SNAP4SOLUTIONS

www.snap4solutions.org

Optimization

Predictions

Generative AI

Explanaible AI

Early Warning

Strategic Plan

ARTIFICIAL INTELLIGENCE

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SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES

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

2025/26

SNAP4CITY

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INTRODUCTION

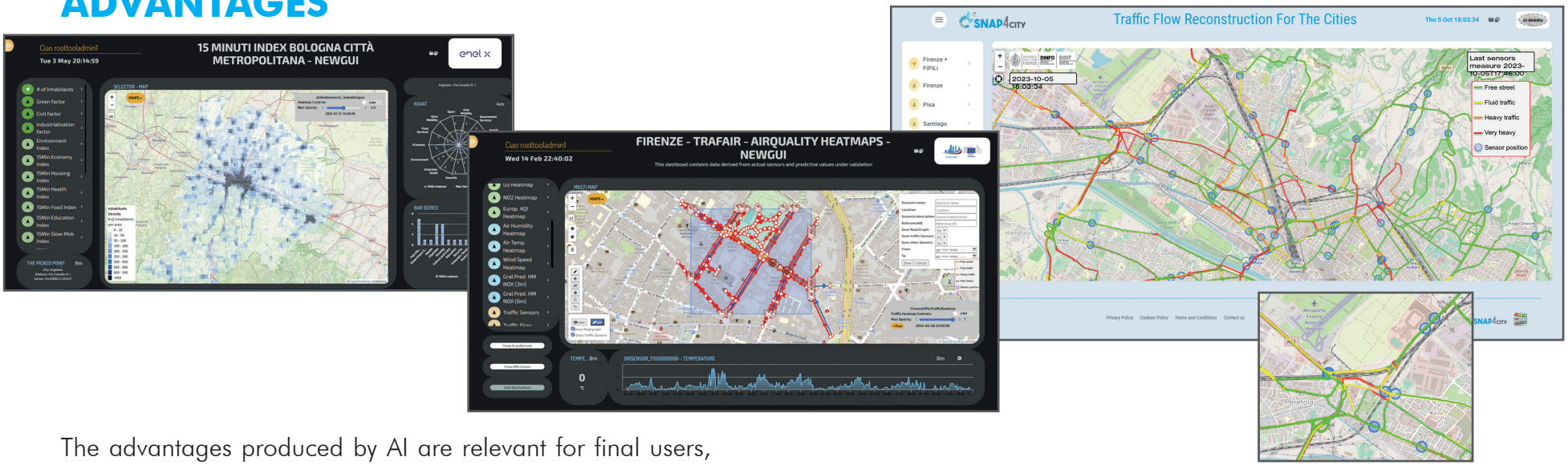
Artificial Intelligence and machine learning solutions have been mainly black box generating scepticisms over their applicability in critical situations in which one should be requested to just trust them. On the other hand, ethical aspects (on data and processes) are very relevant and a wrong assumption in taking data and/or setting up solutions may lead to biased results/suggestions, which may correspond discriminations and may lead to unforeseen costs. This was a real concern for many AI based solutions.

AI has rapidly evolved and started to be used in complex systems and not only to produce only predictions. Decision-makers started to use the AI solutions expecting to see them respecting the ethics (on data and processes), with aim of trusting them as their best experts. To this end, **AI trustworthy, Data Ethics** and **AI Ethics** approaches have been created by international and national bodies to guide AI developers in producing solutions which can actually serve the decision makers without prejudice and with correctness. Data Ethics refers to the aspects that miss considered may provoke a bias and ethical problems since the training phase; for example, training the AI with biased data, unbalanced distribution of cases, violating the ethics of the observed communities, etc. Moreover, specific AI methodologies and solutions for **Explainable Artificial Intelligence, XAI,** are presently providing support in this direction since they are capable to explain the rationales behind the typical results provided (global explainable AI) and may provide specific description/rational for each result/suggestion provided (local explainable AI). XAI typically adds value to the suggested decisions producing hints and discovering implications and correlations never detected before by humans. They are a source of information to train the decision-makers about what has been discovered to be relevant for the AI. On the other hand, the decision makers can also provide to the AI continuous and lifelong training inputs for improving the capabilities of the AI. Thus, in Europe (April 2019) and in recently in other countries normative are going to set up regarding the AI Ethics, proving guidelines on training AI for Ethics, thus for **AI trustworthy, Data Ethics and AI Ethics**.

Snap4 technology is providing **Big Data Analytic** with **Artificial Intelligence, AI,** for leveraging businesses and solutions in producing reliable predictions, prescriptions, early warning, classifications, detections, suggestions, optimizations, simulation, plan, and generation; supporting **AI trustworthy, Data Ethics** and **AI Ethics**. In substance, **Snap4** technologies lead to reduce costs and increase the efficiency of business and/or production processes. This implies to extract value from data, providing hints, prescriptions, suggestions, strategies, mitigations, and discovering solutions, information and implications never detected before, to learn and derive aspects of the phenomena up to now only observed and measured.

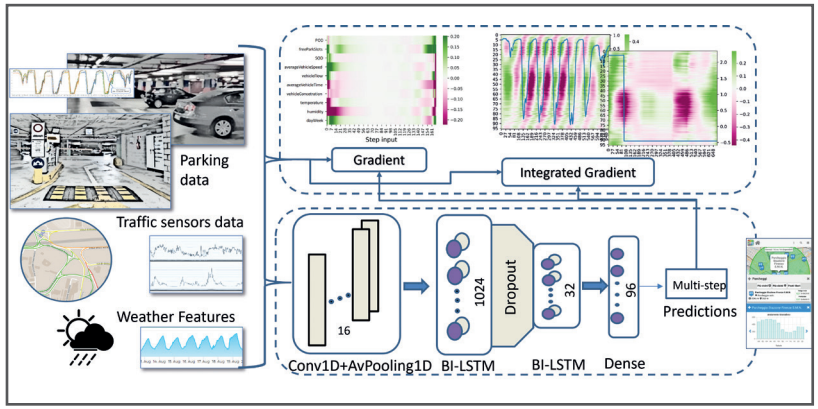
Applications of AI are in all domains of smart city and industry: mobility, health, energy, environment, waste, chemistry, manufactory, delivering, agriculture, boating, building, security, safety, etc.

ADVANTAGES

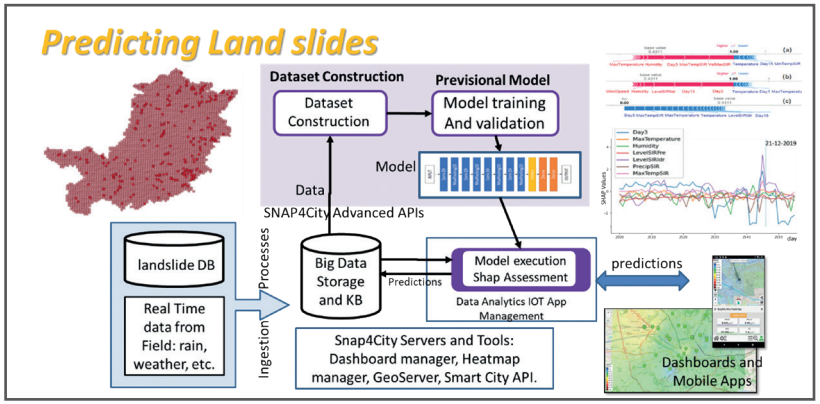


The advantages produced by AI are relevant for final users, decision-makers, commercial, industry, research and cities. Examples can be:

- Monitoring and controlling traffic, making predictions, traffic flow reconstruction, simulating and performing what-if analysis for strategic plan minimizing traffic congestions, reducing emissions, etc.
- Optimized estimation of traffic light plant taking into account public services (tramway, bus rapid transit, DRT) and private traffics, minimizing by reducing: #stops, travel time, #stops for tramways, waiting time, etc.; providing suggestions for travellers.
- Optimized traffic infrastructure viability in terms of roads, directions, lanes, etc., reducing traffic congestion, travel time, emissions, fuel consumption, etc.
- Optimized positioning of bus stops, BRT, increasing the quality of transport experience and avoiding overcrowding, maximizing efficiency, minimizing costs, and decreasing the number of trips.
- Parking predictions to reduce the social costs of looking for parking: reduction of fuel consumption, reduction of produced as NO2/CO2 for the whole community, etc.
- Optimized routing based on present and predicted conditions, regarding traffic and maintenance works, for private drivers and city operators. Thus, for emergency services, reducing travel time, pollution, and the time required to reach the objective and perform services.
- Understanding city usage conditions, and city users' satisfactory and demanded services, etc. Increasing quality of services by solving the identified problems via collective intelligence.
- Optimization of waste collection that reduces costs by minimizing the number of required trucks/trips and prevents waste from escaping bins through the use of predictive analytics. It is an advantage for the quality of life of city users and reduces administrative costs.



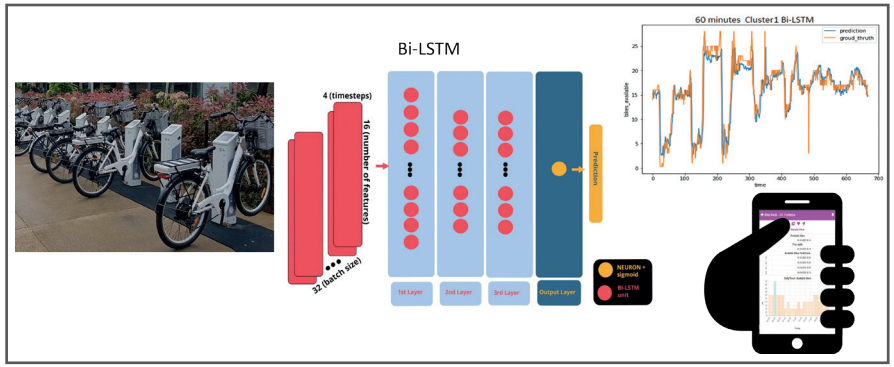
Deep Learning AI for Parking prediction



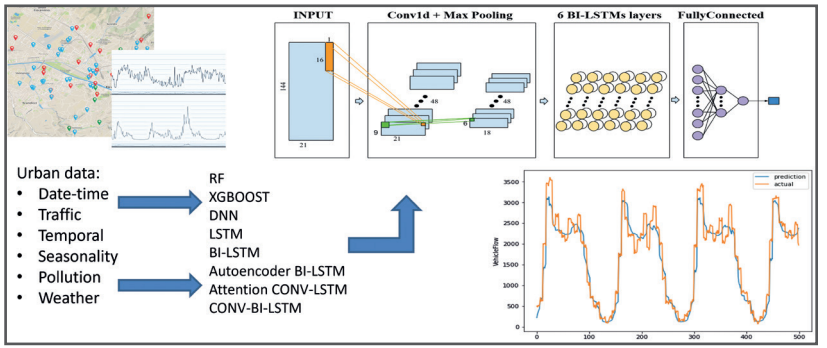
Landslides prediction

- Predicting maintenance (for roads and services) to reduce intervention costs, operating costs associated with unexpected faults and services/productions interruptions, avoiding damages provoked by faults, etc. This also implies a reduction of the costs of production improving efficiency and resilience.
- Sharing service prediction to reduce the time need to get/find a suitable sharing vehicle. Reduce costs and improve efficiency by means of sharing and pooling. Thus, increasing the quality of service also increases its effectiveness.
- Assessing and predicting reputations of services, attractions, based on social media, with the purpose of enhancing the quality of services, reducing prices increase, and promoting alternative offers and solutions.
- Early warning about possible landslides in the territory by computing predictions about landslides. Thus, reducing the risk for population, reducing the reaction time improving resilience of the territory.

- Preparing the city and/or the industry to be more resilient to unexpected unknown events, natural or man-made disasters, by integrating simulations and AI solutions enabling the what-if analysis in real-time, increase resilience and capacity. Rapidly reacting to unanticipated, unforeseen events, so reducing the cost of recovery, which is the risk, and receiving advice to mitigate the risks and damages.
- Understanding the usage of city services to optimize energy and other resources needed for the expected serviceability and quality.
- Dialoguing with decision makers by using natural language, understanding and producing suggestion, generating solutions via Generative AI as LLM.
- Dialoguing with developers to help them in fastening the finalization and deploy of smart solutions, data ingestion, business intelligence tools, etc.
- Solving complex physical equations with Physically Informed Neural Networks, PINN, for Simulating fluid-dynamic flows in autoclaves and machineries, cost reduction, time reduction.

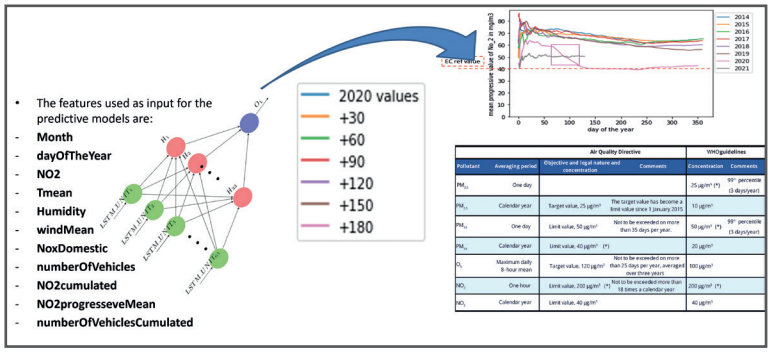


Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations

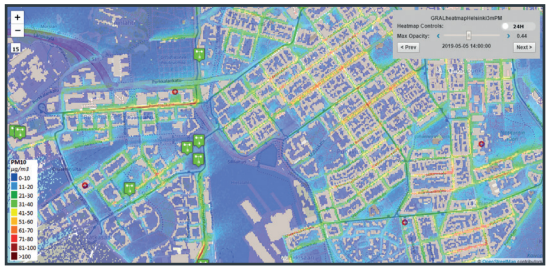


Short-Term Prediction of City Traffic Flow via Convolutional Deep Learning

Snap4 AI/XAI solutions are capable to provide high precisions on predictions, classifications, prescriptions, simulations, suggestions and scenario generations and thus they can actually support decision makers as your best experts without humans' bias. Snap4 AI/XAI solutions can be treated as a trusted expert to support decision makers to collaborate creating optimized tailored solutions, and strategies to mitigate and solve short- and long-terms plan problems, as well as to support processes of What-If analysis, which were previously developed solely through simulations on the basis of hypothesis, and now the most effective solution can be directly generated by AI. Decision-makers can get suggestions shortening the analysis activities and the AI can learn from the decision-makers' objections improving progressively the AI capabilities and your preferences, taking into account additional aspects and elements. The recent solutions based on Large Language Models, LLM, allow decision makers to discuss with the expert in natural language. On the other hand, technical solutions still need to be generated by specialized AI rather than generalist LLM.



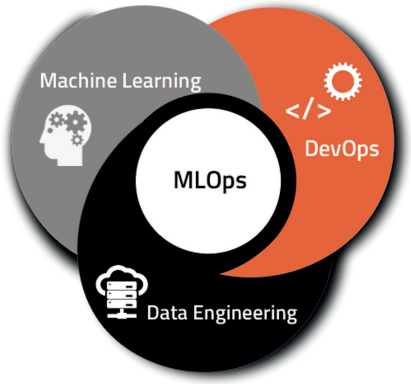
Deep Learning Long Terms
Predictions of NO2 mean values

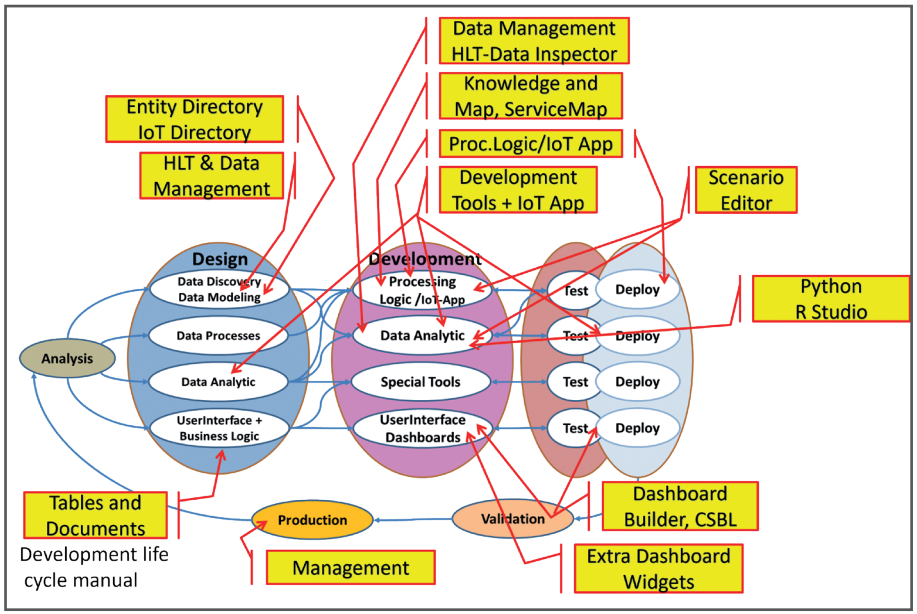


New generation NeuroSymbolic AI: The federated Snap4 AI solutions allow taking into account input of community of users, and this would result in the production of new data for training (suggestions produced by the users to the AI, generative AI, as well as collective intelligence, from Participative solutions as **Snap4** mobile Apps) which can be actually improve the AI precision and capability in modelling the phenomena and providing effective suggestions. Some of the Snap4 AI solution fit in the deep reinforced learning, transfer learning, federated learning, fine tuning, and in the continuous learning techniques.

Moreover, a relevant push has been provided by semantic reasoner tools (such as Km4City since 2013, in **Snap4**, and LLM), which started with the definition of ontologies and collecting data become actual expert systems which can be queries with semantic query (and/or in multilingual natural languages) to perform inference and produce smart suggestions and results, what is called neuro symbolic solutions. Examples are the graph neural network, graph data stores and the spatial, temporal and entities reasoners.

DEVELOPMENT LIFE CYCLE

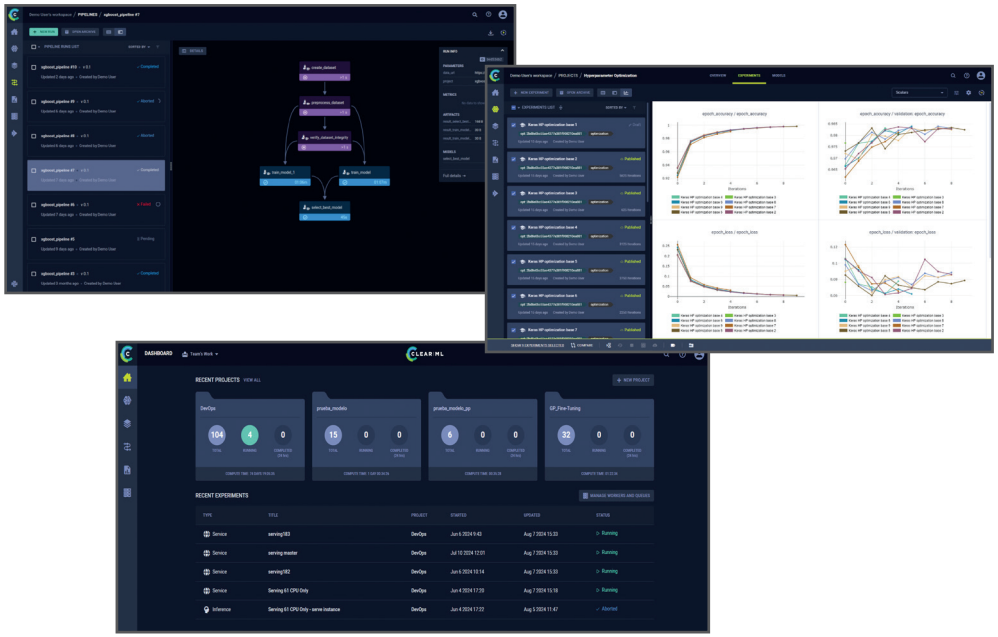




The **Snap4 AI development life cycle** is mature and deterministic. The process to start from data to create the trained and optimized model to put it on production. A set of consolidated methods and techniques are used to identify and process data, identify features, select the best AI models for the purpose, perform the training with hyper-parametrization to reach formal models assessment including AI-Ethics and trust validation. The final assessment of the produced models is the most formally complex phase, in which the effective validation with respect to real conditions is performed to assess the effective satisfactory expectations. Rigorous methods are applied, and a deep knowledge of domain is exploited, and they vary on the basis of the AI task: prediction, classification, prescription, optimisation, anomaly detection, etc. To this purpose, standard benchmarks, metrics and data sets are actually be used for assessing the results in an objective manner. Snap4 AI development environments, solutions include systematic MLOps to allow a number of AI developers to exploit clusters of GPU/CPU and HPC as needed capable to be intimately supported by AI/XAI methods to provide ethical, trustworthy and reliable solutions. And this integrated approach of AI trustworthy, Data Ethics and AI Ethics is enforced into the development process (e.g., data analysis, data selection, data ingestion, data review, AI technique selection, XAI selection).

LEGAL ASPECTS AND PRIVACY

Any AI/XAI solution (including data ingestion, analysis, transformation, training, visualization, etc.) has to respect the data privacy, ethics, and thus has to be compliant with **GDPR** (General Data Protection Regulation of the European Commission) and/or similarly regulations in other non-European Countries (e.g., the California Consumer Privacy, CCPA). These aspects have to be addressed since the beginning of the life cycle, when the data discovery and ingestion are performed, and in particular in the data analysis phase. This also means that the solution has to respect the **Data sovereignty** for which the data are subject to the laws and governance structures of the nation where they were collected. Specific licenses should be modelled and the development tools enabling the development of AI must guarantee the **Data sovereignty and GDPR** for data privacy. On the other hand, the long experience in data analytics also demonstrated that in a large number of cases, several kinds of data can be found (or can be generated) to substitute those that are protected or private to be used. Specific techniques for anonymization preserving validity may help in this sense, and are getting a larger diffusion.



Thus, the first step to enforce the AI in your processes must pass from trusting and deep assessment / validation of the process and solutions proposed to verify its capabilities in being t**rustworthy, Ethics**, and compliant with **GDPR, AI Regulation of EU act**, etc. In this phase, the methodologies of incidental finding have to be applied since, unexpected results and implications could be incidentally discovered, and in some cases could make evident the presence of hidden biased aspects on data and in the processes. The ethic committee has to be promptly informed and the data set used changed and/or adapted to avoid the identified problems.

CHALLENGES

Among the most relevant challenges for the cities in the coming years we see the transporation, parking, energy, waste management, tourism management, and ecological transitions KPI (key performance indicators), the SDG (Sustainable Development Goals) (see https://www.snap4city.org/776), and the push to more liveable cities according to 15 Min City Indexes and driving urban transitions to a sustainable future, DUT. Sustainability and SDG are not something that one can solve with a single action. All the governs and institutions have identified hundreds of indicators which may influence the well-known SDG, SUMI, SUMP/PUMS, DUT and 15MinCityIndex (https://www.snap4city.org/652).

Snap4 has developed the 15MinCityIndex, adopted in the whole Italian territory with the ENEL-X platform. The 15MinCityIndex itself may be used to learn how to improve the SDG for each single micro area of the territory. And a number of solutions which can positively impact on the SDG, as well as tools for the estimation of the SUMI indicators, which can be more formally computed and replicated with standard Snap4City tools.

Some of the AI models can be very computationally intensive/ expensive (especially in the training phase, and some of them also in execution/production, which is typically much less computationally expensive), while acceptable compromises from precision and computational costs can be in most cases proposed, see for example the white papers proposed by Snap4, in which for each high precision solution, the computational costs and the compromises are proposed.

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

7 AFFORDABLE AND CLEAN ENERGY
- Optimization of car sharing/pooling
- Monitoring and Prediction of energy consumption
- Stimulating: Bike sharing, e-bikes, car charge, etc.
- Sizing energy plant

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

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

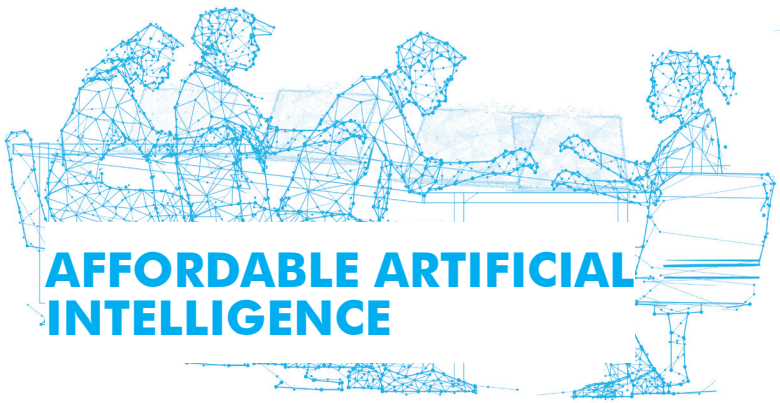
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
- Optimization of Waste Collection
- Business intelligence tools for decision makers
- Reduction production costs
- Monitoring resource consumption

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

16 PEACE, JUSTICE AND STRONG INSTITUTIONS
- Shortening justice time
- Prediction of mediation proneness
- Assisting institution in taking legal decisions
- Anonymization and indexing legal docs
- Ethical Explainable Artificial Intelligence

MAIN SOLUTIONS

- **TRAFFIC OPTIMIZATION**
  https://www.snap4city.org/1014
- **TRAFFIC LIGHT PLANNING**
  https://www.snap4city.org/1015
- **3D DIGITAL TWIN**
  https://www.snap4city.org/749
- **PARKING MANAGEMENT**
  https://www.snap4city.org/1013
- **SMART LIGHT MANAGEMENT**
  https://www.snap4city.org/968
- **CITY USERS' ENGAGEMENT**
  https://www.snap4city.org/1018
- **SECURITY MANAGEMENT**
  https://www.snap4city.org/966
- **SNAPADVISOR**
  https://www.snap4city.org/1116
- **BUILDING MANAGEMENT**
  https://www.snap4city.org/970
- **ENVIRONMENT CONTROL**
  https://www.snap4city.org/1037
- **WASTE MANAGEMENT**
  https://www.snap4city.org/982
- **15MIN CITY INDEX**
  https://www.snap4city.org/652
- **CAR SHARING/POOLING**
  https://www.snap4city.org/1004
- **ENERGY MANAGEMENT**
  https://www.snap4city.org/1038
- **TOURISM MANAGEMENT**
  https://www.snap4city.org/1017
- **ADVANCED ROUTING**
  https://www.snap4city.org/1106
- **SIMULATION SUPPORT**
  https://www.snap4city.org/1121



AFFORDABLE ARTIFICIAL INTELLIGENCE

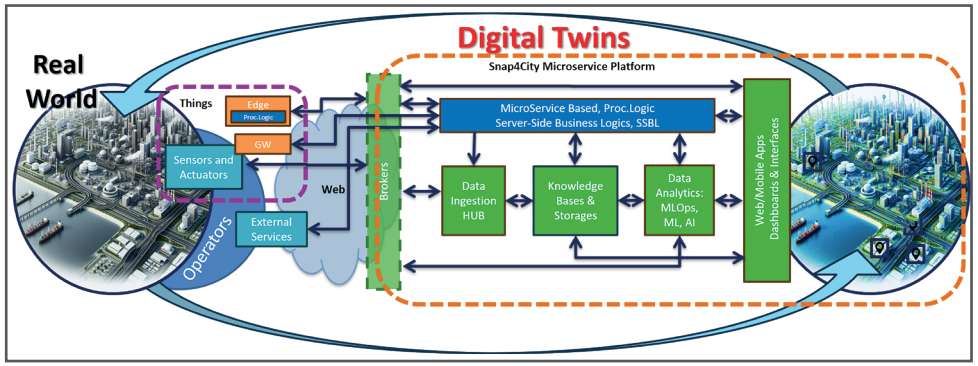
Moreover, the most recent techniques of **transfer learning, fine tuning, and augmented learning**, cmay drastically reduce the costs for setting up AI solutions (reducing the training costs) by starting from similar previous AI/XAI models also developed in similar contexts, and preserve data privacy. The approaches are reducing the amount of data and cases needed for training the AI in the new conditions by exploiting pretrained models, and/or distributing the effort among several sites with federate learning. Activities, which reduce the training costs, in some cases may hide licensing costs of using pretrained models (for instance in data access, or ready to use model exploitation). Mechanism of federated learning allows us to accelerate the training process using data and experiences from several cities and sites at the same time. Techniques such as **reinforced learning, generative AI, lifelong learning**, etc., are more expensive since the training process is used for producing prescriptions, optimization, and generate suggestions, answers, etc. On the other hand, the results produced are very effective with respect to those which can be obtained by classic optimisations techniques of the operating research such as Simulating Annealing, Stochastic Relaxation in general.

To obtain an affordable AI is not a matter of data and neither of API, while is more an issue of AI/XAI models fitting with the expected goals. The model should technically pass from a training experience to a next conserving the AI architecture in primis and thus also the data semantics, the format is less relevant technical aspects, also via neuro-symbolic approaches. In this sense, Snap4 with its Knowledge Base ontology, Km4City, can be a key to make any data interoperable at semantic level, and most of the Snap4 are Neuro-Symbolic, mixing the best of the knowledge modelling and inference with the neural network approaches.

DATA MODELING AND INTEROPERABILITY

The Digital Twin with data modelling, Internet of Things, IoT, and of the Web of Things, WoT, and its integration with AI, ML, XAI, Simulation, Big Data are mature regarding the data collections, in the sense that any kind of data can be collected and aggregated into the most powerful platforms for smart city, Industry 4.0, health, energy, environment, mobility & transport, marketing, commercial, etc. On the other hand, for most of those domains the actual range of needs is much wider. Snap4City/Industry is one of the most powerful platforms in terms of interoperability with high level types, FIWARE Smart Data Models, Data Spaces, IoT Device Models, GIS data, ITS, OPC, OBD2, satellite data, Origin Destination matrices, road graphs, trajectories, shapes, traffic flow, city scenarios, flows in 3D, 3D Digital representation for cities, BIM, typical time trends, trajectories, scenarios, etc.

Snap4City/Industry includes Km4City ontological and semantic model (https://www.km4city.org) to guarantee the data interoperability with EC Data Spaces, FIWARE Smart Data Models, IoT Data Models, and a large range of High Level Types, providing a number of real-time open source solutions to support decision makers in cities and large industries to ground their daily operational actions on solid ethical and explainable AI predictions, deductions, prescription, and assessments. It provides a complete understanding of the context and its trends, receiving early warning, anomaly detections, and performing simulations, optimization and what-if analysis with generative AI. This information is used to suggest and plan strategic/tactic and real time interventions to improve city services and general quality of life, reduce congestions, emissions, costs, in multiple domains (e.g., mobility, transport, energy, government, tourism, security, safety, environment, civil engineering).



Interoperability: In the large range of smart city solutions, Snap4 technology is compliant with more than 190 protocols and formats fully integrating legacy systems, and it capable to fully interoperate and/or integrate any other system/application. It is highly interoperable with any GIS (Geographical Information Systems), BIM (local Digital Twin), CKAN (open data networks), Satellite Services, OSM (Open Street Map), GTFS/NeTex, MQTT, NGSI, SAML, OPC, OGC, transport protocols, and IoT Networks protocols (IoT protocols), WoT, smart data models, Data Spaces, services and databases, mobility and transport protocols, Mobility as a Service protocols, CMS, Authentication and Authorization protocols, Energy data models, Industry 4.0 protocols, cluster GPU/CPU protocols, external services and databases: https://www.snap4city.org/283, https://www.snap4city.org/65

AI has to be totally integrated with Digital Twins. Digital Twin aims at creating a digital counterpart of the physical entities and lead them working together for operational use. On the other hand, most of the physical solutions in operation are not smart at all, this means that the Digital Twin becomes the intelligent engine of the physical one in most of those cases. The **Snap4 technology** Digital Twin (https://digitaltwin.snap4city.org) models all the different entities of a city to represent and manipulate them in 2D/3D as buildings, road network, energy network, services, peoples, vehicles, traffic flow, busses, trees, furniture, IoT devices and sensors, KPI, BIMs, etc. Then, multiple Digital Twins of the city/area can be managed at the same time. The current Digital Twin in operation, as well as a set of Digital Twins which can be regarded as a sort of sandboxes for simulation and assessment of solutions for their plan and analysis at reduced costs.

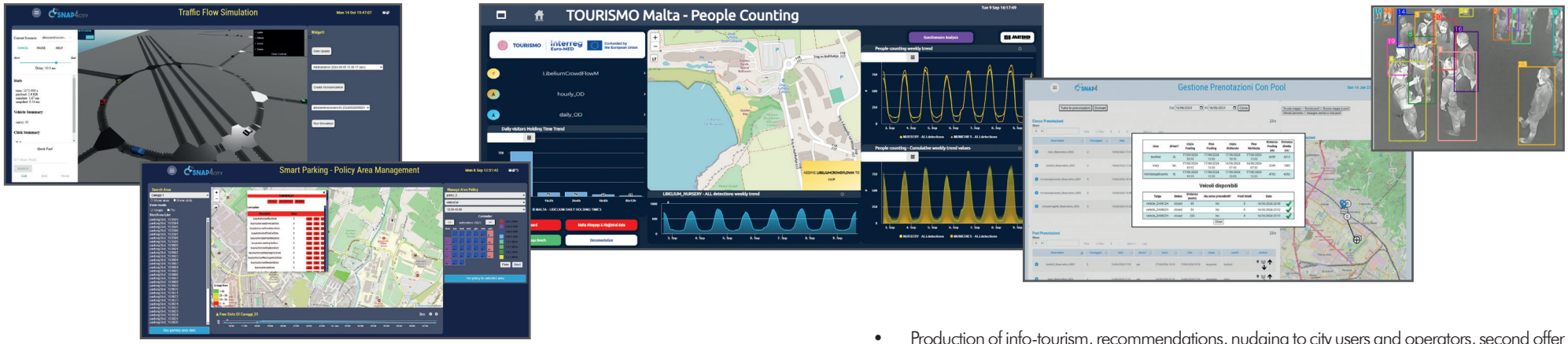
READY TO USE DATA ANALYTICS

Snap4City means: **Smart aNalytic APp builder for sentient Cities and IoT.**

Snap4 Technology has been created by DISIT Lab since the 2017 grounded on AI and respecting ethics and GDPR compliant, and end-2-end secure (passing the PENtest). In these years, DISIT Lab has developed a large number of solutions in the context of Smart City and Industry 4.0. Snap4 solutions fully support the development of real time data analytic processes through ML, AI, ethic trustworthy, XAI via languages such as Python, R-Studio, also exploiting Tensor Flow, Pandas, Keras, BERT, LLM, MLOps, and any kind of library for data analytics, ML and AI. DISIT lab via Snap4City, Snap4Industry, etc., is distributing a number of Open-Source and licensed AI solution and tools for: prediction, anomaly detection, classification, critical condition detection, constrained routing, optimization, analysis of demand vs offers of transportation, production of prescriptions and suggestions, and many others. Most of them have been published on international top-level journals and are tuned on demand on your cases. AI and smart application support are fully integrated into What-If analysis and optimisation tools in control rooms and for the operators, at the service and to simplify the solutions of complex scenarios. DISIT lab has a consolidated experience in the development, validation and transfer AI/XAI solutions (see course https://www.snap4city.org/944). Most of the DISIT lab solutions are based on ML, Deep learning, AI, XAI, LLM, natural language processing (NLP), sentiment analysis (SA), semantic reasoning and computing, neuro symbolic AI, ontological reasoning, generative AI, reinforced learning, federated learning, etc. In the following, a number of examples are listed, while more details can be recovered from the Snap4City course and from technical notes https://www.snap4city.org/997

Mobility and Transport

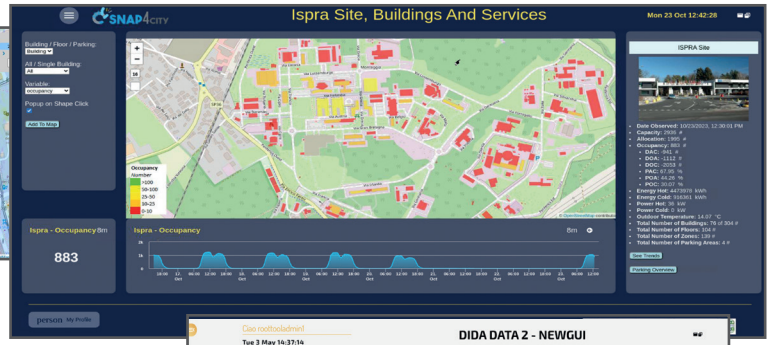
- Goals:
  - Decongestion, Decarbonization, Cost Reduction, Improve Accessibility to services, Improve Security/Safety of city users
- **Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)**
  - Monitoring traffic, parking, people flow, services, boats, ports, beaches, etc.
  - Early detection/warning of critical conditions: traffic, congestion, security/safety
  - Managing Smart Parking, transportation services, fines, etc.
  - Managing fleets: personal, sharing, waste collection, maintenance, etc.
  - Managing E-sharing, pooling services, MaaS, etc.
  - Managing entrances in city areas: restricted areas, touristic busses, etc.
  - Performing routing, multimodal routing, routing for operators, routing for public transport
  - Production of suggestions, recommendations, nudging
  - Computing predictions of any kind
- **Solutions for Planning (optimization and what-if analysis)**
  - Reduction of traffic congestion, via optimization: traffic light plans, viability, routing
  - Reduction of Pollutant Emissions, via optimization: traffic light plans, viability
  - What if analysis, routing Traffic light optimisation
  - Optimization of transportation offers wrt multimodal mobility demand
- **Algorithms and computational solutions**
  - **Optimisation of viability of an area for reducing congestion, waiting time, stops**
  - **Optimisation of Traffic Light Plans, synchronization, in an area for reducing congestion, waiting time, stops**
  - **Predictions** for: traffic flow, smart parking, smart bike sharing, people flows, etc. (ML, DL)
  - **What if analysis**: rrouting, traffic flow, demand vs offer, pollutant, etc. (Simulation + ML)
  - **Traffic flow reconstruction** from sensors and other sources (simulation + ML)
  - **Public Transportation:** Ingestion and modelling of GTFS, Transmodel, NeTEx, etc. (DP)
    - Analysis of the **demand mobility vs offer transport** of according to public transportation and multiple data sources (Simulation)

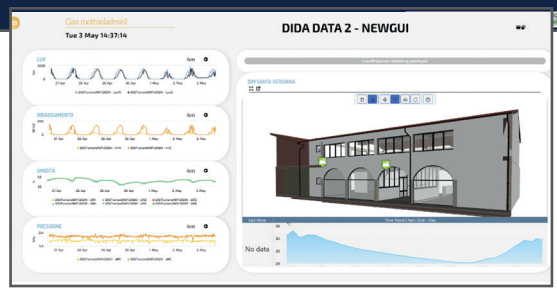


- Assessing **quality of public transportation** (analysis)
- **Accidents** heatmaps, anomaly detection (analysis, ML)
- **Road light controlled by traffic conditions**
- **Tracking fleets**, people, via devices: OBU, OBD2, mobile apps, etc. (DP)
- **Routing** and multimodal routing (multistop travel planning), constrained routing, dynamic routing (DA)
- Computing **Origin Destination Matrices** from different kind of data (analysis, DP, DP)
- Computing **typical trajectories** on the basis of tracks (analysis, ML)
- Fleet management, monitoring, booking, allocation, maintenance
- Computing Messages for Connected drive (DP)
- Slow and Fast Mobility **15 Minute City Indexes** (analysis, DP, …ML)
- Computing and comparing traffic flow on devices and at the city border (analysis)
- **Typical time trends** for traffic flow and IoT Time series. (analysis, ML)
- **Impact of COVID-19** on mobility and transport
- Computing **SUMI, PUMS**, etc. (mainly DP)
- **Definition of Scenarios:** traffic, road graph, conditions, etc.

City User Behaviour/services, Tourism and Safety

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





Environment, waste, land, etc., Domain

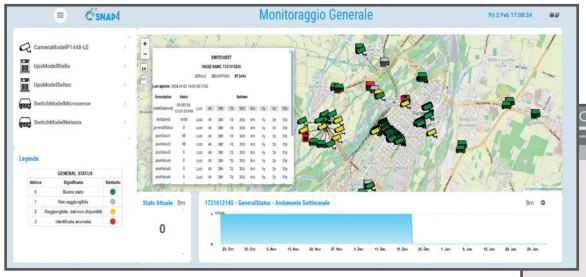
- Goals:
  - Reduction of emissions and EC taxations
  - Cost reduction for waste collection, reduction of waste collection impact on mobility
- **Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)**
  - Monitoring emissions, weather, waste, water, etc.: sensors, traffic, flows, ….
  - Early detection/warning of critical conditions on emissions, weather, waste, water, fire, animals, …
  - Early detection/warning of critical conditions for landslides, water flooding, beach
  - **Smart Waste Management:** bins/lockers, waste collection daily plan, pay as you throw, PAYT, etc.
  - Short terms prediction of emissions: CO2, NO2, etc.
  - Production of suggestions, nudging
  - Computing and predicting of long terms KPI indicators of the European Commission
- **Solutions for Planning (optimization and what-if analysis)**
  - Identification of main CO2/NO2 emissions locations in the city, total production from traffic
  - Reduction of Pollutant Emissions, via optimization: semaphore cycles, viability
- **Algorithms and computational solutions**
  - **Pollutant Predictions: short, long and very long term** European Commission KPIs
    - NOX, PM10, PM2.5 pollution on the basis of traffic flow, 48 hours (ML, AI, DL)
    - Cumulated NO2 average over year (ML, AI, DL)
  - **Computation of CO2** on the basis of traffic flows (DP), computing emission factor (DA)
    - each road for each time slot of the day
  - **Prediction of MicroClimate** conditions for diffusion (ML, AI)
    - NO2, PM10, PM2.5, etc.
  - **Prediction of landslides**, 24 hours in advance (AI, DL)
  - Prediction of **waste collection**, & optimisation of schedule and paths (DP, ML)
  - **Heatmaps production** dense data interpolation (DP) for
    - Weather conditions: temperature, humidity, wind, DEW
    - Pollutants and Aerosol: NO, NO2, CO2, PM10, PM2.5, etc.
  - **Impact of COVID-19** on Environmental aspects (DP)
  - Computing **SDG, SUMI, SUMP,** .. (mainly DP)

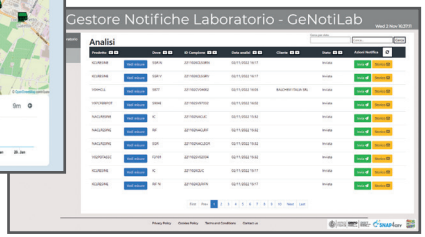
Snap4Building Domain

- Goals:
  - Increase efficiency, cost reduction, sustainability
  - Accessibility to services, Security/Safety
- **Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)**
  - Monitoring: usage, energy, environmental conditions, people flows, services, etc.
  - Early detection/warning, alarm, of critical conditions, notifications, decision support
  - Production of suggestions/prescriptions, nudging
  - Managing smart services: cabinets, dispenser, lockers, etc.
  - Global and local 3D/2D representations of area and buildings
  - Integration with Video Management Systems
  - Computing predictions of any kind
- **Solutions for Planning (optimization and what-if analysis)**
  - Reduction of energy costs via optimization
- **Algorithms and computational solutions**
  - **Digital Twin for monitor, control and manage distributed infrastructures**
  - 2D/3D representations of the whole set of buildings, BIM modelling
  - Entities (building, floors, rooms, parking, charging stations, gates, etc.) with their shapes and descriptors, and data monitoring the allocation to office, meeting, cafeteria, storage, stairs, elevator, etc.
- **Monitoring and computing KPIs on real time for**
  - **Energy** consumed or produced (hot/cold), **parking, logistic, presences, cleaning, air quality, departments, subareas, maintenance, etc.**
  - **Allocation/designation**, dispositions, heating, cooling, temperature, equipment, etc.
  - **Grouped in Zones.**

Energy Domain

- Goals:
  - Energy consumption reduction, increment of efficiency, sustainability
  - Improve area and building sustainability
  - Improve accessibility to services
- **Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)**
  - Monitoring energy consumption (heating, cooling, prod.,..), conditions, charging stations, etc.
  - **Managing Smart Light** for city: dimering, programming, traffic control, controllers, legacy, etc.
  - Early detection/warning, alarm, of critical conditions
  - Managing smart services: cabinets, lockers, etc.
  - Production of suggestions, nudging
  - Global and local 3D/2D representations of area and buildings
  - Managing Communities of Energy, certification via Blockchain
  - Computing predictions of any kind
- **Solutions for Planning (optimization and what-if analysis)**
  - Reduction of energy costs, via optimization
  - Identification of roofs with better orientation
  - Optimization of battery storage size for PV plants
  - Community of Energy planning and viability
- **Algorithms and computational solutions**
  - **Monitoring Energy Consumption in single building, area and per zone**
  - **Smart Light management,** unicast and multi cast management, smart light controlled by **traffic flow data**
  - Monitoring Energy provisioning on **recharging station**
  - **Matching Energy consumption with respect to the actual usage**
  - **Computing Roof orientation for Photovoltaic installations**
  - **Optimisation of Photovoltaic installations** to identify the best parameters of size and storage
  - Collecting and managing **Communities of Energy**
  - Computing **KPIs**
  - **Etc.**





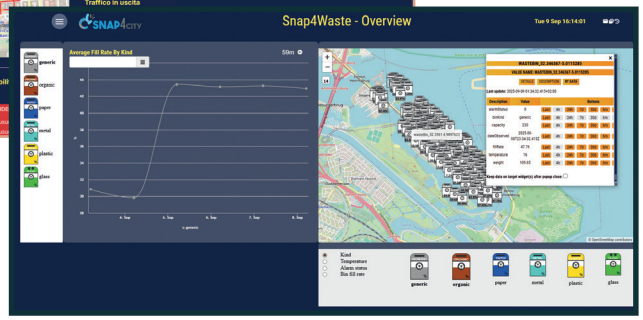
Assets Control Domain

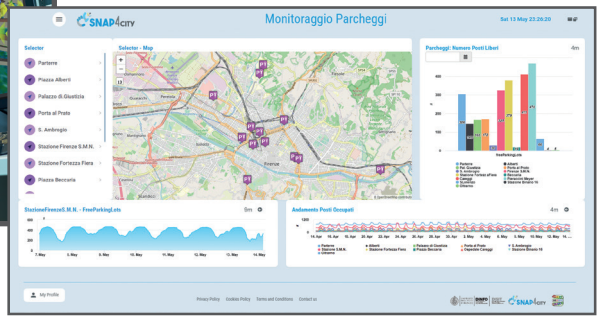
- Goals:
  - Costs reduction, increase service availability, risk reduction,
  - Improve quality Level
- **Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)**
  - Monitoring :
    - **Assets:** switches, Wi-Fi, servers, UPS, sensors, building, TV Cams, etc.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

Industry production Domain

- Goals:
  - Cost reduction, increase control on production, Production optimisation
  - Quality Level
- **Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)**
  - Monitoring KPI: administration, production, commercial, faults, etc.
  - Early detection/warning, alarm, of critical conditions
    - **Multichannel Event reporting**: email, Telegram, mobile apps, SMS, etc.
  - Managing maintenance operation, predictive maintenance
  - Computing predictions on KPI
  - Computing predictive maintenance
  - Generation of patterns in production, design, etc.
  - Solving complex physical equations with Physically Informed Neural Networks, PINN, for Simulating fluid-dynamic flows in autoclaves and machineries, cost reduction, time reduction.
- **Solutions for Planning (optimization and what-if analysis)**
  - Generative AI and predictive AI for production plan optimisation
  - Reduction maintenance costs, reduction of critical SLA conditions, improving quality level.

BENEFITS AND IMPACT





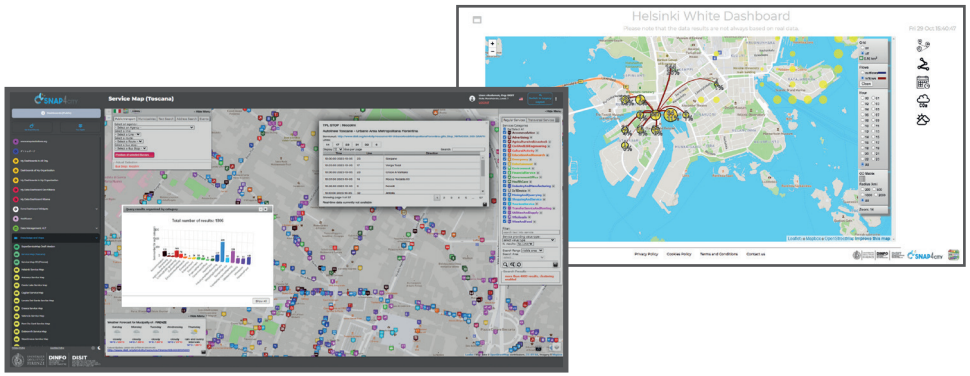
Snap4City has brought great benefits where it has been adopted for operational management, prediction, and plans. The low costs for its adoption and usage allowed many adopters to add functionalities and widely exploit the visual tools. Adopter may delegate the maintenance to Snap4City of may take full control of the platform with limited effort.

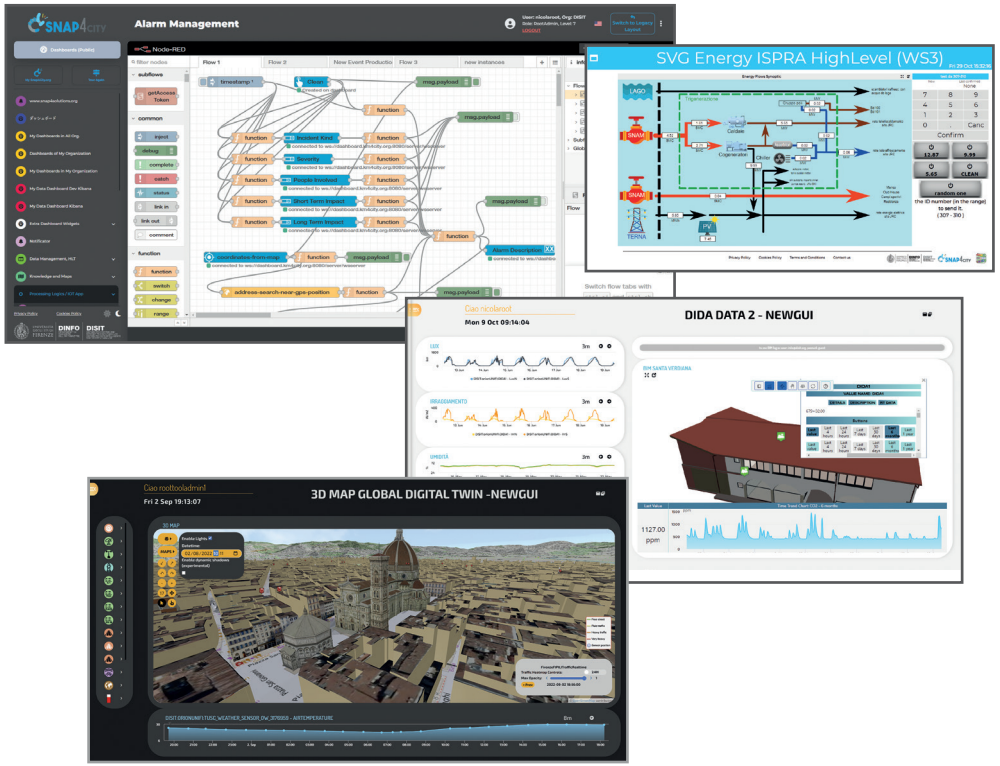
In the following, some recent operational scenarios in which AI solutions of Snap4 are briefly described, more details descriptions can be recovered from the portal.

In **Cuneo**, a Snap4City platform on premise **monitor and control ICT assets** (switched, APC, TV Cameras) and security and by using special AI tools of Snap4City Plugin on AXIS thermal camera to count people and detecting critical cases and notifying events in real time. **Benefits**: reduction of costs, increment of security, increment of reliability. https://www.snap4city.org/975

For **CN MOST** (national center on sustainable mobility in Italy), a Snap4City **national platform** named **Mobility4Future provides solutions as a service for small and medium cities** regarding operation and plan for the reduction of congestion and emissions. To this purpose a number of AI tools of Snap4 are disposal of the cities such as: advanced routing, road infrastructure optimisation, traffic monitoring, simulation of traffic conditions, match demand and offers of public transportation, computation of SUMI, etc. See flagship actions as OPTIFaaS, LeverageOPTIFaaS, SASUAM. **Benefits**: reduction of congestion and emissions, reduction of costs for mobility planning, reduction of costs for KPI computing. https://www.snap4city.org/1008

In **Florence, Valencia, Varna, Malta, Limassol, Rhodes, and Bisevo**, Snap4City.org provides service for monitoring and managing tourism flows in the areas and on major attractions. Services include dashboard and AI tools for: monitoring people counting and flow, analysing questionnaires with LLM and producing suggestions, producing forecasts, providing info Tourism in real time, assessing environmental conditions, computing people flows and ODM, etc. Multiple kind of sensors, cameras, drones, and sniffers are used for the purpose with AI and LLM (SnapAdvisor). Benefits: reduction of services congestion, enabling data driven decisions, better distribution of tourists, increment of resilience and fastening the problem detection. Similar action has been done in Dubrovnik, Mostar, Pont Du Guard, etc. https://www.snap4city.org/1001





In **Careggi Hospital of Florence, SnapAdvisor** shortening the analysis of the decision makers in the legal department providing real time responses on the sensitive information of the disputes. A similar solution has been also used by the Florence Tribunal in the process of disputes which can be pushed on mediation. Benefits: reduction of processing time and costs. https://www.snap4city.org/1116

In **ALTAIR chemical plant**, Snap4 solution collect data regarding the H24/7 continuous production to support the quality control production process, providing notification, and getting feedbacks and decision from decision maker in real time. Benefits: improvement of product quality, reduction of processing time and costs. https://www.snap4city.org/815

Several other installations and services have been performed in multiple cities and areas. See for a large list and for updates: https://www.snap4city.org/4 and/or https://www.snap4city.org/download/video/cov/, installed Snap4City platforms https://www.snap4city.org/661

Snap4City has been adopted in a number of European, national and regional actions and projects: TOURISMO Interreg, AMMIRARE Interreg, ELLIE Horizon Europe, Tuscany X.0 EDIH, CAI4DSA of FAIR PE (national project on Artificial Intelligence for society), CN HPC big data and quantum computing (DI-DTPlatform, UrbanDR4TF), SMART3R-FLITS, SADI-MIAC, REPLICATE lighthouse H2020, RESOLUTE H2020, TRAFAIR CEF, Sii-Mobility MIUR, SODA4.0 of ALTAIR, 5G MIUR, MOBIMART Interreg, HERIT-DATA Interreg lighthouse, Life Weee, IMPETUS, MOSAIC, AMPERE, Enterprise, PANACEA, ALMAFLUIDA, Energia, BullVIT, The, Masterpiece, and PC4City, etc. These actions have involved a large number of partners from private industries and public institutions (cities, regions, universities, foundations) working and using Snap4City platform. For most of them, a dedicated web page is provided on main platform, see the news on these issues on https://www.snap4city.org/135 Moreover, since a number of years Snap4City platform is on progressive adoption of the SOC of ISPRA JRC of the European Commission.

Awards: DISIT lab started the Snap4City line since 2013 with the first data integration for Florence city, and in the 2019, turned out to be the winner of the Select4Cities PCP of EU managed by Antwerp, Helsinki and Copenhagen, one year later won the ENEL-X open data challenge in 2020. Also, Herit-Data action with Snap4City platform received the Lighthouse flag from the European Commission. Currently, Snap4City is one of the platforms of the EOSC (European Open Science Cloud), library of Node-RED, CN MOST, CN HPC big data and quantum computing, etc., and DISIT Lab is a Gold Member of FIWARE and an official FIWARE Platform and Solution, certified Consultant, certified Trainer, provides two certified FIWARE Experts; member if GAIA-X; and recent best awards for Digital Twin platform for Smart Cities from DMS, and ICCSA communities, and from the observatory of Digital Twins of FBK and IFAB in the context of CN HPC big data and quantum computing.

PAOLO NESI

Prof. Eng. PhD **Paolo Nesi** is a full professor at the University of Florence, UNIFI, working at DINFO, Department of Information Engineering (Computer Science Department), Chair of DISIT Lab of UNIFI, and chair of https://www.Snap4City.org which is an official platform of FIWARE, platform of EOSC, Library on Node-RED, etc. P. Nesi main research topics are: big data analytics, AI/XAI, distributed systems, IoT/WoT, cloud, security and privacy, knowledge engineering. He has more than 30 years of experience in developing predictive and prescriptive solutions based on neuro-symbolic, AI, XAI, NLP, computer vision, etc., in a large range of domains, as from more than 400 international papers. He founded and is the Director of the DISIT Lab (https://www.disit.org). He has been scientific coordinator of large international research and innovation projects such as: LeverageOPTIFaaS, CAI4DSA, Snap4City H2020 EC, Resolute H2020, Sii-Mobility national mobility and transport action in Italy, AXMEDIS EC, ECLAP EC, etc., and smart solutions responsible of many others such as TOURISMO, SADIMIAC, Replicate H2020 EC, Trafair CEF, ICARO Cloud, HeritData EC, Mobimart EC, Weee Life, etc. He has been chair of IEEE SC2, IEEE ICSM, IEEE ICECCS, AXMEDIS, DMS, IEEE BDS, .. and programme chair of many others. He is editor of international journals, member of the national Italian center of sustainable mobility CN MOST (national mobility and transport center), member of the CBDAI (Center for Big Data and Artificial Intelligence of the Tuscany Region), member of the EDIH Tuscany-X board, scientific board member of the PhD-AI National PhD Course on Artificial Intelligence, certified FIWARE Expert, scientific board member PhD course of UNIFI on Information Engineering, scientific advisory board member of a number of EC International Projects, of BBC, IFAB, EMDS (mobility data space). He has been the recipient of a number of Awards as: recognized top 15 researchers worldwide in the area of software engineering for two years, Snap4City First place awards, a number of best paper awards, etc., and he has been co-chair of SMR MPEG-4. P. Nesi is a member of IEEE, ACM, AI*IA, CINI, CNIT, ISO, FIWARE, Gaia-X. Currently principal investigator of CAI4DSA, and platform responsible for SASUAM, OPTIFaaS, ELLIE HE, ISPRA JRC SOC, SmartCyprus, BulVit, AMMIRARE, UrbanDT4TF, DI-DTPlatform, all based on Snap4City solutions.

Google Scholar: *https://scholar.google.com/citations?user=c2S3Ni0AAAAJ&hl=en*
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YouTube: *https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandg*

- **SCENARIOUS**
  https://www.snap4city.org/4

- **ORGANIZATIONS**
  https://www.snap4city.org/download/video/cov/

- **INTEROPERABILITY**
  https://www.snap4city.org/65

- **APPLICATIONS / PROCESSING**
  https://www.snap4city.org/997

- **HOW TO INSTALL**
  https://www.snap4city.org/738

- **CLIENT SIDE BUSINESS LOGIC**
  https://www.snap4city.org/911

- **DIGITAL TWIN**
  https://digitaltwin.snap4city.org/

- **LATEST NEWS**
  https://www.snap4city.org/135

- **ARTIFICIAL INTELLIGENCE**
  https://www.snap4city.org/524

- **ARTICLES**
  https://www.snap4city.org/78

- **SNAP4INDUSTRY**
  https://www.snap4industry.org

- **SIMULATORS**
  https://www.snap4city.org/1053

- **DEVELOPMENT LIFE CYCLE**
  https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf
  https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf
  https://www.snap4city.org/91

- **TECHNICAL OVERVIEW**
  https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf

- **SNAP4CITY FIWARE IMPACT STORY**
  https://www.snap4city.org/drupal/sites/default/files/files/FF_ImpactStories_Snap4City.pdf

ONLINE TRAINING MATERIAL OVERVIEW

https://www.snap4city.org/944

The training course is open free of charge and includes frontal slides, full access to the platform and development tools, and exercises during the courses. Participants should be registered on https://www.snap4city.org performing the free registration as DISIT Organization or on their own Organization if they have one on Snap4City.

- **Overview:**
  - Objectives and Tasks, architecture and Digital Twin
  - Monitoring and Control: Mobility, Humans, Engagement, ..
  - Decision Support Systems, planning, what-if and optimization
  - Data Analytics, Artificial Intelligence, XAI, ML
  - Traffic Light Plan Optimisation
  - Traffic Infrastructure Optimization
  - Industry Domain: predictive maintenance
  - Autoclave Cycle: Energy Optimisation
  - Developing on Snap4City platforms
  - Training Suggestion and publications / further reading
  - Development Costs Advantages
  - Accelerating on Smart City Deploy with Snap4City
  - Platform Administration
  - Domains
    - Control and Planning
    - Mobility and Transport
    - Smart Energy and Smart Building
    - Environment and Waste Management
    - City Users' Services and Tourism Management
    - Assistants on Taking Decision, and for training development
    - Industry domain
- **Dashboard Purposes and Uses**
  - Main Data Kinds: data vs representations
  - Dashboards Main Concepts and simple Widgets
  - Creating a Snap4City Dashboard, wizard
  - Multi Data Map Widget
  - High Level Types, video, external services, synoptics
  - Selector for the Multi Data Map Widget
  - Data Inspector vs Data Processes Details
  - Dashboard Management
- **IOT App, Process Logic, Server Side Business Logic**
  - Recall on Snap4City Architecture
  - Node-RED
  - ProcessLogic as IOT App = Node-RED + Snap4City
  - Examples of IOT App for Smartening Solutions
  - Exploiting/Generating data by using: IoT App/ProcessLogic
  - External Service <-> IoT App/ProcessLogic
  - Dashboards <-> IoT App/Process Logic
  - Server Side Business Logic
- **Data Analytics and Artificial Intelligence**
  - Why and Where use DA, AI and XAI -> General Life Cycle, scenario editor, monitoring and control
  - Data Processing: KPI, traffic, emissions, public transport quality
  - From Data Analytics, DA to Artificial Intelligence, AI
  - List of the most relevant available DA and AI Solutions
  - Predictions and Anomaly detections: parking, biking, NOx, landslide, people
  - Computing: Higher Level Types Data and their representations: traffic, heatmaps, 3D
  - Human Behaviour, Engagement, Typical Time trends, WIFI sniffing
  - Using AI in main domains: Mobility and transport, traffic optimization, Smart Energy, Smart Building, routing
  - How AI/XAI, and Life Cycle, AI/ML requirements, XAI,
  - Using DA, AI/XAI in Snap4City infrastructures
  - Data Analytics <-> IoT App / Proc.Logic
  - MLOps, ClearML, exploiting clusters of GPU/CPU, using them from smart applications
  - Decision Support Systems and What-If Analysis, transport offer, DORAM tool
  - Integrated Traffic and mobility Simulation via SUMO
  - Routing, Multimodal Routing, Dynamic Routing
  - Predictive Maintenance
  - Industrial Applications

- **Data Ingestion and Interoperability**
  - When Solutions and tools for Data Ingestion and Interoperability are needed
  - Overview of Snap4City Data Storage and Stack
  - Knowledge Base: Modelling and Setting Up
  - High Level Types vs Ingestion Process
  - Data Ingestion Strategy and Orientation
  - Ingestion of Points of Interest with POI Loader
  - Models vs Devices/Entities and Registration
  - Verification of Data Ingestion
  - Digital Twin Data Inspector vs Data Processes Details
  - My Data Dashboard Dev to assess data on Open Search Storage
  - An Integrated Example for Time Series
  - Entities Ingestion with Data Table Loader
  - High Performance Ingestion via Python
  - FIWARE Smart Data Models on Snap4City
  - Ingestion of MyKPI with Proc.Logic / IoT App
- **Snap4City Platform Architecture, Interoperability, Management and Deploy**
  - Snap4City Architecture
  - Interoperability of Snap4City Platform
  - Exploiting Satellite data
  - Interoperability with respect to Hardware staff
  - Adding Features and Modules to Snap4City
  - FIWARE and Snap4City
  - Snap4City vs State of the Art Solutions
  - Smart City planning with Snap4City Team Support
  - The Role of the Living Lab Support
  - Snap4City Platform: Administration Overview
  - Snap4Tech: Smart Solutions as a Service
  - Deploy Snap4Tech solutions: Docker, Kubernetes, VM based
  - Monitoring with Snap4City Sentinel
- **Exploiting Snap4City API, and Web/Mobile Applications SDK**
  - Smart City API: Internal and External
  - Concepts and tools for using Knowlege Base, ServiceMap, API
  - Federated Knowledge Bases and Smart City APIs
  - Advanced Smart City API
  - Access to Protected data
  - Forging and managing: Mobile and Web Apps, MicroApplications
  - Exploiting AI/ML and microservices from Smart Applications
  - Web and Mobile App Development Kit (an example)
- **Developing Smart Applications & Business Intelligence Solutions**
  - Developing in the smart city IoT/WoT context
  - Smart Solutions Development Life Cycle
  - Analysis for Innovation (Co-Creation and Co-Working)
  - Design: Data, Data Models, Data Relationships
  - Design & Develop: Data Processes Proc.Logic / IoT App
  - Design & Develop of Data Analytics
  - Design & Develop: user interfaces, visual tools
  - Visual Analytic vs Data Analytics: Client Side Business Logic Intelligence
  - Design and Control of Smart Applications
  - What is missing here and you can get from former course

The course includes slides, full access to the platform and development tools.

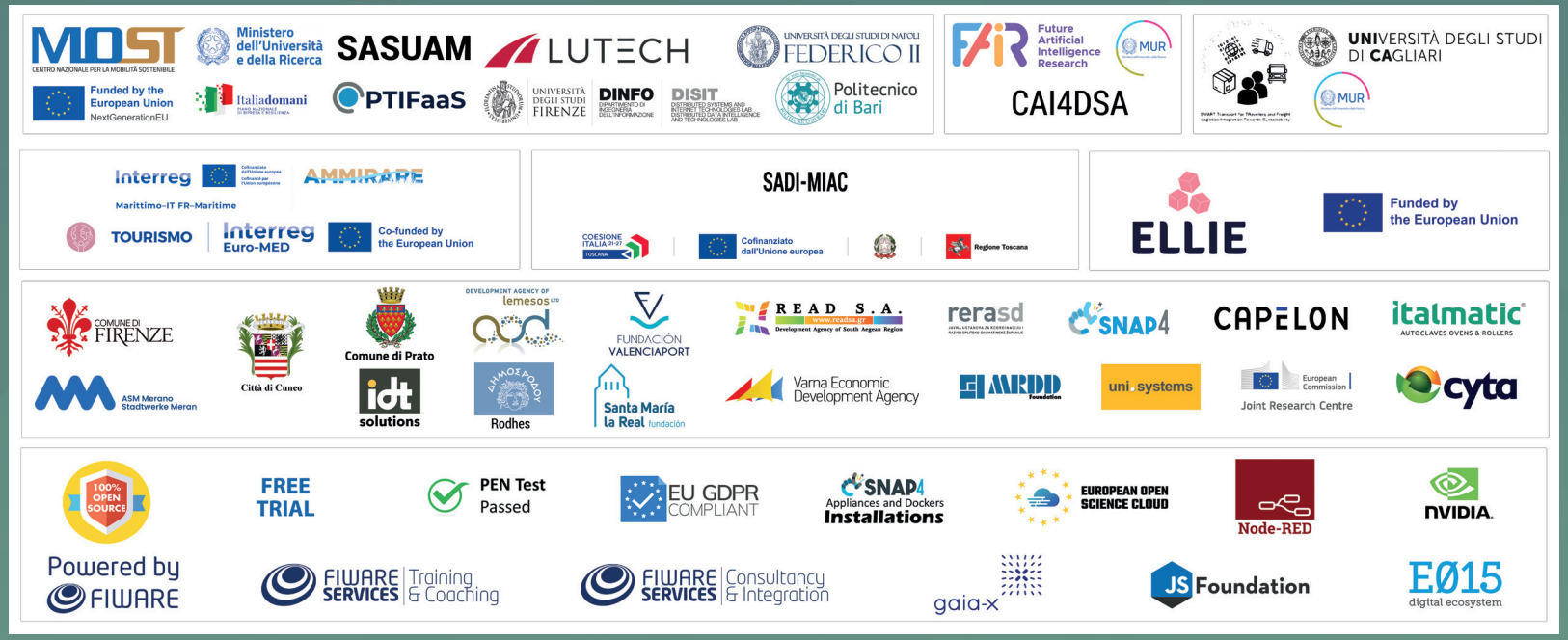
SNAP4CITY

KM4CITY

CITY

INDUSTRY

ARTIFICIAL INTELLIGENCE



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