SNAP4CITY

www.snap4city.org
www.snap4solutions.org

KM4CITY

www.km4city.org

Digital Twin e Città in Movimento: tracciamento in tempo reale dei flussi ed intelligenza artificiale a servizio della città e dei decisori pubblici

SMARTCITY EXPO WORLD CONGRESS
7-9 November 2023, Barcelona, Spain
Visit Snap4City in Hall 1

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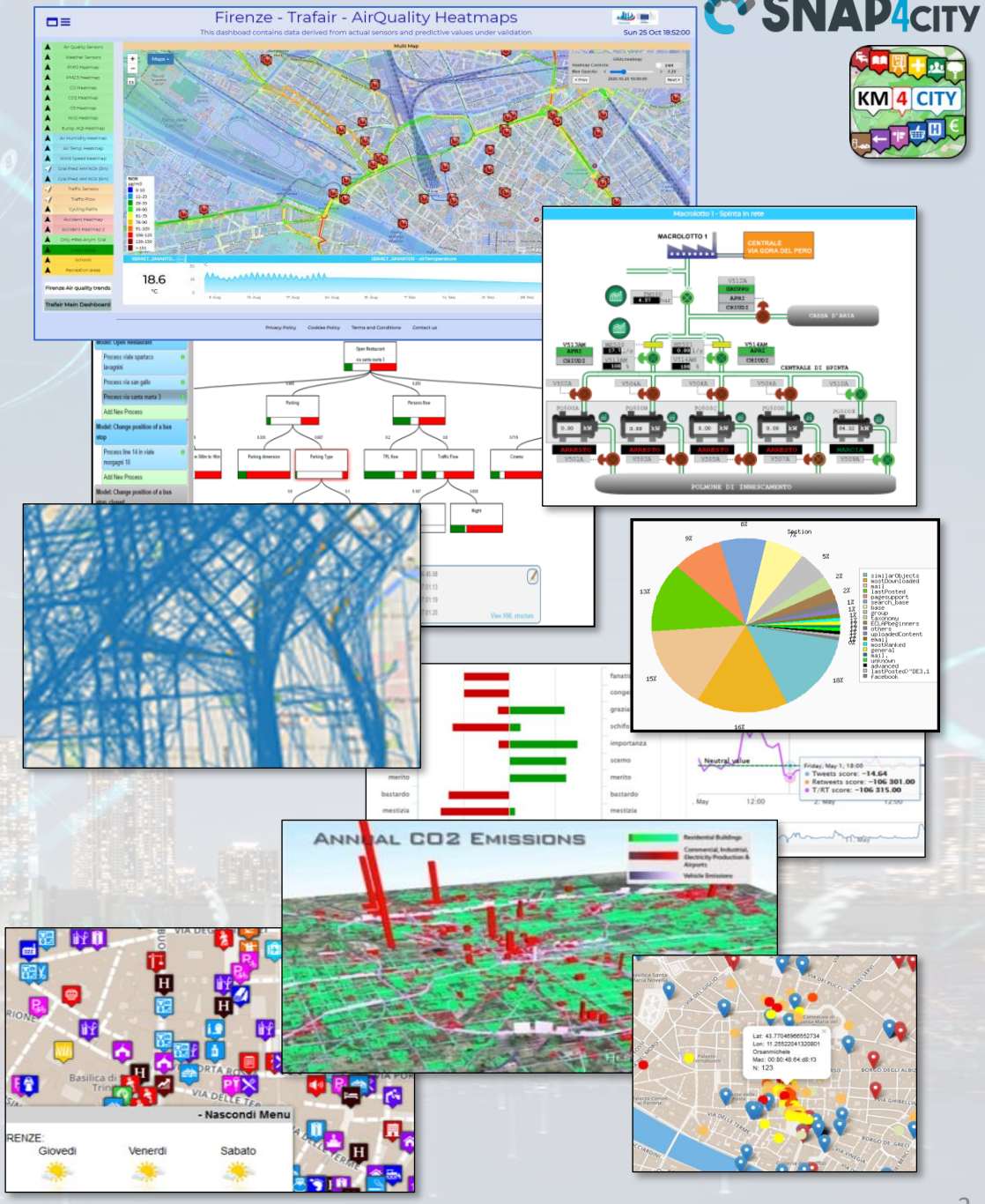
DIGITAL TWIN SOLUTIONS TO SETUP SUSTAINABLE DECISON SUPPORT SYSTEMS AND BUSINESS INTELLIGENCE

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

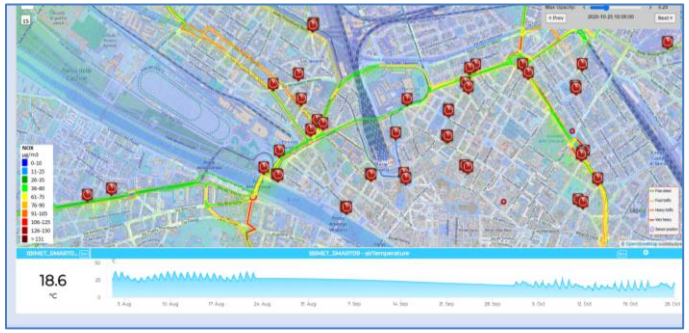
Data Driven Decision Support

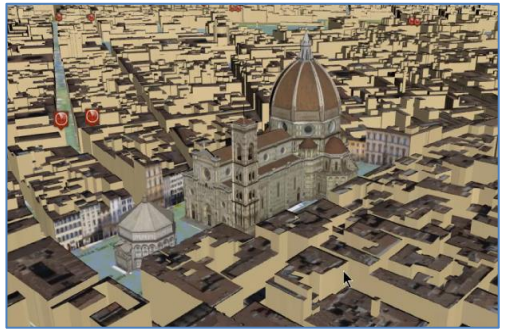
- Decision Support system
- Assessment / Strategies
- Data Rendering,
  - visual analytics, business intel..
- Data Analytics, ML, AI
- Data aggregation, Storage, indexing
- Data Ingestion

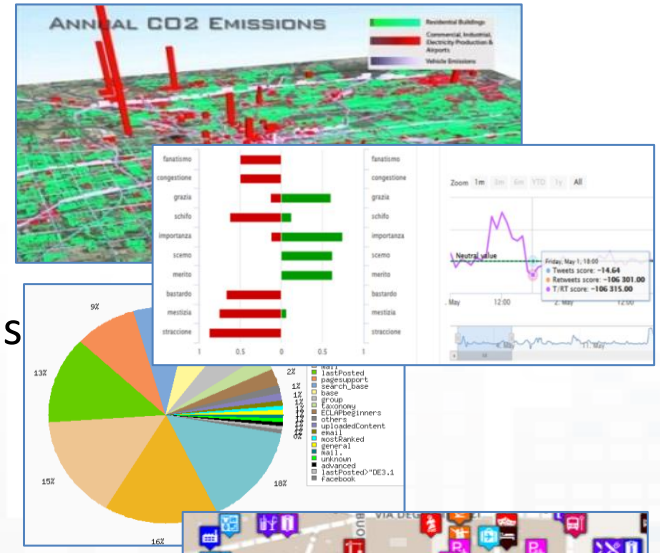


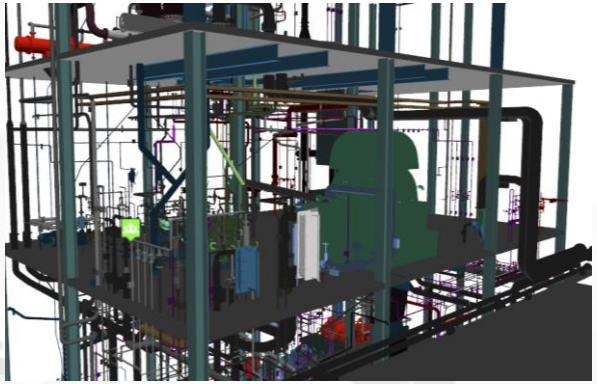
Digital Twin

- **Digital Twin**
  - **Connected** with real systems
  - **Modelling** aspects: structural, visual, informative, real time data sensors (context), POI, functional, resources, etc.
  - **Integration:** AI/XAI techniques, simulations, users' needs, etc.
- **Utility to**
  - Experiment via simulations and analysis by case
    - Reduction of costs to experiments new solutions
    - Share the possibilities with city users
  - Virtual Representation
    - Easier to understand the context, review from multiple points of view
  - Who
    - Discussion with city users, decision makers
    - Support: decision makers, proposers of solutions

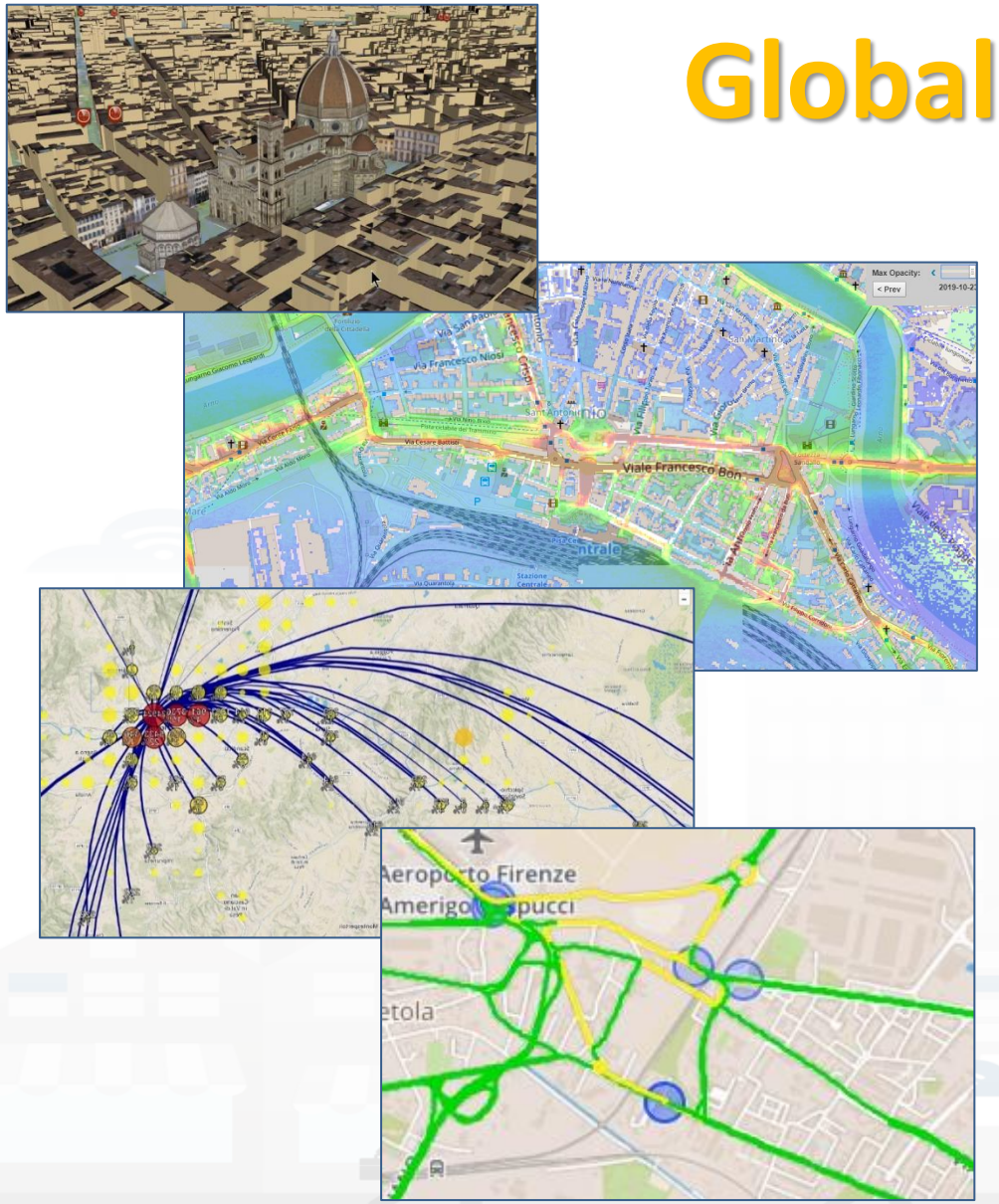








Global Digital Twin



3D representation of the city with…

- geomorphological, hydrogeological aspects,
- private and public transport networks,
- waste recovery systems,
- weather conditions, climate and microclimate,
- events, emergencies, ..., parking, sharing, ...
- tourist and city user flows, origin destination matrices,
- commercial activities, urban decorum, public lighting,
- green areas, cleanliness, safety on the road and in pedestrian areas,
- places for entertainment events, cultural activities, attraction and aggregation points of the city,

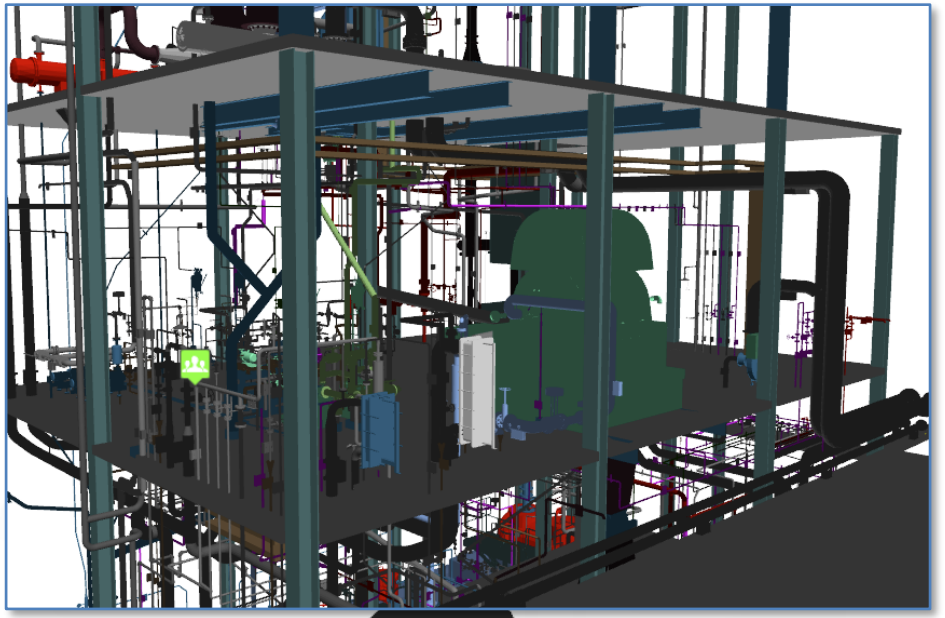
Complex and heterogeneous information, structured and unstructured, historical series and in real time data, public/private and sensitive data for security aspects.

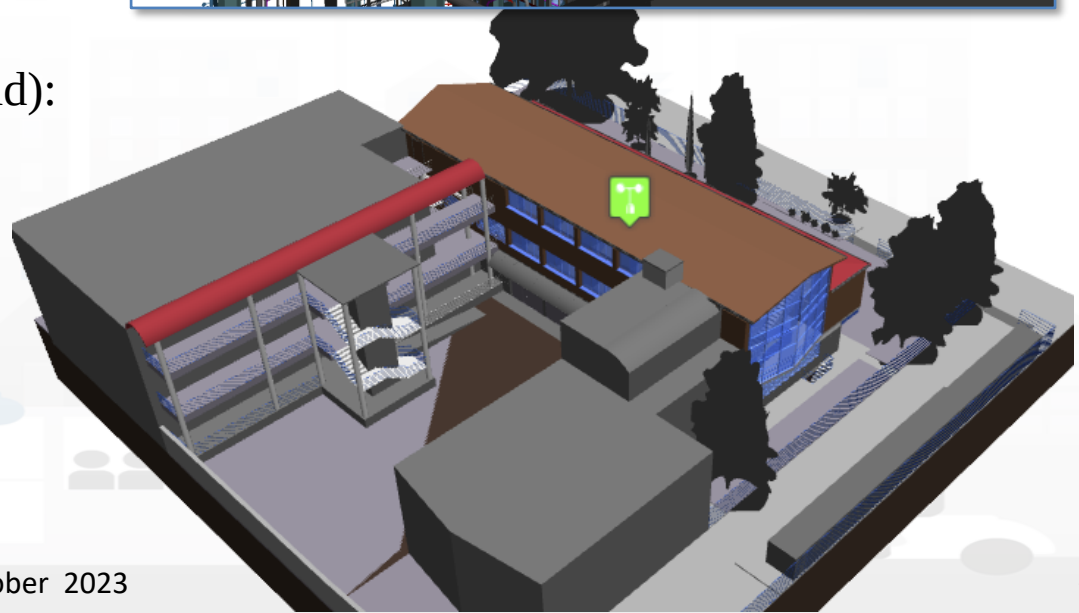
- → **Reuse of legacy systems**
  - GIS (Geographical Information System),
  - ITS (Intelligent Transportation System),
  - AVM (Automatic vehicle monitoring),
  - from IoT (Internet of Thing) systems and networks.

The Local Digital Twin

- **Digital Twin:**
  - From a single sub-system (**Local Digital Twin**) to
  - A whole city or apart of it (**Global Digital Twin**)

- To model various data kind and to keep them connected to each other ad to its counterparts in physical world:
  - a **building with its BIM** (Building Information Modeling) model with details of the floors, plumbing, electrical subsystems, services, construction materials, etc.;
  - **control systems** with their real-time data (data from the IoT world): boilers, air conditioners, electrical systems, sensors, network connection, etc.;
  - **events and the evolution of their status;**
  - **functional and structural aspects;**
  - **How they are used**;
  - **microclimatic aspects,**
  - etc.





Smart Solutions and Decision Support Systems

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

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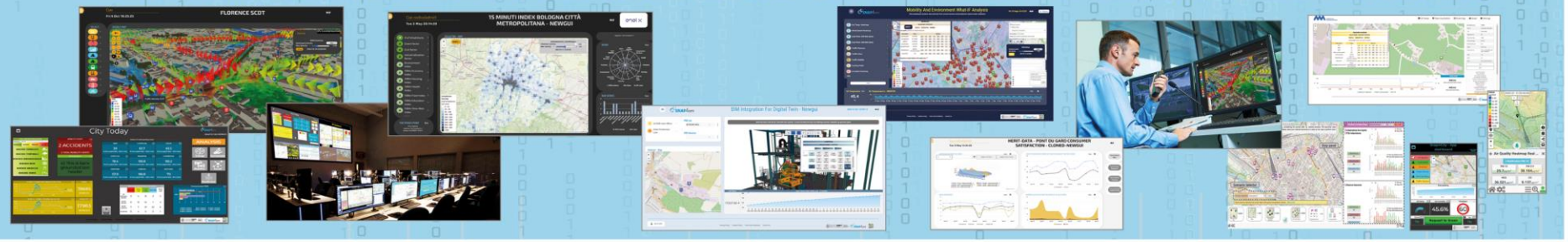
CONTROL ROOMS - DECISION SUPPORT SYSTEMS - WHAT-IF ANALYSIS - BUSINESS INTELLIGENCE - SIMULATIONS - SMART APPLICATIONS



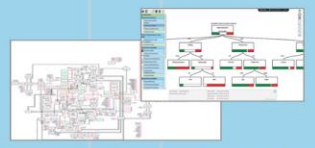
DASHBOARDS - VISUAL ANALYTICS - SYNOPTICS - DIGITAL TWIN - GRAPHICAL WIDGETS - ANALYTICS - GUI CUSTOM STYLES - VISUAL PROGRAMMING

DASHBOARDS, WIDGETS
TEMPLATES

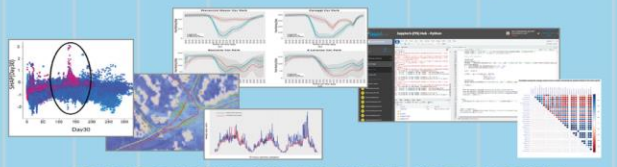
PREDICTION - ANOMALY DETECTION - CLUSTERING - ROUTING - SENTIMENT NLP - TRAFFIC FLOW
PEOPLE FLOWS - SDG - 15 MIN CITY INDEX - KPI - HEATMAPS - ORIGIN DESTINATION - ETC...

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

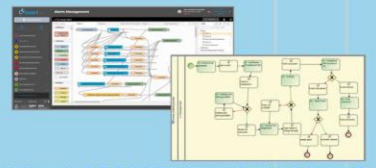
ANY: DATA, BROKER, NETWORK AND VERTICAL



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



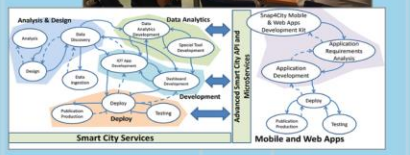
BIG DATA ANALYTICS, ARTIFICIAL INTELLIGENCE
EXPLAINABLE AI, MACHINE LEARNING
OPERATIVE RESEARCH, STATISTICS



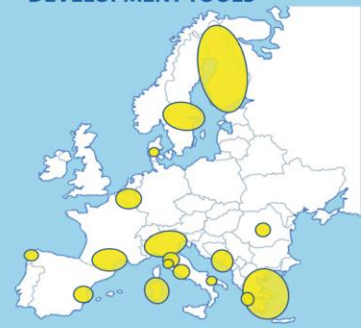
VISUAL PROGRAMMING, ADAPTERS
DATA FLOWS, WORKFLOWS
PARALLEL DISTRIBUTED PROCESSING
DATA DRIVEN

Native and External Smart Applications

- Mobility & Transport
- Light & Energy
- Waste
- Environment
- Building
- Tourism
- Social Media
- ...



METHODOLOGIES
LIVING LABS
COURSES AND COMMUNITY
DEVELOPMENT TOOLS



Standards and Interoperability (9/2022)

Compliant with:

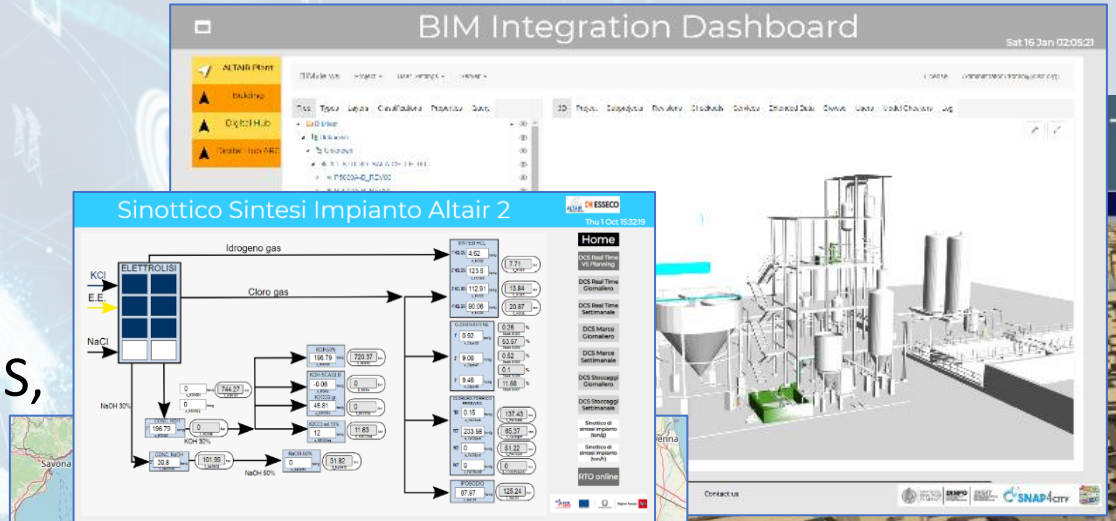
- **IoT:** NGSI V2/LD, LoRa, LoRaWan, MQTT, AMQP, COAP, OneM2M, TheThingsNetwork, SigFOX, Libelium, IBIMET/IBE, Enocean, Zigbee, DALI, ISEMC, Alexa, Sonoff, HUE Philips, Tplink, BACnet, TALQ, Protocol Buffer, KNX, OBD2, Proximus, ..
- **IoT model:** FIWARE Smart Data Model, Snap4City IoT Device Models
- **General**: HTTP, HTTPS, TLS, Rest Call, SMTP, TCP, UDP, SOAP, WSDL, FTP, FTPS, WebSocket, WebSocket Secure, GML, WFS, WMS, RTSP, ONVIF, AXIS TVCam, CISCO Meraki, OSM, Copernicus, The Weather Channel, Open Weather, OLAP, ….
- **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, ..
- **Social**:Twitter, FaceBook, Telegram, ..
- **Events**: SMS, EMAIL, CAP, RSS Feed, ..
- **OS**: Linux, Windows, Android, Raspberry Pi, Local File System, AXIS, ESP32, etc.

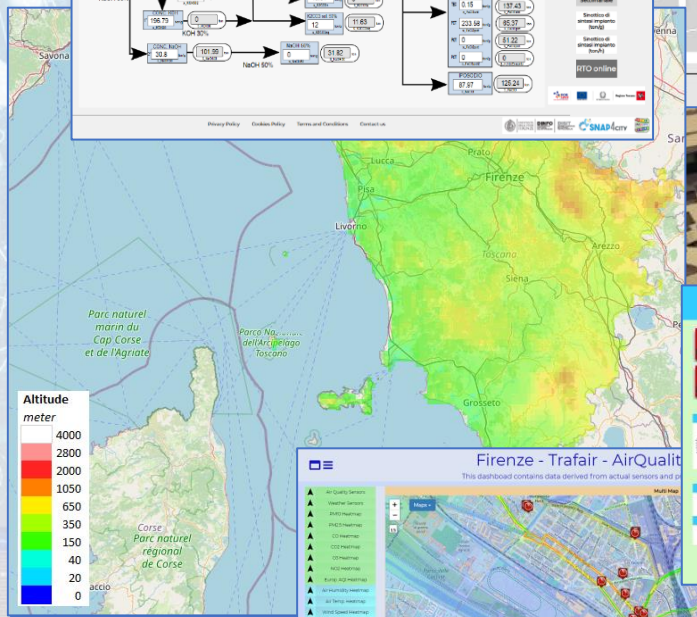
https://www.snap4city.org/65

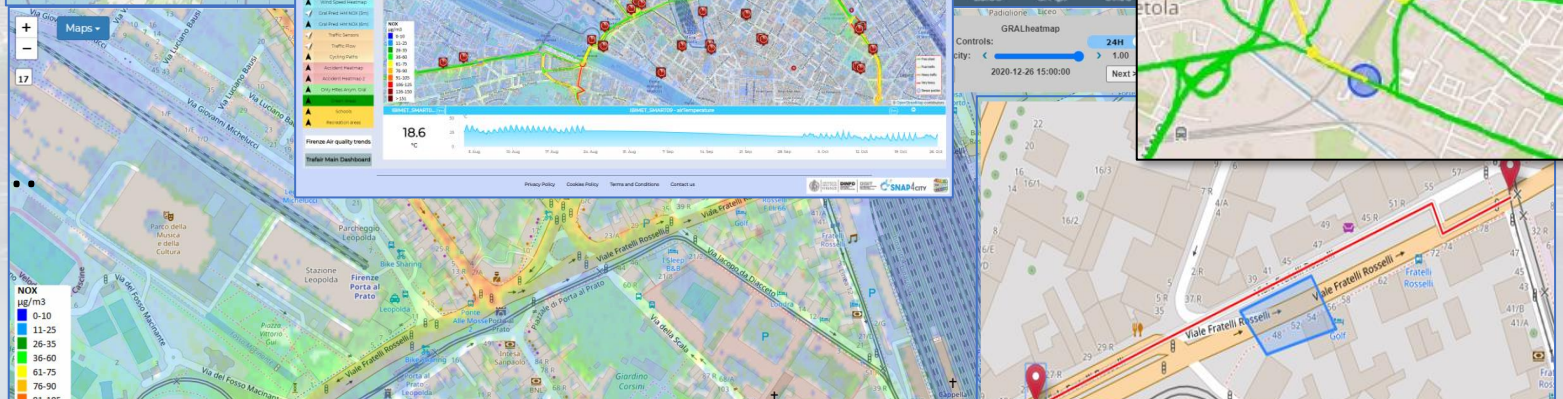
High Level Types

Snap4City (C), October 2023

- POI, IOT Devices, shapes,..
  - FIWARE Smart Data Models,
  - IoT Device Models
- GIS, maps, orthomaps, WFS/WMS, GeoTiff, calibrated heatmaps, ..
- Satellite data, ..
- traffic flow, typical trends, ..
- 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, ..
- decision scenarios, ….
- etc.

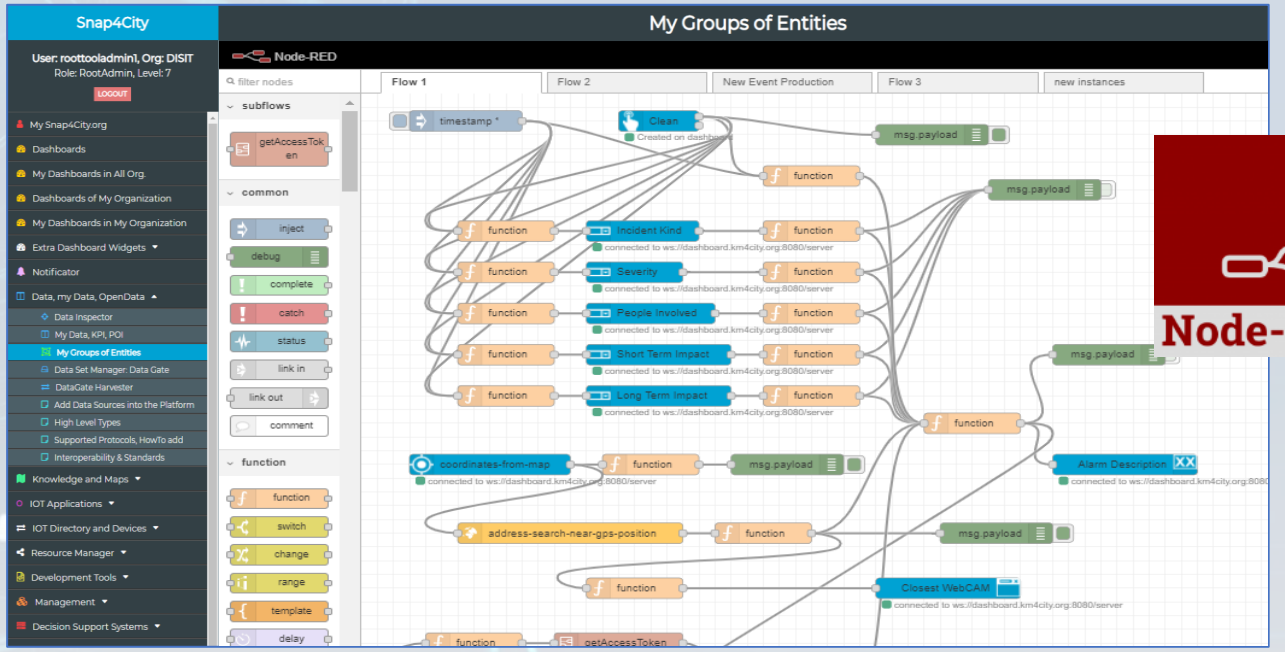


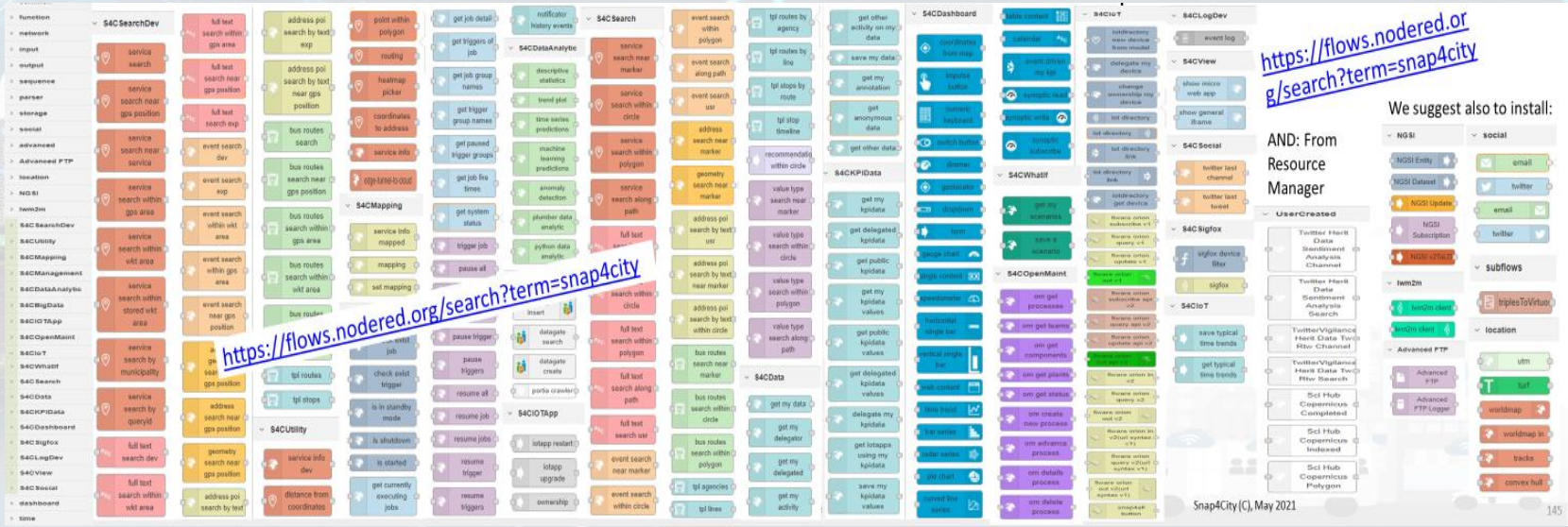




Almost no coding platform

- **IoT App Visual Programming, no coding**
  - **Data transformation**
  - **Integration**
  - **Scripting Data Analytics**
  - **Data ingestion**
  - **Business logic**
- **MicroServices** data driven develop via visual language Node-RED

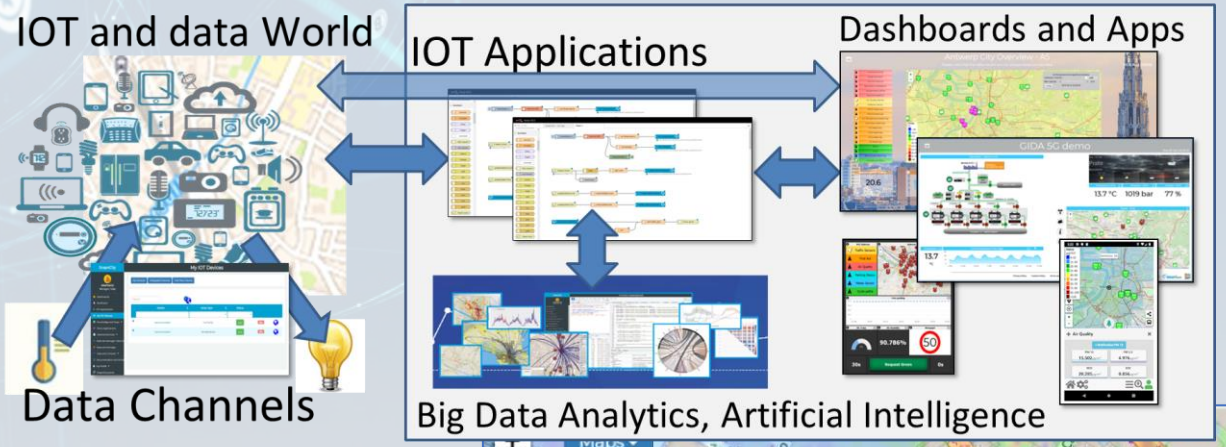


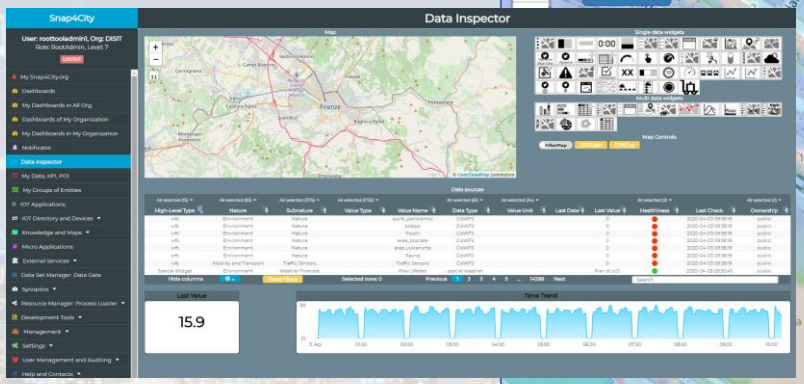


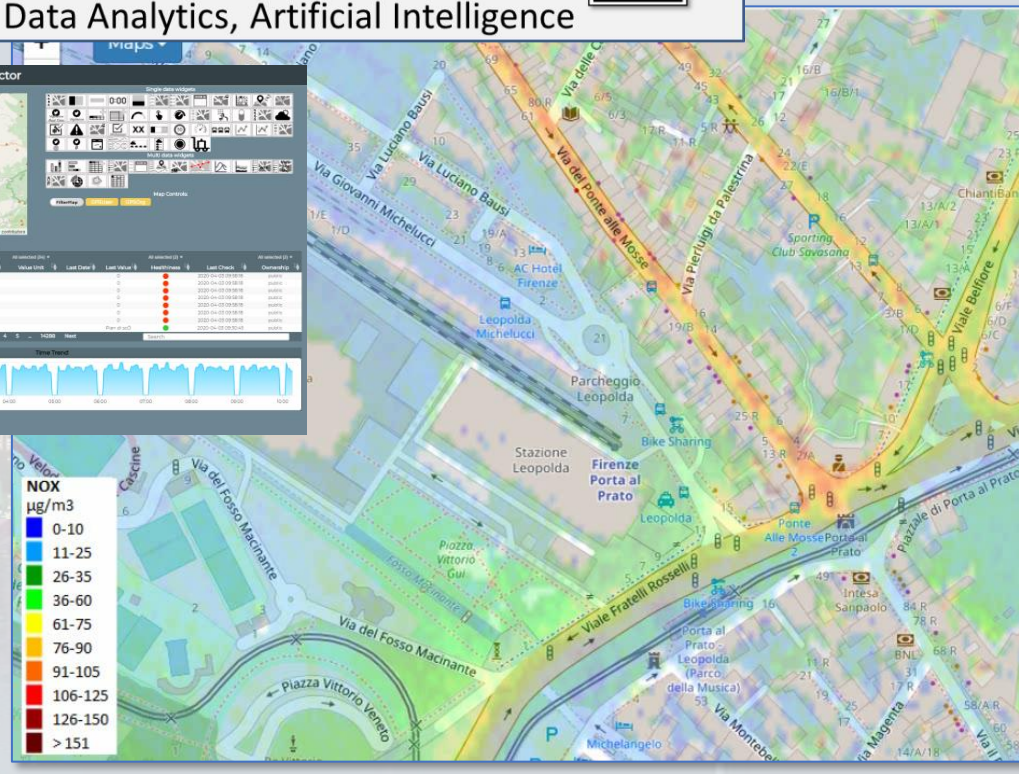
Fast to realize reliable & secure Solutions

- **Via Snap4City tools**
  - **Dashboard Wizard**
  - **Dashboard Builder**
  - **Data/Visual Analytic**

- **Smart Solutions results to be**
  - **Real time data drive**
  - **Secure end-to-end**
  - **GDPR compliant**
  - **Reliable, interoperable**
  - **Auditable, marketable**







indicators

			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);
- **PUMS: mobility and transport vs wnv**
- **SUMI: mobility and transport vs env**
- **ISO indicators: city smartness, digitization. Tech level**
- ….

Global Vs Local

Available DA / AI Solutions on Snap4City

- **Mobility and Transport**
- **Environment, Weather, Waste, Water**
- **City Users Behaviour and Social analysis**
- **Energy and Control, Security, …..**
- **High Level Decision Support Solutions**
  - **Management Strategies**
  - **Resilience and Risks Analysis**
- **Low level Techniques**

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

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

Big Data Analytics + Artificial Intelligence

- **Decision support**
  - **Early warning, City Indexes, etc.**
  - **What-IF analysis** (simulation + AI + data)
- **Predictions**
  - **Short and Long terms predictive models on:**
    - traffic, parking, people flow, maintenance, land sliding, NO2
  - **3D Flow prediction:** Pollutant (NOX, NO2, …)
- **Suggestions and recommendations**
- **Modeling, simulation, routing**
  - **Traffic Flow reconstruction**
  - **Constrained Routing**

AI & XAI:

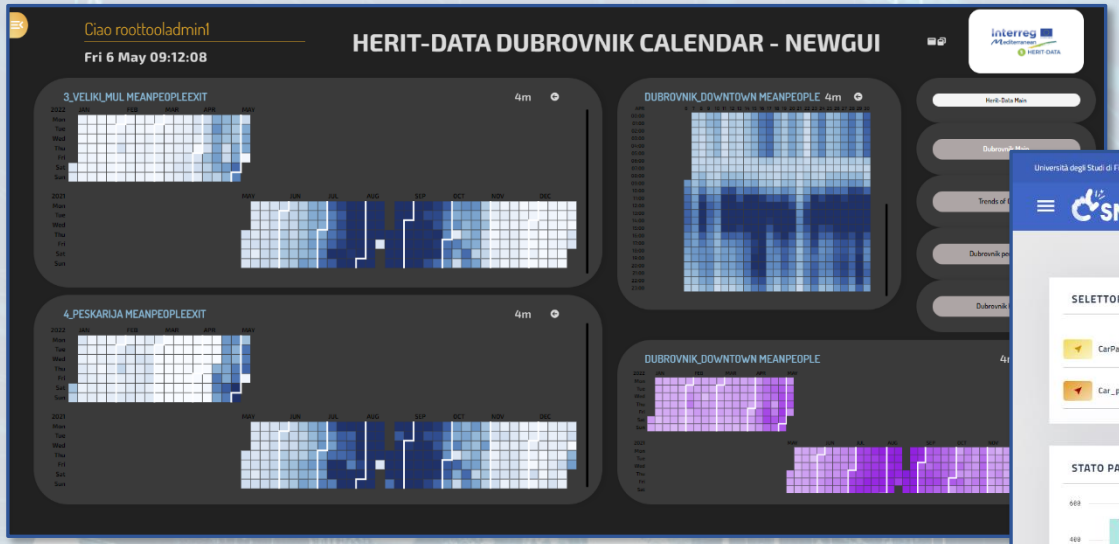
- RF, XGBoost, BRNN, RNN, SVR, DNN, LSTM, CNN-LSTM, Autoencoders, neuro-symbolic..
- Clustering: K-means, K-Medoid, …
- Semantic Reasoning, ..
- XAI: Shap, variations, Lime, gradients, …

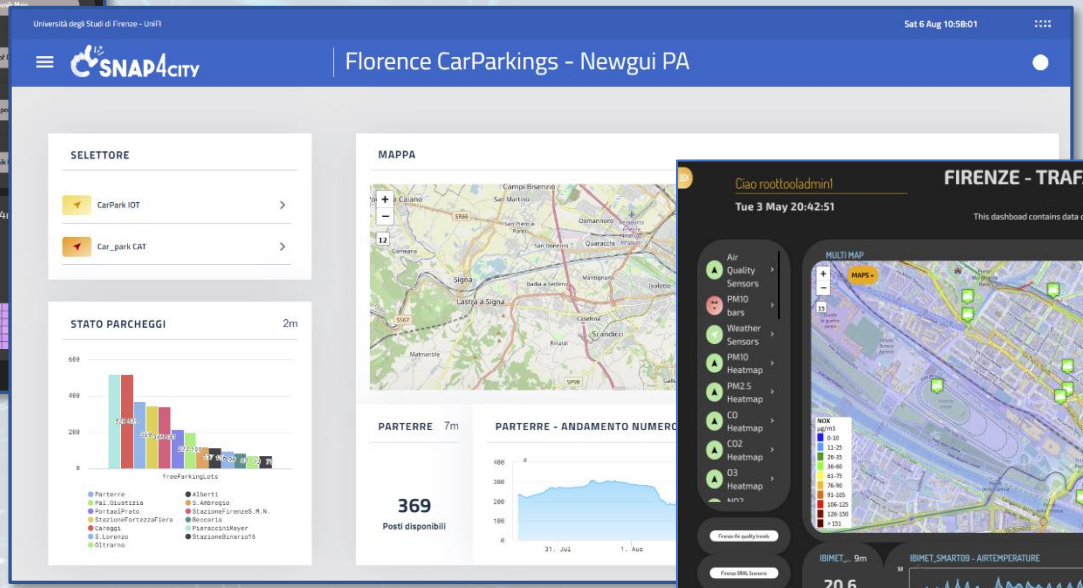
Representations, animated

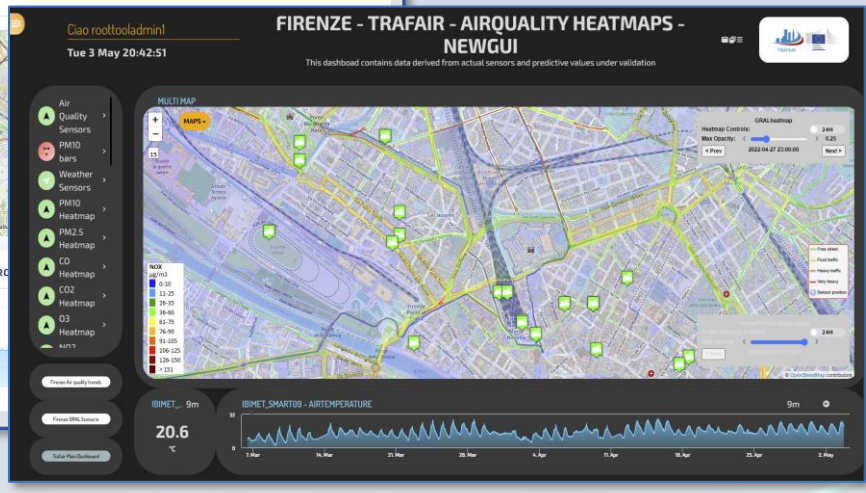
- Heatmaps, Traffic, Flows, ..
- Trajectories, OD matrices,
- 3D Rendering
- Typical Time Trends, etc.

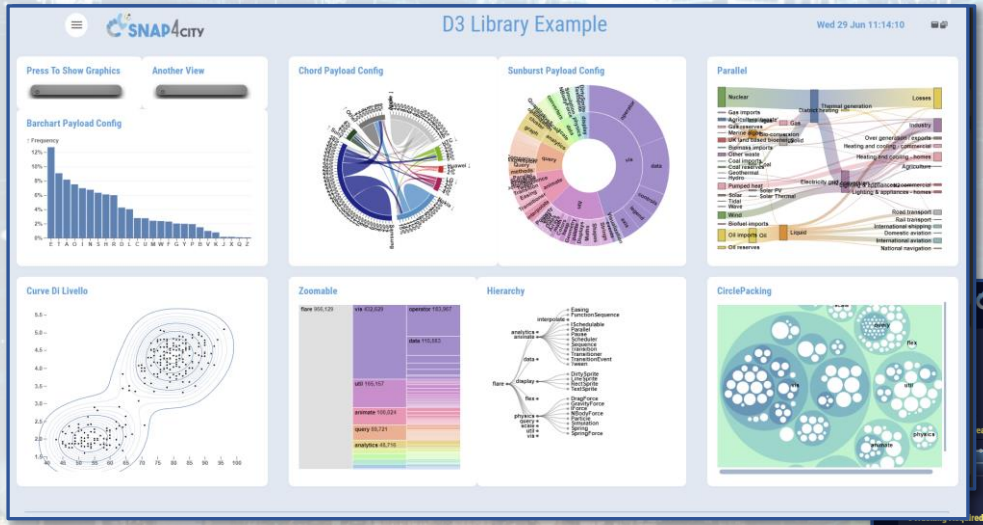
https://www.snap4city.org/download/video/course/da/

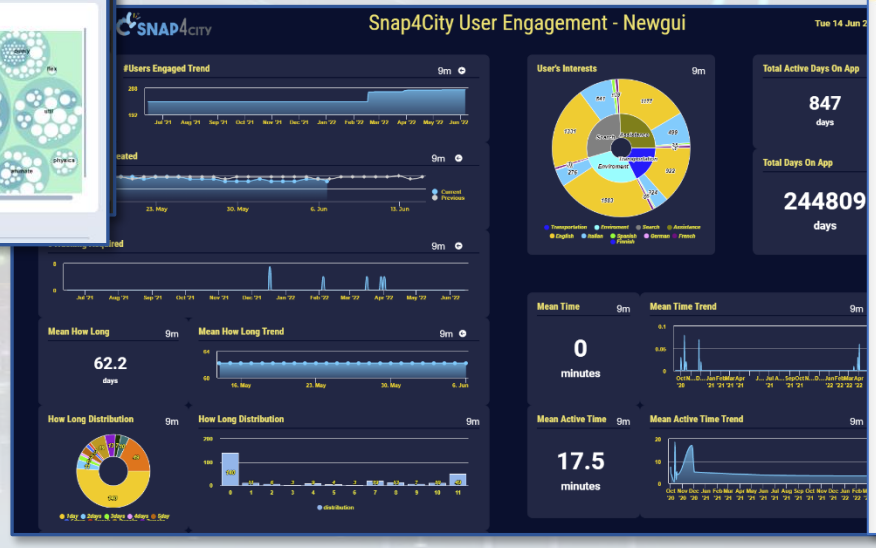
Different Themes

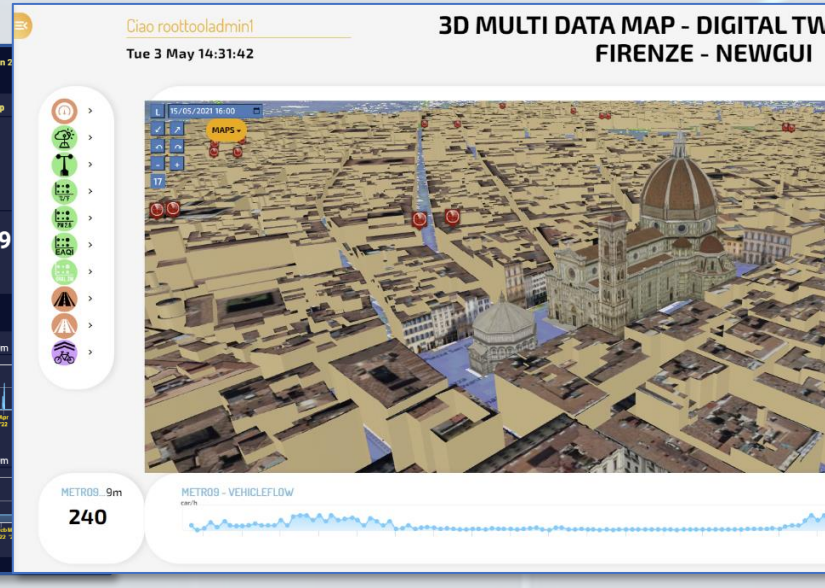












New styles/themes can be developed by specializing a few files from open source

https://www.snap4city.org/793

Smart City Control Room
Florence Metropolitan City

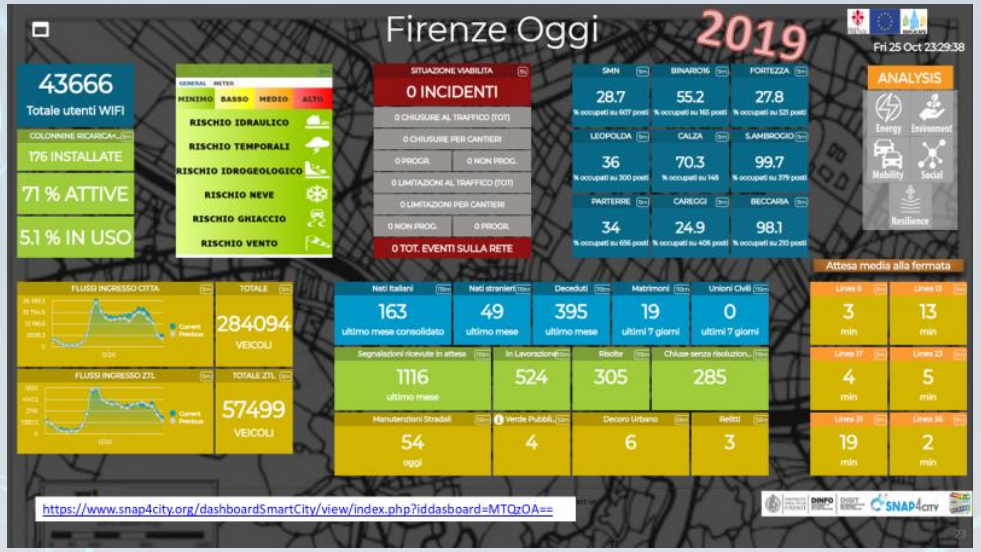
COMUNE DI FIRENZE

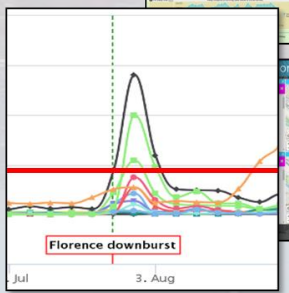
reference

SNAP4CITY

KM 4 CITY

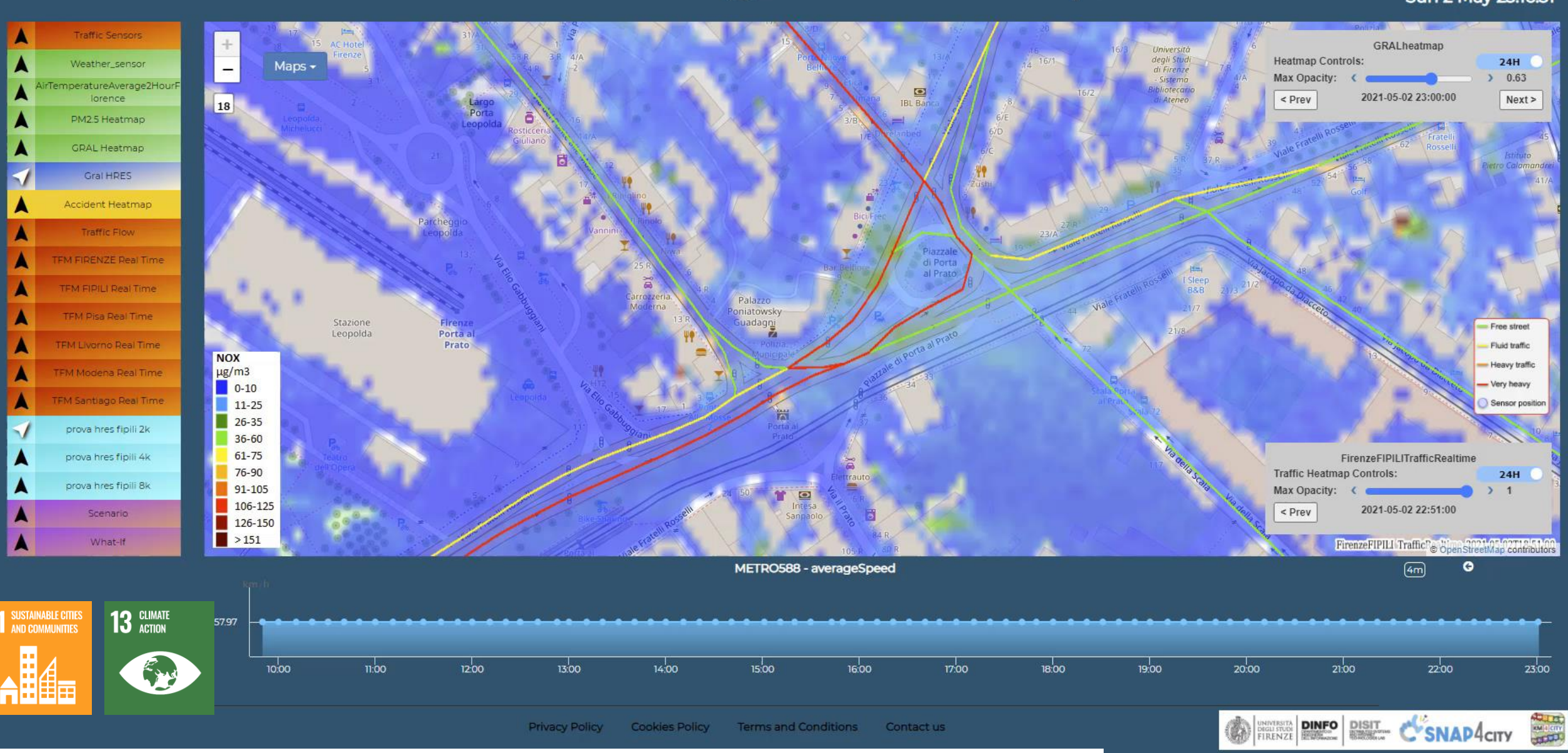
- **Multiple Domain Data**
  - Thousands of Open/Private data, POI, IOT, etc.
  - ***mobility and transport***: accidents, public transport, parking, traffic flow, Traffic Reconstruction, KPI, …
  - ***AND***: environment, civil protection, gov KPI, covid-19, social & social media, people flow, tourism, 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

Traffic Flow Manager on multiple cities

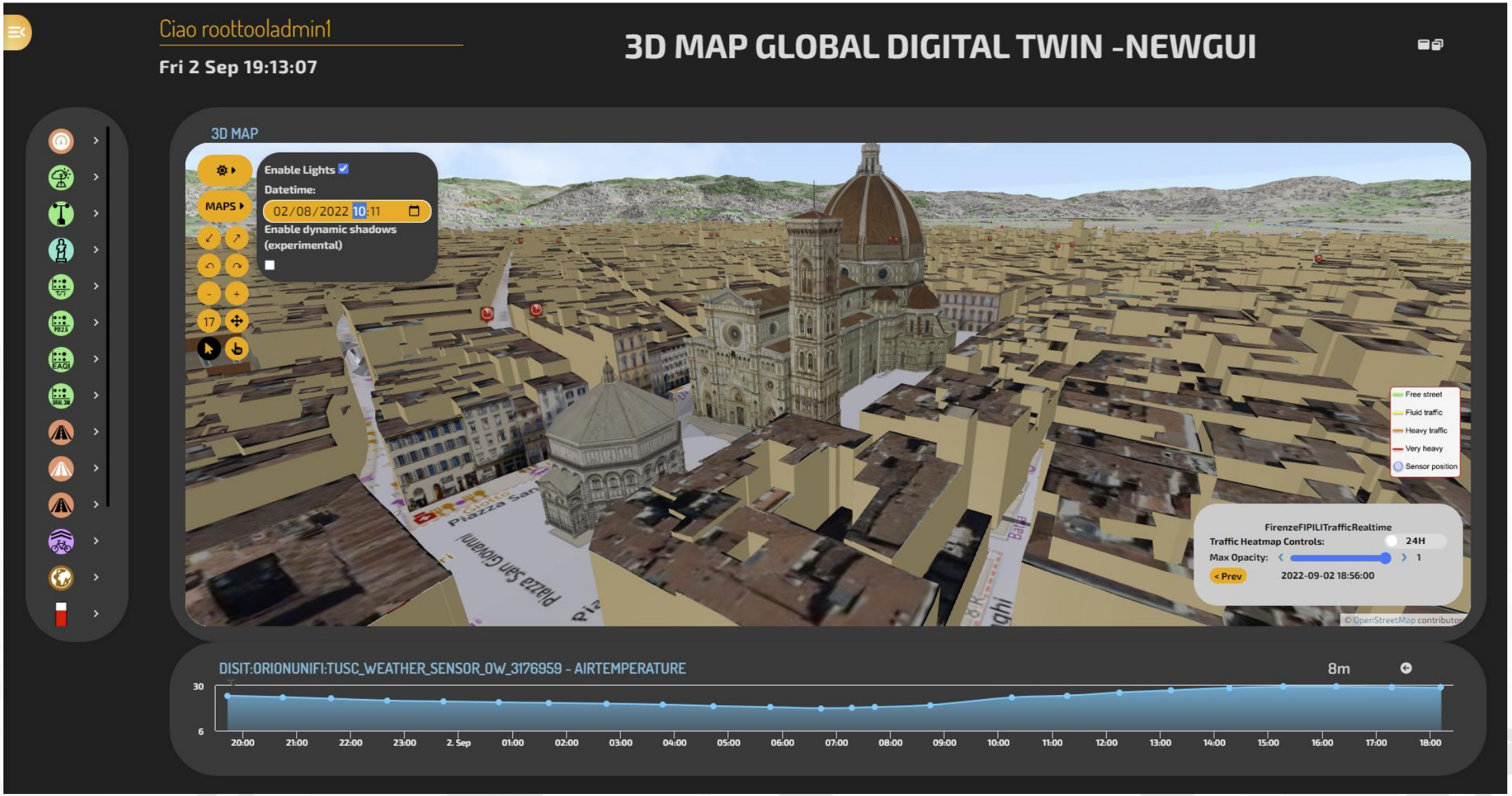


11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

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

3D View


Ciao roottooladmin1
Fri 2 Sep 19:13:07
3D MAP GLOBAL DIGITAL TWIN -NEWGUI
3D MAP
Enable Lights
Datetime:
02/08/2022 10:11
MAPS
Enable dynamic shadows (experimental)
Free street
Fluid traffic
Heavy traffic
Very heavy
Sensor position
FirenzeFIPILITrafficRealtime
Traffic Heatmap Controls:
24H
Max Opacity:
1
< Prev
2022-09-02 18:56:00
© OpenStreetMap contributors
DISIT:ORIONUNIFI:TUSC_WEATHER_SENSOR_OW_3176959 - AIRTEMPERATURE
8m
30
6
20:00
21:00
22:00
23:00
2. Sep
01:00
02:00
03:00
04:00
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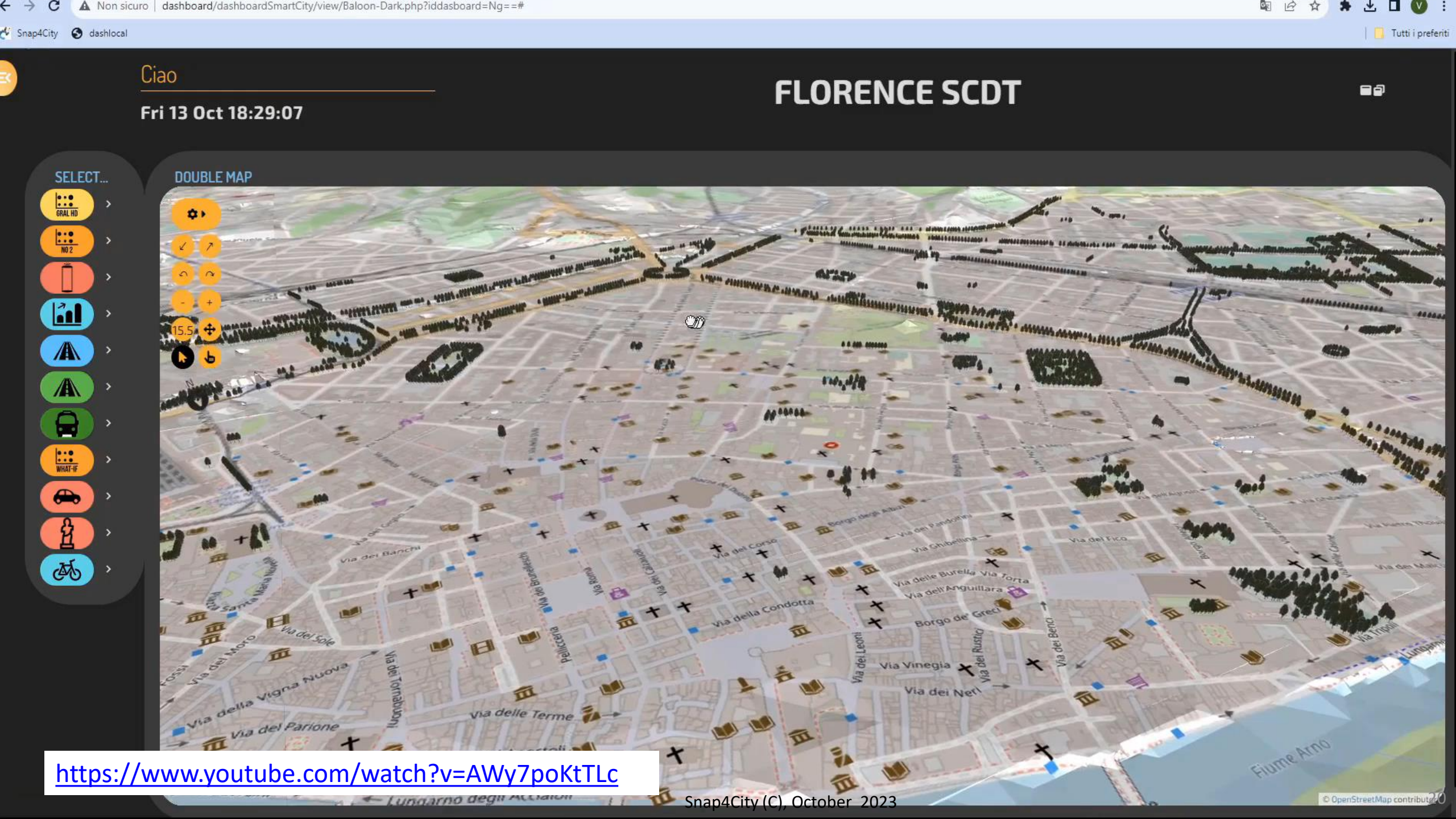


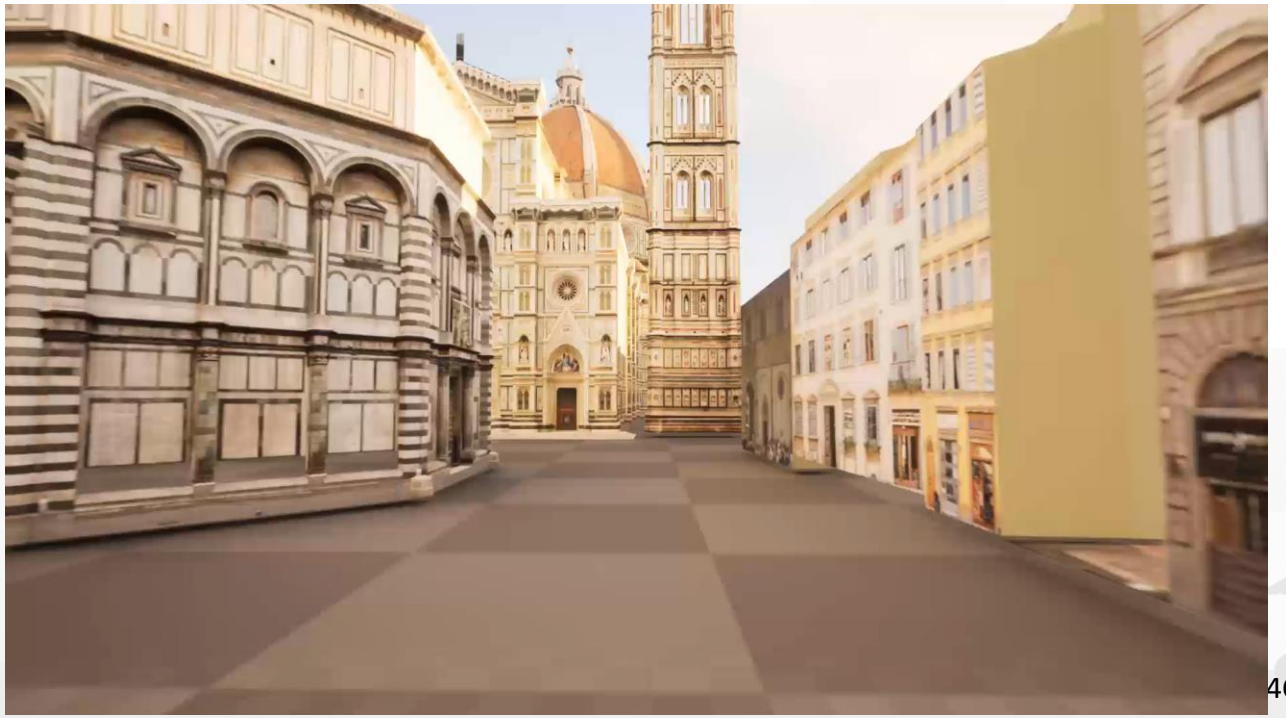
https://www.youtube.com/watch?v=AWy7poKtTLc

Local Digital Twin vs BIM

OCULUS

https://digitaltwin.snap4city.org

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

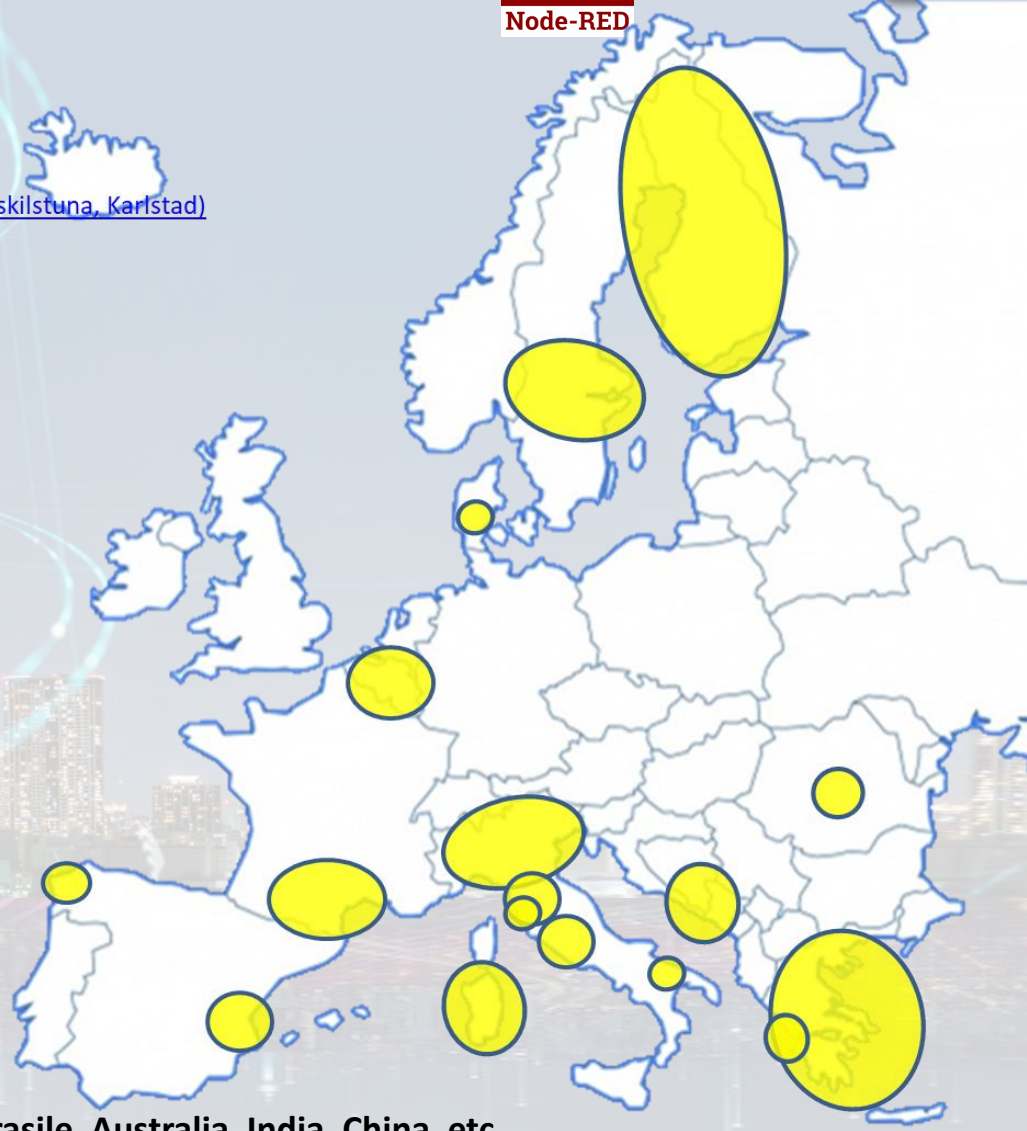


https://www.Snap4City.org

- 11 running installations in Europe
  - Snap4.city.org, Greece, Merano, …
  - Toscana, Pisa, Sweden, ISPRA, Snap4.eu,
  - Altair, Italmatic, Sweden, Romania, ….
- 16 projects, 12 pilots on 10 Countries
  - >40 cities/area
- **Widest MULTI-tenant deploy has**
  - 19 Organizations / tenant
  - > 8000 users on
  - > 1600 Dashboards
  - > 16 mobile Apps
  - **> 2.2 Million of structured data per day**
  - > 520 IoT Applications/node-RED
  - > 700 web pages with training
  - > 70 videos, training videos

Main Organizations/areas

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



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

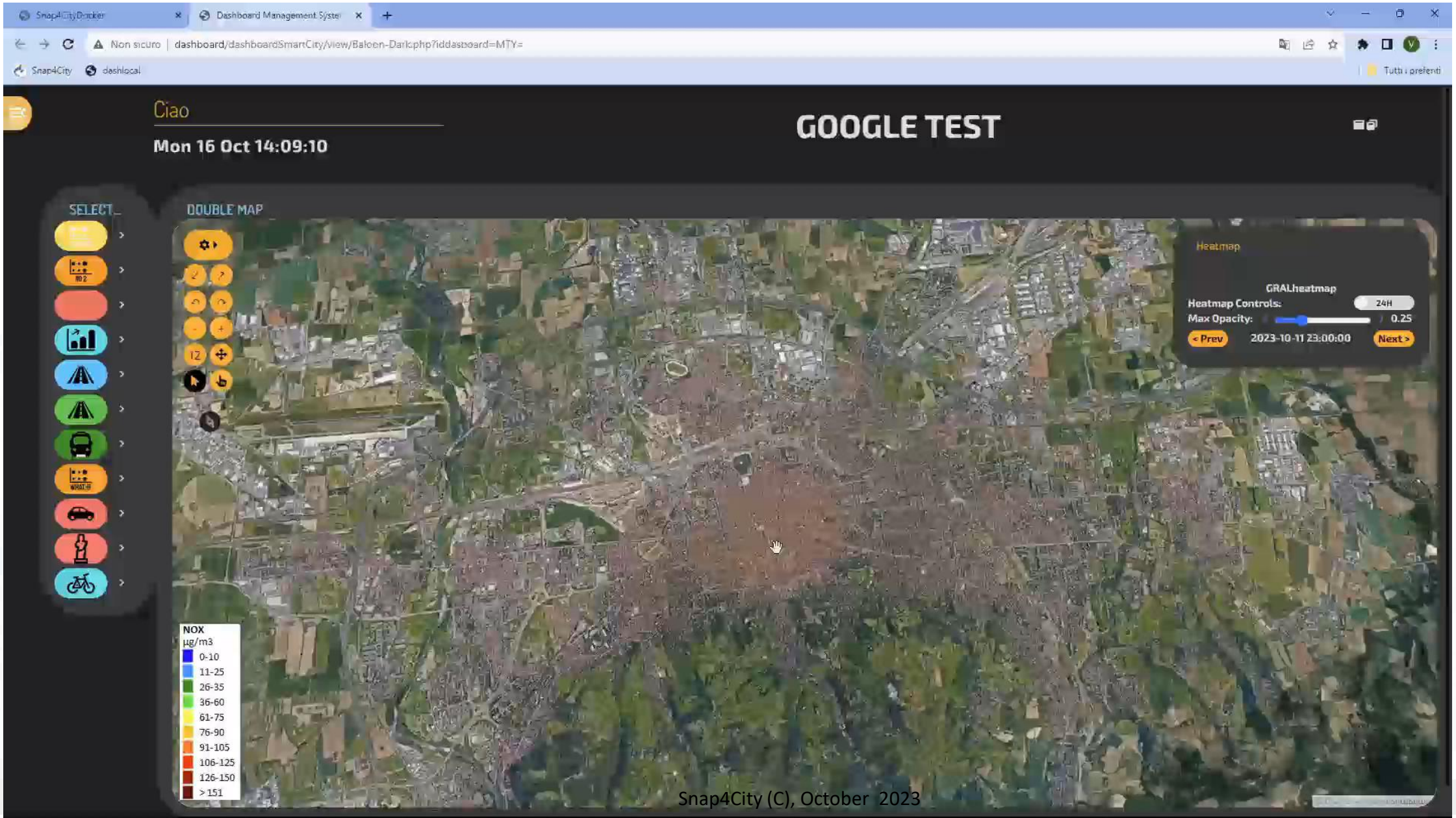
UNIVERSITÀ DEGLI STUDI FIRENZE

DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

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

Bologna

SNAP4CITY KM4CITY



UNIVERSITÀ DEGLI STUDI FIRENZE

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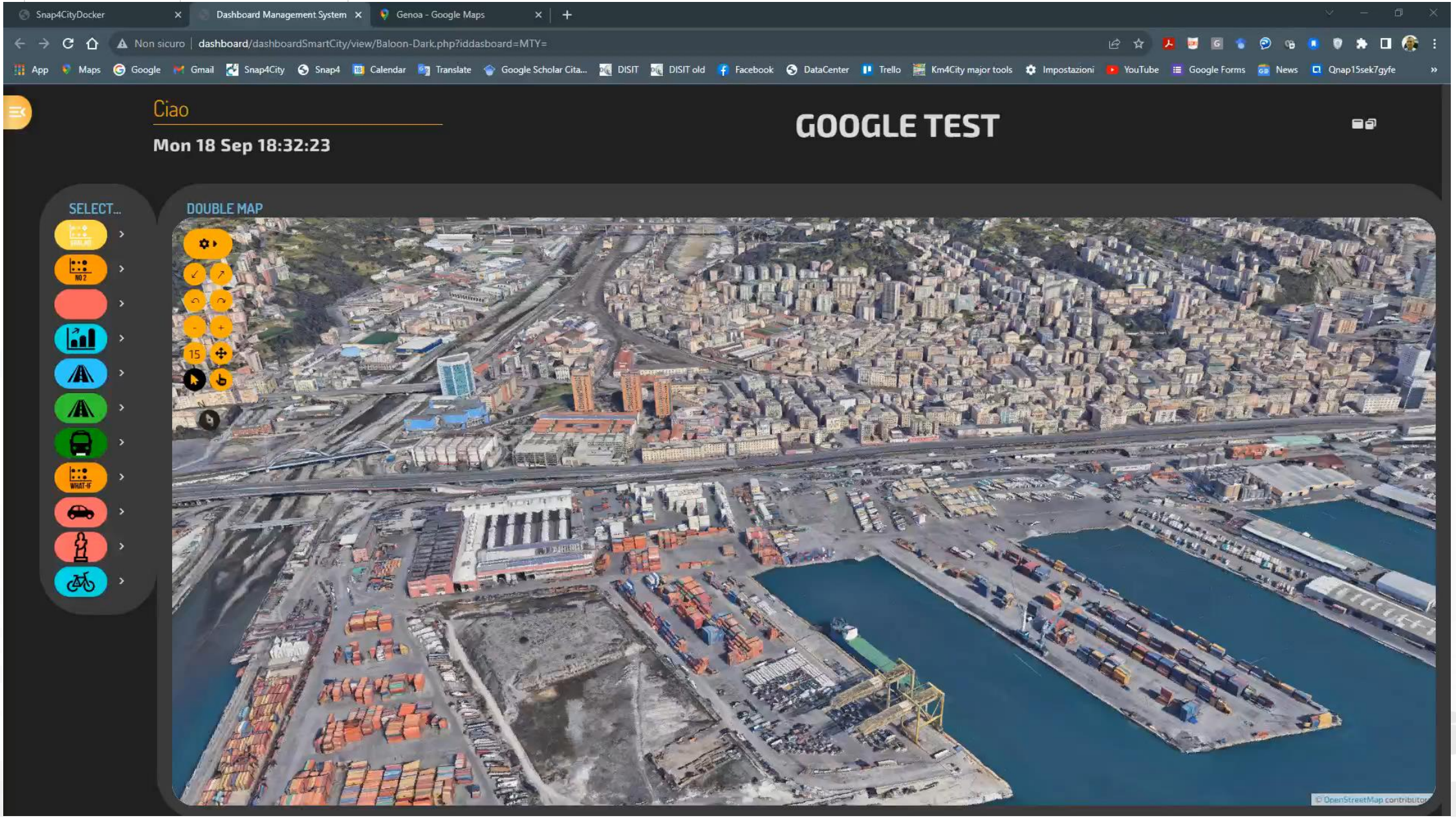
DISIT
DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB
DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB

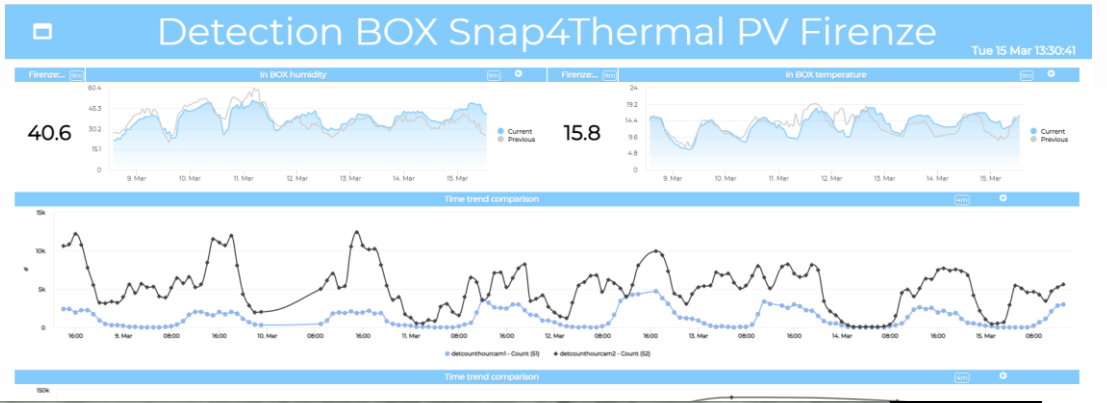
Genova

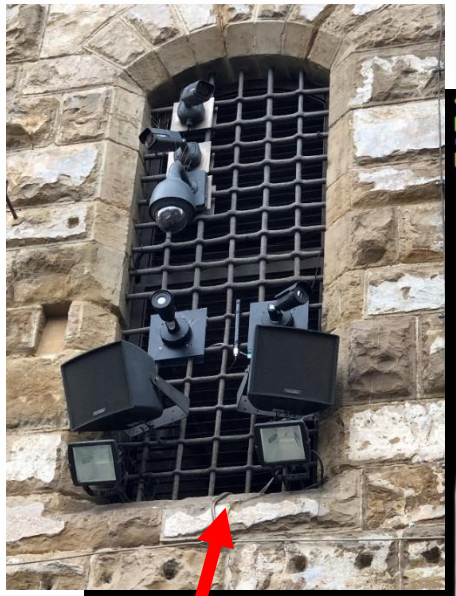
SNAP4CITY

KM4CITY

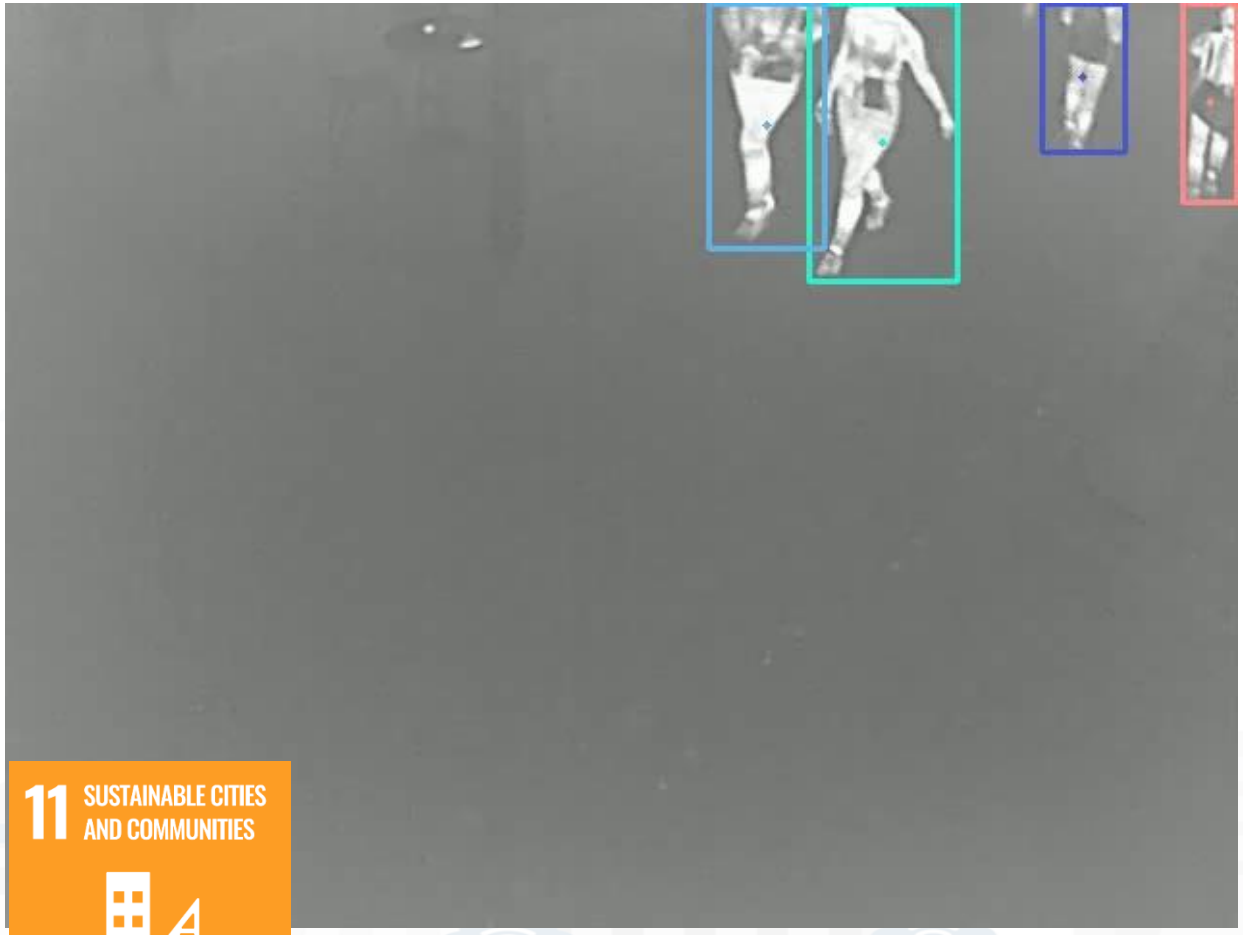


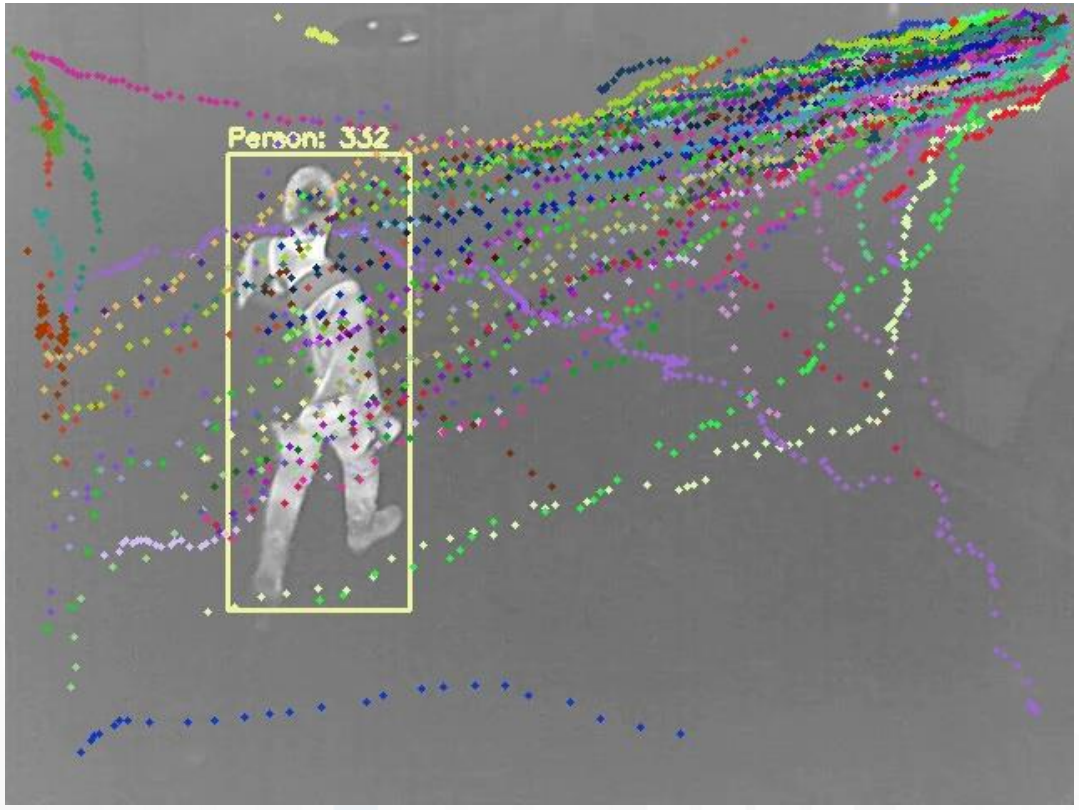
A view and data from the Thermal Camera





People Counting and Tracking





11 SUSTAINABLE CITIES AND COMMUNITIES

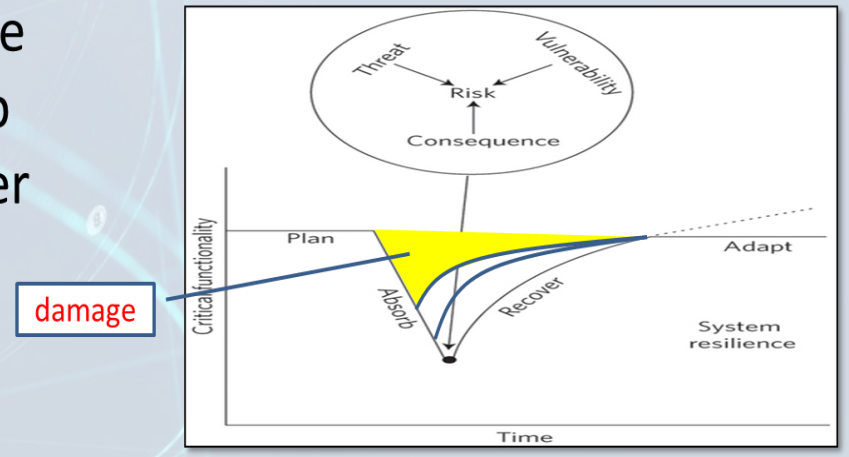
TOP

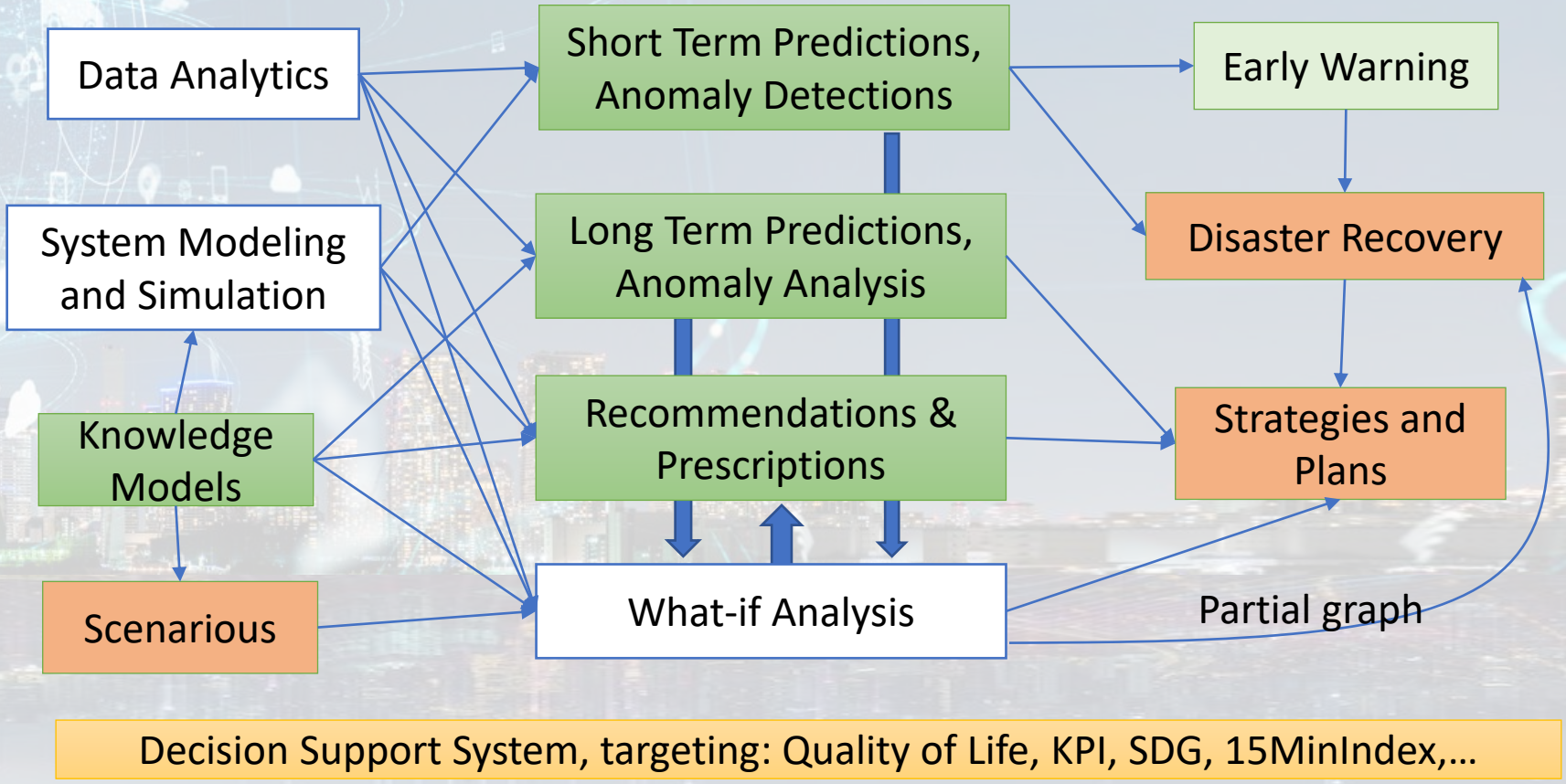
SELECTED: Data Analytic Artificial Intelligence, XAI, Machine and Deep Learning

Snap4City Analytics

- Decision support systems
- Improvement of life quality
- Sustainable Solutions
- Reduction of costs
- Risk Assessment
- Resilience

Prepare
Absorb
Recover
Adapt



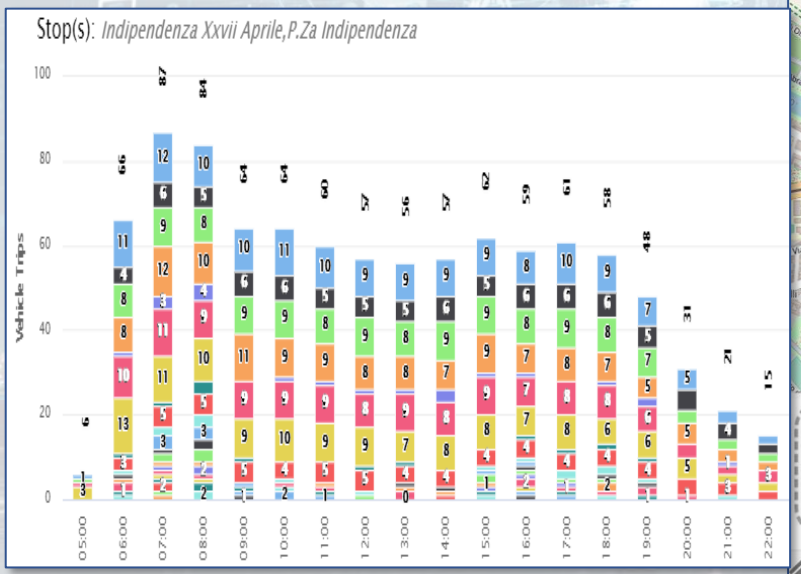


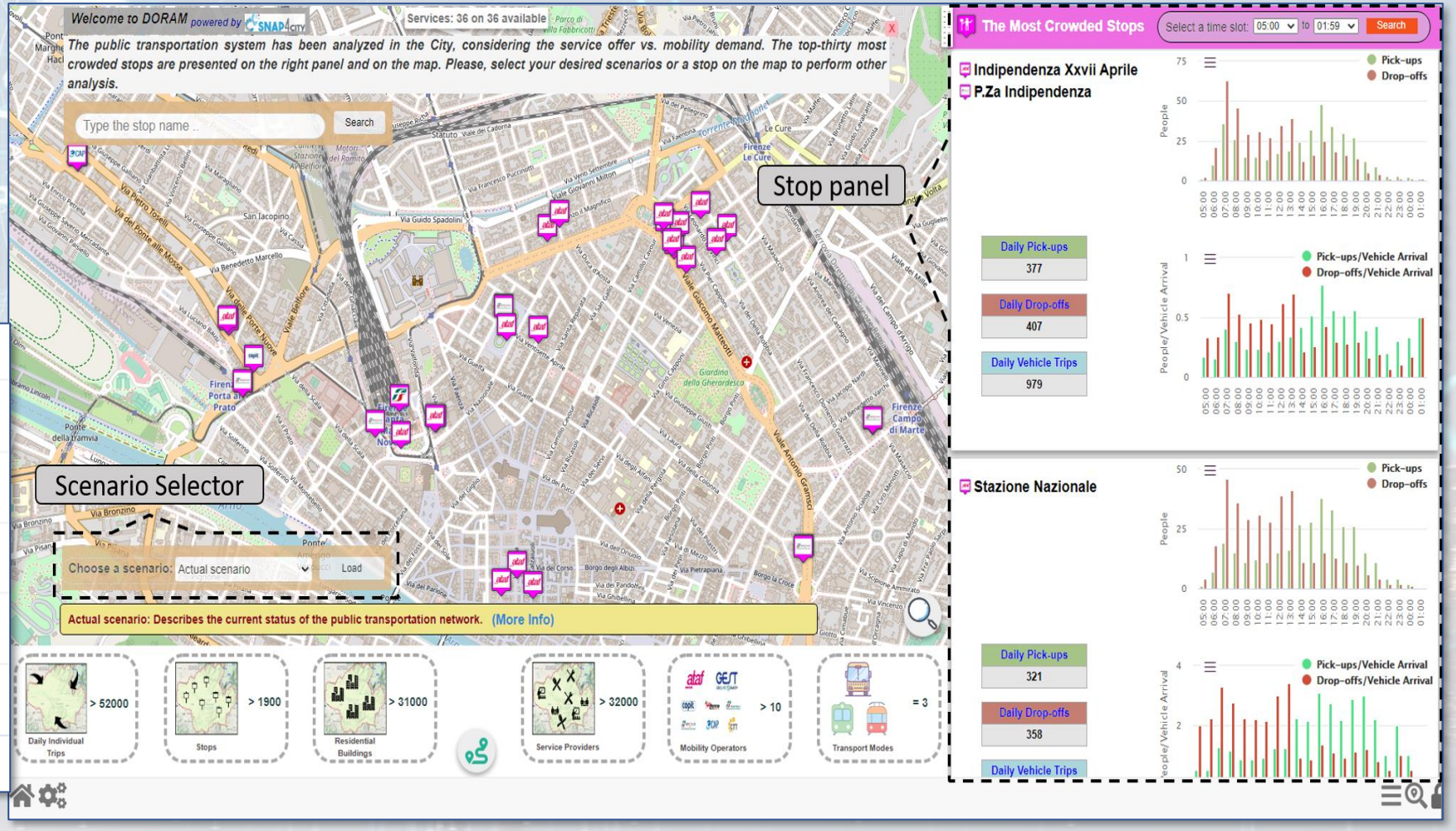
Decision Support System, targeting: Quality of Life, KPI, SDG, 15MinIndex,…

What-if Analysis on Pub Transport

- Definition of scenarious impact on
  - Traffic, Pollutant, parking, public transport, private flows, etc.
  - KPI analysis

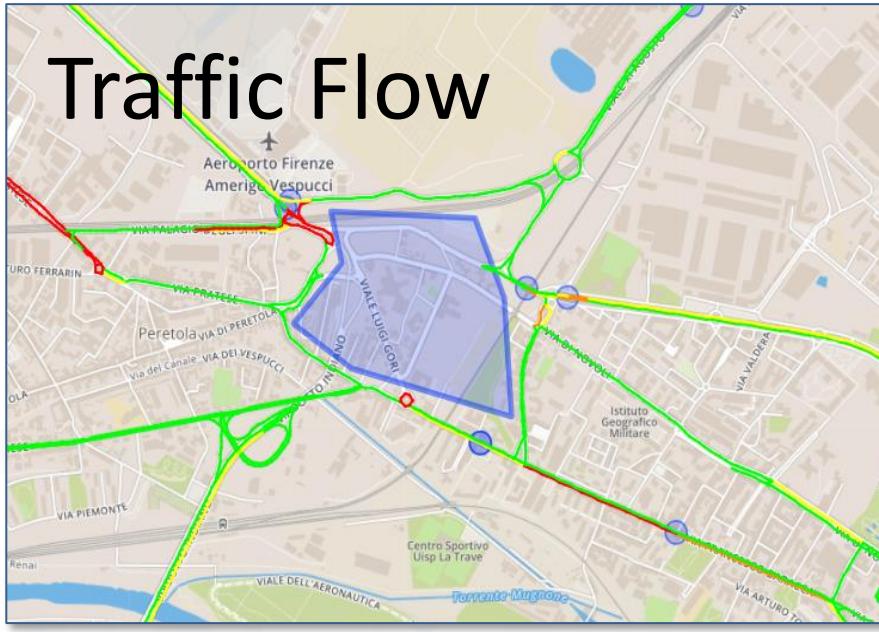
Public Services

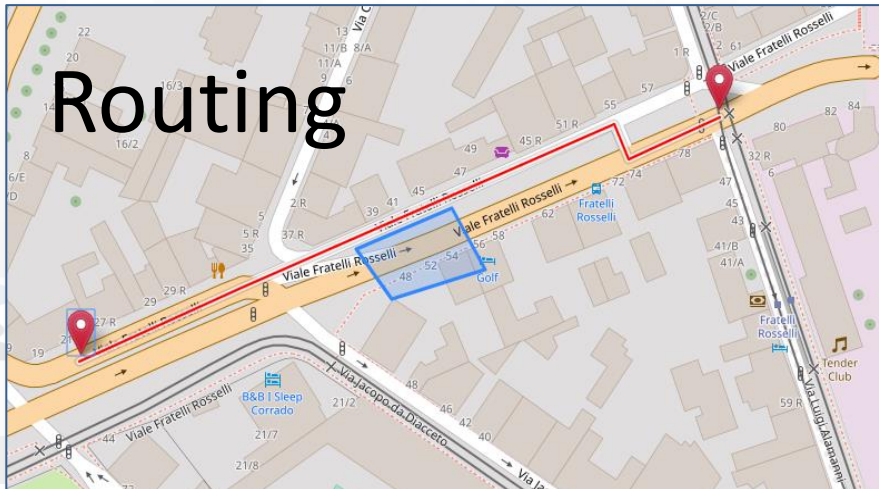




Decision Support Systems, What-if

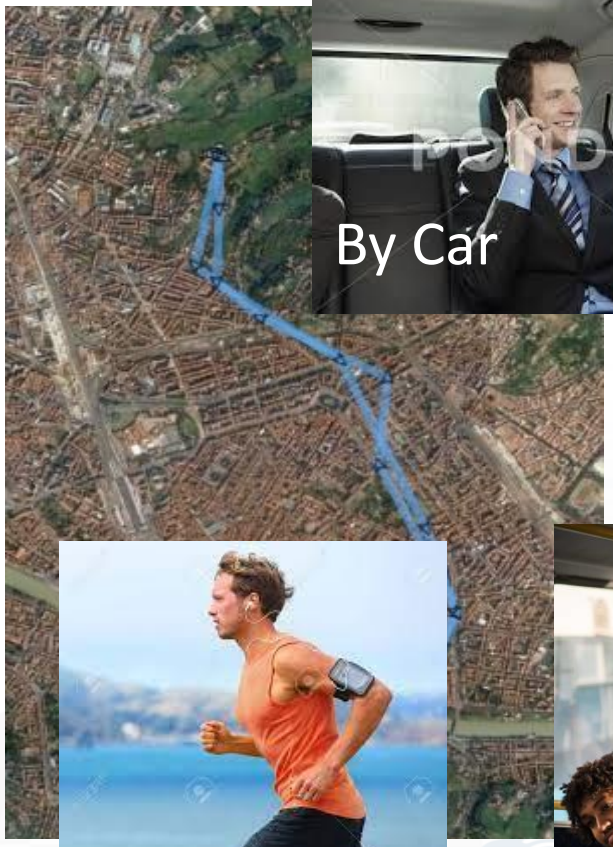
- **Event planning, via what-if analysis**
  - Change in the graph structure of the city
  - Impact on the flow of people and vehicles
  - Adaptation: public transport, traffic, pedestrian management, etc.
- **Immediate reaction to natural events or not**
  - Everything is ready and updated in real time
  - 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



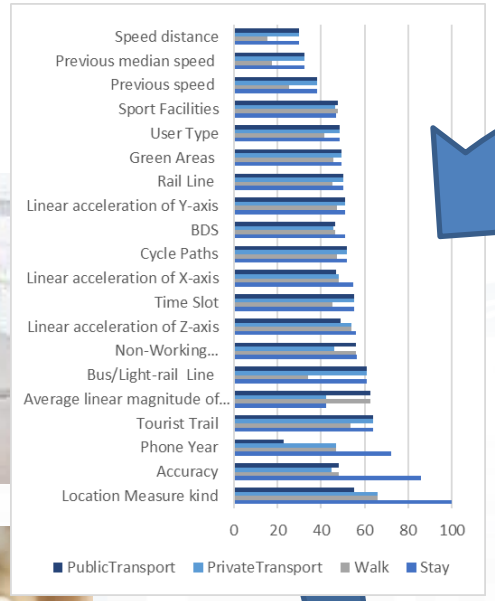


To propose suggestions and Engage city user

we need to know how they are moving

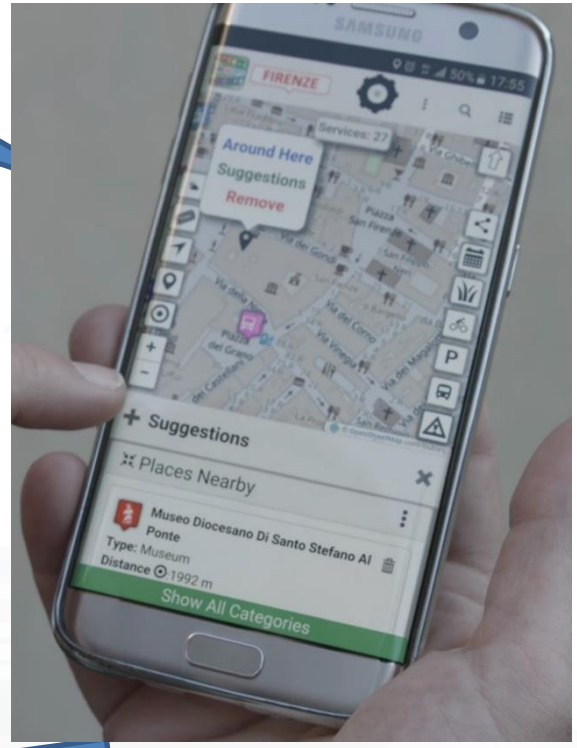


Walk

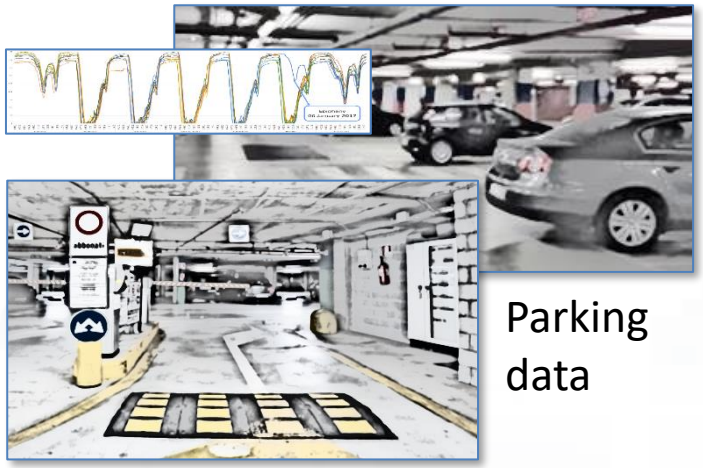


Artificial Intelligence Classification

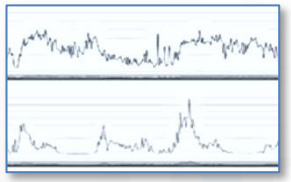
Suggestions



Deep Learning AI to surely Park!

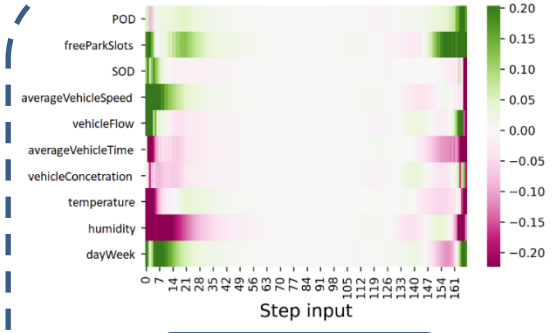


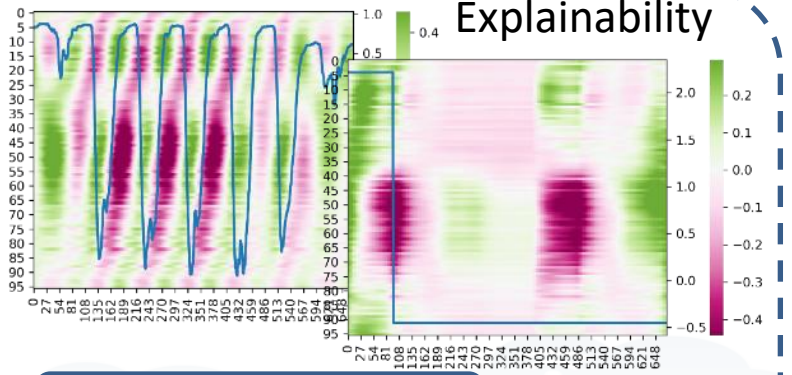
Parking data



Traffic sensors data

Weather Features

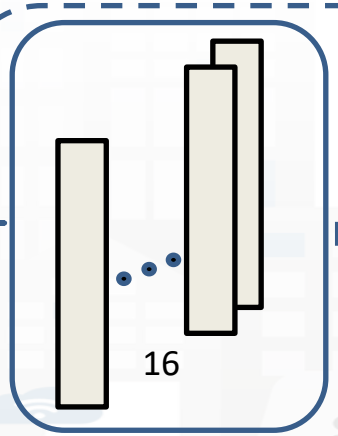


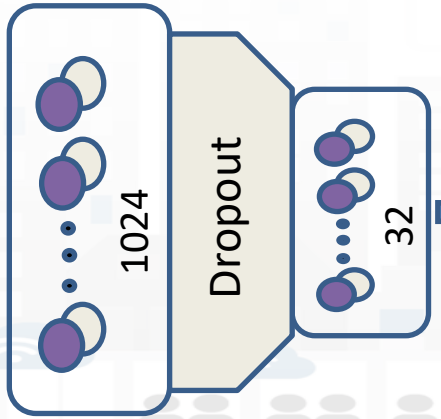


Explainability

Gradient

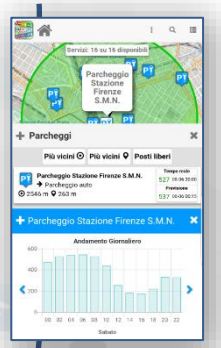
Integrated Gradient





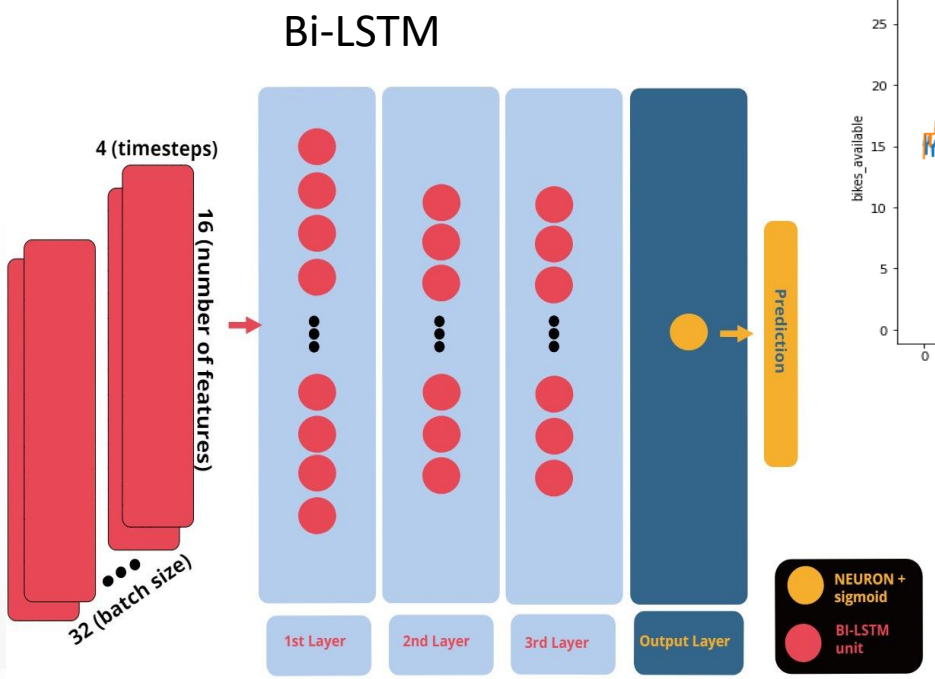
Dropout

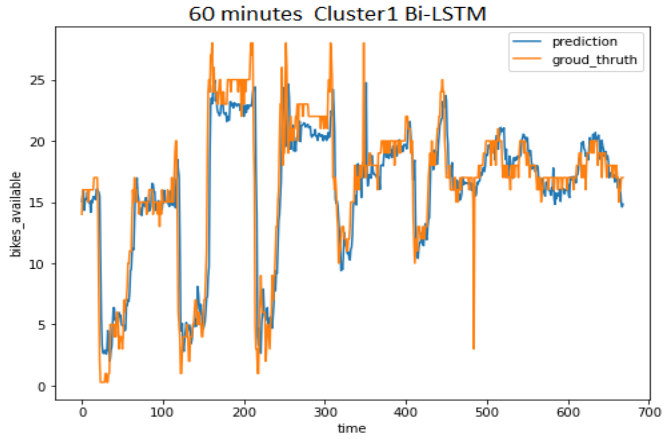
Multi-step Predictions



Conv1D+AvPooling1D BI-LSTM BI-LSTM Dense

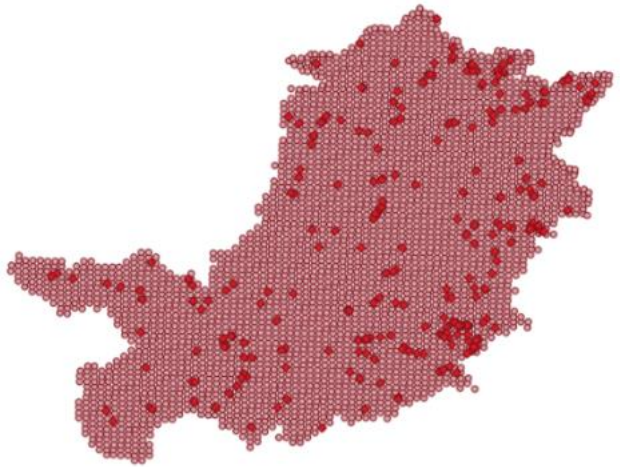
Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations

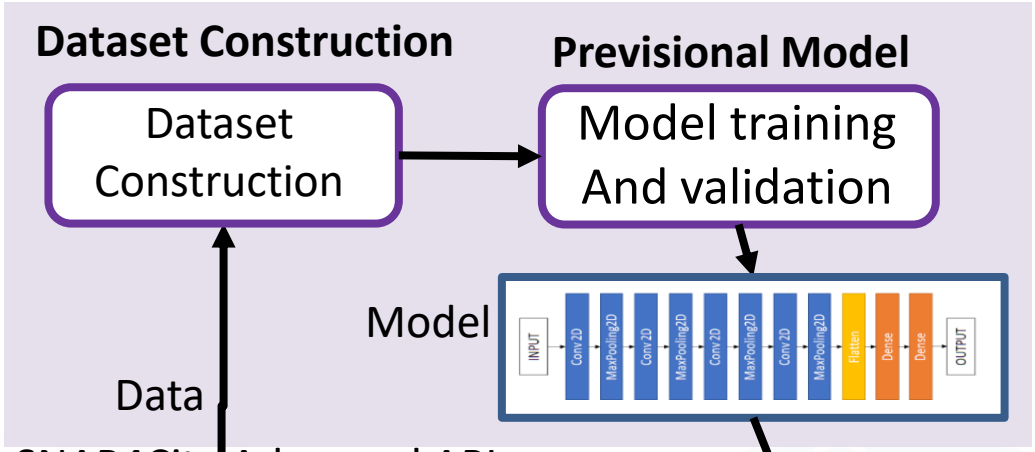


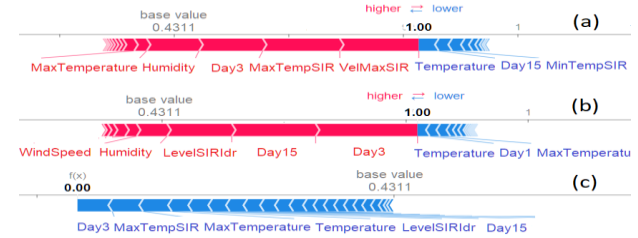


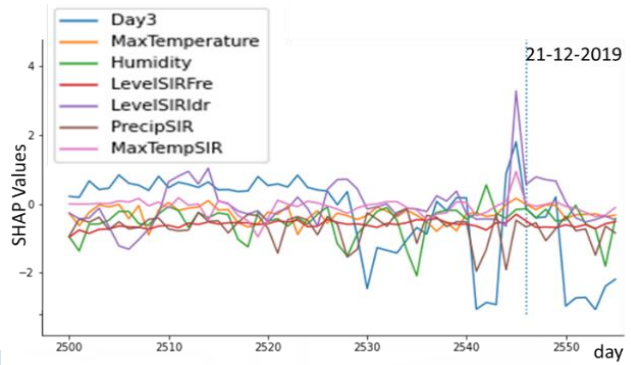
E. Collini, P. Nesi and G. Pantaleo, "Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations," in *IEEE Access*, vol. 9, pp. 124337-124347, 2021, doi: 10.1109/ACCESS.2021.3110794.
https://ieeexplore.ieee.org/abstract/document/9530580

Predicting Land slides









landslide DB

Real Time data from Field: rain, weather, etc.

Ingestion Processes

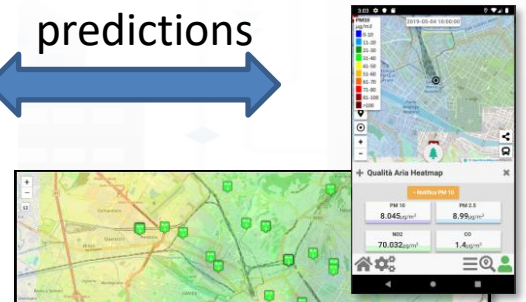
Big Data Storage and KB

Predictions

Model execution Shap Assessment

Data Analytics IOT App Management

predictions

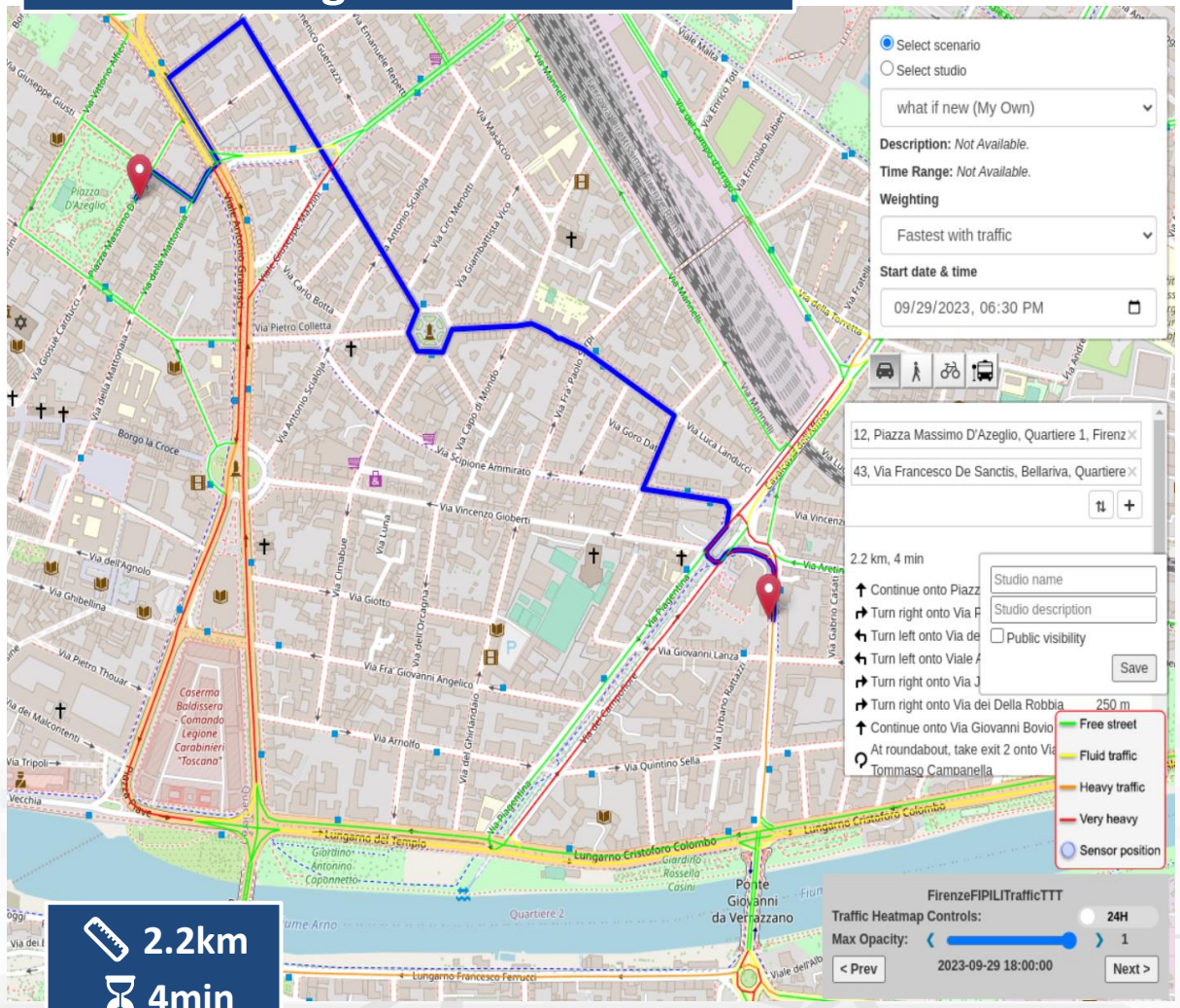


Snap4City Servers and Tools: Dashboard manager, Heatmap manager, GeoServer, Smart City API.

E. Collini, L. A. I. Palesi, P. Nesi, G. Pantaleo, N. Nocentini and A. Rosi, "Predicting and Understanding Landslide Events with Explainable AI," in *IEEE Access*, doi: 10.1109/ACCESS.2022.3158328.
https://ieeexplore.ieee.org/abstract/document/9732490

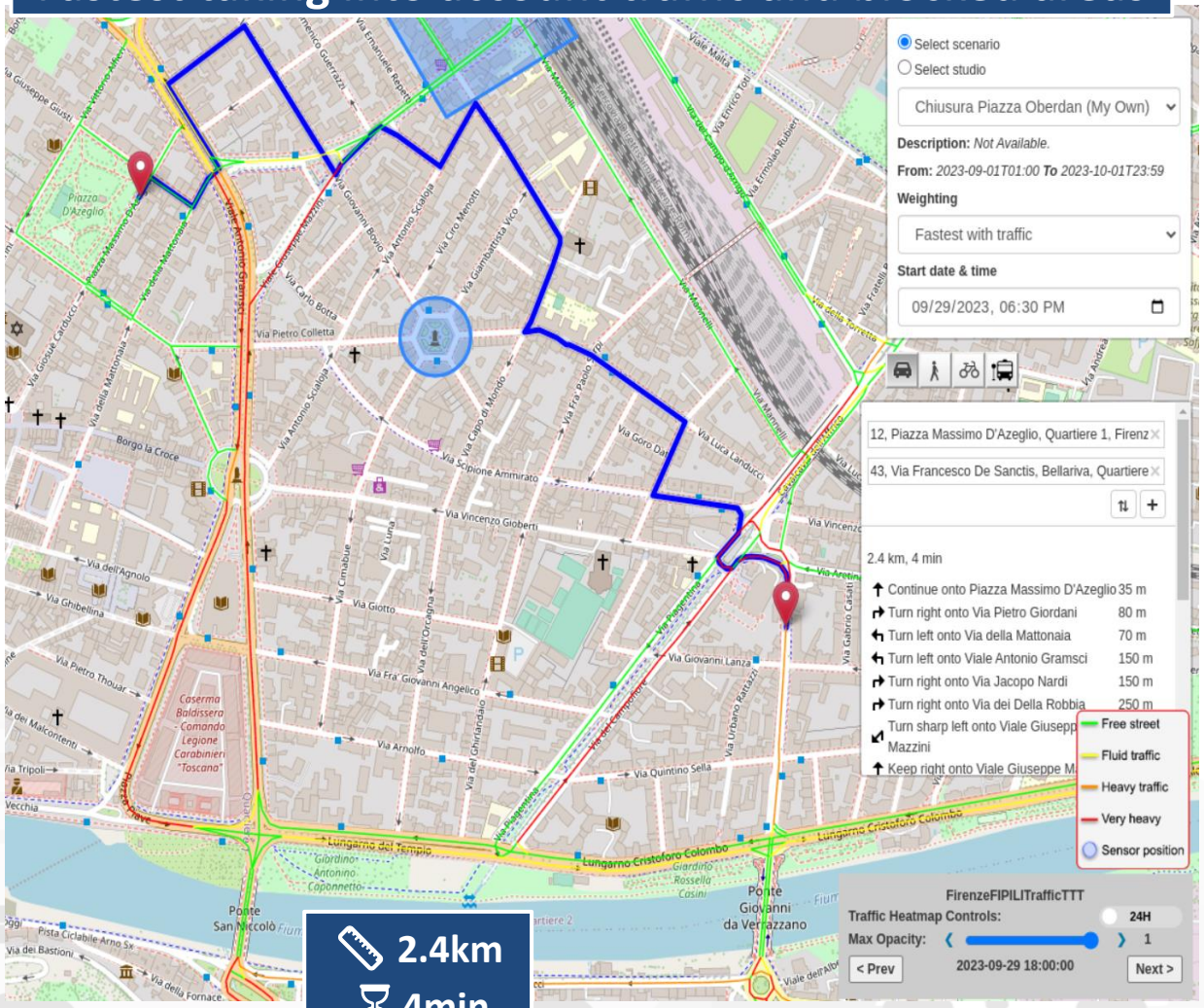
Constrained Dynamic Routing: Traffic Flow

Fastest taking into account traffic



2.2km
4min

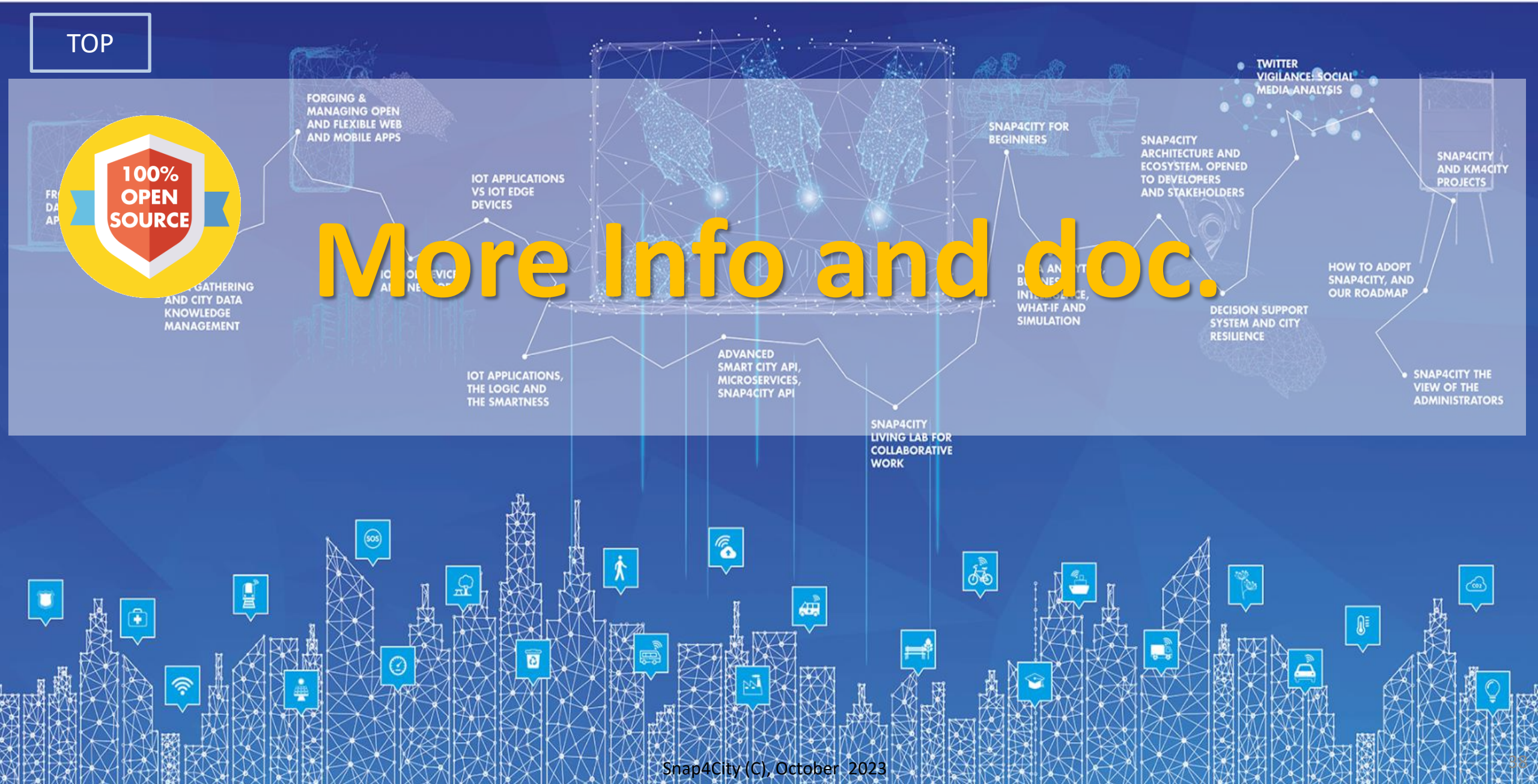
Fastest taking into account traffic and blocked areas



2.4km
4min

SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES

TOP

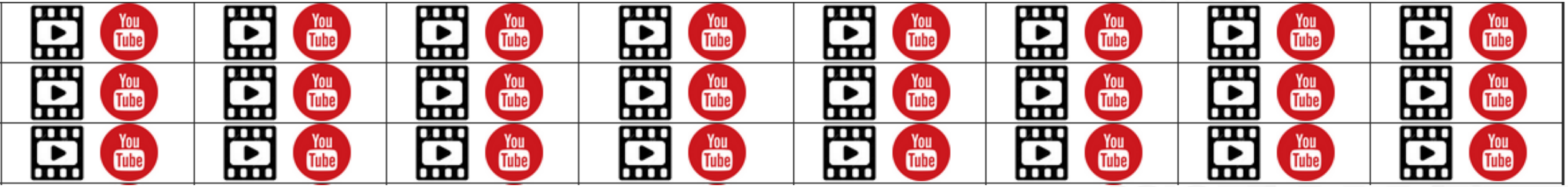


More Info and doc.

https://www.snap4city.org/944

On Line Training Material (free of charge)

1st part	2nd part	3rd part	4th part	5th part	6th part	7th part	8th
Overview	Dashboards	IOT App, IOT Network	Data Analytics	Data Ingestion processes	System and Deploy Install	Smart City API: Web & Mob. App	Design and Develop Smart Solutions



2023 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

TOP

SNAP4CITY

KM 4 CITY

Be smart in a SNAP!

SNAP4
Appliances and Dockers
Installations

CONTACT

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Università degli Studi di Firenze - School of Engineering

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Fax.: +39-055-2758570

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