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Herit-Data: Tourist Flow Management platform

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From: DINFO dept of University of Florence, with its
DISIT Lab, Https://www.disit.org with its Snap4City solution
Snap4City on social**:**

1. Web page**:** Https://www.snap4city.org
2. https://twitter.com/snap4city
3. https://www.facebook.com/snap4city

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The present report is intended to describe the progress made towards the HERIT-DATA Tourist Flow management platform (deliverable 4.3.1.)

1 - Executive Summary

DISIT lab entered into Herit-Data project with the Snap4City solution in order to set up a customized infrastructure for a number of Pilots.
Snap4City, as described in Section 2, is 100% open source, secure encrypted, scalable, modular and flexible smart city solution and service managed by DISIT Lab of University of Florence. It has been developed by a number of collaborations with institutions and companies who have accepted to work on open-source model; it can be used to set up Living Lab and smart city solutions, thus satisfying a large range of requirements by city officers, citizens, and tourists, as well as developers, companies and researchers. The platform is a sustainable data/service ecosystem where cities and stakeholders can exploit resources to set up valuable services, free from the vendor lock-in problems. And, when cities are ready, the support to set up the Living Lab or co-working environment, is gradually provided, in order to create a collaborative context among several cities and international experts, where cities' users and stakeholders are involved in order to profitably exploit, produce and share data and services.

DISIT lab has used the Snap4City tools to realize a Herit Data project platform and a number of data services and data analytics reported in Section 3 and in particular for: Dubrovnik, Florence, Pont Du Gard, Mostar, Valencia and West Greece. The activities performed, as described in the following has been:

1. Setup of the Pilot Organization accessible as a separate Tenant/host for each pilot
2. Setup of the knowledge base, RDF store for each pilot
3. Set up of a specific IoT Broker for data ingestion for each pilot
4. Set up of IoT Applications for data ingestion for each pilot
5. Set up of the big data Storage for each pilot
6. Set up of the MyKPI storage for each pilot
7. Set up of dedicated listening channel on Twitter Vigilance platform for each pilot
8. Collection of Twitters and social media analysis for each pilot
9. Develop for some data analysis on the social media for each pilot
10. Set up specific cases for collecting data on people counting
11. Set up and develop specific dashboard for data analysis in real time.
12. Computing correlation analysis of twitter data vs lockdown period of Covid-19 in the different areas
13. Dashboard and view for specific mobile apps.
14. Etc.

In addition, DISIT lab provided and will keep providing support for training the partners in the usage of the platform at different levels:

1. Final users and decision makers
2. ICT officers and data experts.

2 – Snap4City solution

Snap4city solution applied to the project platform is capable to keep under control the real time city evolution: reading sensors; computing and controlling key performance indicators, KPI; detecting unexpected evolutions (early warnings); performing analytics; taking actions on strategies and alarms; providing interfaces to act upon the city by means of control dashboards. It can support each city of Herit-Data project in the process of continuous innovation on services, infrastructures, with control and supervision, tools for business intelligence, predictions, anomaly detection, early warning, risk assessment, what-if analysis, also by setting up strategies for increasing city resilience with respect to unexpected or unknowns. Thanks to Knowledge Base support, the project platform can provide flexible solutions to get immediate insights and deductions of the city status and evolution, exploiting ultimate artificial intelligence, semantic computing, data analytics and big data technologies, activating sentient solutions collecting, and exploiting heterogeneous data of any kind, from any data source (open and private; static, real time, event driven, streams, certified and personal).

Snap4City is an official solution of FIWARE, but it supports other protocols and brokers as well; it supports a platform of EOSC, a platform of Node-RED, a platform of EO15, etc. It is also a provider of the ISPRA JRC of the European Commission regarding Smart City strategies, and the Winner of Select4Cities PCP Award.

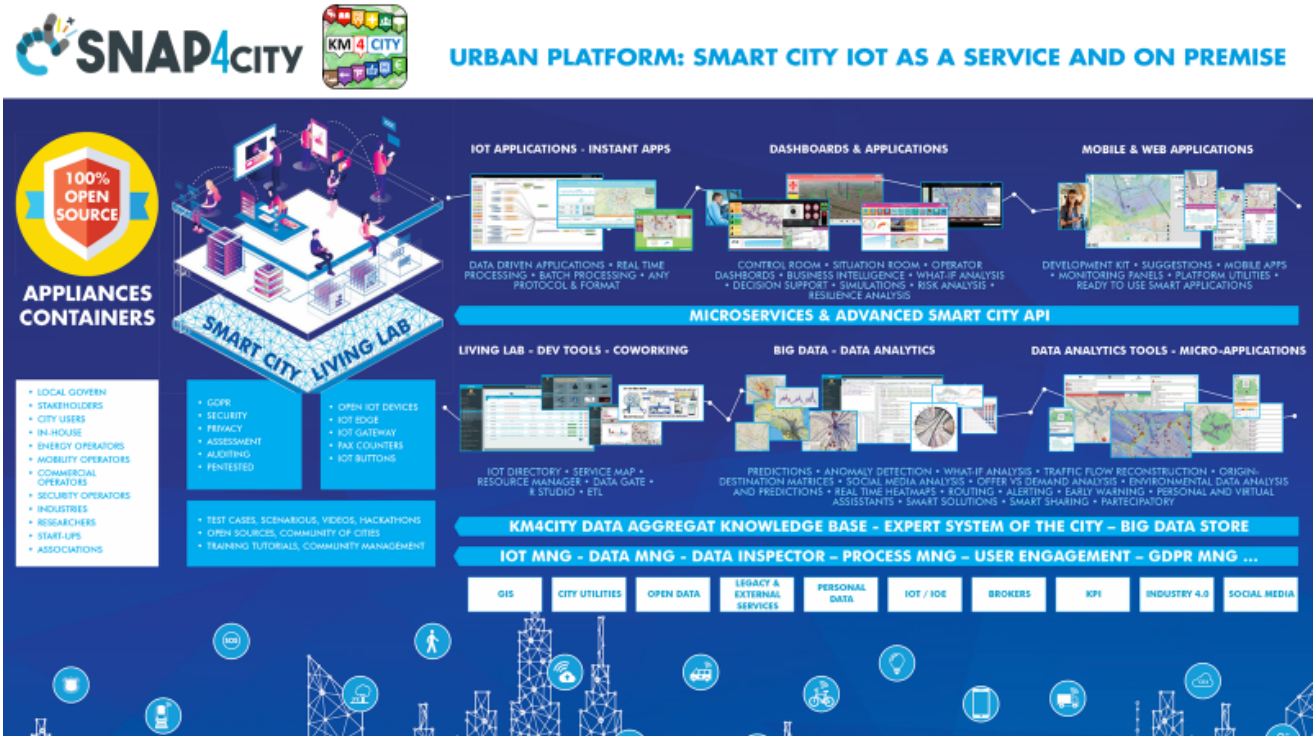
Snap4City solution has been designed to be scalable, flexible, safe and respectful of privacy, endowed of a powerful semantic reasoner. A special attention has been given to enable the development of applications in multiple domains and not only on mobility and transport, environment, tourism, health & welfare, social, Industry 4.0, etc. The proposed solution is flexible enough to support extensions at different levels of granularity: data, analytics, tools and applications.

Snap4City tool ingest and produce data of any domain and according to any kind of data sources: GIS (ArcGIS, QGIS, etc.), city utilities (water, gas, mobility, light, water, etc.), legacy systems, personal data, mobile data, IoT Network and **IoT Broker**, KPI/MyKPI, industry 4.0 protocols and network, social media, telecom data, etc. All the sources are bidirectional channels since Snap4City can ingest and produce data with protocols suitable for any channel. See for interoperability Https://www.snap4city.org/65 Please note that the platform supports any kind of IoT Networks, communication protocols, and data formats, so that **any legacy and vendor solution**.
Data Ingested with any data model are aggregated into the so-called **Knowledge Base** (which is the **Expert System** of the city) and into the **Big Data storage**. This approach eliminated the problems of data silos and pillars. Any legacy solution, as well as new applications and data may be integrated in a uniform model, establishing semantic relationships of any kind.

Ingested data are immediately usable and searchable for snap4City tool such as the **Data Inspector, Big Data Analytics**, **Dashboards**, **Smart City API** for the **Mobile Apps**, and via **MicroServices** for IoT Applications (**IoT Apps**) which are used for integrations. Data can be consumed by data processing/data-analytics, IoT App/integrations, mobile App, and **Dashboard**s, and in real time streaming, that are the so-called data driven processes, even end-to-end (from the device to dashboards).

The **developers and qualified operators** can access to the platform tools via web (without any installations on the local computers) to develop in the **Snap4City** collaborative environment **Data Analytics**, **Dashboards**, and **IoT Apps**. Only the **Mobile Apps** developers need of a local development Environment.

Final users can access to the project platform via Web and mobile devices, dashboards, interfaces for digital signages, tables, panels, etc.



A Snap4City **Living Lab** support allows the **stakeholders** to collaborate for the production of smart solutions and to the innovation of the whole city ecosystem. On this regard, Snap4City provides a methodology for stimulating the innovation identifying the most relevant and effective changes and solutions according to a **quadruple helix** approach. A **Living Lab** with the web based Snap4City **Development Environment** provides a comprehensive set of tools for developers and stakeholders to implement data ingestion and processing flows, **Data Analytics** algorithms, **Dashboards**, **IoT App**, **Synoptics**, **Custom Widgets**, and **Web and Mobile Apps** [BIgDataService2018].

The Snap4City tool:

1. has been the **winner of Select4Cities PCP** https://www.snap4city.org/558 (by Antwerp, Copenhagen and Helsinki), in September 2019.
2. is an **official platform of EOSC** (European Open Science Cloud) marketplace of the European Commission. https://marketplace.docker-fid.grid.cyf-kr.edu.pl/services/snap4city
3. is an **official solution of FIWARE**: https://www.snap4city.org/467 with its network of partners and solutions.
4. is **GDPR compliant** and enforces privacy and security for data, **Dashboards**, **IoT Devices, IoT App, personal data, data analytics** and **processes**, etc., which can be private of the user; and the user may delegate the access to them or pass the full control to other users. https://www.snap4city.org/670
5. provides tools for the administrators to monitor and control the platform status via: auditing, assessment, management, GDPR, network flow monitoring, revoking, request to delete, etc. https://www.snap4city.org/download/video/course2020/sys/Snap4City-6th-slot-system-deploy-v4-6.pdf
6. **GDPR compliant** and enforces privacy and security for data, **Dashboards**, **IoT Devices, IoT App, personal data, data analytics** and **processes**, etc., which can be private of the user; and

the user may delegate the access to them or pass the full control to other users. https://www.snap4city.org/670

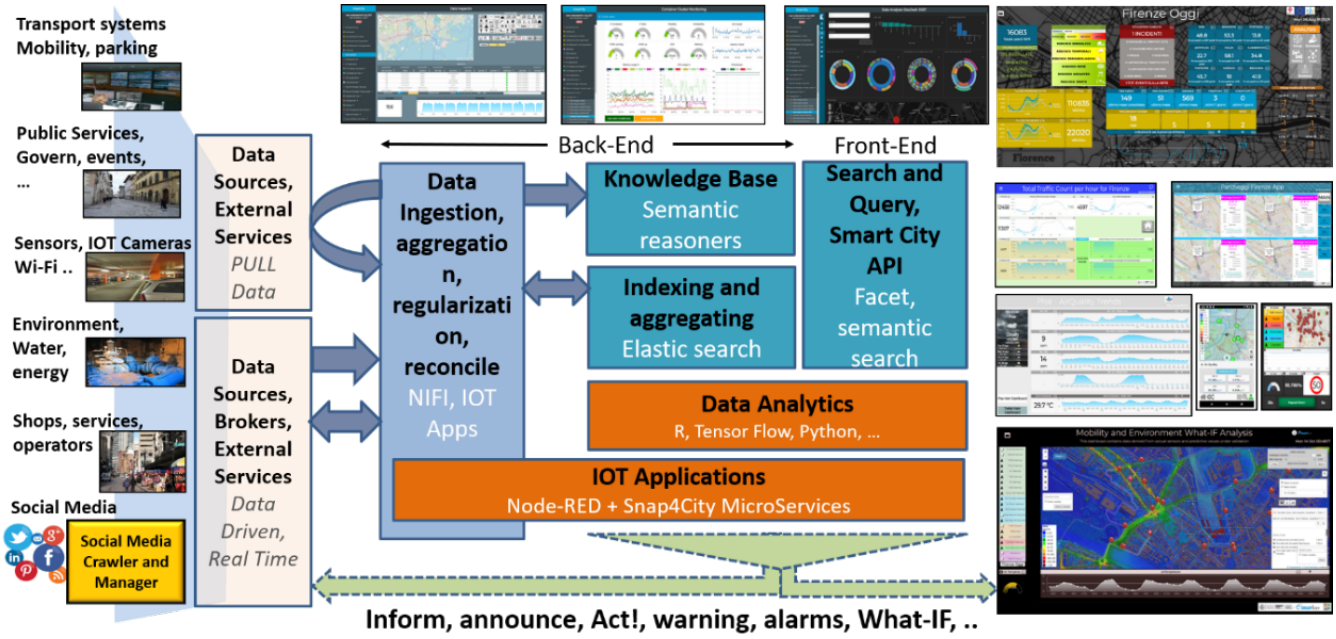
7. passed **PEN Tests** from Setek and Vulnerability test from Thales Mayor expert companies. https://www.snap4city.org/669
8. can be installed on premise as well as on any public or private cloud. https://www.snap4city.org/471
9. can create end-2-end solutions, secure from device to dashboards.

Furthermore the Snap4City solution

1. organized successful international Hackathons for coworking: Florence, Tuscany, Helsinki, Antwerp; https://www.snap4city.org/hackathon
2. is supported by a number of companies and partners: https://www.snap4city.org/577
3. provides continuous training courses with certification. https://www.snap4city.org/622

2.1 – Snap4City Architecture Overview

A **more technical version of the platform architecture is reported in the next figure**, where the main elements are reported and described below.



From Left to right of the above figure.

Data Ingestion and aggregation is performed in push/pull by using: IoT Connectors, IoT Agent, **IoT Adapter, IoT Broker, IoT Apps** in Node-RED, and data gathering tools as **DataGate**/CKAN for open data (https://ckan.org), and **Portia** for Web Scraping. The **Snap4City** solution supports a very large number of protocols push/pull, sync/async among them: MQTT, NGSI, COAP, OneM2M, ModBus, OPC, WMS, WFS, and AMQP. See for the list of the protocols supported.

Data Storage is feed by using **NIFI Cluster** for massive data aggregation/enrichment (collecting data from any **IoT Broker** at which it is automatically registered), and saving data to **Elastic Search** cluster for data storage and indexing, and to the **Knowledge Base** implemented as an RDF store (Virtuoso) which is an index for geo-spatial, relational, and temporal aspects. Every time a new data model is registered in the system, the registration is performed into the **Knowledge Base**. Knowledge base

and Smart City API can be **federated** creating a mutual connection among friend cities see **Section 3.8.** In the Snap4City solution:

- Heatmaps, Orthomaps and Maps are managed by the **Heatmap Server** which is a **GIS** (for example **GeoServer or ArcGIS** if you have one installed with WMS facilities) and can distribute the maps according to WMS/WFS protocols towards Web and Mobiles App and Dashboards;
- Buildings 3D shapes, and Floors are managed and distributed into the **OpenMAINT** tool, standard BIM tools are used for editing and interchange in IFC formats by standard tools as AutoDesk Revit, etc. Buildings and Floors are shown in **Dashboards** for their integration with maps and IoT Devices time trends. Thus, creating a full **Digital Twin** model of any part of the city. The tools for accessing to the **Digital Twin** is the so-called **Data Inspector**. Details can be obtained from: https://www.snap4city.org/download/video/course2020/di/Snap4City-5th-slot-data-ingestion-v4-4.pdf

Data Transformations (reconciliation, regularization, enrichment, etc.) are implemented via **IoT Apps** (IoT Applications) which are processes for ingesting, integrating and manipulating data with PUSH/PULL protocols from any **External Service** and also from **IoT Broker, and Virtual IoT Devices** of any kind. **IoT Apps** are developed by using a visual programming **data flow and/or data driven** flows in **Node-RED** exploiting a large library of more than 150 **Snap4City MicroServices**.

Please note that, in Snap4City Terminology an IoT App is a process in Node-RED plus Snap4City library. The Library is based on nodes and call MicroServices, for this reason also the nodes are called MicroServices. So that often it is state that the Snap4City library in Node-RED provide a large number of MicroServices, in the sense that provide access to MicroServices via a corresponding nodes.

They are also used for implementing user interface logic, **Business Logic** behind smart applications and **Dashboards** also in references of **Custom Widgets** and **Synoptics**, which can be very useful in **Smart City Control Rooms**. Please note that Data Transformation / Integrations may exploit internal and external storages from **any** kind database, **any** connectors from/to data sources, **any External Service**, **any** direct connection with IoT Devices and Networks, etc. A large number of detail regarding the data ingestion are reported in https://www.snap4city.org/download/video/course2020/di/Snap4City-5th-slot-data-ingestion-v4-4.pdf

Data Analytics are processes written in **Rstudio** or **Python** which can perform data access and apply statistics, Machine Learning, Artificial Intelligence, deep learning tools, algorithms also exploiting Tensor Flow, CUDA, Keras, etc. It is also possible to develop processes in JavaScript directly into IoT App, and in Java scheduling processes with **DISCES** (not included in the offer). **Snap4City Data Analytics** in Rstudio, Python and JavaScript are developed with an online development environment which also allows to put in execution the scripts in **Containers** which are deployed as **API** and **MicroService** for **IoT App** and other tools in the platform. Off-line development environments are viable as well, if preferred. **Data Analytics** can produce: predictions, early warning, traffic flow reconstruction, alarms detecting anomalies, KPI and indicators, Typical Time Trends, typical trajectories, Routing and paths, travel plans, query results, simulations, analysis, calibrated heatmaps, smart parking suggestions, car sharing analysis, etc. A large number of examples are provided in: https://www.snap4city.org/download/video/course2020/da/Snap4City-4th-slot-Data-Analytic-v3-4.pdf

Smart City APIs include a large collection of services to: exploit queries and reasoning on the storage and **Knowledge Base**, access/control IoT Network, exploit **Data Analytic** results, exploit **IoT Apps**, etc. All the data and services are accessible via the **Smart City API** which are used by Front End Tools such as **Dashboards**, **Web and Mobile Apps**, **MicroApplications**. Details regarding Smart City API are reported in: https://www.snap4city.org/download/video/course2020/app/Snap4City-7th-day-Mobile-Applications-v2-7.pdf Knowledge base and Smart City API can be **federated** creating a mutual connection among friend cities see **Section 3.8.**

Dashboards can be created by **Dashboard Builder** and/or **Kibana** for different kind of users such as: decision makers, city operators, ICT operators, private for the users, etc., suitable for **Smart City Control Rooms** with video wall, for city Operators on Desktop of multiple monitors, mobile operators, and Situation Rooms with touch panels. **Dashboards** can exploit all kind of data and **Data Analytic**, legacy services, and special tools as traffic flow reconstruction, decision support systems, etc. **Dashboards** area created by using a large range of ready to use **Widgets,** and also **Custom Widgets** creating **Synoptics** as **SVG** elements, or exploiting other graphic libraries, such as D3, Highcharts, etc. Examples on dashboard and how they can be authored are reported in https://www.snap4city.org/download/video/course2020/das/Snap4City-2nd-slot-dashboard-building-v5-4.pdf

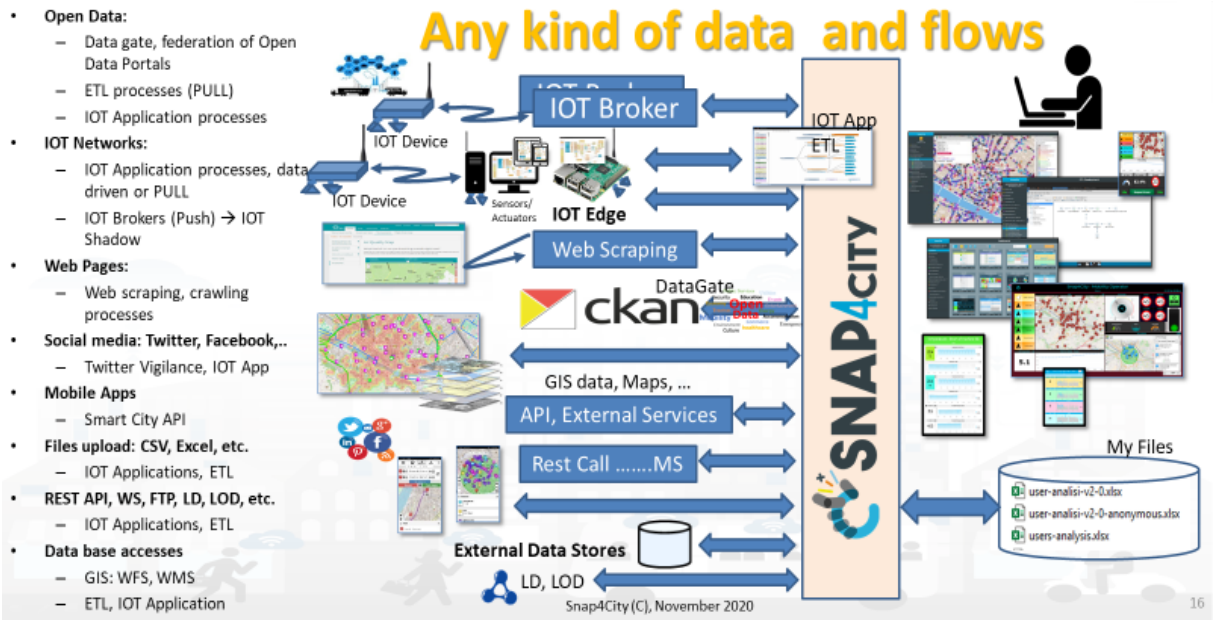
Web and Mobile Applications can be created by developers exploiting **Smart City APIs** and may be controlled by Snap4City tools. For example, to send on the Mobile Apps: engagements, soundages, stimulus, and thus for monitoring user behaviour, creating origin destination matrices, getting reaction from the city users, informing user at the inception of critical conditions, etc. Details regarding Smart City API and their usage for the development of Web and Mobile Apps with related development environment are reported in:
https://www.snap4city.org/download/video/course2020/app/Snap4City-7th-day-Mobile-Applications-v2-7.pdf

Tools of **Snap4City solution for BPM/BIM** are discussed in **Section 3.15**,

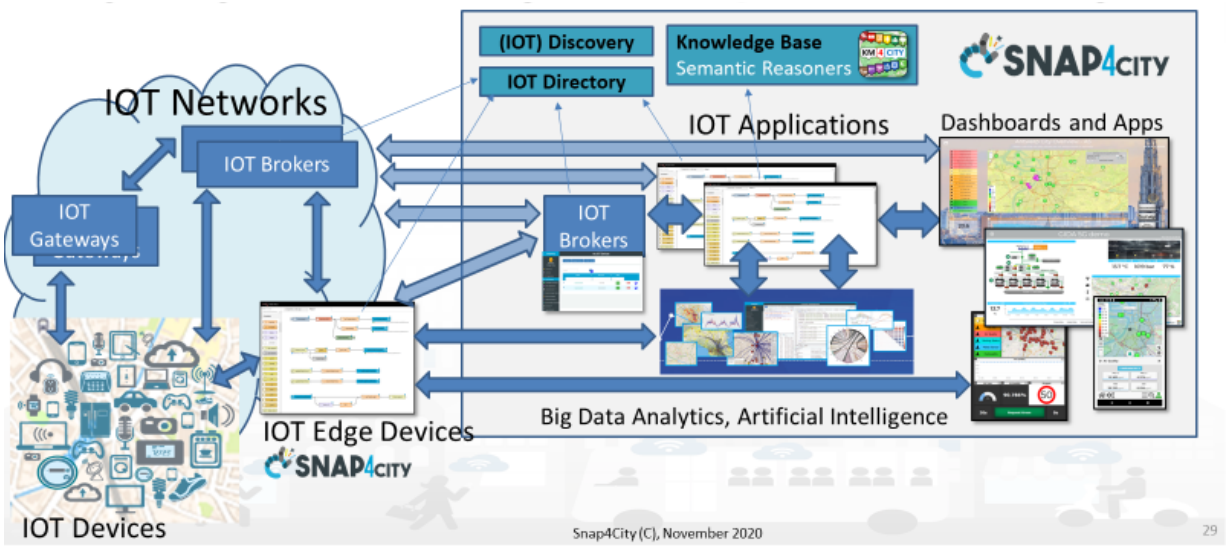
Aspects of Platform **Management and Quality Control** of back-office are presented in Sec**tions 3.16** with managing users' activities, platform setup and control, user auditing, assessment, monitoring, security, process management, and elastic scaling. Details and examples are reported in https://www.snap4city.org/download/video/course2020/sys/Snap4City-6th-slot-system-deploy-v4-6.pdf

2.2– Snap4City Data Sources/Recipients, Bidirectional Channels

One of the first steps to set up a Smart City or add new services can be the data ingestion, and thus connections with data sources/recipients, that in **Snap4City** can be performed in several manners. All the connections can be bidirectional and based on their own protocols. **Snap4City and consequently the project platform is capable to ingest data via those protocols but also produce data back with the same or other protocols**.



It can interact with legacy (of any vender and format) installations on IoT Networks, and thus with IoT Edge Devices, Gateway, etc. They can communicate via their own protocols or using the direction connection with Snap4City exploiting protected communications. IoT Edge devices with Node-RED can directly install Snap4City library to exploit from the platform: data ingestion processes, data model registration, Data Analytic, dashboards, direct interaction with dashboards and users.



2.3 – Snap4City IoT Apps and MicroServices

The **IoT Apps** can be executed on-cloud or IoT Edge Devices (on-premise). When IoT Apps are executed on IoT Edge Devices, they may directly communicate with the IoT Apps or Dashboards on-cloud or by means of IoT Broker (to which all other entities can be subscribed). On such grounds, in Snap4City, the IoT Apps are defined as:

IoT App = Node-RED + Snap4City MicroServices.

The IoT Apps exploit the basic nodes of Node-RED Node.JS plus Snap4City MicroServices and their visual presentation as nodes/blocks, which are suitable for smart city and IOT transformation and processing. The Node-RED platform is based on two components:

(1) a web-based **visual editor** to design flows and
(2) a runtime environment that may execute flows.

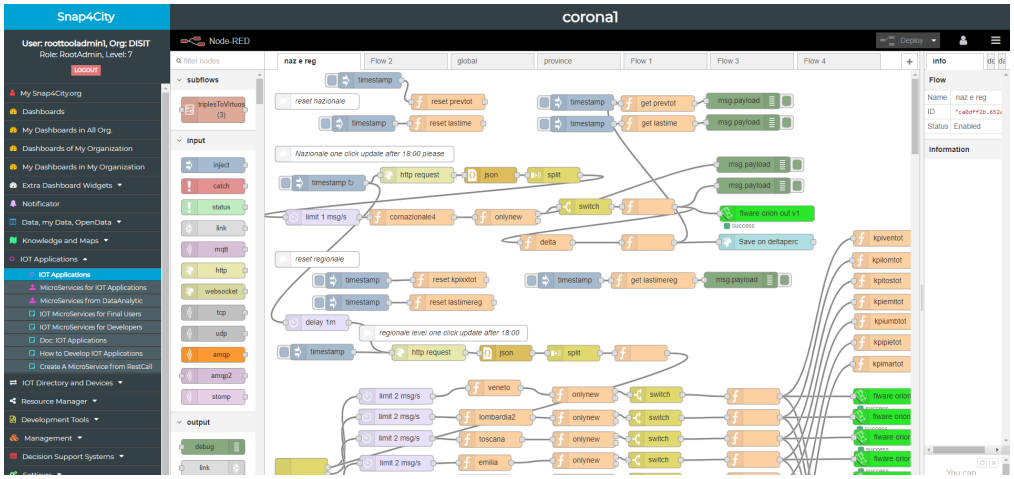
In Snap4City tool, the **IoT App/Node-RED visual editor** is fully integrated into the development environment and it has been improved to:

1. communicate with the Snap4City **Resource Manager** to save and load IoT App and flows, which is a marketplace of resources for sharing and marketing them in the community,
2. login via SSO (Single Sign On), exploiting Snap4City **LDAP** and **KeyCloak (which is an open IAM)**, using **OpenIDConnect** (OAuth and Access Token)
3. manage Smart City / IOT MicroServices, namely, the Snap4City Libraries of Node-RED, which are accessible from the Node-RED official library: https://flows.nodered.org/search?term=snap4city

The runtime engine of Node-RED has also been improved to

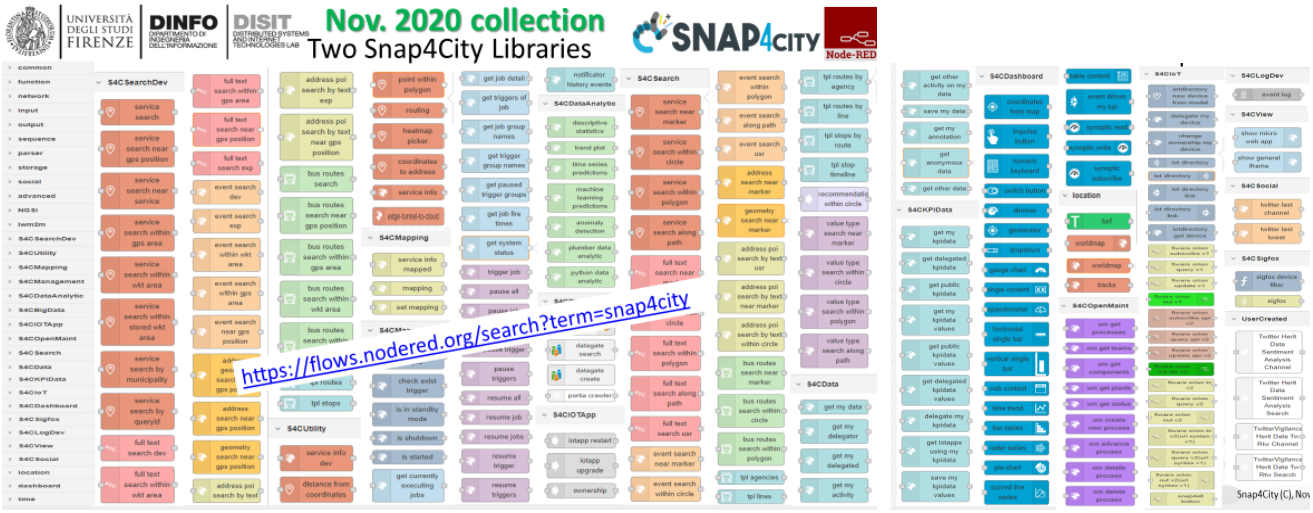
1. manage the security, according to SSO and the Snap4City model also using Access Token for authenticated M2M communications, and
2. execute IoT Apps on Container/Docker, according to the elastic management solution of Snap4City (**Marathon** and **Mesos**, and eventually in **Kubernetes**).

The changes performed on Node-RED have been released as open source and are functional only for large-scale on-cloud use, while the Snap4City MicroServices can be used in any Node-RED installation and thus also on IoT Edge with the standard Node-RED tools, without any restrictions.



Snap4City solution provides a large set of **MicroServices**, which provide an easy and formalized access to all the Smart City services that are available on-cloud from the platform (including the ones to control a part of the platform itself). They are made available in the Node-RED Node.JS environment to create **IoT App** as visual programming language. Among the **MicroServices**, the **IoT Apps** also need to access such services to allow for the exploitation of **Data Analytics**, Visual Analytics and Dashboards. The latter two aspects can be employed to create the Graphic User Interface (GUI) of the **IoT Apps**. These tools, orchestrated by the **IoT App** flows, may automatically inform, announce, act and produce alerts and warnings on **IoT Devices**, networks, the user interface, external services, etc., and provide support to close the loop towards the user acting/reacting on the GUI and/or Devices, including notifications.

In order to satisfy the smart city requirements, in Snap4City, a collection of more than 150 MicroServices, as Nodes for the Node-RED programming environment, has been developed. https://flows.nodered.org/search?term=snap4city
The Node-RED philosophy of visual programming allows for the creation of event-driven data flow applications, where the exchanged messages are in JSON format. On the other hand, periodic processes can also be developed by scheduling one or more internal timers. This means that users that have registered in the platform and have therefore access to it can develop IoT Apps as Node-RED flows, exploiting both Push and Pull data protocols, in the same visual programming environment. In the context of smart cities, both protocols are needed, while IoT Apps are capable of creating flows and exploiting a large number of features that are typically not available in the Node-RED open library, nor in a number of libraries from different providers. Moreover, the Snap4City **MicroServices** are at a level that can allow even non-expert users or people that are approaching for the first time to the project platform to easily develop IoT Applications for smart cities**.**



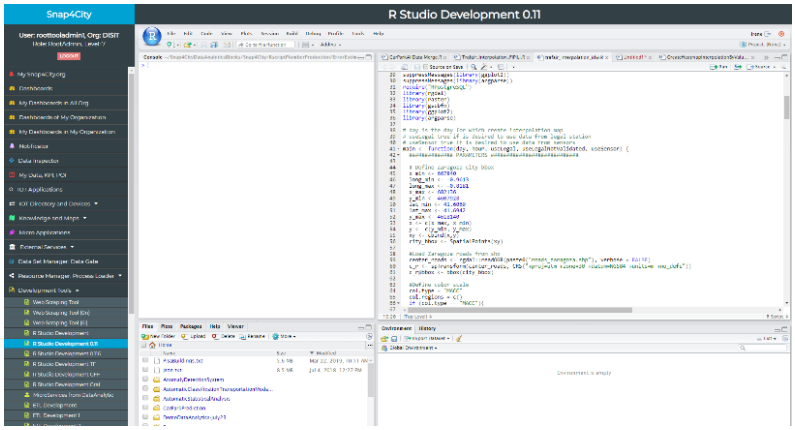
The most relevant families of nodes/MicroServices for smart cities are listed below, and they perform different kinds of activities, which are useful in the IoT App construction. **Snap4City library of MicroServices in Node-RED** include more than 150 nodes
https://flows.nodered.org/node/node-red-contrib-snap4city-user and
https://flows.nodered.org/node/node-red-contrib-snap4city-developer

2.4 – Snap4City Data Analytics Development and Exploitation

For the data analytic development, it is possible to access the Big Data store respecting the privacy and the data licensing by using authenticated Smart City APIs. The access has to permit to read historical and real time data, and to save the resulting data provided by the algorithms, for example, heatmap-related predictions, the assessment of data quality, and labels of detected anomalies. The work of the data scientist could finish once the algorithm has been developed which he/she should be aware of. On the other hand, the same algorithm (e.g., for computing heatmaps, parking prediction), should allow to be:

1. Used on different services of the same kind located in different places and on the basis of a number of parameters (e.g., target precision and list of data sources). This means that data analytic itself has to be designed with the needed flexibility and generality;

2. put in execution from IoT Applications by passing a set of parameters and collecting the results on the Data Storage or as a result of the invocation. The executions can be periodic or event driven — e.g., the arrival of a request or by the arrival of the new set of data values;
3. controlled for collecting eventual errors and mistakes, in debug and at run time for logging. This may be for informing the developer and/or the administrator of eventual mistakes and problems by sending notifications; and
4. dynamically allocated on cloud in one or multiple instances to plan a massive computation of the same data analytic process on several data sets and services at the same time.



Therefore, the solution developed for Snap4City satisfies all the above described requirements. Data analytic processes can be developed using **R Studio** or **Python**. In both cases, the code has to include a library for creating a REST Call, namely: Plumber for R Studio and Flask for Python. In this manner, each process presents a specific API, which is accessible from an IoT Application as a MicroService, that is, a node of the above-mentioned Node-RED visual programming tool for data flow.
Data scientists can develop and debug/test the data analytic processes on Snap4City cloud environment since it is the only way to access at the Smart City API with the needed permissions. The source code can be shared among developers with the tool "Resource Manager", that also allows the developers to perform queries and retrieve source code made available by other developers.

2.5 – Snap4City Contextual Dashboards, and Control Rooms

A **dashboard is substantially a Decision Support System** tool, since it provides evidence of critical conditions, and may offer solutions. On this regard, it may integrate/exploit artificial intelligence algorithms, for example, reporting prediction, identifying anomalies, manifesting early warning, providing relationships among entities exploiting inference geospatial reasoning about what is located in the city: resources, structure, people, areas, critical infrastructures, etc. A concrete example is the possibility to analyse the impact of events of people flows, as happened to the strong manifestation effects occurred in Florence on 30th October 2020 (section 3.3). In the development of a Smart City there is a great emphasis to have a number of different visual rendering tools based on Dashboards, and in particular to satisfy needs of smart city platform **regular users, developers, city operators, operative dashboards for the verticals, data analysis dashboards, decision makers, business intelligence dashboards, up to the system of dashboards to be shown in the Smart City Control Room and in the situation rooms**. [Industry4.0-2020], [Dashboards2019], [DashboardProduction2020].

Snap4City tool allows creating **Dashboards** of any kind which are interactive data & graphics applications including maps, trends, series, tables, gauge, pie, button, dimers, semaphores, time ranges, what-if analysis features, and a large set of special and custom graphic **Widgets** for representing city elements and acting on the city processes: weather forecast, social media and sentiment analysis, traffic flow, event reporting, event selectors, real time vehicle tracking, decision support suggestions, actuators, KPI (key performance indicator), POI (point of interest), IOT/IOE (internet of thing/ everything), trajectories, heatmaps, TV cameras, dynamic routing, etc. Control room with video wall: https://www.snap4city.org/621

Snap4City Dashboard Builder provides a very large library of widgets which can be used to create Dashboards. A number of them are visible in the above reported examples. Please note that, a large number of Widgets in the library and the Wizard are shortening the time for creating contextual dashboards. This is a high value since the Dashboards are often requested when needed, typically they are *requested today for yesterday*, this for example is what can happen in a large city.

2.6 – Snap4City Development Environments and Training

Snap4City.org is a perfect example of the training environment which can be set up using Snap4City services. Snap4City.org is a **multitenant full installation of Snap4City solution** in which several Organizations are hosted, among which those involved in Herit-Data pilot projects.

The list of Organizations accessible from: https://www.snap4city.org/download/video/cov/ The different Organizations have different levels of privacy and are exploiting the Snap4City.org service and project platform in different manners for different purposes. Some of them for tourism, other for mobility and transport, environmental aspects, others for full smart city control room with several domains and smart solutions applied, and others again for verticals as smart parking, smart lighting, and managing mobile applications, etc. So that the Snap4City.org is a multi-organization living lab.
Some of those organizations have also their own installation of Snap4City services on their premise, and use their tenant/host account on Snap4City.org as the sand box in which new features are tested, training courses are given, documentation is published and new examples are accessible.

A Snap4City solution provides to developers, entrepreneurs, public and private sectors, non-profit organizations, researchers, etc. an SDK which includes all the instruments needed to **ONLINE development** (if not otherwise specified) for creating, saving, sharing and editing, their artefacts:

1. **Living Lab environment** for accessing to training information, video, examples; discussing about solution, sharing experiences.
2. **Resource Manager:** to search for solutions, sharing resources, saving back up of their solutions.
3. **Dashboards** and **Widgets on Dashboards, widget collections.**
4. **Synoptics**, **Custom Widgets (custom widgets may need to install open source SVG editor on local computer), custom PINs for animated and dynamic PIN on Maps.**
5. **IoT Apps**: for connectors, integrations, data ingestion, data transformation, business logic behind Dashboards, business intelligence, services. Also managing versioning on GitHub of their flows.
6. **IoT Brokers** and connectors of any kind full features of FIWARE based solution, but not limited to FIWARE solutions and protocols.
7. **IoT Directory for IoT Network management and abstracting from Brokers, Devices.**
8. **IoT Device Models, and SDK to develop code to be placed on physical IoT Devices based on Android, Raspberry Pi, Arduino, ESP32, window, Linux.**
9. **Data Analytics** in various languages: RStudio, Python, also transformed in API services and MicroServices for IoT App. Please note that RStudio can call segments in Python, Java, etc.
10. **External services as web pages to be integrated into Dashboards;**
11. **External services accessible via API, to be integrated as API, and MicroServices in IoT App;**
12. **Web and Mobile Apps: with standard SDK for Apache Cordova to be installed on local computer**
13. **Web Scraping**, Crawling also transformed in API services and MicroServices for IoT App.
14. **Workflows on IoT App and OpenMaint/BPM, also integrated each other.**
15. **HeatMap server:** for automated production of heatmaps and their distribution via other GIS: ArcGIS for example.
16. **Report generator:** at levels of users, devices, dashboard, solution.
17. **BIM models and data, created and edited with third part tools in standard IFC and then integrated into on line OpenMAINT.**

On line training is accessible from Https://www.snap4city.org/577
Training slides contain a large number of real scenarios with real dashboards, IoT App, business intelligence solution, full applications and Data Analytics in place.

2.7 – Snap4City Security

Snap4City solution successfully passed PENtest performed by SETEK and Vulnerability Test performed by Thales Italy in the 2019. **Corrective Actions** performed on **Snap4City** main tool are reported on https://www.snap4city.org/669 . The security of the **Snap4City** solution has been validated in international top journal and publication IEEE Access and it is freely accessible from **[Security2020].**

The OWASP IOT mainly refers to the IoT Network aspects, which are out of the platform control. On the other hand, the aspects referring to the server side of the top 10 problems (e.g., 1) passwords, 2) network services, 3) interface, etc….. https://wiki.owasp.org/index.php/OWASP_Internet_of_Things_Project) are practically also verified by PENtest performed by SETEK and Vulnerability Test performed by Thales.

2.8 – Snap4City Access Control and GDPR Compliance

Snap4City services have been designed and it is GDPR compliant as an IOT/IOE platform. As a consequence, also Heirt-Data project platform is GDPR compliant and allows to collect and manage data according to the rights of the data owners, and to control the data exploitation when they are distributed. In Snap4City, all devices start as **personal private IoT Devices,** such as: Mobile App data, personal devices data, SmartBeds data, Cars data, hearth monitoring, glucometers, etc**.** They may become public or accessible to one or many users, groups, orgs, on the basis of grant authorizations, defined by the owner**.** . GDPR aspects are presented on Snap4City on https://www.snap4city.org/670

See for security and GDPR aspects: [Security2020]

2.9 – Comparison with other market and open sources solutions

Extracted from: Badii, C., Bellini, P., Difino, A., & Nesi, P. (2020). Smart City IoT Platform Respecting GDPR Privacy and Security Aspects. *IEEE Access*, *8*, 23601-23623. **[security2020]**

	IOT Discovery Abstraction	Authentication, Authorization	Security end-2-end, secure on IOT and Dashboards	Open HW and Open SW	Integrated Community management	Data Types: IOT Devices, IOT App, Dashboard, Data	Data Type: Publish/share, Delegation, Consent and change	Data Type: Download and Delete	Auditing on Data Type Access	Open Source end-to-end	Scalability IOT	Visual Programming end-to-end applications	Advanced Smart City API, MicroServices	Multi Domain Semantic Platform	Standard based Modules and IOT, Open Devices	Resource Sharing	Data Analytics integrated	Dashboard H24/7, protected connection	Multi-protocol on IOT
		G				G	G	G	G										
Snap4City	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
KAA [53]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	N	(Y)	N	N	Y	Y
Thingsboard [55]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	MQTT,coap, http
IOT eclipse.org [56]	N	N	N	(Y)	N	Y	N	N	N	Y	Y	N	N	N	Y	N	N	N	Y
IOT IGNITE [57]	N	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	N	N	N	N	N	Y	MQTT
FIWARE [47]	N	Y	N	Y	N	N	N	Y	N	Y	(Y)	(N)	Y	N	Y	N	N	Y	Y
ARM mbed IoT [48]	Y	Y	Y	Y	Y	N	(N)	N	Y	Y	Y	N	N	N	Y	N	N	Y	Limited
Airvantage [51]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	MQTT, HTTP
AWS [43]	Y	Y	Y	Y	N	Y	(N)	Y	Y	N	Y	N	N	N	Y	Y	(Y)	Y	Limited
Azure IOT [44]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	(Y)	Y	Limited
PTC ThingWorkx [59]	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	N	N	Y	N	N	Y	Y
Bosch IoT Suite [58]	Y	Y	Y	Y	Y	(Y)	(N)	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y	Y
CISCO Jasper [55]	Y	Y	Y	Y	N	(Y)	(N)	N	Y	N	Y	N	N	N	N	--	(Y)	Y	N
Siemens MindSphere [60]	Y	Y	Y	(Y)	N	Y	(N)	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	Y
Carriots [54]	Y	Y	Y	(Y)	N	Y	N	N	Y	N	Y	N	N	N	--	N	N	Y	MQTT
Google IOT [45]	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	N	N	N	(Y)	(Y)	MQTT, HTTP
Homekit Apple [50]	Y	Y	Y	Y	N	Y	N	N	Y	N	(Y)	N	N	N	N	Y	N	Y	Limited
Smarthing Samsung [52]	Y	Y	Y	Y	Y	Y	(Y)	Y	Y	N	(Y)	N	N	N	N	N	N	Y	Limited

3 – Terms and Acronyms of Snap4City

Term	Description
Access Token	An access token is an object encapsulating the security identity of a process or thread or of a user. In Snap4City is used for the M2M authentication. For example when a process needs to access a smart city API via data analytics https://www.snap4city.org/650 or when your IoT App needs to access your devices.
AMMA	Application and MicroService Monitor and Analyzer. A Snap4City tool to perform the analysis of data flows among IoT Apps and the several MicroServices. See more on https://www.snap4city.org/198, https://www.snap4city.org/43 In alternative, standard tools may be used.
API	Snap4City API are classified in Internal and External. They are all API Rest and are documented in Swagger: https://www.km4city.org/swagger/external/index.html https://www.km4city.org/swagger/internal/index.html
ArcGIS	Is a commercial GIS solution, which has to provide WFS and WMS modules if not installed. https://www.arcgis.com/index.html ArcGIS is produced by ESRI that has a joined lab with **University of Florence LabGeo** and has been in collaboration with **University of Florence DISIT Lab since long time on Snap4City solution**.
BI	Business Intelligence. In Snap4City, the tool for BI is composed by Dashboard Builder, Wizard, IoT App, and for direct Dashboards with Kibana.
BIM	Business Information Modelling. In Snap4City, the tool for BIM is performed by OpenMAINT (https://www.openMAINT.org/en/home) and its integration with the BIMServer. https://github.com/opensourceBIM/BIMserver OpenMaint can be controlled by IoT Apps.
BPM	Business Process Management. In Snap4City this activity of defining business processworkflows is modelled and performed by means of OpenMAINT tool. See OpenMAINT definition.
Calibrated Heatmap	Calibrated heatmaps are heatmap with stable colors based on a color map not depending on the zoom level or on the different view colors are represented. In Snap4City, both calibrated and gaussian heatmap can be produced and distributed. Calibrated Heatmap are distributed via a GIS with WMS (for example as ArcGIS or GeoServer) and may have billions of points. https://www.snap4city.org/457
City Map Command and Control Center	See Smart City Control Room
CKAN	CKAN is an open source solution for Open Data management and distribution https://ckan.org/ In Snap4City is integrated with **DataGate** module and goes with SSO with the rest of tools. CKAN/DataGate can be controlled by IoT Apps.
Connectors	Connectors can be found/implemented in the Snap4City services by means of different approaches, by using: 1. IoT App, since a large number of connectors with several protocols and formats are accessible on the Node-RED community. A large number is ready to use in the Snap4City IoT App on cloud and on IoT Edge as well. https://flows.nodered.org/ 2. IoT Agents of IoT Orion Broker of FIWARE, when they are present, they convert the format into NGSI. https://www.FIWARE.org/developers/catalogue/ For Snap4City, IoT App possibility is more flexible, since it permits to map and filter models and transform them, as well, when needed. The IoT App can be put in execution on Cloud and on IoT Edge as well, but all controlled with a visual environment from the main Snap4City interface.
Containers	In Snap4City Container are implemented as Dockers. They are used for Snap4City tools as described in https://www.snap4city.org/471 as well as for managing IoT App, Data Analytics in RStudio, Data Analytic in Python, and WebScraping processes.
Copernicus	Satellite data: pollution, weather, land, climate, atmosphere, security, emergency, etc. https://www.copernicus.eu/en
Custom Widget	In Snap4City, widgets are the components of the Dashboard to visualize views on data (with animation, graphics, synoptics, etc.) and also to collect interaction from the users (buttons, faces to be clicked, sliders, keypad, text pad, etc.). see HOW to create custom widgets in SVG, and examples: https://www.snap4city.org/651 https://www.snap4city.org/595 https://www.snap4city.org/644 https://www.snap4city.org/663 How to create widgets by programming: https://www.snap4city.org/153

D3	A library for JavaScript graphic representation: https://d3js.org/ This library may have some costs according to the licensing and usage.
Dashboard	is substantially a Decision Support System tool, since it provides evidence of critical conditions, and may offer solutions. On this regard, it may integrate/exploit artificial intelligence algorithms, for example, reporting prediction, identifying anomalies, manifesting early warning, providing relationships among entities exploiting inference geospatial reasoning about what is located in the city: resources, structure, people, areas, critical infrastructures, etc. See details on dashboard in section 3.10 of this document and from the training course part 2: https://www.snap4city.org/download/video/course2020/das/Snap4City-2nd-slot-dashboard-building-v5-4.pdf
Dashboard Builder	In Snap4city, it is the main tool for creating Dashboards and connect them with IoT Apps, and other dashboards and custom widgets. See details on dashboard in section 3.10 of this document and from the training course part 2: https://www.snap4city.org/download/video/course2020/das/Snap4City-2nd-slot-dashboard-building-v5-4.pdf
Data Analytic	For Data Analytic we intend all deep data transformation on data that produce a new data kind: prediction, heatmap, anomaly detection alarm, traffic flow reconstruction, origin destination matrices, etc. In Snap4City, in the several installations, a large number of them have been developed in Rstudio, Python, Java, JavaScript, etc. In most cases, they exploit statistic, machine learning, data mining, artificial intelligence, semantic computing, etc. See for more info section 3.9 of this document and training course part 4: https://www.snap4city.org/download/video/course2020/da/Snap4City-4th-slot-Data-Analytic-v3-4.pdf
Data Dictionary	A Snap4City tool which allows to define Value_Type, Value_Unit and their relationship; and Nature and Subnature in their relationships. Snap4City is also provided with a set of more than 200 different attribute models into the Dictionary.
Data Inspector	In Snap4City, the Data Inspector is the main tool for the browsing of the information about a data stream entering into the platform. It is directly accessible from the main menu and give access to the Digital Twin representation of data, devices, and all **High Level Types** of the platform. See more details on part 5 of the training course: https://www.snap4city.org/download/video/course2020/di/Snap4City-5th-slot-data-ingestion-v4-4.pdf
Data Shadow	A term adopted to describe the historical data of and IoT Device (sensors and actuators). In most of the platforms (for example: MS Azure, AWS), this feature is optional (please note that most of the Brokers provide only the last values of the IoT Devices). In Snap4City, it is a main feature to save all data messages of devices, and it is implemented saving data into Elastic Search cluster. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
Data_Type	Each Attribute/variable in Snap4City platform is defined in term of Value_Type, Value_Unit and Data_Type (e.g., Energy Power, Kw/h, Float).
DataGate, Data Gate	Module of Snap4City to integrate the solution with CKAN Open Data management and network of services
DevDash	A Snap4City tool for monitoring the global flow of data entering into the platform and reaching the Elastic Search. https://www.snap4city.org/198 https://www.snap4city.org/152 https://www.snap4city.org/145
Digital Twin	See Data Inspector which is the main tool for navigating into the information associated at each Digital Twin.
DISCES	Distributed scheduler for Smart City by Snap4City. It is used for scheduling Java processes in a distributed set of Nodes. It is part of the additional Suite for managing ETL processes. https://www.snap4city.org/236
DISCES-EM	Distributed scheduler for elastic management for Smart City by Snap4City. This tool is used for the elastic management of Container on the Marathon/Mesos cluster of containers. Read more on section 3.14 and on https://www.snap4city.org/232
Docker	Specific kind of Containers adopted by Snap4City, https://www.docker.com/
DockerHub	Socker Hub for Snap4City tools via DISIT lab https://cloud.docker.com/u/disitlab ,
Drupal CMS	A CMS, Content Management System, for Living Lab. See for its usage Https://www.snap4city.org and part 6 of the training course since it is the main support for the Living Lab: https://www.snap4city.org/download/video/course2020/sys/Snap4City-6th-slot-system-deploy-v4-6.pdf
End-2-End	Solution that allows to connect devices to the dashboards full stack. Snap4City can create end-2-end solutions, full stack, and secure with TSL, HTTPS, and Web Socket secure from devices to Dashboards.

EOSC	Snap4City is an official solution of EOSC (European Open Science Cloud) marketplace of the European Commission. https://marketplace.docker-fid.grid.cyf-kr.edu.pl/services/snap4city
ERP	Enterprise Resource Planning. Typically, the ERP may include BPM functionalities. Snap4City is integrated with openMAINT BPM which in turn is integrated with several ERP. Also IoT App are integrated with several ERP among them: https://flows.nodered.org/search?term=erp
ESB	Enterprise Service Bus, a modality for exchanging information among services. It has been replaced in most cases with MicroServices.
ExternalServices, External Services	Snap4City external services can be any external services reachable with some protocol to get data and services. REST Call can be automatically transformed in MicroServices for the IoT App. The other can be called from the IOT Ap directly using a large range of protocols: https://www.snap4city.org/65
Federated Knowledge Base	A set of Snap4City knowledge Basis connected each other via the so-called SuperServiceMap API. This allows the creation of mobile applications that may move from multiple cities and area accessing data and making queries transparently. This solution is presently in place among the **Knowledge Bases**: Antwerp/Helsinki, Tuscany/Firenze, Sardegna, etc. The resulting Service is called **SuperServiceMap** and it is integrated in the Smart City API. See **Section 3.8**. **Km4City ontology** data model https://www.snap4city.org/download/video/DISIT-km4city-City-Ontology-ita-v5-1.pdf
Federated Smart Cities	See Federated Knowledge Base
GDPR	General Data Protection Regulation of the European Commission. https://ec.europa.eu/info/law/law-topic/data-protection/reform/what-does-general-data-protection-regulation-gdpr-govern_en Snap4City is compliant with this directive and passed the assessment with a number of cities https://www.snap4city.org/670
GeoServer	GeoServer is an open source solution/tool for GIS data distribution. http://geoserver.org/ In Snap4City, the Geo Server is used into the HeatMap Server for distributing Heatmaps in GeoTiFF format according to tiled. https://www.snap4city.org/536 https://www.snap4city.org/507 GeoTiFF are used for distributing Orthomaps, Map and Heatmaps in form of images / tiles.
GIS	Geographic Information Server/service. A tool for modelling geo information. In Snap4City this role is covered by ServiceMap, and by the HeatMap Manager which includes a connection to a GIS (ArcGIS of GeoServer) or directly the GeoServer if needed. See https://www.snap4city.org/368 to see all relationships from GIS and Snap4City including interoperability.
Group	A Snap4City Group of User is a community into an Organization. Grant authorizations to resource access can be provided at level of single user, Group and/or Organization.
GTFS	General Transit Feed Specification, https://developers.google.com/transit/gtfs It is a standard file format by used to formalize the public transport information, trips, paths, busstops, time schedule, etc. Snap4City is compliant and can ingest GTFS files using ETL processes, the corresponding information is feed into Knowledge Base.
Heatmap	Are maps of points into Heatmap server, and/or directly images representing data in regular and non regular matrices. When they are in images are distributed via a GIS in WMS protocol as tiles (for example via ArcGIS or GeoServer). See https://www.snap4city.org/457 and https://www.snap4city.org/641 see Calibrated Heatmaps
HeatMap Server, Heatmap Manager	HeatMap Server exposes API for (i) colleting data regarding Heatmaps, (ii) providing information about the value of the map in any GPS point included, the so called heatmap picking, (iii) automated generation of Heatmaps in GeoTiFF format according to tiled which are distributed by a GIS via WMS protocol (they can be ArcGIS or GeoServer). https://www.snap4city.org/536 https://www.snap4city.org/507
High Level Types, HLT	They are the main data entity type managed by Snap4City. They are: sensor, sensor actuator, virtual sensors, external services, MicroApplications, synoptics, MyKPI, personal data, WFS, Complex event, heatmaps, traffic flow, etc. see https://www.snap4city.org/583
HighCharts	A library for JavaScript graphic representation: https://www.highcharts.com/ This graphic library may have according to the usage some licensing conditions.
HLT	See High Level Types
IAM	Identity and Access Management. In Snap4City, this function is solved by KeyClock and LDAP open source tools, and it also provide SSO.

Innovatrix	A methodology for innovation at the ground of Snap4City Innovation model: https://www.imec-int.com/en/innovation/innovatrix
integrations	The instrument to implement inegrations is what is called in Snap4City terminology the IoT App, IoT Applications. SEE IoT App, see section 3.6 in this document. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Adapter	A term adopted in IOT to indicate a remote converter of protocol located from the IoT Device and the IoT Broker. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Agent	A term adopted in IOT to indicate a remote converter of protocol located from the IoT Device and the IoT Broker. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT App, IoT Application	Node-RED process + Snap4City Library of MicroServices SEE IoT App, see section 3.6 in this document. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Application, IoT App	Node-RED process + Snap4City Library of MicroServices SEE IoT App, see section 3.6 in this document. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Broker	An IoT Broker which may support one or more protocols, typically only one. It can support IoT Adapter, it can implement solution for MultiTenant and paths, such as IoT Orion Broker. Other IoT Broker can be: Mosquitto, HiveMQ, etc. https://en.wikipedia.org/wiki/Message_broker There are several brokers that may implement the same protocol such as https://en.wikipedia.org/wiki/Comparison_of_MQTT_implementations Snap4City is almost agnostic about the brokers and accept a number of brokers and protocols registered on IoT Directory of Brokers and Devices. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Connector	A component to connect to a service using a protocol. In Snap4City, a large number of connectors and protocols are supported into the IoT App microservices. See Section 3.7, and interoperability web compliant page Https://www.snap4city.org/65
IoT Device	An IoT Device with sensors and/or actuators. In Snap4City, an IoT Device can be registered on IoT Broker before sending data on the platform. If the Broker is internal, the IoT Device can be registered on IoT Directory that perform all what is needed to register on IoT Broker and also on Knowledge Base and NIFI to automatically perform the Data Shadow of all the data produces by the device. This is possible since NIFI is automatically subscribed to all Devices of the Internal Brokers. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Device Model	A model for an IoT Device, Virtual IoT Device, etc. In Snap4City, an IoT Device Model can be registered once and shared and used many times for instantiating one or many devices with the same model in short time. For example, 40.000 lights of a smart light system. Please note that the Model is a template, and once used can be modified without any impact of the produced instances. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Directory	Snap4City tool for registering IoT Broker and Devices. Snap4City is almost agnostic about the brokers and accept a number of brokers and protocols registered on IoT Directory of Brokers and Devices. The IoT Directory is capable to browse on internal and external brokers to discover IoT Devices and register them on Knowledge Base. https://www.snap4city.org/115 The IoT Directory is also the tool that manage all the network information about the devices deployed and connected. It is capable to exploit NGSI V1 and V2 protocol aspects to inspecting and managing IoT Orion Brokers of FIWARE, so that to manage a large number of them and automatically performing registration of devices in bulk on Knowledge base. See https://www.snap4city.org/76 https://www.snap4city.org/562, https://www.snap4city.org/647 See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Discovery	It is a function of Snap4City IoT Directory and Knowledge base which allow to discover the IoT Devices by a number of filters: geospatial, by type, by value name, by unit, by nature and subnature, etc- https://www.snap4city.org/109 The same Feature is provided in IoT App, IoT Directory, ServiceMap, Data Inspector and Dashboard Builder. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf

IoT Edge Device	An IoT Device capable to execute processes. In Snap4City terminology are typically endowed of Node-RED process which also has installed Snap4City Libraries of MicroServices. See section 3.5, and also 1. https://www.snap4city.org/646 for the remote control of IoT Edges 2. Edges on Linux https://www.snap4city.org/298 3. Android https://www.snap4city.org/278 4. raspberry pi. https://www.snap4city.org/279 5. Snap4Home: https://www.snap4city.org/617 6. Snap4industry: https://www.snap4city.org/369 7. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
IoT Orion Broker	FIWARE component: https://FIWARE-orion.readthedocs.io/en/master/ The IoT Orion Broker support natively the NGSI V1, V2 and LD. It usually provides only the last values of the IoT Devices and not the historical data (data shadow). In order to have the Data Shadow, and thus to perform queries on time series, the IoT Orion Broker has to be connected to a storage. In Snap4City, the storage provided is Elastic Search which provides high capabilities for insert, search and retrieval and scalability. See training part 3 https://www.snap4city.org/download/video/course2020/iot/Snap4City-3rd-slot-IOT-Applications-v5-8.pdf
ISEMC for Video Wall	ISEMC for Video Wall management integrated with IoT App. (https://www.snap4city.org/621)
KB	See Knowledge Base
KeyCloak	For identify and access management, authentication and SAML, and SSO. https://www.keycloak.org/
Km4City Ontology	Km4City means Knowledge Model for the City. It is an Ontological model for the smart city and IoT Applications in smart city and many other domains. It is the core model adopted in Snap4City to design and implement the Knowledge Base, ServiceMap and the federation of **ServiceMaps** and smart city APIs. https://www.snap4city.org/19 https://www.snap4city.org/download/video/DISIT-km4city-City-Ontology-eng-v5-1.pdf
Knowledge Base, KB,	**Km4City Ontology** at the basis of the RDF Store. It is an expert system on the city data and entities in which smart city API can perform queries with spatial, temporal and relational reasoners. https://www.snap4city.org/19 https://www.snap4city.org/download/video/DISIT-km4city-City-Ontology-eng-v5-1.pdf
KPI	Key Performance Indicator, see MyKPI
LD	See LOD
LDAP	Lightweight Directory Access Protocol, for user registration role management https://en.wikipedia.org/wiki/Lightweight_Directory_Access_Protocol
Living Lab	Snap4City Living lab Support and Methodology, see Section 3.2. https://www.snap4city.org/206 https://www.snap4city.org/82
LOD, LD	Linked Open Data, Linked Data, see LOG.DISIT, LOG.DISIT.ORG tool for their reading https://en.wikipedia.org/wiki/Linked_data https://lod-cloud.net/
Log, LOGS	In Snap4City (as in many professional solutions and operating systems), LOGS/logs are produced reporting errors with different level of severity (e.g., warning, severe, etc.), they are produced in standard format as **SYSlog**. Those logs can be browsed, queried with tools, for example: standard **LogStash** which is based on Elastic Search, and Snap4City AMMA also based on Elastic Search.
LOG.DISIT, Log.disit.org	Linked Open Graph tool (noting to do with Logs). LOG.DISIT is a tool for accessing and browsing Linked Open Data in the world and in the local Knowledge base, KB. https://log.disit.org/service/
LogStash	See Log, https://www.elastic.co/logstash an open source tool for inspecting logs
Marathon	A Tool Open Source, standard for the management of containers https://mesosphere.github.io/marathon/
Market Place	Resource Manager of Snap4City https://www.snap4city.org/205
MESOS	A Tool Open Source, standard for the management of containers http://mesos.apache.org/

MicroApplications	A snap4City set of views implemented in HTML5 JavaScript for realizing specific functionalities. They are substantially views of Web and/or Mobile Apps which can be called independently and placed into Dashboard external content Widget as well as into Totems. https://www.snap4city.org/dashboardSmartCity/management/microApplications.php https://www.snap4city.org/54 https://www.snap4city.org/99
MicroServices	Snap4City tool is based on MicroServices. They are realized on the basis of the API (both internal and external). In Snap4City, the term MicroService is a synonym of Node in the Node-RED terminology. Each Snap4City node in the Snap4city Libraries for Node-RED is a MicroService of the solution. Other MicroServices can be easily added for customization and mapping of REST CALL APIs internal or of third party or of additional services, or from Container with Data Analytics. https://www.snap4city.org/22 https://www.snap4city.org/106 https://www.snap4city.org/129 For the recent list of MicroServices you have to see the documentation into the Library: https://flows.nodered.org/node/node-red-contrib-snap4city-user https://flows.nodered.org/node/node-red-contrib-snap4city-developer
MultiTenant	is a reference to the mode of operation of software where multiple organizations with their applications operate in a shared environment. The instances (tenants) are logically isolated, but physically integrated.
MyKPI, MyPOI	Snap4City tool for collecting and managing personal KPI, POI. A MyKPI is a variable with may change over time determining a TimeSeries with variable GPS position at each time instant. https://www.snap4city.org/396 https://www.snap4city.org/414
MyPOI	See MyKPI
NIFI Apache	Apache NIFI supports powerful and scalable directed graphs of data routing, transformation, and system mediation logic. https://nifi.apache.org/
Node-RED	A visual Editor for Node.JS processes from JS Foundation. https://nodered.org/ https://flows.nodered.org/
OpenMAINT	Workflow Management System, Incident Management, Business process Management, BIM and GIS integrated with Snap4City. The tool is capable to define workflow integrating activities of humans and machines with the main focus on maintenance and ticketing. It is presently integrated with IoT App of Snap4City. https://www.openMAINT.org/en/home
Organization	Snap4City Organizations inside the platform represent a tenant partitioning of maps and data and users. Typically, the users may belong to a single Organization with their email address and nickname. An Organization may have multiple Groups. A user may belong to multiple Groups. Grant authorizations to resource access can be provided at level of single user, Group and/or Organization.
Out of the Box	Component ready to be used without development, already in use in Snap4City applications and/or solutions.
Platform Management	See Quality Assessment and User Management and Control. **See Section 3.16.**
POI	Point of Interest, services on map, with some GPS location and service classification
Portia	A Tool for Web Scraping, extracting data from web pages. Processes of Portia in Snap4City are converted in MicroServices executed on containers. https://portia.readthedocs.io/en/latest/index.html
Python Server	Snap4City Python server for developing Python processes for machine learning, AI and statistical purpose on data. It can access to data via Smart City API and the Python processes can be transformed into Containers. They can exploit Tensor Flow and Keras and CUDA provided that specific NVIDIA boards are present on the servers, and VM can exploit them with some VGPU of the virtualization environment.
Quadruple Helix	describes university-industry-government-public-environment interactions within a knowledge economy. In innovation helix framework theory, first developed by Henry Etzkowitz and Loet Leydesdorff and used in innovation economics and theories of knowledge, such as the knowledge society and the knowledge economy, each sector is represented by a circle (helix), with overlapping showing interactions. https://en.wikipedia.org/wiki/Quadruple_and_quintuple_innovation_helix_framework
Quality Assessment	A process of quality control regarding several aspects of the platform. A quality control is also performed when the Reports are produced according to specific KPI. See **Section 3.16.** They are default KPI and Dashboards for quality control on Snap4City solution with the views on: 8. API reachability / availability performed by E015 external service: https://www.snap4city.org/388

	9. Smart City API performance: https://dashboard.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTkw 10. DISCES performance: https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjE3Mw== 11. MyKPI monitoring: https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTY0NA== 12. Traffic Analyzer: see **AMMA** 13. Data Flow Global analyzer: see **DevDash** 14. Container Cluster healthiness: see section 3.14, only internally accessible 15. Mobile App monitoring: only internally accessible 16. WEB Server Performance and monitoring: only internally accessible 17. Marathon and Mesos Monitoring: only internally accessible 18. Cloud Services Monitoring and control: from VMware, only internally accessible 19. NIFI Monitoring: an IoT App which uses NIFI API to monitor critical conditions and send alerts 20. IoT Orion Broker Monitoring: the broker provides some statistics on notifications and logs. https://FIWARE-orion.readthedocs.io/en/master/admin/perf_tuning/index.html 21. HTTP server tuning + Notification modes and performance
Quality Assessment of IOT Data and services	A process of quality control regarding IOT data. Snap4City platform performs a control on the healthiness of the IoT Devices automatically on the basis of criteria set up on the IoT Directory. In this case, the control is performed at level of ServiceMap. An additional quality control may be performed in parallel to a dedicated process quality assessment. It is based on Machine Learning. This latter solution is optional for the large amount of resources needed to adopt it. A quality control can be also performed when the Reports are produced according to specific KPI which has to be defined and computed. **See Section 3.16.**
Reports	In Snap4City, the report generator can create consumptive views on the platform status on specific programmable aspects for users and administrators, for example at level of IoT Devices, Dashboards. Specific Reports can be created to produce quality assessment aspects.
ResilienceDS	Resilience and sustained adaptability in urban transport systems (UTS) Today, enhancing resilience in Urban Transport Systems is considered imperative for two main reasons: a) such systems provide critical support to every socio-economic activity and are currently themselves one of the most important economic sectors in Europe; b) the paths that convey people, goods and information, are the same through which risks are propagated. ResilienceDS (https://www.snap4city.org/520).
Resource Manager	Is a Market Place of Snap4City artefacts: IoT App, Flows/subflows, data analytics, ETL, Kibana Dashboards, etc. They can be searched, shared and promoted via a web portal. https://www.snap4city.org/27 https://www.snap4city.org/205 https://www.snap4city.org/188 https://www.snap4city.org/134
Roles	Snap4City users are classified in Roles. Typical Roles are RootAdmin, ToolAdmin, AreaManager and Manager. Other Roles can be defined as well.
Routing, Travel plans	A detailed set of travel segments to start from Point A and reach Point B in the map at the certain time and day. It may be done by car, bus, and multimodal. A specific tool is needed to compute the travel plan, and detailed data are needed on the Knowledge Base to take decision about the planning. Some of the data can be recovered from OSM, Open Street Map, and their availability may depend on the geo zone.
Rstudio Server	Snap4City RStudio server (open source tool) for developing RStudio processes for machine learning, AI and statistical purpose on data. It can access to data via Smart City API and the RStudio processes can be transformed into Containers. They can exploit Tensor Flow and Keras and CUDA. https://rstudio.com/
SDK Mobile App	Software Development Kit for the production of Mobile Apps, exploiting the smart City API of Snap4City. Also this kit is provided in Open Source.
ServiceMap	Visual map interface to make Smart City API query on RDF store and test queries, and request samples of queries via email https://www.snap4city.org/19 https://www.snap4city.org/184 https://www.snap4city.org/155 https://www.snap4city.org/180

ServiceURI	In Snap4City terminology the service URI is the unique identifier of the Service and it is in substance an URI in the Linked Data model and Km4City Ontology and Expert system. It allows to identify univocally any entity of the city.
Smart City API	In Snap4City, a large collection of services to: exploit queries and reasoning on the storage and Knowledge Base, access/control IoT Network, exploit Data Analytic results, exploit IoT Apps, etc. All the data and services are accessible via the Smart City API which are used by Front End Tools such as Dashboards, Web and Mobile Apps, MicroApplications. Details regarding Smart City API are reported in: https://www.snap4city.org/download/video/course2020/app/Snap4City-7th-day-Mobile-Applications-v2-7.pdf
Smart City Control Room	A solution for centralized control of the smart city via a set of view wall and operator console of 3-4 monitors. See Florence Control Room https://www.snap4city.org/531 ISEMC for Video Wall management integrated with IoT App. (https://www.snap4city.org/621)
Smart City Control Rooms	See the following example of the Smart City Control Room, SCCR, of Florence Metropolitan City which has more than 1.5 million of inhabitants. The figure reports the main dashboard used by the Mayor (namely: Dario Nardella) and the second level dashboards. Please note that a third and a fourth level are present as well. https://www.snap4city.org/525 control room with video wall: https://www.snap4city.org/621
SmartDS	The **SmartDS** (Smart Decision System) of DISIT is an Advanced System Thinking solution for Decision Support System, DSS, on smart city problems and data. SmartDS is a tool presently in trial that allows you to model decision processes by using an Advances System Thinking formalism defining weights on branches and value of the Italian Flags probabilities on processes, etc. (the application of verification and validation algorithms on data are also provided). http://smartds.km4city.org/dss/ see (https://www.snap4city.org/520).
Snap4City Innovation Matrix.	The methodology for innovation of Smart City derived from the **Innovatrix** method and it has been adopted for the leveraging the Innovation into the European Commission JRC ISPRA in the 2019, in Pisa 2020, and other locations. A few details about its implementation and processes are reported in section 3.2 regarding the Living Lab in which the Methodology is largely used. See training course 2020 part 6. https://www.snap4city.org/download/video/course2020/sys/Snap4City-6th-slot-system-deploy-v4-6.pdf
Snap4Home	22. Snap4Home: https://www.snap4city.org/617
Snap4Home	A subset of the Snap4City solution which is suitable for smart home control and automation. It may include, Snap4City IoT App also installed at home, in some IoT Edge Device hosting Node-RED. See the list of supported protocols and those in Node-RED https://www.snap4city.org/65
Snap4industry	23. Snap4industry: https://www.snap4city.org/369
Snap4Industry	A subset of the Snap4City solution which is suitable for smart industry/industry4.0 control and automation. It may include, Snap4City IoT App also installed in the factor or into the retail shops, and in particular in IoT Edge Device hosting Node-RED. They can be: raspberry Pi, Linux, windows, etc. See the list of supported protocols and those in Node-RED https://www.snap4city.org/65
Snp4City IoT App	See IoT App, IoT Application Node-RED process + Snap4City Library of MicroServices
SSM2ORION	SSM2ORION a module for connecting an IoT Orion Broker with its Data Shadow implemented by using Quantum Leap with the Federation of Knowledge Base. This solution allows to connect at the Smart City also other already in place FIWARE solutions which may have local storage. The queries performed on Snap4City Smart City API provide seamlessly the results also providing the geo data which are stored into that Orion Broker without the need to register the IoT Devices of that IoT Orion Broker into the Knowledge Base. Some limitations are present on the security aspects.
SSO	Single Sign On, In Snap4City, this function is performed by LDAP and KeyCloak at which all tool are referring to exploiting OpenID Connect.
SUMO	Simulation of Urban Mobility, open source tool, which can be integrated with the solution provided. https://www.eclipse.org/sumo/ https://sumo.dlr.de/docs/

	https://en.wikipedia.org/wiki/Simulation_of_Urban_Mobility
SuperServiceMap	See **Federated Knowledge Base**. A tool on top of Smart City API, which is the API interface of ServiceMap, **Knowledge Base**
Swagger	Standard API documentation and design tool https://swagger.io/
Synoptics	See **Custom Widgets**
SYSLog	Standard format for Logs: https://en.wikipedia.org/wiki/Syslog
Time Series	Is a series of data values over time associated to a variable, sensor, actuator. A Time Serie may have change GPS location of measure, and in that case is a Moving Object Time Series. In Snap4City, all the variable of IoT Devices, area HTL Sensors/Actuator and may be Time Series; also MyKPI variable may be Moving Object Rime Series.
Tracker	A Specific Widget for tracking moving devices, which can be located into Snap4City Dashboards.
Traffic Flow Reconstruction	Algorithm and Tool for computing the traffic flow in ay point of the city on the basis of the data collected from a limited number of sensors located on roads and scattered in the city.
Typical Time Trends	A typical trend of the data, highlighting one or more seasonality aspects of the data. They can be daily, weekly, weekly on day, monthly, etc.
User Management and control	24. User vs registration: LDAP and KeyCloak 25. User Limits management 26. User vs consumption of resources 27. Content vs publication 28. Auditing data access try-out, Elements and Ownerships, personal data, accesses authentications, user activities, queries, articles, web pages, dashboards, IoT Directory, etc- 29. Org vs Groups, user vs orgs 30. Chat management **See Section 3.16.**
Value_type	Each Attribute/variable in Snap4City is defined in term of Value_Type, Value_Unit and Data_Type (e.g., Energy Power, Kw/h, Float). They can be defined with the Data Dictionary.
Value_Unit	Each Attribute/variable in Snap4City is defined in term of Value_Type, Value_Unit and Data_Type (e.g., Energy Power, Kw/h, Float). They can be defined with the Data Dictionary.
Virtual IoT Devices	An IoT Device which has not a physical counterpart. It can be a just defined in the IoT Broker for passing data from one service to another. Virtual IoT Devices having sensors and actuators can be also the Widgets on Dashboards by which a user can see value and act on them to send values.
VM	Virtual Machine
Web Socket Secure, WSs	A TLS version of the WS. In Snap4City it is used for communicating from Client Dashboards, Custom widgets, event driven widgets, etc., to the platform on which IoT App and MyKPI/storage are connected in real time.
Web Socket Variable	A single Variable connected via WSs
Web Socket. WS	A communication protocol for real time connection. In Snap4City is only used in its TLS version Web Socket Secure.
What-IF analysis	The What-IF analysis is a modality of work recently included in the Snap4City suite which aim to exploit in a multicontextual environment most of the former tools as dashboards and Data Analytic with IoT App intelligence. See Section 3.9.2
WS	See Web Socket
WS Secure	See Web Socket Secure, WSs