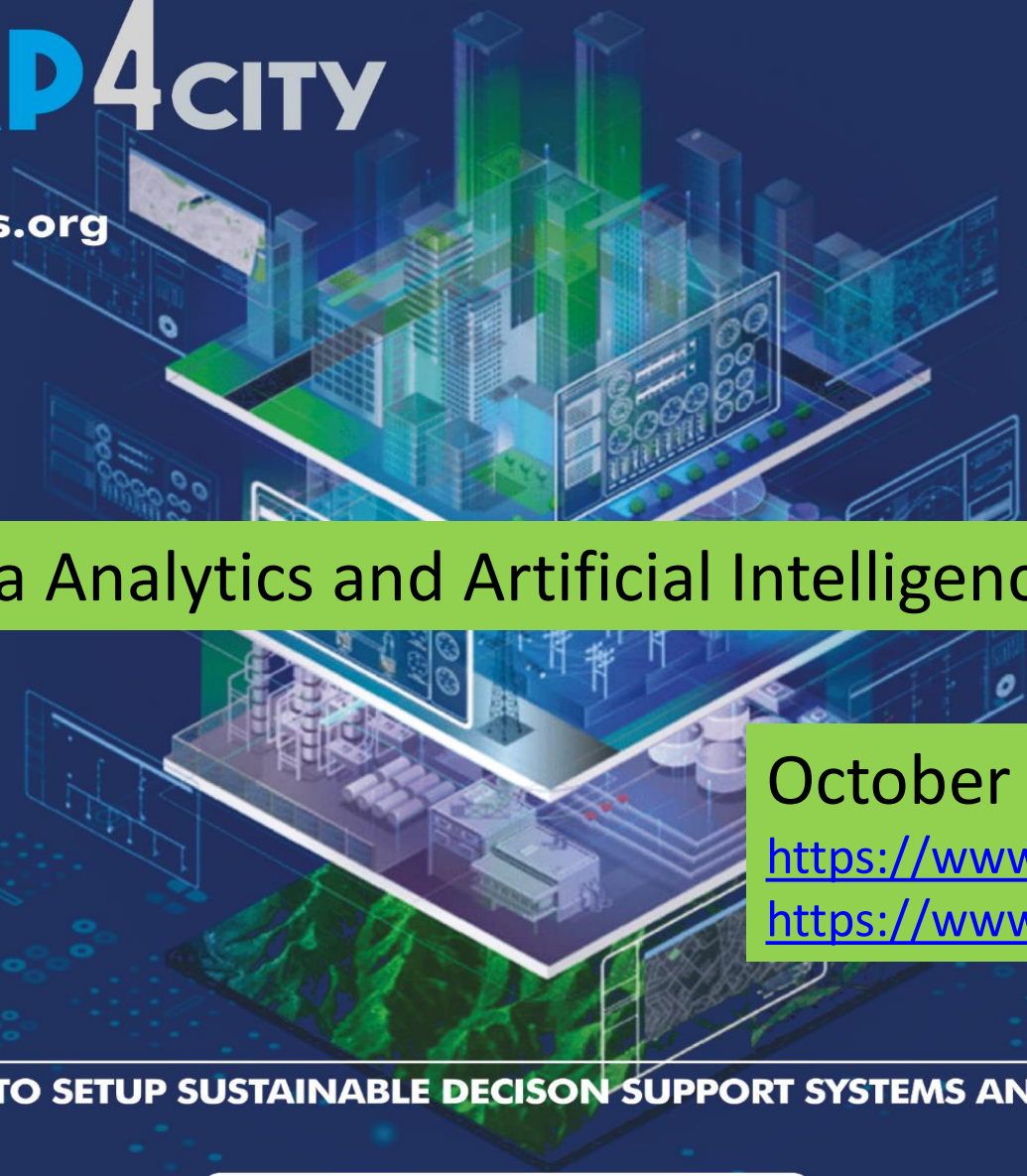
SNAP4CITY

www.snap4city.org
www.snap4solutions.org

KM4CITY

www.km4city.org



Data Analytics and Artificial Intelligence

October 2025, Course, Part 4

https://www.snap4city.org/944
https://www.snap4city.org/577

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

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Paolo Nesi, paolo.nesi@unifi.it
https://www.Km4City.org
https://www.disit.org

SNAP4CITY

KM4CITY

SNAP4 Appliances and Dockers Installations

100% OPEN SOURCE

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Node-RED

SMARTCITY EXPO WORLD CONGRESS

LIVING LAB

Data Analytics and Artificial Intelligence

Data Analytic



October 2025, Course, Part 4

https://www.snap4city.org/944
https://www.snap4city.org/577

SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES

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

SNAP4CITY · KM4CITY

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

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SNAP4 Appliances and Dockers Installations

EUROPEAN OPEN SCIENCE CLOUD

Node-RED

JS Foundation

E015 digital ecosystem

NVIDIA

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

HORIZONTAL AI PLATFORM



MOBILITY AND TRANSPORT



SMART ENERGY AND SMART BUILDING



ENVIRONMENT AND WASTE MANAGEMENT



CITY USER'S SERVICES AND TOURISM MANAGEMENT



SNAPADVISOR



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



DASHBOARDS, WIDGETS
TEMPLATES



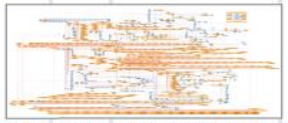
PREDICTION - ANOMALY DETECTION - CLUSTERING - ROUTING - SENTIMENT NLP - TRAFFIC FLOW - PEOPLE FLOWS - SDG
15 MIN CITY INDEX - KPI - HEATMAPS - ORIGIN DESTINATION - MAPS - VECTOR FIELD - ETC...



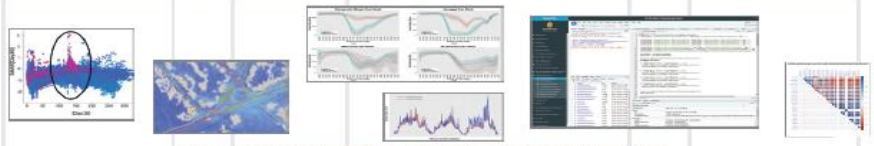
API - MICROSERVICES - GIS - BPM
VIDEO - REPORTS - MAPS - 3D ...

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





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



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



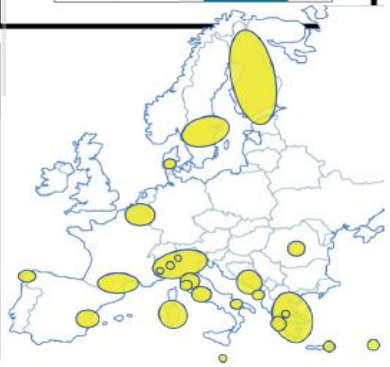
VISUAL PROGRAMMING, ADAPTERS
DATA FLOWS, WORKFLOWS
PARALLEL DISTRIBUTED PROCESSING
DATA DRIVEN

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

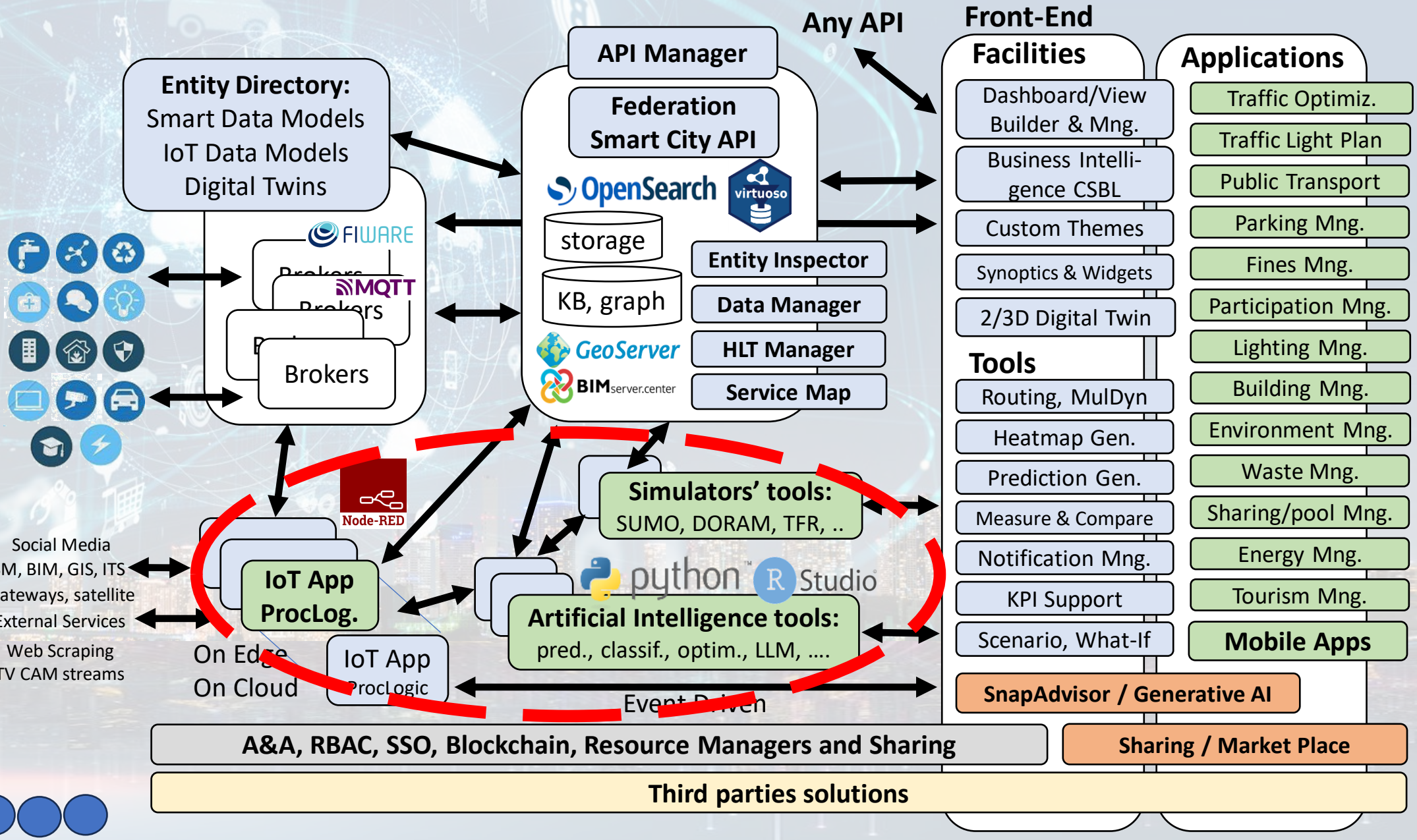


NATIVE AND EXTERNAL APPLICATIONS

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

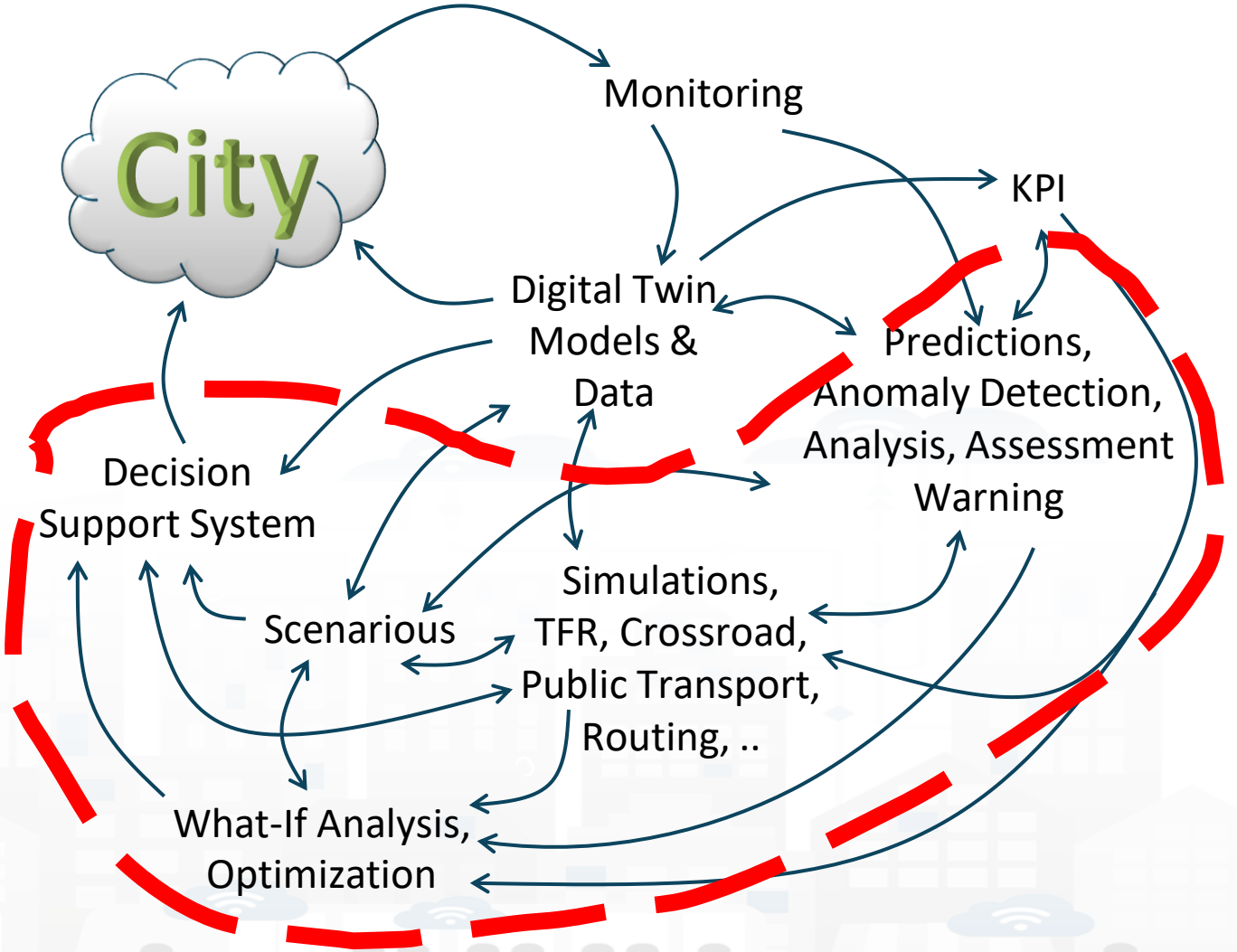


Technical Architecture



Main tasks

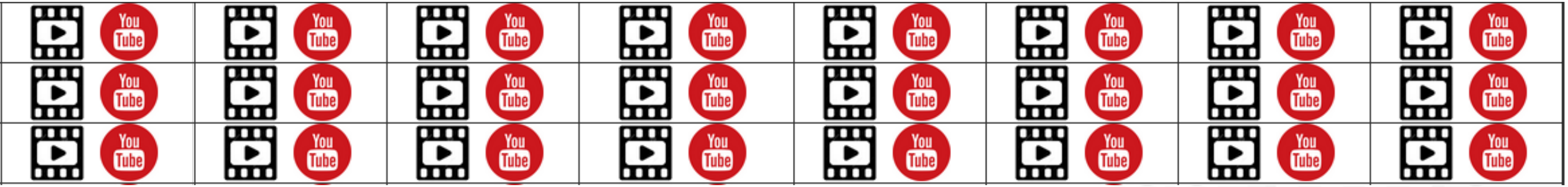
- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Early warning on critical conditions
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders



https://www.snap4city.org/944

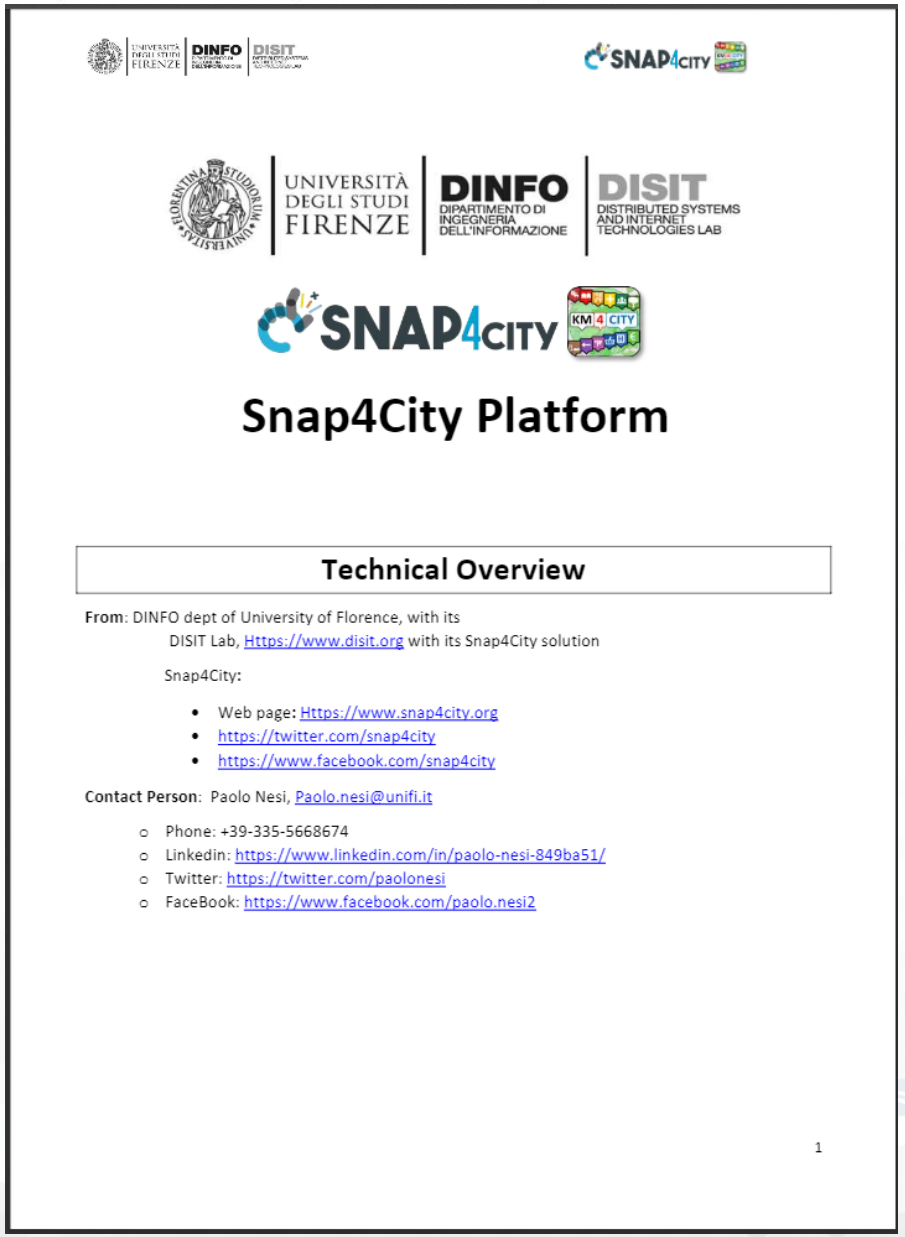
On Line Training Material (free of charge)

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
							
							



Note on Training Material

- **Course 2023**: https://www.snap4city.org/944
  - Introductionary course to Snap4City technology
- **Course** https://www.snap4city.org/577
  - Full training course with much more details on mechanisms and a wider set of cases/solutions of the Snap4City Technology
- **Documentation** includes a deeper round of details
  - Snap4City Platform Overview:
    - https://www.snap4city.org/drupal/sites/default/files/files/Snap4City-PlatformOverview.pdf
  - Development Life Cycle:
    - https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
  - Client Side Business Logic:
    - https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- **On line cases and documentation**:
  - https://www.snap4city.org/108
  - https://www.snap4city.org/78
  - https://www.snap4city.org/426



Snap4City Platform

Technical Overview

From: DINFO dept of University of Florence, with its
DISIT Lab, Https://www.disit.org with its Snap4City solution

Snap4City:

- Web page: Https://www.snap4city.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city

Contact Person: Paolo Nesi, Paolo.nesi@unifi.it

- Phone: +39-335-5668674
- Linkedin: https://www.linkedin.com/in/paolo-nesi-849ba51/
- Twitter: https://twitter.com/paolonesi
- FaceBook: https://www.facebook.com/paolo.nesi2

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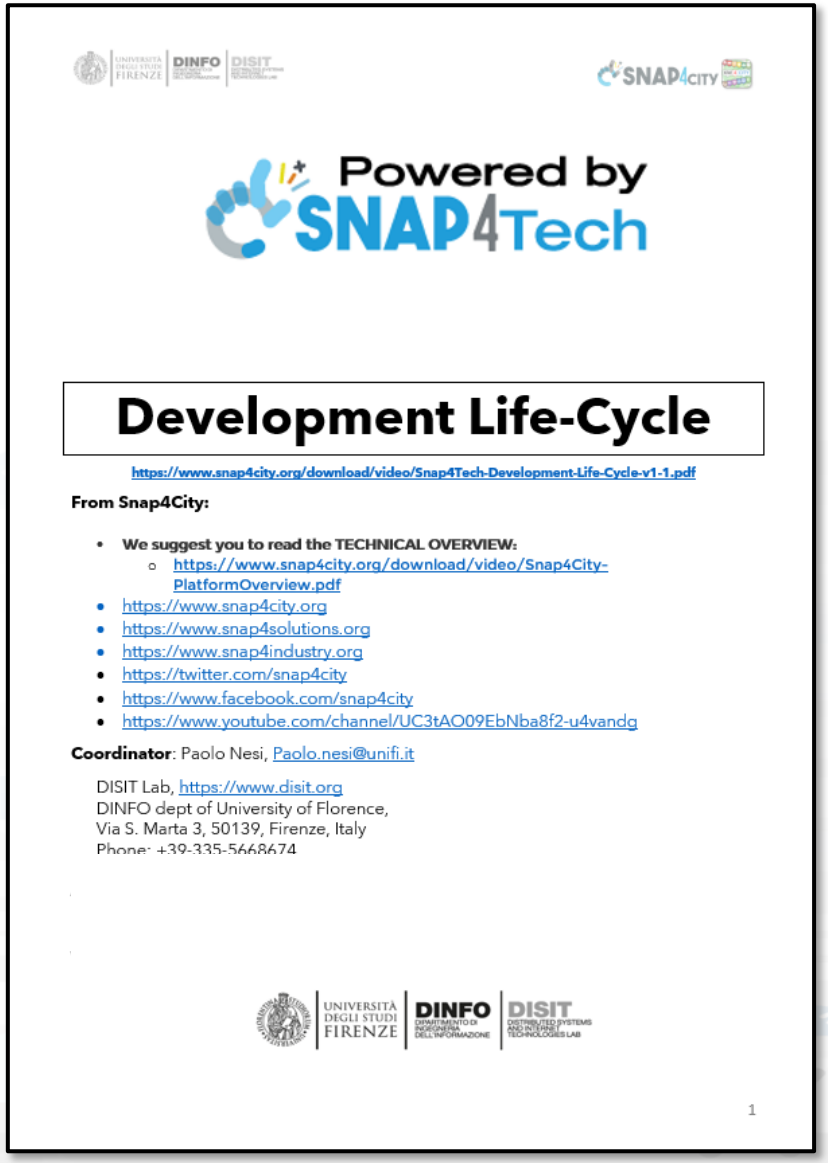
Tech Overview

- https://www.snap4city.org/drupal/sites/default/files/files/Snap4City-PlatformOverview.pdf

Development



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Development Life-Cycle

https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle-v1-1.pdf

From Snap4City:

- **We suggest you to read the TECHNICAL OVERVIEW:**
  - https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city
- https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandg

Coordinator: Paolo Nesi, Paolo.nesi@unifi.it

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Phone: +39-335-5668674

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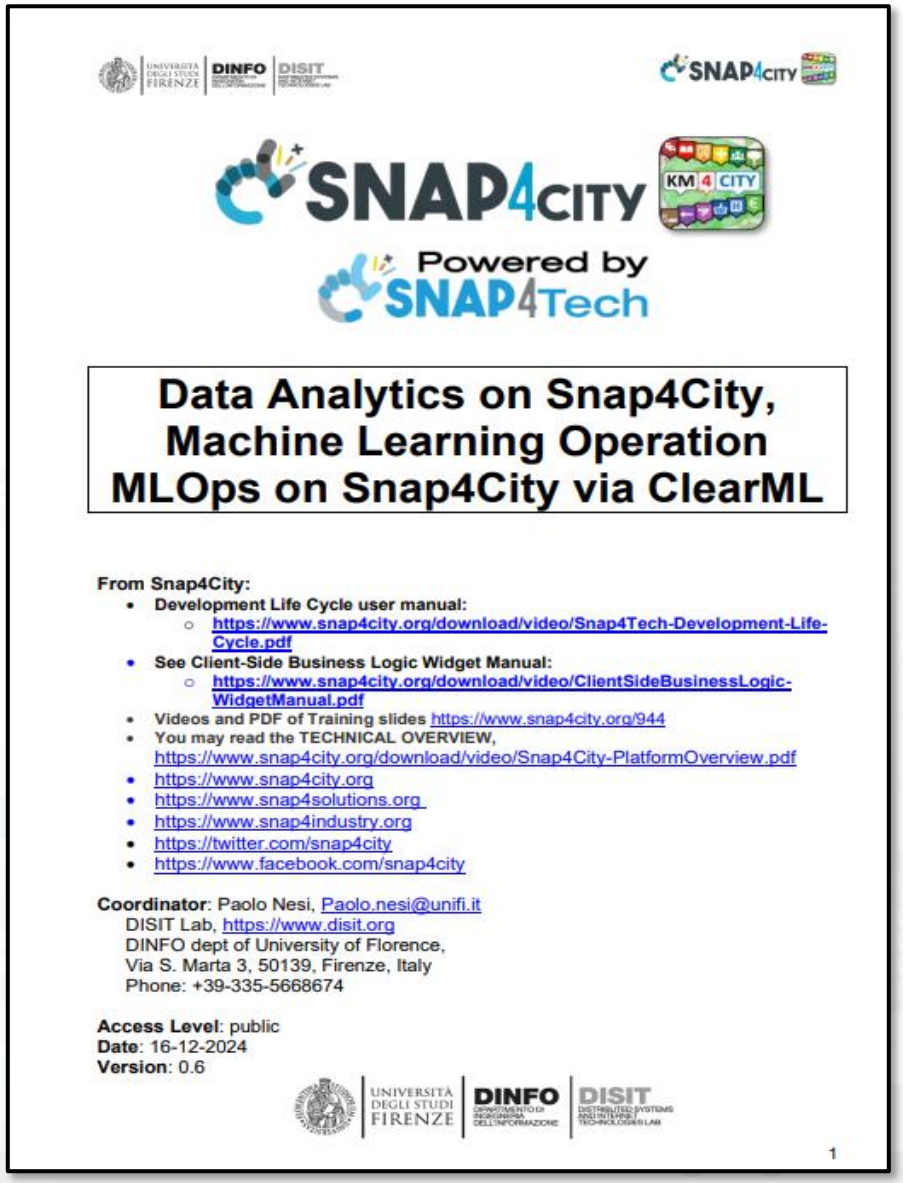
https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf

MLOperations

https://www.snap4city.org/download/video/Snap4City-MLOps-Manual.pdf



SNAP4CITY

Powered by SNAP4Tech

Data Analytics on Snap4City, Machine Learning Operation MLOps on Snap4City via ClearML

From Snap4City:

- **Development Life Cycle user manual:**
  - https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
- **See Client-Side Business Logic Widget Manual:**
  - https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- Videos and PDF of Training slides https://www.snap4city.org/944
- You may read the TECHNICAL OVERVIEW, https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city

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Phone: +39-335-5668674

Access Level: public
Date: 16-12-2024
Version: 0.6

1



Logged in as:
edoardo_tester

Your Profile

Logout

SnapAssistant model:

Llama3.3

New Chat

EdoChat1

EdoChat2

EdoChat3

EdoChat4

prova

chatNuova

chatTest1LLAMA

chatTest2LLAMA

testGianniLLAMA

testTastoInvioPreChanges

ChatTestPostPSWINVIO

SnapAdvisor

Current chat: debug0

Visualize references

Personal Advisor LLM

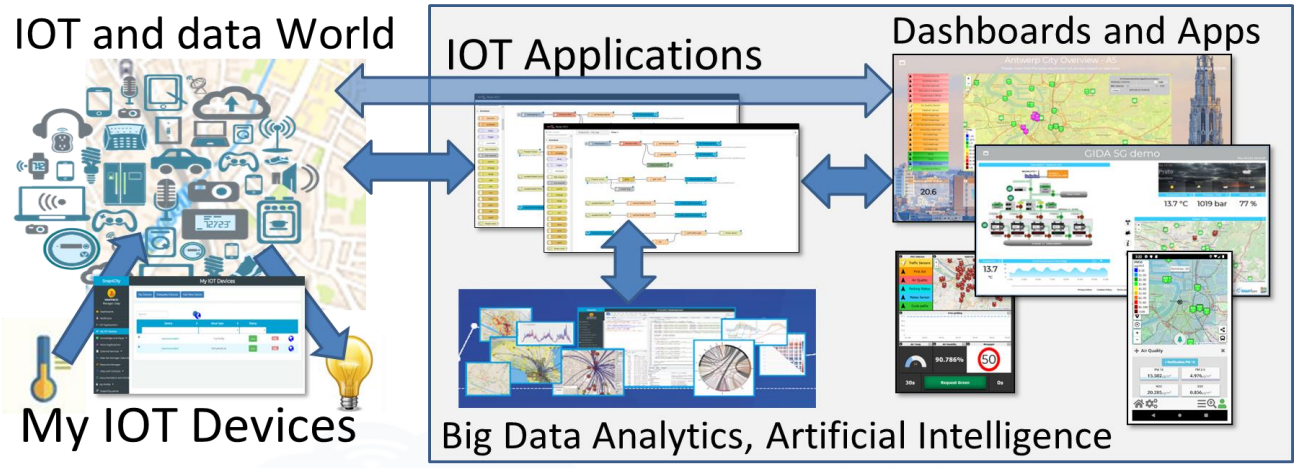
Come creo una dashboard?

Per creare una dashboard, puoi utilizzare la piattaforma Snap4City. La dashboard si compone di un insieme di widget grafici che possono essere impostati separatamente assegnando una serie di parametri, come origine dati, dimensioni, colori, forma, font, allarmi, relazioni con altri, ecc. (SOURCE: Snap4 City per la creazione di Smart City Control Room, SCCR). Inoltre, la piattaforma offre la possibilità di creare vere e proprie applicazioni interattive, multipagina/multidashboard, e non semplici storie monopagina da scrollare. Puoi anche condividere la dashboard con altri utenti anche fuori dalla Smart City Control Room tramite canali autenticati e protetti in HTTPS, in accordo al GDPR (SOURCE: Snap4 City per la creazione di Smart City Control Room, SCCR). Per vedere alcuni esempi di dashboard, puoi visitare il sito https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjU0Mg== (SOURCE: Snap4 City 1st Overview v4 8 annot). Tuttavia, non ho trovato informazioni dettagliate sulla procedura di creazione di una dashboard. Se hai bisogno di ulteriore assistenza, ti consiglio di contattare direttamente il team di supporto di Snap4City. Non so dirti altro in merito.

Write a message...

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

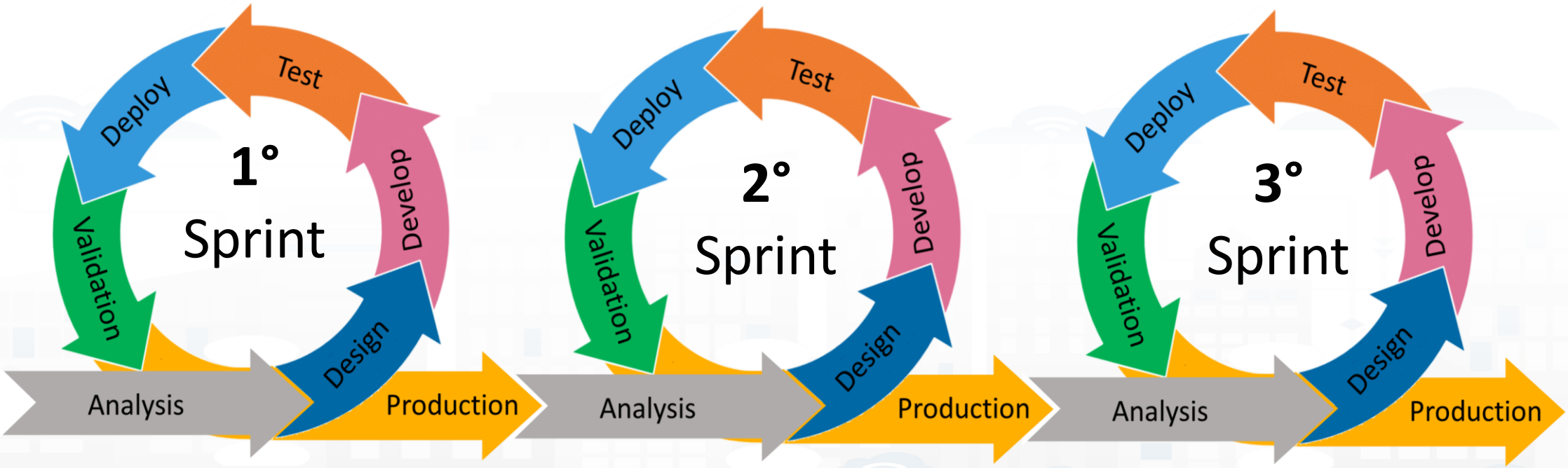


IF you need to go more in deep you can ask us to pass at the next Role becoming full AreaManager with full rights of development, also for Data Analytics, machine learning, etc.

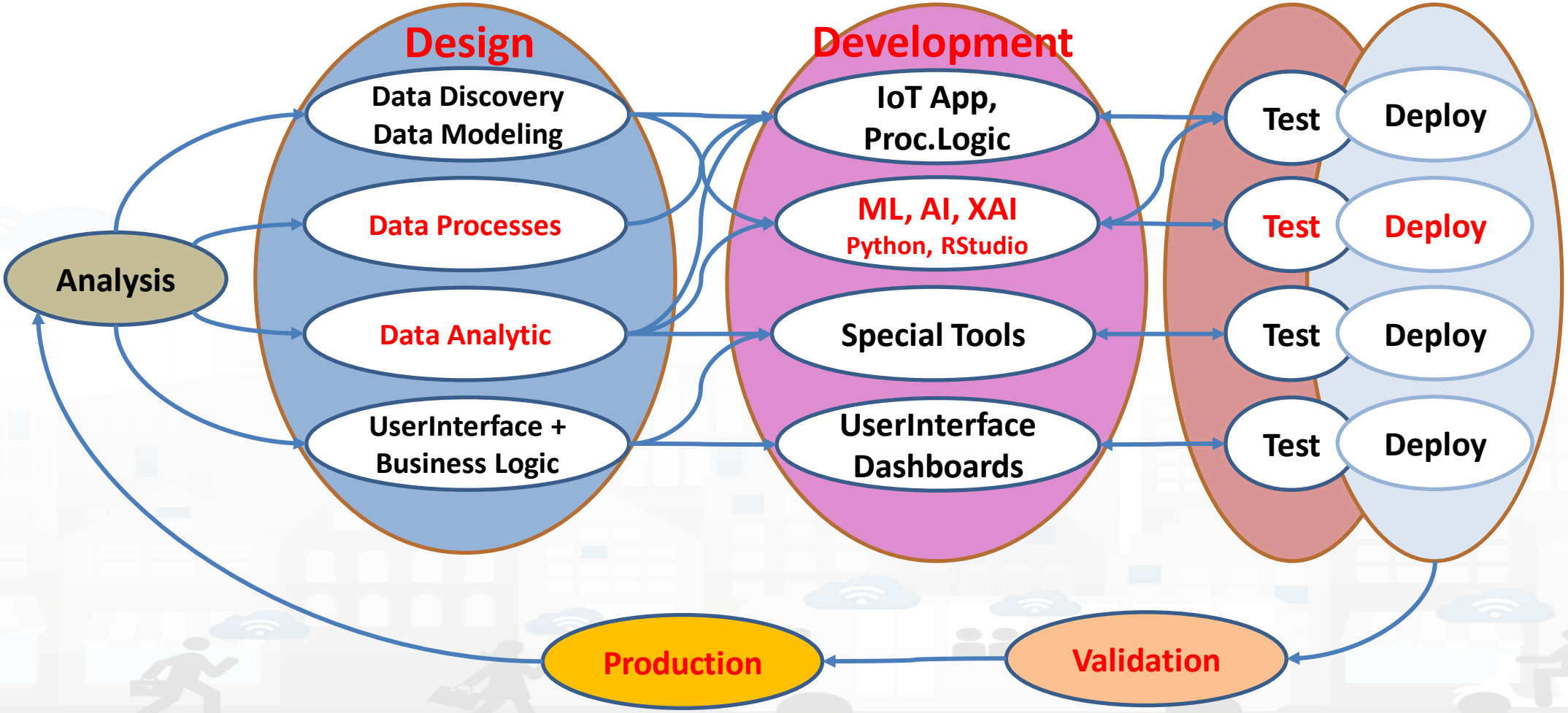
Agenda of forth part

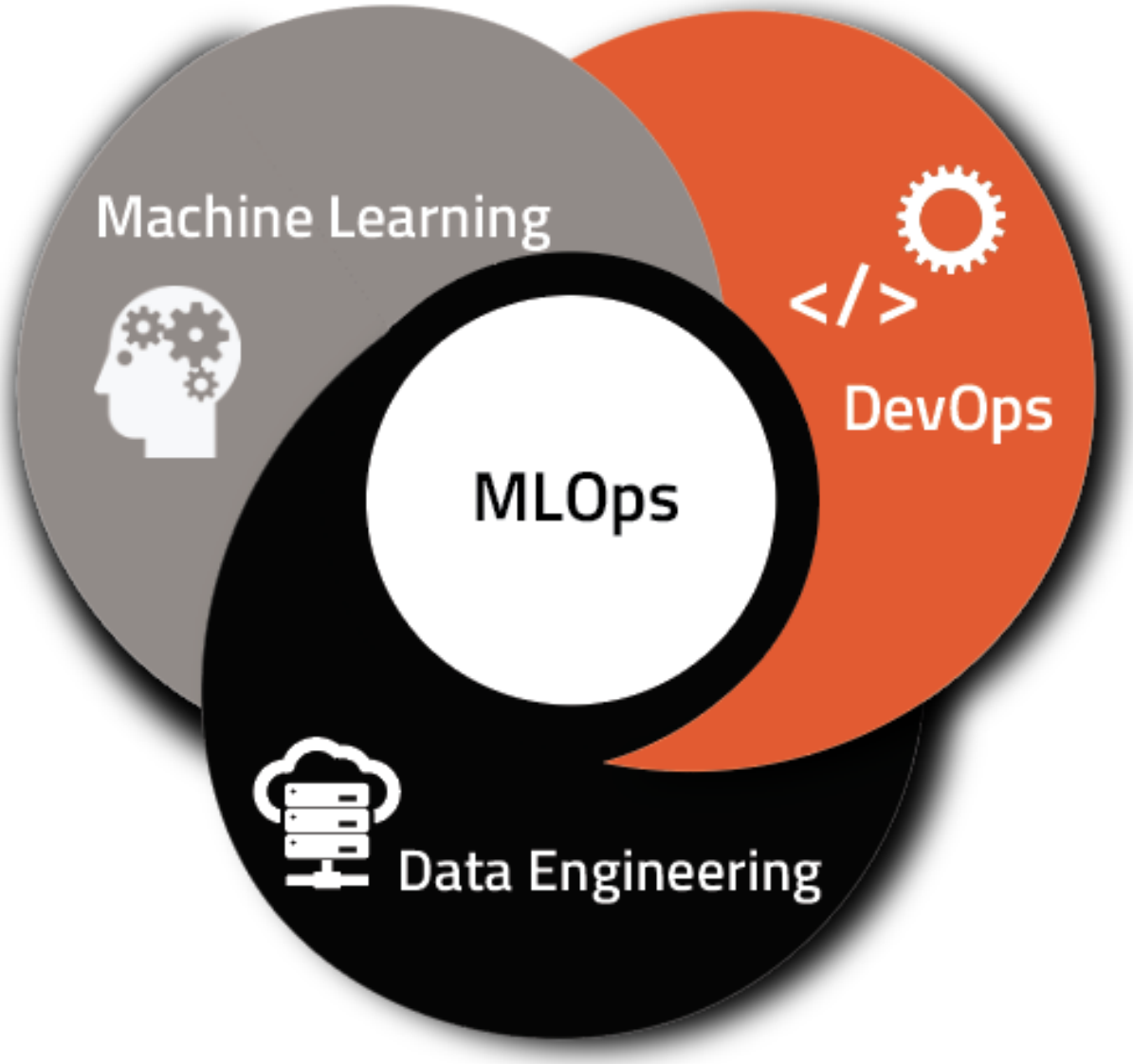
- Why and Where use DA, AI and XAI → General Life Cycle, scenario editor, monitoring and control
- Data Processing: KPI, traffic, emissions, public transport quality, ..
- From Data Analytics, DA to Artificial Intelligence, AI
- List of the most relevant available DA and AI Solutions
- Predictions and Anomaly detections: parking, biking, NOx, landslide, people
- Computing: Higher Level Types Data and their representations: traffic, heatmaps, 3D
- Human Behavior, Engagement, Typical Time trends, WIFI sniffing
- Using AI in main domains: Mobility and transport, traffic optimization, Smart Energy, Smart Building,
- How AI/XAI, and Life Cycle, AI/ML requirements, XAI,
- Using DA, AI/XAI in Snap4City infrastructures
  - Data Analytics ←→ IoT App / Proc.Logic
  - MLOps, ClearML, exploiting clusters of GPU/CPU
- Decision Support Systems and What-If Analysis, transport offer, DORAM tool
- Routing, Multimodal Routing, Dynamic Routing
- Predictive Maintenance
- Training Material

Agile Development Life Cycle by sprint Smart Solutions



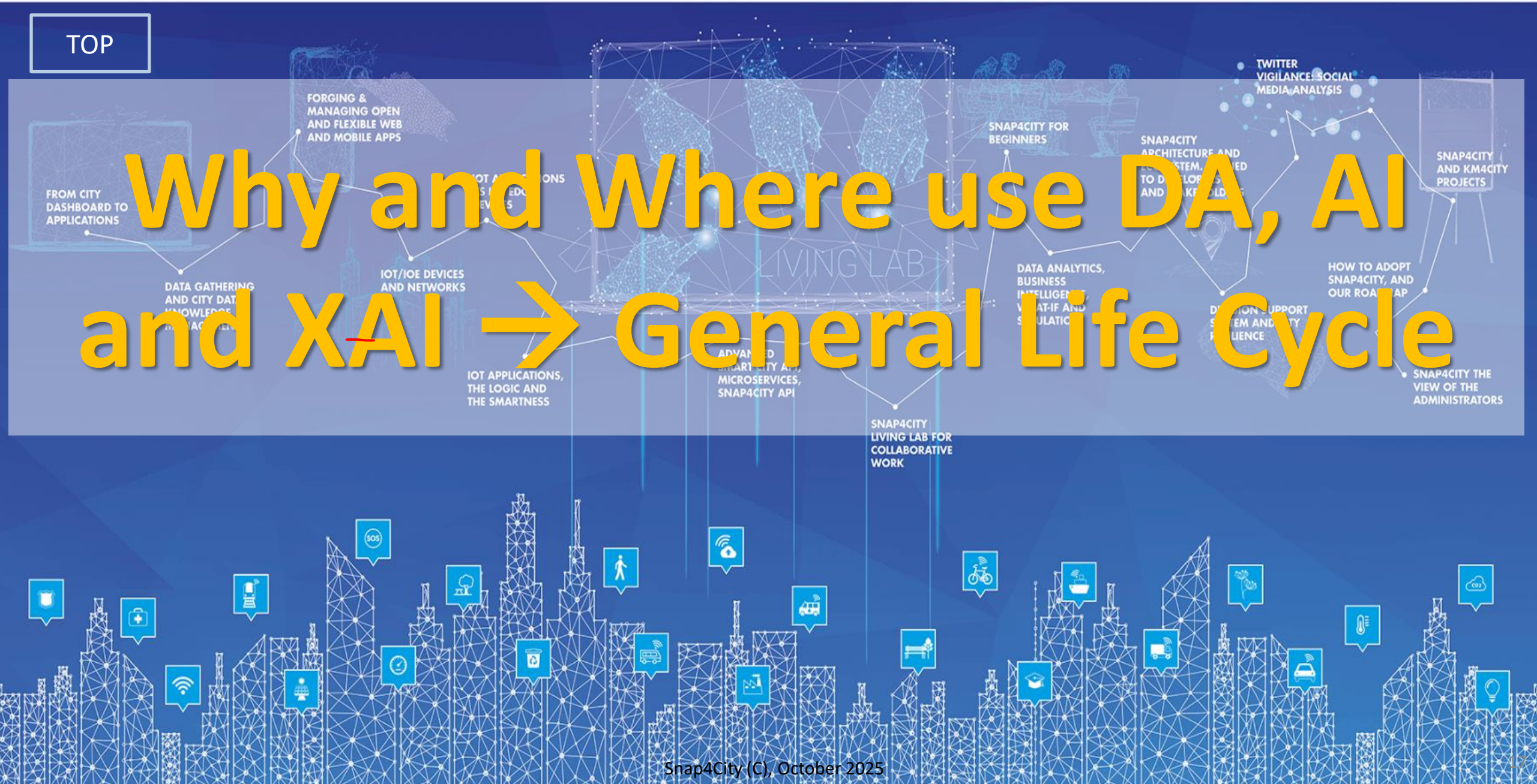
Development Life Cycle Smart Solutions




Machine Learning
DevOps
MLOps
Data Engineering

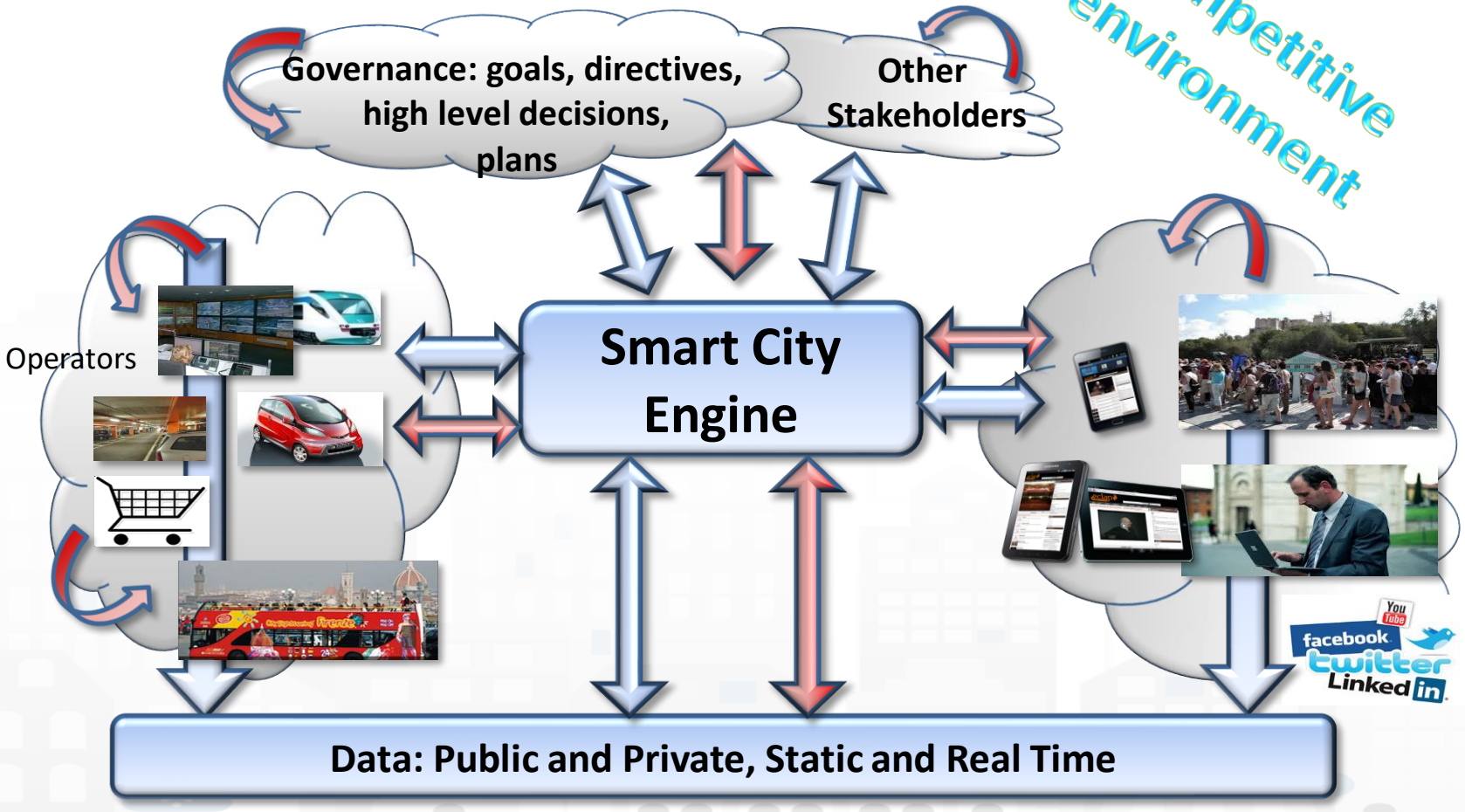
TOP

Why and Where use DA, AI and XAI → General Life Cycle



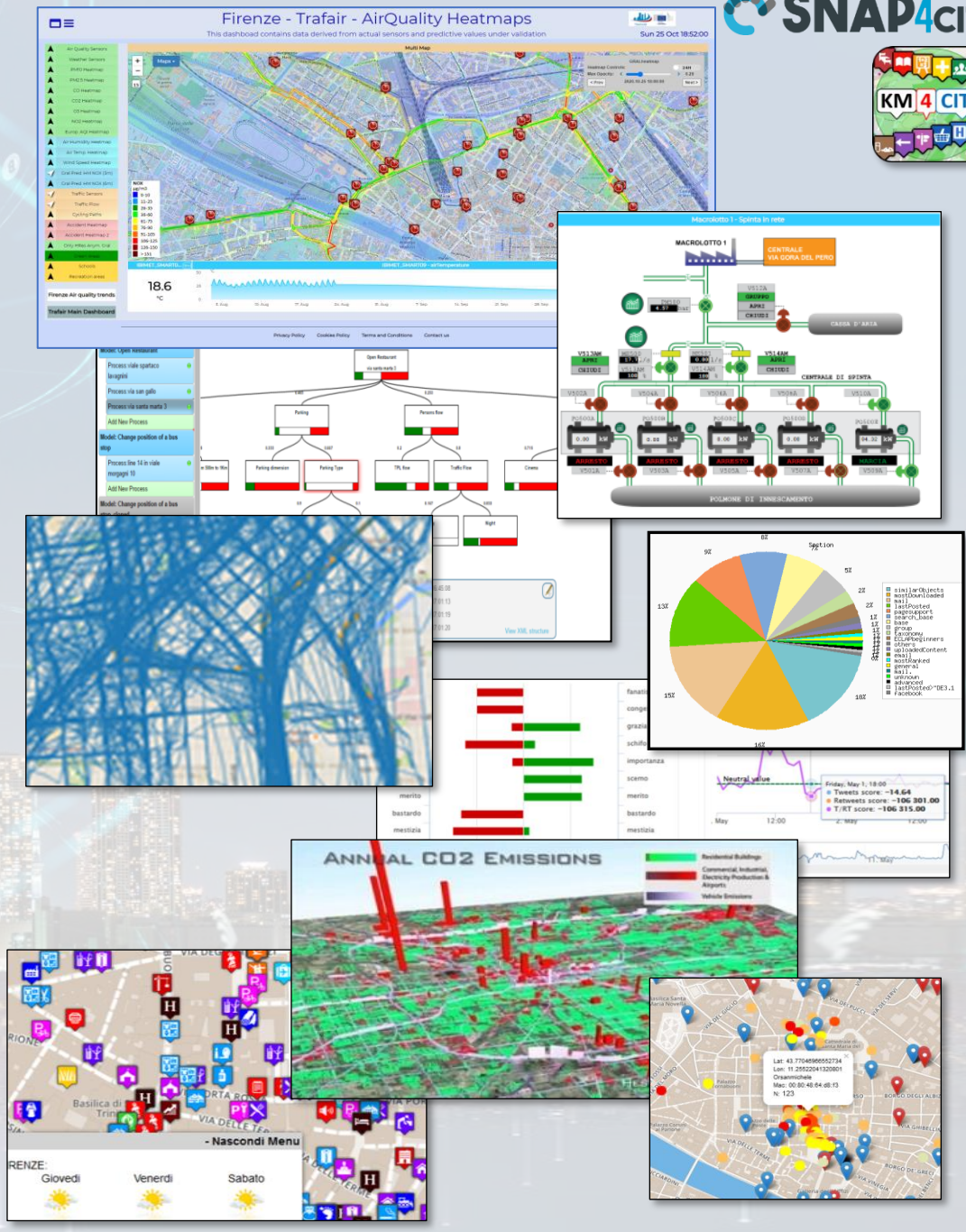
From Strategies to (re-)Actions

- Analyze
- Alerting, Early Warning
- Support Decision makers
- Plans
- Prescriptions
- Inform
- Suggest
- Engage
- Research



Data Driven Decision Support

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



Public Spaces as Critical Infrastructures

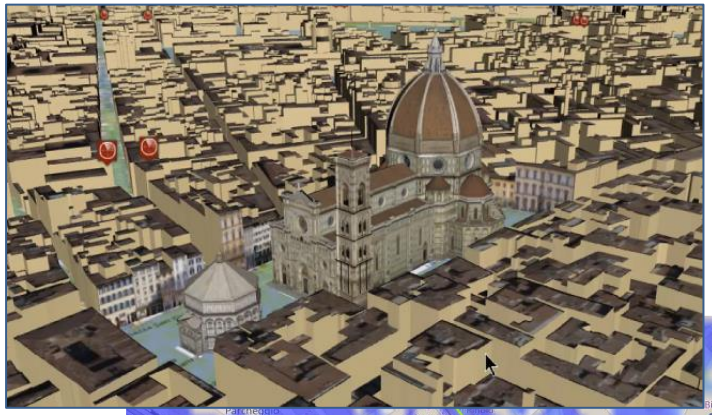
- The City is a system of systems for city users
  - Cascading effects
- **Transport** networks
  - Main means for rescue teams, food, water, etc.
- **Communication**, ICT infrastructure
  - TV cam, switches, cyber,
- **Energy** networks
  - power supply for health, cyber systems, etc.
- **Hospitals** networks
- Aggregation areas

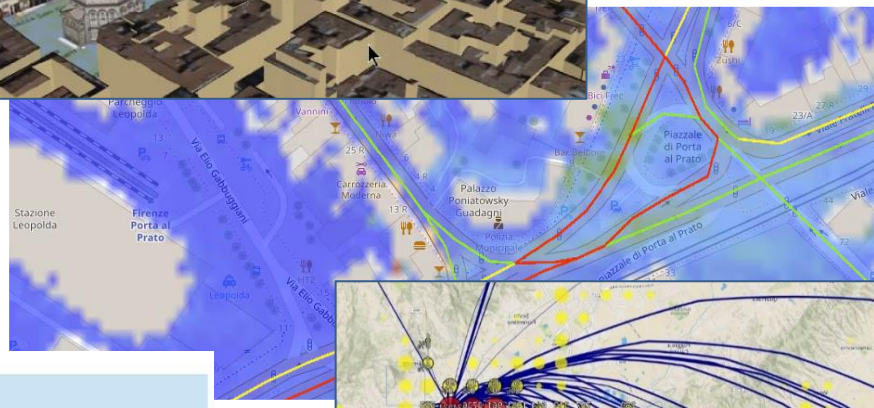


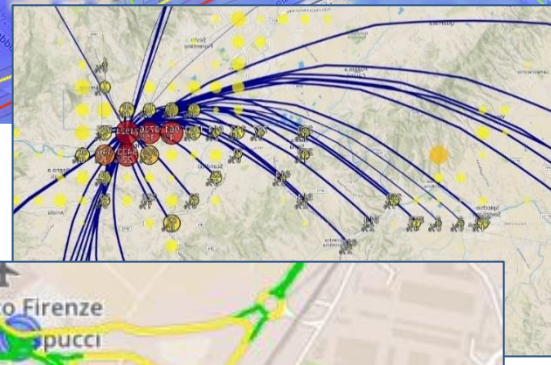
https://www.snap4city.org/download/video/DPL_SNAP4SOLU.pdf

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**





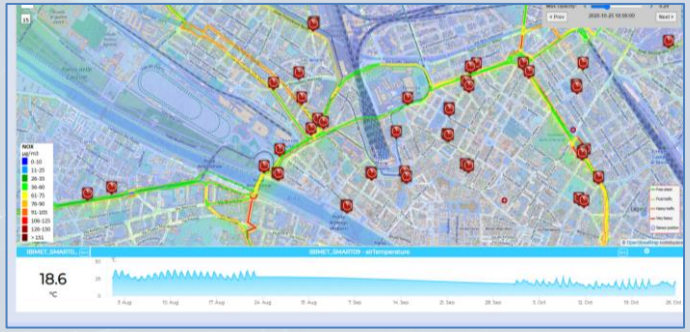




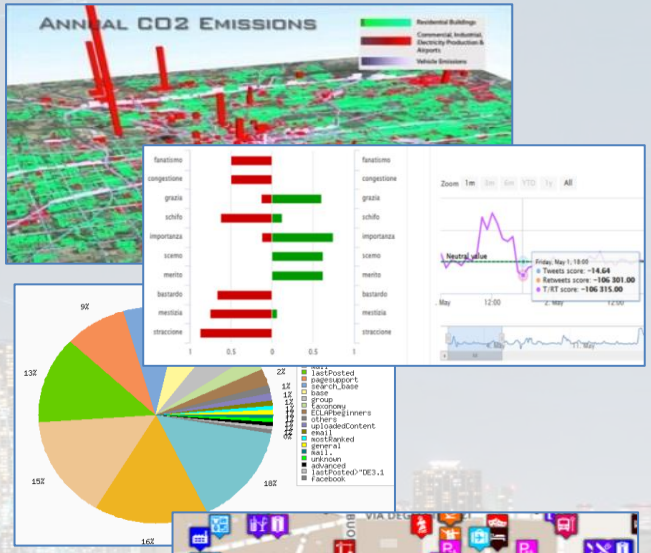


Digital Twin

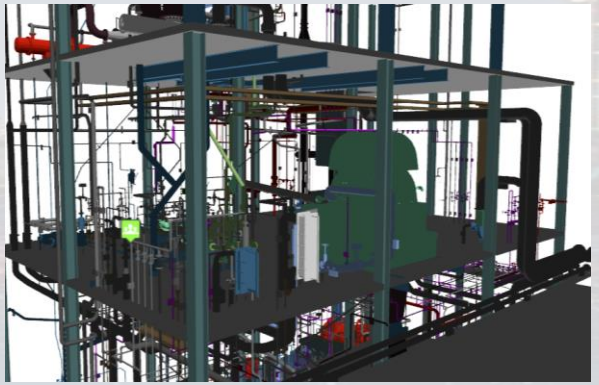
- **Digital Twin**
  - **Connected** with real systems
  - **Modelling** aspects: structural, visual, informative, real time data sensors (context), POI, functional, resources, etc.
  - **Analytics:** AI/XAI techniques, simulations, users' needs, etc.
- **Easier to understand the context, review from multiple points of view**
- **Useful to perform**
  - Discussion with city users
  - Support decision makers
  - By Case Experiments for analysing
    - New solutions, impact of disaster (natural and provoked)
    - Reduction of costs in the analysis, in reduction of mistakes





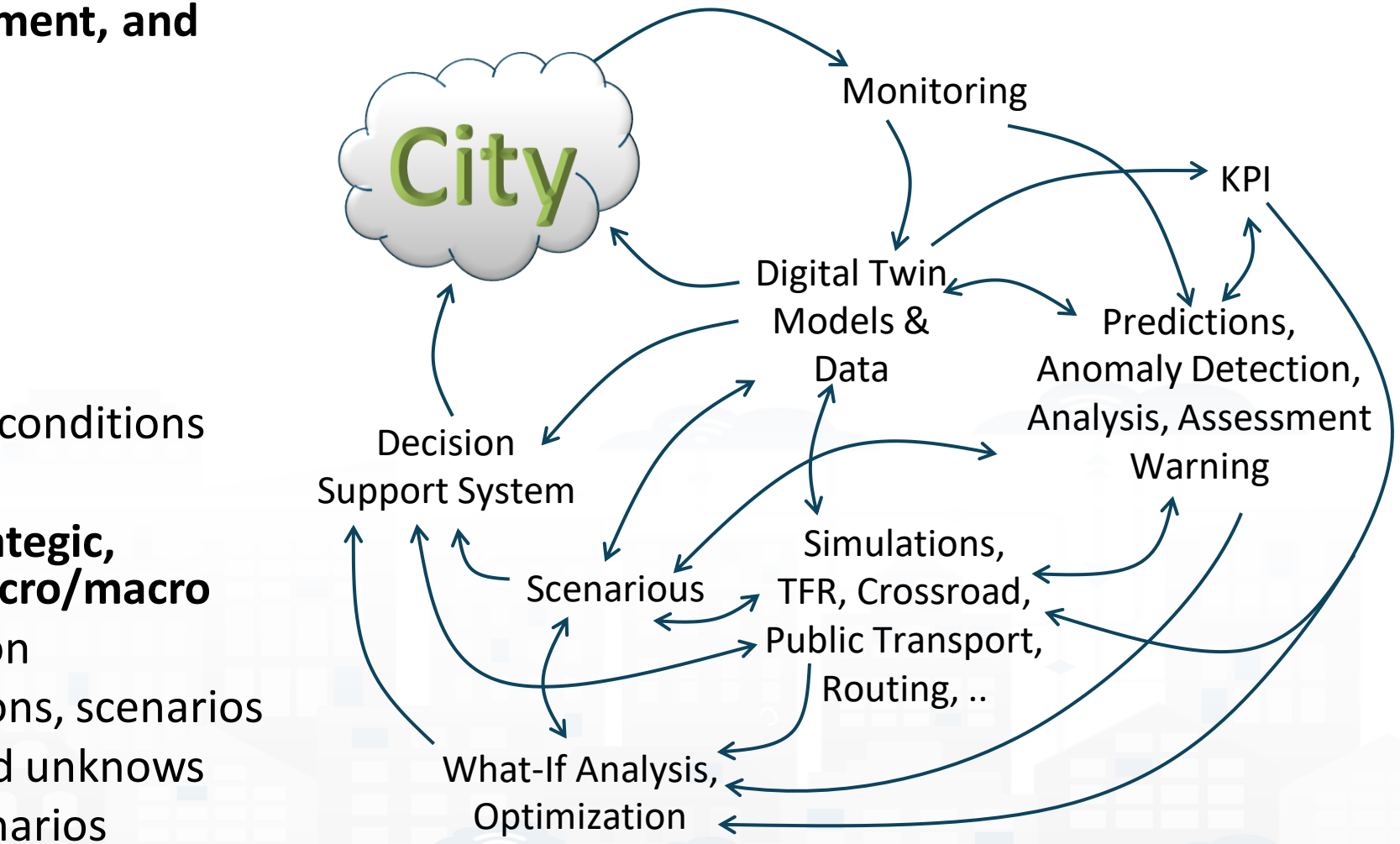






Main tasks

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Early warning on critical conditions
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders





City

Monitoring

KPI

Digital Twin
Models &
Data

Predictions,
Anomaly Detection,
Analysis, Assessment
Warning

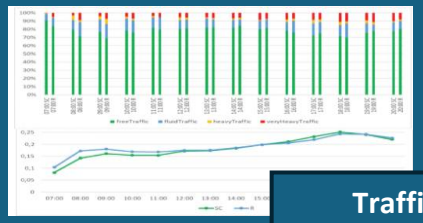
Decision
Support System

Scenarious

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

What-If Analysis,
Optimization

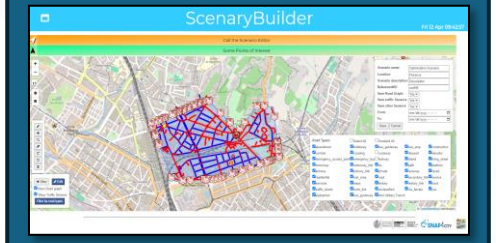
KPI, Predictions, ...



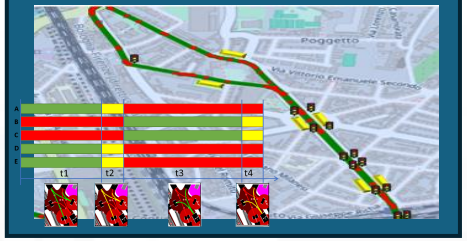
Traffic Reconstruction



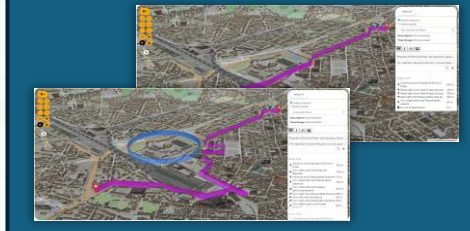
Scenario Editor



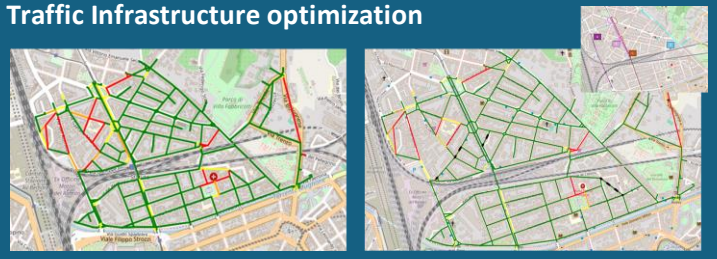
Traffic Light Plan optimization



Routing / Dynamic Routing



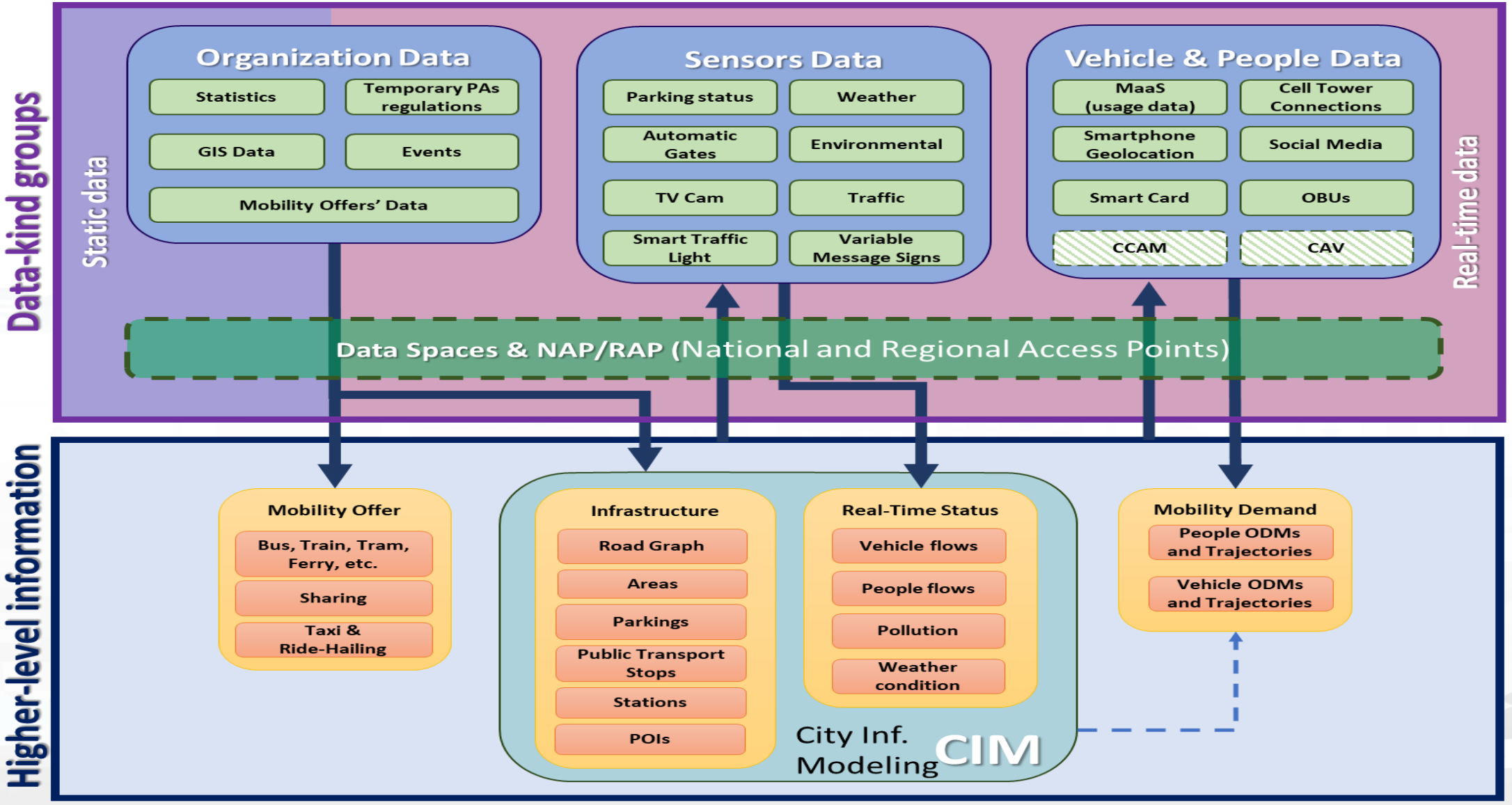
Traffic Infrastructure optimization



Complex Smart Applications

- **Recent solutions**
  - MaaS, sharing, evolution of info-mobility
  - Connected and Autonomous Vehicles/solutions
  - Integrated Energy & Environmental applications
  - Etc.
- **Most of them share the same modules, differently implemented and combined, but the same modules**
  - Real time data gathering and derived info distribution
  - Predictive and/or simulative models, on edge or cloud
  - Data gathering + monitoring + plan + rendering: dashboard, visual analytics, mobile apps

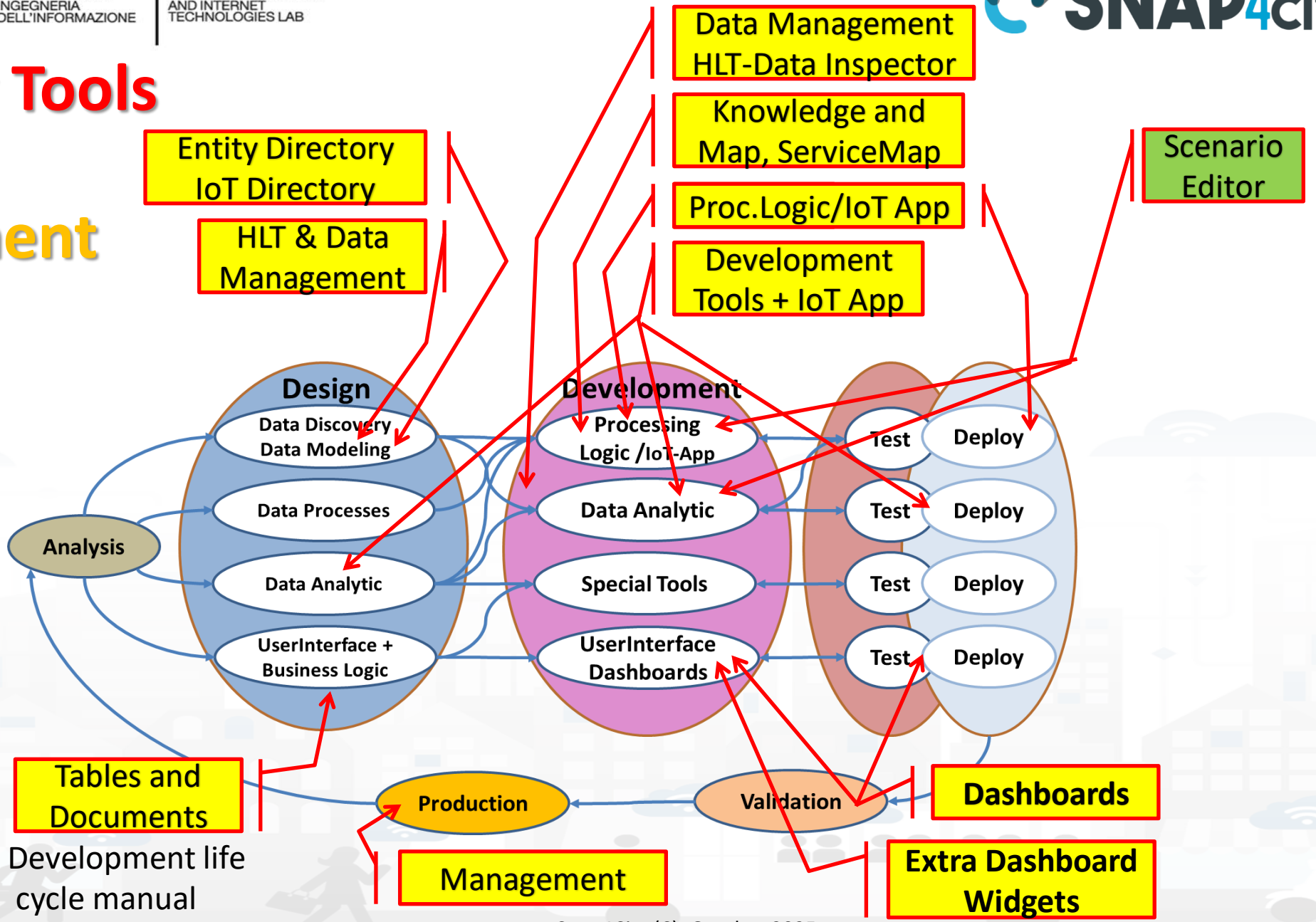
From data to higher level information: Mob.Dom.



Scenario Editor:
Snap4City Infrastructures

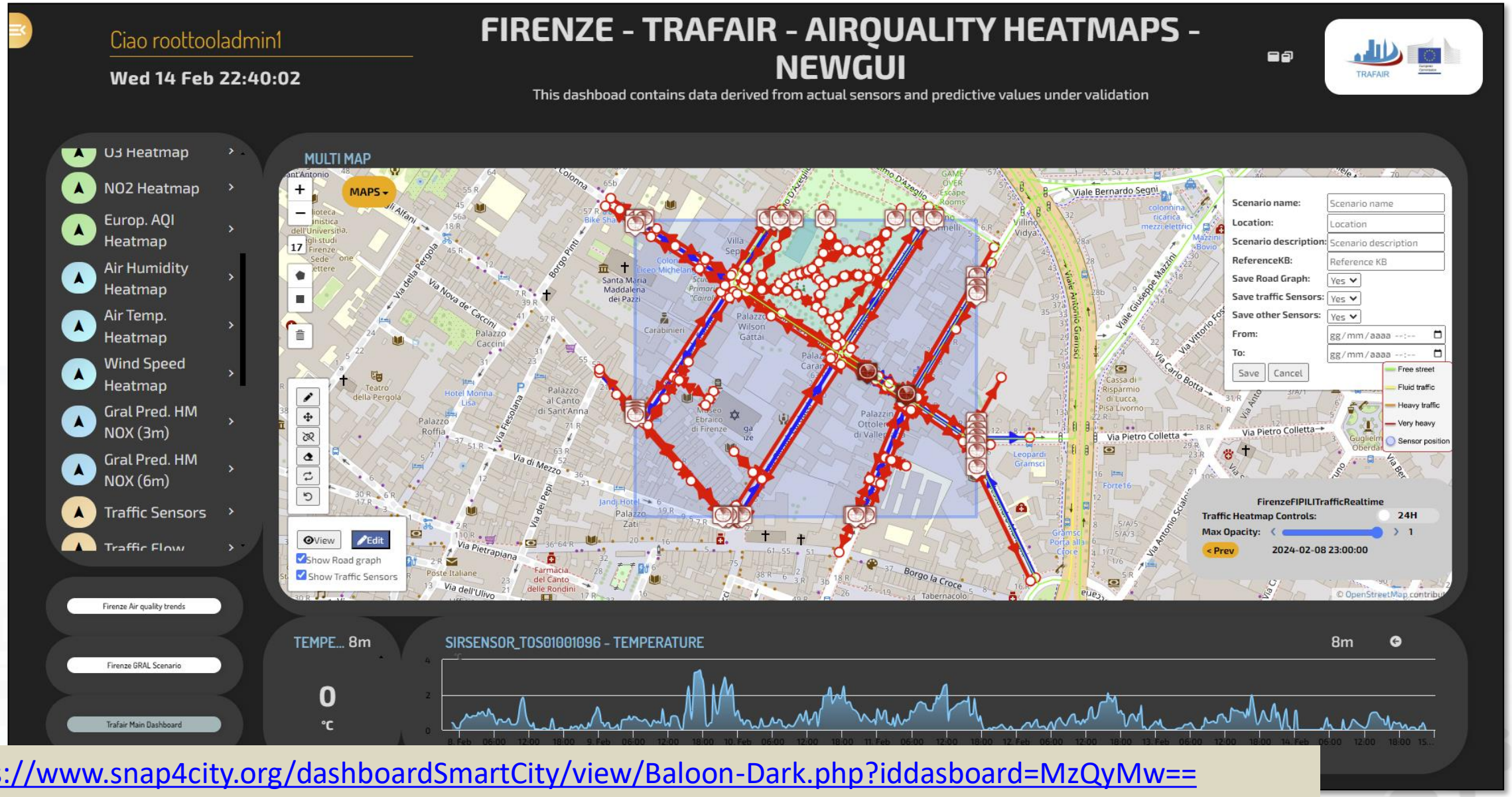


Snap4City Tools vs Development Life Cycle



Development life cycle manual

Trial:



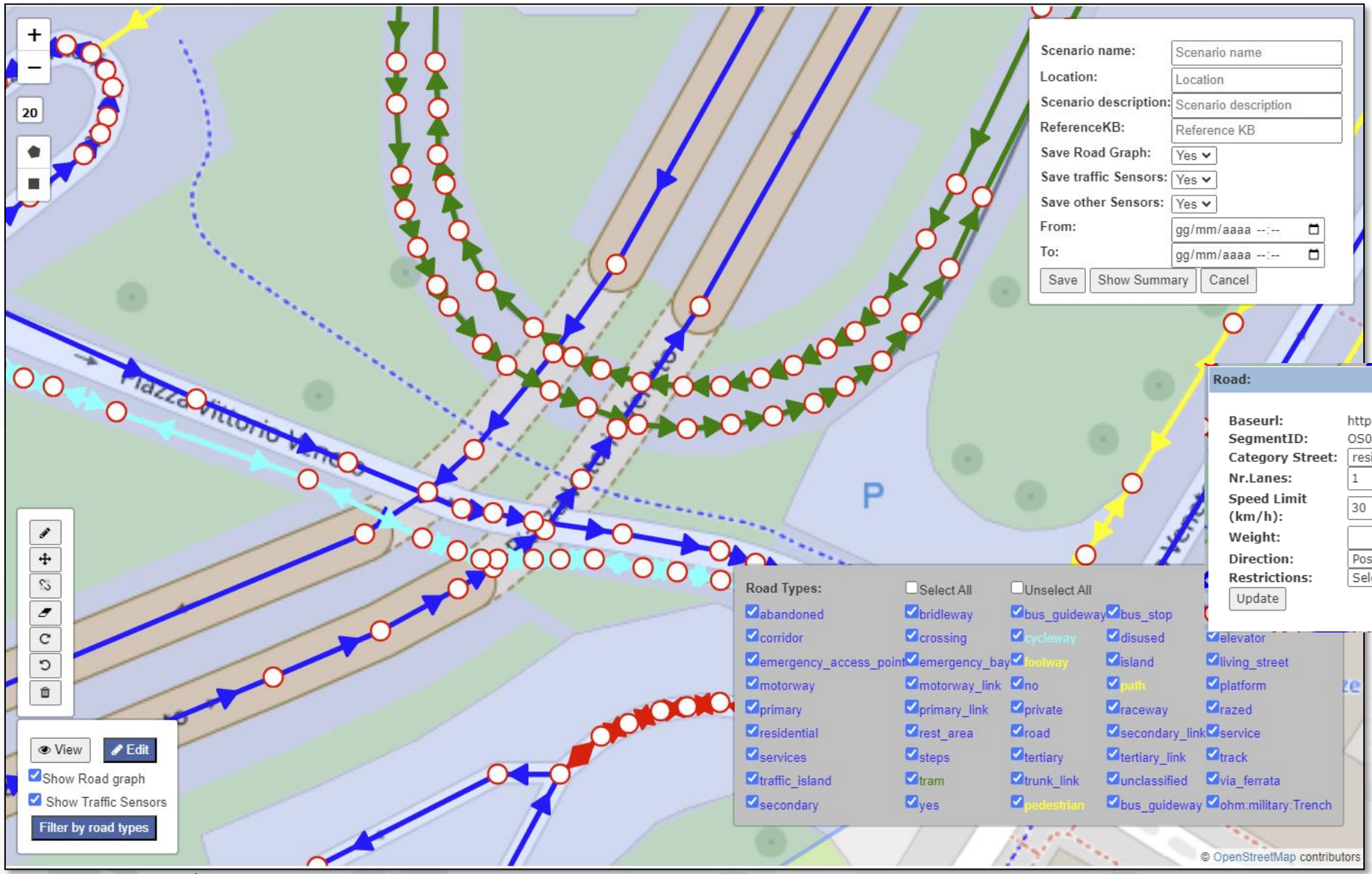
https://www.snap4city.org/dashboardSmartCity/view/Baloon-Dark.php?iddasboard=MzQyMw==

Scenario Editor

Zoom/Pan

Select map

New Scenario
- Editing
  - Drag & drop
  - Split & Join
  - Delete
  - Do and Undo



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

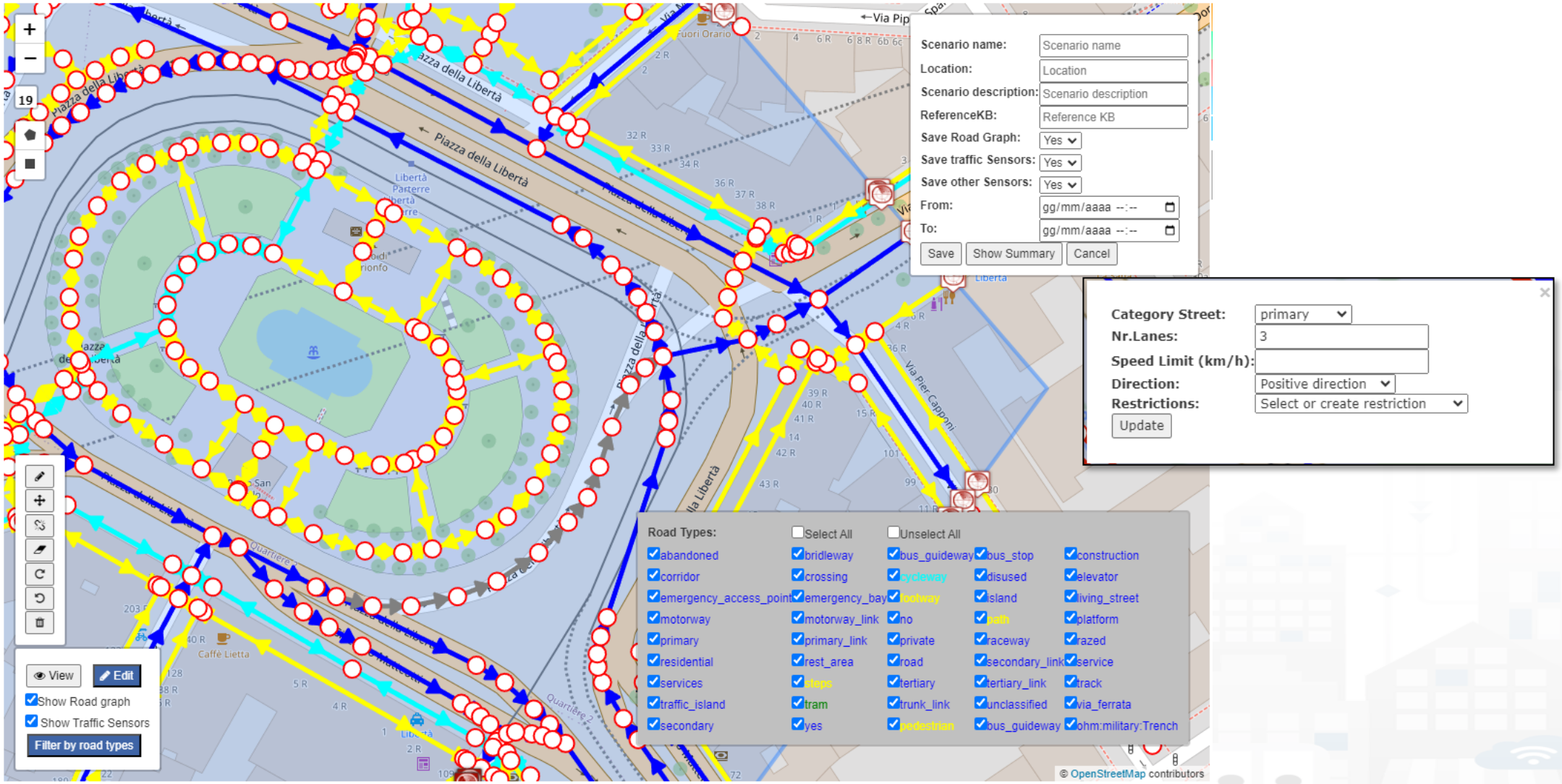
Edit Road Segment

Properties of Road Elements

https://www.snap4city.org/976

Scenario Data and Scenario Editor

- A Scenario is saved over time as a Time Series which represent it versions, each version can be in INIT or ACC status:
  - The Scenario Editor works on INIT and ACC status only so far
- **INIT scenarios** provide:
  - Road Graphs (graph of any kind of road (according to the user selection), restrictions, length, weights, lanes, kinds, etc..), sensors at the border (which can be Virtual Sensors, associated with TTT or actual sensors), internal sensors/entities or POI of any kind
- **AC/ACC scenarios** (created by a specific tool) provide:
  - All the INIT info plus: straight simplified graph from junctions, road Weights for TDM, and a graph called JS20 with road segments of 20m, eventual road splitting of bidirectionals.
- **Each Scenario version** is loaded as an Entity plus a BigData information which are stored in separated data storage.


Scenario name:
Location:
Scenario description:
ReferenceKB:
Save Road Graph:
Save traffic Sensors:
Save other Sensors:
From:
To:
Save
Show Summary
Cancel
Category Street:
primary
Nr.Lanes:
3
Speed Limit (km/h):
Direction:
Positive direction
Restrictions:
Select or create restriction
Update
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
View
Edit
Show Road graph
Show Traffic Sensors
Filter by road types
© OpenStreetMap contributors

Trial:

Firenze - Trafair - AirQuality Heatmaps

This dashboad contains data derived from actual sensors and predictive values under validation

Wed 14 Feb 22:41:17

- Air Quality Sensors
- PM10 bars
- Weather Sensors
- PM10 Heatmap
- PM2.5 Heatmap
- CO Heatmap
- CO2 Heatmap
- O3 Heatmap
- NO2 Heatmap
- Europ. AQI Heatmap
- Air Humidity Heatmap
- Air Temp. Heatmap
- Wind Speed Heatmap
- Gral Pred. HM NOX (3m)
- Gral Pred. HM NOX (6m)
- Traffic Sensors
- Traffic Flow
- Traffic Flow Manager New
- Cycling Paths
- Accident Heatmap
- Accident Heatmap 2
- Only HRes Anym. Gral
- Green Areas
- Schools
- Recreation areas
- Cultural POI
- new scenario
- ODM Area-grids

Firenze Air quality trends

Firenze GRAL Scenario

Trafair Main Dashboard

Multi Map

Maps

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

GRALheatmap — Heatmap Controls: 24H — Max Opacity: 0.25 — < Prev — 2024-02-14 23:00:00

FirenzeFIPILITrafficRealtime — Traffic Heatmap Controls: 24H — Max Opacity: 1 — < Prev — 2024-02-08 23:00:00

Free street, Fluid traffic, Heavy traffic, Very heavy, Sensor position

© OpenStreetMap contributors

SMART04 — 20.6 °C

SMART04 - airTemperature

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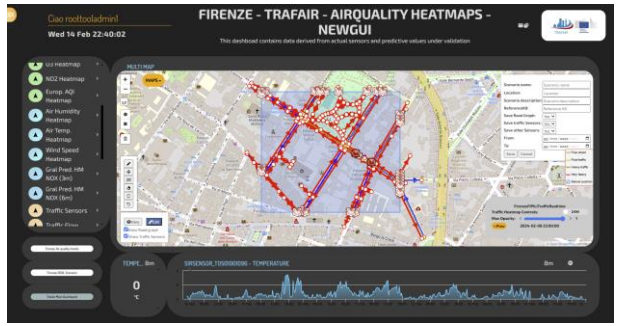
https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTUzMg==

The actual Scenario Exploitation





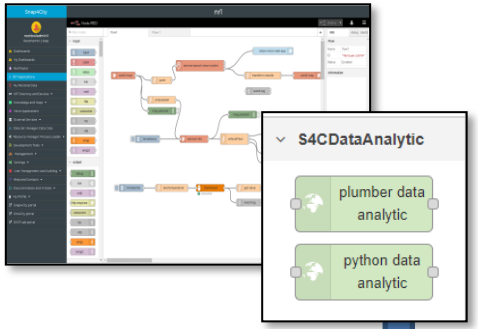
Defining Context via Editing Scenario:

- Select area and data
- Editing roads, POI, IoT entities, ..
- Save/load, share
- Change status



A Scenario includes:

- Metadata as Entity/Device
  - Status and versions, date time
  - Period of validity
- Big data:
  - Road graphs, cycling, pedestrian seg.
  - List of data, sensors
- Etc.

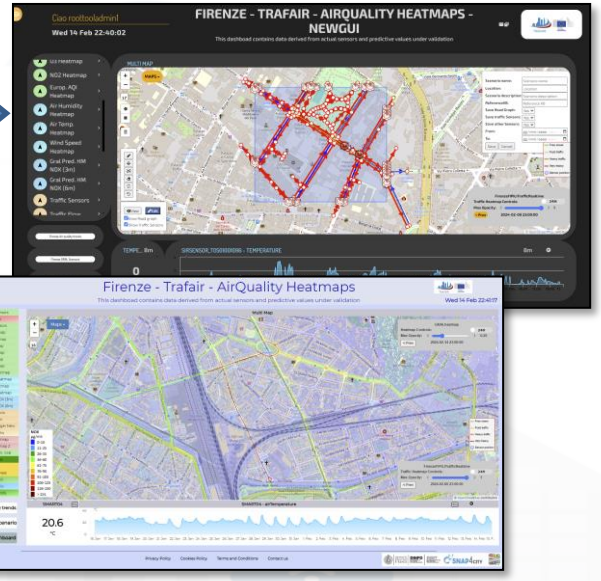


Computing in the Scenario Context as:

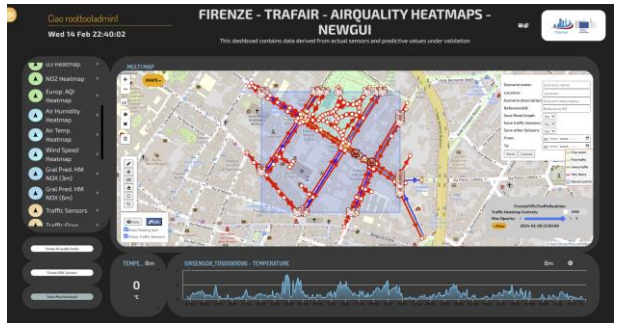
- KPI, Metrics, SUMI, SUMP, 15MinCity Index
- Heatmaps
- OD Matrices
- Traffic Flow reconstructions
- Predictions
- Routing, constrained routing
- Early Warnings
- Etc.

ReLoading Scenario in JavaScript

- Evolve Scenarios
- Use Scenario to context the Data Analytics: R Studio, Python for computing



The CSBL Scenario Exploitation





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- Select area and data
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- Save/load, share
- Change status



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  - Status and versions, date time
  - Period of validity
- Big data:
  - Road graphs, cycling, pedestrian seg.
  - List of data, sensors
- Etc.



CSBL

S4CDataAnalytic

Computing in the Scenario Context as:

- KPI, Metrics, SUMI, SUMP, 15MinCity Index
- Heatmaps
- OD Matrices
- Traffic Flow reconstructions
- Predictions
- Routing, constrained routing
- Early Warnings
- Etc.

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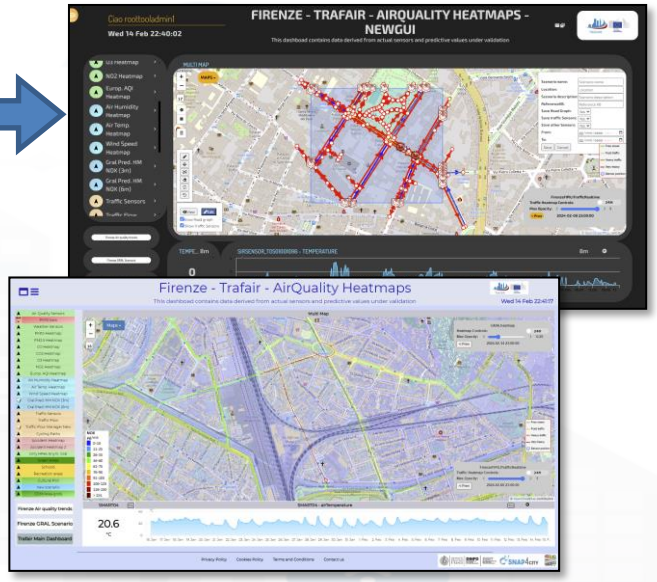
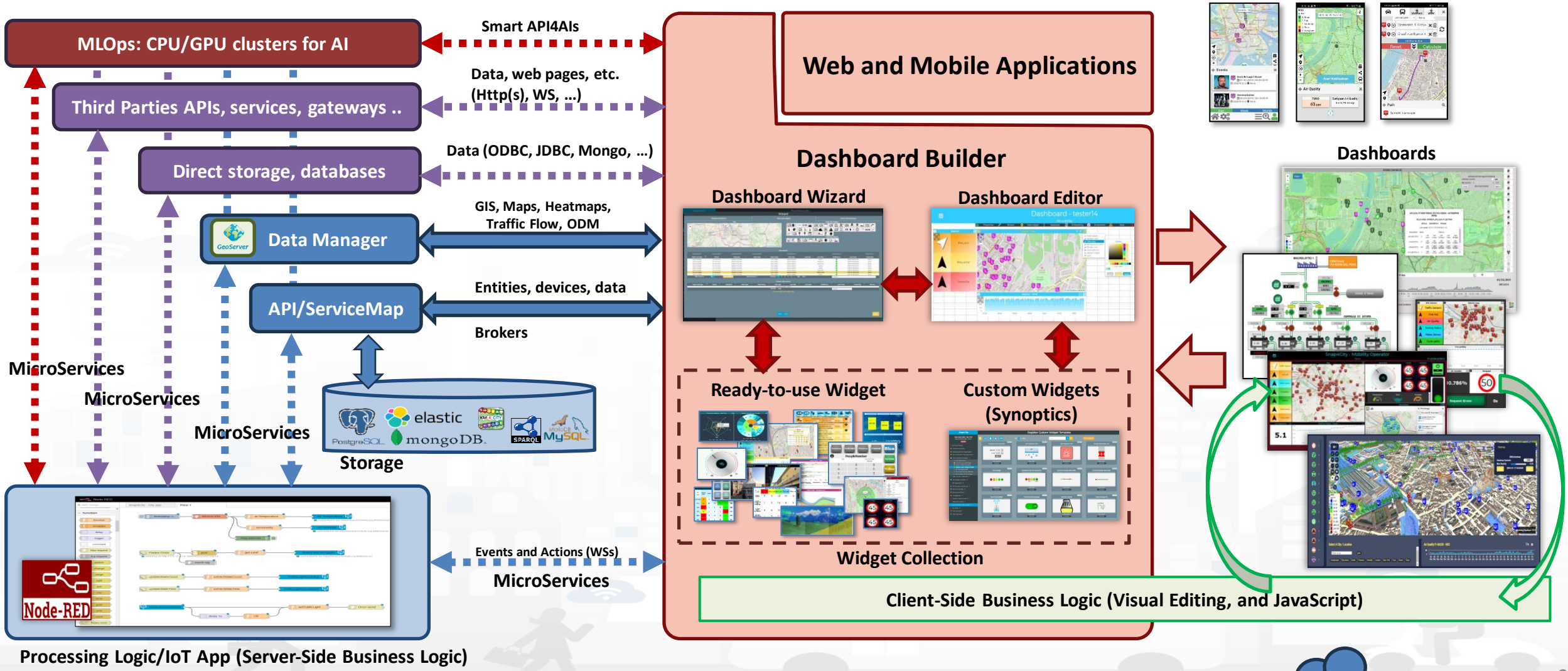


How the Dashboards / Apps Exchange data (2024/8)

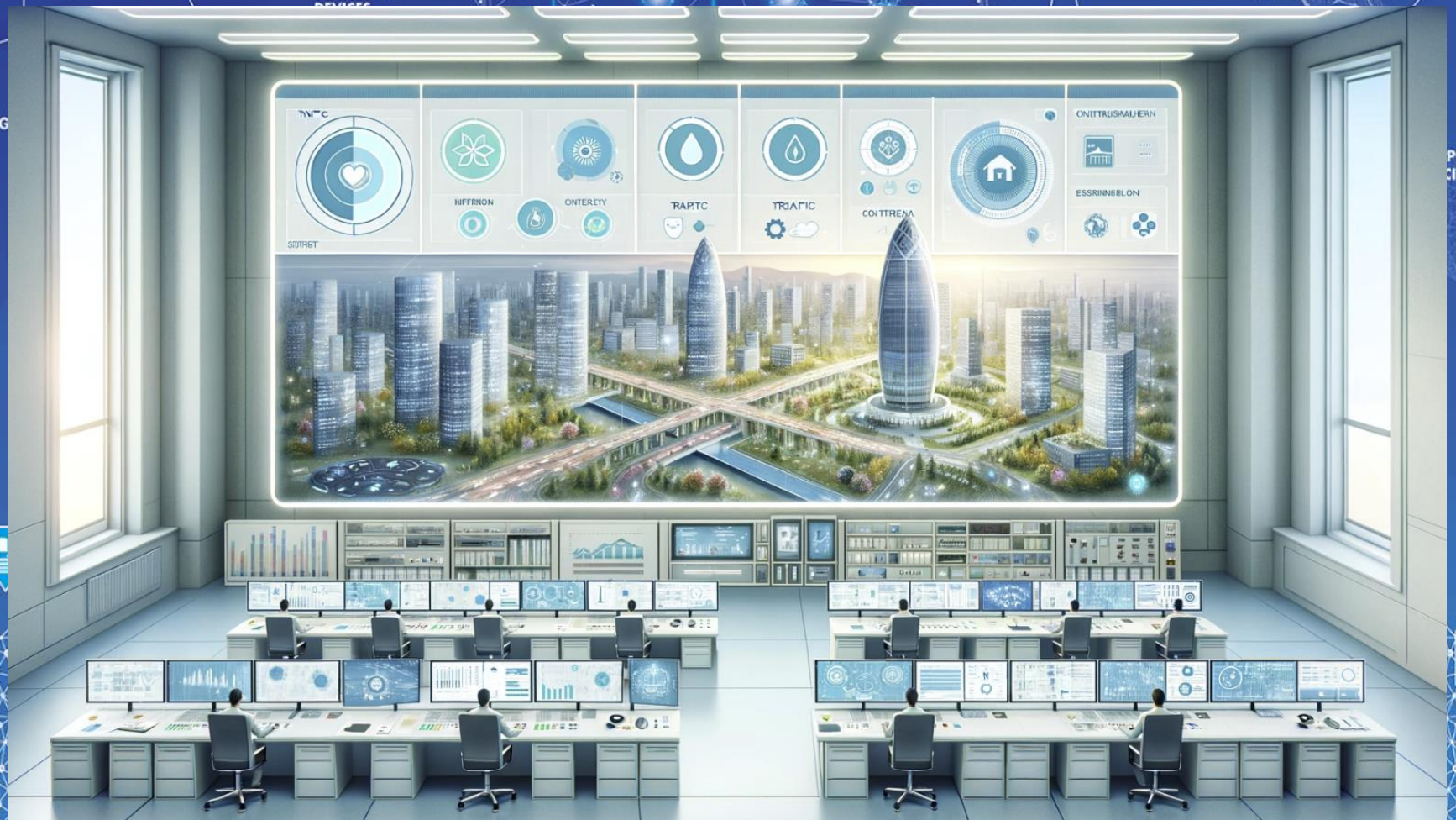


What you can do with advanced tools

- Basic Scenario editor
  - Single and multiple blocked areas, which can be share among users
- What-if analysis tool
  - Ready to use tools for exploiting Basic Scenarios as blocked areas and simulating/computing in real time routing, in different traffic conditions
- Advanced Scenario Editor
  - Create complex and full detailed scenario, with road graph, sensors, of any kind, even new roads, restrictions, parameters, etc.
  - Exploit these scenarios to create
    - Simulation
    - Business intelligence tools and visual/business analytic tools also working in eal time
    - Traffic flow reconstruction
    - Traffic infrastructure optimisation
    - Traffic light plan optimization
    - Pedestrian analysis and simulation
    - Match demand vs Offer, simulation and analysis
    - Computation of SUMI, SUMP, 15 Min City Indexes, etc.
    - Heatmaps computation
    - Etc. etc.

TOP

Monitoring and control



FROM CITY DASHBOARD TO APPLICATIONS

DATA GATHERING AND CITY DATA KNOWLEDGE MANAGEMENT

IOT APPLICATIONS VS IOT EDGE

TWITTER VIGILANCE: SOCIAL MEDIA ANALYSIS

TO DEVELOPERS AND STAKEHOLDERS

SNAP4CITY AND KM4CITY PROJECTS

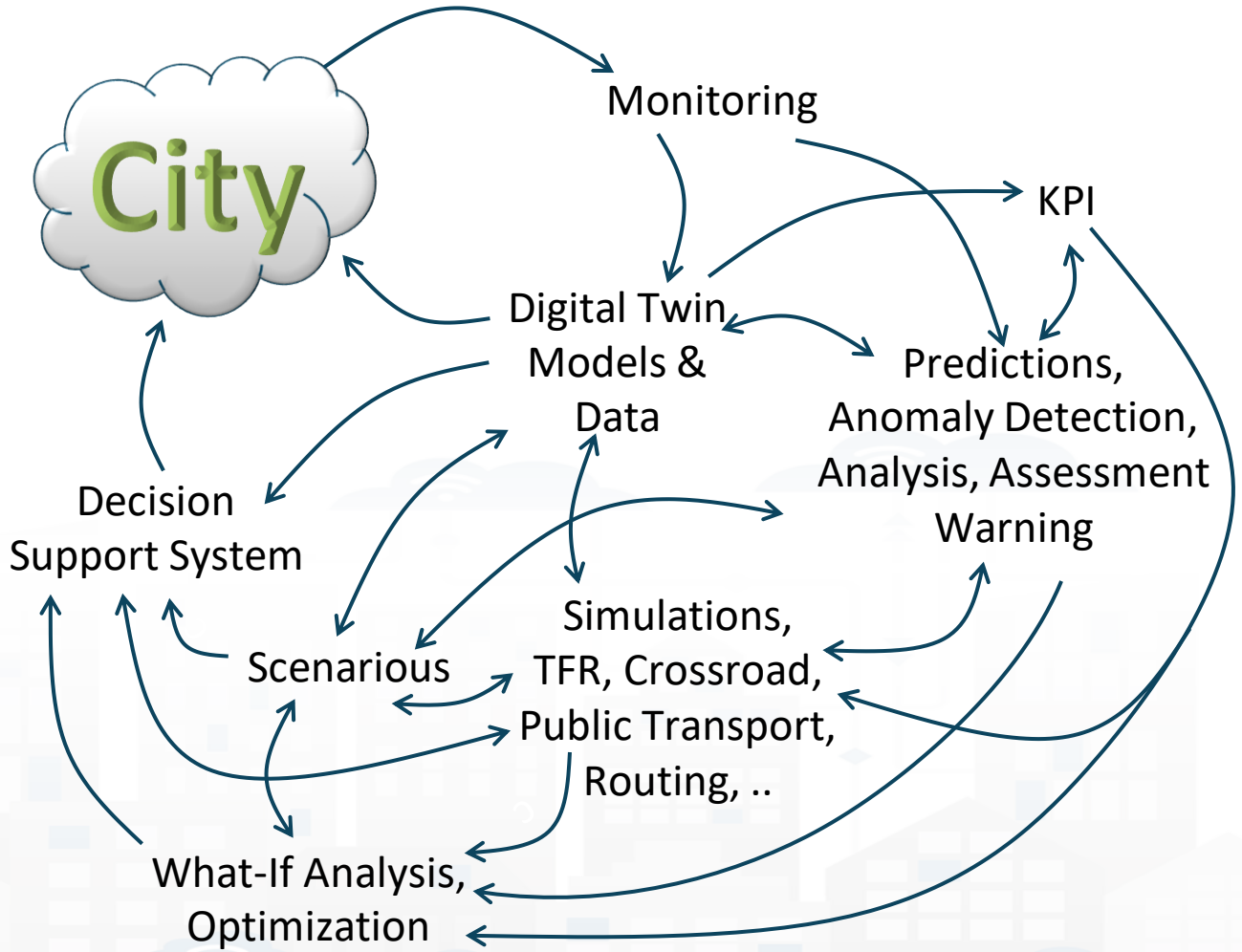
HOW TO ADOPT SNAP4CITY, AND OUR ROADMAP

SNAP4CITY THE VIEW OF THE ADMINISTRATORS

100% OPEN SOURCE

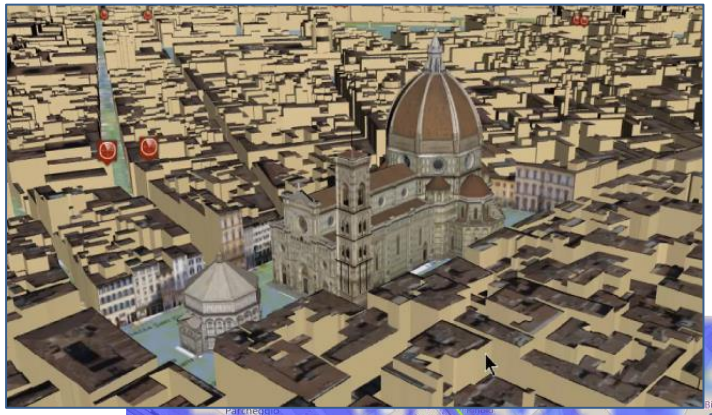
Main tasks

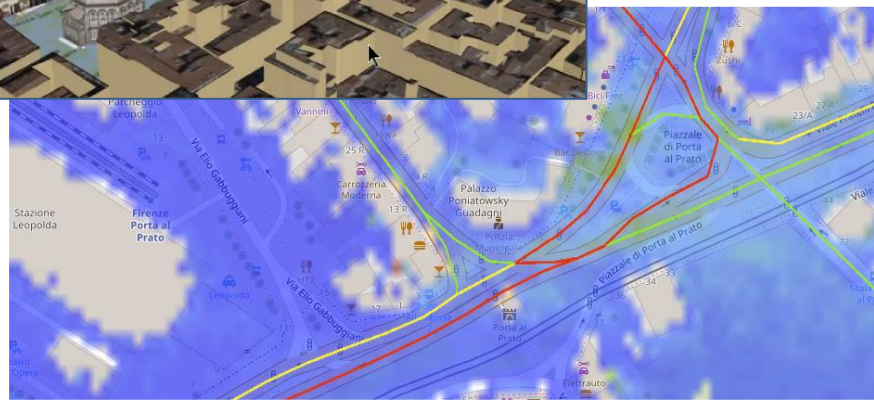
- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Early warning on critical conditions
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders



Monitoring

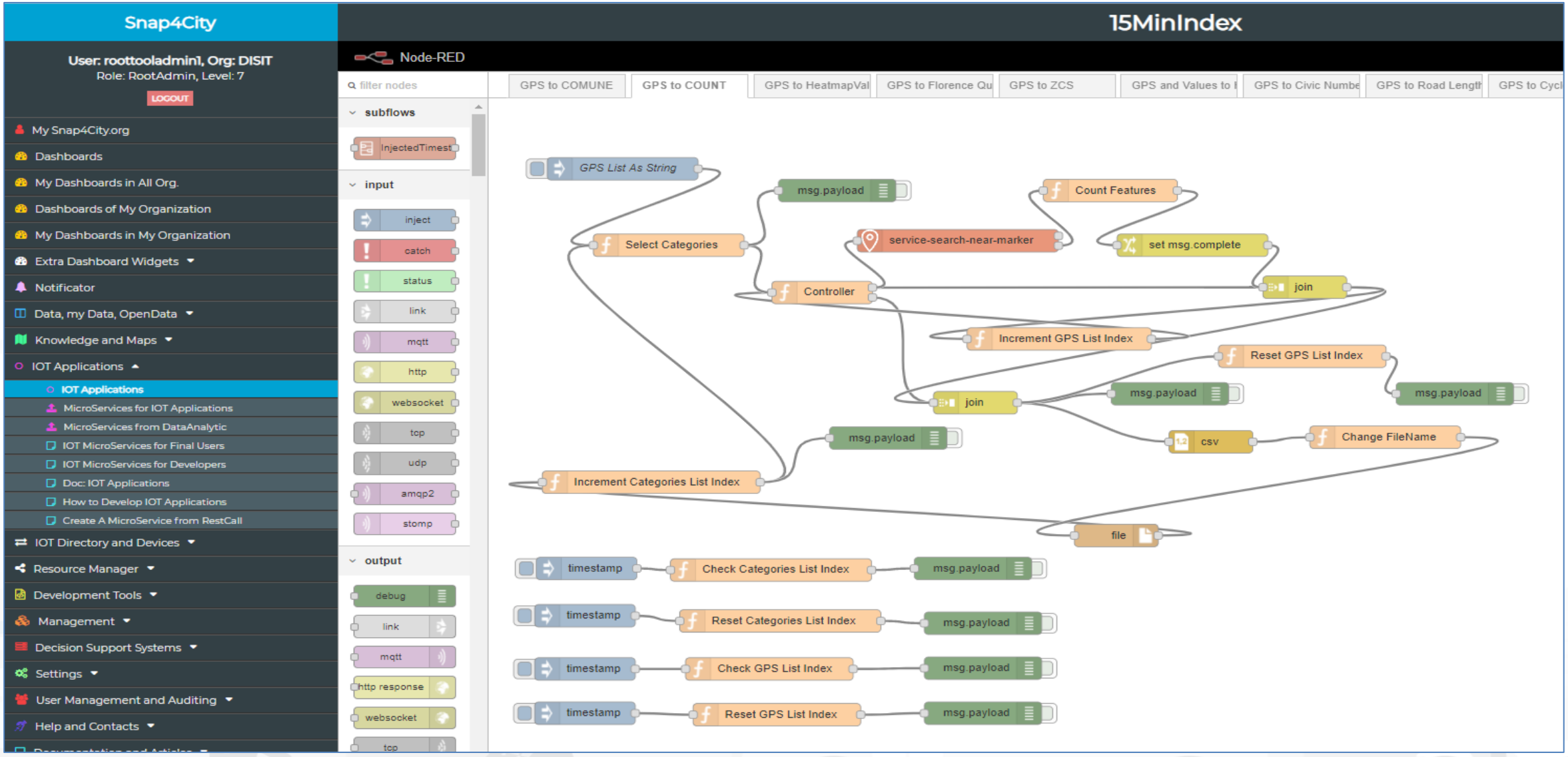
- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Computing predictions and KPI
  - Anomaly detection, Early warning
  - Control Rooms, situation rooms
- **Reacting: Computing in real time**
  - Changing semaphore maps
  - Changing Dynamic signage
  - Real time Info Mobility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





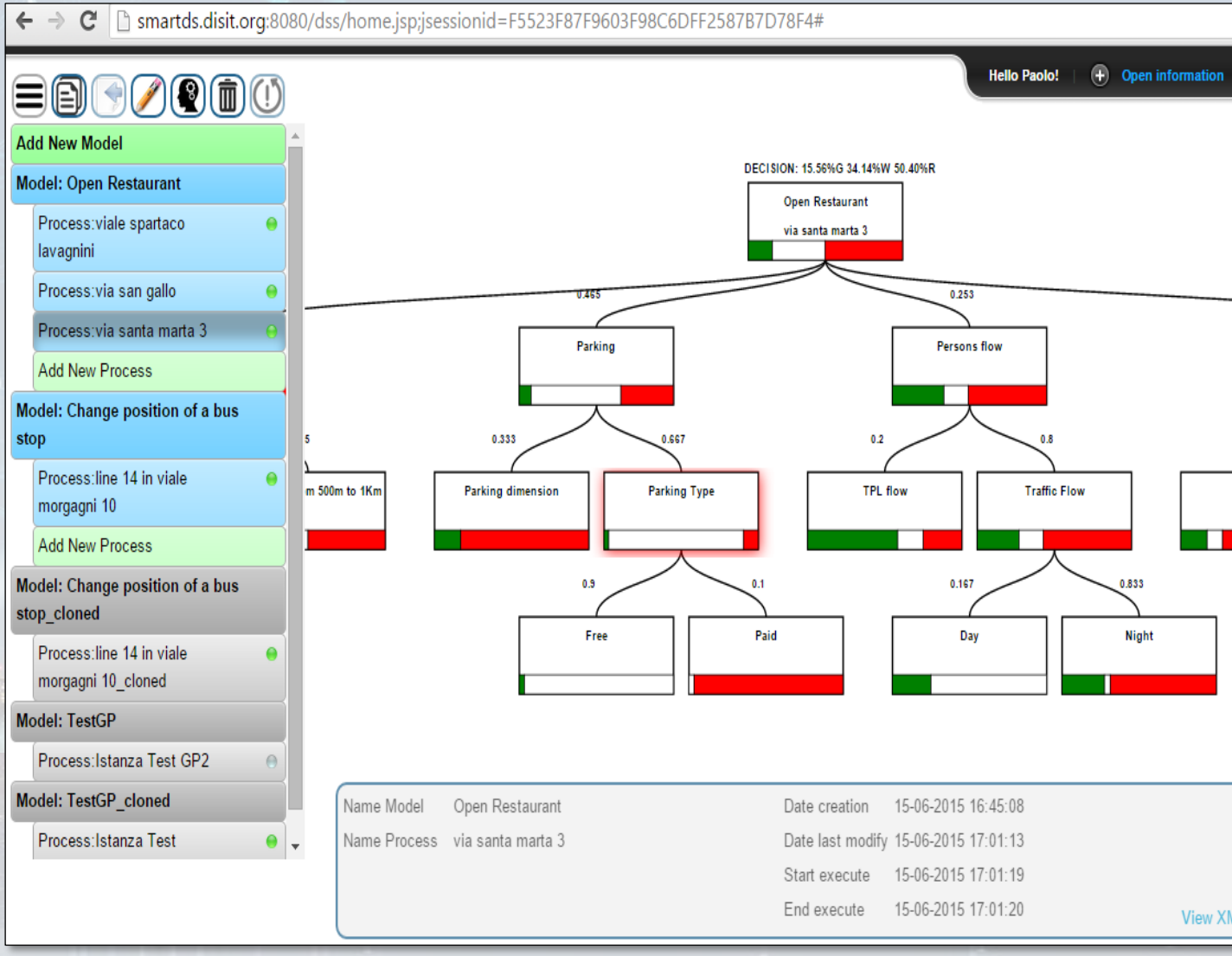


IoT App....


Snap4City
User: roottooladmin1, Org: DISIT
Role: RootAdmin, Level: 7
LOGOUT
My Snap4City.org
Dashboards
My Dashboards in All Org.
Dashboards of My Organization
My Dashboards in My Organization
Extra Dashboard Widgets
Notificator
Data, my Data, OpenData
Knowledge and Maps
IOT Applications
IOT Applications
MicroServices for IOT Applications
MicroServices from DataAnalytic
IOT MicroServices for Final Users
IOT MicroServices for Developers
Doc: IOT Applications
How to Develop IOT Applications
Create A MicroService from RestCall
IOT Directory and Devices
Resource Manager
Development Tools
Management
Decision Support Systems
Settings
User Management and Auditing
Help and Contacts
15MinIndex
Node-RED
filter nodes
subflows
InjectedTimest
input
inject
catch
status
link
mqtt
http
websocket
tcp
udp
amqp2
stomp
output
debug
link
mqtt
http response
websocket
tcp
GPS to COMUNE
GPS to COUNT
GPS to HeatmapVal
GPS to Florence Qu
GPS to ZCS
GPS and Values to I
GPS to Civic Numbe
GPS to Road Length
GPS to Cycl
GPS List As String
msg.payload
Count Features
Select Categories
service-search-near-marker
set msg.complete
Controller
join
Increment GPS List Index
Reset GPS List Index
msg.payload
msg.payload
join
msg.payload
csv
Change FileName
Increment Categories List Index
file
timestamp
Check Categories List Index
msg.payload
timestamp
Reset Categories List Index
msg.payload
timestamp
Check GPS List Index
msg.payload
timestamp
Reset GPS List Index
msg.payload

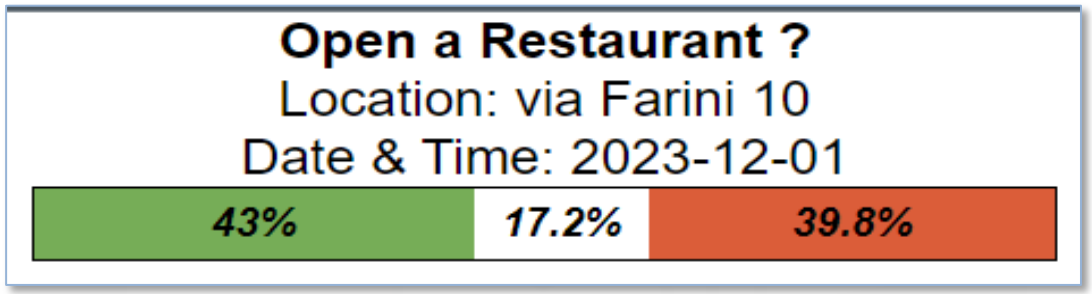
Smart Decision Support , system thinking

- **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, …



SmartDSS

- Supports the definition of the **Decision Tree Model, DTM**, in terms of System Thinking, with Italian Flag and combinations
- Allows the **statistic composition** of subDecisions probabilities
- **Generating a DTM as an IoT App,**
- **IoT Apps with DTM can**
  - **be customized**
  - **compute root values in real time in** any context: location, parameters, etc.
    - Single DTM root value can be produced on Dashboard
    - Several DRM root values can be represented on dashboard as heatmaps for Green/White/Red values





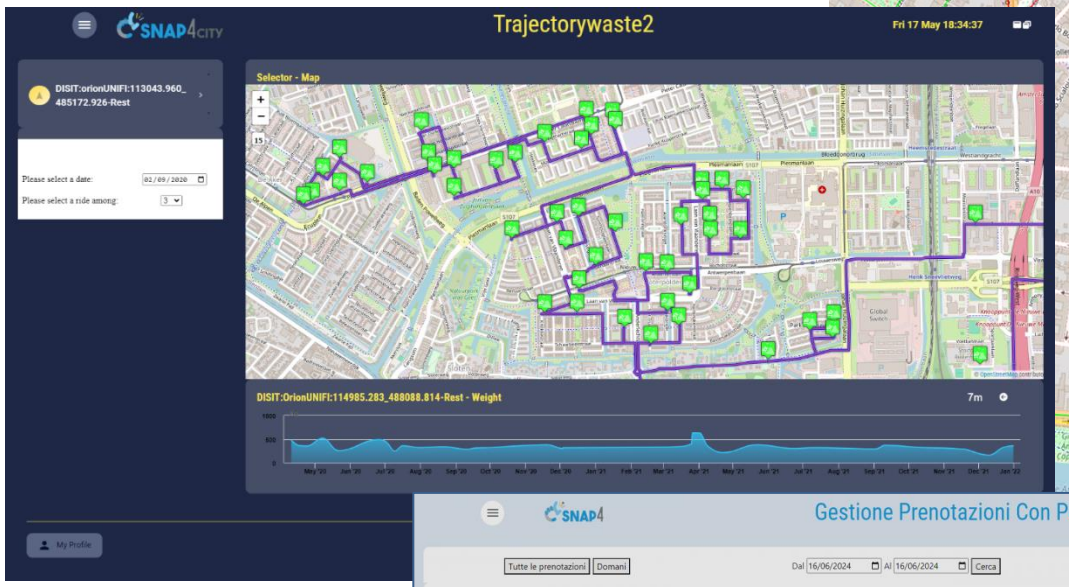
Routing Optimization

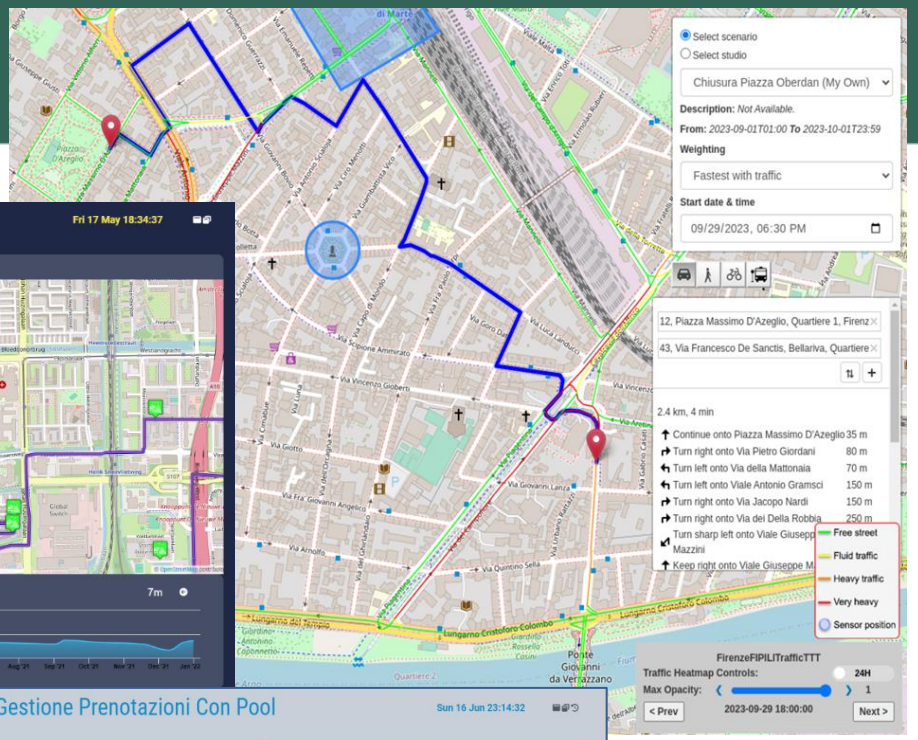
Goals on planning:

- Reduction **of costs on plan**
- **waste collection** optimization, Reduction of Km
- **car pooling trajectories** optimization for maximize the pool usage
- **delivering optimization**, reduction of travel time, reduction of Km
- etc.

Dynamic Routing on operation:

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





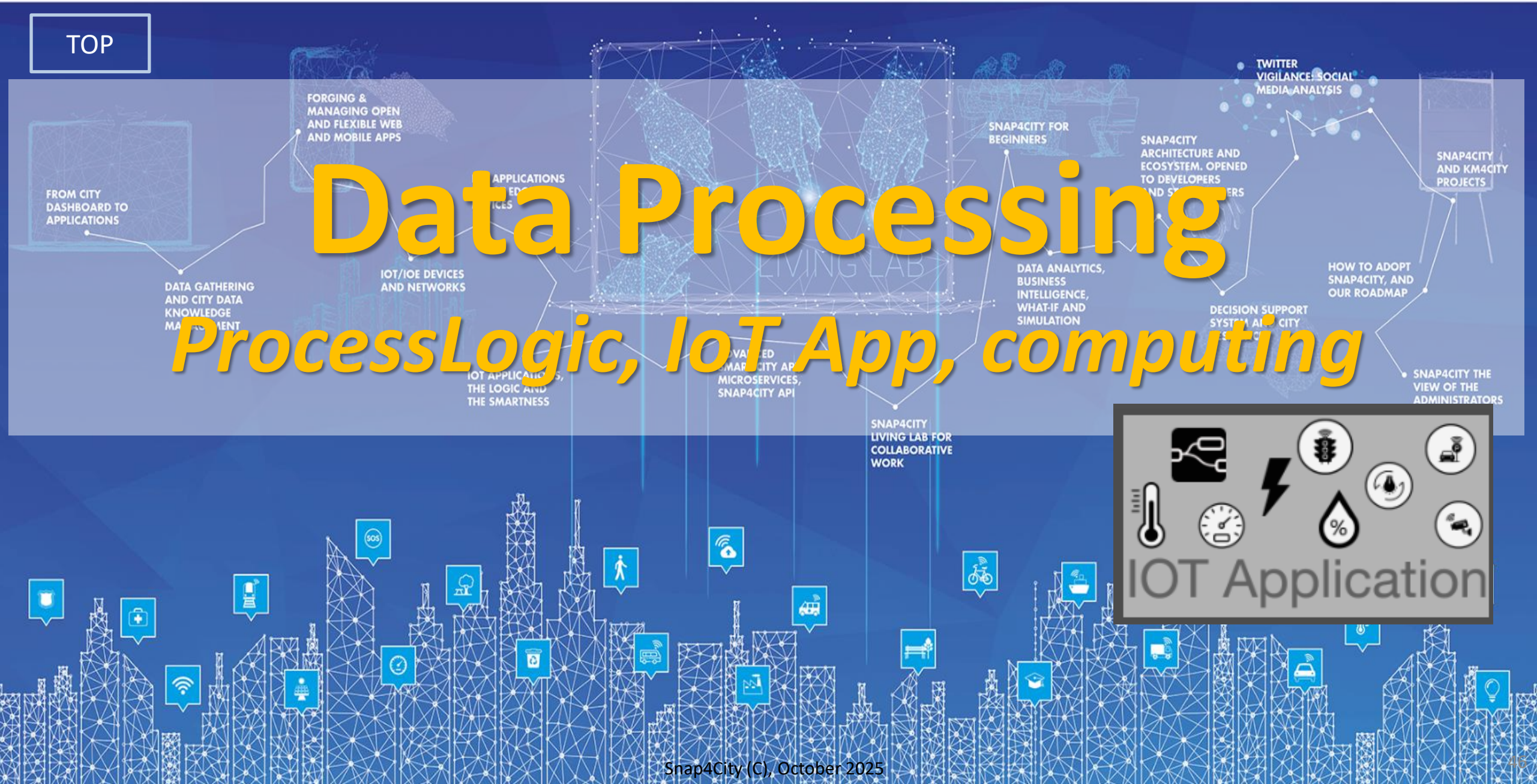


TUSCANY X.0 | EDIH European Digital Innovation Hubs Network | Finanziato dall'Unione europea NextGenerationEU | UNIVERSITÀ DEGLI STUDI FIRENZE | DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE | DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB

TOP

Data Processing

ProcessLogic, IoT App, computing



In This Section



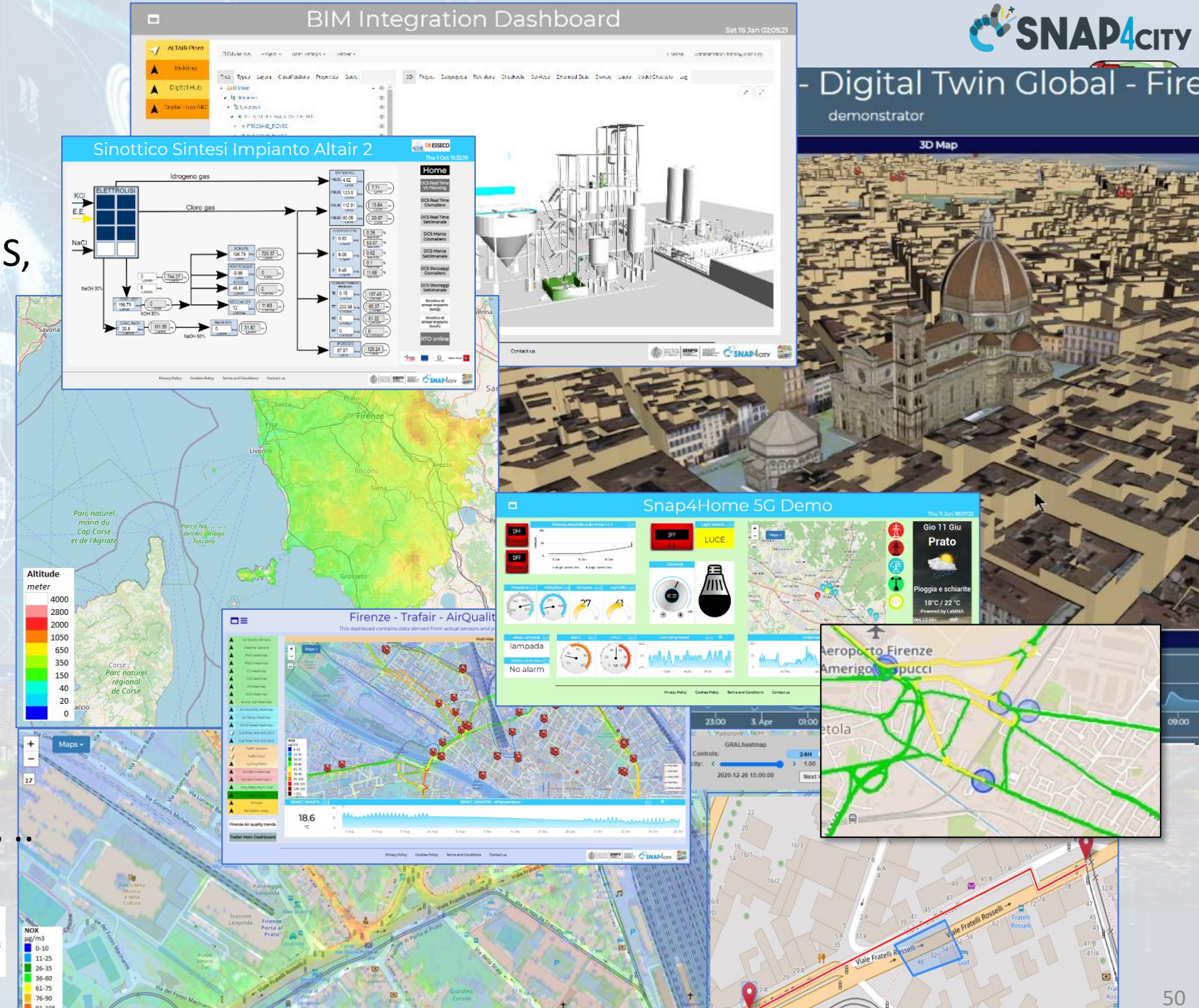
- Data Processing, definition
- Computing KPI & Indexes
- Traffic flow data
  - Computing Traffic Flow In/out of the city
  - Computing CO2 from traffic flow data
- Computing quality of Public Transportation

Definition: Data processing

- **Data Processing:** transformation of data into meaningful information through various operations and manipulations.
  - make informed decisions, and support various business processes
  - **Via:** collecting, data entry, organizing, analyzing, interpreting data to extract insights, validation, sorting, filtering, aggregation, computing indexes, calculation, and reporting.
  - → convert data into a more usable and valuable form for further analysis or decision-making purposes.
- ***Snap4City provides support for implementing Data processing:***
  - *Proc.Logic / IoT Apps: on cloud and on Edge*
  - *Python processes in containers or on Edge*
  - *R Studio processes in containers, on server, on premise*

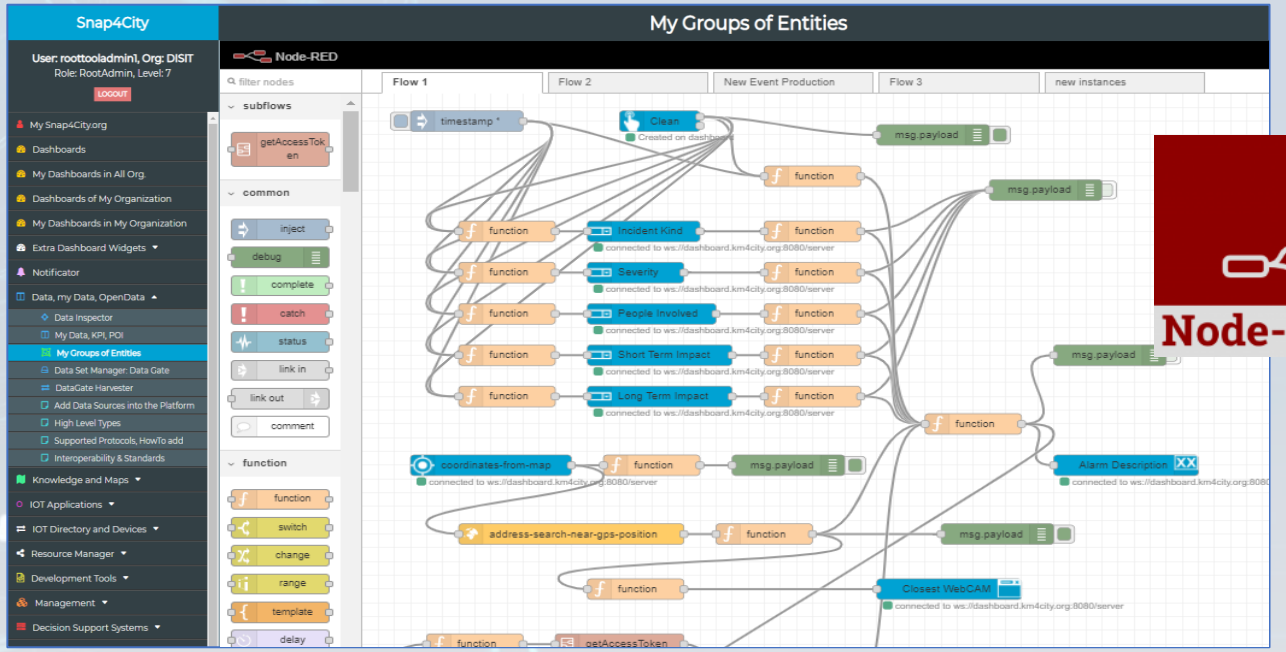
High Level Types

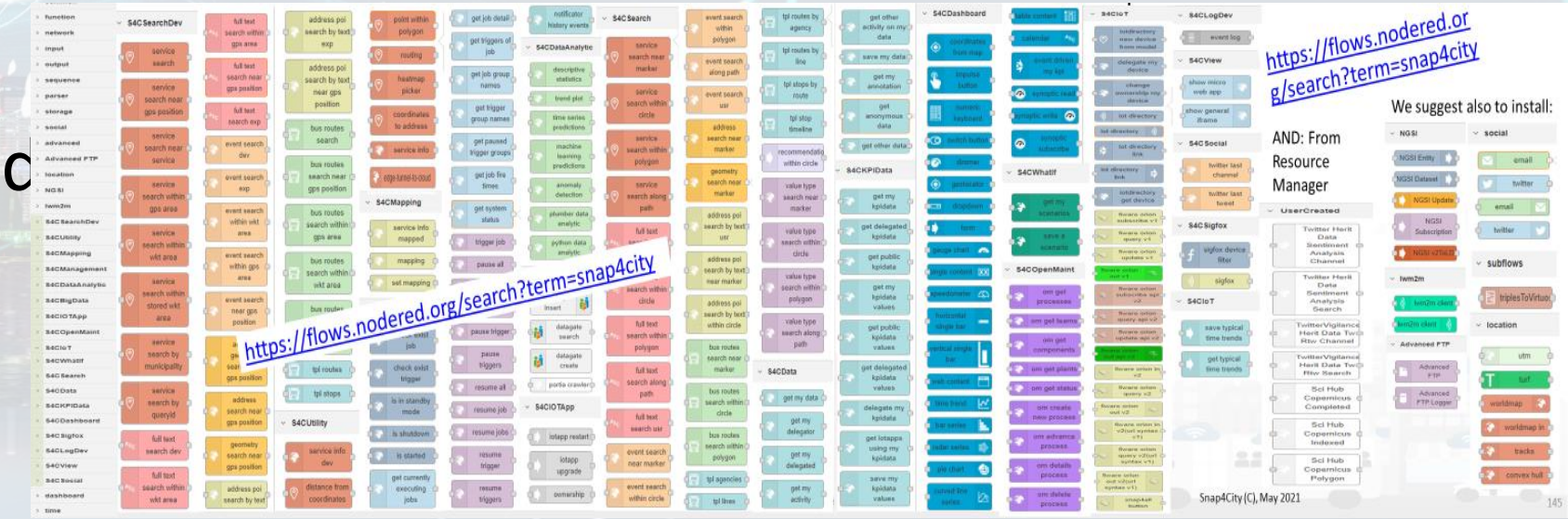
- POI, IOT Devices, shapes,..
  - FIWARE Smart Data Models,
  - IoT Device Models
- GIS, maps, orthomaps, WFS/WMS, GeoTiff, calibrated **heatmaps**, ..
- **Satellite data, ..**
- **traffic flow**, **typical trends**, ..
- **trajectories**, events, Workflow, ..
- **3D Models**, BIM, Digital Twins, ..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



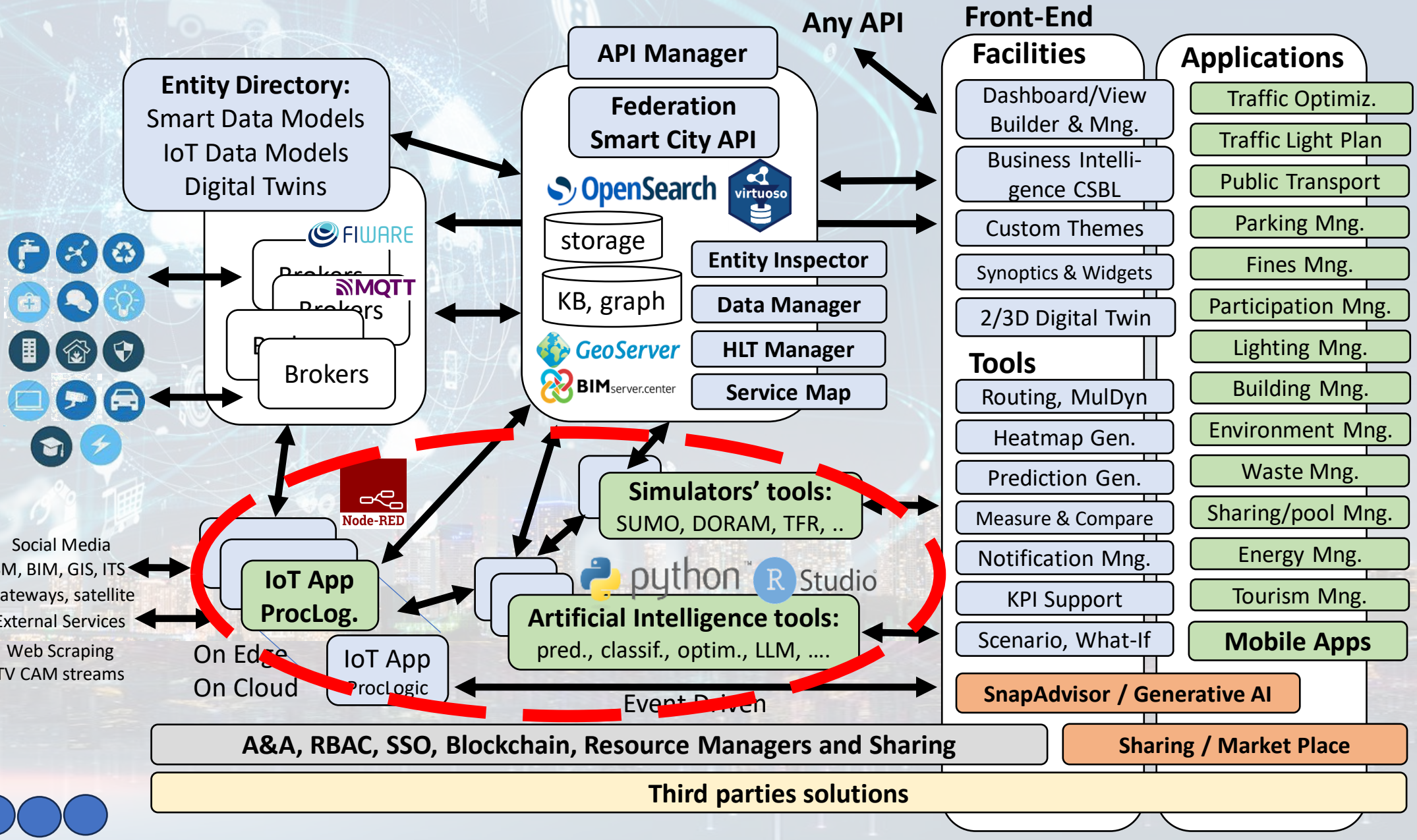
Ingestion, aggreg. → exploitation

- **IoT App Visual Programming, no coding**
  - **Data transformation**
  - **Integration, Interoperab.**
  - **Scripting Data Analytics, AI..**
  - **Data ingestion**
  - **Business logic**
- **Edge and Cloud**
- **MicroServices** data c
  develop via
  visual language
  Node-RED





Technical Architecture



Computing, kpi & Indexes



Key Performance Indicators, KPI





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

- **United Nations Sustainable Development Goals, SDGs** (for which cities can do more to achieve some of the 17 SDGs, https://sdgs.un.org/goals);
- **15 minutes cities** (where primary services must be accessible within 15 minutes on foot);
- **objectives of the European Commission** in terms of pollutant emissions for: NO2, PM10, PM2.5 (https://environment.ec.europa.eu/topics/air_en);
- **SUMI: mobility and transport vs env**
  - **https://www.snap4city.org/951**
- **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

UNIVERSITÀ DEGLI STUDI FIRENZE

DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

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

SNAP4CITY

KM4CITY

UNITED NATIONS

SUSTAINABLE DEVELOPMENT GOALS



Sustainable Development Goals (SDGs) - Obiettivi di sviluppo sostenibile

RAPPORTO 2021

Istat | Istituto Nazionale di Statistica

1 SCONFIGGERE LA POVERTÀ — 21 indicatori

9,4%

persone in **POVERTÀ ASSOLUTA**

2 SCONFIGGERE LA FAME — 16 indicatori

15,8%

COLTIVAZIONI BIOLOGICHE su **SUPERFICIE AGRICOLA** utilizzata

3 SALUTE E BENESSERE — 37 indicatori

66,5%

COPERTURA VACCINALE ANTINFLUENZALE età 65+

4 ISTRUZIONE DI QUALITÀ — 34 indicatori

26,9

POSTI autorizzati negli **ASILI NIDO** e servizi integrativi per la prima infanzia

per 100 bambini di 0-2 anni

5 PARITÀ DI GENERE — 17 indicatori

49,6

DONNE VITTIME DI VIOLENZE segnalate al numero di pubblica utilità contro la violenza e lo stalking 1522

per 100.000 donne

6 ACQUA PULITA E SERVIZI IGIENICO-SANITARI — 18 indicatori

58,0%

ACQUA EROGATA agli utenti sulla immessa in rete

7 ENERGIA PULITA E ACCESSIBILE — 12 indicatori

18,2%

ENERGIA DA FONTI RINNOVABILI sul consumo finale lordo di energia

8 LAVORO DIGNITOSO E CRESCITA ECONOMICA — 28 indicatori

62,6%

tasso di **OCCUPAZIONE** (20-64 anni)

9 IMPRESE, INNOVAZIONE E INFRASTRUTTURE — 26 indicatori

3,6%

OCCUPATI con posizioni specializzate sulle **ICT**

10 RIDURRE LE DISUGUAGLIANZE — 15 indicatori

177.254

NUOVI PERMESSI DI SOGGIORNO rilasciati

11 CITTÀ E COMUNITÀ SOSTENIBILI — 32 indicatori

28,3%

persone che vivono in **ABITAZIONI SOVRAFFOLLATE**

12 CONSUMO E PRODUZIONE RESPONSABILI — 26 indicatori

2,5%

IMPRESE che redigono bilanci e/o **RENDICONTAZIONI AMBIENTALI** e di **SOSTENIBILITÀ**

13 LOTTA CONTRO IL CAMBIAMENTO CLIMATICO — 15 indicatori

7,1

EMISSIONI di CO_2 e altri gas clima alteranti

tonnellate per abitante

14 LA VITA SOTT'ACQUA — 4 indicatori

65,5%

COSTE marine **BALNEABILI**

15 LA VITA SULLA TERRA — 21 indicatori

31,7%

AREE FORESTALI in rapporto alla superficie terrestre

16 PACE, GIUSTIZIA E ISTITUZIONI SOLIDE — 19 indicatori

105,5

DETENUTI in istituti di detenzione

per 100 posti disponibili

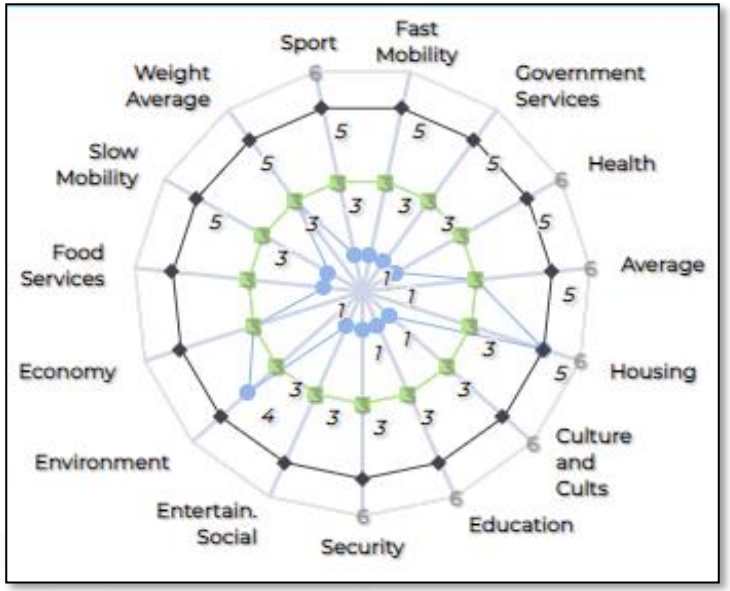
17 PARTNERSHIP PER GLI OBIETTIVI — 9 indicatori

0,22%

AIUTO PUBBLICO ALLO SVILUPPO come quota del reddito nazionale lordo



Indicators, KPI, etc.



- Can be **formally defined or not**
  - Italian PUMS is not fully formally defined
  - SUMI is formally defined
  - SDG is not formally defined
- In any case they are **based on SubIndicators / SubIndex**
  - They can and have to be evaluated with ***some formulas*** and compounded to obtain the general indicator, and the formulas should be validated
  - To use the SubIndicator/Index is a way to reduce the problem and complexity

Concept 15MinIndex



Assessing in each point of the area (city or rural) the capability of providing services ad 15 Min walking distance for the city users

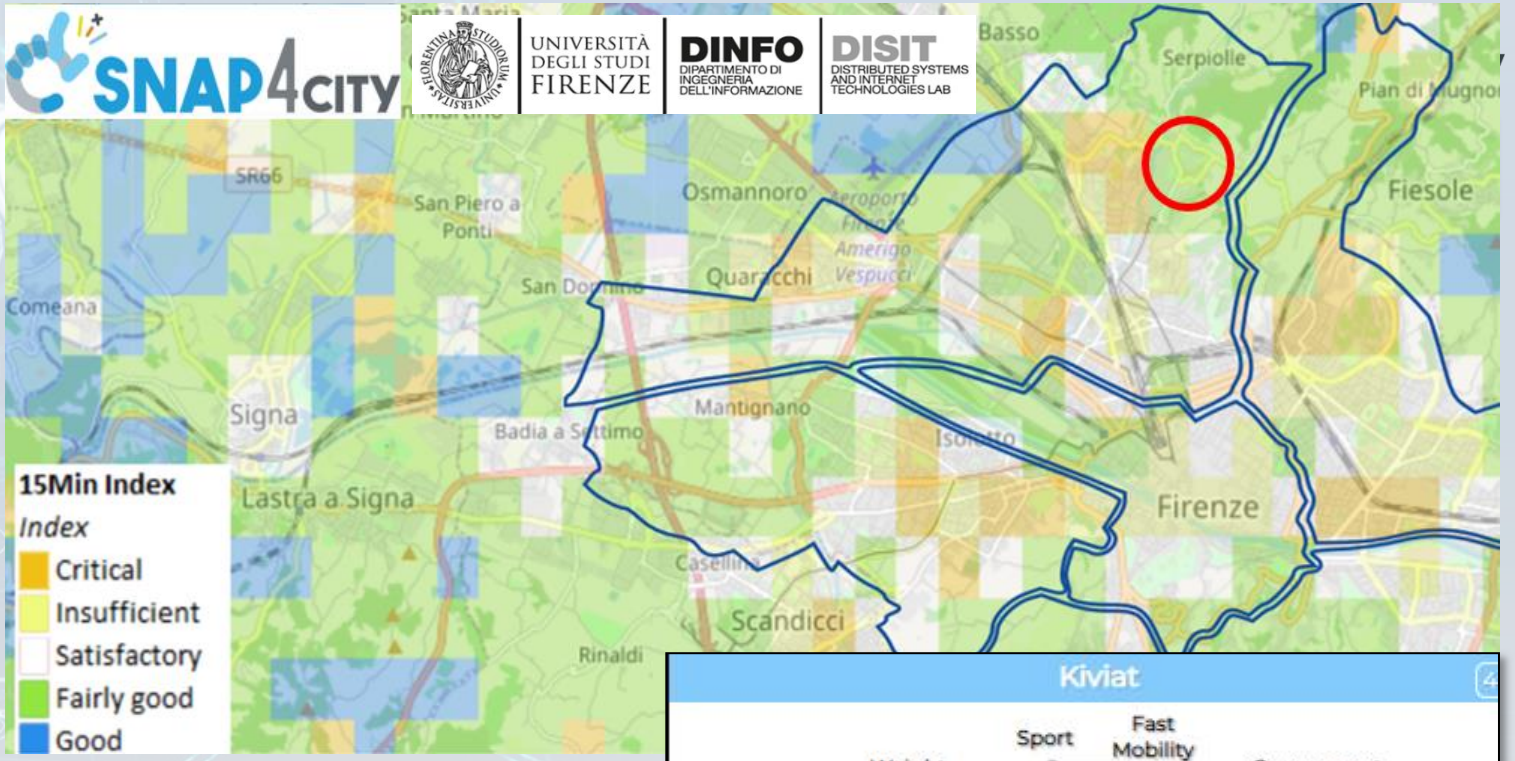
- Several different approaches from early Carlos Moreno concept
- Several different subindexes

Carlos Moreno Functions	Li et al., 2019	15MinCityIndex subindexes
living		Housing viability
	Gov	Govern Services
		Safety Services
		Culture and Cults Services
		Environment Quality
	Roads	Slow Mobility Services
		Fast Mobility Services
	[Medical]	Sport Services
working		Economy/ sustainability
	pension	
commerce	commerce	
	dining	Food Services
healthcare	medical	Health Services
education	edu	Education Services
entertainment	entertainment	Entertainment Services

15MinCityIndex

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

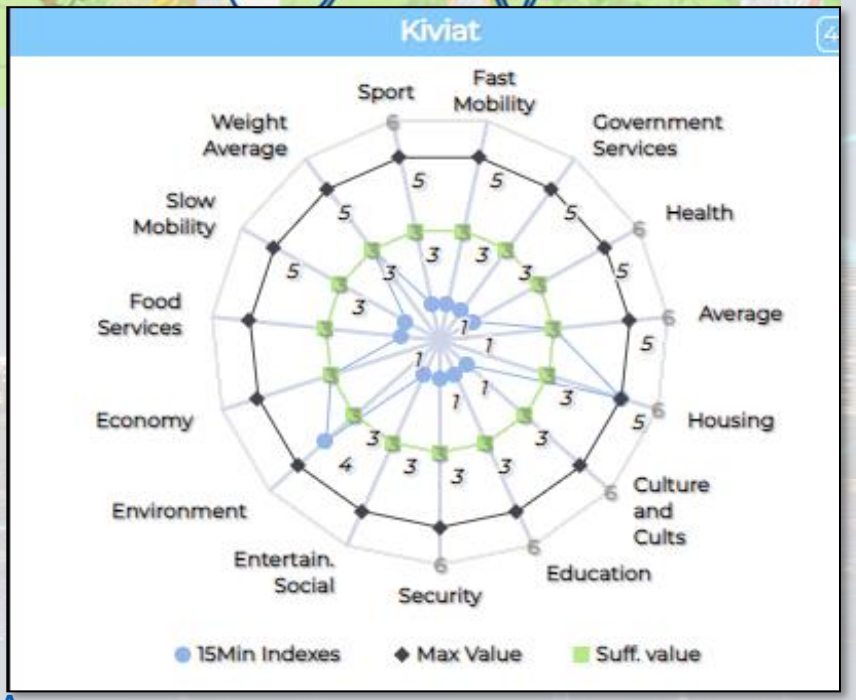
Using the Open Data:
We developed a data analytic tool based on municipal and national open data to assess services adequacy for people living in each 15 minutes areas of the city.



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



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

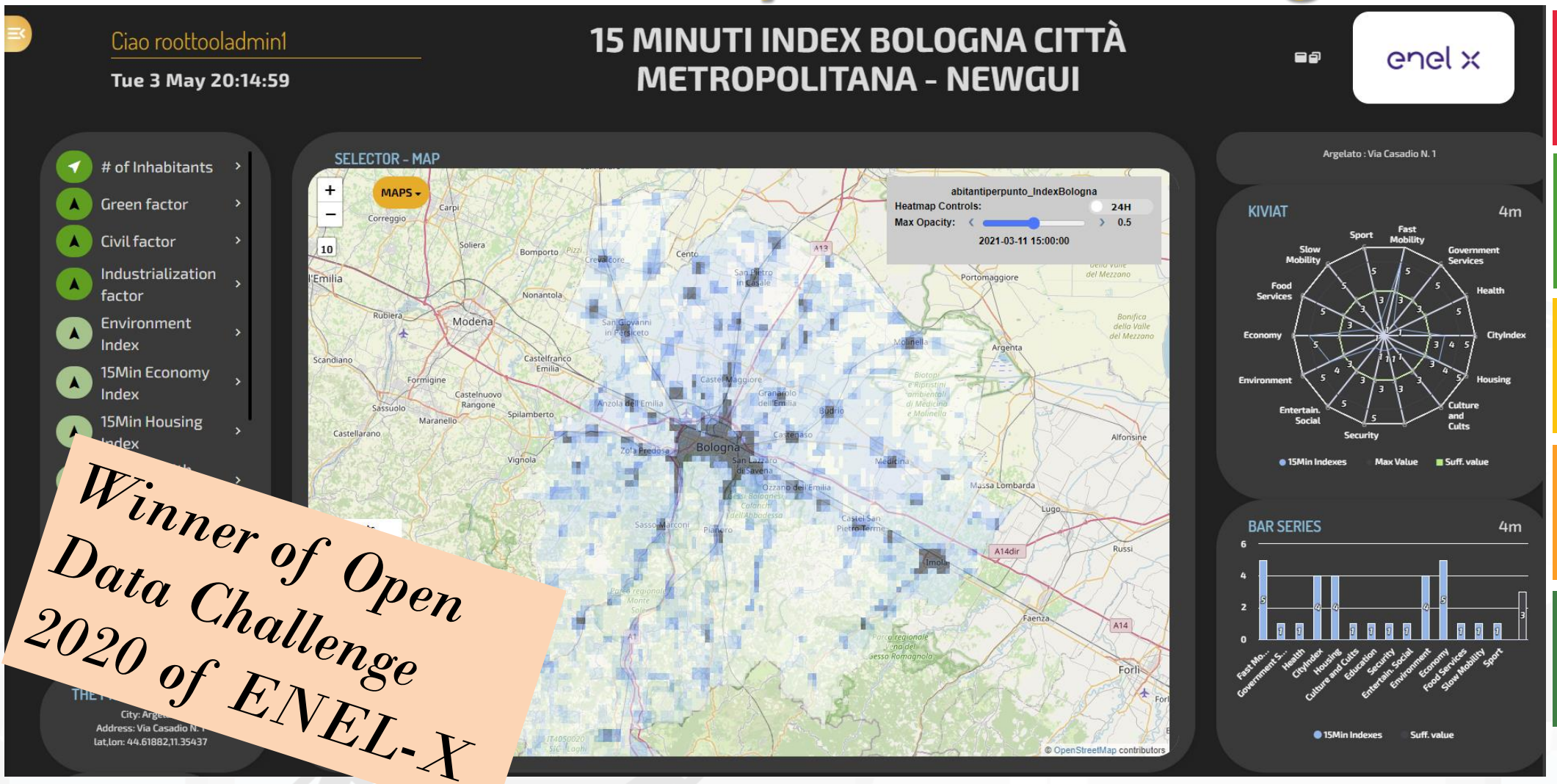


Careggi/Rifredi is a relevant district in Florence because of hosting the main Florence/Tuscany hospitals Careggi and Meyer, but also university headquarters and many other workplaces.



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

15MinCityIndex on Bologna



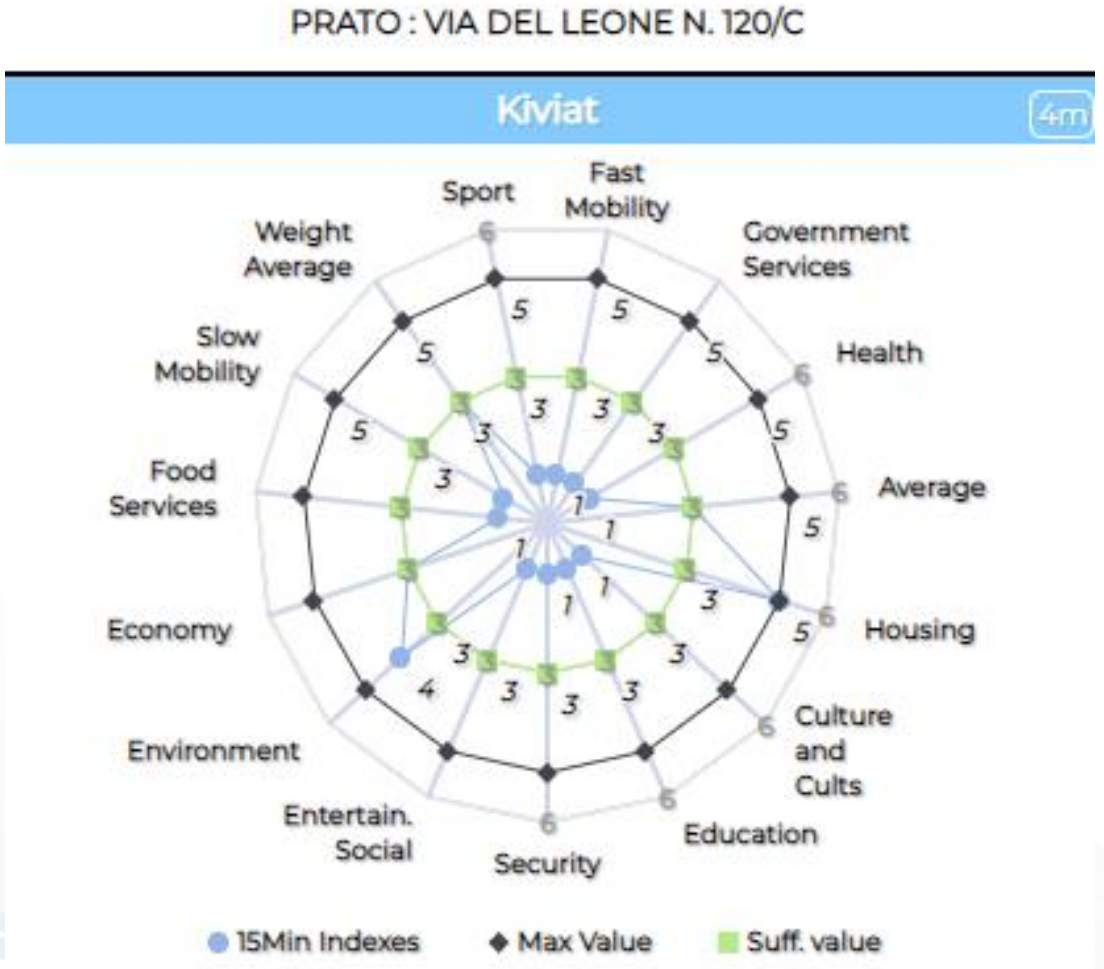
Winner of Open Data Challenge 2020 of ENEL-X

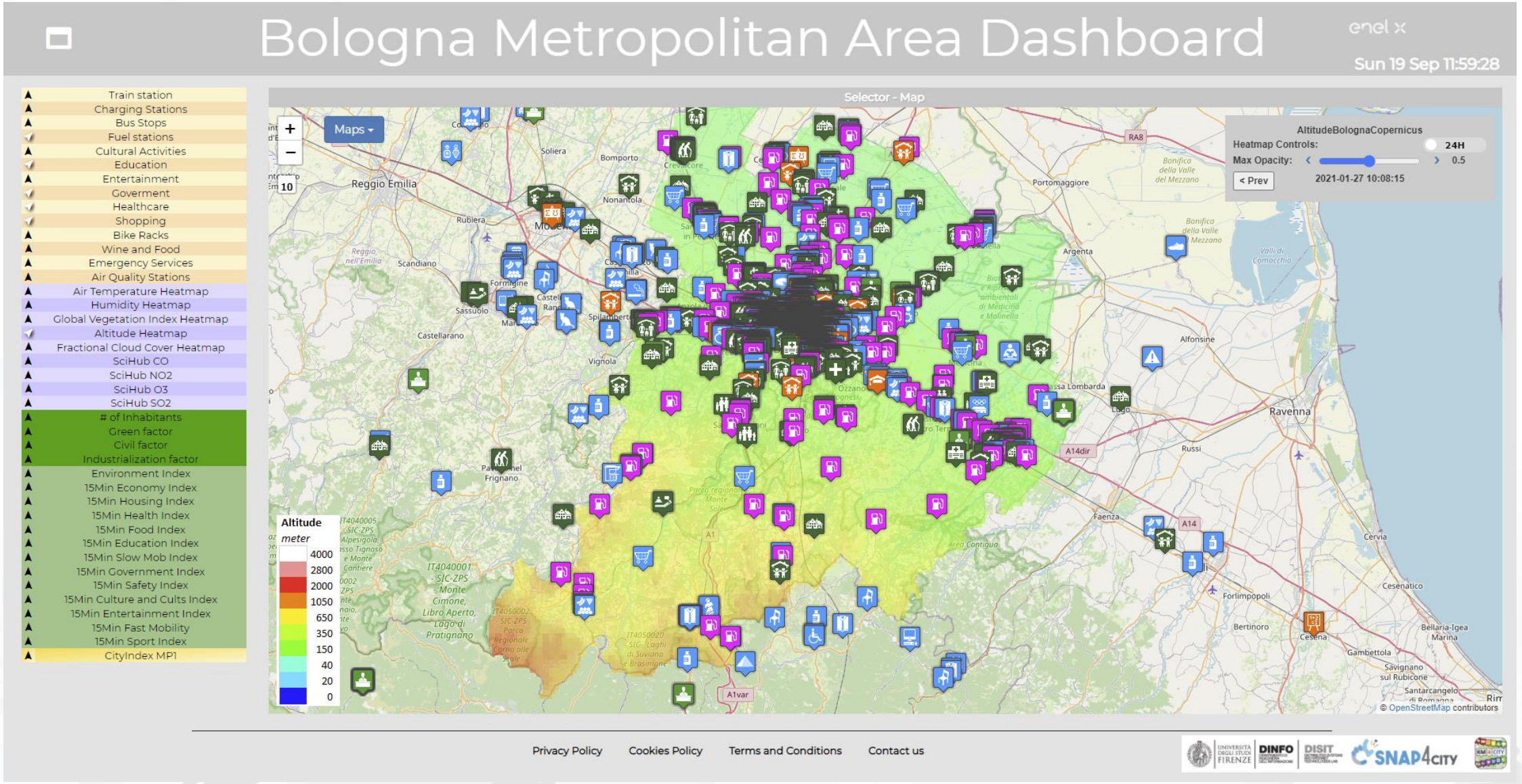
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
7 AFFORDABLE AND CLEAN ENERGY
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
15 LIFE ON LAND

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

15MinCityIndex

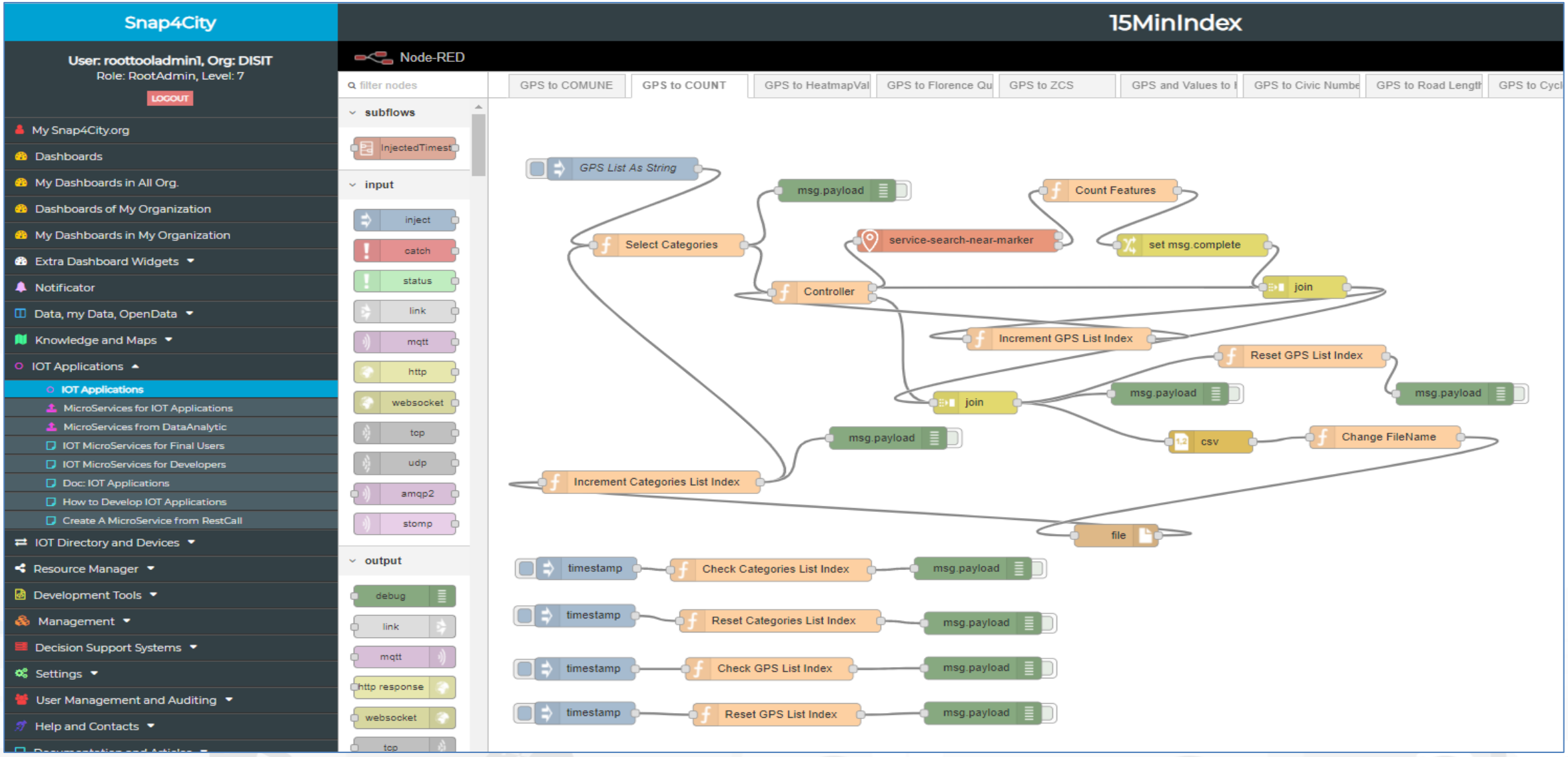
- Derived and extended from Carlos Moreno 15 Minute concept
  - But with 13 different subindexes
- Computable on the basis of Open Data
- Validated on major city area
- Extendable to whole national level or large regions
- Accessible as Dashboard to play with
- ***Winner of the ENEL-X Open Data Challenge 2020.***





https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzA1OA==

IoT App....


Snap4City
User: roottooladmin1, Org: DISIT
Role: RootAdmin, Level: 7
LOGOUT
My Snap4City.org
Dashboards
My Dashboards in All Org.
Dashboards of My Organization
My Dashboards in My Organization
Extra Dashboard Widgets
Notificator
Data, my Data, OpenData
Knowledge and Maps
IOT Applications
IOT Applications
MicroServices for IOT Applications
MicroServices from DataAnalytic
IOT MicroServices for Final Users
IOT MicroServices for Developers
Doc: IOT Applications
How to Develop IOT Applications
Create A MicroService from RestCall
IOT Directory and Devices
Resource Manager
Development Tools
Management
Decision Support Systems
Settings
User Management and Auditing
Help and Contacts
15MinIndex
Node-RED
filter nodes
subflows
InjectedTimest
input
inject
catch
status
link
mqtt
http
websocket
tcp
udp
amqp2
stomp
output
debug
link
mqtt
http response
websocket
tcp
GPS to COMUNE
GPS to COUNT
GPS to HeatmapVal
GPS to Florence Qu
GPS to ZCS
GPS and Values to I
GPS to Civic Numbe
GPS to Road Length
GPS to Cycl
GPS List As String
msg.payload
Count Features
Select Categories
service-search-near-marker
set msg.complete
Controller
join
Increment GPS List Index
Reset GPS List Index
msg.payload
msg.payload
join
msg.payload
csv
Change FileName
Increment Categories List Index
file
timestamp
Check Categories List Index
msg.payload
timestamp
Reset Categories List Index
msg.payload
timestamp
Check GPS List Index
msg.payload
timestamp
Reset GPS List Index
msg.payload

SUSTAINABLE DEVELOPMENT GOALS

SNAP4CITY

KM 4 CITY









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



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



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





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



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



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



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

Traffic Flow Data




60

Vehicle Flow

- Traffic Flow data can be used for a number of applications:
  - Traffic Flow Analysis and reconstruction
  - What-if-analysis
  - forecasting of pollutants
- The main problem is the need of consistent data:
  - Traffic Flow sensor are not 100% reliable
  - There could be some problem in data acquisition process



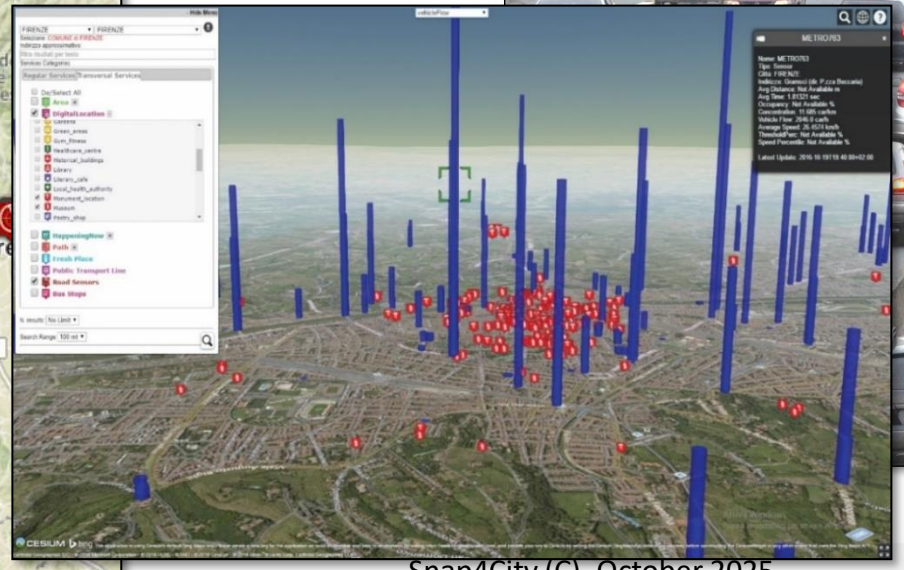
providing **PREDICTIONS** can be useful to improve quality of service

Traffic Flow Tools

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

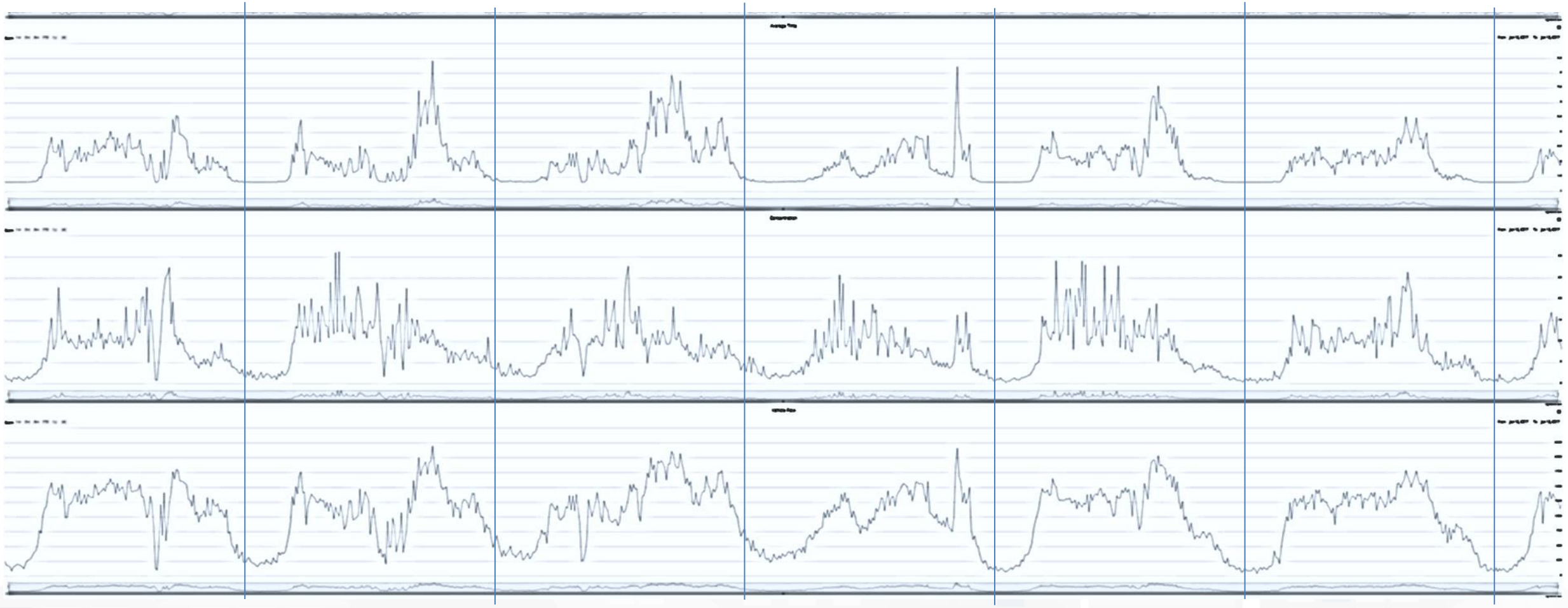
Specifically located: along, around, on gates, on x...







Traffic Flow data



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

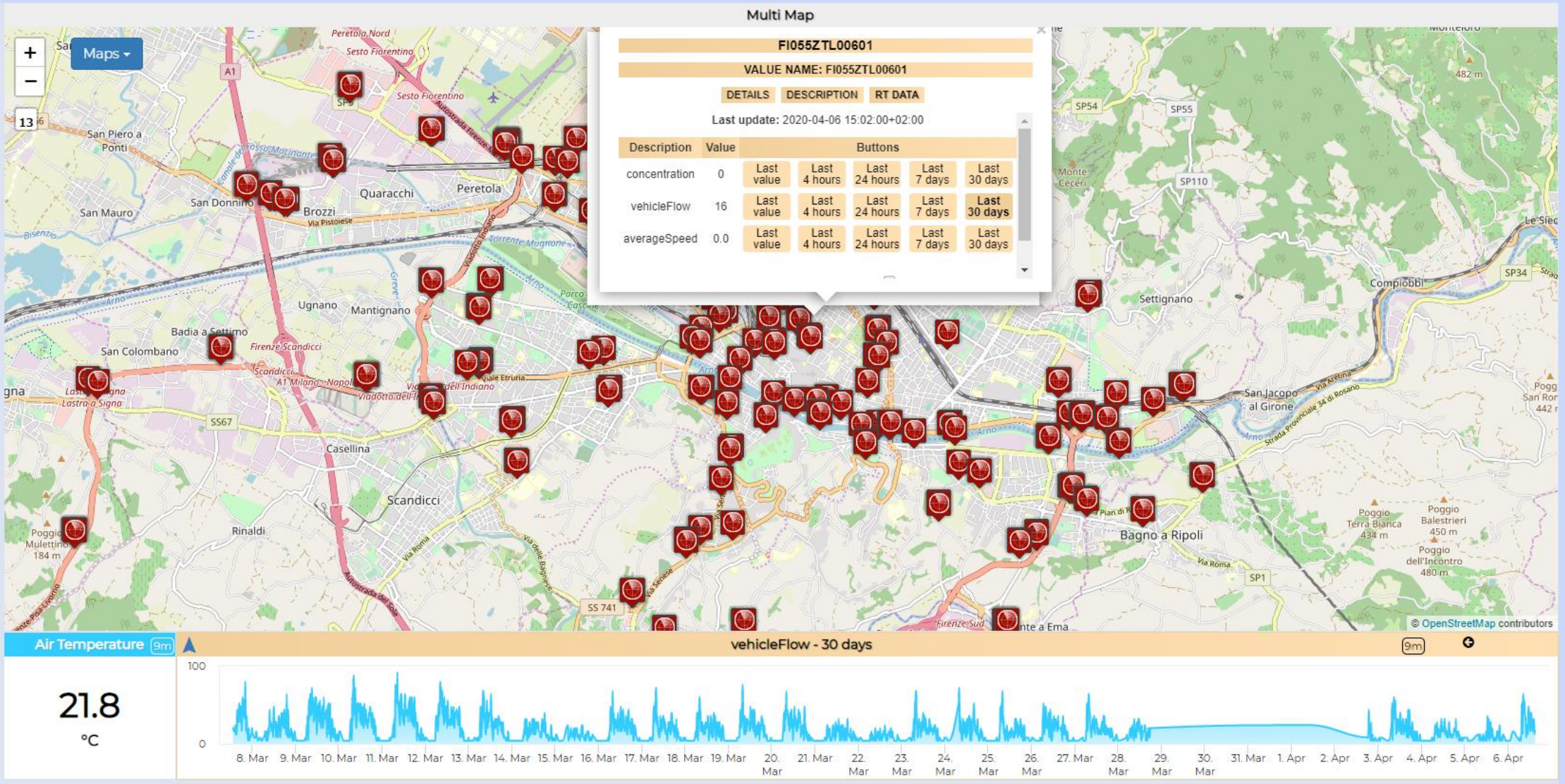
Firenze - Trafair - AirQuality Heatmaps

This dashboad contains data derived from actual sensors and predictive values under validation

Mon 6 Apr 15:12:27

- Air Quality Sensors
- Weather Sensors
- PM10 Heatmap
- PM2.5 Heatmap
- CO Heatmap
- CO2 Heatmap
- O3 Heatmap
- NO2 Heatmap
- Europ. AQI Heatmap
- Air Humidity Heatmap
- Air Temp. Heatmap
- Wind Speed Heatmap
- Gral Pred. HM NOX (3m)
- Gral Pred. HM NOX (6m)
- Traffic Sensors
- Traffic Flow
- Cycling Paths
- Accident Heatmap
- Accident Heatmap 2
- Only HRes Anym. Gral
- Green Areas
- Schools

Air quality trends



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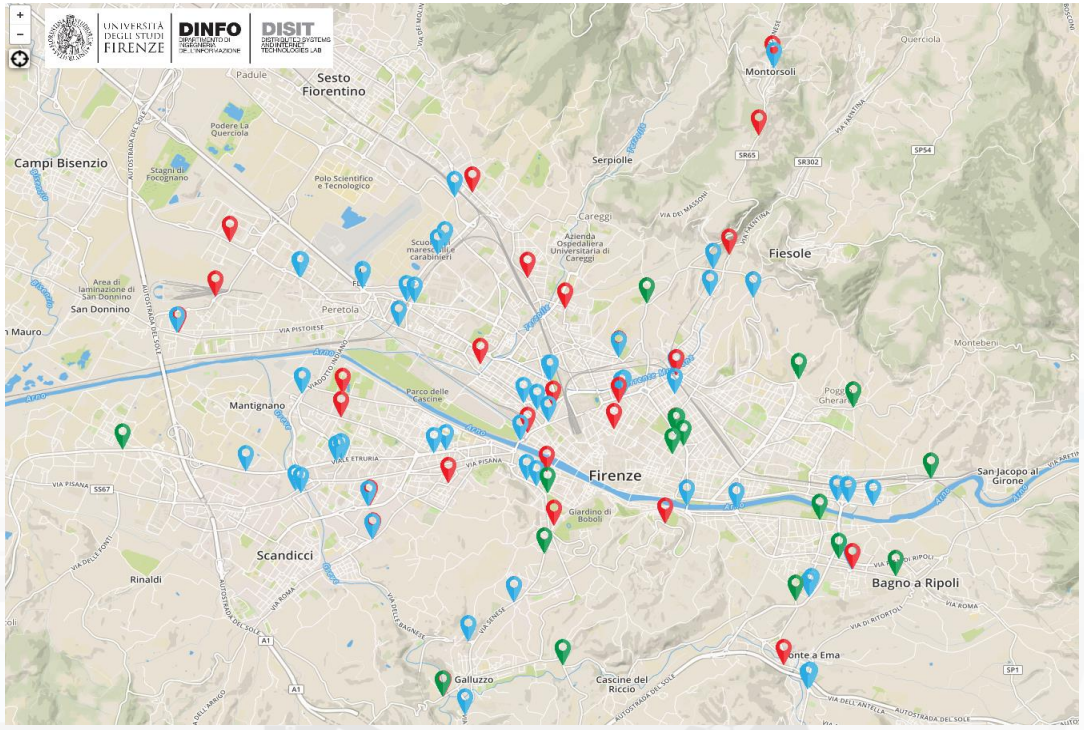
https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTUzMg==

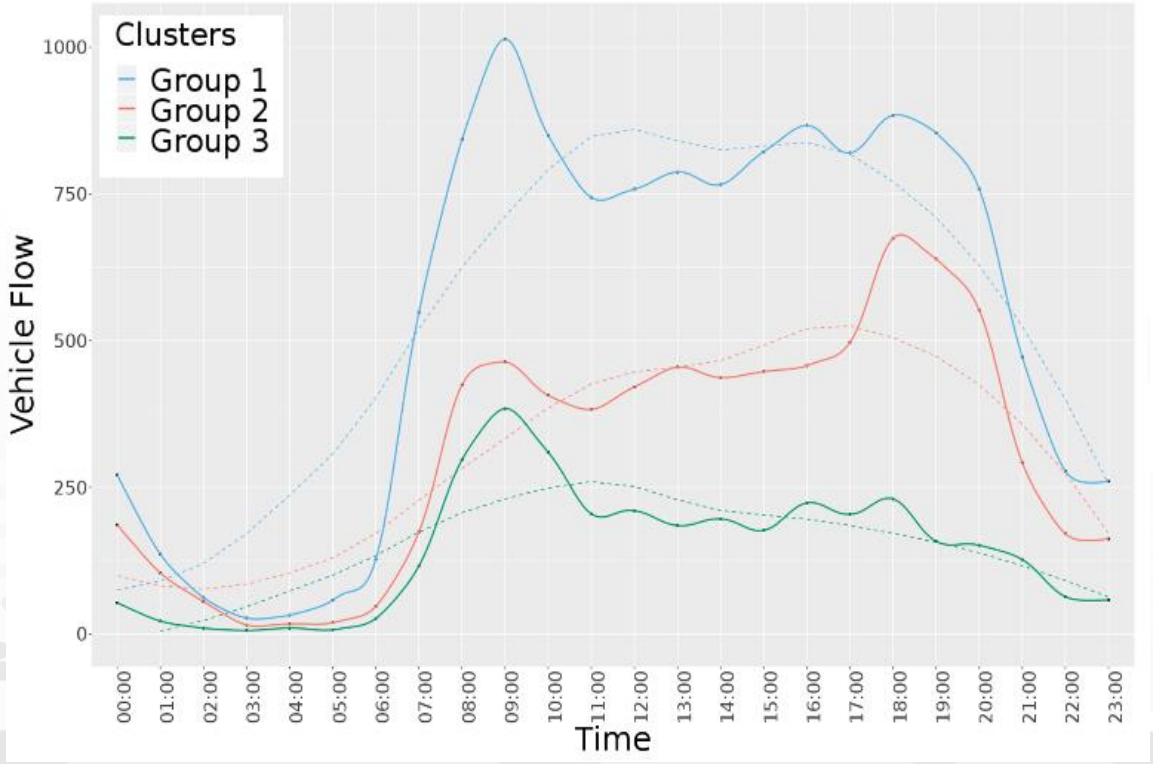
Traffic Flow Data Analysis



Map of the traffic sensors location per cluster in Florence municipality



Hourly median vehicle flow trends per cluster



Example of Volume of data



- Sensors: 150
- Variables per sensor: 15 + datetime, etc.
  - Bytes per sensor per message: 150 Byte
- Days per year: 365
- Hours in the day: 24
- Samples for hour: 6, one each 10 minutes
- → 150*365*150*24*6 = 1.127 GB

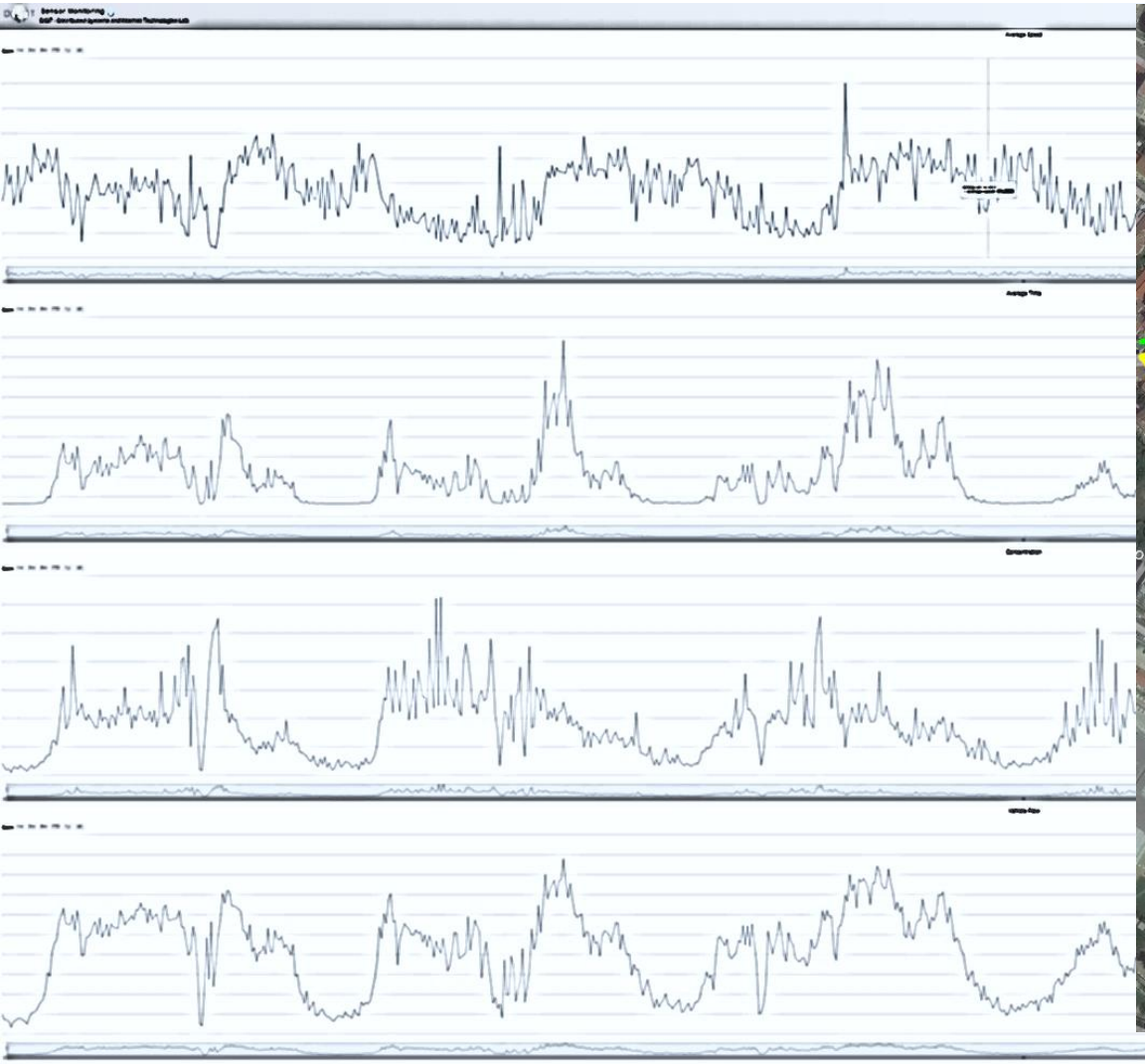
- More: Platform factor: number of replicas, indexing, etc…
  - May range from 100 to 2000 Byte per Variable

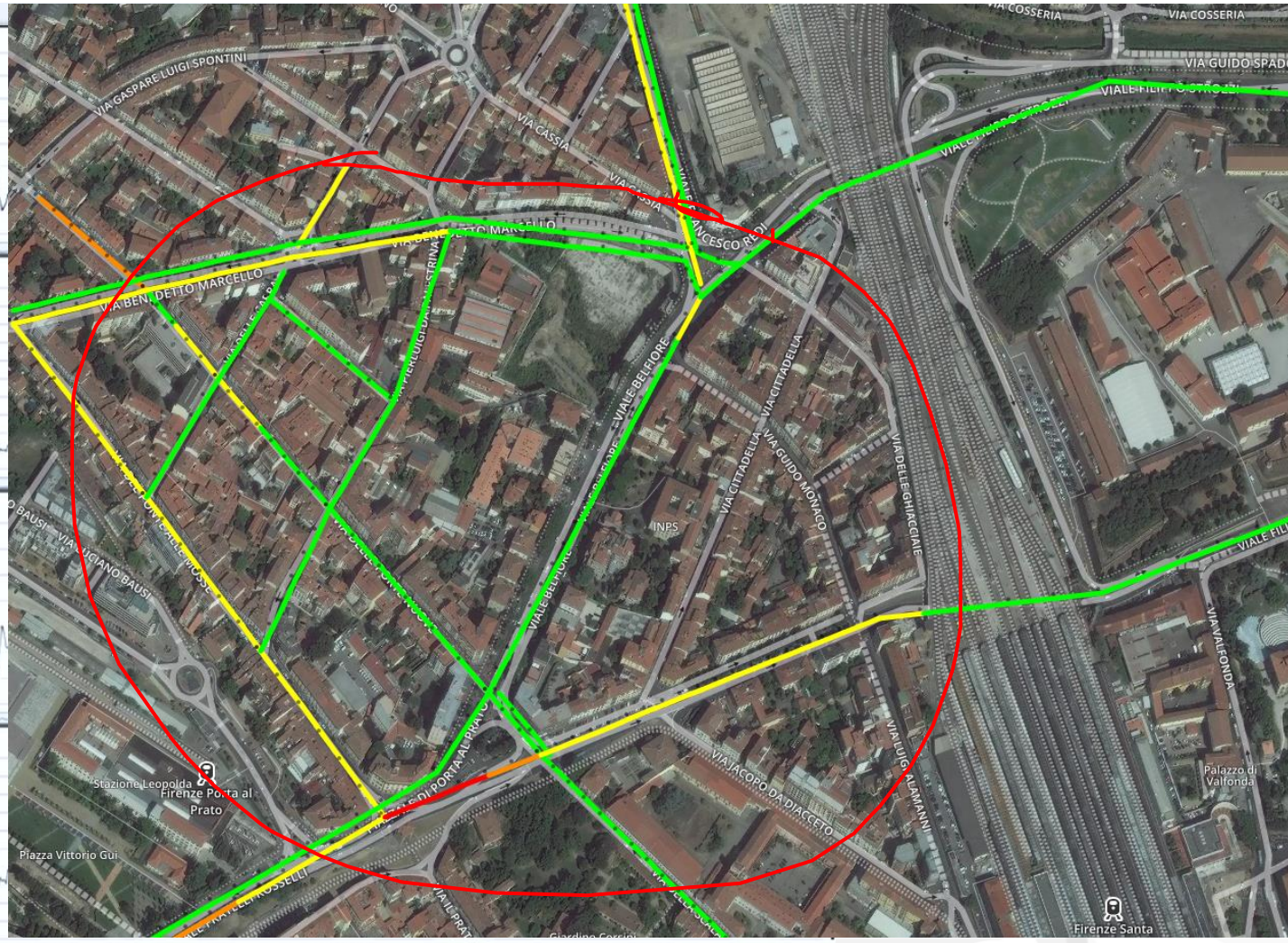
Computing Traffic Flow

In/out of the city

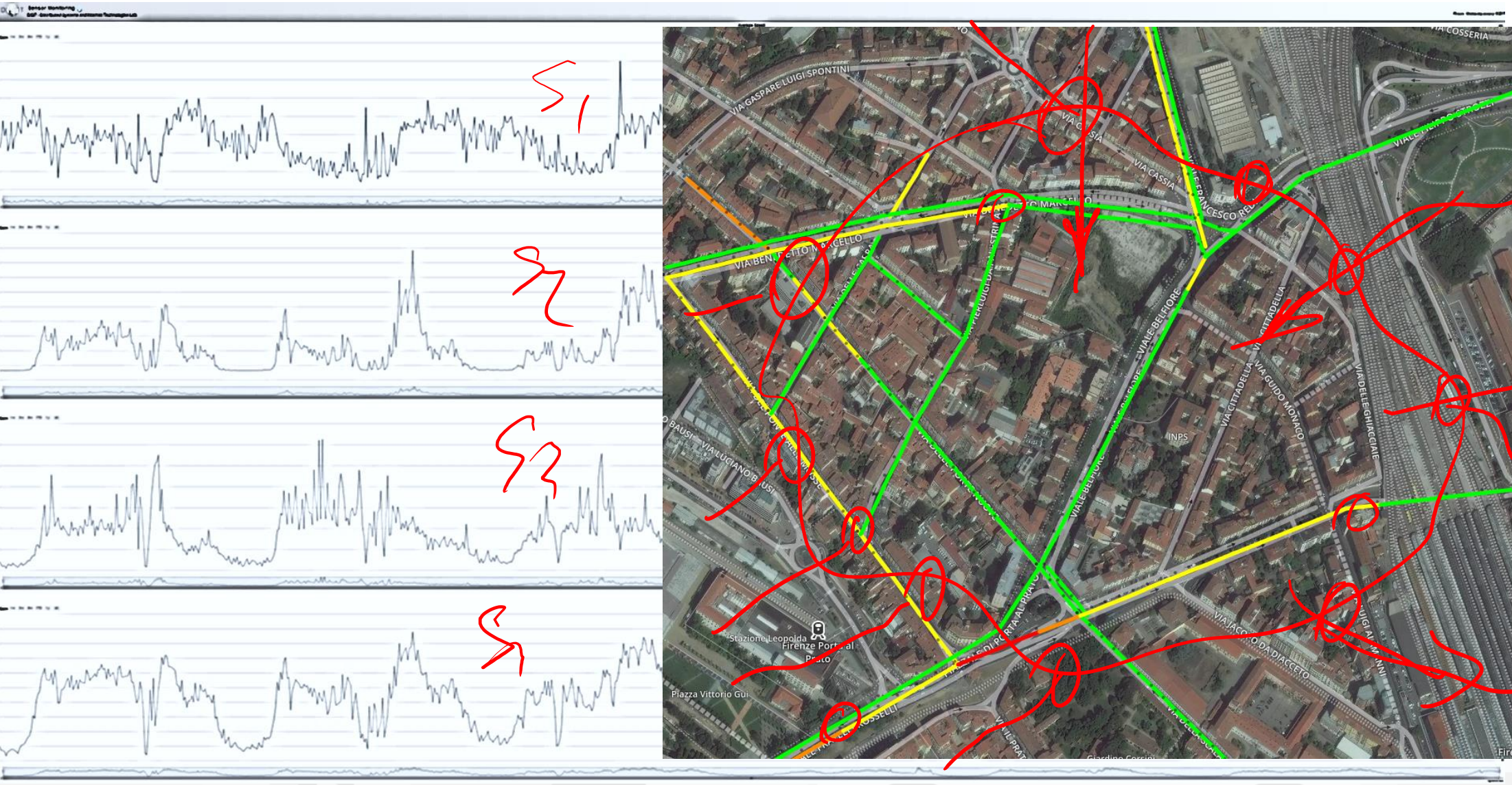


Traffic Flow data





Traffic Flow data



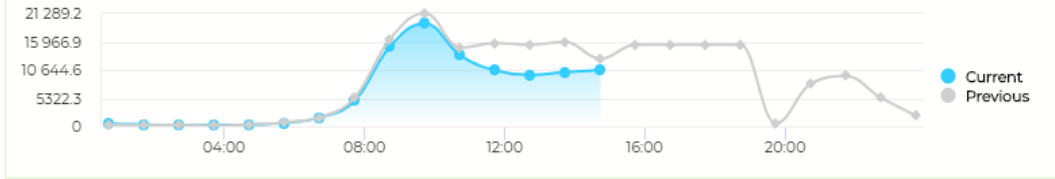
Traffic Flow Monitoring - Firenze - Cloned2

Wed 11 Nov 15:01:32

 # IN FLOW 9m

10549 #ofvehicles

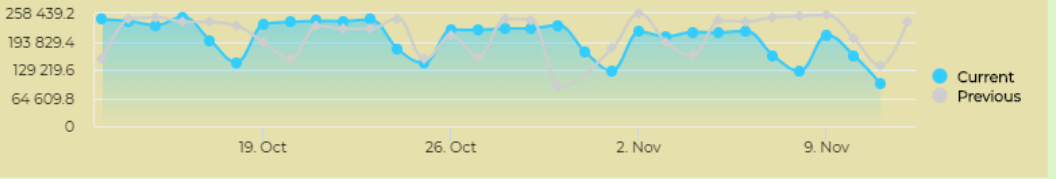
Firenze IN Traffic Flow (number of vehicles) 9m



Inc Daily Inp... 9m

97137 #ofvehicles

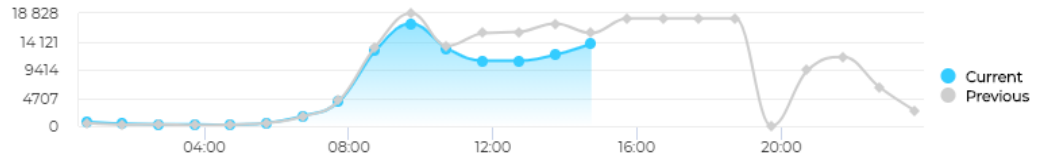
Daily Inputs (monthly) (last value is incremental, real time) 9m



 # OUT FLOW 9m

13720 #ofvehicles

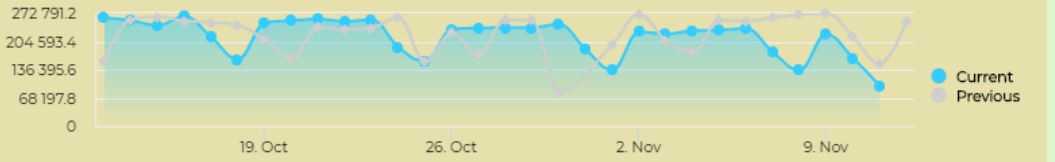
Firenze OUT Traffic Flow (number of vehicles) 9m



Inc Daily Out... 9m

97457 #ofvehicles

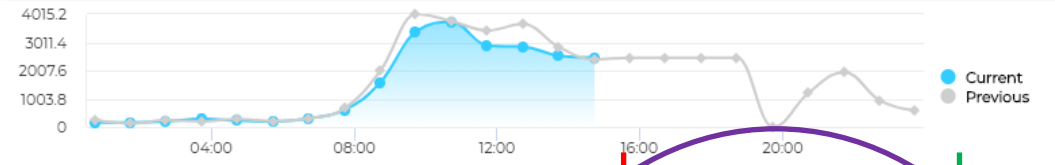
Daily Outputs (monthly) (last value is incremental real time) 9m



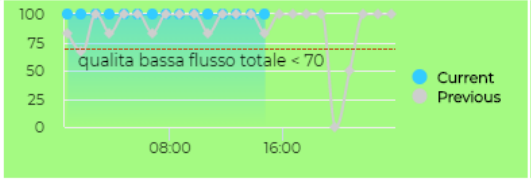
ZTL in 9m

2468 #ofvehicles

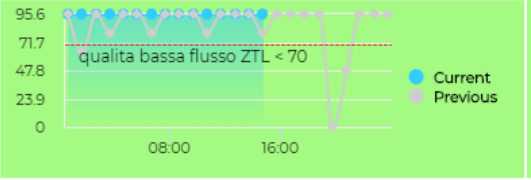
ZTL in Traffic Flow daily trend, entering in ZTL 9m



QoS as perc. of measures taken 9m



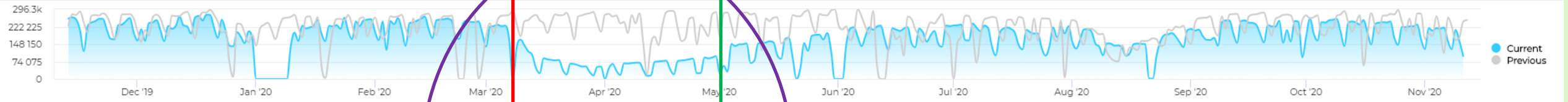
QoS as perc. of measures in ZTL 9m



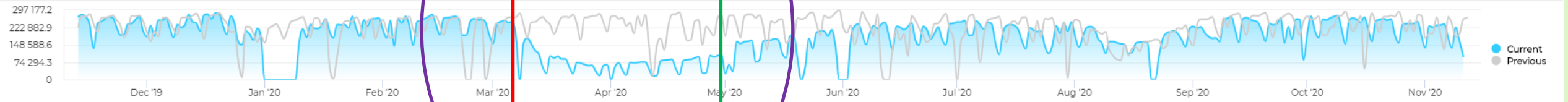
11/11/2020

15:01:33

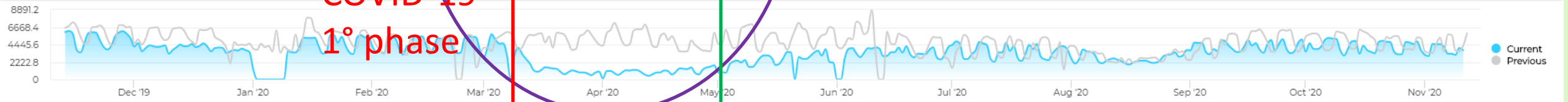
inflow total of the day, yearly 9m



outflow total over the day Yearly 9m



in ZTL yearly compare 9m



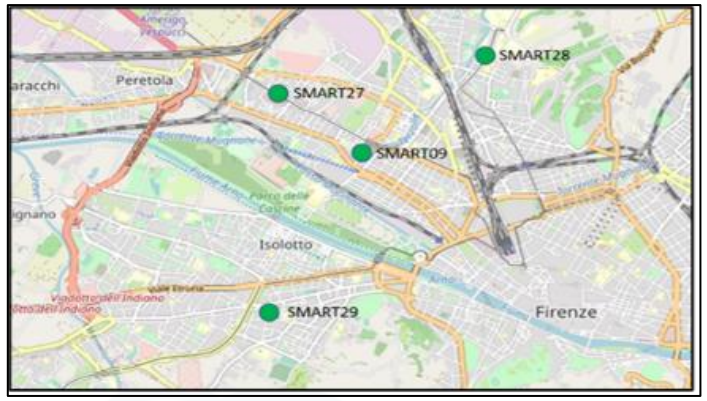
COVID-19

1° phase

Computing CO2 Emissions from traffic Data

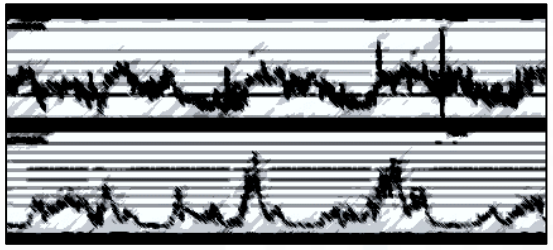


Estimating City Local CO2 from Traffic Flow Data



- CO2 sensors are very expensive and thus few



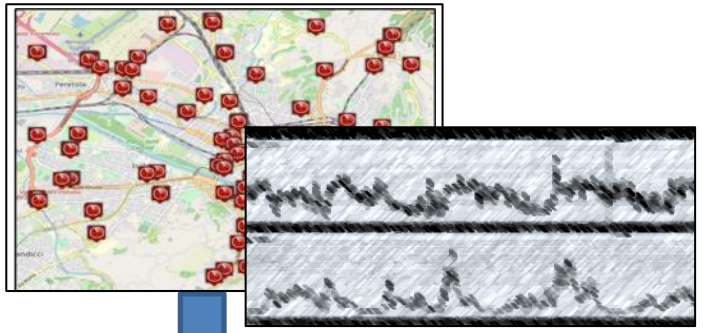




- Traffic Flow is one the main source of CO2
- Most of the cities have many sensors on traffic flow
- **Dense estimation of CO2 into the city** is very useful to know to target the EC limits/KPI

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/

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



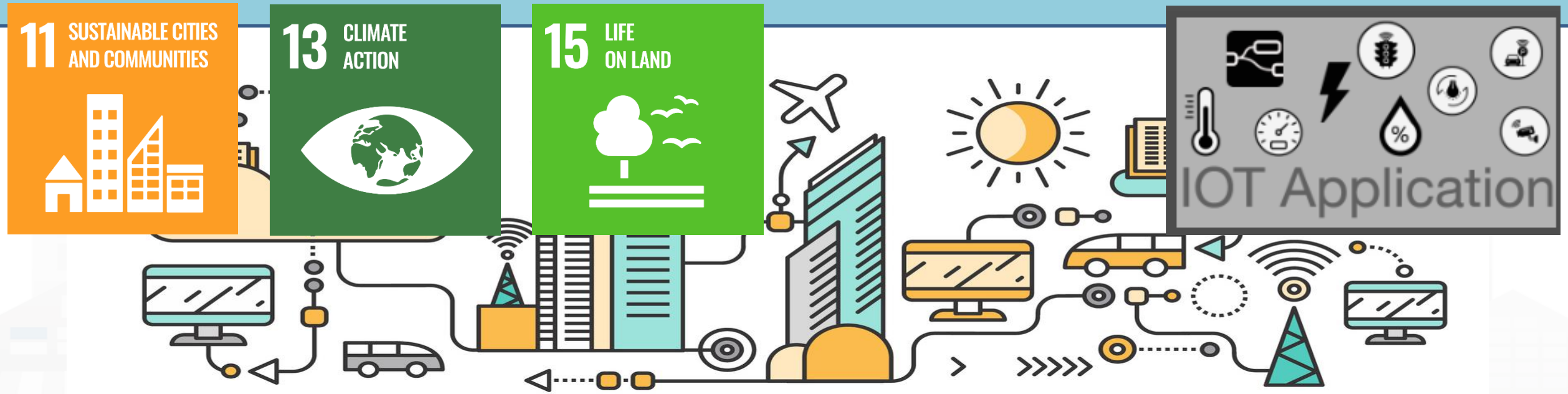
CO2 estimation





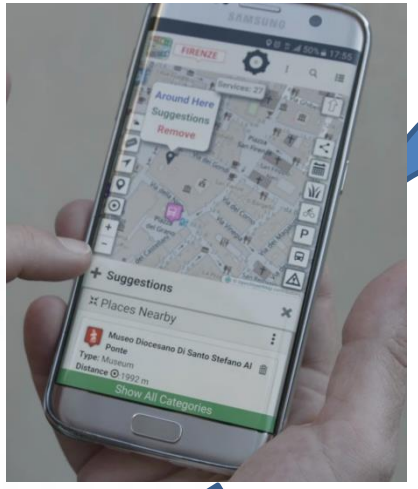
S. Bilotta, P. Nesi, "Estimating CO2 Emissions from IoT Traffic Flow Sensors and Reconstruction", Sensors, MDPI, 2022. https://www.mdpi.com/1424-8220/22/9/3382/

Computing Quality of Public Transportation Service



How much confident is the guess for bus arrival





Assessment and prediction

Customer satisfaction



Qualità Trasporto Pubblico - Cloned

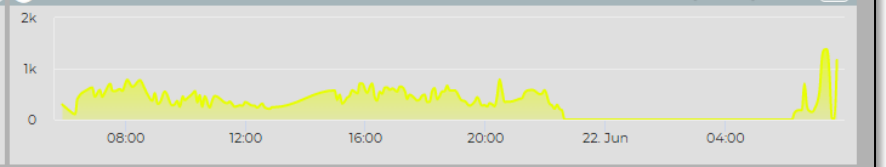
Firenze - 6 linee

Sat 22 Jun 07:45:48

Linea 13 — 825 — Ritardo medio corse attive nei 5min in sec



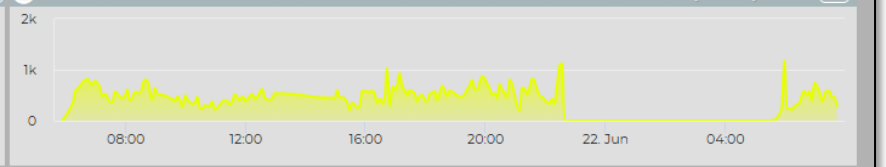
Linea 31 — 1166 — Ritardo medio corse attive nei 5min in sec



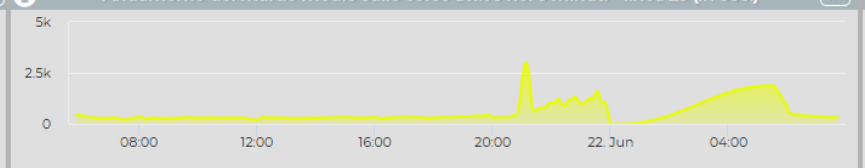
Linea 17 — 222 — Ritardo medio corse attive nei 5min in sec



Linea 36 — 289 — Ritardo medio corse attive nei 5min in sec

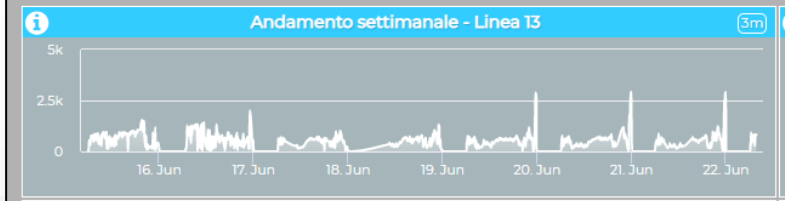


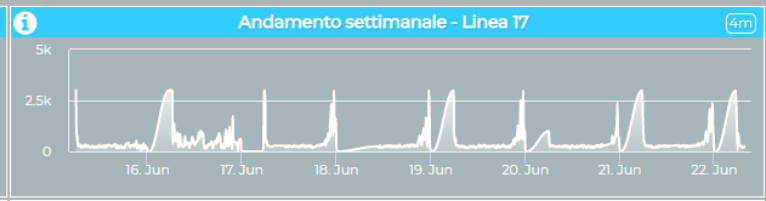
Linea 23 — 337 — Ritardo medio corse attive nei 5min in sec

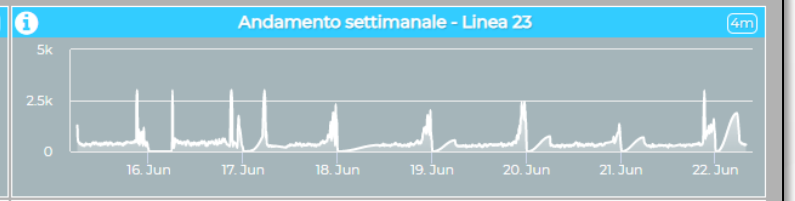


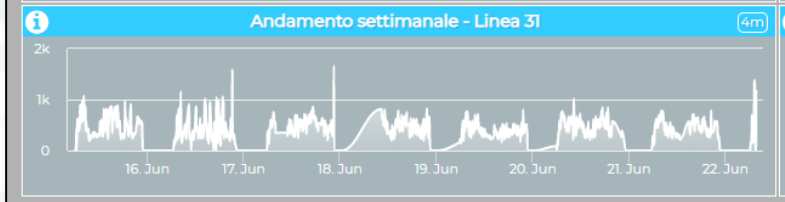
Linea 6 — 411 — Ritardo medio corse attive nei 5min in sec

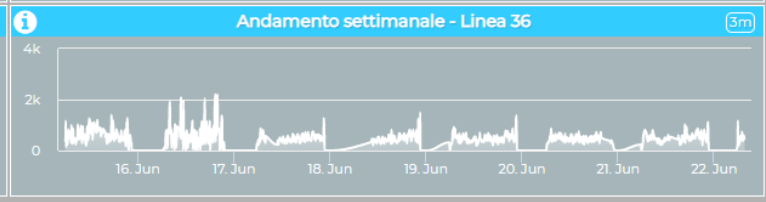


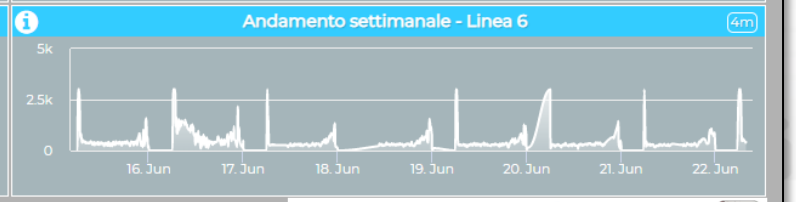












Firenze Oggi

Sun 20 Oct 23:35:33

26976
Totale utenti WIFI

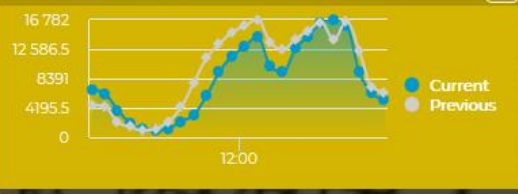
COLONNINE RICARICA... 9m
176 INSTALLATE
71 % ATTIVE
5.1 % IN USO

9m
GENERAL | METEO
MINIMO | BASSO | MEDIO | ALTO
RISCHIO IDRAULICO
RISCHIO TEMPORALI
RISCHIO IDROGEOLOGICO
RISCHIO NEVE
RISCHIO GHIACCIO
RISCHIO VENTO

SITUAZIONE VIABILITA 55s
0 INCIDENTI
0 CHIUSURE AL TRAFFICO (TOT)
0 CHIUSURE PER CANTIERI
0 PROGR. | 0 NON PROG.
0 LIMITAZIONI AL TRAFFICO (TOT)
0 LIMITAZIONI PER CANTIERI
0 NON PROG. | 0 PROGR.
0 TOT. EVENTI SULLA RETE

SMN 9m	BINARIO16 9m	FORTEZZA 9m
21.6 % occupati su 607 posti	43 % occupati su 165 posti	19.2 % occupati su 521 posti
LEOPOLDA 9m	**CALZA 9m**	**S.AMBROGIO 9m**
34 % occupati su 300 posti	39.2 % occupati su 148	21.6 % occupati su 379 posti
PARTERRE 9m	**CAREGGI 9m**	**BECCARIA 9m**
31.1 % occupati su 656 posti	4.4 % occupati su 406 posti	23.3 % occupati su 210 posti

ANALYSIS
Energy | Environment | Mobility | Social | Resilience

FLUSSI INGRESSO CITTA 9m


TOTALE 9m
176560
VEICOLI

FLUSSI INGRESSO ZTL 9m


TOTALE ZTL 9m
47368
VEICOLI

Nati Italiani 119m	Nati stranieri 119m	Deceduti 119m	Matrimoni 119m	Unioni Civili 119m
164 ultimo mese consolidato	57 ultimo mese	399 ultimo mese	18 ultimi 7 giorni	0 ultimi 7 giorni

Segnalazioni ricevute in attesa 119m	In Lavorazio... 119m	Risolte 119m	Chiuse senza risoluzion... 119m
1116 ultimo mese	524	305	285

Manutenzioni Stradali 59m	Verde Pubbl... 59m	Decoro Urbano 59m	Relitti 59m
6 oggi	3	5	0

Attesa media alla fermata

Linea 6 9m	Linea 13 9m
3 min	13 min
Linea 17 9m	**Linea 23 9m**
4 min	5 min
Linea 31 9m	**Linea 36 9m**
19 min	2 min

TOP

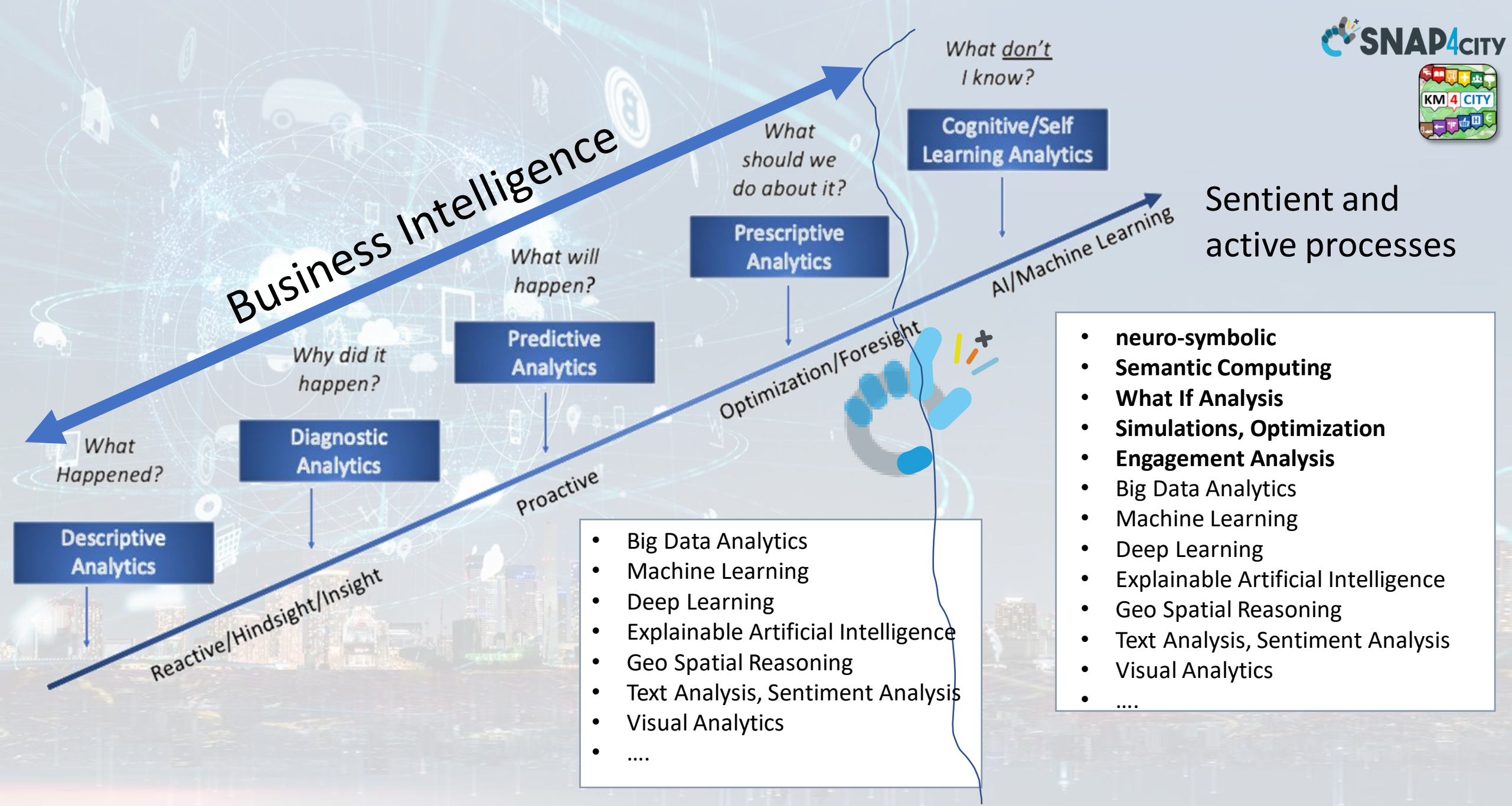
From Data Analytics, DA to Artificial Intelligence, AI



Data Analytics

- **examining data** to
  - uncover patterns, trends, and insights that can be used to make informed decisions.
  - extracting meaningful information from data and typically involves statistical analysis, data mining, and visualization techniques.
- **Data analysts** use tools like tables, data base queries, and programming languages to process and analyze data, identify correlations, and create reports.
- ***Snap4City provides support for implementing DA on:***
  - *Proc.Logic / IoT Apps: on cloud and on Edge*
  - *Python processes in containers or on Edge*
  - *R Studio processes in containers, servers, premise, etc.*



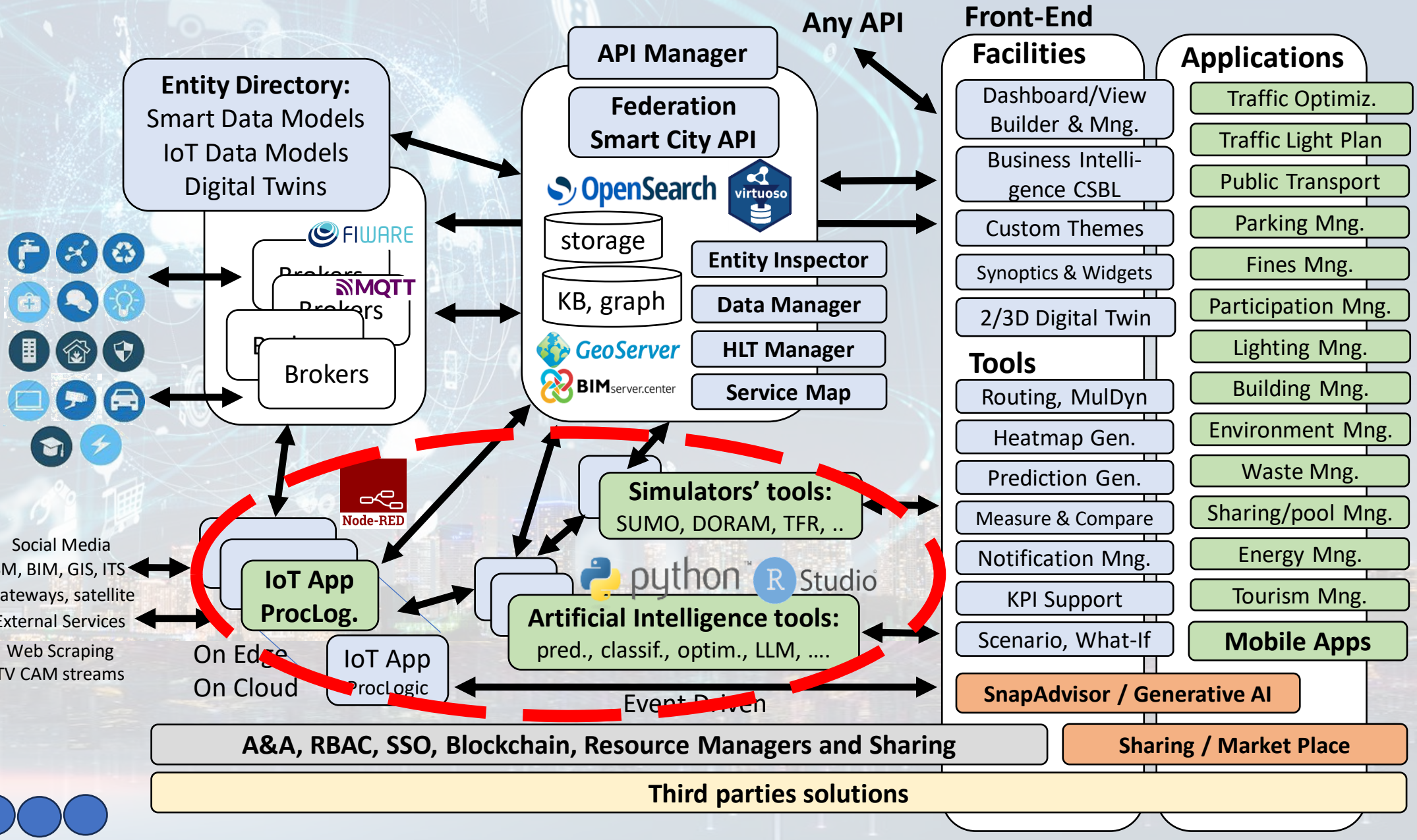

Business Intelligence
What Happened?
Descriptive Analytics
Why did it happen?
Diagnostic Analytics
What will happen?
Predictive Analytics
What should we do about it?
Prescriptive Analytics
What don't I know?
Cognitive/Self Learning Analytics
Reactive/Hindsight/Insight
Proactive
Optimization/Foresight
AI/Machine Learning
Sentient and active processes
• Big Data Analytics
• Machine Learning
• Deep Learning
• Explainable Artificial Intelligence
• Geo Spatial Reasoning
• Text Analysis, Sentiment Analysis
• Visual Analytics
• ….
• neuro-symbolic
• Semantic Computing
• What If Analysis
• Simulations, Optimization
• Engagement Analysis
• Big Data Analytics
• Machine Learning
• Deep Learning
• Explainable Artificial Intelligence
• Geo Spatial Reasoning
• Text Analysis, Sentiment Analysis
• Visual Analytics
• ….

Advanced Computing

- **cutting-edge technologies**, techniques, and methodologies to solve complex computational problems that are beyond the capabilities of traditional computing approaches.
  - optimization problems, pattern recognition, natural language processing
  - **Via:** artificial intelligence (AI), machine learning, high-performance computing (HPC), big data analytics, and cloud computing.
  - **On:** massive volumes of data, complex simulations, computationally intensive tasks, on HPC infrastructures
  - → accelerate problem-solving, and enable breakthroughs in scientific research, engineering, business intelligence, and other domains.
- ***Snap4City provides support for implementing AC:***
  - *Python processes in containers, servers, etc.*
  - *R Studio processes in containers, servers, etc.*



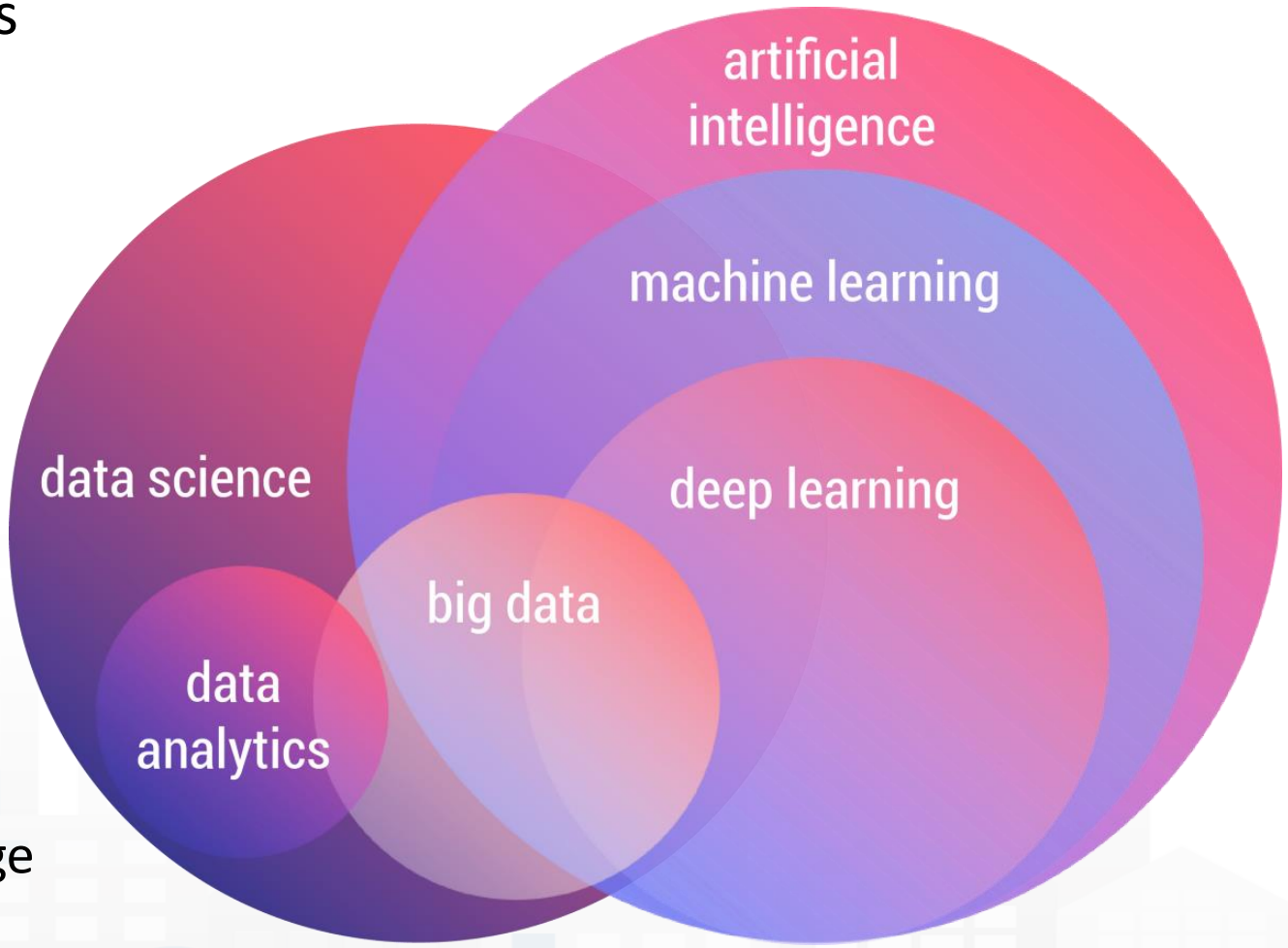
Technical Architecture



Snap4City and DA and AC (summary)

- allows to create simple data processing as well as massive computing solutions exploiting statistics, machine learning, operating research, HPC, etc. for computing:
  - predictions, anomaly detection, early warning, OD Matrix, simulation, trajectories, typical trends, what-if analysis, smart routing, heatmaps, optimization, etc.
- **can be developed** in:
  - R Studio, Java, Python, exploiting NVIDIA clusters, HPC, MLOps, etc.
  - ETL, IOT Applications
  - If Snap4City is a version with HDFS/Hadoop/Hbase/Phoenix, it includes also: MapReduce, Spark, etc.
- **may be shared** with other colleagues, and organizations via the Resource Manager

- **Artificial Intelligence** usually also includes
  - Code, learning and reasoning
  - Semantic computing, Knowledge Bases
  - Neuro-symbolic reasoning
  - Decision Support Systems
  - Problem solving
- **Machine Learning** usually includes
  - Learn without coding
  - Predictions, decisions (classifications)
  - Supervised or not
  - NLP, vision, pattern recognition
- **Deep Learning** usually includes
  - Capability to learn complex patterns on huge amount of data
  - Generative AI, continous learning, graph NN, etc.
  - Specialized ML solutions



Snap4 Solutions and Technologies

- **Indexes, KPI, Indicators**
- **Predictions: short, long, very long:**
  - traffic, parking, people flow, maintenance, land sliding, NO2, etc.
  - 3D Flow prediction: Pollutant (NOX, NO2, …)
- **Anomaly detections, critical condition detection:**
  - early warning, recovery, etc.
- **Simulation and optimization**
  - Traffic Flow reconstruction
  - Routing, multimodal routing, constrained dynamic routing, etc.
  - Public transportation load, optimisation of traffic condition and traffic lights
- **What-IF analysis** (simulation + predictions + data + scenarious)
- **AI: technologies: operating research, ML, AI, XAI, DL, NLP:**
  - Semantic computing, neuro symbolic
  - RF, XGBoost, BRNN, RNN, SVR, MLP, …
  - DNN, LSTM, CNN-LSTM, Autoencoders, BERT, …
  - Clustering: K-means, K-Medoid, …
  - XAI: Shap, variations, Lime, ..
- **Based on several computational models**:
  - trajectories, OD matrices, Typical Time Trends, etc.

to cope with

- *any data, format*
- *any channel, protocol*
- *any AI/ML*
- *any place*
- *online development*
- *multi-tenant*
- *Secure, PENTest*
- *GDPR, privacy*
- ***→low costs***
- ***→easy to evolve***

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

Lesson Learnt for Recipes



- **Data identification and finalization**:
  - Collection of data, acquisition of data from provider, construction of data
    - easy to use data or surrogated data ?
  - Data quality ?
    - To work and produce results any way even in presence of Missing and poor quality data
- **Computation Models** depending on the case
  - Statistics, Optimisation
  - Simulation and computation, or mixt
  - Identification of the most effective ML/AI techniques to obtain the best possible results with:
    - respect to the state of the art
    - the accessible data
    - the provided resource, sustainability compromise
  - ML/AI techniques: training and execution
- **Data Representation Models and tools**

- ***Before*** *entering into how to do it, it is better to see some examples*

TOP

List of the most relevant Snap4City DA and AI Solutions



Available AI Solutions on Snap4City

https://www.snap4city.org/997

More than 80 Available Solutions & 300 AI applic.

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



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

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

Control Planning Goals

Control

Management and Operational
(monitoring, KPI, anomaly detection, early warning)

Planning

Tactic and strategic, medium and long range, micro/macro
(simulations and predictions, what-if analysis)

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



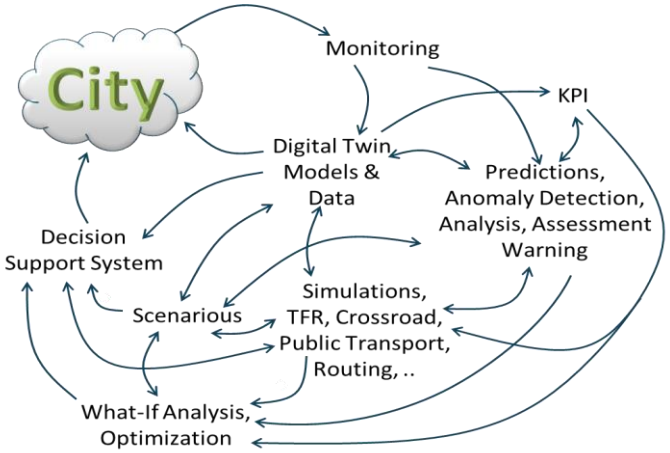
- **Horizontal homogeneous platform Uniform Technology for**
  - **Any Vertical operation/plan:** mobility, energy, environment, security, tourism, infrastructure and assets control, buildings, etc.
  - **AI Solutions**: early warning, predictions, simulations, what-if, optimization; Deep Learning, ML, 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.

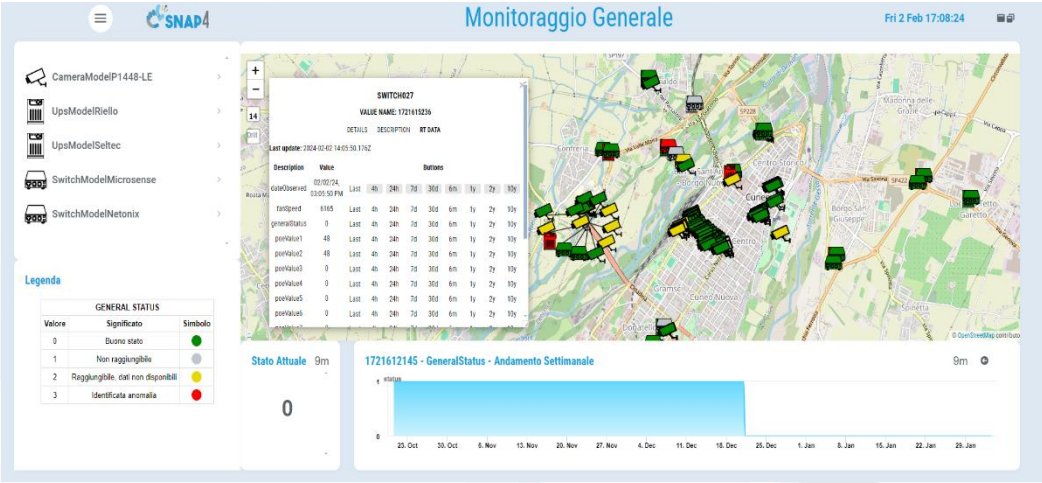


- **KPI:** multidomain KPI, general management, early warning, early detection of critical conditions, 15 Min City Index, SDG
- **Mobile App:** modular applications, operators' modules, multiple cities, etc.
- **Participatory**: problem reporting, ticketing, etc.
- **Integration of any kind**

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





Mobility and Transport goals



Decongestion



Safety



Accessibility



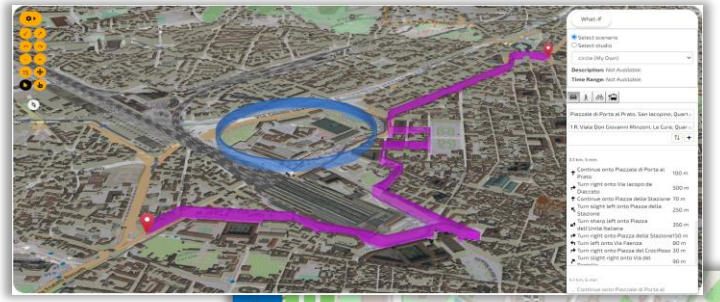
Cost Reduction

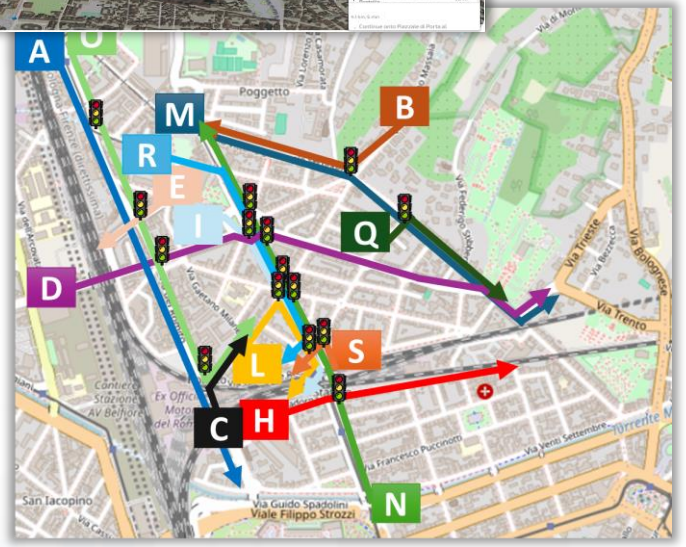


Decarbonization

Mobility & Transport

- **Goals:**
  - Decongestion, Decarbonization, costs reductions
  - Improve Accessibility to services
  - Improve Security/Safety of city users
- **Operation and Plan**:
  - Traffic monitoring, prediction, reconstruction, identification of critical conditions (early warning), fleet management, dynamic routing, multimodal routing, city user behaviour analysis
- **Optimization and what-if analysis traffic light, infrastructure**
  - **Reduction**: travel time, waiting time, stops, CO2 emissions, consume fuel, travel time for tramways
- **Public Transport**: analysis of Mobility Demand vs Offer of Transportation
- **Parking Management:** monitoring, prediction, any payments, on/off-road
- **Sharing / Pooling Management**: eShare and mobile app, bikesharing, smart bike, fleet management
- **KPI:** SUMI/SUMP, travel time, emissions, traffic status, accessibility, ..
- **Mobile App**: final users and operators
  - Info Mobility, traffic reconstruction, charging, participation,
  - Parking, payments, overparking, fine reporting, ..
- **Participatory**: problem reporting, ticketing, etc.
- **Data Integration of any kind: env, weather. Tickets, presences, POI, sat, etc.**

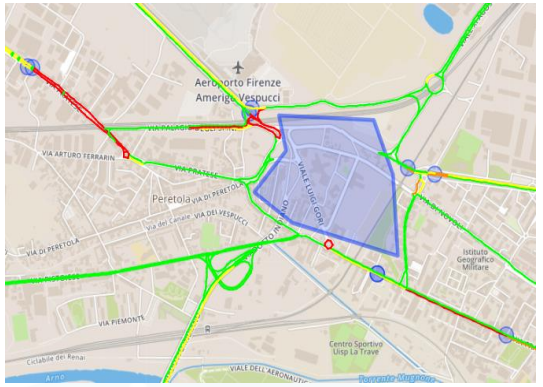


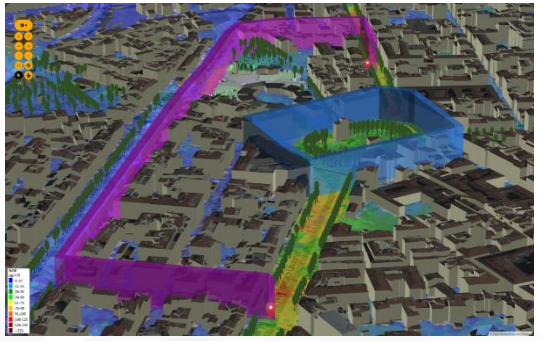




Mobility and Transport Domain (2024/8)

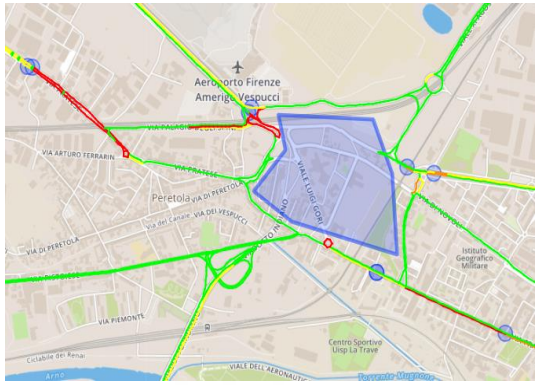
- Goals:
  - Decongestion
  - Decarbonization
  - Accessibility to services
  - Security/Safety of city users
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
  - Monitoring traffic, parking, people flow, services, boats, ports, beaches, etc.
  - Early detection/warning 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

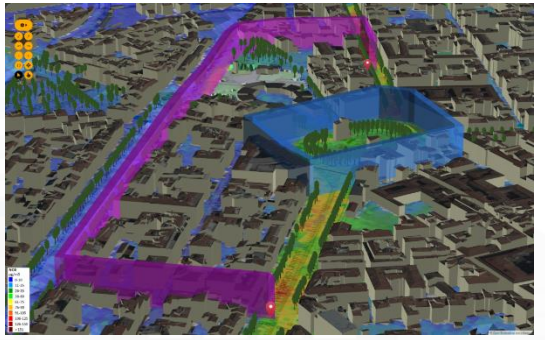




Tools for Mobility and Transport (2024/8)

- **Optimisation of viability of an area for reducing congestion, waiting time, stops**
- **Optimisation of Traffic Light Plans, synchronization, in an area for reducing congestion, waiting time, stops**
- **Predictions** for: traffic flow, smart parking, smart bike sharing, people flows, etc. (ML, DL)
- **What if analysis**: routing, traffic flow, demand vs offer, pollutant, etc. (Simulation + ML)
- **Traffic flow reconstruction** from sensors and other sources (simulation + ML)
- **Public Transportation**: Ingestion and modelling of GTFS, Transmodel, NeTEx, etc. (DP)
  - Analysis of the **demand mobility vs offer transport** of according to public transportation and multiple data sources (Simulation)
  - Assessing **quality of public transportation** (analysis)
- **Accidents** heatmaps, anomaly detection (analysis, ML)
- **Road light controlled by traffic conditions**
- **Tracking fleets**, people, via devices: OBU, OBD2, mobile apps, etc. (DP)
- **Routing** and multimodal routing (multistop travel planning), constrained routing, dynamic routing (DA)
- Computing **Origin Destination Matrices** from different kind of data (analysis, DP, DP)
- Computing **typical trajectories** on the basis of tracks (analysis, ML)
- Fleet management, monitoring, booking, allocation, maintenance
- Computing Messages for Connected drive (DP)
- Slow and Fast Mobility **15 Minute City Indexes** (analysis, DP, …ML)
- Computing and comparing traffic flow on devices and at the city border (analysis)
- **Typical time trends** for traffic flow and IoT Time series. (analysis, ML)
- **Impact of COVID-19** on mobility and transport
- Computing **SUMI, PUMS**, etc. (mainly DP)
- **Definition of Scenarios:** traffic, road graph, conditions, etc.
- Etc.





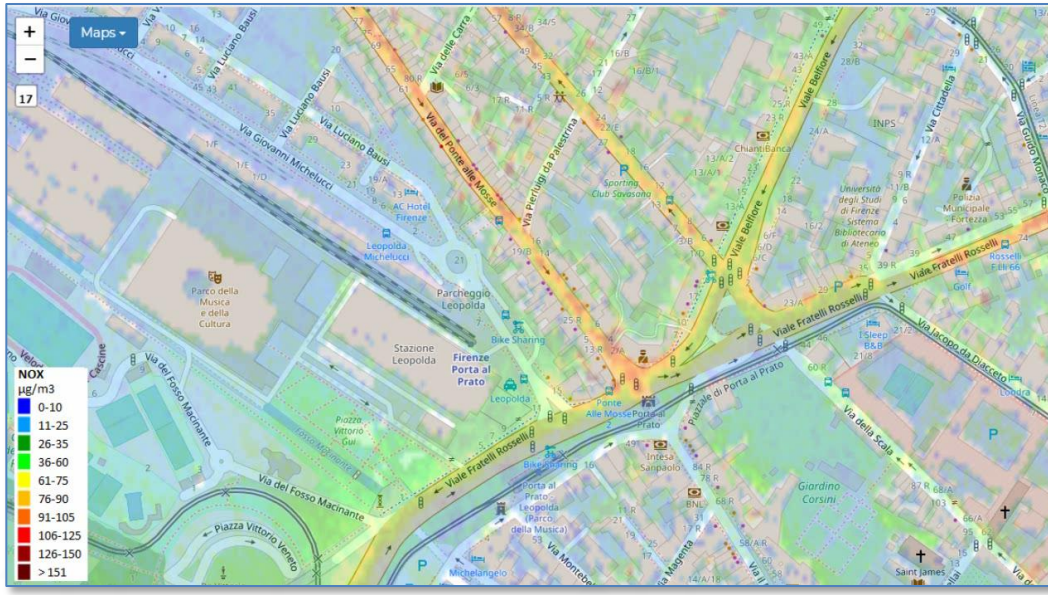
Environment and Waste Management

Goals

Control of emissions
Reduction of emissions
Early warning
Meet the EC targets
Reduction of EC taxation

Environment and Waste

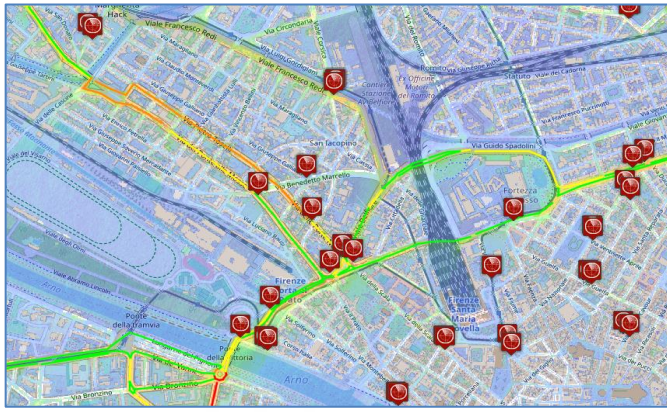
- **Goals:**
  - Reduction of emissions and EC taxations
  - Cost reduction for waste collection,
  - reduction of waste collection impact on mobility
- **AIR quality (Indexes) monitoring and warning**
- **Environment Management & producing prescriptions:**
  - Monitoring, long and short-term predictions, warning for:
    - GHG, emissions, pollutants, aerosol, chemical plants analysis
  - Traffic Flow impact emissions, predictions
  - Sea conditions, UV conditions, etc.
- **Land slide prediction warning**
- **Coastal erosion monitoring and analysis**
- **Smart 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)

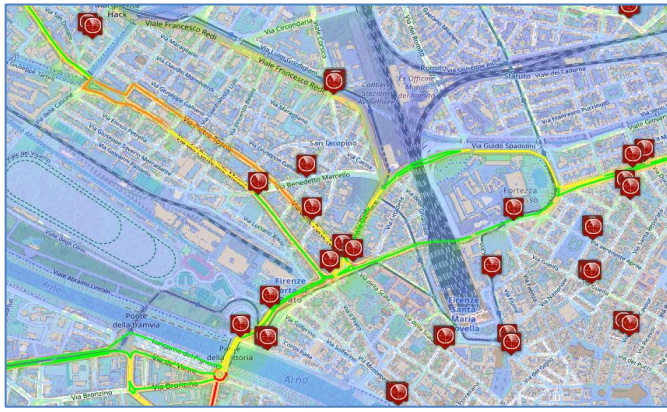
- Goals:
  - Reduction of emissions and EC taxations
  - Cost Reduction for waste collection, reduction of waste collection impact on mobility
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
  - Monitoring emissions, weather, waste, water, etc.: sensors, 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





Tools: Environment, waste, land, (2024/8)

- **Pollutant Predictions: short, long and very long term** European Commission KPIs
  - NOX, PM10, PM2.5 pollution on the basis of traffic flow, 48 hours (ML, AI, DL)
  - Cumulated NO2 average over year (ML, AI, DL)
- **Computation of CO2** on the basis of traffic flows (DP), computing emission factor (DA)
  - each road for each time slot of the day
- **Prediction of MicroClimate** conditions for diffusion (ML, AI)
  - NO2, PM10, PM2.5, etc.
- **Prediction of landslides**, 24 hours in advance (AI, DL)
- prediction of **waste collection, & o**ptimisation of schedule and paths (DP, ML)
- **Heatmaps production** dense data interpolation (DP) for
  - Weather conditions: temperature, humidity, wind, DEW
  - Pollutants and Aerosol: NO, NO2, CO2, PM10, PM2.5, etc.
- **Impact of COVID-19** on Environmental aspects (DP)
- Computing **SDG, SUMI, SUMP,** .. (mainly DP)
- Etc.



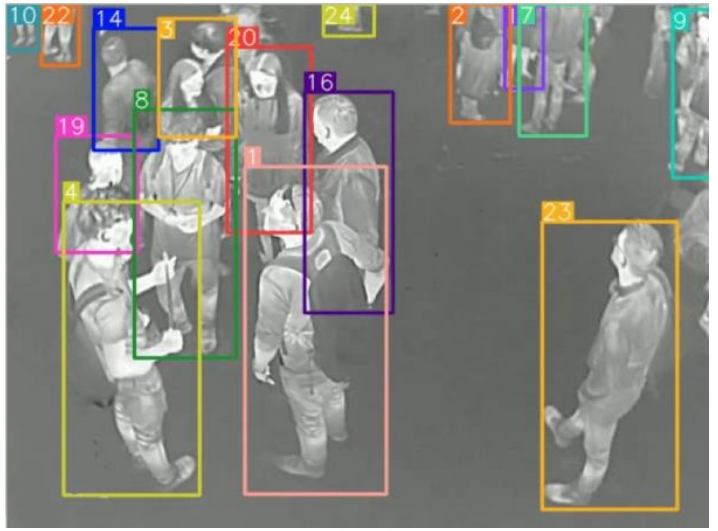


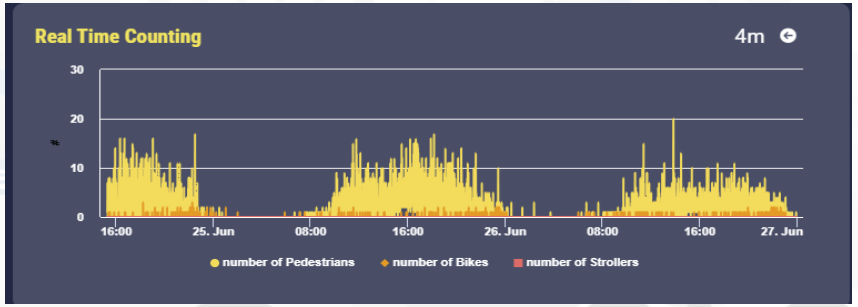
City Users' Services and Tourism Management

Goals

City User Behaviour/services, Tourism and Safety

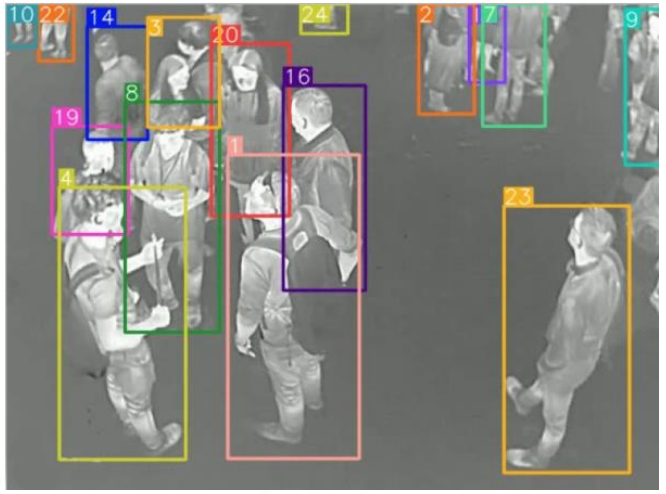
- **Goals:**
  - Improve Quality of Life and quality of services,
  - Over tourism mitigation, sustainability
  - Costs reduction of services
  - Improve accessibility to services: citizens, Tourists, commuters, etc.
  - Improve Security/Safety of city users
- **People Flow Analysis / Management:** in/out-door, retail, attractions
  - Counting, tracking, Flows, ODM, sentiment, recency/frequency, 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)

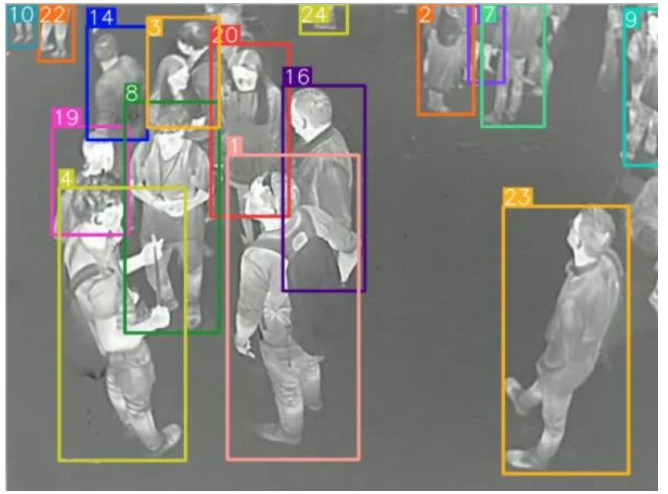
- Goals:
  - Quality of Life, quality of services, over tourism mitigation, sustainability
  - Costs reduction of services
  - Accessibility to services: citizens, Tourists, commuters, etc.
  - Security/Safety of city users
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, 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





City Users Behaviour, Safety, Security and Social Analysis (2024/8)

- **People detection and classification**: persona, strollers, bikes, etc. (ML, DL)
- **people counting and tracking**, head counting, people trajectories (via thermal cameras, ML, DL)
- **People flows prediction** and reconstruction, (ML, DL)
  - Wi-Fi data, mobile apps data, Mobile Data, etc.
- **User's behaviour analysis**, **People flow analysis** from PAX Counters and heterogenous data sources (ML, AI)
  - origin destination matrices, hot places, time schedule,
  - Recency and frequency, permanence, typical trajectory, etc.
- **Computing User engagement and suggestions** for sustainable mobility (Rule Based, ML)
- **Social media analysis** on specific channel, specific keywords: see Twitter Vigilance,
  - Reputation, service assessment: MultiLingual NLP and Sentiment Analysis, SA
  - Tweet proneness, retweet-ability of tweets, impact guessing
  - Audience predictions on TV channels and physical events, locations
  - Prediction of attendance of events and on attractions
- **Virtual Assistant construction, LLM, NLP, Sentiment Analysis (DL, NLP)**
- **Video management System integration for security**
- **15 Minute City Index**, etc. (modeling and computability)
- Computing **SDG**, etc., (DP)
- Etc





Smart Energy and Smart Building

Goals



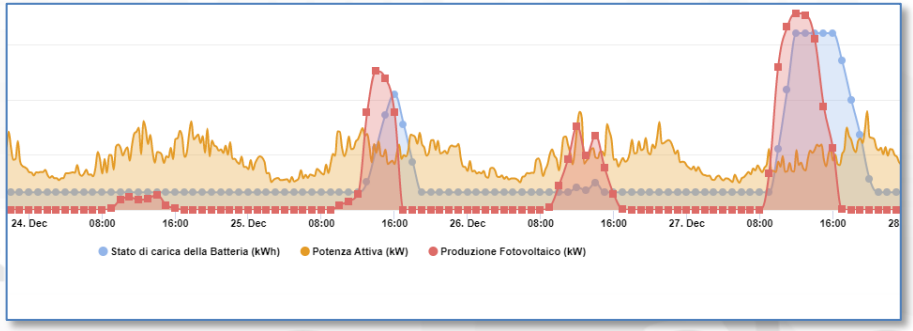
Cost Reduction

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**

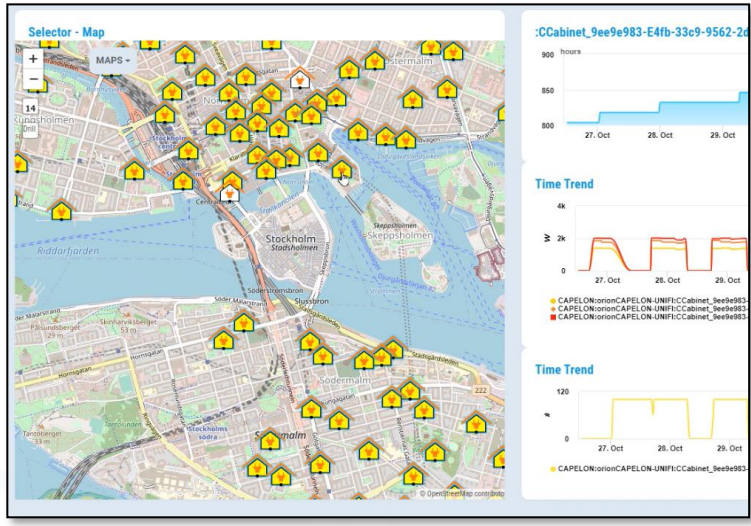


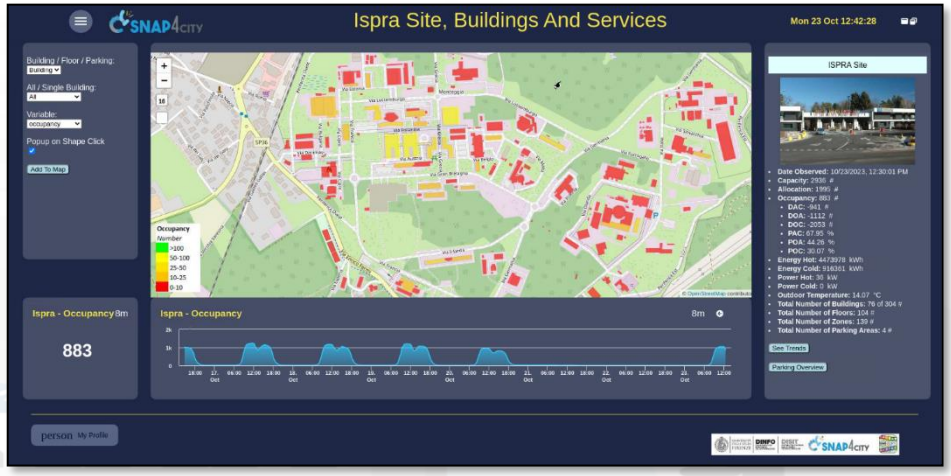




Energy Domain (2024/8)

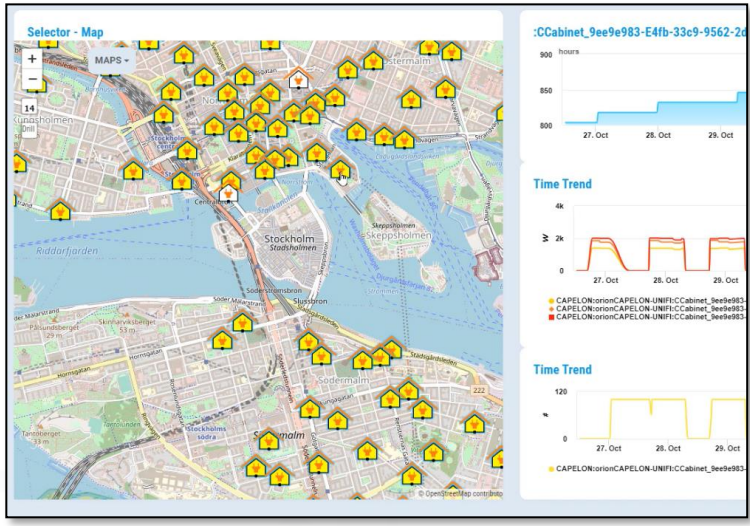
- Goals:
  - Energy consumption reduction, increment of efficiency, sustainability
  - accessibility to services
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
  - Monitoring energy consumption (heating, cooling, prod.,..), conditions, charging stations, etc.
  - Managing Smart Light for city: dimering, programming, traffic control, controllers, legacy, etc.
  - Early detection/warning, alarm, of critical conditions
  - Managing smart services: cabinets, lockers, etc.
  - Production of suggestions, nudging
  - Global and local 3D/2D representations of area and buildings
  - Managing Communities of Energy, certification via Blockchain
  - Computing predictions of any kind
- Solutions for Planning (optimization and what-if analysis)
  - Reduction of energy costs, via optimization
  - Identification of roofs with better orientation
  - Optimization of battery storage size for PV plants
  - Community of Energy planning and viability
- Algorithms and computational solutions, see next slide





Tools: Energy Domain (2024/8)

- **Monitoring Energy Consumption in single building, area and per zone**
- **Smart Light management**, unicast and multi cast management, smart light controlled by **traffic flow data**
- Monitoring Energy provisioning on **recharging station**
- **Matching Energy consumption with respect to the actual usage**
- **Computing Roof orientation for Photovoltaic installations**
- **Optimisation of Photovoltaicc installations** to identify the best parameters of size and storage
- Collecting and managing **Communities of Energy**
- Computing **KPI**
- Etc.

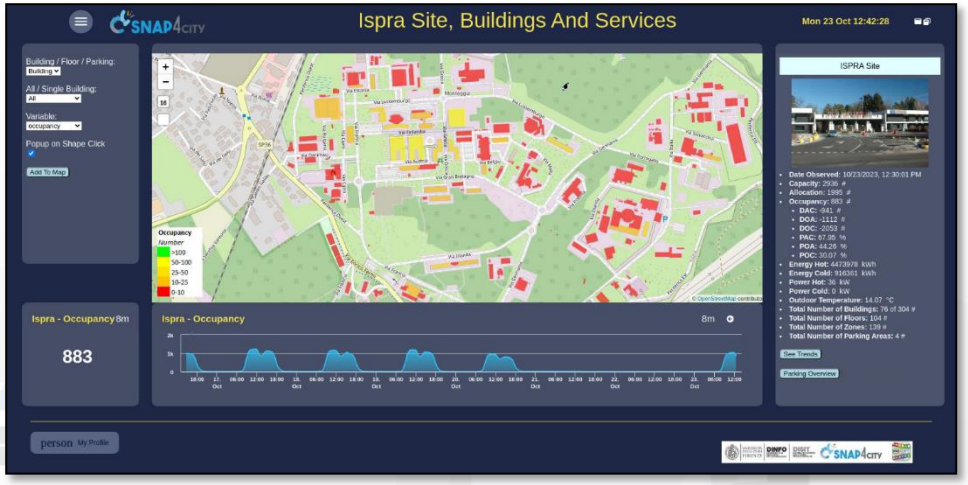




Snap4Building Domain (2024/8)

- Goals:
  - increase efficiency, cost reduction, sustainability
  - Accessibility to services, Security/Safety
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
  - Monitoring: usage, energy, environmental conditions, people flows, services, etc.
  - Early detection/warning, alarm, of critical conditions, notifications, decision support
  - Production of suggestions/prescriptions, nudging
  - Managing smart services: cabinets, dispenser, lockers, etc.
  - Global and local 3D/2D representations of area and buildings
  - Integration with Video Management Systems
  - Computing predictions of any kind
- Solutions for Planning (optimization and what-if analysis)
  - Reduction of energy costs via optimization
- Algorithms and computational solutions, see next slide

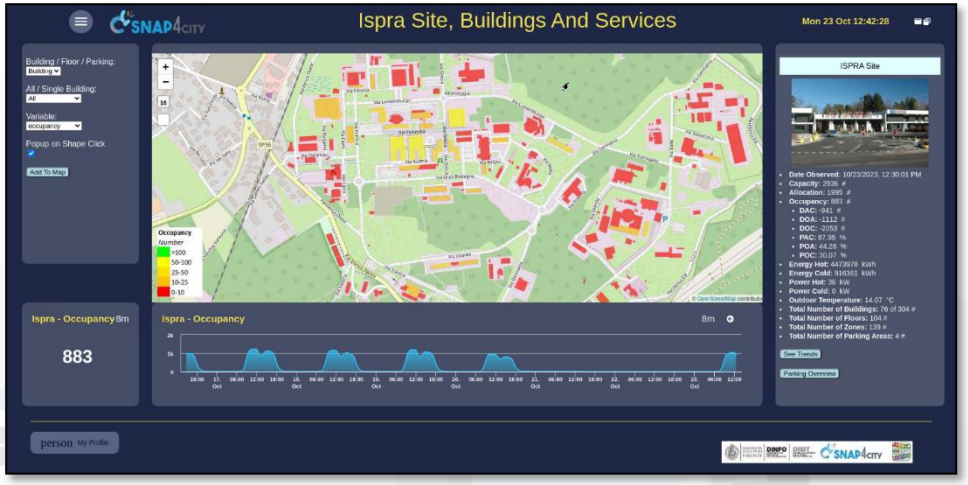




Smart Buildings, Snap4Building (2024/8)

- **Digital Twin for monitor, control and manage distributed infrastructures**
  - 2D/3D representations of the whole set of buildings, BIM modeling
  - Entities (building, floors, rooms, parking, charging stations, gates, etc.) with their shapes and descriptors, and data monitoring the allocation to office, meeting, cafeteria, storage, stairs, elevator, etc.
- **Monitoring and computing KPIs on real time for**
  - **energy** consumed or produced (hot/cold), **parking, logistic, presences, cleaning, air quality, departments, subareas, maintenance, etc.**
  - **allocation/designation**, dispositions, heating, cooling, temperature, equipment, etc.
  - **grouped in Zones**





SNAP4INDUSTRY

Tools for
rapid implementation of
- Sustainable Smart Solutions
- Decision Support Systems
as a no-coding, low-coding

info@disit.org
https://www.Snap4city.org,
https://www.Snap4Industry.org

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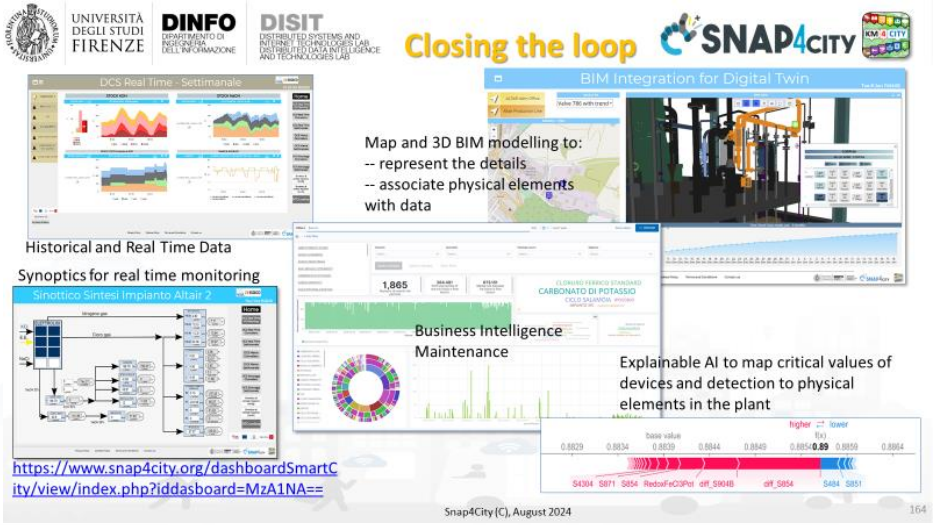
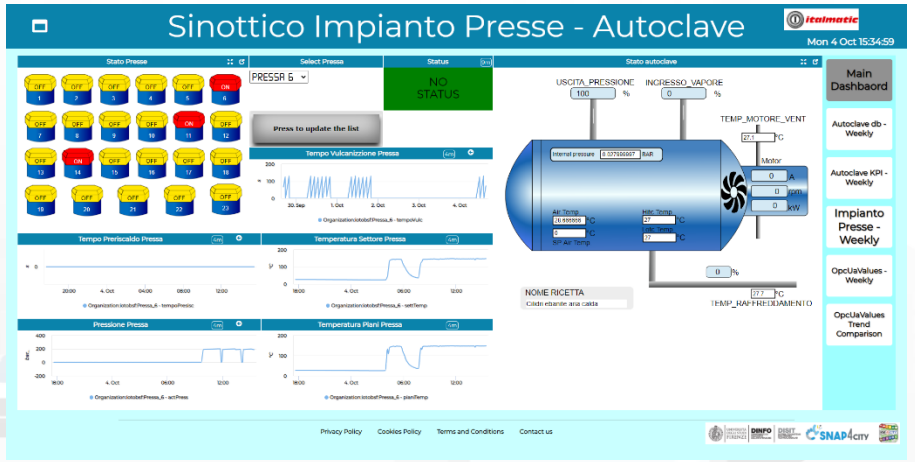
Industry production Domain (2024/8)

- 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





SUSTAINABLE DEVELOPMENT GOALS

SNAP4CITY

KM 4 CITY









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



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



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





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



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



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



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

Disappearing Data Analytics

	Antwerp					Helsinki								Where				
SNAP4CITY	City official	ICT official	Developer	Citizen, tourist, visitor	Business owner	City officials	City officials Domain experts	City officials City developers	Third party developers	Citizen	Citizens with respiratory problems	Tourists	Business owners	Mobile	MIcroApplication	Tool, via Portal (ICT Developers)	Dashboards	RULE OF THUMB Main Data Sources
Discovery near to me	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			POI, OSM
Discovery along a path	x	x	x	x		x		x	x	x	x	x		x	x			POI, OSM
Discovery in an area, shape	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		POI, OSM
browsing Public Transport	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			OSM, GTFS
Full Text search	x	x	x	x	x	x		x	x	x	x	x	x	x		x		POI, OSM
Routing: pedestrian				x	x			x	x	x	x	x	x	x				OSM
Routing: pedestrian quite				x	x			x	x	x	x	x	x	x				OSM
Routing: private vehicles	x		x	x		x		x	x	x	x			x	x			OSM
Routing: Multimodal Public Transport				x					x	x	x				x	x		OSM, GTFS
heatmaps: weather (Temp, Humidity)	x	x		x	x	x	x		x	x	x	x	x	x			x	Sensors data, OSM
heatmaps: environmental variables, PM10, PM2.5, NO2, EAQI	x	x		x	x	x	x		x	x	x	x	x	x			x	Sensors data, OSM
heatmaps: environmental variables, Noise						x	x			x			x	x			x	Sensors data, OSM
heatmaps: safe on bike (Antwerp)	x	x		x	x									x			x	Spec. Portal
heatmaps: Enfuser prediction, PM10, PM2.5, AQI						x	x		x		x	x	x	x			x	Enfuser data
heatmaps piking values any place	x	x			x	x		x	x				x				x	Computed Heatmps
heatmaps: GRAL prediction, PM10						x				x	x	x	x	x			x	OSM, Traffic, Weather
Comparsison: Enfuser, Gral, Real Time							x										x	Enfuser, Sensors, GRAL
Sensors Data Time Trends, & drill down	x	x	x		x	x	x	x					x			x	x	Sensors data, OSM
Weather Forecast	x	x		x	x	x	x		x	x	x	x	x	x			x	Forecast Service
Origin Destination Matrices	x	x	x		x		x	x	x				x				x	Snap4City Mobile App
Typical trajectories	x	x	x		x		x	x	x				x			x	x	Snap4City Mobile App
Hot Area in the city	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x	Snap4City Mobile App
Hot Places in Smart Zone	x	x	x	x										x		x	x	Snap4City PAXcounters
Services Suggestions on mobiles										x	x	x		x	x			Snap4City Mobile App
Alerts on critical cases: several variables	x			x	x	x	x			x	x		x	x				Sensors data, OSM
The most used services		x		x	x		x			x	x	x	x				x	Snap4City Mobile App
Twitter Trends Daily	x	x	x		x	x	x	x	x				x			x	x	Twitter Vigilance
The auditing of user and living lab		x				x		x								x		Snap4City Portal
Self assessment	x	x	x	x	x	x	x	x	x	x	x	x	x			x		Snap4City Portal
Trajectories reg from mobile PAX Counters	x	x	x			x	x	x							x		x	PAX Counters
Engagement real time assessment	x	x	x			x	x	x									x	Snap4City Mobile App

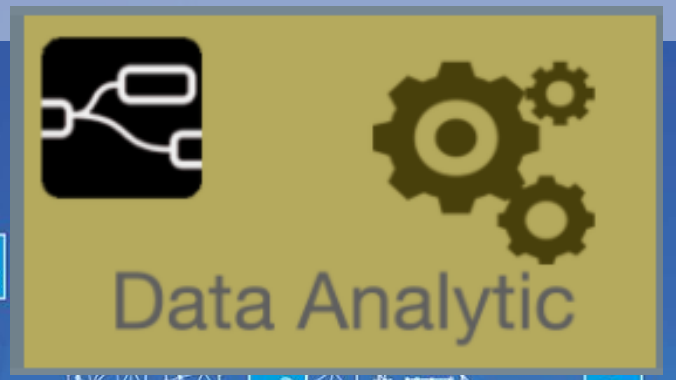
Data Analytics for targeted users
Via specific Tools and Visual Analytics

TOP

Predictions and Anomaly detections







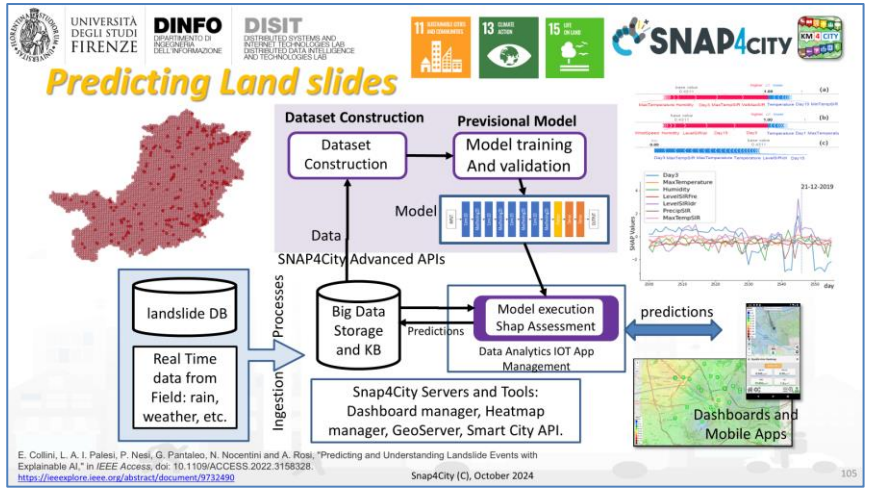
Predictions on .....selected.....

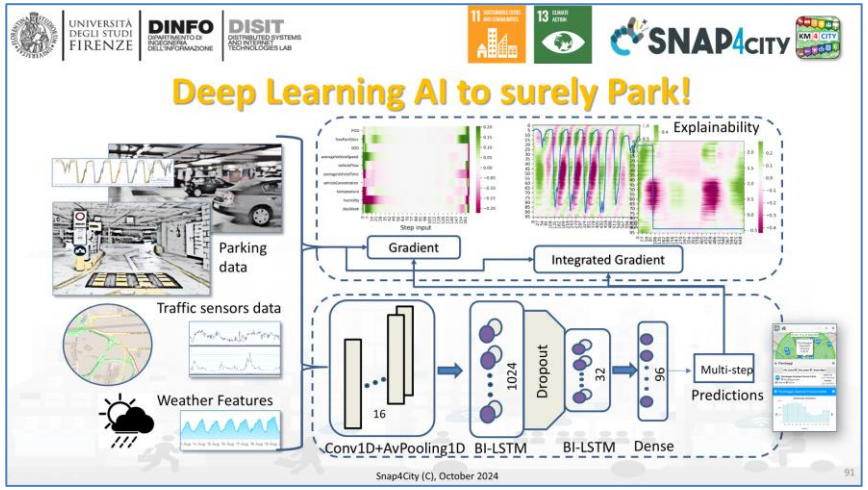
Aim in operation:

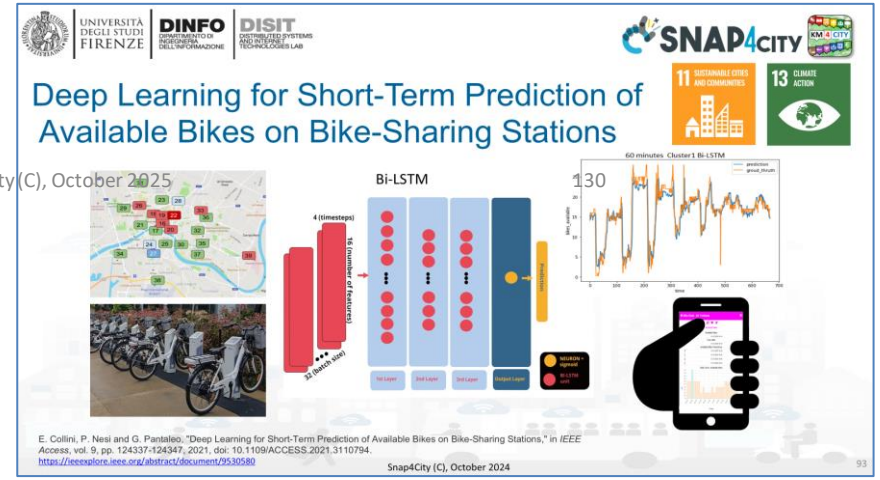
- Short Term predictions
- Reduction of costs, prevention
- Early warning of critical conditions
- Reduction of emissions
- Seasonality

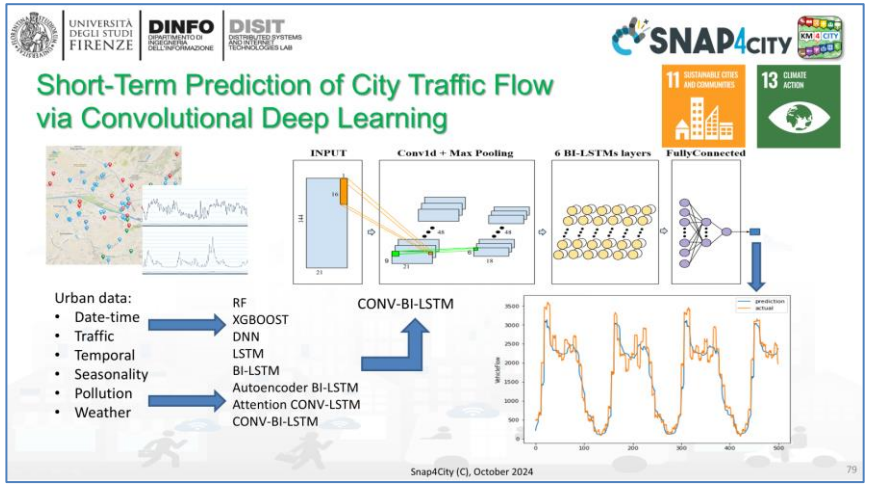
AI inject:

- Deep Learning
- Data integration
- XAI addition for suggestions









Predictions

- **Computing predictions**
  - **Why?**
  - **They can be always computed**?
    - Time series, time trends, seasonality, etc.
  - **Which data are needed?**
  - **Precision needed and precision which can be obtained?**
  - **Computational costs?**



- **Technically:**
  - **Time range**, in most cases they are defined such as:
    - Short: 5-15 Minutes;
    - Long: 1 day, week;
    - Mid: 30-45 minutes;
    - very long: weeks / months / years
  - **Computational Model needed ?**

Management

Tactics/strategy

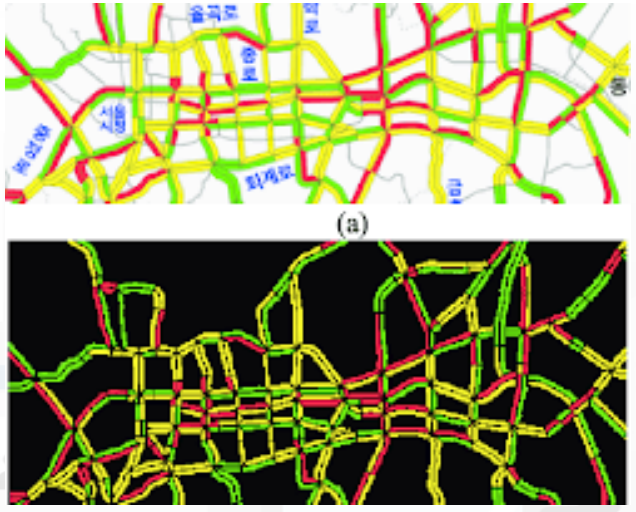
Why Computing Predictions

- if I know how many people will attend an event
  - I can **detect anomalies** earlier if an unexpected event will occur, intervene
  - I can **organize** better services, cleaning and preventive security
  - I can **inform, mitigate, plan**, **save money and time**, etc.
- Other Cases:
  - **Traffic** → pollutant, luminaries, city plan, be prepared critical conditions
  - **Parking** → inform in advance the users**,** save money and time, ….
  - **Energy** → be prepared for critical conditions
  - **Pollutant** → to avoid taking taxes, planning trips, etc.
  - **Waste** → save money and time, …….

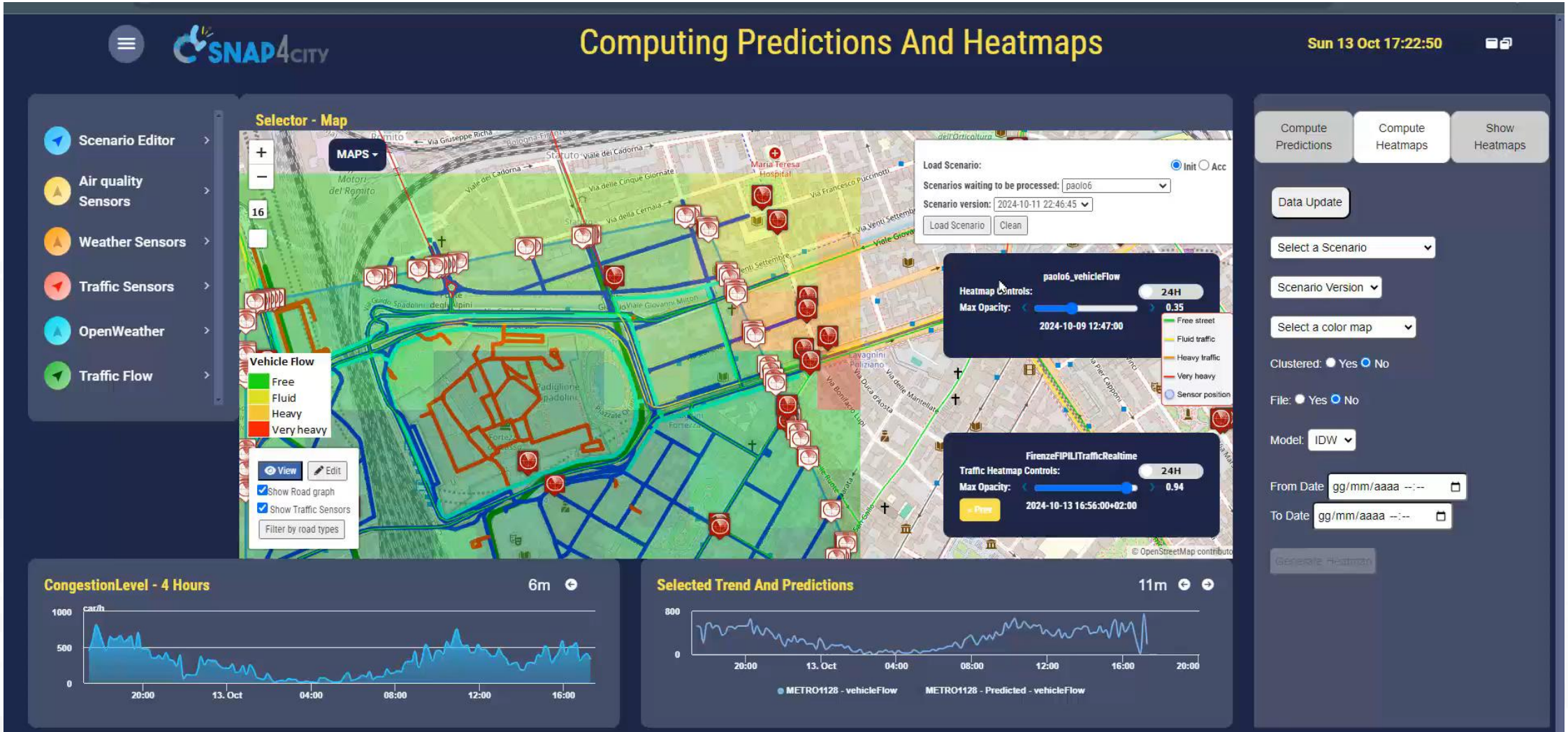
Predictions

- **For Cases:**
  - Free parking slots
  - Free bikes, and free slots on bike racks
  - Pollutant: NOX, NO2, CO2
  - Land Slide
  - People behavior
  - Energy consumption
  - Waste production for collection
  - Etc.
- → **Anomaly Detections**



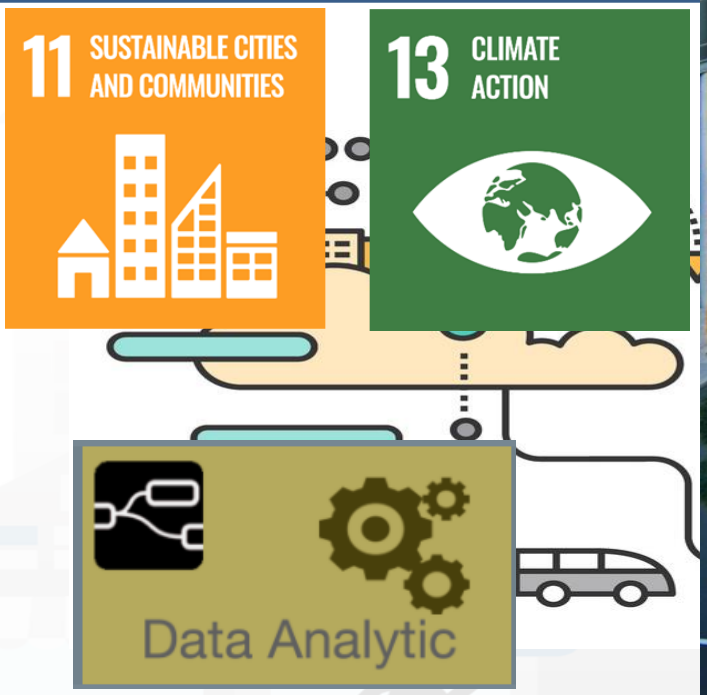


Predictions and Heatmaps in Real Time



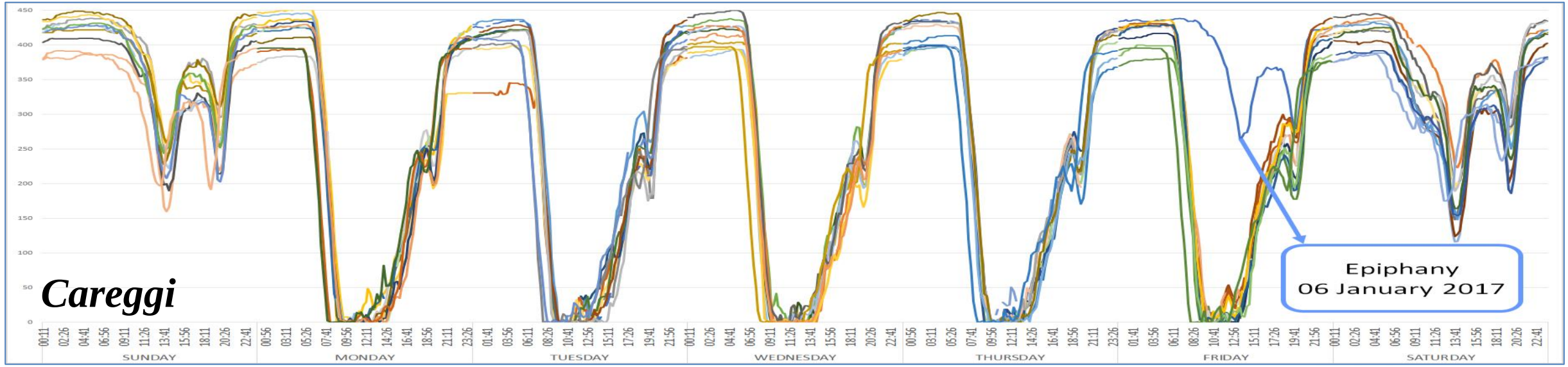
Smart Parking:

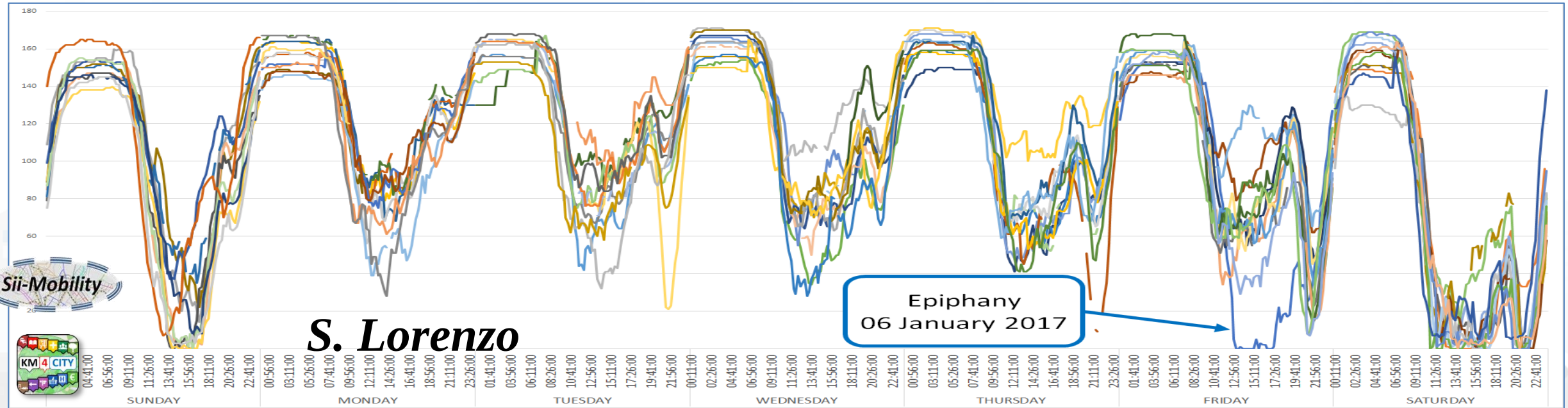
#free slots predictions





Free Parking space trends

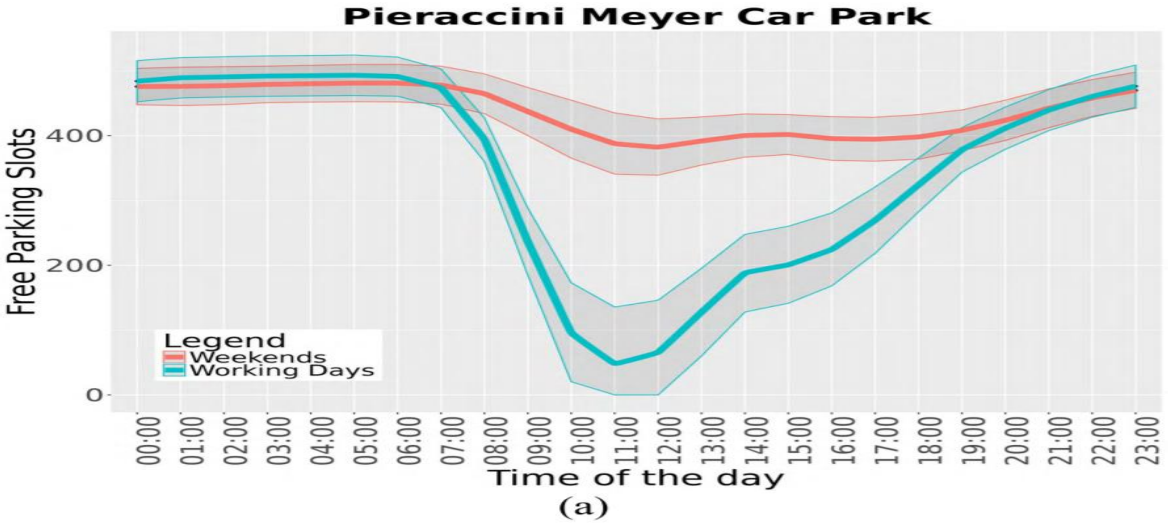


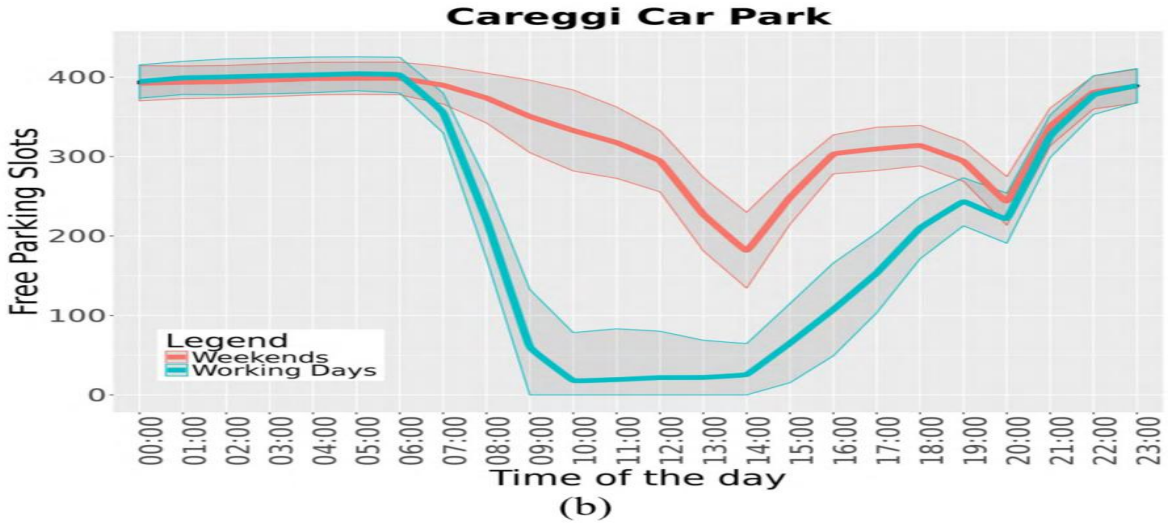


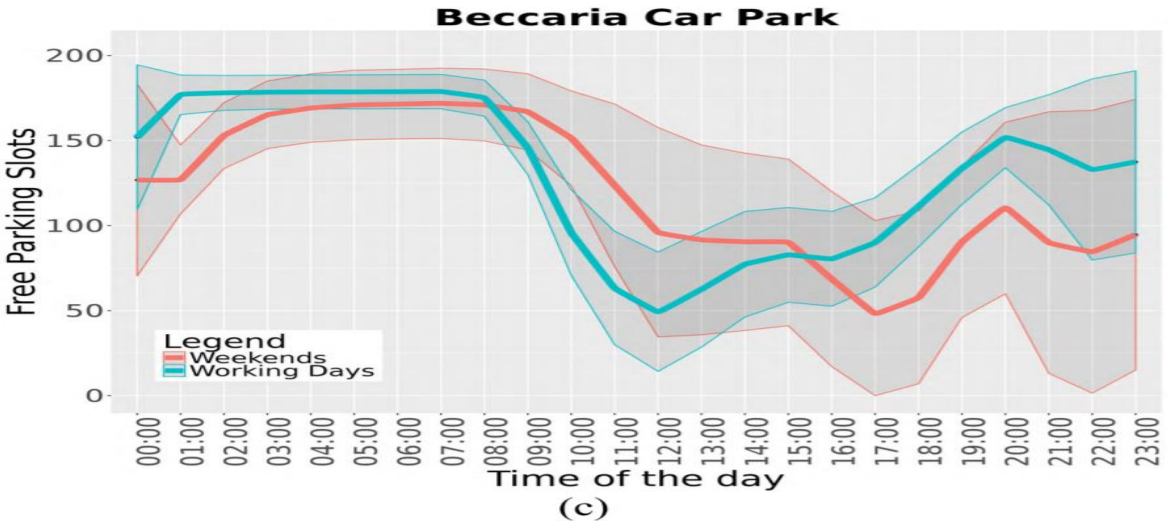
Sii-Mobility

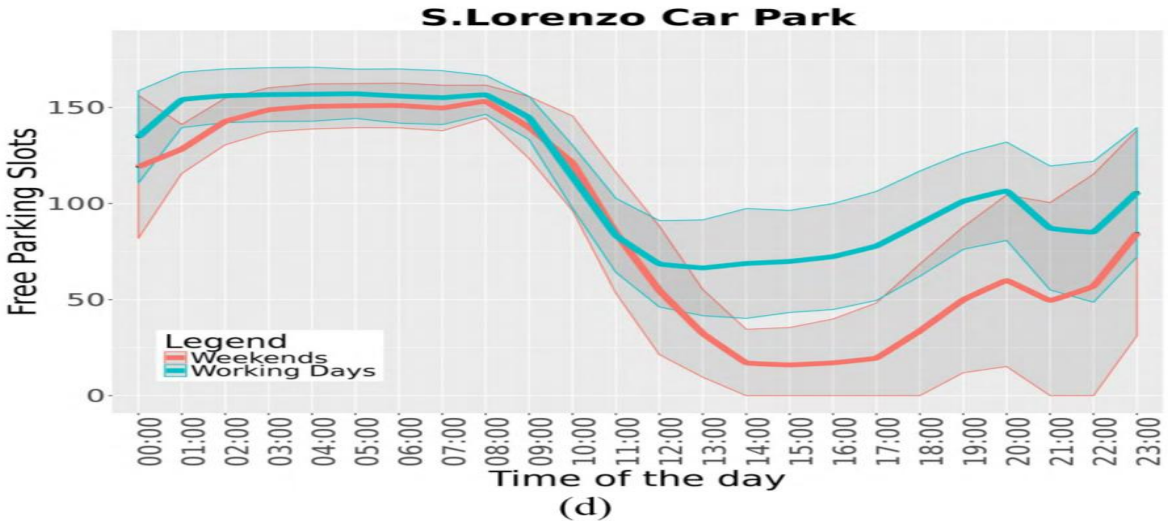
KM 4 CITY

Free Parking space trends



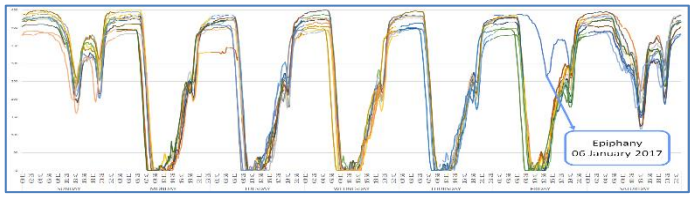






12 parking areas in Florence

I would arrive to surely Park in 45 Minutes??

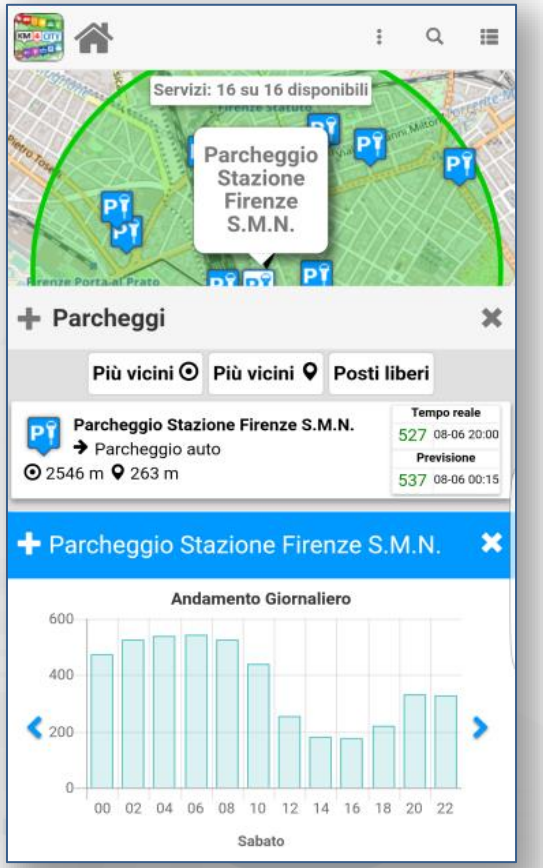


Category	Features	Description of features variable
Baseline features of free slot data	Free parking slots	Real number of available slots recorded every 15 minutes
	Time	Hours and minutes
	Month	Month of the year (1-12)
	Day	Day of the month (1-31)
	Day week	Day of the week (0-6)
	Weekend	0 for working days, 1 else
	Previous observation's difference (POD)	Difference between the number of free spaces at time i and number of free spaces at time (i − 15 minutes) recorded in the previous week
	Subsequent observation's difference (SOD)	Difference between the number of free spaces at time i, and the number of free spaces at time (i + 15 minutes) recorded in the previous week
Weather features	Temperature	City temperature measured one hour earlier than Time (°C)
	Humidity	City humidity measured one hour earlier than Time (%)
	Rainfall	City rainfall measured one hour earlier than Time (mm)
Traffic Sensors features	Average Vehicle Speed	Average speed of vehicles on the road being closest to the parking, over one-hour period (km/h)
	Vehicle Flow	Number of vehicles passing by closest to the parking, over one-hour period
	Average Vehicle Time	Average of distance between vehicles, over one-hour period
	Vehicle Concentration	Number of vehicles per kilometer, over one-hour period



Artificial Intelligence Predictions

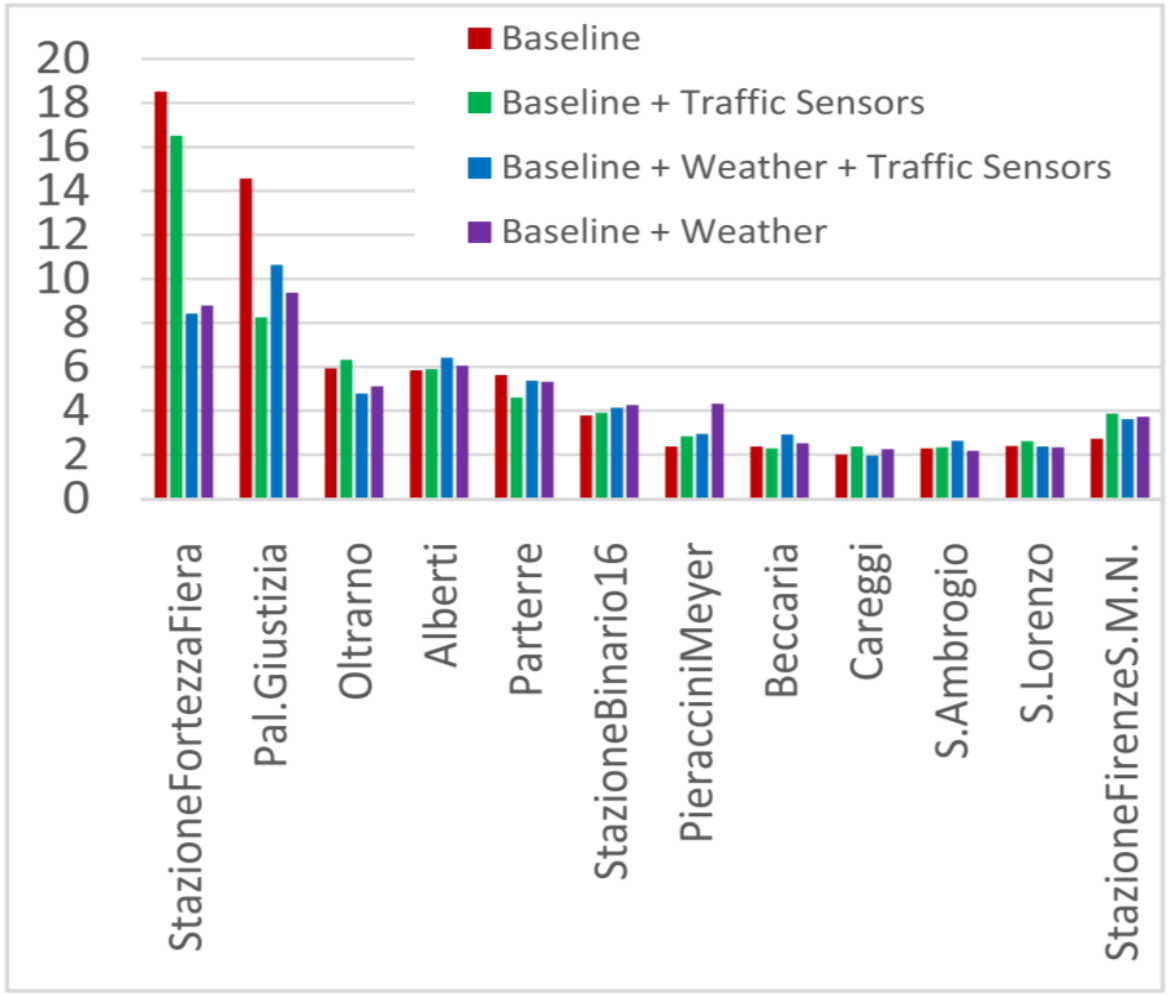
97% of precision



Free Parking PREDICTIONS

C. Badii, P. Nesi, I. Paoli, "Predicting available parking slots on critical and regular services exploiting a range of open data", IEEE Access, preprint, 2018, https://ieeexplore.ieee.org/abstract/document/8430514/

Comparison Error	Forecasting Techniques		
	BRANN	SVR	RNN
Careggi car park			
MASE Night	34.85	16.29	20.01
MASE Morning	0.76	1.42	2.82
MASE Afternoon	1.89	4.34	3.66
MASE Evening	1.99	1.51	2.33
MASE	1.87	2.34	3.16
Pieraccini Meyer car park			
MASE Night	6.08	12.83	10.03
MASE Morning	0.86	1.27	4.90
MASE Afternoon	1.87	2.91	6.75
MASE Evening	1.36	1.57	10.23
MASE	1.37	2.06	6.67
S. Lorenzo car park			
MASE Night	10.33	11.81	18.34
MASE Morning	2.13	1.91	3.93
MASE Afternoon	2.70	3.15	2.37
MASE Evening	2.15	3.09	3.82
MASE	2.72	3.21	4.19
Beccaria car park			
MASE Night	9.32	7.80	12.47
MASE Morning	0.95	1.25	4.87
MASE Afternoon	2.49	2.14	2.45
MASE Evening	2.96	4.75	5.91
MASE	2.13	2.67	4.85



ML models

The best selected models for the purpose have been:

- BRNN/BRANN:
  - Bayesian Regularized Artificial Neural Network
- SVR:
  - Support Vector Regression
- ARIMA
  - Autoregressive Integrated Moving Average
- RNN
  - Recurrent neural networks



Free Parking Predictions

Careggi car park			
Model features	BRNN model results		
	R-squared	RMSE	MASE
Baseline	0.974	24	1.87
Baseline + Weather	0.975	24	1.75
Baseline + Traffic sensors	0.975	24	2.04
Baseline + Weather + Traffic sensors	0.975	24	1.87

Best compromize



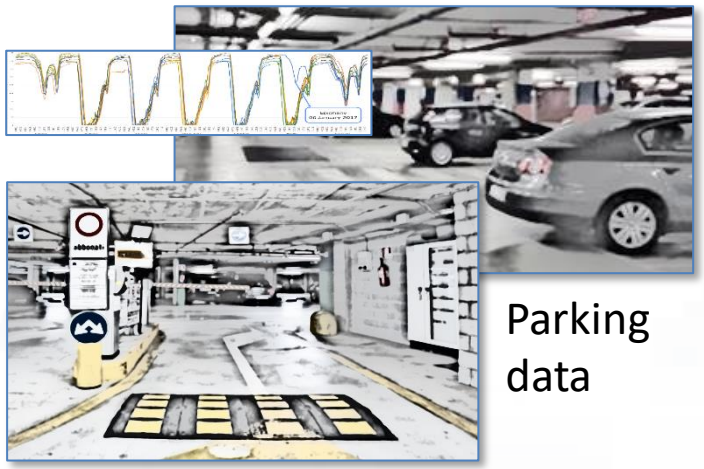
Active on Mobile Apps as:

- «Firenze dove cosa»
- «Toscana dove cosa»

Precision: 97,5%

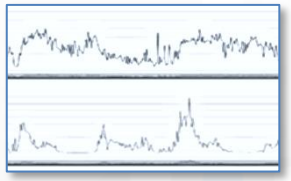

autostrada
FIESOLE
SIENA
AREZZO - FORLI'

Deep Learning AI to surely Park!



Parking data



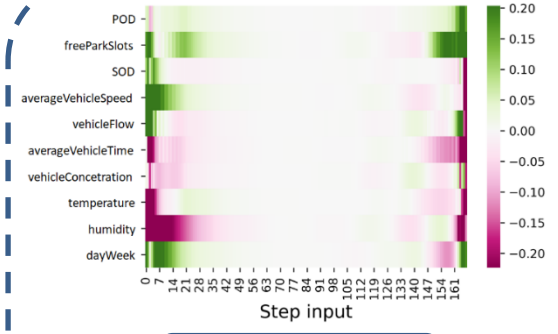


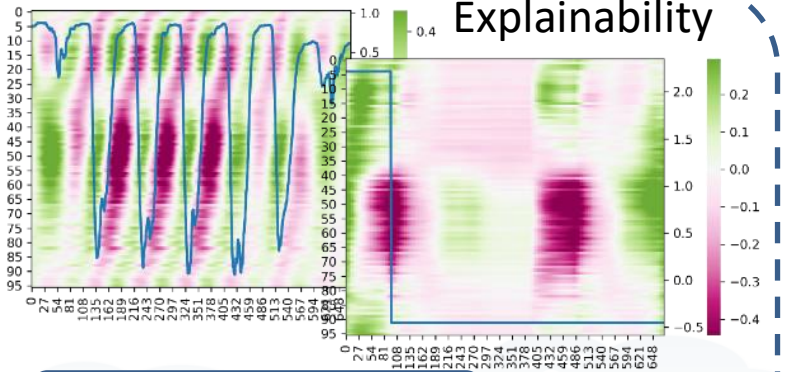
Traffic sensors data





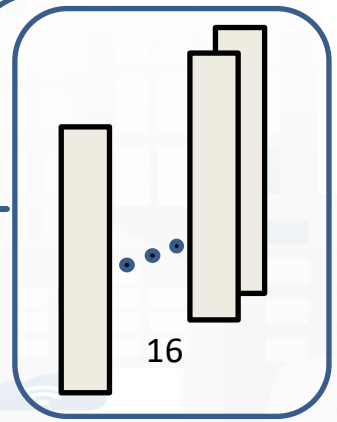
Weather Features

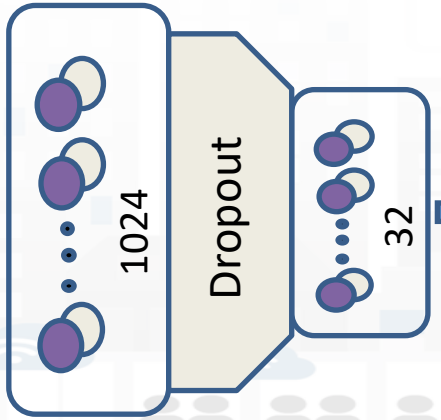


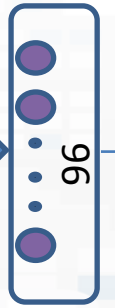


Gradient

Integrated Gradient



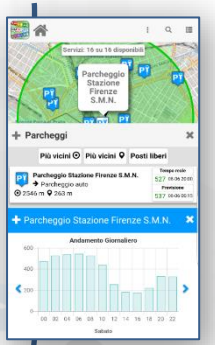




Multi-step

Predictions

95%



Conv1D+AvPooling1D BI-LSTM BI-LSTM Dense

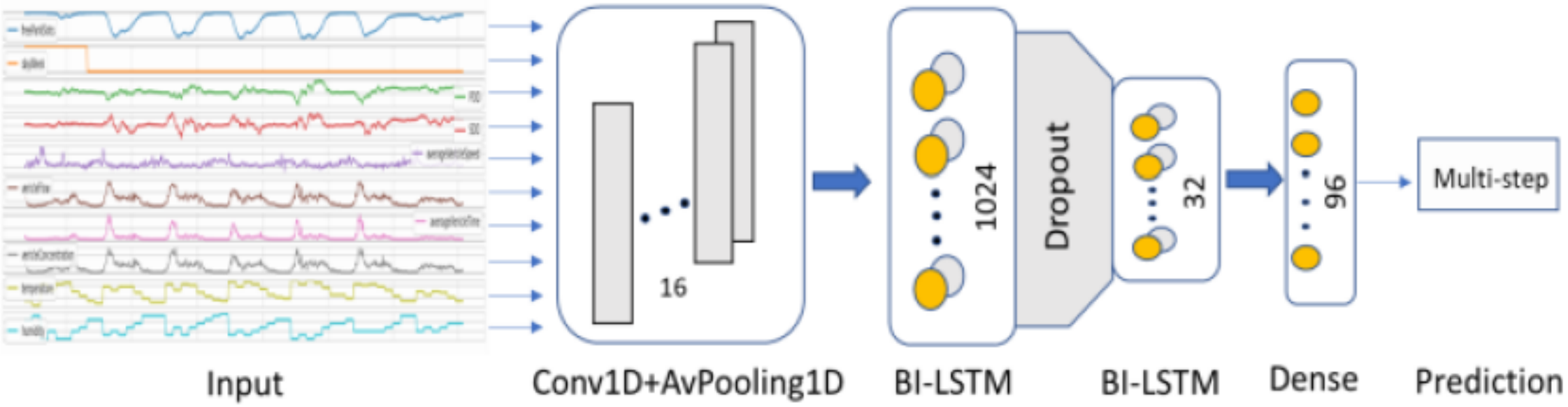
- **Gradients**
  - Gradients measure the slope or variation of a quantity with respect to another. In mathematics, the gradient of a function represents the direction and magnitude of its maximum change.

$$\nabla f(x, y, z) = \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z} \right)$$

- **Integrated gradients**
  - Integrated gradients are a generalization of gradients that take into account the accumulation of variations along a path.

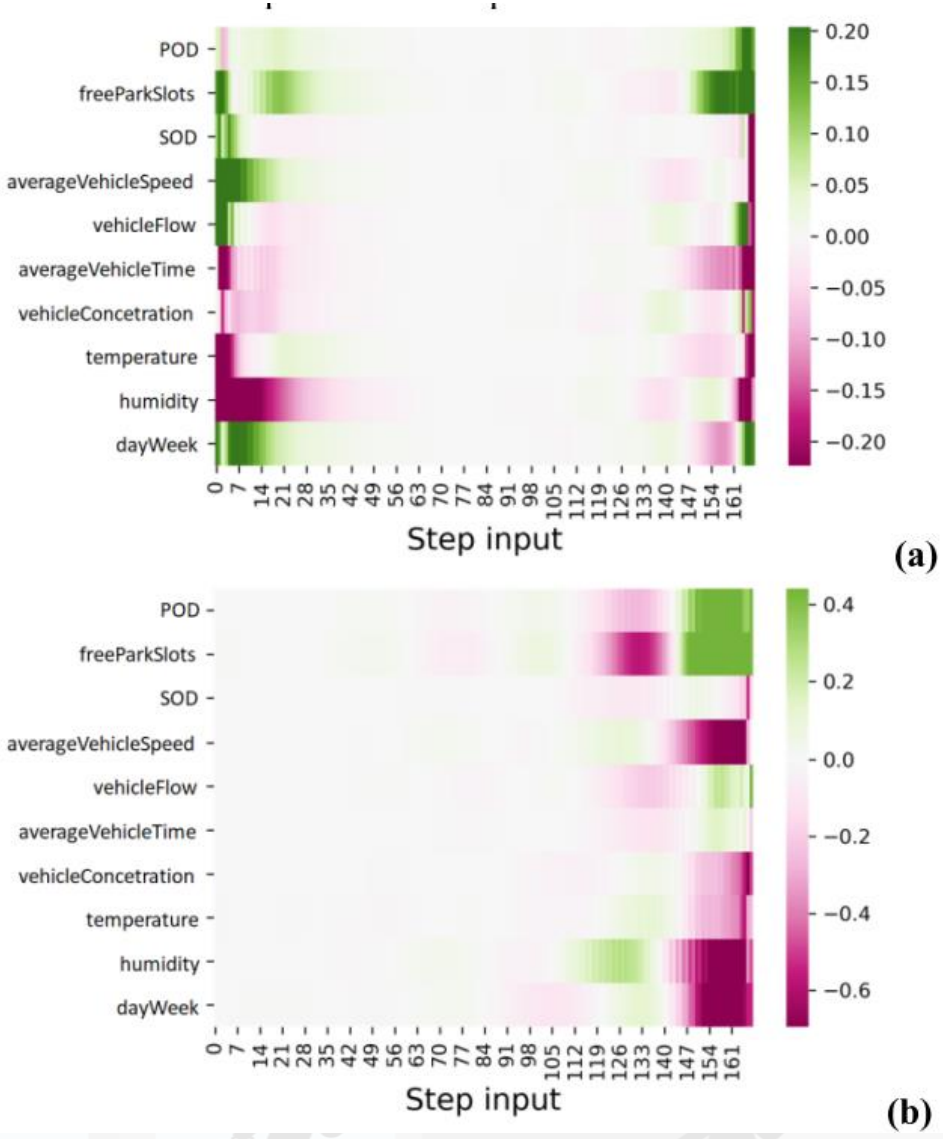
$$IG_i = (x_i - x'_i) \cdot \int_{\alpha=0}^{1} \frac{\partial F(x' + \alpha \cdot (x - x'))}{\partial x_i} \, d\alpha$$

CNN-BI-LSTM model architecture

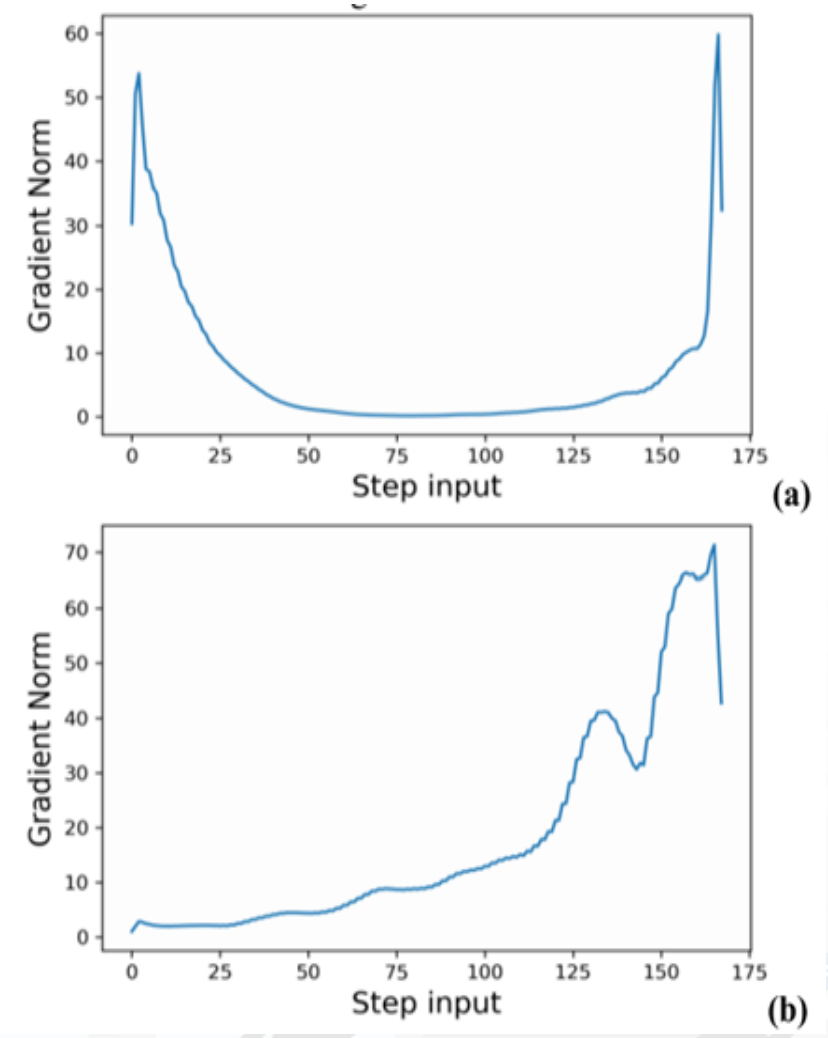


1-week data
observations sampled each hour
(168 samples / timestamps)

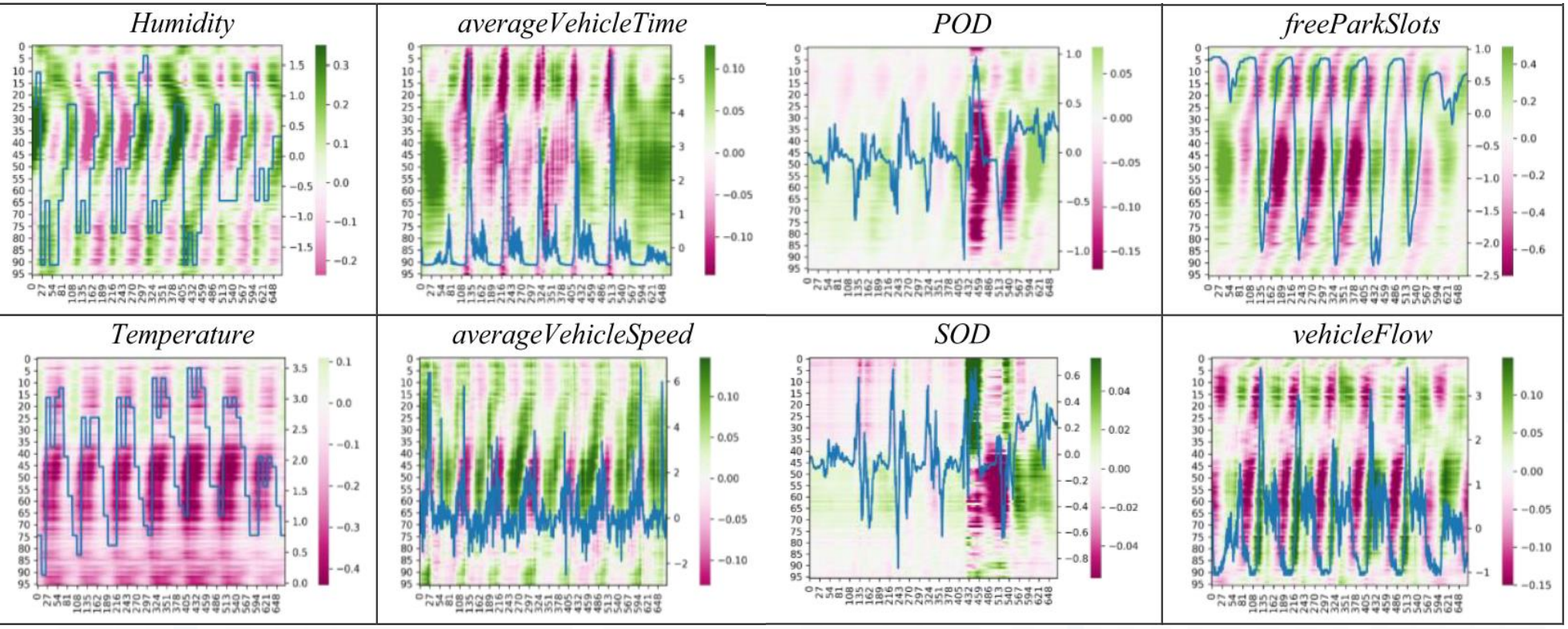
96 timestamps per day (24 hours and samples every 15 minutes)



- Gradient for features for the (a) CNN-BI-LSTM and (b) CNN-LSTM models. In green, red and white the steps that influence positively, negatively and marginally the predictions, respectively. (Careggi Car Park).



- Normalized cumulated gradient plot for the CNN-BI-LSTM and CNN-LSTM models, from 1 to 168 samples, Careggi car park.

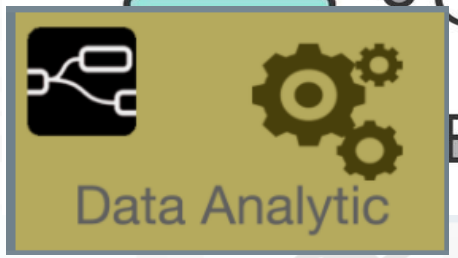


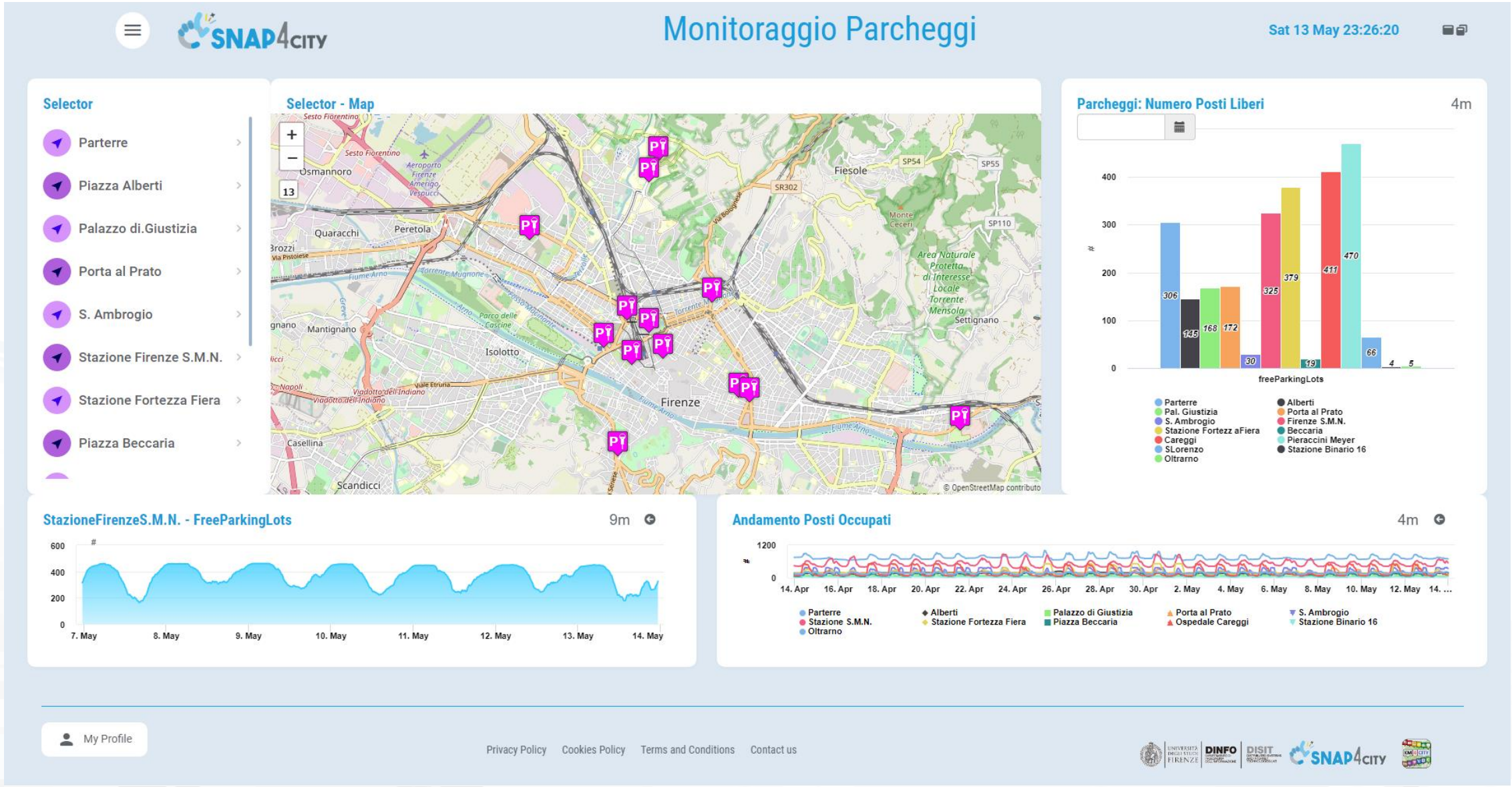
- Integrated Gradient for predictions with respect to the features, for Careggi Car Park. In green, red and white the steps that influence positively, negatively and marginally the predictions, respectively. In blue the time trend of the feature.

Parking management





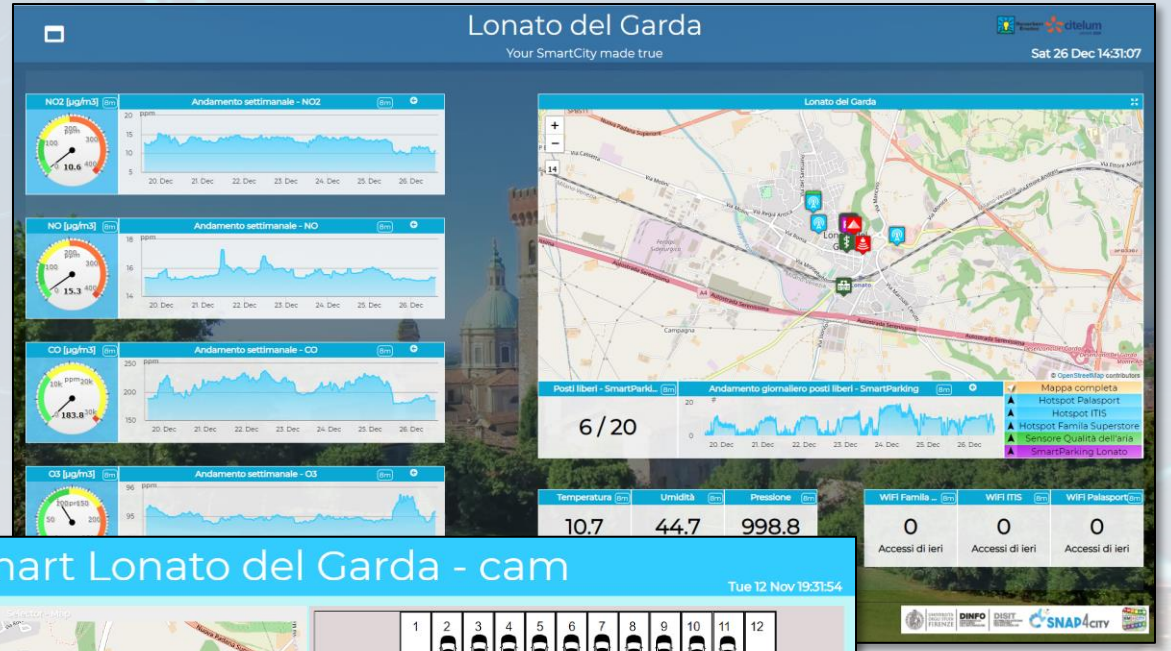



SNAP4CITY
Monitoraggio Parcheggi
Sat 13 May 23:26:20
Selector
Parterre
Piazza Alberti
Palazzo di.Giustizia
Porta al Prato
S. Ambrogio
Stazione Firenze S.M.N.
Stazione Fortezza Fiera
Piazza Beccaria
Selector - Map
Sesto Fiorentino
Osmannoro
Aeroporto Firenze Amerigo Vespucci
Quaracchi
Peretola
Fiesole
SP54
SP55
SR302
SP110
Monte Ceceri
Area Naturale Protetta di Interesse Locale Torrente Mensola
Settignano
Mantignano
Isolotto
Parco delle Cascine
Viadotto dell'Indiano
Firenze
Fiume Arno
Casellina
Scandicci
© OpenStreetMap contributo
Parcheggi: Numero Posti Liberi
4m
400
300
200
100
0
306
145
168
172
30
325
379
19
411
470
66
4
5
freeParkingLots
Parterre
Pal. Giustizia
S. Ambrogio
Stazione Fortezz aFiera
Careggi
SLorenzo
Oltrarno
Alberti
Porta al Prato
Firenze S.M.N.
Beccaria
Pieraccini Meyer
Stazione Binario 16
StazioneFirenzeS.M.N. - FreeParkingLots
9m
600
400
200
0
7. May
8. May
9. May
10. May
11. May
12. May
13. May
14. May
Andamento Posti Occupati
4m
1200
0
14. Apr
16. Apr
18. Apr
20. Apr
22. Apr
24. Apr
26. Apr
28. Apr
30. Apr
2. May
4. May
6. May
8. May
10. May
12. May
Parterre
Stazione S.M.N.
Oltrarno
Alberti
Stazione Fortezza Fiera
Palazzo di Giustizia
Piazza Beccaria
Porta al Prato
Ospedale Careggi
S. Ambrogio
Stazione Binario 16
My Profile
Privacy Policy
Cookies Policy
Terms and Conditions
Contact us

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

reference

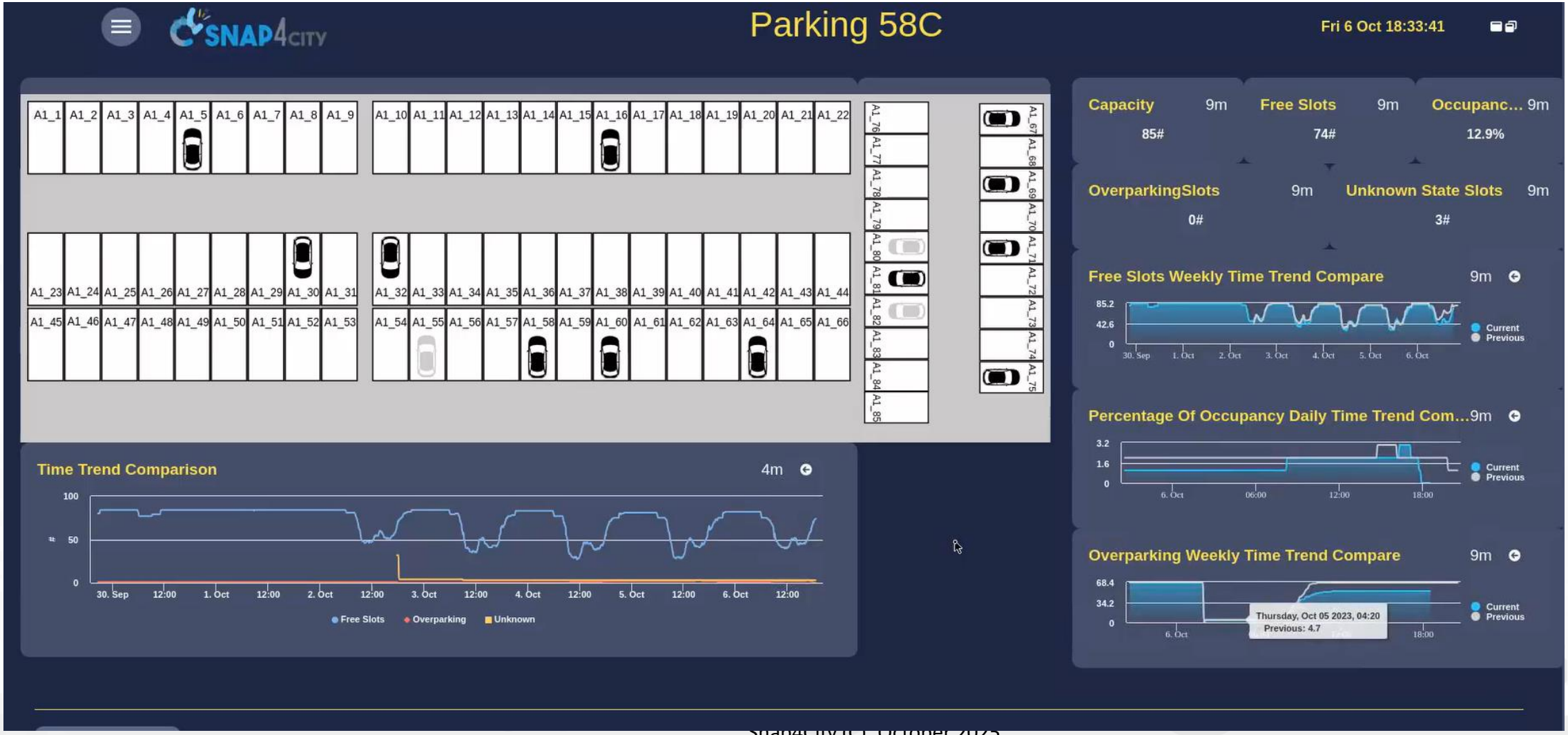
- **Multiple Domain Data**
  - Smart Parking, Environment, Wi-Fi
- **Multiple Decision Makers**
  - City Officer, operators
  - Data monitoring, alerting
  - analytics
- **Historical and Real Time data**
  - Dashboards
- **Services Exploited on:**
  - Dashboards, API
- **Since 2019**





11 SUSTAINABLE CITIES AND COMMUNITIES

Snap4ISPRA Parking



Smart Bike

Free Bike predictions



Bike Sharing



- Pros:
  - Eco-friendly
  - Prevent traffic congestions
  - Reduce the probability of social contacts in public transports
  - Regular bikes or e-bikes
- Problems:
  - Irregular distribution of bikes on racks/areas
  - Difficulty of knowing in advance their status with a certain degree of confidence
    - available bikes at a specific bike-station
    - free slot for leaving the rented bike

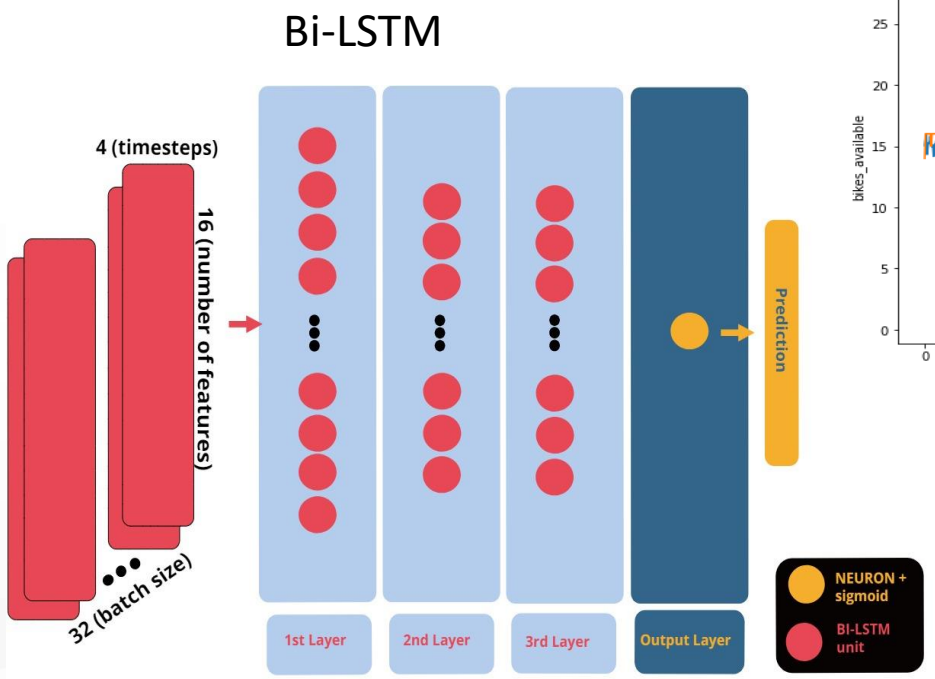


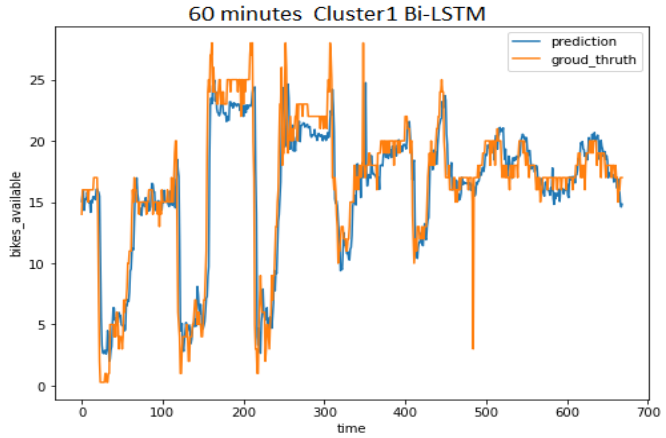
→ providing **PREDICTIONS** can be useful to improve quality of service

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









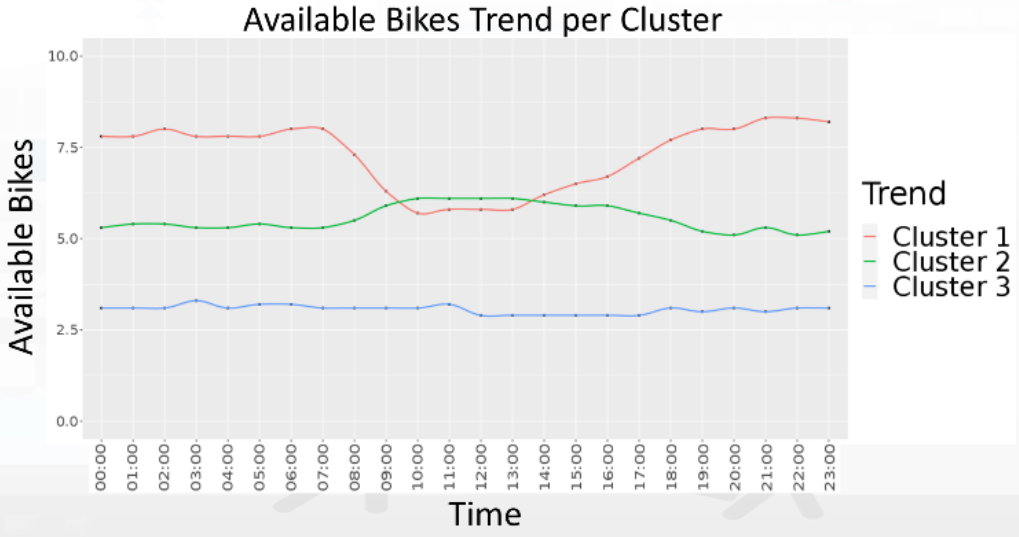


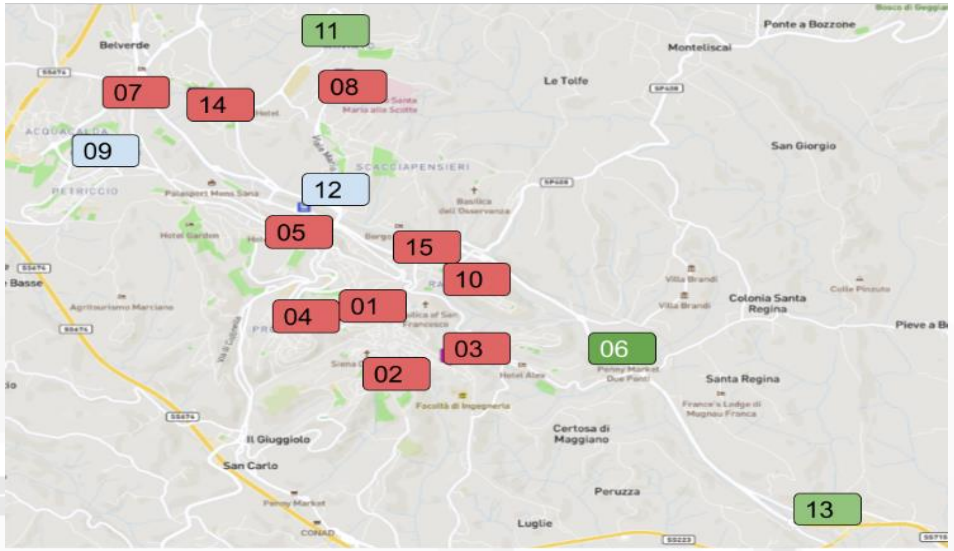
E. Collini, P. Nesi and G. Pantaleo, "Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations," in *IEEE Access*, vol. 9, pp. 124337-124347, 2021, doi: 10.1109/ACCESS.2021.3110794.
https://ieeexplore.ieee.org/abstract/document/9530580

Clustering

- A **clustering** approach has been applied in order to classify Pisa and Siena stations based on their mean trend H24 of bikes availability
  - This is also correlated to the typical services in the neighbourhoods
- **K-means** clustering method has been applied to identify clusters
  - The optimal number of clusters resulted to be equal to **3**, and it has been identified by using the **Elbow criteria**







Features

Category	Feature	Description
target	#Available Bikes	Number of available Bikes
Baseline-Historical	Time	The observation time hh-mm-ss
	month	Month of observation {1-12}
	Day Of The Week	Day of the week {1-7}
	Weekend	1 if the observation day is Saturday of Sunday, 0 otherwise
Differences Over Time	dP	the difference between the number of available bikes in the observation day (d) at the time slot t and the number of available bikes during the previous time slot (t-1) of the previous day (d-1)
	dS	the difference between the number of available bikes in the observation day (d) at the time slot t and the number of bikes during the successive time slot (t+1) of the previous day (d-1).
	PwAB	the number of available bikes of the previous week (d-7) in the same time slot (t).
Real-time weather and weather forecast	Temperature	Air temperature at the observation time, in °C
	Max Temperature	Forecast of max temperature of the observation day, in °C
	Min Temperature	Forecast of Min temperature of the observation day, in° C
	Humidity	Humidity of the hour prior to the observation time, in percentage
	Rain	mm of rain registered in the hour prior to the observation time
	Pressure	Pressure at the observation time, in millibar (mb)
	Wind Speed	Average wind speed registered in the hour prior to the observation time, in km/h
	Cloud Cover Percentage	Cloud Cover Percentage at the observation time

Analysis of the state of the art (Phase)

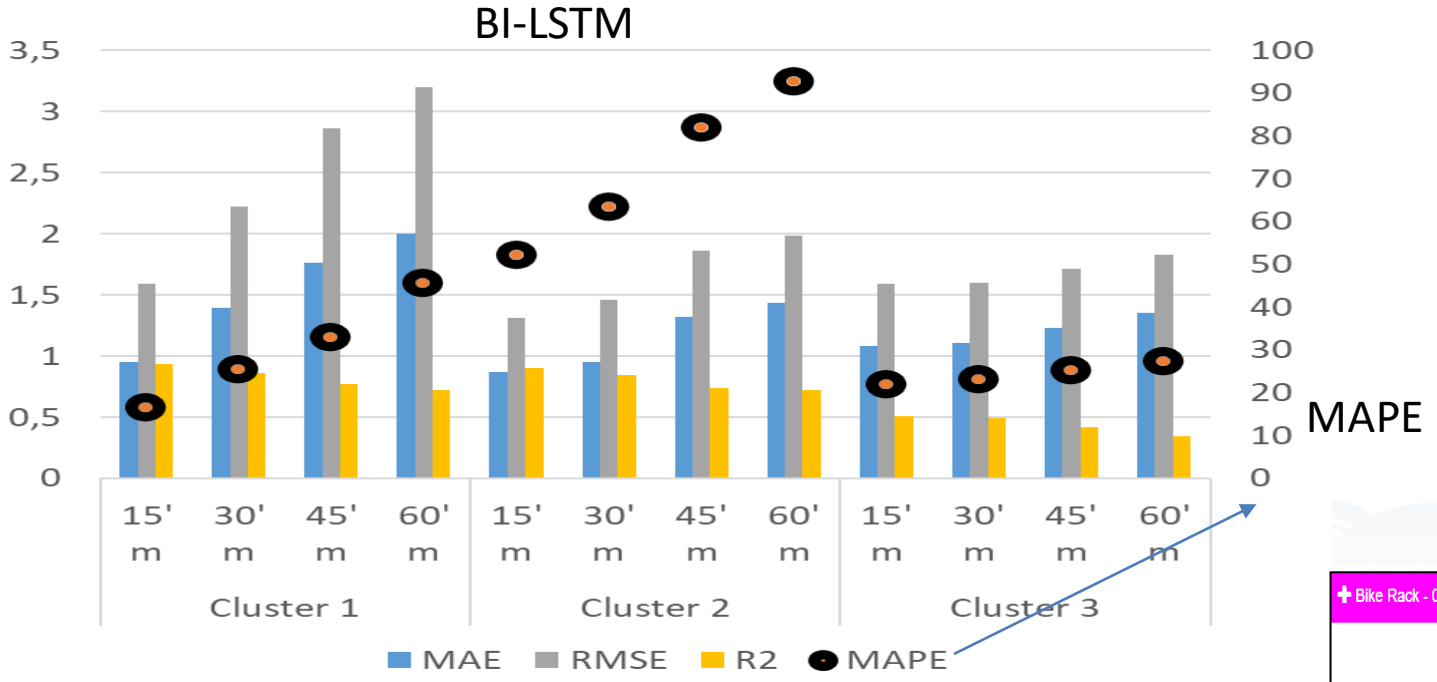
TABLE I

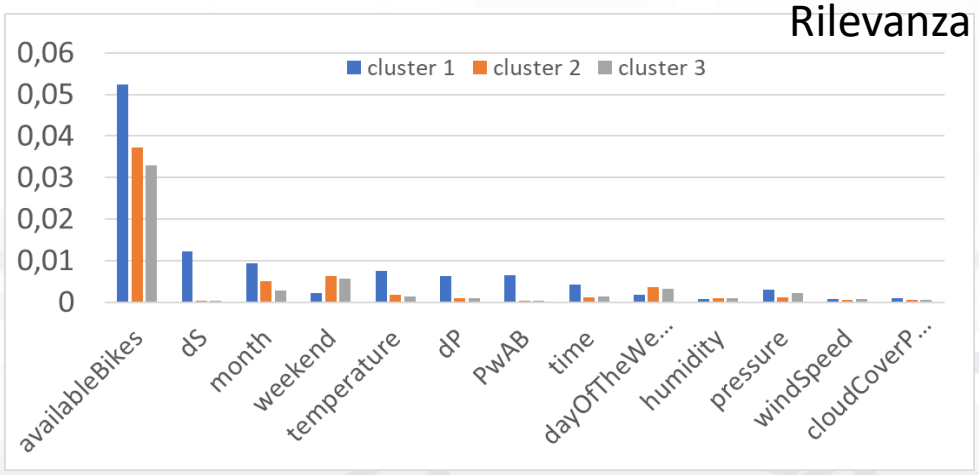
COMPARISON OF RELATED WORK SOLUTIONS, WITH MAIN ATTENTION TO DEEP LEARNING ASPECTS AND BETTER RESULTS.

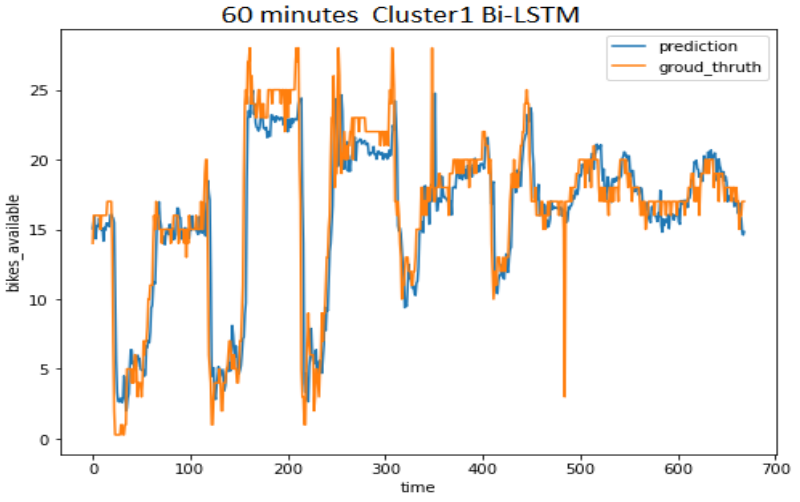
citation	Target	Features	Dataset	Model	Reported Best Results
[25]	1h, 2h, 3h bike rentals and returns	Bike rented, Bike returned, Avg temperature, Wind speed, Sky cover, Rain, holiday or Sunday, time, weekday, month, year	ThessBike	RF, XGBoost, GB, DNN	RF: Rentals / returns MAE: 0.85 / 0.82 MSE: 2.77 / 2.76 RMSLE: 0.46 / 0.46 R2: 0.64 / 0.63
[24]	Hourly Bike number change in station	Usage features, spatial features, temporal features	Citi Bike dataset July – August 2017	XGBoost tree, RF, DNN	XGBoost tree MAE: 1.8159 AP: 0.7085
[26]	1h rental bikes rented	Rental bikes rented, Weekend/weekday, Day of the week, Holidays, Functional/non functional, Temperature, Humidity , Windspeed, Visibility, Dew Point, temperature, Rainfall, snowfall	Seoul (South Korea)	RF, SVM, k-Nearest neighbours (KNN), Classification and Regression Trees (CART)	RF results: R2: 0.88 RMSE: 216.01 MAE: 130.52 CV: 30.63 PI: 0.73
[27]	Hourly rental bike demand	Temperature, Humidity, Windspeed, Visibility, Dewpoint, Solar radiation, Snowfall, Rainfall, number of bikes rented per hour, date information.	Seoul (South Korea	LR, XGBoost, SVM, Boosted Trees, XGBoost Trees	XGBoost results: R2: 0.92 RMSE: 174.68 MAE: 109.89 CV: 24.92
[28]	Long terms predictions	Timestamp, count of new bike shared, temperature, humidity, windspeed, weather code, is holiday, is weekend, season	London	LR, RF, XGBoost, SVM, AB, BGR	RF results: MAE: 0.04 MSE: 0.01 RMSLE: 0.03 R2: 0.95
[23]	1h number of rider	Number of riders, Season, year, month, hour, day, holiday, weekday, working, weather	Rental Company	DNN	80% accuracy

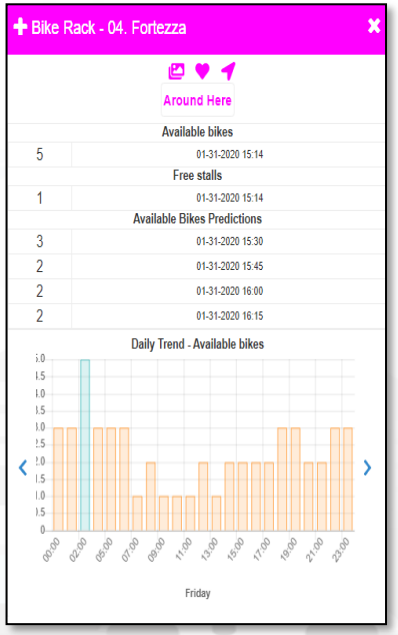
Siena Bike Sharing

- For each Bike Rack, Prediction of the number of
  - available bikes in sharing
  - free slots for leaving the bike









Feature Selection

Why don't we give all the features to the ML algorithm and let it decide which feature is important?

- **Curse of dimensionality**: as the number of features or dimensions grows, the amount of data we need to generalize accurately grows exponentially.
- **Occam's Razor**: We want our models to be simple and explainable. We lose explainability when we have a lot of features.
- **Garbage In Garbage out**: Most of the times, we will have many non-informative features. For Example, Name or ID variables. Poor-quality input will produce Poor-Quality output.

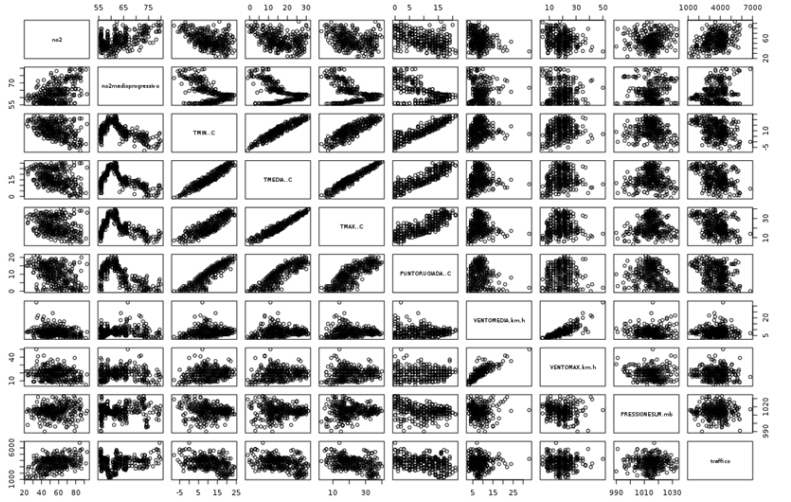
There are plenty of possibilities to conduct a feature selection analysis

- Linear Correlation Analysis
- Principal Component Analysis

Linear Correlation Analysis

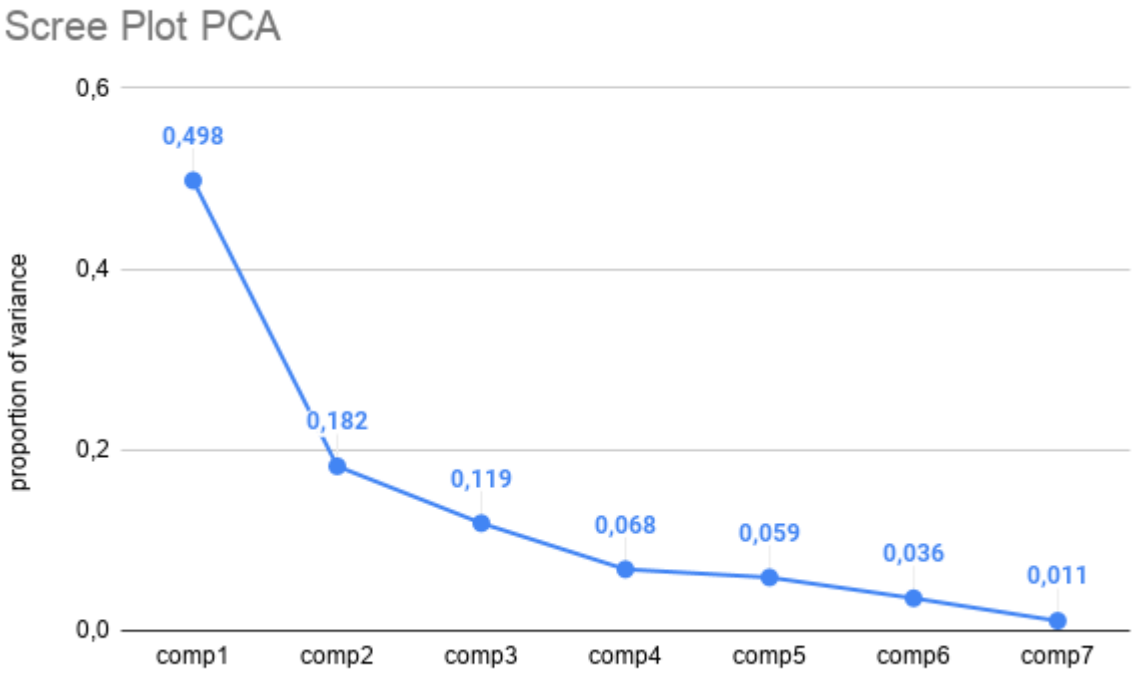
- Through correlation, we can predict one variable from the other.
- The logic behind using correlation for feature selection is that the good variables are highly correlated with the target.
- Otherwise If two variables are correlated, we can predict one from the other. Therefore, if two features are correlated, the model only really needs one of them, as the second one does not add additional information

	NO_2	NO_2medPro	TMIN	TMED	TMAX	PuntRug	VentMed	VentMax	PressSLM	numVeiCum	umidità
NO_2	1	0.494	-0.452	-0.371	-0.297	-0.441	-0.216	-0.200	0.097	0.355	-0.408
NO_2medPro	0.494	1	-0.512	-0.4591	-0.388	-0.584	0.060	0.008	0.102	0.198	-0.192
TMIN	-0.452	-0.512	1	0.945	0.854	0.905	0.162	0.218	-0.147	-0.381	-0.250
TMED	-0.371	-0.459	0.945	1	0.969	0.868	0.092	0.170	-0.022	-0.411	-0.408
TMAX	-0.297	-0.388	0.854	0.969	1	0.802	-0.001	0.109	0.071	-0.420	-0.465
PuntRug	-0.441	-0.584	0.905	0.868	0.802	1	-0.096	0.022	-0.225	-0.344	0.061
VentMed	-0.216	0.060	0.162	0.092	-0.001	-0.0969	1	0.833	-0.046	0.001,	-0.442
VentMax	-0.200	0.008	0.218	0.170	0.109	0.022	0.833	1	-0.138	-0.029	-0.379
PressSLM	0.097	0.102	-0.147	-0.022	0.071	-0.225	-0.046	-0.138	1	-0.010	0.395
numVeiCum	0.355	0.198	-0.381	-0.411	-0.420	-0.344	0.001	-0.029	-0.010	1	0.171
umidità	-0.0408	-0.192	-0.250	-0.408	-0.465	0.061	-0.442	-0.379	0.395	0.171	1



Principal Component Analysis

- PCA is a multivariate data analysis based on projection methods that results in a matrix that summarizes how our variables all relate to one another in different **principal components**.
- data reduction technique that transform the dataset into a compressed form that capture maximum information (**proportion of variance** top principal components)



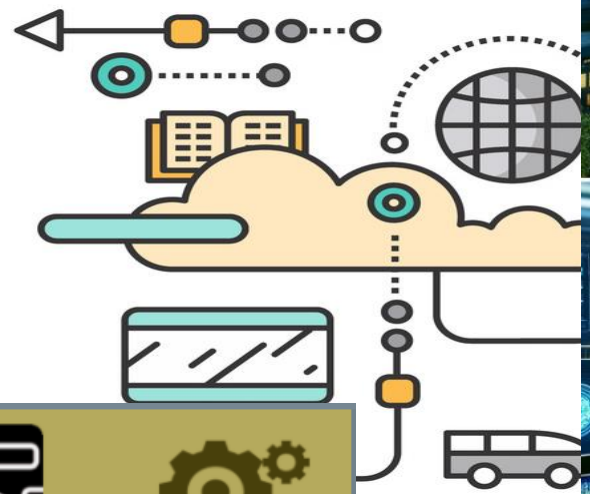
parametro	comp1	comp2	comp3	comp4	comp5
NO_2	0.21492	0.03753	0.21523	0.12079	**0.49583**
NO_2cumulated	-0.29702	**0.33402**	-0.09504	-0.03905	0.03549
NO_2progressiveMean	**0.31897**	-0.25867	0.10213	0.05706	-0.04563
Tmin..C	**-0.30745**	-0.27795	0.06725	0.10825	0.08754
Tmean..C	-0.29595	**-0.31203**	0.16324	0.00393	0.13399
Tmax..C	-0.2687	**-0.31676**	0.24441	-0.06649	0.1375
dewPoint..C	**-0.31326**	-0.15871	0.17945	0.23102	0.04431
windMean.km.h	-0.00725	-0.28206	**-0.6145**	-0.14964	0.07701
windMax.km.h	-0.03454	-0.30142	**-0.59137**	-0.03938	0.09913
humidity	0.01218	**0.43378**	0.04680	-0.42877	-0.07932
pressioneSLM.mb	0.04822	-0.01663	0.18496	**-0.91479**	0.22794
numberOfVehicles	0.14502	0.16311	-0.12736	0.21015	**0.78224**
numberOfVehiclesCumulated	**-0.29235**	0.34455	-0.0991	-0.03161	0.03886
NO_xDomestic	**0.30408**	0.27471	-0.06801	0.00842	-0.13415
NO_xDomesticCumulated	-0.30356	**0.30434**	-0.11701	-0.04954	0.05715
NO_xDomesticProgressiveMean	**0.34165**	-0.1894	0.07221	0.05133	-0.04398

Table 2. Principal Components analysis (a part).

Traffic Flow Prediction

11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION



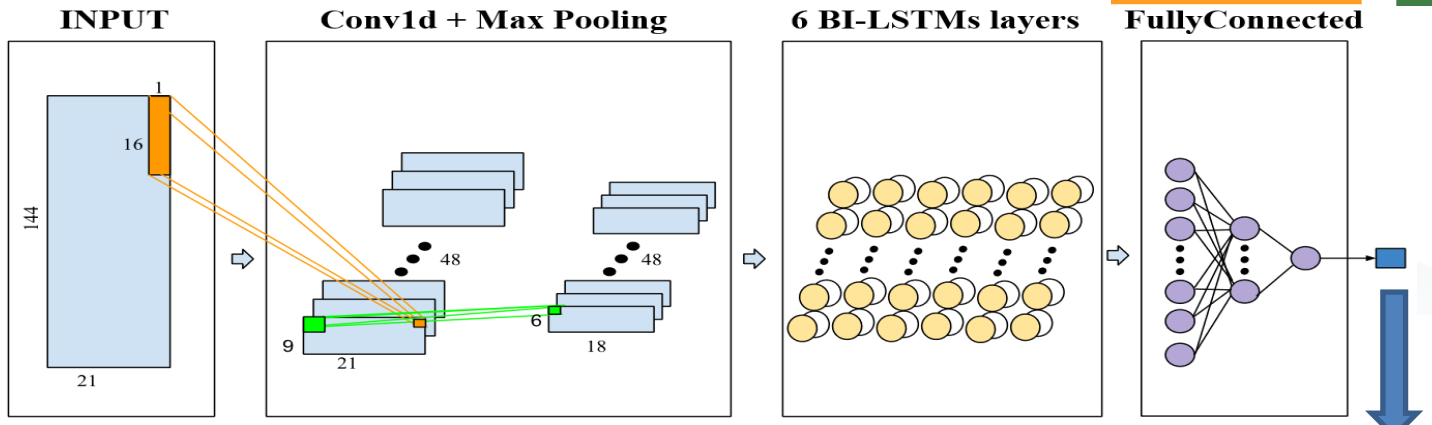






Short-Term Prediction of City Traffic Flow via Convolutional Deep Learning



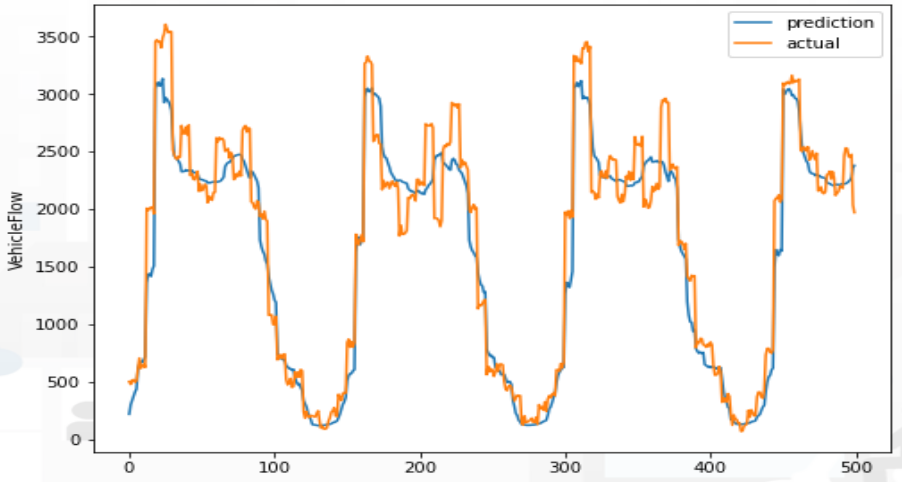


Urban data:

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

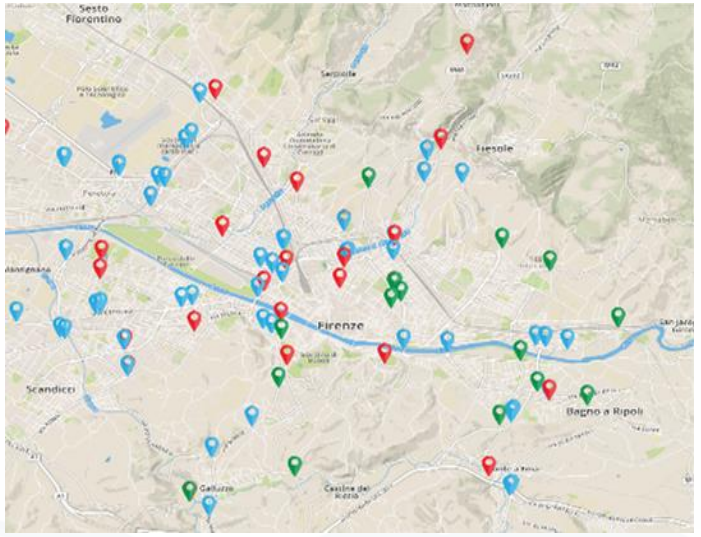
RF
XGBOOST
DNN
LSTM
BI-LSTM
Autoencoder BI-LSTM
Attention CONV-LSTM
CONV-BI-LSTM

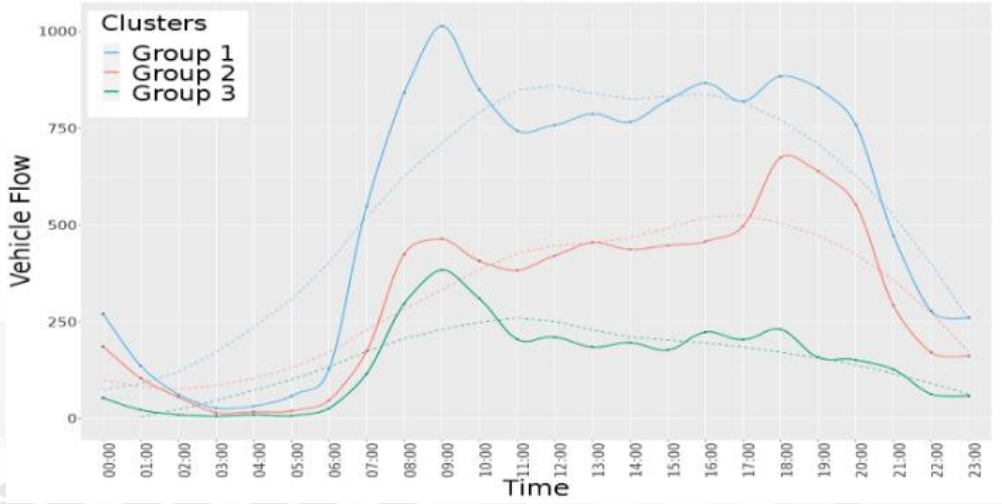
CONV-BI-LSTM



Clustering traffic flow sensors

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





Best compromize

Selected Features

Category	Feature	Description
Traffic Trafplus	Traffic Flow	Real number of vehicles recorded every 10 minutes
	AverageSpeed	Average speed of vehicles (Km/h)
	Concentration	Number of vehicles in terms of road occupancy (%)
DateTime	timeOfTheDay	Time of the day {1, 144}
	dayOfTheYear	Day of the year {1, 366}
seasonality	dayOfTheWeek	Day of the week {1,7}
	Weekend	0 for working days, 1 else
	Year	The year of the observation
Temporal	Previous observation's difference of the previous week (dP)	the difference between the number of vehicles in the observation day (d) at the time slot t and the number of available vehicles during the previous time slot (t-1) of the previous day (d-1)
	Subsequent observation's difference of the previous week (dS)	the difference between the number of vehicles in the observation day (d) at the time slot t and the number of vehicles during the successive time slot (t+1) of the previous day (d-1).
	Previous week observation ($PwVF$)	the number of vehicles of the previous week (d-7) in the same time slot (t).
Weather	Air Temperature	City temperature one hour earlier than Time (°C)
	Humidity	City humidity one hour earlier than Time (%)
	Pressure	City pressure one hour earlier than Time (millibar mb)
	Wind Speed	City wind speed one hour earlier than Time (KM/h)
AirPoll	CO	Concentration of CO one hour earlier than Time
	NO2	Concentration of NO2 one hour earlier than Time
	O3	Concentration of O3 one hour earlier than Time
	PM10	Concentration of PM10 one hour earlier than Time
	PM2.5	Concentration of PM2.5 one hour earlier than Time

Best Model for traffic flow prediction

- With a temporal target of 1h, which is the most critical short-term prediction slot ensemble learning techniques such as **Random Forest** (RF) and **Extreme Gradient Boosting Machines** (XGBOOST) are powerful techniques that must be considered for this type of problem.

- Regarding the deep learning techniques for this research project it has been proposed a new architecture **CONV-BI-LSTM** that will be compared to other solutions as **Deep Neural Network** (DNN), Deep **LSTM**, Deep **BI-LSTM** Neural Network , **Autoencoder BI-LSTM**, and an **attention-based CONV-LSTM** to assess the research question of which will be the best AI architecture for the problem of short-term prediction of vehicle flow based on this case study.

Analysing Features vs ML/AI Models

Chose the best model and/or the best compromise

ID	Features adopted in the model						Median value of MAPE for prediction results by technique								min
	Date time	Traf plus	Temp oral	Season ality	Air poll	weath er	RF	XGBO OST	DNN	LSTM	BI-LSTM	Autoenco der BI-LSTM	Attention CONV-LSTM	CONV-BI-LSTM	
C1	Y	Y	Y	Y	Y	Y	29.342	34.552	42.754	49.407	34.865	34,708	37,059	31.365	29.342
C2	Y	Y	Y	Y	Y	N	29.682	35.545	43.400	49.832	35.870	35,707	39,506	35.613	29.682
C3	Y	Y	Y	Y	N	Y	28.782	34.441	35.465	36.824	31.555	32,998	33,179	30.894	28.782
C4	Y	Y	Y	Y	N	N	30.935	35.373	38.942	35.383	30.564	32,969	35,713	32.485	30.564
C5	Y	Y	Y	N	Y	Y	29.776	34.469	33.425	42.301	39.865	37,167	35,161	36.897	29.776
C6	**Y**	**Y**	**Y**	**N**	**Y**	**N**	**29.598**	**35.547**	**33.865**	**36.792**	**35.097**	35,322	29,923	**25.981**	**25.981**
C7	Y	Y	Y	N	N	Y	29.421	33.711	31.377	34.736	40.510	37,110	30,741	30.106	29.421
C8	Y	Y	Y	N	N	N	31.245	34.414	32.026	37.823	40.662	37,538	31,263	30.500	30.500
C9	Y	Y	N	Y	Y	Y	29.626	36.919	42.187	**37.068 [38]**	34.297	35,608	36,651	**31.115**	29.626
C10	Y	Y	N	Y	Y	N	29.964	35.802	47.201	41.334	34.743	35,272	40,658	34.116	29.964
C11	Y	Y	N	Y	N	Y	29.785	35.976	45.451	44.756	41.620	38,798	37,345	29.240	29.240
C12	Y	Y	N	Y	N	N	31.262	35.792	36.040	37.228	32.727	34,259	32,701	29.363	29.363
C13	Y	Y	N	N	Y	Y	29.431	35.935	34.448	35.829	34.619	35,277	32,287	30.126	29.431
C14	Y	Y	N	N	Y	N	29.764	36.374	36.203	43.510	35.744	36,059	33,015	29.827	29.764
C15	Y	Y	N	N	N	Y	29.972	35.423	31.526	46.201	37.209	36,316	32,919	34.313	29.972
C16	Y	Y	N	N	N	N	**30.960 [14]**	34.235	30.338	**37.068 [23]**	**38.082 [39]**	**34,235[45]**	**29,455[46]**	**28.573**	28.573
C17	Y	N	Y	Y	Y	Y	29.281	34.503	72.909	64.557	48.685	41,594	51,026	29.144	29.144
C18	Y	N	Y	Y	Y	N	30.184	35.350	59.458	68.127	46.874	41,112	44,810	30.163	30.163
C19	Y	N	Y	Y	N	Y	28.711	34.316	45.679	46.211	33.404	33,86	37,125	28.571	28.571
C20	Y	N	Y	Y	N	N	31.211	34.784	51.603	45.188	48.643	41,713	46,862	30.122	30.122
C21	Y	N	Y	N	Y	Y	30.689	35.774	36.428	48.608	40.092	37,933	34,801	33.175	30.689
C22	Y	N	Y	N	Y	N	30.505	36.165	37.337	61.168	34.420	35,292	34,385	31.434	30.505
C23	Y	N	Y	N	N	Y	30.036	34.779	37.583	64.341	51.063	42,921	33,455	29.328	29.328
C24	Y	N	Y	N	N	N	32.629	34.312	36.849	53.854	41.512	38,112	33,257	29.665	29.665
C25	Y	N	N	Y	Y	Y	28.766	35.906	71.829	65.565	54.403	45,154	52,023	32.218	28.766
C26	Y	N	N	Y	Y	N	30.008	37.317	67.870	49.366	46.880	42,098	53,256	38.642	30.008
C27	Y	N	N	Y	N	Y	28.986	35.218	57.938	50.333	59.419	47,318	43,298	28.658	28.658
C28	**Y**	**N**	**N**	**Y**	**N**	**N**	**31.068**	**35.878**	**66.634**	**50.957**	**55.096**	45,487	47,097	**27.561**	**27.561**
C29	Y	N	N	N	Y	Y	29.301	37.532	58.325	40.677	50.303	43,917	35,554	32.784	29.301
C30	Y	N	N	N	Y	N	29.323	37.284	37.149	48.801	55.064	46,174	34,721	32.294	29.323
C31	Y	N	N	N	N	Y	29.964	36.331	34.638	56.157	45.016	40,673	35,293	35.949	29.964
C32	**Y**	**N**	**N**	**N**	**N**	**N**	**29.281**	**34.574**	**33.028**	**57.961**	**44.977**	39,775	29,320	**25.612**	**25.612**

Quite good model, RF
1 data source
Easy to compute and manage

Best model
1 data source
CONV-BI-LSTM

Comparing performance

	Training execution		Prediction execution (s)
Processing time	Duration (s)	Max GPU	
RF	14.681	On CPU	0.023
XGBOOST	4.352	On CPU	0.002
DNN	748.431	25%	0.056
LSTM	527.623	40%	0.017
BI-LSTM	681.874	42%	0.021
Autoencoder BI-LSTM	3240.564	38%	0.033
Attention-based CONV-LSTM	2579.248	41%	0.023
CONV-BI-LSTM	353.672	39%	0.102

Please take note of the wide difference from the training and the execution times

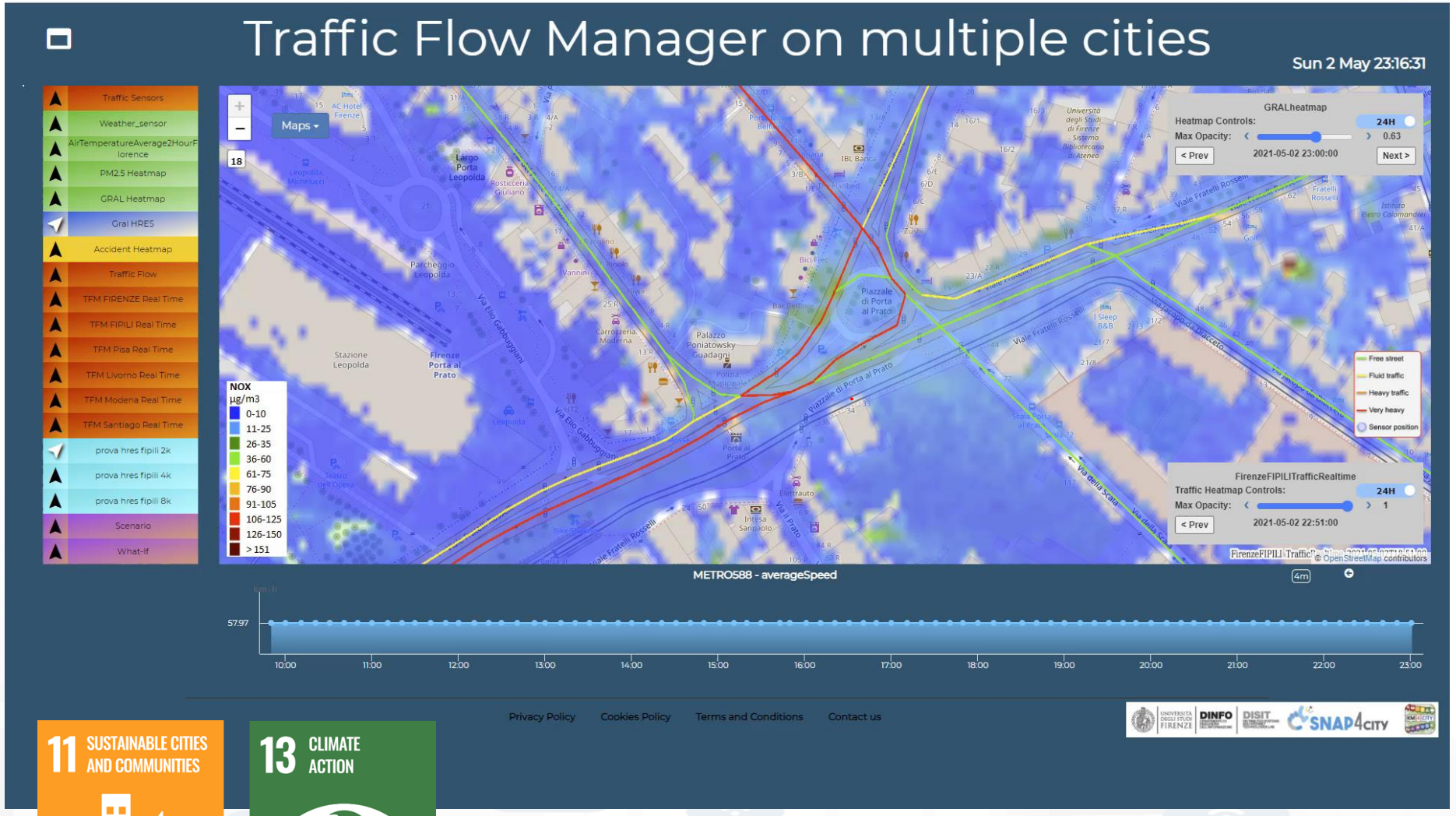
Best compromize

1-48 Hour prediction of NOx



Environment

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

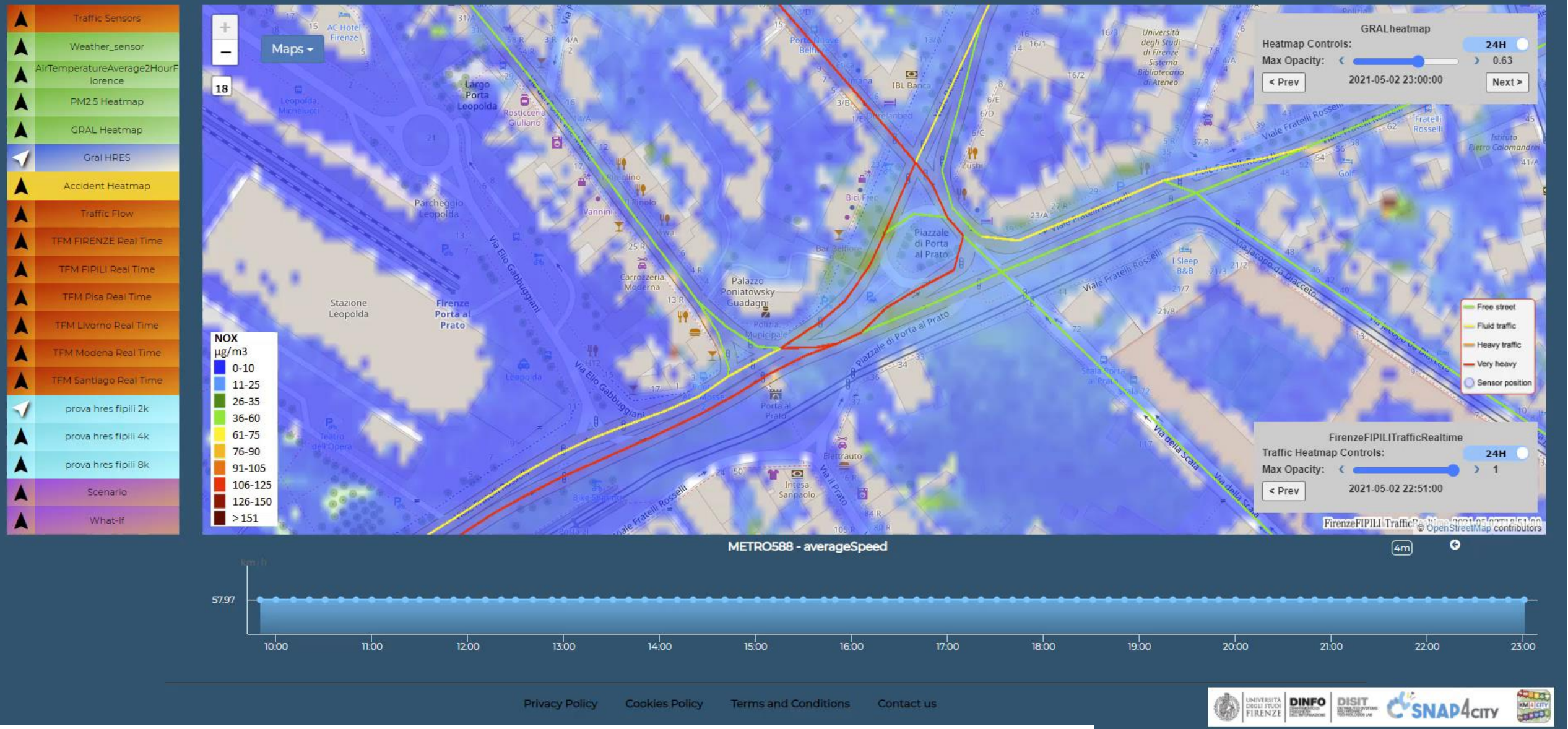


11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

Traffic Flow Manager on multiple cities

Sun 2 May 23:16:31



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

How it works: NOX predictions

Road Graph

3D City Structure

Traffic Flow Predictions

Weather Forecast: Temp, wind…

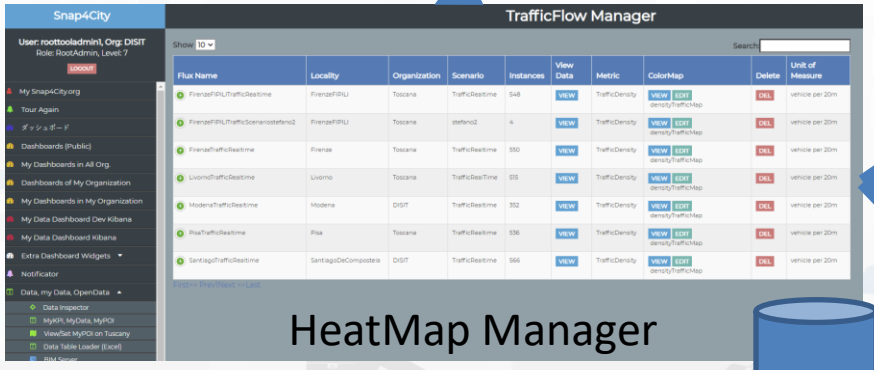
Particles Flow Simulation

Heatmap

JSON

JSON

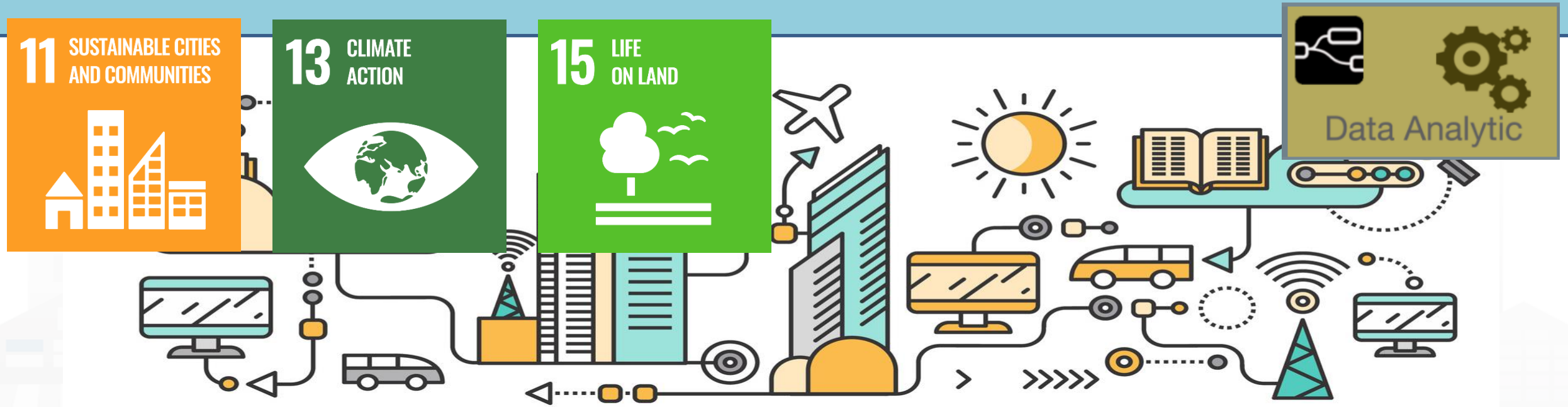
WMS



GeoServer



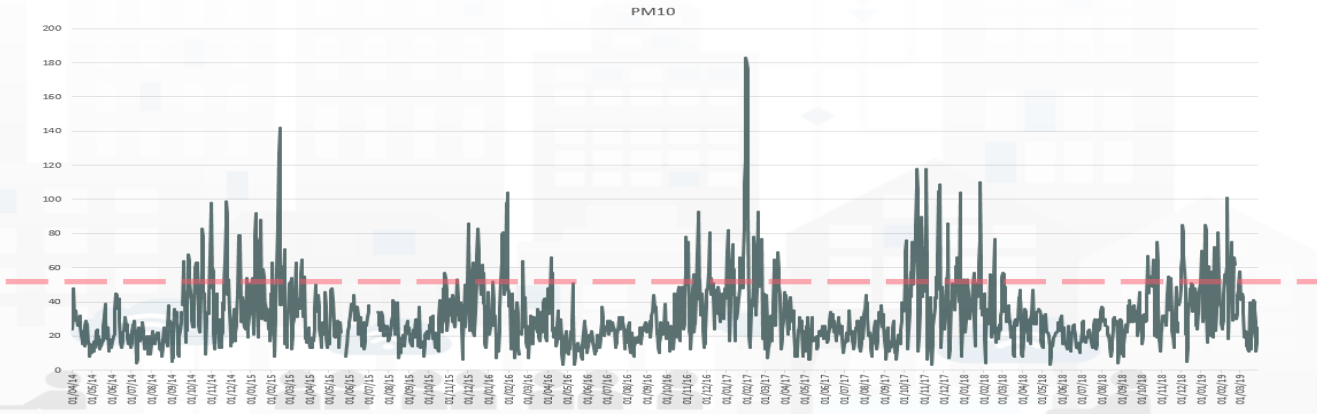
Long Term Prediction of Annual Mean of NO2 index of EC



Predicting Air Quality

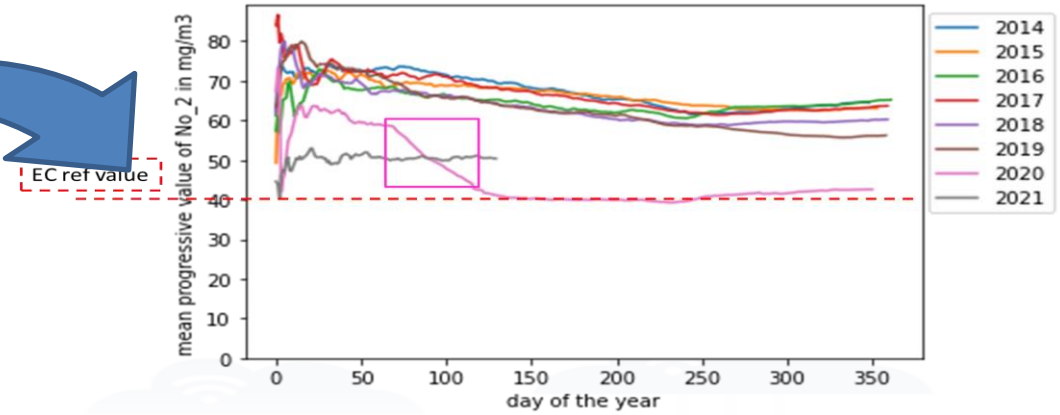
- European Air Quality Directive
- Predicting critical days
  - PM10 with an accuracy of more than 90% and precision of 85%;
  - PM2.5 with an accuracy of 90% and precision greater than the 95%.
- Simulating Long terms values
  - For long terms predictions

		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	

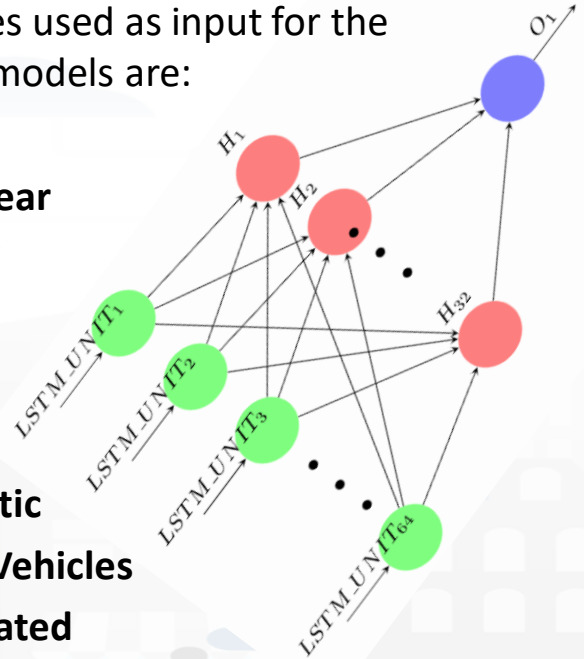


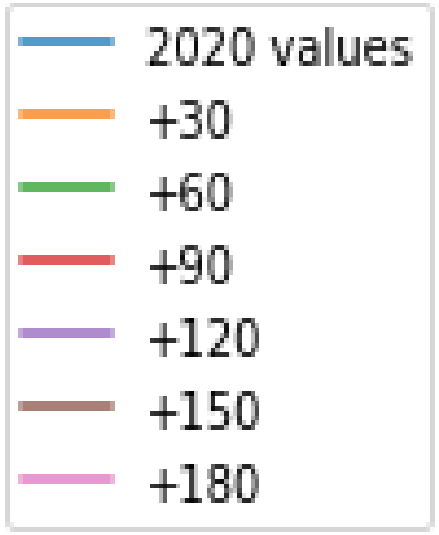
Predicting EC's KPI on NO2 months in advance

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**

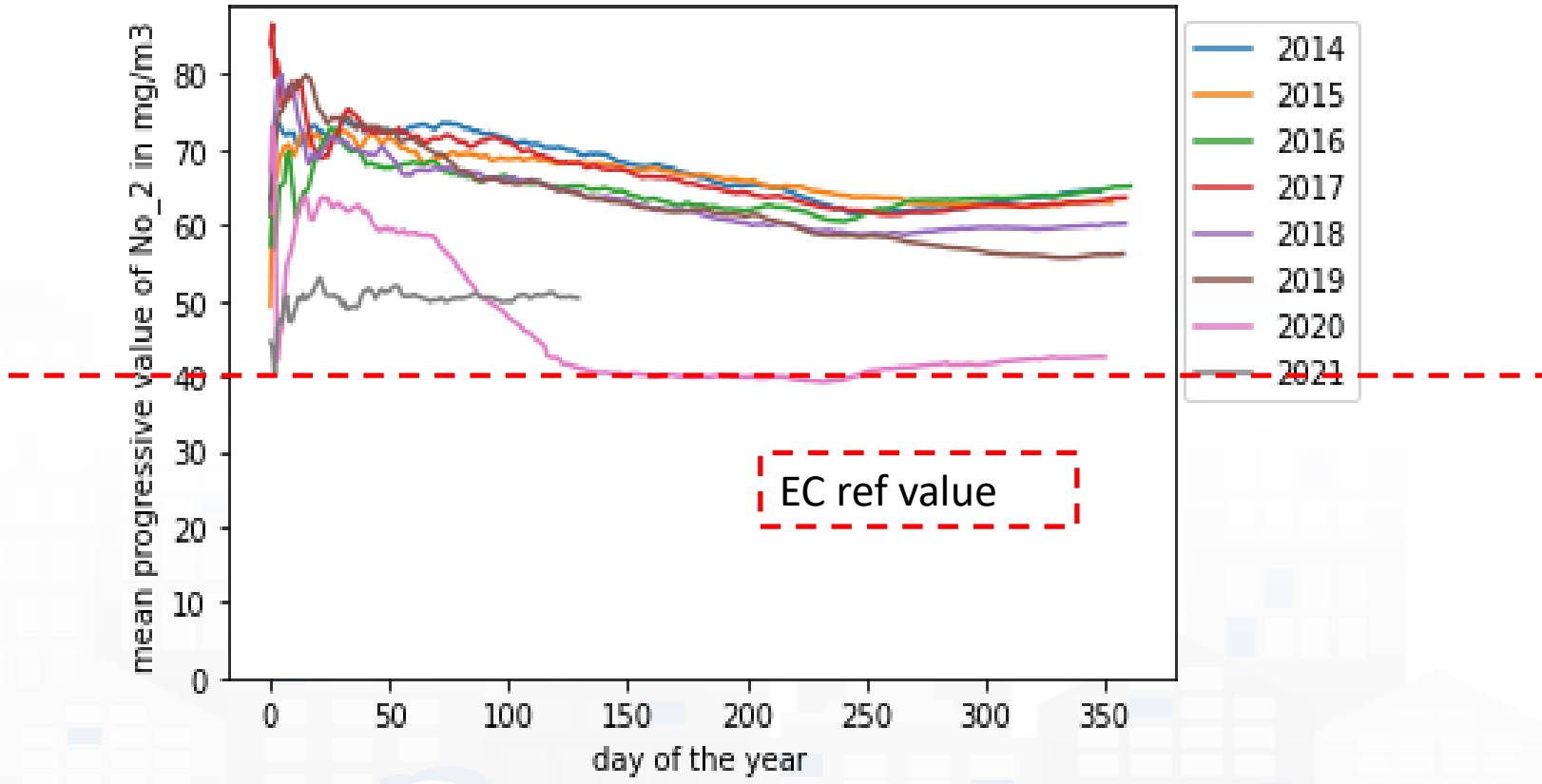




	Air Quality Directive			WHO guidelines	
Pollutant	Averaging period	Objective and legal nature and concentration	Comments	Concentration	Comments
$PM_{2.5}$	One day			25 µg/m³ (*)	99th percentile (3 days/year)
$PM_{2.5}$	Calendar year	Target value, 25 µg/m³	The target value has become a limit value since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

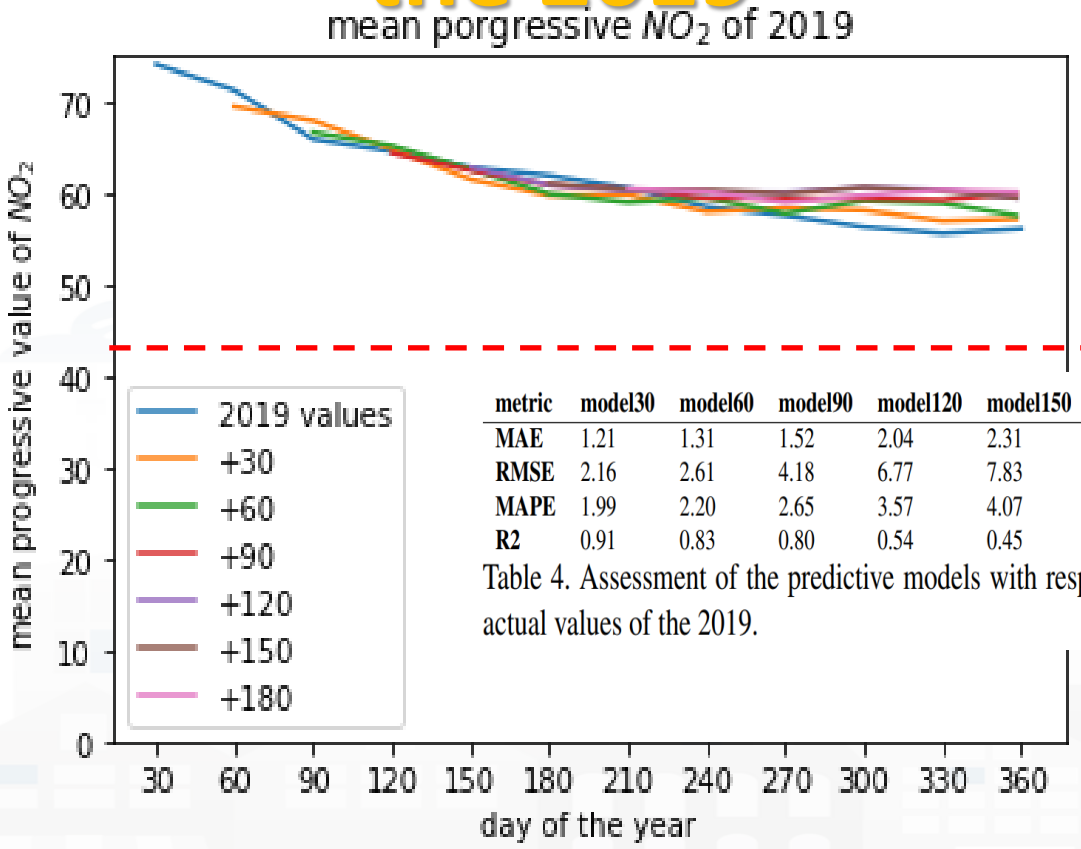
Actual Time Trend of the mean progressive NO2

- The data used refers to the years from 2014 to 2020.
- Training set 2014 – 2017
- Test set 2019



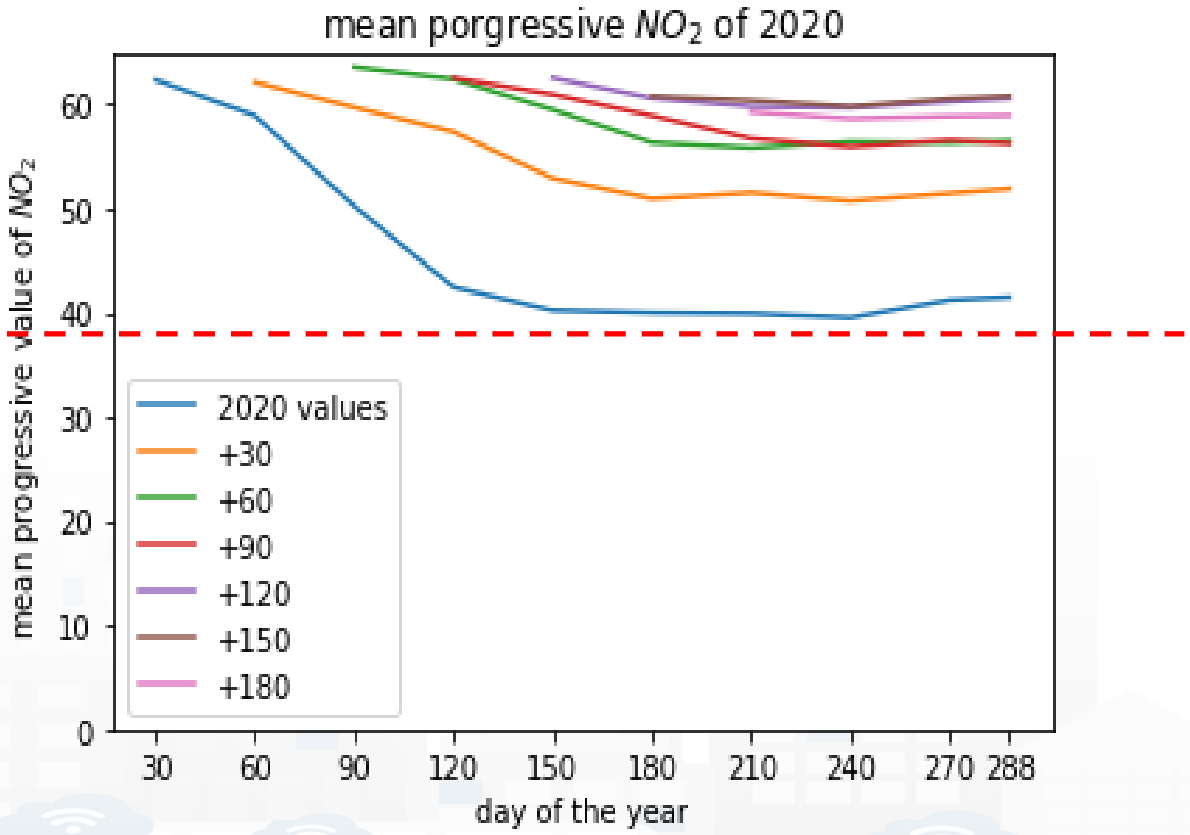
Using data since 2014

Very long term predicting Mean NO2: the 2019 the 2020



metric	model30	model60	model90	model120	model150	model180
MAE	1.21	1.31	1.52	2.04	2.31	2.37
RMSE	2.16	2.61	4.18	6.77	7.83	7.93
MAPE	1.99	2.20	2.65	3.57	4.07	4.18
R2	0.91	0.83	0.80	0.54	0.45	0.14

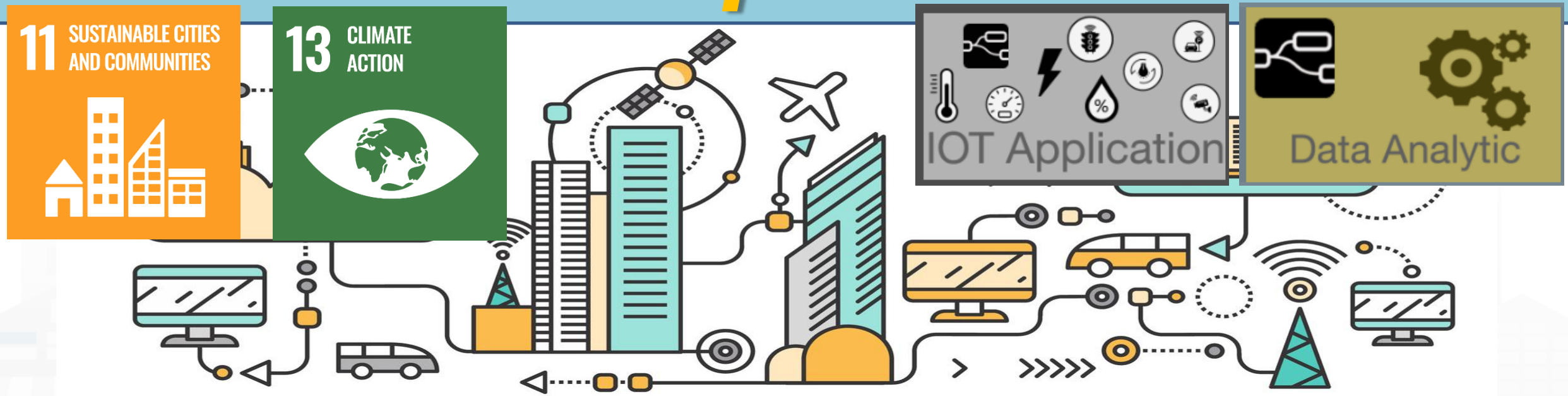
Table 4. Assessment of the predictive models with respect to the actual values of the 2019.



Deep Learning Approach

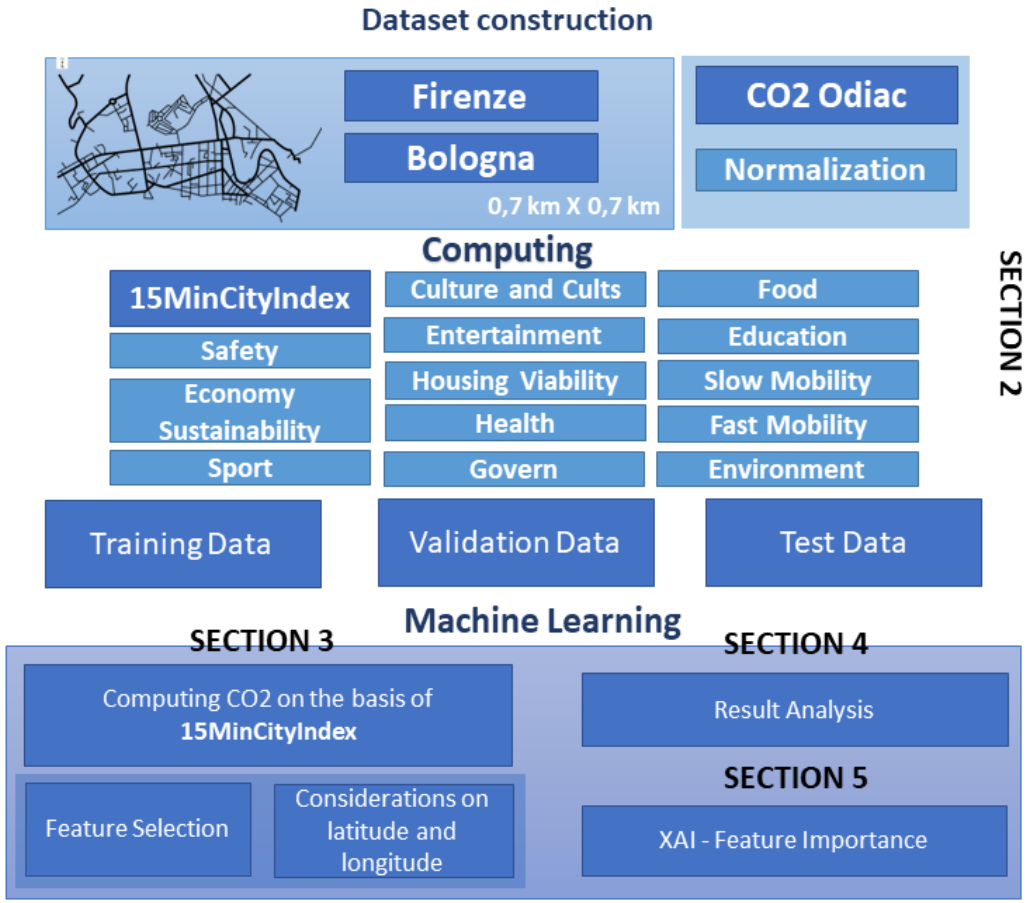
EC ref value

Computing CO2 from Open Data



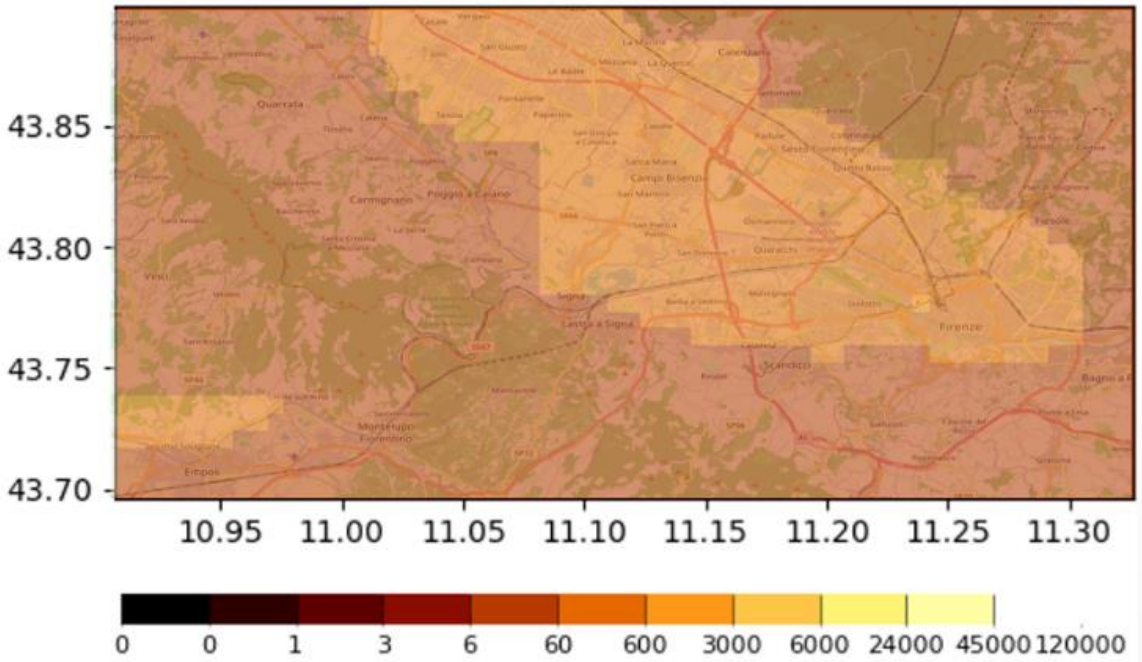
Computing CO2 from Open Data Validation via Satellite

- Number of inhabitants
- Number of green areas
- Surface area of green areas
- Number of Taxpayers
- Average taxable income
- Value of the economy
- Number of shopping and services
- Number of industry and manufacturing
- Cost of house per square meter
- Number of Health services
- Number of Supermarket
- Number of food trades
- Number of Schools
- Number of bicycle paths
- Length of bicycle paths
- Number of Bike racks
- Length of Roads
- Number of Govern services
- Number of Churches
- Number of theatres
- Number of Charging station
- Number of bus stops
- Number of bus lines
- Number of Fuel stations
- etc. Etc.

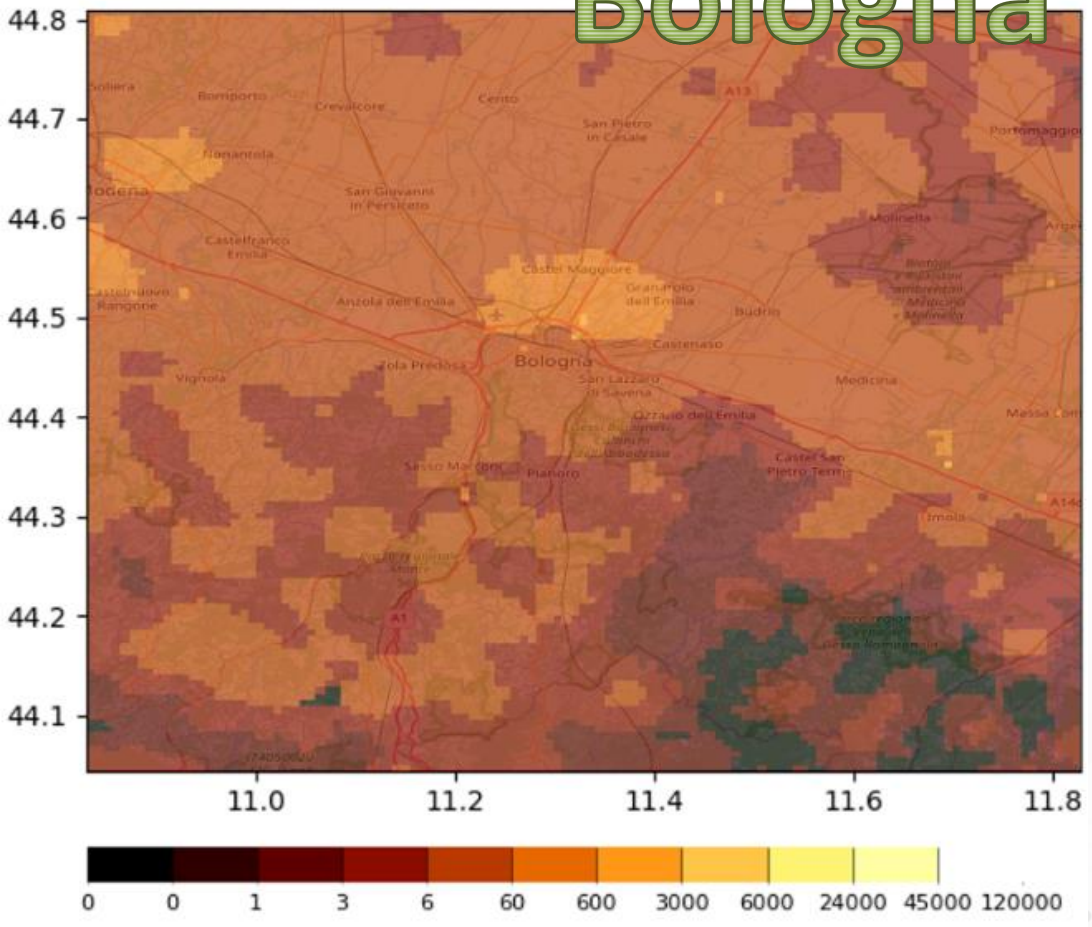


CO2 emissions from satellite data

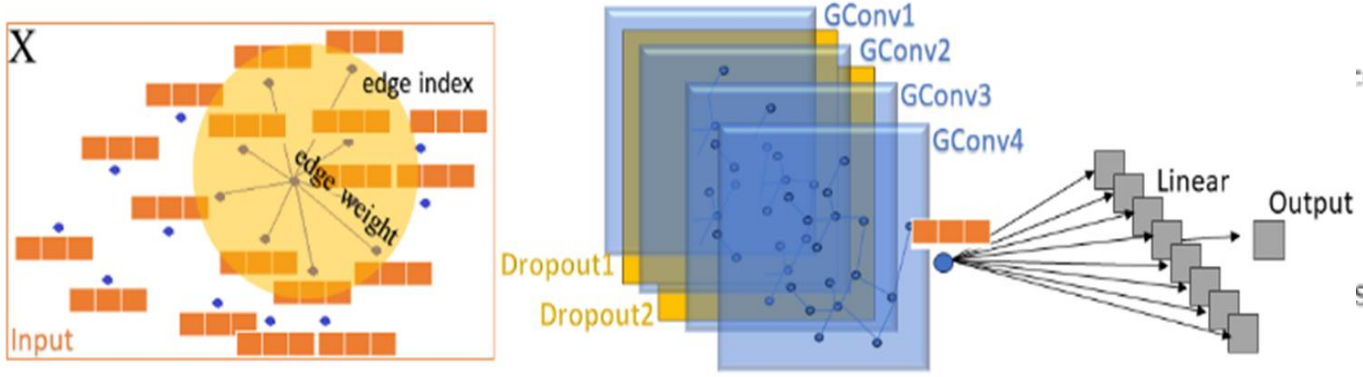
Florence



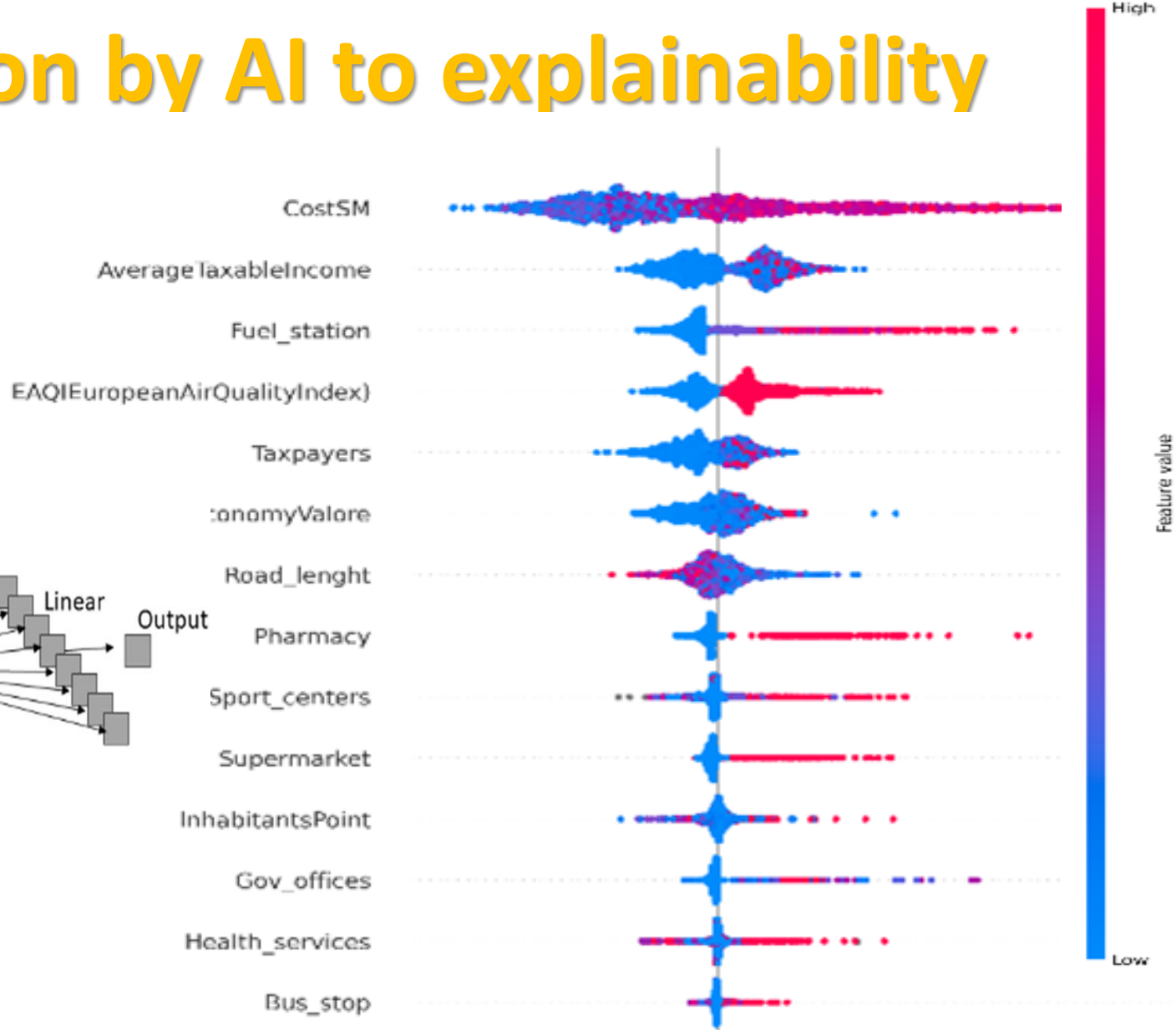
Bologna



From CO2 estimation by AI to explainability



XGBoost, GCN



Predicting Land sliding





Landslide Prediction

Rainfall induced landslide is one of the main geological hazard in Italy and in the world.

- Worldwide based on the study [1] of Natural Hazards and Earth System Sciences
  - from 2004 to 2016, 55997 people were killed in 4862 non seismic landslide events worldwide
  - The same authors identified rainfall as the main the triggering factor of 79% of non-seismic landslides.
- In Italy based on the ISPRA report:
  - 19.9% of the Italian territory is at risk of landslides (59981km^2)
  - Tuscany is among the regions with the largest areas at risk (26%)



Accurate short-term **PREDICTIONS** (1 day in advance) of landslides can be extremely important and useful, in order to both provide local authorities with efficient prediction/ early warning and increase the resilience to manage emergencies.

[1] Froude, M. J. and Petley, D. N.: Global fatal landslide occurrence from 2004 to 2016, Nat. Hazards Earth Syst. Sci., 18, 2161–2181, https://doi.org/10.5194/nhess-18- 2161-2018

Scenario

- The solution and its validation have been performed by using data collected in in the area of the **Metropolitan City of Florence** with
  - 41 Municipalities
  - 3514 Km^2 of Surface Area
  - altitude between 100-1000 above the sea level
  - land predominantly of deciduous forests and cultivated areas
  - 1.5 M inhabitants
- The data history covers the years 2013-2019 with a total of **341** landslide events



Prediction | Susceptibility

per municipality

dynamic hazard heatmaps



Useful for early warning systems

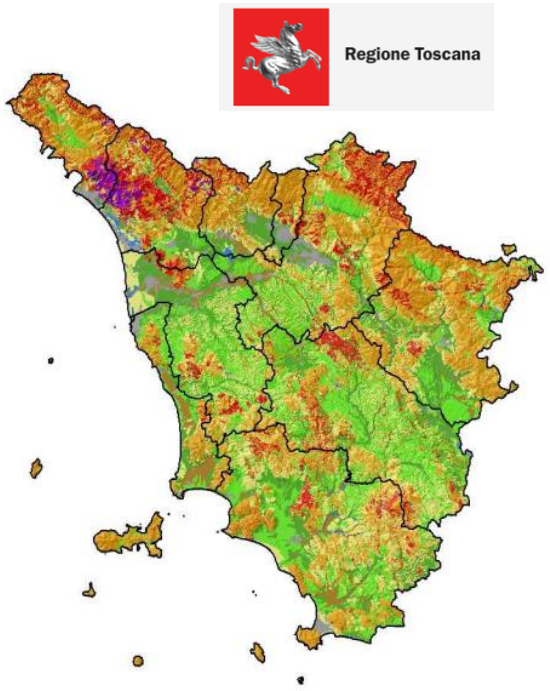
static + dynamic features

Can be computed daily

Useful for long term land usage planning

static features based

1 or 2 times per year



UNIVERSITÀ DEGLI STUDI FIRENZE

DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

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

11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

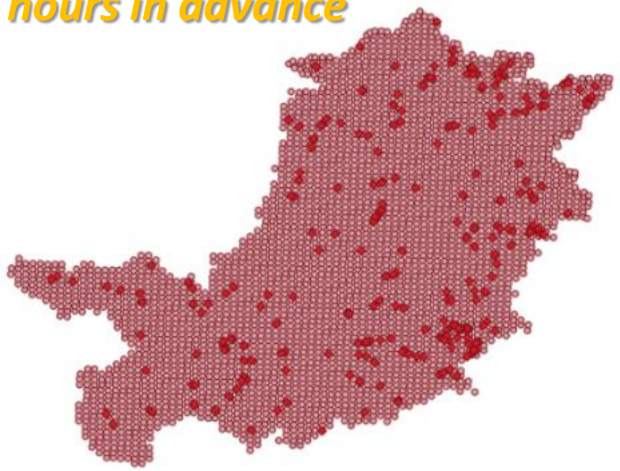
15 LIFE ON LAND

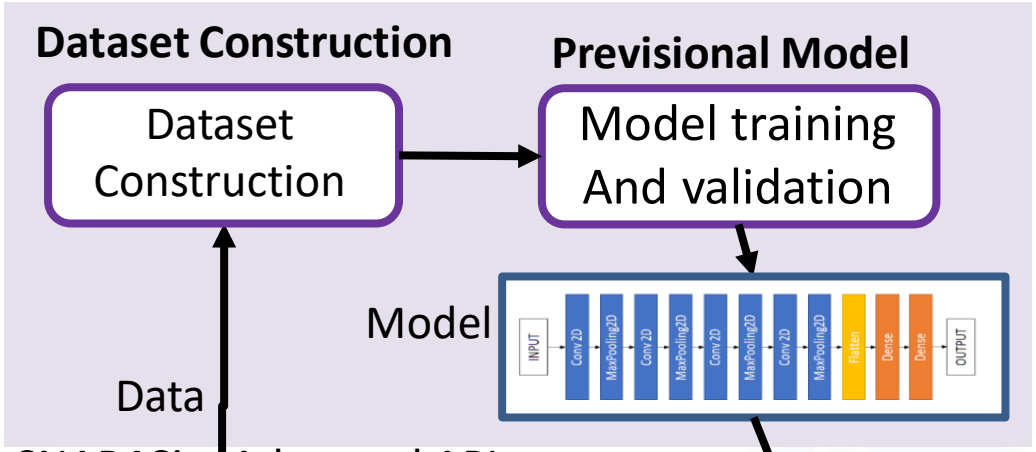
SNAP4CITY

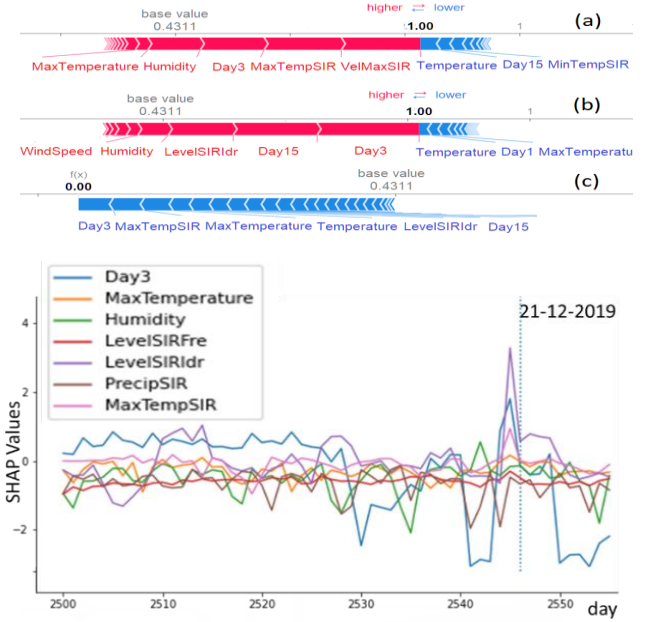
KM 4 CITY

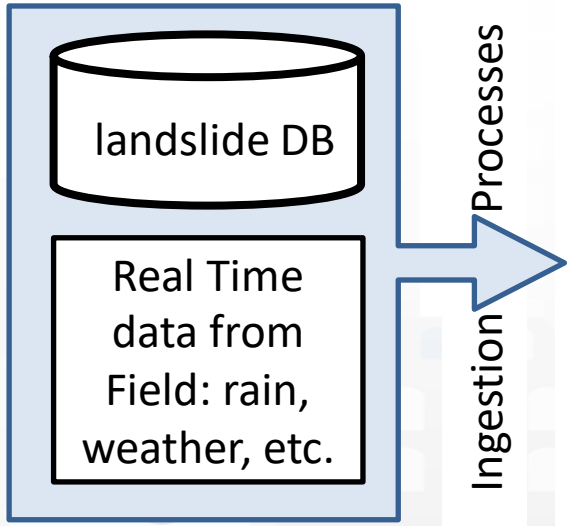
Predicting Land slides

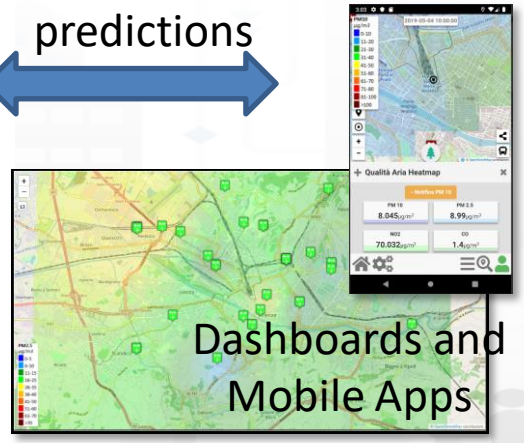
24 hours in advance





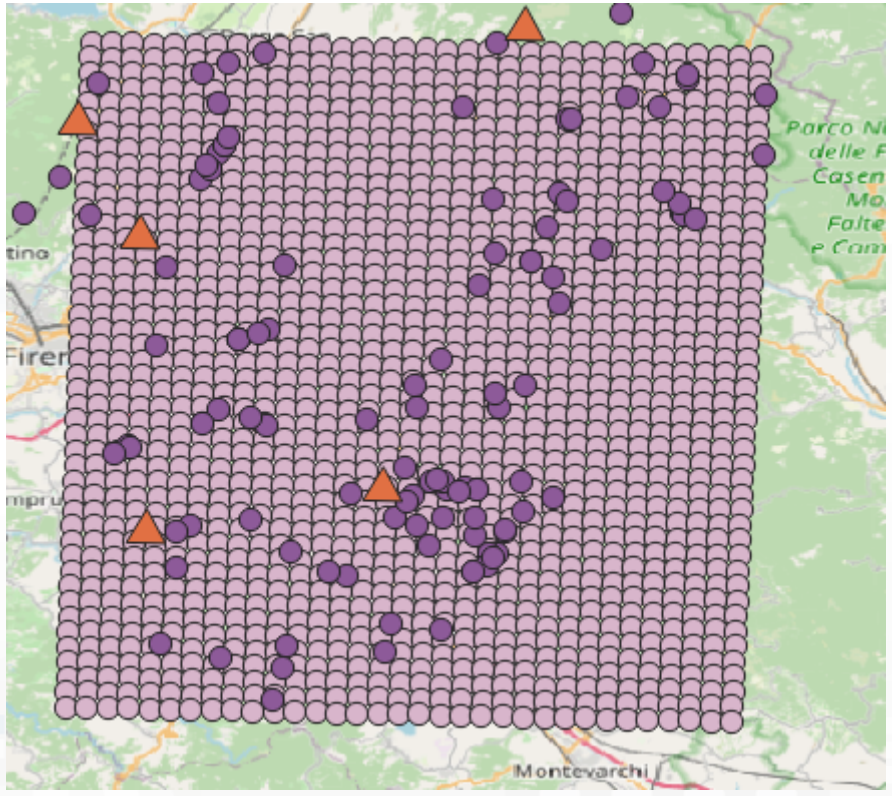






E. Collini, L. A. I. Palesi, P. Nesi, G. Pantaleo, N. Nocentini and A. Rosi, "Predicting and Understanding Landslide Events with Explainable AI," in *IEEE Access*, doi: 10.1109/ACCESS.2022.3158328.
https://ieeexplore.ieee.org/abstract/document/9732490

Features as Predictors: static + dynamic data



landslide events rain gauges grid

Feature	Description	Unit	Example
Date	Observation date, in the format YYYY-MM-DD	Day	2013-01-14
Latitude	Latitude of the area, EPSG:4326 format	Deg	43.86239
Longitude	Longitude of the area in the EPSG:4326 format	Deg	11.51586
Altitude	Altitude of the area	m	467.204
Slope	Acclivity of the area	%	45.942
Vegetation	Vegetation of the area	%	0.262
Ground	Soil type at the event site (class UCS)		223-Oliveti
Day1	Rainfall on the day before the observation	mm	12.453
Day3	Rainfall on the 3 days preceding the observation	mm	15.072
Day15	Rainfall on the 15 days preceding the observation	mm	16.160
Day30	Rainfall on the 30 days preceding the observation	mm	51.515
Temperature	Mean Temperature on the observation day (IlMeteo.it)	°C	6.965
MinTemperature	Minimum temperature on the observation day (IlMeteo.it)	°C	2.99
MaxTemperature	Maximum temperature on the observation day (IlMeteo.it)	°C	9.942
Humidity	Humidity (average) on the observation day (IlMeteo.it)	%	92.96
WindSpeed	Average wind speed on the observation day (IlMeteo.it)	Km/h	5.991
VelMedSIR	Average wind speed on the observation day (SIR)	m/s	0.9
VelMaxSIR	Maximum wind speed on the day of observation (SIR)	m/s	1.8
LevelSIRFre	phreatimetric data on the observation day (SIR)	m	-4.34
LevelSIRIdr	Water (river) level recorded on the observation day (SIR)	m	0.8
PrecipSIR	Precipitation on the observation day (SIR)	mm	0
MinTempSIR	Minimum temperature on the observation day (SIR)	°C	0.5

Data Analytic Solutions

- Aiming at creating an early warning can be traced back to the estimation of areas presenting a high probability of landslide event occurrence in the **next day**, as in this case.

- On the basis of the above-described dataset, a number of techniques to predict landslide events has been tested:
  - Random Forest, **RF**
  - eXtreme Gradient Boosting, **XGBoost**
  - Convolutional Neural Network, **CNN**
  - Autoencoders, **AE**
  - decisional algorithm **SIGMA**

Comparing Predictive Model Architectures

- The considered dataset is composed of about 9 million estimations, among which 2342 positive events (labeled with Value = 1)
- The dataset was divided into two groups: training set (80%) and test set (20%)

TABLE III COMPARISON OF RESULTS OBTAINED USING MODELS FOR SHORT TERMS PREDICTION OF LANDSLIDES, BEST RESULTS IN BOLD.

Model	XGBoost	RF	CNN	Auto encoder	SIGMA
MAE	**0.000173**	0.000334	0.000600	0.009218	0.004169
MSE	**0.000173**	0.000334	0.000259	0.009218	0.004169
RMSE	**0.0131**	0.0182	0.0160	0.0960	0.064572
Accuracy	0.99	0.99	0.99	0.99	0.99
Sensitivity	**0.79**	0.36	0.24	0.19	0.06
Specificity	0.99	0.99	0.99	0.99	0.99
TSS	**0.78**	0.35	0.23	0.18	0.05
PfA	**0.01%**	0.02%	**0.01%**	0.11%	0.39%
Precision	0.63	0.35	0.33	**0.64**	0.003
F1 score	**0.70**	0.36	0.27	0.29	0.007
MCC	**0.70**	0.36	0.28	0.35	0.01
OA	**2.40**	1.72	1.55	1.64	1.02
Kappa	**0.70**	0.36	0.27	0.29	0.01
AUC	0.89	0.68	**0.99**	0.92	0.53

Comparing Predictive Model/architectures

Model	XGBoost	RF	CNN	Auto encoder	SIGMA
MAE	0.000173	0.000334	0.000600	0.009218	0.004169
MSE	0.000173	0.000334	0.000259	0.009218	0.004169
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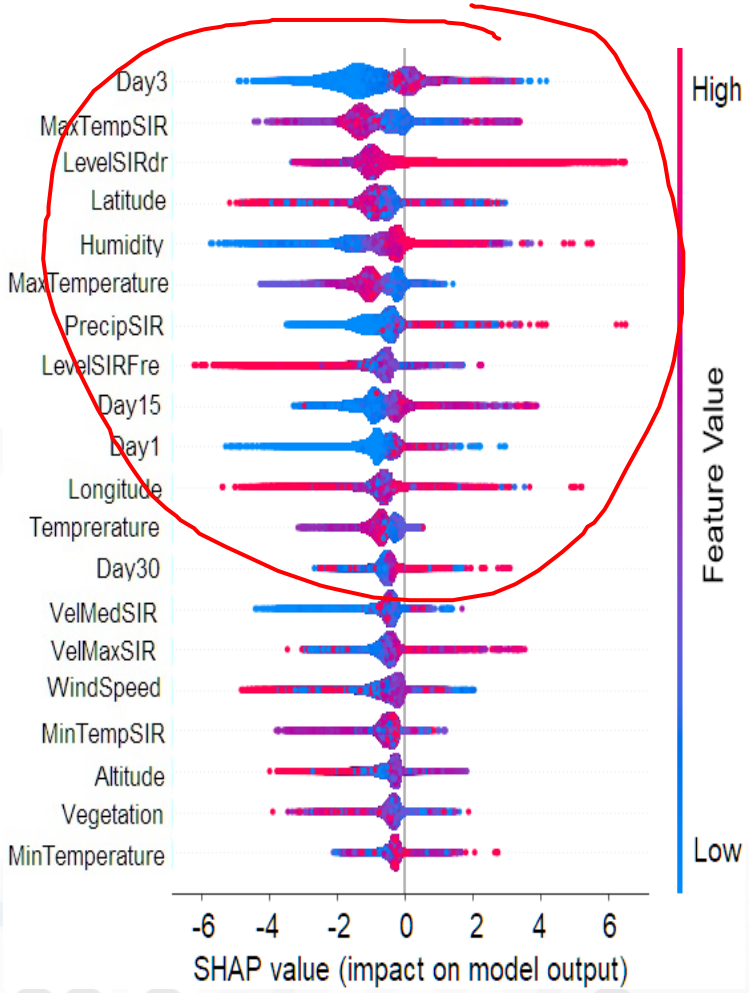
Specificity	0.99	0.99	0.99	0.99	0.99
TSS	0.78	0.35	0.23	0.18	0.05
PfA	0.01%	0.02%	0.01%	0.11%	0.39%
Precision	0.63	0.35	0.33	0.64	0.003
F1 score	0.70	0.36	0.27	0.29	0.007
MCC	0.70	0.36	0.28	0.35	0.01
OA	2.40	1.72	1.55	1.64	1.02
Kappa	0.70	0.36	0.27	0.29	0.01
AUC	0.89	0.68	0.99	0.92	0.53





Global Explainable AI

- Feature relevance

- Red: positive, blue: negeative;
- vs intensity and impact

Local Explainable AI - understanding the single event

- The local explanation puts in evidence the features which provided major contribution to the prediction
- For example considering Figure10a, the value of VelMaxSIR, MaxTempSIR, Day3 and Humidity contributed significantly to the classification of the observation as a **landslide event**

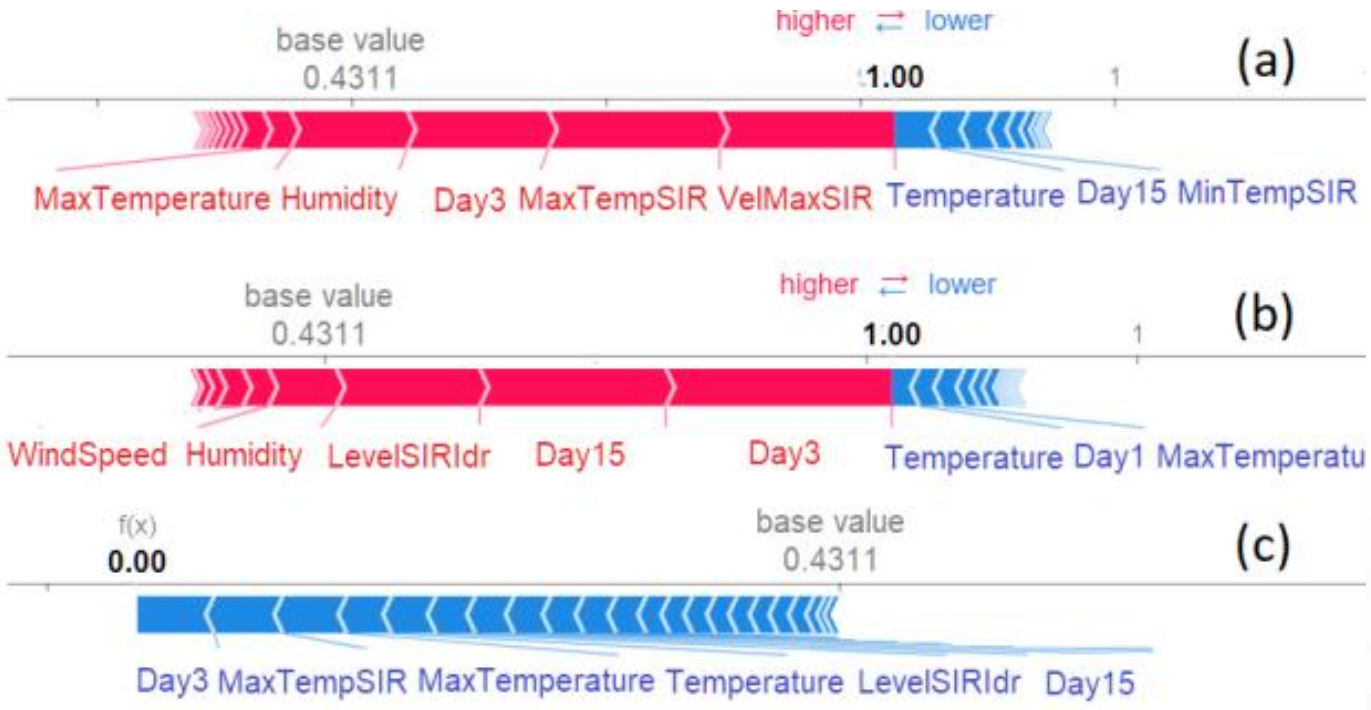


FIGURE 10. **Local feature relevance via SHAP, as interpretation of events in terms of feature values: (a) and (b) are events with predictions of landslide, (c) a no landslide event.**

Local Explainable AI - understanding the single event

The trends of the SHAP values of the most relevant features have been plot with respect to the time/days.

It can be noted that in coincidence of the day before the event, most of the SHAP values of the relevant features assumed a relevant value at the same time. And in particular for this event: **LevelSIRIdr, Day3 and MaxTempSIR**.

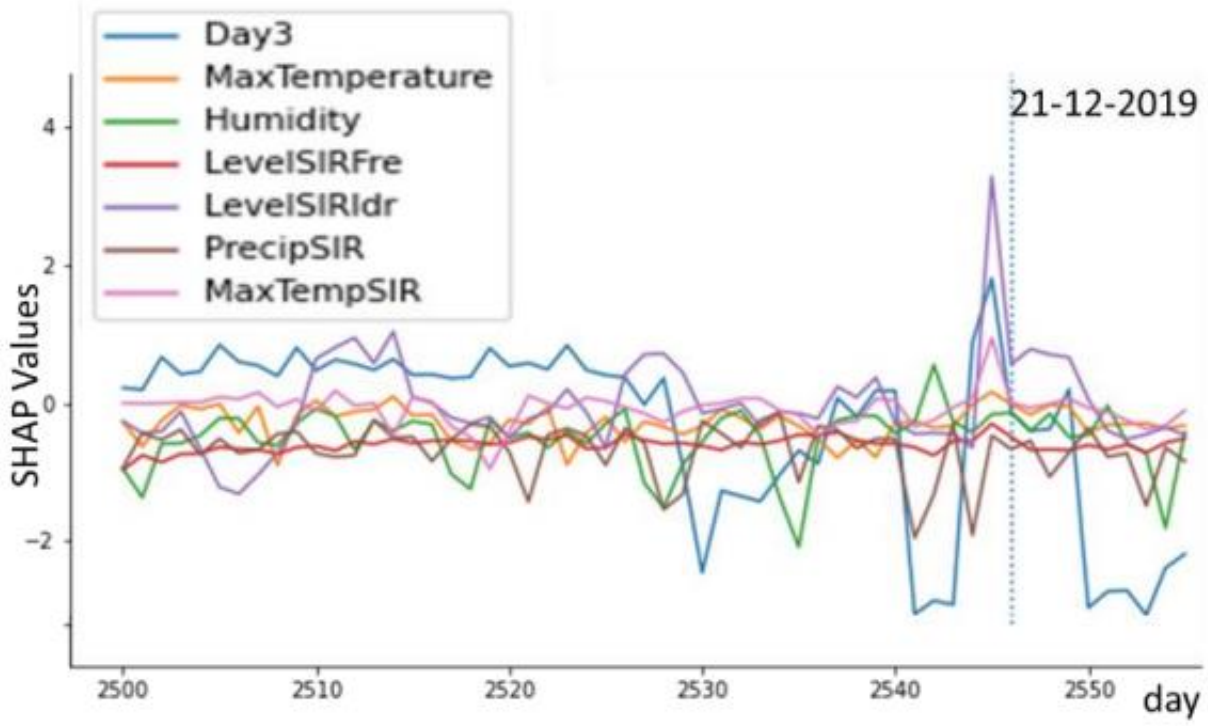


FIGURE 11. Time trend of SHAP values of most relevant features around the landslide event of 21-12-2019: values estimated by using data collected in the neighboring area of the event.

Consideration

- **The problem of landslide event prediction** has been addressed, for early warning specific to the case study in the Metropolitan City of Florence, using
  - static land description,
  - dynamic features as rain fall, temperature, wind, etc.
- **Numerous AI solutions has been compared**
  - **t**he best performing architecture has been XGBOOST
- **XAI: based on Shapley** additive explanation (SHAP), global and local, derived relevance:
  - rain the last 3 days, max temperature in the previous day, lever of water in the river
  - land static features are preconditions for landslide, while they are not efficient in creating an early warning system.
- **Computationally**: predictions can be assess every day,
  - susceptibility map usually are computed 1 or two times per year.
- **Prediction** models can prevent disaster
  - susceptibility map are mainly used for taking decision on planning.

Predicting People Presences

to major events

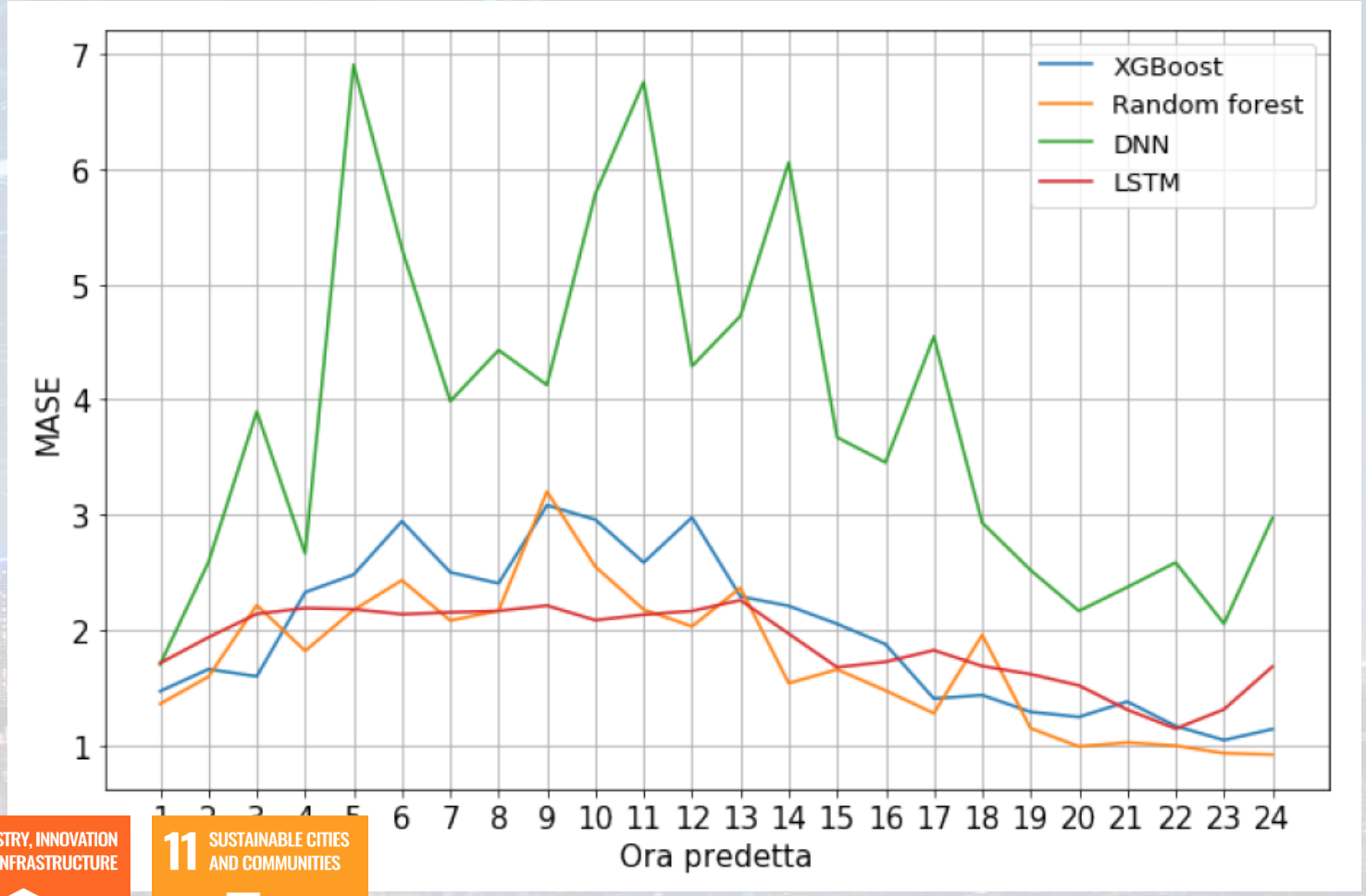


Twitter Vigilance

Pont du Gard: data analytics

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

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



Twitter Vigilance

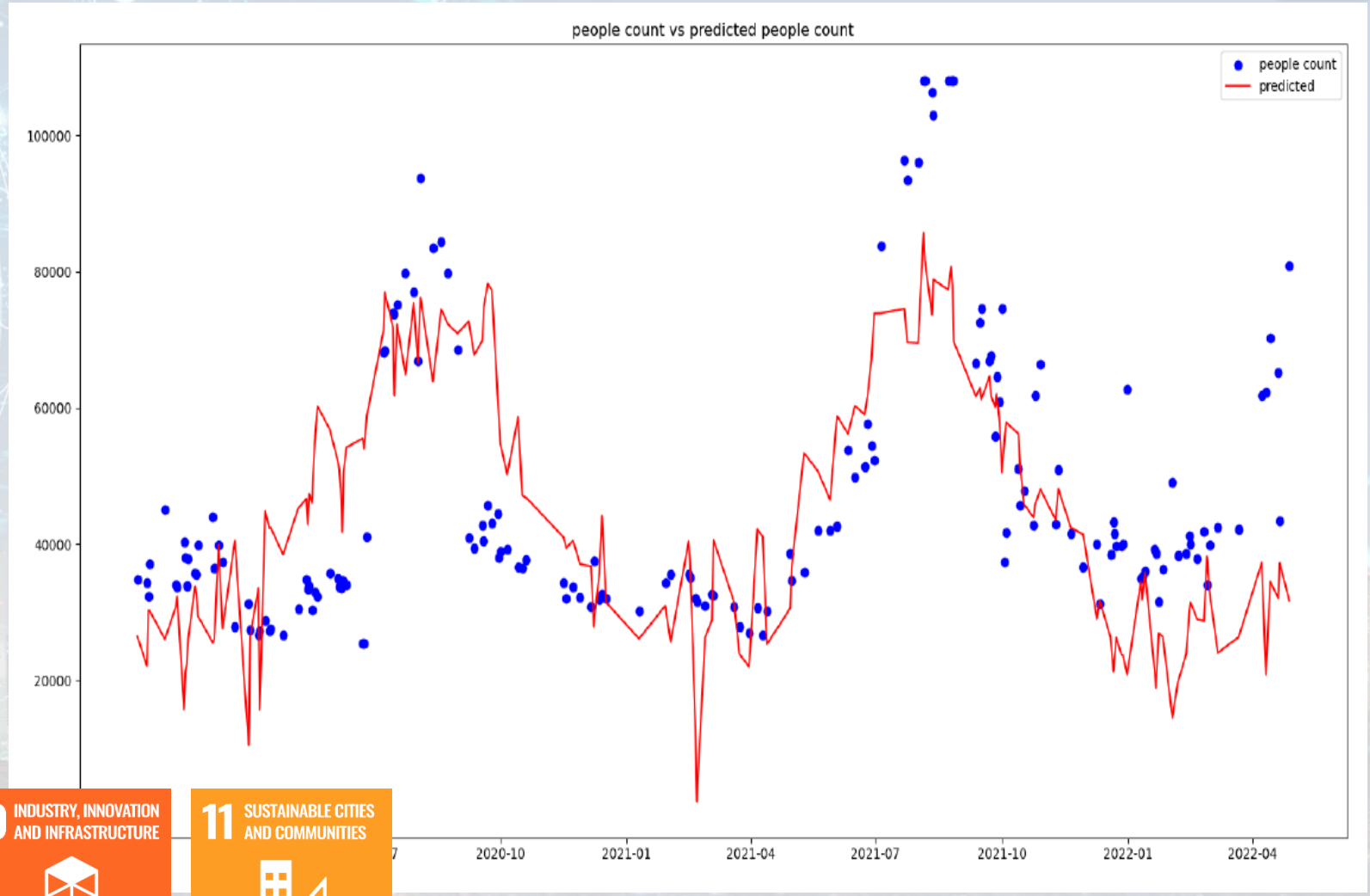
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

11 SUSTAINABLE CITIES AND COMMUNITIES

Dubrovnik: Data Analytics

- Assessing impact of advertising

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



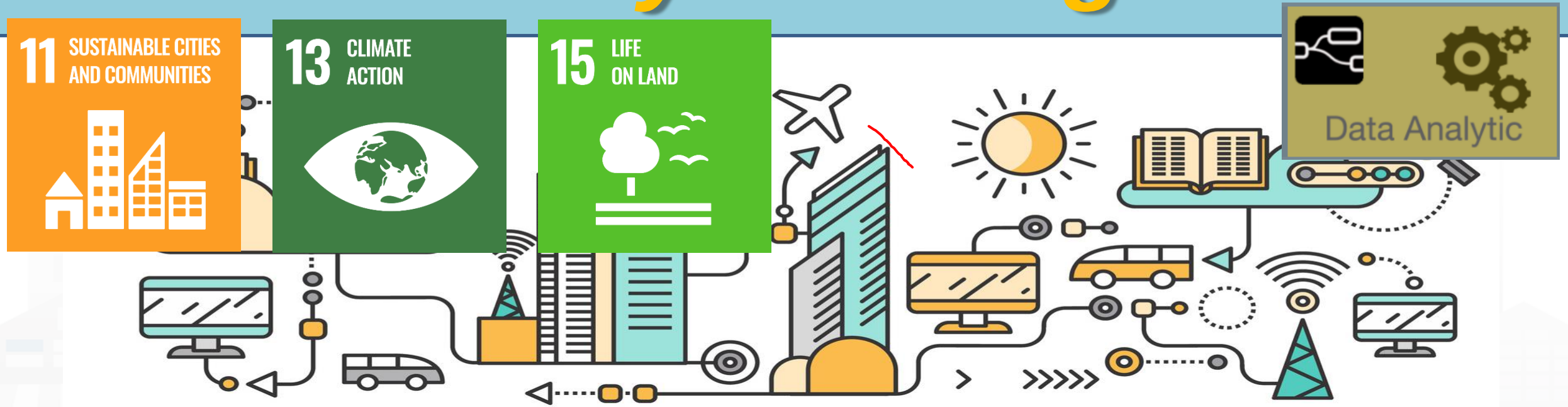
Twitter Vigilance

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

11 SUSTAINABLE CITIES AND COMMUNITIES

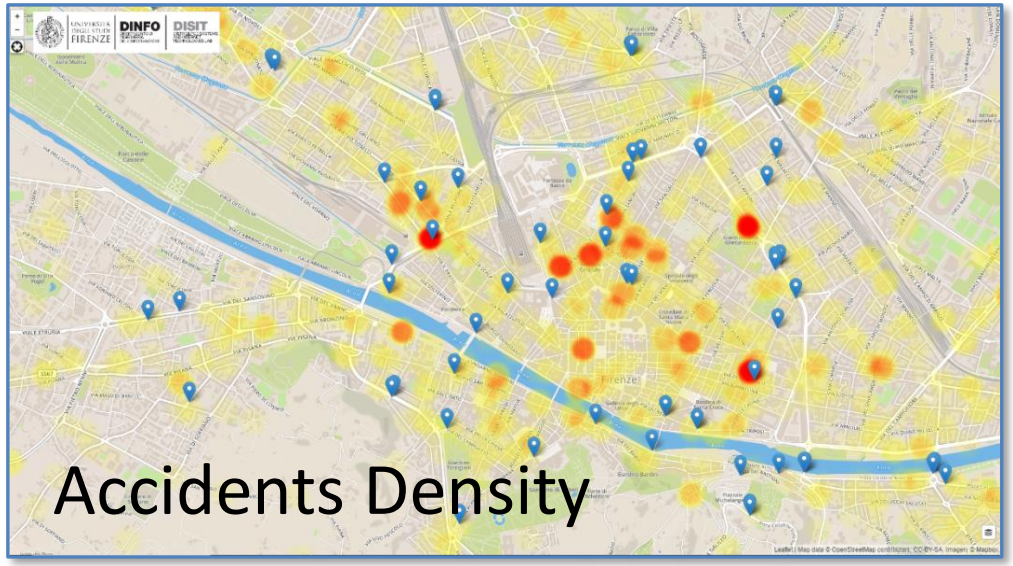
Anomaly Detection

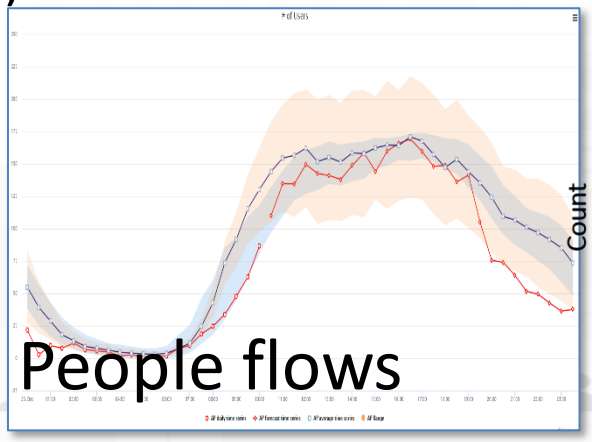
Early Warning

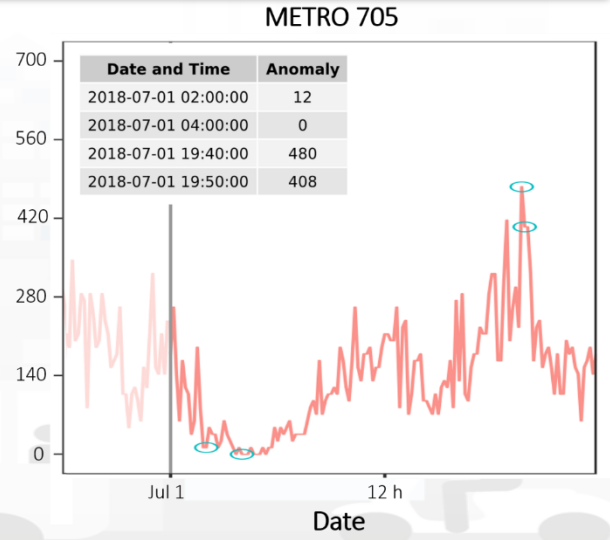


Anomaly Detections

- About the IoT Devices status
  - Eventual problems on IoT Devices, connections, etc.
- About People Flows and Density
  - Early warning of the ineption of critical events
- About traffic flow
  - Early warning on eventual incidents, or on the inception of critical conditions on the traffic (e.g., a reduction in viability, a broken bus, ..)
- About….
  - Early warning, early detection of problems,
- Recurrence analysis
- Causal Analysis

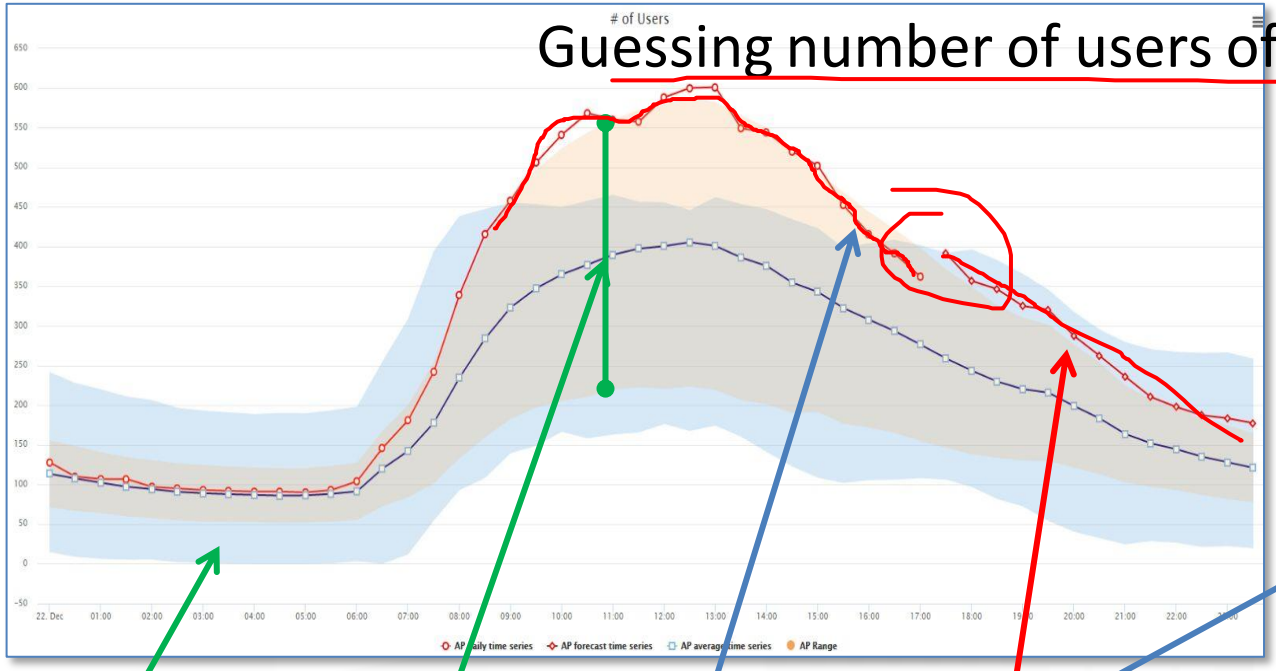


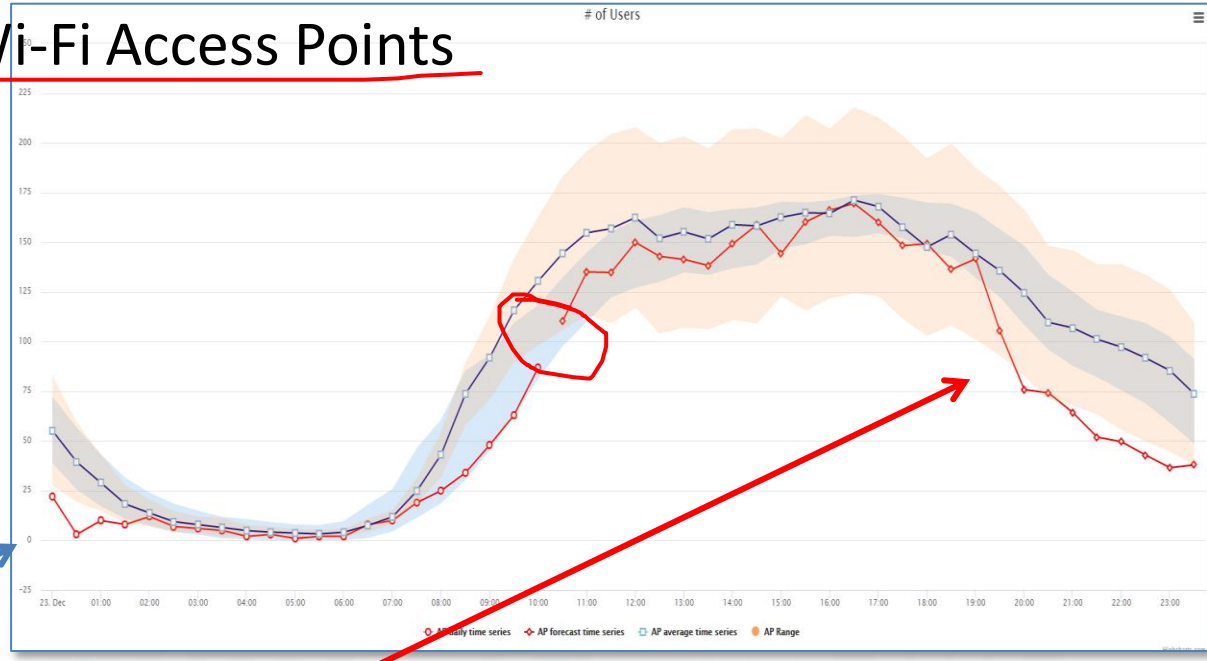




Prediction and Identification of Anomalies

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 precision of the 95%

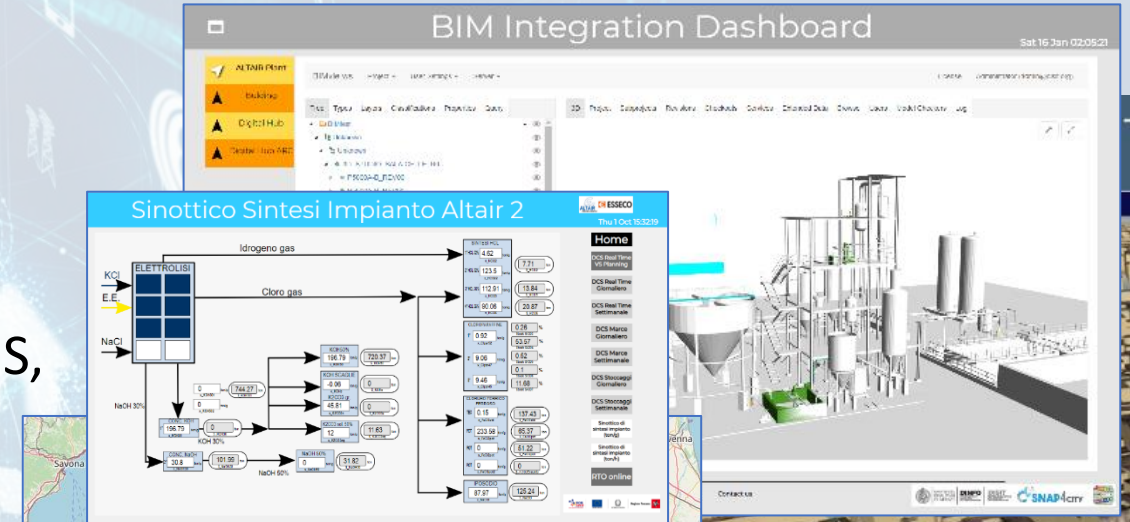
TOP

Computing: High Level Types
Data and their representations

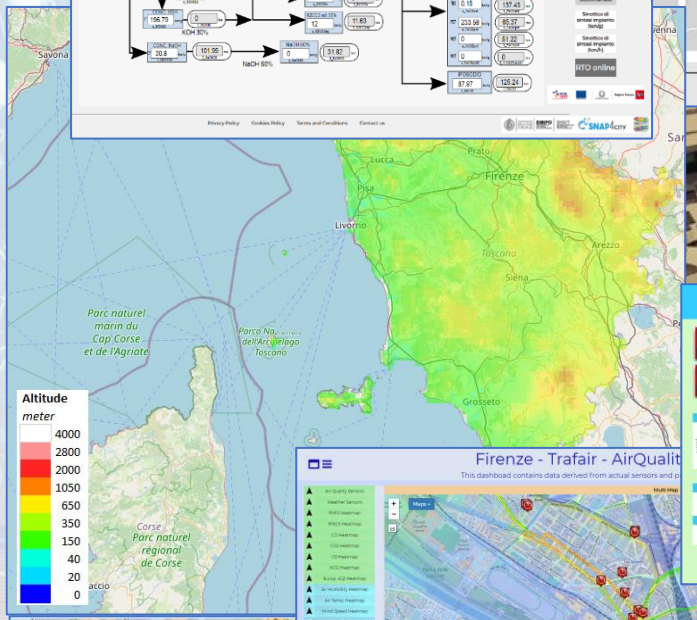


High Level Types

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



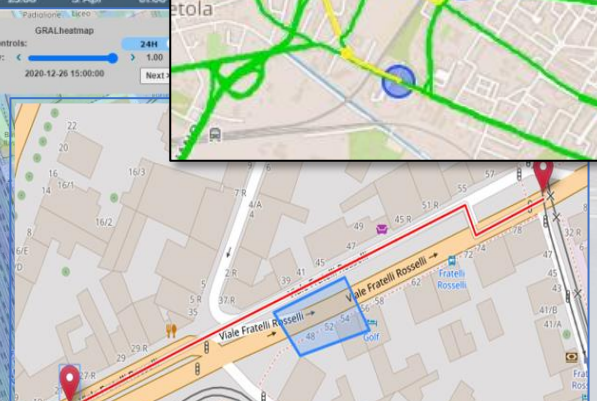












Why computing Higher Level Types

- They are a more **direct representations for the decision makers**
  - fast awareness of the situation
  - fast reaction and decision making

- **High Level Types and their representations**
  - Traffic Flow and animations
  - Heatmaps and animations
  - Origin Destination Matrices, ODM; and animations
  - Trajectories, ….
  - Digital Twin and 3D digital representation of the city
  - User behavior representation
  - Typical trends, different time spam
  - etc.

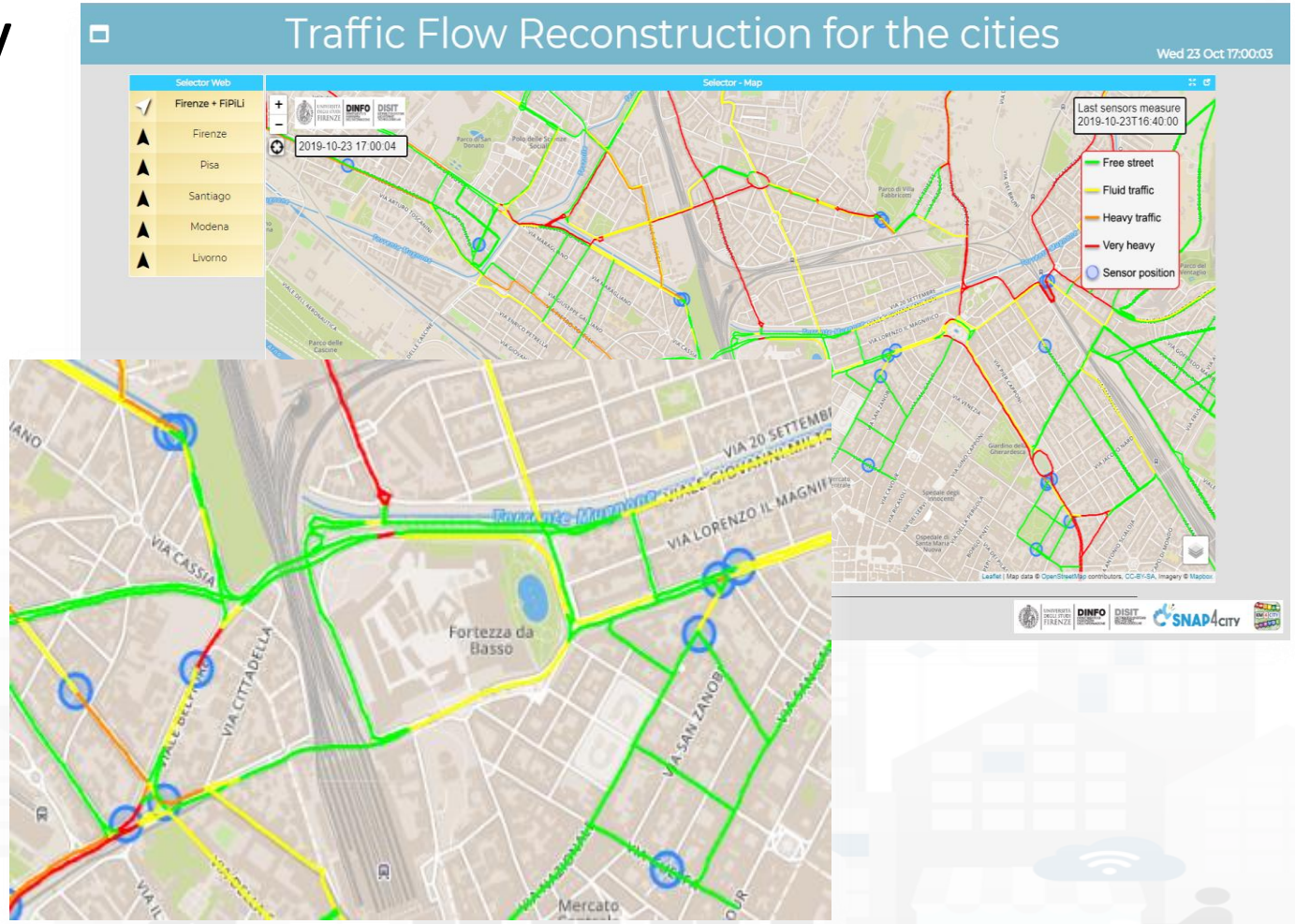


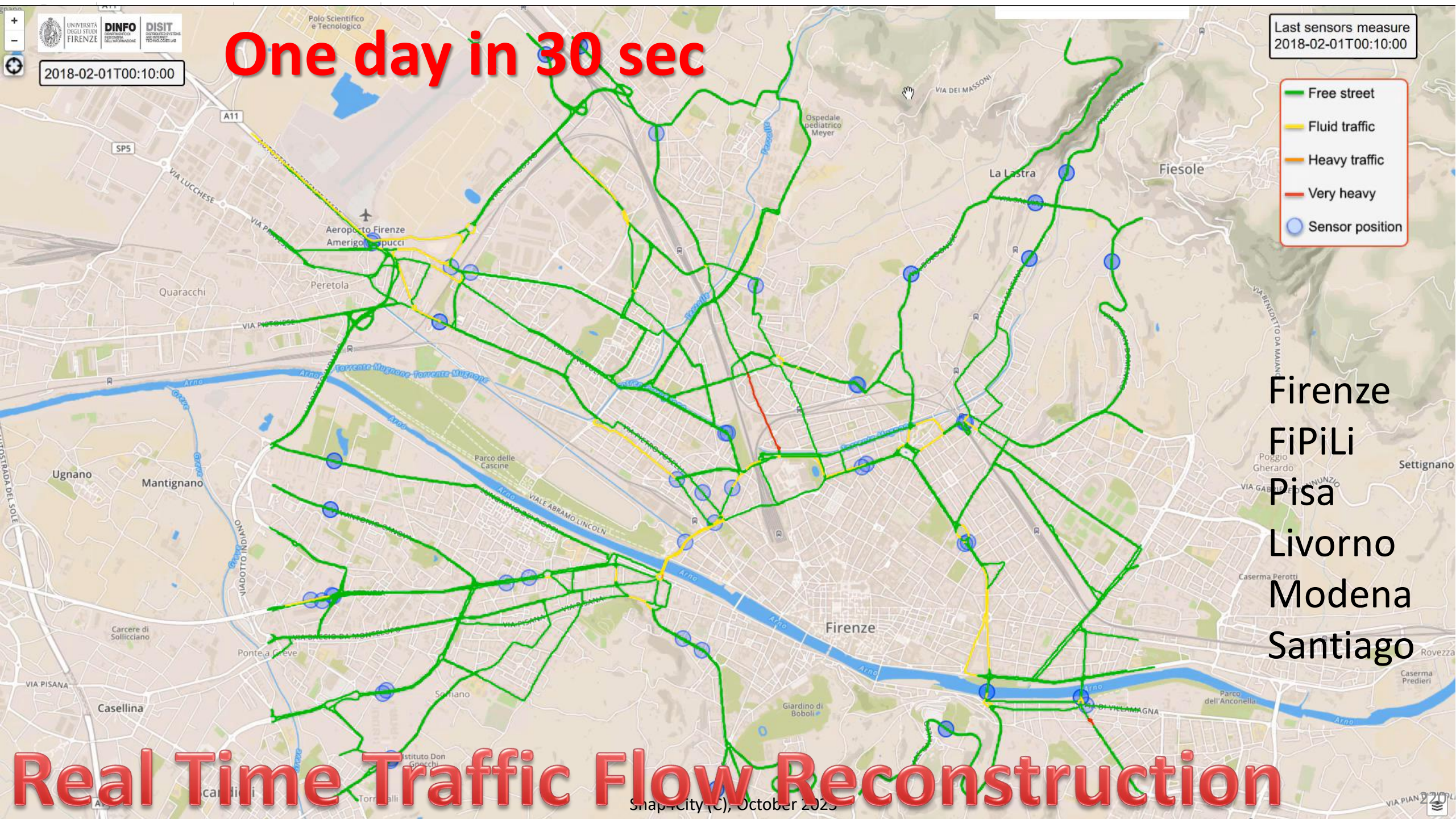
Traffic Flow Reconstruction from Traffic Sensors Data



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




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

How it works: Traffic Flow Manager

Historic Traffic Flow Data

Road Graph

Training

Road Graph Model

Traffic Flow Reconstruction

Real Time Traffic Flow Sensor Data

Traffic Flow

JSON

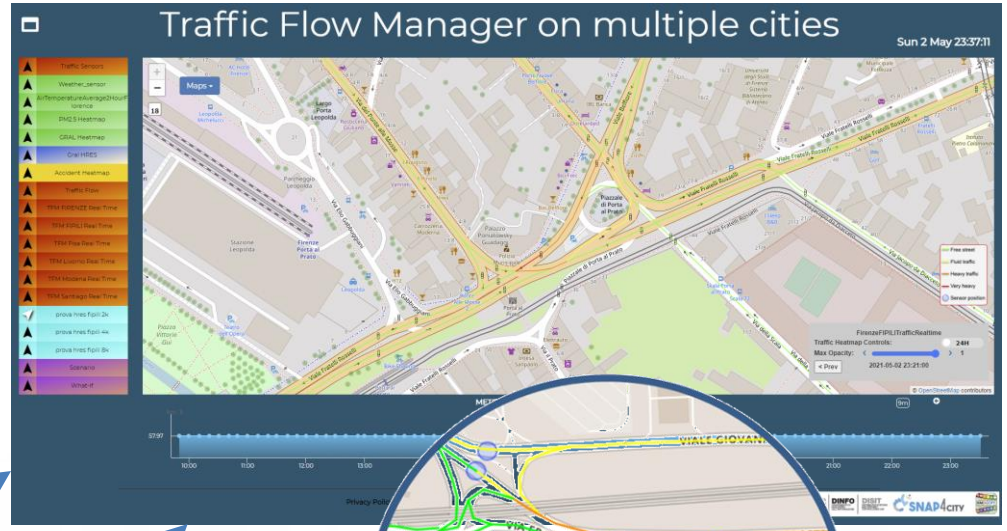
JSON

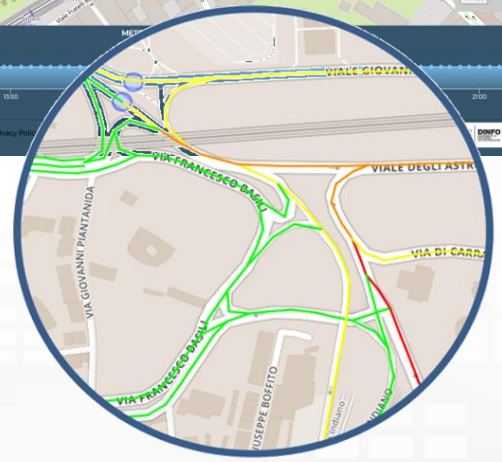
WMS



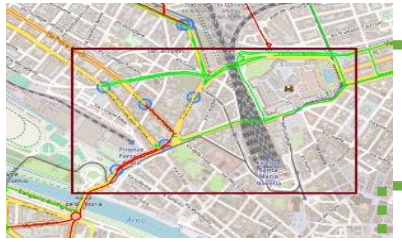
Traffic Flow Manager

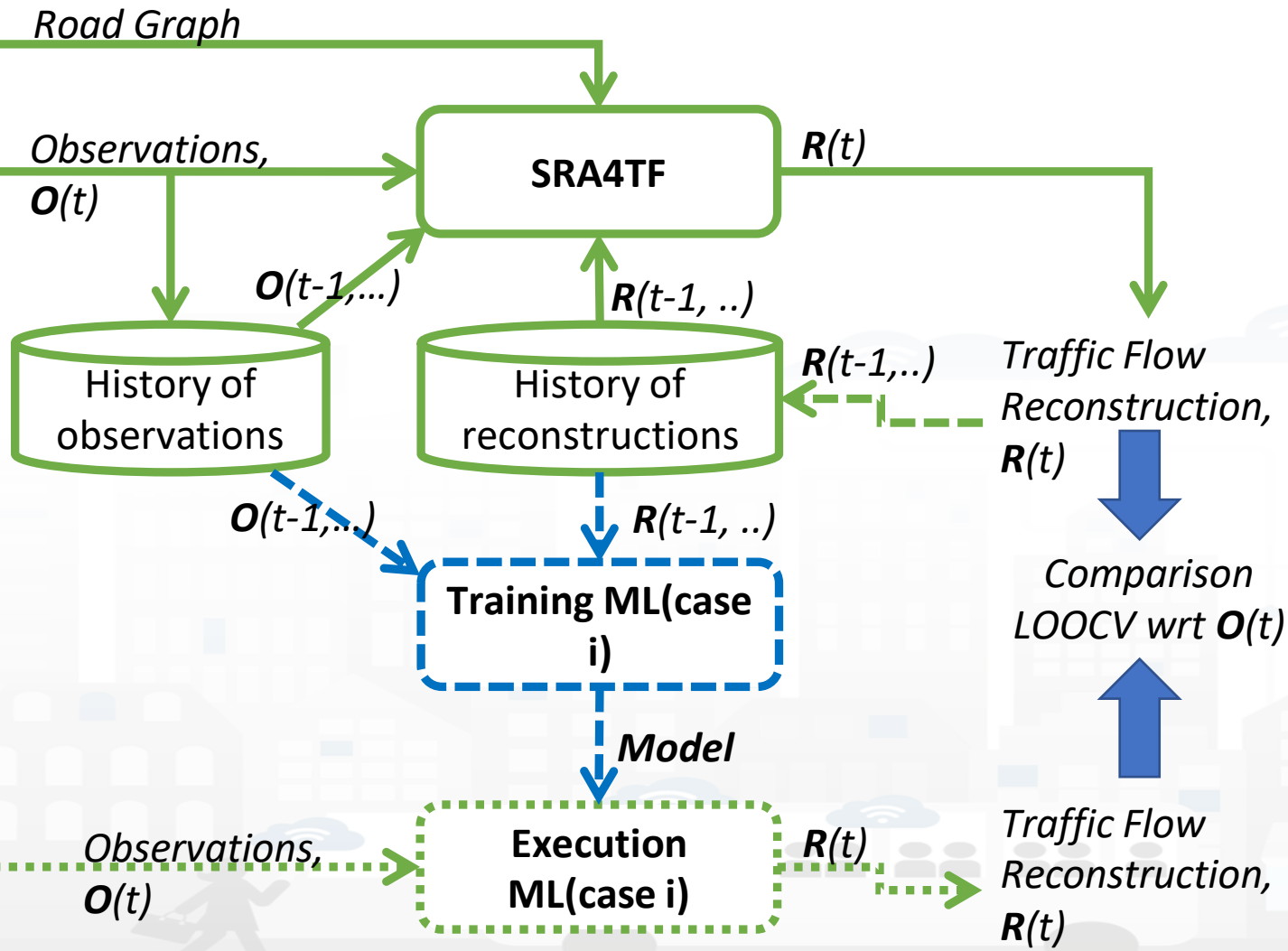
GeoServer



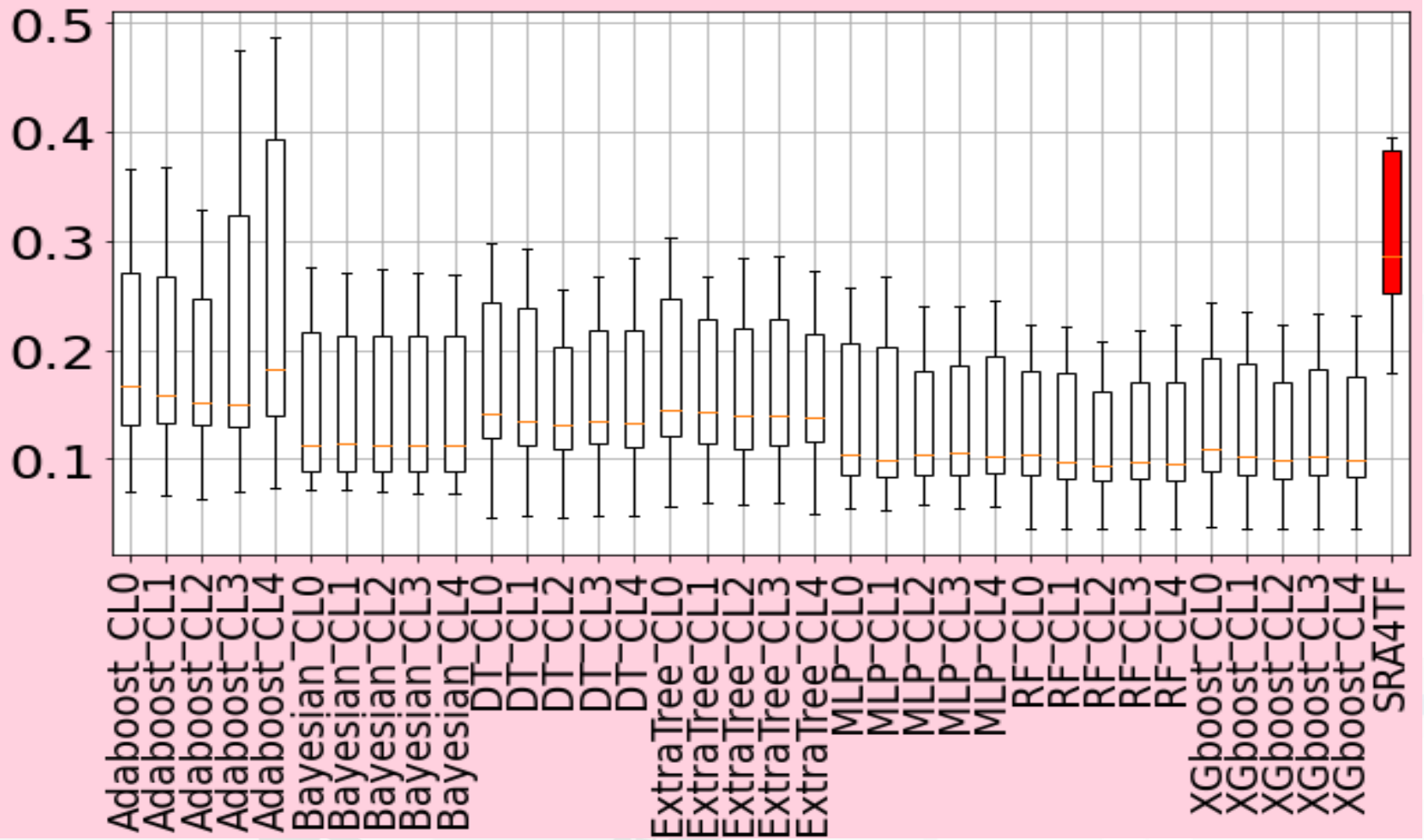


Hybrid Traffic Flow reconstruction





Comparisong among different NN solutions

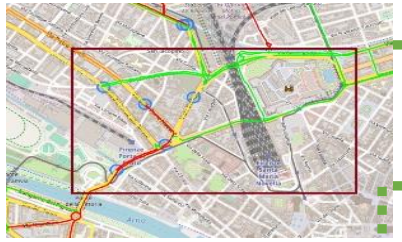


RF resulted the best in increase the precision of TFR in the network
Resulting MAE close to 0.1

Traffic Flow Reconstruction hybrid: neuro-symbolic



Hybrid Traffic Flow reconstruction



Road Graph

Observations, **O**(t)

SRA4TF

R(t)

O(t-1,…)

R(t-1, ..)

History of observations

History of reconstructions

R(t-1,..)

Traffic Flow Reconstruction, **R**(t)

O(t-1,..)

R(t-1, ..)

Training ML(case i)

Comparison LOOCV wrt **O**(t)

Model

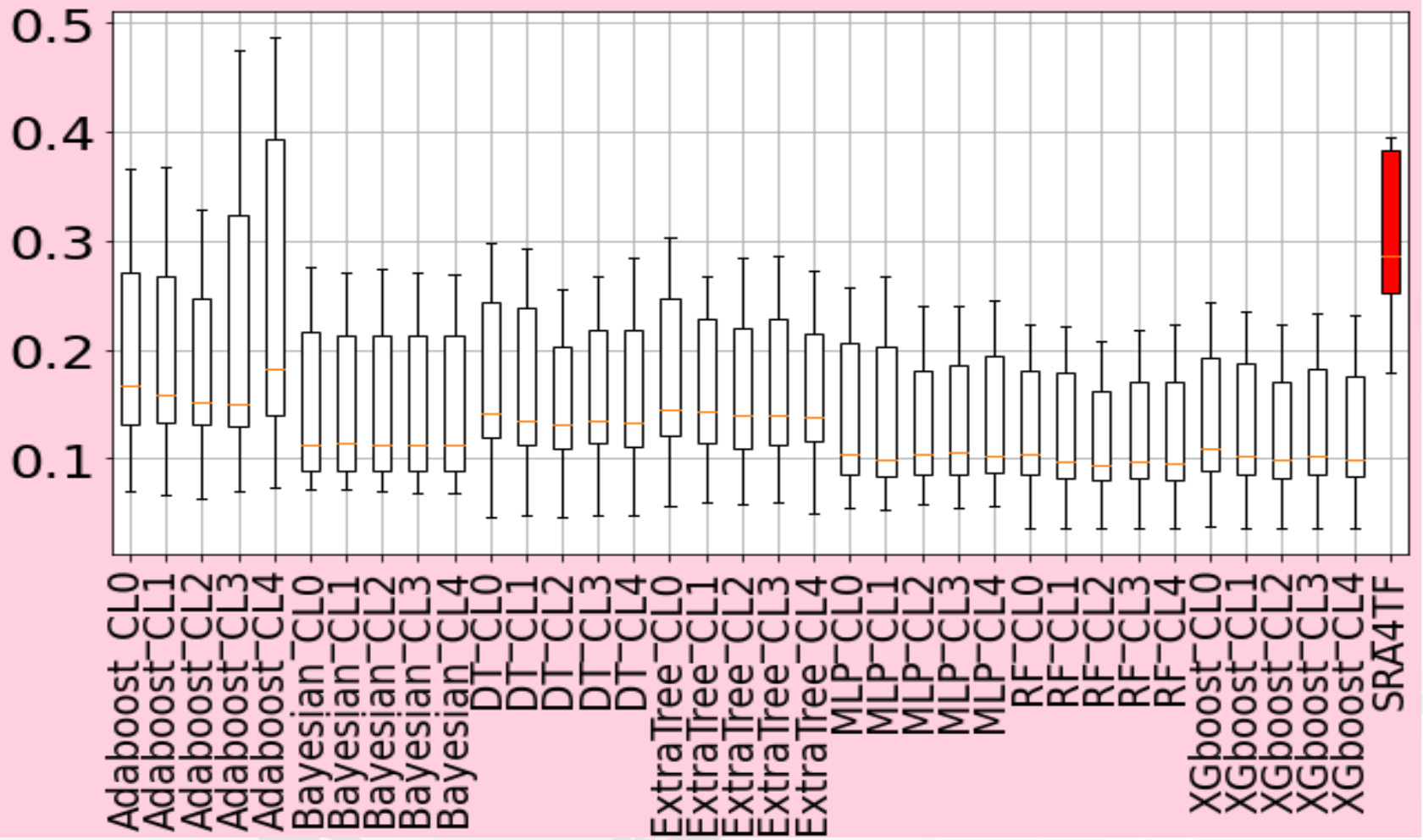
Observations, **O**(t)

Execution ML(case i)

R(t)

Traffic Flow Reconstruction, **R**(t)

Comparisong among different NN solutions

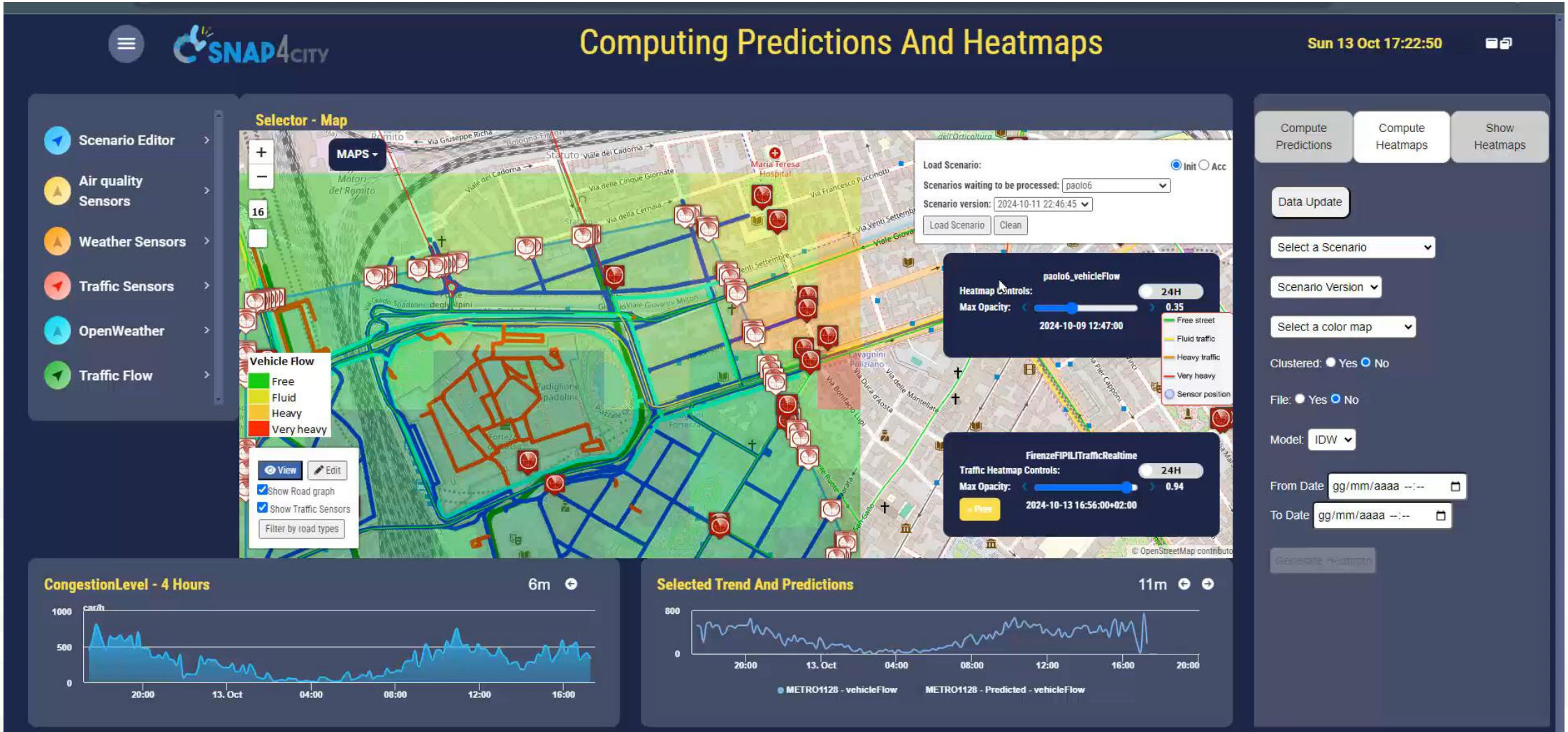


RF resulted the best in increase the precision of TFR in the network
Resulting MAE close to 0.1

Heatmaps and animations



Predictions and Heatmaps in Real Time

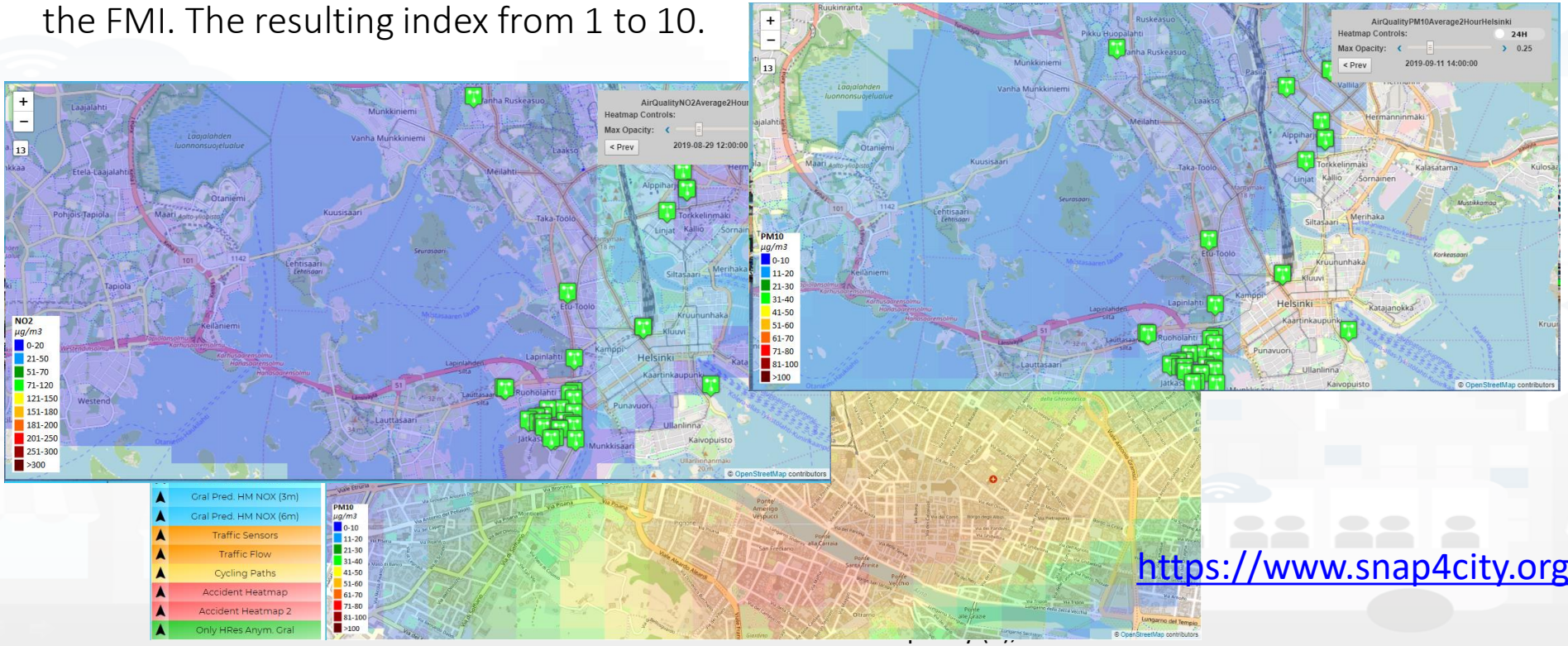


Devices data

- **Air Quality sensors are**
  - Collected on scattered positions
  - Not all sensors have sull set of data, complexity of computing AQI
- **AirQuality Services**
  - AirQuality indicators independent on the sensors' position, in any GPS position of the area
  - **Multiple data:** PM_{10}, $PM_{2.5}$, CO, CO_2, SO_2, O_3, H_2S, NO, NO_2, NO_x, air temperature, air humidity, velocity of wind speed, dew point, etc.
- **Applications**
  - Control Room Rendering
  - Alerting on specific personal GPS locations
  - Constrained routing for: runners, walking with baby, people with pulmonary problems,
  - Mobile Phone Rendering, this means to have thousands of users active at the same time, and a reasonable memory consumption in the server.

Environmental Real Time Measures

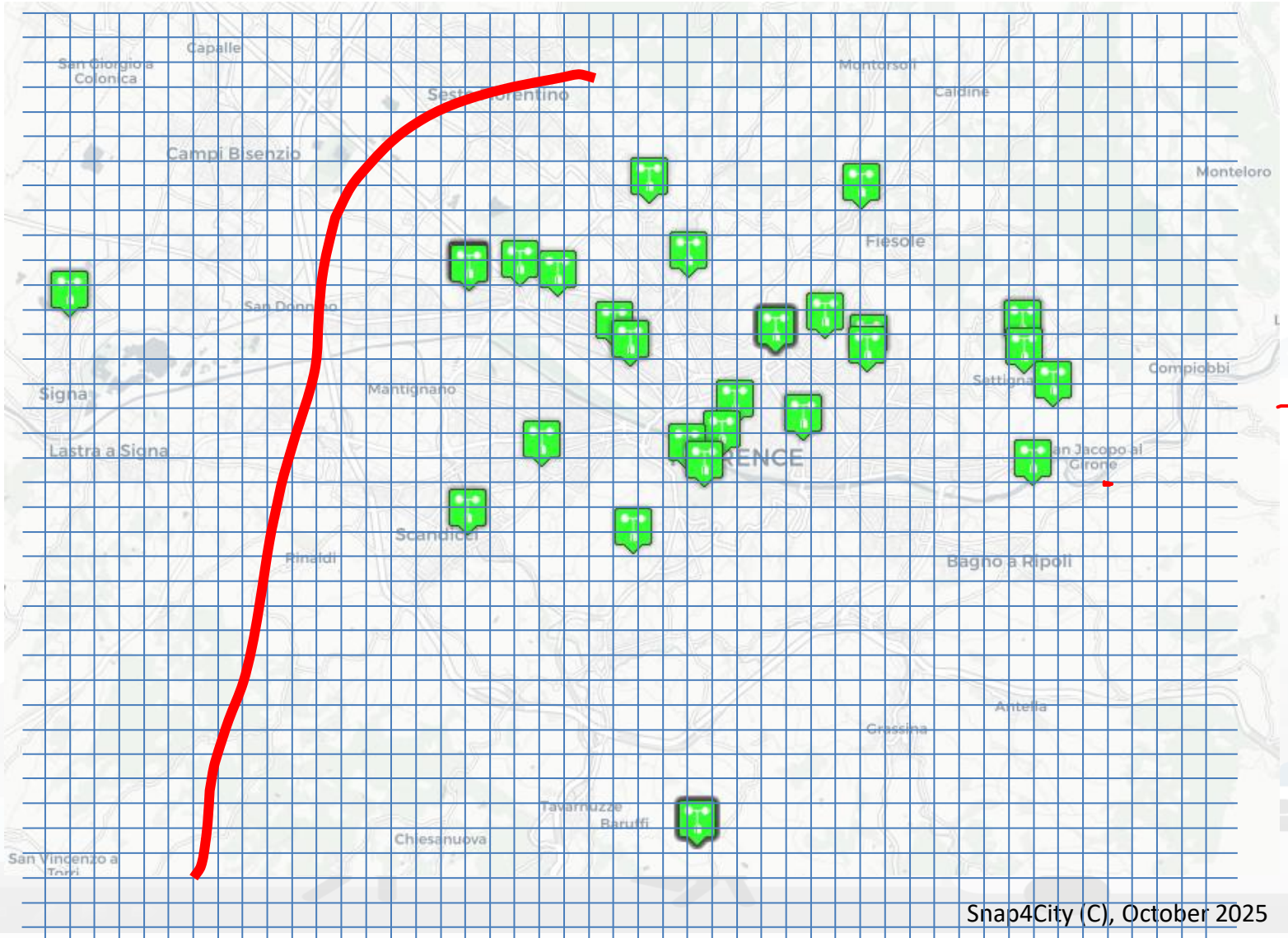
- **Noise:** real time noise levels (measured in dBA).
- **PM_{10}:** real time pollutant levels in air in terms of PM_{10}(measured in $\mu g/m_3$) particles.
- **$PM_{2,5}$**: real time pollutant levels in air in terms of $PM_{2.5}$(measured in $\mu g/m_3$) particles
- **NO_2**: real time pollutant levels in air in terms of nitrogen dioxide (measured in $\mu g/m_3$).
- **Air Quality Index (AQI):** real time air quality index of the Helsinki area, provided by the FMI. The resulting index from 1 to 10.



- BusStop
- Ticket sale
- Traffic Sensor
- Weather sensor
- Air Temp heatmap
- Humidity Heatmap
- Air Quality Sensors
- Noise sensors
- Noise Heatmap
- PM10 heatmap
- PM2.5 Heatmap
- NO2 heatmap
- Air Quality Index HeatM.
- EAQI HeatM.
- CAQI HeatM.
- Enfuser pred. AQI
- Enfuser pred. PM10
- Enfuser pred. PM2.5
- Gral pred. PM10
- Gral pred. PM10 (6m)
- PM10 Jätkäsaari
- PM2.5 Jätkäsaari
- EAQI Jätkäsaari
- Appreciated POIs

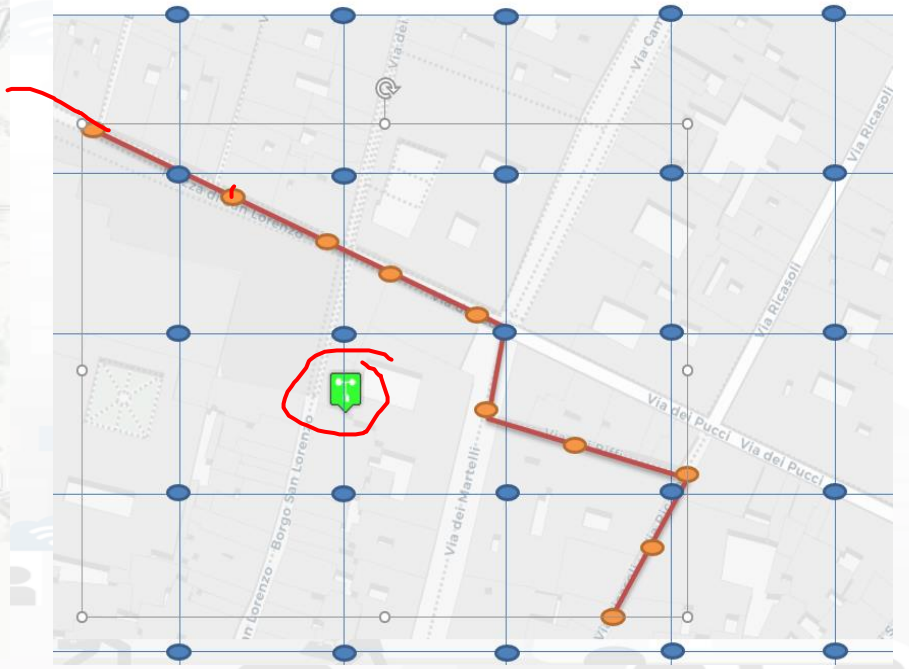
https://www.snap4city.org/435

The GRID density is never enough



4x4 meters grid is really too expensive

1000x1000 area (small town)
4x4mt * 10 variables * 24 hours per day
→ 3.8 Billions of data



AQI Indexes estimation via R studio and IOT App

European Air Quality Index **EAQI**

http://airindex.eea.europa.eu/

Pollutant	Index level (based on pollutant concentrations in µg/m3)				
	Good	Fair	Moderate	Poor	Very poor
Particles less than 2.5 µm ($PM_{2.5}$)	0-10	10-20	20-25	25-50	50-800
Particles less than 10 µm (PM_{10})	0-20	20-35	35-50	50-100	100-1200
Nitrogen dioxide (NO_2)	0-40	40-100	100-200	200-400	400-1000
Ozone (O_3)	0-80	80-120	120-180	180-240	240-600
Sulphur dioxide (SO_2)	0-100	100-200	200-350	350-500	500-1250

Measurements of up to five key pollutants supported by modelled data determine the index level that describes *the current air quality situation at each monitoring station*.

The index corresponds to **the poorest level for any of five pollutants according to the following scheme.**

Common Air Quality Index **CAQI**

http://www.airqualitynow.eu

Qualitative name	Index or sub-index	Pollutant (hourly) density in µg/m³			
		NO_2	PM_{10}	O_3	$PM_{2.5}$(optional)
Very low	0–25	0–50	0–25	0–60	0–15
Low	25–50	50–100	25–50	60–120	15–30
Medium	50–75	100–200	50–90	120–180	30–55
High	75–100	200–400	90–180	180–240	55–110
Very high	>100	>400	>180	>240	>110

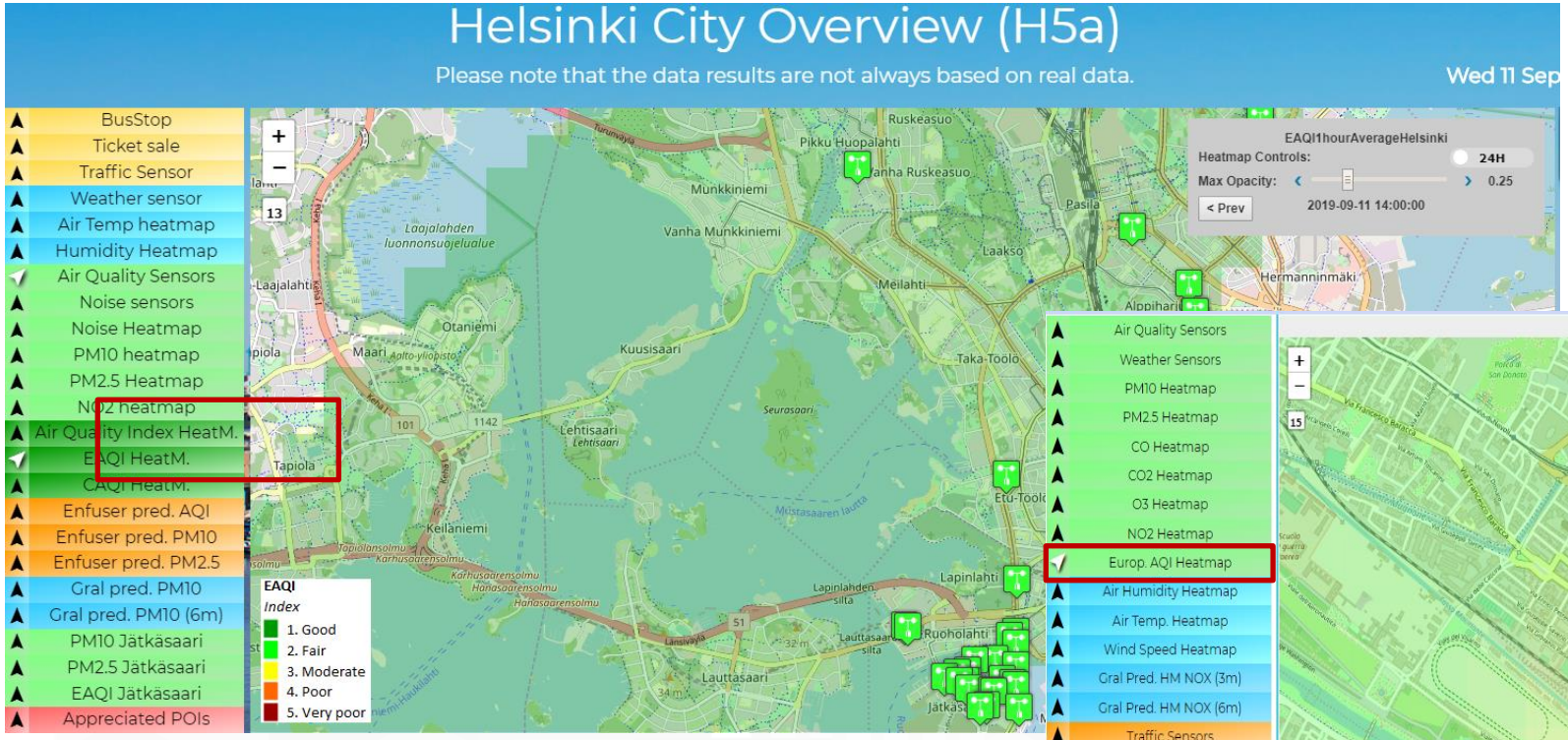
The index is defined away from roads (a "background" index). **CAQI** is computed on the basis of NO_2, $PM_{2,5}$, PM_{10} and O_3.

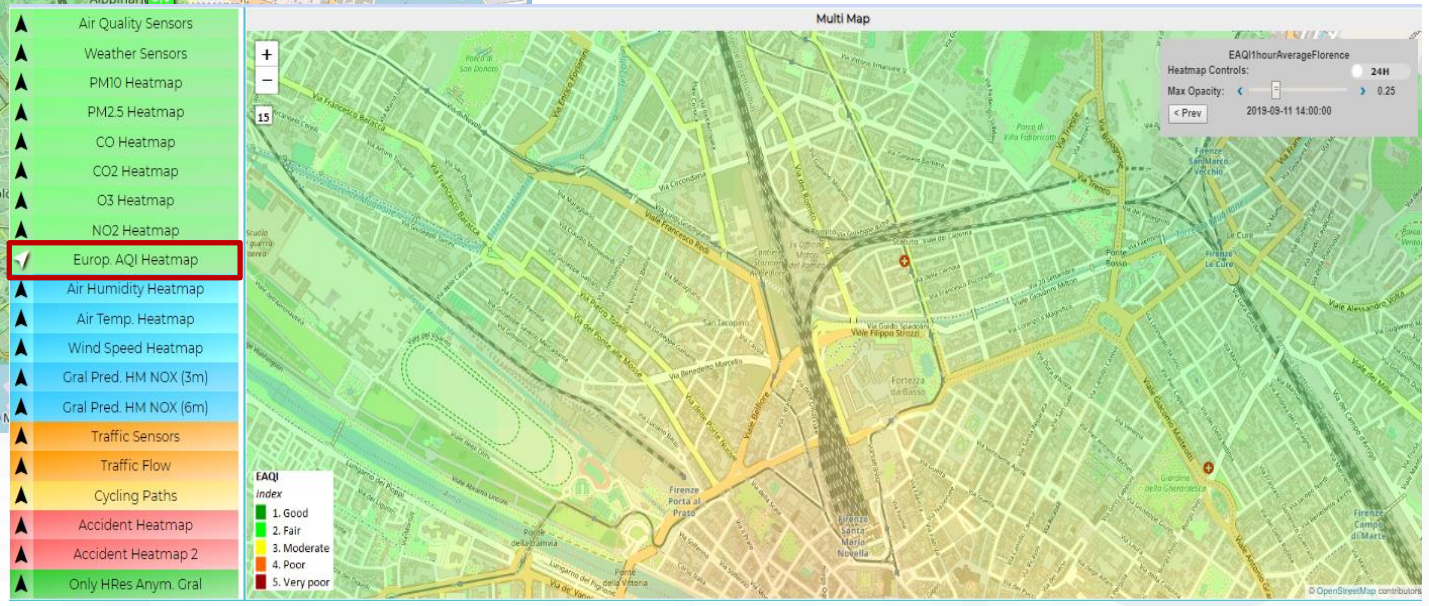
Legend of Environmental data:

https://www.snap4city.org/435

AQI Indexes estimation Heatmaps

Hourly pollutant concentration





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

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

Helsinki

The Life of Helsinki (H5b)

Please note that the data results are not always based on real data.

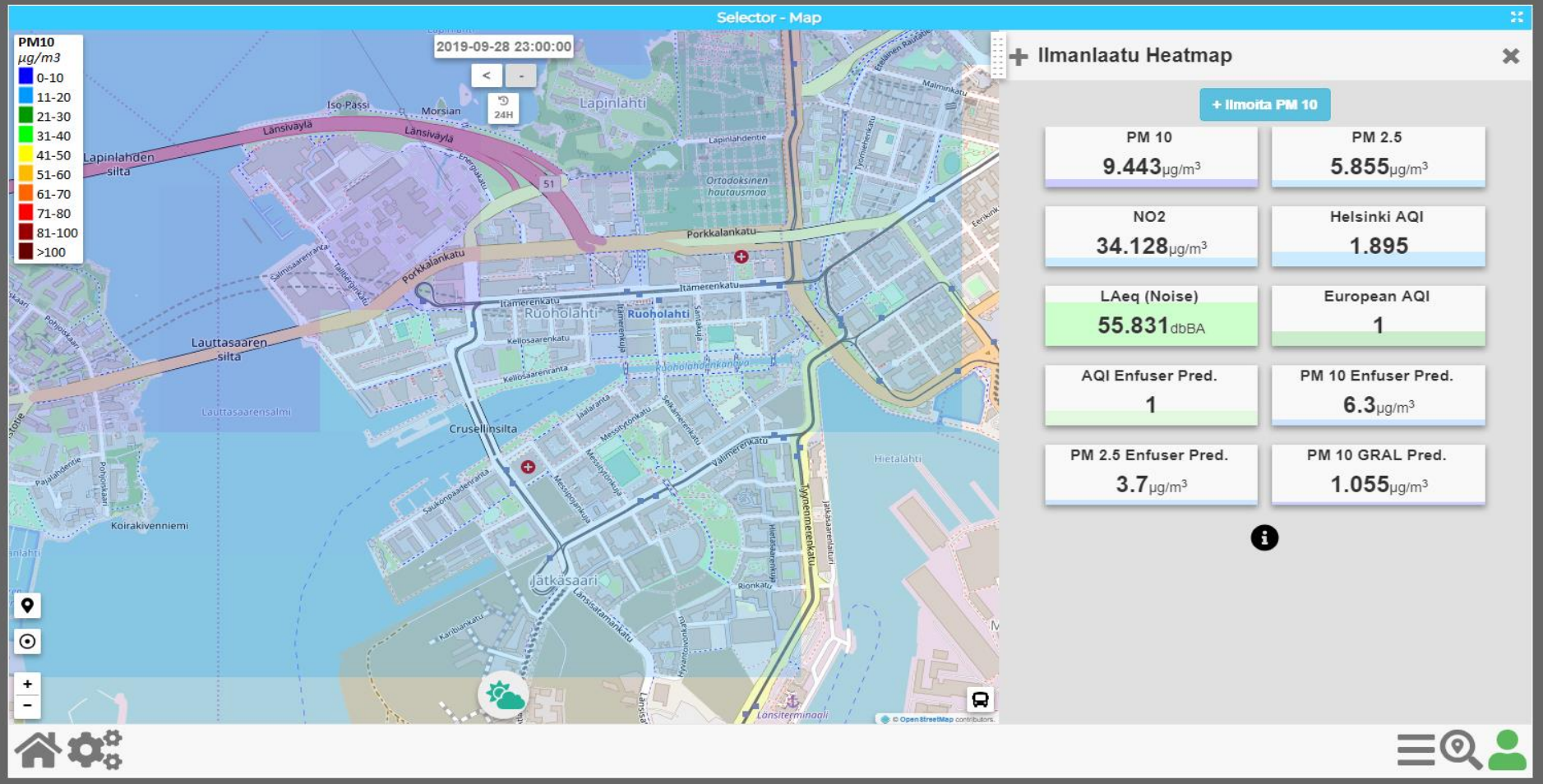
Sun 29 Sep 00:42:50

- Origin Dest. Matrix
- Typical Trajectories
- Twitter Vigilance
- Twitter Vig. Real Time
- Entertainment Events
- Shopping: POI
- Wine and Food: POI
- Discovery Helsinki
- Points of Interest
- 3D view POI
- Routing on Helsinki
- Line of Transport
- Public Transport
- Air Quality
- Air Quality Jätkäsaari
- Weather
- Forum Discussion

Documentation

Survey

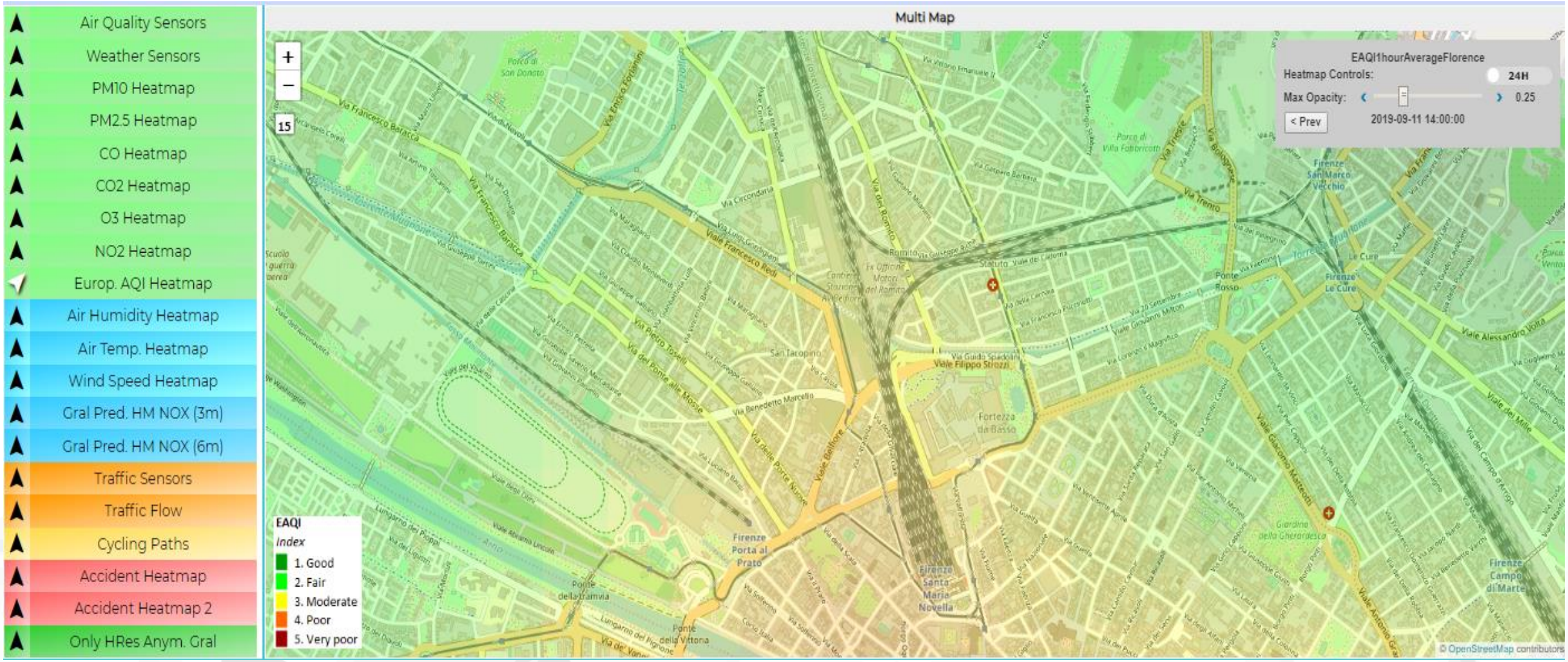
Environment



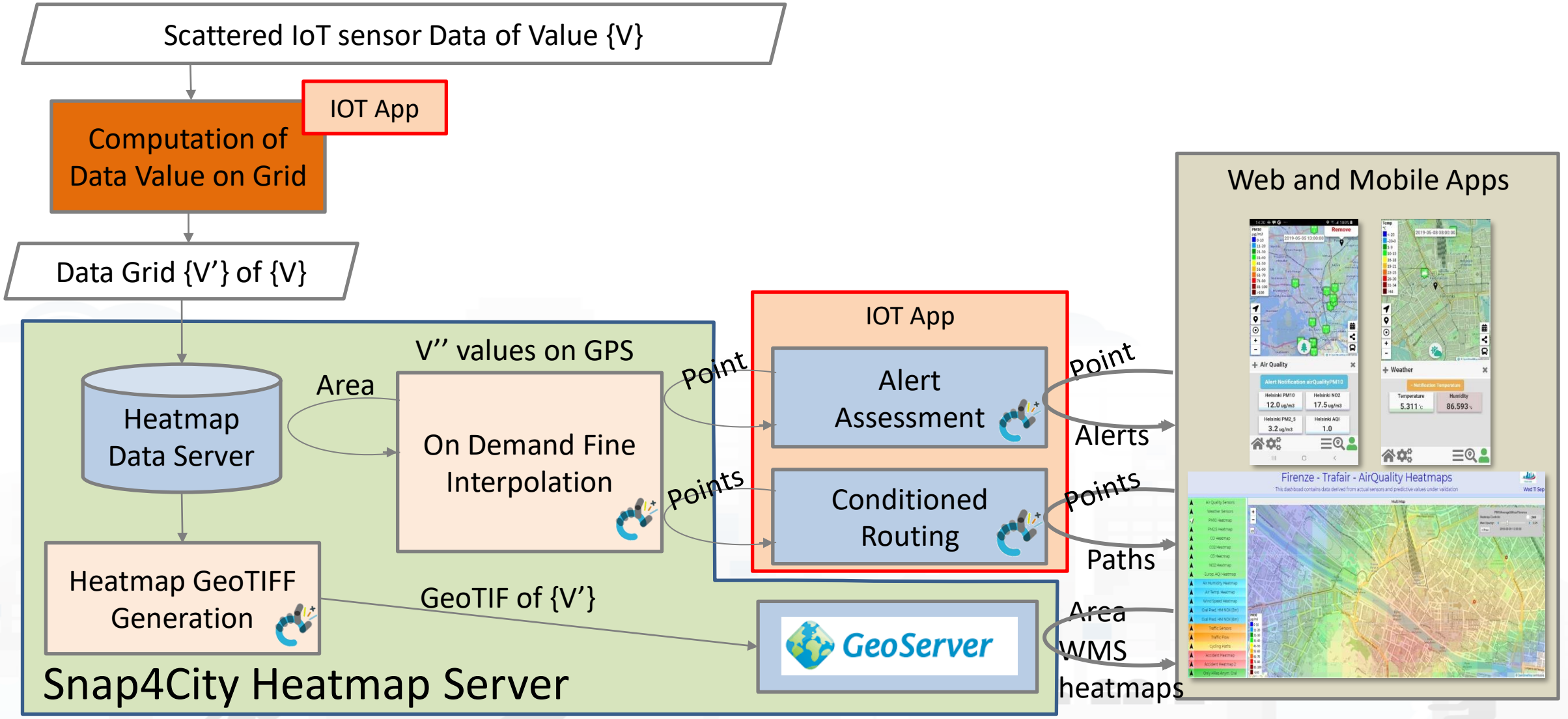
Privacy Policy Cookies Policy Terms and Conditions Contact us

https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTc1Mg==

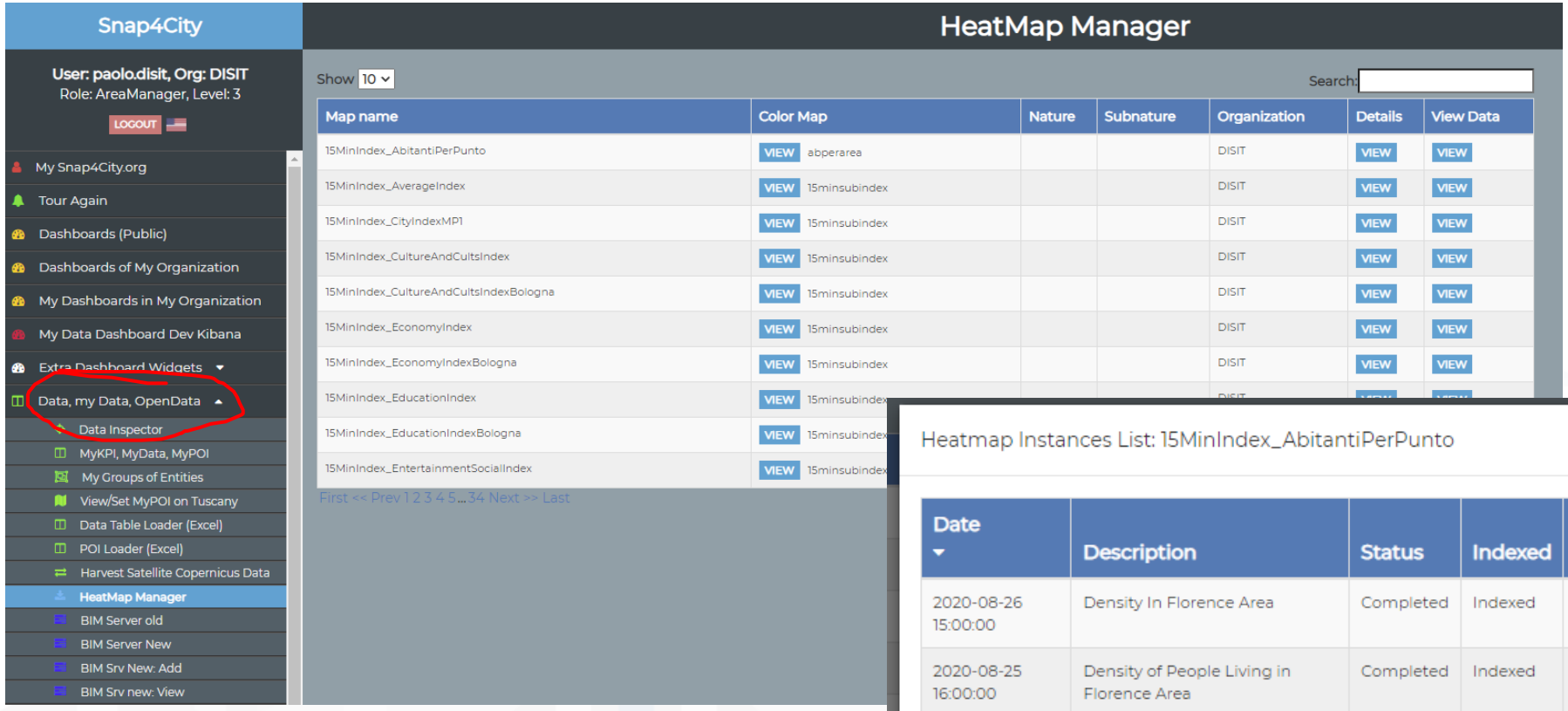
EAQI Heatmap and sequence



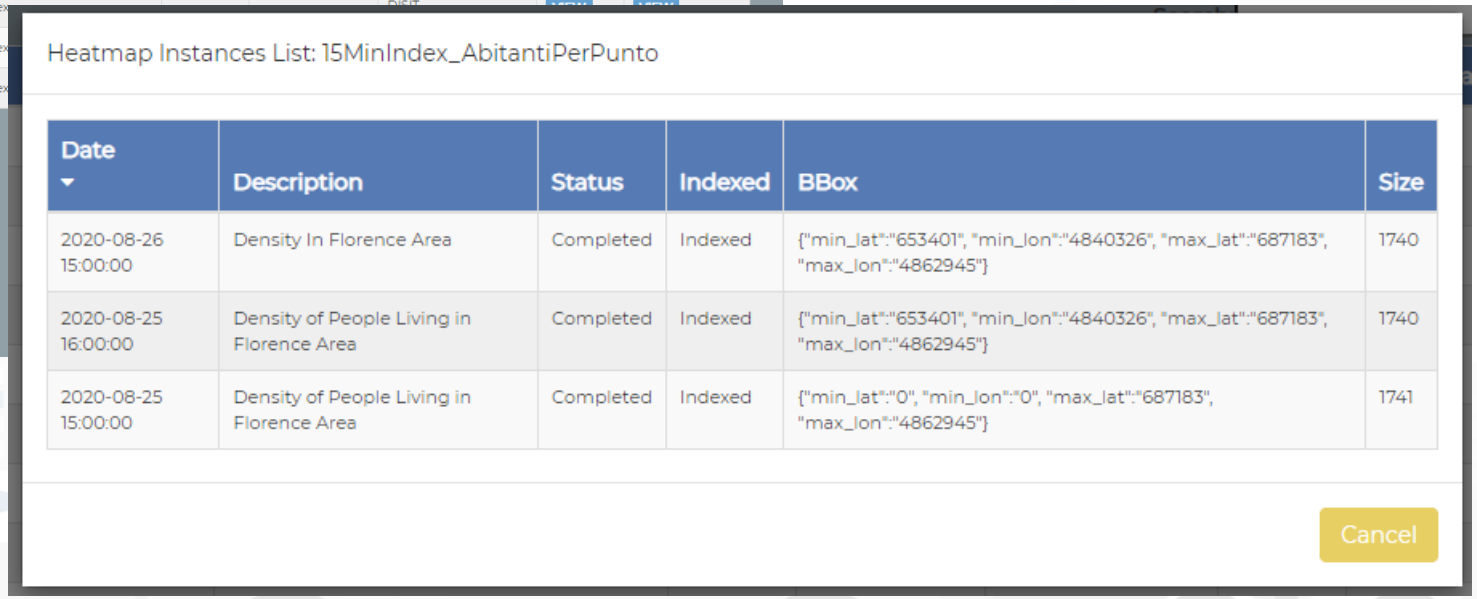
Workflow


Scattered IoT sensor Data of Value {V}
IOT App
Computation of Data Value on Grid
Data Grid {V'} of {V}
Heatmap Data Server
Area
V'' values on GPS
On Demand Fine Interpolation
Point
Points
IOT App
Alert Assessment
Conditioned Routing
Point
Alerts
Points
Paths
Heatmap GeoTIFF Generation
GeoTIF of {V'}
GeoServer
Area
WMS
heatmaps
Snap4City Heatmap Server
Web and Mobile Apps
Firenze - Trafair - AirQuality Heatmaps

HeatMap Manager (Area Manager view)

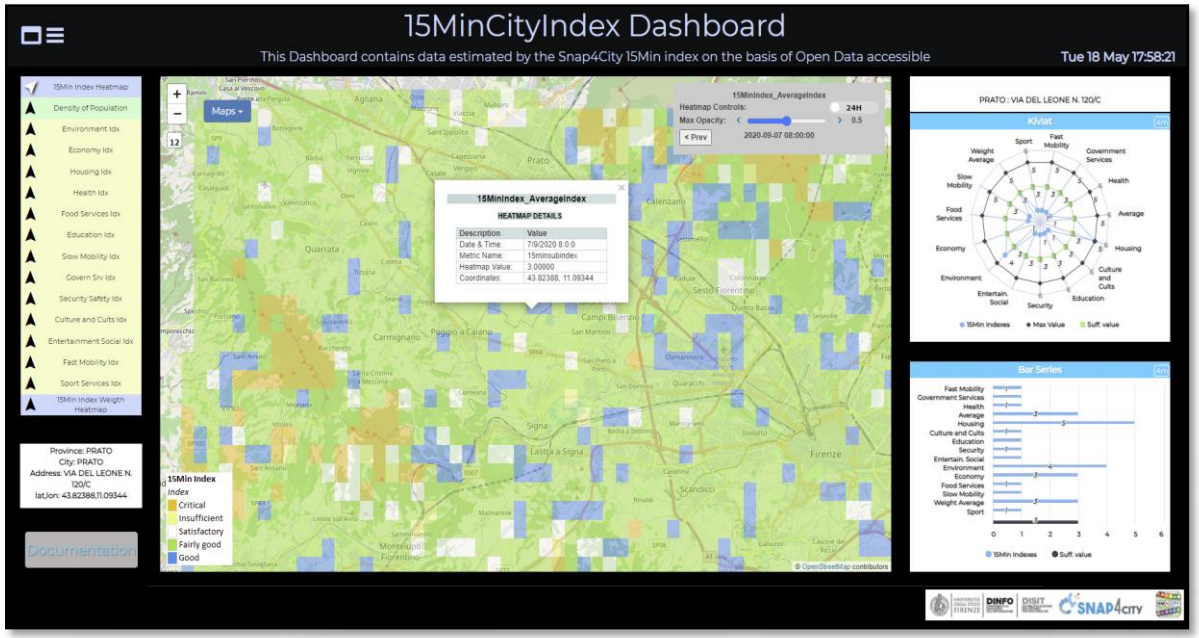


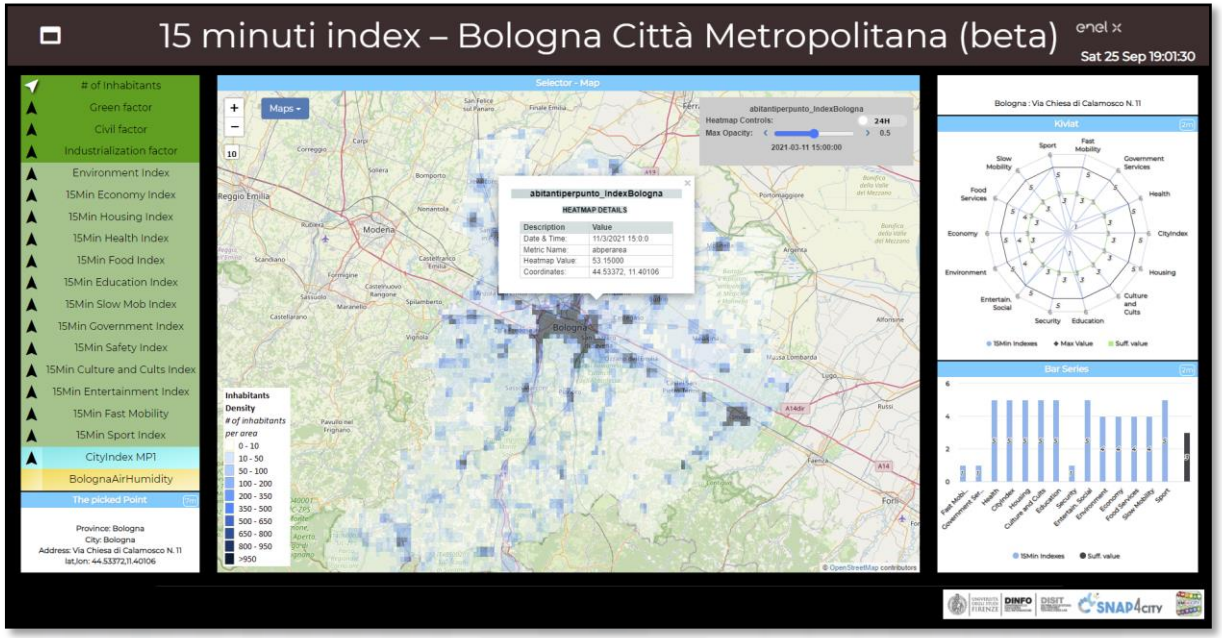
- Sequence of Heatmaps
- Colormap used
- Details



Editing Mode for RootAdmin only

15MinCityIndex





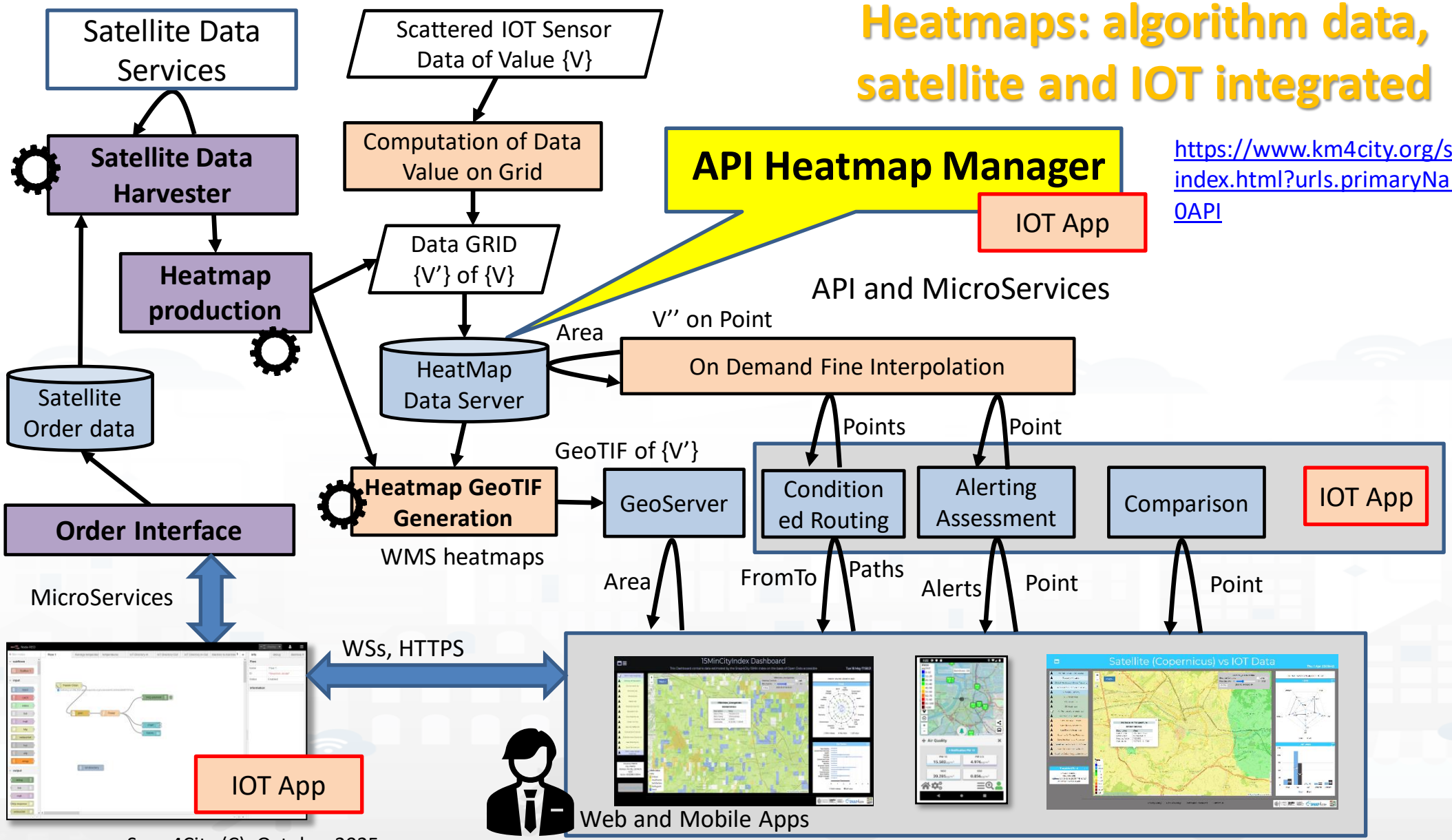
[FLORENCE metro city](https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjkzOA=)

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

[Bologna metro city](https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzA1OQ==)

https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzA1OQ==

Heatmaps: algorithm data, satellite and IOT integrated



https://www.km4city.org/swagger/external/index.html?urls.primaryName=Heatmap%20API

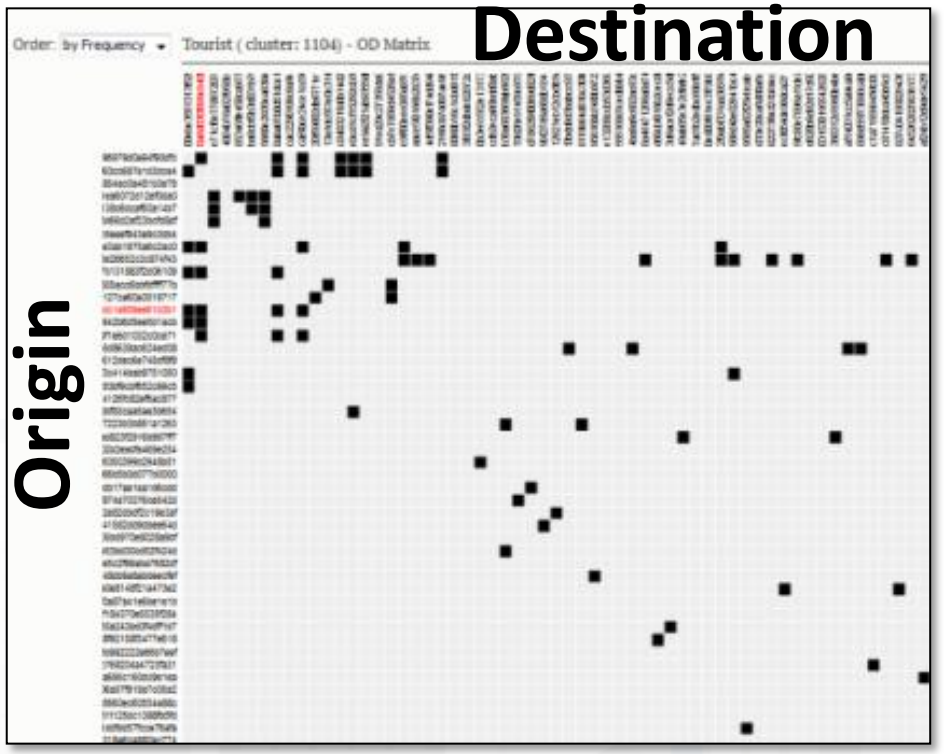
Origin Destination Matrices and Trajectories





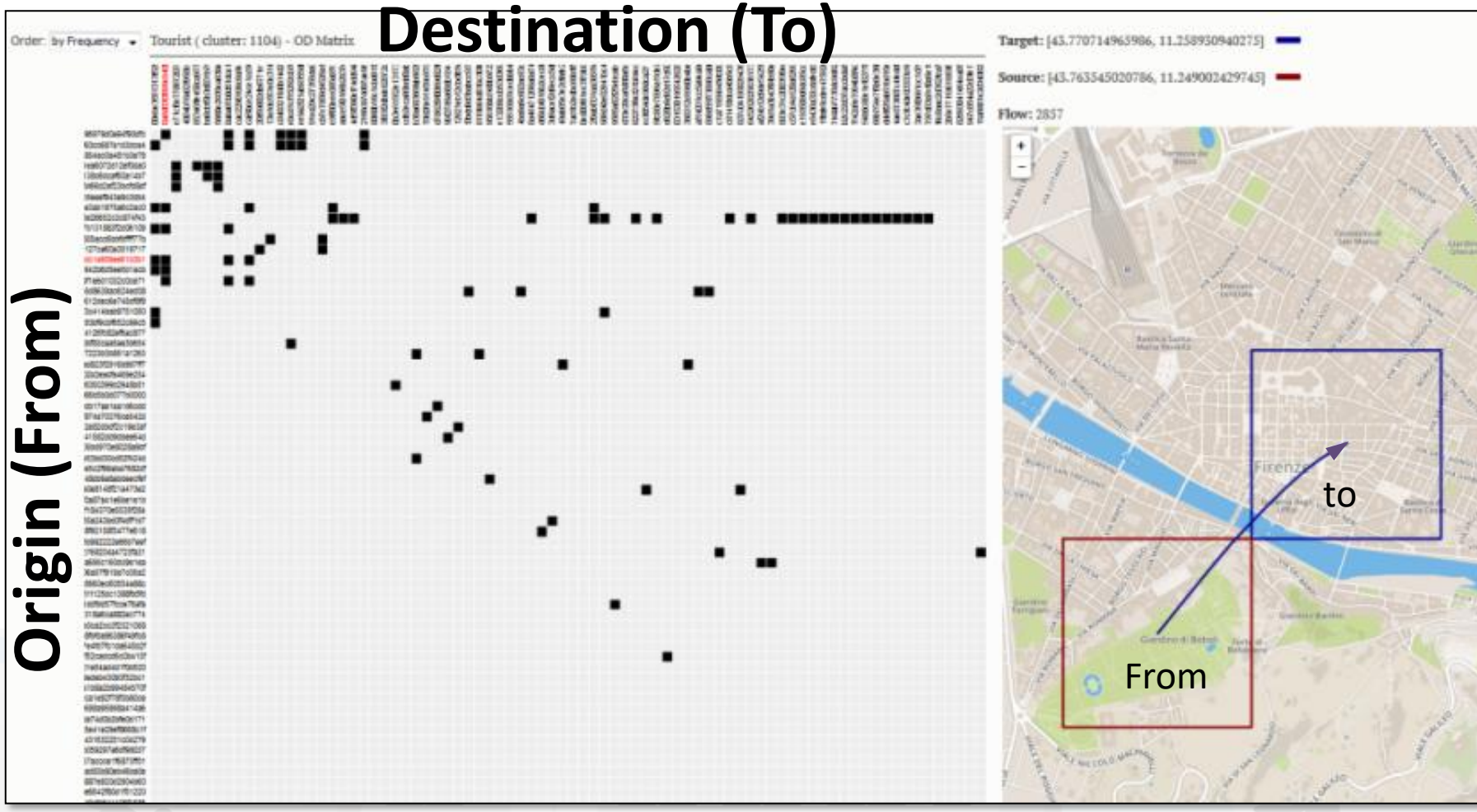
Origin Destination Matrices

- **computed** from several kinds of data
  - Census Data
  - Cellular Mobile Data
  - Mobile App Data **trajectories**
  - OBU from vehicles **trajectories**
  - Composition of multiple sources: ODM + Trj
- **may represent:**
  - Demand of mobility
  - Offer of transportation
- **refer** to different area kinds for Origin and of Destination
  - Different kinds of OD areas
  - Different kinds of temporal resolutions → animations
    - Hourly, daily, weekly, monthly, etc…

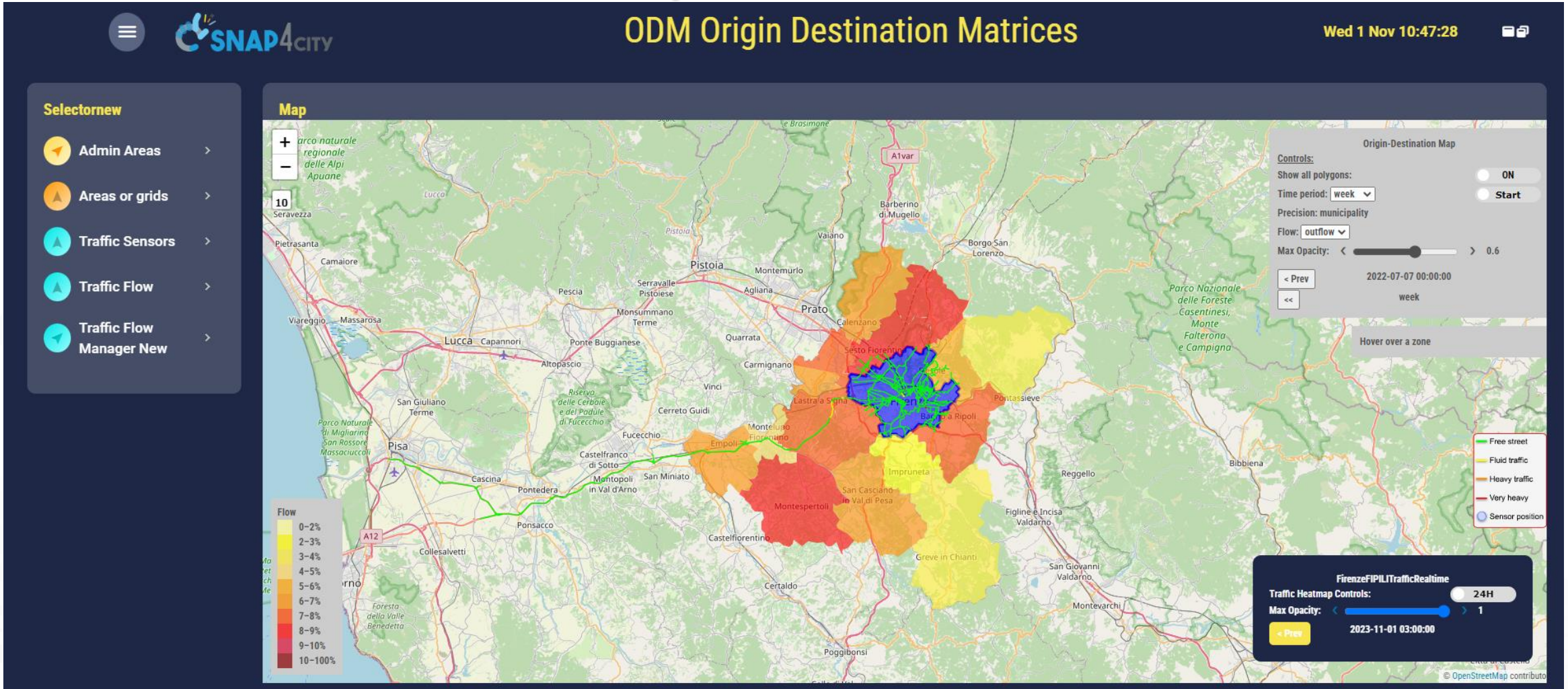


OD Matrices, ODM

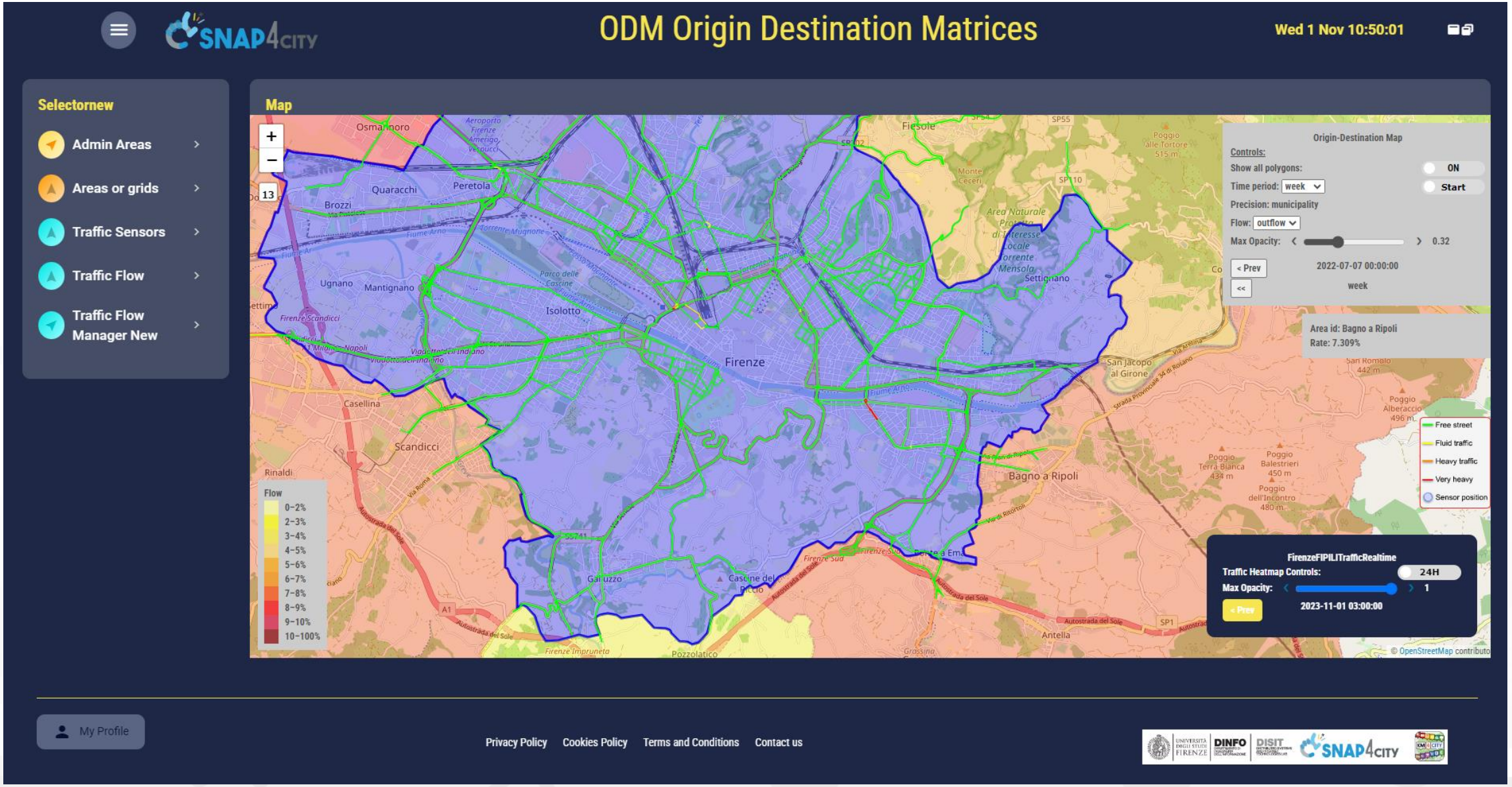
- Origins and destinations
  - Any area of the zone
  - From to
  - To from
- By inflow or outflow
- By temporal slice
  - Hour, day,…
  - Series by hour, day, etc.
- By user profile:
  - Age, nationality,
  - Commuter, citizen, etc.
- By motivations
- By travel means:
  - car, bike, walk..
- By extraction technique
- By civic area VS segmented GPS area
- ….



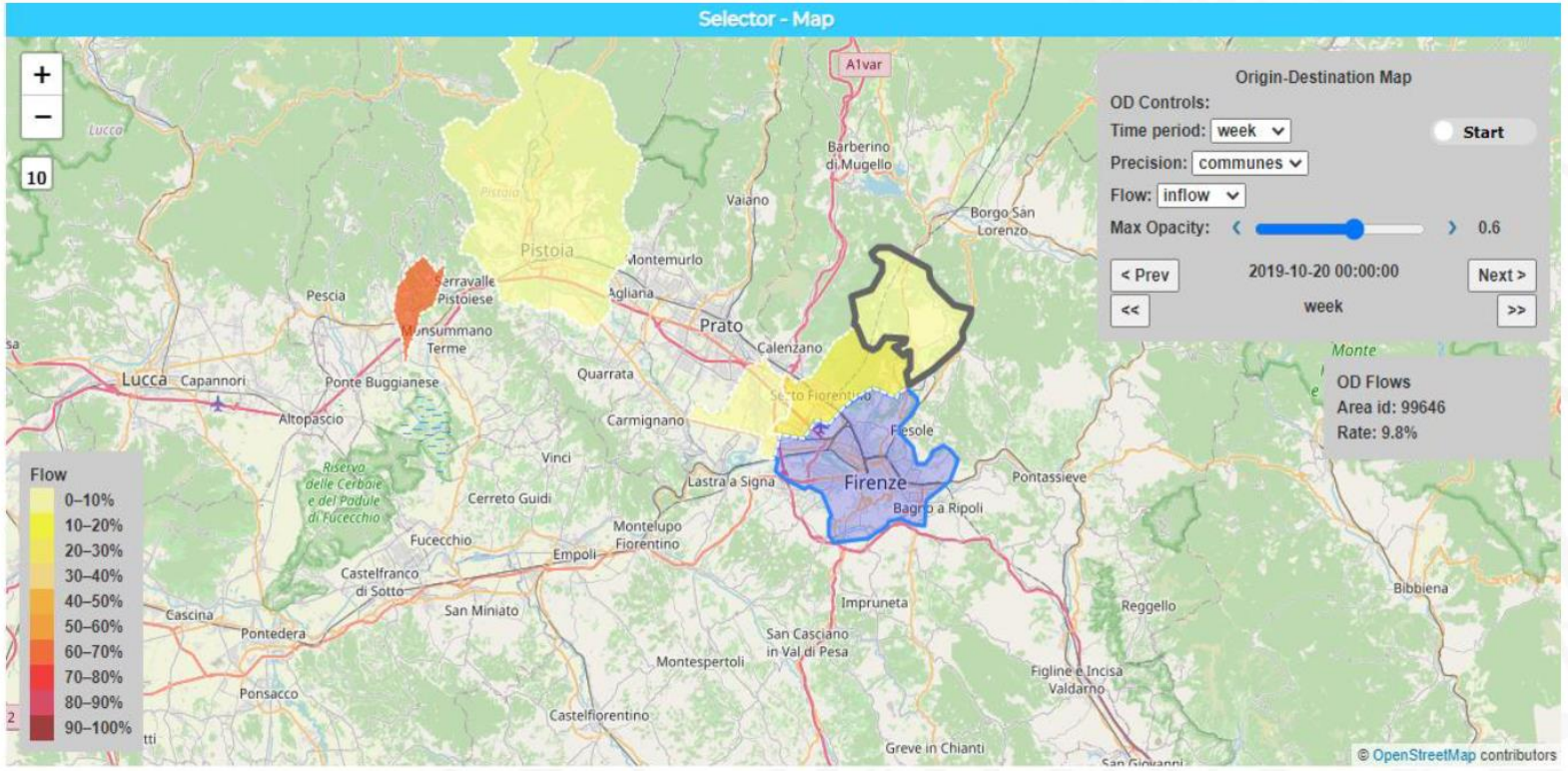
ODM, Traffic Flow



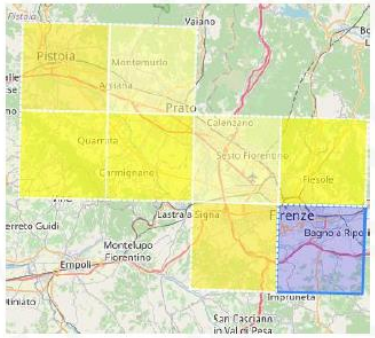
https://www.snap4city.org/dashboardSmartCity/view/Gea-Night.php?iddasboard=Mzk3Nw==

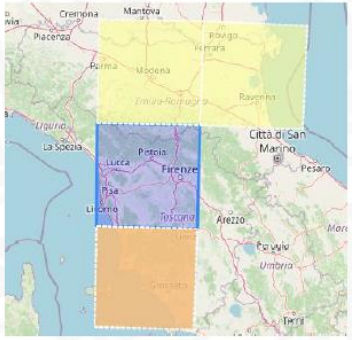

ODM Origin Destination Matrices
Wed 1 Nov 10:50:01
Selectornew
Admin Areas
Areas or grids
Traffic Sensors
Traffic Flow
Traffic Flow Manager New
Map
Origin-Destination Map
Controls:
Show all polygons:
ON
Time period: week
Start
Precision: municipality
Flow: outflow
Max Opacity:
0.32
< Prev
2022-07-07 00:00:00
week
Area id: Bagno a Ripoli
Rate: 7.309%
Free street
Fluid traffic
Heavy traffic
Very heavy
Sensor position
Flow
0-2%
2-3%
3-4%
4-5%
5-6%
6-7%
7-8%
8-9%
9-10%
10-100%
FirenzeFIPILITrafficRealtime
Traffic Heatmap Controls:
24H
Max Opacity:
1
< Prev
2023-11-01 03:00:00
© OpenStreetMap contributors
My Profile
Privacy Policy
Cookies Policy
Terms and Conditions
Contact us

Different Origin Destination Matrices







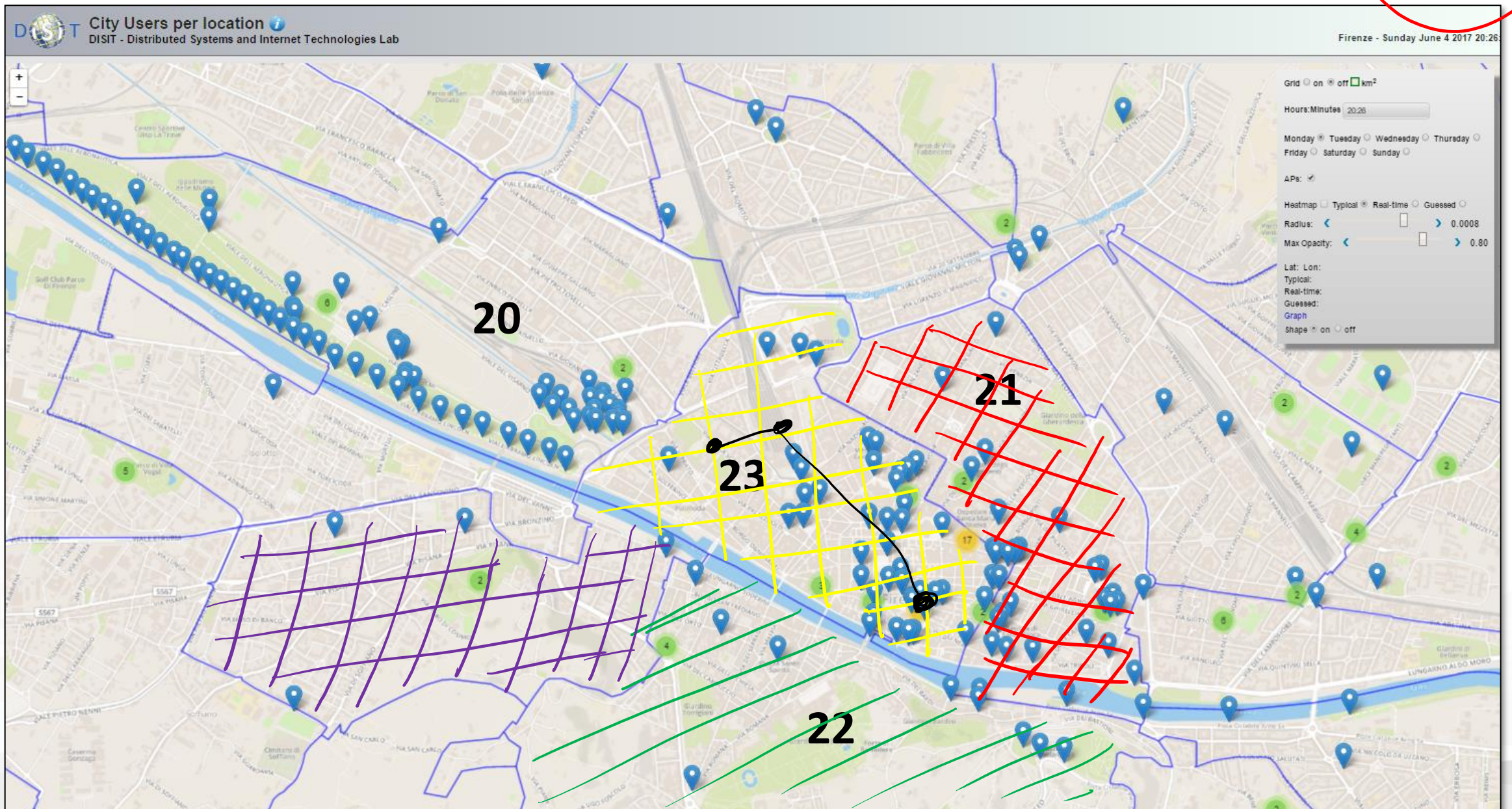


- Get specific value
- Time window
- Opacity
- Animation
- Inflow/outflow
- Sequence of OD matrices: next/prev

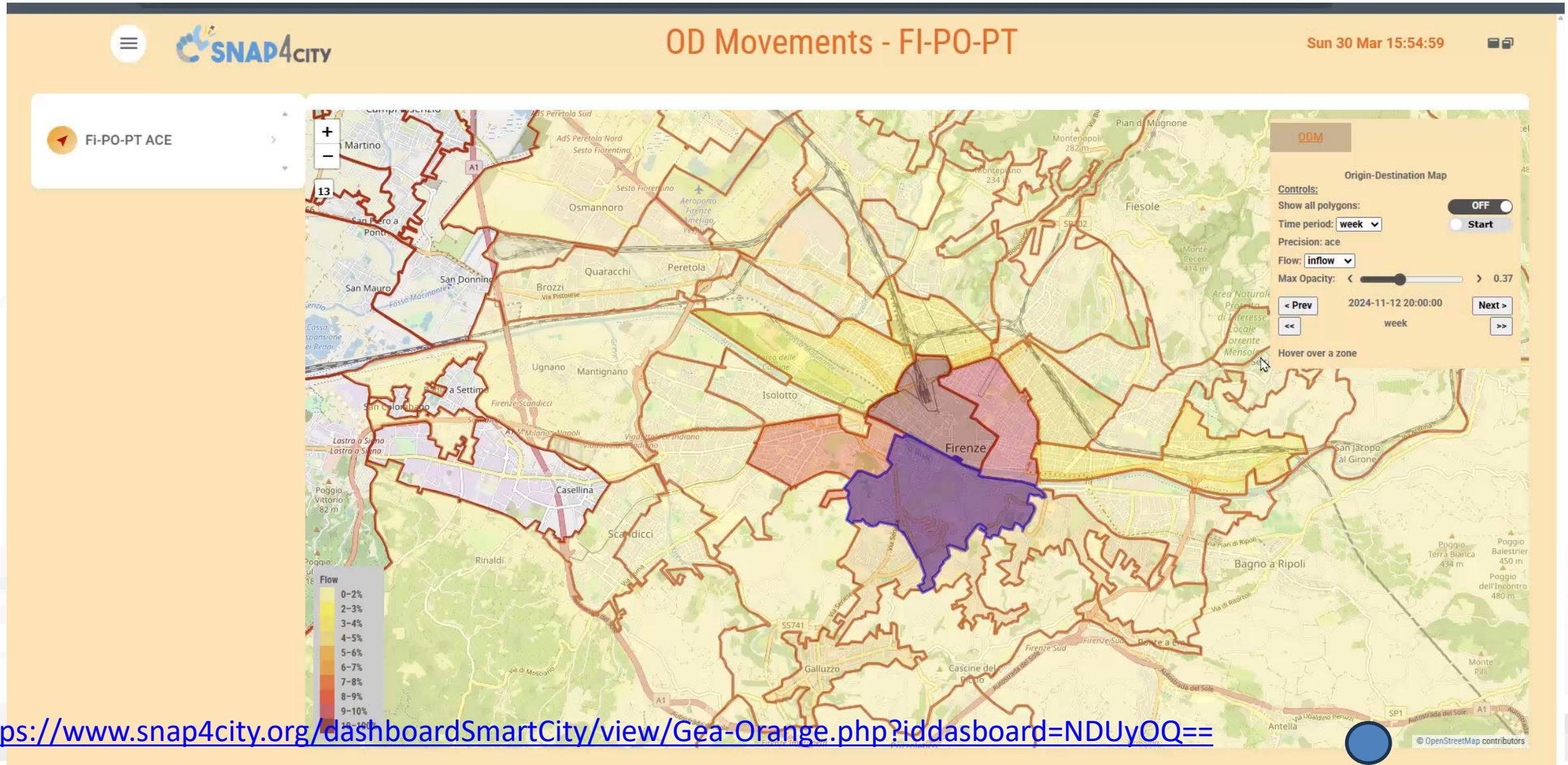
shapes

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

Firenze Wi-Fi vs ACE



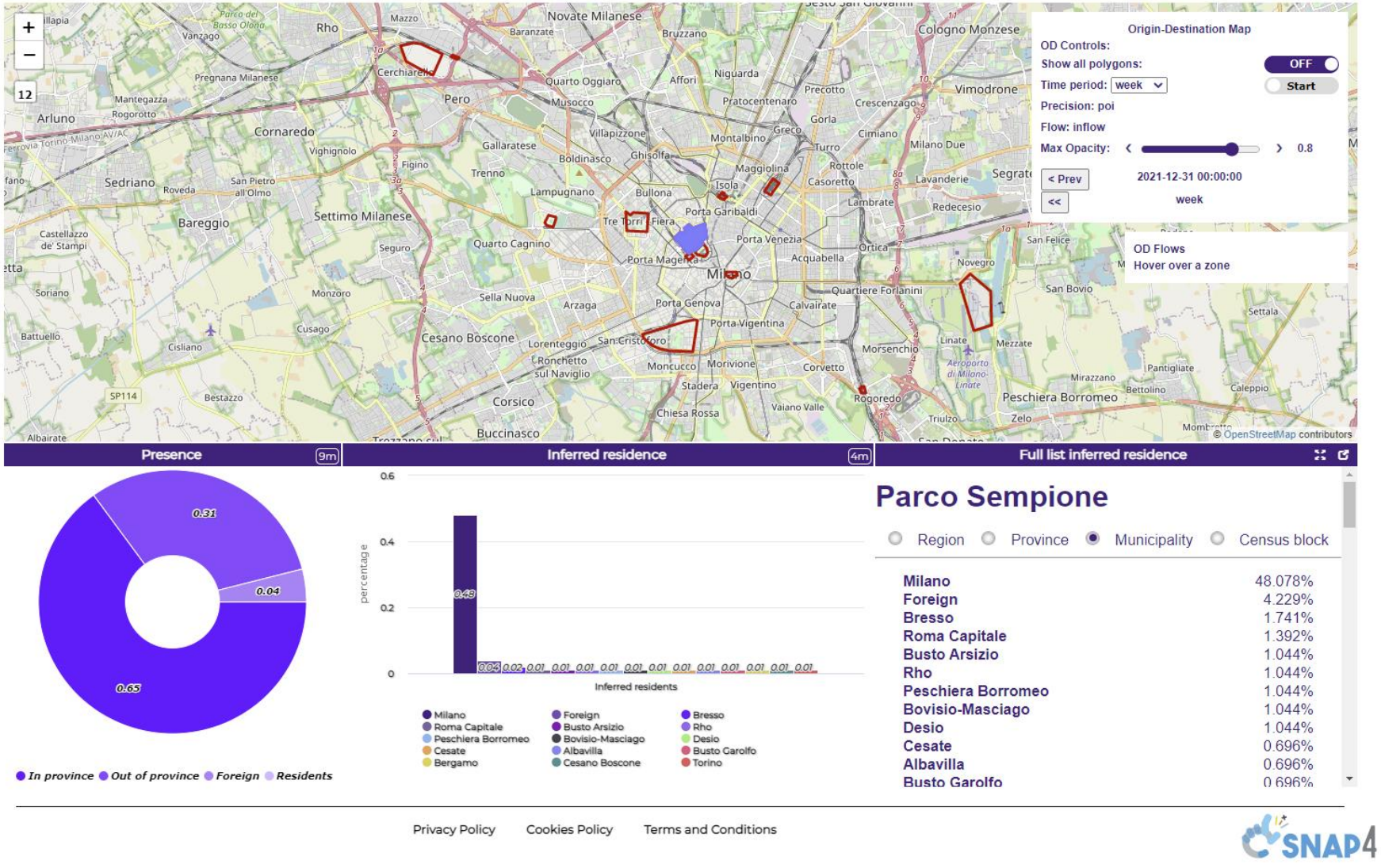
Origin Destination Matrices: Mobility Demand



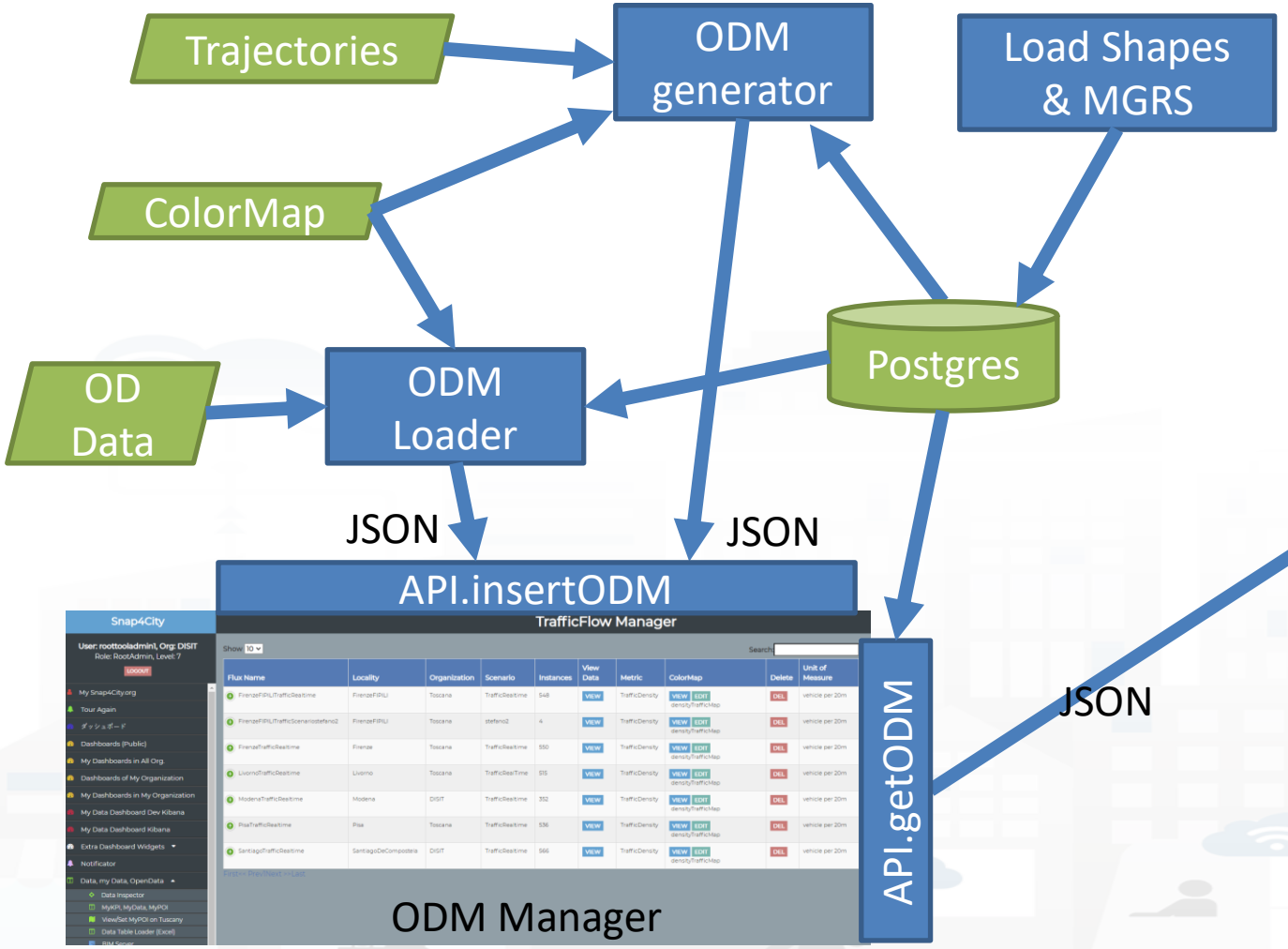
https://www.snap4city.org/dashboardSmartCity/view/Gea-Orange.php?iddasboard=NDUyOQ==

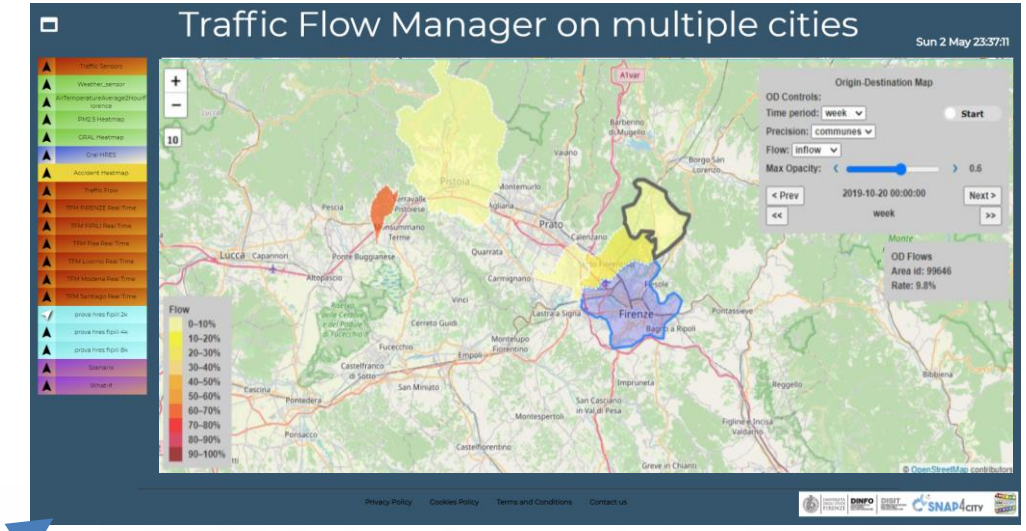
ODM Visual Analytic on Milan Area

11 SUSTAINABLE CITIES AND COMMUNITIES



How Origin Destination Manager works

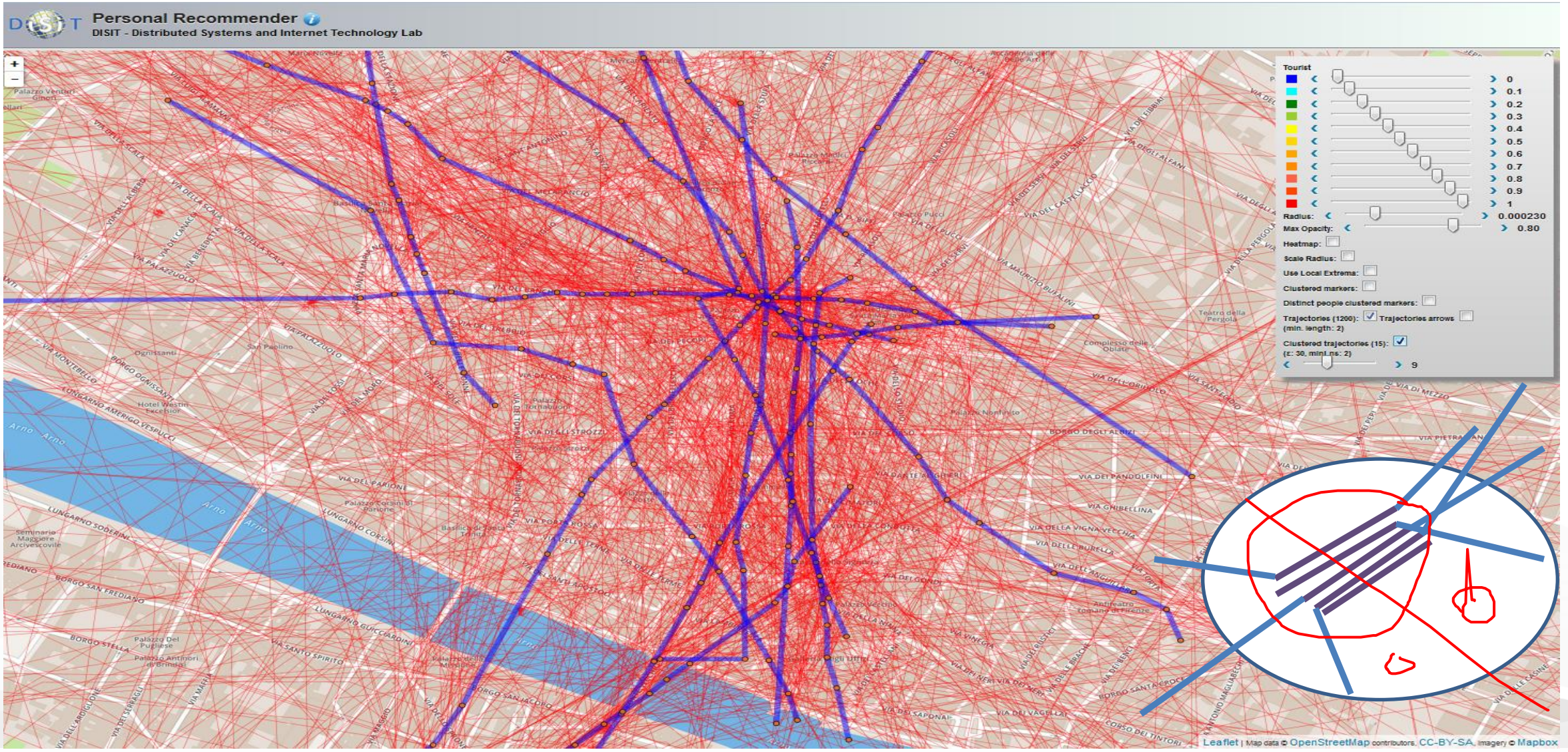




Postgress loaded for

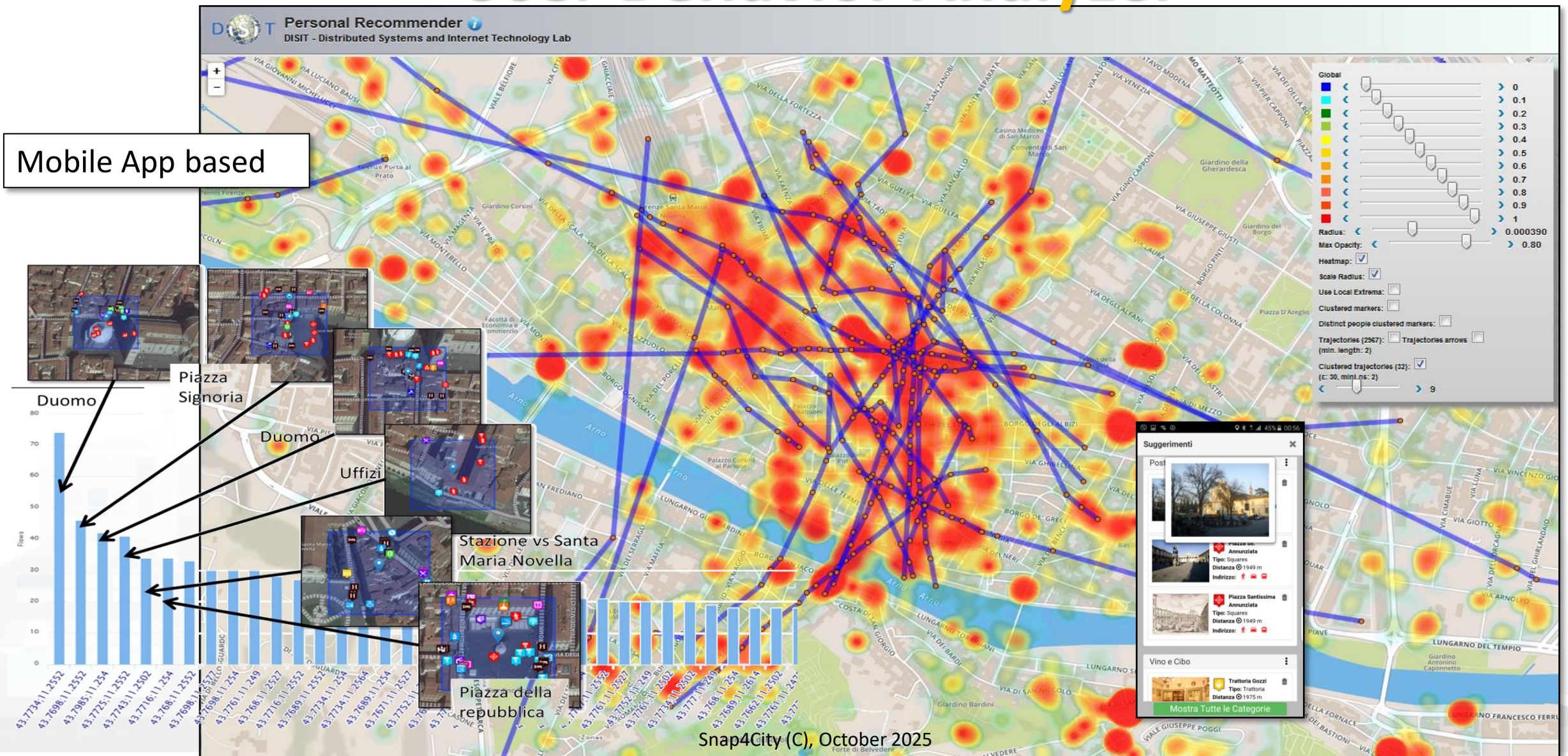
- **Shapes**: city, region, territories, etc.
  - GADM https://gadm.org/ , and ACE
- **Squared** MGRS:
  - 1m, 10m, 100m, **1Km, 10Km, 100Km**

Cluster di Trajectories



User Behavior Analyzer

Mobile App based



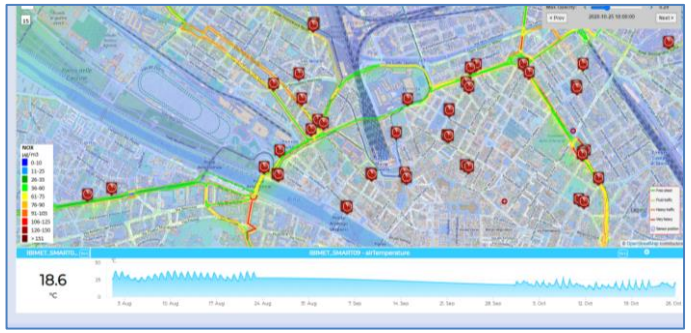
Digital Twin and 3D Digital Representation of the City

11 SUSTAINABLE CITIES AND COMMUNITIES



Digital Twin

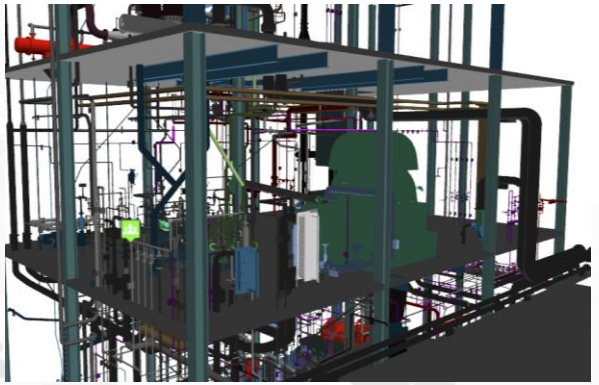
- **Digital Twin**
  - **Connected** with real systems
  - **Modelling** aspects: structural, visual, informative, real time data sensors (context), POI, functional, resources, etc.
  - **Integration:** AI/XAI techniques, simulations, users' needs, etc.
- **Utility to**
  - Experiment via simulations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

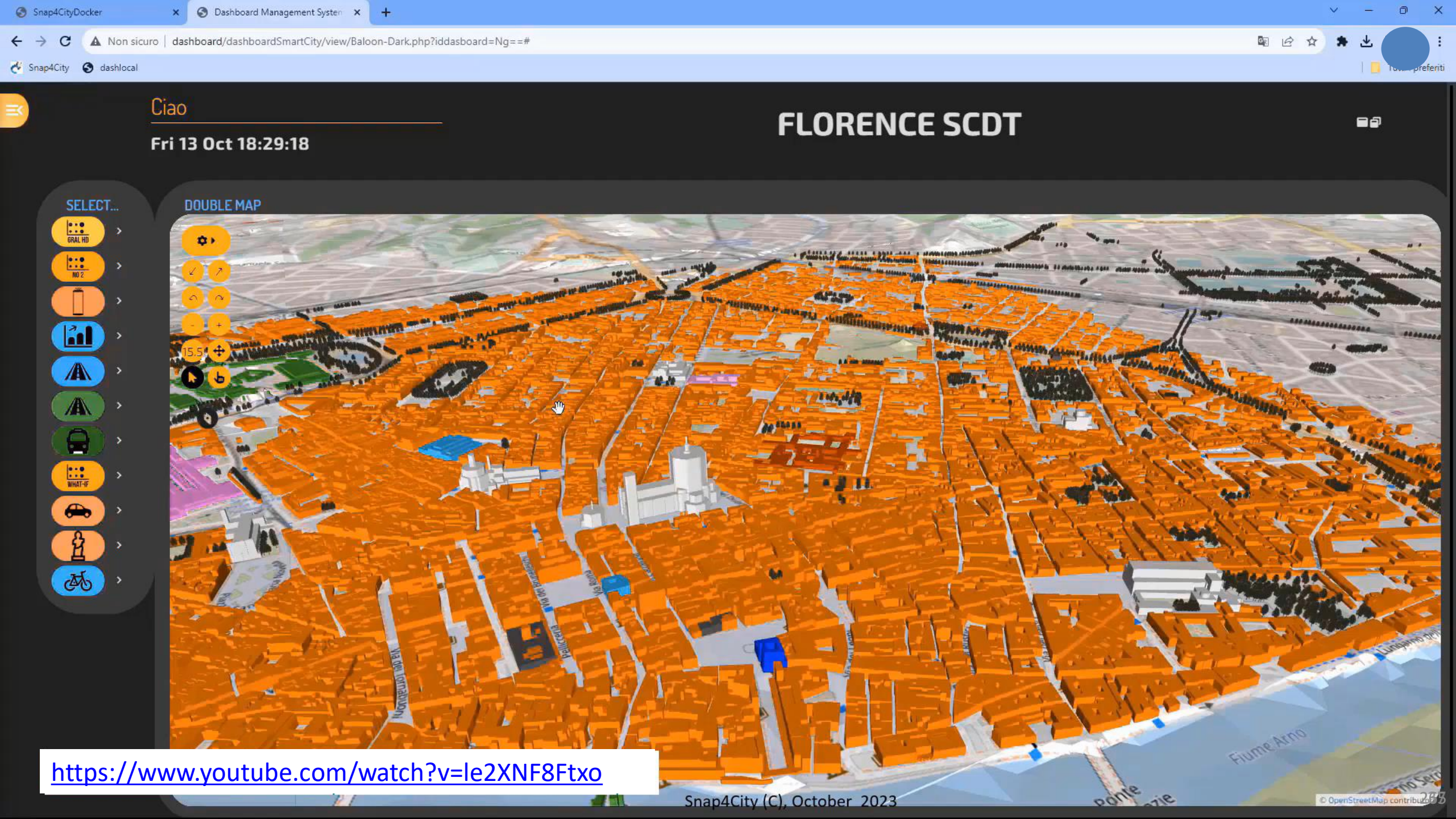











Snap4CityDocker
Dashboard Management Syster
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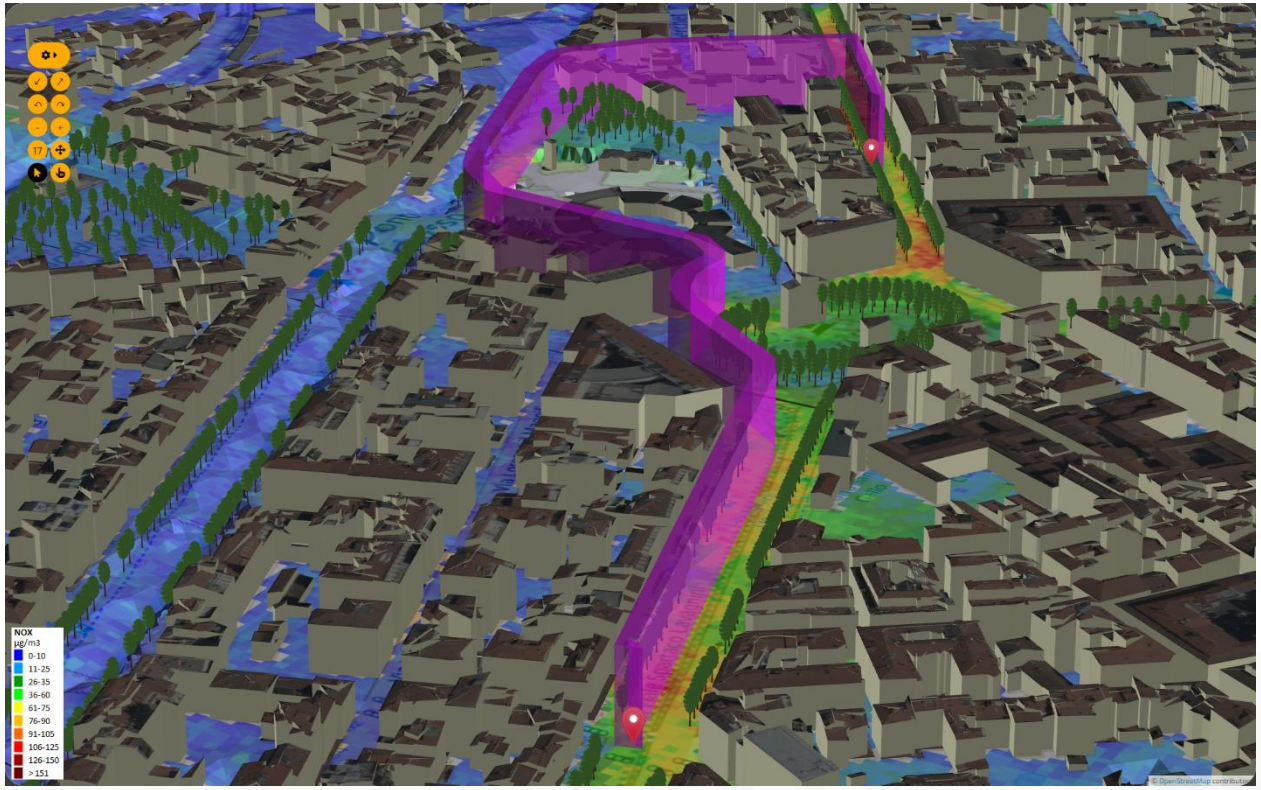
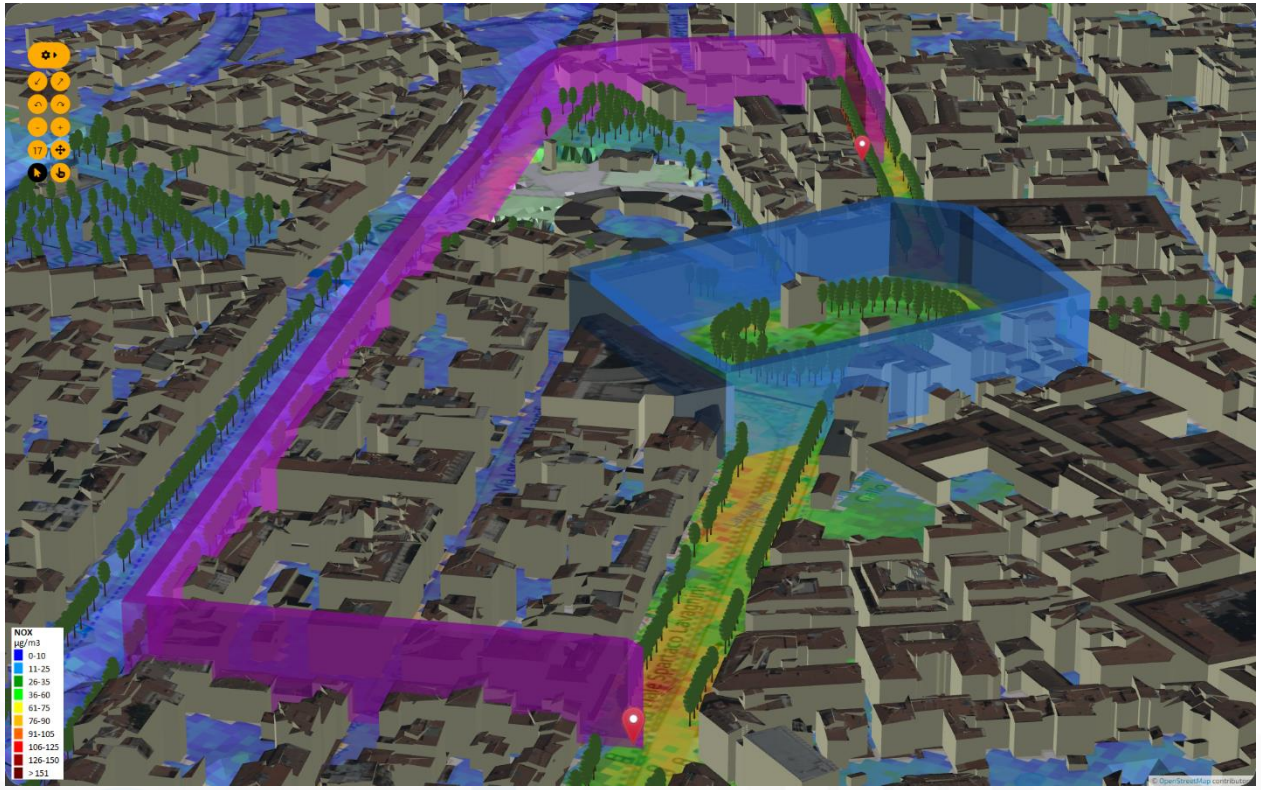
Snap4City
dashlocal
Ciao
Fri 13 Oct 18:29:18
FLORENCE SCDT
SELECT...
GRAL HD
NO 2
WHAT-IF
DOUBLE MAP
Fiume Arno
Snap4City (C), October 2023
https://www.youtube.com/watch?v=le2XNF8Ftxo

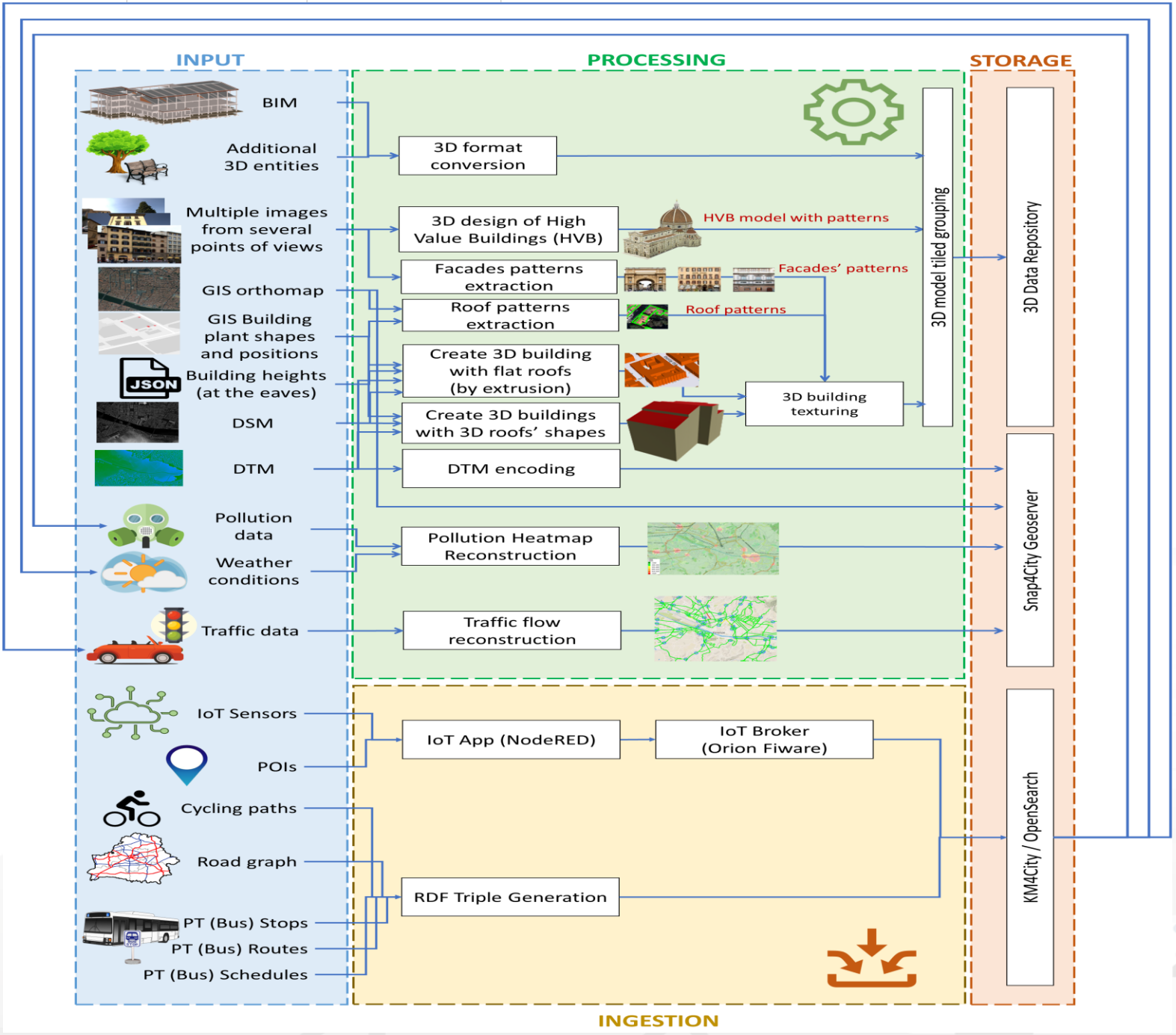
Global City Digital Twin

- **Real Time Rendering Maps with 3D City Digital Twin**
  - Full control:
    - pan, zoom, tilt, rotation, etc.,
    - simulation of light conditions: over the daylight and night
    - Plus Full control with right button and wheel of the mouse
  - Full control of pre-setting for direct show specific condition when loading
  - Section modality to pick the single Building or part of it, and to start a navigation towards other views, via relationships managed by an IoT App of reference
- **3D City Construction is an comprehensive and scalable process**

Dyamic Routing in 3D space







From data to Interoperable and interactive Digital Twin

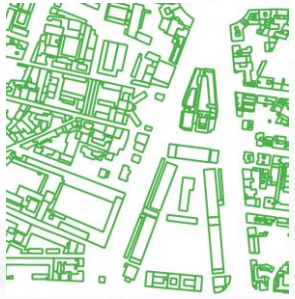
3D Map Texturing



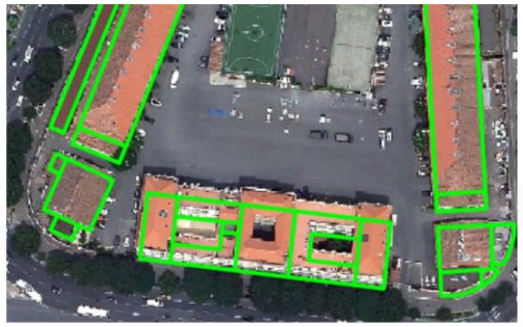
HVB inclusion

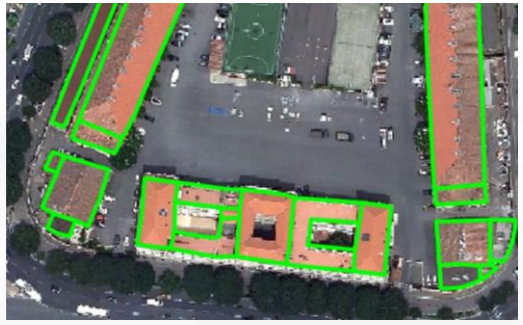


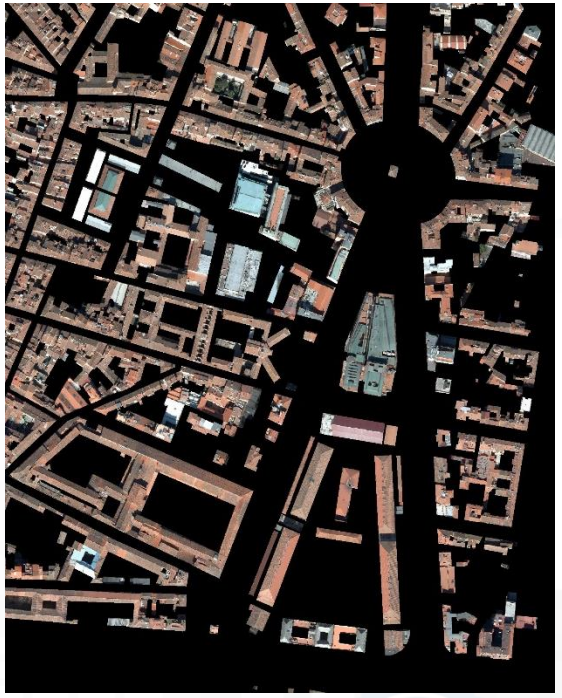
Orthomaps

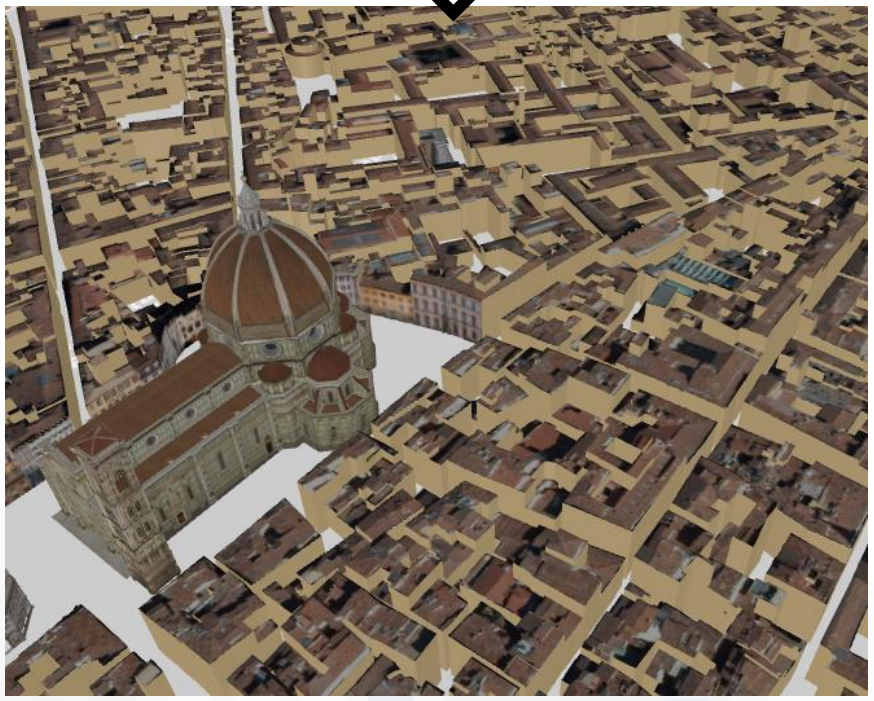


Building shapes

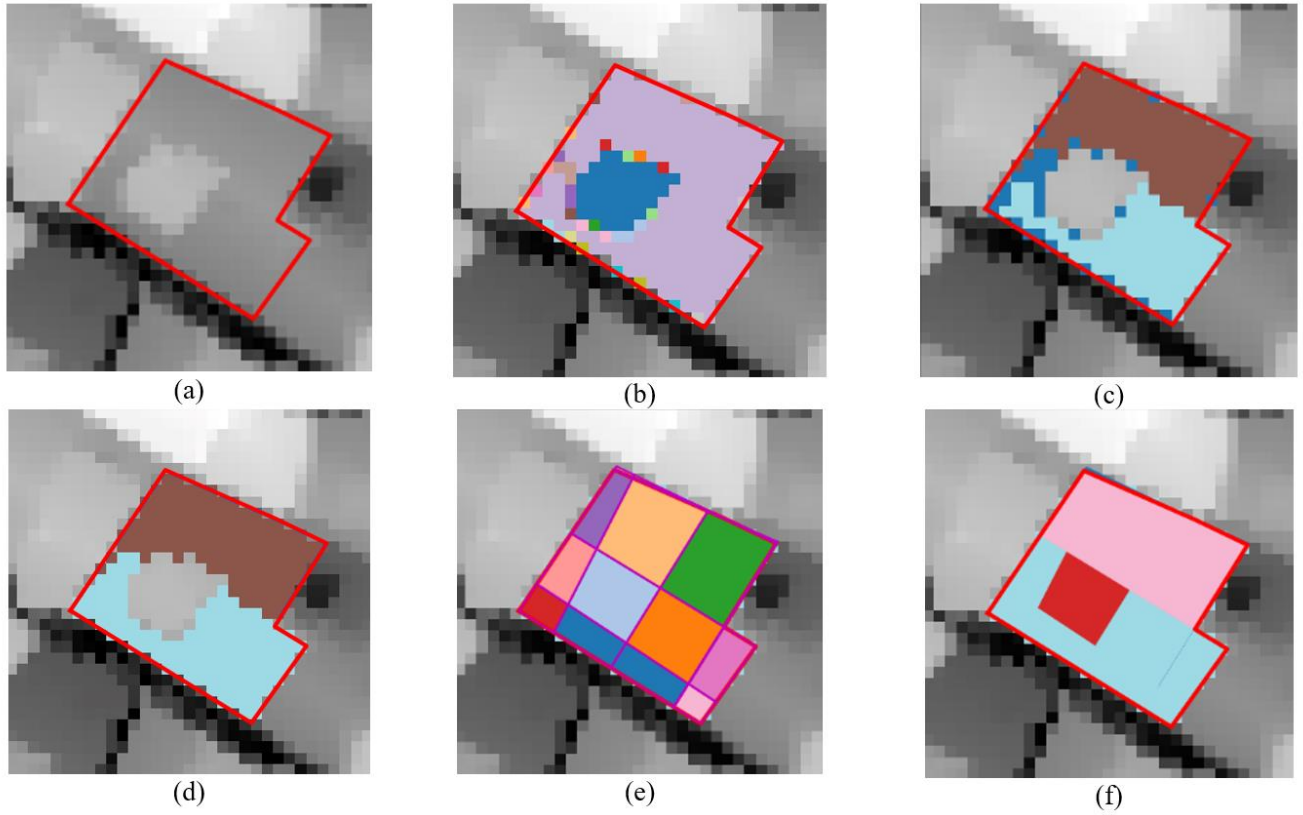


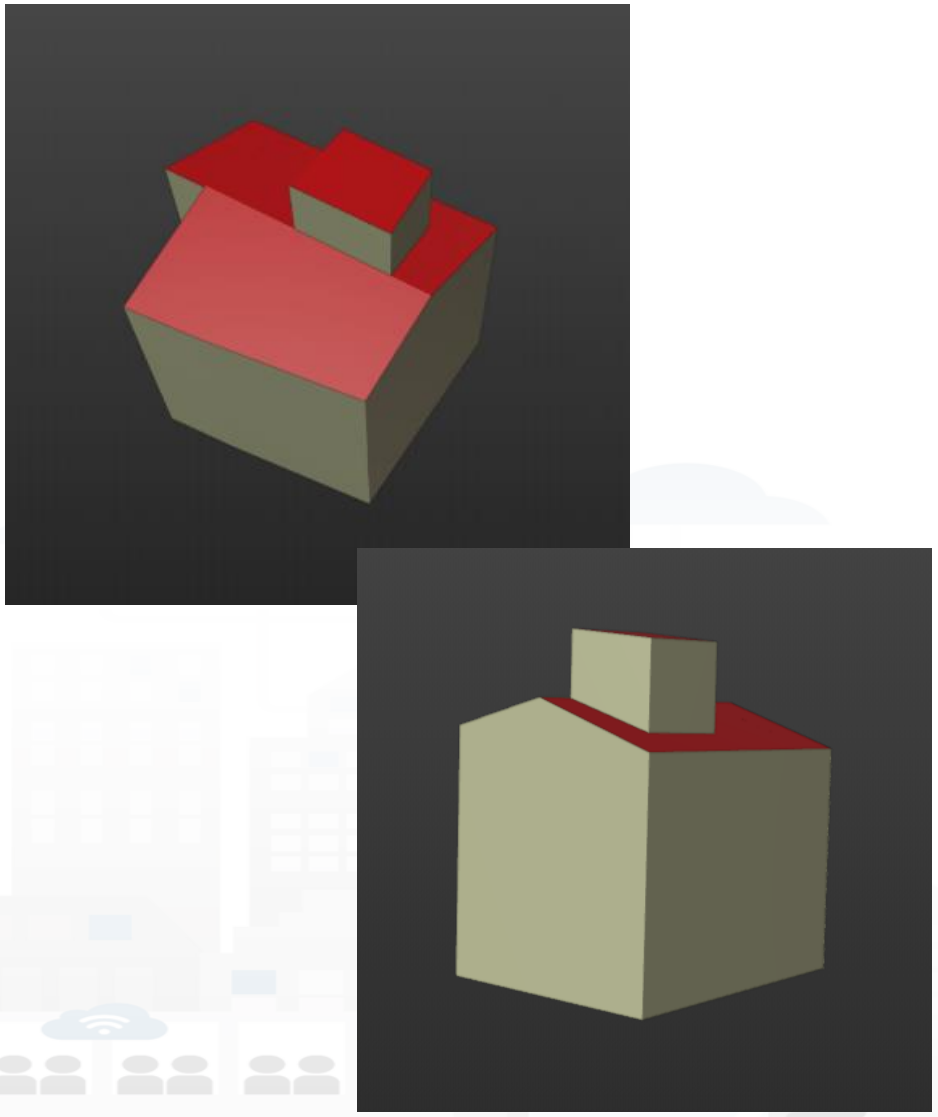






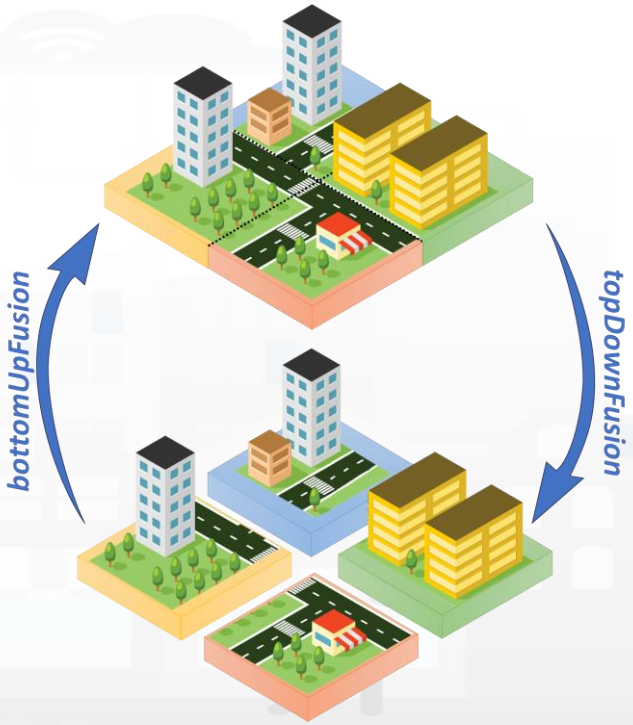
Input → **Deep network alignment** → **Rooftop texture extraction and warping** → **Final textured 3D map**

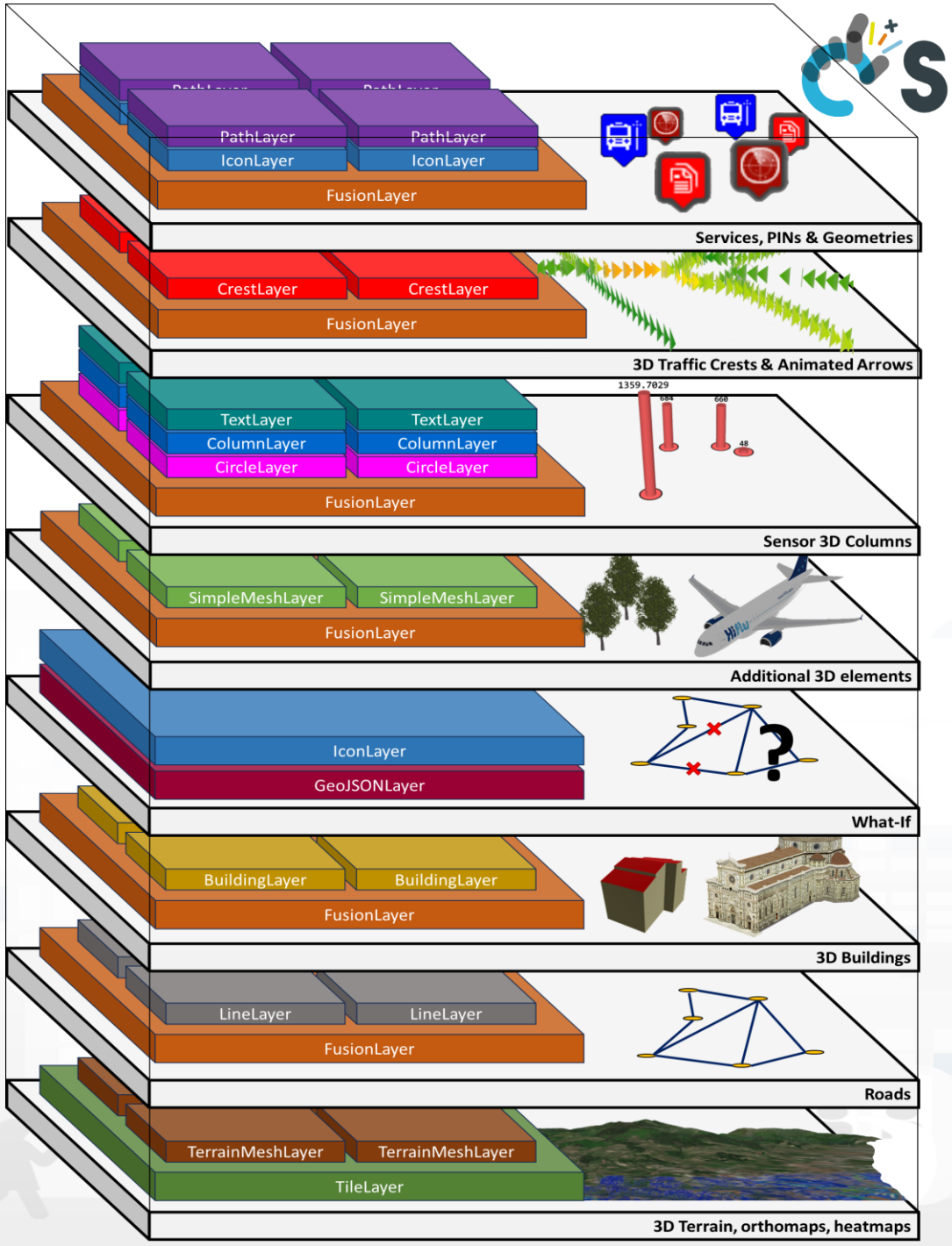




Computational steps of the pipeline to obtain building model with 3D roof from LiDAR based DSM data. (a) input DSM with superimposed the building shape polygon in red, (b) initial output of the region growing clustering, (c) an intermediate step of the plane-cluster expansion, (d) the final plane-clusters, (e) rooftop planar patches, (f) planar roof segments obtained after fusion of the planar patches.

Layers vs Fusion Layers





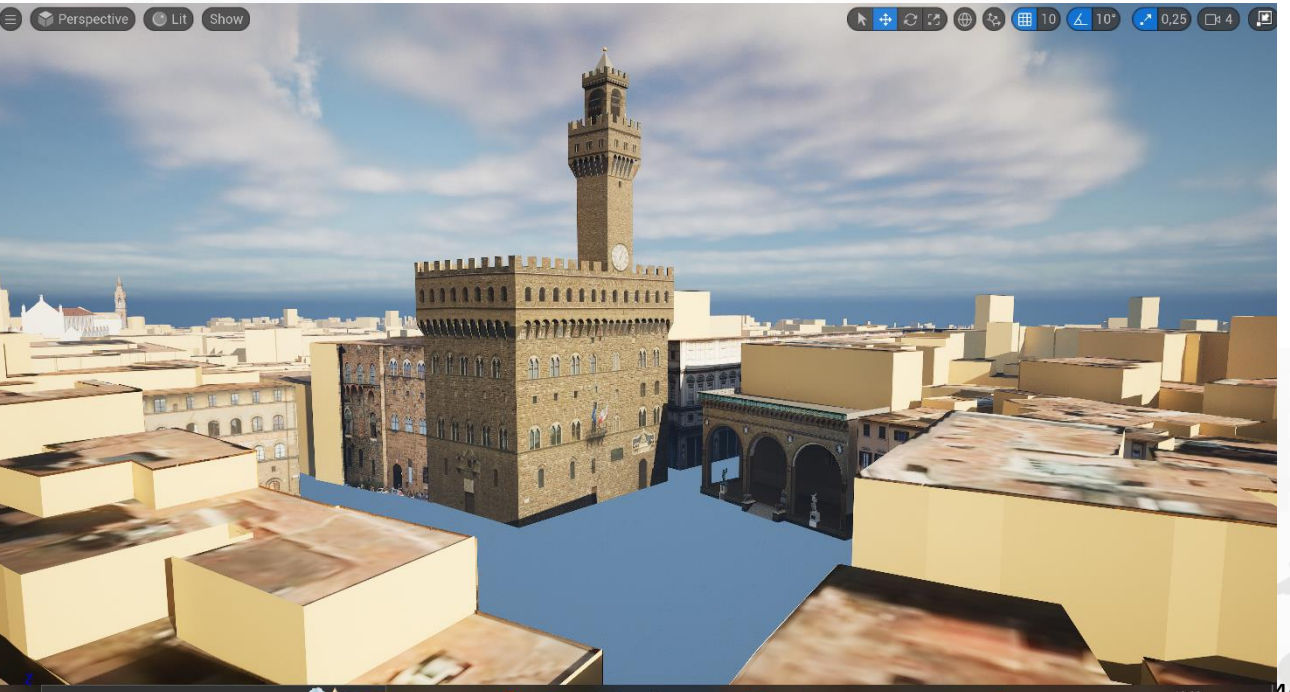
Interacting with 3D City Digital Twin

- You can see in the 3D model
  - Terrain model defining the level of the terrain and of the building
  - Generic Buildings, high value buildings, HVB (e.g., Dome, Palazzo Vecchio, etc.), facades, roofs, etc.
  - Sky pattern: sun, cloudy, etc.
  - Orthomaps below the buildings, by selection
  - Heatmaps, over orthomaps, and below buildings:
    - temperature, traffic, pollutant
  - Cycling paths and other shapes, polylines
  - Traffic Flows: as crests shaping the traffic flow density in high and color according to color map
  - POI, Sensors: PopUps to see real time data
  - Pillars reporting in 3D the values of specific sensors: temperature, traffic flow, people counting, pollutant, etc.
  - Blocked parts from the Scenarios
  - Routing, conditioned routing, dynamic routing



OCULUS




Perspective
Lit
Show
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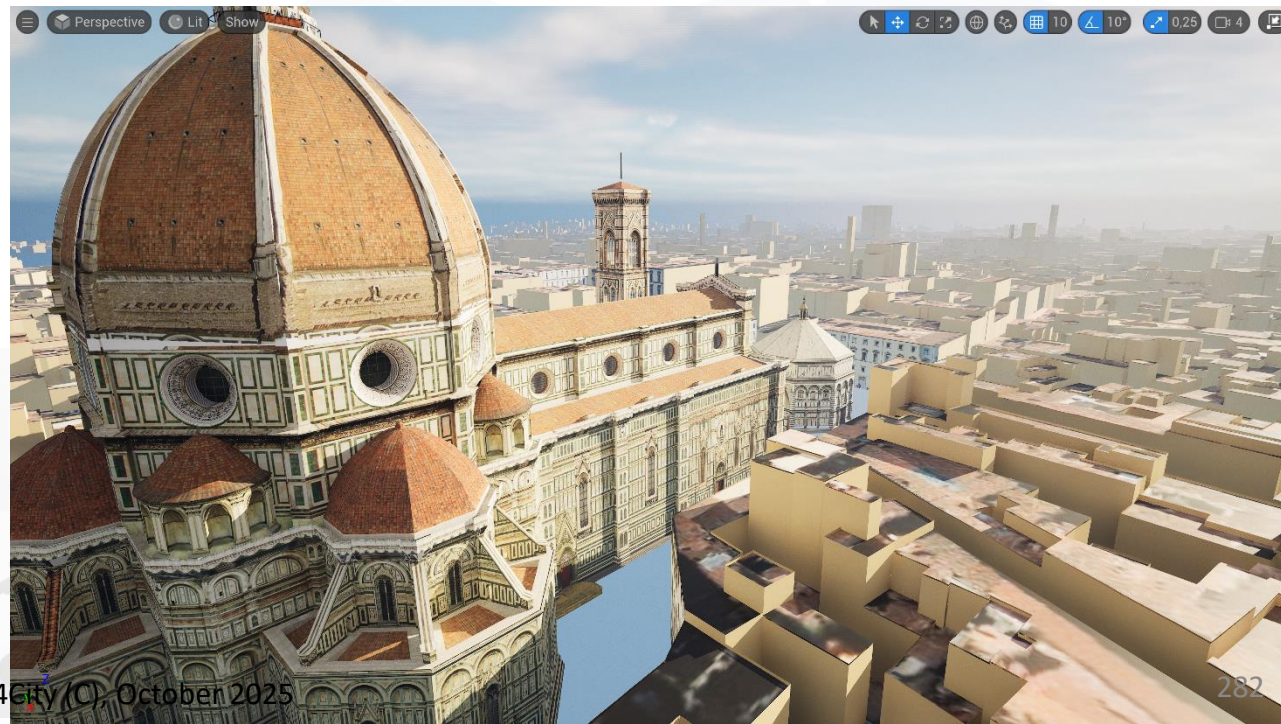

Perspective
Lit
Show

OCULUS

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

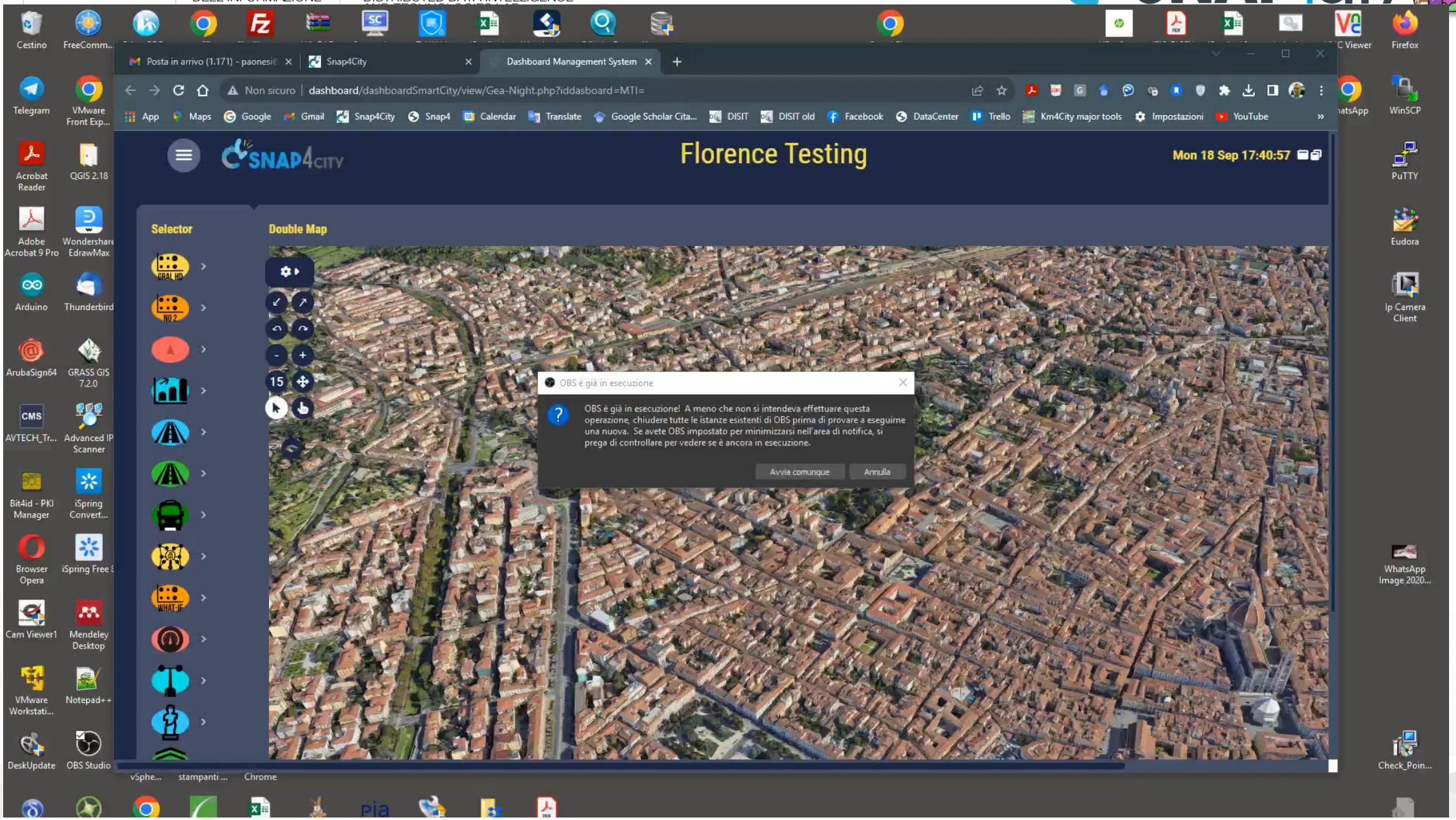


Exploiting Google API with Snap4City engine

- Select any city/locality and see if 3D Representation of your city is Available
- Snap4City redendering and distribution engine allows to
  - Optimize distribution of data
  - Integrate any kind of data on Digital Twin with 3D tiles of Google
    - PIN, IoT Data
    - Traffic Flows
    - Cycling paths
    - 3D shapes superimposed
    - Etc.

Snap4City Digital Twin Engine and data + 3D Google Data

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Snap4City
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App Maps Google Gmail Snap4City Snap4 Calendar Translate Google Scholar Cita... DISIT DISIT old Facebook DataCenter Trello Km4City major tools Impostazioni YouTube
SNAP4CITY
Florence Testing
Mon 18 Sep 17:40:57
Selector
Double Map
OBS è già in esecuzione
OBS è già in esecuzione! A meno che non si intendeva effettuare questa operazione, chiudere tutte le istanze esistenti di OBS prima di provare a eseguirne una nuova. Se avete OBS impostato per minimizzarsi nell'area di notifica, si prega di controllare per vedere se è ancora in esecuzione.
Avvia comunque
Annulla
Cestino
FreeComm...
Telegram
VMware Front Exp...
Acrobat Reader
QGIS 2.18
Adobe Acrobat 9 Pro
Wondershare EdrawMax
Arduino
Thunderbird
ArubaSign64
GRASS GIS 7.2.0
AVTECH_Tr...
Advanced IP Scanner
Bit4id - PKI Manager
iSpring Convert...
Browser Opera
iSpring Free
Cam Viewer1
Mendeley Desktop
VMware Workstati...
Notepad++
DeskUpdate
OBS Studio
Firefox
WinSCP
PuTTY
Eudora
Ip Camera Client
WhatsApp Image 2020...
Check_Poin...
vSphe...
stampanti ...
Chrome

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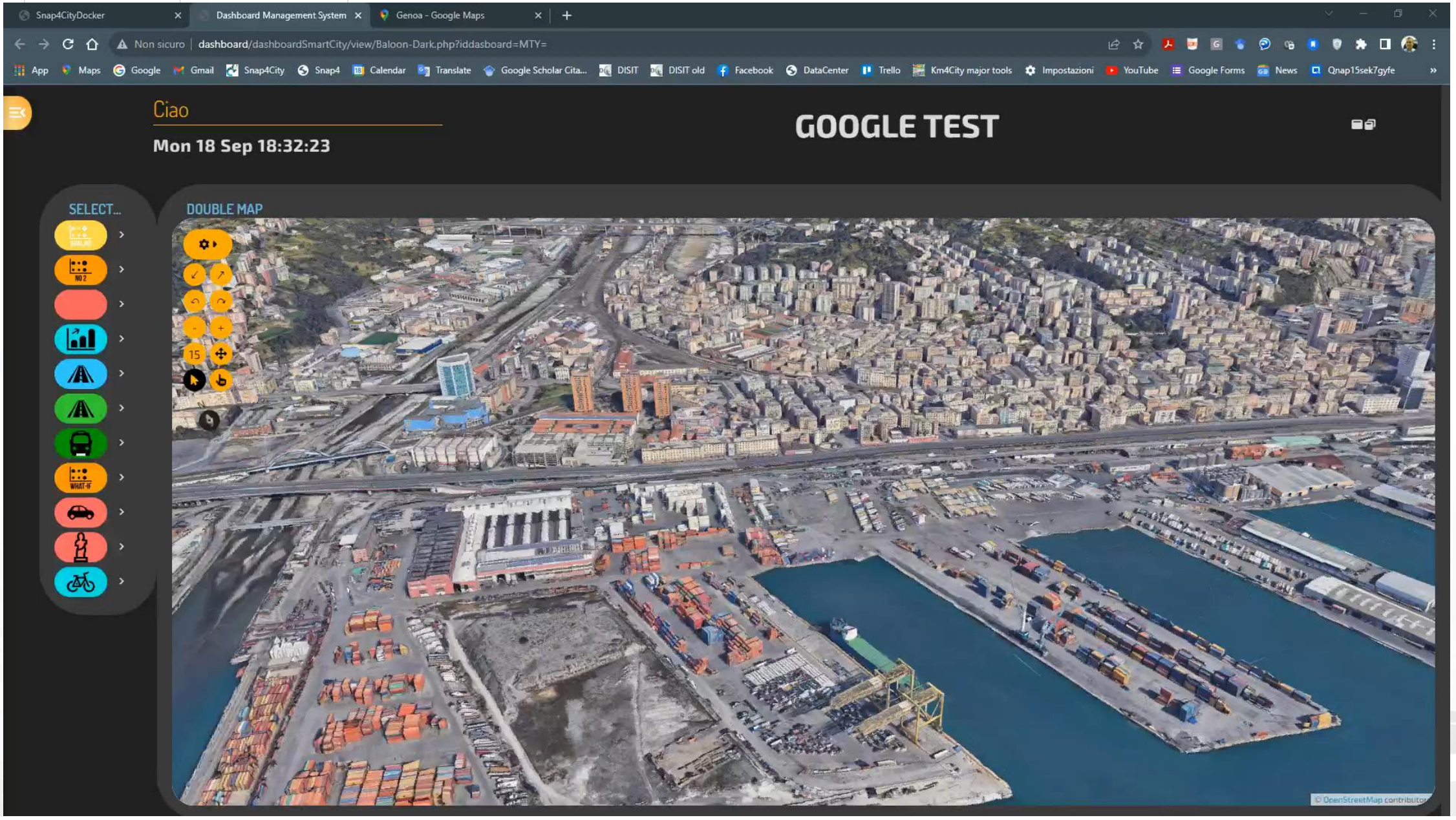
Genova

SNAP4CITY KM4CITY



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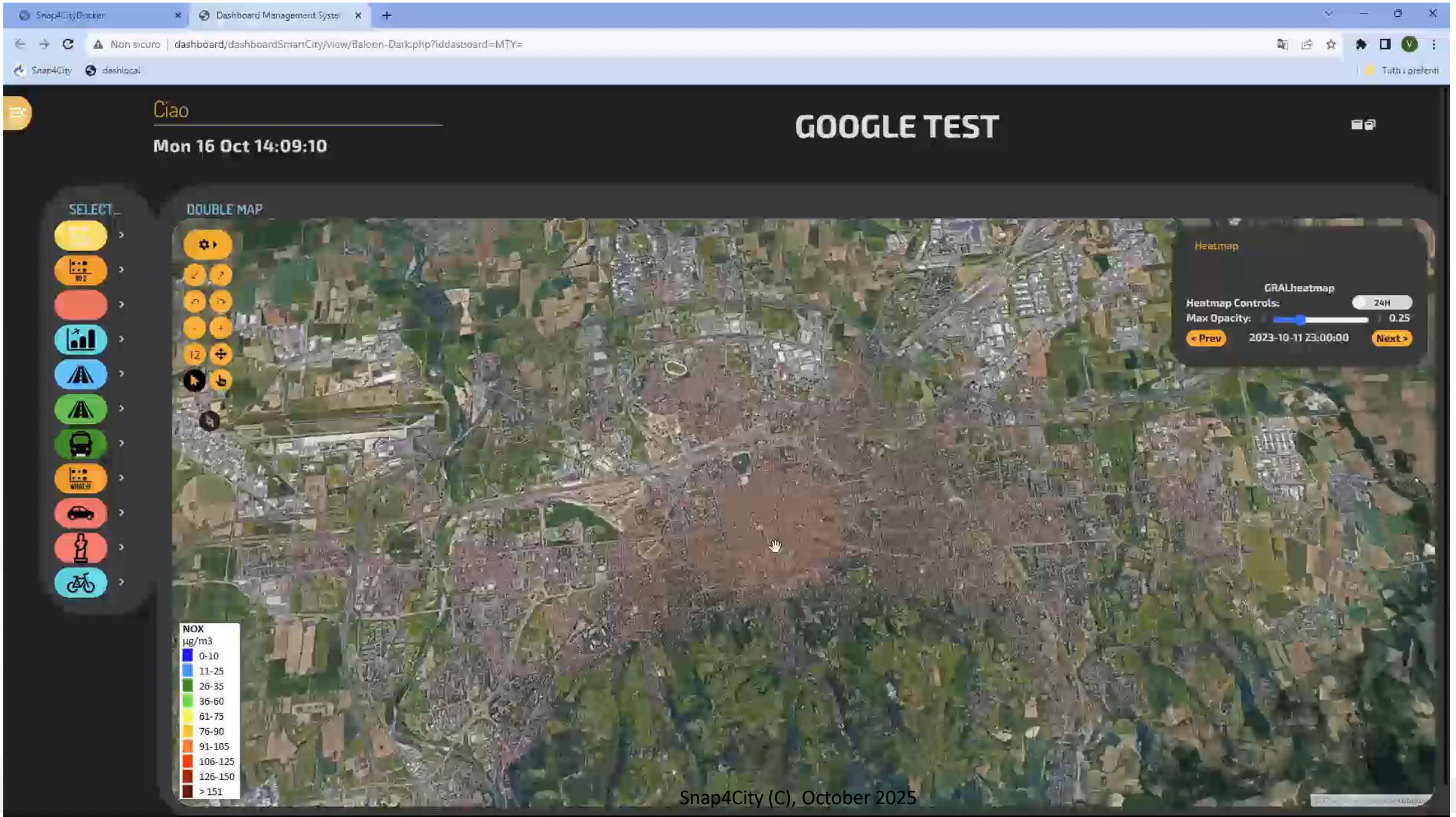
Bologna

SNAP4CITY KM4CITY



Human Behavior Monitoring



User Behaviour Analysis:

Trajectories, Heatmap, typical…



Engaging via Mobile Apps

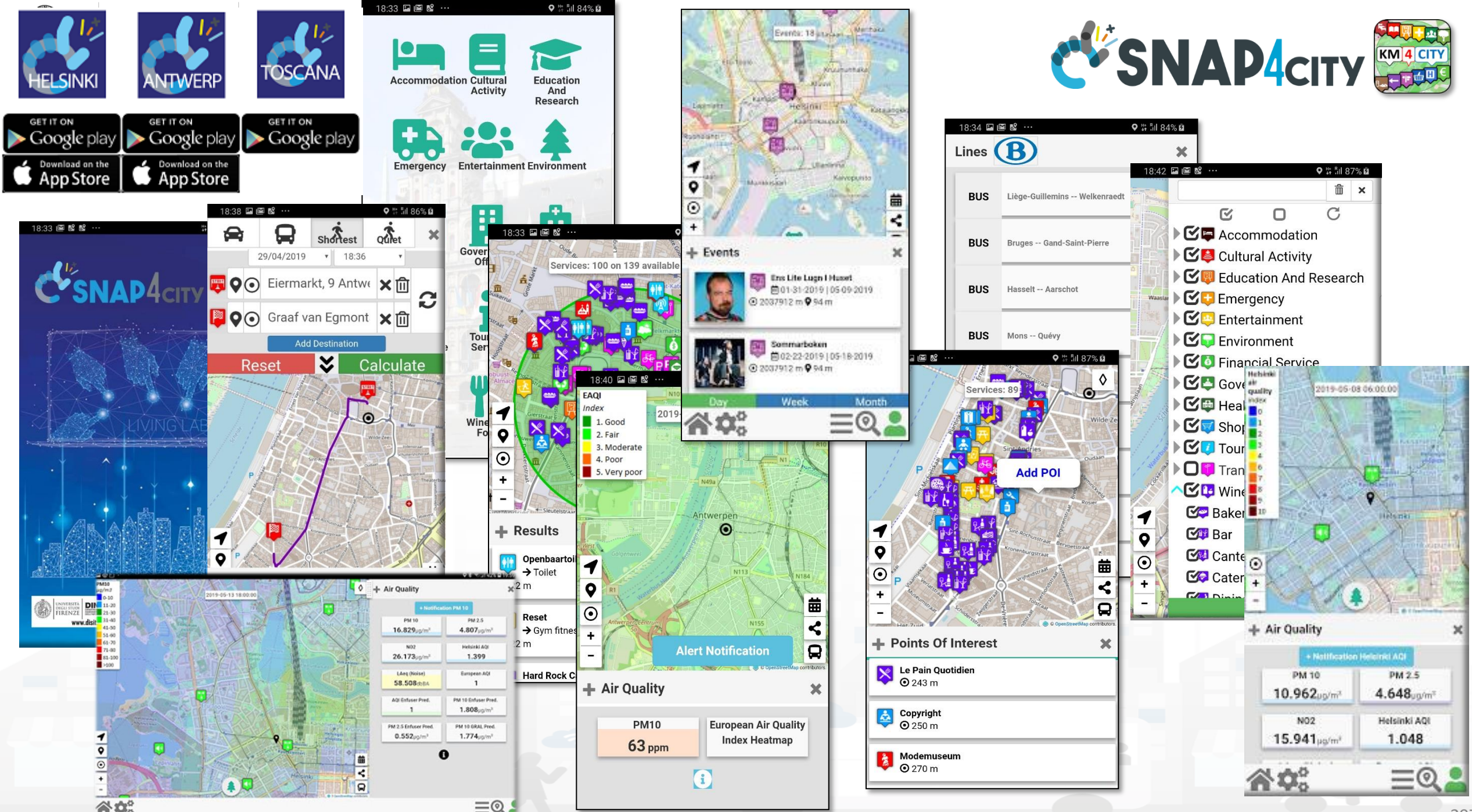


FROM CITY DASHBOARD TO APPLICATIONS

SNAP4CITY AND KM4CITY PROJECTS

SNAP4CITY THE VIEW OF THE ADMINISTRATORS

100% OPEN SOURCE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ANTWERP
TOSCANA
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Download on the App Store
SNAP4CITY
KM 4 CITY
Accommodation
Cultural Activity
Education And Research
Emergency
Entertainment
Environment
Shortest
Quiet
Add Destination
Reset
Calculate
Events
Day
Week
Month
Services: 100 on 139 available
EAQI
Index
1. Good
2. Fair
3. Moderate
4. Poor
5. Very poor
Results
Antwerpen
Alert Notification
Air Quality
PM10
63 ppm
European Air Quality Index Heatmap
Lines
BUS
Liège-Guillemins -- Welkenraedt
Bruges -- Gand-Saint-Pierre
Hasselt -- Aarschot
Mons -- Quévy
Add POI
Points Of Interest
Le Pain Quotidien
243 m
Copyright
250 m
Modemuseum
270 m
Air Quality
PM 10
10.962
PM 2.5
4.648
NO2
15.941
Helsinki AQI
1.048

The App is a Bidirectional Device

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

Produced information

- Viewed ?
- Accepted ?
- Performed ?
- …

Users



Derived information

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

Produced information

- Suggestions
- Engagements
- Notifications
- …

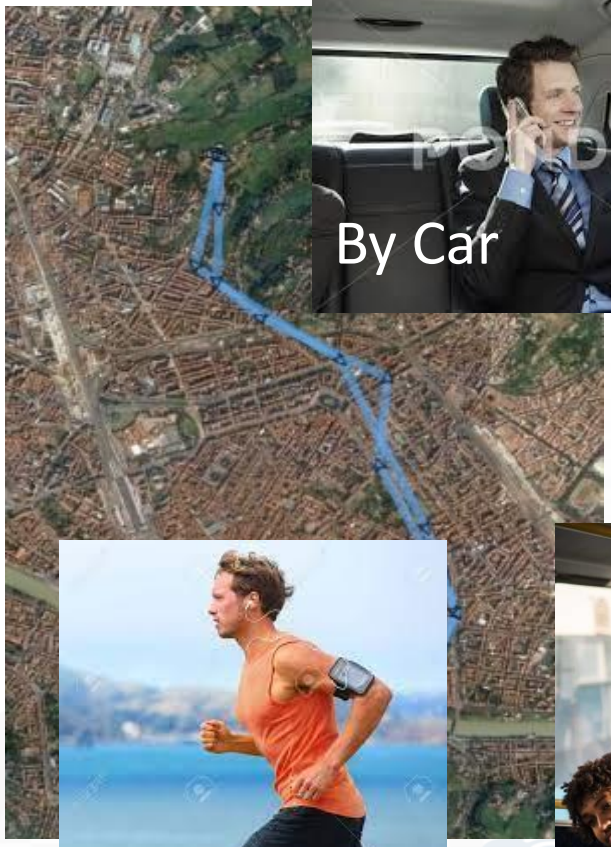
System

Recognition of City Users' Transportation means



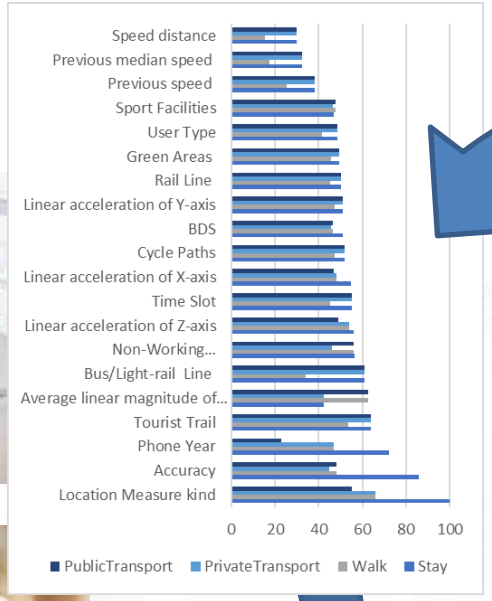
To propose suggestions and Engage city user

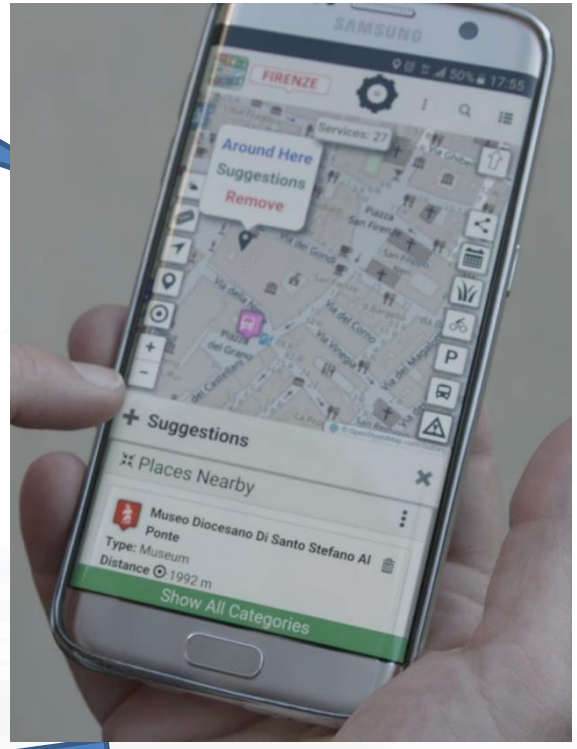
we need to know how they are moving



Walk









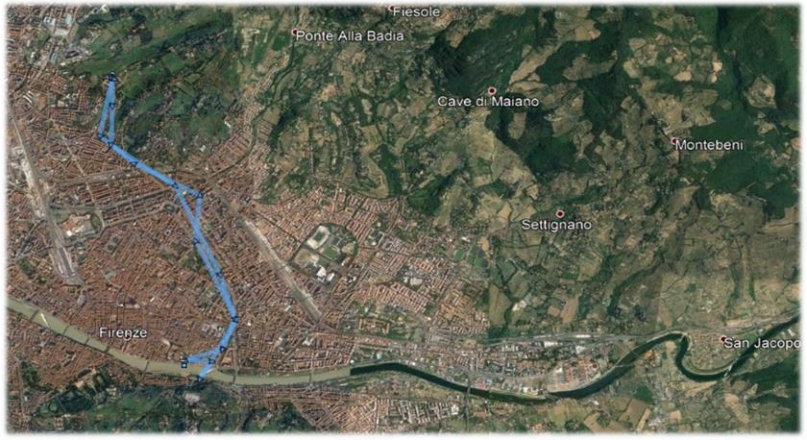
Artificial Intelligence Classification

Suggestions

Automated Classification of Users' Transportation Modality in Real Conditions

Variables taken into account:

- ***Day/Time Baseline and GPS***:
- ***Accelerometer***
- ***Proximity***
- ***Temporal window***



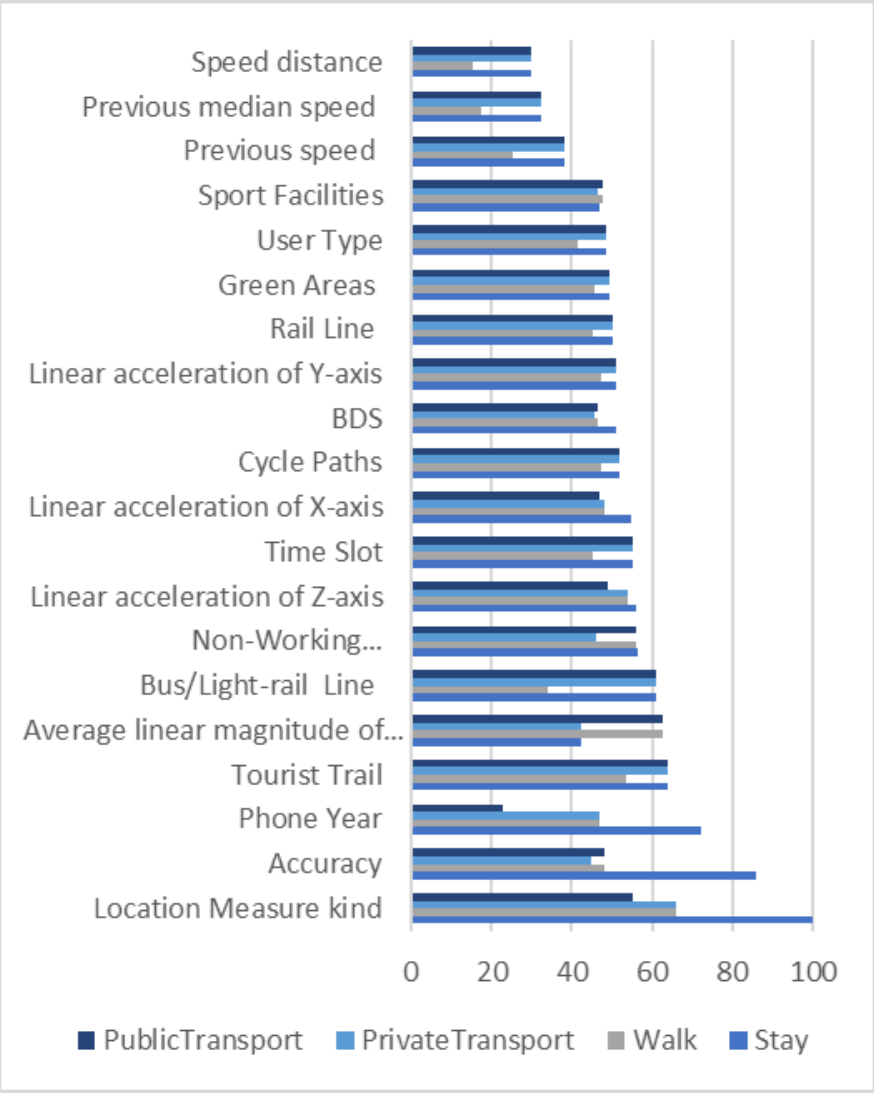
Dataset:

- 30K observations
- 25 variables
- 38 different users
- 30 different kinds of devices
- 4 classes (Stationary, Walking, Private Transport, Public Transport)

Four combinations of the different categories of data:

1. Baseline features and distance feature
2. Baseline, distance feature and accelerometer features
3. Baseline, distance feature and temporal window features
4. Baseline, distance, accelerometer, temporal features together

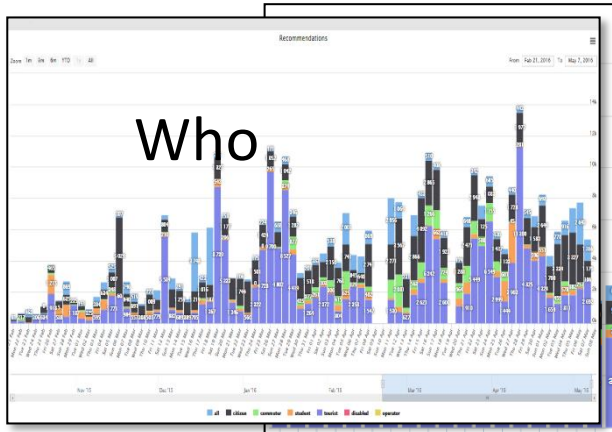
Note that, *each user have used the mean of transport of his/her own preference*.
When the mode of transport is changed, the user was asked to notify the change to the App for creating the learning set and for validation.

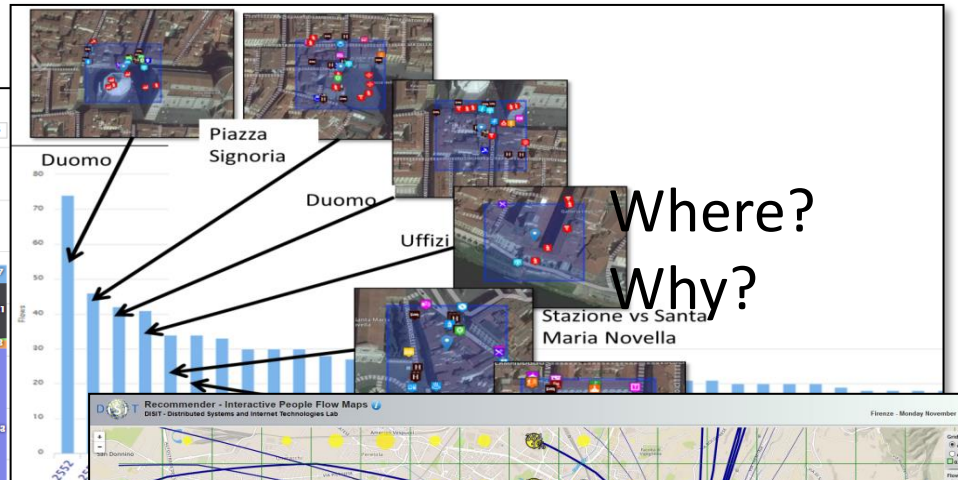


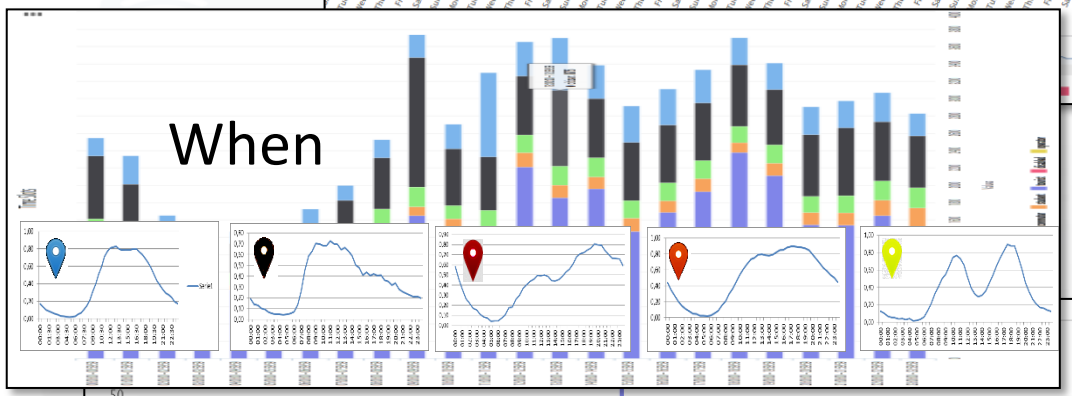
Feature relevance

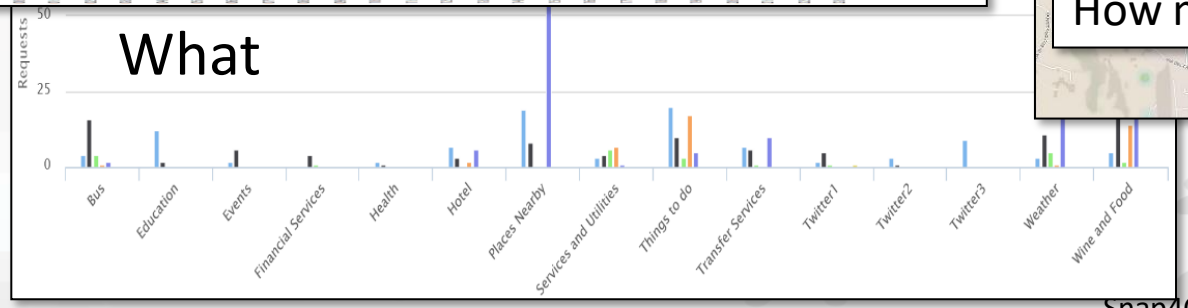
Model features categories	Extra Tree Model results			
	Accuracy %	Precision %	Recall %	F_1 Score
Baseline and GPS	91.0	68.2	75.1	0.714
Baseline and GPS + proximity	92.4	73.9	69.1	0.715
Baseline and GPS + proximity + Accelerometer	92.6	81.4	74.4	0.777
Baseline and GPS + proximity + Temporal window	94.9	80.5	78.7	0.787
Baseline and GPS + proximity + Accelerometer + Temporal window	95.3	82.7	86.9	0.847

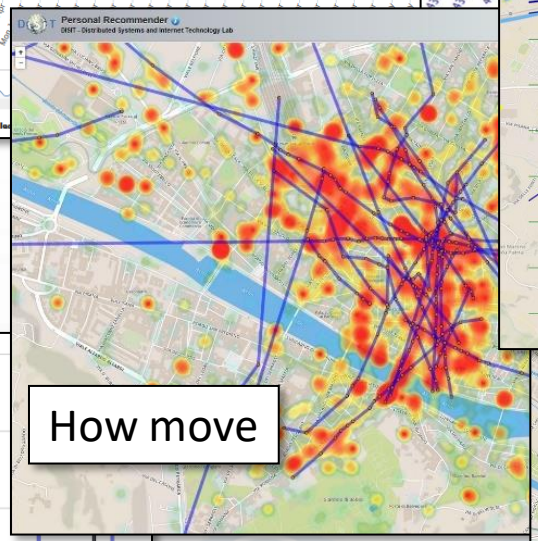
User Behavior Analyser for Collective Profiling

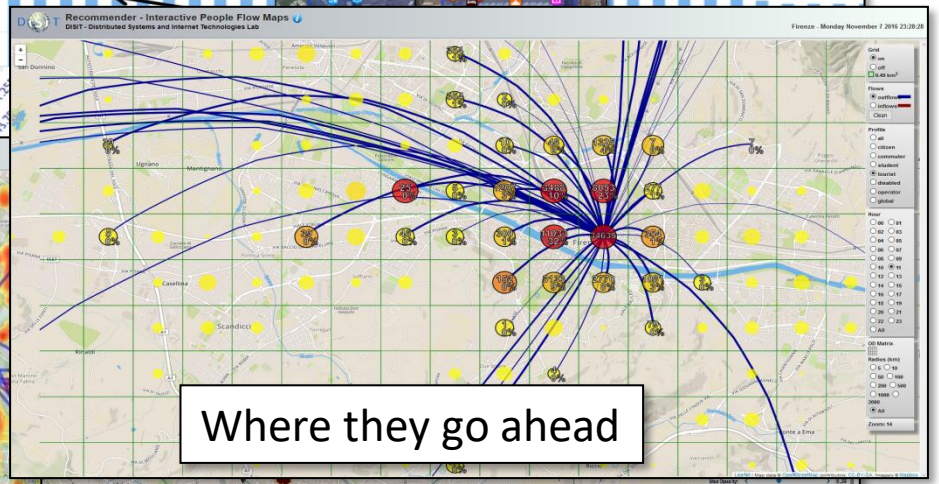


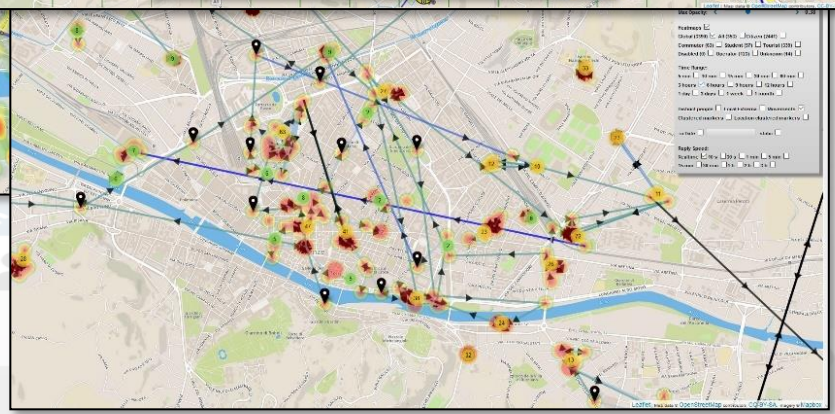










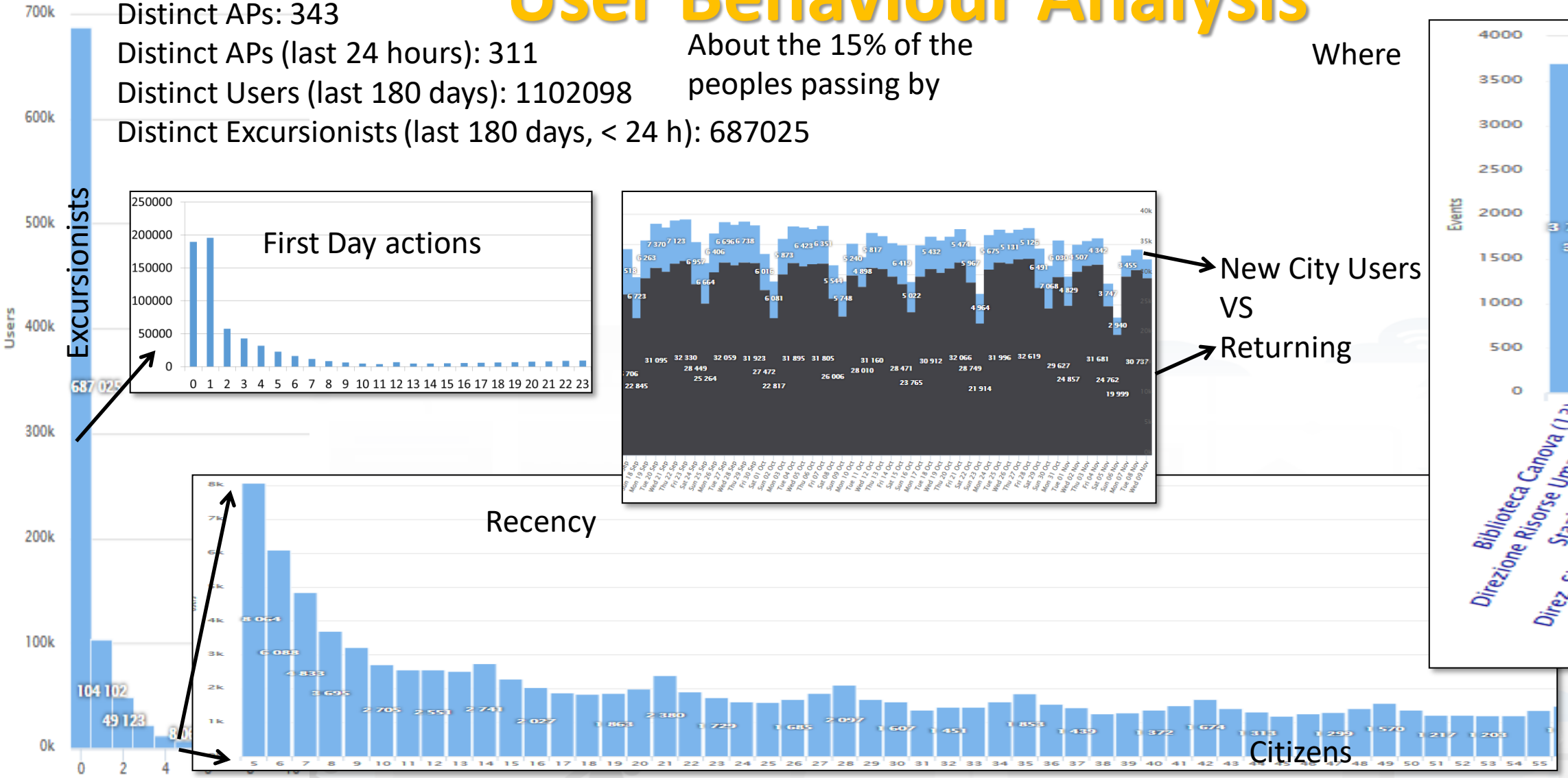


User Behaviour Analysis

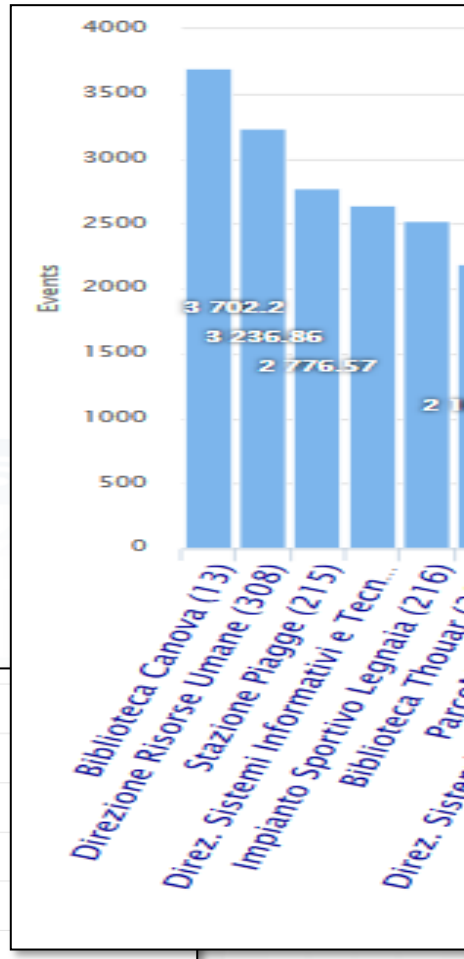
Distinct APs: 343
Distinct APs (last 24 hours): 311
Distinct Users (last 180 days): 1102098
Distinct Excursionists (last 180 days, < 24 h): 687025

About the 15% of the peoples passing by

Where



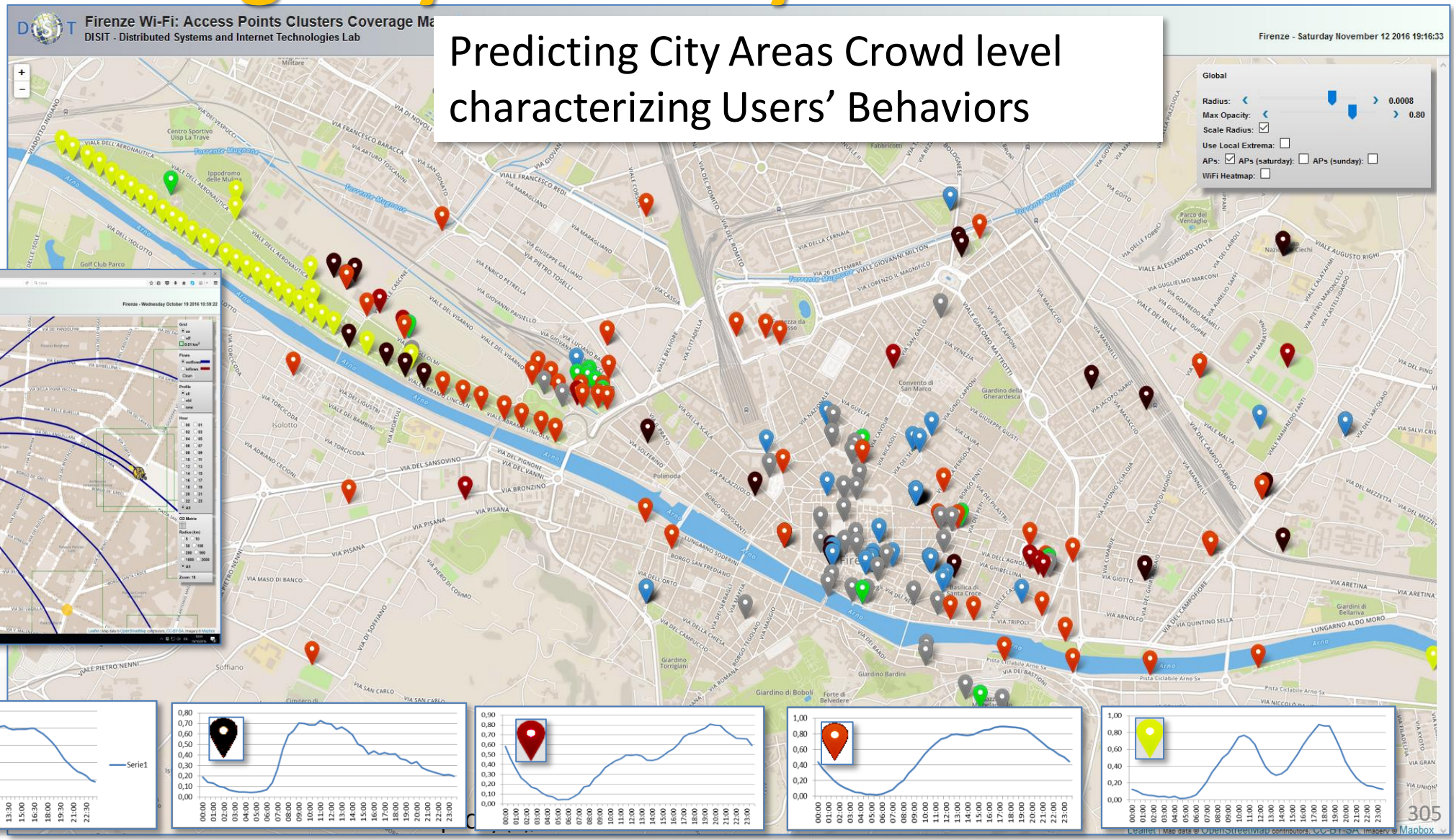
New City Users
VS
Returning

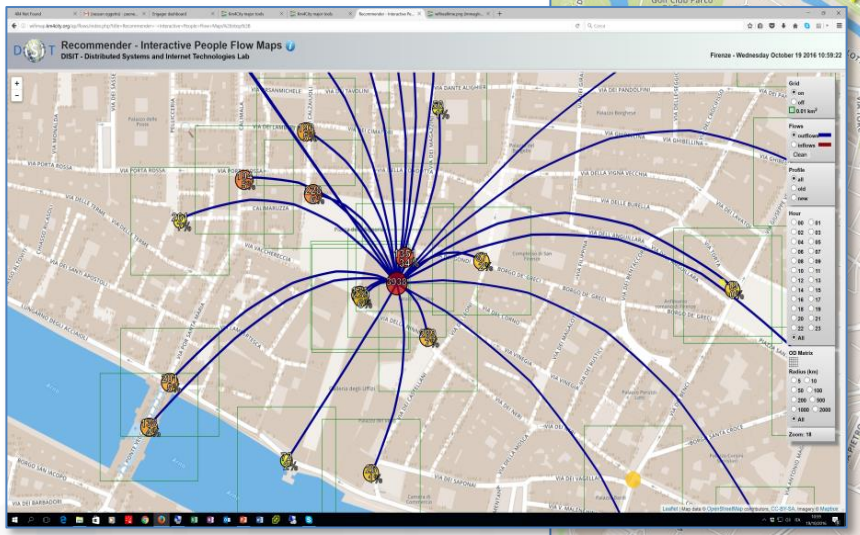


Characterizing City Areas by User Behavior

Wi-Fi based

Predicting City Areas Crowd level characterizing Users' Behaviors





UNIVERSITÀ DEGLI STUDI FIRENZE

DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

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

Interreg Mediterranean HERIT-DATA

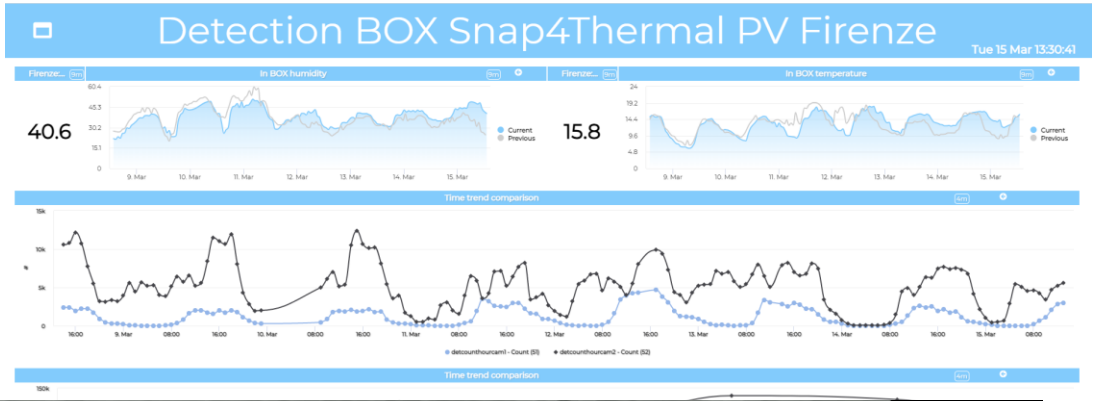
AXIS COMMUNICATIONS

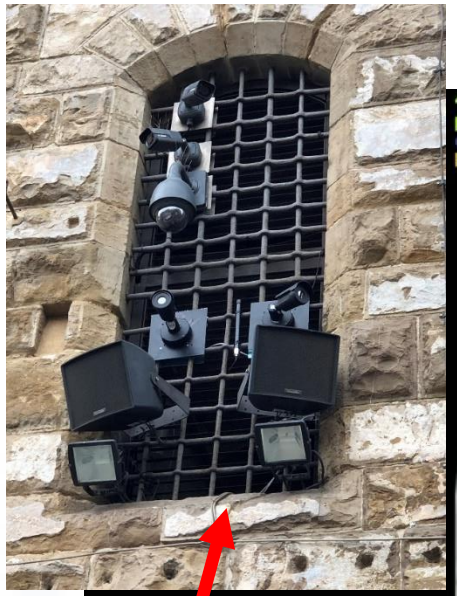
SNAP4CITY

KM 4 CITY

A view and data from the Thermal Camera









11 SUSTAINABLE CITIES AND COMMUNITIES





People Detection Plugin on AXIS Camera



AXIS COMMUNICATIONS

- **Machine Learning**
- **Detection, classification, count**:
  - people, bikes, and strollers
- **Counting Accuracy:**
  - **mAP_0.5 (0-75): 0.92-0.99**
- **Supported** and tested models
  - Q1951, Q1952
- **Output** on MQTT
- Large range of application no tuning



1

ject Detector - DISIT

Avvia

Stato: In esecuzione

Versione: 1.0.0

Fornitore: DISIT

Apri avvisi di terze parti

Registro app

Apri

2

ecution model

Times:

1

Execute

Basic Settings

Times to execute on startup:

1

Sleep (ms):

5000

MQTT Connection:

On

Save

MQTT Client Connection

Address:

tcp://192.168.1.216

Port:

1883

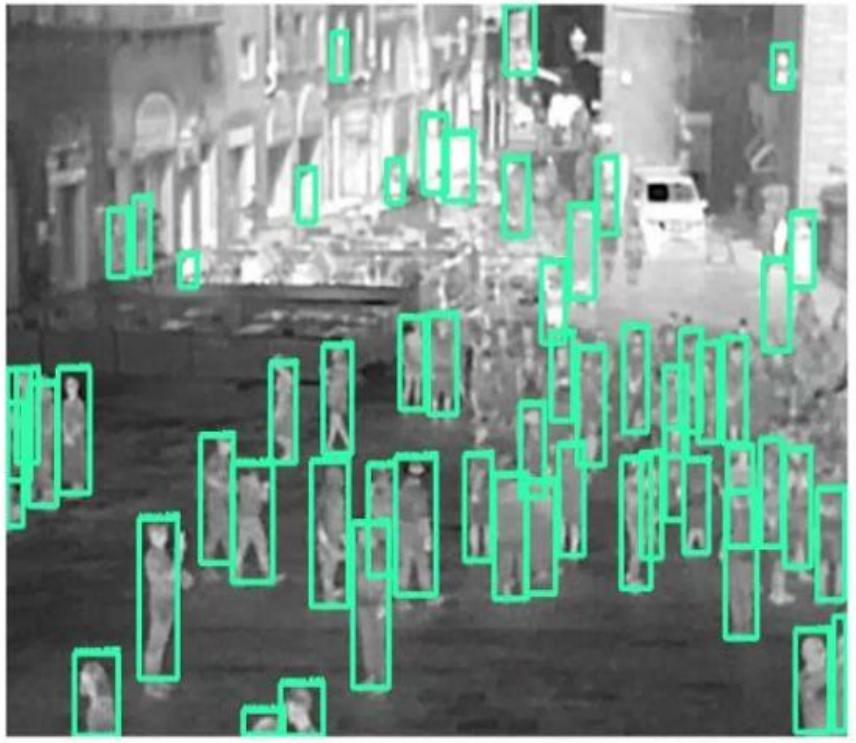
Topic Name:

3

AXIS Q1951-E Disit_app | Object Detector - DISIT | Results - DISIT

Non sicuro | 192.168.188.23:2001/results

Video Stream



Box Output

1/1

Time: 18.467603

Results: [[359.103638,246.654480,383.342926,320.320862,0.908089,person],
[206.960709,361.242645,245.294067,455.995239,0.904191,person],
[289.708099,268.565735,317.013062,355.144409,0.892965,person],
[504.246674,346.042816,529.062439,434.507538,0.891071,person],
[445.203094,370.814117,476.298676,469.302185,0.886001,person],
[121.531105,404.572266,158.478043,532.019104,0.884107,person],

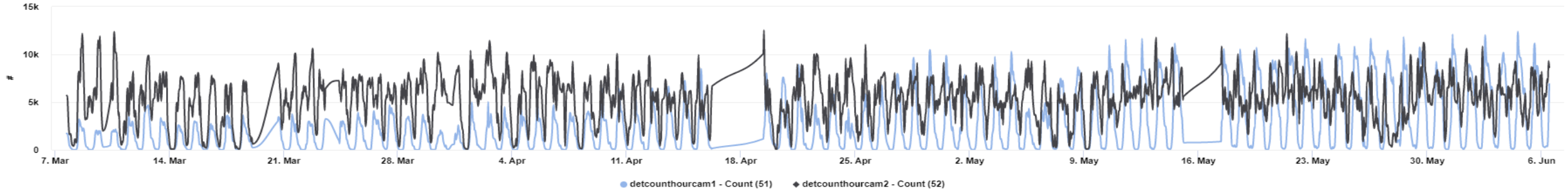
Advanced_People_Detection

https://www.snap4city.org/dashboardSmartCity/view/Gea.php?iddasboard=MzM3Ng==

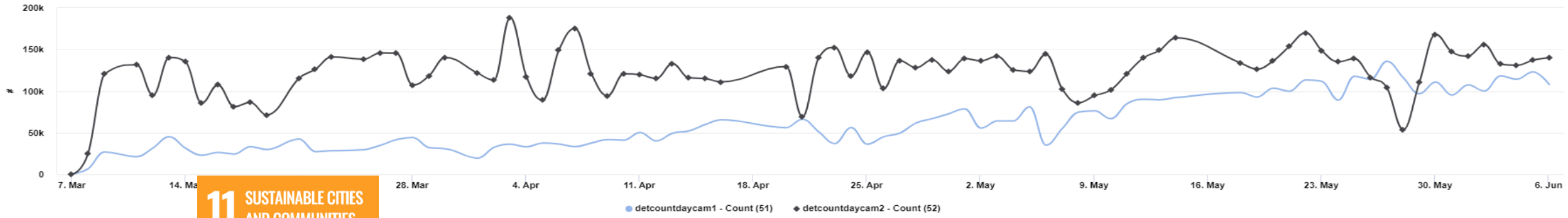
Detection BOX Snap4Thermal PV Firenze

Thu 30 Mar 23:55:16

Time Trend Comparison



Time Trend Comparison

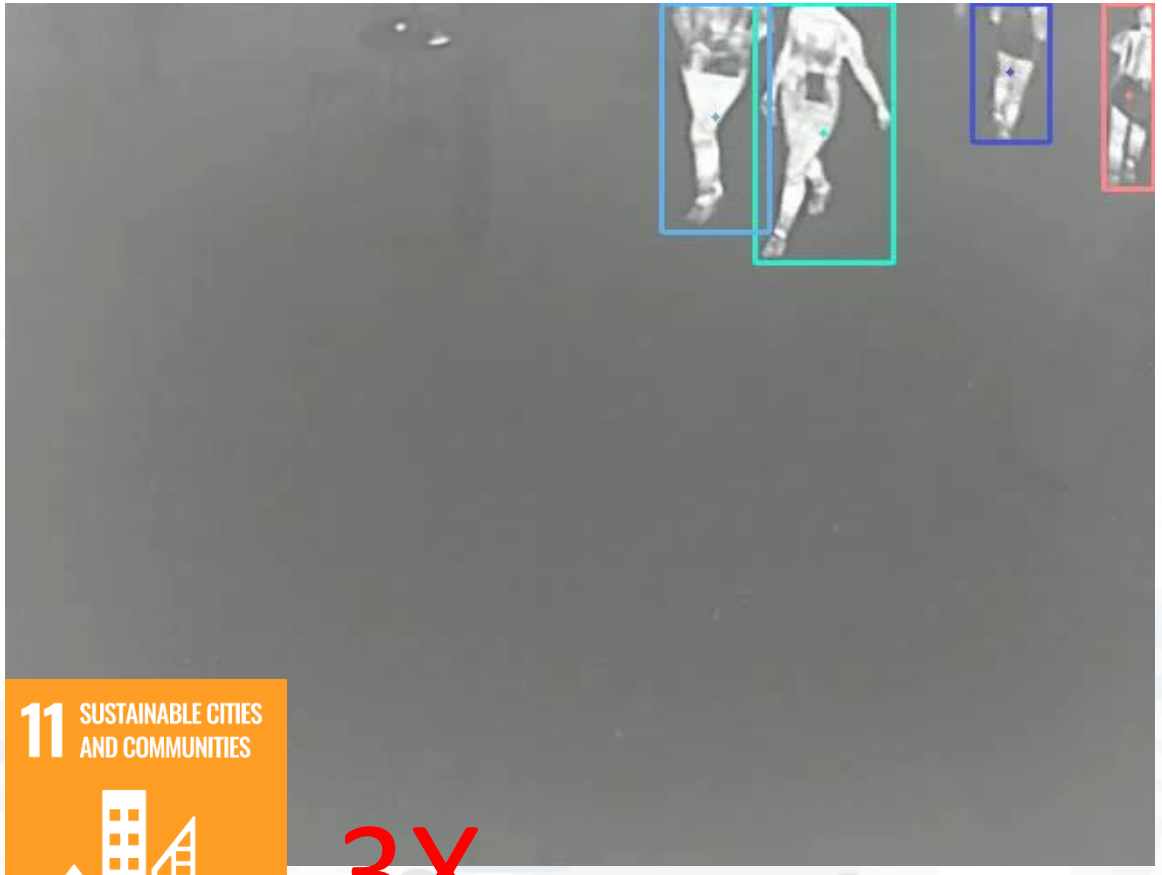


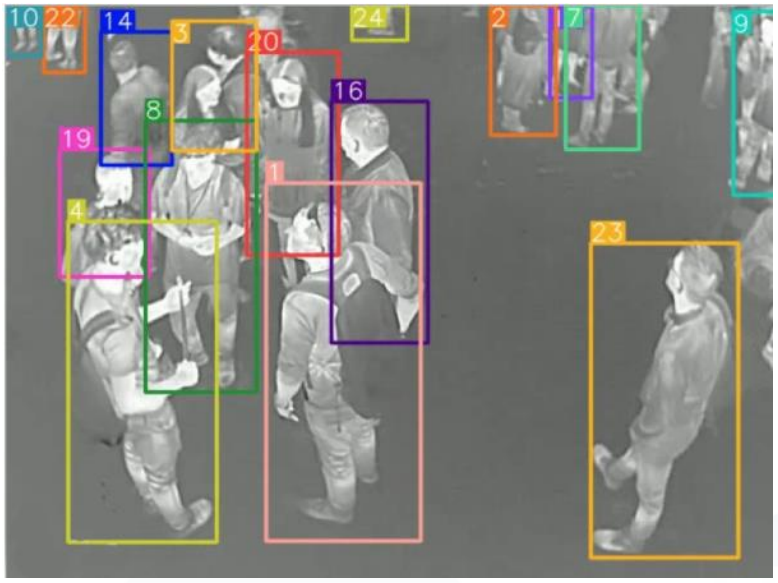
11 SUSTAINABLE CITIES AND COMMUNITIES

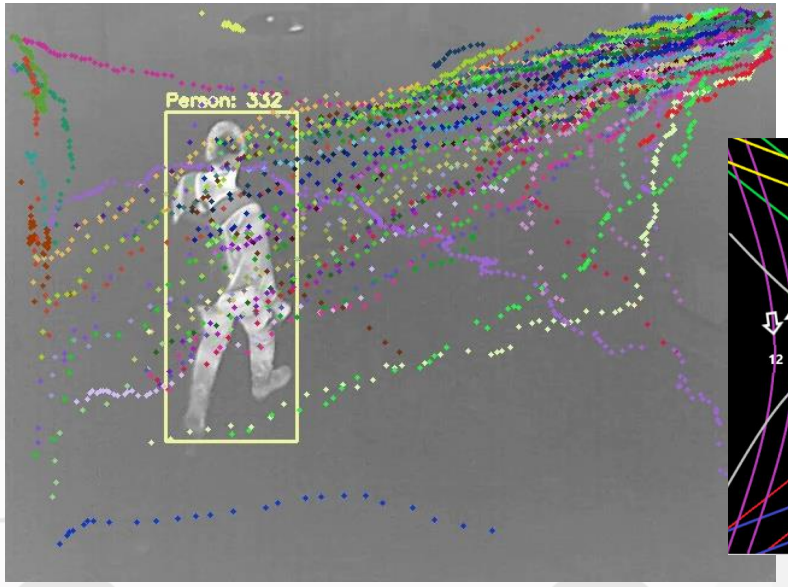
My Profile

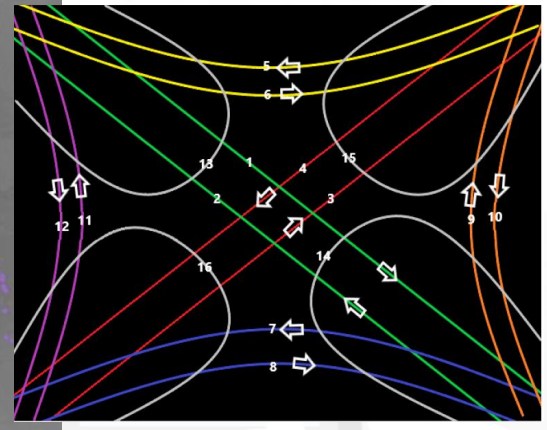
Privacy Policy Cookies Policy Terms and Conditions Contact us

People Counting and Tracking









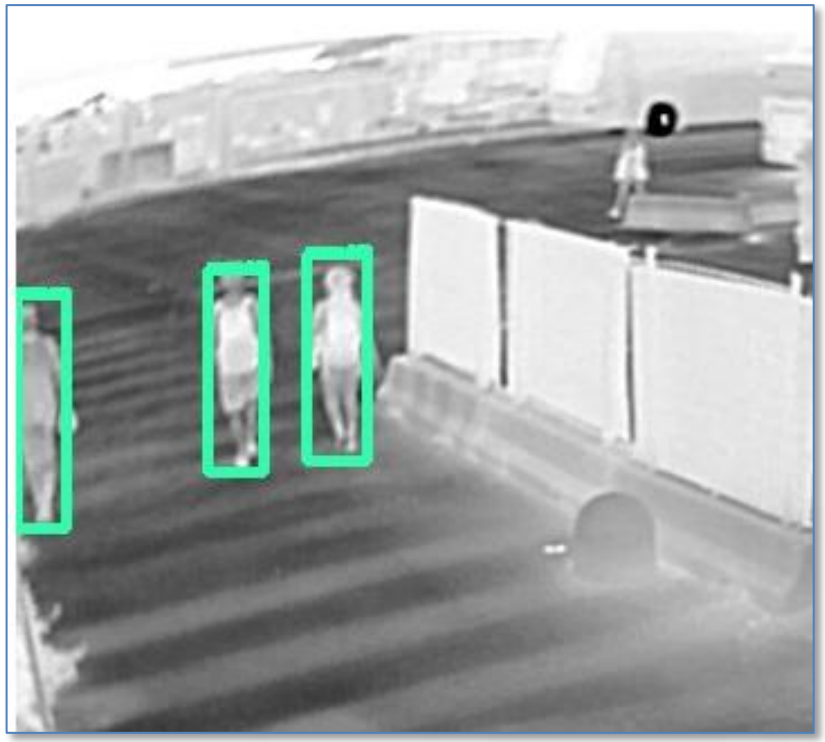
11 SUSTAINABLE CITIES AND COMMUNITIES

3X

Barc 2022


SNAP4CITY
AXIS
COMMUNICATIONS
SPAIN
SPAIN
3D MAP GLOBAL DIGITAL TWIN -NEWGUI
FREE TRIAL
E015

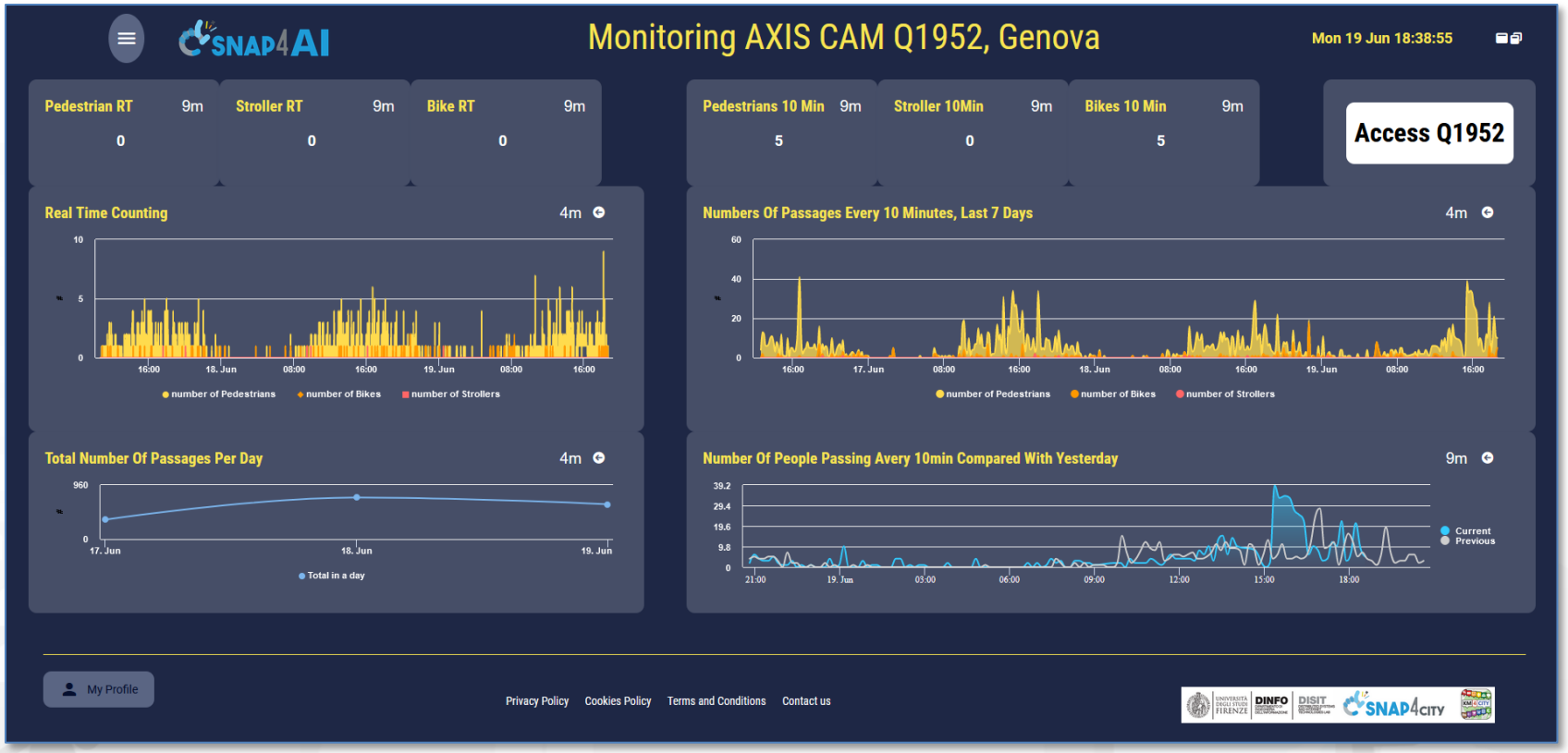

1
2
3
4
5
6
7



Monitoring Passages AXIS Q1952



- Genova: Ocean Race, 2023





VMS vs Snap4City: sending and getting events, AI solutions

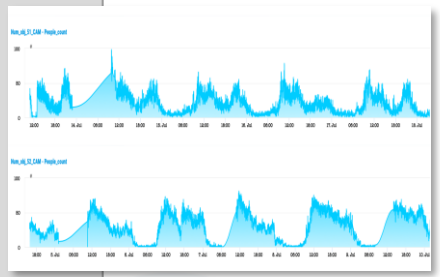


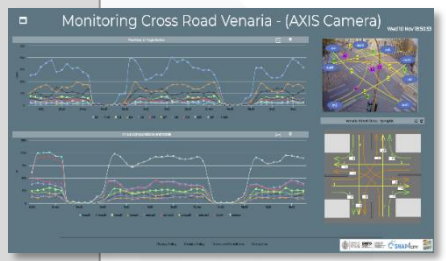
Events + info

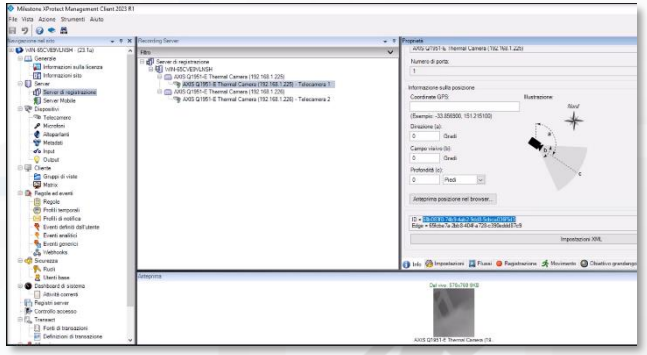
Snap4City Data Analytics

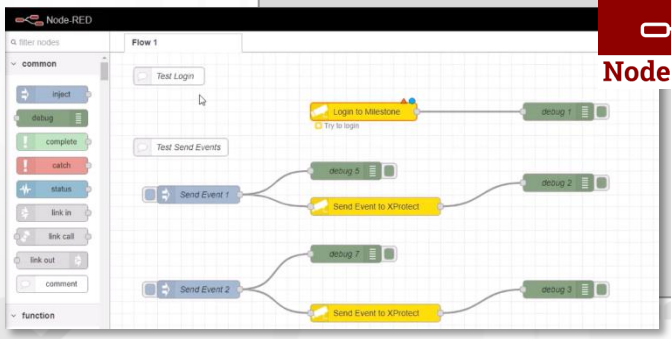
Snap4City Dashboards

Snap4City Data Interoperability





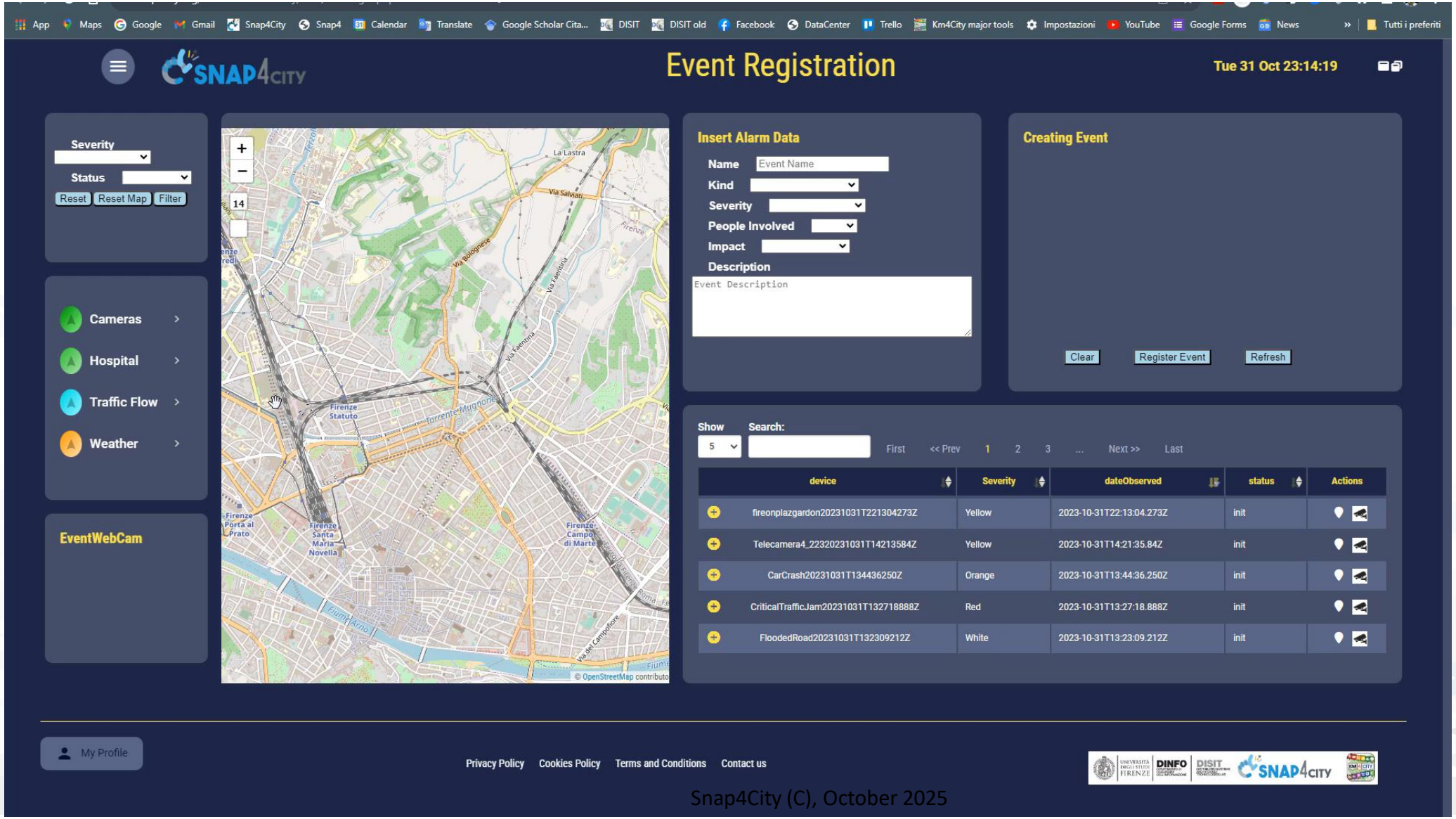




Node-RED

SNAP4CITY

Event Management



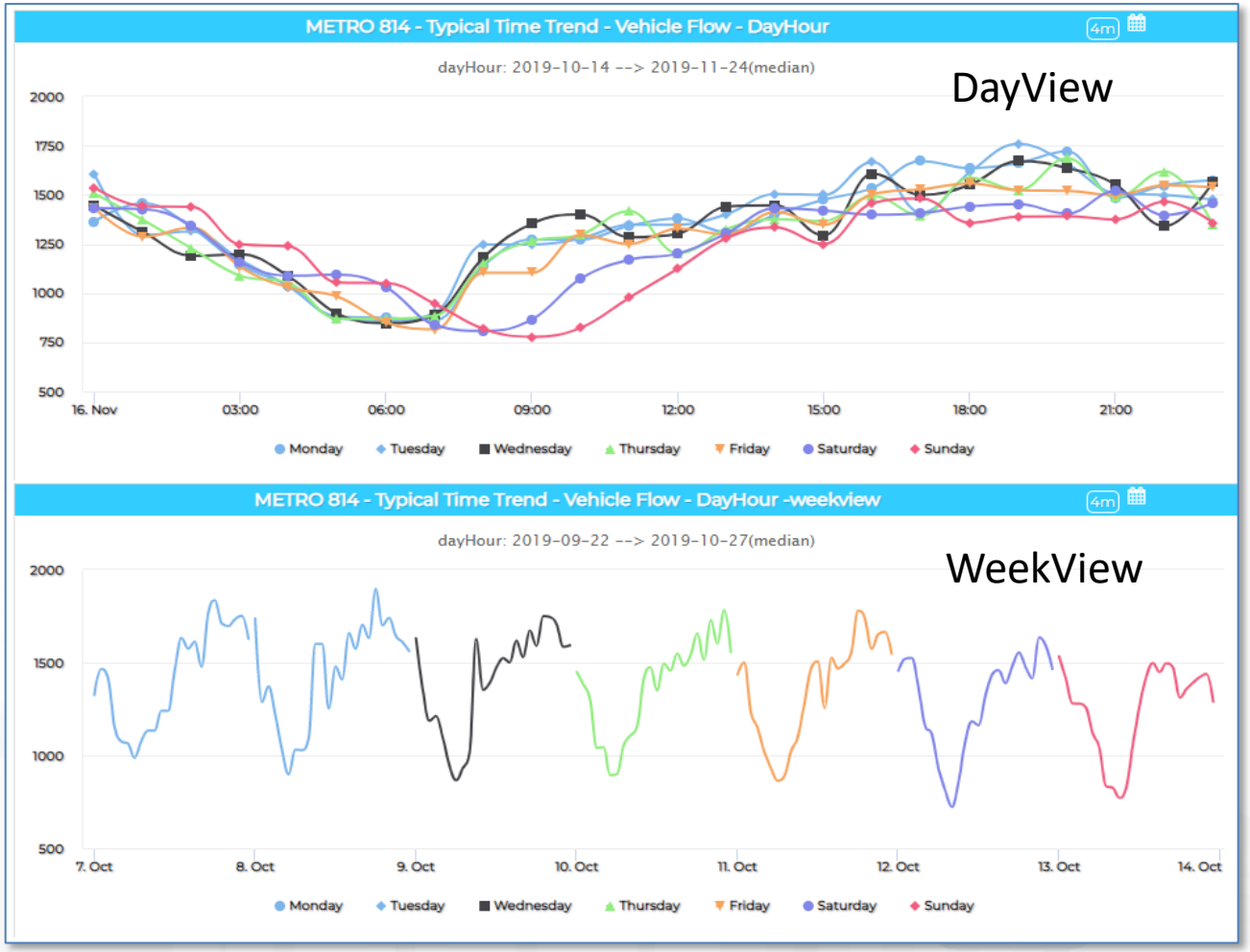
Typical Time Trends



Typical Time Trend



- They:
  - **need to be computed in advance** on the basis of a Time Serie variable, and a reference period of computation.
  - **represent typical trends of: min, max, average, median**
  - You can change the data on view
- **Formats**:
  - **DayHour**: 7 time trends, one for each day of the week, each hour, 24 values.
    - As DayView or WeekView, start monday
  - **MonthDay**: a value per day, 30 values of the month.
  - **MonthWeek**: a value per day aligned to week days: 28 values, 4 weeks.
    - 1st Monday of the month
    - 3rd Friday, etc.

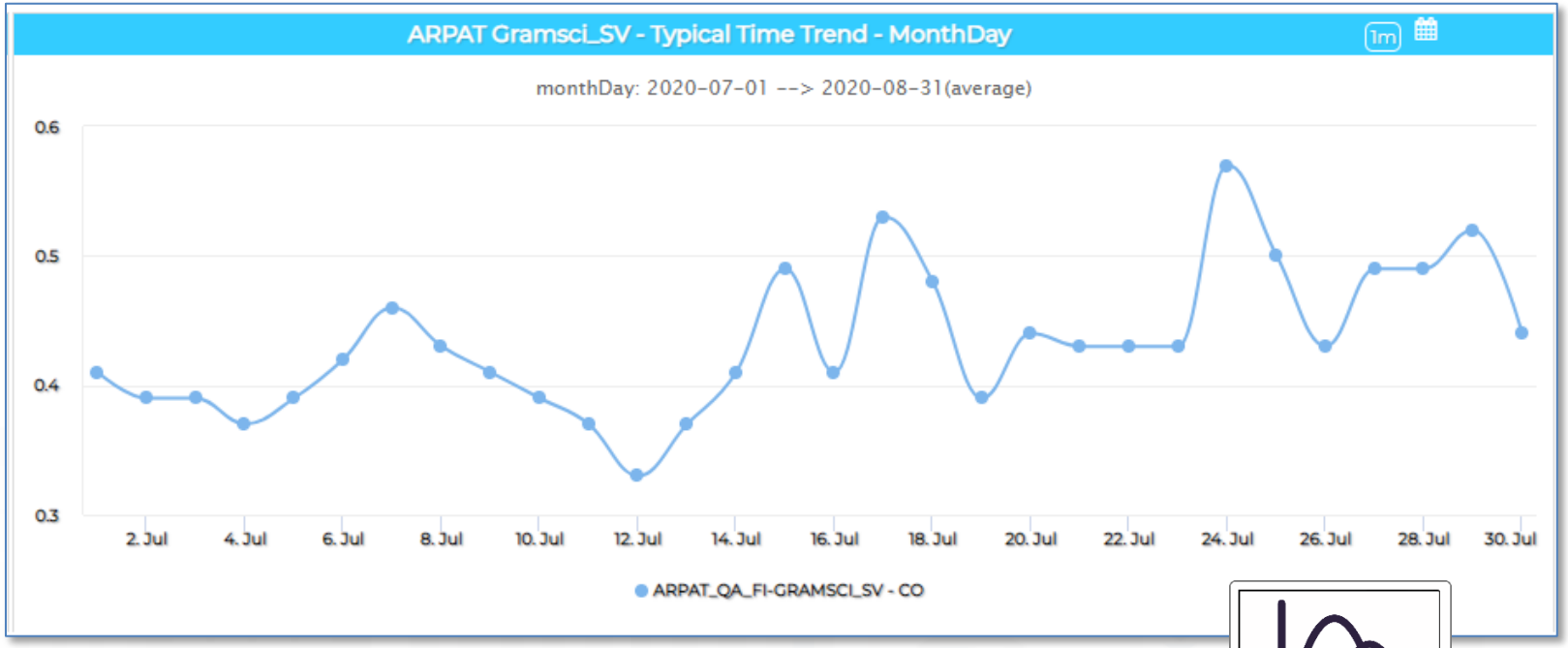


https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzA4NA==

Usage of TTT, Typical Time Trends H24

- Sensor data:
  - Traffic flow, pollutant, emission, temperature, etc.
- Tariffs for:
  - Parking, city centers, etc.
- Permitted Velocity:
  - Speed limits, etc.

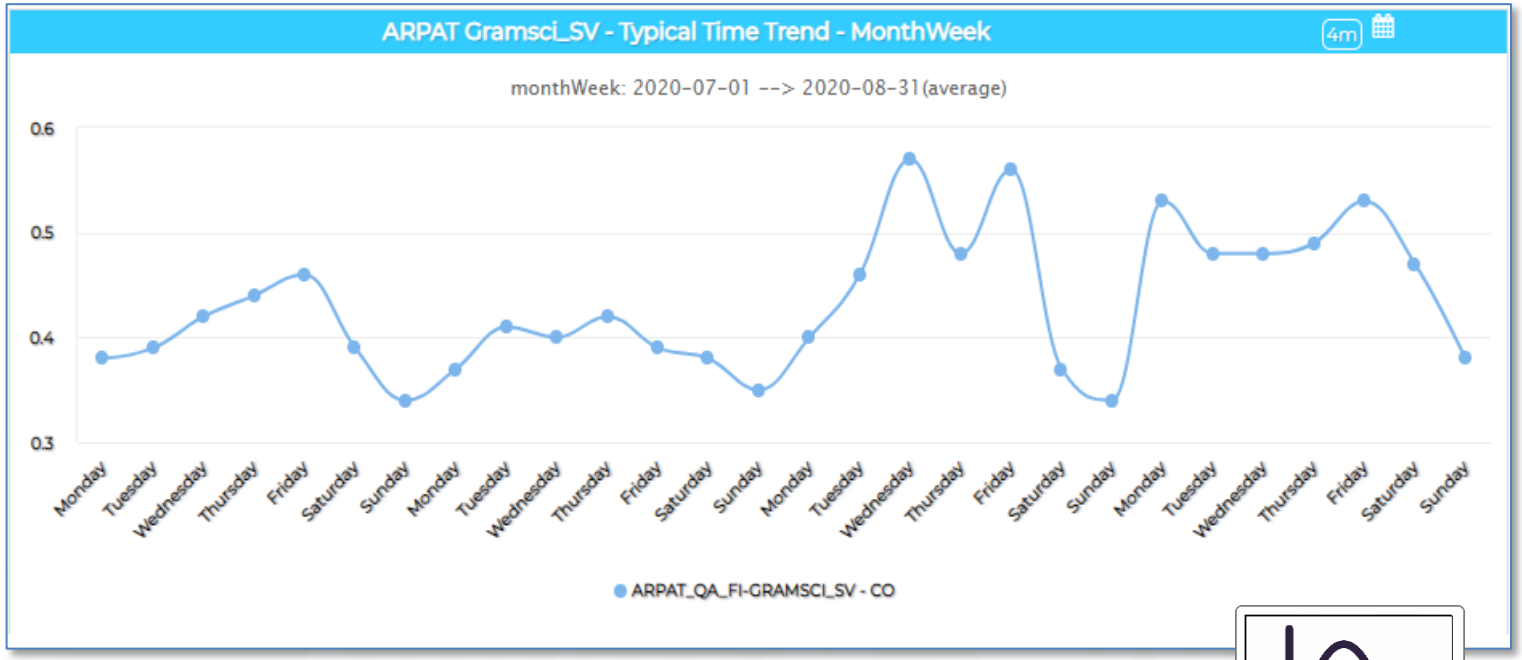
TTT: Month Day





- **MonthDay**:
  - a value per day,
  - 30 values of the month.
  - Aligned from the first day of the month
  - computed on the basis of a Time range: from-to including that date
    - e.g.: 2 months
    - As min, max, average, median
    - You can change the data on view

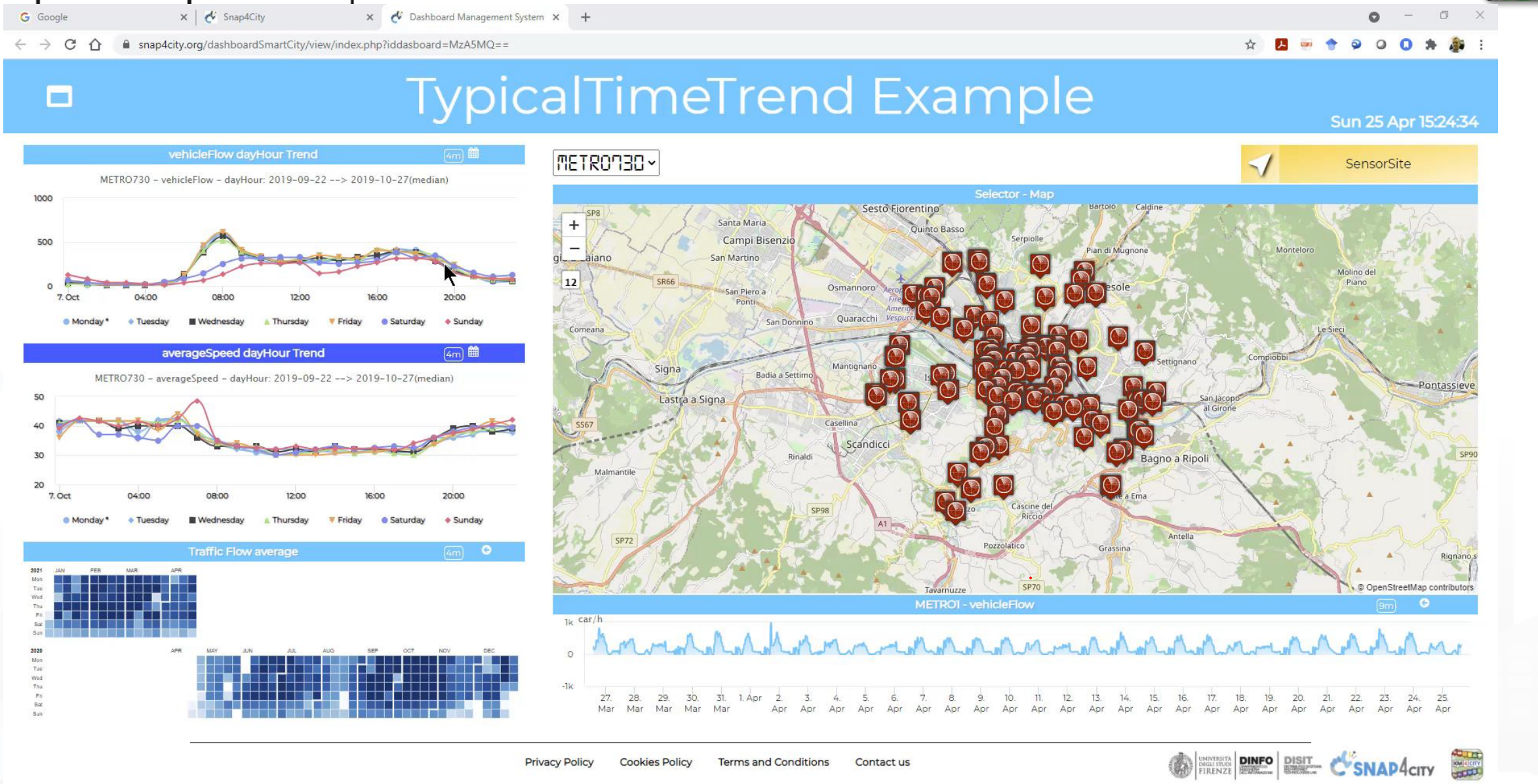
TTT: Month Week



- **MonthWeek**:
  - a value per day,
  - 30 values of the month.
  - Aligned from the first Monday of the first week of the month
  - computed on the basis of a Time range: from-to including that date
    - e.g.: 2 months
    - As min, max, average, median
    - You can change the data on view

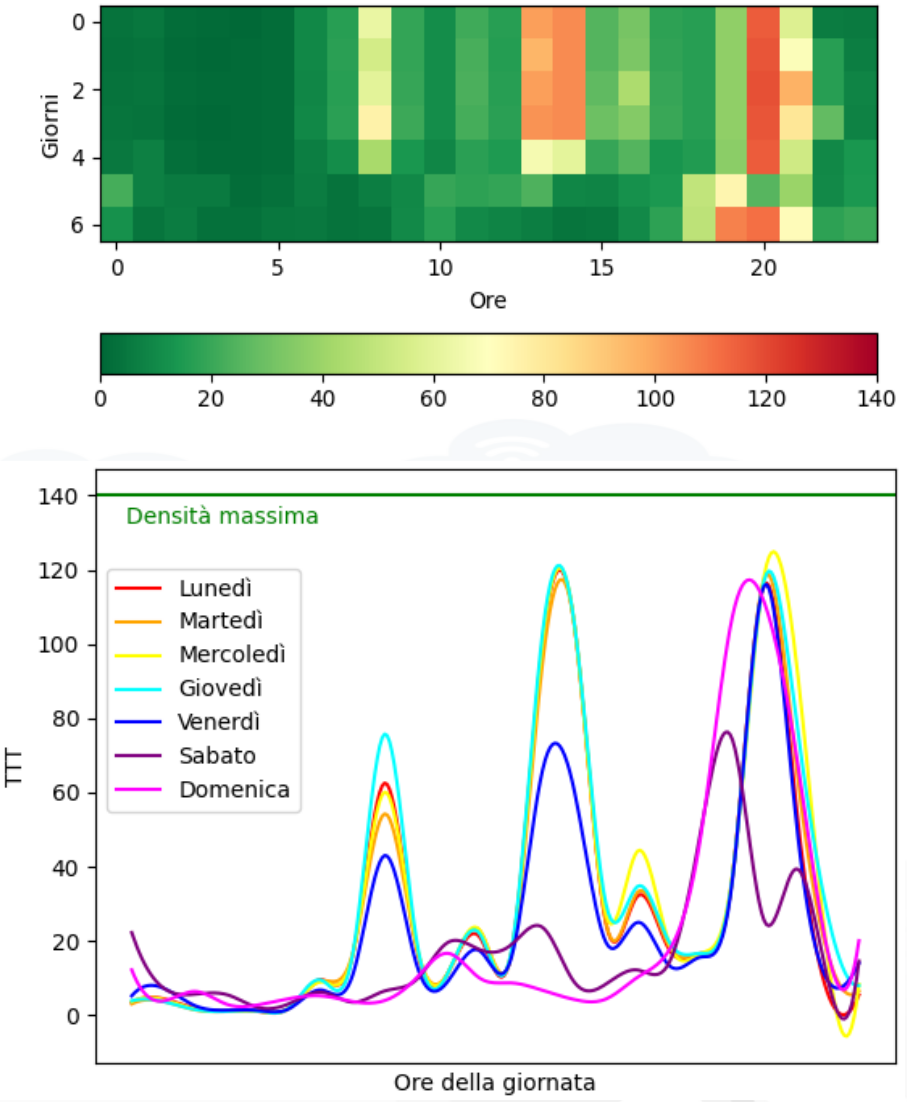


Typical Time Trends

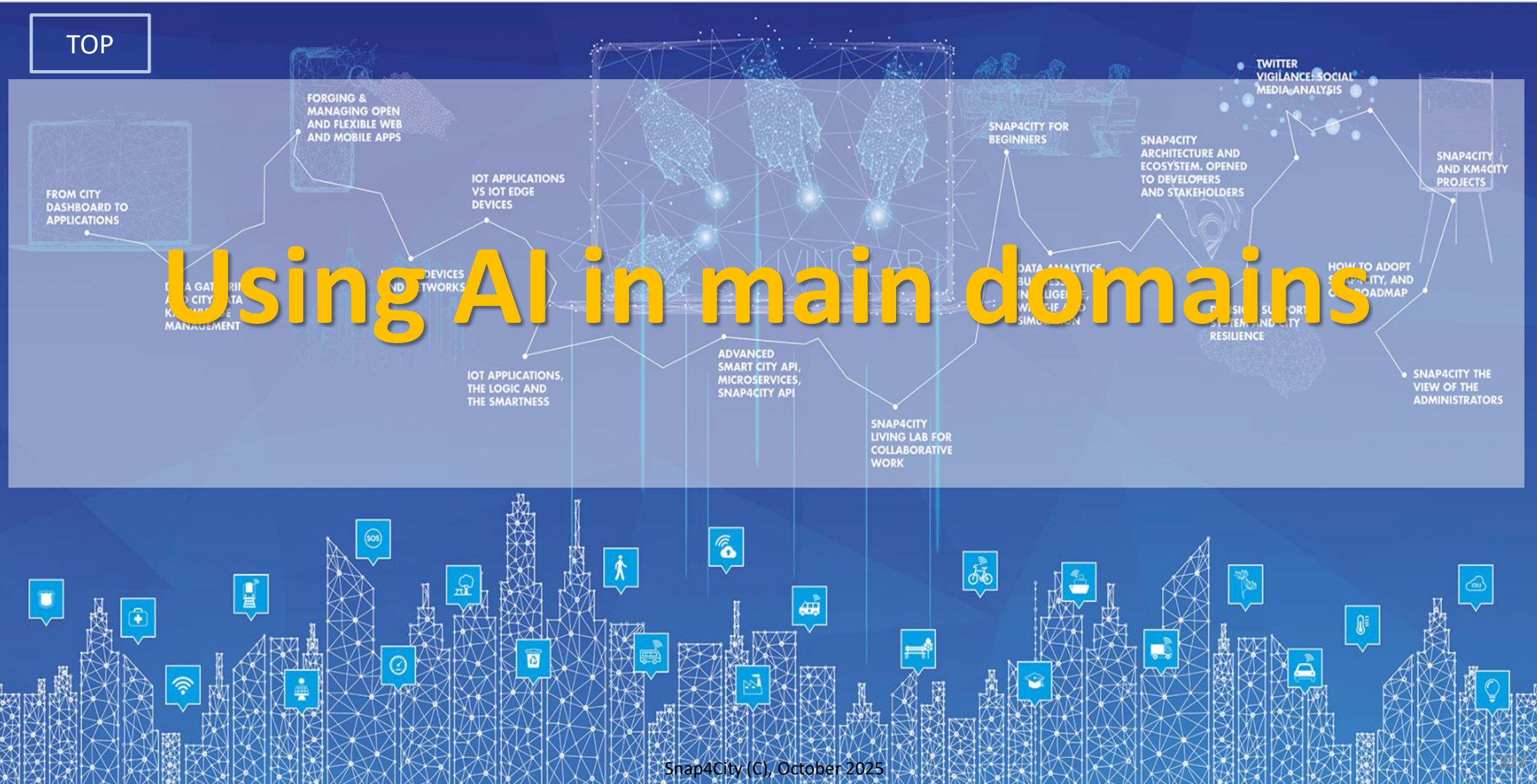


Typical Time Trends

- They can be used for:
  - Computing traffic flow reconstruction
  - Long terms predictions
  - Scenarios and conditions
  - Semaphores conditions
  - Smart Lights conditions



TOP



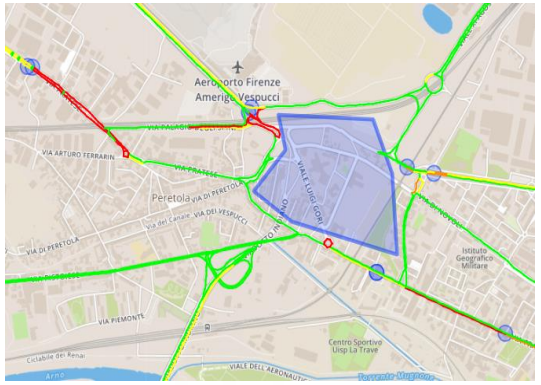
Using AI in main domains

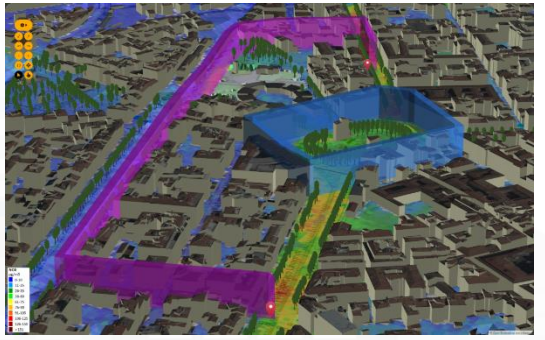
Mobility and Transport



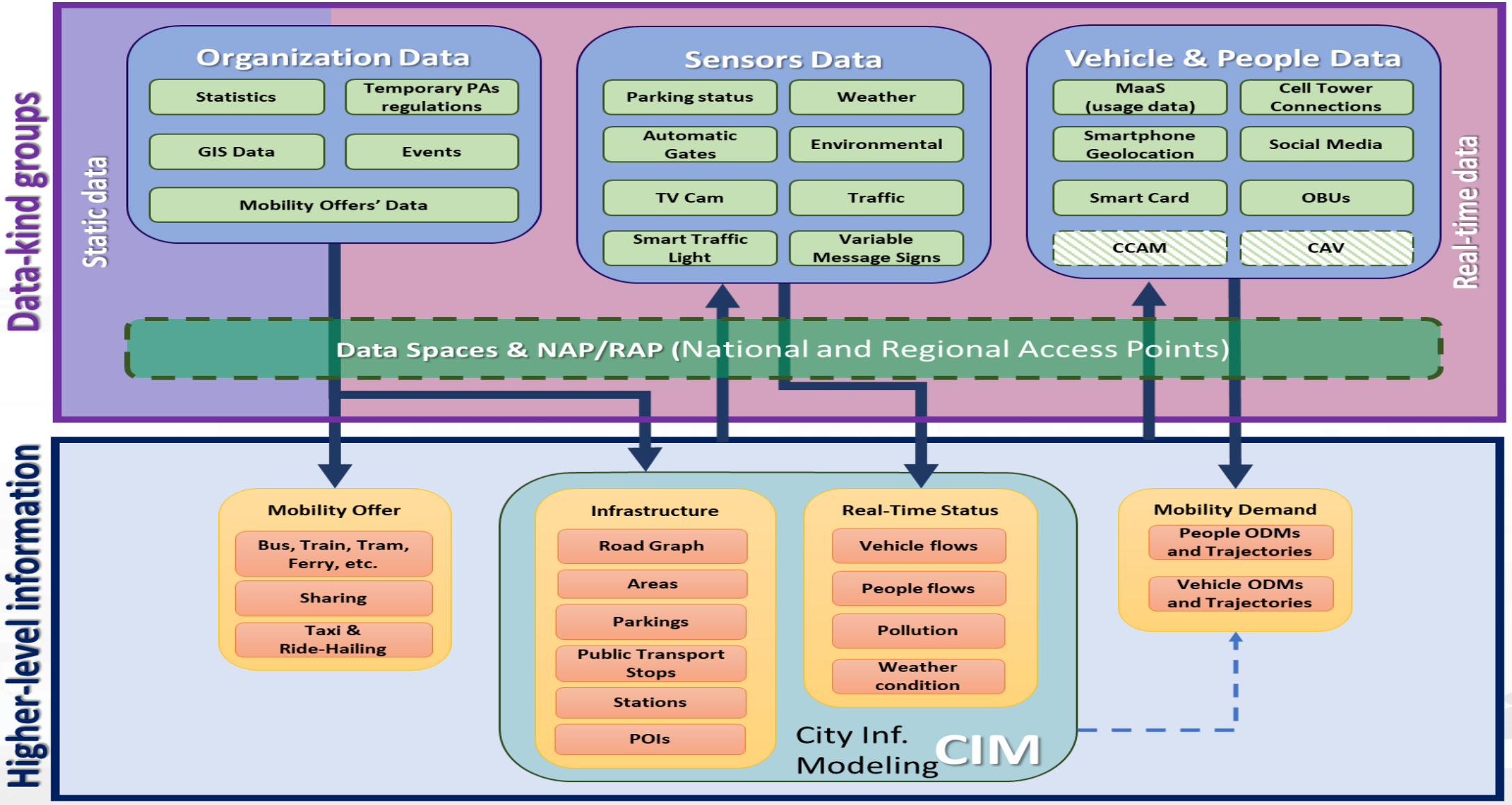
Tools for Mobility and Transport (2024/8)

- Optimisation of viability of an area for reducing congestion, waiting time, stops
- Optimisation of Traffic Light Plans, synchronization, in an area for reducing congestion, waiting time, stops
- Predictions for: traffic flow, smart parking, smart bike sharing, people flows, etc. (ML, DL)
- What if analysis: routing, traffic flow, demand vs offer, pollutant, etc. (Simulation + ML)
- Traffic flow reconstruction from sensors and other sources (simulation + ML)
- Public Transportation: Ingestion and modelling of GTFS, Transmodel, NeTEx, etc. (DP)
  - Analysis of the demand mobility vs offer transport of according to public transportation and multiple data sources (Simulation)
  - Assessing quality of public transportation (analysis)
- Accidents heatmaps, anomaly detection (analysis, ML)
- Road light controlled by traffic conditions
- Tracking fleets, people, via devices: OBU, OBD2, mobile apps, etc. (DP)
- Routing and multimodal routing (multistop travel planning), constrained routing, dynamic routing (DA)
- Computing Origin Destination Matrices from different kind of data (analysis, DP, DP)
- Computing typical trajectories on the basis of tracks (analysis, ML)
- Fleet management, monitoring, booking, allocation, maintenance
- Computing Messages for Connected drive (DP)
- Slow and Fast Mobility 15 Minute City Indexes (analysis, DP, …ML)
- Computing and comparing traffic flow on devices and at the city border (analysis)
- Typical time trends for traffic flow and IoT Time series. (analysis, ML)
- Impact of COVID-19 on mobility and transport
- Computing SUMI, PUMS, etc. (mainly DP)
- Definition of Scenarios: traffic, road graph, conditions, etc.
- Etc.

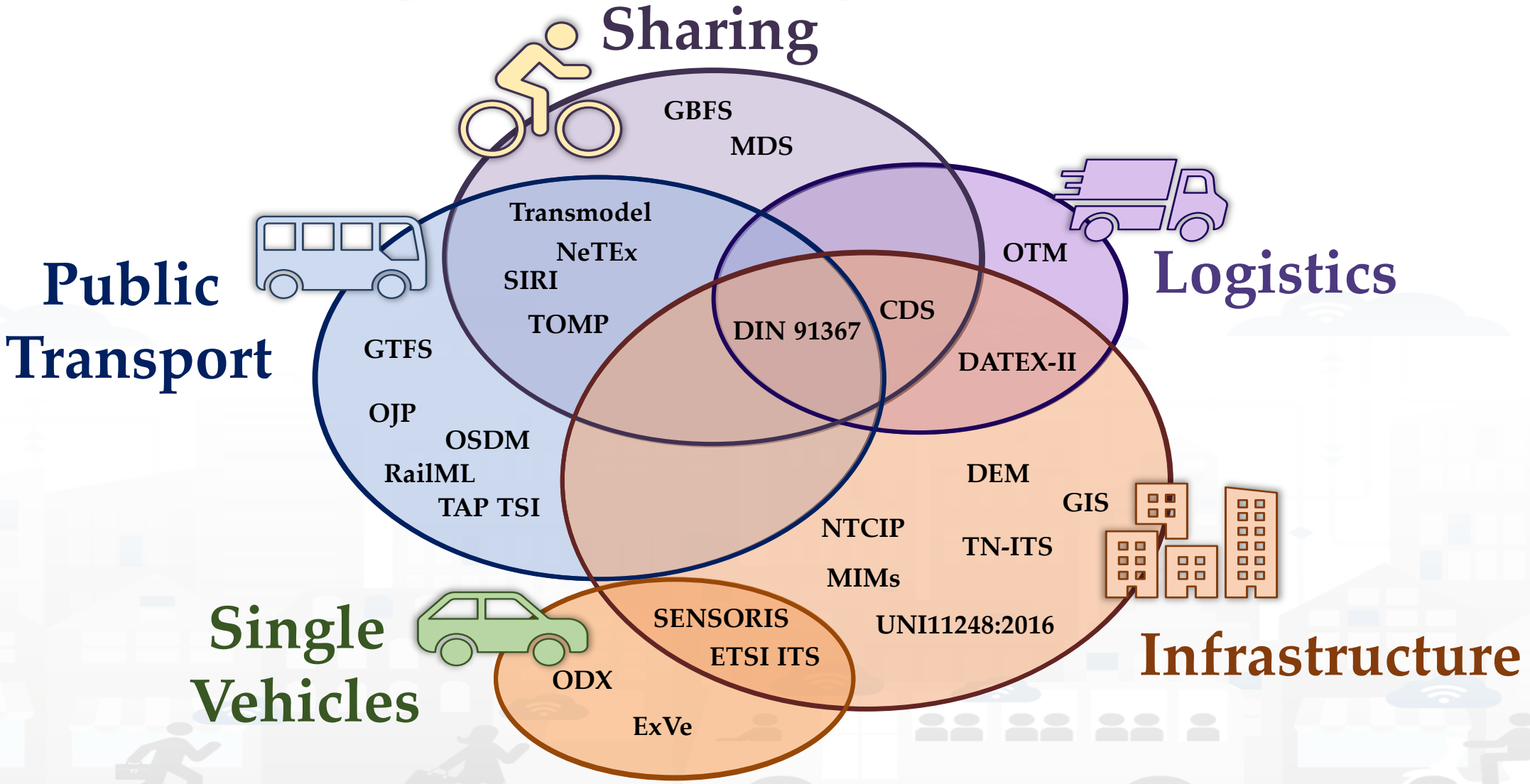




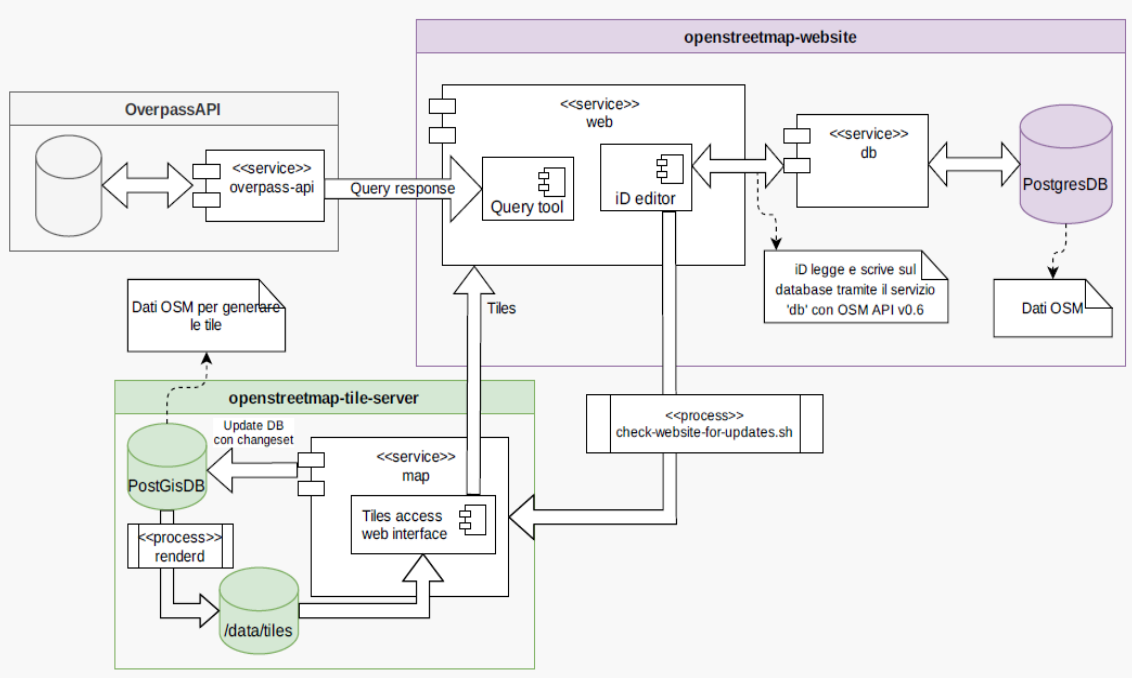
From data to higher level information: Mob.Dom.

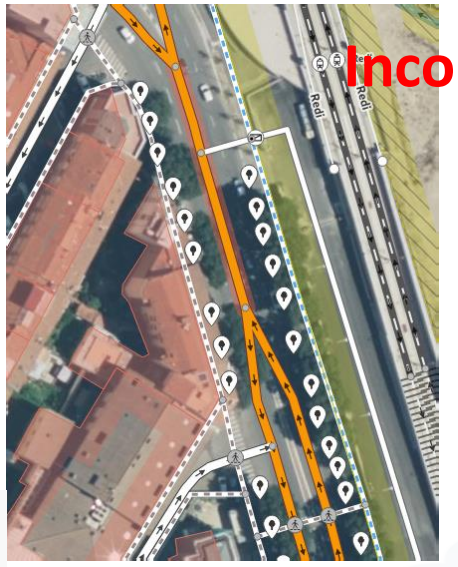


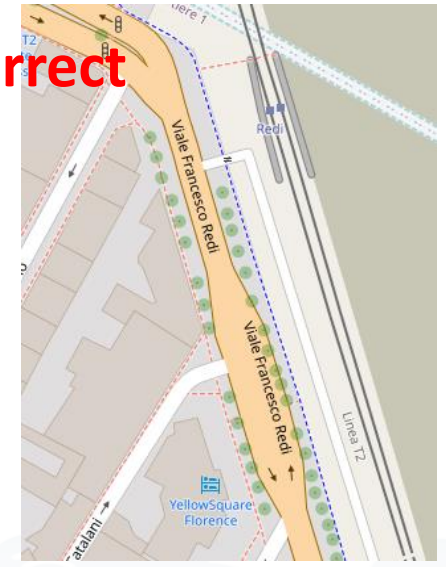
Coverage of Mobility data formats



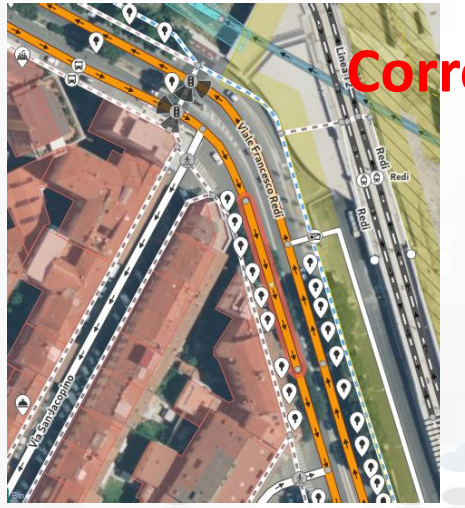
Correcting road graphs from OSM

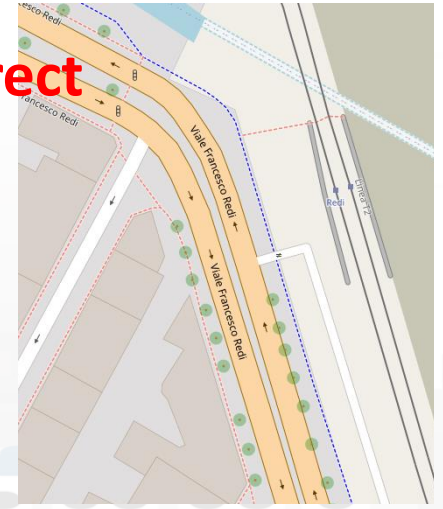






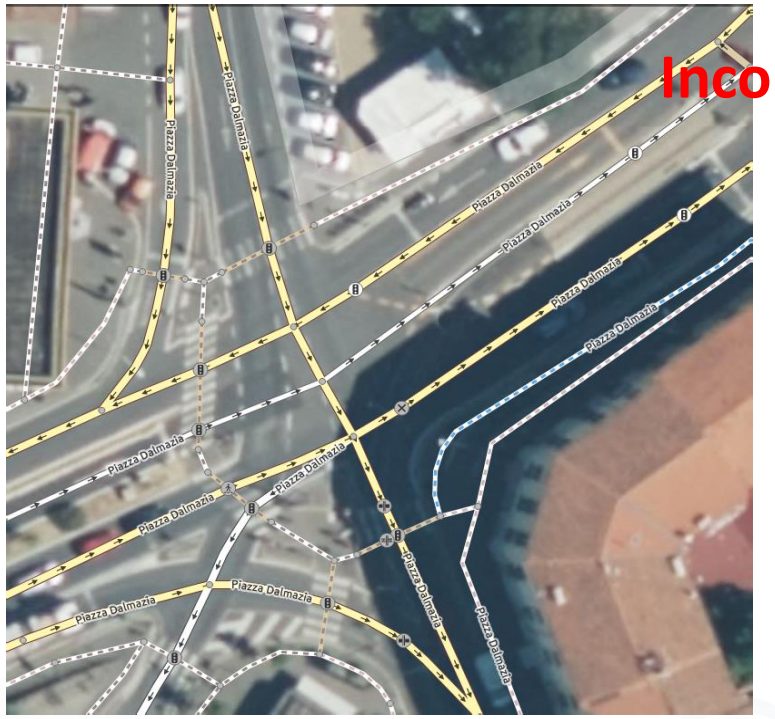
OSM data with non clear double bidirection lane on Viale Redi, Florence.
Editing OSM data and present Tiles



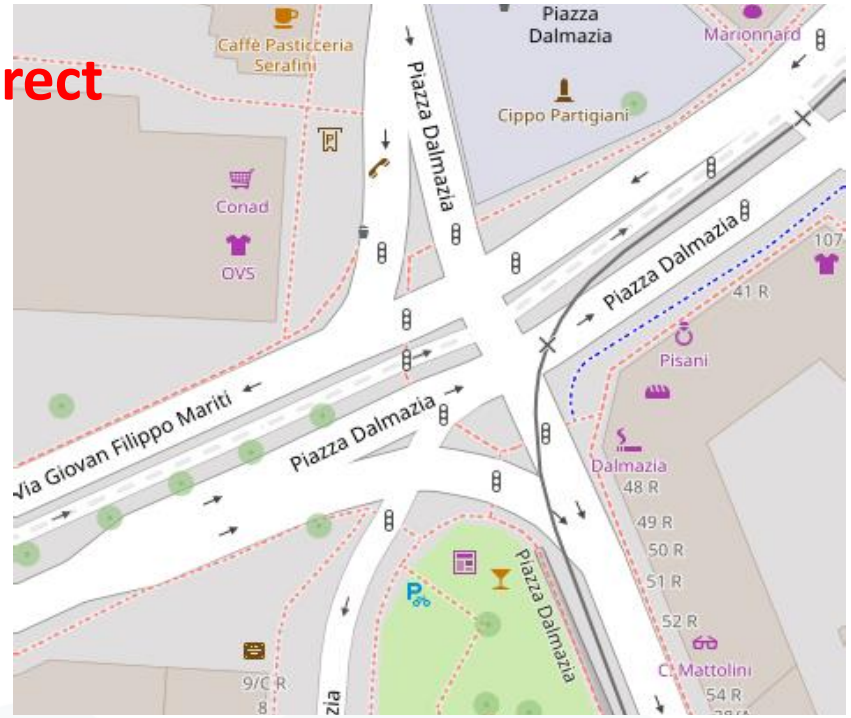


After Corretion of OSM data defining a clear double bidirection lane on Viale Redi, Florence.
Regeneration of the TILEs for the maps

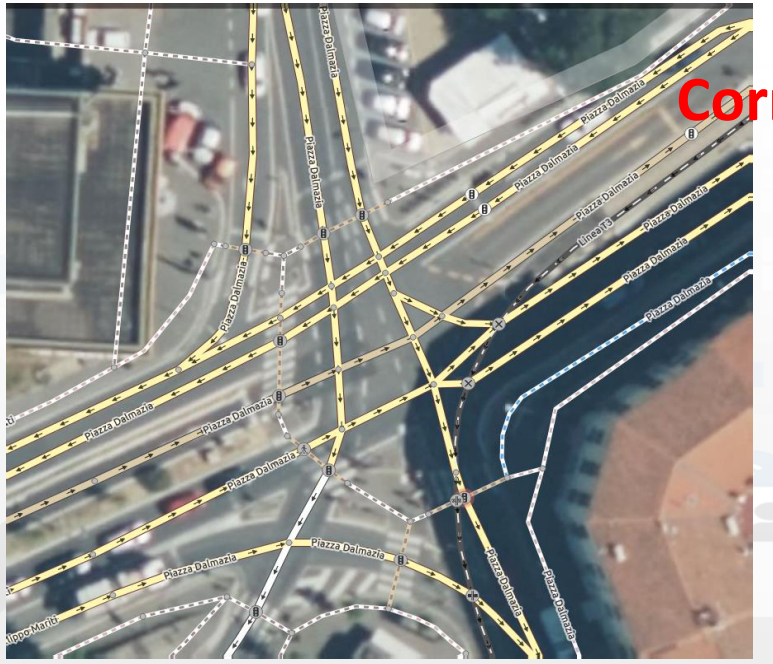
OSM data with non correct viability in Piazza Dalmazia, Firenze



Incorrect



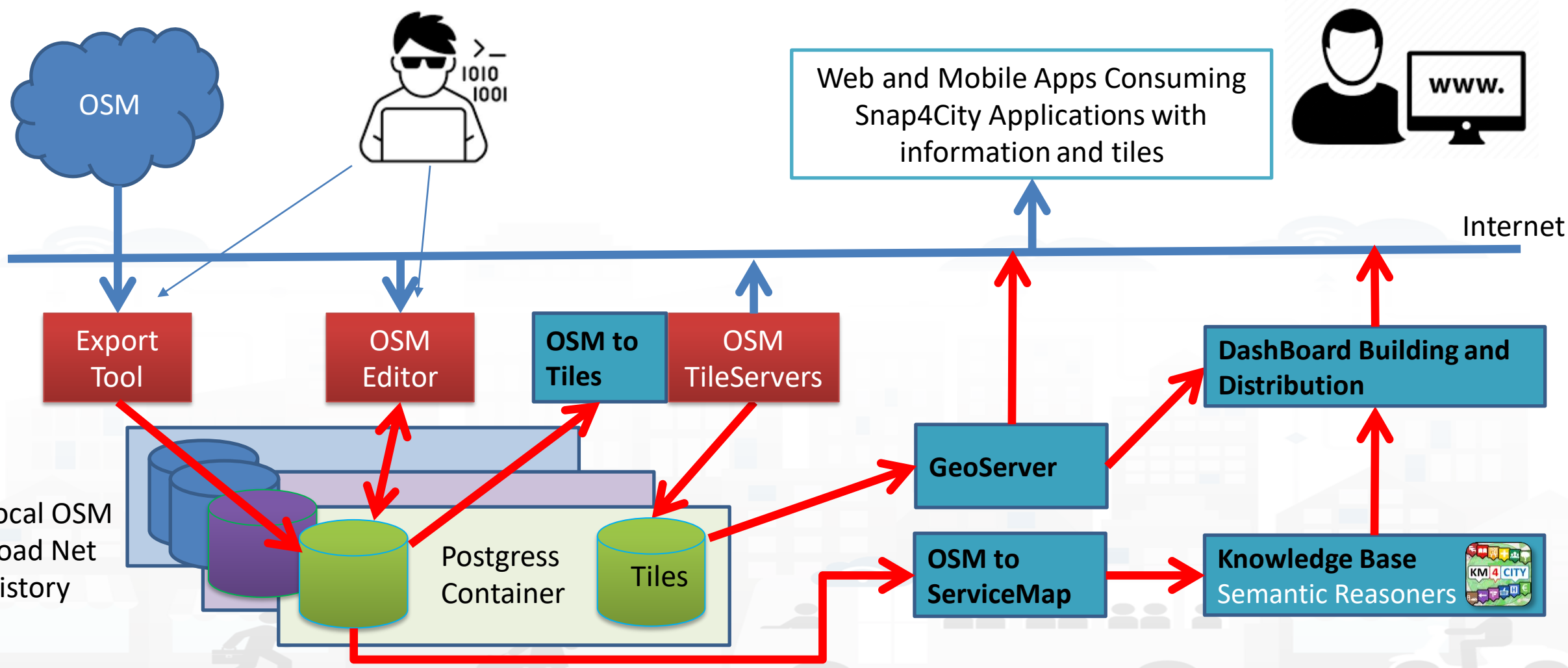
After Correction of OSM data defining a correct viability of Piazza Dalmazia, Florence. Regeneration of the TILEs for the maps



Correct

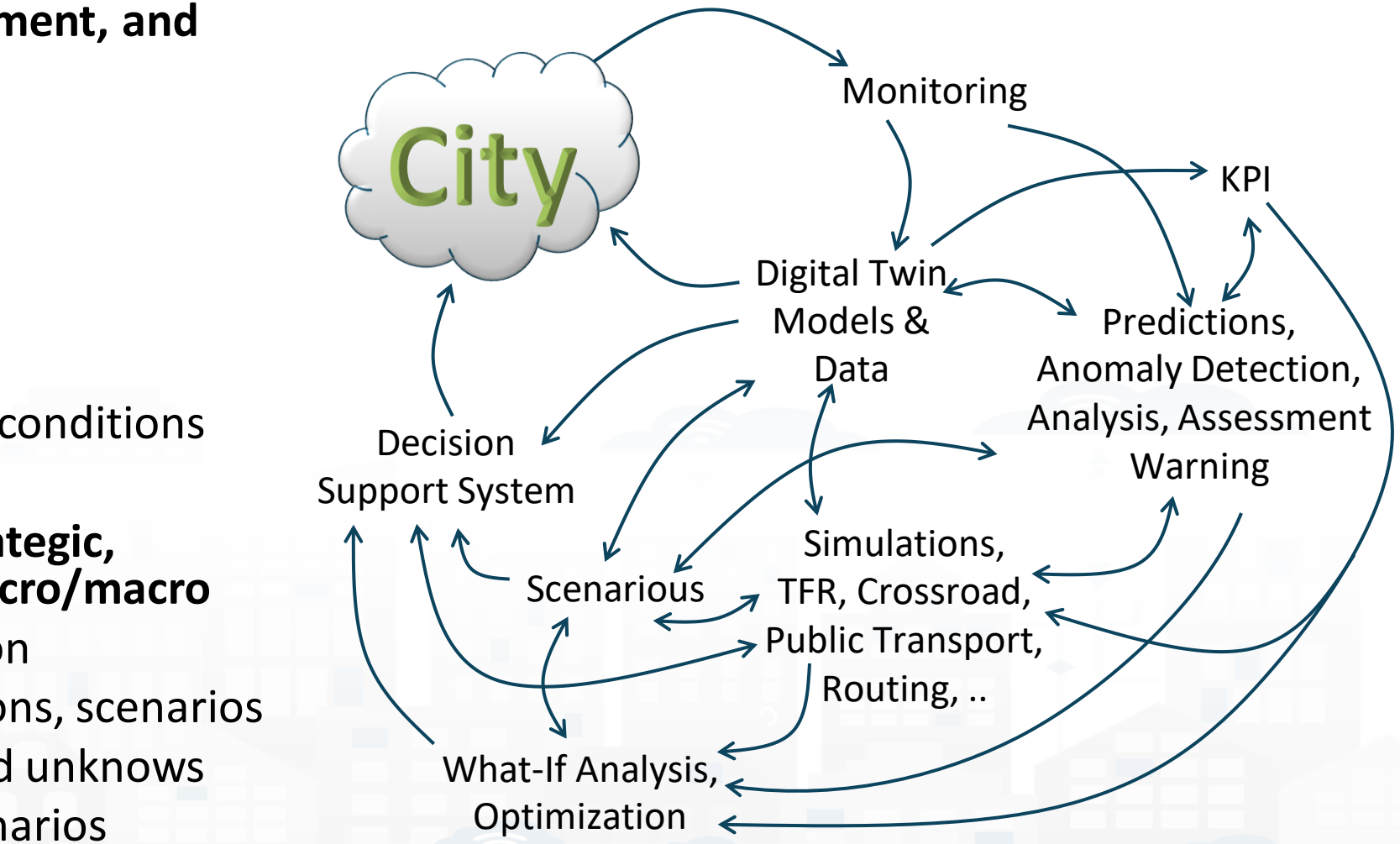


From OSM to ServiceMap / Km4City

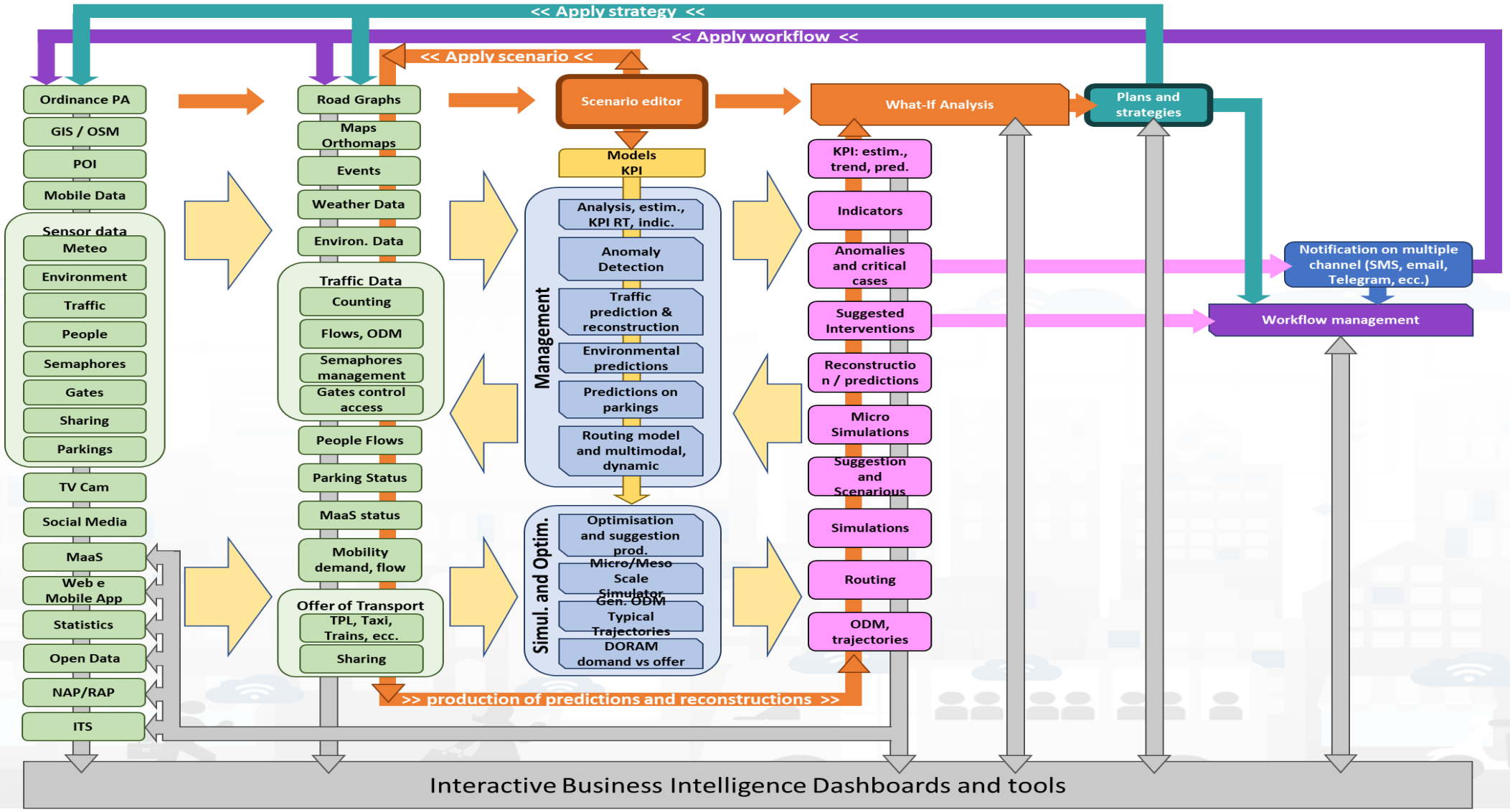


Main tasks

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Early warning on critical conditions
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders



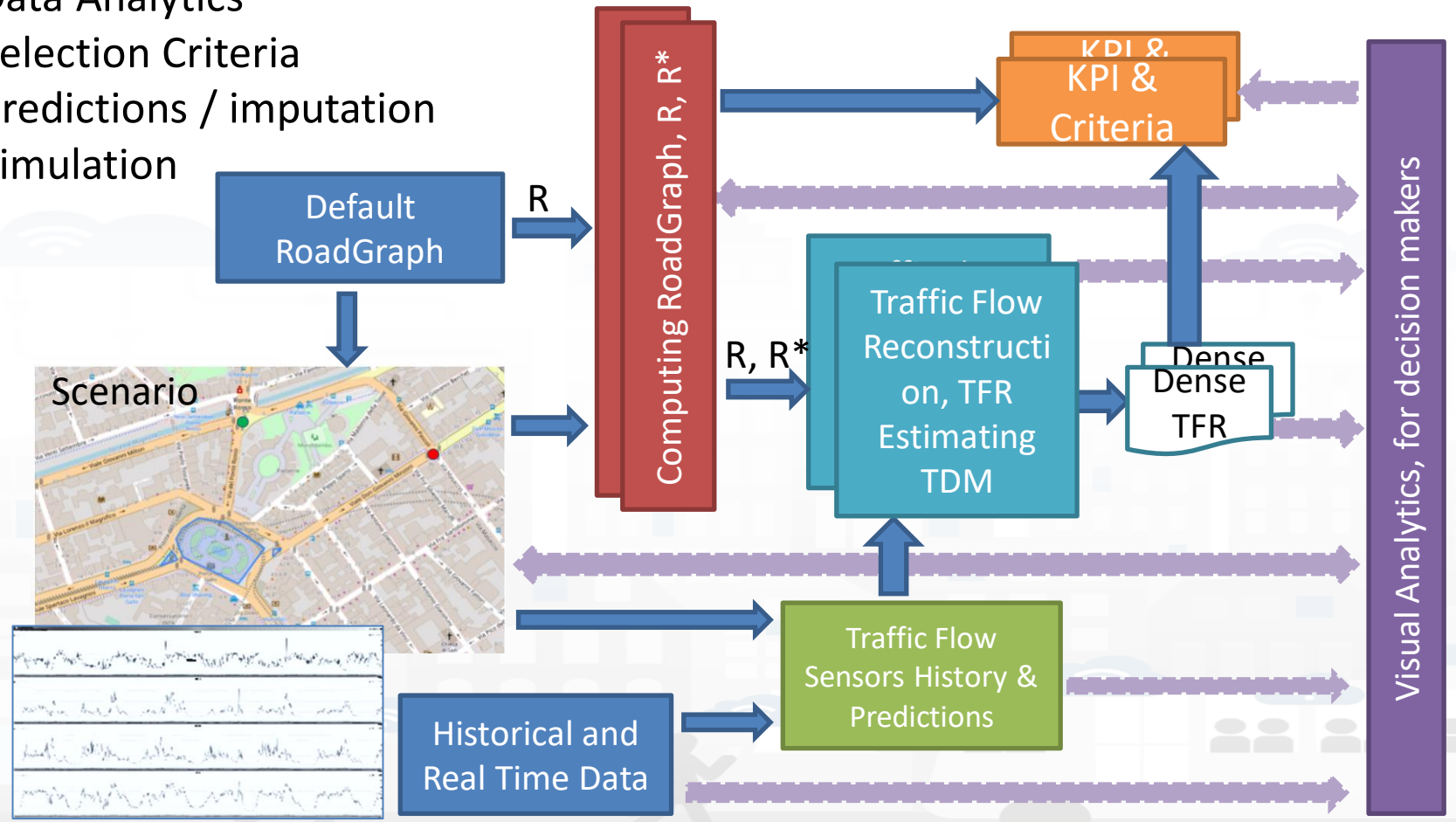
Data Flows among data formats/models



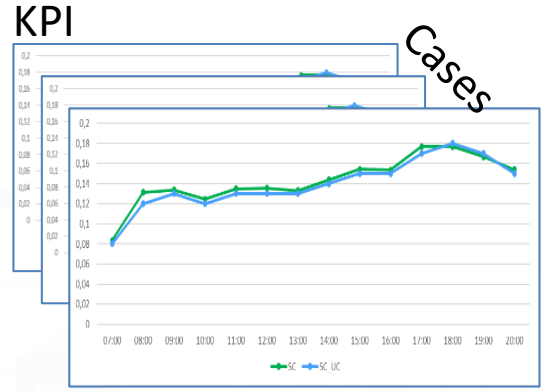
What-if: Simulation for Traffic Flow

At the same color corresponds the same area:

- Data / information
- Data Analytics
- Selection Criteria
- Predictions / imputation
- Simulation

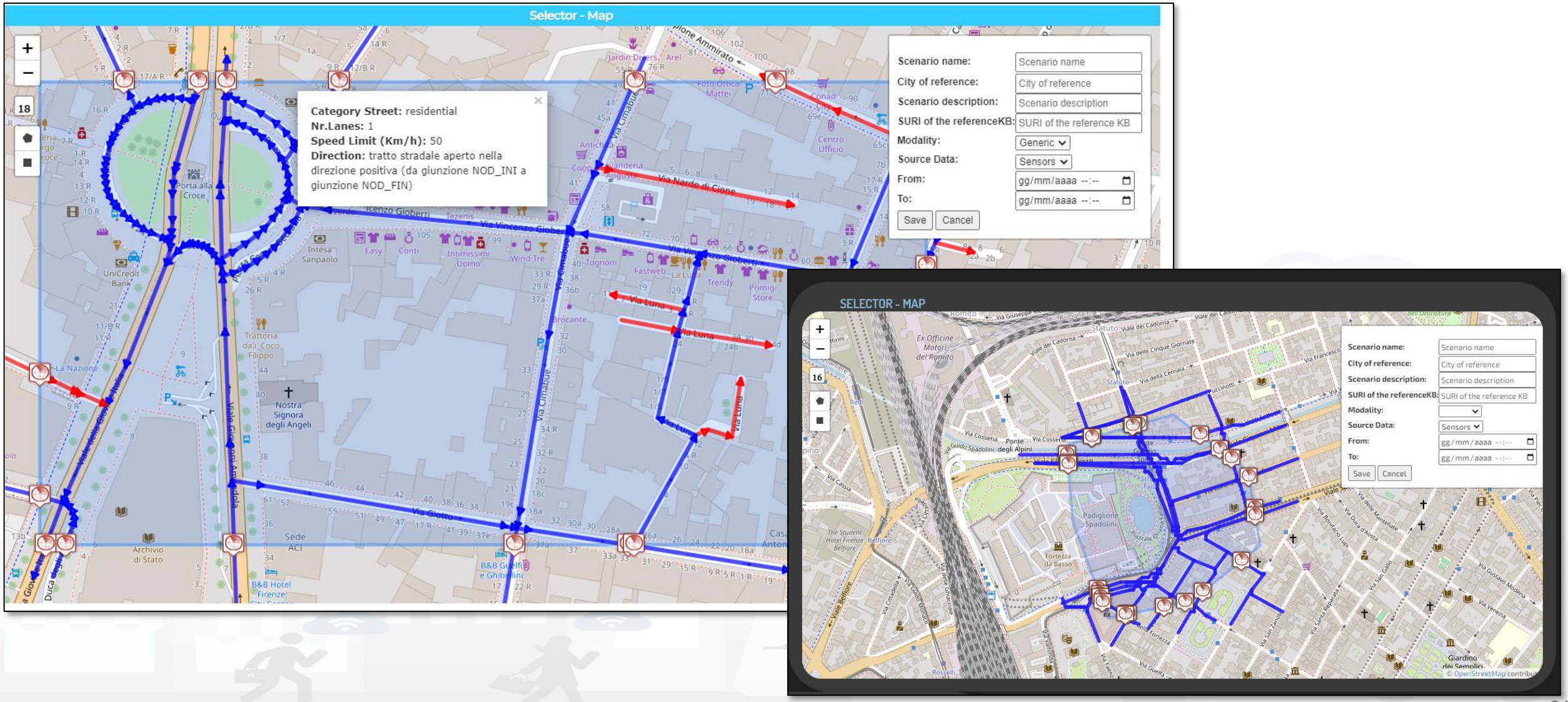


Data Driven Decision

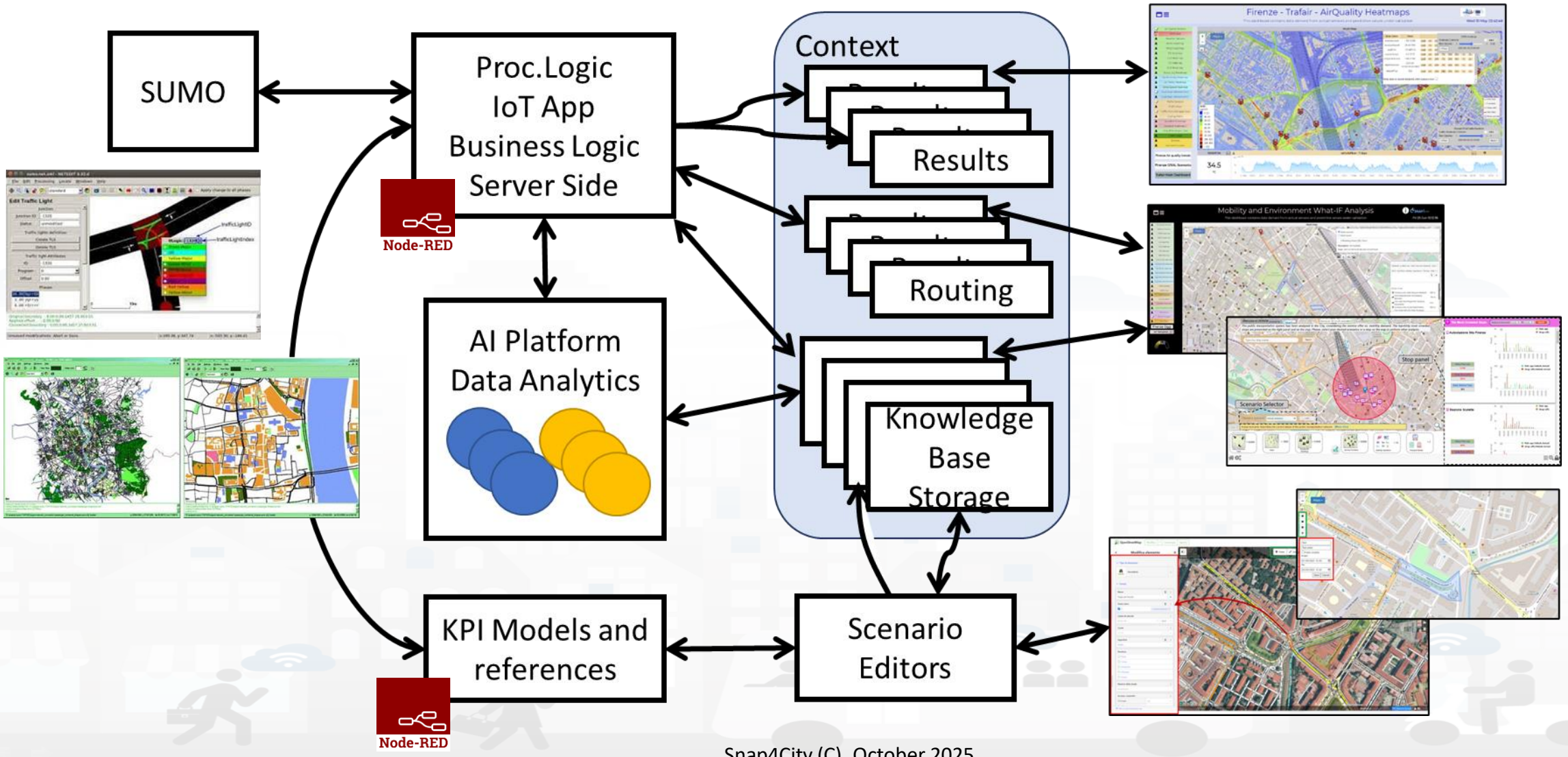




An instance of Scenario Editor



Micro / Macro Simulation



What-if-Analysis and Infrastructure Optimization ….

Aim of Decongestion, Sustainability

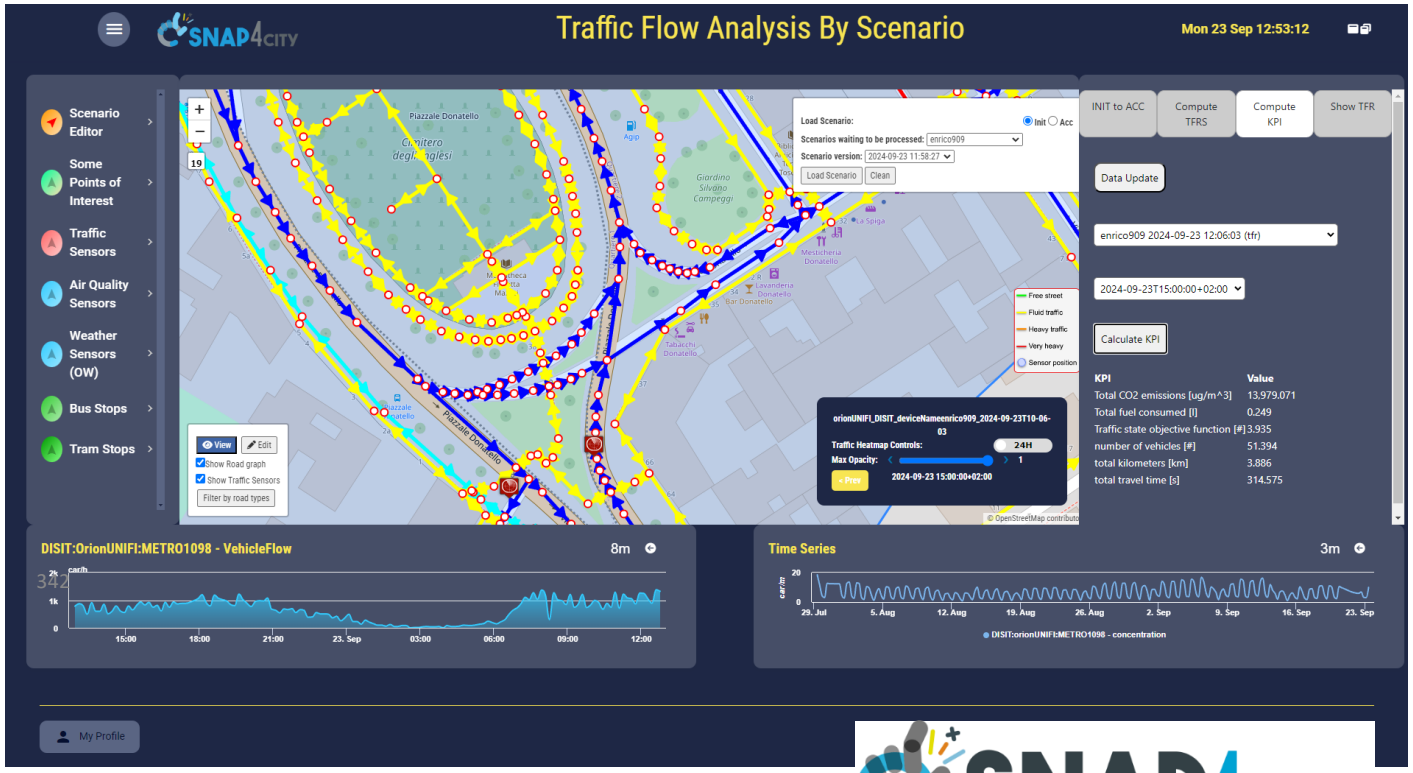
- Reduction of emissions, # stops
- Reduction of travel time

What-if analysis on Operation/Plan

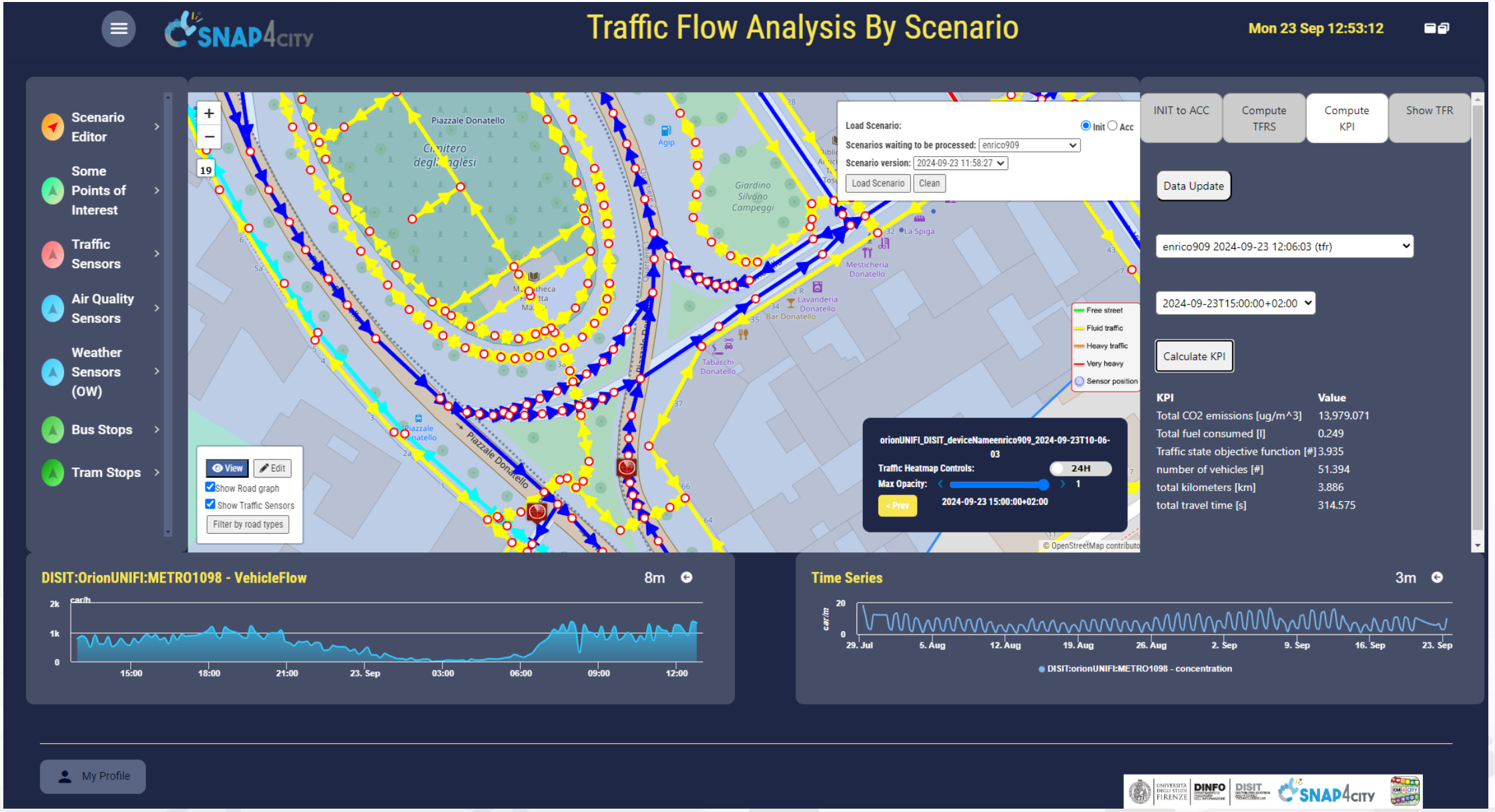
- Working by scenarios making Hyp.
- Simulating the results on conditions
  - **Generative AI and/or neuro-Symbolic**
- Computing KPI and providing suggestions

Optimisation on Plan

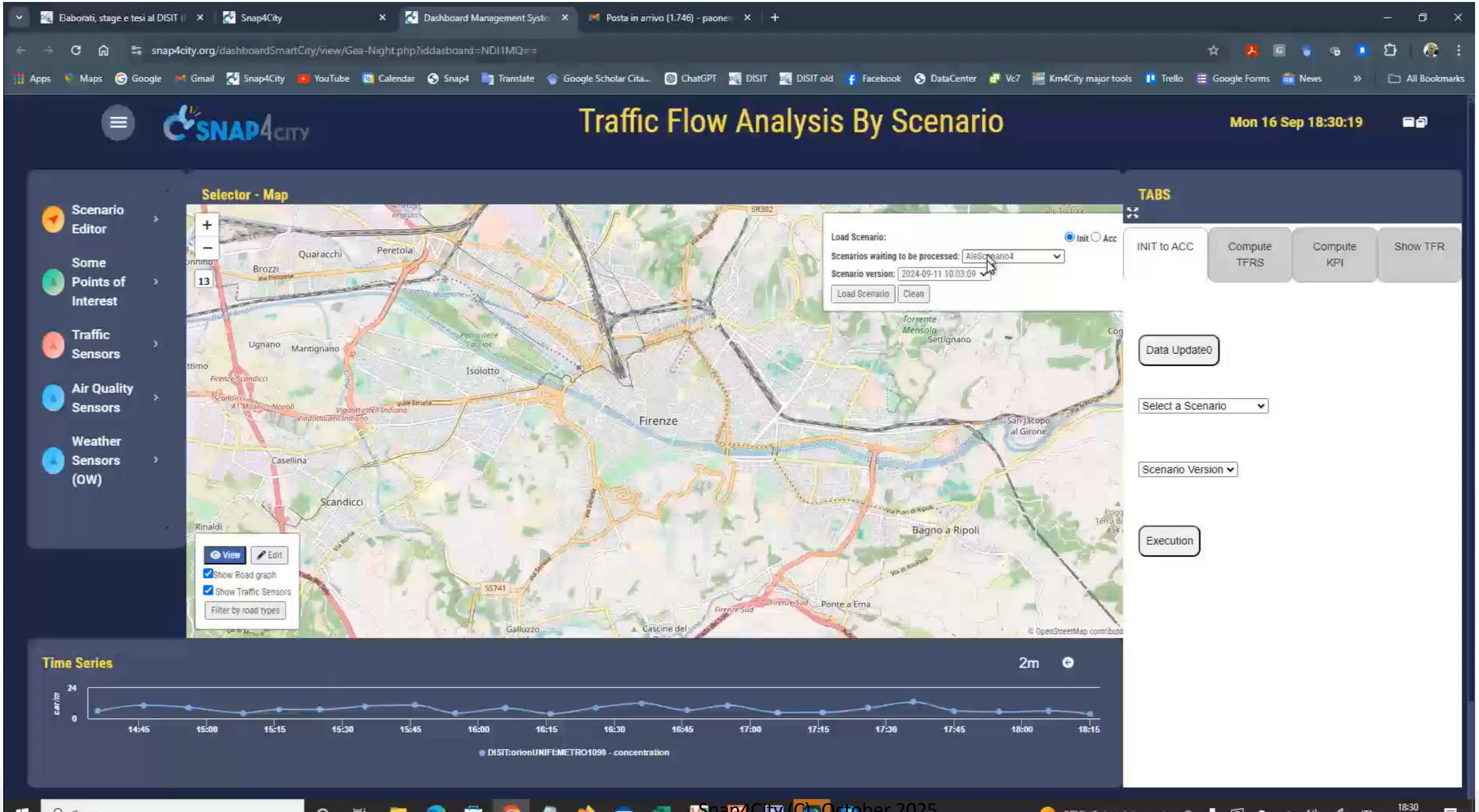
- Making Scenario for the context
- Defining constraints and conditions
- Asking to AI to **generate best solutions**
- **Offering Optimal Solution** in terms of
  - Solutions and Explanations



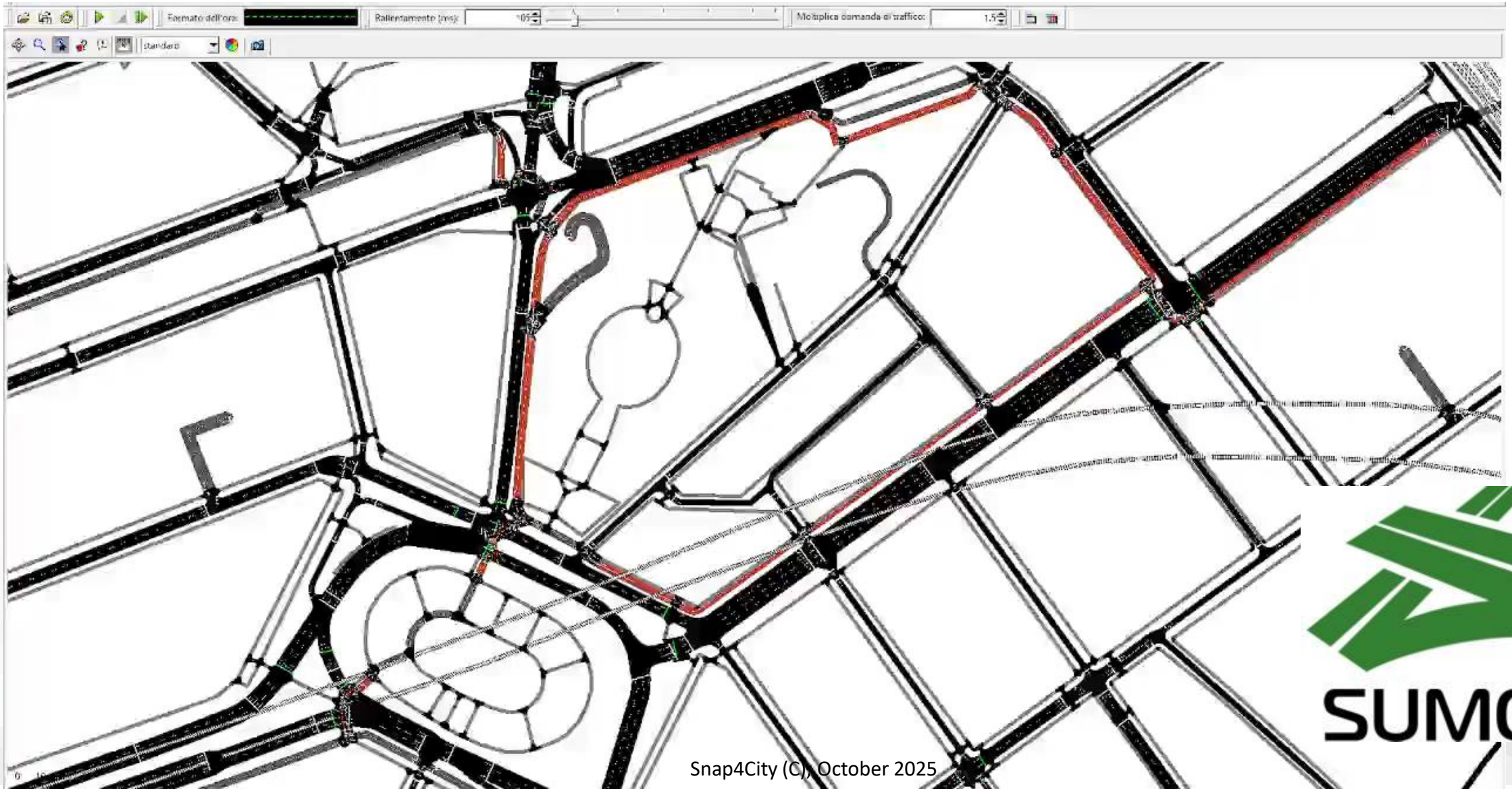
What-if on TFR



What-if on TFR



Micro Simulation



SUMO

High Computational Complexity Tasks

- optimization of trip routing for waste collection (Day by day, Real time, by scenarios)
- learning of TDM for traffic flow reconstruction (PDE solution), used for computing in real time or by scenarios:
  - traffic flow reconstruction
  - semaphore time cycle optimisation, semaphore synchronization
- computing 3D shapes from Lidar Scanning, AND
  - photogrammetric mapping of images on 3D shapes from Lidar or extruded solids
- Traffic flow/pollutant predictions on large number of devices and networks
- computing in real time KPI for anomaly detection, early warning, etc.
- etc.

Considerations

- **Simulations, Generative AI, Reinforced Learning AI:**
  - Would produce a number of conditions, C, with eventual number of contexts, X, for which a large number of parameters can produce a set of KPI at the basis of the Loss to be minimized.
  - The explosion of combination would create an explosion on the memory space (which can be number of containers) and the computation can be performed in parallel if they can access to a corresponding number of computational resources.
- **Predictions and optimisation**
  - by scenarios can be very heavy in the training phases and more efficient in real time execution.

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Traffic Light Plan Optimization

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





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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

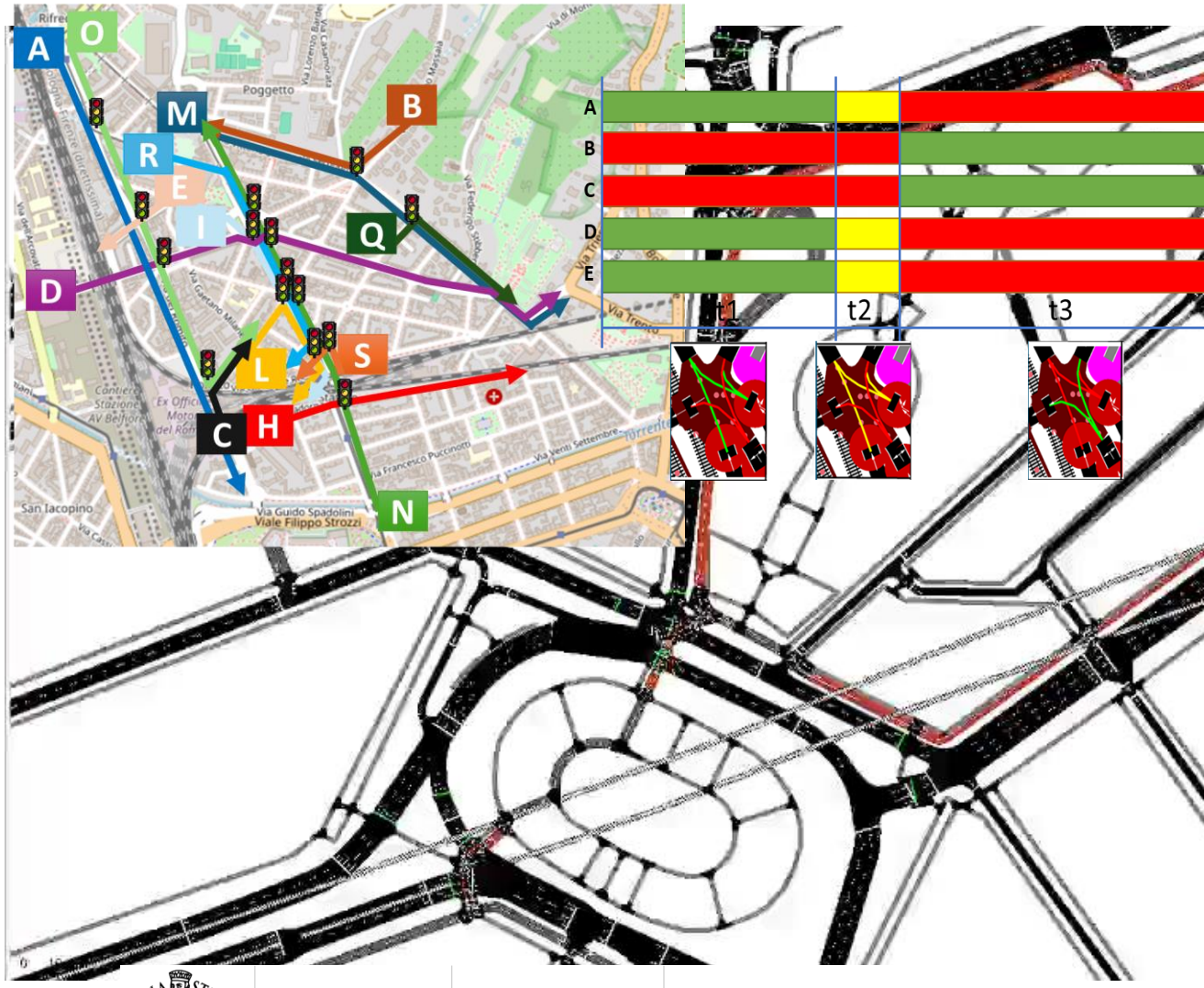
AI: Genetic Algorithms, Reinforced Learning

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

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

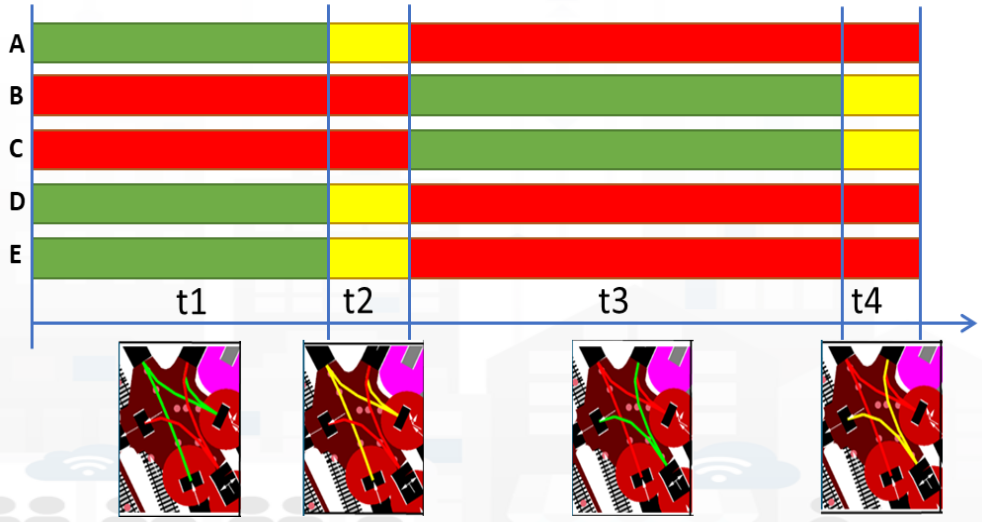
  - Travel Time, waiting time, waiting count
  - Specific travel time on directions
  - CO2 emissions, etc.

Reductions from 5% to 15%

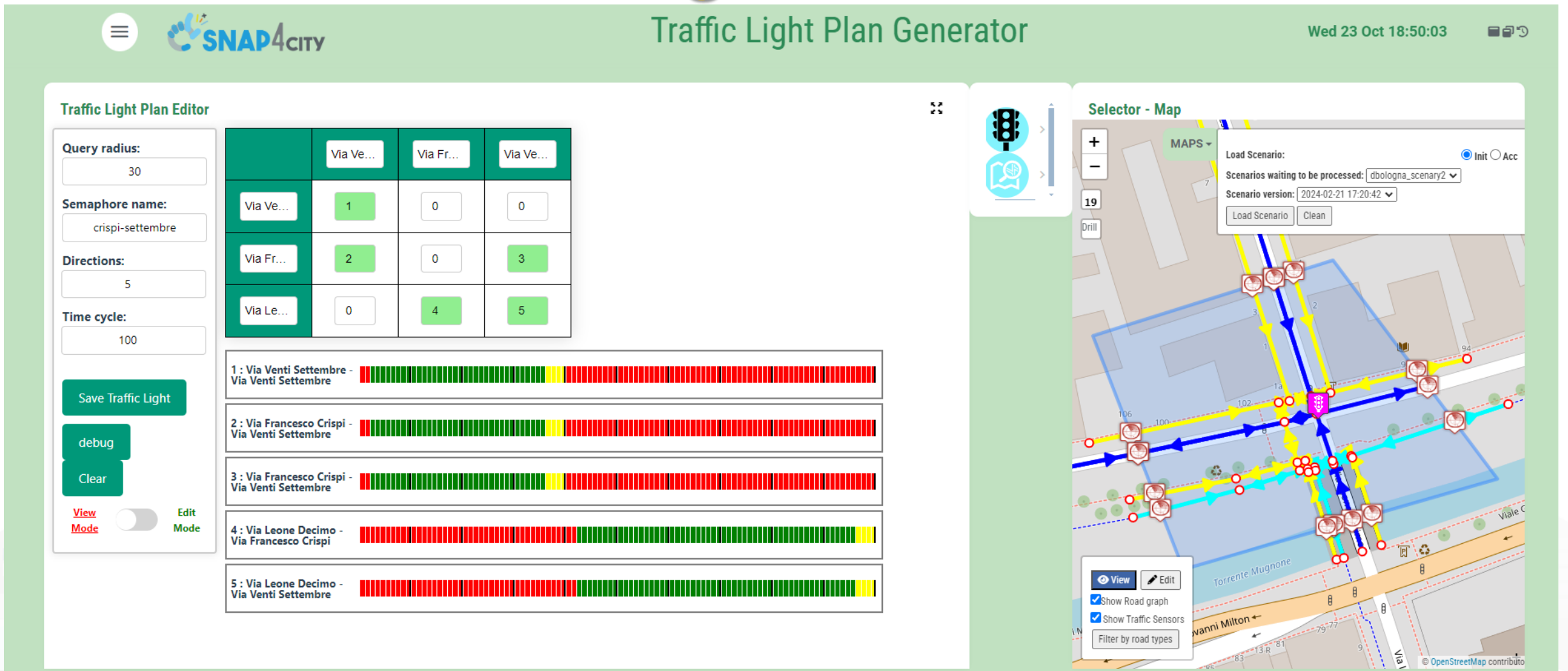


Traffic Light Plan Optimisation, Digital Twin

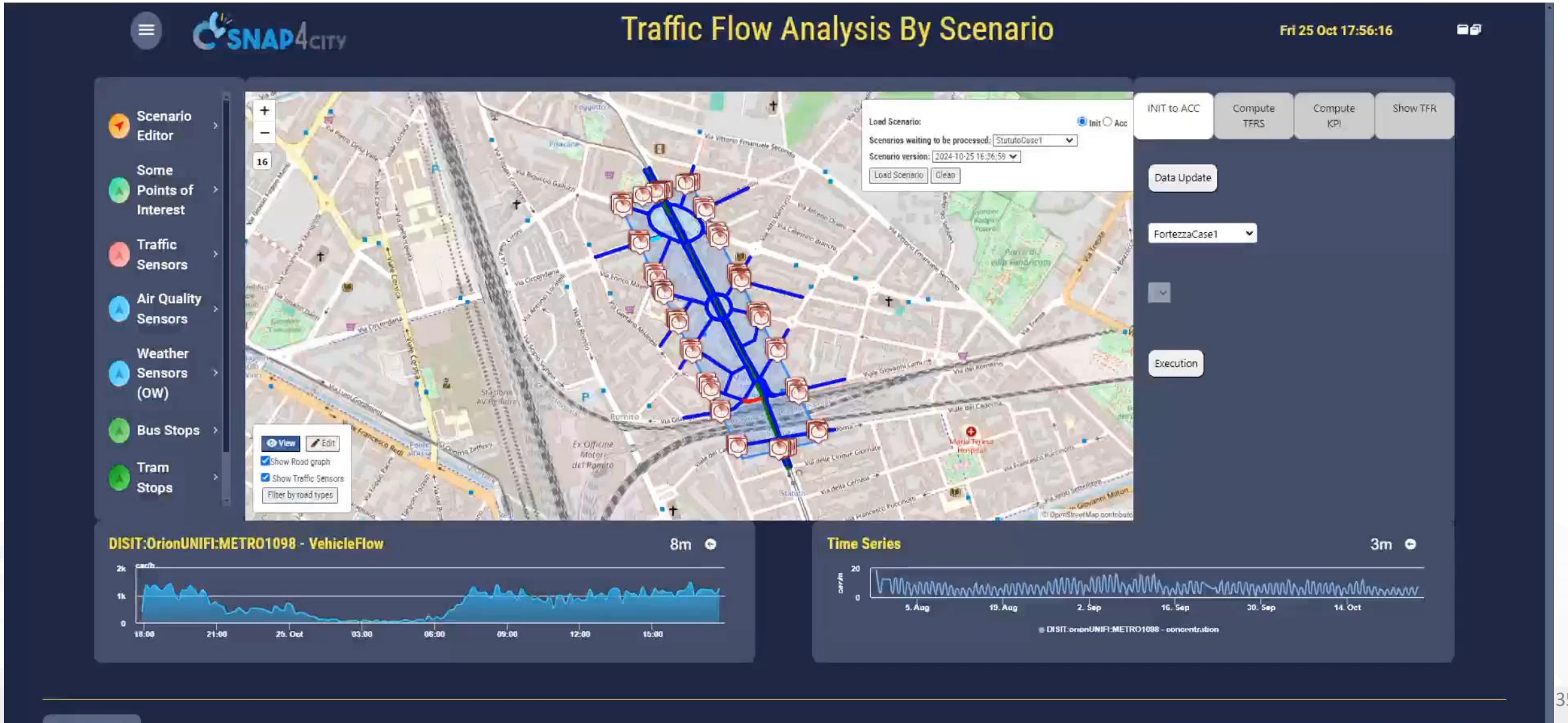
- **Match Multiple Objectives and Synchronization:**
  - public and private traffic, tramway priority
  - Micro and Macro Scales
  - **AI: Genetic Algorithms, Reinforced Learning**
    - Fixed and Actuated Cycles
    - Adjusted on Demand
- **Validation/integ.** with ***SUMO*** simulation
  - Travel Time, waiting time, waiting count, specific travel time on directions, CO2 emissions, etc.
- **Reductions from 5% to 15%**



Traffic Light Plan Editor



Optimization of Traffic Light Plan



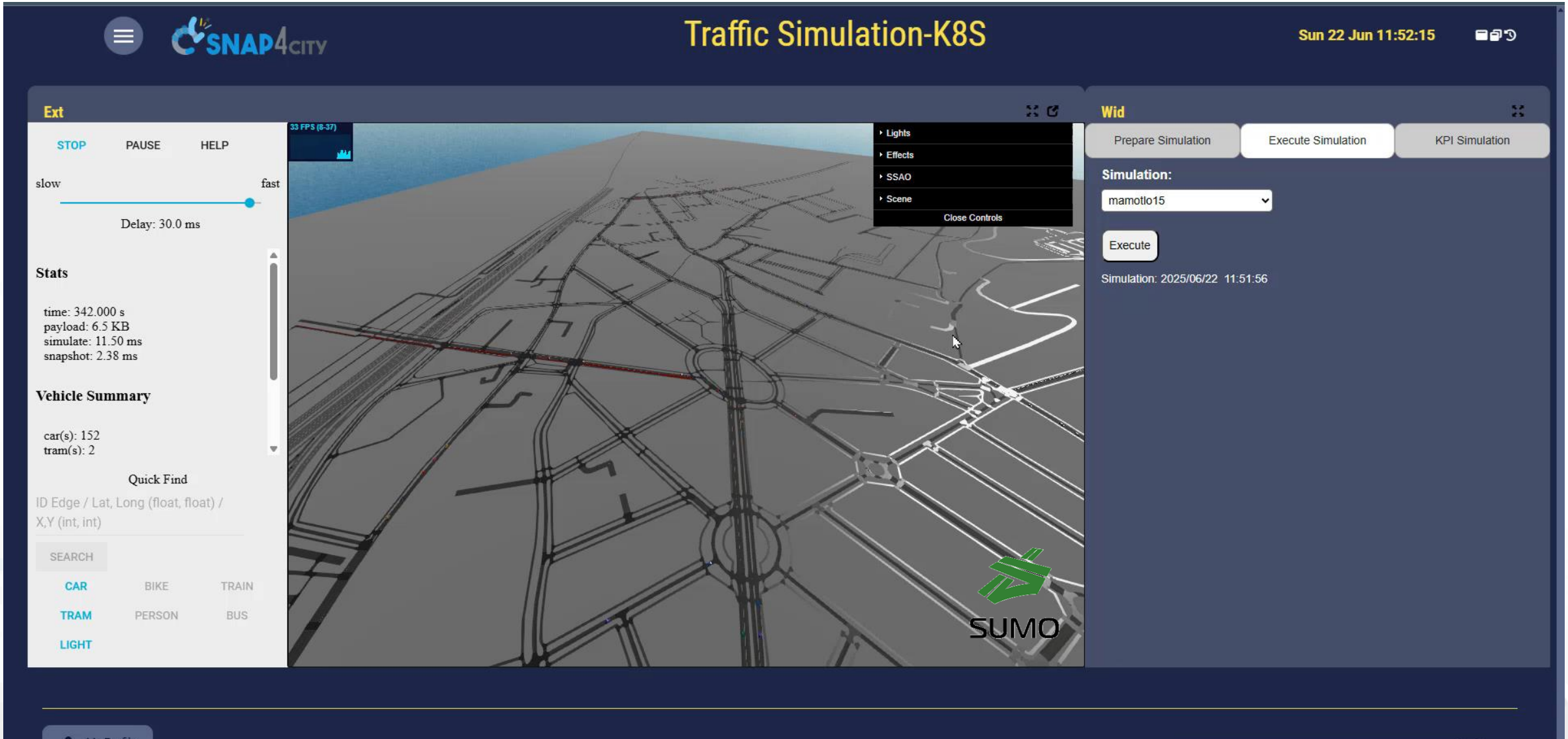
GA based: Mean Travel Time

	Traffic Load	MTTall	MTT dir_N	MTT dir_M	MTT dir_A	MTT TW Careggi	MTT TW Costanza
4TW-NTNS-MWD-P	1.5	3542.50	198.90	**242.14**	197.64	**436.00**	**427.00**
4TW-NTNS-MWD-A	1.5	**3242.71**	**178.33**	**243.28**	**195.79**	**436.00**	**427.00**
4TW-NTNS-MWD-P-A	1.5	**3242.71**	**178.33**	**243.28**	**195.79**	**436.00**	**427.00**
2TW-NTNS-MWD-P	1.5	4538.02	207.40	456.14	615.00	**436.00**	**427.00**
2TW-NTNS-MWD-A	1.5	3940.07	**179.30**	428.67	481.53	**436.00**	429.75
2TW-NTNS-MWD-P-A	1.5	4380.63	182.05	456.59	654.21	**436.00**	**427.00**
SUMO Actuated	1.5	3409.13	280.09	515.34	200.66	497.54	499.81
Webster	1.5	6474.95	465.45	441.93	210.50	1379.25	493.87
WebsterAdjusted	1.5	4035.08	195.82	441.09	205.66	463.87	447.06
		-5%	**-8%**	**-45%**	**-3%**	**-6%**	**-4.5%**

Reductions of Travel time of 3-45% and elimination of the #stops for the tramways

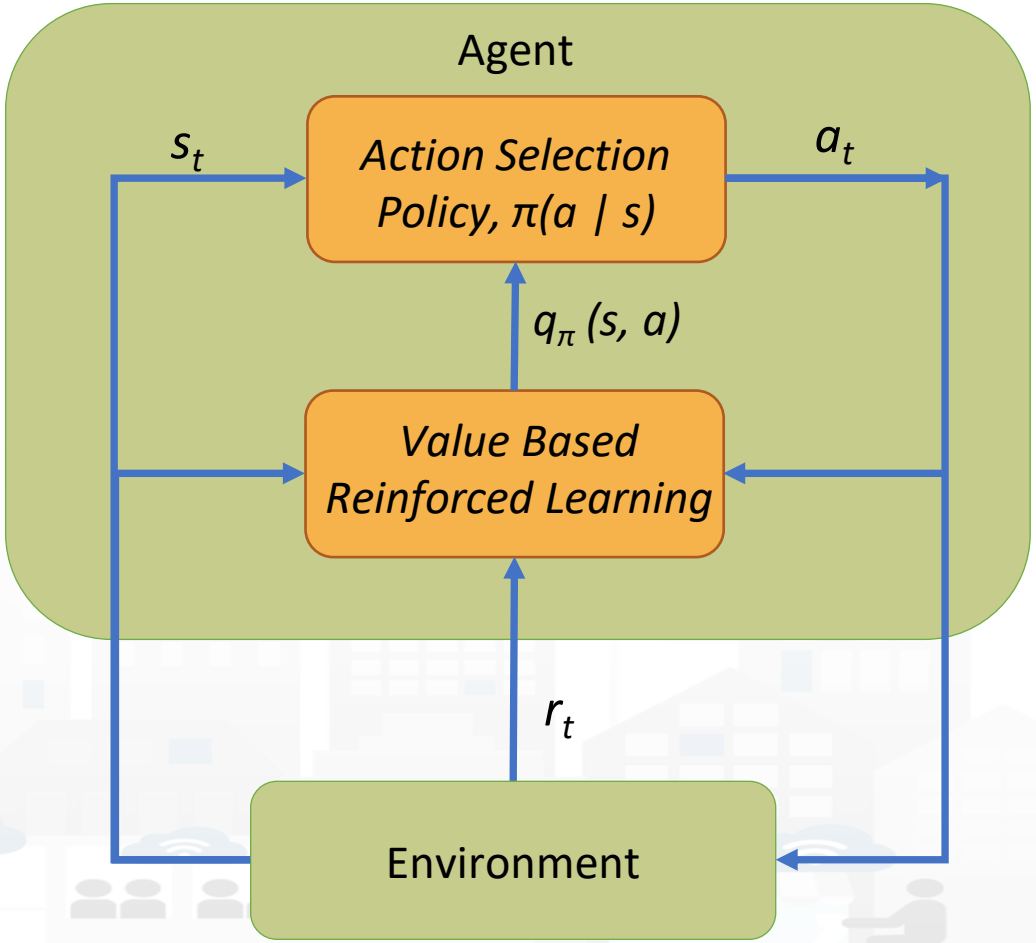
4TWD-NTNS-MWD-P-A: optimization by prioritizing traffic **directions,** the normalized number of **vehicles stops, *NTNS* , the mean waiting delay *MWD***, for all traffic lights, and post synchronization, with Penalty and Adjust dynamically performed

S. Bilotta, Z. Fereidooni, L.A. Ipsaro Palesi, P. Nesi, "Macroscopic GA-based Multi-Objective Traffic Light Optimization Prioritizing Tramways", Applied Soft Comp. Journal, Elsevier, 2025.



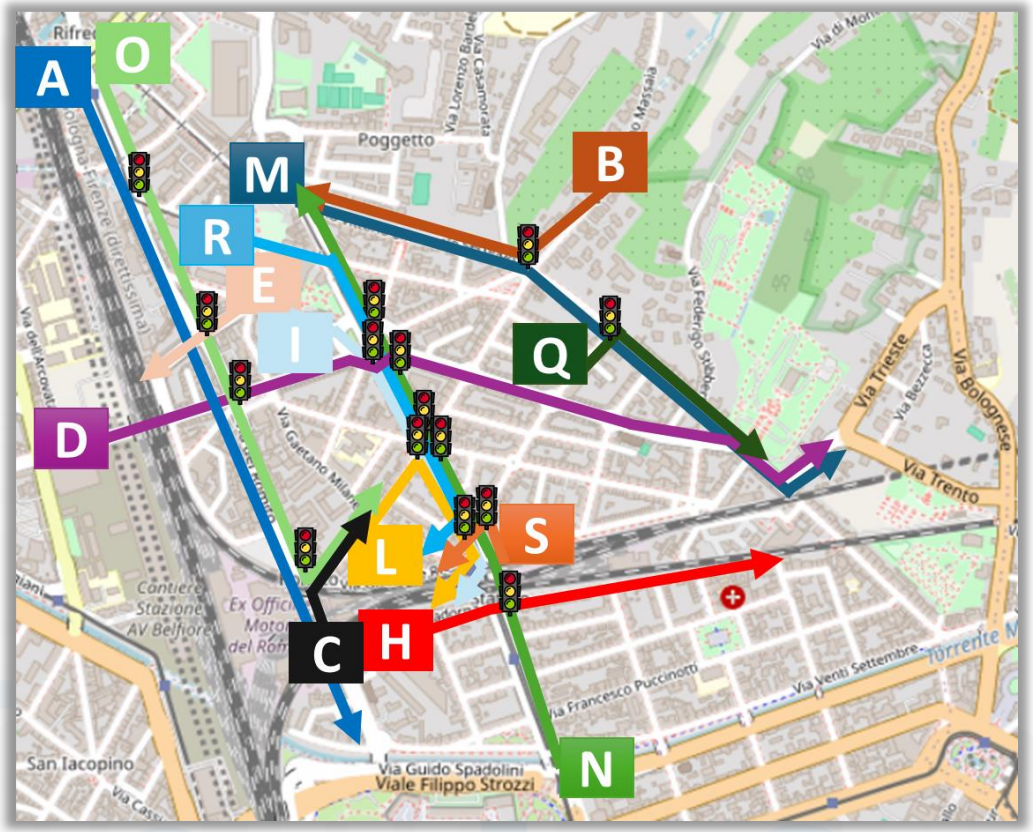
Multi Agent Reinforced Learning

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

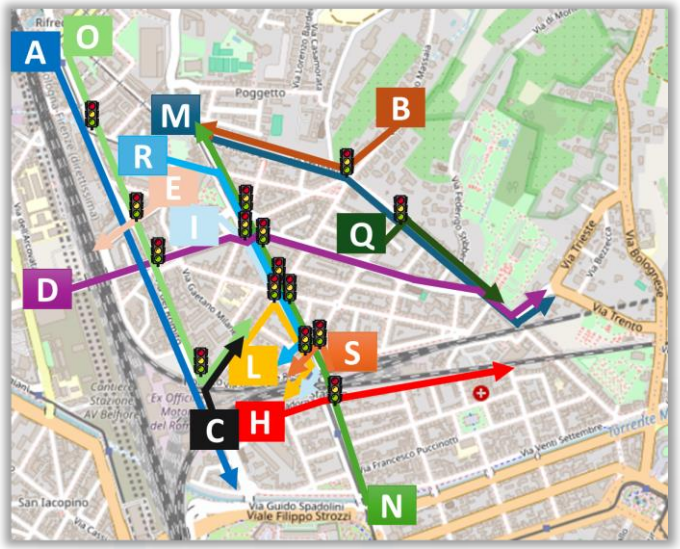


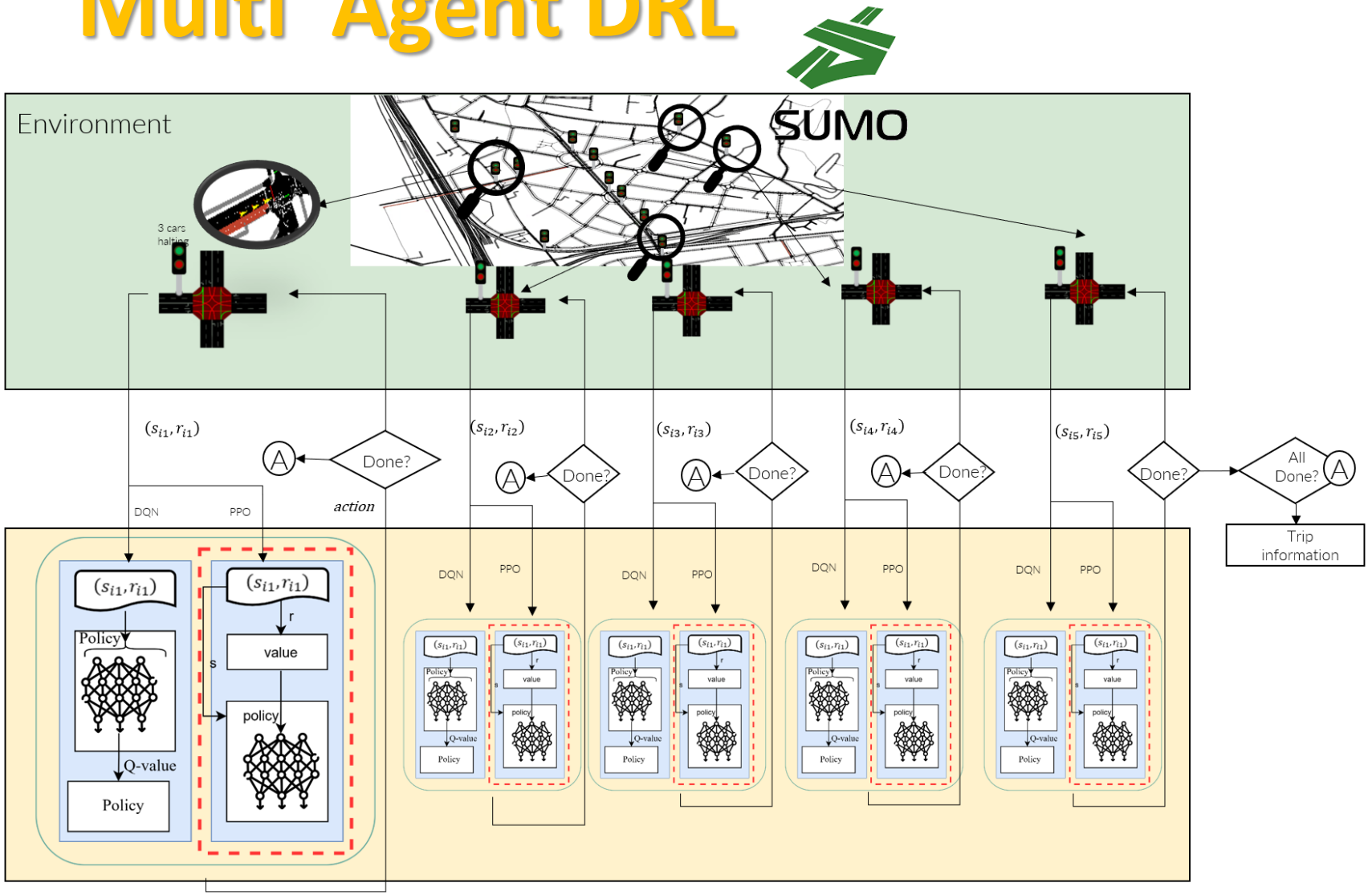
Optimization Drivers

- ***MTT*, Mean Travel Time** on
  - Multiple Directions or globally
  - For specific service
- ***MWT*, Mean Waiting Time** on
  - specific direction or globally
  - For specific service
- ***MNS*, Mean Number of Stops** on
  - specific direction or globally
  - For specific service



Multi Agent DRL





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

MTT for Multi Agent DRL for TLP

Model	TL	all	dir_N	dir_M	dir_A	dir_D	Careggi	Costanza
4TWD-NTNS-MWD-A	1	3013.85	176.93	233.75	194.46	237.65	436.00	427.00
4TWD-NTNS-MWD-P-A	1	3013.85	176.93	233.75	194.46	237.65	436.00	427.00
SUMO Actuated	1	2935.41	249.60	209.77	202.42	270.86	486.73	478.36
Webster	1	5188.87	211.66	242.32	205.46	562.31	984.00	427.00
Webster A	1	2968.90	183.50	242.67	201.27	251.76	482.27	427.00
SARL-FC DQN	1	2834.93	206.68	244.78	199.21	243.26	486.72	485.00
SARL-FC DQN A	1	2760.12	206.35	244.63	198.00	244.76	436.00	427.00
MADRL-FC DQN	1	3089.20	188.29	220.91	205.07	248.06	485.00	445.00
MADRL-FC DQN A	1	2983.69	189.11	220.70	187.00	248.79	436.00	427.00
MARL-FC PPO	1	2910.76	200.38	235.41	198.14	237.78	547.00	445.00
MARL-FC PPO A	1	2855.12	200.93	235.53	196.39	237.97	436.00	427.00
SMART A	1	2599.13	182.14	200	188.28	235.11	436.00	427.00

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Traffic Infrastructure Optimization



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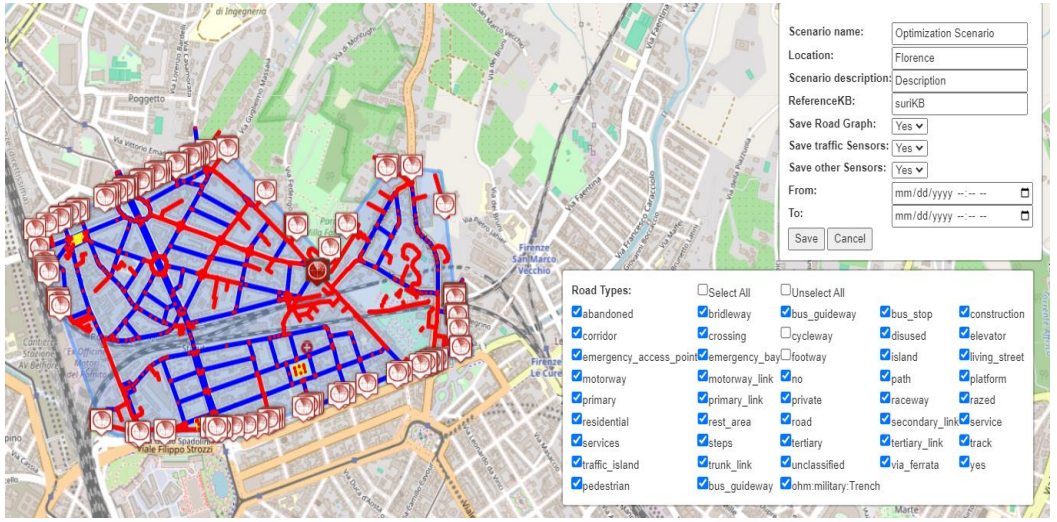
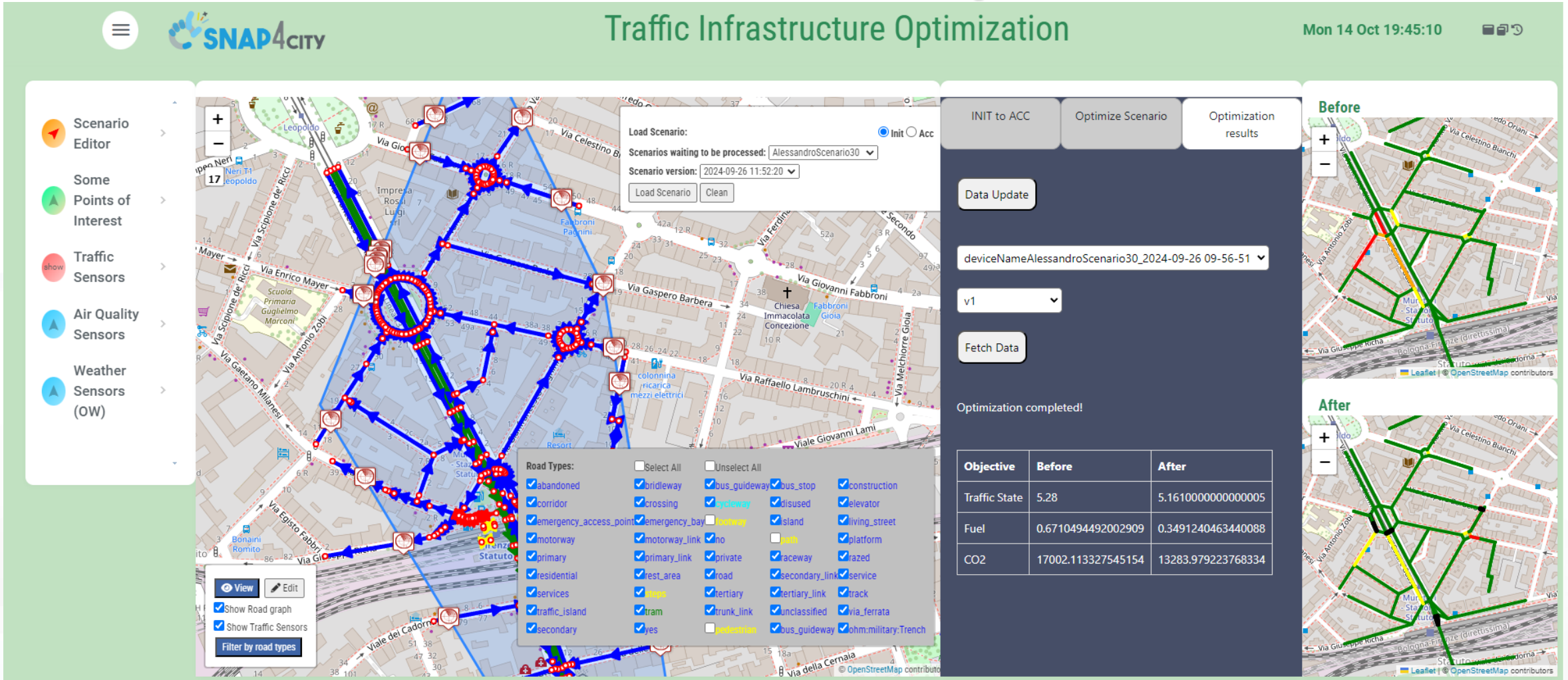
Traffic Infrastructure Optimisation, Digital Twin

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



Traffic Infrastructure Optimization



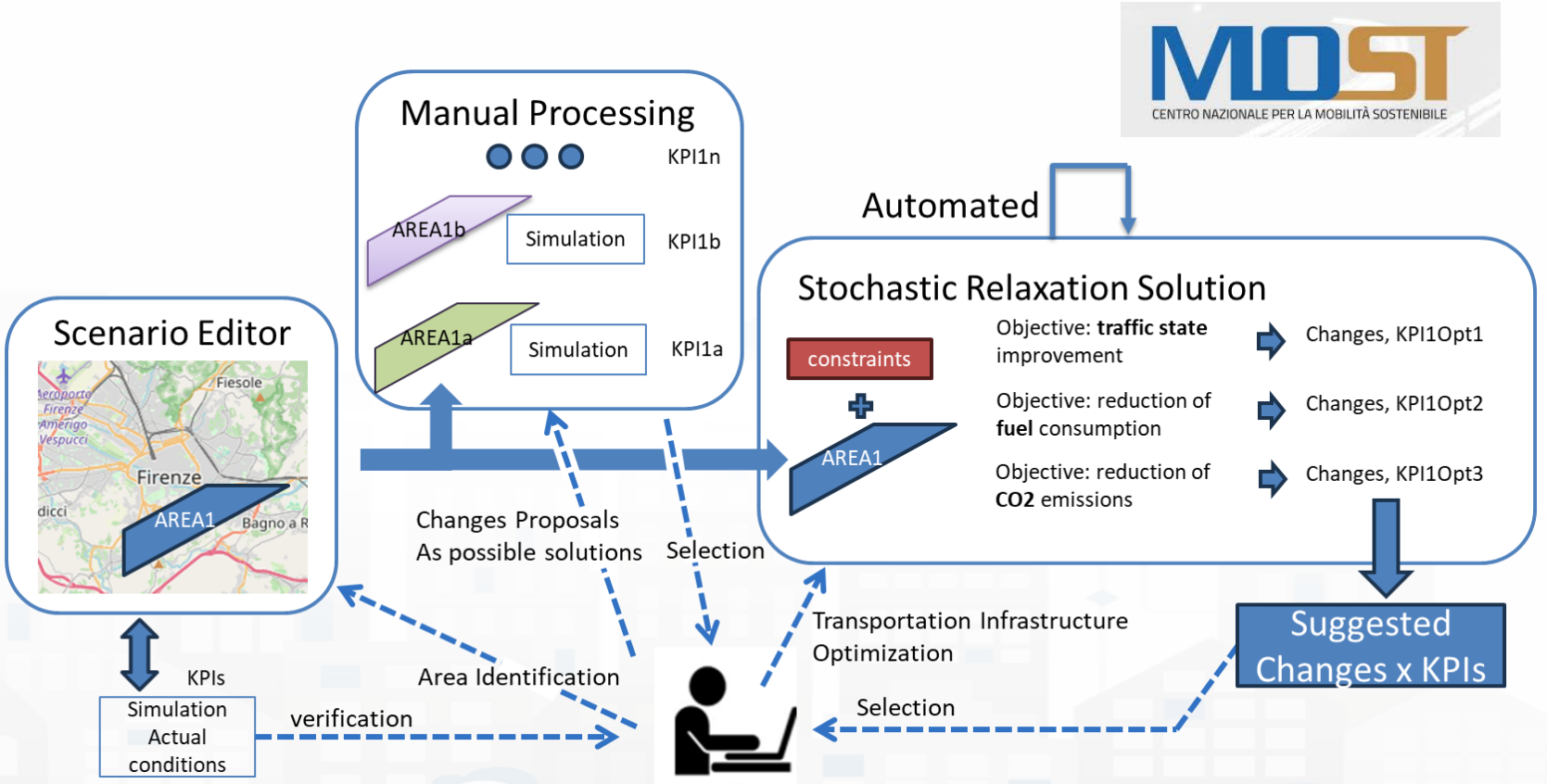
Traffic Infrastructure Optimisation

What Does Minimization/ Maximization Mean?

- In optimization, we often seek to minimize or maximize a function, such as cost, time, or energy, subject to constraints.
- Common in real-world problems like minimizing costs or maximizing efficiency.

Challenges:

- The problem may have multiple local minima/ maxima.
- It's not always easy to find the global minimum/ maximum, especially in complex or large search spaces.



Mobility Scenario Optimization Method Proposed

```
Parameters = Variable initialization // see in the following
CurrentBestScenario = {Load_Initial_Scenario()};
Solutions = [CurrentBestScenario]
Functional = "Traffic_State";
Iteration = 0
Annealings = {set_initial_value()}
Do:
    NewCases=New_Generation(CurrentBestScenario, Parameters
    For each C in NewCases
        TFR = Traffic_Flow_Reconstruction(C);
        If ( ErrControl(TFR) < ErrRefControl ) then
            KPI = KPI_Evaluation (TFR, Functional);
            Solutions.ProposeInTheBest (C, KPI);
        Endif
    Endfor

    If Annealings >0:
        // Select top 'Annealings' solutions
        AnnealingsSolutions = Solutions.GetTop(Annealings);

        For each A in AnnealingsSolutions
            NewCases = New_Generation (A, Parameters)
            For each C in NewCases
                TFR = Traffic_Flow_Reconstruction(C);
                If ( ErrControl(TFR) < ErrRefControl ) then
                    KPI = KPI_Evaluation (TFR, Functional);
                    Solutions.ProposeInTheBest (C, KPI);
                Endif
            Endfor
        Endfor

    CurrentBestScenario = Solutions.GetTop(N); //the best set
    Annealings = max(Annealings - 1, 0);
    Iteration ++;
While Max_Iterations>Iteration and not Early_Stop(KPI)
ResultCase = CurrentBestScenario
```

Figure 5 – Pseudocode of the proposed Stochastic Relaxation.

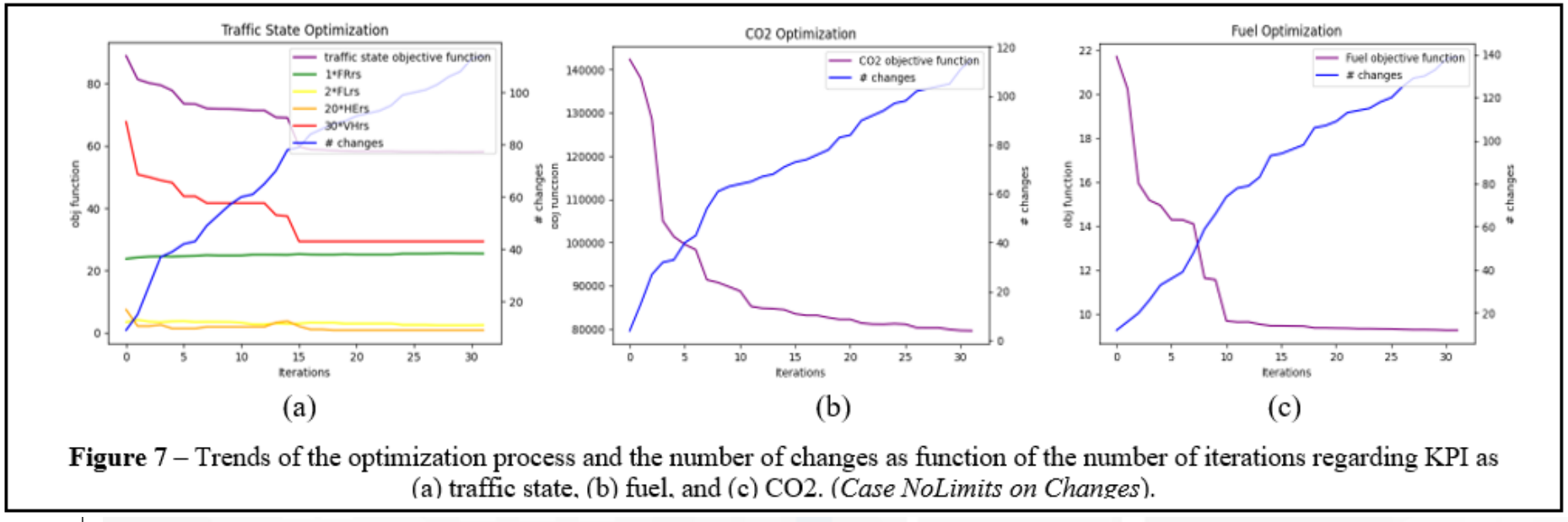
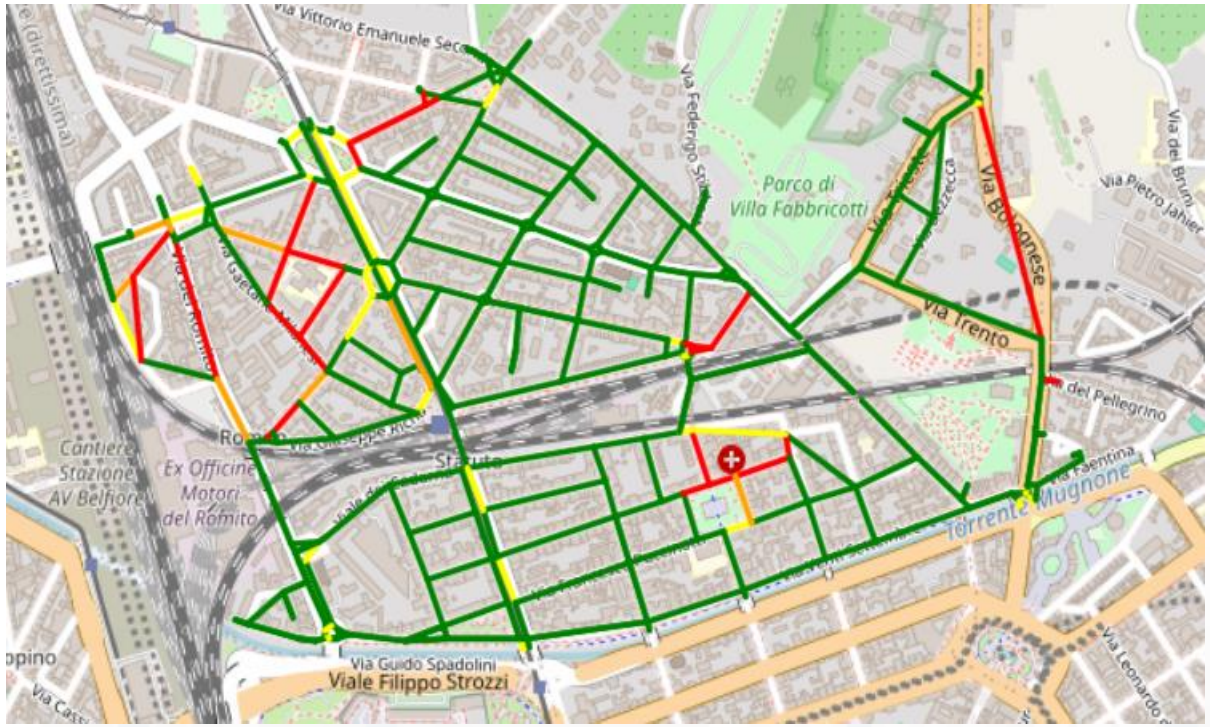
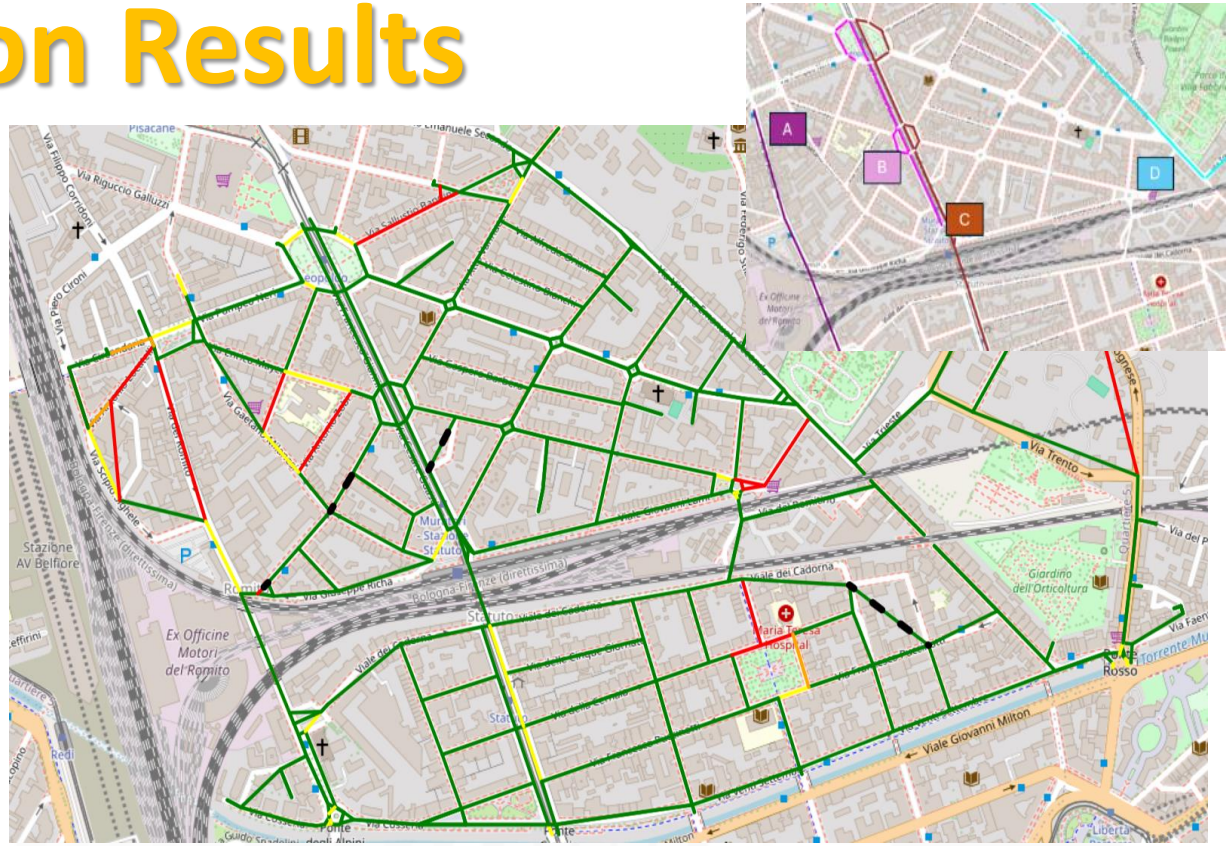


Figure 7 – Trends of the optimization process and the number of changes as function of the number of iterations regarding KPI as (a) traffic state, (b) fuel, and (c) CO2. (*Case NoLimits on Changes*).

Optimization Results





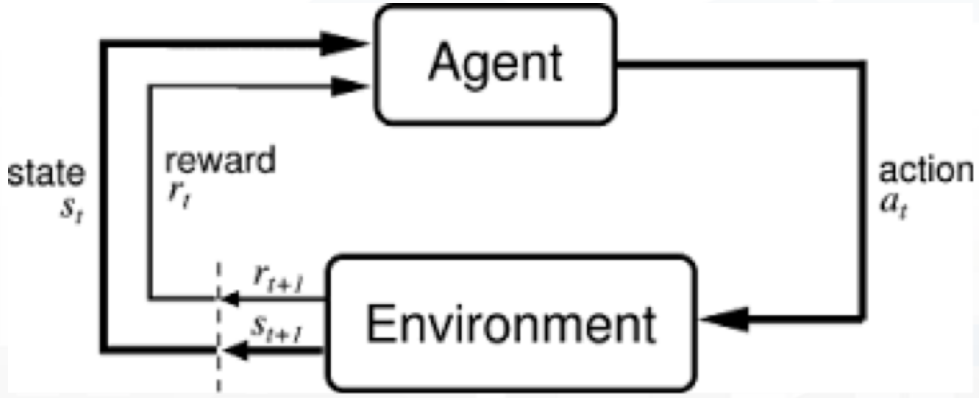
Case max 4 changes	*KPI estimation on the best solution*		
Optimization Target	***Traffic State***	***Fuel***	***CO2***
Optim 4 Traffic State	**91.341** -21%	17.964	128536
Optim 5 Fuel	91.514	**16.633** -35%	128227
Optim 6 CO2	92.859	19.192	**127876** -23%
Original	115.475	25.680	165822

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%	

Are there better solutions ?

Deep Reinforcement Learning (Deep RL) for Optimization

- Deep Reinforcement Learning combines **Reinforcement Learning (RL)** with **Deep Learning** techniques. The agent learns to make decisions by interacting with an environment, using neural networks to approximate the expected utility of a given action.



PROS

The agent "explores" different solutions and "exploits" the best-performing ones based on rewards.

CONS

its effectiveness depends on the problem size and the ability to learn effectively from the environment

Temporal-Differences Deep RL

Q-learning objective is to find an optimal policy regarding a sequential decision structured problem in which an agent needs to decide the action that maximizes the cumulative reward.

The main components of the system are:

State: the current configuration (ex. the city sequence for the TSP)

Action: the changes that the agent can perform (change the order of 2 cities to visit in the path)

Reward: the environment feedback (KPI length of agent path)

Q-function: Estimation of the quality of a couple state-action.

Policy: Mix of Exploitation (select best estimated action on the specific state) and Exploration (random action for exploring new possibilities)

Q-Learning with DNN for TSP

DNN can be used for Q-function approximation:

State: The current path that can be used as **input** for the DNN

Action: Can be the **output** from the DNN.

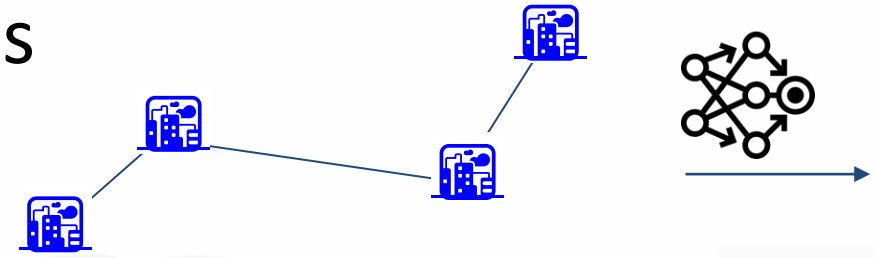
Functioning: For very possible change between two cities in the path the DNN will output the Q- values.

$$r = \frac{KPI(s) - KPI(s')}{KPI(s)}$$

$$Q(s,a) = r + \gamma \cdot \max_{a'} Q(s',a')$$

DNN Q-Learning workflow

s

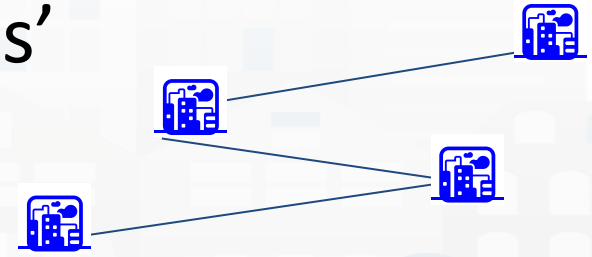


KPI(s)

policy π -> action a

s,a -> s’

s’



KPI(s’)

Temporal Difference methodologies
use estimates of actions incrementally, updating the value future estimates of states and actions … next slide

$$r = \frac{KPI(s) - KPI(s')}{KPI(s)}$$

DNN Q-Learning workflow

```
# Generate all possible pairs of cities to swap
swap_actions = list(itertools.combinations(cities, 2))
```



KPI(s_a1)
KPI(s_a2)
...
KPI(s_aN)

} max $Q(s,a) = r + \gamma \cdot \max_{a'} Q(s',a')$

https://colab.research.google.com/drive/1Q6bQdsyf4DldBHhgcSRam2JT6XLs-uVD?usp=sharing

Discount factor (γ): It determines how much future rewards influence the value of the Q-function. A higher γ (closer to 1) means that the agent places more importance on future rewards, while a lower γ (closer to 0) means that the agent prioritizes immediate rewards.

Smart Energy



FROM CITY DASHBOARD TO APPLICATIONS



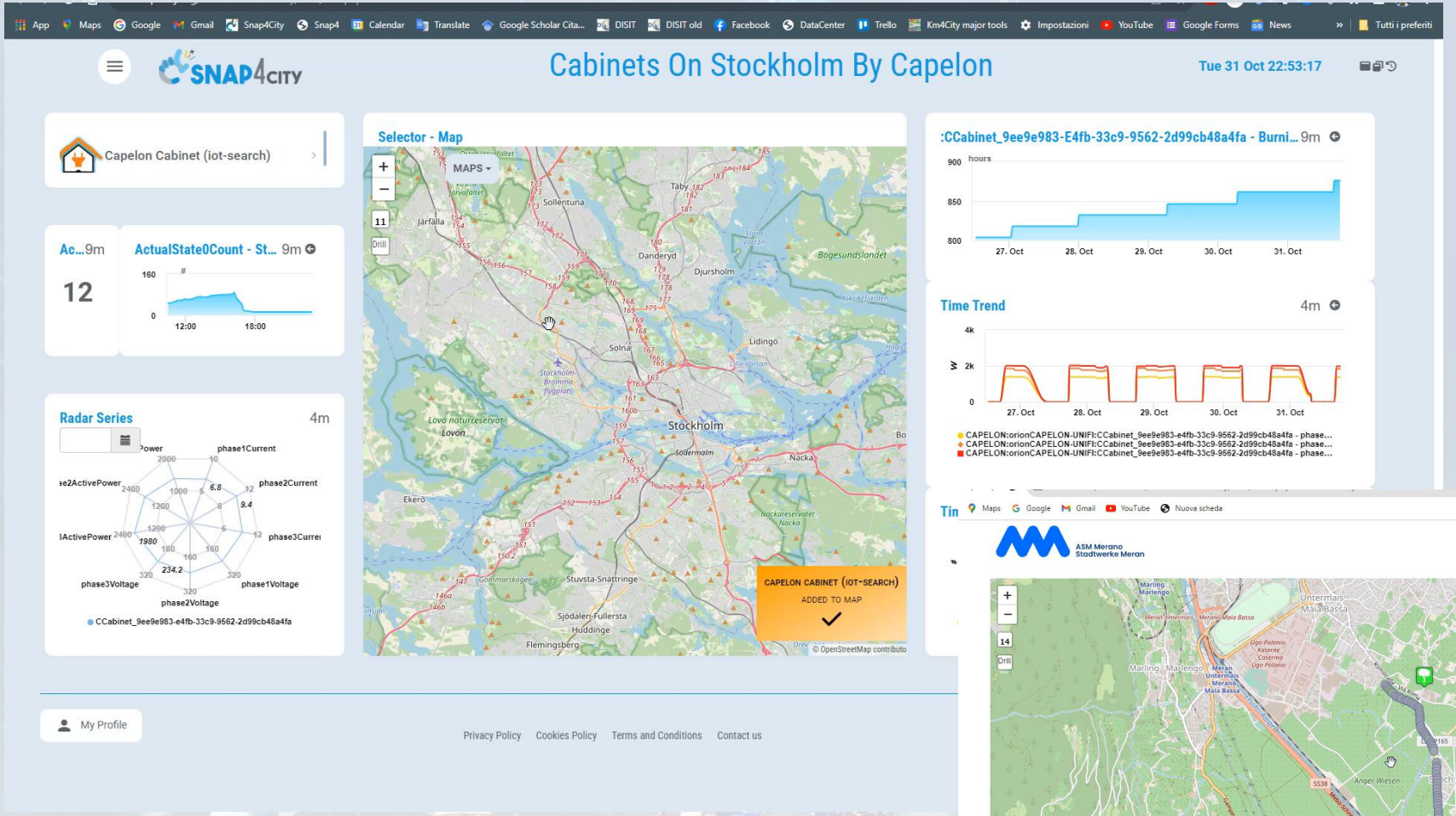


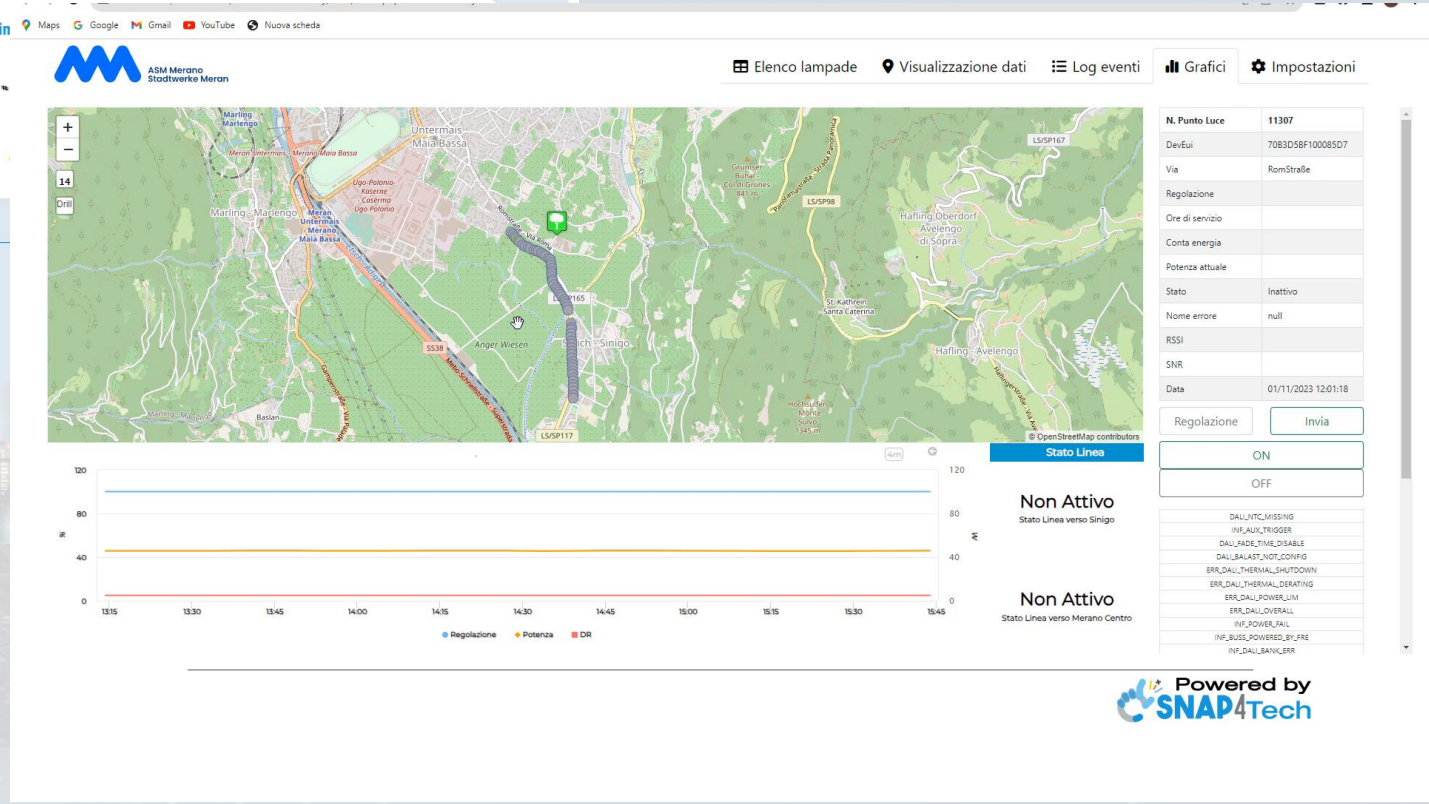


100% OPEN SOURCE

Energy

- Monitoring Energy Consumption in single building, area and per zone
- Matching Energy consumption with respect to the actual usage
- Computing Roof orientation for Photovoltaic installations
- Simulation of Photovoltaicc installations to identify the best parameters of size and storage
- Smart Light management, unicast and multi cast management, smart light controlled by traffic flow data
- Collecting and managing Communities of Energy
- Monitoring Energy provisioning on recharging station
- Optimization of battery life
- Computing KPI
- Etc.





Smart Light Management

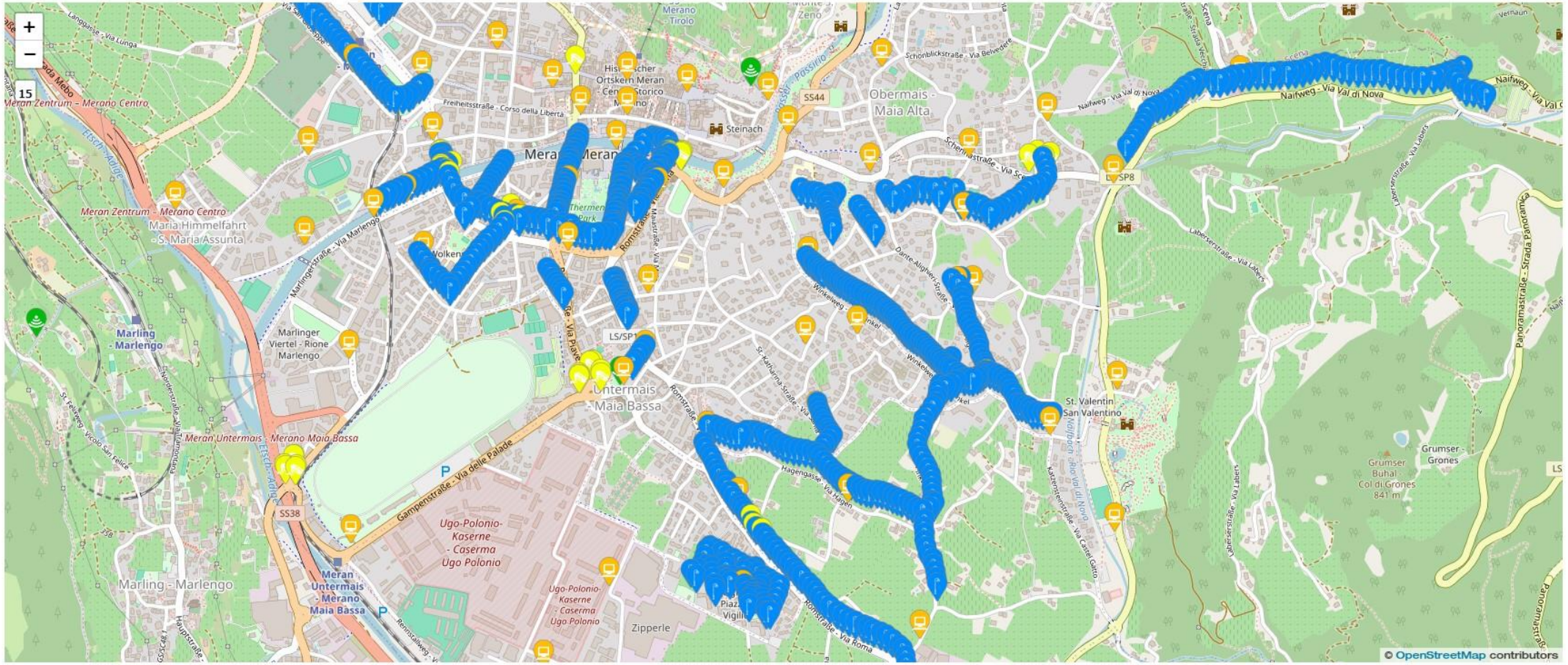
Smart Light in Merano



ASM Merano
Stadtwerke Meran

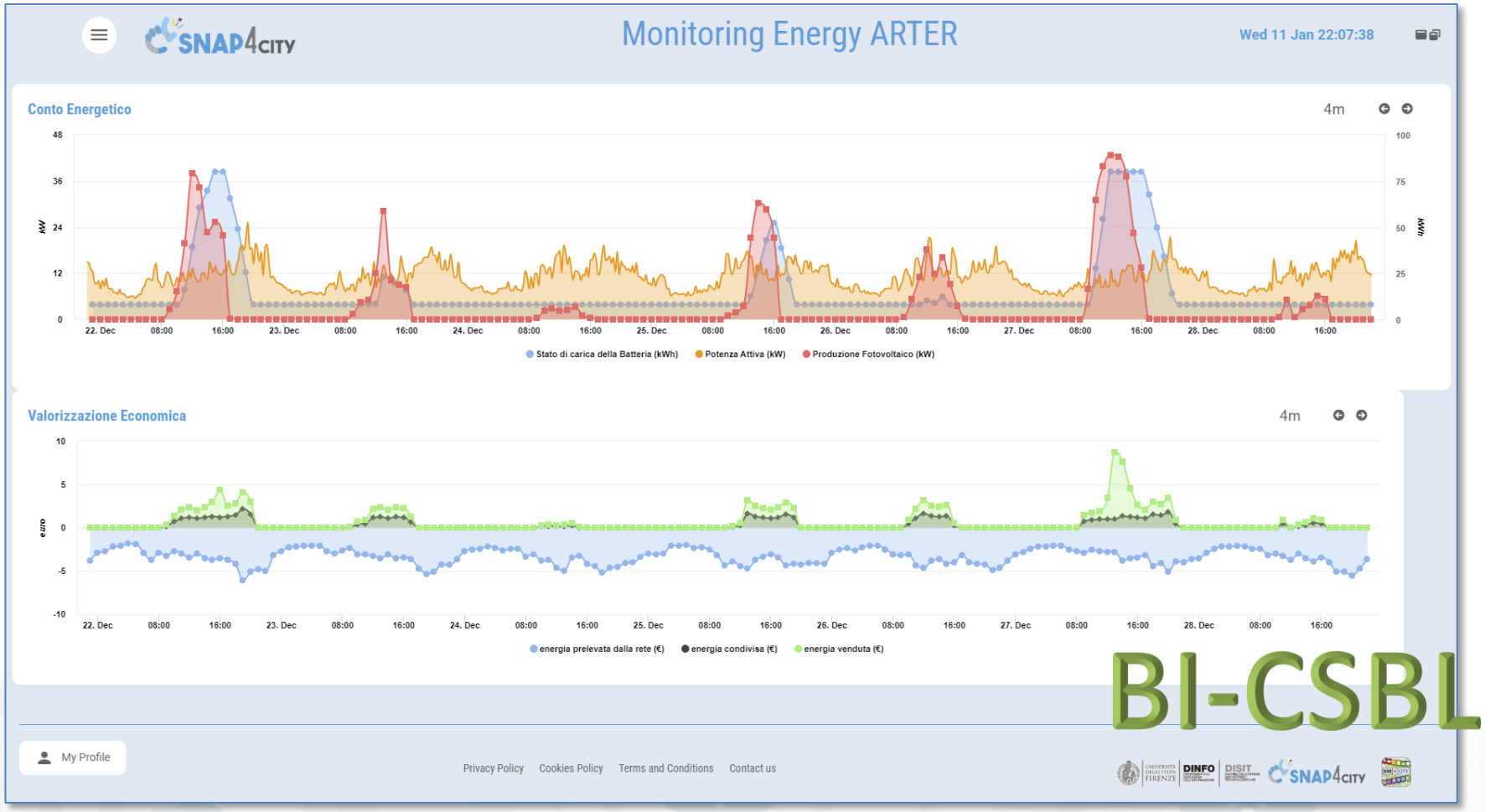
Merano - tutti i servizi

Wed 13 Dec 15:34:57



Powered by SNAP4Tech

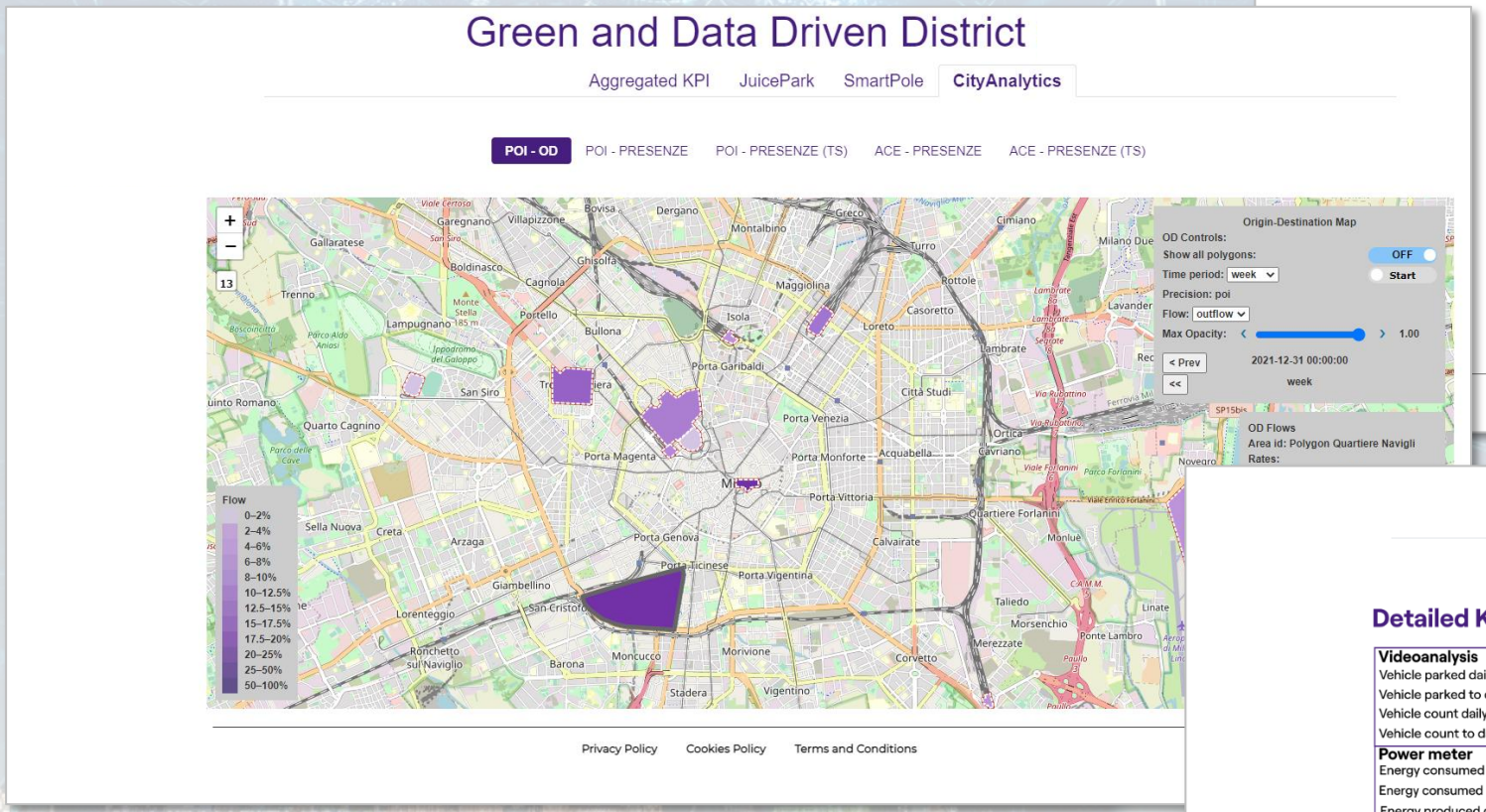
- **Field-tested energy community: the self-consumer condominium**
- The Self User project creates in the pilot condominium, through the collection and analysis of data, a model for calculating and enhancing the impact of an energy community on a community of people, with a view to actions to combat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

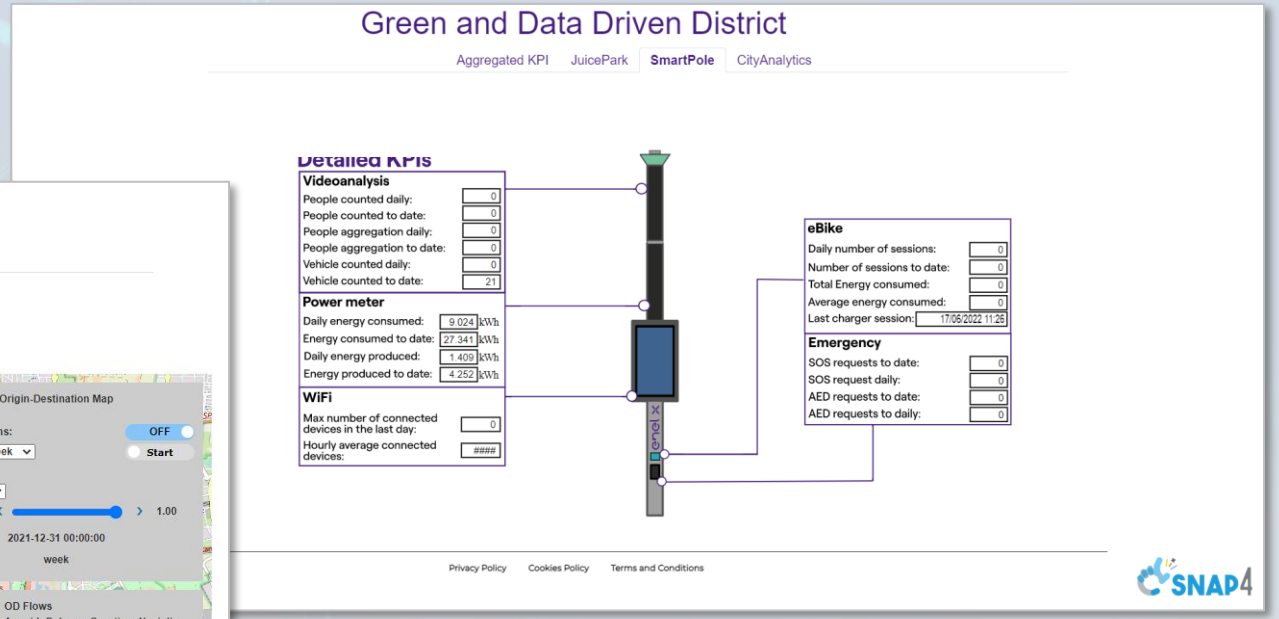


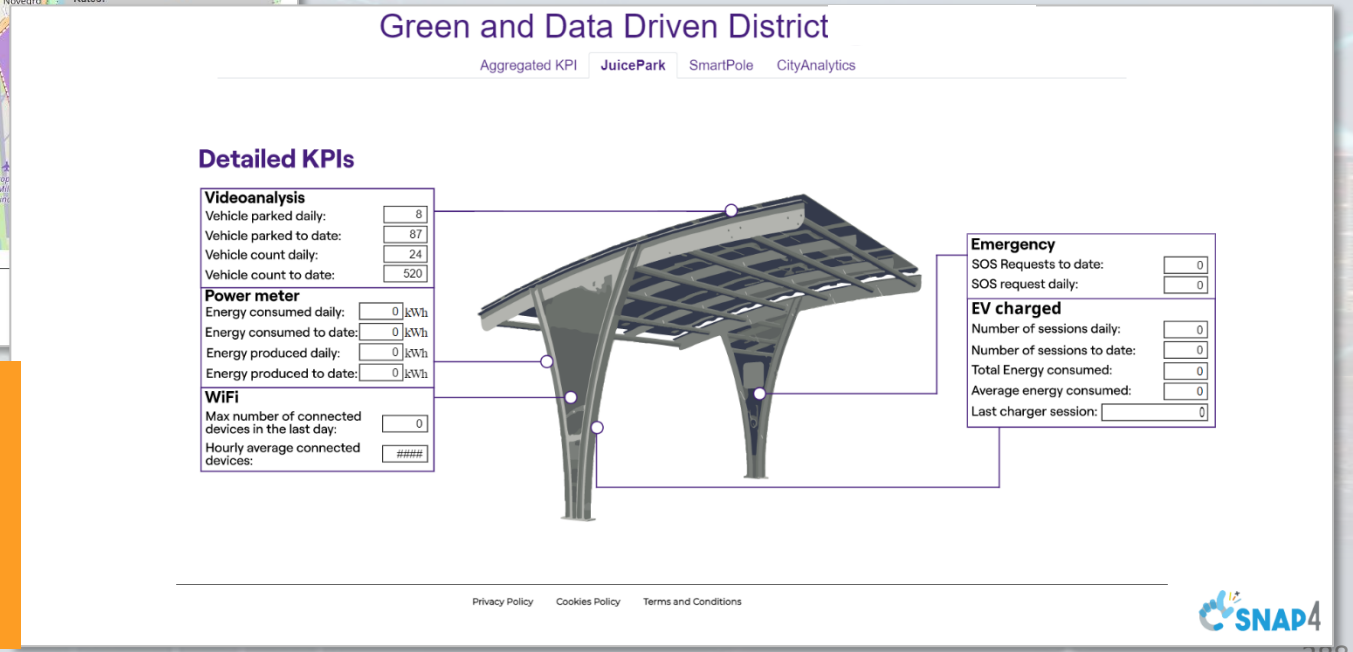
BI-CSBL

https://www.selfuser.it

Energy monitoring and business intelligence







7 AFFORDABLE AND CLEAN ENERGY

11 SUSTAINABLE CITIES AND COMMUNITIES

https://www.snap4city.org/dashboardSmartCity/view/Baloon.php?iddasboard=MzczNg==

Ciao roottooladmin1

Sat 11 Nov 17:26:28

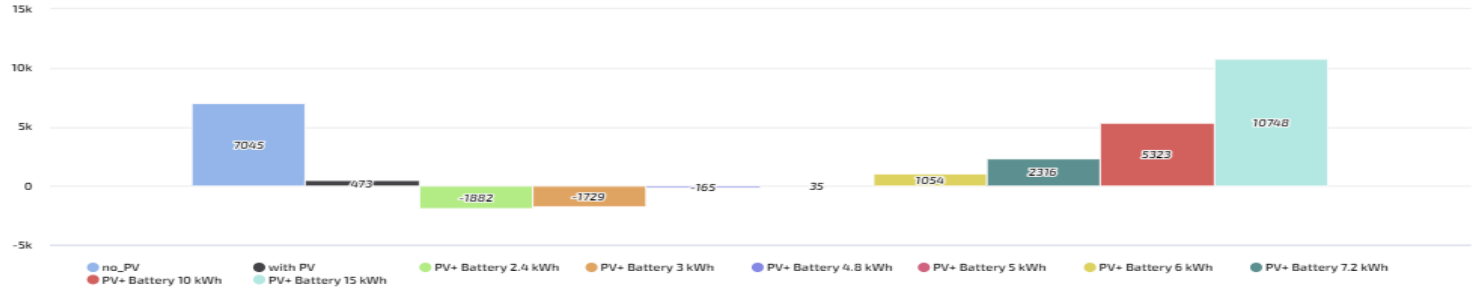
ONLINE PHOTOVOLTAIC SYSTEM SIMULATOR

User Manual

Italian Version

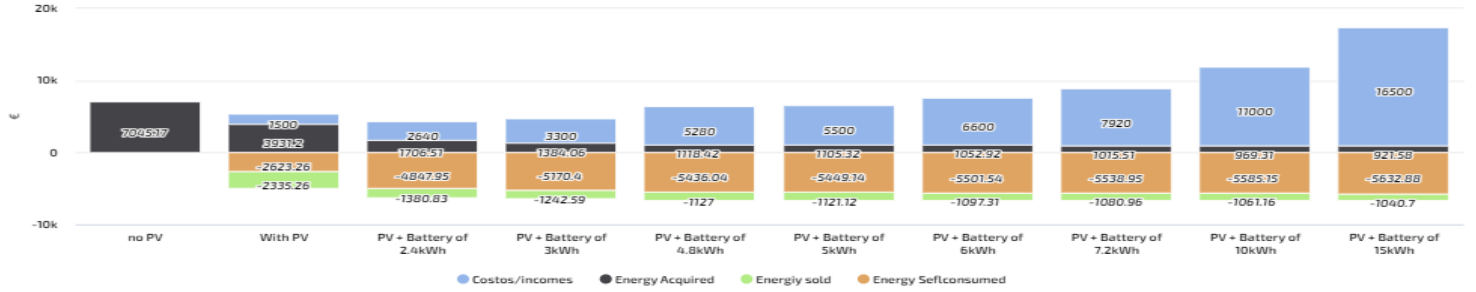
TOTAL COSTS OVER THE INVESTMENT YEARS

599m



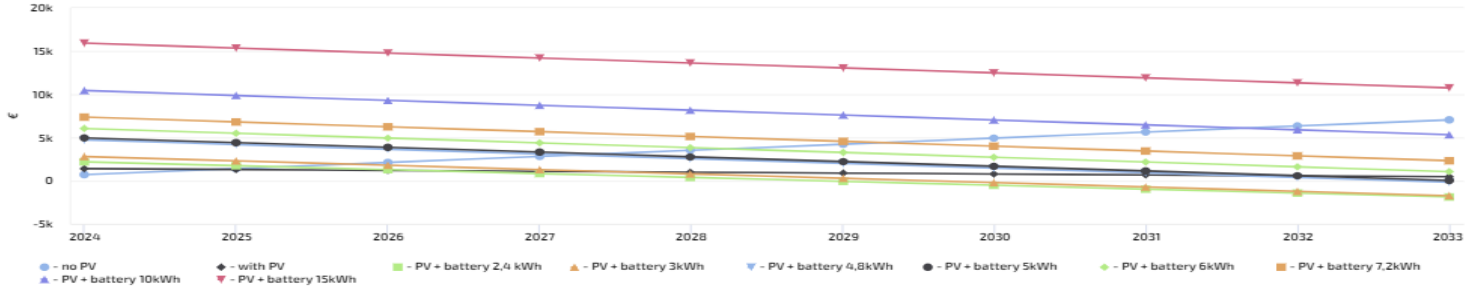
TOTAL COSTS OVER YEARS DECOMPOSED IN COSTS AND INCOMES

599m



BREAK EVEN TREND FOR THE DIFFERENT KIND OF PLANTS

599m



PARAMETERS OF YOUR PV PLANT

We suggest you PV plus battery of 2.4 kWh

Annual Consumption	2000 kWh
Price of energy sold (€/kWh)	0,15
Price of Energy Acquired (€/kWh)	0,35
Years of Investiment	10
Months for typical trends	Gennaio

Compute

7 AFFORDABLE AND CLEAN ENERGY

SNAP4CITY

KM4CITY

Smart Building

FROM CITY DASHBOARD TO APPLICATIONS







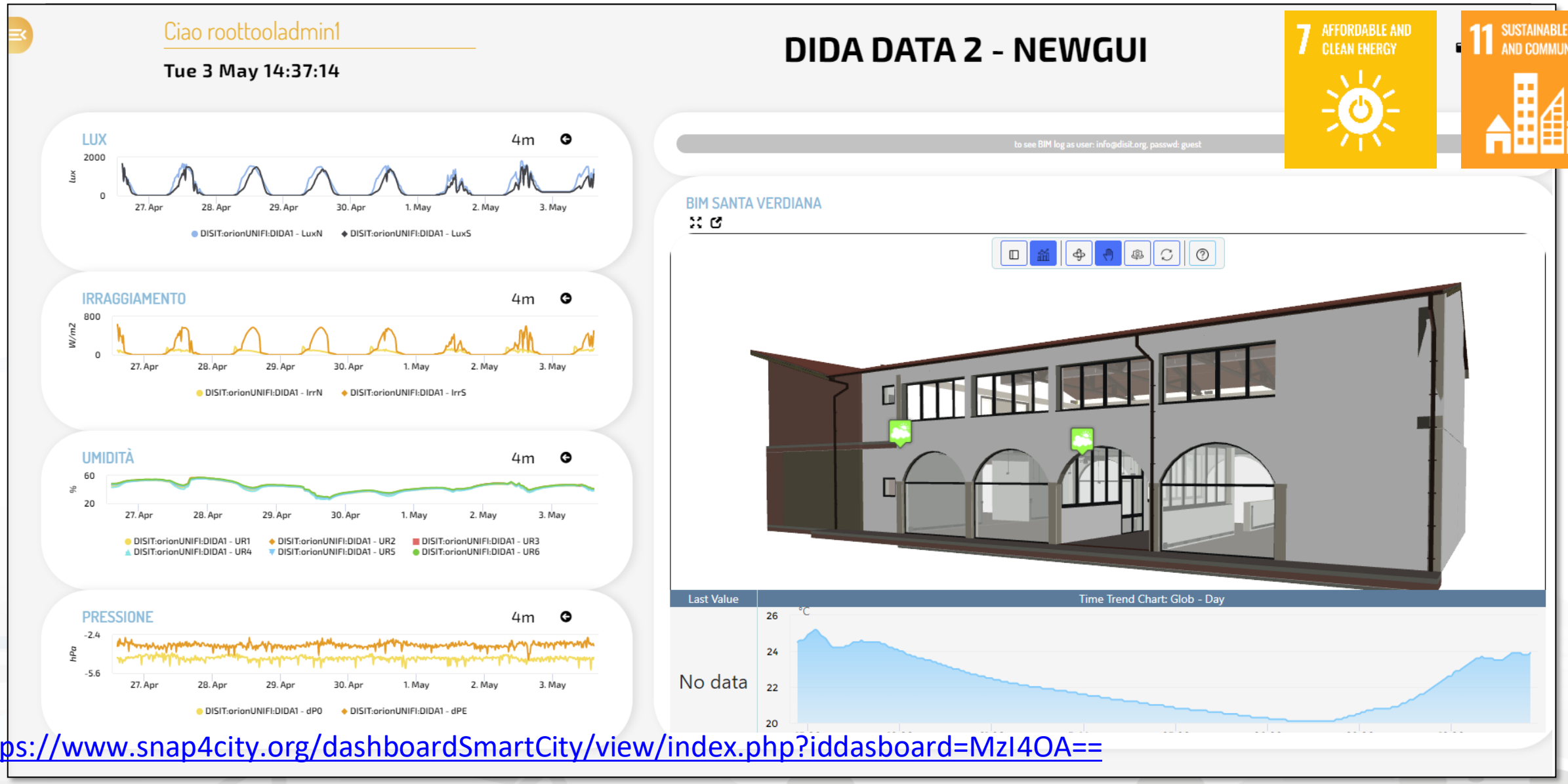


100% OPEN SOURCE

Smart Buildings, Snap4Building

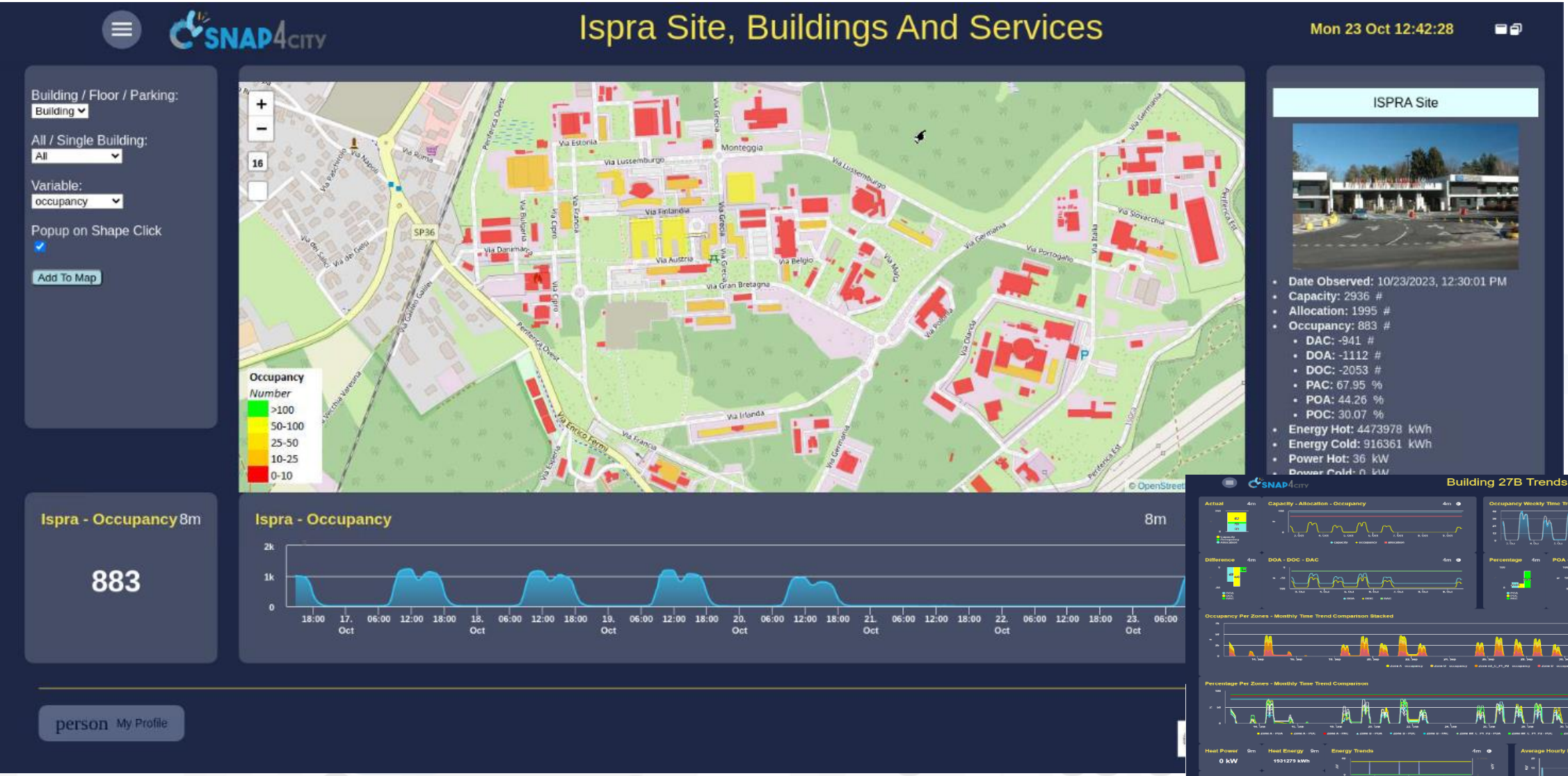
- **Digital Twin for monitor, control and manage distributed infrastructures**
  - 2D/3D representations of the whole set of buildings, BIM modeling
  - Entities (building, floors, rooms, parking, charging stations, gates, etc.) with their shapes and descriptors, and data monitoring the allocation to office, meeting, cafeteria, storage, stairs, elevator, etc.
- **Monitoring and computing KPI on real time for**
  - **energy** consumed or produced (hot/cold)**, parking, logistic, presences, cleaning, air quality, departments, subareas, maintenance, etc.**
  - **allocation/designation**, dispositions, heating, cooling, temperature, equipment, etc.
  - **grouped in Zones**

Smart Building



https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzI4OA==

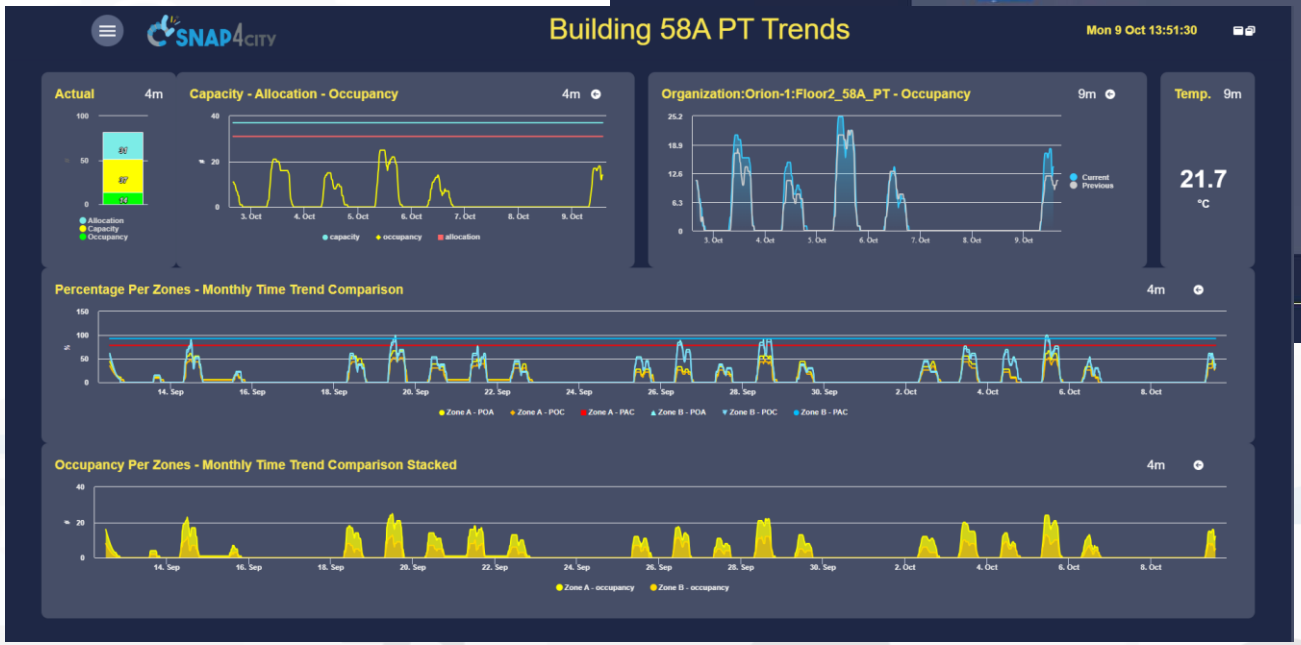
ISPRA JRC Site

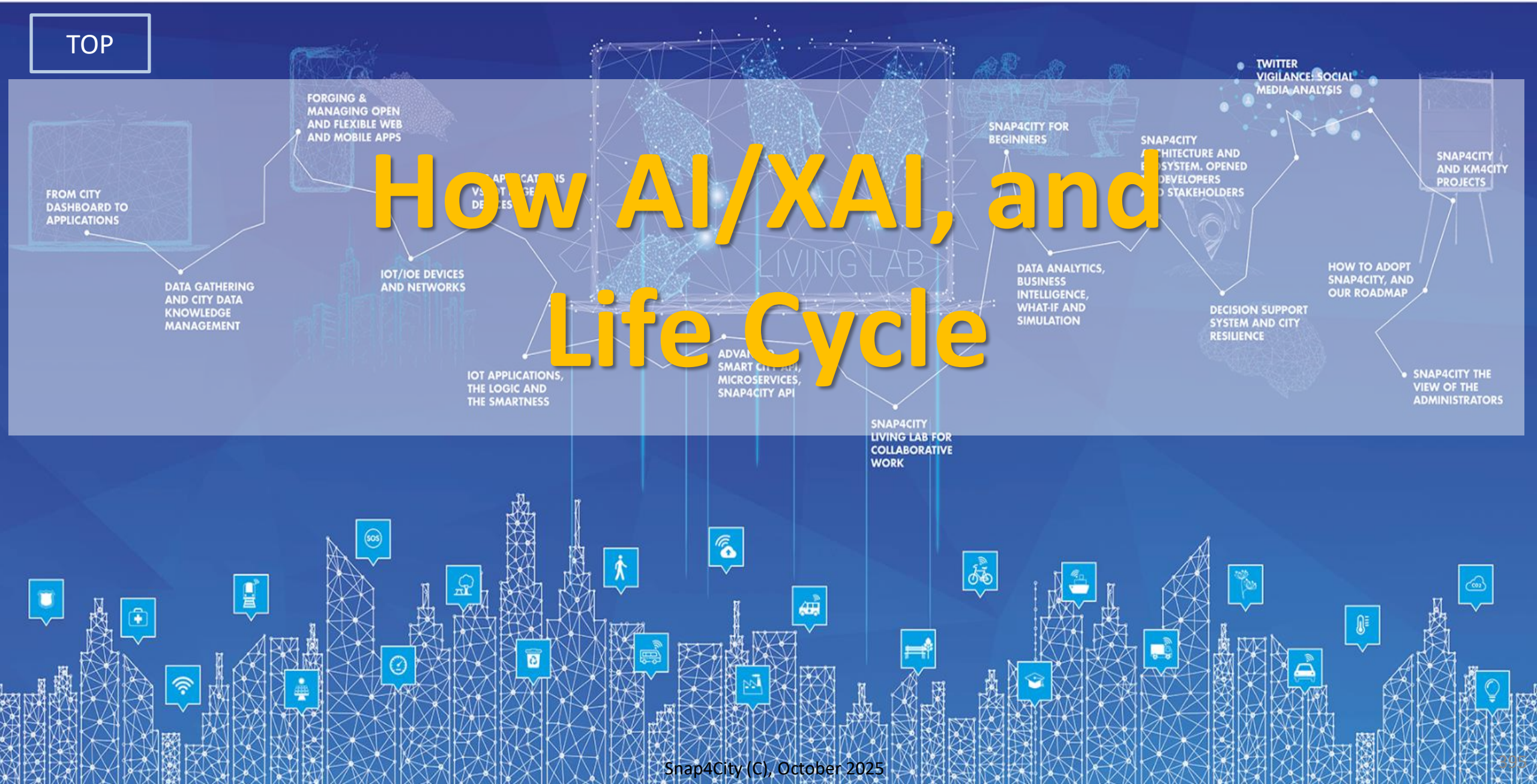


Floor Details

ISPRA JRC Site

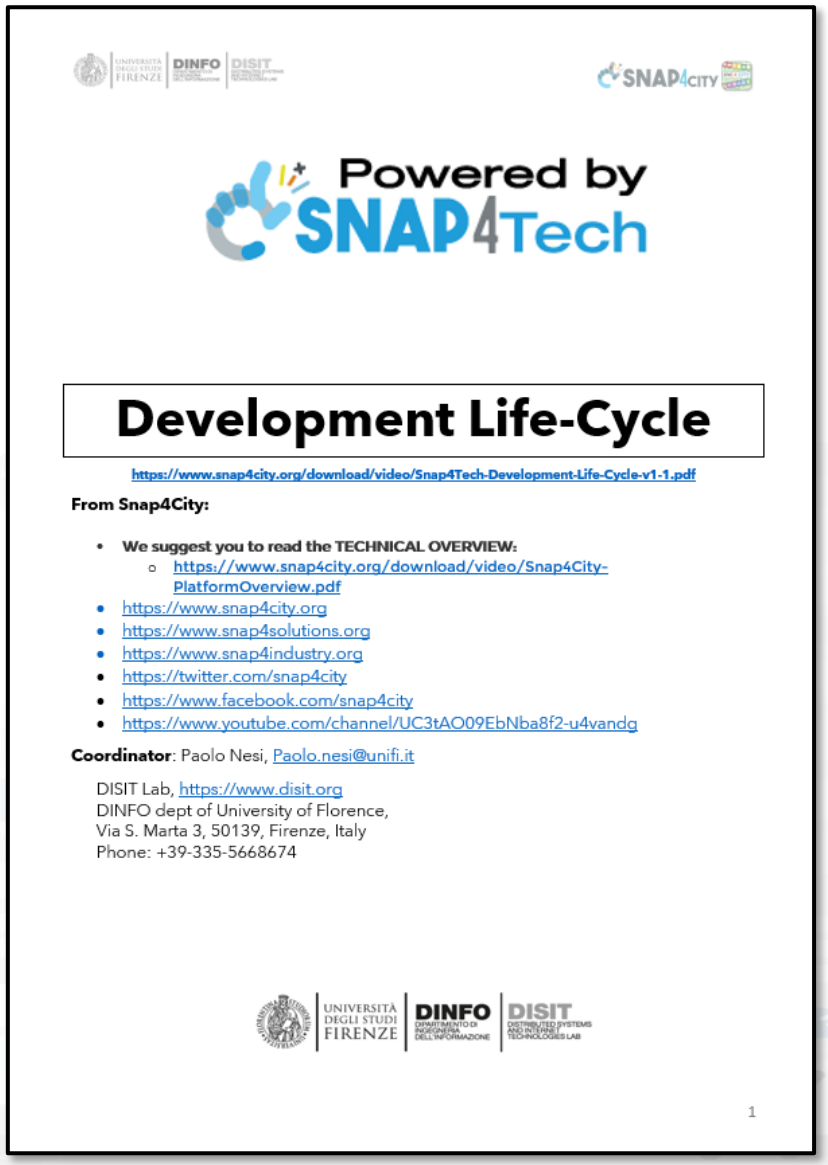






How AI/XAI, and Life Cycle

Development



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Development Life-Cycle

https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle-v1-1.pdf

From Snap4City:

- **We suggest you to read the TECHNICAL OVERVIEW:**
  - https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city
- https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandg

Coordinator: Paolo Nesi, Paolo.nesi@unifi.it

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Via S. Marta 3, 50139, Firenze, Italy
Phone: +39-335-5668674

UNIVERSITÀ DEGLI STUDI FIRENZE DINFO DISIT

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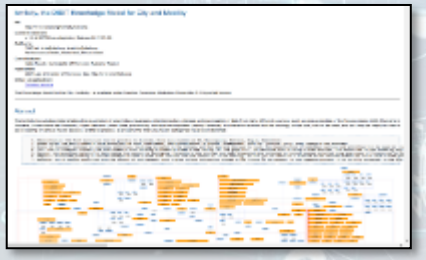
https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf

Data Analytics on Snap4City platform

Swagger







Ontology Schema



LOG.disit.org



Big Data Store Facility

Smart City API from Knowledge Base and other tools

TensorFlow

NVIDIA CUDA

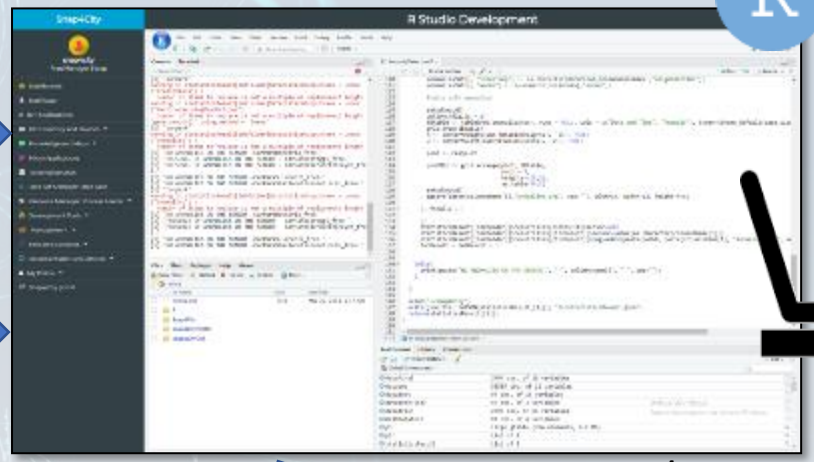
python

jupyter

R Studio

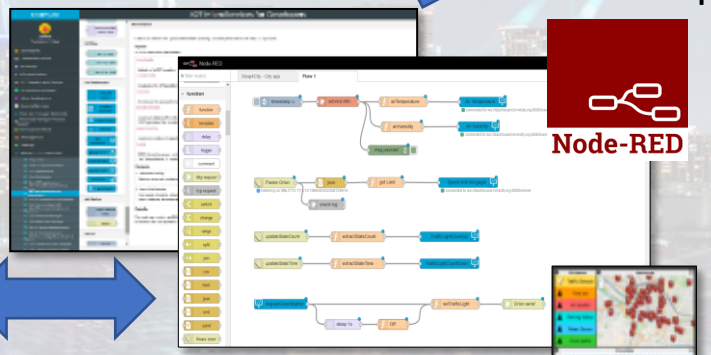
SNAP4CITY

KM4CITY





Creating MicroServices



Using them into IOT Applications

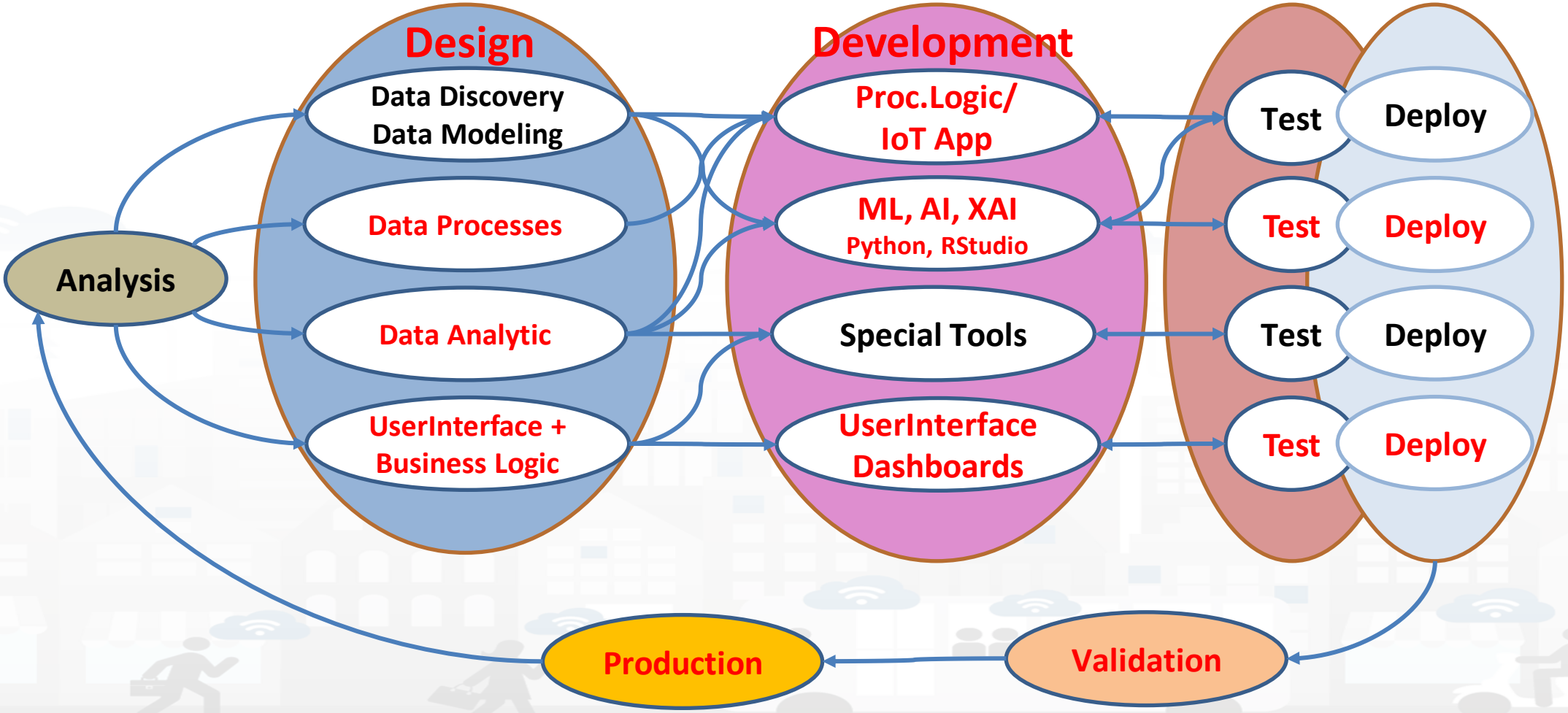
Saving / Sharing reusing



Resource Manager



Development Life Cycle Smart Solutions



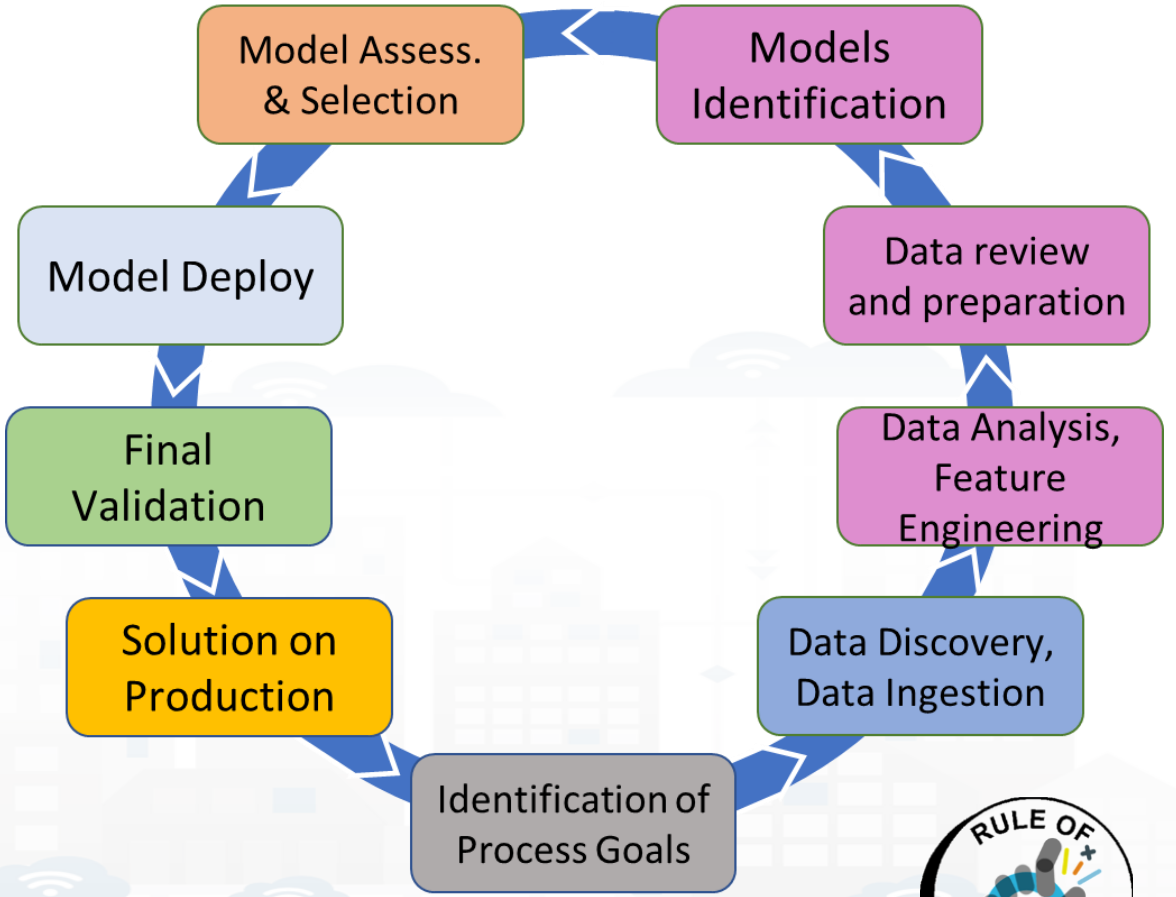
Data Analytics Life Cycle



- **Problem analysis**, business requirements
- **Data Discovery**, Data Licensing, ingestion, and acquisition
- **Data set preparation**, transformation, identification of features, normalization, scaling, imputation, feature engineering, etc.
- **Target Assessment Model Definition**
  - Identification of metrics for the assessment, KPI
- **Screening on Models/Techniques, for each Model/Technique or for the selection Model/Technique** perform the
  - ***Model/Technique Development/testing , also hyper-parametrization***
- **Best Model selection among those tested**
  - If needed reiterate for different parameters, features, etc.
  - Comparison with state of the art results on the basis of KPI/metrics
  - Needs of Explainable AI solutions: global and local
- **Deploy best Model in production, monitoring in production**

Model/Technique Development/testing

- **Identification of Process goals and Planning (problem definition)**
  - Which goals
  - How to compute, which language
  - Which environment, which libraries
- **Data Discovery and Ingestion (from the general life cycle)**
  - Data Collection, Data Preprocessing if needed
- **Data Analysis: feature engineering, feature selection**
  - Data ethics assessment
- **Data review and preparation for the model, splitting, encoding**
- **Model Identification and building: ML, AI, etc….**
  - Model Training
  - Tuning hyperparameters when possible
- **Model Assessment and Selection (Evaluation)**
  - Validation in testing
  - Assessment on a set of metrics depending on the goals: global relevant and feature assessment
  - Assessing computational costs
  - Impact Assessment, Ethic Assessment and incidental findings
  - Global and Local Explanation via Explainable AI techniques
- **Model Deploy and Final Validation**
  - Optimisation of computation cost for features, if needed reiterate
  - Solution on Production (security, scalability, etc.)
- **Monitoring and Maintenance on production**
- **Documentation, incremental documentation**

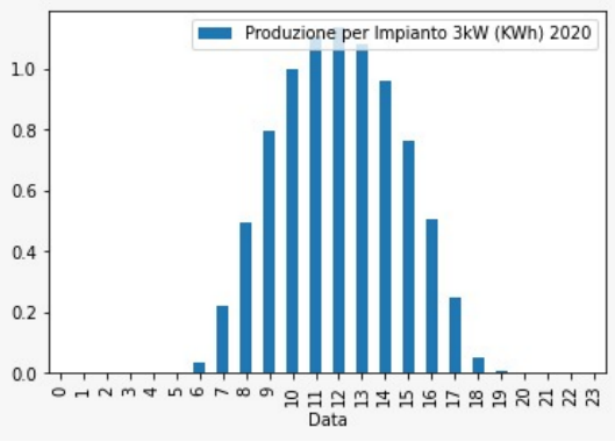


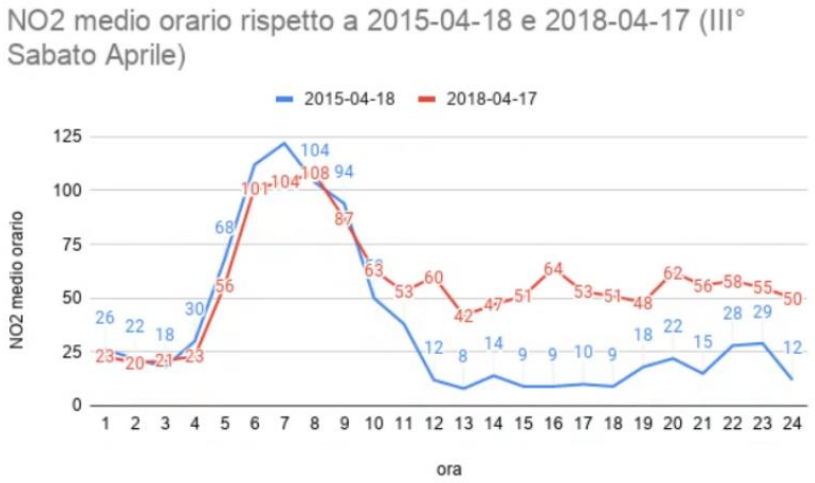
Explore Data

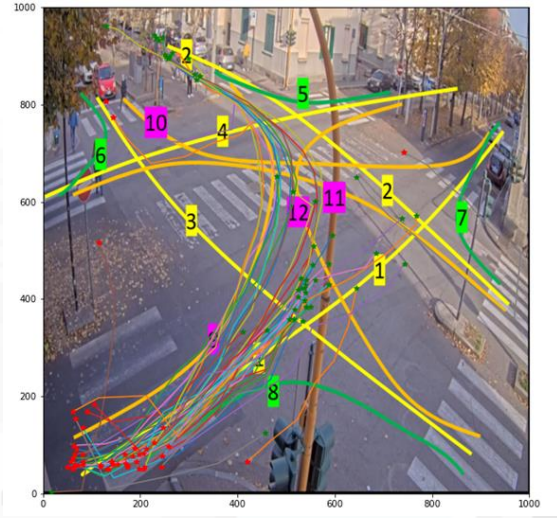
Once your data is ready to be used, and right before you jump into AI and Machine Learning, you will have to examine the data.

-> Does your data meet the assumptions of your intended analysis type

- Distributions
- Patterns / Trends
- Clustering







Road to Time Series Forecasting

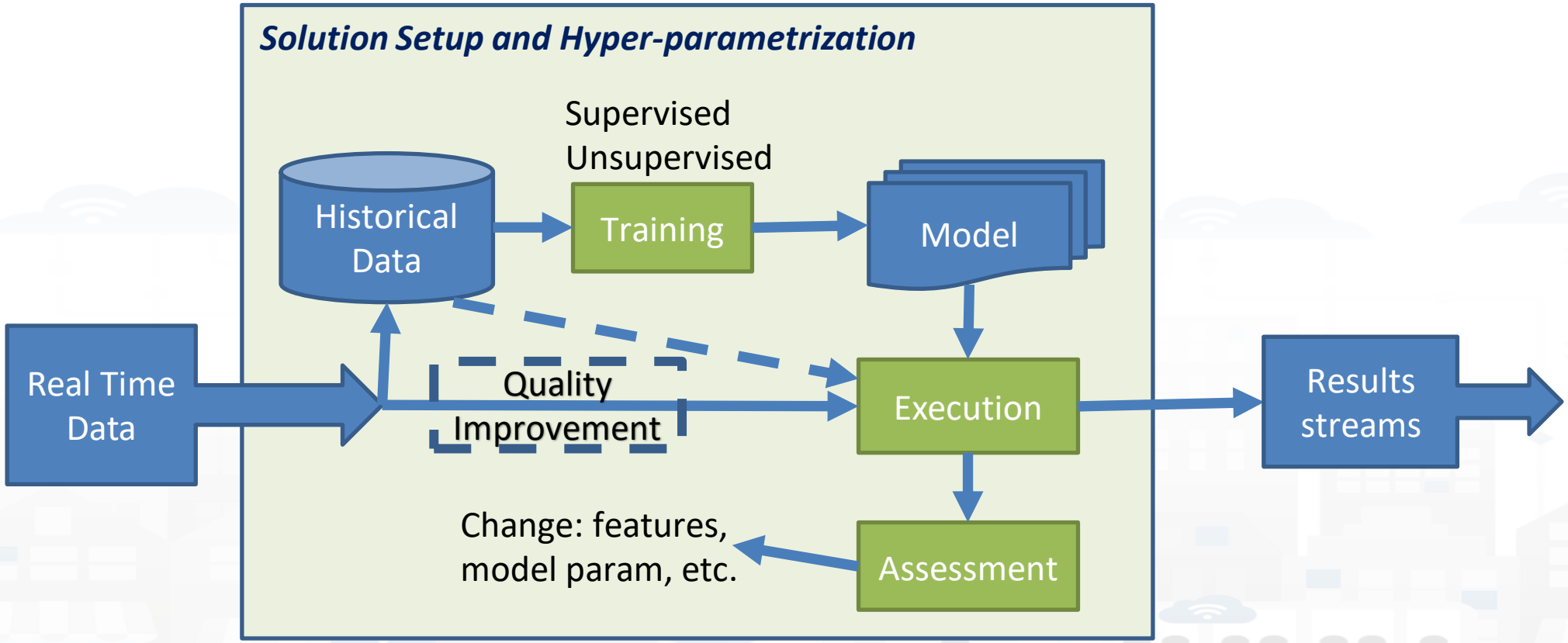
- Time Series Characteristics
  - Mathematical formulation of Time Series
  - Autocorrelation
  - Seasonality
  - Stationarity



Forecasting Methods Selection

Simplified Training and Deploy process





Prediction
Prescriptions
Anomalies
Classifcation
Detection
Etc.

Evaluation Metrics

Root Mean Squared Error (RMSE)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(obs_i - pred_i)^2}{n}}$$

R-Squared(R2)

- $\overline{y} = \frac{1}{n}\sum_{i=1}^{n} \text{obs}_i$
- $R^2 = 1 - \left(\frac{\sum_{i=1}^{n}(obs_i - pred_i)^2}{\sum_{i=1}^{n}(obs_i - \overline{y})^2}\right)$

Mean Absolute Scaled Error (MASE)

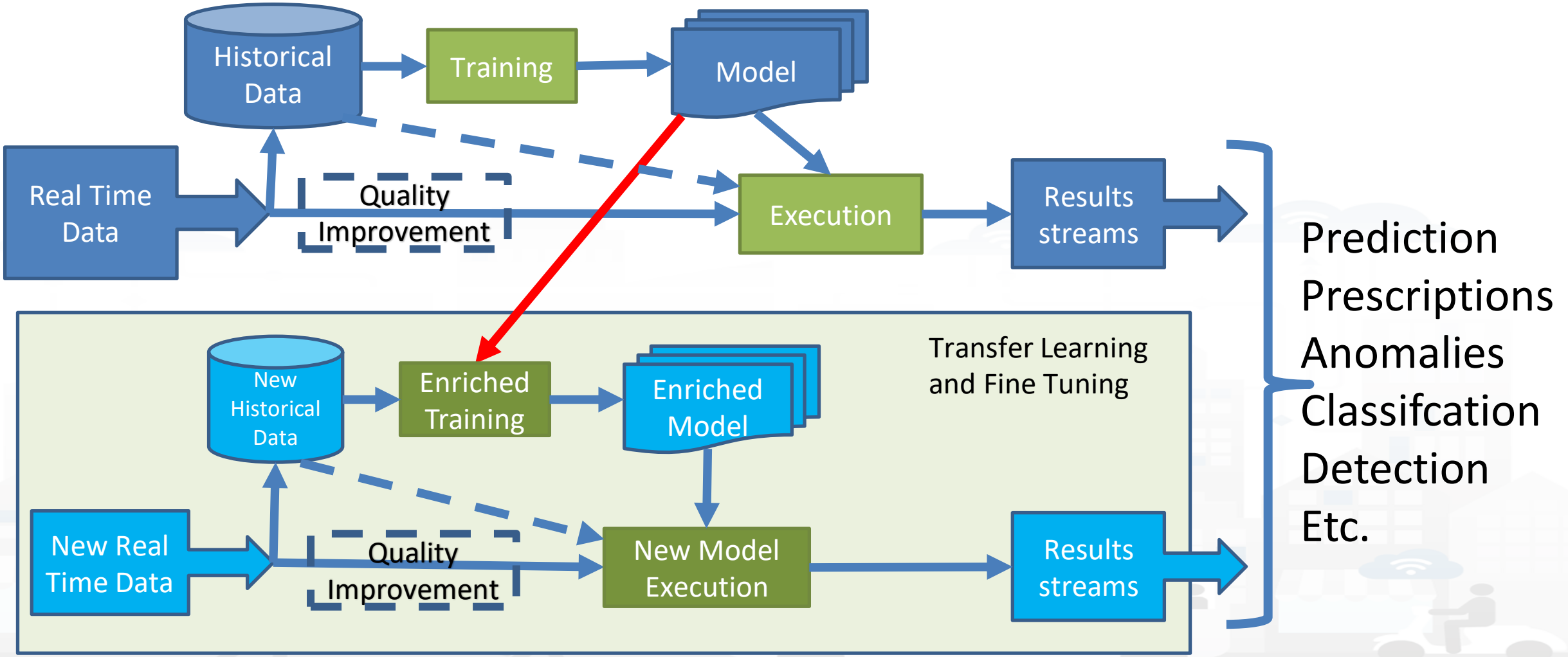
$$q_t = \frac{obs_t - pred_t}{\frac{1}{n-1}\sum_{i=2}^{n}|obs_i - obs_{i-1}|}$$

$$MASE = mean(|q_t|), \quad t = 1, \ldots, n$$

Mean Absolute Error (MAE)

$$MAE = \frac{\sum_{i=1}^{n}|obs_i - pred_i|^2}{n}$$

Simplified Deploy of Transfer Learning Model



Other AI/XAI approaches

- Any other AI approach can be applied on Snap4City platform:
  - Generative AI, Reinforced Learning, etc.
  - LLM

Model/Technique Development/testing

- **Identification of Process goals and Planning (problem definition)**
  - Which goals
  - How to compute, which language
  - Which environment, which libraries
- **Data Discovery and Ingestion (from the general life cycle)**
  - Data Collection, Data Preprocessing if needed
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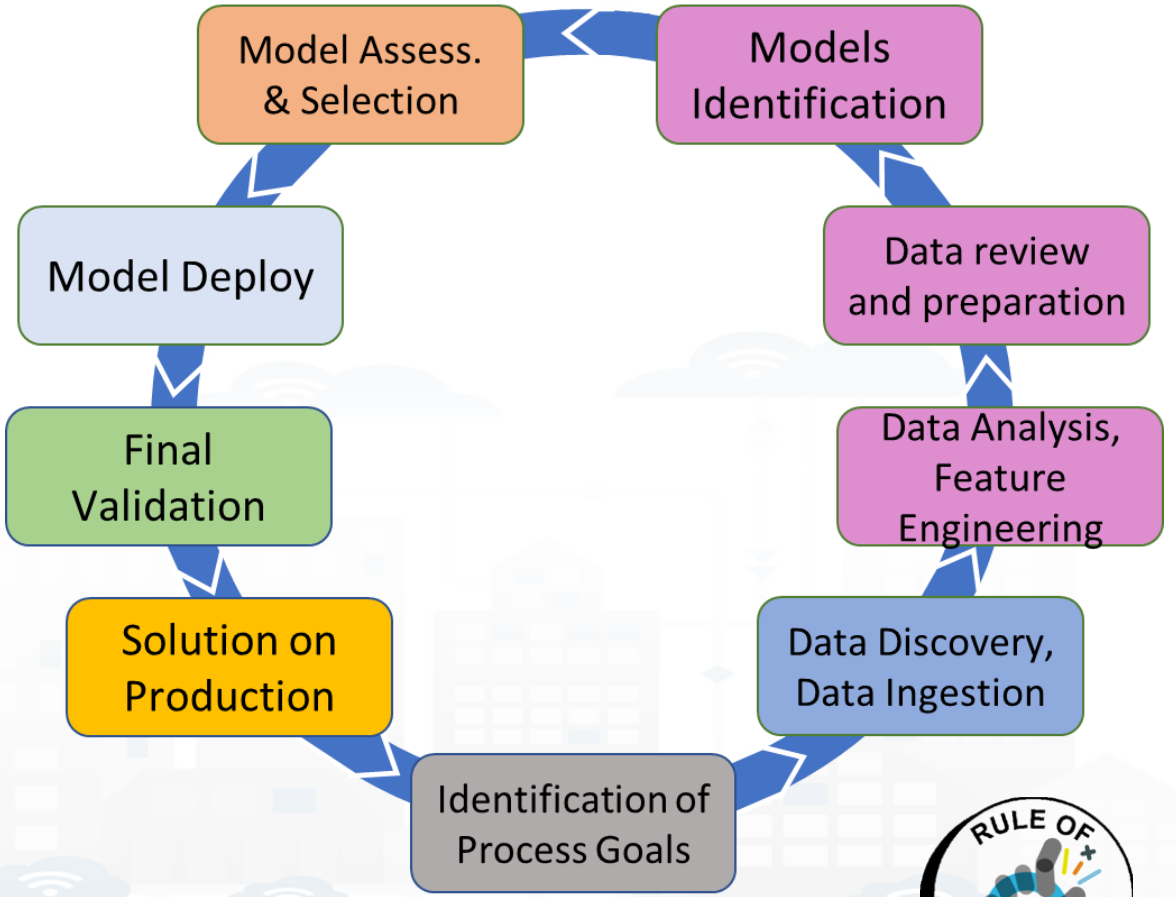
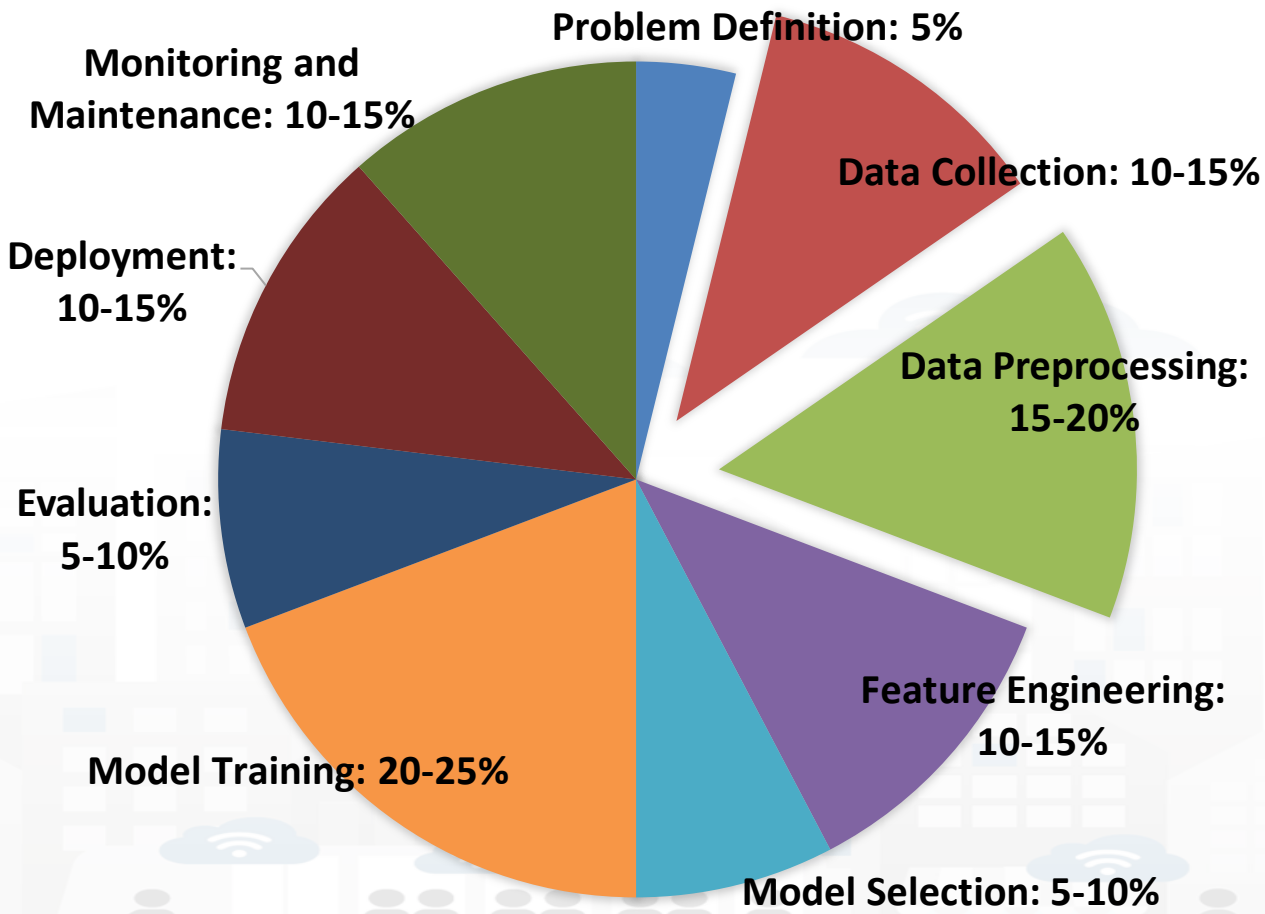


Typical Effort of Phases without Snap4City

- Please note the ***effort for Data Preprocessing and Data Collection***
  - 25-35%
- Please note that the **pie has not taken into account the effort** for creating
  - an actual **applications** or
  - simple **web results rendering** on dashboard

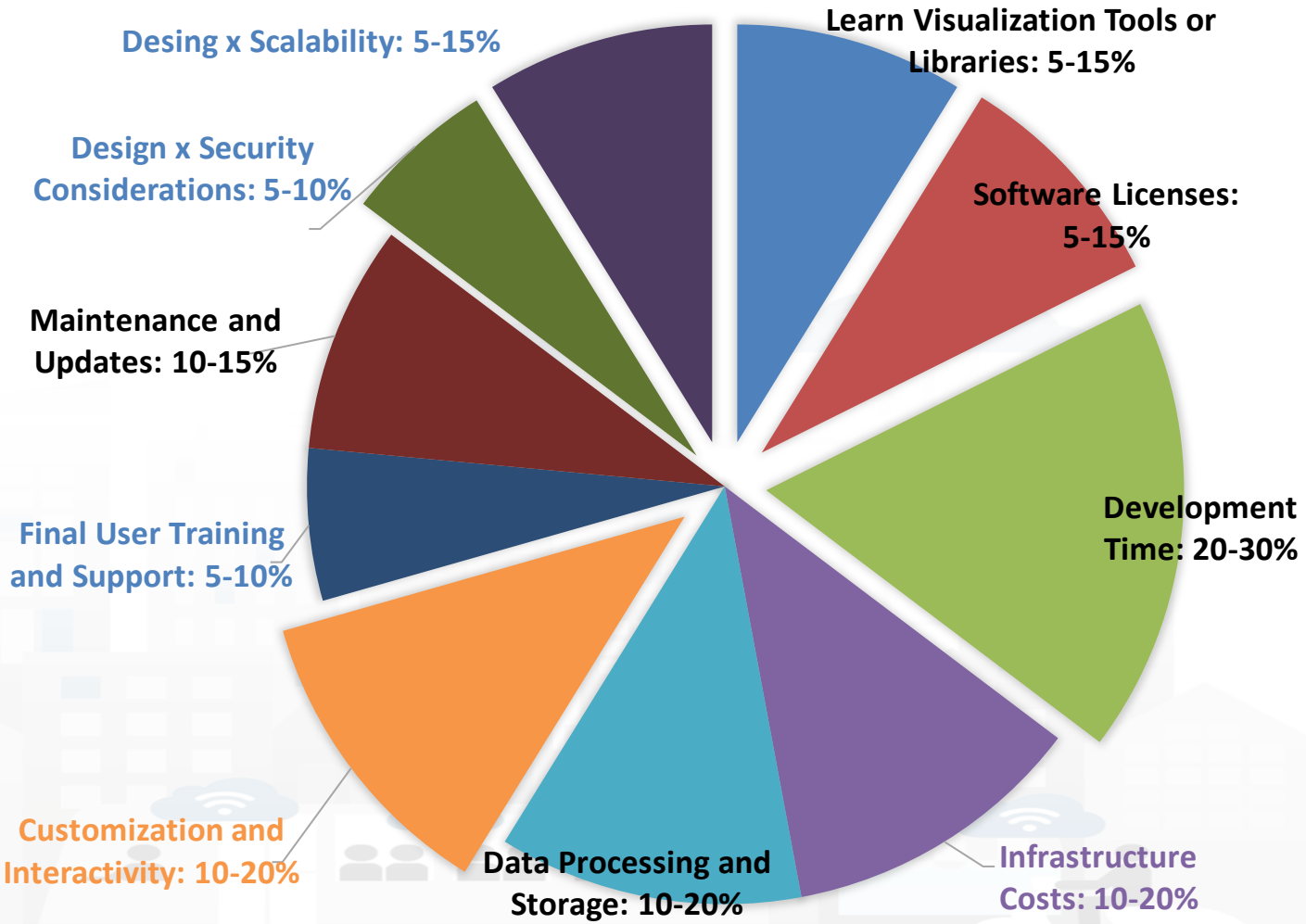


Snap4City on *Data Collection and PreProcess*

- **Effort reduction from 25-35% to 10-15%, >55% reduction of effort for**
  - **Data Collection** via
    - Direct collection access with Brokers, harvesting of external brokers and data models
    - Usage of library of data models, more than 1700 models: saving analysis
      - Custom data models, massive automated construction of entities
    - Automated enrichment of Km4City Ontology and knowledge base: saving time analysis
    - IoT App / Node-red development of data collection processes: fast development
  - **Data PreProcess** via
    - Node-red visual programming (node.js) for preprocessing, transcoding, thousands of microservices and libraries, reuse of blocks and data flows, etc.
    - Semantic recovering of data relationships via semantic graph DB with Km4City models
    - Eventually usage of Python or R-studio or others when needed
  - *Reuse and share of Node-RED solutions, large number of cases*

Typical costs to setup operative conditions

- Learn Visualization Tools or Libraries: 5-15%
- Software Licenses: 5-15%
- Development Time: 20-30%
- Infrastructure Costs: 10-20%
- Data Processing and Storage: 10-20%
- Customization and Interactivity: 10-20%
- Final Users Training and Support: 5-10%
- Maintenance and Updates: 10-15%
- Design for Security/privacy: 5-10%
- Design for Scalability: 5-15%



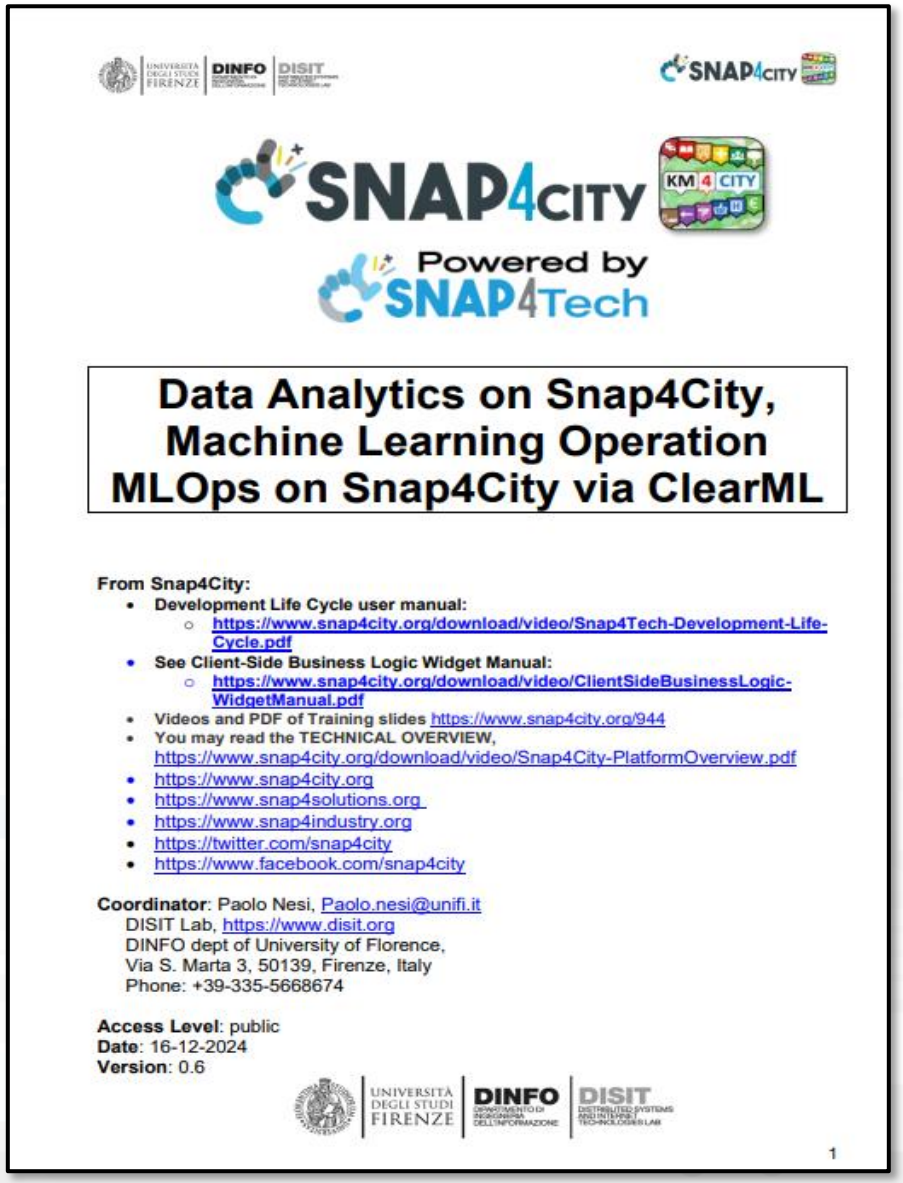
Snap4City strongly reduces the effort/costs for

- **Learn Visualization Tools or Libraries**: 5-15% → **10%**
  - Visual tools, visual programming, training course, dev. Manuals, etc.
- **Software Licenses**: 5-15% → **0%**
  - Development environment fully open source
- **Development Time**: 20-30% → **5%**
  - Dashboard builder, synoptics, widget exchange, dashboard exchange, clone, delegations, etc.
  - Reused cloned and shared solutions, artefacts
- **Customization and Interactivity**: 10-20% → **10%**
  - Dashboards with Business Logic: CSBL, Node-red SSBL
  - Direct development of Business Intelligence without coding all details
- **Design for Security/privacy**: 5-10% → **only respect the guidelines**
  - Snap4City is end-to-end secure and GDPR compliant, all is already in place
- **Design for Scalability**: 5-15% → **only respect the guidelines**
  - Snap4City is scalable from Back-End to Front-End, all is already in place

- ***Reduction of: 45% for development effort of smart city solutions***

MLOperation

https://www.snap4city.org/download/video/Snap4City-MLOps-Manual.pdf



SNAP4CITY KM4CITY

Powered by SNAP4Tech

Data Analytics on Snap4City, Machine Learning Operation MLOps on Snap4City via ClearML

From Snap4City:

- **Development Life Cycle user manual:**
  - https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
- **See Client-Side Business Logic Widget Manual:**
  - https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- Videos and PDF of Training slides https://www.snap4city.org/944
- You may read the TECHNICAL OVERVIEW, https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city

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Access Level: public
Date: 16-12-2024
Version: 0.6

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1

AI/ML Requirements



AI/ML desired requirements



- **Reliable**: capable to produce results in reliable manner, repeatable in operative conditions
- **Trustworthy**: capable to behave such as your best expert, that you can trust
- **Not Biased**: not influenced by some preconcept neither based on some data that can structurally for definition influence the decisions/results!
  - Identified **Goals** of the model can be biased (e.g., approach the solution logistically or predicting a value)
  - **Data Set** for training can be biased (e.g., including variables which can discriminate wrt law/regulations)
  - **AI architecture** can be biased (e.g., selecting one that can see only a specific aspects, reducing the solution space, not addressing non linearity, preprocessing data losing a part of information),
- **Ethical**:
  - **Data Ethics**: to address the ethical non bias aspects on data
  - **AI Ethics (DA Ethics)**: to address the ethical non bias aspects on Data Analytics process from training, to model selection and assessment
  - **Incidental Finding**: what happen if the results or partial results provide hints on unexpected aspects
  - **Etc**….
- ***→→ AI Regulation of EU Act, AI Act:***
  - ***https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence***

Data Analytics vs Data Law

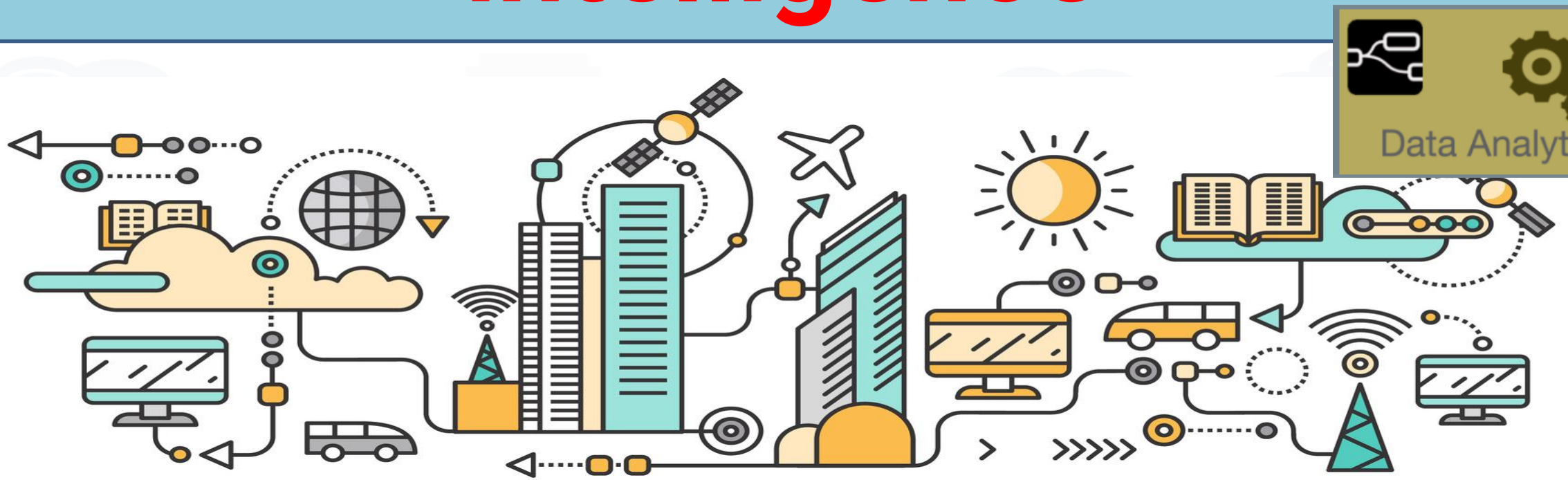


- **Respect Data Sovereignty**:
  - data are subject to the laws and governance structures of the nation (*Jurisdiction*) where they were collected
  - Specific licenses can be modelled and the development tools enabling the development of AI must guarantee
- **Privacy, Respecting GDPR in Europe, other Acts on other countries**: a set of guidelines and techniques
  - **Anonymization**: several kind of approaches, from drastic to those that preserve the: statistical validity, semantics, etc.
  - **Encryption**: of personal data
  - **Decoupling** of data and personal identification data
  - **Channel protection**: SSL, TLS, etc.
  - **Signed Consent**: not any more of Informed Consent, signed per data type
    - Usage of data have to be provided by the user, for each single data type
  - **Data Types**: any kind of user's data, which could be exploited , reused, sold, etc.
  - Any **data start as private** data.

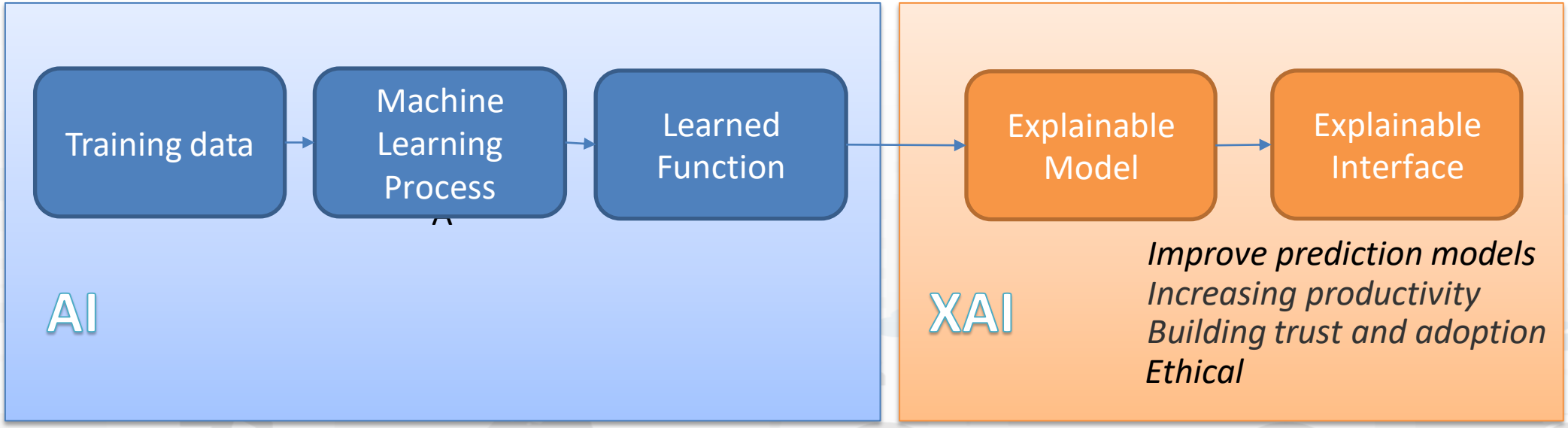
AI Explainability

- **Global Explainability, GE**
  - Given the features adopted in some ML/AI solution, the GE is a description of relevance or important of those features in the production of all the results.
  - The Relevance/Importance is estimated by taking into account the typical impact/incidence of features values on the estimation of results (prediction, classification, etc.)
- **Local Explainability, LE**
  - Given the features adopted in some ML/AI solution, the LE is a description of relevance or important of those features in the production of a specific result, by case.
  - The LE Relevance is estimated by taking into account the specific impact/incidence of a feature value on the estimation of a specific result (prediction, classification, etc.)
- **A number of tools can be used for example:**
  - SHAP, Shapley Additive Explanations

XAI: Explainable artificial intelligence



Explainable artificial intelligence (XAI) is a set of processes and methods that allows human users to comprehend and trust the results and output created by machine learning algorithms.



White Box vs. Black Box Models

A **white-box** model is explainable by design. Therefore, it does not require additional capabilities to be explainable:

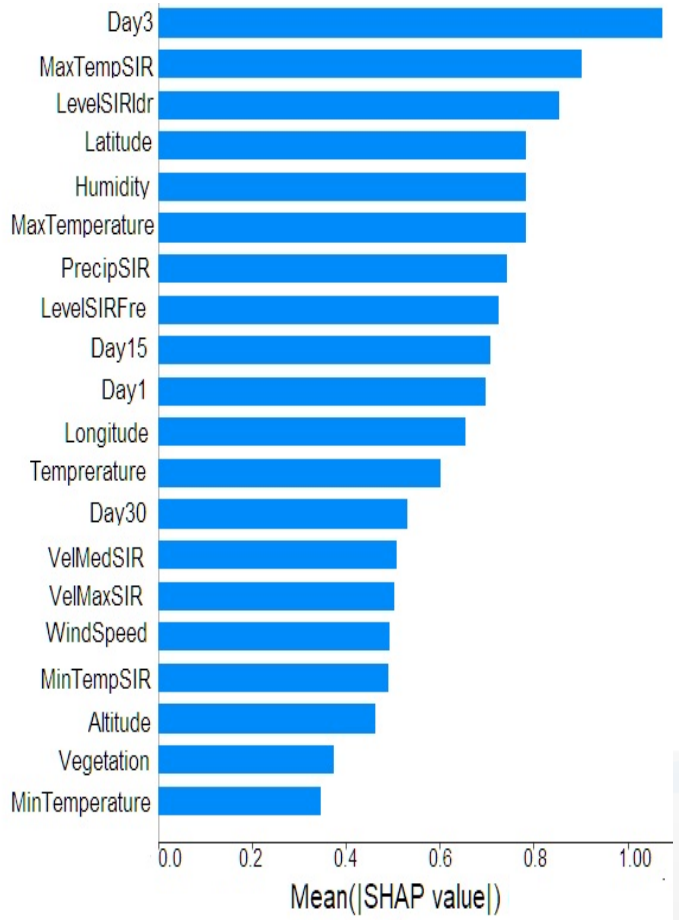
- Linear regression,
- Logistic regression,
- Decision Tree,
- Naive Bayes,
- KNNs
- ……

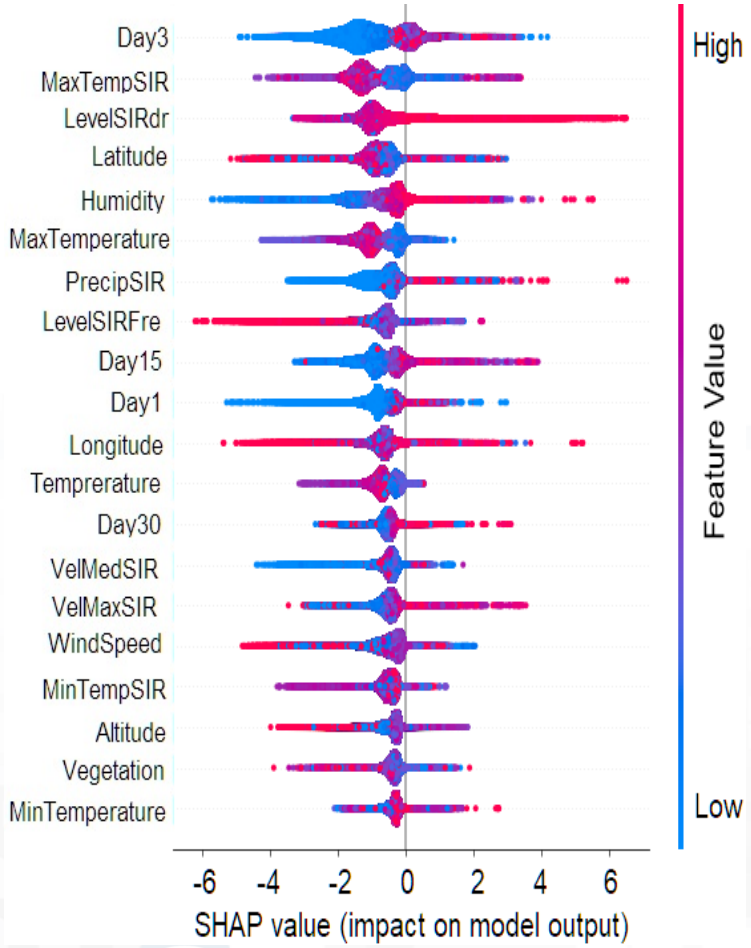
A **black-box model** is not explainable by itself. Therefore, to make a black-box model explainable, we have to adopt several techniques to extract explanations from the inner logic or the outputs of the model.

- CNN, DNN, …
- LSTM
- ……

SHAP Global interpretability

```
with tf.device('/device:GPU:0'):
    explainer = shap.TreeExplainer(MODEL)
    shap_values = explainer.shap_values(X_train)
```





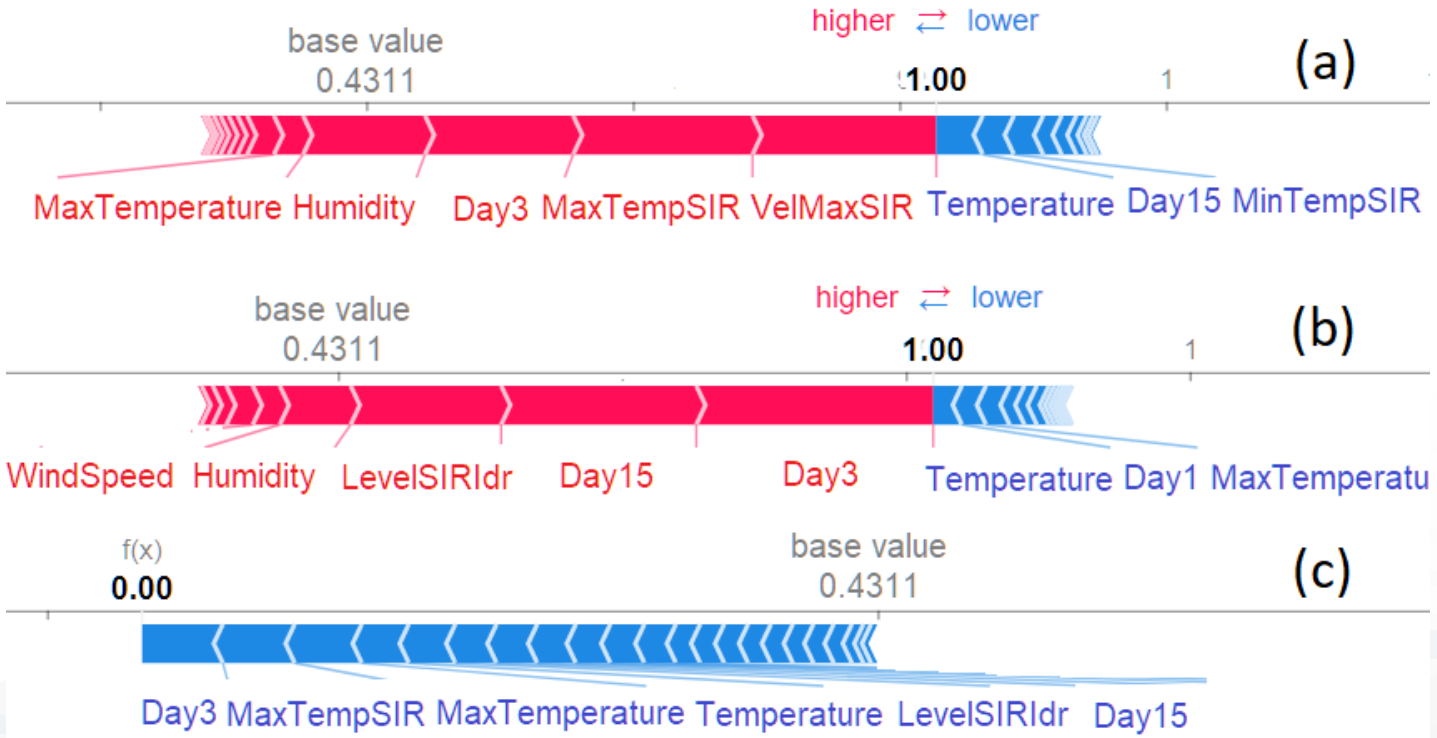
- ***Feature importance**:* Variables are ranked in descending order.
- ***Impact**:* The horizontal location shows whether the effect of that value *is associated with a higher or lower prediction*.
- ***Original value**:* Color shows whether that variable is high (in red) or low (in blue) for that observation.
- ***Correlation**:* A *high* level of "Day3" or "PrecipiSIR" content has a high and *positive* impact on the classification. The "high" comes from the red color, and the "positive" impact is shown on the X-axis.

```
shap.summary_plot(shap_values, features_names, plot_type="bar")
```

```
shap.summary_plot(shap_values, X_train,features_names)
```

SHAP: Local interpretability

```
with tf.device('/device:GPU:0'):
    explainer = shap.TreeExplainer(MODEL)
    shap_values = explainer.shap_values(X_train)
```




```
shap.force_plot(explainer.expected_value,
shap_values[7,:],fields)
```

The ability to explain each prediction, is a very important promise in an explainable AI.

(a) value of VelMaxSIR, MaxTempSIR, Day3 and Humidity contributed significantly to the classification of the observation as a landslide event.

(b) values related to rainfall in the last days, LevelSIRIdr and Humidity given a relevant contribution to the landslide event prediction.

(c) the value of features: Day3, MaxTempSIR, MaxTemperature, Temperature and LevelSIRdr have been determinant for the classification of the observation into a no landslide event.

TOP

Using DA, AI, XAI in Snap4City infrastructures

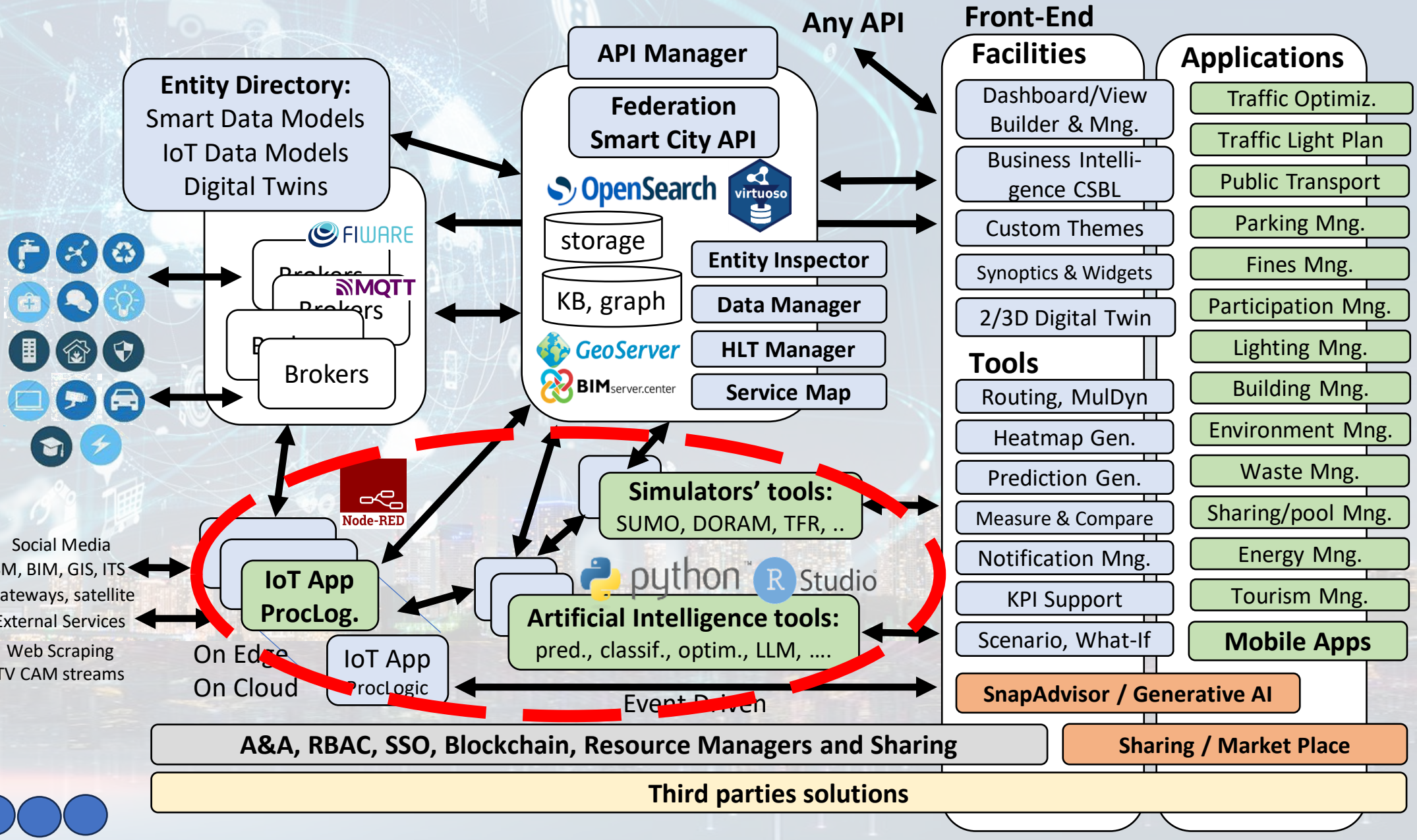
Data Analytics ←→ IoT App / Proc.Logic



Data Processing for different purposes on Snap4City

- **Node-RED** Proc.Logic → see Part 3 and 5
  - On Cloud and/or on Edge
- **Python or R-Studio** → see this Part 4
  - On Cloud
  - On Premise on special hardware with NVIDIA boards, HPC infrastructures, etc.
  - On Edge is needed also with Node-RED

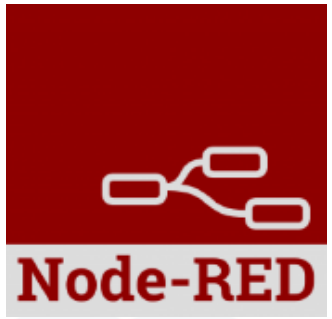
Technical Architecture



IoT App / Proc.Logic

- Storage → IoT App / Proc.Logic
- External Service ←→ IoT App / Proc.Logic
- Dashboards ←→ IoT App / Proc.Logic

Part 3



- Data Analytics ←→ IoT App / Proc.Logic

Part 4

- Broker → Storage
- IoT App / Proc.Logic → Broker
- Broker → IoT App / Proc.Logic
- IoT App / Proc.Logic → Storage

Part 5

DP, for DA, AI, XAI on Container an Example

Data Analytics ←→ IoT App / Proc.Logic



AI/ML Infrastruct.

SNAP4CITY KM4CITY

SNAP4CITY



DEVELOPMENT

python jupyter RStudio

API

Snap4City API

API

EXECUTION

Node-RED

IOT Application

S4CDataAnalytic

plumber data analytic

python data analytic

docker

API

API

API

CLEAR|ML

NVIDIA CUDA

NVIDIA CUDA

NVIDIA CUDA

CPU

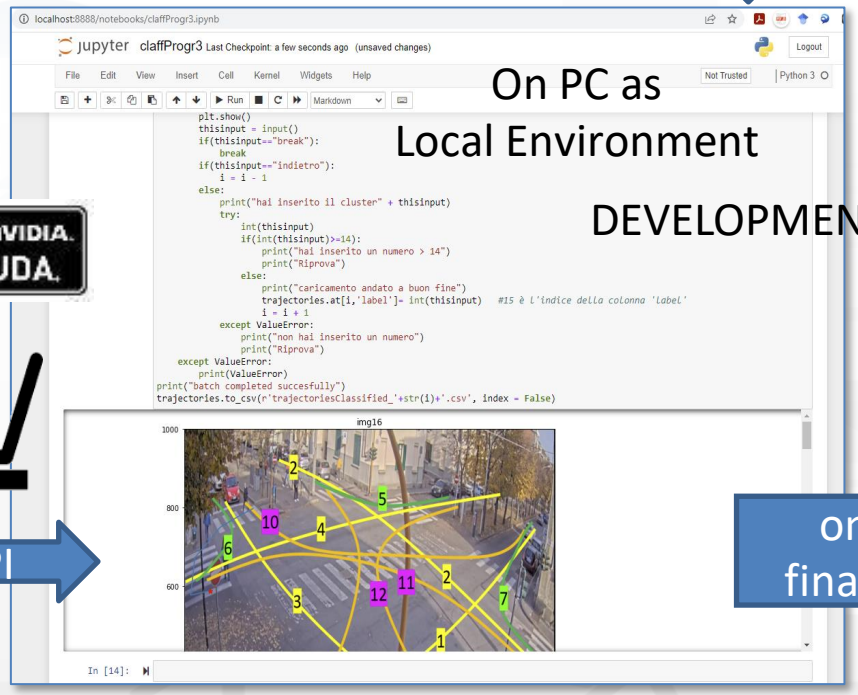
HPC

API

Servers

On Server or On PC

NVIDIA CUDA



On PC as Local Environment

DEVELOPMENT

Any API

once finalized

A

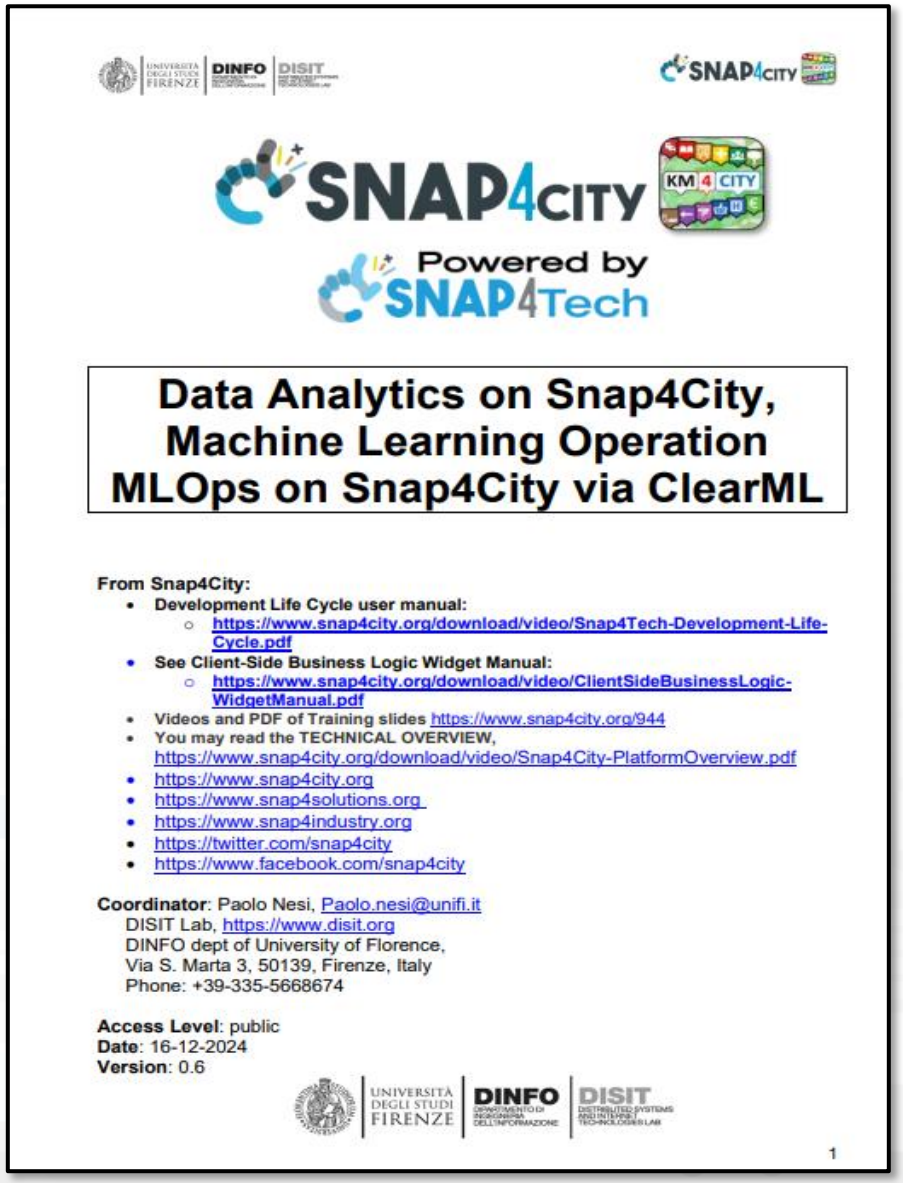
B

C

NVIDIA CUDA API

Server Execution

Process: file .R or .Py (+ the AI/ML model, data) can be put in execution with local scheduler or Cron



SNAP4CITY

Powered by SNAP4Tech

Data Analytics on Snap4City, Machine Learning Operation MLOps on Snap4City via ClearML

From Snap4City:

- **Development Life Cycle user manual:**
  - https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
- **See Client-Side Business Logic Widget Manual:**
  - https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- Videos and PDF of Training slides https://www.snap4city.org/944
- You may read the TECHNICAL OVERVIEW, https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city

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DISIT Lab, https://www.disit.org
DINFO dept of University of Florence,
Via S. Marta 3, 50139, Firenze, Italy
Phone: +39-335-5668674

Access Level: public
Date: 16-12-2024
Version: 0.6

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1

MLOperation

https://www.snap4city.org/download/video/Snap4City-MLOps-Manual.pdf

Data Analytics on Snap4City platform

Swagger







Ontology Schema



LOG.disit.org

Knowledge Base, Km4City



Big Data Store Facility

Smart City API from Knowledge Base and other tools

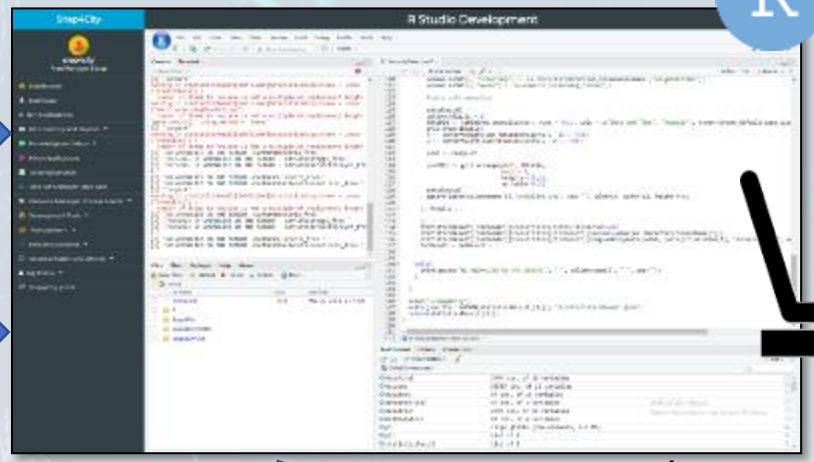
TensorFlow

NVIDIA CUDA

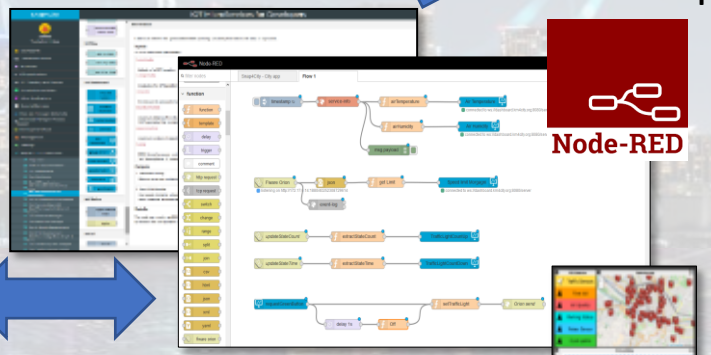
python

jupyter

R Studio



Creating MicroServices



Node-RED

Using them into IOT Applications

Saving / Sharing reusing



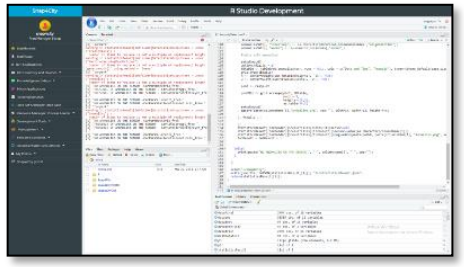
Resource Manager





Development



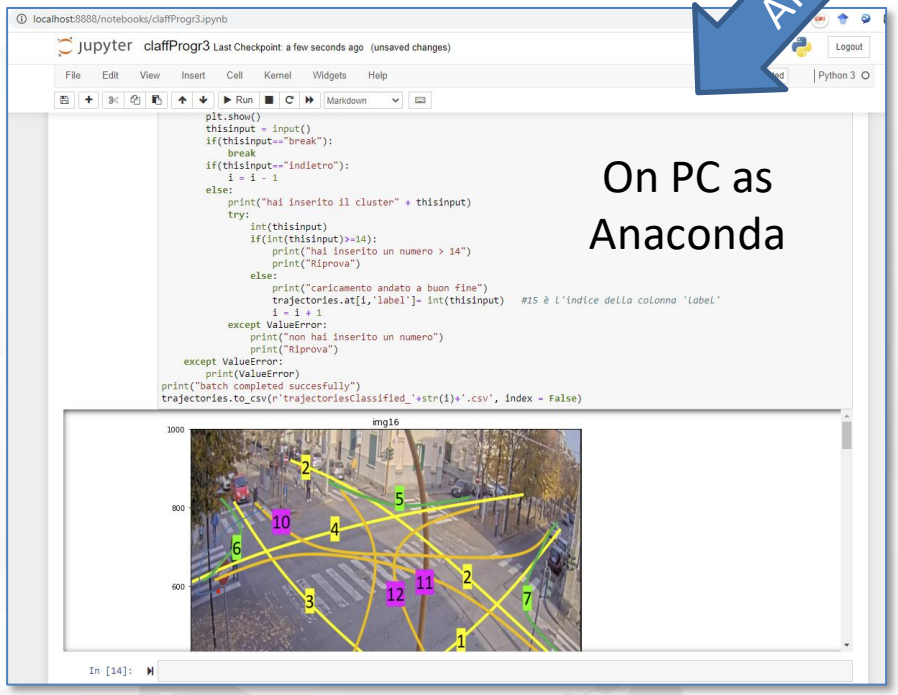


API

Big Data Store Facility

API

On Server
Or
On PC



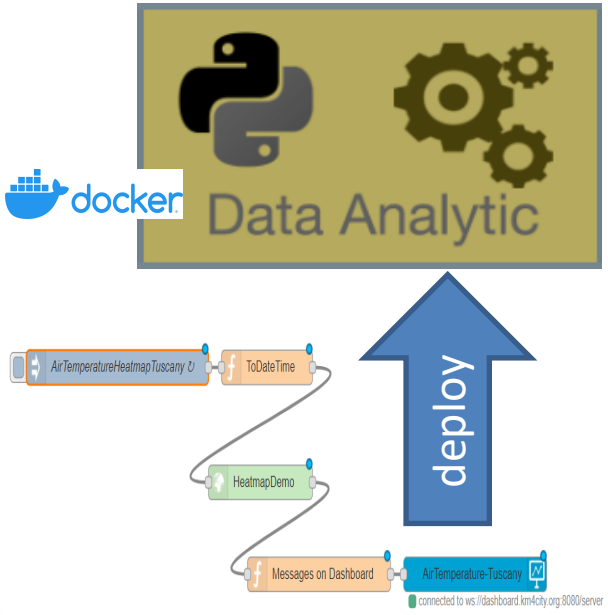
On PC as Anaconda

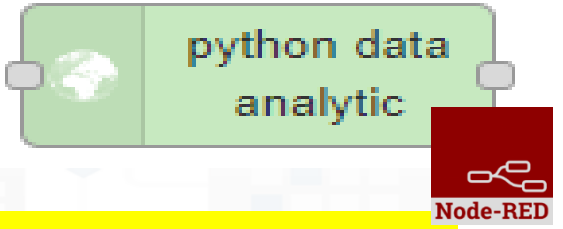
Once finalized

File.py
AI Model
Mapping
Data..

ZIP

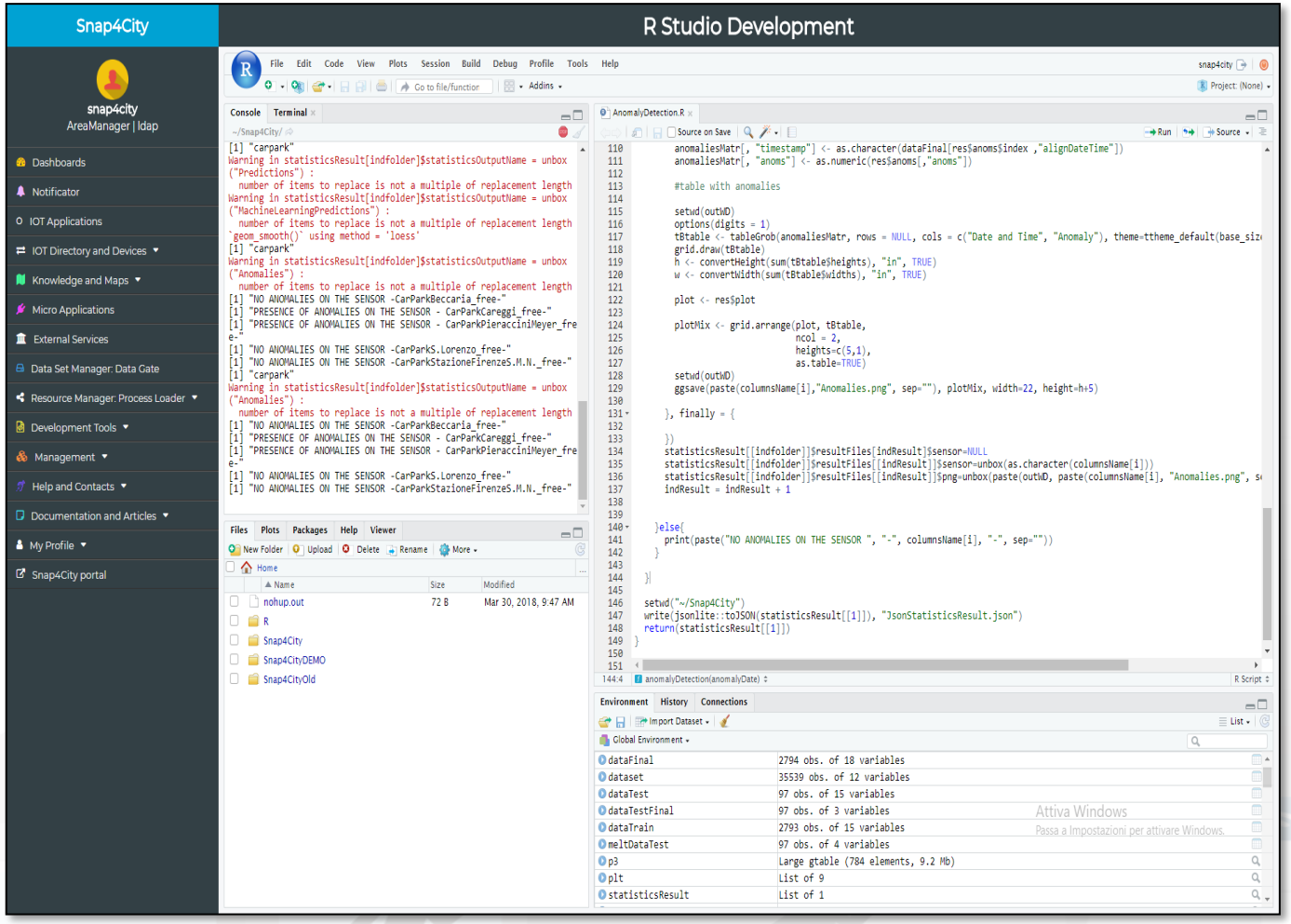
Load
File.py
or .zip





To make the .PY usable as MicroService you need to adapt it to get and send data in/out with Node-RED from a Container.
If you provide a .zip file the main .py inside has to be called doScript.py

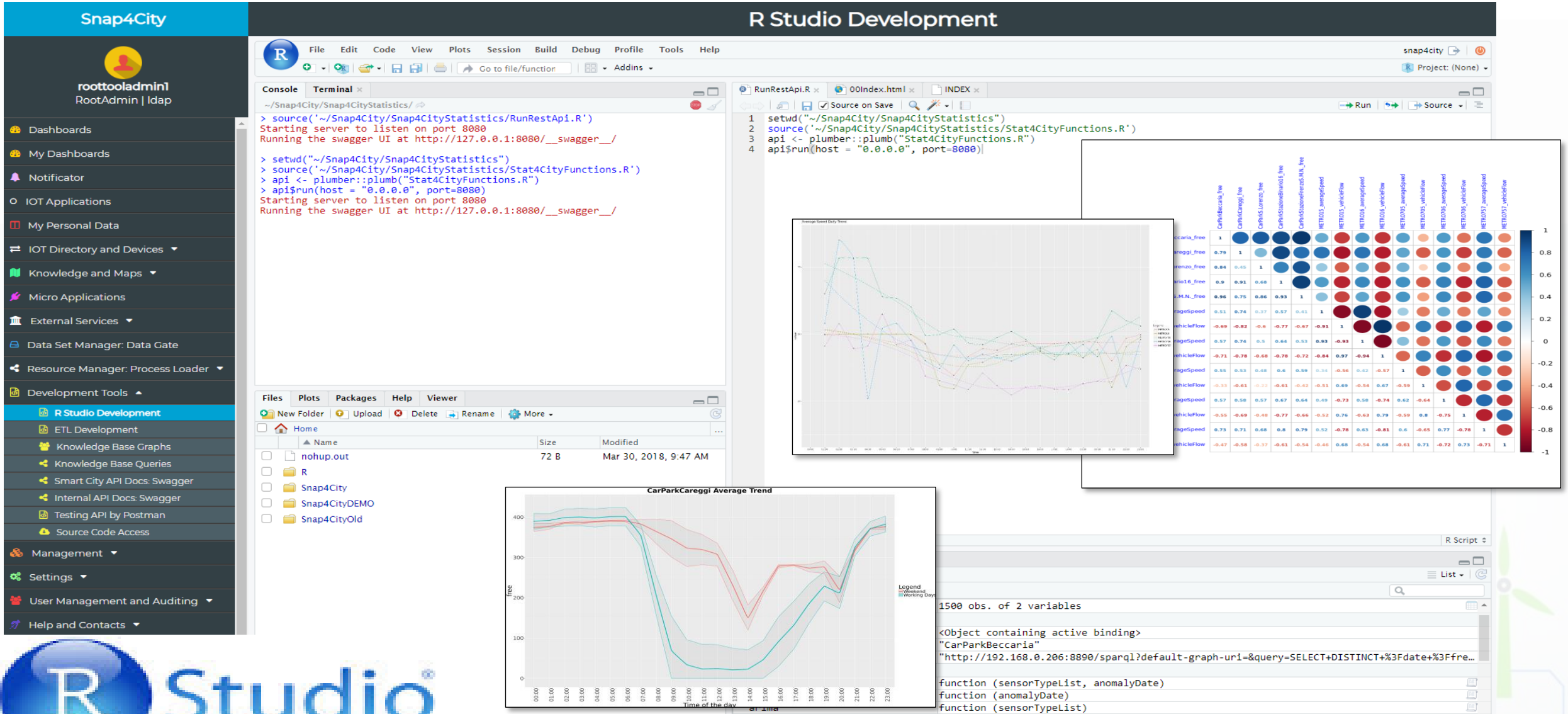
1 Developer in R Studio + Tensor Flow





Data Analytics in R Studio Con Tensor Flow

1



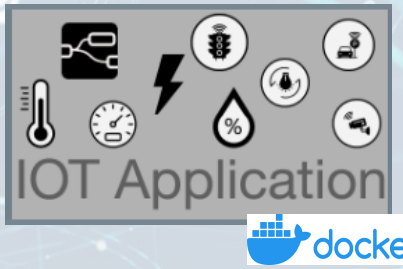
Data Analytic Container

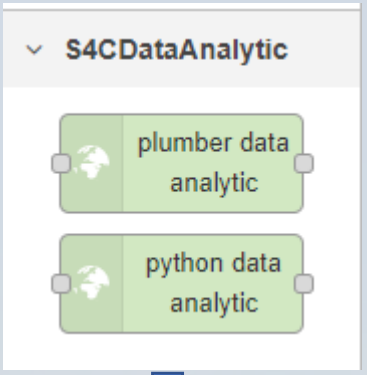


1

Develop .py **or** .r program on (i) Snap4City platform online, or (ii) your Development Machine.
The code has to respect the guidelines provided for creating API.
The API are called as a MicroService
For example see:
https://www.snap4city.org/641
https://www.snap4city.org/645

2 Open an Advanced IoT App / Node-RED

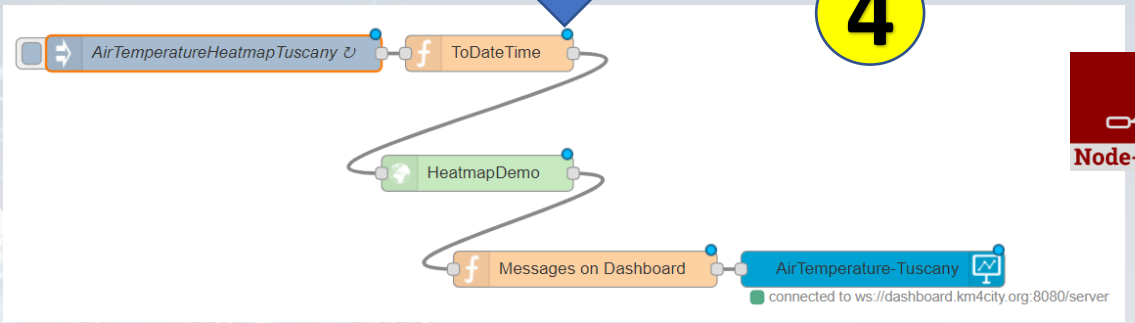




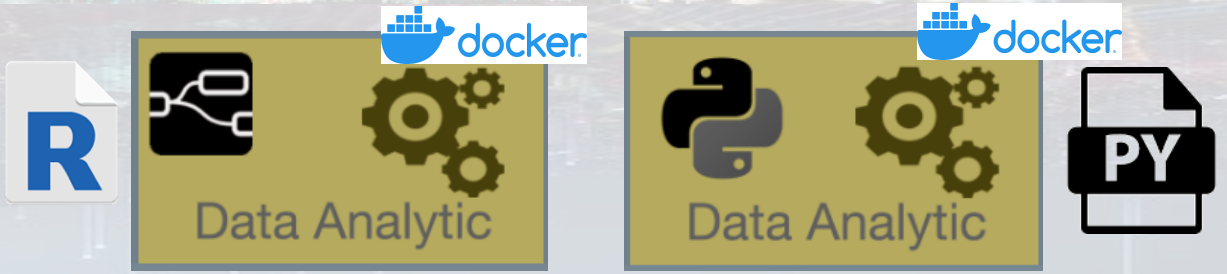
3

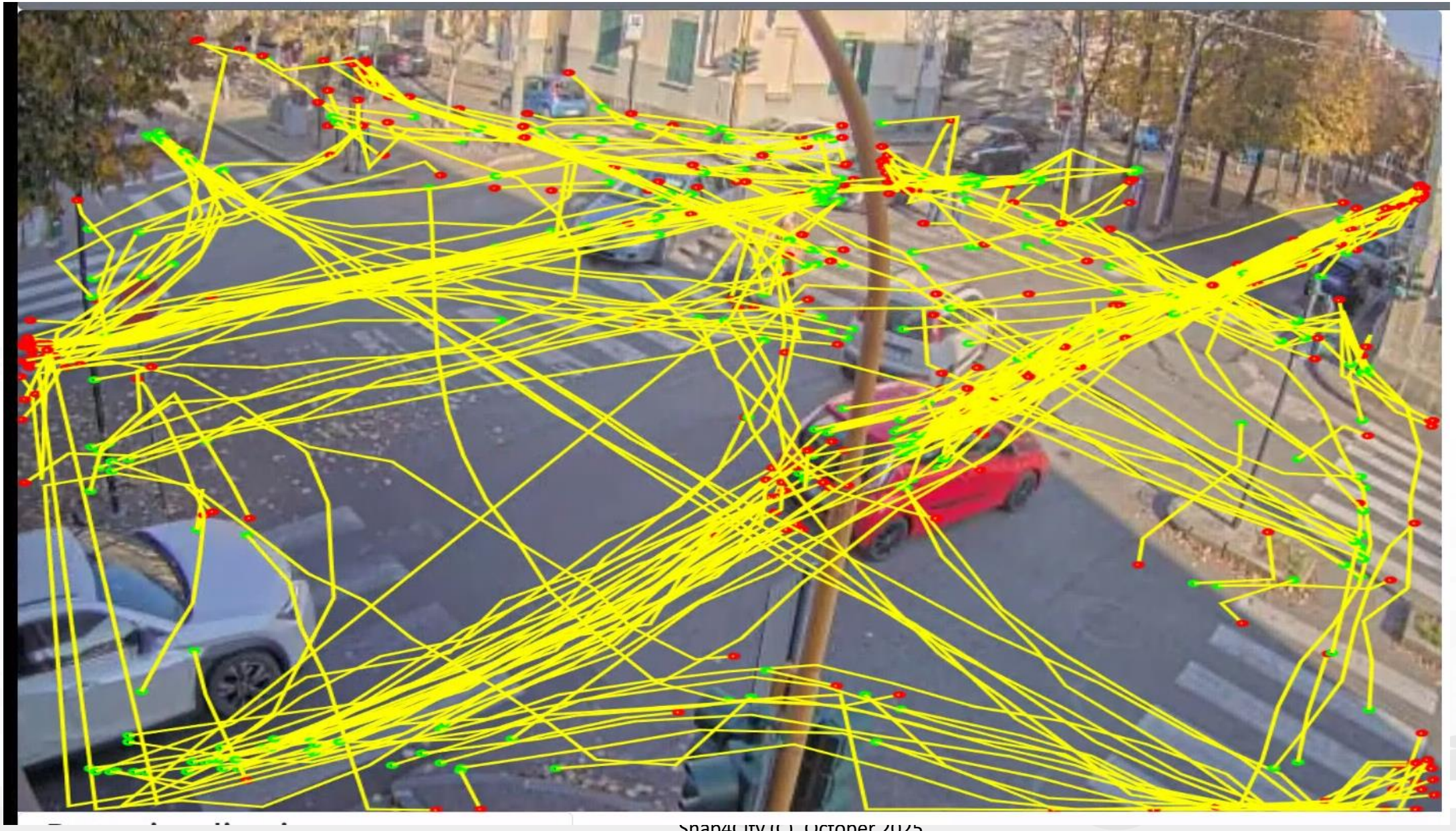
Use Snap4City Data Analytic Node, and load in the code you developed.

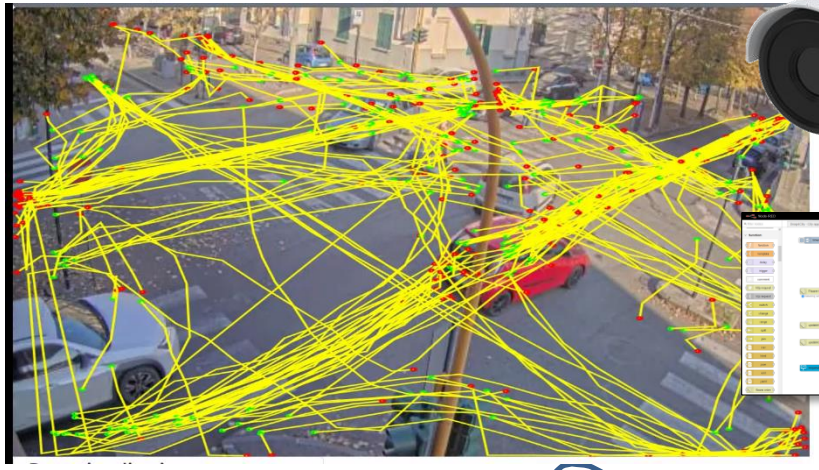
4



5 Deploy the IoT App → Snap4City Container Manager based on Marathon/Mesos is creating a Container for your Data Analytic code

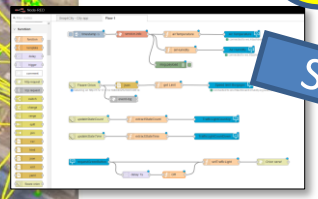






IoT edge on TV Camera

1



Send data to Broker

Send Trajectories

2

IOT Broker

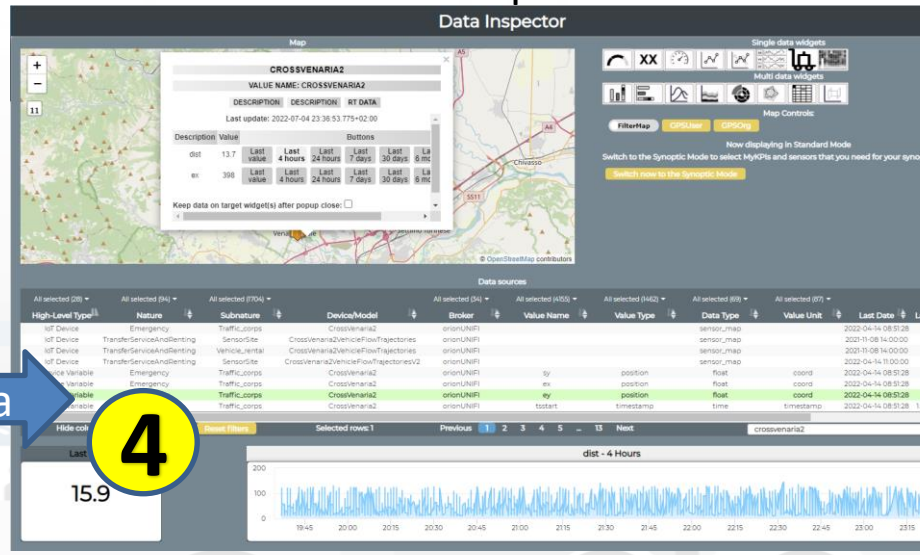
Device: CrossVenaria2 with trajectories

Save data

3

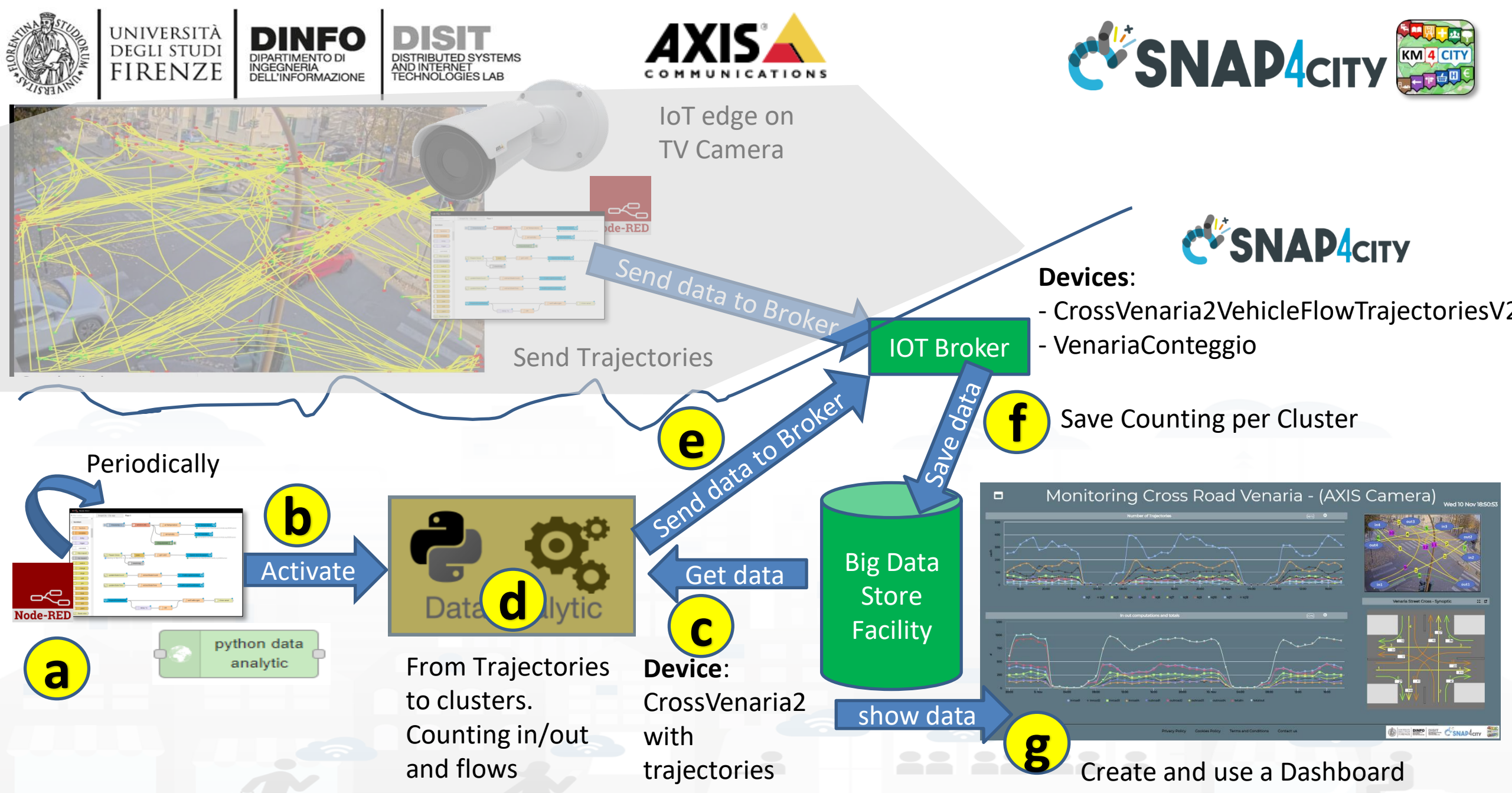
Big Data Store Facility

Data Inspector



show data

4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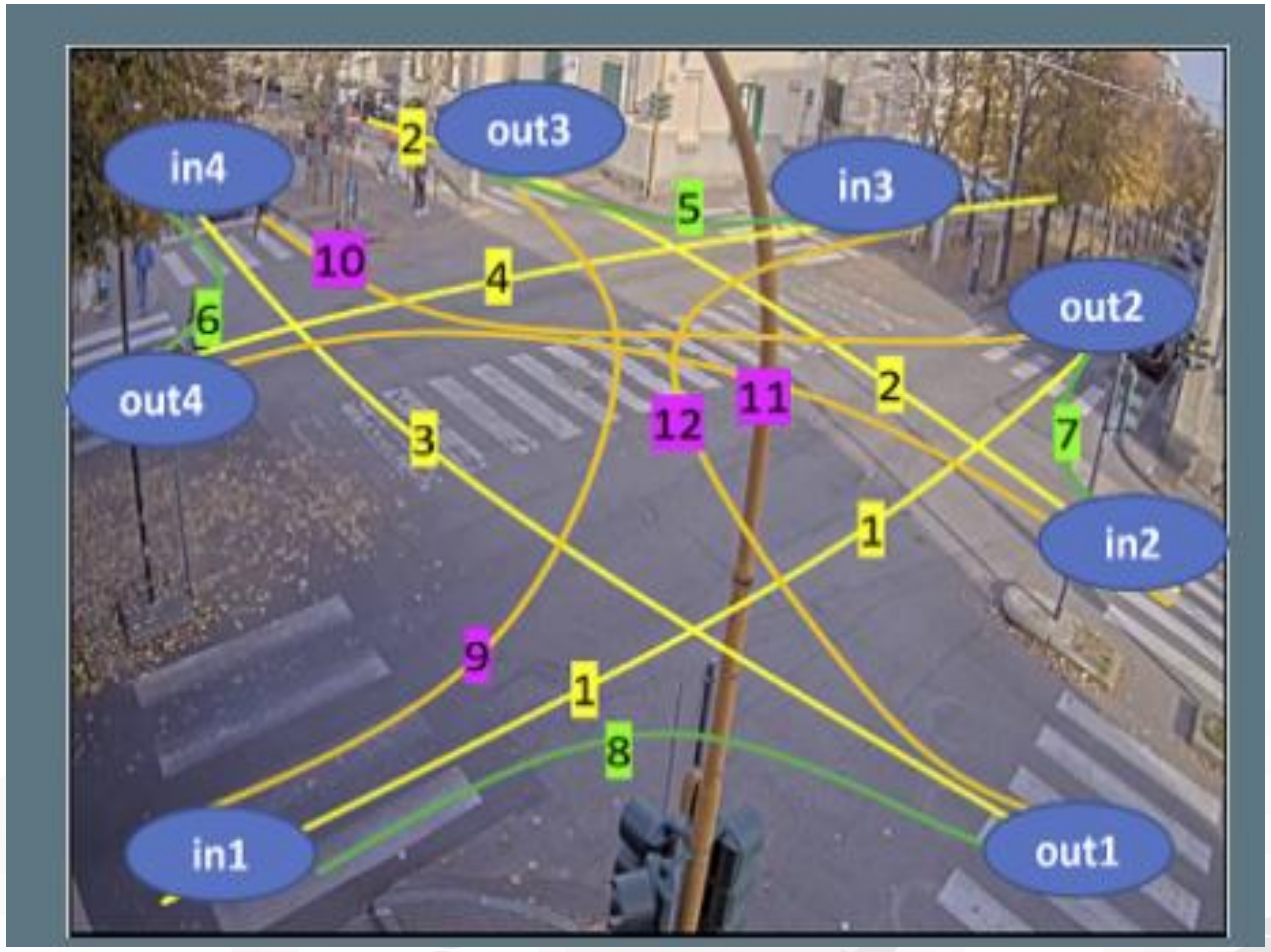
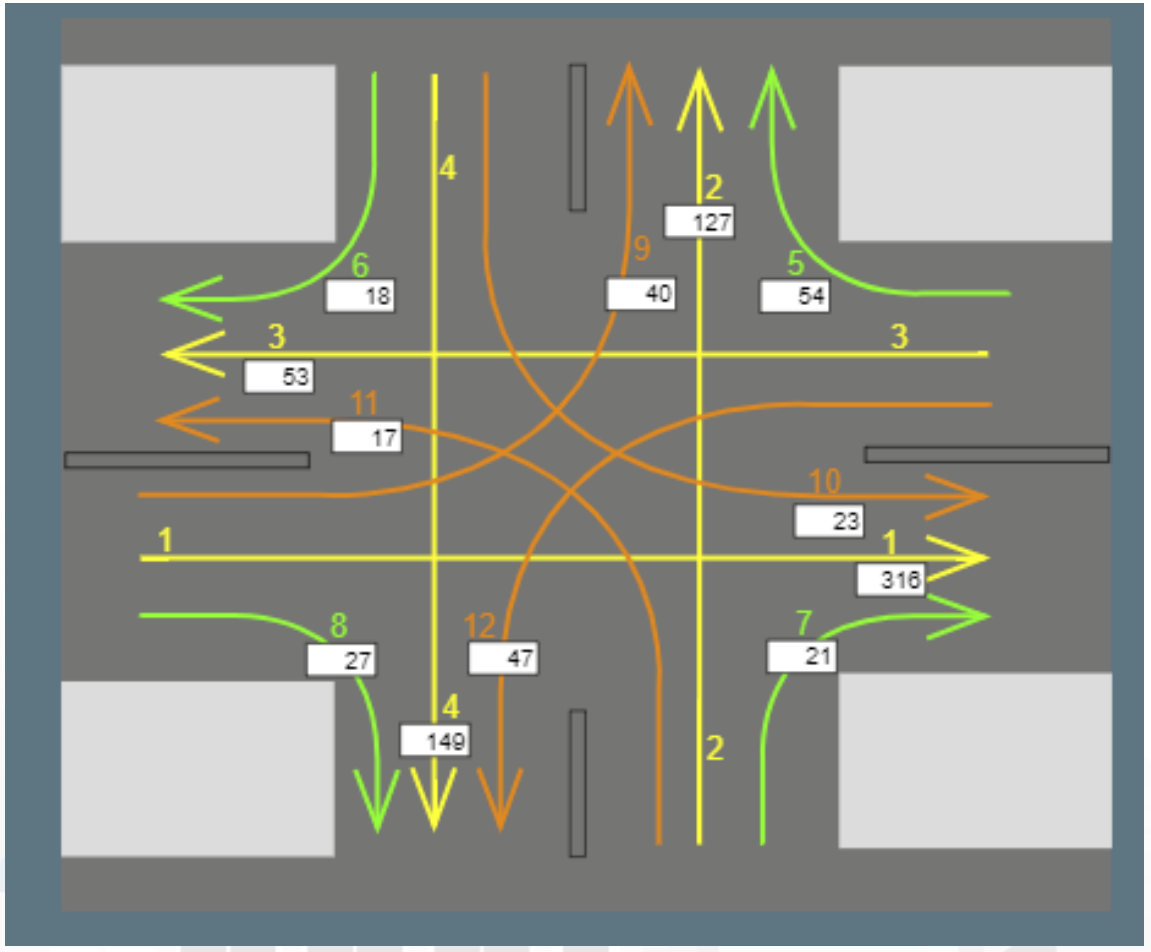
DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB
AXIS COMMUNICATIONS
SNAP4CITY
KM4CITY
IoT edge on TV Camera
Send data to Broker
Send Trajectories
IOT Broker
SNAP4CITY
Devices:
- CrossVenaria2VehicleFlowTrajectoriesV2
- VenariaConteggio
Save data
f
Save Counting per Cluster
e
Send data to Broker
Periodically
Node-RED
a
b
Activate
python data analytic
d
Data Analytic
From Trajectories to clusters. Counting in/out and flows
Get data
c
Device: CrossVenaria2 with trajectories
Big Data Store Facility
show data
Monitoring Cross Road Venaria - (AXIS Camera)
g
Create and use a Dashboard

Real time Clustering: legenda and synoptic



Legenda

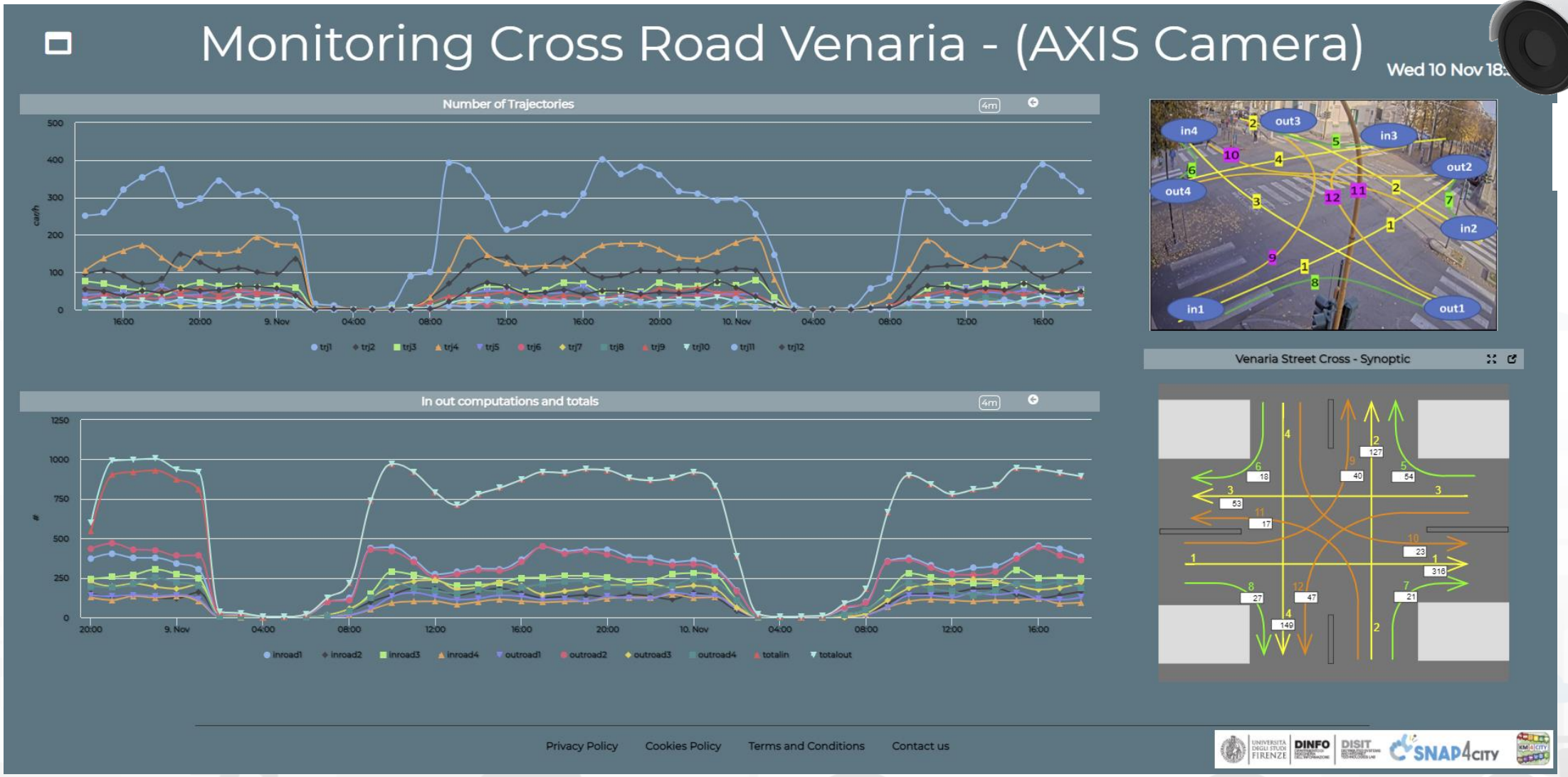


Synoptic with real time data

An example

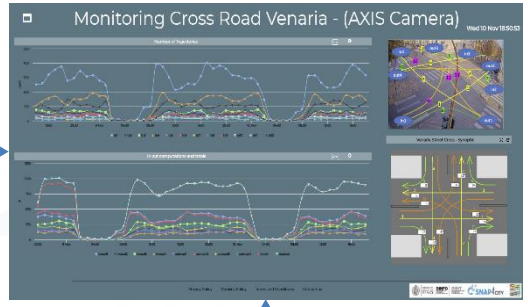
Traffic Flow Analysis via TV Camera and Clustering on cloud





Managing TV Cam





SNAP4CITY

IOT Directory

triples

Knowledge Base
Semantic Reasoners

IOT Devices
Registration

SURI Link

push

subscription note

IOT Orion Broker

Real Time

Indexing and Aggregating
NIFI, OpenSearch

Node-RED

IOT
App

Real Time data in Pull, Push
Any gateway, server

Processing if needed

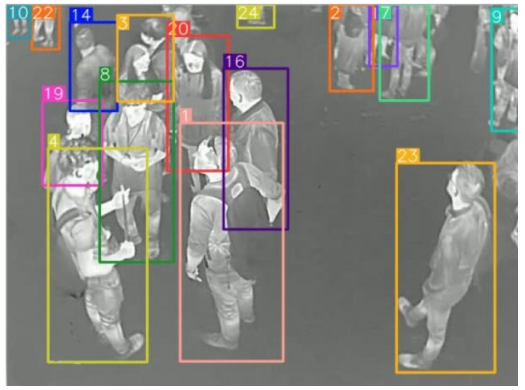
Data Analytics

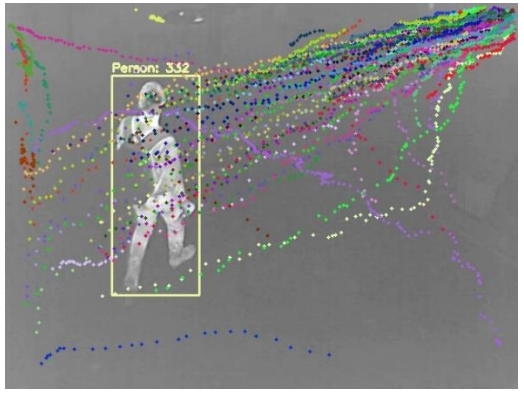
Data Analytic

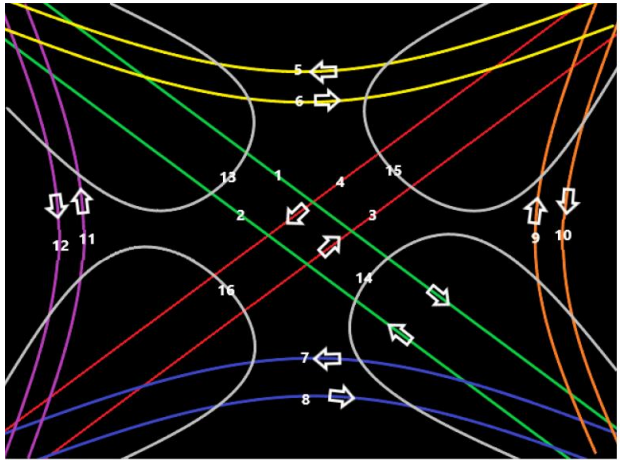
User Behaviour: People Counting, Tracking, etc.

- **Behavior analysis in open or closed spaces**
  - HUB, metro, stations, production lines, parking lots, critical areas in cities,
  - shopping centers, retail, etc.
- **Thermal Cameras**
  - GDPR compliant
- **AI injection**
  - classification and counting
  - Identification of critical situations
  - Early warning
  - Integration with PAX counters, and with ODM data from operators
- **Real-time estimation**
  - Directly on the camera
  - High precision and reliability
  - Used by: Cuneo, Florence, Genoa, etc

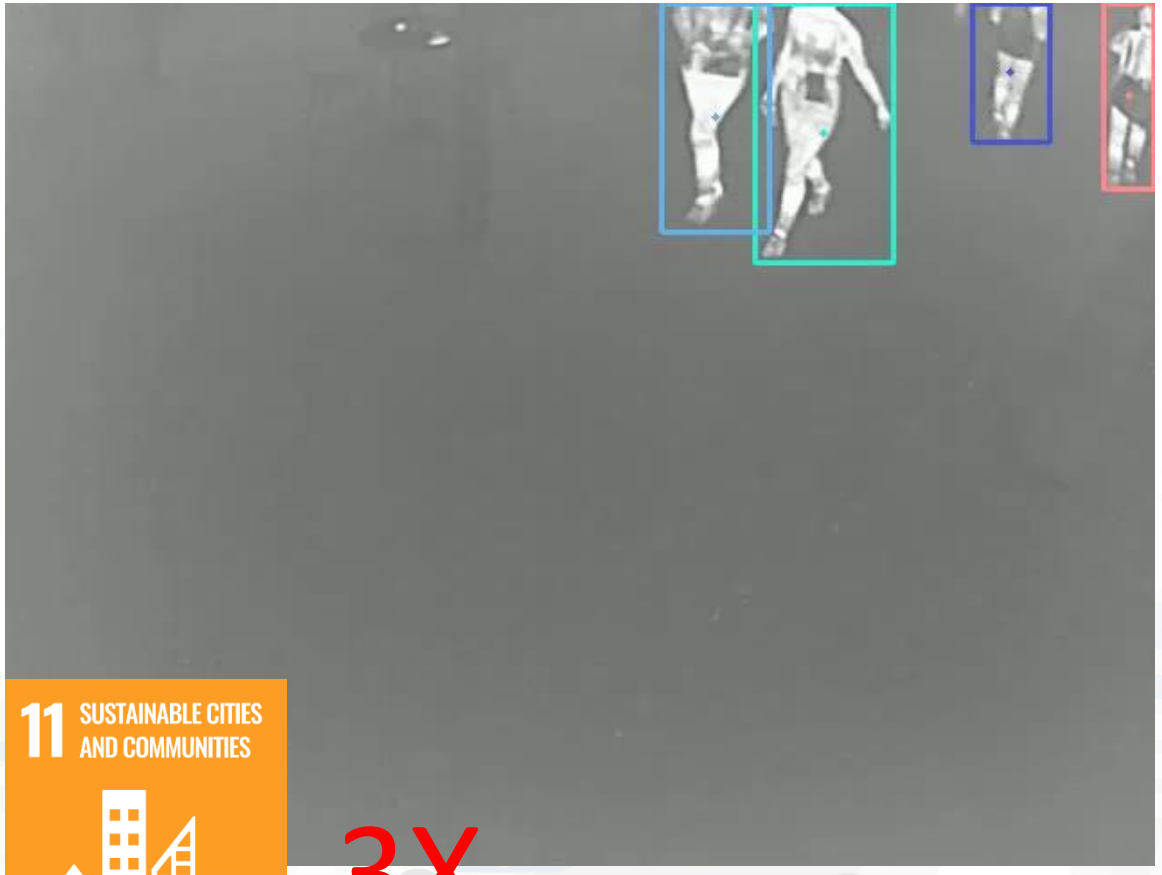


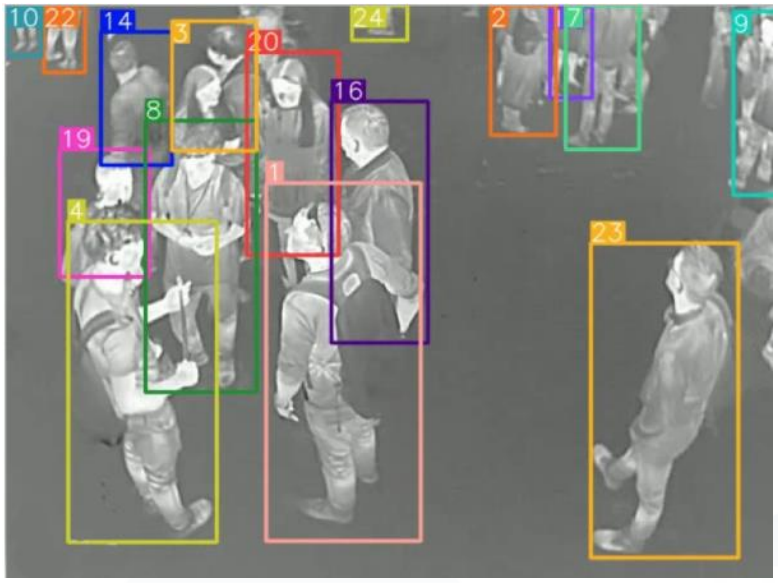


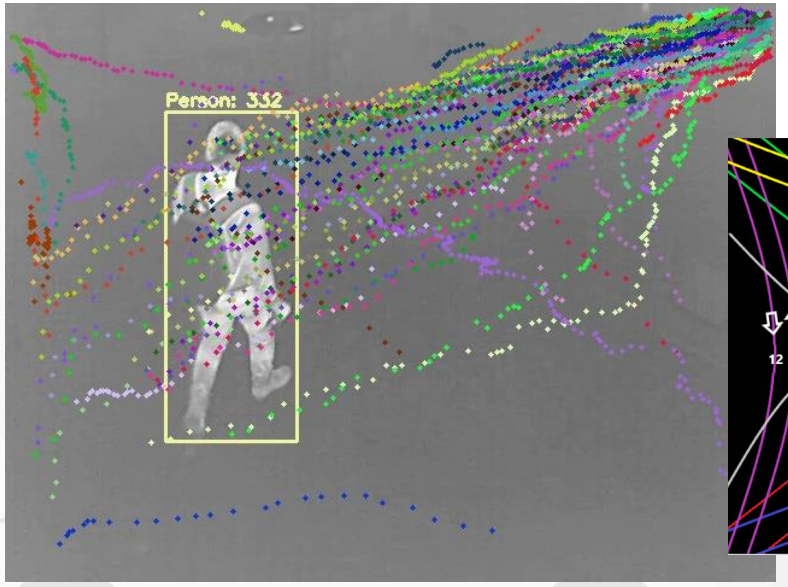


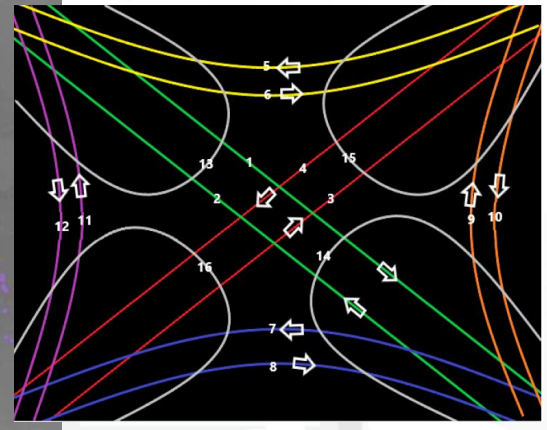


People Counting and Tracking



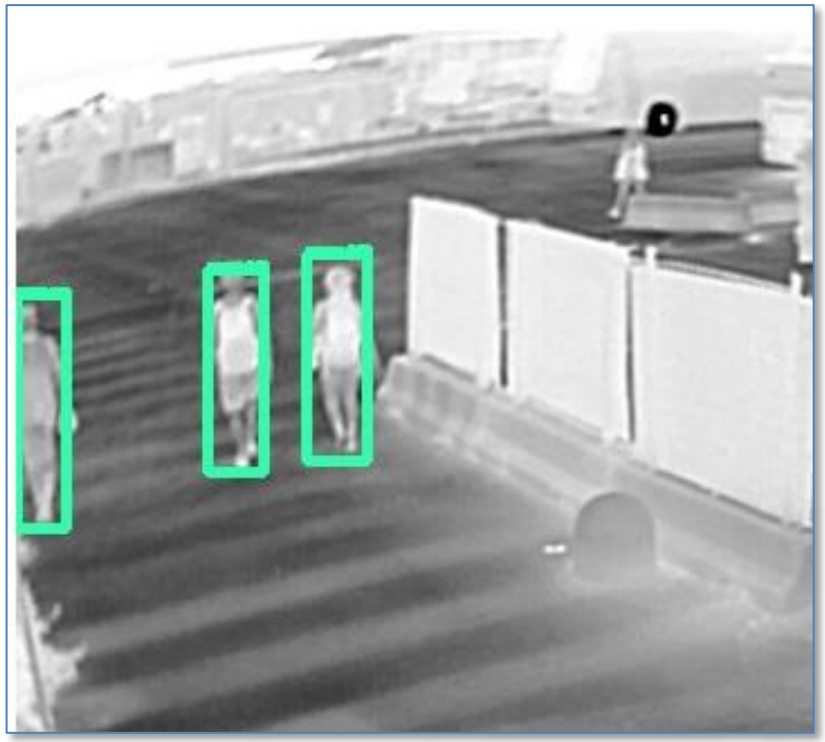






11 SUSTAINABLE CITIES AND COMMUNITIES

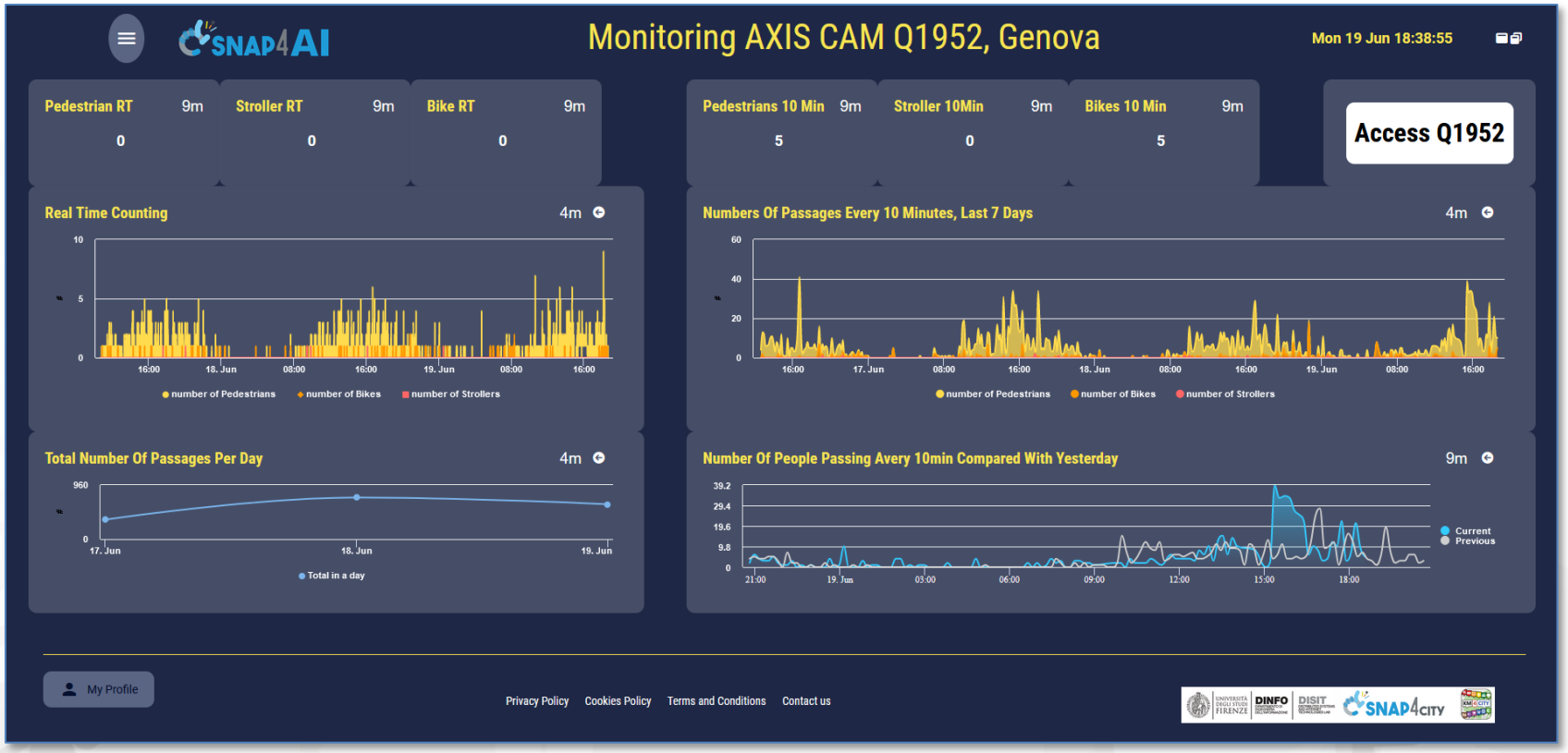
3X



Monitoring Passages AXIS Q1952



- Genova: Ocean Race, 2023





SNAP4AI

Monitoring AXIS CAM Q1952, Genova

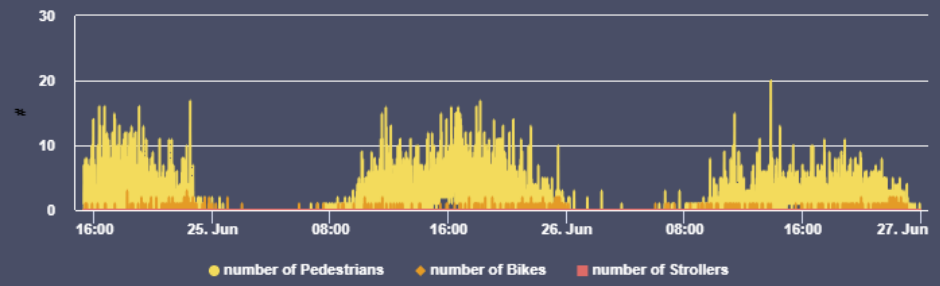
Mon 26 Jun 23:56:21

Pedestrian RT 9m	Stroller RT 9m	Bike RT 9m
0	0	0

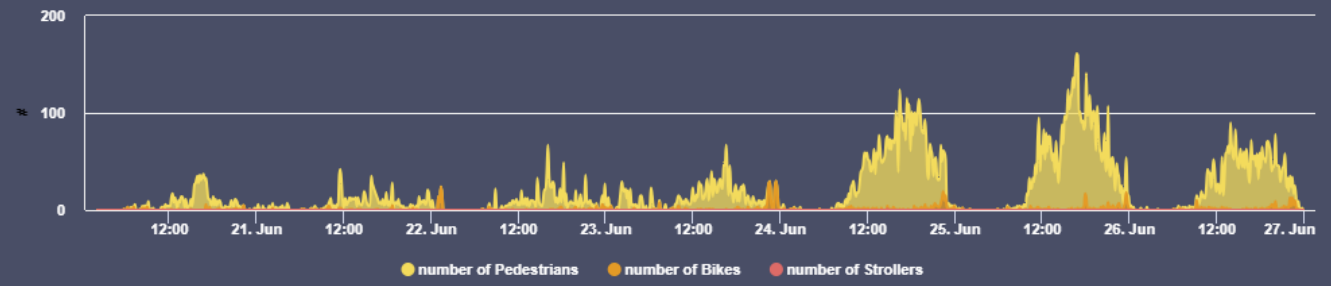
Pedestrians 10 Min 9m	Stroller 10Min 9m	Bikes 10 Min 9m
0	0	0

Access Q1952

Real Time Counting 4m



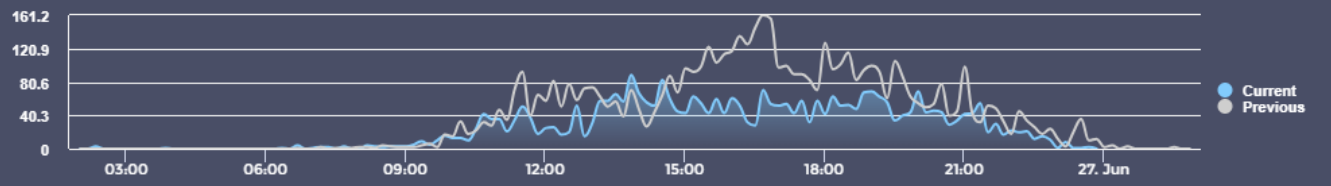
Numbers Of Passages Every 10 Minutes, Last 7 Days 4m



Total Number Of Passages Per Day 4m



Number Of People Passing Avery 10min Compared With Last 24 Hours 9m



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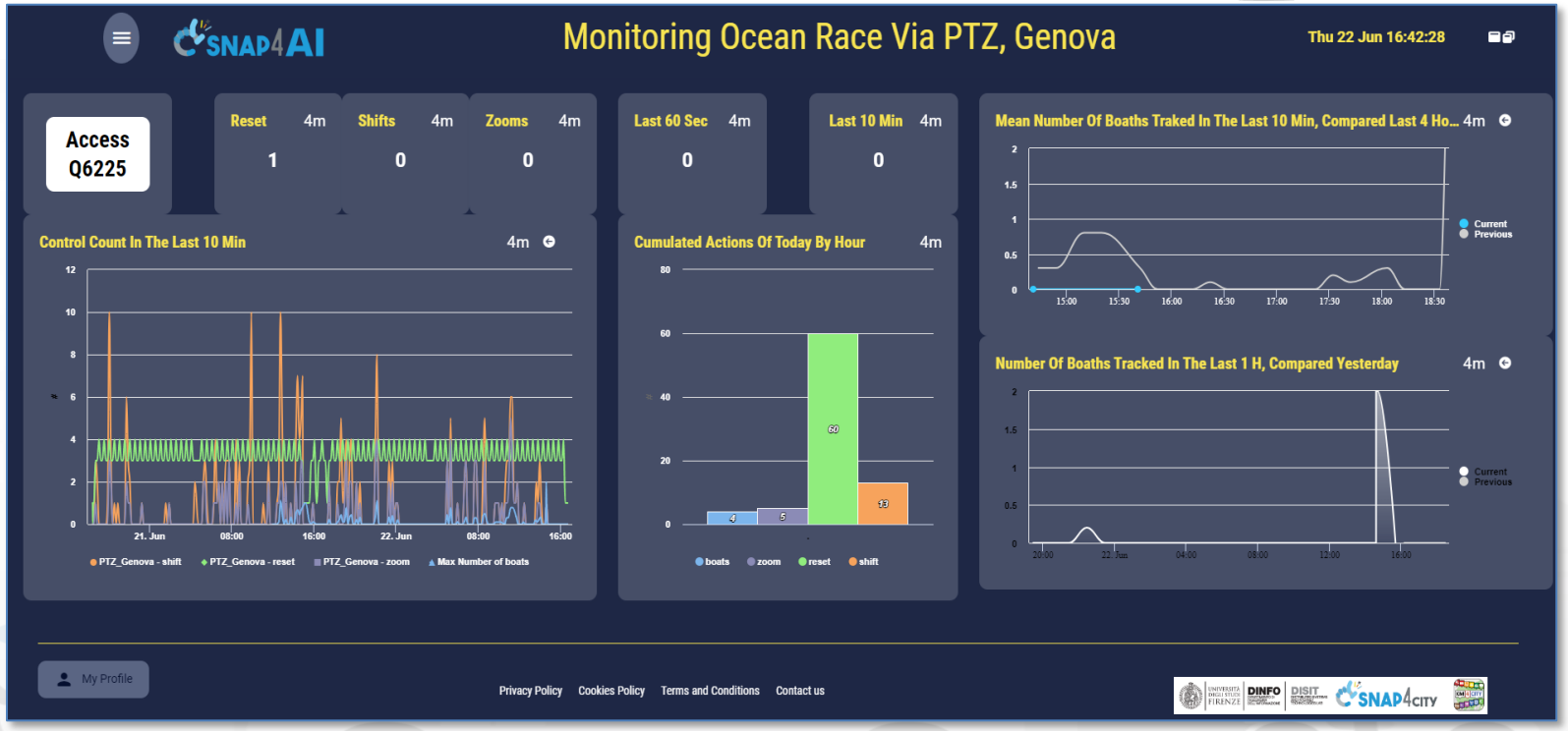
Monitoring Boats
AXIS Q6225





- Genova: Ocean Race, 2023



11 SUSTAINABLE CITIES AND COMMUNITIES

SNAP4AI

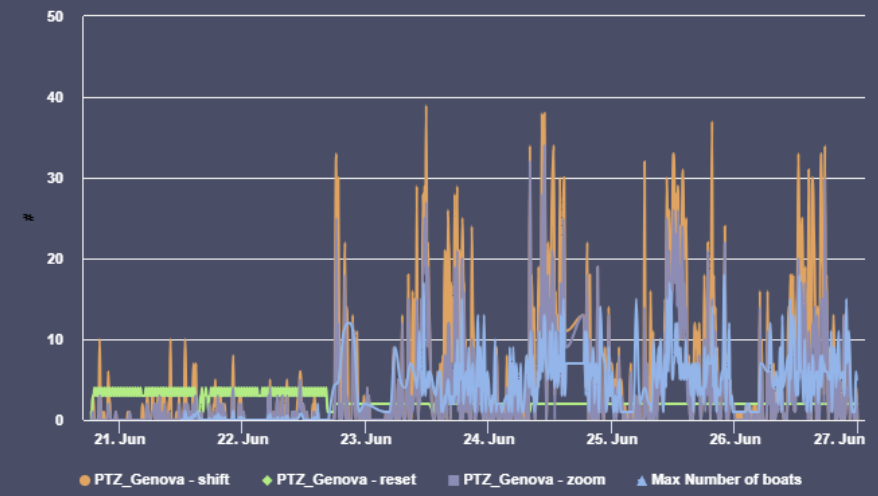
Monitoring Ocean Race Via PTZ, Genova

Mon 26 Jun 23:57:01

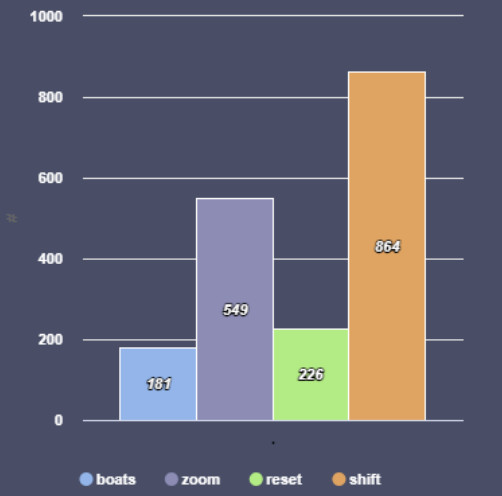
Access Q6225

Reset 9m	Shifts 9m	Zooms 9m	Last 60 Sec 9m	Last 10 Min 9m
2	0	0	2	5

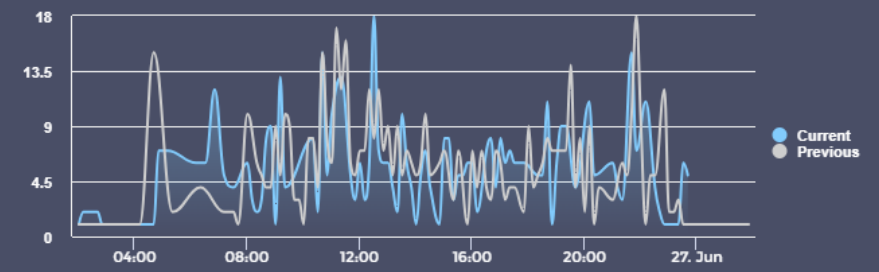
Control Count In The Last 10 Min 4m



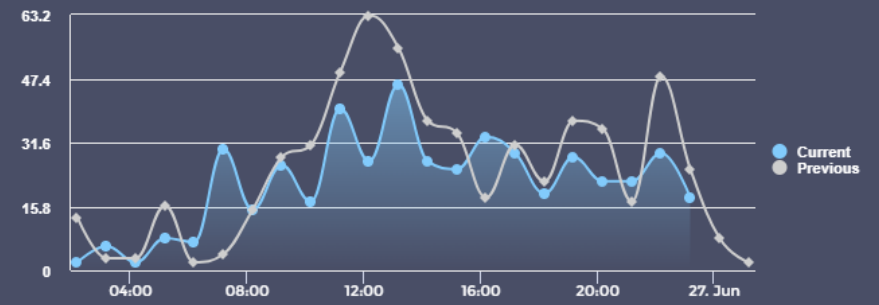
Cumulated Actions Of Today By Hour 4m



Mean Number Of Boaths Traked In The Last 10 Min, Compared Last 24 H... 9m



Number Of Boaths Tracked In The Last 1 H, Compared Last 24 Hours 9m



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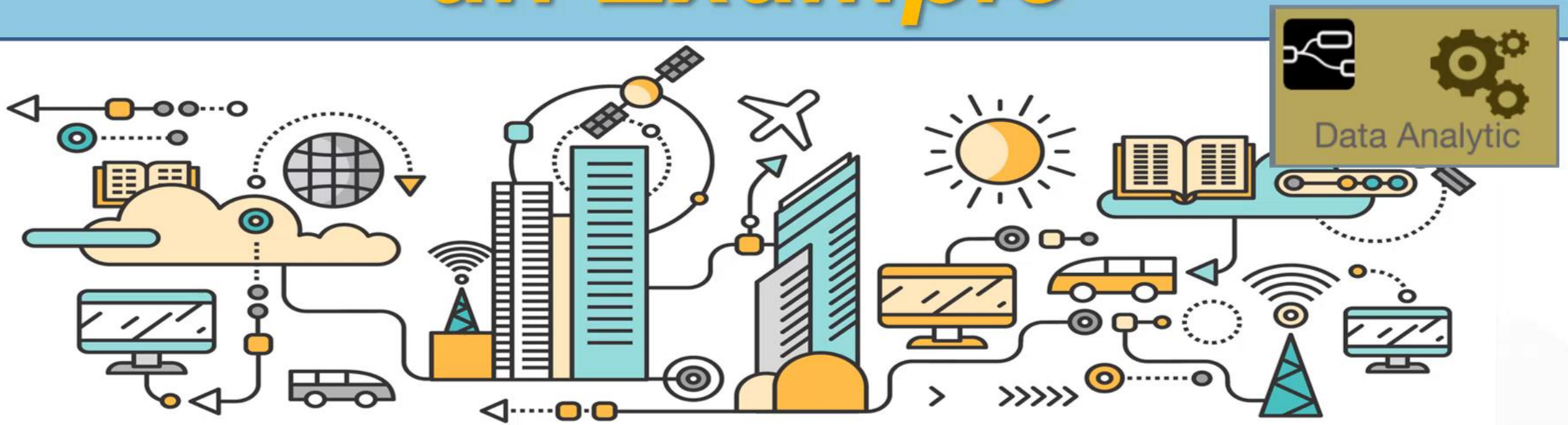
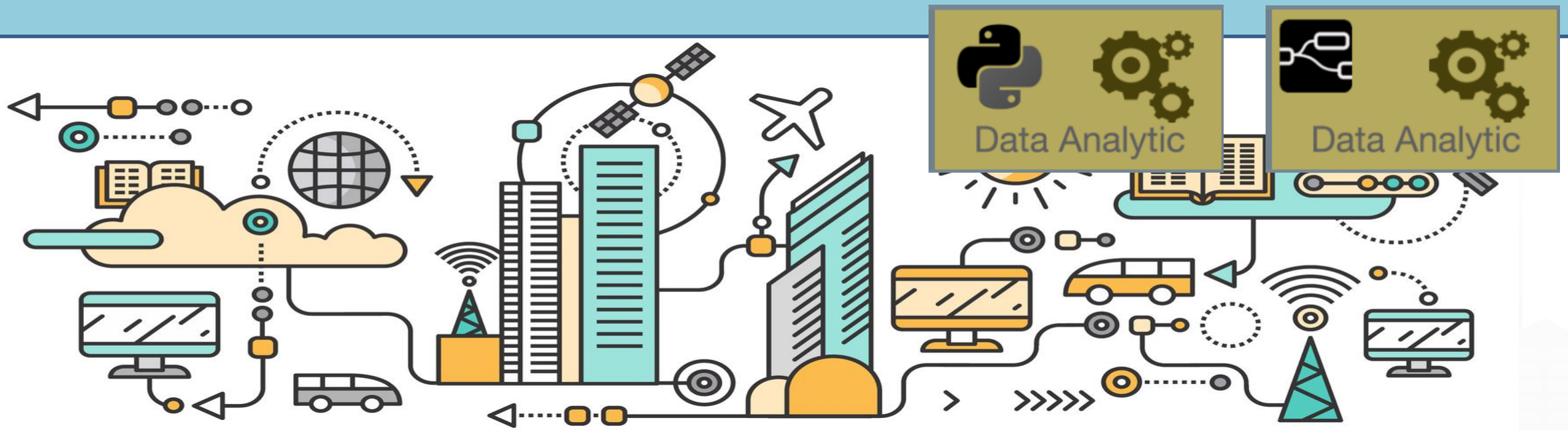
Data Analytic on Container an Example



DP, for DA, AI, XAI on Container vs Proc.Logic: Python/RStudio



VIDEO

WorkShop
working with Data Analytics on Node-Red
using the SCAPI

- R data retrieval from a public sensor in a specific window of time
- Python data retrieval from a private sensor in a specific window of time

Min - Mean - Max computing

https://www.youtube.com/watch?v=axAR6u4suQU

Premi Esc per uscire dalla modalità a schermo intero

WorkShop
working with Data Analytics on Node-Red using the SCAPI

- R data retrieval from a public sensor in a specific window of time
- Python data retrieval from a private sensor in a specific window of time

→ Min - Mean - Max computing

Device selection

- You can choose between a multitude of Devices inside the Snap4City Platform
- A useful online user interface is available at http://servicemap.km4city.org/WebAppGrafo/
- Or you can of course use your devices created in the platform

For this workshop we have identified two sensors:

- a public one whose service_uri (the link identifier of the resource) is `http://www.disit.org/km4city/resource/iot/orionUNIFI/DISIT/METRO762`



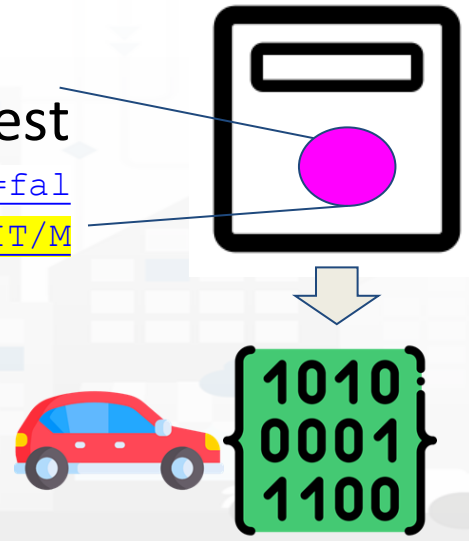
- a private one accessible through an authentication procedure whose service_uri is `http://www.disit.org/km4city/resource/iot/orionUNIFI/DISIT/118907.682_485819.390-Plastic`



SCAPI ?

- The Snap4City API allows you to formulate requests to get different results based on your needs
- The documentation is accessible at: https://www.km4city.org/swagger/external/index.html
- Under Services it is possible to retrieve data from a specific device
  - identified by its service_uri
  - specifying the temporal windows fromTime - toTime
- regarding the public traffic sensor it is reported below the GET request

https://servicemap.disit.org/WebAppGrafo/api/v1/?maxResults=10000&lang=en&geometry=false&format=json&serviceUri=http://www.disit.org/km4city/resource/iot/orionUNIFI/DISIT/METRO762&realtime=true&fromTime=2021-04-14T00:00:00&toTime=2021-07-13T08:04:21



Private Device Data Retrieval

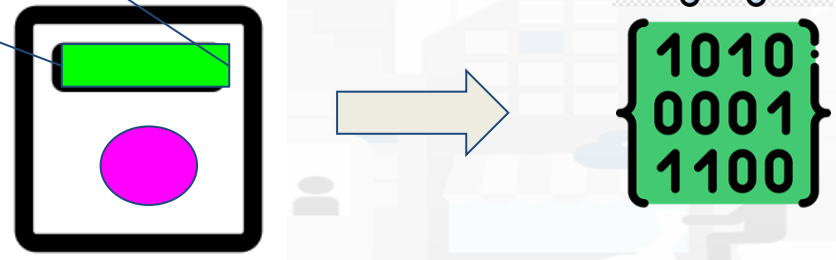
1) for accessing a private device data you'll need to have an

ACCESS TOKEN 

2) to get the access_token you'll to make a POST request specifying the username and password of the owner of the resource or the delegated ones.

```
url = "https://www.snap4city.org/auth/realms/master/protocol/openid-connect/token/"
data = {"client_id": client_id,"grant_type":"password","username":utente,"password":password}
r=requests.post(url, data)
```

```
{
  "access_token":"eyJz93a...k4laUWw",
  "token_type":"Bearer",
  "expires_in":86400
}
```



3) same get request for the one of the traffic sensor, but with the additional header with the access_token

HANDS ON!



```
"toTime": "2021-07-13T08:04:21",
    "fromTime":"2021-07-
01T08:04:21",
```



```
"start_date" : "2021-01-21T00:00:00",

"end_date" : "2022-03-09T00:00:00",
```

Min - Mean - Max computing

Sources for the example

- IoT App / Proc.Logic
  - https://www.snap4city.org/download/video/course/p4/flussoWorkshop-DA-AI-2023.zip
- Example in Python
  - https://www.snap4city.org/download/video/course/p4/PythonScriptPrivateDataRetrievalAndStatistics.zip
- Example in RStudio
  - https://www.snap4city.org/download/video/course/p4/RscriptPublicDataRetrievalAndStatistics.zip

DP, for DA, AI, XAI on Premise, Specific Hardware



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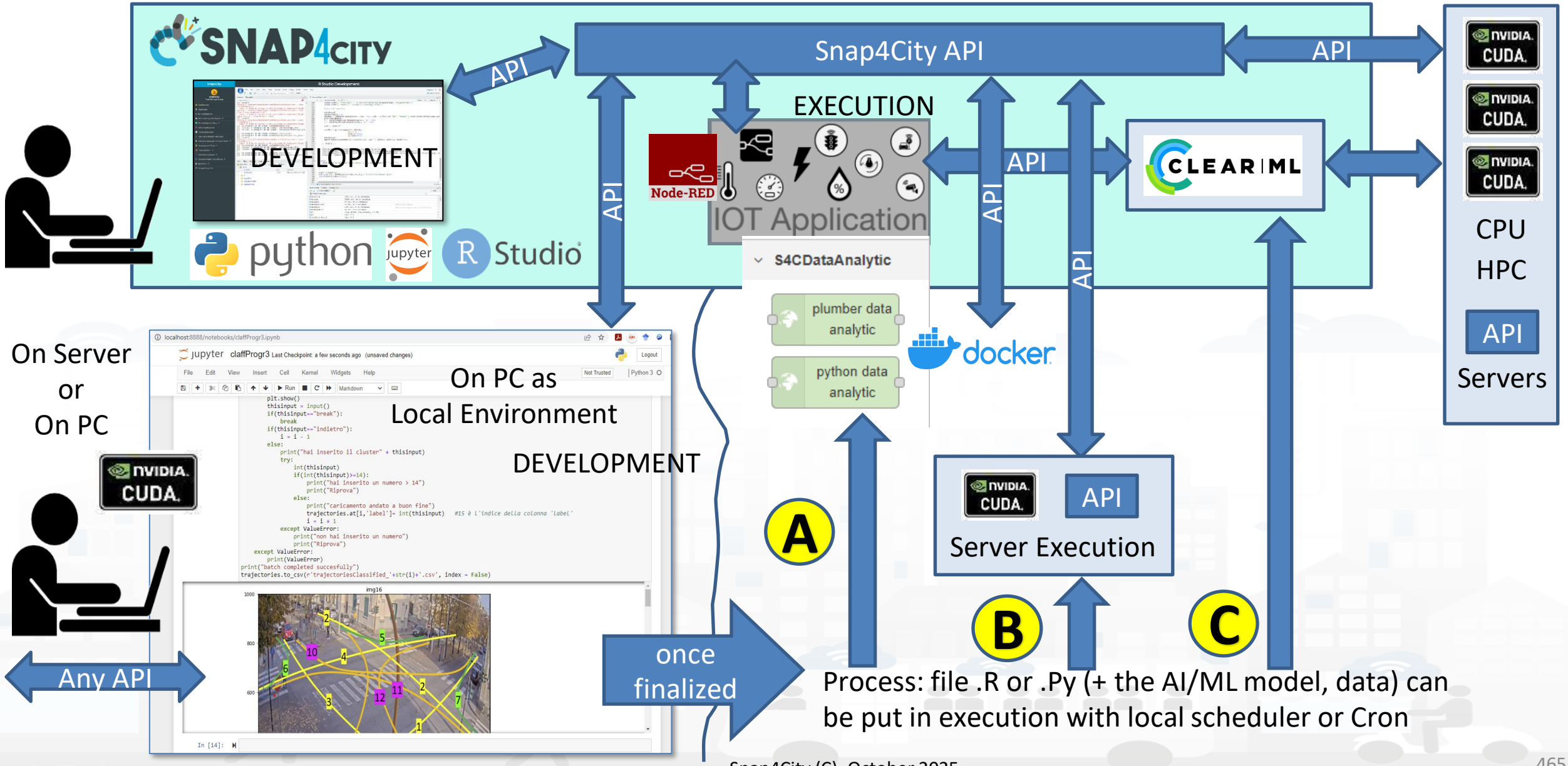
AI/ML Infrastruct.



Process: file .R or .Py (+ the AI/ML model, data) can be put in execution with local scheduler or Cron

Data Analytics on Snap4City platform
Dev on Premise, Custom

Swagger







Ontology Schema



LOG.disit.org

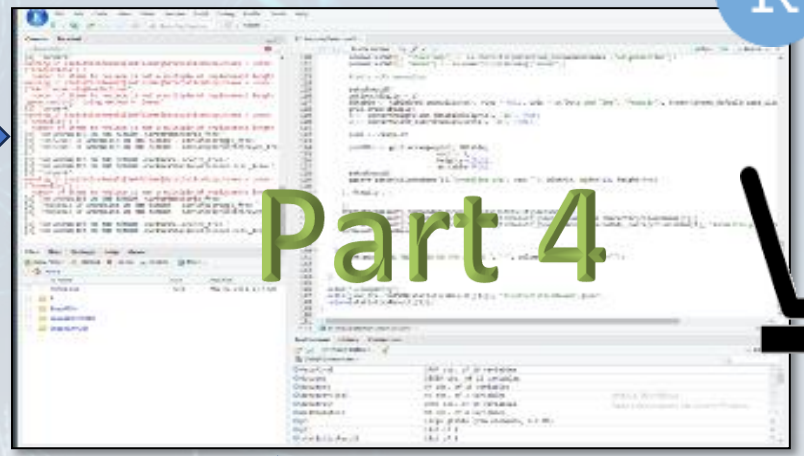


Big Data Store Facility

Smart City API from Knowledge Base and other tools

SCAPI

NGSI





Saving / Sharing reusing

SCAPI

NGSI

TensorFlow

NVIDIA CUDA

- Python *file.py* .....
- Rscript *file.r* .....



Resource Manager

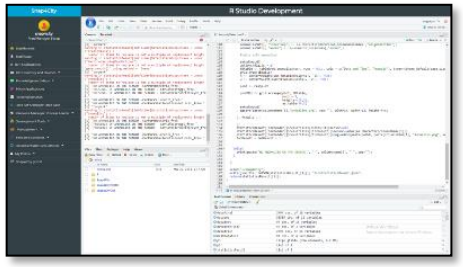


Development

python jupyter

R Studio





API

SNAP4CITY

Big Data Store Facility

Save data

Get data

EXECUTION

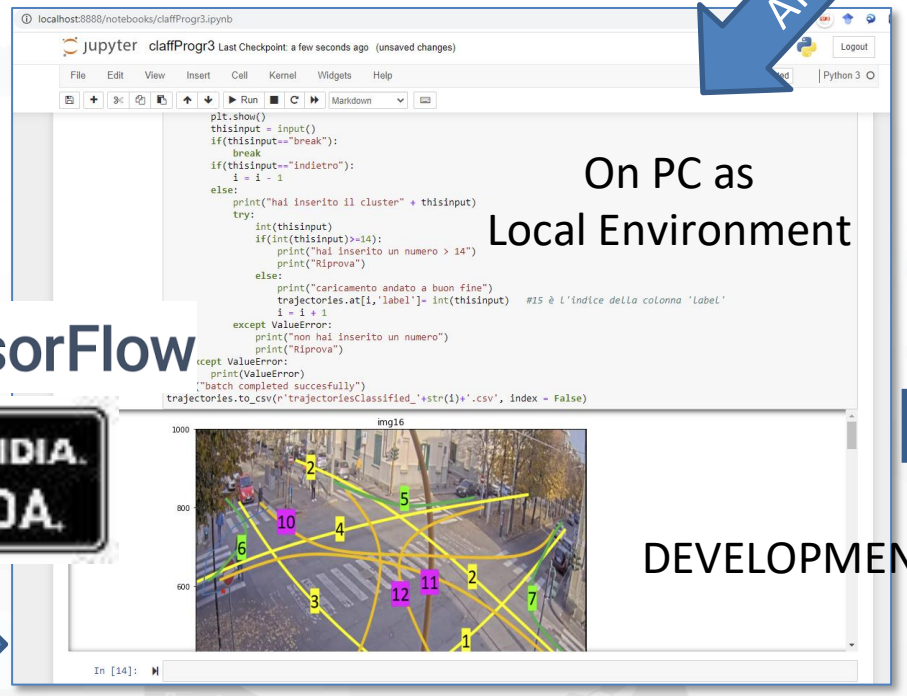
TensorFlow

NVIDIA CUDA

- Python file.py……..
- Rscript file.r…….

API

On Server
Or
On PC



On PC as
Local Environment

TensorFlow

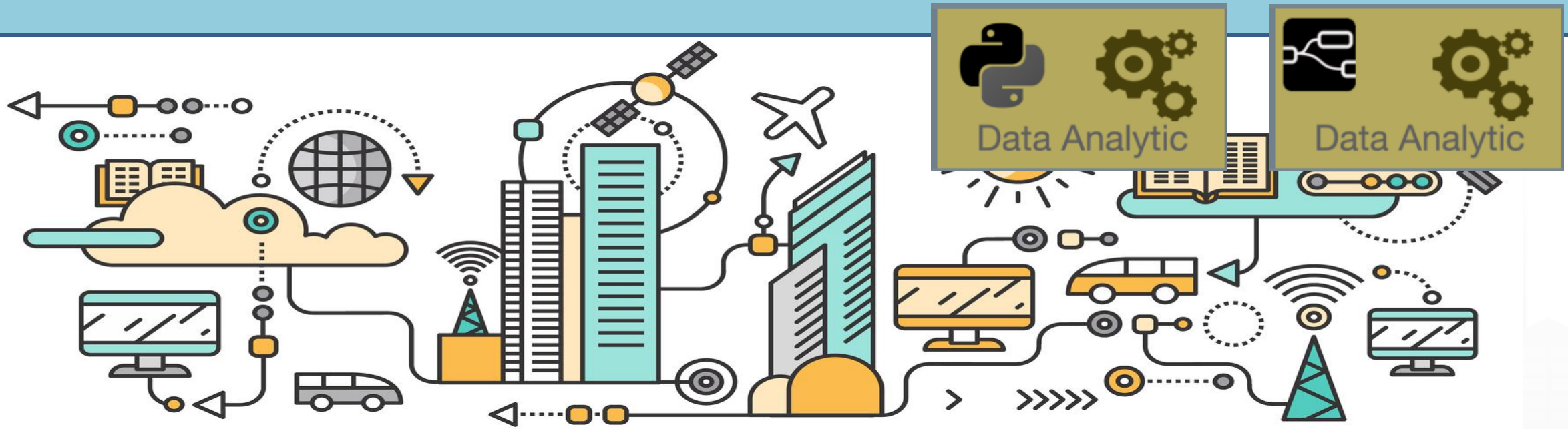
NVIDIA CUDA

DEVELOPMENT

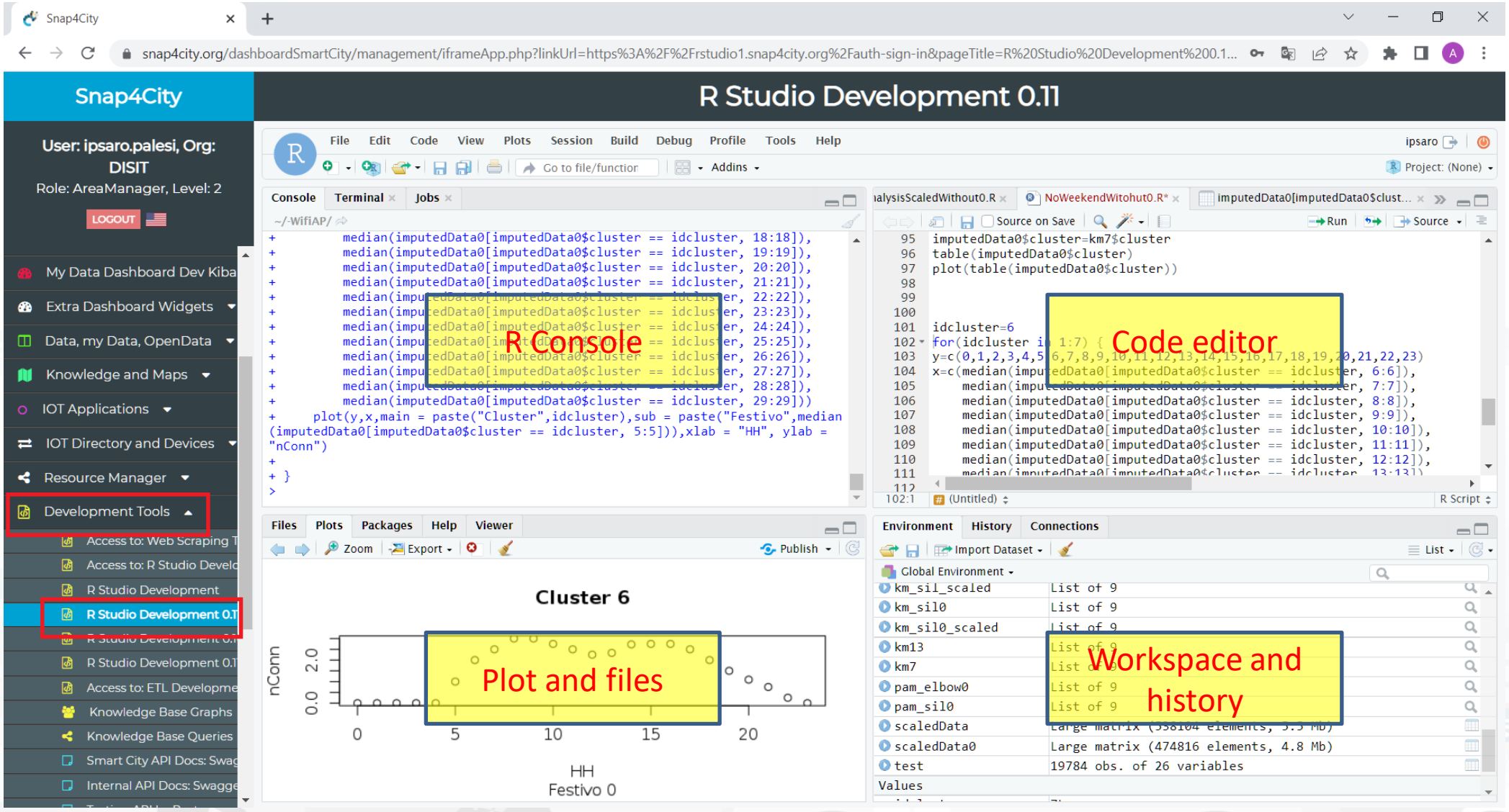
Once finalized

Process: file .R or .Py (+ the AI/ML model, data) can be put in execution with local scheduler or Cron

DP, for DA, AI, XAI on Container RStudio



Rstudio


Snap4City
R Studio Development 0.11
User: ipsaro.palesi, Org: DISIT
Role: AreaManager, Level: 2
LOGOUT
My Data Dashboard Dev Kiba
Extra Dashboard Widgets
Data, my Data, OpenData
Knowledge and Maps
IOT Applications
IOT Directory and Devices
Resource Manager
Development Tools
Access to: Web Scraping T
Access to: R Studio Develo
R Studio Development
R Studio Development 0.T
R Studio Development 0.1
Access to: ETL Developme
Knowledge Base Graphs
Knowledge Base Queries
Smart City API Docs: Swag
Internal API Docs: Swagge
File Edit Code View Plots Session Build Debug Profile Tools Help
ipsaro
Console Terminal Jobs
R Console
Code editor
Files Plots Packages Help Viewer
Cluster 6
nConn
HH
Festivo 0
Plot and files
Environment History Connections
Import Dataset
Global Environment
km_sil_scaled List of 9
km_sil0 List of 9
km_sil0_scaled List of 9
km13 List of 9
km7 List of 9
pam_elbow0 List of 9
pam_sil0 List of 9
scaledData Large matrix (358104 elements, 3.3 Mb)
scaledData0 Large matrix (474816 elements, 4.8 Mb)
test 19784 obs. of 26 variables
Values
Workspace and history

R code

- Installing and loading R packages

install.packages("cluster")

From GitHub

install.packages("devtools")

devtools::install_github("kassambara/factoextra")

- Getting help with functions in R

?kmeans

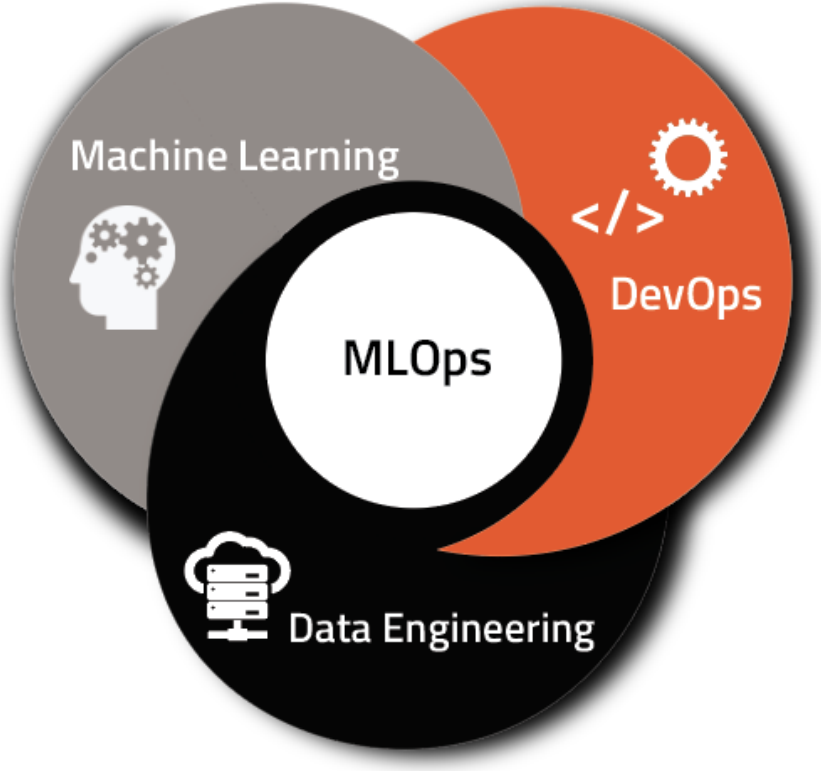
- Importing your data into R

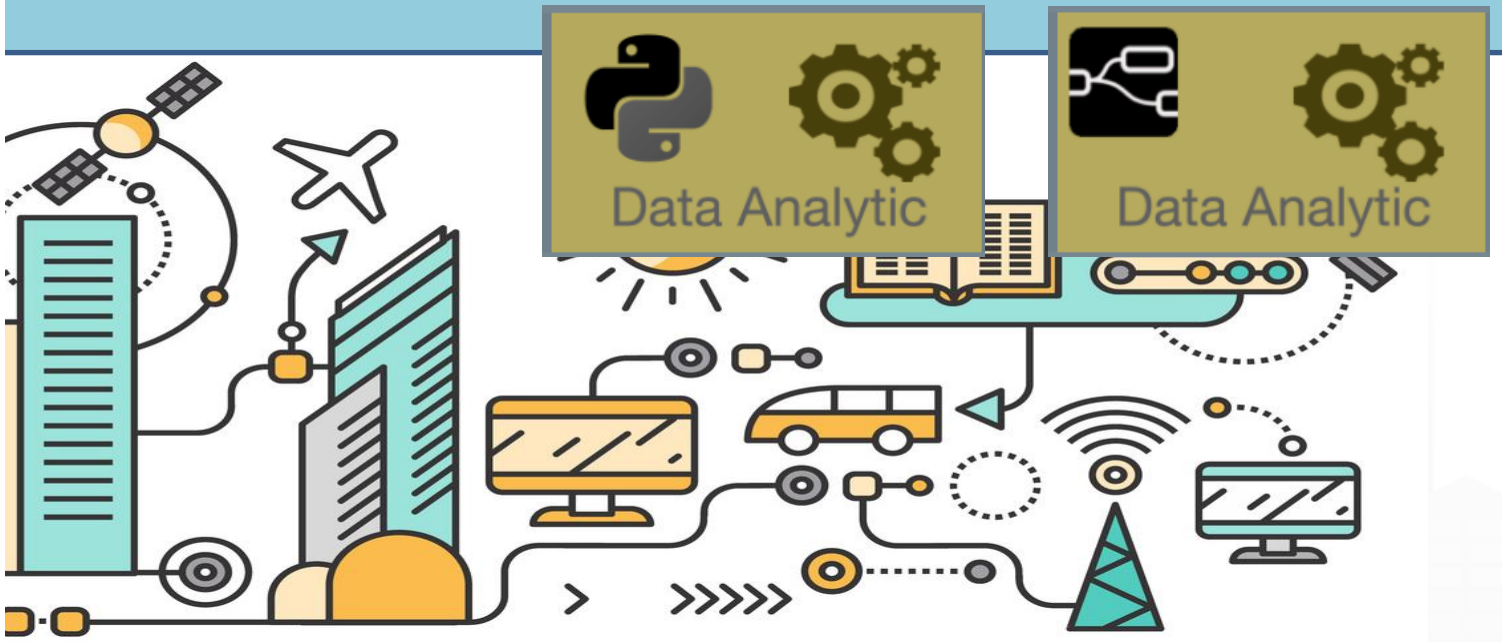
 # .csv file: Read comma (",") separated values

my_data <- read.csv(file.choose())

AI/ML Operation and Development

MLOps





Managing AI/ML operation/development: MLOps

- **Management of AI/ML processes**: training and execution
- **Training needs**: several processes
  - with different parameters and models to be trained, validated and test in batch to find the best results wrt metrics
  - High computational costs, time consuming if the processes have to be sent on GPU/CPU manually
- **Execution needs**, single executions in most cases singularly cheaper, but expensive for large volume of executions:
  - periodically as predictions (saving time if the model is loaded permanent)
  - on demand as optimisation, clustering, etc. (loading model, burning time)

AI Training on Snap4City Infrastructure

- The training processes can be performed:
  - **On Jupyter HUB provided** by Snap4City in Python using ASCAPI, in this case the Jupyter HUB can be on CPU or CPU/GPU server
    - **By using ClearML** for the Training and/or Execution, on Cluster of GPU/CPU
      - Only Jupiter HUB of Snap4City can access to ClearML and Cluster of GPU/CPU
      - The access at ClearML facility has to be authorized by Snap4City Administrator
  - **On Jupyter HUB provided** by Snap4City in Python using ASCAPI, in this case the Jupyter HUB can be on CPU or CPU/GPU server
  - **On Jupyter HUB** in Python using ASCAPI, in this case the Jupyter HUB can be on CPU or CPU/GPU server, not provided by Snap4City, not accessing to CPU/GPU of Snap4City
  - **On your computer in Python** using ASCAPI, not accessing to on cloud CPU/GPU of Snap4City.

AI/ML Infrastruct.

SNAP4CITY KM4CITY

SNAP4CITY

DEVELOPMENT

python jupyter RStudio

API

Snap4City API

API

EXECUTION

Node-RED

IOT Application

S4CDataAnalytic

plumber data analytic

python data analytic

docker

API

CLEAR|ML

API

NVIDIA CUDA

CPU
HPC

API

Servers

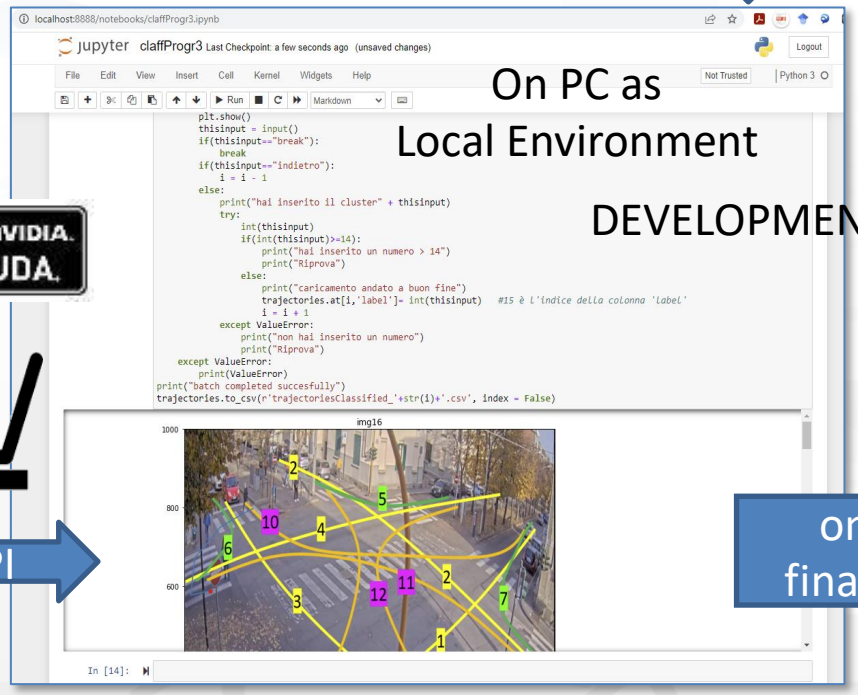
On Server
or
On PC

NVIDIA CUDA

Any API

On PC as
Local Environment

DEVELOPMENT



once finalized

A

B

C

NVIDIA CUDA API

Server Execution

Process: file .R or .Py (+ the AI/ML model, data) can be put in execution with local scheduler or Cron

MLOps Possibilities on Snap4City infrastructure

The developers can create their AI models using Snap4City data and infrastructure (Jupiter Hub):

- 1) **to put them in execution** (they could develop the solution on their Computer as well)
  - A) on stable container on CPUs via Node-RED, Docker
  - B) on some server with GPU/CPUs
- 2) **using ClearML and to put them in execution** on a process managed by ClearML on some cluster of GPU/CPU
  - 2a) as stable process on ClearML managed Docker, via API (usable from Rest Calls as well as from Node-RED Snap4City MicroServices, from the platform)
  - 2b) as sporadic process ClearML managed, via API (usable from Rest Calls as well as from Node-RED Snap4City MicroServices, from the platform)

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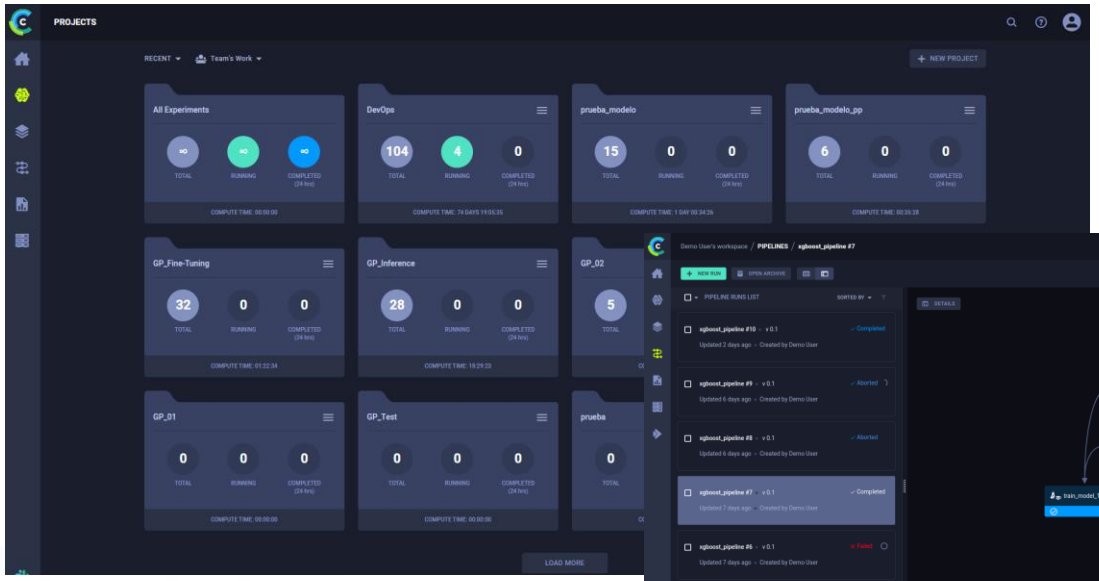
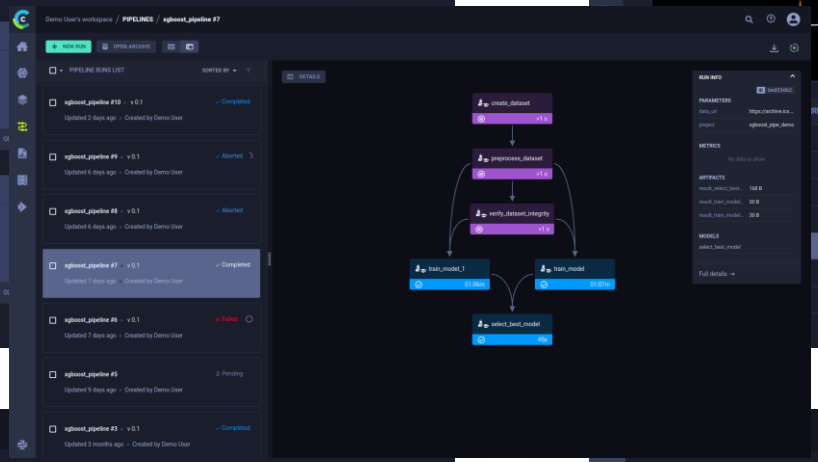
ClearML on S4C

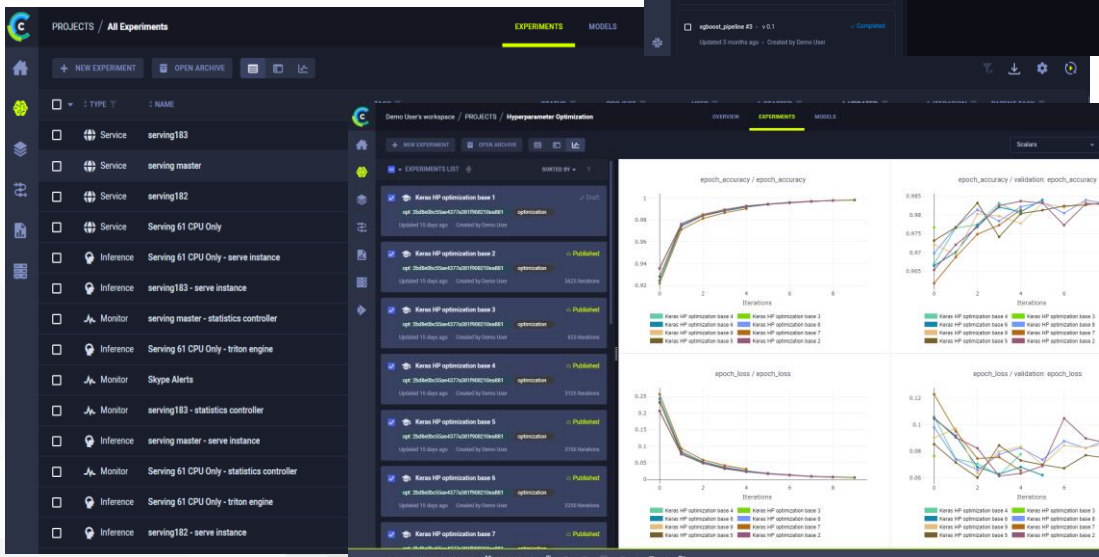
SNAP4CITY KM4CITY

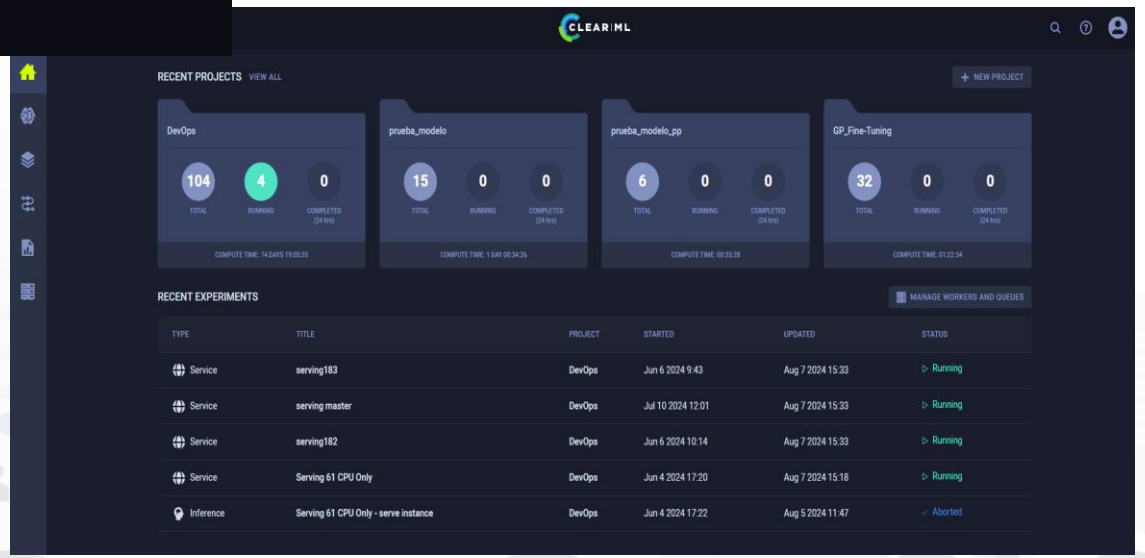




CLEAR|ML

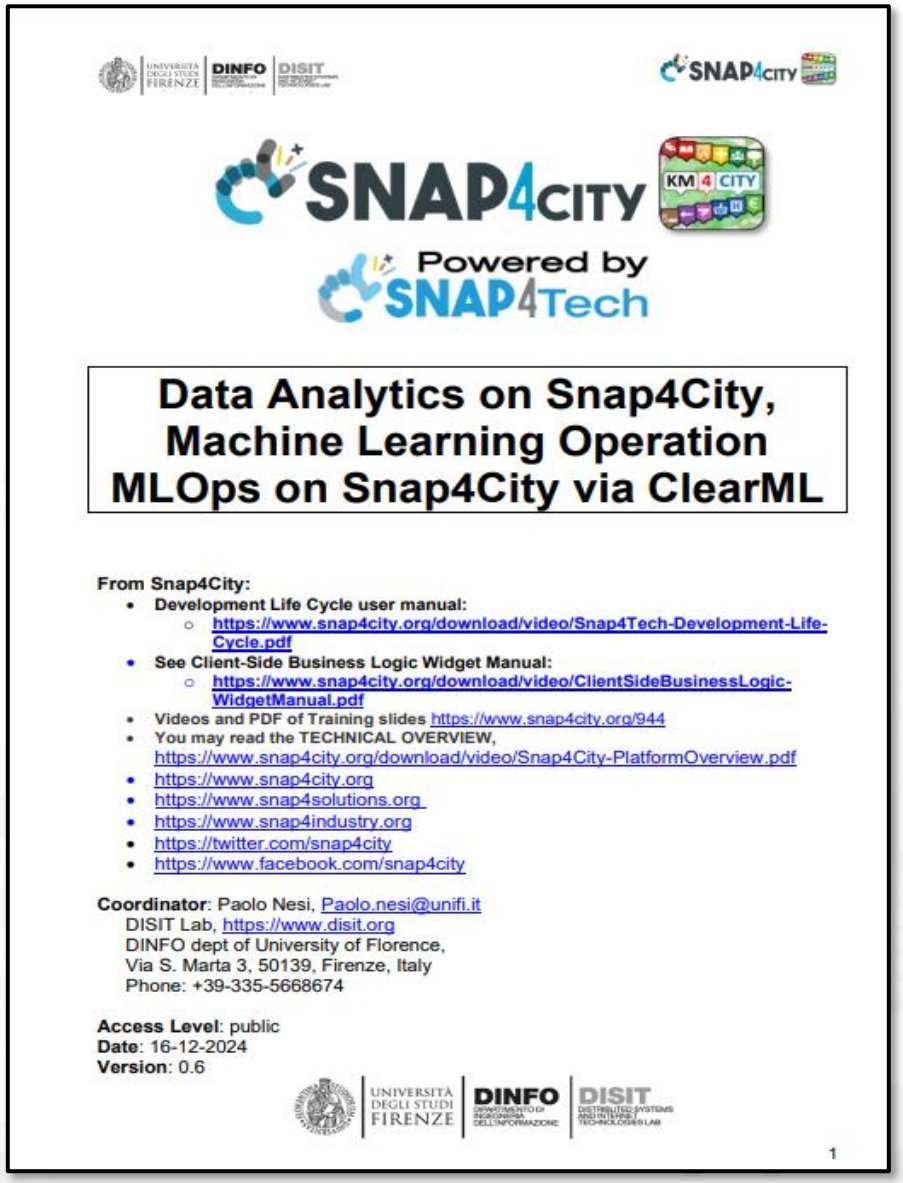






ClearML Features

- **Experiment Tracking:** Provides advanced features for experiment tracking, including automatic logging of metrics, output, source code, and the execution environment. This ensures that each experiment is reproducible, and its results are easily shareable and comparable.
- **Data and Model Management:** Provides tools for efficient management of datasets and models, allowing for easy versioning, archiving, and sharing. Users can track model versions and easily associate them with corresponding experiments.
- **Integration and Compatibility**: ClearML is designed to integrate with existing development environments and tools, such as **Jupyter Notebooks, TensorFlow, PyTorch, and many others**, thus supporting a wide variety of workflows and technology stacks.
- **User Interface and Dashboard:** offers an intuitive dashboard that allows users to monitor the status of experiments in real time, view metrics and outputs, and manage resources and execution queues, all from a single interface.
- **Automation and Orchestration:** It allows the remote execution of experiments on any machine and distributes the tasks to be executed according to a system of queues and priorities. Also automating Hyper-parametrization via **Optuna**



SNAP4CITY

Powered by SNAP4Tech

Data Analytics on Snap4City, Machine Learning Operation MLOps on Snap4City via ClearML

From Snap4City:

- **Development Life Cycle user manual:**
  - https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
- **See Client-Side Business Logic Widget Manual:**
  - https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- **Videos and PDF of Training slides** https://www.snap4city.org/944
- **You may read the TECHNICAL OVERVIEW,** https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city

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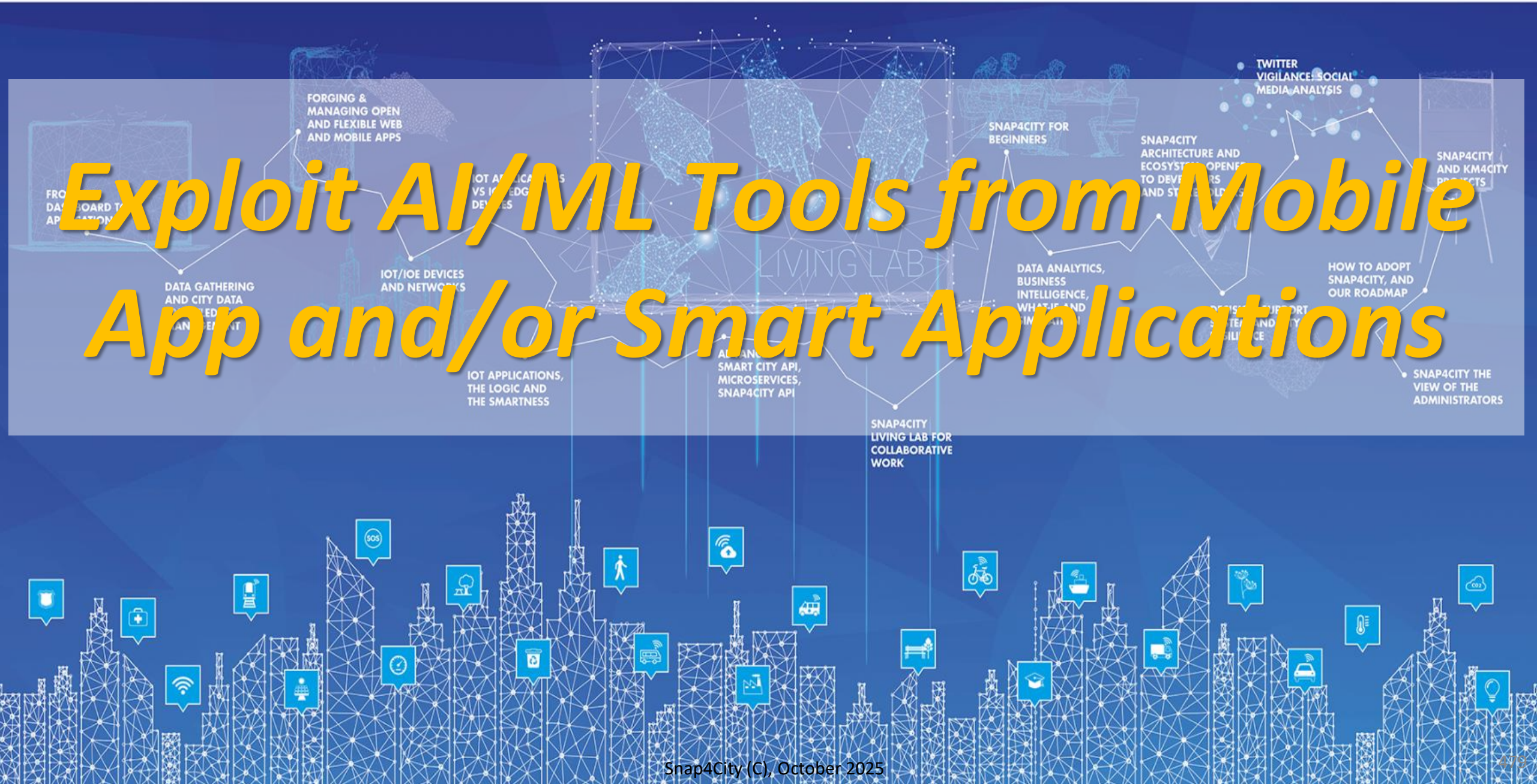
1

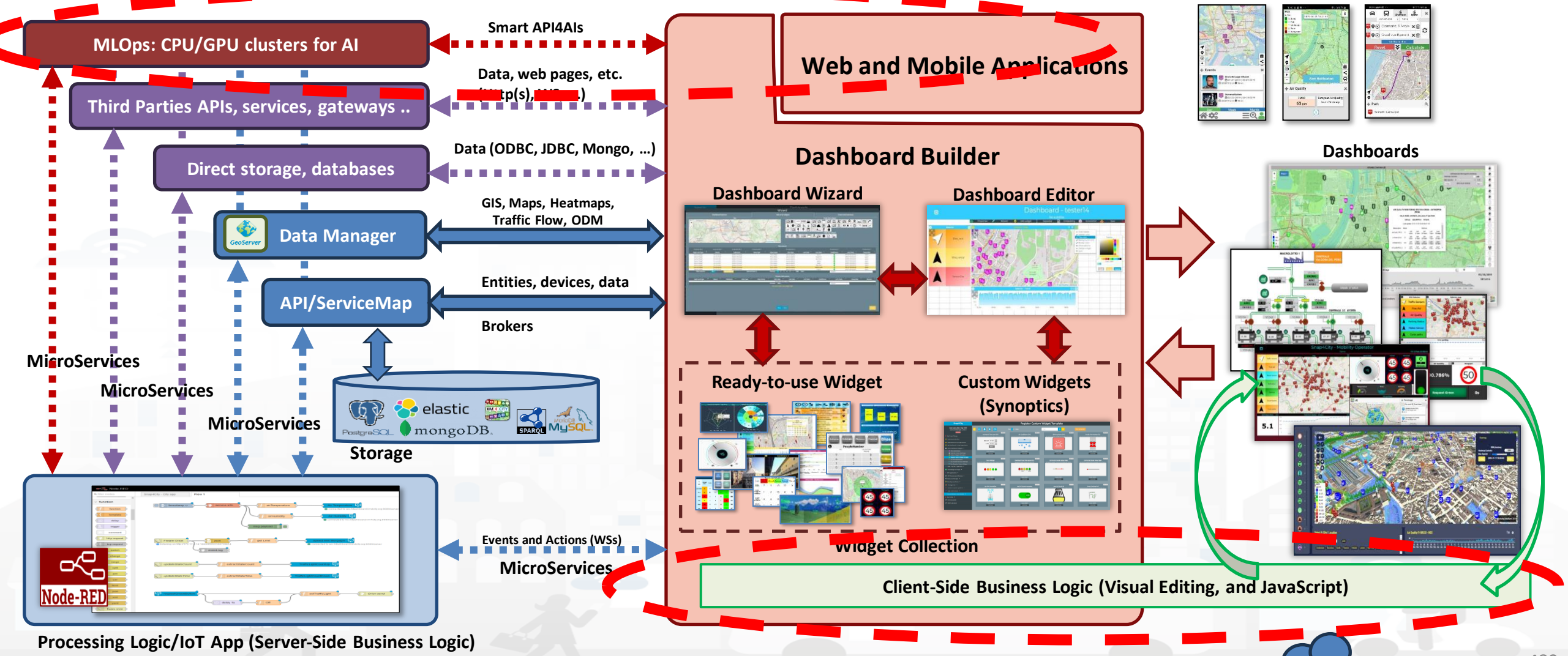
MLOperation

https://www.snap4city.org/download/video/Snap4City-MLOps-Manual.pdf

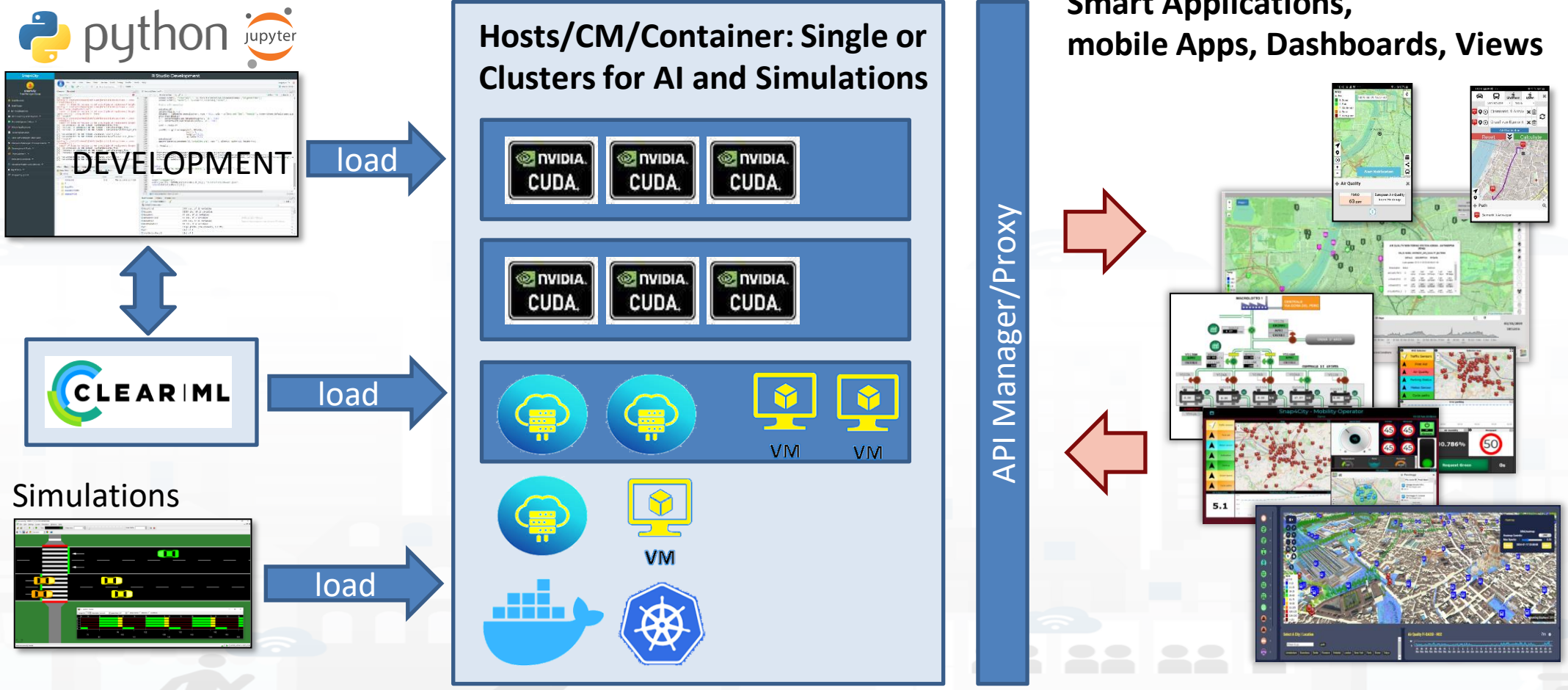


Exploit AI/ML Tools from Mobile App and/or Smart Applications

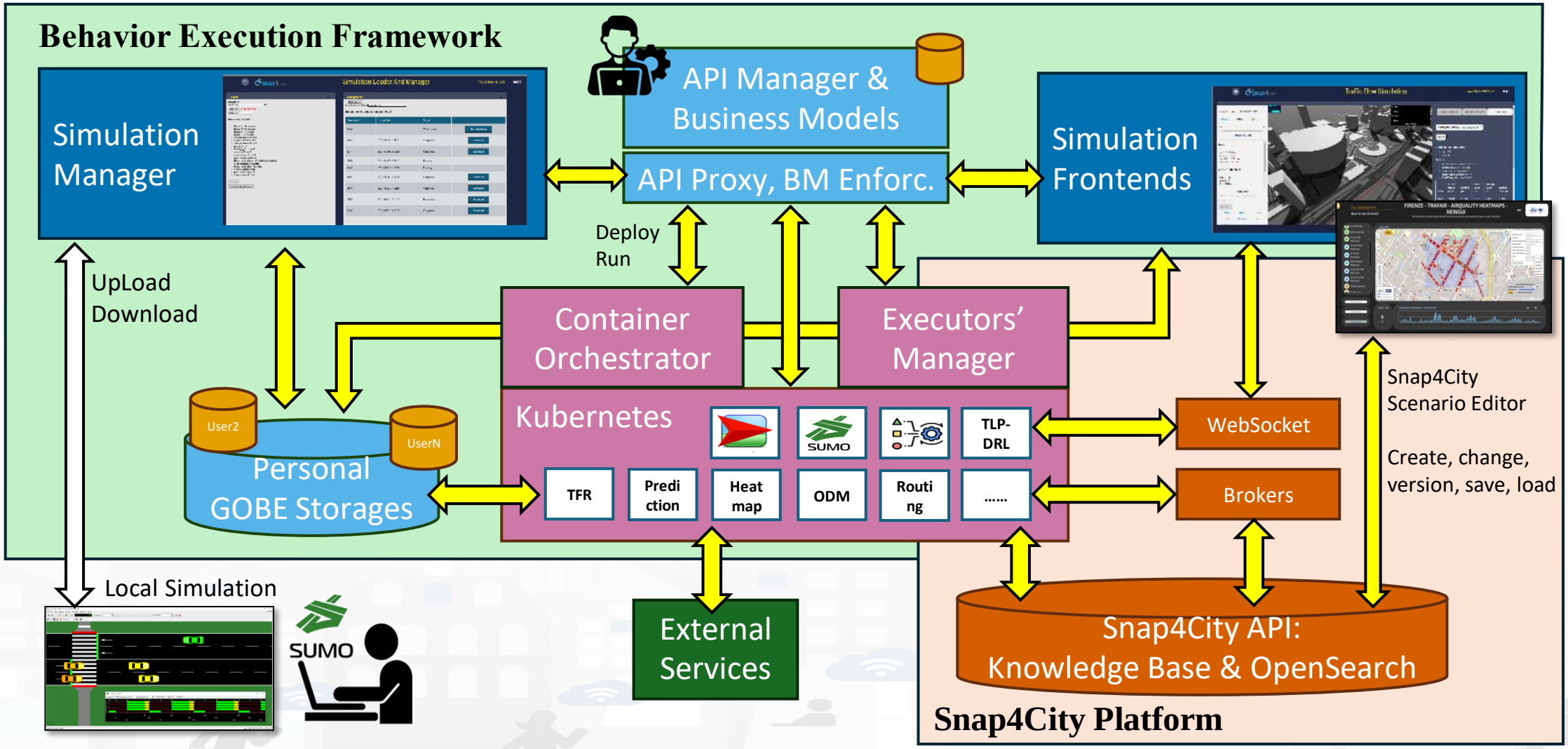
How the Dashboards / Apps Exchange data (2024/8)



Exploiting Intelligence from Applications



BEFDIT Architecture





Exploit LLM for the Assistant

SnapAdvisor

https://www.snap4city.org/1116

SnapAdvisor

Current chat: debug0

Visualize references

Personal Advisor LLM

Logged in as:
edoardo_tester

Your Profile

Logout

SnapAssistant model:

Llama3.3

New Chat

- EdoChat1
- EdoChat2
- EdoChat3
- EdoChat4
- prova
- chatNuova
- chatTest1LLAMA
- chatTest2LLAMA
- testGianniLLAMA
- testTastoInvioPreChanges
- ChatTestPostPSWINVIO

Come creo una dashboard?

Per creare una dashboard, puoi utilizzare la piattaforma Snap4City. La dashboard si compone di un insieme di widget grafici che possono essere impostati separatamente assegnando una serie di parametri, come origine dati, dimensioni, colori, forma, font, allarmi, relazioni con altri, ecc. (SOURCE: Snap4 City per la creazione di Smart City Control Room, SCCR). Inoltre, la piattaforma offre la possibilità di creare vere e proprie applicazioni interattive, multipagina/multidashboard, e non semplici storie monopagina da scrollare. Puoi anche condividere la dashboard con altri utenti anche fuori dalla Smart City Control Room tramite canali autenticati e protetti in HTTPS, in accordo al GDPR (SOURCE: Snap4 City per la creazione di Smart City Control Room, SCCR). Per vedere alcuni esempi di dashboard, puoi visitare il sito https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjU0Mg== (SOURCE: Snap4 City 1st Overview v4 8 annot). Tuttavia, non ho trovato informazioni dettagliate sulla procedura di creazione di una dashboard. Se hai bisogno di ulteriore assistenza, ti consiglio di contattare direttamente il team di supporto di Snap4City. Non so dirti altro in merito.

Write a message...

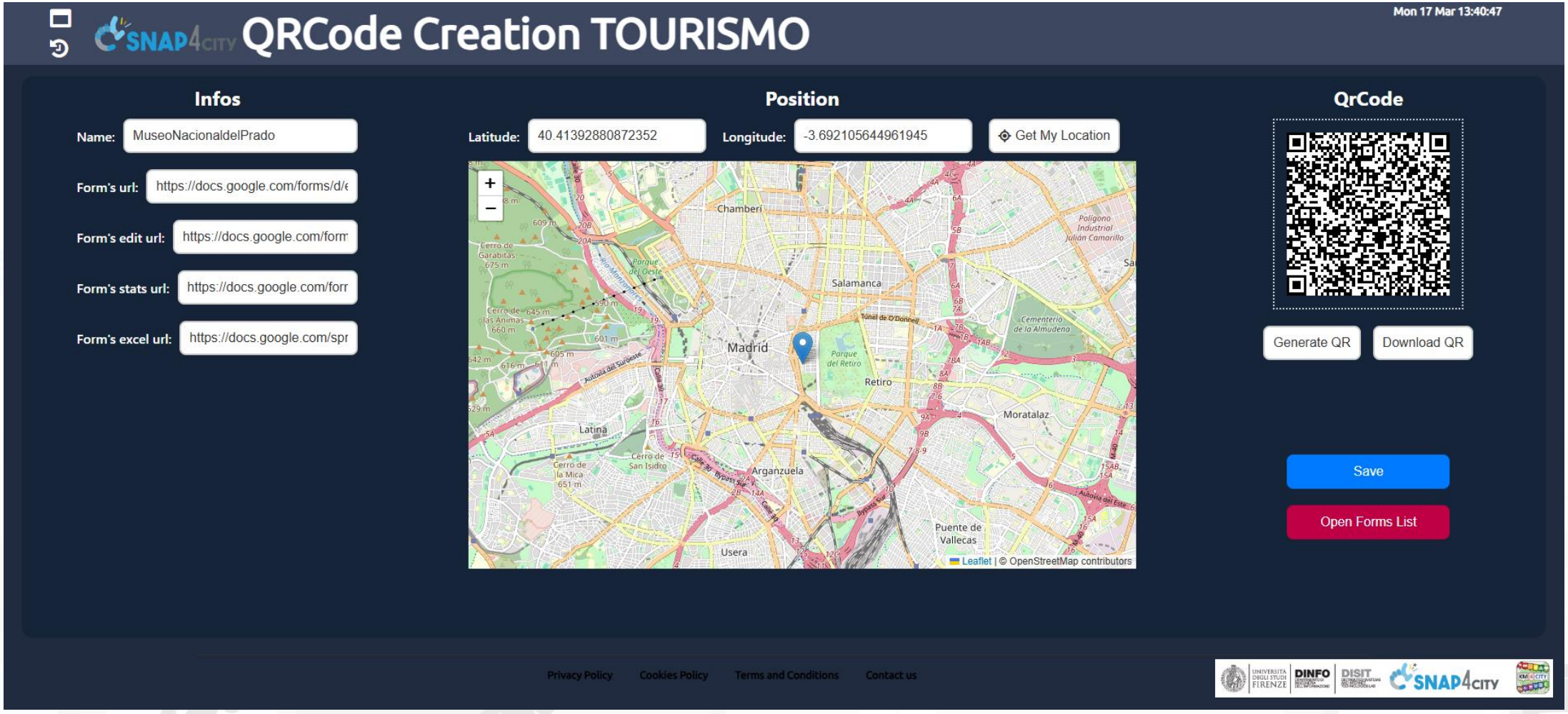
SnapAdvisor: AI based Assistants, DSS

- **Sna4CityAdvisor:**
  - for developers and promoters knowing all Snap4City and DISIT Lab literature, articles, manuals, slides, codes, etc. The SnapAdvisor with this skill is accessible only for selected Snap4City users. It allows users of saving a lot of time by providing answers to facilitate the development of smart solutions, to the exploitation of Snap4City tools, and recently on data and services accessible on the platform, producing offers, etc.
- **Legal Advisor**
  - expert on specific disputes at service of the Legal department of Careggi Hospital of Florence. It allows to save time in recovering precise information from complex legal documents, ordering of events, understanding causes and effects, producing reports, etc.
- **Expert of industrial machines, user manuals, technical manuals, rules,**
  - Answering on technical manuals
- **Complains and Questionnaire analysis**
  - Answering on trends, via questionnaires collected via QR, blobs, emails, etc.
- **Commercial Advisor:**
  - processing orders understanding them and preparing the offer, thus reducing the time to process them.
- **Generative Designs:**
  - Multimodal Generative AI supporting designers in producing innovations
- etc.

SnapAdvisor

- **working on your private content** and thus producing answers.
  - Select a subset of documents
- **domain control**: you can decide the knowledge base (internal wikis, PDFs, APIs),
- **explainability** capability, provide references to your documents
- **multilingual via content**
- **modularity**: it is possible to pass from one collection of documents to another, and multiple users can work on the advisor asking for different topic on different collections/domains at the same time, independently as needs change, without any interferences among them.
- **lower hallucinations**

Complains Analysis to Support Decision Making Processes



Complains Analysis to Support Decision Making Processes

Standard data/form creation
for reputation analysis:

- Initial Sentiment Analysis/NLP by analysing questionnaires collected from QR code distribution.

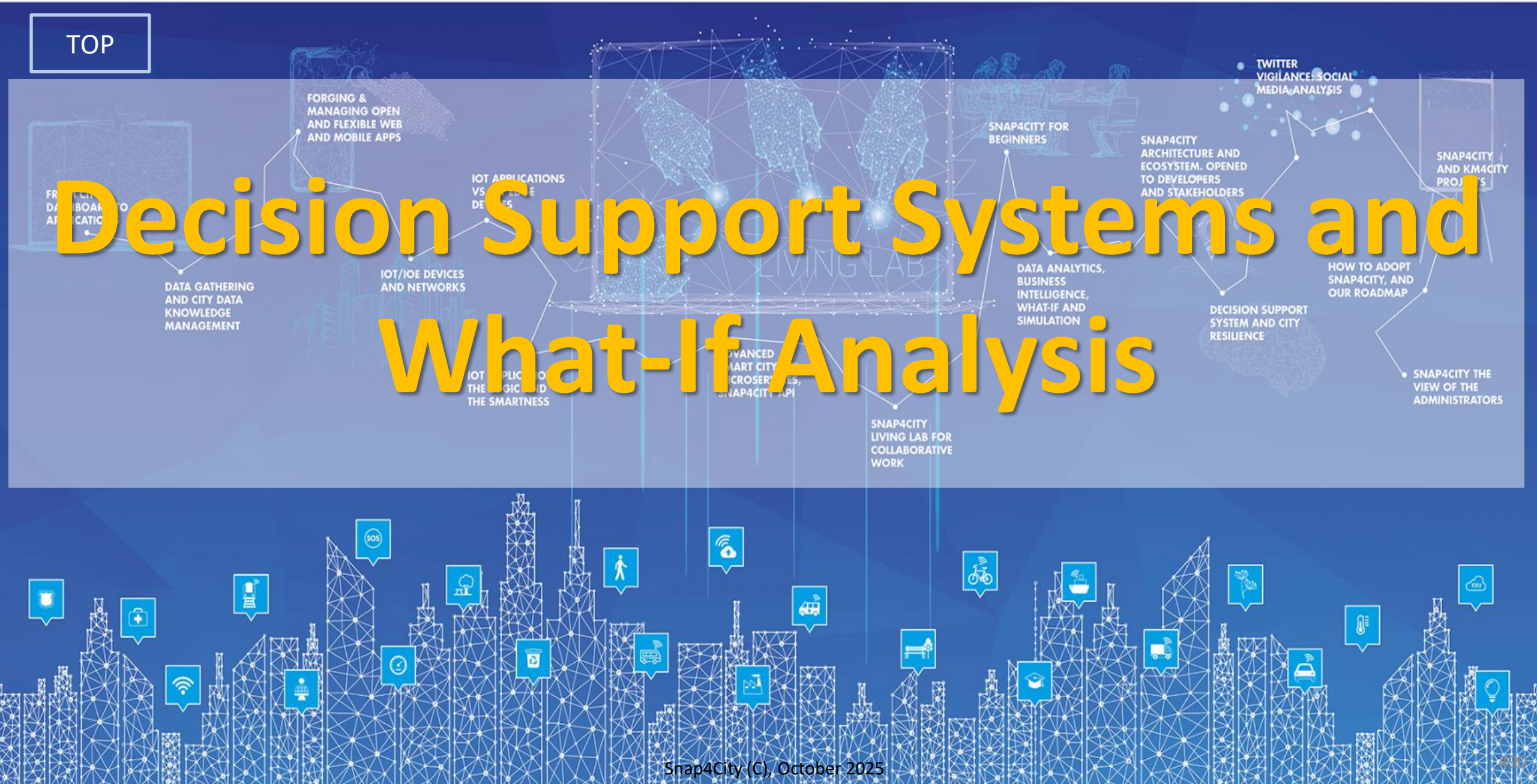
Summary of Findings (June–August 2025, 36 responses received - Golden Bay, Malta) produced by a Large Language Model (LLM) based on the responses obtained from questionnaire

Average Ratings (scale -2 to +2)

Overall experience: +0.67 → slightly positive but inconsistent (range -2 to +2)
Toilets: -0.83 → strongly negative, among the worst-rated aspects.
Showers: -0.31 → generally negative.
Bins distribution: -0.33 → slightly negative, with complaints about lack of bins.
Safety & lifeguard services: +0.55 → moderately positive.
Cleanliness: -0.52 → overall negative, many complaints about cigarette butts and plastics.
Natural conditions (dunes, seawater, etc.): -0.40 → negative, issues with seagrass, water quality.

TOP

Decision Support Systems and What-If Analysis



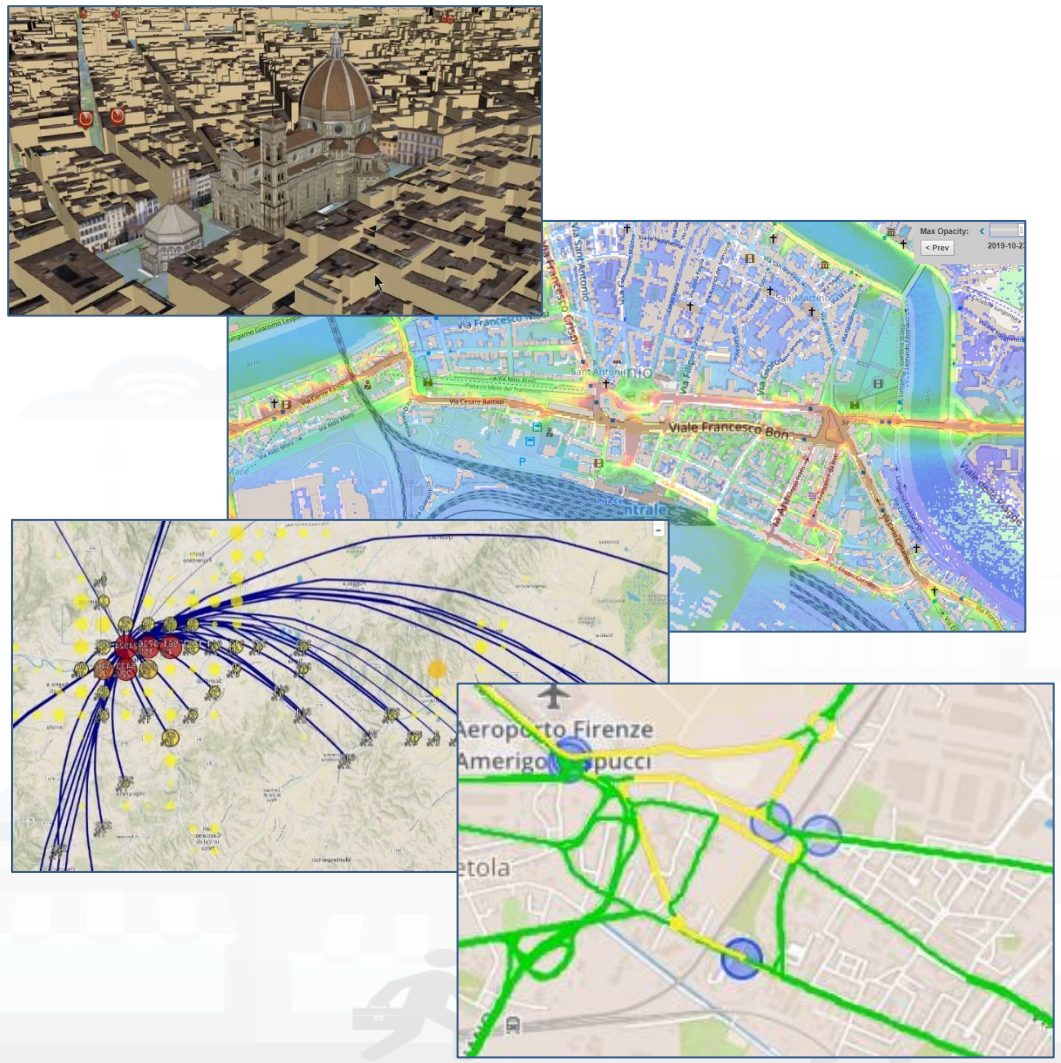
Public Spaces as Critical Infrastructures

- The City is a system of systems for city users
  - Cascading effects
- **Transport** networks
  - Main means for rescue teams, food, water, etc.
- **Communication**, ICT infrastructure
  - TV cam, switches, cyber,
- **Energy** networks
  - power supply for health, cyber systems, etc.
- **Hospitals** networks
- Aggregation areas



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

Smart City Digital Twin



City Digital Model with…

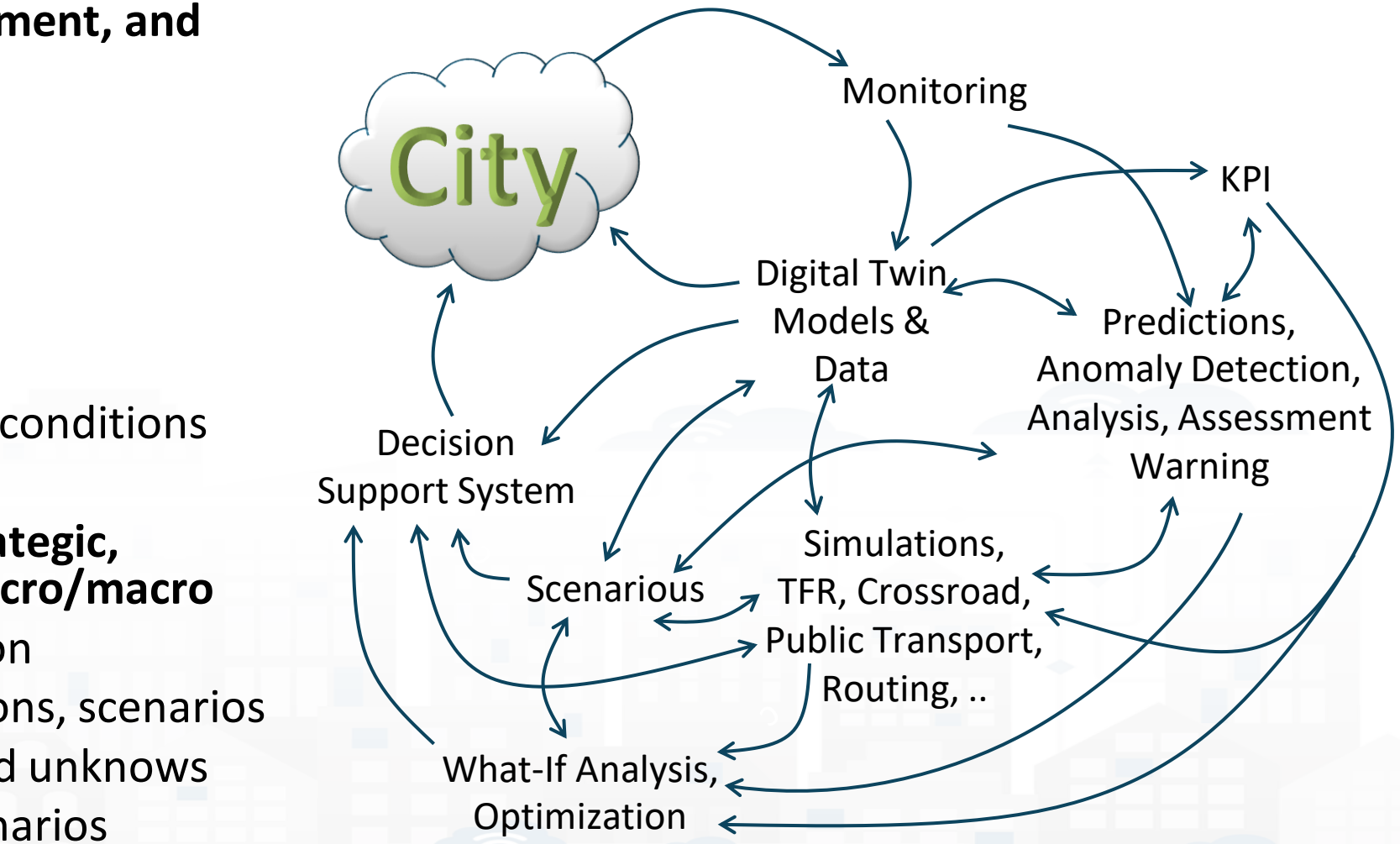
- Intuitive platform
- Any Data TYPE, any data source, any protocol
- Data storage seamless
- Data analytics → artificial intelligence, AI/XAI
- Data Ethics, AI Ethics, GDPR
- Interactive Data Representation, any kind
- Key Performance Indicators, any kind
- What-IF analysis – Simulation, prediction, 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.

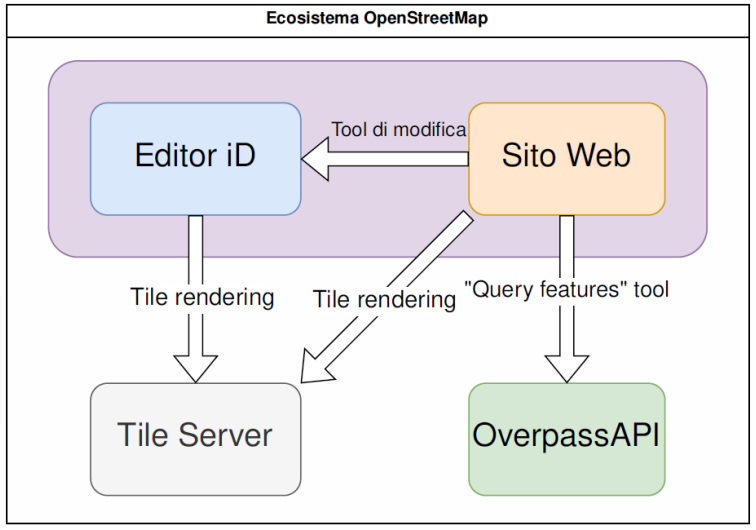
Main tasks

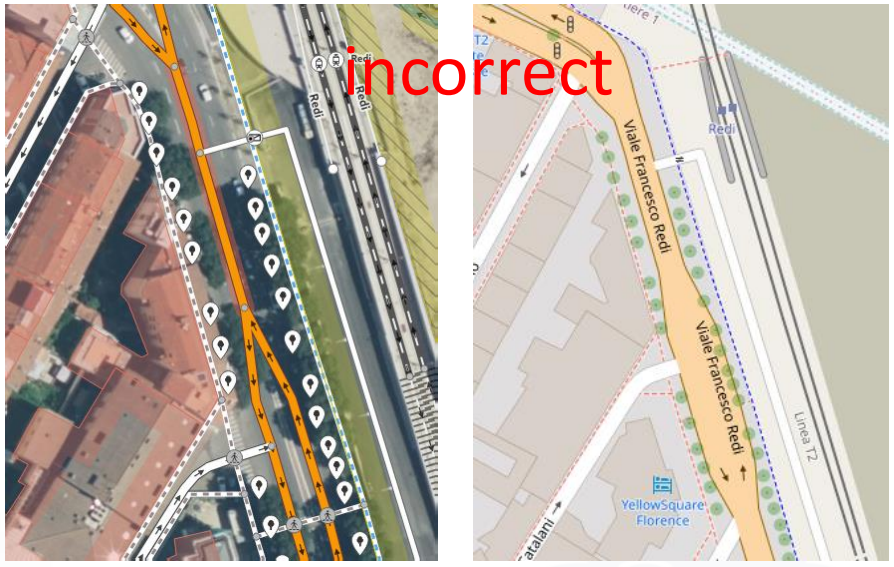
- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Early warning on critical conditions
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders



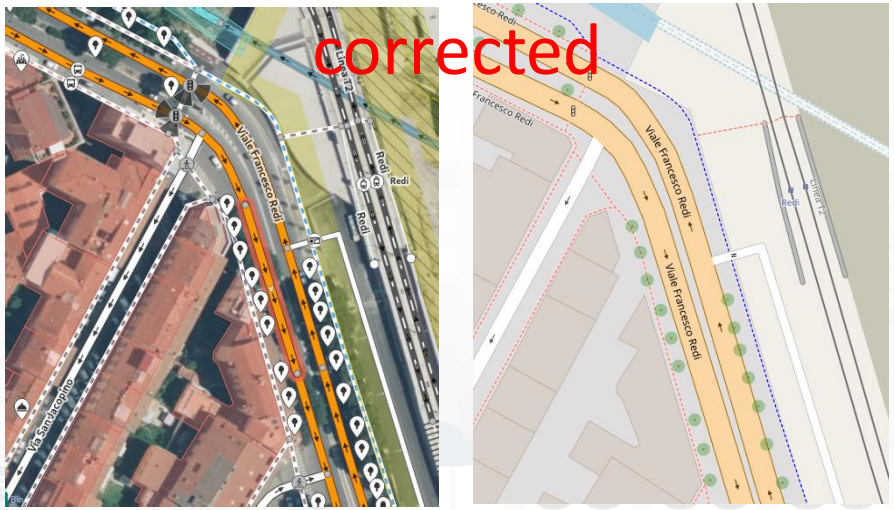
Tactic and/or Strategic Planning

Correction of road graphs which is present on OSM





OSM data with non clear double bidirection lane on Viale Redi, Florence.
Editing OSM data and present Tiles



After Corretion of OSM data defining a clear double bidirection lane on Viale Redi, Florence.
Regeneration of the TILEs for the maps

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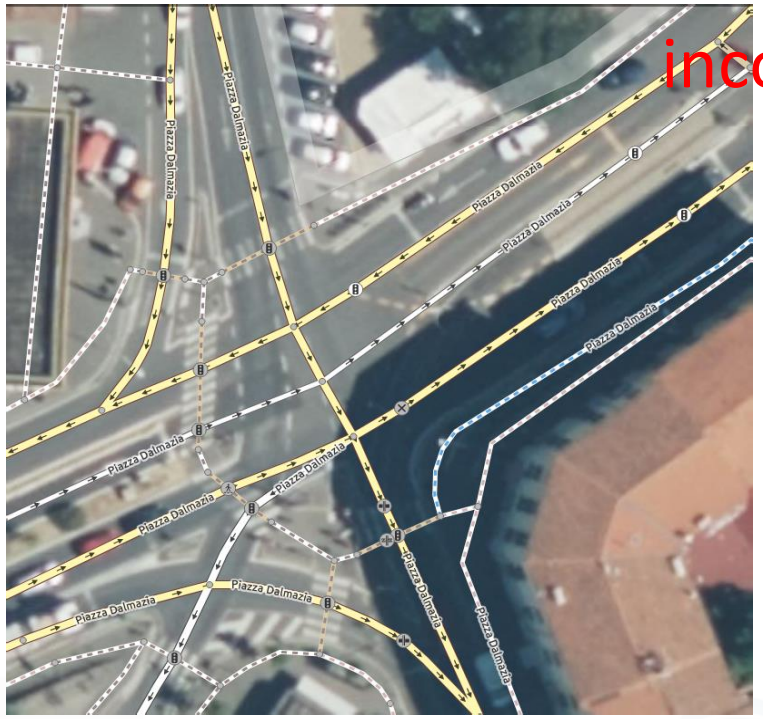
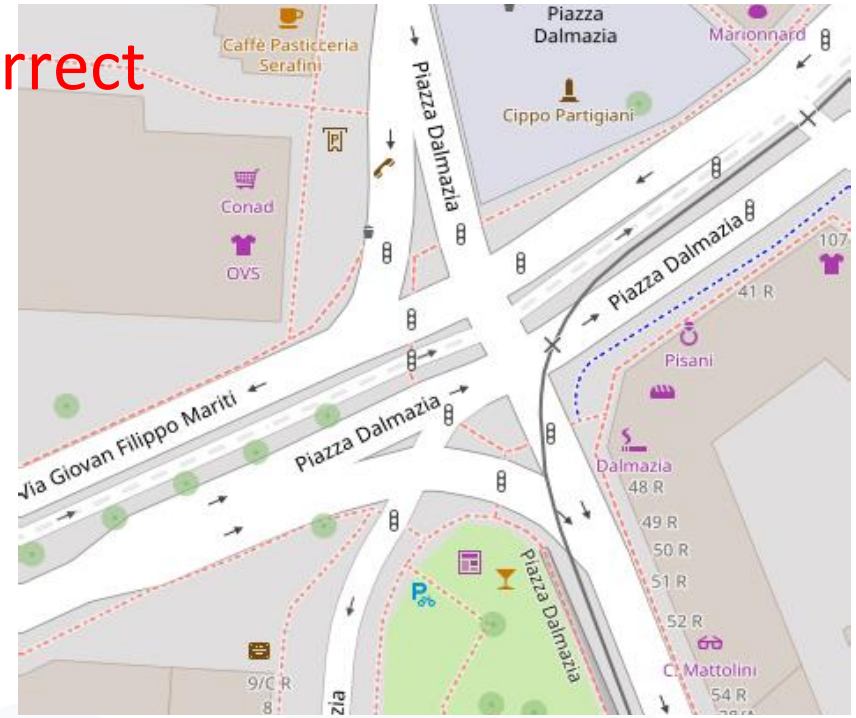
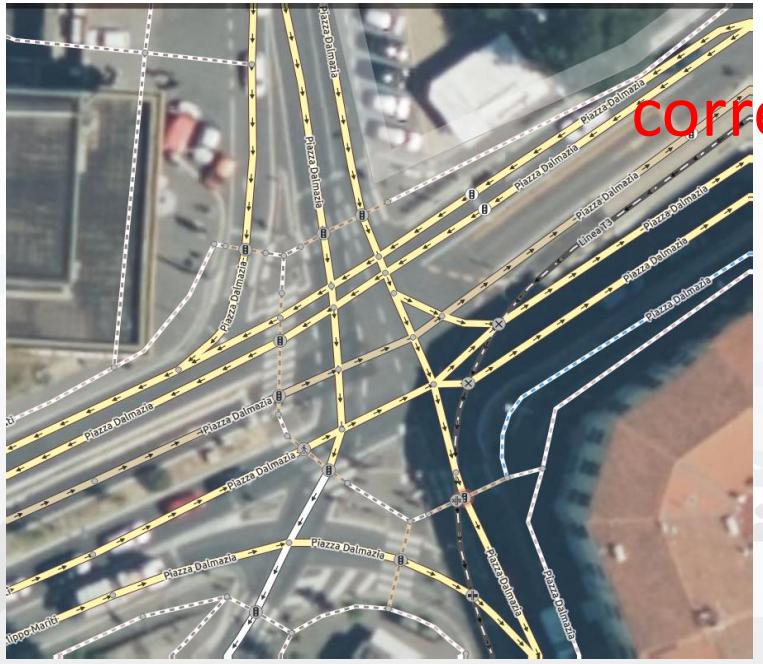
OSM data with non correct viability in Piazza Dalmazia, Firenze



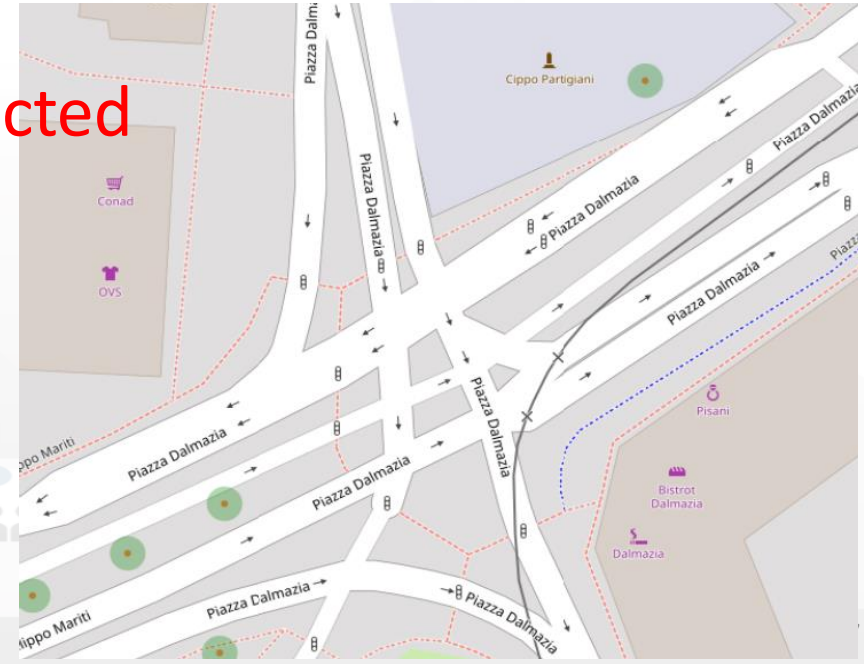
incorrect



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



corrected





Control Room



What-If Analysis

Available data and techniques	What happened	What is going on now	What is going to happen	What-If: what is going to happen if a scenario occurs in the future	Which is the best solution
Historical Data, HD	Yes	No	No	No	No
Real Time Data, RTD	No	Yes	No	No	No
HD + RTD + Short term Predictions, STP(.)	Yes	Yes	Yes	No	No
HD + RTD + Analytical Model, AM(.) + Scenario Model, SM(.)	Yes	Yes	Yes	(Yes)	No
HD + RTD + Short and Very Long Term Predictions, SVLTP(.) + AM(.) + SM(.) + Simulation, S(.)	Yes	Yes	Yes	Yes	No
HD + RTD + SVLTP(.) + AM(.) + SM(.) + S(.) + KPI(.) based Decision	Yes	Yes	Yes	Yes	Yes

Early Warning, Detection

Issue:

- Detection of critical condition
- Not easily detected with other means

Impact:

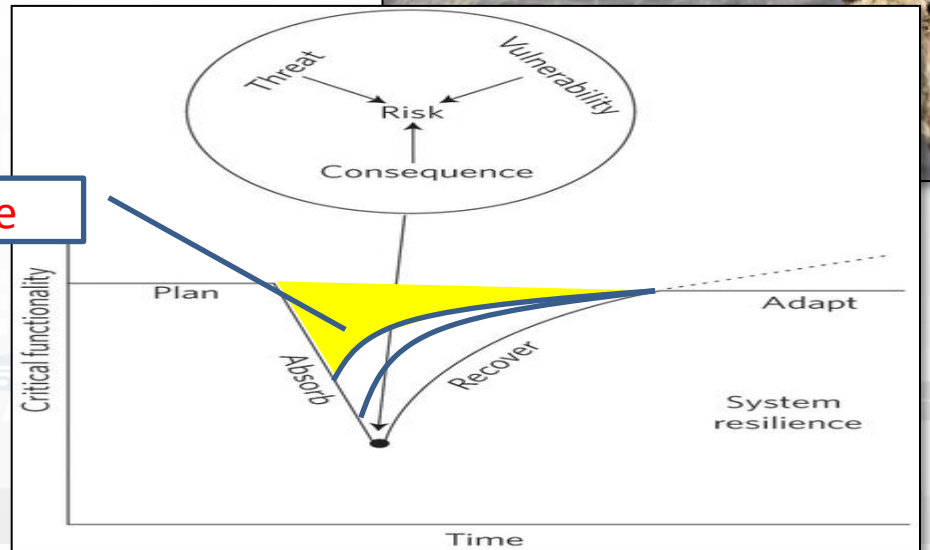
- Early warning, faster reaction
- Increased resilience

Several metrics related to:

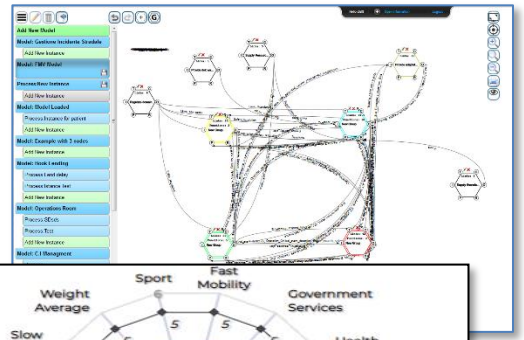
- Volume of retweets
- Sentiment analysis

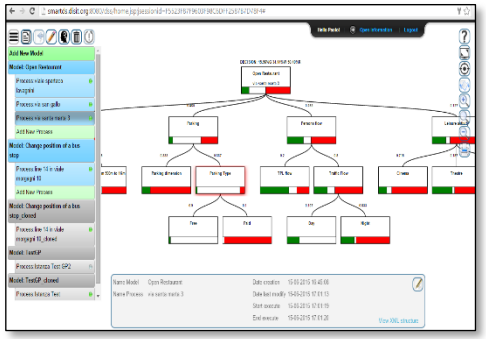
Prepare
Absorb
Recover
Adapt



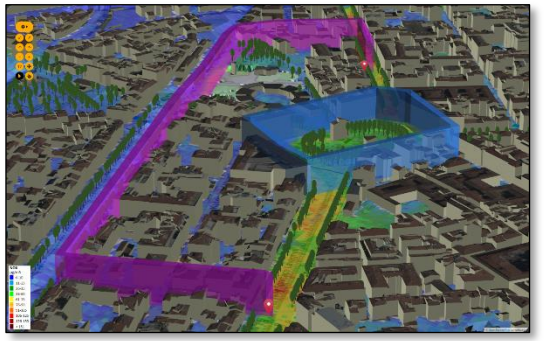


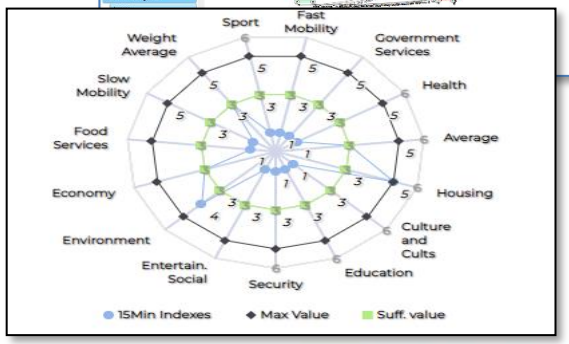
ERMG: European Resilience Management Guide











CRAMSS
Collaborative Resilience Assessment and Management Support System

MONITORING



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

LEARNING



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

ANTICIPATING



- European Resilience Management Guidelines
- Game Based Training

RESPONDING



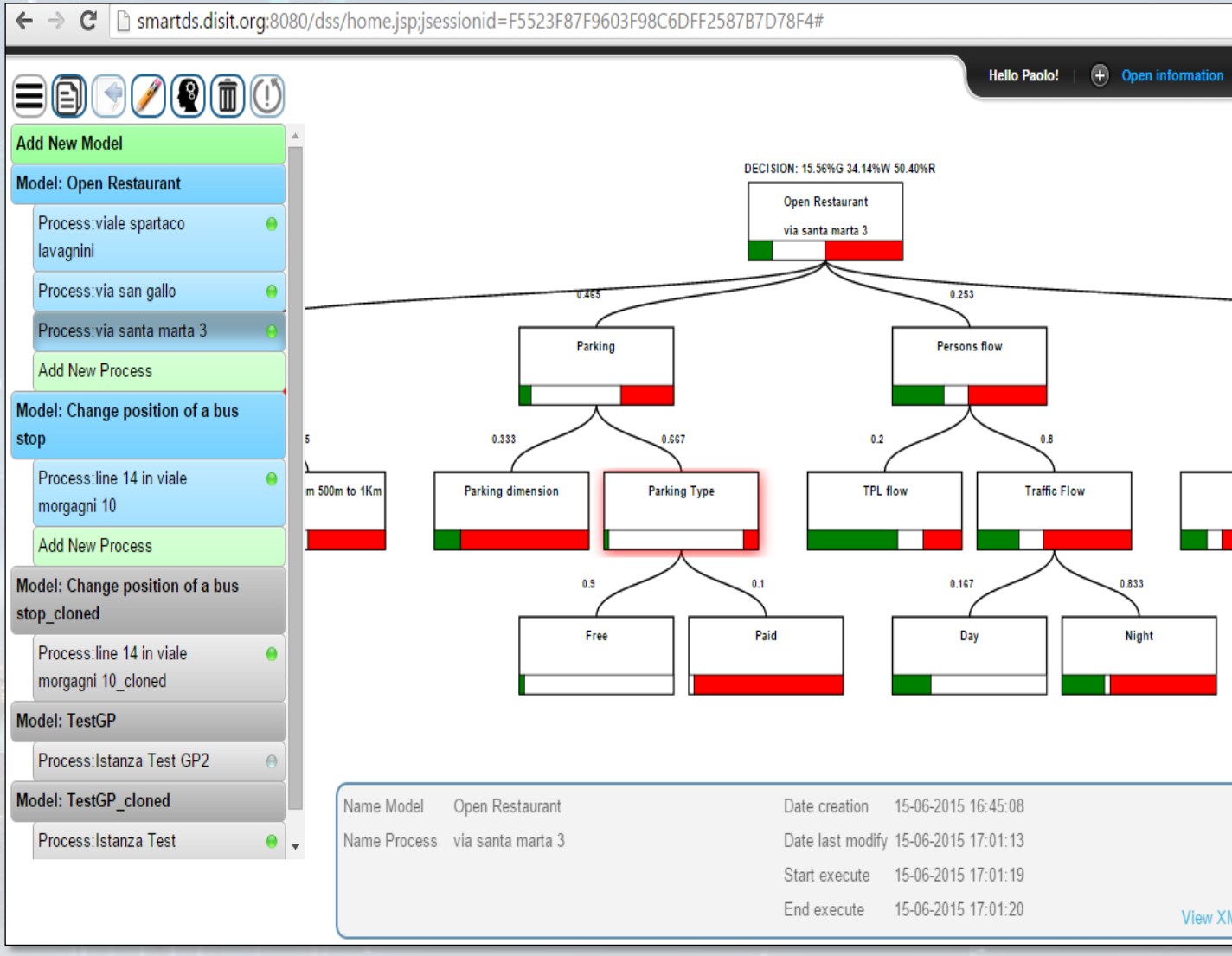
- Smart Decision Support Systems (DSS)
- Evacuation Decision Support
- Smart Intelligent Transport Systems
- Emergency Support Smart App
- Resilience DSS





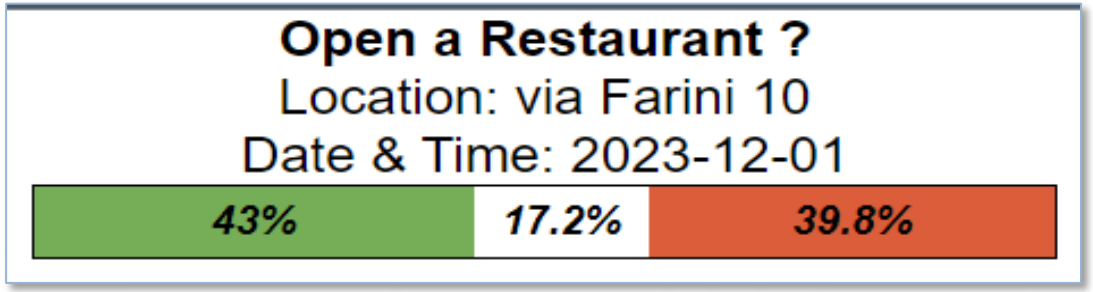
Smart Decision Support , system thinking

- **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, …



SmartDSS

- Supports the definition of the **Decision Tree Model, DTM**, in terms of System Thinking, with Italian Flag and combinations
- Allows the **statistic composition** of subDecisions probabilities
- **Generating a DTM as an IoT App,**
- **IoT Apps with DTM can**
  - **be customized**
  - **compute root values in real time in** any context: location, parameters, etc.
    - Single DTM root value can be produced on Dashboard
    - Several DRM root values can be represented on dashboard as heatmaps for Green/White/Red values





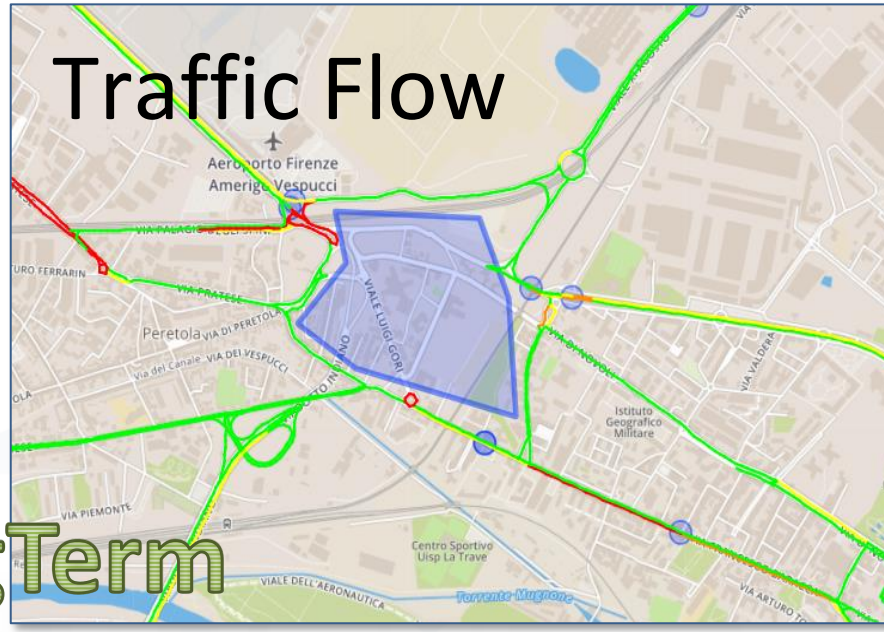
WHAT-IF Analysis

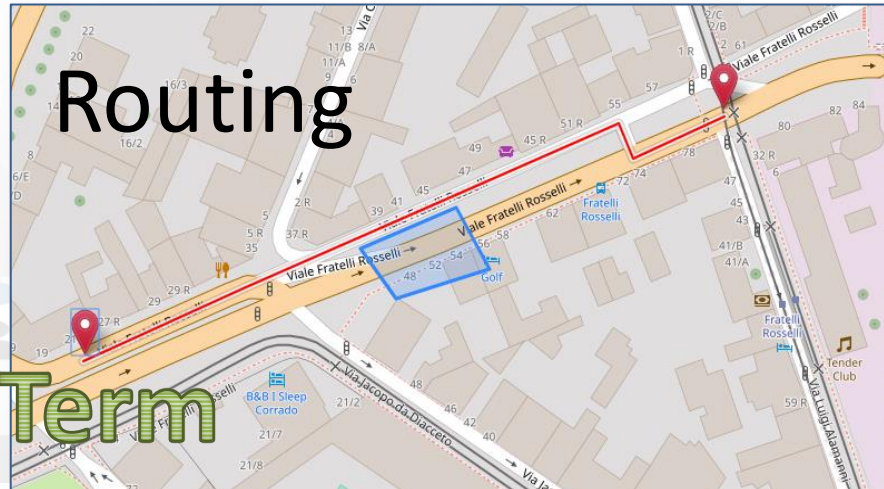




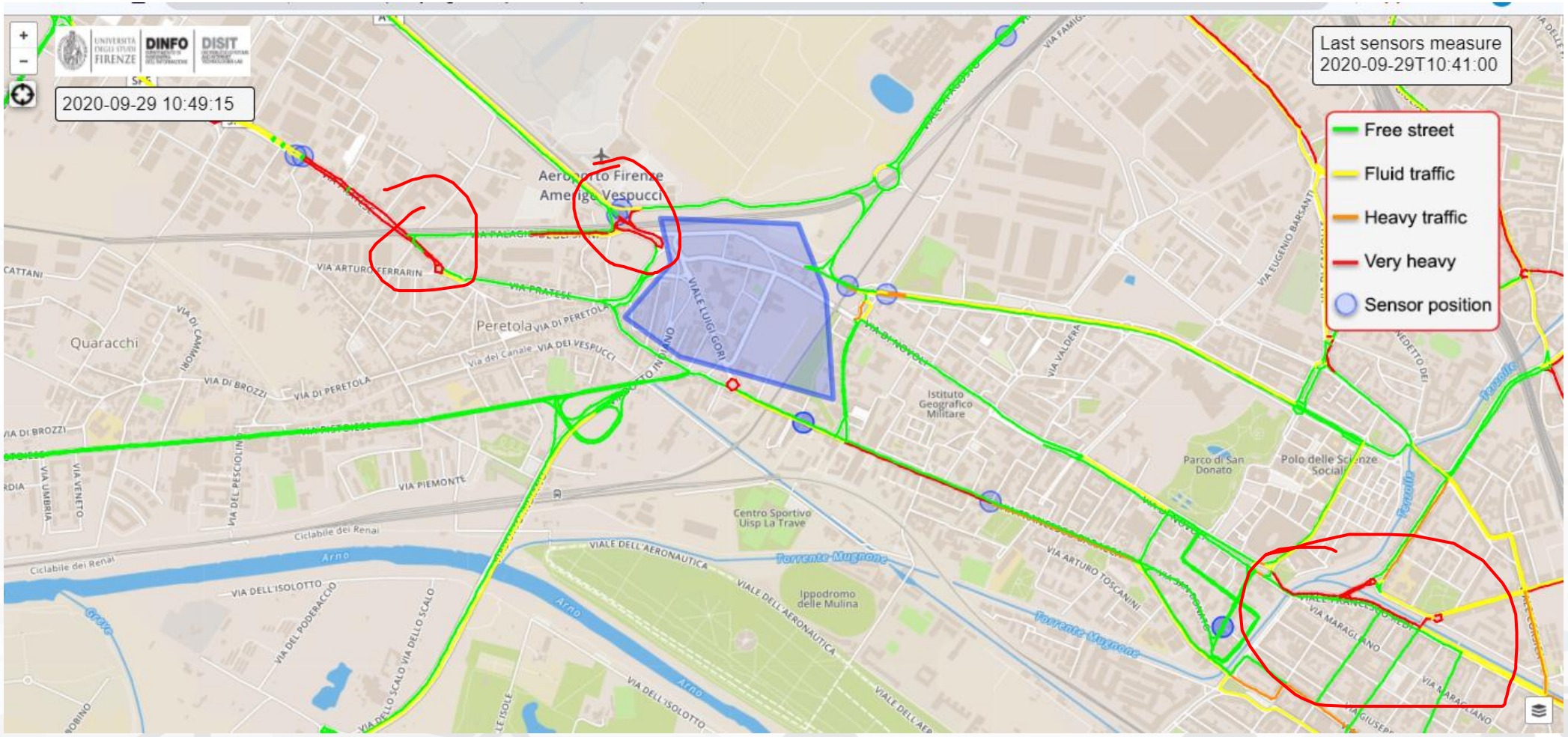
Decision Support Systems, What-if

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



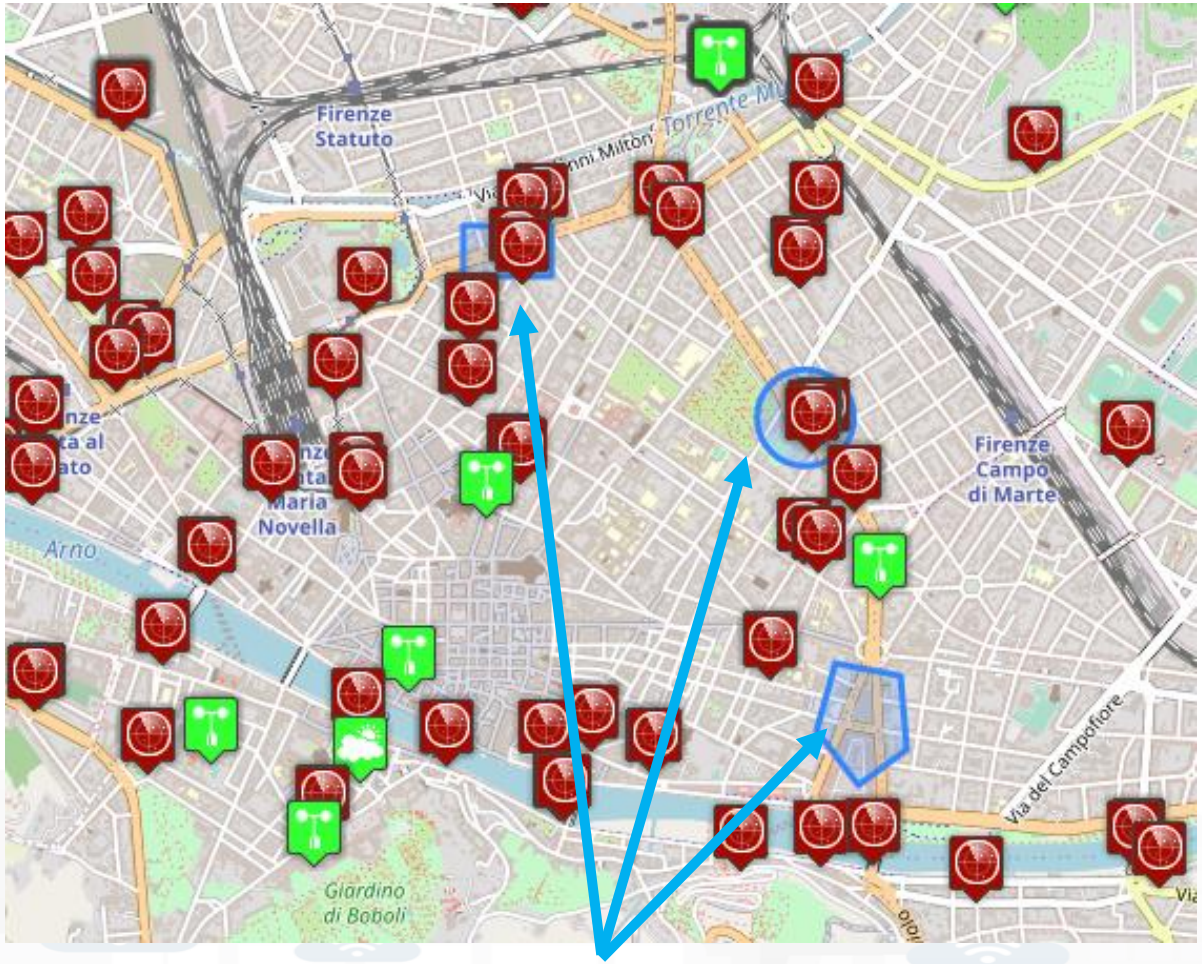


Computation of Traffic Flow Evolution, cascade effects



What-If Analysis Concepts

- What is going to happen at Services if certain conditions/cases are going to occur
- Formalize: Conditions/cases, Services
- Scenarios of Cases+Services Vs Solutions are Studios
- You can define, save, load:
  - Scenarios and Studios

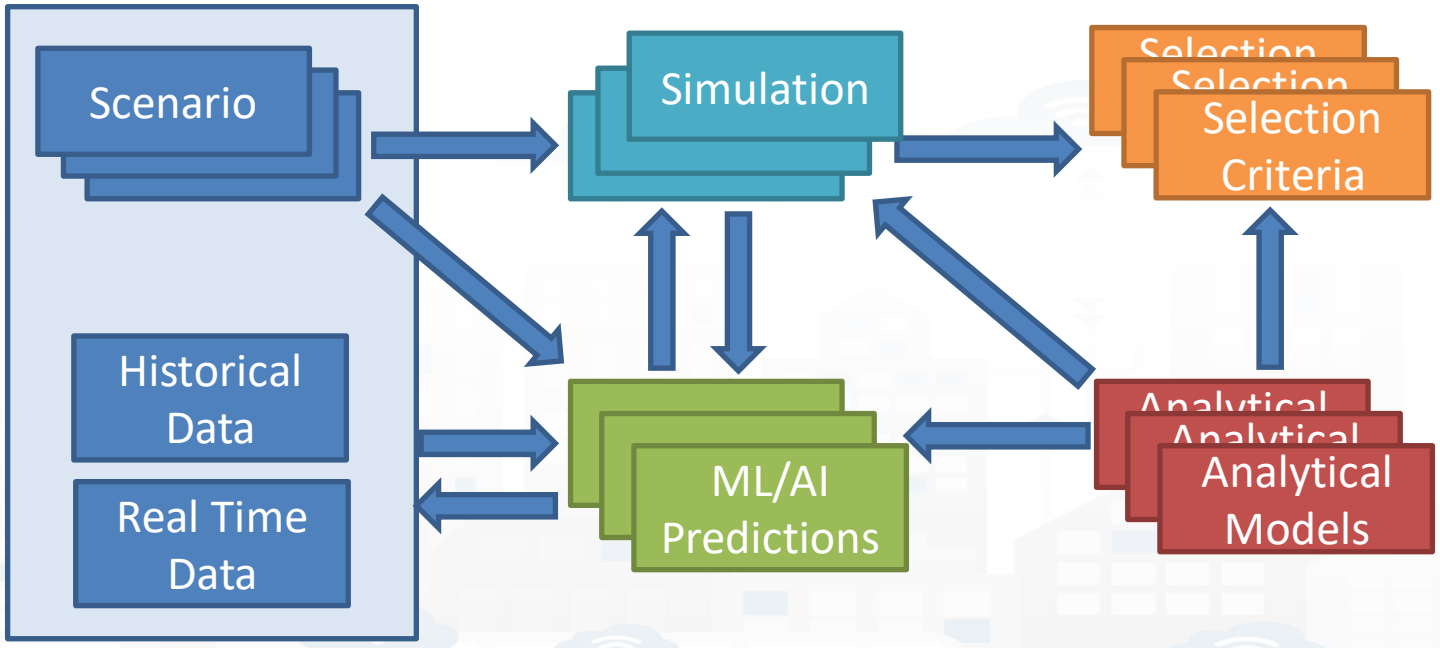


Scenario

What-if: what is going to happen if …. this and that

- **What is going to happen at:**
  - People, Economy, Society, ..
  - Traffic, Pollutant, Parking, structures
  - Equipment, .. …
- **if certain unexpected events would occur**
  - Scenario definition
  - Guessing future data…
- **Taking into account**
  - Historical Data
  - Real Time Data
  - Contextual data

Decision Support System
KPI, Optimization
Visual Analytic: animations



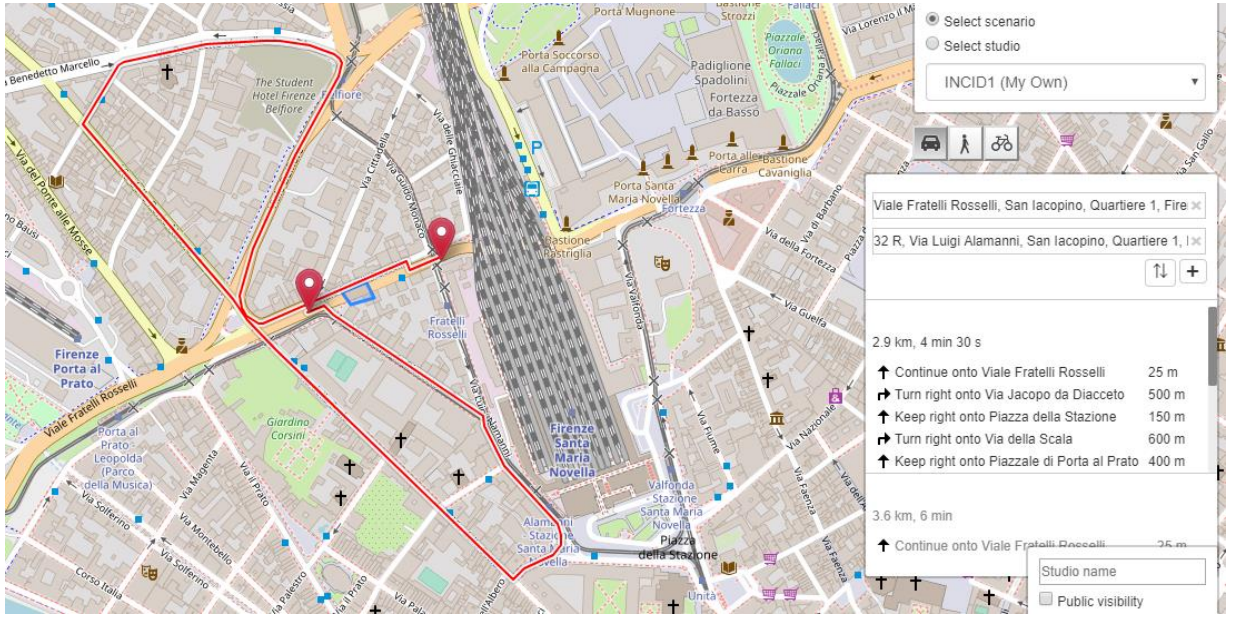
What-If Analysis

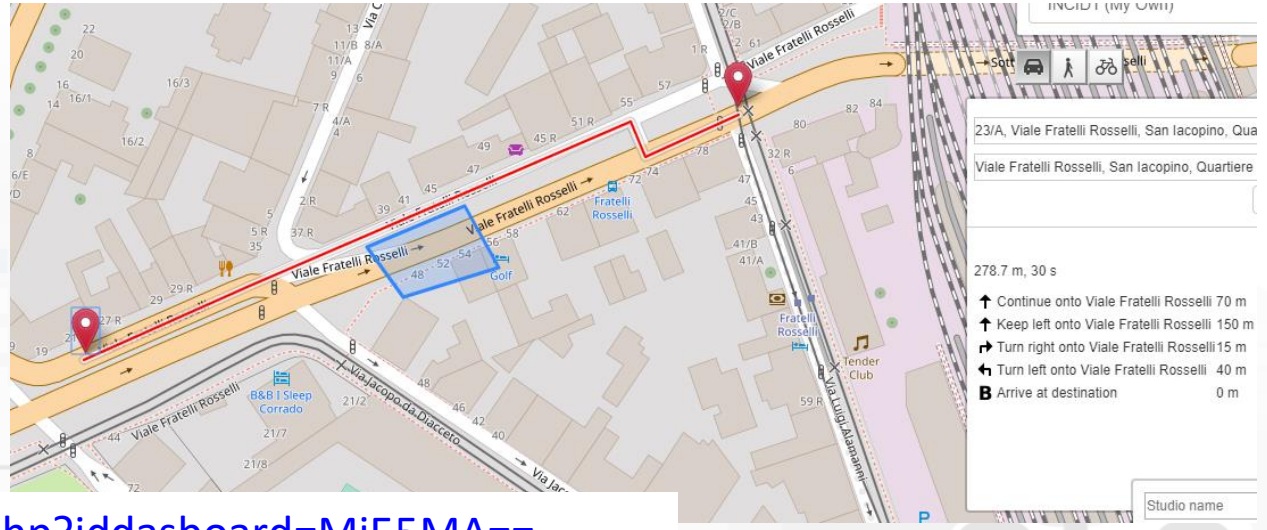
Accidents and elements blocking Points and Shapes taken into account for:

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

Assessment on the basis of changes:

- Mobility demand assessment
- Mobility Offer assessment

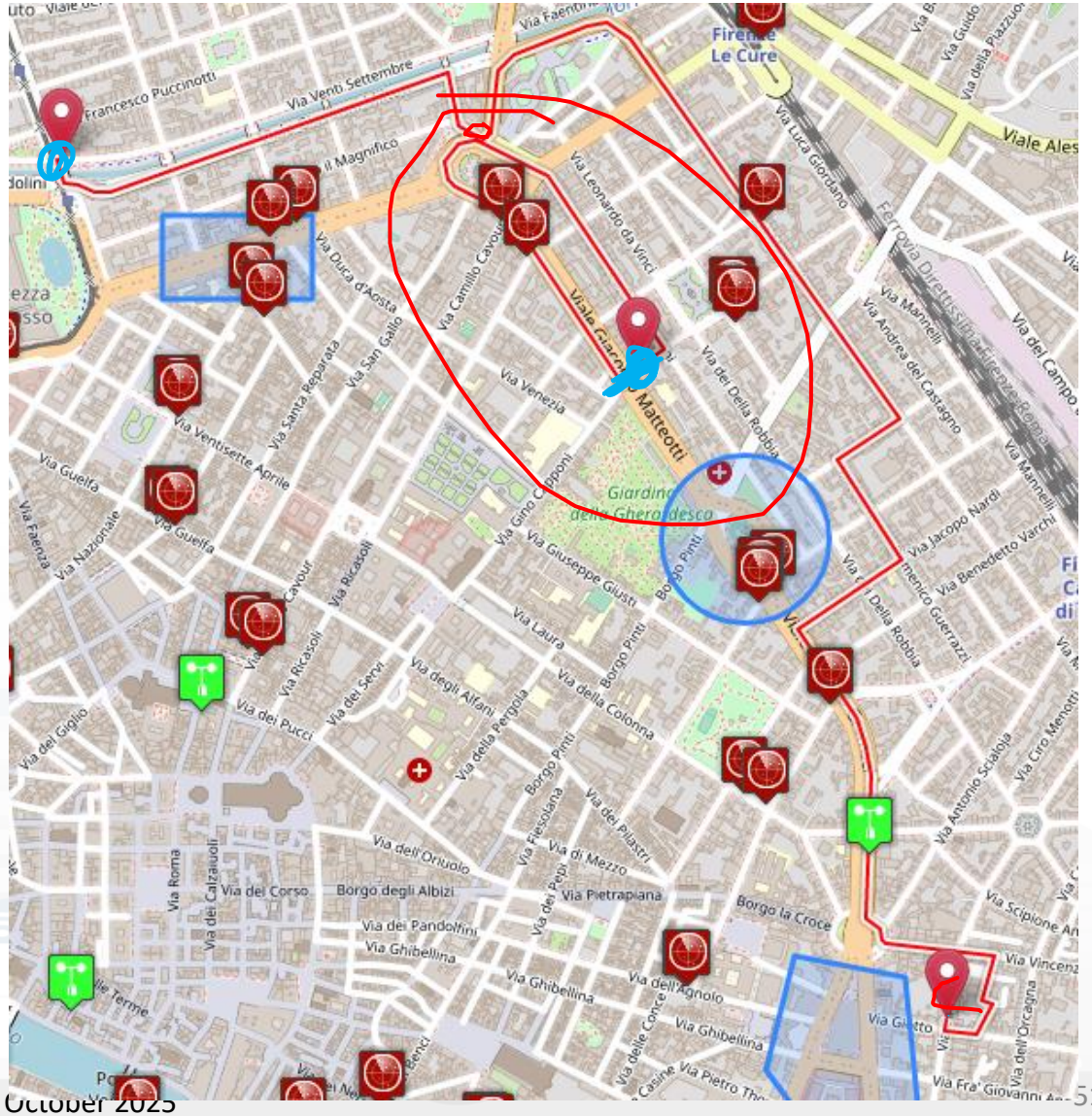




https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjE5MA==

Impact on Routing

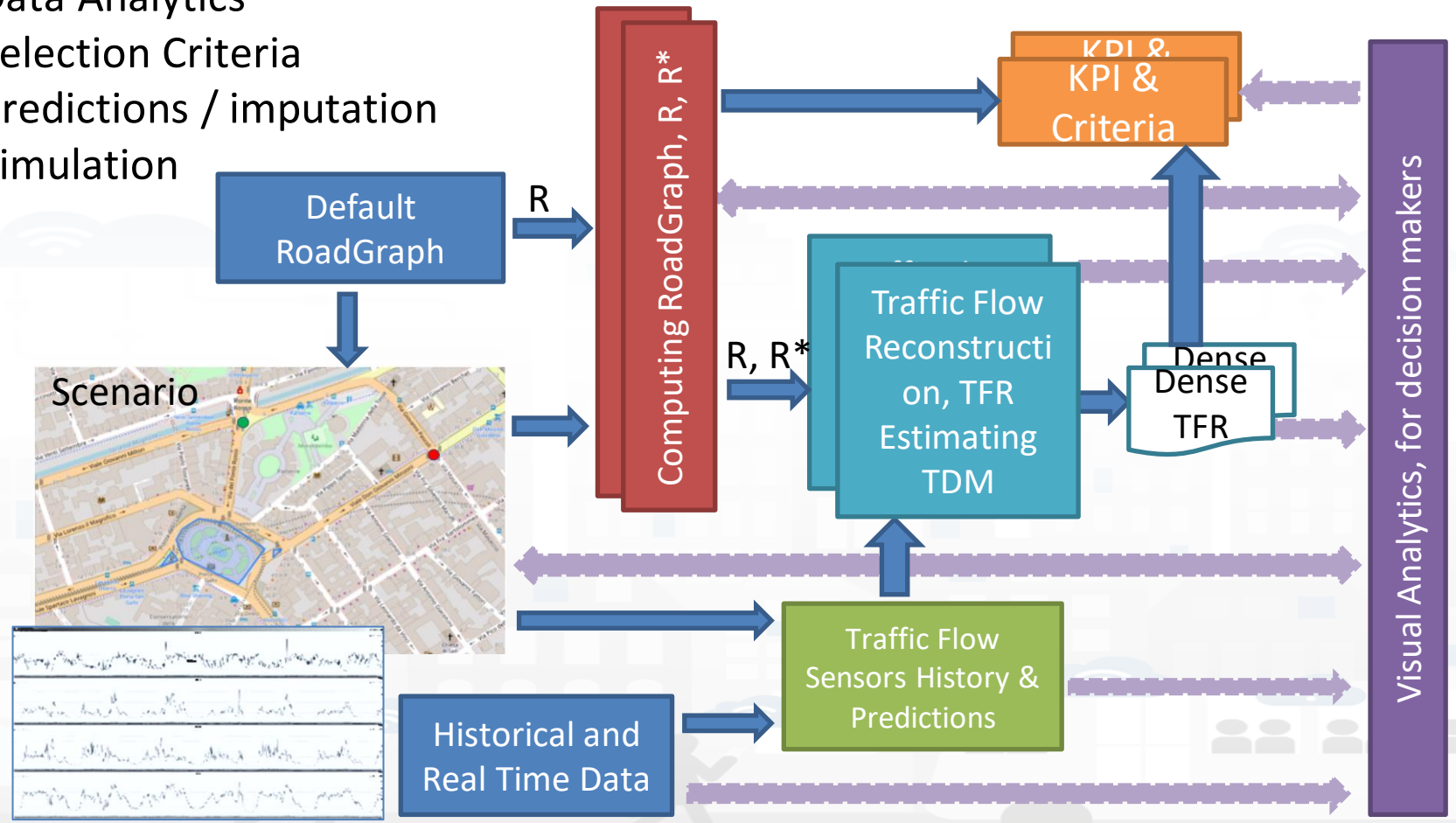
- Scenario with multiple shapes
- Conditional Routing
  - avoiding areas or
  - reducing traffic in those areas
  - Multiple stop points



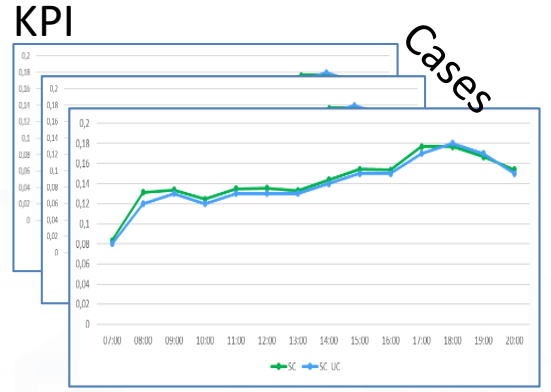
What-if: Simulation for Traffic Flow

At the same color corresponds the same area:

- Data / information
- Data Analytics
- Selection Criteria
- Predictions / imputation
- Simulation

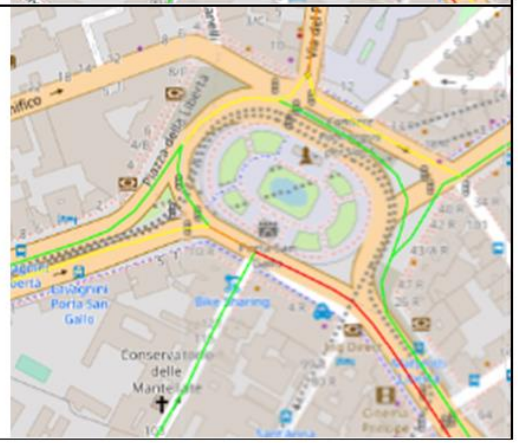


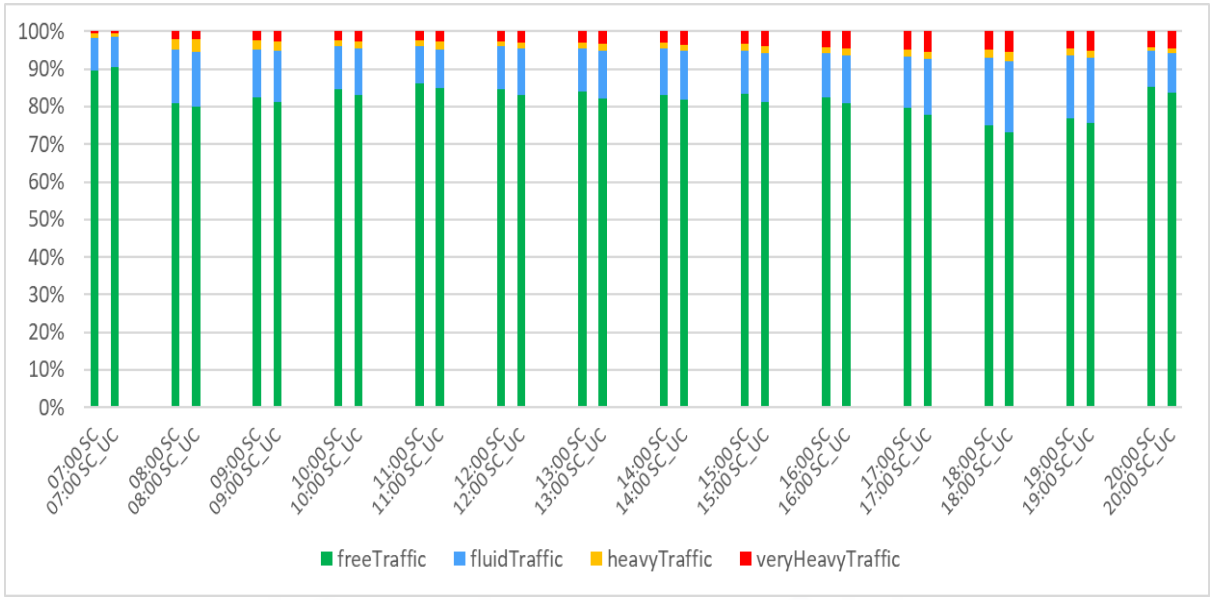
Data Driven Decision

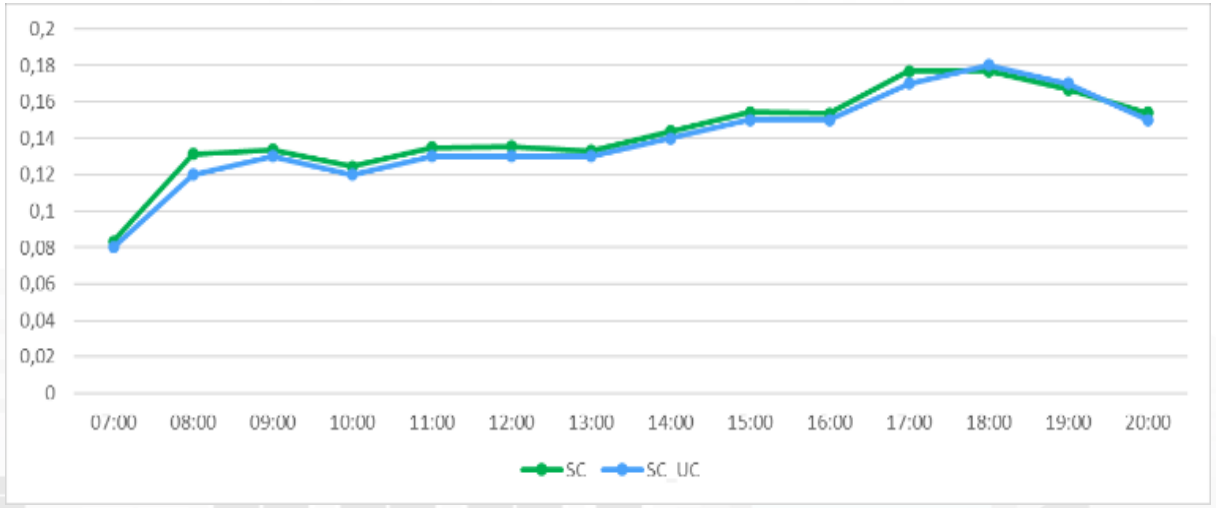


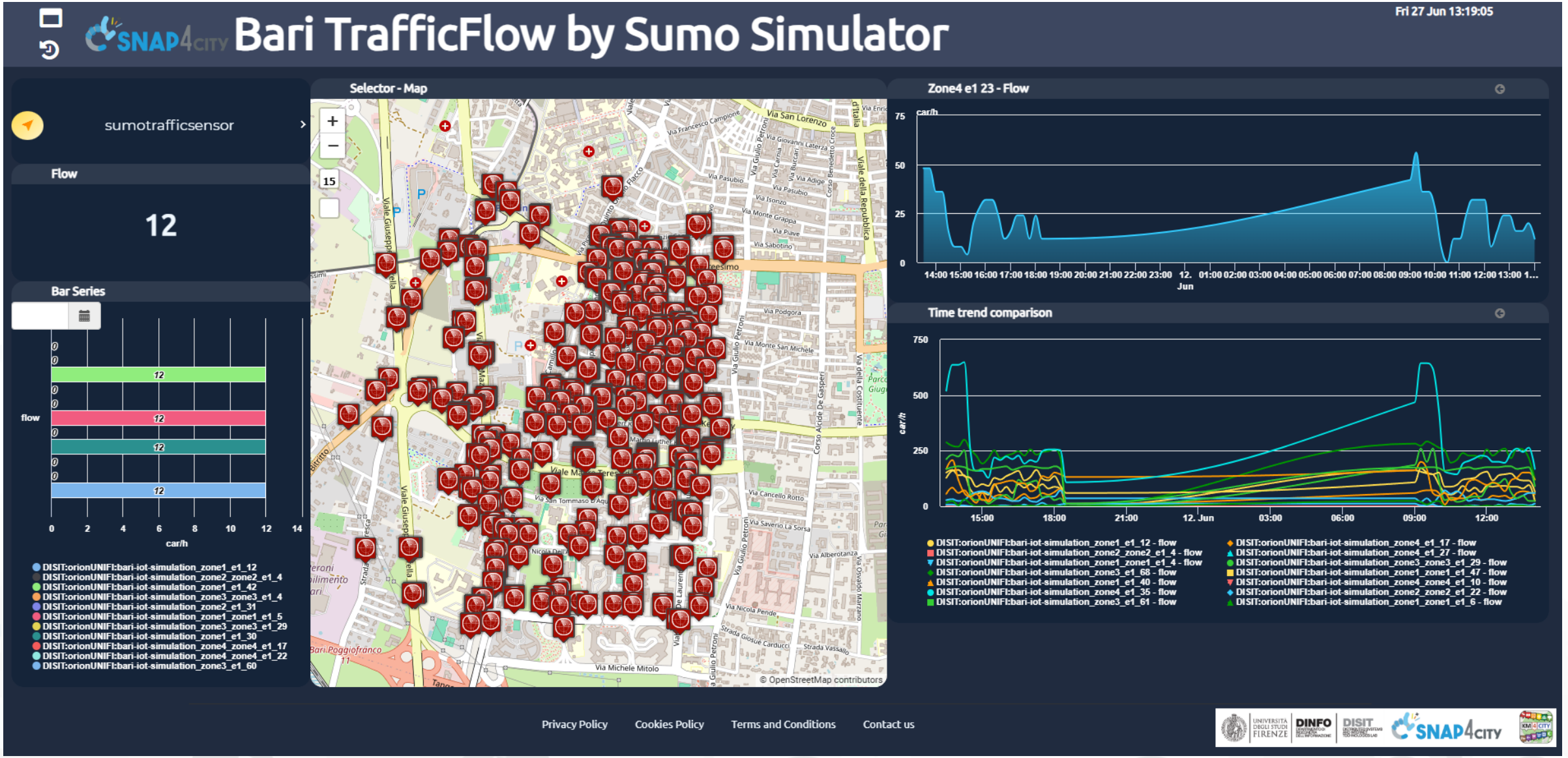


What-if

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






Bari TrafficFlow by Sumo Simulator
Fri 27 Jun 13:19:05
sumotrafficsensor
Flow
12
Bar Series
flow
car/h
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DISIT:orionUNIFI:bari-iot-simulation_zone2_zone2_e1_4
DISIT:orionUNIFI:bari-iot-simulation_zone1_e1_42
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Selector - Map
© OpenStreetMap contributors
Zone4 e1 23 - Flow
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Time trend comparison
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DISIT:orionUNIFI:bari-iot-simulation_zone4_e1_35 - flow
DISIT:orionUNIFI:bari-iot-simulation_zone3_e1_61 - flow
DISIT:orionUNIFI:bari-iot-simulation_zone4_e1_17 - flow
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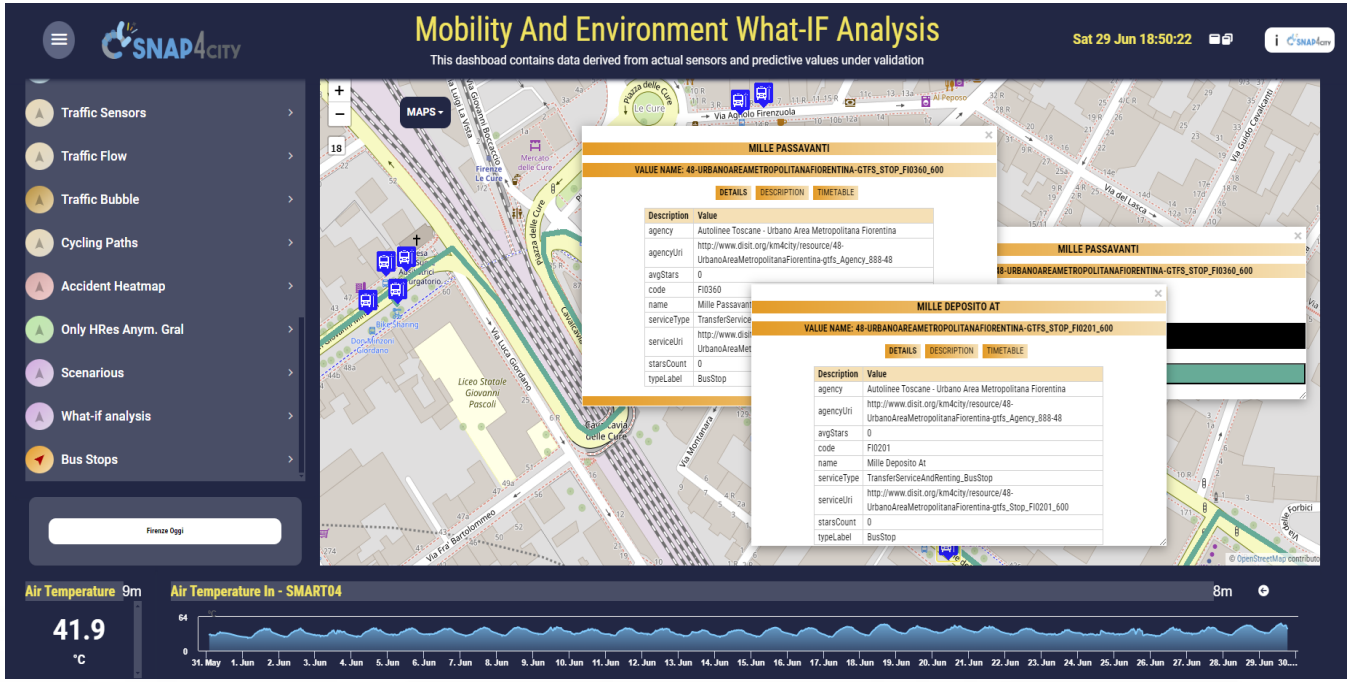
Cookies Policy
Terms and Conditions
Contact us

Transport Offer



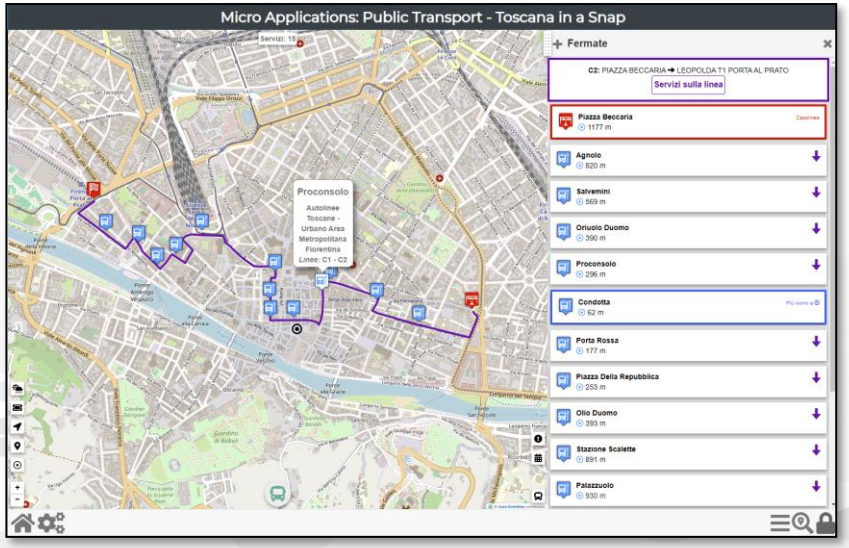
Public Transport Offer

- Via
  - Dashboards
  - MicroApplications
  - Mobile Apps
  - ServiceMap

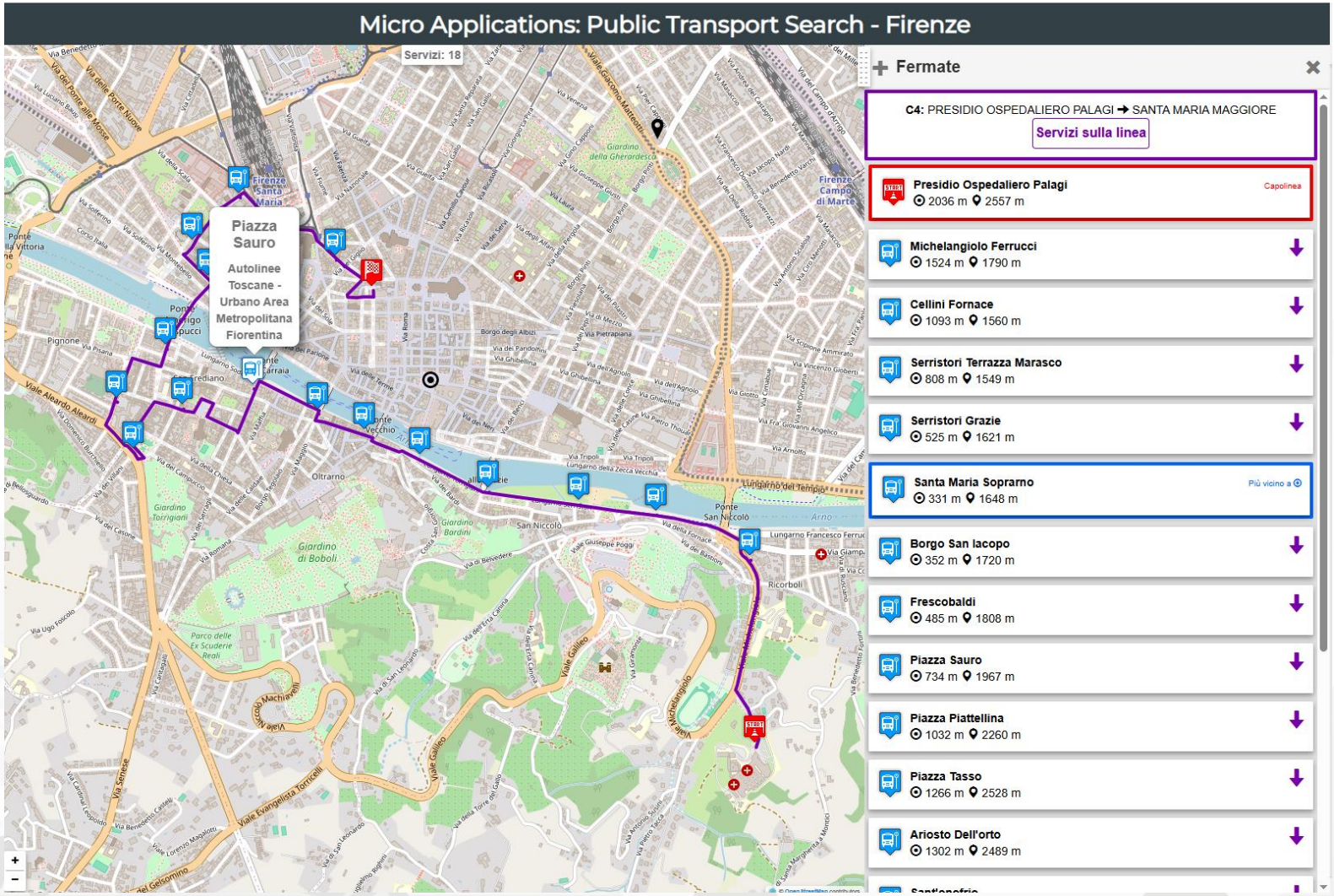








Offer of Transportation, GTFS, for example



Public Transport Information/file/streams

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

DORAM: Demand of Mobility vs Offer of Transportation





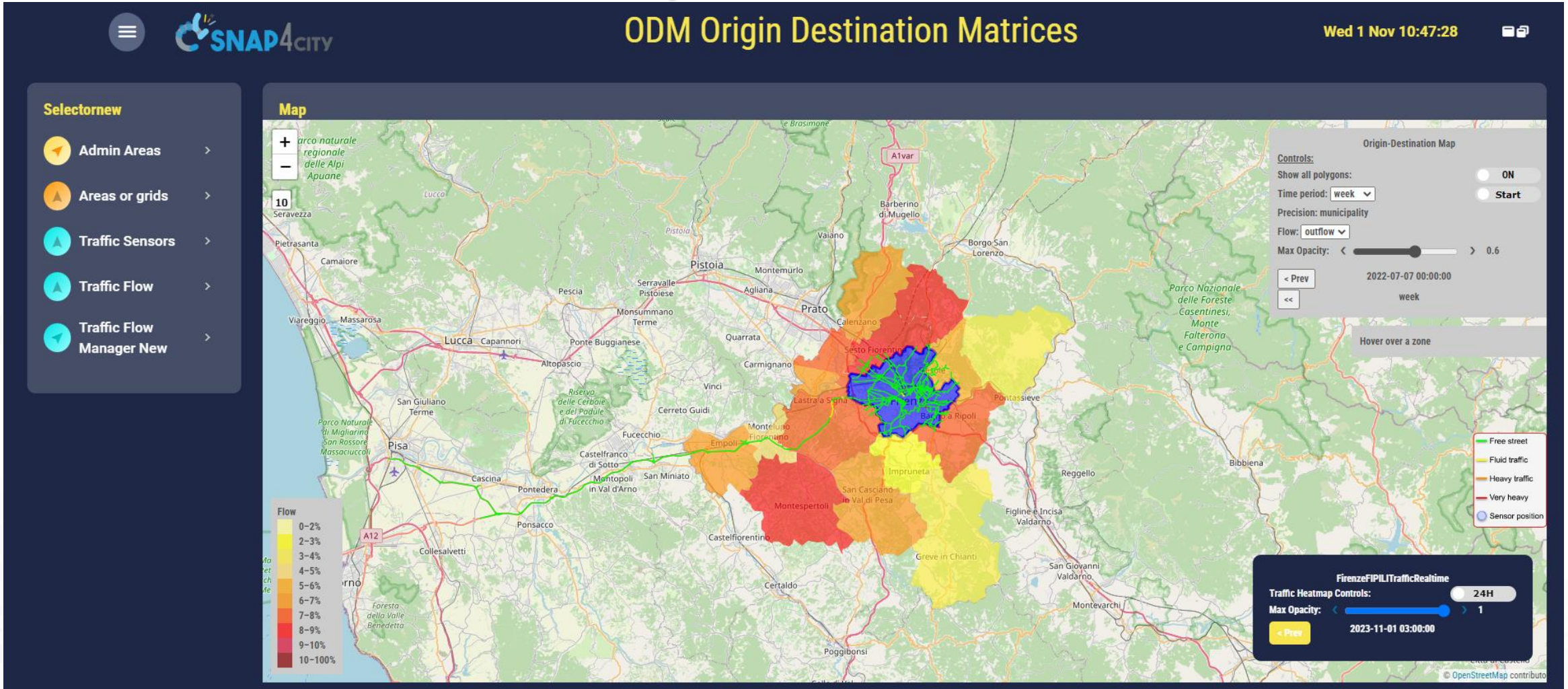
Mobility Demand vs Transportation Offer



In the large

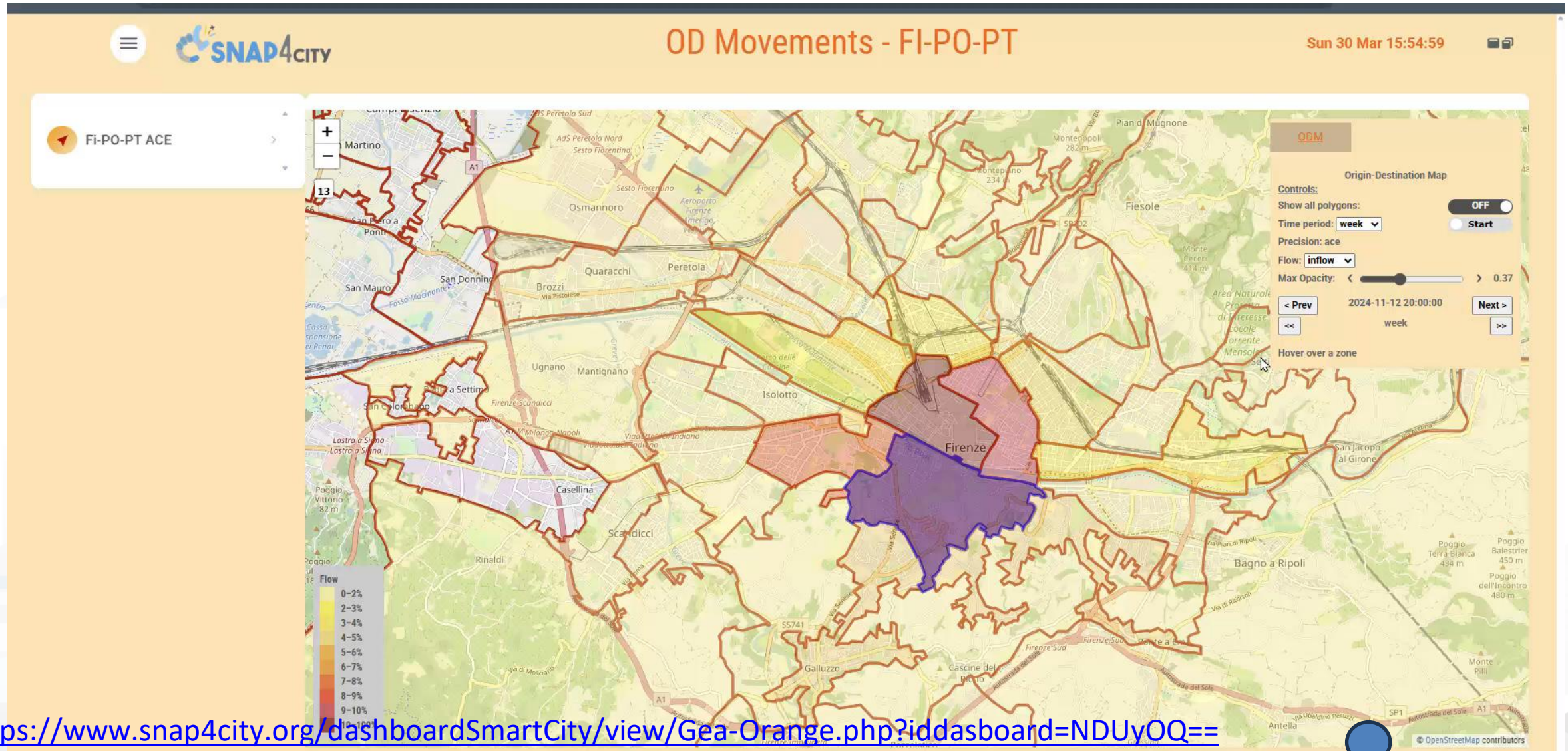
- **Mobility Demand → ODM:**
  - Telecom Operator ODM, all movements on ACE Area
  - Reduction on local actual percentage
  - Matching on MGRS 200 mt, exploiting presence data of Telecom Operator
- **Transportation offer**
  - Road graph
  - GTFS/NeTex, transmodel
  - Bike sharing, carsharing, scooters, etc.

ODM, Traffic Flow



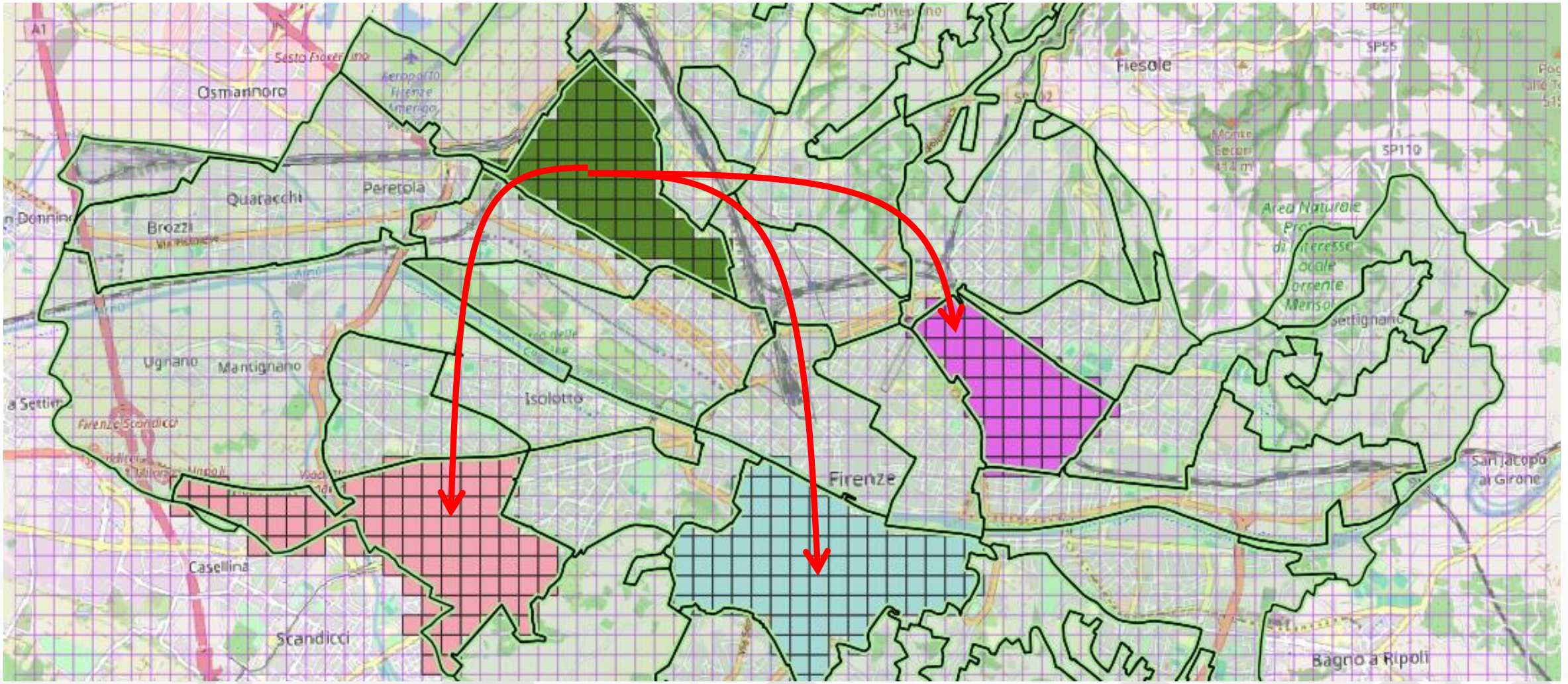
https://www.snap4city.org/dashboardSmartCity/view/Gea-Night.php?iddasboard=Mzk3Nw==

Origin Destination Matrices: Mobility Demand

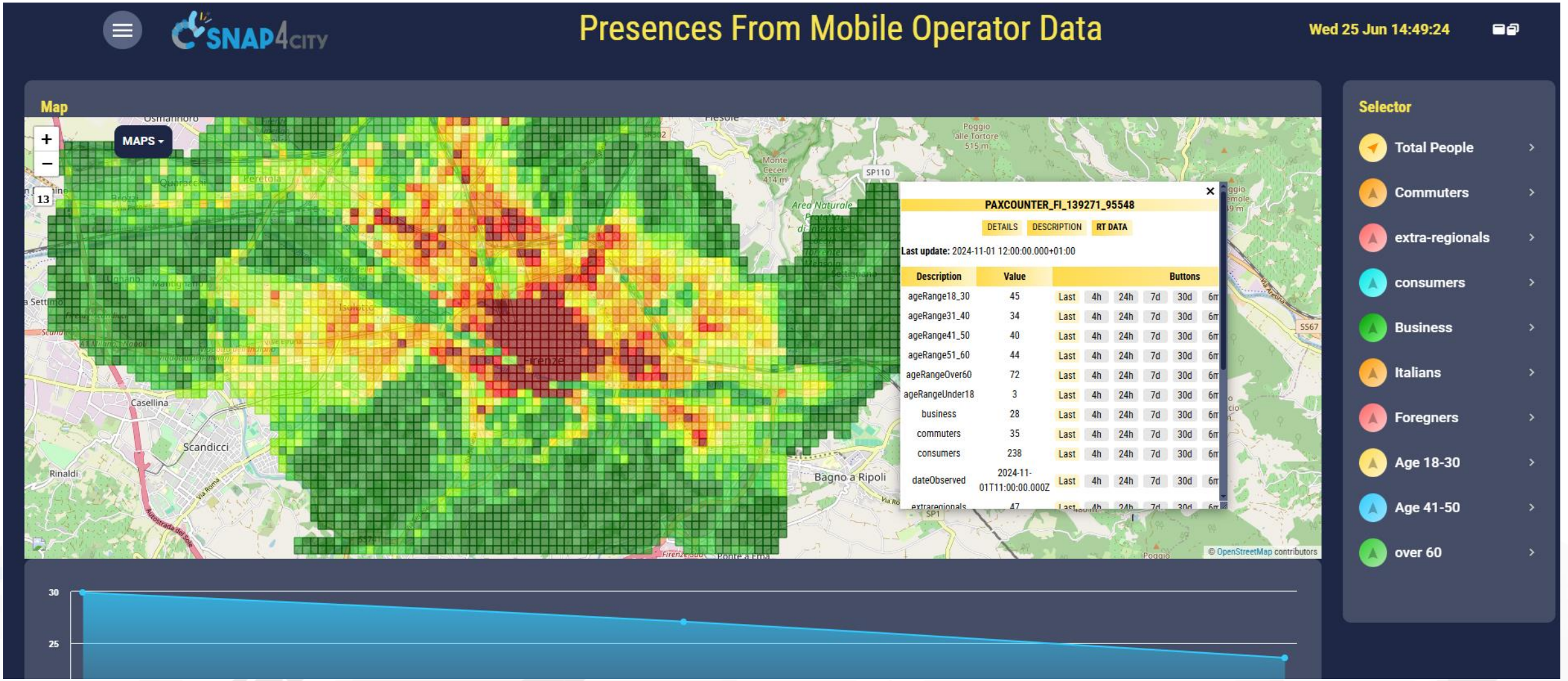


https://www.snap4city.org/dashboardSmartCity/view/Gea-Orange.php?iddasboard=NDUyOQ==

Mapping ODM ACE based on MGRS



Presences from Mobile Operator



DORAM

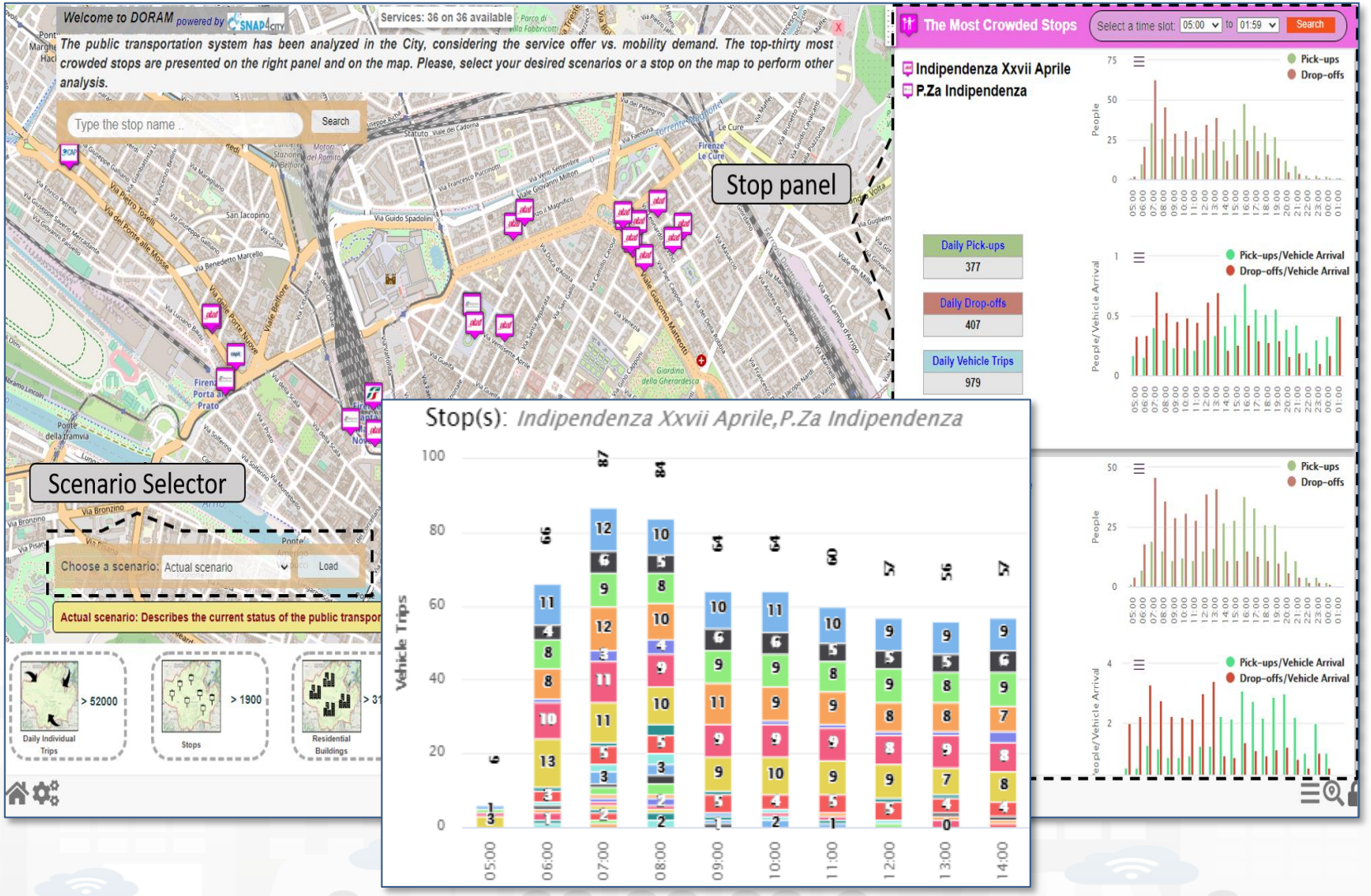
Analysis of

- **Demand** of Mobility
  - Action Based
  - Via OD matrices, several kinds
  - POI, city structure, etc.

With respect to

- **Offert** of Transportation:
  - Public services
  - Private services
  - Multiple agencies
  - GTFS

Critical Busses, busstops, paths, rides, etc.



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

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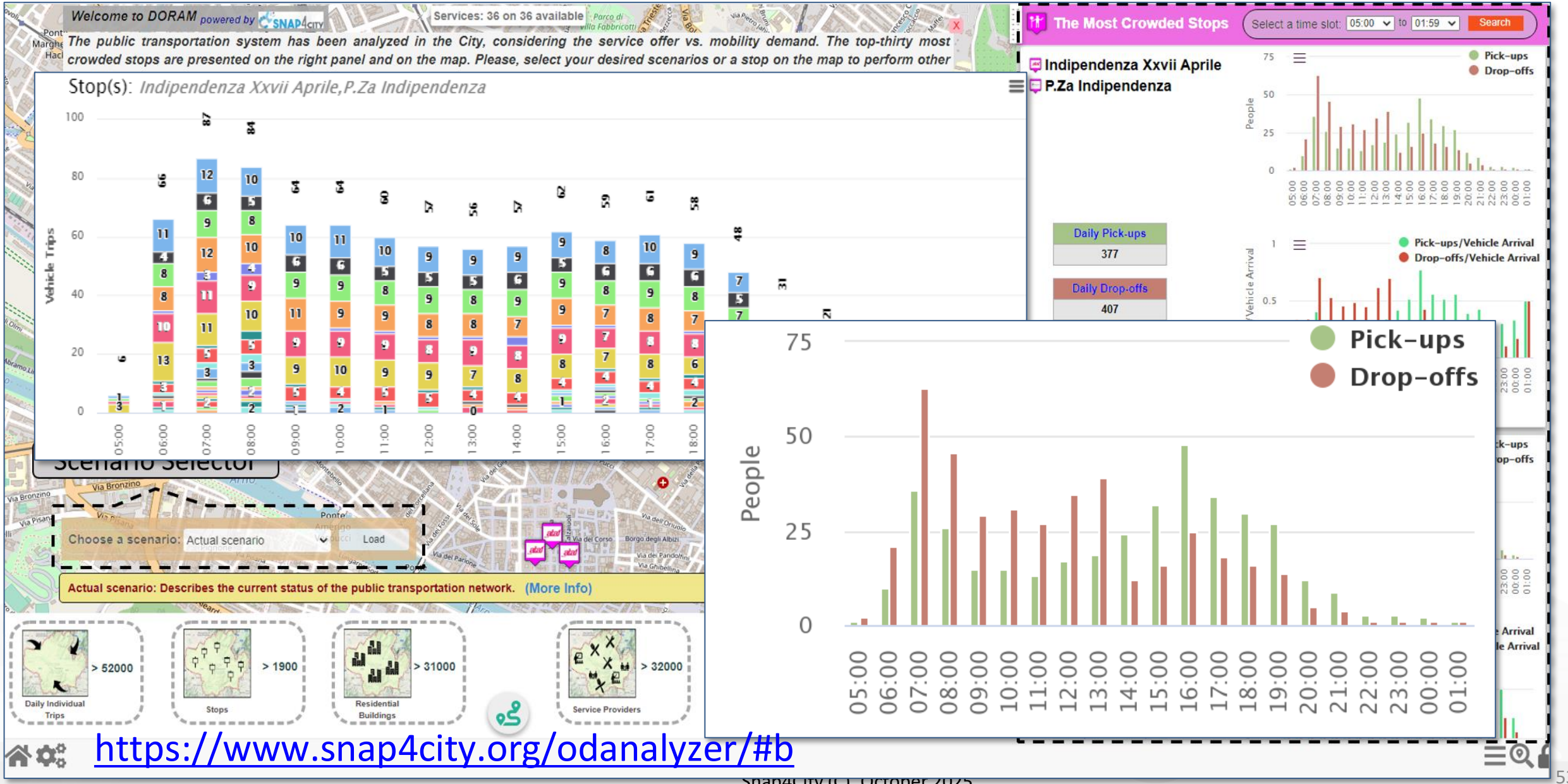
DORAM

SNAP4CITY | KM 4 CITY



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

What can produce the Analysis tool by KPI

- Identification of critical Bus Stops over time
- Identification of critical courses of bus lines, over day and week
- Effects of changing the position of Bus Stops, courses and line schedules, bus size, etc.
- Effects of changing the contextual conditions:
  - The opening of shopping centers, cinemas, schools, etc..
  - Changes on city structure and paths
  - Size of the buses

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

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SNAP4CITY KM4CITY

SNAP4CITY

Traffic Simulation-K8S

Sun 22 Jun 11:53:30

Ext

STOP PAUSE HELP

slow fast

Delay: 30.0 ms

Stats

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

Vehicle Summary

Quick Find

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

SEARCH

CAR BIKE TRAIN TRAM PERSON BUS LIGHT



Wid

Prepare Simulation | Execute Simulation | KPI Simulation

Simulation:

firenzeodbus

Execute

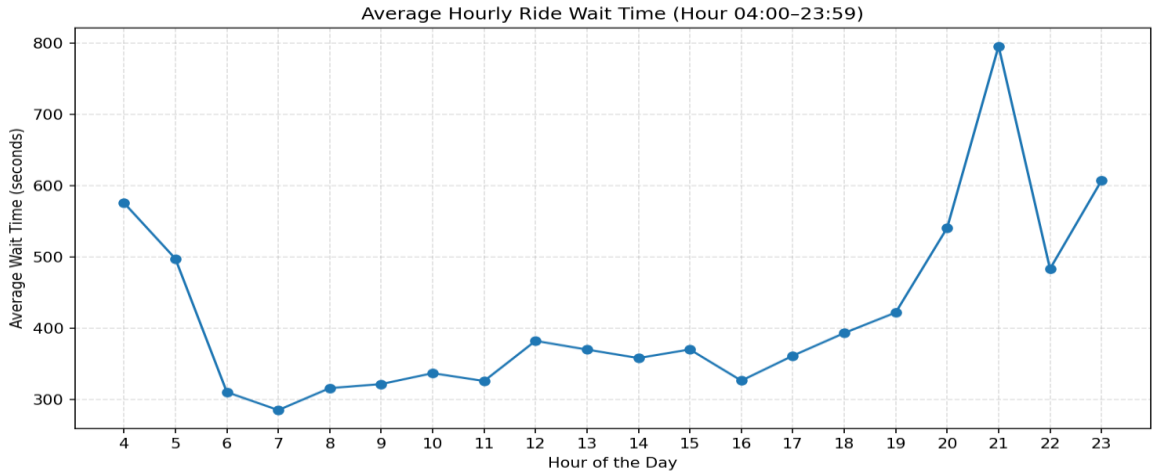
Simulation: 2025/06/22 11:53:27

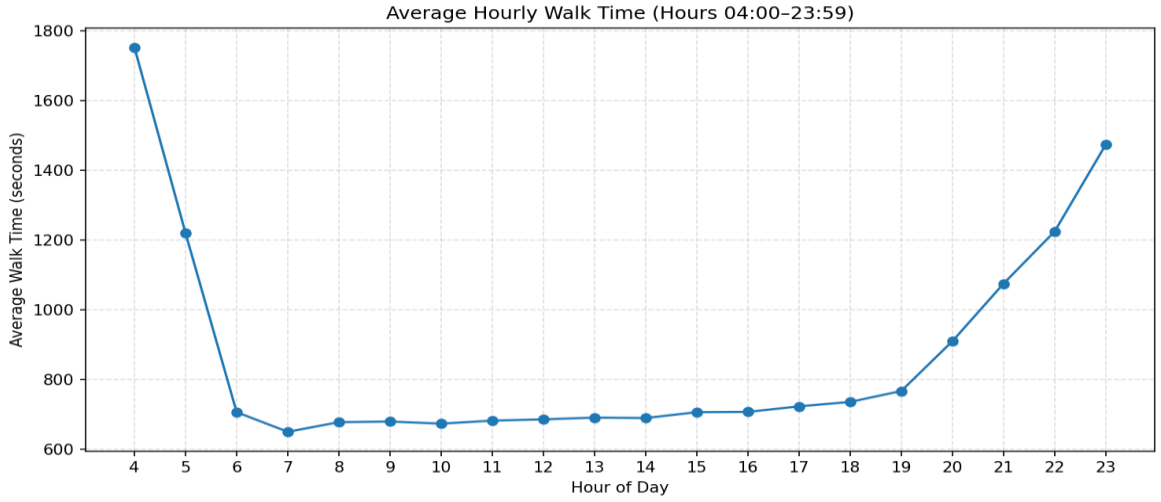
My Profile

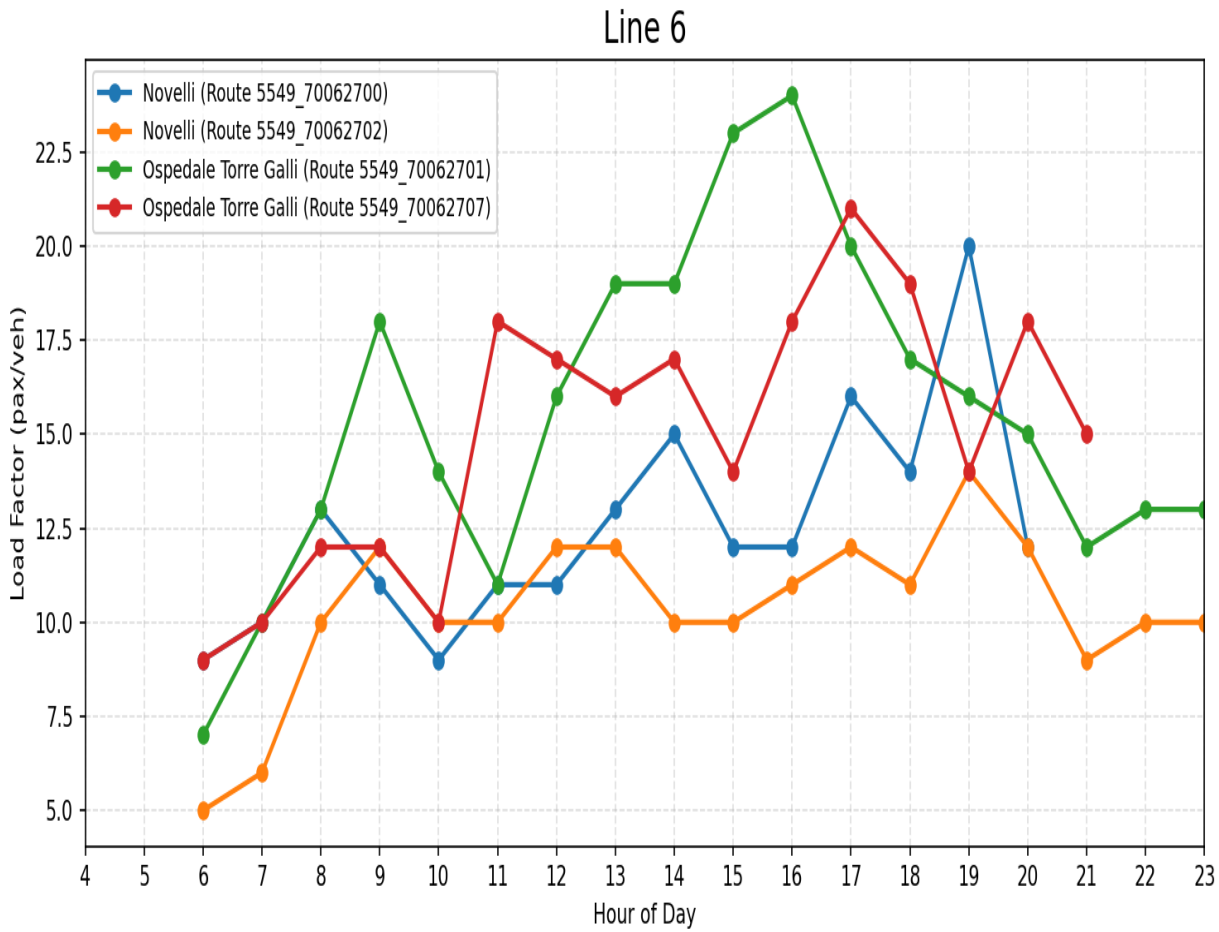
KPI on Match D-O of Collective Transport

- **On users**
  - **Unmet Demand**
    - Number of passengers who could not board their planned bus
  - **Average Walk Time**
    - The average time spent by passengers during walking before and after taking a ride from source to destination of their trip.
- **On Service performance**
  - **Average Ride Wait Time**
    - The average amount of time spent by passengers at bus stops while waiting for their desired vehicle.
  - **Average Ride Duration**
    - The average time spent by passengers in a vehicle taking a ride from source to destination of their trip.
  - **Average Vehicle Occupancy**
    - The average number of people boarded in vehicles of different bus lines at different timestamps of a day.
  - **Critical Bus Lines**
    - Bus lines for which the load factor of a bus line exceeds the threshold value of 15 in the service hours.
  - **Critical Bus Stops**
    - Bus stops where the crowding ratio is highest at top 20 bus stops served by different bus lines.
  - **Average Vehicle Depart Delay**
    - Vehicles which depart later than their expected time from the bus stops.

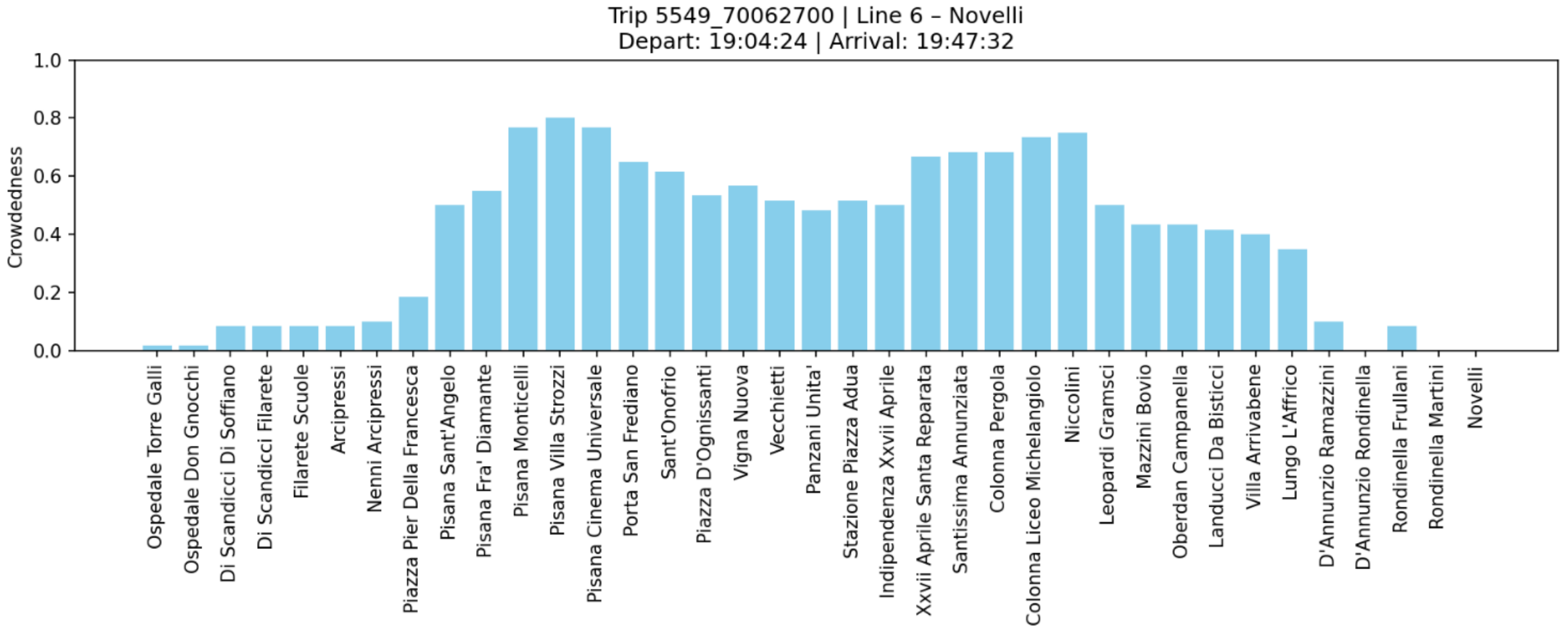
The typical working day





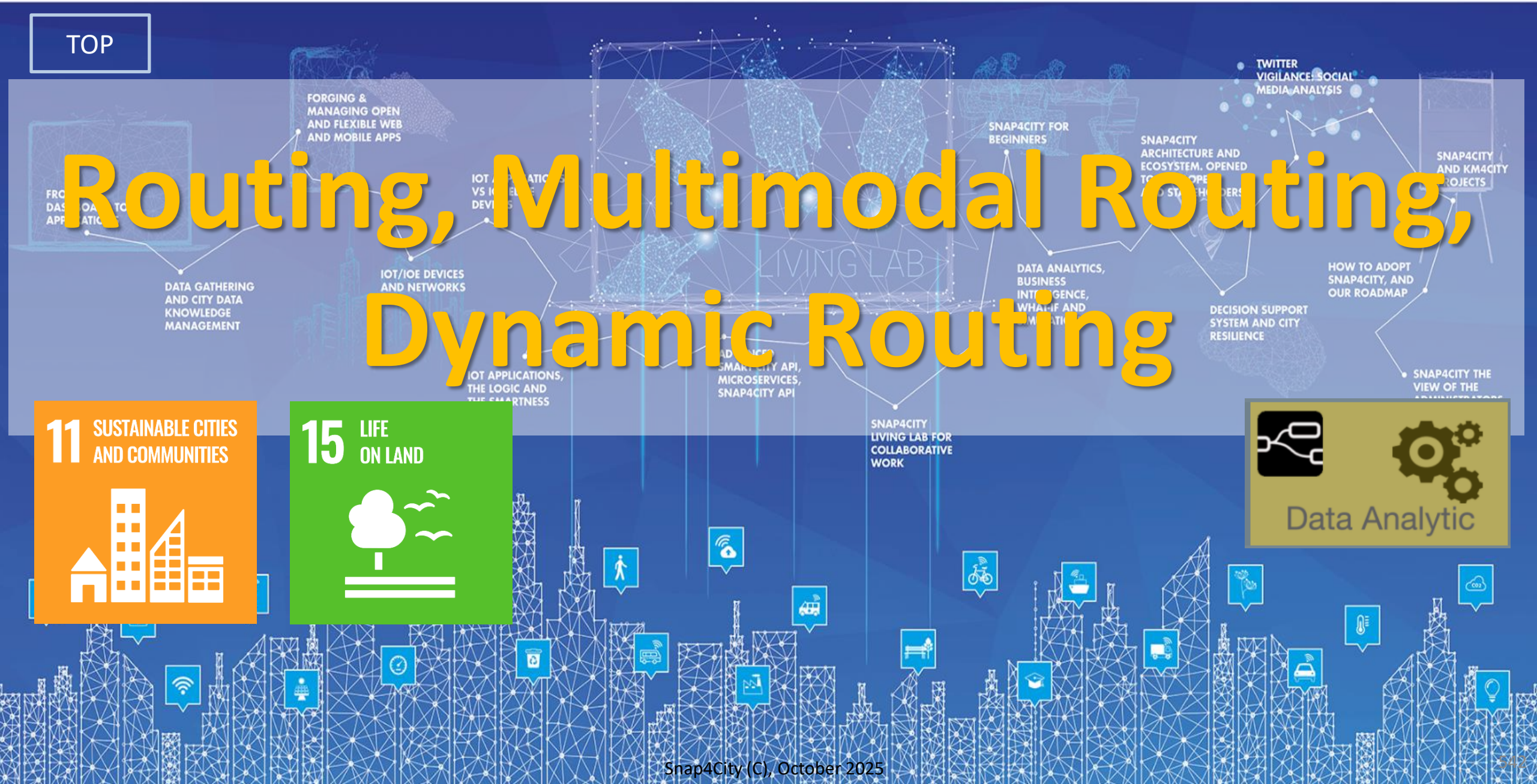


Crowdedness



TOP

Routing, Multimodal Routing, Dynamic Routing



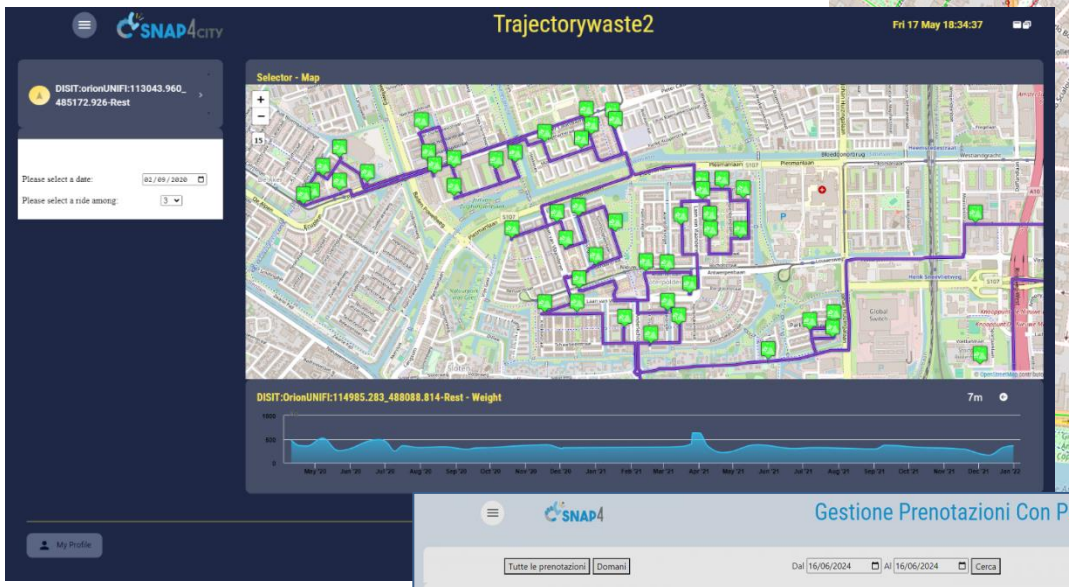
Routing Optimization

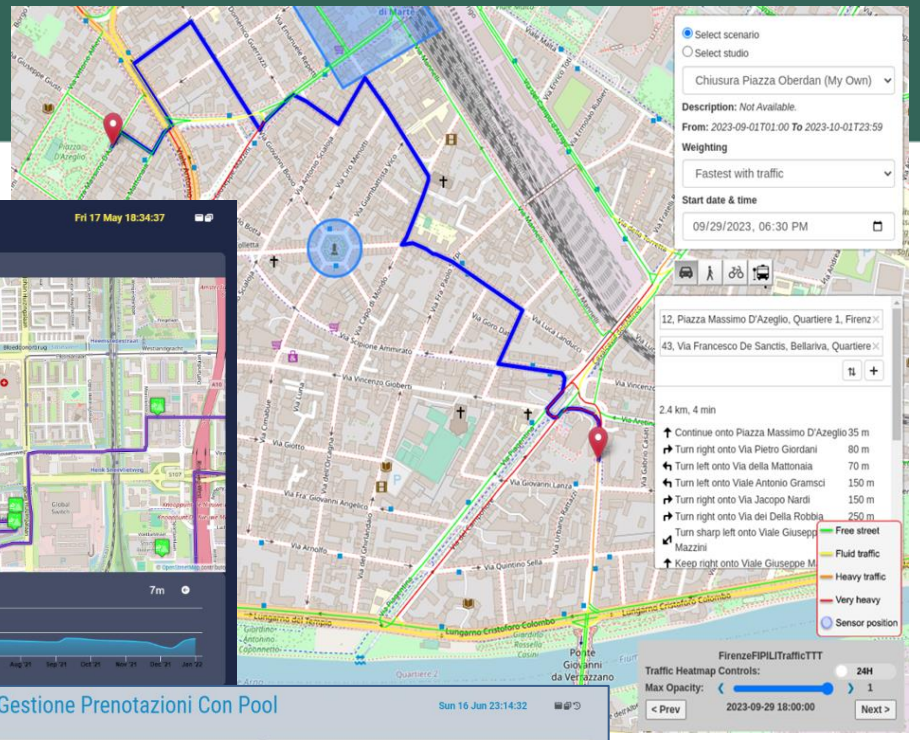
Goals on planning:

- Reduction **of costs on plan**
- **waste collection** optimization, Reduction of Km
- **car pooling trajectories** optimization for maximize the pool usage
- **delivering optimization**, reduction of travel time, reduction of Km
- etc.

Dynamic Routing on operation:

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







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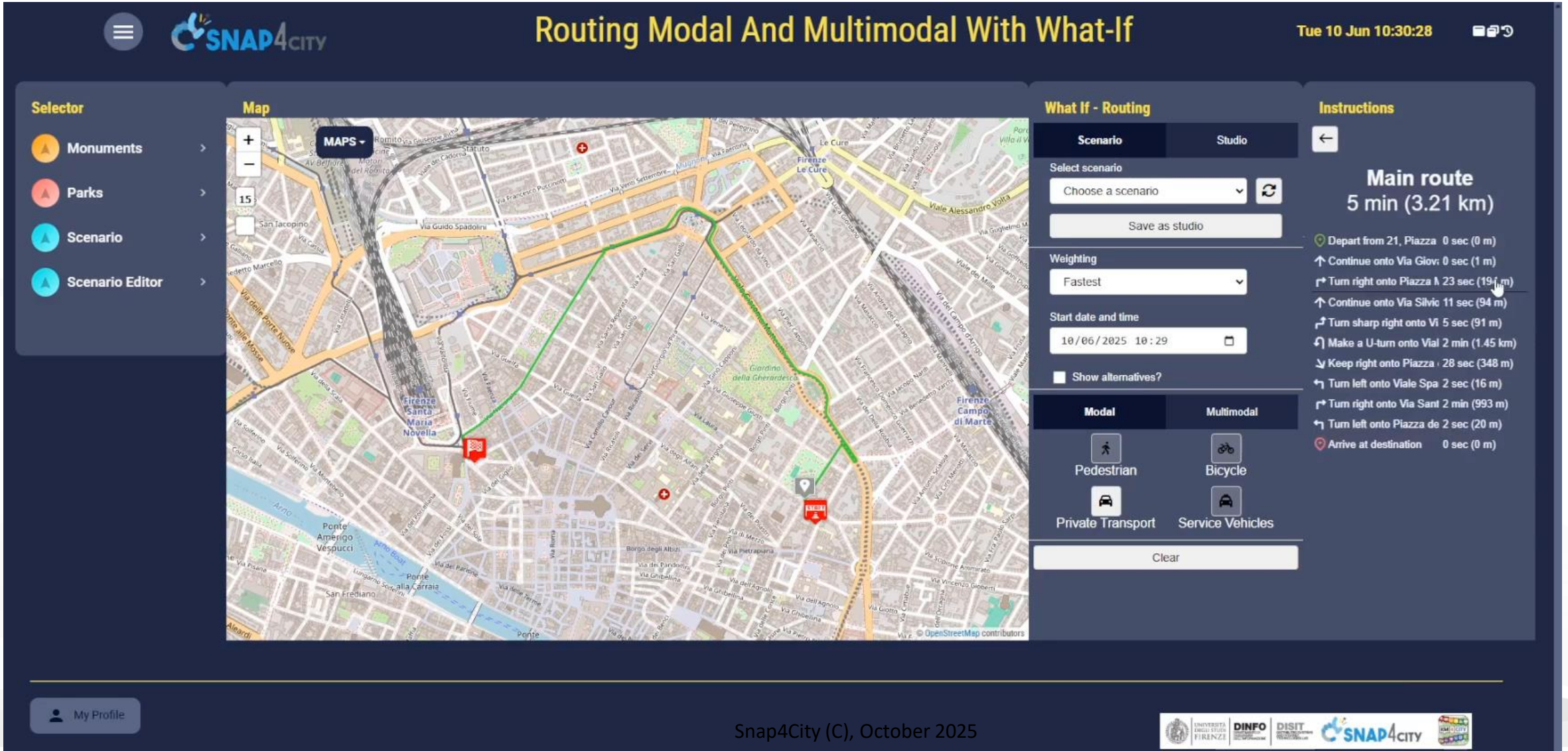
SNAP4CITY

Routing Facilities

- **modal routing: private vehicles, bikes, pedestrian**
  - with start, end and multiple intermediate points
  - selecting: shorter, faster, quitter, etc..
  - dynamic conditional routing taking into account the effective traffic flow status, or typical traffic flow status
  - dynamic conditional routing taking into account eventual blocked areas (by scenario) for example for street working, restoring, etc. (what-if cases and analysis)
- **multimodal routing** for the city users to walk and take the public collective transport
- **modal routing for public administrations** (ambulance, fire brigade, police, busses, etc.) exploiting the reserved lanes, etc.
- **a combination of cases**.
- **Full API for exploitation from your applications**

Some Routing Service Capabilities

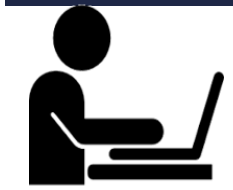


Routing with What-if exploitation details



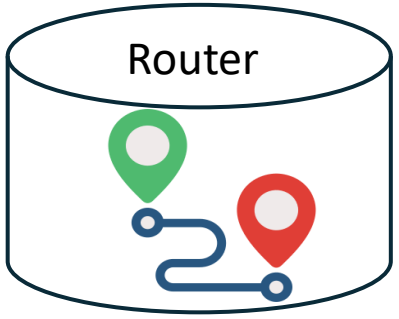


Translate addresses
Text ⇔ Coordinates

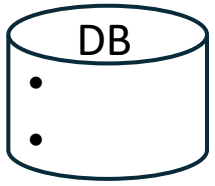


Defining Context:

- Select areas by drawing or loading existing ones
- Set waypoints by position or address
- Customize Router parameters
- Save/load your works



Find routes among points



Save scenarios/studios

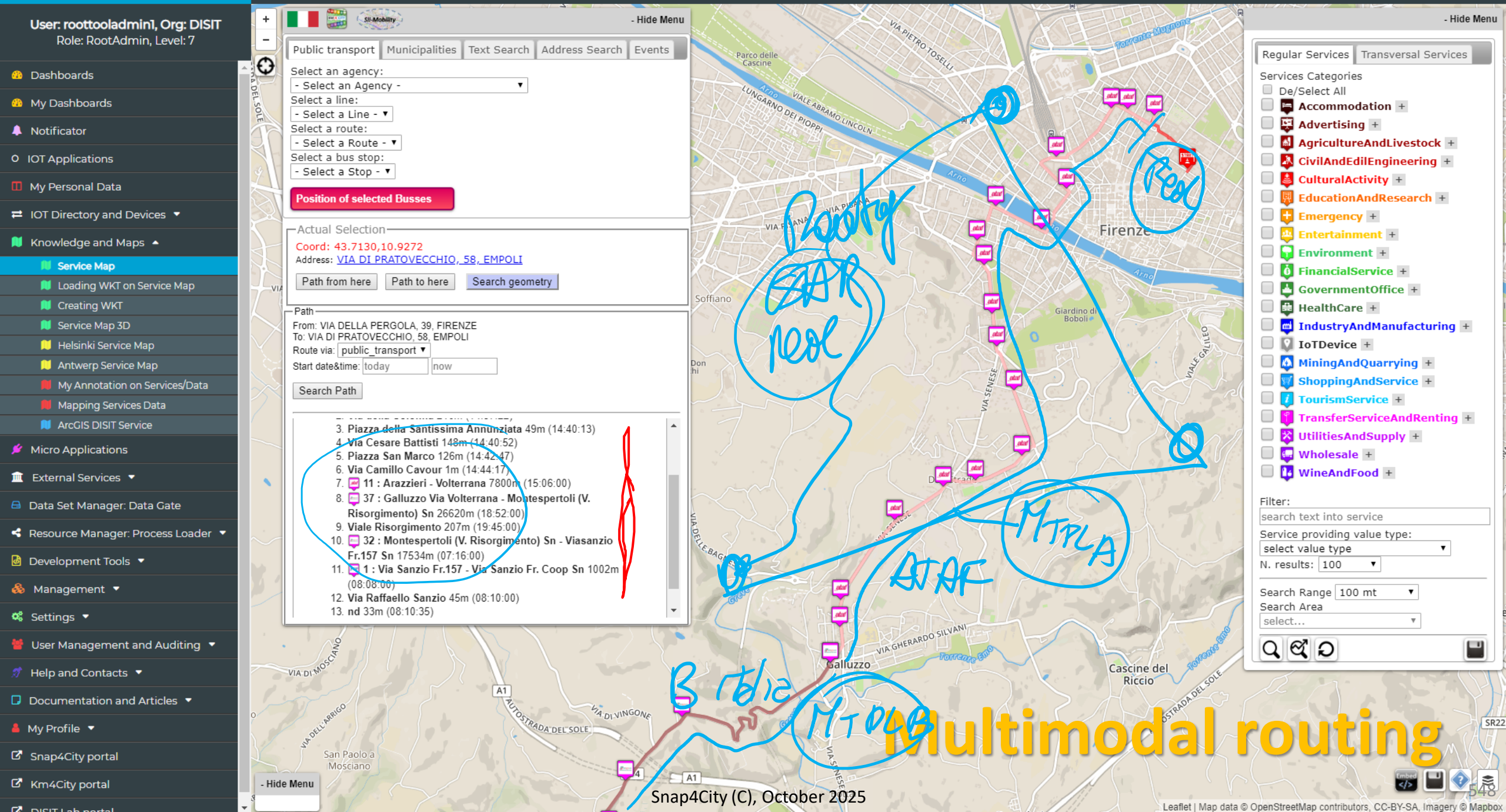




Evolve Context:

- See routes
- Take the road following instructions
- Analize results




User: roottooladmin1, Org: DISIT
Role: RootAdmin, Level: 7
Dashboards
My Dashboards
Notificator
IOT Applications
My Personal Data
IOT Directory and Devices
Knowledge and Maps
Service Map
Loading WKT on Service Map
Creating WKT
Service Map 3D
Helsinki Service Map
Antwerp Service Map
My Annotation on Services/Data
Mapping Services Data
ArcGIS DISIT Service
Micro Applications
External Services
Data Set Manager: Data Gate
Resource Manager: Process Loader
Development Tools
Management
Settings
User Management and Auditing
Help and Contacts
Documentation and Articles
My Profile
Snap4City portal
Km4City portal
- Hide Menu
Public transport
Municipalities
Text Search
Address Search
Events
Select an agency:
- Select an Agency -
Select a line:
- Select a Line -
Select a route:
- Select a Route -
Select a bus stop:
- Select a Stop -
Position of selected Busses
Actual Selection
Coord: 43.7130,10.9272
Address: VIA DI PRATOVECCHIO, 58, EMPOLI
Path from here
Path to here
Search geometry
Path
From: VIA DELLA PERGOLA, 39, FIRENZE
To: VIA DI PRATOVECCHIO, 58, EMPOLI
Route via: public_transport
Start date&time: today now
Search Path
3. Piazza della Santissima Annunziata 49m (14:40:13)
4. Via Cesare Battisti 148m (14:40:52)
5. Piazza San Marco 126m (14:42:47)
6. Via Camillo Cavour 1m (14:44:17)
7. 11 : Arazzieri - Volterrana 7800m (15:06:00)
8. 37 : Galluzzo Via Volterrana - Montespertoli (V. Risorgimento) Sn 26620m (18:52:00)
9. Viale Risorgimento 207m (19:45:00)
10. 32 : Montespertoli (V. Risorgimento) Sn - Viasanzio Fr.157 Sn 17534m (07:16:00)
11. 1 : Via Sanzio Fr.157 - Via Sanzio Fr. Coop Sn 1002m (08:08:00)
12. Via Raffaello Sanzio 45m (08:10:00)
13. nd 33m (08:10:35)
- Hide Menu
Regular Services
Transversal Services
Services Categories
De/Select All
Accommodation
Advertising
AgricultureAndLivestock
CivilAndEdilEngineering
CulturalActivity
EducationAndResearch
Emergency
Entertainment
Environment
FinancialService
GovernmentOffice
HealthCare
IndustryAndManufacturing
IoTDevice
MiningAndQuarrying
ShoppingAndService
TourismService
TransferServiceAndRenting
UtilitiesAndSupply
Wholesale
WineAndFood
Filter:
search text into service
Service providing value type:
select value type
N. results: 100
Search Range 100 mt
Search Area
select...
Firenze
Galluzzo
Cascine del Riccio
Multimodal routing
- Hide Menu
Leaflet | Map data © OpenStreetMap contributors, CC-BY-SA, Imagery © Mapbox

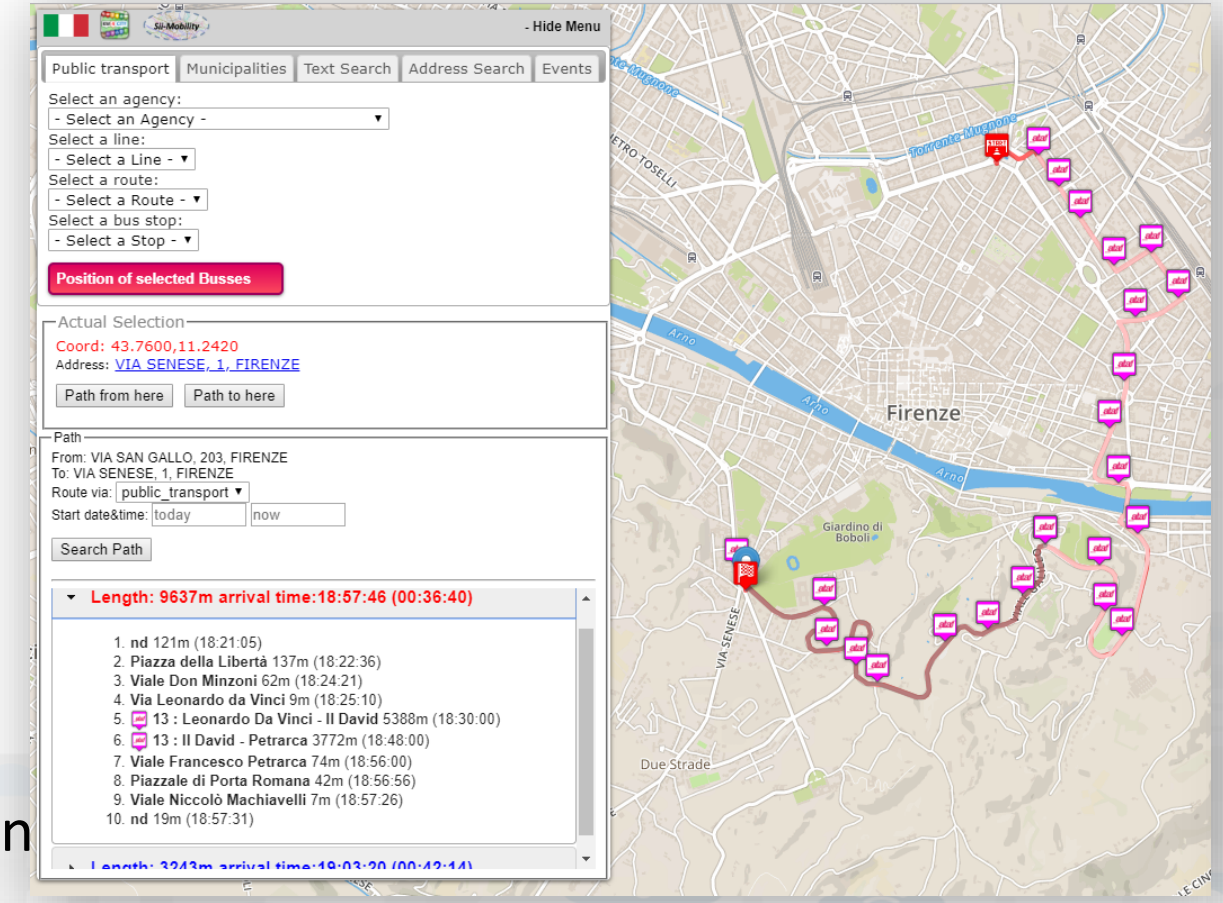
Routing and Multimodal Routing

Modes:

- Pedonal, Vehicles
- Public Multimodal
- Multi Point for Delivering
- Constrained: quite, blocked, etc.

Test it on our:

- Mobile Apps
- MicroApplication
- Dashboard
- ServiceMap service on Tuscany in Snap4City





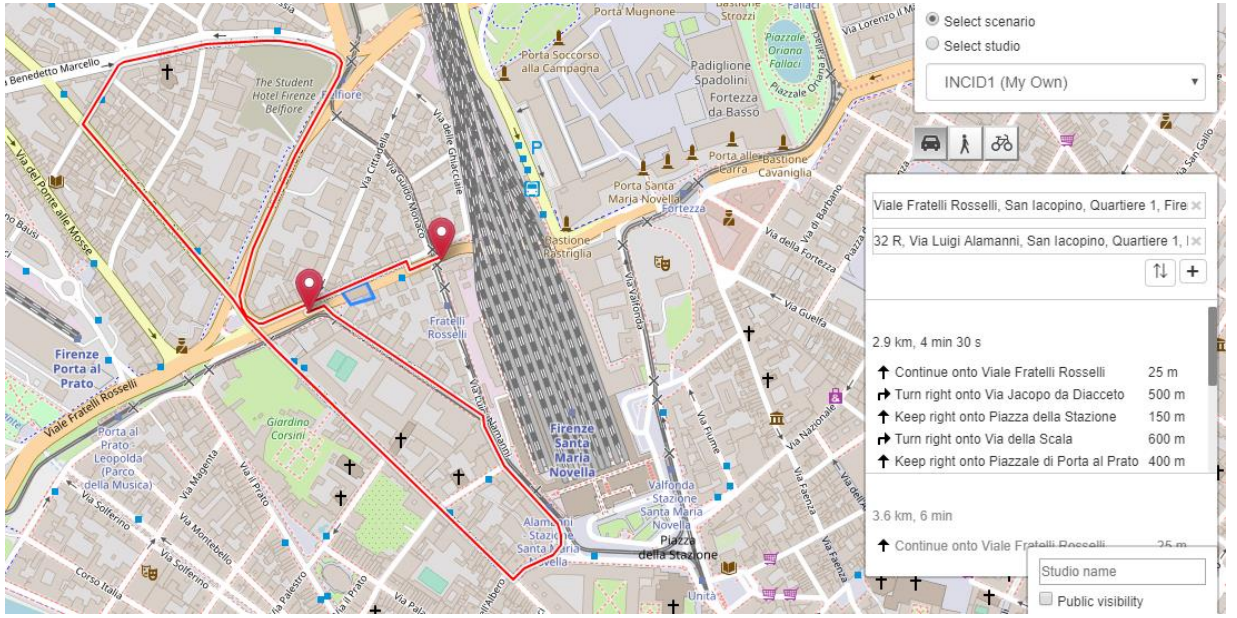
What-If Analysis

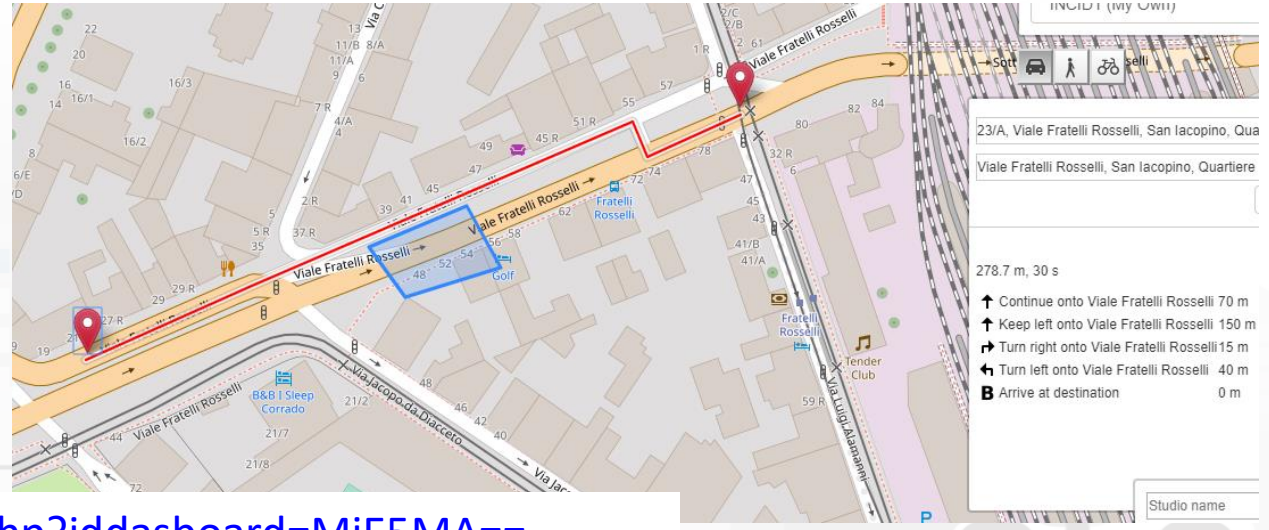
Accidents and elements blocking Points and Shapes taken into account for:

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

Assessment on the basis of changes:

- Mobility demand assessment
- Mobility Offer assessment

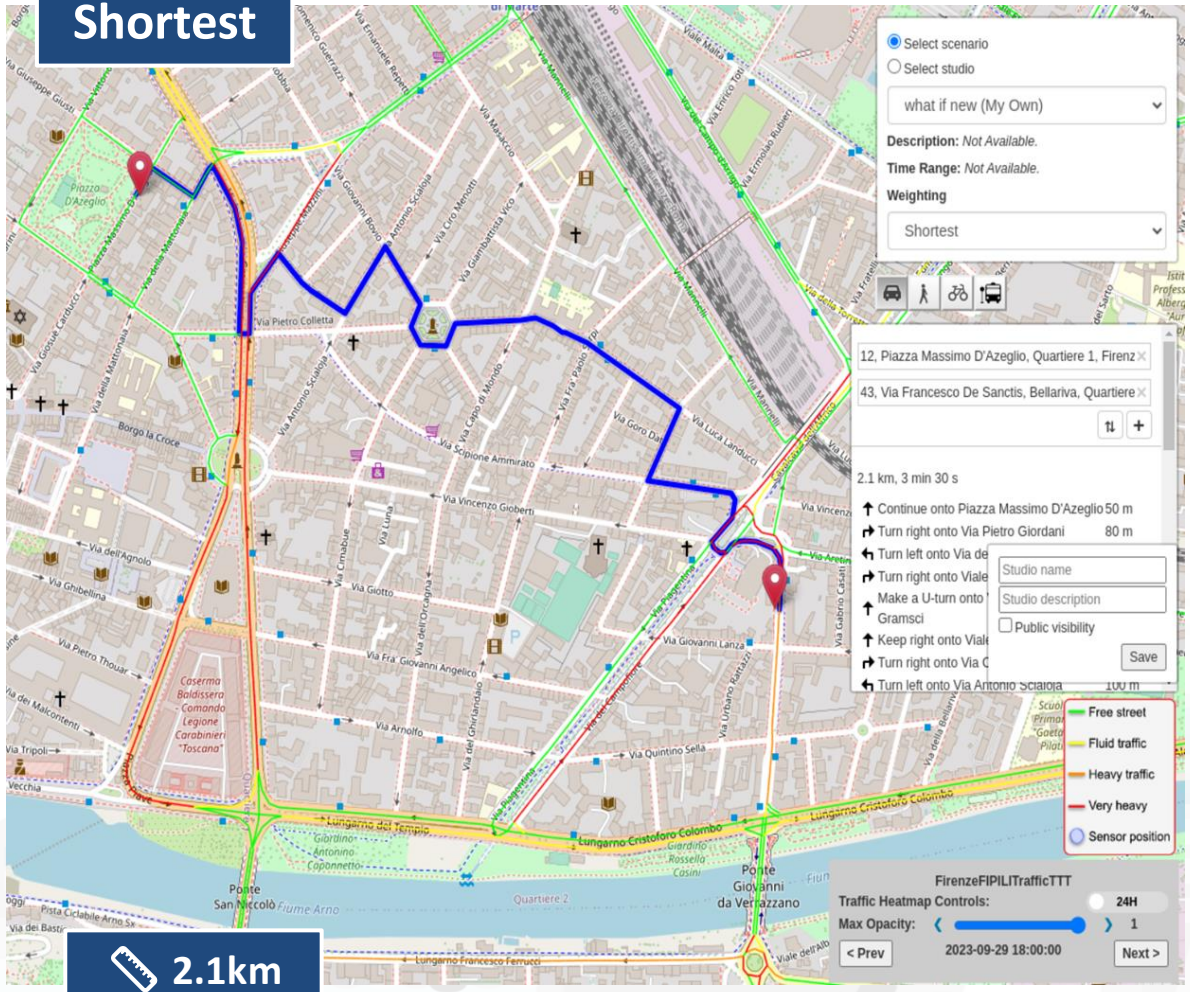




https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjE5MA==

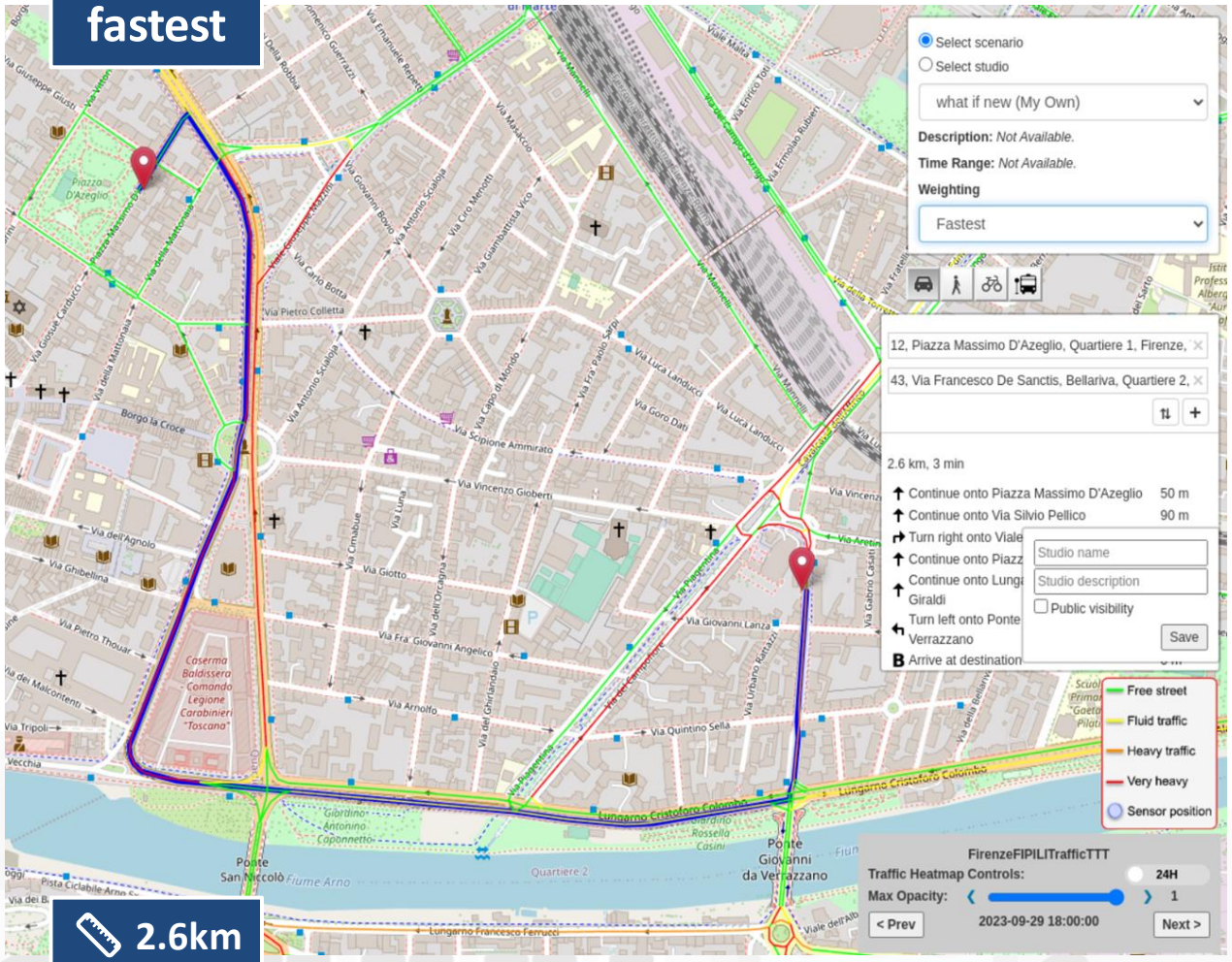
Constrained Dynamic Routing: Traffic Flow

Shortest



2.1km
3min 30s

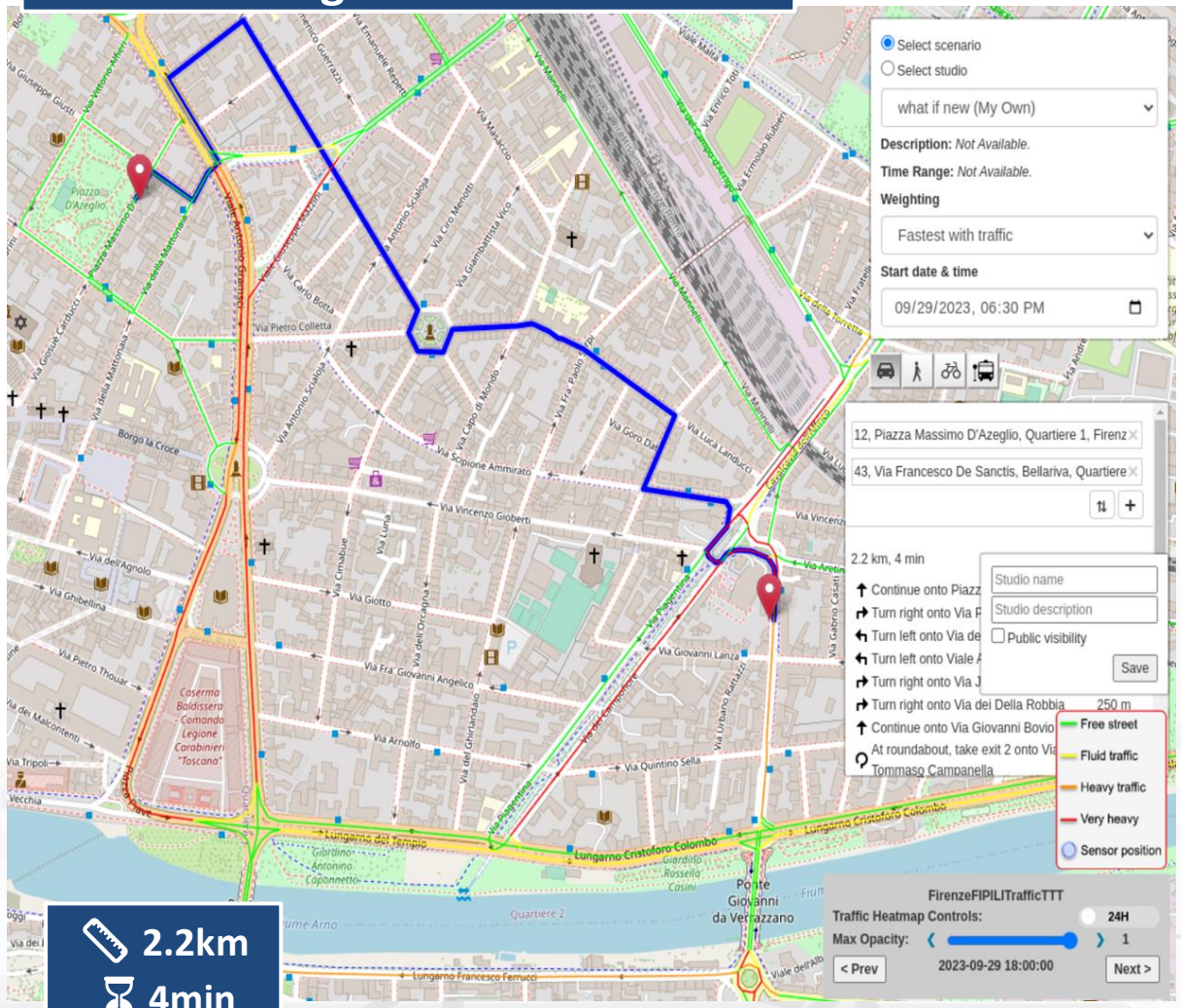
fastest



2.6km
3min

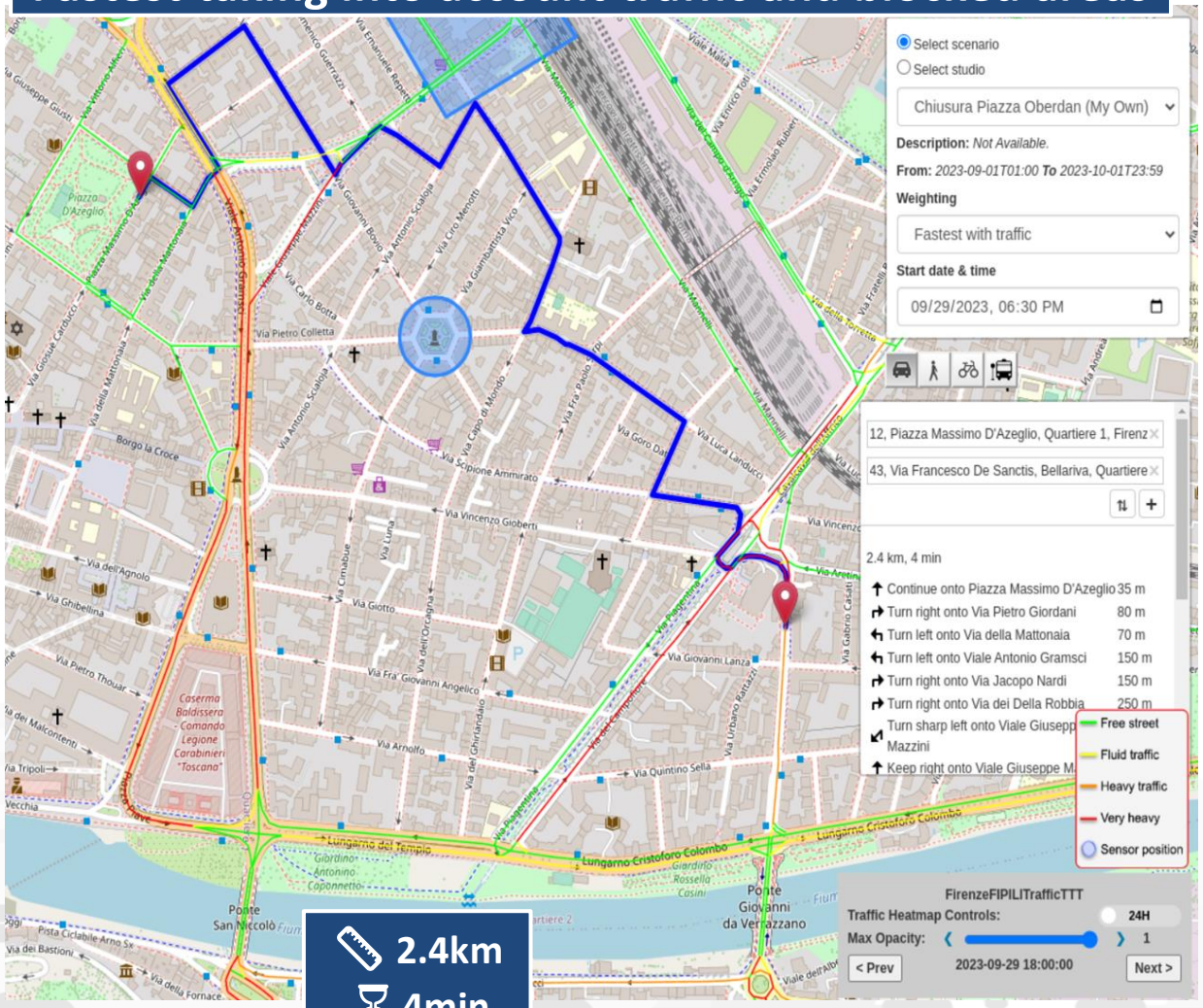
Constrained Dynamic Routing: Traffic Flow

Fastest taking into account traffic



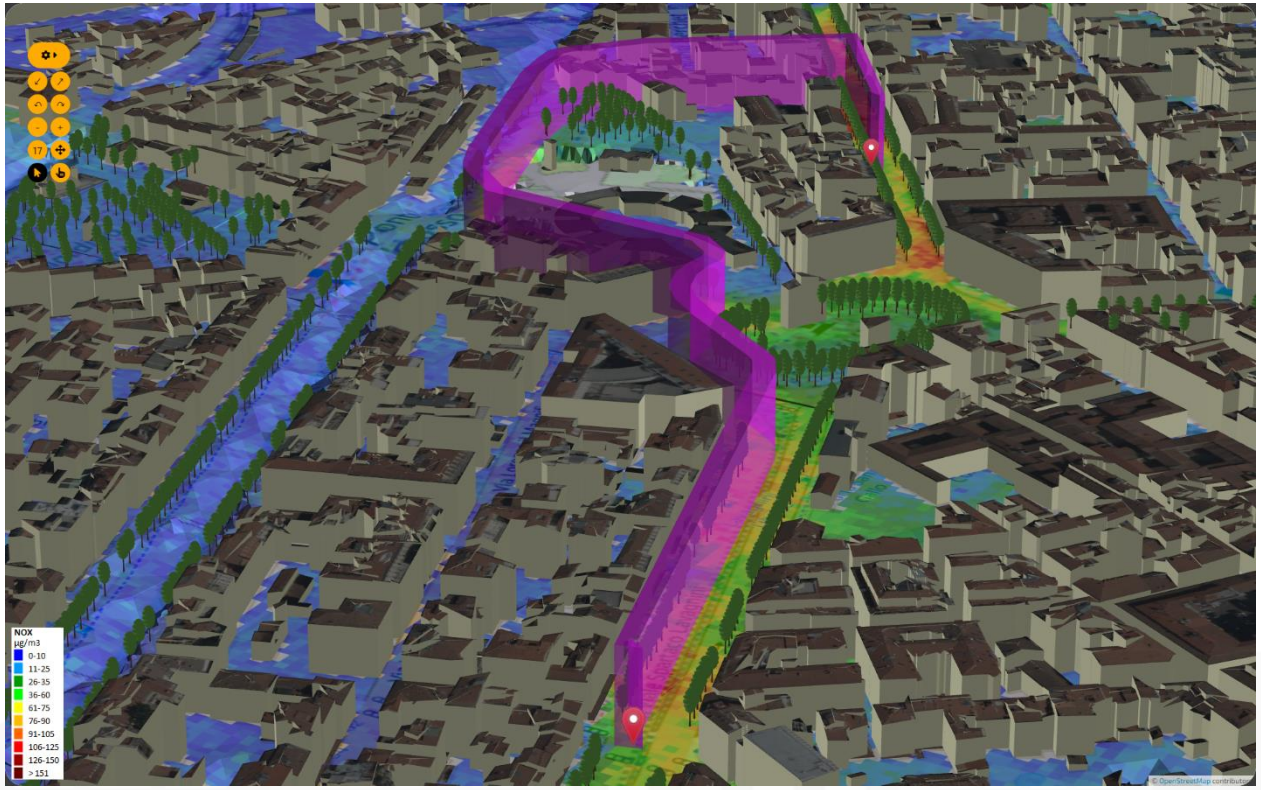
2.2km
4min

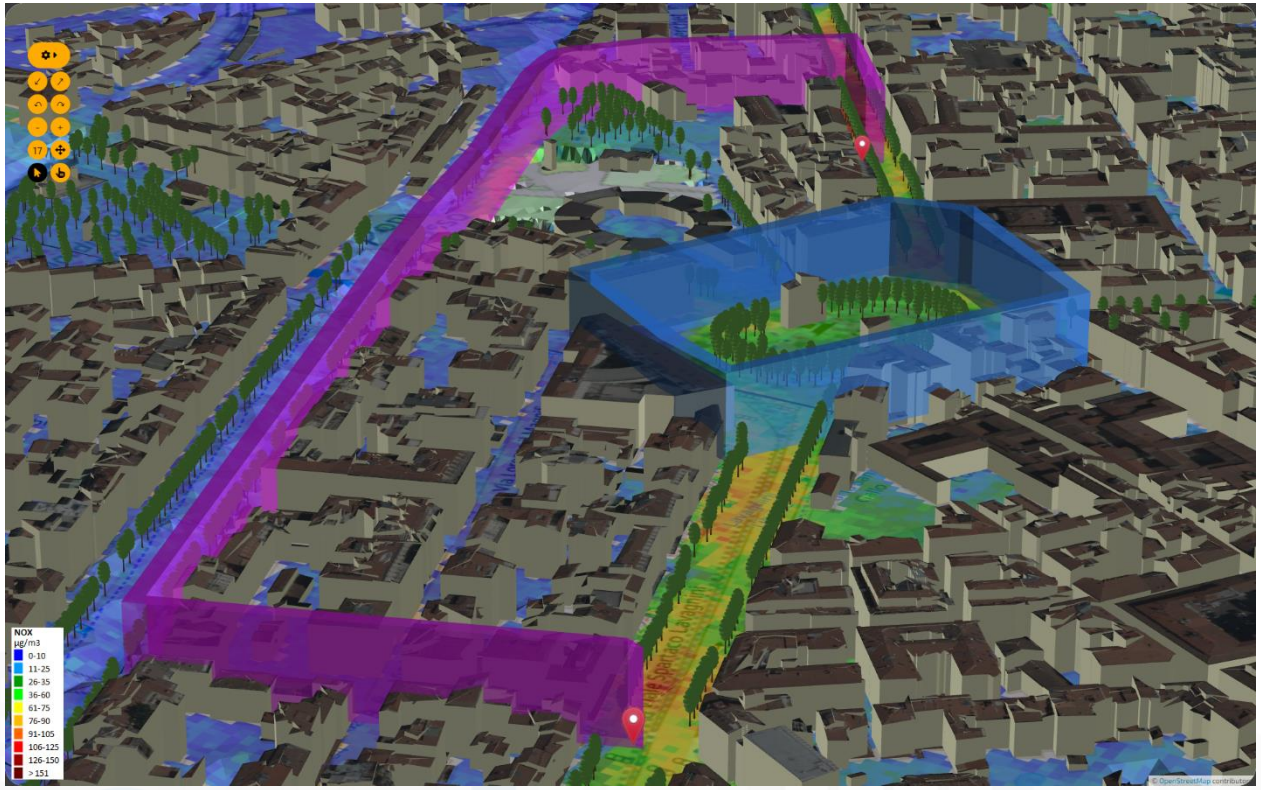
Fastest taking into account traffic and blocked areas



2.4km
4min

Dyamic Routing in 3D space





TOP

Predictive Maintenance

FROM CITY DASHBOARD TO APPLICATIONS

FORGING & MANAGING OPEN AND FLEXIBLE WEB AND MOBILE APPS

IOT APPLICATIONS VS IOT EDGE DEVICES

DATA GATHERING AND CITY DATA KNOWLEDGE MANAGEMENT

ADVANCED SMART CITY API, MICROSERVICES, SNAP4CITY API

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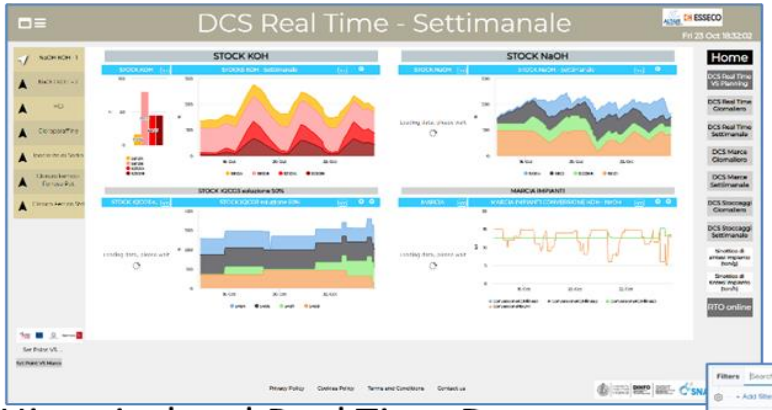
7 AFFORDABLE AND CLEAN ENERGY

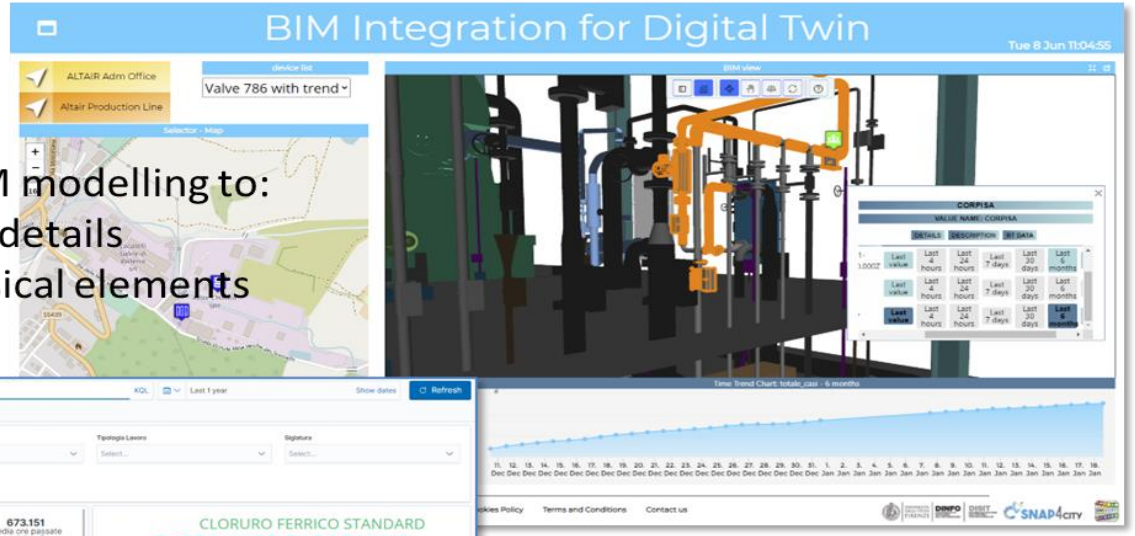
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Data Analytic

Predictive Maintenance

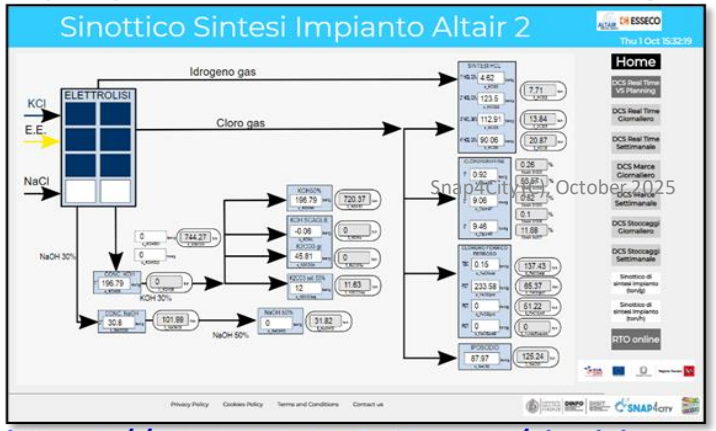


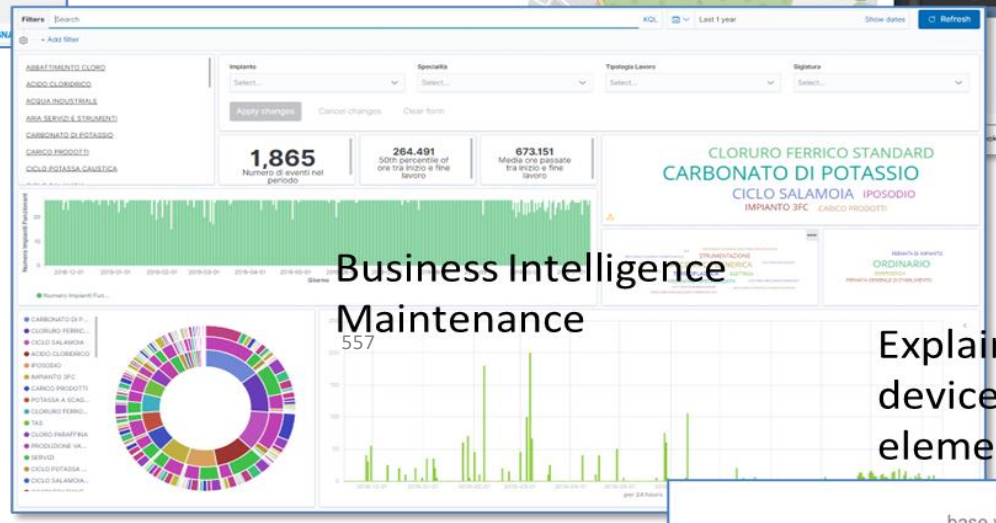
Historical and Real Time Data



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

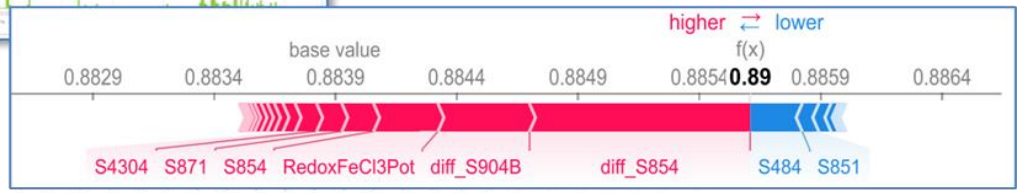
Synoptics for real time monitoring





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==

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

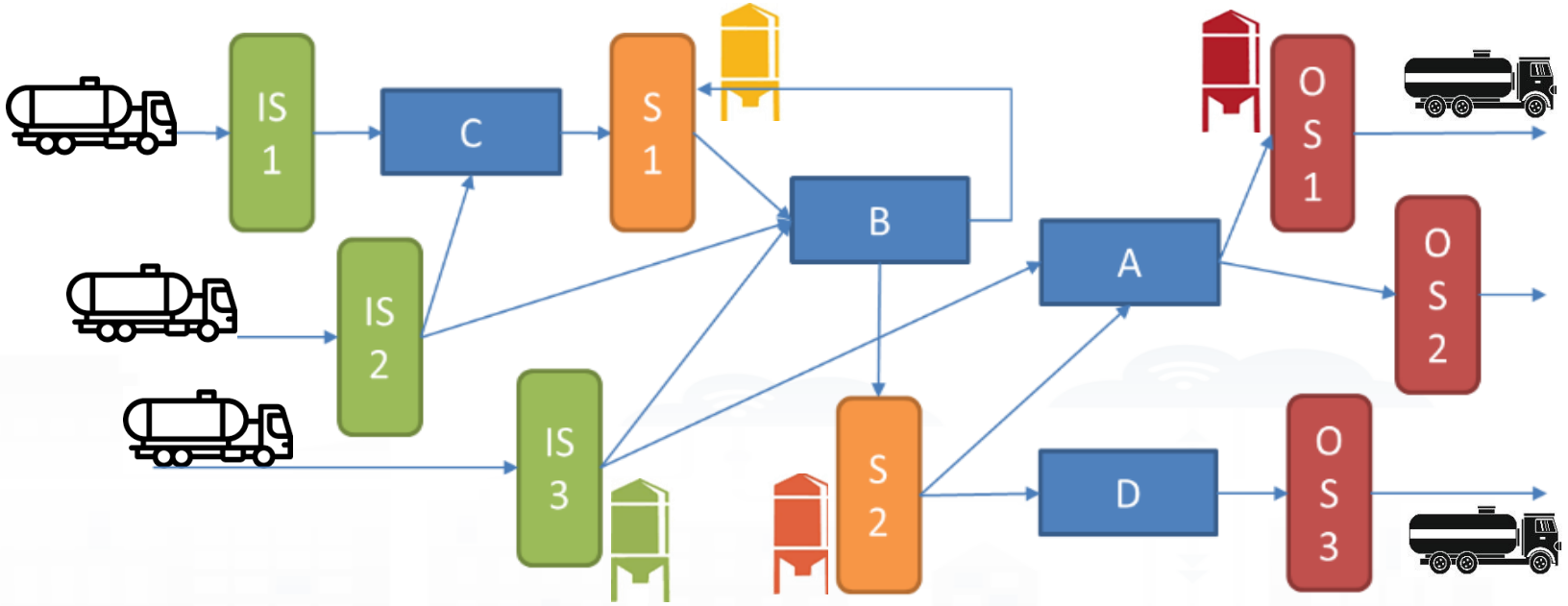
Industry 4.0

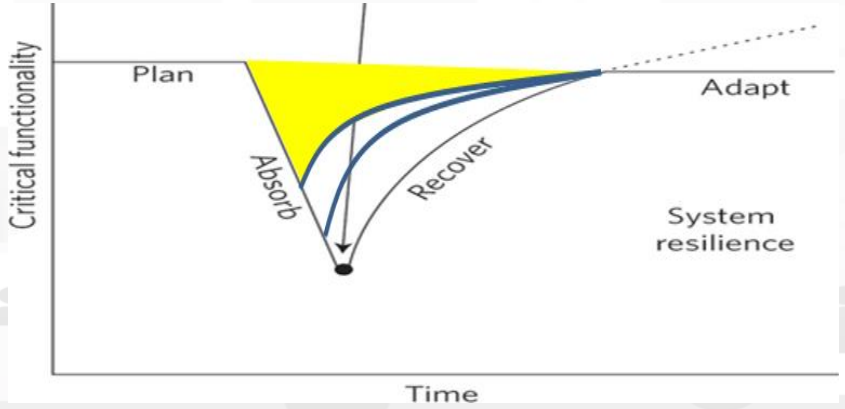
- **ALTAIR SODA-4.0 project**
  - maximize the efficiency and productivity of plants, reducing downtime
  - in order to improve competitiveness in the market

- **Goals and drivers:**
  - Business intelligence tools on maintenance data
  - predictive maintenance approach into the whole control and management systems Predictive models for engagement
  - predict plant failures 60 minutes before it happens
  - Provide indications on the area of failure via XAI

Complex cause-effect realtionships

- **Elements:**
  - Machines: A…C
  - Storage: silos…
  - Flows:…
- **Dependencies**
  - Cascade effects
- **Early warning**
  - Reduction of costs
  - Recovering from failure is more expensive than correcting in advance
  - Possible advanced replan and reschedule: secondary solutions





Workflow

Data acquisition
Production - Maintenance

Feature selection,
Feature engineering

CNN-LSTM Training

Validation AI
Model

Classification
Model

CNN-LSTM
Engine

F/NF

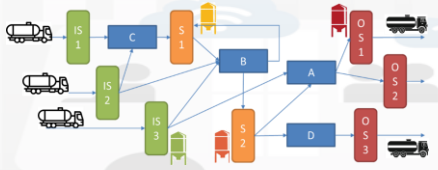
Explainable/XAI
(Shap)

{features (t)}

Business Intelligence for
Maintenance

integration of workflow management system for maintenance with general control systems and data flow

Structure of the plant



Decision making
on more cases

KPI

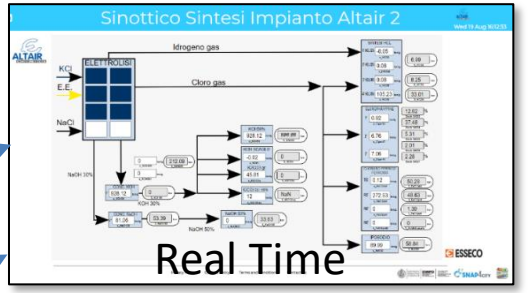
CNN: Convolutionary NN
LSTM: Long Short-Term Memory
(deep learning model)

Solution

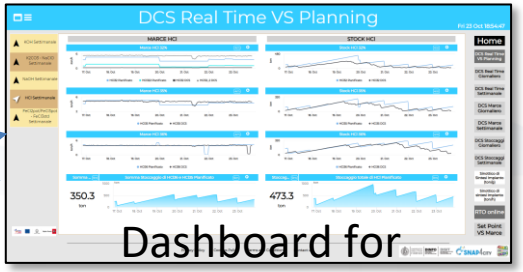


Plant Status



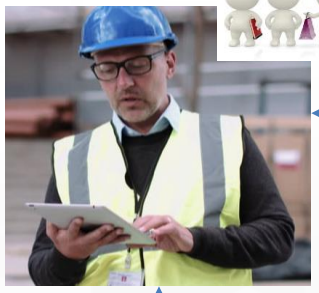


Real Time Production Synoptic



Dashboard for Production Control

Control Supervisor

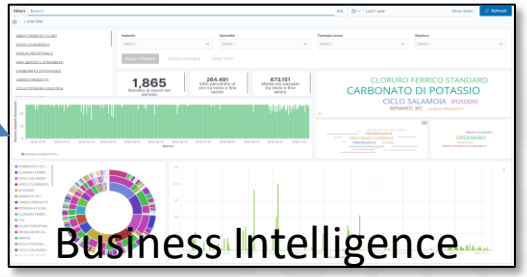


Business Logic

IoT App

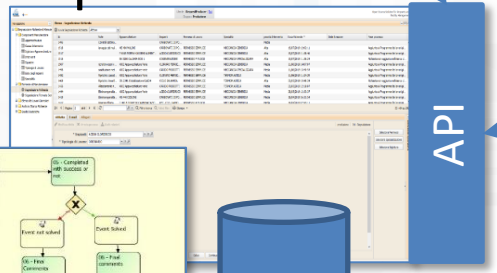
Data Storage

Elastic Search

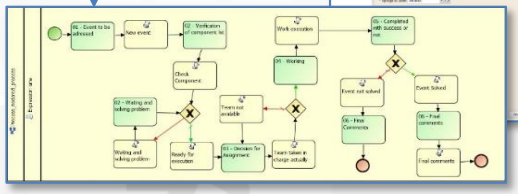


Business Intelligence Maintenance

OpenMaint



API



IoT App

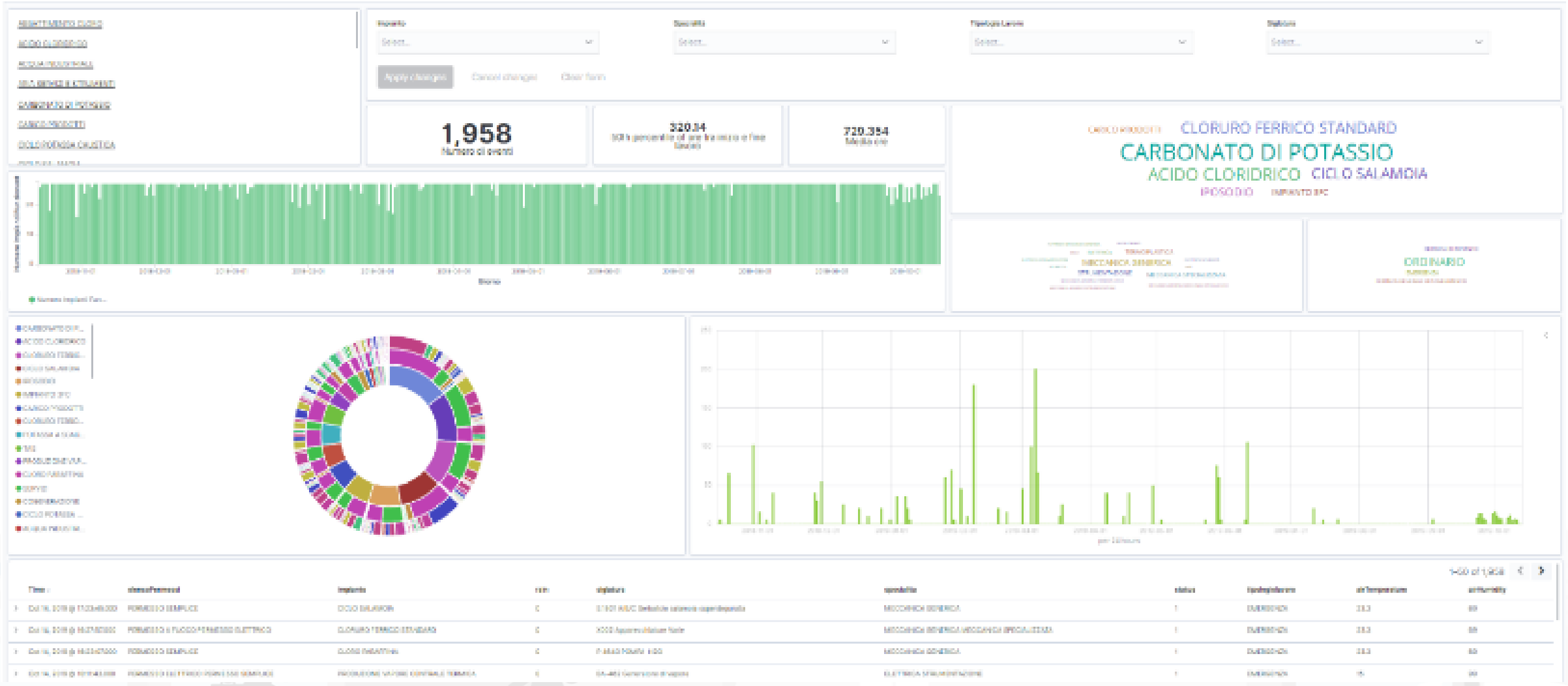
IoT App

Business Logic 2

Predictive Maintenance

Predictive Training

Business Intelligence



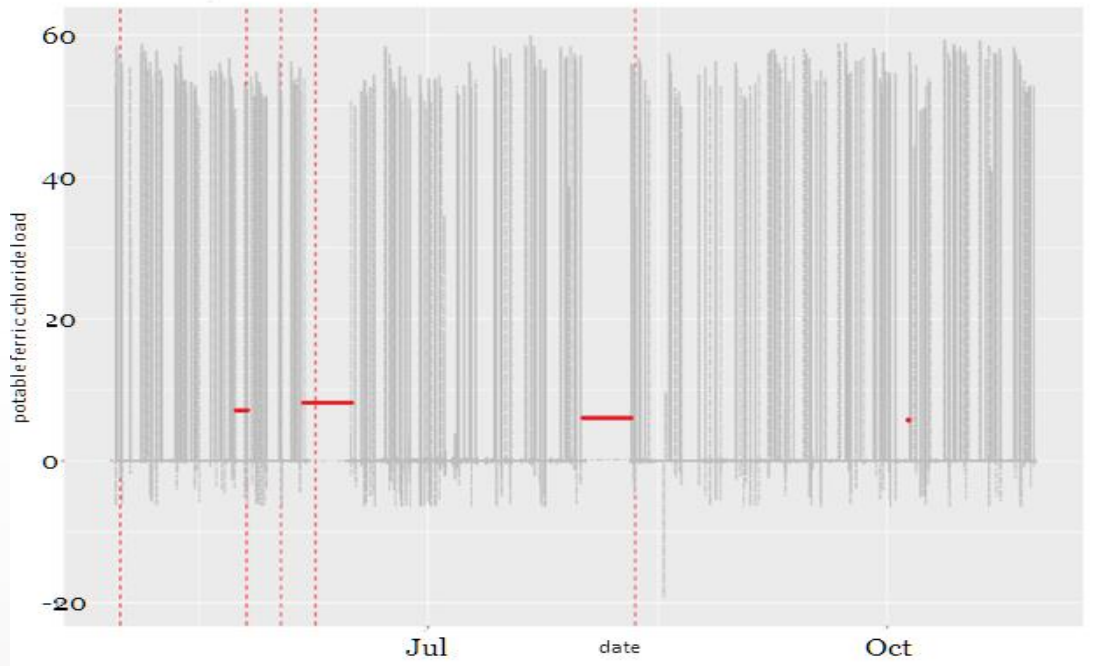
Production:

- 1-minute observation from 2020-04-28 to 2021-01-04
- 343.183 observations for 147 features/variables
- production, storage, status, several temperatures of elements, gear plants, process/safety parameters, chemicals compounds produced

Fault:

- List all the details: event datetime, Permission List, Plant, Signature, Specialty, Status, Job Type, Air Temperature, air humidity and rain
- Ticket and stop classification as "GENERAL PLANT STOP", "ORDINARY", "PLANT STOP" and "EMERGENCY "

Example of a failure



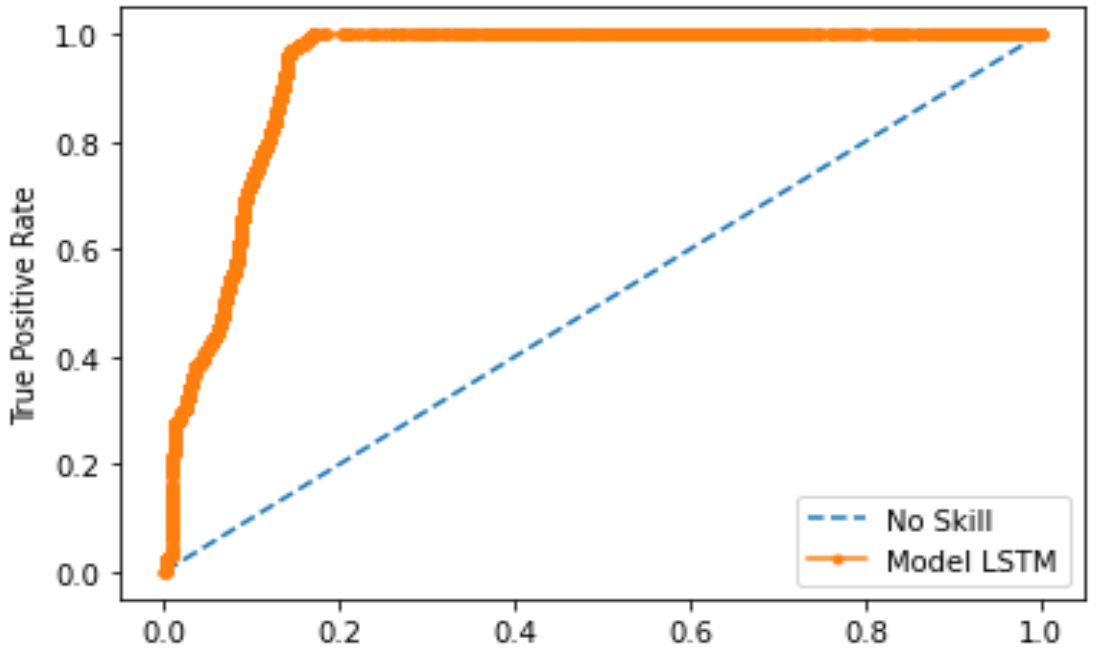
Overview Features

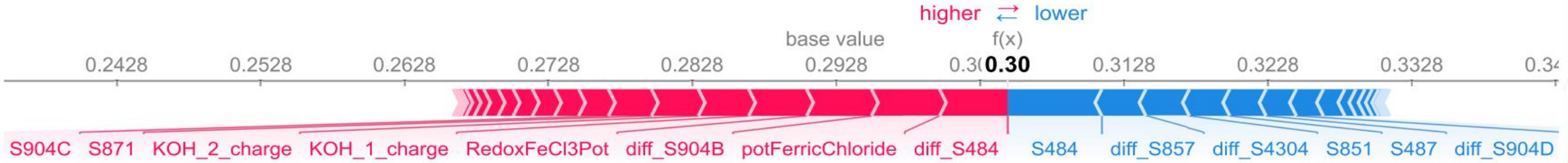
Feature	Plant	Description	Unit of measure
TempreactoreR4001 - TempreactoreR4002 - TempreactorR4003	chlorine paraffins (CPS)	reactor temperature indication	°C
S904A - S904B - S904C	Potable Ferric std	Storage level indication	%
S4304	chlorine paraffins (CPS)	Storage level indication	%
standardFerric Chloride	Potable Ferric std	flow rate measurement and totalization	m3
potFerricChloride	Potable Ferric Chloride	flow rate measurement and totalization	m3
S904E - S904D	Potable Ferric Chloride	Storage level indication	%
QuantNaOHperBatchNaClO - QuantNaOHBatchNaClO_2	NaOH KOH	flow rate measure and totalization	lt – m3
ConversionNaOH - ConversionKOHlinea1	NaOH KOH	electrolysis load adjustment (production)	kA
KOH_1_charge - KOH_2_charge	NaOH KOH	flow rate measure and totalization	m3
S487 - S484 - S5104	NaOH KOH	Storage level indication	%
hypo sodium	sodium hypochlorite	quantity of material produced	m3
S851 - S852 - S854 - S856 - S857	sodium hypochlorite	Storage level indication	%
S871	HCl	Storage level indication	%
RedoxFeCl3Pot	Ferric Chloride std	potential measure redox Ferric Chloride	mV

Preditive capabilities

- Deep Learning: LSTM, CNN-LSTM approached
- Explainable AI: Identification of possible causes of fault

	Precision %	Recall %	F_1 score %
weighted avg	0.90	0.92	0.90



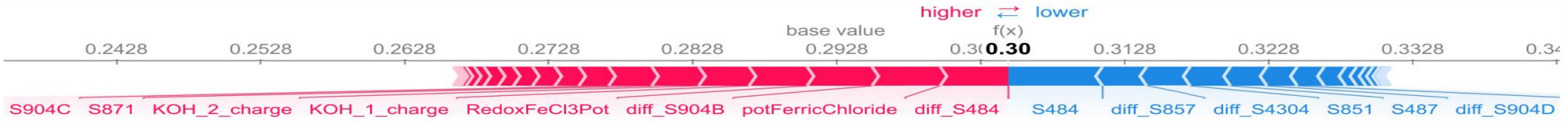


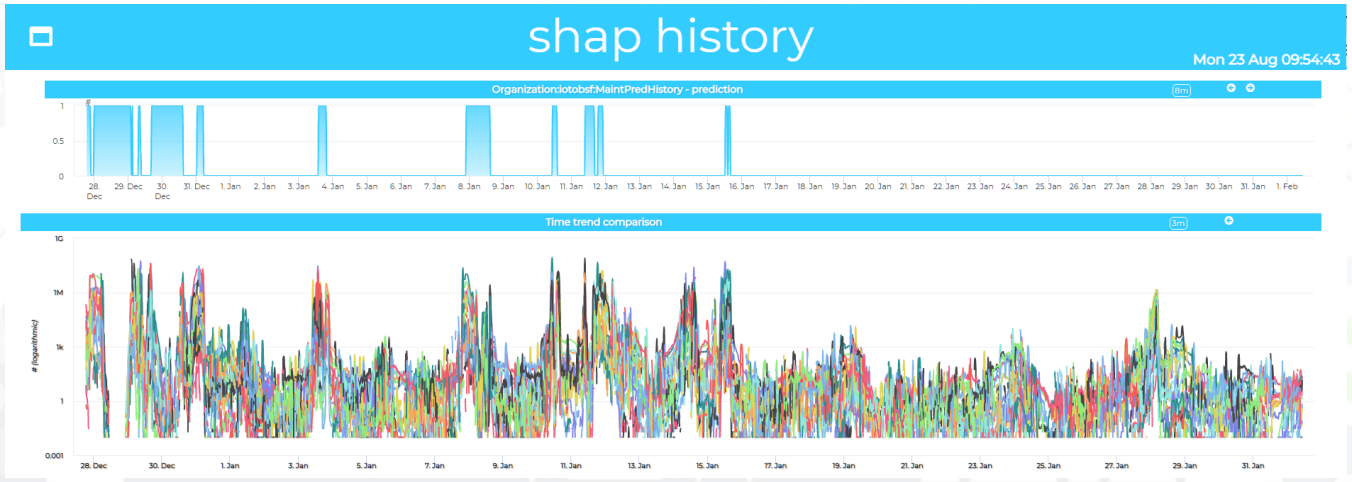
Explainable/XAI - CNN-LSTM (SHAP)

Explanation of prediction generated by model for fault

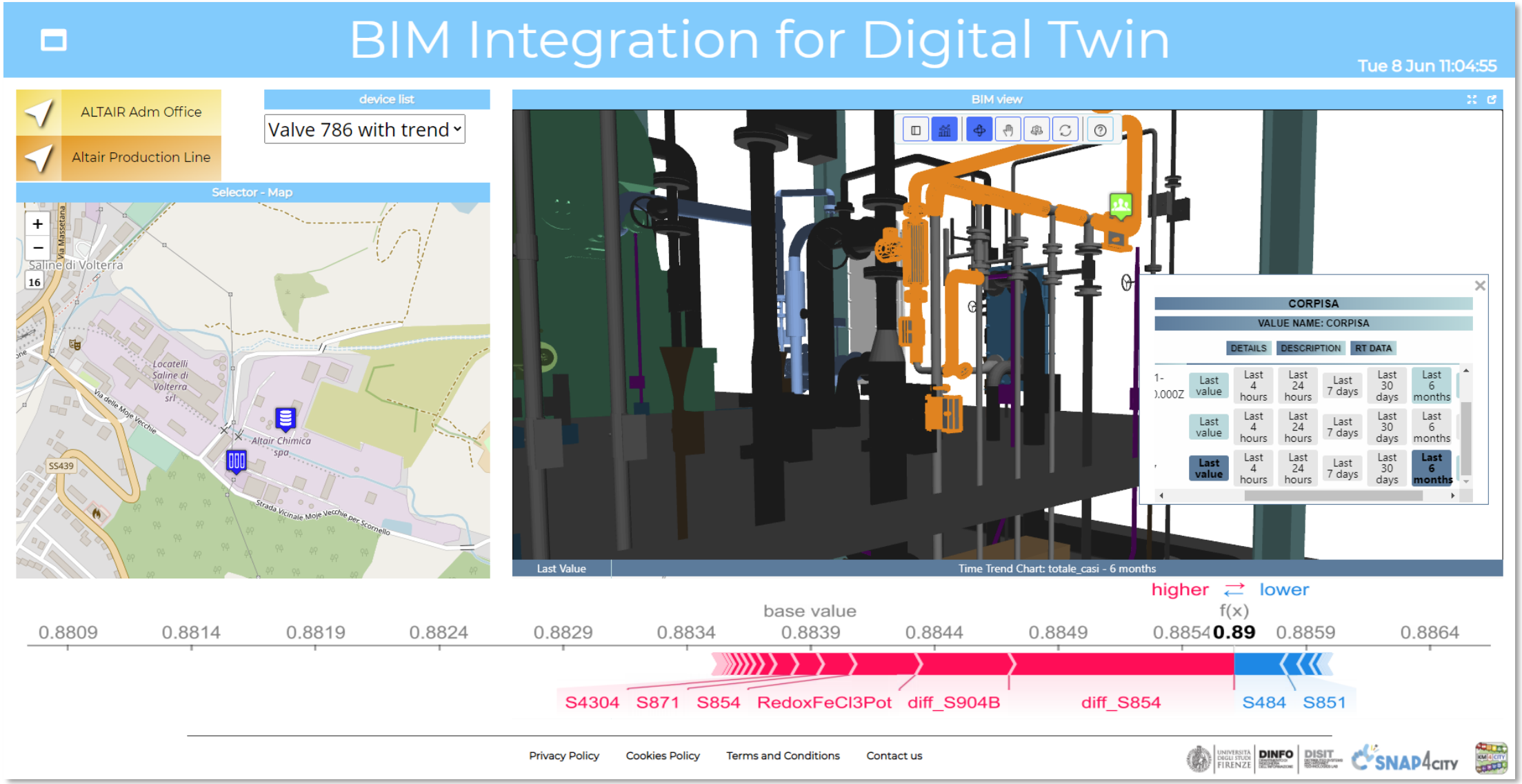


Explanation of prediction generated by model for normality





Digital Twin Local, 3D vs Real Time Data



Considerations

- results shown an average Accuracy of 91.8% and an average F1-score of 90%, which are very satisfactory results
- Explanation of the predictions provides suggestions for the maintenance teams in terms of areas of intervention.
- Large renovation of the production infrastructure.

EN.TE.R.PR.I.S.E.

(**EN**hanced **TE**chnological **R**&D of new **PR**oducts and Processes for **I**nnovation, **S**mart factory and green **E**conomy)

ALTAIR CHIMICA

Administrative Data from AS400

Real Time Data, Historical, Events from DCS

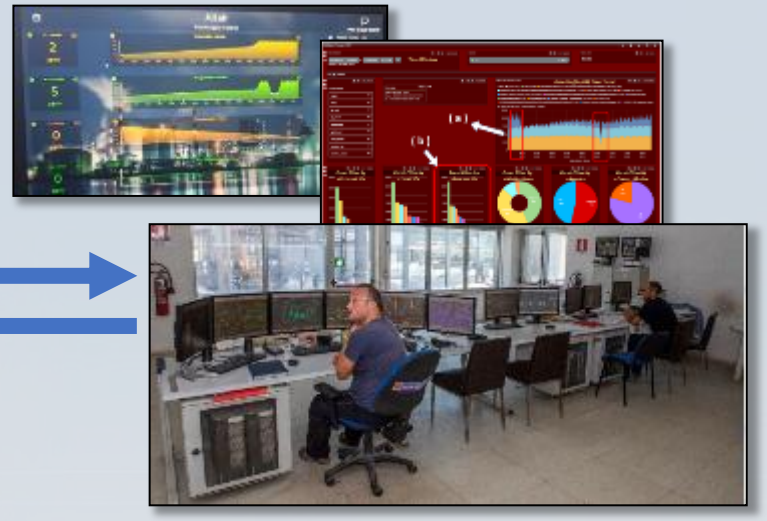
OPC UA

Unique National Energy Costs (PUN)

Big Data Analytics Artificial Intelligence Engine

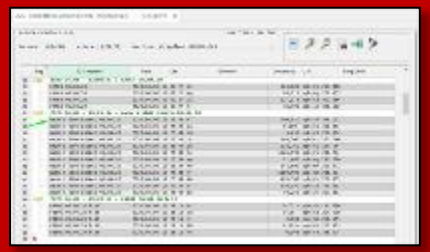
SNAP4INDUSTRY





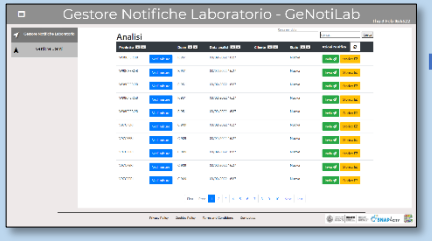
Analytical Data from the product quality Lab (LIMS/SAM)





SNAP4

GeNotiLab





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GeNotiLab Architecture for ALTAIR

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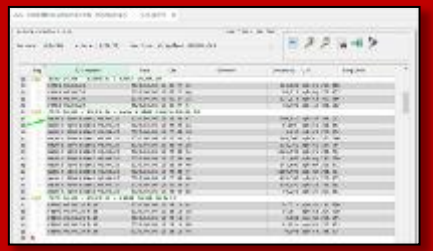


AS400

IOT App



Users

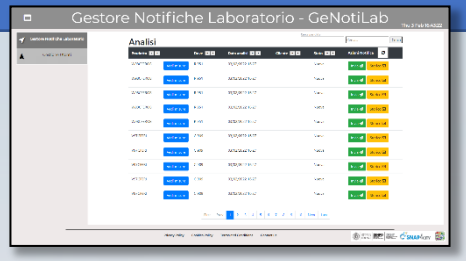
Analysis

Notifications



IOT App Analytics

Dashboards



IOT App Management



Tools:
-- List of Chemical Analyses
-- List of Notifications
-- Define notifications
-- Program, send notifications
-- see notification status



IOT App Vs Telegram

Telegram Bot



TOP

Industrial Applications

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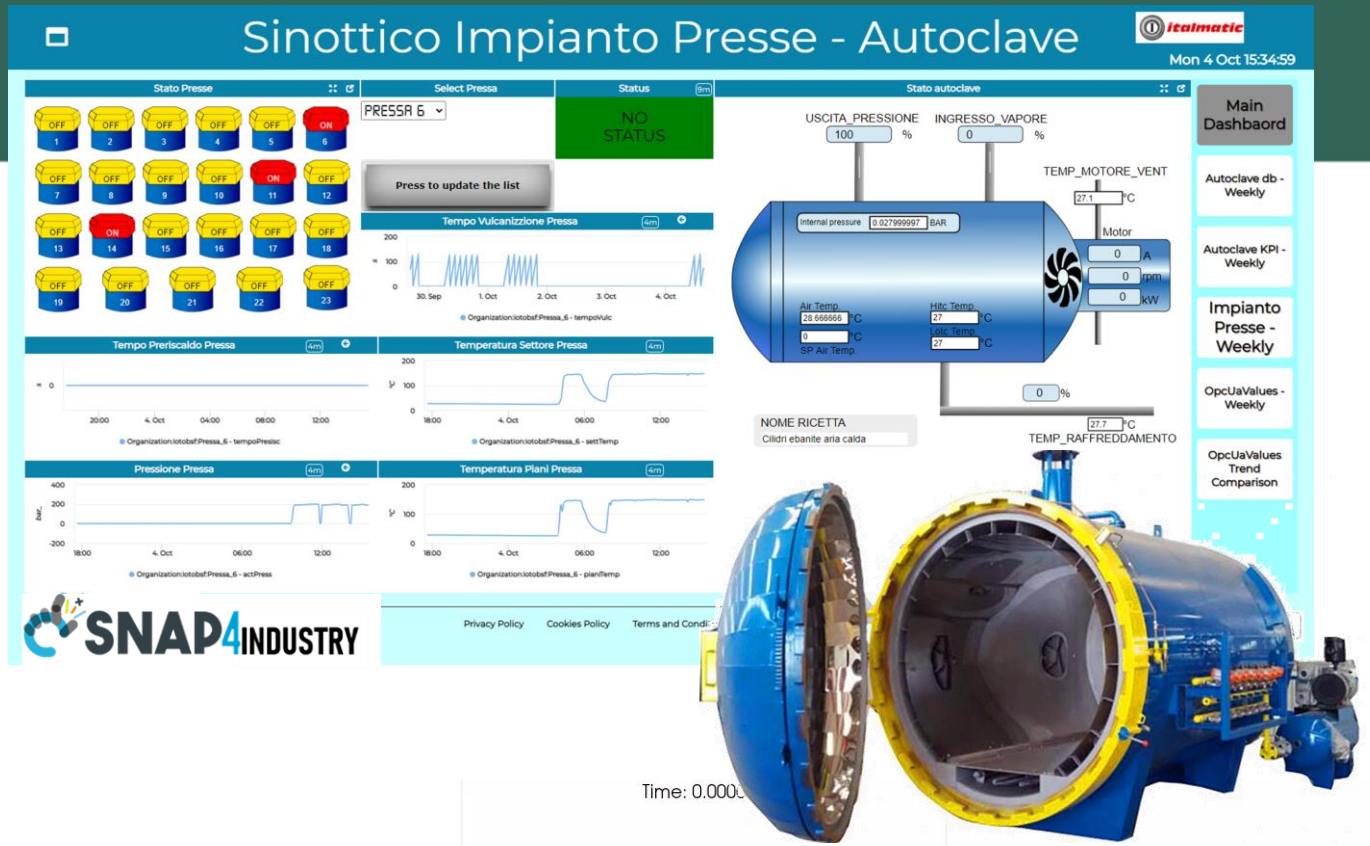
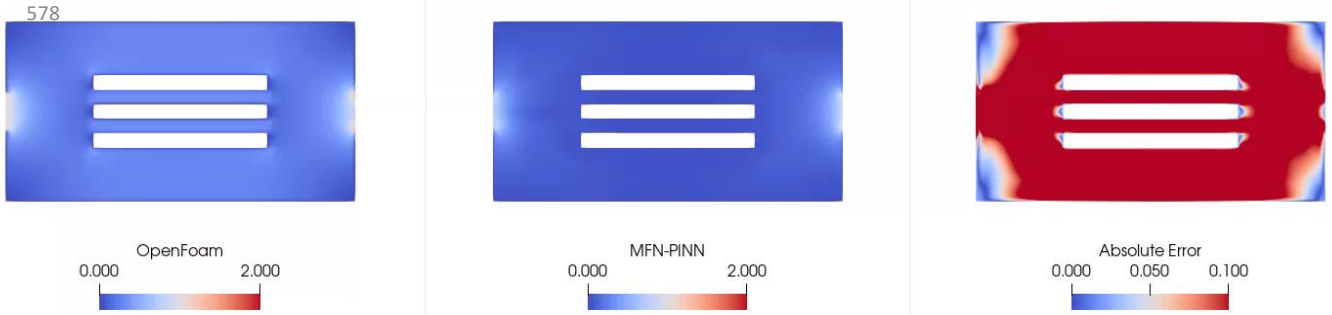
Data Analytic

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





TUSCANY X.0

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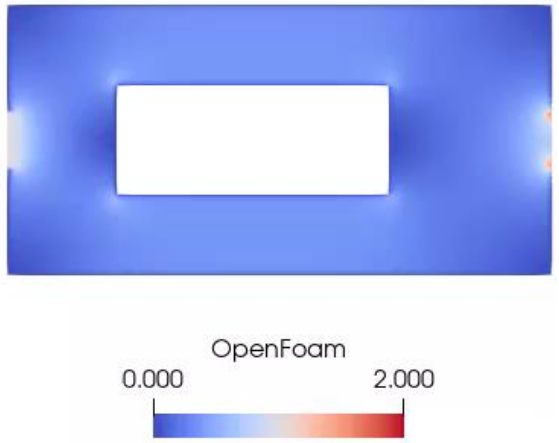
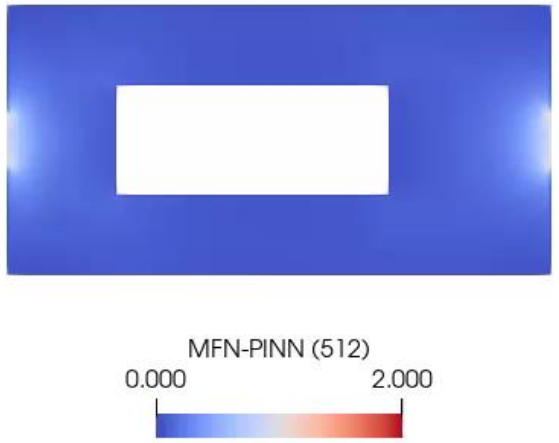
PINN: Physically Informed Neural Neworks Models

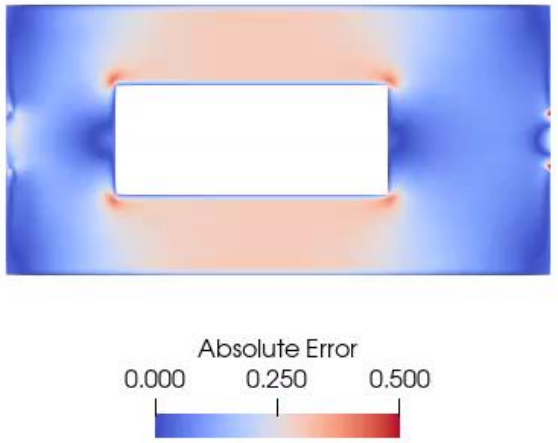
- **Solving Navier-Stokes PDE** (partial differential equations) equation, **via PINN** approach
  - Reduction of computing costs for simulating load effect into the autoclaves curing process
  - Validation wrt Open Foam
  - Precision on steady and transitory cases
  - Definition of Transfer Learning techniques
- Videos on https://www.snap4city.org/1010

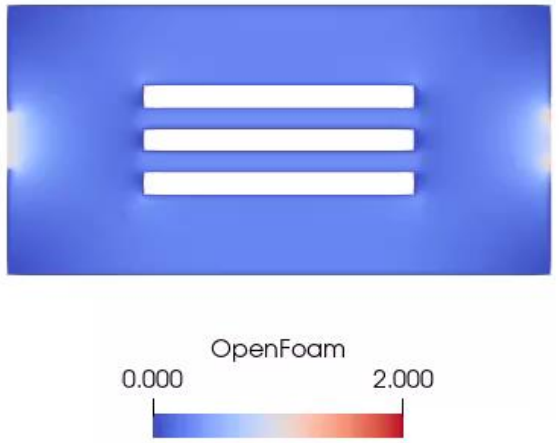


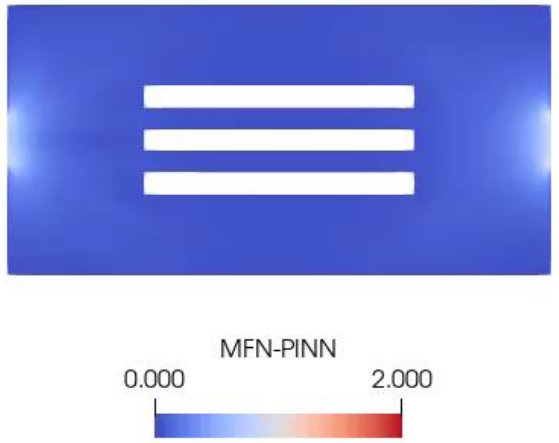
Comparison of PINN vs OpenFoam and error

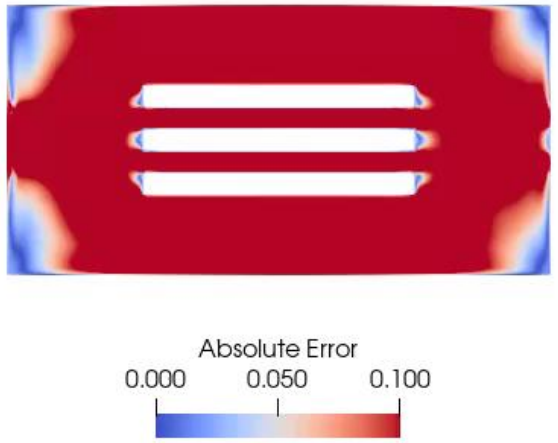








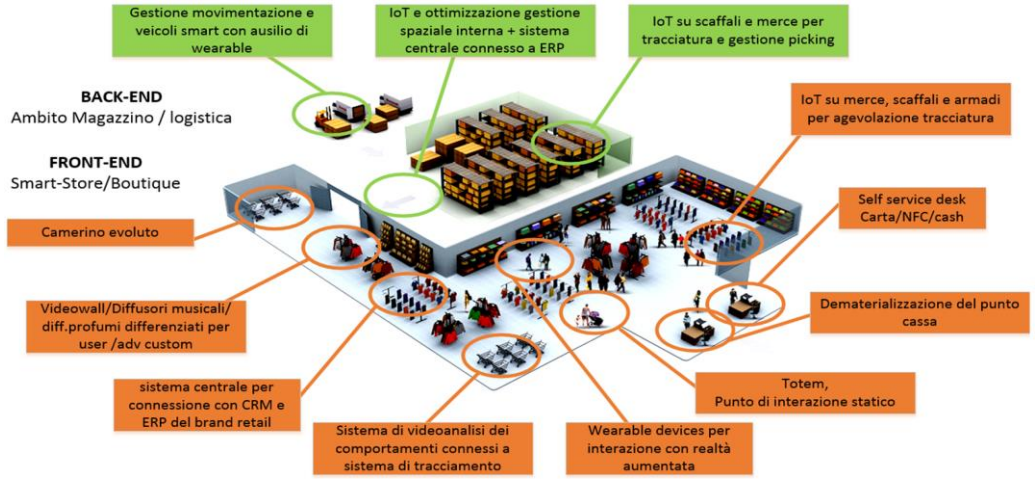


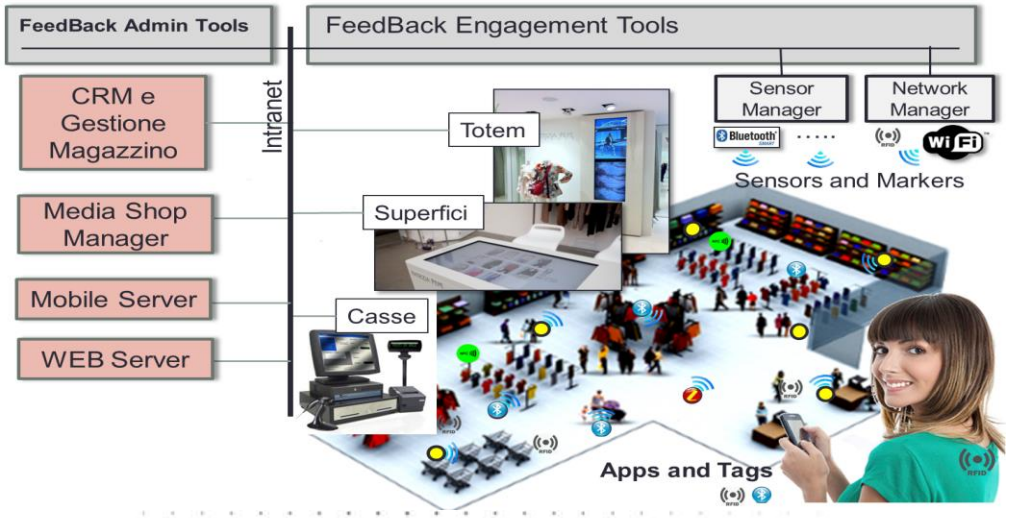


Smart Retail

feedback

- **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





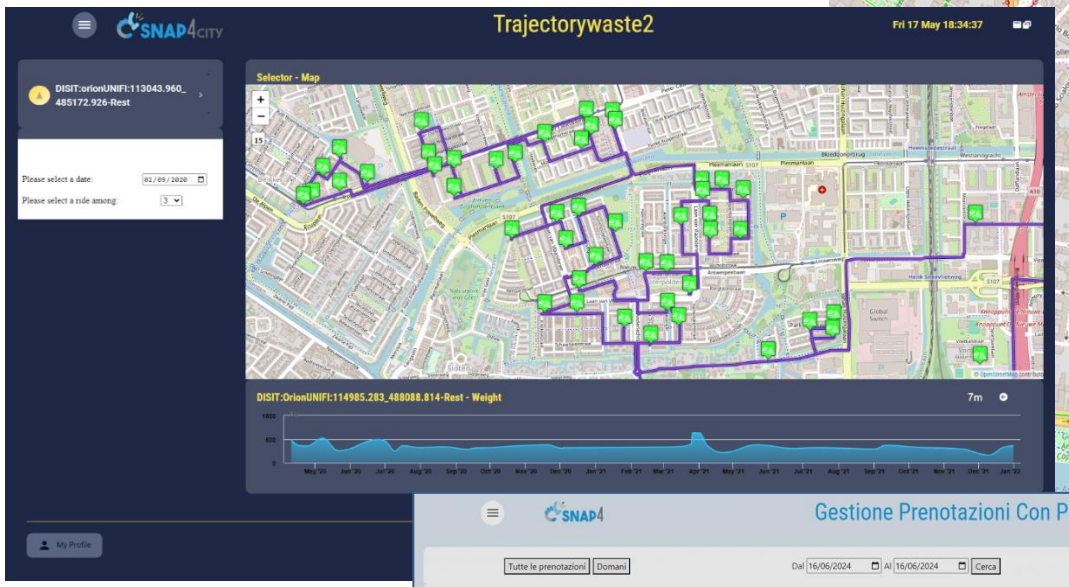
TUSCANY X.0 EDIH European Digital Innovation Hubs Network Finanziato dall'Unione europea NextGenerationEU

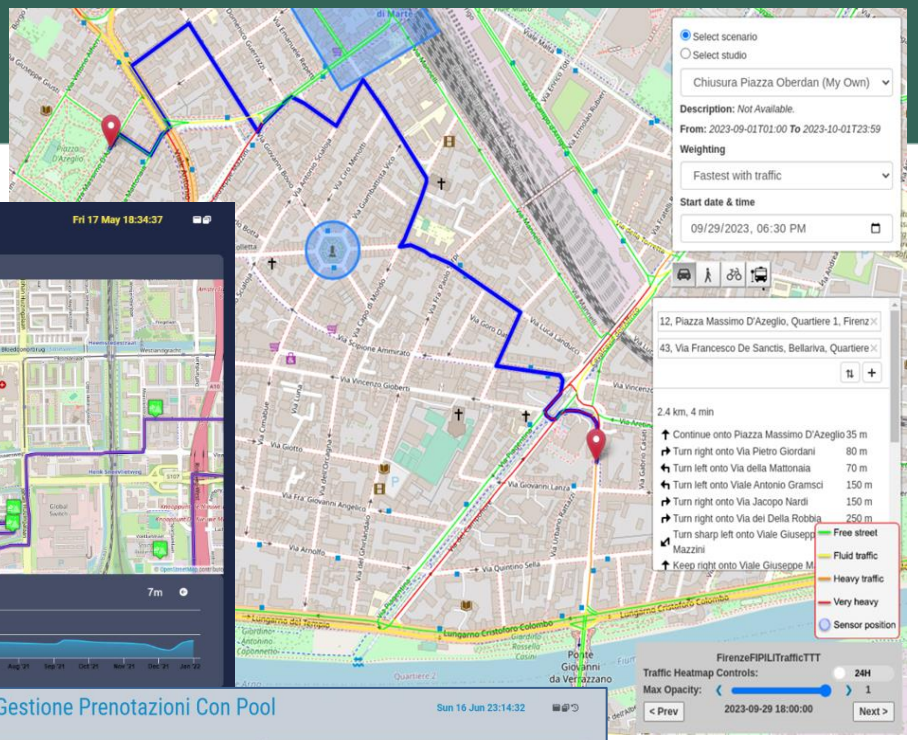
UNIVERSITÀ DEGLI STUDI FIRENZE DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB

Routing Optimization

Goals on planning:

- Reduction **of costs on plan**
- **waste collection** optimization, Reduction of Km
- **car pooling trajectories** optimization for maximize the pool usage
- **delivering optimization**, reduction of travel time, reduction of Km
- etc.







Dynamic Routing on operation:

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

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EDIH European Digital Innovation Hubs Network
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DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB

Virtual Assistants, Answering systems

Aim, Cost reduction in managing

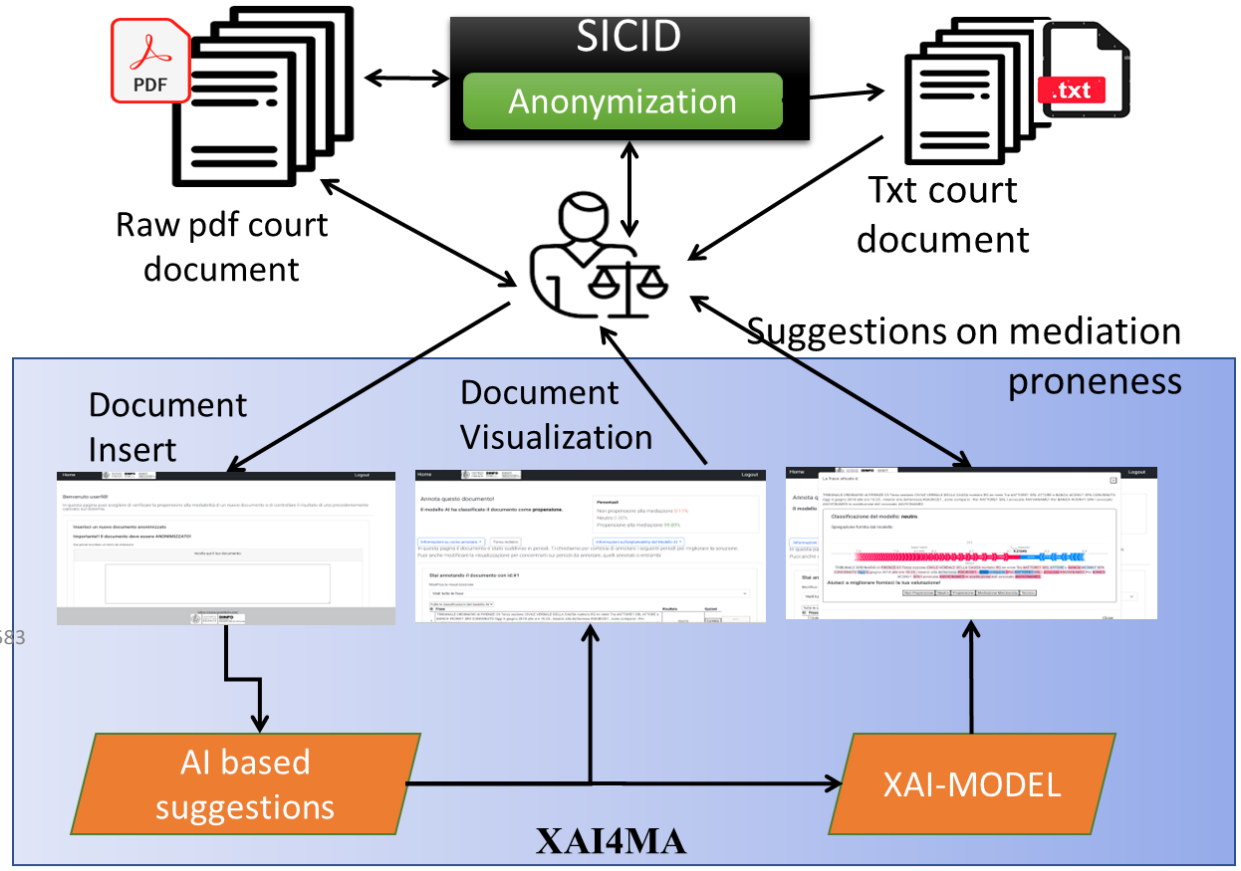
- Large volume of text, short time
- Getting fast non bias answers

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**





What you can find in the former course

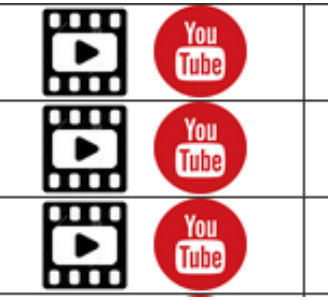
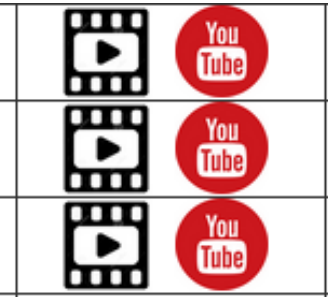
In addition in the former course you can find:

- Detecting and Counting People
- Recommendations for retail
- Predictive Maintenance
- Time Series Analysis and Characterization
- GeoTIFF management vs Heatmaps
- Heatmap modeling and generation
- User Engagement
- Decision Support Systems, SmartDS, System Thinking
- Decision Support System, FRAM
- Social Media Analysis: Twitter data (prediction, early warning, reputation)
- Impact of COVID-19

https://www.snap4city.org/577

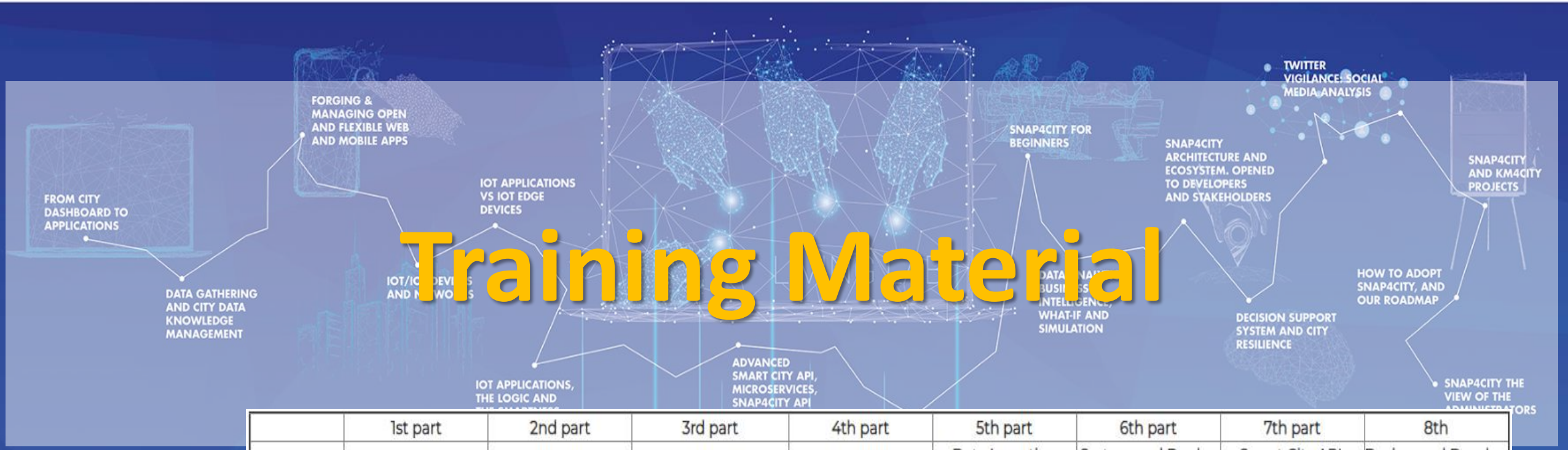
https://www.snap4city.org/944

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
							
							
							

SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT

SNAP4INDUSTRY



Training Material

	1st part	2nd part	3rd part	4th part	5th part	6th part	7th part	8th
what	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
PDF 2022								
Interactive (2022) with video and animations								


SNAP4CITY
www.snap4solutions.org
www.snap4city.org
HIGH LEVEL TYPES
SMART CITY LIVING LAB
SPAIN
SMARTCITY
EXPO WORLD CONGRESS
15 - 17 NOV 2022
BARCELONA & ONLINE
Visit our stand:
Pavillon 2, stand B86
CAPELON
3D MAP GLOBAL DIGITAL TWIN
Ciao
Wed 16 Nov 17:03:10
3D MAP
VEHICLEFLOW - 7 DAYS
Play (k)

Note on Training Material

- **Course 2023**: https://www.snap4city.org/944
  - Introductionary course to Snap4City technology
- **Course** https://www.snap4city.org/577
  - Full training course with much more details on mechanisms and a wider set of cases/solutions of the Snap4City Technology
- **Documentation** includes a deeper round of details
  - Snap4City Platform Overview:
    - https://www.snap4city.org/drupal/sites/default/files/files/Snap4City-PlatformOverview.pdf
  - Development Life Cycle:
    - https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
  - Client Side Business Logic:
    - https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- **On line cases and documentation**:
  - https://www.snap4city.org/108
  - https://www.snap4city.org/78
  - https://www.snap4city.org/426

Welcome: how to start using Snap4City for beginners

We suggest you:

Congratulations! You have really contributed to Snap4City and successfully passed all first levels!

You have reached a level in which you can contribute with competence to the city improvement and smartness. We hope you interested in helping other users in conquering higher levels on the city smartness ranking, and provising of smart services to all city users!
So that we could be interested in engaging and elevating your role in the Snap4City community as coordinator of thematic groups, for example on **Mobile APP development**, **Dashboard** on Mobility, **IOT Application** Development, etc., according to your preferences.

Please contact **paonesi@gmail.com** !

Share / Save ...

Add to your favorites



- TECHNICAL OVERVIEW: https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- Development Life Cycle: https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
- Client-Side Business Logic Widget Manual: https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- Booklet Data Analytics, Snap4Solutions: https://www.snap4city.org/download/video/DPL_SNAP4SOLU.pdf

Please start a fully guided training cases:

- HOW TO: create a Dashboard in Snap4City
- HOW TO: add a device to the Snap4City Platform
- HOW TO: add data sources to the Snap4City Platform



Organization Groups

DISIT

- Developer
- Operativo

Updates on Tools

Training Course Snap4City - 2023 Edition new
drupaladmin

Snap4City Newsletter of April 2023 new
roottooladmin1

Dashboards (Public)

My Snap4City.org | Tour Again

www.snap4solutions.org
Dashboards of My Organization
My Dashboards in My Organization
My Data Dashboard Dev Kibana
Extra Dashboard Widgets
Data Management, HLT
Knowledge and Maps
Processing Logics / IOT App
Entity Directory and Devices
Resource Manager
Development Tools
Management
Decision Support Systems
Deploy and Installation
Help and Contacts
Documentation and Articles

Privacy Policy | Cookies Policy



Snap4City: Smart aNalytic APp builder for sentient Cities and IOT

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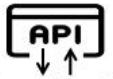















- TECHNICAL OVERVIEW: https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- Development Life Cycle: https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
- Client-Side Business Logic Widget Manual: https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- Booklet Data Analytics Snap4Solutions: https://www.snap4city.org/download/video/DPL_SNAP4SOLU.pdf

Username: paolo.disit

Search

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Training on Tools and Platform

Powered by www.km4city.org

FIWARE | Node-RED

Sii-Mobility

Organization Groups

DISIT
- Developer
- Operativo

Updates on

booklets

- Smart City



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

- Industry



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

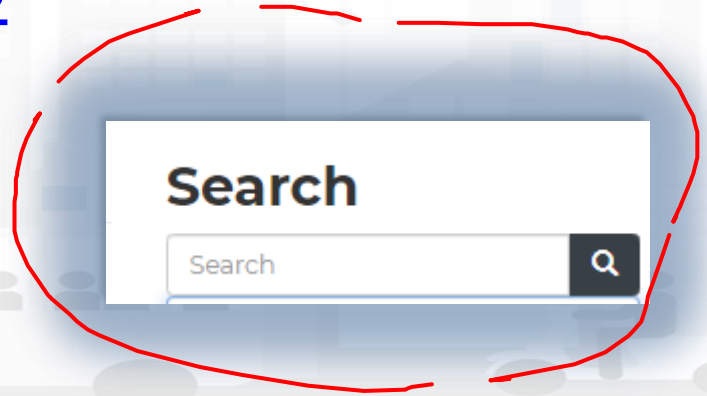
- Artificial Intelligence

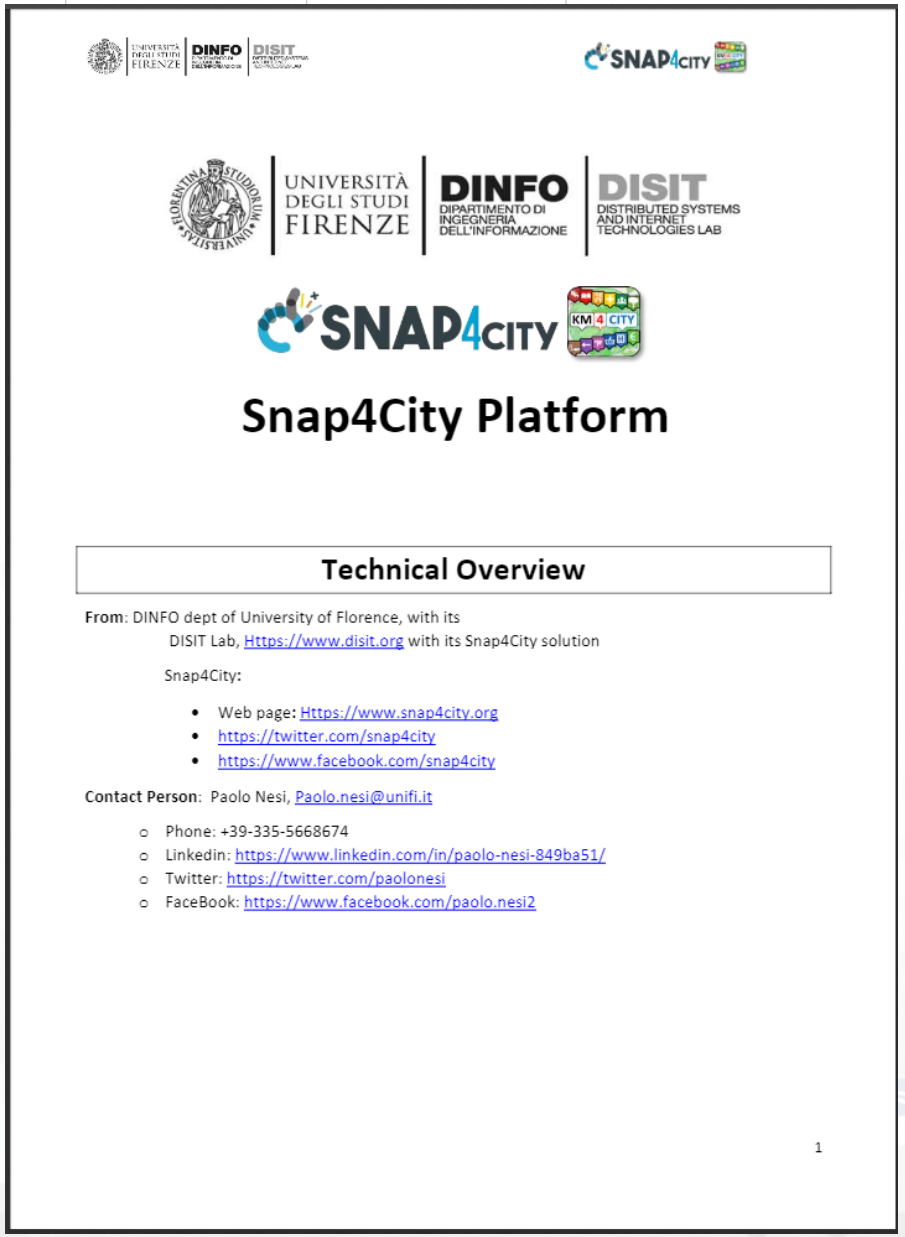


https://www.snap4city.org/download/video/DPL_SNAP4SOLU.pdf

The Platform

- **Free Registration on Snap4City.org**
  - Please select DISIT ORG to be sure to access at the examples
  - Most of the cities / tenant are private and they do not left much visible
- **What you get** is probably the 10% of what is on the platform ☺
- **Training**: https://www.snap4city.org/577
- **Scenarious**: https://www.snap4city.org/4
- **Publications**: https://www.snap4city.org/426
- **WEB pages**: https://www.snap4city.org/78
- ***SEARCH on the right side***





Snap4City Platform

Technical Overview

From: DINFO dept of University of Florence, with its
DISIT Lab, Https://www.disit.org with its Snap4City solution

Snap4City:

- Web page: Https://www.snap4city.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city

Contact Person: Paolo Nesi, Paolo.nesi@unifi.it

- Phone: +39-335-5668674
- Linkedin: https://www.linkedin.com/in/paolo-nesi-849ba51/
- Twitter: https://twitter.com/paolonesi
- FaceBook: https://www.facebook.com/paolo.nesi2

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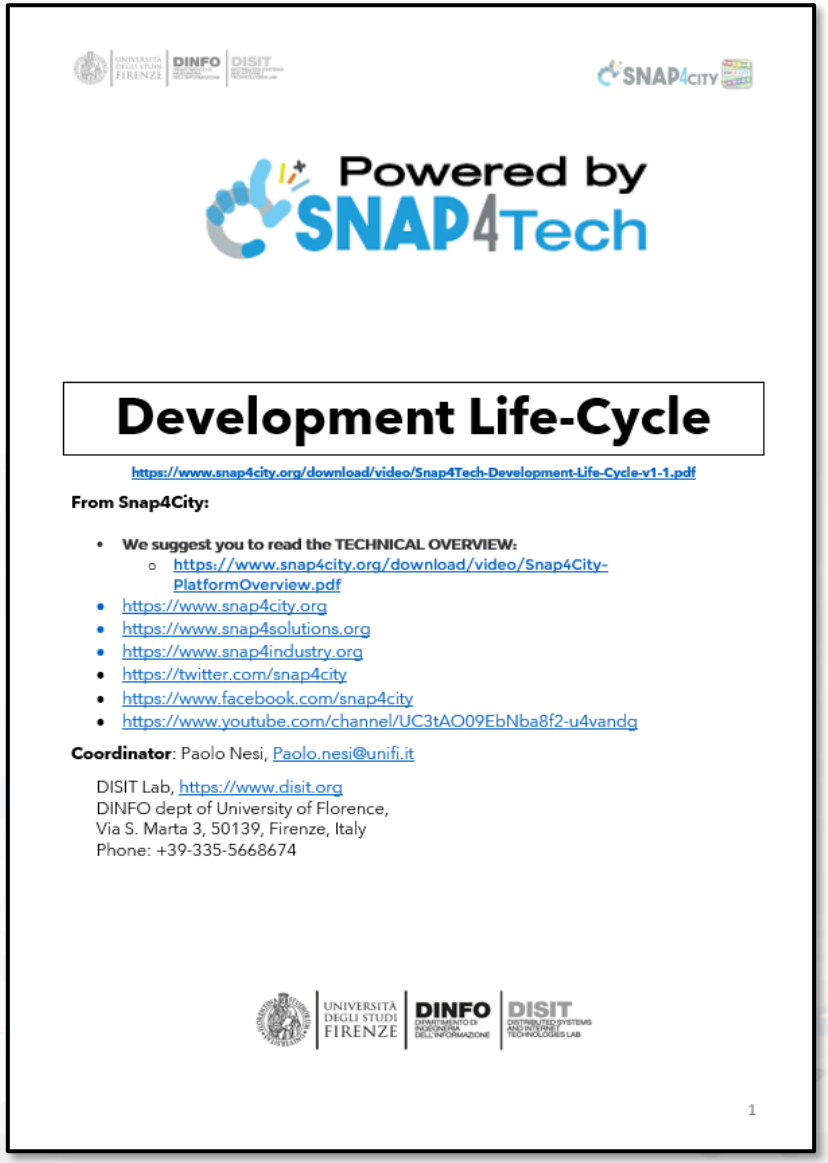
Tech. Overview

- **https://www.snap4city.org/drupal/sites/default/files/files/Snap4City-PlatformOverview.pdf**

Development



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Development Life-Cycle

https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle-v1-1.pdf

From Snap4City:

- **We suggest you to read the TECHNICAL OVERVIEW:**
  - https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city
- https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandg

Coordinator: Paolo Nesi, Paolo.nesi@unifi.it

DISIT Lab, https://www.disit.org
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Via S. Marta 3, 50139, Firenze, Italy
Phone: +39-335-5668674

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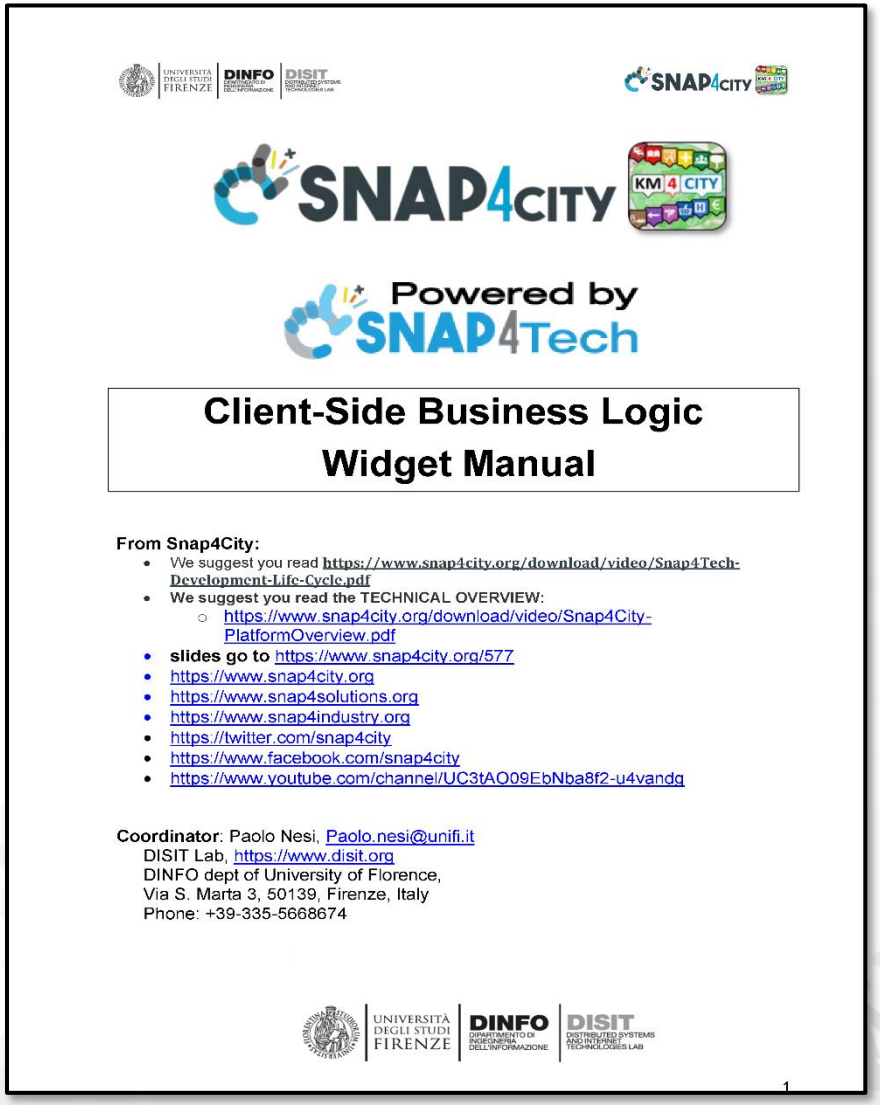
https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf

CSBL

Client Side Business Logic



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Client-Side Business Logic Widget Manual

From Snap4City:

- We suggest you read **https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf**
- **We suggest you read the TECHNICAL OVERVIEW:**
  - https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- **slides go to** https://www.snap4city.org/577
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city
- https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandg

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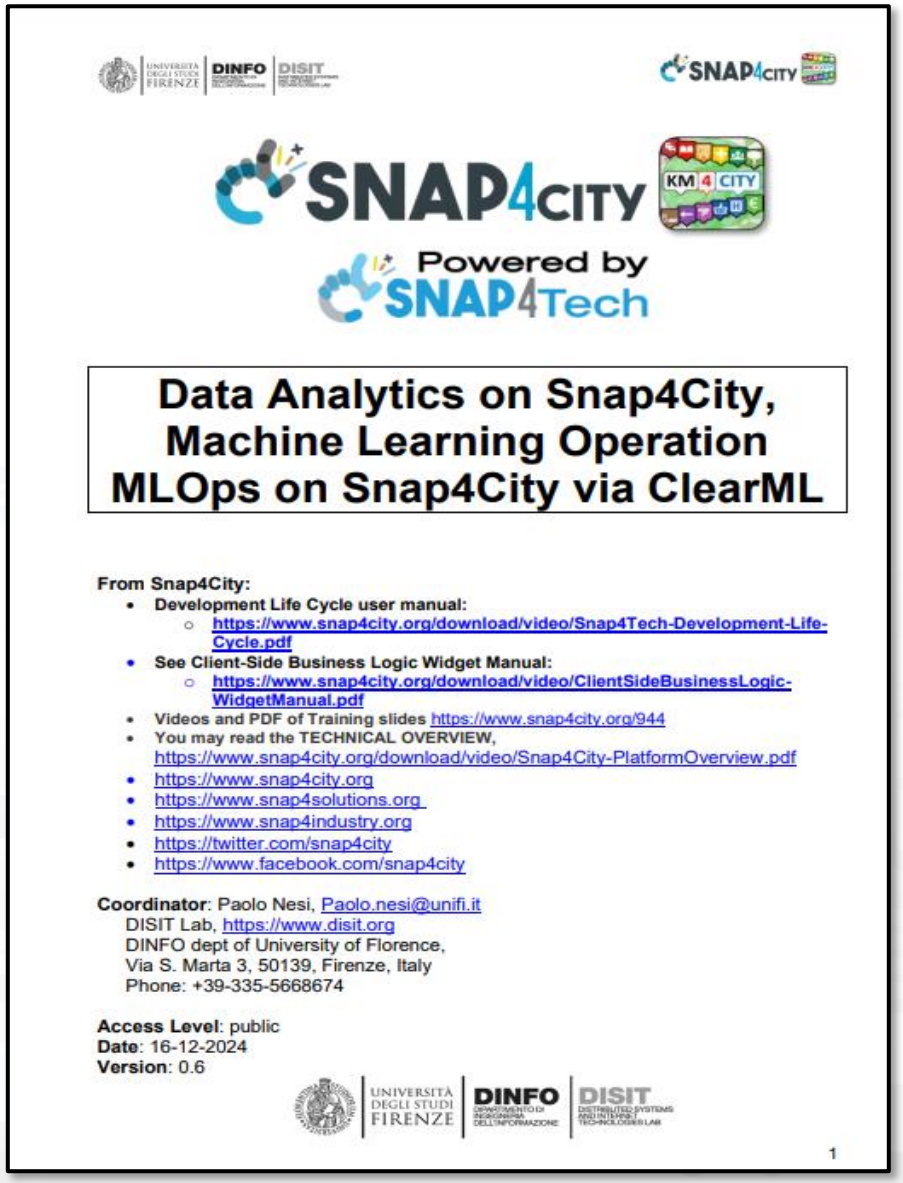
https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf



SNAP4CITY

Powered by SNAP4Tech

Data Analytics on Snap4City, Machine Learning Operation MLOps on Snap4City via ClearML

From Snap4City:

- **Development Life Cycle user manual:**
  - https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
- **See Client-Side Business Logic Widget Manual:**
  - https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
- Videos and PDF of Training slides https://www.snap4city.org/944
- You may read the TECHNICAL OVERVIEW, https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
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Access Level: public
Date: 16-12-2024
Version: 0.6

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MLOperation

https://www.snap4city.org/download/video/Snap4City-MLOps-Manual.pdf



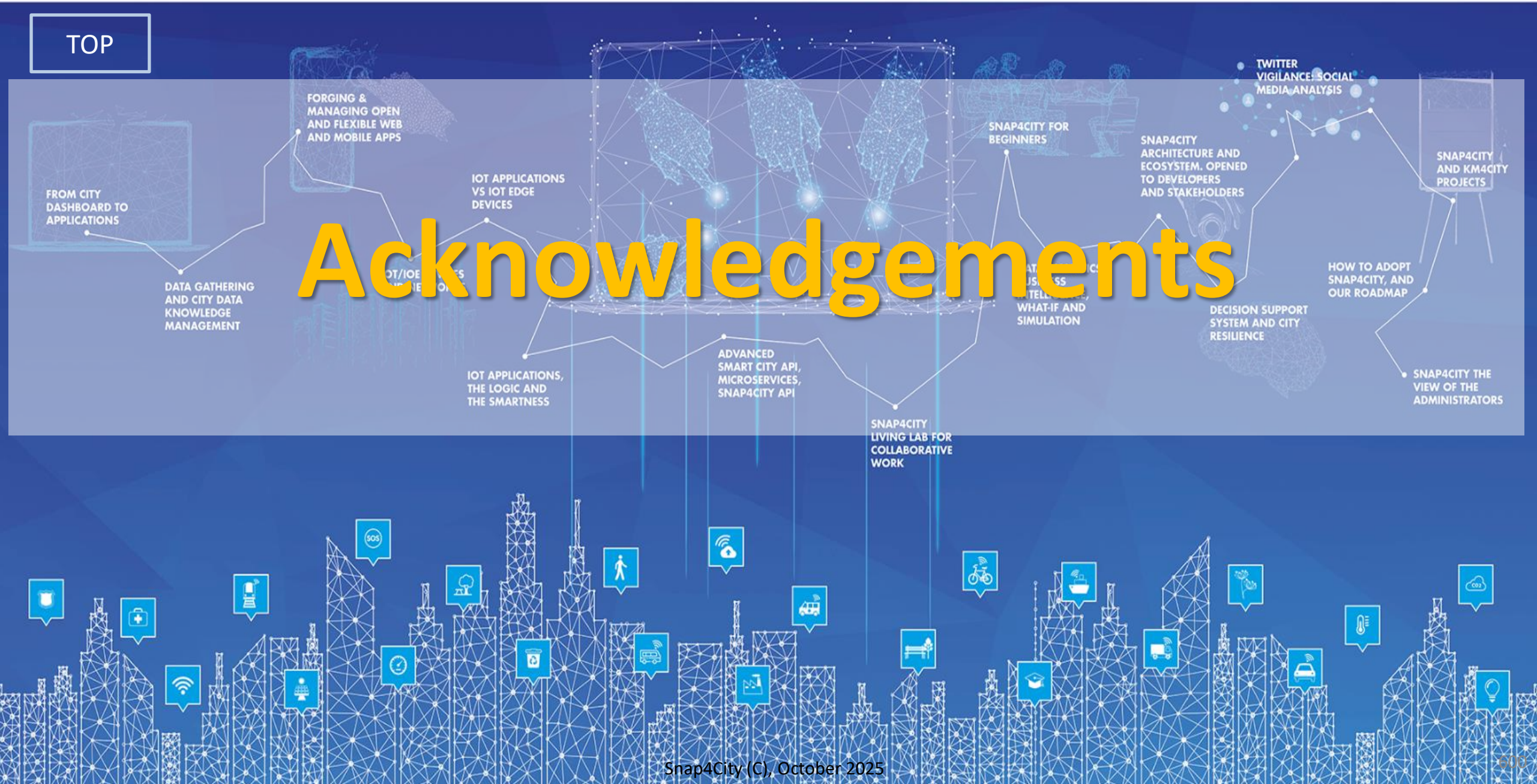
Commercial Overview

FIWARE

- https://fiware-foundation.medium.com/snap4city-fiware-powered-smart-app-builder-for-sentient-cities-acfe24df49d5
- https://www.snap4city.org/drupal/sites/default/files/files/FF_ImpactStories_Snap4City.pdf

TOP

Acknowledgements



SNAP4CITY roadmap

2020

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

- Smart Mobility
- PISA, PUMS
- Living lab

Km4City 1.6.7

2021

Smart Ambulance (2021-22)

Enterprise (2021-22) Industry 4.0

Sii-Mobility Contract

JRC Contract

PC4City (2020-21) Monitoring Terrain

Winner of Open Data Challenge of enel x

- Smart Light
- Sweden

2022

Almafluida Industry 4.0 (2021-22)

AMPERE (2021-22) Industry 4.0

SYN-RG-AI SmartCity

Gruppo Pretto Industry 4.0

uni.systems SmartCity, 2021-23

AXIS collab SmartCity

Asymmetrica Smart City, 2022-23

2023

JRC Contract, 2022-23

ART-ER Contract, 2022-23

Filippi 2022-2023

enel x Contract, 15min

IMPETUS Security and Risk

Smartea

Italferr, Smart City

CN MOST, 2022-26

EI THE, 2022-26

G. Agile, 2021-23

TUSCANY EDIH 2023-26 Finanziato dall'Unione europea NextGenerationEU

Merano, smart light

OceanRace, Genova, AWS

Cuneo, smart city

2024

Km4City 1.6.8

TOURISMO

ELLIE IA 2025-2027

UrbanDT4TF

JRC Contract, 2024-25

CAI4DSA

FAIR Future Artificial Intelligence Research

OPTIFaaS

SASUAM

Rhodes, smart city

eShare UNIFI TUSS

AMMIRARE

Interreg Euro-MED Co-funded by the European Union

Interreg MARITTIMO-IT FR-MARITIME

Currently 2025

- **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/
- **The IE**, PNRR: AI, NLP, LLM, Legal Aspects
- **BullVIT** , RT, conv**:** NLP, LLM
- **Energia**, RT, conv: AI, PINN, DSS
- **RFI contract**: mobility, AI, DSS
- **Salerno Port**: container ID recognition and tracking
- **Talent Hub**, ECRF, conv: NLP, match demand vs offer

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

https://www.Snap4City.org

100% OPEN SOURCE

PEN Test Passed

EU GDPR COMPLIANT

SNAP4CITY

Node-RED

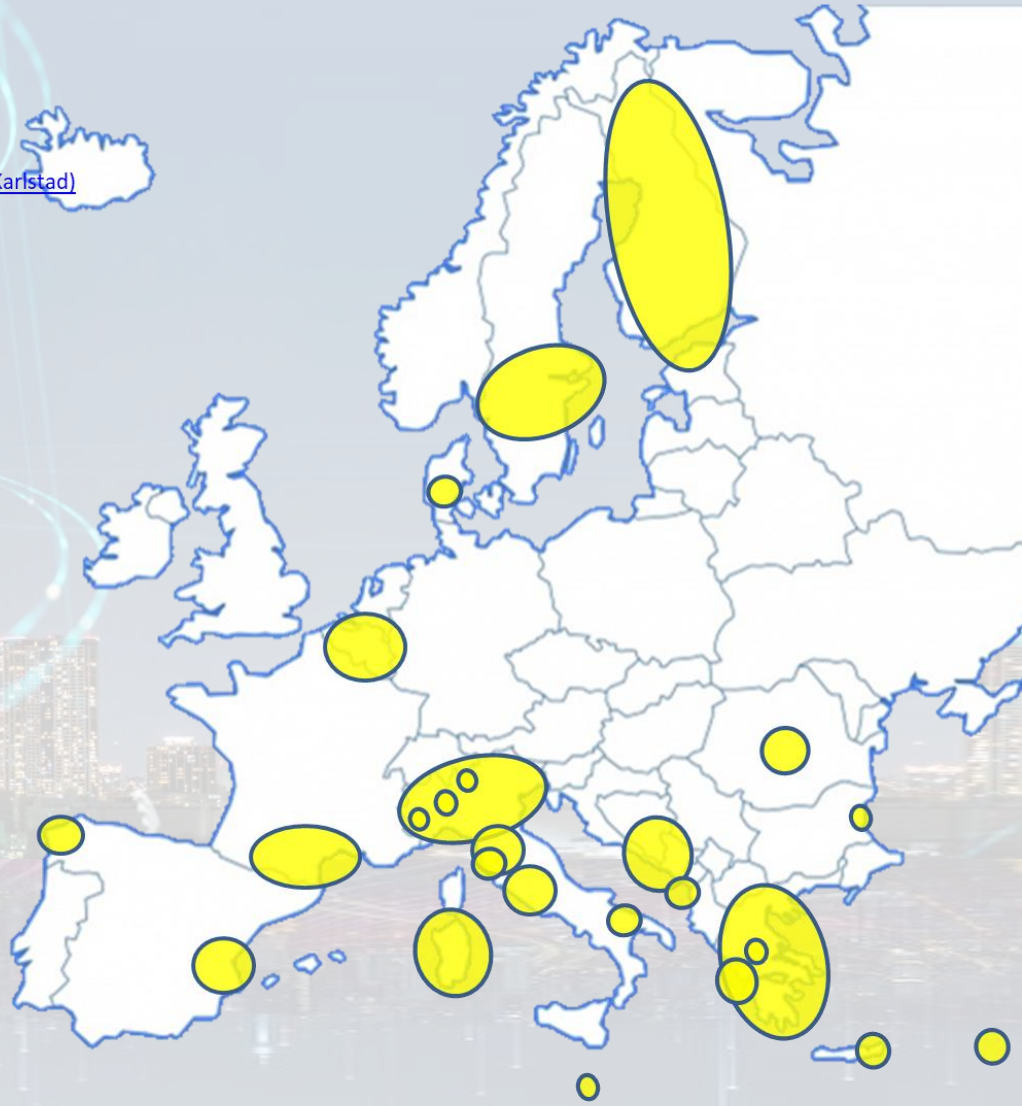
FIWARE

KM4CITY

- 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

KM4CITY

CITY

INDUSTRY

ARTIFICIAL INTELLIGENCE

MOST Centro Nazionale per la Mobilità Sostenibile

SASUAM

LUTECH

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PTIFaaS

Università degli Studi Firenze

DINFO Dipartimento di Ingegneria dell'Informazione

DISIT

Politecnico di Bari

FAIR Future Artificial Intelligence Research

MUR

CAI4DSA

UNIVERSITÀ DEGLI STUDI DI CAGLIARI

MUR

Interreg Maritime-IT FR-Maritime

AMMIRARE

TOURISMO

Interreg Euro-MED

Co-funded by the European Union

SADI-MIAC

Coesione Italia Toscana

Cofinanziato dall'Unione europea

Regione Toscana

ELLIE

Funded by the European Union

Comune di Firenze

ASM Meran Stadtwerke Meran

Città di Cuneo

Rodhes

Development Agency of Iemesos LTD

Santa María la Real fundación

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