Snap4City Digital Twin meeting European CityVerse action

Conferenza Nazionale di Geomatica e Informazione Geografica
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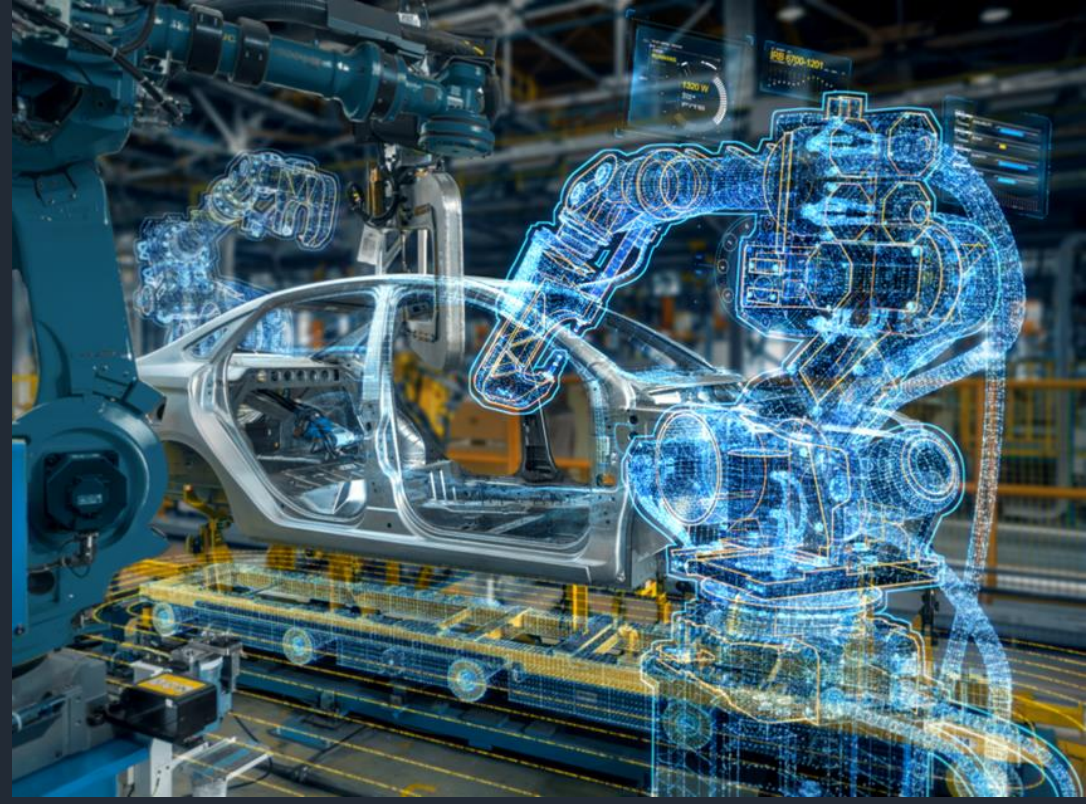
Michael Grieves, *Digital Twin: Manufacturing Excellence through Virtual Factory Replication*, 2014

Grieves considered the replication of the virtual factory as a push toward manufacturing excellence and thus actually contributed to the spread of the use of this metaphor in production engineering.

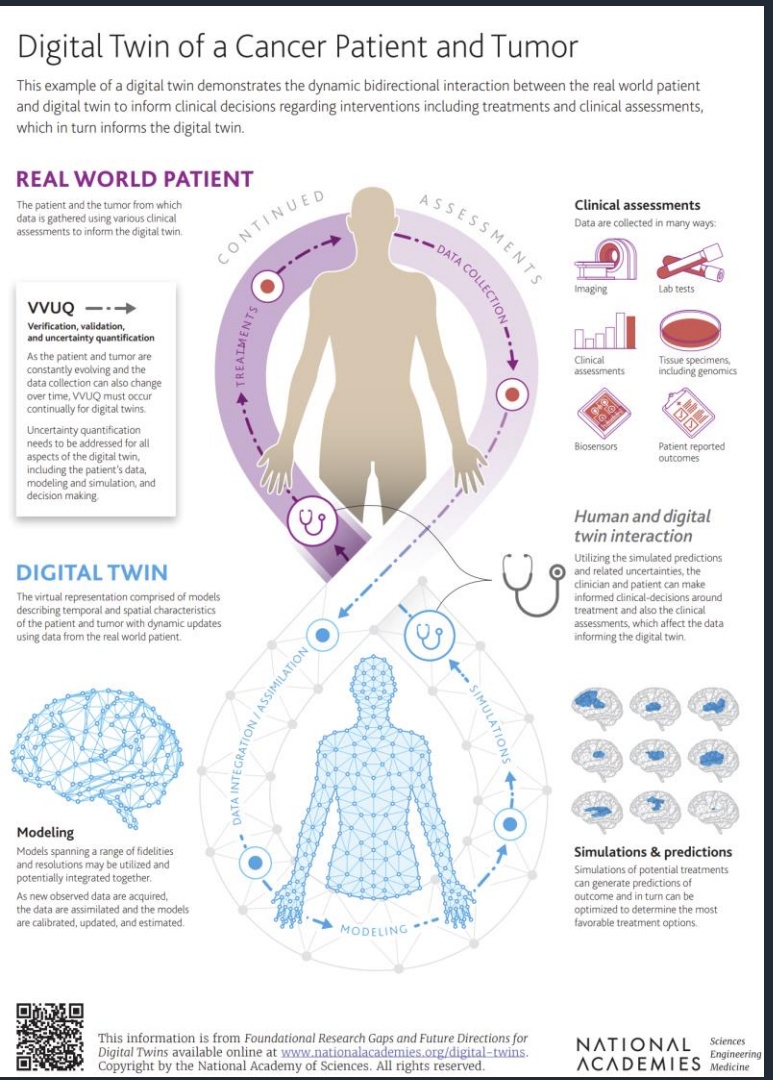
In this context, a digital twin is understood to be a mirror image of a physical process that can reproduce or simulate its operation, while it is developing in parallel with the physical process itself.



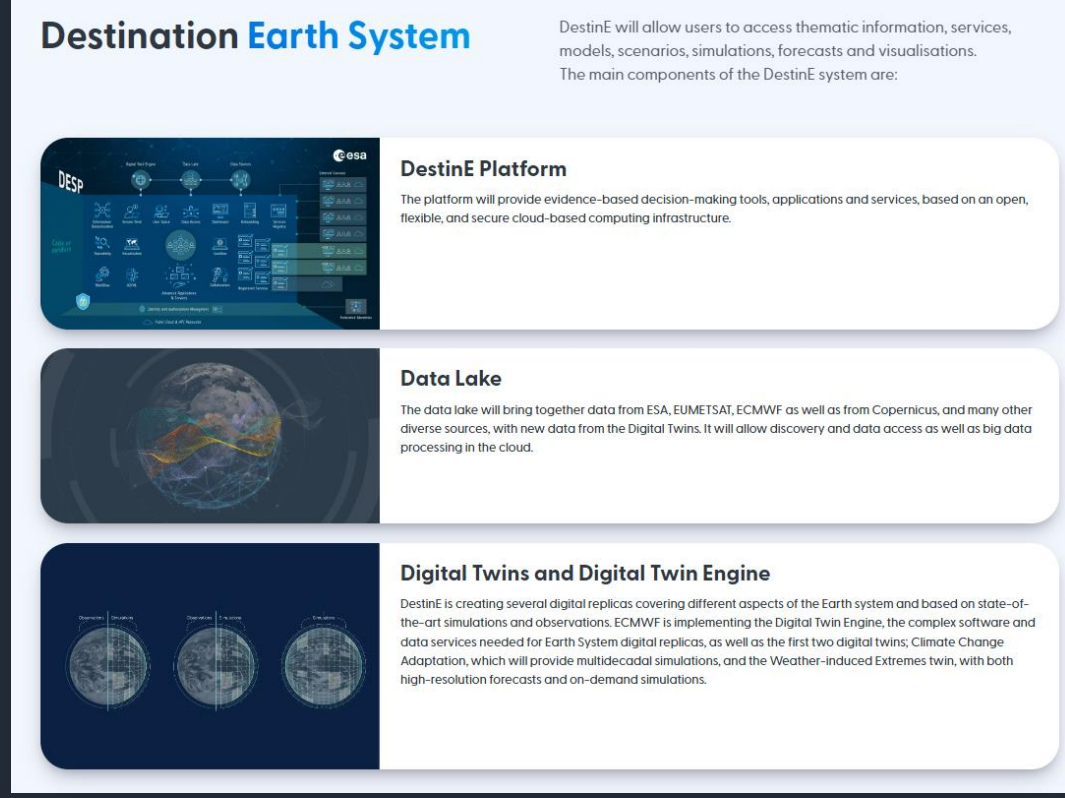
Very quickly this concept has adapted to other areas of design that are not strictly manufacturing until it has extended, with a significant leap in scale, to the design and management of more complex portions of space, from single buildings to entire cities.

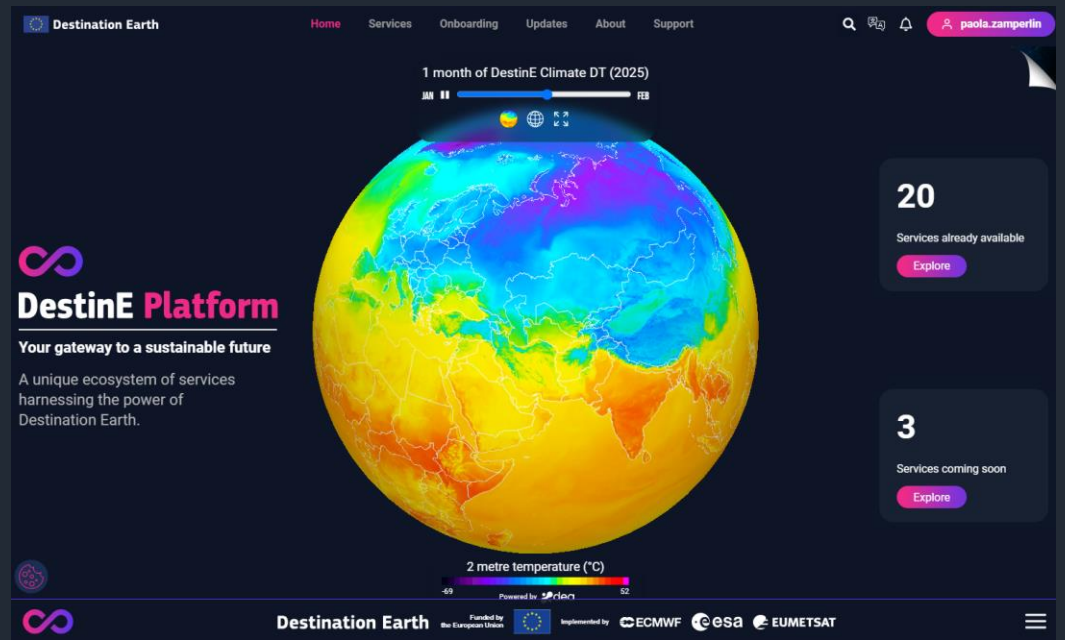
The leap in scale involves an increase in the complexity of factors and variables to be considered to create a copy of reality and the processes that occur in it.

The concept is now used to characterize various digital simulation models that develop parallel to real-time processes concerning physical, social, and economic systems.

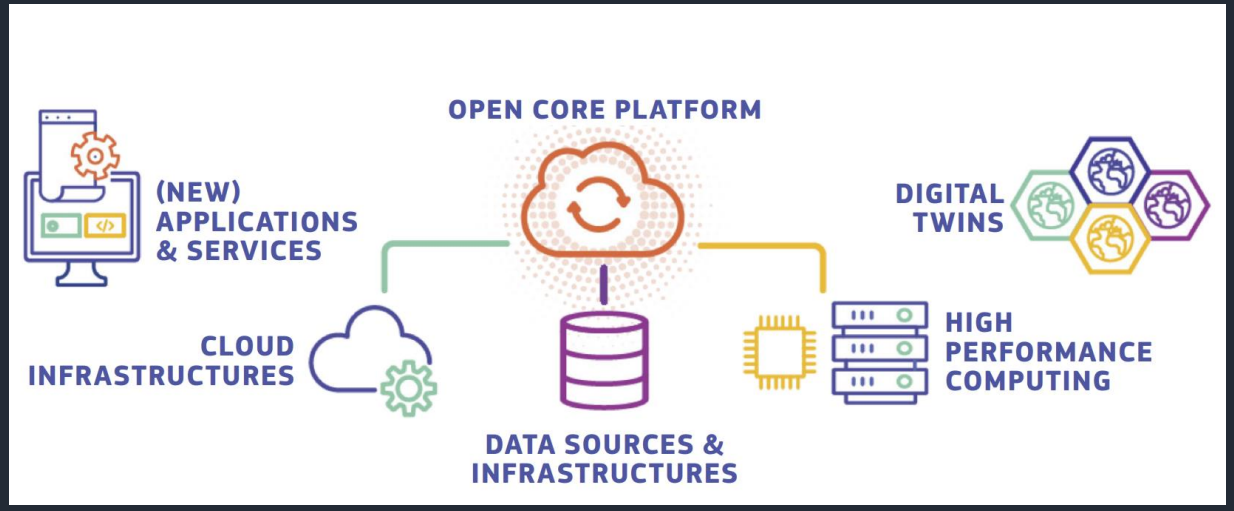


A matter of scale





DestinE



Earth replication based on digital modeling aims to be a breakthrough in terms of accuracy, detail, access to information, speed, and interactivity

Plus: European HPC computers and AI capacity

Focus: climate change, natural hazards, extreme events, marine, and urban ecosystems (socio-economic impacts and risk mitigation)

Objectives:

- to produce accurate, interactive, and dynamic simulations of the Earth system
- to improve predictive capabilities (water, renewable energy, and food management; risk mitigation)
- to support decision-making and implementation processes

→ Europe chooses DT as a key tool in the green transition (A key component of the **European Strategy for data)**

The DS4SSCC Blueprint

DATA SPACE FOR SMART AND SUSTAINABLE CITIES AND COMMUNITIES

European data space for smart communities

Part of the **European Data Space for Smart Communities (DS4SSCC-DEP) initiative**, is a comprehensive framework designed to develop a unified, secure, and scalable data space for smart and sustainable cities and communities across Europe.

Co-funded by the Digital Europe program, this initiative brings together municipalities, private organizations, and academic institutions to promote the **European Green Deal and Sustainable Development Goals**. It focuses on advancing innovative data-sharing and governance practices to drive sustainable urban development

i) **Multi-Stakeholder Governance Scheme**: Establishes core principles, defines roles and responsibilities, and sets governance structures and legal frameworks to ensure secure and reliable data transactions within the data space ecosystem.

ii) **Technical Blueprint**: Provides a catalog of specifications and a reference architecture model for building the necessary technical infrastructure. It promotes data sharing and stakeholders' trust by recommending standards, technologies, and clear governance mechanisms.

iii) **Roadmap and Action Plan**: Outlines a strategic approach to developing a pan-European data space for smart communities, focusing on middleware service solutions to enable data sharing and management. This phase also involves refining the blueprint based on insights from local pilot projects.

The CityVerse initiative

Key component of the **European Commission's Digital Decade Policy Program 2030.**

CityVerse aims to promote collaborative investments in knowledge and funding across Europe, to advance digital infrastructure and technological capabilities to support the development of digital twins across Europe, according to the EU's digital transformation goals.

Minimal Interoperability Mechanisms (MIMs):

technical specifications developed under the Living-in.EU initiative to promote **interoperability** across European cities and communities

This approach prevents vendor lock-in, fosters innovation, and supports the development of smart cities by ensuring that diverse systems can communicate and collaborate effectively.

MIMs aim to create a flexible, standardized foundation for data exchange, driving local digital transformation and contributing to broader sustainability goals, efficiency, and innovation across Europe.

Snap4City Digital Twin solution

Framework developed by the DISIT Lab of the University of Florence, Snap4City is an officially certificated platform of **EOSC (European Open Science Cloud Marketplace)** and Gold Member of **FIWARE** and an officially recognized FIWARE platform.

Snap4City complies with protocols, such as NGSI (Next Generation Service Interface), for robust interaction with various IoT connections, applications, and dashboards.

It supports multiple other protocols, including JSON, MQTT, Lightweight M2M, LoraWAN, OPC, SigFOX, and more, enabling versatile data integration and communication.

DIGITAL TWIN SOLUTIONS AND DECISION SUPPORT SYSTEMS

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

HORIZONTAL AI PLATFORM

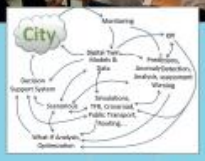
MOBILITY AND TRANSPORT

SMART ENERGY AND SMART BUILDING

ENVIRONMENT AND WASTE MANAGEMENT

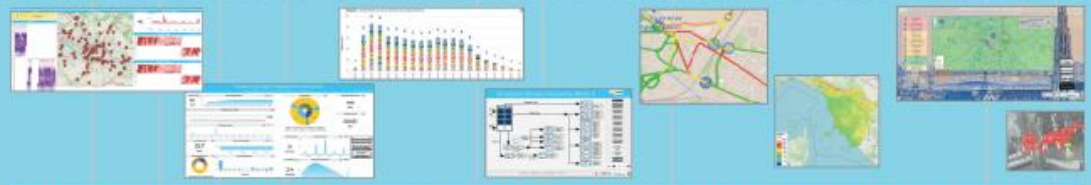
CITY USER'S SERVICES AND TOURISM MANAGEMENT

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



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

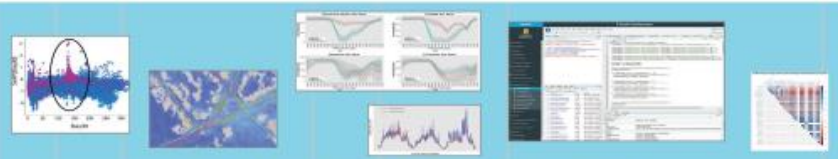
DASHBOARDS, WIDGETS
TEMPLATES



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

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

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



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

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

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

Snap4City and

DS4SSCC (**European Data Space for Smart Communities**)

- Interoperable Data Spaces
- Sustainability and Innovation
- Governance and Technical Infrastructure
- Pilot Projects and Innovation
- Middleware Services for Data Sharing

CityVerse

- Open-source and Interoperable Platform
- Comprehensive IoT Integration
- Support for Sustainable Development Goals (SDGs)
- Digital Twin Technology
- Training and Development Support

MIMs Requirements

MIM	Subject	Name	Status	Snap4City
MIM1	Context	OASC MIM1: Context Information Management	Governance	Fully compliant, NGSI V2 and LD
MIM2	Data Models	OASC MIM2: Shared Data Models	Governance	Fully compliant. Devices can be directly deployed using Smart Data Models, custom data models, and Snap4City IoT Device Models. Reference ontologies are available. By default, it is provided with Km4City ontology based on several standard vocabularies (SAREF, OTN, SSN, FOAF, etc.). Other ontologies can be added to the Knowledge Base.
MIM3	Contracts	OASC MIM3: Ecosystem Transactions Management	Capability	Secure by design, GDPR compliant, passed PENtest, Vulnerability test, etc. And devices and transactions can be tracked by Blockchain.
MIM4	Trust	OASC MIM4: Personal Data Management	Capability	Secure by design, GDPR compliant. Personal and public data can be managed.
MIM5	Transparency	OASC MIM5: Fair Artificial Intelligence	Capability	Possibility to develop ML/AI/XAI including Explainability modules that are GDPR compliant. Able to enforce verification to be fair, and replicable, etc. according to AI-Act, etc.
MIM6	Security	OASC MIM6: Security management	Work item	Snap4City is secure by design, is GDPR compliant, passed PENtest, Vulnerability test, etc.
MIM7	Places	OASC MIM7: Geospatial information management	Capability	Ability to manage 2D and 3D data at local and global scales integrated. It accepts multiple formats and protocols for delivering 2D/3D elements, for example, OCG, WFS, WMS, etc., and entities in NGSI.
MIM8	Indicators	OASC MIM8: Ecosystem indicator management	Work item	Several indicators already available: 15 Min City Index, SUMP/PUMS, SUMI, SDG, etc.
MIM9	Analytics	OASC MIM9: Data Analytics Management	Work item	Full support for Data Analytic Management. DA processes include statistics, ML, AI, XAI, operating research, simulations, etc., and can be developed in Python, RStudio, or other languages, exploiting MLOps, NVIDIA boards, or other accelerators, and containers.
MIM10	Resources	OASC MIM10: Resource Impact Assessment	Work item	Full support for monitoring resource consumption and performing impact assessment.

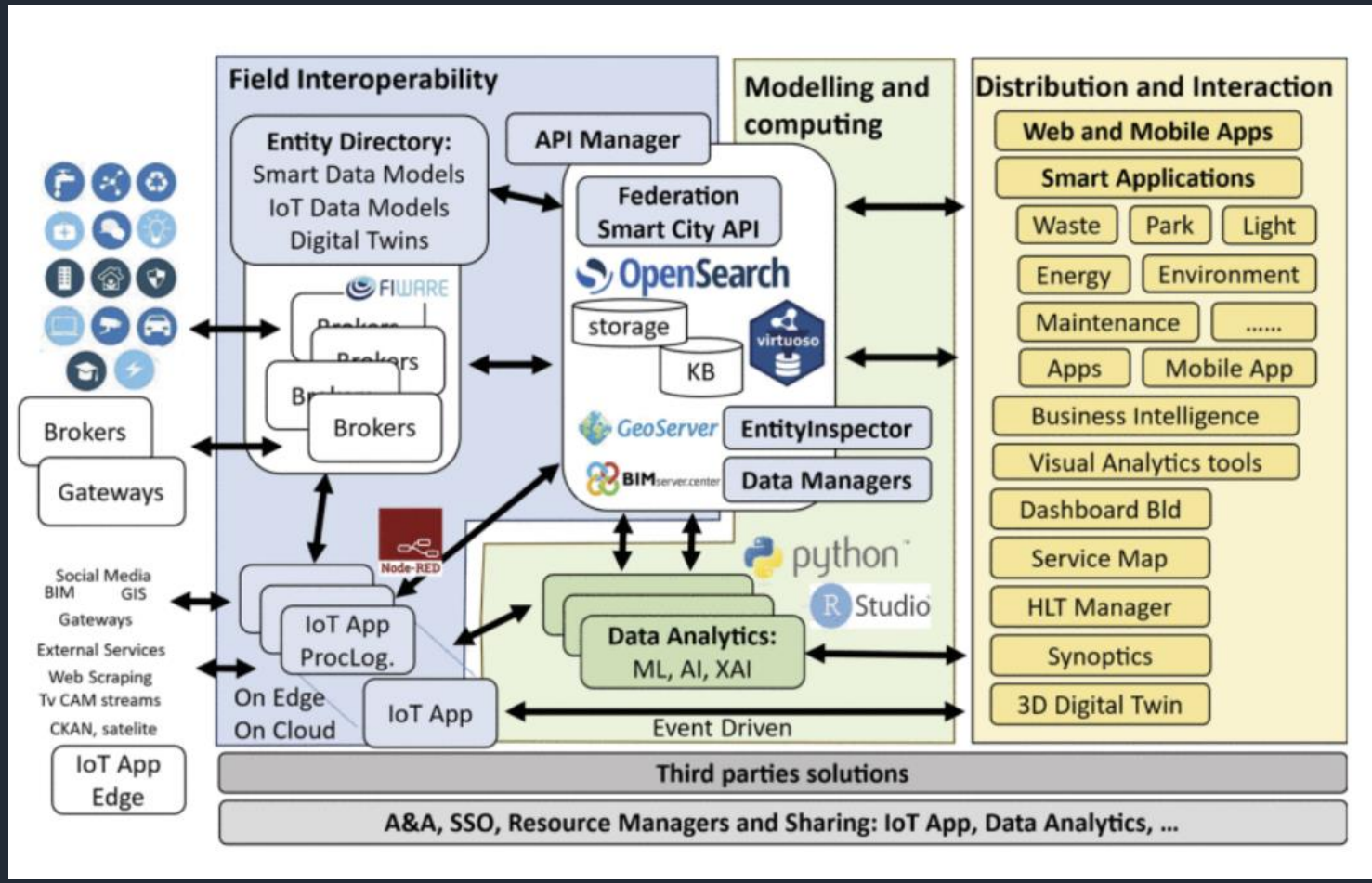
Snap4City architecture

Snap4City ingests real-time and event-driven data streams using IoT brokers, indexed and shadow-stored in an OpenSearch cluster, making them accessible to various consumer processes.

Internal brokers utilize Orion Broker NGSI, supporting smart data models, with data retrievable in push or event-driven modes.

Node-RED flows facilitate interoperability with external services like GIS, ITS, TV cam services, CKAN, BIM servers, and social media, with dedicated libraries and microservices for data transformation

Data is stored across multiple systems: a Virtuoso RDF store for Km4City ontology, an OpenSearch cluster for real-time and time-series data, and the Snap4City GeoServer for georeferenced data, supporting analysis of pollutants, temperature, energy, traffic, and population density.



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

SNAP4CITY | KM4CITY

City

Monitoring

KPI

Digital Twin
Models &
Data

Predictions,
Anomaly Detection,
Analysis, Assessment
Warning

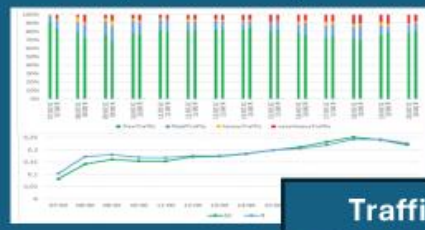
Decision
Support System

Scenarious

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

What-If Analysis,
Optimization

KPI, Predictions, ...



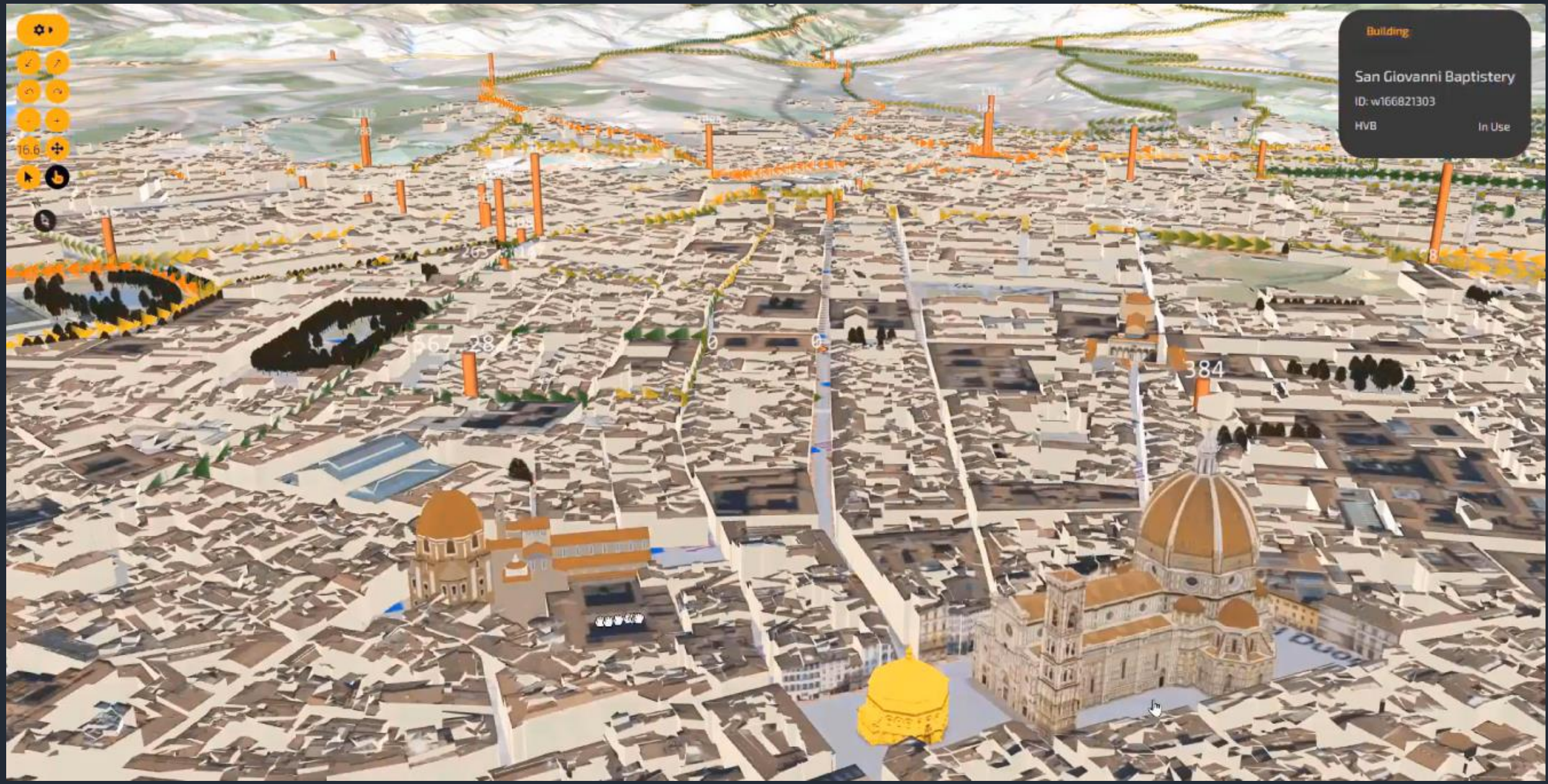
Traffic Reconstruction

Scenario Editor

Traffic Light Plan optimization

Routing / Dynamic Routing

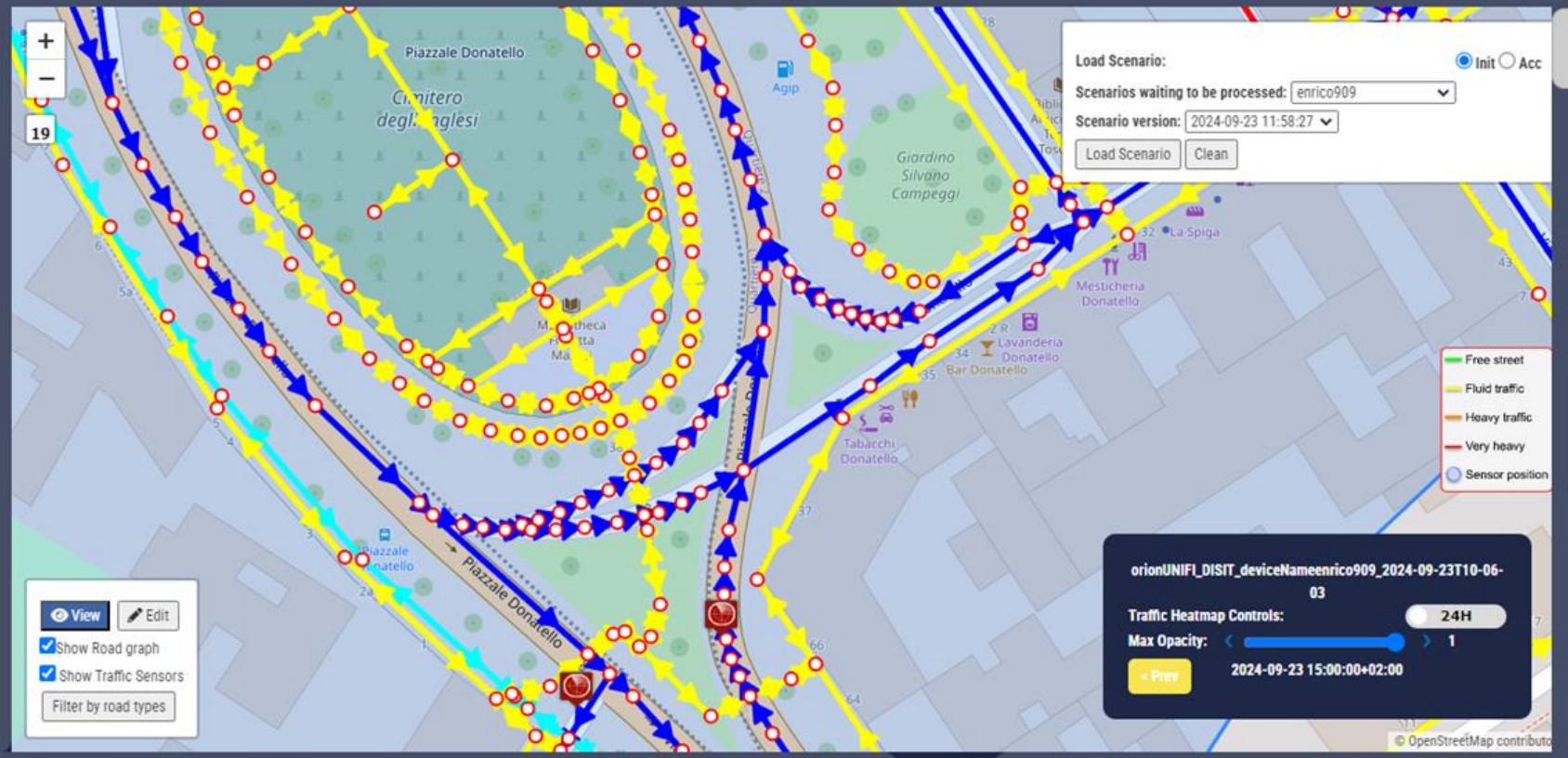
Traffic Infrastructure optimization


Building
San Giovanni Baptistery
ID: w166821303
HVB
In Use

Traffic Flow Analysis By Scenario

Mon 23 Sep 12:53:12

- Scenario Editor
- Some Points of Interest
- Traffic Sensors
- Air Quality Sensors
- Weather Sensors (OW)
- Bus Stops
- Tram Stops



INIT to ACC | Compute TFRS | Compute KPI | Show TFR

Data Update

enrico909 2024-09-23 12:06:03 (tfr)

2024-09-23T15:00:00+02:00

Calculate KPI

KPI	Value
Total CO2 emissions [ug/m^3]	13,979.071
Total fuel consumed [l]	0.249
Traffic state objective function [#]	3.935
number of vehicles [#]	51.394
total kilometers [km]	3.886
total travel time [s]	314.575

DISIT:OrionUNIFI:METRO1098 - VehicleFlow 8m

Time Series 3m

My Profile

Traffic Flow Simulation

Wed 16 Oct 23:50:45

Current Scenario: downtown-toron...

CANCEL PAUSE HELP

slow fast

Delay: 450.0 ms

Stats

time: 112.000 s
payload: 5.0 KB
simulate: 12.35 ms
snapshot: 1.68 ms

Vehicle Summary

bike(s): 48
car(s): 55
person(s): 5

Quick Find

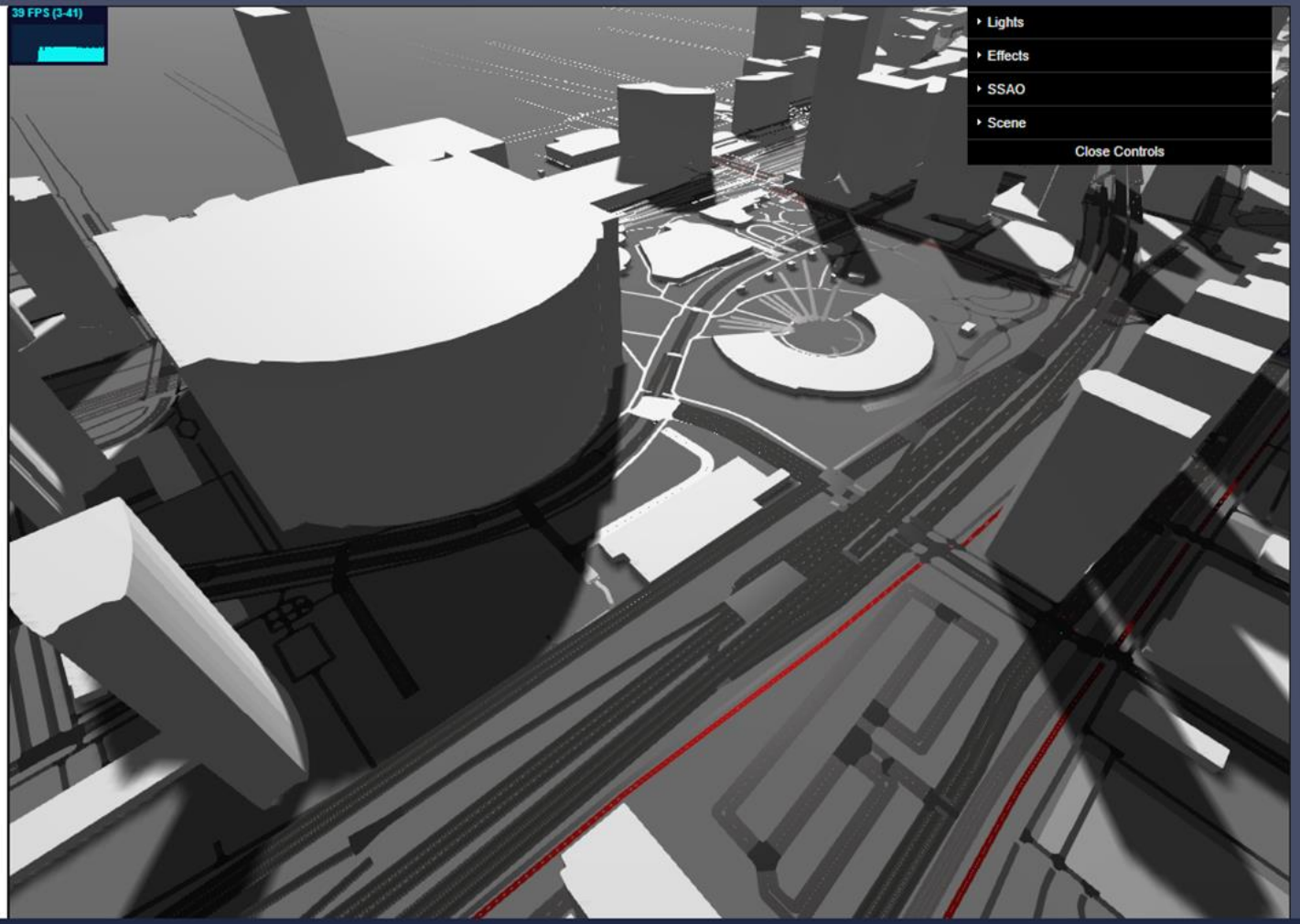
OSM ID / Lat, Long (float, float) / X,Y (int, int)

SEARCH

CAR BIKE TRAIN

TRAM PERSON BUS

LIGHT



Prepare Simulation | Execute Simulation | KPI Simulation

AlessandroScenario30_20240926095651

Get KPI

Vehicles in simulation

- car: 1548
- tram: 16

Totals

- Mean Arrival Speed (m/s): 13.723
- Total Duration (s): 1193.980
- Total Time Loss (s): 601.207
- Total Waiting Count (#): 6.177
- Total Waiting Time (s): 63.047

Flow	Arrival Speed (m/s)	Duration (s)	Time Loss (s)	Waiting Count (#)	Waiting Time (s)
flow1	13.634	41.161	25.211	0.036	0.089
flow10	16.611	95.131	58.090	0.404	2.253
flow11	17.330	23.485	12.397	0.000	0.000
flow12	15.420	94.908	60.891	0.980	8.082

My Profile

15MinCityIndex Dashboard

This Dashboard contains data estimated by the Snap4City 15Min index on the basis of Open Data accessible

Thu 5 Dec 17:43:42

15Min Index Heatmap
Density of Population
Environment Idx
Economy Idx
Housing Idx
Health Idx
Food Services Idx
Education Idx
Slow Mobility Idx
Govern Srv Idx
Security Safety Idx
Culture and Cults Idx
Entertainment Social Idx
Fast Mobility Idx
Sport Services Idx
15Min Index Weigth Heatmap

Province: FIRENZE
City: SESTO FIORENTINO
Address: VIA TORTA N. 60/A
lat,lon: 43.80457,11.16722

Documentation

Maps

15MinIndex_AverageIndex
Heatmap Controls: 24H
Max Opacity: 0.5
< Prev
2022-05-03 17:00:00

15Min Index
Index
Critical
Insufficient
Satisfactory
Fairly good
Good

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SESTO FIORENTINO : VIA TORTA N. 60/A

Kiviat 4m

Fast Mobility
Health
Average
Housing
Culture and Cults
Education
Security
Entertain. Social
Economy
Food Services
Slow Mobility
Weight Average

15Min Indexes
Suff. value
Max Value

Bar Series 4m

Fast Mobility
Health
Housing
Education
Entertain. Social
Economy
Slow Mobility
Sport

15Min Indexes
Suff. value

Mobility and Environment What-IF Analysis

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

Thu 5 Dec 18:05:25

Air Quality Sensors
Historical 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
Traffic Bubble
Cycling Paths
Accident Heatmap
Only HRes Anym. Gral
Scenarious
What-if analysis
Bus Stops

Firenze Oggi

Maps

External Providers Open Orthomaps
Default Map
Light Map
Dark Map
Light Map 2
Dark Map 2
Light Buildings Map
Satellite Map

WMS & GeoJSON Orthomaps
Tuscany Buildings (Volumetric Units)
Tuscany Photographic Orthomap
Tuscany Historical Map (Catasto Inghirami, 1830)
Tuscany Boundaries
Tuscany Provinces

Air Temperature 6m
23.3 °C

Air Temperature In - SMART04 6m

Antwerp City Overview - A5 - Newgui

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

NO2 Heatmap
SO2 Heatmap
O3 Heatmap
EAQI
CAQI
Biking Safe Heatmap
Tunnels and Ferry
Routing Scenario
What-IF Routing

MAPS

EAQI1hourAverageAntwerp
Heatmap Controls: 24H
Max Opacity: 0.25
< Prev
2021-09-30 14:00:00

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

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Weather Sensor Zwijndr... 8m
8.8

Weather Sensor Zwijndrecht - AirTemperature 8m

Florence Heatmaps

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

Selector

Florence_PM10
Heatmap Controls: 24H
Max Opacity: 0.25
< Prev
2021-08-19 21:00:00

PM10
µg/m3
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-100
>100

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Wind Speed 9m

Air Temperature in Florence: Daily Trend 9m

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DELL'INFORMAZIONE

DISIT
DISTRIBUTED SYSTEMS AND
INTERNET TECHNOLOGIES LAB
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AND TECHNOLOGIES LAB

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