SNAP4CITY
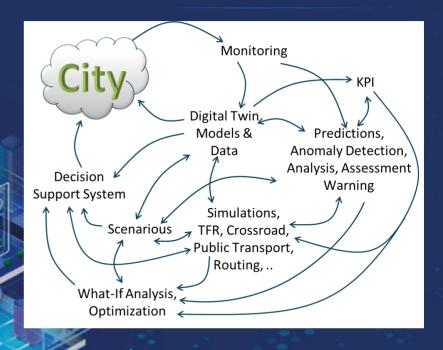www.snap4city.org
www.snap4solutions.org

A multidomain digital twin platform
Prof. Paolo Nesi

City
Monitoring
KPI
Digital Twin Models & Data
Predictions, Anomaly Detection, Analysis, Assessment Warning
Decision Support System
Simulations, TFR, Crossroad, Public Transport, Routing, ..
Scenarious
What-If Analysis, Optimization

Osserv-azioni su...
SMART CITY E DIGITAL TWIN
Tendenze e applicazioni del Supercalcolo, Big Data e Quantum Computing

● LIVE WEBINAR   📅 Lunedì 25 Novembre 2024   🕐 16:00 - 17:30

#snap4city
#km4city
#disitlab
@snap4city

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

1

Digital Twin Solutions for Sustainability

UNIVERSITÀ DEGLI STUDI FIRENZE · DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE · DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB · SNAP4CITY · KM4CITY

100% OPEN SOURCE

Powered by FIWARE

FREE TRIAL

PEN Test Passed

EU GDPR COMPLIANT

SNAP4 Appliances and Dockers Installations

EUROPEAN OPEN SCIENCE CLOUD

Node-RED

JS Foundation

E015 digital ecosystem

NVIDIA.

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

HORIZONTAL AI PLATFORM	MOBILITY AND TRANSPORT	SMART ENERGY AND SMART BUILDING	ENVIRONMENT AND WASTE MANAGEMENT	CITY USER'S SERVICES AND TOURISM MANAGEMENT

- DEVELOMENT ENVIRONMENT AND METHODOLOGY
- VISUAL PROGRAMMING, ML, AI, HPC
- TRAINING COURSES
- LIVING LABS
- GUI CUSTOM STYLES
- FULL APPLICATIONS, DASHBOARDS AND VIEWS
- MOBILE APPS

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

DASHBOARDS, WIDGETS TEMPLATES

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

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

SMART CITY LIVING LAB

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

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

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

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

INDUSTRY4.0 · SHARING · PARKING · AGRICOLTURE · ENVIRONMENT · ENERGY · MOBILE · SHOPPING · SECURITY · CONTROL ROOM · WASTE · BUILDING · SATELLITE · TRANSPORT · TOURISM

City · Monitoring · KPI · Digital Twin Models & Data · Predictions, Anomaly Detection, Analysis, Assessment, Warning · Decision Support System · Simulations, TFF, Crossroad, Public Transport, Routing · Scenarios · What if Analysis, Optimization

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**
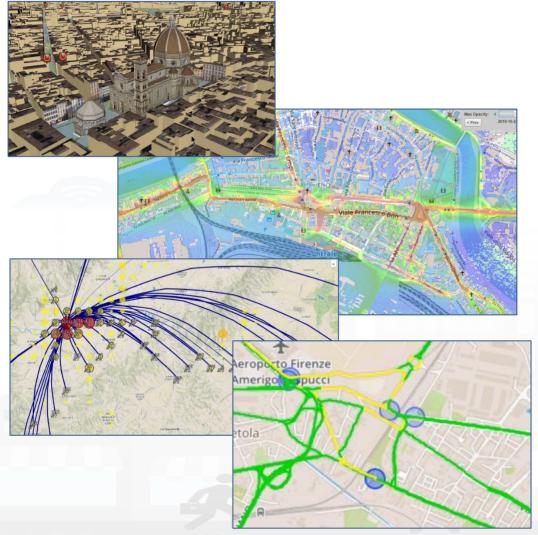
- **Big Data, AI/XAI**
- **Public and private data**

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

- GIS, ITS, AVM, IoT, BIM, CKAN, etc.
- Satellite services
- MaaS, last-mile delivery HUBs
- etc.
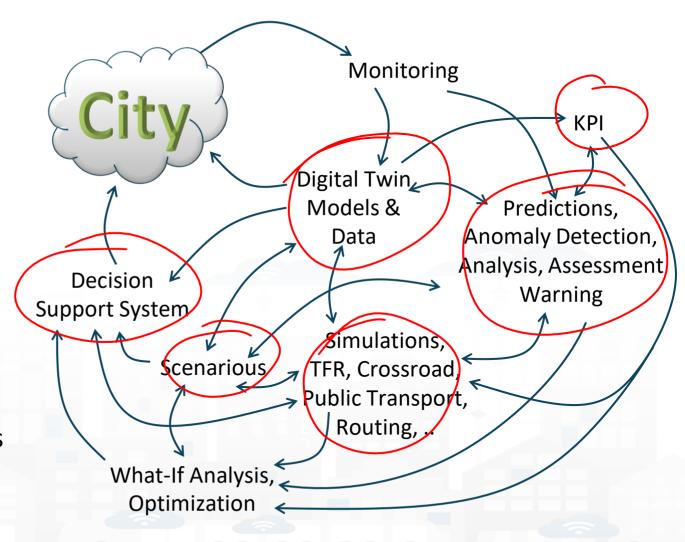
- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Early warning on critical conditions
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders

2024/8

Horizontal AI Platform/Control

- **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, simulations, what-if, optimization; Deep Learning, ML, BERT, LLM, XAI (Shap/Lime),
  – **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
- **Mobile App:** modular applications, operators' modules, multiple cities, etc.
- **Participatory**: problem reporting, ticketing, etc.
- **Integration of any kind**
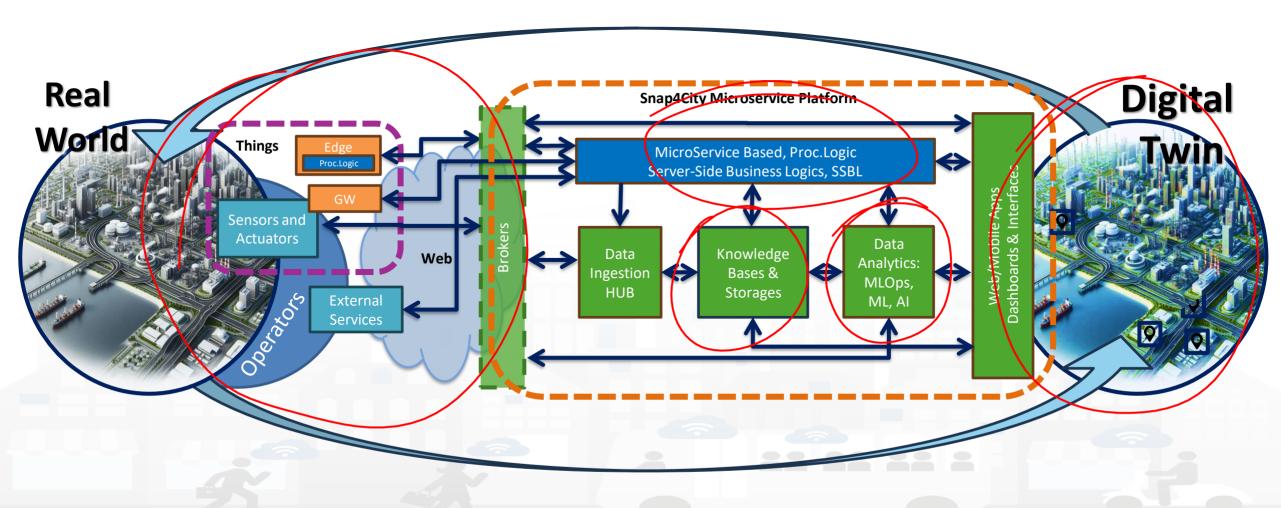
Digital Twin Development Platform

Standards and Interoperability (10/2024)

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, RTSP, ONVIF, AXIS TVCam, CISCO Meraki, OSM, Copernicus, The Weather Channel, Open Weather, OLAP, VMS Milestone, TIM, HERE, ….
- **Formats**: JSON, GeoJSON, XML, CSV, GeoTIFF, OWL, WKT, KML, SHP, db, XLS, XLSX, TXT, HTML, CSS, SVG, IFC, XPDL, OSM, Enfuser FMI, Lidar, glTF, GLB, DTM, GDAL, Satellite, D3 JSON, …
- **Database**: Open Search, MySQL, Mongo, HBASE, SOLR, SPARQL, ODBC, JDBC, Elastic Search, Phoenix, PostGres, MS Azure, ..
- **Industry**: OPC/OPC-UA, OLAP, ModBUS, RS485, RS232,..
- **Mobility**: DATEX, GTFS, Transmodel, ETSI, NeTEx, ..
- **Social**: Twitter, FaceBook, Telegram, ..
- **Events**: SMS, EMAIL, CAP, RSS Feed, ..
- **OS**: Linux, Windows, Android, Raspberry Pi, Local File System, AXIS, ESP32, etc.
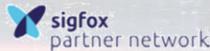
https://www.snap4city.org/65

High Level Types
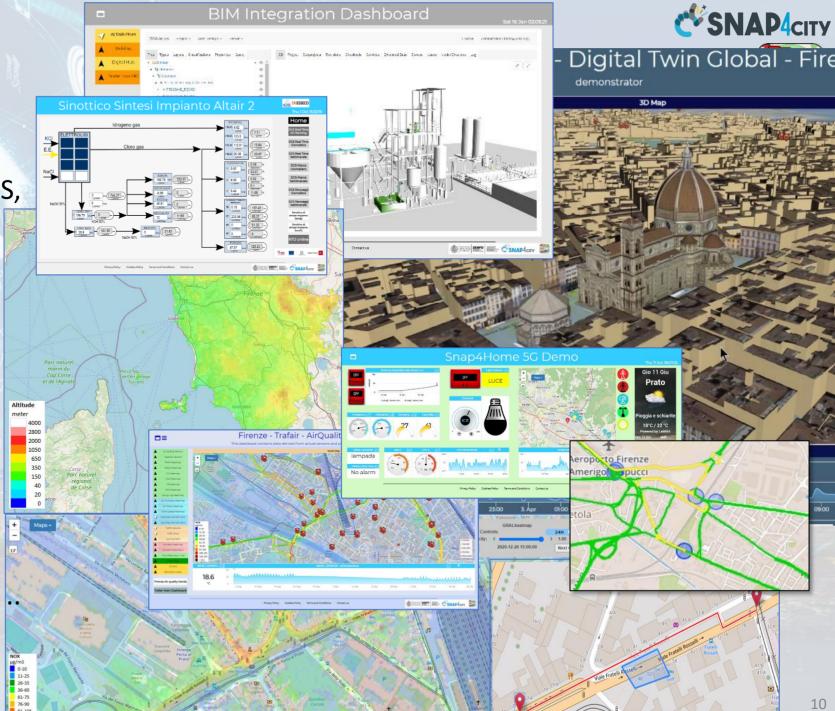
Snap4City (C), November 2024

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

2024/8
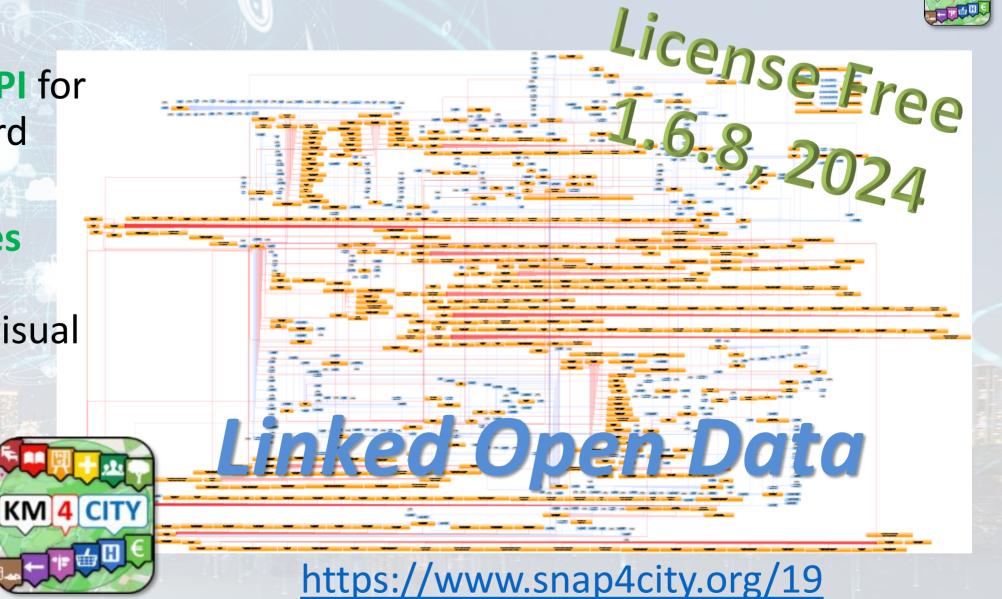
Expert System *semantic queries*

- **via**:

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

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

License Free
1.6.8, 2024

Linked Open Data

https://www.snap4city.org/19

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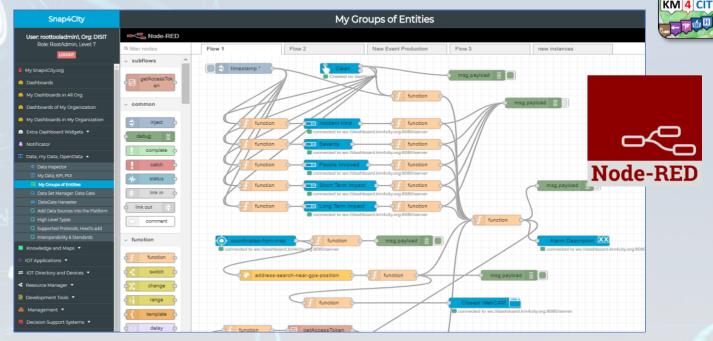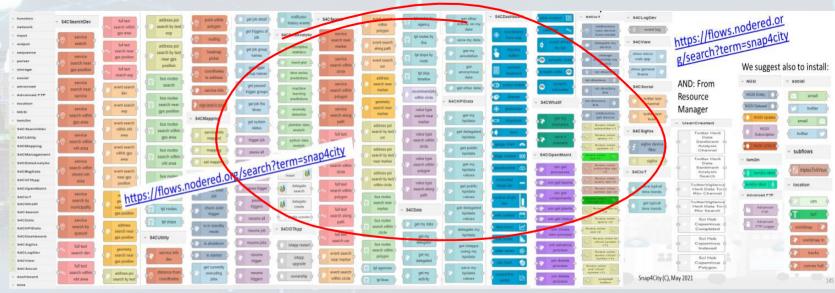
- **IoT App Visual Programming, no coding**
  - **Data transformation**
  - **Integration, Interoperab.**
  - **Scripting Data Analytics**
  - **Data ingestion**
  - **Business logic**

- **Edge and Cloud**

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

MicroServices Areas

> 60.000 downloads

External Service Integration:
- Open Data CKAN
- Ticket Management, workflow
- BIM Servers
- Social Networks
- Video Management system
- Gateways

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

Snap4City Microservices Proc.Logic SSBL

- Entities Management
- Visualization Interaction
- Platform Management
- other Node-RED Libraries
- Third party microservices

Visualization Interaction:
- 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
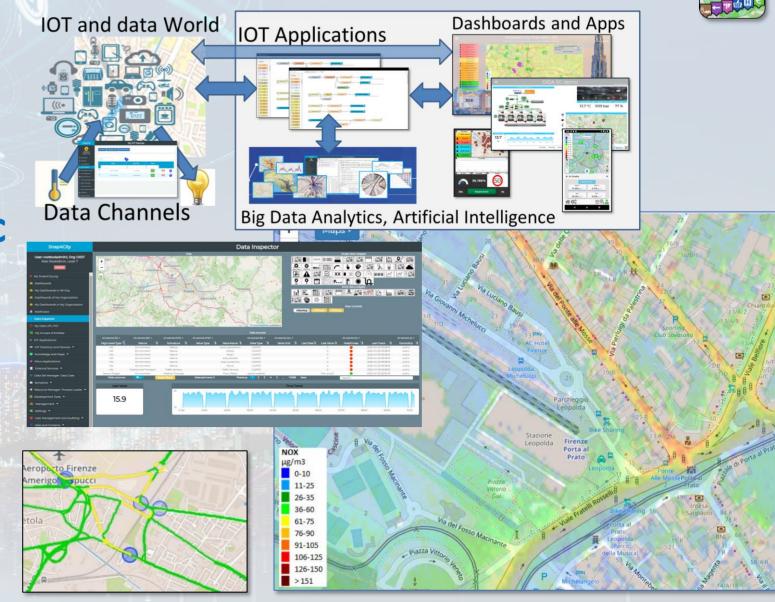
Platform Management (Dashboards):
- Dashboards
- Widgets: Graphic Libraries
- Interactive Widgets
- Maps, 3D representations
- Synoptics, External Content
- Micro Web App
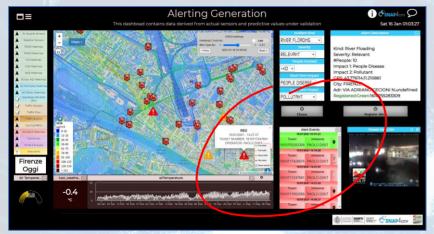
Platform Management:
- IoTApp Management
- Data Logs, A&A, Security
- Ownership Management
- VPN remote access
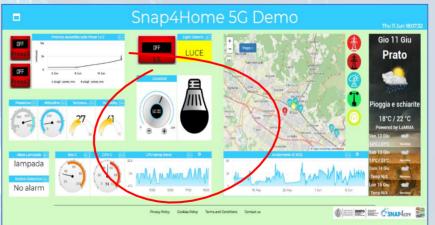
Solutions: reliable, secure and fast to realize
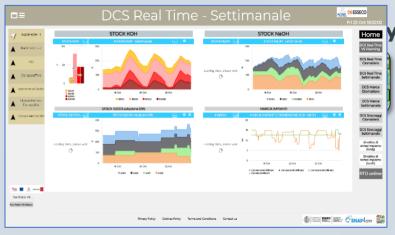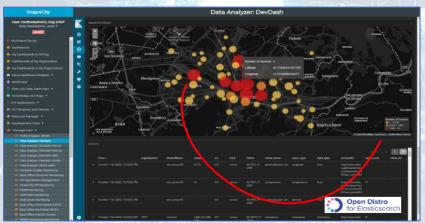
- **Via Snap4City tools**
  - **Dashboard Wizard**
  - **Dashboard Builder**
  - **Data/Visual Analytic**

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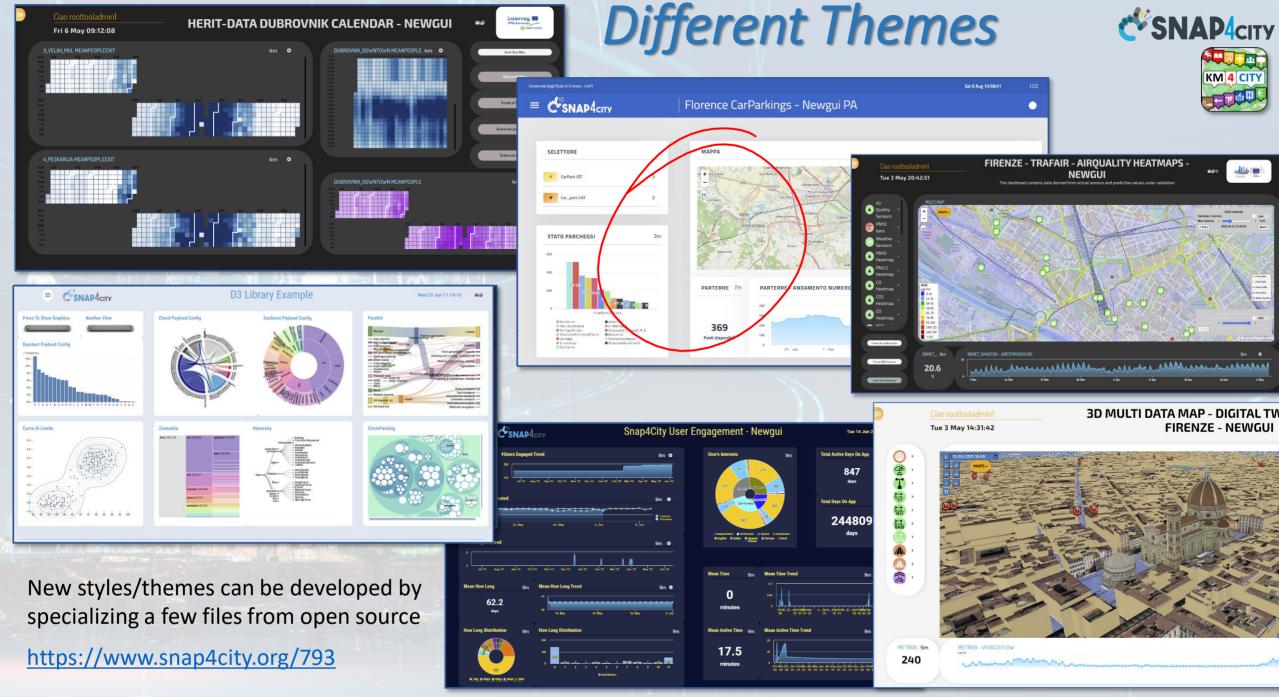 - **Reliable, interoperable**
  - **Auditable, marketable**

Different Themes

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

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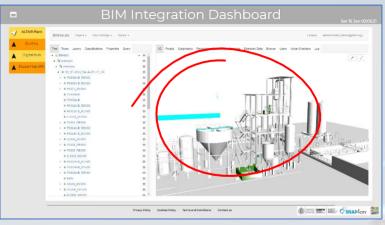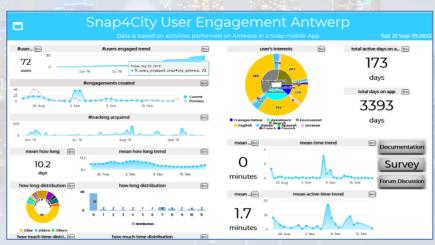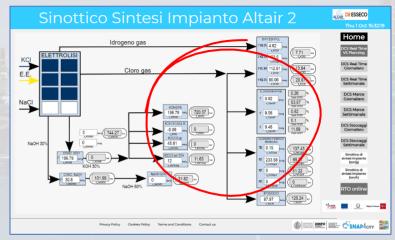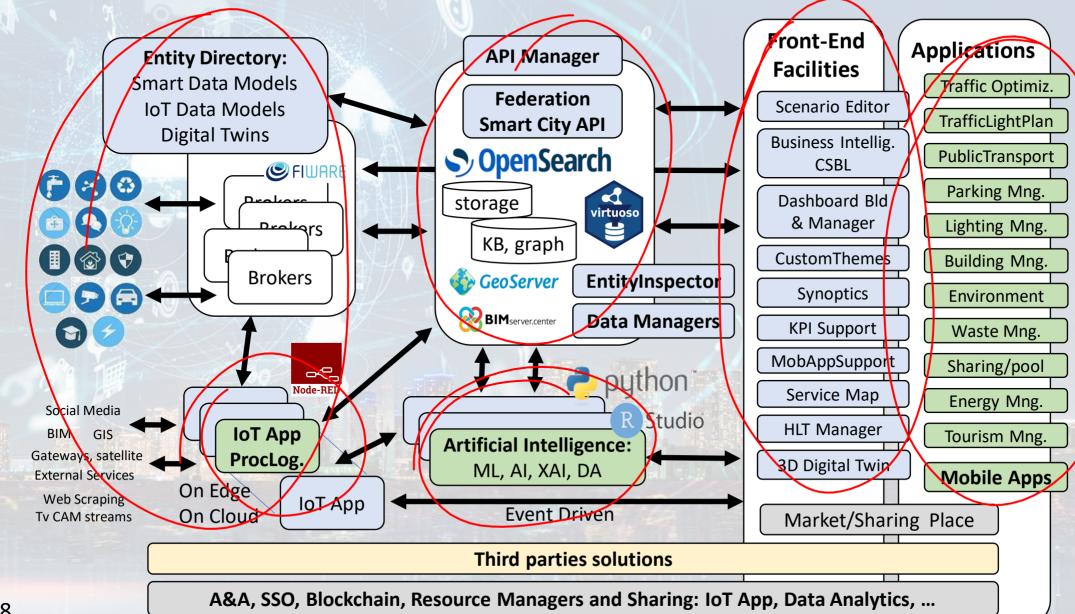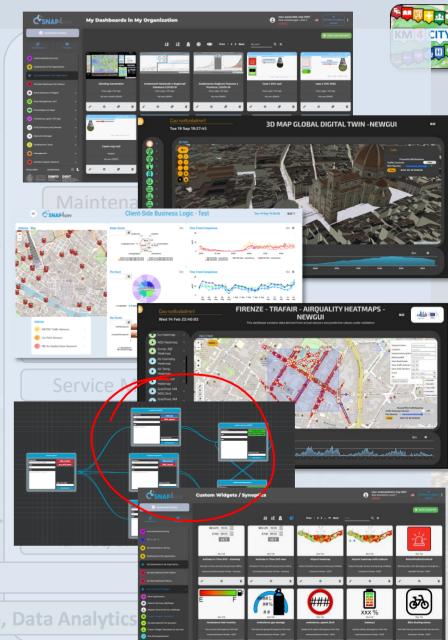
Technical Architecture

SNAP4CITY · KM4CITY

Entity Directory:
Smart Data Models
IoT Data Models
Digital Twins

FIWARE

Brokers
Brokers
Brokers

API Manager

Federation Smart City API

OpenSearch

storage

KB, graph

virtuoso

GeoServer

BIMserver.center

EntityInspector

Data Managers

Front-End Facilities

Scenario Editor

Business Intellig. CSBL

Dashboard Bld & Manager

CustomThemes

Synoptics

KPI Support

MobAppSupport

Service Map

HLT Manager

3D Digital Twin

Market/Sharing Place

Applications

Traffic Optimiz.

TrafficLightPlan

PublicTransport

Parking Mng.

Lighting Mng.

Building Mng.

Environment

Waste Mng.

Sharing/pool

Energy Mng.

Tourism Mng.

Mobile Apps

Node-RED

IoT App ProcLog.

On Edge
On Cloud

IoT App

python

R Studio

Artificial Intelligence:
ML, AI, XAI, DA

Event Driven

Social Media
BIM   GIS
Gateways, satellite
External Services
Web Scraping
Tv CAM streams

Third parties solutions

A&A, SSO, Blockchain, Resource Managers and Sharing: IoT App, Data Analytics, …

2024/8

17

Visual Development Tools

Snap4City (C), November 2024

19

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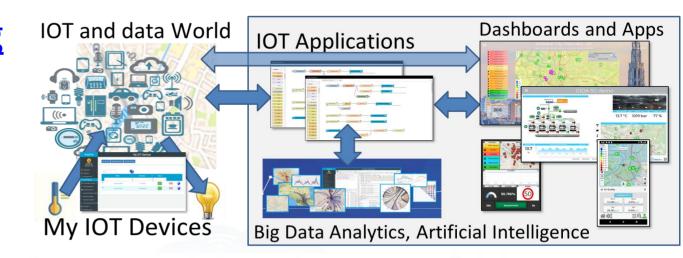
- Register on WWW.snap4city.org
  - Subscribe on **DISIT Organization**

- **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
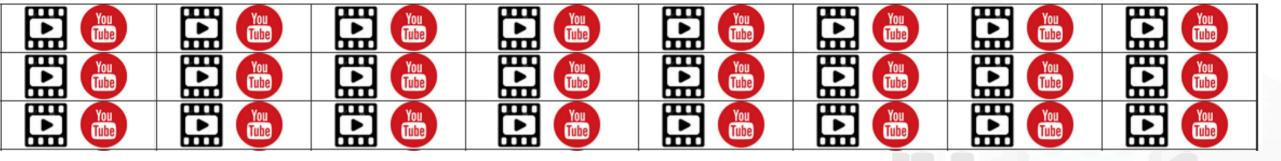
https://www.snap4city.org/944

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

https://www.Snap4City.org

PEN Test Passed

EU GDPR COMPLIANT

Node-RED

FIWARE

KM4CITY

SNAP4CITY

- Update: 29-10-2024

- **12 running installations in Europe**
  - Snap4.city.org, Greece, Merano, Cuneo, …
  - Toscana, Pisa, Sweden, ISPRA, Snap4.eu,
  - Altair, Italmatic, Romania, Rhodes, ….

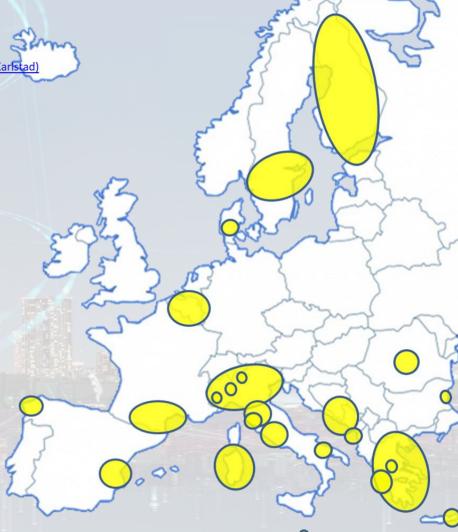- **16 projects, 12 pilots on 10 Countries**
  - >40 cities/area

- **Widest MULTI-tenant deploy has**
  - 24 Organizations / tenant
  - > 8850 users on
  - > 1800 Dashboards
  - > 17 mobile Apps
  - **> 2.2 Million of structured data per day**
  - > 580 IoT Applications/node-RED
  - > 750 web pages with training
  - > 75 videos, training videos
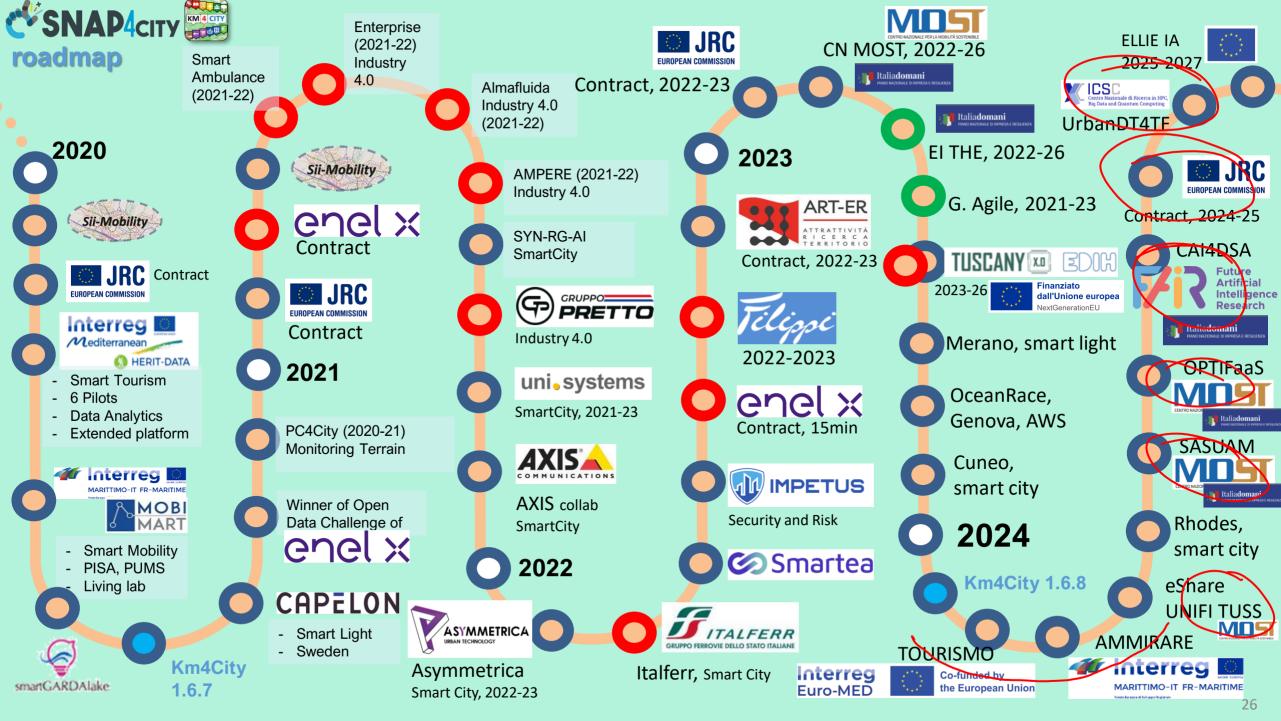
Main Organizations/areas
- Antwerp area (Be)
- Bari (I)
- Bisevo, Croatia
- Bologna (I)
- Brasov (Ro), by ICEBERG
- Capelon (Sweden: Västerås, Eskilstuna, Karlstad)
- Cuneo (I)
- DISIT demo (multiple)
- Dubrovnik, Croatia
- Firenze area (I)
- Garda Lake area (I)
- Greece (Gr)
- Helsinki area (Fin)
- 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)

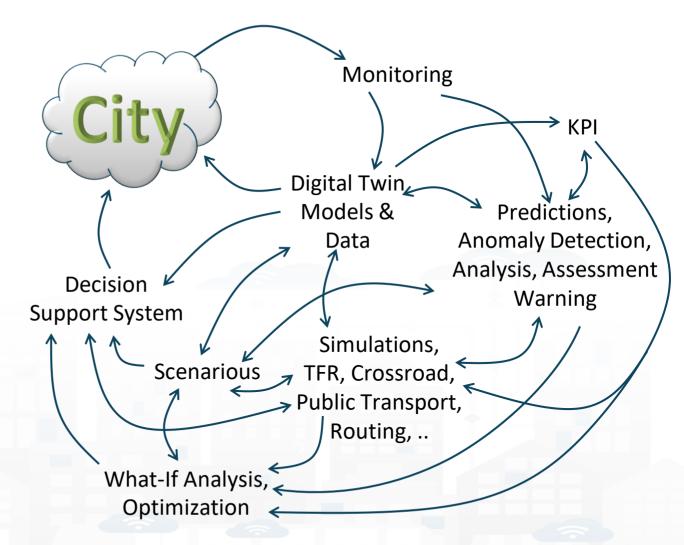- **+ Israel, Colombia, Brasile, Australia, India, China, etc.**

Snap4City

Snap4City (C), November 2024

- **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

Operation:
Monitoring and control

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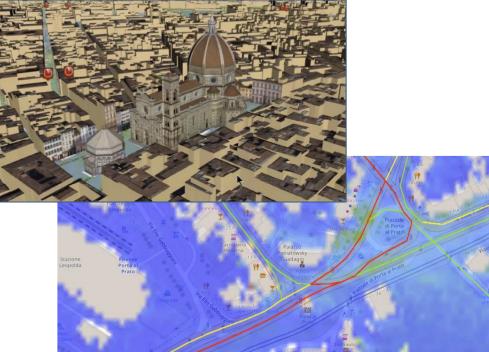
- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Computing predictions and KPI
  - Anomaly detection, Early warning
  - Control Rooms, situation rooms
  - Early warning on critical conditions
- **Reacting: Computing in real time**
  - Changing semaphore maps
  - Changing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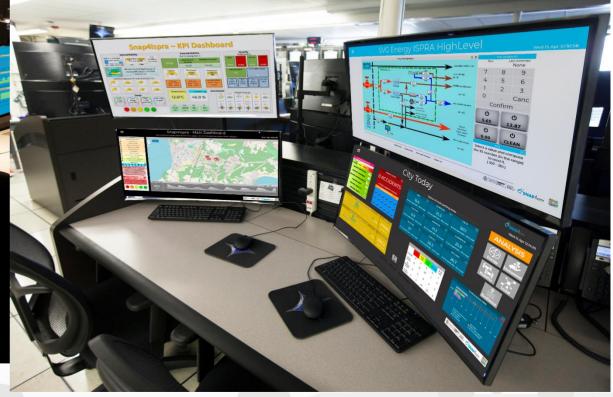 - User engagement via Mobile Apps
  - What-if analysis
  - etc.,

Control Room

Early Warning, Detection

Issue:
- **Detection of critical condition**
- **Not easily detected with other means**

Impact:
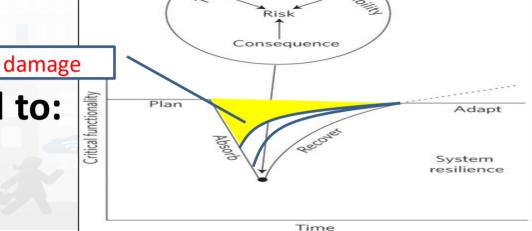- **Early warning, faster reaction**
- **Increased resilience**

Several metrics related to:
- **Volume of retweets**
- **Sentiment analysis**

*P*repare
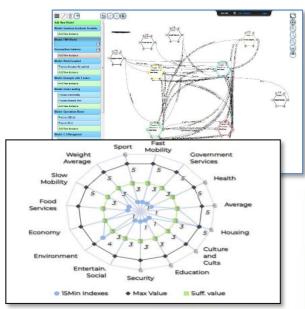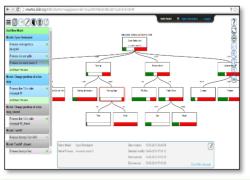*A*bsorb
*R*ecover
*A*dapt

damage

ERMG: European Resilience Management Guide

CRAMSS
Collaborative Resilience Assessment and Management Support System

MONITORING

LEARNING

ANTICIPATING

RESPONDING

- European Resilience Management Guidelines
- Game Based Training

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

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

- Human Behavior Analysis
- Predictive Analytics
- Urban Transport System Dynamic Analysis
- Resilience Quantification
- Network Analysis

KM4CITY

SNAP4CITY

METRO25

VALUE NAME: METRO25

DETAILS   DESCRIPTION   ATTRIBUTE

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

Description	Value
anomalyLevel	1.541174
averageSpeed	43.649723
avgTime	8.115
concentration	3.115796
congestionLevel	115

Air Quality FI-BASSI - NO2

Free street
Fluid traffic
Heavy traffic
Very heavy
Sensor position

New York   Paris   Rome   Tokyo

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**

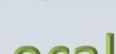https://www.snap4city.org/747

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.
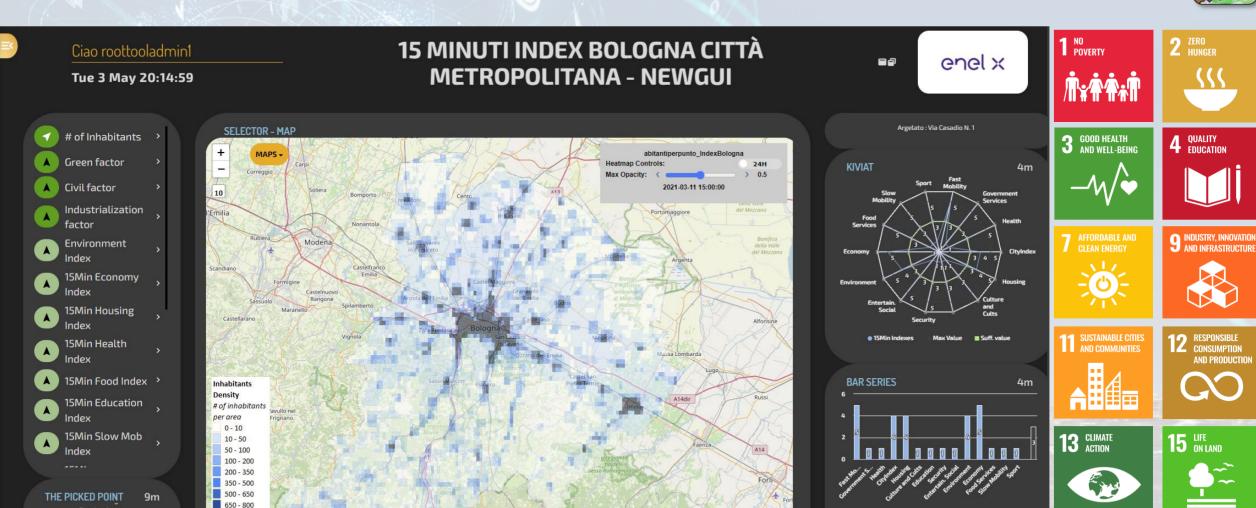
Global & Local

Periodic & Realtime

Pollutant	Averaging period	Air Quality Directive		WHO guidelines	
		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	

15MinCityIndex on Bologna

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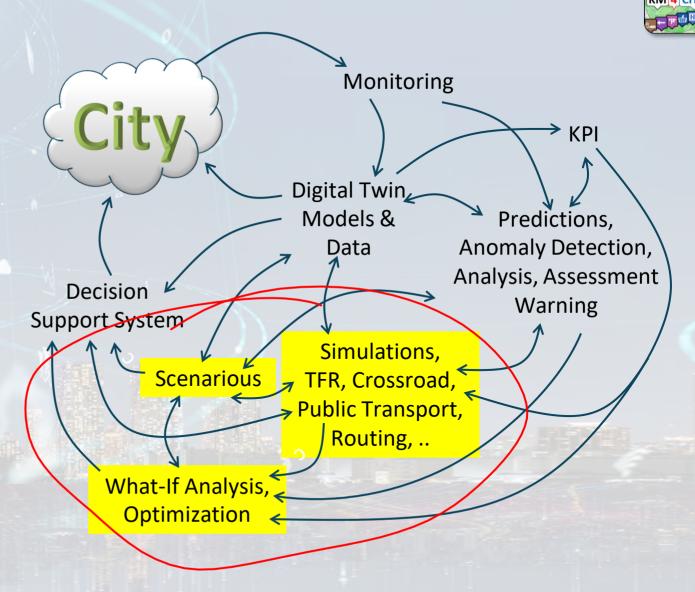# Immediate response and Tactic and Strategic Plans, via What-if Analysis

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
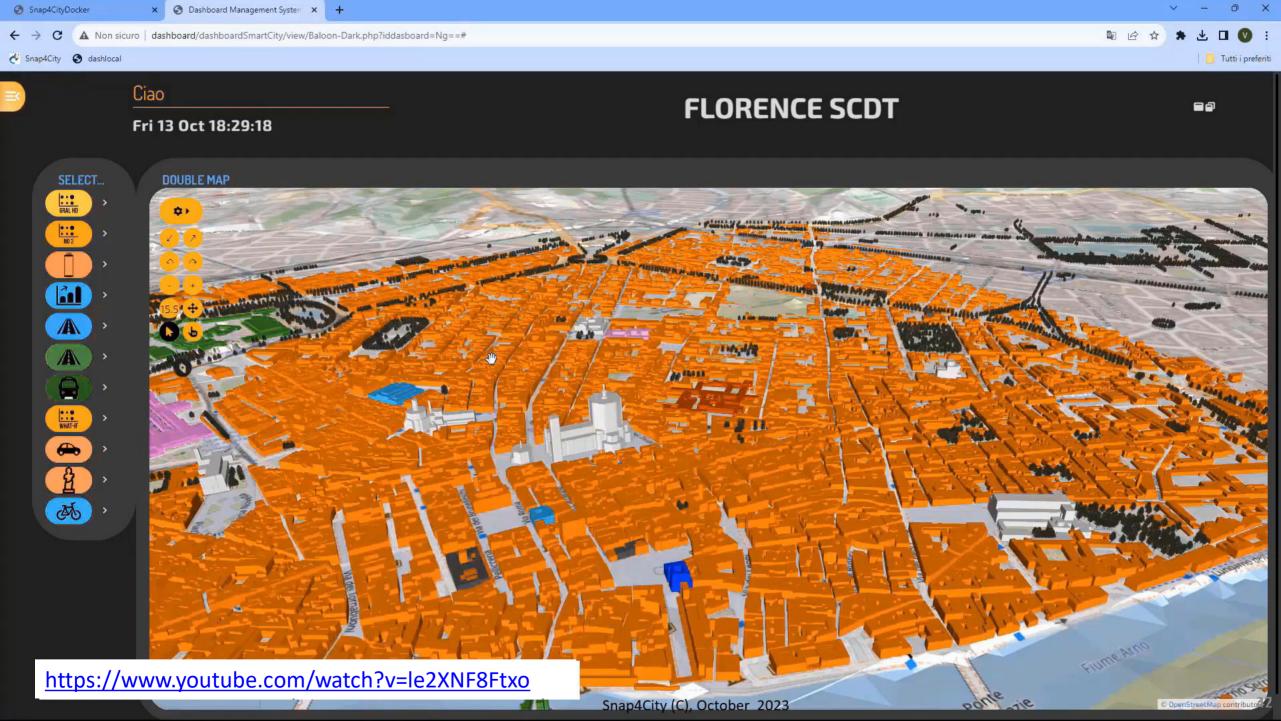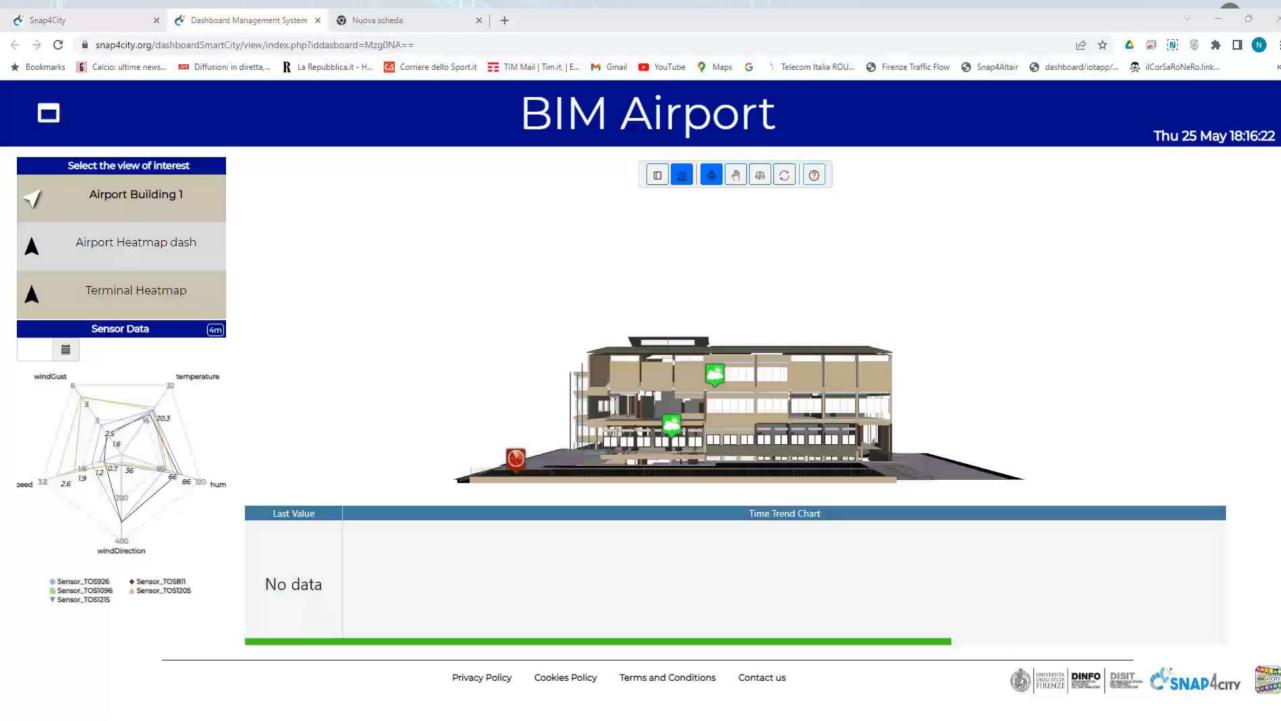 - Collaboration with stakeholders

City

Monitoring

KPI

Digital Twin Models & Data

Predictions, Anomaly Detection, Analysis, Assessment Warning

Decision Support System

Scenarious

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

What-If Analysis, Optimization

3D Digital Twin

https://www.youtube.com/watch?v=le2XNF8Ftxo
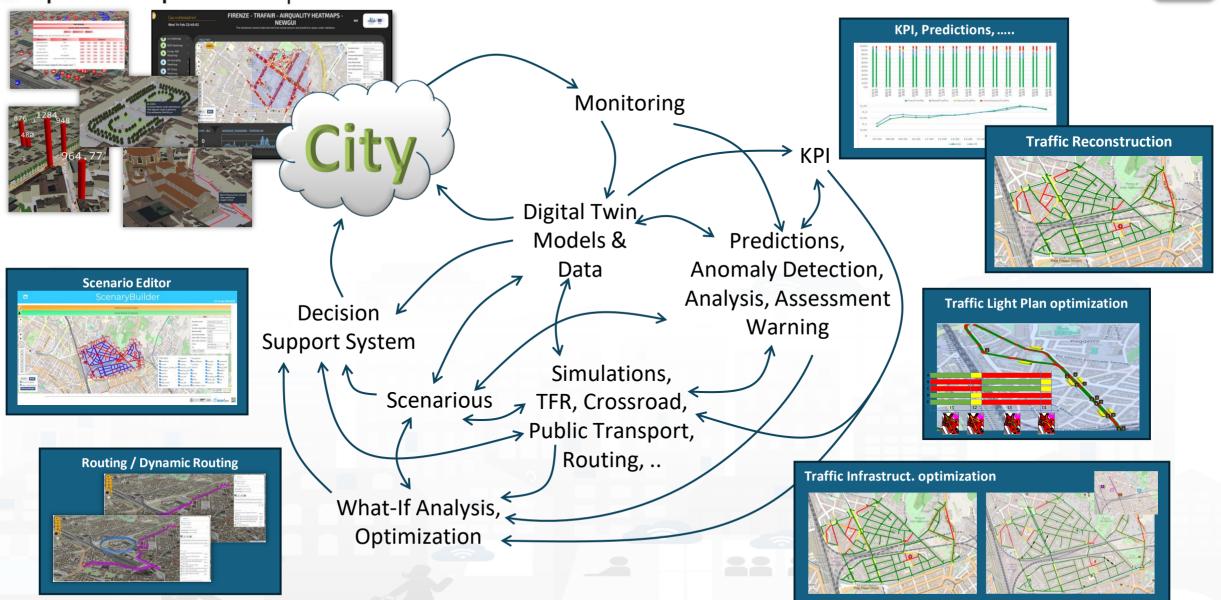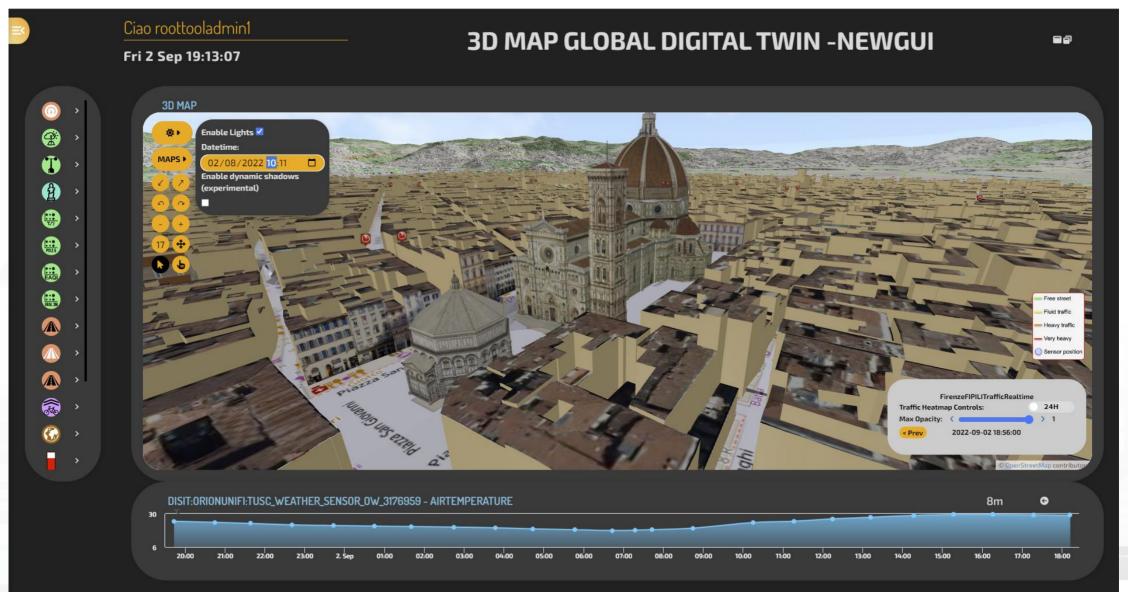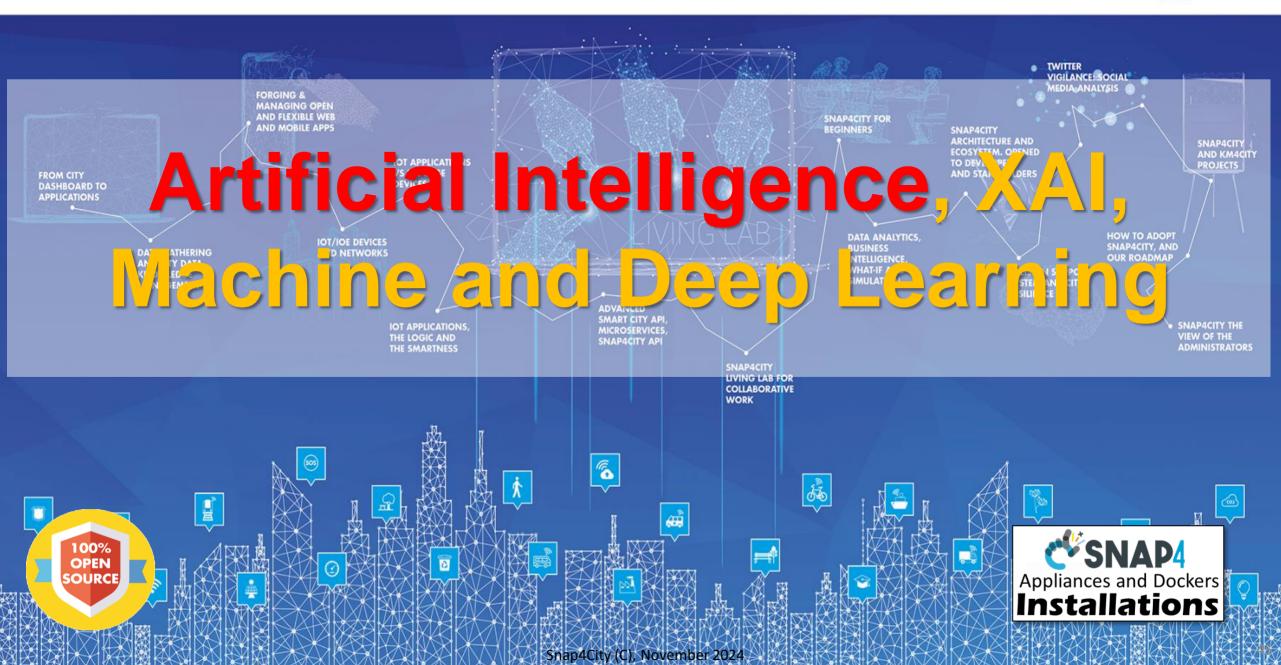
Local Digital Twin vs BIM

Snap4City × Dashboard Management System × Nuova scheda × +

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

★ Bookmarks 6 Calcio: ultime news... Diffusioni in diretta,... R La Repubblica.it - H... C&S Corriere dello Sport.it TIM Mail | Tim.it, | E... M Gmail YouTube Maps Telecom Italia ROU... Firenze Traffic Flow Snap4Altair dashboard/iotapp/... ilCorSaRoNeRo.link...

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
6   32
5
20.3
3   16
2.5
1.6
1.8 0.7 36   66
1.2
peed 3.2 2.6 1.9   86 120 hum
200

400
windDirection

● Sensor_TOS926   ◆ Sensor_TOS811
■ Sensor_TOS1096 ▲ Sensor_TOS1205
▼ Sensor_TOS1215

Last Value	Time Trend Chart
No data	

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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

Snap4City (C), November 2024

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

SDG 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

SDG 9 – INDUSTRY, INNOVATION AND INFRASTRUCTURE
- Predictive maintenance
- Decisions Support Systems
- Process optimization, control
- Industry 4.0 integrated solutions

SDG 11 – SUSTAINABLE CITIES AND COMMUNITIES
- Reduction of emission, reduction of congestion
- Smart City infrastructure: monitoring and resilience, long terms predictions
- Effective and Low cost smart solutions
- What-if analysis, Simulations
- Origin Destination matrices computation

SDG 12 – RESPONSIBLE CONSUMPTION AND PRODUCTION
- Optimization of Waste Collection
- business intelligence tools for decision makers
- Reduction production costs
- Monitoring resource consumption

SDG 13 – CLIMATE ACTION / SDG 15 – LIFE ON LAND
- Reduction of emission, reduction of congestion
- Monitoring and Predicting: NO2, NOX, CO2, Traffic flow, pollutant, landslide, waste, etc.
- Traffic flow reconstruction
- Demand vs Offer of Mobility analysis

SDG 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
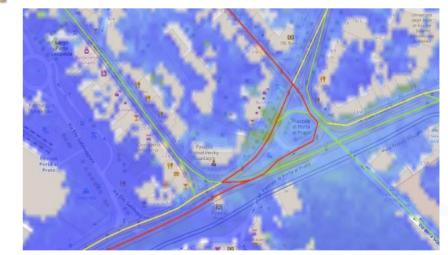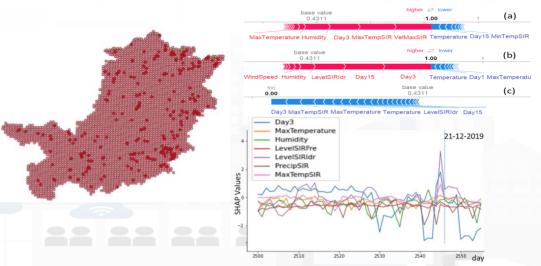
The difference is on computational models

- **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

FROM CITY DASHBOARD TO APPLICATIONS

DATA GATHERING AND CITY DATA KNOWLEDGE MANAGEMENT

TWITTER VIGILANCE-SOCIAL

100% OPEN SOURCE

Mobility
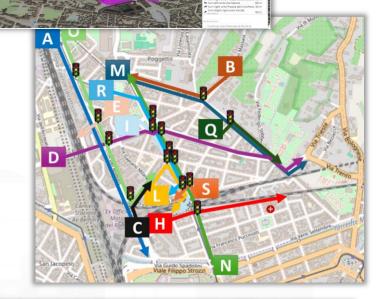
- **Goals:**
  - Decongestion, Decarbonization, costs reductions
  - Improve Accessibility to services
  - Improve Security/Safety of city users

- **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
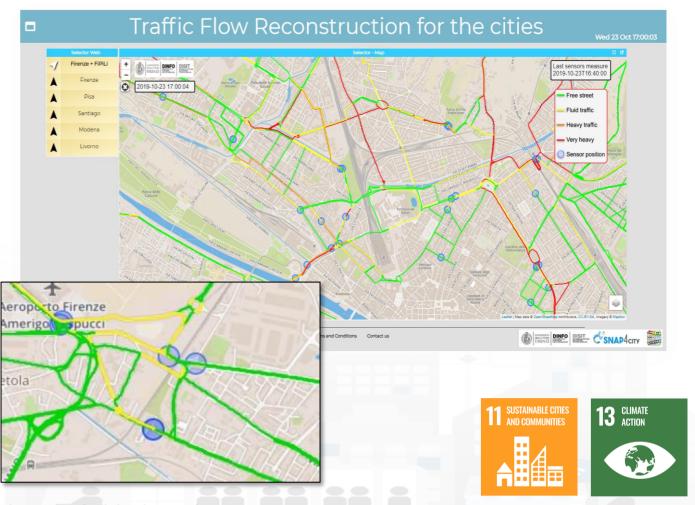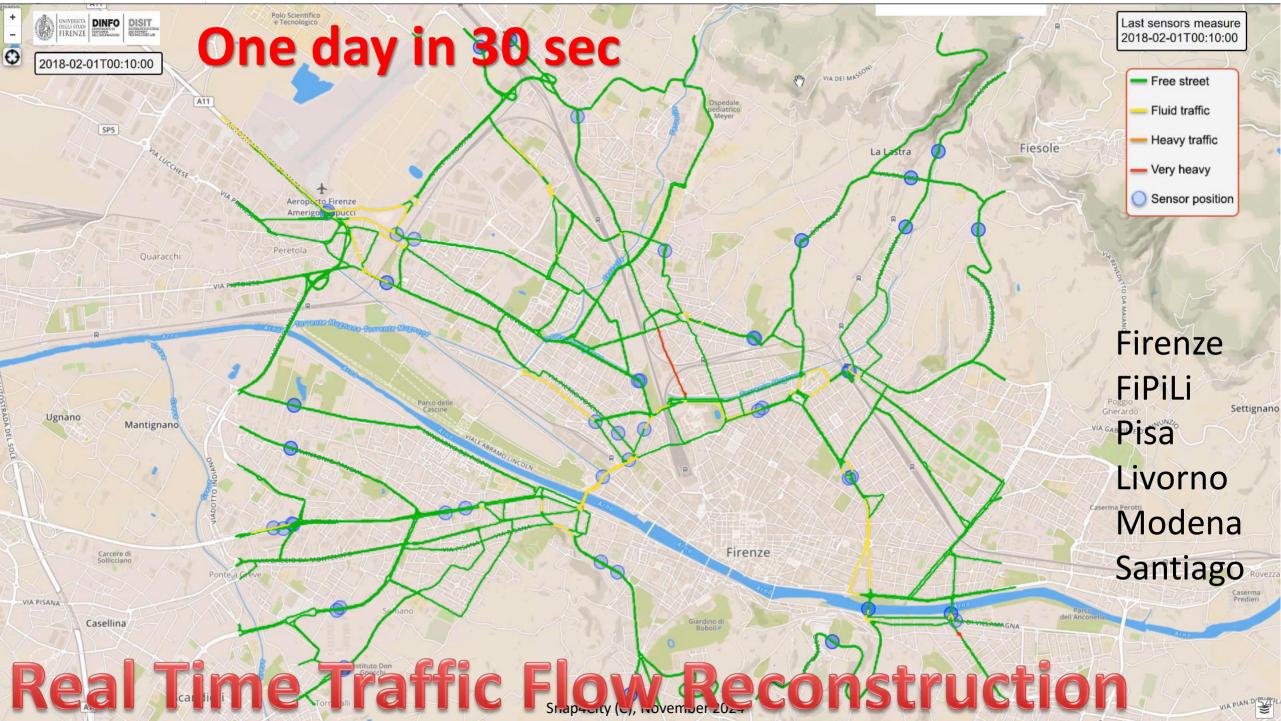
Why Dense Traffic Flow Reconstruction ?

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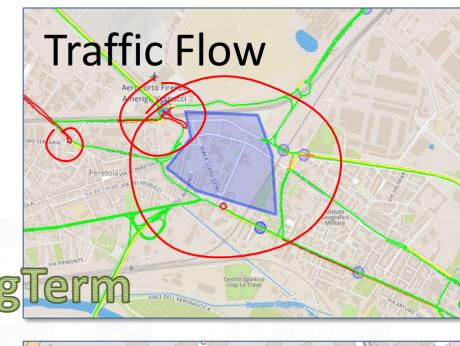
- o Change in the graph structure of the city
- o Impact on the flow of people and vehicles
- o Adaptation: public transport, traffic, pedestrian management, etc.

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

SNAP4CITY

Select map
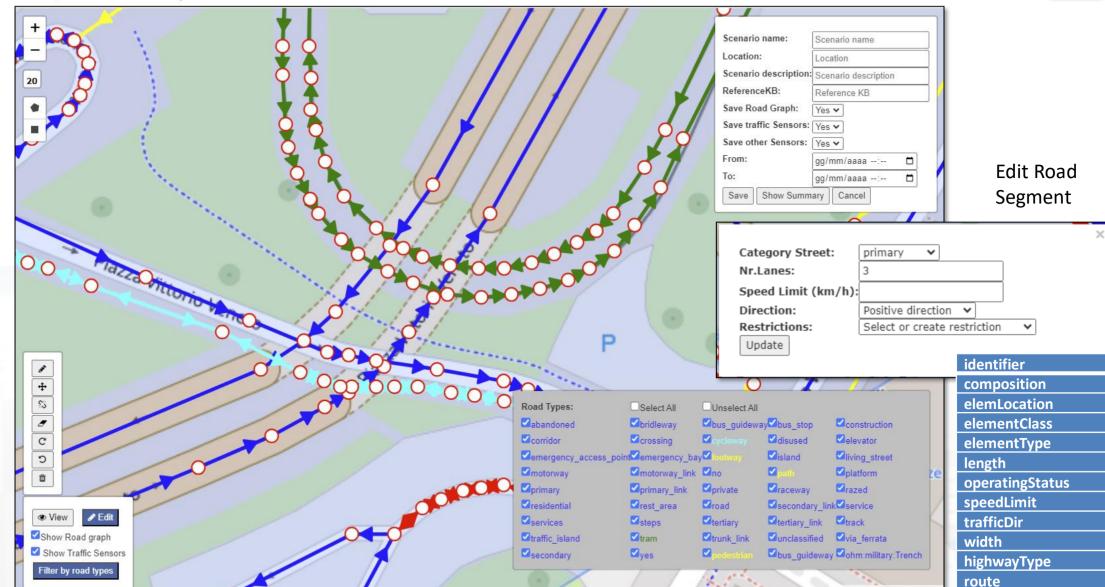
Zoom

New Scenario

Editing
Drag & drop
Split & Join
Delete
Do and Undo
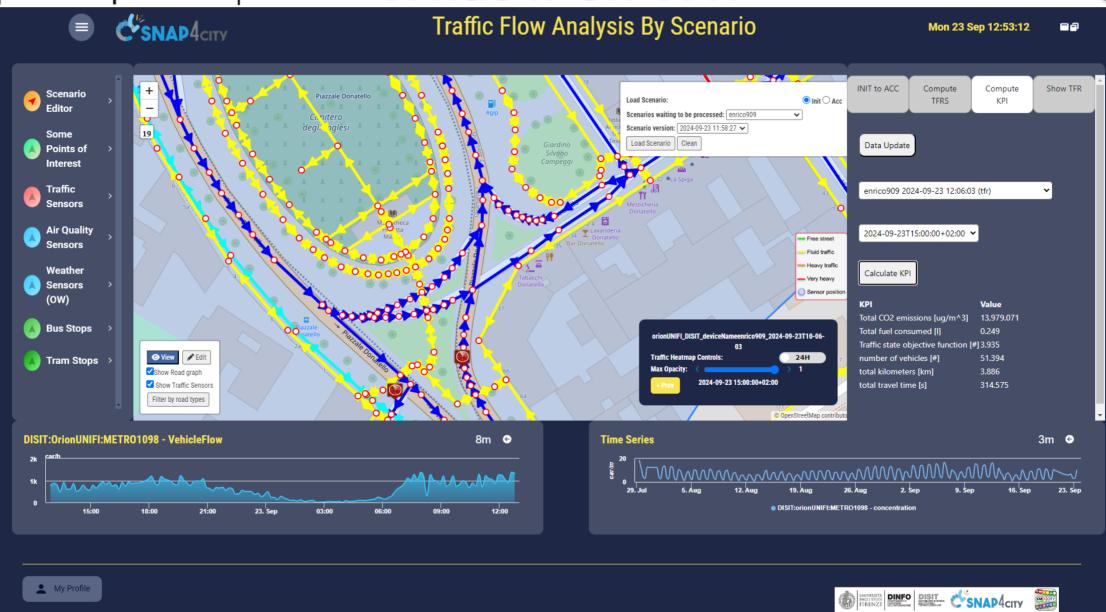
Edit Road Segment

Properties of Road Elements

https://www.snap4city.org/976

Snap4City (C), November 2024

56

What-if on TFR

Traffic Flow Analysis By Scenario
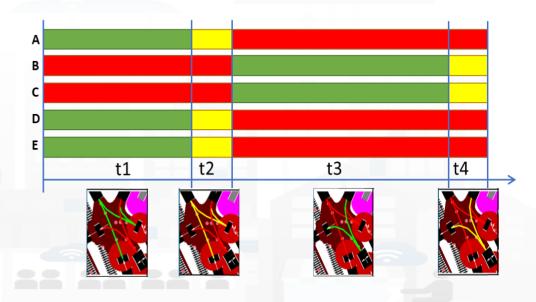
Traffic Light Plan Optimisation, Digital Twin

- **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%**
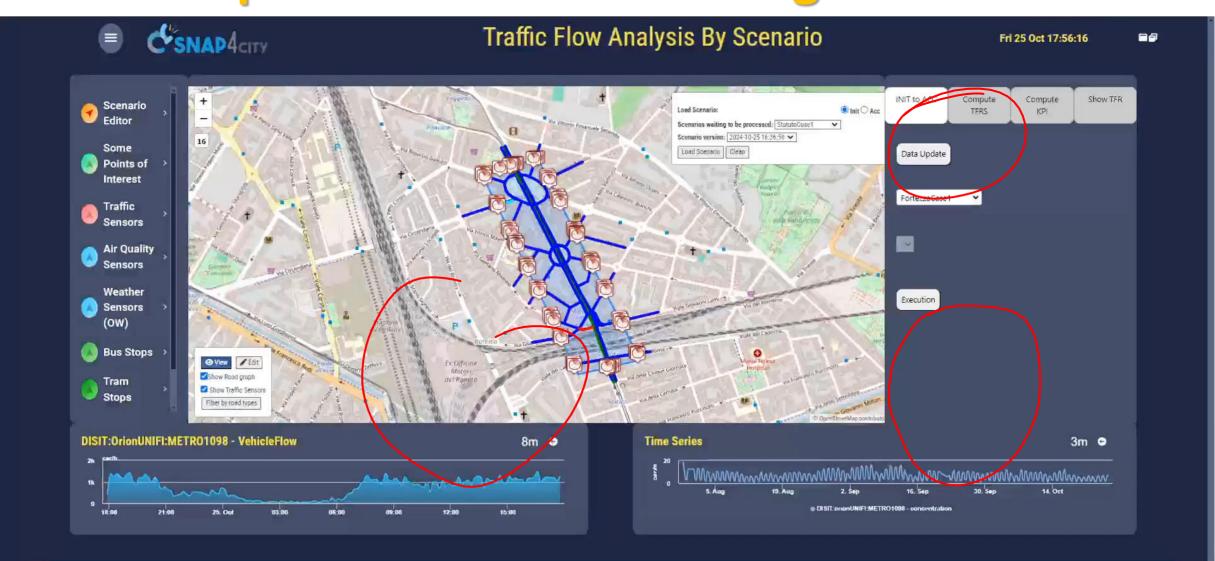
Optimization of Traffic Light Plan

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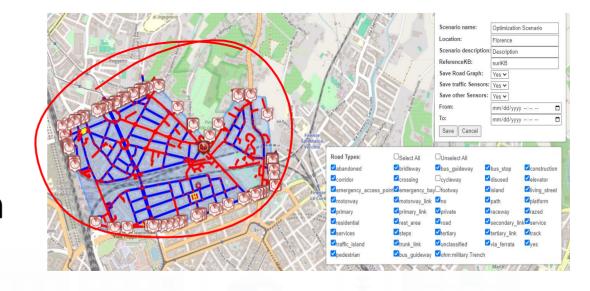
4TWD-NTNS-MWD-P-A: optimization by prioritizing traffic **directions,** the normalized number of **vehicles stops,** *NTNS* **, the mean waiting delay** *MWD*, for all traffic lights, and post synchronization, with Penalty and Adjust dynamically performed

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
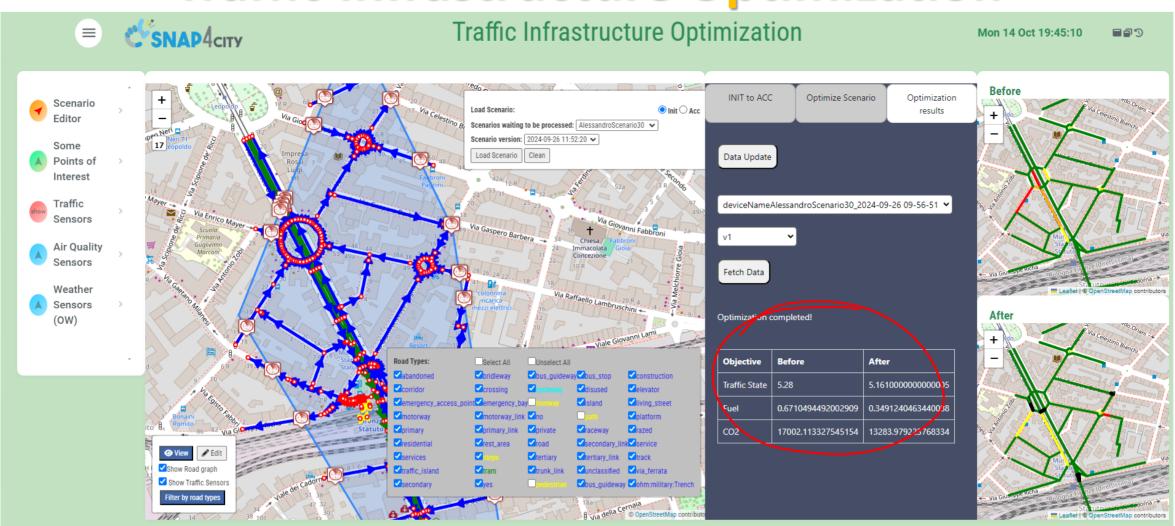
Traffic Infrastructure Optimization
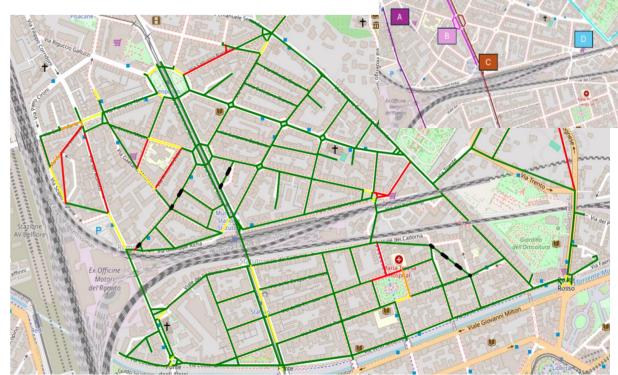
Optimization Results

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%**	
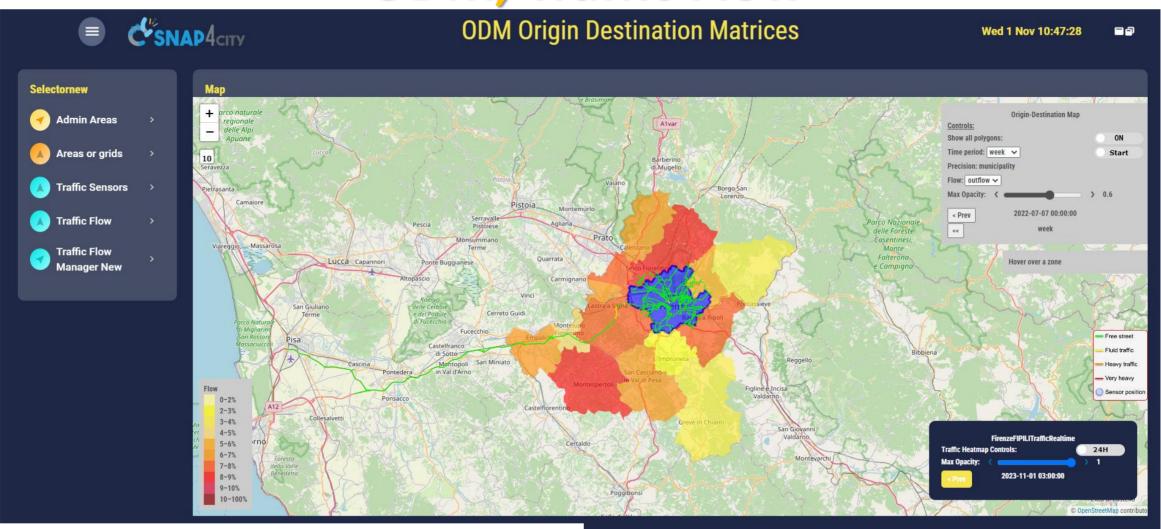
ODM, Traffic Flow

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

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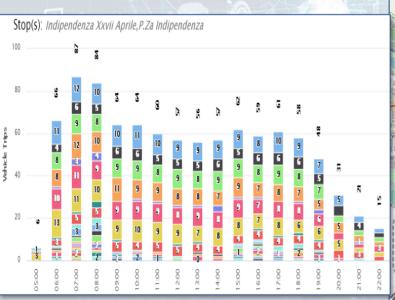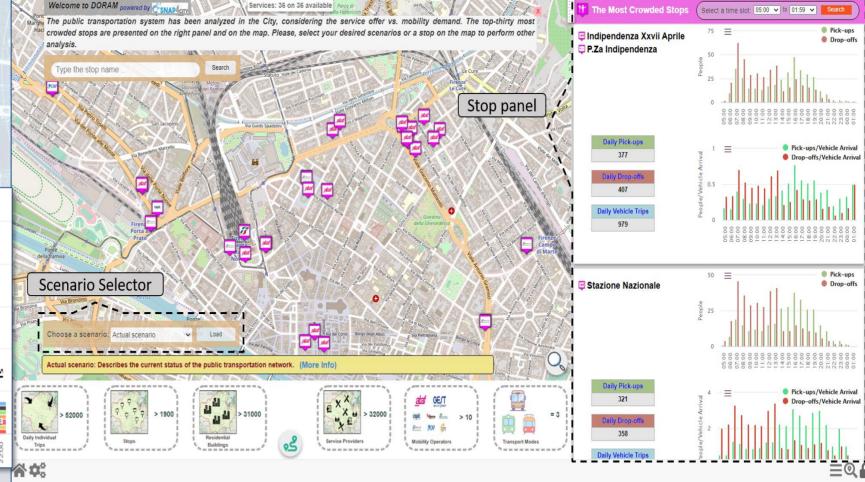
- Definition of scenarious impact on
  - Traffic, Pollutant, parking, public transport, private flows, etc.
  - KPI analysis

Public Services

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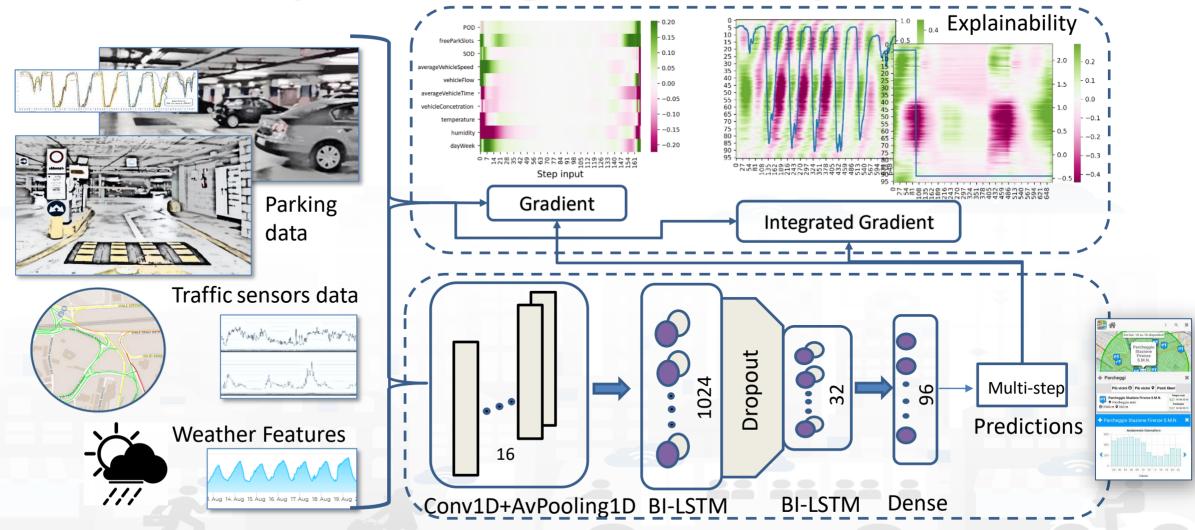
Deep Learning AI to surely Park!
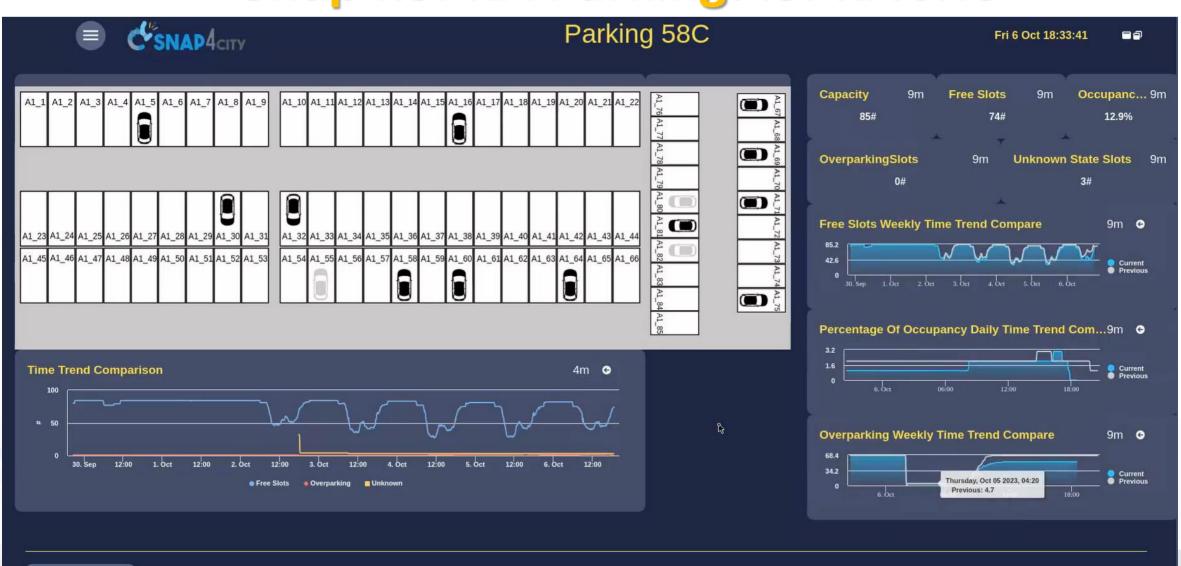
Snap4ISPRA Parking: ISPRA JRC
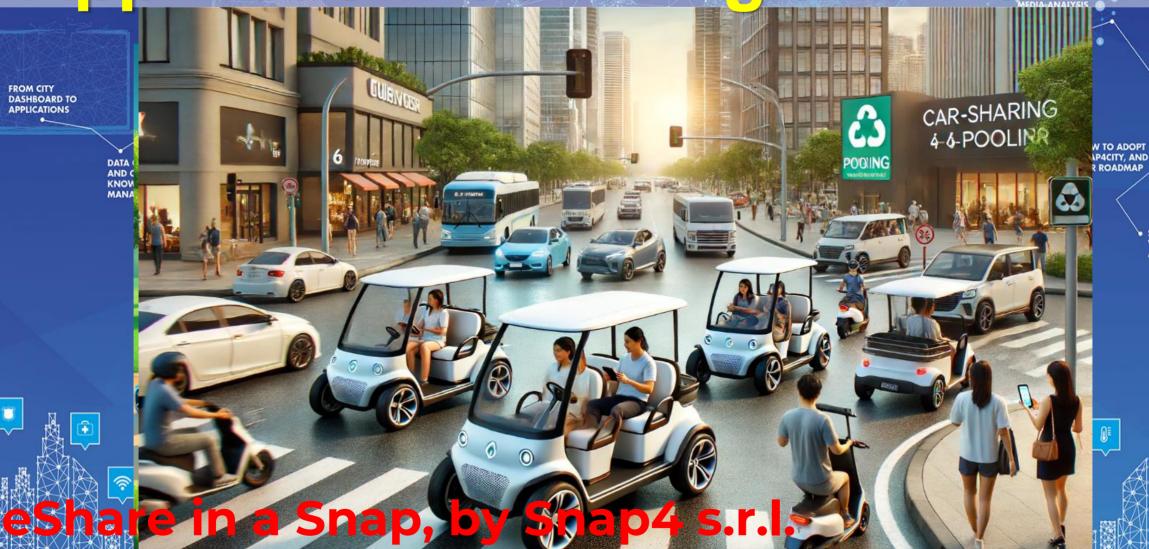
Application: eSharing and Pooling

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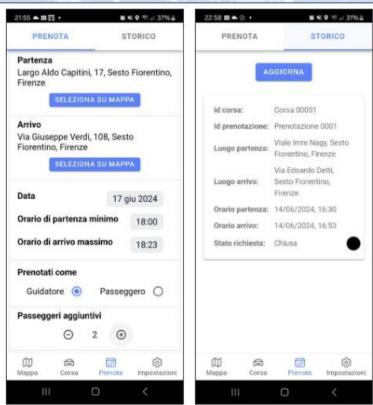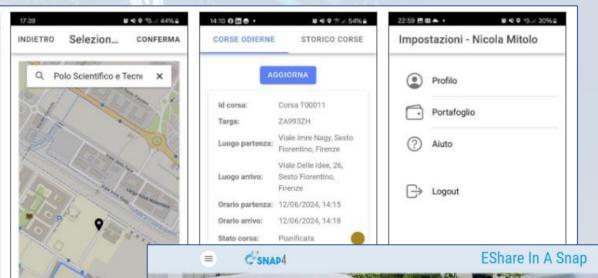
eShare in a Snap, by Snap4

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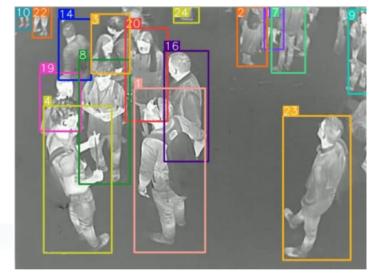Dynamic pooling and e-sharing

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, ..**
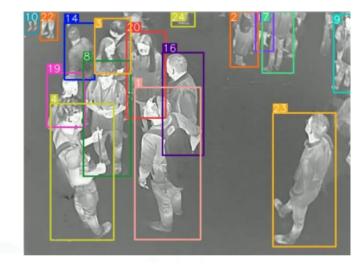
City User Behaviour/services, Tourism and Safety (2024/8)

- 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
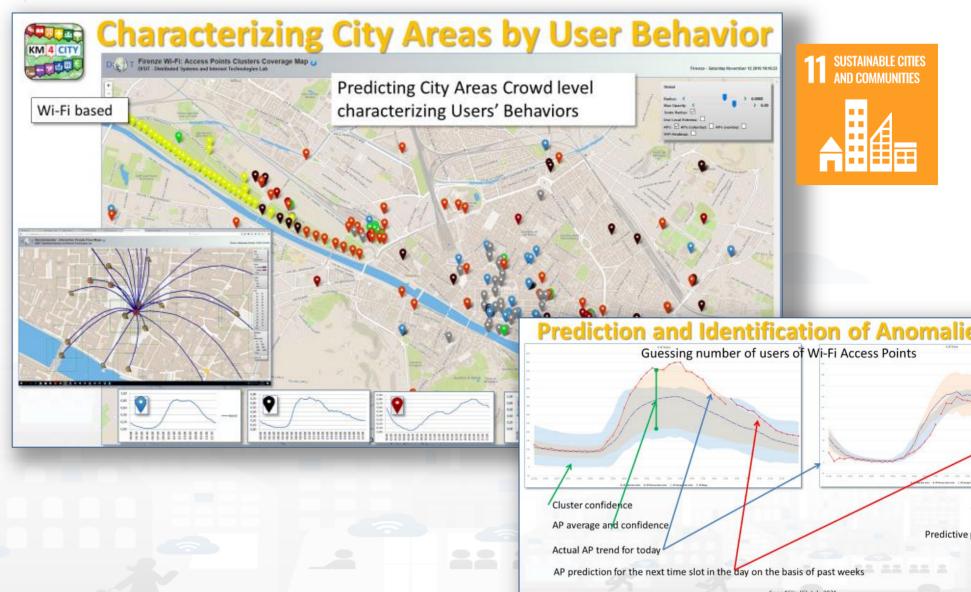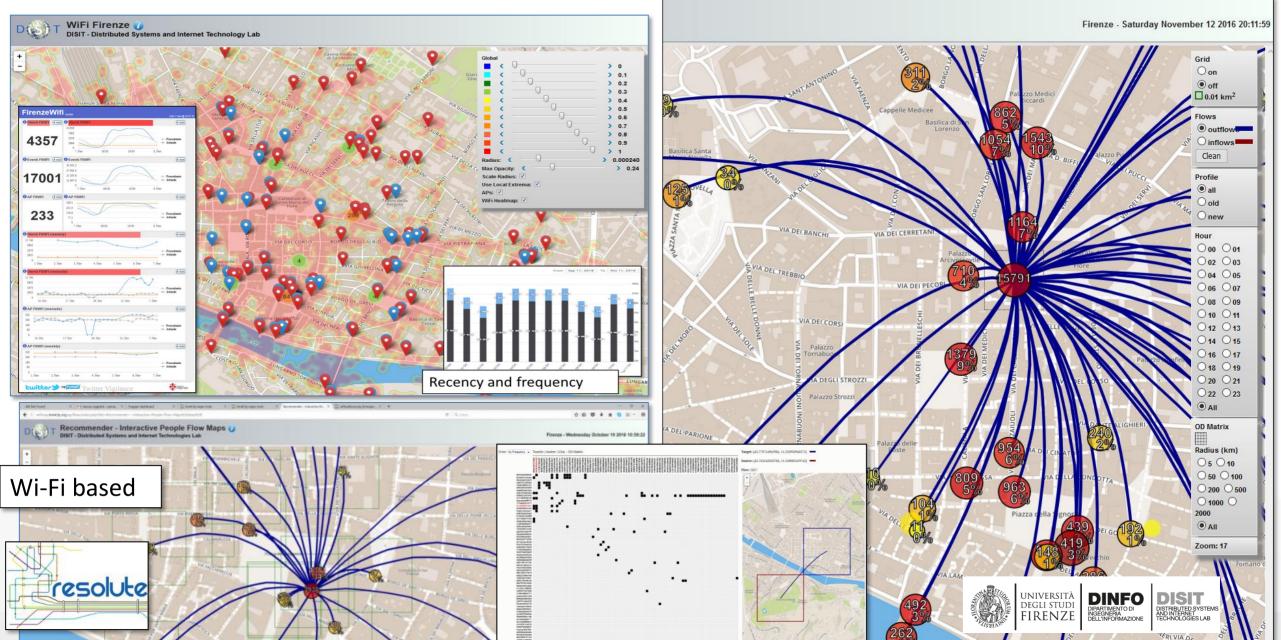- Algorithms and computational solutions, see next slide

La Cattedrale stowcentury - istockphoto.com

People Flows

- **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

Predictive

Snap4City (C), July 2021

11 SUSTAINABLE CITIES AND COMMUNITIES

Origin Destination Matrix Estimation

Recency and frequency

Wi-Fi based
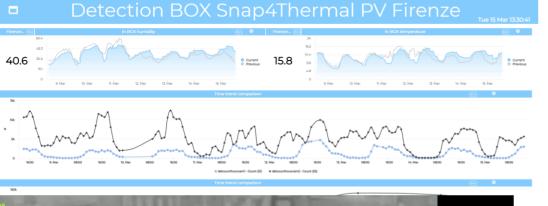
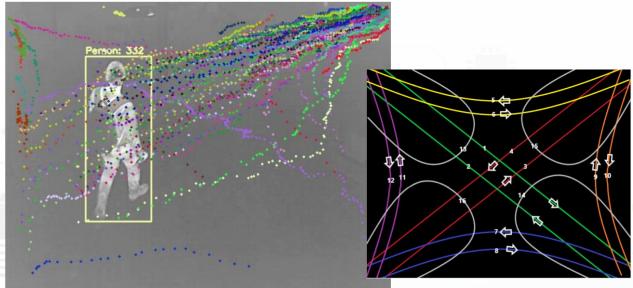# A view and data from the Thermal Camera
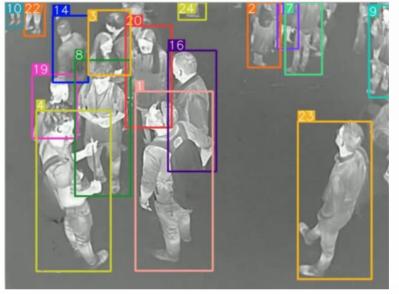
People Counting and Tracking

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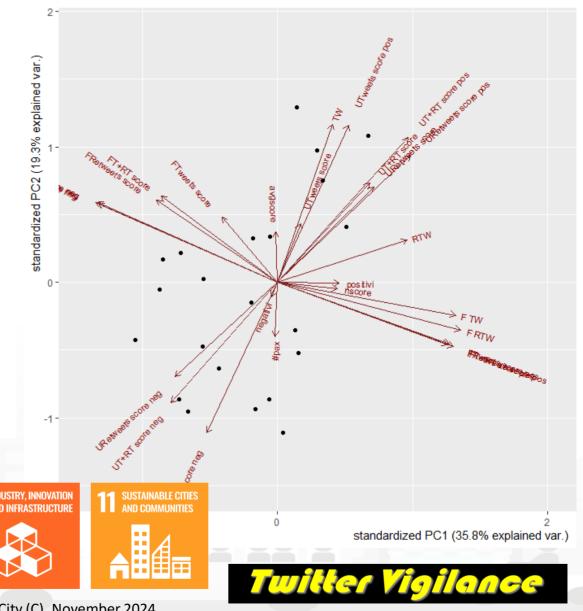
- Prediction/estimation of **Average Score of Trip Advisor** as a function of *Twitter Vigilance Metrics + other information*

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

- Assessing impact of advertising

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

Twitter Vigilance

people count vs predicted people count

Safety Control Integration with Video Management Systems

Integration with **MILESTONE XProtect** Video Management

milestone
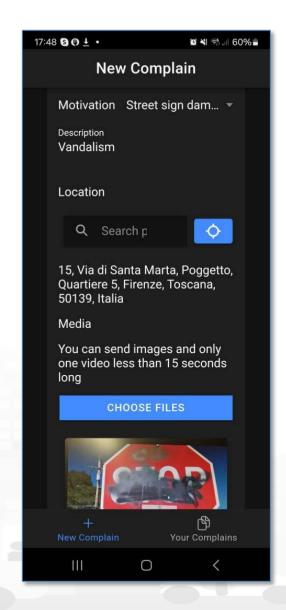
Event Managements

- **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, ...
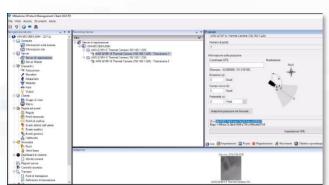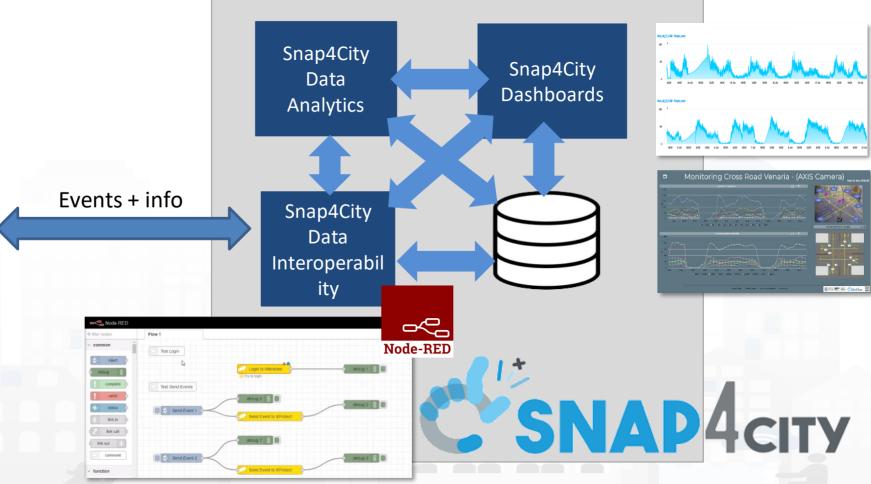 - Other channels, ...
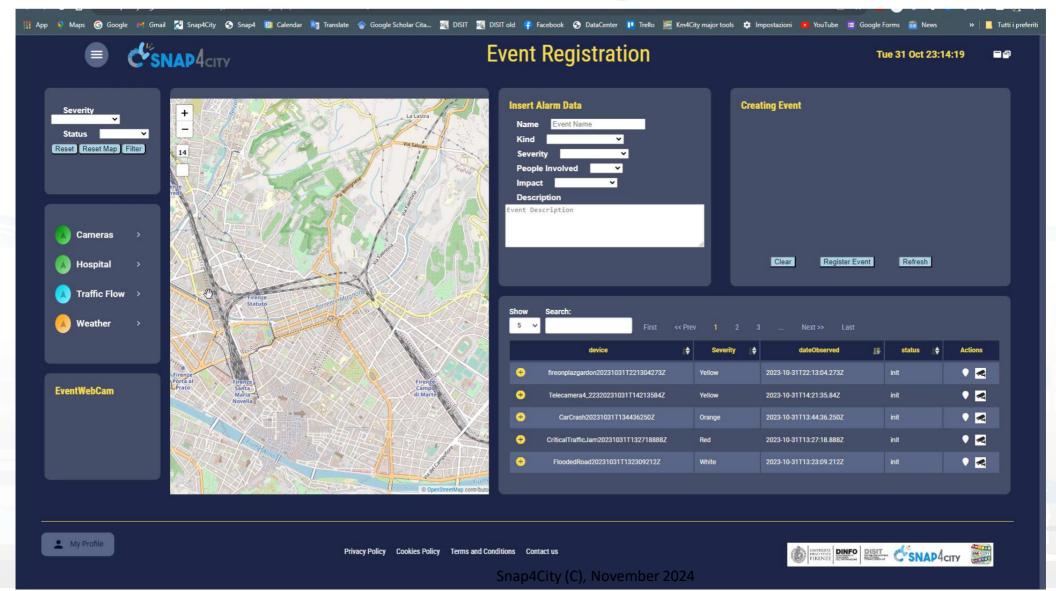
Event Management

VMS vs Snap4City: sending and getting events, AI solutions

Events + info

Snap4City Data Analytics

Snap4City Dashboards

Snap4City Data Interoperability

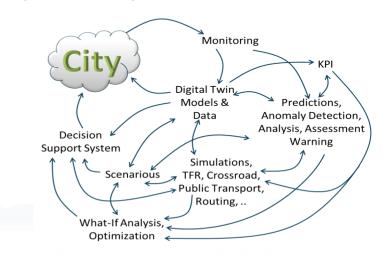Node-RED

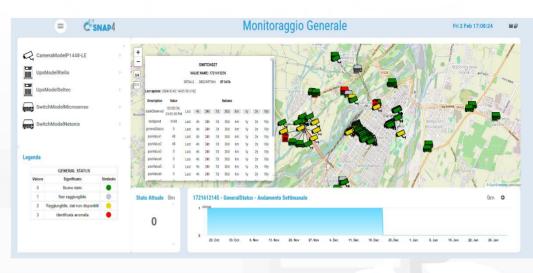# Assets Management & Control

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
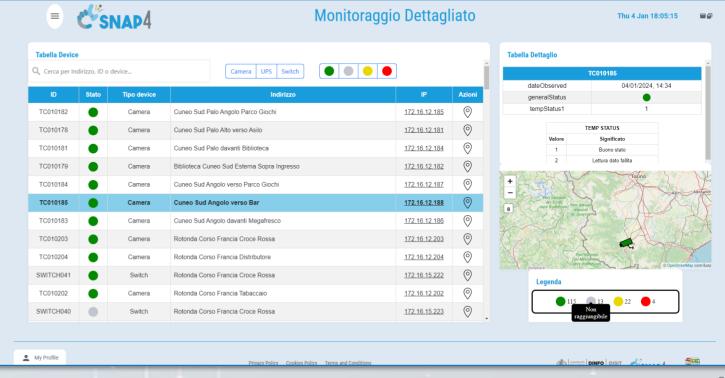

- More than 400 devices

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

Engaging via Mobile Apps

User Behavior Analyser for Collective Profiling

Who

When

What

Where?
Why?

Duomo

Piazza Signoria

Duomo

Uffizi

Stazione vs Santa Maria Novella

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: CO_2, NO_2, 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 CO_2/NO_2 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

- **Multiple Domain Data**
  - Traffic Flow data, Pollutant: NOX, CO2, PM10, PM2.5, O3, ….
  - 3D City structure, weather, …
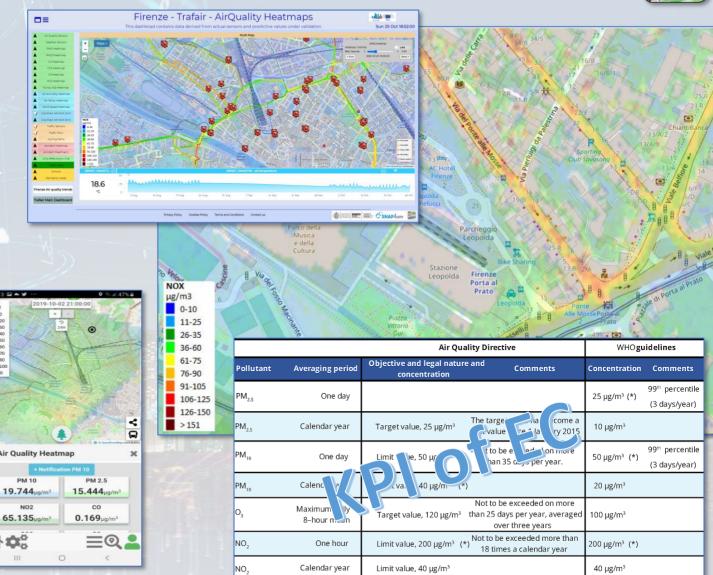
- **Multiple Decision Makers**
  - Pollutant Predictions: NOX, NO2, ..
  - City officers, energy industries
  - Dashboards, What-IF analysis
  - Traffic Flow Reconstruction

- **Historical and Real Time data**
  - Billions of Data

- **Services Exploited on:**
  - Dashboards, Mobile App

- **Since 2020**

		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... come a ...value ...re 1 la...ry 2015	10 µg/m³	
PM10	One day	Limit ...ue, 50 µg/m³	...t to be e...ed...on more ...han 35 d...s per year.	50 µg/m³ (*)	99th percentile (3 days/year)
PM10	Calend...ear	...va...40 µg/m³ (*)		20 µg/m³	
O3	Maximum ...ily 8-hour m...n	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	

KPI of EC

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

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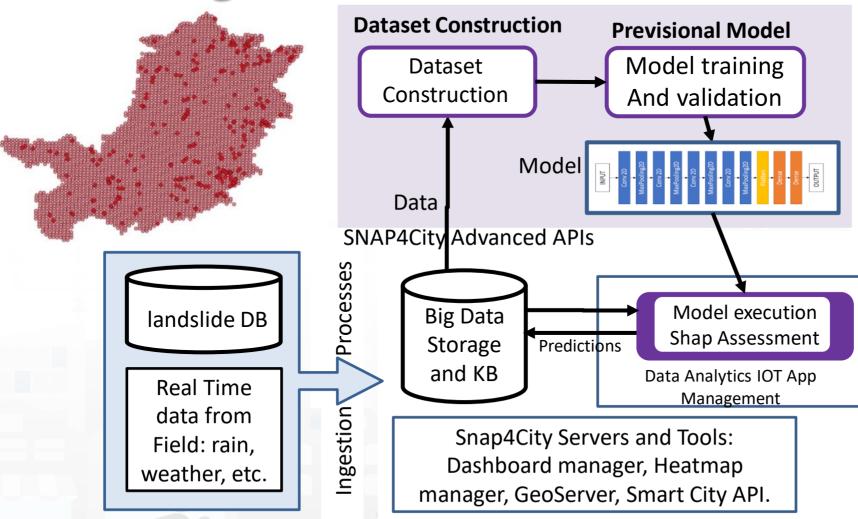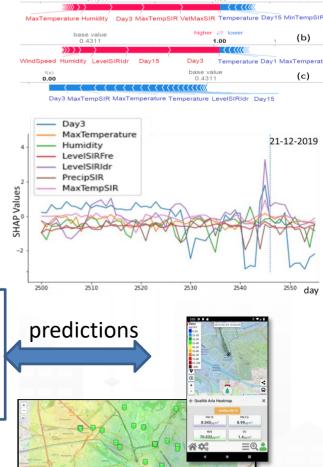 - Mixed solutions of Fluidinamics modeling and AI

Traffic Flow Manager on multiple cities

11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

Predicting Land slides

Dataset Construction

Previsional Model

Dataset Construction → Model training And validation

Model

Data

SNAP4City Advanced APIs

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
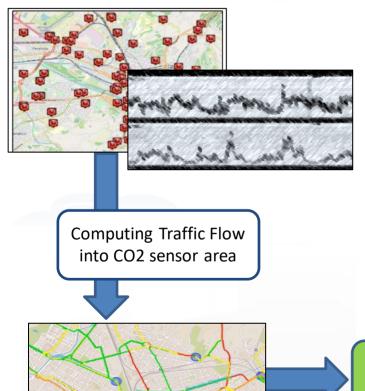
Estimating City Local CO2 from Traffic Flow Data

- 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 Traffic Flow into CO2 sensor area

Traffic Flow data

Computing CO2 on the basis of traffic flow data

CO2 estimation

CO2 ppm
<390
390-395
395-400
400-410
410-420
>420

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/
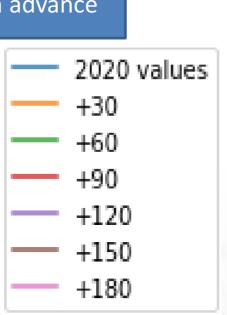
Predicting EC's KPI on NO2 months in advance
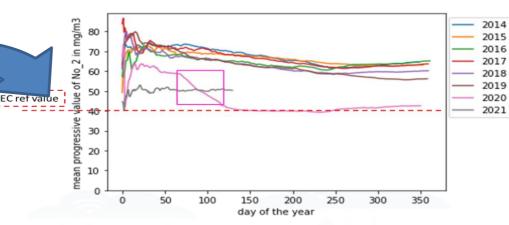
Deep Learning Long Terms Predictions of NO2 mean values, From 30 to 180 days in advance

- 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

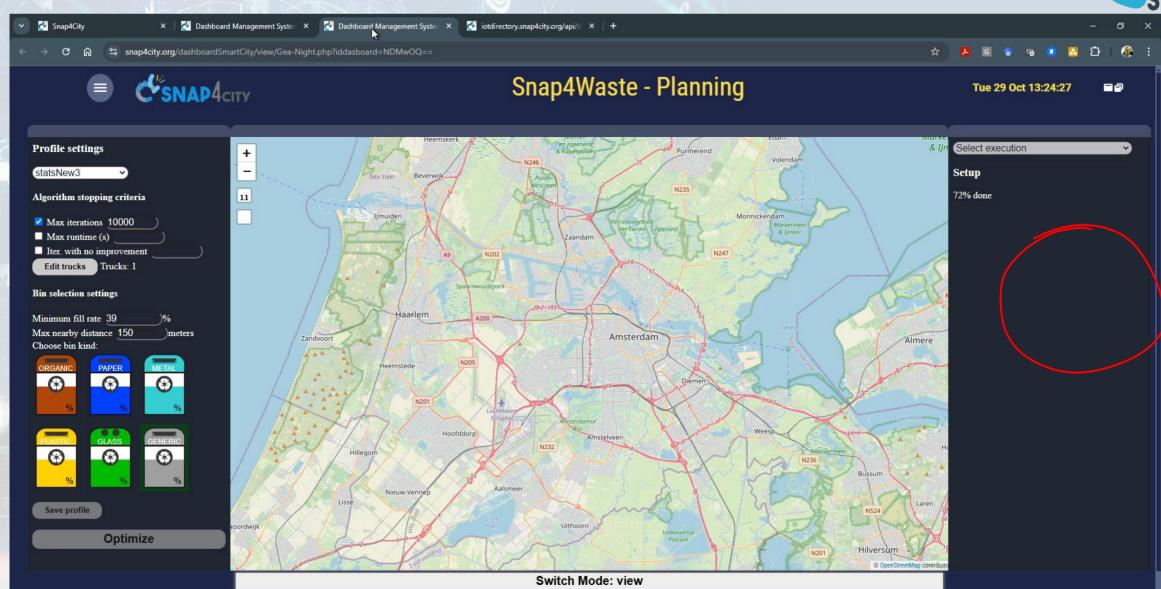|		Air Quality Directive		WHO guidelines	
Pollutant	Averaging period	Objective and legal nature and concentration	Comments	Concentration	Comments
PM$_{2.5}$	One day			25 µg/m³ (*)	99th percentile (3 days/year)
PM$_{2.5}$	Calendar year	Target value, 25 µg/m³	The target value has become a limit value since 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	

Waste Collection Optimization
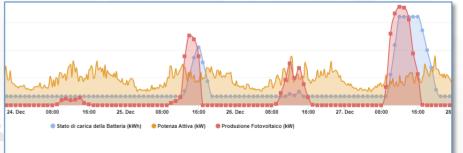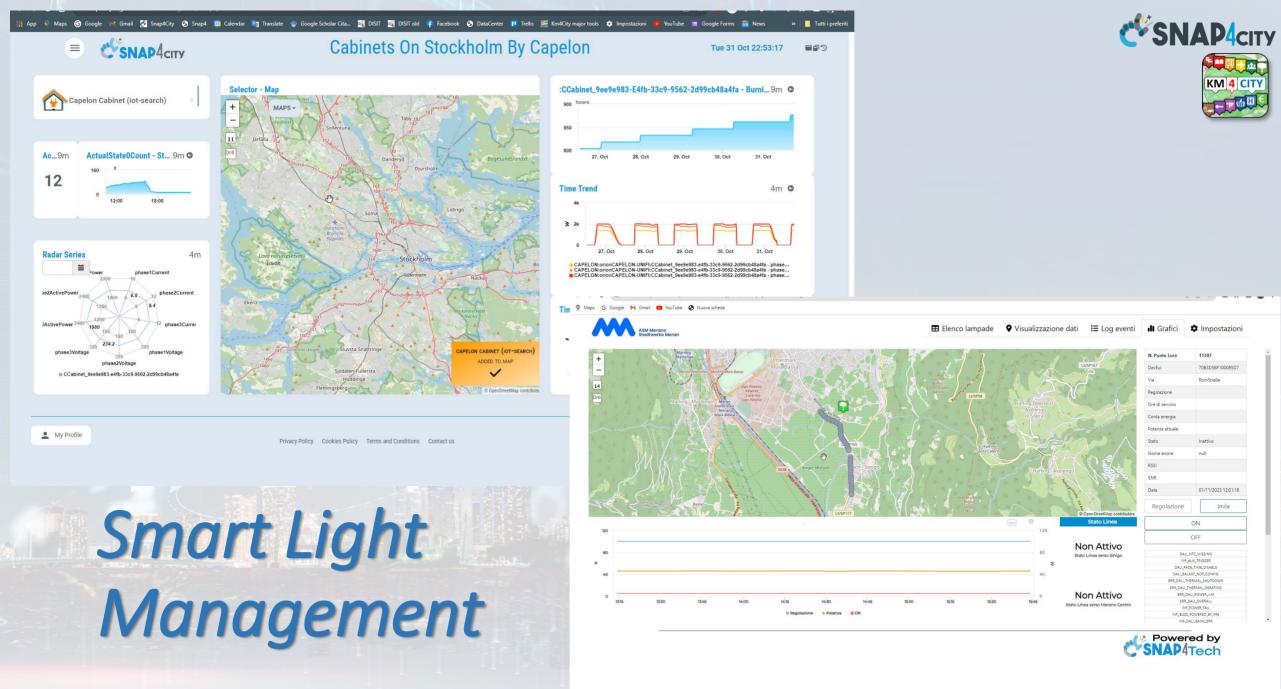
City Energy and Buildings

- **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 Management

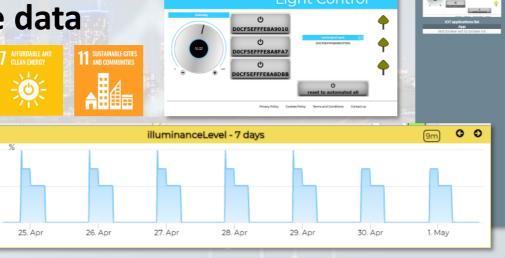# *Smart Light Control of* CAPELON

- **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 Building

Smart Building

Buildiings Floors, etc.
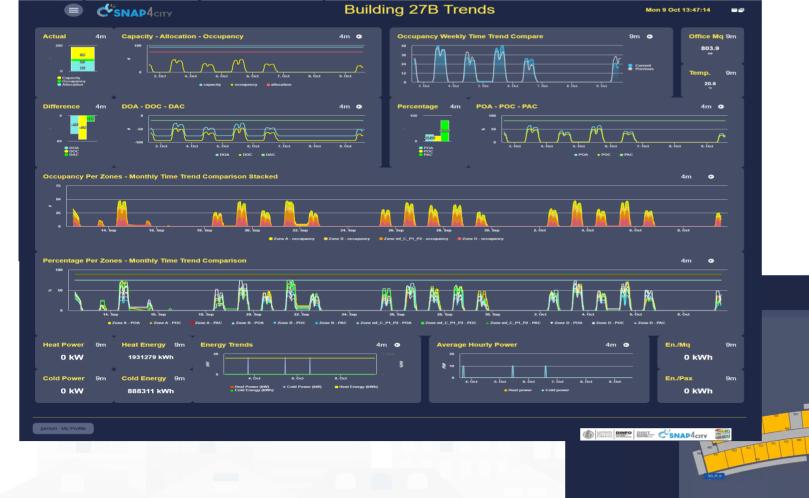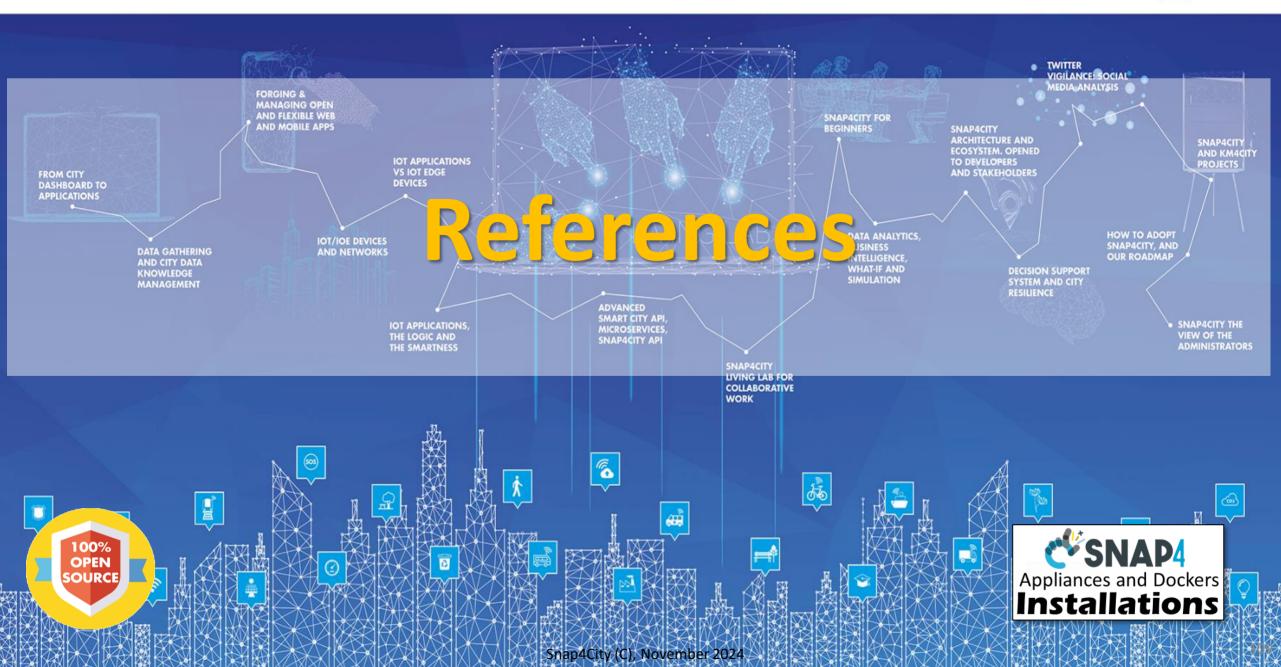
References

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