

Mobility and Transport Overview Lab Congiunto More 14-03-2023 Paolo Nesi Paolo.nesi@unifi.it



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







FROM CITY DASHBOARD TO APPLICATIONS

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100% OPEN SOURCE TITITI

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Mobility and Transport

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SNA Providence Social ANALYSIS

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METHODOLOGIES LIVING LABS **COURSES AND COMMUNITY DEVELOPMENT TOOLS**

Standards and Interoperability (6/2023)

Snap4City (C), March 2024

Compliant with:

- IoT: NGSI V2/LD, LoRa, LoRaWan, MQTT, AMQP, COAP, OneM2M, TheThingsNetwork, SigFOX, Libelium, IBIMET/IBE, Enocean, Zigbee, DALI, ISEMC, Alexa, Sonoff, HUE Philips, Tplink, BACnet, TALQ, Protocol Buffer, KNX, OBD2, Proximus, ..
- IoT model: FIWARE Smart Data Model, Snap4City IoT Device Models
- **General**: HTTP, HTTPS, TLS, Rest Call, SMTP, TCP, UDP, SOAP, WSDL, FTP, FTPS, WebSocket, WebSocket Secure, GML, WFS, WMS, RTSP, ONVIF, AXIS TVCam, CISCO Meraki, OSM, Copernicus, The Weather Channel, Open Weather, OLAP, VMS,
- Formats: JSON, GeoJSON, XML, CSV, GeoTIFF, OWL, WKT, KML, SHP, db, XLS, XLSX, TXT, HTML, CSS, SVG, IFC, XPDL, OSM, Enfuser FMI, Lidar, glTF, GLB, DTM, GDAL, Satellite, D3 JSON, ...
- Database: Open Search, MySQL, Mongo, HBASE, SOLR, SPARQL, ODBC, JDBC, Elastic Search, Phoenix, PostGres, MS Azure, ...
- Industry: OPC/OPC-UA, OLAP, ModBUS, RS485, RS232,..
- Mobility: DATEX, GTFS, Transmodel, ETSI, NeTEx, ..
- Social:Twitter, FaceBook, Telegram, ..
- Events: SMS, EMAIL, CAP, RSS Feed, ..
- OS: Linux, Windows, Android, Raspberry Pi, Local File System, AXIS, ESP32, etc.





https://www.snap4city.org/65

High Level Types

Snap4City (C), March 2024

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

IRENZE

• decision scenarios,

etc.

10/22









- Controlling Status: management, and operational
 - Monitoring via KPI
 - $\,\circ\,$ Computing predictions vs KPI
 - $\,\circ\,$ Anomaly detection
 - Neuro-Symbolic analysis
 - Risk assessment
 - $\,\circ\,$ 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



















 Controlling Status: management, and operational

• Monitoring via KPI

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

Monitoring



Key Performance Indicators, KPI



		Air Quality Directive		WHOguidelines	
Pollutant	Averaging period	Objective and legal nature concentration	and Comments	Concentration	Comments
PM _{2.5}	One day			25 µg/m³ (*)	99 th 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 (*)	99 th percentile (3 days/year)
PM ₁₀	Calendar year	Limit value, 40 µg/m³ (*)		20 µg/m³	
0,	Maximum daily 8–hour mean	Target value, 120 µg/m³	Not to be exceeded on more than 25 days per year, averaged over three years	100 µg/m³	
NO ₂	One hour	Limit value, 200 µg/m³ (*	Not to be exceeded more than 18 times a calendar year	200 µg/m³ (*)	
NO ₂	Calendar year	Limit value, 40 µg/m³		40 µg/m³	

- United Nations Sustainable Development Goals, SDGs (for which cities can do more to achieve some of the 17 SDGs, <u>https://sdgs.un.org/goals</u>);
- **15 minutes cities** (where primary services must be accessible within 15 minutes on foot);
- objectives of the European Commission in terms of pollutant emissions for: NO2, PM10, PM2.5 (<u>https://environment.ec.europa.eu/topics/air_en</u>);
- SUMI: mobility and transport vs env
 - https://www.snap4city.org/951
- SUMP/PUMS: mobility and transport vs env.
- ISO indicators: city smartness, digitization, tech level.
- Low Level/Real Time: global traffic, quality of service, betweenness, centrality, queue, time to travel, etc.



Periodic

Realtime













15MinCityIndex

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

Using the Open Data:

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

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



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



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Services

Economy

Environment

Entertain.

15Min Indexes

Socia

Security

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C'SNAP4city

https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjkzOA== Snap4City (C), March 2024

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Health

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Culture

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Education

Average

Housing

15MinCityIndex on Bologna

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

Smart Decision Support, system thinking

- Smart Decision Support System based on System Thinking plus
- Actions to city reaction, resilience, smartness, ...
- Enforcing Mathematical model for propagation of decision confidence..
- Collaborative work, ...
- Processes connected to city data: DB, RDF Store, Twitter, etc.
- Production of alerts/alarms
- Data analytics process
- Twitter Processes
- reuse, copy past, ...



Model: TestGP

Process:Istanza Test GP2

Model: TestGP cloned

Process:Istanza Test

C

Add New Model

Model: Open Restaurant

🗅 smartds.disit.org:8080/dss/home.jsp;jsessionid=F5523F87F9603F98C6DFF2587B7D78F4# Open information Hello Paolo! DECISION: 15.56%G 34.14%W 50.40%R Open Restaurant via santa marta 3 0.253 Parking Persons flow 0.333 0.2 Traffic Flow Parking dimension Parking Type TPL flow 0.167 0.9 0.833 Paid Free Day Night Name Model Open Restaurant Date creation 15-06-2015 16:45:08 Name Process via santa marta 3 Date last modify 15-06-2015 17:01:13 Start execute 15-06-2015 17:01:19 End execute 15-06-2015 17:01:20 View X







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















Smart City Digital Twin City Digital Model with...



- Intuitive platform
- Any Data TYPE, any data source, any protocol
- Data storage seamless
- Data analytics \rightarrow artificial intelligence, AI/XAI
- Data Ethics, AI Ethics, GDPR
- Data Representation, any kind
- Key Performance Indicators, any kind
- What-IF analysis Simulation, prediction, 2D/3D
- Micro, Meso e macro scales
- Operation, planning tactic and strategic
- Collaborative and shared representation
- Sustainable, shared, open source 100%

Complex and heterogeneous information, interoperability

- GIS, ITS, AVM, IoT, BIM, CKAN, etc.
- Satellite services
- MaaS, last-mile delivery HUBs
- etc. 0













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MyKPI: Tracking of Devices and Mobiles Real Time Trajectories for



- Moving IOT Devices •
- **OBU**, Vehicular Kits ٠
- Multiple tracks ٠
- Day by day

Mobile

OBD2

PAX Counter

Micro Application











Custom Dynamic Pins

Custom Pins on Map - test GP









Snap4City Analytics

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



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







Decision Support Systems, What-if

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Event planning, via what-if analysis

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

\odot Immediate reaction to natural events or not

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

Digital Twin

- More detail in the context integrated data
- Greater realism in deductions and representations
- Less fragmentation and non-uniformity in the views to support decisions



Routing







Computation of Traffic Flow Evolution, cascade effects





OSM data with non correct viability in Piazza Dalmazia, Firenze

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





















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https://www.snap4city.org/976

Properties of Road Elements





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🞸 Dashboard Management Syster 🗙 🕂 Presentazione senza titolo ×

snap4city.org/dashboardSmartCity/view/index.php?iddasboard=NDAwNw== C

ScenaryBuilder

Tue 12 Mar 15:53:34

D

E

Call the Scenario Editor Some Points of Interest ● Init ○ Acc ○ TDM Load Scenario: Scenarios waiting to be processed: FDSA ✓ Load Scenario 16 mp.com Via Guido Spadolini - Viale Filippo Strozzi Padiglion View 🖋 Edit Show Road graph Show Traffic Sensors Filter by road types



Tue 12 Mar 16:26:34

Usability Assessment

Usability Assessment for Scenario Editor



https://www.snap4city.org/dashboardSmartCity/view/index.ph p?iddasboard=NDE2MQ==

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The actual Scenario Exploitation





Defining Context via Editing Scenario:

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



A Scenario includes:

Status and versions,

Road graphs, cycling,

List of data, sensors

Period of validity

pedestrian seg.

Metadata

date time

Etc.

•

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Computing in the Scenario Context as:

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

ReLoading Scenario in JavaScript

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







- Accidents and elements blocking Points and Shapes taken into account for:
 - Routing
 - Traffic Flow reconstruction
 - Evacuation paths
 - Rescue team paths

Assessment on the basis of changes:

- Mobility demand assessment
- Mobility Offer assessment





Studio name



Constrained Dynamic Routing: Traffic Flow



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Fastest taking into account traffic and blocked areas




Available AI Solutions on Snap4City

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

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







https://www.snap4city.o rg/download/video/DPL SNAP4SOLU.pdf





Mobility and Transport

- **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)
- Predictions for: traffic flow, smart parking, smart bike sharing, people flows, etc. (ML, DL)
- What if analysis: routing, traffic flow, demand vs offer, pollutant, etc. (Simulation + ML)
- Traffic flow reconstruction from sensors and other sources (simulation + ML)
- Tracking fleets, people, via devices: OBU, OBD2, mobile apps, etc. (DP)
- Routing and multimodal routing (multistop travel planning), constrained routing, dynamic routing (DA)
- Computing Origin Destination Matrices from different kind of data (analysis, DP, DP)
- Computing typical trajectories on the basis of tracks (analysis, ML)
- Computing Messages for Connected drive (DP)
- Slow and Fast Mobility 15 Minute City Indexes (analysis, DP, ...ML)
- Computing and comparing traffic flow on devices and at the city border (analysis)
- Typical time trends for traffic flow and IoT Time series. (analysis, ML)
- Impact of COVID-19 on mobility and transport
- Computing SUMI, PUMS, etc. (mainly DP)
- Etc.

Mobility and Transport Traffic Flow Analysis

- Multiple Domain Data
 - Traffic Flow sensors, city structure, weather

Decision Makers Multiple Locations

- Real time Monitoring, predictions
- Traffic Flow Predictions,
- Traffic Reconstructions, routing
- Dashboards, What-IF analysis
- Mobile App, people flows
- Historical and Real Time data
- Services Exploited on:
 - Dashboards, Mobile App
- Since 2017, 2019

Cities: Firenze, Pisa, Livorno, Modena, Santiago di Compostela







TOP







Traffic Flow







Traffic Flow Tools

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

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



Firenze - Trafair - AirQuality Heatmaps

1.0

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

Mon 6 Apr 15:12:27



Snap4City (C), March 2024





SUSTAINABLE CITIES

AND COMMUNITIES

13 CLIMATE ACTION

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



Traffic Flow Monitoring - Firenze - Cloned2







Why Dense Traffic Flow Reconstruction ?

- Making decision on mobility and transport solutions → what if analysis
- Controlling pollution

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- Dynamic Routing for Firebrigade, Ambulances, general public
- Planning Public
 Transportation routing

















Real time Clustering: legenda and synoptic





Monitoring Cross Road Venaria - (AXIS Camera)

Wed 10 Nov 18:50:53

80

Venaria Street Cross - Synoptic

53 11

27

47 4 149 40

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Origin Destination Matrices



ODN, Traffic Flow





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



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Fillenze

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

shapes

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



Origin Destination Matrix based on Mobile App data

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Origin Destination Matrix Estimation











Smart Parking



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

Slot 1 - Stat

0

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





DACITY







Snap4ISPRA Parking







Deep Learning AI to surely Park!



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ΤΟΡ







Smart Bike Free Bike predictions 13 CLIMATE ACTION SUSTAINABLE CITIES AND COMMUNITIES **Data Analytic** (((10 0 0 0











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



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



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Public Transport Analysis



What-if Analysis on Pub Transport

- Definition of scenarious impact on
 - Traffic, Pollutant, parking, public transport, private flows, etc.

Welcome to DORAM

• KPI analysis



Services: 36 on 36 available

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Snap4City (C), May 2022



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

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ne Most Crowded Stops











TOP







User Behavior





UNIVERSITÀ DEGLI STUDI FIRENZE Prediction of



- Prediction of people flows
 on the basis
 of Wi-Fi data
- Anomaly detection
- Resolute H2020
- Classification of city areas



Origin Destination Matrix Estimation











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The App is a Bidirectional Device

+ Air Quality

Notification

PM 10

10.962

à ¢°

2019-05-08 06:00:0

9

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Show

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S4chelsinkitrackerlog

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

Users

Produced information

Viewed ?

...

- Accepted ?
- Performed ?

11.25

Delegate

DataTime JF Latitude J1 Longitude

< 2019-05-08

08/05/2019. 43.792

Annulla

Derived information

- Trajectories ٠
- Hot Places by click and by move
- Origin destination matrices
- Most interested topics
- Most interested POI ٠
- **Delegation and relationships** •
- Accesses to Dashboards ٠
- **Cumulated Scores from Actions**
- **Requested information**
- **Routing performed**

Produced information

-System

- Suggestions
- Engagements
- **Notifications**











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



User Behavior Analyser for Collective





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TOP

Computing CO2/NO2 from traffic Data






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Traffic Flow data

- Traffic Flow is one the main source of CO2
 - K1: Fluid Flow
 - K2: Stop and Go
- **Dense estimation of CO2 into** the city is very useful to know to target EC's KPIs

Computing CO2 on the basis of traffic flow data





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

Snap4City (C), March 2024







Environment **C^CSNAP4**city

Traffic Flow Manager on multiple cities



Sun 2 May 23:16:31

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



SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES





2023 booklets

• Smart City





https://www.snap4city.org /download/video/DPL_SN AP4CITY.pdf Snap4City (C), March_2024

https://www.snap4city.org/d ownload/video/DPL_SNAP4I NDUSTRY.pdf

Industry

Artificial Intelligence





https://www.snap4city.o rg/download/video/DPL SNAP4SOLU.pdf

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7-9 November 2023, Barcelona, Spain

SMARTCITY EXPO WORLD CONGRESS

Visit Snap4City in Hall 1



CONTACT

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