SNAP4CITY

www.snap4city.org
www.snap4solutions.org

Monitoring

City

Digital Twin Models & Data

KPI

Predictions, Anomaly Detection, Analysis, Assessment Warning

Decision Support System

Scenarious

Simulations, TFR, Crossroad, Public Transport, Routing

What-If Analysis, Optimization

Control and Plan an Horizontal **AI** Platform Digital Twin for all

DIGITAL TWIN SOLUTIONS TO SETUP SUSTAINABLE DECISON SUPPORT SY...

UNIVERSITÀ DEGLI STUDI FIRENZE

DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

1

Main Tasks

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Computing predictions data from the field and KPI
  - Anomaly detection
  - Early warning on critical conditions
- **Making plan: tactic and strategic, medium and long range**
  - Optimisation: Prescriptions, suggestions
  - Risk assessment
  - What-if analysis on scenarios
    - Simulation and predictions
  - Resilience
- **Be ready for Unexpected Unknows**

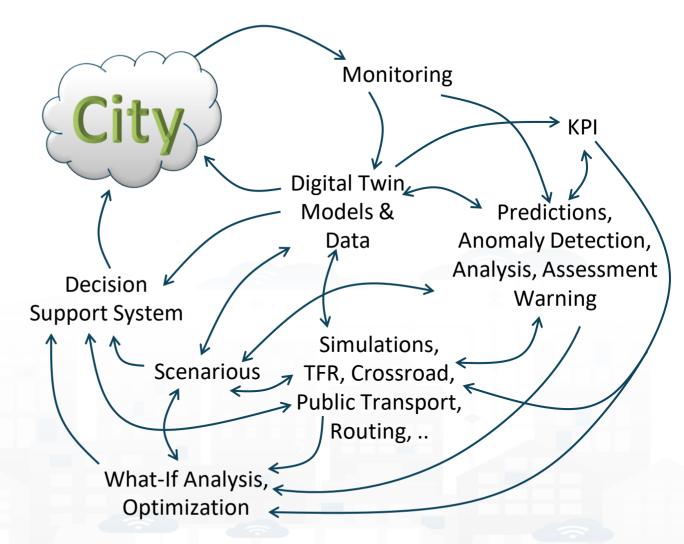|	
Strategic	• Big picture and Long-term focused (2 to 5+ years) • Vision, Mission, Why, Policies and Direction • Executive-management • What is the right direction for the company?
Tactical	• Short-term focused (3 months to 2 years) • Focused on specific business department • Middle-management • What activities to be planned in strategic alignment?
Operational	• Focused on day-to-day running • Detail level processes for specific outcomes • Execution by teams and managers • Are we acting in alignment with strategy?
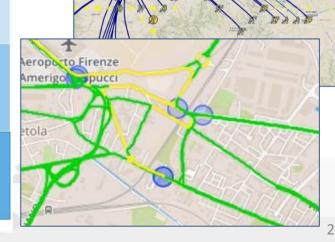
- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Early warning on critical conditions
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders

Control Horizontal Platform

- **Goals:**
  - Increasing quality of Life, quality of services,
  - Decongestion, Decarbonization, Sustainability
  - increase efficiency and production optimization
  - Improve accessibility to services: citizens, Tourists, commuters, etc.
  - Improve security/Safety of city users, risk reduction
  - Costs reduction of services, energy consumption reduction
  - Reduction of emissions and EC taxations

- **Horizontal homogeneous platform Uniform Technology for**
  - **Any Vertical operation/plan:** mobility, energy, environment, security, tourism, infrastructure and assets control, buildings, etc.
  - **AI Solutions: early warning, predictions, simulation, what-if, optimisation, MLOps;**
    - AI: Deep Learning, ML, BERT, LLM/RAG, XAI (Shap/Lime), etc.
    - Simulations: SUMO, DORAM, Routing, TFR, Flooding, people flow, etc.
  - **Development Environment for any vertical, Digital Twin**: City Global and Local, IoT, VR, Visual Programming, business intelligence, CSBL, SSBL, etc.
  - **Interoperability**: any format, any protocol, any video management system, any sensor, any device, etc.

- **KPI:** multidomain KPI, general management, early warning, early detection of critical conditions, 15 Min City Index, SDG, SUMI/SUMP
- **Mobile App:** modular applications, operators' modules, multiple cities, etc.
- **Participatory**: problem reporting, ticketing, etc.
- **Integration of any kind**
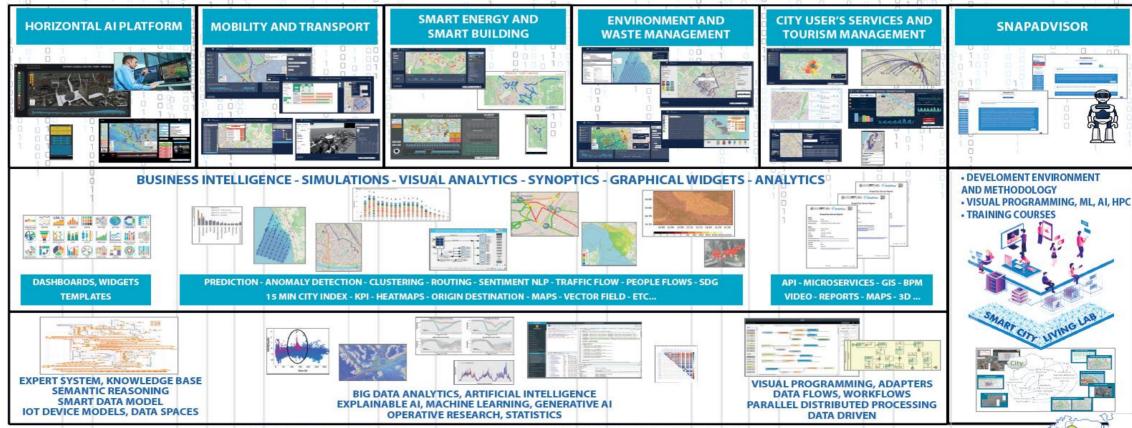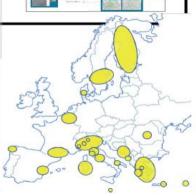
Domains (2024/8)

- **Smart City, control room**
- **Mobility and transport**
- **Energy, light, recharge**
- **Buildings and Assets**
- **Tourism and People**
- **Environment, pollutant**
- **Waste Optimisation**
- **Security and Safety**
- **Risk and Resilience**
- **Social Media**
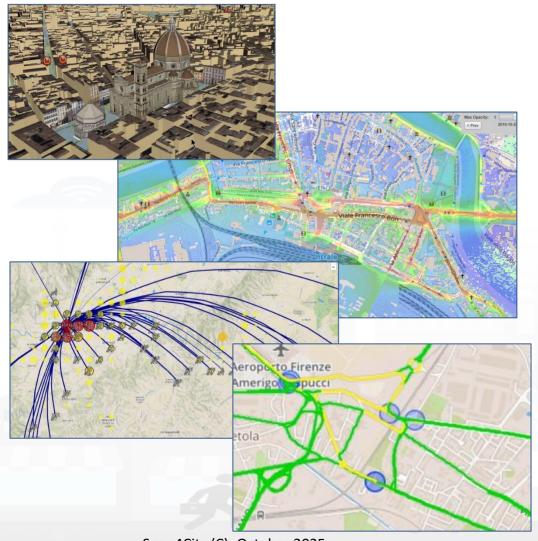
- **Big Data, AI/XAI**
- **Public and private data**

http://www.snap4city.org/997

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

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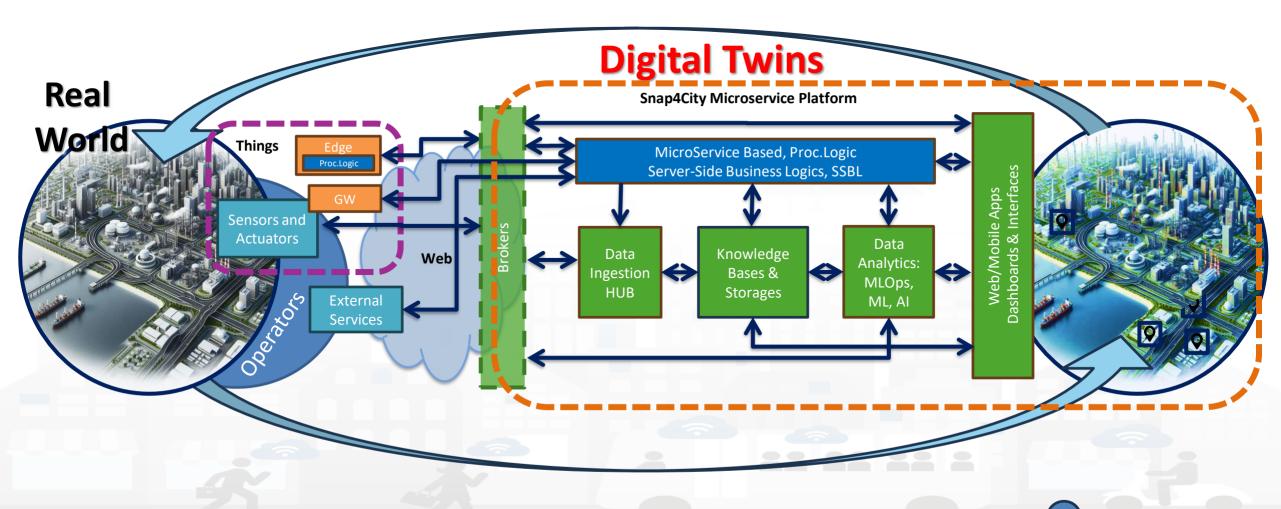- o MaaS, last-mile delivery HUBs
- o etc.

Digital Twin Development Platform

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, OGC, ….
- **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.
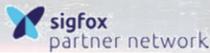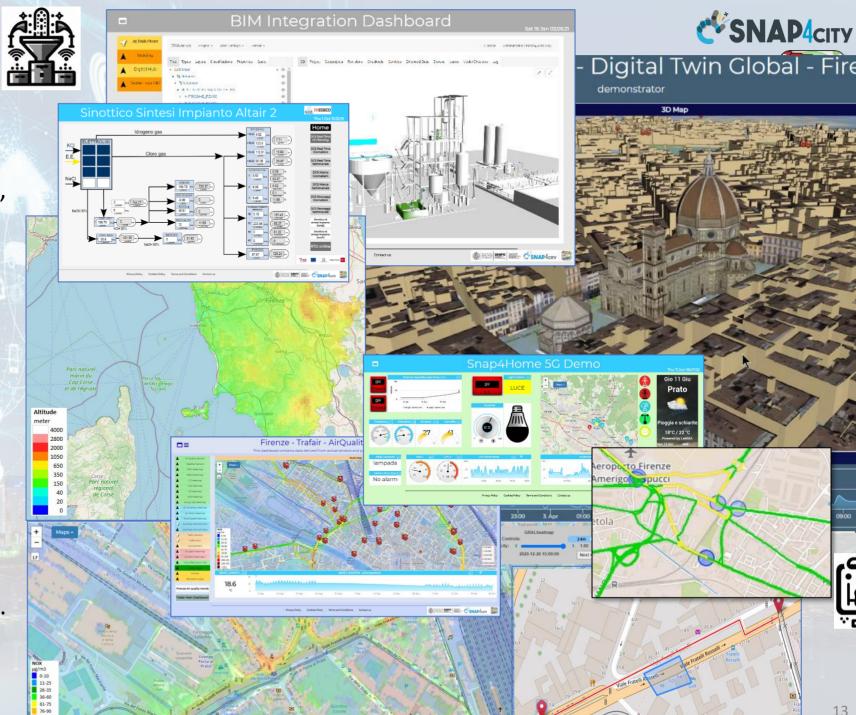
https://www.snap4city.org/65

High Level Types

Snap4City (C), October 2025

- 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.

5/25

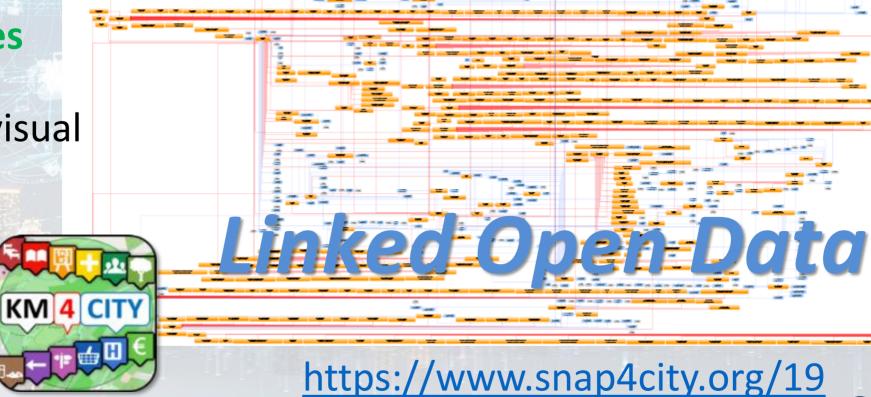# Expert System *semantic queries*

- **via**:

- **Smart City API** for Apps and third party

- **MicroServices** data driven develop via visual language Node-RED

License Free
1.6.8

Linked Open Data

https://www.snap4city.org/19
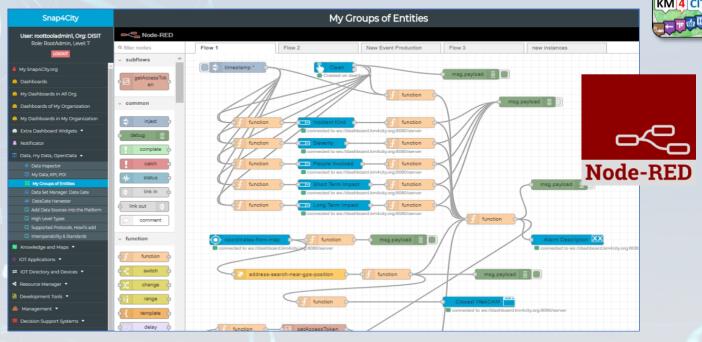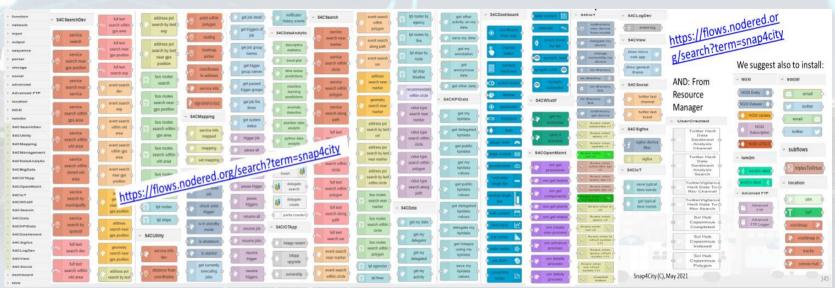
Ingestion, aggreg. → exploitation

- **IoT App Visual Programming, no coding**
  - **Data transformation**
  - **Integration, Interoperab.**
  - **Scripting Data Analytics**
  - **Data ingestion**
  - **Business logic**

- **Edge and Cloud**

- **MicroServices** data driven develop via visual language Node-RED

https://flows.nodered.org/search?term=snap4city

MicroServices Areas

> 60.000 downloads (up to 2024)

Open Data CKAN
Ticket Management, workflow
BIM Servers
Social Networks
Video Management system
Gateways

Data Analytics
Statistic, Optimization
Simulation
Artificial Intelligence
What-if Analysis Support
Geo Utilities Support
Routing & Traffic Flow
MLOps support
Python support
R Studio Support

Data Load / Search / Retrieval
KPI, POI, GIS Data, Scenarios
Time Series, Public transport
High Level Types: heatmaps, ODM,…
IoT / Entity Discovery
Delegation Management
Data Mapping

Dashboards
Widgets: Graphic Libraries
Interactive Widgets
Maps, 3D representations
Synoptics, External Content
Micro Web App

IoTApp Management
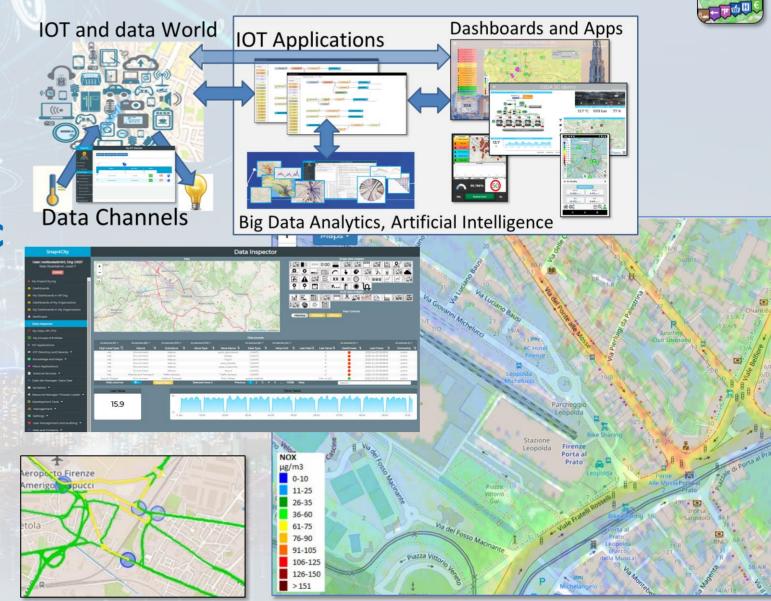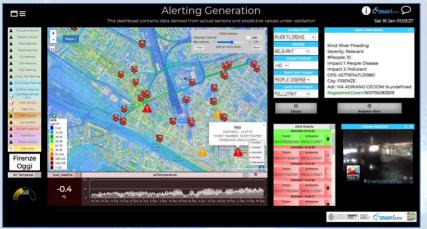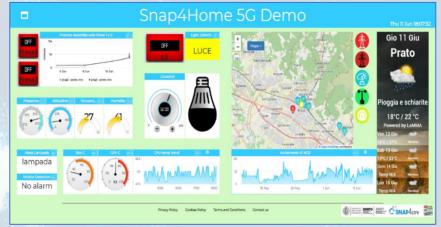Data Logs, A&A, Security
Ownership Management
VPN remote access

External Service Integration · **Entities Management** · **Visualization Interaction** · **Analytic Services** · **Snap4City Microservices Proc.Logic SSBL** · **Platform Management** · **other Node-RED Libraries** · **Third party microservices**

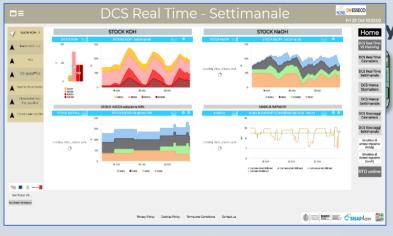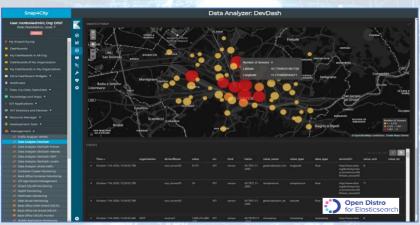# *Solutions: reliable, secure and fast to realize*

- **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
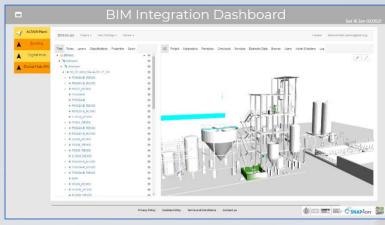 - Reliable, interoperable
  - Auditable, marketable

Different Themes

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

https://www.snap4city.org/793
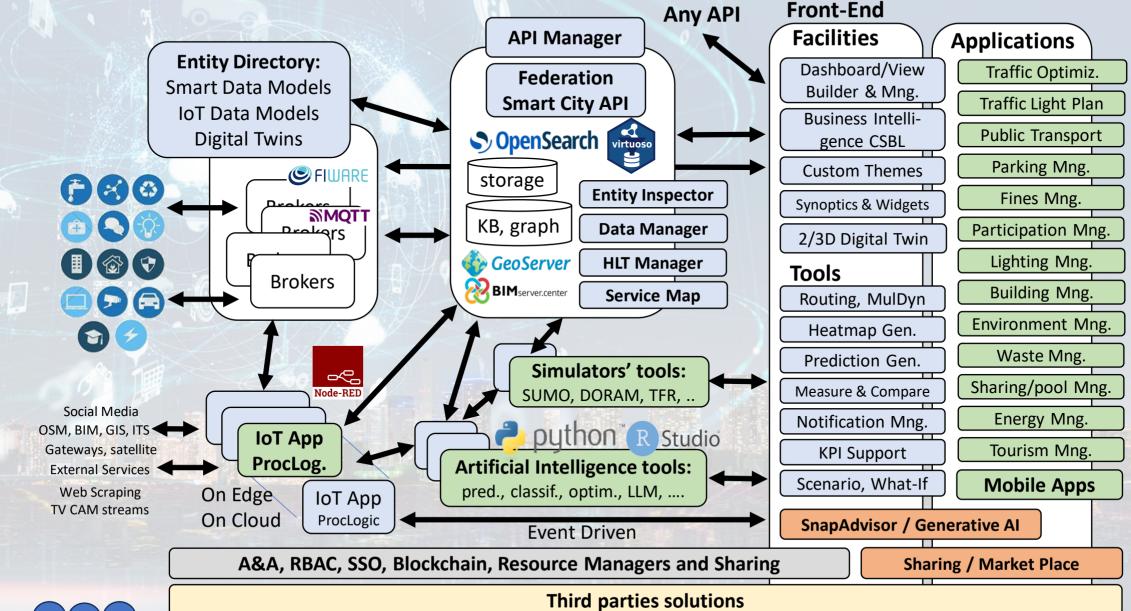
Technical Architecture

KM4CITY

Entity Directory:
Smart Data Models
IoT Data Models
Digital Twins

FIWARE

MQTT

Brokers
Brokers
Brokers

Any API

API Manager

Federation Smart City API

OpenSearch virtuoso

storage

KB, graph

GeoServer

BIMserver.center

Entity Inspector

Data Manager

HLT Manager

Service Map

Node-RED

Social Media
OSM, BIM, GIS, ITS
Gateways, satellite
External Services
Web Scraping
TV CAM streams

IoT App ProcLog.

On Edge
On Cloud

IoT App
ProcLogic

Simulators' tools:
SUMO, DORAM, TFR, ..

python R Studio

Artificial Intelligence tools:
pred., classif., optim., LLM, ...

Event Driven

Front-End Facilities

Dashboard/View Builder & Mng.

Business Intelli-gence CSBL

Custom Themes

Synoptics & Widgets

2/3D Digital Twin

Tools

Routing, MulDyn

Heatmap Gen.

Prediction Gen.

Measure & Compare

Notification Mng.

KPI Support

Scenario, What-If

SnapAdvisor / Generative AI

Applications

Traffic Optimiz.

Traffic Light Plan

Public Transport

Parking Mng.

Fines Mng.

Participation Mng.

Lighting Mng.

Building Mng.

Environment Mng.

Waste Mng.

Sharing/pool Mng.

Energy Mng.

Tourism Mng.

Mobile Apps

Sharing / Market Place

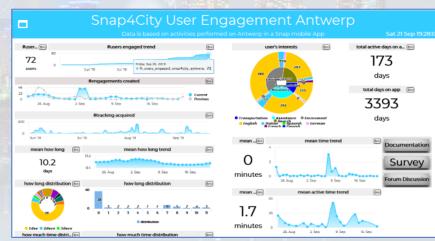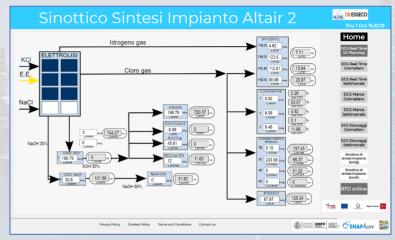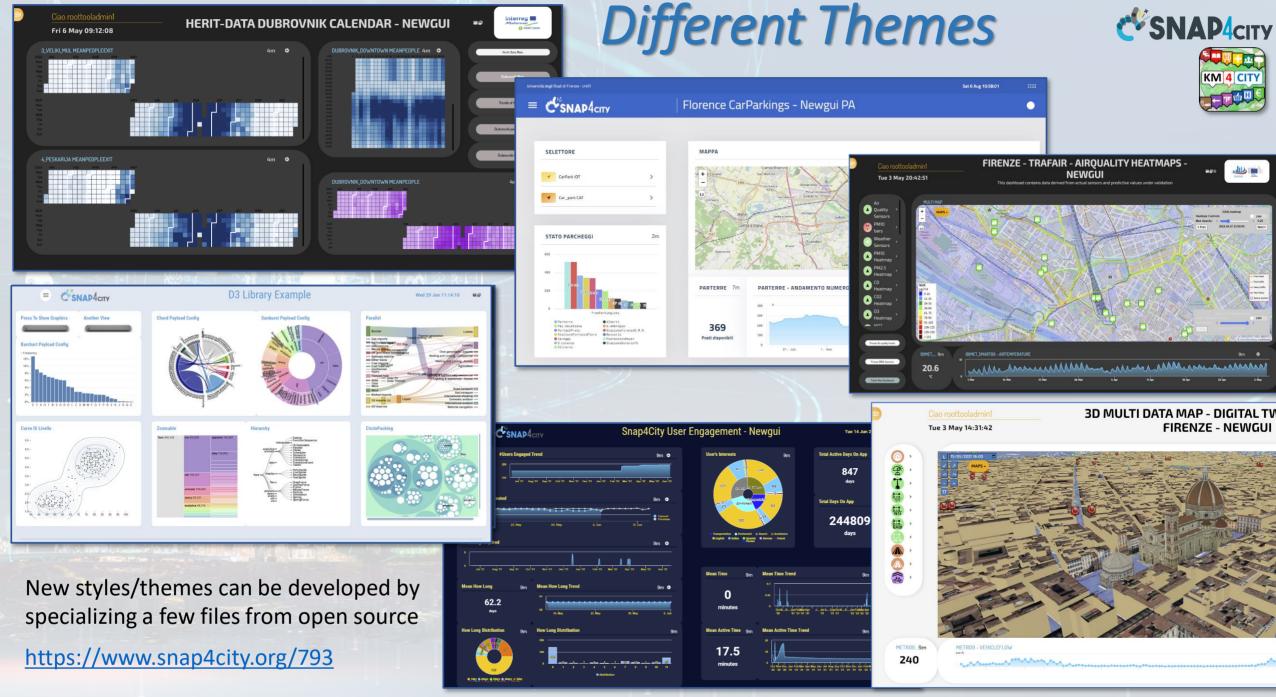**A&A, RBAC, SSO, Blockchain, Resource Managers and Sharing**
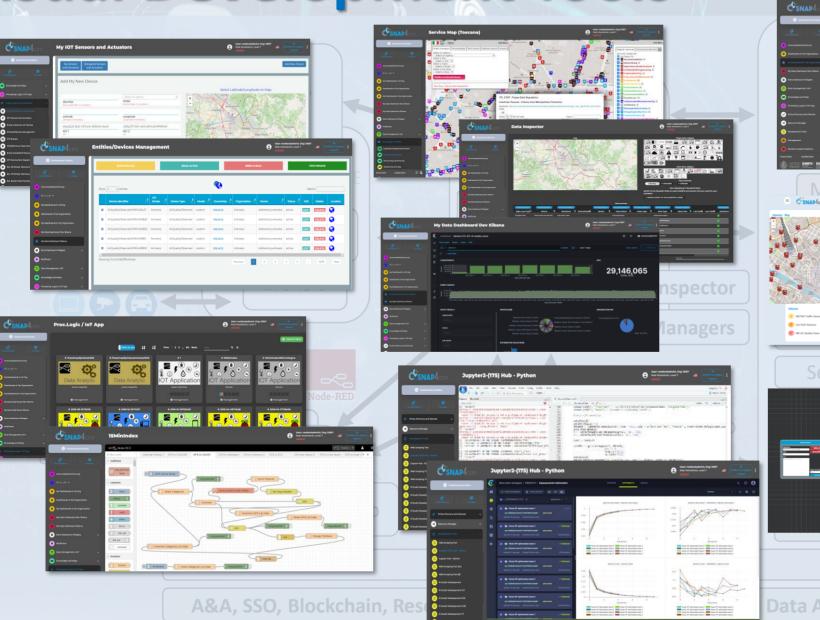
Third parties solutions

Visual Development Tools

Snap4City (C), October 2025

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Free Trial

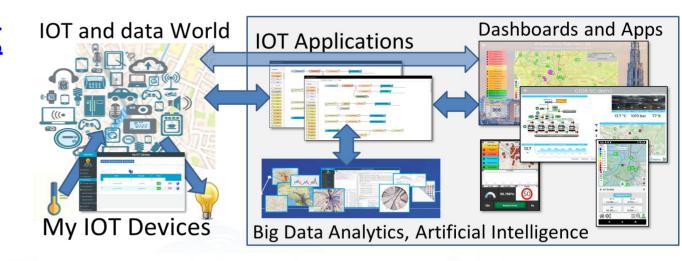- Register on WWW.snap4city.org
  - Subscribe on **DISIT Organization**

- **You can:**
  - Access on basic Tools
  - Access to a large volume of Data
  - Create Dashboards
  - Create IOT Applications
  - Connect your IOT Devices
  - Exploit Tutorials and Demonstrations

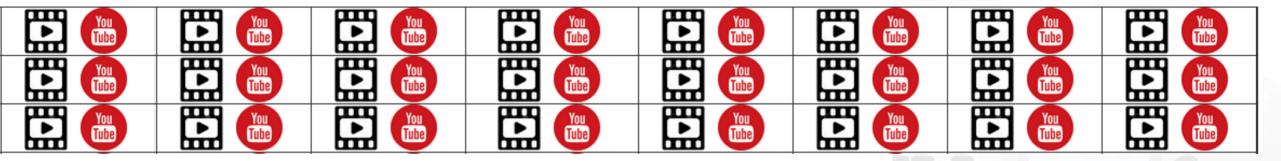*License Free Installation scripts for: Pub cloud & on premises*

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

Development
https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf

AI/ML Infrastruct.

Snap4City (C), October 2025

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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
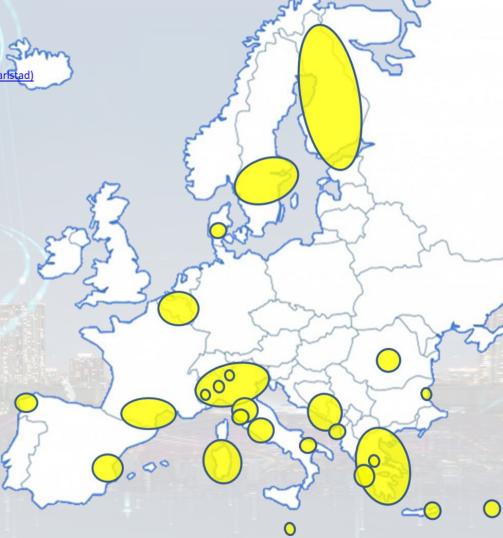
- **Widest MULTI-tenant deploy has**
  - 26 Organizations / tenant
  - > 8850 users on
  - > 1800 Dashboards
  - > 17 mobile Apps
  - **> 2.2 Million of structured data per day**
  - > 580 IoT Applications/node-RED
  - > 850 web pages with training
  - > 85 videos, training videos

Main Organizations/areas
- Antwerp area (Be)
- Bari (I)
- Bisevo, Croatia
- Bologna (I)
- Brasov (Ro), by ICEBERG
- Capelon (Sweden: Västerås, Eskilstuna, Karlstad)
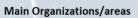- Cuneo (I)
- DISIT demo (multiple)
- Dubrovnik, Croatia
- Firenze area (I)
- Garda Lake area (I)
- Greece (Gr)
- Helsinki area (Fin)
- Limassol (Cy)
- Livorno area (I)
- Lonato del Garda (I)
- Malta (Malta)
- Merano (I)
- Modena (I)
- Mostar, Bosnia-Herzegovina
- Oslo & Padova (Impetus)
- Pisa area (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.

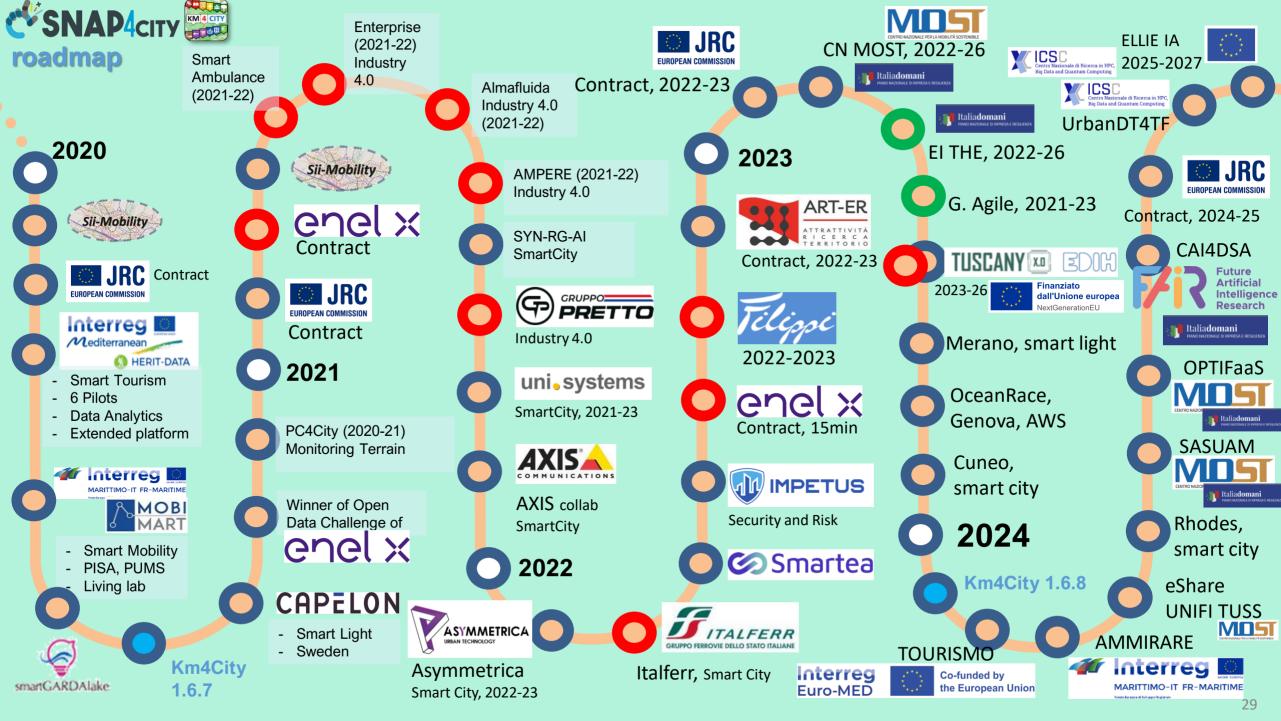# SNAP4CITY roadmap

2020
- Smart Tourism
- 6 Pilots
- Data Analytics
- Extended platform

Contract (Sii-Mobility)

Contract (JRC)

Interreg Mediterranean HERIT-DATA

- Smart Mobility
- PISA, PUMS
- Living lab

smartGARDAlake

Km4City 1.6.7

2021

PC4City (2020-21) Monitoring Terrain

Winner of Open Data Challenge of enel x

CAPELON
- Smart Light
- Sweden

Smart Ambulance (2021-22)

Enterprise (2021-22) Industry 4.0

Sii-Mobility

enel x Contract

JRC Contract

Asymmetrica Smart City, 2022-23

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 COMMUNICATIONS
AXIS collab SmartCity

Italferr, Smart City

TOURISMO
Interreg Euro-MED Co-funded by the European Union

JRC Contract, 2022-23

CN MOST, 2022-26

2023

ART-ER ATTRATTIVITÀ RICERCA TERRITORIO
Contract, 2022-23

Filippi 2022-2023

enel x Contract, 15min

IMPETUS Security and Risk

Smartea

EI THE, 2022-26

G. Agile, 2021-23

TUSCANY X.0 EDIH 2023-26 Finanziato dall'Unione europea NextGenerationEU

Merano, smart light

OceanRace, Genova, AWS

Cuneo, smart city

2024

Km4City 1.6.8

ELLIE IA 2025-2027

UrbanDT4TF

JRC Contract, 2024-25

CAI4DSA

Future Artificial Intelligence Research

OPTIFaaS MOST

SASUAM MOST

Rhodes, smart city

eShare UNIFI TUSS MOST

AMMIRARE Interreg MARITTIMO-IT FR-MARITIME

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- **UrbanDT4TF**, CN HPC: Digital Twin mobility, https://www.snap4city.org/drupal/node/1057
- **DI-DTPlatform**, CN HPC: Digital Twin, mobility, environment, https://www.snap4city.org/drupal/node/1097
- **Sasuam**, CN MOST, PNRR: AI, mobility, https://www.snap4city.org/drupal/node/999
- **OPTIFaaS**, CN MOST, PNRR: AI, mobility, DSS, https://www.snap4city.org/drupal/node/1008
- **LeverageOPTIFaaS**, CN MOST: PNRR, mobility, https://www.snap4city.org/drupal/node/1064
- **TOURISMO**, Interreg, EC: Tourism, NLP, DSS, https://www.snap4city.org/drupal/node/1001
- **ELLIE**, Horizon Europe, EC: AI, VR, https://www.snap4city.org/drupal/node/1056
- **CN MOST**, PNRR: sustainable mobility, platform, https://www.snap4city.org/drupal/node/1050
- **ISPRA JRC contract**, EC: DSS, SOC, control room, energy, https://www.snap4city.org/drupal/node/970
- **AMMIRARE**, Interreg, EC: AI, environment, Big Data, https://www.snap4city.org/drupal/node/1002
- **CAI4DSA**, FAIR PE1, PNRR: AI, Neuro-Symbolic, PINN, NG-DSS, https://www.snap4city.org/drupal/node/1016
- **SADI-MIAC**, RT, partner: AI, Tourism, Retail, Computer Vision, https://www.snap4city.org/drupal/node/1055
- **SMART3R,** PRIN UNICagliari: mobility, DSS, https://www.snap4city.org/drupal/node/1087
- **Tuscany X.0, EDIH,** TestBeforeInvest, Training on AI, Big Data, Security, HPC: https://www.tuscanyx.eu/
- **Reg4IA**, AI for regional public administration, A project of presidency of national council
- **SmartCyprus**, a project of Cyprus Ministry of Digital Innovation and Policy
- **The IE**, PNRR: AI, NLP, LLM, Legal Aspects
- **BullVIT**, RT, conv: AI, NLP, LLM on commercial phases
- **Energia**, RT, conv: AI, PINN, DSS, on manufacturing
- **RFI contract**: mobility, AI, DSS
- **Salerno Port**: AI for container ID recognition and tracking
- **Talent Hub**, ECRF, conv: NLP, match demand vs offer

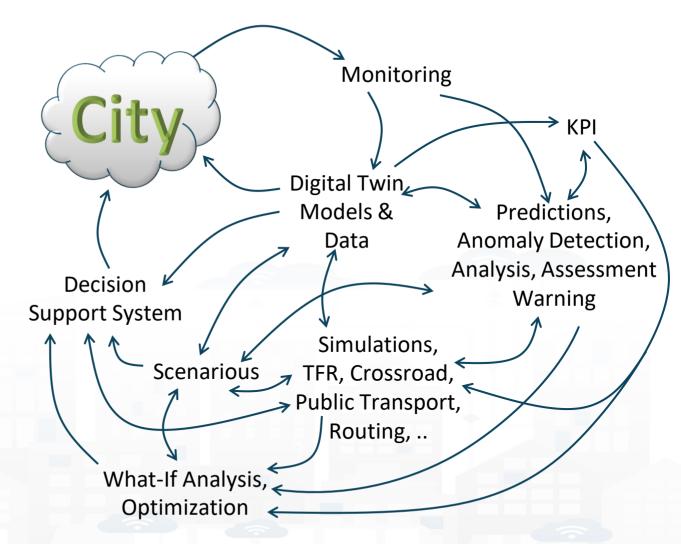+ currently: Merano, Salerno, Cuneo, Rhodes, Reverberi, Florence, IDTS, ALTAIR, etc.

Snap4City

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  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
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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

Traffic Infrastructure optimization

Scenario Editor

Routing / Dynamic Routing

Operation: Monitoring and control

Monitoring

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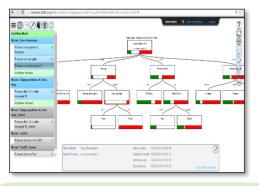   - User engagement via Mobile Apps
    - What-if analysis
    - etc.,

Control Room
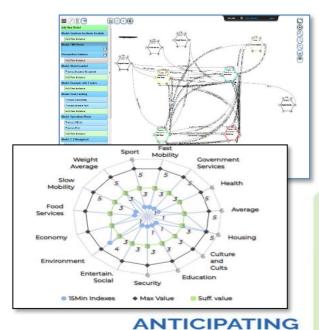
ERMG: European Resilience Management Guide

CRAMSS
Collaborative Resilience
Assessment and Management
Support System

MONITORING

LEARNING

ANTICIPATING

RESPONDING

KM4CITY

- Big Data Platform
- IoT/IoE/Open Data
- Real Time Dashboard
- Resilience Control Room
- Data Analytics
- Early Warnings
- Urban Traffic Manager Data Exchange

- Human Behavior Analysis
- Predictive Analytics
- Urban Transport System Dynamic Analysis
- Resilience Quantification
- Network Analysis
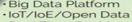
- European Resilience Management Guidelines
- Game Based Training

- Smart Decision Support Systems (DSS)
- Evacuation Decision Support
- Smart Intelligent Transport Systems
- Emergency Support Smart App
- Resilience DSS

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Smart City Control Room
Florence Metropolitan 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

Key Performance Indicators, KPI

- **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

	Air Quality Directive			WHO guidelines	
Pollutant	Averaging period	Objective and legal nature and concentration	Comments	Concentration	Comments
PM2.5	One day			25 µg/m³ (*)	99th percentile (3 days/year)
PM2.5	Calendar year	Target value, 25 µg/m³	The target value has become a limit value since 1 January 2015	10 µg/m³	
PM10	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)
PM10	Calendar year	Limit value, 40 µg/m³ (*)		20 µg/m³	
O3	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	
NO2	One hour	Limit value, 200 µg/m³ (*)	Not to be exceeded more than 18 times a calendar year	200 µg/m³ (*)	
NO2	Calendar year	Limit value, 40 µg/m³		40 µg/m³	

15MinCityIndex

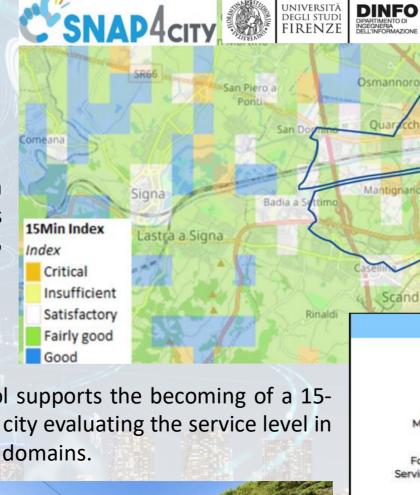What would support my neighborhood to become a 15-Minute City?

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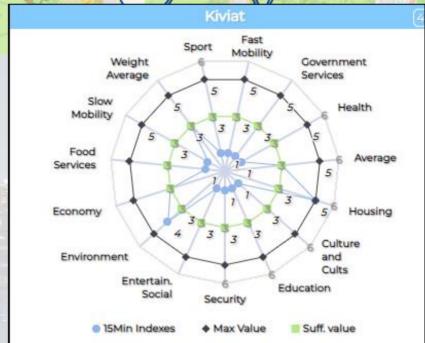
The tool supports the becoming of a 15-Minute city evaluating the service level in various domains.

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.

15Min Index

Index
- Critical
- Insufficient
- Satisfactory
- Fairly good
- Good

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

15MinCityIndex on Bologna

SUMI: Sustainable Urban Mobility Indicators
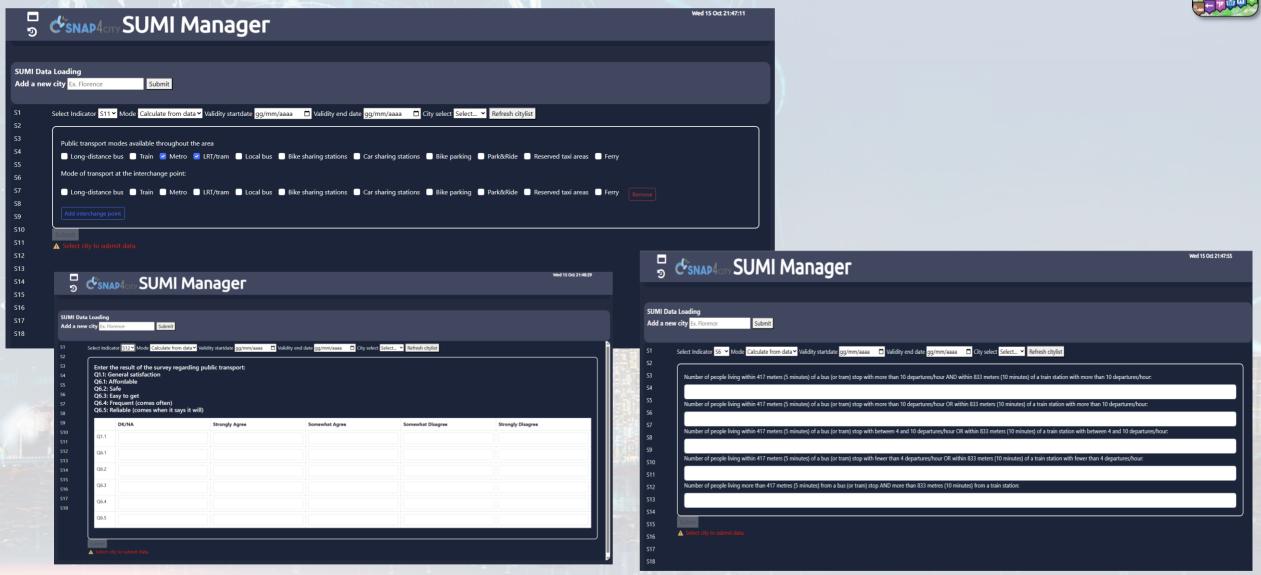
SUMI: Sustainable Urban Mobility Indicators

SNAP4CITY

KM 4 CITY

METRO25

VALUE NAME: METRO25

DETAILS   DESCRIPTION   ATTRIBUTE

Last update: 2023-11-07 08:41:00.000+01:00

Description	Value
anomalyLevel	1.941174
averageSpeed	43.649723
avgTime	9.115
concentration	3.185796
congestionLevel	115

Air Quality FI-BASSI - NO2

16.5

°C/F

PM 2.5

EAQI

GRAL 3M

Free street
Fluid traffic
Heavy traffic
Very heavy
Sensor position

New York   Paris   Rome   Tokyo

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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, ...

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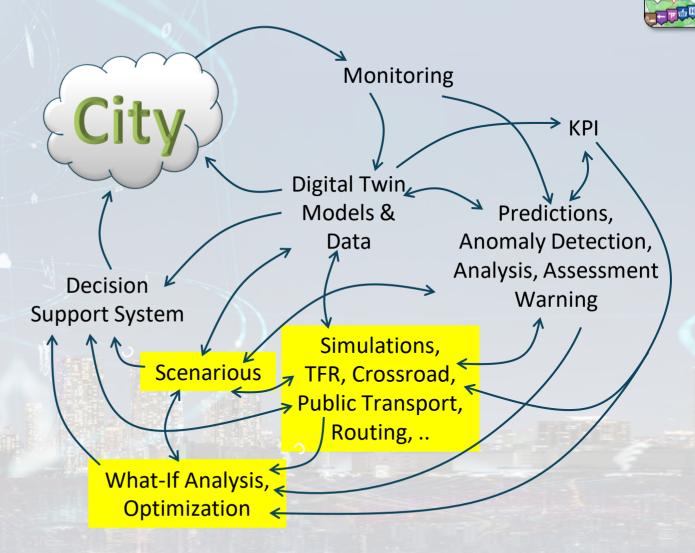
From What-If to Decision Support System

- **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

2024/8

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

Traffic Infrastructure optimization

Scenario Editor

Routing / Dynamic Routing
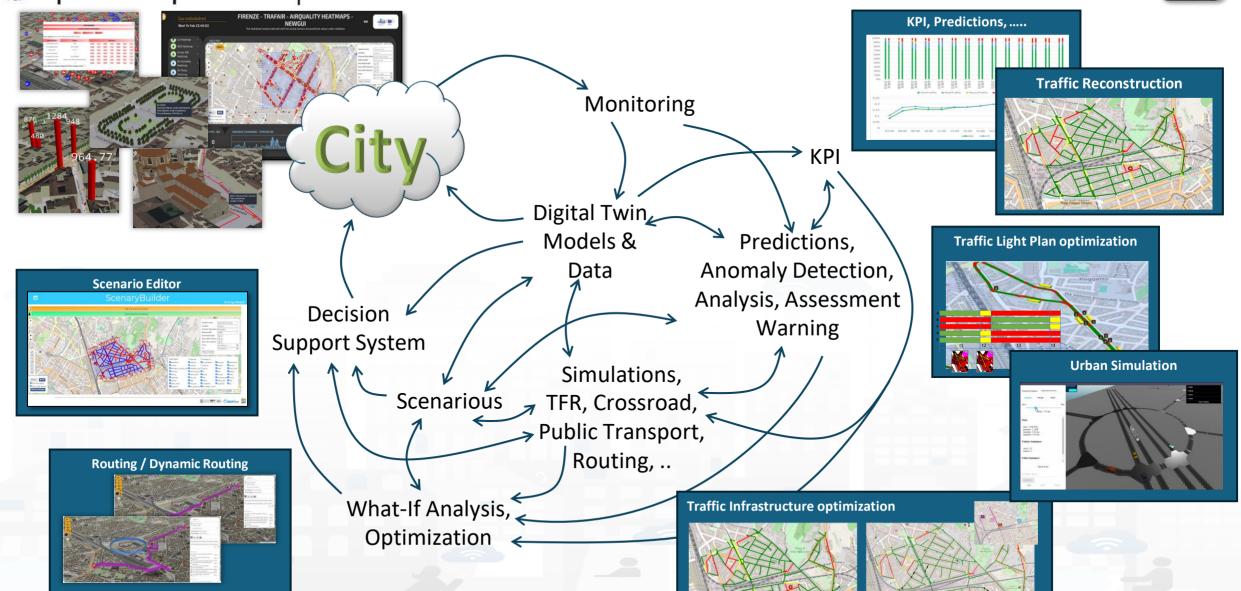
OSM data with non correct viability in Piazza Dalmazia, Firenze

incorrect

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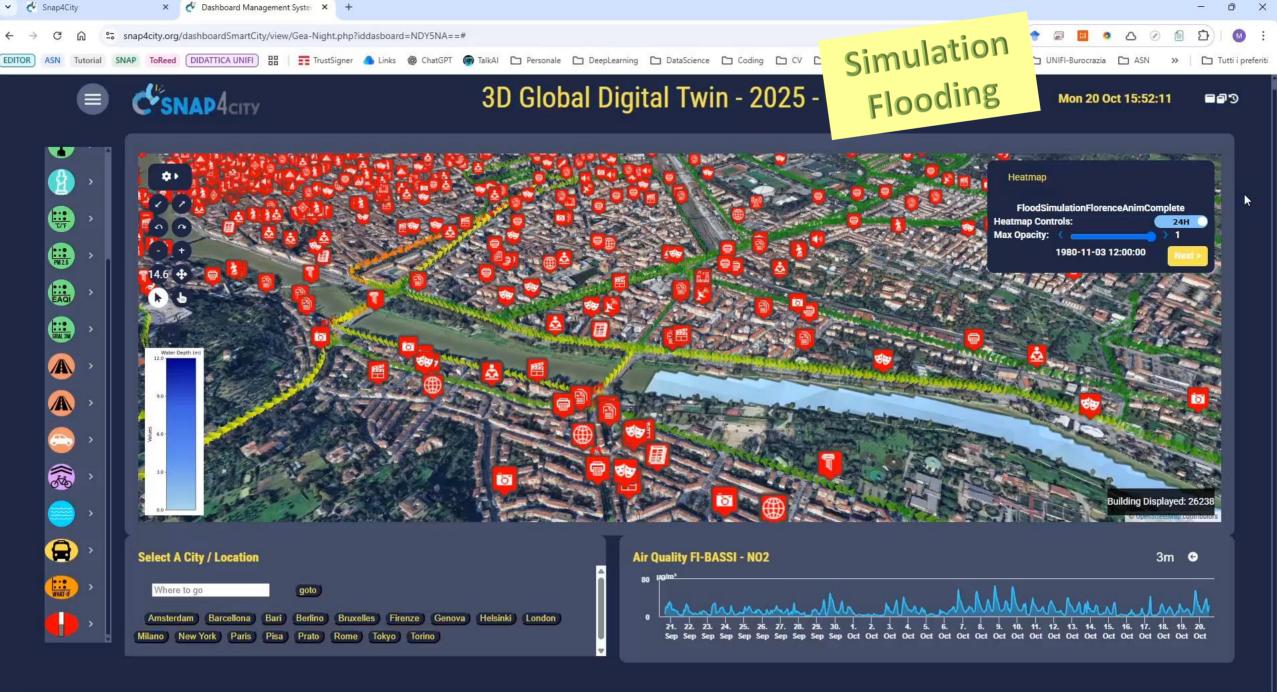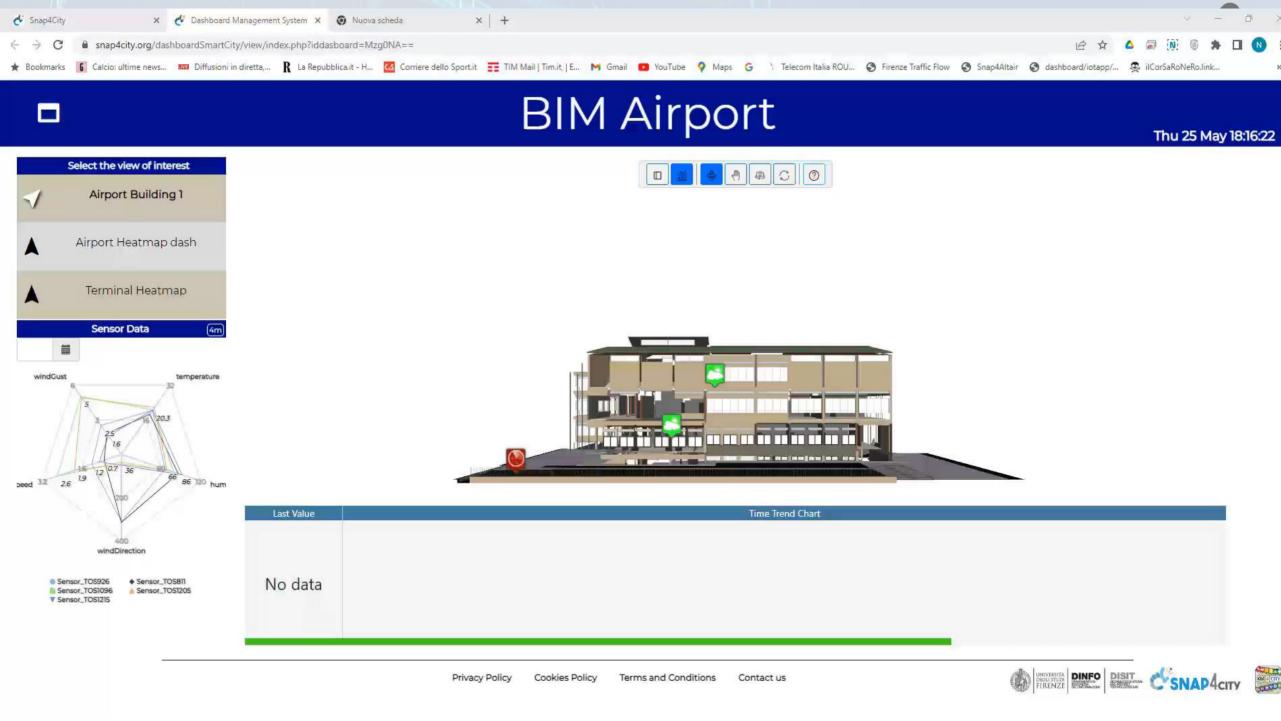
corrected

From OSM to Snap4City

https://www.youtube.com/watch?v=le2XNF8Ftxo

snap4city.org/dashboardSmartCity/view/index.php?iddasboard=Mzg0NA==

BIM Airport

Thu 25 May 18:16:22

Select the view of interest

◢ **Airport Building 1**

▲ Airport Heatmap dash

▲ Terminal Heatmap

Sensor Data (4m)

windGust

temperature

windDirection

● Sensor_TOS926 ◆ Sensor_TOS811
■ Sensor_TOS1096 ▲ Sensor_TOS1205
▼ Sensor_TOS1215

Last Value	Time Trend Chart
No data	

Simulators in What-If analysis and Optimisations

- **Mobility and Transport: infrastructure, data, TLP, by Scenario or Wall**
  - Traffic flow reconstruction: from sensors to full traffic flows (Meso, Macro) (Snap4City)
  - Multimodal Traffic: cars, tram, busses, pedestrian (SUMO micro-meso + Snap4City meso-macro)
  - Public Transport: match demand vs offer (Snap4City:DORAM1, DORAM2 beta + SUMO: micro-meso-macro)
  - Routing, dynamic routing: micro, meso, macro scales (GraphHopper + Snap4City)
  - Multimodal routing: micro, meso, macro scales (GraphHopper + Snap4City)
  - Road Parking simulator and management system (Snap4City)
  - KPI: travel time, emissions, waiting time, etc. (Snap4City, SUMO)

- **Environment**
  - Impact on NO_2, CO_2 by traffic flow, heating emissions, wind, weather, etc. (Snap4City)
  - Waste Collection Simulator and Management system (Snap4City)

- **Energy**
  - Photovoltaic plant: home level, area data (Snap4City)
  - Computing roof orientations and patterns from LIDAR data, positioning of PV panels (Snap4City)
  - Smart Light management systems (by Snap4 srl, on top of Snap4City
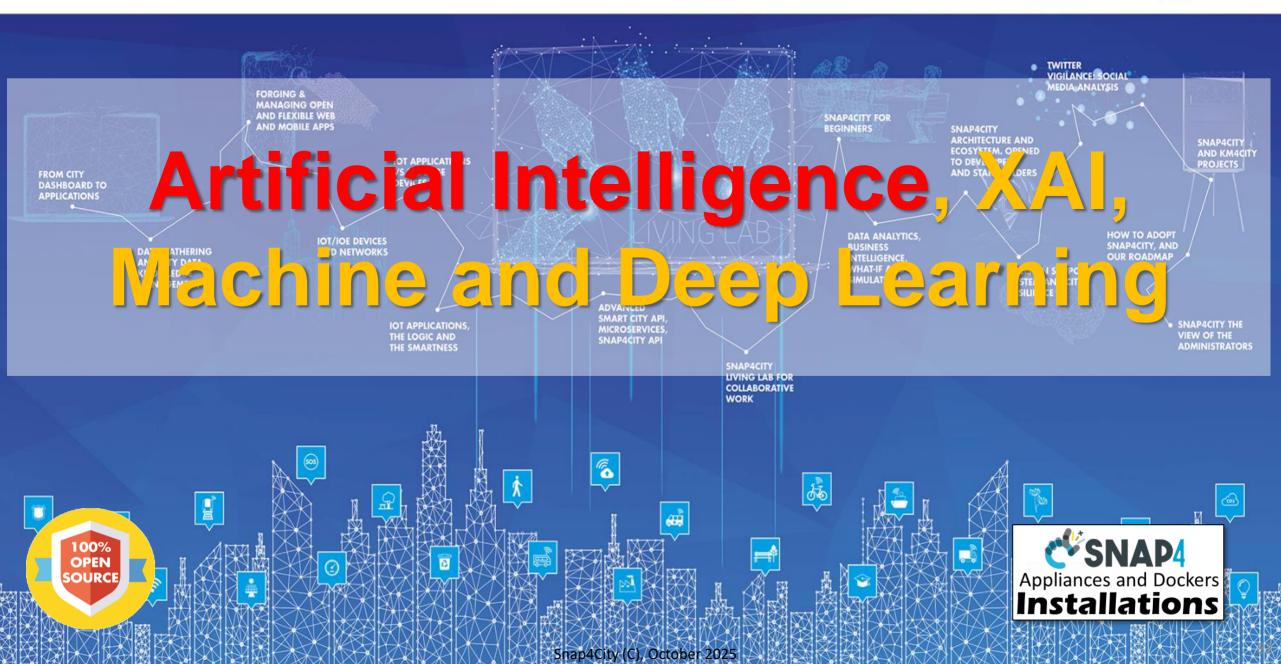
- **Other:**
  - 15 Min City Index: 13 subindexes, (Snap4City)
  - SUMI indexes, partial; SUMP indexes, partial; SDG…; etc. (Snap4City)
  - 3D Tiles from plant shape extrusions and patterning, Google 3D Tiles, working on other formats (Snap4City)

Artificial Intelligence, XAI, Machine and Deep Learning

Available AI Solutions on Snap4City

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**
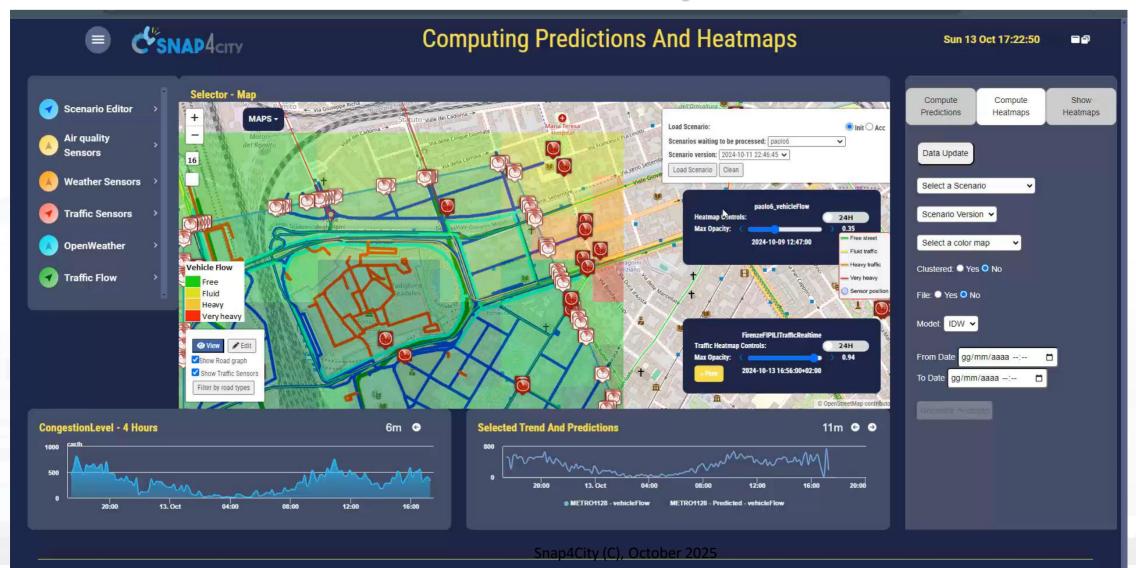
Predictions and Heatmaps in Real Time

15 Minute City Index:

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

7 AFFORDABLE AND CLEAN ENERGY
- 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

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
- Predictive maintenance
- Decisions Support Systems
- Process optimization, control
- Industry 4.0 integrated solutions
- AI assistant for commercial activities

11 SUSTAINABLE CITIES AND COMMUNITIES
- 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

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

13 CLIMATE ACTION / 15 LIFE ON LAND
- 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
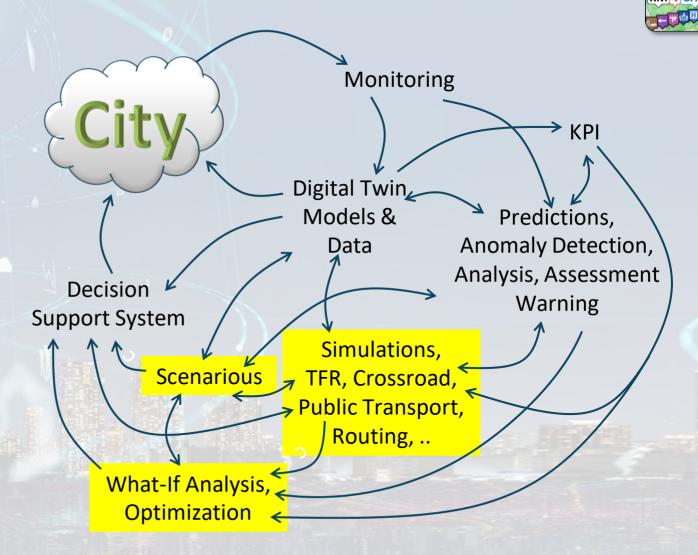
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
- Shortening justice time
- Prediction of mediation proneness
- Assisting institution is taking legal decisions
- Anonymization and indexing legal docs.
- Ethical Explainable Artificial Intelligence
- Advisor for legal documentation, generative AI

From What-If to Decision Support System

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Early warning on critical conditions
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- **Making plan: tactic and strategic, medium and long range, micro/macro**
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  - Collaboration with stakeholders
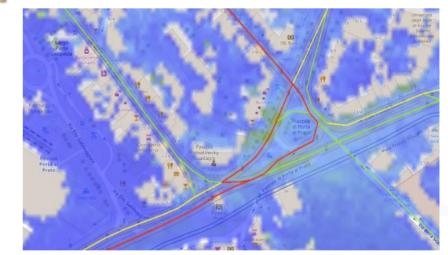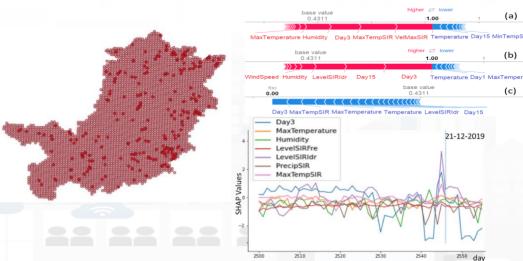
The difference is on computational models

- **Simulation models,**
- **statistics and operations research techniques**
- Machine Learning and Artificial Intelligence techniques
  - exploitation of heterogeneous data, **BIG DATA**
    - Predictions, Early Warning, Anomaly Detection, …
    - **What-If Analysis** integrating predictive models and simulations
  - **Explainable AI, XAI, providing to the decision-maker**
    - **detailed explanations** on the motivations behind the suggestions provided, so that the decision maker can understand the process and the motivations
    - **evidence of compliance with ethical aspects with confidence**
  - *To be able to use the systems as a trusted expert system.*

Mobility and Transport

Mobility

- **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, CO_2 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.**
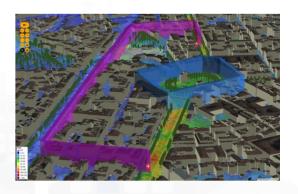
Mobility and Transport Domain (2024/8)

- 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
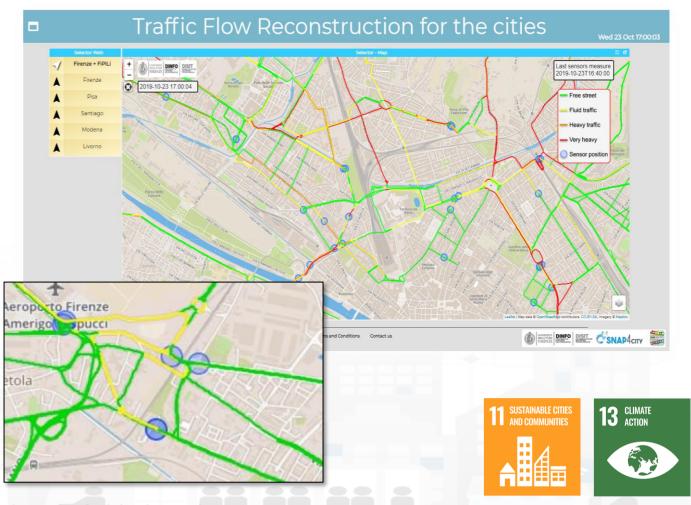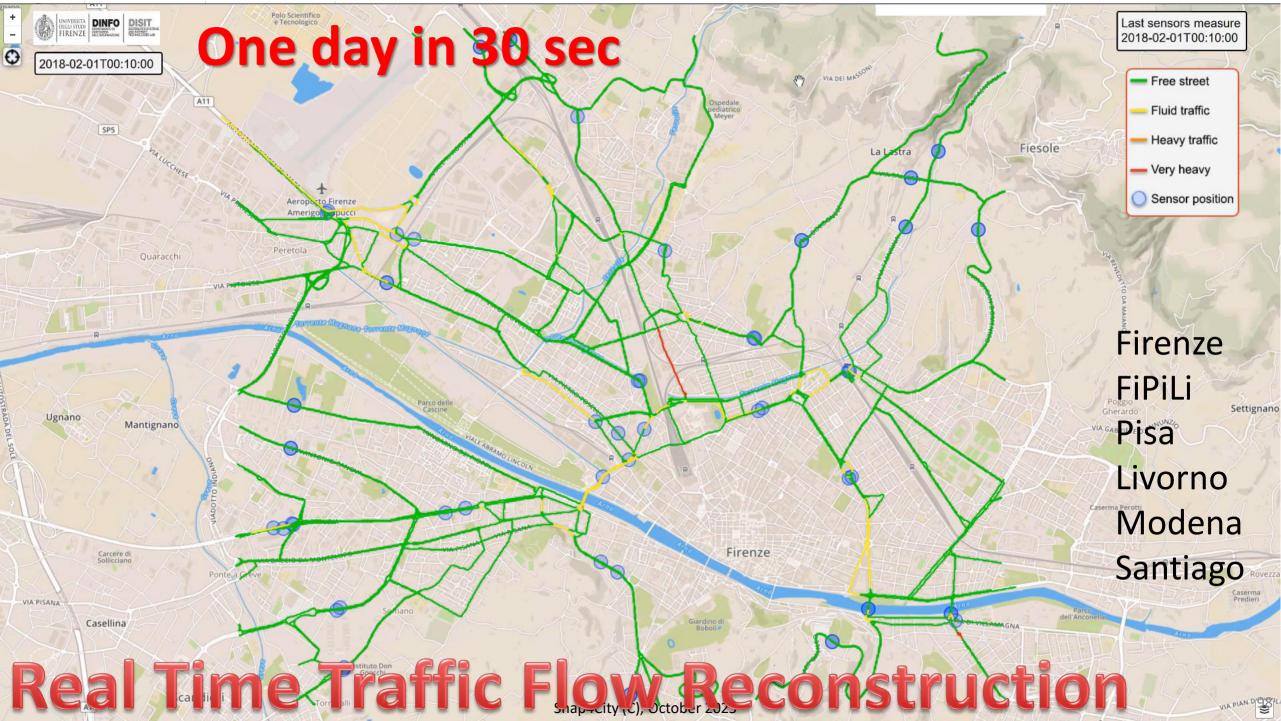
Why Dense Traffic Flow Reconstruction ?

- 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==

Decision Support Systems, What-if

o **Event planning, via what-if analysis**

- o Change in the graph structure of the city
- o Impact on the flow of people and vehicles
- o Adaptation: public transport, traffic, pedestrian management, etc.

o **Immediate reaction to natural events or not**

- o Everything is ready and updated in real time
- o Each view is contextualized in terms of data: descriptive and prescriptive

o **Digital Twin**

- o More detail in the context integrated data
- o Greater realism in deductions and representations
- o Less fragmentation and non-uniformity in the views to support decisions

Traffic Flow

LongTerm

Routing

ShortTerm

Scenario Editor

Select map

Zoom

New Scenario

Editing
Drag & drop
Split & Join
Delete
Do and Undo

Edit Road Segment

Scenario name: Scenario name
Location: Location
Scenario description: Scenario description
ReferenceKB: Reference KB
Save Road Graph: Yes
Save traffic Sensors: Yes
Save other Sensors: Yes
From: gg/mm/aaaa --:--
To: gg/mm/aaaa --:--
Save | Show Summary | Cancel

Category Street: primary
Nr.Lanes: 3
Speed Limit (km/h):
Direction: Positive direction
Restrictions: Select or create restriction
Update

View | **Edit**
☑ Show Road graph
☑ Show Traffic Sensors
Filter by road types

Road Types: ☐ Select All ☐ Unselect All
☑ abandoned ☑ bridleway ☑ bus_guideway ☑ bus_stop ☑ construction
☑ corridor ☑ crossing ☑ cycleway ☑ disused ☑ elevator
☑ emergency_access_point ☑ emergency_bay ☑ footway ☑ island ☑ living_street
☑ motorway ☑ motorway_link ☑ no ☑ path ☑ platform
☑ primary ☑ primary_link ☑ private ☑ raceway ☑ razed
☑ residential ☑ rest_area ☑ road ☑ secondary_link ☑ service
☑ services ☑ steps ☑ tertiary ☑ tertiary_link ☑ track
☑ traffic_island ☑ tram ☑ trunk_link ☑ unclassified ☑ via_ferrata
☑ secondary ☑ yes ☑ pedestrian ☑ bus_guideway ☑ ohm:military:Trench

© OpenStreetMap contributors

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

Properties of Road Elements

https://www.snap4city.org/976

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
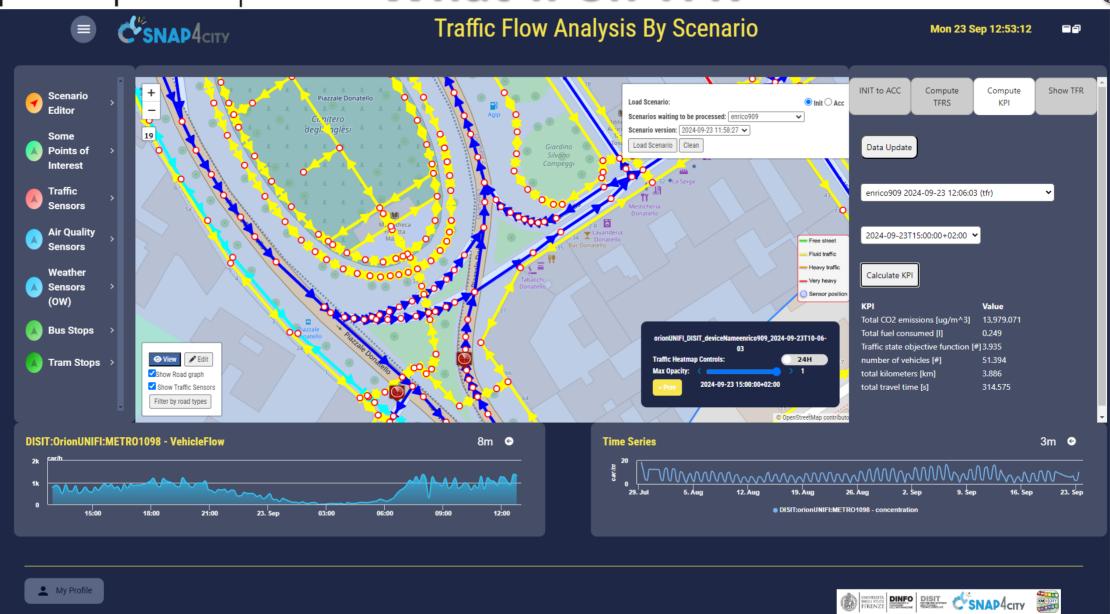
Snap4City(C), October 2025

What-if on TFR

Traffic Flow Analysis By Scenario

Snap4City (C), October 2025

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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
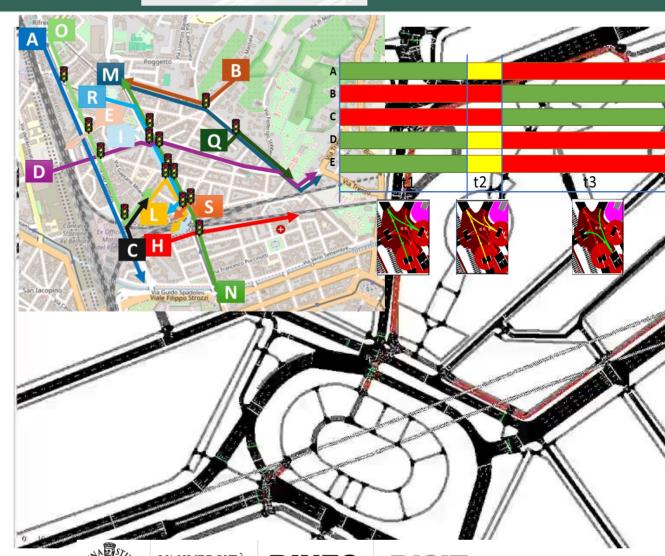
- Travel Time, waiting time, waiting count
- Specific travel time on directions
- CO_2 emissions, etc.

Reductions from 5% to 15%
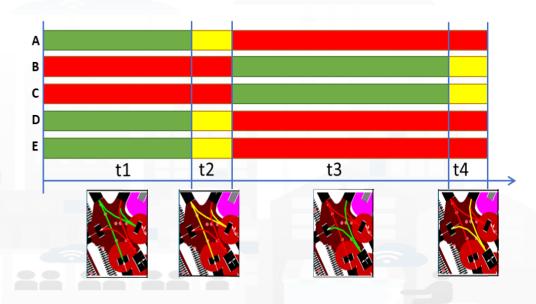
Traffic Light Plan Optimisation, Digital Twin

- **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
  - CO_2 emissions, etc.

- **Reductions from 5% to 15%**
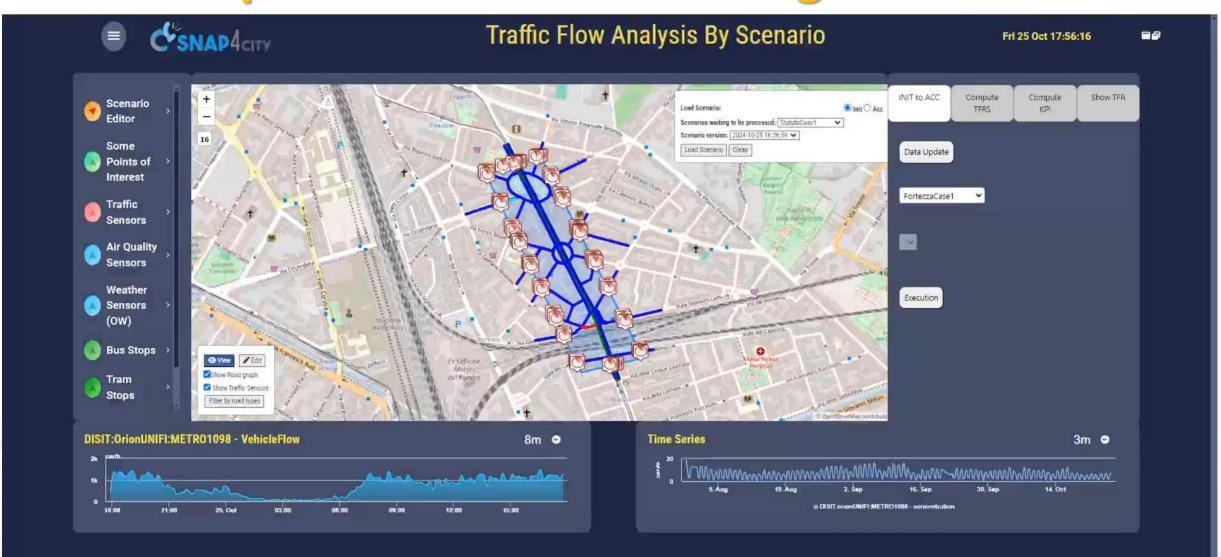
Optimization of Traffic Light Plan

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
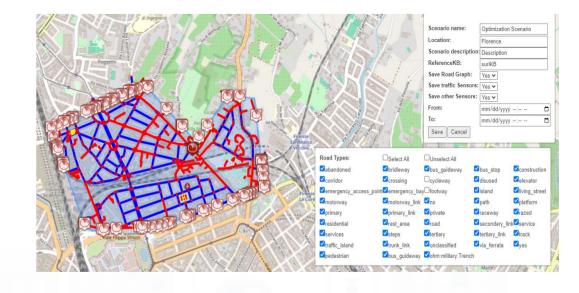
Traffic Infrastructure Optimisation, Digital Twin

- **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
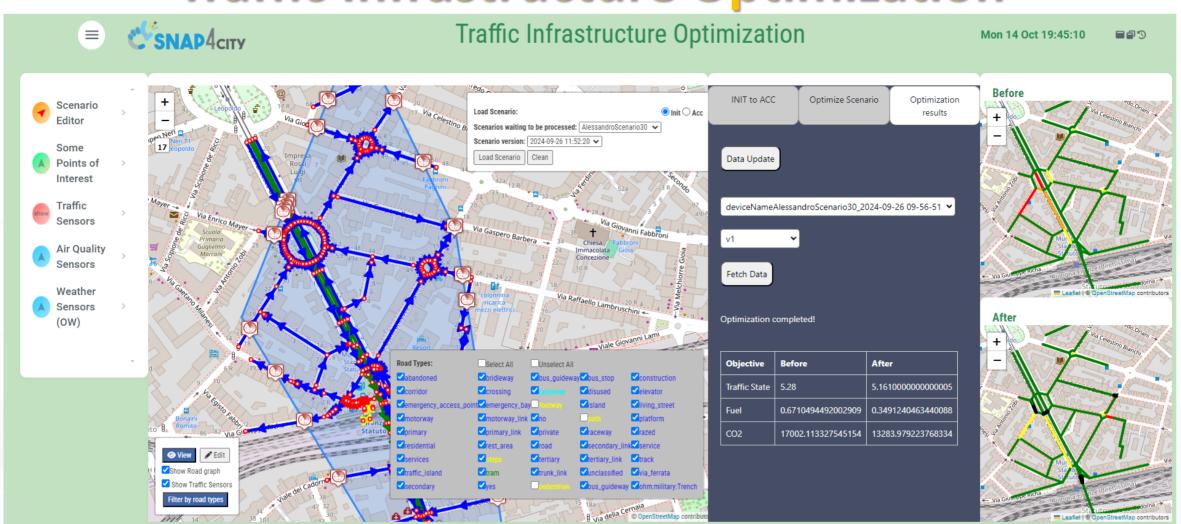
Traffic Infrastructure Optimization
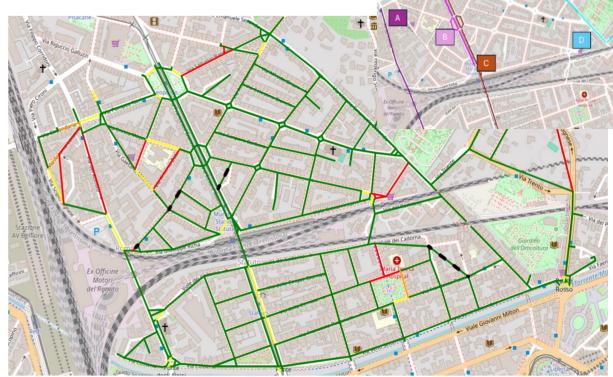
Optimization Results

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%	
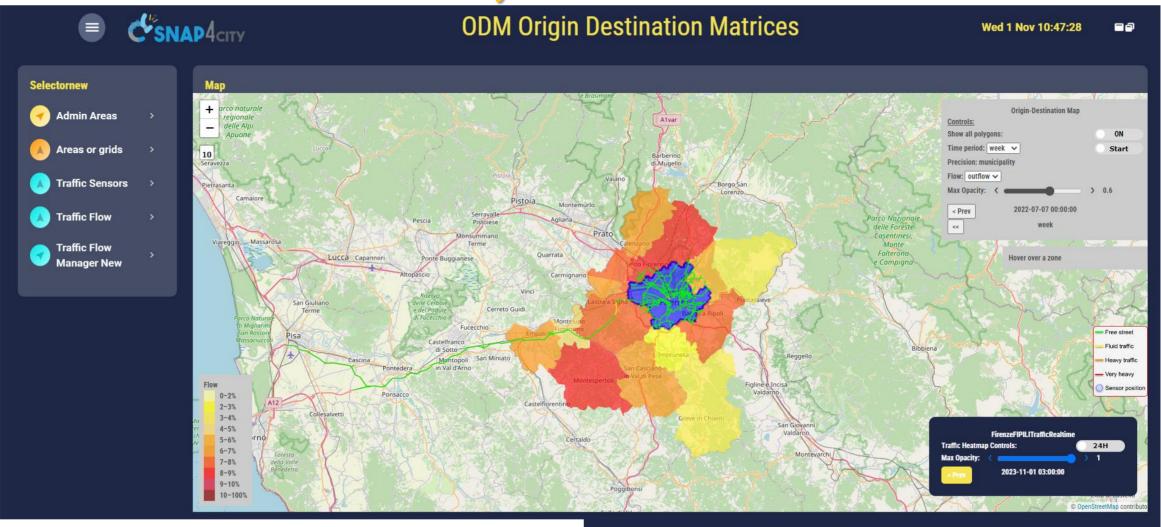
ODM, Traffic Flow

What-if Analysis on Pub Transport
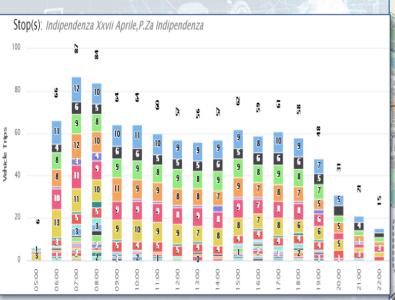
- Definition of scenarious impact on
  - Traffic, Pollutant, parking, public transport, private flows, etc.
  - KPI analysis

Public Services

DORAM

https://www.snap4city.org/odanalyzer/#b
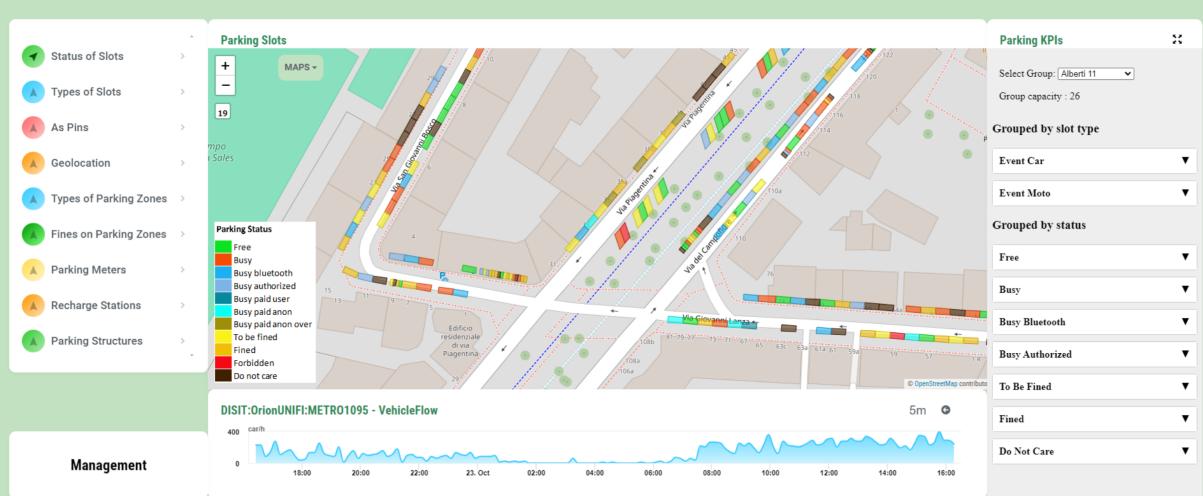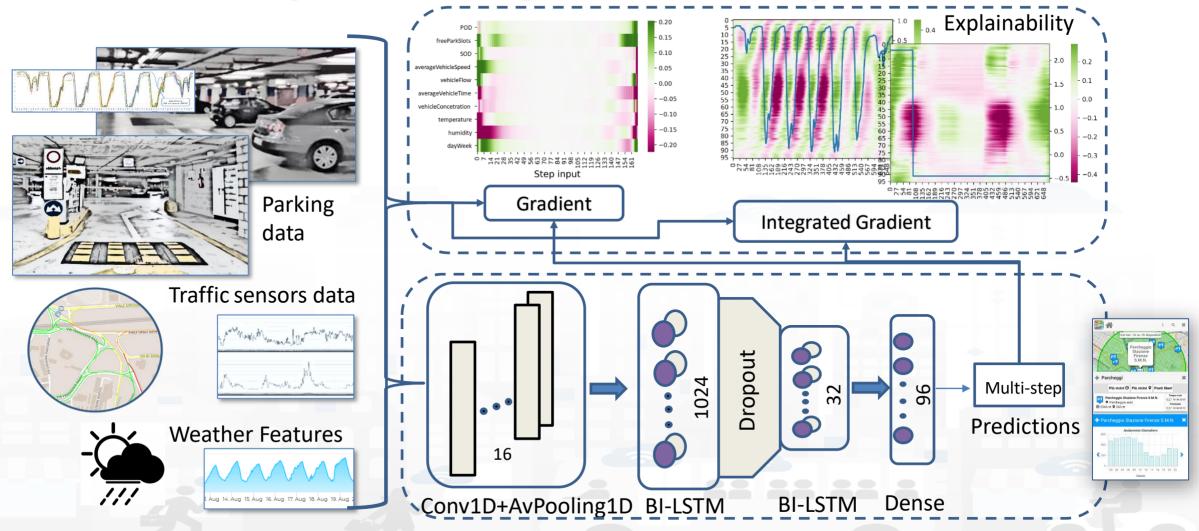
Road Parking — Parking Conditions Monitoring

Road Parking

Deep Learning AI to surely Park!
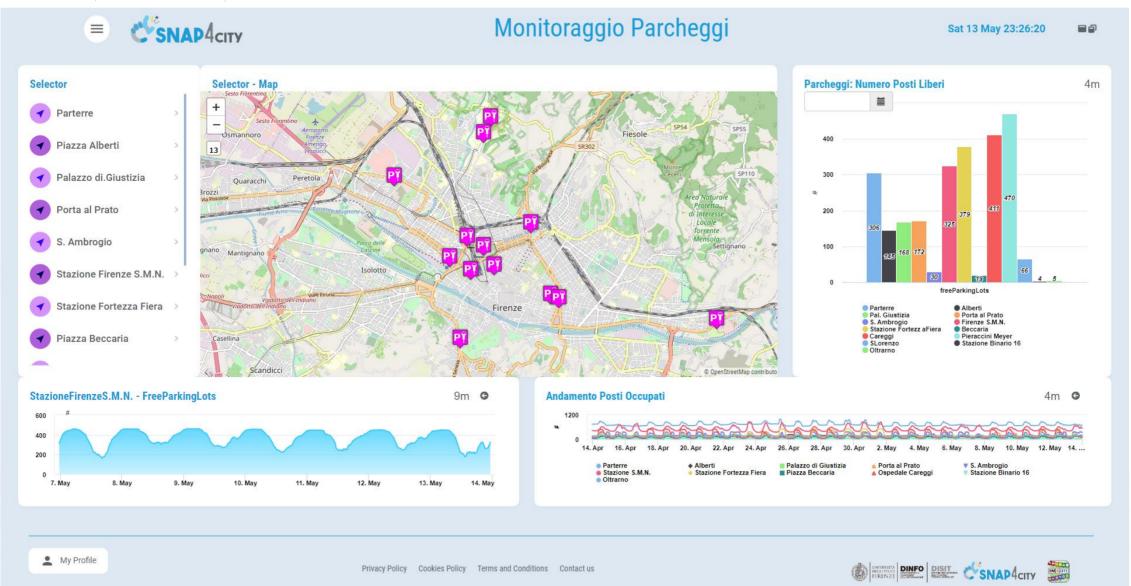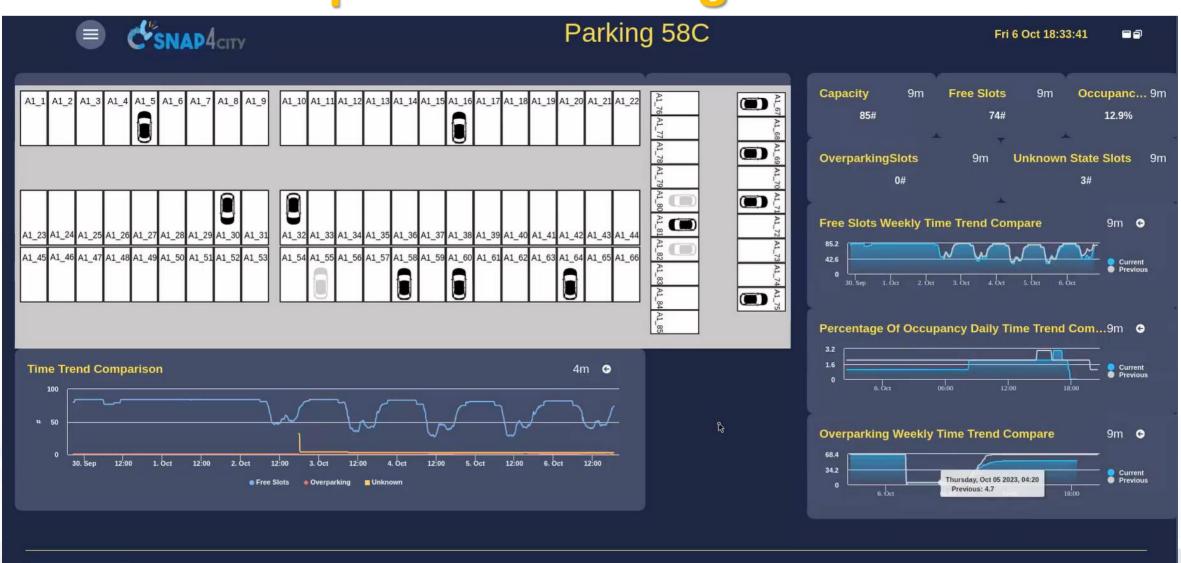
Snap4ISPRA Parking: ISPRA JRC
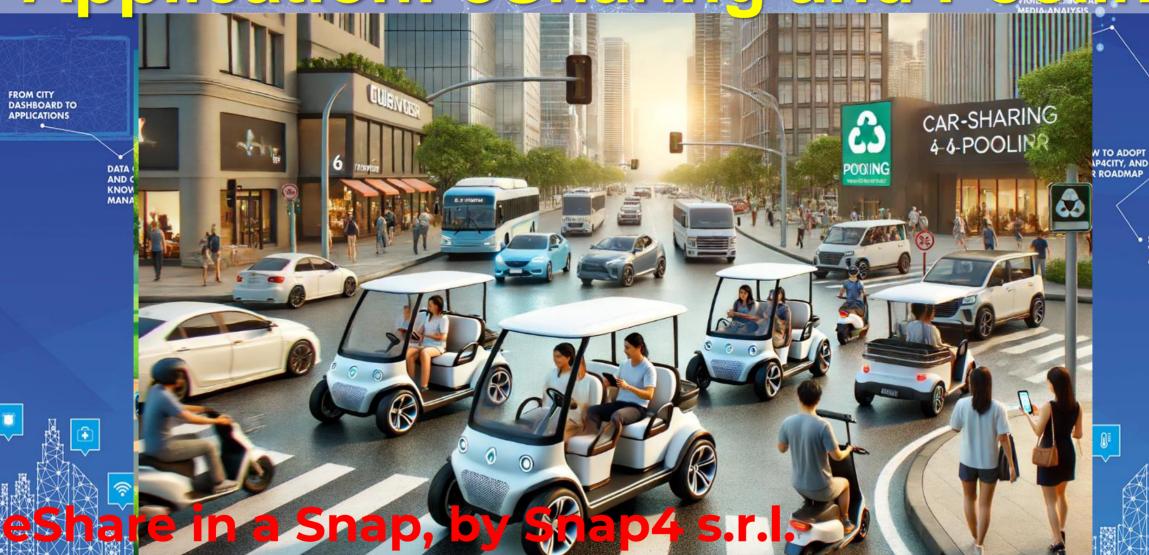
Application: eSharing and Pooling

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

Solution: Fleet Monitoring and tracking
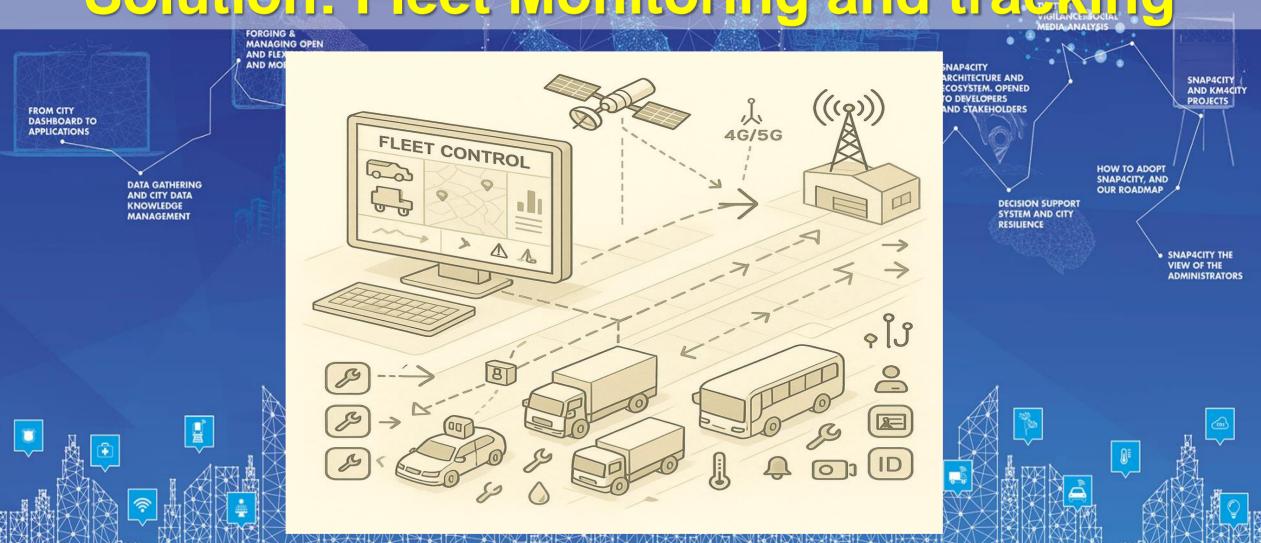
Fleet Monitoring and Management
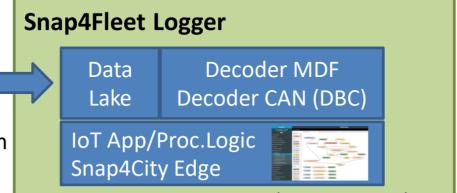

Snap4Fleet Logger

Data Lake | Decoder MDF Decoder CAN (DBC)

IoT App/Proc.Logic Snap4City Edge

OBD2
LTE
GPS

ASAM MDF Configuration

CAN Logger
https://www.csselectronics.com/

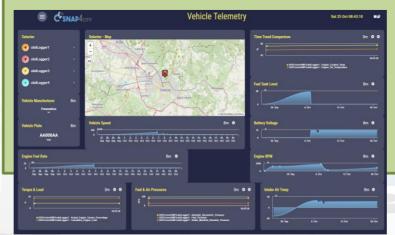**Snap4Fleet Manager**

on Snap4City Platform

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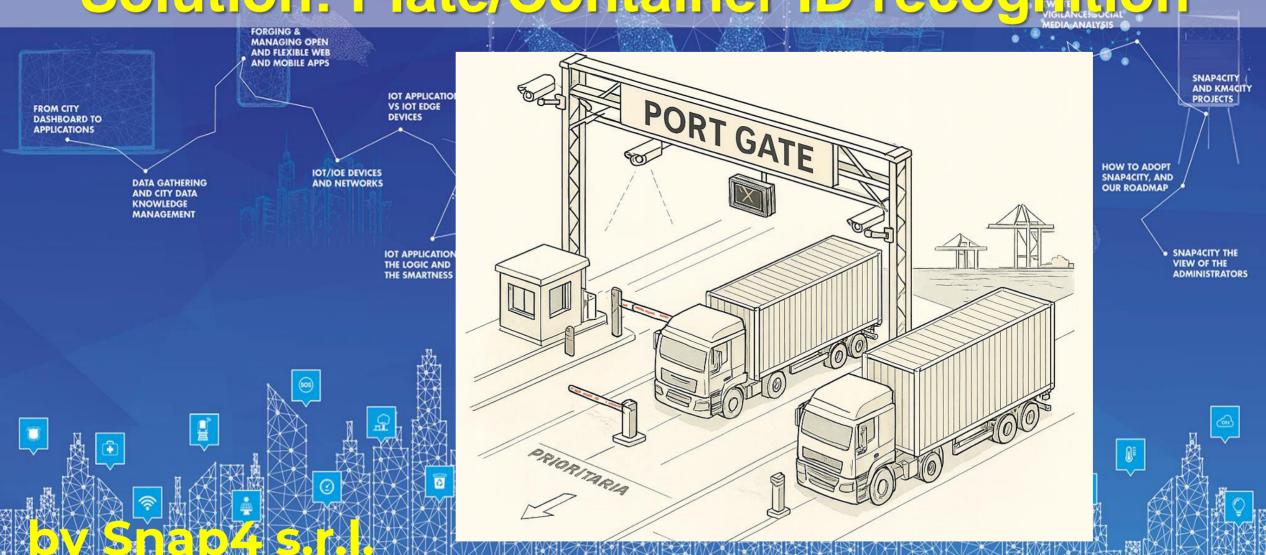- Toward the Snap4Fleet Manager

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

Human Behavior: analysis & security
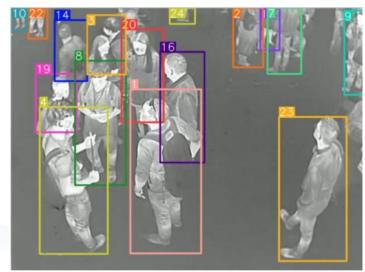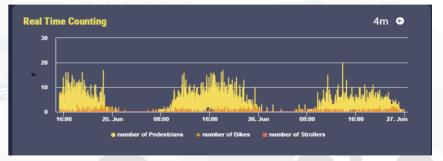
City User Behaviour/services, Tourism and Safety

- **Goals:**
  - Improve Quality of Life and quality of services,
  - Over tourism mitigation, sustainability
  - Costs reduction of services
  - Improve accessibility to services: citizens, Tourists, commuters, etc.
  - Improve Security/Safety of city users

- **People Flow Analysis / Management:** in/out-door, retail, attractions
  - Counting, tracking, Flows, ODM, sentiment, etc.,
  - multiple sources: thermal & TV cameras, radar sensors, PAX sniffers, mobile data, …
  - Data and/or OD matrices from: Wi-Fi, traffic data, mobile phone data
  - **Suggestions**: info Tourism, digital signages, engagement, ..

- **Tourists Flows & Retail Management**: predictions of presences, services' reputations, suggestions on second offer, over-tourism, notifications, early warning,

- **KPI**: 15 MinCityIndex, energy vs people, over-tourism, accepted suggestions, precision

- **Mobile App**: final users services/informing and operators
  - Info Tourism, people flows, info mobility, sharing, …
  - Participation, engagement, ..

- **Participatory**: problem reporting, ticketing, etc.

- **Integration of any kind: env/weather, mobility, ticketing, presences, POI, ..**
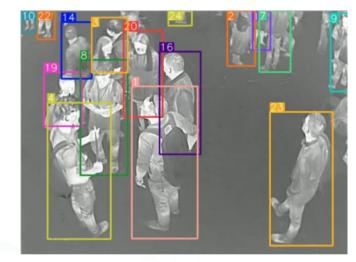
City User Behaviour/services, Tourism and Safety (2024/8)

- Goals:
  - Quality of Life, quality of services, over tourism mitigation, sustainability
  - Costs reduction of services
  - Accessibility to services: citizens, Tourists, commuters, etc.
  - Security/Safety of city users
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
  - Monitoring services: tickets, reputation, usages, areas, etc.
  - Monitoring user behaviour (counting, trajectories): indoor/outdoor, hot places/services, ports, beaches,
  - Computing: origin destination, trajectories, travel means, etc.
  - Early detection/warning of critical conditions, connection with Video Management Systems
  - Managing entrances in city areas: restricted areas, touristic busses, etc.
  - Production of info-toursim, recommendations, nudging to city users and operators, second offer promotion
  - Providing Virtual Assistants for City Services, Tourist Offices, etc.
  - Monitoring reputation of services via: social media, blogs, etc.
  - Collecting complains, requests, participations from City users via mobile apps
  - Computing predictions of any kind
- Solutions for Planning (optimization and what-if analysis)
  - Reduction of Pollutant Emissions, via optimization
  - Optimization plan to distribution of workload on multiple touristic offers/services, area cleaning, etc.
  - Predicting reputation of services, touristic and operative
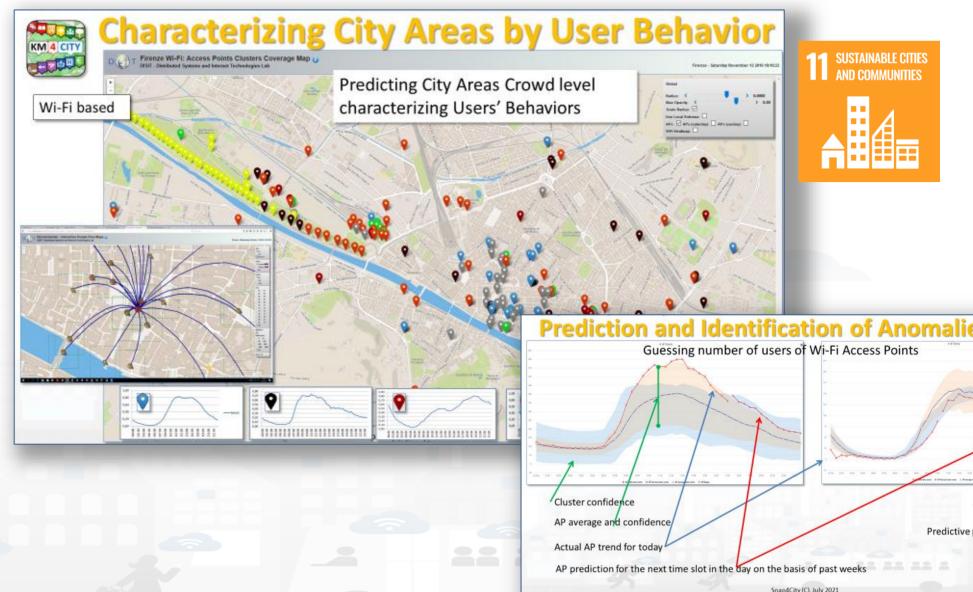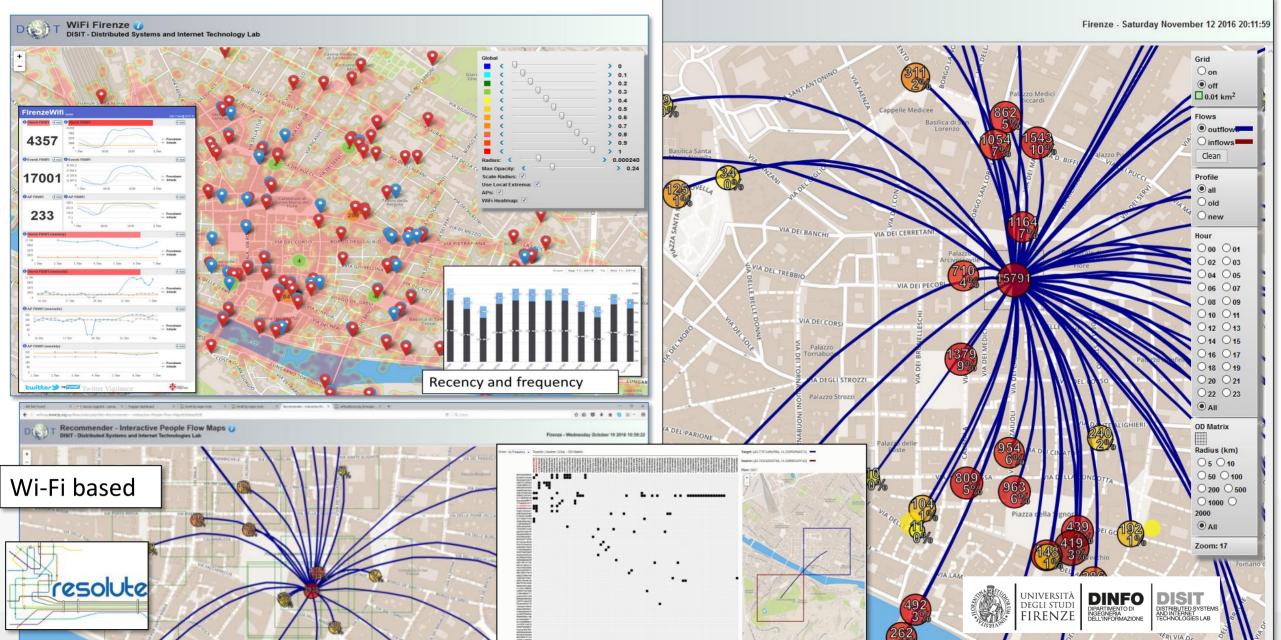- Algorithms and computational solutions, see next slide

La Cattedrale_slowcentury - istockphoto.com

- **Prediction of people flows** on the basis of Wi-Fi data

- **Anomaly** detection

- **Resolute** H2020

- Classification of city areas

Characterizing City Areas by User Behavior

Wi-Fi based

Predicting City Areas Crowd level characterizing Users' Behaviors

Prediction and Identification of Anomalies

Guessing number of users of Wi-Fi Access Points

Cluster confidence

AP average and confidence

Actual AP trend for today

AP prediction for the next time slot in the day on the basis of past weeks

Snap4City (C), July 2021

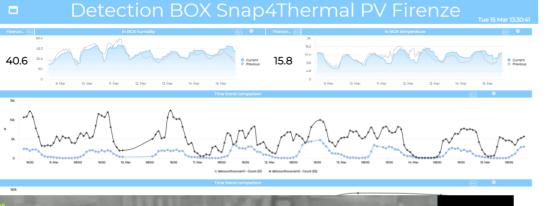# Origin Destination Matrix Estimation

Recency and frequency

Wi-Fi based

A view and data from the Thermal Camera
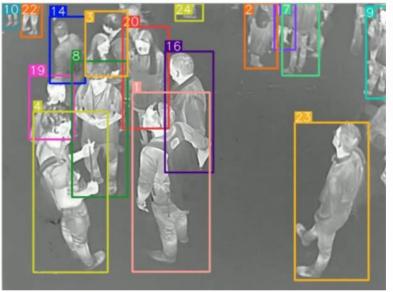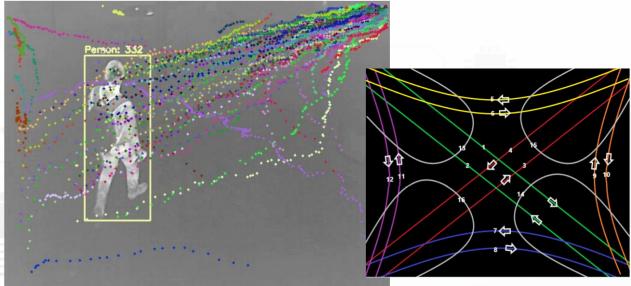
People Counting and Tracking
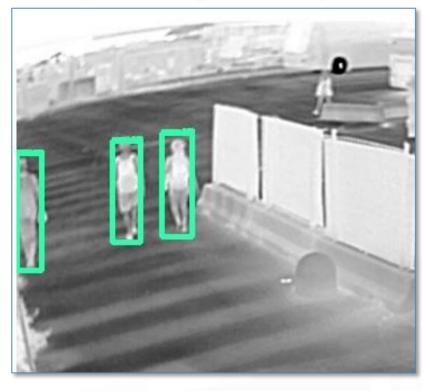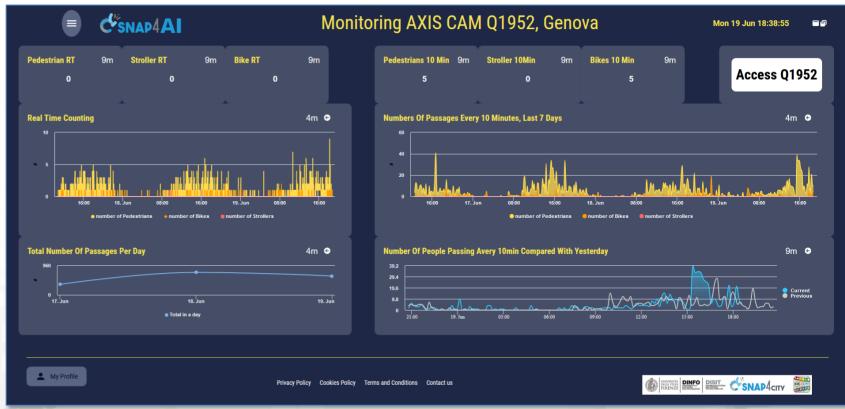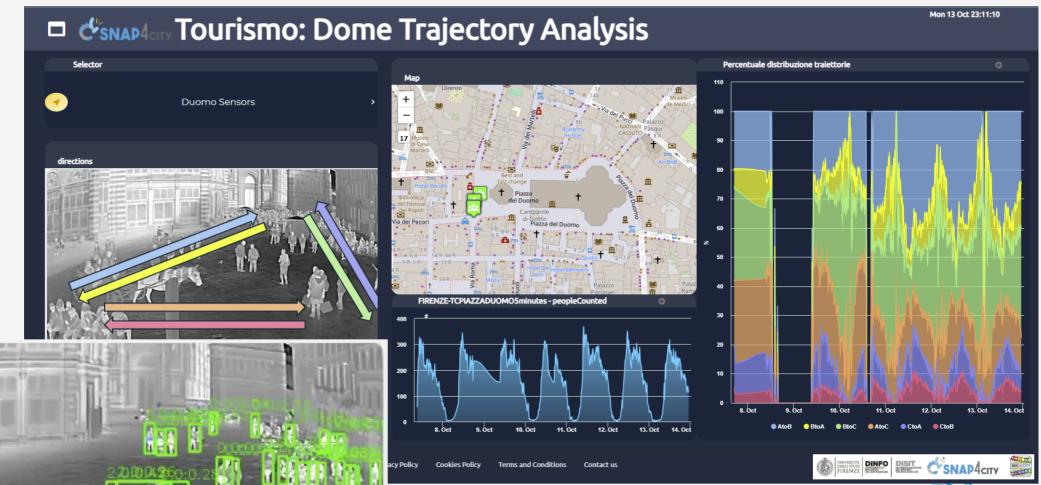
Monitoring Passages AXIS Q1952

- Genova: Ocean Race, 2023

Tourism management, over-tourism

- **Operation**:
  - Monitoring: counting, tracking, flows, ODM, etc.
    - Differentiating: tourists, commuters, resident, students, etc.
    - Differentiating on Restricted zone: permissions
  - Early warning detection, predictions, etc.
  - Collecting participation, complains, etc.
  - Producing suggestions towards second offers, diversification
  - Informing of crowed conditions
- **Management**
  - Promoting best moments for visiting, pushing event organizers
  - Simulation and plan, improve services: transportation, sharing
  - Assessing and predicting reputation
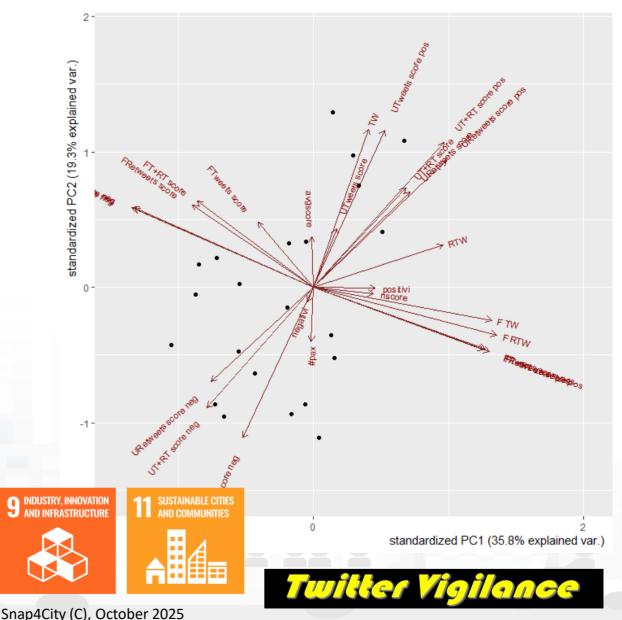
Reputation

- Prediction/estimation of **Average Score of Trip Advisor** as a function of *Twitter Vigilance Metrics + other information*

- Prediction/estimation of **Negative Scores on specific Museum** or service as a function *of Twitter Vigilance Metrics + other information*
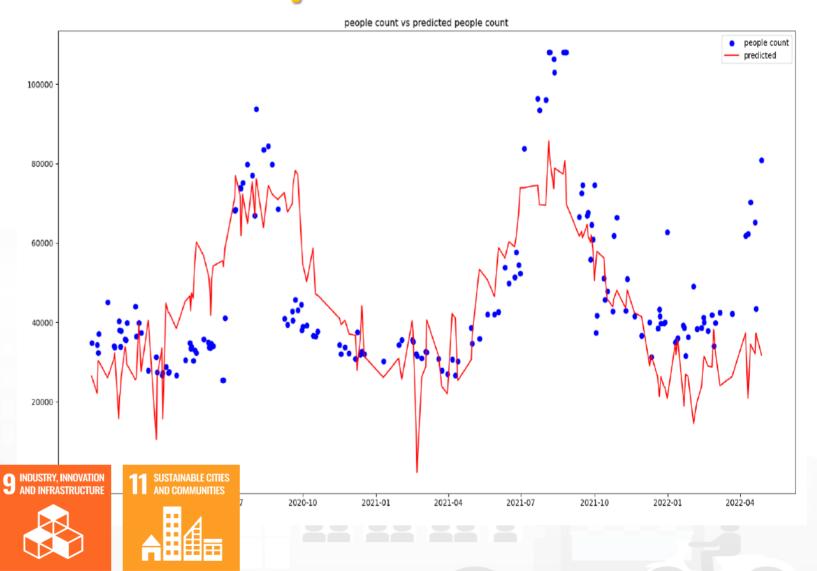
Dubrovnik: Data Analytics

- Assessing impact of advertising

- Prediction of presences on the basis of
  - Social Media Twitter Vigilance
  - weather conditions
  - Historical data

people count vs predicted people count

Pont du Gard: data analytics

- Prediction of the number of sold tickets 24 hours in advance

- Using:
  - Historical data
  - Weather conditions
  - Social Media

Safety Control Integration with Video Management Systems

Integration with
MILESTONE
XProtect
Video
Management

milestone
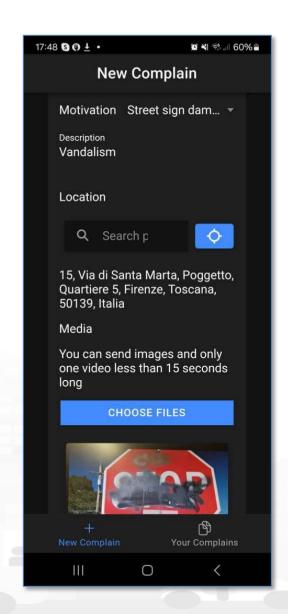
Event Managements

- **Bidirectional events**: from VMS to Snap4City and viceversa
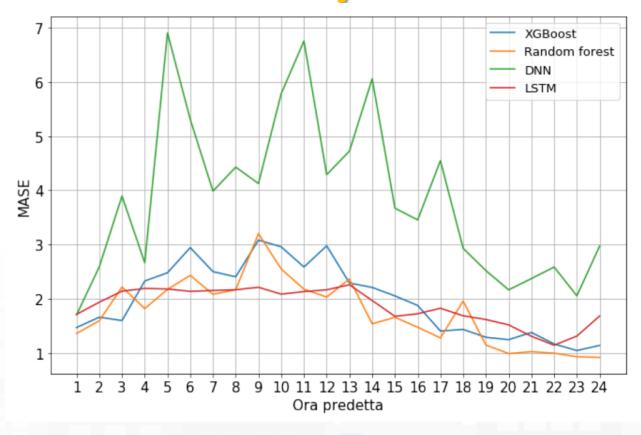 - From/to Snap4City to any service…
- **Snap4City collects and manages** events from:
  - Video Management System
  - Mobile Apps, city user complaints, operators, etc.
  - Web Apps, city users and operators
  - Early warning detected from Snap4City, etc.
  - Maintenance management tools, …
  - Other channels, …

Event Management
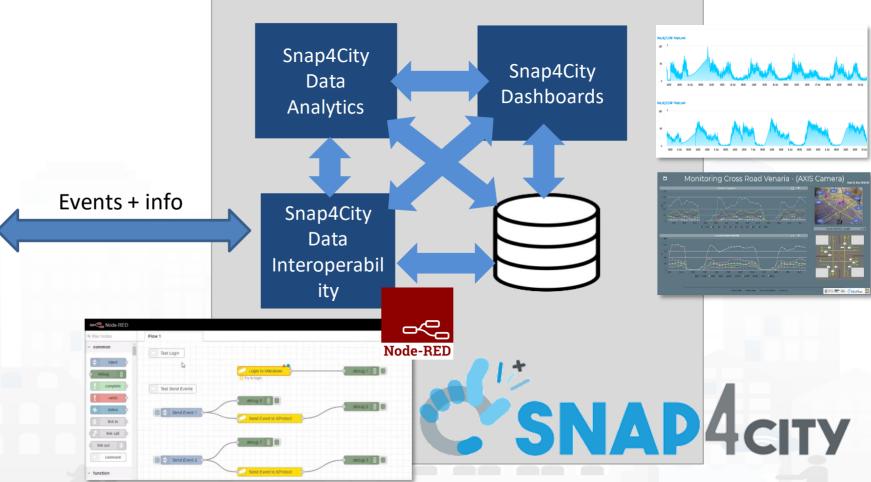
VMS vs Snap4City: sending and getting events, AI solutions

Events + info

Assets Management & Control
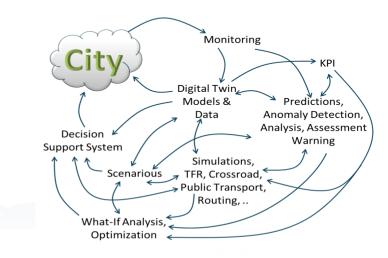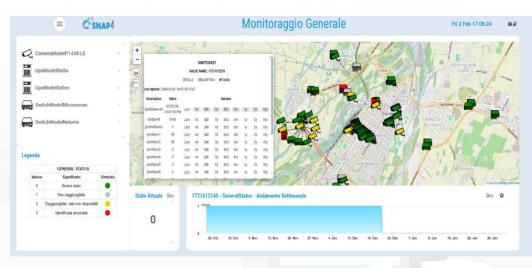
Assets Control Domain (2024/8)

- Goals:
  - Costs reduction, increase service availability, risk reduction
  - Quality Level
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
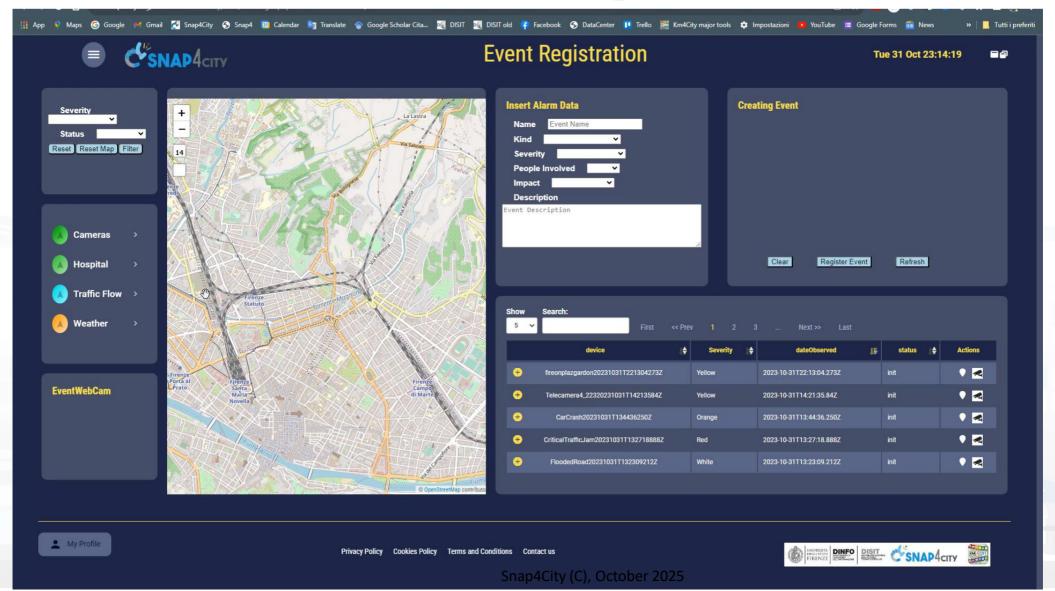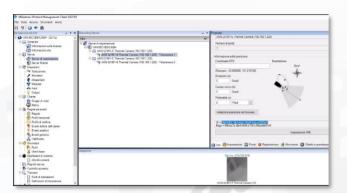 - Monitoring :
    - **Assets**: switches, Wi-Fi, servers, UPS, sensors, building, TV Cams, etc.
    - **Energy**: consumption, operative conditions, UPS continuity, etc.
    - **Production**: continuous serviceability analysis
    - Etc.
  - Early detection/warning, alarm, of critical conditions
    - **Multichannel** Event reporting, notifications: email, Telegram, mobile apps, SMS, etc.
  - Managing maintenance operation, predictive maintenance
  - Computing predictions of any kind
- Solutions for Planning (optimization and what-if analysis)
  - Reduction maintenance costs, reduction of critical SLA conditions, improve service level
- Algorithms and computational solutions, see next slide

Cuneo Assets' Monitoring, Safety

- More than 400 devices

- TV Cams: color, Thermal
- Traffic Gates
- Switches
- UPS

Cuneo Assets' Monitoring, Safety

Engaging via Mobile Apps

User Behavior Analyser for Collective Profiling

Who

When

What

Where? Why?

Where they go ahead

How move

Environmental Domain

Environment and Waste

- **Goals:**
  - Reduction of emissions and EC taxations
  - Cost reduction for waste collection,
  - reduction of waste collection impact on mobility

- **Environment Management producing predictions/prescriptions:**
  - Monitoring and long and short-term predictions, warning for:
    - GHG, emissions, pollutants, aerosol, chemical plants analysis
    - land slide, coastal erosion (blue economy)
  - Traffic Flow impact emissions, predictions
  - What-if analysis, optimisation tools

- **Waste Management and Optimisation:**
  - costs reduction, optimal routing production, pay as you throw,
  - avoiding out of bins, predictions of waste production on bins, alarms

- **KPI:** SDG, 15MinCityIndex, QOS, costs, Km, colleting time, EC KPI, emissions

- **Mobile App**: final users services/informing and operators
  - Info Waste for operators, participation, optimal routing, RAEE Collection, ..

- **Participatory**: problem reporting, ticketing, etc.

- **Integration of any kind: env/weather, mobility, ticketing, presences, POI, ..**

Environment, waste, land, etc., domain (2024/8)

- Goals:
  - Reduction of emissions and EC taxations
  - Cost Reduction for waste collection, reduction of waste collection impact on mobility
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
  - Monitoring emissions, weather, waste, water, etc.: sensors, traffic, flows, ...
  - Early detection/warning of critical conditions on *emissions, weather, waste, water, fire, animals, ...*
  - Early detection/warning of critical conditions for *landslides, water flooding, beach*
  - Smart Waste Management: bins/lockers, waste collection daily plan, pay as you throw, PAYT, etc.
  - Short terms prediction of emissions: CO2, NO2, etc.
  - Production of suggestions, nudging
  - Computing and predicting of long terms KPI indicators of the European Commission
- Solutions for Planning (optimization and what-if analysis)
  - Identification of main CO2/NO2 emissions locations in the city, total production from traffic
  - Reduction of Pollutant Emissions, via optimization: semaphore cycles, viability
- Algorithms and computational solutions, see next slide

Environment and Quality of Life Air Quality Predictions

Cities of: Firenze, Pisa, Livorno

- **Multiple Domain Data**
  - Traffic Flow data, Pollutant: NOX, CO2, PM10, PM2.5, O3, ….
  - 3D City structure, weather, …
- **Multiple Decision Makers**
  - Pollutant Predictions: NOX, NO2, ..
  - City officers, energy industries
  - Dashboards, What-IF analysis
  - Traffic Flow Reconstruction
- **Historical and Real Time data**
  - Billions of Data
- **Services Exploited on:**
  - Dashboards, Mobile App
- **Since 2020**
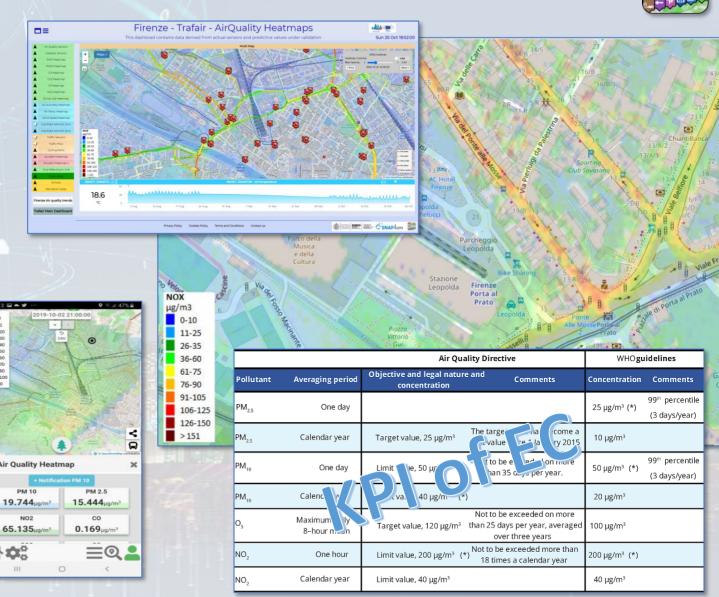
Firenze - Trafair - AirQuality Heatmaps
This dashboard contains data derived from actual sensors and predictive values under validation

NOX µg/m3
0-10
11-25
26-35
36-60
61-75
76-90
91-105
106-125
126-150
> 151

KPI of EC

		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 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	

PM10 µg/m³
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-100
>100

2019-10-02 21:00:00

Air Quality Heatmap
+ Notification PM 10

PM 10 19.744 µg/m³
PM 2.5 15.444 µg/m³
NO2 65.135 µg/m³
CO 0.169 µg/m³

18.6 °C

- **Prediction**
  - **NOX Pollutant** diffusion on the basis of Traffic Flow (prediction), weather and 3D structure
  - **NO2 progressive average** (Long term)

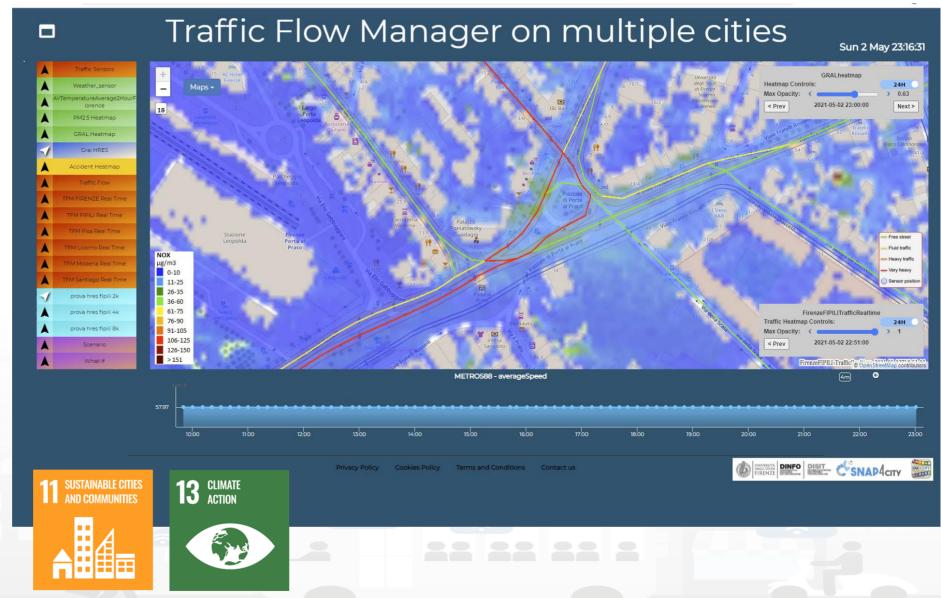- **Project:**
  - **Trafair** CEF EC
  - Mixed solutions of Fluidinamics modeling and AI

Traffic Flow Manager on multiple cities

Predicting Land slides

Dataset Construction

Previsional Model

Dataset Construction → Model training And validation

Data

SNAP4City Advanced APIs

Model

landslide DB

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

Processes

Ingestion

Big Data Storage and KB

Predictions

Model execution Shap Assessment

Data Analytics IOT App Management

predictions

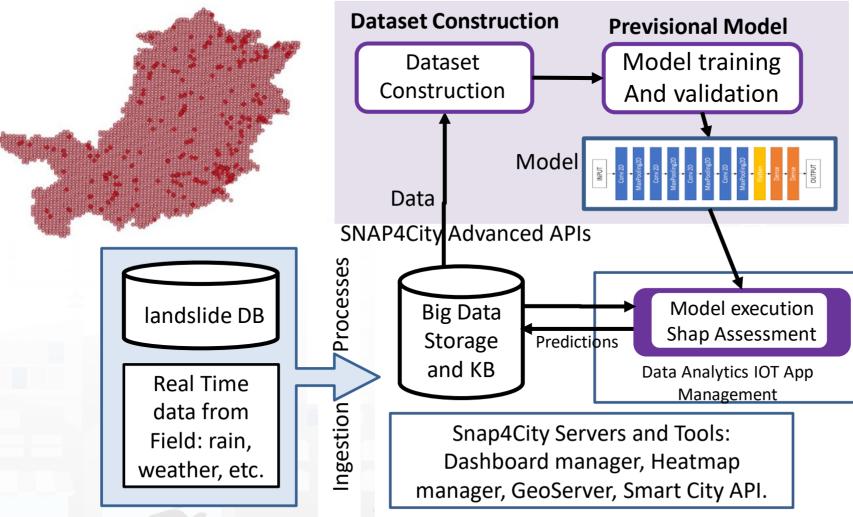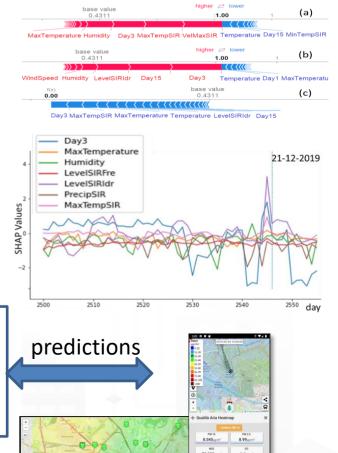Snap4City Servers and Tools: Dashboard manager, Heatmap manager, GeoServer, Smart City API.

Dashboards and Mobile Apps

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.
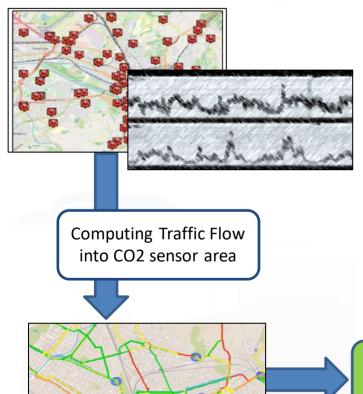https://ieeexplore.ieee.org/abstract/document/9732490

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)**
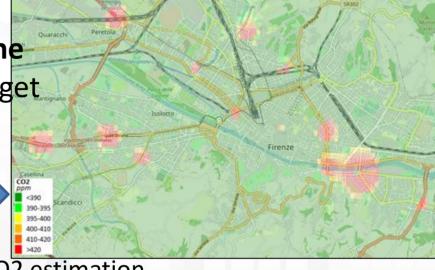 - **K1: Fluid Flow**
  - **K2: Stop and Go**
- **Dense estimation of CO2 into the city** is very useful to know to target EC's KPIs

Computing CO2 on the basis of traffic flow data

CO2 estimation

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/
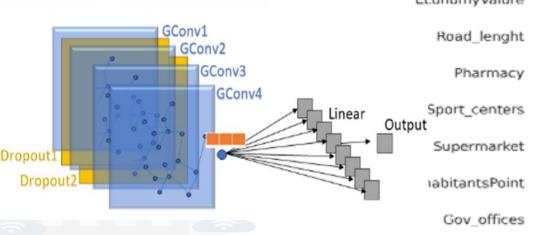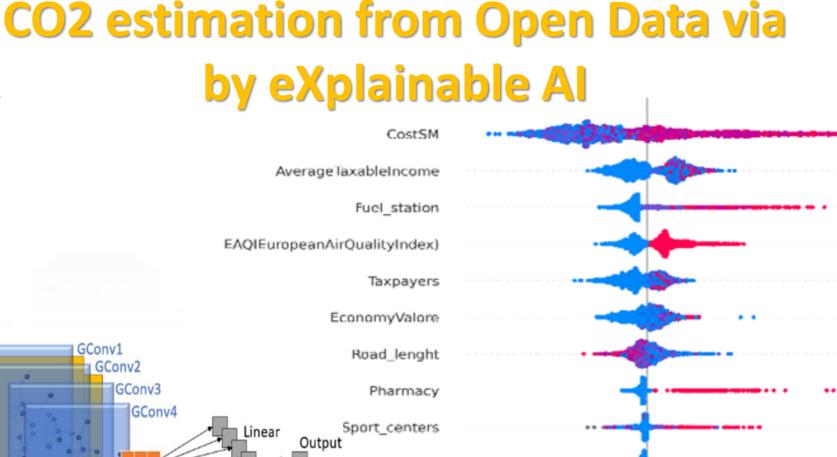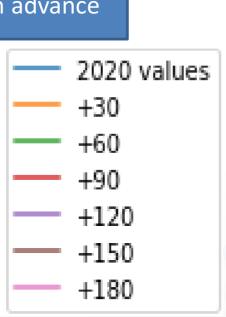
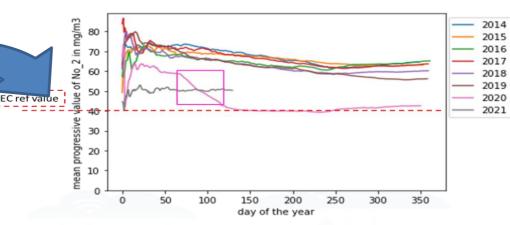# Predicting EC's KPI on NO2 months in advance

Deep Learning Long Terms Predictions of NO2 mean values, From 30 to 180 days in advance

- The features used as input for the predictive models are:
  - **Month**
  - **dayOfTheYear**
  - **NO2**
  - **Tmean**
  - **Humidity**
  - **windMean**
  - **NoxDomestic**
  - **numberOfVehicles**
  - **NO2cumulated**
  - **NO2progresseveMean**
  - **numberOfVehiclesCumulated**

Legend:
- 2020 values
- +30
- +60
- +90
- +120
- +150
- +180

		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	

Smart Waste – Map view

Search bins on map by filtering per:

- **Kind** (All, generic, plastic, paper, glass, metal, organic)
- **Status** (Active, Not Active)
- **Fullness** (Full, Half-full, Empty)
- **Address**
- **Group of bins** (by GroupID)

- Reduction of costs for waste collection
  - Optimization of waste collection for the next day, forecast
  - Production of rides and paths for the drivers on waste collection
- Operator:
  - Refine a search by using the filters on the left side
  - Click on a waste bin pin on the map:
  - A popup with real time data is shown
  - The fullness status of the selected group of bins is shown in the synoptic below the map
  - Specific fullness weekly trends are shown below the map
  - Chick on the «Table view» button to access the other dashboard

Optimal Routing Collection

Waste Collection Optimization

Smart Energy
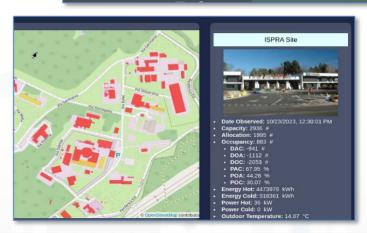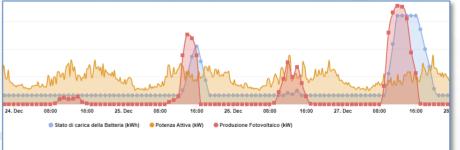
City Energy and Buildings

- **Goals:**
  - Energy consumption reduction, increment of efficiency,
  - Areas and building sustainability
  - Improve accessibility to services, security and safety
- **Energy Monitoring:** Building, floors, rooms, recharging poles, cabinets, Community of Energy, Data centers, Energy for Hot / cold, air condition, energy vs temperature and usage, etc.
- **Energy Management:** Predictions, early warning, identification of critical conditions
- **Smart Light Management**: LED/mixt, cabinets, lights vs traffic, lights vs security, energy saving, luminaries profiling, group management.
- **Smart Building Management:** consumption, number of people, etc.
  - Communities of Energy, Photovoltaic plants, sustainability
  - What-if analysis, optimisation tools
- **KPI: Energy consumption, efficiency, pros/cons**
 - Light profiling and adaptation
  - Autoclave industrial plants simulation, Photovoltaic plant simulation
  - consumption / usage, energy vs temperature
- **Mobile App:** monitoring, info-recharge, eSharing, booking, ..
- **Participatory**: problem reporting, ticketing, etc.
- **Integration of any kind**

Smart Light Control of CAPELON
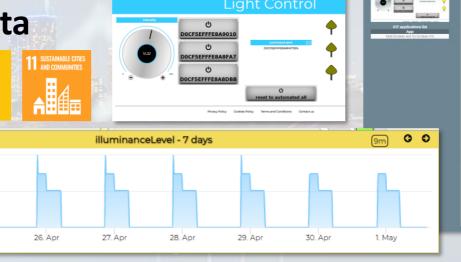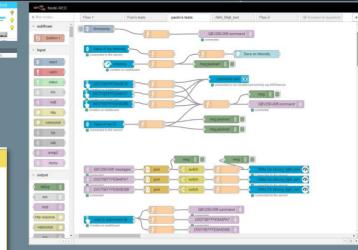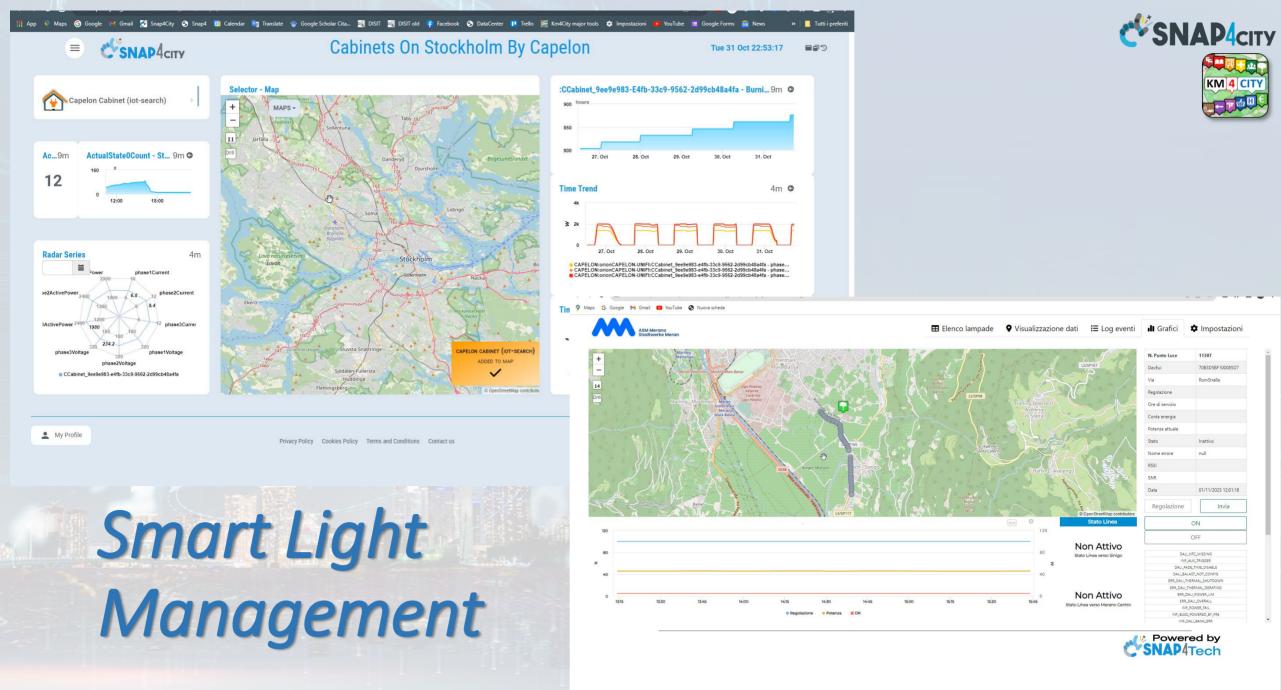
- **Energy Domain**
  - Smart Light, MQTT, ...
  - IoT Orion Broker FIWARE

- **Dashboards**
  - Map coverage on Sweden
  - Monitoring and real time control
  - Energy control, analytics
  - Direct control

- **Historical and Real Time data**

- **Services Exploited on:**
  - Multiple Levels, API
  - Dashboards

- **Since 2020**

Smart Light Management

Smart Light in Merano
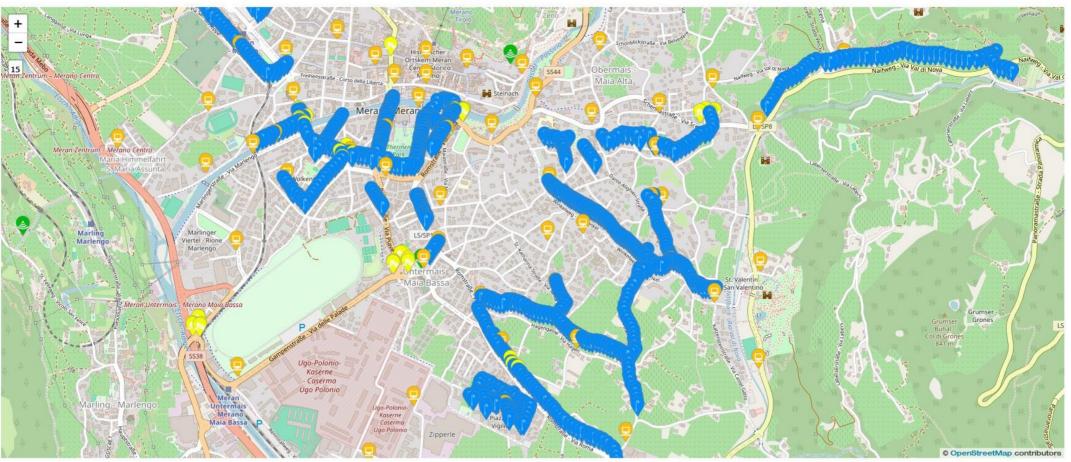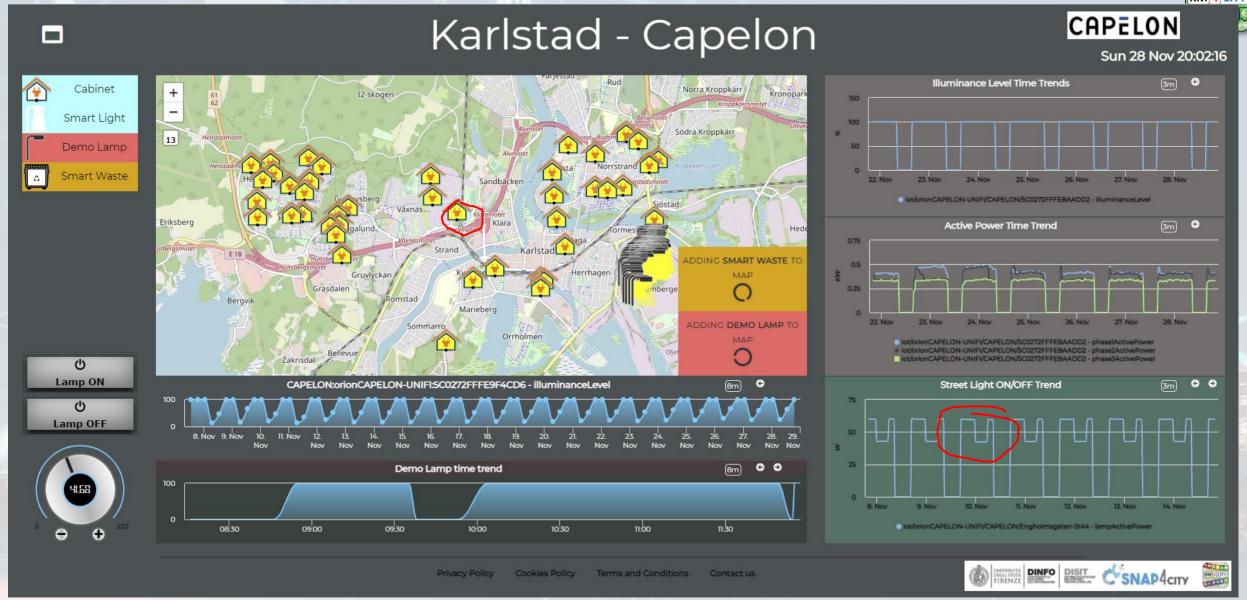
Karlstad Street Lights
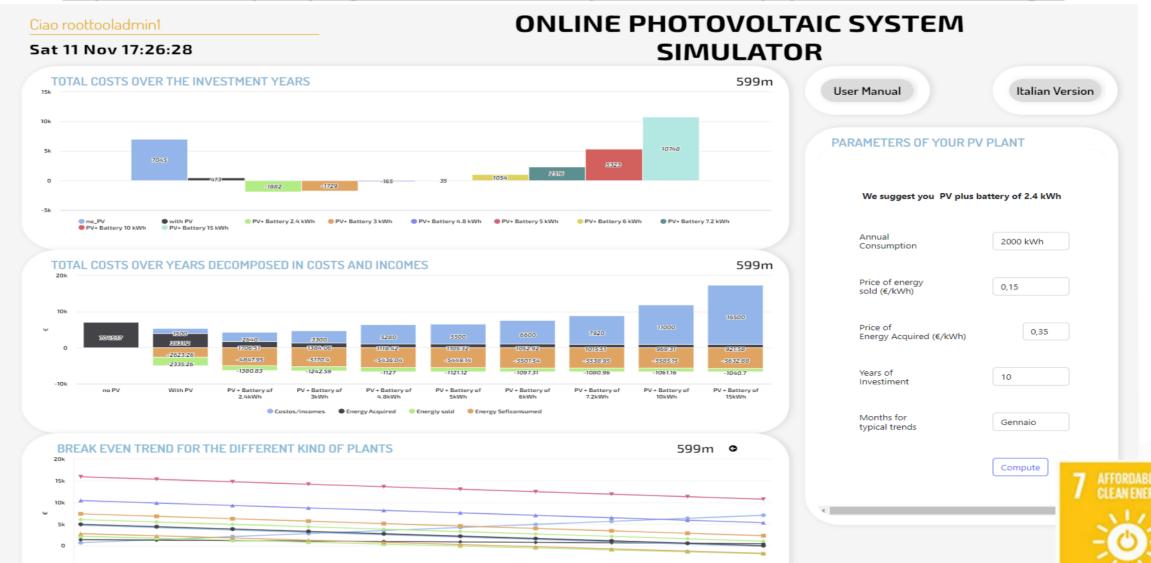
https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzI5NQ==
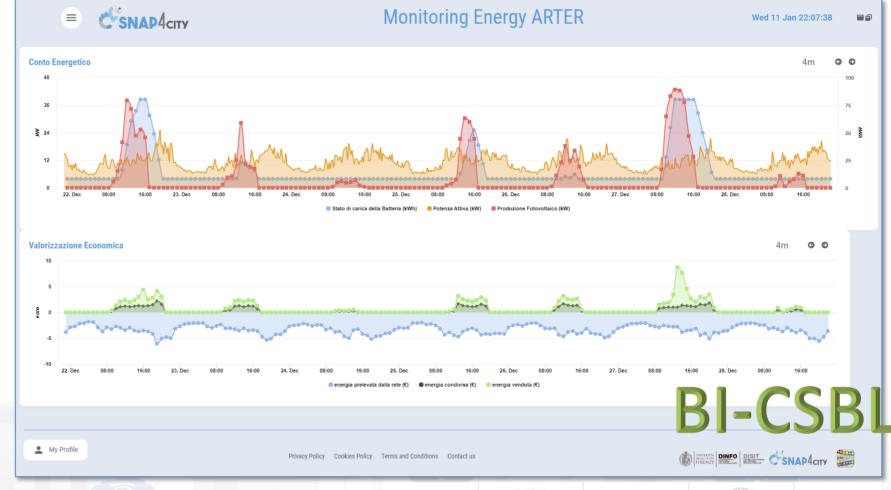
- **Field-tested energy community: the self-consumer condominium**

- The Self User project creates in the pilot condominium, through the collection and analysis of data, a model for calculating and enhancing the impact of an energy community on a community of people, with a view to actions to combat energy poverty

https://www.selfuser.it
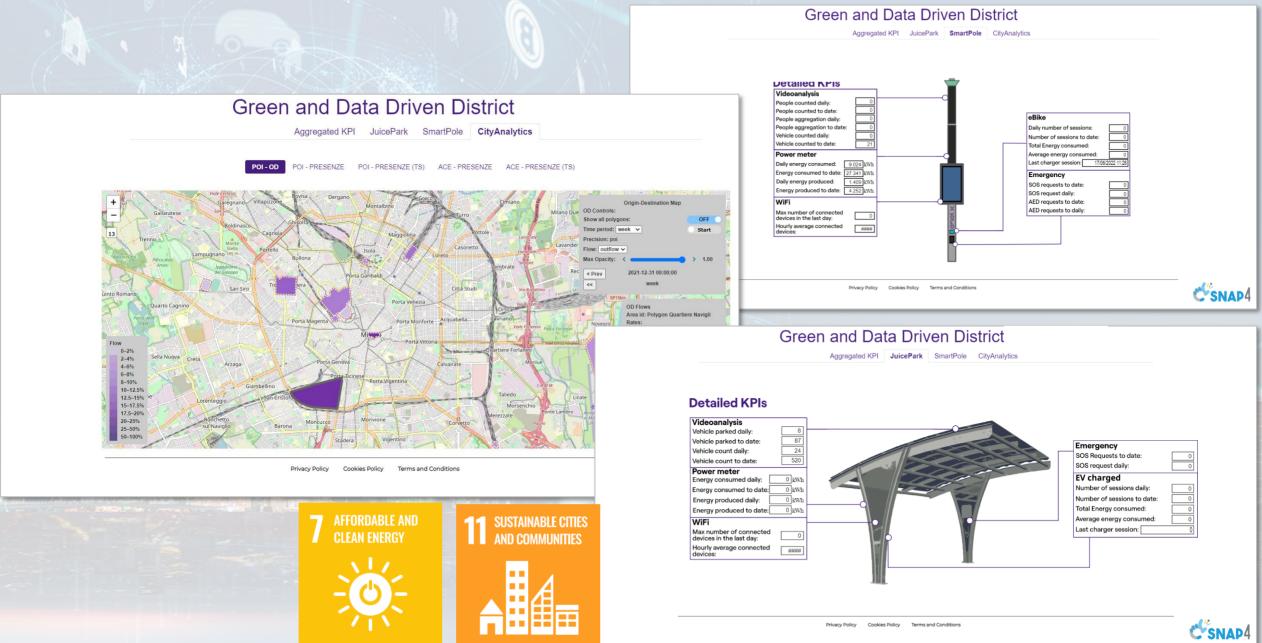
Energy monitoring and business intelligence

Cuneo Assets' Monitoring, Safety
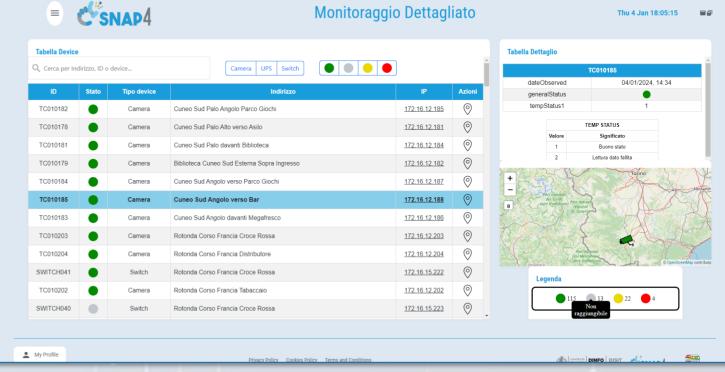
- More than 400 devices

- TV Cams: color, Thermal
- Traffic Gates
- Switches
- UPS

Smart Building

SNAP4CITY

Actual — 4m

- 200
- 94
- 20
- 76
- 0

- Capacity
- Occupancy
- Allocation

Capacity - Allocation - Occupancy — 4m

- capacity
- occupancy
- allocation

Occupancy Weekly Time Trend Compare — 9m

- Current
- Previous

Office Mq — 9m

803.9 m2

Temp. — 9m

20.6 °C

Difference — 4m

- 0
- -18
- -66
- -54
- -80

- DOA
- DOC
- DAC

DOA - DOC - DAC — 4m

- DOA
- DOC
- DAC

Percentage — 4m

- 100
- 80.85
- 26.52
- 0

- POA
- POC
- PAC

POA - POC - PAC — 4m

- POA
- POC
- PAC

Occupancy Per Zones - Monthly Time Trend Comparison Stacked — 4m

- Zone A - occupancy
- Zone B - occupancy
- Zone mf_C_P1_P2 - occupancy
- Zone D - occupancy

Percentage Per Zones - Monthly Time Trend Comparison — 4m

- Zone A - POA
- Zone A - POC
- Zone A - PAC
- Zone B - POA
- Zone B - POC
- Zone B - PAC
- Zone mf_C_P1_P2 - POA
- Zone mf_C_P1_P2 - POC
- Zone mf_C_P1_P2 - PAC
- Zone D - POA
- Zone D - POC
- Zone D - PAC

Heat Power — 9m

0 kW

Heat Energy — 9m

1931279 kWh

Cold Power — 9m

0 kW

Cold Energy — 9m

888311 kWh

Energy Trends — 4m

- Heat Power (kW)
- Cold Power (kW)
- Heat Energy (kWh)
- Cold Energy (kWh)

Average Hourly Power — 4m

- Heat power
- Cold power

En./Mq — 9m

0 kWh

En./Pax — 9m

0 kWh

person My Profile

200

UNIVERSITÀ DEGLI STUDI FIRENZE   DINFO   DISIT   SNAP4CITY

Floor Details

Smart Building

Industry Domain
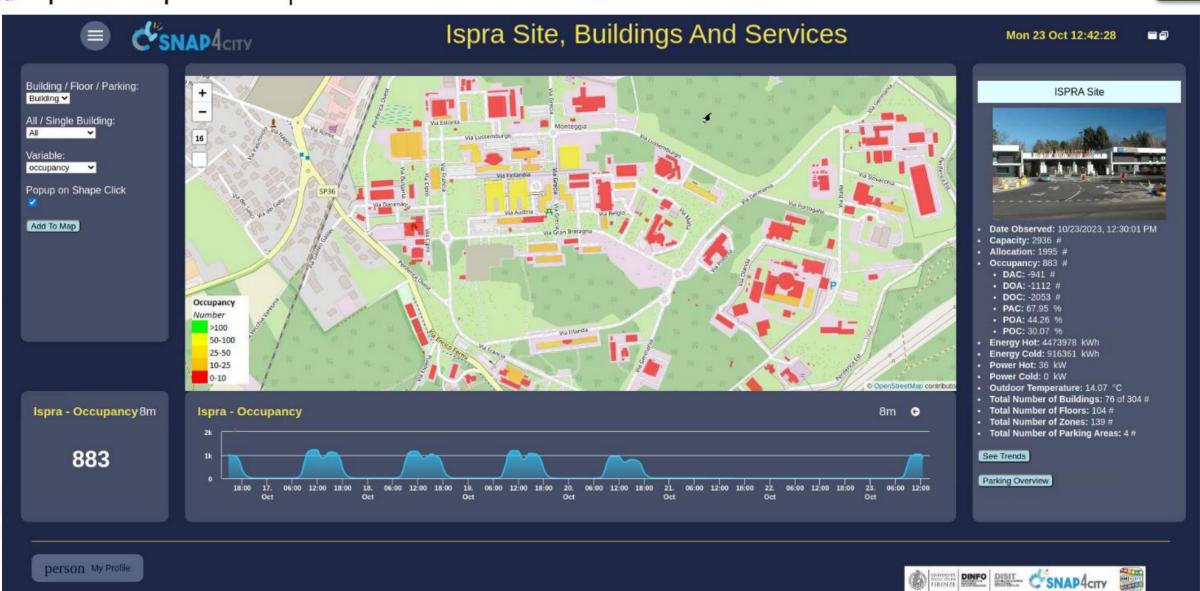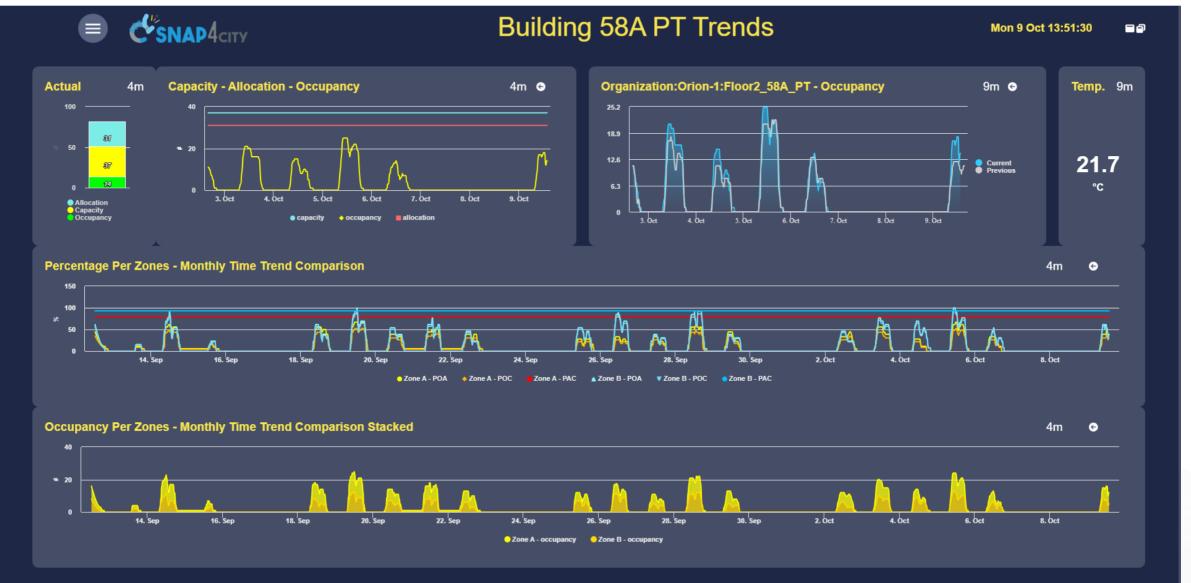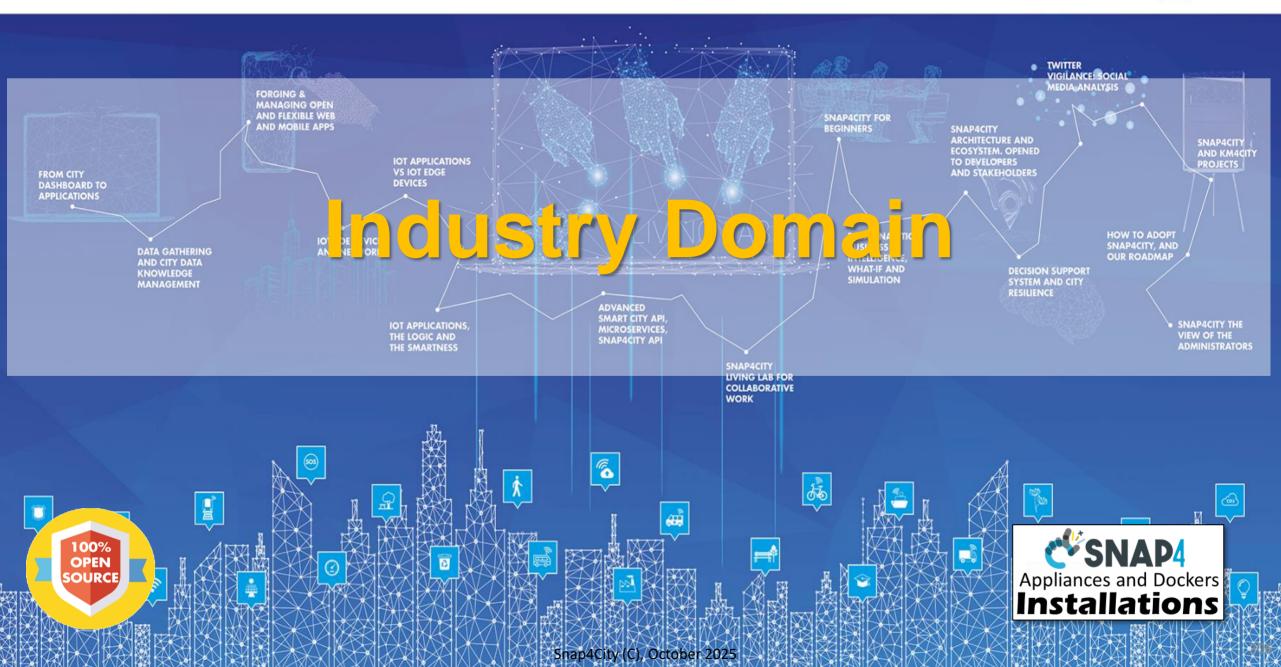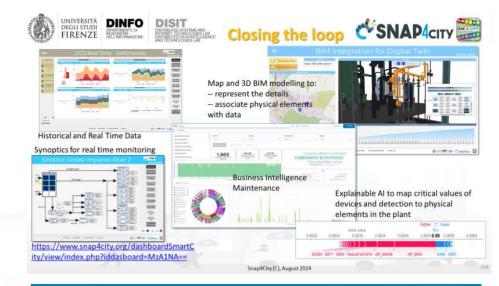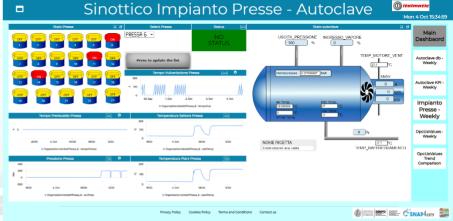
Industry production Domain (2024/8)

- Goals:
  - Cost reduction, increase control on production
  - Production optimisation
  - Quality Level
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
  - Monitoring KPI: administration, production, commercial, faults, etc.
  - Early detection/warning, alarm, of critical conditions
    - **Multichannel** Event reporting: email, Telegram, mobile apps, SMS, etc.
  - Managing maintenance operation
  - Computing predictions on KPI
  - Computing predictive maintenance
- Solutions for Planning (optimization and what-if analysis)
  - Generative AI and predictive AI for production plan optimisation
  - Reduction maintenance costs, reduction of critical SLA conditions, improving quality level
- Algorithms and computational solutions, see next slide
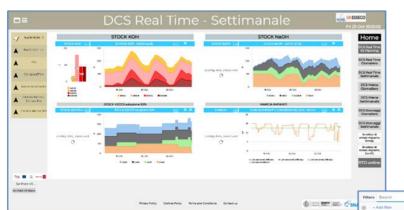
Predictive Maintenance

Historical and Real Time Data

Synoptics for real time monitoring

Map and 3D BIM modelling to:
-- represent the details
-- associate physical elements with data

Business Intelligence Maintenance

Explainable AI to map critical values of devices and detection to physical elements in the plant

https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzA1NA==
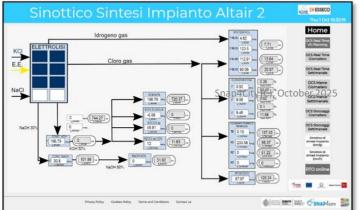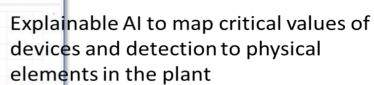
Snap4Altair Decision Support supervision and control, Industry 4.0

- **Multiple Domain Data**
  - Distributed Control System: energy, flows, storage, chemical data, settings, ..
  - Cost of energy, Orders,
  - Production Parameters
  - Maintenance data

- **Multiple Levels & Decision Makers**
  - Optimized planning on chemical model
  - Business Intelligence on Maintenance data
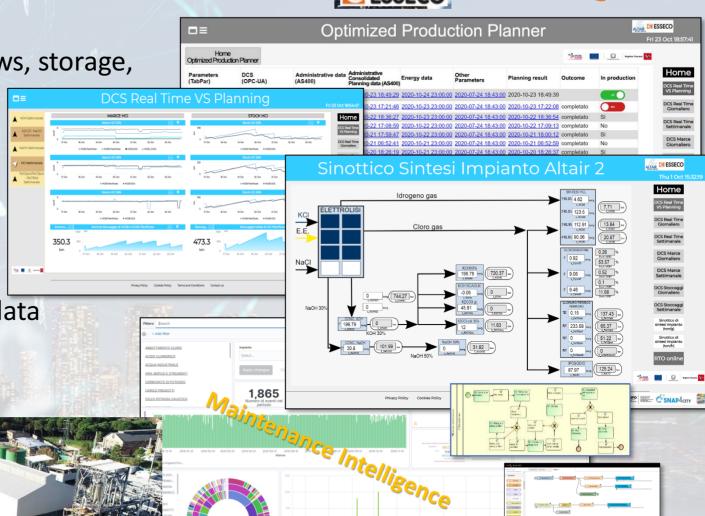
- **Historical and Real Time data**
  - Billions of Data

- **Services Exploited on:**
  - Multiple Levels, Mobile Apps, API

- **Since 2020**
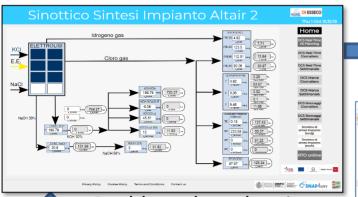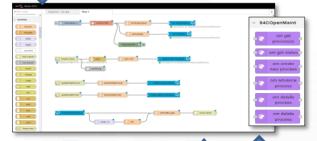
Workflow for Ticket management

Consumptions/productions

Events/actions

Business Intelligence Maintenance

Dashboards and actions

OpenMaint: BPM Workflow management, team assignement, material control, …
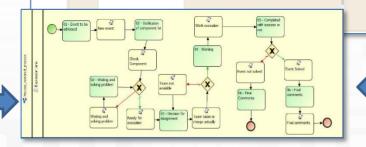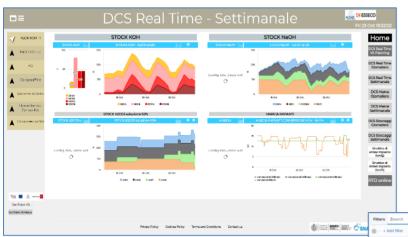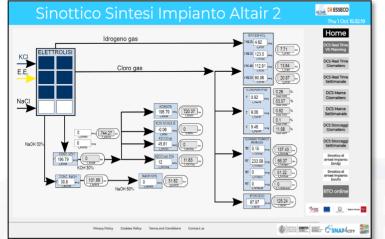
IOT App, Data event firing, event detection and firing Critical event management

OpenMaintCloseEvent

Closing the loop

Historical and Real Time Data

Synoptics for real time monitoring

Map and 3D BIM modelling to:
-- represent the details
-- associate physical elements with data

Business Intelligence Maintenance

Explainable AI to map critical values of devices and detection to physical elements in the plant

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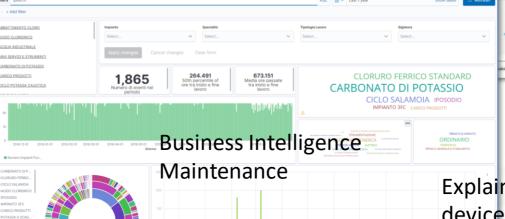
Smart Manufacturing

- **Autoclave:** curation process for: composite materials, rubber, ..
  - **Reduction of computing costs** for simulating load effect into the autoclaves curing process
  - **Similar to design problems to be validated in wind galleries**
- **Solving Navier-Stokes PDE** (partial differential equations) equation,
  - **PINN plus new** Transfer Learning techniques
  - Precision on steady and transitory cases
  - Validation wrt Open Foam
  - Reduction of computational time
- **Videos** on https://www.snap4city.org/1010
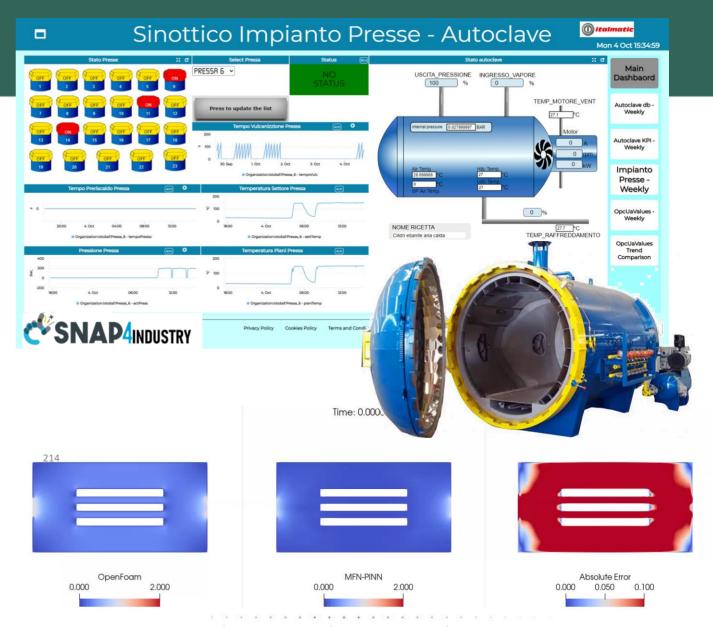
Snap4City (C), October 2025

- **Goals and drivers:**
  - adaptive user engagement,
  - Improving customer experience
  - Increasing of sales, understand use behaviour
- **How**
  - Advanced user profiling, user behaviour analysis
  - Predictive models for engagement
  - IoT and integrated instrumentation
  - Digital Twin of customer and related experience
- **AI injection**
  - Clustering of user, product, behaviour, ..
  - Classification, recognition in real time
  - Production of suggestion in real time (retail) and for on-line selling
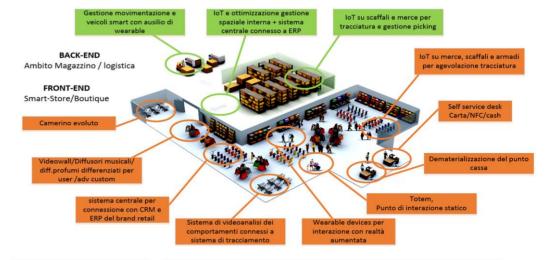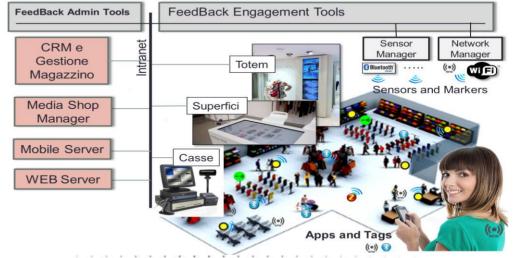
Snap4City (C), October 2025 — 215

Virtual Assistants, Answering systems

Aim, Cost reduction in managing
- Large volume of text, short time
- Getting fast non bias answers

AI support for:
- Text analysis and classification,
- Text comprehension, BERT/LLM
- Natural language queries and answers with LLM/RAG
- XAI support for explanations

Multiple Actual Examples
- prediction of the probability of mediation
  – **Court of Florence**
- DSS on disputes
  – **Careggi Hospital Legal Office**
- Answers/Help on manuals
  – **Assistant for Snap4City**
- Answers on tourist information
  – **PAVAL Assistant**
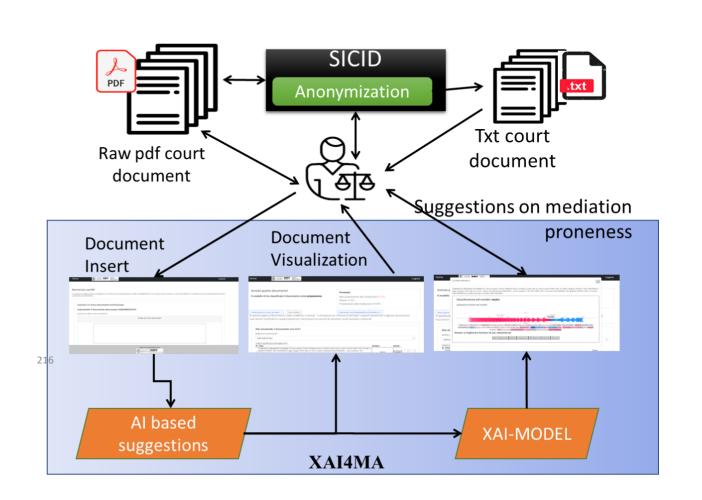
Blockchain for Certification, Contracts, NFT, etc.

BlockChain vs Snap4City

- A feature optionally installed and optimally used to certify locally or in federation with other installations.

- Blockchain technology on Snap4City can be used for:
  - Certification of Data Messages →
    - Time Series, NFT with history of transactions, cold chains, transactions chains
    - MaaS, Waste collection Pay as you Throw (PAYT), etc.
  - Certification of Devices/Entities →
    - Contracts, transaction, micro-transactions
  - Certification of IoT Devices/Entities Models
    - Usage of Standard models and templates

Architecture
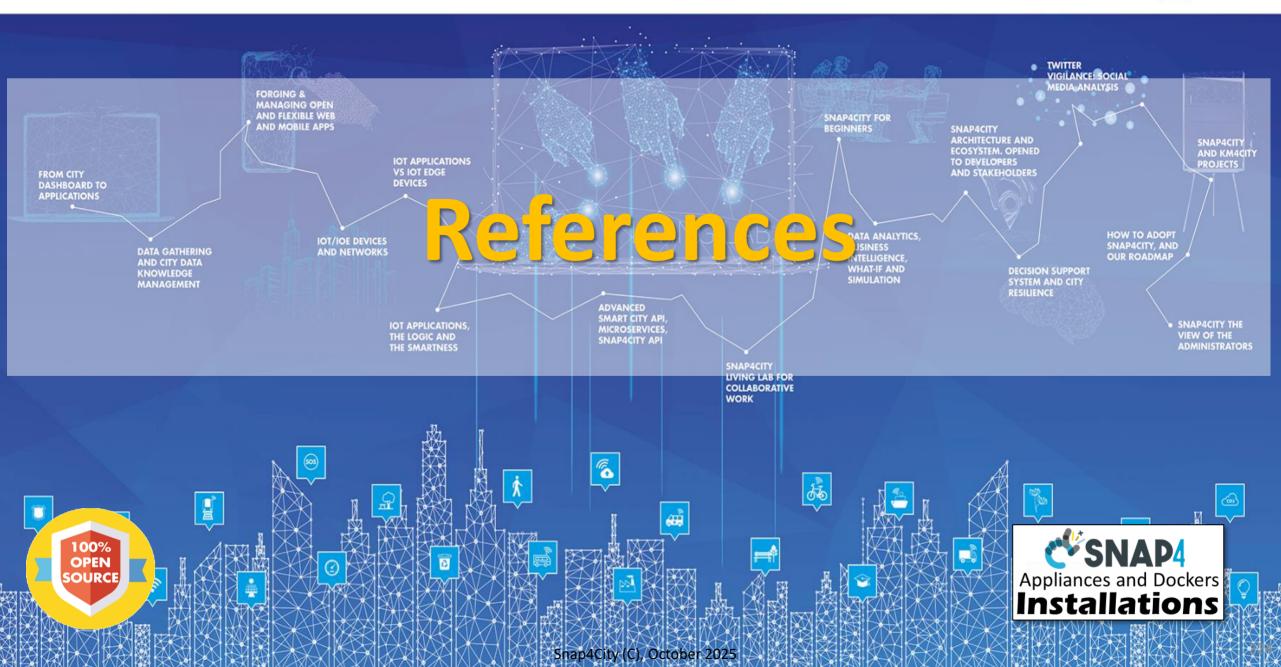
References

booklets

- Smart City
- Industry
- Artificial Intelligence

https://www.snap4city.org/download/video/DPL_SNAP4CITY.pdf
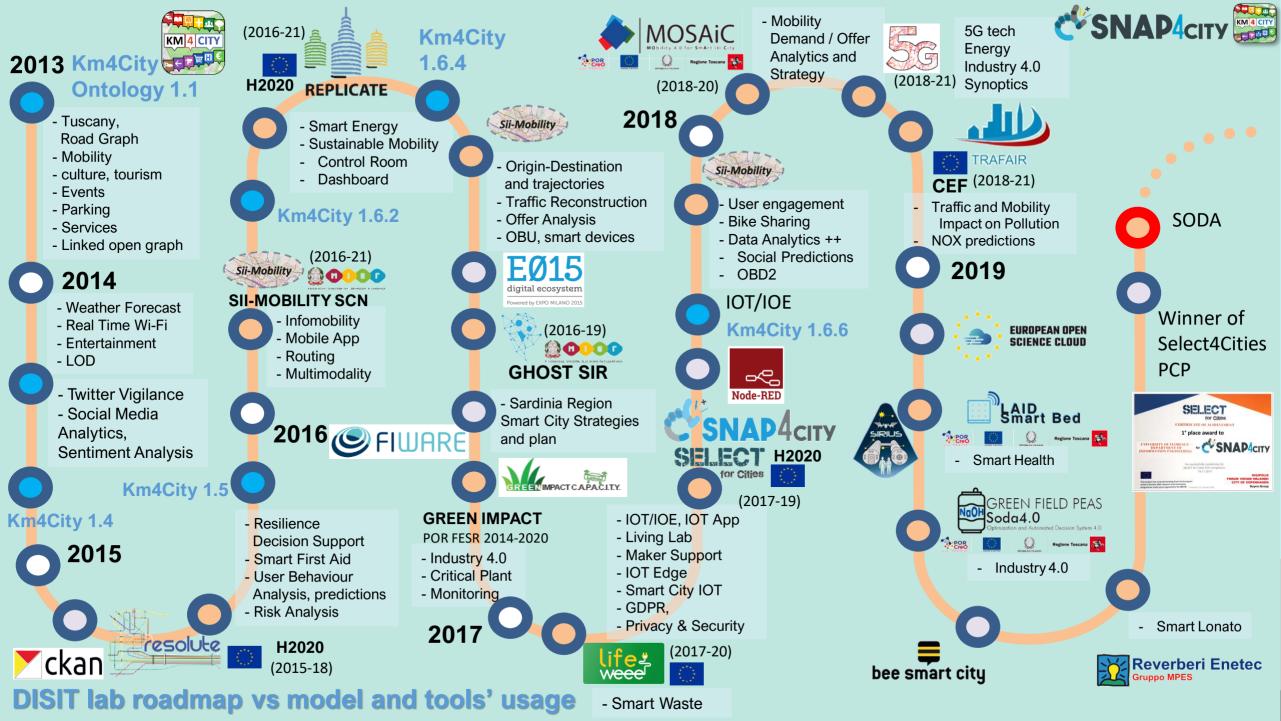
https://www.snap4city.org/download/video/DPL_SNAP4INDUSTRY.pdf

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

DISIT lab roadmap vs model and tools' usage

2013 Km4City Ontology 1.1
- Tuscany, Road Graph
- Mobility
- culture, tourism
- Events
- Parking
- Services
- Linked open graph

2014
- Weather Forecast
- Real Time Wi-Fi
- Entertainment
- LOD

- Twitter Vigilance
- Social Media Analytics, Sentiment Analysis

Km4City 1.4

Km4City 1.5

2015

(2016-21) H2020 REPLICATE
- Smart Energy
- Sustainable Mobility
- Control Room
- Dashboard

Km4City 1.6.2

(2016-21) SII-MOBILITY SCN
- Infomobility
- Mobile App
- Routing
- Multimodality

2016 FIWARE

2017 H2020 (2015-18)
- Resilience Decision Support
- Smart First Aid
- User Behaviour Analysis, predictions
- Risk Analysis

ckan **resolute**

Km4City 1.6.4

Sii-Mobility
- Origin-Destination and trajectories
- Traffic Reconstruction
- Offer Analysis
- OBU, smart devices

E015 digital ecosystem
Powered by EXPO MILANO 2015

(2016-19) GHOST SIR
- Sardinia Region Smart City Strategies and plan

GREEN IMPACT
POR FESR 2014-2020
- Industry 4.0
- Critical Plant
- Monitoring

GREEN IMPACT C.A.P.A.C.I.T.Y.

life weee (2017-20)
- Smart Waste

MOSAiC MObility 4.0 for SmArt (il) City
(2018-20)

2018

Sii-Mobility
- User engagement
- Bike Sharing
- Data Analytics ++
- Social Predictions
- OBD2

IOT/IOE

Km4City 1.6.6

Node-RED

SNAP4CITY

SELECT for Cities **H2020 (2017-19)**
- IOT/IOE, IOT App
- Living Lab
- Maker Support
- IOT Edge
- Smart City IOT
- GDPR,
- Privacy & Security

- Mobility Demand / Offer Analytics and Strategy

5G (2018-21)

TRAFAIR CEF (2018-21)
- Traffic and Mobility Impact on Pollution
- NOX predictions

2019

EUROPEAN OPEN SCIENCE CLOUD

SIRIUS

LAID Smart Bed
- Smart Health

GREEN FIELD PEAS Soda4.0 Optimization and Automated Decision System 4.0
- Industry 4.0

bee smart city

5G tech Energy Industry 4.0 Synoptics

SNAP4CITY

SODA

Winner of Select4Cities PCP

SELECT for Cities CERTIFICATE OF ACHIEVEMENT 1° place award to SNAP4CITY

- Smart Lonato

Reverberi Enetec Gruppo MPES

SNAP4CITY roadmap

2020
- Contract (JRC, EUROPEAN COMMISSION)
- Interreg Mediterranean HERIT-DATA
  - Smart Tourism
  - 6 Pilots
  - Data Analytics
  - Extended platform

Sii-Mobility

smartGARDAlake

Km4City 1.6.7

Interreg MARITTIMO-IT FR-MARITIME MOBI MART
  - Smart Mobility
  - PISA, PUMS
  - Living lab

2021
- Sii-Mobility
- enel x — Contract
- JRC EUROPEAN COMMISSION — Contract
- PC4City (2020-21) Monitoring Terrain
- Winner of Open Data Challenge of enel x
- CAPELON
  - Smart Light
  - Sweden

Smart Ambulance (2021-22)

Enterprise (2021-22) Industry 4.0

2022
- Asymmetrica Urban Technology
  Asymmetrica Smart City, 2022-23

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 COMMUNICATIONS — AXIS collab SmartCity

Italferr GRUPPO FERROVIE DELLO STATO ITALIANE — Italferr, Smart City

JRC EUROPEAN COMMISSION — Contract, 2022-23

2023

ART-ER ATTRATTIVITÀ RICERCA TERRITORIO — Contract, 2022-23

Filippi 2022-2023

enel x — Contract, 15min

IMPETUS — Security and Risk

Smartea

Interreg Euro-MED — TOURISMO — Co-funded by the European Union

CN MOST, 2022-26 — Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA — EI THE, 2022-26

G. Agile, 2021-23

ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

ELLIE IA 2025-2027

ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing — UrbanDT4TF

TUSCANY X0 EDIH 2023-26 — Finanziato dall'Unione europea NextGenerationEU

Merano, smart light

OceanRace, Genova, AWS

Cuneo, smart city

2024

Km4City 1.6.8

JRC EUROPEAN COMMISSION — Contract, 2024-25

CAI4DSA

FAIR Future Artificial Intelligence Research — Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

OPTIFaaS — MOST CENTRO NAZIONALE — Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

SASUAM — MOST CENTRO NAZIONALE — Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

Rhodes, smart city

eShare UNIFI TUSS — MOST CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

AMMIRARE — Interreg MARITTIMO-IT FR-MARITIME

227

- **UrbanDT4TF**, CN HPC: Digital Twin mobility, https://www.snap4city.org/drupal/node/1057
- **DI-DTPlatform**, CN HPC: Digital Twin, mobility, environment, https://www.snap4city.org/drupal/node/1097
- **Sasuam**, CN MOST, PNRR: AI, mobility, https://www.snap4city.org/drupal/node/999
- **OPTIFaaS**, CN MOST, PNRR: AI, mobility, DSS, https://www.snap4city.org/drupal/node/1008
- **LeverageOPTIFaaS**, CN MOST: PNRR, mobility, https://www.snap4city.org/drupal/node/1064
- **TOURISMO**, Interreg, EC: Tourism, NLP, DSS, https://www.snap4city.org/drupal/node/1001
- **ELLIE**, Horizon Europe, EC: AI, VR, https://www.snap4city.org/drupal/node/1056
- **CN MOST**, PNRR: sustainable mobility, platform, https://www.snap4city.org/drupal/node/1050
- **ISPRA JRC contract**, EC: DSS, SOC, control room, energy, https://www.snap4city.org/drupal/node/970
- **AMMIRARE**, Interreg, EC: AI, environment, Big Data, https://www.snap4city.org/drupal/node/1002
- **CAI4DSA**, FAIR PE1, PNRR: AI, Neuro-Symbolic, PINN, NG-DSS, https://www.snap4city.org/drupal/node/1016
- **SADI-MIAC**, RT, partner: AI, Tourism, Retail, Computer Vision, https://www.snap4city.org/drupal/node/1055
- **SMART3R,** PRIN UNICagliari: mobility, DSS, https://www.snap4city.org/drupal/node/1087
- **Tuscany X.0, EDIH,** TestBeforeInvest, Training on AI, Big Data, Security, HPC: https://www.tuscanyx.eu/
- **Reg4IA**, AI for regional public administration, A project of presidency of national council
- **SmartCyprus**, a project of Cyprus Ministry of Digital Innovation and Policy
- **The IE**, PNRR: AI, NLP, LLM, Legal Aspects
- **BullVIT**, RT, conv: AI, NLP, LLM on commercial phases
- **Energia**, RT, conv: AI, PINN, DSS, on manufacturing
- **RFI contract**: mobility, AI, DSS
- **Salerno Port**: AI for container ID recognition and tracking
- **Talent Hub**, ECRF, conv: NLP, match demand vs offer

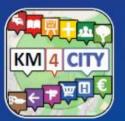+ currently: Merano, Salerno, Cuneo, Rhodes, Reverberi, Florence, IDTS, ALTAIR, etc.