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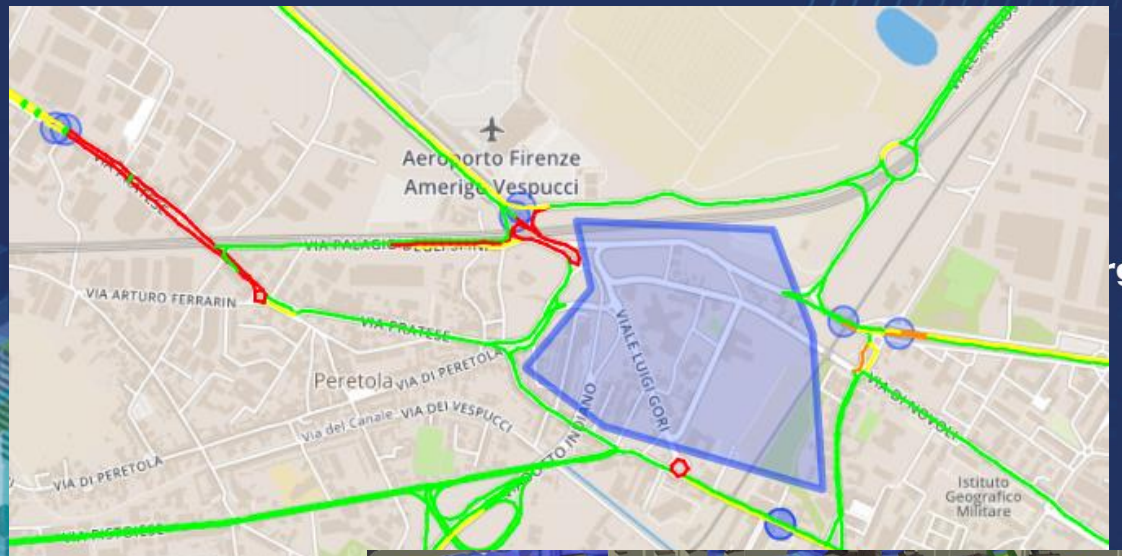
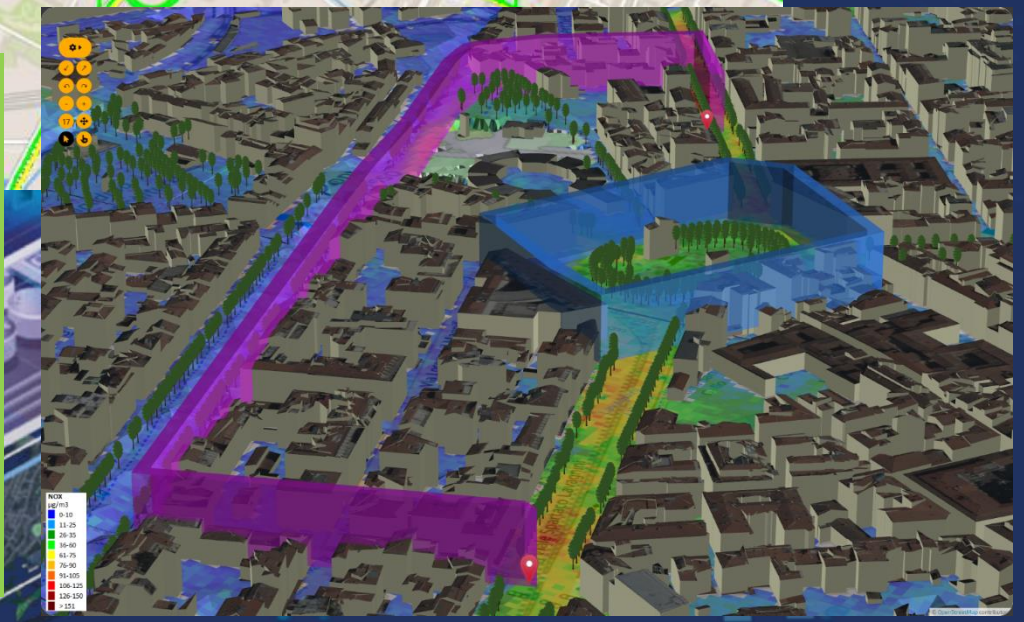


Mobility and Transport Operation and Plan Digital Twin



DIGITAL TWIN SOLUTIONS TO SETUP SUSTAINABLE DECISON SUPPORT SYSTEMS AND BUSINESS INTELLIGENCE

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

Mobility and Transport goals

Decongestion

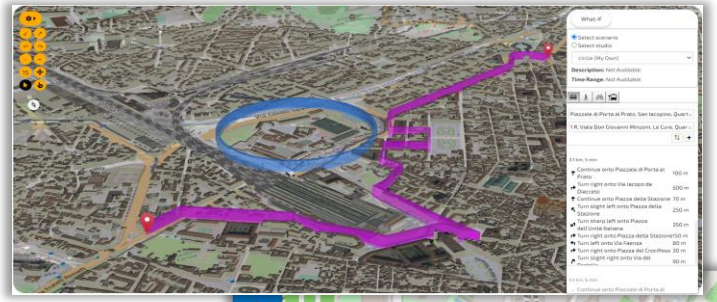
Safety

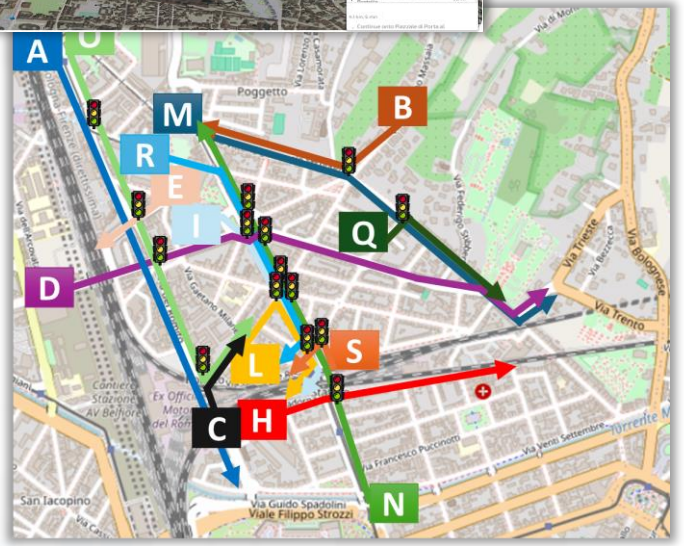
Accessibility

Cost Reduction

Decarbonization

Mobility & Transport

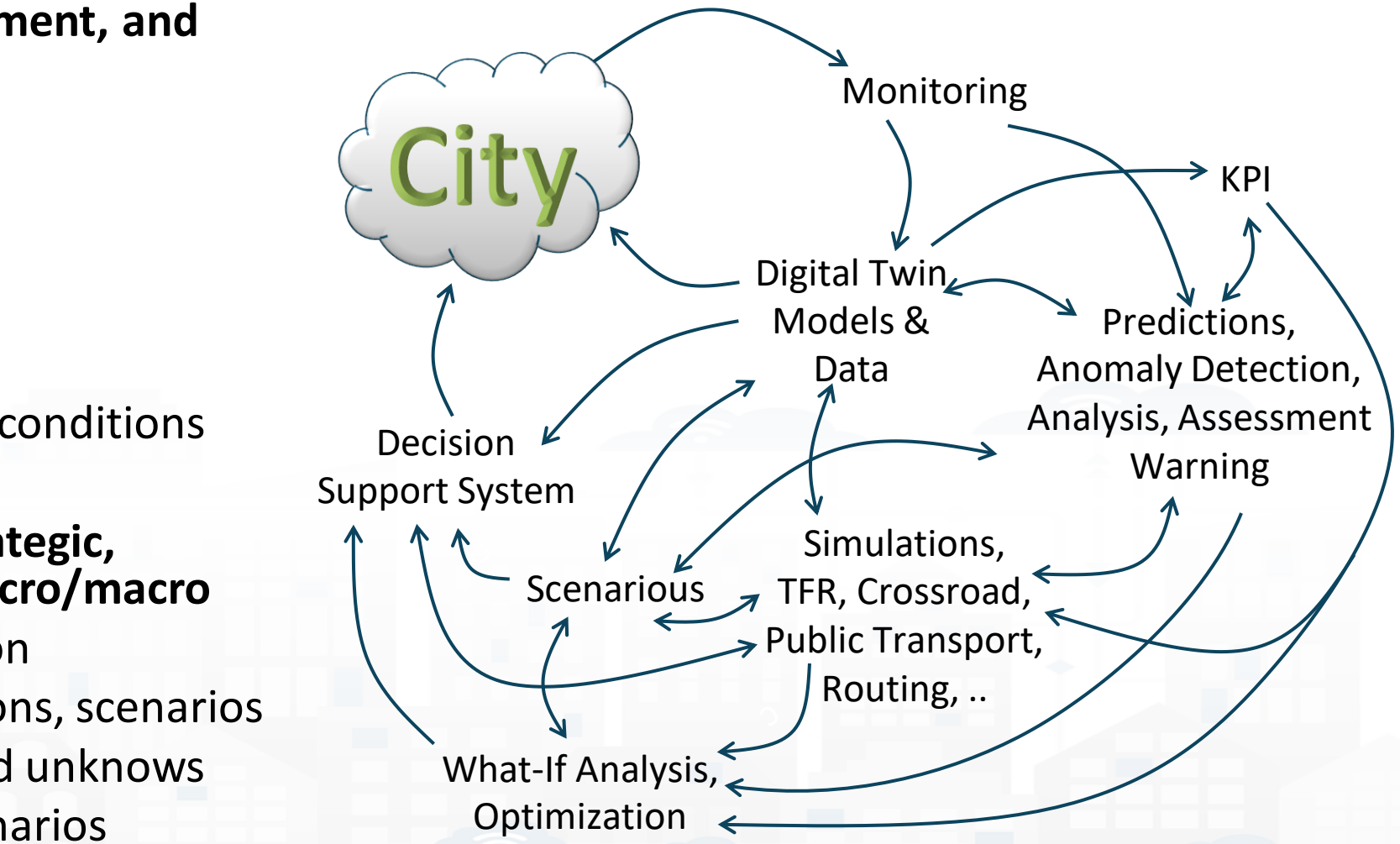




- **Goals:**
  - Decongestion, Decarbonization, costs reductions
  - Improve Accessibility to services
  - Improve Security/Safety of city users
- **Operation and Plan**:
  - Traffic monitoring, prediction, reconstruction, identification of critical conditions (early warning), fleet management, dynamic routing, multimodal routing, city user behaviour analysis
- **Optimization and what-if analysis traffic light, infrastructure**
  - **Reduction**: travel time, waiting time, stops, CO2 emissions, consume fuel, travel time for tramways
- **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.**

Main tasks

- **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 unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders



City

Monitoring

KPI

Digital Twin
Models &
Data

Predictions,
Anomaly Detection,
Analysis, Assessment
Warning

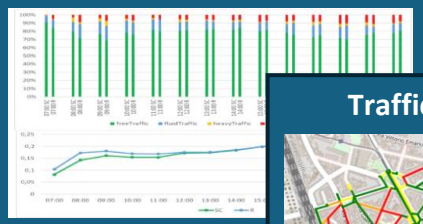
Decision
Support System

Scenarious

Simulations,
TFR, Crossroad,
Public Transport,
Routing, ..

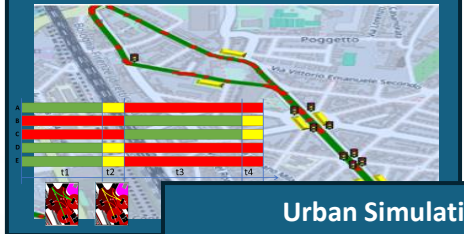
What-If Analysis,
Optimization

KPI, Predictions, ...



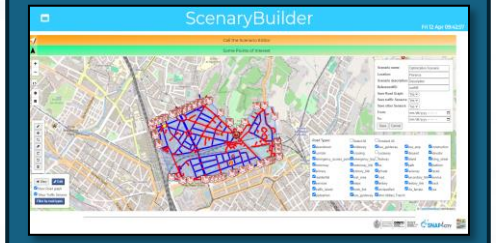
Traffic Reconstruction

Traffic Light Plan optimization

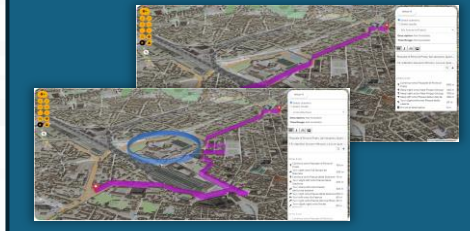


Urban Simulation

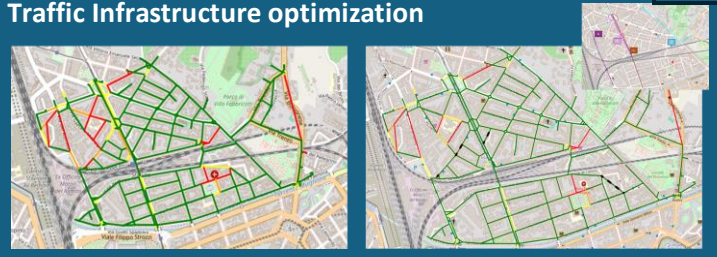
Scenario Editor



Routing / Dynamic Routing



Traffic Infrastructure optimization



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

SNAP4CITY · KM4CITY

www.snap4city.org

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100% OPEN SOURCE

Powered by FIWARE

FREE TRIAL

PEN Test Passed

EU GDPR COMPLIANT

SNAP4 Appliances and Dockers Installations

EUROPEAN OPEN SCIENCE CLOUD

Node-RED

JS Foundation

E015 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

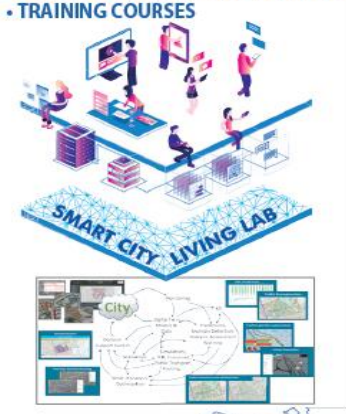
BUSINESS INTELLIGENCE - SIMULATIONS - VISUAL ANALYTICS - SYNOPTICS - GRAPHICAL WIDGETS - ANALYTICS

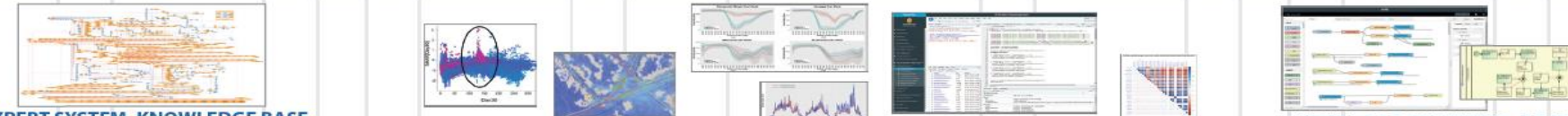
DASHBOARDS, WIDGETS TEMPLATES

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

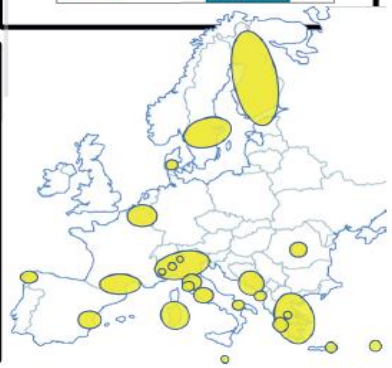
BIG DATA ANALYTICS, ARTIFICIAL INTELLIGENCE
EXPLAINABLE AI, MACHINE LEARNING, GENERATIVE AI
OPERATIVE RESEARCH, STATISTICS

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

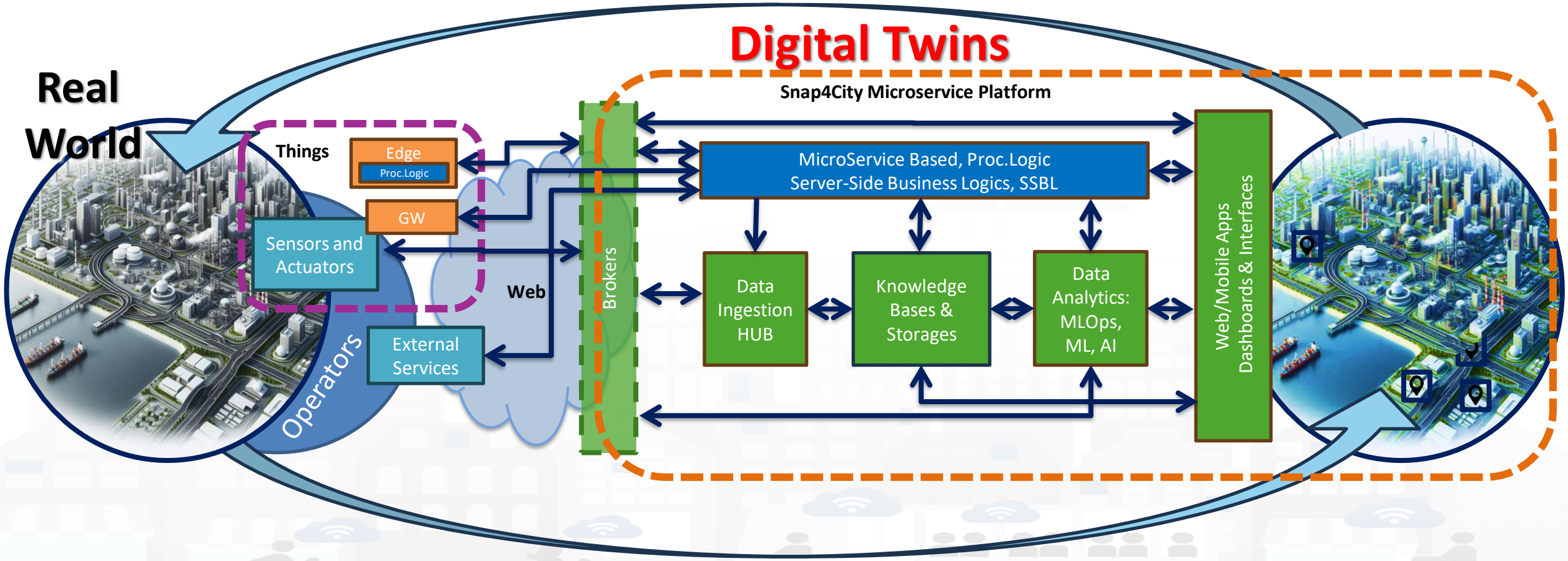
FULL INTEROPERABILITY, ANY: DATA, BROKERS, NETWORKS AND VERTICALS

NATIVE AND EXTERNAL APPLICATIONS

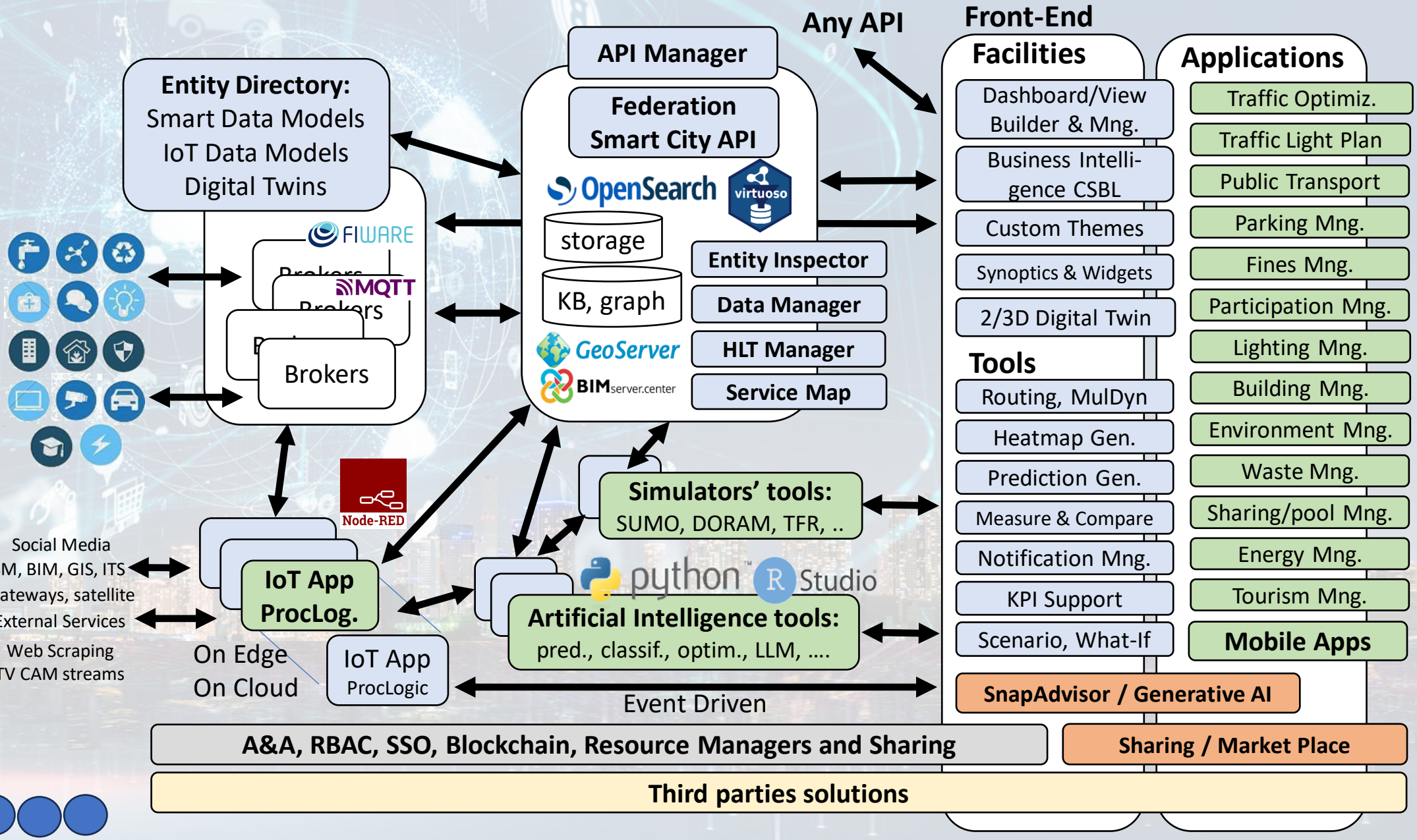
- Smart Parking
- Smart Light
- Smart Waste
- Smart Energy
- Smart Building
- Smart Tourism
- ...



Digital Twin Development Platform



Technical Architecture



Standards and Interoperability

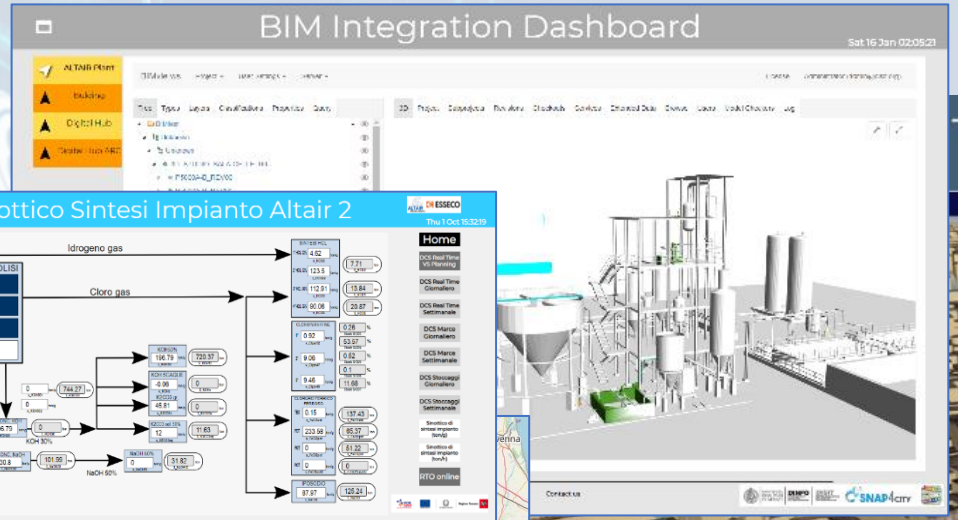
Compliant with:

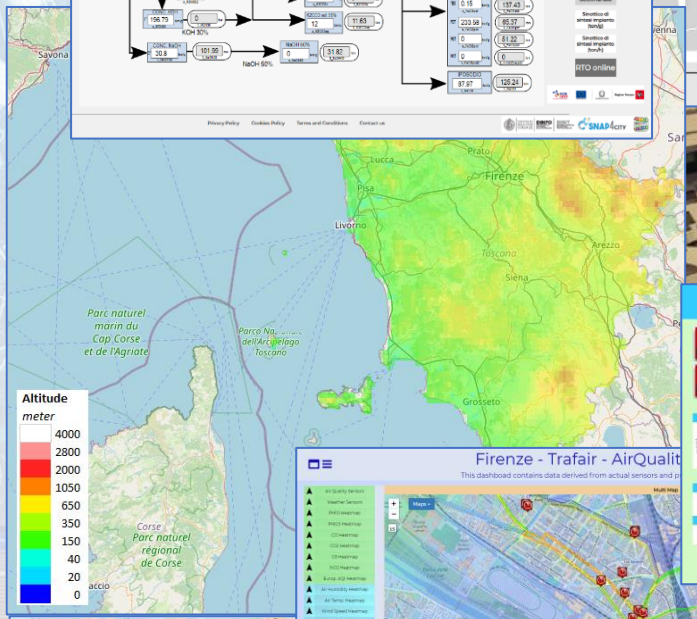
- **IoT:** NGSI V2/LD, LoRa, LoRaWan, MQTT, AMQP, COAP, OneM2M, TheThingsNetwork, SigFOX, Libelium, IBIMET/IBE, Enocean, Zigbee, DALI, ISEMC, Alexa, Sonoff, HUE Philips, Tplink, BACnet, TALQ, Protocol Buffer, KNX, OBD2, Proximus, ..
- **IoT model:** FIWARE Smart Data Model, Snap4City IoT Device Models
- **General**: HTTP, HTTPS, TLS, Rest Call, SNMP, TCP, UDP, SOAP, WSDL, FTP, FTPS, WebSocket, WebSocket Secure, GML, WFS, WMS, WCS, RTSP, ONVIF, AXIS TVCam, CISCO Meraki, OSM, Copernicus, The Weather Channel, Open Weather, OLAP, VMS Milestone, TIM, HERE, ….
- **Formats**: JSON, GeoJSON, XML, CSV, GeoTIFF, OWL, WKT, KML, SHP, db, XLS, XLSX, TXT, HTML, CSS, SVG, IFC, XPDL, OSM, Enfuser FMI, Lidar, glTF, GLB, DTM, GDAL, Satellite, D3 JSON, …
- **Database**: Open Search, MySQL, Mongo, HBASE, SOLR, SPARQL, ODBC, JDBC, Elastic Search, Phoenix, PostGres, MS Azure, ..
- **Industry**: OPC/OPC-UA, OLAP, ModBUS, RS485, RS232,..
- **Mobility**: DATEX, GTFS, Transmodel, ETSI, NeTEx, ..
- **Social**:Twitter, FaceBook, Telegram, ..
- **Events**: SMS, EMAIL, CAP, RSS Feed, ..
- **OS**: Linux, Windows, Android, Raspberry Pi, Local File System, AXIS, ESP32, etc.

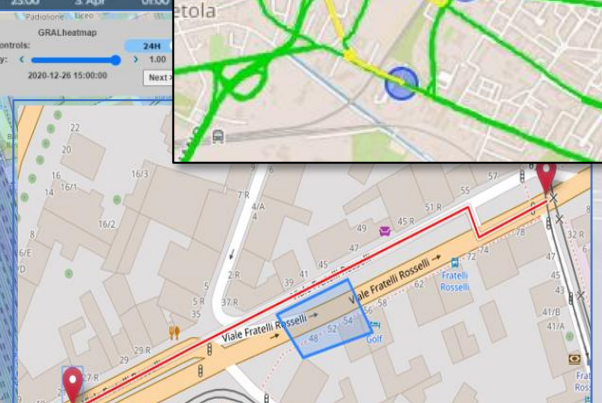
https://www.snap4city.org/65

High Level Types

- POI, IOT Devices, shapes,..
  - FIWARE Smart Data Models,
  - IoT Device Models
- GIS, maps, orthomaps, WFS/WMS, GeoTiff, calibrated heatmaps, ..
- Satellite data, any kind..
- traffic flow, typical trends, ..
- Vector fields + heatmaps, ..
- trajectories, events, workflow, ..
- 3D Models, BIM, Digital Twins, ..
- OD Matrices of several kinds, ..
- Dynamic icons/pins, ..
- Synoptics, animations, ..
- KPI, personal KPI,..
- social media data, TV Stream,
- routing, multimodal, constraints, ..
- scenarios, ….
- etc.







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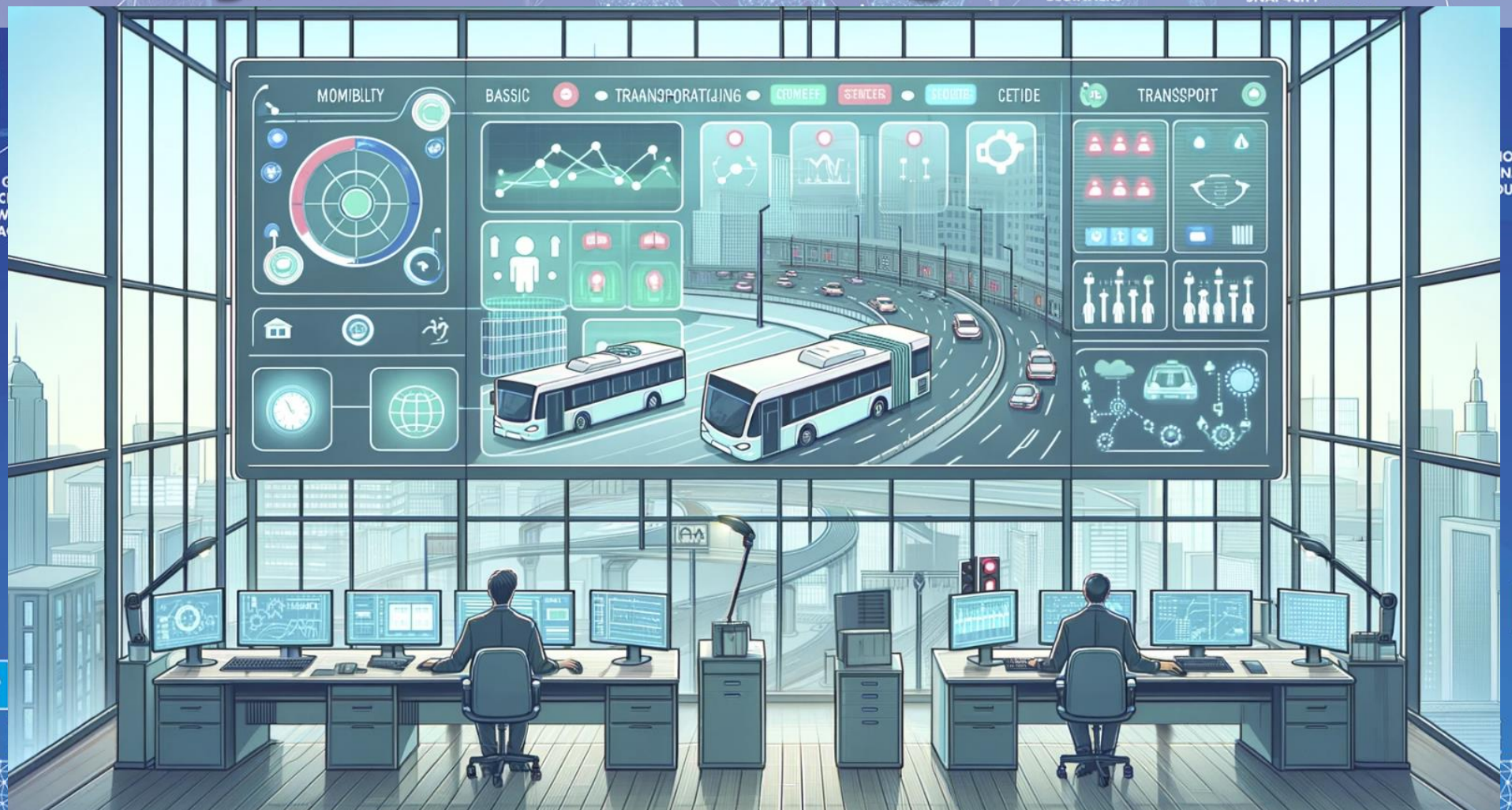
Mobility Monitoring and Control



FROM CITY DASHBOARD TO APPLICATIONS

SNAP4CITY FOR BEGINNERS

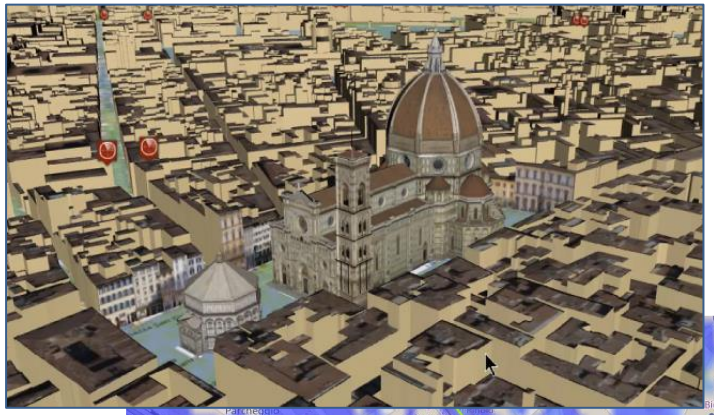
SNAP4CITY

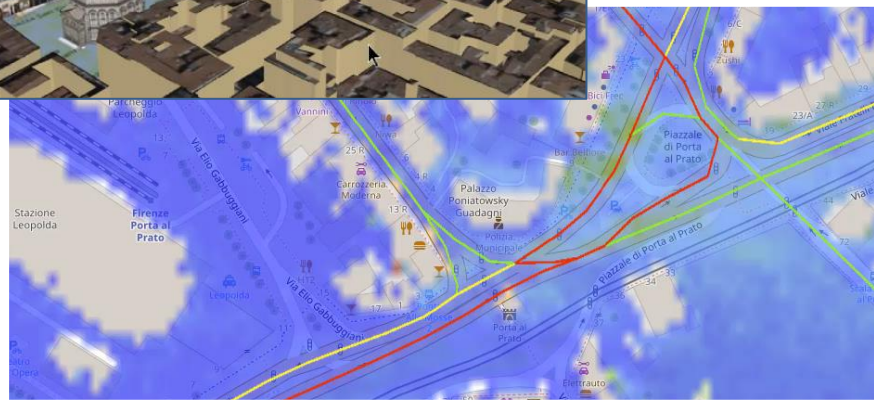
SNAP4CITY AND KM4CITY PROJECTS

SNAP4CITY THE VIEW OF THE ADMINISTRATORS

Monitoring

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Computing predictions and KPI
  - Anomaly detection, Early warning
  - Control Rooms, situation rooms
- **Reacting: Computing in real time**
  - Changing semaphore maps
  - Changing Dynamic signage
  - Real time Info Mobility
  - User engagement via Mobile Apps
  - What-if analysis
  - etc.,





Key Performance Indicators, KPI

Air Quality Directive				WHO guidelines	
Pollutant	Averaging period	Objective and legal nature and concentration	Comments	Concentration	Comments
$PM_{2.5}$	One day			25 µg/m³ (*)	99th percentile (3 days/year)
$PM_{2.5}$	Calendar year	Target value, 25 µg/m³	The target value has become a limit value since 1 January 2015	10 µg/m³	
PM_{10}	One day	Limit value, 50 µg/m³	Not to be exceeded on more than 35 days per year.	50 µg/m³ (*)	99th percentile (3 days/year)
PM_{10}	Calendar year	Limit value, 40 µg/m³ (*)		20 µg/m³	
O_3	Maximum daily 8-hour mean	Target value, 120 µg/m³	Not to be exceeded on more than 25 days per year, averaged over three years	100 µg/m³	
NO_2	One hour	Limit value, 200 µg/m³ (*)	Not to be exceeded more than 18 times a calendar year	200 µg/m³ (*)	
NO_2	Calendar year	Limit value, 40 µg/m³		40 µg/m³	

- **United Nations Sustainable Development Goals, SDGs** (for which cities can do more to achieve some of the 17 SDGs, https://sdgs.un.org/goals);
- **15 minutes cities** (where primary services must be accessible within 15 minutes on foot);
- **objectives of the European Commission** in terms of pollutant emissions for: NO2, PM10, PM2.5 (https://environment.ec.europa.eu/topics/air_en);
- **SUMI: mobility and transport vs env**
  - **https://www.snap4city.org/951**
- **SUMP/PUMS: mobility and transport vs env.**
- **ISO indicators:** city smartness, digitization, tech level.
- **Low Level/Real Time:** global traffic, quality of service, betweenness, centrality, queue, time to travel, etc.

Global & Local

Periodic & Realtime

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

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

- 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

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

- 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

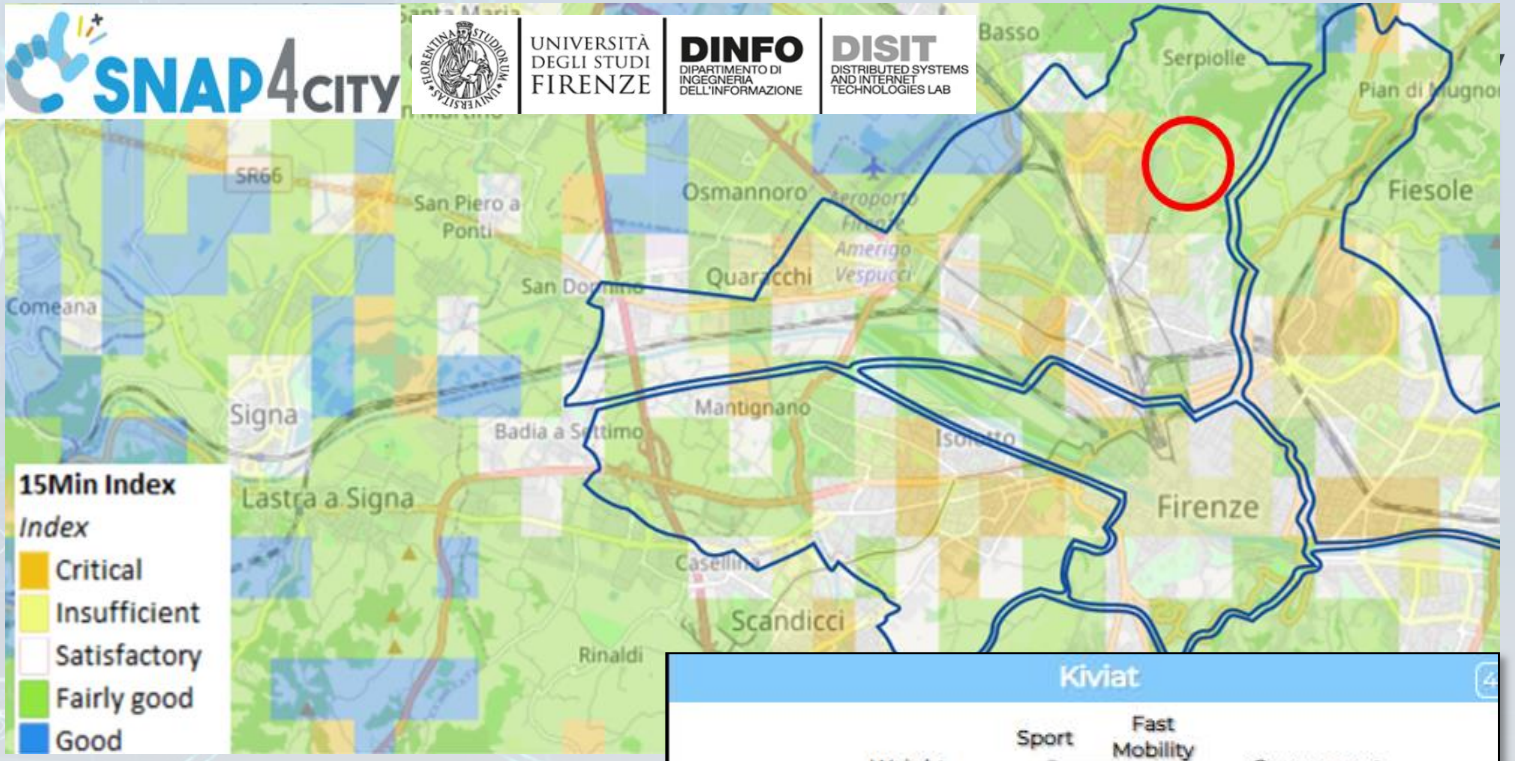
- Shortening justice time
- Prediction of mediation proneness
- Assisting institution is taking legal decisions
- Anonymization and indexing legal docs.
- Ethical Explainable Artificial Intelligence
- Advisor for legal documentation, generative AI

(9/2025)

15MinCityIndex

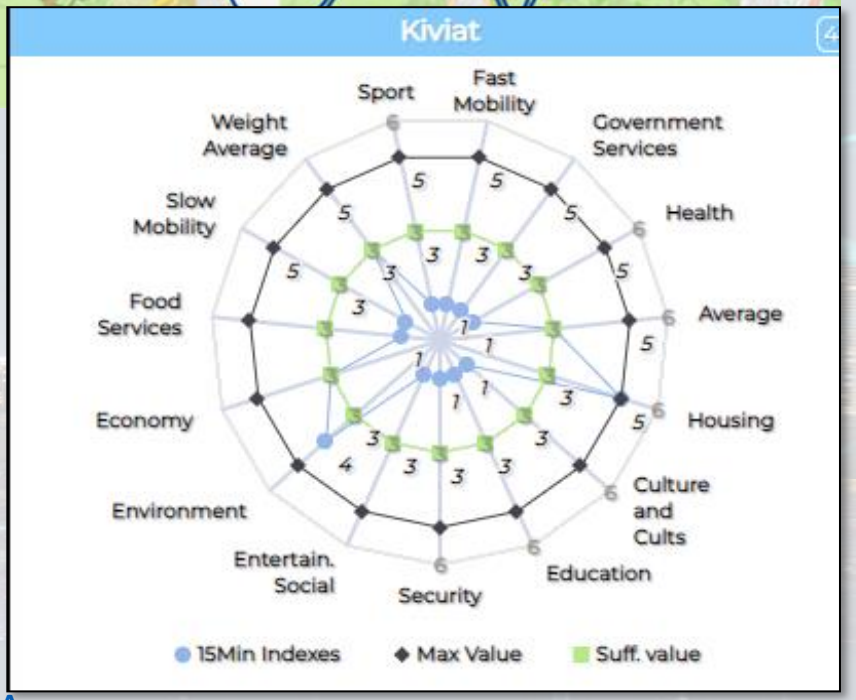
What would support my neighborhood to become a 15-Minute City?

Using the Open Data:
We developed a data analytic tool based on municipal and national open data to assess services adequacy for people living in each 15 minutes areas of the city.



Good public transport services: bus, new tram line, train stations, cycle paths.

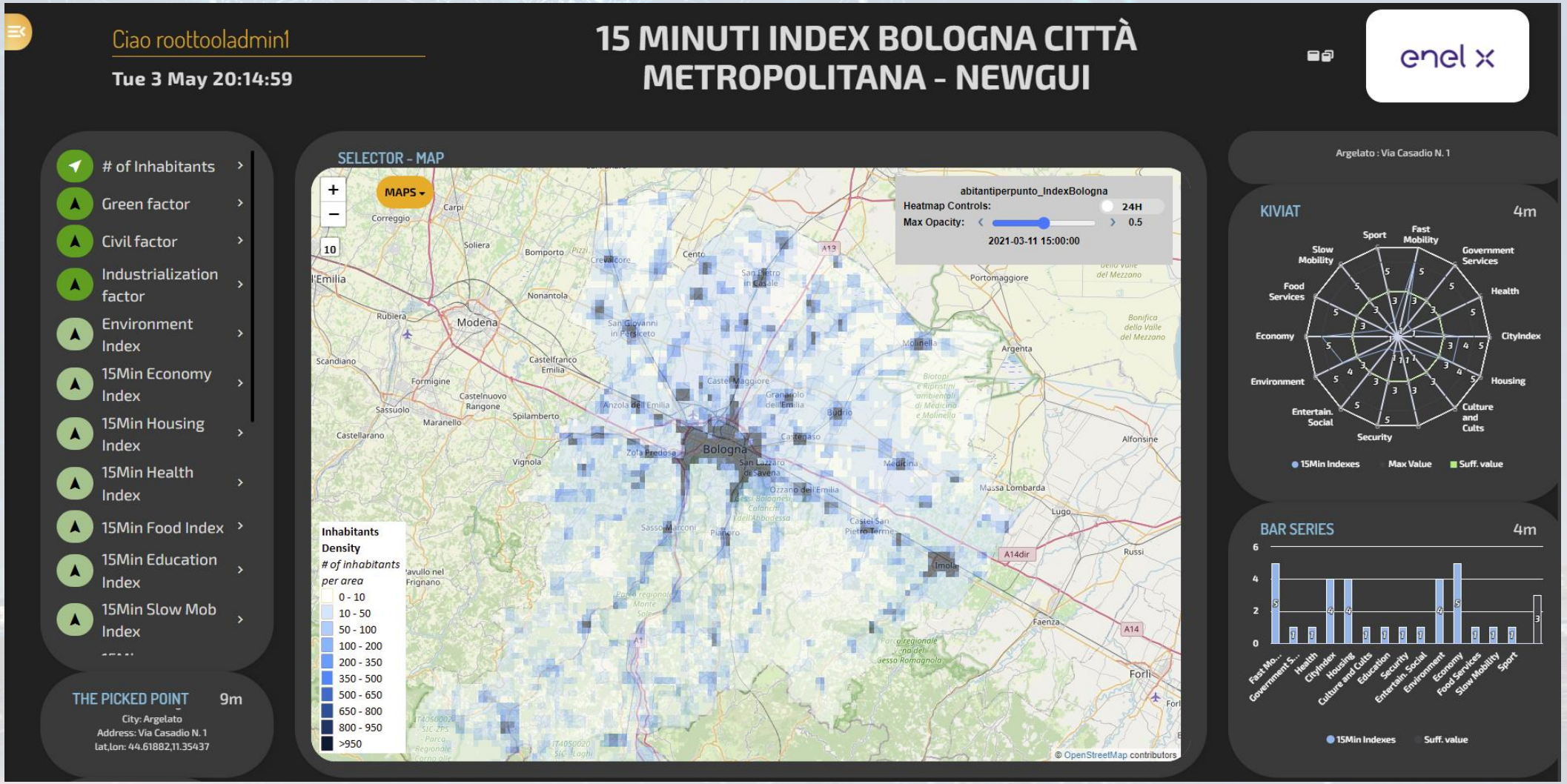
The tool supports the becoming of a 15-Minute city evaluating the service level in various domains.



Careggi/Rifredi is a relevant district in Florence because of hosting the main Florence/Tuscany hospitals Careggi and Meyer, but also university headquarters and many other workplaces.

https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjkzOA==

15MinCityIndex on Bologna



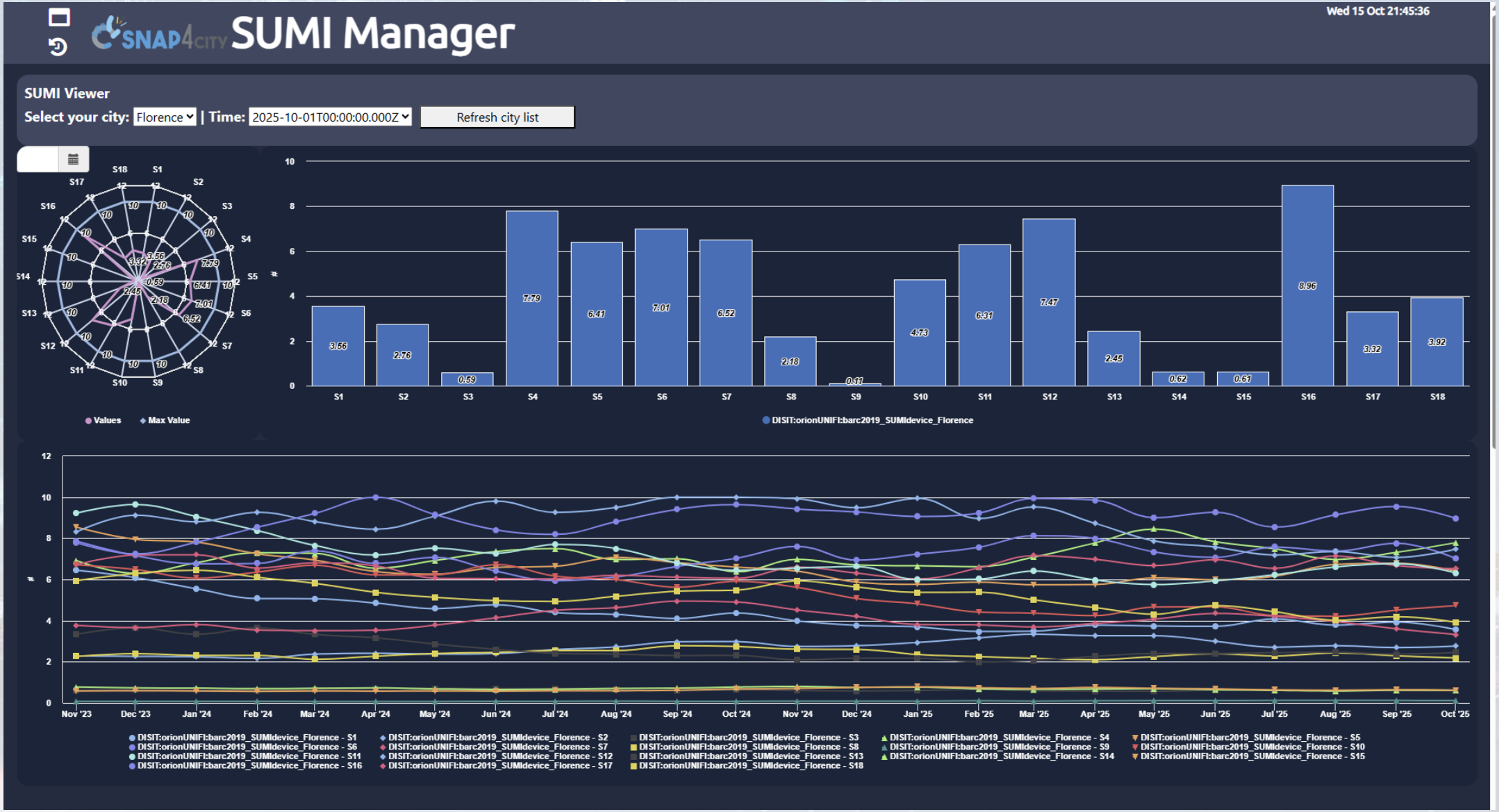
https://www.snap4city.org/dashboardSmartCity/view/Baloon-Dark.php?iddasboard=MzQxMg==

SUMI: Sustainable Urban Mobility Indicators

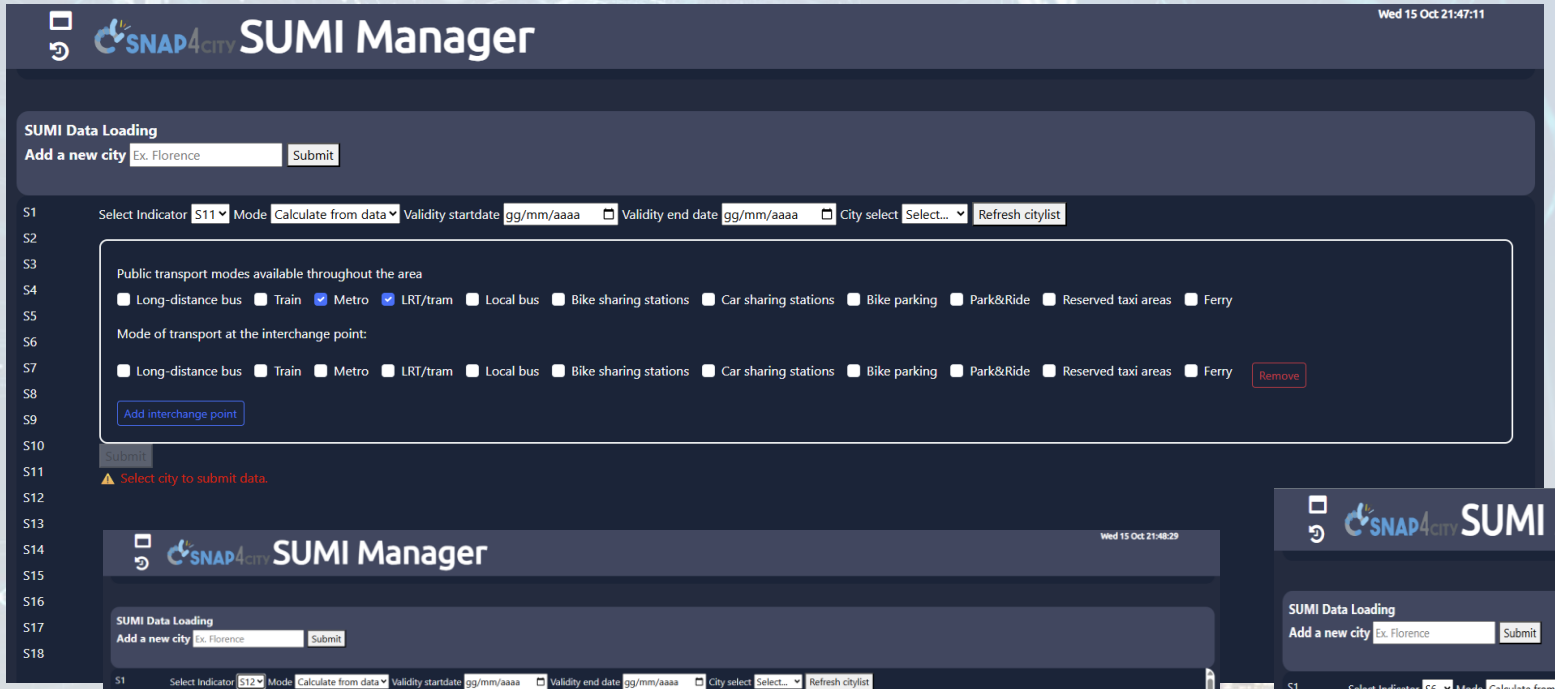
- **Core indicators (13)**
  1. Affordability of public transport for the poorest group
  2. Accessibility of public transport for mobility-impaired groups
  3. Air pollutant emissions
  4. Noise hindrance
  5. Road deaths
  6. Access to mobility services
  7. Greenhouse gas emissions (GHG)
  8. Congestion and delays
  9. Energy efficiency
  10. Opportunity for active mobility
  11. Multimodal integration
  12. Satisfaction with public transport
  13. Traffic safety (active modes)

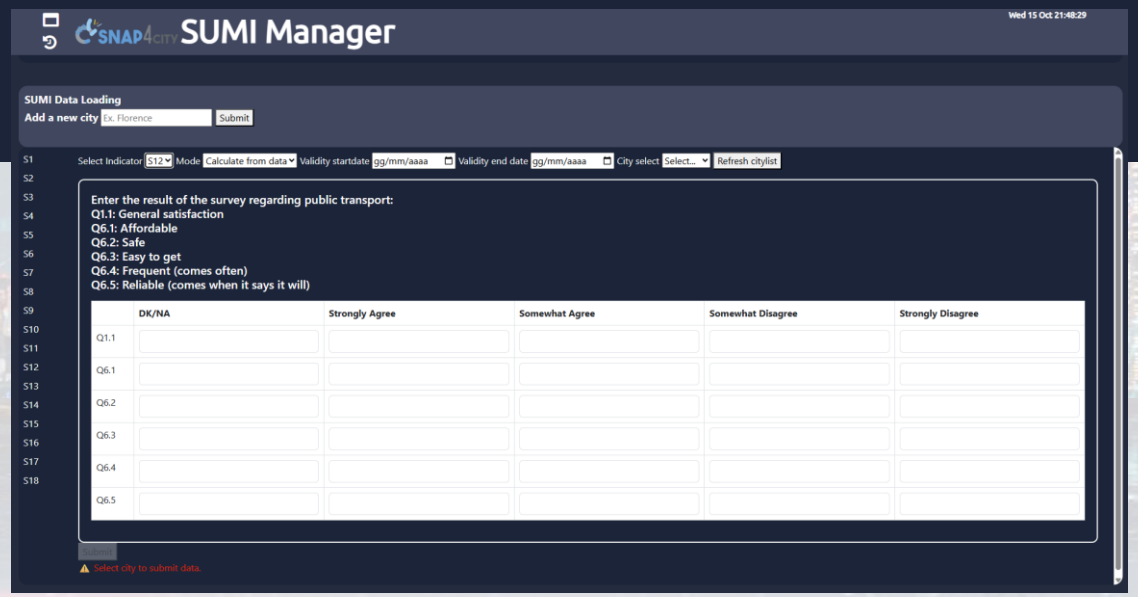
- **Non-core indicators (5)**
  14. Quality of public spaces
  15. Urban functional diversity
  16. Commuting travel time
  17. Mobility space usage
  18. Security on mobility and transport

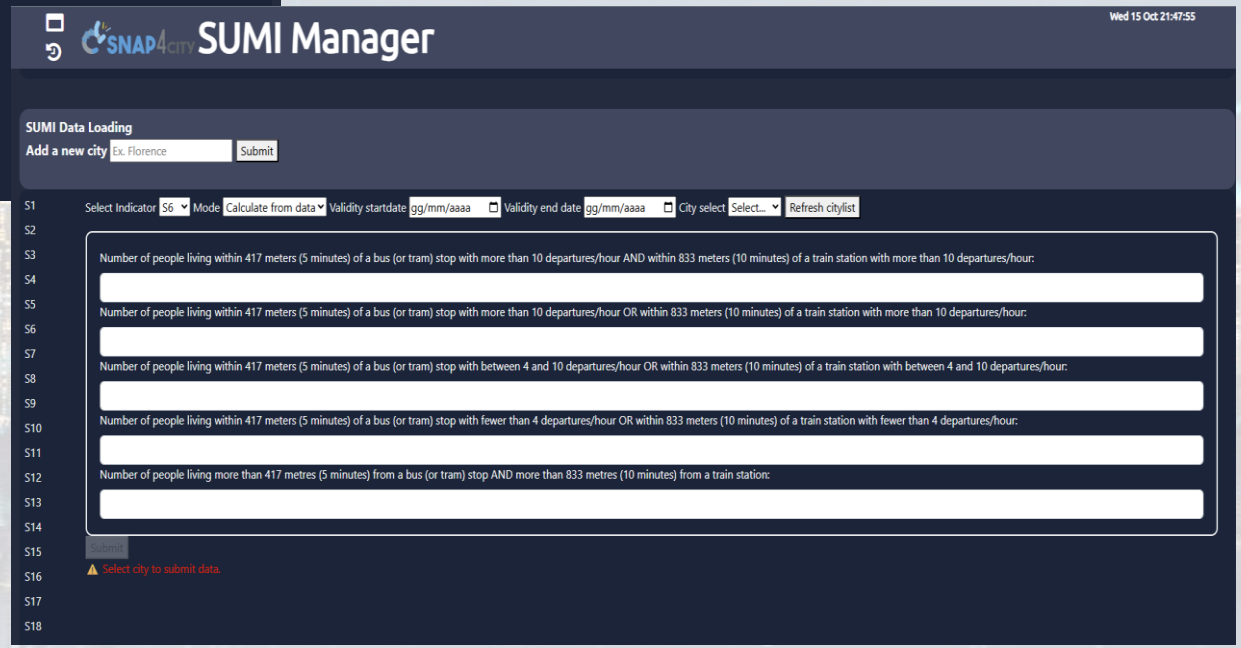
SUMI: Sustainable Urban Mobility Indicators



SUMI: Sustainable Urban Mobility Indicators







Smart City Control Room
Florence Metropolitan City

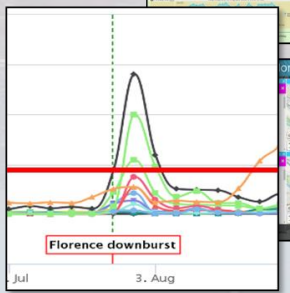
COMUNE DI FIRENZE

reference

SNAP4CITY

KM 4 CITY

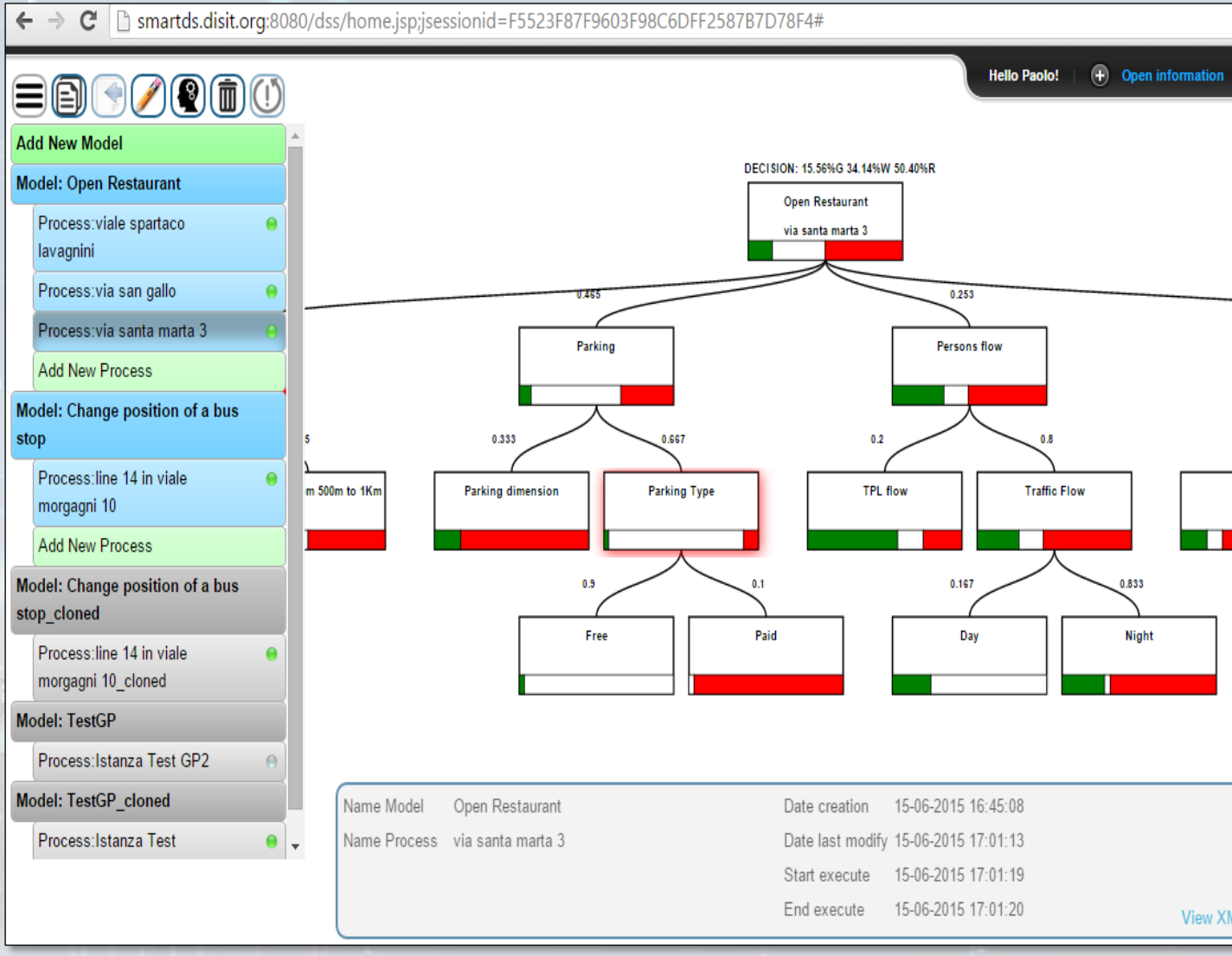
- **Multiple Domain Data**
  - Thousands of Open/Private data, POI, IOT, etc.
  - ***mobility and transport***: accidents, public transport, parking, traffic flow, Traffic Reconstruction, KPI, …
  - ***AND***: environment, civil protection, gov KPI, covid-19, social & social media, people flow, tourism, energy, culture, …
- **Multiple dash/tool Levels & Decision Makers**
  - Real Time monitoring, Alerting, quality assess.
  - Predictions, KPI, DSS, what-if analysis
- **Historical and Real Time data**
  - Billions of Data
- **Services Exploited on:**
  - Multiple Levels, Mobile Apps, API
- **Since 2017**



https://www.snap4city.org/747

Smart Decision Support , system thinking

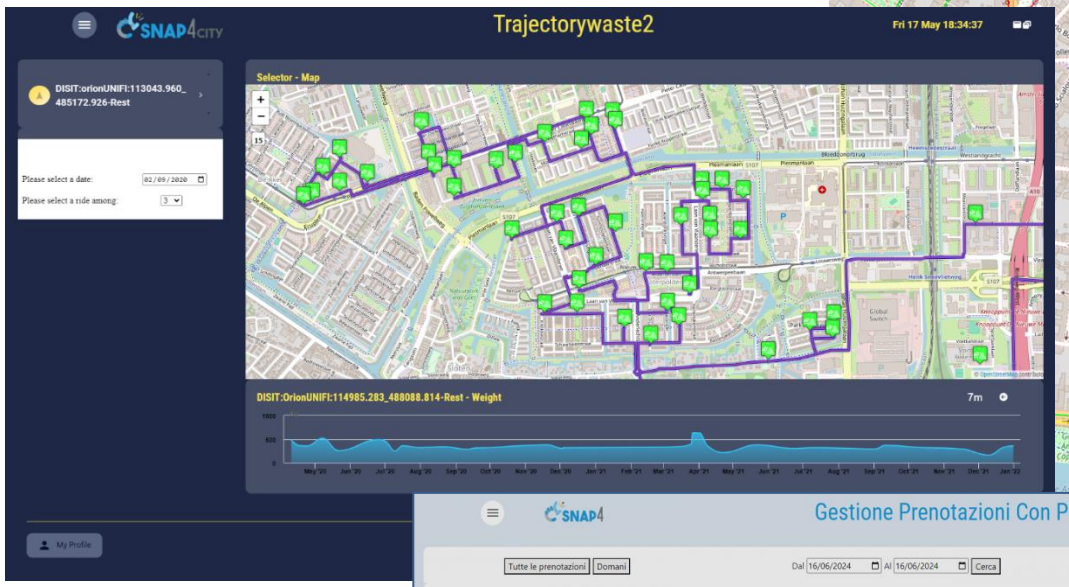
- **Smart Decision Support System** based on System Thinking plus
- Actions to city reaction, resilience, smartness, …
- Enforcing Mathematical model for propagation of decision confidence..
- Collaborative work, …
- Processes connected to city data: DB, RDF Store, Twitter, etc.
- Production of alerts/alarms
- Data analytics process
- Twitter Processes
- reuse, copy past, …

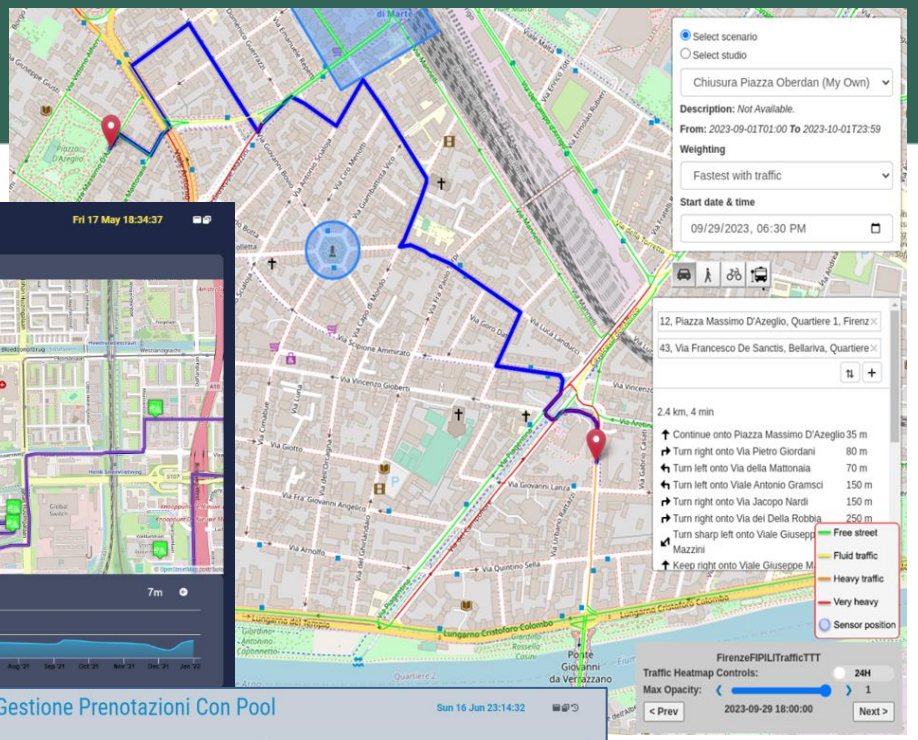


Routing Optimization

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.





Dynamic Routing on operation:

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

TUSCANY X.0
EDIH European Digital Innovation Hubs Network
Finanziato dall'Unione europea NextGenerationEU
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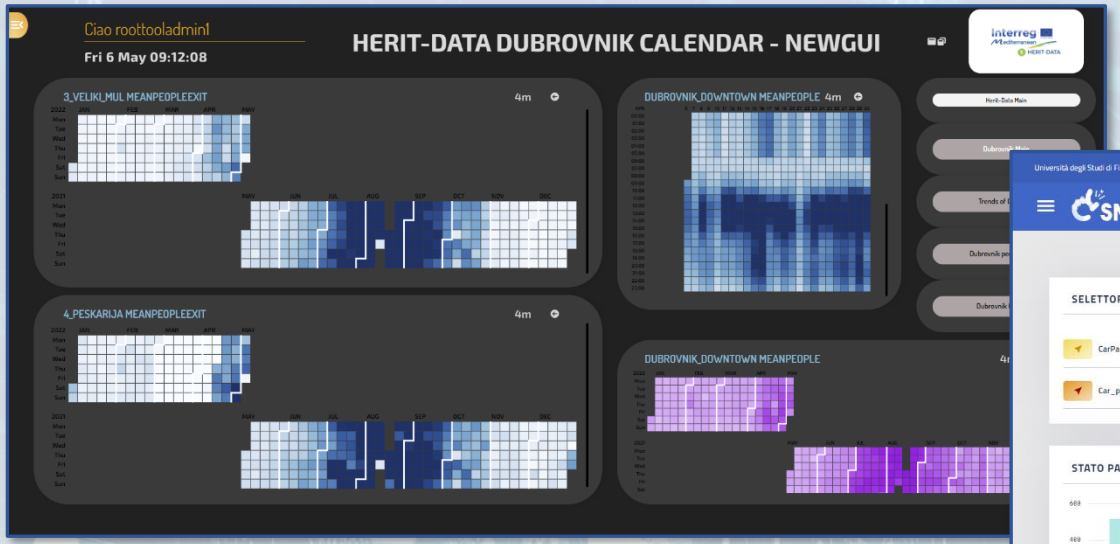
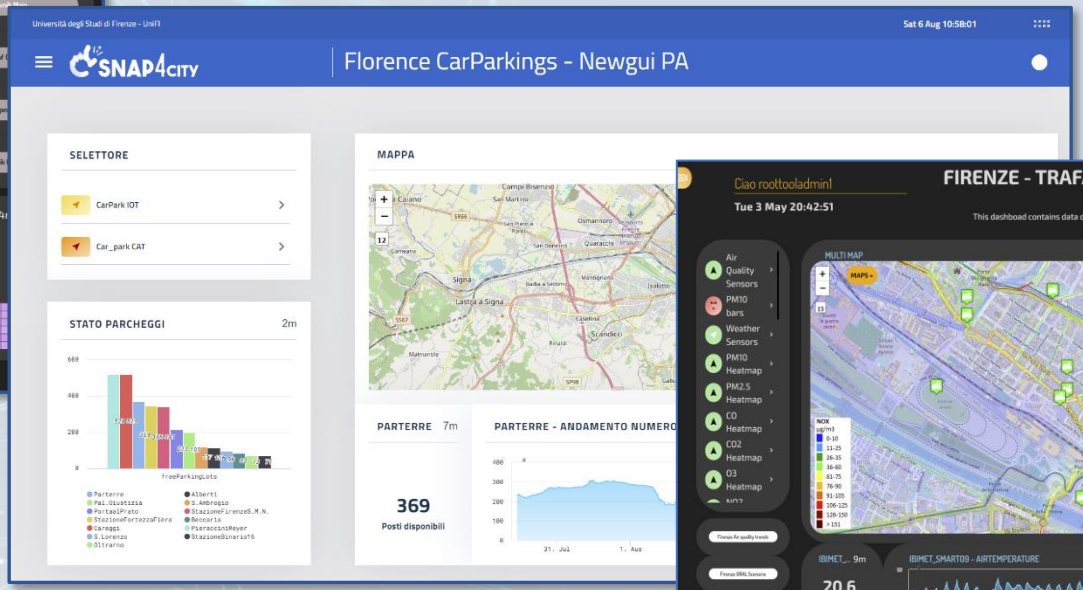
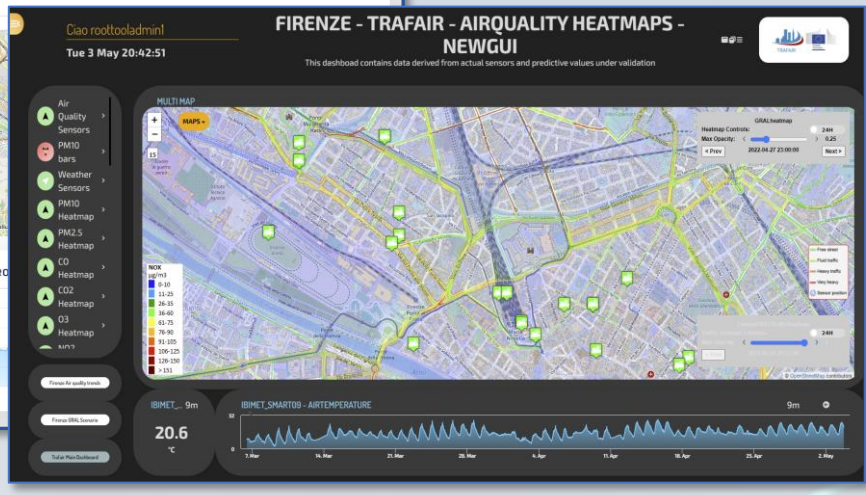
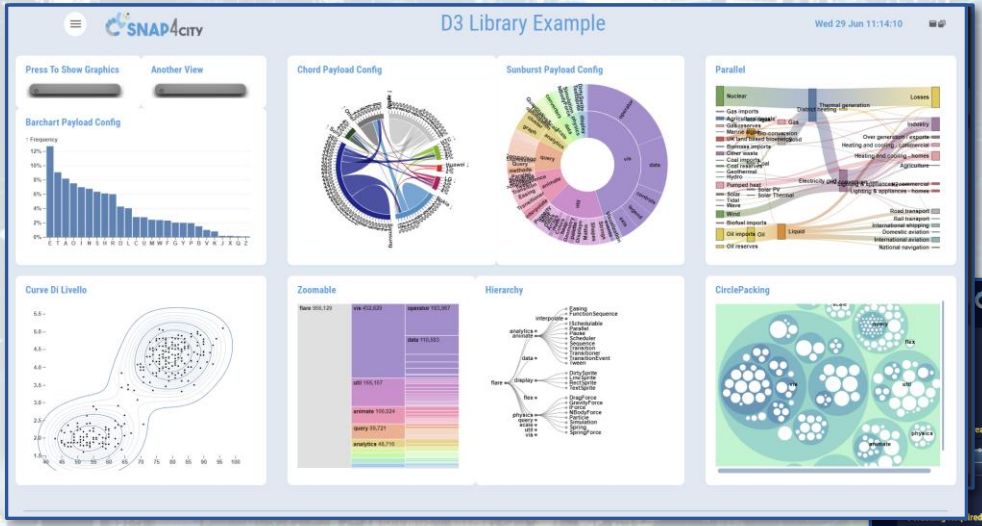
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB

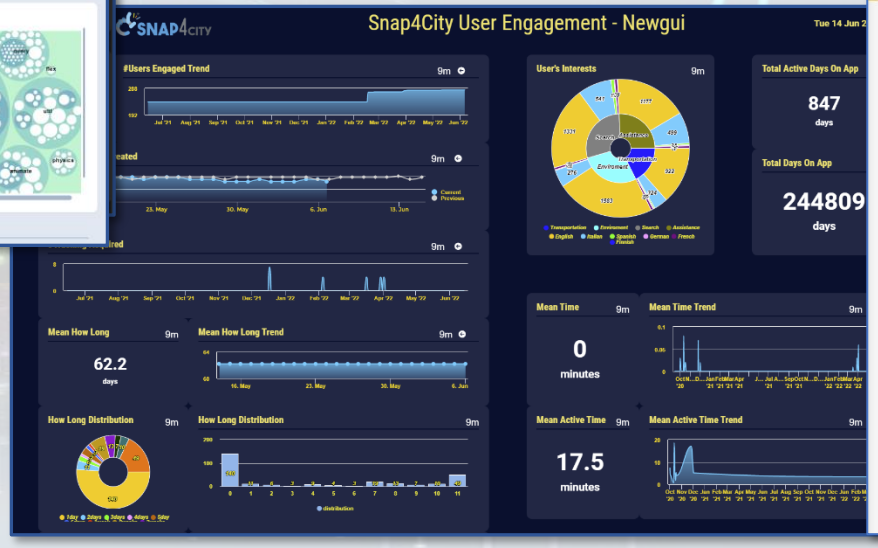
Different Themes

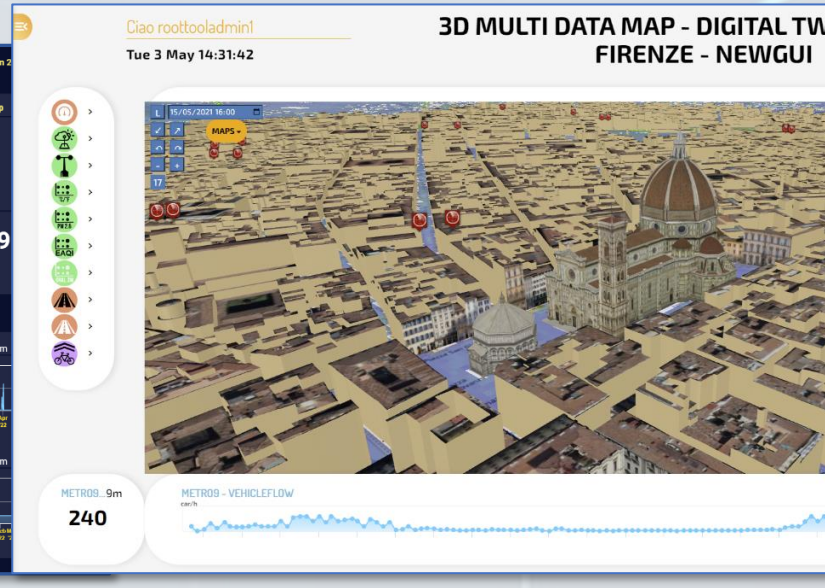








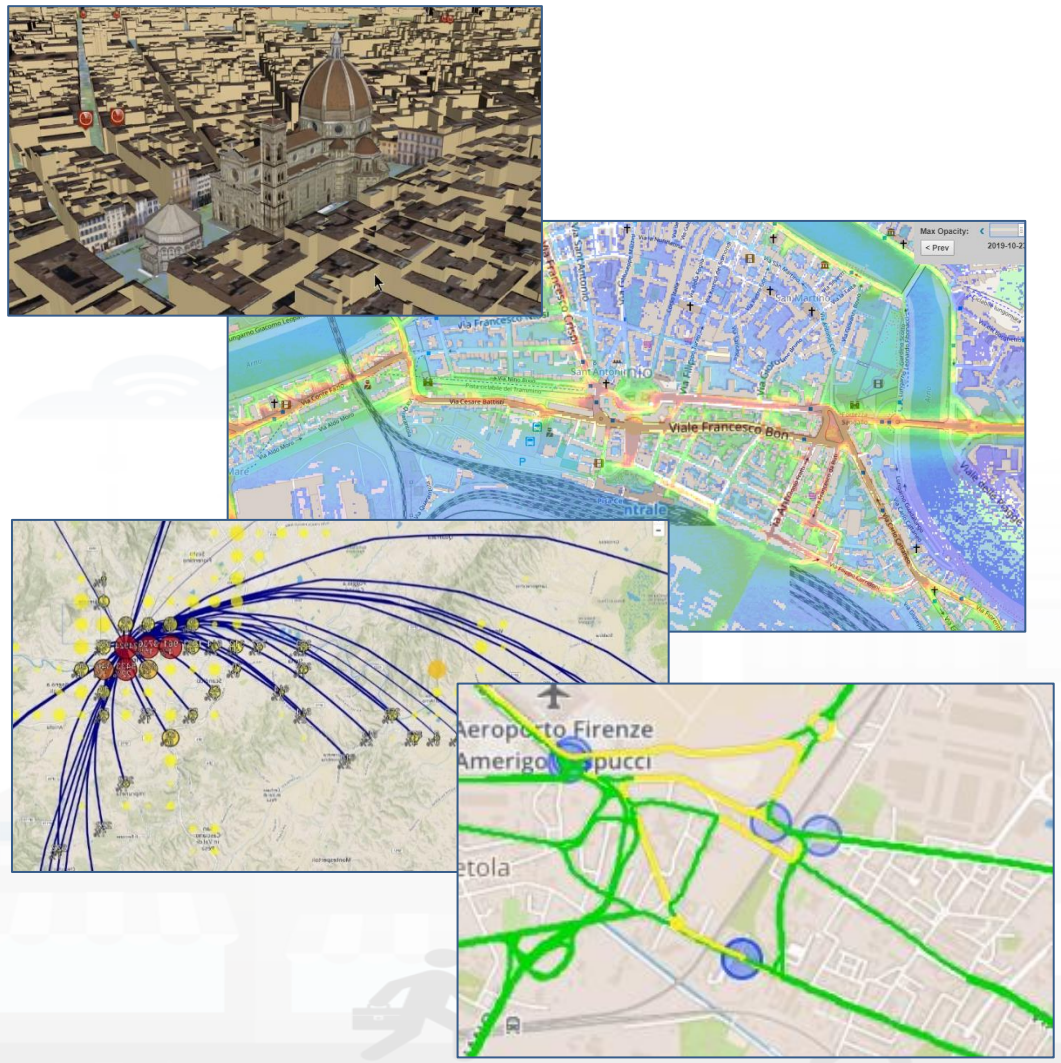




New styles/themes can be developed by specializing a few files from open source

https://www.snap4city.org/793

Smart City Digital Twin



City Digital Model with…

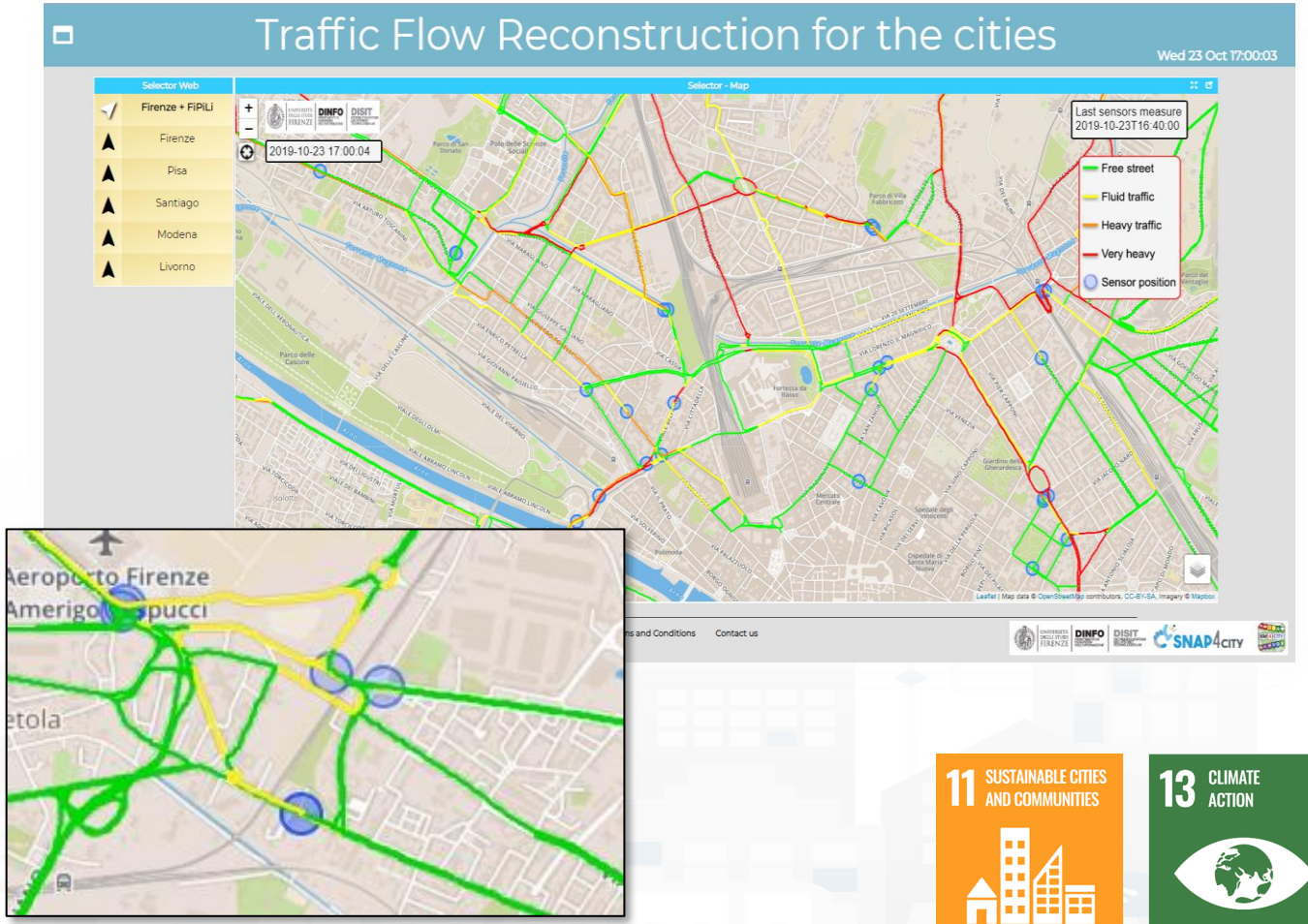
- Intuitive platform
- Any Data TYPE, any data source, any protocol
- Data storage seamless
- Data analytics → artificial intelligence, AI/XAI
- Data Ethics, AI Ethics, GDPR
- Interactive Data Representation, any kind
- Key Performance Indicators, any kind
- What-IF analysis – Simulation, prediction, 2D/3D
- Micro, Meso e macro scales
- Operation, planning tactic and strategic / optimization
- Collaborative and shared representation
- Sustainable, shared, open source 100%

Complex and heterogeneous information, interoperability

- GIS, ITS, AVM, IoT, BIM, CKAN, etc.
- Satellite services
- MaaS, last-mile delivery HUBs
- etc.

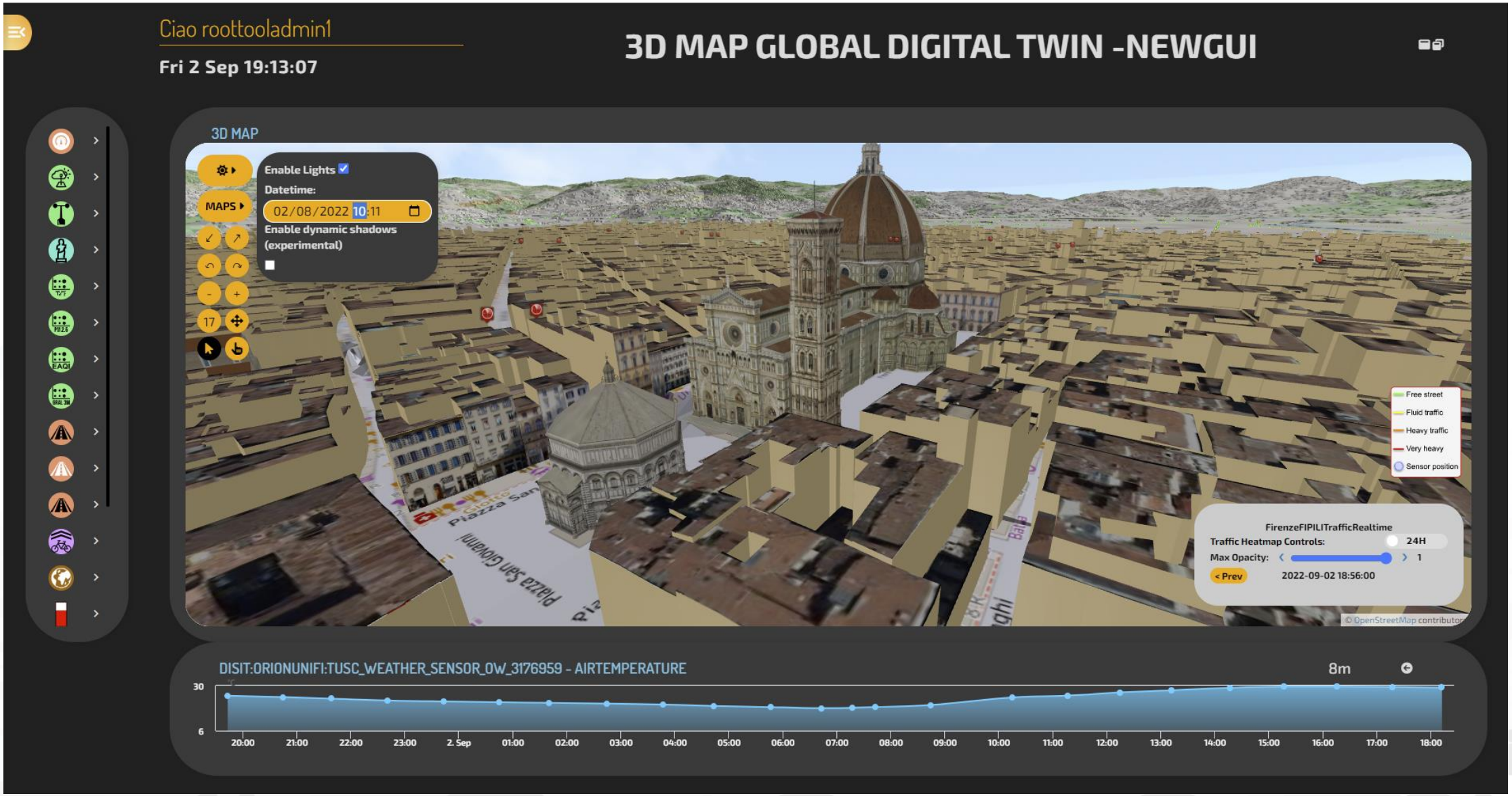
Why Dense Traffic Flow Reconstruction ?

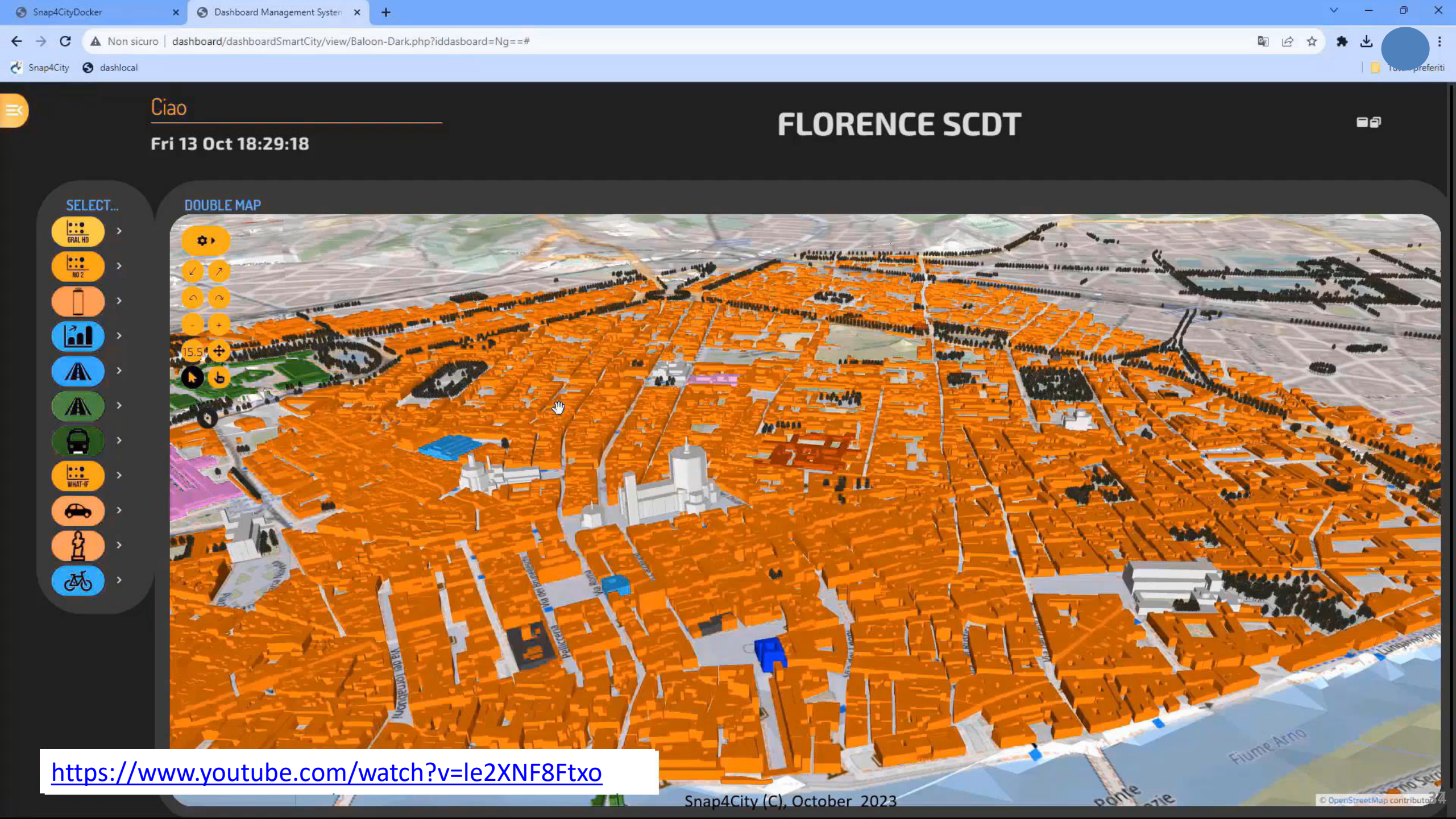
- Making decision on mobility and transport solutions → what if analysis
- Controlling pollution
- Dynamic Routing for Firebrigade, Ambulances, general public
- Planning Public Transportation routing



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

3D Digital Twin




Snap4CityDocker
Dashboard Management Syster
Non sicuro | dashboard/dashboardSmartCity/view/Baloon-Dark.php?iddasboard=Ng==#
Snap4City
dashlocal
Ciao
Fri 13 Oct 18:29:18
FLORENCE SCDT
SELECT...
DOUBLE MAP
GRAL HD
NO 2
WHAT-IF
Fiume Arno
© OpenStreetMap contributors
https://www.youtube.com/watch?v=le2XNF8Ftxo
Snap4City (C), October 2023
34

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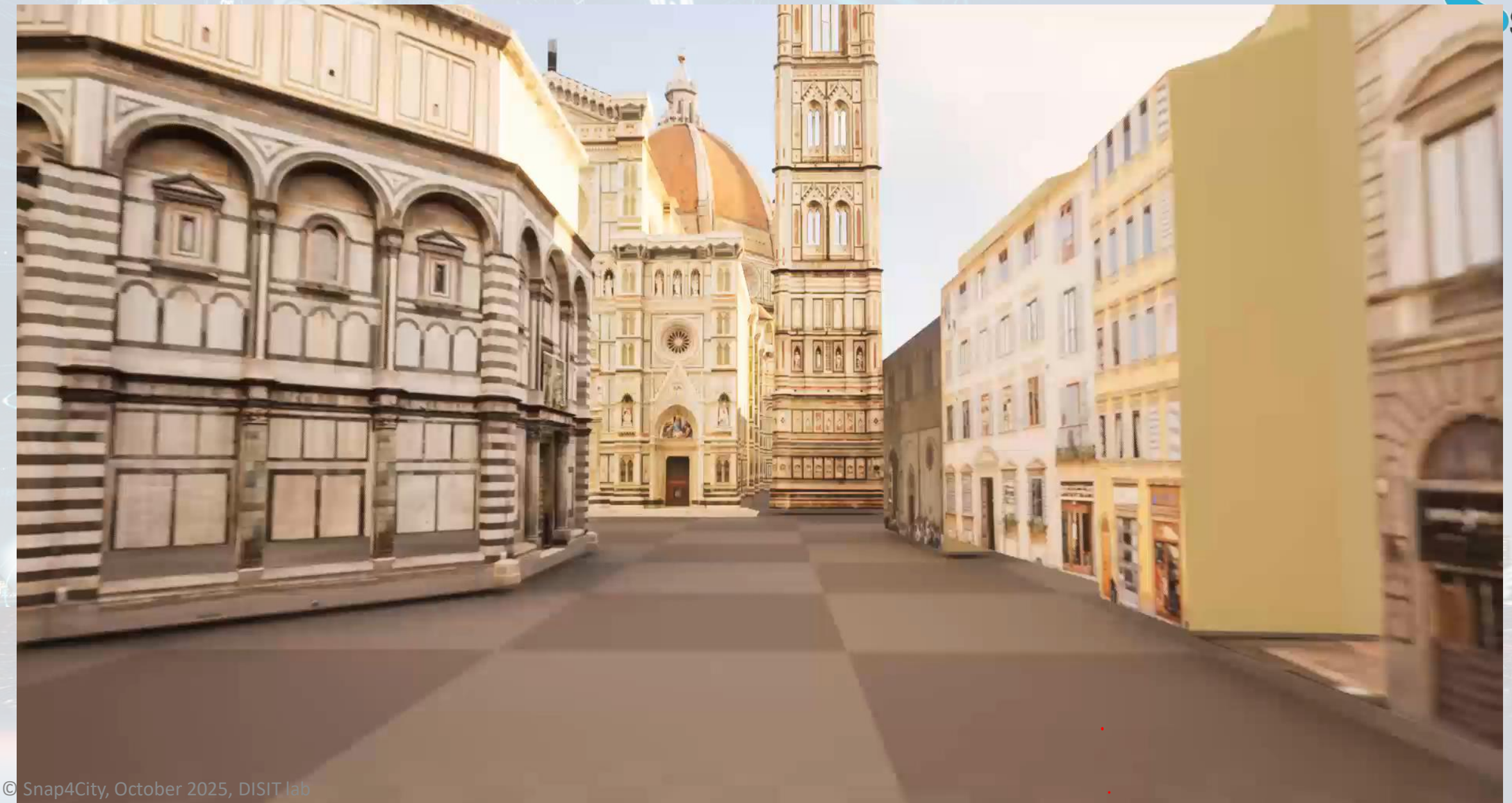
SNAP4CITY

KM 4 CITY

OCULUS

OCULUS

https://www.youtube.com/watch?v=Rcf_B2_GOio



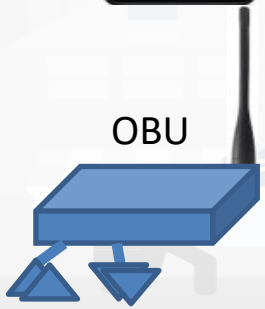
MyKPI: Tracking of Devices and Mobiles

- Real Time Trajectories for
  - Mobile Phone
  - Moving IOT Devices
  - OBU, Vehicular Kits
  - Multiple tracks
  - Day by day
- Micro Application

Mobile
PAX Counter

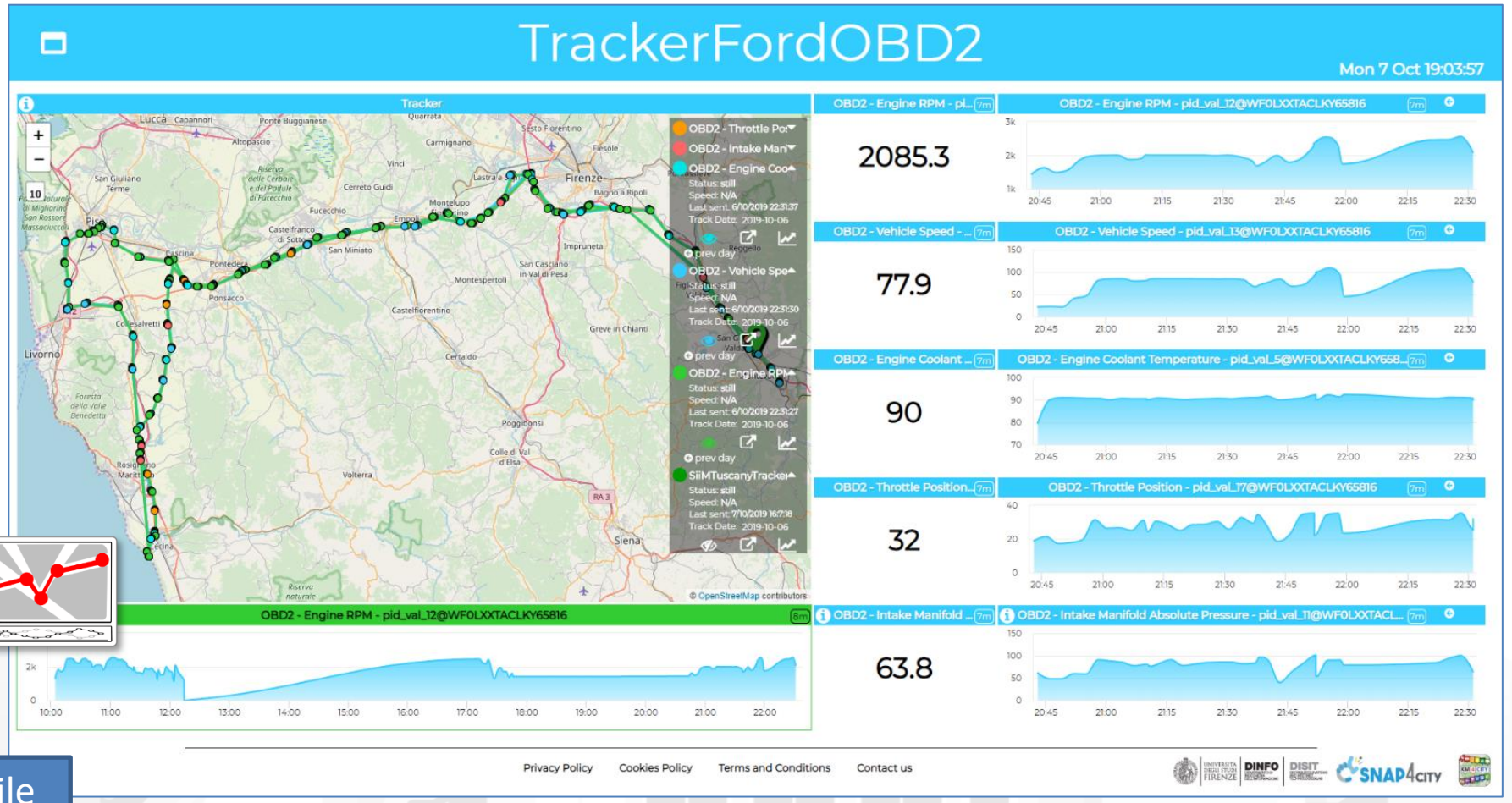
Apps

OBD2



OBU

Mobile sensors



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SNAP4CITY

KM4CITY

Solution: eSharing and Pooling

FROM CITY DASHBOARD TO APPLICATIONS

DATA GATHERING AND CITY DATA KNOWLEDGE MANAGEMENT

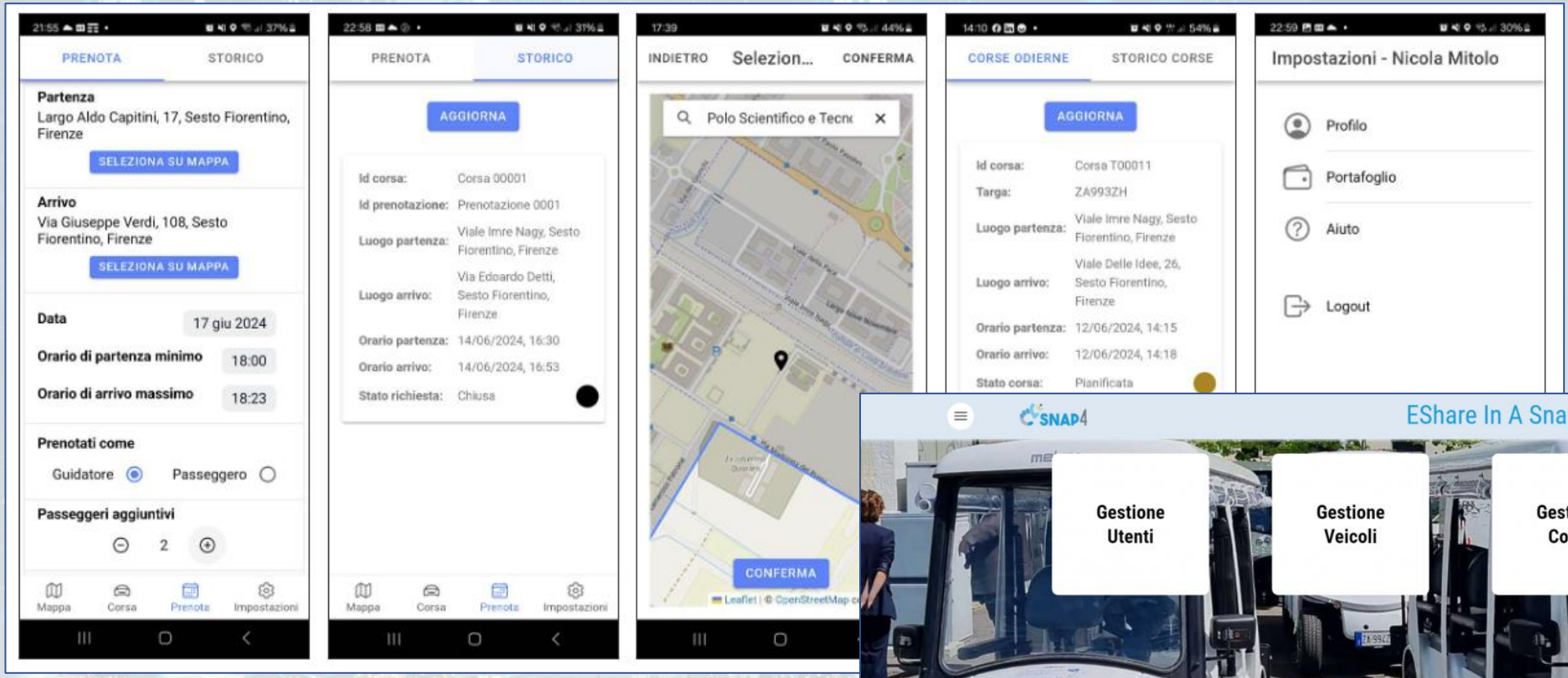
SNAP4CITY AND KM4CITY PROJECTS

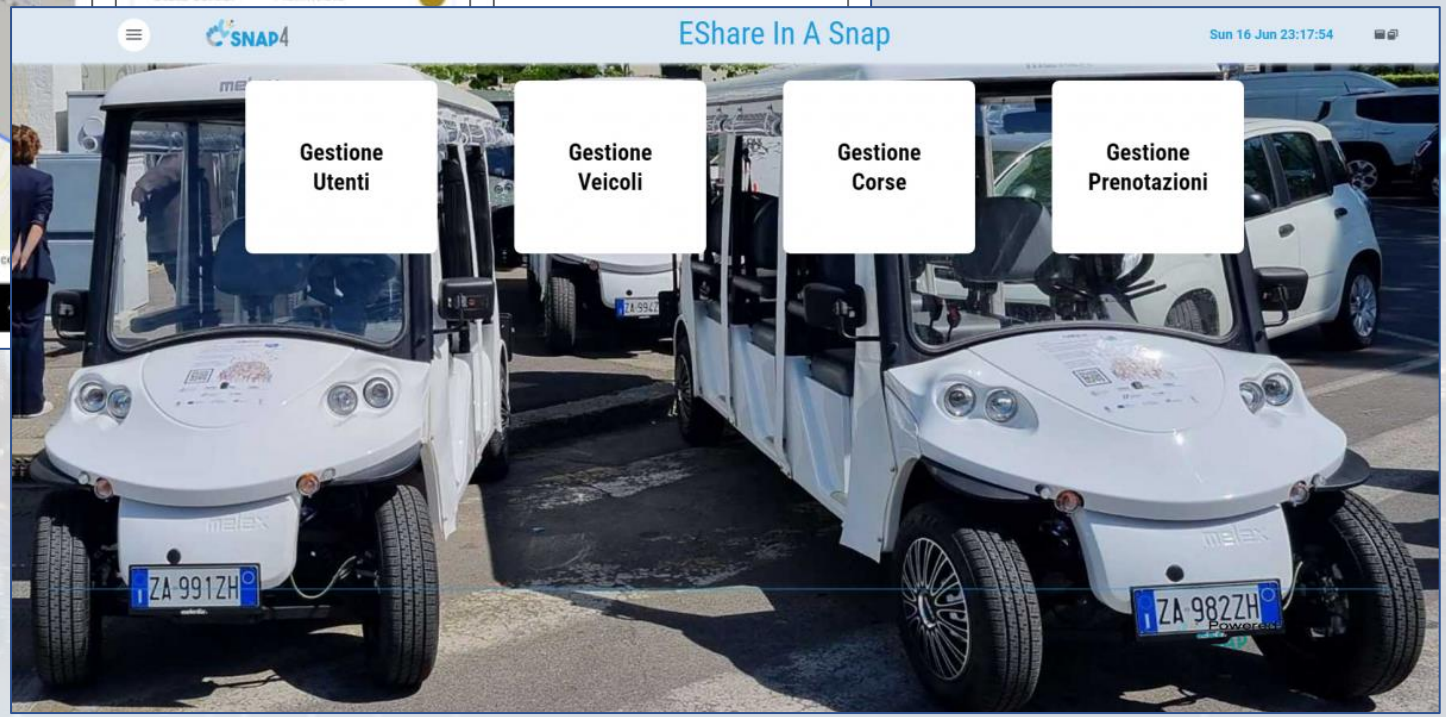
HOW TO ADOPT SNAP4CITY, AND OUR ROADMAP

SNAP4CITY THE VIEW OF THE ADMINISTRATORS

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

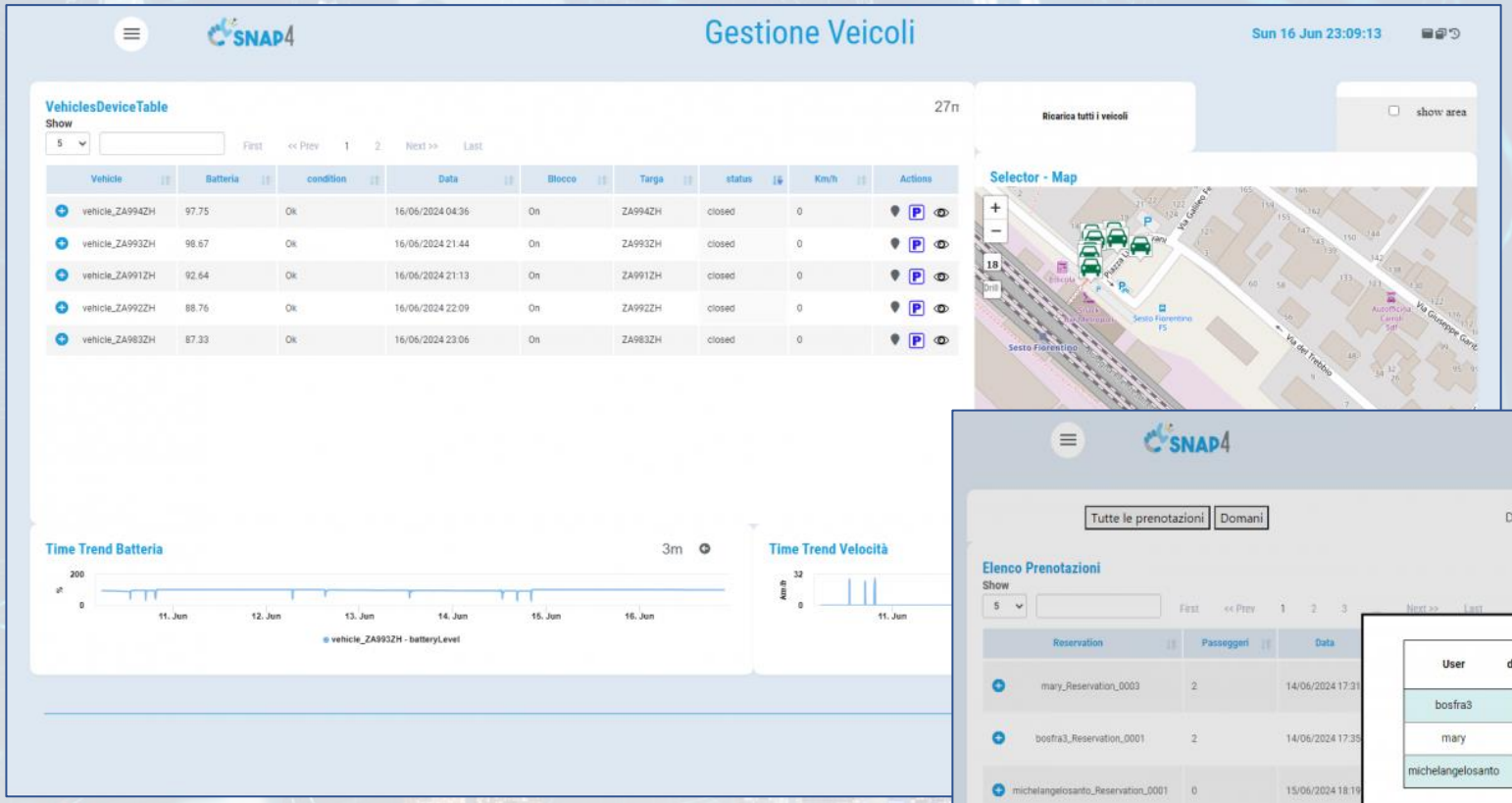
eShare in a Snap, by Snap4





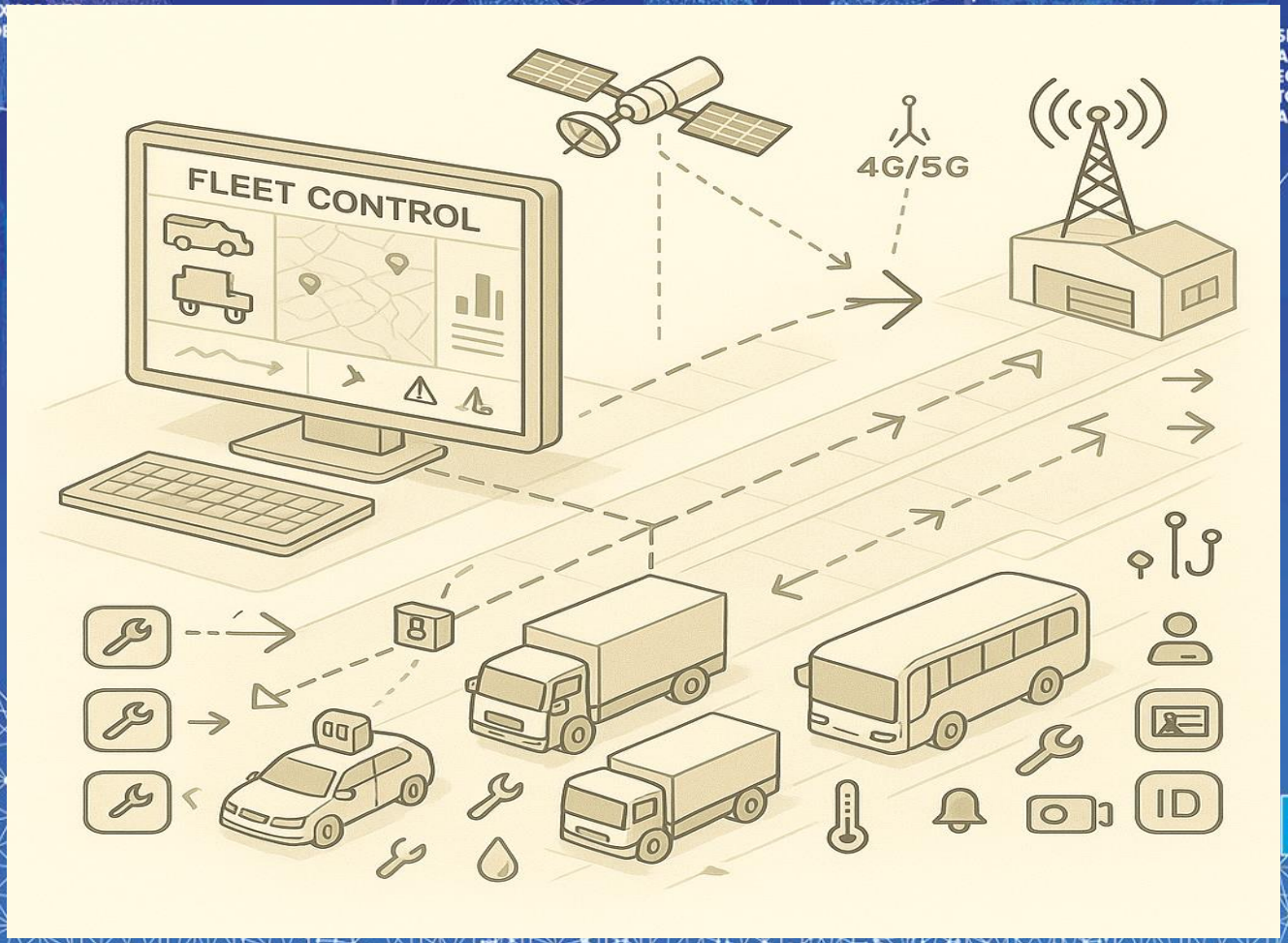
Integrated car sharing and pooling
Multiple drivers on the same means
Dynamic pooling and e-sharing

eShare in a Snap, by Snap4



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

Solution: Fleet Monitoring and tracking



Fleet Monitoring and Management

https://www.csselectronics.com/

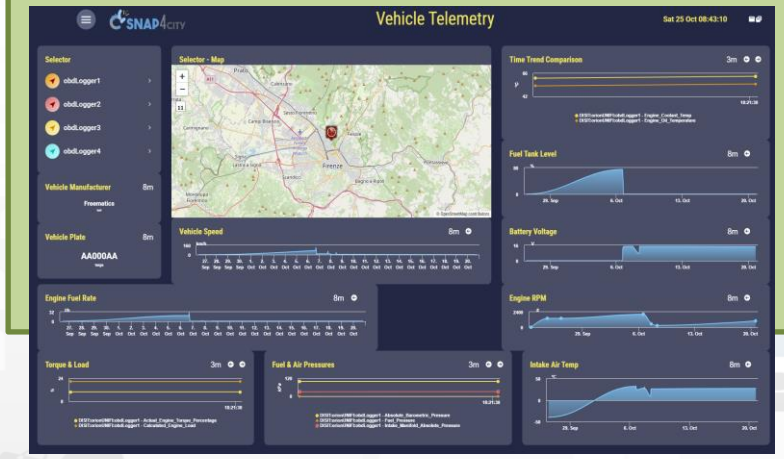
ASAM MDF
Configuration

Snap4Fleet Logger

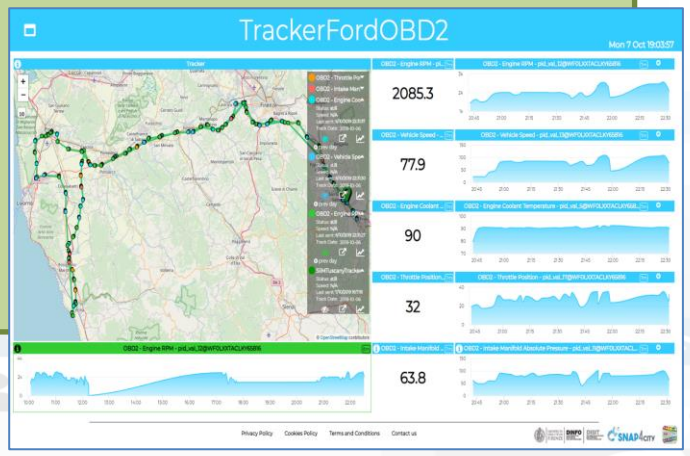
Data Lake	Decoder MDF Decoder CAN (DBC)
IoT App/Proc.Logic Snap4City Edge	

- Configuring data logger
- Selecting parameters
- Decoding and pushing data on Snap4City Platform AI enabled platform
- Toward the Snap4Fleet Manager

Snap4Fleet Manager



on Snap4City Platform



For Fleet Management

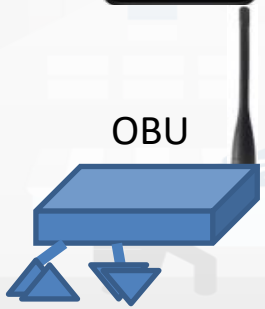
MyKPI: Tracking of Devices and Mobiles

- Real Time Trajectories for
  - Mobile Phone
  - Moving IOT Devices
  - OBU, Vehicular Kits
  - Multiple tracks
  - Day by day
- Micro Application

Mobile
PAX Counter

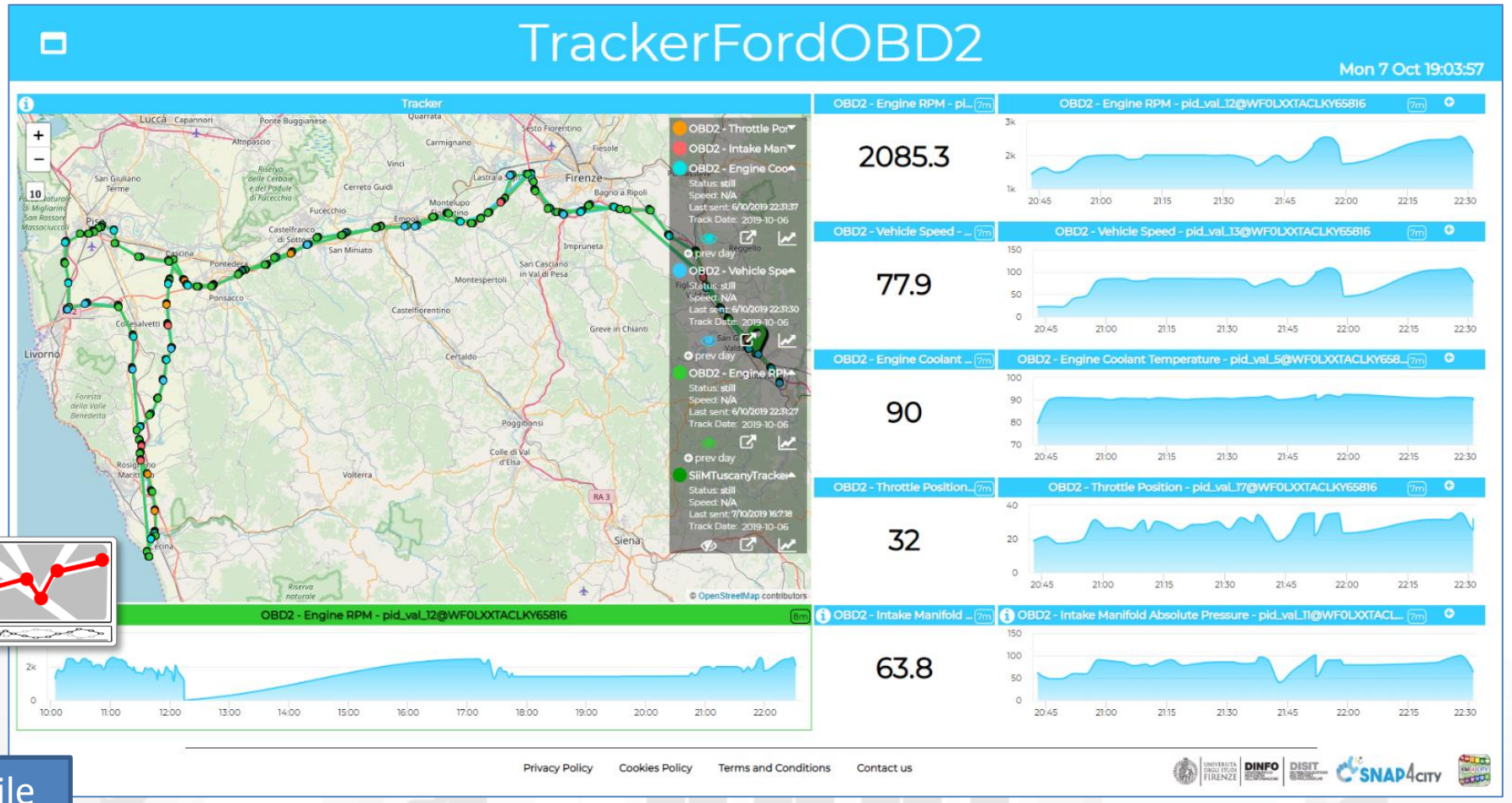
Apps

OBD2



OBU

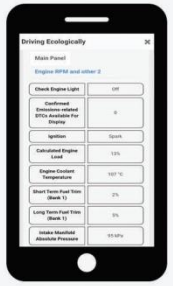
Mobile sensors

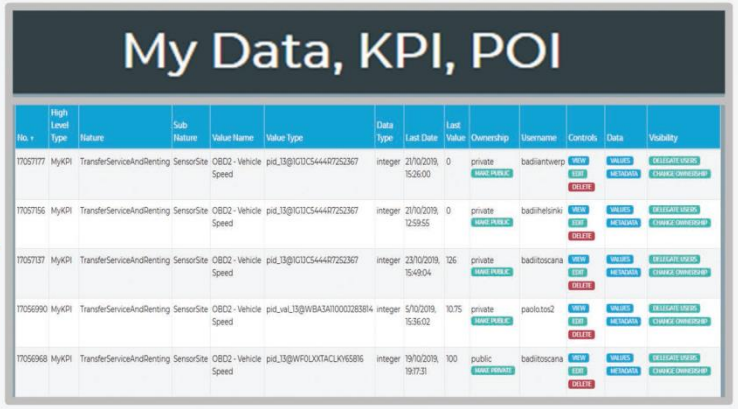


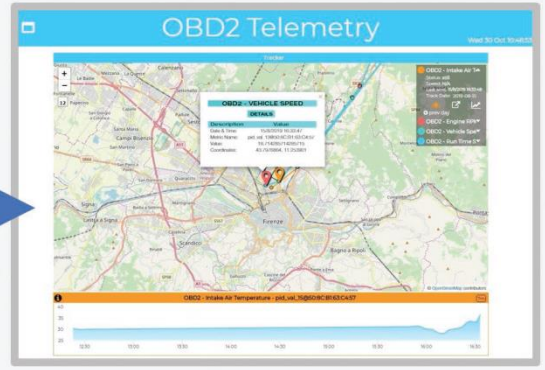
IOE – Vehicle Monitoring

CANBUS sniffer

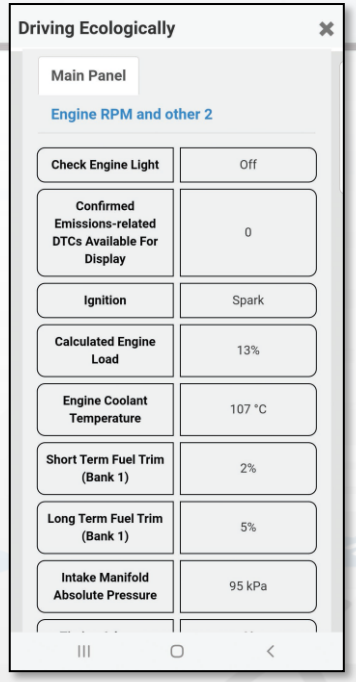
Bluetooth

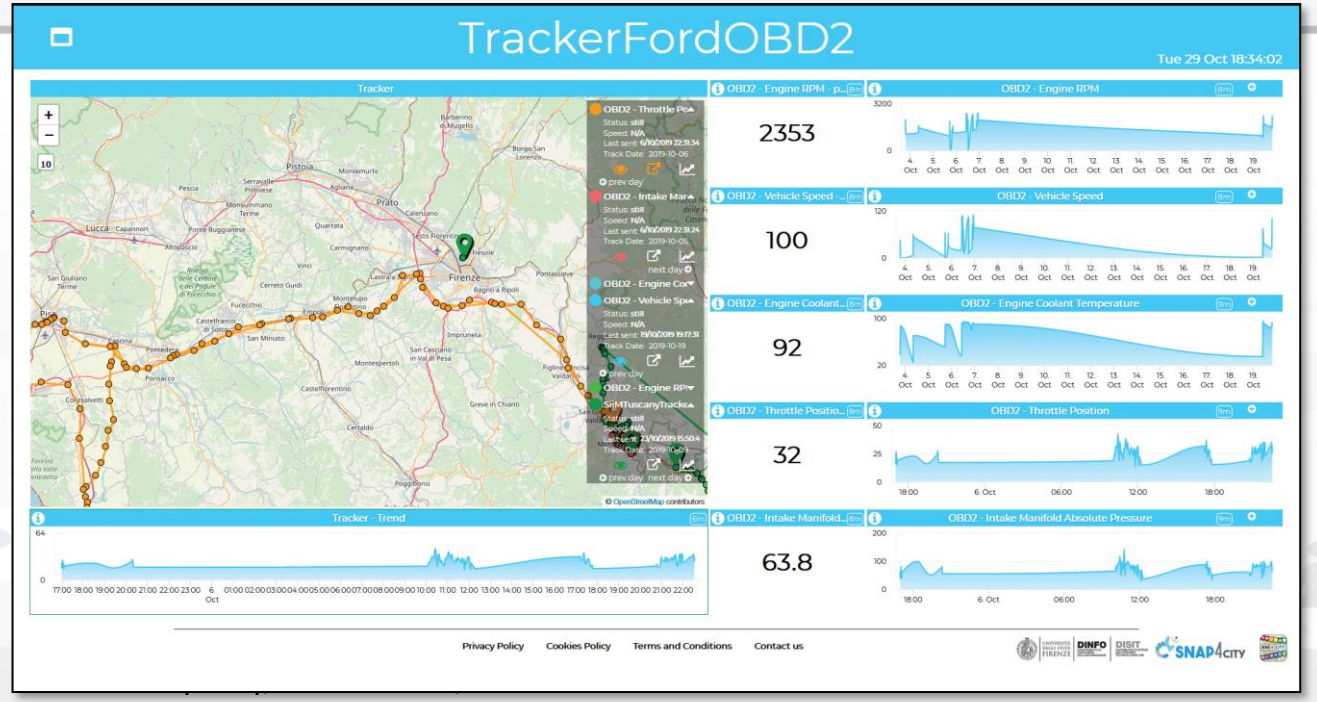




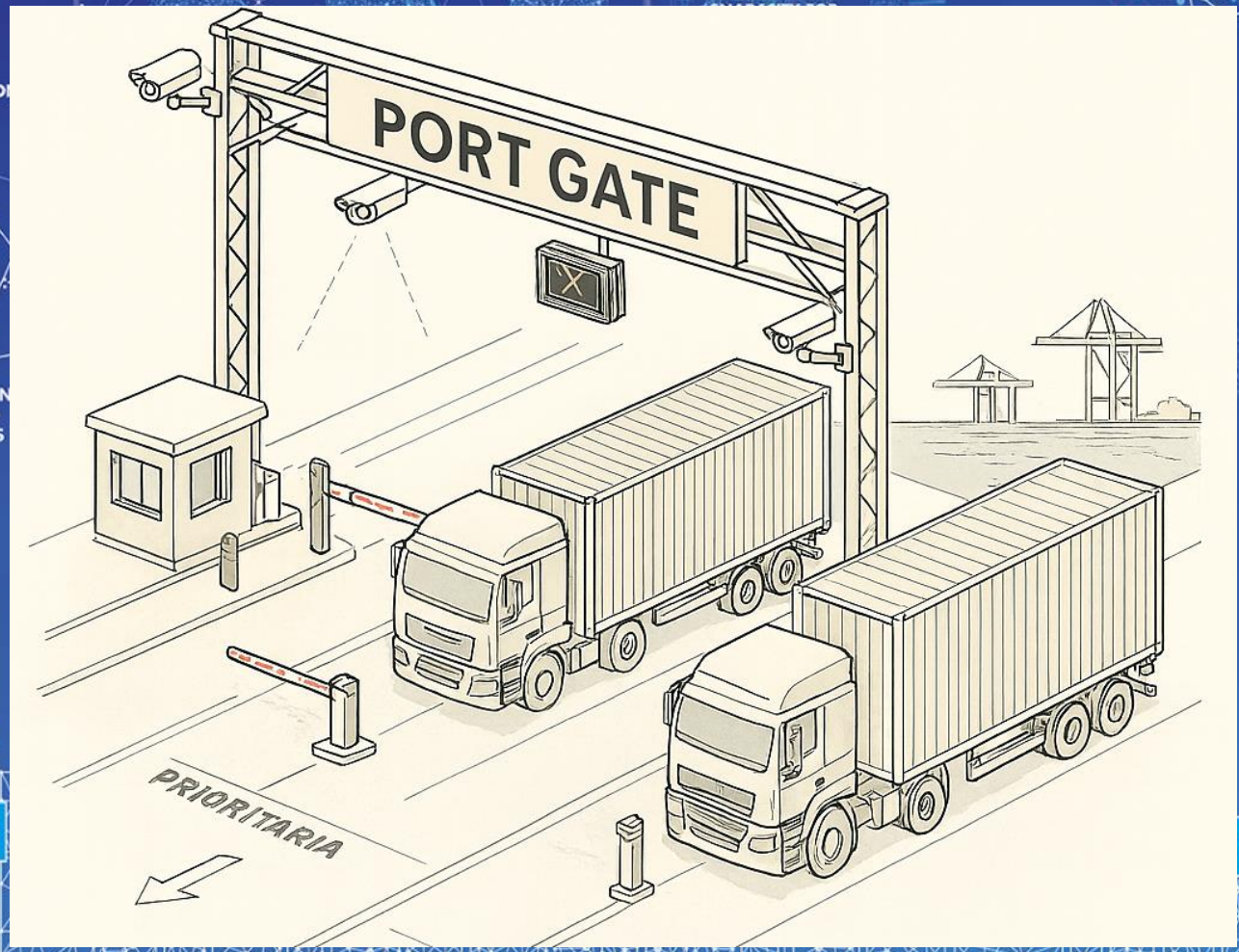


Tuscany in a Snap Mobile App on Android



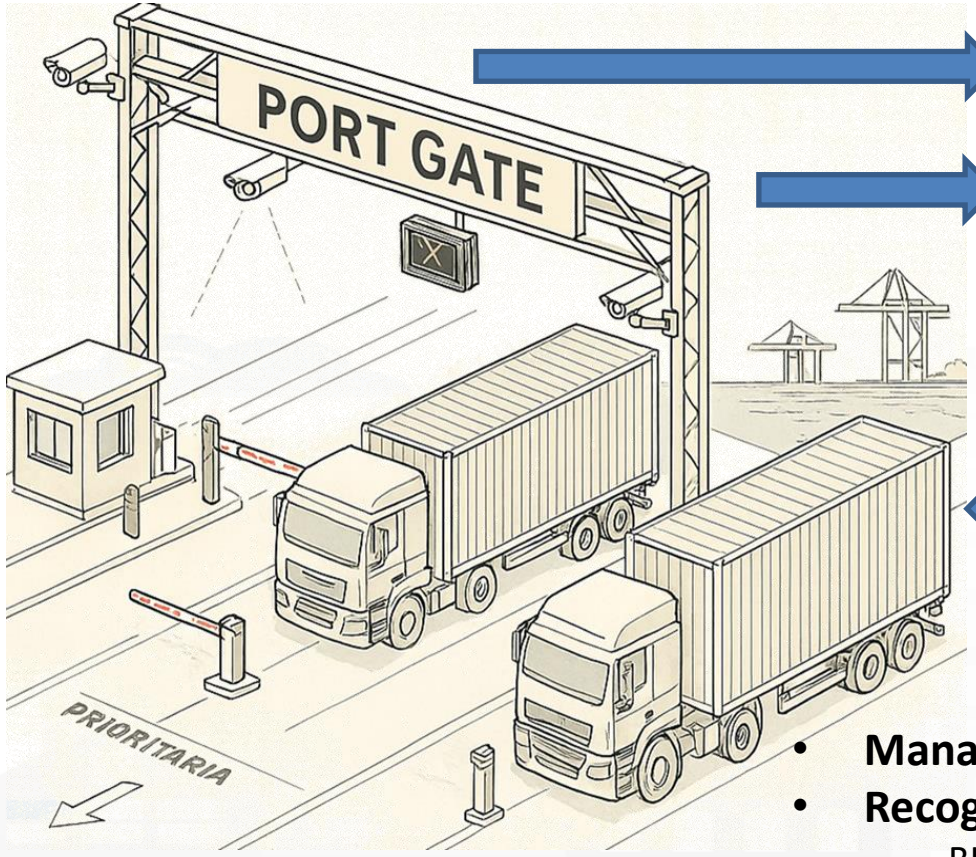


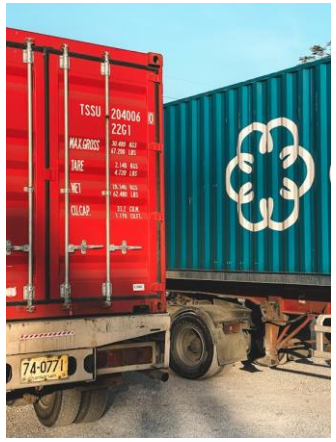
Solution: Plate/Container ID recognition



by Snap4 s.r.l.

Trucks' Plates and Container ID Recognition





Interoperability

Snap4City Platform

Signage/Control

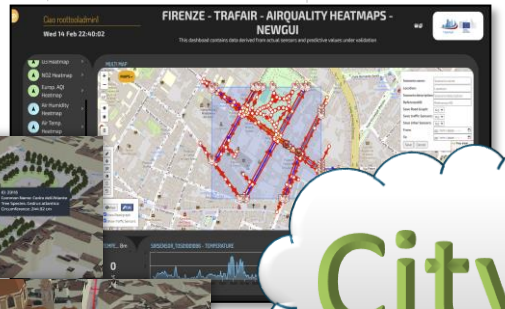
- **Managing Gates** in/out
- **Recognition and decoding**
  - BIC code: FCIU 964484 8
  - ISO code: 45G1
  - Seal status: on/off
  - Multi-national Plates: EX 398AE

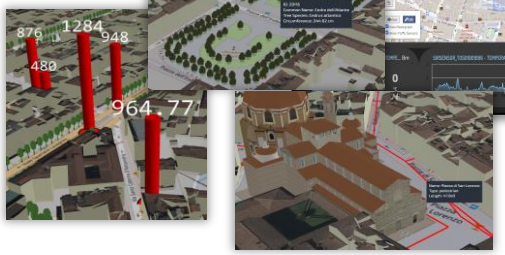
Trucks' Plates and Container ID Recognition

- **Managing Gates to Salerno Port**
  - Multiple Gates/Lanes and multiple TV Cameras: in/out
  - Measuring accuracy
  - Recognition of nationality
  - Single of Multipoint detection
  - Trucks and trailers
  - Storing images for Furter analysis
  - History of in/out events, administration, interoperability

- **Recognition and decoding**
  - BIC code: FCIU 964484 8
  - ISO code: 45G1
  - Enabled for Seal status detection: on/off
  - Multi-national Plates: EX 398AE

Decision Support System: Immediate response and Tactic and Strategic Plans, via What-if Analysis





City

Monitoring

KPI

Digital Twin Models & Data

Predictions, Anomaly Detection, Analysis, Assessment Warning

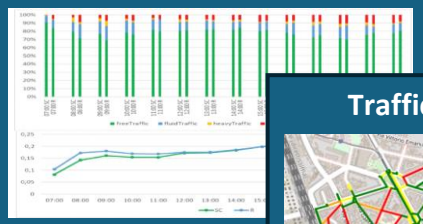
Decision Support System

Scenarious

Simulations, TFR, Crossroad, Public Transport, Routing, ..

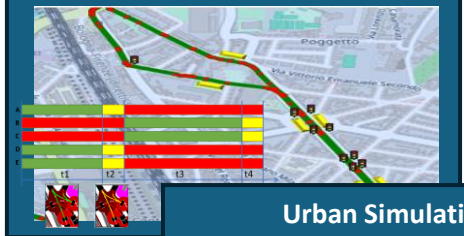
What-If Analysis, Optimization

KPI, Predictions, ...



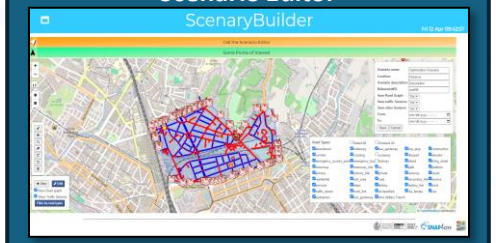
Traffic Reconstruction

Traffic Light Plan optimization

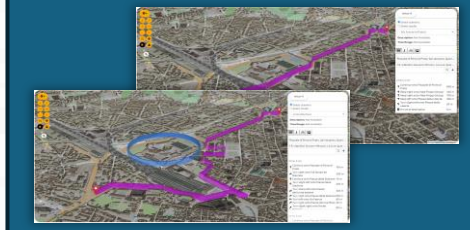


Urban Simulation

Scenario Editor

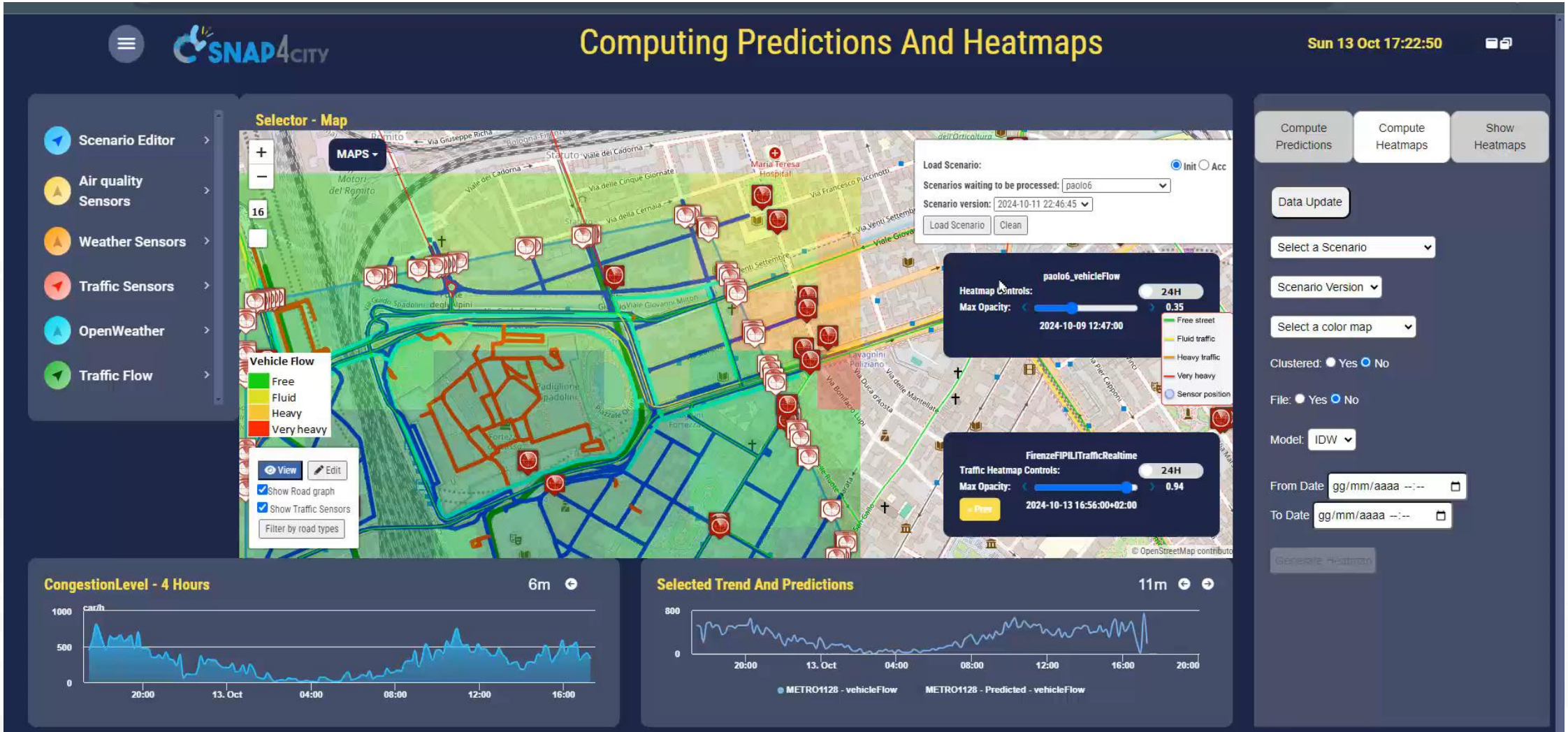


Routing / Dynamic Routing



Traffic Infrastructure optimization

Predictions and Heatmaps in Real Time



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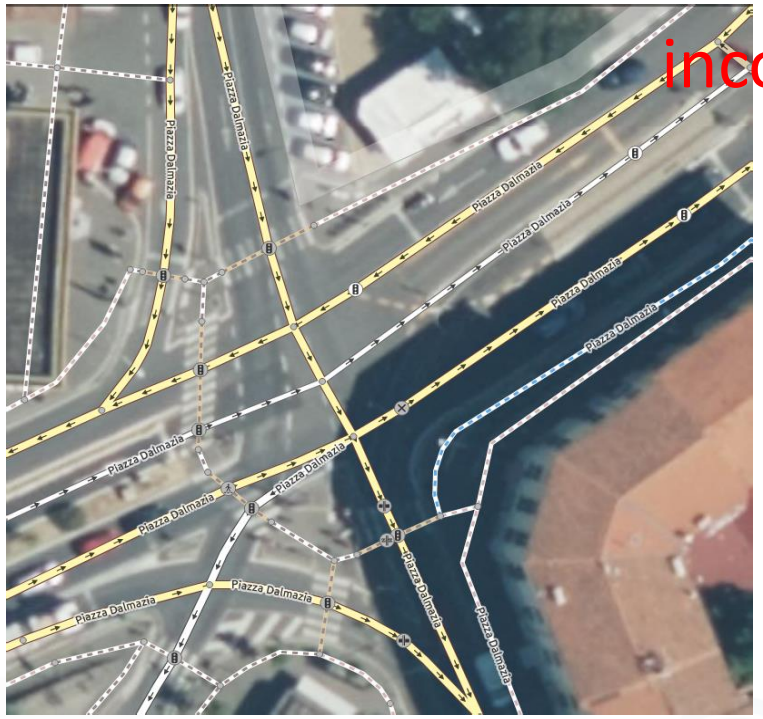
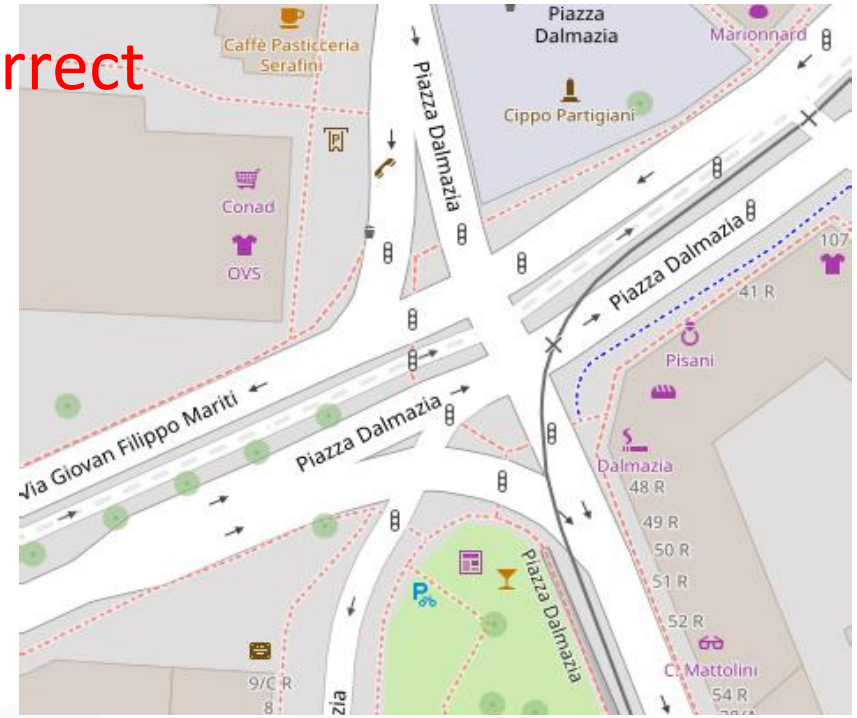
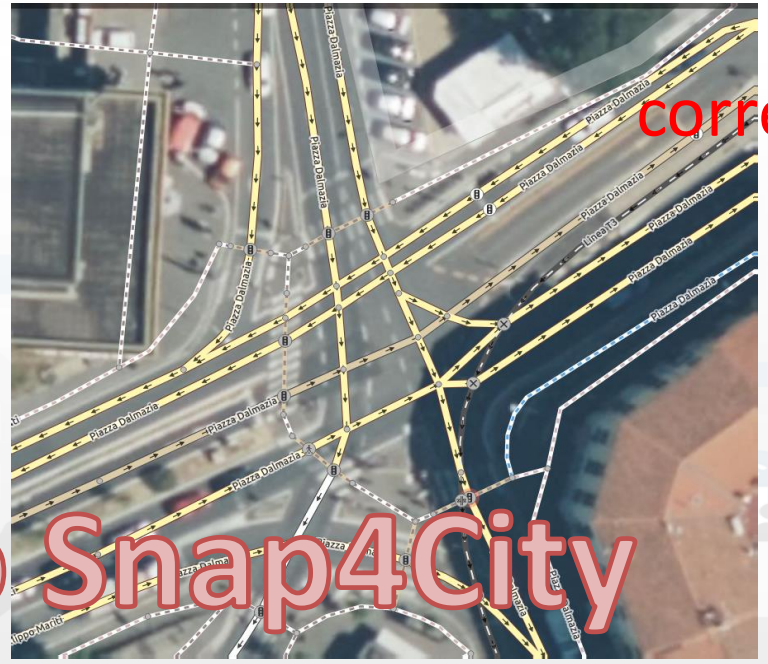
OSM data with non correct viability in Piazza Dalmazia, Firenze



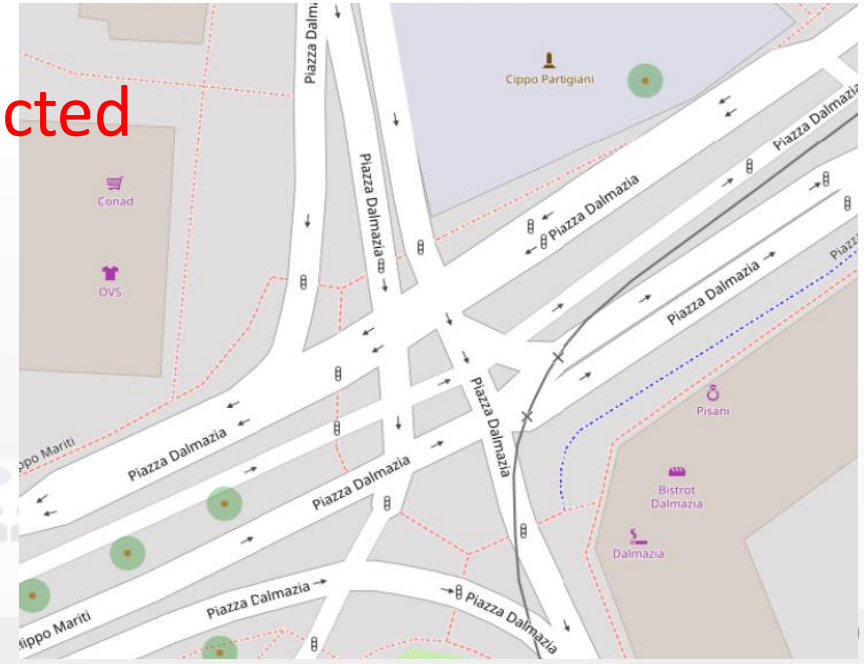
incorrect



After Correction of OSM data defining a correct viability of Piazza Dalmazia, Florence. Regeneration of the TILEs for the maps

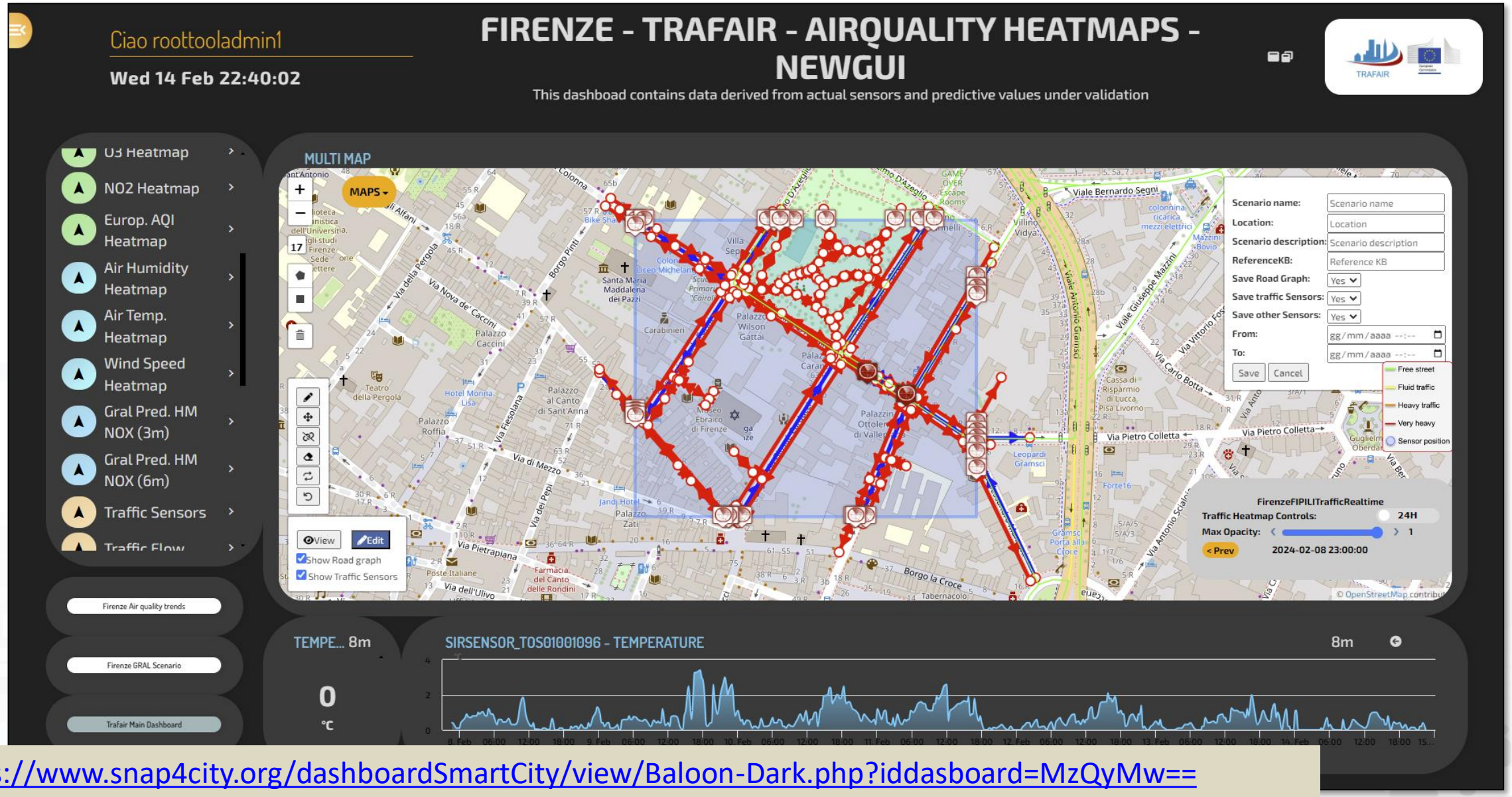


corrected



From OSM to Snap4City

Scenarious Editor



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

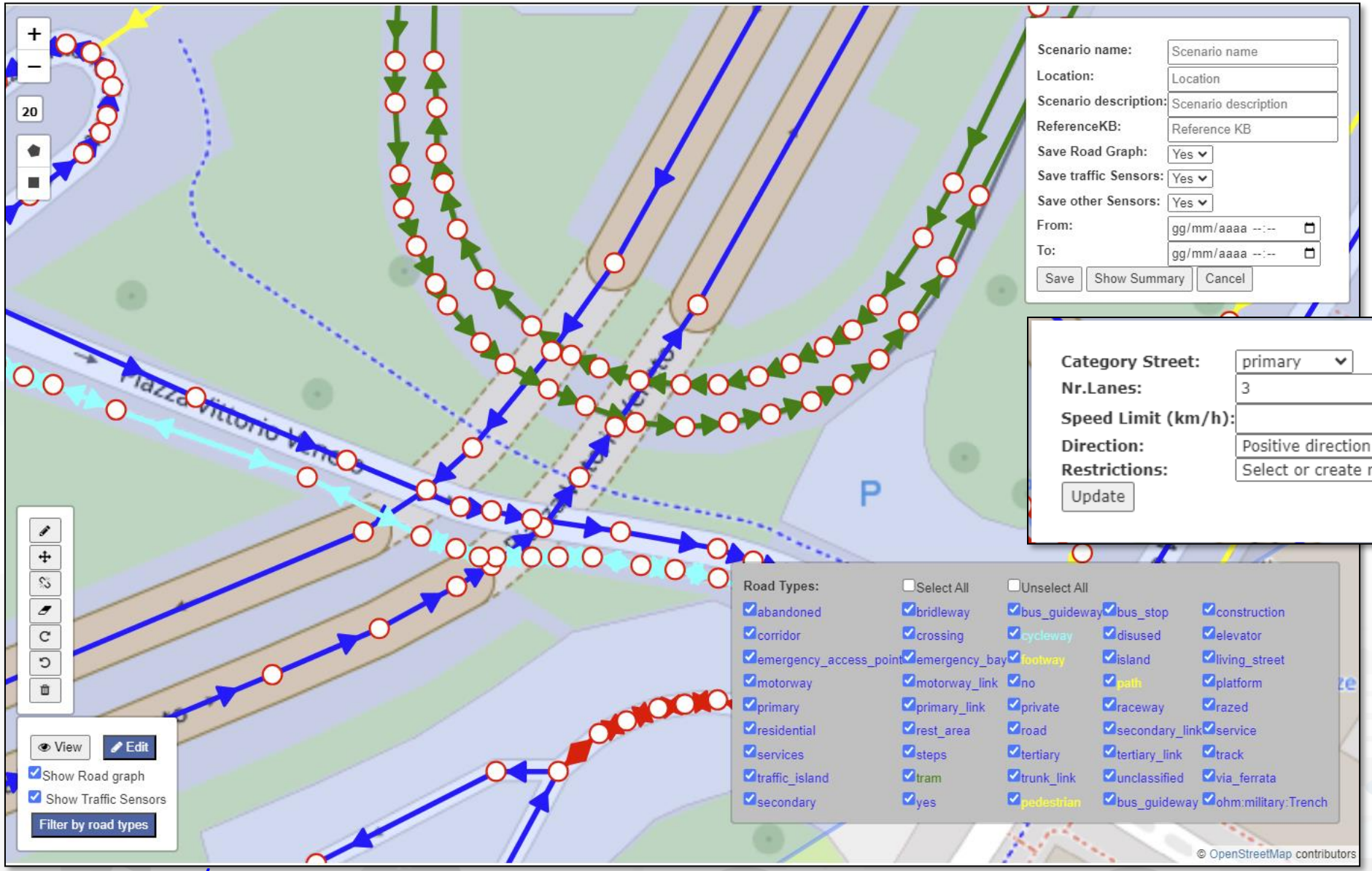
Scenario Editor

Select map

Zoom

New Scenario

Editing
Drag & drop
Split & Join
Delete
Do and Undo



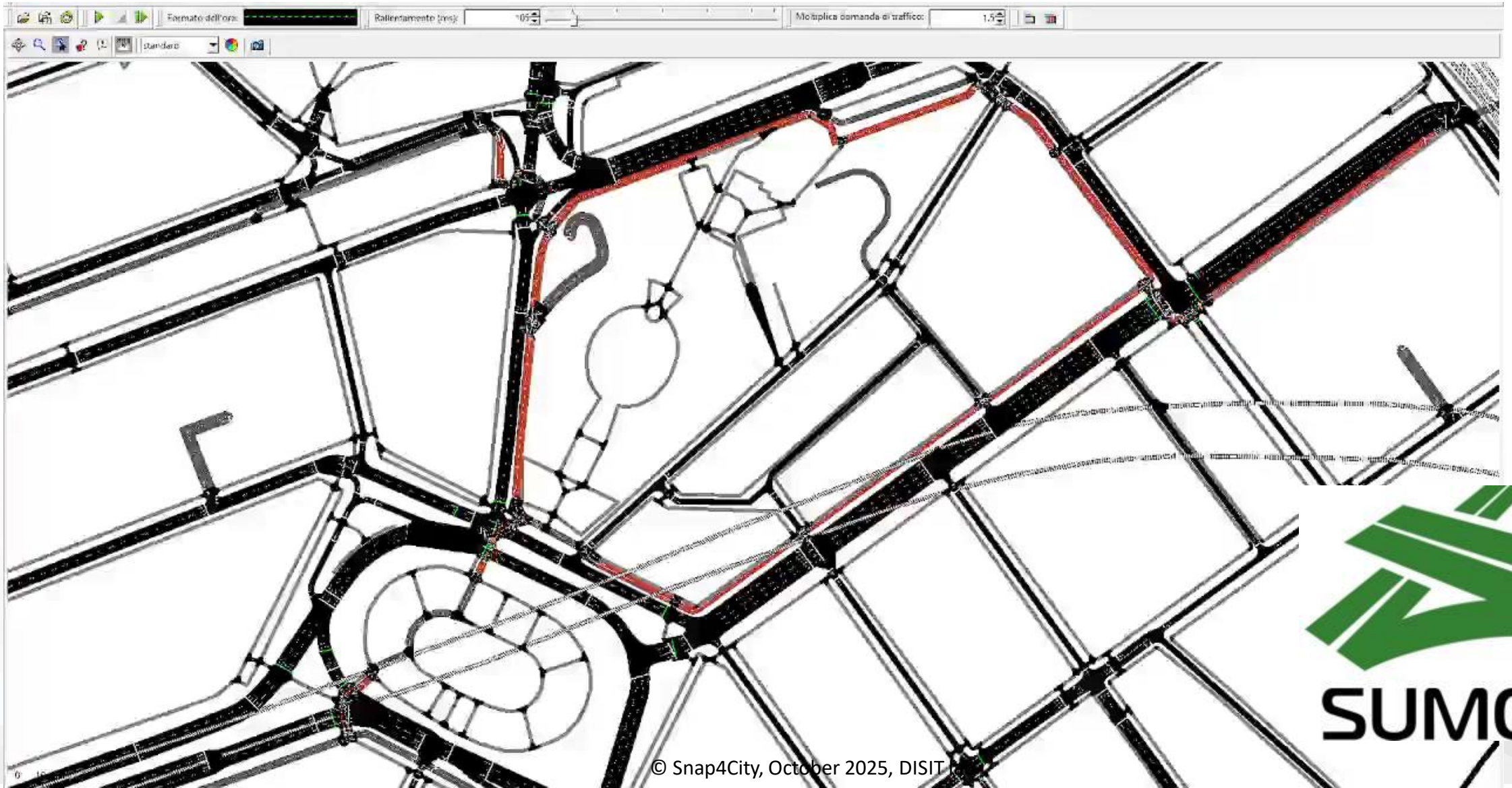
Edit Road Segment

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

Properties of Road Elements

https://www.snap4city.org/976

Micro Simulation



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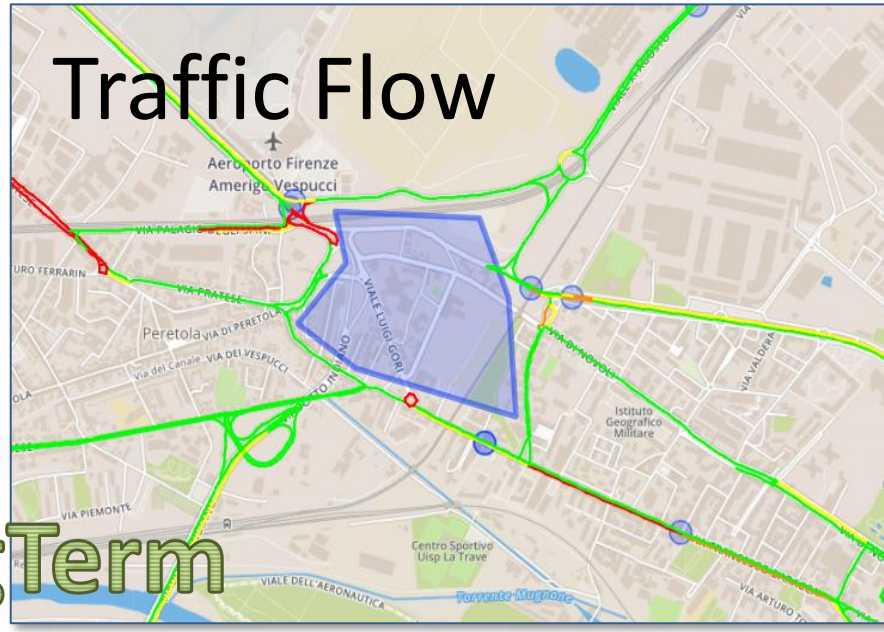
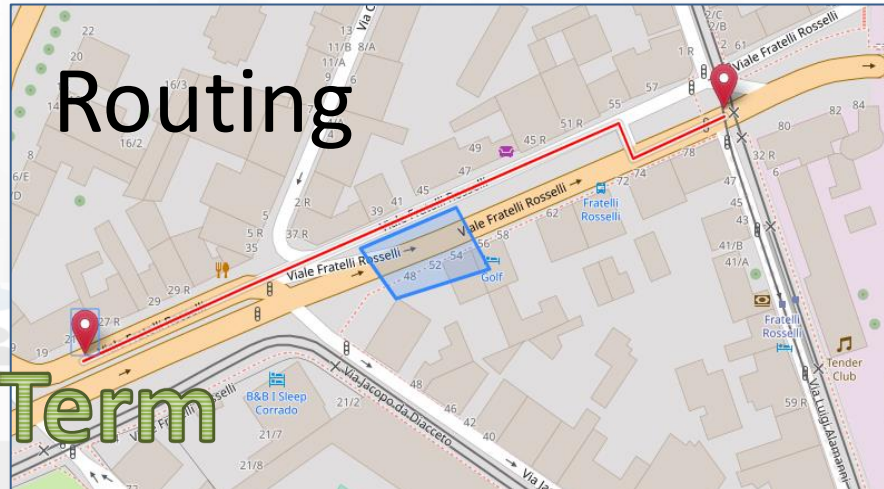
SNAP4CITY KM4CITY

Decision Support Systems, What-if

- **Event planning, via what-if analysis**
  - Change in the graph structure of the city
  - Impact on the flow of people and vehicles
  - Adaptation: public transport, traffic, pedestrian management, etc.
- **Immediate reaction to natural events or not**
  - Everything is ready and updated in real time
  - Each view is contextualized in terms of data: descriptive and prescriptive
- **Digital Twin**
  - More detail in the context integrated data
  - Greater realism in deductions and representations
  - Less fragmentation and non-uniformity in the views to support decisions

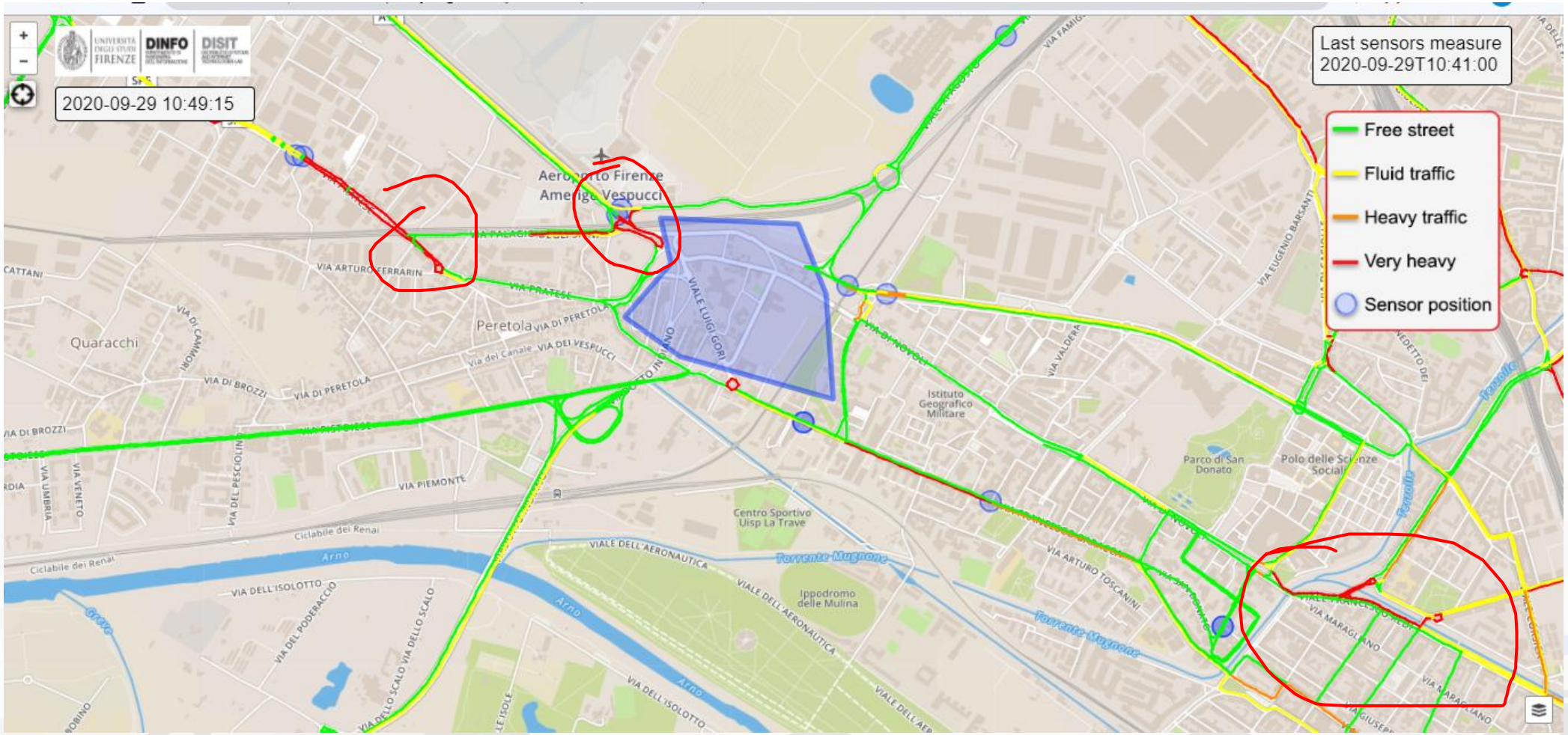


LongTerm

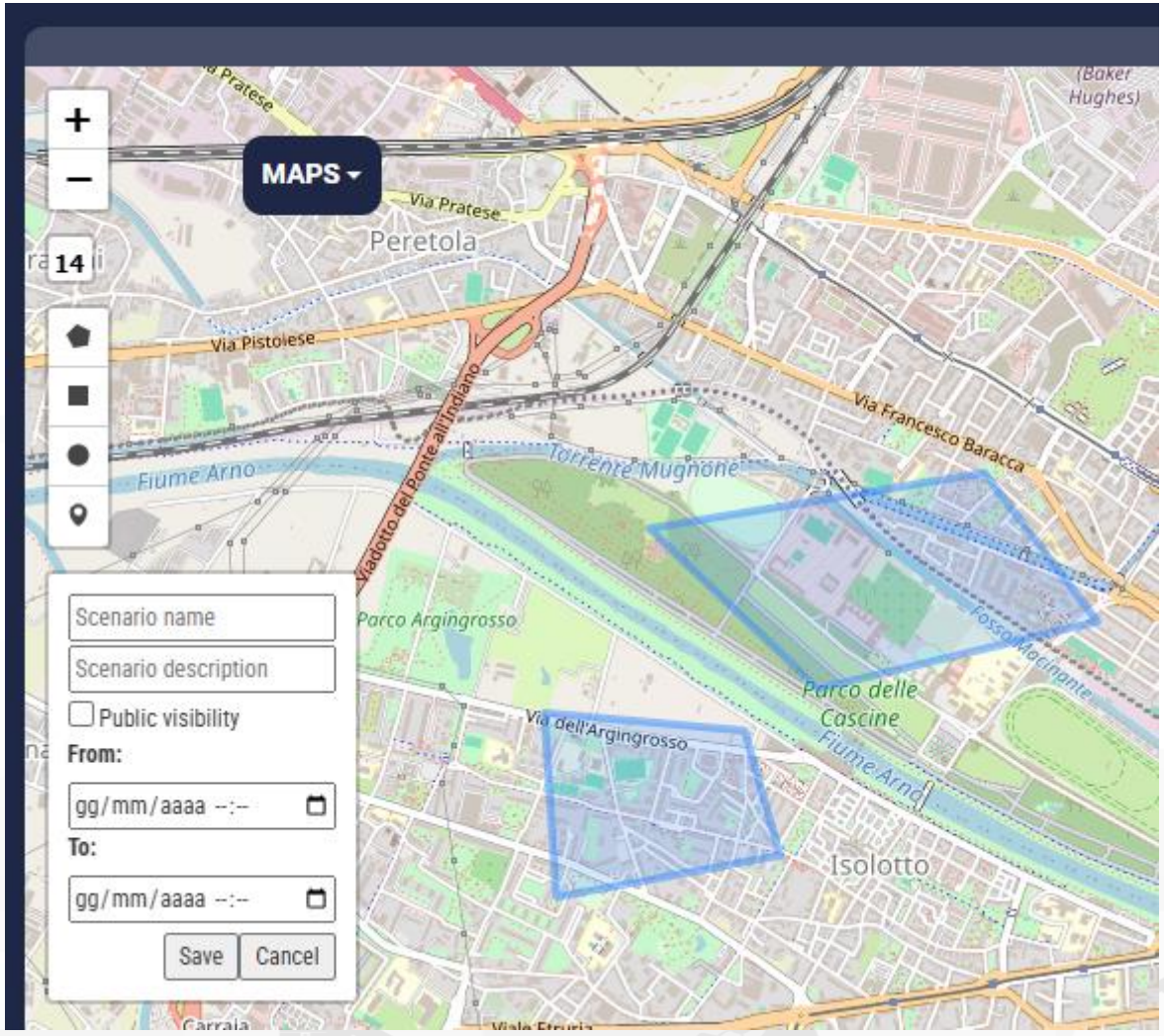


ShortTerm

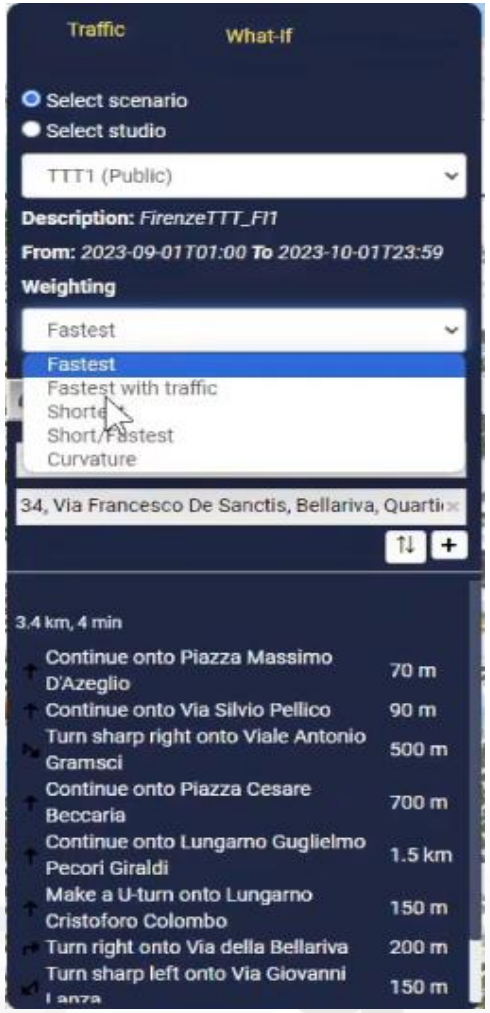
Computation of Traffic Flow Evolution, cascade effects



What you can do with advanced tools

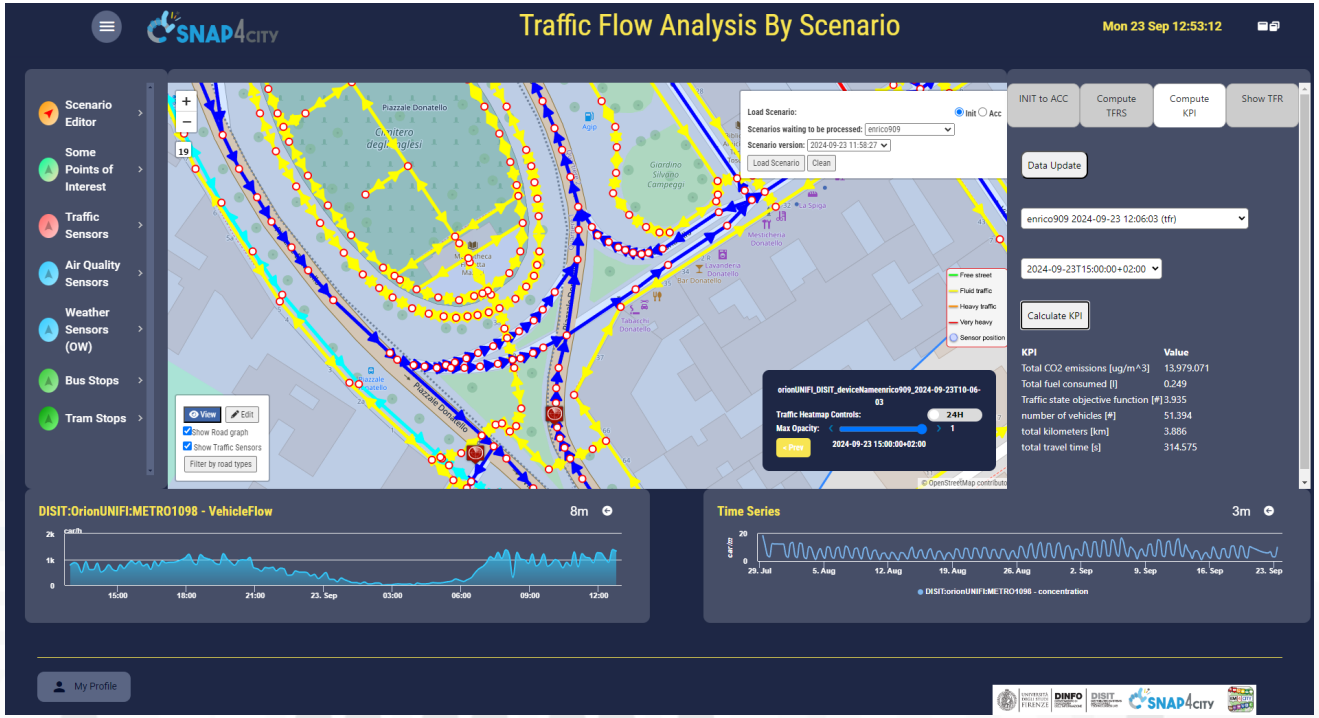


- **Basic Scenario editor**
  - Single and multiple blocked areas, which can be shared among users
- **What-if analysis tool**
  - Ready to use tools for exploiting Basic Scenarios as blocked areas and simulating/
  - computing in real time routing, in different traffic conditions



What you can do with advanced tools

- **Advanced Scenario Editor**
  - Create complex and full detailed scenario, with road graph, sensors, of any kind, even new roads, restrictions, parameters, etc.
  - Exploit these scenarios to create
    - Simulation
    - Business intelligence tools and visual/business analytic tools also working in real time
    - Traffic flow reconstruction
    - Traffic infrastructure optimisation
    - Traffic light plan optimization
    - Pedestrian analysis and simulation
    - Match demand vs Offer, simulation and analysis
    - Computation of SUMI, SUMP, 15 Min City Indexes, etc.
    - Heatmaps computation
    - Etc. etc.



What-if-Analysis and Infrastructure Optimization ….

Aim of Decongestion, Sustainability

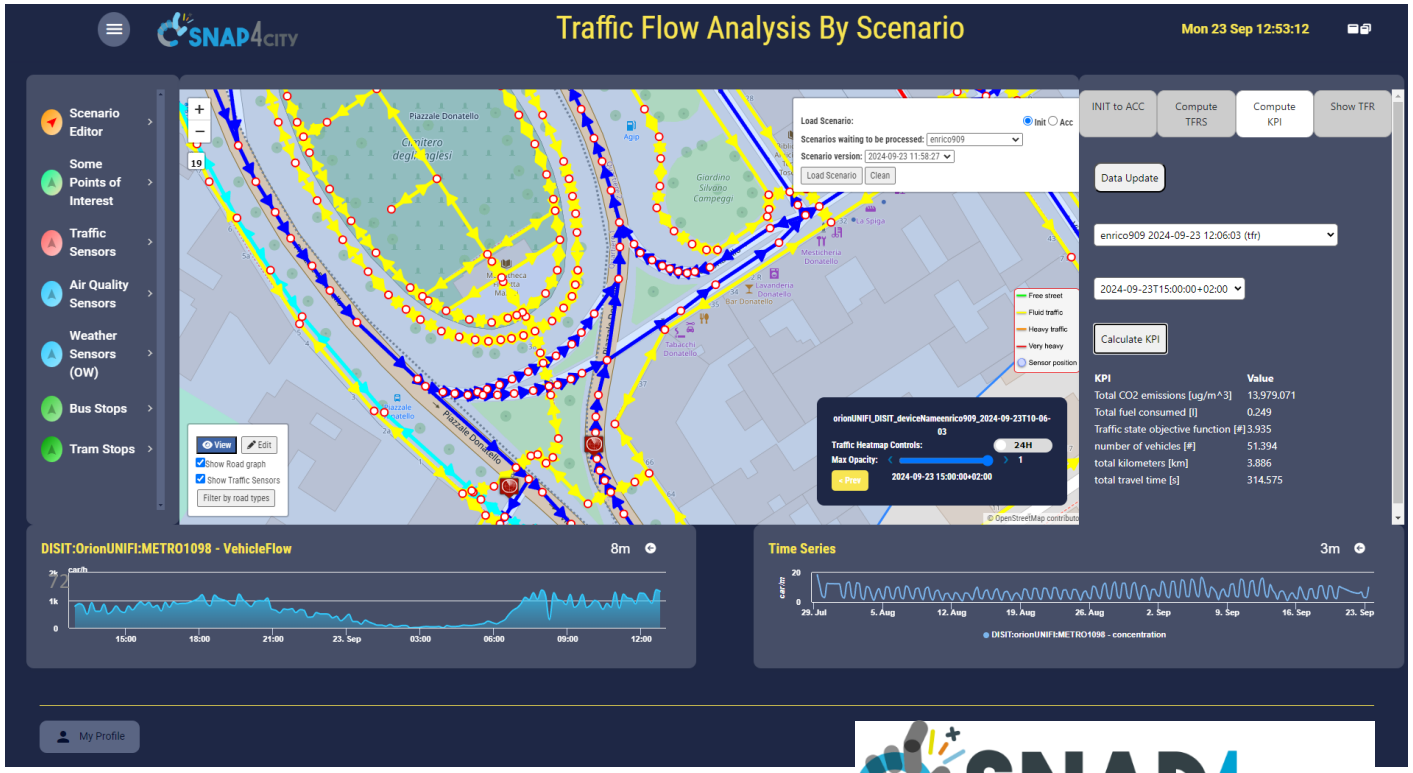
- Reduction of emissions, # stops
- Reduction of travel time

What-if analysis on Operation/Plan

- Working by scenarios making Hyp.
- Simulating the results on conditions
  - **Generative AI and/or neuro-Symbolic**
- Computing KPI and providing suggestions

Optimisation on Plan

- Making Scenario for the context
- Defining constraints and conditions
- Asking to AI to **generate best solutions**
- **Offering Optimal Solution** in terms of
  - Solutions and Explanations



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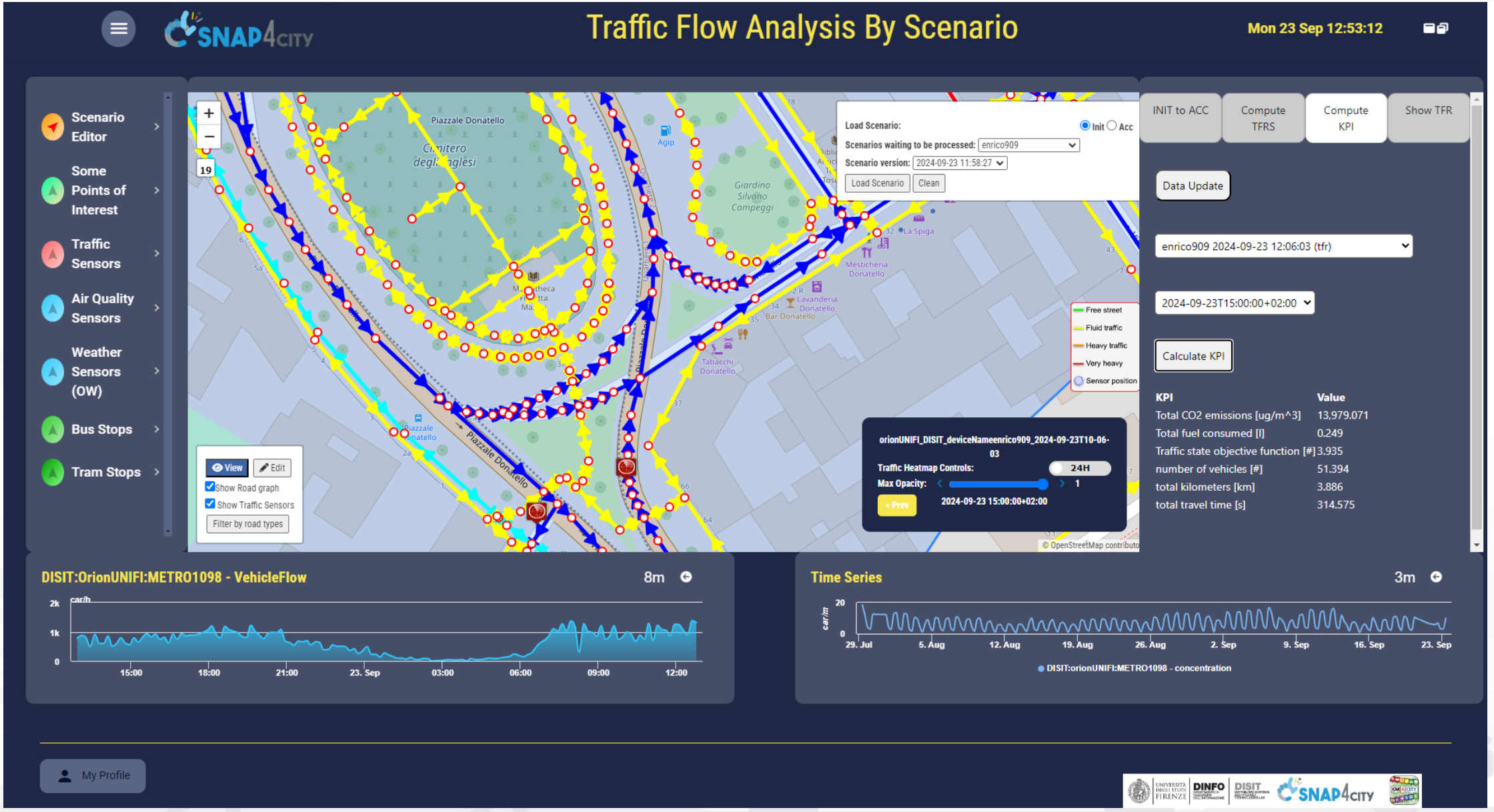
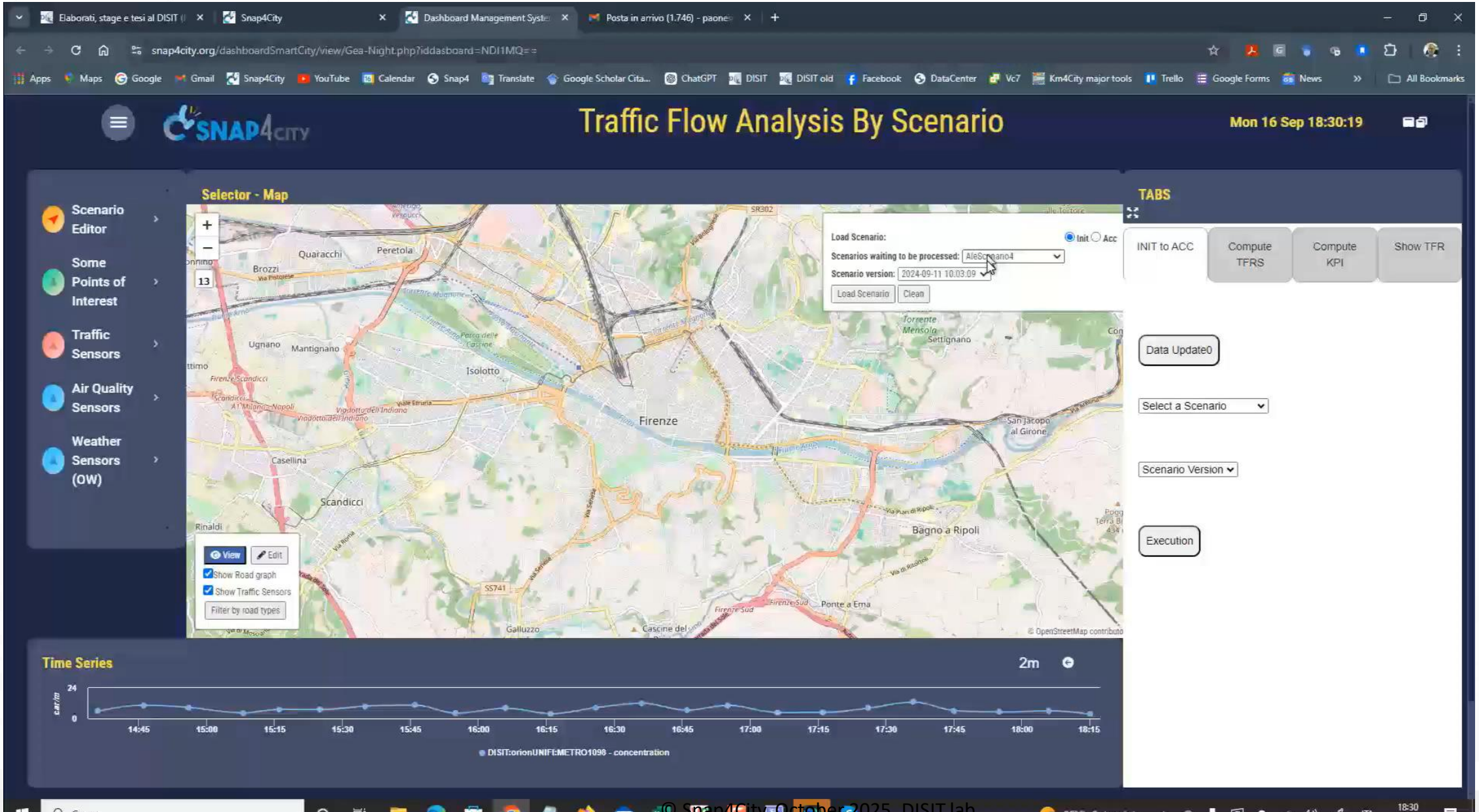
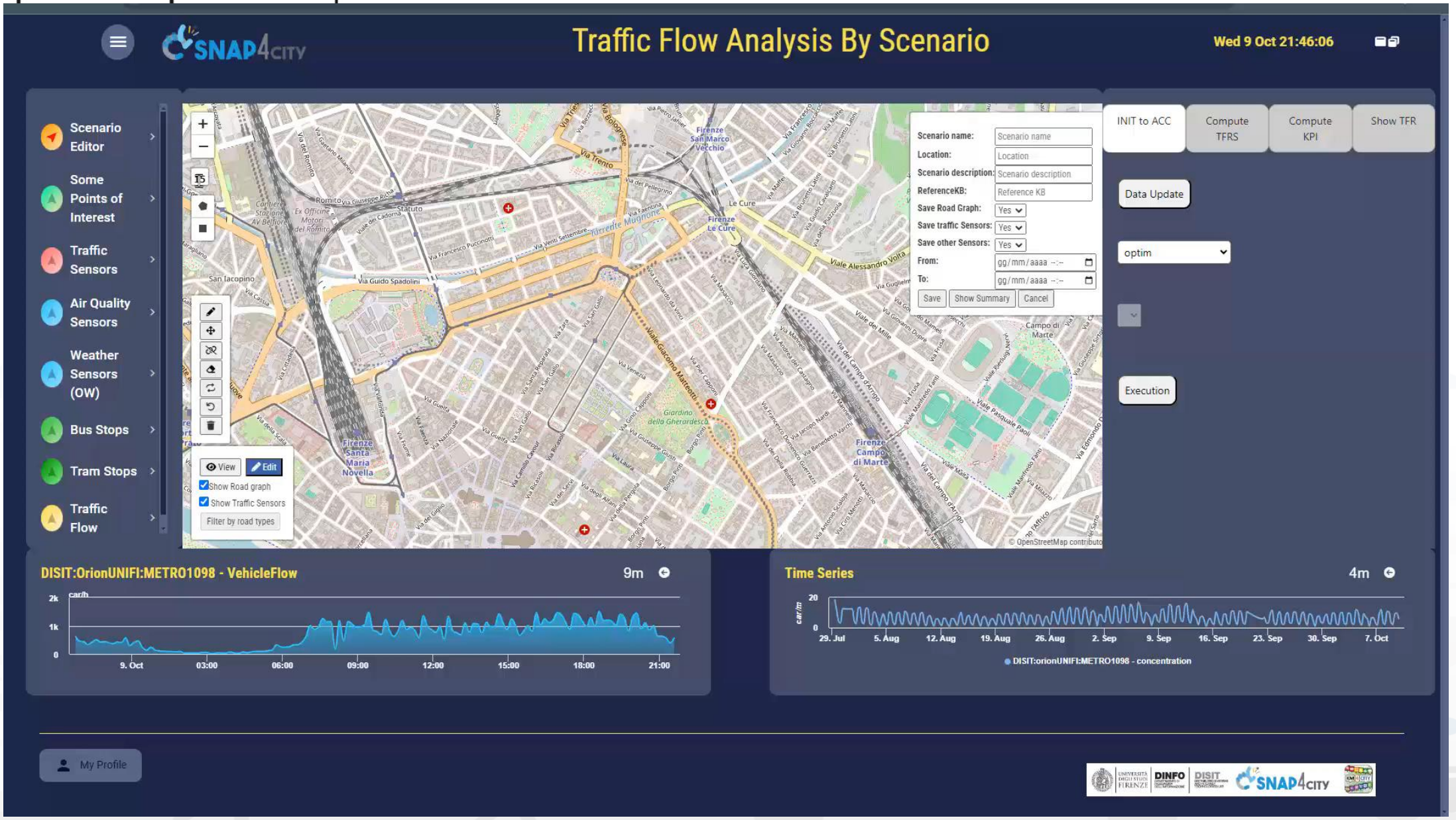
What-if on TFR

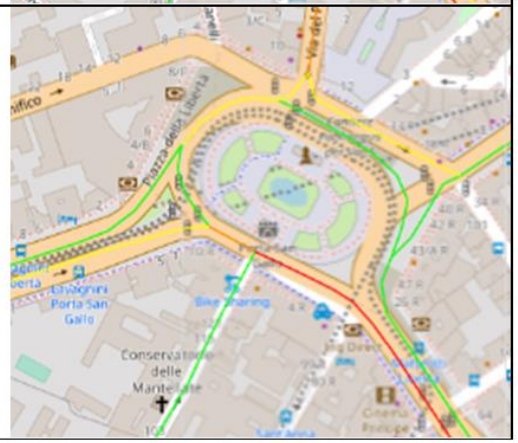


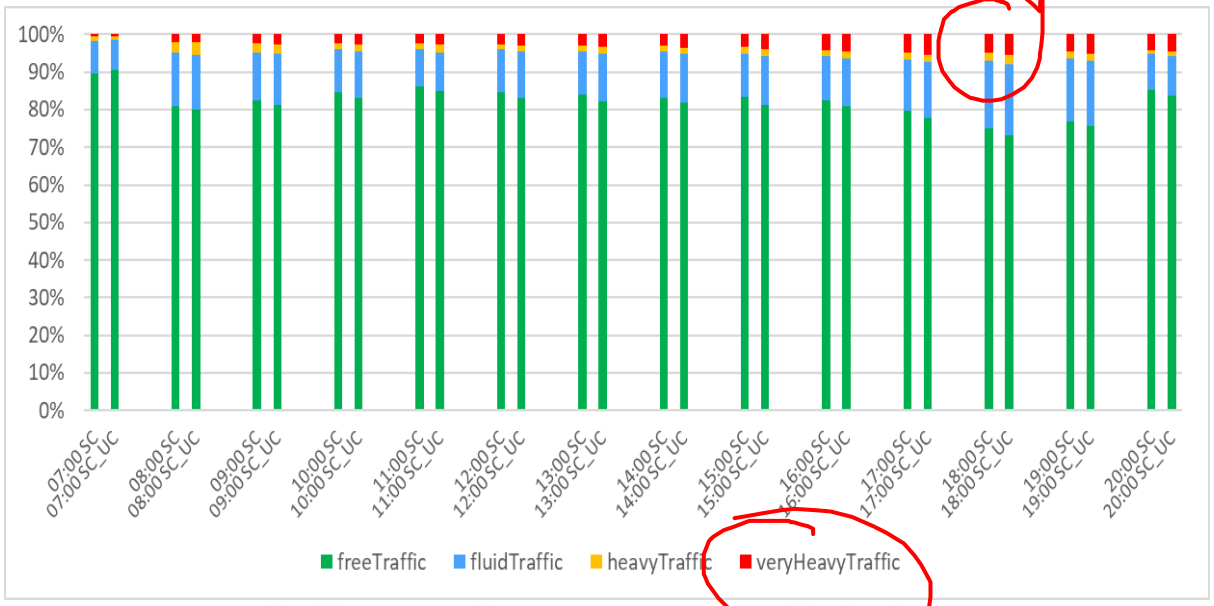
What-if on TFR

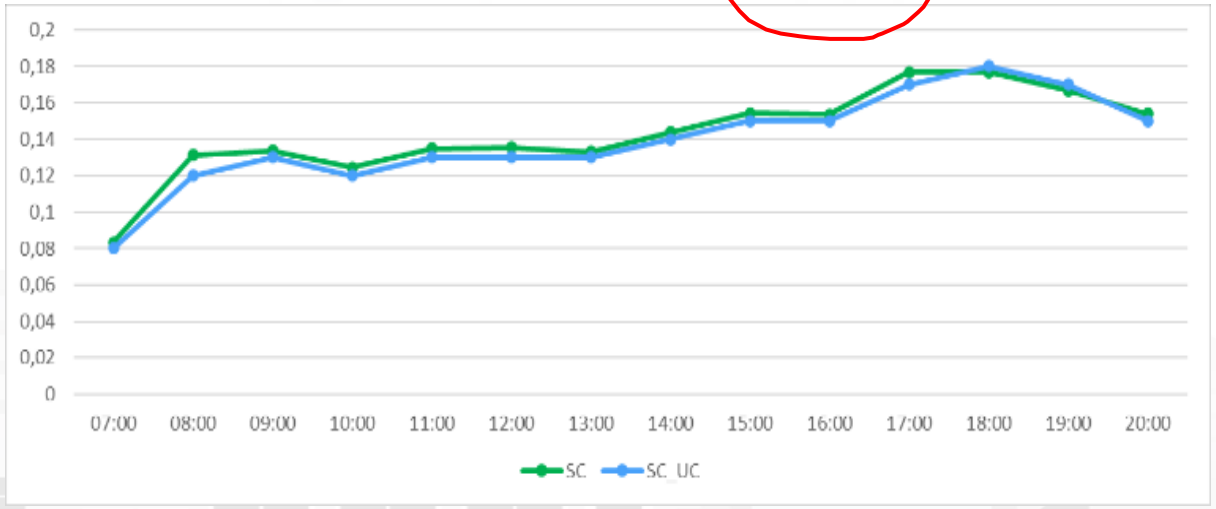



Traffic Flow Analysis By Scenario
Wed 9 Oct 21:46:06
Scenario Editor
Some Points of Interest
Traffic Sensors
Air Quality Sensors
Weather Sensors (OW)
Bus Stops
Tram Stops
Traffic Flow
View
Edit
Show Road graph
Show Traffic Sensors
Filter by road types
Scenario name:
Location:
Scenario description:
ReferenceKB:
Save Road Graph:
Save traffic Sensors:
Save other Sensors:
From:
To:
Save
Show Summary
Cancel
INIT to ACC
Compute TFRS
Compute KPI
Show TFR
Data Update
optim
Execution
DISIT:OrionUNIFI:METRO1098 - VehicleFlow
9m
Time Series
4m
DISIT:orionUNIFI:METRO1098 - concentration
My Profile

What-if

	analysis results of $SC_{i,\hat{T}}$	Actual Traffic Flow results of $R_{\hat{T}1}$
09:00		
15:00		

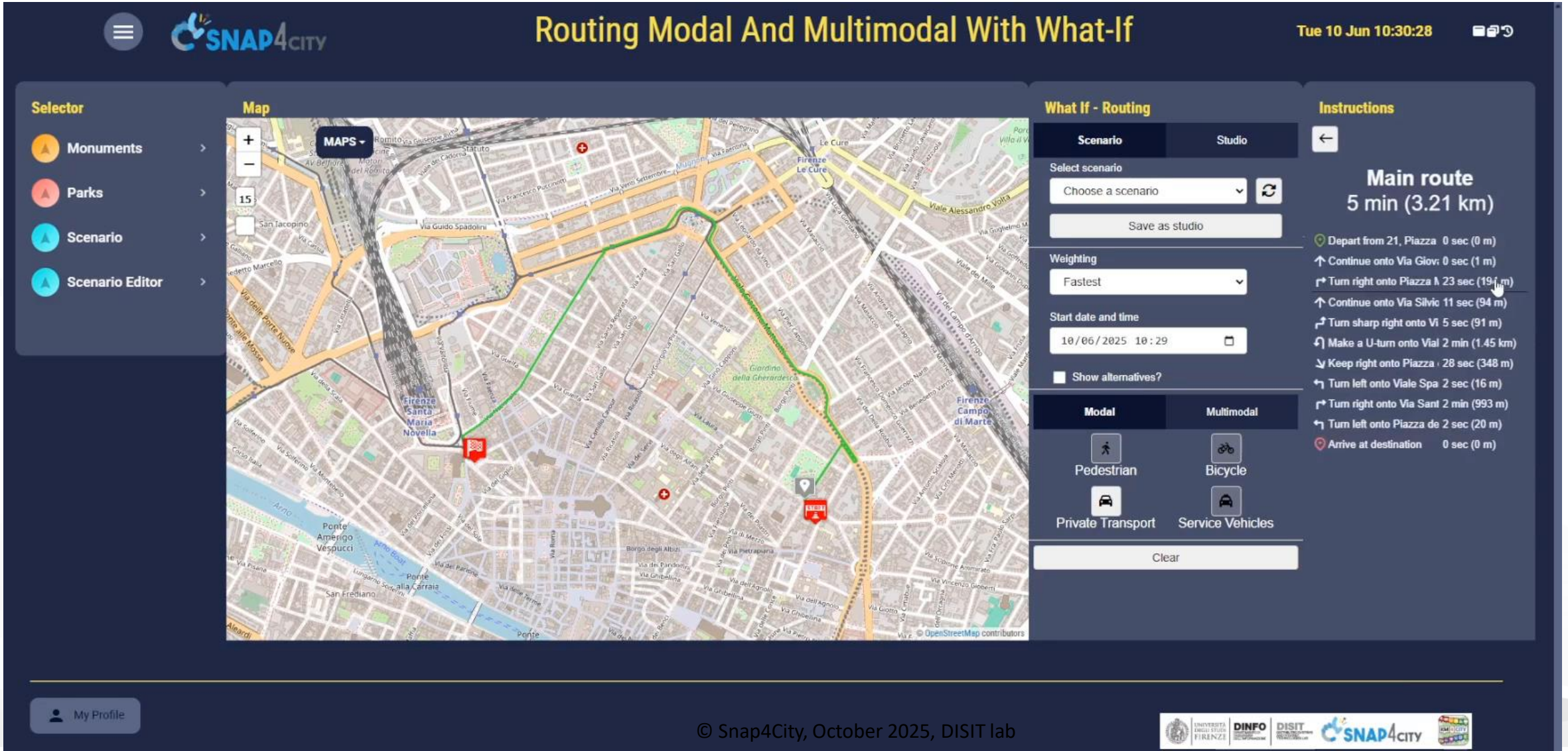




Routing Facilities

- **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**

Some Routing Service Capabilities



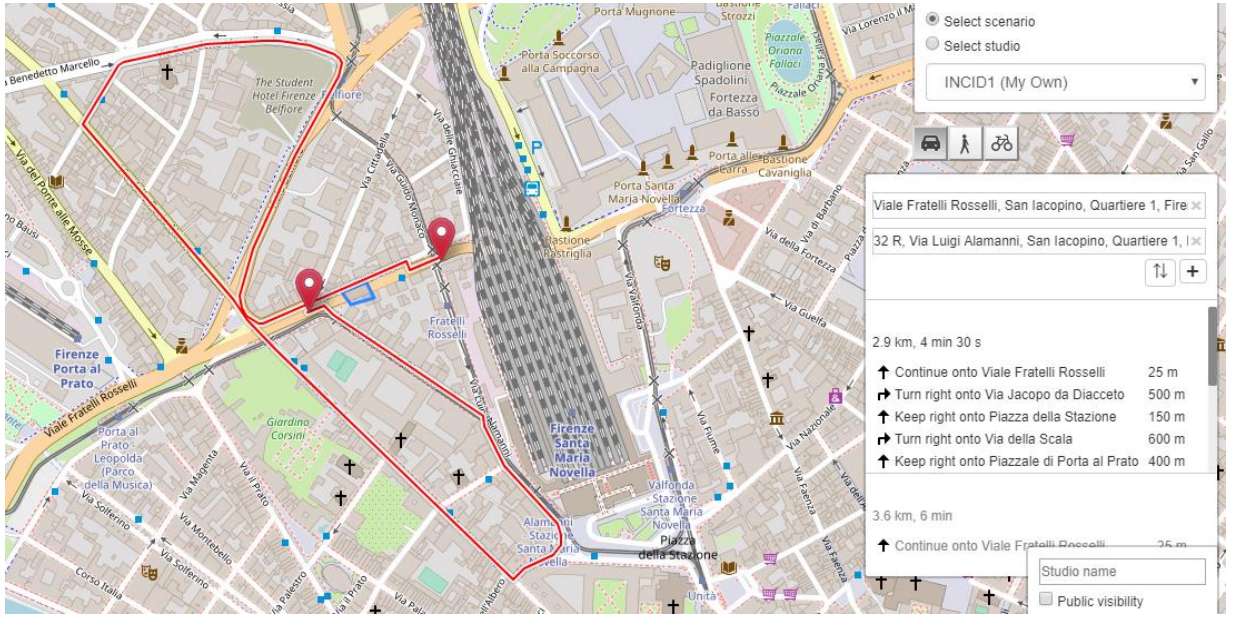
What-If Analysis

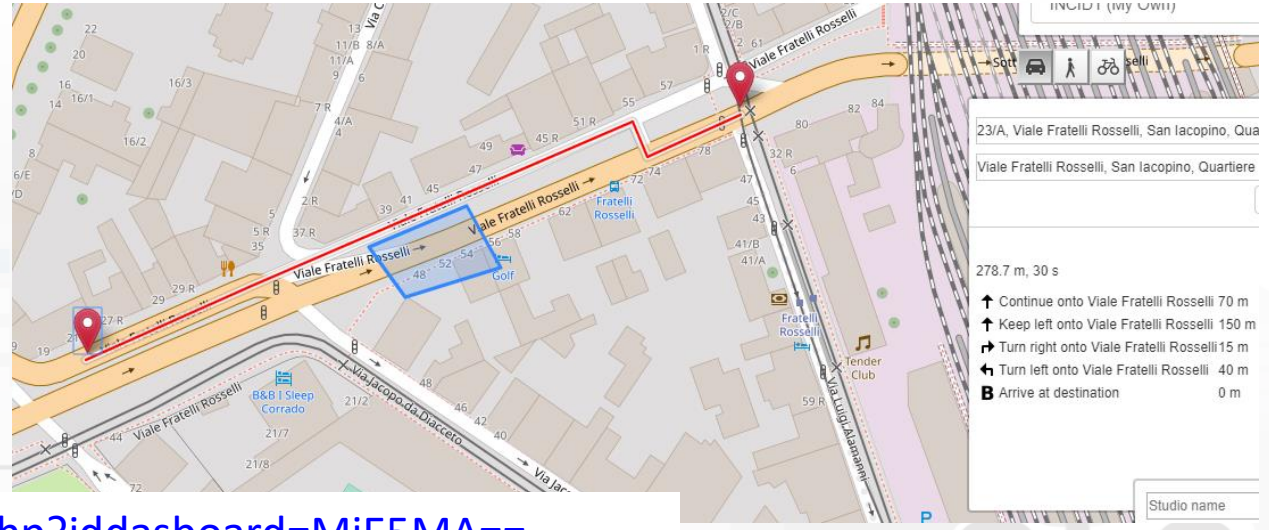
Accidents and elements blocking Points and Shapes taken into account for:

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

Assessment on the basis of changes:

- Mobility demand assessment
- Mobility Offer assessment

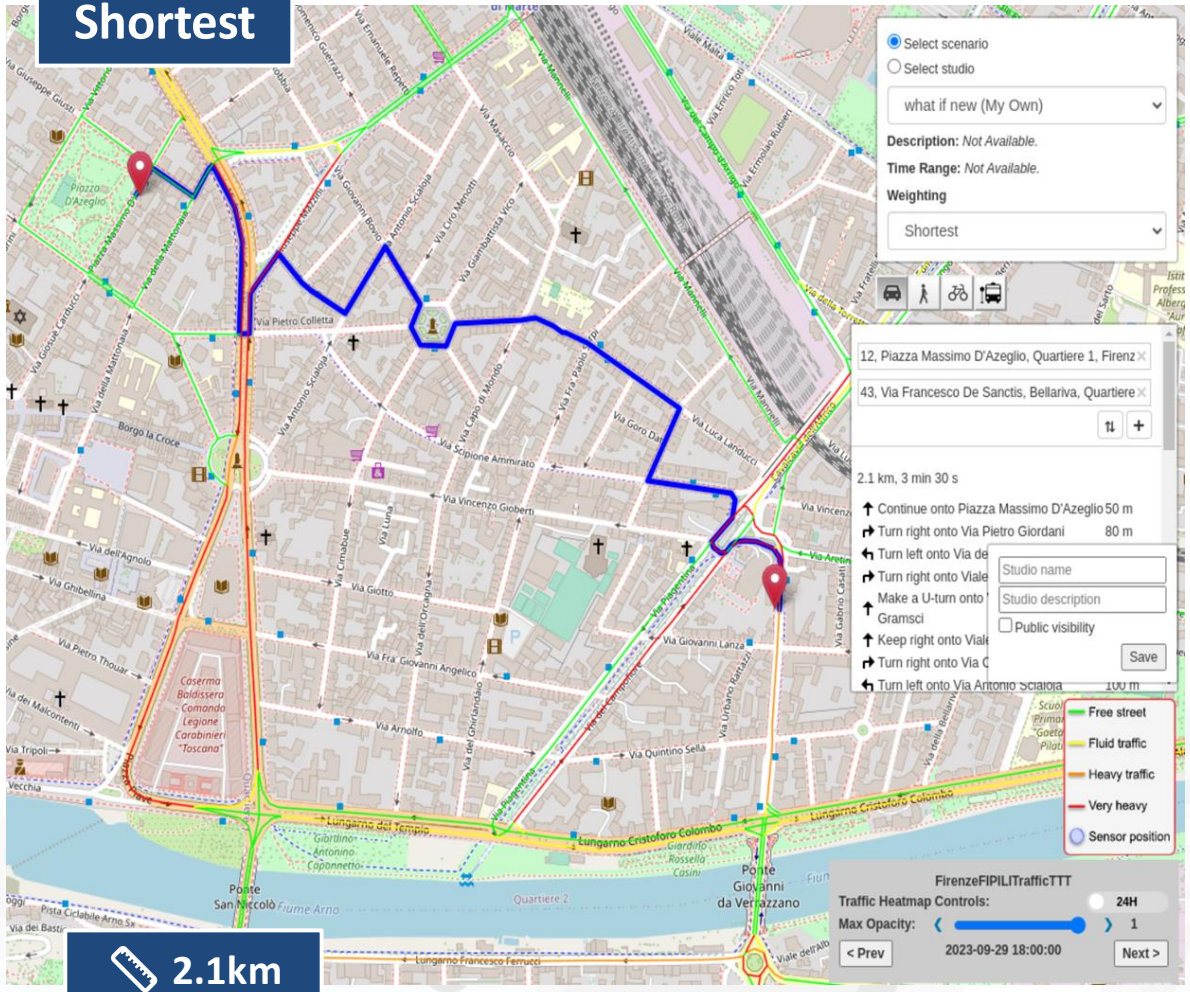




https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjE5MA==

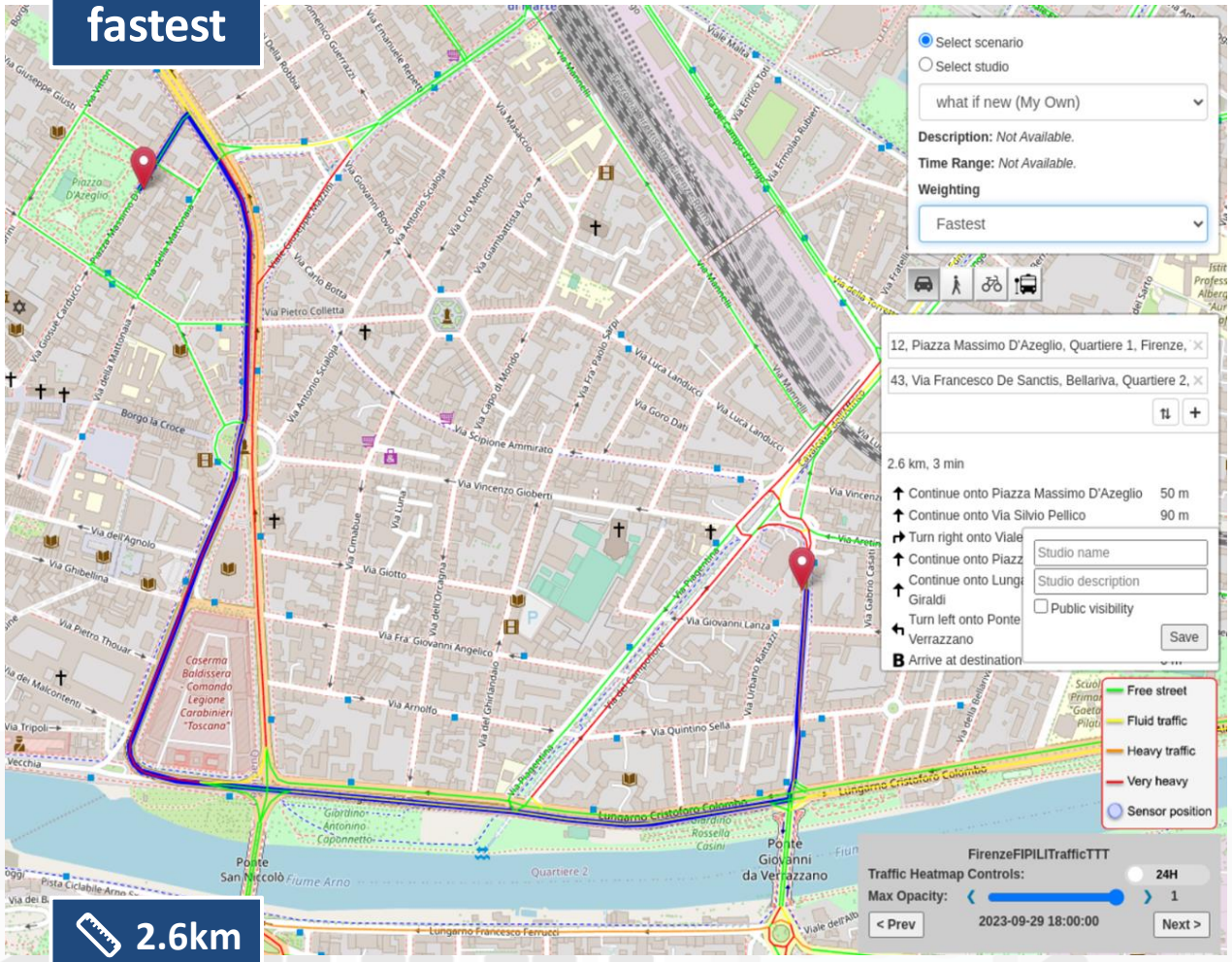
Constrained Dynamic Routing: Traffic Flow

Shortest



2.1km
3min 30s

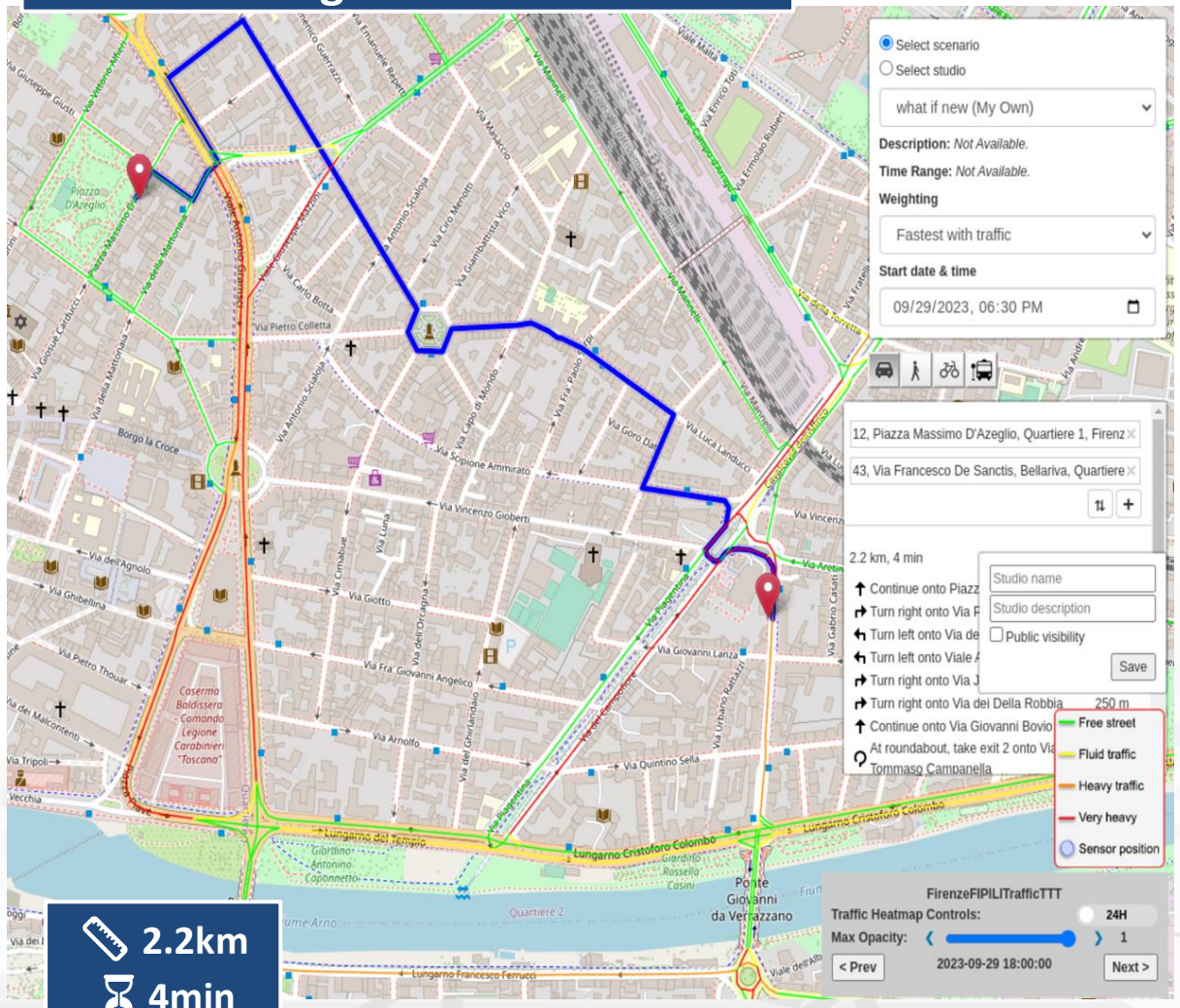
fastest



2.6km
3min

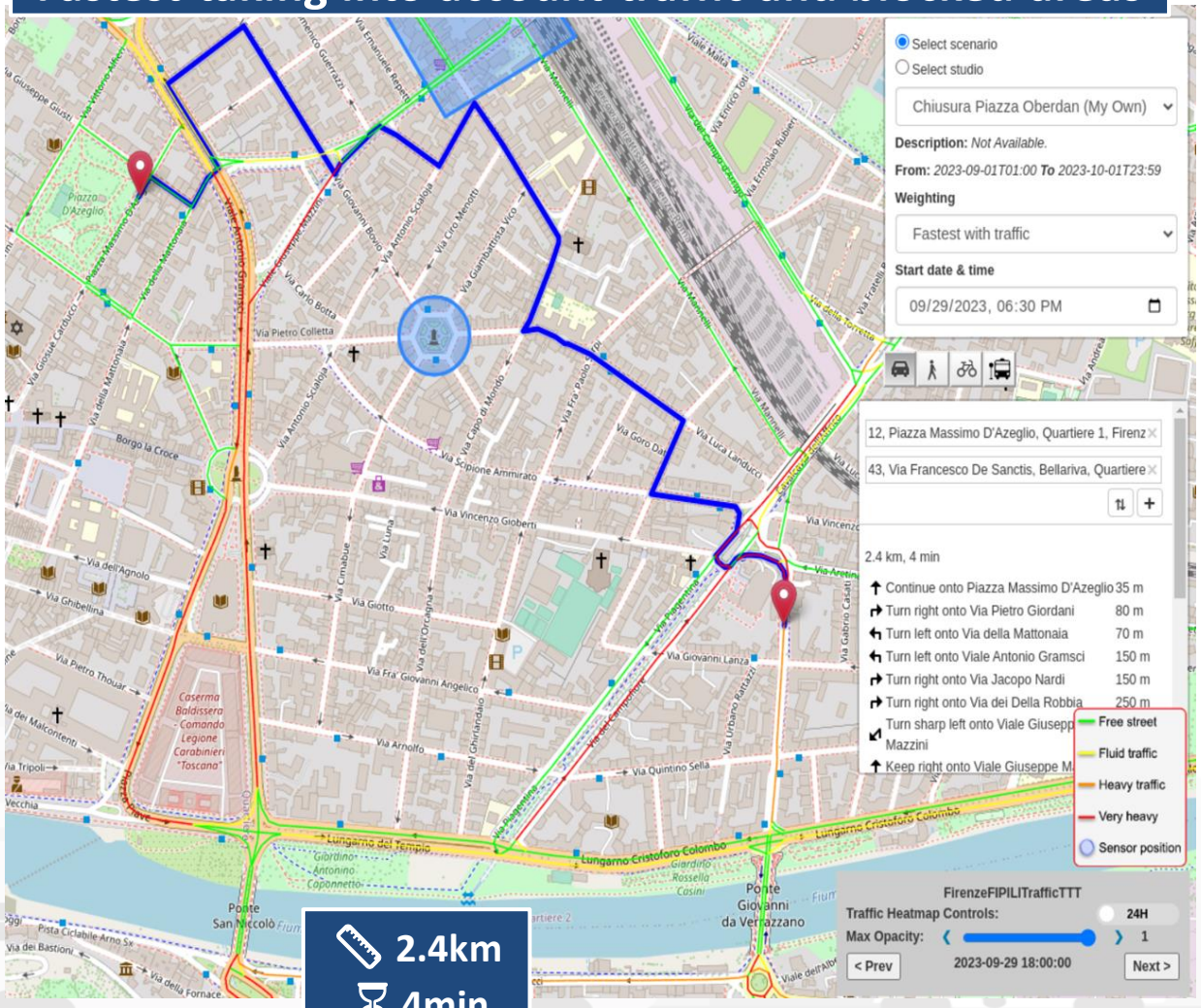
Constrained Dynamic Routing: Traffic Flow

Fastest taking into account traffic



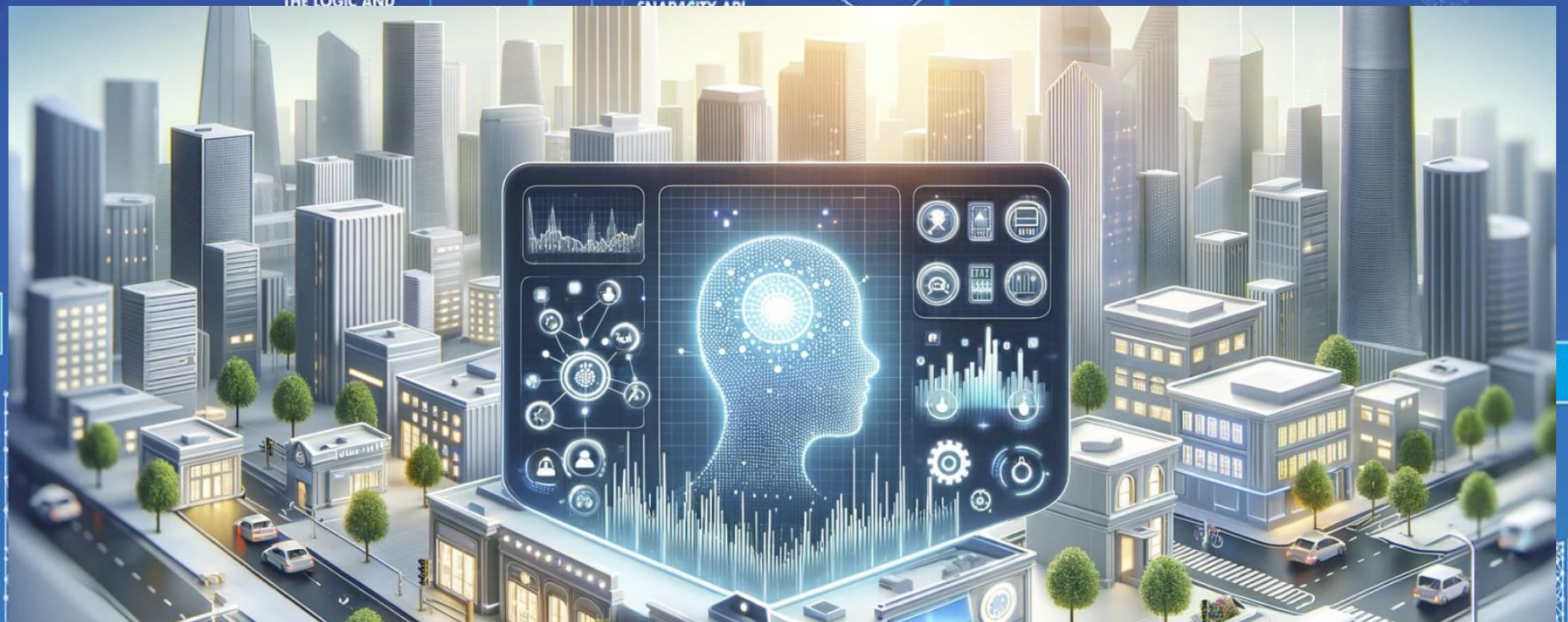
2.2km
4min

Fastest taking into account traffic and blocked areas



2.4km
4min

Data Analytic Artificial Intelligence, XAI, Machine and Deep Learning



100% OPEN SOURCE

Available AI Solutions on Snap4City

https://www.snap4city.org/997

More than 80 Available Solutions & 300 AI applic.

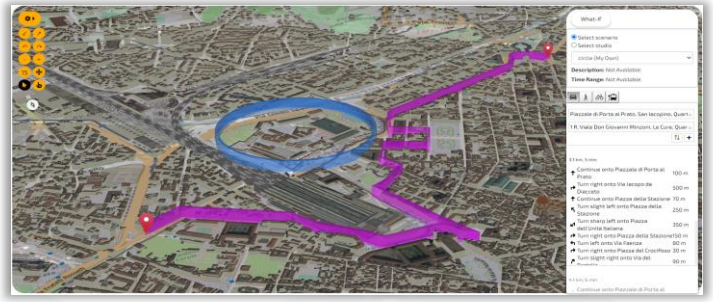
- Mobility and Transport
- Environment, Weather, Waste, Water
- City Users Behaviour and Social analysis
- Energy and Control
- Tourism and People
- Security and Safety
- High Level Decision Support Solutions
  - Asset management
  - Resilience and Risks Analysis
- Low level Techniques

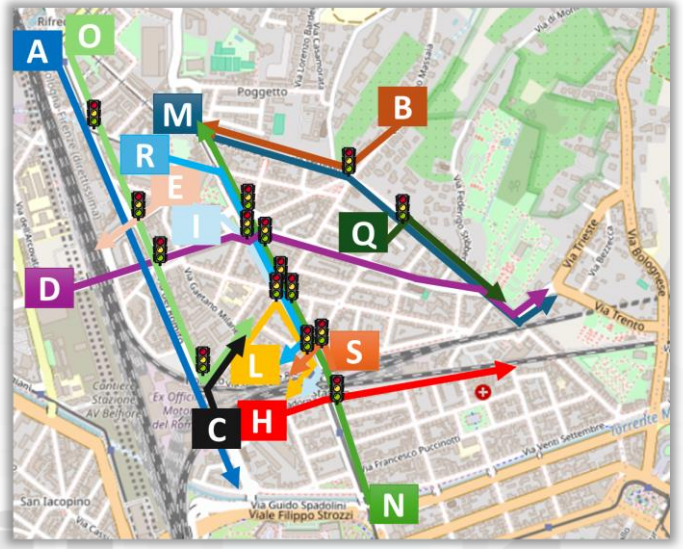
https://www.snap4city.org/download/video/DPL_SNAP4SOLU.pdf

https://www.snap4city.org/download/video/course/p4/

AI vs Mobility and Transport: DSS

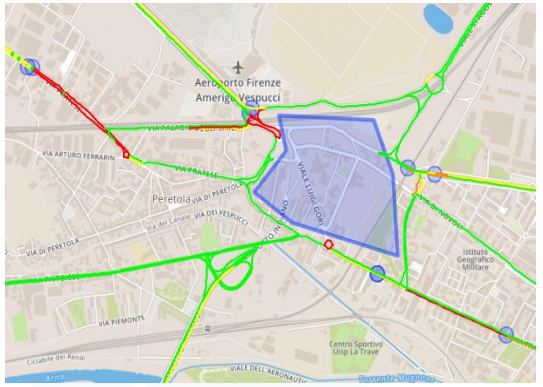
- From traffic flow, TF, data of scattered sensors to dense TF graph
  - Computation of TF partitioning at junctions
  - PDE solutions with hybrid methods: Finite elements plus NN
- Predictions and XAI of
  - TF data of sensors
  - Parking slots, Bike slots, bike rack status, etc.
- Anomaly detection on TF, etc.
- Optimisation of Traffic Light Plans: GA, DRL, agent and multiagent
- Match mobility demand vs transportation offer: agent based

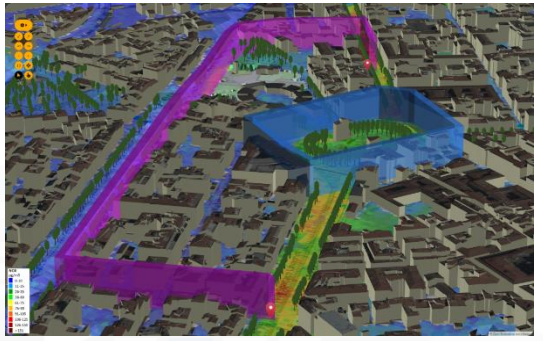




Mobility and Transport Domain (2024/8)

- Goals:
  - Decongestion
  - Decarbonization
  - Accessibility to services
  - Security/Safety of city users
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
  - Monitoring traffic, parking, people flow, services, boats, ports, beaches, etc.
  - Early detection/warning of critical conditions: traffic, congestion, security/safety
  - Managing Smart Parking, transportation services, fines, etc.
  - Managing fleets: personal, sharing, waste collection, maintenance, etc.
  - Managing E-sharing, pooling services, MaaS, etc.
  - Managing entrances in city areas: restricted areas, touristic busses, etc.
  - Production of suggestions, recommendations, nudging
  - Computing predictions of any kind
- Solutions for Planning (optimization and what-if analysis)
  - Reduction of traffic congestion, via optimization: traffic light plans, viability, routing
  - Reduction of Pollutant Emissions, via optimization: traffic light plans, viability
  - Optimization of transportation offers wrt multimodal mobility demand
- Algorithms and computational solutions, see next slide



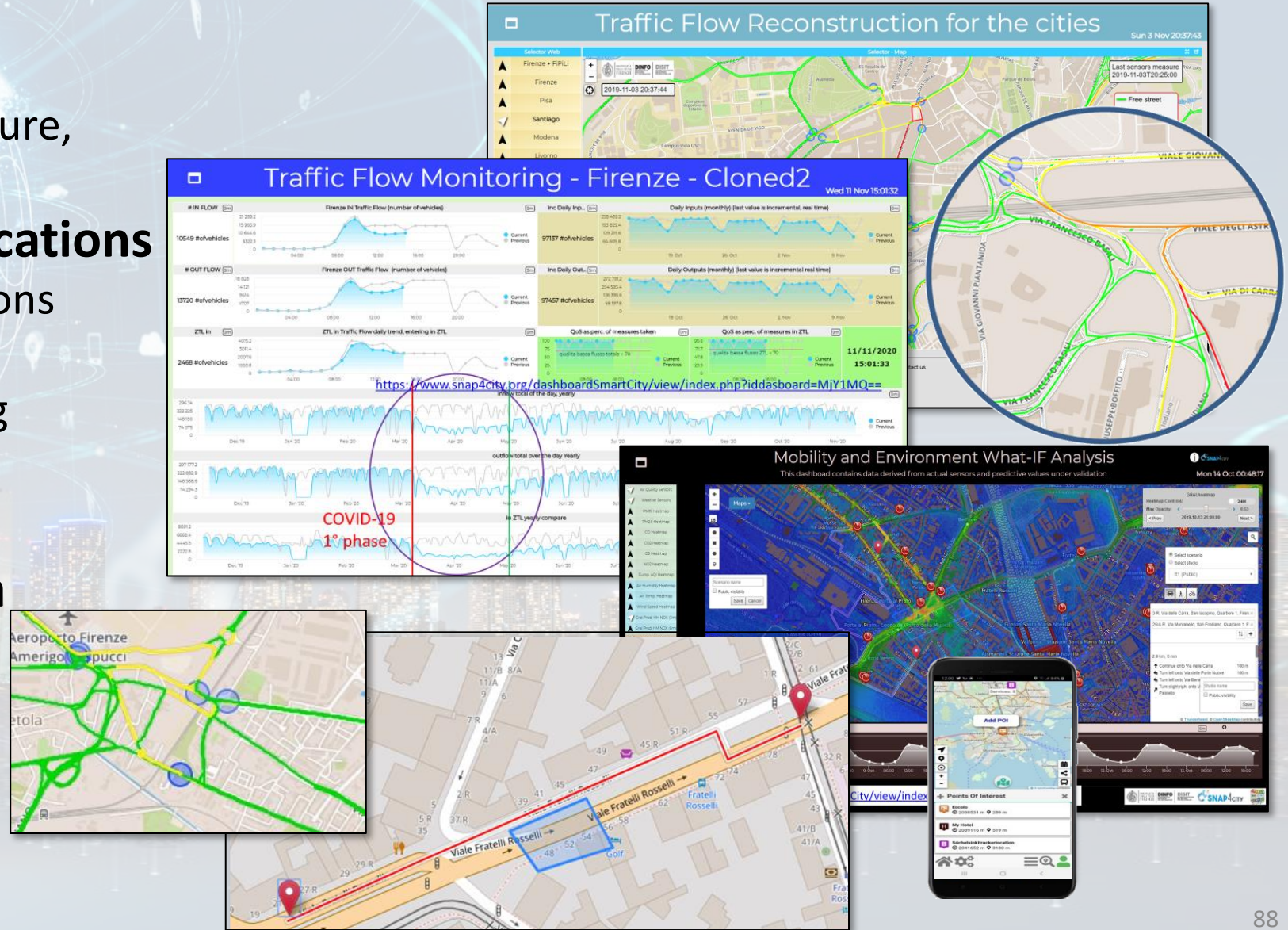


Mobility and Transport Traffic Flow Analysis

Cities: Firenze, Pisa, Livorno, Modena, Santiago di Compostela

reference

- **Multiple Domain Data**
  - Traffic Flow sensors, city structure, weather
- **Decision Makers Multiple Locations**
  - Real time Monitoring, predictions
  - Traffic Flow Predictions,
  - Traffic Reconstructions, routing
  - Dashboards, What-IF analysis
  - Mobile App, people flows
- **Historical and Real Time data**
- **Services Exploited on:**
  - Dashboards, Mobile App
- **Since 2017, 2019**



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Traffic Light Plan Optimization

Macroscopic GA-based Multi-Objective Traffic Light Optimization (MaMoTLO)

MOST
CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

11 SUSTAINABLE CITIES AND COMMUNITIES

https://www.snap4city.org/1015

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

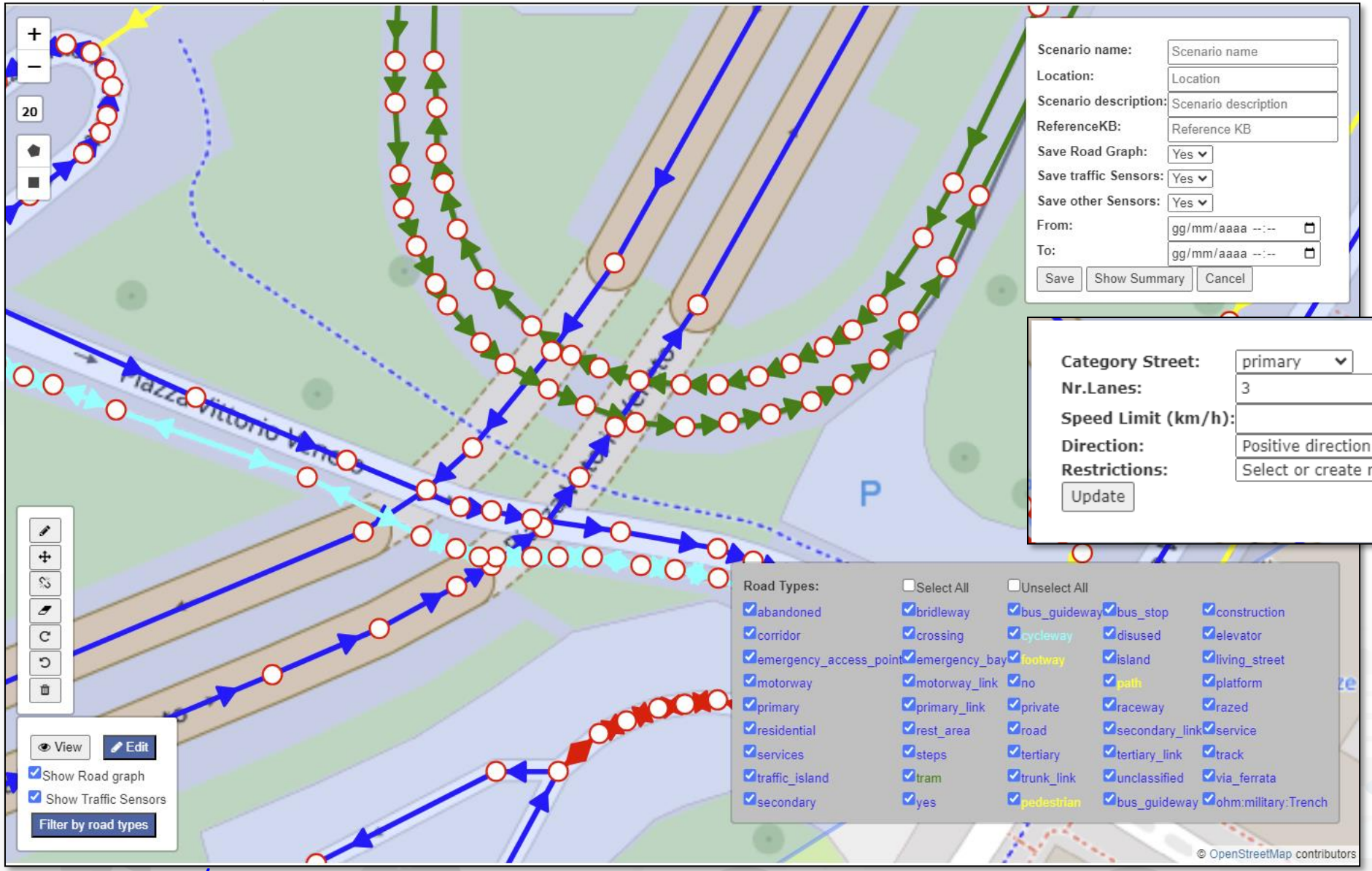
Scenario Editor

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

Properties of Road Elements

https://www.snap4city.org/976

Traffic Light Optimization

Aims, Multiple Objectives

- Decongestion, reduction of emission
- Reduction of travel time
- Synchronization, green wave
- public and private traffic, tramway priority
- Micro and Macro Scales

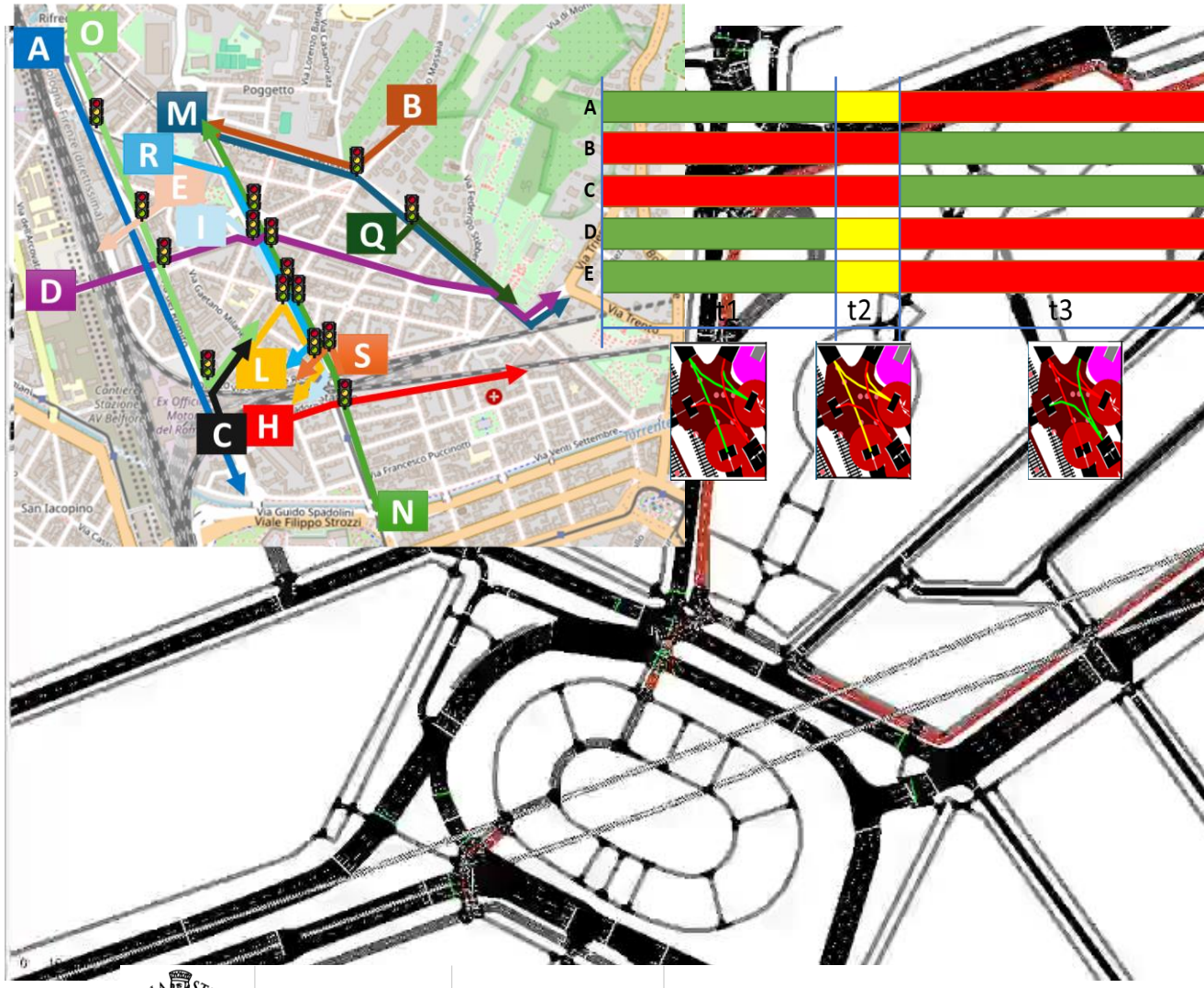
AI: Genetic Algorithms, Reinforced Learning

- Multiple Traffic Light Plan generation
- Fixed and Actuated Cycles
- Adjusted on Demand, in operation

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

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

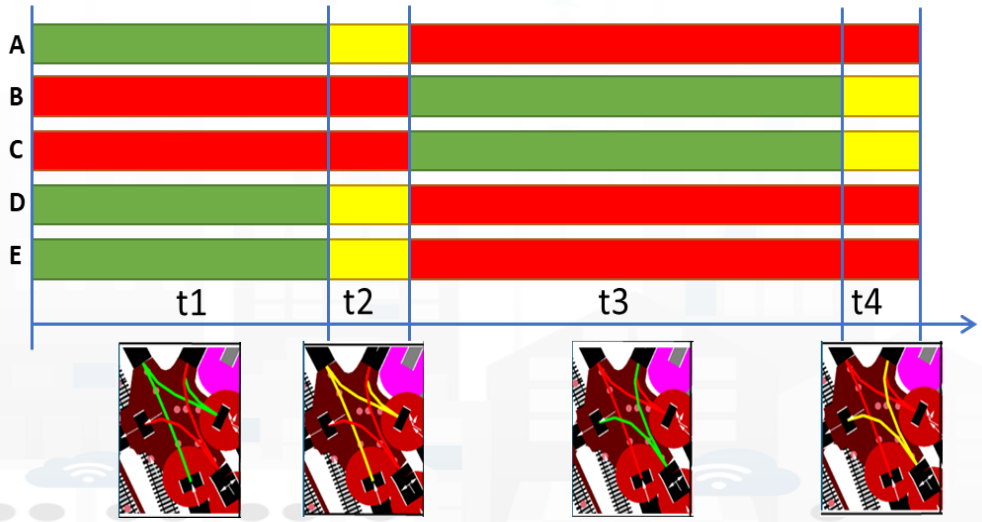
Reductions from 5% to 15%



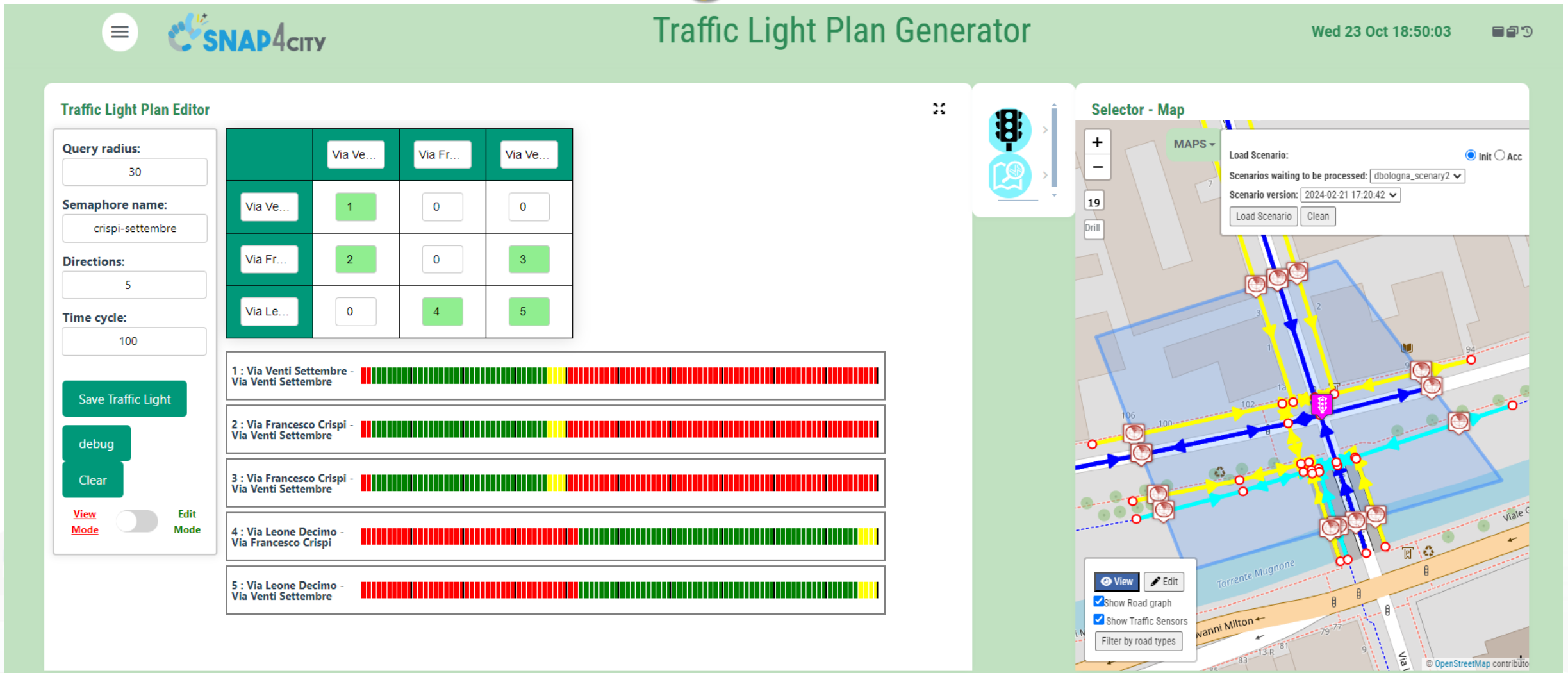
Traffic Light Plan Optimisation, Digital Twin

- **Match Multiple Objectives and Synchronization:**
  - public and private traffic, tramway priority
  - Micro and Macro Scales
  - **AI: Genetic Algorithms, 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%**

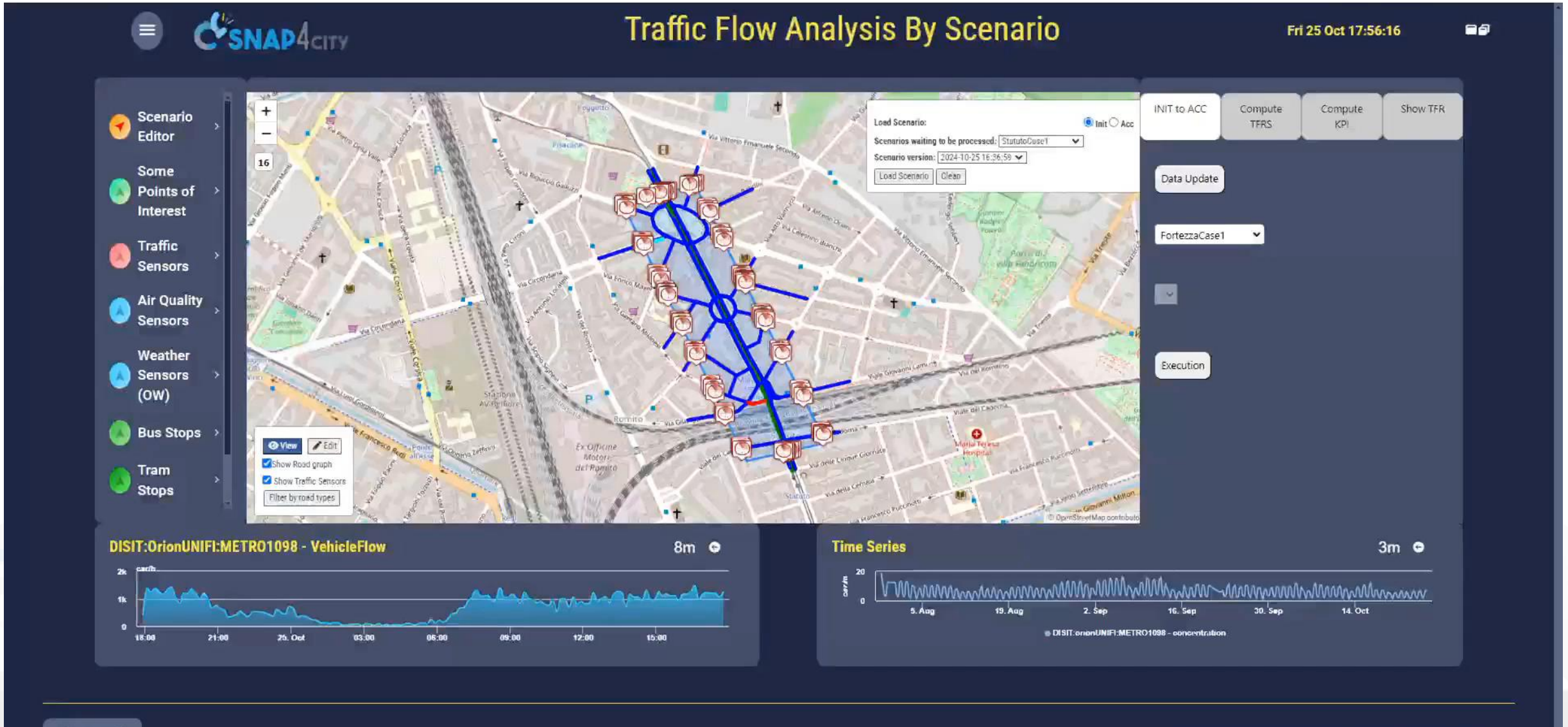
MOST CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE



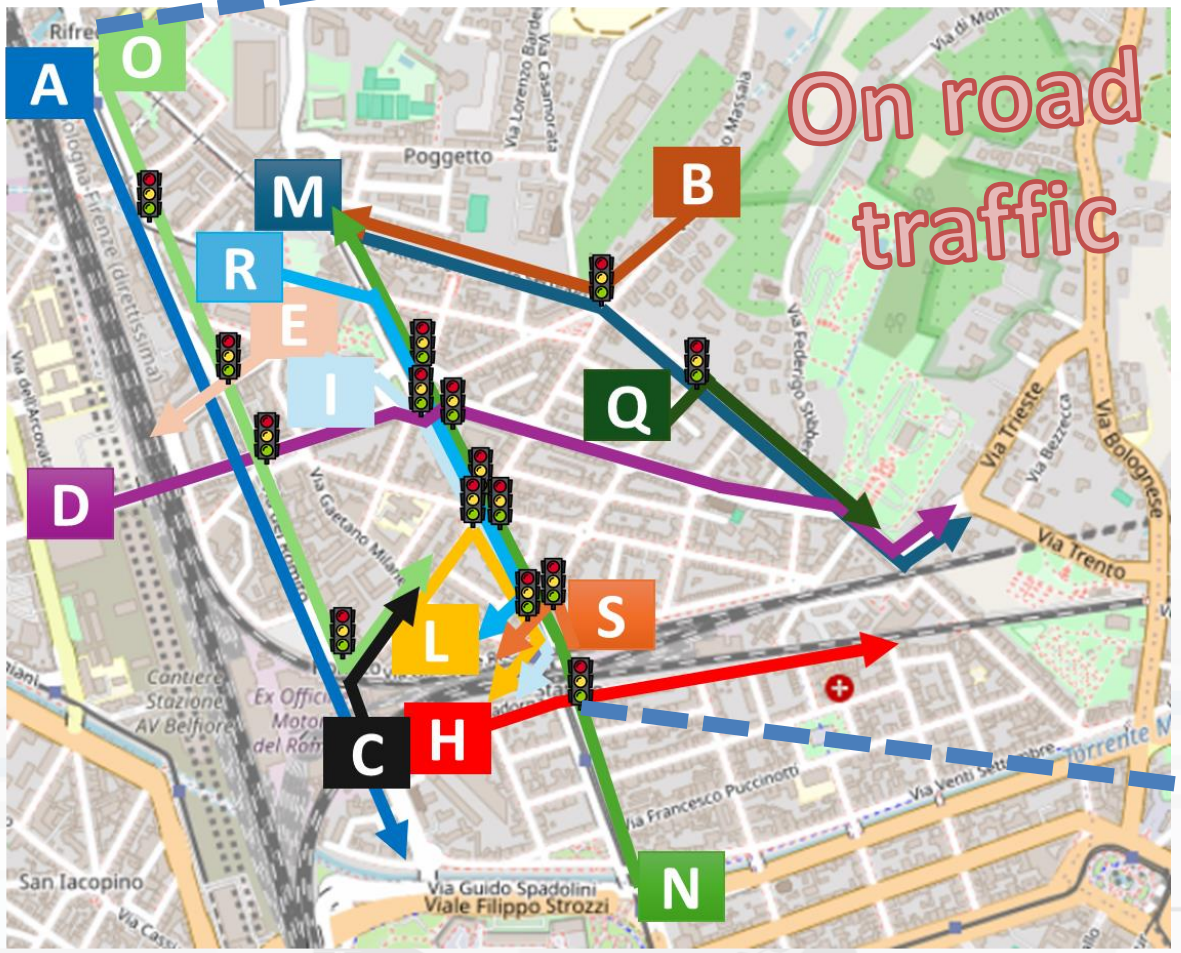
Traffic Light Plan Editor



Optimization of Traffic Light Plan



Example, main paths



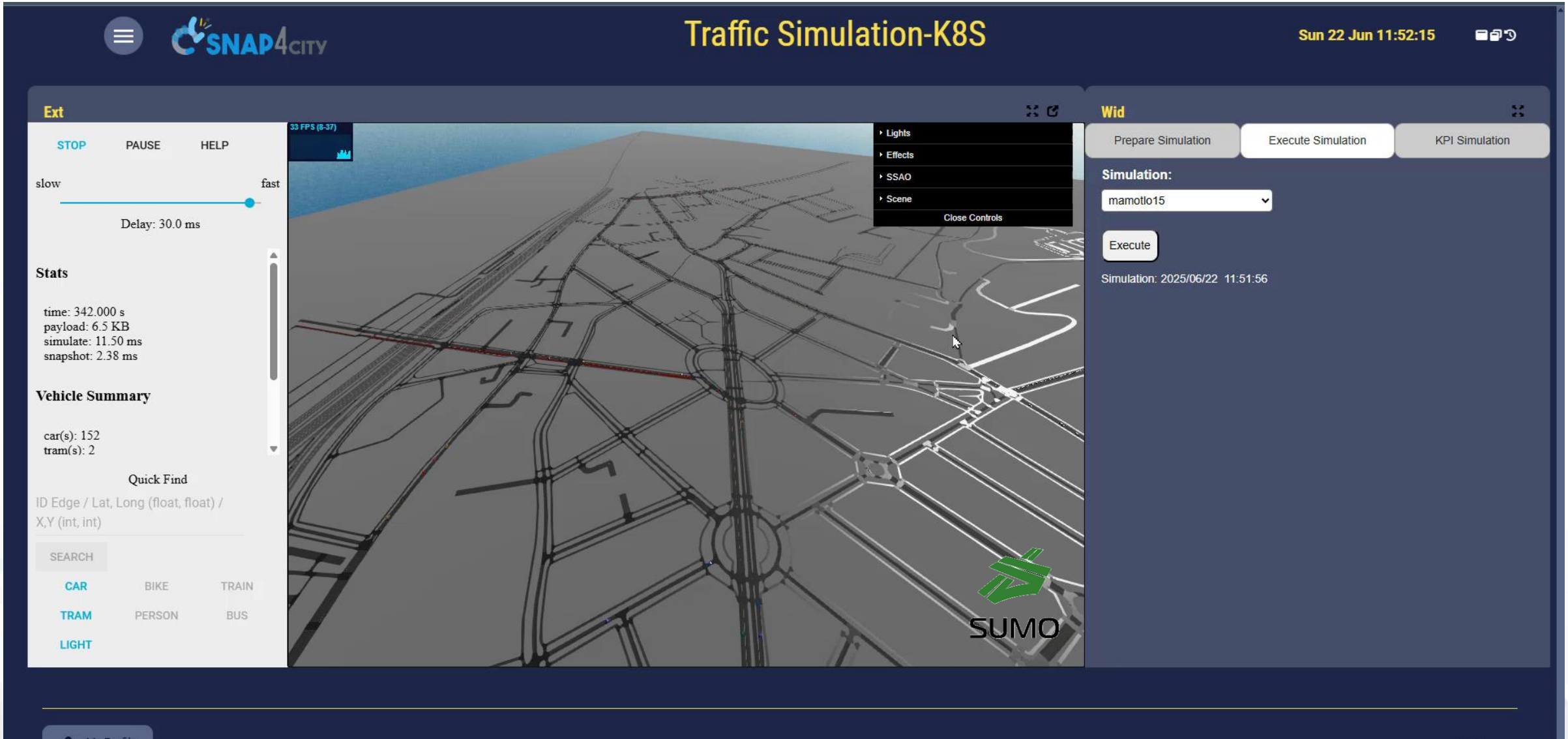
Mean Travel Time

	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

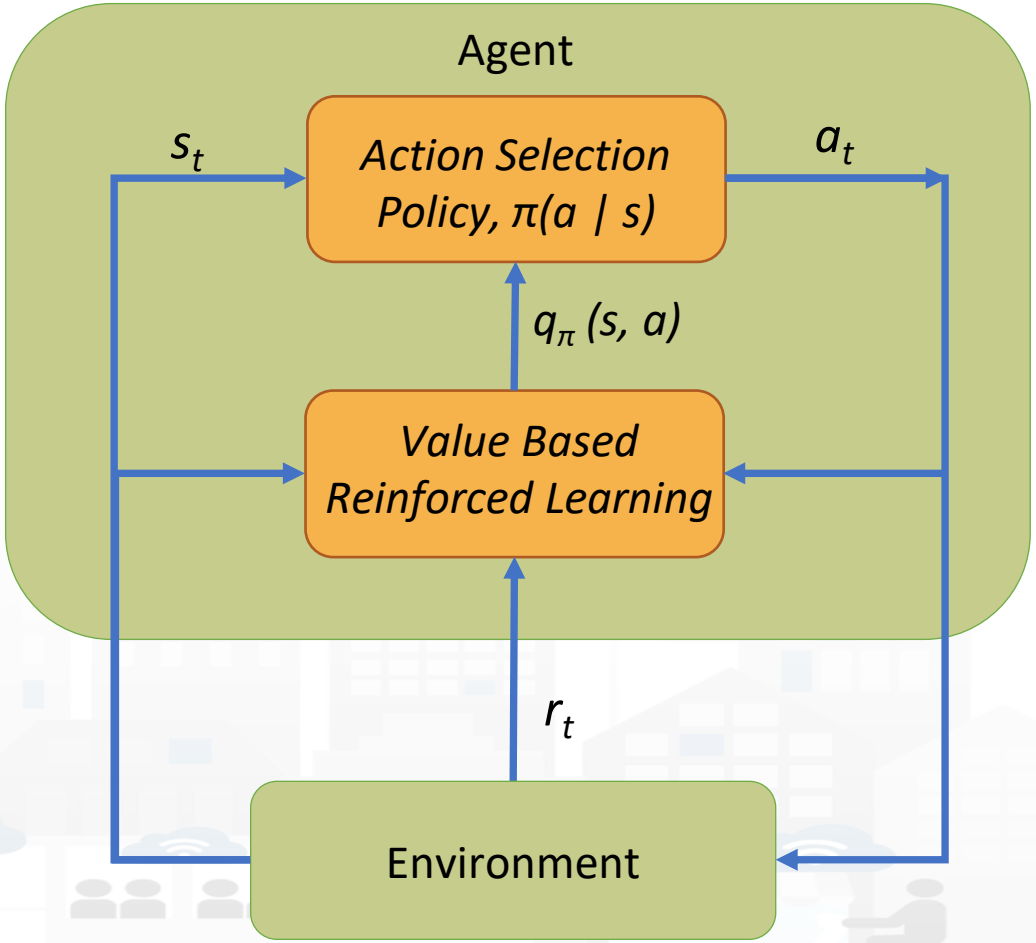
4TWD-NTNS-MWD-P-A: optimization by prioritizing traffic **directions,** the normalized number of **vehicles stops, *NTNS* , the mean waiting delay *MWD***, for all traffic lights, and post synchronization, with Penalty and Adjust dynamically performed

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.



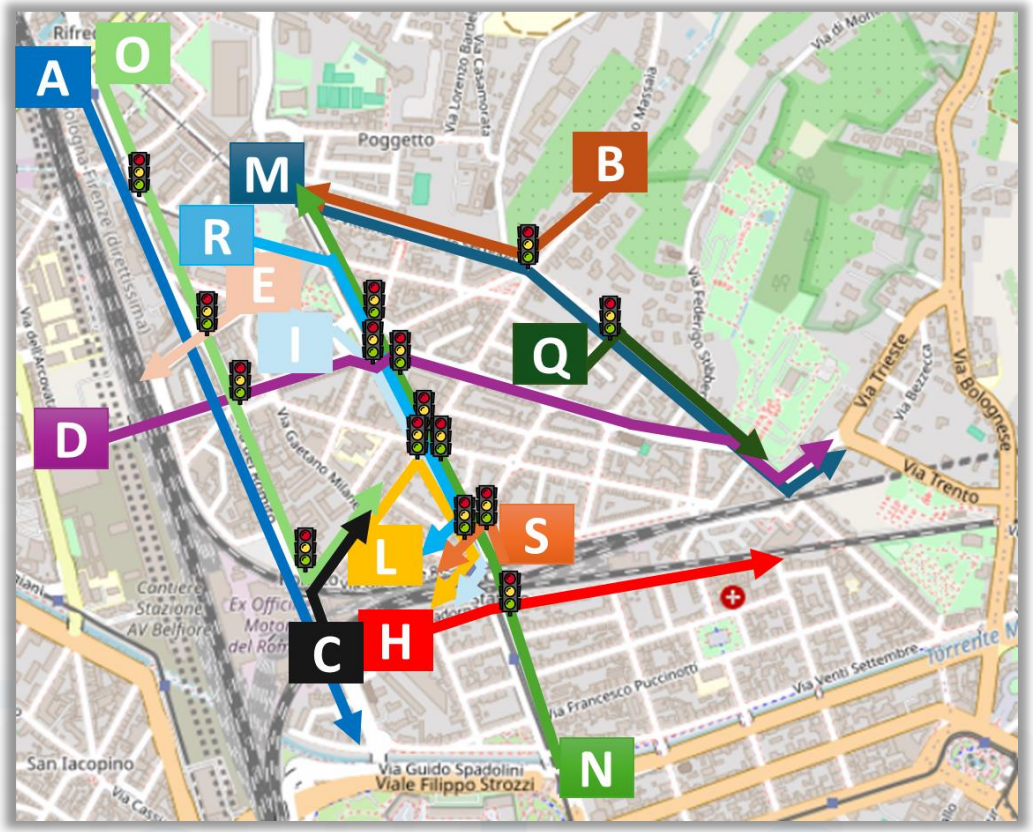
Multi Agent Reinforced Learning

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

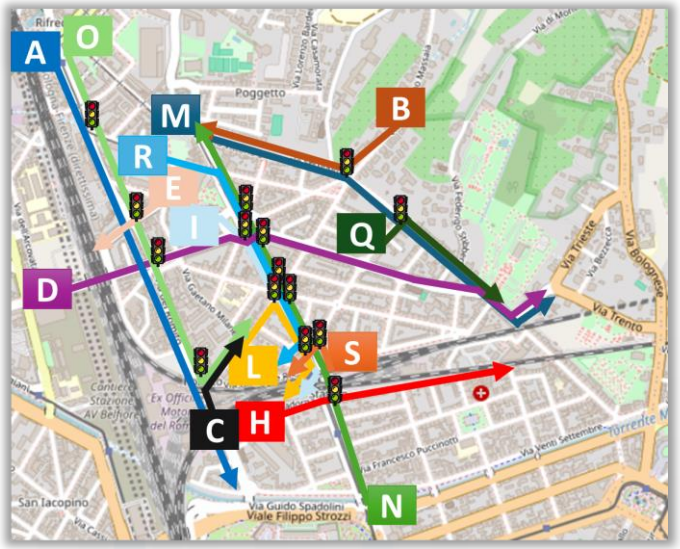


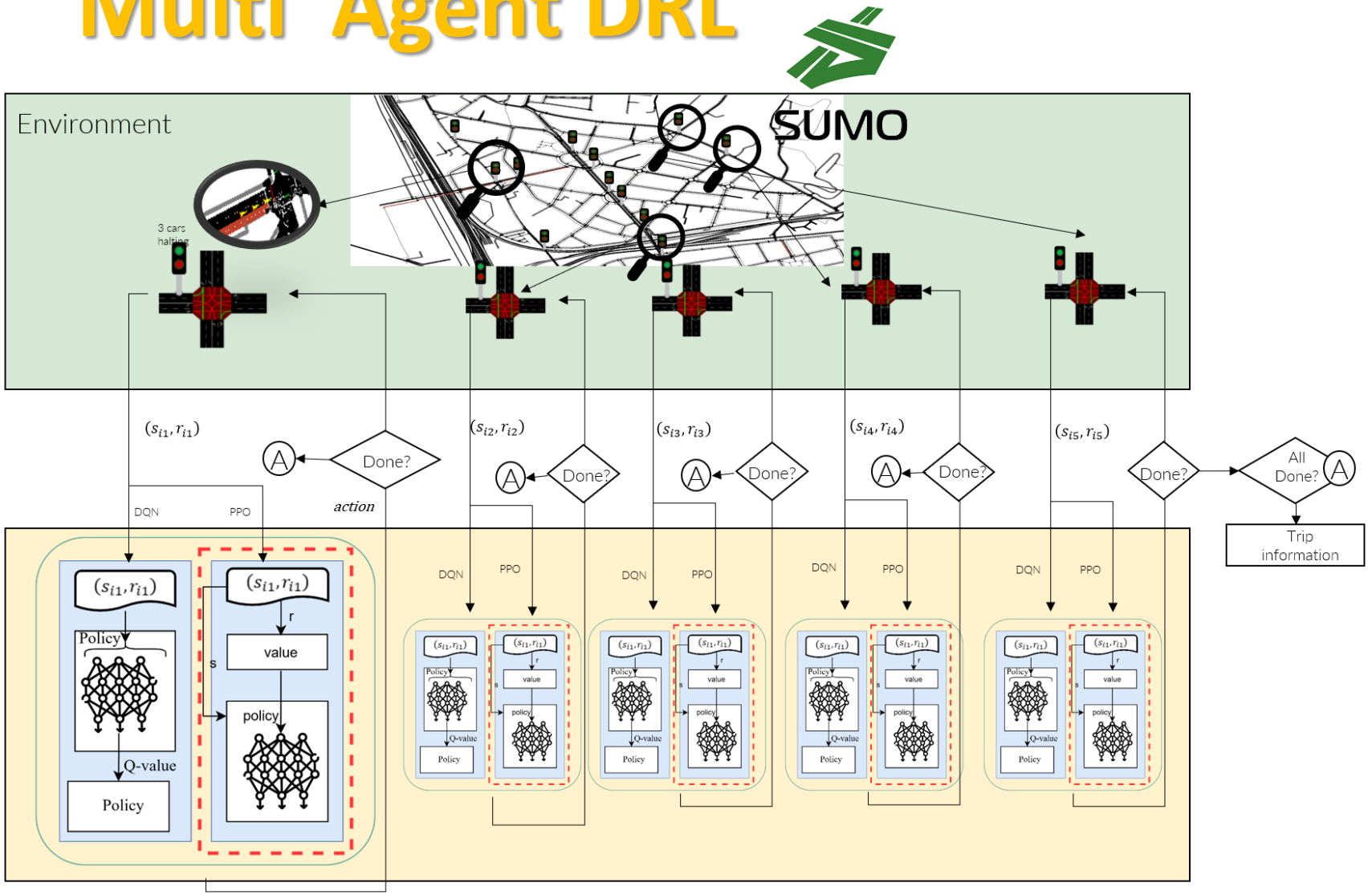
Optimization Drivers

- ***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



Multi Agent DRL





Z. Fereidooni, L.A. Ipsaro Plaesi, P. Nesi, Multi Agent Optimizing Traffic Light Signals Using Deep Reinforcement Learning, IEEE Access, 2025.

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

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SNAP4CITY

KM 4 CITY

Traffic Infrastructure Optimization

MOST
CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

FROM CITY DASHBOARD TO APPLICATIONS

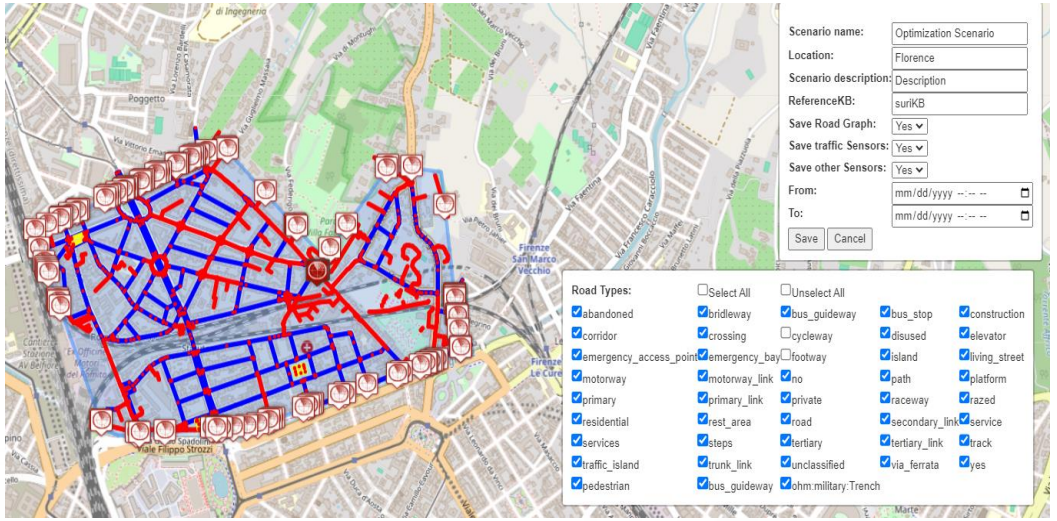
SNAP4CITY THE VIEW OF THE ADMINISTRATORS

11 SUSTAINABLE CITIES AND COMMUNITIES

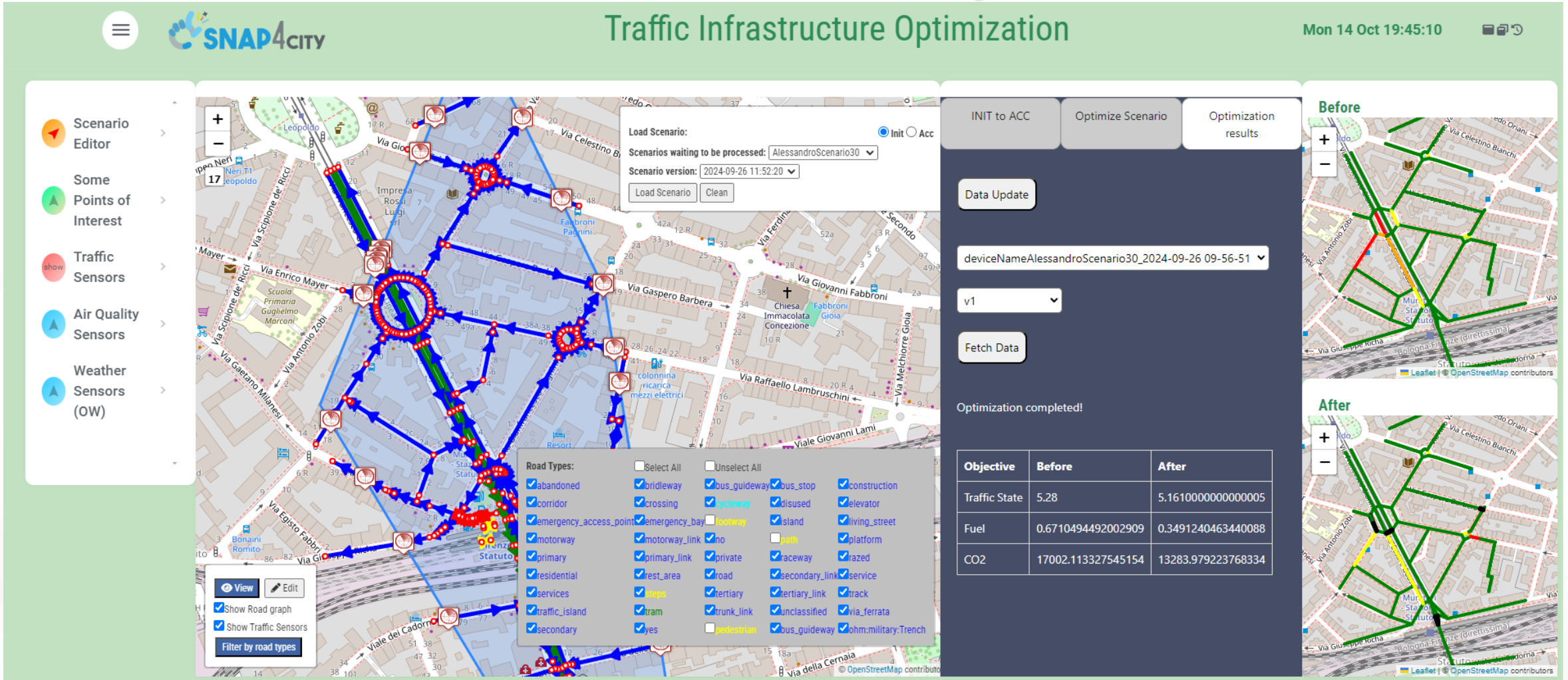
https://www.snap4city.org/1014

Traffic Infrastructure Optimisation, Digital Twin

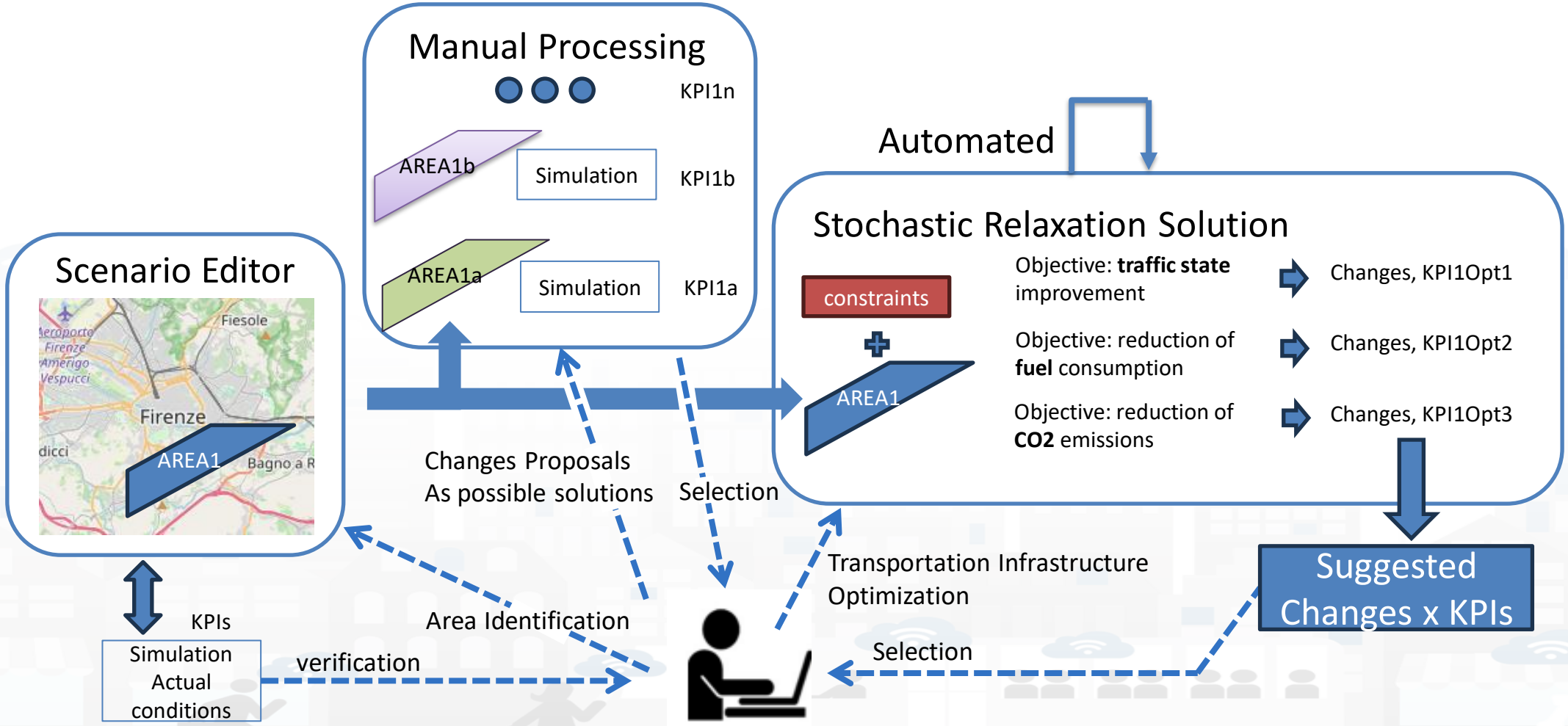
- **Identification of Scenario** (Scenario Editor), any changes
  - Definition of traffic loads by flows
- What-if or Automated Optimisation
- **Automated Optimisation:**
  - Stochastic Relaxation, Simulated Annealing, Traffic Flow Reconstruction
  - Multiple objectives targeting
    - Travel time, emissions, fuel consumption, traffic status
  - Limiting the number of changes



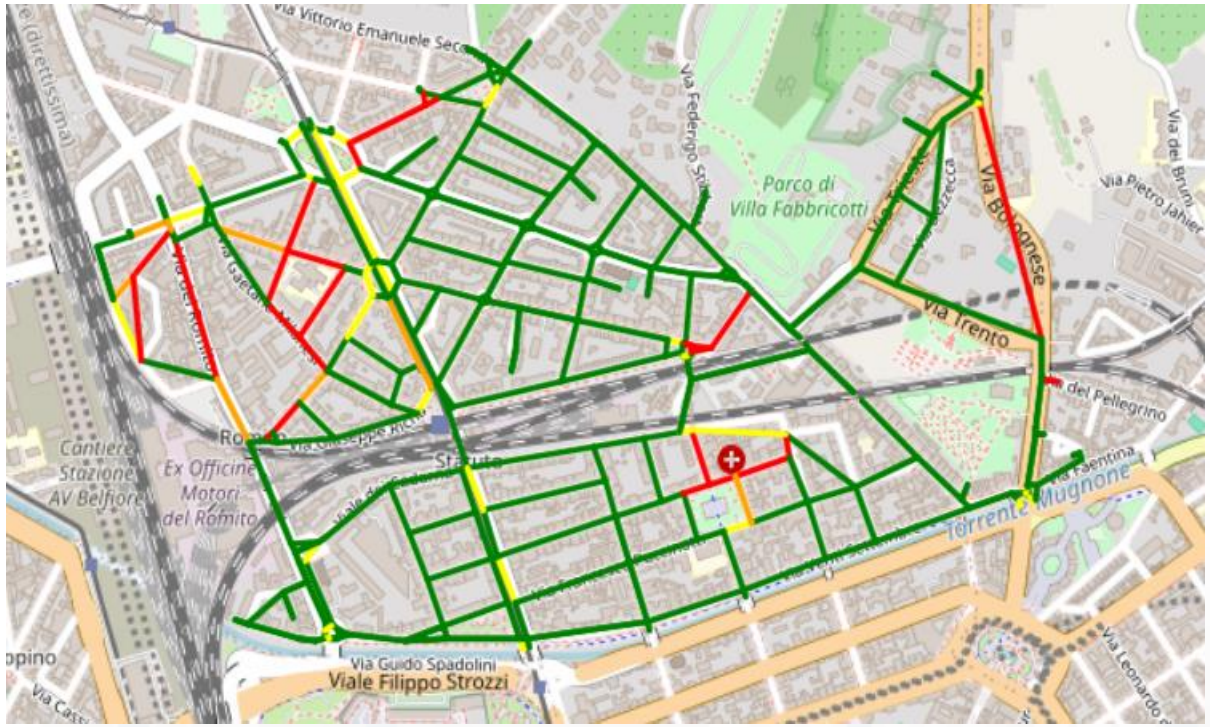
Traffic Infrastructure Optimization

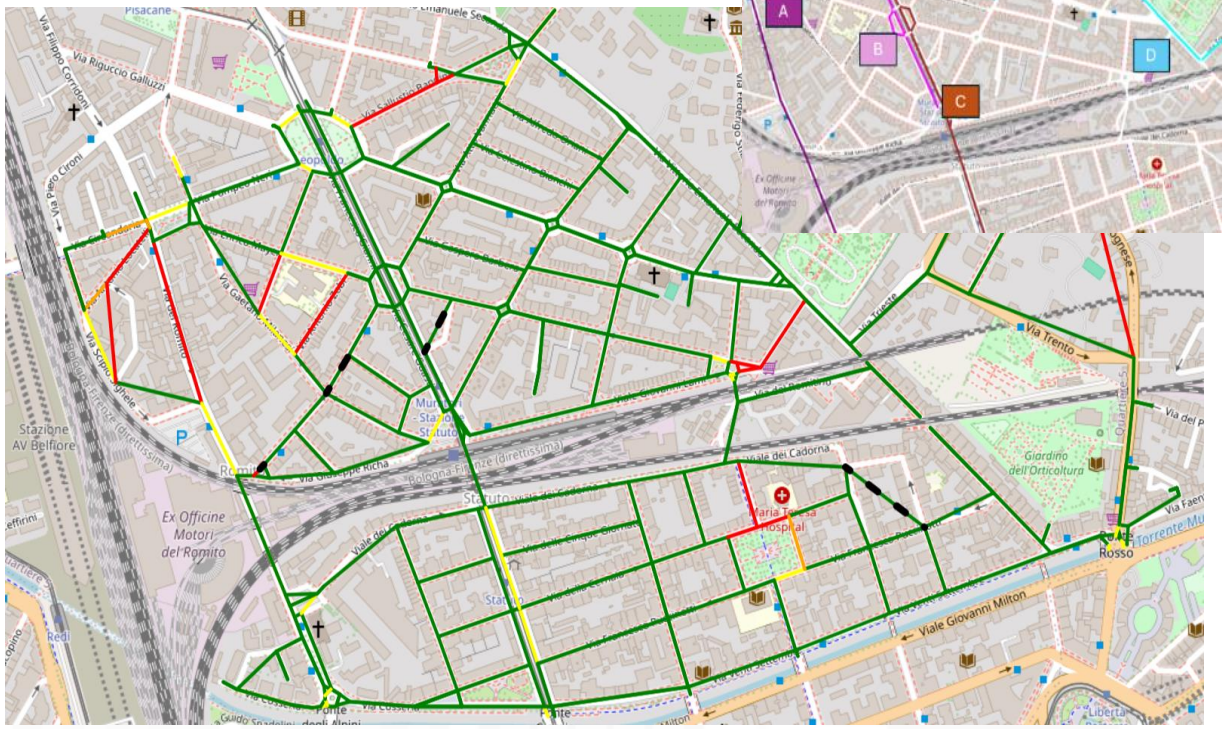


Traffic Infrastructure Optimisation



Optimization Results





Case max 4 changes	KPI estimation on the best solution		
Optimization Target	**Traffic State**	**Fuel**	**CO2**
Optim 4 Traffic State	**91.341** -21%	17.964	128536
Optim 5 Fuel	91.514	**16.633** -35%	128227
Optim 6 CO2	92.859	19.192	**127876** -23%
Original	115.475	25.680	165822

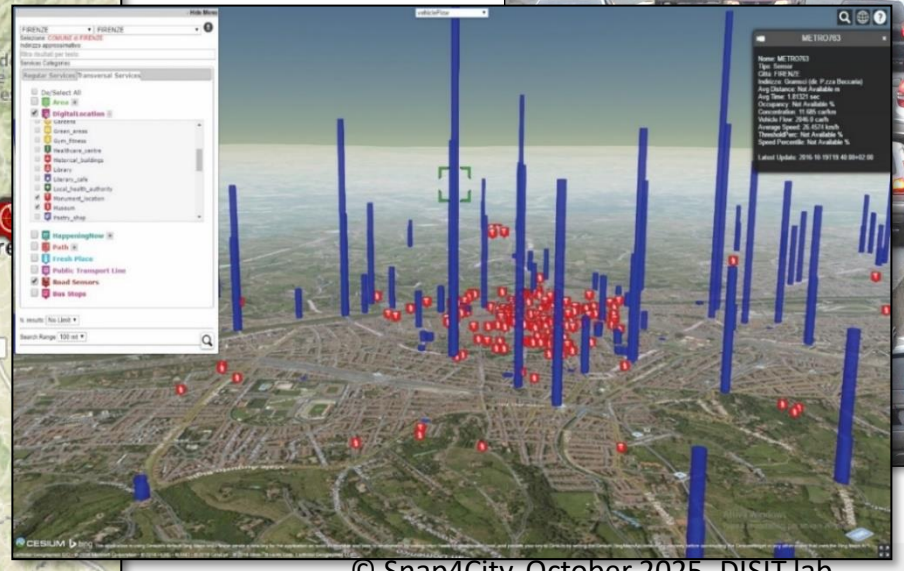
Travel Time [s]	Path A	Path B	Path C	Path D	Total Time
Original Scenario	183.2	59.6	80.9	132.5	456.4
Optim 4 Traffic State	93.2	60.0	63.7	**96.0**	313.1
Optim 5 Fuel	89.6	**51.2**	59.7	96.4	**296.9**
Optim 6 CO2	**89.5**	53.2	**58.4**	100.1	301.3
	-51%	-14%	-28%	-28%	

Traffic Flow

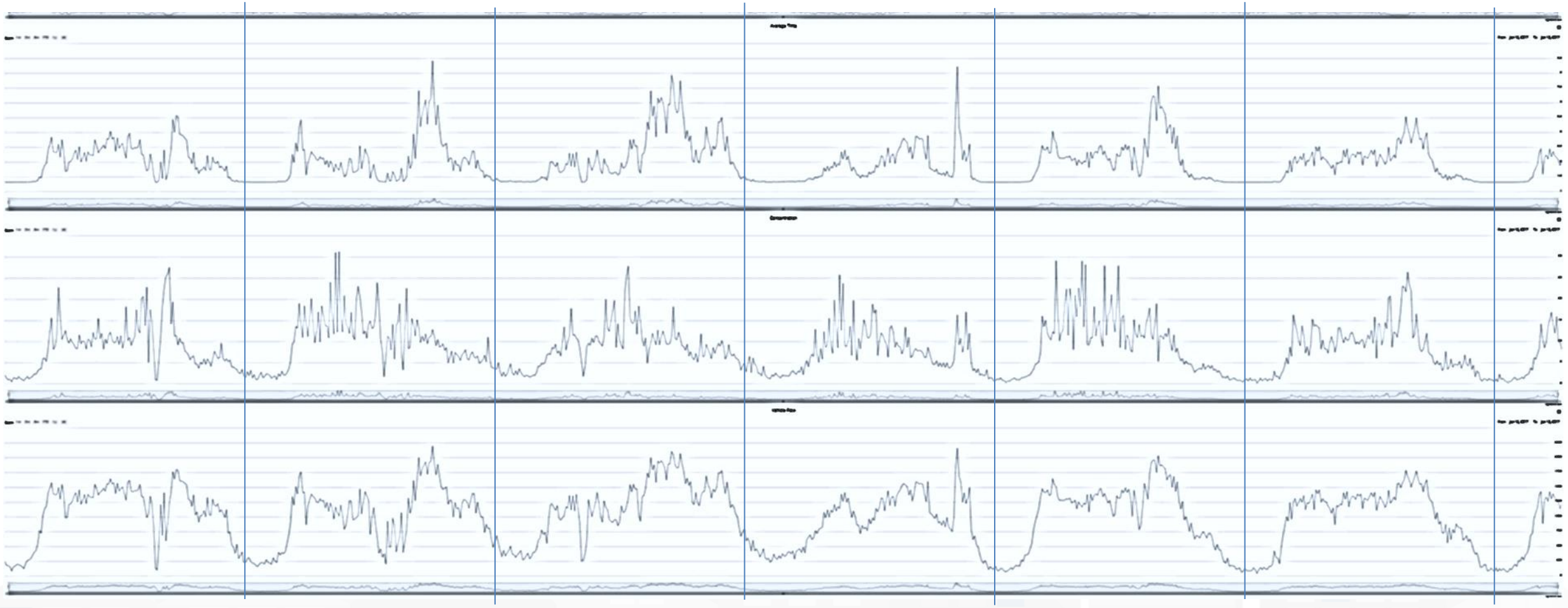
Traffic Flow Tools

Spire and Virtual Spires (cameras), Bluetooth, ...

Specifically located: along, around, on gates, on x...



Traffic Flow data



- Day by day traffic flow, on the week data from 3 sensors

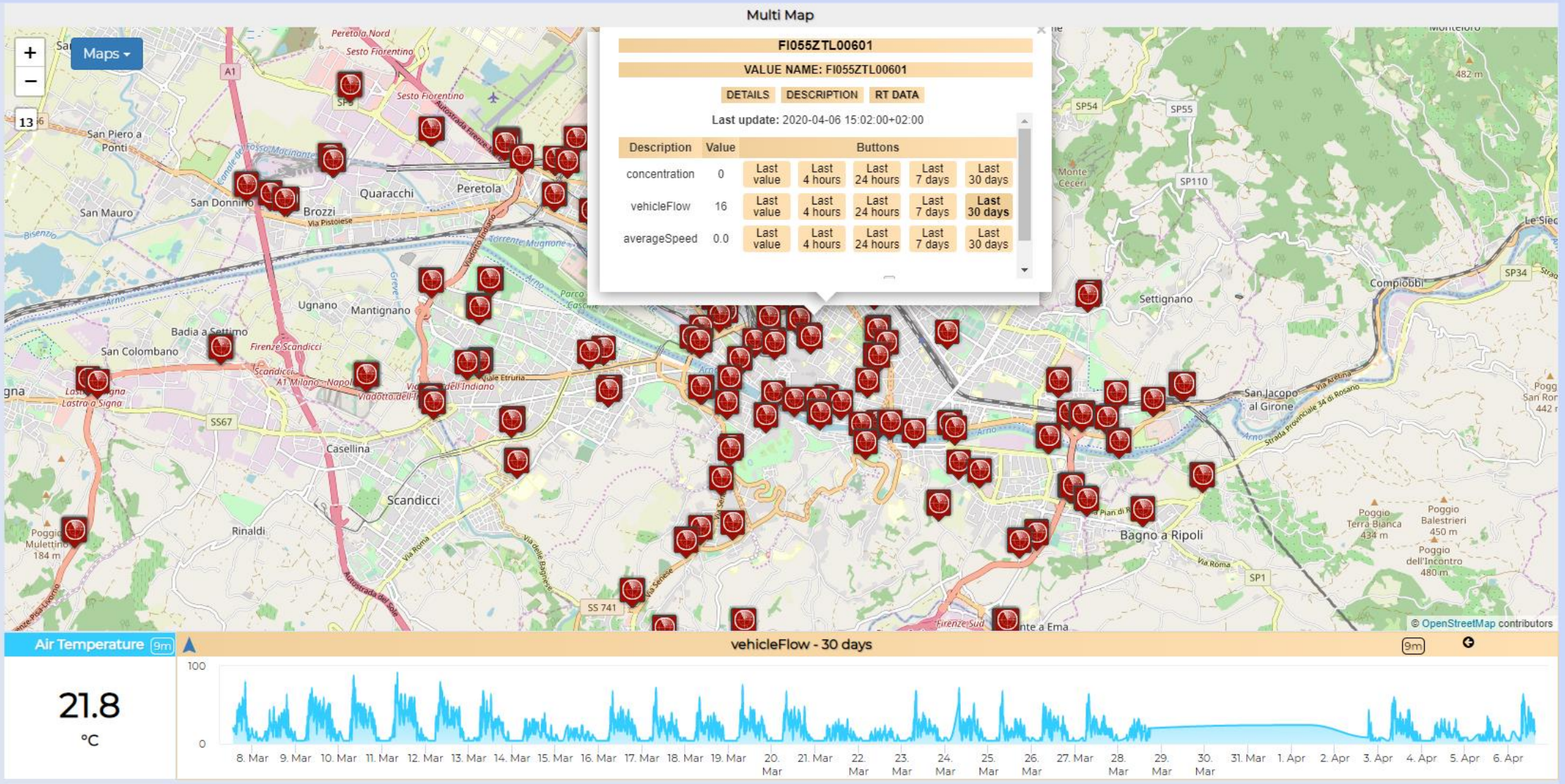
Firenze - Trafair - AirQuality Heatmaps

This dashboad 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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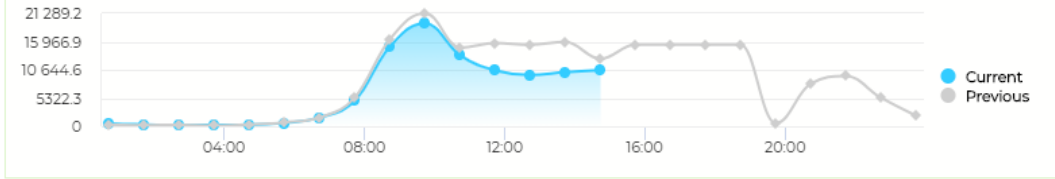
Traffic Flow Monitoring - Firenze - Cloned2

Wed 11 Nov 15:01:32

 # IN FLOW 9m

10549 #ofvehicles

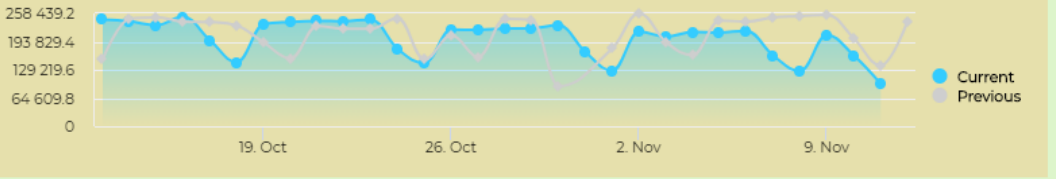
Firenze IN Traffic Flow (number of vehicles) 9m



Inc Daily Inp... 9m

97137 #ofvehicles

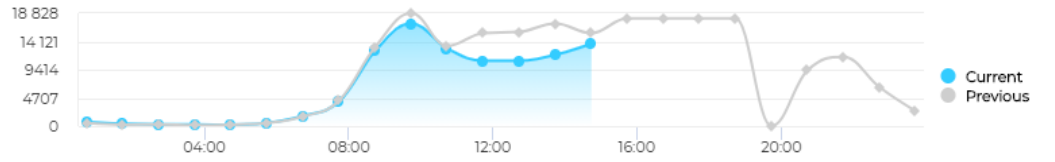
Daily Inputs (monthly) (last value is incremental, real time) 9m



 # OUT FLOW 9m

13720 #ofvehicles

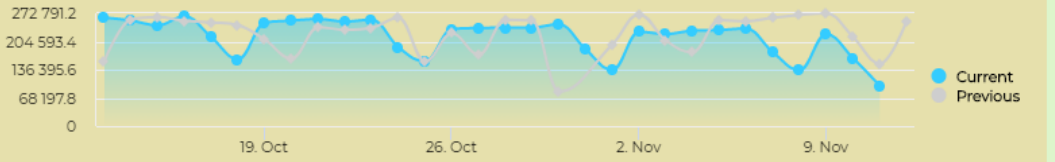
Firenze OUT Traffic Flow (number of vehicles) 9m



Inc Daily Out... 9m

97457 #ofvehicles

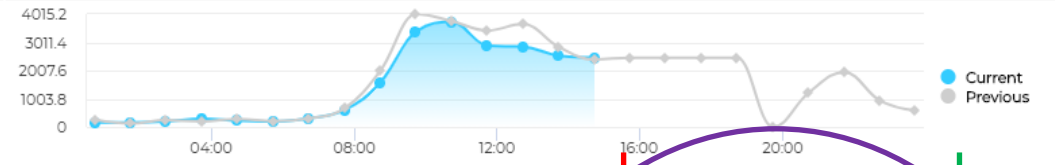
Daily Outputs (monthly) (last value is incremental real time) 9m



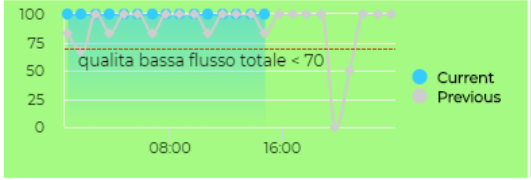
ZTL in 9m

2468 #ofvehicles

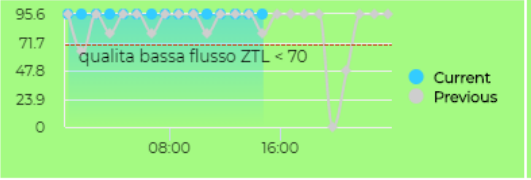
ZTL in Traffic Flow daily trend, entering in ZTL 9m



QoS as perc. of measures taken 9m



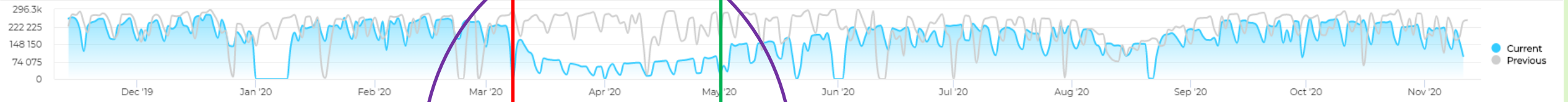
QoS as perc. of measures in ZTL 9m



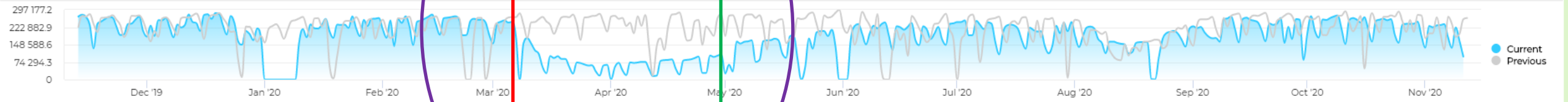
11/11/2020

15:01:33

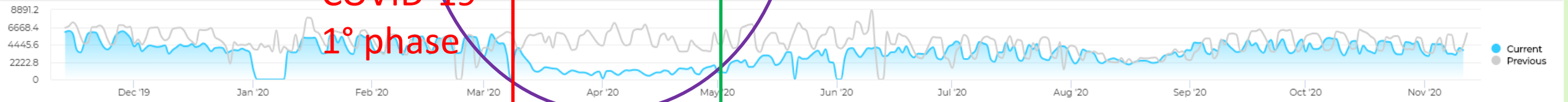
inflow total of the day, yearly 9m



outflow total over the day Yearly 9m



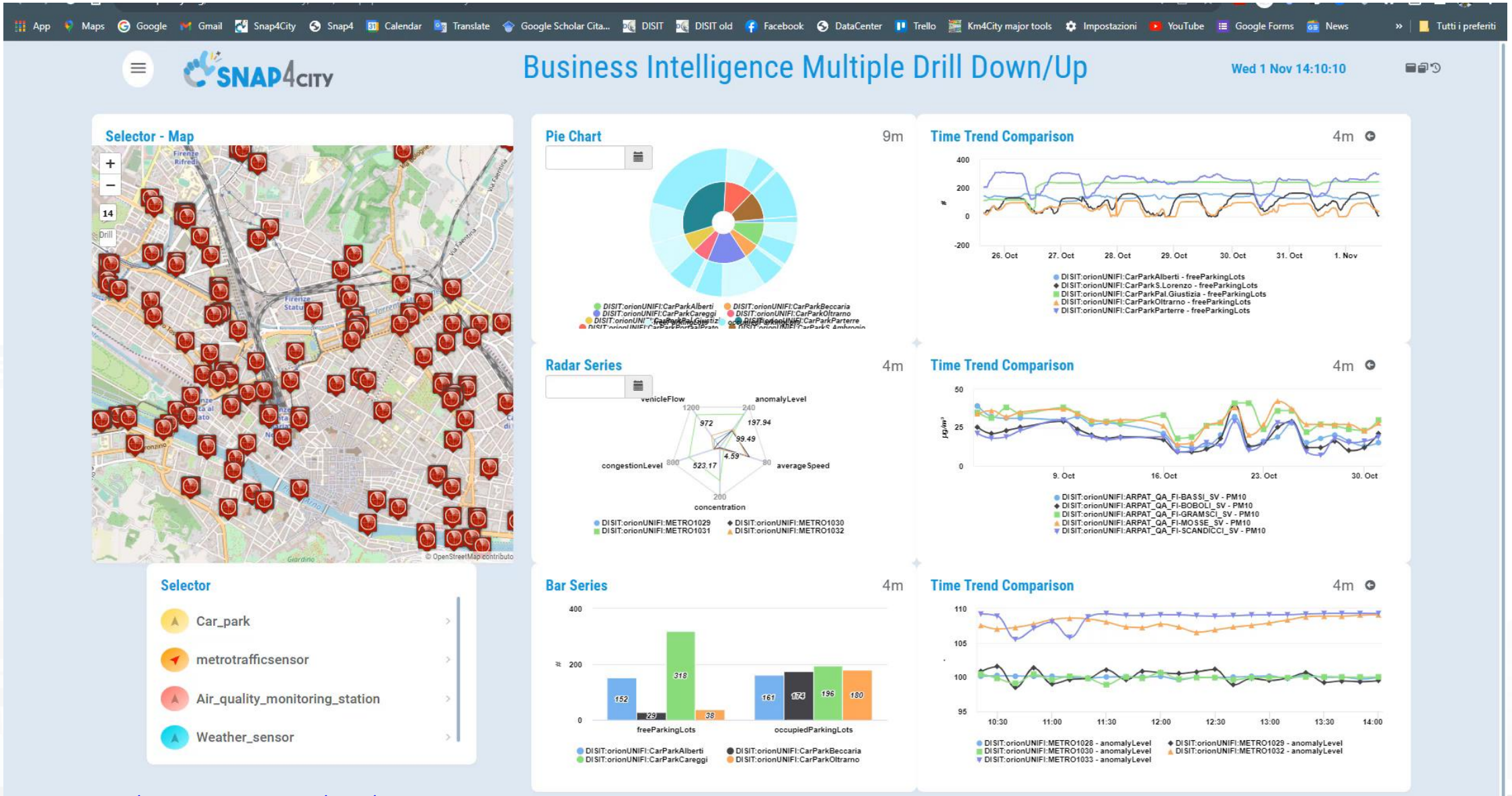
in ZTL yearly compare 9m



COVID-19

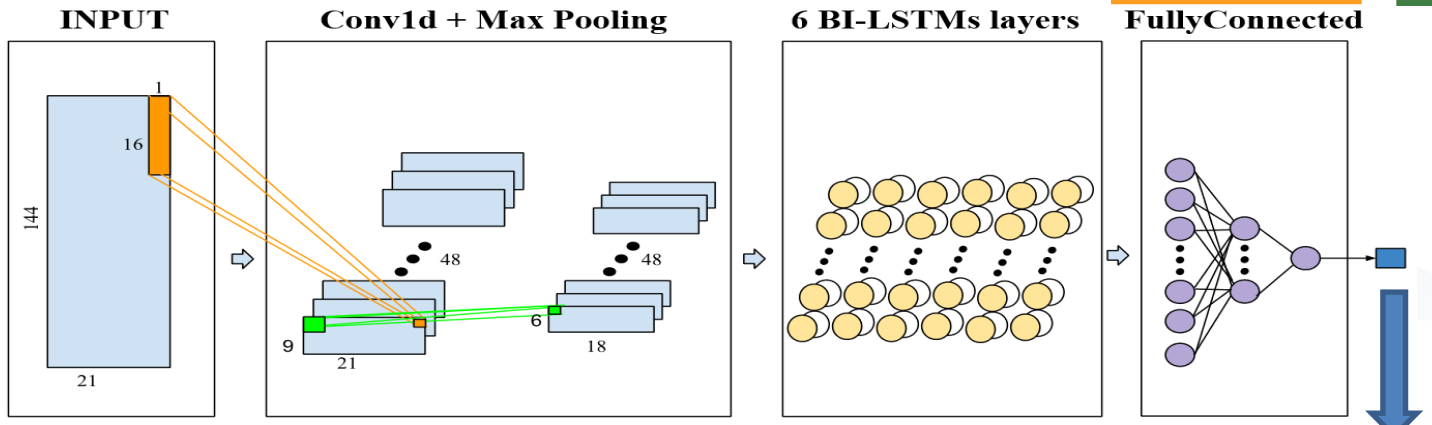
1° phase

BI on data



https://www.snap4city.org/dashboardSmartCity/view/Gea.php?iddasboard=MzcyNA==

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



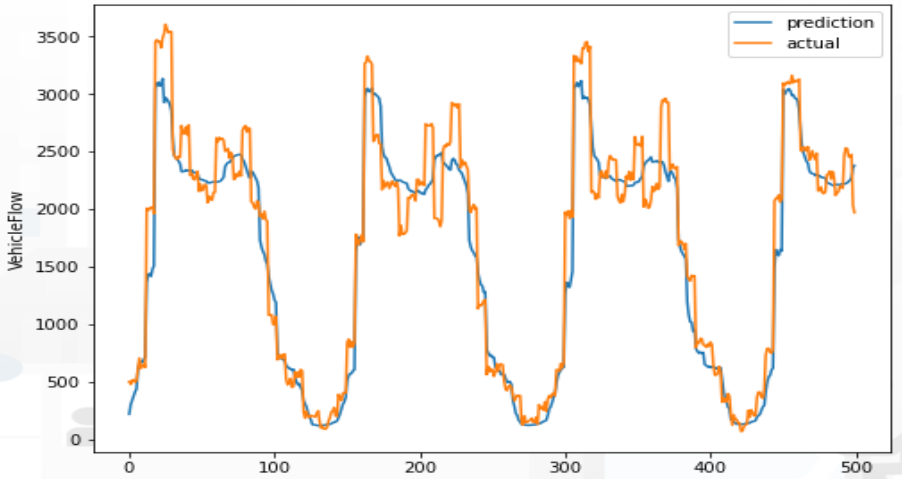
Urban data:

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

RF
XGBOOST
DNN
LSTM
BI-LSTM
Autoencoder BI-LSTM
Attention CONV-LSTM
CONV-BI-LSTM

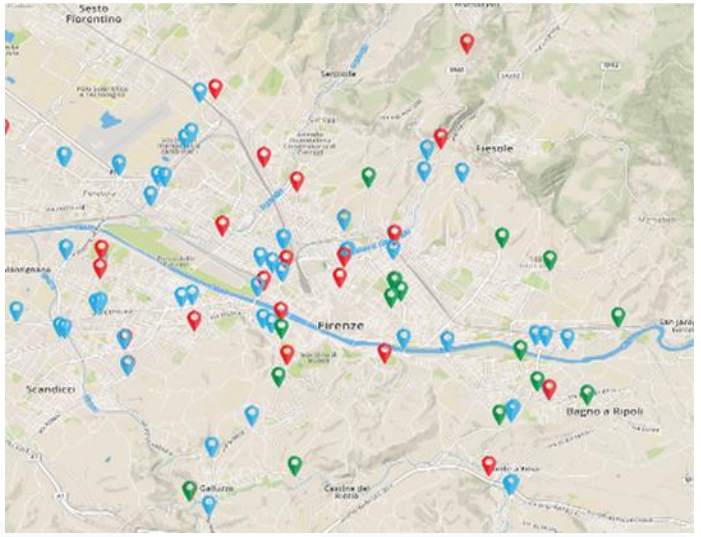
CONV-BI-LSTM

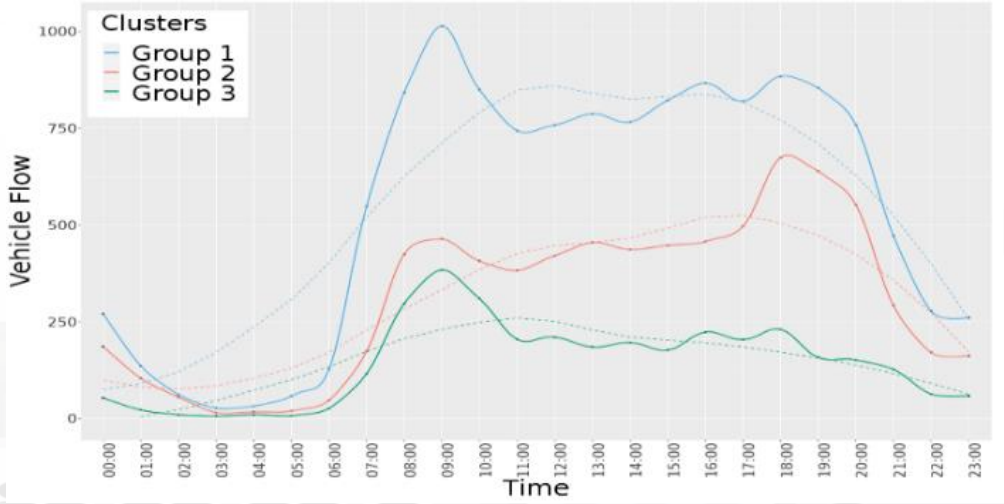
97% accuracy



Clustering traffic flow sensors

- The clustering has been performed on the basis of the time trend H24, considering the normalized vehicle flow measures.
- The optimal number of clusters turned out to be 3 and it has been identified by using **elbow** criteria
- **K-means** clustering method has been applied to identify clusters
  - The optimal number of clusters resulted to be equal to **3**, and it has been identified by using the **Elbow criteria**

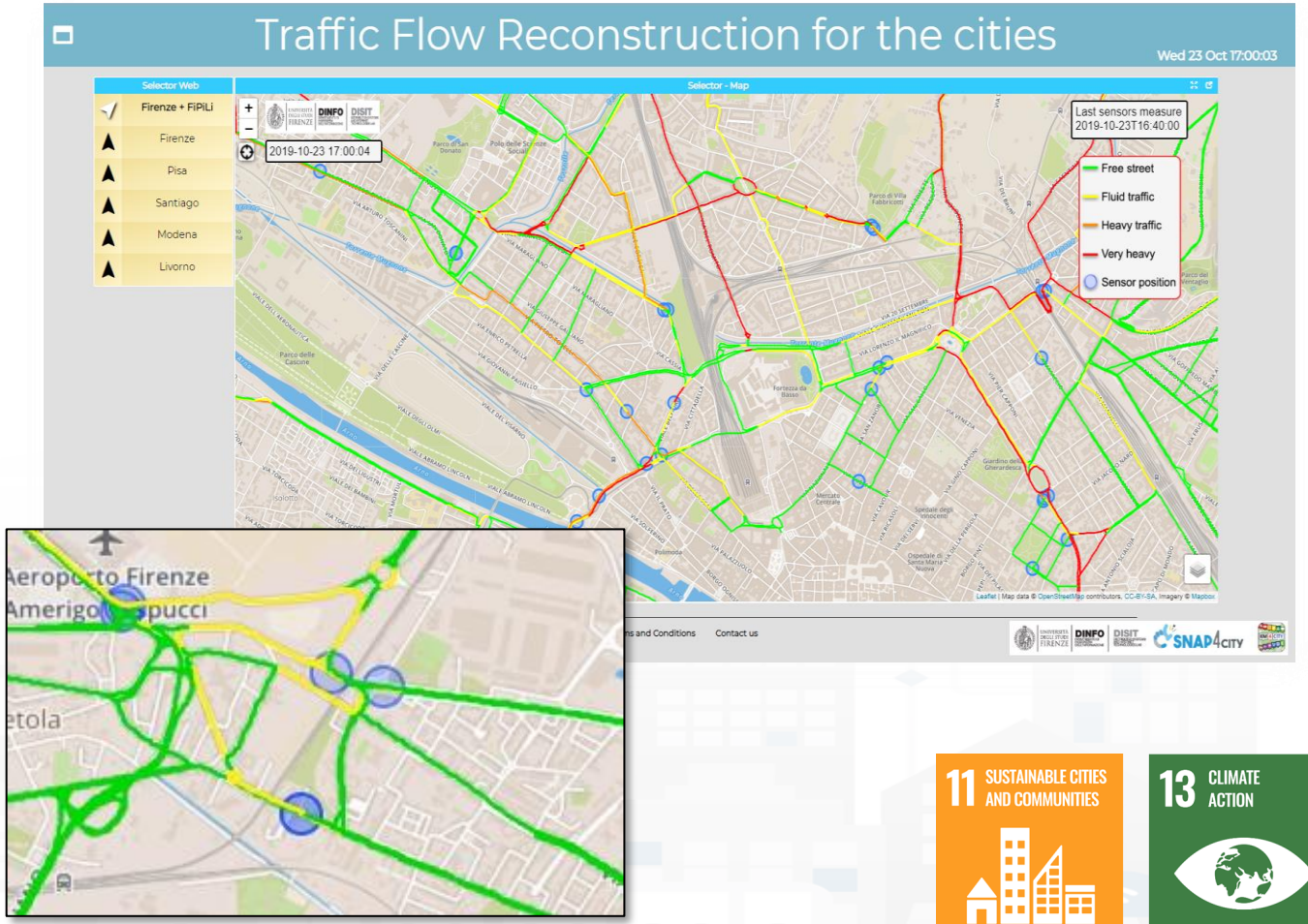




Best compromize

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



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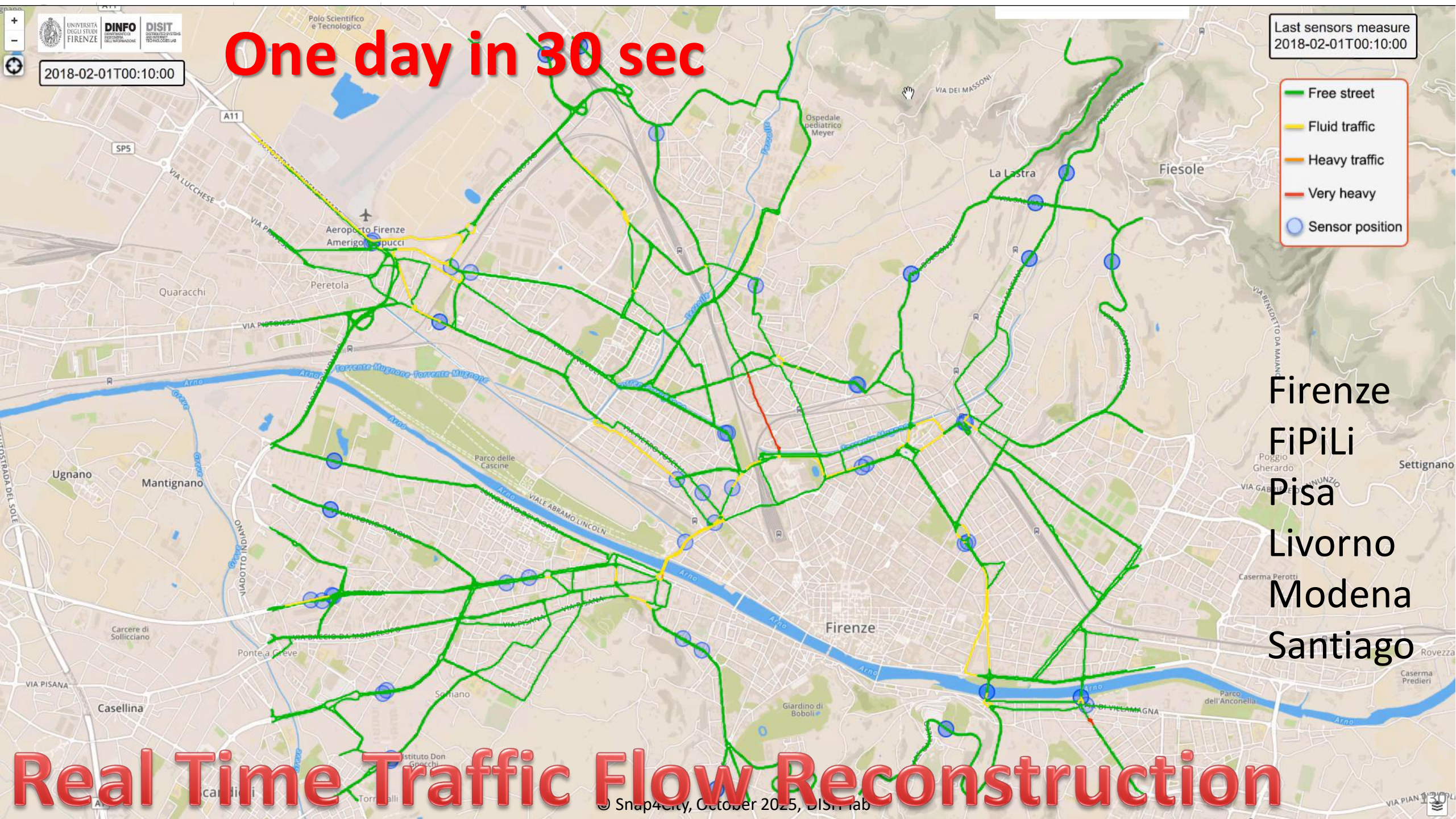
One day in 30 sec
2018-02-01T00:10:00
Last sensors measure
2018-02-01T00:10:00
Free street
Fluid traffic
Heavy traffic
Very heavy
Sensor position
Firenze
FiPiLi
Pisa
Livorno
Modena
Santiago
Real Time Traffic Flow Reconstruction
© Snap4City, October 2025, DISIT Lab

Traffic Flow Reconstruction for the cities

Sun 3 Nov 20:37:43

Santiago di Compostela

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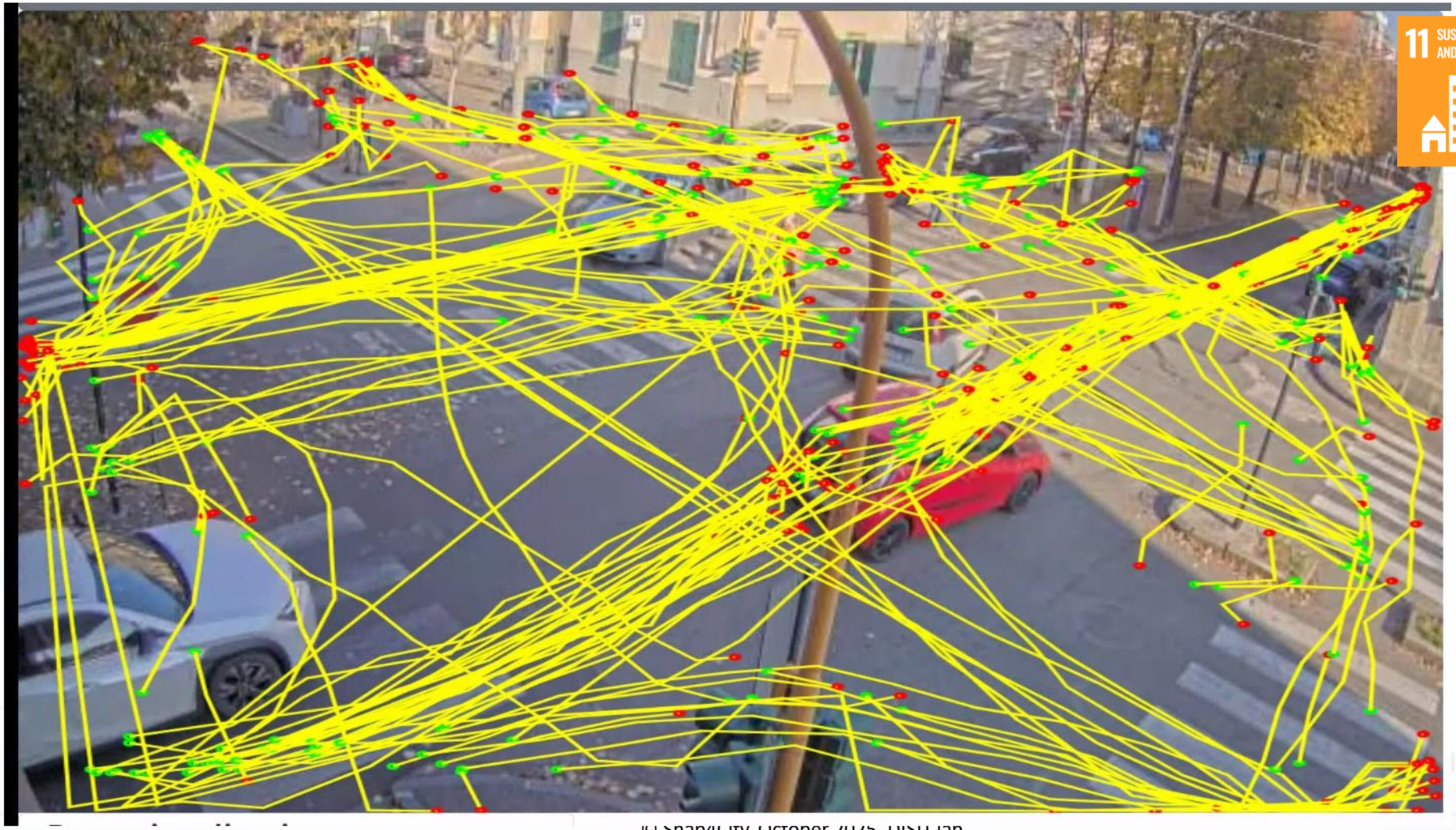
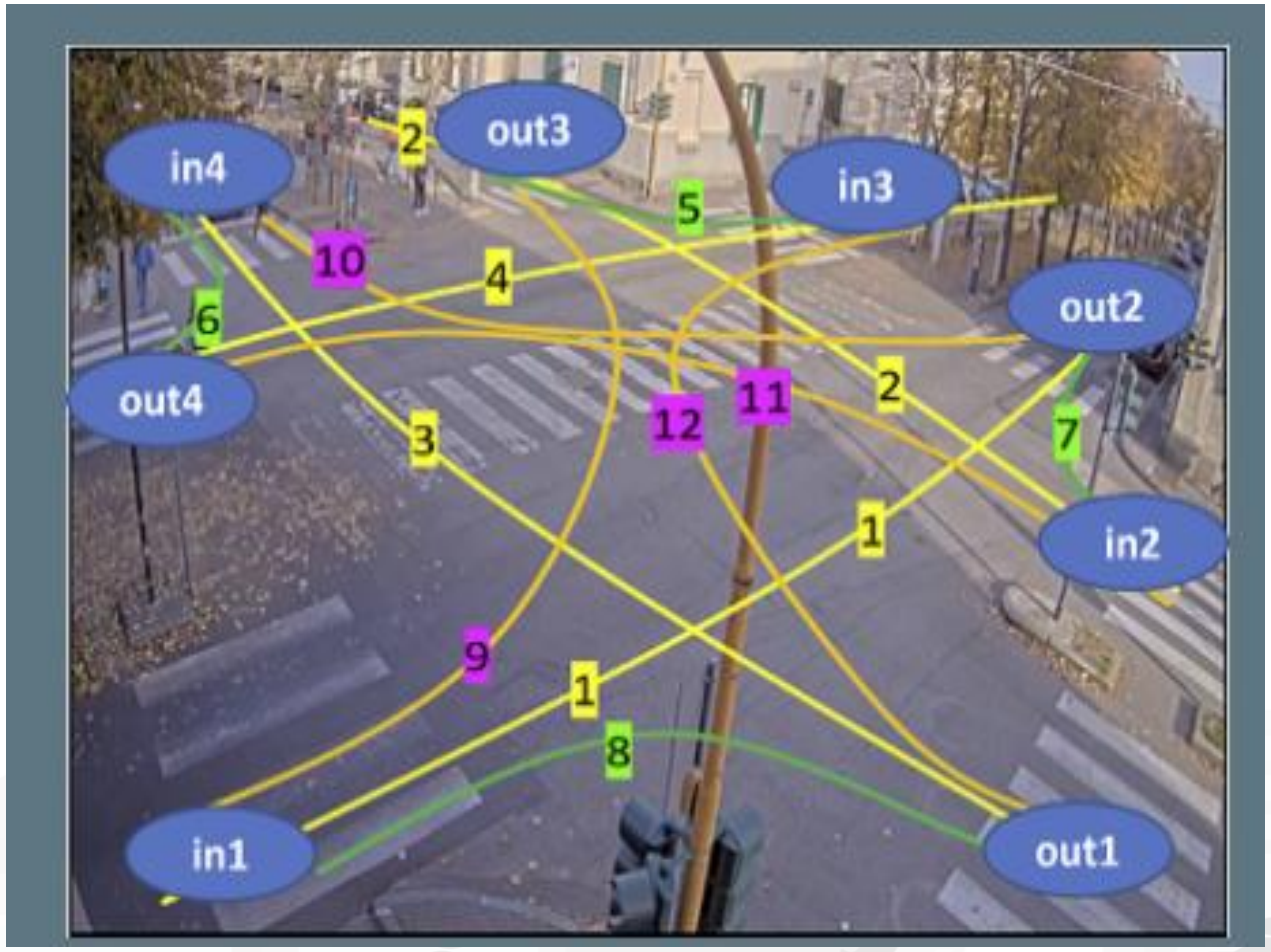
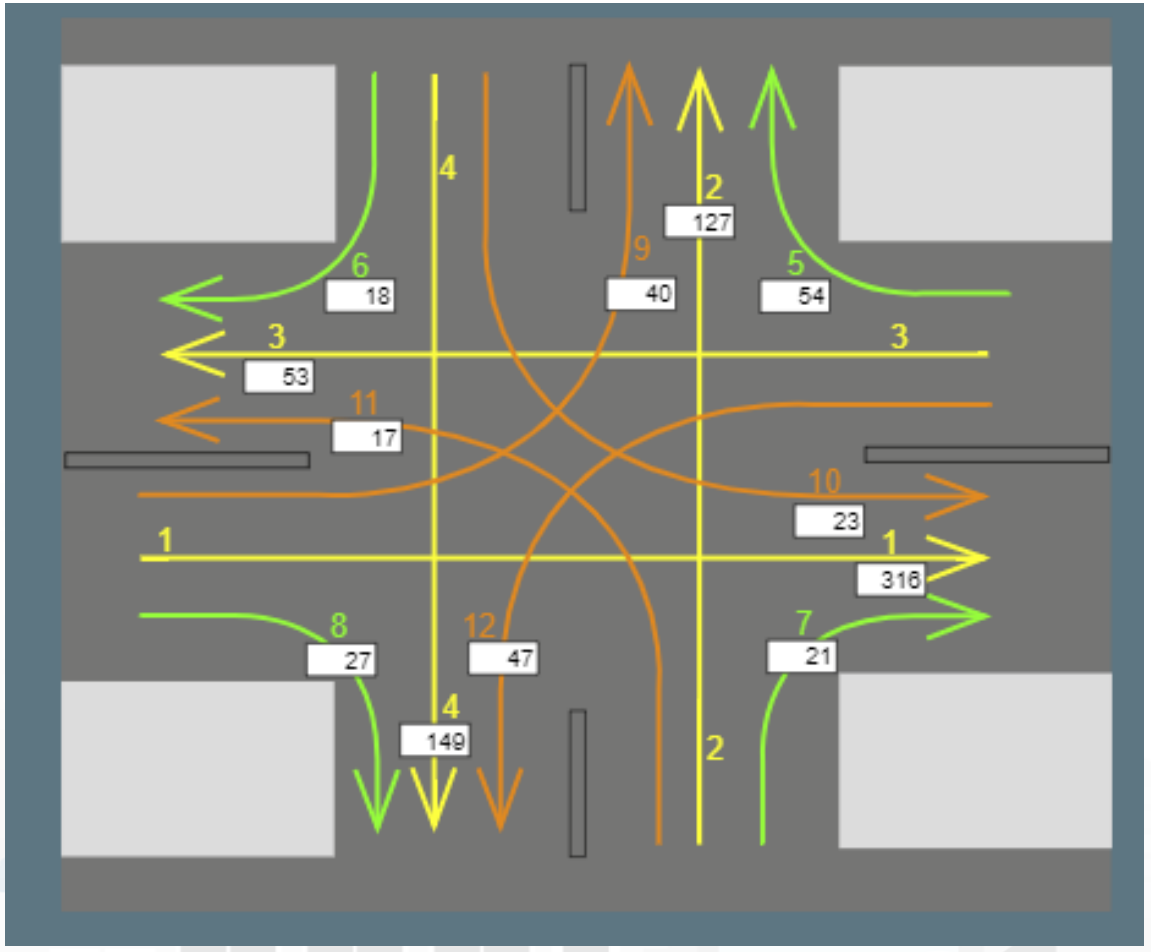


11 SUSTAINABLE CITIES AND COMMUNITIES

Real time Clustering: legenda and synoptic



Legenda

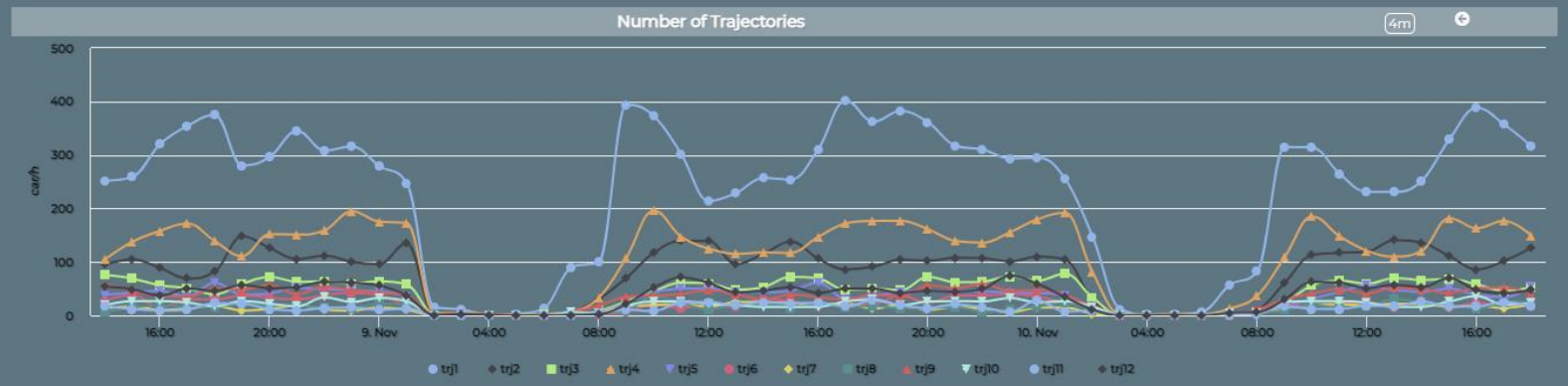


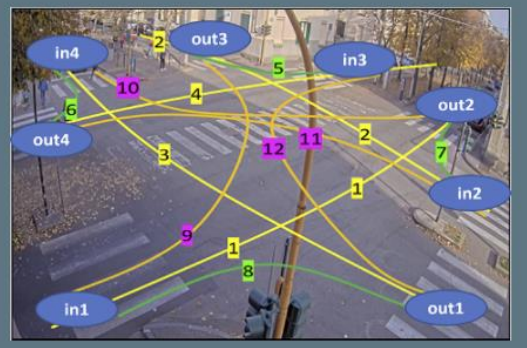
Synoptic with real time data

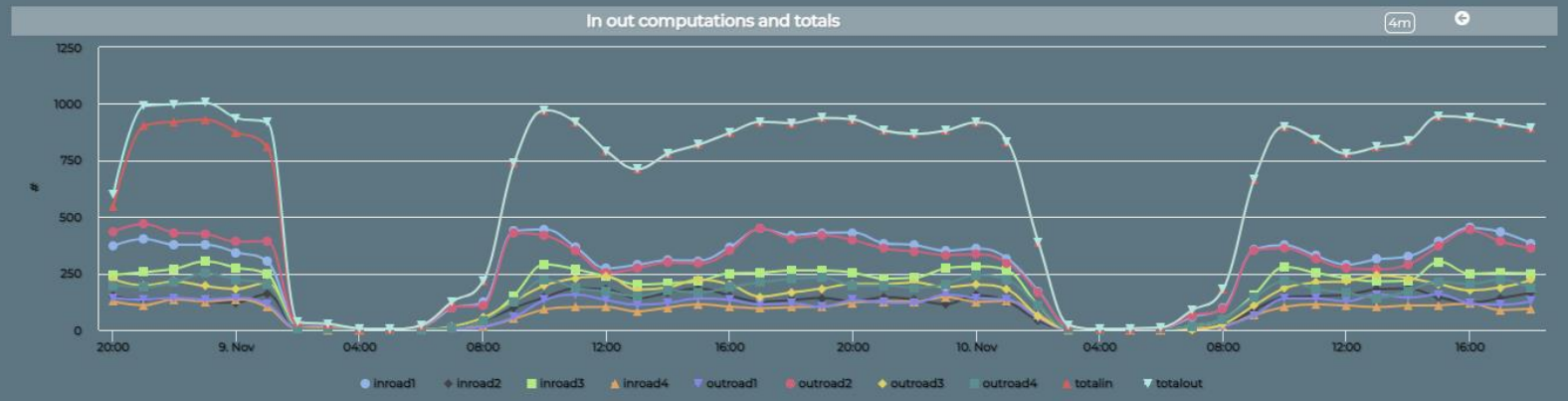
Venaria Reale

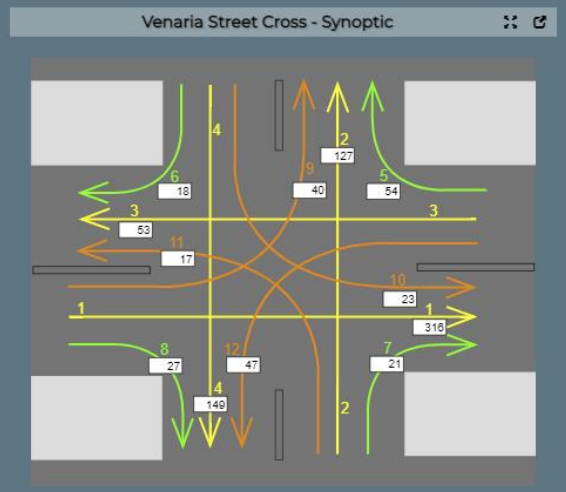
Monitoring Cross Road Venaria - (AXIS Camera)

Wed 10 Nov 18:50:53







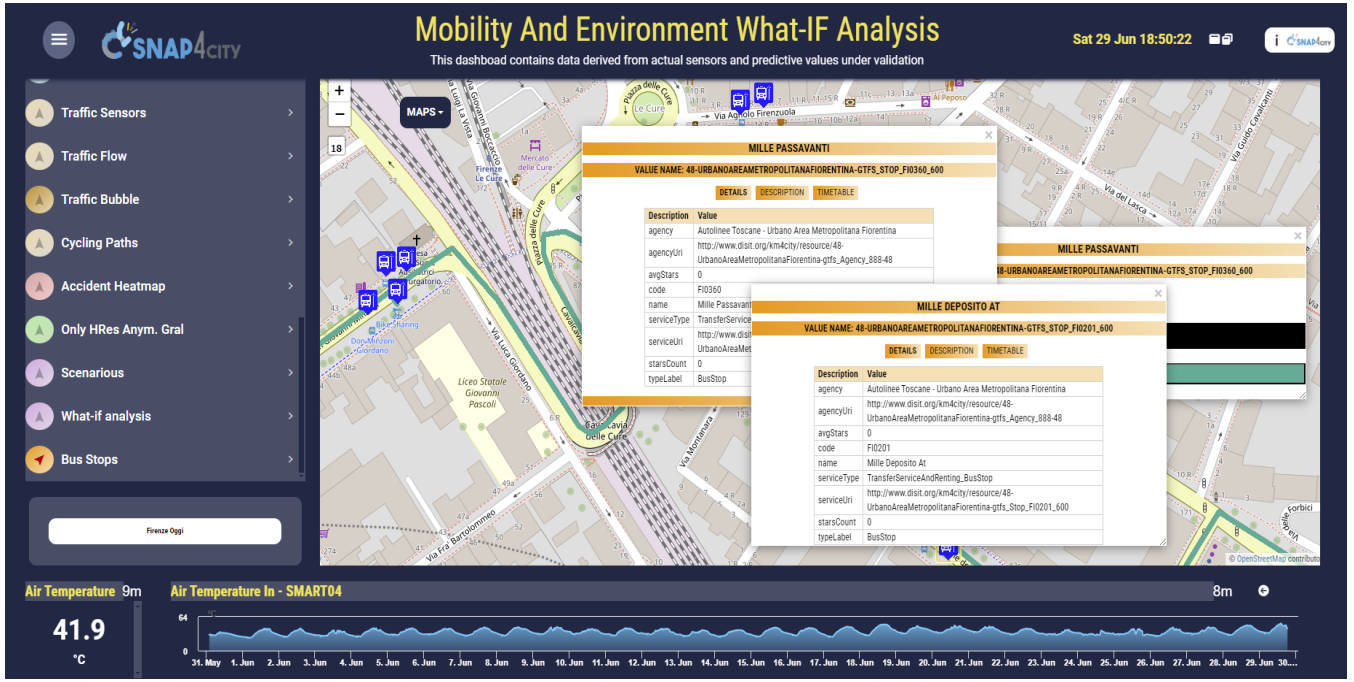


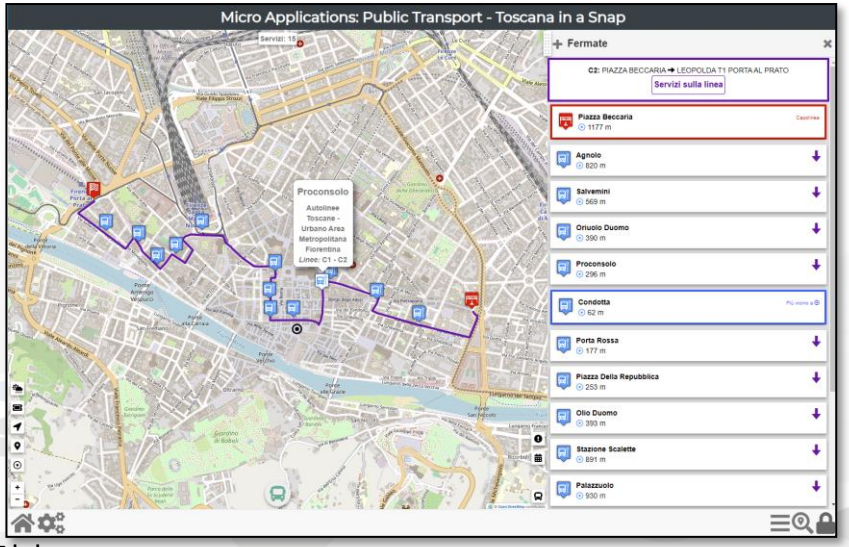
https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzI5Ng==

Public Transport Offer

Public Transport Offer

- Via
  - Dashboards
  - MicroApplications
  - Mobile Apps
  - ServiceMap





Public Transport Information/file/streams

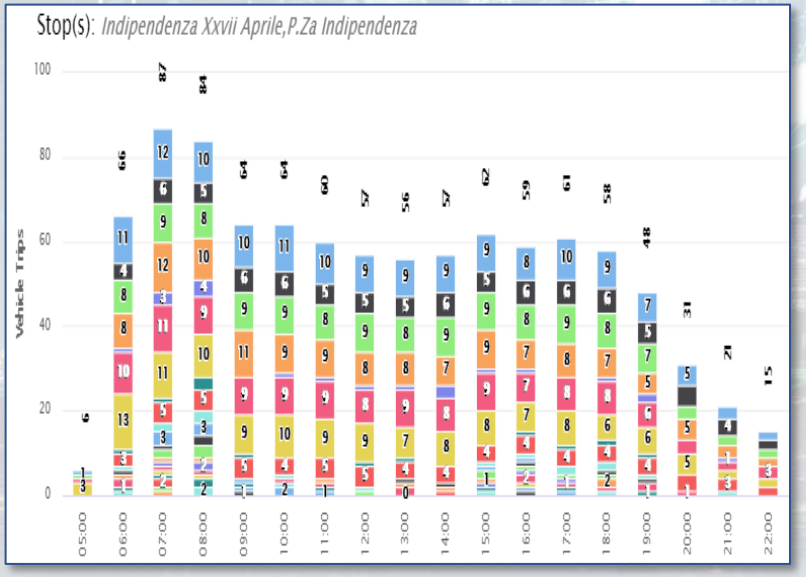
- **Other sources as ODM and POI: parking, sharing, etc.**
- **Models used for**: busses, train, ferry, metro, tramways, etc. **Including**:
  - Public Transport Lines, Rides with paths and timeline, stops, polylines for paths, etc.
  - real time data about the position of the vehicles: train, busses, etc.
  - Multi operator data
- **Information is modelled as**
  - **GTFS** format: multiple files in XML, **Transmodel** format, **Netex** format
- **GTFS files can be ingested on Snap4City via**
  - **Python** which takes GTFS files and convert them in triples «.n3» file for the Knowledge Base
    - https://github.com/disit/smart-city-etl/tree/master/TrasformazioneTPLBus_new_model/Triplification/Models
    - Former version: https://www.snap4city.org/download/snap4cityETL/TPL_bus_gtfs/
  - **GTFS RT can be ingested via IoT App and sent to the Broker**
  - **Chouette** and then using a Python developed by **Snap4City to converter** to produce Triples for the Knowledge Base, service map
    - https://github.com/disit/snap4city/blob/master/Snap4CityGTFS/chouette-gtfs-n3.py
- **Transmodel (EN12896) or Neptune files can be ingested in Snap4City via**
  - **Chouette** and then, with a certain level of adaptation,
    - using a Python developed by **Snap4City to converter** to produce Triples for the Knowledge Base, service map
    - https://github.com/disit/snap4city/blob/master/Snap4CityGTFS/chouette-gtfs-n3.py

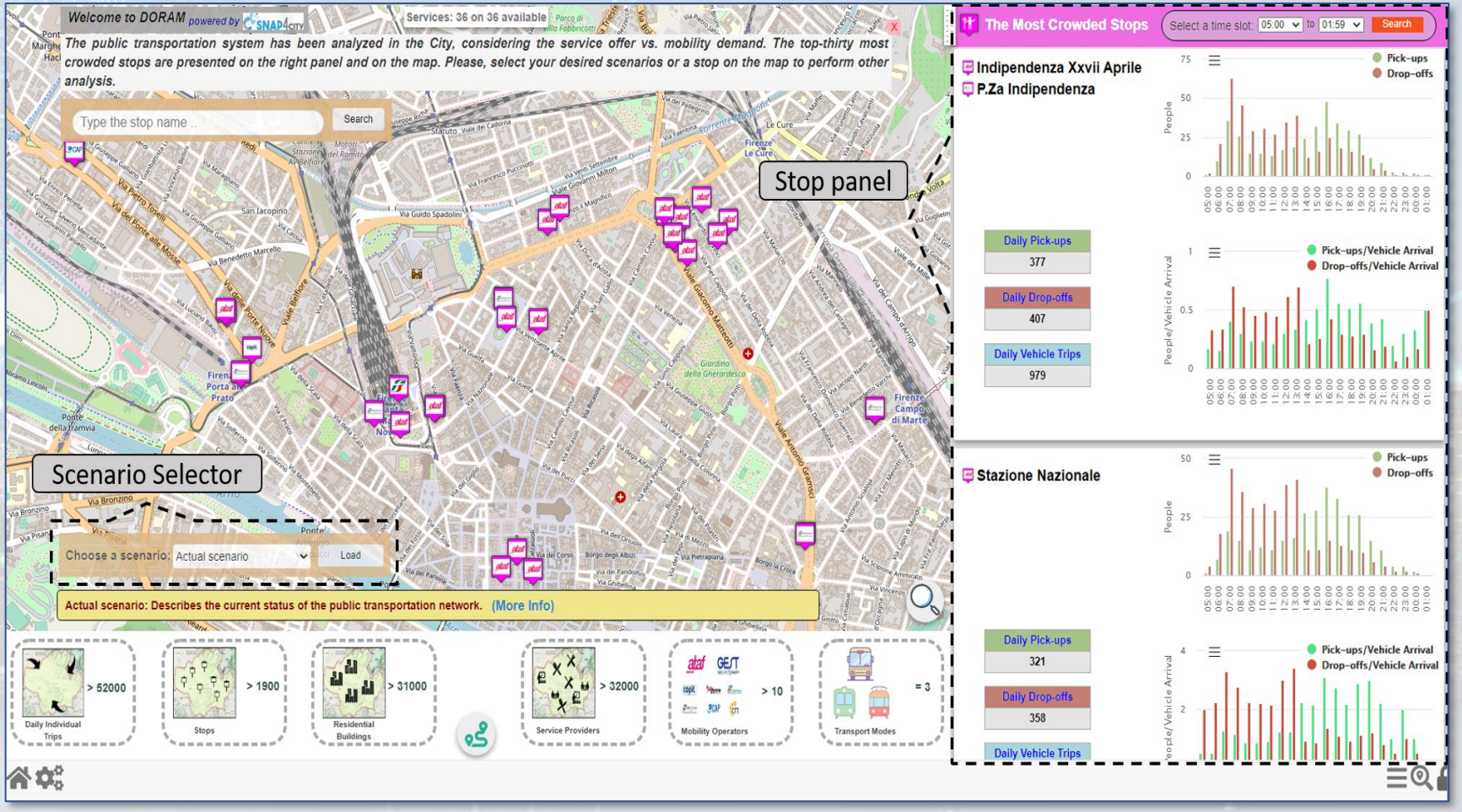
Mobility Demand vs Transportation Offer

What-if Analysis on Pub Transport

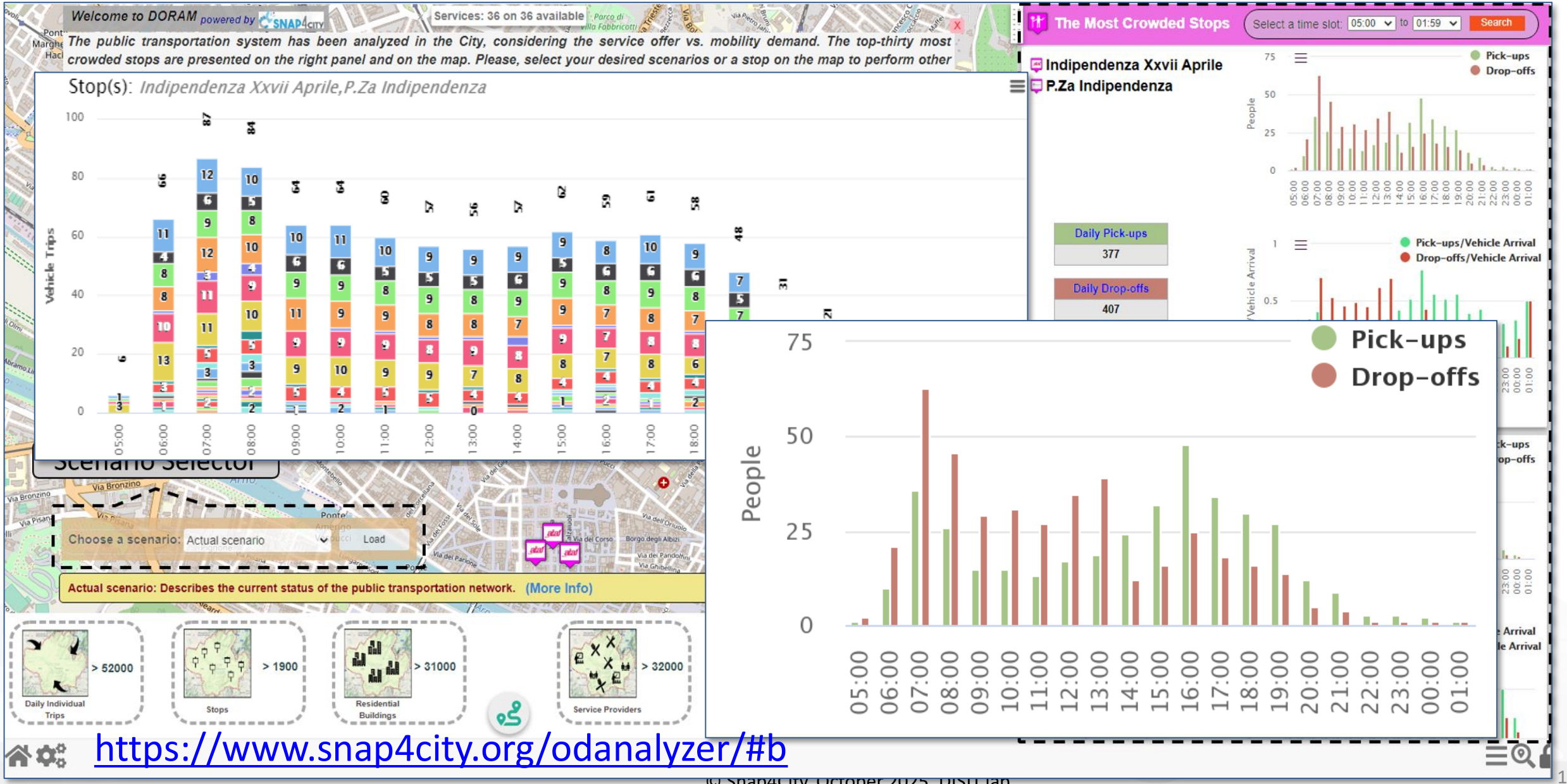
- Simulation / analysis of Mobility Demand wrt Transportation Offer
- Definition of scenarious impact on
  - Traffic, Pollutant, parking, public transport, private flows, etc.
  - KPI analysis

Public Services



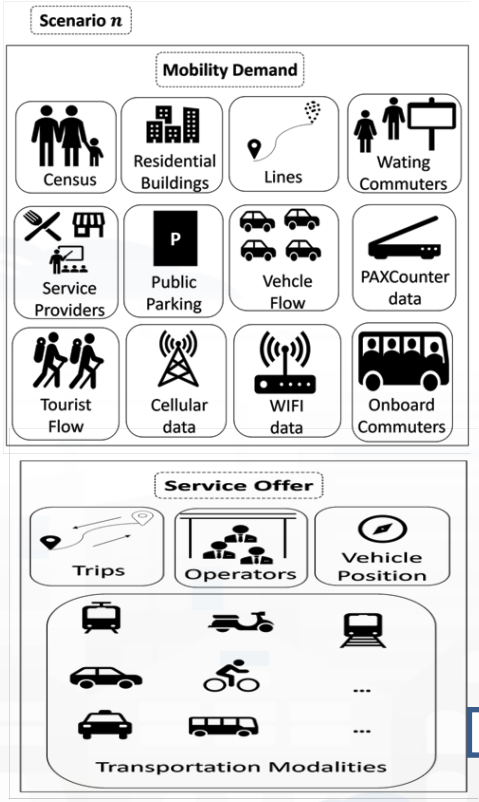


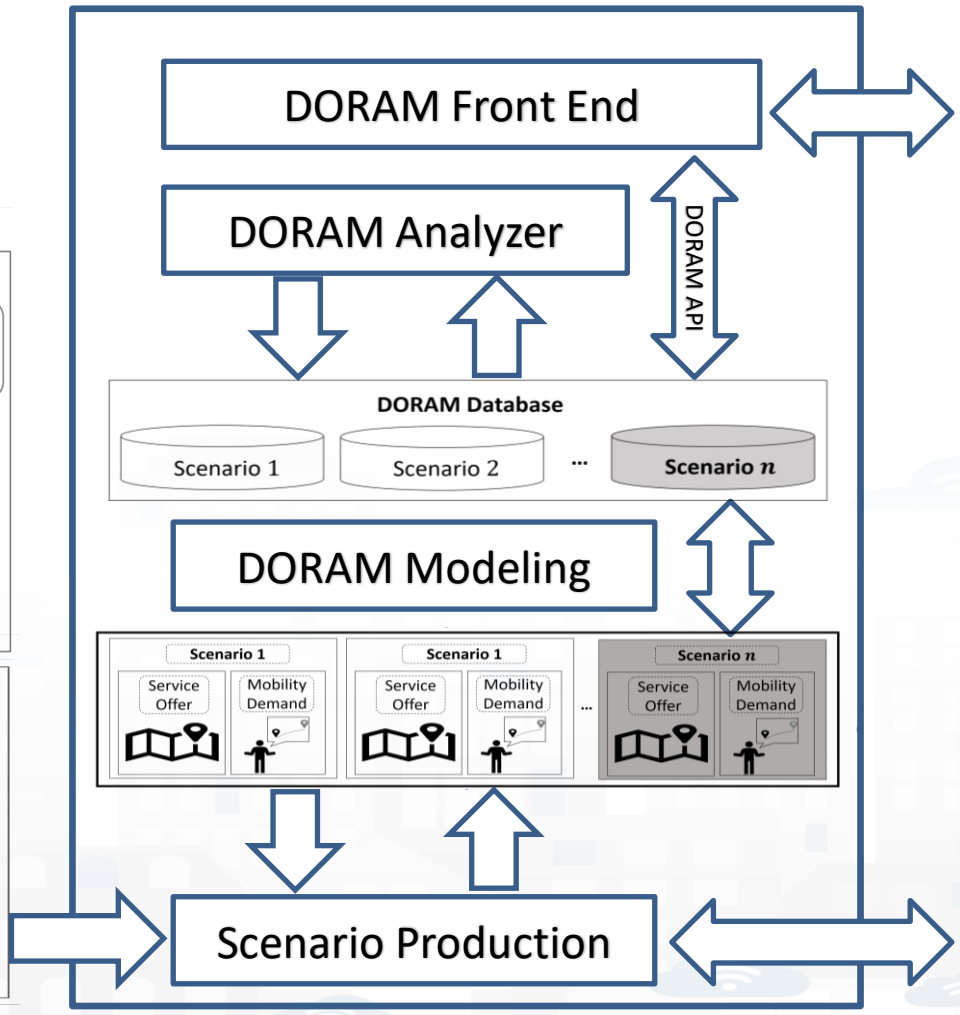
DORAM

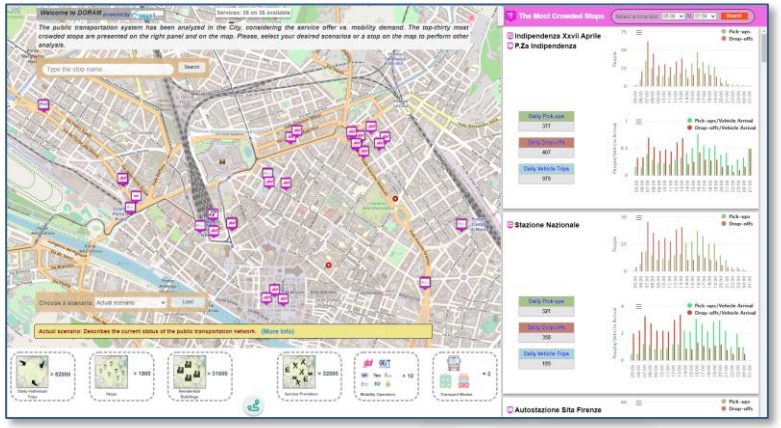


https://www.snap4city.org/odanalyzer/#b

DORAM

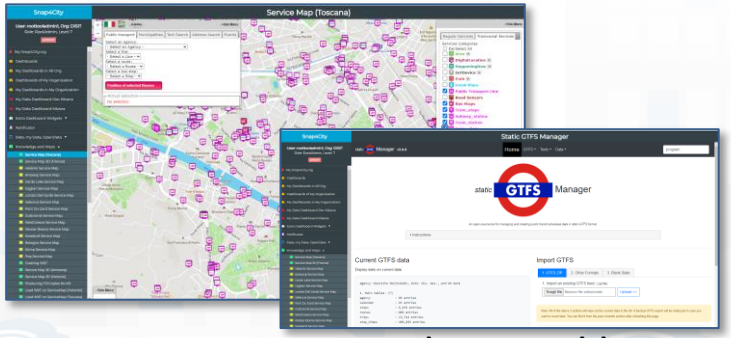






DORAM tool

Snap4City tools for City data



GTFS Editor and browser

https://www.snap4city.org/odanalyzer/#b

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

SNAP4CITY KM4CITY

SNAP4CITY

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

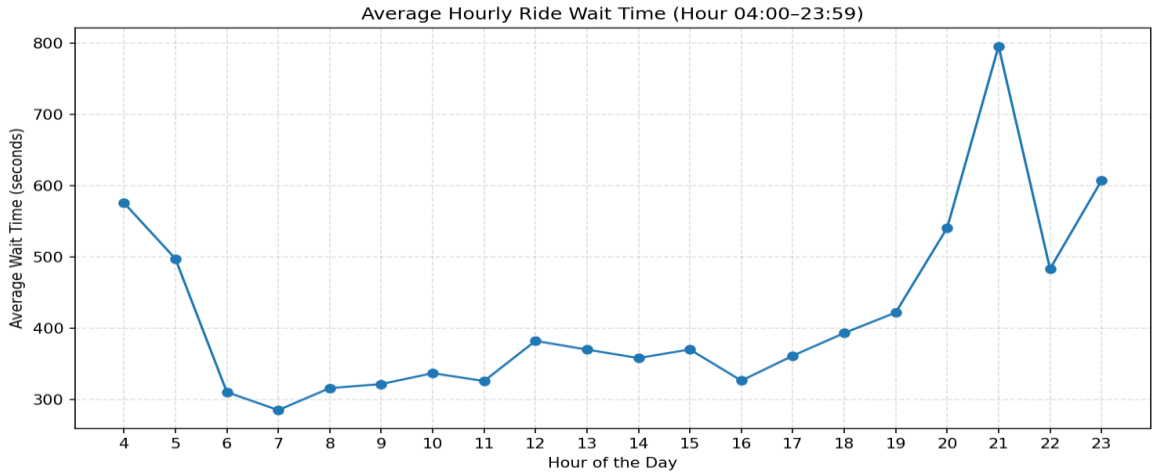
Simulation: 2025/06/22 11:53:27

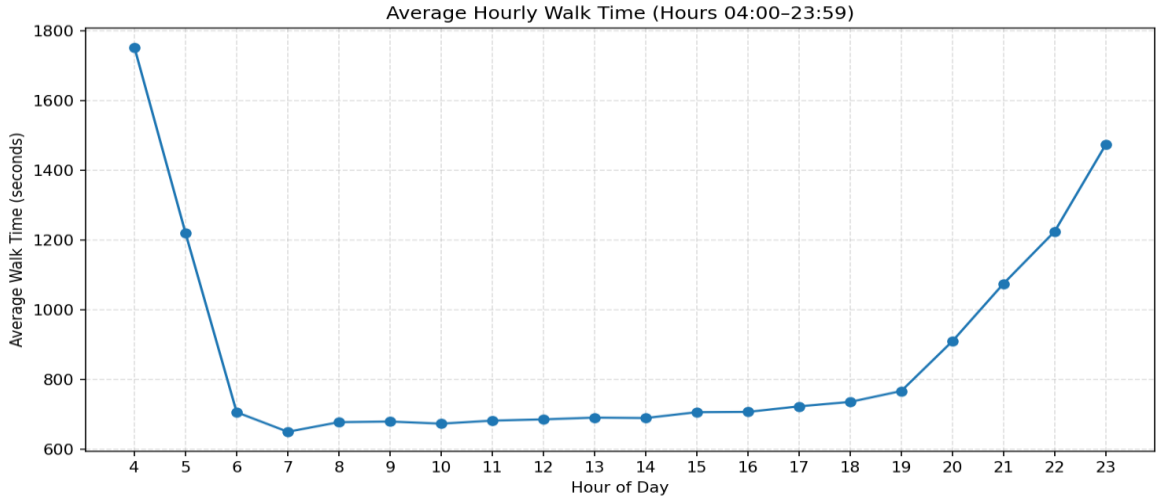
My Profile

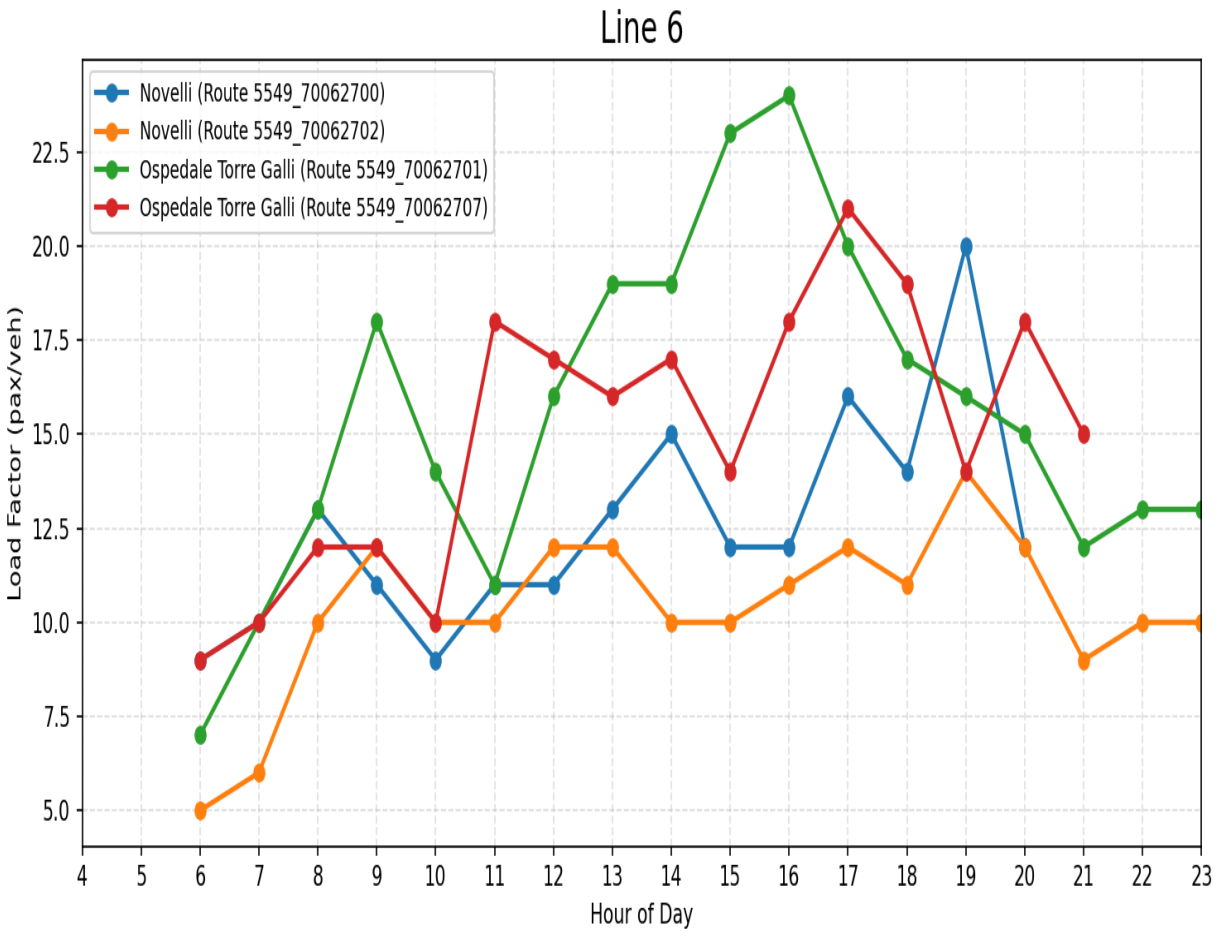
KPI on Match D-O of Collective Transport

- **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.
- **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.

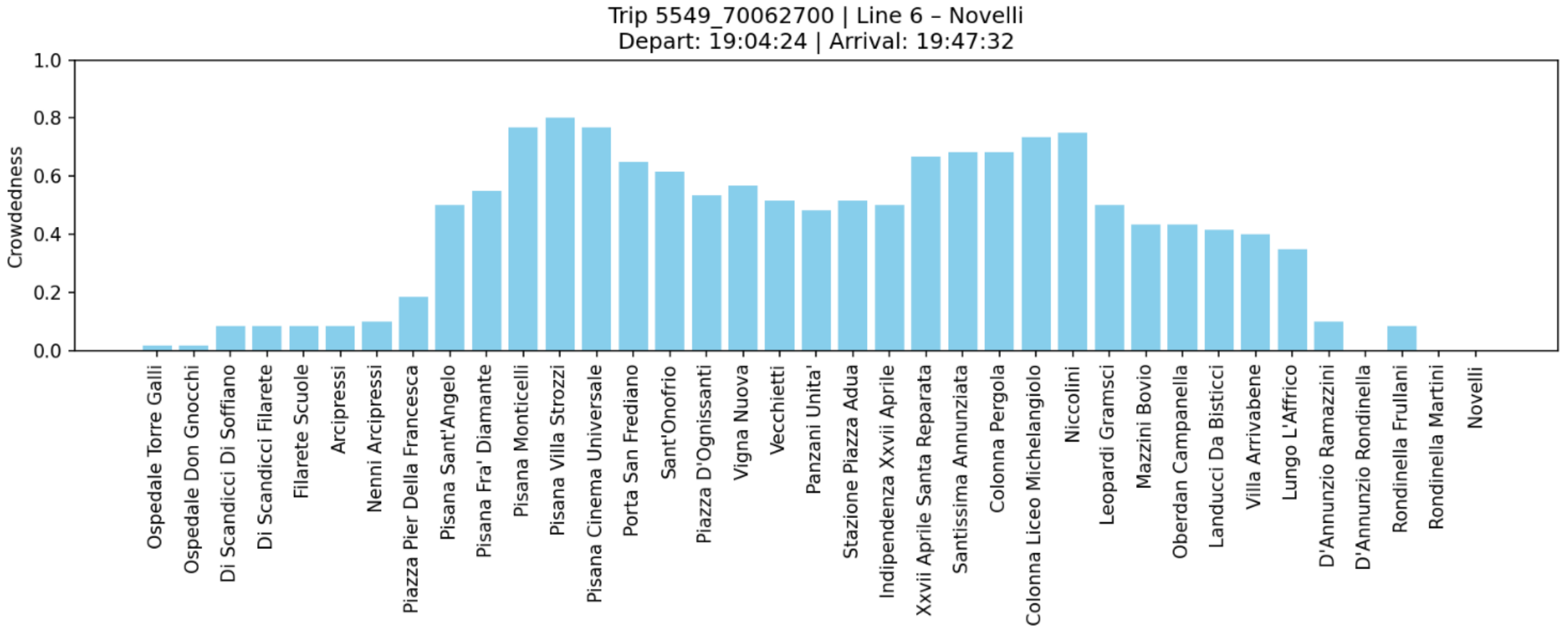
The typical working day





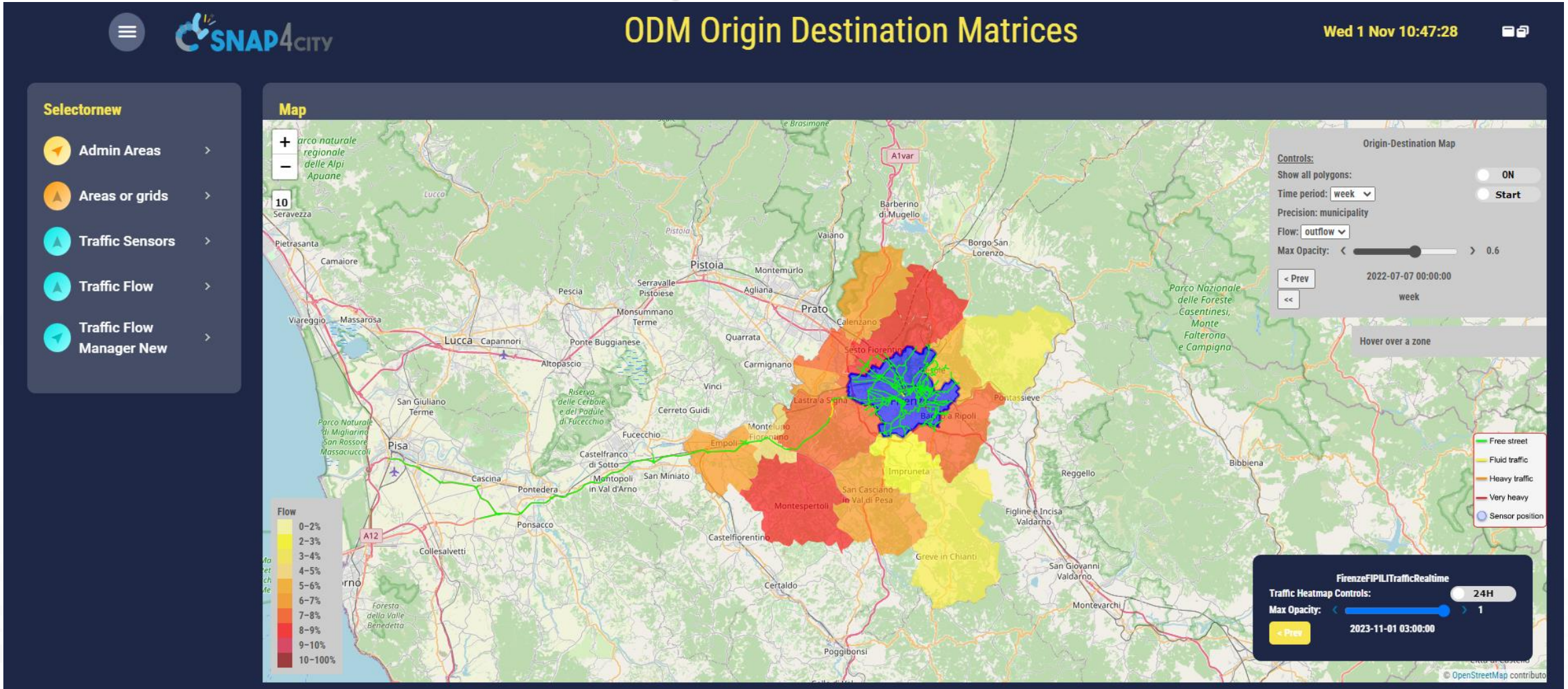


Crowdedness



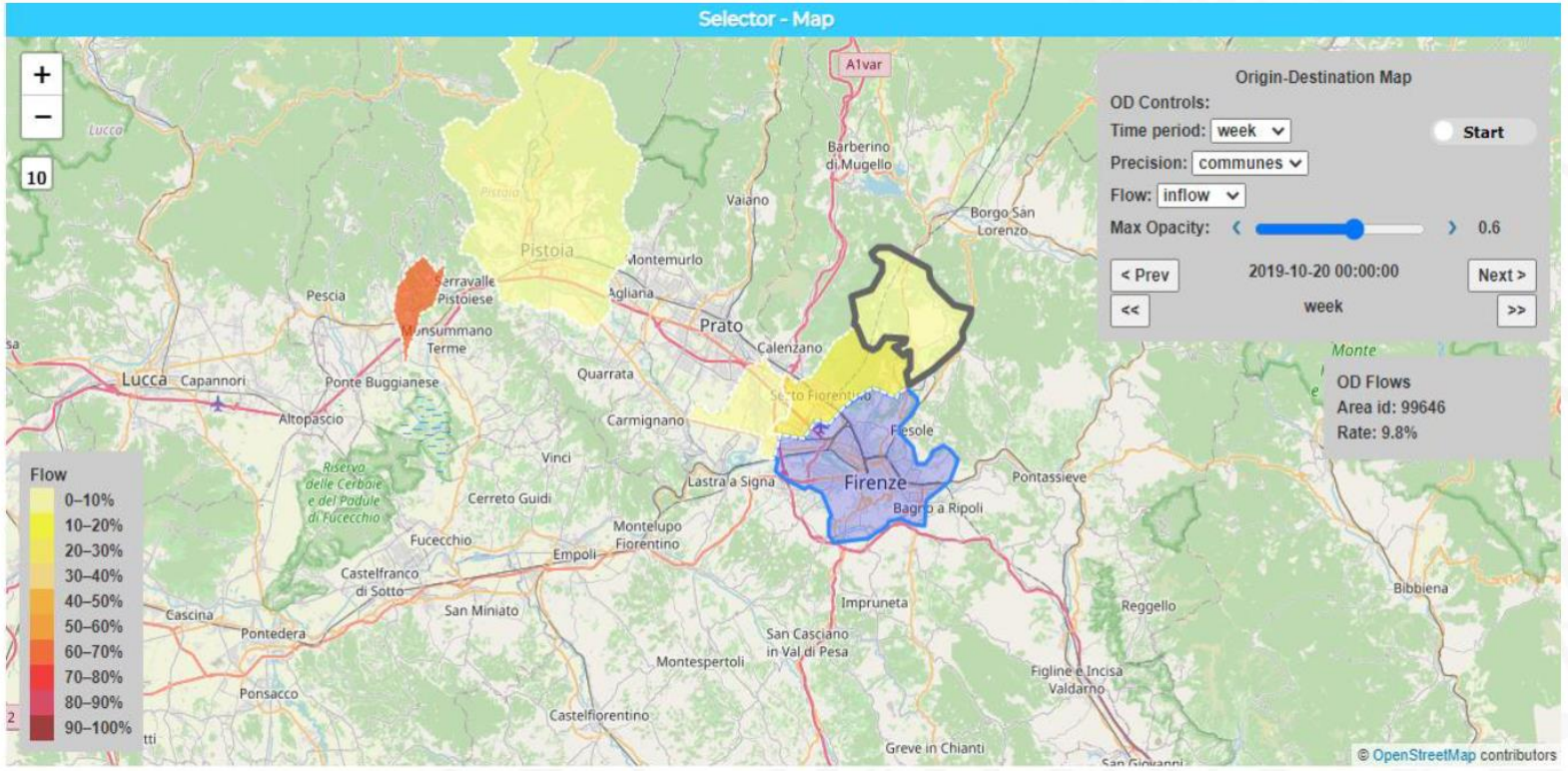
Origin Destination Matrices

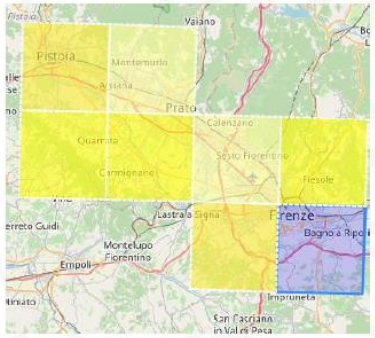
ODM, Traffic Flow

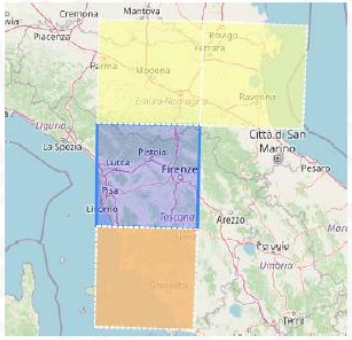


https://www.snap4city.org/dashboardSmartCity/view/Gea-Night.php?iddasboard=Mzk3Nw==

Different Origin Destination Matrices





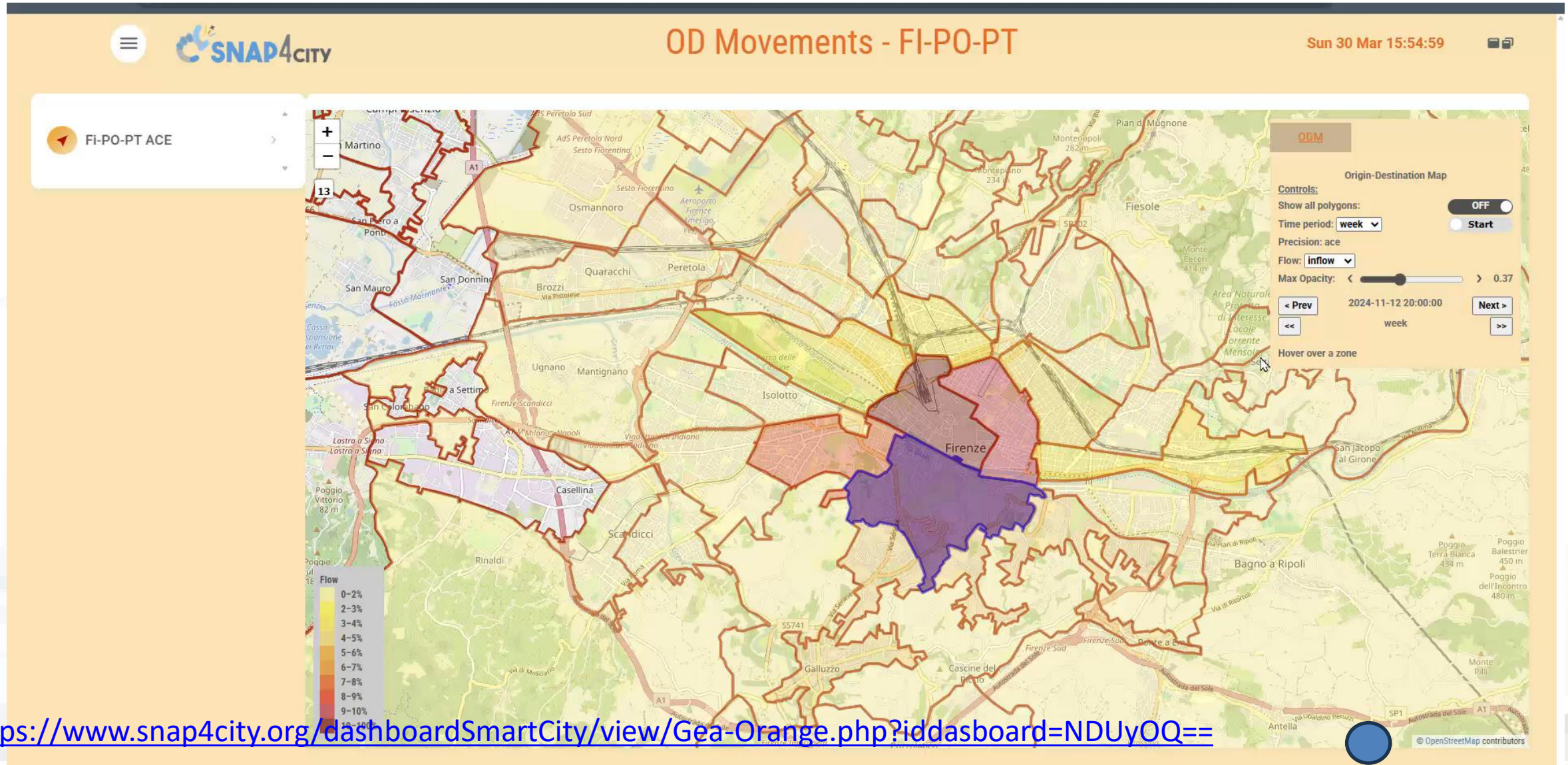


- **Get specific value**
- **Time window**
- **Opacity**
- **Animation**
- **Inflow/outflow**
- **Sequence of OD matrices: next/prev**

shapes

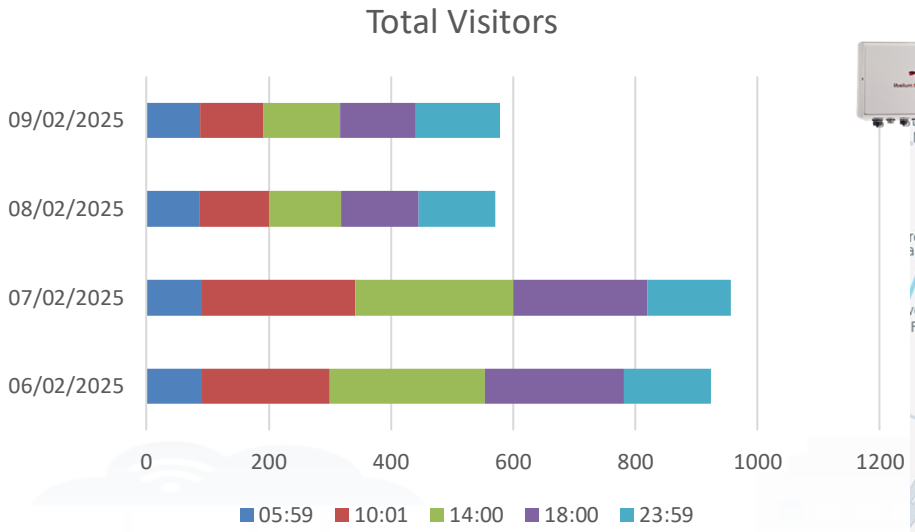
- **Shapes**: city, region, territories, etc.
  - GADM https://gadm.org/ , and ACE
- **Squared** MGRS:
  - 1m, 10m, 100m, **1Km, 10Km, 100Km**

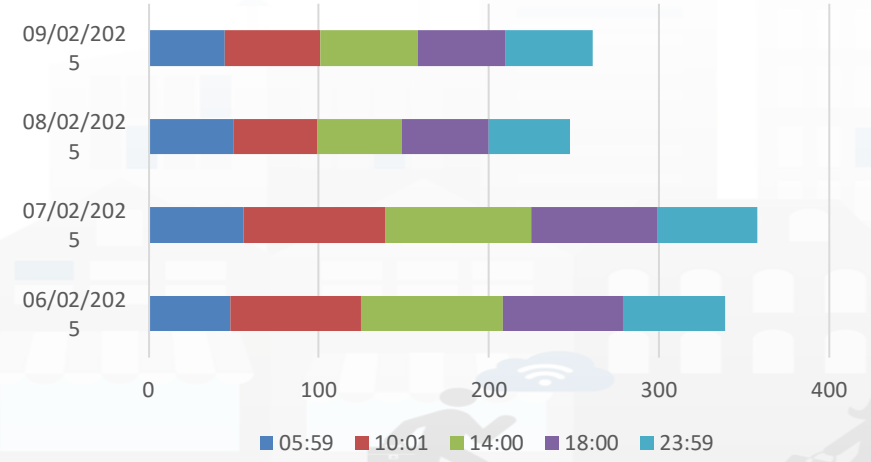
Origin Destination Matrices: Mobility Demand

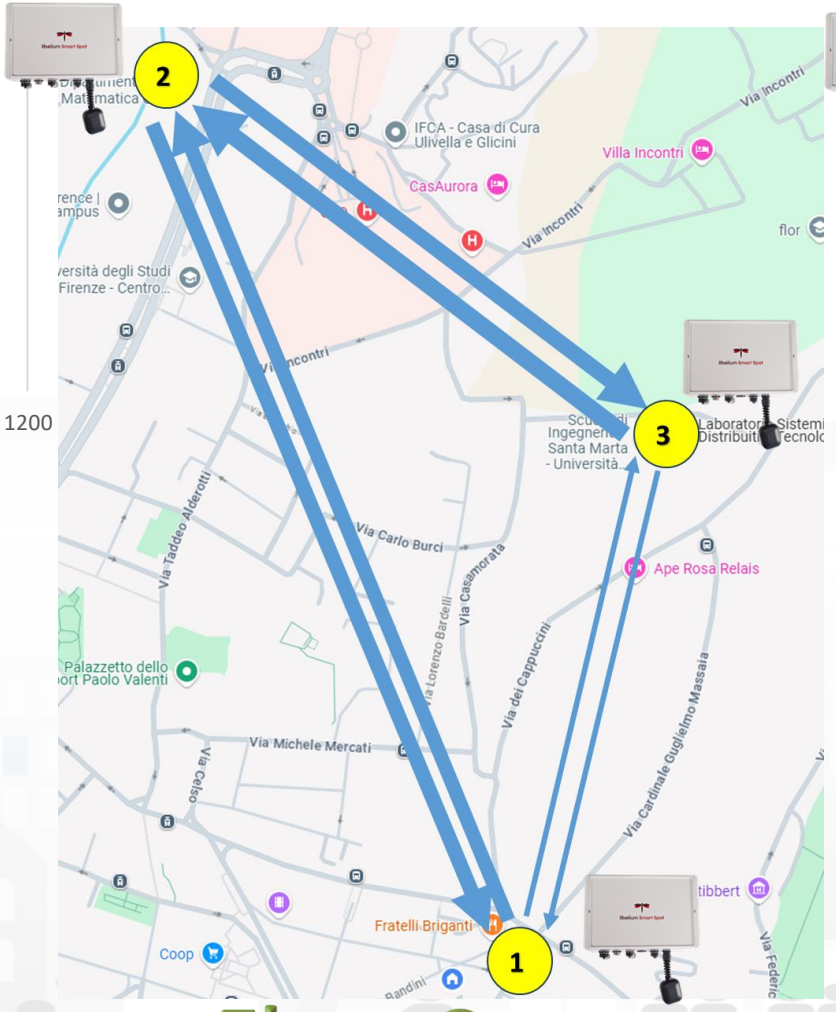


https://www.snap4city.org/dashboardSmartCity/view/Gea-Orange.php?iddasboard=NDUyOQ==

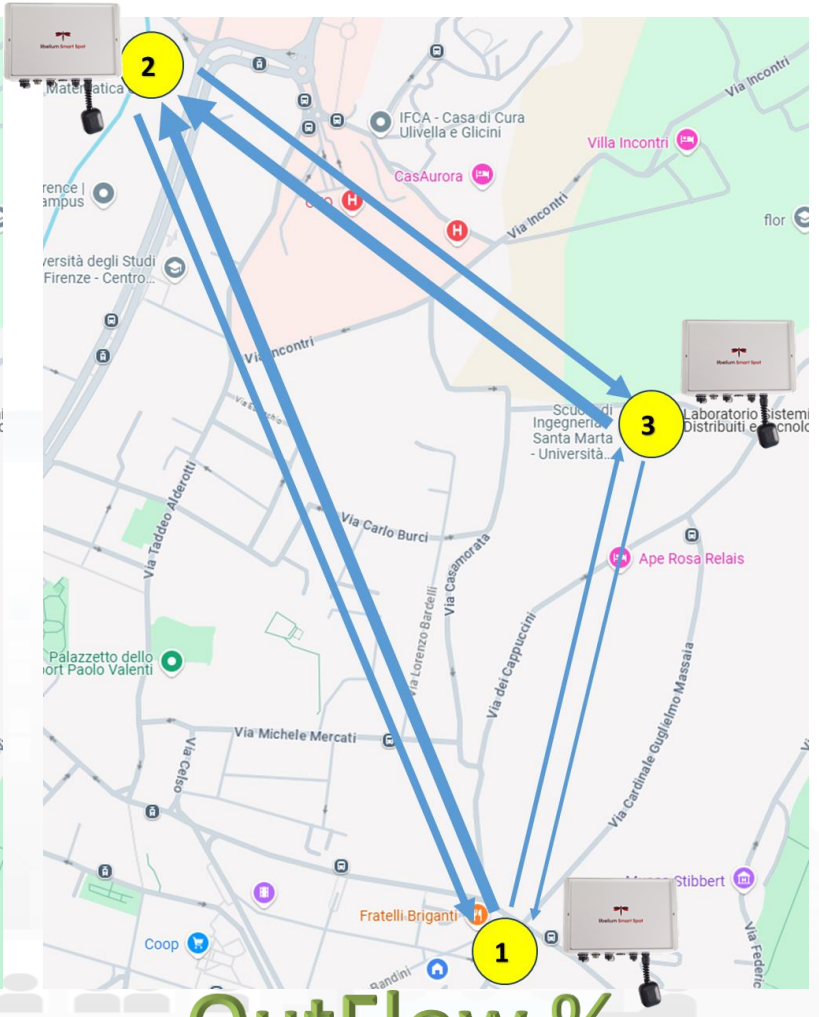
Libelium PaxCounters





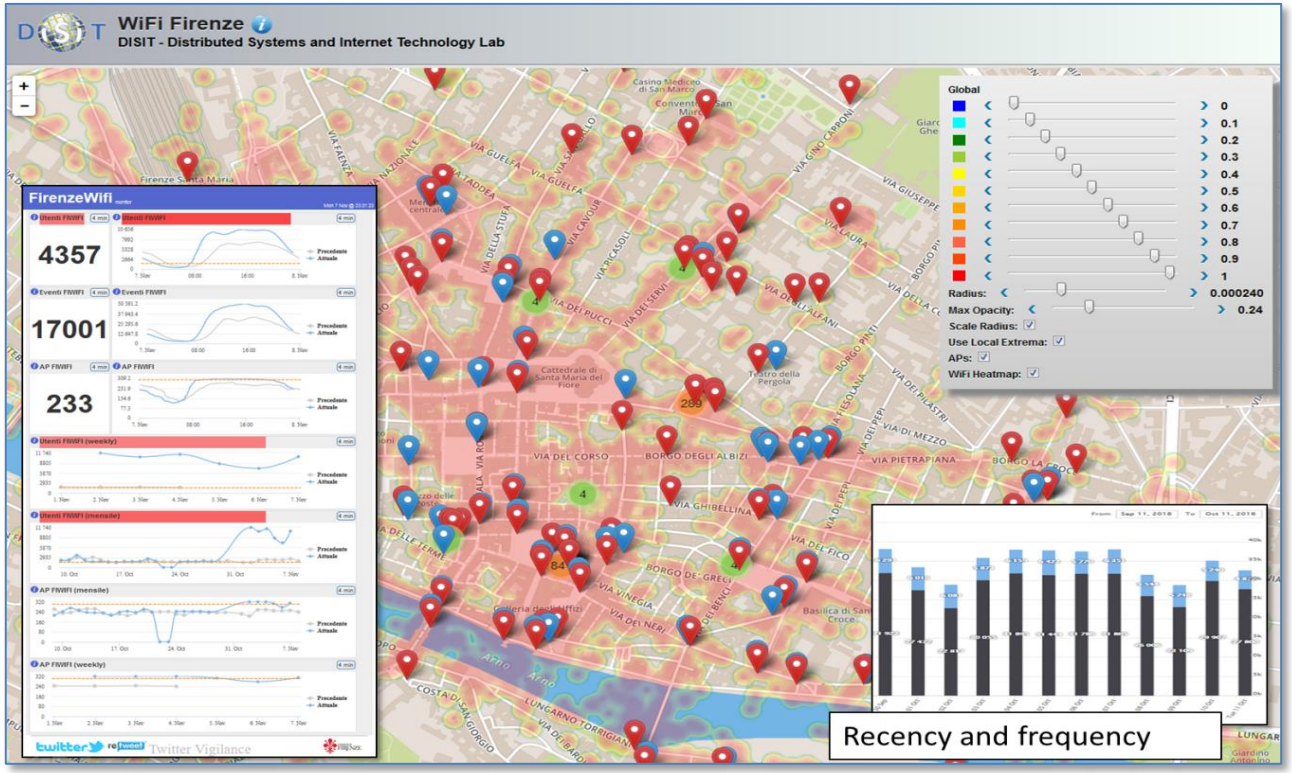


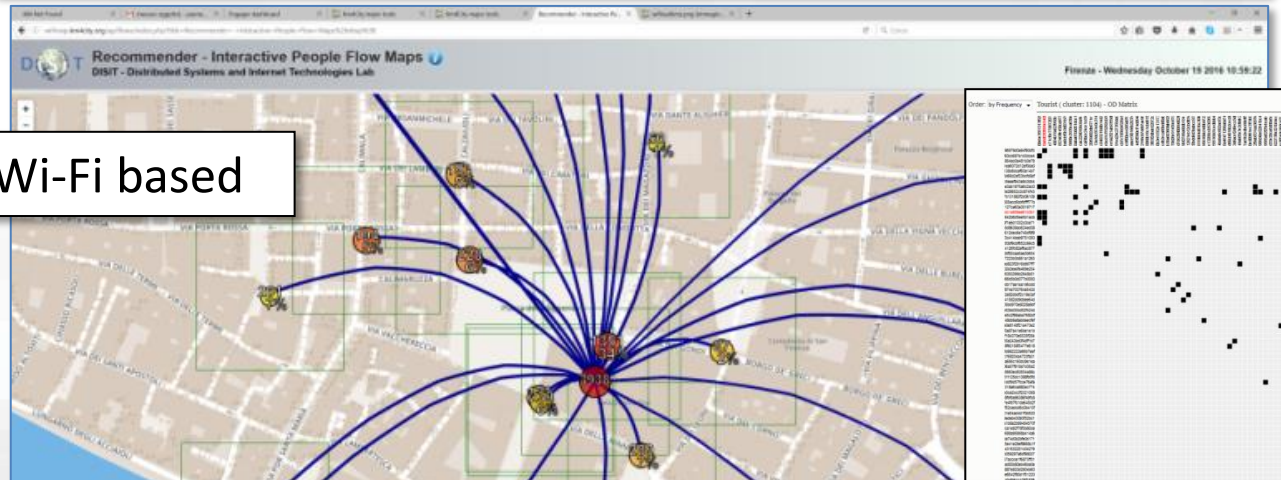
Flow Counts



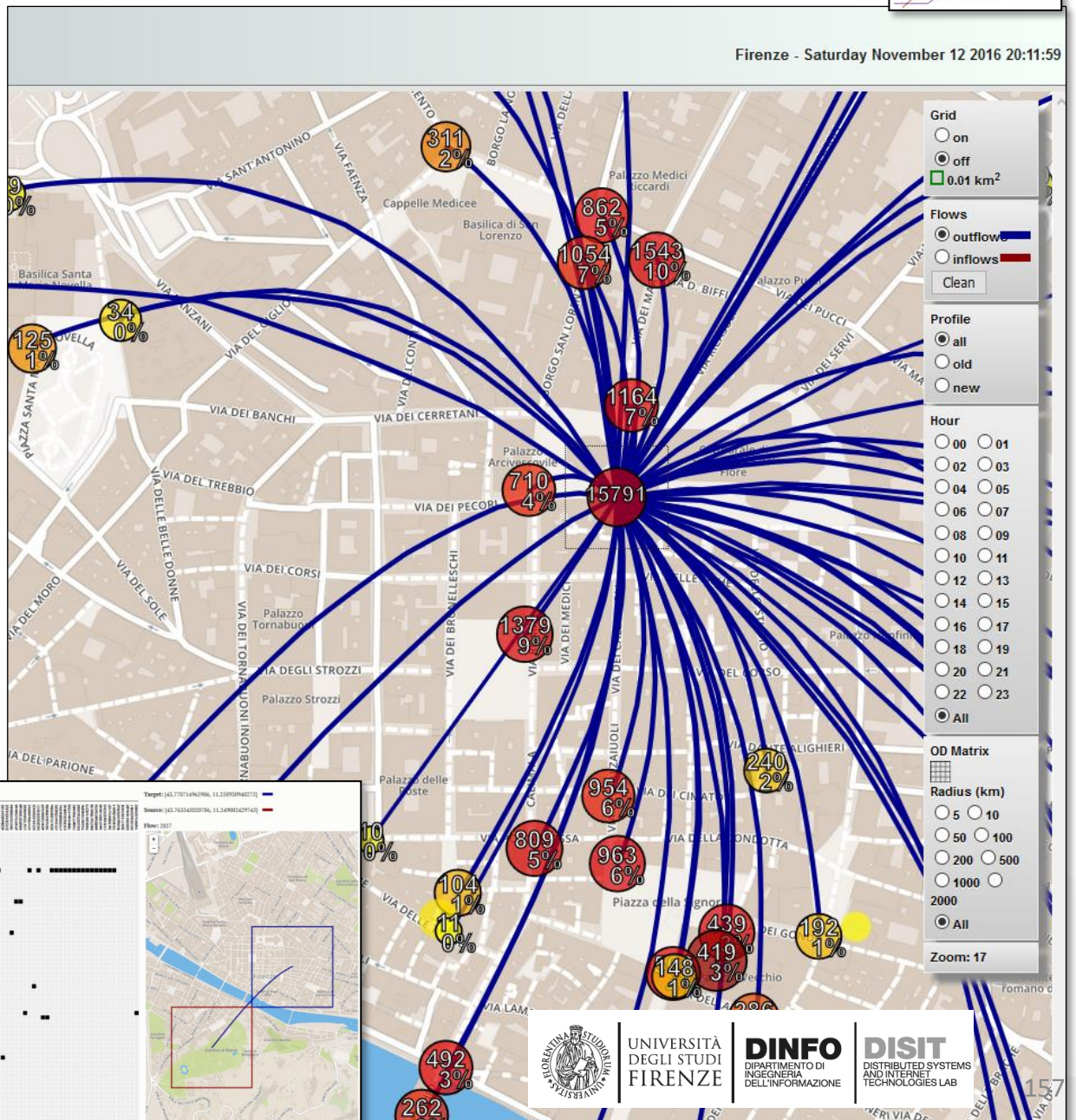
OutFlow %

Origin Destination Matrix Estimation

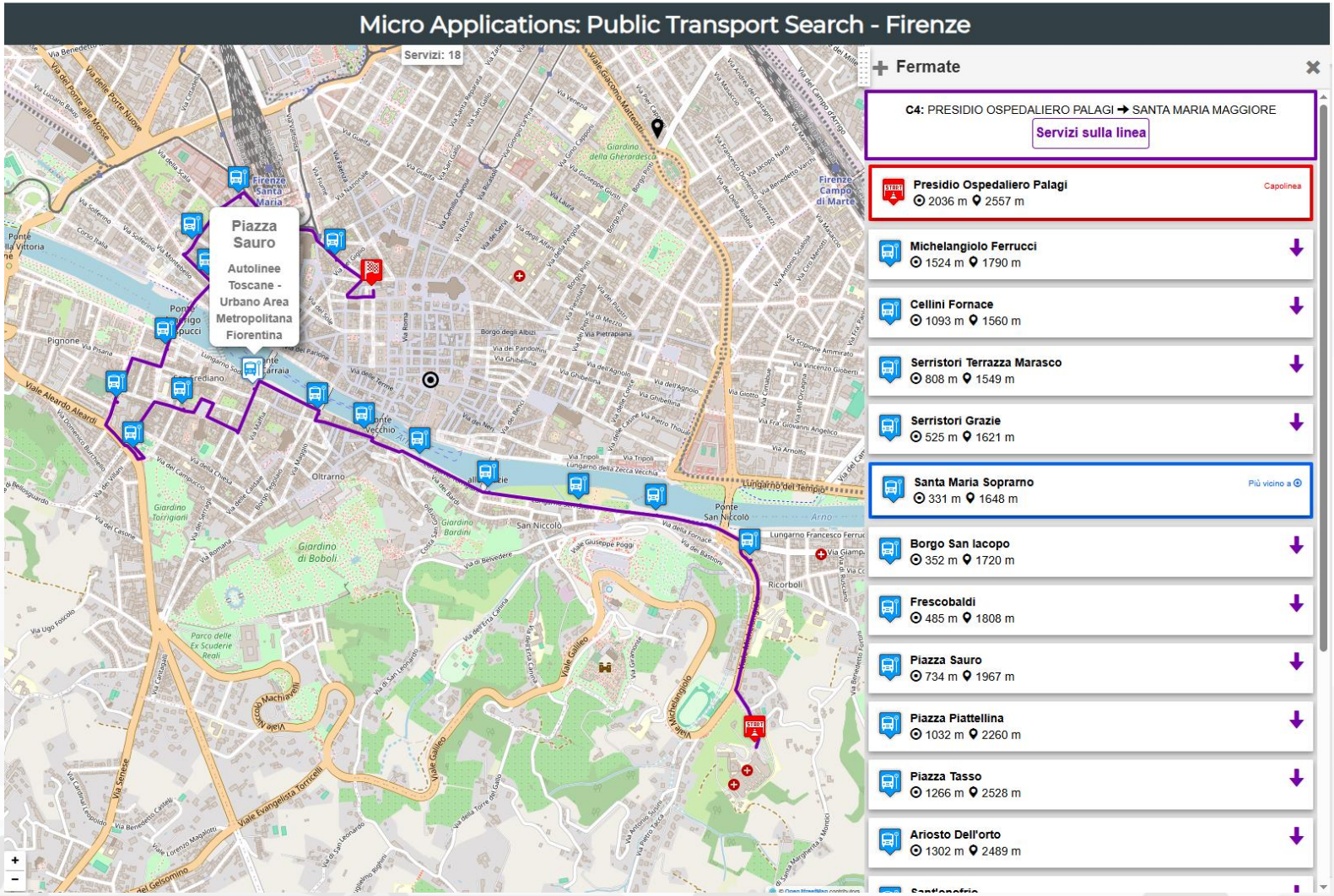




Wi-Fi based



Offer of Transportation, GTFS, for example



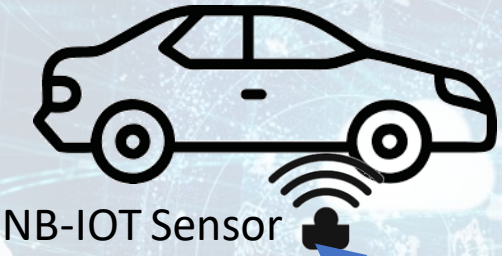
Smart Parking

11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

Data Analytic

Snap4Parking Conceptual Architecture



NB-IOT Sensor

GW Urbiotica

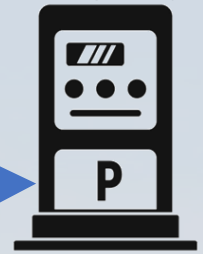
City Operator

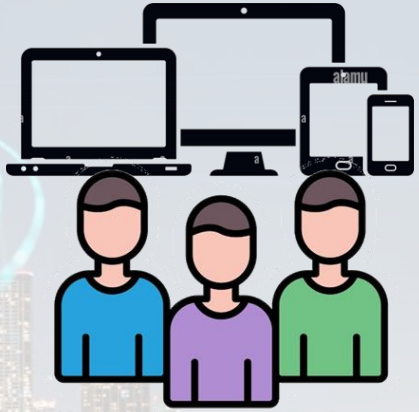
Snap4City Platform

- User Registration
- User Mng
- Slot Gathering/Mng
- Slot Monitoring
- Payment Policies
- Area & Slot Loading
- Permissions Mng
- Participation Mng
- Alarms Mng
- KPI Estimation
- Fines Mng

City Users on parking and participation, mobile app

Parking Payment Pole





Final City Users on:
- Permissions
- Monitoring historical data

Police Operator for Fines

Smart Parking

- **Main features**
  - On-road and off-road, multiple sensors kinds
  - Profiled parking slots: regular, residential, disable, charging, forbidden, etc.
  - Multiple: areas, cities, and business models/profiles
  - Multiple payment modalities and wallets
    - Mobile apps, parking meters, etc.
  - User profiling and models (regular, disabled, etc.), parking areas, etc.
  - Fine detection and management, overparking, etc.
- **Mobile App** for City Users and on road Operators
- **Smart Parking Manager**: operator controller and notifications to on-road operators

Road Parking

Parking Conditions Monitoring

Wed 23 Oct 16:30:45

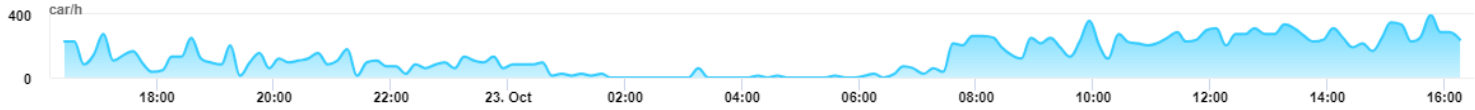
- Status of Slots
- Types of Slots
- As Pins
- Geolocation
- Types of Parking Zones
- Fines on Parking Zones
- Parking Meters
- Recharge Stations
- Parking Structures

Management

Parking Slots

DISIT:OrionUNIFI:METRO1095 - VehicleFlow

5m



Parking KPIs

Select Group: Alberti 11

Group capacity : 26

Grouped by slot type

- Event Car
- Event Moto

Grouped by status

- Free
- Busy
- Busy Bluetooth
- Busy Authorized
- To Be Fined
- Fined
- Do Not Care

My Profile

Road Parking

Parking Conditions Monitoring

Wed 23 Oct 16:24:41

- Status of Slots
- Types of Slots
- As Pins
- Geolocation
- Types of Parking Zones
- Fines on Parking Zones
- Parking Meters
- Recharge Stations
- Parking Structures

Management

Parking Slots

DISIT:OrionUNIFI:METRO1095 - VehicleFlow

8m

Parking KPIs

Select Group: Alberti 11

Group capacity : 26

Grouped by slot type

Event Car

Free Slots: 4/22

Busy Slots: 2/22

Busy Bluetooth Slots: 3/22

Busy Authorized Slots: 5/22

To Be Fined Slots: 5/22

Fined Slots: 1/22

Do Not Care Slots: 2/22

Event Moto

Free Slots: 0/4

Busy Slots: 1/4

Busy Authorized Slots: 0/4

To Be Fined Slots: 1/4

Fined Slots: 1/4

My Profile

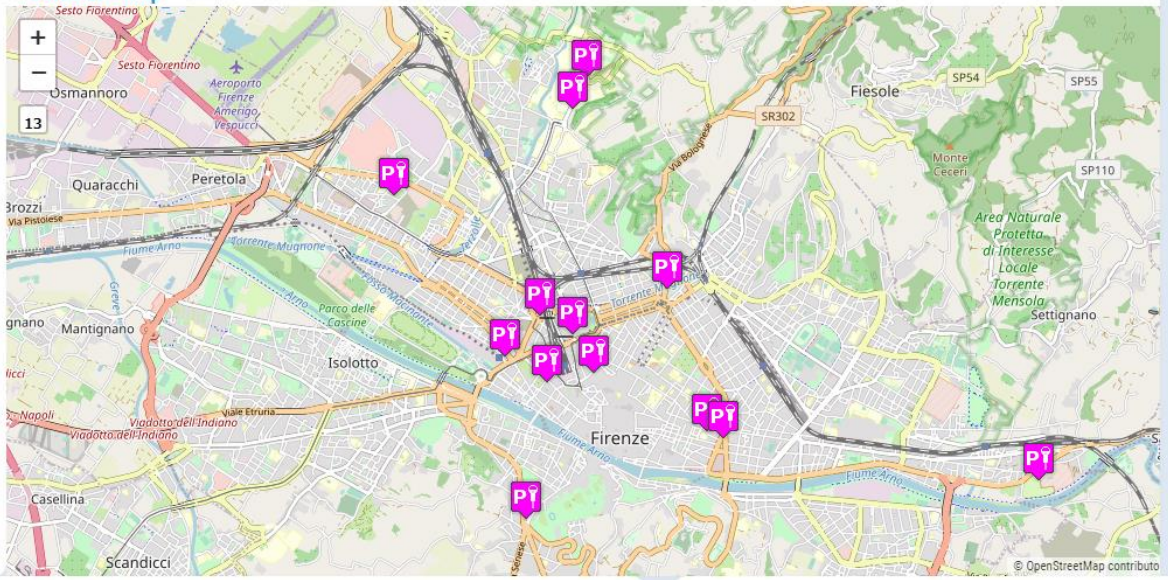
Monitoraggio Parcheggi

Sat 13 May 23:26:20

Selector

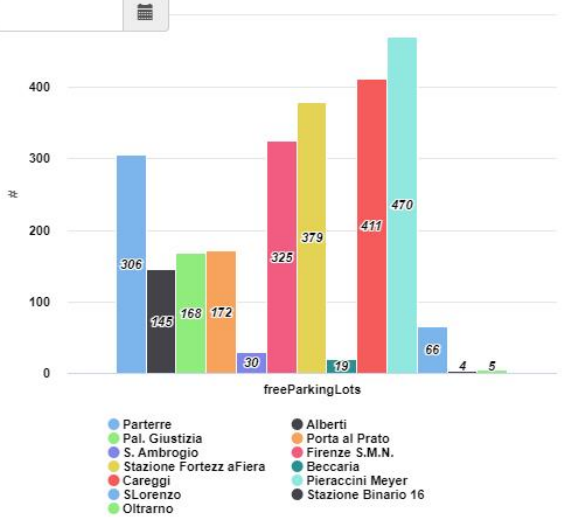
- Parterre
- Piazza Alberti
- Palazzo di.Giustizia
- Porta al Prato
- S. Ambrogio
- Stazione Firenze S.M.N.
- Stazione Fortezza Fiera
- Piazza Beccaria

Selector - Map



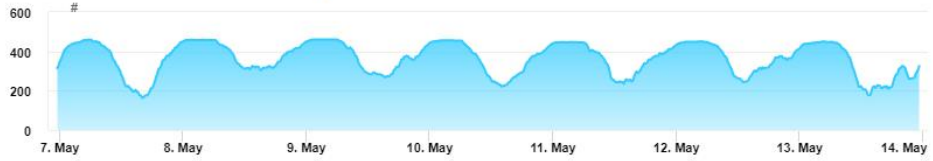
Parcheggi: Numero Posti Liberi

4m



StazioneFirenzeS.M.N. - FreeParkingLots

9m



Andamento Posti Occupati

4m

My Profile

Privacy Policy | Cookies Policy | Terms and Conditions | Contact us

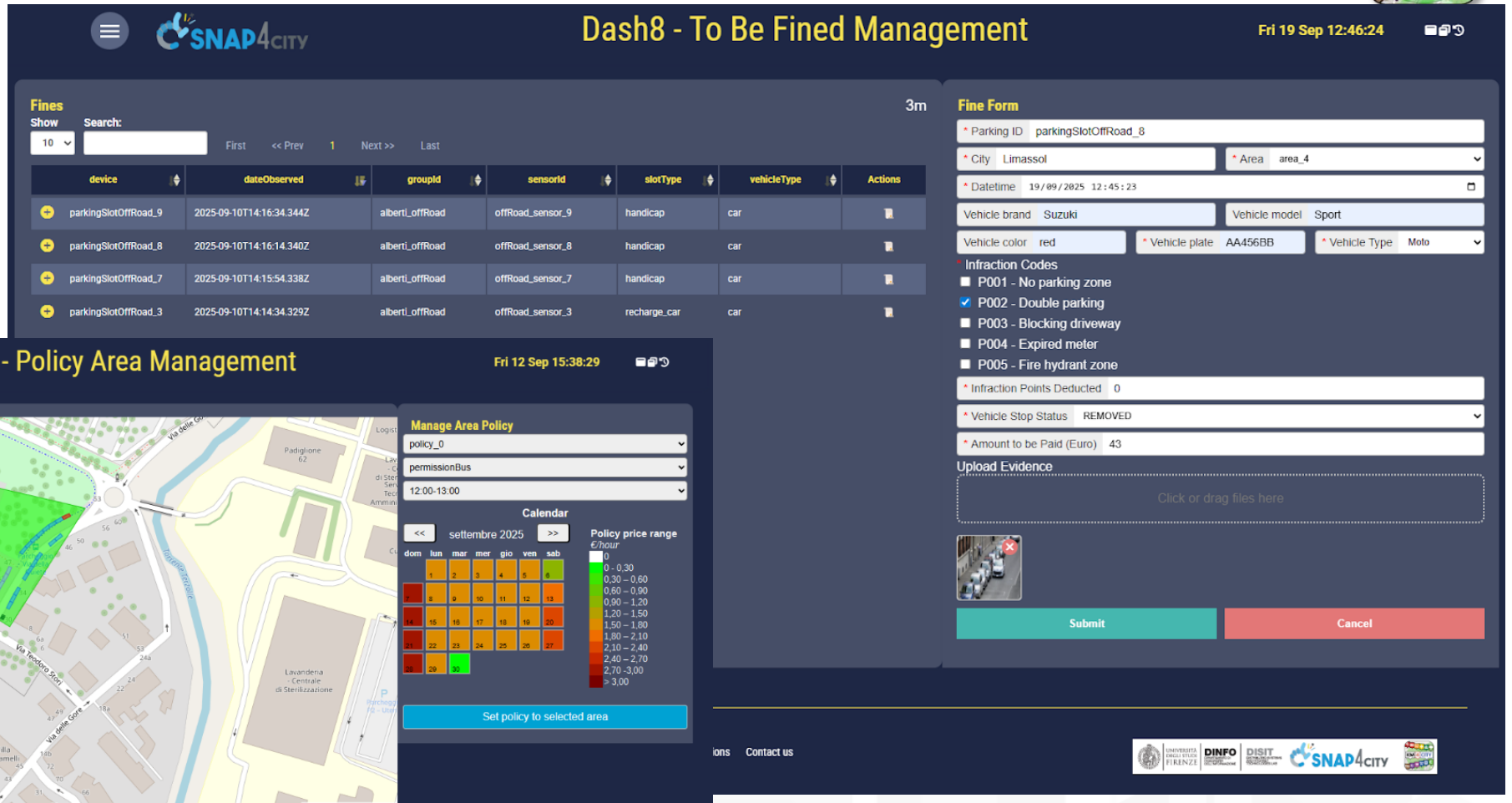
Snap4Parking

Smart Parking

-- payments, profiles

-- Fines

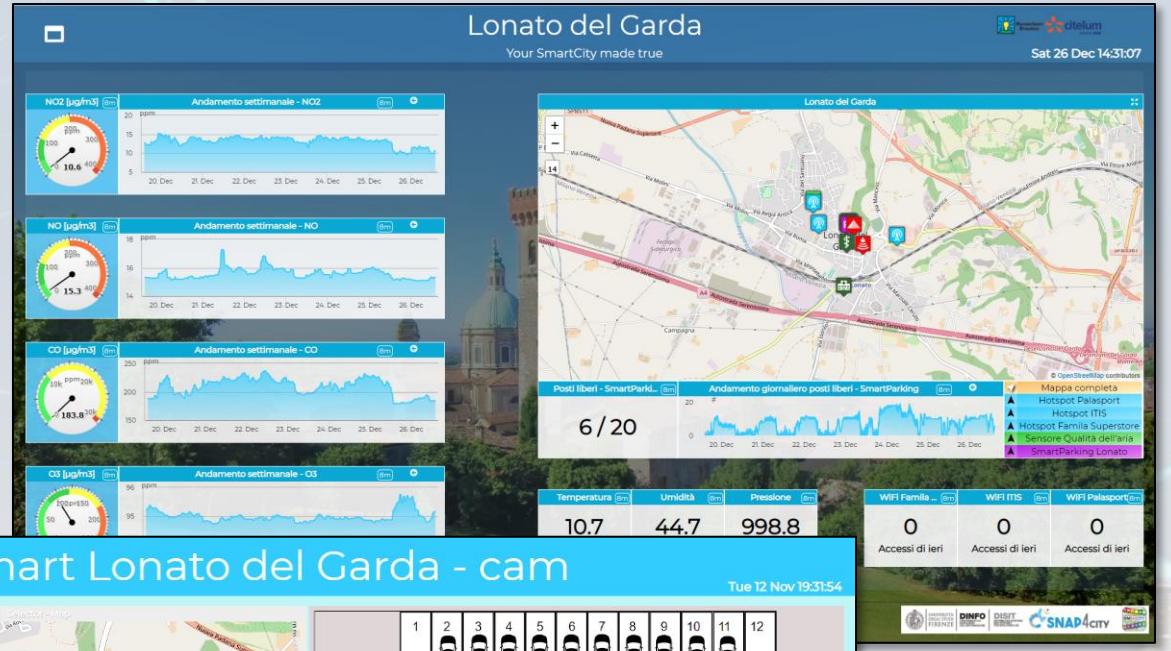
-- mobile for parking

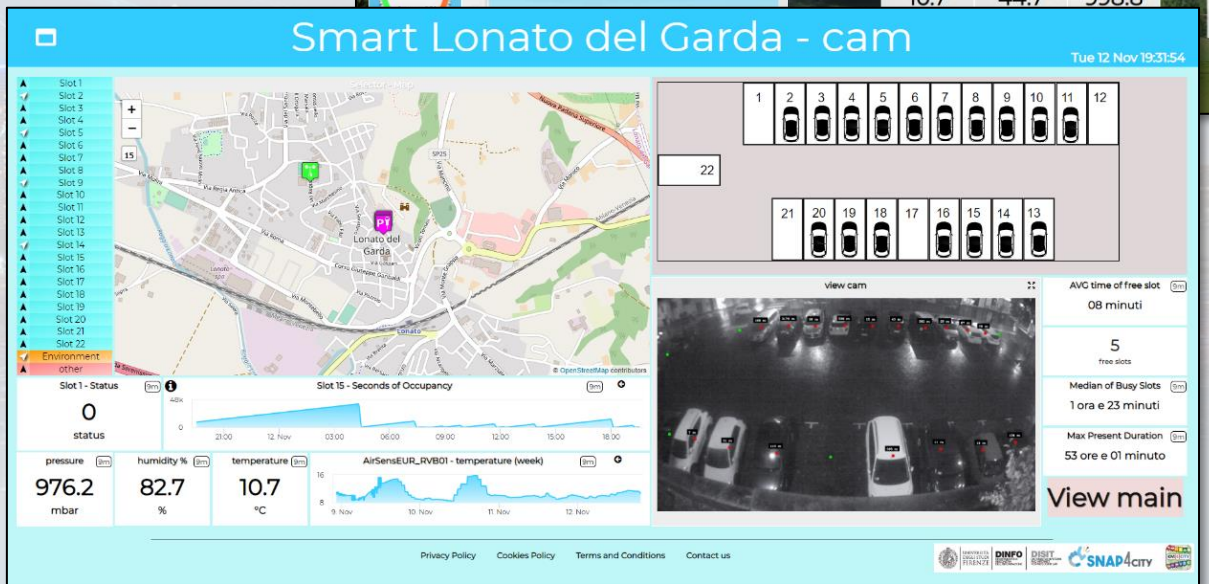


Smart City / Smart Parking + Environment Reverberi, Lonato del Garda

reference

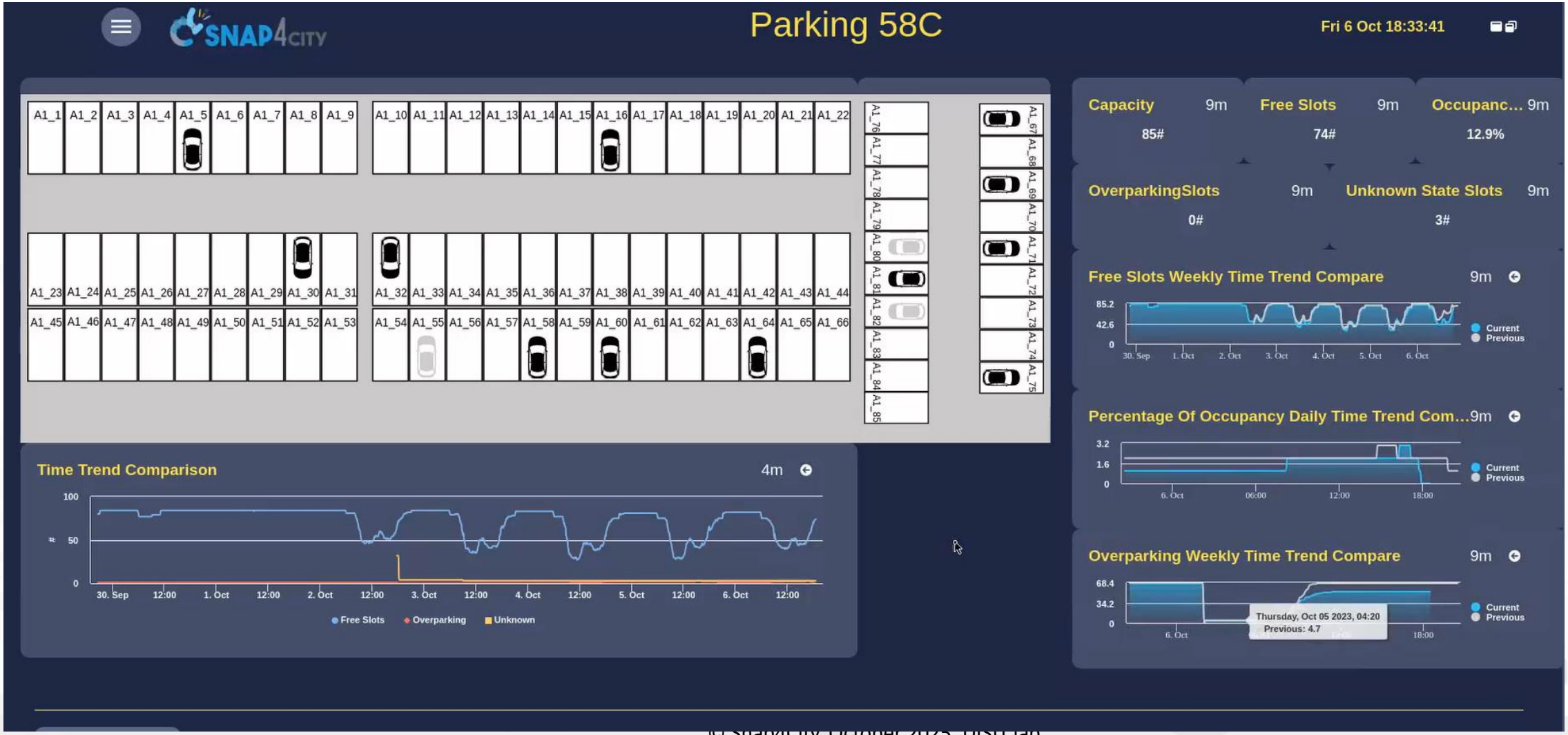
- **Multiple Domain Data**
  - Smart Parking, Environment, Wi-Fi
- **Multiple Decision Makers**
  - City Officer, operators
  - Data monitoring, alerting
  - analytics
- **Historical and Real Time data**
  - Dashboards
- **Services Exploited on:**
  - Dashboards, API
- **Since 2019**



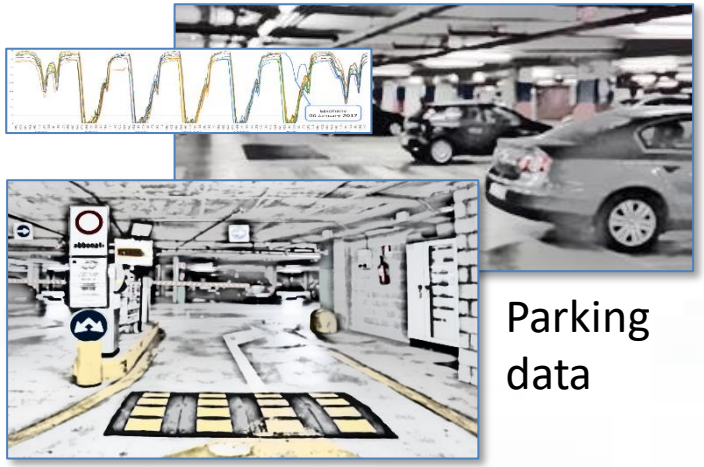


11 SUSTAINABLE CITIES AND COMMUNITIES

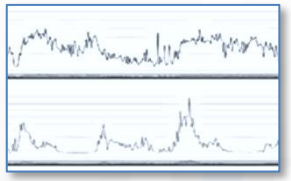
Snap4ISPRA Parking



Deep Learning AI to surely Park!

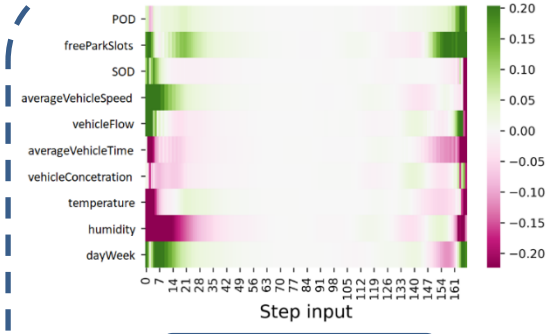


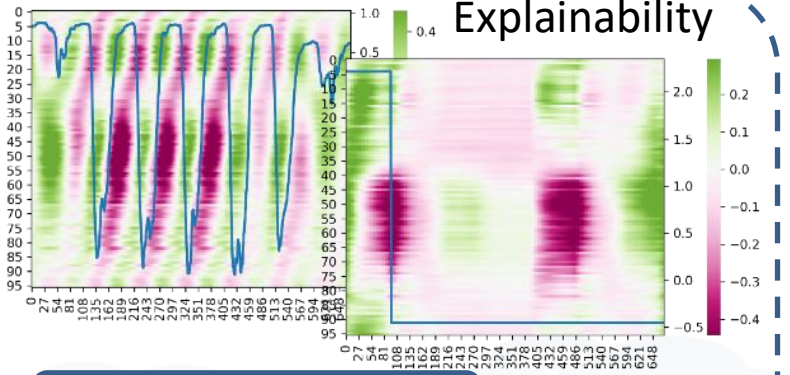
Parking data



Traffic sensors data

Weather Features

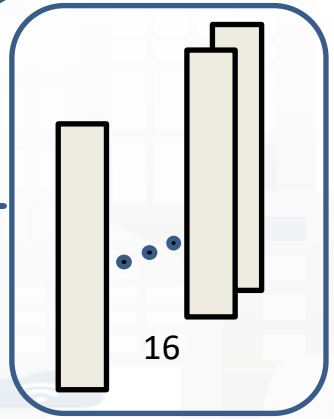


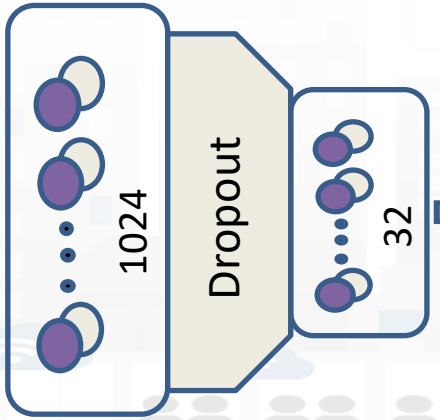


Explainability

Gradient

Integrated Gradient

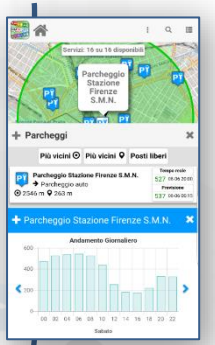




Conv1D+AvPooling1D BI-LSTM BI-LSTM Dense

Multi-step Predictions

95%



Smart Bike

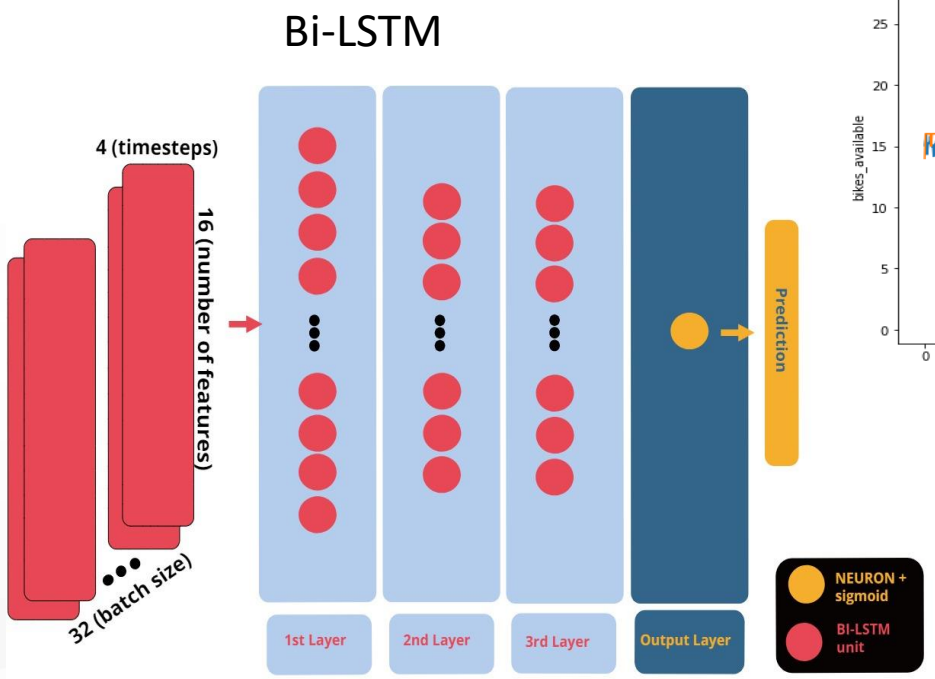
Free Bike predictions

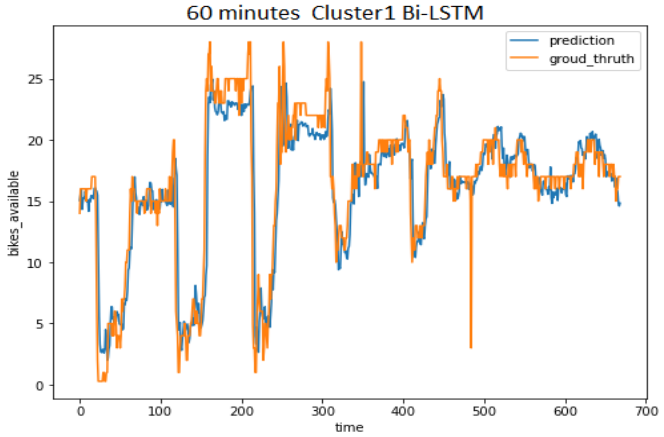
11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

Data Analytic

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



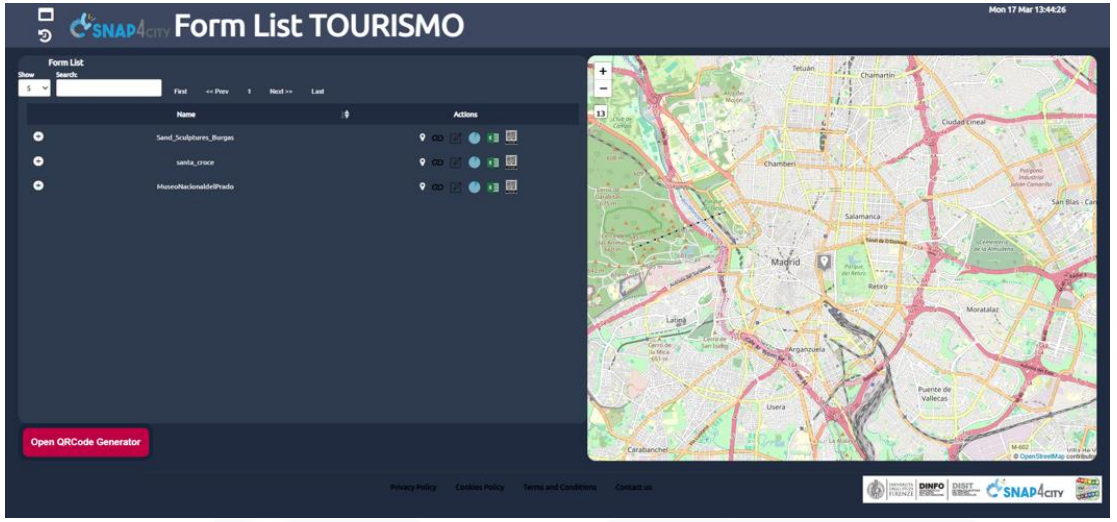


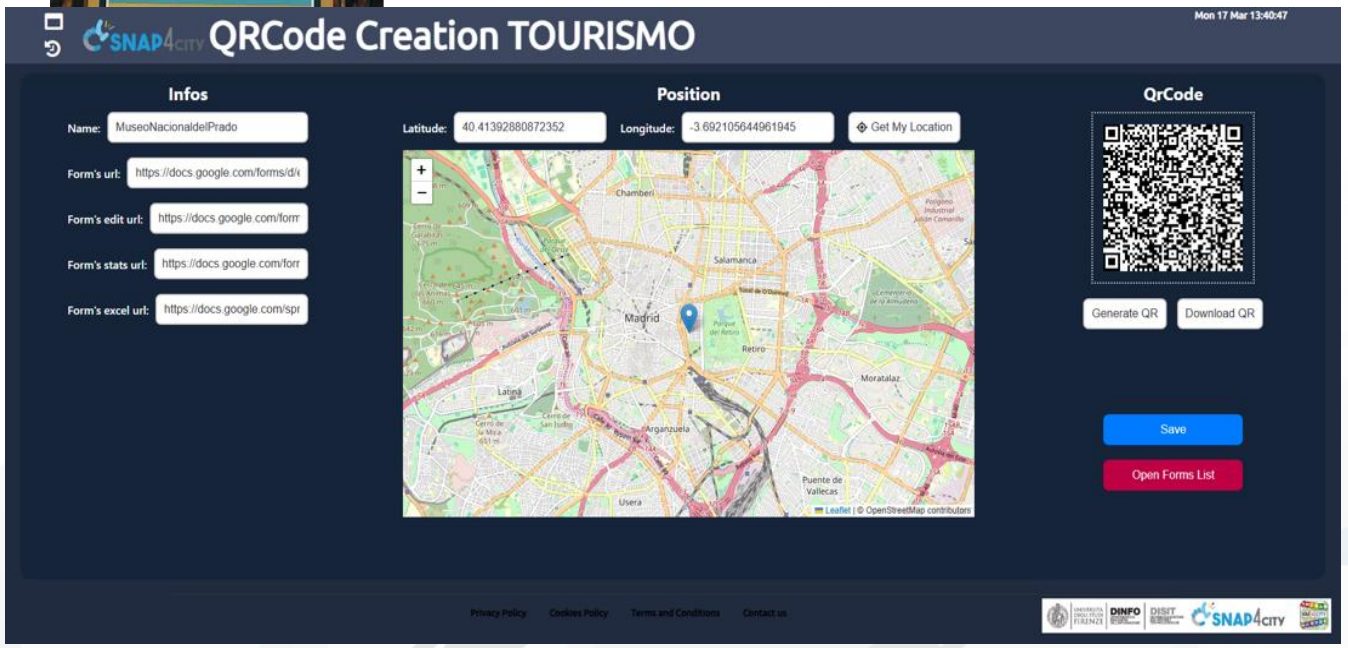
95% accuracy

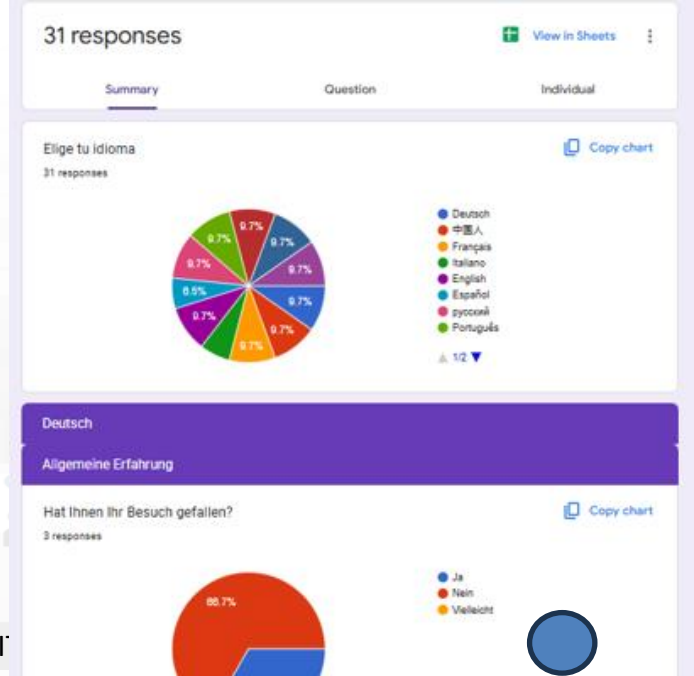
E. Collini, P. Nesi and G. Pantaleo, "Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations," in *IEEE Access*, vol. 9, pp. 124337-124347, 2021, doi: 10.1109/ACCESS.2021.3110794.
https://ieeexplore.ieee.org/abstract/document/9530580

User Behavior Analysis

QR Engagement

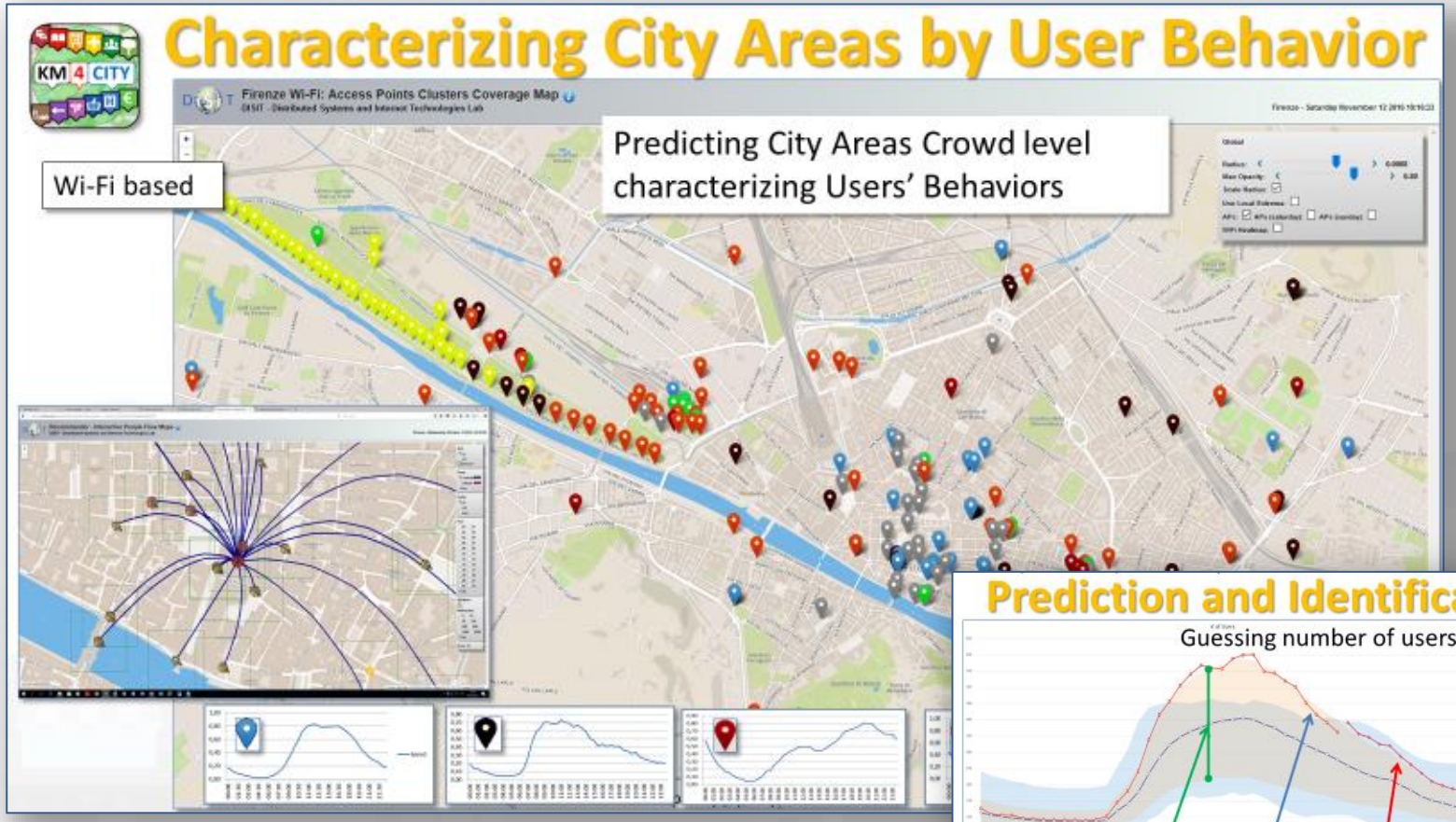






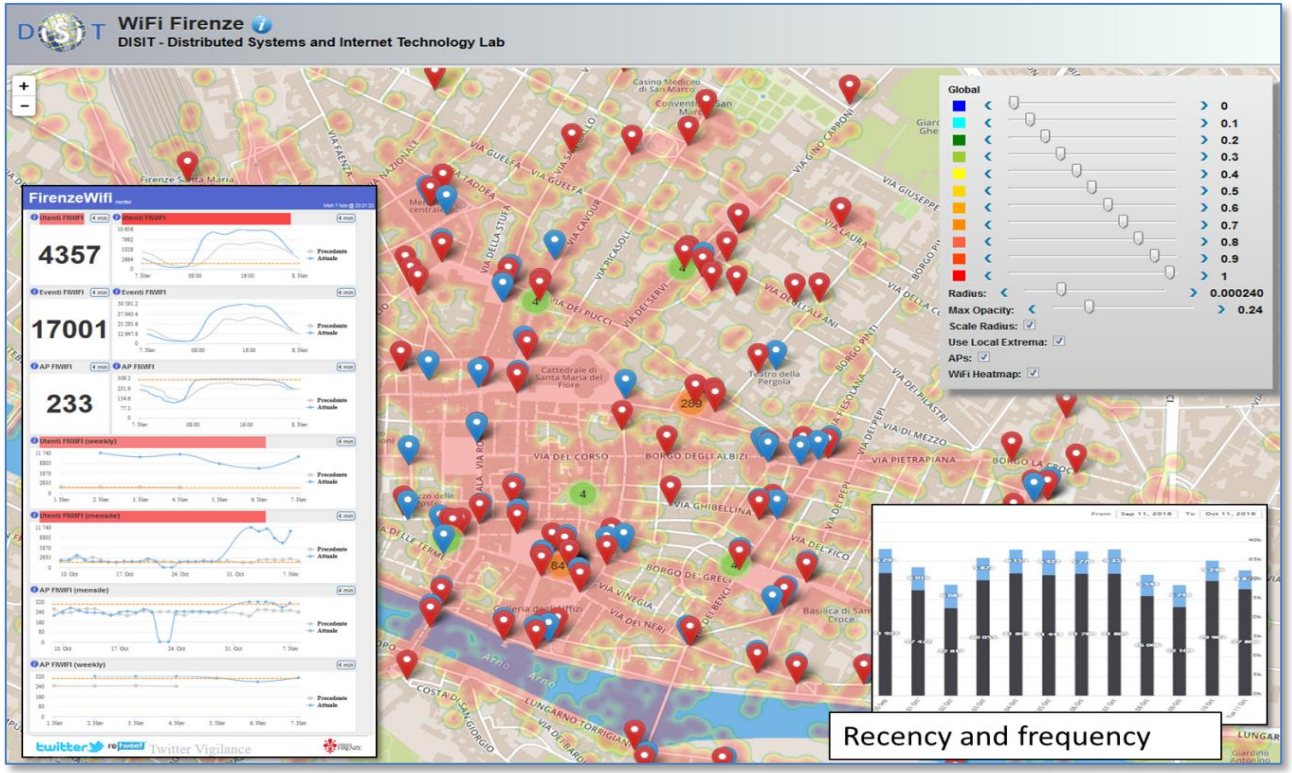
People Flows

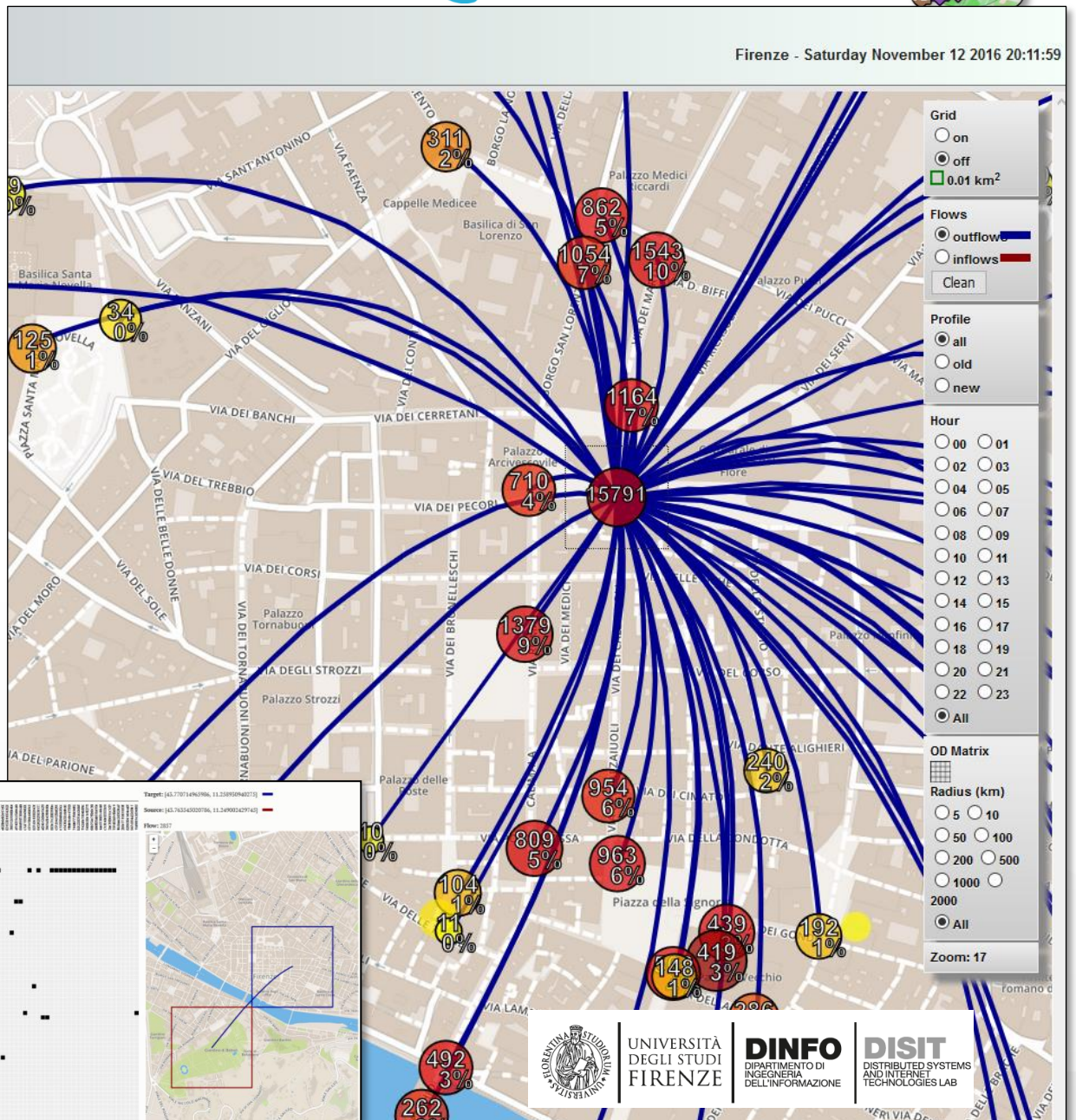
- **Prediction of people flows** on the basis of Wi-Fi data
- **Anomaly** detection
- **Resolute** H2020
- Classification of city areas

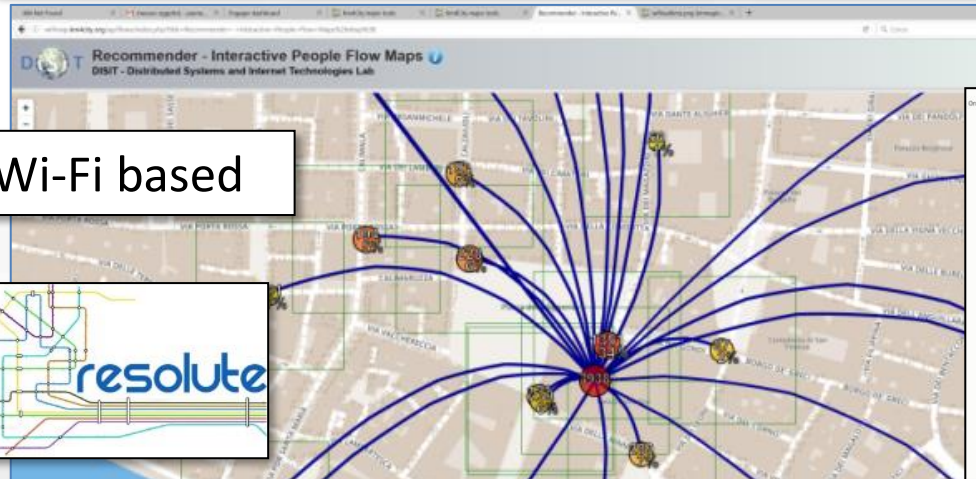


11 SUSTAINABLE CITIES AND COMMUNITIES

Origin Destination Matrix Estimation



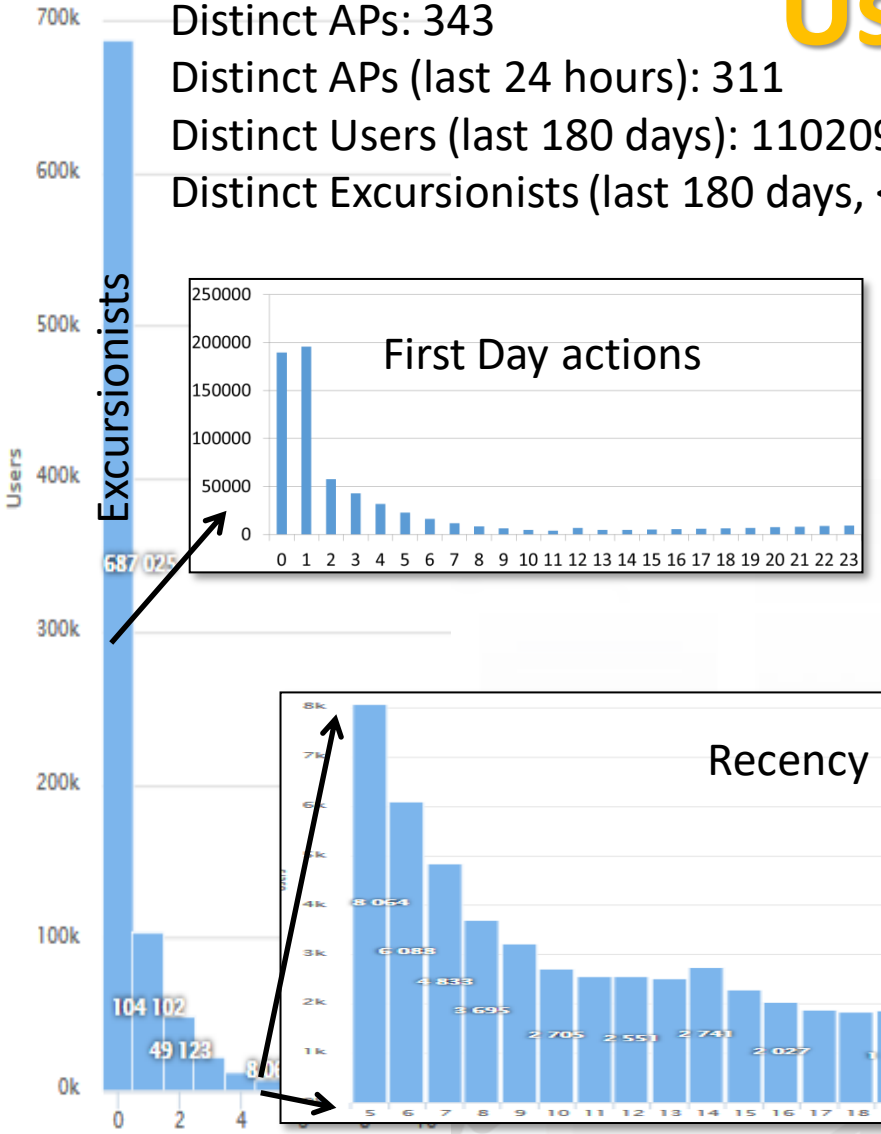


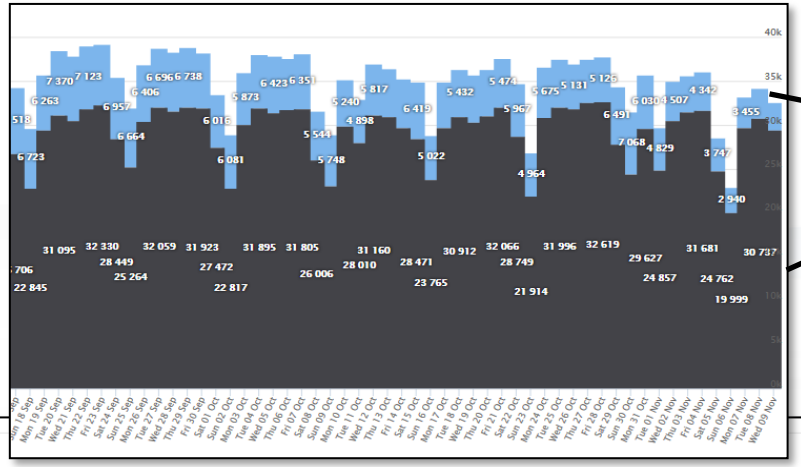


Wi-Fi based

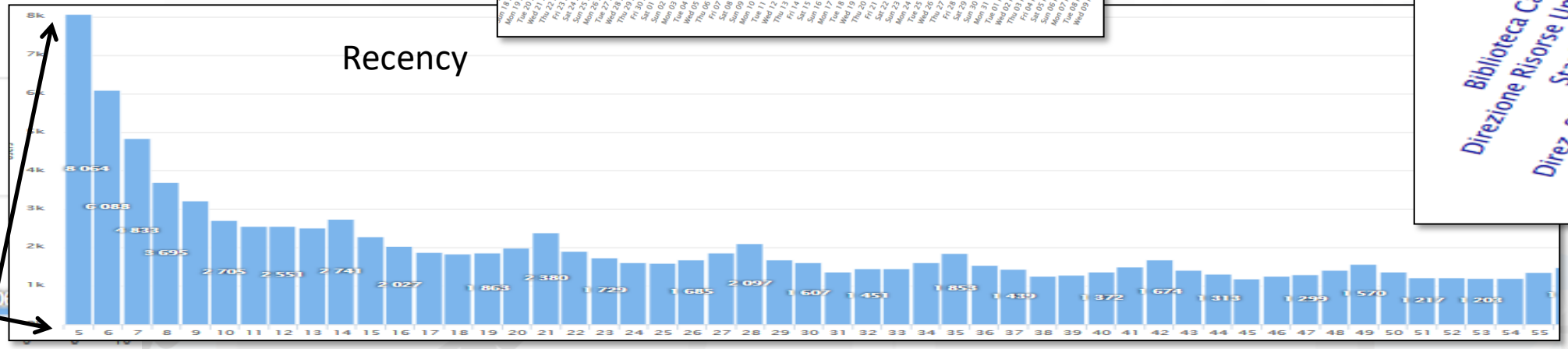
User Behaviour Analysis

Distinct APs: 343
Distinct APs (last 24 hours): 311
Distinct Users (last 180 days): 1102098
Distinct Excursionists (last 180 days, < 24 h): 687025

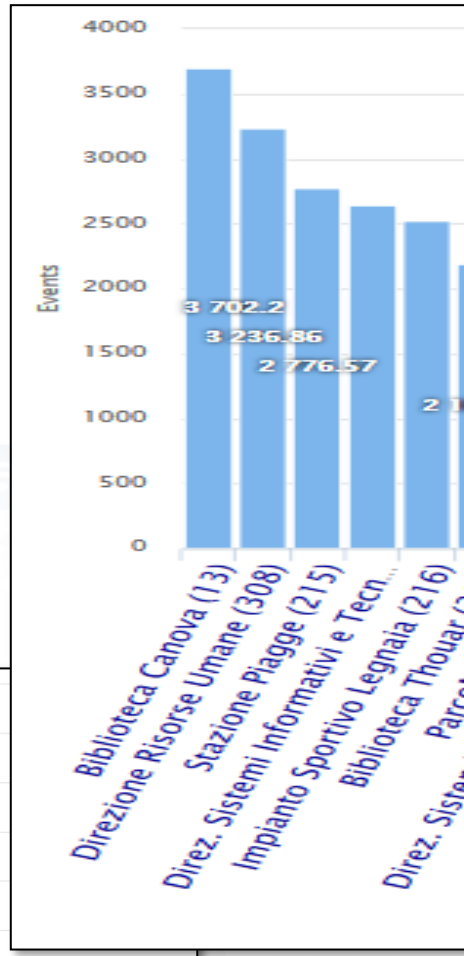




New City Users
VS
Returning

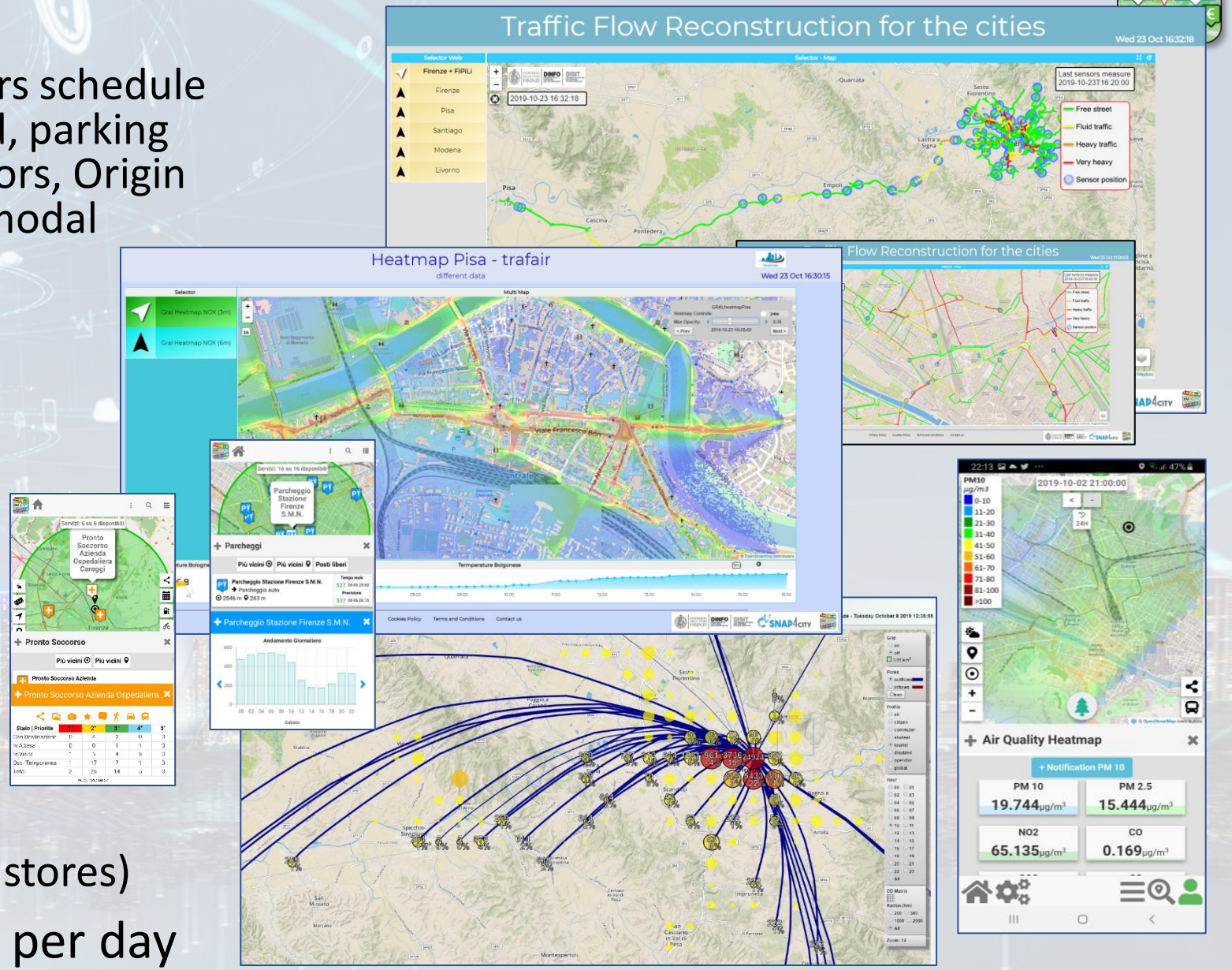


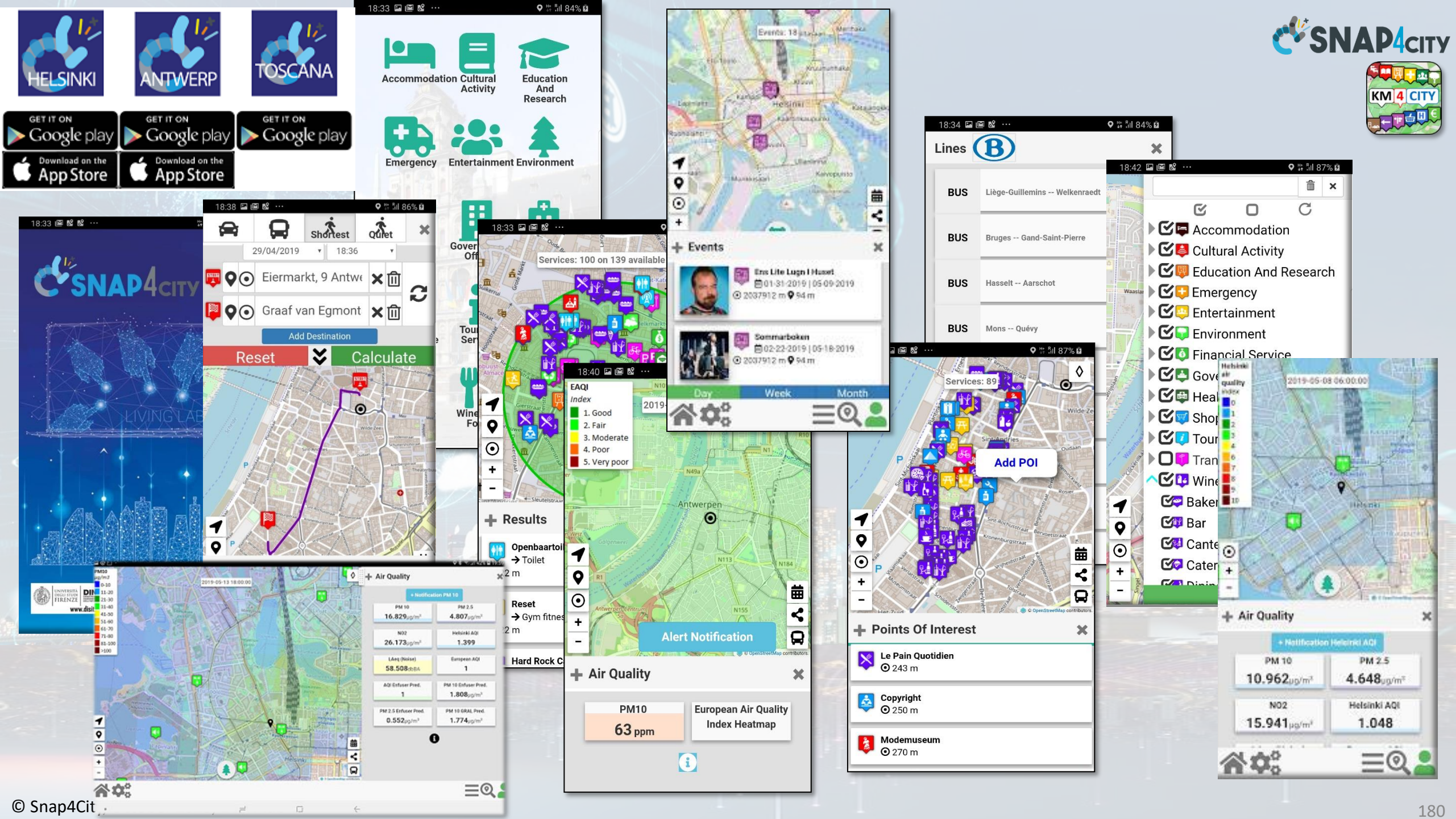
Where



Tuscany Region

- **Dashboards & Services**:
  - **Mobility**: public transport operators schedule and paths, traffic Fi-Pi-Li main road, parking status and predictions, traffic sensors, Origin Destination matrix, routing, multimodal routing, etc.
  - **Social**: Hospitals and triage, etc.
  - **Environment**: sensors, heatmaps,
  - alerting,
    - **Pollution** Forecast: NOX, NO2
    - **Weather** Forecast,
  - **Culture** and **Tourisms**
  - Etc.
- **Mobile App and MicroApplications:**
  - Tuscany in a Snap (all stores)
  - Tuscany where what… km4city (all stores)
- **Numbers**: 1.5 M complex events per day

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ANTWERP
TOSCANA
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KM 4 CITY
Accommodation
Cultural Activity
Education And Research
Emergency
Entertainment
Environment
Shortest
Quiet
Add Destination
Reset
Calculate
Events
Day
Week
Month
Lines
BUS
Liège-Guillemins -- Welkenraedt
Bruges -- Gand-Saint-Pierre
Hasselt -- Aarschot
Mons -- Quévy
Services: 100 on 139 available
EAQI
Index
1. Good
2. Fair
3. Moderate
4. Poor
5. Very poor
Results
Alert Notification
Air Quality
PM10
63 ppm
European Air Quality Index Heatmap
Add POI
Points Of Interest
Le Pain Quotidien
243 m
Copyright
250 m
Modemuseum
270 m
Financial Service
Bar
Air Quality
PM 10
10.962
PM 2.5
4.648
NO2
15.941
Helsinki AQI
1.048

Citizen Engagement via Mobile Apps

- GPS Positions
- Selections on menus
- Views of POI
- Access to Dashboards
- searched information
- Routing
- Ranks, votes
- Comments
- Images
- Subscriptions to notifications
- ….

Produced information

- Viewed ?
- Accepted ?
- Performed ?
- …

Users

Derived information

- Trajectories
- Hot Places by click and by move
- Origin destination matrices
- Most interested topics
- Most interested POI
- Delegation and relationships
- Accesses to Dashboards
- **Cumulated Scores from Actions**
- Requested information
- Routing performed
- …..

Produced information

- Suggestions
- Engagements
- Notifications
- …

System

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DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB
DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB

7 AFFORDABLE AND CLEAN ENERGY

11 SUSTAINABLE CITIES AND COMMUNITIES

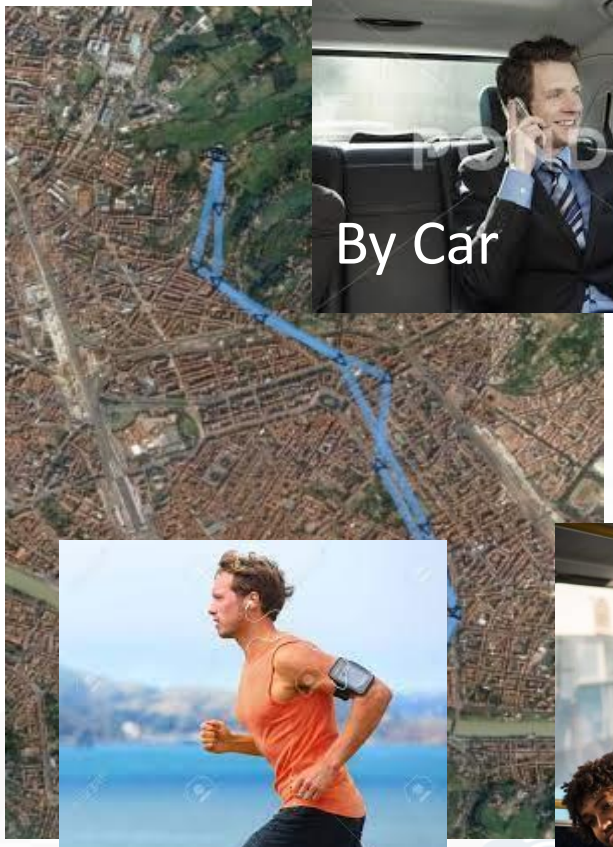
13 CLIMATE ACTION

SNAP4CITY

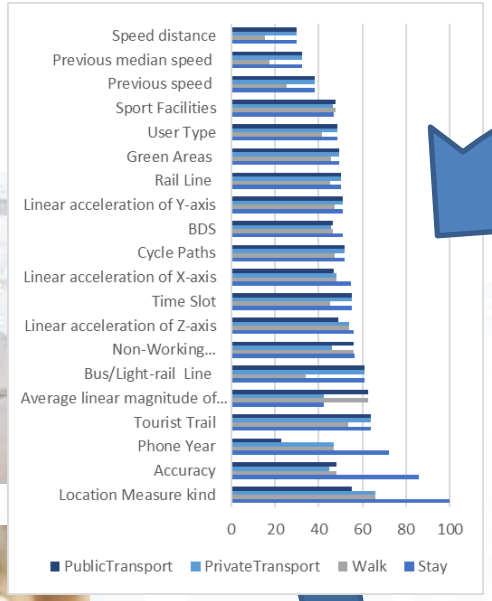
KM4CITY

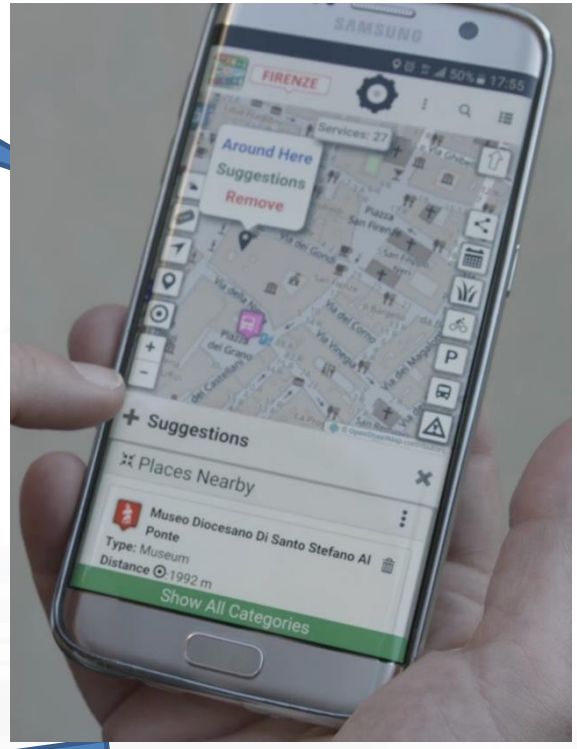
To propose suggestions and Engage city user

we need to know how they are moving



Walk

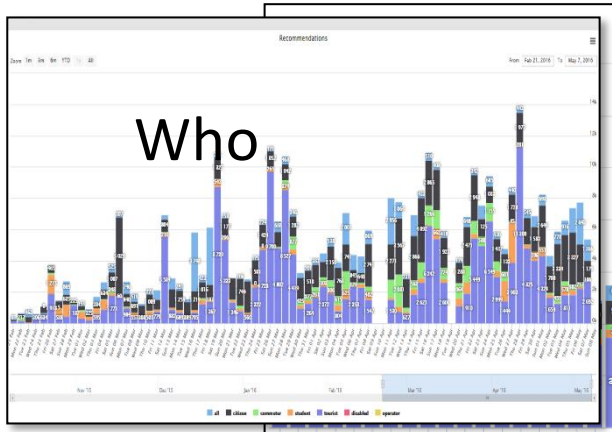


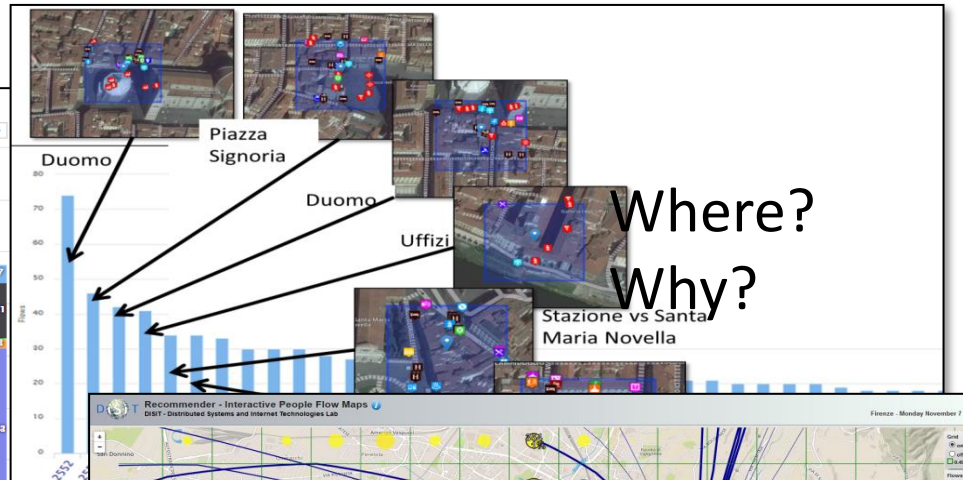


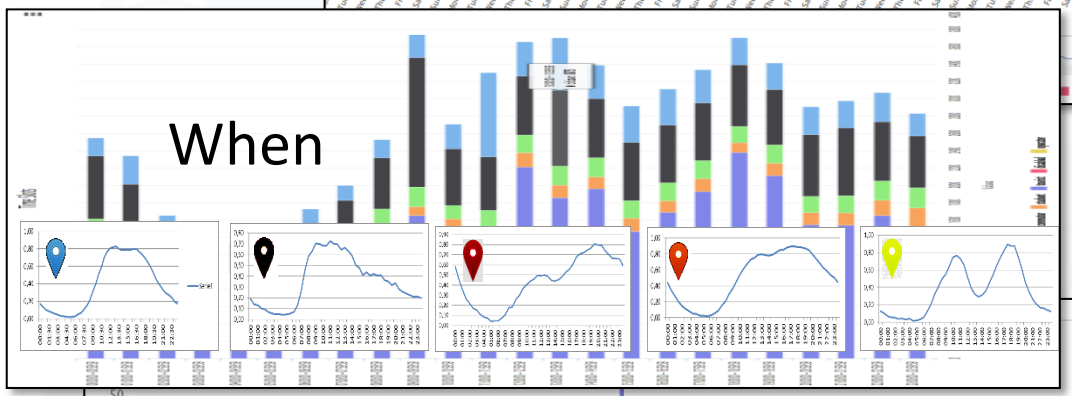
Artificial Intelligence Classification

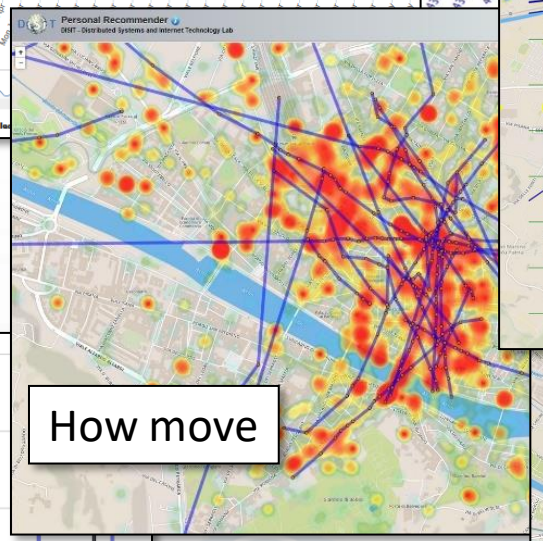
Suggestions

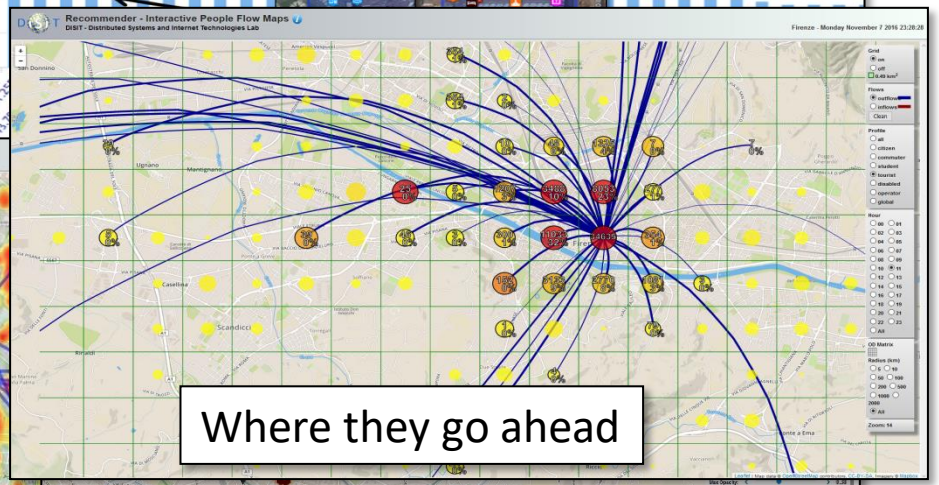
User Behavior Analyser for Collective Profiling

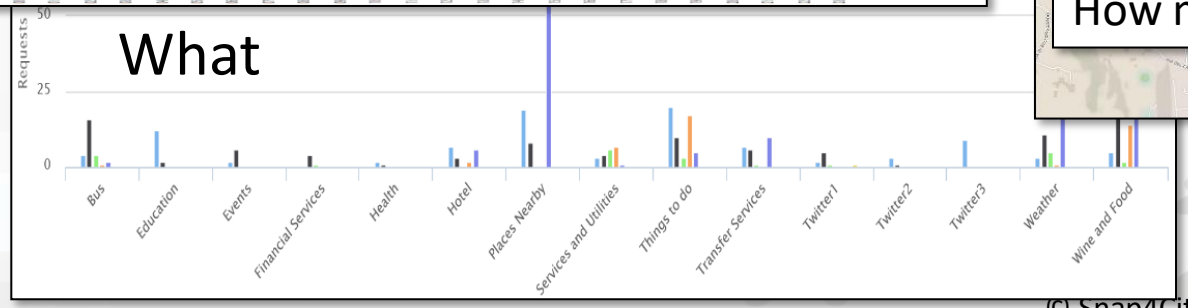


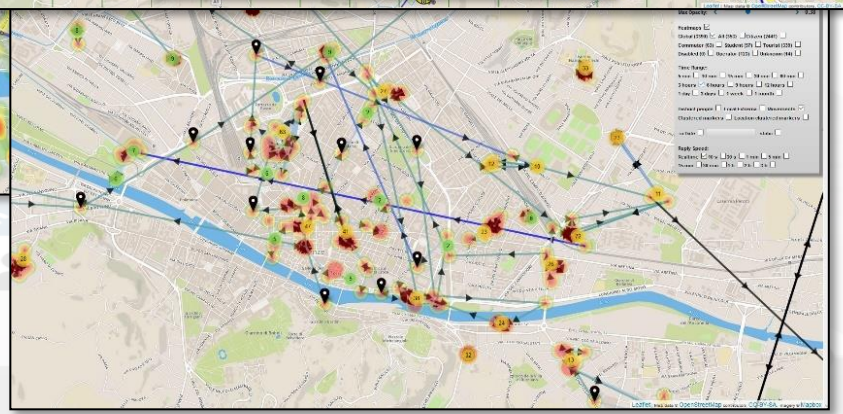




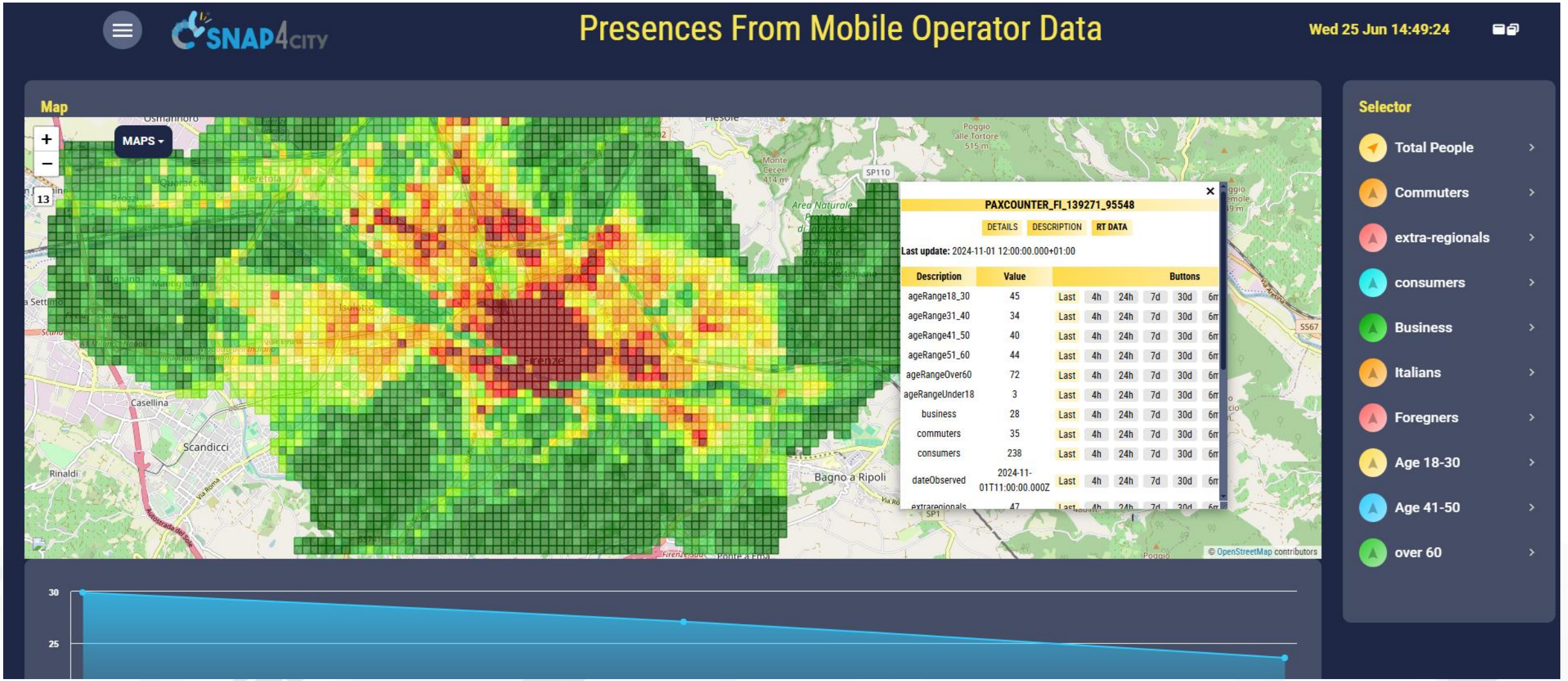






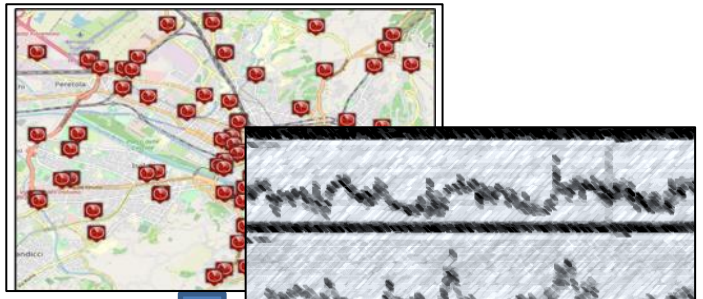


Presences from Mobile Operator



Computing / predicting CO2/NO2 from traffic Data

Estimating City Local CO2 from Traffic Flow Data



Computing Traffic Flow into CO2 sensor area

Traffic Flow data

- Traffic Flow is one the main source of CO2 **(ton of CO2 x Km x Vehicle)**
  - **K1: Fluid Flow**
  - **K2: Stop and Go**
- **Dense estimation of CO2 into the city** is very useful to know to target EC's KPIs

Computing CO2 on the basis of traffic flow data

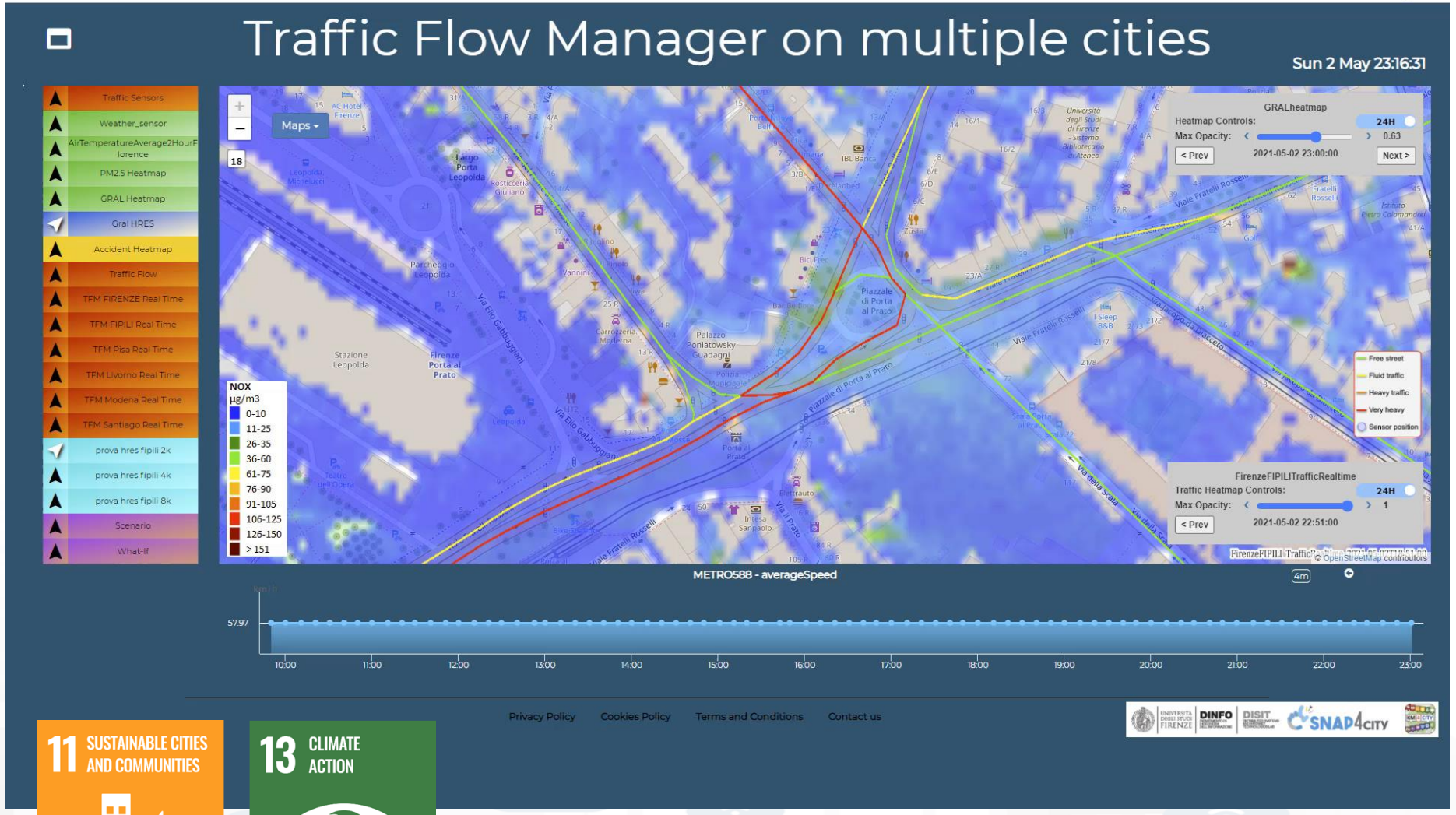
CO2 estimation

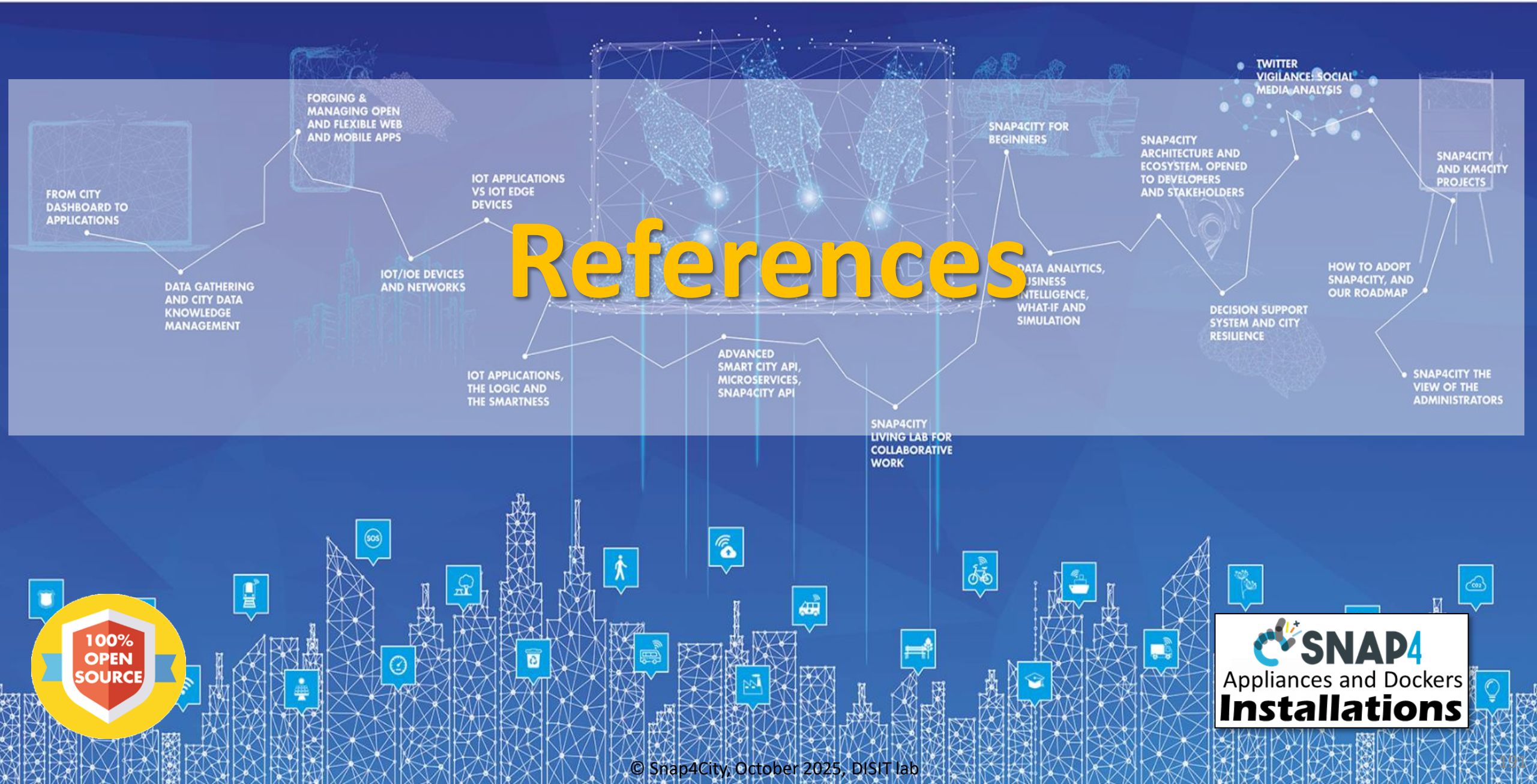
94% accuracy

S. Bilotta, P. Nesi, "Estimating CO2 Emissions from IoT Traffic Flow Sensors and Reconstruction", Sensors, MDPI, 2022. https://www.mdpi.com/1424-8220/22/9/3382/

Environment

- **Prediction**
  - **NOX Pollutant** diffusion on the basis of Traffic Flow (prediction), weather and 3D structure
  - **NO2 progressive average** (Long term)
- **Project:**
  - **Trafair** CEF EC
  - Mixed solutions of Fluidinamics modeling and AI





References

100% OPEN SOURCE

SNAP4 Appliances and Dockers **Installations**

booklets

- Smart City

https://www.snap4city.org/download/video/DPL_SNAP4CITY.pdf

- Industry

https://www.snap4city.org/download/video/DPL_SNAP4INDUSTRY.pdf

- Artificial Intelligence

https://www.snap4city.org/download/video/DPL_SNAP4SOLU.pdf

SNAP4CITY roadmap

2020

- Smart Tourism
- 6 Pilots
- Data Analytics
- Extended platform

- Smart Mobility
- PISA, PUMS
- Living lab

Km4City 1.6.7

2021

Smart Ambulance (2021-22)

Enterprise (2021-22) Industry 4.0

Sii-Mobility Contract

JRC Contract

PC4City (2020-21) Monitoring Terrain

Winner of Open Data Challenge of enel x

- Smart Light
- Sweden

2022

Almafluida Industry 4.0 (2021-22)

AMPERE (2021-22) Industry 4.0

SYN-RG-AI SmartCity

Gruppo Pretto Industry 4.0

uni.systems SmartCity, 2021-23

AXIS collab SmartCity

Asymmetrica Smart City, 2022-23

2023

JRC Contract, 2022-23

ART-ER Contract, 2022-23

Filippi 2022-2023

enel x Contract, 15min

IMPETUS Security and Risk

Smartea

Italferr, Smart City

CN MOST, 2022-26

EI THE, 2022-26

G. Agile, 2021-23

TUSCANY EDIH 2023-26 Finanziato dall'Unione europea NextGenerationEU

Merano, smart light

OceanRace, Genova, AWS

Cuneo, smart city

2024

Km4City 1.6.8

TOURISMO

Interreg Euro-MED Co-funded by the European Union

ELLIE IA 2025-2027

UrbanDT4TF

JRC Contract, 2024-25

CAI4DSA

FAIR Future Artificial Intelligence Research

OPTIFaaS

SASUAM

Rhodes, smart city

eShare UNIFI TUSS

AMMIRARE

Interreg MARITTIMO-IT FR-MARITIME

Currently 2025

- **UrbanDT4TF**, CN HPC: Digital Twin mobility, https://www.snap4city.org/1057
- **DI-DTPlatform**, CN HPC: Digital Twin, mobility, environment, https://www.snap4city.org/1097
- **Sasuam**, CN MOST, PNRR: AI, mobility, https://www.snap4city.org/999
- **OPTIFaaS**, CN MOST, PNRR: AI, mobility, DSS, https://www.snap4city.org/1008
- **LeverageOPTIFaaS**, CN MOST: PNRR, mobility, https://www.snap4city.org/1064
- **TOURISMO**, Interreg, EC: Tourism, NLP, DSS, https://www.snap4city.org/1001
- **ELLIE**, Horizon Europe, EC: AI, VR, https://www.snap4city.org/1056
- **CN MOST**, PNRR: sustainable mobility, platform, https://www.snap4city.org/1050
- **ISPRA JRC contract**, EC: DSS, SOC, control room, energy, https://www.snap4city.org/970
- **AMMIRARE**, Interreg, EC: AI, environment, Big Data, https://www.snap4city.org/1002
- **CAI4DSA**, FAIR PE1, PNRR: AI, Neuro-Symbolic, PINN, NG-DSS, https://www.snap4city.org/1016
- **SADI-MIAC**, RT, partner: AI, Tourism, Retail, Computer Vision, https://www.snap4city.org/1055
- **SMART3R,** PRIN UNICagliari: mobility, DSS, https://www.snap4city.org/1087
- **Tuscany X.0, EDIH,** TestBeforeInvest, Training on AI, Big Data, Security, HPC: https://www.tuscanyx.eu/
- **The IE**, PNRR: AI, NLP, LLM, Legal Aspects: https://www.snap4city.org/1116
- **Energia**, RT, conv: AI, PINN, DSS: https://www.snap4city.org/1060
- **MasterPiece**, RT: cultural heritage, predictions: https://www.snap4city.org/1119
- **BullVIT** , RT, conv**:** NLP, LLM
- **RFI contract**: mobility, AI, DSS
- **Salerno Port**: container ID recognition and tracking
- **Talent Hub**, ECRF, conv: NLP, match demands vs offers

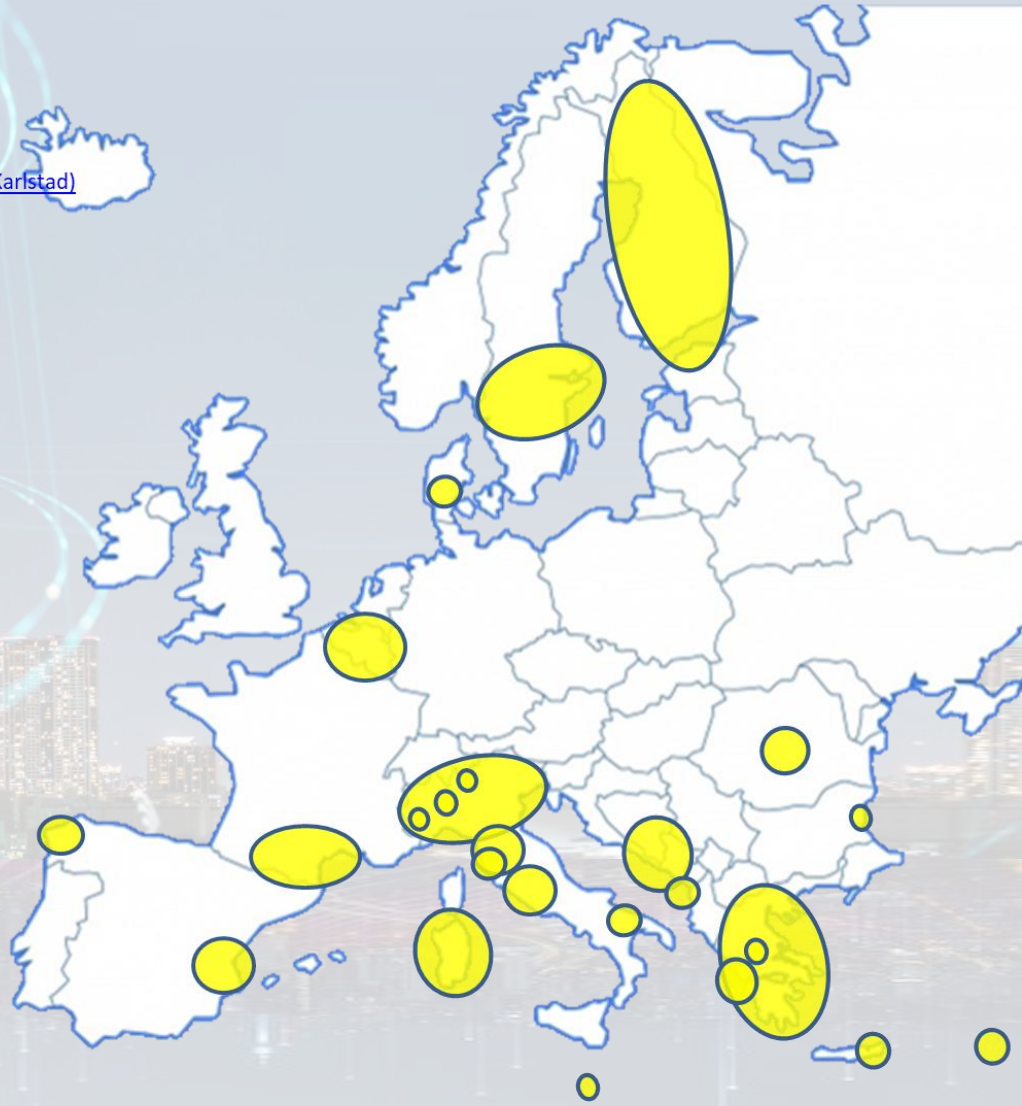
+ currently: Merano, Cuneo, Rhodes, Reverberi, Florence, IDTS, ALTAIR, etc.

https://www.Snap4City.org

- 11 running installations in Europe
  - Snap4city.org, Greece, Merano, Cuneo, …
  - Toscana, Pisa, Sweden, ISPRA, Snap4.eu,
  - Altair, Italmatic, M4F, Romania, ….
- 20 projects, 12 pilots on 10 Countries
  - >40 cities/area
- **Widest MULTI-tenant deploy has**
  - 26 Organizations / tenant
  - > 8850 users on
  - > 1800 Dashboards
  - > 17 mobile Apps
  - **> 2.2 Million of structured data per day**
  - > 580 IoT Applications/node-RED
  - > 850 web pages with training
  - > 85 videos, training videos

Main Organizations/areas

- Antwerp area (Be)
- Bari (I)
- Bisevo, Croatia
- Bologna (I)
- Brasov (Ro), by ICEBERG
- Capelon (Sweden: Västerås, Eskilstuna, Karlstad)
- Cuneo (I)
- DISIT demo (multiple)
- Dubrovnik, Croatia
- Firenze area (I)
- Garda Lake area (I)
- Greece (Gr)
- Helsinki area (Fin)
- Limassol (Cy)
- Livorno area (I)
- Lonato del Garda (I)
- Malta (Malta)
- Merano (I)
- Modena (I)
- Mostar, Bosnia-Herzegovina
- Oslo & Padova (Impetus)
- Pisa area (I)
- Pistoia (I)
- Pont du Gard, Occitanie (Fr)
- Prato (I)
- Rhodes (Gr)
- Roma (I)
- Santiago de Compostela (S)
- Sardegna Region (I)
- Siena (I)
- SmartBed (multiple)
- Toscana Region (I), SM
- Valencia (S)
- Varna (Bulgaria)
- Venezia area (I)
- WestGreece area (Gr)



- **+ Israel, Colombia, Brasile, Australia, India, China, etc.**

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CITY

INDUSTRY

ARTIFICIAL INTELLIGENCE

MOST Centro Nazionale per la Mobilità Sostenibile

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LUTECH

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PTIFaaS

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Politecnico di Bari

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Coesione Italia Toscana

Cofinanziato dall'Unione europea

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ASM Meran Stadtwerke Meran

Città di Cuneo

Rodhes

Development Agency of Iemesos LTD

Santa María la Real fundación

Fundación Valenciaport

READ S.A. Development Agency of South Aegean Region

Varna Economic Development Agency

rerasd

MRDD Foundation

SNAP4 CAPELON

uni.systems

European Commission Joint Research Centre

italmatic Autoclaves Ovens & Rollers

cyta

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FREE TRIAL

PEN Test Passed

EU GDPR COMPLIANT

SNAP4 Appliances and Dockers Installations

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Node-RED

NVIDIA

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FIWARE SERVICES Training & Coaching

FIWARE SERVICES Consultancy & Integration

gaia-x

JS Foundation

E015 digital ecosystem

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SNAP4 Appliances and Dockers **Installations**

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