Snap4City
A big data platform for smart cities

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Since the idea of smart city has become a practice to be implemented, urban planners and policy makers have needed tools that would allow them to exploit the information potential of the amount of data that the city itself produced in order to understand and manage its growing complexity. This article, after examining the close relationship between good governance based on a data-driven approach and the economic and social development of a city, describes the Snap4City Open Source solution, a Big Data Smart City Platform, adopted in European cities and region (Antwerp, Florence, Pisa, Santiago, France, Belgium, Finland, Tuscany, Sardinia, Croatia, Greece, etc.). Snap4City is GDPR compliant and designed to support city planners, combining strong tools for data integration, analytics, forecasting and visualization with the possibility of set Living Labs to enhance the collaboration among operators. Four scenarios have been selected and described (a. Florence Smart City Control Room; b. Traffic Flow Reconstruction and Air Quality predictions in Firenze, Pisa, Livorno; c. Air Quality in Helsinki for the citizens; d. People flows in Antwerp). The main KPIs have been briefly exposed, in order to evaluate the Snap4city impact in Smart City planning.

Introduction

The decision-making processes and operational tools which have been involved in the management of cities in recent decades have undergone a necessary redefinition which has gradually been adapted to the growing expansion of urban areas, the increase in the urban population and available technologies and data. The urban phenomenon for its quantitative dimensions, therefore, but also for the different qualitative meanings that it is assuming, obliges to push towards the adoption of innovative strategies capable of facing the expressed and potential needs of all the communities operating on a specific context, at different scales, ranging from hyperlocal, metropolitan and regional to global ones (Sassen, 1991).

The recent and well-known estimates of the United Nations (UN, 2018) describe an urban growth that will involve 75% of the world's population by 2050.

If, as it seems, the forecast trend is verified by the facts, we must expect at least two macro-areas of related issues, which will see cities engaged in maintaining internal cohesion, efficiency in the provision of services and in the improvement of the quality of life of city users; and on the other in the need to maintain high international competitiveness, minimizing the factors of economic and social marginalization and maximizing those of attractiveness in global contexts. The state of solidity and well-being of a nation is increasingly measured through the well-being of its cities.

In Italy, as in many European countries, urban centers are delimited by a historical administrative perimeter that no longer corresponds to the area of the actual vital and productive settlement, but that conditions the adoption of adequate planning strategies. Without neglecting factors such as historical characteristics, morphogenesis and socio-economic structure, with the growth of its dimensions, an urban ecosystem also increases the degree of internal complexity and therefore requires the adoption of an integrated tool capable of understanding and managing its growing complexity (Mitolo et al., 2020).

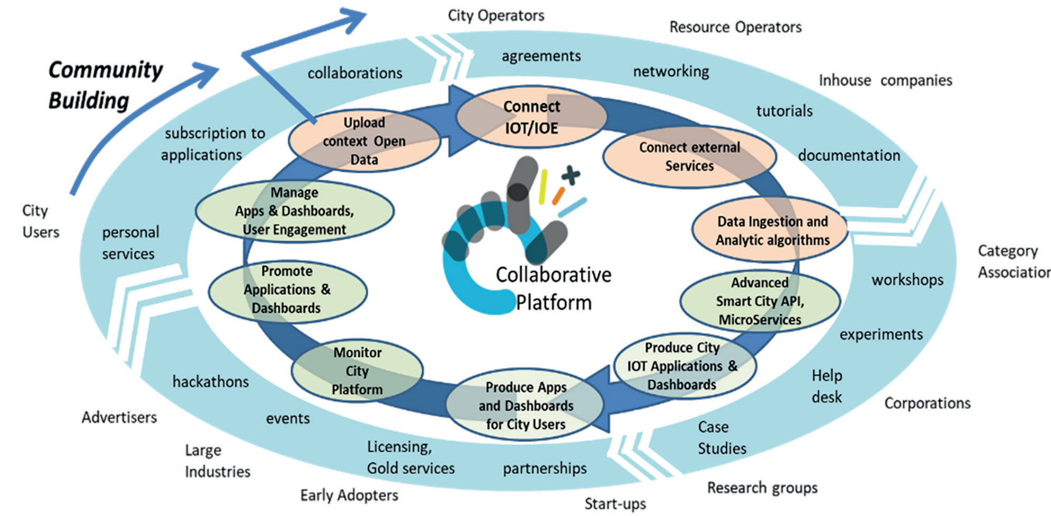
The governance of such an urban fabric must take into account a fair distribution of land use (residential, recreational, service, productive, agricultural, etc.) and the network of connections between the different parts, so its primary objective is to make the mobility a well-organized and efficient system. Studies carried out in this regard have shown that an integrated transport system, flanked by agile and accessible pricing, for example, is a priority for territorial governance and a precondition for growth and development (OECD, 2015a).

The successful characteristics of a city can be analyzed in three dimensions: population growth, economic performance and functional organization and considering the importance of good governance arrangements. "The fragmentation of a city's administration and the quality of its governance structure is directly reflected in its economic strength" (OECD, 2015a, p. 37 ff.), while, on the contrary, where the conditions of cohesion and integration of government structures are lacking, the city responds with an increase in inefficiency and consequently a decrease in wealth.
If it is true that the productivity of a city depends on a multiplicity of factors related to national economic policies, many others are due to local characteristics such as the quality of the infrastructures and the solidity of the market and local institutions. Good governance of urban agglomerations is essential for their functioning (Ahrendi et al., 2015) and it is becoming more automatic and based on the predictive power and anticipatory capacities of digital technologies and computational intelligence (Dodge, 2010). It is also appropriate to consider that good governance structures are not alone a guarantee of good policies, but it is very difficult to design and implement good policies without them. Some studies have highlighted how the presence of governance bodies can be an instrument of co-ordination within metropolitan areas, which are reflected, for example, in a better organization of land use and efficiently integrated transport system, in general a more forward-looking spatial planning (OECD, 2015b). In contexts where these assumptions are missing, on average, cities have higher levels of air pollution (i.e. as measured by the amount of particulate matters in the air), while where coordinated decision-making bodies are present the provision of the services across a metropolitan area could also improve their quality or reduce their costs, with positive spillover effects.
In *Triumph of the City*, Edward Glaeser (2011) states that "Not every city will succeed, because not every city has been adept at adapting to the age of information, in which ideas are the ultimate creator of wealth". This adaptability is based on two decisive conditions, namely the availability and access to relevant data and the time that separates the moment in which the data is produced from that one in which it's possible to analyze them and produce useful information for decision-making process.
"Innovation and technological progress are generally believed to be the main driver of long-term economic growth" (Aghion, Howitt, 2005), but technological innovation must be supported both on the strategic vision and on the possibility of triggering rapid and highly adaptable decision-making processes to sudden and unforeseen changes of state. For these reasons, human capital is crucial in fostering the capacity of a region in creating innovation and adapting that to new scenarios (Rodriguez-Pose, Crescenzi, 2008).
In the planning and management processes of a complex ecosystem such as cities, where many distinct aspects coexist, and many kinds of actors interact – such as public administration, citizens, enterprises, stakeholders, research organizations, universities – therefore, the conditions to enhance innovation and technological development must be put in place as a precondition for improving the quality of life of all end-users.
In this continuous process of adaptation to information, applications that are based on multiple paradigms such as data-based processing, streams and batches, at the same time activate new work paradigms aimed at improving collaboration between all the heterogeneous actors involved (Mitolo et al., 2020). It follows from this that two are the key axes on which it is necessary to focus on in the design of a system that intends to manage urban complexity: data and people. An efficient architecture must be able to collect and analyze data for the areas identified as strategic and allow all stakeholders to be able to participate in the processes of selection, collection, integration, analysis, visualization of data.
The main areas on which the city planners are usually interested in are: Mobility, Environment, Energy, Weather, People (social and flows), Governance and Communications, Economy, Culture and Tourism, and Security. For each of these areas, data must be available that provide information on the status and established performance indicators that allow to evaluate the effectiveness of the solutions adopted or identify problems and alert thresholds. Obviously, these areas are non-independent of each other. Urban sprawl often accompanies increased costs in terms of traffic congestion and lack of adequate infrastructure that affect both the quality and quantity of urban traffic and the consequent spillover effects on pollution, quality of life and variations of the real estate market (OECD, 2015b, 29-54). Sensors for monitoring traffic and public lighting, for example, or variable direction signs used to steer traffic flows or to show parking spaces, together with an integrated public transport improve mobility within metropolitan area by lowering travel time and improving accessibility and quality of life.
Snap4City, the big data platform that we are going to describe in the next paragraphs, is currently at the last stage of development of an ecosystem made of integrated technologies that over the years has been modeling itself on the specific needs that smart cities were expressing. This architecture

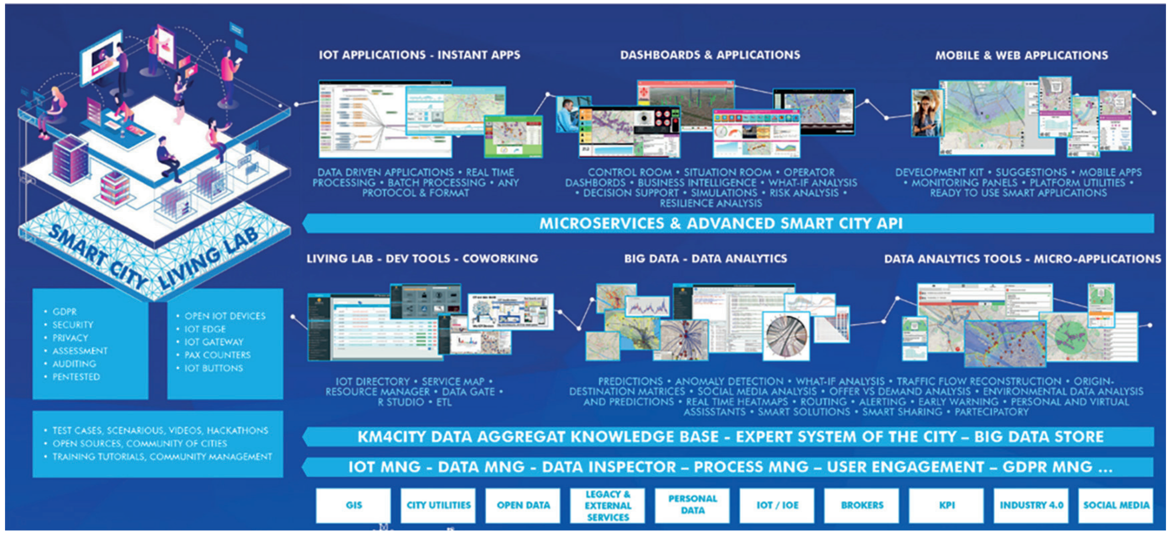
brings together the results of important national and international projects, such as SELECT4Cities Pre-Commercial Procurement EU Project (https://www.select4cities.eu), REPLICATE EU project (https://replicate-project.eu), TRAFAIR CEF project (http://trafair.eu), Sii-Mobility National Smart City project, Italy, (http://www.sii-mobility.org), just to mention the main ones. It is therefore able to collect, integrate and manage data, analytics, predictions and applications related to the public transport system (operators schedule and paths, traffic flow sensors, parking status and positions, cycling paths, road graph, accidents and traffic events, etc., cfr. Bellini et al., 2018b); waste, pollution, pollination and air quality (PM2.5, PM10, CO, Benzene, NO, NO2, etc.); energy (recharging stations, consumption meters, smart light); weather (temperature, wind, humidity, rainfall, forecast and actual); social and cultural events (POI, entertainment, Twitter monitoring, sentiment analysis); triage status of major hospitals; people flows (from the Wi-Fi access points; Origin-Destination matrices). All this happens in a robust way, having Snap4City passed two vulnerability tests, efficient, capable of ingesting data from all types of different sources, interoperable with all IoT standards and respectful of data protection regulations, being fully compliant to the GDPR (CDPR)[1]. Planning tools need performance indicators that summarize the complexity of reality in constant updating with the changes that occur, creating a cognitive framework on which the decision-making process is based. Quantity, quality, availability and updating of data, especially for historic urban areas, are essential conditions for the development of effective policies (Cundari, 2015). The heterogeneity of data is parallel to the variety of actors (decision- makers, planners, stakeholders, end users) who, starting from these, intervene directly or indirectly on urban policies.
Therefore, the activation of collaboration environments is necessary, which are not mere virtual rooms, but real Living Labs where to define strategies and implement specific services in response to specific needs (Cosgrave et al., 2013).
The Snap4City architecture provides customizable tools and solutions to create a large range of smart city applications, created thanks to the collaboration of different kind of organizations (Universities, Public Administrations, Enterprises, Start-ups) and city users (operators, inhouse companies, tech providers, corporations, research groups, citizens, commuters, etc.) as part of a large and heterogenous community (see Figure 1).
The question of how technology and innovation influence social and economic development has always been debated among economists (Fagerberg et al., 2010). The ability to innovate and assimilate

Snap4City Collaborative Workflow Process

Fig.1:
Mitolo et al., 2020



innovation are considered by many authors as key factors in the growth of an area and "it has now become widely accepted that innovation is a territorially-embedded process and cannot be fully understood independently of the social and institutional conditions of every space" (Rodrigues-Pose, Crescenzi, 2008). In light of this, Snap4City can be considered a space where geographically relevant information, innovative technologies and users with different profiles are made to coexist and operate in order to allow social innovation processes.
Big Data, due to their growing importance in terms of volume, velocity and variety, have determined a gradual shift towards a data-driven socio-economic model, where "data are a core asset for creating significant competitive advantages and for driving innovation, sustainable growth and development" (Ubaldi, 2013). It is fair to say that data and data analytics play a decisive role for the formation of knowledge-based capital, precondition for economic growth and sustainable development of society (OECD, 2013).
One of the expected impacts in the use of big data in urban contexts lies in the increase in resilience capabilities, given that the degree of effective response to both daily and catastrophic scenarios can measure whether a city is well-functioning. Identification of possible risks and adoption of prompt measures implies information sharing between different levels of government, public administration and final users of both the public and private actors.
There are also not secondary aspects, but to which we will dedicate only a brief mention, which concern the creation of a framework of awareness and trust – "subtle, yet important issue for the functioning of cities" (OECD, 2015a) – that generally triggers virtuous mechanisms of governance and public participation.



A model like the one proposed here, which provides for data generation, data collection, aggregation and processing, data analytics and visualisation, and which is the expression of planned governance, has as its first effect that of improving government accountability, transparency, responsiveness and then of promoting citizens self-empowerment, social participation and engagement. Promoting innovation is therefore expected to increase efficiency and effectiveness in public services and generate value for the economy in general (Ubaldi, 2013).

Snap4City Solution

Snap4City is a Big Data Platform applied in the context of many European Smart Cities, providing innovative approaches flanked by consolidated technical solutions. Snap4City supports decision makers in their urban organization processes to involve citizens themselves, triggering a participatory process of evolution and innovation of their city. In this paradigm it is easy to recognize the combination of two complementary concepts of translation (how cities are translated into code), and transduction (how code reshapes city life) suggested by Robert Kitchin (2011). The solution proposed has been improved thanks to the experience had in the different geo-political contexts in which is applied: Italian (Firenze, Pisa, Livorno, Prato, Cagliari, Modena, Lonato del Garda, etc.) and European Cities (Antwerp, Helsinki, Santiago De Compostela, Valencia, Dubrovnik, etc.) and their surrounding geographical area (such as in Italy the region of Tuscany, Sardinia and Lombardia but also Belgium and Finland), (Azzari et al., 2018). The strength of Snap4City lies precisely in supporting the city's decision-makers in all the phases that involve the city's evolution processes, proposing alternative modes of communication to the classic ones: it promotes coworking activities and provides Living Lab services, which allow

Snap4City Architecture: IoT management, data ingestion and processing, data analytics, Mobile and Wep Apps,
Fig. 2
Mitolo et al., 2020

an immediate communication between the groups of people involved and an exchange of ideas supported by analysis and advanced visualization of concrete data in real time. Snap4City, as visible in Fig.2 in which its architecture is represented, manages a noteworthy amount of heterogeneous data in terms of protocols and formats, open and private data, static/periodical and real-time data, GIS and Maps, data stream, data driven, Industry 4.0., data coming from IoT Devices and networks, IoT Edges, gateways, IoT Brokers or via different protocols and formats, that are uniformly managed on IoT Directory via Knowledge Base for discovery. Another modality of data ingestion is the web scraping process that may be used for grabbing data from public web pages according to the exposed terms of use. Moreover, additional information comes directly from the final users (e.g., citizens, tourists, shopkeepers, students, etc.) via Mobile Apps and Social Media (Bellini et al. 2018b; Badii et al., 2017). For this reason Living Lab activities on the platform are fundamental and at the basis of a work process promoted and actuated that: i) starts from the identification of the final objectives that the smart city decisors want to achieve; ii) identifies the types of significant data and relevant stakeholders; iii) involves the different types of people providing effective technological tools for everyone; iv) realizing the final ad-hoc solution based on the needs expressed by the decision makers of the city and which can be a combination of various tools for visualization and interaction. For example, through the realization of dashboards or Mobile/Web Apps able to highlight the results obtained from the data analysis carried out, which translates in terms of visualization and interaction with: historical data, real time and future forecasts, connection with groups of decision makers, etc. (Nesi et al., 2018). Once the data have been identified, they are uploaded into the platform with the more effective ingestion tool among those available in the platform (e.g., IoT App via Node-RED for sensors and for real time data, ETL (Extract Transform Load) processes for Static or periodical Data, web scraping tools for web pages, scripts for complex data, etc.) and stored basing on their frequency of update. Moreover the data are semantically processed so that the information is enriched and connected each other, this aggregation process is managed in automatic or semi-automatic way by the platform, depending on the data type and on the methodology adopted to ingest the data and in compliance with the Km4City Smart City multi-ontology (https://www.km4city.org). All the data are stored in the Snap4City Knowledge Base on graphDB and in a Big Data store for data shadow based on Elastic Search and/or HBase noSQL database.

Smart City Control Room in the City of Florence: connections and What-IF analysis
Fig. 3

The ingestion and storage phase are at the basis of data Analytics processes and Data Transformation algorithms capable to analyze all the data present in the Snap4City KB, including personal data produced by users and respecting their privacy.
The platform is GDPR compliant and perfectly capable to manage the different level of privacy connected to each dataset, user, user role, group of users (called organizations). This aspect is fundamental for decision-makers who have to understand what kind of services provide to their citizens, what kind data can be viewed and by which category of people, what license has to be connected to each dataset.
Data Analytics and data transformations processes and tools can be created and shared in a reliable and scalable cloud infrastructure to provide advanced smart services, making prediction, signalling early warning, detecting anomalies, creating analysis, heatmaps, supporting decision makers with insights and reports, etc. Analytics and data processing exploit the Snap4City Smart City API, can be developed in ETL, R, Python, Java, IoT App Node-RED, etc., and can be executed on demand/on events, periodically and in real-time. Resulting data are also saved and indexed into the platform. Dashboards for city decision makers and mobile Apps for citizens, are the most suitable visualization tools both as decision support systems with high levels of interaction and to have a real time view of what is happening in the city.
The next section describes fours scenarios dealing with different issues and adopted in different European contexts. These scenarios highlight how the Snap4City platform has contributed in a relevant and innovative way in speeding up the urban development processes in different contexts.

Scenarios

The Big Data Snap4City Solution manages, elaborates data and provides services in different cities and geographical areas and it is applied in the contexts of Mobility, Environment, Energy, Weather, People (social and flows), Governance and Communications, Economy, Culture and Tourism. In this section, four scenarios are described, with the purpose to demonstrate the potentialities of the Solution and the advantages obtained. They are different in terms of City's needs and geographical areas, type of data managed, final users.

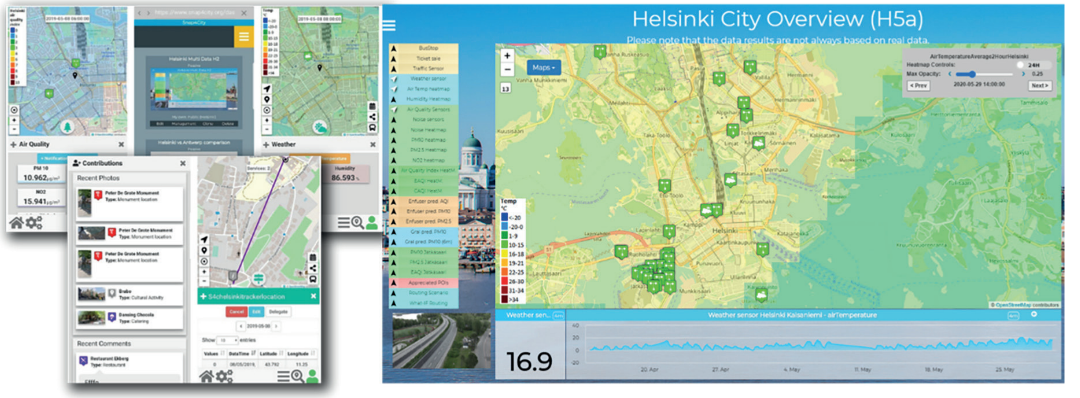
Scenario1: Florence Smart City Control Room

In the city of Florence, Snap4City is at the basis of the Smart City Control Room (SCCR), in the contest of the Replicate EU project (https://replicate-project.eu). The city's decision-makers and in particular the mayor and his staff, need to monitor the general state of the city in order to verify the usual daily course of the city's activities, to be able to intervene quickly in the event of catastrophic events and to make concrete short- and long-term forecasts. The Florence SCCR shows in Real Time data, statistics and graphics, provides services for drill down on data, shows real time and provisional maps, allow interactions, etc. The main thematic area covered are: Mobility, Environment, Energy, Weather, Social Media, People Flows, Governmental and Communications, Tourism and Culture. The Control room is organized with a starting view to which all the other dashboards are connected, as can be viewed in Fig. 3. In this way, the decision makers can navigate among the different dashboards basing on the contingent needs, can explore data and receive predictions or suggestions in real time. They can be put in contact with a restricted group of responsibles to analyze data, thus triggering shared decision-making processes. The Smart City Control Room in Florence is furthermore the result of the Snap4City's Living Lab support: some of the Dashboards and the available KPI, have been directly realized/estimated by the decision makers of the City of Florence. Users who do not have a strictly technical profile, have the possibility to work in full autonomy or in semi-guided mode. Having at disposal virtual spaces on which develop processes to ingest and manage data (IoT Applications) or services to share/download/view tutorials and simplified routines/IoT Applications/programs/etc., in addition to the possibility to make comparison with the work done in other Smart Cities, in which Snap4City is applied. Some interactive tools, such as the What-If analysis, visible in Fig. 3 (on the right), play a fundamental role to answer to questions such as: what happens if I close a road or change it in terms of traffic and reorganize public transport? Which parking spaces are expected to be occupied in the next few days, also according to the cultural events that will take place? Looking at the SCCR, the city decisors can analyzes the situation in Florence knowing and visualizing: structure of the city, position of the services, paths of the public transportation, real time value of traffic (Bellini et al., 2018a), environmental variables, air quality (PM10, PM2.5, CO, Benzene, NO, NO2, O3, etc.), people flows, weather conditions and forecasts (temperature, humidity, wind, etc.), cycling paths, hospitals first aid, etc. And thus, defining restrictions to be applied, areas to be closed, the new paths for public and private vehicles and pedestrians, etc.

Traffic flow reconstruction, Air Quality predictions and historical data on NOx in the City of Pisa
Fig. 4

Scenario2: Traffic Flow Reconstruction and Air Quality predictions in Firenze, Pisa, Livorno
One of the needs that is increasingly growing for cities is to have a forecast of air quality in individual neighborhoods and areas of the city, to understand the reasons for any exceedances of permitted limits in order to amend city regulations to improve air quality. The source of pollution that has the greatest impact on air quality in cities is related to traffic. It is fundamental for the city operators, to monitor and have previsions on the air quality in each street of the city so that they may regulate urban mobility and providing the evidence at citizens that they are living in a city sensitive to the quality of life, predicting the overruns of law limits.
To this end, specific sensors and solutions become fundamental, such as: traffic flow sensors for monitoring urban mobility, traffic flow reconstruction, sensors for assessing air quality parameters, parking, traffic and RTZ sensors, weather forecasts, etc., together with the knowledge of the city structure, prediction model for environmental variables. Snap4city, thanks to the work done in the TRAFAIR CEF EU project (http://trafair.eu), is applied in three Tuscany cities, Pisa, Firenze and Livorno, in realizing air quality predictions, perfectly fitting the above described needs. In order to assess the air quality in each street of the city, the level of pollution aspects have to be measured, for example those regarding: SO2, NO, NO2, O3, CO, CO2, PM10, PM2.5, etc. and derived Air Quality Indexes. Most of the environmental pollutants are influenced by relevant traffic flows in different manners, while others are influenced by house heating, industries, waste, etc. Specific measures may depend on the sensor position and location context, on calibration, on the time of the measure, season, etc. A measure performed along a primary street in terms of traffic may strongly differ with respect to the actual values just in the garden of the house behind the primary street. To this end, mathematical methods have been set up to perform predictions of pollution diffusion and deductions.
In Fig. 4 the Pisa Dashboards with traffic in real time and air quality predictions are shown. The predictions are performed on NOX (depending on NO and NO2), for each hour in the next 48 hours, with a spatial resolution up to 4x4m, based on the GRAL dispersion Model (http://lampz.tugraz.at), both at 3 and 6 meters. The same Dashboards are available also for the cities of Firenze and Livorno and are all accessible from the main Tuscany Air Quality Dashboard (https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MjY4MQ==). The air quality regarding NOX is primarily related to the production of pollution from the vehicles running in the city. The computation of the traffic flow in all primary and secondary streets of the city, realized with the DISIT Traffic Reconstruction tool (one of the results of the Sii-Mobility project, http://www.sii-mobility.org) is used to estimate the number of vehicles passing and producing pollutant in each road segment of the urban graph, by exploiting a limited number of measures of traffic by the city sensors. The production of traffic pollution is an input data for the predictive GRAL model to determine the air quality state in a city. Air quality predictions are visible in the dashboards that show the air quality in the individual streets and around the buildings, allowing not only the decision-makers but also the individual citizens to assess the air quality in their neighborhood and in their homes thanks to the color scale of values present to correctly interpret the colors on the map.

Scenario 3: Air Quality in Helsinki for the citizens
An environmental monitoring use case has been performed also in the of City of Helsinki, in a new smart district of Jätkäsaari: a small connected island to the South of the city. Jätkäsaari, is an expanding urban area, with more than 20.000 inhabitants, many are the works in progress for the construction of new buildings and services, including various hotels and office facilities. The city of Helsinki plans that at least 6.000 people who will live on the peninsula as a place to live or work. Jätkäsaari also encompasses the main part of Helsinki's passenger harbour. The large construction sites, the intensive and obstructed traffic, and the growing population create environmental challenges in Jätkäsaari. In this scenario, there was a strong involvement of citizens who collaborated with the public administration in the monitoring of pollutants. A set of low-cost sensors has been provided to citizens by the local administrations, in collaboration with city

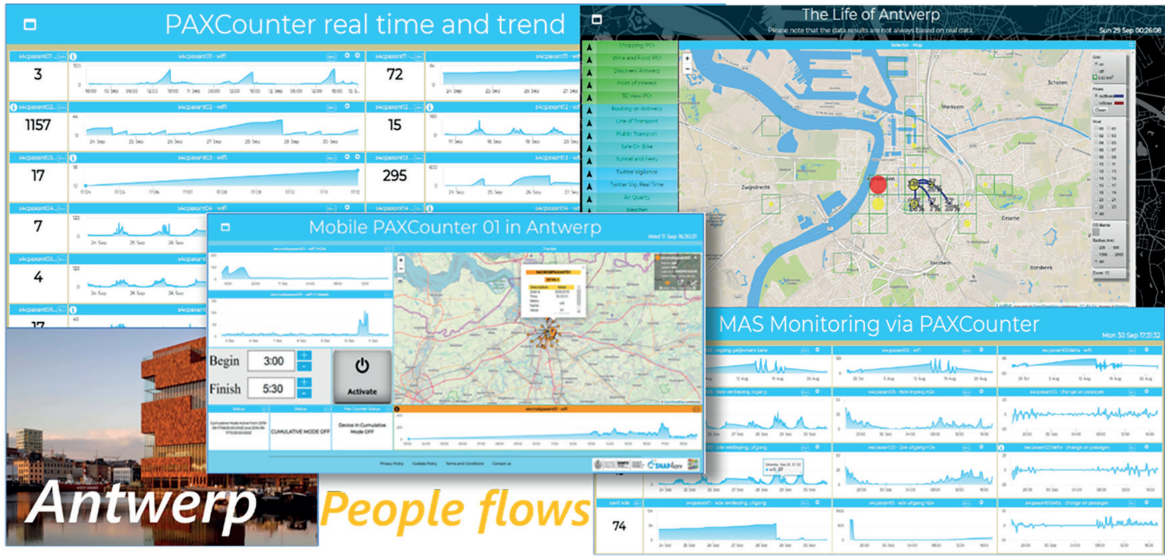


Air Quality predictions: Mobile App and IoT Sensors
Fig. 5

innovation companies. Citizens placed them in their terraces, in ad-hoc selected areas: near to renovation works in progress, close to green areas or to the port. This process has allowed to receive targeted and localized data in areas relevant to the analysis of the specific problem, in addition to the official ones from the Finnish Meteorological Institute, but it also established greater communication among public authorities and citizens who feel active part of the city.
From a technical point of view, there was the need for Snap4City of integrating data coming from different sources and services, provide tools for data analytics about the current state of the air quality in different parts of Jätkäsaari both to the city decisors and to the citizens. Therefore, a number of Dashboards have been developed for the City Operators and ICT Officials (https://www.snap4city.org/dashboardSmartCity/view/index.php?iddasboard=MTQwNg==), while a Mobile App able to monitor in real time the different pollutants and fine particles produced, to have available basic information on commercial activities, events and public transport, etc. has been developed and published both on the Google Play Store and the Apple Store for the Citizens and Tourists, Fig. 5, (Badii et al., 2020). Moreover, the mobile App allows the city users to access the heatmaps, and to subscribe to notifications that are activated on their POI when the selected pollutant is above the critical values.

Scenario 4: People flow in Antwerp.
A further aspect at the basis of the organisation of a Smart City is to have tools to monitor people flows. The city of Antwerp is working on the construction of a smart zone in one of the city's districts. With this in mind, and in the context of the Select4City project (https://www.select4cities.eu), Antwerp city decisors expressed the need to monitor the influx of citizens and tourists into the smart zone to support local traders (museums, hotels, restaurants, etc.), to monitor events and to provide police support in road traffic management and to improve and make public transport services more efficient. The Snap4City platform worked with Antwerp for the positioning of pax-counters sensors, in order to monitor people and analyse the city flow (Badii et al, 2019). Obviously in this scenario, privacy aspects are fundamental, so the fact that the Snap4City platform is GDPR compliant was an essential starting point, without which the experimentation in the smart zone could not have been realised. The pax-counters can be located on fixed places, using WiFi to send the obtained measures including additional sensors or can also count the number of people on the move.
2 Mobile pax-counters are entrusted to local cops who take the sensors with them on daily patrol, are used to monitor the citizens movements on the streets in relation with sports or entertainment events. Each newly measured count is associated with GPS coordinates and sent to the platform, thus obtaining trajectories with the associated values, as shown in Figure 6 (central dashboard), using the Snap4City Widget tracker. In 'The Life of Antwerp' Dashboards the flows of people entering and leaving the smart zone are highlighted, also indicating where people come from and where they go. A number of devices have been installed in Museums and other public facilities in Antwerp. In this case also a series of dashboards have been created, showing in real time the number of people who are in the facilities, producing statistics and data trends, etc. In Figure 6, the Dashboard presenting the time trends of the entrances and exits of the museum and derived data is shown (Mas Monitoring PaxCounter, below right). All the derived values of the initial real time data can be computed in real time, saved on personal storage device and shown on dashboard via an IoT Application exploiting MicroServices of Snap4City. At the same time as calculating the sums, the difference between the people entering the museum and those leaving to obtain the number of people inside the museum in another entity is also made.

Key Indicators to evaluate the Snap4city impact in Smart Cities
As seen above, through the dashboards within Smart City control rooms, the data collected and aggregated are summarized and made accessible for the decision makers and shared to the city operators. For each of the scenarios described, dashboards and/or Mobile Apps have been created, which can be public and consulted by all citizens or have restricted access to employees of municipalities. The data displayed do not only have a descriptive value of the state of the phenomenon observed, but in some cases measure the degree of efficiency of the solutions adopted, when they express through KPI (Key Performance Indicator) the present condition with respect to threshold values deemed sensitive by experts in the field of analysis.
Much of the KPI is representative of the resources deployed in the city and is not necessarily geo-localized, although the



People flows in Antwerp
Fig. 6

geographical component is increasingly important, considering that urban planning must combine a broad strategic vision with the specific needs of local contexts. Transportation and mobility, energy, weather, health, water, waste, security, civil protection, ICT are the main fields the city planners can monitor combining KPIs. In Snap4City, KPIs are saved in the Knowledge Base, specifically in the Dashboard Engine database. They can be values with which position and time or entity attributes are associated, such as shape (region), paths (lines, trajectories, etc.), administrative boundaries, etc. The principle on which they are based is to distribute data values over time and space, in order to follow the trend of different phenomena, correlating them to the geographical dimension in which they occur, a crucial objective for urban planners or decision-makers in general. Following this principle, cities must establish what are their strategic priorities and consequently define data to be acquired and related performance indicators. In this light, the analysis of dashboards of different cities shows in their own articulation what are the results of the local planning processes, of their integration with ICT infrastructures and of their ability to interpret citizens' requests or sentiment.

The possible examples are manifold, an examination and a punctual comparison would exceed the space of this article, so for the consultation of some of the dashboards currently created and publicly accessible, see the specific sections on Snap4city.org.

To give an idea of the analytical potential of the platform, consider that for Florence and Tuscany Region described in scenario 1), that alone it is able to 'digest' over 1.5M complex events per day (static data, dynamic/real-time data, mobile app), which after being analyzed can be returned through tables, gauges or graphs of various types (Kiviat, pies, curved lines, barlines, etc.).

Being able to count on a synoptic framework that can show together, for example, structure of the city, position of the services, paths of the public transportation, real time value of traffic, environmental variables, people flows, weather conditions and forecasts, cycling paths, hospitals first aid, sets the best conditions to establish restrictions to be applied, areas to be closed, new paths for public and private vehicles or for pedestrians, etc.

Recent analysis on the behaviors of different users show that mobility and environment are the areas where attention is most concentrated (more than 6.000 accesses and 340.000 minutes, which is an average of 57 minute per access) (Mitolo et al. 2020).

According to what is suggested by the European Resilience Management Guide[2], issued following the findings of the pilots of the RESOLUTE project (http://www.resolute-eu.org), the definition of performance indicators is an essential step if you intend to implement a life cycle for a resilient system, i.e. anticipate, monitor, respond, learn. "Monitoring resources generates information on resource allocation and the understanding of their flows, which represents one of the fundamental tools for planning activities, both as a primary input and as indicators for the potential need of planning revision or reassessment" (Gaitanidou et al., 2018 p. 20 and passim). When a KPI shows values lower than the threshold a priori defined, the response actions are prepared. This is only one, probably the most evident, of the effects produced on a city intended as a complex ecosystem. Some secondary effects are given by the fact that the aggregation of KPIs acts as a coordination mechanism between different parts of the system.

Furthermore, Snap4City allows anyone to manage, for example, their IoT devices by establishing personal KPIs (MyKPI, data, POI), which each user can decide whether to make it public or with a restricted use and manage their ownership. Whatever the choice, such a powerful architecture available to all constitutes a further step in the direction of public engagement and in the growth of civic awareness, that is the primary condition of a smart city.

Conclusions and future work

This article examines the influence had by the Snap4City Solution in sustaining and providing support to a good governance in a Smart City. This environment gives a clear insight on how data and digital technologies are changing the way people "understand and plan cities", "manage urban services and utilities", and "live urban lives" (Kitchin, 2011). In particular four different scenarios have been taken into account that have highlighted how the platform is on the one hand versatile because it is able to adapt to different political and geographical contexts. On the other hand, the solutions described the different use cases underline that Snap4City is not only an evolved ICT infrastructure, is 100% Open Source, secure and GDPR compliant solution designed to support city planners, combining strong tools for data integration, analytics, forecasting and visualization but it is also based on Living Labs strategies to support the development and actuation of urban strategies.

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Note

[1] This compliance is not only imposed by European regulations, but responds to a need to code ethically, focusing primarily on who has access to data, what should be collected, how should it be used, etc. (Kitchin, Dodge, 2011)

[2] https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5be08fd14&appId=PPGMS

Bibliografia

Aghion P., Howitt P. 2005, *Growth with quality-improving innovations: An integrated framework*, in Aghion, P., Durlauf (eds.) *Handbook of Economic Growth*, Vol 1A, Ch.2, pp. 67-111. DOI: 10.1016/S1574-0684(05)01002-6

Ahrendi, R., Farchyi, E., Kaplanisi, I., Lembckei, A.C. 2014, *What Makes Cities More Productive? Evidence on the Role of Urban Governance from Five OECD Countries*, OECD Regional Development Working Papers, 2014/05, *https://doi.org/10.1787/5jz432cf2d8p-en*

Azzari M., Garau C., Nesi P., Paolucci M., Zamperlin P. 2018, *Smart City Governance Strategies to better move towards a Smart Urbanism*, in *The 18th International Conference on Computational Science and Its Applications (ICCSA)*, July 2-5, 2018 in Melbourne, Australia in collaboration with the Monash University, Australia.

Badii C., Bellini P., Nesi P., Paolucci M. 2017, *A smart city development kit for designing Web and mobile Apps*, IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computed, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI), 10.1109/UIC-ATC.2017.8397569.

Badii, C., Bilotta, S., Cenni, D., Difino, A., Nesi, P., Paoli, I., Pantaleo, G., Paolucci M. *Real-Time Automatic Air Pollution*. Accepted paper in 10th IEEE ISCC MoCS Workshop 2020. https://mocs20.gforge.uni.lu/

Badii C., Bellini P., Cenni D., Difino A., Nesi P., Paolucci M. 2017, *User Engagement Engine for Smart City Strategies*, in *IEEE International Conference on Smart Computing*, IEEE SMARTCOMP, Hong Kong.

Bellini P., Bilotta S., Nesi P., Paolucci M., Soderi M. 2018a, *WiP: Traffic flow reconstruction from scattered data*, *IEEE International Conference on Smart Computing*, SMARTCOMP, art. no. 8421365, pp. 264-266. DOI: 10.1109/SMARTCOMP.2018.00052

Bellini P., Nesi P., Paolucci M., Zaza I. 2018b, *Smart city architecture for data ingestion and analytics: Processes and solutions*, in *Proceedings IEEE 4th International Conference on Big Data Computing Service and Applications, BigDataService*, pp. 137-144, March 26 - 29, 2018. DOI: 10.1109/BigDataService.2018.00028

Cosgrave E., Arbuthnot K., Tryfonas T. 2013, *Living Labs, Innovation Districts and Information Marketplaces: A Systems Approach for Smart Cities*, in *Procedia Computer Science*, Volume 16, 668-677.

Cundari C. 2015, *Il rilievo urbano per sistemi complessi. Un nuovo protocollo per un sistema informativo di documentazione e gestione della città*, Edizioni Kappa, Roma. ISBN:978-88-7890-668-6

Dodge M. 2010, *Code/space*, in «Urbis Research Forum Review», Vol. 1, Issue 2, pages 15-25.

Duraton G., Puga D. 2014, *The growth of cities*, in Aghion, P., Durlauf (eds.), *Handbook of Economic Growth*, vol. 2, ch. 5, pp. 781-853, Elsevier. DOI: 10.1016/B978-0-444-53540-5.00005-7

Fagerberg J., Srholec M., Verspagen B. 2010, *Innovation and Economic Development*, in *Handbook of the Economics of Innovation*, vol. 2, ch. 20, pp. 833-872. DOI: 10.1016/S0169-7218(10)02004-6

Glaeser E. 2011, *Triumph of the City. How our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and*

Happier. New York, Penguin.

GDPR: General Data protection Regulation, *https://eur-lex.europa.eu/eli/reg/2016/679/oj*

Kitchin R., Dodge M., 2011, *Code/Space: Software and Everyday Life,* MIT Press, Cambridge MA.

Kitchin R., 2011, *The programmable city*, in «Environment and Planning B: Planning and Design», Vol. 38, No. 6, pp. 945-51.

Mitolo N., Nesi P., Pantaleo G., Paolucci M. 2020, *Snap4City Platform to Speed Up Policies*. Accepted paper in SSPCR conference, *Smart and Sustainable Planning for Cities and Regions*, 2020. *https://www.sspcr.eurac.edu/*

Nesi P., Paolucci M. 2018, *Supporting living lab with life cycle and tools for smart city environments. In DMSVIVA: 24th International DMS Conference on Visualization and Visual Languages*, 10.18293/DMSVIVA2018-019

OECD 2013, *Exploring Data-Driven Innovation as a New Source of Growth: Mapping the Policy Issues Raised by "Big Data"*. OECD Digital Economy Papers, No. 222, OECD Publishing, Paris. *https://doi.org/10.1787/20716826*

OECD 2015a, *The Metropolitan Century. Understanding Urbanisation and its Consequences*. OECD Publishing, *https://doi.org/10.1787/9789264228733-en*

OECD 2015b, *Governing the City*. OECD Publishing, *https://doi.org/10.1787/9789264226500-en*

Rodríguez-Pose A., Crescenzi R. 2008, *Research and development, spillovers, innovation systems, and the genesis of regional growth in Europe*, in «Regional studies», 42 (1). pp. 51-67. DOI: 10.1080/00343400701654186

Sassen S. 1991, *The Global City*. New York, London, Princeton University Press, Tokyo.

Ubaldi B. 2013, *Open Government Data. Towards Empirical Analysis of Open Government Data Initiatives*, OECD Working Papers on Public Governance No. 22. *https://doi.org/10.1787/19934351*

United Nations 2018, *World Urbanization Prospects 2018. Highlights*. Department of Economic and Social Affairs, *https://population.un.org/wup/Publications/Files/WUP2018-Highlights.pdf*

Gaitanidou E., Bellini E., Ferreira P. 2018, *European Resilience Management Guide*, RESOLUTE D3.6.