Paolo Nesi
Paolo.nesi@unifi.it

https://www.disit.org
https://www.Snap4city.org
https://www.Snap4Industry.org

Intelligenza Artificiale (IA) e Machine Learning:

- algoritmi per computare
  - predizioni, classificazioni, riconoscimento di pattern, pattern
- X prendere decisioni e migliorare le operazioni e pianificazione.
- Fornire
  - Suggestion
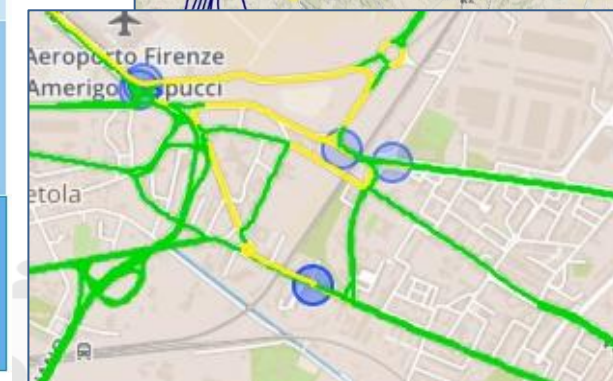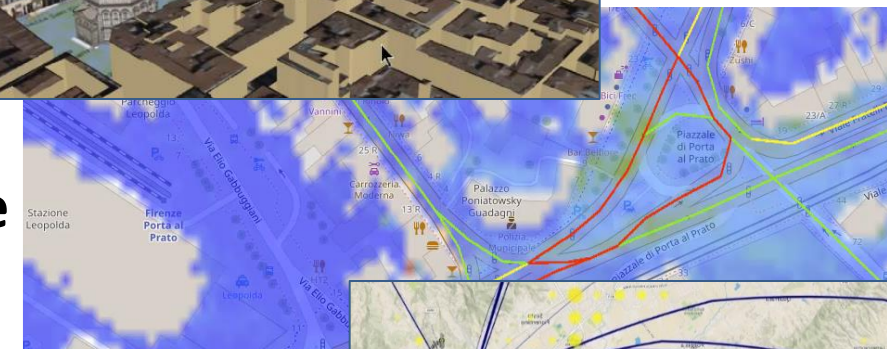 - Prescription
  - ottimizzazioni
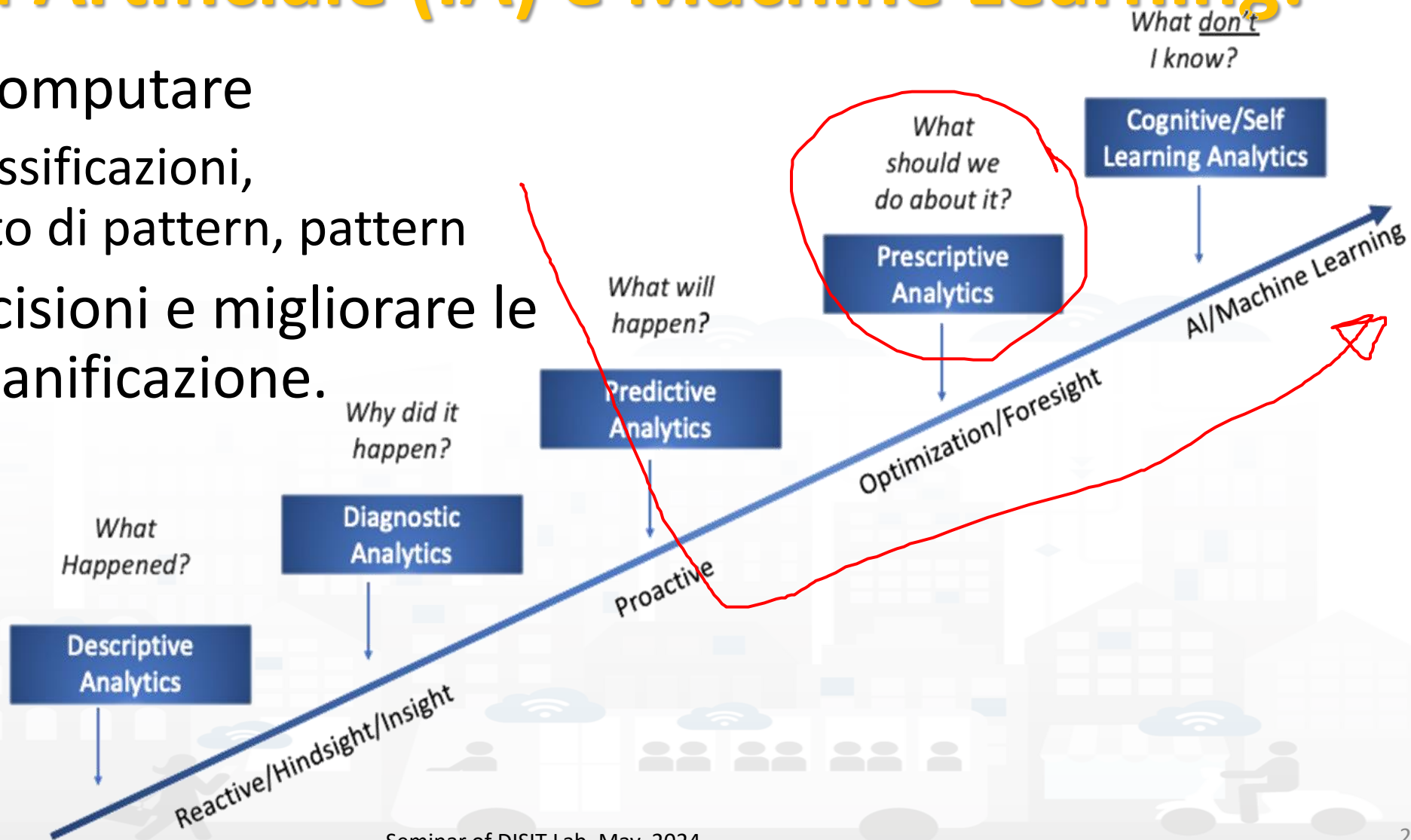
- **Artificial Intelligence** usually also includes
  - Code, learn and reasoning
  - Semantic computing, Knowledge Bases
  - Neuro-symbolic reasoning
  - Decision Support Systems
  - Problem solving
- **Machine Learning** usually includes
  - Learn without coding
  - Predictions, decisions (classifications)
  - Supervised or not
  - NLP, vision, pattern recognition
- **Deep Learning** usually includes
  - Capability to learn complex patterns on huge amount of data
 - Specialized ML solutions
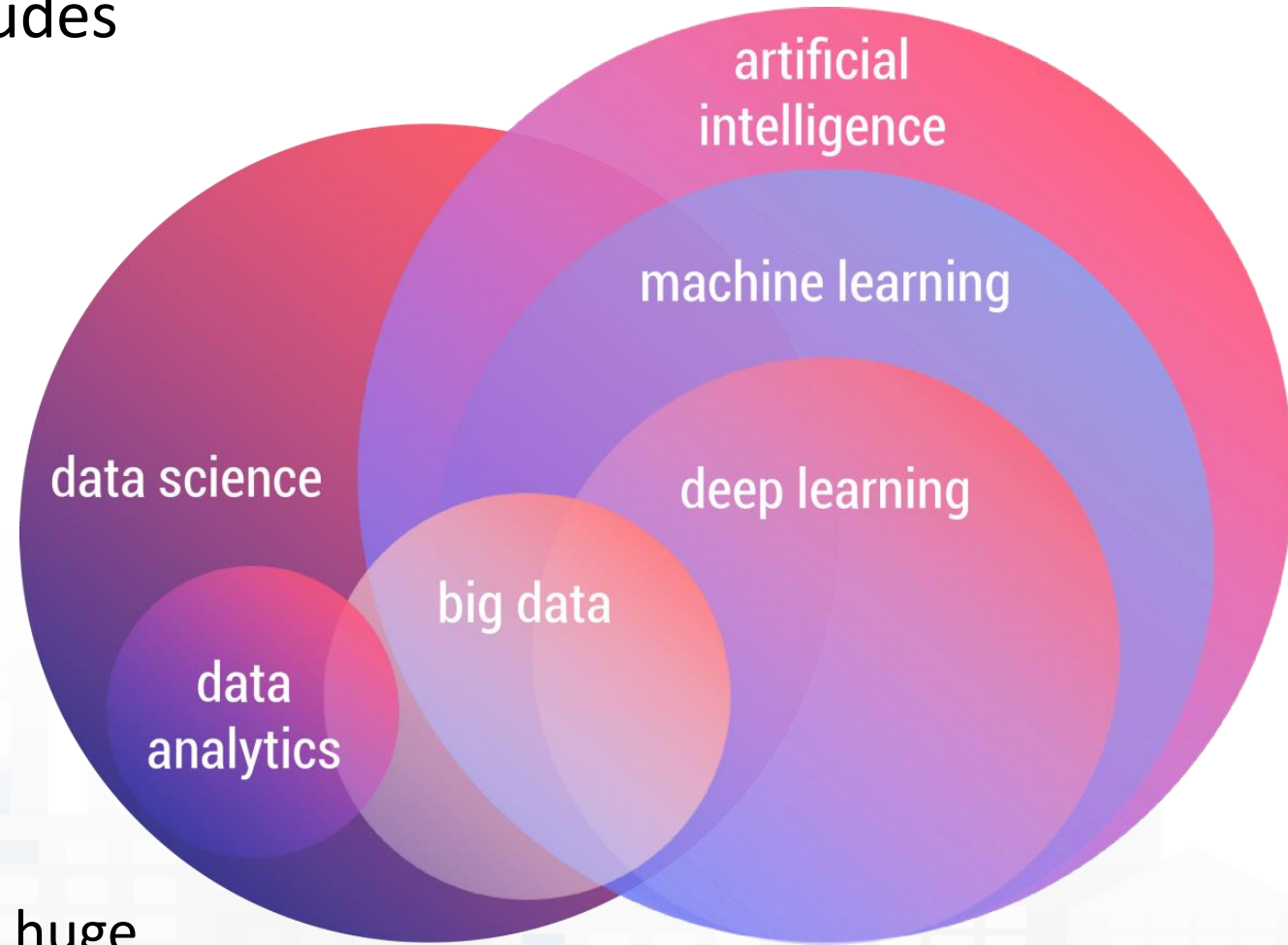
Main Tasks

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

Strategic	• Big picture and Long-term focused (2 to 5+ years) • Vision, Mission, Why, Policies and Direction • Executive-management • What is the right direction for the company?
Tactical	• Short-term focused (3 months to 2 years) • Focused on specific business department • Middle-management • What activities to be planned in strategic alignment?
Operational	• Focused on day-to-day running • Detail level processes for specific outcomes • Execution by teams and managers • Are we acting in alignment with strategy?

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - 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 unknows
  - What-if analysis wrt scenarios
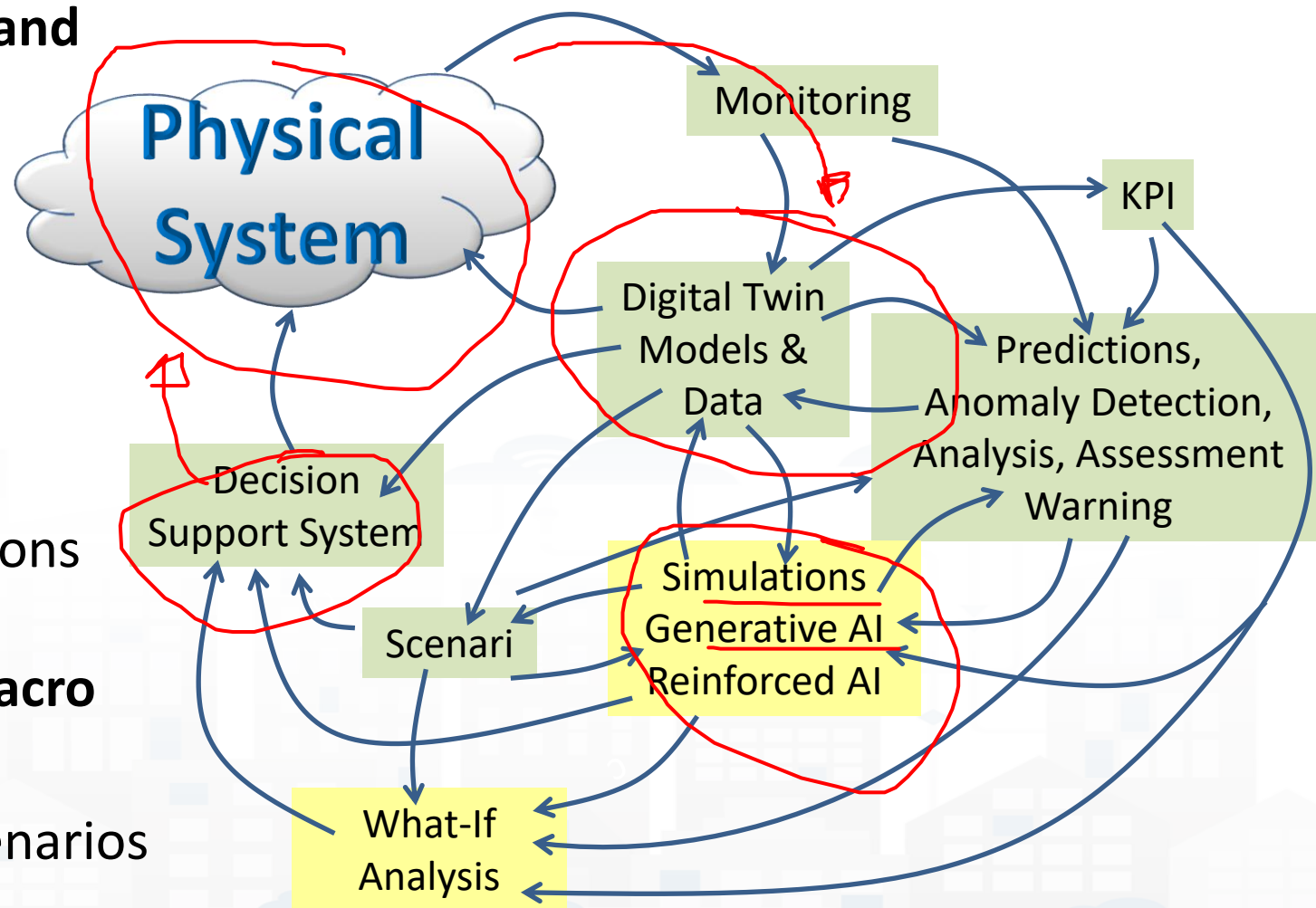
Available AI Solutions at DISIT Lab

https://www.snap4city.org/997

- **Mobility and Transport**
- **Environment, Weather, Waste, Water**
- **City Users Behaviour and Social analysis**
- **Energy and Control, Security, …..**
- **Tourism and People**
- **Industry applications**
- **Security and Safety**

- **Decision Support Solutions**
 - **Asset management**
  - **Resilience and Risks Analysis**

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

https://www.snap4city.org/download/video/DPLSNAP4SOLU.pdf

Model/Technique Development/testing

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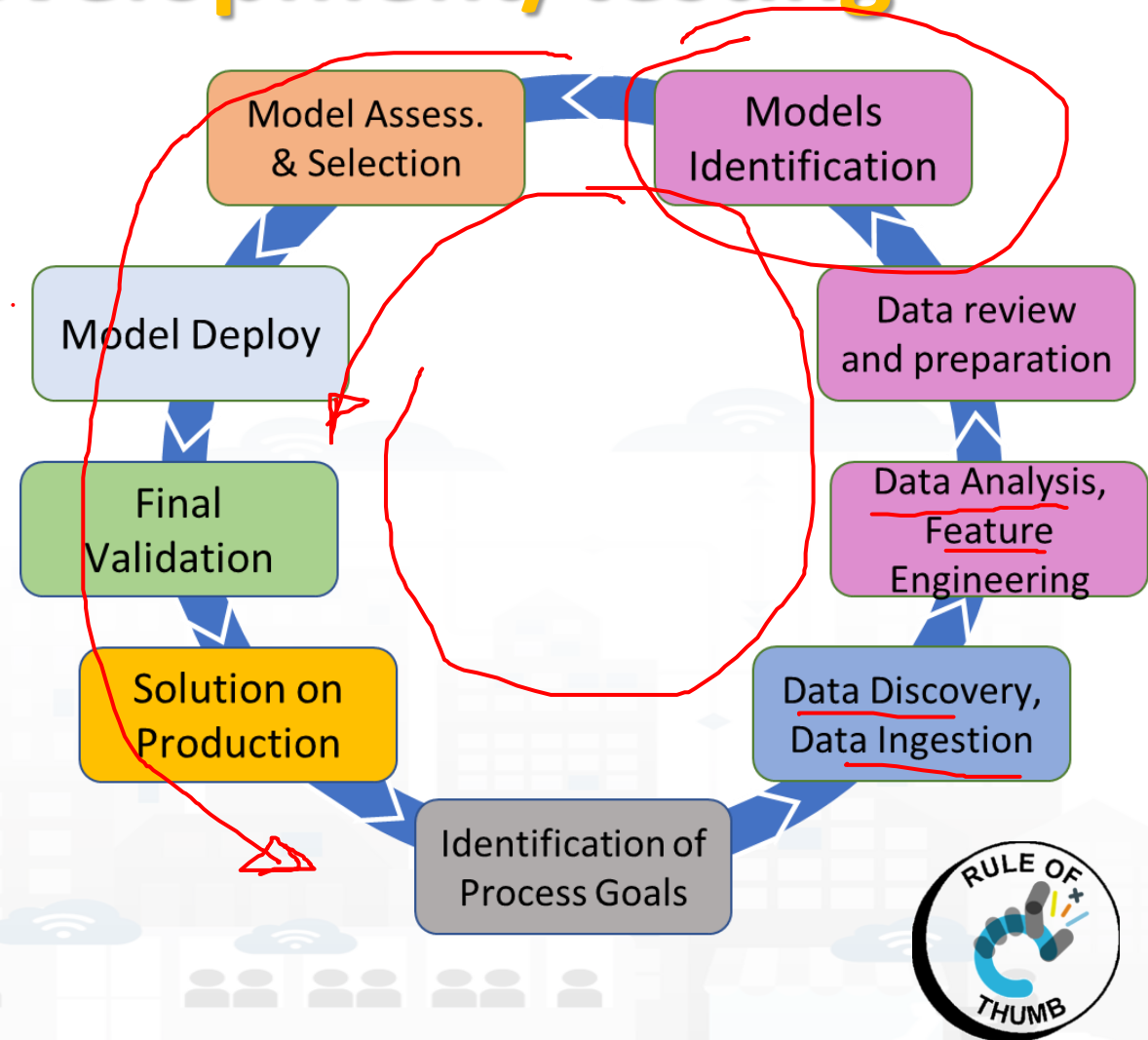
Predictions

- ## 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?
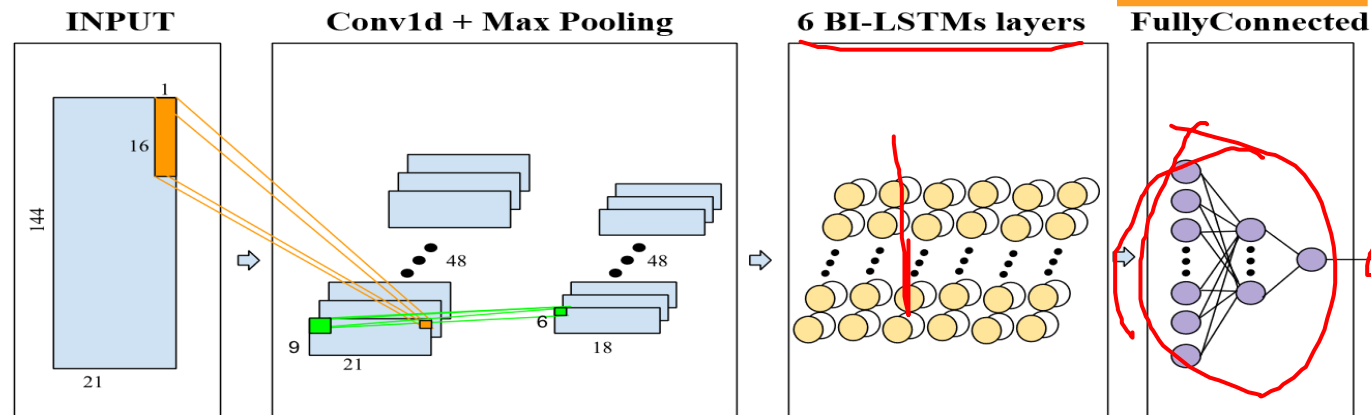 - ### Computational costs?

Management
Tactics/strategy

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

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

INPUT | Conv1d + Max Pooling | 6 BI-LSTMs layers | FullyConnected

Urban data:
- Date-time
- Traffic
- Temporal
- Seasonality
- Pollution
- Weather

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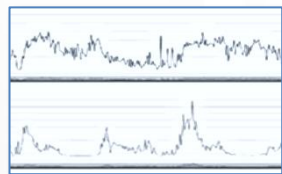Autoencoder BI-LSTM
Attention CONV-LSTM
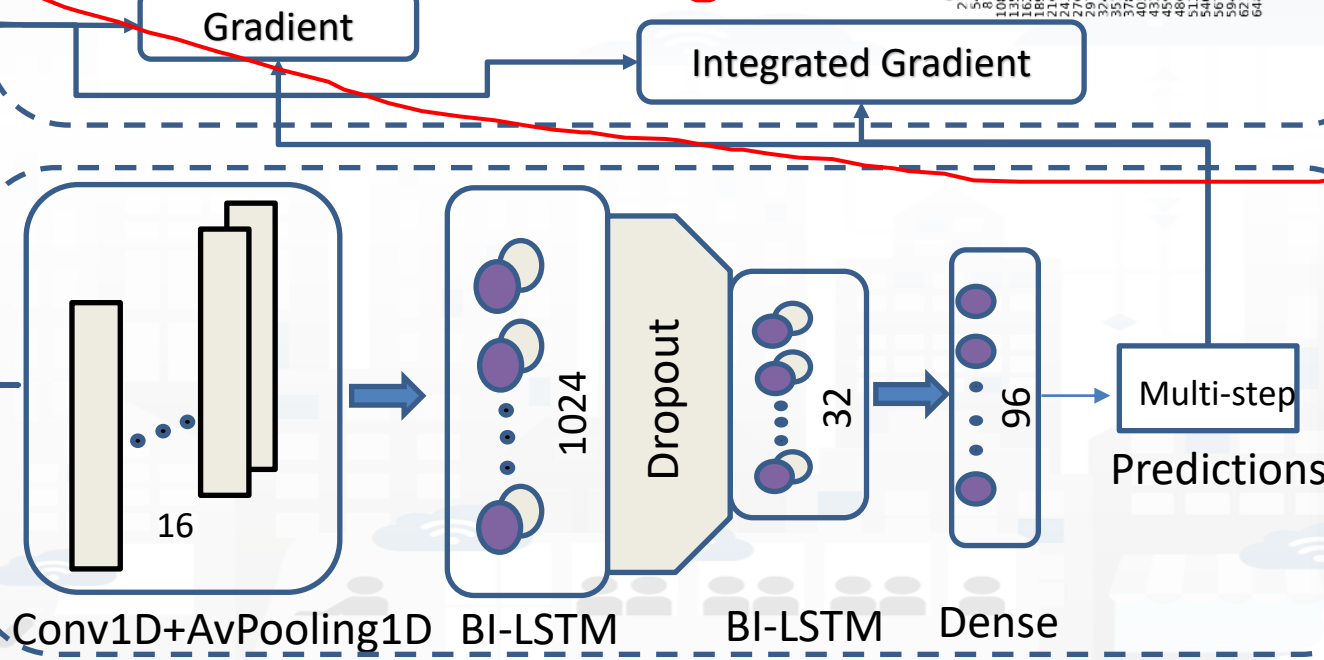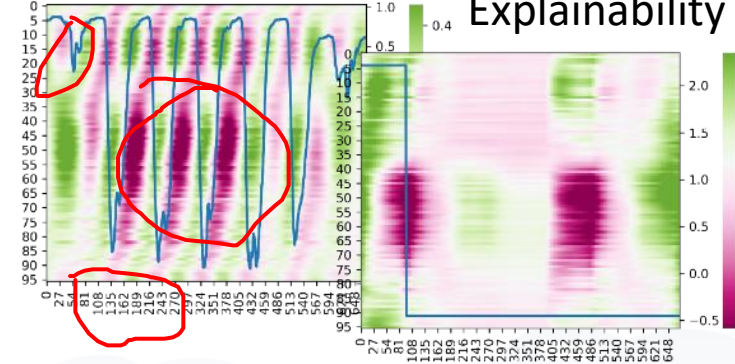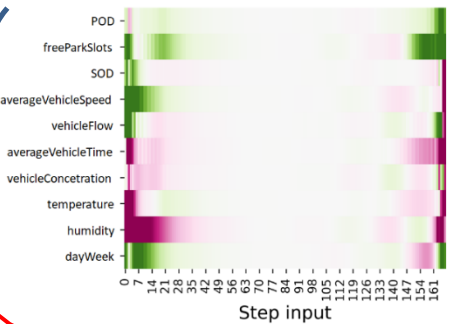CONV-BI-LSTM

CONV-BI-LSTM
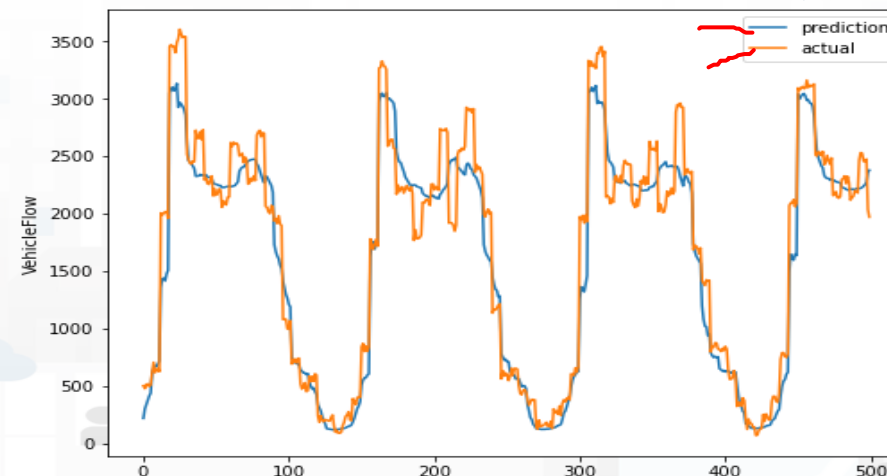
Deep Learning AI to surely Park!
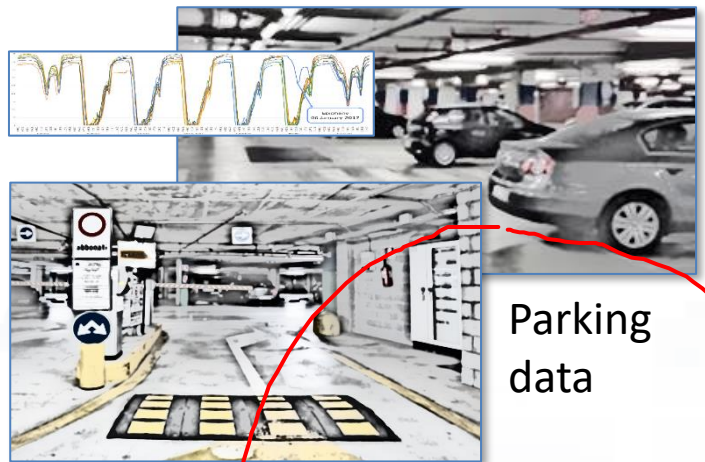
Traffic Flow Manager on multiple cities

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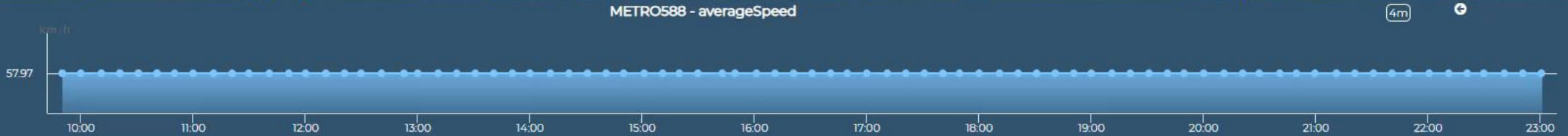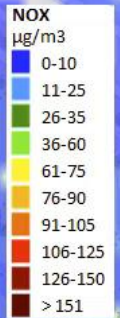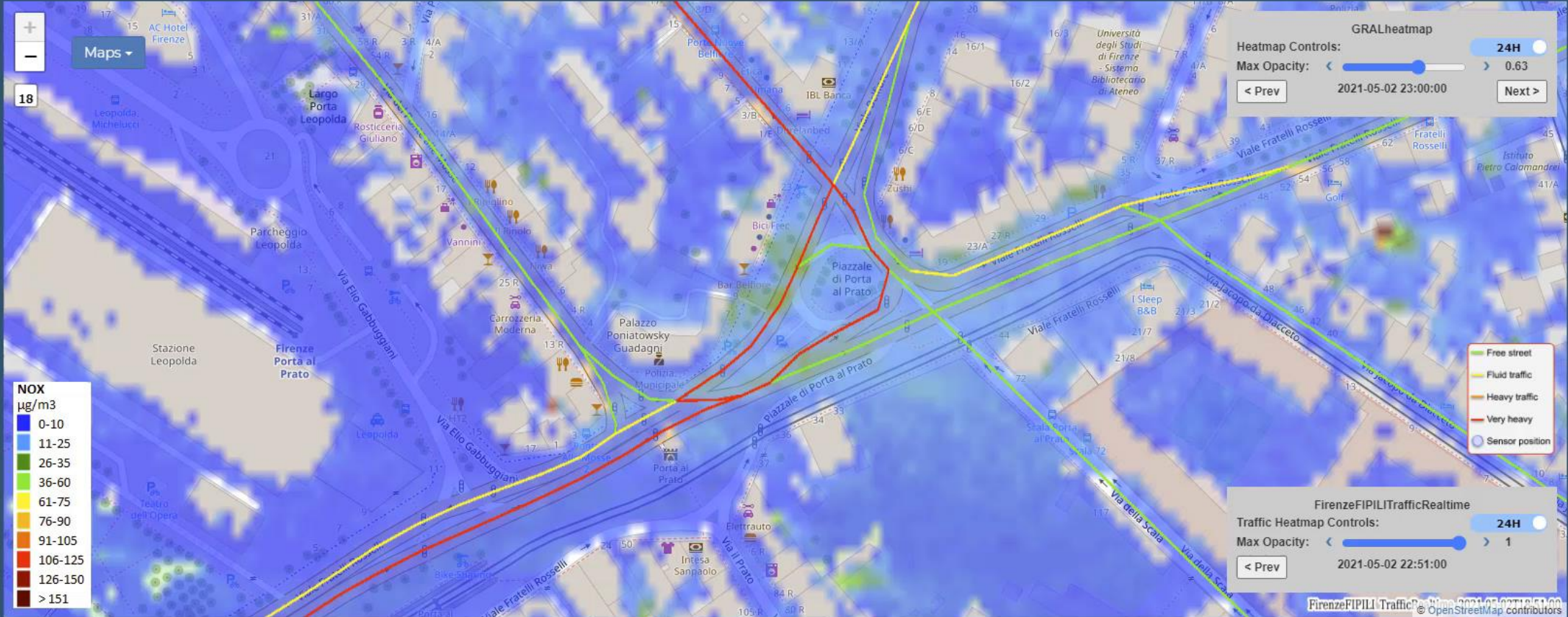
Predicting Land slides

24 hours in advance
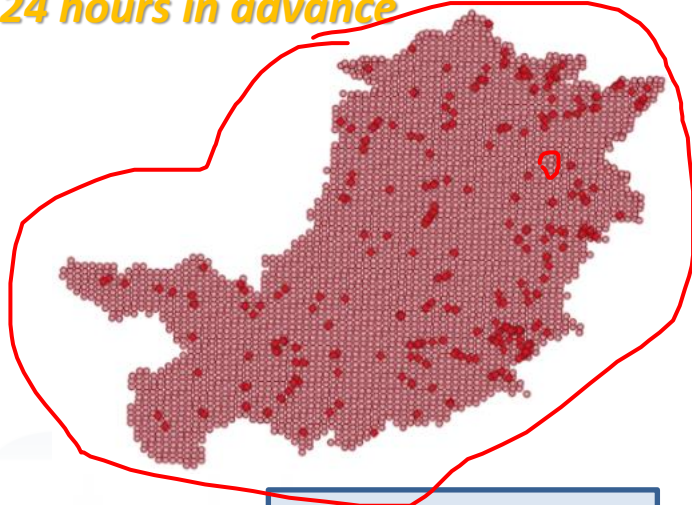
Dataset Construction

Previsional Model

Dataset Construction → Model training And validation

Model

Data
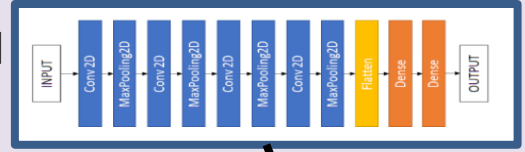
SNAP4City Advanced APIs

Processes

Ingestion

landslide DB

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

Big Data Storage and KB

Predictions

Model execution Shap Assessment

Data Analytics IOT App Management

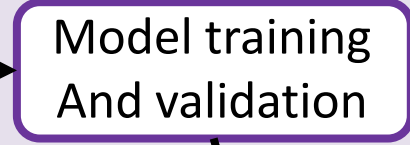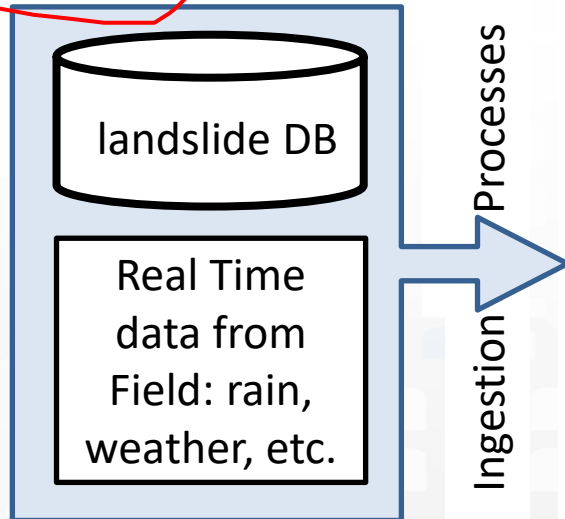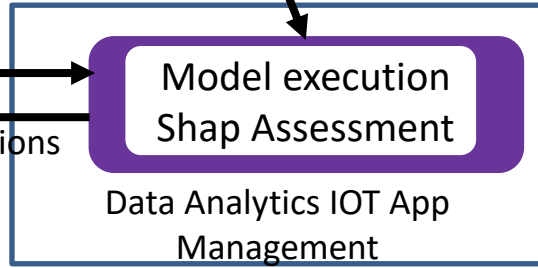Snap4City Servers and Tools: Dashboard manager, Heatmap manager, GeoServer, Smart City API.

predictions

Dashboards and Mobile Apps

E. Collini, L. A. I. Palesi, P. Nesi, G. Pantaleo, N. Nocentini and A. Rosi, "Predicting and Understanding Landslide Events with Explainable AI," in *IEEE Access*, doi: 10.1109/ACCESS.2022.3158328.
https://ieeexplore.ieee.org/abstract/document/9732490
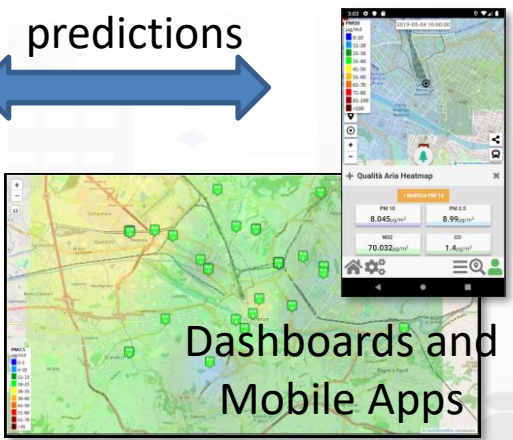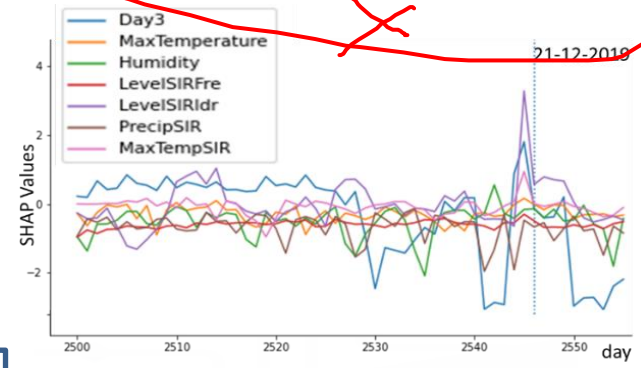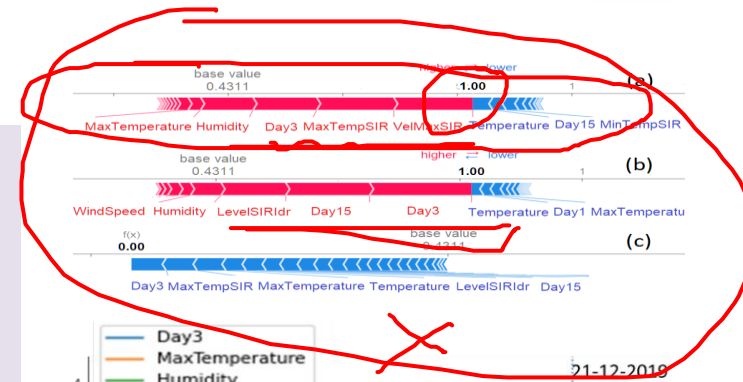
Predicting EC's KPI on NO2 months in advance

Deep Learning Long Terms Predictions of NO2 mean values, From 30 to 180 days in advance
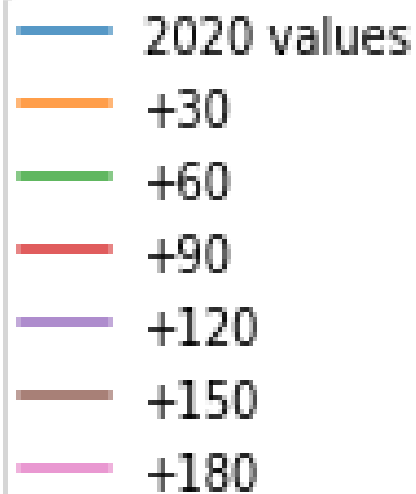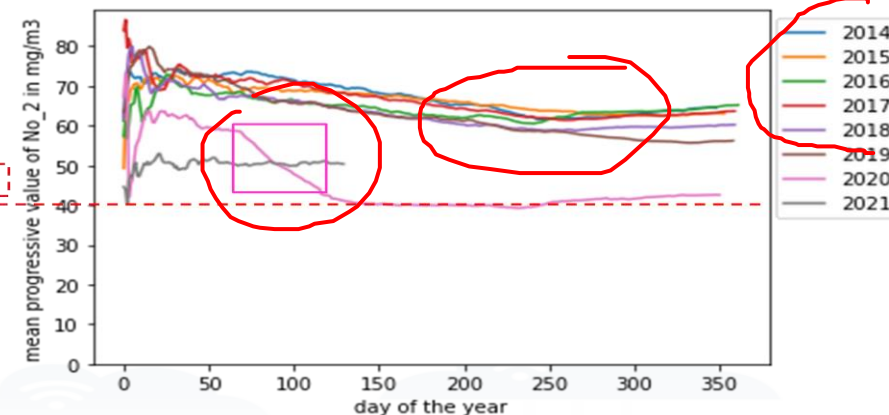
- The features used as input for the predictive models are:
- **Month**
- **dayOfTheYear**
- **NO2**
- **Tmean**
- **Humidity**
- **windMean**
- **NoxDomestic**
- **numberOfVehicles**
- **NO2cumulated**
- **NO2progresseveMean**
- **numberOfVehiclesCumulated**

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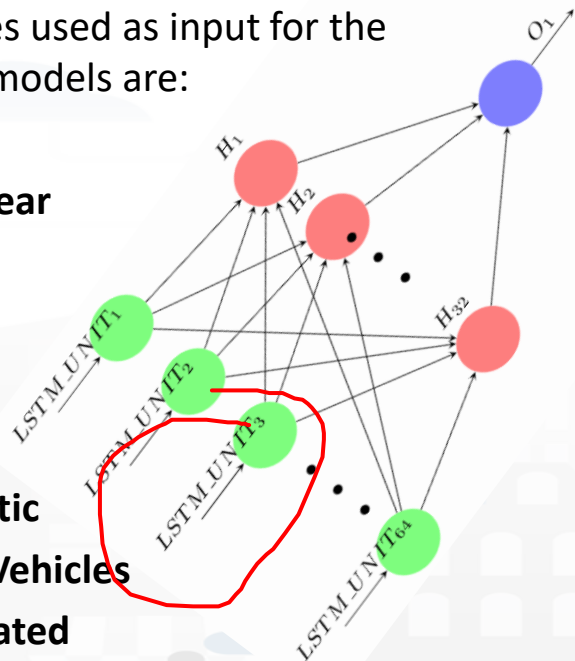- +30
- +60
- +90
- +120
- +150
- +180

Pollutant	Averaging period	Air Quality Directive		WHO guidelines	
		Objective and legal nature and concentration	Comments	Concentration	Comments
PM$_{2.5}$	One day			25 μg/m³ (*)	99th percentile (3 days/year)
PM$_{2.5}$	Calendar year	Target value, 25 μg/m³	The target value has become a limit value since 1 January 2015	10 μg/m³	
PM$_{10}$	One day	Limit value, 50 μg/m³	Not to be exceeded on more than 35 days per year.	50 μg/m³ (*)	99th percentile (3 days/year)
PM$_{10}$	Calendar year	Limit value, 40 μg/m³ (*)		20 μg/m³	
O$_3$	Maximum daily 8–hour mean	Target value, 120 μg/m³	Not to be exceeded on more than 25 days per year, averaged over three years	100 μg/m³	
NO$_2$	One hour	Limit value, 200 μg/m³ (*)	Not to be exceeded more than 18 times a calendar year	200 μg/m³ (*)	
NO$_2$	Calendar year	Limit value, 40 μg/m³		40 μg/m³	

Closing the loop
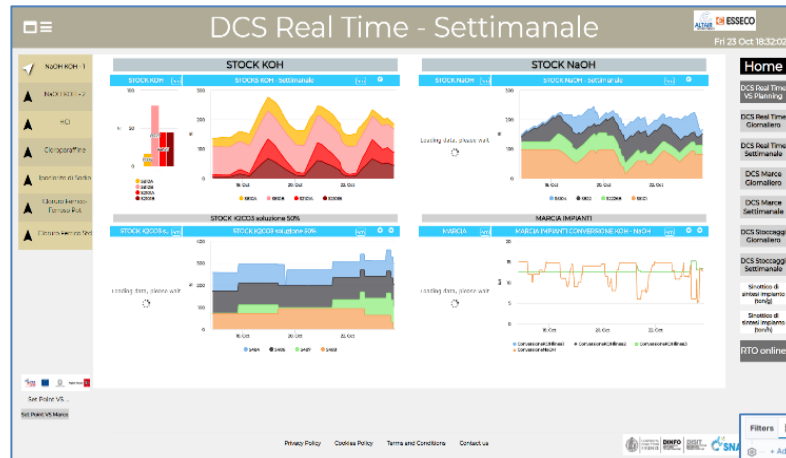
Historical and Real Time Data

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

Synoptics for real time monitoring
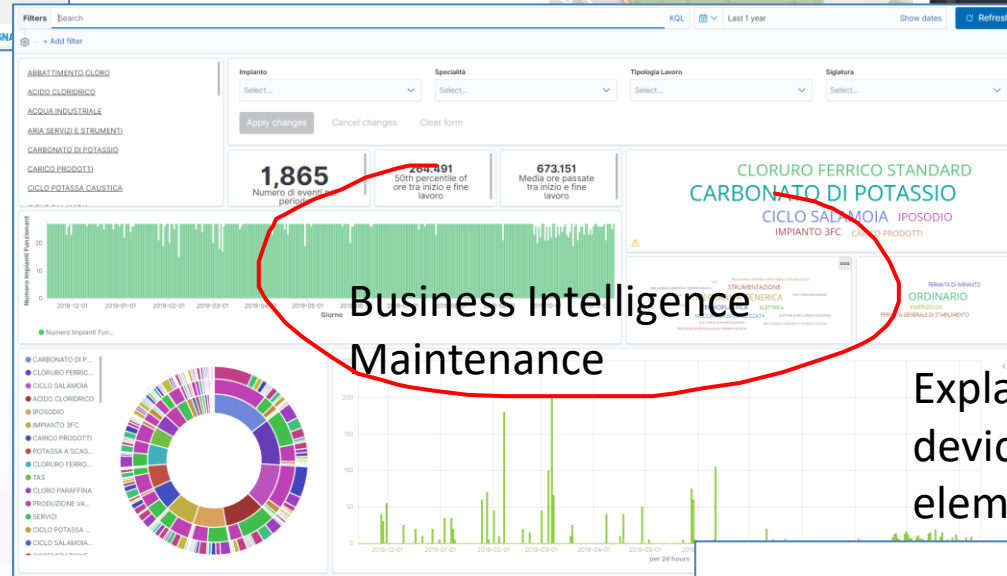
Business Intelligence
Maintenance

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

https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MzA1NA==
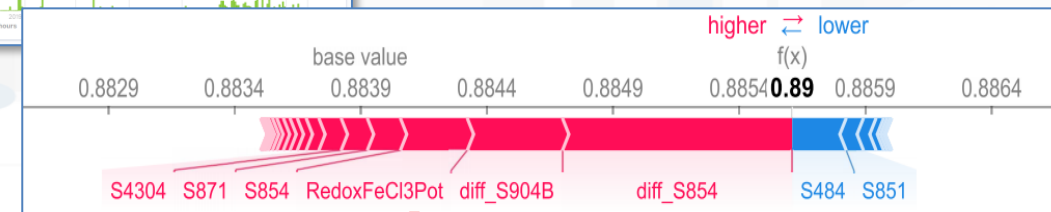
Explainable/XAI - CNN-LSTM (SHAP)

Explanation of prediction generated by model for fault

Explanation of prediction generated by model for normality
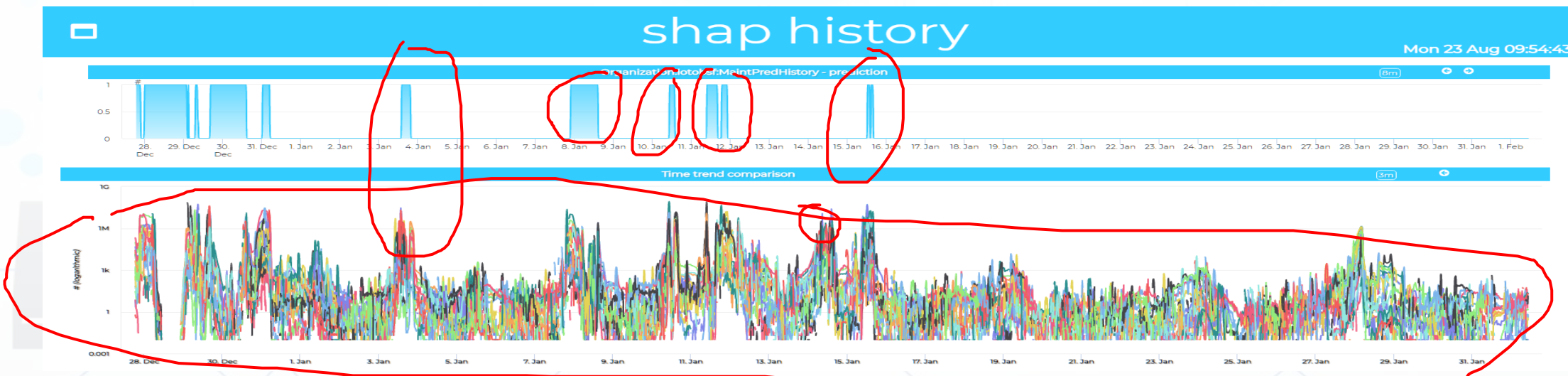
- **Controlling Status: management, and operational**
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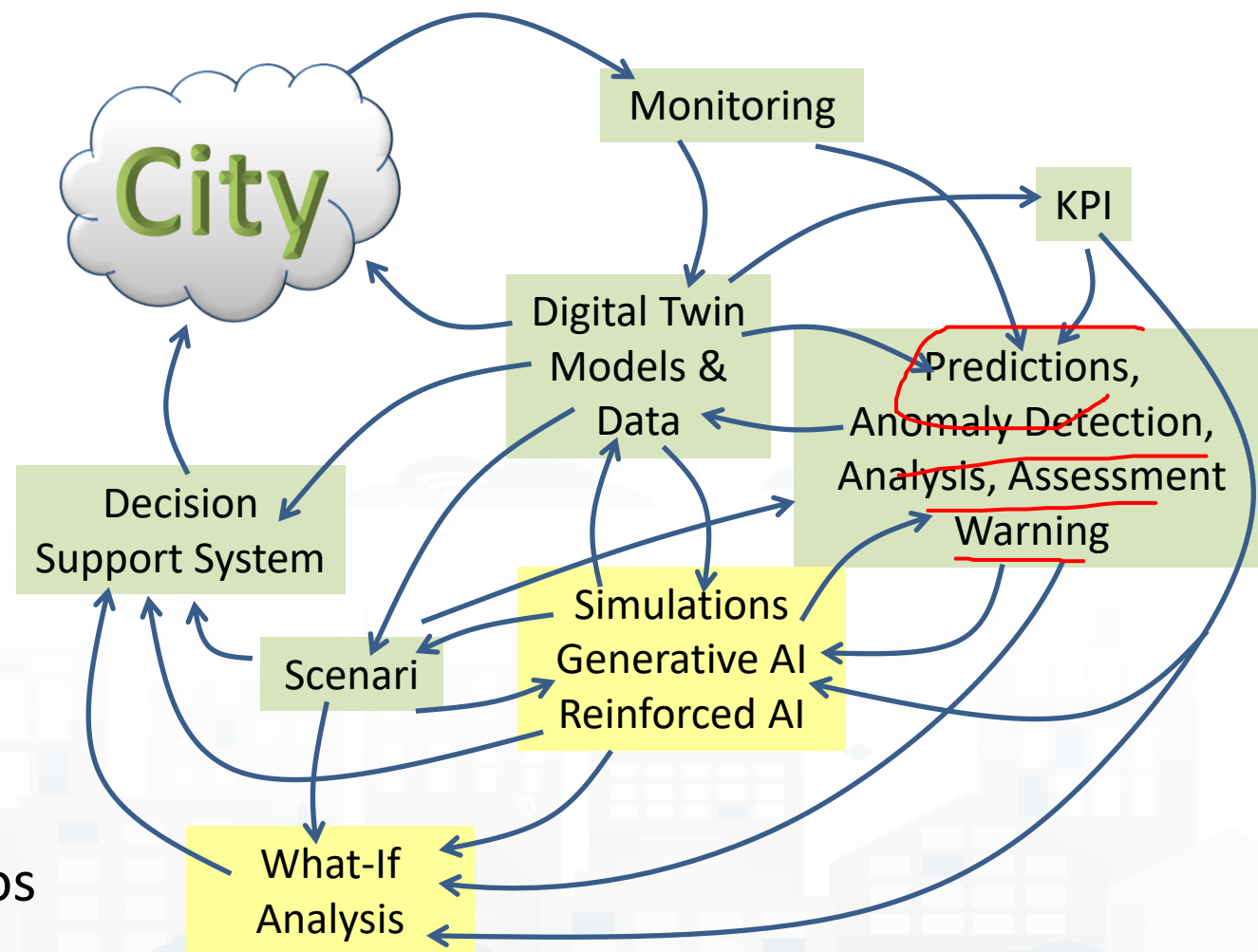
Generative AI

- creates new samples based on learned patterns from existing data

- **Techniques:**

  - **Generative Adversarial Networks**: a Generator and a Discriminator

  - **Variational Autoencoders**: generate samples in the compressed domain…

  - **Transformers**: mainly to generate coherent sequences of elements / text

    - GPT: Generative Pre-trained Transformer → ChatGPT

  - **Recurrent NN, as LSTM**: generate predictions of sequences, use in text and music

- **Applications can be:**

  - Text generation, Code Generation, …

  - Pattern generation: images, sequence of images, time series, etc.
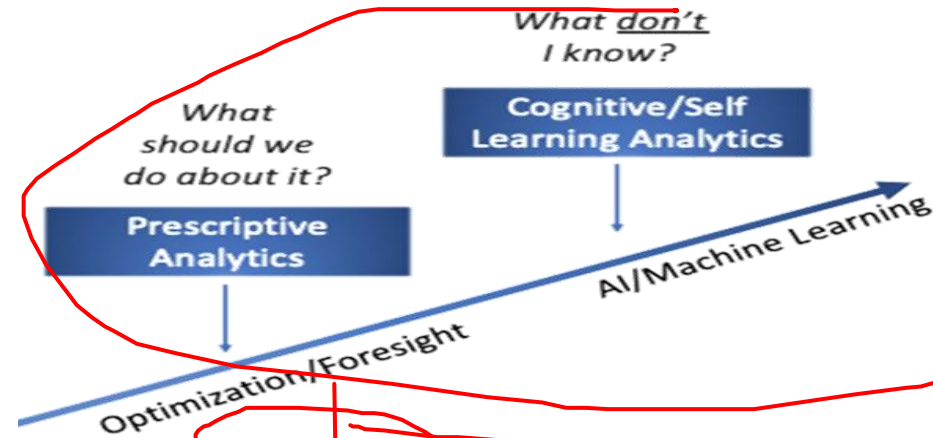
Generative AI in industrial Applications

- **Content Generation…..**
- **Product Design and Prototyping**: suggesting innovative designs.
- **Art and Media Production**: generating music tracks, visual effects, and even entire scenes for movies and games.
- **Virtual Reality and Augmented Reality**: generate realistic textures, environments, and characters, enhancing the overall experience.
- **Drug Discovery and Material Science**: accelerate the drug discovery process and the development of advanced materials.
- **Supply Chain Optimization**: generating demand forecasts, designing efficient transportation routes, and optimizing inventory management strategies.
- **Natural Language Processing (NLP) Applications**: legal, and healthcare, generative AI can be used for generating responses, drafting legal documents, medical diagnosis
- **Creative Collaboration Tools**: generating ideas, concepts, and designs, in brainstorming sessions and design reviews.

Neuro-Symbolic /Hybrid approaches

- Combine NN and Symbolic approaches
  - Refinement, counterpart, etc.

- **Symbolic/Hybrid**
  - May provide hints/discriminatory rules on patterns and models Generation
  - Are providing
    - Math models, equations and thus solutions, …
    - Logic solutions, including experts systems, grounded on knowledge base and ontologies
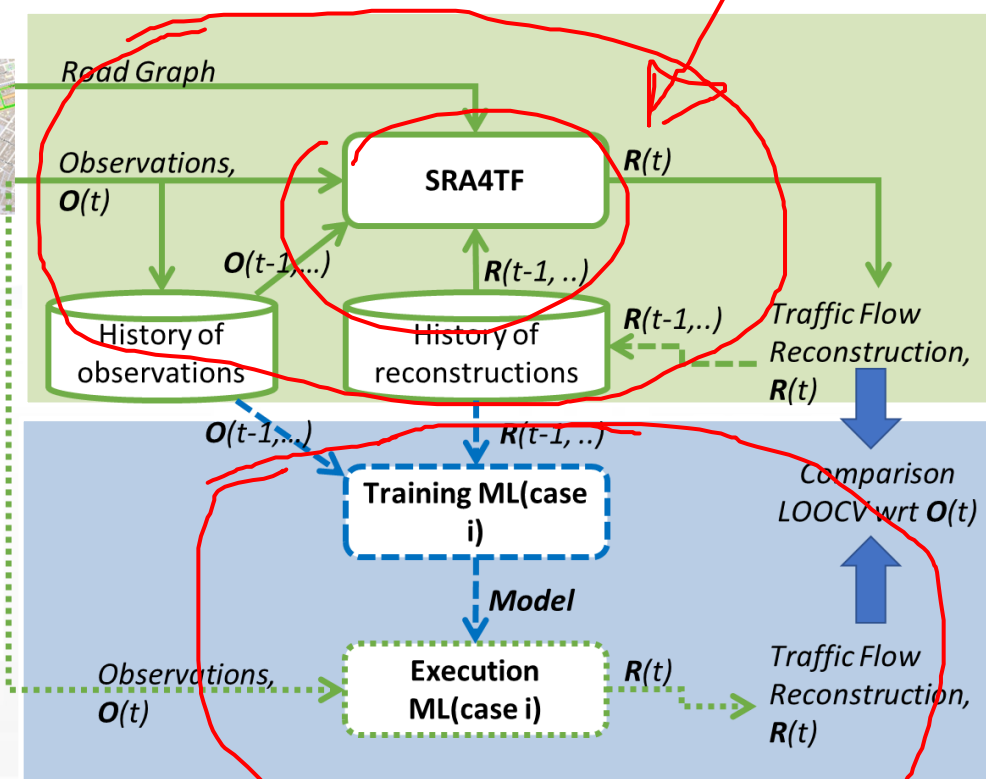
Physics-informed neural networks (PINN)

Solve complex fluid-dynamic problems based on **partial differential equation (PDE)** using neural networks

SNAP4CITY roadmap
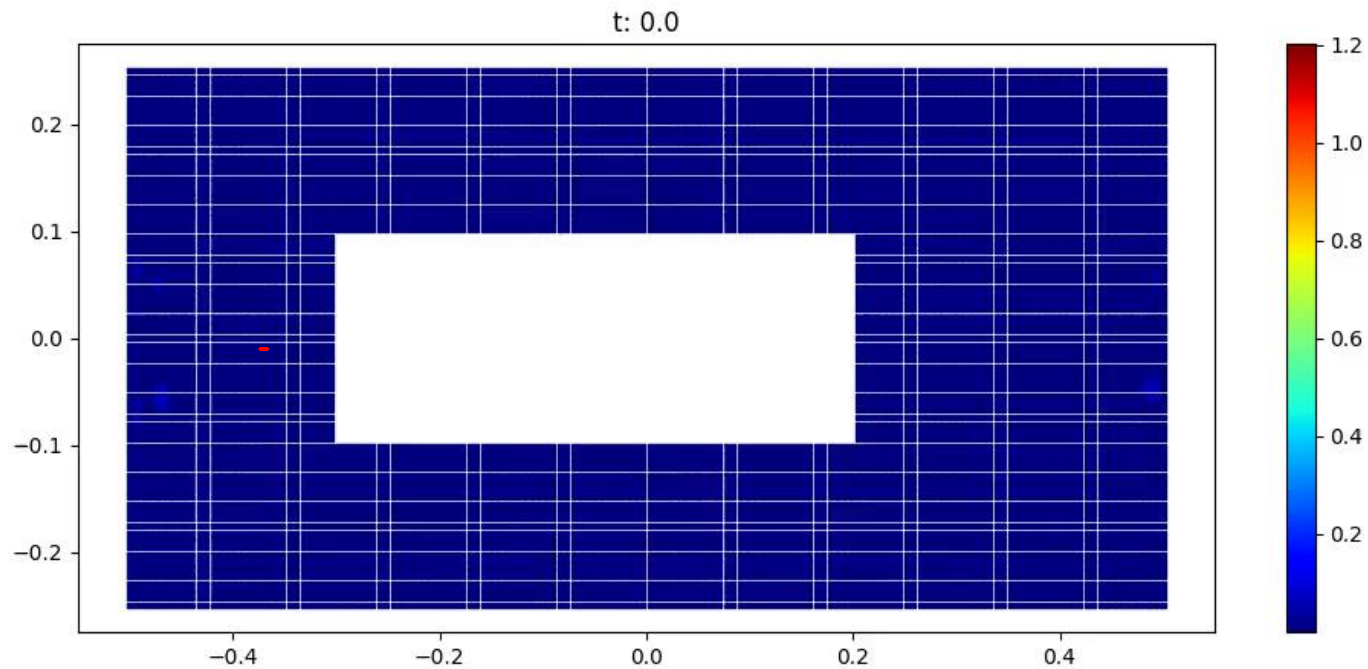
2020
- Smart Tourism
- 6 Pilots
- Data Analytics
- Extended platform

JRC EUROPEAN COMMISSION — Contract

Interreg Mediterranean — HERIT-DATA

- Smart Mobility
- PISA, PUMS
- Living lab

Interreg MARITTIMO-IT FR-MARITIME — MOBIMART

smartGARDAlake

Km4City 1.6.7

2021

Smart Ambulance (2021-22)

Enterprise (2021-22) Industry 4.0

Sii-Mobility

enel x — Contract

JRC EUROPEAN COMMISSION — Contract

PC4City (2020-21) Monitoring Terrain

Winner of Open Data Challenge of enel x

CAPELON
- Smart Light
- Sweden

2022

Asymmetrica Urban Technology
Asymmetrica Smart City, 2022-23

Almafluida Industry 4.0 (2021-22)

AMPERE (2021-22) Industry 4.0

SYN-RG-AI SmartCity

GRUPPO PRETTO — Industry 4.0

uni systems — SmartCity, 2021-23

AXIS COMMUNICATIONS — AXIS collab SmartCity

ITALFERR GRUPPO FERROVIE DELLO STATO ITALIANE — Italferr, Smart City

2023

JRC EUROPEAN COMMISSION — Contract, 2022-23

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

Filippi — 2022-2023

enel x — Contract, 15min

IMPETUS — Security and Risk

Smartea

MOST CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE — CN MOST, 2022-26 — Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

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

G. Agile, 2021-23

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

Merano, smart light

OceanRace, Genova, AWS

Cuneo, smart city

2024

JRC EUROPEAN COMMISSION — Contract 2024-25

SASUAM — MOST CENTRO NAZION... — Italiadomani

CAI4DSA — FAIR Future Artificial Intelligence Research — Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

Rhodes, smart city

eShare UNIFI TUSS

AMMIRARE

Interreg MARITTIMO-IT FR-MARITIME

TOURISMO

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

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https://www.Snap4city.org,
https://www.Snap4Industry.org