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Alcune nuove tecniche dell'intelligenza artificiale possono risolvere i problemi della mobilità e dei trasporti e quali dati sono necessari

new artificial intelligence techniques can solve mobility and transportation problems and what data is needed

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UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

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#km4city
#disitlab
@snap4city

Why mobility is an AI problem now

Mobility systems are networks with feedback loops: travel demand, road conditions, signals, parking, emissions, public transport, and shared mobility all change together.

Recent AI solutions are not based on single model!

A decision pipeline is needed combining sensing, reconstruction, prediction, simulation, optimization, and explainability.

Congestion
waiting time
stops

Parking
search traffic
emissions

Public transport
reliability
accessibility

AI turns sparse, messy data into three capabilities:

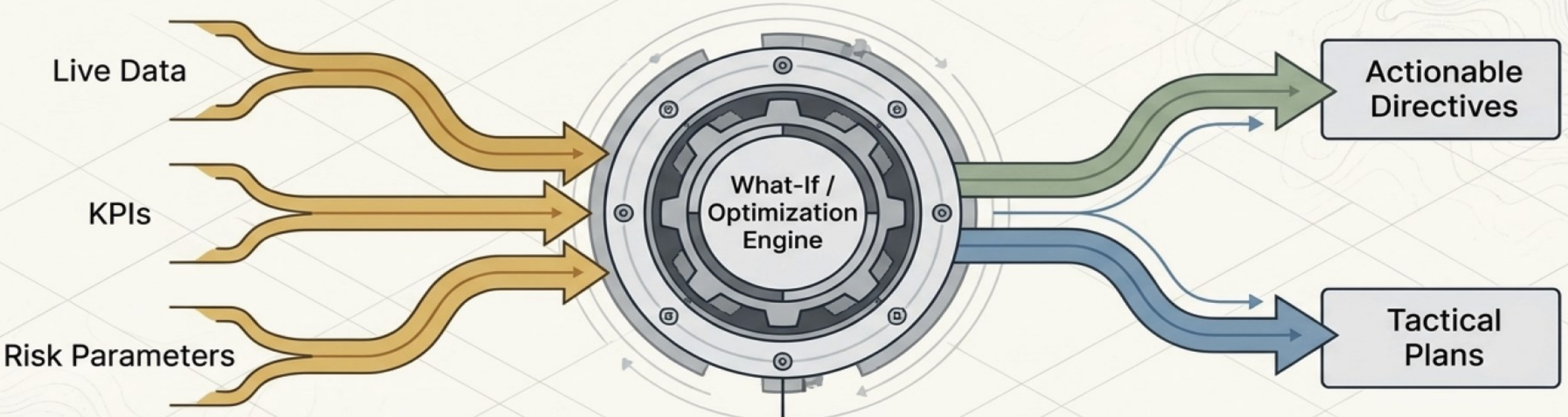
1. See the whole network
2. Predict what happens next
3. Optimize services under constraints

Why mobility is an AI problem now

1	2	3	4	5
Predict	**Reconstruct**	**Simulate**	**Optimize**	**Govern**
parking demand, traffic, CO2	unmeasured road conditions	demand-offer and what-if scenarios	signals and public transport priority	data quality, privacy, and KPIs

I am going to provide a concrete data checklist and implementation roadmap for a city or mobility operator.

Decision Support Systems



What-If Analysis:
Grounded on robust predictive algorithms and simulations.

Scenario-Based Optimization:
Test traffic light plan optimizations digitally. Evaluate major traffic infrastructure changes. Assess tactical risks and generate prescriptions before spending public funds.

100% OPEN SOURCE

THE POWER OF ARTIFICIAL INTELLIGENCE AT THE SERVICE OF YOUR OPERATION AND PLAN

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Powered by FIWARE

FREE TRIAL

PEN Test Passed

EU GDPR COMPLIANT

SNAP4 Appliances and Dockers Installations

EUROPEAN OPEN SCIENCE CLOUD

Node-RED

JS Foundation

EØ15 digital ecosystem

NVIDIA

OPERATION AND PLAN - CONTROL ROOMS - DECISION SUPPORT SYSTEMS - WHAT-IF ANALYSIS - OPTIMIZATION - APPLICATIONS

HORIZONTAL AI PLATFORM

MOBILITY AND TRANSPORT

SMART ENERGY AND SMART BUILDING

ENVIRONMENT AND WASTE MANAGEMENT

CITY USER'S SERVICES AND TOURISM MANAGEMENT

SNAPADVISOR

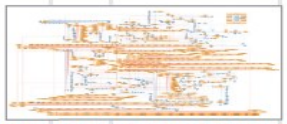
BUSINESS INTELLIGENCE - SIMULATIONS - VISUAL ANALYTICS - SYNOPTICS - GRAPHICAL WIDGETS - ANALYTICS

DASHBOARDS, WIDGETS
TEMPLATES

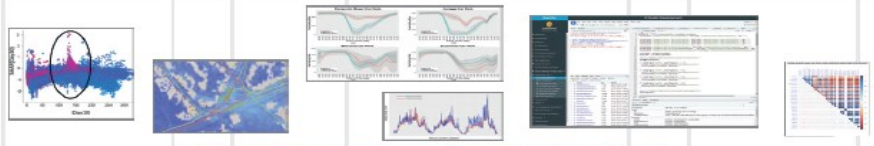
PREDICTION - ANOMALY DETECTION - CLUSTERING - ROUTING - SENTIMENT NLP - TRAFFIC FLOW - PEOPLE FLOWS - SDG
15 MIN CITY INDEX - KPI - HEATMAPS - ORIGIN DESTINATION - MAPS - VECTOR FIELD - ETC...

API - MICROSERVICES - GIS - BPM
VIDEO - REPORTS - MAPS - 3D ...

- DEVELOMENT ENVIRONMENT AND METHODOLOGY
- VISUAL PROGRAMMING, ML, AI, HPC
- TRAINING COURSES



EXPERT SYSTEM, KNOWLEDGE BASE
SEMANTIC REASONING
SMART DATA MODEL
IOT DEVICE MODELS, DATA SPACES



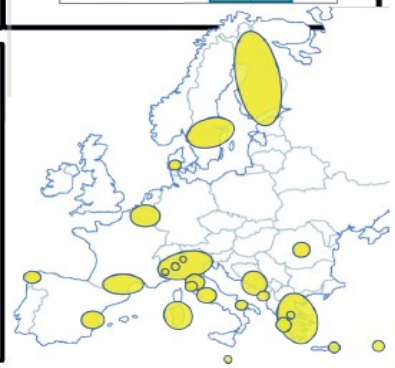
BIG DATA ANALYTICS, ARTIFICIAL INTELLIGENCE
EXPLAINABLE AI, MACHINE LEARNING, GENERATIVE AI
OPERATIVE RESEARCH, STATISTICS

VISUAL PROGRAMMING, ADAPTERS
DATA FLOWS, WORKFLOWS
PARALLEL DISTRIBUTED PROCESSING
DATA DRIVEN

FULL INTEROPERABILITY, ANY: DATA, BROKERS, NETWORKS AND VERTICALS

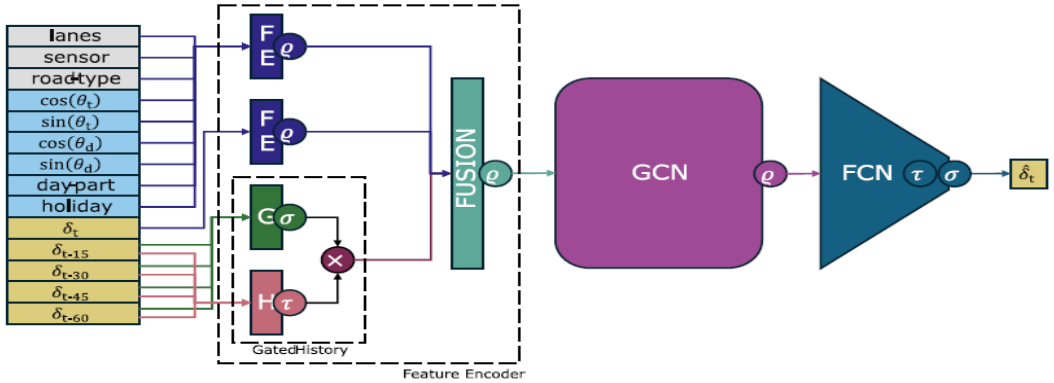
NATIVE AND EXTERNAL APPLICATIONS

- Smart Parking
- Smart Light
- Smart Waste
- Smart Energy
- Smart Building
- Smart Tourism
- ...

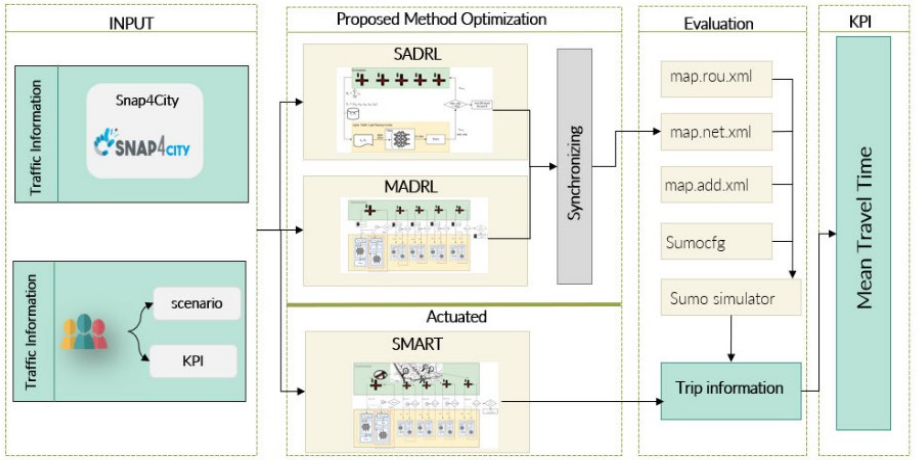


Technique families and the problems they solve

Technique	Best for	Mobility application
Deep learning on Time Series	Forecast temporal patterns	Free parking slots and short/mid-term demand
Hybrid physics + ML Neuro-Symbolic	Fill gaps in sparse sensing	Dense traffic flow reconstruction
Graph neural networks, GNN	Learn on road topology	Continuous density on unmonitored roads, traffic flow reconstruction
GA and DRL optimization	Choose actions under constraints. Optimized viability	1) Traffic light plans for tramway/BRT priority and compromise 2) Traffic infrastructure optimisation
Agentic AI based digital twins + XAI	Test scenarios and explain drivers	Demand-offer matching and CO2 levers



Road graphs + sensor data make modern AI spatial



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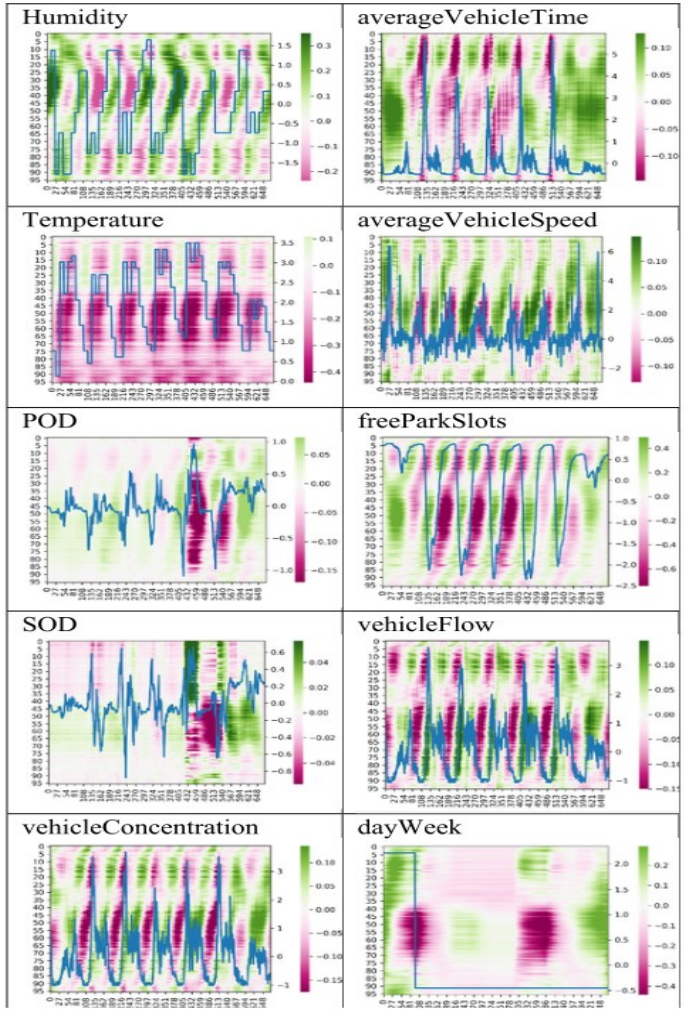
Parking predict slot availability before drivers start searching



AI technique

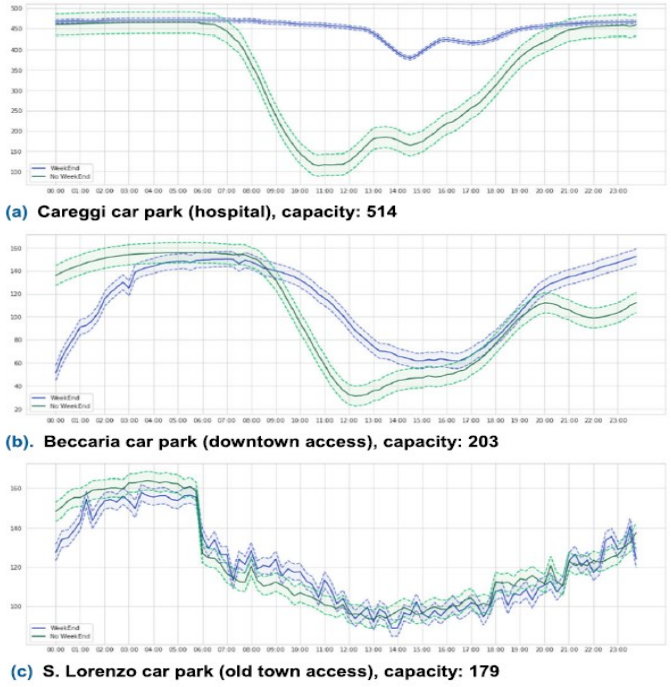
Convolutional Bidirectional LSTM forecasts free spaces 24 hours ahead at 15-minute resolution.

Explainability of the effects of variables over time to the preditions

What it solves

Reduces cruising for parking and lets users plan trips one day ahead; the articles stress critical conditions when free slots approach zero.
Reduce costs for predictions.

Mean Average Error 9.6-14.8
In predicting free slots for 1-hour forecast
Careggi / Beccaria / S. Lorenzo


(a) Careggi car park (hospital), capacity: 514

(b). Beccaria car park (downtown access), capacity: 203

(c) S. Lorenzo car park (old town access), capacity: 179

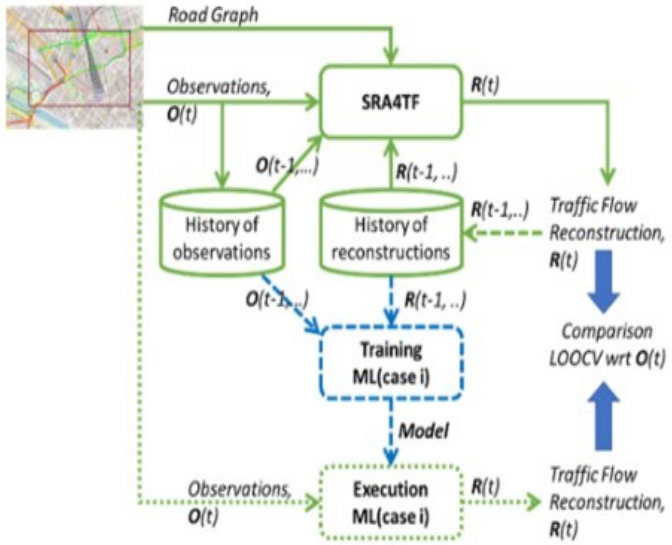
Traffic flow reconstruction: infers the roads without sensors

The core data problem: cities can measure a few links, but mobility decisions need every road segment.

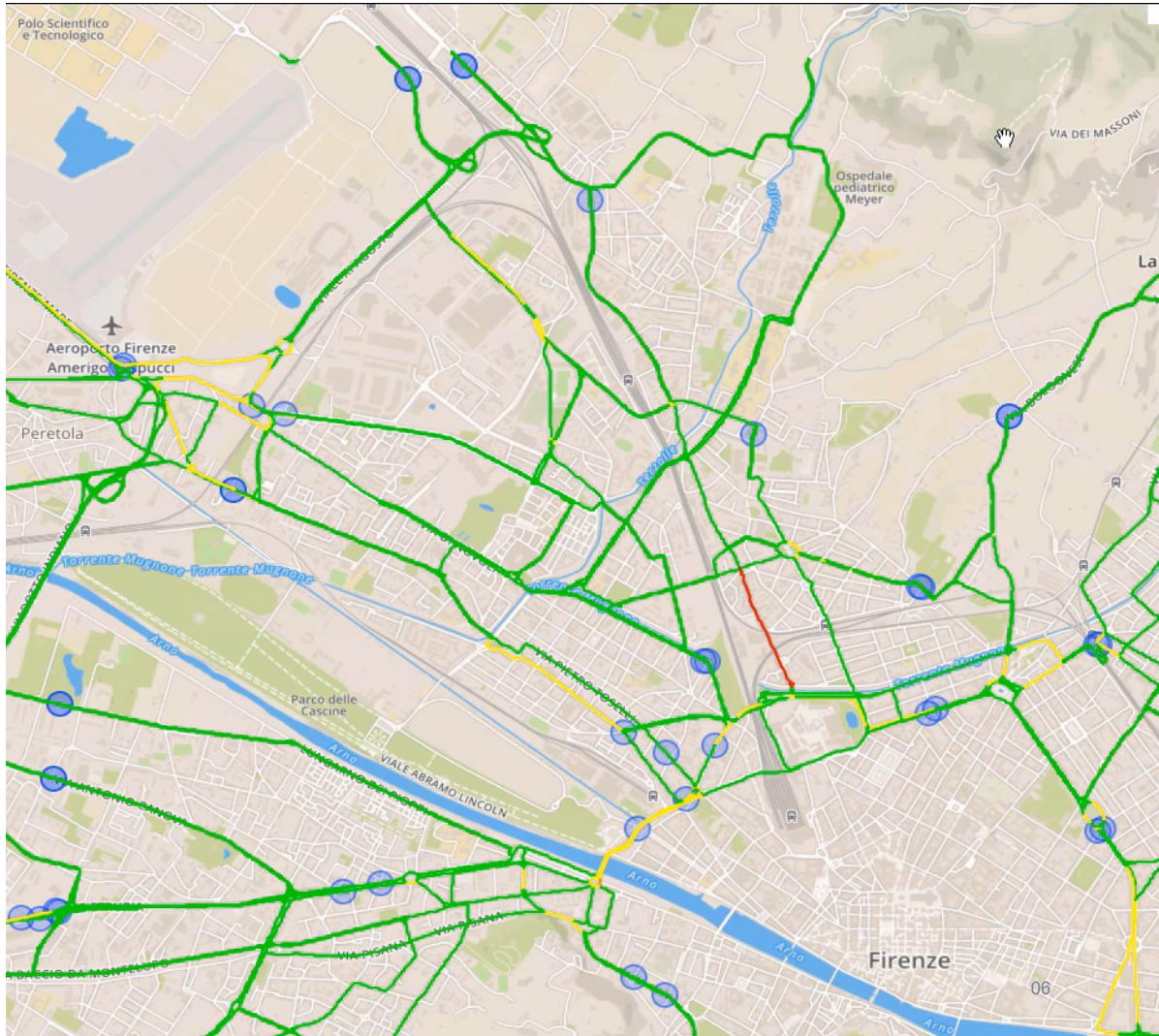
Few fixed sensors counts + density + speed

Hybrid PDE + ML or lightweight GNN

Dense network state for operations



Evidence point: one GNN reconstructs a 20775-segment road network from 96 sensors, with a RMSE 0.33 #veh/20m at sensor measurements and mean of RMSE 0.05 #veh/20m network-wide.



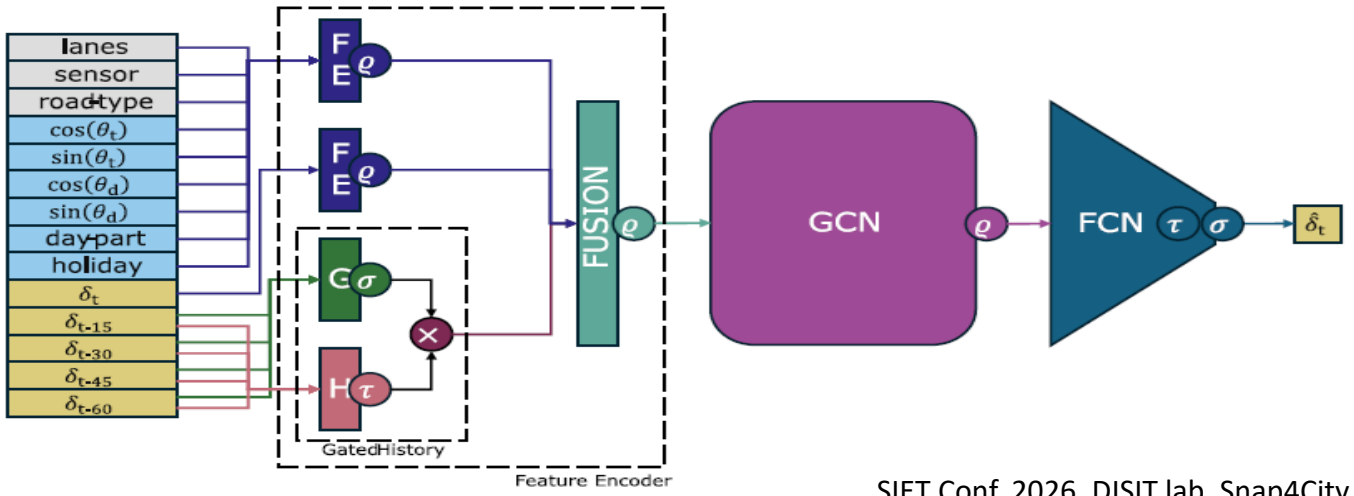
Graph neural networks, GNN, make road topology part of the model

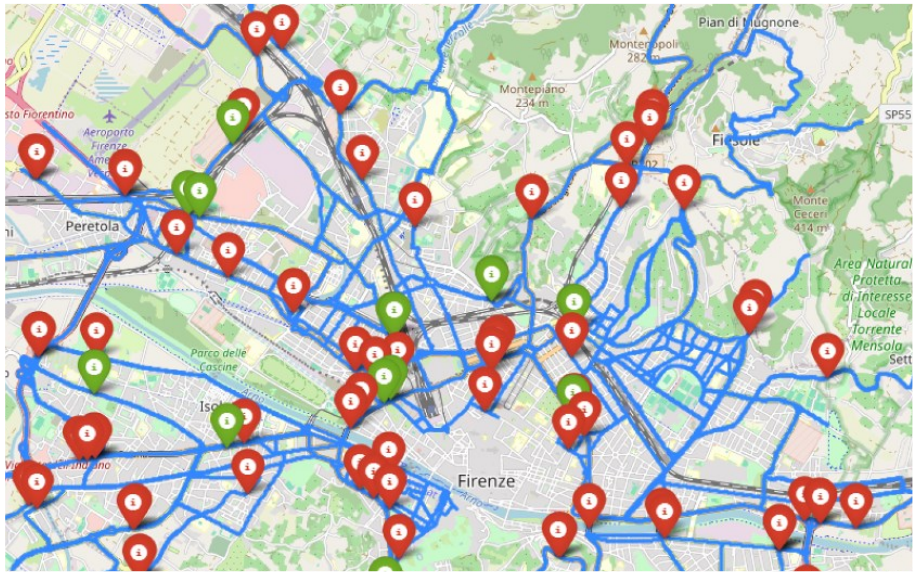
Why it matters

Roads are not independent time series. Congestion propagates through junctions, and it can also back-propagate from bottlenecks.

What data is needed

Road graph with lanes and road type; time-of-day and holiday features; current and lagged density estimates; sensor status; typical trends to cover missing observations.

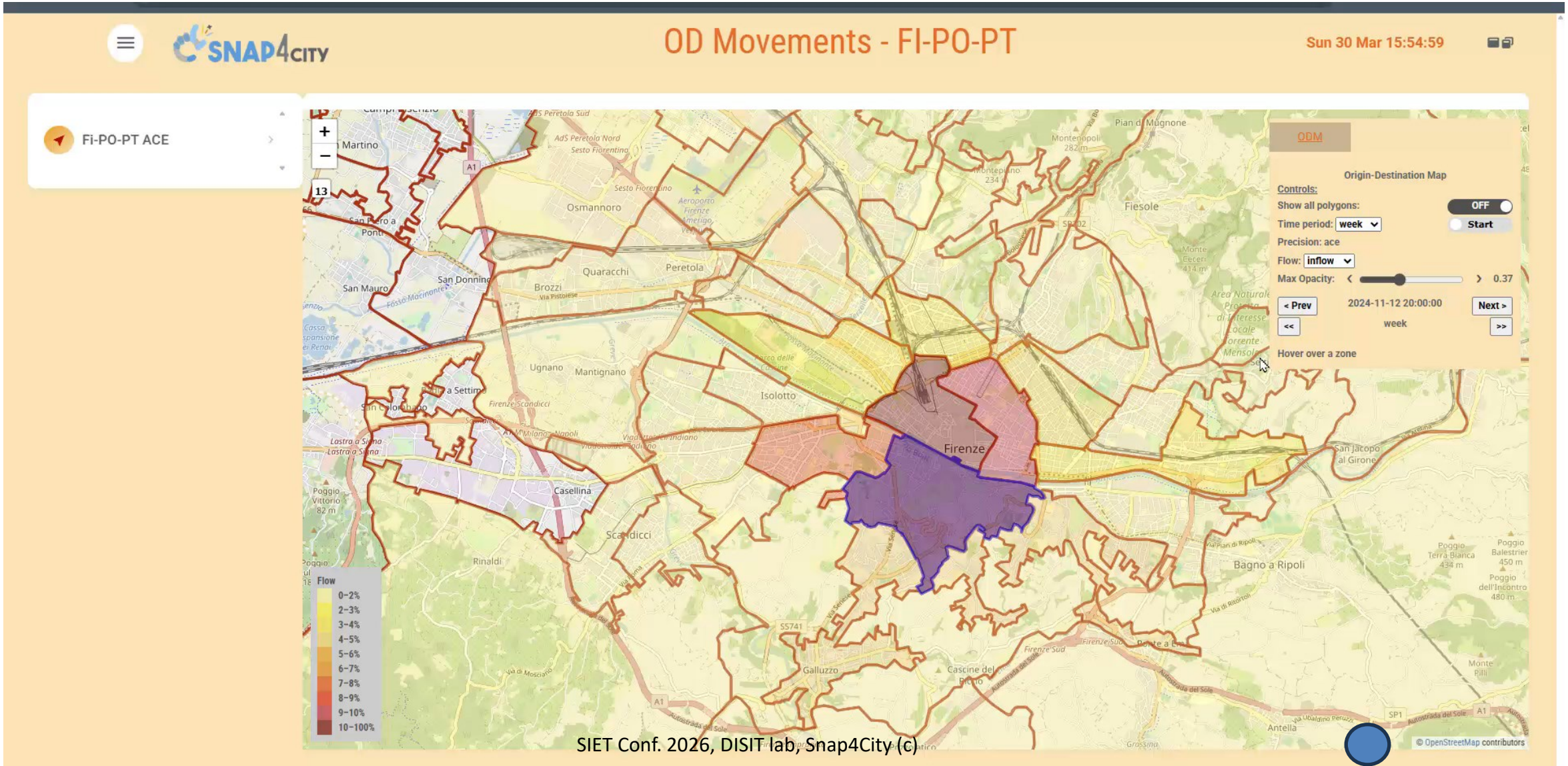




Producing in real time:

- Predictions of traffic on dense network
  RMSE 0.3-0.4 #Veh/20m
- Traffic distribution at junctions, TDM

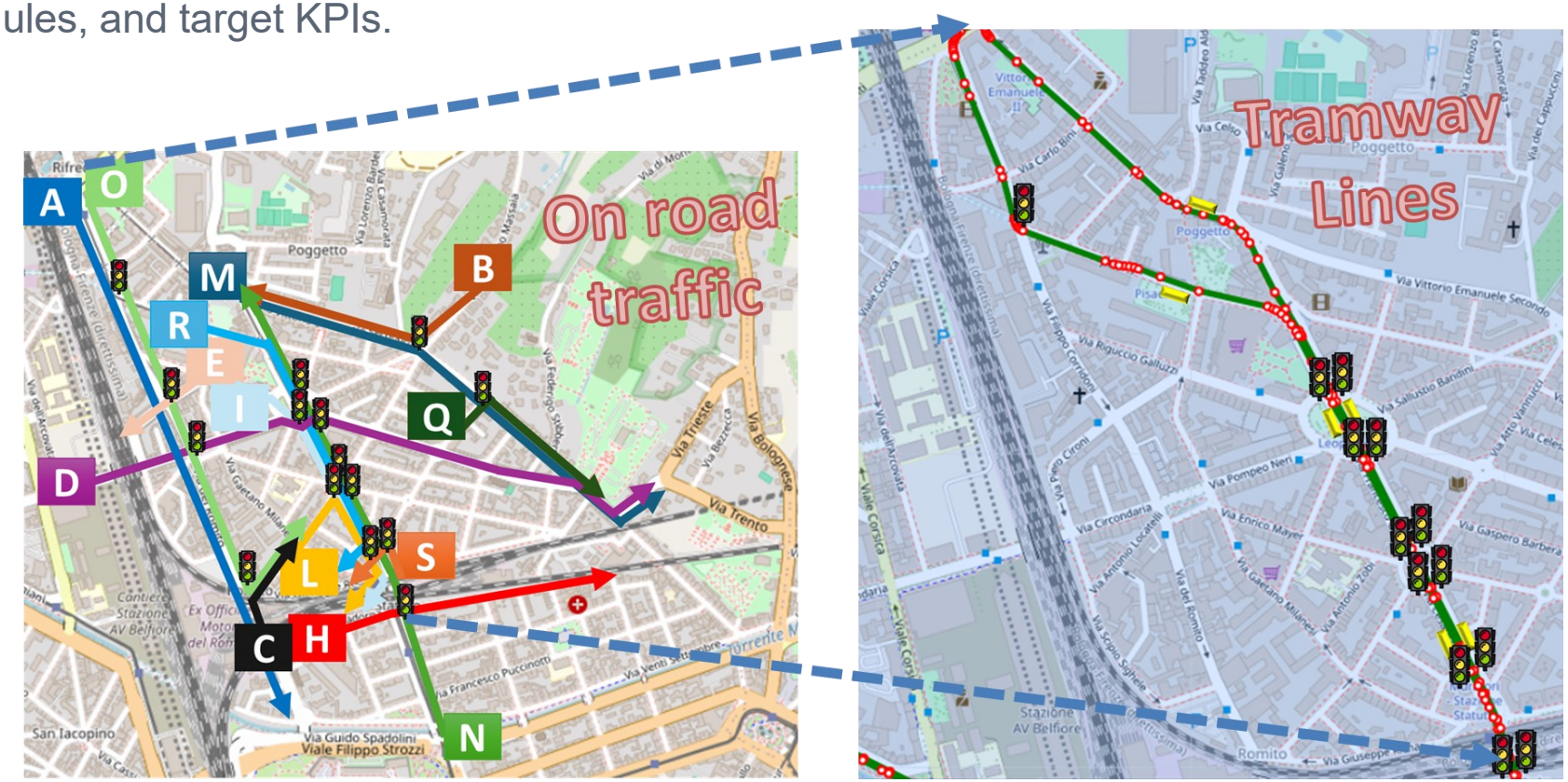
Origin Destination Matrices: Mobility Demand



Traffic Lights, TLP production: *optimize under multiple objectives*

Uses GA or Multi Agent DRL to balance travel time, waiting time, stops, queue constraints, and tramway priority at a macroscopic urban scale.

Data needed: junction topology, signal phases, legal constraints, traffic flow/density/speed, queue lengths, tram/BRT routes and schedules, and target KPIs.




Traffic Simulation-K8S
Sun 22 Jun 11:52:15
Ext
STOP
PAUSE
HELP
slow
fast
Delay: 30.0 ms
Stats
time: 342.000 s
payload: 6.5 KB
simulate: 11.50 ms
snapshot: 2.38 ms
Vehicle Summary
car(s): 152
tram(s): 2
Quick Find
ID Edge / Lat, Long (float, float) / X,Y (int, int)
SEARCH
CAR
BIKE
TRAIN
TRAM
PERSON
BUS
LIGHT
33 FPS (8-37)
Lights
Effects
SSAO
Scene
Close Controls
SUMO
Wid
Prepare Simulation
Execute Simulation
KPI Simulation
Simulation:
mamotlo15
Execute
Simulation: 2025/06/22 11:51:56
My Profile
Privacy Policy
Cookies Policy
Terms and Conditions
Contact us

Mean-Travel-Time 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		2834.93	206.68	244.78	199.21	243.26	486.72	485.00
SARL-FC DQN A		2760.12	206.35	244.63	198.00	244.76	436.00	427.00
MADRL-FC DQN		3089.20	188.29	220.91	205.07	248.06	485.00	445.00
MADRL-FC DQN A		2983.69	189.11	220.70	187.00	248.79	436.00	427.00
MARL-FC PPO		2910.76	200.38	235.41	198.14	237.78	547.00	445.00
MARL-FC PPO A		2855.12	200.93	235.53	196.39	237.97	436.00	427.00
SMART A		2599.13	182.14	200	188.28	235.11	436.00	427.00

Single-agent DRL

Multi-agent DRL

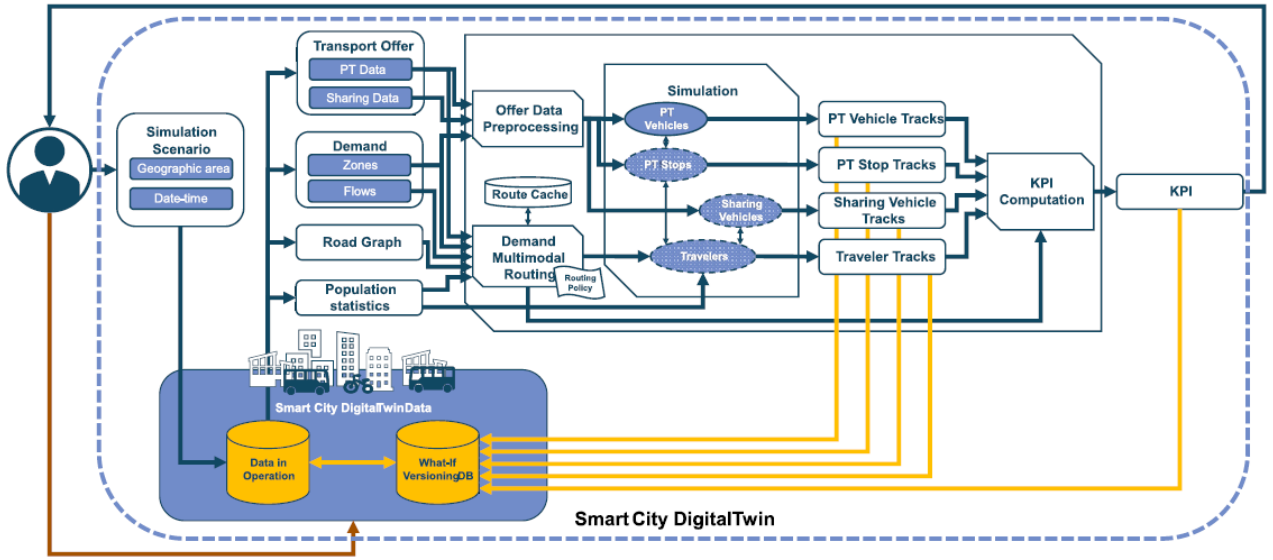
Actuated SMART

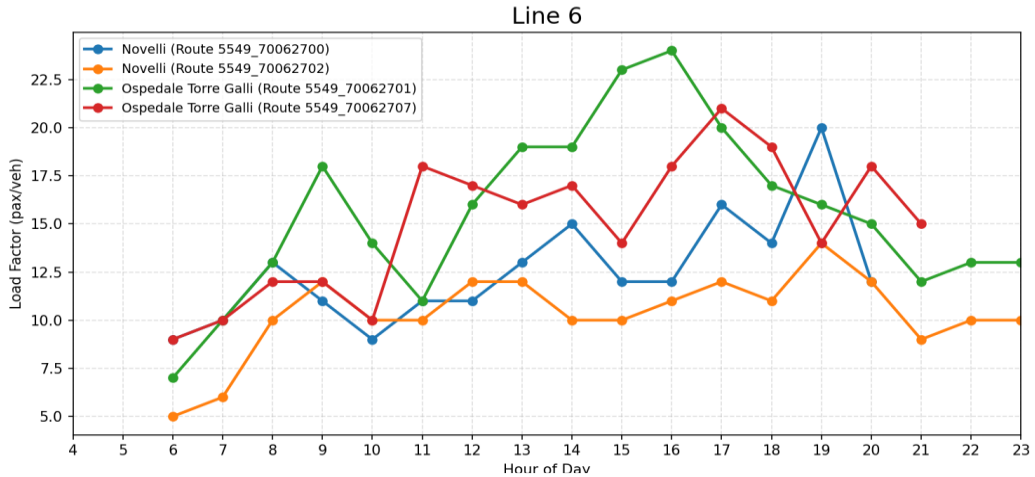
Evaluation uses SUMO trip information - travel distance, wait time, CO2 emissions - with mean travel time as a key KPI.

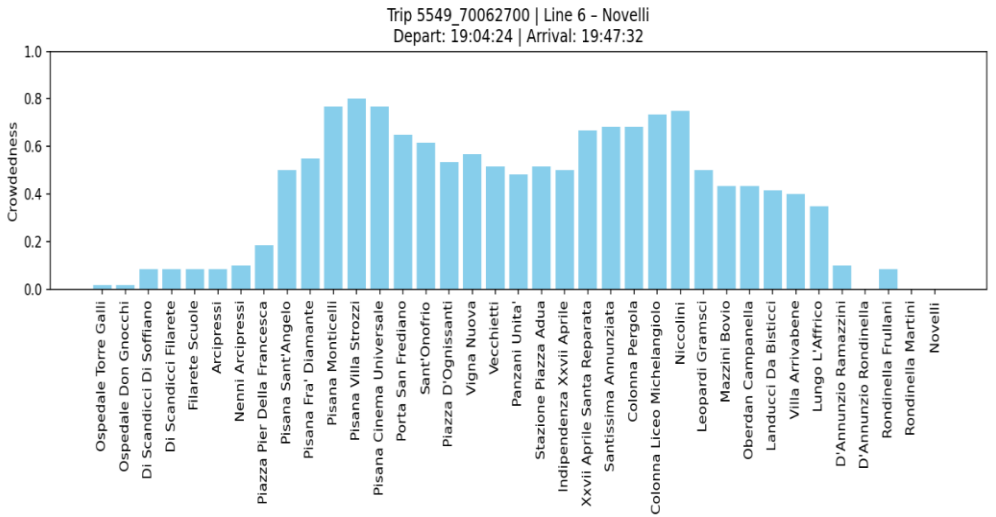
What data is needed: real-time traffic observations, scenario files, signal definitions, road network, public transport movements, and reward/KPI definitions.

Demand vs Offer Matching: simulate multimodal alternatives, KPIs

MODOM evaluates how public transport, sharing services, and micro-mobility satisfy city users' demand. It is built for what-if planning inside a smart city digital twin.







~4 min
city-wide full-day simulation

GTFS
directly instantiates public transport offer

KPIs
tracks PT, stops, sharing, and traveler events

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Traffic Simulation-K8S

Sun 22 Jun 11:53:30

Ext

STOP PAUSE HELP

slow fast

Delay: 30.0 ms

Stats

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

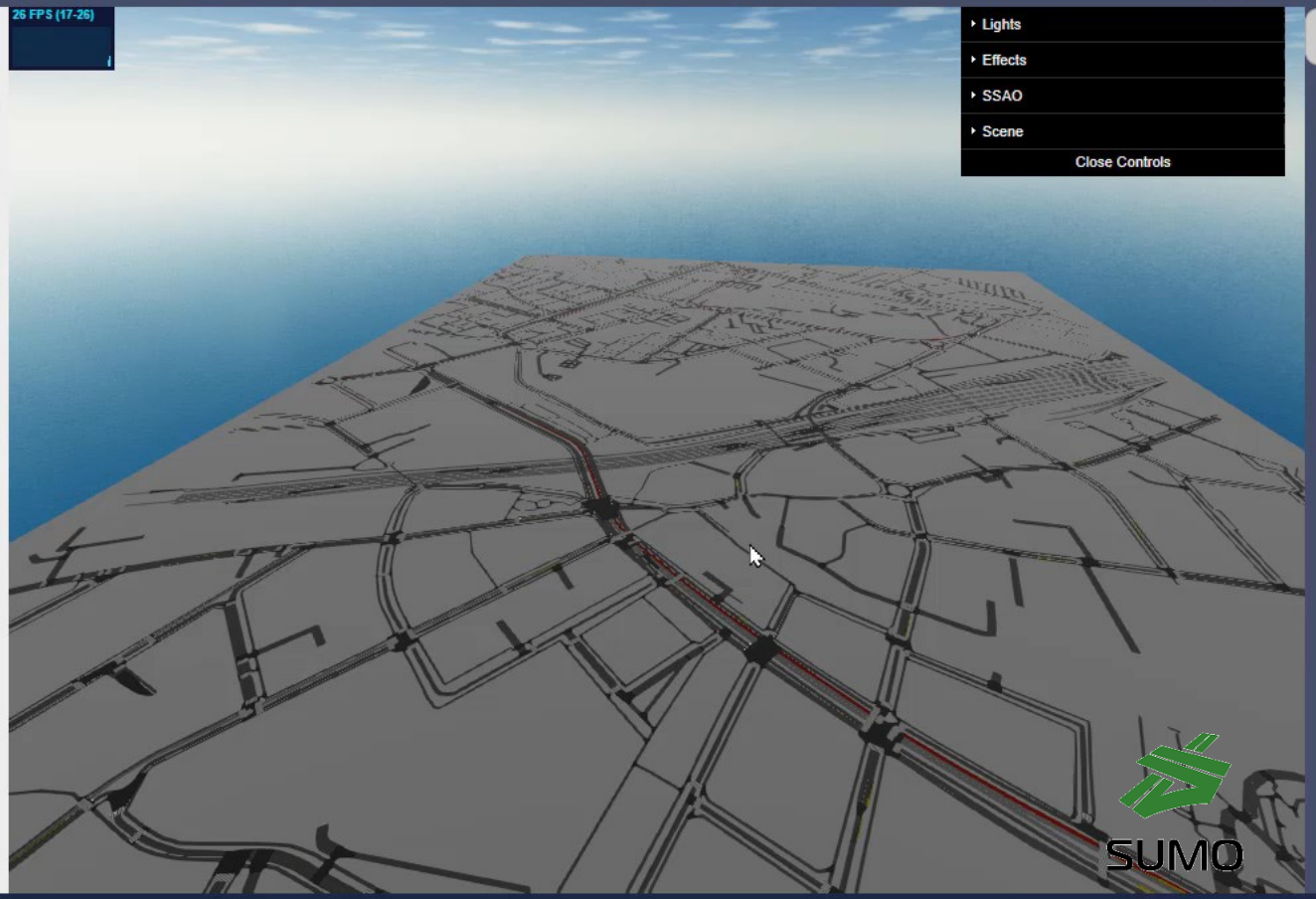
Vehicle Summary

Quick Find

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

SEARCH

CAR BIKE TRAIN TRAM PERSON BUS LIGHT



Wid

Prepare Simulation | Execute Simulation | KPI Simulation

Simulation:

firenzeodbus

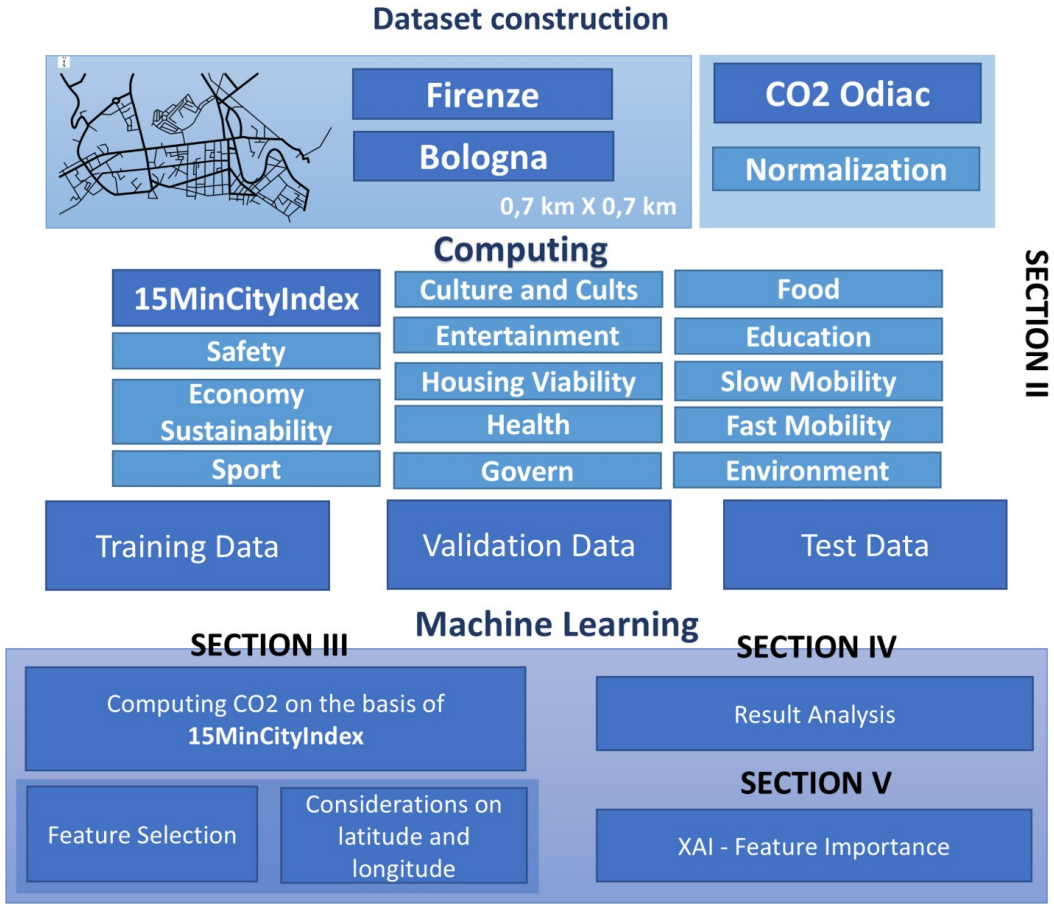
Execute

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

My Profile

CO2 and policy: explainable AI turns data into measures

The CO2 study used open urban data and satellite CO2 reference data to estimate emissions at fine spatial scale, then used XAI to reveal influential predictors.



Data needed: 15MinCityIndex, spatial grid, satellite CO2 target data, urban service locations, socio-economic indicators, mobility/environment features, and coordinates or graph/proximity data.

7.79%
Bologna XGBoost MAPE with GPS

10.72%
Florence XGBoost MAPE with GPS

0.96
R^2 for best XGBoost models

SnapAdvisor Agentic AI support for decision makers

- **Colloquial interface** for Decision Makers with **Agentic AI expert** on Mobility and Transport, which knows:
  - Domain research innovations
  - historic data evolutions and conditions/events for the city
  - Real time data of any kind
    - Traffic, services, events, etc.
  - To represent data
  - To make What-if analysis
  - To make optimisations

SUSTAINABLE DEVELOPMENT GOALS

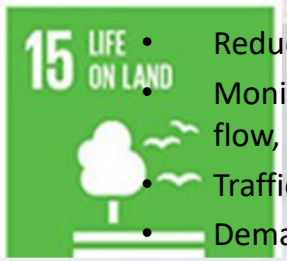
SNAP4CITY

KM 4 CITY

- ***15 Minute City Index:***
  - 13 subindexes: energy, slow mobility, fast mobility, housing, economy education, culture and cults, health, entertainment, gov, food, security…

- Optimization of car sharing/pooling
- Monitoring and Prediction of energy consumption
- Stimulating: Bike sharing, e-bikes, car charge, etc.
- Sizing energy plants, Community of energy

- Reduction of emissions, reduction of congestions
- Smart City infrastructure: monitoring and resilience, long terms predictions, optim. operation and plan
- Effective and Low cost smart solutions
- What-if analysis, Simulations, optimization
- Origin Destination matrices computation



- Reduction of emissions, reduction of congestions
- Monitoring and Predicting: NO2, NOX, CO2, Traffic flow, pollutant, landslide, waste, etc.
- Traffic flow reconstruction, optimisation
- Demand vs Offer of Mobility analysis

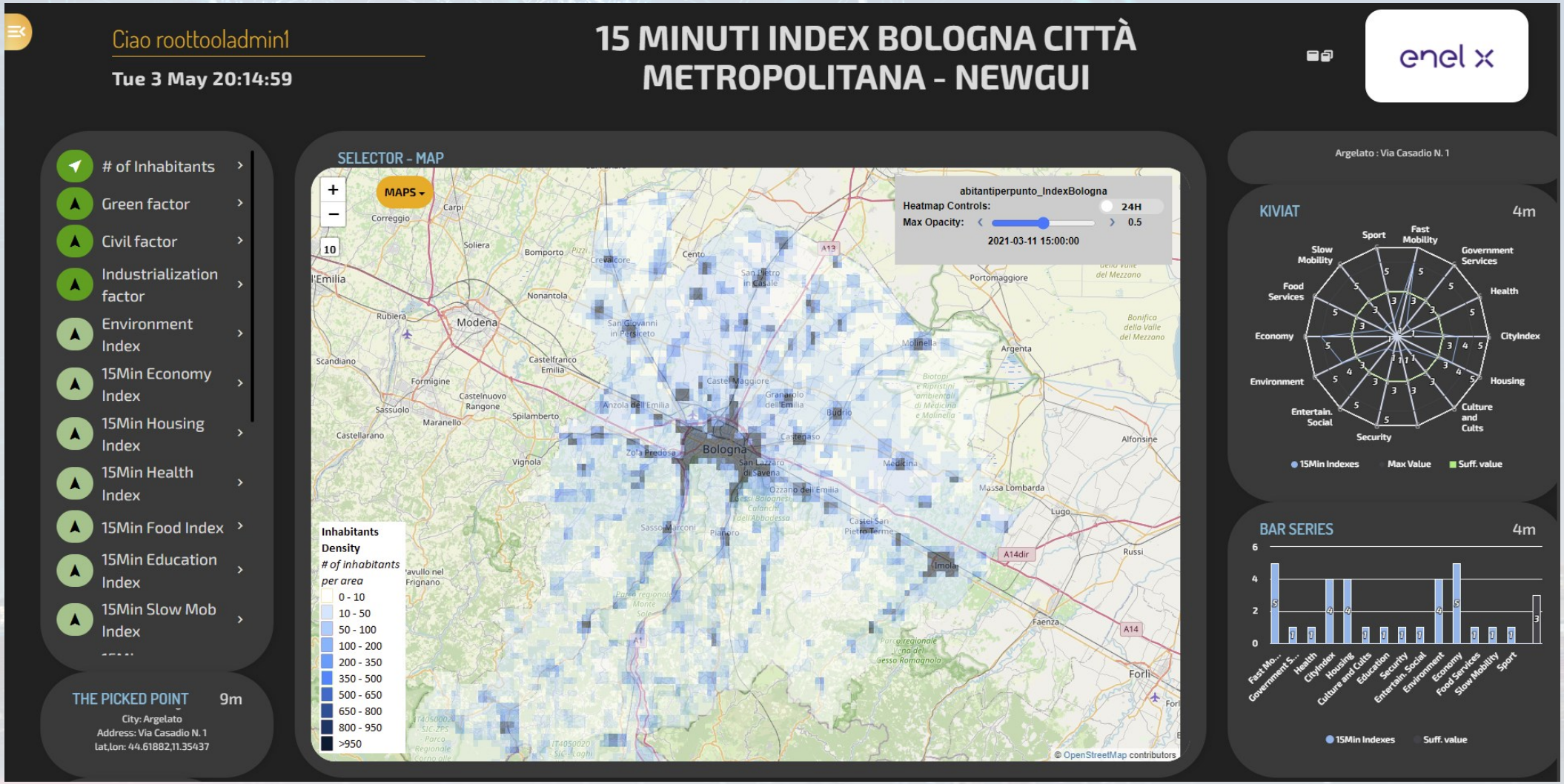
- Predictive maintenance
- Decisions Support Systems
- Process optimization, control
- Industry 4.0 integrated solutions
- AI assistant for commercial activities

- Optimization of Waste Collection
- business intelligence tools for decision makers
- Reduction production costs
- Monitoring resource consumption
- Advisor for documentation, generative AI

- Shortening justice time
- Prediction of mediation proneness
- Assisting institution is taking legal decisions
- Anonymization and indexing legal docs.
- Ethical Explainable Artificial Intelligence
- Advisor for legal documentation, generative AI

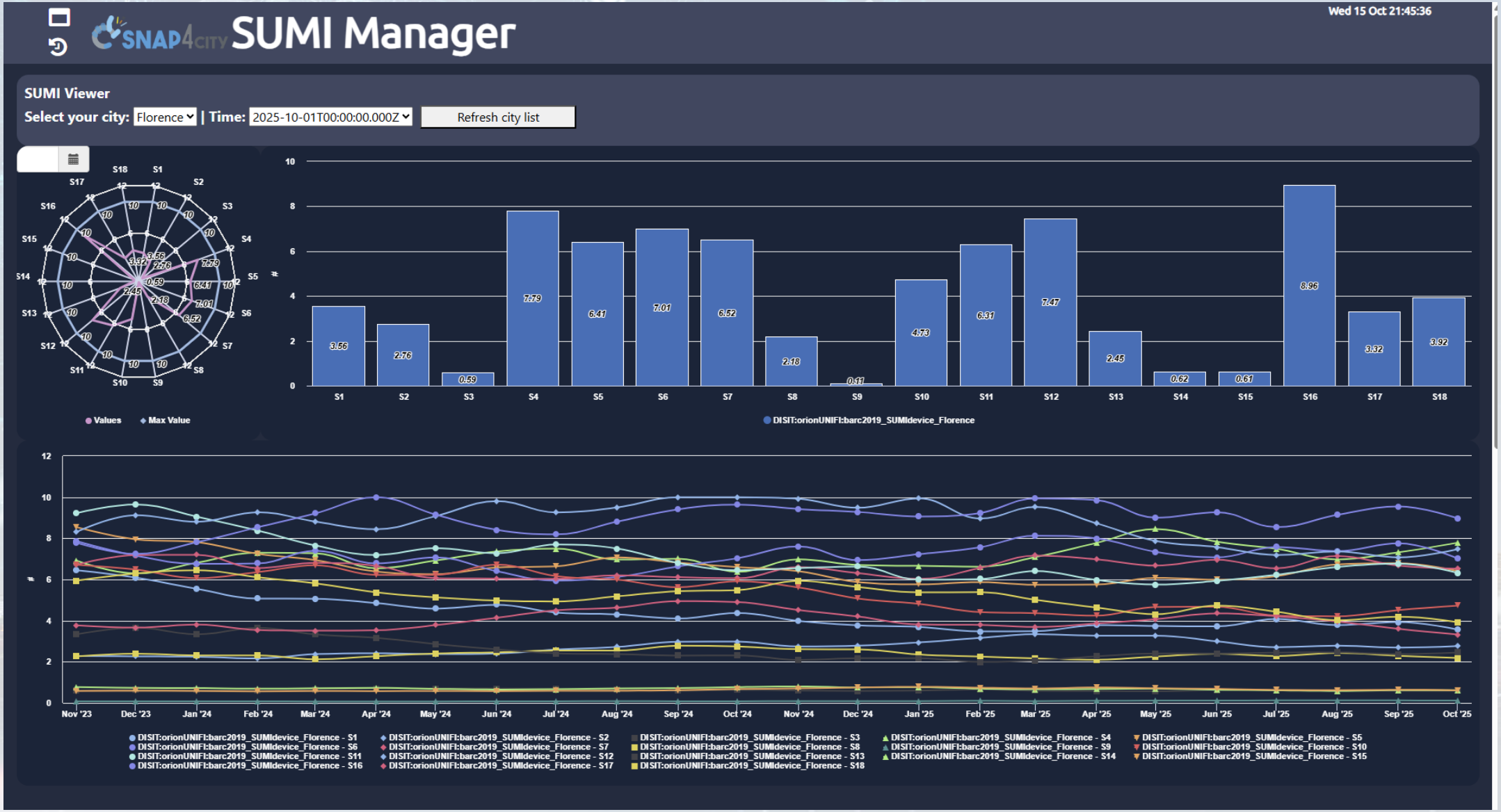
(9/2025)

15MinCityIndex on Bologna



https://www.snap4city.org/dashboardSmartCity/view/Baloon-Dark.php?iddasboard=MzQxMg==

SUMI: Sustainable Urban Mobility Indicators



More details can be obtained from DISIT lab articles appeared on top international Journals

- "Graph Neural Network for Continuous Traffic Density Estimation on Unmonitored Roads from Very Few Scattered Measurements", **Expert Systems With Applications, Elsevier**, ESWA, 2026. https://www.sciencedirect.com/science/article/pii/S095741742601626X
- "Data-Driven Mobility Demand-versus-Offer Matching by Dynamic Integration of Public and Sharing Services", **IEEE Access,** 2026. https://ieeexplore.ieee.org/document/11373175 https://doi.org/10.1109/ACCESS.2026.3661850
- "Exploiting Open Data for CO_2 Estimation via Artificial Intelligence and eXplainable AI", **Expert Systems With Applications, Elsevier, ESWA,** 2025 https://doi.org/10.1016/j.eswa.2025.128598
- "Multi Agent Optimizing Traffic Light Signals Using Deep Reinforcement Learning", **IEEE Access,** 2025. https://doi.org/10.1109/ACCESS.2025.3578518
- "Macroscopic GA-based Multi-Objective Traffic Light Optimization Prioritizing Tramways", **Applied Soft Computing Journal, Elsevier,** 2025. https://doi.org/10.1016/j.asoc.2025.113269
- "High Precision Traffic Flow Reconstruction via Hybrid Method", **IEEE Transactions on Intelligent Transportation Systems,** 2023, https://doi.org/10.1109/TITS.2023.3329544
- "Predicting free parking slots via deep learning in short-mid terms explaining temporal impact of features", **IEEE Access,** 2023. https://ieeexplore.ieee.org/abstract/document/10247516, 10.1109/ACCESS.2023.3314660 https://www.ngen-ai.org
- "An LLM-Based Multi-Agent Framework for Natural Language Interrogation and Exploitation of Smart City Services", Int. Conf. on Next Generation AI Systems, NGEN-AI 2026, Trento, https://www.ngen-ai.org, 1-4 September 2026.

A five-layer data blueprint fuels the AI algorithms solving smart-city transportation problems

DATA LAYER	SPECIFIC INPUT VARIABLES	ENABLED AI / ML TECHNIQUES	PRIMARY SOURCES
1. ROAD GRAPH	Directed nodes and arcs, lane counts, travel directions, road class (primary, secondary, residential), junction phases.	GNN Node Labeling, MaMoTLO (NSGA-II), SMART Actuated DRL, Map-Matching.	OpenStreetMap (OSM), Snap4City Semantic KB
2. SENSOR TELEMETRY	Real-time vehicle counts, concentration, velocities, historical typical time trends (TTT), garage ticket entries.	GNN-TFR, Hybrid PDE-ML (Random Forest, MLP), Conv-Bi-LSTM Parking Forecast.	Inductive loops, traffic cams, off-street garage gates
3. MOBILITY DEMAND	Origin-Destination Matrices (ODMs), hourly telecom cell phone presence logs, passenger transit schedules.	MODOM Agent-Based Simulation, Probabilistic Grid Resampling (200m MGRS).	Telecom operator logs, Census data, survey records
4. TRANSIT OFFER	Public bus, tram, and train timetables, vehicle capacities, stops, GBFS free-floating sharing fleets.	MODOM ABM, MaMoTLO Tramway Priority, Webster Coordination, SMART.	GTFS schedules, GBFS parking feeds, transit operators
5. SOCIO-ECONOMIC	Point-of-Interest densities (schools, health, food, govern), average taxable income, taxpayers, housing cost per m2.	XGBoost CO2 Estimation, GCN Proximity Modeling, SHAP Explainability.	Open Data Portals, Chamber of Commerce, satellite ODIAC
6. Agentic Operative KNOWLEDGE	Multidomain Knowledge, real time data, historical data, road graph, web info, etc.	Agentic AI, LLM, AI, Digital Twin, Simulation, Predictions	A large kind of knowledge on all research activities in the domain, on AI, and on data analytics

Conclusions: Agentic AI Engines are the new Kings

1	**Data is the incipit, KPI are the driver**	Road graphs, feeds, sensors, open data, and governance determine impact. One data can be in most cases surrogated by others. KPI are mandatory
2	**AI can make sparse data operational.**	Traffic reconstruction fills unmonitored roads without sensor saturation.
3	**Prediction enables prevention.**	Parking, traffic, critical conditions, and emissions can be anticipated rather than only observed.
4	**Digital twins convert models into planning tools.**	AI + simulations allow many what-if scenarios before street-level changes.
5	**Optimization must encode policy.**	Signals should balance efficiency, public transport priority, and fairness. *Also infrastructure can be optimized to better structured to sustain the traffic and reduce travel time, costs, consumption,…*

Bottom line: new AI techniques do not remove the need for transport expertise - they multiply its reach

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Alcune nuove tecniche dell'intelligenza artificiale possono risolvere i problemi della mobilità e dei trasporti e quali dati sono necessari

new artificial intelligence techniques can solve mobility and transportation problems and what data is needed

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