



www.snap4city.org
www.snap4solutions.org



www.km4city.org

Data Analytics and Artificial Intelligence

Nov. 2023, Course, Part 4

<https://www.snap4city.org/944>

<https://www.snap4city.org/577>

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

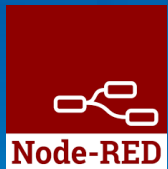


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DISIT
DISTRIBUTED SYSTEMS
AND INTERNET
TECHNOLOGIES LAB

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

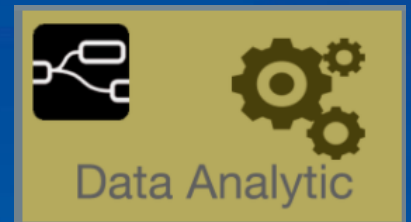


7-9 November 2023, Barcelona, Spain

SMARTCITY
EXPO WORLD CONGRESS

Visit Snap4City in Hall 1

Data Analytics and Artificial Intelligence



Nov. 2023, Course, Part 4
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SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES



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TECNOLOGIE LAB



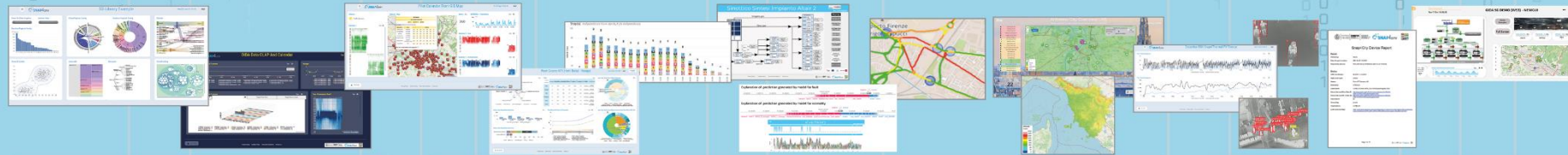


Smart Solutions and Decision Support Systems

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



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



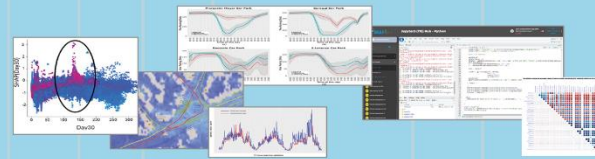
DASHBOARDS, WIDGETS
TEMPLATES

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

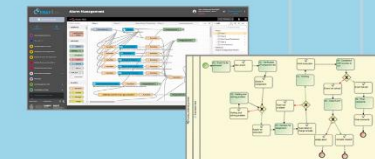
API - MICROSERVICES - GIS - BPM
VIDEO - REPORTS - MAPS - 3D ...

ANY: DATA, BROKER, NETWORK AND VERTICAL

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



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



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

Native and External
Smart Applications

Mobility & Transport

Light & Energy

Waste

Environment

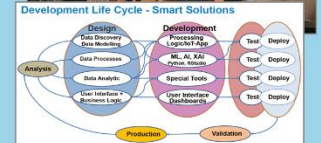
Building

Tourism

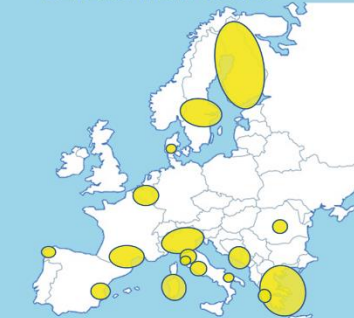
Asset Management

Security and Safety

Social Media



METHODOLOGIES
LIVING LABS
COURSES AND COMMUNITY
DEVELOPMENT TOOLS



Powered by
FIWARE

FREE
TRIAL

PEN Test
Passed

EU GDPR
COMPLIANT

SNAP4
Appliances and Dockers
Installations

EUROPEAN OPEN
SCIENCE CLOUD

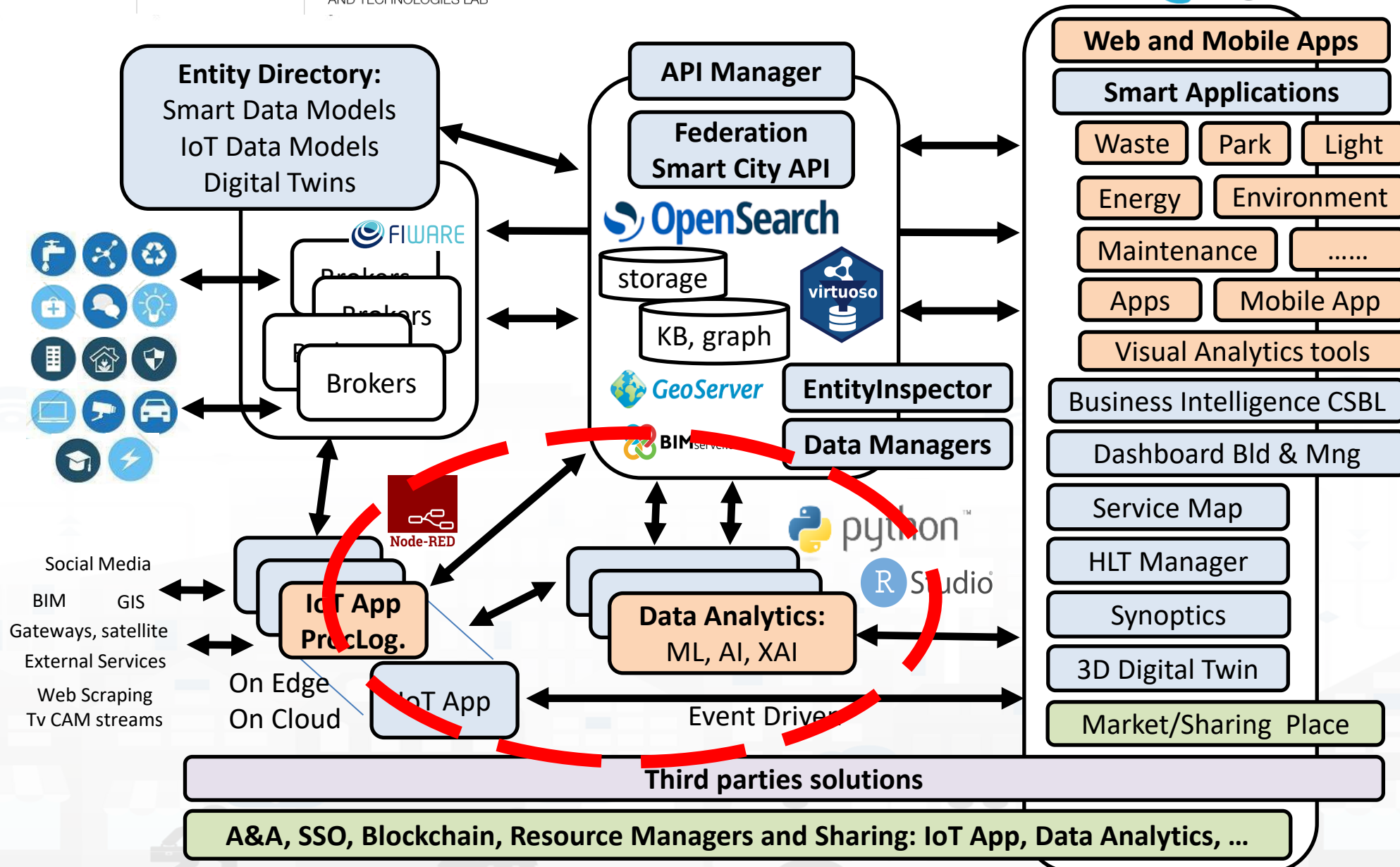
Node-RED

JS Foundation

E015
digital ecosystem

NVIDIA

Tech Arch



<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>

Tech Overview

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



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

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

Development

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



Development Life-Cycle

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

From Snap4City:

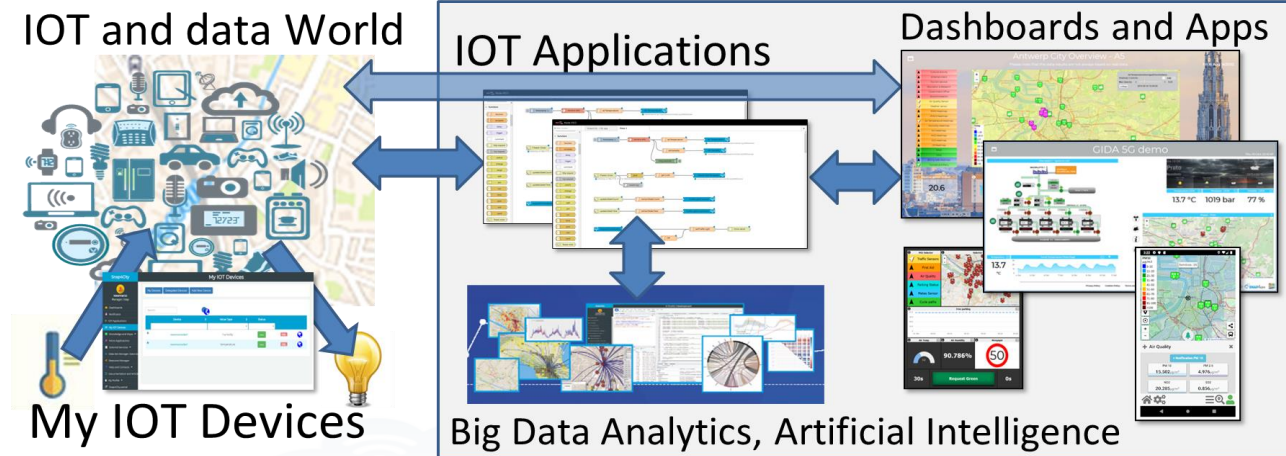
- We suggest you to read the **TECHNICAL OVERVIEW**:
 - <https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf>
- <https://www.snap4city.org>
- <https://www.snap4solutions.org>
- <https://www.snap4industry.org>
- <https://twitter.com/snap4city>
- <https://www.facebook.com/snap4city>
- <https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandq>

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

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

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



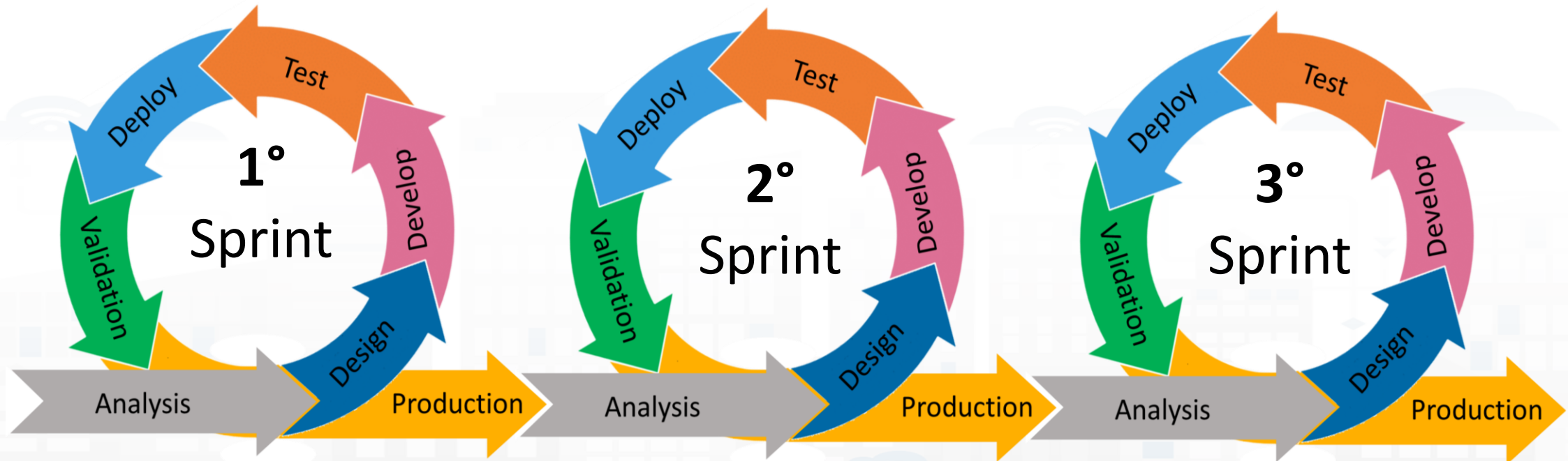
IF you need to go more in deep you can ask us to pass at the next Role becoming full AreaManager with full rights of development, also for Data Analytics, machine learning, etc.

Agenda of forth part

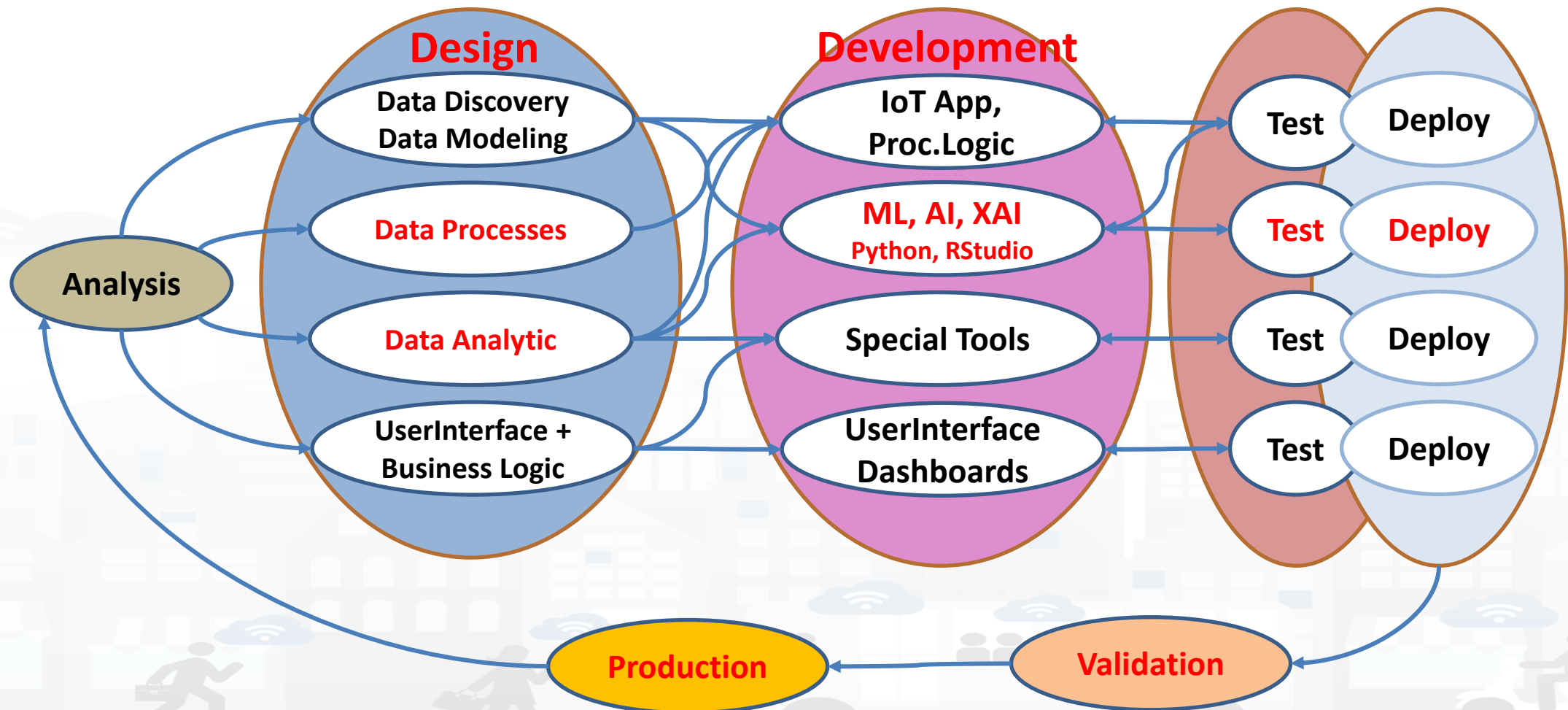
- Why and Where use DA, AI and XAI ? General Life Cycle
- Data Processing
- What is Data Analytics, DA and Artificial Intelligence, AI
- List of the most relevant available DA and AI Solutions
- Predictions and Anomaly detections
- Computing: Higher Level Types Data and their representations
- How AI/XAI, and Life Cycle
- Using DA, AI, XAI in Snap4City infrastructures
 - Data Analytics \leftrightarrow IoT App / Proc.Logic
- Decision Support Systems and What-If Analysis
- Routing, Multimodal Routing, Dynamic Routing
- Business Intelligence and Visual Analytics
- Training Material



Agile Development Life Cycle by sprint Smart Solutions



Development Life Cycle Smart Solutions



TOP

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

FORGING & MANAGING OPEN AND FLEXIBLE WEB AND MOBILE APPS

FROM CITY DASHBOARD TO APPLICATIONS

DATA GATHERING AND CITY DATA KNOWLEDGE MANAGEMENT

IOT/IOE DEVICES AND NETWORKS

IOT APPLICATIONS, THE LOGIC AND THE SMARTNESS

ADVANCED SMART CITY APPS, MICROSERVICES, SNAP4CITY API

SNAP4CITY LIVING LAB FOR COLLABORATIVE WORK

SNAP4CITY FOR BEGINNERS

SNAP4CITY ARCHITECTURE AND ECOSYSTEM, HOW TO DEVELOPERS AND MAKEFIELD

DATA ANALYTICS, BUSINESS INTELLIGENCE, WHAT-IF AND SIMULATIONS

TWITTER VIGILANCE, SOCIAL MEDIA ANALYSIS

HOW TO ADOPT SNAP4CITY, AND OUR ROADMAP

DEVELOPER SUPPORT SYSTEM AND CITY INFLUENCE

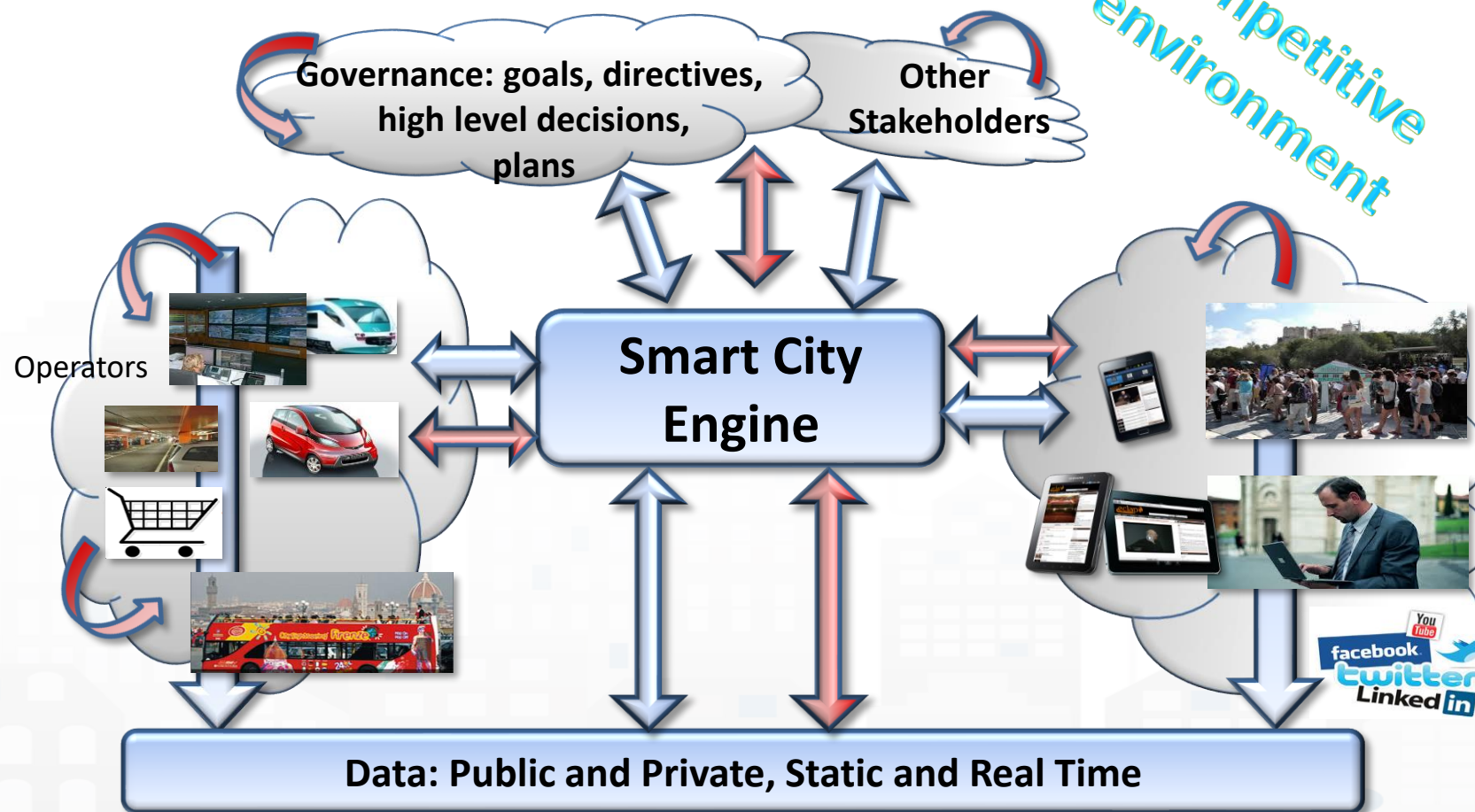
SNAP4CITY AND KM4CITY PROJECTS

SNAP4CITY THE VIEW OF THE ADMINISTRATORS



From Strategies to (re-)Actions

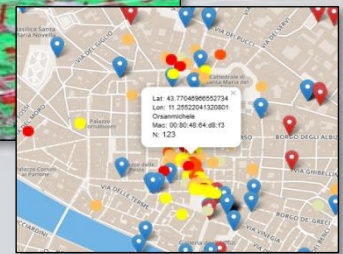
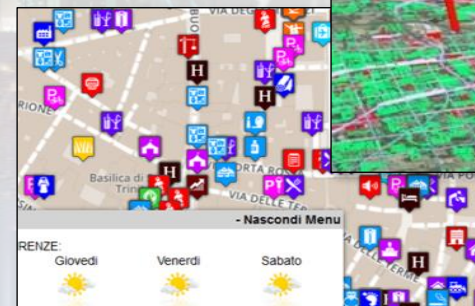
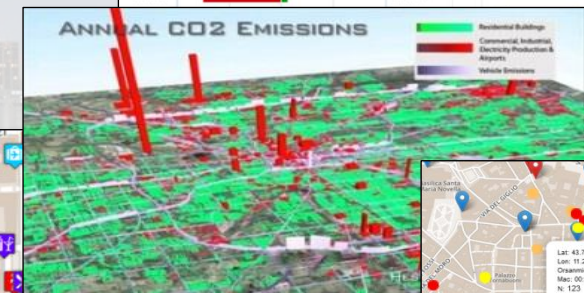
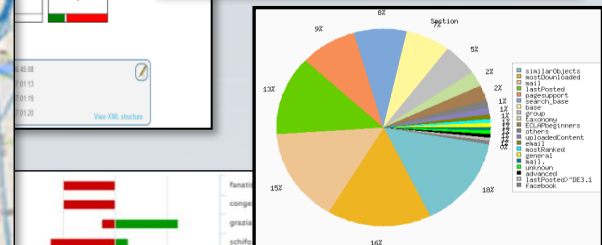
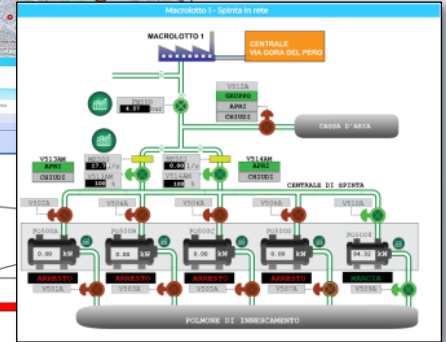
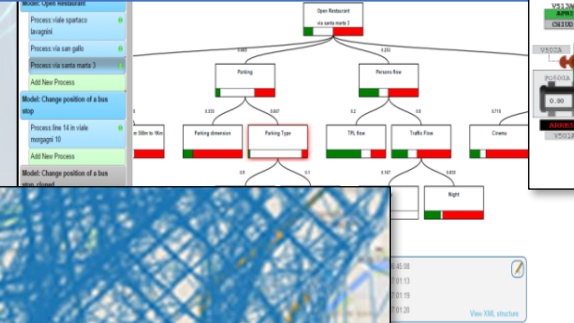
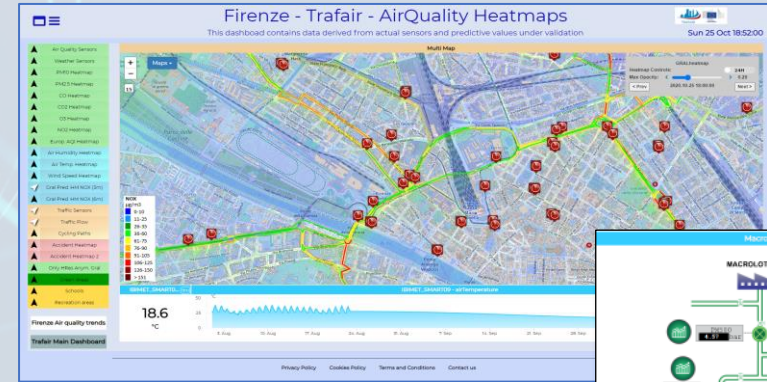
- Analyze
- Alerting, Early Warning
- Support Decision makers
- Plans
- Prescriptions
- Inform
- Suggest
- Engage
- Research



Data Driven Decision Support



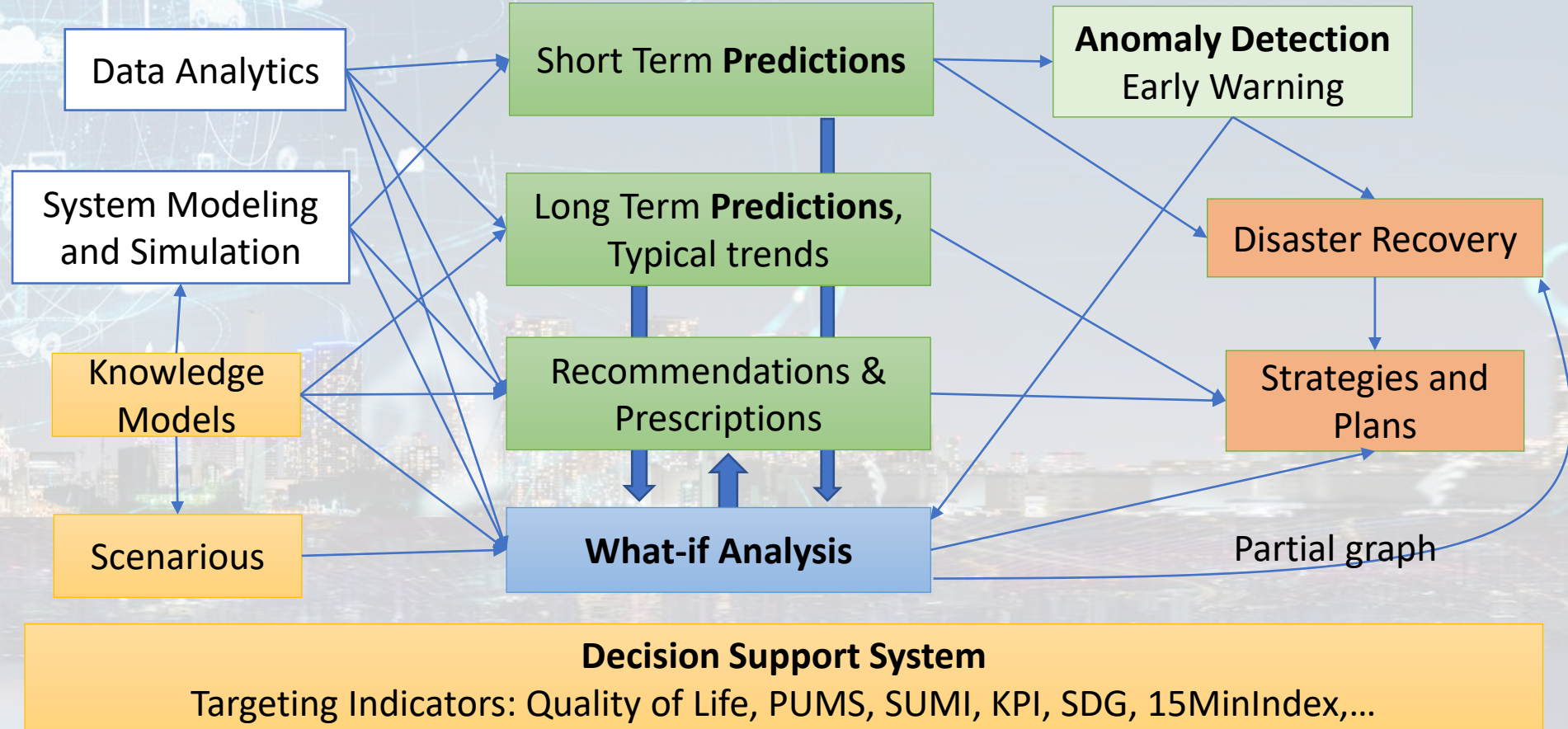
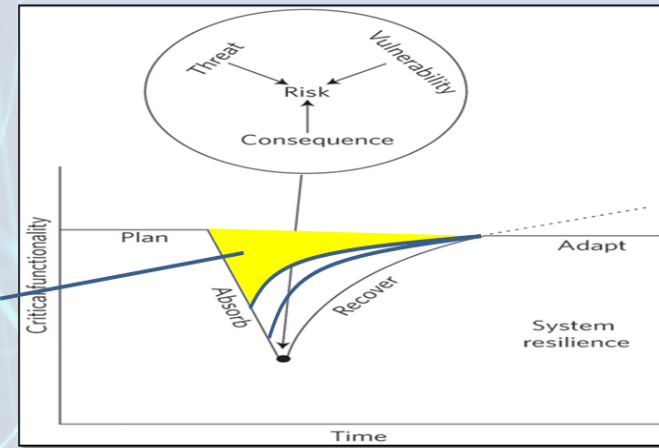
- Decision Support system
- Assessment / Strategies
- Data Rendering,
 - visual analytics, business intel..
- Data Analytics, ML, AI
- Data aggregation, Storage, indexing
- Data Ingestion



Snap4City Analytics

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

Prepare
Absorb
Recover
Adapt

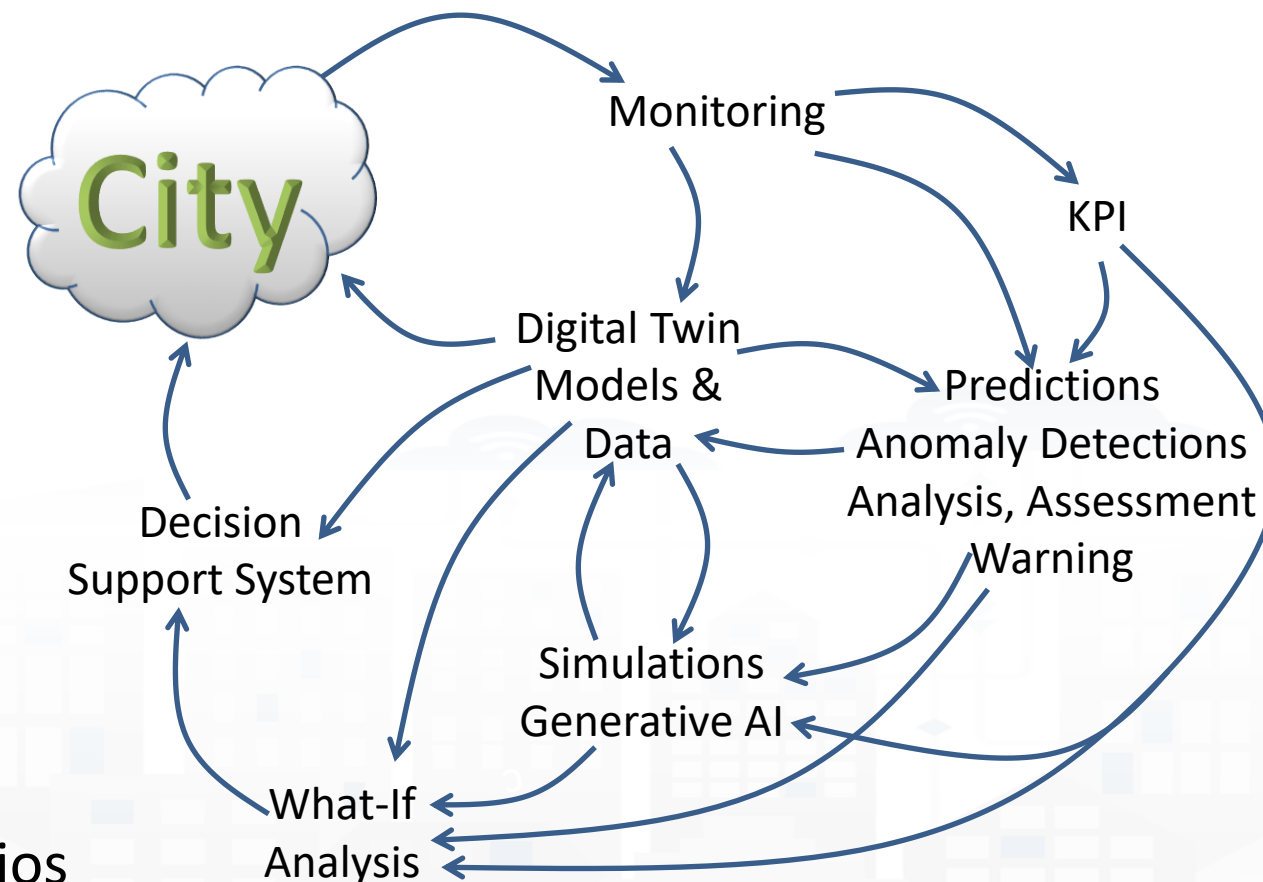


- **Controlling Status: management, and operational**

- Monitoring via KPI
- Computing predictions vs KPI
- Anomaly detection
- Neuro-Symbolic analysis
- Risk assessment
- Early warning on critical conditions

- **Making plan: tactic and strategic, medium and long range**

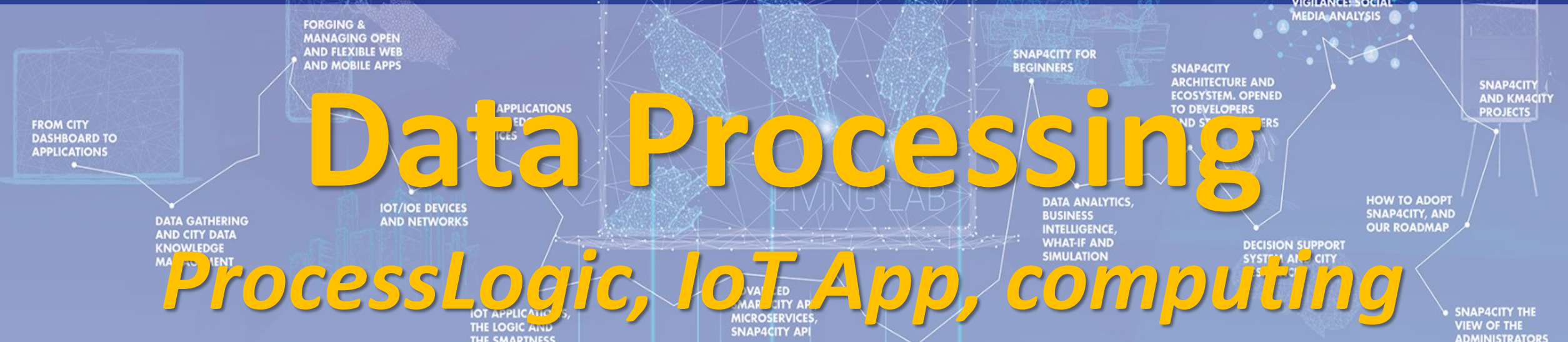
- Simulation & predictions
- Generative AI Prescriptions, scenarios
- Resilience to Unexpected unknowns
- What-if analysis wrt scenarios



TOP

Data Processing

ProcessLogic, IoT App, computing



IOT Application

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



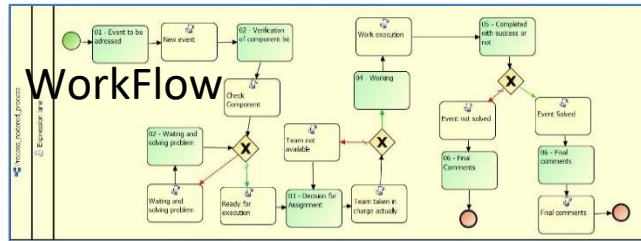
Definition: Data processing

- **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*

Concept

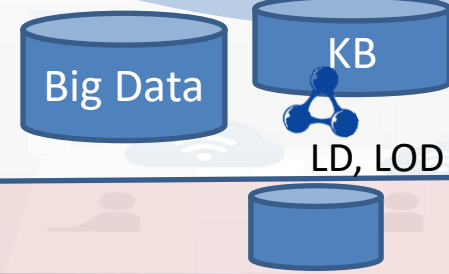


KPI, POI, MyKPI, ...
API, External Services
Web Scraping





IOT Brokers
IOT Broker
IOT Broker



Dashboards and Apps



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.

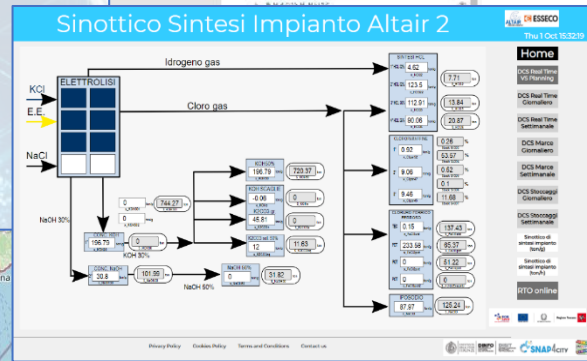
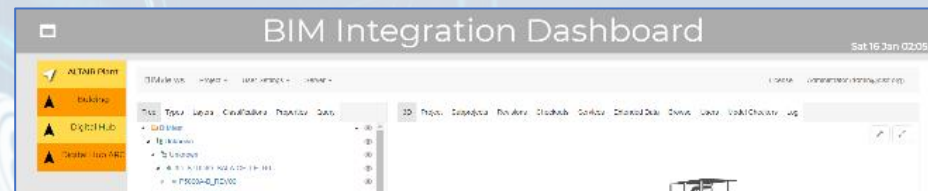


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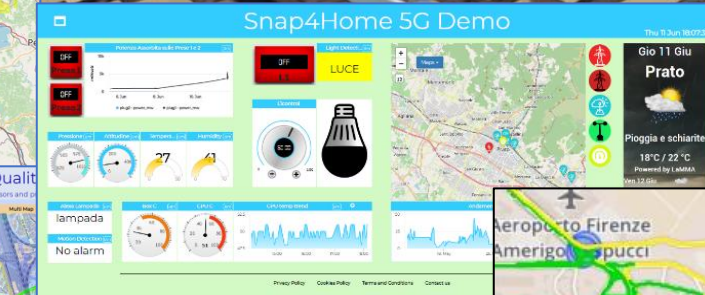
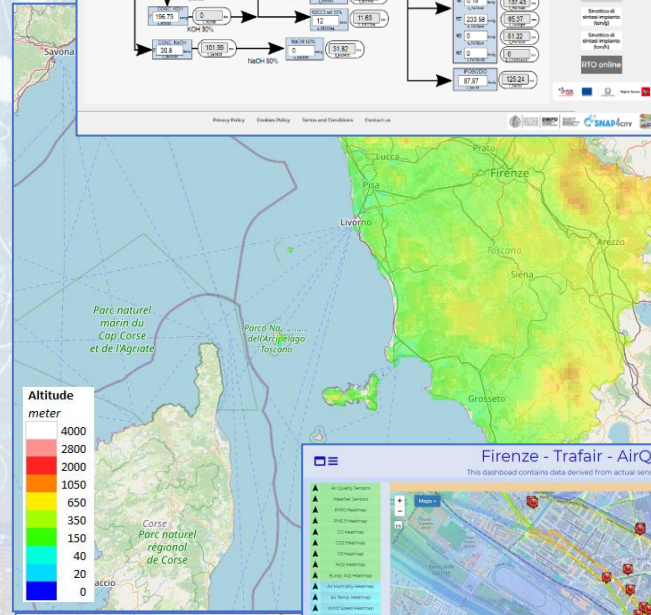
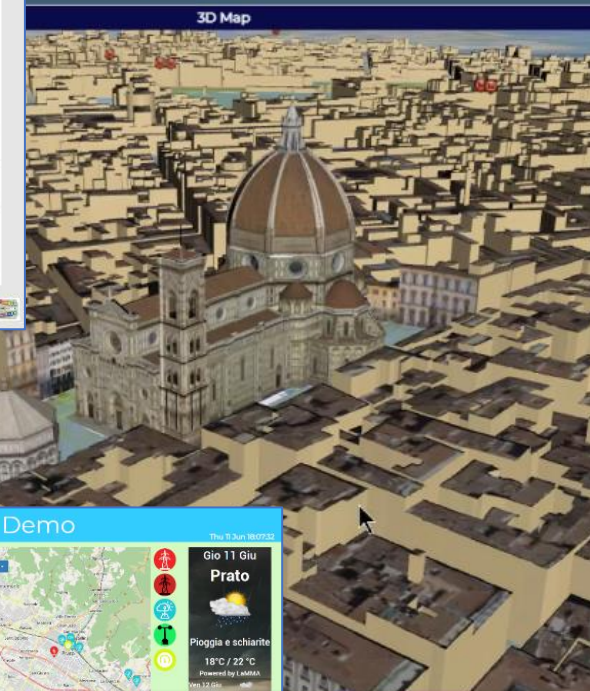
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Snap4City (C), November 2023



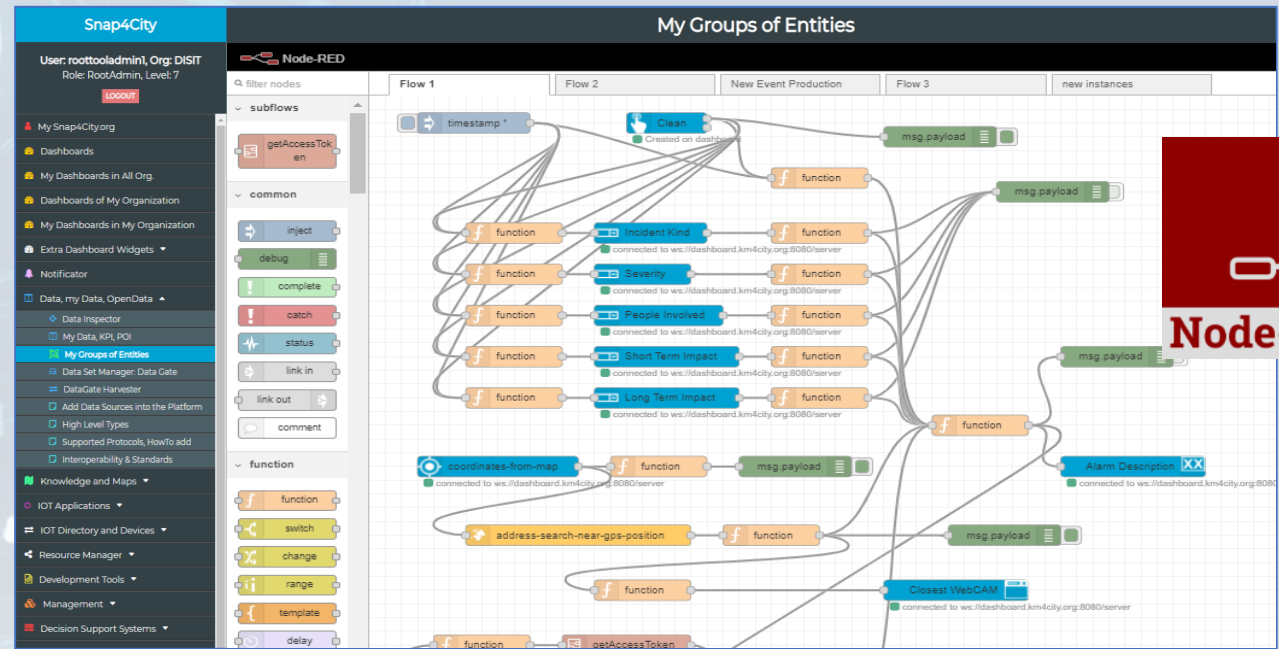
SNAP4CITY
- Digital Twin Global - Fire
demonstrator



Ingestion, aggreg. → exploitation



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



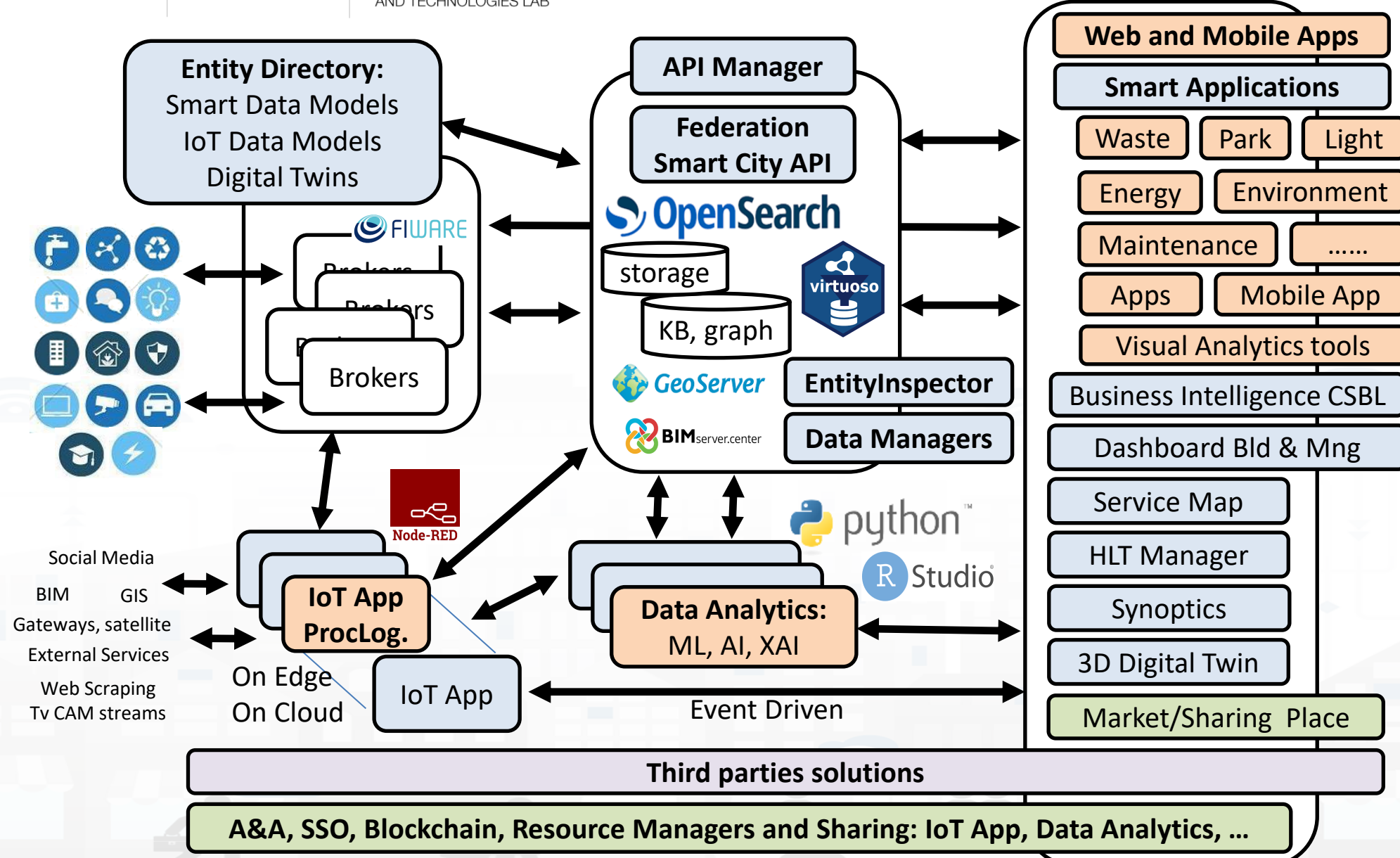
- Edge and Cloud
- MicroServices data o develop via visual language Node-RED

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

We suggest also to install:

- AND: From Resource Manager
- NGSI
- social
- twitter
- twitter
- twitter
- subflows
- twitter
- location
- Advanced FTP
- Advanced FTP Logger
- convex hub

Snap4City(C), May 2021



Computing, kpi & Indexes



indicators



- **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, PM_{2.5} (https://environment.ec.europa.eu/topic/air_en);
- **PUMS: mobility and transport vs wnv**
- **SUMI: mobility and transport vs env**
- **ISO indicators: city smartness, digitization. Tech level**
-

Global
Vs
Local



Pollutant	Averaging period	Objective and legal nature and concentration	Comments	WHO guidelines	
				Concentration	Comments
PM _{2.5}	One day			25 µg/m ³ (*)	99 th percentile (3 days/year)
PM _{2.5}	Calendar year	Target value, 25 µg/m ³	The target value has become a limit value since 1 January 2015	10 µg/m ³	
PM ₁₀	One day	Limit value, 50 µg/m ³	Not to be exceeded on more than 35 days per year.	50 µg/m ³ (*)	99 th percentile (3 days/year)
PM ₁₀	Calendar year	Limit value, 40 µg/m ³ (*)		20 µg/m ³	
O ₃	Maximum daily 8-hour mean	Target value, 120 µg/m ³	Not to be exceeded on more than 25 days per year, averaged over three years	100 µg/m ³	
NO ₂	One hour	Limit value, 200 µg/m ³ (*)	Not to be exceeded more than 18 times a calendar year	200 µg/m ³ (*)	
NO ₂	Calendar year	Limit value, 40 µg/m ³		40 µg/m ³	



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SNAP4CITY

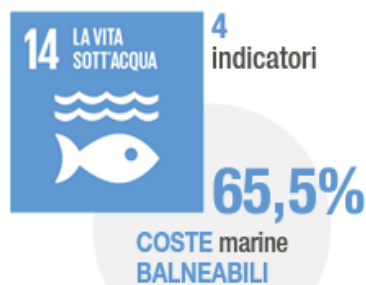
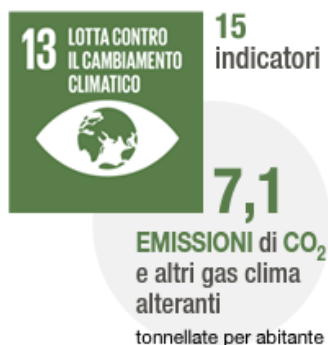
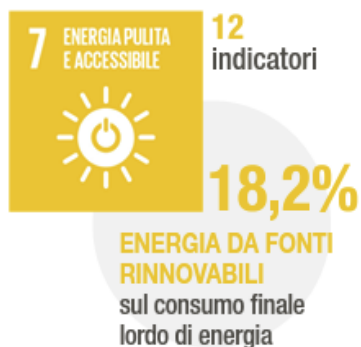
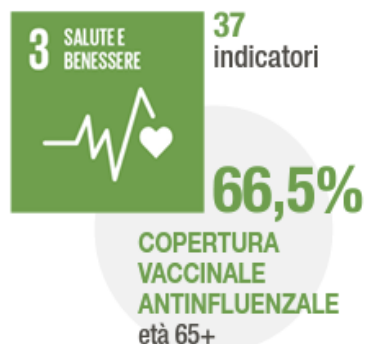
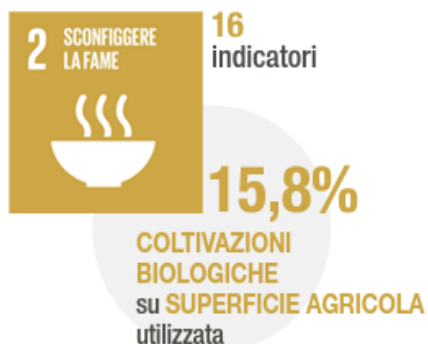


SUSTAINABLE DEVELOPMENT GOALS

<p>1 NO POVERTY</p>	<p>2 ZERO HUNGER</p>	<p>3 GOOD HEALTH AND WELL-BEING</p>	<p>4 QUALITY EDUCATION</p>	<p>5 GENDER EQUALITY</p>	<p>6 CLEAN WATER AND SANITATION</p>
<p>7 AFFORDABLE AND CLEAN ENERGY</p>	<p>8 DECENT WORK AND ECONOMIC GROWTH</p>	<p>9 INDUSTRY, INNOVATION AND INFRASTRUCTURE</p>	<p>10 REDUCED INEQUALITIES</p>	<p>11 SUSTAINABLE CITIES AND COMMUNITIES</p>	<p>12 RESPONSIBLE CONSUMPTION AND PRODUCTION</p>
<p>13 CLIMATE ACTION</p>	<p>14 LIFE BELOW WATER</p>	<p>15 LIFE ON LAND</p>	<p>16 PEACE, JUSTICE AND STRONG INSTITUTIONS</p>	<p>17 PARTNERSHIPS FOR THE GOALS</p>	<p>SUSTAINABLE DEVELOPMENT GOALS</p>

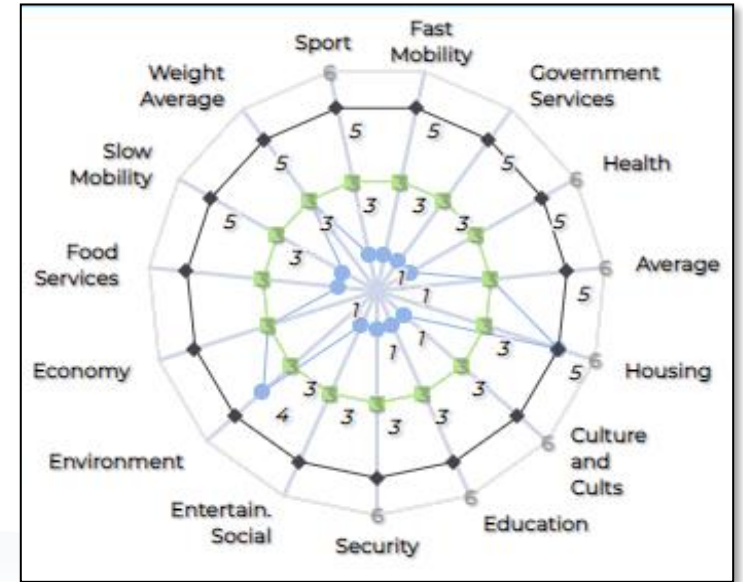
Sustainable Development Goals (SDGs) - Obiettivi di sviluppo sostenibile

RAPPORTO 2021



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	Gov	Housing viability Govern Services Safety Services Culture and Cults Services	
	Roads	Environment Quality Slow Mobility Services Fast Mobility Services	
	[Medical]	Sport Services	
	working	Economy/ sustainability	
	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?

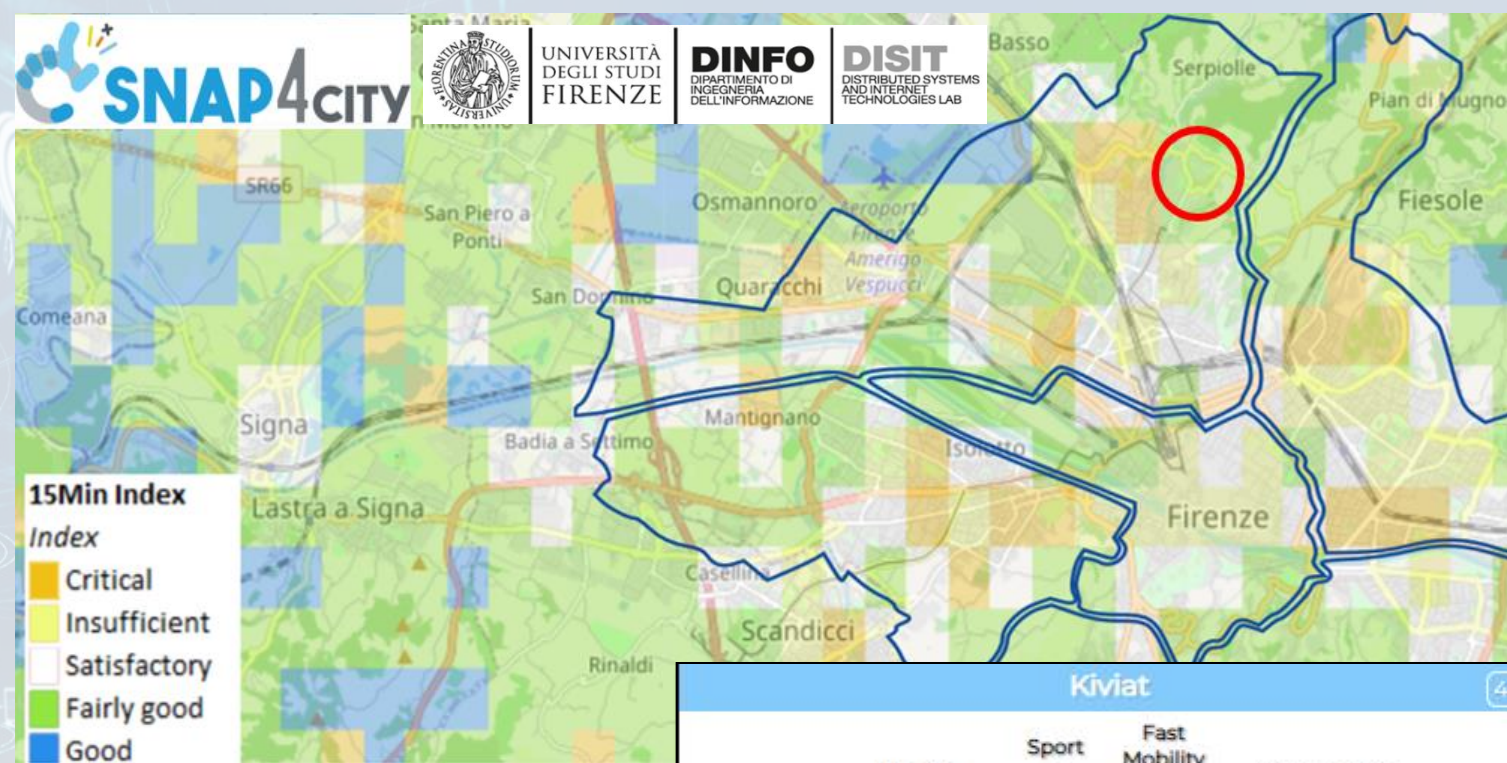
Using the Open Data:

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.

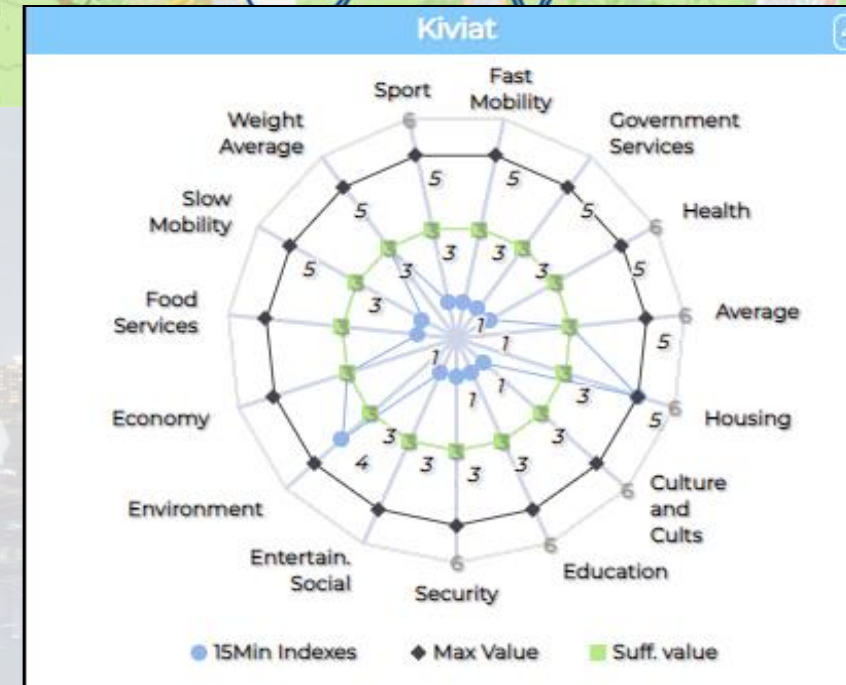
Good public transport services: bus, new tram line, train stations, cycle paths.



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.



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



<https://www.snap4city.org/dashboardSmartCity/view/index.php?iddashboard=MjkzOA==>

15MinCityIndex on Bologna

Ciao roottooladmin! Tue 3 May 20:14:59

15 MINUTI INDEX BOLOGNA CITTÀ METROPOLITANA - NEWGUI

enel x

abitanterpunto_IndexBologna
Heatmap Controls: 24H
Max Opacity: 0.5
2021-03-11 15:00:00

SELECTOR - MAP

- # of Inhabitants
- Green factor
- Civil factor
- Industrialization factor
- Environment Index
- 15Min Economy Index
- 15Min Housing Index

Argelato : Via Casadio N. 1

KIVIAT

BAR SERIES

Winner of Open Data Challenge 2020 of ENEL-X

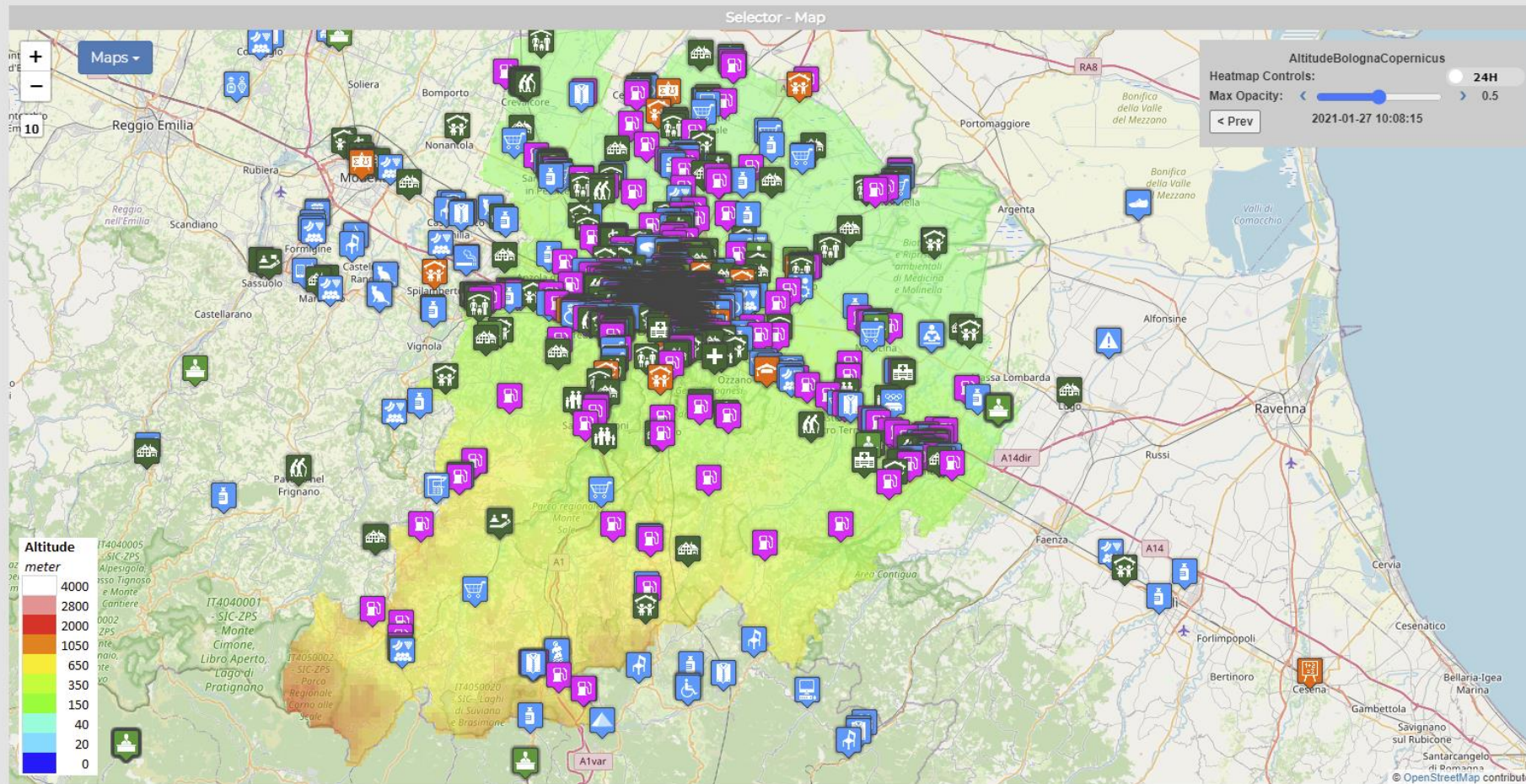


Bologna Metropolitan Area Dashboard

enel x

Sun 19 Sep 11:59:28

- ▲ Train station
- ▲ Charging Stations
- ▲ Bus Stops
- ▲ Fuel stations
- ▲ Cultural Activities
- ▲ Education
- ▲ Entertainment
- ▲ Government
- ▲ Healthcare
- ▲ Shopping
- ▲ Bike Racks
- ▲ Wine and Food
- ▲ Emergency Services
- ▲ Air Quality Stations
- ▲ Air Temperature Heatmap
- ▲ Humidity Heatmap
- ▲ Global Vegetation Index Heatmap
- ▲ Altitude Heatmap
- ▲ Fractional Cloud Cover Heatmap
- ▲ SciHub CO
- ▲ SciHub NO2
- ▲ SciHub O3
- ▲ SciHub SO2
- ▲ # of Inhabitants
- ▲ Green factor
- ▲ Civil factor
- ▲ Industrialization factor
- ▲ Environment Index
- ▲ 15Min Economy Index
- ▲ 15Min Housing Index
- ▲ 15Min Health Index
- ▲ 15Min Food Index
- ▲ 15Min Education Index
- ▲ 15Min Slow Mob Index
- ▲ 15Min Government Index
- ▲ 15Min Safety Index
- ▲ 15Min Culture and Cults Index
- ▲ 15Min Entertainment Index
- ▲ 15Min Fast Mobility
- ▲ 15Min Sport Index
- ▲ CityIndex MP1



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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
- Notifier
- 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

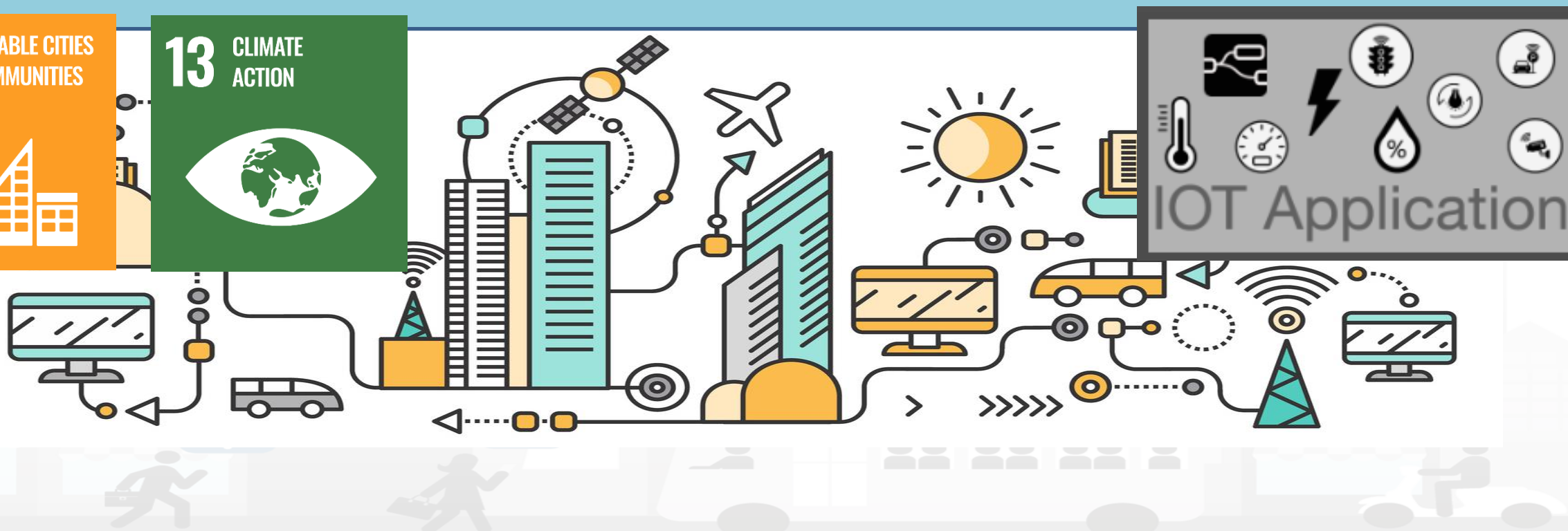
- GPS to COMUNE
- GPS to COUNT
- GPS to HeatmapVal
- GPS to Florence Qu
- GPS to ZCS
- GPS and Values to
- GPS to Civic Numbe
- GPS to Road Length
- GPS to Cycl

Traffic Flow Data

11 SUSTAINABLE CITIES
AND COMMUNITIES



13 CLIMATE
ACTION





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

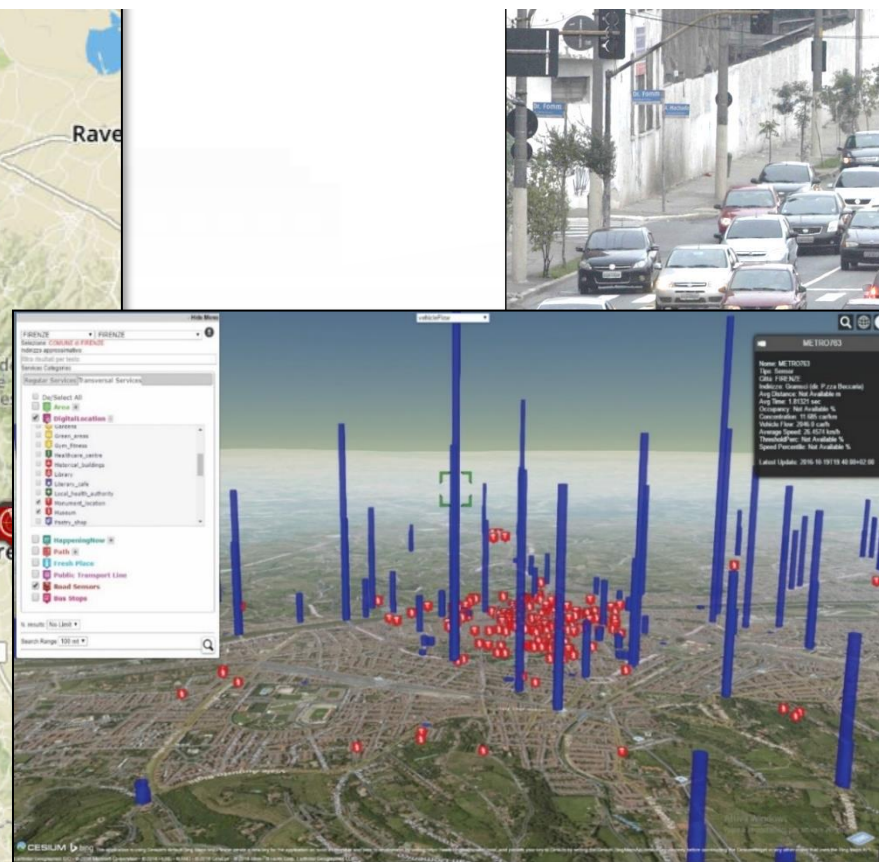
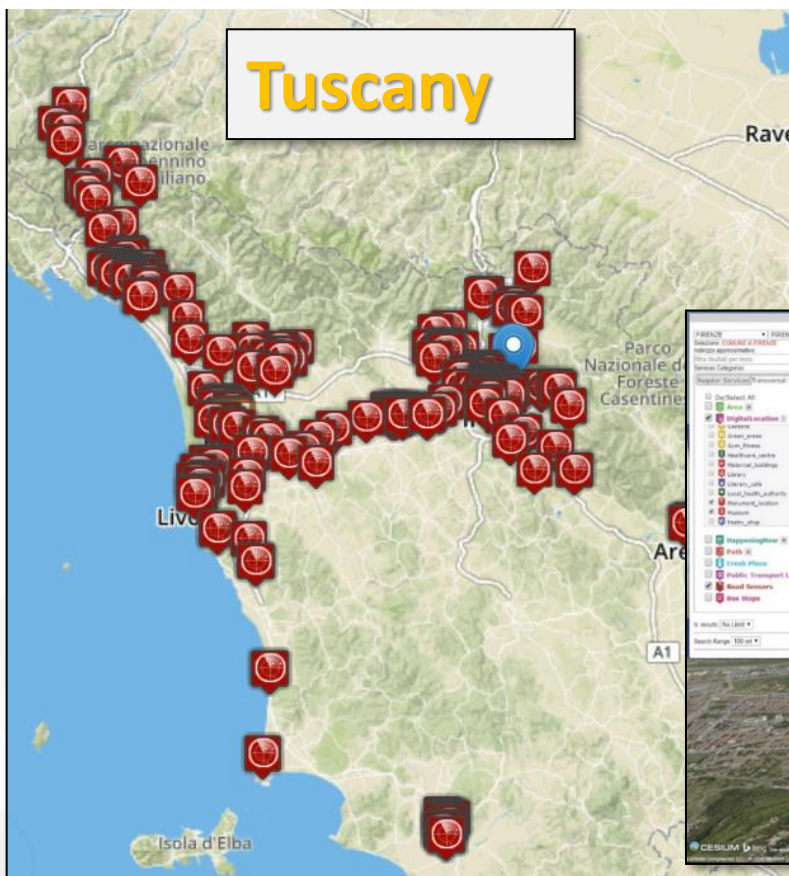


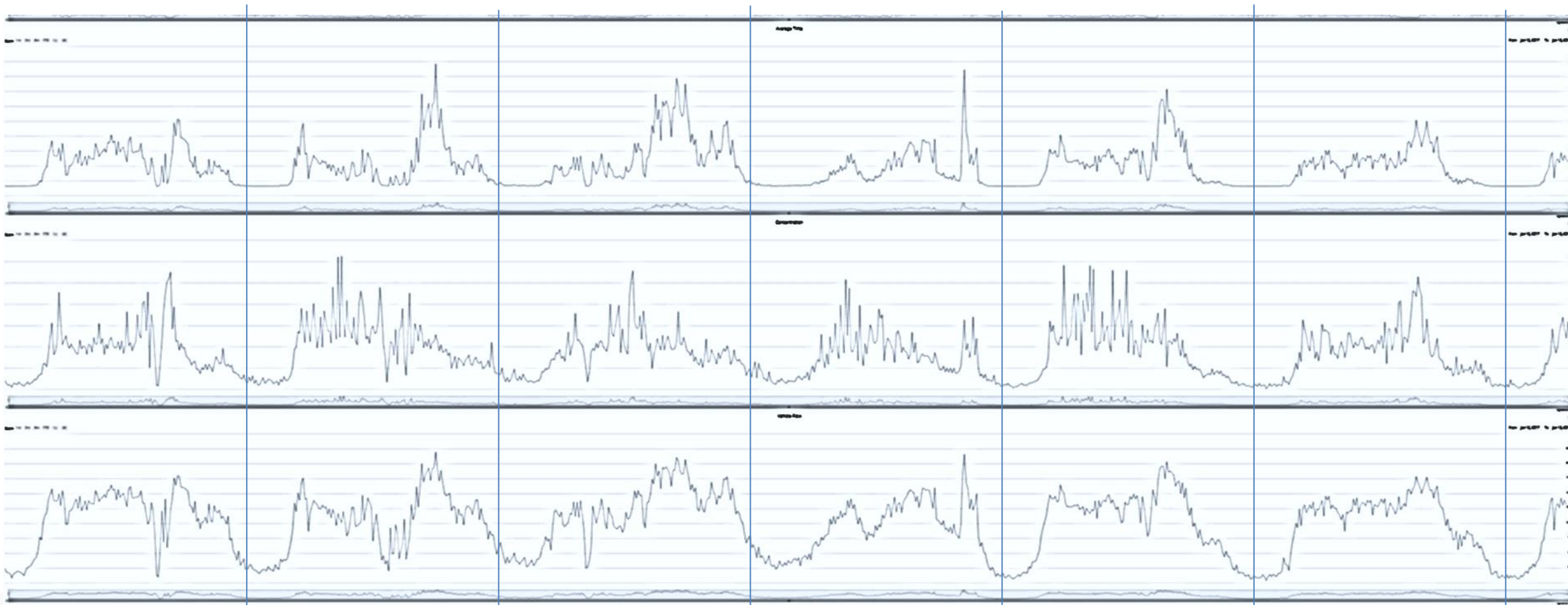
providing **PREDICTIONS** can be useful to improve quality of service

Traffic Flow Tools

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

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





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

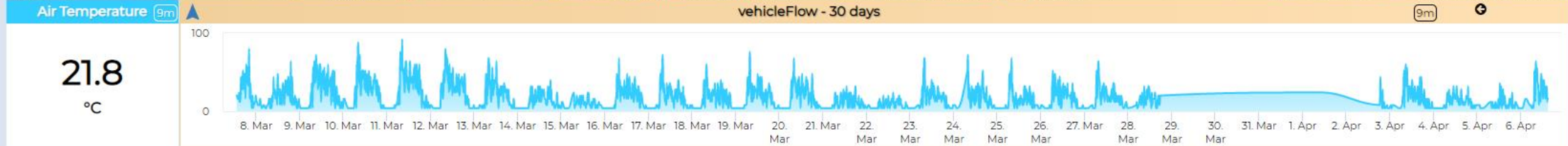
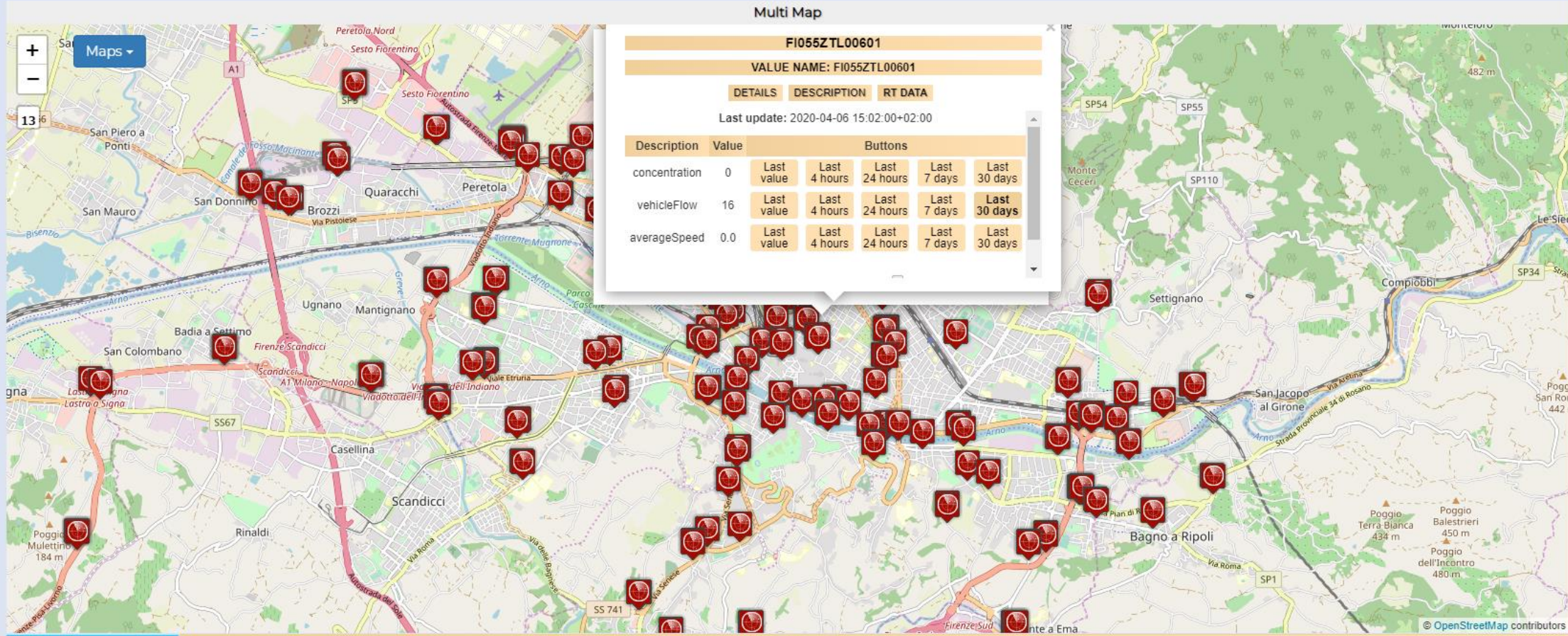
Firenze - Trafair - AirQuality Heatmaps



This dashboard 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



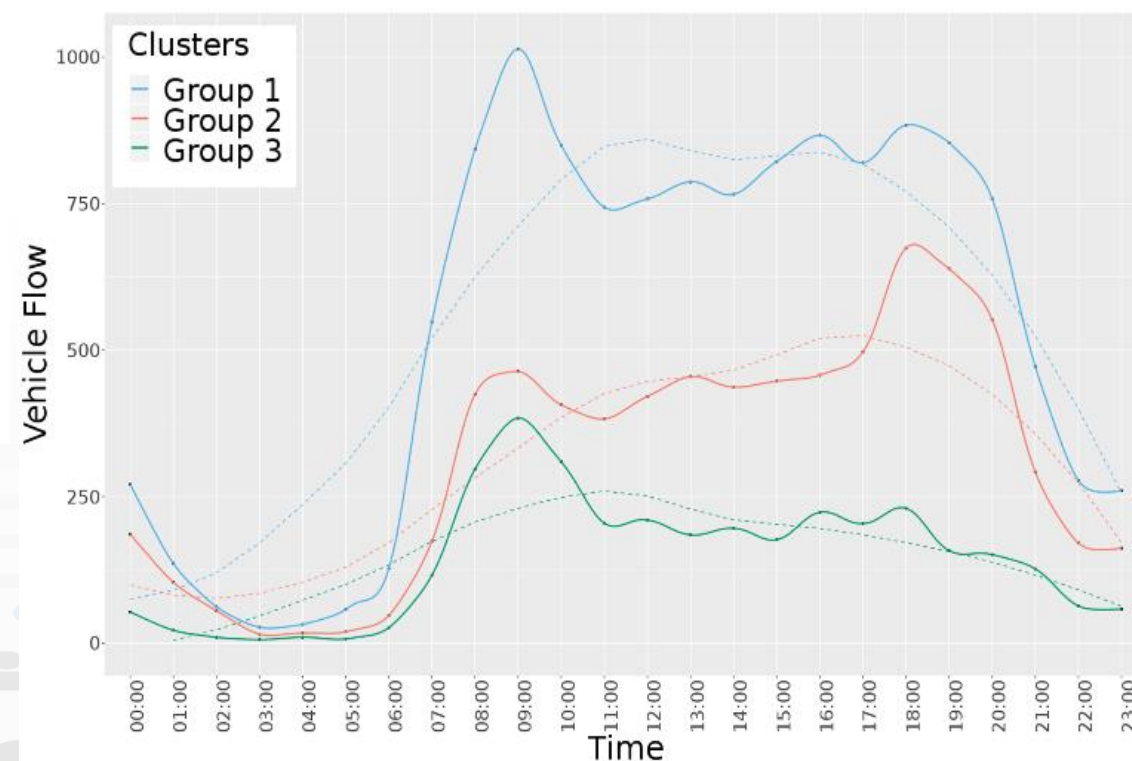
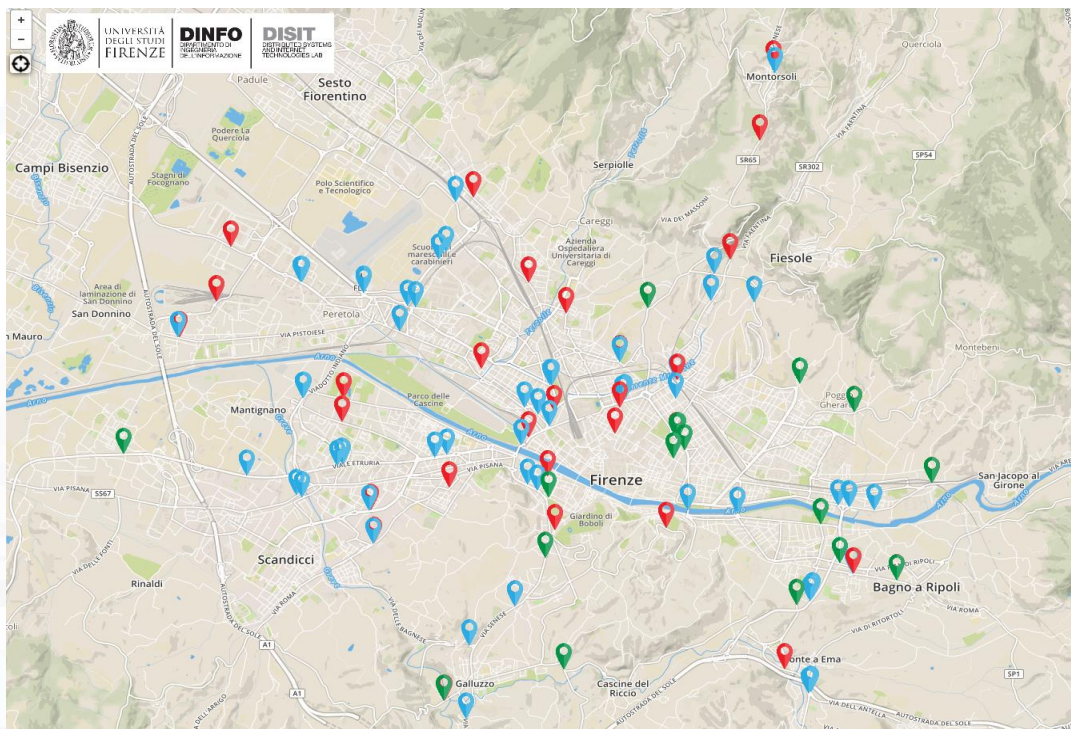
Air quality trends

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
- → $150 * 365 * 150 * 24 * 6 = 1.127 \text{ GB}$

- 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

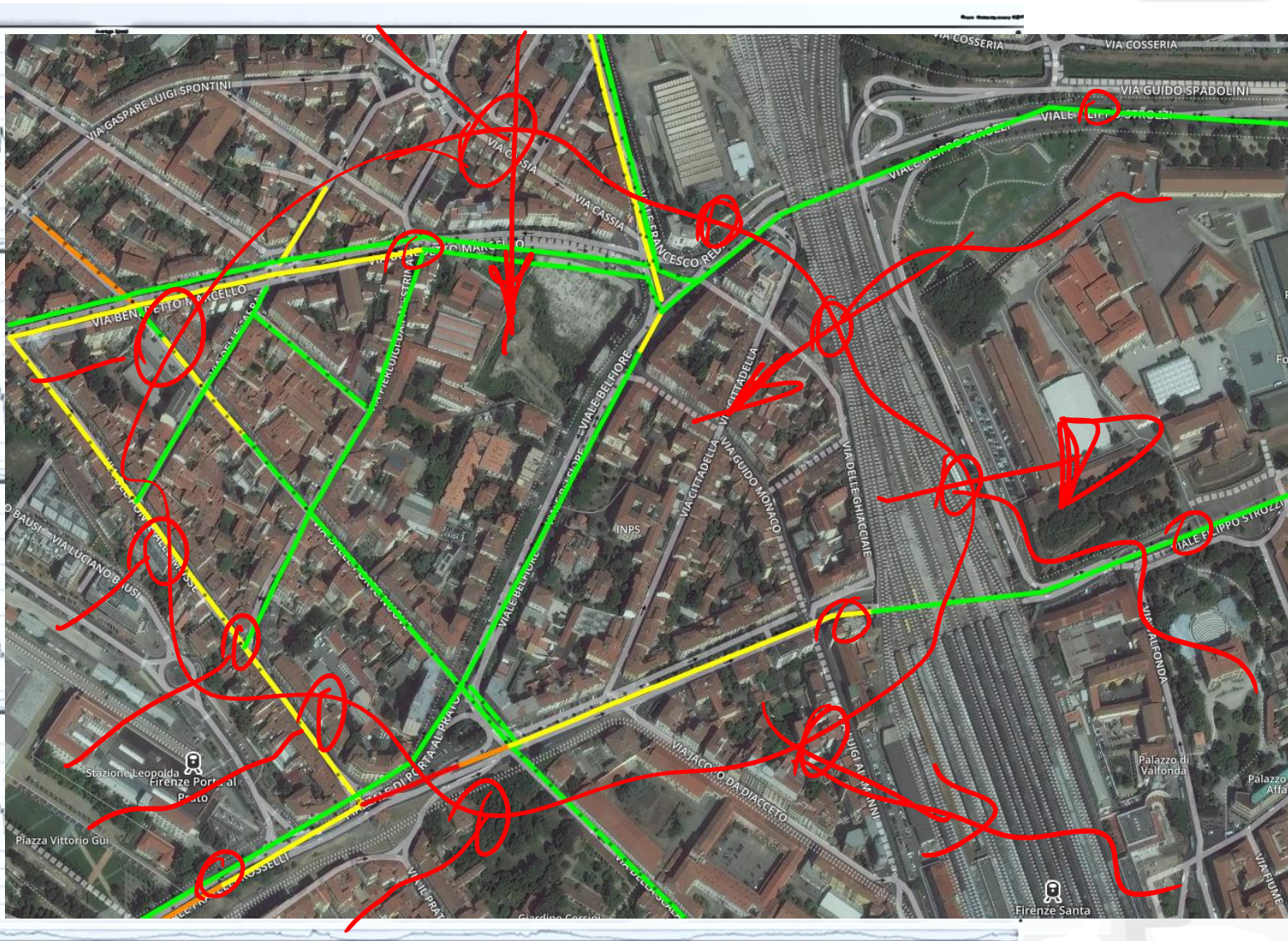
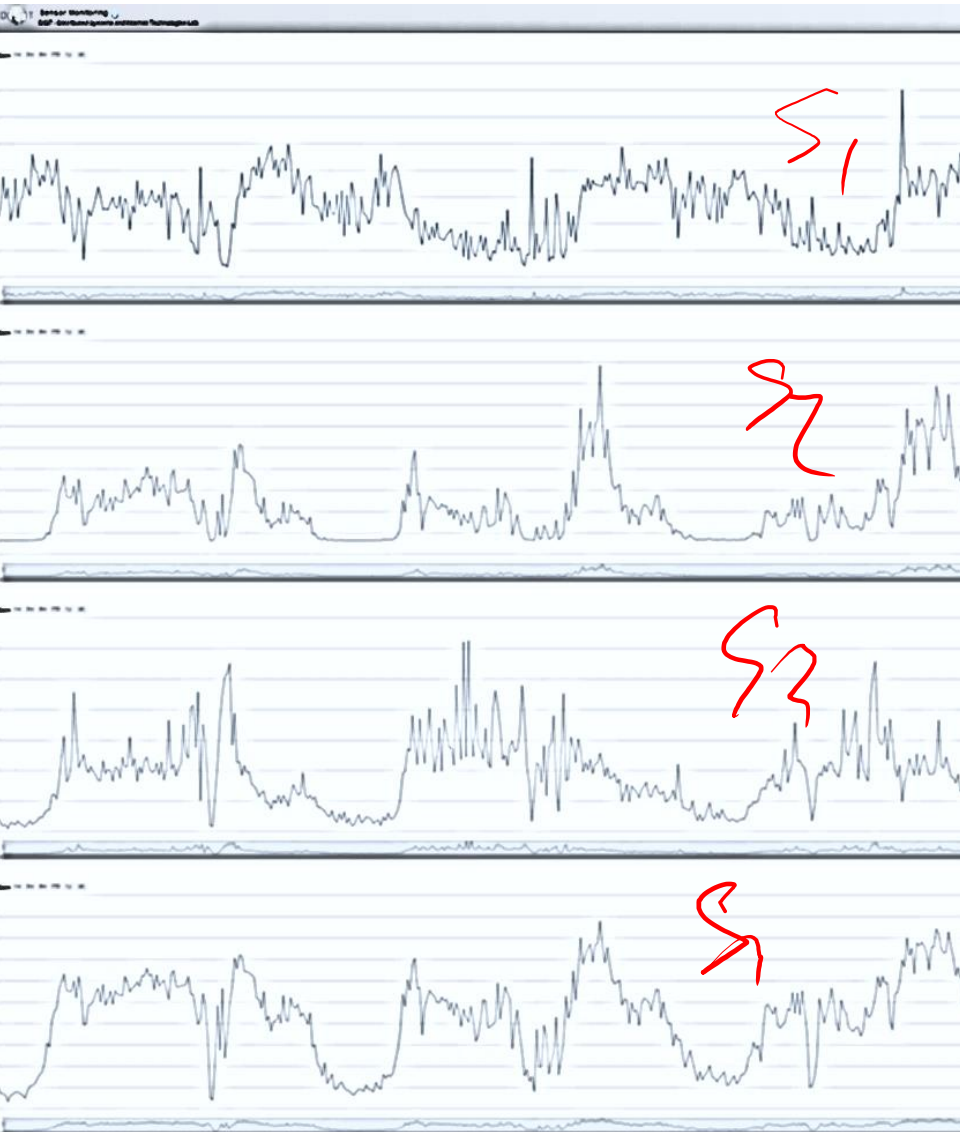
11 SUSTAINABLE CITIES
AND COMMUNITIES



13 CLIMATE
ACTION



Traffic Flow data





Traffic Flow Monitoring - Firenze - Cloned2

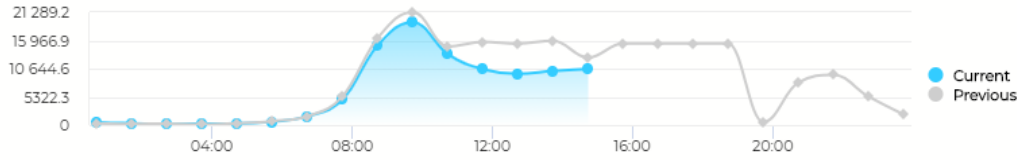
Wed 11 Nov 15:01:32

IN FLOW 9m

Firenze IN Traffic Flow (number of vehicles)

9m

10549 #ofvehicles

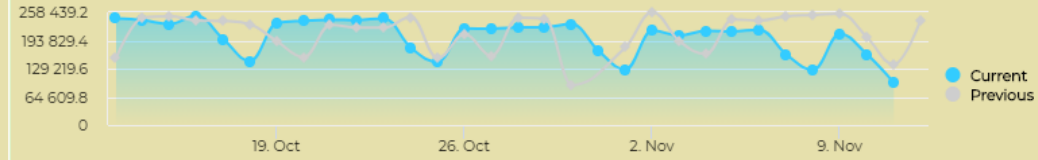


Inc Daily Inp... 9m

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

9m

97137 #ofvehicles

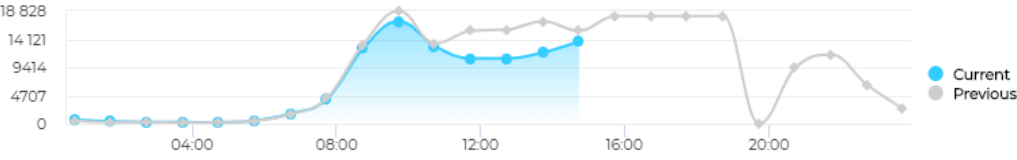


OUT FLOW 9m

Firenze OUT Traffic Flow (number of vehicles)

9m

13720 #ofvehicles

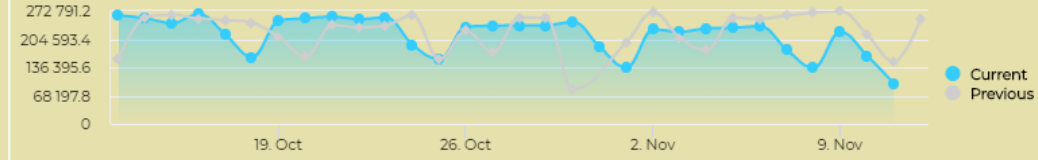


Inc Daily Out... 9m

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

9m

97457 #ofvehicles

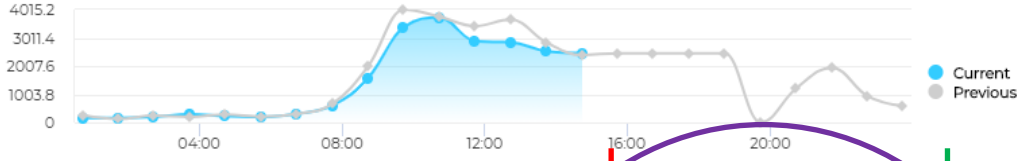


ZTL in 9m

ZTL in Traffic Flow daily trend, entering in ZTL

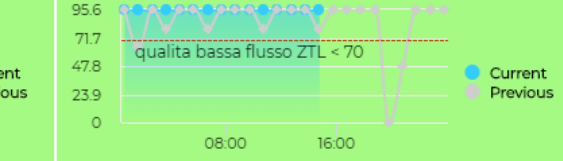
9m

2468 #ofvehicles



QoS as perc. of measures taken

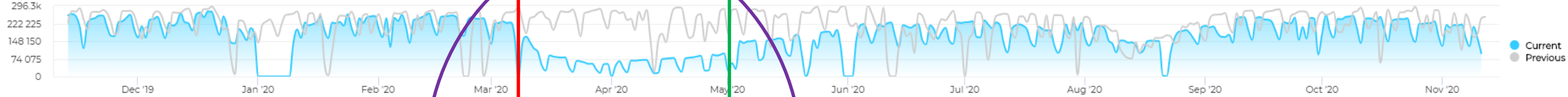
QoS as perc. of measures in ZTL



11/11/2020
15:01:33

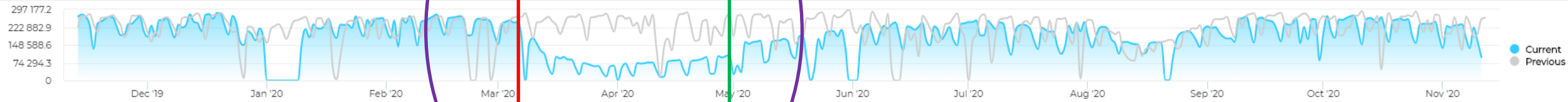
inflow total of the day, yearly

9m



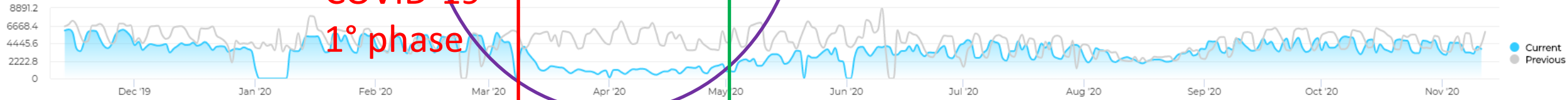
outflow total over the day Yearly

9m



in ZTL yearly compare

9m



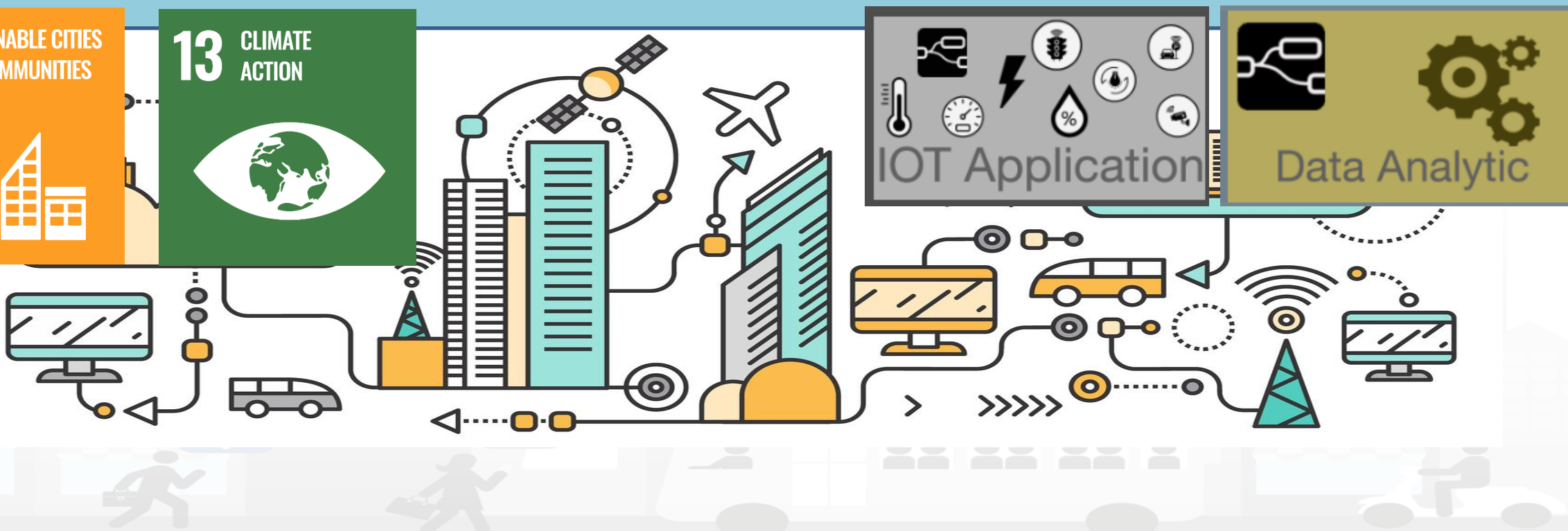
COVID-19
1° phase

Computing CO2 from traffic Data

11 SUSTAINABLE CITIES
AND COMMUNITIES



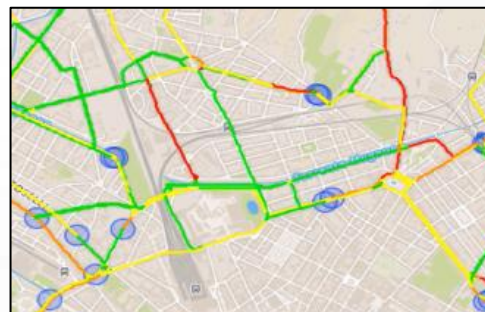
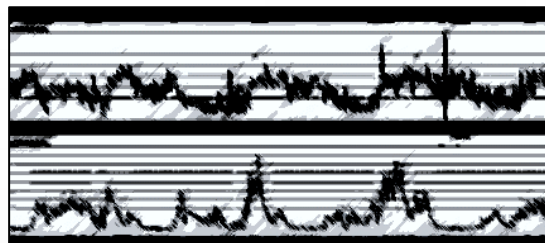
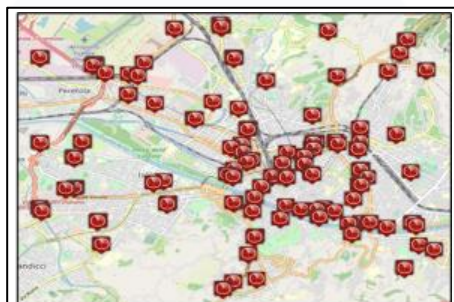
13 CLIMATE
ACTION



Estimating City Local CO2 from Traffic Flow Data



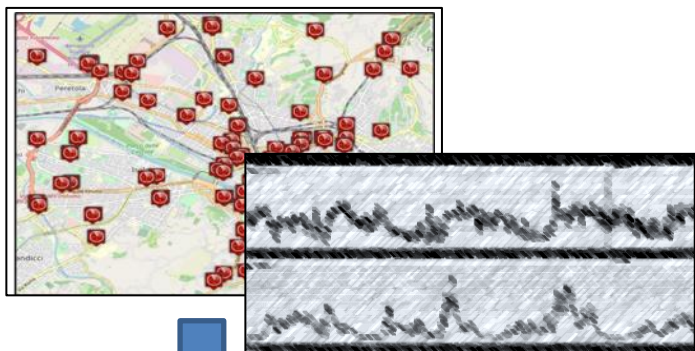
- CO2 sensors are very expensive and thus few



- 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



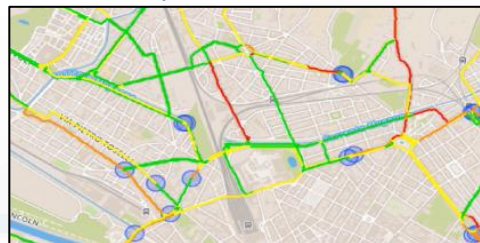
Computing Traffic Flow
into CO2 sensor area

- Traffic Flow is one the main source of CO2
 - 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



Traffic Flow data



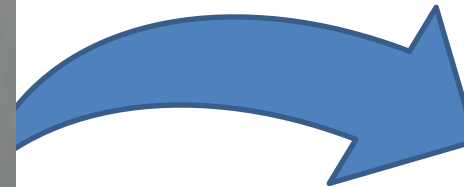
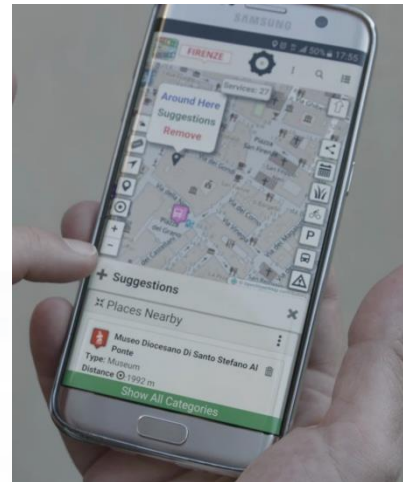
CO2 estimation

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



How much confident is the guess for bus arrival



Customer
satisfaction

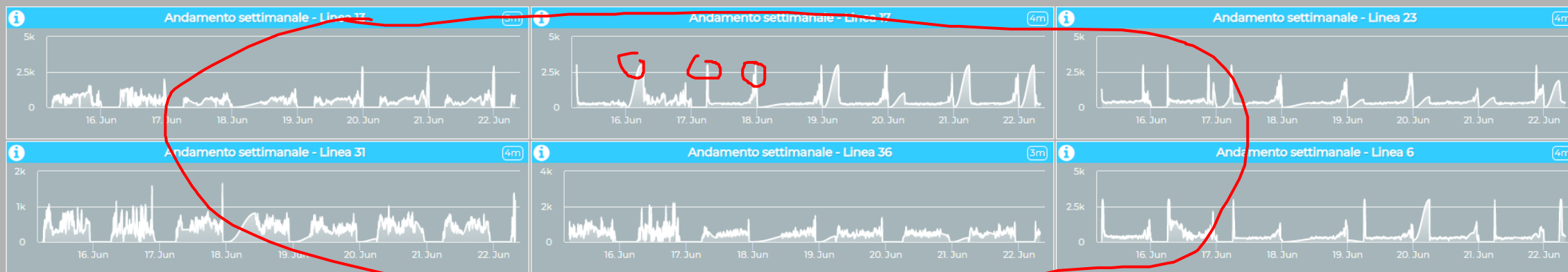
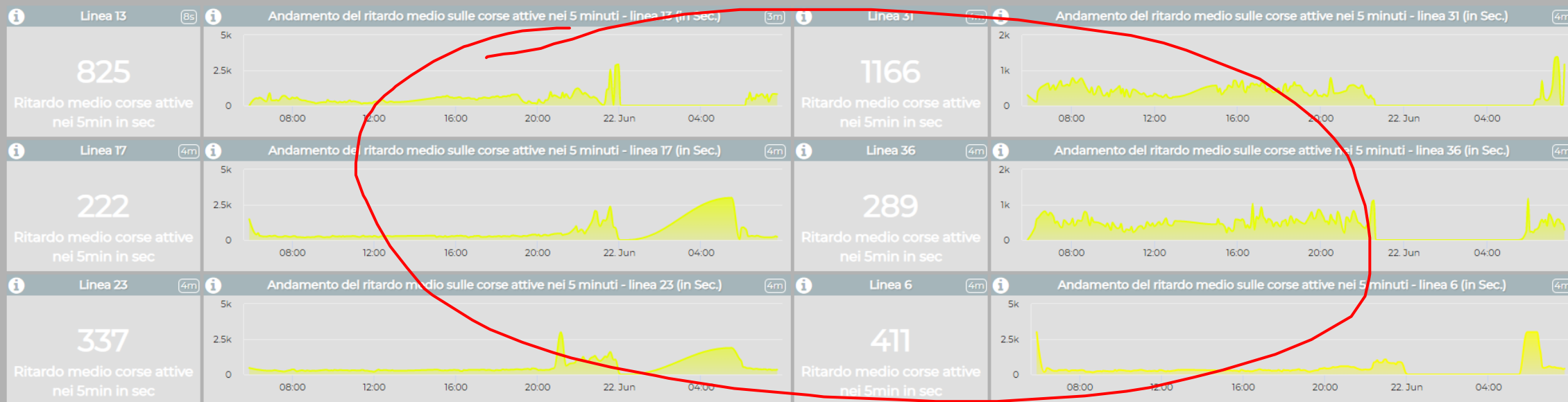


Assessment and
prediction

Qualità Trasporto Pubblico - Cloned

Firenze - 6 linee

Sat 22 Jun 07:45:48





Firenze Oggi



Sun 20 Oct 23:35:33

26976

Totale utenti WIFI

COLONNINE RICARICA... ^{9m}

176 INSTALLATE

71 % ATTIVE

5.1 % IN USO

GENERAL **METEO** ^{9m}

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

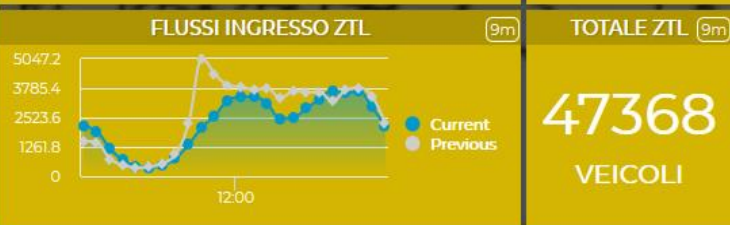
Energy

Environment

Mobility

Social

Resilience



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 risoluzione... ^{119m}	
1116 ultimo mese	524	305	285	
Manutenzioni Stradali ^{59m}	Verde Pubbl... ^{59m}	Decoro Urbano ^{59m}	Relitti ^{59m}	
6 oggi	3	5	0	

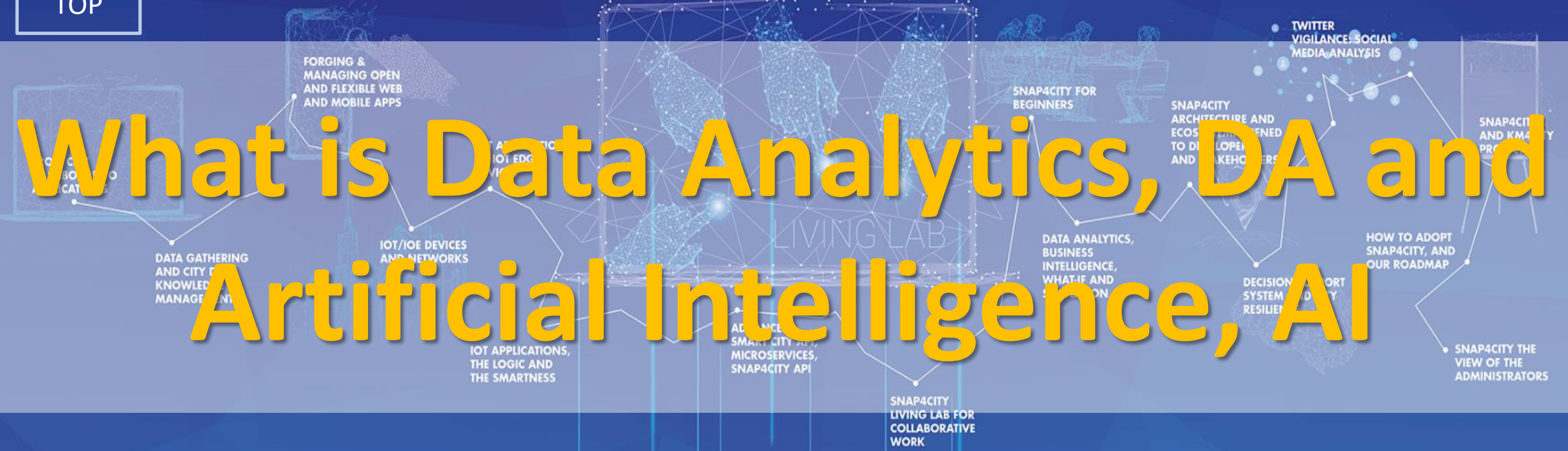
Attesa media alla fermata

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

Florence

TOP

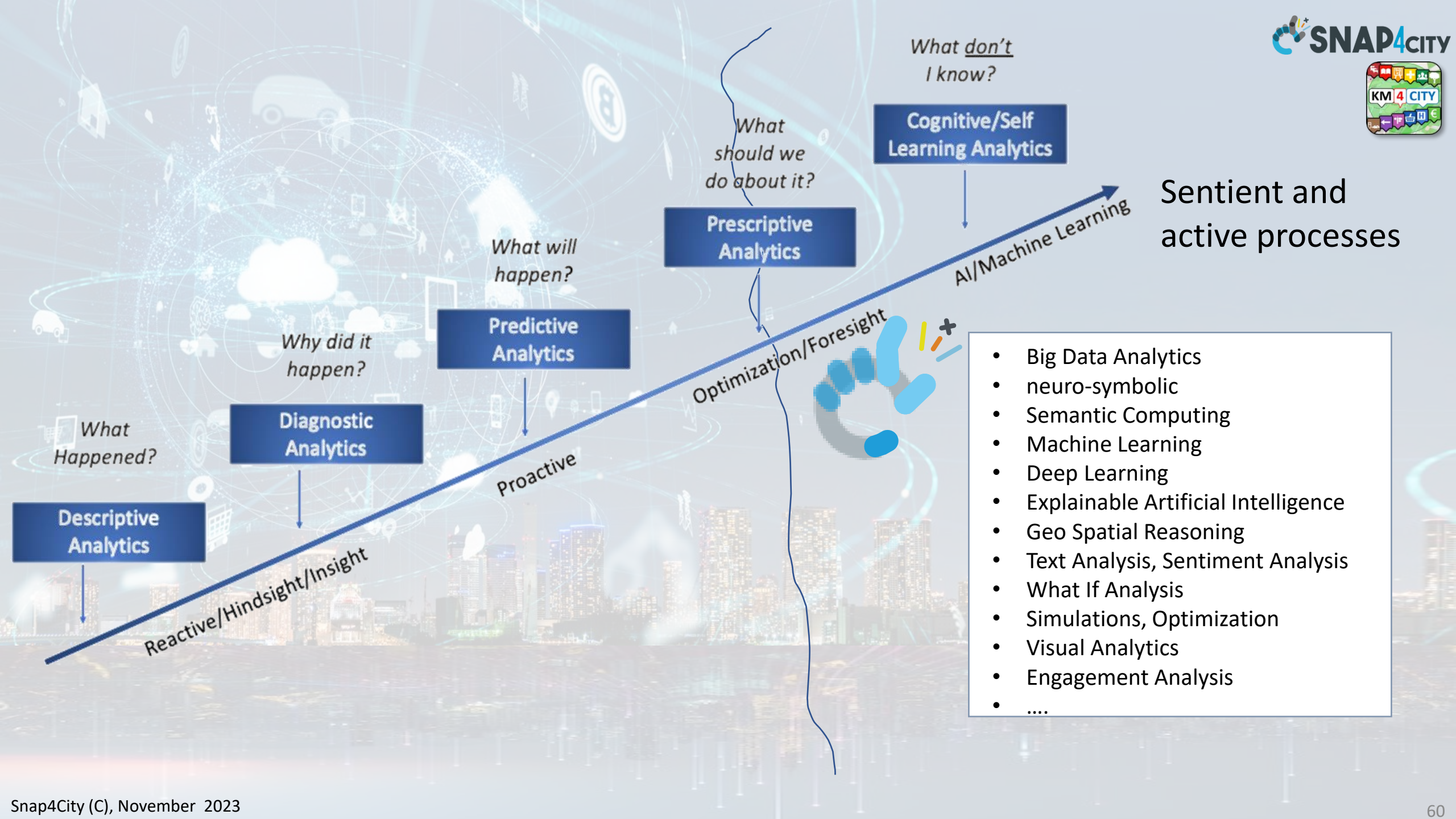
What is Data Analytics, DA and Artificial Intelligence, AI



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.*





What Happened?

Descriptive Analytics

Reactive/Hindsight/Insight

Why did it happen?

Diagnostic Analytics

What will happen?

Predictive Analytics

Proactive

What should we do about it?

Prescriptive Analytics

Optimization/Foresight

What *don't* I know?

Cognitive/Self Learning Analytics

AI/Machine Learning

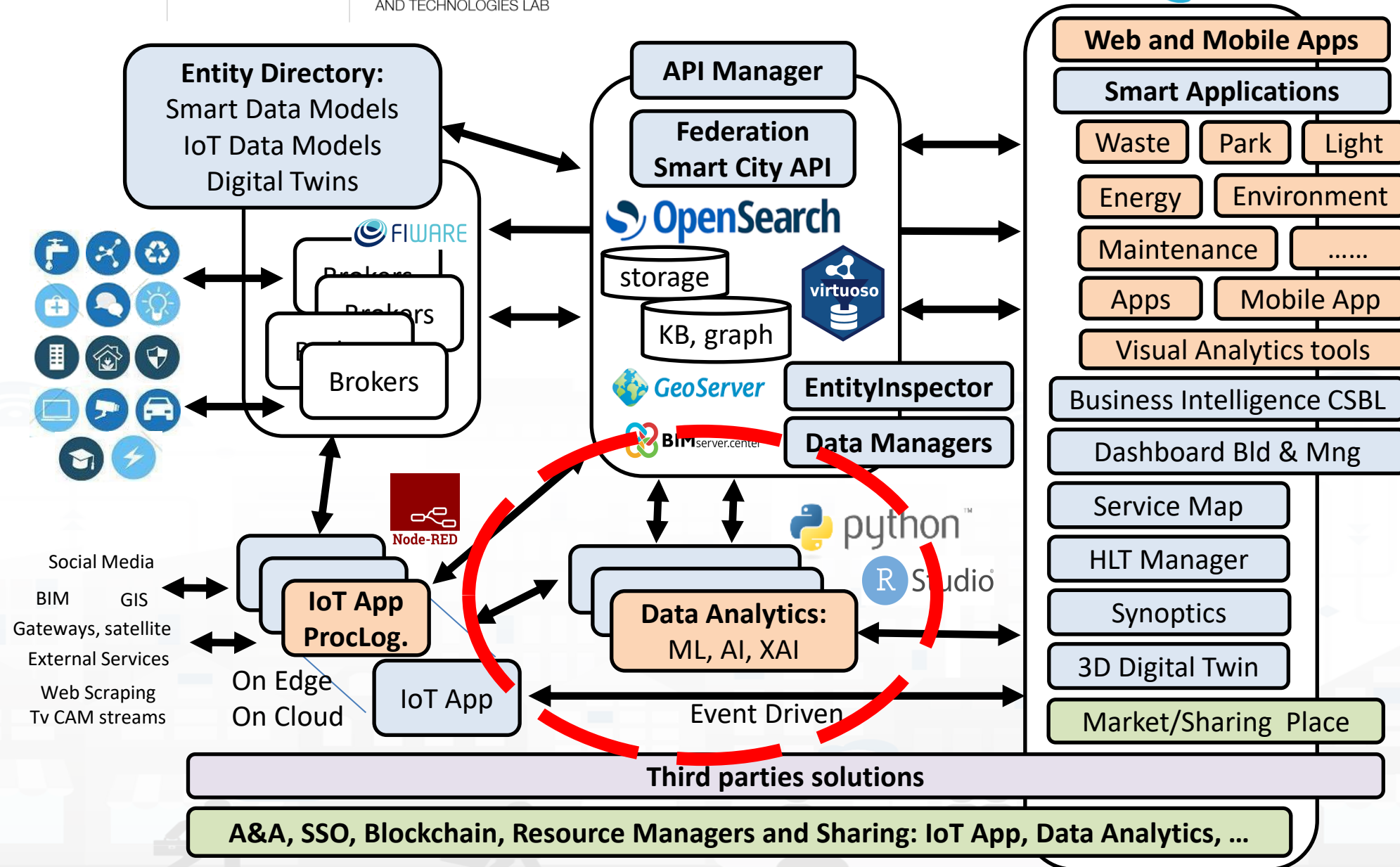
Sentient and active processes

- Big Data Analytics
- neuro-symbolic
- Semantic Computing
- Machine Learning
- Deep Learning
- Explainable Artificial Intelligence
- Geo Spatial Reasoning
- Text Analysis, Sentiment Analysis
- What If Analysis
- Simulations, Optimization
- Visual Analytics
- Engagement Analysis
-

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
 - → 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.*

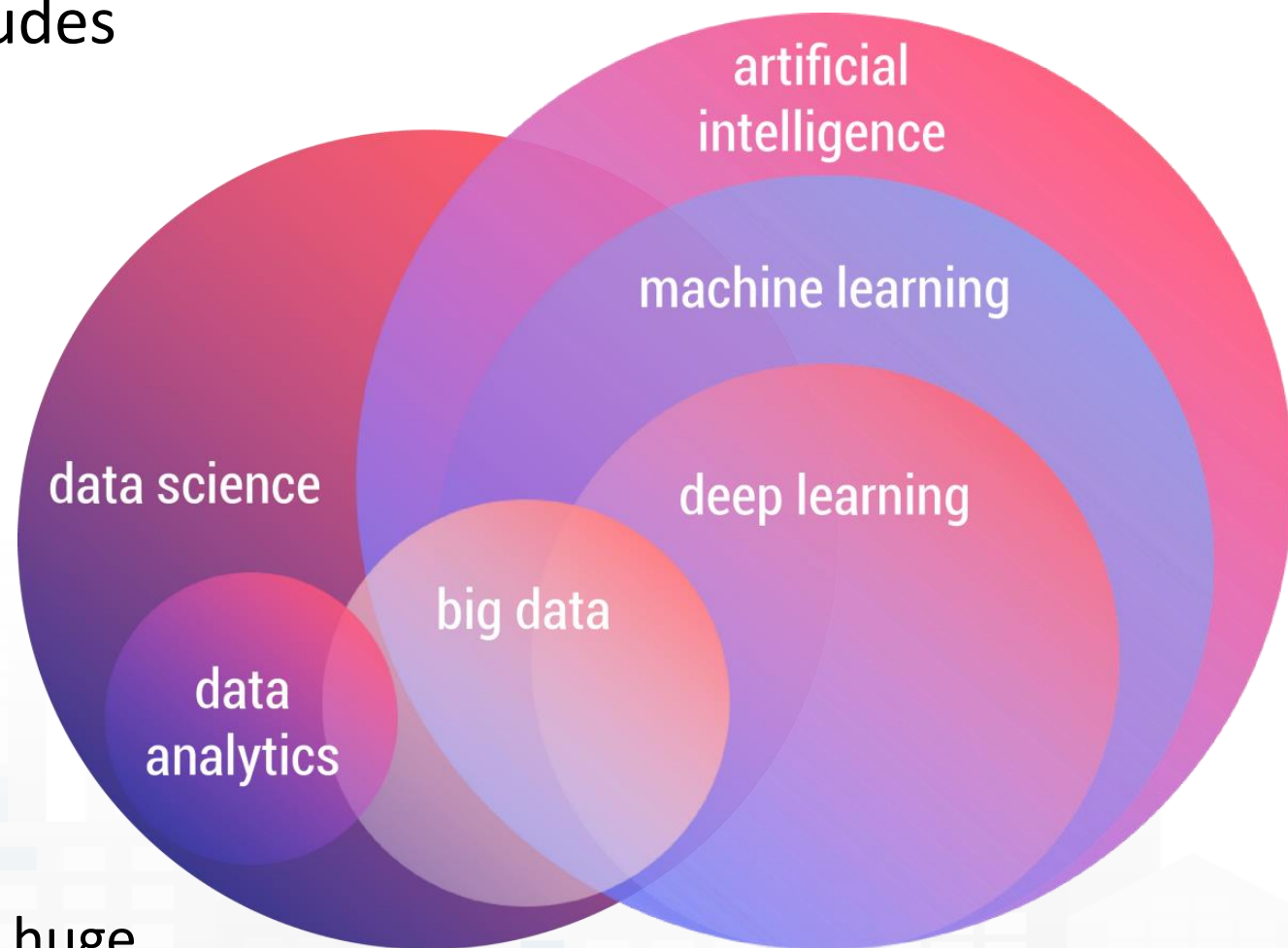




Snap4City and DA and AC (summary)

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

- **Artificial Intelligence** usually also includes
 - Code, learn 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
 - 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
- **What-IF analysis** (simulation + predictions + data + scenarios)
- **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
 - reasonable results with the accessible data
 - the reasonable and cheers results 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 DA / AI Solutions on Snap4City

- **Mobility and Transport**
- **Environment, Weather, Waste, Water**
- **City Users Behaviour and Social analysis**
- **Energy and Control, Security,**
- **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/course/p4/>



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

Mobility and Transport

- **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)
- **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)
- 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 Weather

- **Pollutant Predictions: short, long and very long term** European Commission KPIs
 - NOX, PM10 pollution on the basis of traffic flow, 48 hours (ML, AI, DL)
 - Cumulated NO2 average value over the 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)
- **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)
- Optimisation of **waste collection** schedule and paths (DP, ML)
- Computing **SDG, SUMI, PUMS**, .. (mainly DP)
- Etc.

City Users Behaviour, Safety, Security and Social Analysis

- **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.

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 Photovoltaic 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.

Energy and Control, Security

- **Smart Light Solutions:** monitoring luminaries, profiling luminaries, managing error conditions (DP)
- Design by Simulation of **Photovoltaic Plants:** using real statistical data from the area (ML, Dp)
- **Energy Community:** Energy Districts (in Italy, CER) (ML, DP)
 - Monitoring, design and simulation of energy community
- Monitoring and controlling **recharging stations, recharging poles**
- Monitoring **energy production and consumption** over: plant, building, floors, offices, server rooms, etc.
- Monitoring **healthiness of Smart City Network of devices**
- Monitoring **critical areas** for: people, traffic, boats, etc.
- Etc.

High Level Decision Support Systems

• Management and strategies

- Estimation of KPI and local indexes
- Anomaly detection and **Early warning** computation
- **What-if analysis**, dynamic routing, origin destination matrices production from a large range of sources
- **Planning and Monitoring** renovation works via objective KPIs
- **Managing Maintenance** and teams
- **Predictive Maintenance** and costs predictions: chemical plant, vehicles, boats

• Resilience and Risks Analysis

- **Resilience analysis** wrt European Guidelines on Resilience of critical infrastructure, and transport systems
- **Risk analysis**: natural and non natural disaster

Low level Techniques

• Time Series

- Time Series Anomaly detection: any kind
- Data quality assessment and control: any kind
- short and long term prediction: any kind
- Interpolation/extrapolation of Data on regular grid for calibrated heatmaps

• Semantic Reasoning

- Ontology Modelling and integration, expert system construction
- Knowledge modelling and reasoning on RDF stores: spatial, temporal, relational

• Matrices, Images, Maps and 3D Digital Models

- Conversion of Satellite data images into regular ground images
- Extraction information from Orthomaps, LIDAR, etc., regarding city structures
- 3D Digital Twin of Cities and Objects: pattern extraction, 3D model reconstruction



• **15 Minute City Index:**

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



- Monitoring and Prediction of energy consumption
- Stimulating: Bike sharing, e-bikes, car charge, etc.



- Industry 4.0 integrated solutions
- Decisions Support Systems
- Process optimization, control
- Predictive maintenance



- Smart City infrastructure: monitoring and resilience, long terms predictions
- Effective and Low cost smart solutions
- What-if analysis, Simulations
- Origin Destination matrices computation



- business intelligence tools for decision makers
- Reduction production costs
- Monitoring resource consumption
- Optimization of Waste Collection



- Monitoring and Predicting: NO2, NOX, CO2, Traffic flow, pollutant, landslide, waste, etc
- Traffic flow reconstruction
- Demand vs Offer of Mobility analysis



- Shortening justice time
- Anonymization and indexing legal docs.
- Prediction of mediation proneness
- Ethical Explainable Artificial Intelligence

	Antwerp					Helsinki								Where					Main Data Sources
	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		
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		POI, OSM	
Routing: pedestrian				X	X			X	X	X	X	X		X				OSM	
Routing: pedestrian quite				X	X			X	X	X	X	X		X				OSM	
Routing: private vehicles	X		X	X		X		X	X	X	X	X		X	X			OSM	
Routing: Multimodal Public Transport				X				X	X	X	X	X		X		X		OSM, GTFS	
heatmaps: weather (Temp, Humidity)	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	Sensors data, OSM	
heatmaps: environmental variables, Noise						X	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	Enfuser data	
heatmaps piking values any place	X	X			X	X	X		X	X	X	X					X	Computed Heatmps	
heatmaps: GRAL prediction, PM10						X	X		X	X	X	X		X			X	OSM, Traffic, Weather	
Comparsion: Enfuser, Gral, Real Time						X	X										X	Enfuser, Sensors, GRAL	
Sensors Data Time Trends, & drill down	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	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	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	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		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

- **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

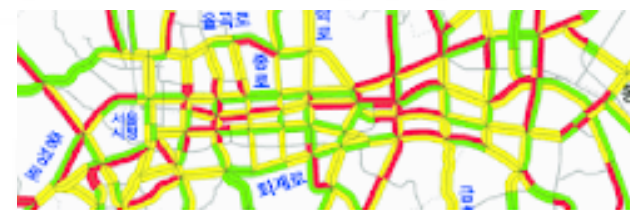
Tactics/strategy

Why Computing Predictions

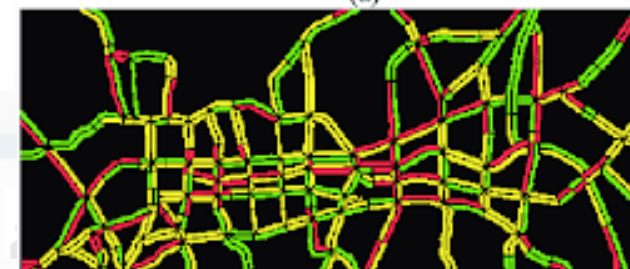
- if I know how many people will attend an event
 - I can **detect anomalies** earlier if an unexpected event will occur, intervene
 - I can **organize** better services, cleaning and preventive security
 - I can **inform, mitigate, plan, save money and time**, etc.
- Other Cases:
 - **Traffic** → pollutant, 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
 - Etc.
- **→ Anomaly Detections**



(a)



TOP

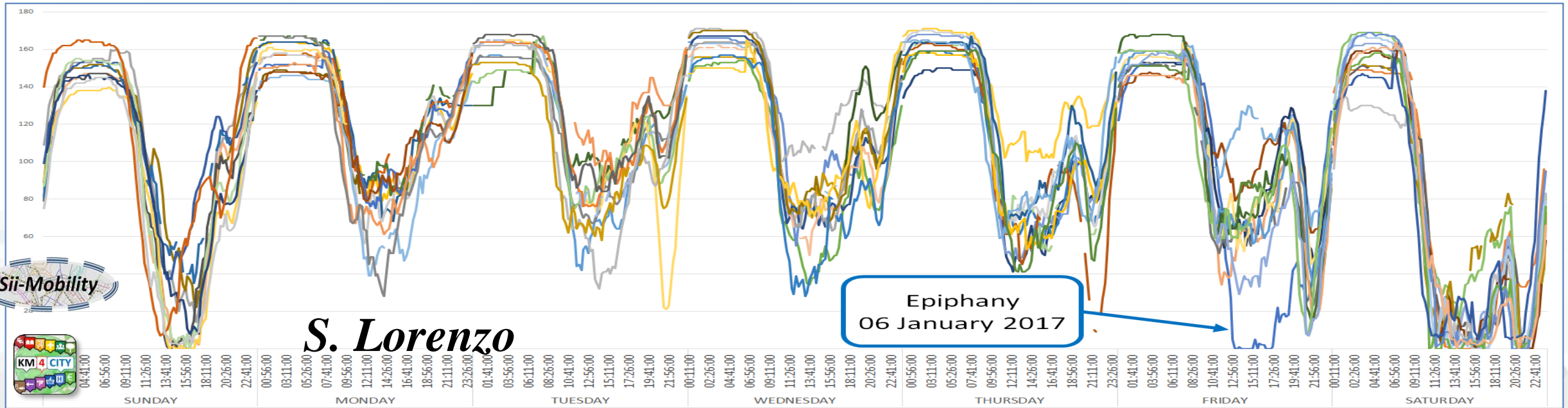
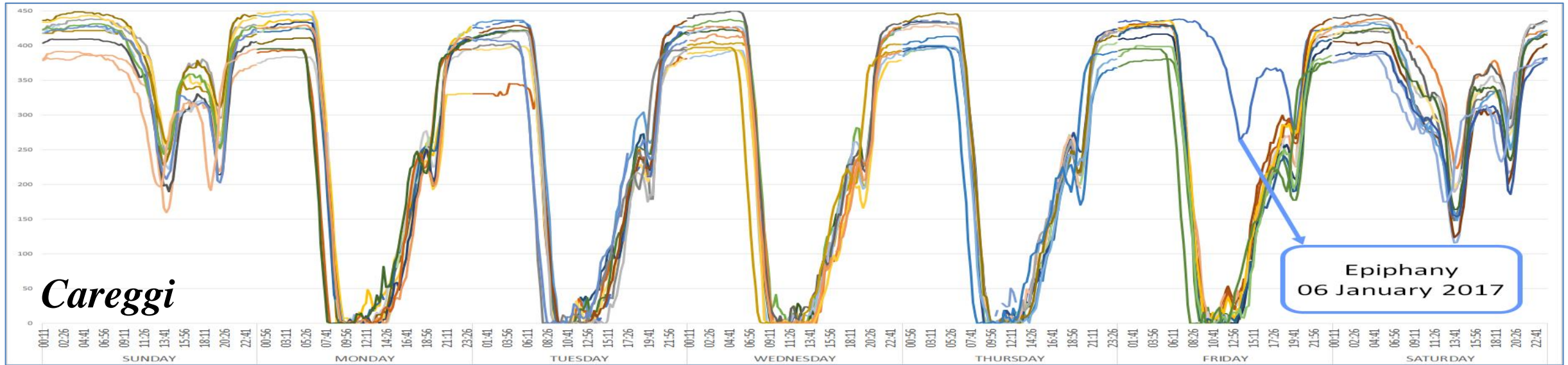
Smart Parking: free slots predictions



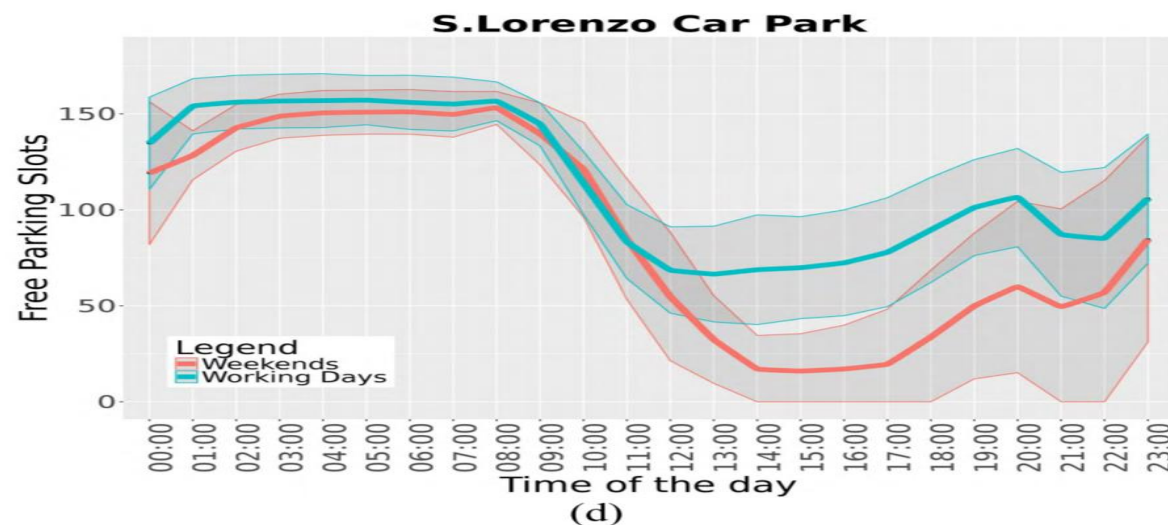
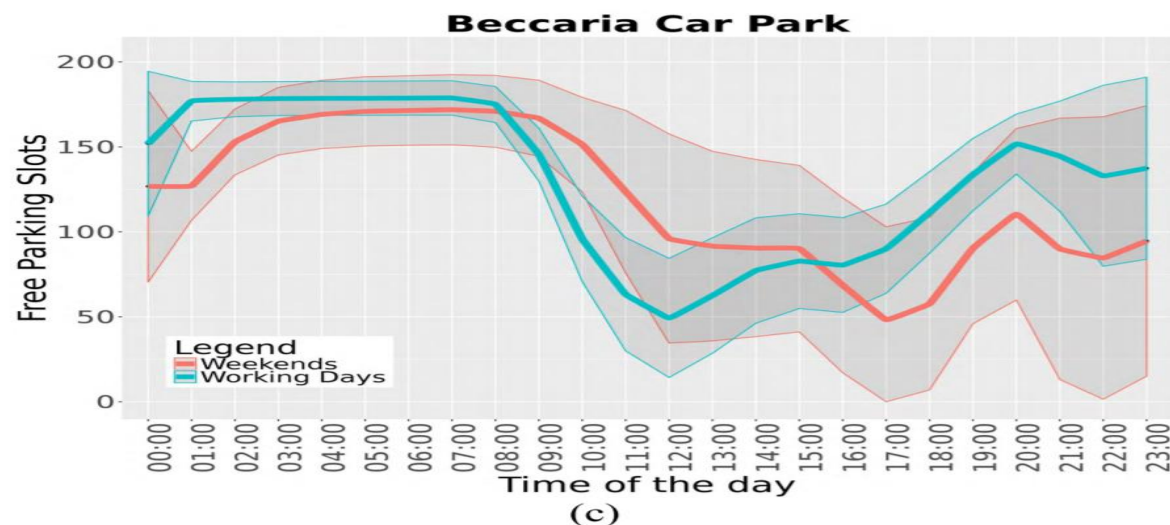
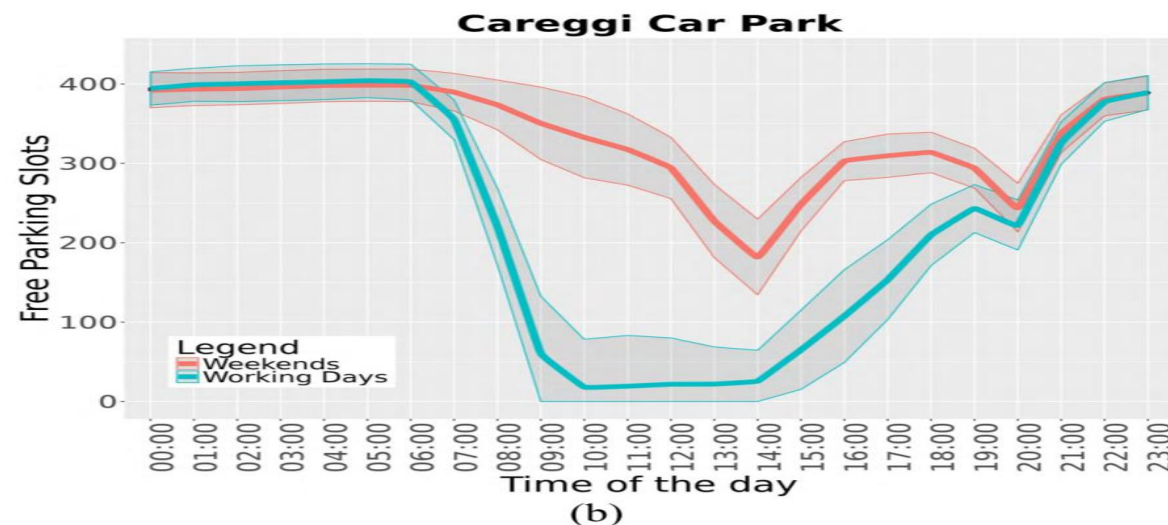
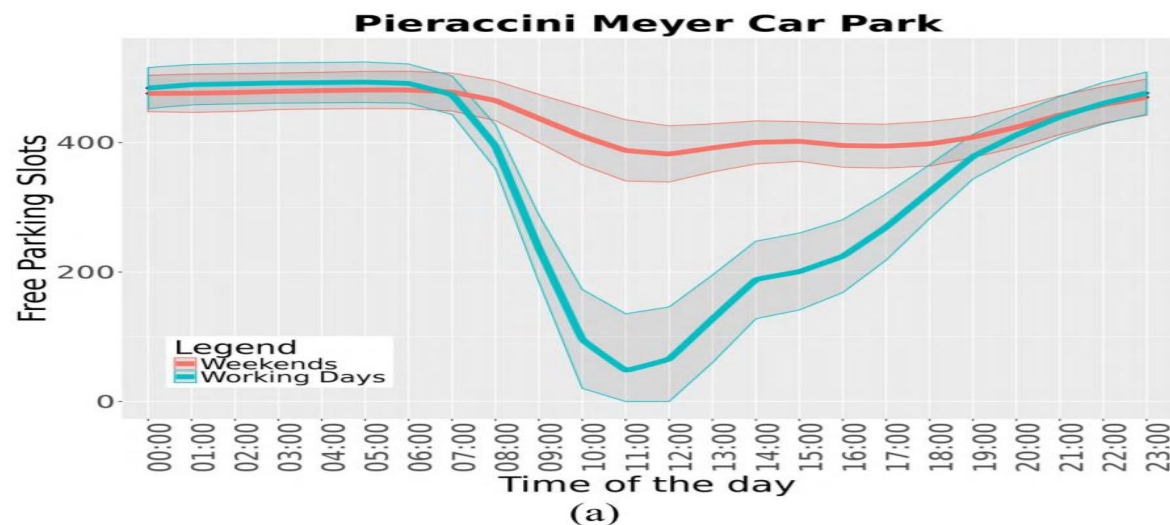




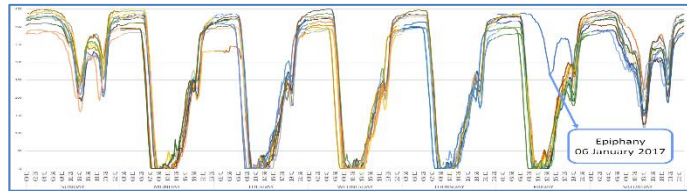
Free Parking space trends



Free Parking space trends



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 $(i - 15 \text{ minutes})$ recorded in the previous week
Weather features	Subsequent observation's difference (SOD)	Difference between the number of free spaces at time i , and the number of free spaces at time $(i + 15 \text{ minutes})$ recorded in the previous week
	Temperature	City temperature measured one hour earlier than Time ($^{\circ}\text{C}$)
Traffic Sensors features	Humidity	City humidity measured one hour earlier than Time (%)
	Rainfall	City rainfall measured one hour earlier than Time (mm)
	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

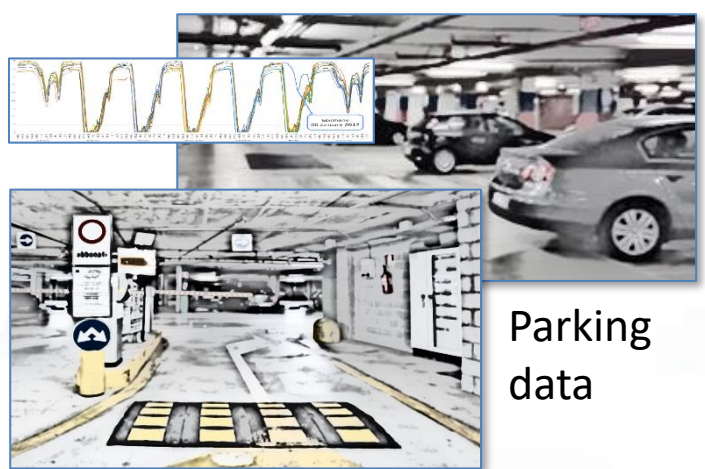


Artificial Intelligence Predictions

97% of precision



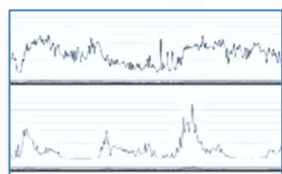
Deep Learning AI to surely Park!



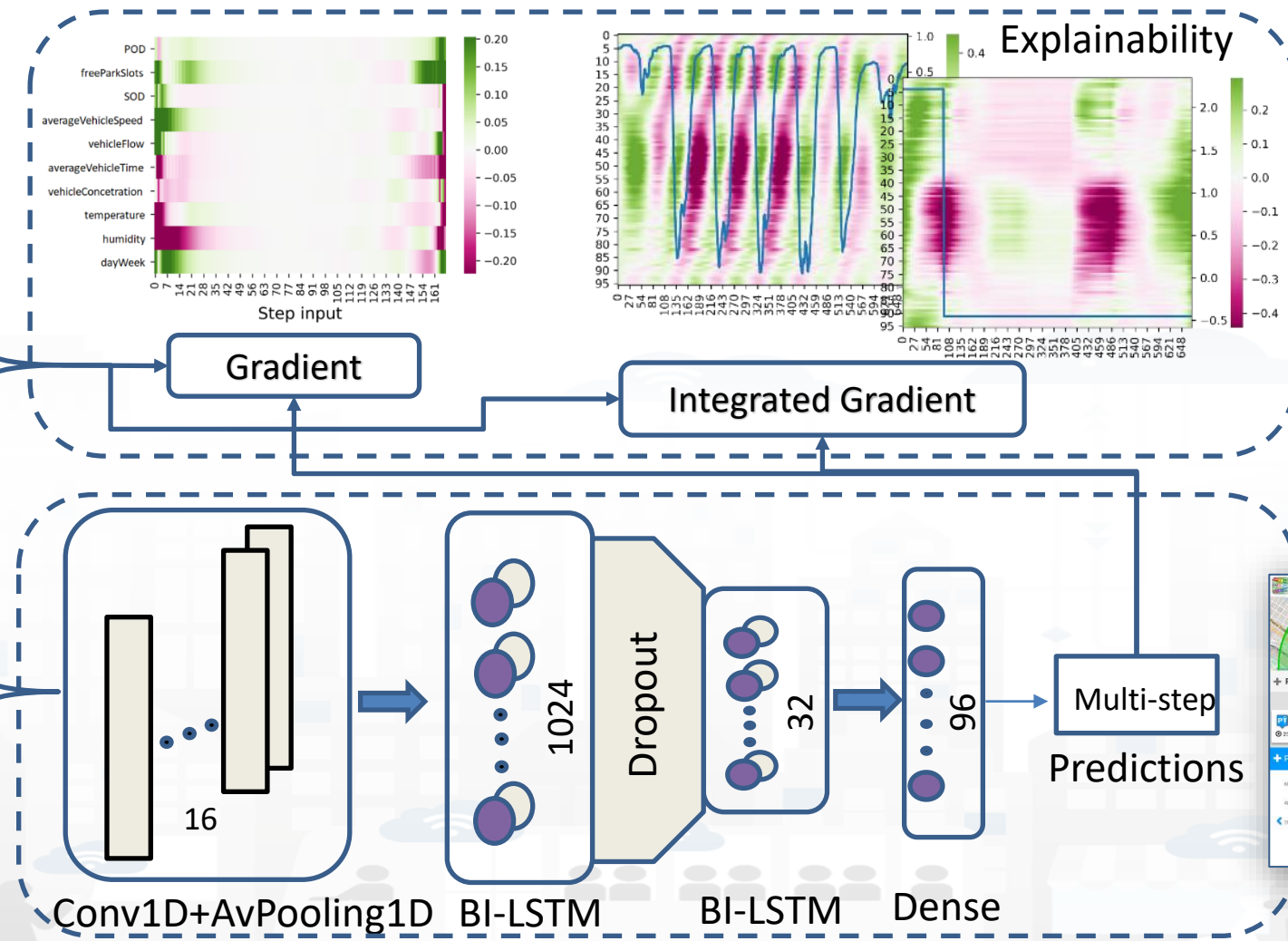
Parking data



Traffic sensors data



Weather Features

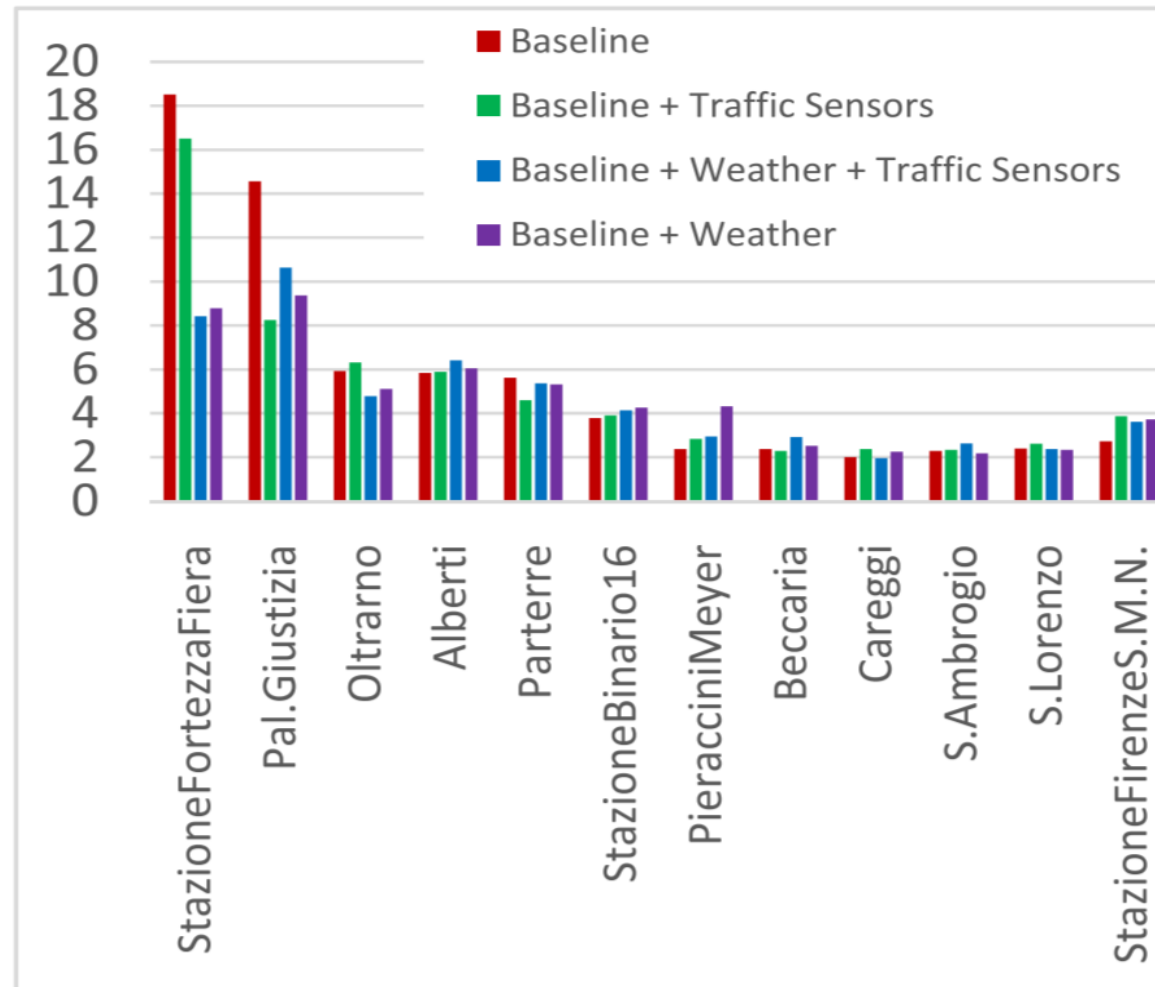


Free Parking PREDICTIONS



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
<i>Careggi car park</i>			
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
<i>Pieraccini Meyer car park</i>			
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
<i>S. Lorenzo car park</i>			
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
<i>Beccaria car park</i>			
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



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 compromise

Active on Mobile Apps as:

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

Precision: 97,5%

Smart Bike

Free Bike predictions

11 SUSTAINABLE CITIES
AND COMMUNITIES



13 CLIMATE
ACTION



Bike Sharing

– Pros:

- Eco-friendly
- Prevent traffic congestions
- Reduce the probability of social contacts in public transports
- Regular bikes or e-bikes

– Problems:

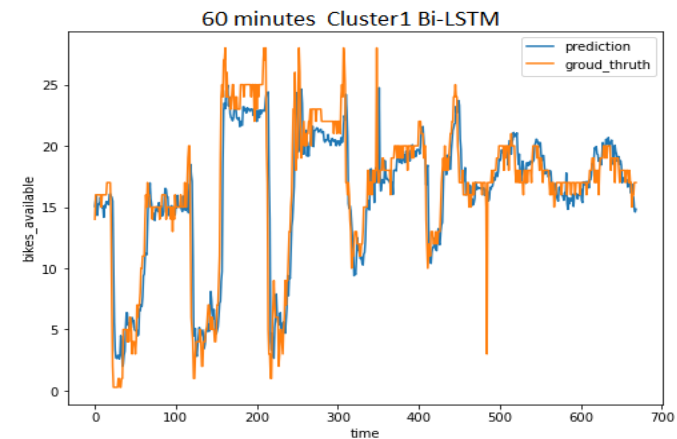
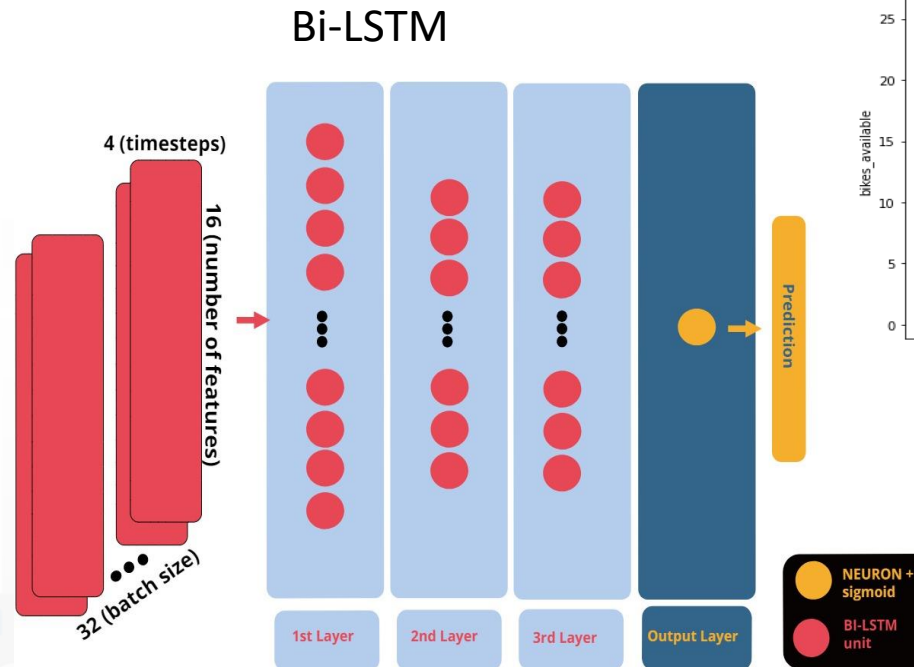
- Irregular distribution of bikes on racks/areas
- Difficulty of knowing in advance their status with a certain degree of confidence
 - available bikes at a specific bike-station
 - free slot for leaving the rented bike



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

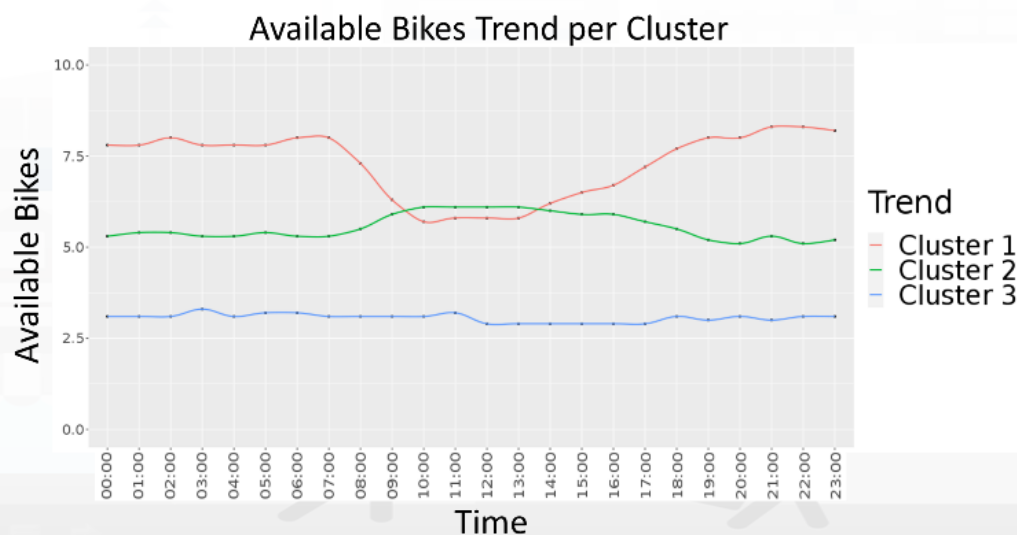
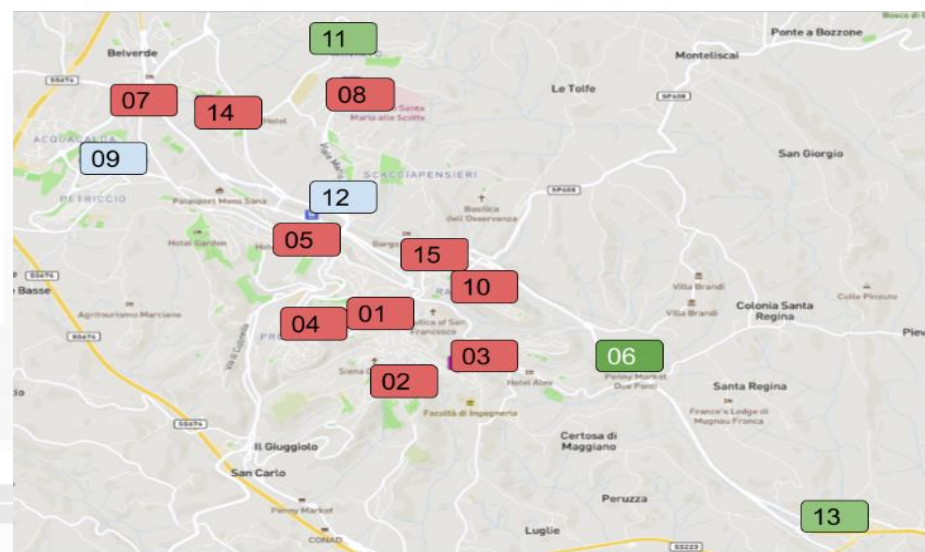


Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations



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>

- 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**



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 or 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	

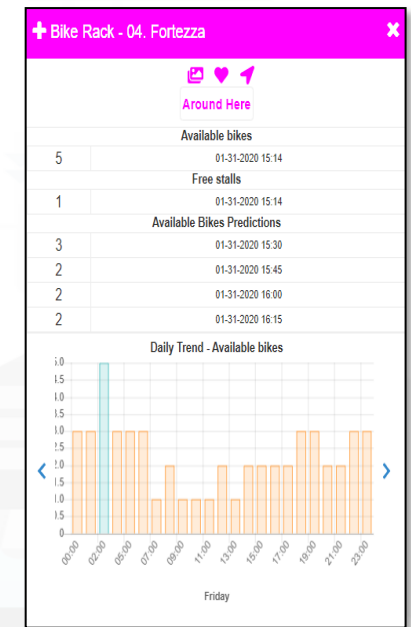
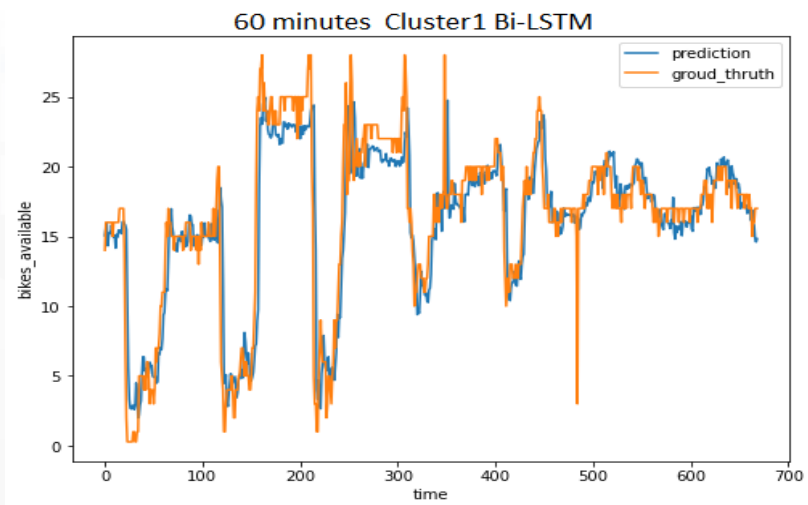
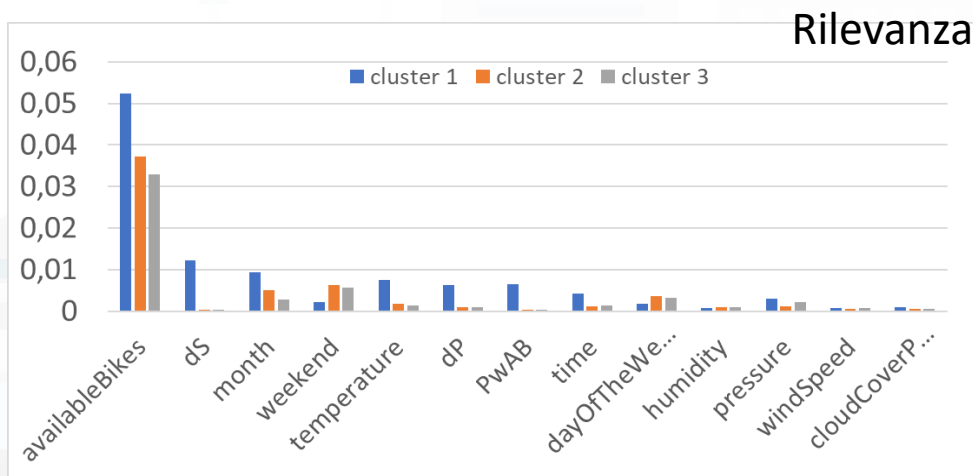
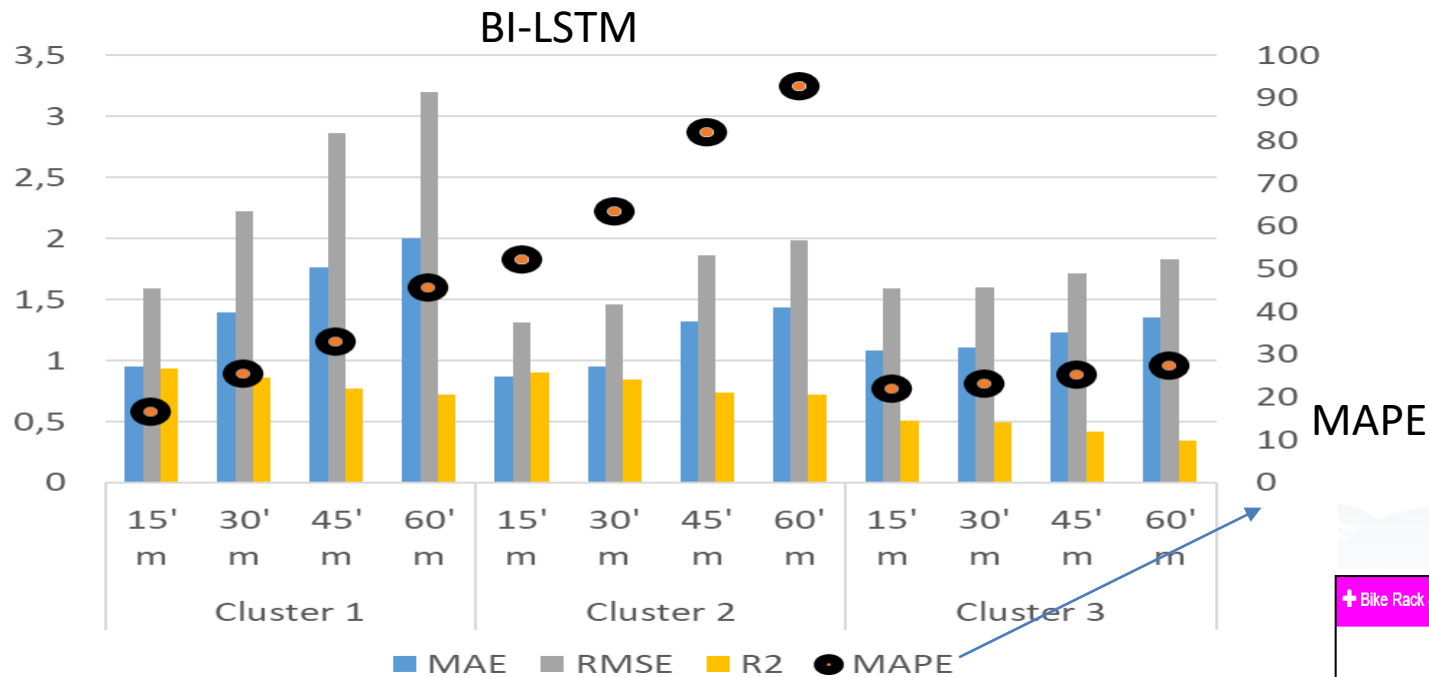
Analysis of the state of the art (Phase)

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	<u>ThessBike</u>	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 riders	Number of riders, Season, year, month, hour, day, holiday, weekday, working, weather	Rental Company	DNN	80% accuracy		

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

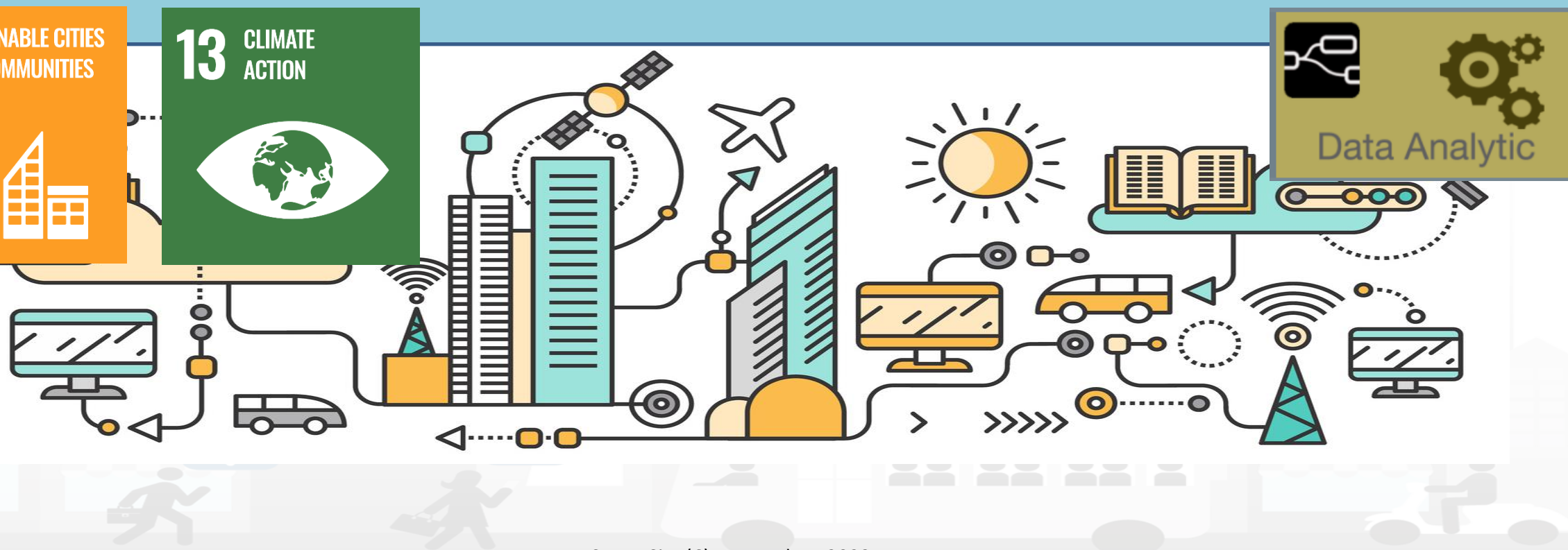


Traffic Flow Prediction

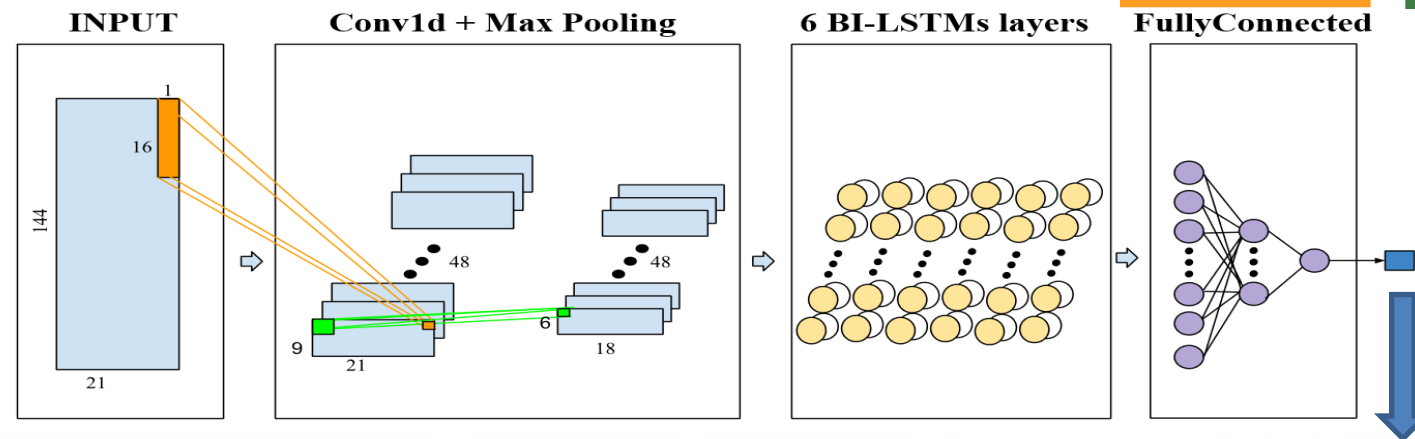
11 SUSTAINABLE CITIES
AND COMMUNITIES



13 CLIMATE
ACTION



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



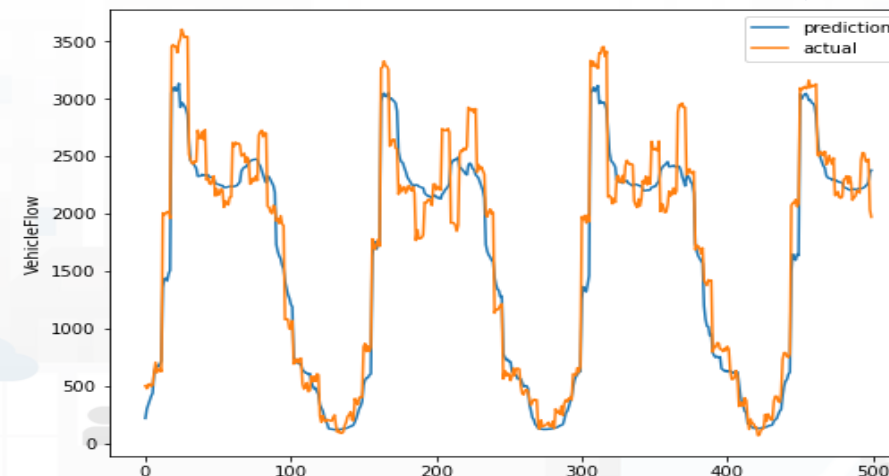
Urban data:

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



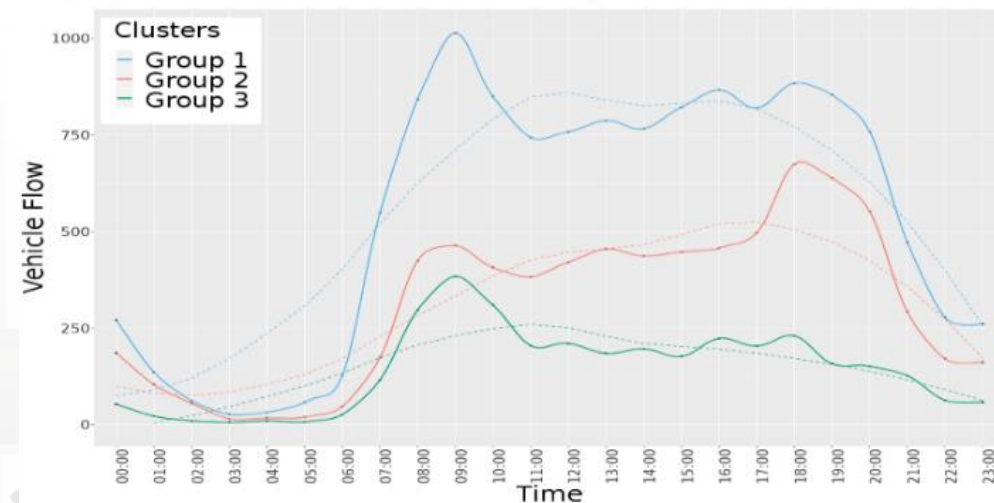
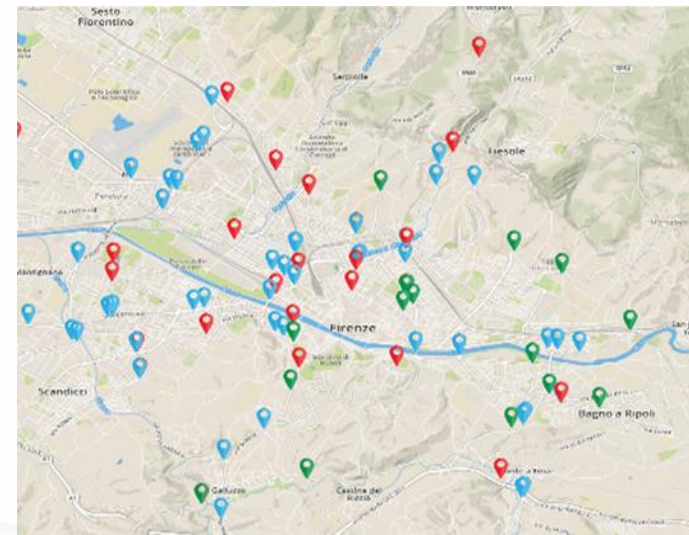
- RF
- XGBOOST
- DNN
- LSTM
- BI-LSTM
- Autoencoder BI-LSTM
- Attention CONV-LSTM
- CONV-BI-LSTM

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 compromise

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	40,862	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	41,912	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	49,386	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	35,049	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

Processing time	Training execution		Prediction execution (s)
	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 compromise

1-48 Hour prediction of NOx

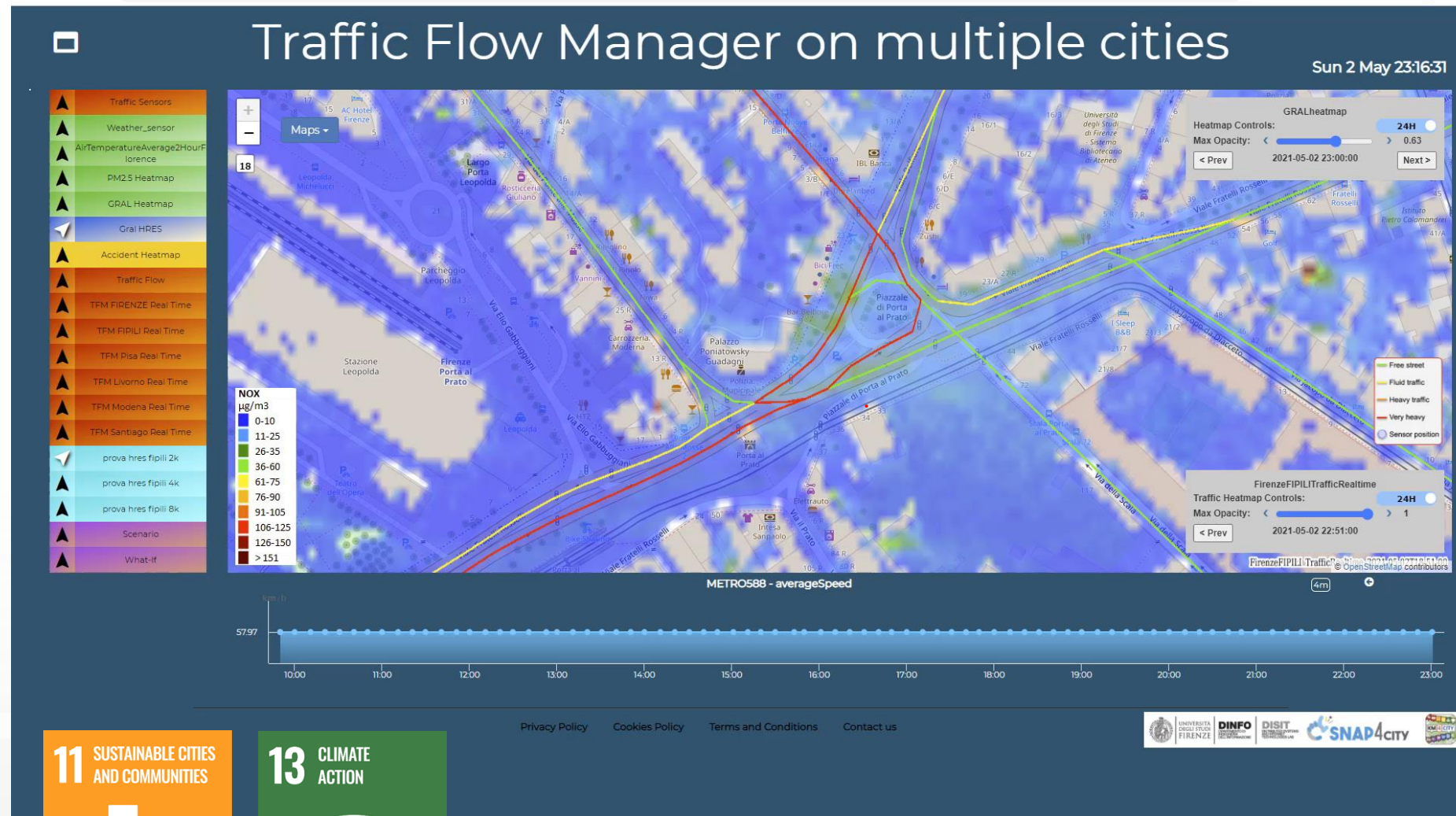


- **Prediction**

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

- **Project:**

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

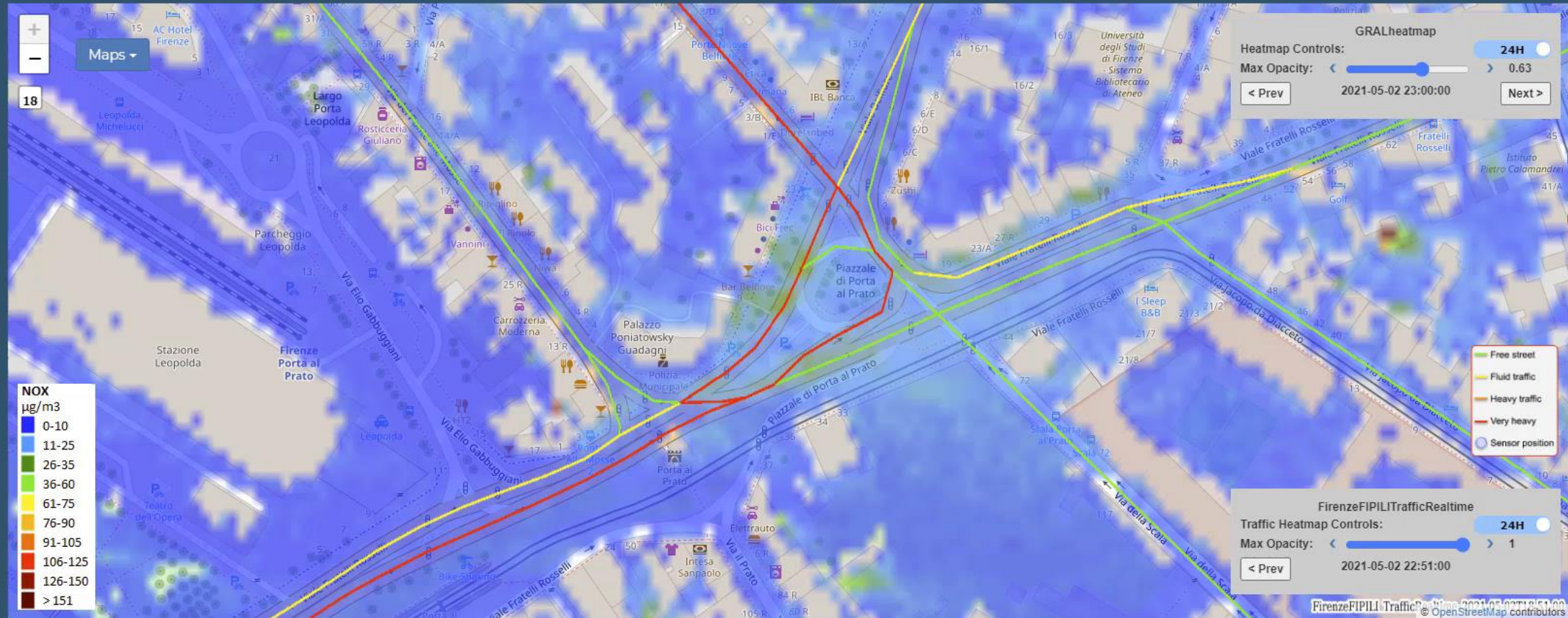




Traffic Flow Manager on multiple cities

Sun 2 May 23:16:31

- Traffic Sensors
- Weather_sensor
- AirTemperatureAverage2HourFlorence
- PM2.5 Heatmap
- GRAL Heatmap
- Gral HRES
- Accident Heatmap
- Traffic Flow
- TFM FIRENZE Real Time
- TFM FIPILI Real Time
- TFM Pisa Real Time
- TFM Livorno Real Time
- TFM Modena Real Time
- TFM Santiago Real Time
- prova hres fipili 2k
- prova hres fipili 4k
- prova hres fipili 8k
- Scenario
- What-if

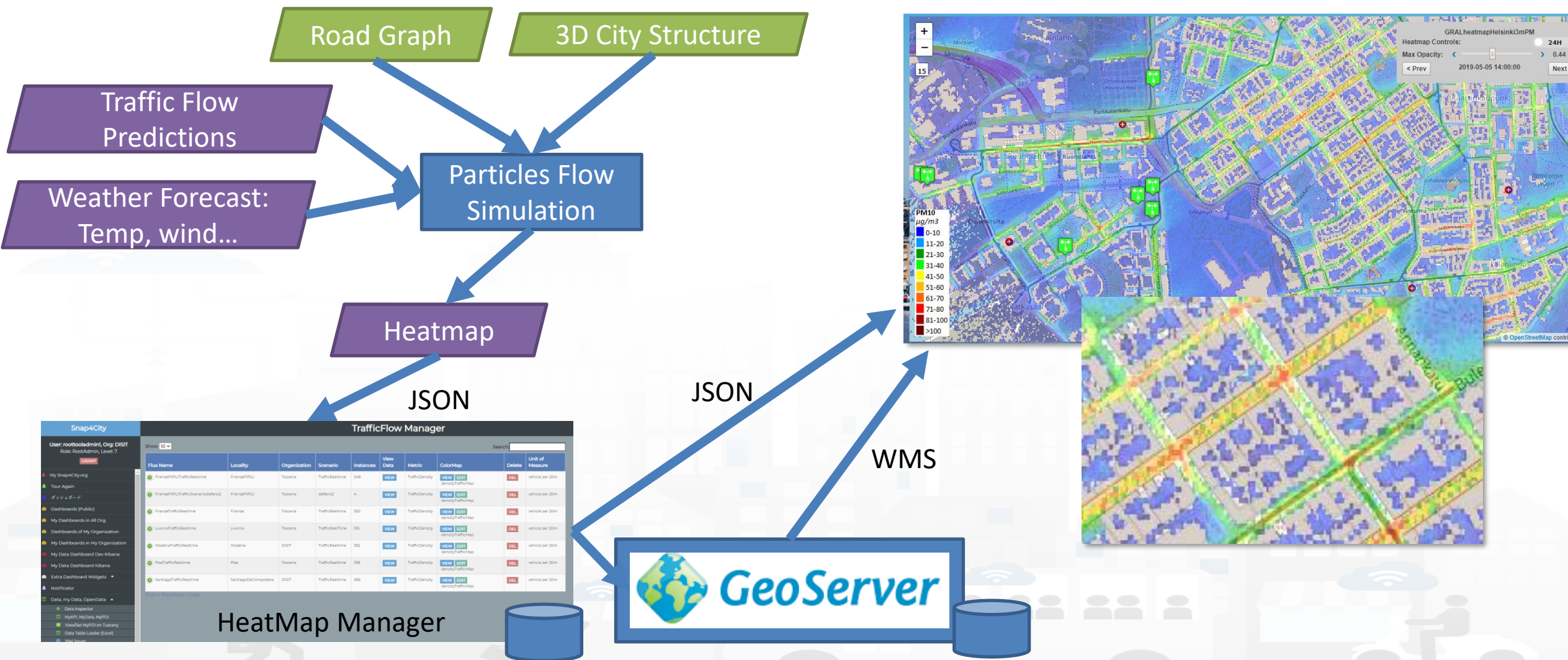


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<https://www.snap4city.org/dashboardSmartCity/view/index.php?iddashboard=MzEyNg==>

How it works: NOX predictions



TOP

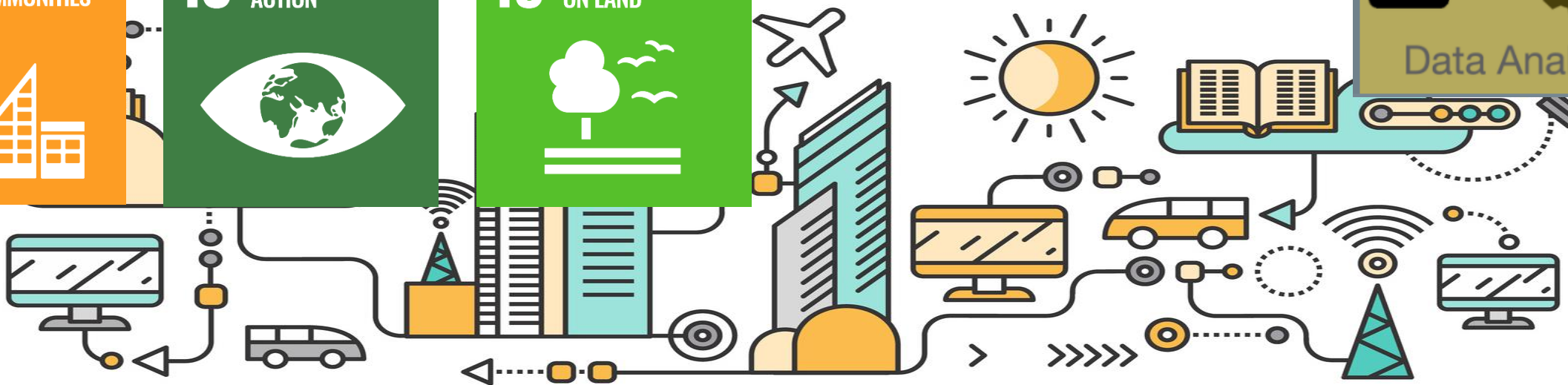
Long Term Prediction of Annual Mean of NO₂ index of EC

11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

15 LIFE ON LAND

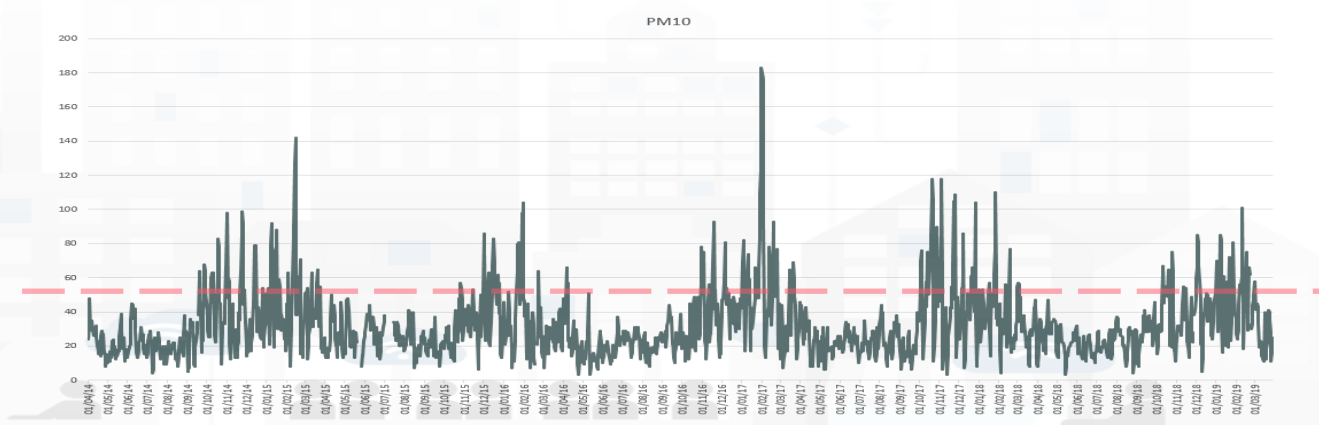
Data Analytic



Predicting Air Quality

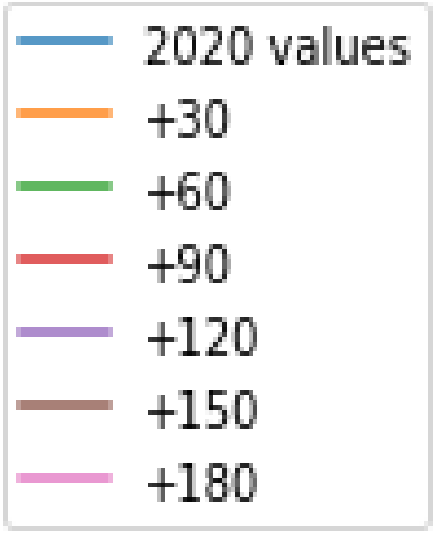
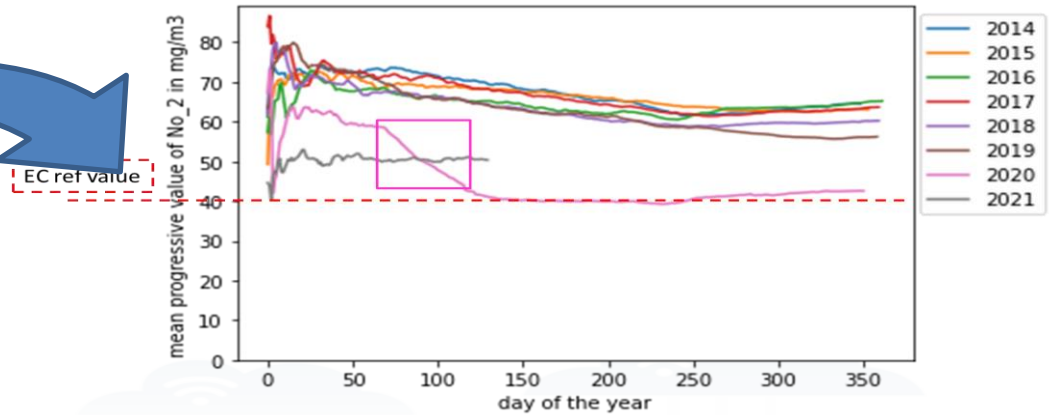
- European Air Quality Directive
- Predicting critical days
 - PM10 with an accuracy of more than 90% and precision of 85%;
 - PM2.5 with an accuracy of 90% and precision greater than the 95%.
- Simulating Long terms values
 - For long terms predictions

Air Quality Directive				WHOguidelines	
Pollutant	Averaging period	Objective and legal nature and concentration	Comments	Concentration	Comments
PM _{2.5}	One day			25 µg/m ³ (*)	99 th percentile (3 days/year)
PM _{2.5}	Calendar year	Target value, 25 µg/m ³	The target value has become a limit value since 1 January 2015	10 µg/m ³	
PM ₁₀	One day	Limit value, 50 µg/m ³	Not to be exceeded on more than 35 days per year.	50 µg/m ³ (*)	99 th percentile (3 days/year)
PM ₁₀	Calendar year	Limit value, 40 µg/m ³ (*)		20 µg/m ³	
O ₃	Maximum daily 8-hour mean	Target value, 120 µg/m ³	Not to be exceeded on more than 25 days per year, averaged over three years	100 µg/m ³	
NO ₂	One hour	Limit value, 200 µg/m ³ (*)	Not to be exceeded more than 18 times a calendar year	200 µg/m ³ (*)	
NO ₂	Calendar year	Limit value, 40 µg/m ³		40 µg/m ³	



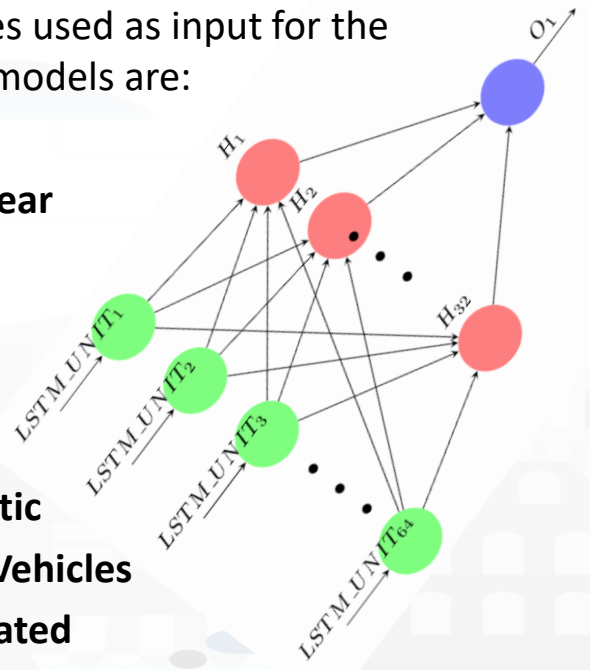
Predicting EC's KPI on NO2 months in advance

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**
- **NO2progesseveMean**
- **numberOfVehiclesCumulated**

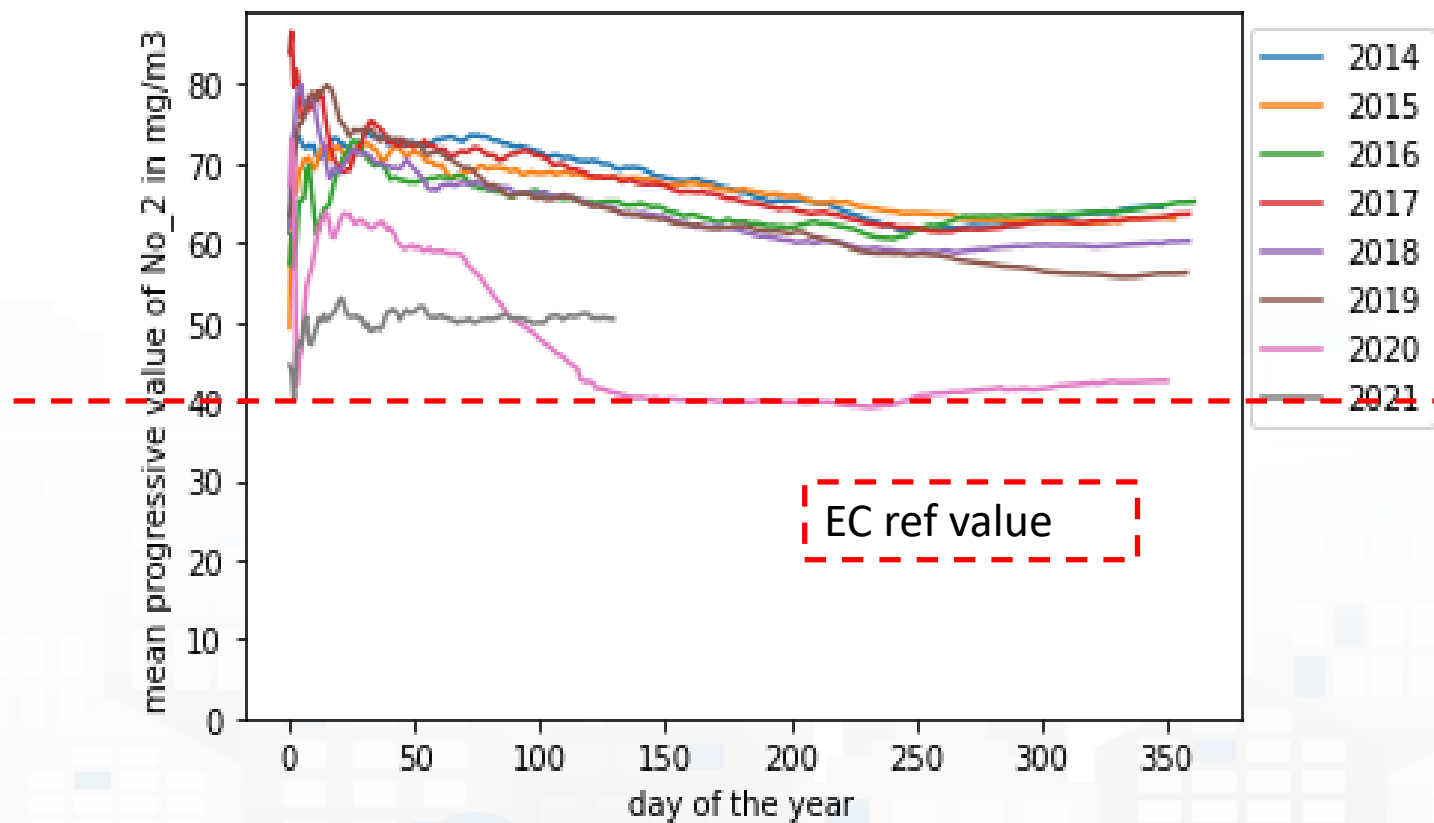


Pollutant	Averaging period	Air Quality Directive		WHOguidelines	
		Objective and legal nature and concentration	Comments	Concentration	Comments
PM _{2.5}	One day			25 µg/m ³ (*)	99 th percentile (3 days/year)
PM _{2.5}	Calendar year	Target value, 25 µg/m ³	The target value has become a limit value since 1 January 2015	10 µg/m ³	
PM ₁₀	One day	Limit value, 50 µg/m ³	Not to be exceeded on more than 35 days per year.	50 µg/m ³ (*)	99 th percentile (3 days/year)
PM ₁₀	Calendar year	Limit value, 40 µg/m ³ (*)		20 µg/m ³	
O ₃	Maximum daily 8-hour mean	Target value, 120 µg/m ³	Not to be exceeded on more than 25 days per year, averaged over three years	100 µg/m ³	
NO ₂	One hour	Limit value, 200 µg/m ³ (*)	Not to be exceeded more than 18 times a calendar year	200 µg/m ³ (*)	
NO ₂	Calendar year	Limit value, 40 µg/m ³		40 µg/m ³	



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



Very long term predicting Mean NO₂:

the 2019

mean progressive NO₂ of 2019

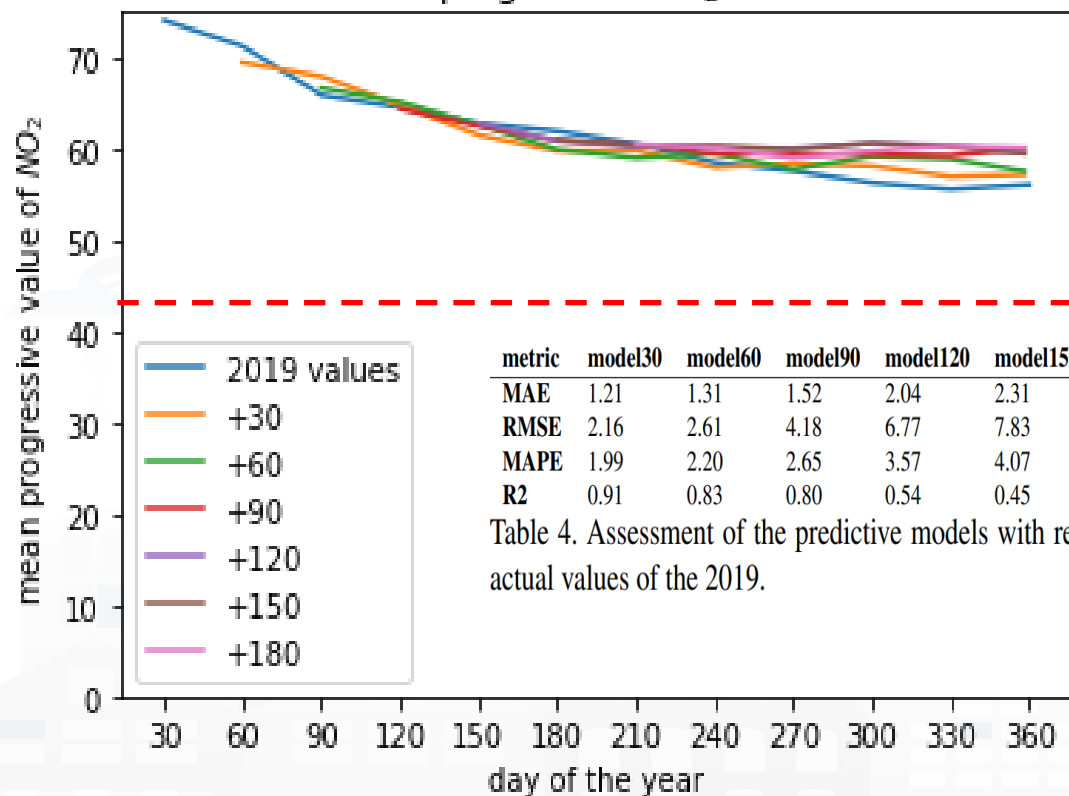
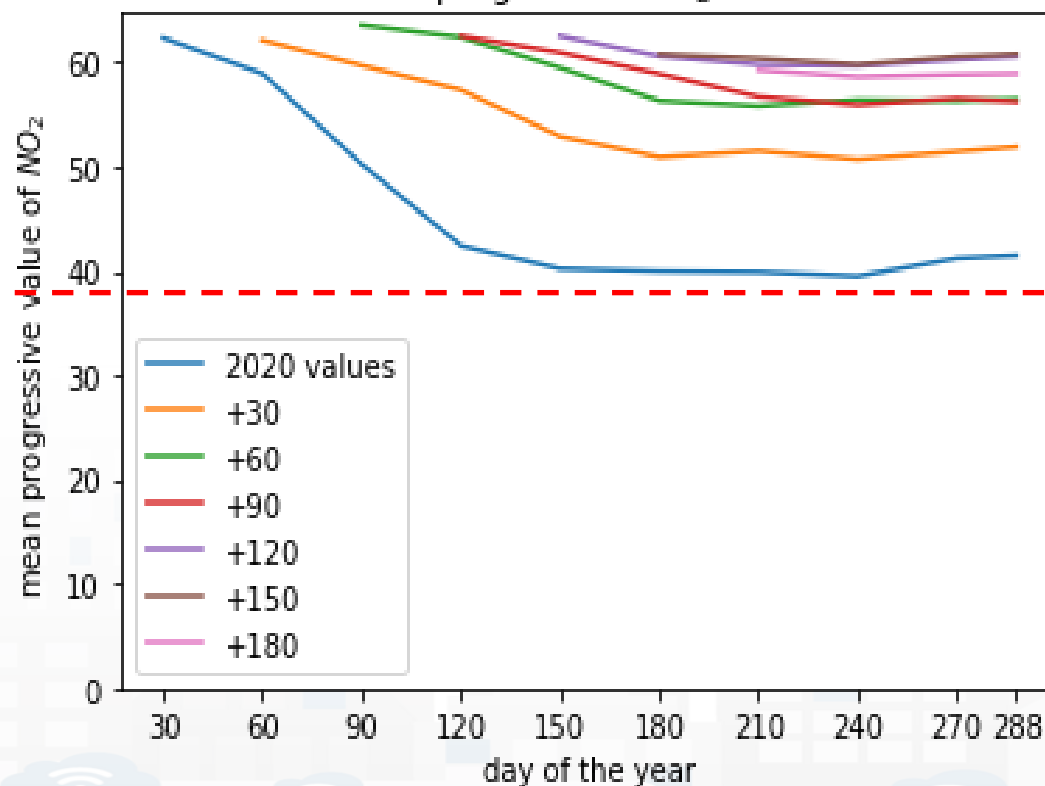


Table 4. Assessment of the predictive models with respect to the actual values of the 2019.

the 2020

mean progressive NO₂ of 2020



EC ref value

Deep Learning Approach

Predicting Land sliding



15 LIFE ON LAND



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 (59981km²)
 - 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.



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 Km² 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

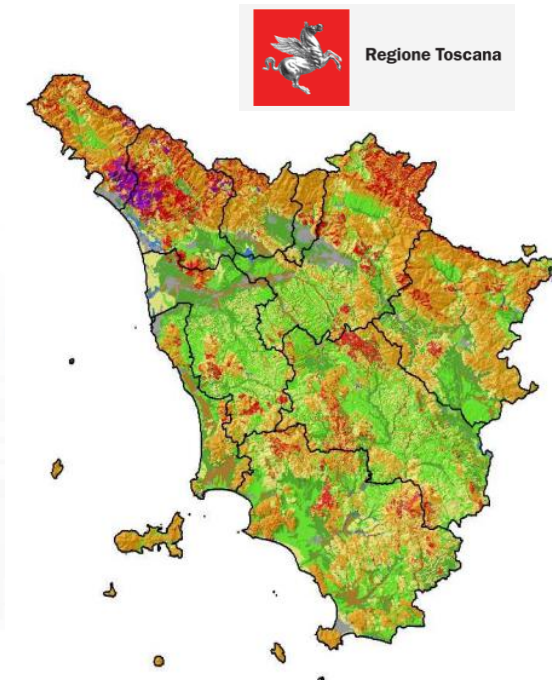
static + dynamic
features

Can be computed daily

Useful for long term
land usage planning

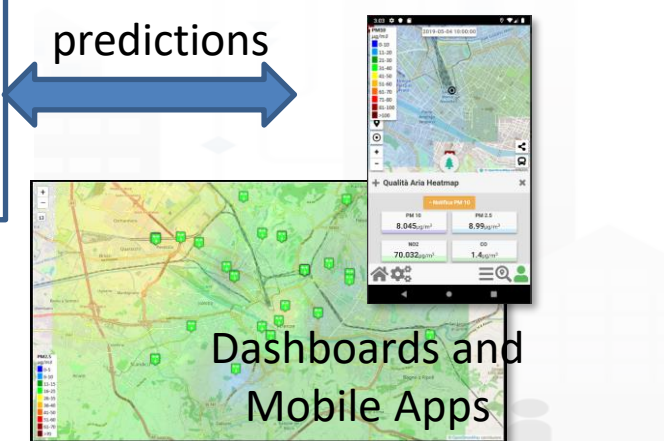
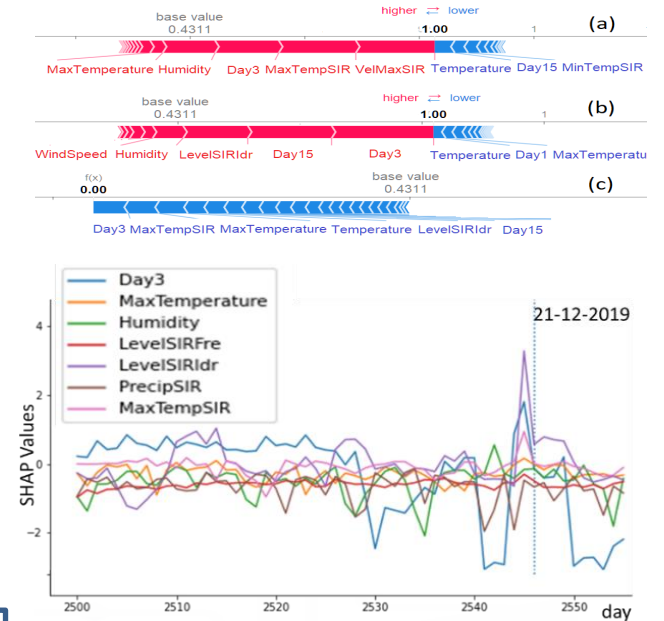
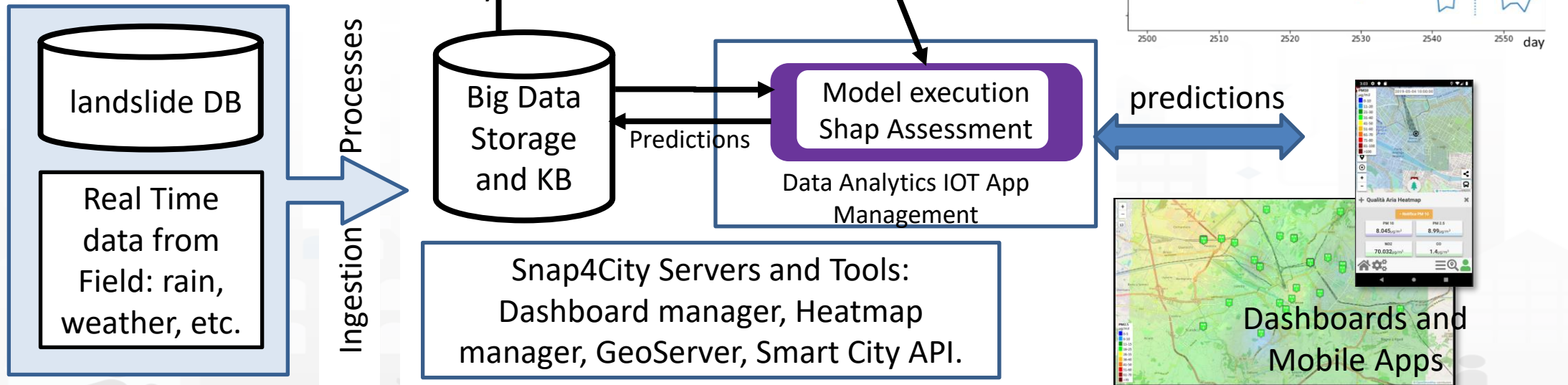
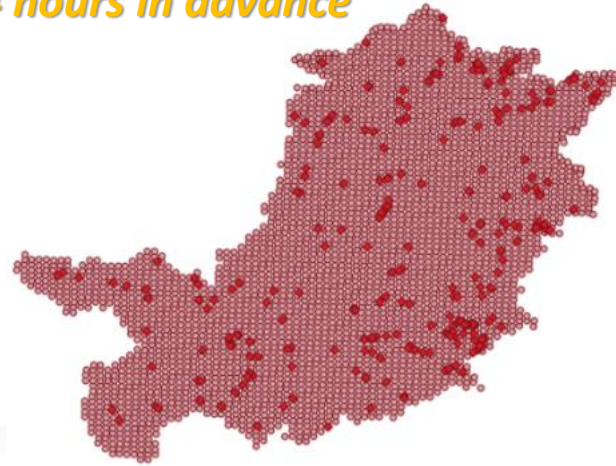
static features based

1 or 2 times per year

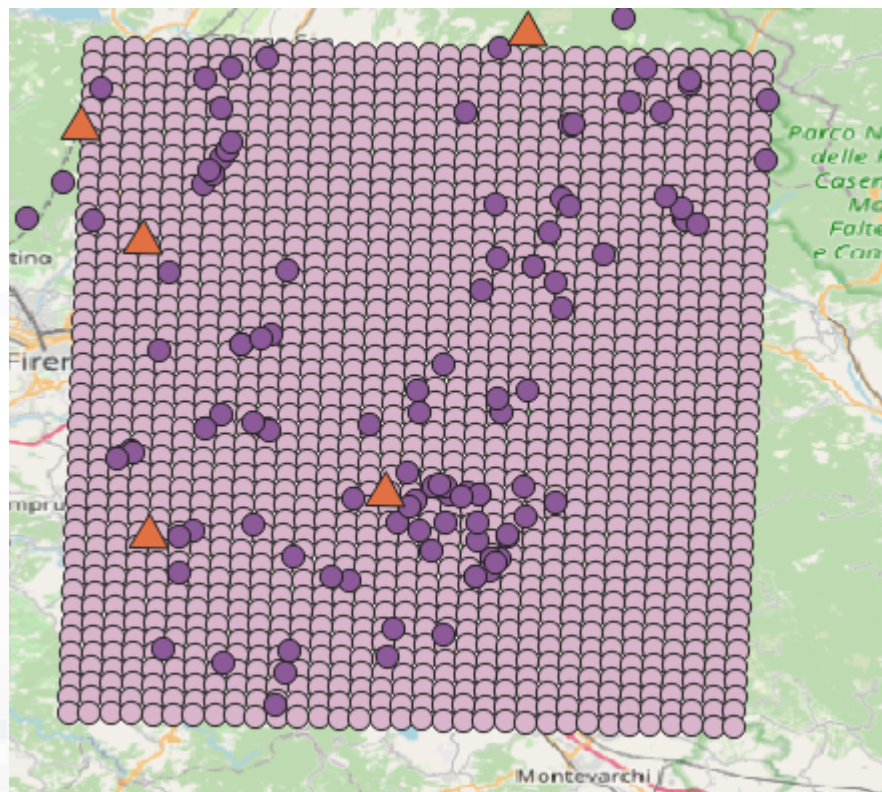


Predicting Land slides

24 hours in advance



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 (IIMeteo.it)	°C	6.965
MinTemperature	Minimum temperature on the observation day (IIMeteo.it)	°C	2.99
MaxTemperature	Maximum temperature on the observation day (IIMeteo.it)	°C	9.942
Humidity	Humidity (average) on the observation day (IIMeteo.it)	%	92.96
WindSpeed	Average wind speed on the observation day (IIMeteo.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
LevelSIRldr	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

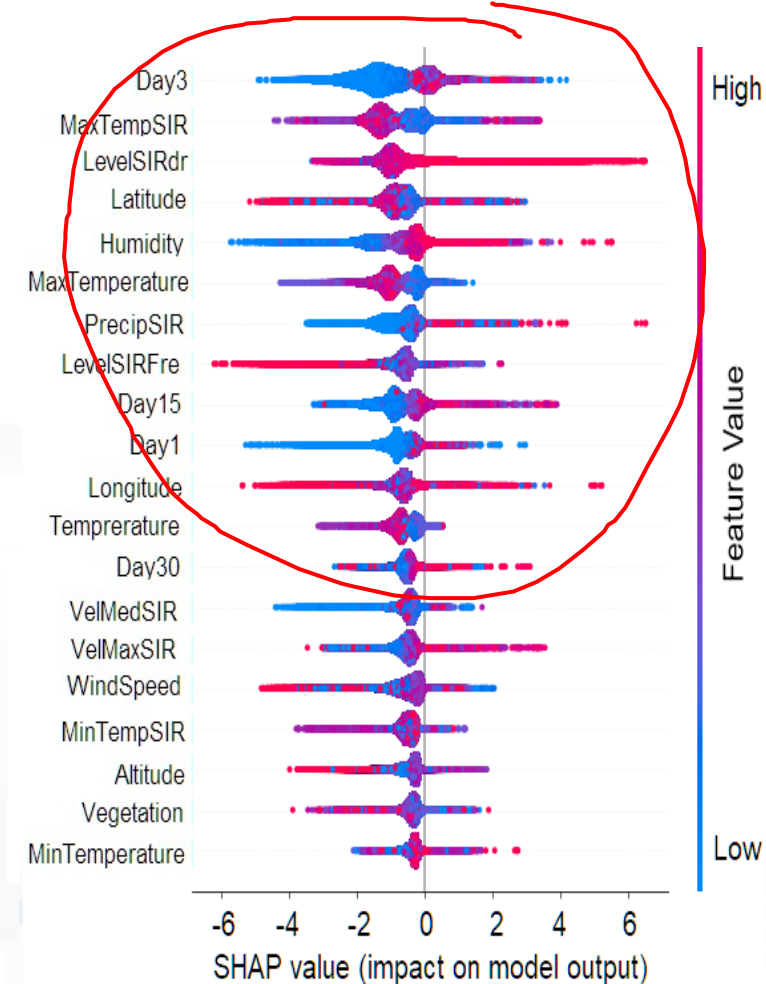
- The considered dataset is composed of about 9 million estimations, among which 2342 positive events (labeled with Value = 1)
- The dataset was divided into two groups: training set (80%) and test set (20%)

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
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



Global Explainable AI
- Feature relevance

- Red: positive, blue: negative;
- 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 Figure 10a, 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: **LevelSIRldr**, **Day3** and **MaxTempSIR**.

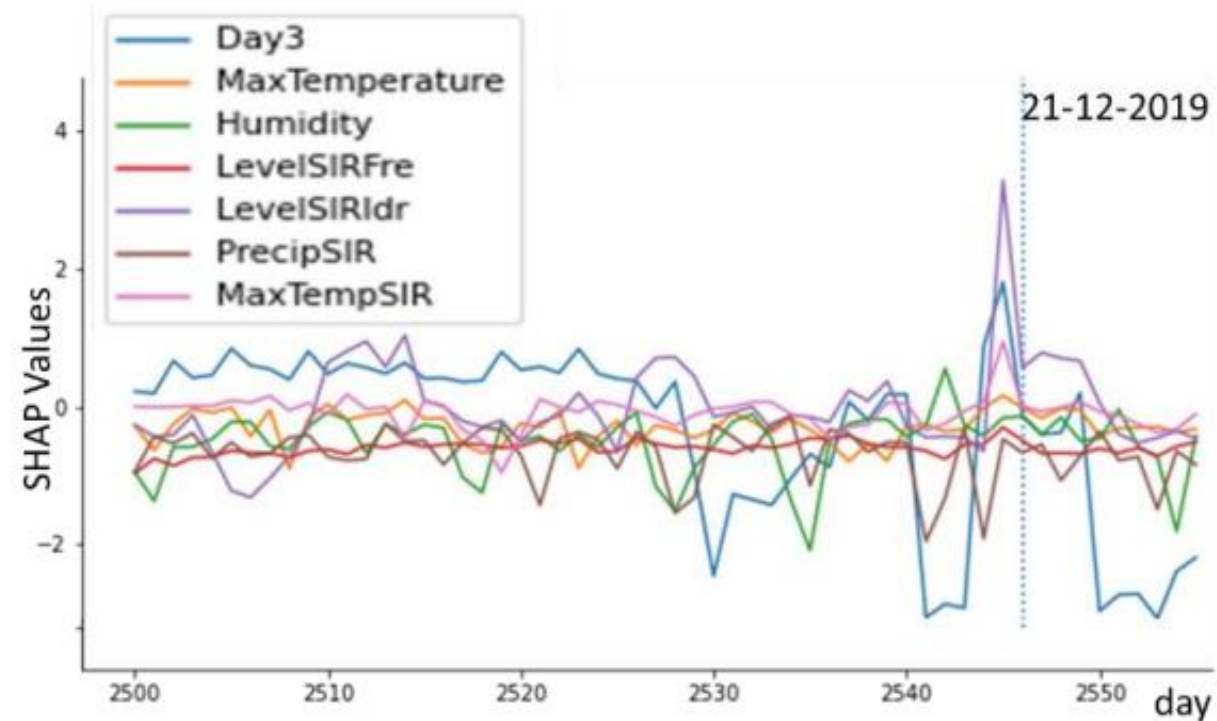


FIGURE 11. Time trend of SHAP values of most relevant features around the landslide event of 21-12-2019: values estimated by using data collected in the neighboring area of the event.

- **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**
 - the 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.

TOP

Predicting Presences *to major events*

9 INDUSTRY, INNOVATION
AND INFRASTRUCTURE



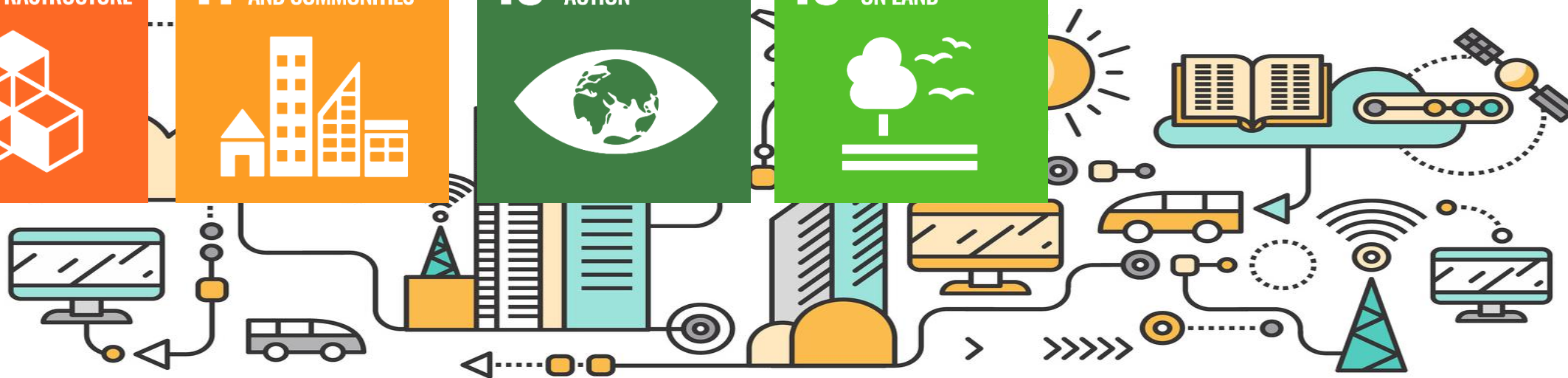
11 SUSTAINABLE CITIES
AND COMMUNITIES



13 CLIMATE
ACTION



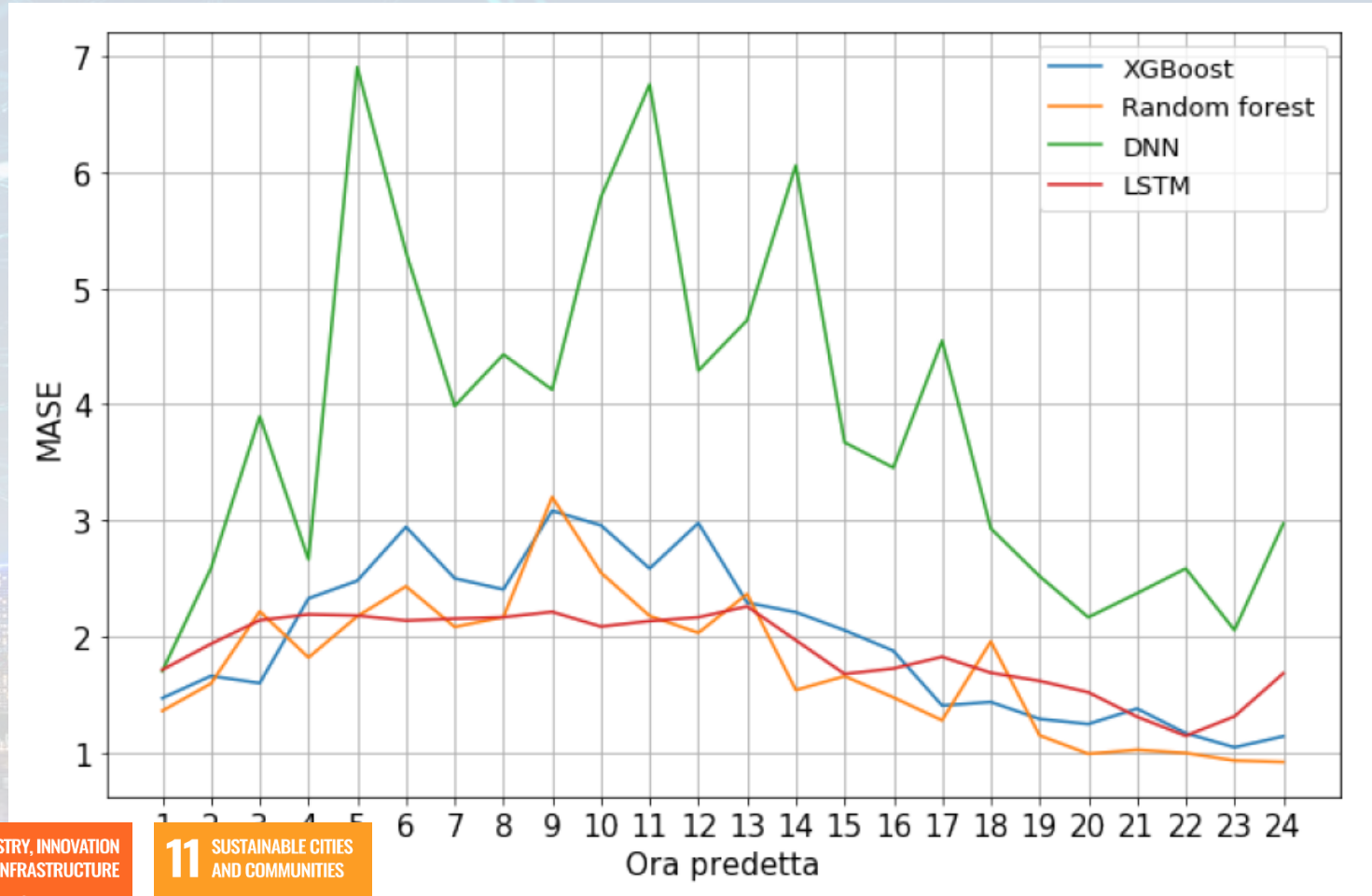
15 LIFE
ON LAND



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

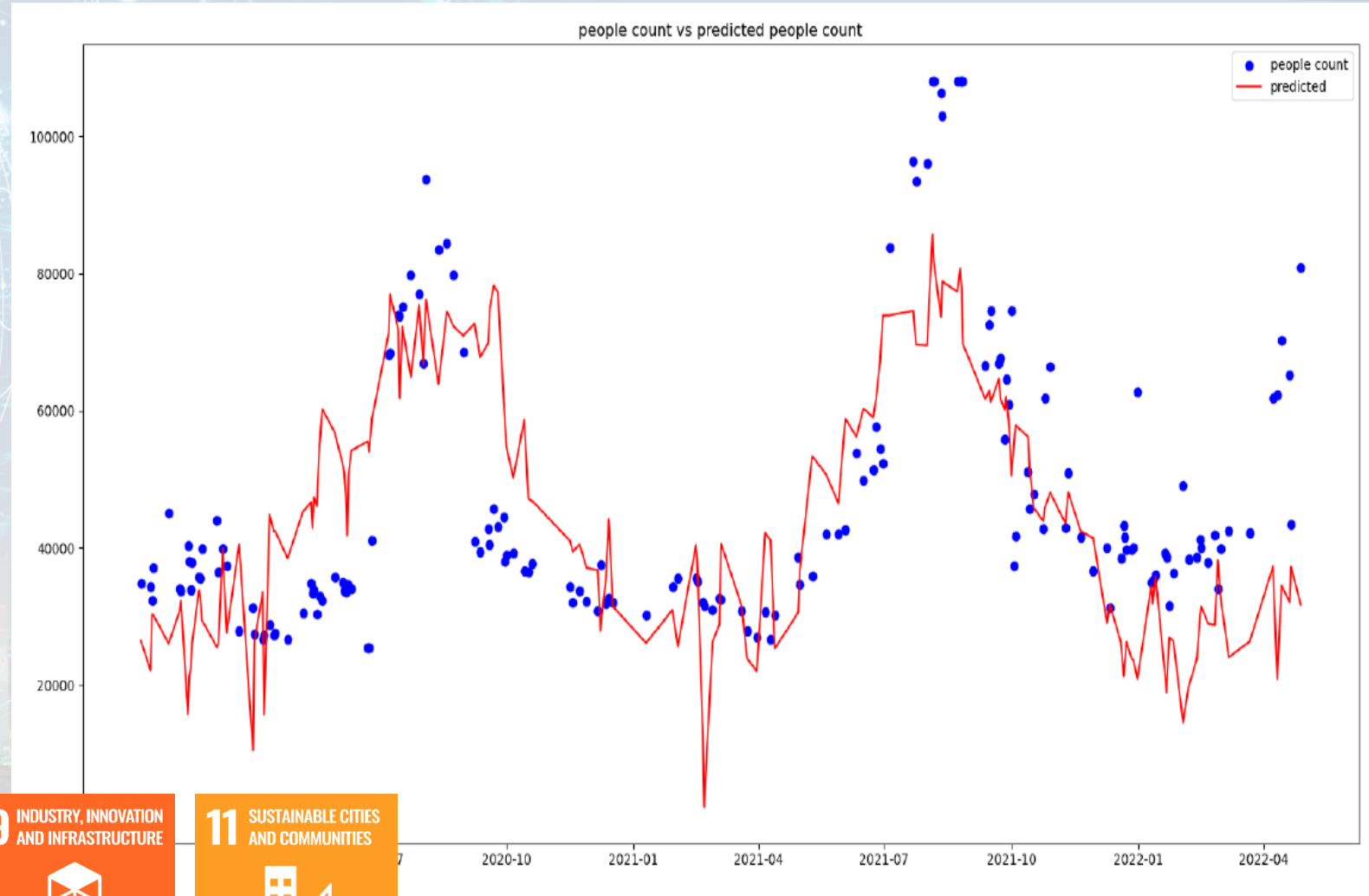


11 SUSTAINABLE CITIES AND COMMUNITIES



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



TOP

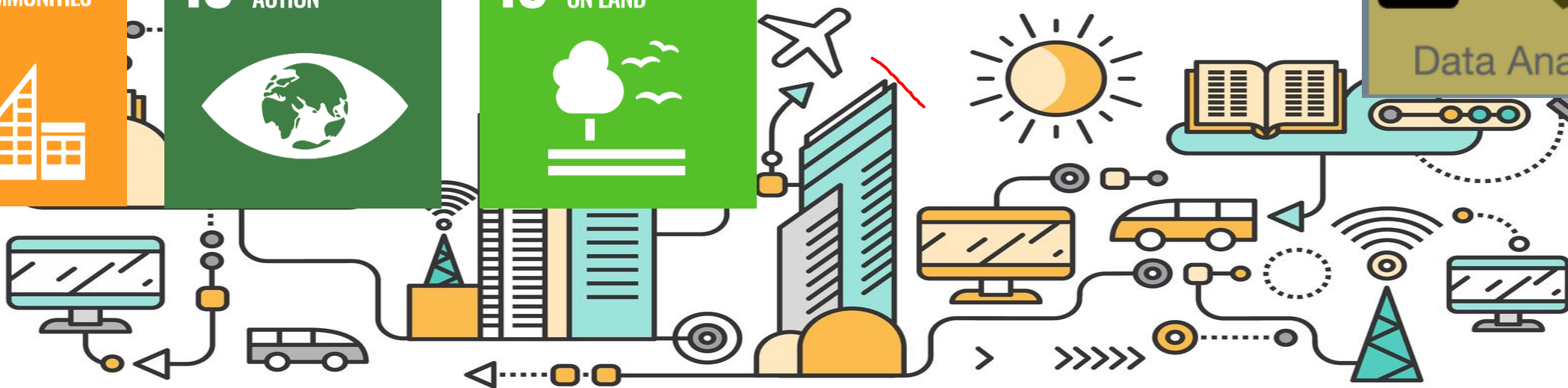
Anomaly Detection Early Warning

11 SUSTAINABLE CITIES
AND COMMUNITIES

13 CLIMATE
ACTION

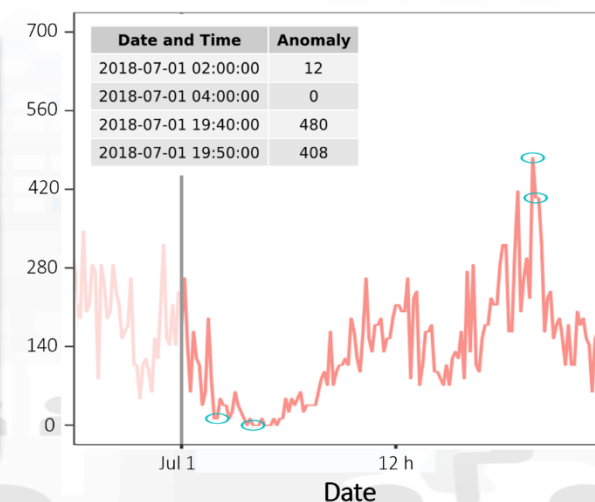
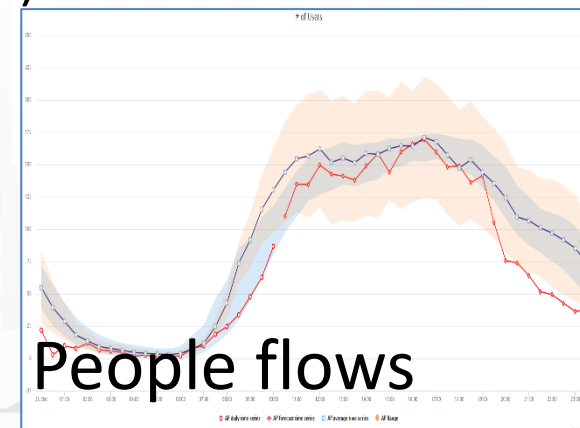
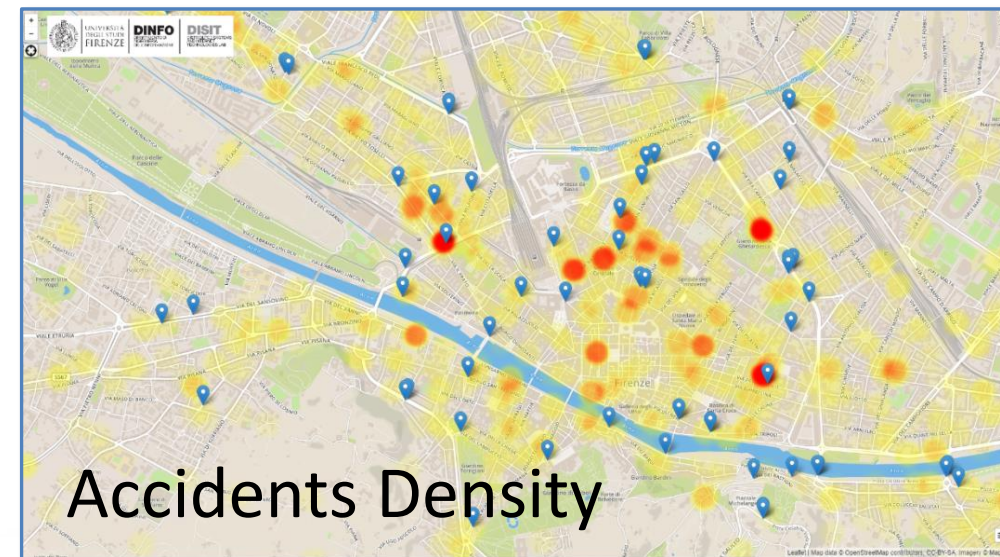
15 LIFE
ON LAND

Data Analytic



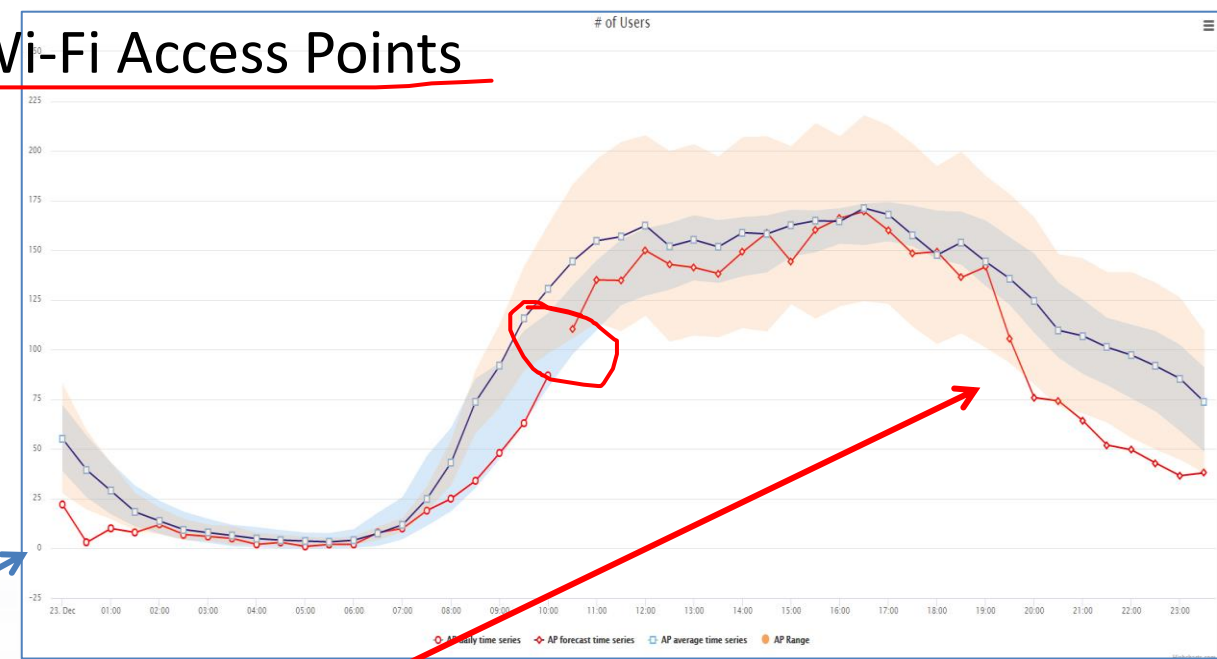
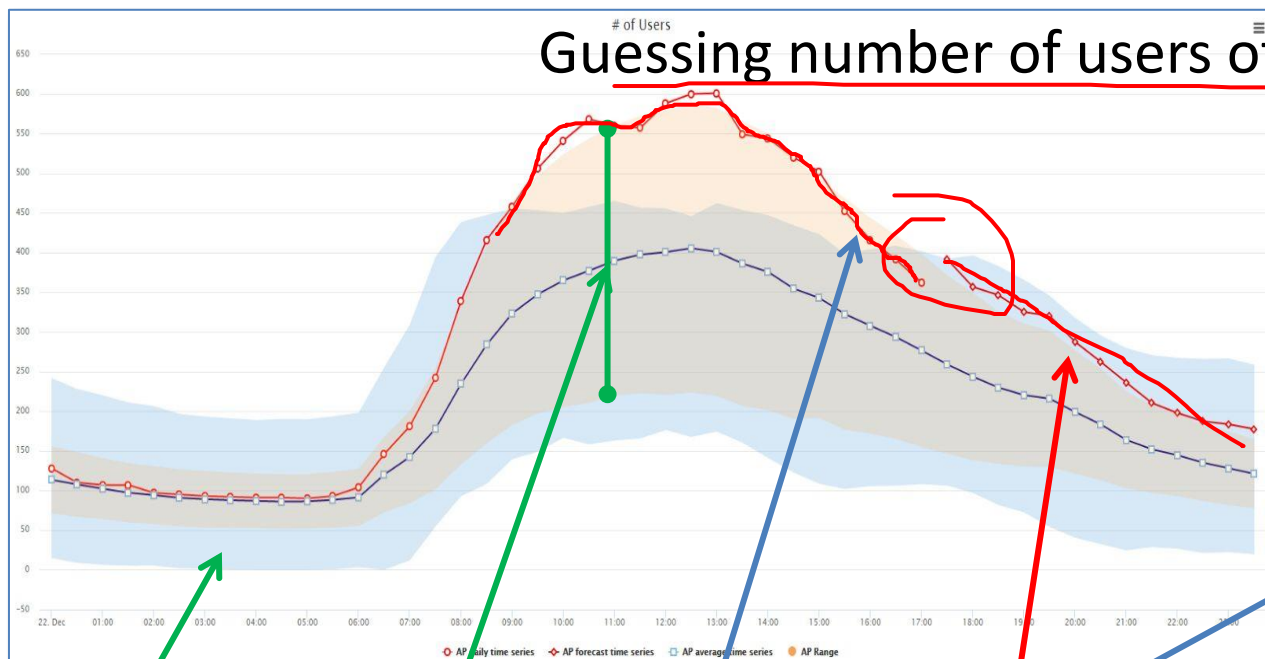
Anomaly Detections

- About the IoT Devices status
 - Eventual problems on IoT Devices, connections, etc.
- About People Flows and Density
 - Early warning of the inception 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.

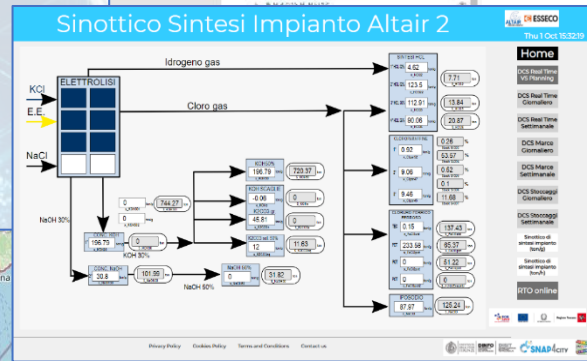
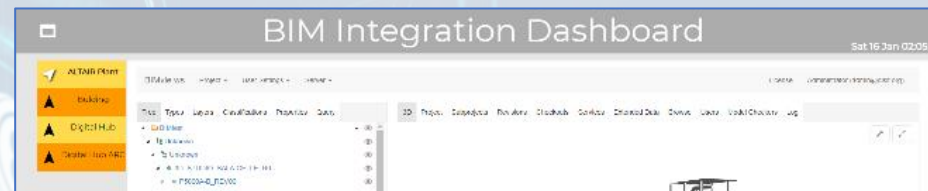


UNIVERSITÀ
DEGLI STUDI
FIRENZE

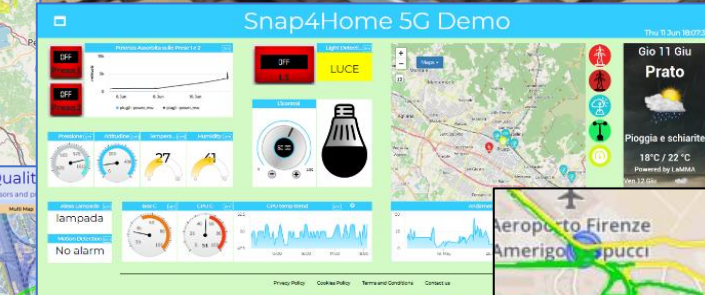
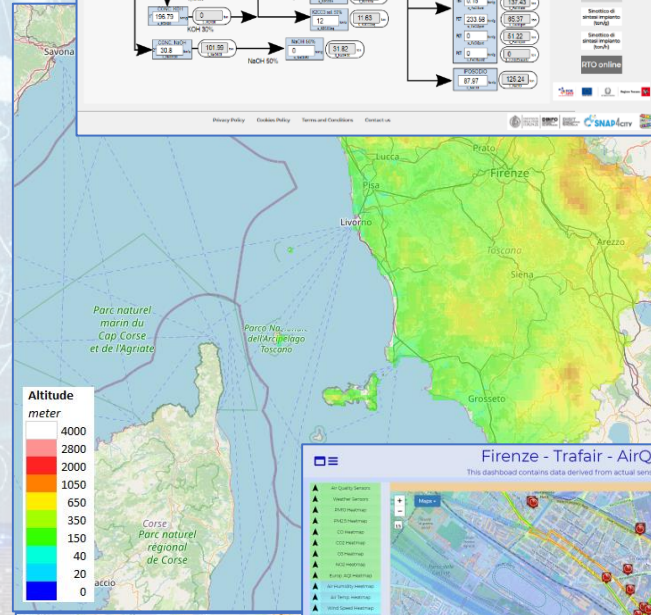
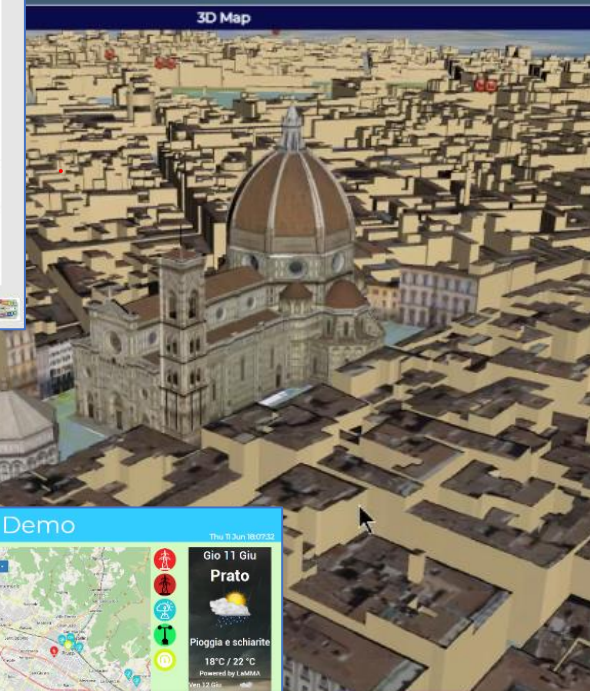
DINFO
DIPARTIMENTO DI
INGEGNERIA
DELL'INFORMAZIONE

DISIT
DISTRIBUTED SYSTEMS
AND INTERNET
TECHNOLOGIES LAB

Snap4City (C), November 2023



SNAP4CITY
- Digital Twin Global - Fire
demonstrator



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.



TOP

Traffic Flow Reconstruction from Traffic Sensors Data

11 SUSTAINABLE CITIES
AND COMMUNITIES

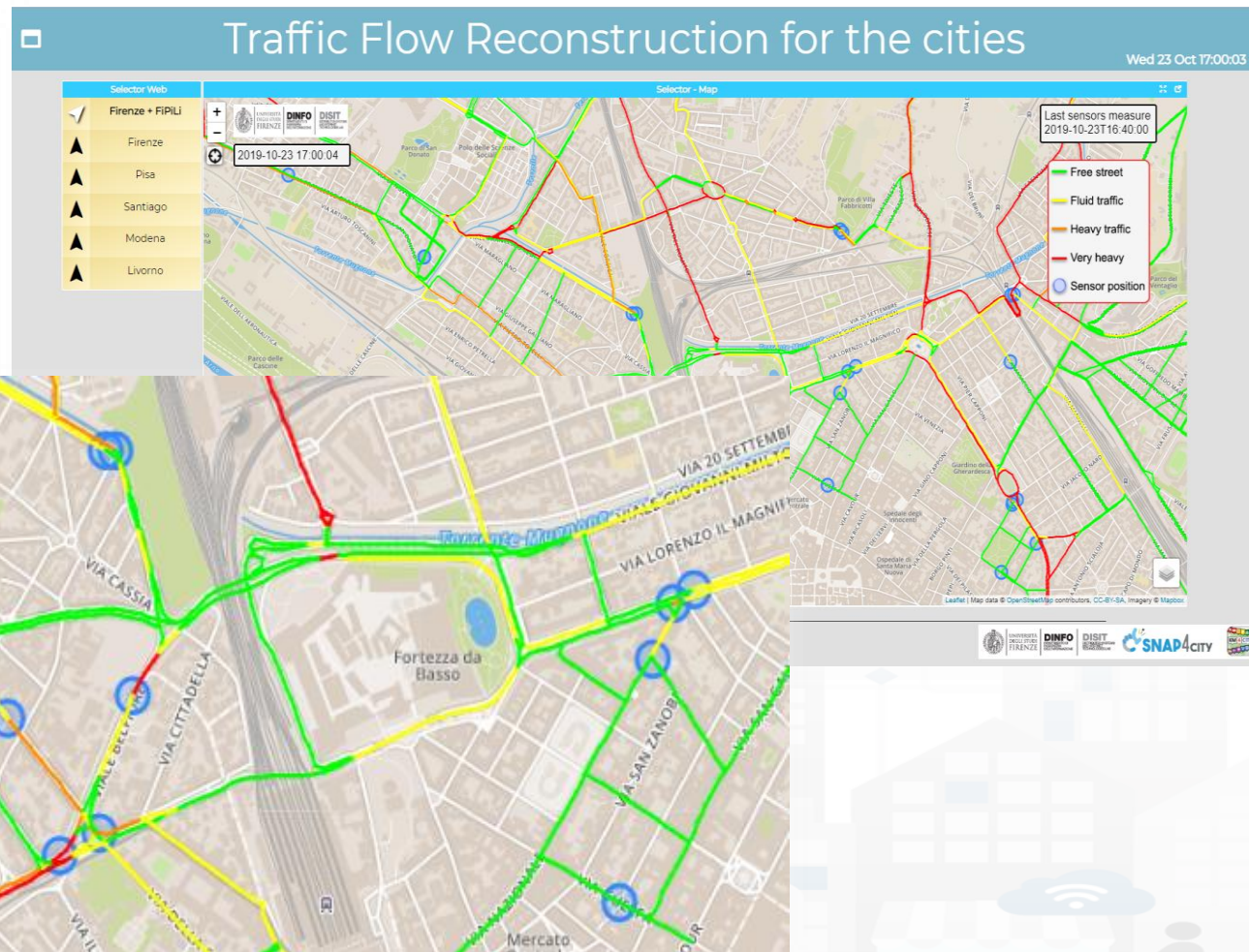


13 CLIMATE
ACTION



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

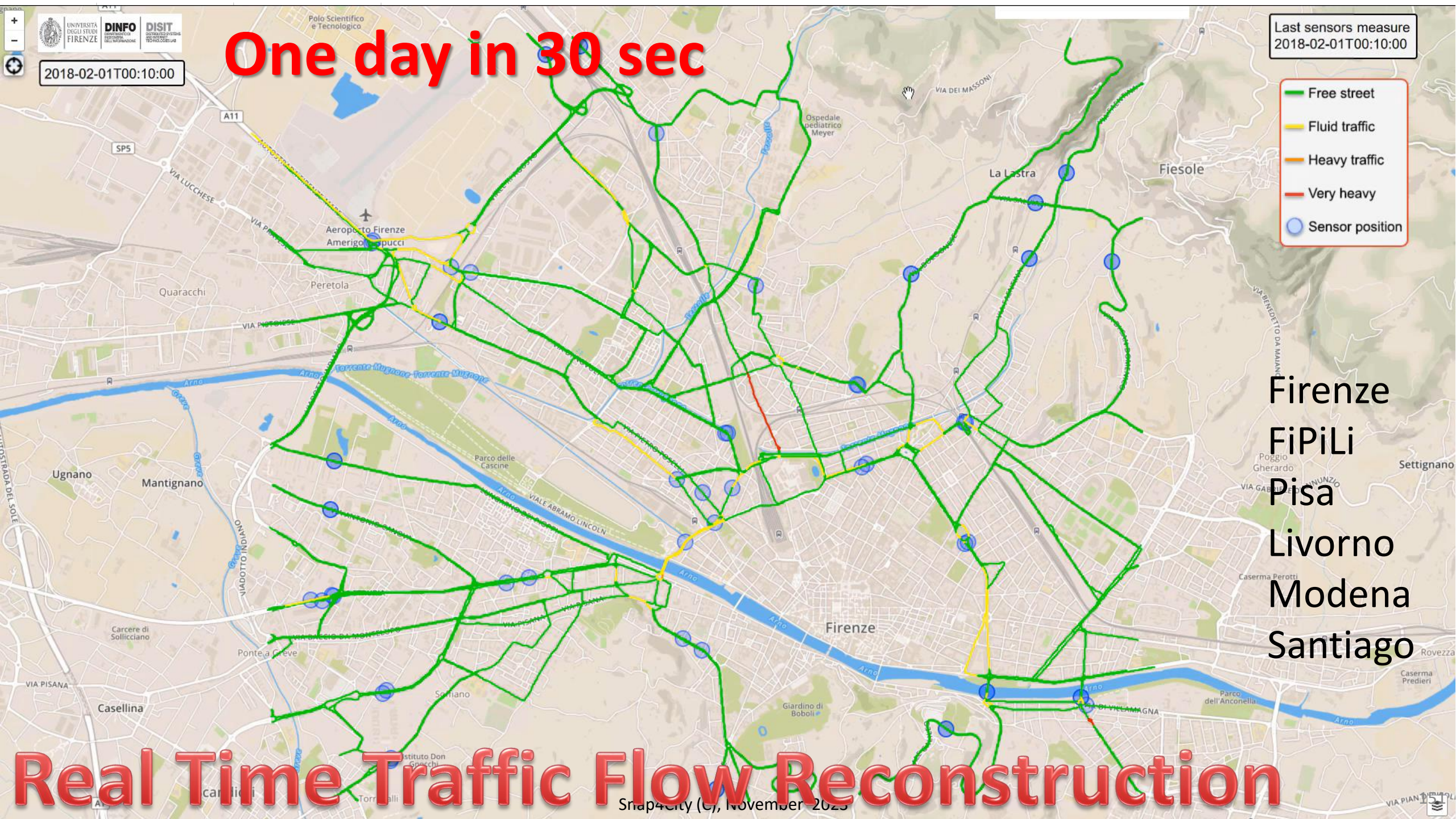


2018-02-01T00:10:00

One day in 30 sec

Last sensors measure
2018-02-01T00:10:00

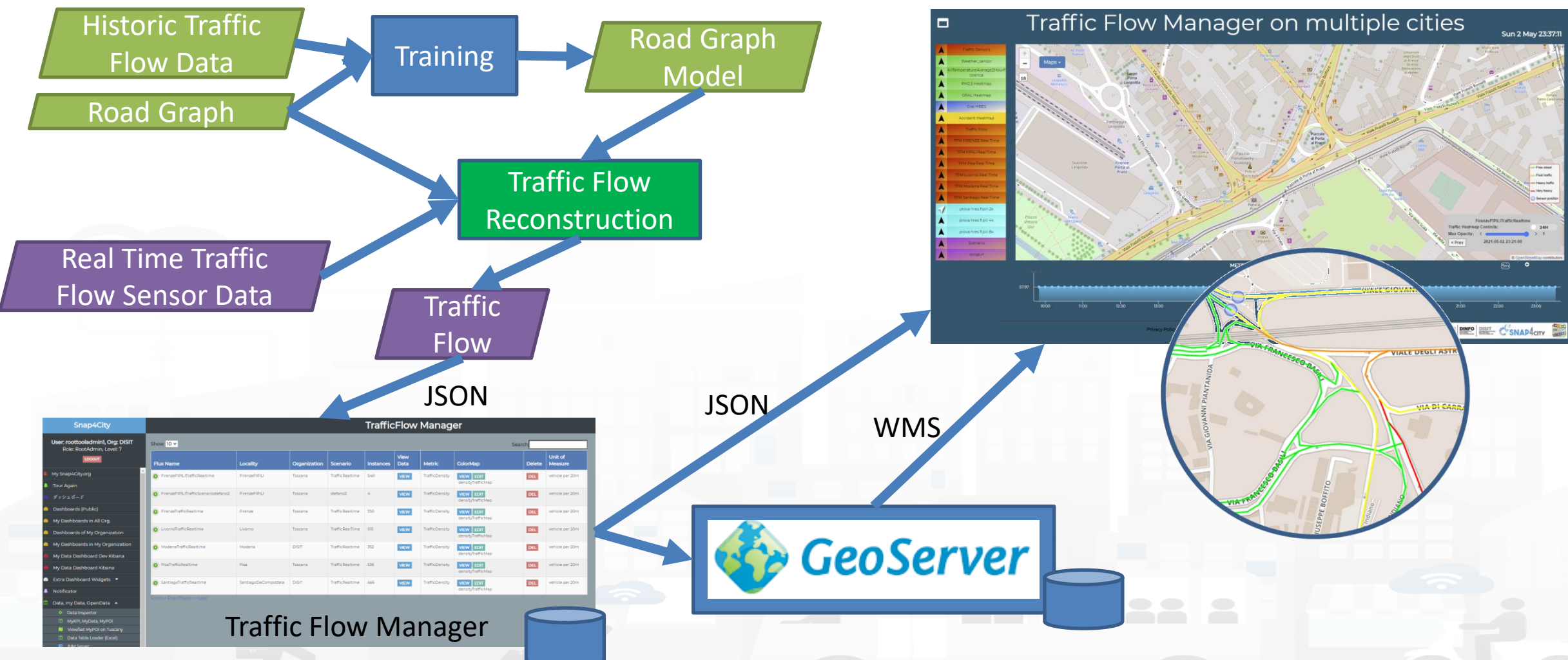
- Free street
- Fluid traffic
- Heavy traffic
- Very heavy
- Sensor position



Firenze
FiPiLi
Pisa
Livorno
Modena
Santiago

Real Time Traffic Flow Reconstruction

How it works: Traffic Flow Manager



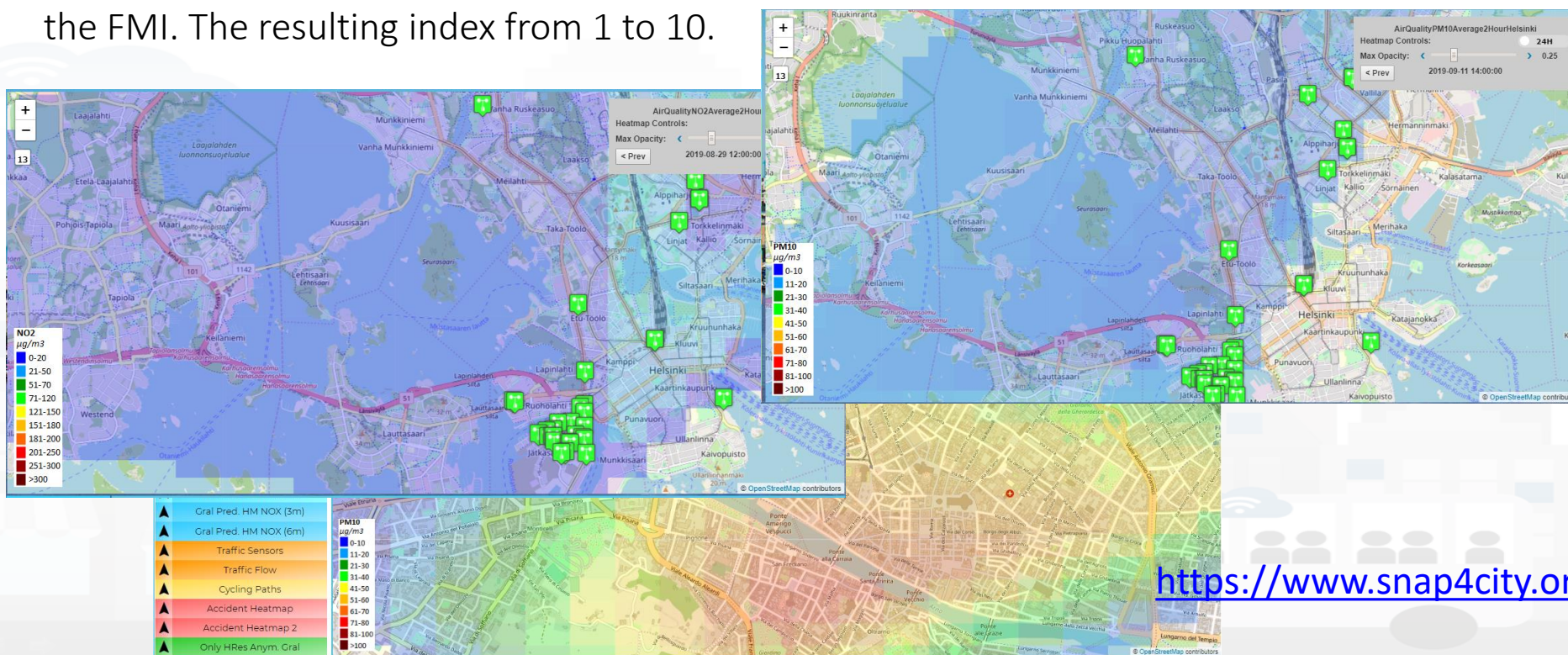
Heatmaps and animations



- **Air Quality sensors are**
 - Collected on scattered positions
 - Not all sensors have full 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

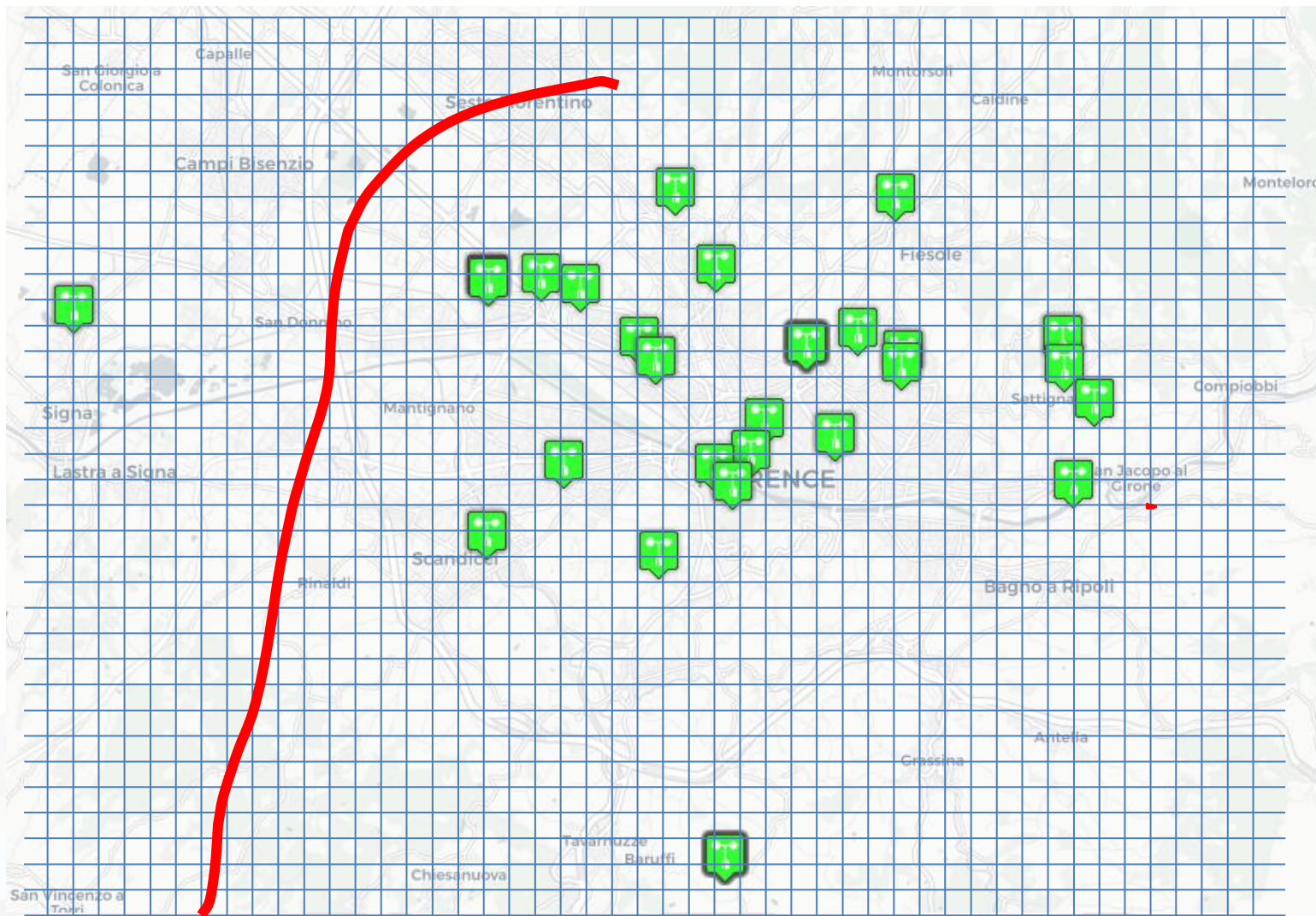
- **Noise:** real time noise levels (measured in dBA).
- **PM₁₀:** real time pollutant levels in air in terms of PM₁₀ (measured in $\mu\text{g}/\text{m}^3$) particles.
- **PM_{2,5}:** real time pollutant levels in air in terms of PM_{2,5} (measured in $\mu\text{g}/\text{m}^3$) particles
- **NO₂:** real time pollutant levels in air in terms of nitrogen dioxide (measured in $\mu\text{g}/\text{m}^3$).
- **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

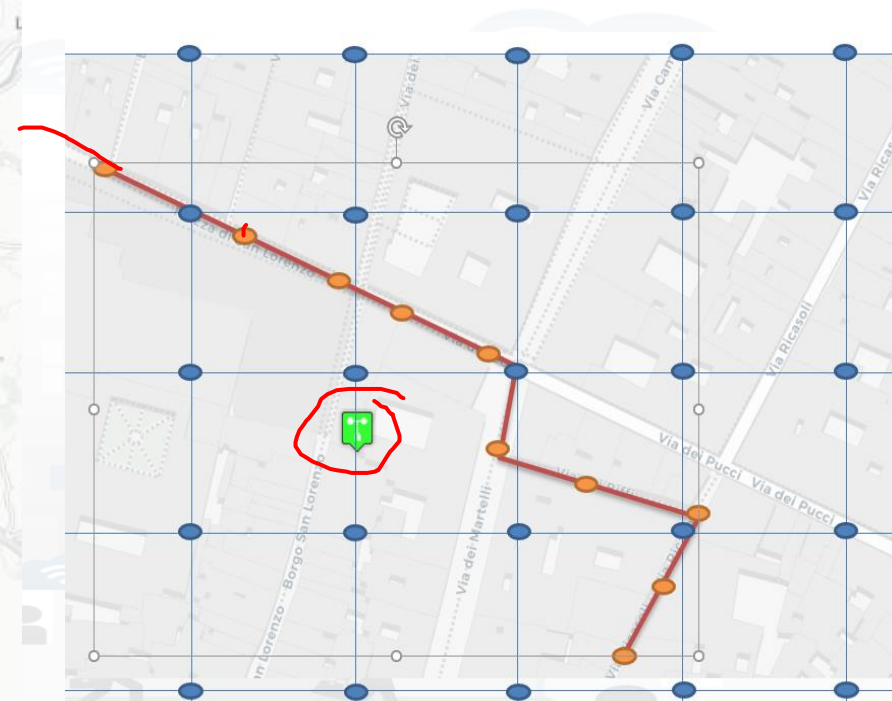


4x4 meters grid is really too expensive

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 $\mu\text{g}/\text{m}^3$)				
	Good	Fair	Moderate	Poor	Very poor
Particles less than 2.5 μm ($\text{PM}_{2.5}$)	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.

Legend of Environmental data:

<https://www.snap4city.org/435>

Common Air Quality Index CAQI

<http://www.airqualitynow.eu>

Qualitative name	Index or sub-index	Pollutant (hourly) density in $\mu\text{g}/\text{m}^3$			
		NO_2	PM_{10}	O_3	$\text{PM}_{2.5}$ (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 , $\text{PM}_{2.5}$, PM_{10} and O_3 .

AQI Indexes estimation Heatmaps

Hourly pollutant concentration

Helsinki City Overview (H5a)

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

Wed 11 Sep

- ▲ 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 Jatkasaari
- ▲ PM2.5 Jatkasaari
- ▲ EAQI Jatkasaari
- ▲ Appreciated POIs

EAQI Index

- 1. Good
- 2. Fair
- 3. Moderate
- 4. Poor
- 5. Very poor

- ▲ 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

EAQI Index

- 1. Good
- 2. Fair
- 3. Moderate
- 4. Poor
- 5. Very poor

<https://www.snap4city.org/dashboardSmartCity/view/index.php?iddashboard=MTQwNg==>

<https://www.snap4city.org/dashboardSmartCity/view/index.php?iddashboard=MTUzMg==>

The Life of Helsinki (H5b)

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

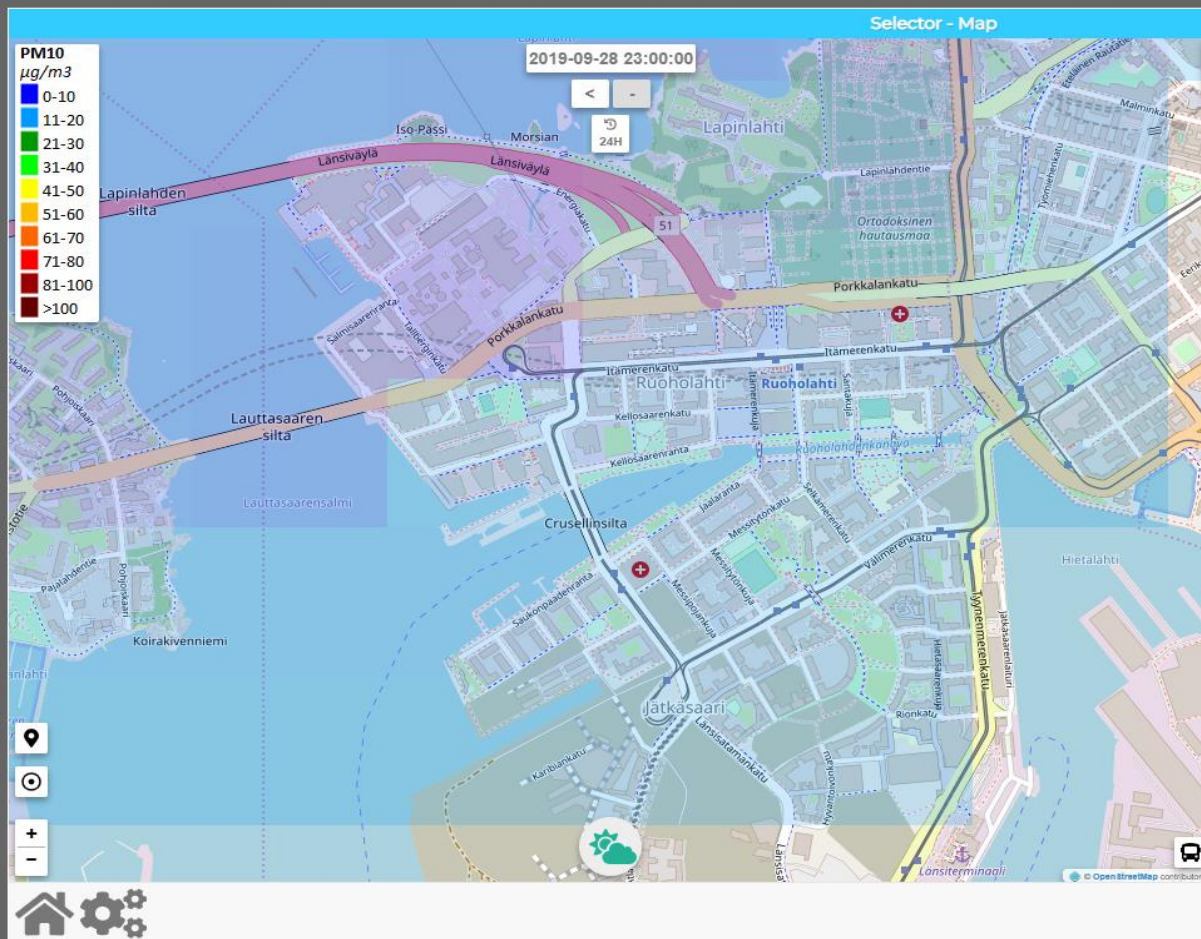
Sun 29 Sep 00:42:50

- ▲ 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



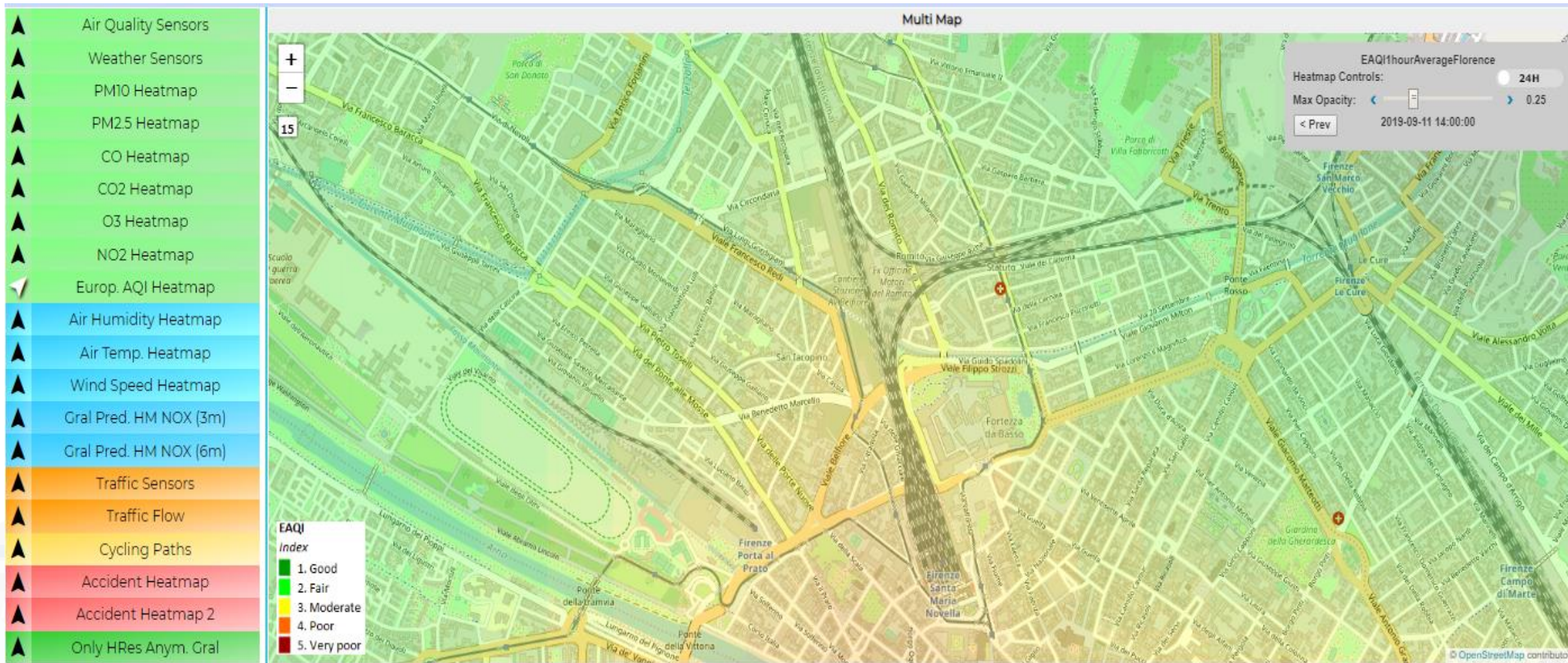
+ Ilmanlaatu Heatmap

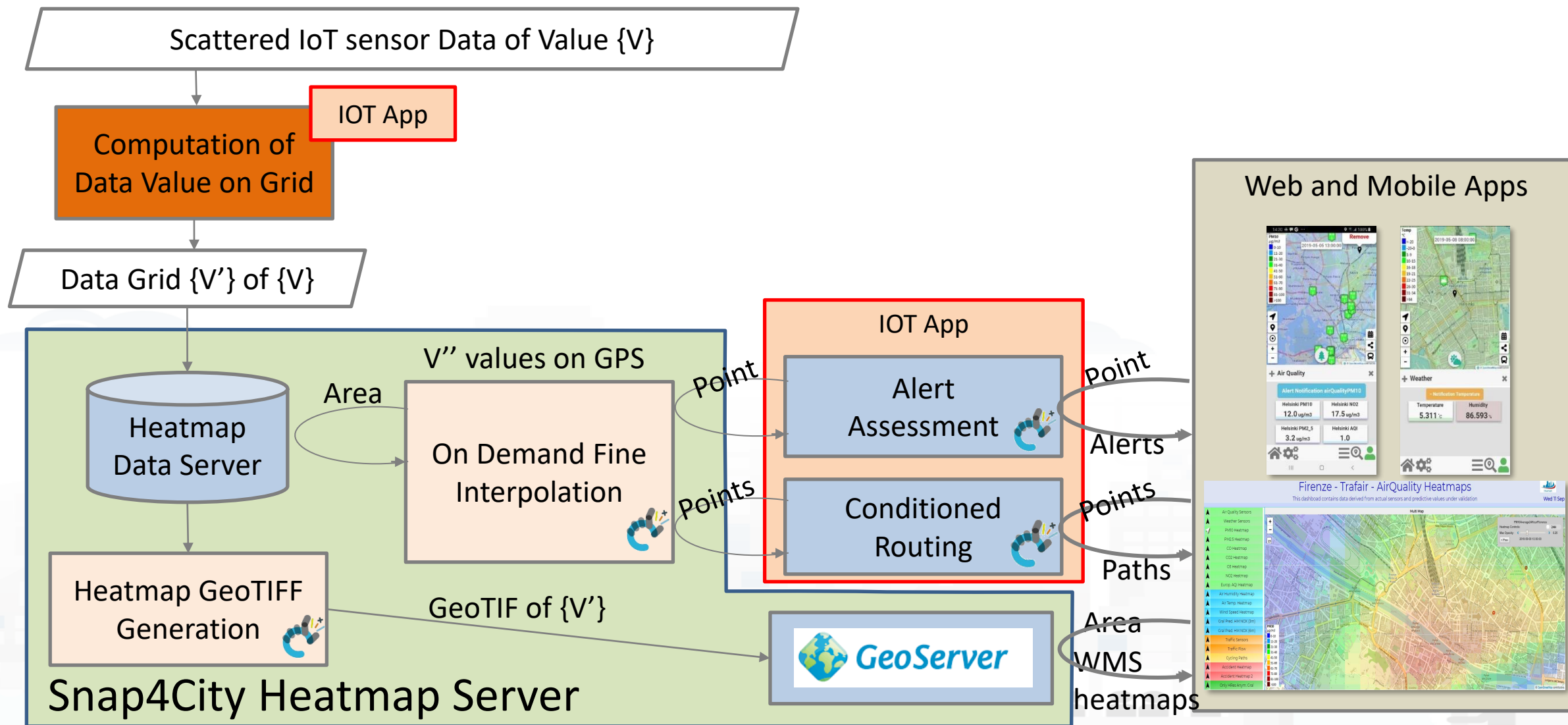
+ Ilmoita PM 10

PM 10 9.443 µg/m ³	PM 2.5 5.855 µg/m ³
NO2 34.128 µg/m ³	Helsinki AQI 1.895
LAeq (Noise) 55.831 dbBA	European AQI 1
AQI Enfuser Pred. 1	PM 10 Enfuser Pred. 6.3 µg/m ³
PM 2.5 Enfuser Pred. 3.7 µg/m ³	PM 10 GRAL Pred. 1.055 µg/m ³



EAQI Heatmap and sequence





HeatMap Manager (Area Manager view)

Snap4City

User: paolo.disit, Org: DISIT
Role: AreaManager, Level: 3

Logout

- My Snap4City.org
- Tour Again
- Dashboards (Public)
- Dashboards of My Organization
- My Dashboards in My Organization
- My Data Dashboard Dev Kibana
- Extra Dashboard Widgets
- Data, my Data, OpenData**
- Data Inspector
- MyKPI, MyData, MyPOI
- My Groups of Entities
- View/Set MyPOI on Tuscany
- Data Table Loader (Excel)
- POI Loader (Excel)
- Harvest Satellite Copernicus Data
- HeatMap Manager**
- BIM Server old
- BIM Server New
- BIM Srv New: Add
- BIM Srv new: View

HeatMap Manager

Show 10

Search:

Map name	Color Map	Nature	Subnature	Organization	Details	View Data
15MinIndex_AbitantiPerPunto	VIEW abperarea			DISIT	VIEW	VIEW
15MinIndex_AverageIndex	VIEW 15minsubindex			DISIT	VIEW	VIEW
15MinIndex_CityIndexMPI	VIEW 15minsubindex			DISIT	VIEW	VIEW
15MinIndex_CultureAndCultsIndex	VIEW 15minsubindex			DISIT	VIEW	VIEW
15MinIndex_CultureAndCultsIndexBologna	VIEW 15minsubindex			DISIT	VIEW	VIEW
15MinIndex_EconomyIndex	VIEW 15minsubindex			DISIT	VIEW	VIEW
15MinIndex_EconomyIndexBologna	VIEW 15minsubindex			DISIT	VIEW	VIEW
15MinIndex_EducationIndex	VIEW 15minsubindex			DISIT	VIEW	VIEW
15MinIndex_EducationIndexBologna	VIEW 15minsubindex			DISIT	VIEW	VIEW
15MinIndex_EntertainmentSocialIndex	VIEW 15minsubindex			DISIT	VIEW	VIEW

First << Prev 1 2 3 4 5 ... 34 Next >> Last

- Sequence of Heatmaps
- Colormap used
- Details

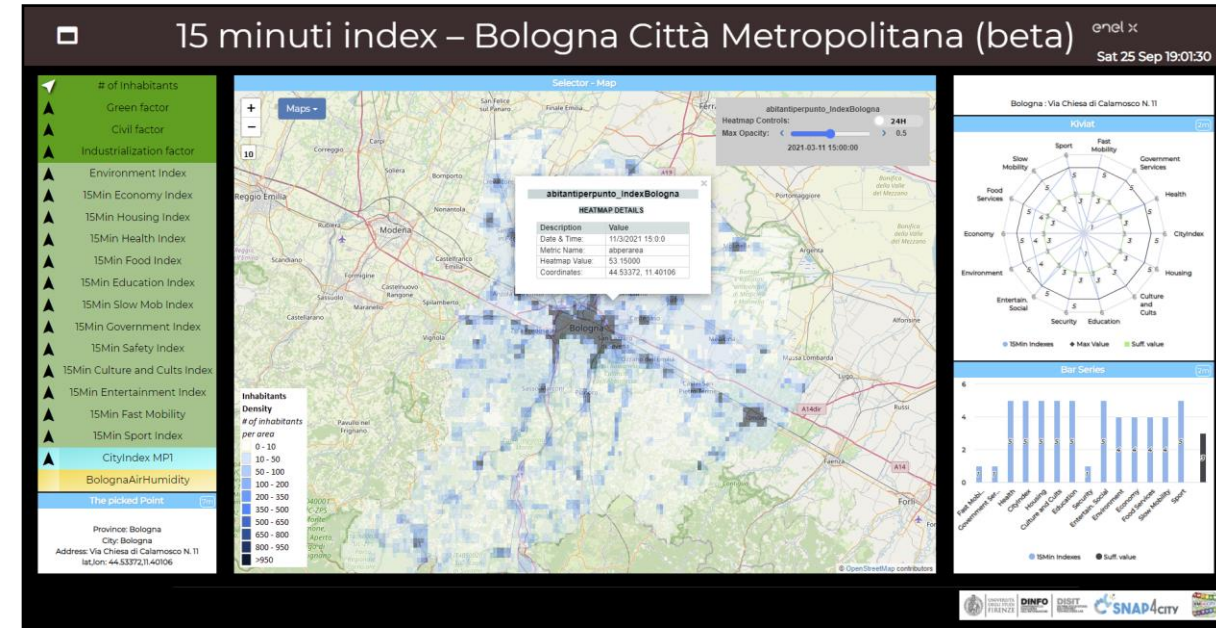
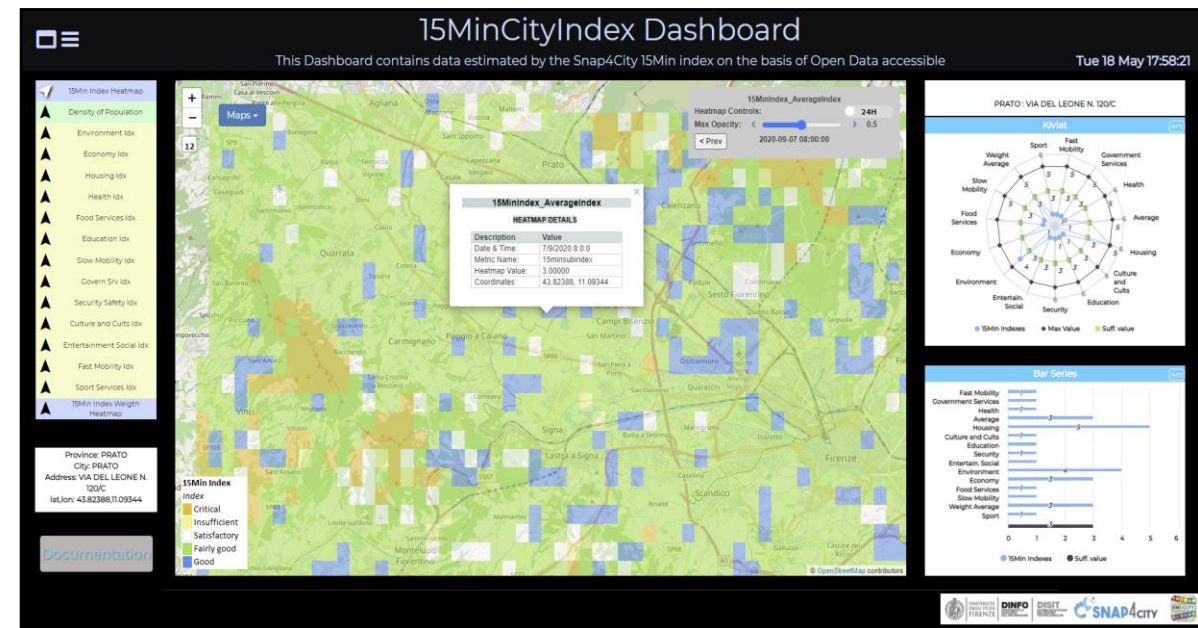
Heatmap Instances List: 15MinIndex_AbitantiPerPunto

Date	Description	Status	Indexed	BBox	Size
2020-08-26 15:00:00	Density In Florence Area	Completed	Indexed	{"min_lat": "653401", "min_lon": "4840326", "max_lat": "687183", "max_lon": "4862945"}	1740
2020-08-25 16:00:00	Density of People Living in Florence Area	Completed	Indexed	{"min_lat": "653401", "min_lon": "4840326", "max_lat": "687183", "max_lon": "4862945"}	1740
2020-08-25 15:00:00	Density of People Living in Florence Area	Completed	Indexed	{"min_lat": "0", "min_lon": "0", "max_lat": "687183", "max_lon": "4862945"}	1741

Cancel

Editing Mode for
RootAdmin only

15MinCityIndex



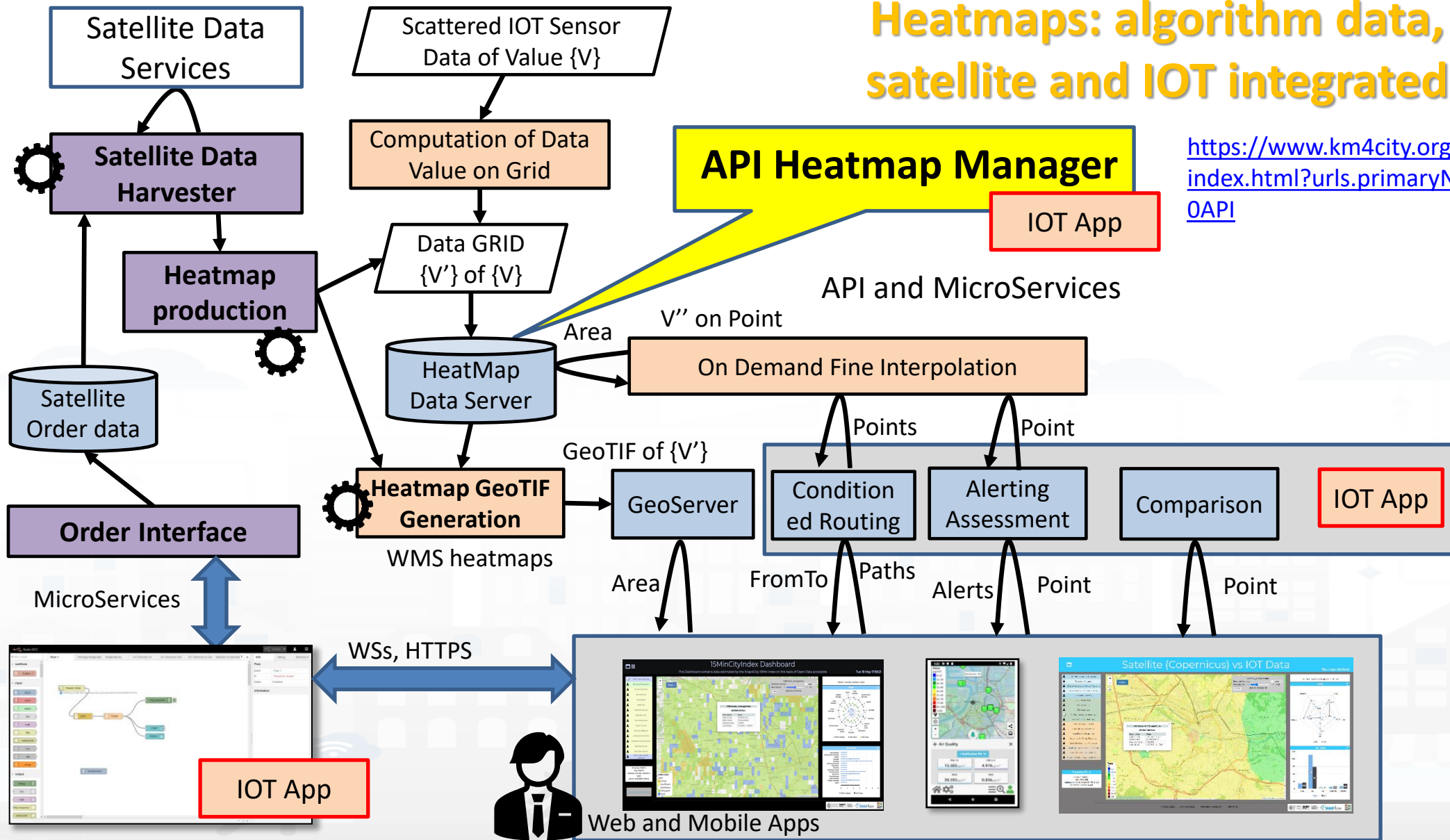
[FLORENCE metro city](#)

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

[Bologna metro city](#)

<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>

TOP

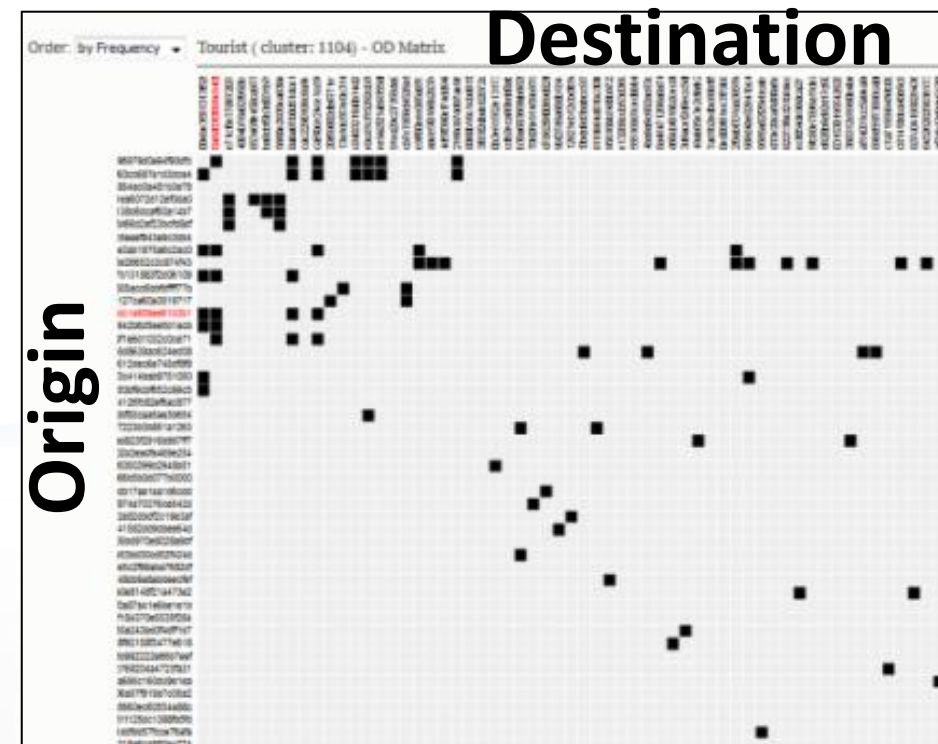
Origin Destination Matrices and Trajectories





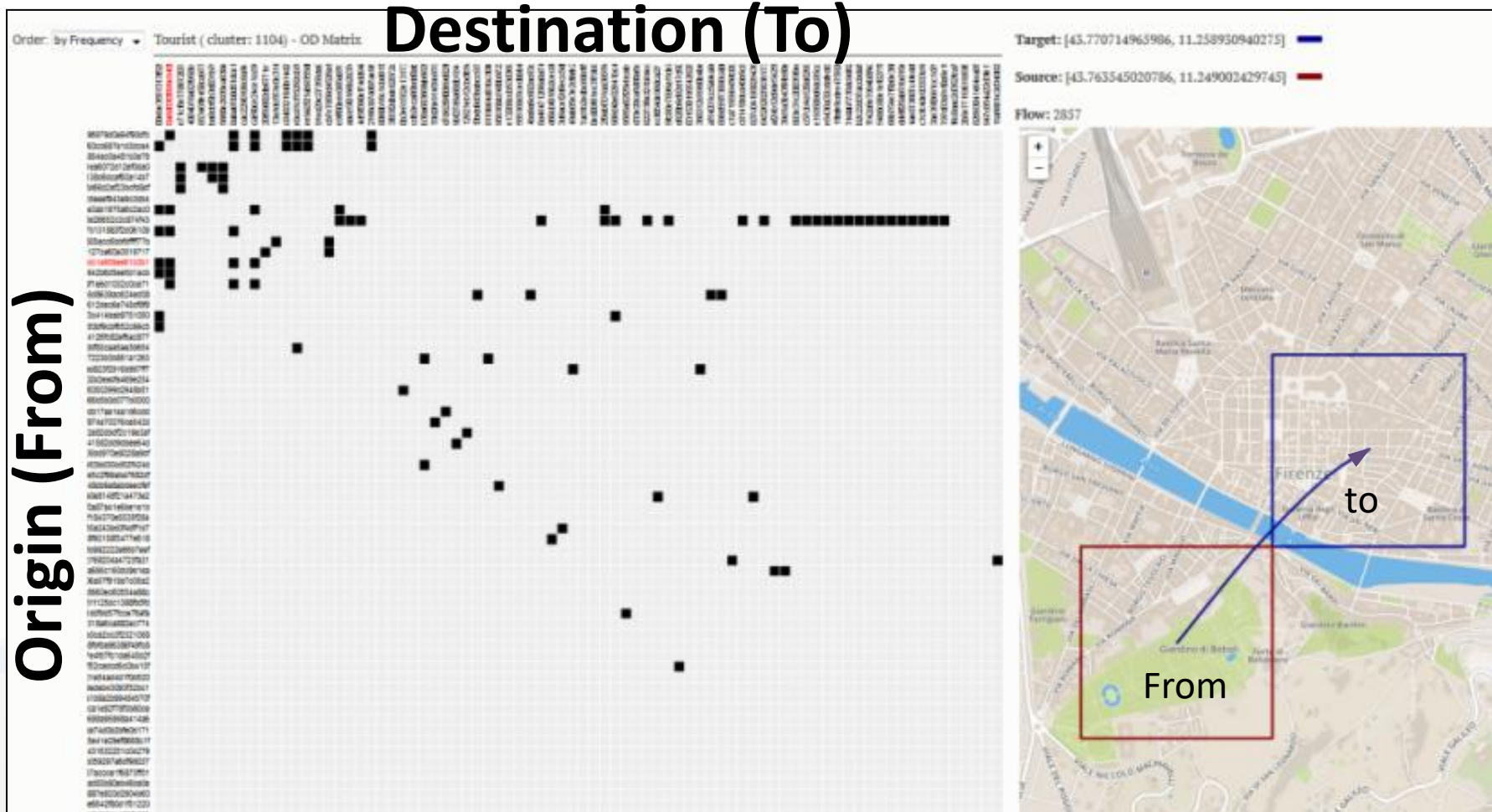
Origin Destination Matrices

- **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

Destination (To)



- 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

ODM Origin Destination Matrices

Selectornew

- Admin Areas
- Areas or grids
- Traffic Sensors
- Traffic Flow
- Traffic Flow Manager New

Map

Flow

0-2%
2-3%
3-4%
4-5%
5-6%
6-7%
7-8%
8-9%
9-10%
10-100%

Origin-Destination Map Controls:

- Show all polygons: ON
- Time period: week
- Precision: municipality
- Flow: outflow
- Max Opacity: 0.6
- 2022-07-07 00:00:00

Traffic Heatmap Controls:

- 24H
- Max Opacity: 1
- 2023-11-01 03:00:00

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



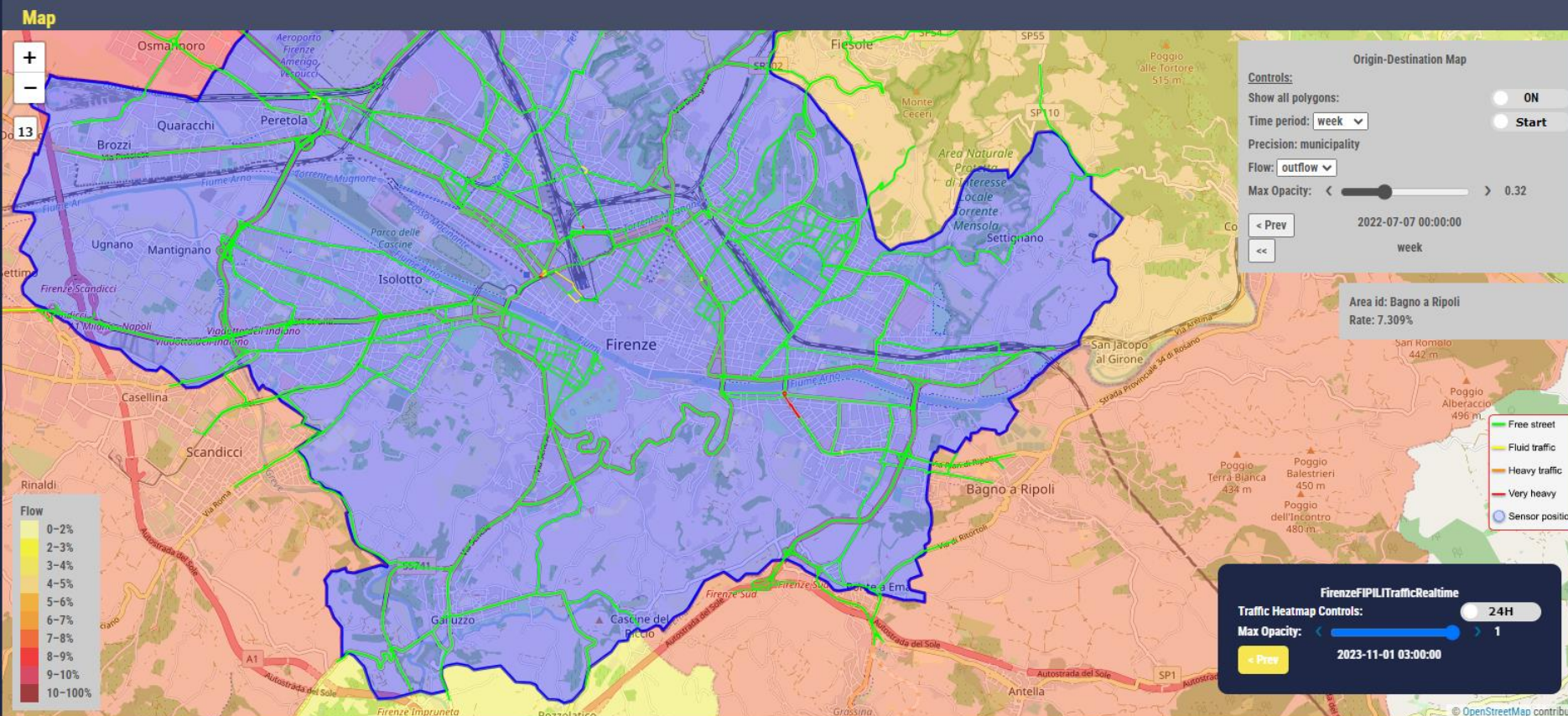
ODM Origin Destination Matrices

Wed 1 Nov 10:50:01



Select or new

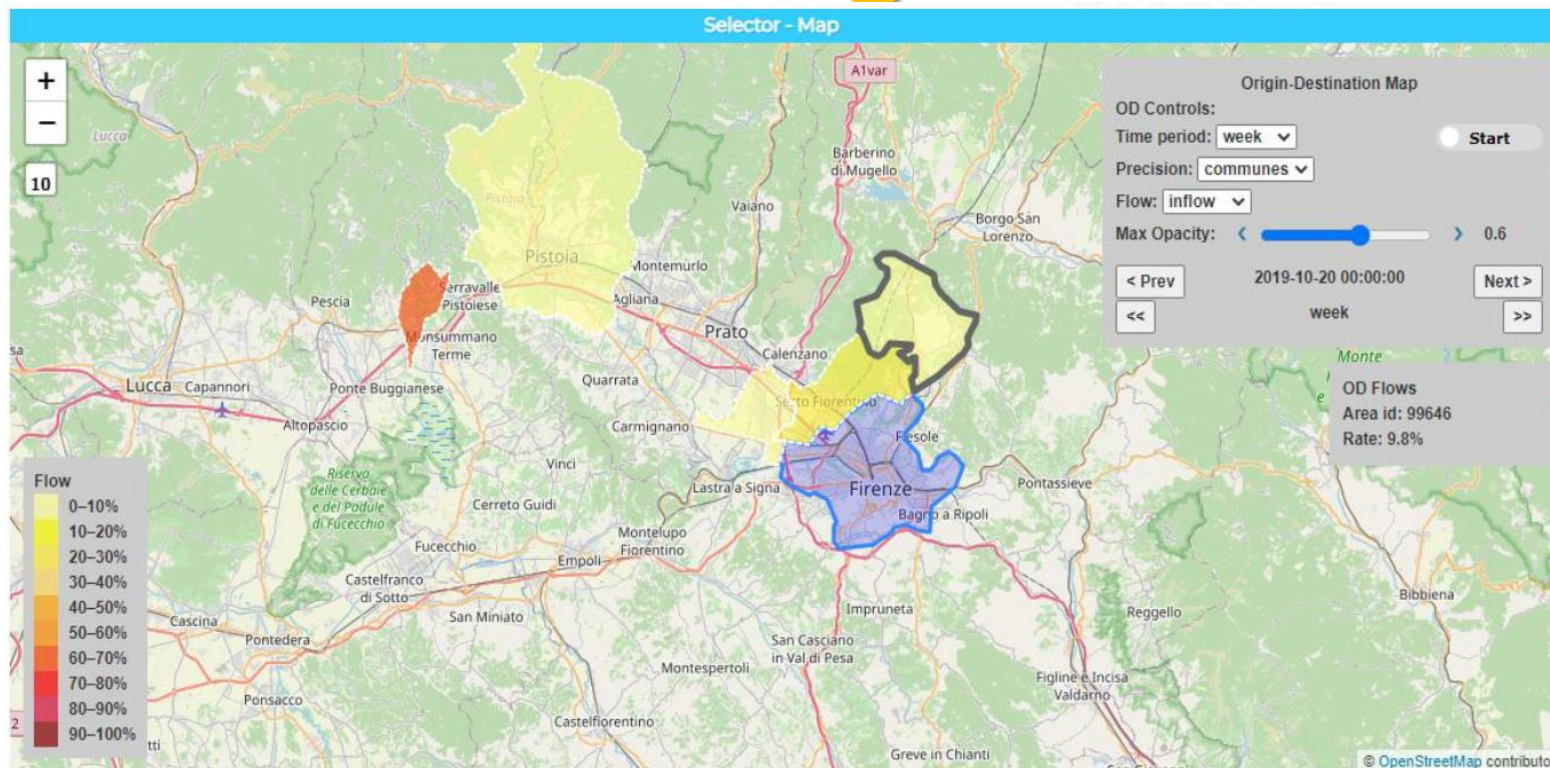
- Admin Areas >
- Areas or grids >
- Traffic Sensors >
- Traffic Flow >
- Traffic Flow Manager New >



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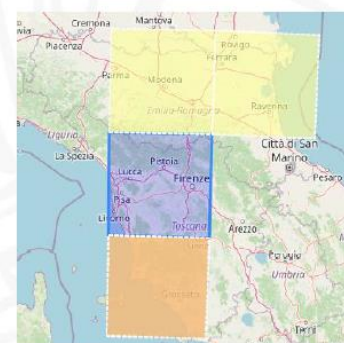
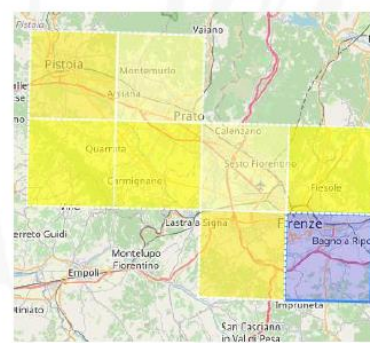
Different Origin Destination Matrices



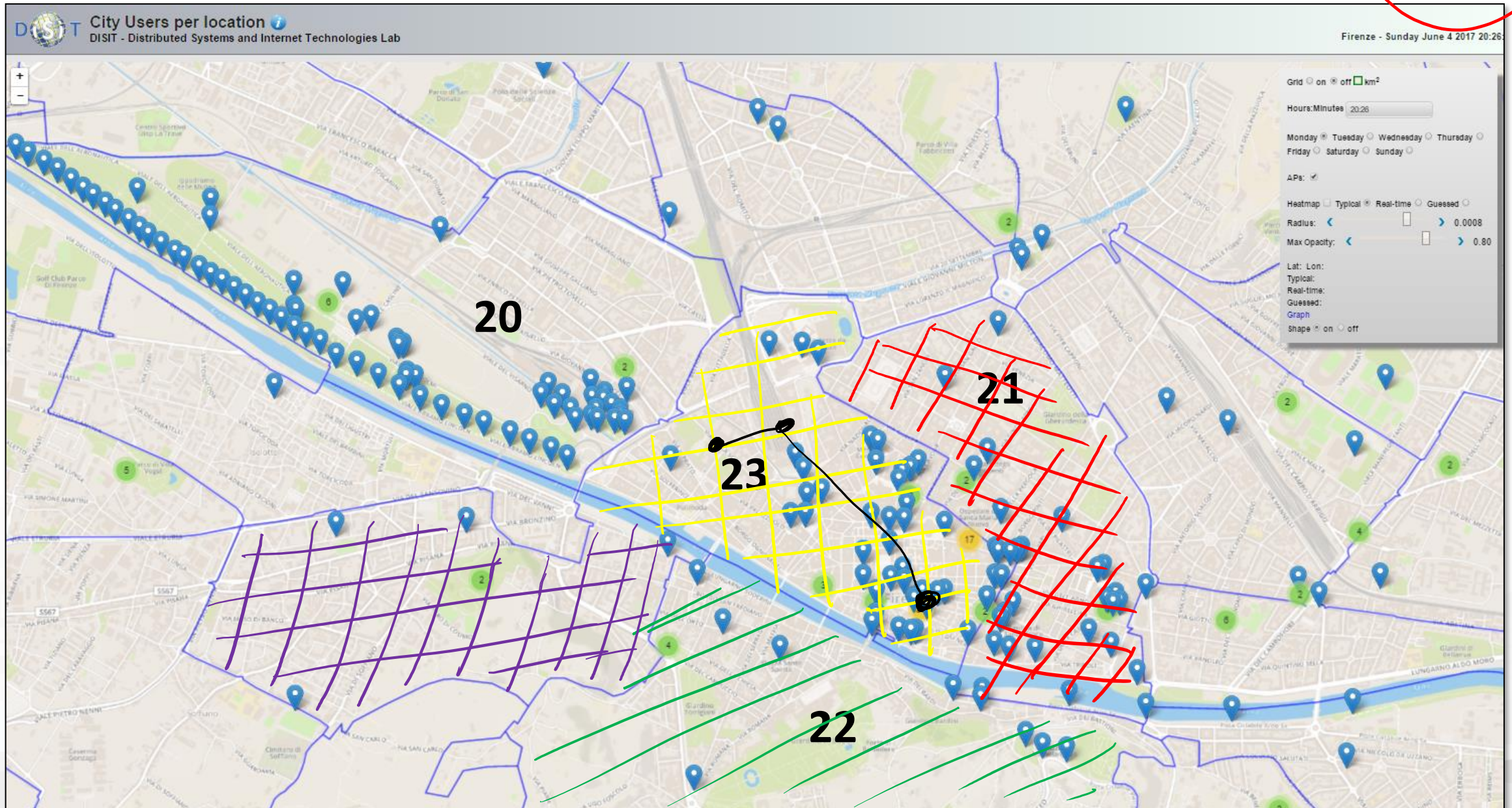
- Get specific value
- Time window
- Opacity
- Animation
- Inflow/outflow
- Sequence of OD matrices: next/prev

shapes

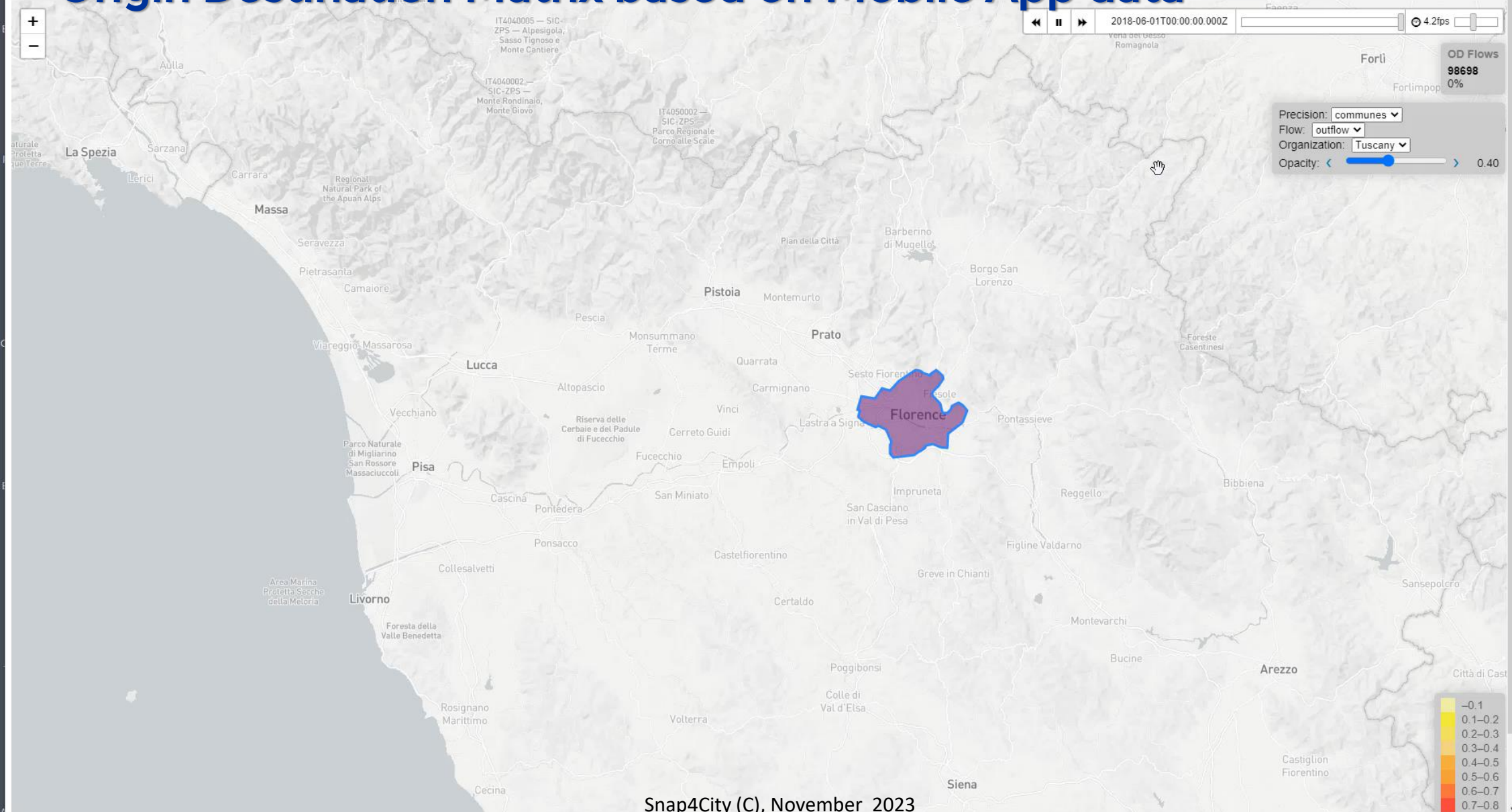
- Shapes: city, region, territories, etc.
 - GADM <https://gadm.org/>, and ACE
- Squared MGRS:
 - 1m, 10m, 100m, 1Km, 10Km, 100Km



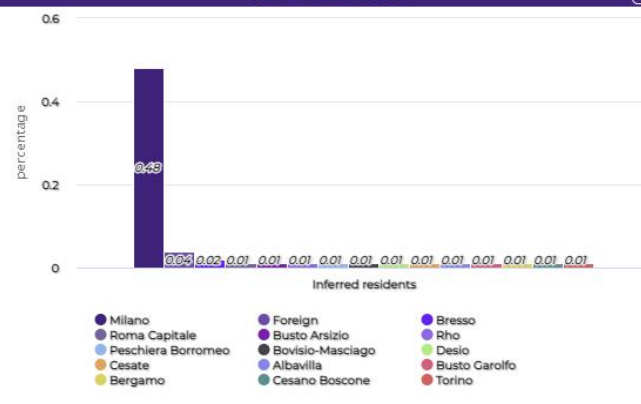
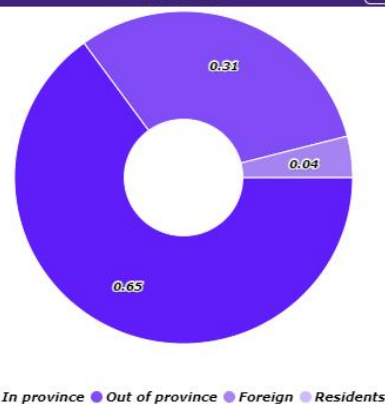
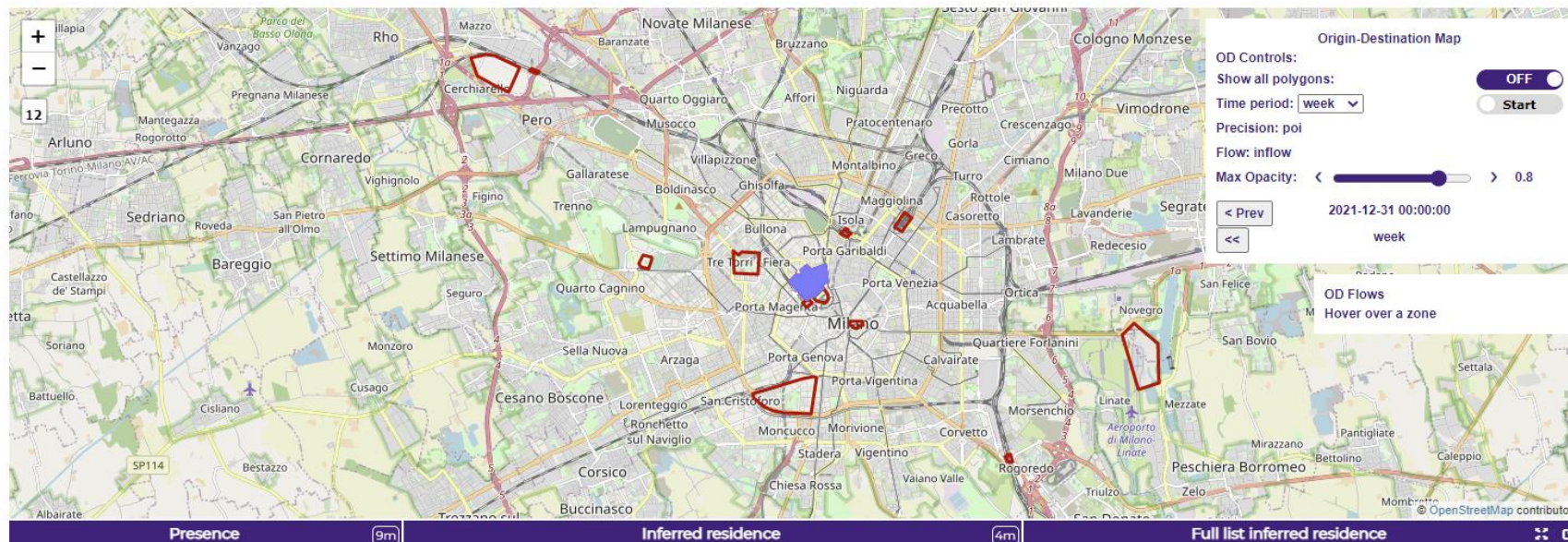
Firenze Wi-Fi vs ACE



Origin Destination Matrix based on Mobile App data



ODM Visual Analytic on Milan Area

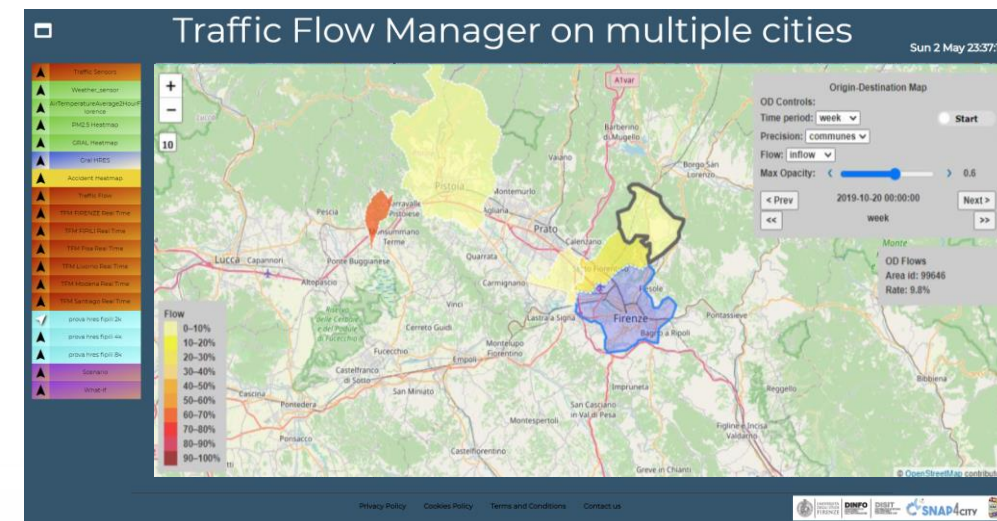
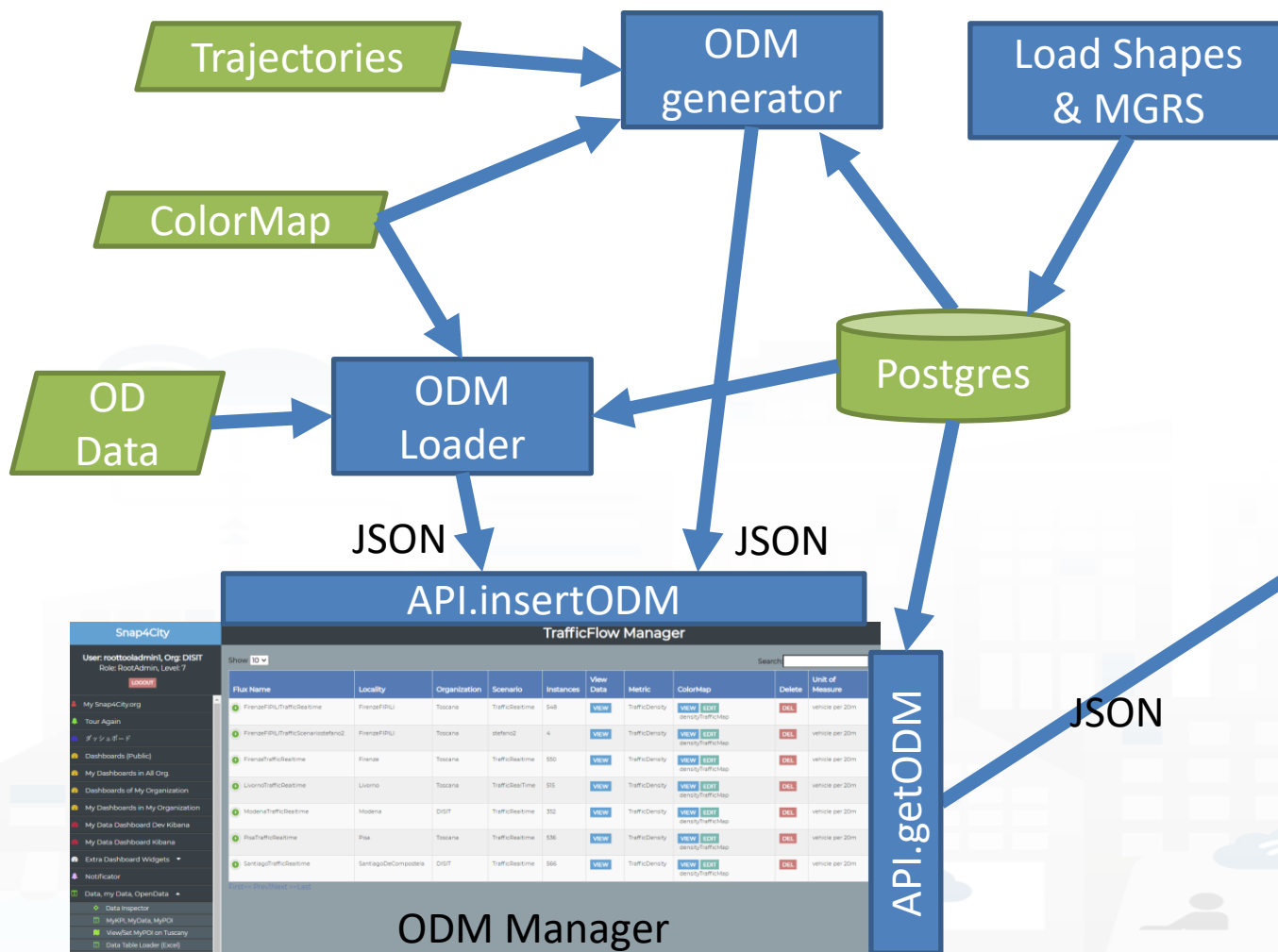


Parco Sempione

Region Province Municipality Census block

Milano	48.078%
Foreign	4.229%
Bresso	1.741%
Roma Capitale	1.392%
Busto Arsizio	1.044%
Rho	1.044%
Peschiera Borromeo	1.044%
Bovisio-Masciago	1.044%
Desio	1.044%
Cesate	0.696%
Albavilla	0.696%
Busto Garolfo	0.696%

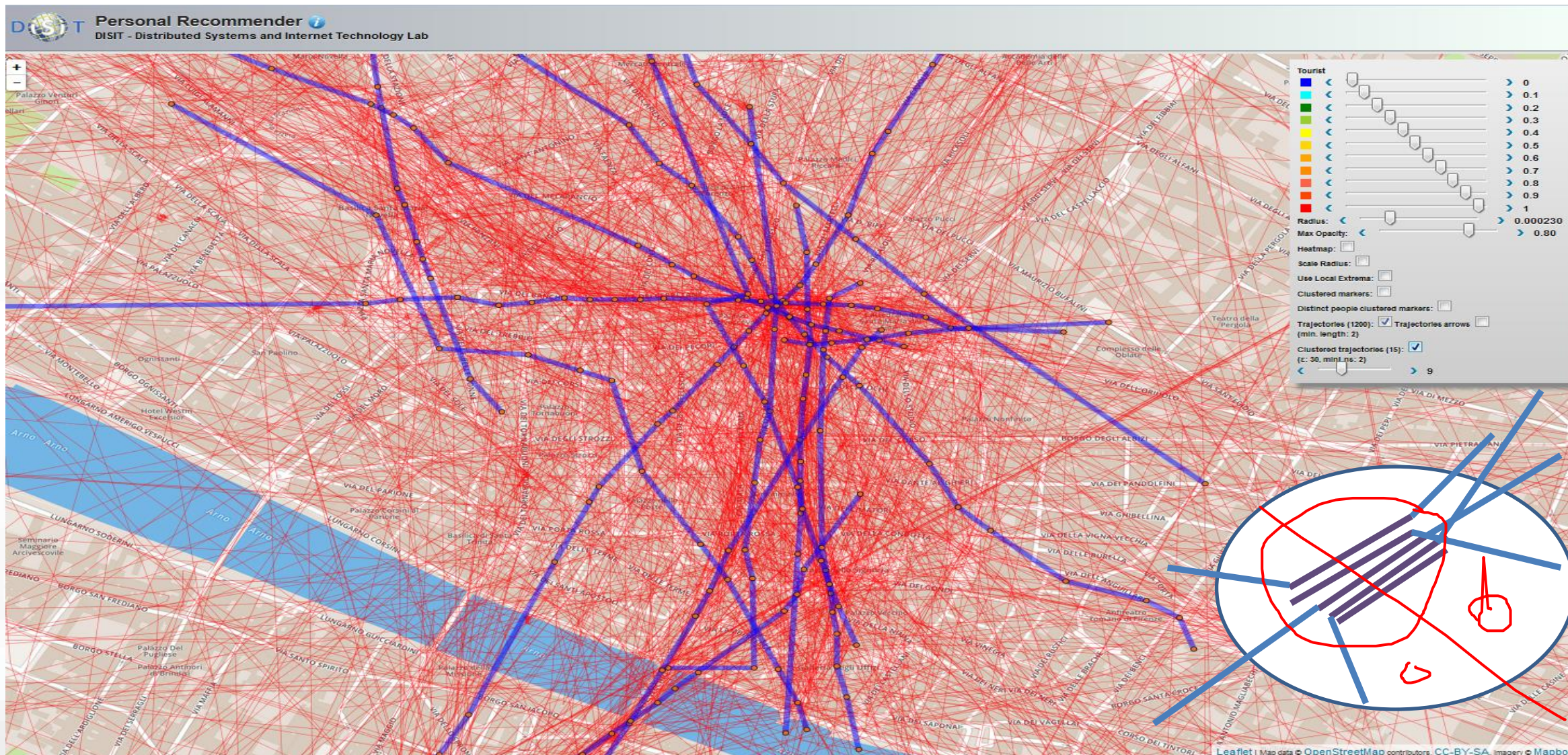
How Origin Destination Manager works



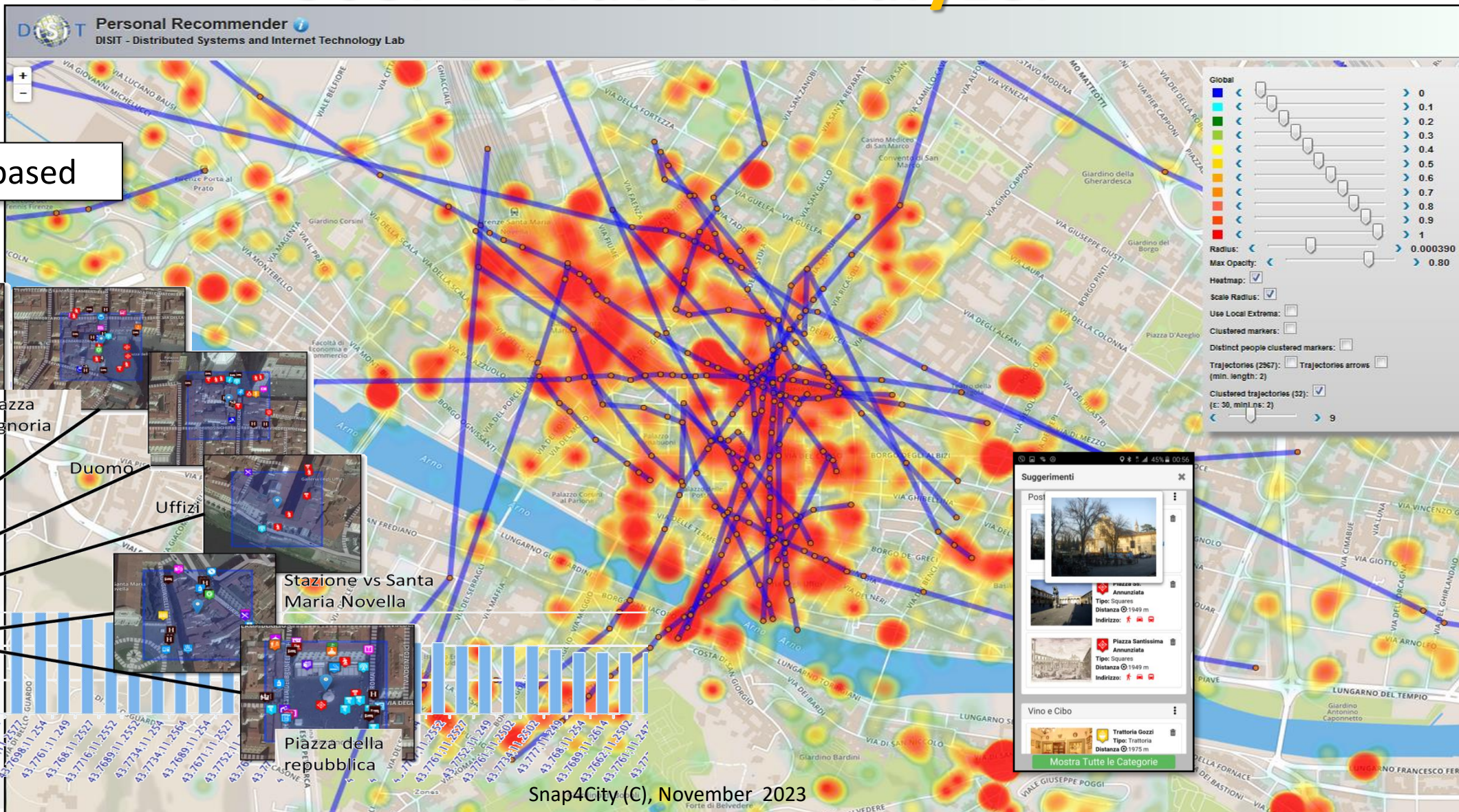
Postgress loaded for

- **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



TOP

Digital Twin and 3D Digital Representation of the City

11 SUSTAINABLE CITIES AND COMMUNITIES



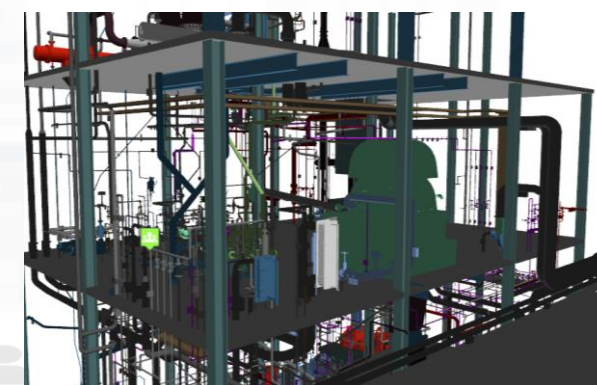
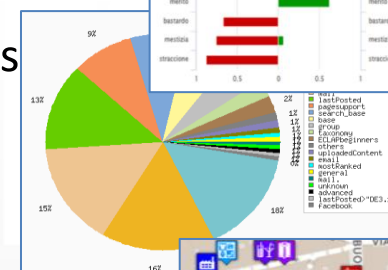
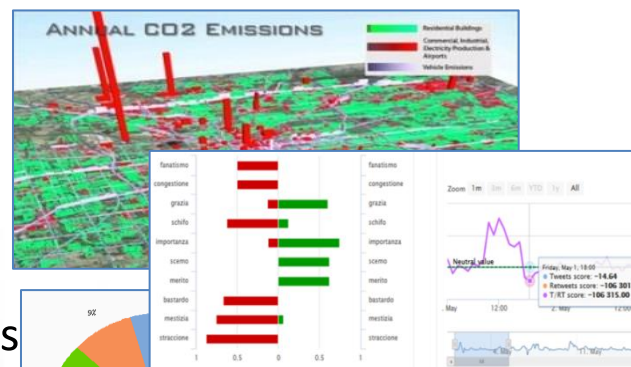
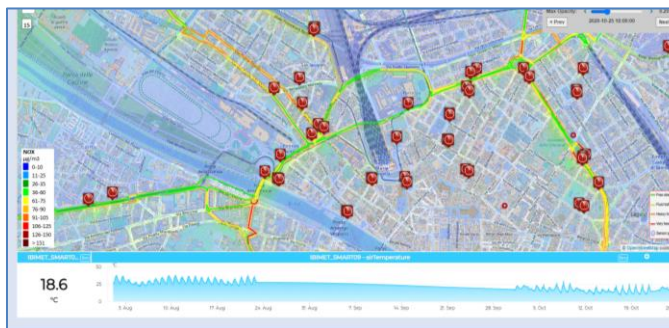
Digital Twin

- **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



Ciao

Fri 13 Oct 18:29:18

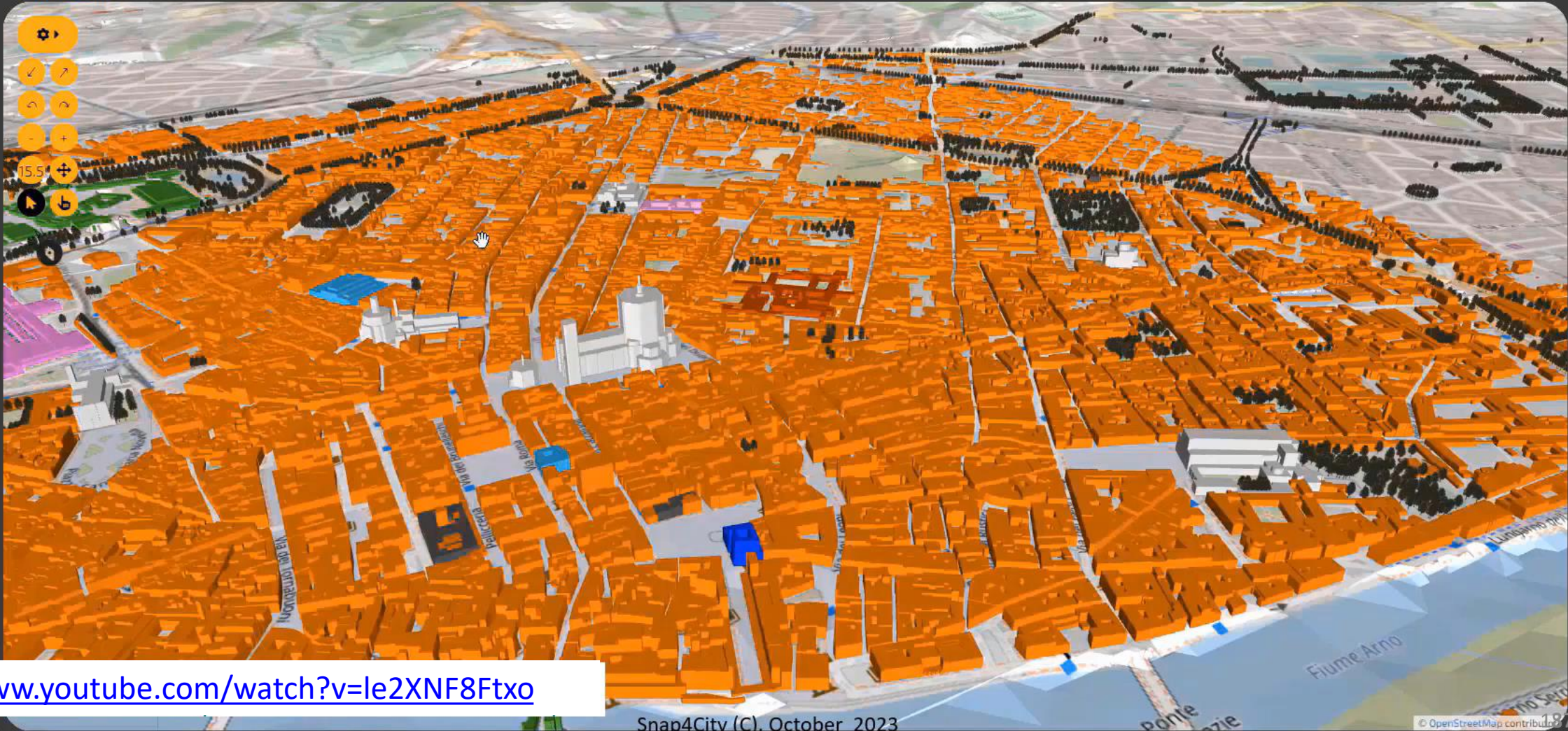
FLORENCE SCDT

SELECT...

- GRAL HD
- NO 2
-
-
-
-
-
- WHAT-IF
-
-

DOUBLE MAP

-
-
-
- 15.5
-
-

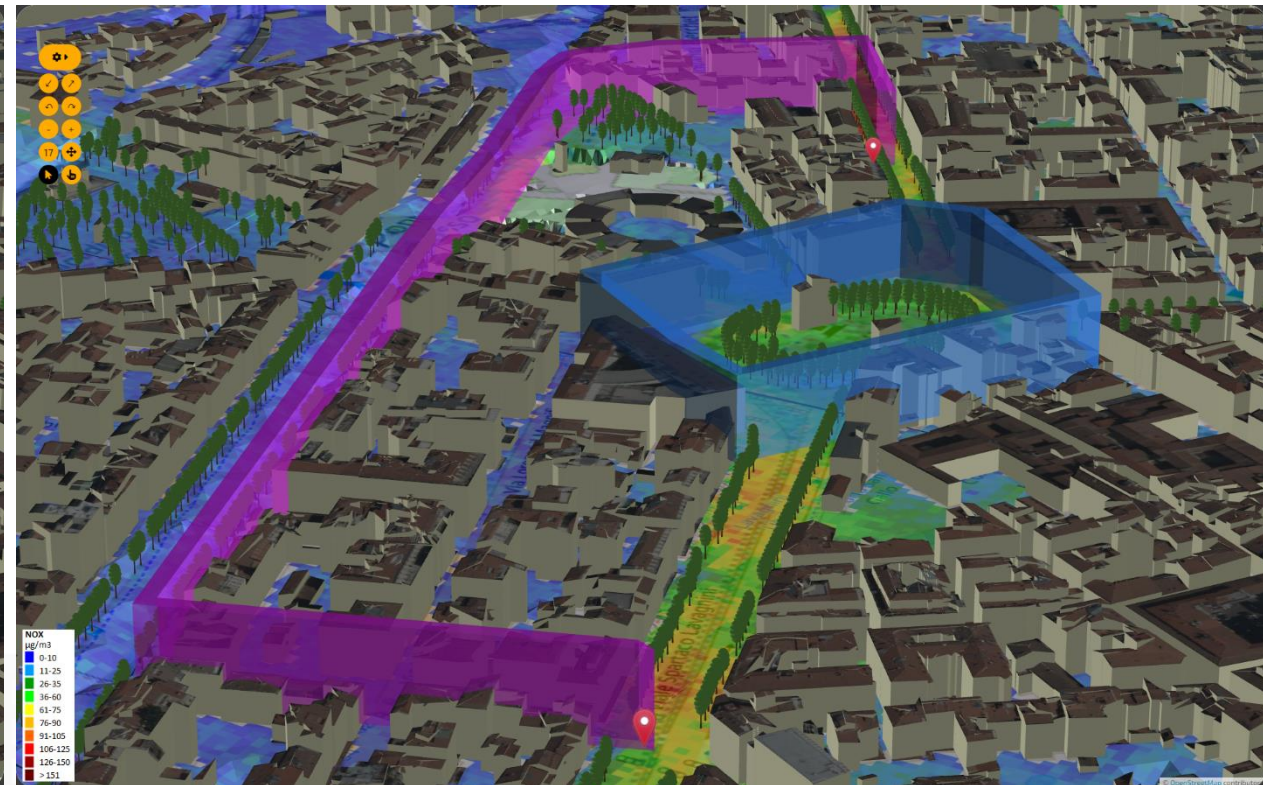
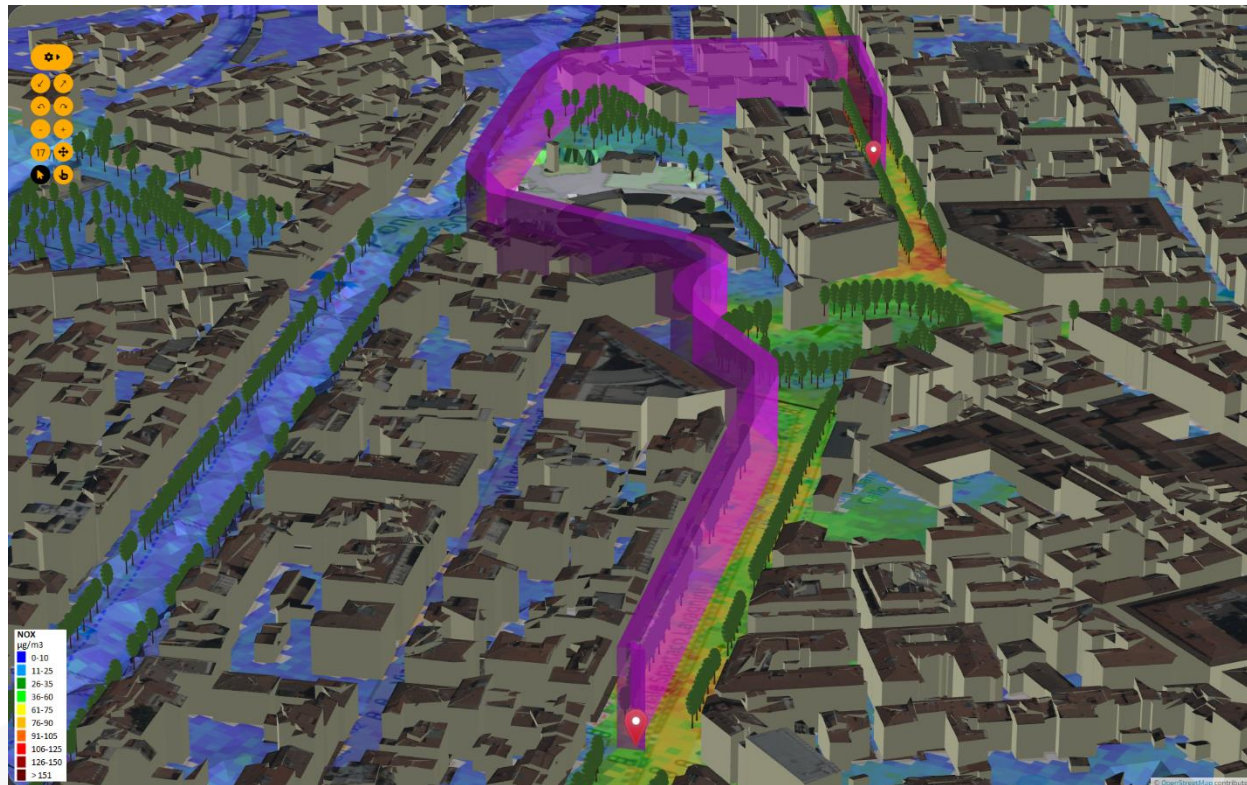


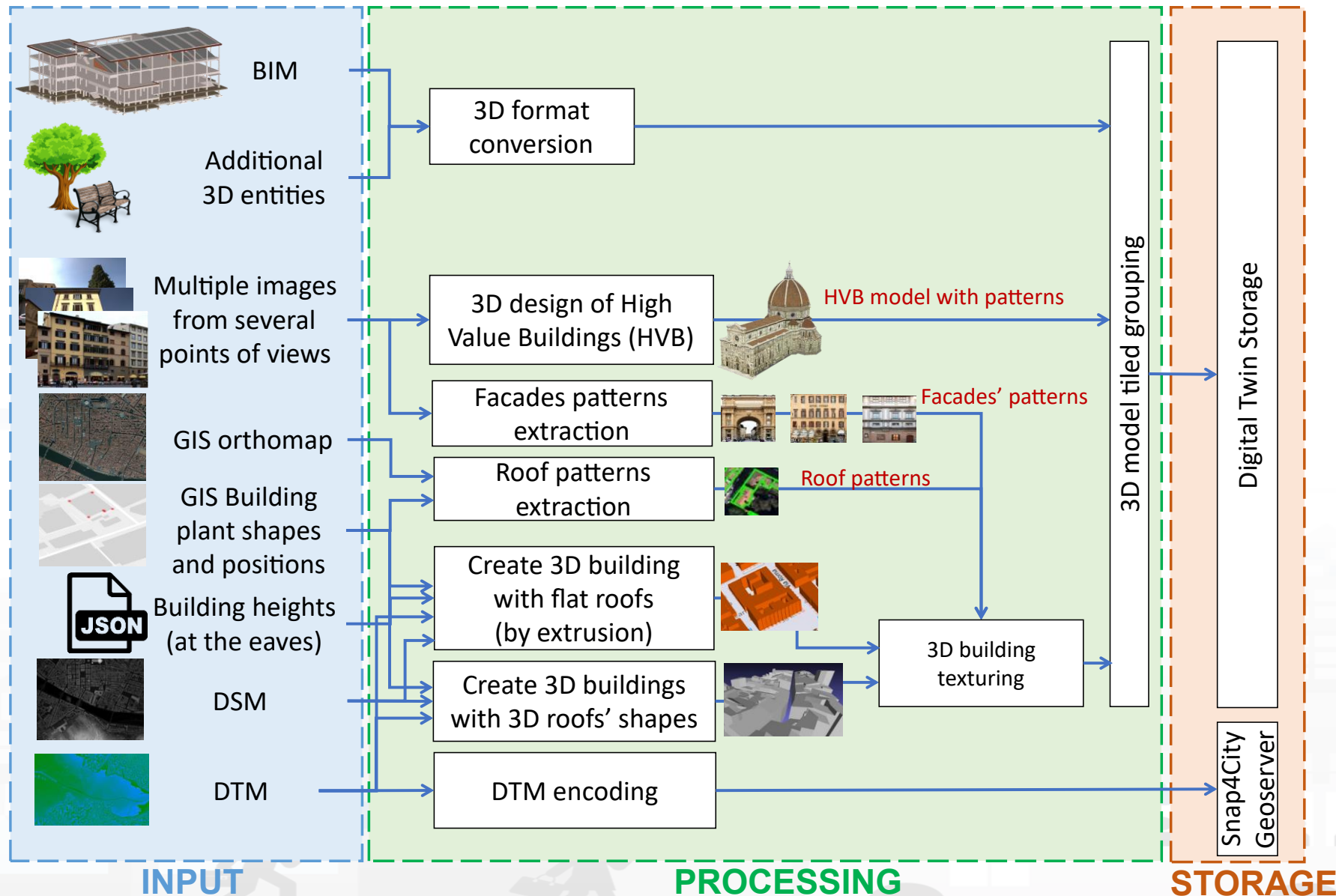
<https://www.youtube.com/watch?v=le2XNF8Ftxo>

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**

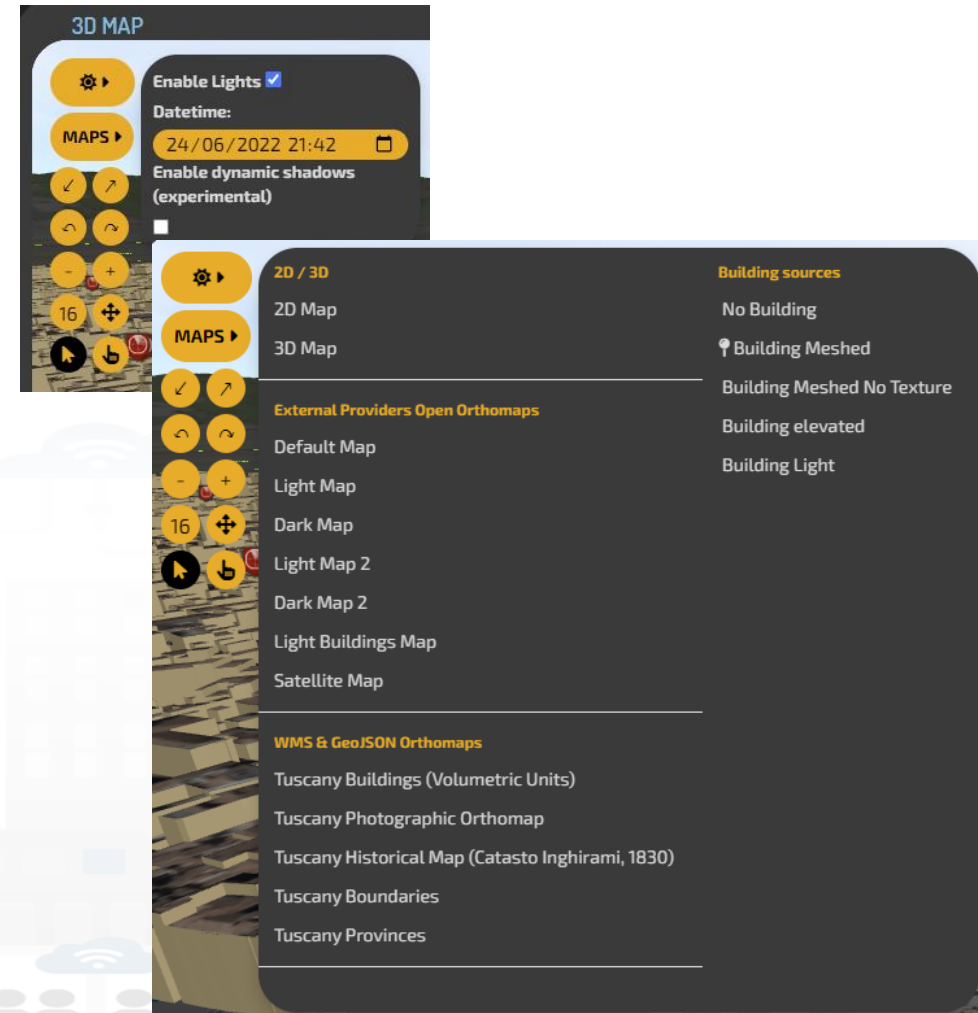
Dyamic Routing in 3D space





Interacting with 3D City Digital Twin

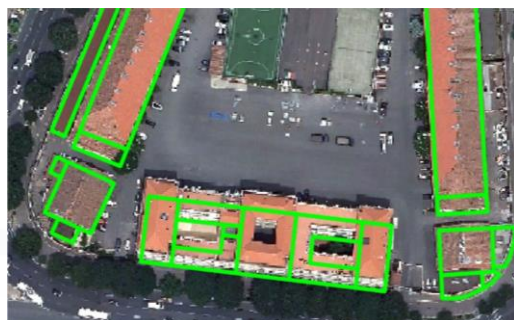
- You can see in the 3D model
 - Terrain model defining the level of the terrain and of the building
 - Generic Buildings, high value buildings, HVB (e.g., Dome, Palazzo Vecchio, etc.), facades, roofs, etc.
 - Sky pattern: sun, cloudy, etc.
 - Orthomaps below the buildings, by selection
 - Heatmaps, 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.



3D Map Texturing



Orthomaps



Building shapes

Input



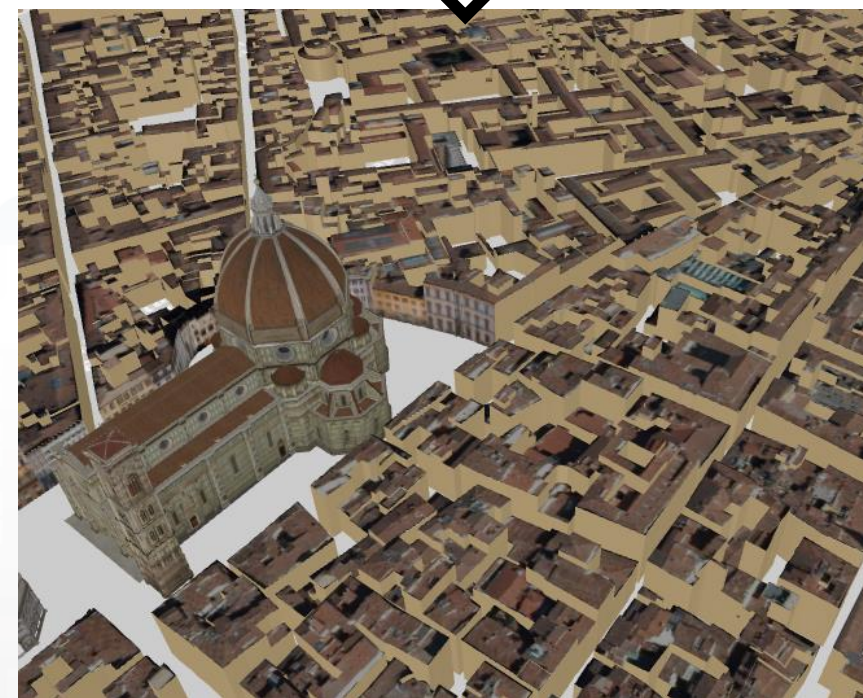
Deep network
alignment

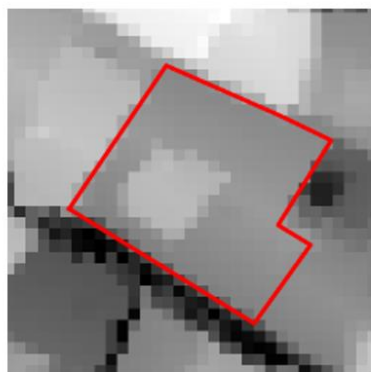


Rooftop texture
extraction and warping

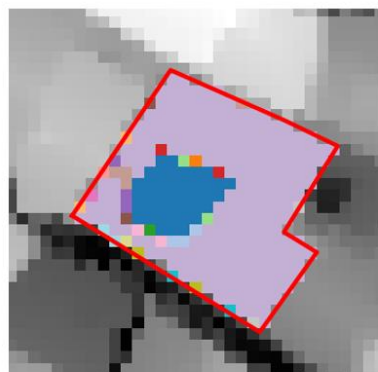


Final textured 3D map

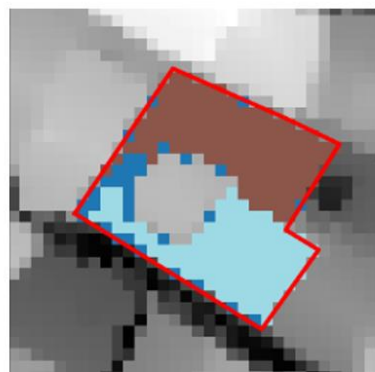




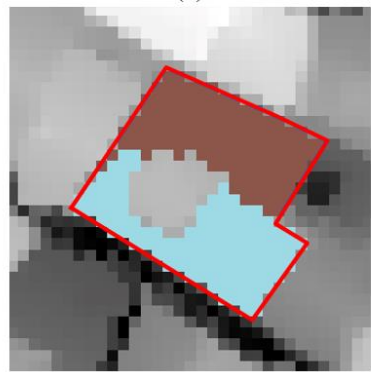
(a)



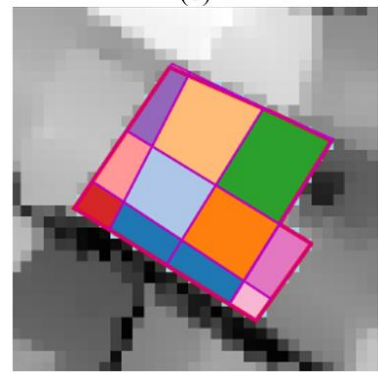
(b)



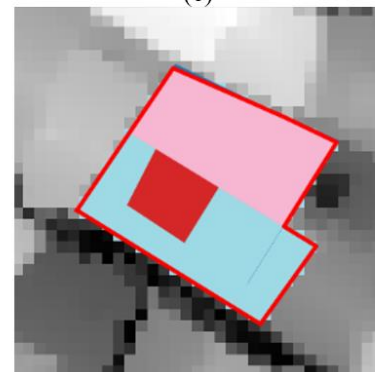
(c)



(d)

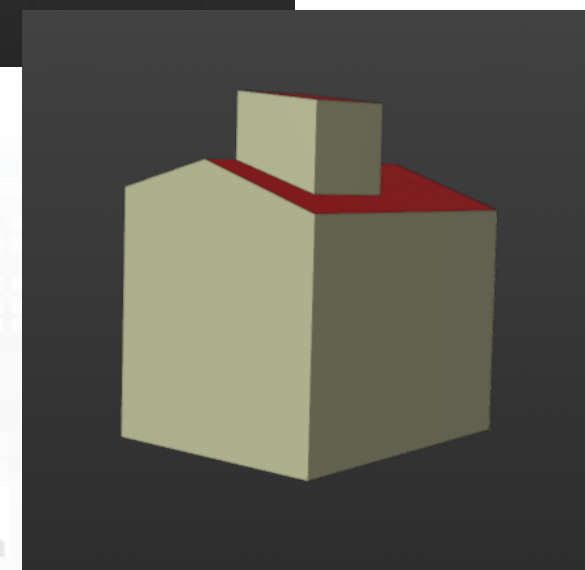
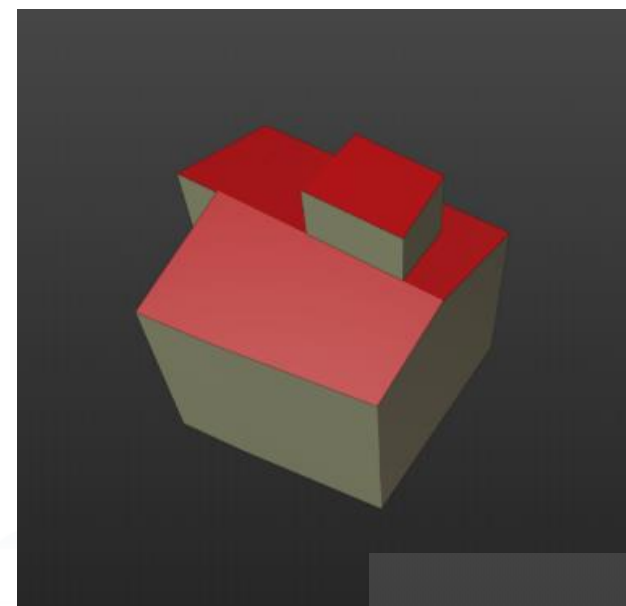


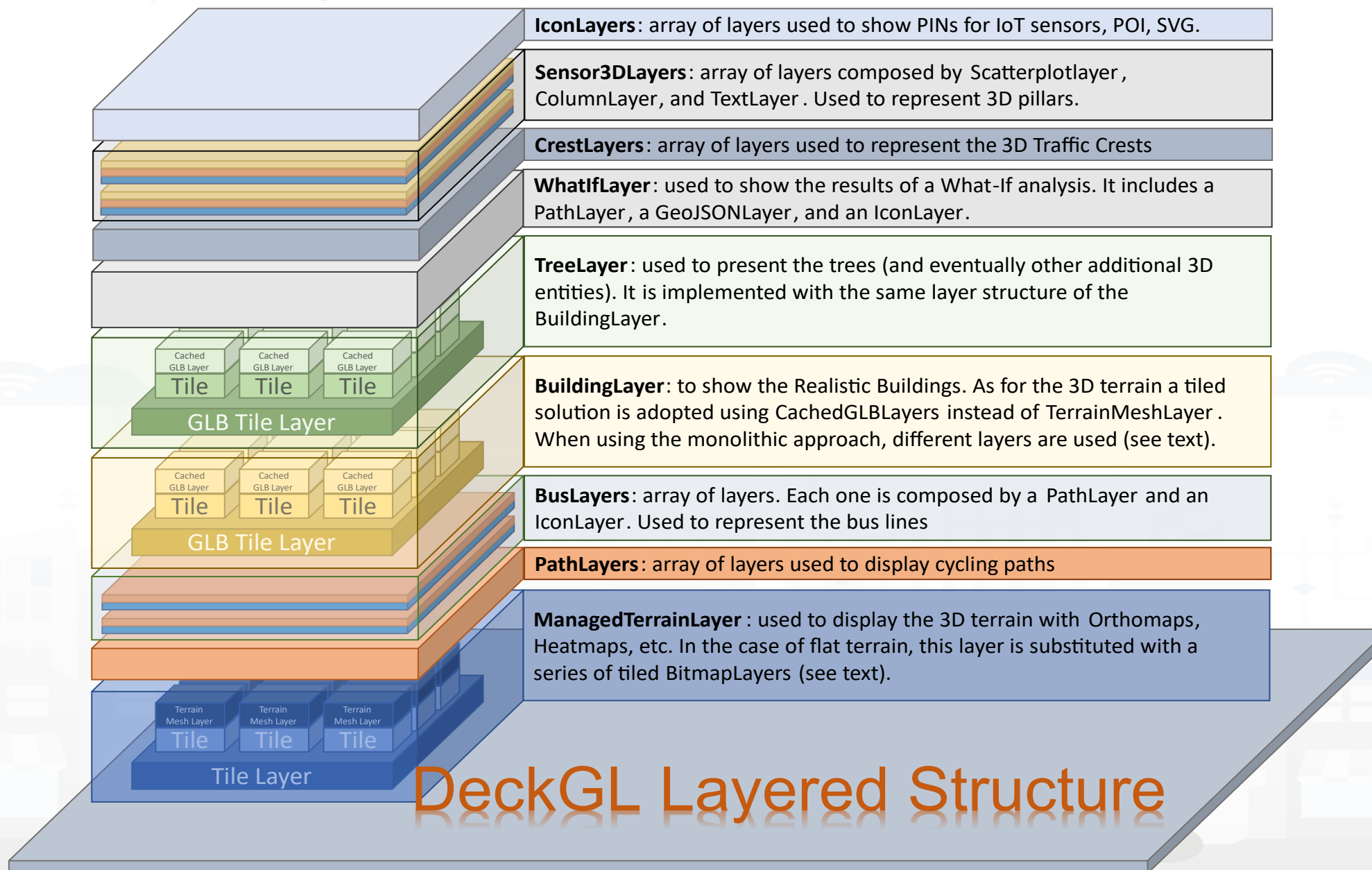
(e)



(f)

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.





DeckGL Layered Structure



UNIVERSITÀ
DEGLI STUDI
FIRENZE

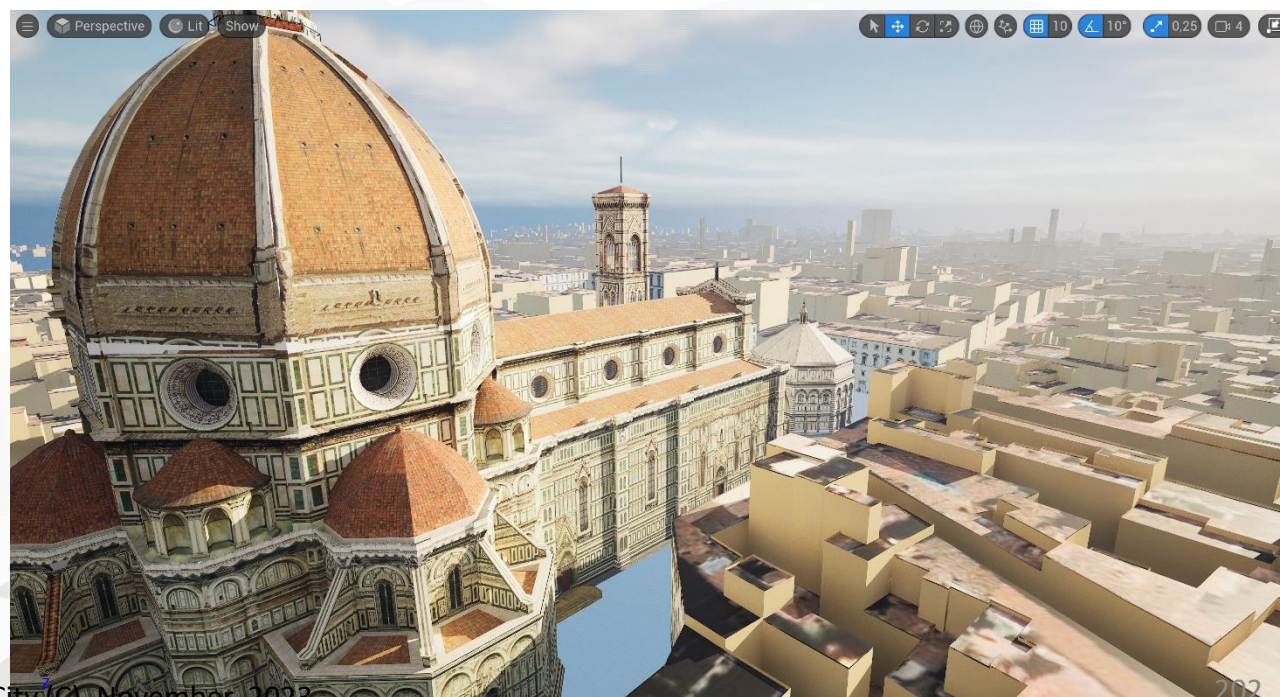
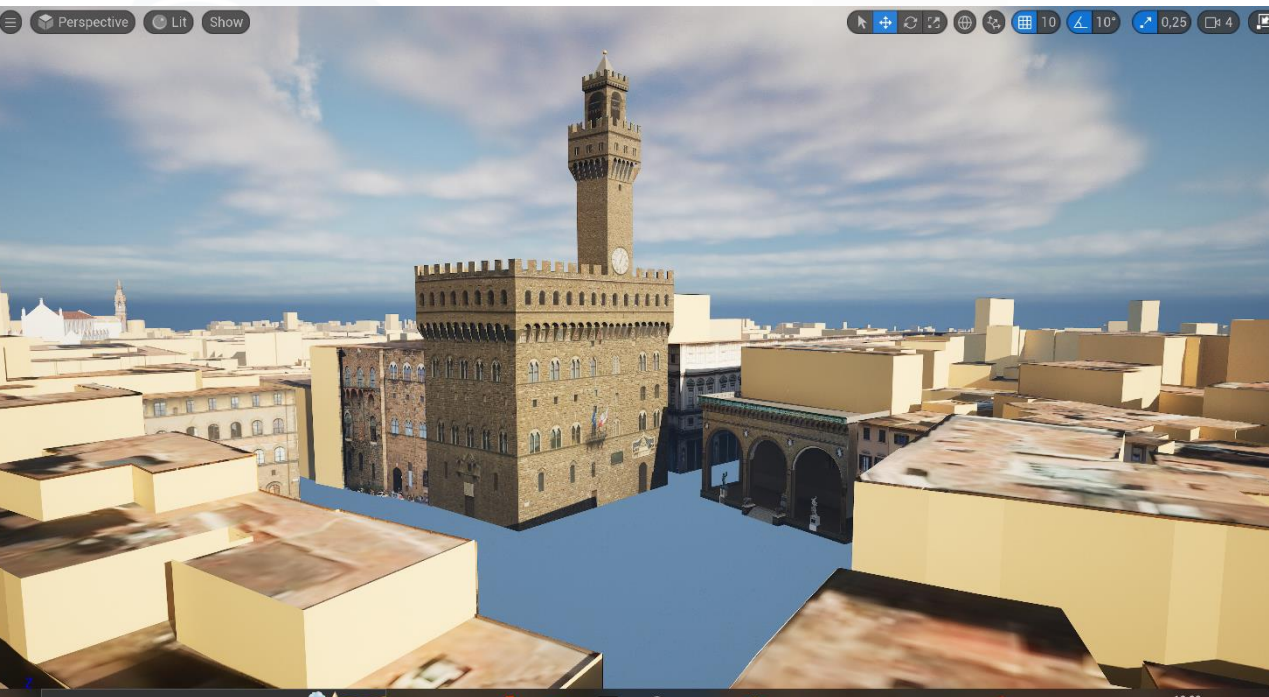
DINFO
DIPARTIMENTO DI
INGEGNERIA
DELL'INFORMAZIONE

DISIT
DISTRIBUTED SYSTEMS
AND INTERNET
TECHNOLOGIES LAB

 **SNAP4CITY**



OCULUS



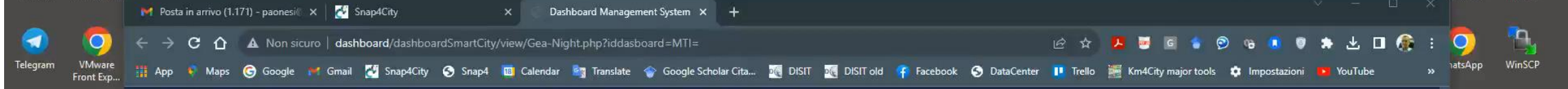



Exploiting Google API with Snap4City engine

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

Snap4City Digital Twin Engine and data + 3D Google Data







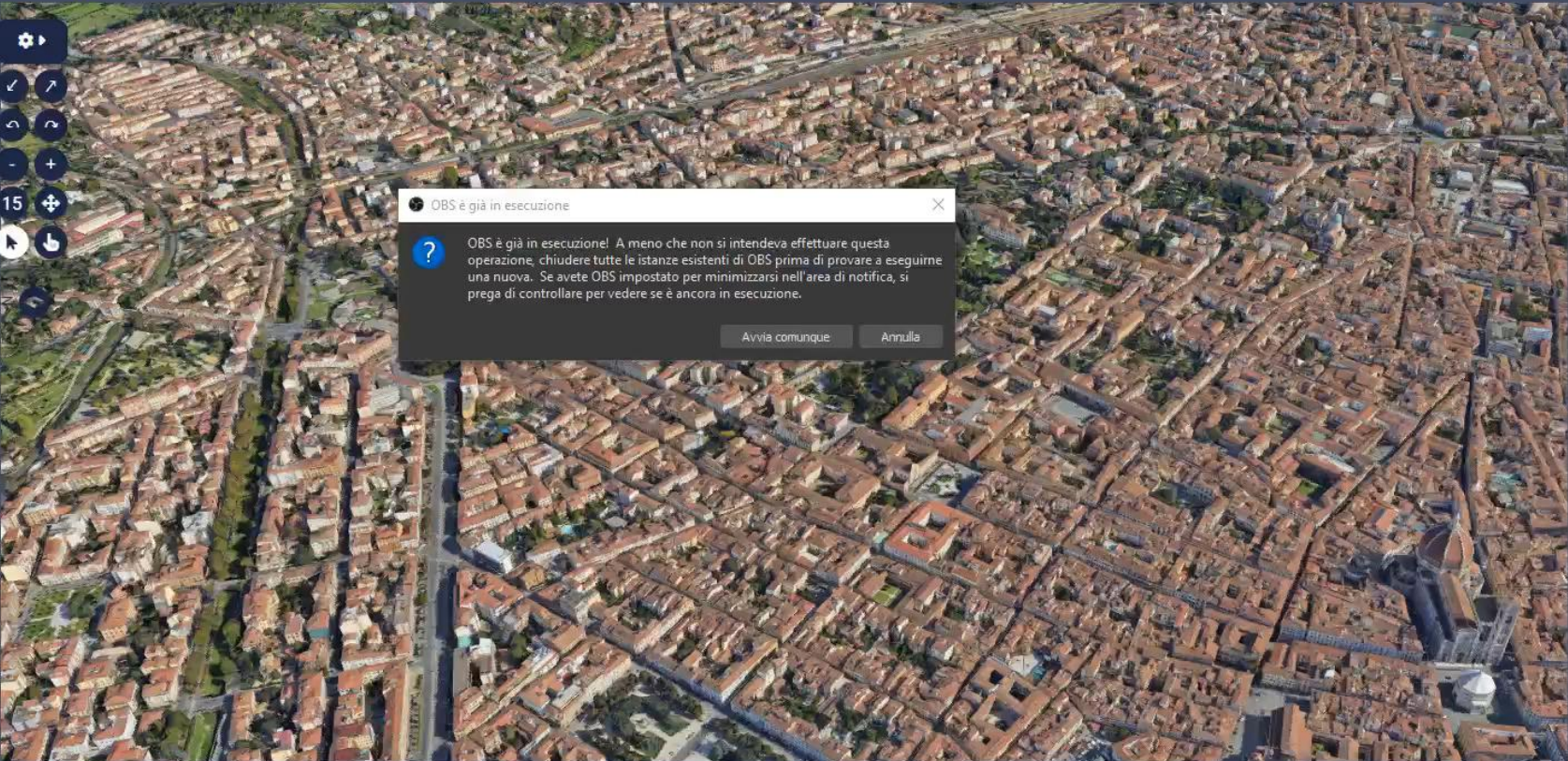
Florence Testing

Mon 18 Sep 17:40:57

Selector

- >
- >
- >
- >
- >
- >
- >
- >
- >
- >
- >
- >
- >

Double Map





Snap4CityDocker | Dashboard Management System | Genoa - Google Maps

Non sicuro | dashboard/dashboardSmartCity/view/Baloon-Dark.php?iddashboard=MTY=

App | Maps | Google | Gmail | Snap4City | Snap4 | Calendar | Translate | Google Scholar Cita... | DISIT | DISIT old | Facebook | DataCenter | Trello | Km4City major tools | Impostazioni | YouTube | Google Forms | News | Qnap15sek7gyfe

Ciao

Mon 18 Sep 18:32:23

GOOGLE TEST

SELECT...

- SELECT...
- NO 2
- Bar chart
- Map
- 15
- What-if
- Car
- Person
- Bicycle

DOUBLE MAP

© OpenStreetMap contributors

Ciao

Mon 16 Oct 14:09:10

GOOGLE TEST

SELECT

- Home
- Map
- 102
- Bar Chart
- Line Chart
- Area Chart
- Bus
- Car
- WHAT?
- Car
- Person
- Bicycle

DOUBLE MAP

Heatmap

GRALheatmap

Heatmap Controls: 24H

Max Opacity: 0.25

< Prev 2023-10-11 23:00:00 Next >

NOX
µg/m3

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

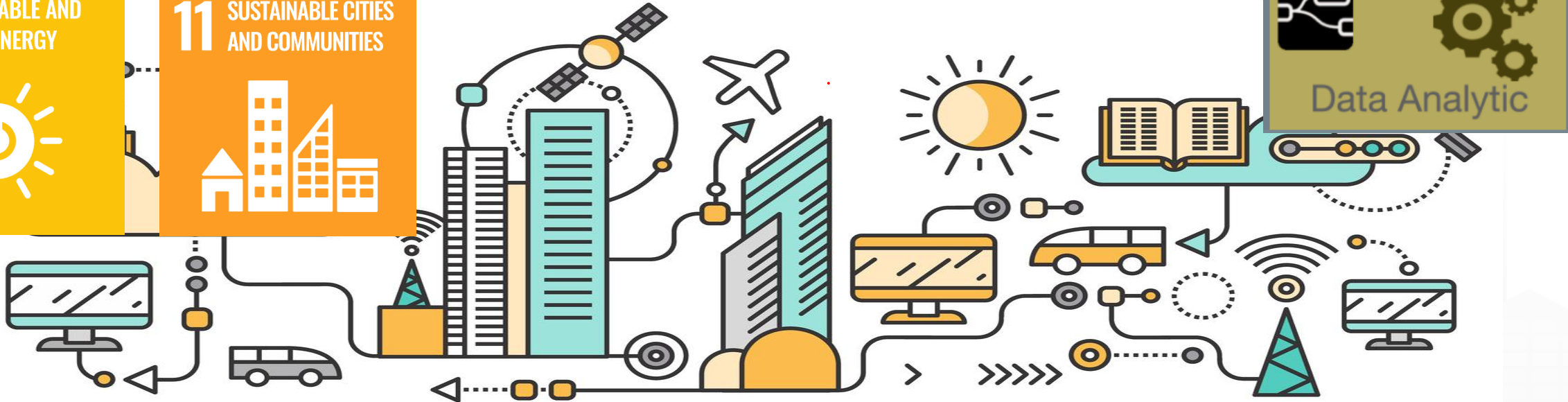
Snap4City (C), November 2023

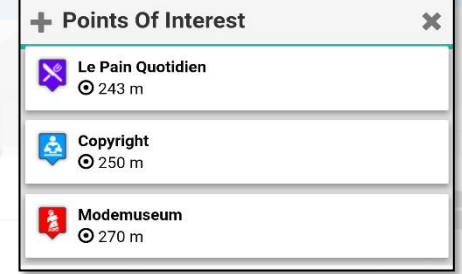
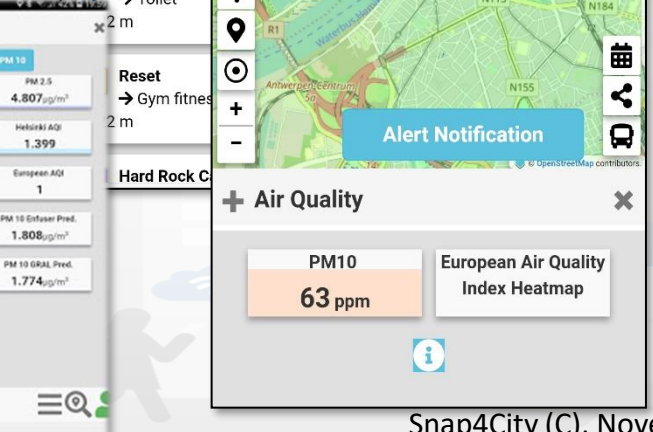
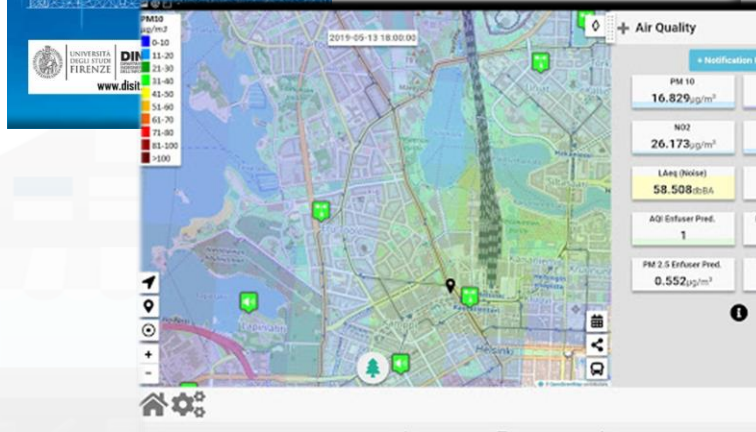
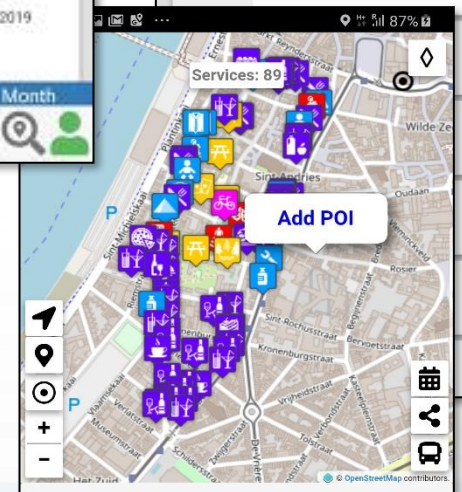
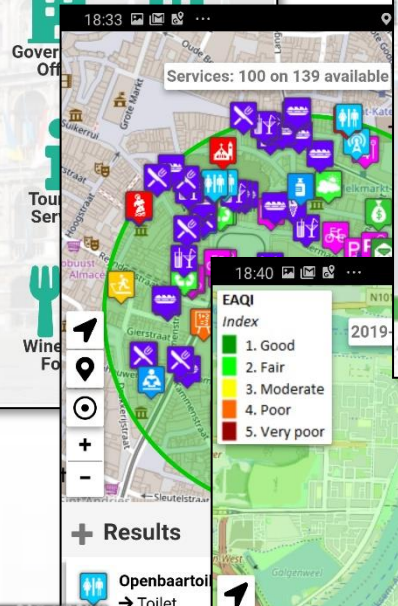
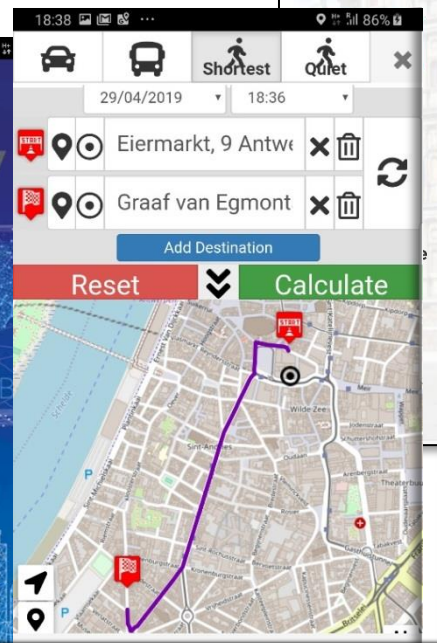
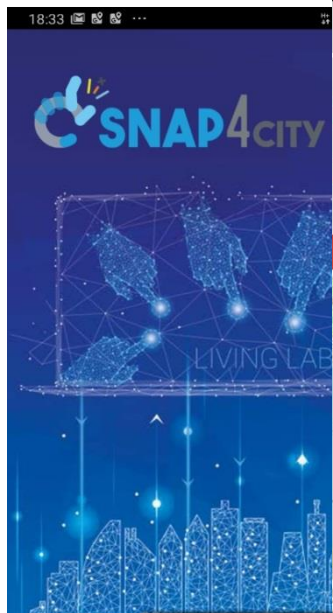
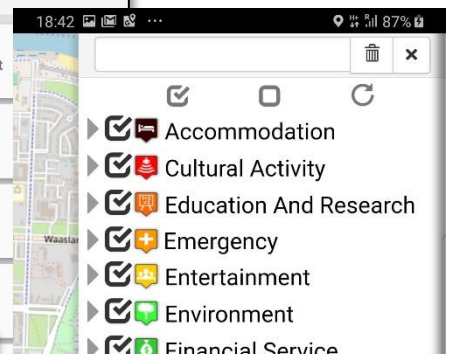
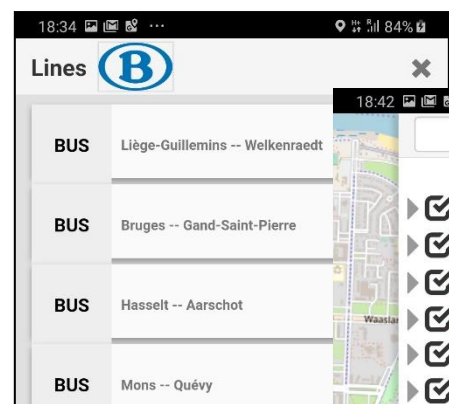
User Behaviour Analysis: Trajectories, Heatmap, typical...

7 AFFORDABLE AND
CLEAN ENERGY



11 SUSTAINABLE CITIES
AND COMMUNITIES





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

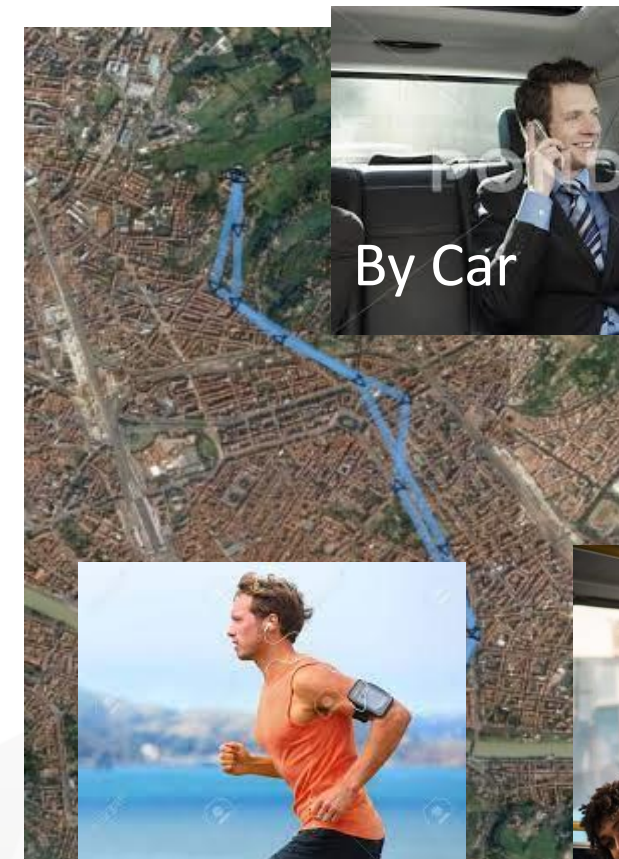
- Trajectories
- Hot Places by click and by move
- Origin destination matrices
- Most interested topics
- Most interested POI
- Delegation and relationships
- Accesses to Dashboards
- **Cumulated Scores from Actions**
- Requested information
- Routing performed
-

Produced information

- Suggestions
- Engagements
- Notifications
- ...

System

To propose suggestions and Engage city user we need to know how they are moving



By Car



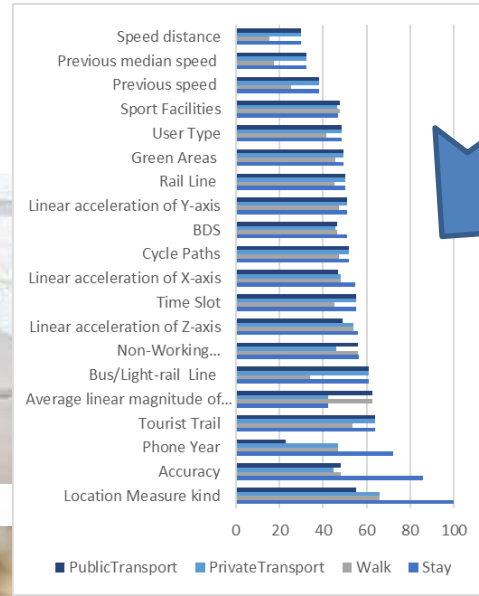
Walk



By BUS

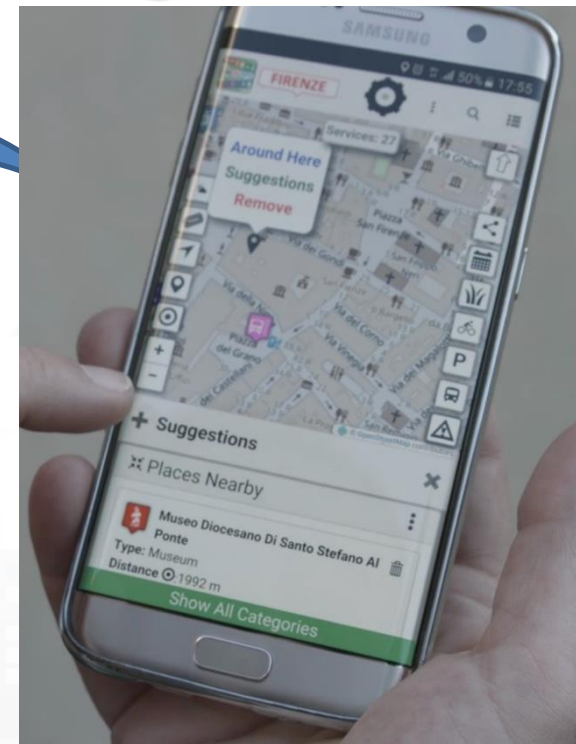


Run



Artificial Intelligence
Classification

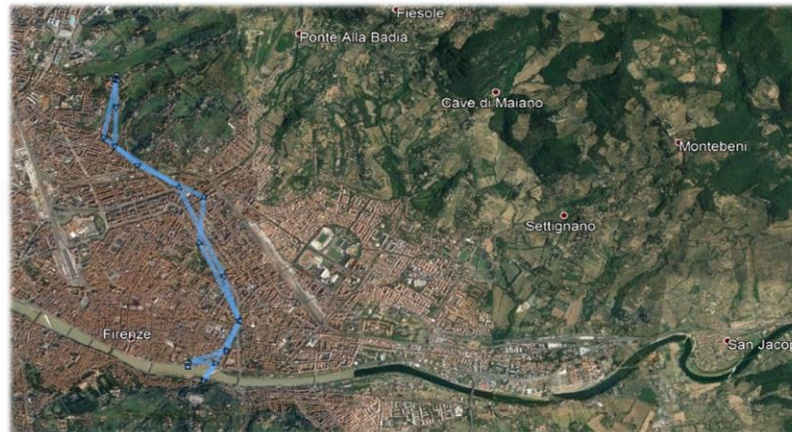
Suggestions



Automated Classification of Users' Transportation Modality in Real Conditions

Variables taken into account:

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



Four combinations of the different categories of data:

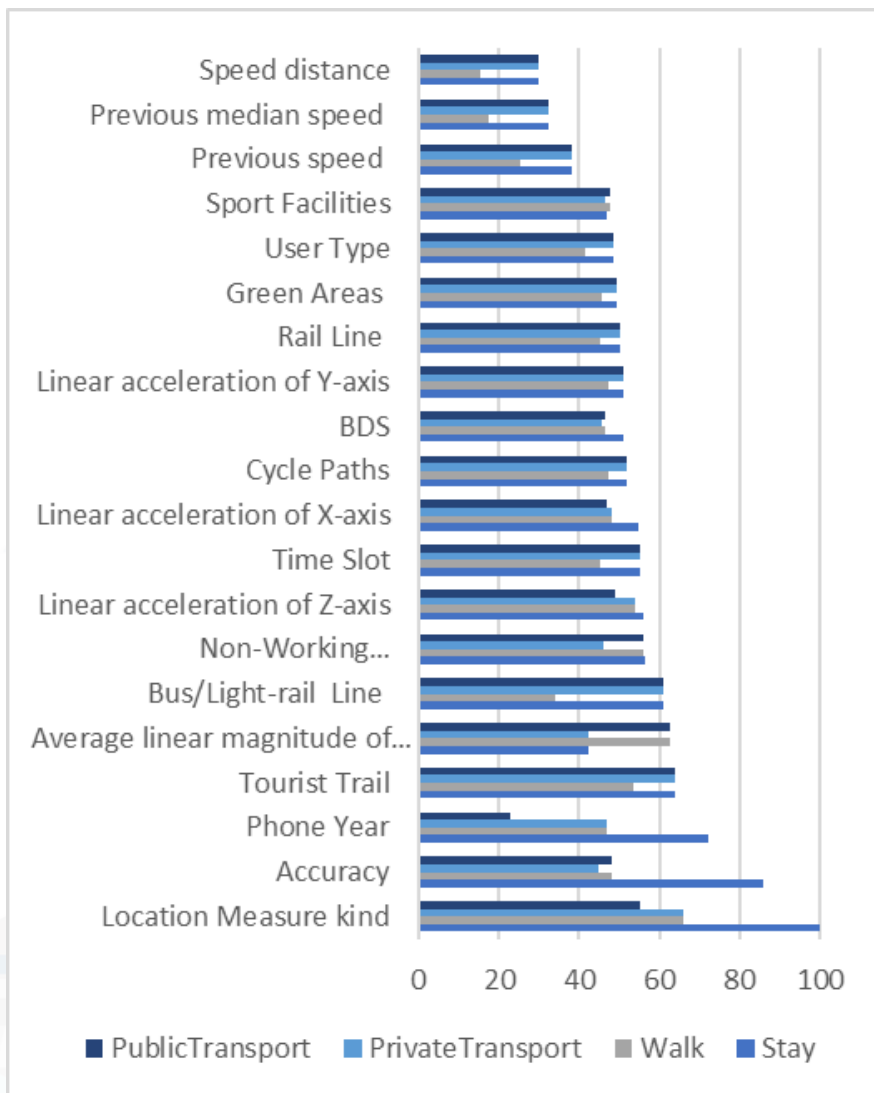
1. Baseline features and distance feature
2. Baseline, distance feature and accelerometer features
3. Baseline, distance feature and temporal window features
4. Baseline, distance, accelerometer, temporal features together

Dataset:

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

Note that, *each user have used the mean of transport of his/her own preference.*

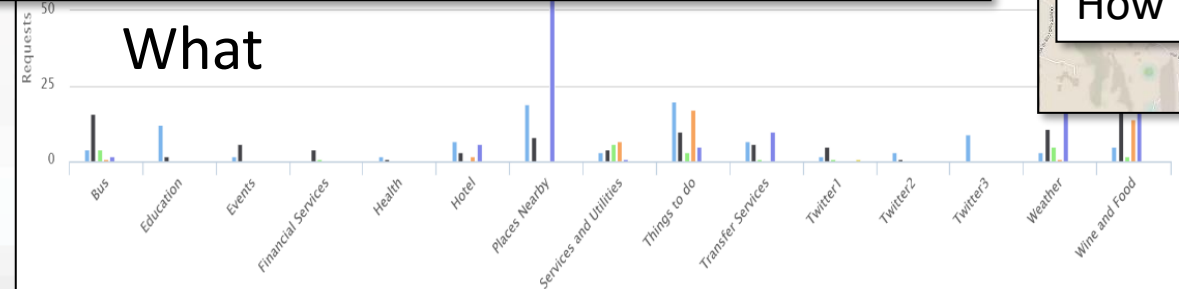
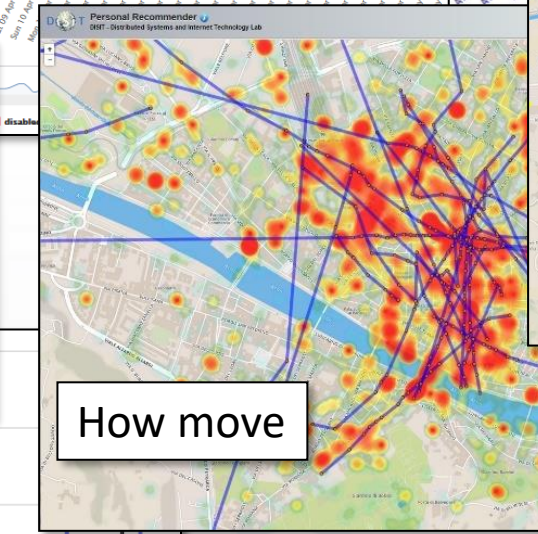
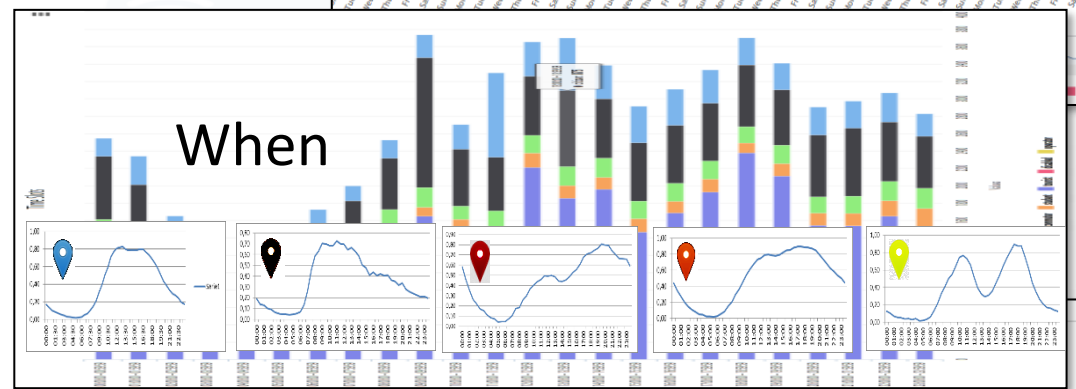
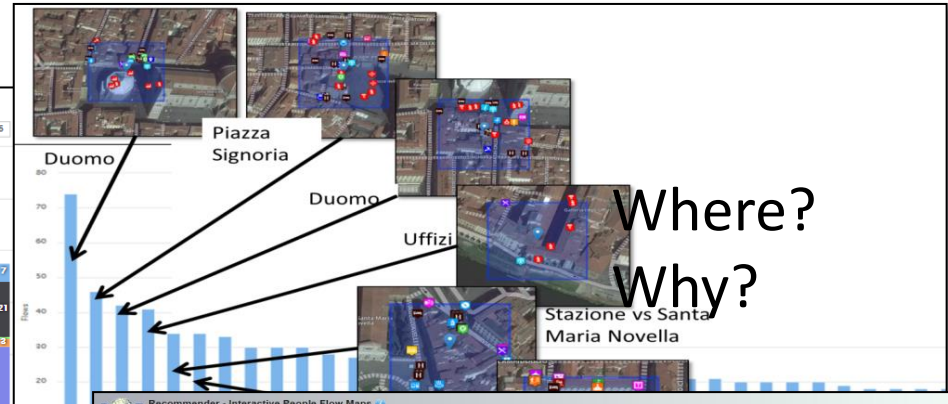
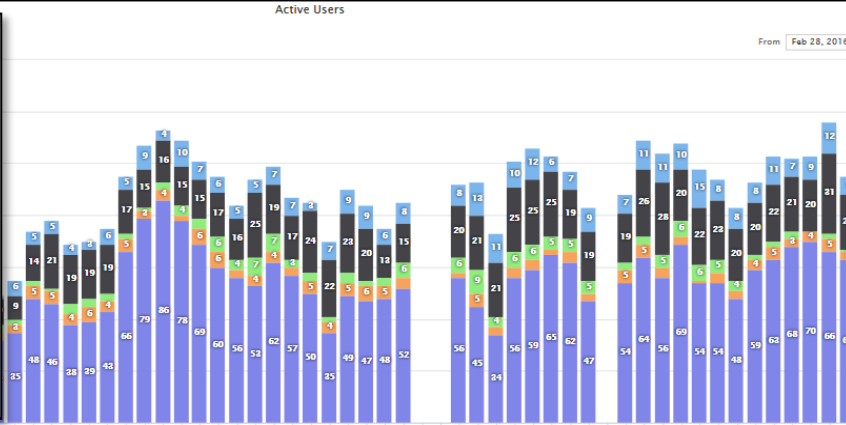
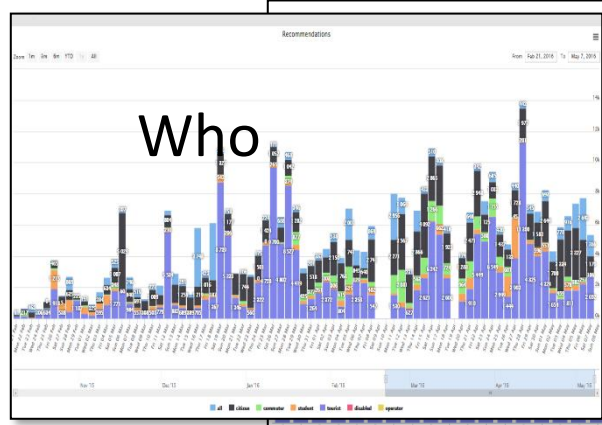
When the mode of transport is changed, the user was asked to notify the change to the App for creating the learning set and for validation.



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

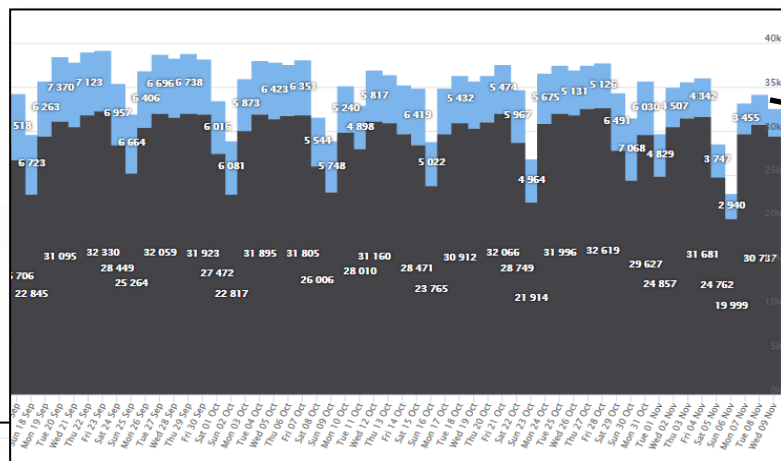
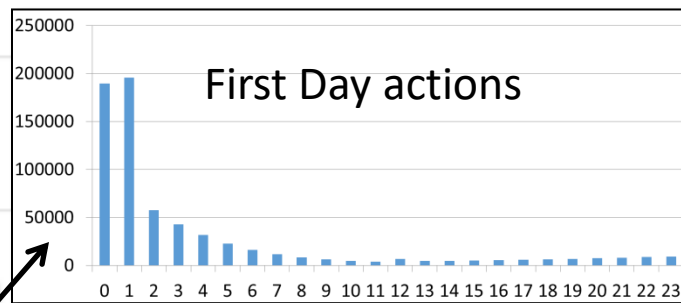
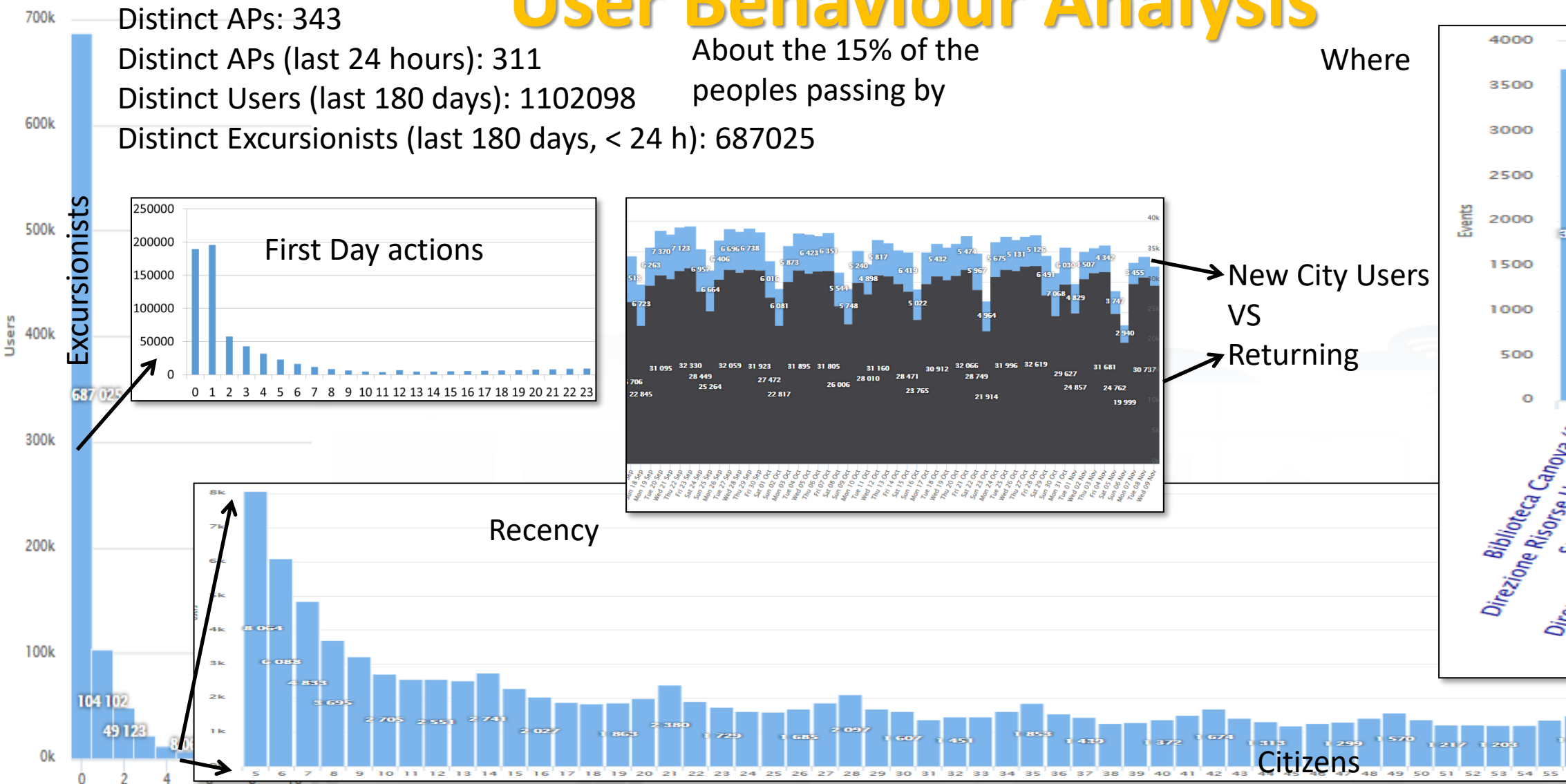


User Behaviour Analysis

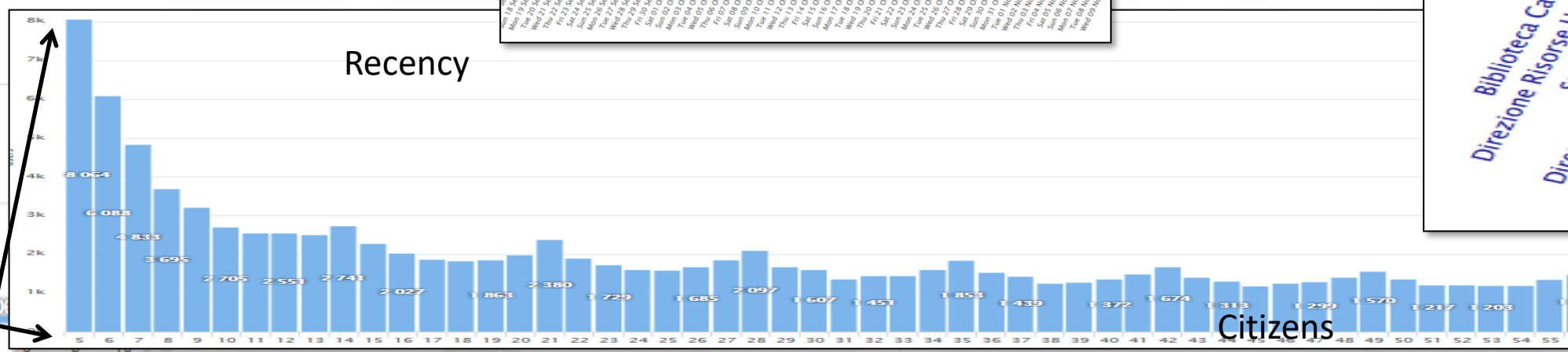
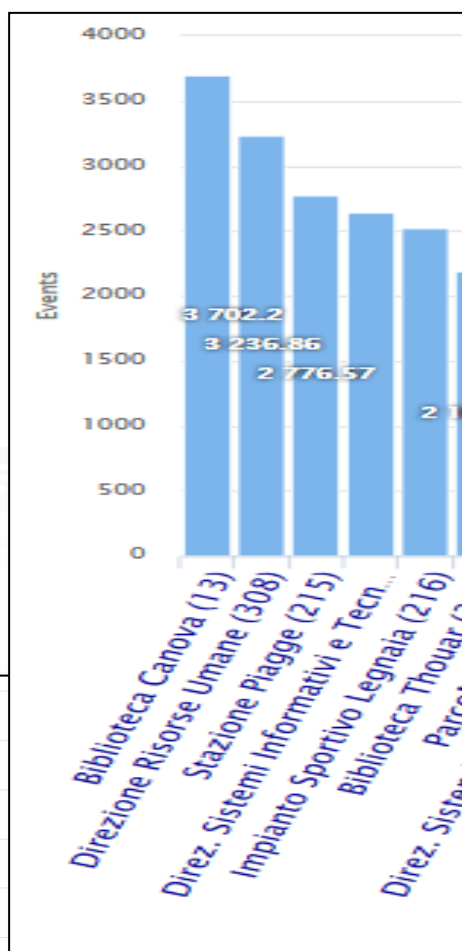
Distinct APs: 343
 Distinct APs (last 24 hours): 311
 Distinct Users (last 180 days): 1102098
 Distinct Excursionists (last 180 days, < 24 h): 687025

About the 15% of the
 peoples passing by

Where



New City Users
 VS
 Returning

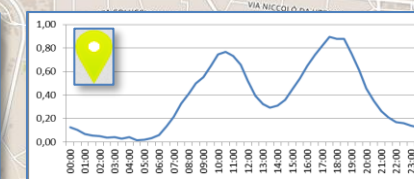
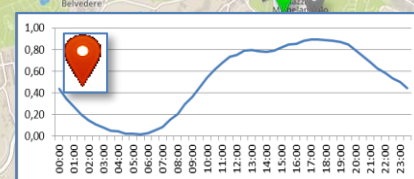
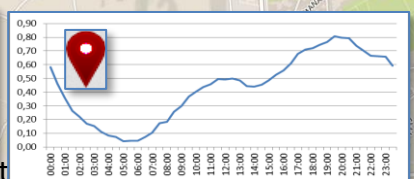
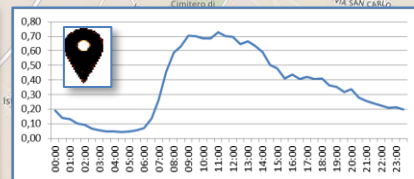
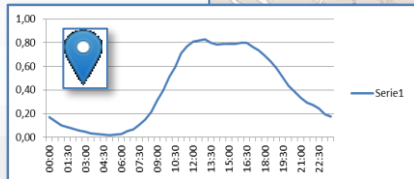
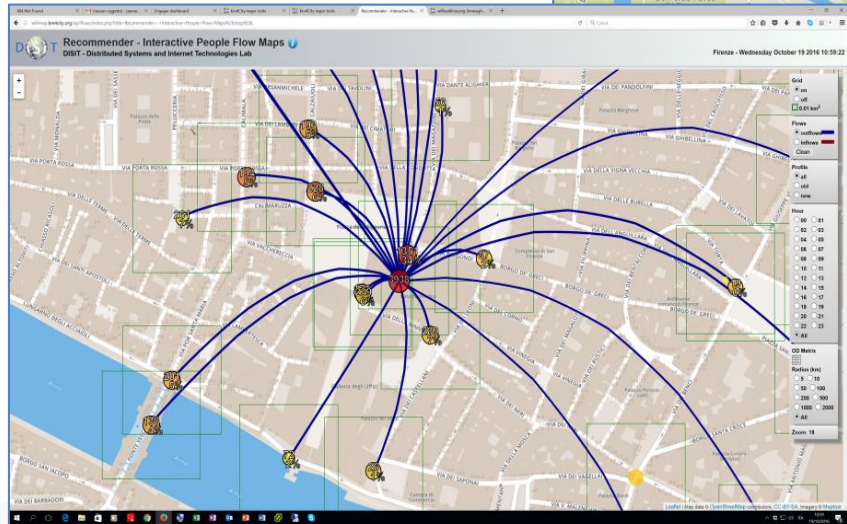
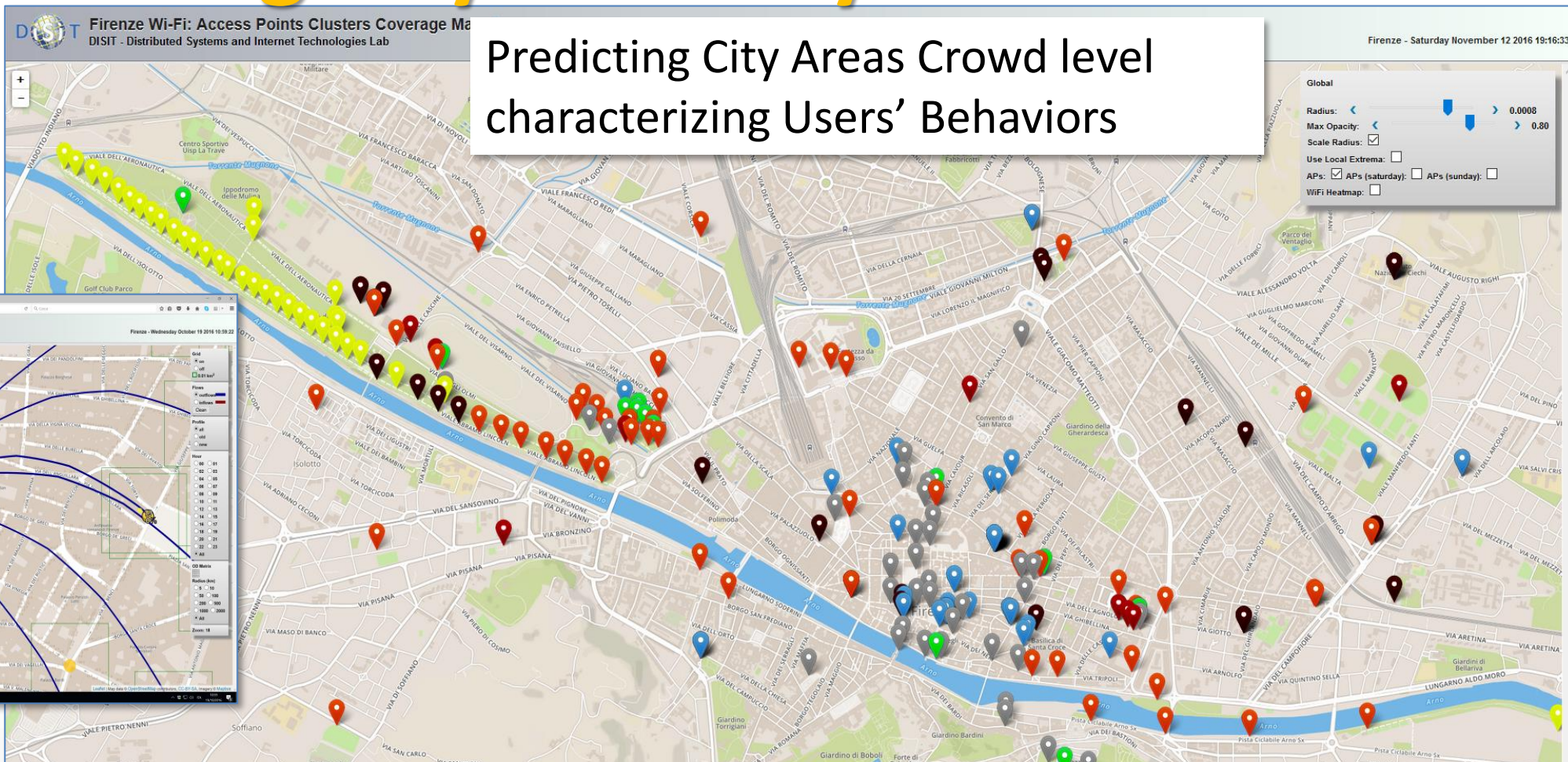


Citizens

Characterizing City Areas by User Behavior

Wi-Fi based

Predicting City Areas Crowd level characterizing Users' Behaviors



A view and data from the Thermal Camera



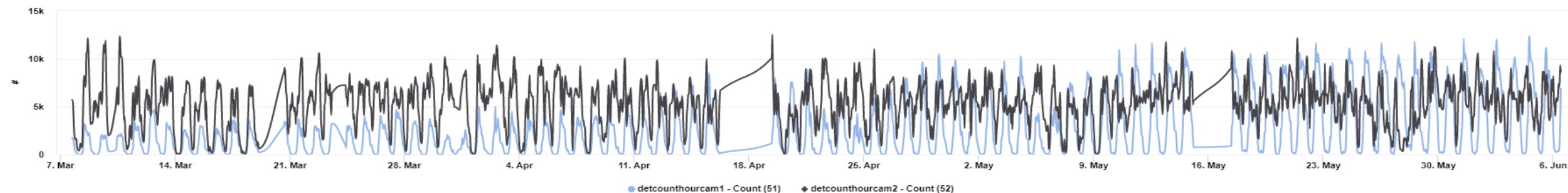
Detection BOX Snap4Thermal PV Firenze Tue 15 Mar 13:30:41



<https://www.snap4city.org/dashboardSmartCity/view/Gea.php?iddashboard=MzM3Ng==>

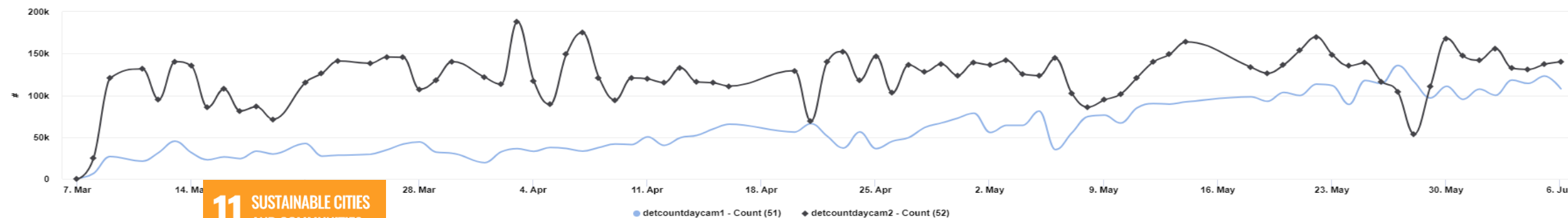
Time Trend Comparison

4m



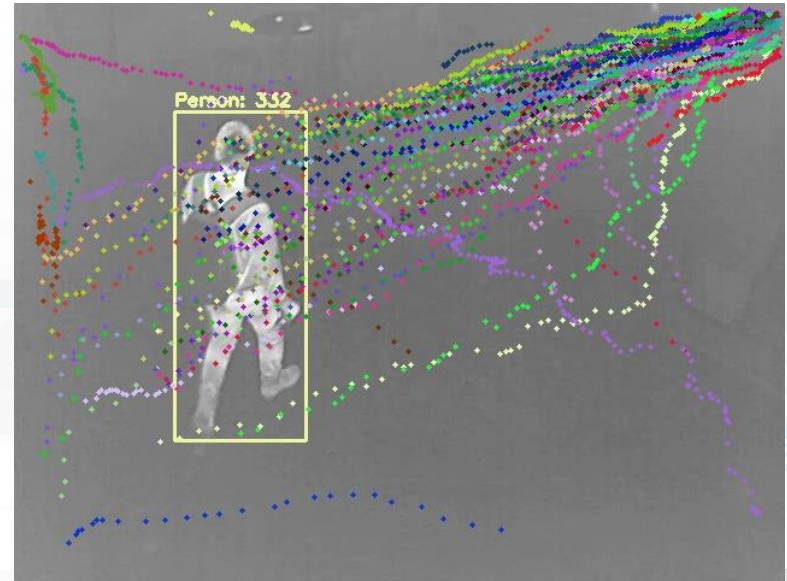
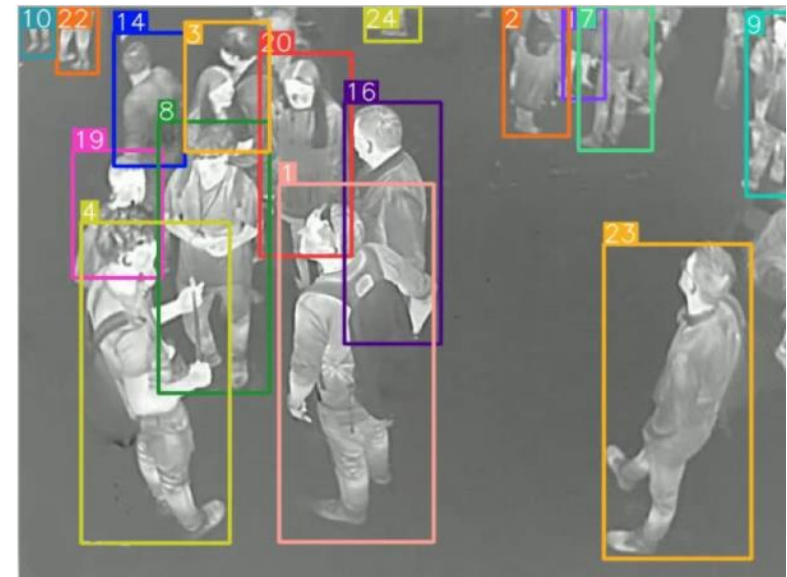
Time Trend Comparison

4m



11 SUSTAINABLE CITIES AND COMMUNITIES

People Counting and Tracking



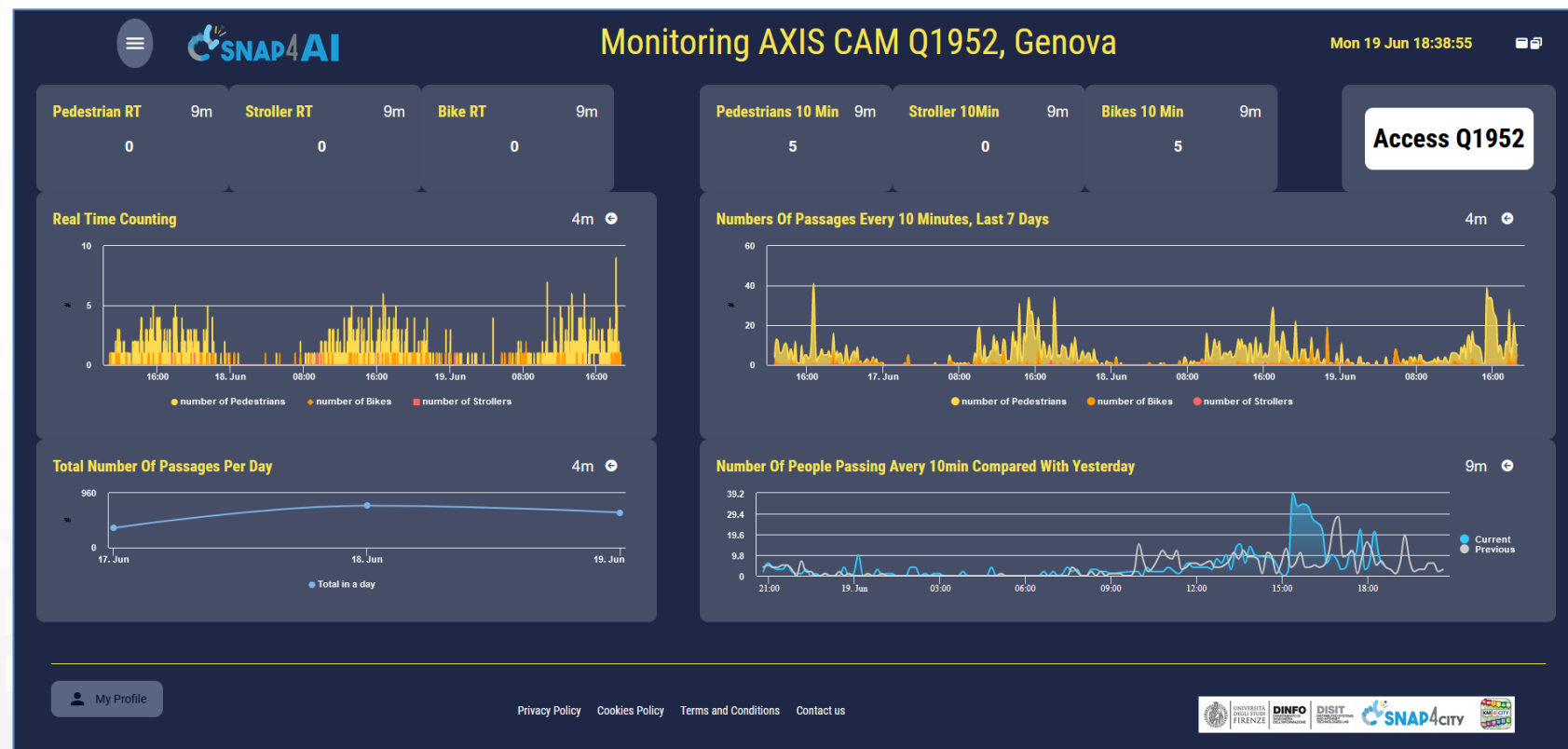
11 SUSTAINABLE CITIES
AND COMMUNITIES

3X



Monitoring Passages AXIS Q1952

- Genova: Ocean Race, 2023



11 SUSTAINABLE CITIES AND COMMUNITIES

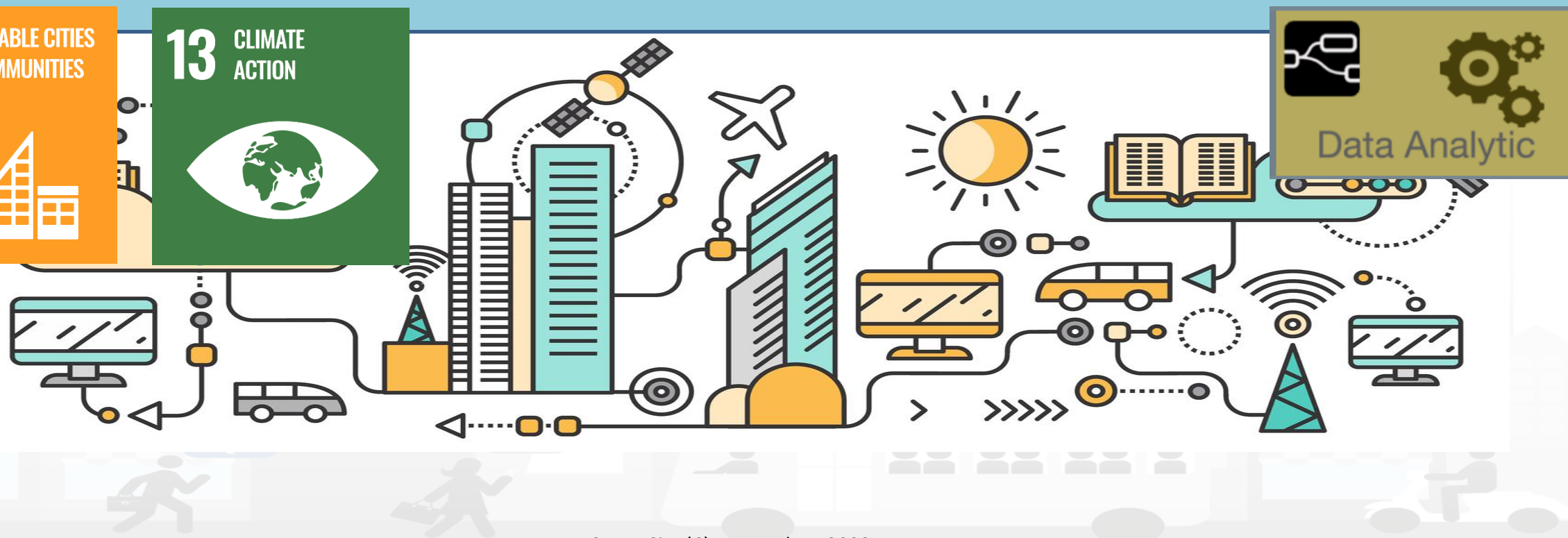


Typical Time Trends

11 SUSTAINABLE CITIES
AND COMMUNITIES



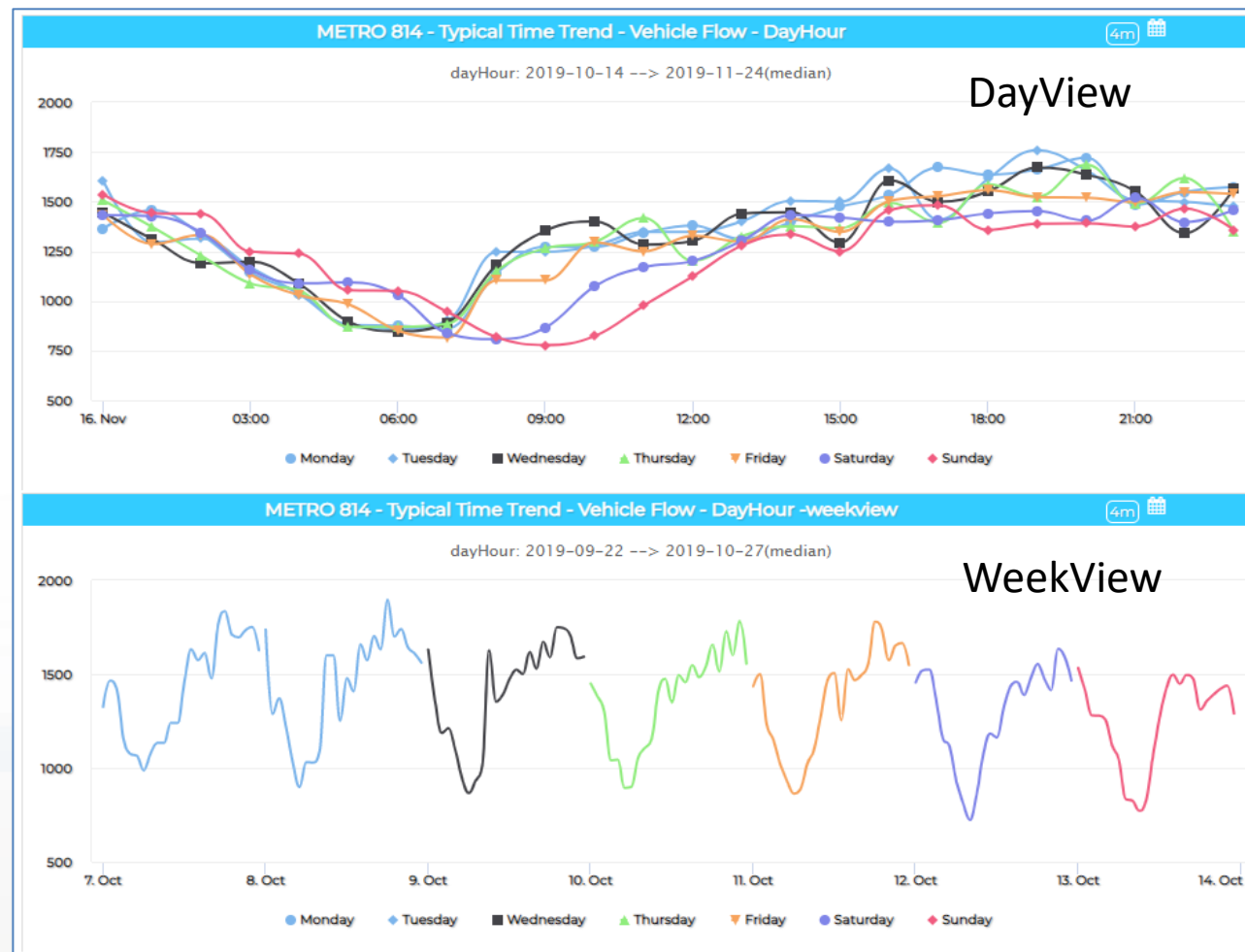
13 CLIMATE
ACTION



Typical Time Trend

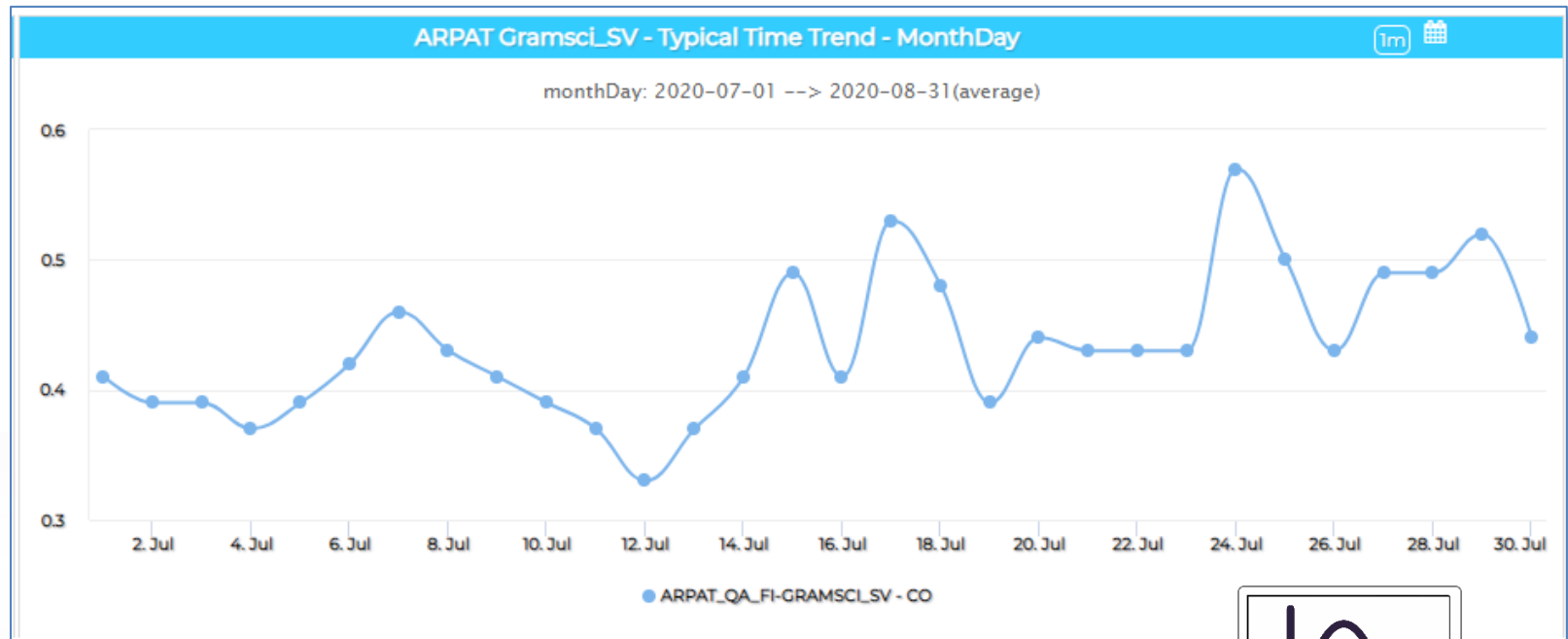


- They:
 - need to be computed in advance on the basis of a Time Serie variable, and a reference period of computation.
 - represent typical trends of: min, max, average, median
 - You can change the data on view
- Formats:
 - **DayHour**: 7 time trends, one for each day of the week, each hour, 24 values.
 - 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?iddashboard=MzA4NA==>

TTT: Month Day



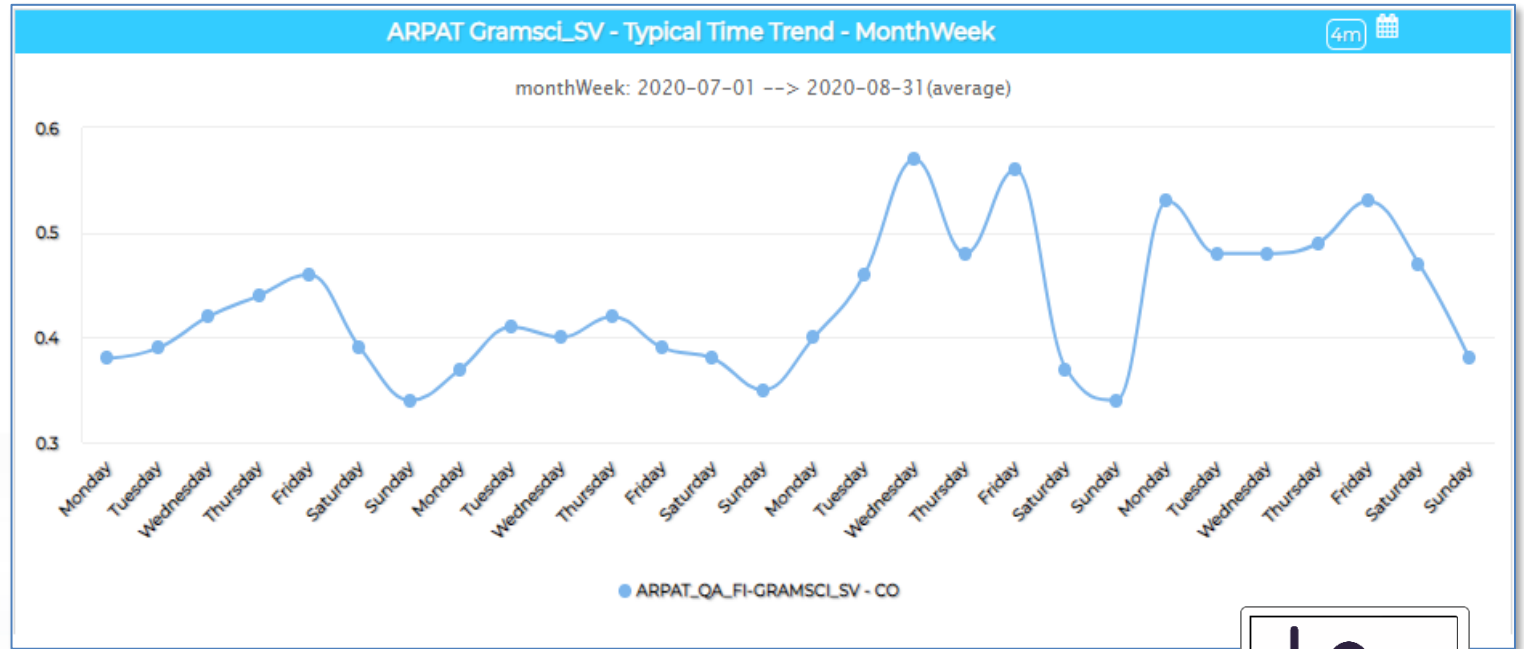
- **MonthDay:**

- 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:**

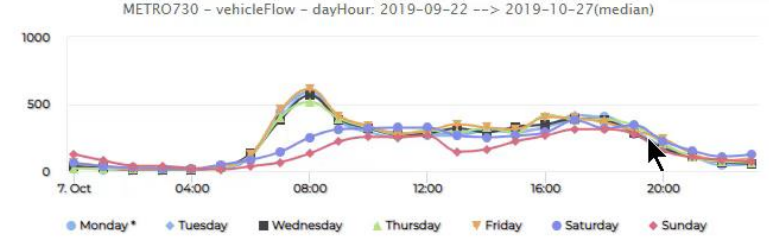
- a value per day,
- 30 values of the month.
- Aligned from the first Monday of the first week of the month
- computed on the basis of a Time range: from-to including that date
 - e.g.: 2 months
 - As min, max, average, median
 - You can change the data on view



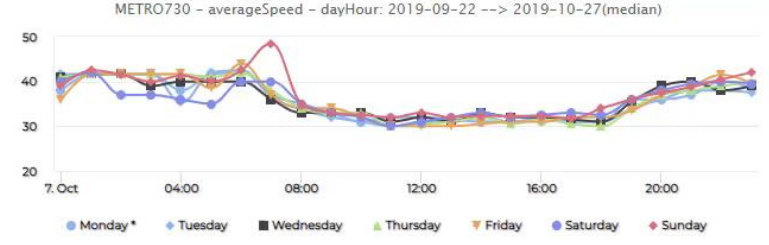
Typical Time Trend Example

Sun 25 Apr 15:24:34

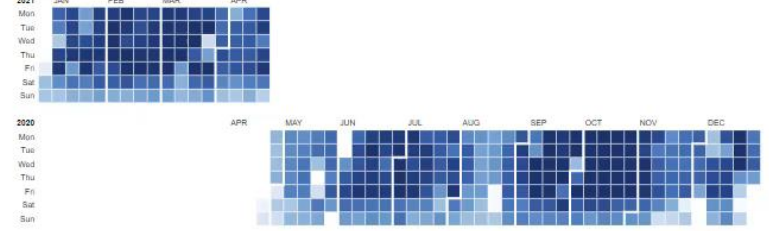
vehicleFlow dayHour Trend



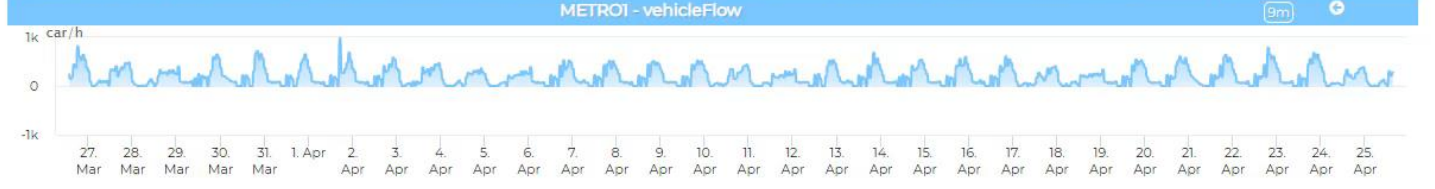
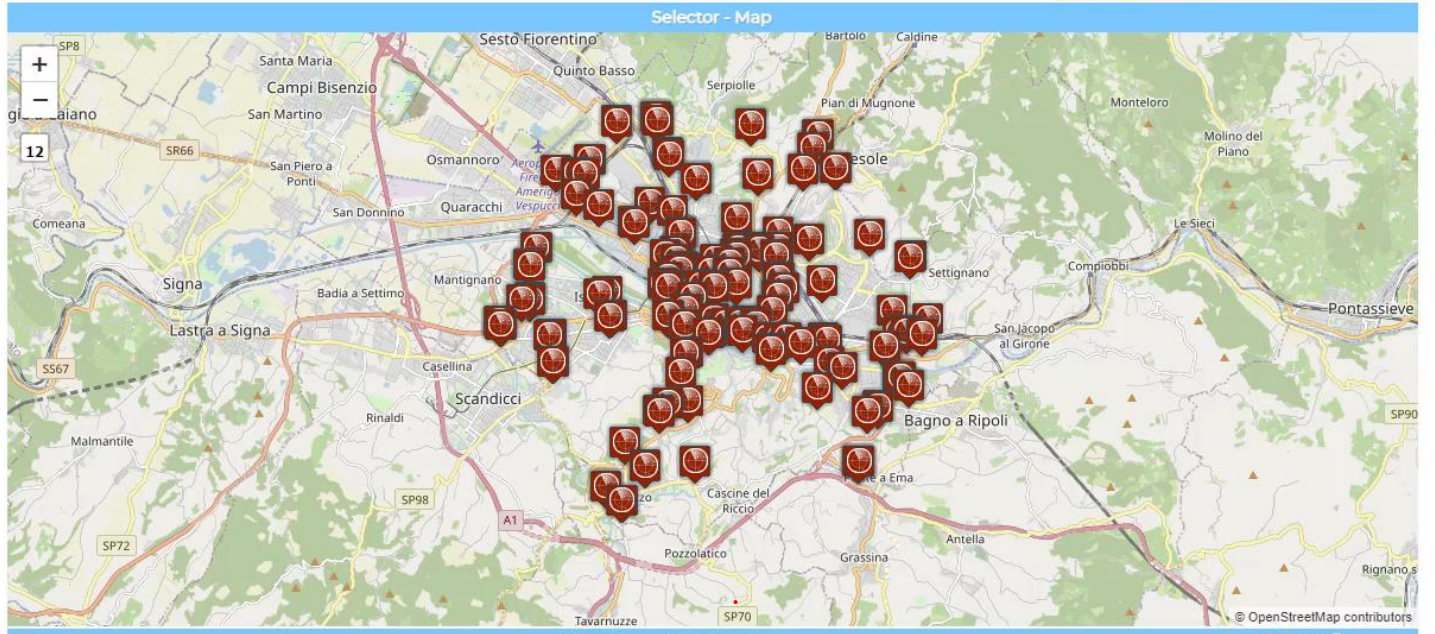
averageSpeed dayHour Trend



Traffic Flow average

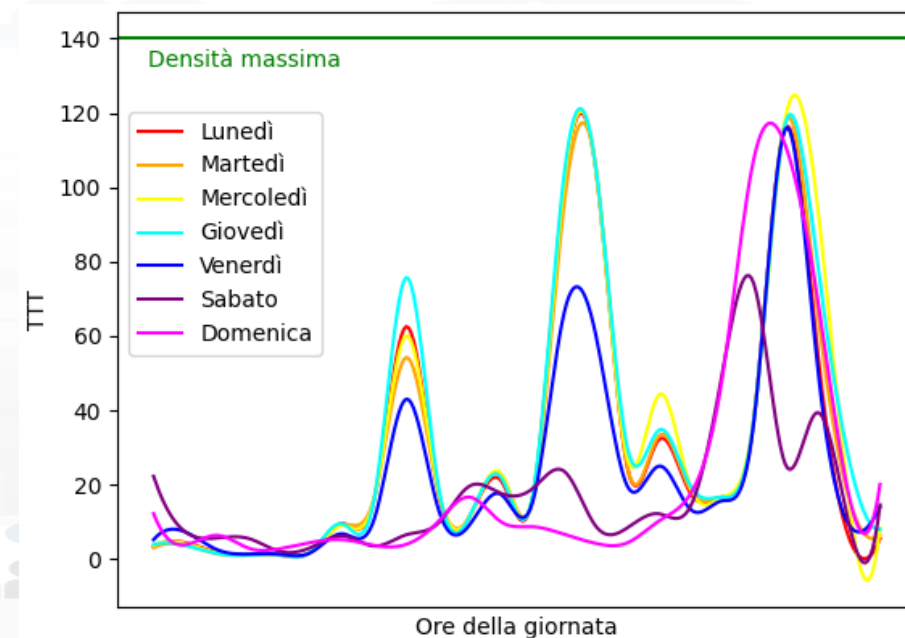
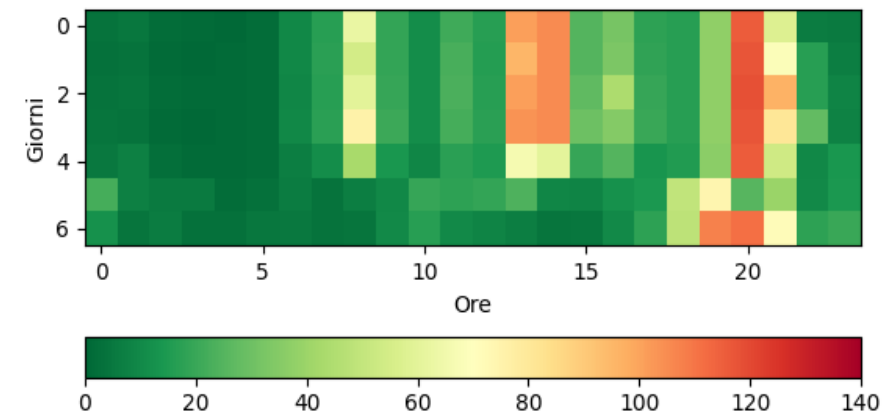


METRO730 Selector - Map SensorSite



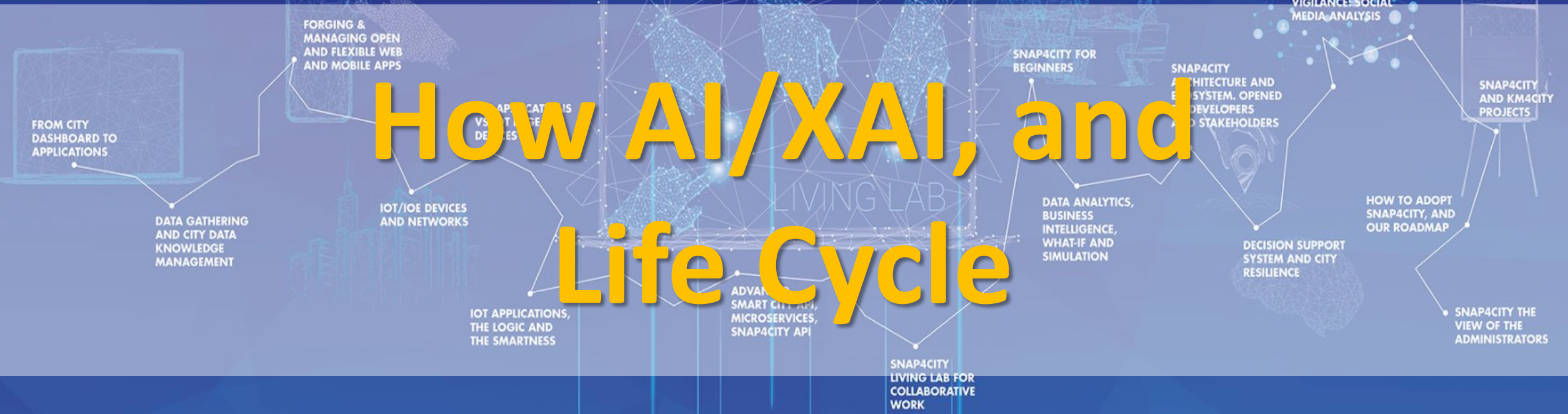
Typical Time Trends

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



TOP

How AI/XAI, and Life Cycle



Development

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



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>

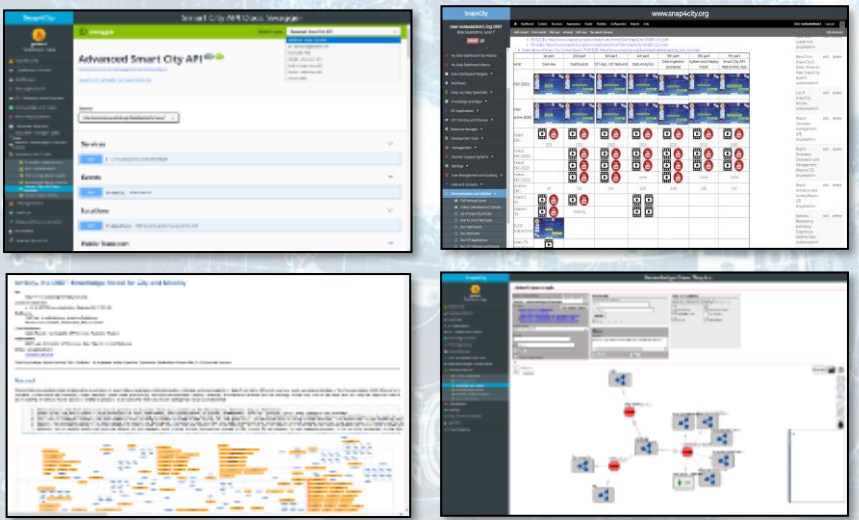
Coordinator: Paolo Nesi, Paolo.nesi@unifi.it

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

Data Analytics on Snap4City platform



Swagger

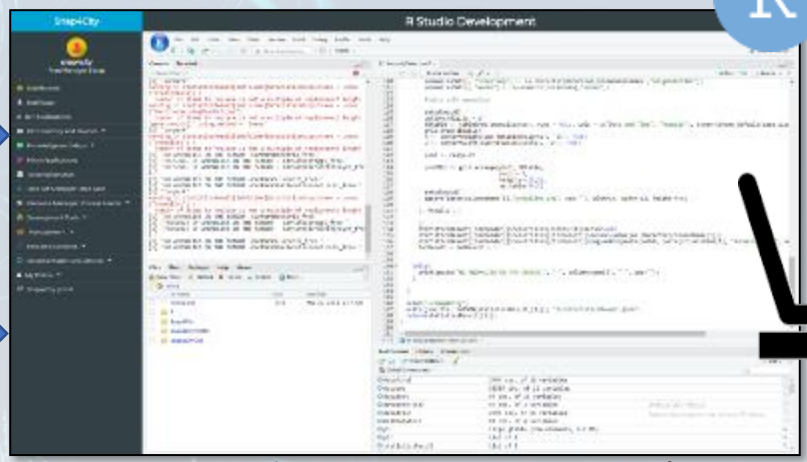


Ontology Schema

LOG.disit.org



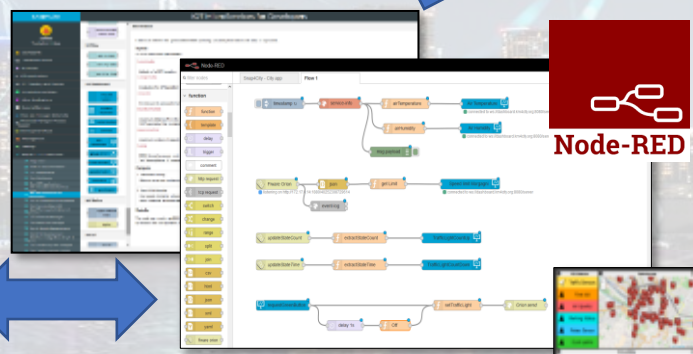
Smart City API from Knowledge Base and other tools



Creating MicroServices



Saving / Sharing reusing



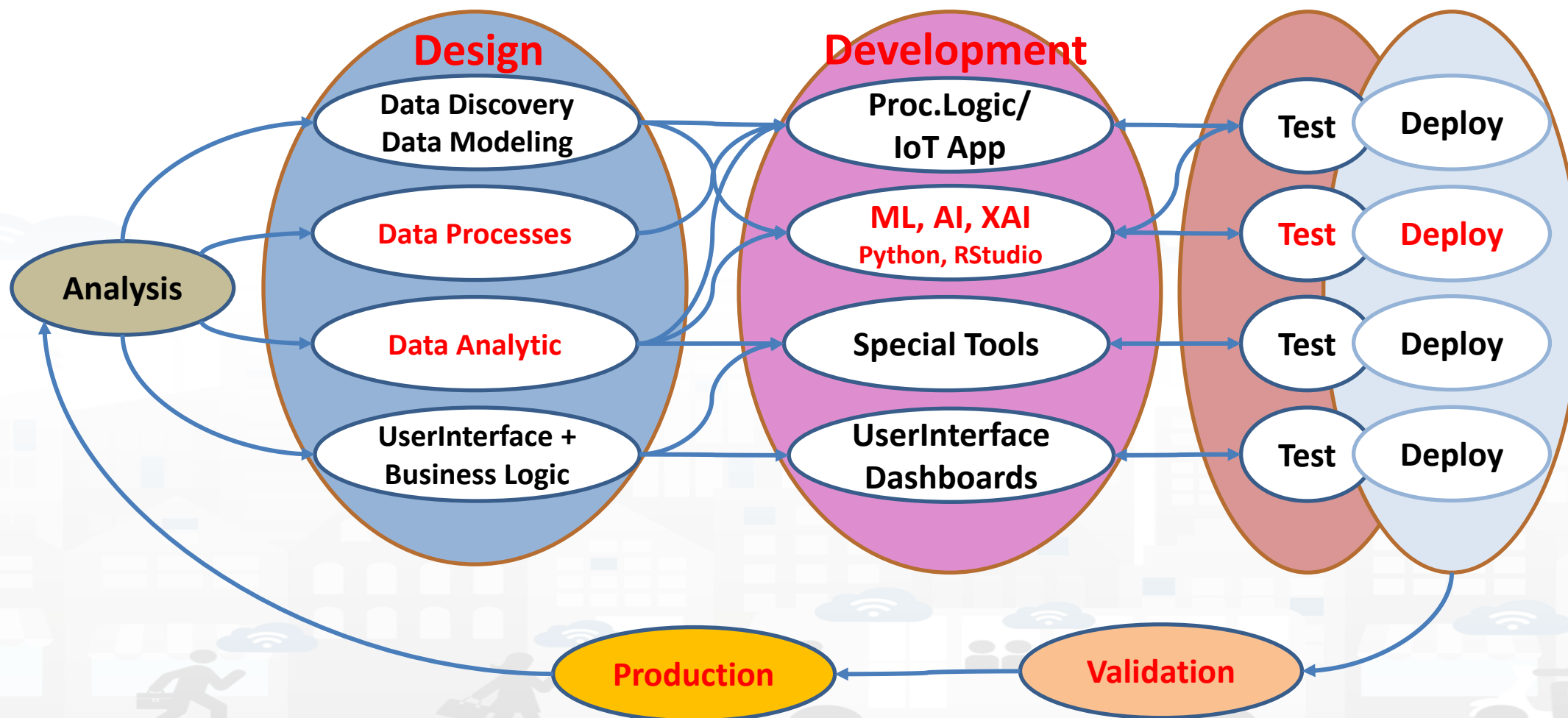
Using them into IOT Applications



Resource Manager



Development Life Cycle Smart Solutions

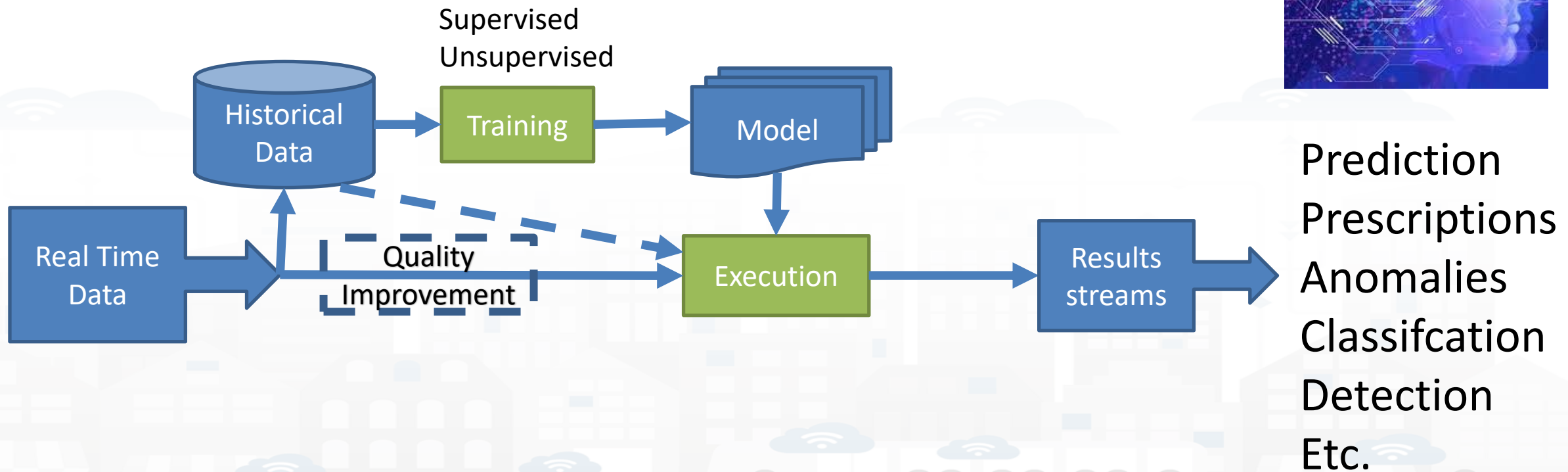


Data Analytics Life Cycle



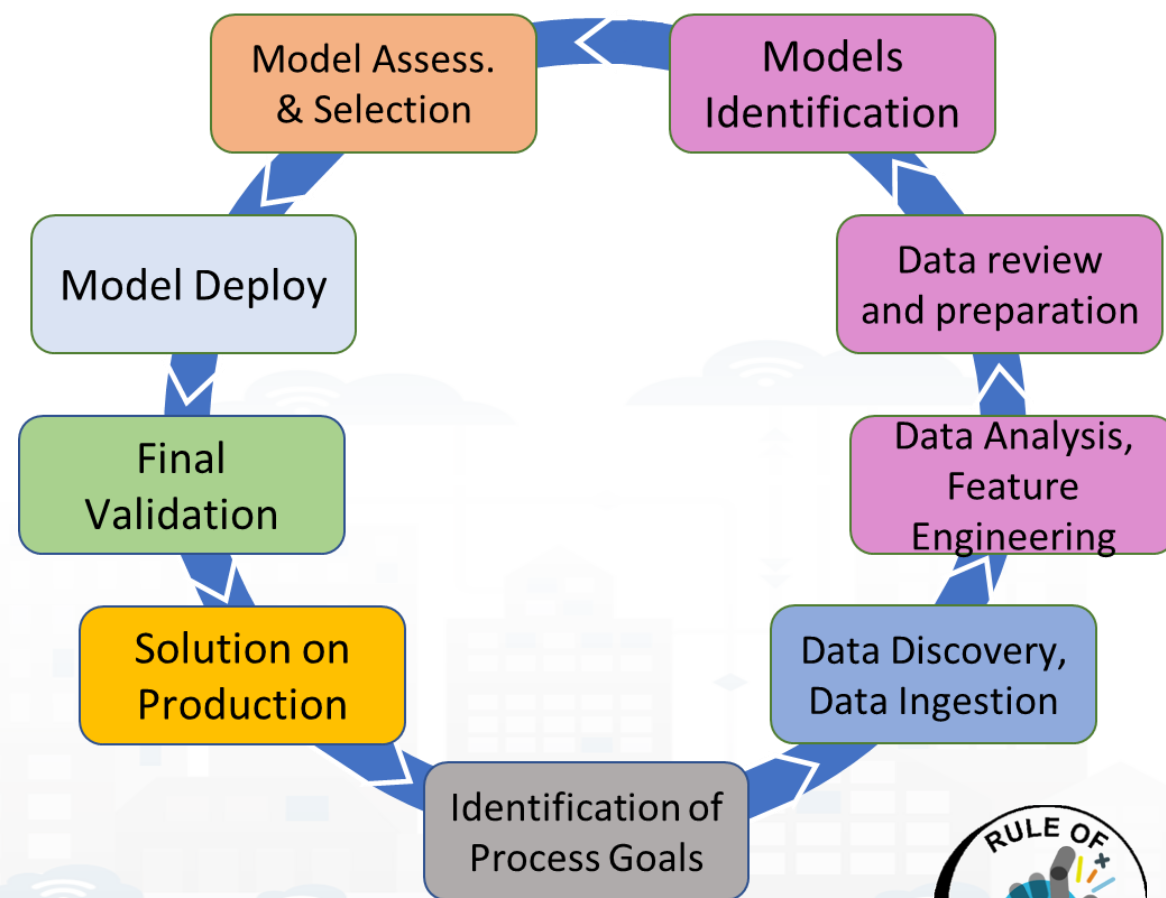
- **Problem analysis**, business requirements
- **Data Discovery**, Data Licensing, ingestion, and acquisition
- **Data set preparation**, transformation, identification of features, normalization, scaling, imputation, feature engineering, etc.
- **Target Assessment Model Definition**
 - Identification 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**

Simplified Training and Deploy process

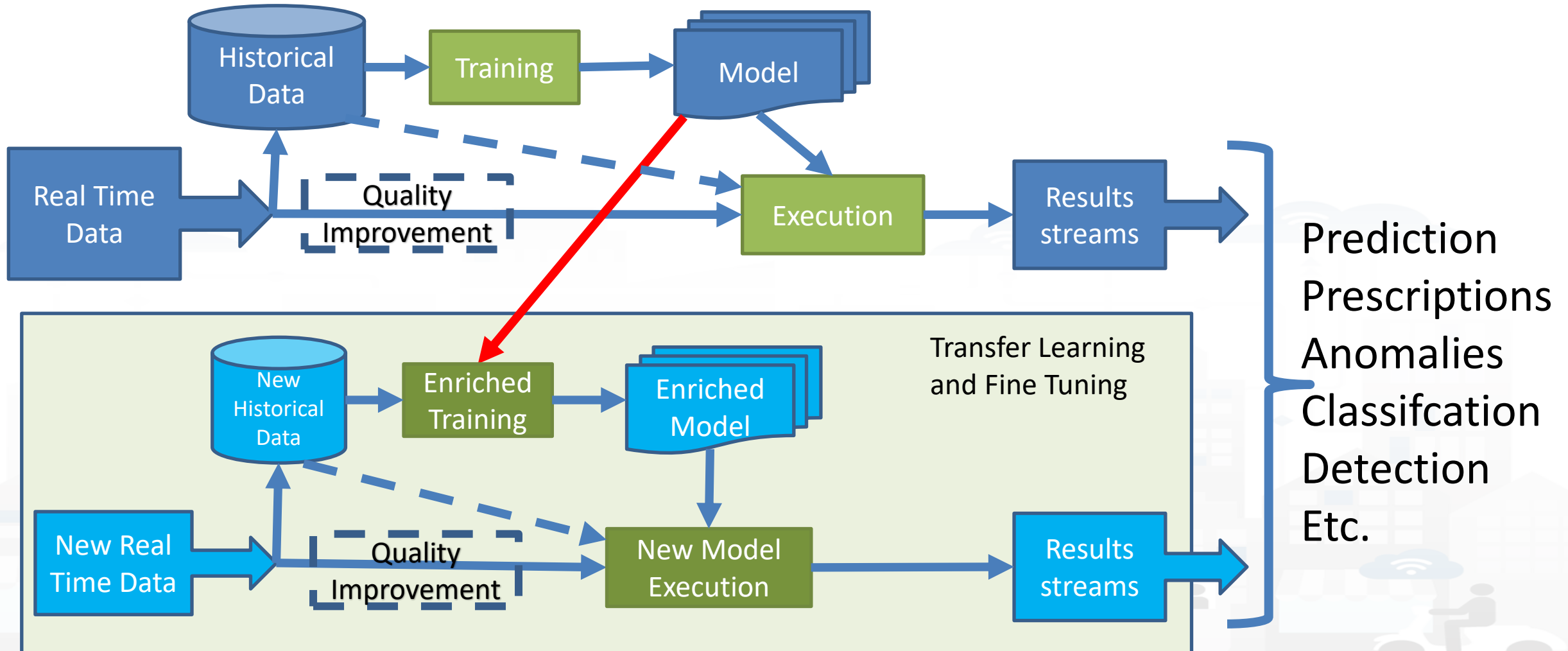


Model/Technique Development/testing

- **Identification of Process goals and Planning**
 - Which goals
 - How to compute, which language
 - Which environment, which libraries
- **Data Discovery and Ingestion (from the general life cycle)**
- **Data Analysis: feature engineering, feature selection**
- **Data review and preparation for the model**
- **Model Identification and building: ML, AI, etc....**
 - Training
 - Tuning hyperparameters when possible
- **Model Assessment and Selection**
 - 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.)**



Simplified Deploy of Transfer Learning Model



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 importance 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.)

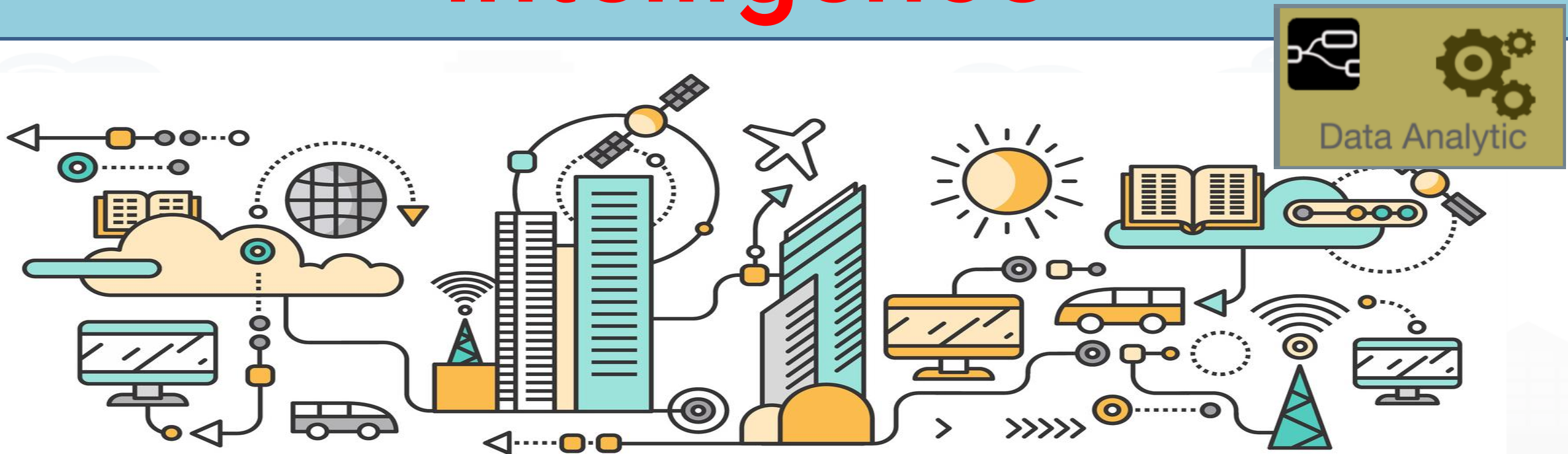
- **Local Explainability, LE**

- Given the features adopted in some ML/AI solution, the LE is a description of relevance or importance 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.)

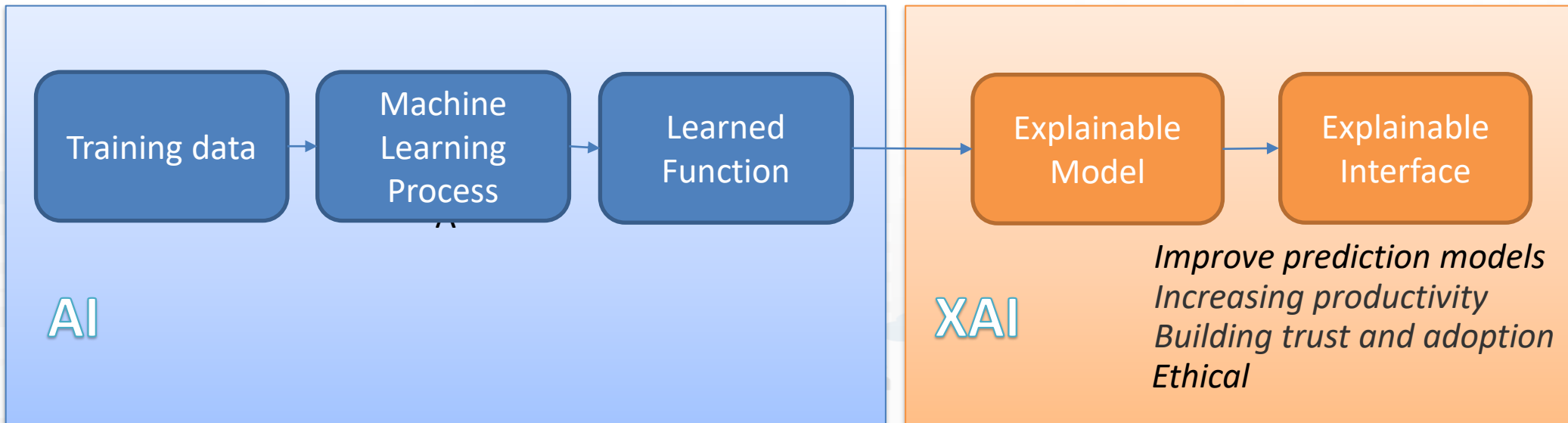
- **A number of tools can be used for example:**

- 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:

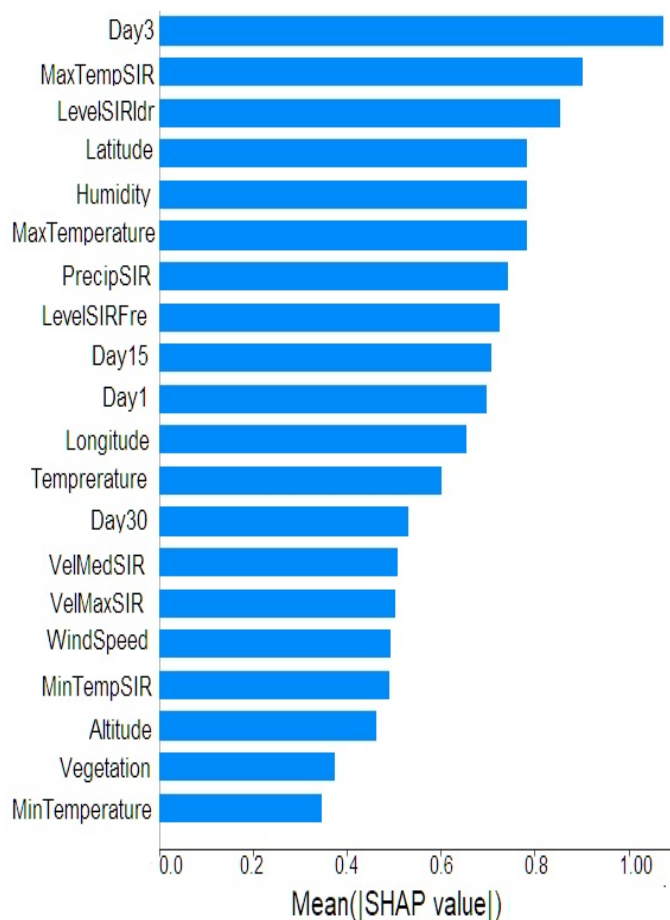
- Linear regression,
- Logistic regression,
- Decision Tree,
- Naive Bayes,
- KNNs
-

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.

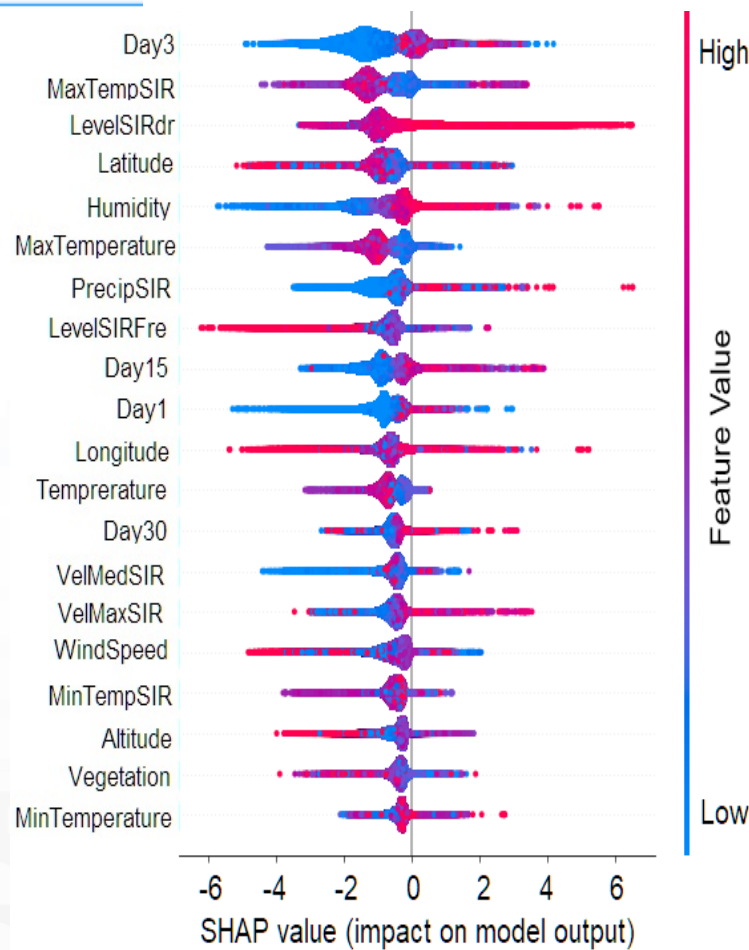
- CNN, DNN, ...
- LSTM
-

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

SHAP Global interpretability



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

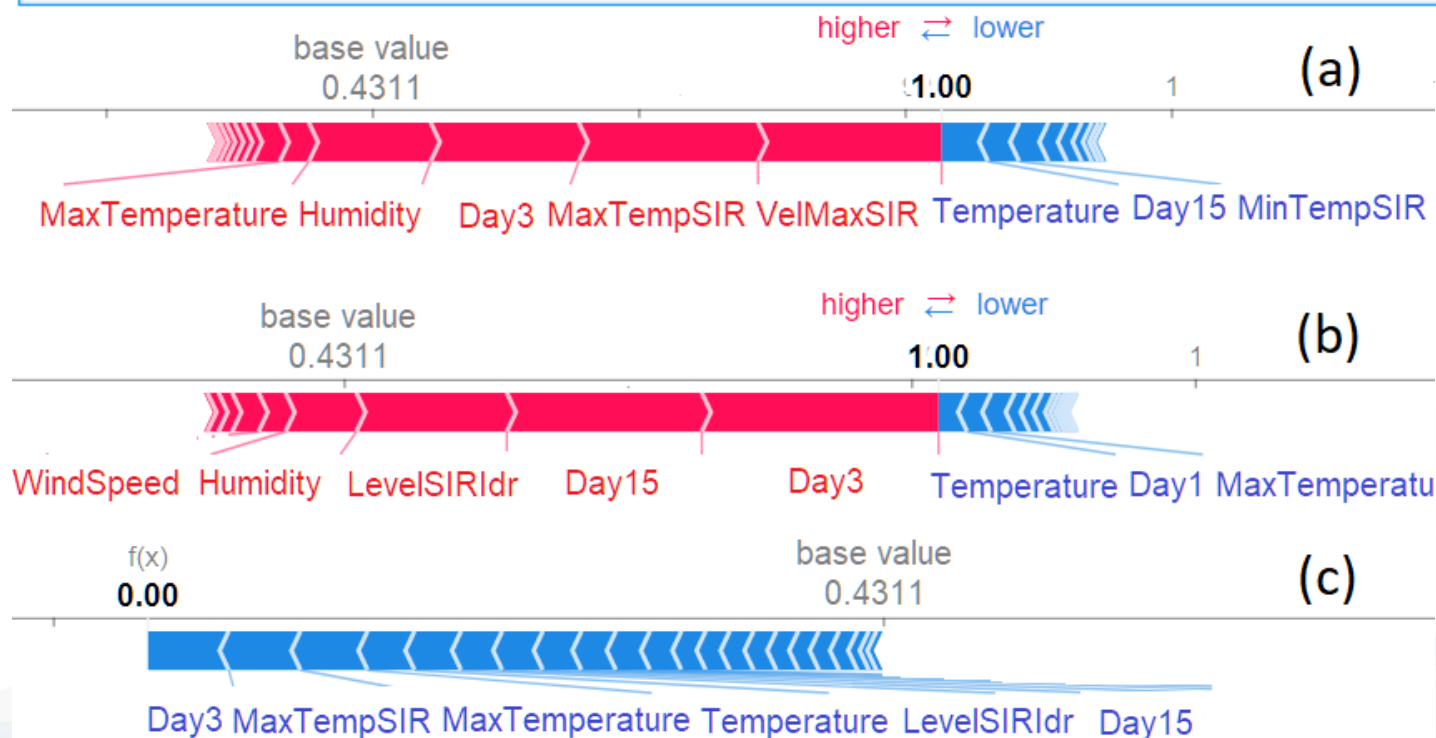


```
shap.summary_plot(shap_val
ues, X_train,features_names)
```

- **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: 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, LevelSIRldr and Humidity given a relevant contribution to the landslide event prediction.
 - (c) the value of features: Day3, MaxTempSIR, MaxTemperature, Temperature and LevelSIRldr have been determinant for the classification of the observation into a no landslide event.

TOP

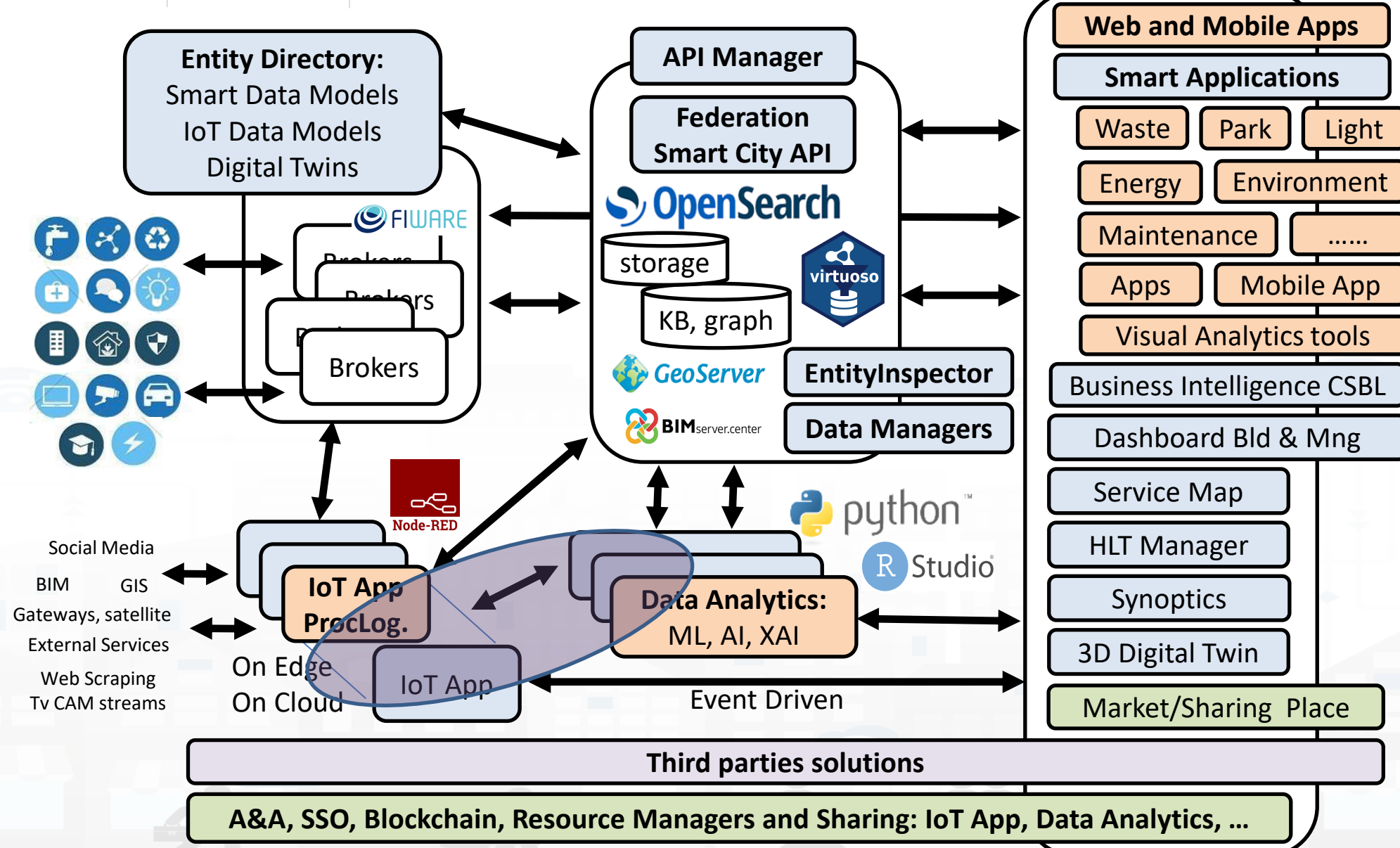
Using DA, AI, XAI in Snap4City infrastructures

Data Analytics ↔ IoT App / Proc.Logic



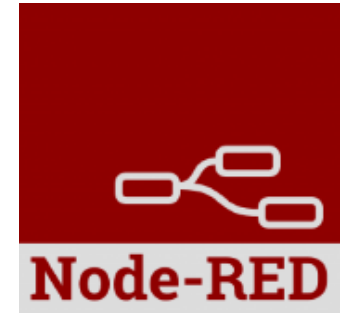
Data Processing for different purposes on Snap4City

- **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



IoT App / Proc.Logic

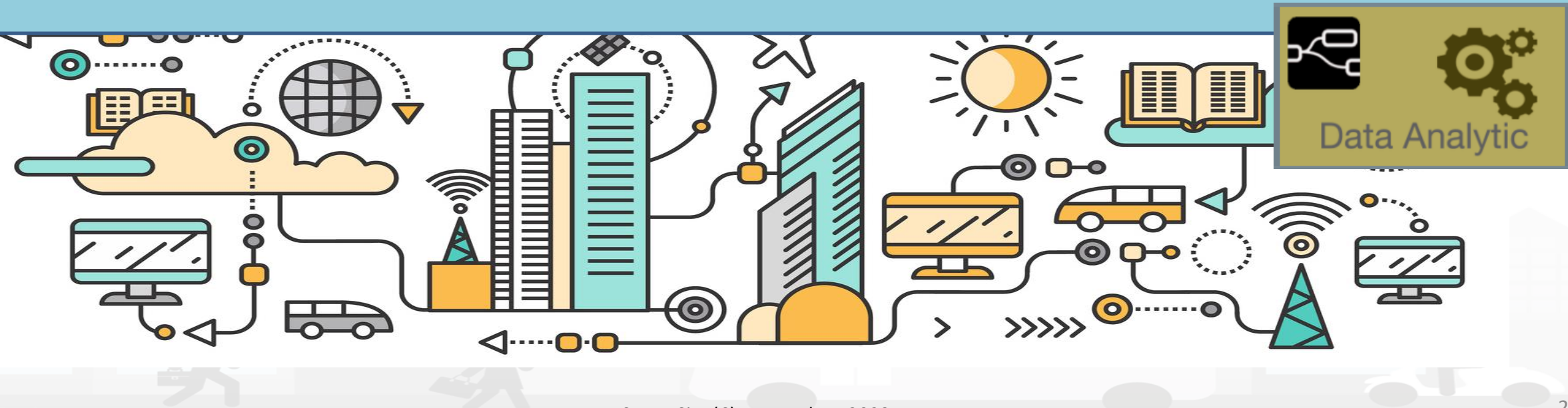
- Storage → IoT App / Proc.Logic
- External Service ↔ IoT App / Proc.Logic **Part 3**
- Dashboards ↔ IoT App / Proc.Logic



- **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

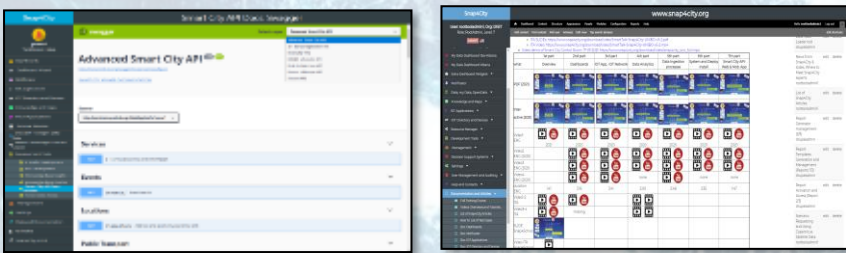
Data Analytics \leftrightarrow IoT App / Proc.Logic



Data Analytics on Snap4City platform



Swagger



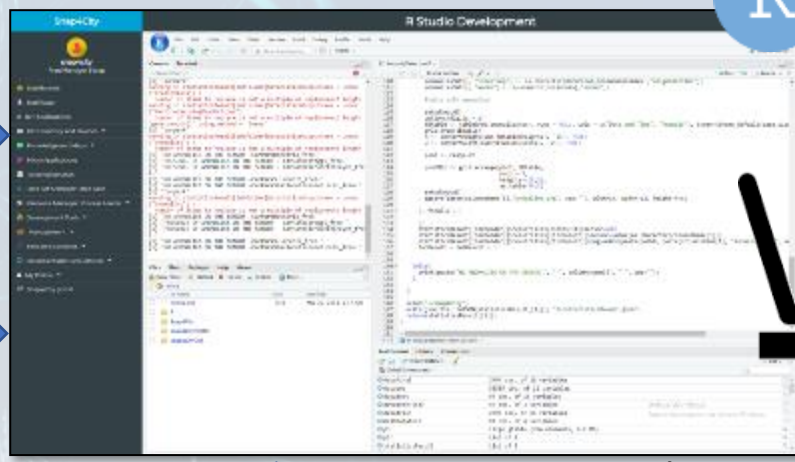
Ontology Schema



LOG.disit.org



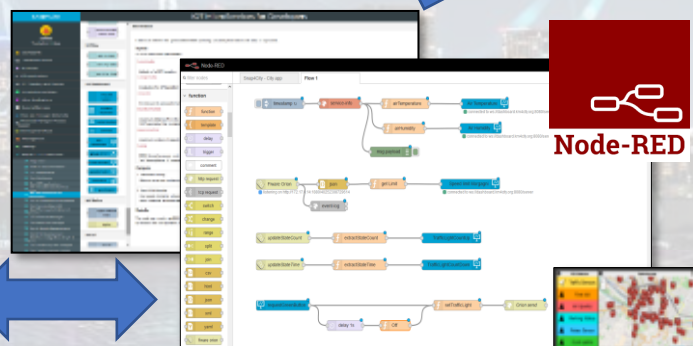
Smart City API from Knowledge Base and other tools



Creating MicroServices

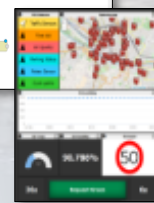


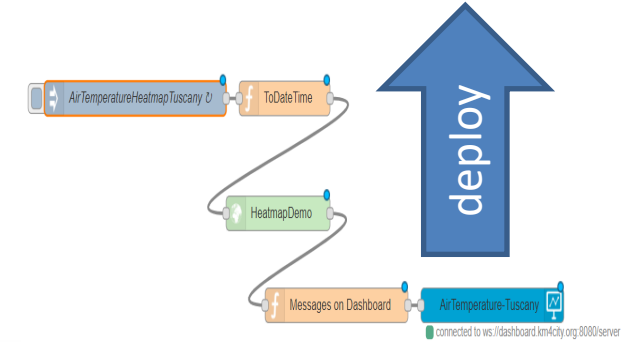
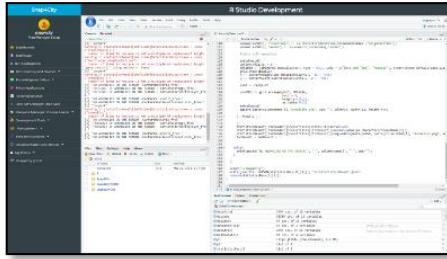
Saving / Sharing reusing



Resource Manager

Using them into IOT Applications





On Server
Or
On PC

On PC as Anaconda

```

jupyter claffProgr3 Last Checkpoint: a few seconds ago (unsaved changes)
File Edit View Insert Cell Kernel Widgets Help
Run | Markdown
plt.show()
thisinput = input()
if(thisinput=="break"):
    break
if(thisinput=="indietro"):
    print("hai inserito il cluster" + thisinput)
    i = i - 1
else:
    print("hai inserito il cluster" + thisinput)
    try:
        int(thisinput)
        if(int(thisinput)>=14):
            print("hai inserito un numero > 14")
            print("Riprova")
        else:
            print("caricamento andato a buon fine")
            trajectories.at[i,'label'] = int(thisinput) #15 è l'indice della colonna 'label'
            i = i + 1
    except ValueError:
        print("non hai inserito un numero")
        print("Riprova")
    except ValueError:
        print(ValueError)
print("batch completed successfully")
trajectories.to_csv("trajectoriesClassified_"+str(i)+".csv", index = False)

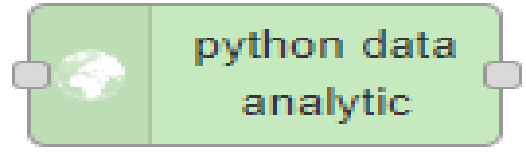
```



File.py
AI Model
Mapping
Data..



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

The screenshot shows the R Studio interface with the following components:

- Console:** Shows output messages such as "Warning in statisticsResult[indfolder]\$statisticsOutputName = unbox", "number of items to replace is not a multiple of replacement length", and "NO ANOMALIES ON THE SENSOR - CarParkBeccaria_free-".
- Code Editor:** Contains R code for processing data, including:


```
anomaliesMatr[, "timestamp"] <- as.character(dataFinal[res$anoms$index, "alignDateTime"])
anomaliesMatr[, "anoms"] <- as.numeric(res$anoms[, "anoms"])
#table with anomalies
setwd(outID)
options(digits = 1)
tTable <- tableRob(anomaliesMatr, rows = NULL, cols = c("Date and Time", "Anomaly"), theme=ttheme_default(base_size=
grid.draw(tTable)
h <- convertHeight(sum(tTable$heights), "in", TRUE)
w <- convertWidth(sum(tTable$widths), "in", TRUE)
plot <- res$plot
plotrix <- grid.arrange(plot, tTable,
ncol = 2,
heights=c(5,1),
as.table=TRUE)
setwd(outID)
ggsave(paste(columnsName[i], "Anomalies.png", sep=""), plotrix, width=22, height=h+5)
}, finally = {
statisticsResult[[indfolder]]$resultFiles[indResult]$sensor=NULL
statisticsResult[[indfolder]]$resultFiles[[indResult]]$sensor=unbox(as.character(columnsName[i]))
statisticsResult[[indfolder]]$resultFiles[[indResult]]$png=unbox(paste(outID, paste(columnsName[i], "Anomalies.png", sep=""), indResult = indResult + 1)
}else{
print(paste("NO ANOMALIES ON THE SENSOR ", "-", columnsName[i], "-", sep=""))
}
setwd("~/Snap4City")
write(jsonlite::toJSON(statisticsResult[[i]]), "JsonStatisticsResult.json")
return(statisticsResult[[i]])
}
```
- Files Panel:** Shows a file browser with folders like "nohttp.out", "R", "Snap4City", "Snap4CityDEMO", and "Snap4CityOld".
- Environment Panel:** Lists objects in the global environment:

dataFinal	2794 obs. of 18 variables
dataset	35539 obs. of 12 variables
dataTest	97 obs. of 15 variables
dataTestFinal	97 obs. of 3 variables
dataTrain	2793 obs. of 15 variables
meltDataTest	97 obs. of 4 variables
p3	Large gtable (784 elements, 9.2 Mb)
plt	List of 9
statisticsResult	List of 1

The screenshot shows a file explorer window with a list of files:

- AverageSpeedDailyTrend.png
- CarParksDailyTrend.png
- CorrelationMatrix.png
- PredictedFreeParking.png
- SensorsMeanPerDayMoment.png
- StatisticsBySensors.png
- StatisticsBySensorsAndDayMoment.png
- VehicleFlowDailyTrend.png

A red callout box with white text says: "Click on each .png file to visualize the statistics: a new tab will be opened". Below the callout, several preview images are shown, including line graphs, a heatmap, and a table of data.



Data Analytics in R Studio Con Tensor Flow

1

Snap4City

rootooladmin1
RootAdmin | Idap

- Dashboards
- My Dashboards
- Notificator
- IOT Applications
- My Personal Data
- IOT Directory and Devices
- Knowledge and Maps
- Micro Applications
- External Services
- Data Set Manager: Data Gate
- Resource Manager: Process Loader
- Development Tools
 - R Studio Development**
 - ETL Development
 - Knowledge Base Graphs
 - Knowledge Base Queries
 - Smart City API Docs: Swagger
 - Internal API Docs: Swagger
 - Testing API by Postman
 - Source Code Access
- Management
- Settings
- User Management and Auditing
- Help and Contacts

R Studio Development

File Edit Code View Plots Session Build Debug Profile Tools Help

Console Terminal

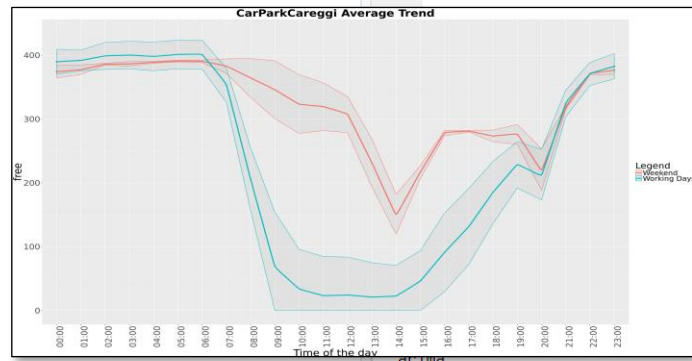
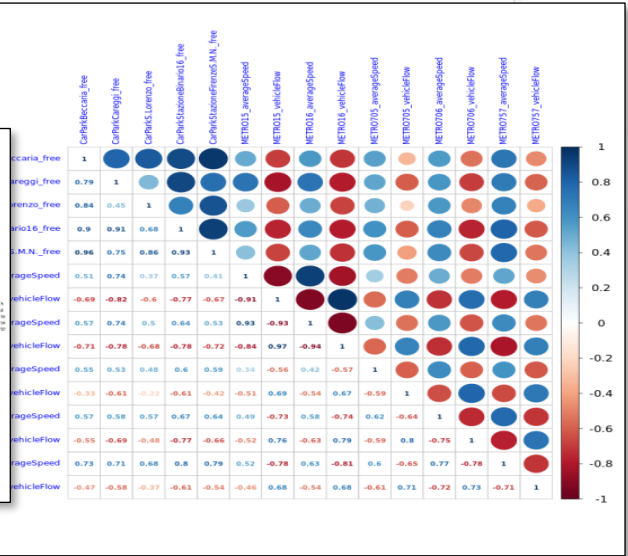
```
~/Snap4City/Snap4CityStatistics/
> source("~/Snap4City/Snap4CityStatistics/RunRestApi.R")
Starting server to listen on port 8080
Running the swagger UI at http://127.0.0.1:8080/___swagger___/

> setwd("~/Snap4City/Snap4CityStatistics")
> source("~/Snap4City/Snap4CityStatistics/Stat4CityFunctions.R")
> api <- plumber::plumb("Stat4CityFunctions.R")
> api$run(host = "0.0.0.0", port=8080)
Starting server to listen on port 8080
Running the swagger UI at http://127.0.0.1:8080/___swagger___/
```

```
RunRestApi.R
1 setwd("~/Snap4City/Snap4CityStatistics")
2 source("~/Snap4City/Snap4CityStatistics/Stat4CityFunctions.R")
3 api <- plumber::plumb("Stat4CityFunctions.R")
4 api$run(host = "0.0.0.0", port=8080)
```

Files Plots Packages Help Viewer

Name	Size	Modified
nohup.out	72 B	Mar 30, 2018, 9:47 AM
R		
Snap4City		
Snap4CityDEMO		
Snap4CityOld		



R Script

1500 obs. of 2 variables

```
<Object containing active binding>
"CarParkBeccaria"
"http://192.168.0.206:8890/sparql?default-graph-uri=&query=SELECT+DISTINCT+%3Fdate+%3Ffre..."

function (sensorTypeList, anomalyDate)
function (anomalyDate)
function (sensorTypeList)
function (sensorToPredict)
```

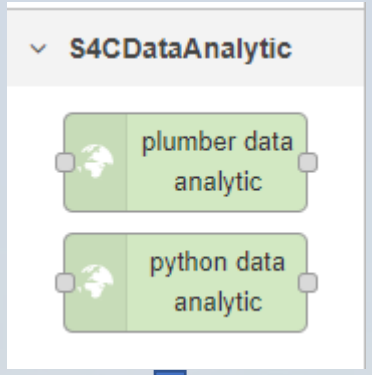
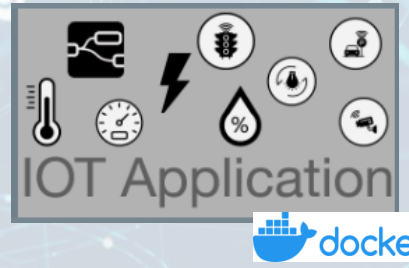




Data Analytic Container



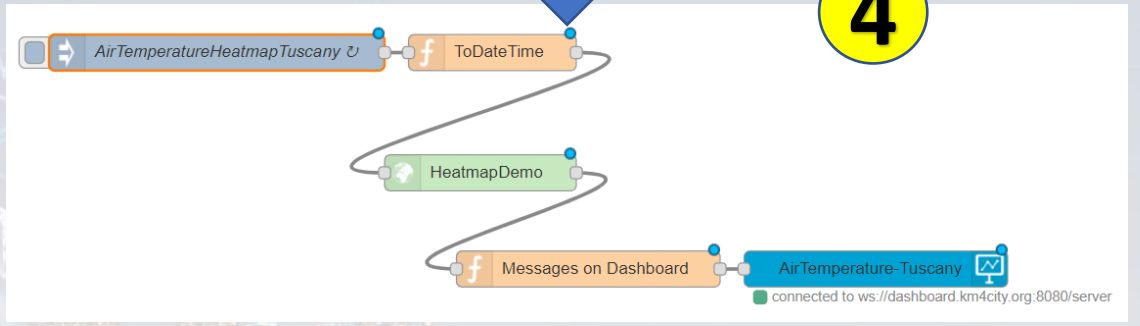
2 Open an Advanced IoT App / Node-RED



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

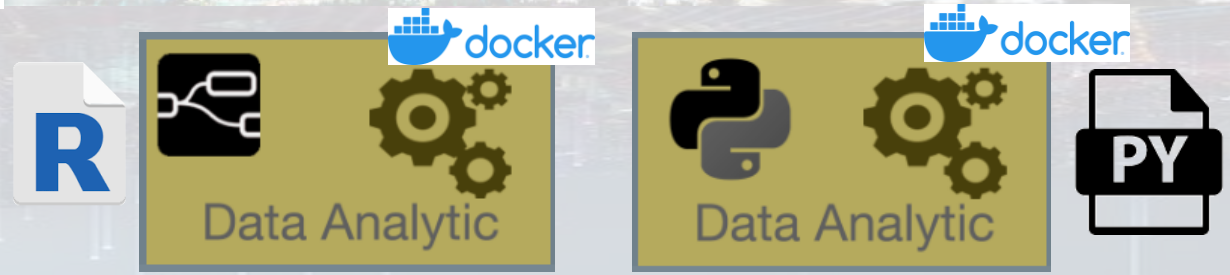
1 Develop .py or .r program on (i) Snap4City platform online, or (ii) your Development Machine.

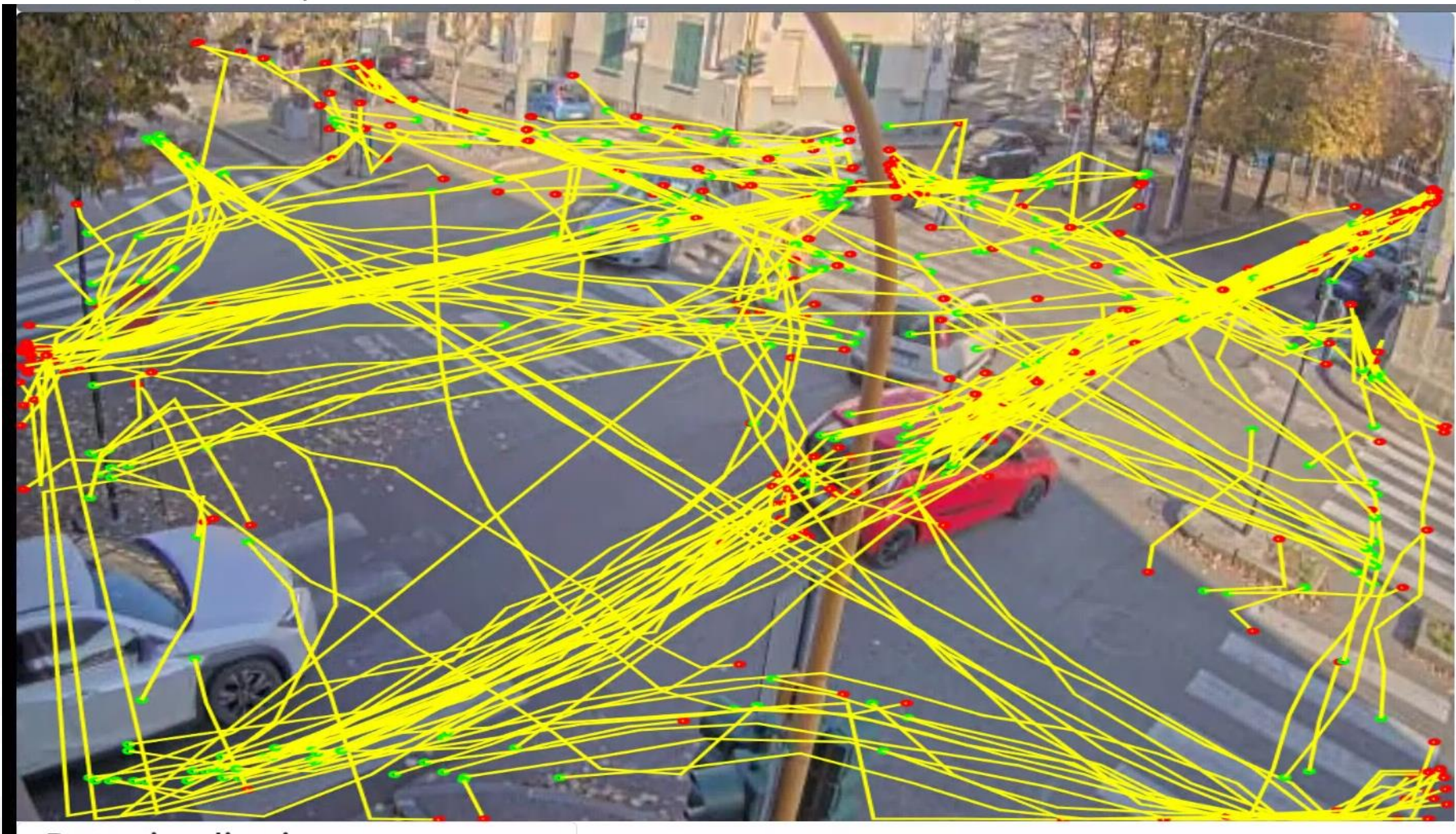
The code has to respect the guidelines provided for creating API.
The API are called as a MicroService
For example see:
<https://www.snap4city.org/641>
<https://www.snap4city.org/645>



4

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



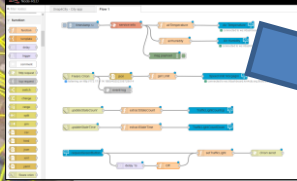




IoT edge on
TV Camera

1

Send data to Broker



Send Trajectories

2

Device: CrossVenaria2
with trajectories

IOT Broker

3

Save data

Big Data
Store
Facility

show data

4

Data Inspector

Data Inspector

Map

CROSSVENARIA2

DESCRIPTION: DESCRIPTION: RT DATA

Last update: 2022-07-04 23:35:53 175-02:00

Description	Value	Last Value	Last 4 hours	Last 24 hours	Last 7 days	Last 30 days	Last 90 days
dist	13.7	Last Value	Last 4 hours	Last 24 hours	Last 7 days	Last 30 days	Last 90 days
en	308	Last Value	Last 4 hours	Last 24 hours	Last 7 days	Last 30 days	Last 90 days

Keep data on target widget(s) after popup close:

Data sources

High-Level Type	Nature	Subnature	Device/Model	Broker	Value Name	Value Type	Data Type	Value Unit	Last Data
IoT Device	Emergency	Traffic_corps	CrossVenaria2	orionUNIFI	sensor_map	sensor_map	sensor_map		2022-04-14 08:51:28
IoT Device	TransferServiceAndSanting	SensorSite	CrossVenaria2	orionUNIFI	sensor_map	sensor_map	sensor_map		2022-04-14 08:51:28
IoT Device	TransferServiceAndSanting	Vehicle_rental	CrossVenaria2	orionUNIFI	sensor_map	sensor_map	sensor_map		2022-04-14 11:00:00
IoT Device	TransferServiceAndSanting	SensorSite	CrossVenaria2	orionUNIFI	sensor_map	sensor_map	sensor_map		2022-04-14 08:51:28
Variable	Emergency	Traffic_corps	CrossVenaria2	orionUNIFI	ey	position	float	coord	2022-04-14 08:51:28
Variable	Emergency	Traffic_corps	CrossVenaria2	orionUNIFI	en	position	float	coord	2022-04-14 08:51:28
Variable	Emergency	Traffic_corps	CrossVenaria2	orionUNIFI	timestamp	timestamp	time	timestamp	2022-04-14 08:51:28

dist - 4 Hours



IoT edge on
TV Camera

Send Trajectories

Send data to Broker

IOT Broker

Devices:

- CrossVenaria2VehicleFlowTrajectoriesV2
- VenariaConteggio



e

Send data to Broker

f

Save data

Save Counting per Cluster

Big Data
Store
Facility

Get data

c

Device:
CrossVenaria2
with
trajectories

Periodically

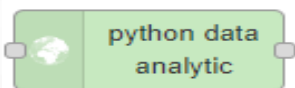
b

Activate



d

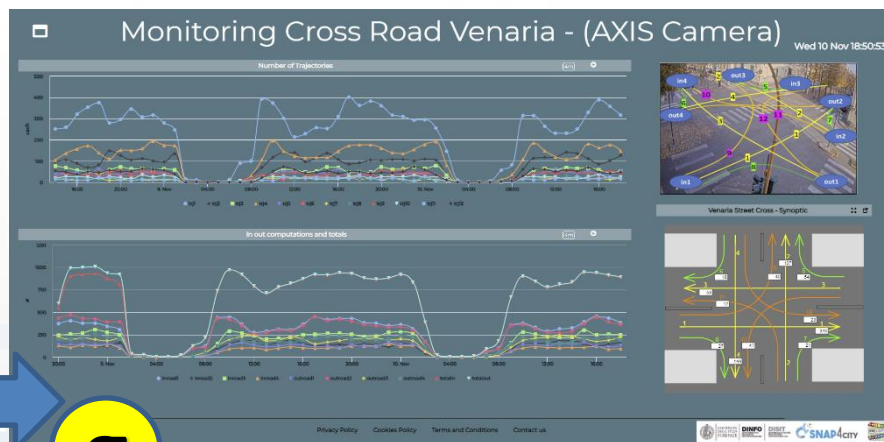
From Trajectories
to clusters.
Counting in/out
and flows



a

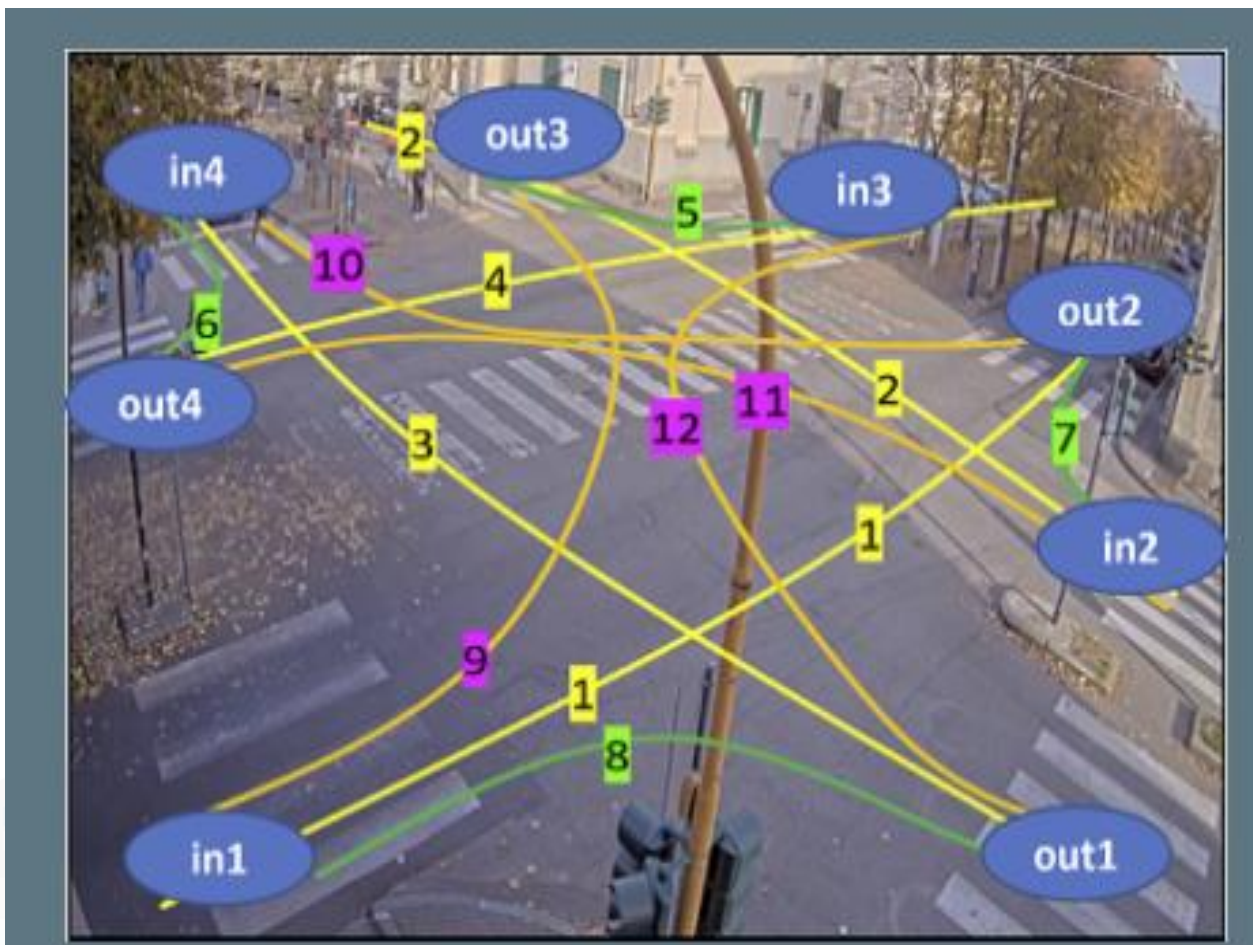
g

show data

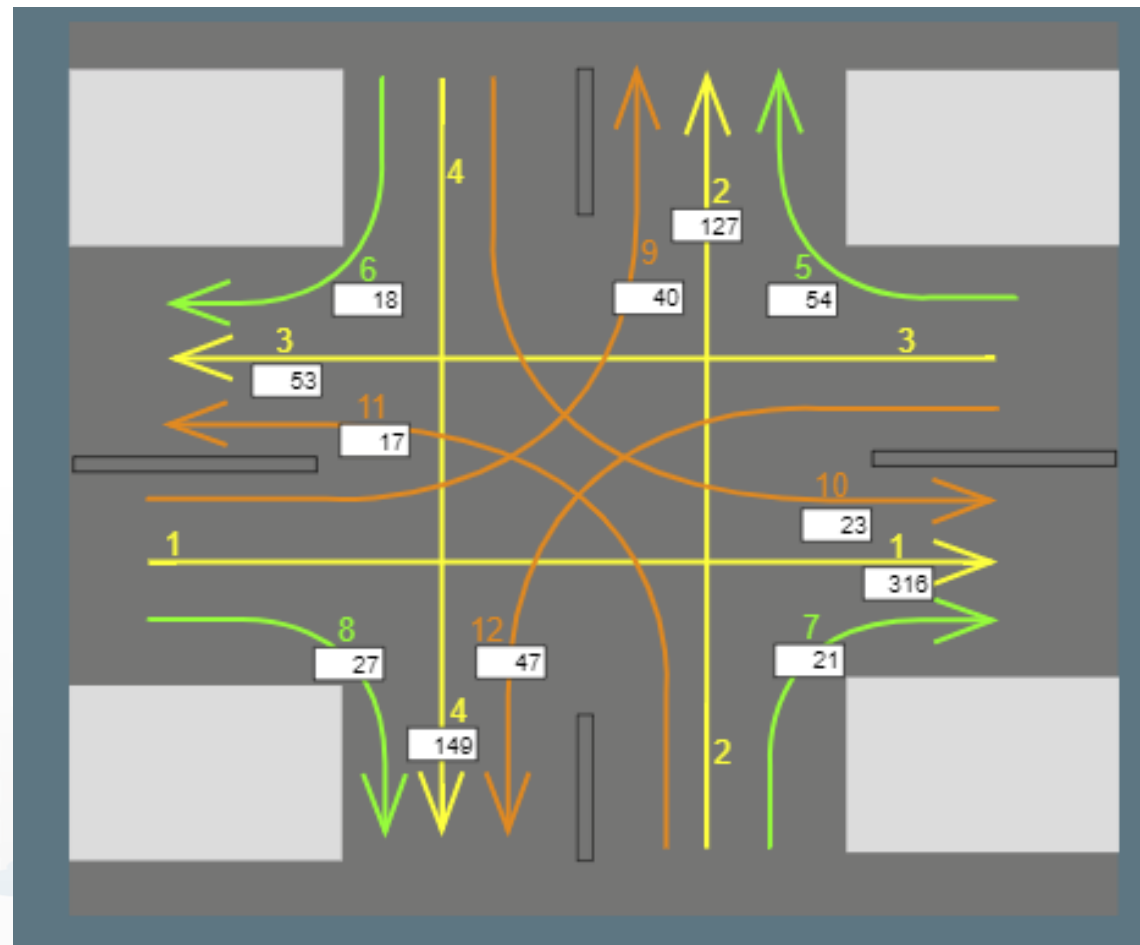


Create and use a Dashboard

Real time Clustering: legenda and synoptic



Legenda



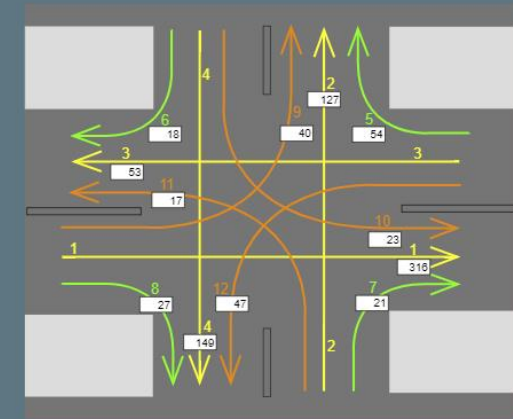
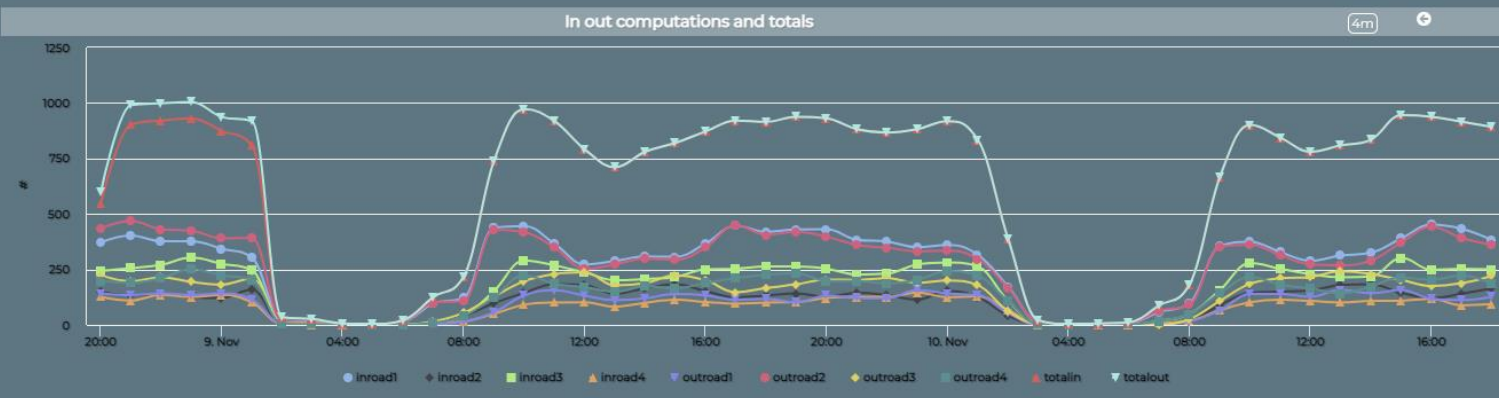
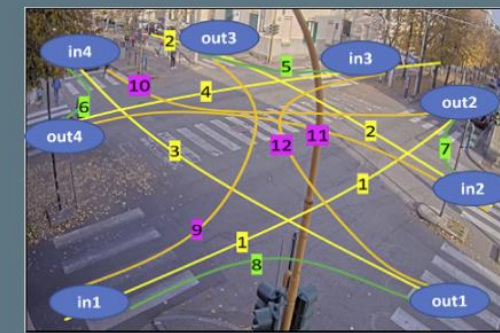
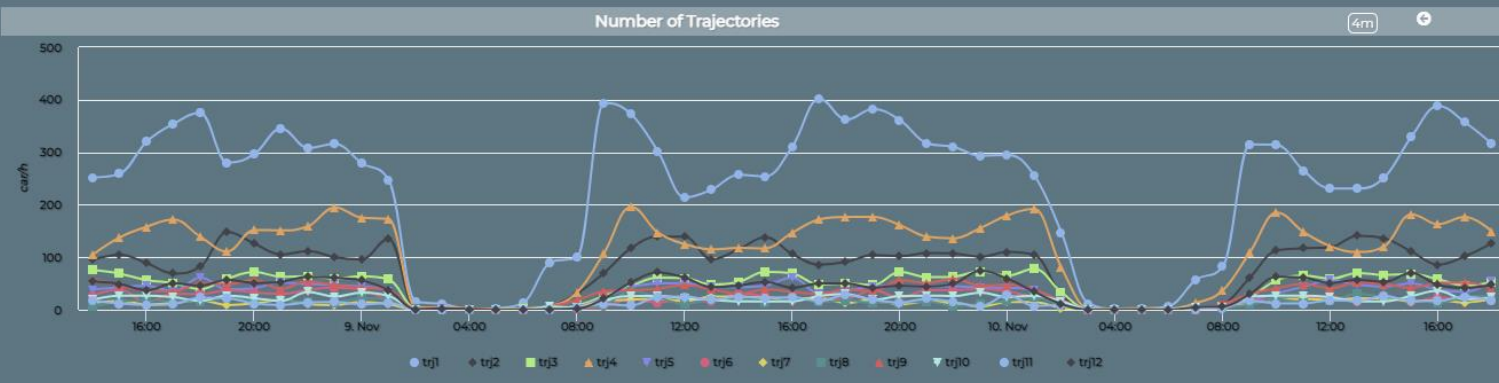
Synoptic with real time data

Traffic Flow Analysis via TV Camera and Clustering on cloud

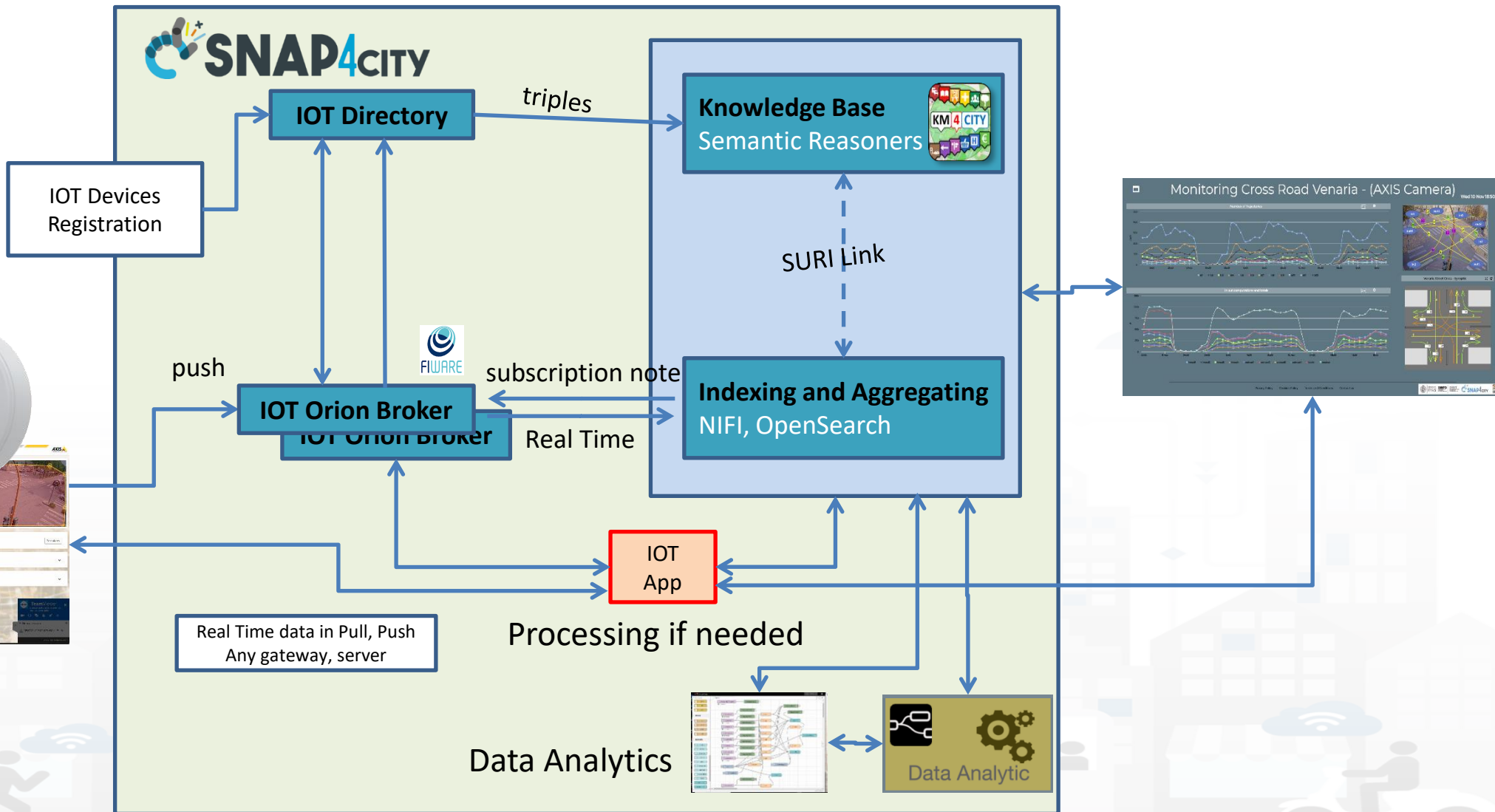


Monitoring Cross Road Venaria - (AXIS Camera)

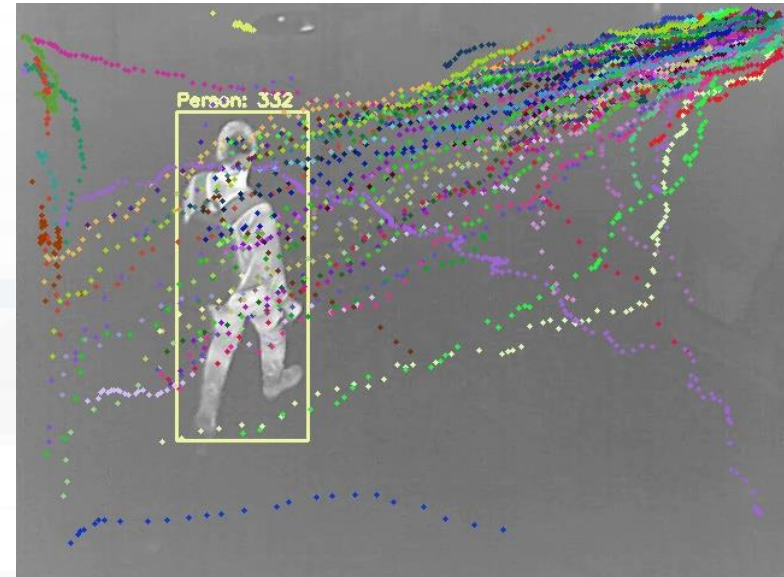
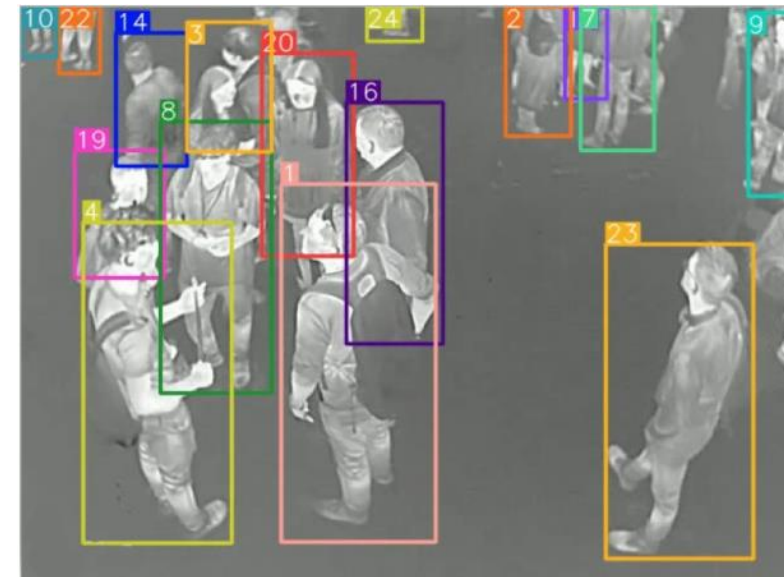
Wed 10 Nov 18:00



Managing TV Cam



People Counting and Tracking



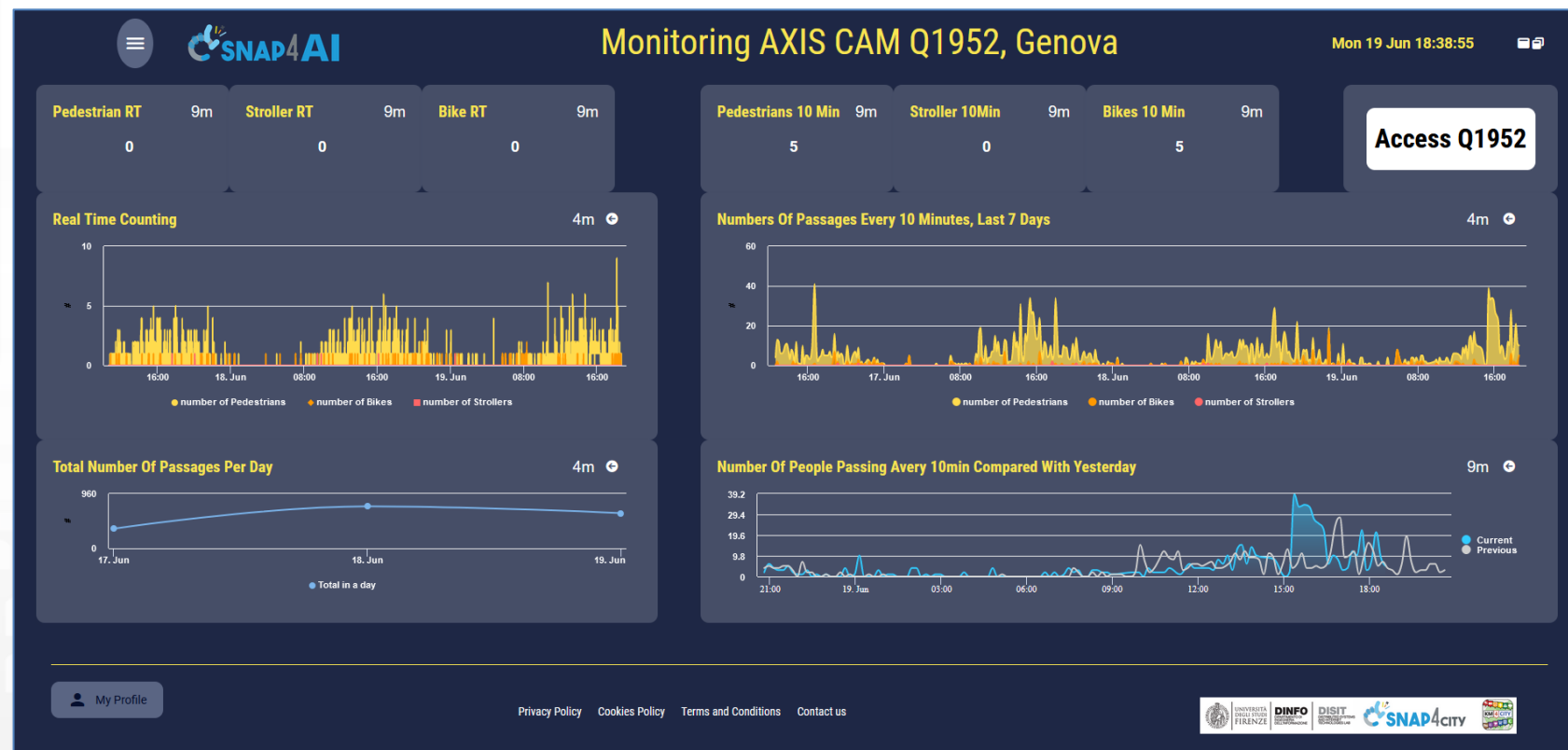
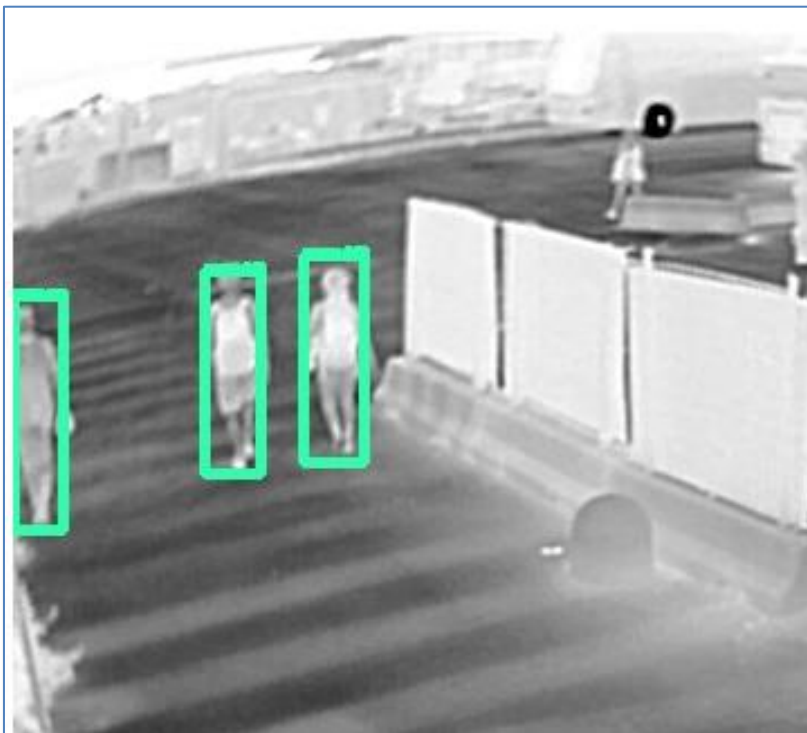
11 SUSTAINABLE CITIES
AND COMMUNITIES

3X



Monitoring Passages AXIS Q1952

- Genova: Ocean Race, 2023



11 SUSTAINABLE CITIES
AND COMMUNITIES



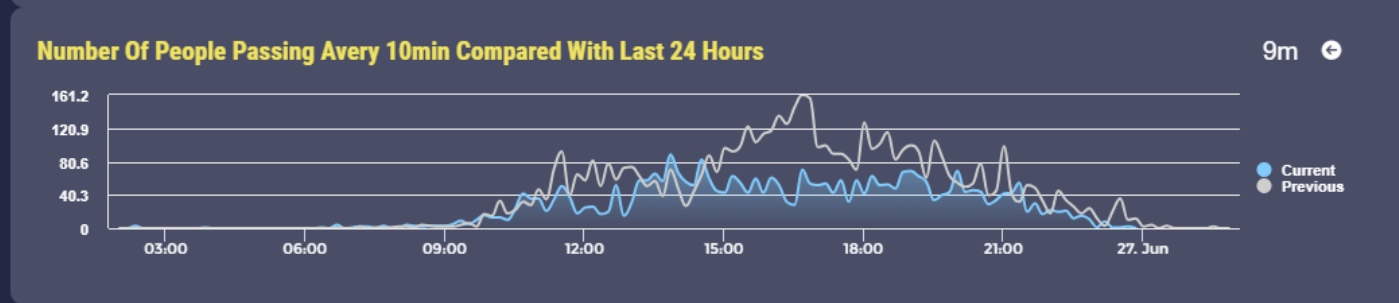
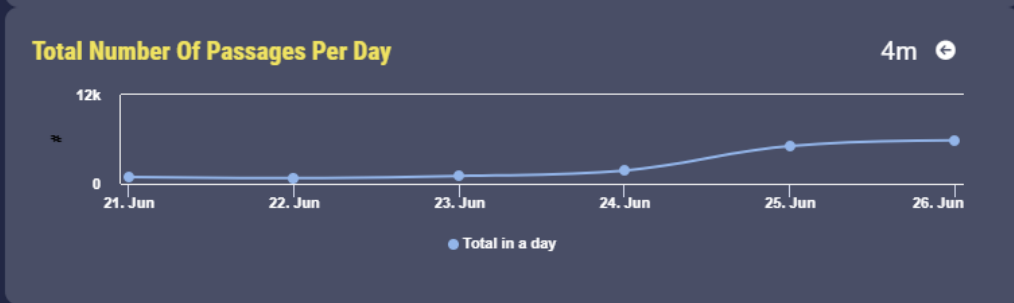
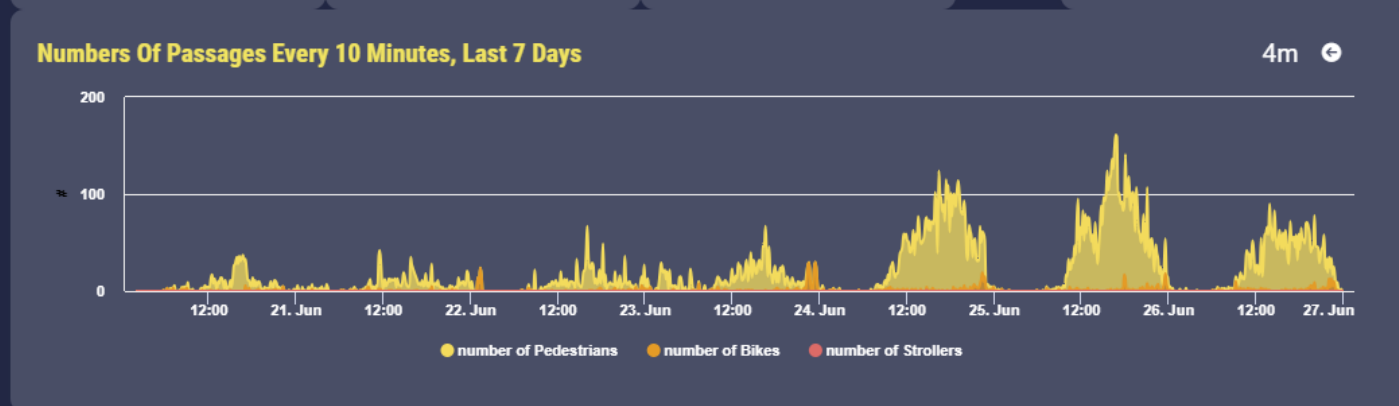
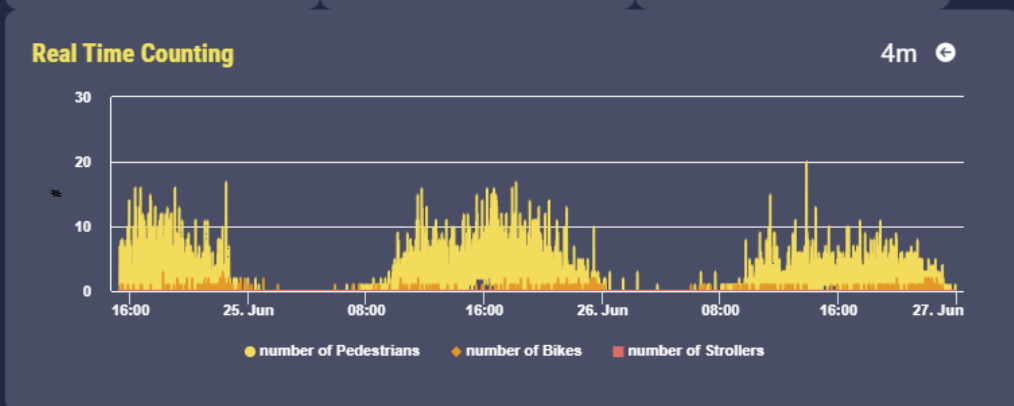
Pedestrian RT 9m **Stroller RT** 9m **Bike RT** 9m

0 0 0

Pedestrians 10 Min 9m **Stroller 10Min** 9m **Bikes 10 Min** 9m

0 0 0

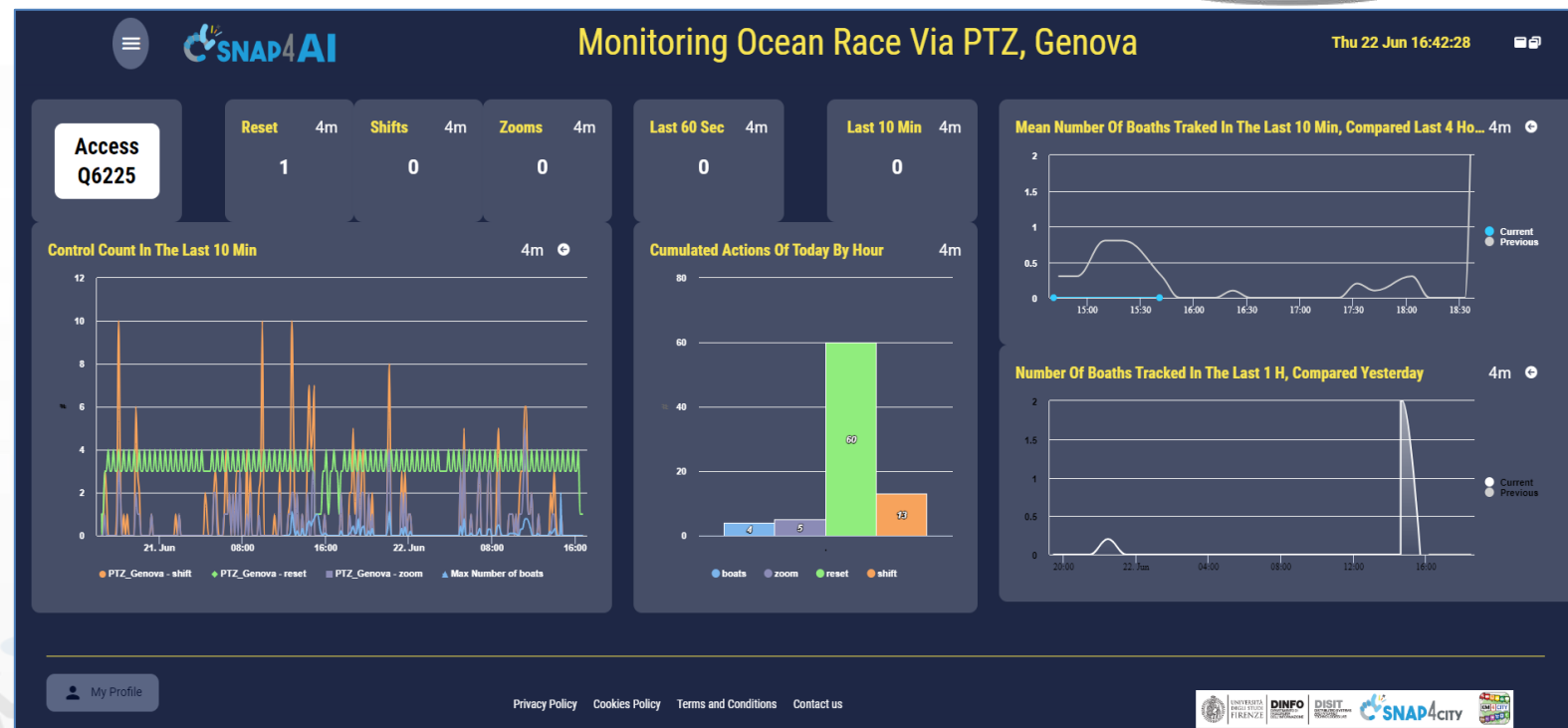
Access Q1952



Monitoring Boats AXIS Q6225



- Genova: Ocean Race, 2023



11 SUSTAINABLE CITIES AND COMMUNITIES





Monitoring Ocean Race Via PTZ, Genova

Mon 26 Jun 23:57:01



Access
Q6225

Reset 9m Shifts 9m Zooms 9m

2 0 0

Last 60 Sec 9m

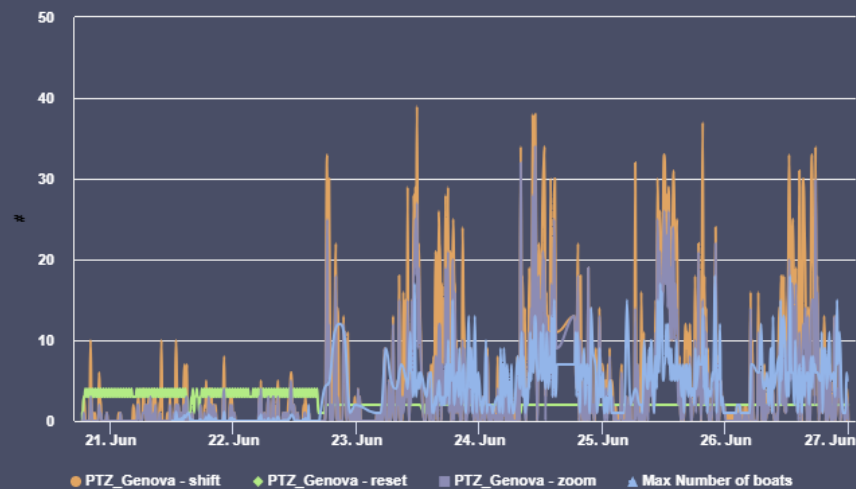
2

Last 10 Min 9m

5

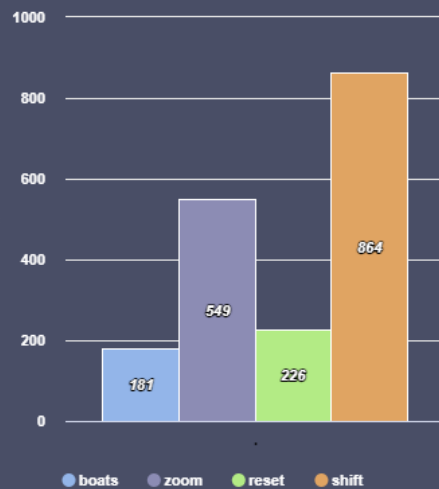
Control Count In The Last 10 Min

4m



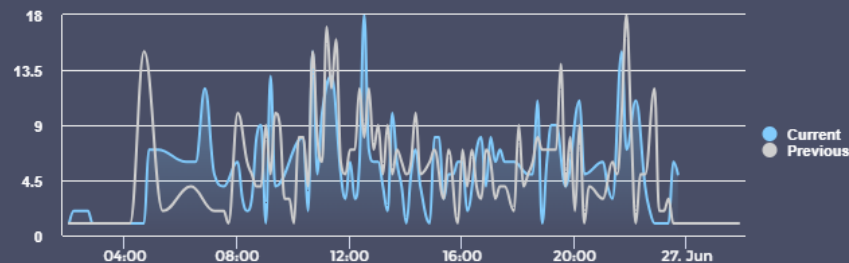
Cumulated Actions Of Today By Hour

4m



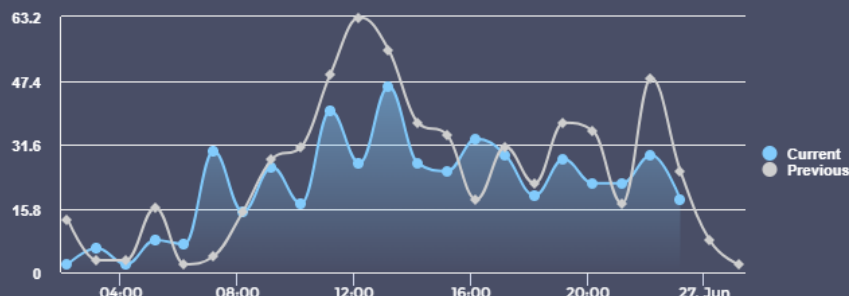
Mean Number Of Boaths Traked In The Last 10 Min, Compared Last 24 H...

9m



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

9m



TOP

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



VIDEO

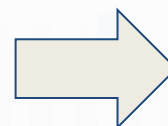
WorkShop working with Data Analytics on Node-Red using the SCAPI



- 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>

WorkShop

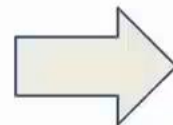
working with Data Analytics on Node-Red using the SCAPI



- 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

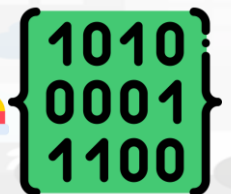
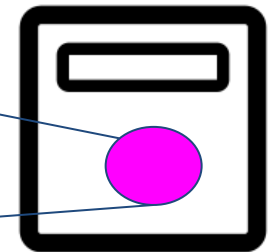
- You can choose between a multitude of Devices inside the Snap4City Platform
- A useful online user interface is available at <http://servicemap.km4city.org/WebAppGrafo/>
- Or you can of course use your devices created in the platform

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

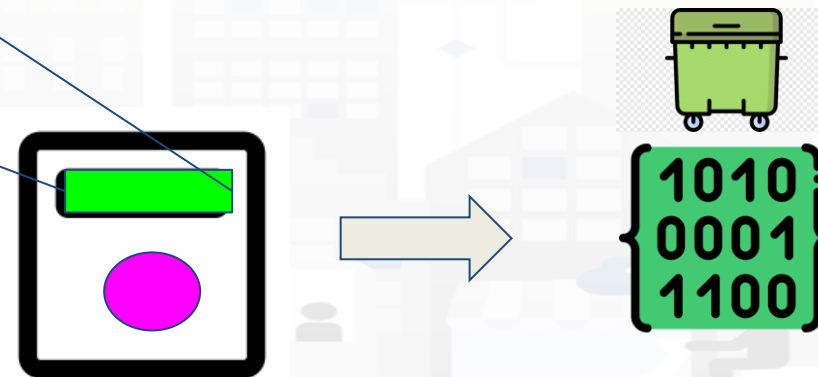
ACCESS TOKEN



```
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...k41aUWw",  
  "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>

TOP

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

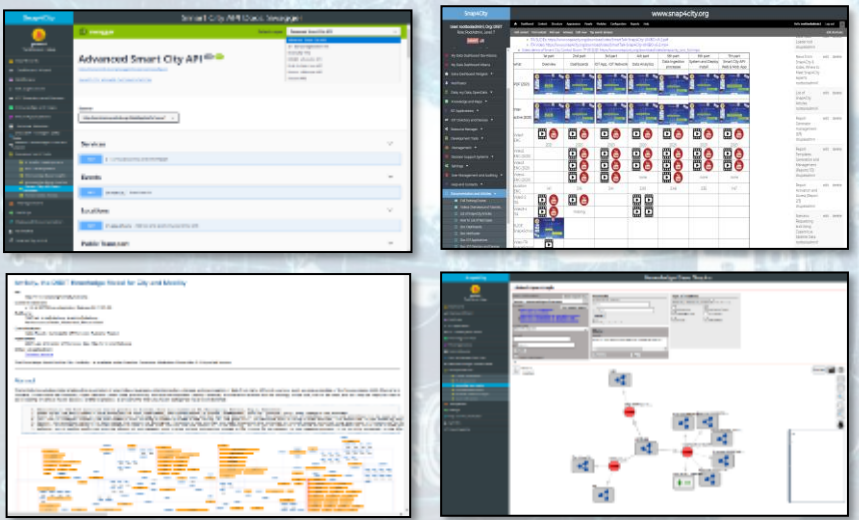




Data Analytics on Snap4City platform

Dev on Premise, Custom

Swagger

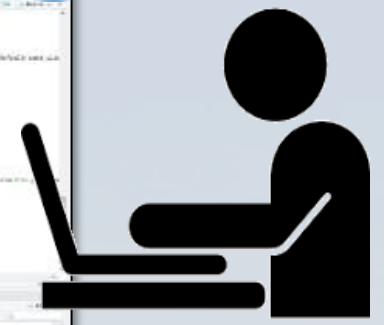
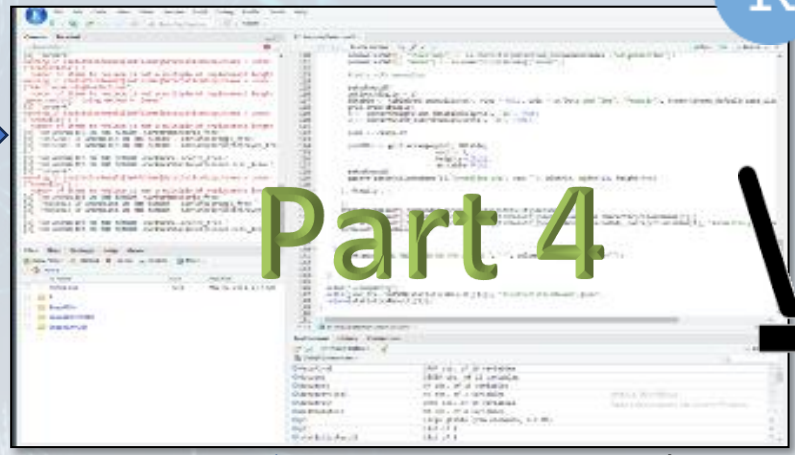


Ontology Schema

LOG.disit.org



Smart City API from Knowledge Base and other tools

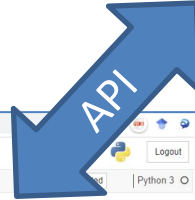
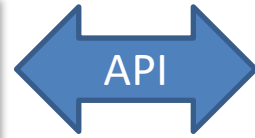
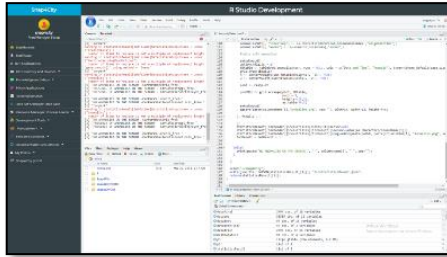


Saving / Sharing reusing



Resource Manager





EXECUTION



On Server
Or
On PC

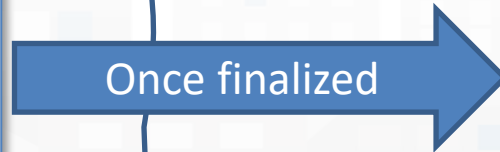
On PC as Local Environment

```

plt.show()
thisinput = input()
if(thisinput=="break"):
    break
if(thisinput=="endletro"):
    i = i - 1
else:
    print("hai inserito il cluster" + thisinput)
    try:
        int(thisinput)
        if(int(thisinput)>=14):
            print("hai inserito un numero > 14")
            print("Riprova")
        else:
            print("caricamento andato a buon fine")
            trajectories.at[i,'label'] = int(thisinput) #15 è l'indice della colonna 'label'
            i = i + 1
    except ValueError:
        print("non hai inserito un numero")
        print("Riprova")
    except ValueError:
        print(ValueError)
        print("batch completed successfully")
        trajectories.to_csv("trajectoriesClassified_"+str(i)+".csv", index = False)

```

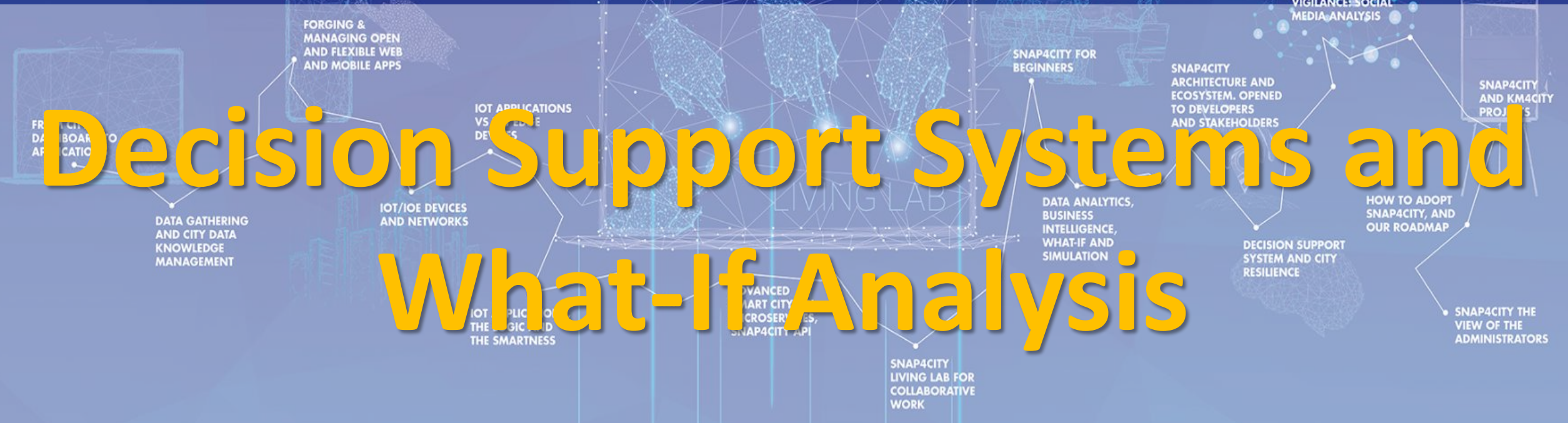
DEVELOPMENT



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

TOP

Decision Support Systems and What-If Analysis



Public Spaces as Critical Infrastructures

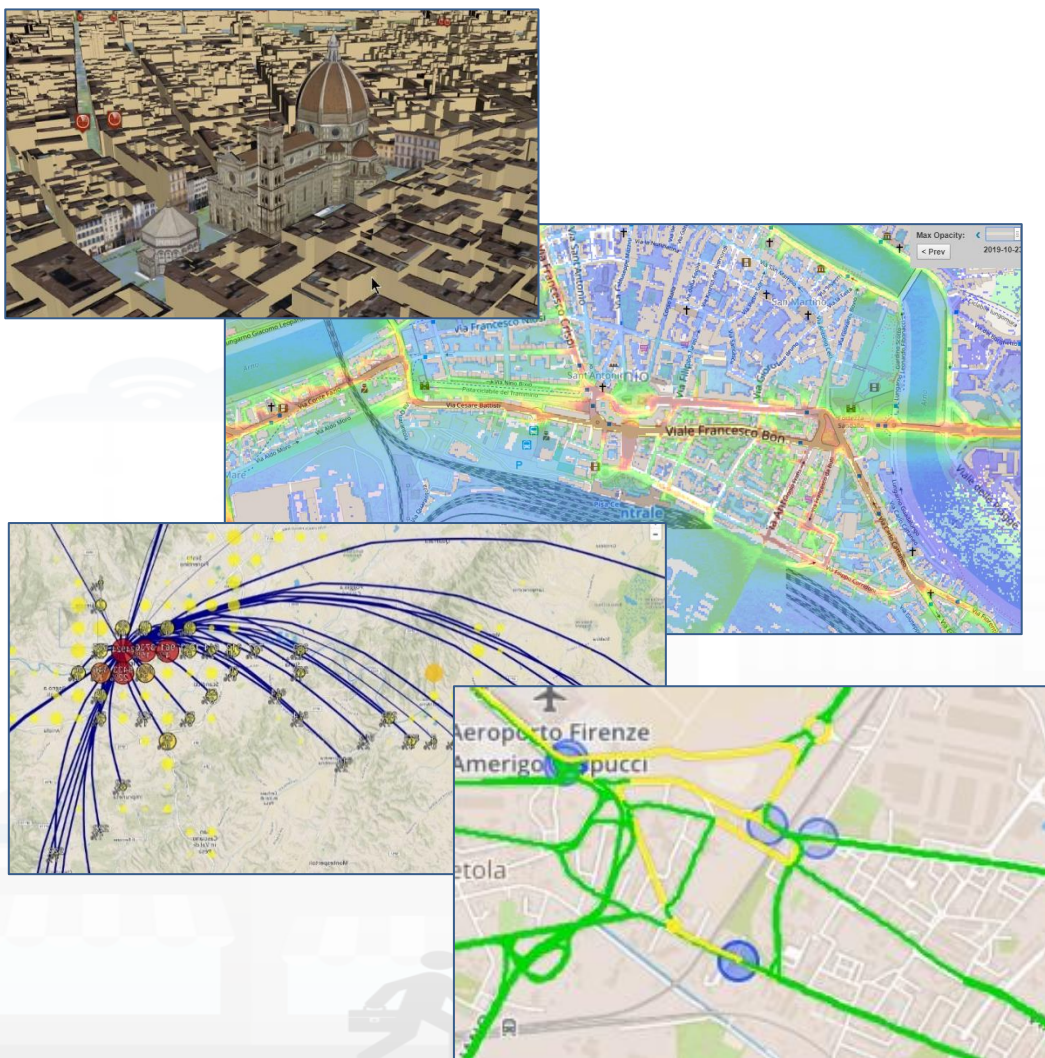
- The City is a system of systems for city users
 - Cascading effects
- **Transport** networks
 - Main means for rescue teams, food, water, etc.
- **Communication**, ICT infrastructure
 - TV cam, switches, cyber,
- **Energy** networks
 - power supply for health, cyber systems, etc.
- **Hospitals** networks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



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

Smart City Digital Twin

Digital representation of the city 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
- Data Representation
- Key performance Indicators
- What-IF analysis – Simulation, prediction, 2D/3D
- Operation, planning tactic and strategic
- Collaborative and shared representation
- Sustainable, shared, open source 100%

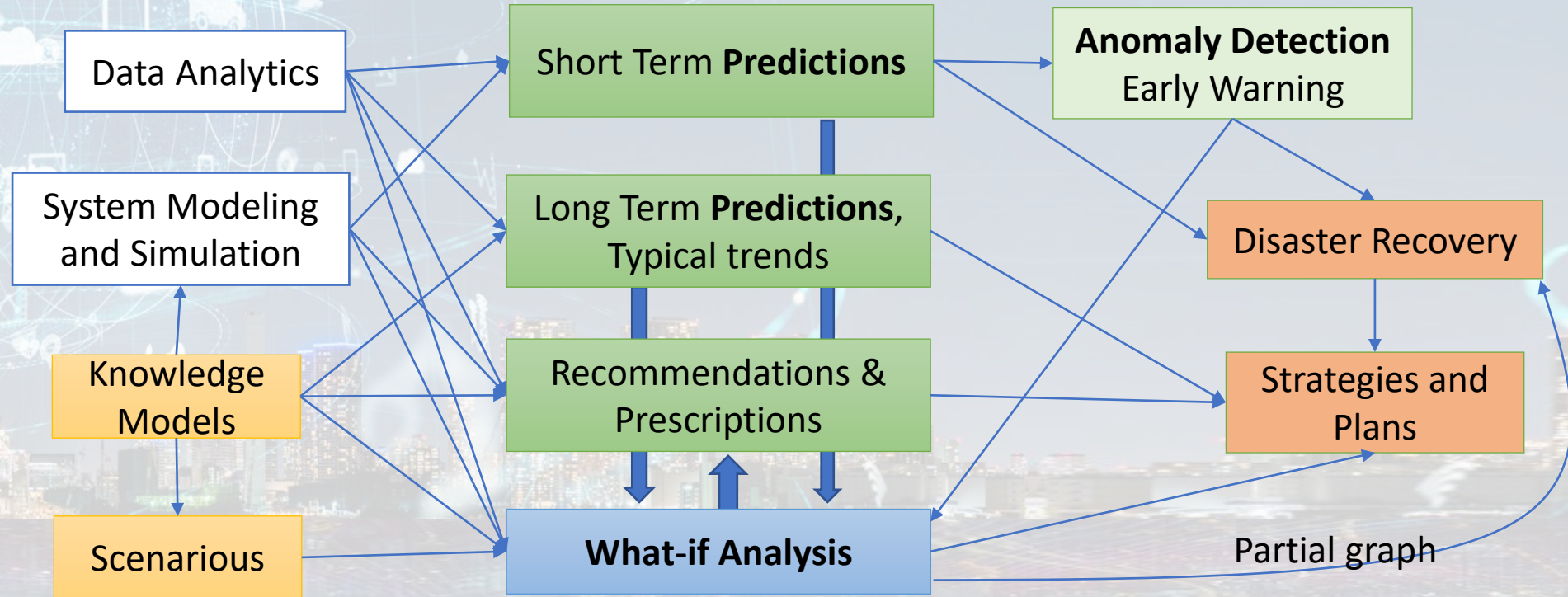
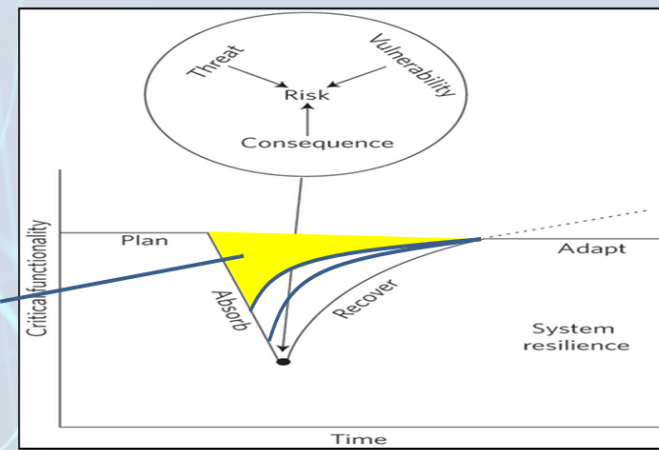
Complex and heterogeneous information, interoperability

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

Snap4City Analytics

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

Prepare
Absorb
Recover
Adapt



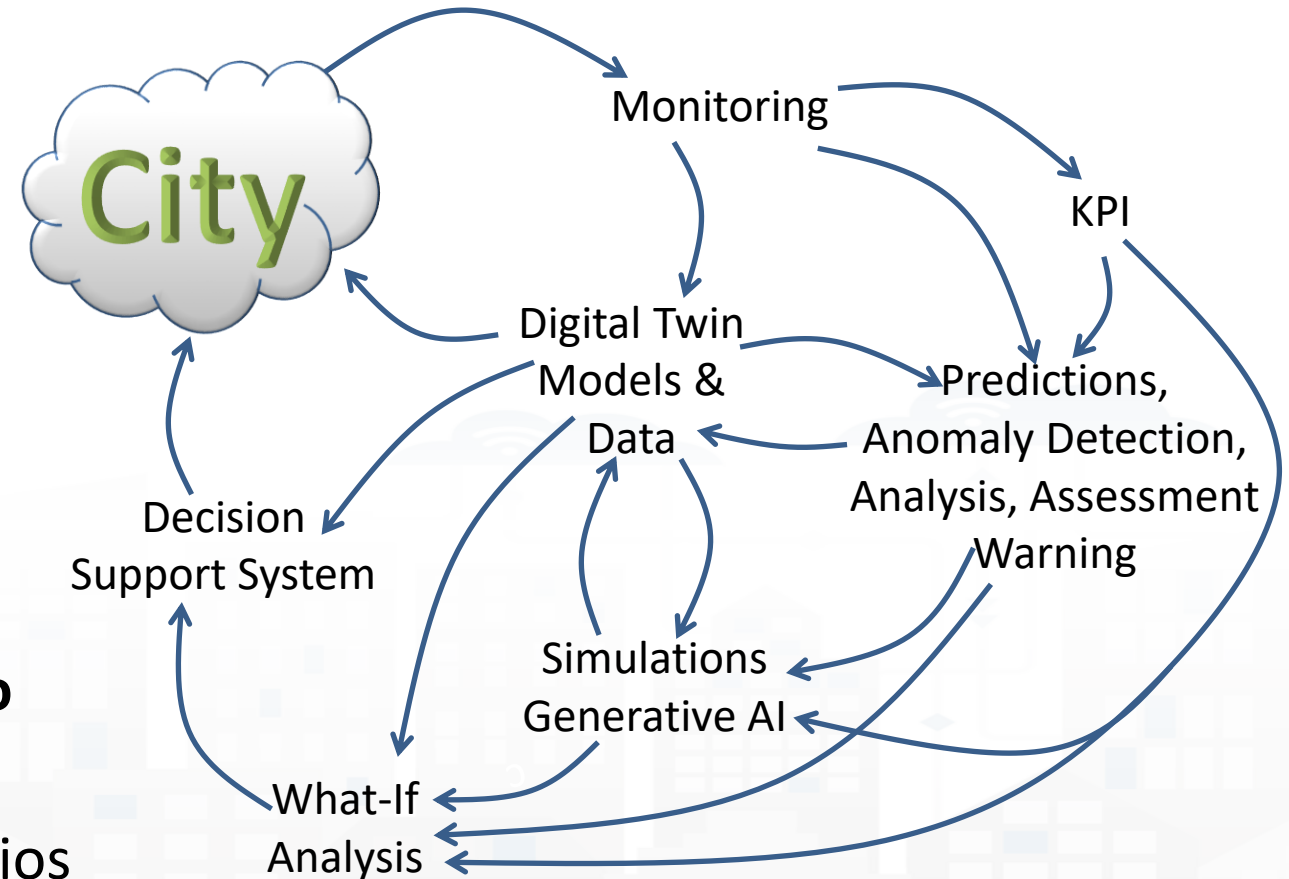
Decision Support System: neuro-symbolic reasoning
 targeting Indicators: Quality of Life, PUMS, SUMI, KPI, SDG, 15MinIndex,...

- **Controlling Status: management, and operational**

- Monitoring via KPI
- Computing predictions vs KPI
- Anomaly detection
- Neuro-Symbolic analysis
- Risk assessment
- Early warning on critical conditions

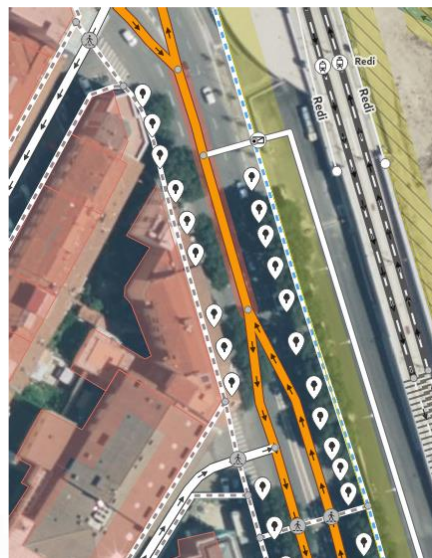
- **Making plan: tactic and strategic, medium and long range, micro/macro**

- Simulation & predictions
- Generative AI Prescriptions, scenarios
- Resilience to Unexpected unknowns
- What-if analysis wrt scenarios



Tactic and/or Strategic Planning

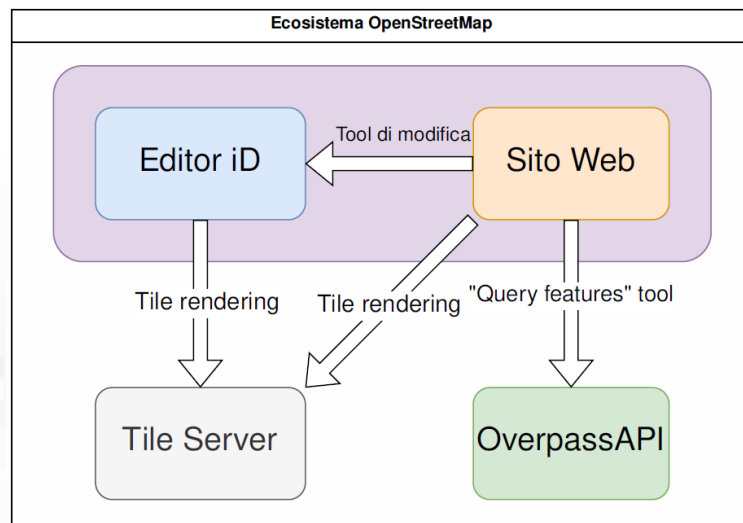
Correction of road graphs
which is present on OSM



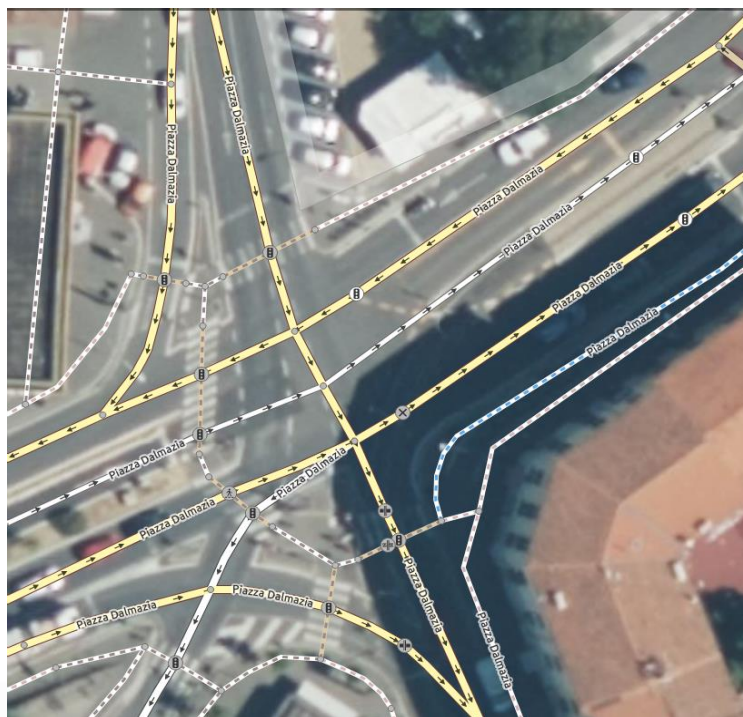
OSM data with non clear double bidirection lane on Viale Redi, Florence.
Editing OSM data and present Tiles



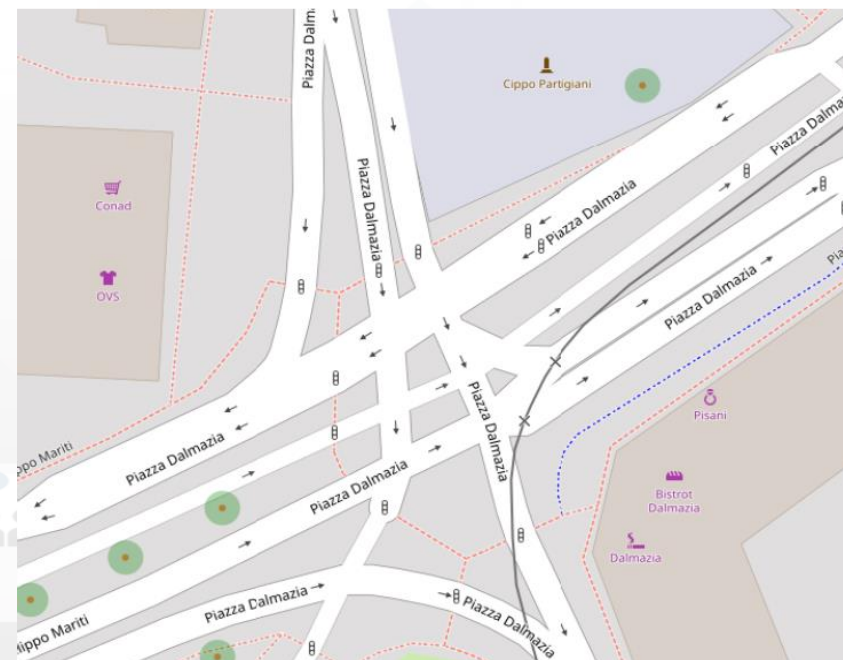
After Corretion of OSM data defining a clear double bidirection lane on Viale Redi, Florence. Regeneration of the TILES for the maps



OSM data with non correct viability in Piazza Dalmazia, Firenze



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





Control Room



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

Prepare
Absorb
Recover
Adapt

Impact:

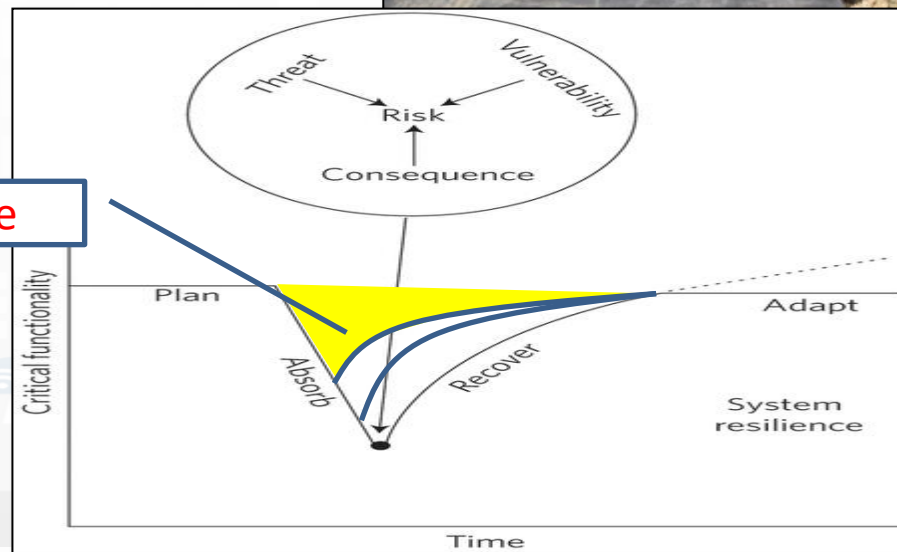
- Early warning, faster reaction
- Increased resilience

Several metrics related to:

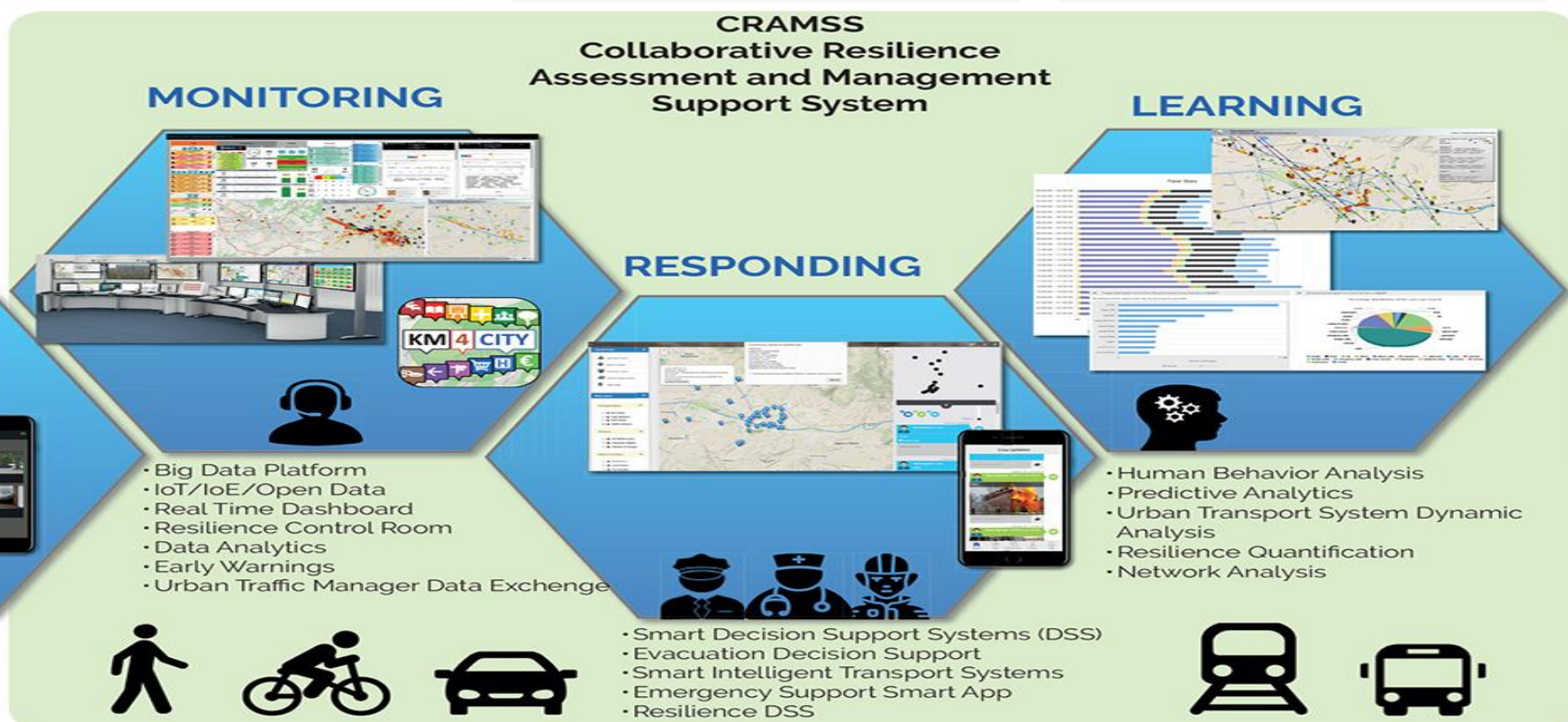
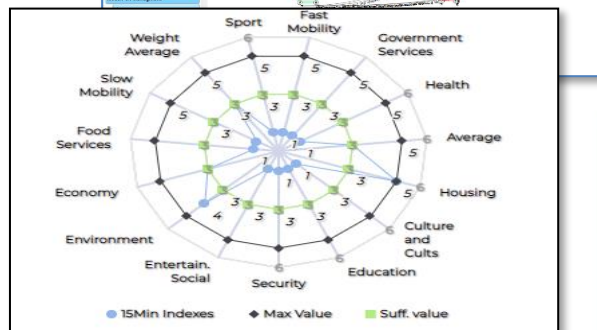
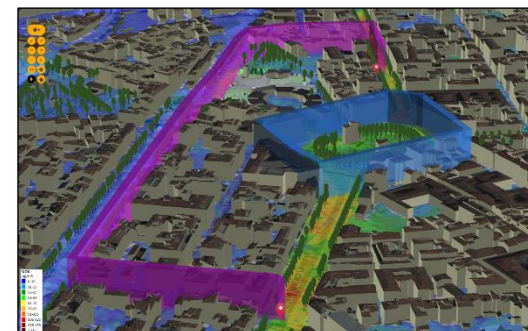
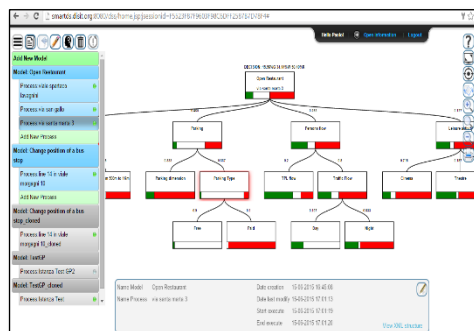
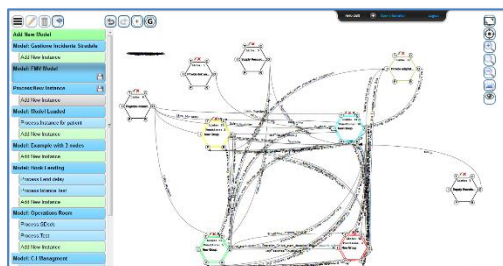
- Volume of retweets
- Sentiment analysis



damage



ERMIG: European Resilience Management Guide



ANTICIPATING

MONITORING

RESPONDING

LEARNING

- European Resilience Management Guidelines
- Game Based Training

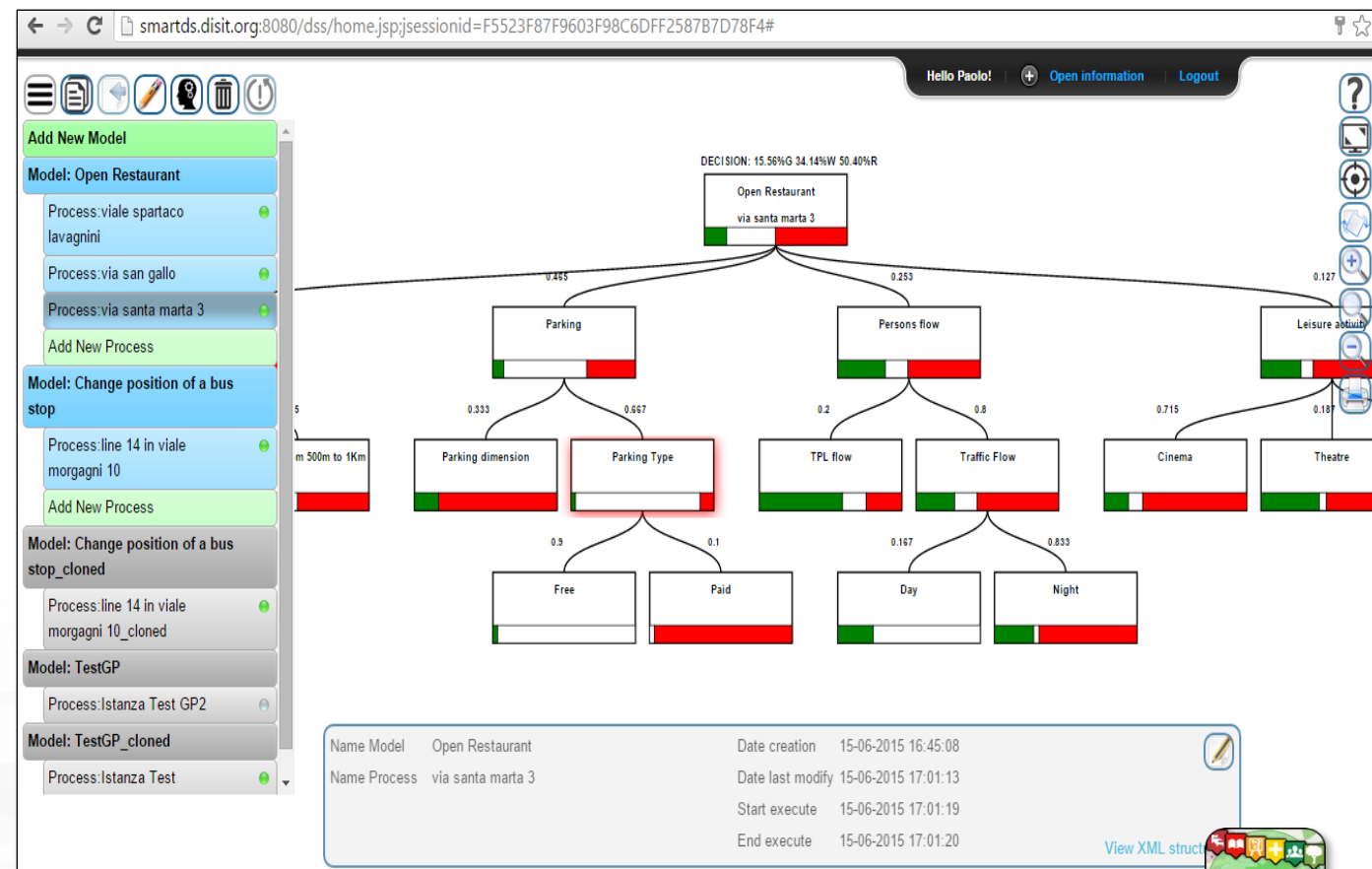


- Smart Decision Support Systems (DSS)
- Evacuation Decision Support
- Smart Intelligent Transport Systems
- Emergency Support Smart App
- Resilience DSS



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, ...



<http://smartds.km4city.org>

WHAT-IF Analysis

9 INDUSTRY, INNOVATION
AND INFRASTRUCTURE



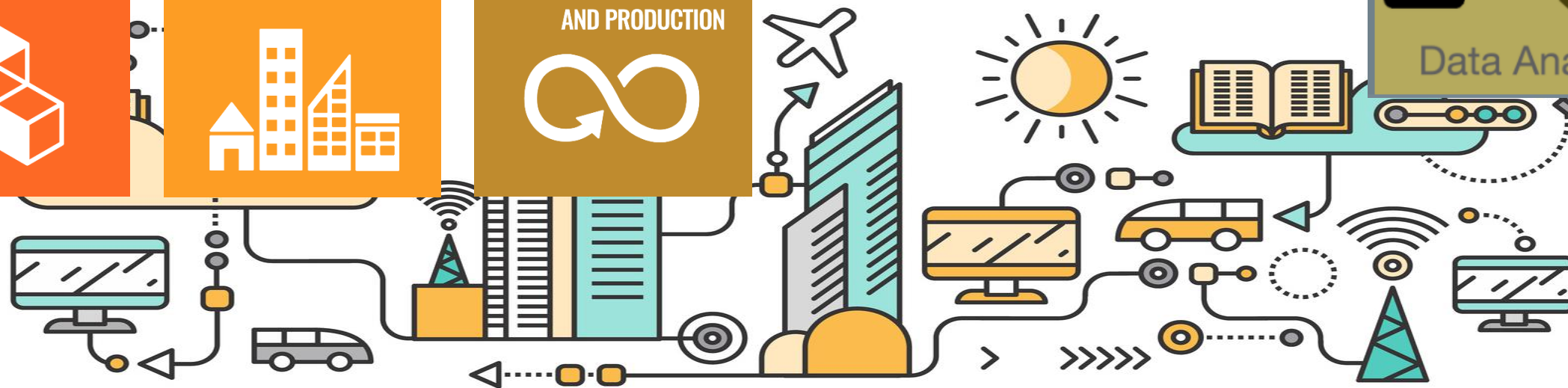
11 SUSTAINABLE CITIES
AND COMMUNITIES



12 RESPONSIBLE
CONSUMPTION
AND PRODUCTION



Data Analytic





Decision Support Systems, What-if

○ Event planning, via what-if analysis

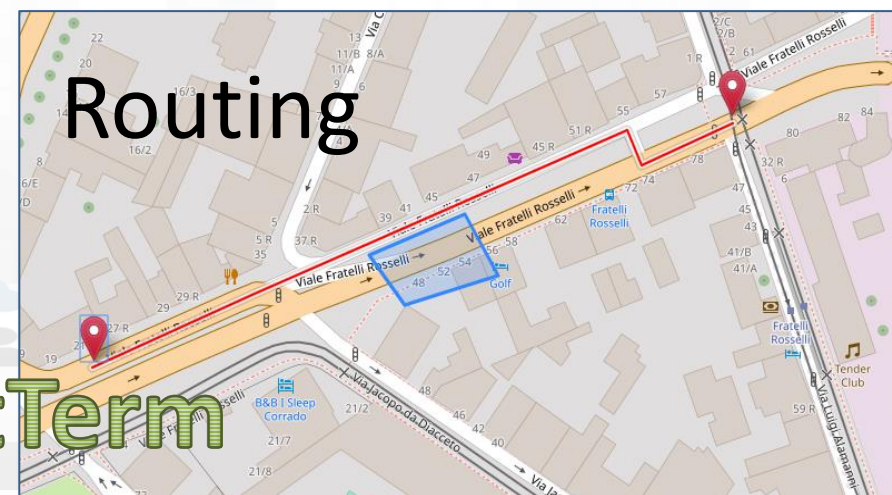
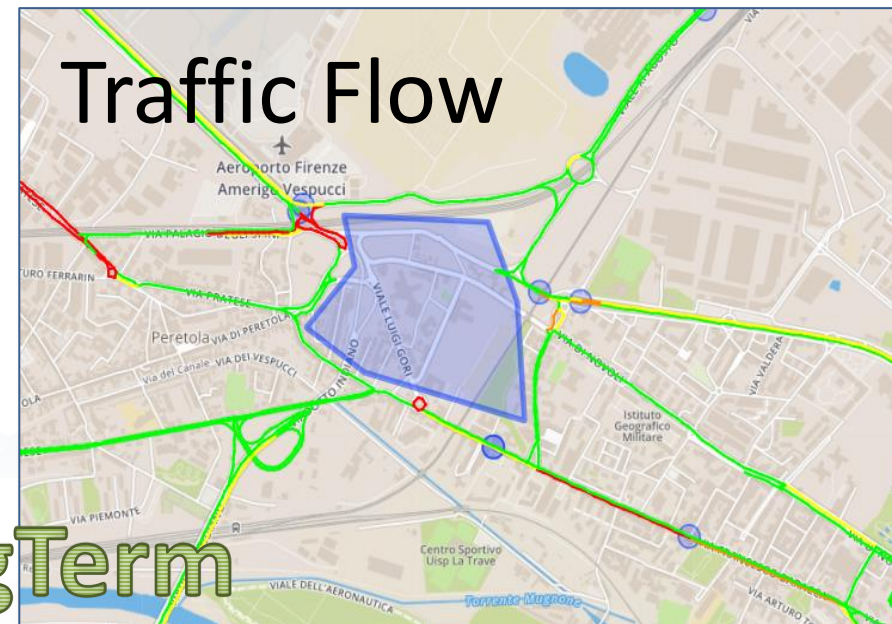
- Change in the graph structure of the city
- Impact on the flow of people and vehicles
- Adaptation: public transport, traffic, pedestrian management, etc.

○ Immediate reaction to natural events or not

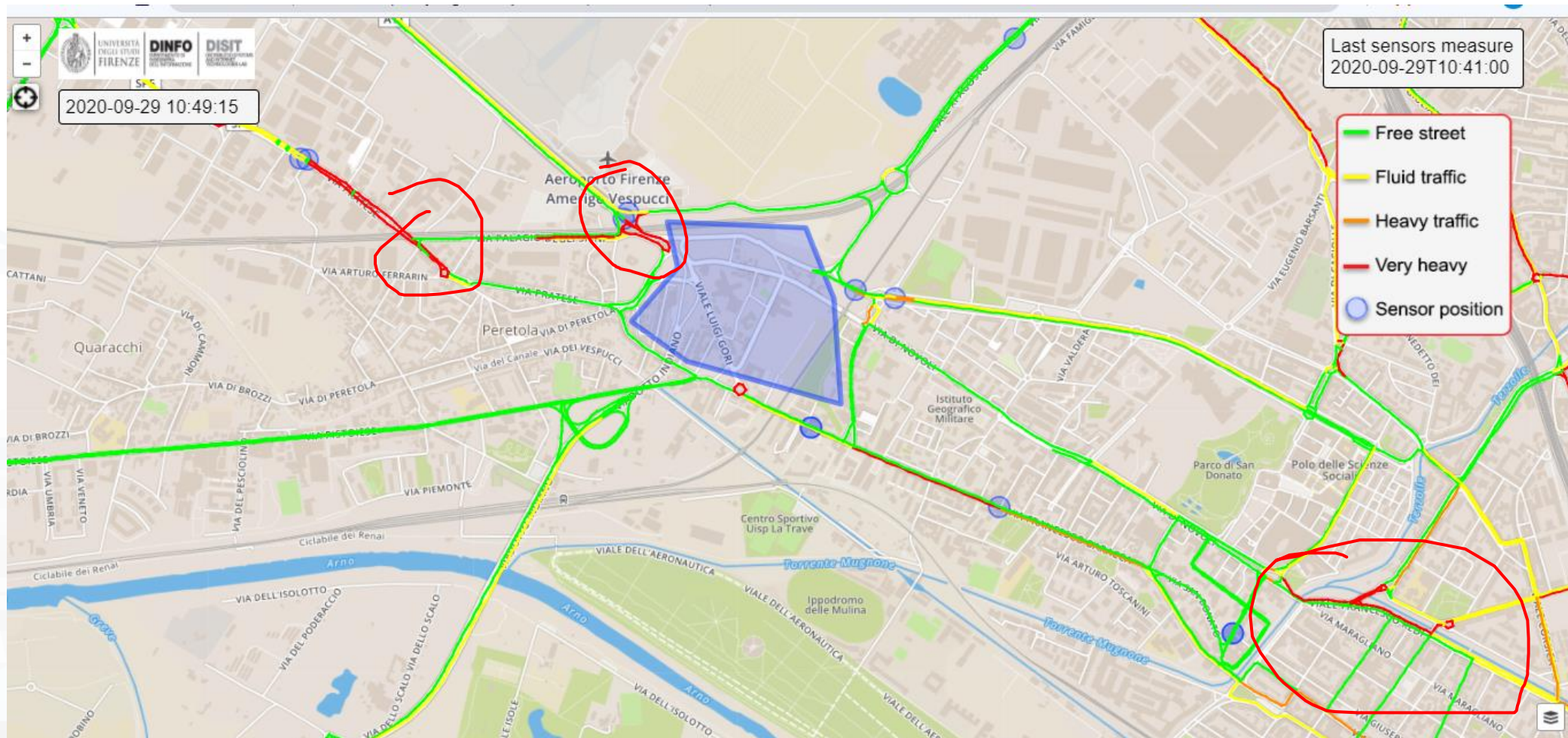
- Everything is ready and updated in real time
- Each view is contextualized in terms of data: descriptive and prescriptive

○ 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

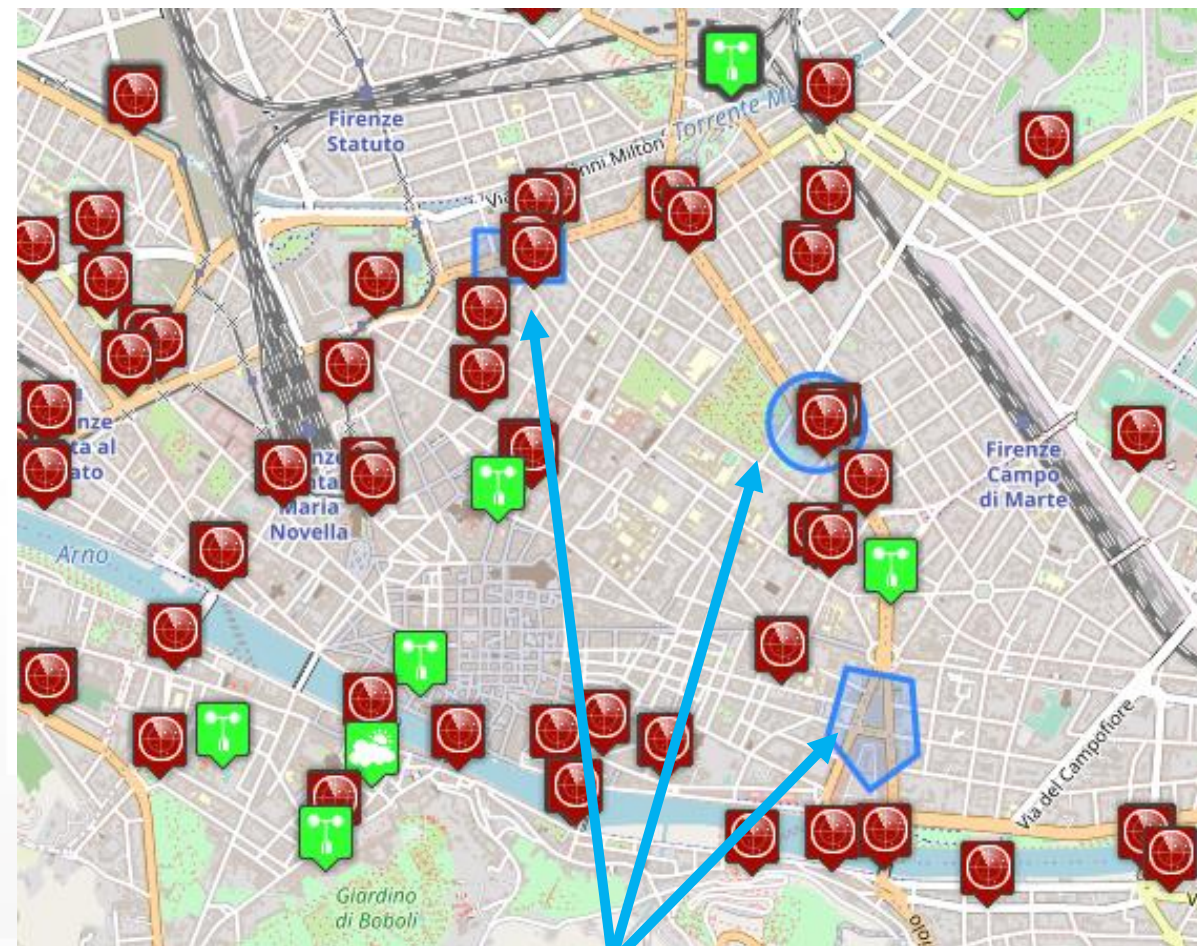


Computation of Traffic Flow Evolution, cascade effects



What-If Analysis Concepts

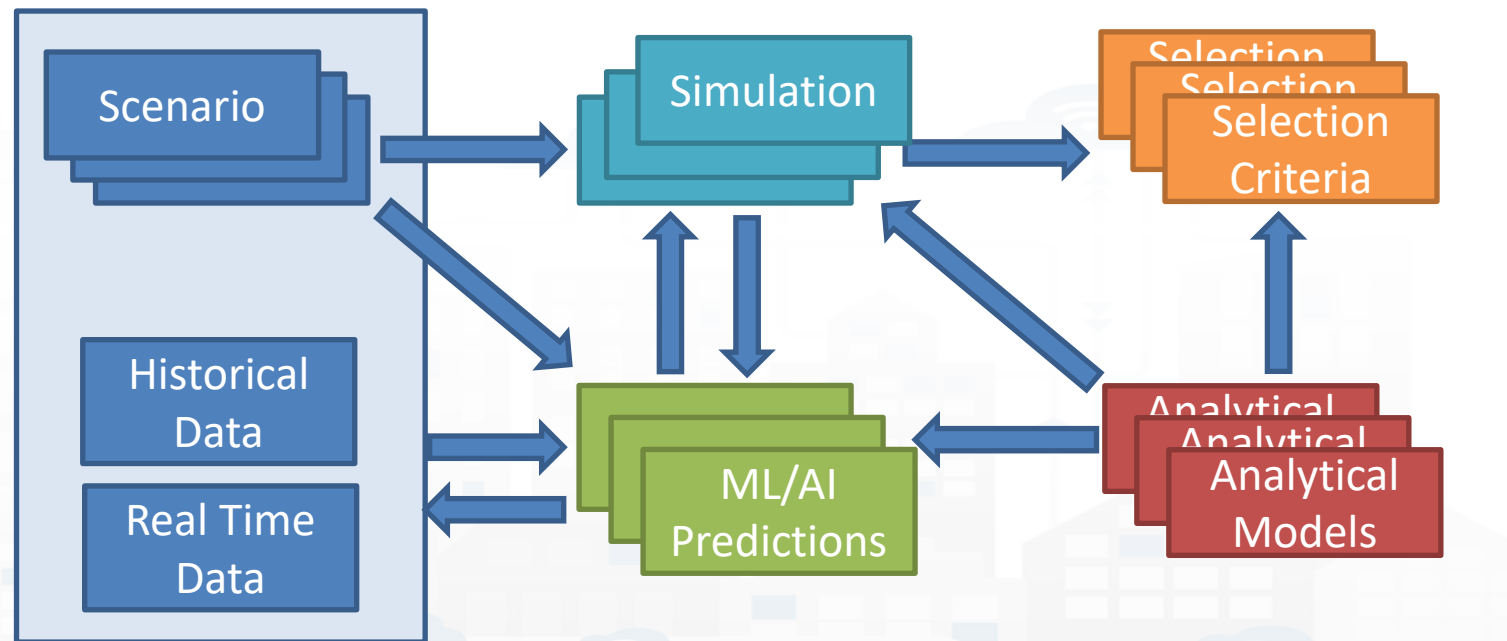
- What is going to happen at Services if certain conditions/cases are going to occur
- Formalize: Conditions/cases, Services
- Scenarios of Cases+Services Vs Solutions are Studios
- You can define, save, load:
 - Scenarios and Studios



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

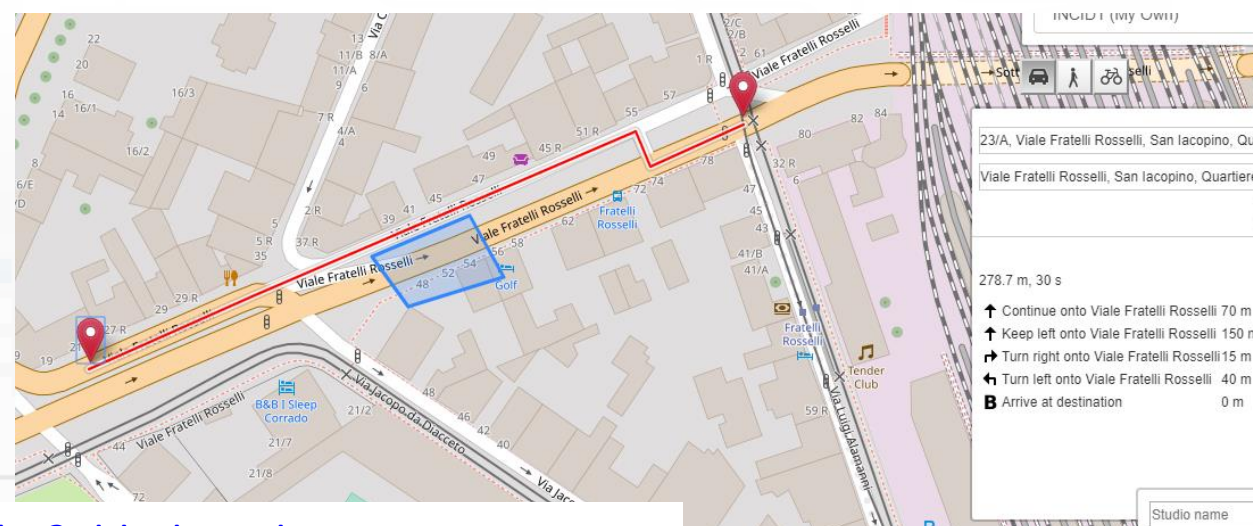
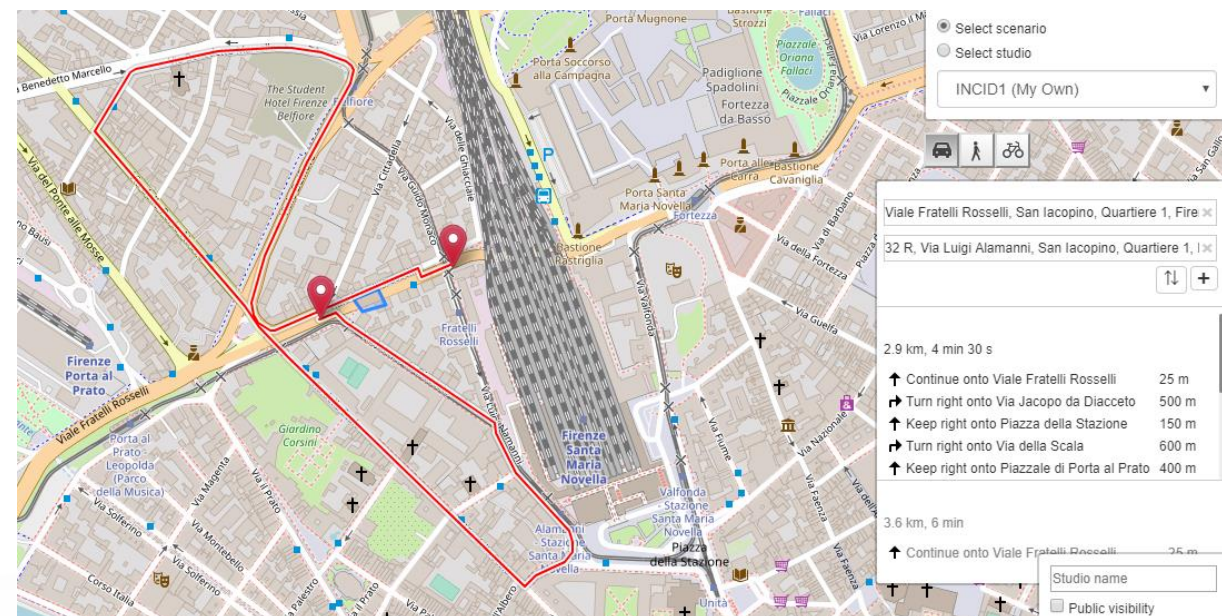


Accidents and elements blocking Points and Shapes taken into account for:

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

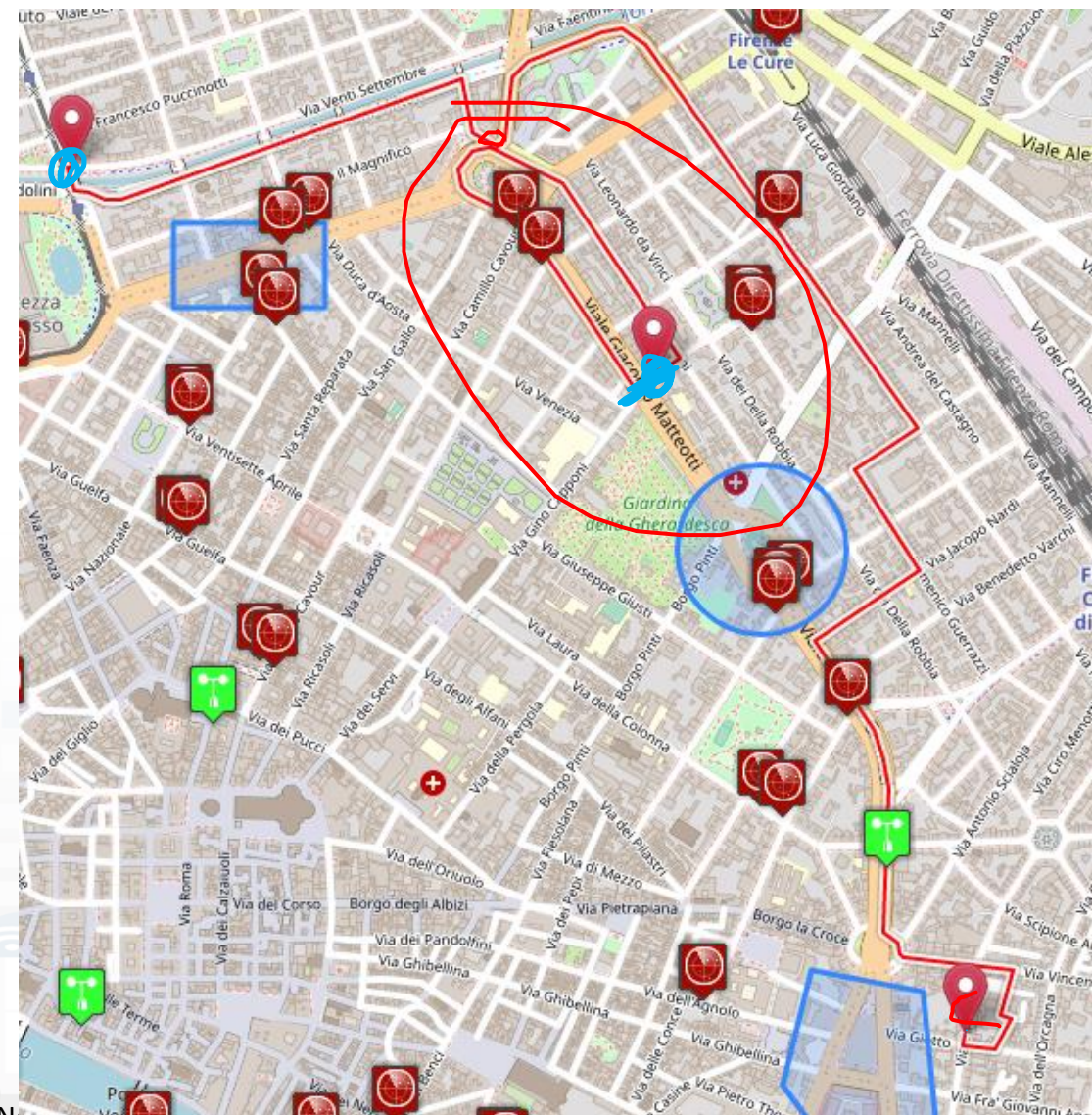
Assessment on the basis of changes:

- Mobility demand assessment
- Mobility Offer assessment



Impact on Routing

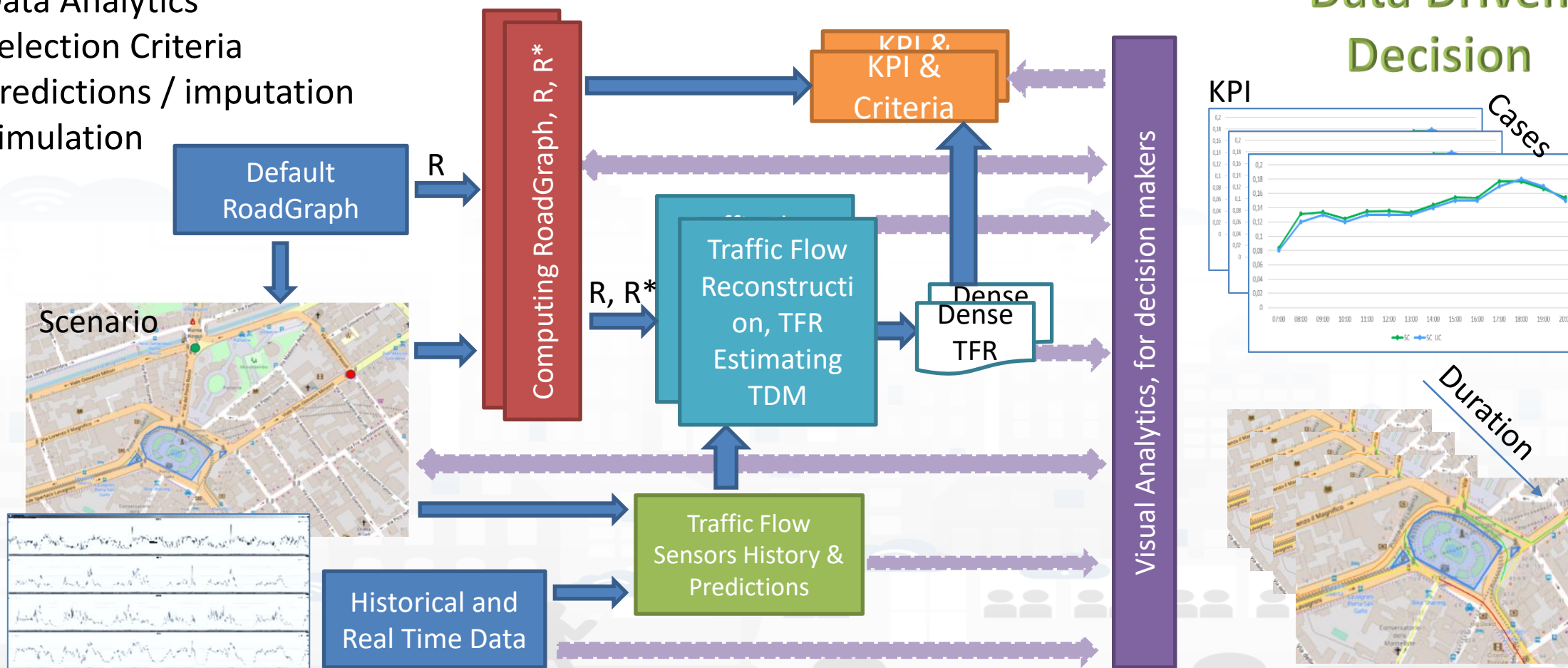
- Scenario with multiple shapes
- Conditional Routing
 - avoiding areas or
 - reducing traffic in those areas
 - Multiple stop points



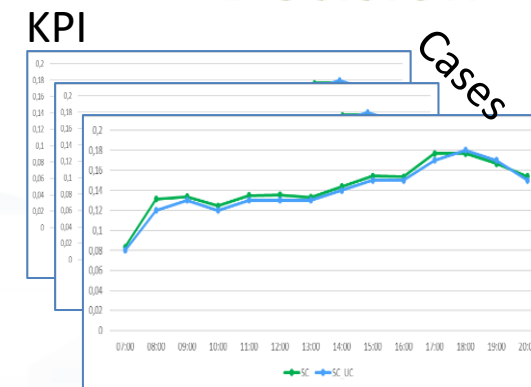
What-if: Simulation for Traffic Flow

At the same color corresponds the same area:

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



Data Driven Decision



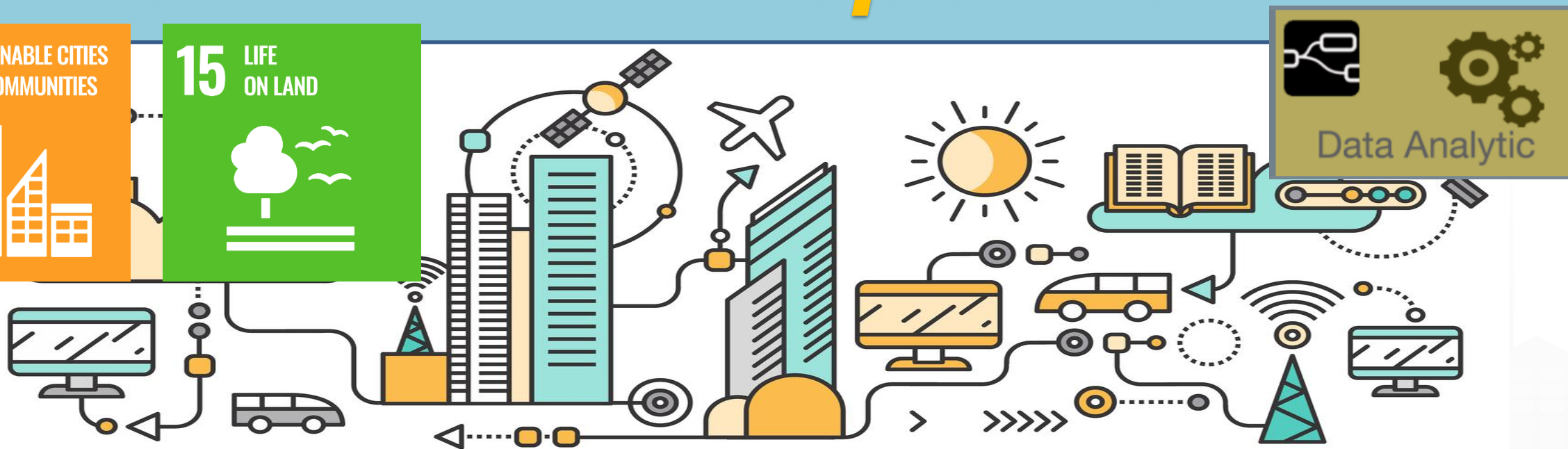
TOP

DORAM: Demand of Mobility vs Offer of Transportation

11 SUSTAINABLE CITIES
AND COMMUNITIES



15 LIFE
ON LAND





Analysis of

- **Demand of Mobility**

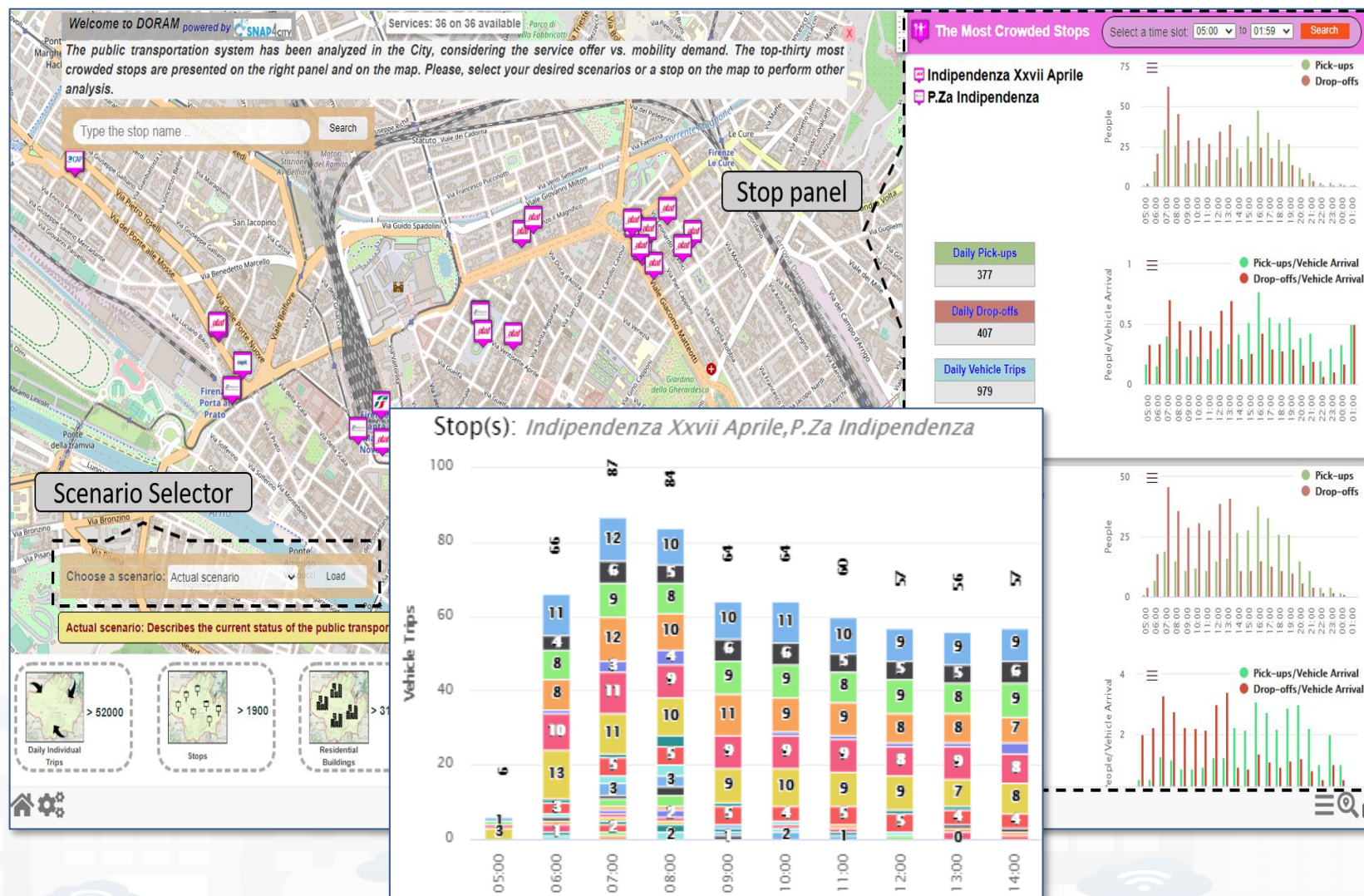
- Action Based
- Via OD matrices, several kinds
- POI, city structure, etc.

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>

Welcome to DORAM powered by SNAP4CITY

Services: 36 on 36 available

The public transportation system has been analyzed in the City, considering the service offer vs. mobility demand. The top-thirty most crowded stops are presented on the right panel and on the map. Please, select your desired scenarios or a stop on the map to perform other

Stop(s): Indipendenza Xxvii Aprile, P.Za Indipendenza

Hour	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00
Total	6	66	87	84	64	64	60	57	56	57	62	59	61	58

The Most Crowded Stops | Select a time slot: 05:00 to 01:59 | Search

Indipendenza Xxvii Aprile | **P.Za Indipendenza**

Daily Pick-ups: 377
Daily Drop-offs: 407

Vehicle Arrival

Pick-ups/Vehicle Arrival (green)
Drop-offs/Vehicle Arrival (red)

Scenario Selector

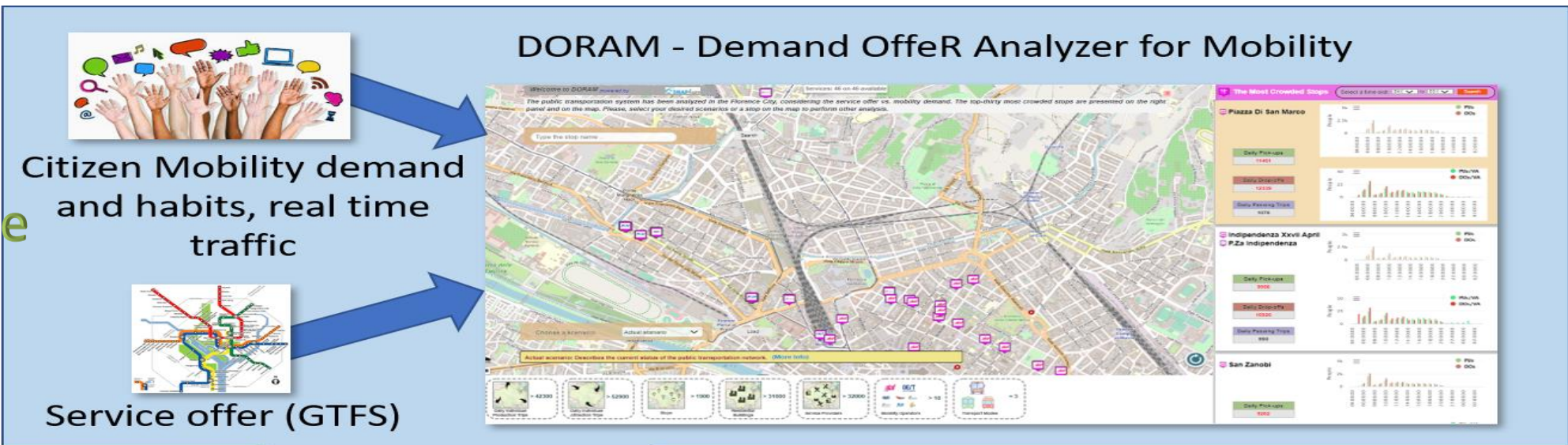
Choose a scenario: Actual scenario | Load

Actual scenario: Describes the current status of the public transportation network. (More Info)

- Daily Individual Trips: > 52000
- Stops: > 1900
- Residential Buildings: > 31000
- Service Providers: > 32000

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

Action based
using
Snap4City
Knowledge Base



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



City Mobility Operator(s)

analysis of the offer vs demand (DORAM)

GTFS variation to improve the efficiency of the service

Planned Bus/Tram/Train/ etc. stops/trips and timetables (GTFS)



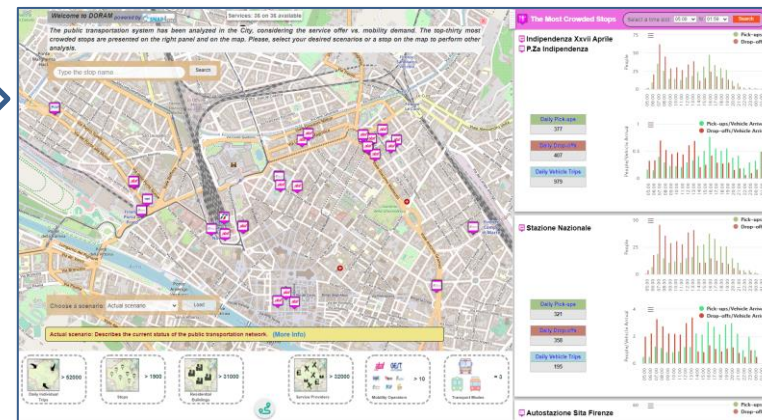
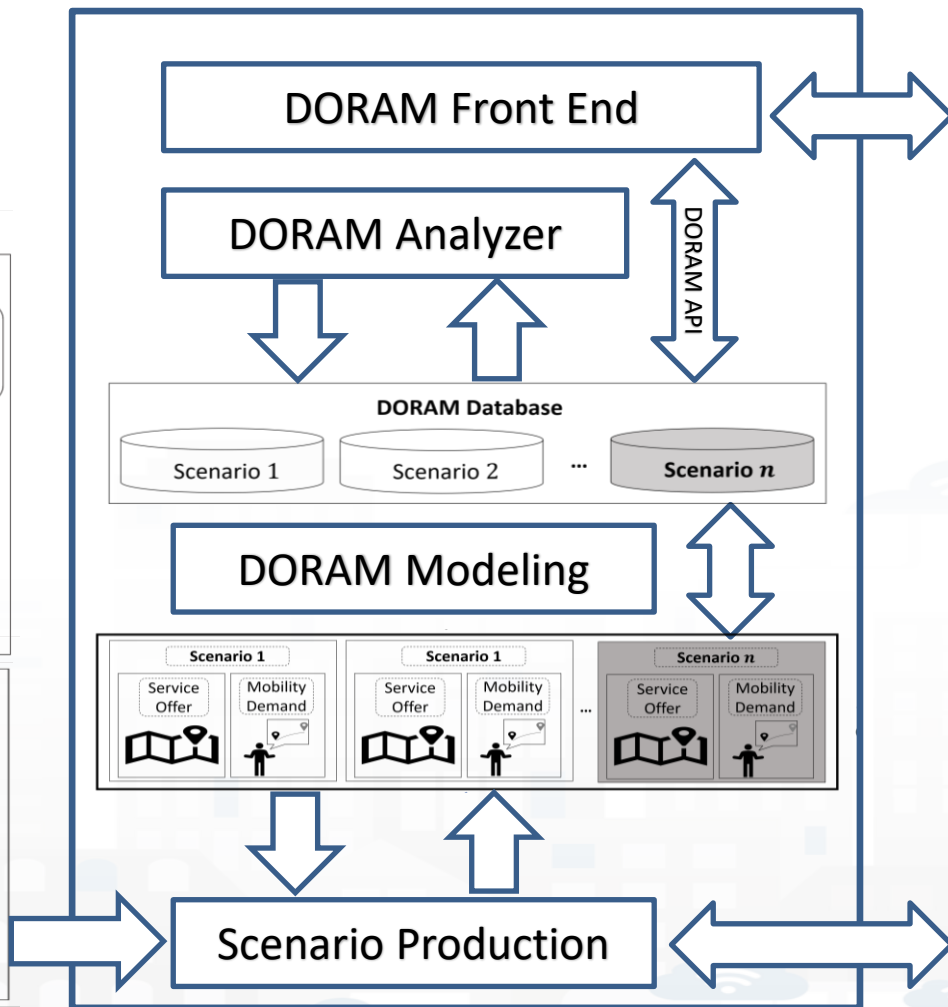
What can produce the Analysis tool by KPI

- 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>

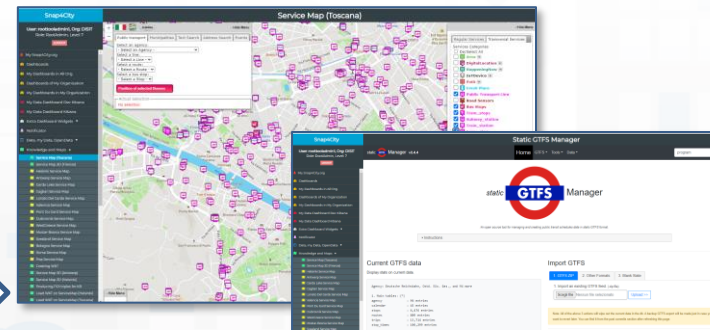


DORAM



DORAM tool

Snap4City tools for City data



GTFIS Editor and browser

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

Welcome to DORAM powered by SNAP4CITY

Services: 36 on 36 available

The public transportation system has been analyzed in the City, considering the service offer vs. mobility demand. The top-thirty most crowded stops are presented on the right panel and on the map. Please, select your desired scenarios or a stop on the map to perform other analysis.

Type the stop name .. Search

Stop panel

Scenario Selector

Choose a scenario: Actual scenario Load

Actual scenario: Describes the current status of the public transportation network. (More info)

Daily Individual Trips > 52000

Stops > 1900

Residential Buildings > 31000

Service Providers > 32000

Mobility Operators > 10

Transport Modes = 3

The Most Crowded Stops

Select a time slot: 05:00 to 01:59 Search

Indipendenza Xxvii Aprile
P.Za Indipendenza

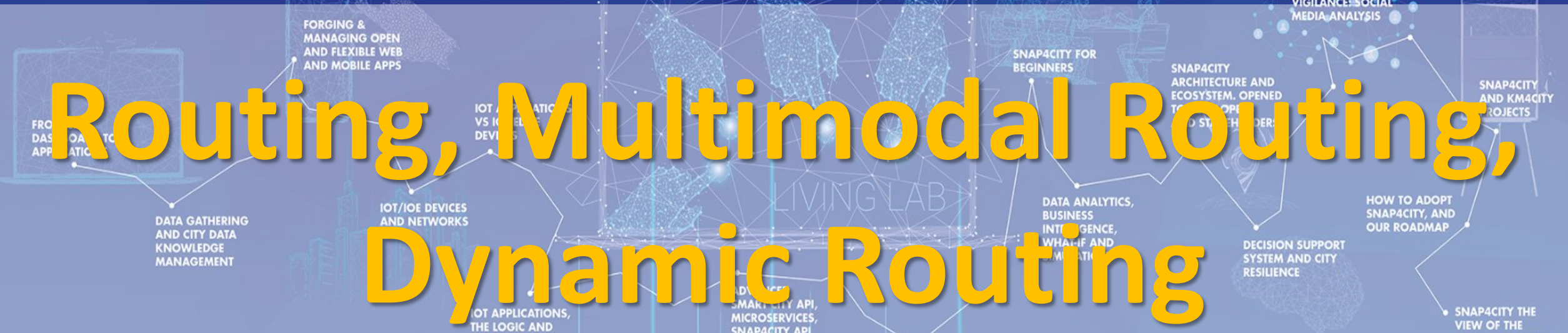
Stazione Nazionale

Daily Pick-ups: 377
Daily Drop-offs: 407
Daily Vehicle Trips: 979

Daily Pick-ups: 321
Daily Drop-offs: 358
Daily Vehicle Trips: 671

TOP

Routing, Multimodal Routing, Dynamic Routing



11 SUSTAINABLE CITIES AND COMMUNITIES

15 LIFE ON LAND

Data Analytic

Routing

- **Routing:** From XX to YY, Travel means:
 - private as cars, bike, pedestrian, public transport ..
 - Public: busses, tramway, train, etc.
- **Multimodal routing:** public travel means (busses, train, metro, etc.), pedestrian, etc.
- **2D and 3D routings**
- **Taking into account:**
 - Multiple intermediate points
 - Constraints/preferences:
 - size of roads, pollutant, traffic flow, obstacle/barriers, noise
 - Limitations on paths per travel means / vehicle kind
- **Dynamic Routing** enabling the addition of constraints on the user interface. For example: *barriers and/or selecting constraints*

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
- DISIT Lab portal

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](#)

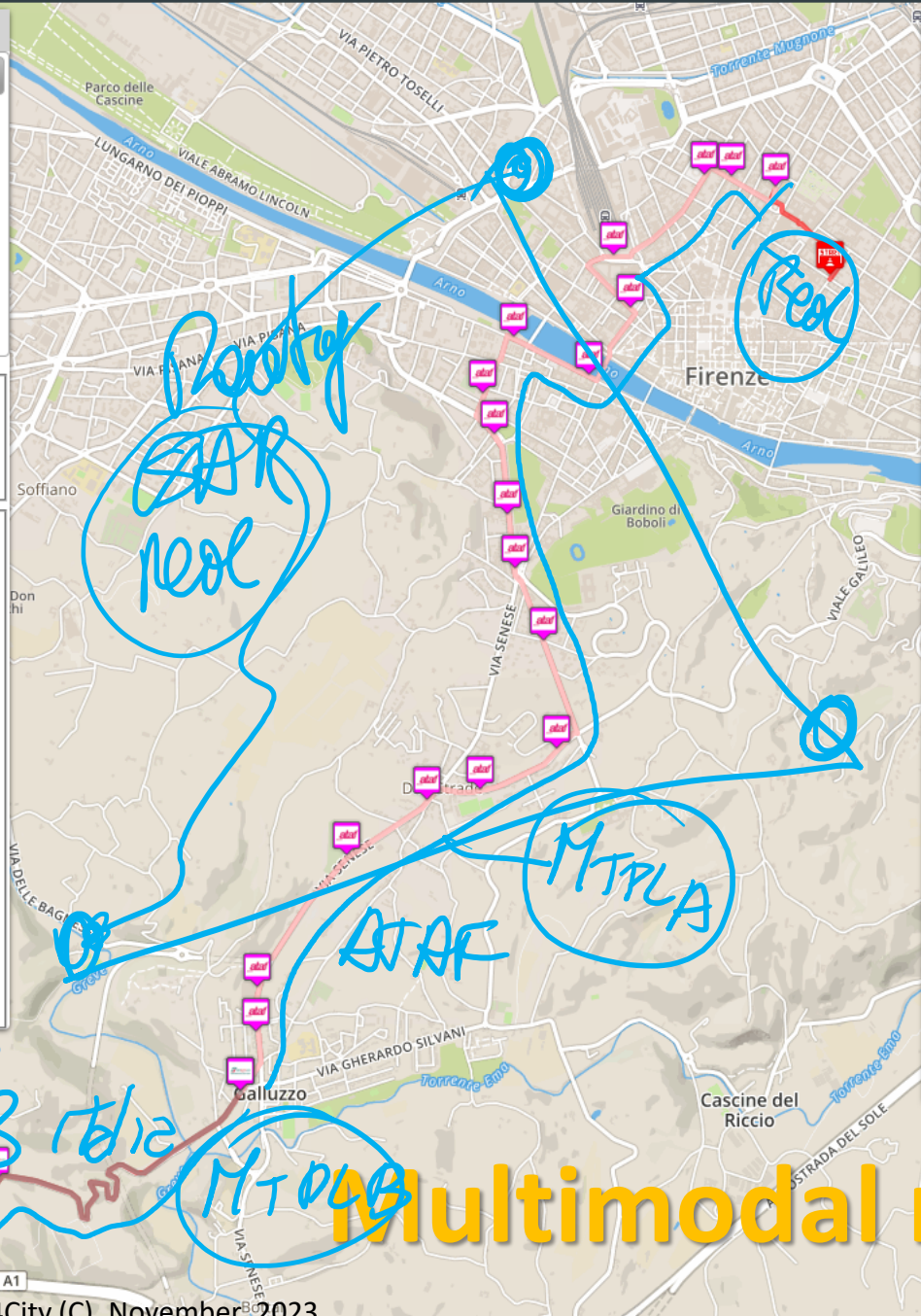
Path from here | Path to here | Search geometry

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)



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...

Multimodal routing



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

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: 43.7600,11.2420
Address: [VIA SENESE, 1, FIRENZE](#)

Path from here Path to here

Path
From: VIA SAN GALLO, 203, FIRENZE
To: VIA SENESE, 1, FIRENZE
Route via: public_transport
Start date&time: today now

Search Path

Length: 9637m arrival time:18:57:46 (00:36:40)

1. nd 121m (18:21:05)
2. Piazza della Libertà 137m (18:22:36)
3. Viale Don Minzoni 62m (18:24:21)
4. Via Leonardo da Vinci 9m (18:25:10)
5. 13 : Leonardo Da Vinci - Il David 5388m (18:30:00)
6. 13 : Il David - Petrarca 3772m (18:48:00)
7. Viale Francesco Petrarca 74m (18:56:00)
8. Piazzale di Porta Romana 42m (18:56:56)
9. Viale Niccolò Machiavelli 7m (18:57:26)
10. nd 19m (18:57:31)

03/11/2018 22:13

VIA GIANDOMENICO ROM
VIA DELLA TORRE DEL G/

Aggiungi Destinazione

Azzera Calcola

+ Percorso

VIA GIANDOMENICO ROMAGNOSI, 8 FIRENZE

Distanza: 10637m
Durata:00:57:41
Arrivo Previsto: 23:11:09

777m

20 : Romito Richa - Beslan T1 Fortezza
3 Fermate
22:28:00 - 22:33:00

13 : Beslan T1 Fortezza - Il David
18 Fermate
22:34:00 - 22:53:00

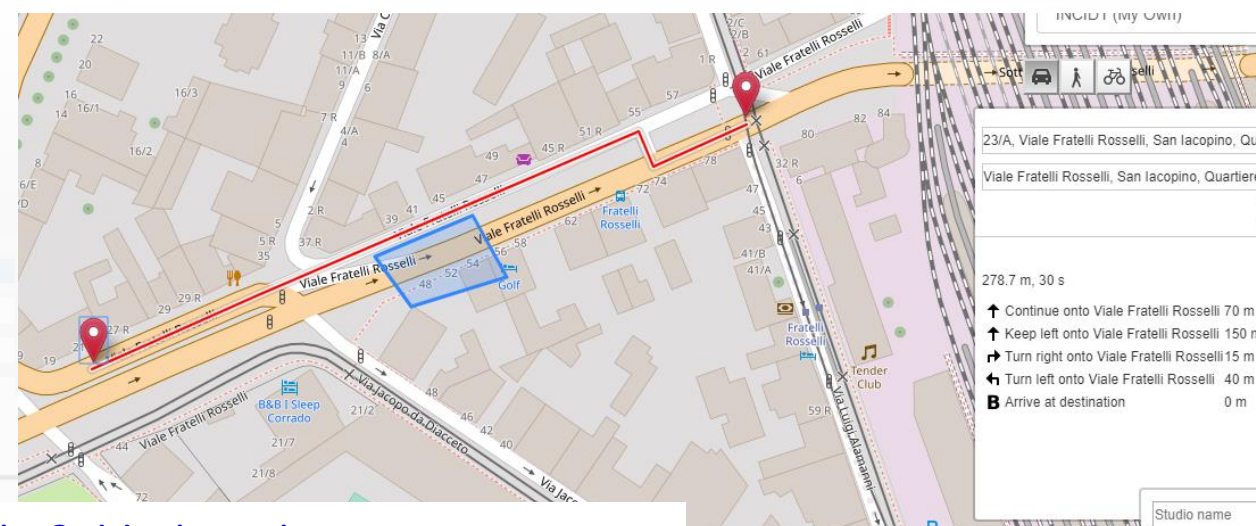
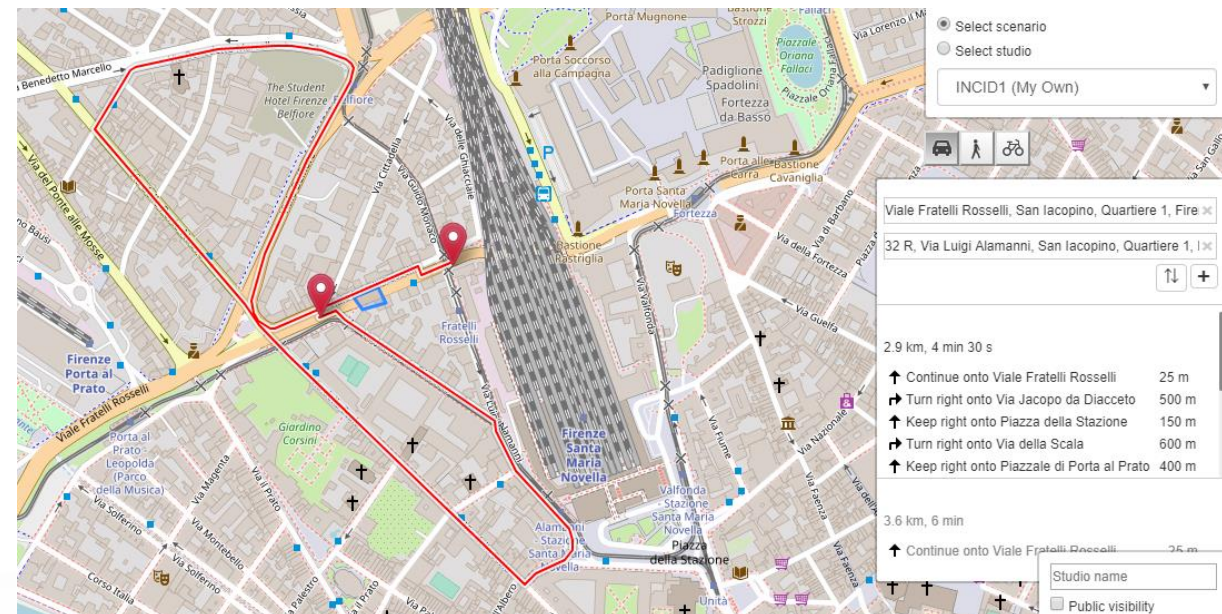
13 : Il David - Erta Canina
2 Fermate

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

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

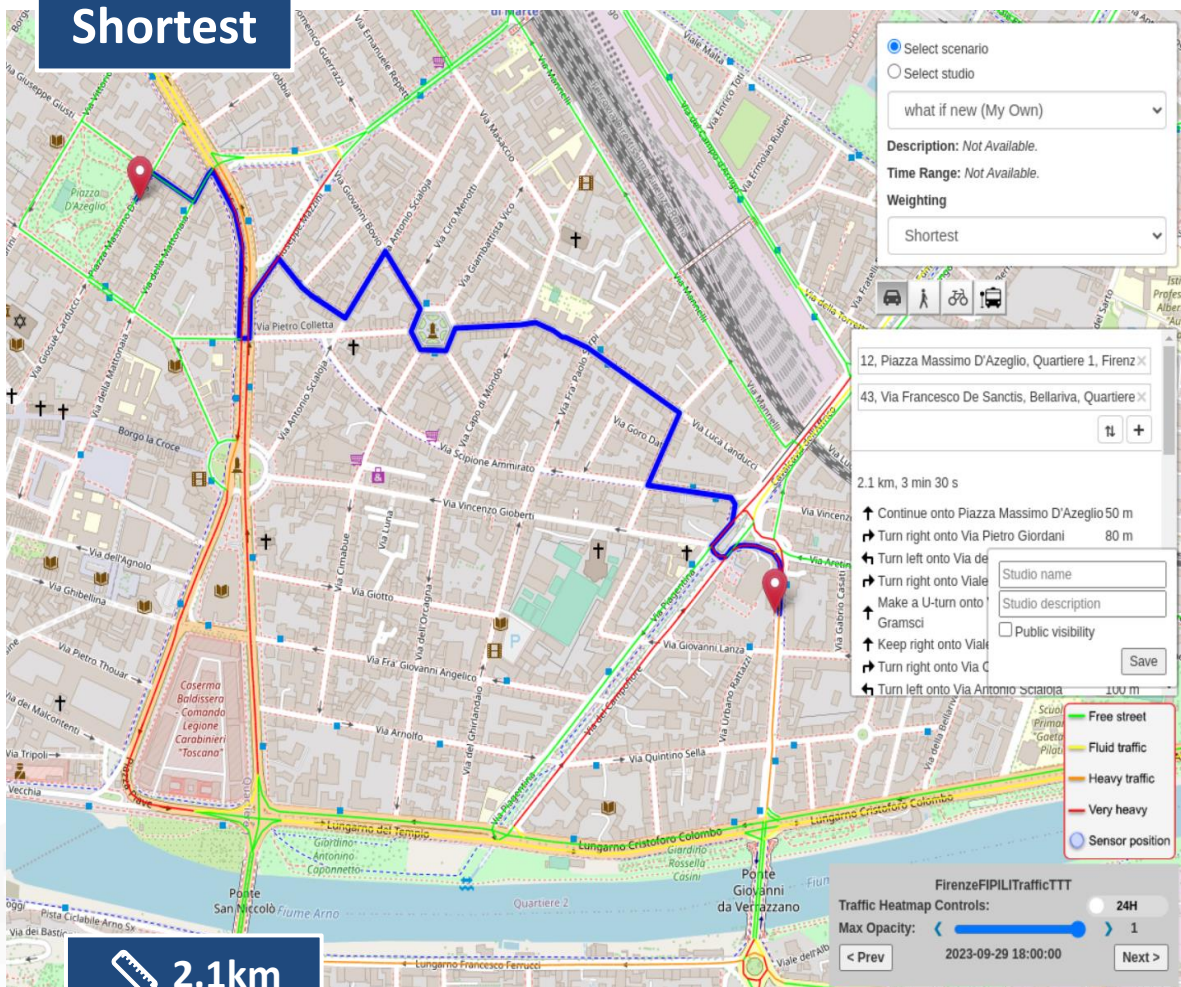
Assessment on the basis of changes:

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- Mobility Offer assessment

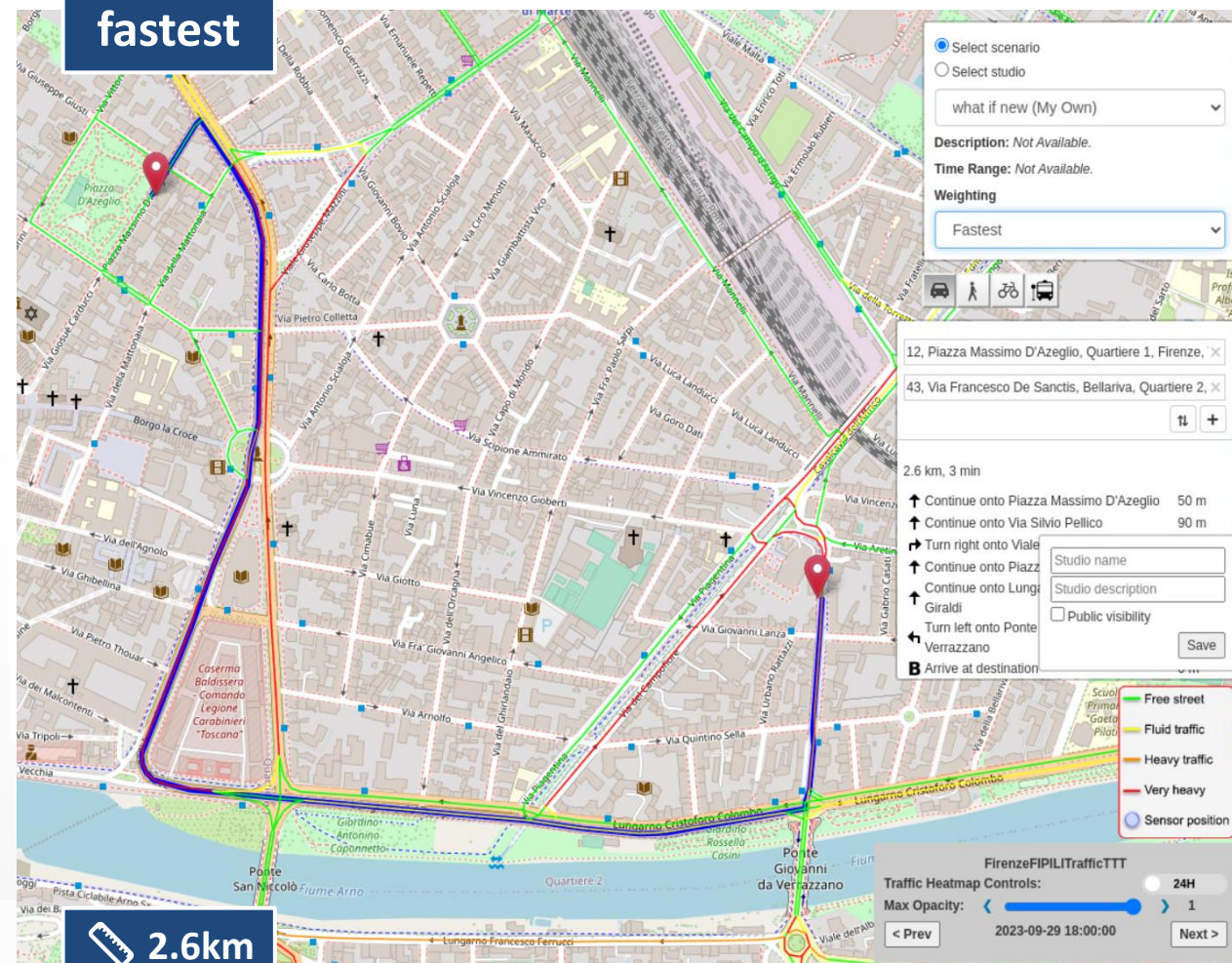


Constrained Dynamic Routing: Traffic Flow

Shortest

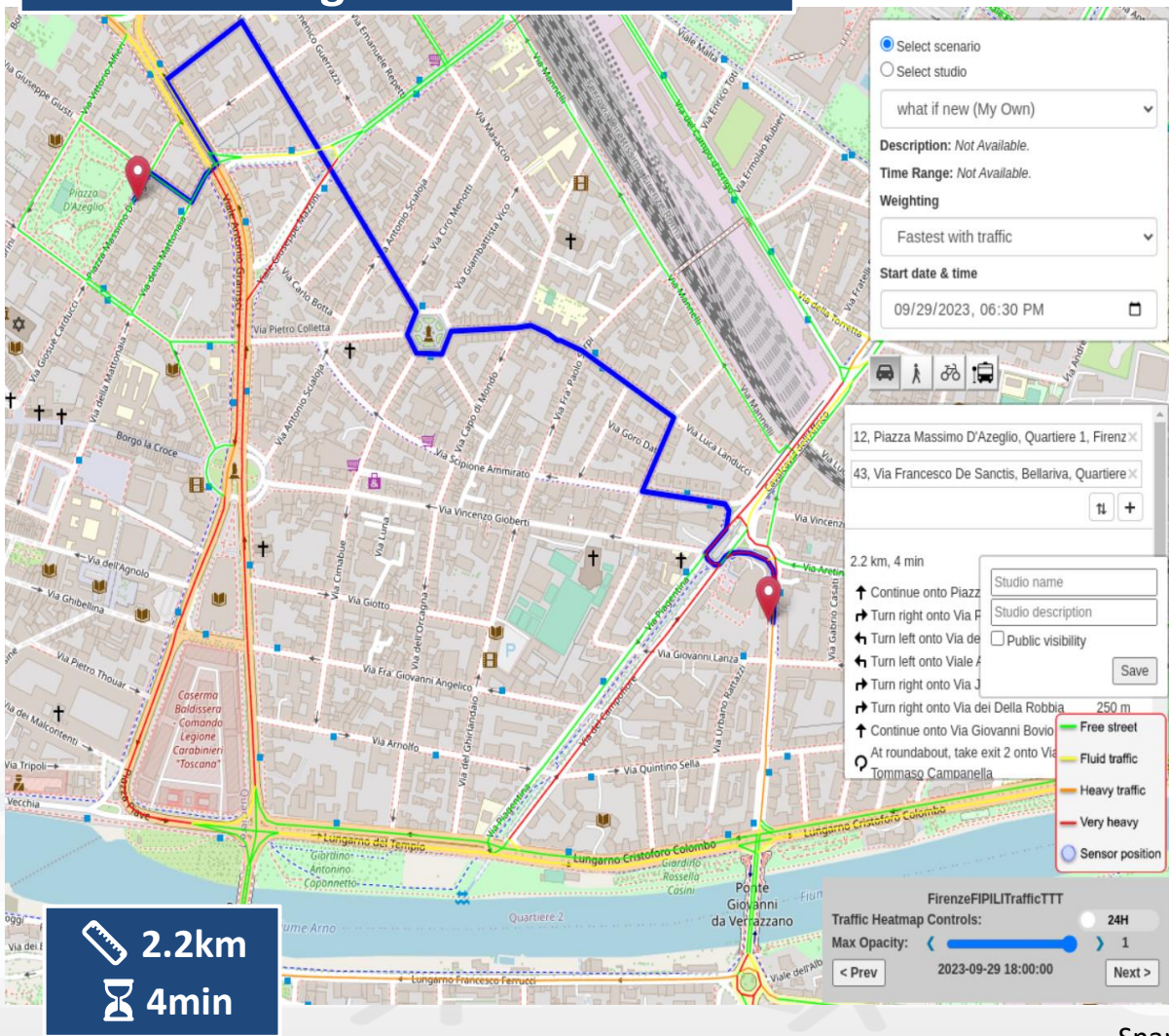


fastest

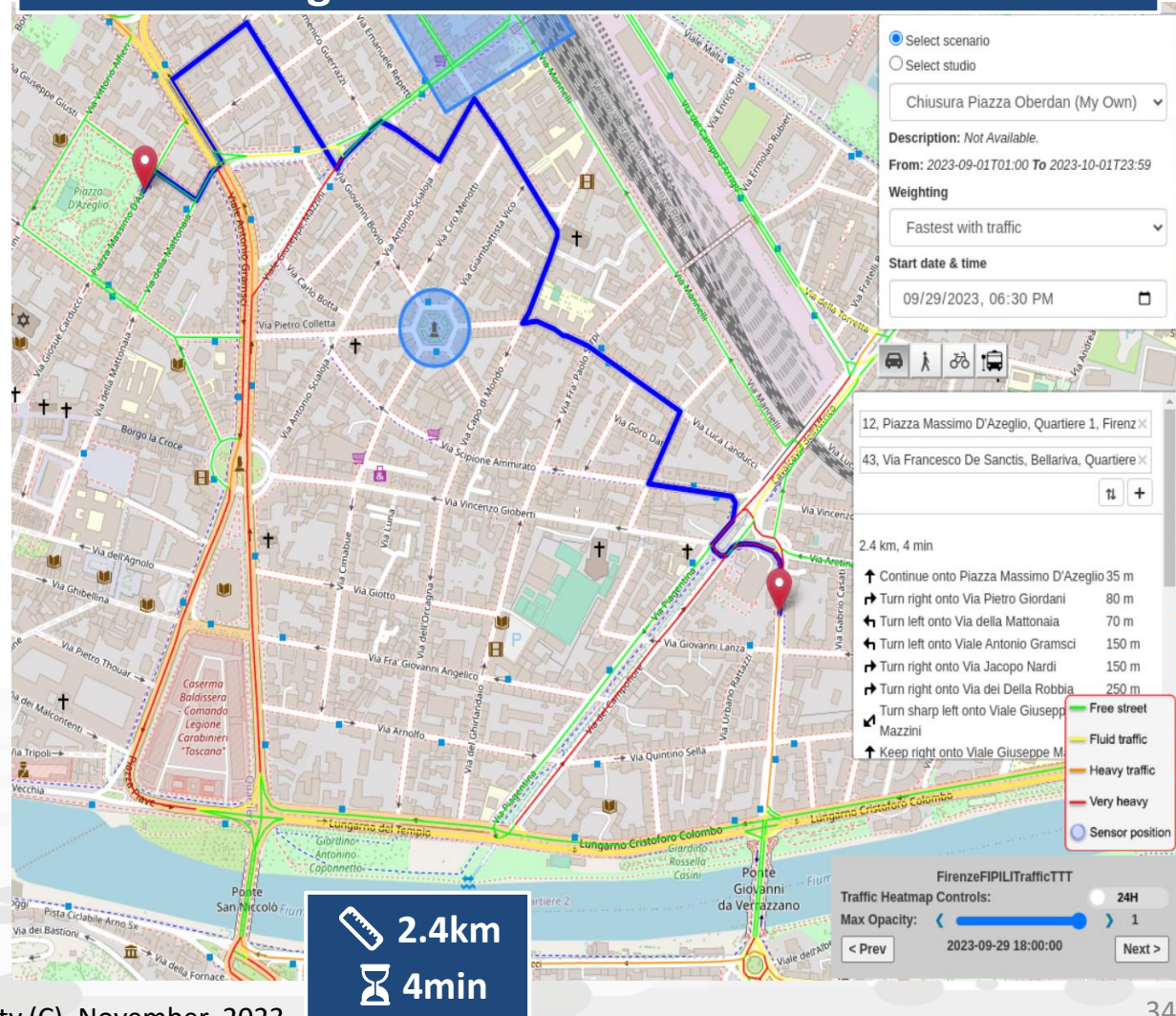


Constrained Dynamic Routing: Traffic Flow

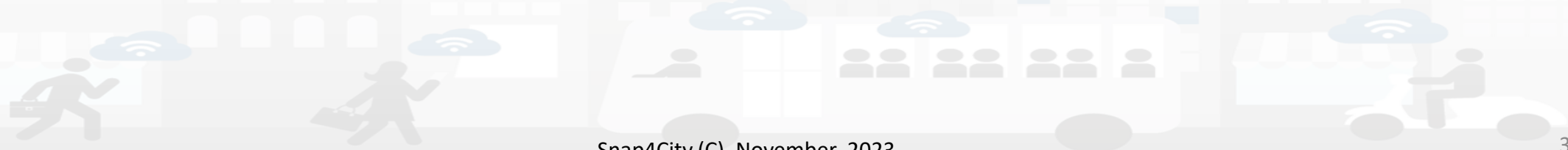
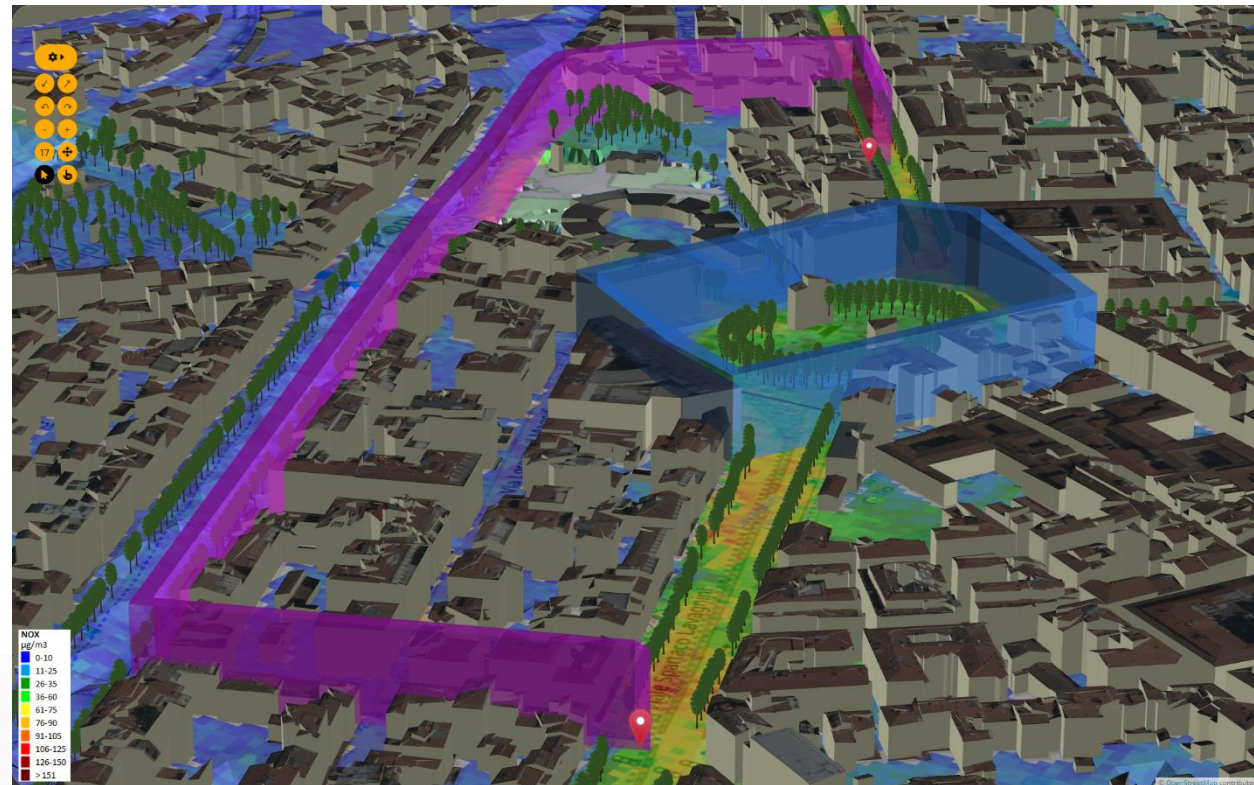
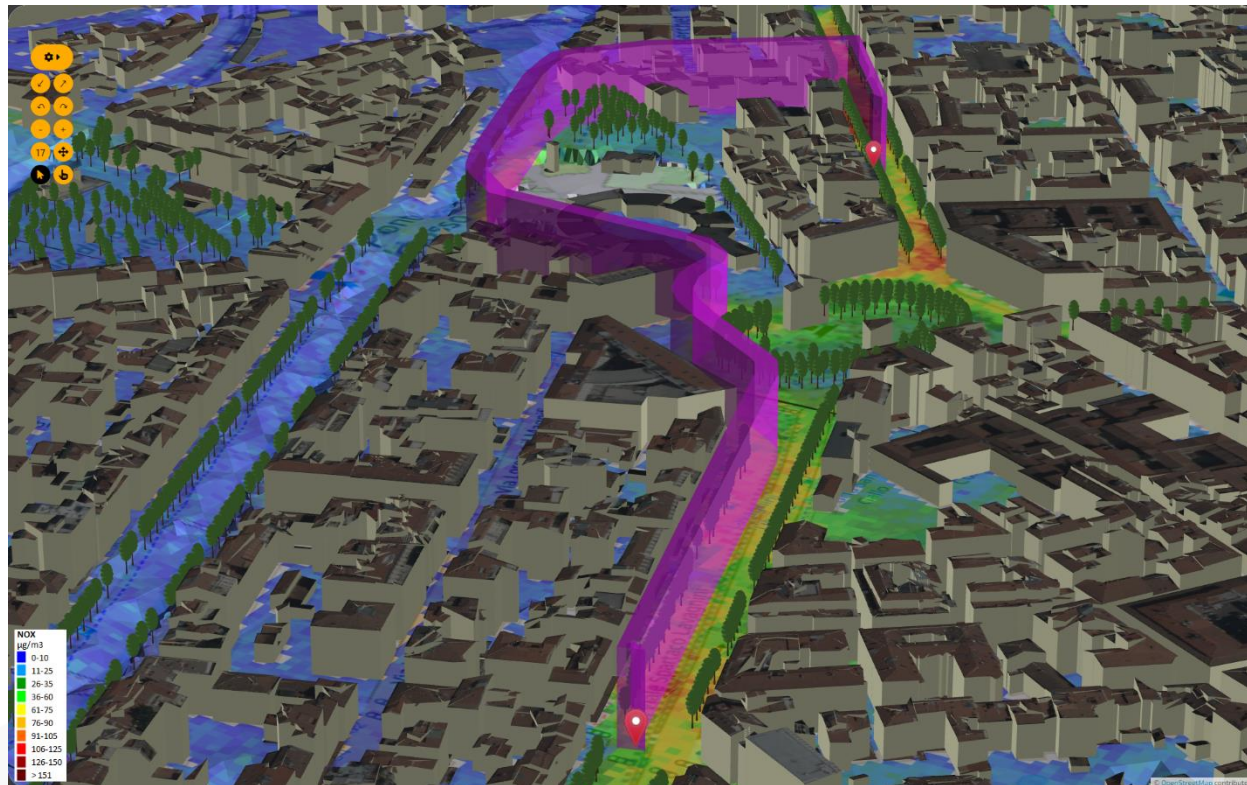
Fastest taking into account traffic



Fastest taking into account traffic and blocked areas



Dyamic Routing in 3D space



TOP

Predictive Maintenance

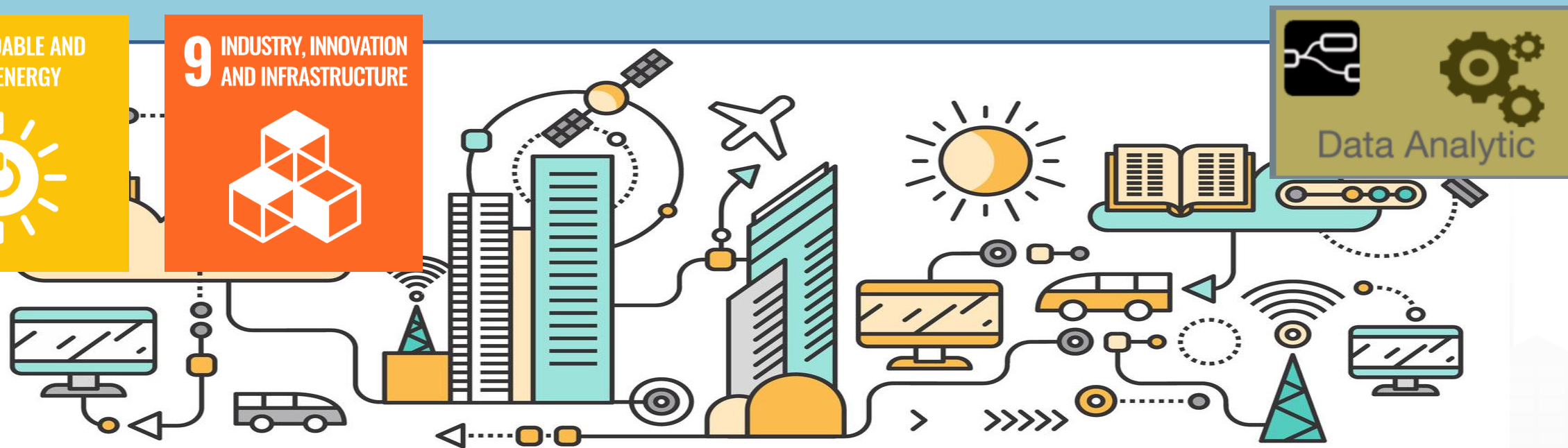


Predictive Maintenance

7 AFFORDABLE AND
CLEAN ENERGY



9 INDUSTRY, INNOVATION
AND INFRASTRUCTURE



- **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 relationships

- **Elements:**

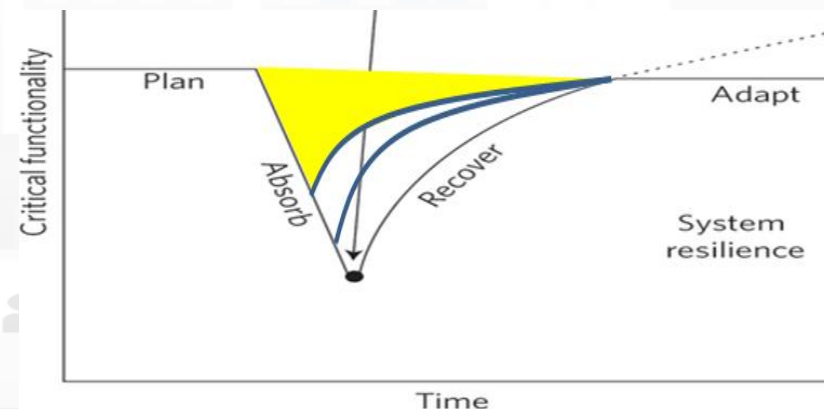
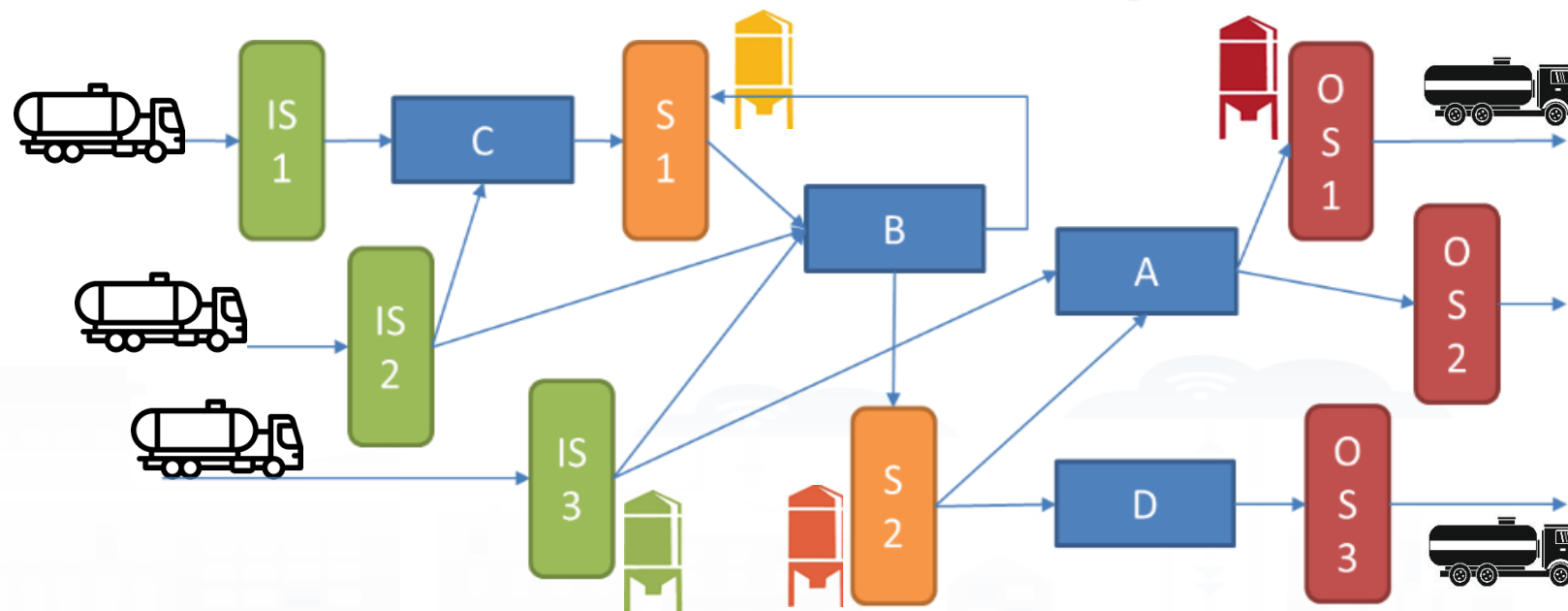
- Machines: A...C
- Storage: silos...
- Flows:...

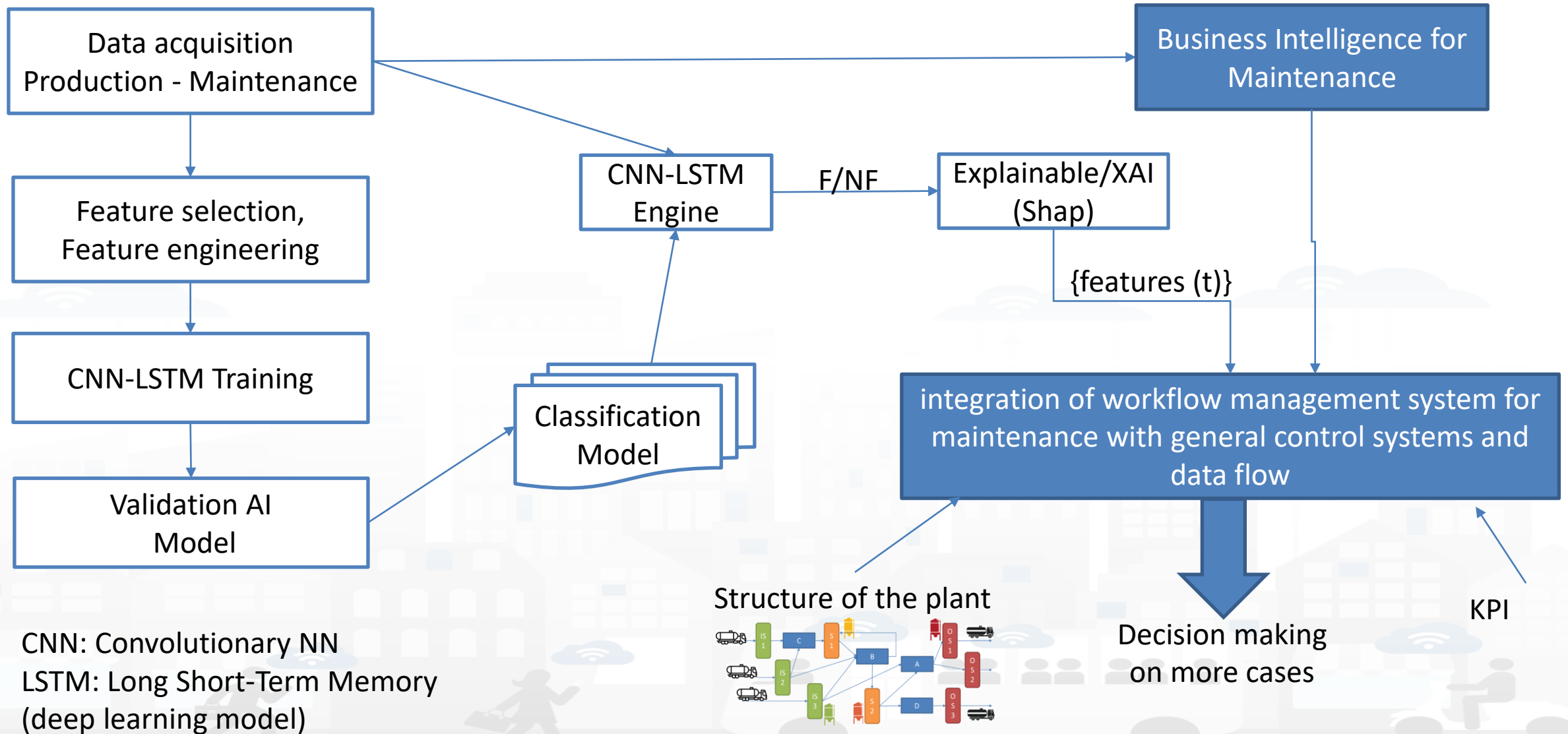
- **Dependencies**

- Cascade effects

- **Early warning**

- Reduction of costs
- Recovering from failure is more expensive than correcting in advance
- Possible advanced replan and reschedule: secondary solutions





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

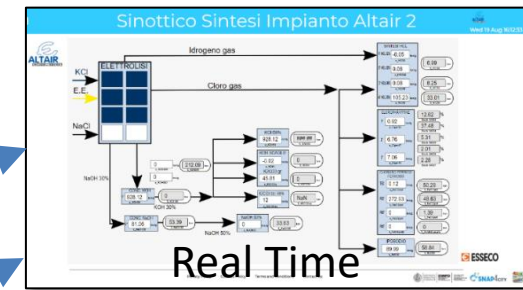
Solution



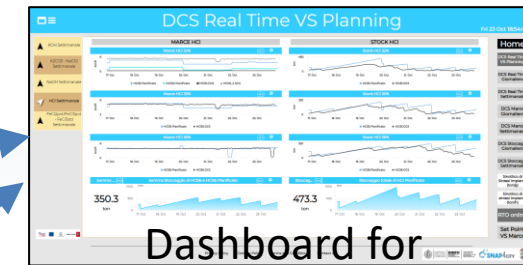
Plant
Status



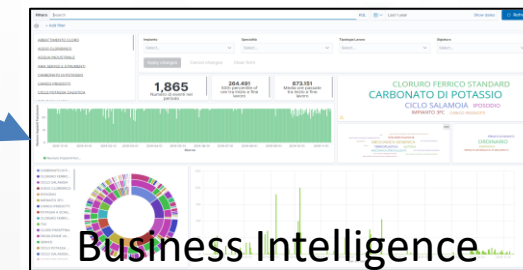
Control
Supervisor



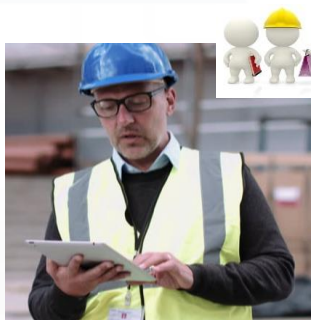
Production Synoptic



Dashboard for
Production Control



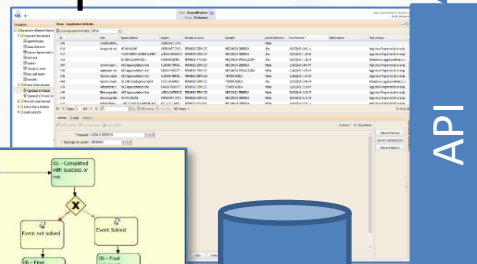
Business Intelligence
Maintenance



Business Logic

IoT App

OpenMaint



Data
Storage

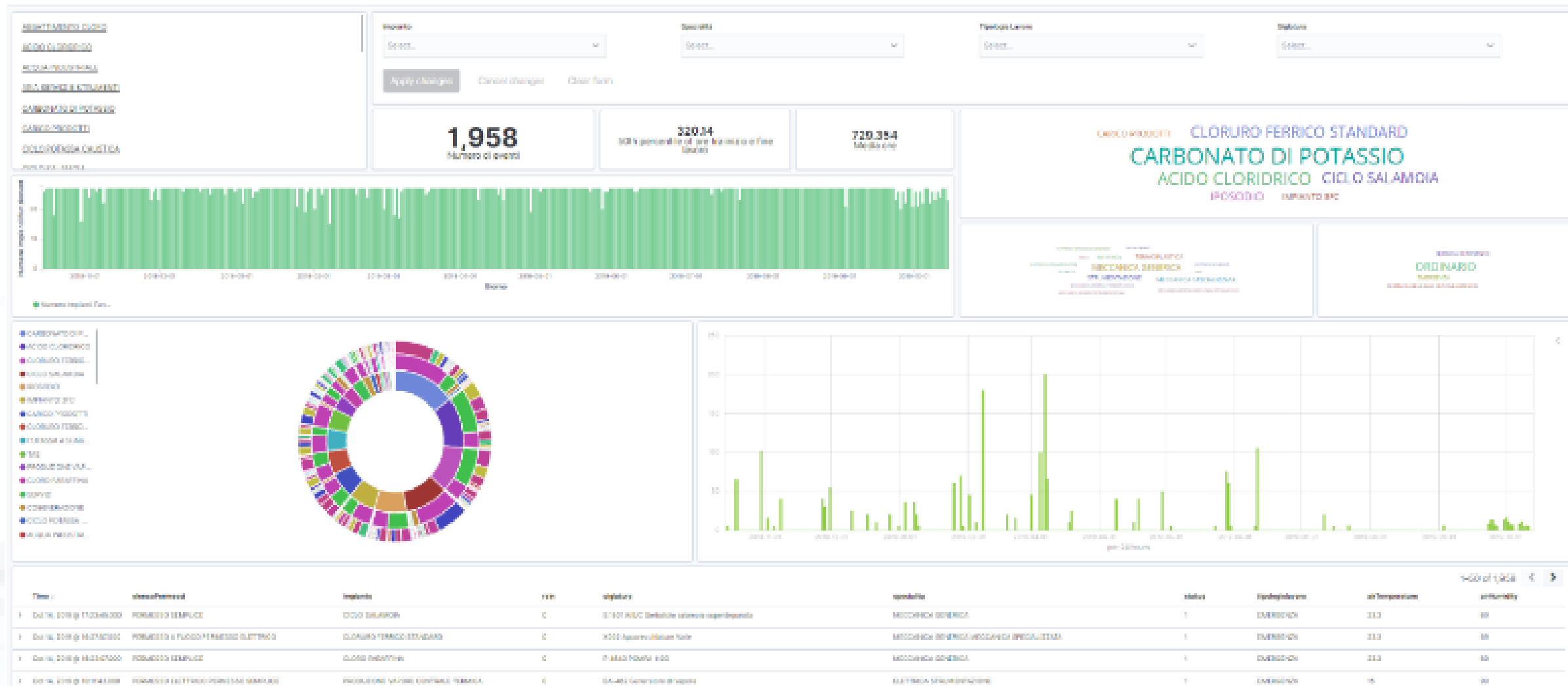
Elastic
Search

Business
Logic 2

Predictive
Maintenance

Predictive
Training

Business Intelligence



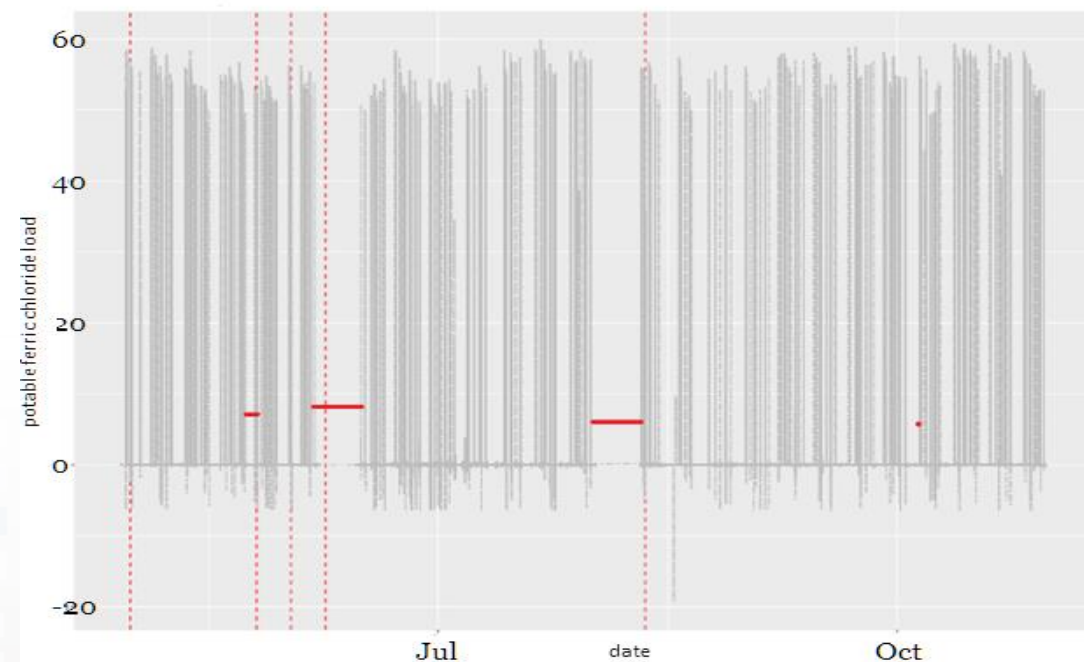
Production:

- 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

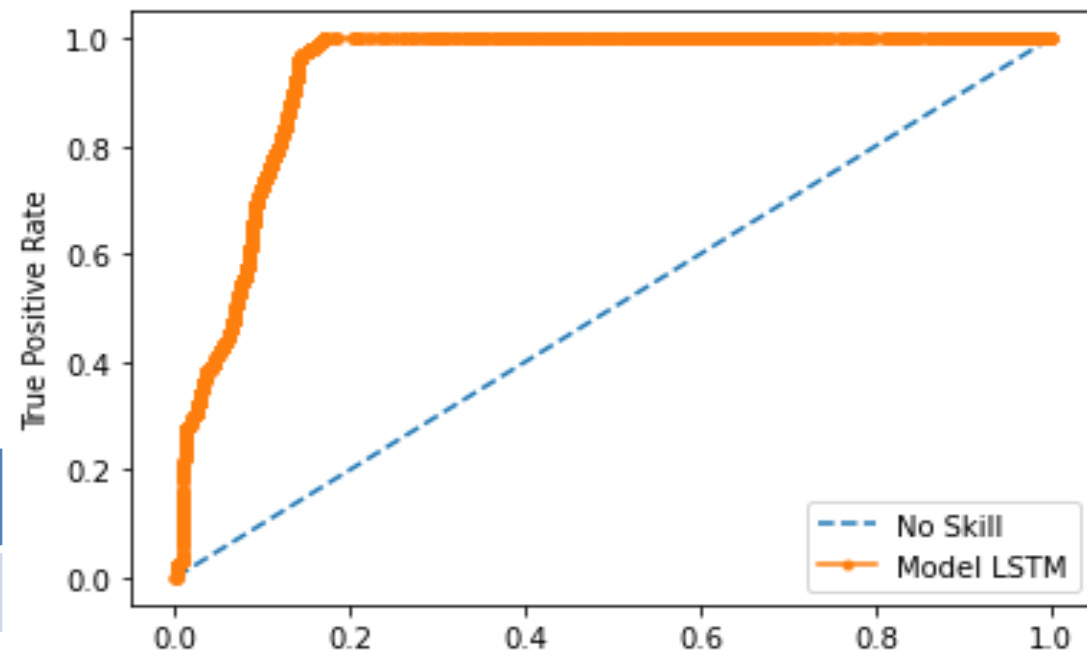


Overview Features

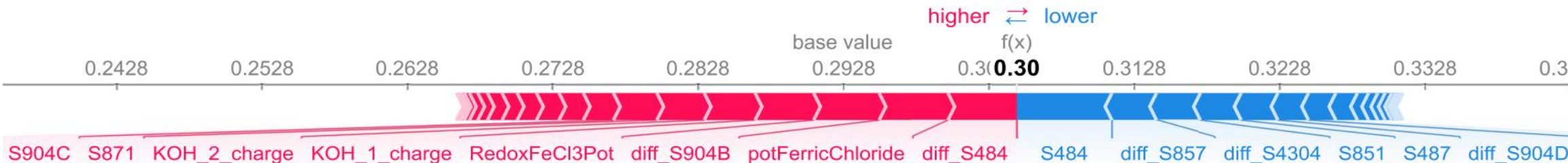
Feature	Plant	Description	Unit of measure
TempreatoreR4001 - TempreatoreR4002 - TempreactorR4003	chlorine paraffins (CPS)	reactor temperature indication	°C
S904A - S904B - S904C	Potable Ferric std	Storage level indication	%
S4304	chlorine paraffins (CPS)	Storage level indication	%
standardFerric Chloride	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

Predictive 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

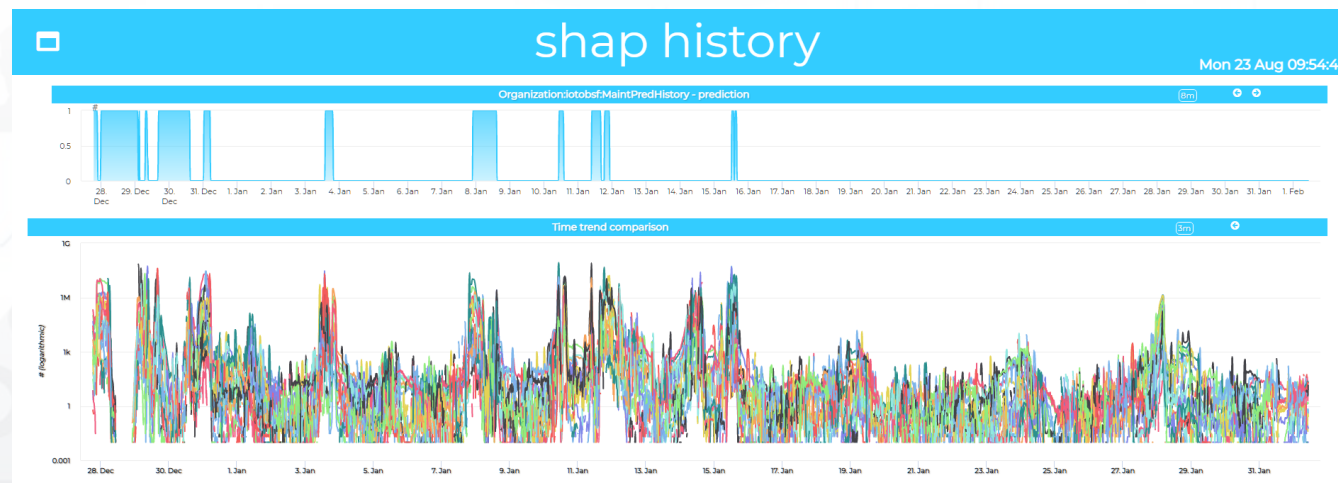


Explainable/XAI - CNN-LSTM (SHAP)

Explanation of prediction generated by model for fault



Explanation of prediction generated by model for normality



Digital Twin Local, 3D vs Real Time Data



UNIVERSITÀ
DEGLI STUDI
FIRENZE

DINFO
DIPARTIMENTO DI
INGEGNERIA
DELL'INFORMAZIONE

DISIT
DISTRIBUTED SYSTEMS
AND INTERNET
TECHNOLOGIES LAB

Tue 8 Jun 11:04:55

BIM Integration for Digital Twin

device list

Valve 786 with trend ▾

Selector - Map

BIM view

CORPISA

VALUE NAME: CORPISA

	DETAILS	DESCRIPTION	RT DATA			
1-0000Z	Last value	Last 4 hours	Last 24 hours	Last 7 days	Last 30 days	Last 6 months
	Last value	Last 4 hours	Last 24 hours	Last 7 days	Last 30 days	Last 6 months
	Last value	Last 4 hours	Last 24 hours	Last 7 days	Last 30 days	Last 6 months

Last Value | Time Trend Chart: totale_casi - 6 months

base value $f(x)$

0.8809 0.8814 0.8819 0.8824 0.8829 0.8834 0.8839 0.8844 0.8849 0.8854 **0.89** 0.8859 0.8864

higher ↔ lower

S4304 S871 S854 RedoxFeCl3Pot diff_S904B diff_S854 S484 S851



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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.

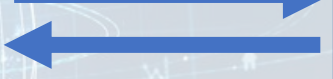
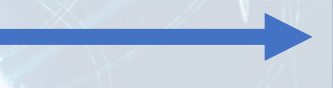
(ENhanced **TE**chnological **R**&D of new **PR**oducts and Processes for Innovation, Smart factory and green **E**conomy)



Administrative Data from AS400

Real Time Data, Historical, Events from DCS

Unique National Energy Costs (PUN)



**Big Data Analytics
Artificial Intelligence
Engine**



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

SNAP4 GeNotiLab

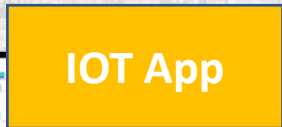
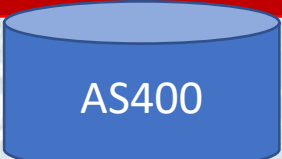


GeNotiLab Architecture for ALTAIR



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

Sample ID	Parameter	Value	Unit	Status
ALTAIR-001	Moisture	12.5	%	OK
ALTAIR-002	Moisture	15.2	%	Warning
ALTAIR-003	Moisture	18.7	%	Alert
ALTAIR-004	Moisture	21.3	%	Alert
ALTAIR-005	Moisture	24.8	%	Alert



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



What you can find in the former course

FROM CITY DASHBOARD TO APPLICATIONS

DATA GATHERING AND CITY DATA KNOWLEDGE MANAGEMENT

FORGING & MANAGING OPEN AND FLEXIBLE WEB AND MOBILE APPS

IOT APPLICATIONS FROM EDGE TO CLOUD

IOT/IOE DEVICES AND NETWORKS

IOT APPLICATIONS, THE LOGIC AND THE SMARTNESS

ADVANCED SMART CITY API, MICROSERVICES, SNAP4CITY API

SNAP4CITY LIVING LAB FOR COLLABORATIVE WORK

SNAP4CITY FOR BEGINNERS

DATA ANALYTICS, BUSINESS INTELLIGENCE, WHAT IS AND IS NOT IM

SNAP4CITY ARCHITECTURE AND Ecosystem. OPENED TO DEVELOPERS AND SOLUTION BUILDERS

TWITTER VIGILANCE: SOCIAL MEDIA ANALYSIS

DECISION SUPPORT SYSTEM AND CITY RESILIENCE

HOW TO ADOPT SNAP4CITY, AND OUR ROADMAP

SNAP4CITY AND KM4CITY PROJECTS

SNAP4CITY THE VIEW OF THE ADMINISTRATORS



In addition in the former course you can find:

- Detecting and Counting People <https://www.snap4city.org/577>
- 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/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

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								



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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>

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Username: paolo.disit

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 !

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Innovations



Interoperability



Installations



What People say



Mobile Apps



IOT Devices



IOT Applications



Data Analytics



Dashboards



Living Lab



Smart City API



Smart City Ontology



Work with Us



Articles



SNAP4CITY on EUROPEAN OPEN SCIENCE CLOUD MARKETPLACE



SNAP4CITY HACKATHON



INDUSTRY 4.0 Snap4Industry



Snap4Home

- 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](#)

Search

Training on Tools and PlatformPowered by www.km4city.org

Organization Groups

DISIT

- Developer
- Operativo

Updates on Tools

Training Course Snap4City - 2023 Edition [new](#)
drupaladminSnap4City 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



Home / Snap4City: Smart aNalytic APp builder for sentient Cities and IOT

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Snap4City: Smart aNalytic APp builder for sentient Cities and IOT

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FIWARE

Sii-Mobility

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- TECHNICAL OVERVIEW: <https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf>
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- Booklet Data Analytics, Snap4Solutions: https://www.snap4city.org/download/video/DBL_SNAP4SOLU.pdf

2023 booklets



- Smart City



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

- Industry



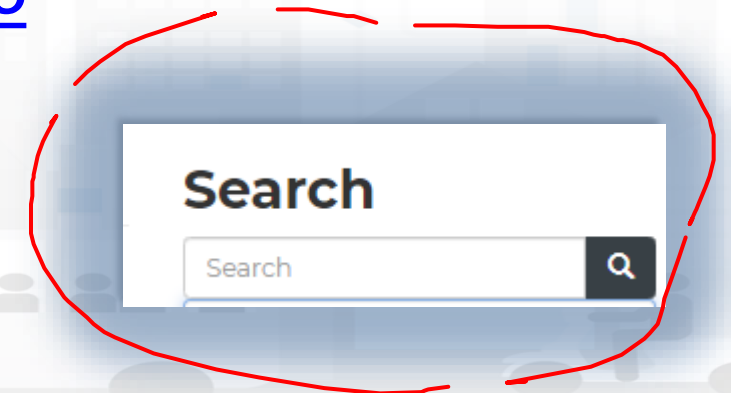
https://www.snap4city.org/download/video/DPL_SNAP4INDUSTRY.pdf

- Artificial Intelligence



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

- **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>
- **Scenariious:** <https://www.snap4city.org/4>
- **Publications:** <https://www.snap4city.org/426>
- **WEB pages:** <https://www.snap4city.org/78>
- ***SEARCH on the right side***



Tech. Overview

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



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

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

Development

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



Development Life-Cycle

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

From Snap4City:

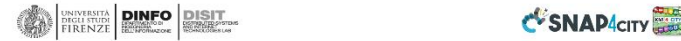
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- <https://www.snap4city.org>
- <https://www.snap4solutions.org>
- <https://www.snap4industry.org>
- <https://twitter.com/snap4city>
- <https://www.facebook.com/snap4city>
- <https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandg>

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

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

Client Side Business Logic

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



Client-Side Business Logic Widget Manual

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- 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/UC3tAQ09EbNba8f2-u4vandu>

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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



Commercial Overview



- <https://fiware-foundation.medium.com/snap4-city-fiware-powered-smart-app-builder-for-sentient-cities-acfe24df49d5>
- https://www.snap4city.org/drupal/sites/default/files/files/FF_ImpactStories_Snap4City.pdf

FIWARE
Open APIs for Open Minds

**FIWARE
IMPACT
STORIES**

SMART CITIES AND SMART INDUSTRY

Snap4City:
**FIWARE powered smart app
builder for sentient cities**

With the contribution of

TOP

FORGING & MANAGING OPEN AND FLEXIBLE WEB AND MOBILE APPS

FROM CITY DASHBOARD TO APPLICATIONS

DATA GATHERING AND CITY DATA KNOWLEDGE MANAGEMENT

IOT APPLICATIONS VS IOT EDGE DEVICES

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WHAT-IF AND SIMULATION

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DECISION SUPPORT SYSTEM AND CITY RESILIENCE

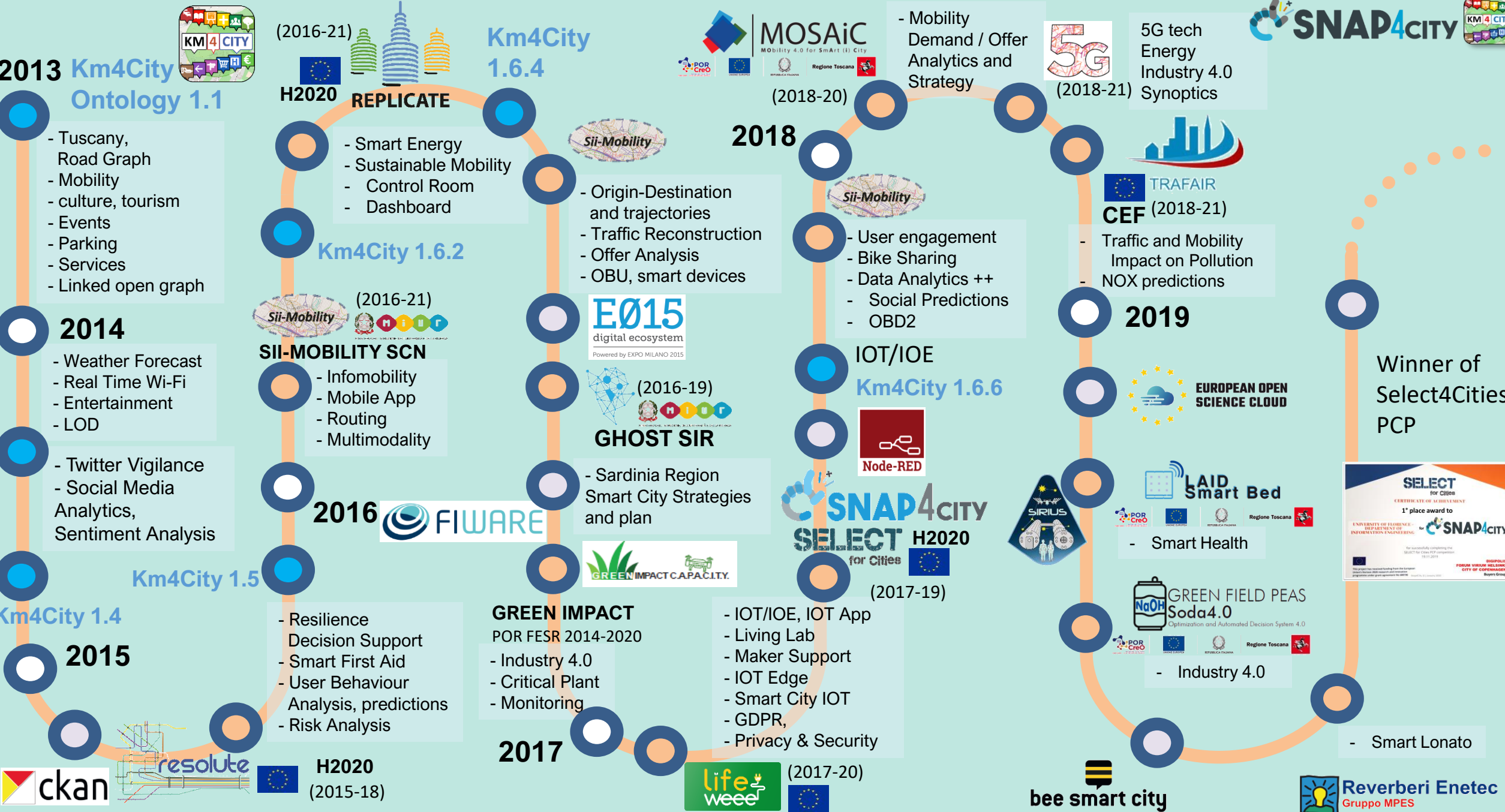
HOW TO ADOPT SNAP4CITY, AND OUR ROADMAP

SNAP4CITY AND KM4CITY PROJECTS

SNAP4CITY THE VIEW OF THE ADMINISTRATORS

Acknowledgements





2013 Km4City Ontology 1.1

- Tuscany, Road Graph
- Mobility
- culture, tourism
- Events
- Parking
- Services
- Linked open graph

2014

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

- Twitter Vigilance
- Social Media Analytics, Sentiment Analysis

Km4City 1.4

2015

- Resilience Decision Support
- Smart First Aid
- User Behaviour Analysis, predictions
- Risk Analysis

ckan, resolute, H2020 (2015-18)

DISIT lab roadmap vs model and tools' usage

(2016-21) H2020 REPLICATE

- Smart Energy
- Sustainable Mobility
- Control Room
- Dashboard

Km4City 1.6.2

(2016-21) SII-MOBILITY SCN

- Infomobility
- Mobile App
- Routing
- Multimodality

2016 FIWARE

Km4City 1.5

- Resilience Decision Support
- Smart First Aid
- User Behaviour Analysis, predictions
- Risk Analysis

H2020 (2015-18)

Km4City 1.6.4

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

E015 digital ecosystem

(2016-19) GHOST SIR

- Sardinia Region Smart City Strategies and plan

GREEN IMPACT CAPACITY

GREEN IMPACT POR FESR 2014-2020

- Industry 4.0
- Critical Plant
- Monitoring

2017

life weee (2017-20)

- Smart Waste

MOSAiC Mobility 4.0 for Smart (II) City (2018-20)

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

IOT/IOE Km4City 1.6.6

Node-RED

SNAP4CITY SELECT for Cities H2020 (2017-19)

- IOT/IOE, IOT App
- Living Lab
- Maker Support
- IOT Edge
- Smart City IOT
- GDPR, Privacy & Security

bee smart city

5G tech Energy Industry 4.0 Synoptics (2018-21)

- Traffic and Mobility Impact on Pollution
- NOX predictions

2019

EUROPEAN OPEN SCIENCE CLOUD

LAI Smart Bed

- Smart Health

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

- Industry 4.0

Smart Lonato

Reverberi Enetec Gruppo MPES

SNAP4CITY

- Winner of Select4Cities PCP

2019

SELECT for Cities 1st place award to SNAP4CITY

UNIVERSITY OF FERUGINE DEPARTMENT OF INFORMATION ENGINEERING

FORUM VIRIDIS BELGIUM CITY OF COPENHAGEN

Smart Lonato

Reverberi Enetec Gruppo MPES



2020

- Sii-Mobility
- JRC EUROPEAN COMMISSION
- Interreg Mediterranean
- HERIT-DATA
- Smart Tourism
- 6 Pilots
- Data Analytics
- Extended platform
- Interreg MARITTIMO-IT FR-MARITIME
- MOBI MART
- Smart Mobility
- PISA, PUMS
- Living lab

Smart Ambulance (2021-22)



enel x
Contract



2021

PC4City (2020-21)
Monitoring Terrain

Winner of Open Data Challenge of
enel x

CAPÉLON
- Smart Light
- Sweden

Km4City 1.6.7

Enterprise (2021-22)
Industry 4.0

Almafluida
Industry 4.0 (2021-22)

AMPERE (2021-22)
Industry 4.0

SYN-RG-AI
SmartCity

GRUPPO PRETTO
Industry 4.0

uni.systems
SmartCity, 2021-23

AXIS COMMUNICATIONS

AXIS collab
SmartCity

2022

ASYMMETRICA
URBAN TECHNOLOGY

Asymmetrica
Smart City, 2022-23

ITALFERR
GRUPPO FERROVIE DELLO STATO ITALIANE

Italferr, Smart City



Contract, 2022-23

2023

ART-ER
ATTRATTIVITÀ
RICERCA
TERRITORIO
Contract, 2022-23

Filippi
2022-2023

enel x
Contract

IMPETUS
Security and Risk

Smarteia

CN MOST, 2022-26

EI THE, 2022-26

G. Agile, 2021-23

TUSCANY X.O **EDIH**
2023-26

Merano, smart light

OceanRace,
Genova, AWS

Cuneo, smart city

AMMIRARE
 Interreg
MARITTIMO-IT FR-MARITIME

TOP



Be smart in a SNAP!



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www.snap4city.org


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