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Km4City: an ecosystem from city resilience to city users assistant

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ABSTRACT: In Km4City Ecosystem a unified model and services based on aggregated data and services, data hub, is the first instrument to control city evolution, provide services to city stakeholders, accelerate commercial activities, create a common environment on which new data and services can be easily added to the ecosystem for all. For a city, to cover the role of data aggregator is strategic decision that put the control back in the hands of the city and not in those of the multinational commercial operators. Km4City models and simplify the production of semantically integrated data from different domains, takes advantage of inferential deductions, enables a set of solutions for setting up Control Rooms, perform data business intelligence, data analytics, decision support, risk analysis, user behaviour analysis, suggestion and stimulus towards city users, etc. Examples of services guided by the city strategy may be: personal assistants for city users and operators, connected drive, decision support systems for risk prevention and resilience analysis, personalized suggestions to stimulate city users to move towards virtuous behaviours (more sustainable, less consumptions, conservative parking, inter-modality, etc.), bonus system for pushing city user to use public transport, shared logistic delivering, personal car sharing, promotion of commercial activities and districts, etc. All of them are strategic models to understand the population and for communicating with them via specific thematic areas. The efficient delivering of these solutions strongly depends on computing of user behaviour, and can enable the acceleration of commercials and art-craft activities. The application of smart decision support systems and the assessment of city resilience against natural and non-natural disasters, taking into account of resilience of critical infrastructures in the city. This paper presents Km4City solution, major tools and innovation, impact and feasibility providing the evidence that the solution is viable as adopted in Sii-Mobility SCN, RESOLUTE H2020 and REPLICATE H2020.

1 - Introduction

Different kinds of Smart City solutions can be set up with the aim of enabling Smart City Services and Applications, and their corresponding architectural solutions. They mainly differ each other from the strategy to transform data to services for the city (from data to business).
Case (a): the Info Integrators collects information about several APIs provided by different data and/or service providers in the city (including their authentication and licensing), and provides a common place for developers and other city operators to browse and learn how to access at the exposed API services and data. Data/service providers can be city operators such as: mobility operators, energy operators, waste and water operators. They may provide some open and/or private data, static and/or real time data. In Case (a), the data/services are not integrated each other, each API set allows to access the specific data/service of a single operator. Thus, the API and the data are not semantically interoperable, and the problems in

managing the semantic integration of data and services are left in the hands of the developers, that have to cope with different, not harmonized APIs and providers, different authentications, and so on. The developers have to select the data, get them and integrate them every time they change. An example of this Case (a) is the E015 solution for Milan [EO15], where structured information is requested to the API providers via Excel files, and published in their original formats on the E015 Web portal. The approach enabling the passage from "data to services" is not well activated, since the data is not interoperable, and the licensing agreement is in multiple relationships arranged between each developer and several data providers. The solutions belonging to this category does not satisfy most of the sub-goals of the EIP document about the Urban Platforms [EIP_SCC].

Case (b): the Data and Metadata Aggregator collect data and metadata information (mainly open data) to index and aggregate them in a common model according to the structure of the open data files and tables in input. The resulting aggregated data are made accessible to web and mobile App via some automatically generated APIs disregarding their semantics and thus the match among entities collected from different data sets and representing the same elements. In some cases, graphic rendering is provided via some data visualization tool, presenting the similar problems of semantic. The automatically produced model does not lead to a satisfactory semantic interoperable data service [Bellini et al., 2014]. The data are not re-conciliated each other, and maintain the same quality of the original, missing data are still missing. The data integration is mainly performed on the basis of syntactic and lexical forms of data names and content values. In some cases, a semantic model for data access is provided as marketing strategy for the 5 stars; and thus they provide SPARQL based API and service. The generated ontological model is a mere representation of tables and does not provide significant inferential support. This also means to have limited reasoning on time and space. Belong to this category of solutions CKAN [CKAN], ArcGIS OpenData [ArcGIS], OpenDataSoft [OpenDataSoft] based on ArcGIS, SOCRATA [SOCRATA] also based on ArcGIS. The solutions based on ArcGIS provide more capabilities on geospatial queries. Case (b) approaches can be regarded as first level solutions for data interoperability, and can be viable when mainly open data are integrated, without real-time and/or private data. The solutions compliant to Case (b) do not cover all sub-goals of the Urban Platforms [EIP_SCC] since data are not harmonized.

Case (c): the Semantic Aggregators and Reasoners collect data and services from the City Operators, to aggregate and integrate them in a unified and semantically interoperable model based on a multi-domain ontology. This approach allows re-conciliating data and exploiting a coherent model to reduce the errors, integrating data representing the same concept and coming from different structures, operators, and sources. The usage of a multi-domain ontology allows the adoption of a model representing relationships of specialization among classes and relationships, aggregation, association, and similarity, that enable the inferential processes in the RDF Graph Database [Bellini et al., 2015], [Bellini et al., 2014], [RDF]. Thus, the obtained knowledge base can be used for creating strategies for data quality improvement and for setting up algorithms and reasoning about the several aspects and services belonging to multiple domains. This advantage is also evident on the provided API and tools for Decision Makers. For the same reason, the obtained Knowledge Base, by populating the ontology with data and inference, can be profitably and easily used for producing smart services such as routing, multimodal routing, suggestions on demand, personal assistants, connected drive, etc. With respect to a perfect Case c solution, CitySDK [CitySDK] provides some limitations involving major cities and providing specific REST API; and OASC (Open & Agile Smart Cities) adopted the FIWARE NGSI API agnostic model [OASC] for producing smart city API based on CitySDK with the corresponding limitations; Transport.API [Transport.API] is a service for providing

aggregated open data in the UK. This startup makes available, via a Rest API system a relevant number of datasets integrating both static and real-time data, mainly regarding mobility aspects. It can only be partially classified as a Case (c) solution for the lack of an effective semantic engine. The proposed Km4City (Knowledge Model for the City) [Bellini et al., 2014] more widely covers features of Case c. Km4City is exploited by Sii-Mobility Smart City project (http://www.sii-mobility.org), RESOLUTE H2020 Project (http://www.resolute-eu.org) and REPLICATE H2020 Project of the European Commission (http://www.zabala.co.uk/en/projects/replicate), providing Smarty City API of Km4City [ServiceMap], [Bellini et al., 2014].
Solutions of Case (c) mainly differ from those of (b) for the presence of a real ontological model among city entity and not on data structure of the tables. The solutions of Case (c) are better ranked with respect to the sub-goals of the Urban Platforms [EIP_SCC] covering aspects connected to the harmonization of data, and production of intelligent services. Moreover, the implementation of user experience for value added services (subgoal 5) is only accessible in a few of them as analyzed in the following. The ontology can model city domains entities and their relationships and not only metadata of data sets and tables as in Case (b). An effective integration at semantic level of the data domain enables the creation of Smart Decision Support Systems that exploit the possibility of making semantic queries on multiple domains, to make probabilistic reasoning on Bayesian decision support [Bartolozzi et al., 2015], and to enable the production of algorithms for implementing personalized routing and Personal Assistants in the city. Case (c) solutions have to cope with Graph Database collecting huge amount of data, thus resulting in Big Data cases and scenarios presenting relevant data such as variety, velocity, veracity, volume, etc. [Bellini et al., 2013].
In this paper, Km4City open source smart city ecosystem is presented. Km4City is grounded on an ontology driven smart city Case (c) aggregation solution, and provide a set of integrated tools that allow collecting data and exploiting them for smart city decision support, resilience analysis and for providing to the city users general and specialized personal assistants. In Section 2, the high level tools of Km4City are presented as: dashboard solution, city resilience modeling tool, and smart decision support. Section 3 presents the tool for social media monitoring and analysis called Twitter Vigilance. In Section 4, the main features that the Km4City ecosystem provides regarding the smart city personal assistant via smart city API are presented. The solution allows providing services on demand to commercial and city operators, and at the same time monitor and analysing the city communities. Section 5 provides some notes about the adoption of the Km4City solution and actual cases, and thus the present Km4City roadmap for development. Conclusions are drawn in section 6.

2 - Smart City Control and Resilience Assessment

Smart Cities need to computer in real time high level city indicators to keep under control on some cockpit/dashboard, Control Room for city monitoring and decision support. The whole set of city operators and their infrastructures have to be kept under control with specific service level agreements they have with the city: public transport, traffic, energy on public services, welfare, parking, cultural services, governmental services, people flows, Wi-Fi, water services, traffic flows, environment, air pollution, water supply, weather, waste, economic indicators, social media, taxi, car sharing, etc. The classical dashboard tools for data rendering are unsuitable since are only focused on presenting graphs according to some database, disregarding the complexity of multiservices, service level agreement, historical collection of data, and by the fact that data may be obtained by using pull and push.

The Dashboard tool in the Km4City environment [Bellini et al., 2014] allows multiple users to build multiple dashboards by means of a visual composition tool allowing the production of the dashboard as a set of graphics widget representing data, tickets, critical conditions, smart decision support, etc. The example on a Florence dashboard is accessible on http://dashboard.km4city.org (see Figure 1). It has been developed for REPLICATE H2020 EC project.

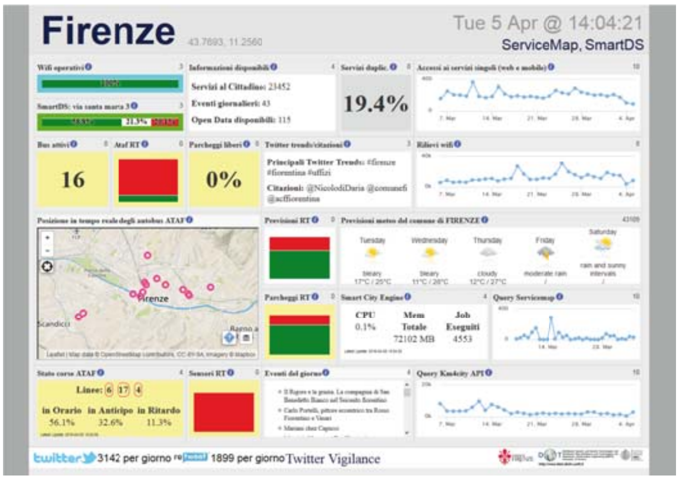

Figure 1. Example of dashboard, http://dashboard.km4city.org

A city and its infrastructures are resilient if they provide the ability to sustain required services and operations in both expected and unexpected conditions. This means that some capability of continuously adapting its operational environment to persecute system intention/ purpose, the quality of life for its city users. Understanding resilience for city and its critical infrastructure is becoming more and more important: transport, water, communication, hospital, energy, etc., are even more connected and depending each other. A failure in one of those subsystems may affect the system as whole. Resilience analysis and assessment aims to tackle the challenges of the uncertainty and interdependency expanding and integrating the current Risk Management approach, usually based on known threats.

The aim of a Resilience Decision Support, **ResilienceDS** (http://www.disit.org/fram), is to support decisions at strategic, tactic and operational levels to develop sustained adaptability capacity as well as to be effective during the preparation, plan, absorption, recovering and adapting phases (see Figure 2).

The ResilienceDS tool extends the Functional Resonance Analysis Method (FRAM) for several aspects. It is a visual tool for system resilience modelling and risk focuses on system interdependencies, their dynamics and complexity, exploiting different decision support systems, including the identification of conditions on Km4City data. Within this context, a system functionality/process can transform its state on the basis of actions performed by human, technological devices or natural. Thus the model of the city with respect to all causes and affects is modelled and studied. ResilienceDS is operatively modeling the European Resilience Guidelines developed in RESOLUTE H2020 project (http://www.replicate-eu.org).

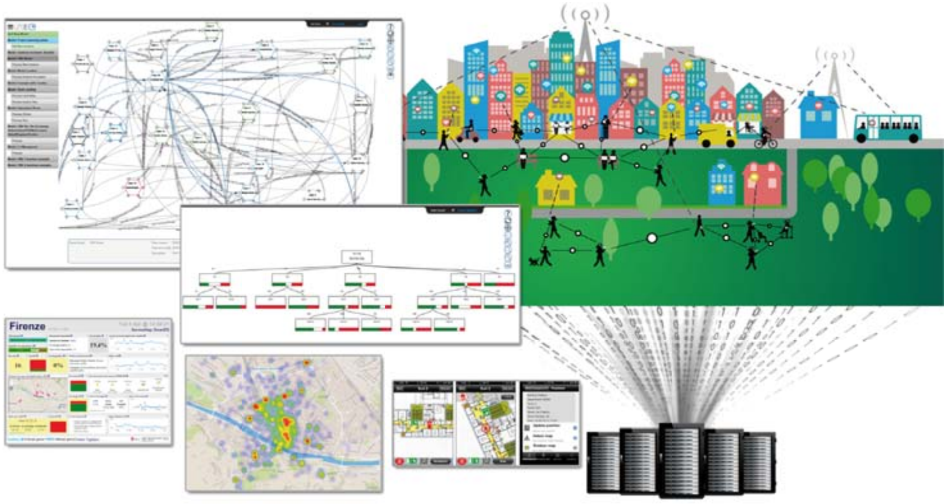

Figure 2. Resilience Smart Decision solution based on Km4City data collection and dashboard

The ResilienceDS is capable to take into account the non-linear nature of city performance, as opposed to building cause-effect sequences of events over time. It is based on the principle that accidents in complex sociotechnical systems are produced by unexpected combinations (resonance) of “normal performance” variability. Hence the visual tool supports resilience assessment by providing an understanding and steering option towards controlling (damping) sources of variability. Functions, selection, coupling and the identification of their potential sources of variability can be investigated through Smart City Big Data Analytics on Km4City or other data assets as well as through the classical stakeholders workshops and focus groups with Decision Makers, Critical Infrastructure managers, First Responders, Civil Protection, Citizen association, etc. The making decision processes can be modelled by using **SmartDS** (Smart Decision Support System) of Km4City which in turn compose uncertainties combining data and stakeholders experiences (http://smartds.disit.org). SmartDS is based on the evolution of the Analytical Hierarchical Process model (which support System Thinking model), which has been integrated with the Italian Flag 3-values logic representation. SmartDS integrates social and data processes by accessing and querying external repositories, to gather Smart City related data assisting decision makers, through the use of properly defined functions and thresholds; directly update the assessment of the decision model according to the updated data and to communicate them to decision makers and making visible on a widget of the Km4City Dashboard.

In Km4City, the integrated resilience analysis tools allow to produce and validate models for resilience and decision making in case of emergency and hazardous cases of critical infrastructures by composing different data: open data, real time data, and other data coming from surveys, stakeholders opinion assessments, collaborative platforms, services reports, city operators, user behaviours, city users apps, social media, etc. it allows city managers to tackling classical decisions under critical conditions, to be prepared and to absorb and react to them at the best.

3 - Twitter Vigilance on Smart City

Social Media channels are: (i) sources of information for assessing the moods of the city users, for assessing services, for predicting audience at large events, predicting flue, (ii) channels for communicating with the city users, etc. Among the several social media platforms Twitter is probably one of the most reactive in terms of velocity by which the information is flooding in it. Twitter has been successfully used for prediction and measuring events in the cities. Together with the measures performed by the mobiles it completes the view about the occurrences and city users in the territory. Twitter Vigilance (http://www.disit.org/tv) is a multi-user tool for Twitter analysis capable to monitor and analyse slow and explosive events on Twitter with same efficiency and precision, acquiring all tweets and retweets, performing statistical computation, natural language processing and sentiment analysis (see **Figure 3).** A fast or explosive event occurs with several hundred thousands of tweets per day/per hour. Slow events can occur with very few tweets per day or week or their absence. Twitter Vigilance provides adaptive algorithms to allow effectively cope with slow events that become explosive without losses

Figure 3. Twitter Vigilance: monitoring city moods via social media, http://www.disit.org/tv .

4 - Smart City Personal Assistants via Smart City API

The duty of a city is to provide access to data, aggregated data and services, so that a set of mobile and web Apps can be produced by city operators and firms. Business of Apps are hardly sustainable since the offer is high, most of the Apps are vertically focused on specific services and offered for free, multi-service Apps are very expensive to be created and maintained if the data have to be singularly accessed and personally aggregated. Aggregated data and Apps are becoming commodities and city users expect to have them free of charge. Thu a wide range of Apps are produced and promoted by public, operators, supporting private transport, tickets services, parking, commercial mall, etc. Specific Apps can only give a partial view of the city service. Therefore, the Open Km4City App allows to freely putting in the hands of the city users and city operators a range of strong and valuable multipurpose Apps in short time and at low costs by exploiting the Km4City development tools, Smart City API and model (supporting REST Call, SPARQL Calls [SPARQL] and query ID calls), which can:

- provide access to multi-domain integrated data, searching them by text, GPS, region, by navigation;
- provide suggestions for instilling virtuous behaviour for the city according to their profile and city purpose;
- inform population about city hot issues and alarms from: civil protection, environmental aspects, weather forecasts, hot events, major communications, cycle paths, changes in the viability;

- collect comments and feedbacks about services to enrich their information and improve them;
- measure service efficiency in the city, measuring Wi-Fi and Bluetooth iBeacon fields.

Each Personal Assistant derived from Km4City Mobile App exploit the Smart City API and services on demand (see **Figure 4** and Km4City App on all stores). The resulting App can be regarded as a sensor and front end desk for the city in the hands of the city users. All data are collected in a completely anonymous manner, while they inform and maps collective behaviour of city users. The Open Km4City Mobile App exploits the Km4City Smart City API. Km4City Mobile App provides suggestions based on the user profile selected (citizen, commuter, tourist, student, and all) and on past anonymous action; measures the power of Wi-Fi and iBeacon. The user can deactivate suggestions totally or selecting categories. These are classified as suggestions of: events, weather forecast, mobility and transportation, interesting issue to be done, utilities, accommodations, restaurants, twitter informative channels, etc. The Km4City suggestion engine is at the disposal of the city and of city operators, learns from the city users, is an intelligent assistant for the city users, detecting problems in advance, suggesting best places to park, etc. The collective profiles can be exploited by the city for tuning services, extract what, when, which, where, and how they use the city services; and thus for producing Origin Destination matrices, also suitable for city operators. Exploiting Smart City API, other Mobile App can be realized by City Operators, and commercial operators; Thus enabling a wide range of commercial and business applications.

Figure 4. Personal Assistant on demand from Km4City ecosystem, city user analyser (only a small part of data are shown)

The derived Apps can be used to distribute information to the city users in the case of critical conditions and events, as well as it is used to understand the people flows and typical paths in the city for tuning public services, improving access to attractions and as a support for commercial applications.

5 - Km4City Roadmap and adopting projects

Km4City is a knowledge model for Smart City solutions and services. It allows semantically integrate data coming from different operators. Data which can be static and realtime, open and private. In the process of data aggregation it allows to establish all needed relationships among elements, thus making a general data set semantically interoperable at model level

(e.g., associating the street names with toponimous coding, resolving ambiguities in names, removing errors in data, completing missing data, etc.).
Km4City multi-domain ontological model is

- open, well documented and accessible free of charge, aggregating open and private data, static and real time data;
- modeling services and relationships in the city as: accommodation, advertising, agriculture, engineering, cultural, education, research, emergency, entertainment, environment, financial, governmental, health, industry, manufacturing, mining, shopping, tourist, transfer and mobility, utility, wine and food, etc. for over than 500 different specific categories;
- representing localized and relationships among: services, areas (e.g., districts, LTZ, parking, green area), paths (e.g., cycle, tramline, busses), weather forecasts, events, Wi-Fi access points, iBeacon, sensors (e.g., traffic, environment),..;
- covering: street and geographical aspects, point of interests and services, public local transport, environmental and traffic sensors, temporal aspects of data, data licensing, real time events, etc.

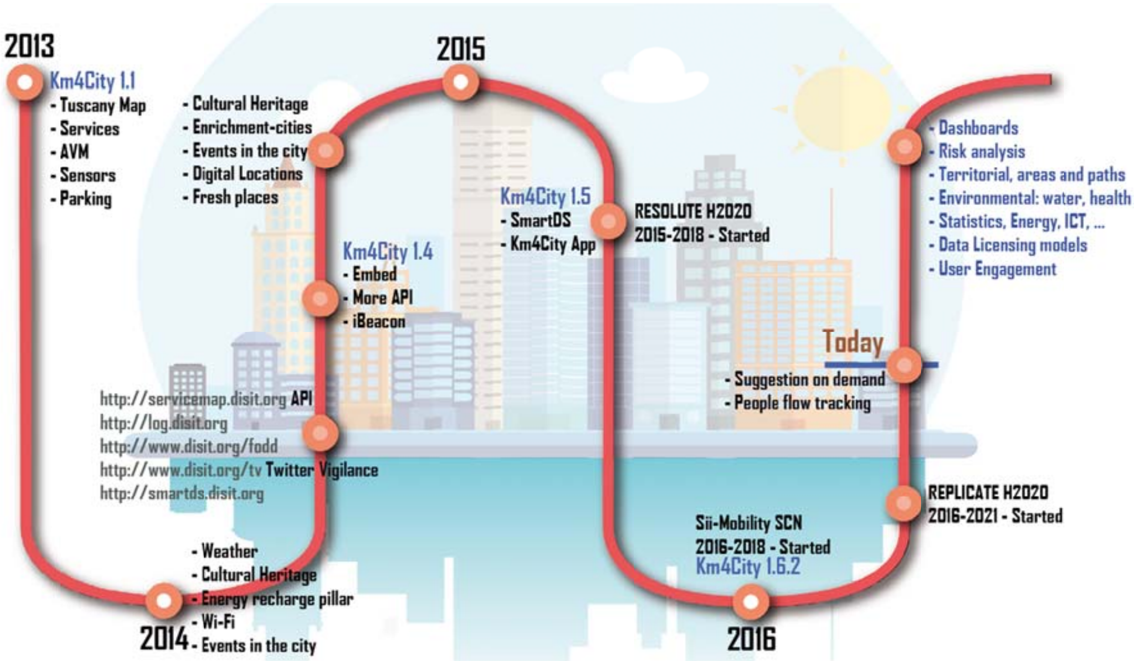

Figure 5. Km4City roadmap with respect to projects adopting it: Sii-Mobility SCN, RESOLUTE H2020, REPLICATE H2020, …

The Km4City model and ontology has a certain and founded roadmap to evolve with the support of a number of projects (see Figure 5) investing on its technology and solutions, such as:

- Sii-Mobility is providing a regional level environment for inter-modality and advanced services on mobility and transport, licensing;
- RESOLUTE DRS14 H2020: on risk and resilience analysis and tools, people and traffic flows, etc.;
- REPLICATE SCC1 H2020: on integrating sensors, IOT, energy aspects, lighting, smart benches, etc.

For example, the Florence and Tuscany case, accessible from http://servicemap.disit.org and "Firenze what where, …" mobile App on all platforms. The identification of the most relevant data sets was performed to activate the data aggregation process by integrating information for the city users about services and mobility/transport. Geographic data have been integrated from MIIC (Mobility Integration Information Center of the Tuscany Region), many open data from Florence Municipality, sensors, weather forecast from LAMMA agency, several information about commercial activities from the web, and social media. The data which are present on Km4City for Florence and Tuscany are presently covering the whole Tuscany region with all districts and more dense data on Florence Metropolitan Area for a total of more than 120 million of elements including among them

- Elements: Road Graph (Tuscany region) as 132,923 Roads, 389,711 Road Elements, 318,160 Road Nodes, 1,508,207 Street Civic Numbers; 110,374 Services (20 main categories, 512 subcategories); 2,326 Bus stops & 86 bus lines (up to now only in Florence); 210 Parking areas in Tuscany; 424 Traffic Sensors in many cities; information on elements that are located on GPS points, paths, areas, etc.;
- hundred thousands of measures per day about: position of busses, parking status, traffic sensors, weather forecast, new events, power measures about Wi-Fi and iBeacon, restricted traffic zones, etc.

6 - Conclusions

Most of the smart cities projects are based on sectorial targets related to specific vertical applications, with closed technologies and high costs. This makes impossible any replication unless substantial funding for adaptation and replication. This approach is no longer viable and neither sustainable. Public administrations need to manage complexity in the smart city services and corresponding sustainability issues. This is highlighted by the fact that proposed services are scalable and moving to city level become inadequate. They need sustainable solutions based on open standard, open source, interoperability, scalability and flexibility.

A Km4City based smart city project can be easily started exploiting the experience of the Km4City team, which can easily pass from your objective to a plan realized in months and not years. The plan includes: identification of possible scenarios; training activity to coach in the public administration; analysis of the available data; identification of the information to activate any use case and scenario. From these activities, a report is defined with the details of possible scenarios and use cases, a detailed roadmap of activities and time schedule, the definition of the architecture and a detailed costs planning for the solution. Then, the infrastructure configuration and the start of the phase of customization of the Km4City tools and solutions is activated, and progressively other feature added.

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