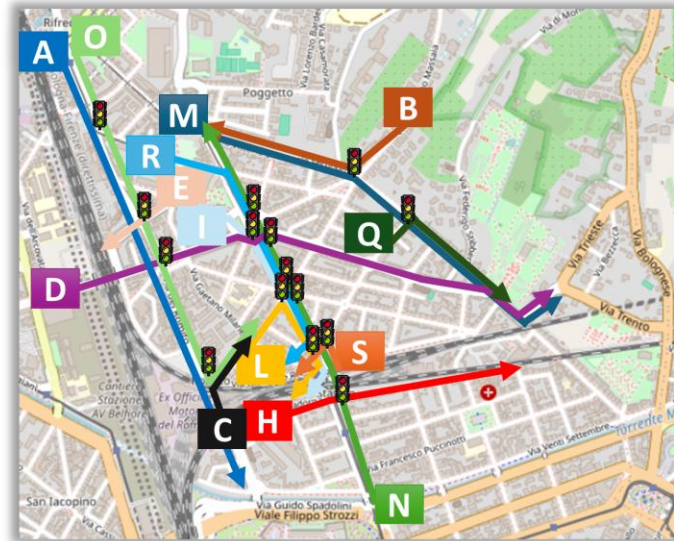
- Left Panel (Ext):** Contains controls for simulation speed (slow to fast slider, Delay: 30.0 ms), a 'Stats' section (time: 342.000 s, payload: 6.5 KB, simulate: 11.50 ms, snapshot: 2.38 ms), a 'Vehicle Summary' (car(s): 152, tram(s): 2), and a 'Quick Find' search bar with filters for CAR, TRAM, LIGHT, BIKE, PERSON, and TRAIN.
- Top Center:** Displays the title 'Traffic Simulation-K8S' and the date/time 'Sun 22 Jun 11:52:15'.
- Right Panel (Wid):** Includes buttons for 'Prepare Simulation', 'Execute Simulation', and 'KPI Simulation'. Below these, a 'Simulation:' dropdown menu is set to 'mamotio15', with an 'Execute' button and a timestamp 'Simulation: 2025/06/22 11:51:56'.
- Bottom Right:** Features the SUMO logo.

Multi Agent Reinforced Learning

- **Single Actuated**
 - Taking into account the status of each traffic source of each Junction
 - Computing the best compromise of G/R ratio
 - Act on the next cycle
- **Multi Agent**
 - As Single Actuated
 - Taking into account synchronization, as condition and travel time of main specific travel means



Multi Agent DRL



MTT for Multi Agent DRL for TLP

Model	TL	all	dir_N	dir_M	dir_A	dir_D	Careggi	Costanza
4TWD-NTNS-MWD-A	1	3013.85	176.93	233.75	194.46	237.65	436.00	427.00
4TWD-NTNS-MWD-P-A	1	3013.85	176.93	233.75	194.46	237.65	436.00	427.00
SUMO Actuated	1	2935.41	249.60	209.77	202.42	270.86	486.73	478.36
Webster	1	5188.87	211.66	242.32	205.46	562.31	984.00	427.00
Webster A	1	2968.90	183.50	242.67	201.27	251.76	482.27	427.00
SARL-FC DQN	1	2834.93	206.68	244.78	199.21	243.26	486.72	485.00
SARL-FC DQN A	1	2760.12	206.35	244.63	198.00	244.76	436.00	427.00
MADRL-FC DQN	1	3089.20	188.29	220.91	205.07	248.06	485.00	445.00
MADRL-FC DQN A	1	2983.69	189.11	220.70	187.00	248.79	436.00	427.00
MARL-FC PPO	1	2910.76	200.38	235.41	198.14	237.78	547.00	445.00
MARL-FC PPO A	1	2855.12	200.93	235.53	196.39	237.97	436.00	427.00
SMART A	1	2599.13	182.14	200	188.28	235.11	436.00	427.00

Ottimizzazione Trasporto Collettivo

Prof. Paolo Nesi, UNIFI DISIT



UNIVERSITÀ
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FIRENZE

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DIPARTIMENTO DI
INGEGNERIA
DELL'INFORMAZIONE

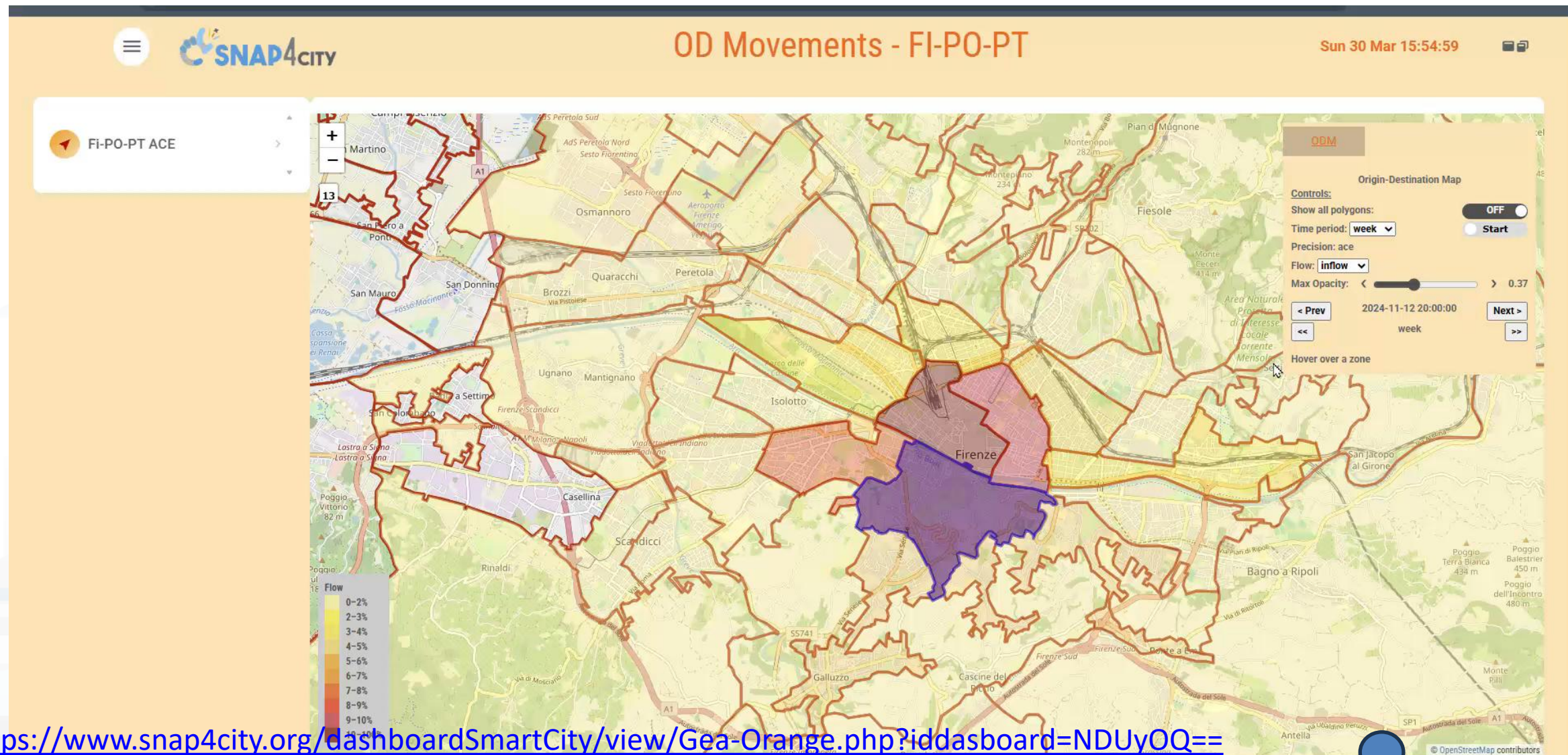
DISIT
DISTRIBUTED SYSTEMS
AND INTERNET
TECHNOLOGIES LAB



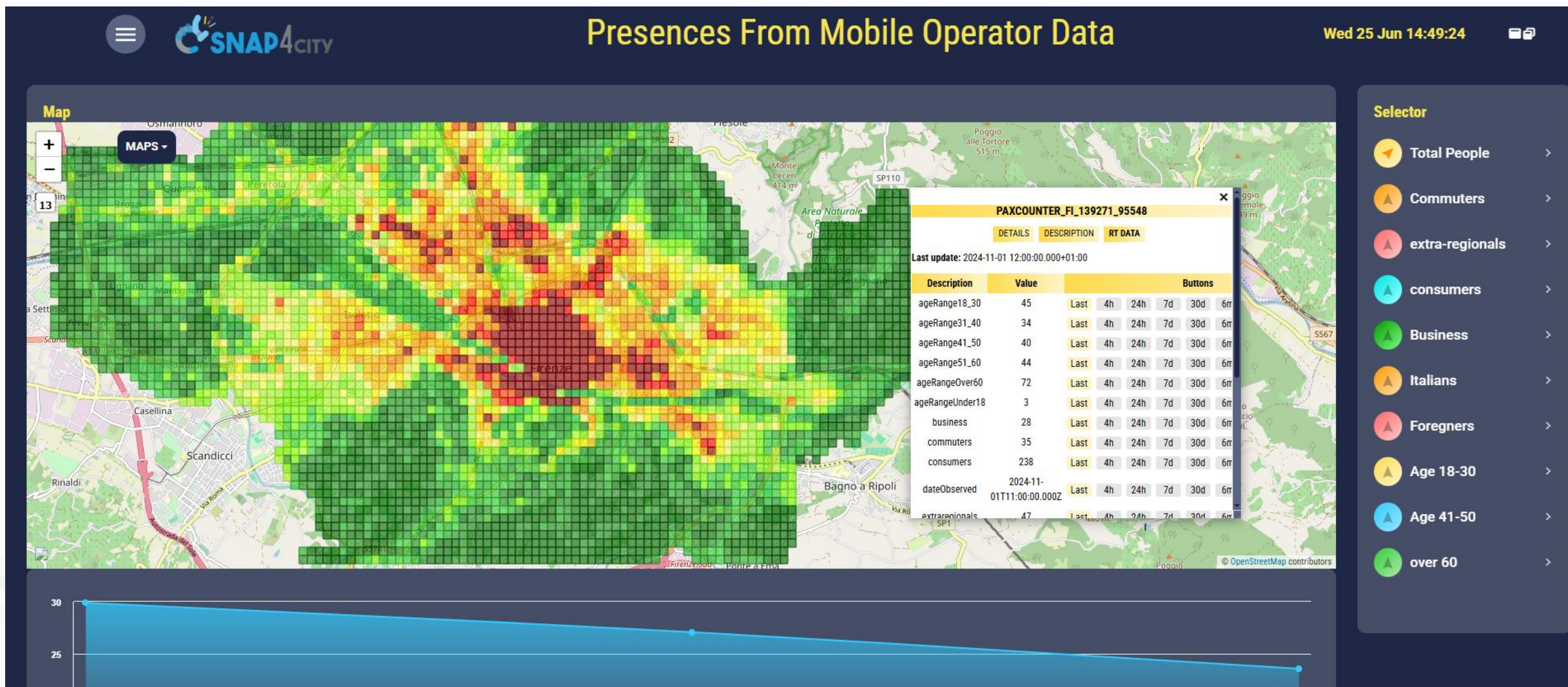
In the large

- **Mobility Demand → ODM:**
 - Telecom Operator ODM, all movements on ACE Area
 - Reduction on local actual percentage and behaviour distributions
 - Matching on MGRS 200 mt, exploiting presence data of Telecom Operators
- **Transportation offer**
 - Road graph
 - GTFS/NeTex, transmodel
 - Bike sharing, carsharing, scooters, etc.

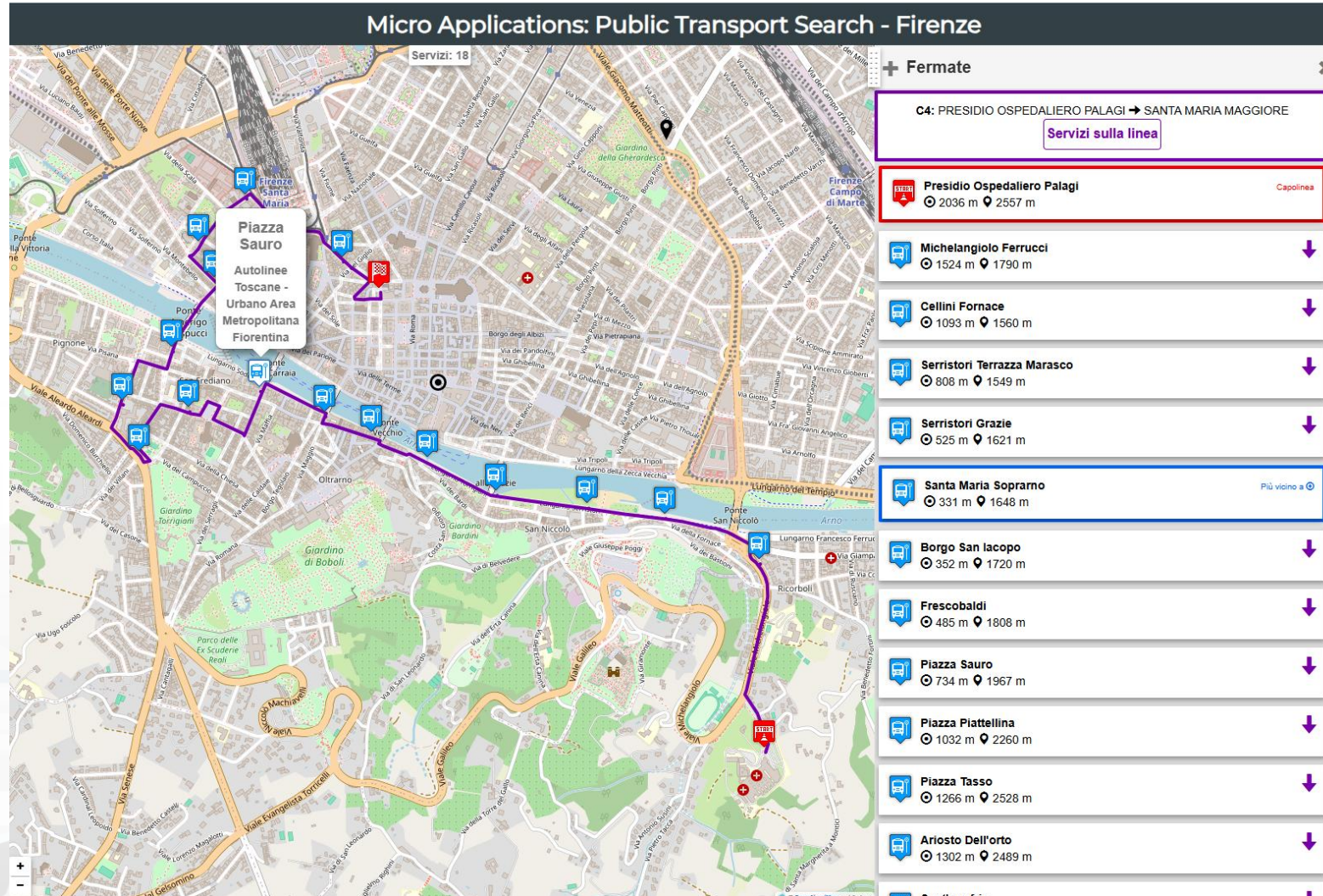
Origin Destination Matrices: Mobility Demand



Presences from Mobile Operator



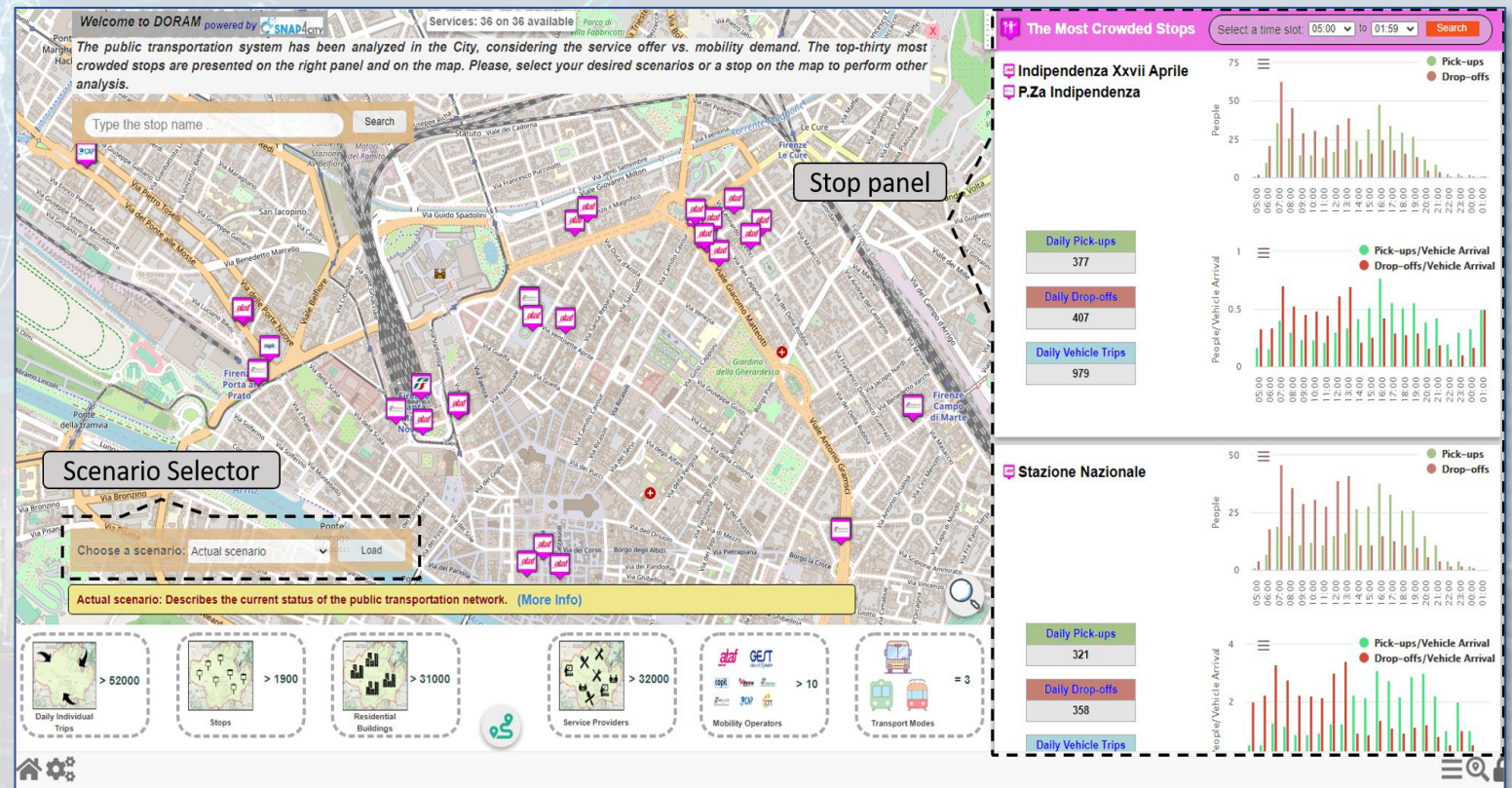
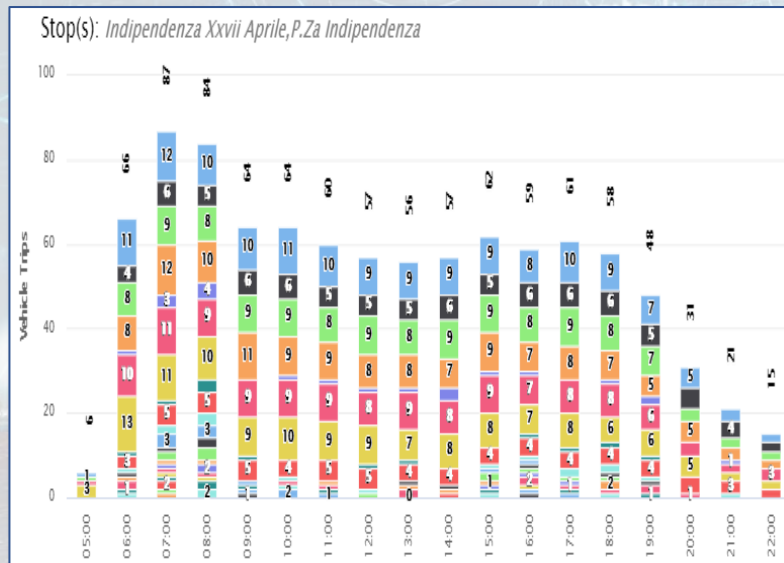
Offer of Transportation, GTFS, for example

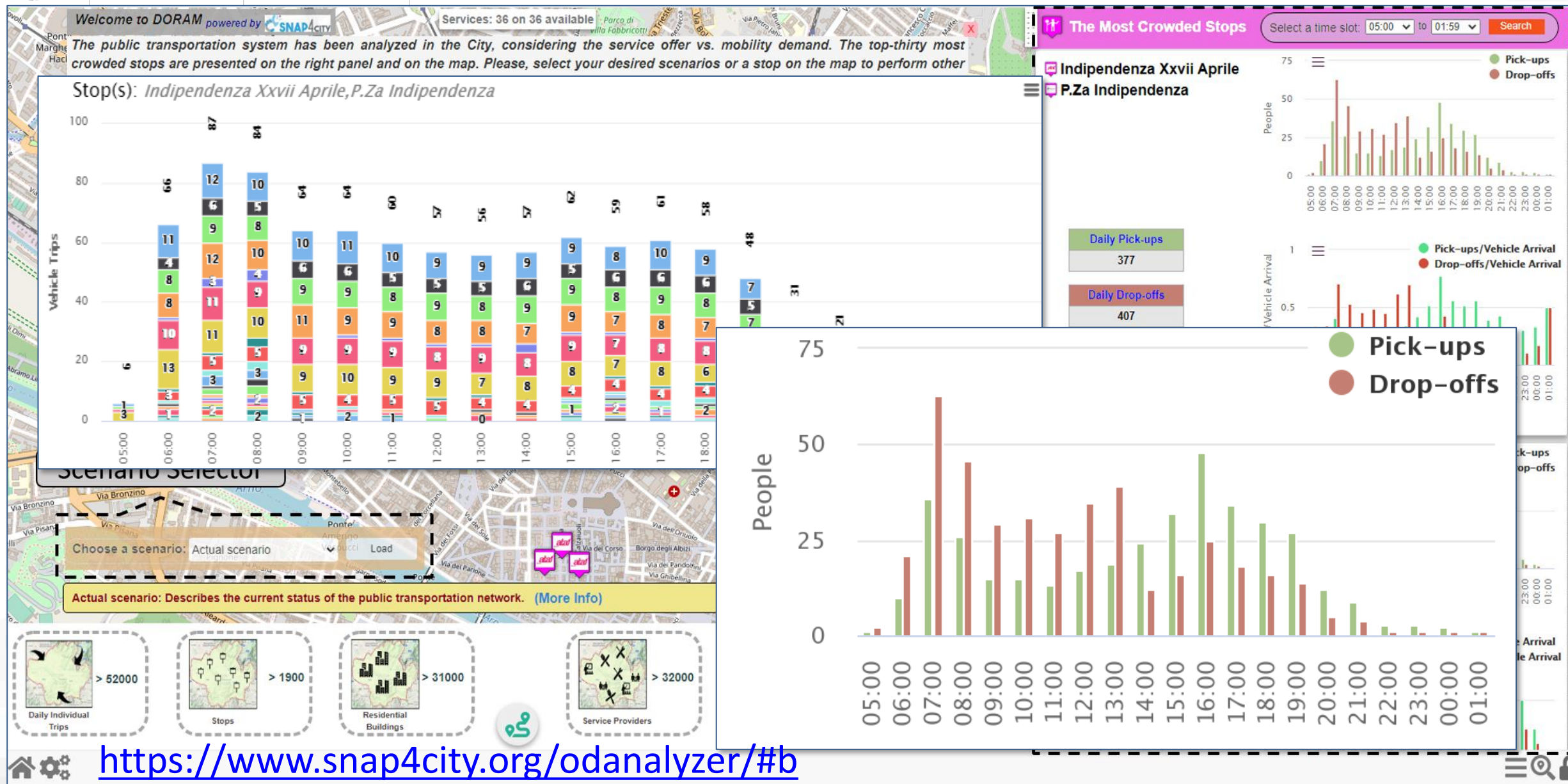


What-if Analysis on Collective Transport: DORAM

- Simulation / analysis of Mobility Demand wrt Transportation Offer
 - GTFS/TranSmodel vs ODM, taking into account road graph and services
- Definition of scenarios impact on
 - Traffic, Pollutant, parking, public transport, private flows, etc.
 - KPI analysis

Public Services







Traffic Simulation-K8S

Sun 22 Jun 11:53:30



Ext

STOP

PAUSE

HELP

26 FPS (17-26)

slow

fast

Delay: 30.0 ms

Stats

time: 0.000 s
payload: 0.0 KB
simulate: 0.00 ms
snapshot: 0.00 ms

Vehicle Summary

Quick Find

ID Edge / Lat, Long (float, float) /
X,Y (int, int)

SEARCH

CAR

BIKE

TRAIN

TRAM

PERSON

BUS

LIGHT

▸ Lights

▸ Effects

▸ SSAO

▸ Scene

Close Controls

Wid

Prepare Simulation

Execute Simulation

KPI Simulation

Simulation:

firenzeodbus

Execute

Simulation: 2025/06/22 11:53:27

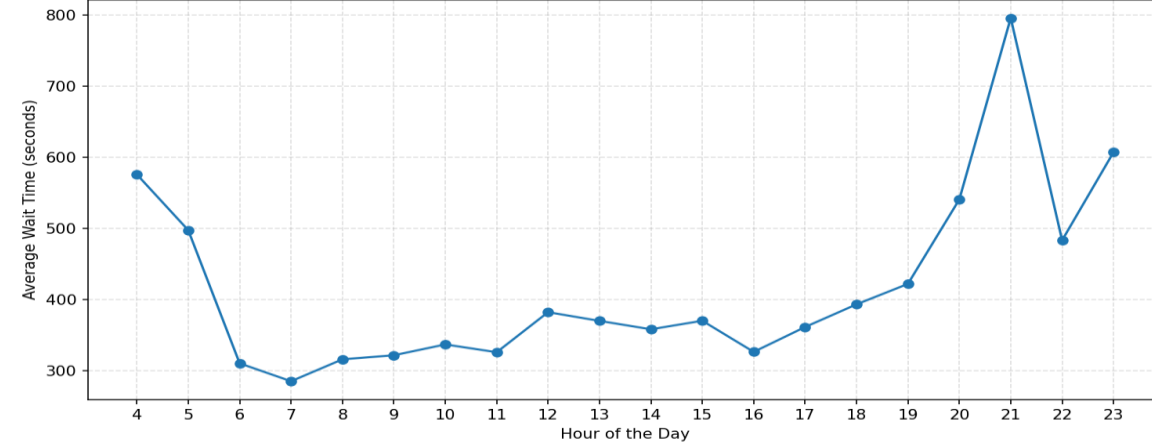


KPI on Match D-O of Collective Transport

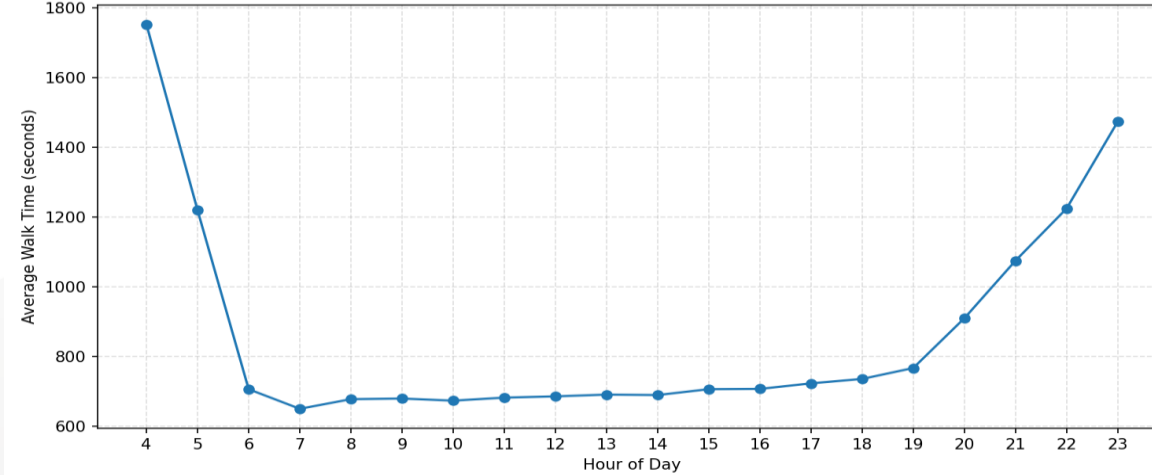
- **On users**
 - **Unmet Demand**
 - Number of passengers who could not board their planned bus
 - **Average Walk Time**
 - The average time spent by passengers during walking before and after taking a ride from source to destination of their trip.
 - Etc.
- **On Service performance**
 - **Average Ride Wait Time**
 - The average amount of time spent by passengers at bus stops while waiting for their desired vehicle.
 - **Average Ride Duration**
 - The average time spent by passengers in a vehicle taking a ride from source to destination of their trip.
 - **Average Vehicle Occupancy**
 - The average number of people boarded in vehicles of different bus lines at different timestamps of a day.
 - **Critical Bus Lines**
 - Bus lines for which the load factor of a bus line exceeds the threshold value of 15 in the service hours.
 - **Critical Bus Stops**
 - Bus stops where the crowding ratio is highest at top 20 bus stops served by different bus lines.
 - **Average Vehicle Depart Delay**
 - Vehicles which depart later than their expected time from the bus stops.
 - Etc.

The typical working day

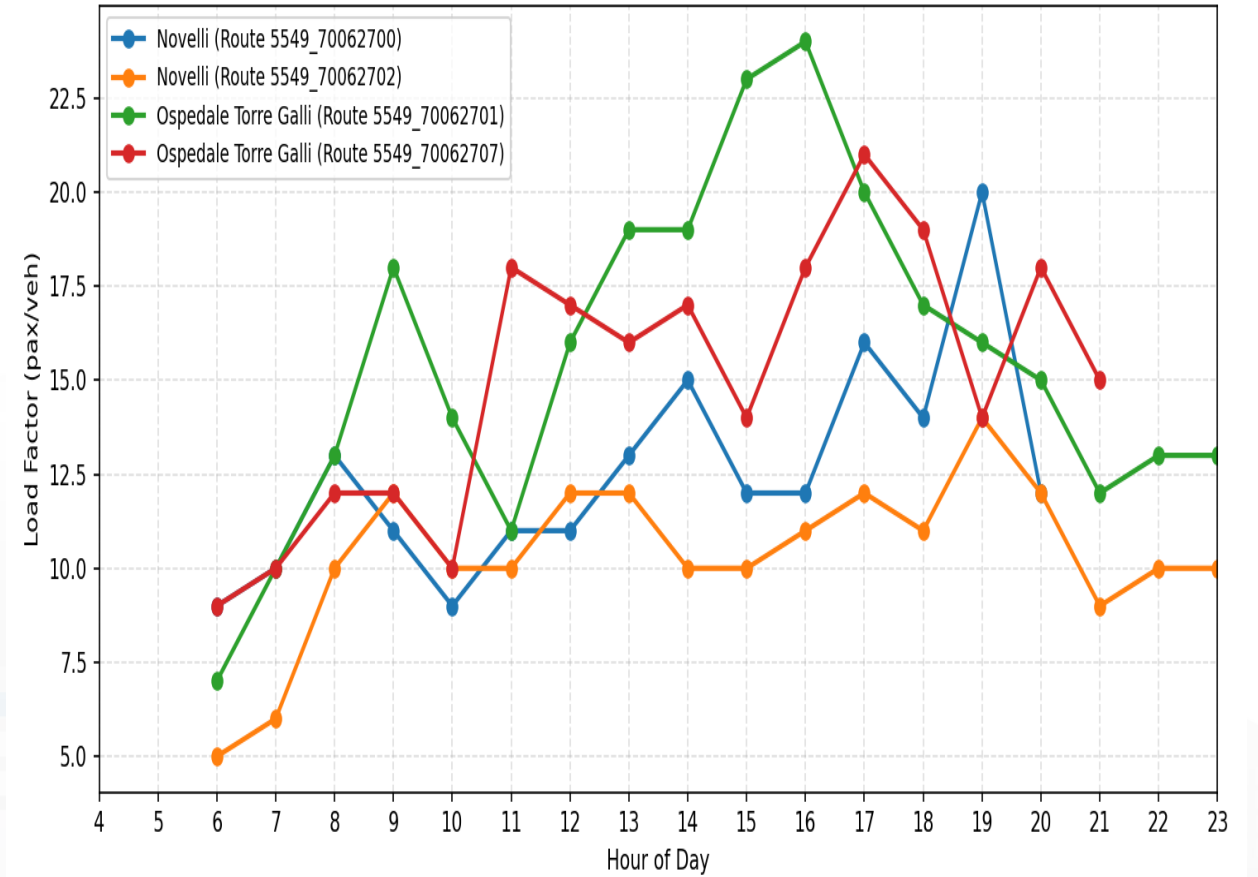
Average Hourly Ride Wait Time (Hour 04:00–23:59)



Average Hourly Walk Time (Hours 04:00–23:59)

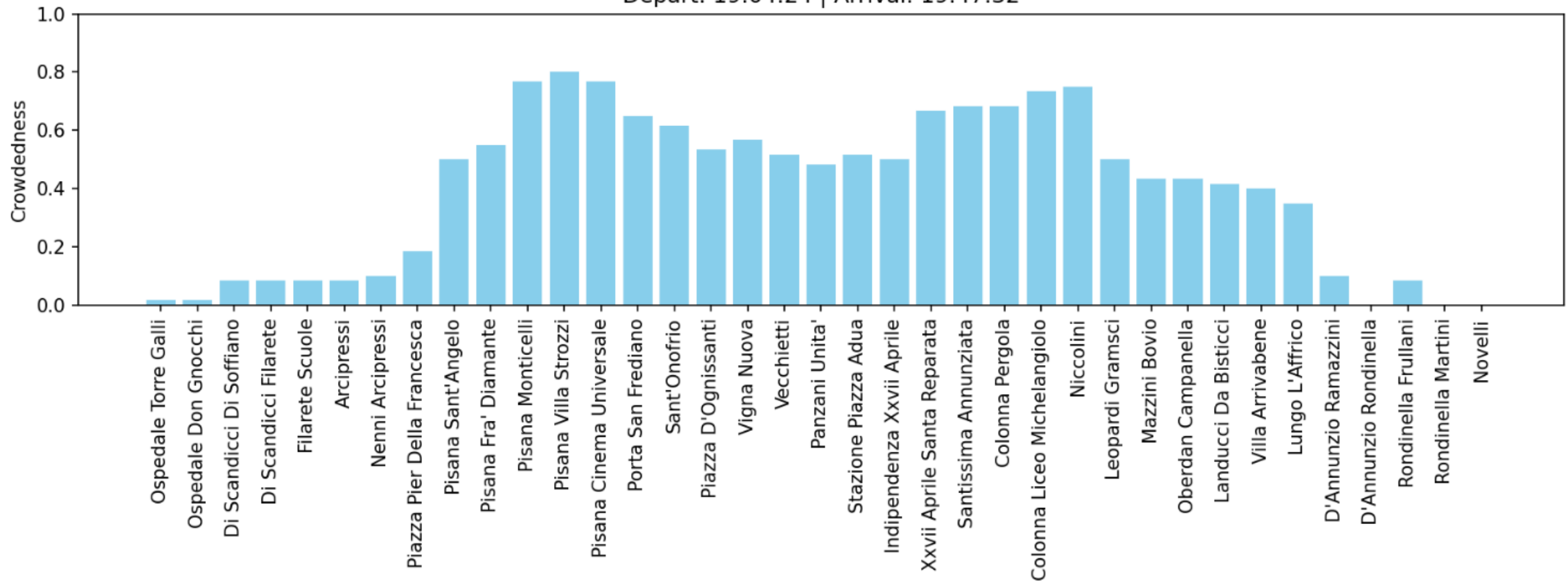


Line 6



Crowdedness

Trip 5549_70062700 | Line 6 - Novelli
Depart: 19:04:24 | Arrival: 19:47:32



Registrazione	10:00 - 10:30	Registrazione e Welcome Coffee Saluti
Avvio Lavori	10:30 - 10:40	- Prof. Paolo Nesi , UNIFI DISIT Lab/Snap4City - Franco Prampolini , Head of R&D and Innovative Industry Solutions Lutech Group
CN MOST SPOKE 8	10:40 - 11:00	Mobility-as-a-Service: tra integrazione e sostenibilità - Prof. Mario Marinelli , Politecnico di Bari
Overview OPTIFaaS	11:00 - 11:20	Presentazione generale e obiettivi di OPTIFaaS - Mauro Starinieri , Head of Smart City & Mobility Solutions CoE Lutech Group
Strumenti OPTIFaaS	11:20 - 11:50	Presentazione dell'infrastruttura - Prof. Paolo Nesi , UNIFI DISIT Lab/Snap4City
Scenario OPTIFaaS	11:50 - 12:10	Ottimizzazione del Traffico - Ing. Alessio Tesone , Università degli Studi di Napoli
Scenario OPTIFaaS	12:10 - 12:40	Ottimizzazione Semaforica e di Infrastruttura. Ottimizzazione del Trasporto Collettivo - Prof. Paolo Nesi , UNIFI DISIT Lab/Snap4City
Q&A	12:40 - 13:00	Sessione aperta
Light Lunch (offered)	13:00 - 14:00	
Incontri 1:1	14:00 -	Incontri 1:1 con i referenti di Snap4City/OPTIFaaS (in presenza)



IL FUTURO DELLA MOBILITA' INTELLIGENTE E SOSTENIBILE

Digital Twin & Intelligenza Artificiale.
Innovazione tecnologica “As a Service “
per la gestione operativa
e la pianificazione tattico-strategica
della mobilità urbana sostenibile e interconnessa



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