Facility Management Services in Smart Cities: Trends and Perspectives

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Abstract. A Smart City can be defined as a complex socio-technical system in which services are optimized by the use of digital telecommunication technologies for the benefit of its inhabitants and business activities. The Smart City topic is today at the centre of many debates at European and international levels, also for the potential impact of the innovation of urban services within the overall performance of cities. Literature and virtuous cases of Smart Cities at the European level envisage optimization and innovation scenarios for traditional Urban Facility Management (UFM) services, based on the application of Information and Communication Technologies (ICTs), in particular Internet of Things (IoT) and Big Data management. Although the interest in the transition of the cities towards Smart Cities by administrations is growing, this transformation process appears to be still experimental and not much supported by shared knowledge references and tools. In light of this premise, the contribution - that is part of the PRIN research "Metropolitan cities: economic-territorial strategies, financial constraints and circular regeneration" - introduces the main results of the study conducted on a sample of 21 cities at the European scale with the aim of deepening and analyzing: (i) current innovation scenarios of UFM services enabled by ICTs that allow information sharing (Big Data flows) and a continuous monitoring of infrastructures and physical assets at the urban scale; (ii) characteristics and main trends in the implementation by public administrations of information platforms for the provision of smart UFM services and, more in general, for the smart management of cities; (iii) the potentialities of Milan, investigating the evolution of the offered smart urban services and of the adopted cognitive tools to manage city information, highlighting main trends, strengths and possible scenarios of improvement.

Keywords: Urban Facility Management (UFM) · Smart City · Urban services · Internet of Things · Big Data Management · Information platforms

1 Smart Cities and Scenarios of Innovation of Traditional Urban Services

The adoption of Information and Communication Technologies (ICTs) is redefining the scenario of traditional Urban Facility Management (UFM), understood as the integrated management of support services for the operation, use and enhancement of urban goods [1]. These services are today affected by important changes, especially in metropolitan areas, due to the evolution of ICT solutions and the application of Internet of Things

C. Bevilacqua et al. (Eds.): NMP 2020, SIST 177, pp. 220–230, 2020.
https://doi.org/10.1007/978-3-030-52869-0_19

(IoT) and Big Data paradigms, which concern aspects such as: methods of data detection, analysis and management; methods of communication/interaction with users; monitoring of performance; methods of response of systems, network interactions, etc. The digitalization of urban management processes is not simply bringing services towards ICT-based solutions, but it is redefining in a disruptive way the meanings of the concept of the city itself (digital, eco, green, intelligent, sustainable, etc.) [2, 3], multiplying the interpretive keys of its cognitive methods [4], dynamically expanding its boundaries (from the smart city to the smart region) in relation to the growth of networks based on smart specialization strategies [5, 6]. It is a scenario characterized by a heterogeneity of interpretations and experiments [7–10] in which the evolution of the new ICT technological offer plays an important role in placing the importance of services as enablers of transformations of the behaviors of the different categories of stakeholders [11] as well as in the management of tangible and intangible assets and related parameters for urban performance assessment [8]. Thus, it arises the need to acquire interpretation tools, capable of relating the consolidated methods of analysis and forecasting of the dynamics of development of urban systems with phenomena linked to the evolution of services, considered in a smart perspective [12]. Therefore, the paper aims to highlight trends and propose new classification schemes useful for describing new/renewed UFM services affected by digital evolution, new service management models, enabling technologies and information sources. To this end, it has been developed a European-scale analysis of smart urban services, here offered in a sample of significant Smart City experiences. The sample was defined by selecting cities that: (i) have been involved in projects concerning ICT applications in urban service management under the EU's 7th Framework Program or Horizon2020; (ii) are developing/have developed initiatives, policies, guidelines and/or strategies relating to the integration of ICTs in the management of urban FM services. The sample consists of 21 cities[1]. The analysis of smart urban services assumes and relates the following three levels:

- Domains of the Smart City. They are widely shared in literature [13, 14] and they represent the different sectors of urban development, classified as follows: People, Economy, Governance, Mobility, Environment, Living [15, 16];
- Domains of UFM. By comparing the traditional UFM services with the Smart City domains, it arises the need to propose a new set of urban FM domains [1, 17, 18]. The urban FM domains thus identified are: Building, Energy, Education, Governance, Environment, Business, Mobility, Health, Waste, Safety & Security, Water;
- Smart services in relation to different application fields. According to Rapaccini and Gaiardelli (2015) it is possible to "*define the service as intelligent or smart when this is provided in order to anticipate problems/needs of the customer, thanks to ICTs that favor the acquisition and processing of contextual information. The objective is to provide proposals for intervention in less time and with less effort*

[1] Antwerp (Belgium), Barcelona (Spain), Berlin (Germany), Bristol (UK), Copenhagen (Denmark), Eindhoven (The Netherlands), Espoo (Finland), Geneva (Switzerland), Genoa (Italy), Lisbon (Portugal), London (UK), Lyon (France), Milan (Italy), Munich (Germany), Nice (France), Padova (Italy), Santander (Spain), Stavanger (Norway), Stockholm (Sweden), Vienna (Austria), Warsaw (Poland).

and costs" [19]. Examples of smart UFM services are: Smart Street Lighting Mgmt; Energy Grid Mgmt; Smart Bins Monitoring & Dynamic Scheduling; Smart Water Mgmt & Real-time Leakage Detection; etc. Parallel to these innovative services, there are also sharing and delivery services - such as bike/car sharing, co-working, food delivery, etc. - which represent another important emerging ICT-based service category [20].

In relation to this classification structure, a qualitative comparative analysis was conducted to identify the smart city and UFM domains most affected by the adoption of advanced ICT solutions and to identify the main characteristics of smart services. Table 1 shows a summary of the sample review.

Table 1. Summary of the survey on 21 European Smart Cities: smart UFM services, trends by domain and innovative strategies for the planning and delivery of services. Adapted from [2]

SC domain	Service Strategy Innovation	Smart Cities
Energy	• Continuous monitoring of energy consumption and data analyses provide insights on energy demand at urban/district scale for the identification and location (GIS) of peak hours and for the identification of areas with energy surplus able to support any neighbouring areas in energy deficit • Smart lighting systems (motion and presence sensors and actuators for switching street lighting on/off) to improve citizens' perception of safety	Eindhoven, Milan, Padova, Stockholm, Espoo, Nice
Waste	• Wireless ultrasonic sensors that detect the filling level of waste containers • Planning and optimization of waste collection routes: geo-location data of the containers together with data from the sensors about their filling level allow to identify real-time the most efficient routes for waste collection • Municipal waste management platform: drivers of collection vehicles can use mobile apps to scan, confirm and generate report on any event (e.g. automatic billing for the collection of waste on request)	Berlin, Vienna, Barcelona, Lisbon, Stockholm
Building	• Real-time monitoring of energy consumption (e.g. identification of peaks) • Real-time adjustment of the energy distribution • Scheduling maintenance and cleaning interventions based on actual use (no longer periodic interventions with frequencies defined on a statistical basis but real-time monitoring of the operating conditions of the elements and interventions according to real conditions) • Real-time monitoring of user behaviour (use of as-sets, fixed furnishings, preferences, etc.) to improve the management of spaces and internal layout	Stavanger, Warsaw, Antwerp, Lyon, Geneva, Lisbon, Genoa

(*continued*)

Table 1. (*continued*)

SC domain	Service Strategy Innovation	Smart Cities
Environment	• Network of wireless sensors for monitoring environmental parameters (e.g. CO2, noise, temperature, etc.) to improve the city environmental quality Air quality monitoring through wireless sensor networks and mobile device networks for the detection and monitoring of air pollution (e.g. sensors on smartphones) that allow people to keep track of pollution levels in real time and feed a central database	Berlin, Munich, Genoa, Milan, Nice, Stavanger, Eindhoven, Antwerp, Bristol, Santander
Mobility	• Real-time monitoring and communication for: (i) public transport (e.g. real-time updates of waiting times, etc.); (ii) parking management (e.g. real-time updates of available parking spaces, etc.); (iii) traffic management (e.g. real-time updates of traffic conditions, notification of the best routes, etc.)	Berlin, Munich, Santander, Copenhagen, Barcelona, London
Governance	• Municipality Open Platforms provide digital services (e-government): Public services provided by PAs are managed electronically, promoting communication with PAs and engaging citizens into public affairs • Collection and use of citizens' online feedback to support decision making and to inform the policy development process	Eindhoven, Berlin, Munich, Santander, Barcelona, Copenhagen, Stockholm
Safety & Security	• Platforms with call management, intelligent mapping, field communications, data reporting and analysis to obtain an updated common operational framework to increase the city response capabilities • Sharing and combining real-time CCTV video surveillance networks of municipal agencies with other public and private security systems for problem detection and cooperation of agencies and related staff	Eindhoven, Bristol, Lisbon
Water	• Smart water meters together with sensors on electric motors, pumps, valves, etc. and water management software applications allow: (i) real-time detection of leaks, reducing non-revenue water; (ii) optimized pressure management, reducing energy consumption and losses; (iii) better accuracy in cost calculation and automatic billing • Smart Water platform for: end-users participation in improving water distribution systems; cooperation between water suppliers and end users	Santander, Barcelona, Bristol, Lyon, Milan

From the investigation and comparison of the observed cases, it is possible to highlight some recurring aspects of interests and trends linked with the key role of the technological component such as: (i) use of digital ICT infrastructures and IoT solutions to improve the ability of public administrations to collect, manage and analyze data; (ii) activation of virtuous circular and integrated information flows on urban scale, together with standardized communication processes for the exchange of information in real time between the city administration and citizens; (iii) overcoming of the "physical place" as an unavoidable dimension of the activities, guaranteeing, for example, multimodal accessibility to useful data and digital services. Focusing on smart UFM services, several common trends emerge from the analysis of case studies:

1. Bottom-up approach to the planning and delivery of urban services and the rise of a new social entrepreneurship. Unlike traditional UFM services, that essentially follow a top-down approach in design [21, 22], in the case of smart services it is possible to observe a bottom-up approach. These services are created mainly through "bottom-up" processes, enabled by ICTs, with the involvement of various actors (developers, users, etc.), who have an active role in the recognition of problems and needs and, in some cases, in the definition of application proposals, such as: reporting of accidents and roadblocks (London), the case of voluntary citizens' organizations to carry out cleaning and maintenance of local common goods (Barcelona), or the more structured cases of car pooling applications or short-term hosting proposed directly by citizens. This new concept of services derives from the integration of public administrations (in an open government logic, thanks to databases, web applications and open information platforms for data sharing made available to all by PAs) and the "privates", no longer intended only as traditional private players (e.g. private service provider companies), but as an aggregation of small players, such as developers, interested citizens, researchers, technology suppliers, etc., which generates novel forms of social entrepreneurship;

2. Services based on real-time data and data-driven decision-making processes. Smart services involve increasingly dynamic data flows available in real time. This makes possible a continuous monitoring (as in the cases of the Real Time Networks in Vienna and the London Datastore in London) and the application of different forms of "sensing and responding" [23];

3. Existence of two main approaches in acquiring both static (from statistical sources) and dynamic data from smart devices (sensors, tags, GPS, GIS, smart-phones, etc.), confirming the two approaches described by the British Standard Institute in the City data survey report [24]. A first approach which consists in the targeted collection of data, following the identification of one or more urban issues (as in the case of London which focuses on optimizing the provision of public transport in less central areas of the city). The limit of this approach is an excessive siloed vision focused on single services within the same domain, which if - on one hand - has the benefit of optimizing a certain service - on the other - presents the risk of precluding the possibility of integrating large amounts of data coming from other domains or other services. The second approach consists in the massive collection of large amounts of real-time data concerning several aspects of the city useful for several services (cross-domain), with a view to Big Data Analytics systems (as in the case of SmartSantander project which envisaged the implementation of 20,000 sensors in Belgrade, Guildford, Lübeck and Santander - which alone has 12,000 sensors - to test and exploit the potential of data analysis technologies and techniques). The risk of this approach is an overabundance of data, from which it may be difficult to derive effective value in absence of clear aims;

4. Integrated approach to the management of urban services. The pursuit of integrated approaches to city management supported by ICT-oriented services can be extensively observed (e.g. Vienna, London, Eindhoven, Santander, Berlin, etc.). This marks a trend towards the shift from a siloed approach to integrated approaches in the organizational models of municipalities. It means the transition from organizations based on independent decision-making and operational centres referring to individual vertical domains, with problems of communication and information sharing [25], to functions of "integrated holistic governance" [26, 27], relying on shared knowledge bases thanks to the use of information platforms and organizational models based on integrated and collaborative decision-making centres [7, 28].

The case studies highlight how the achievement of this systemic and holistic vision of urban management depends on the implementation of a Smart City Platform which, in this context, represents a key enabling factor.

2 Enabling Technologies and Tools for Information Management Within Smart Cities

The analysis of the sample reveals a particular attention paid by municipalities to implement information platforms. Although this implementation process appears to be still at an experimental stage and little supported by shared references and support tools, the investigated cities contribute to recognize the key role of the platforms in enabling the delivery of new digital services. The Smart City Platform has the potential to gather experiences, skills and knowledge and to set up a common development plan for all the sets of smart services offered within the various city domains. The cases of Barcelona, Berlin, London and Vienna highlight a further meaning of platform, on which it is worth paying attention, defined as *Open* Smart City Platform. This meaning refers to the fundamental concepts of:

- accessibility. Public administrations are increasingly aware that their data represent a heritage for the community. The accessibility and diffusion of city data play an important role for various stakeholders (investors, facility managers, urban planners, developers, service providers, citizens, etc.) to support decision-making processes at different levels (strategic, operational) [29];
- interoperability, i.e. the ability of the platform to work in a coordinated way with other systems (e.g. other databases, devices and sensors, Continuous Monitoring System, Energy Management System, Data Analysis System, etc.) by exchanging data in interoperable formats in order to exploit the benefits of data systemization and the potential of calculation and analysis of specialized software [30]. In this way it is possible to overcome the problem of integration of heterogeneous data (different languages, formats, etc.) coming from different systems;
- open and expandable platform structure. An open platform is based on the use of IoT technologies and exploits the capabilities of Big Data Management. The analysis of the platforms available on the market has highlighted a recurrence in the characteristics of their structure: modular, multi-layer, multi-tenant, scalable and expandable over time [31]. In particular, the performed analysis highlighted the

main technological layers of an information platform: Sensing Layer (data collection and device management); Network and Gateway Layer (connectivity and normalization); Platform Layer (central dynamic database); Data Analytics layer (data analysis and proactive responses); Application Layer (user interfaces and data visualization).

Despite the majority of the analyzed cities has developed platforms that share the general characteristics described above, they are following different implementation approaches that can be summarized into three main configurations with increasing level of complexity in terms of economic and organizational efforts necessary for the implementation, development and management of the platform:

– implementation of individual platform segments. These are open source and interoperable components, that over time can be assembled and combined with other platform components offered by the same supplier or by third parties. This reality represents an evidence of the interest of municipalities in adopting this technological infrastructure and it opens up possibilities for its diffusion at different levels of city size (for specific urban areas, for cities of size medium-small, etc.). This is the case, for example, of Copenhagen, which has implemented a single segment of the entire CISCO Kinetic for Cities platform, dedicated to environmental sustainability;
– implementation of existing platforms on the market. A review of the products on the market made it possible to verify the presence of predefined Open Smart City Platform solutions that have already been implemented by some cities, such as the CitySDK platform for managing Amsterdam Smart City;
– implementation of customized platforms (e.g. choice of functional modules, APIs, etc.) according to the needs and requirements defined by administrations starting from the models available on the market. For example, this is the case of Vienna, that implemented an adapted version of the FIWARE Platform (by Fiware Foundation EU), which expands the potential of real-time data visualization - including functions of interpolation of data coming from different projects (e.g. Smarter Together, eLogistik, etc.) through open source Real Time Networks [32].

3 The Case of Milan Smart City

The evolution of Milan in a Smart City began almost a decade ago and has recorded a continuous progress over time. Thanks to the interventions in the field of digitalization of the territory with the distribution of optical fibers, Wi-Fi hot spots and digital islands, the Milanese territory has been a place of development and diffusion of experimental smart practices in different sectors - such as social streets, e-tourism, co-working spaces, etc. - with relevant consequences for social inclusion. This evolution is confirmed, among others, by ForumPA ICity Rate 2019 that certifies the leadership of Milan, confirming it for the sixth year the 1st Smart City at national level, and by the Booklet Smart City 2019 of Assolombarda and EY (Ernest & Young) which demonstrates a good positioning of Milan also with respect to the European benchmarks.

Analyzing the city according to three macro-categories of observation of smartness - namely: services and applications; sensing technology; database and data analysis - it is possible to observe how Milan has already widely undertaken smart projects. These projects are now consolidated in some domains (e.g. mobility and energy) in terms of sensor installation and provision of smart services through various digital applications and interfaces available to citizens. In particular, among the services offered in Milan, sharing mobility services (e.g. car and bike sharing, etc.) and sustainable energy services (e.g. district heating networks, etc.) appear to be competitive with respect to the European benchmarks [11]. As regards the digitalization of infrastructures through sensors and smart devices, Milan presents a remarkable development of the application of sensors in the public transport and road networks (e.g. sensors for detecting availability of bike and car sharing vehicles, GPS sensors for local public transport vehicles, traffic detection sensors, occupancy sensors for public car parks), public lighting and energy network monitoring (e.g. smart metering for water and gas networks). The big data generated by these sensor systems should be processed through the information platform in order to improve the offered services. However, the city seems to be not yet fully able to exploit dynamic data for understanding frequencies and intensity of use of the different offered services, users behaviors, etc., useful for outlining possible future city service strategies. In particular, Milan owns an Open Database [33], accessible through the municipal website, but it has not yet developed solutions for integrating dynamic data from sensors and from smart services. Milan published on the Municipality portal about 420 open datasets, a substantially lower number of datasets compared to cities such as London, Berlin and Lyon (more than 1000 datasets). Furthermore, the majority of published Open Data are still of a “static” nature (e.g. km of road infrastructure, no. bus stops, no. subway lines and stops, etc.) or statistics (e.g. from censuses, reports, etc.) and not coming in real time from sensors/services. In this regard, it is important to underline that the number of datasets present within the open database is partially influenced by the willingness - expressed by the managers of smart services - to share dynamic data with the city administration. To sensitize public and private actors to the topic of Open Data, Milan has joined from 2015 the Digital Ecosystem E015, an initiative promoted by Lombardy Region, with Confindustria, CCIAA di Milano, Confcommercio, Assolombarda, Unione del Commercio and technical-scientific coordination by Cefriel. This initiative aims to encourage “*the creation of digital relationships between public and private subjects interested in enhancing their digital heritage by sharing it or in enriching the software solutions for their users with the features and information shared by the other participants*” [34]. Digital Ecosystem E015 aims to develop a platform for the collection and integration of heterogeneous and multi-thematic data useful for the development of new services in different sectors (e.g. tourism, transport, culture, etc.). The initiative involved the development and publication of various APIs (Application Programming Interfaces), written according to common guidelines, which allow the sharing of information and functionalities. Currently the E015 catalogue has more than a hundred APIs of which about one fifth related to Milan (e.g. Around Me, etc.). The apps developed for Milan from the data made available on the platform mainly relate to mobility, tourism and culture (e.g. ATM GiroMilano; Milan Airports; etc.). Following the example of London, Lyon and Amsterdam, Milan could update the geo-localized data coming in real time from sensors and services and use this database to feed third-party applications relating to various fields of interest for the city itself and its citizens. Milan open database could expand the range of thematic data categories becoming more attractive to app developers, as is already the case of London where the majority of applications and services are developed on the basis of the London Datastore, the open database of the municipality of London. In London, the open data and APIs of the London Datastore have supported thousands of developers working on the design of innovative applications, services and tools [35], facilitating the development of small and medium-sized technological enterprises. Concluding, this future prospective for Milan can be translated into the optimization of the platform into a digital ecosystem capable of involving public and private apps, in order to allow the integration and combination of multi-sectoral data, accessible for development of third party services in multiple sectors, such as transport, hospitality, energy, sustainability, culture, sport, tourism, waste, business, housing, employment, safety, health, etc.

4 Conclusions

The ICTs application to UFM field allows to optimize existing services and develop new digital ones, based on the key concepts of IoT, Big Data and information sharing. New capabilities characterize UFM services (e.g. real-time data collection, continuous performance monitoring, proactive system response, interaction with users through digital interfaces, etc.) which represent a key enabling factor for the realization of the Smart City concept. Despite the diversity of approaches in the adoption of ICTs, the analyzed Smart City case studies and the recent studies on Smart City management converge in proposing a change of approach from siloed vertical management to integrated holistic governance. The transfer of this integrated systemic approach to UFM management practices can be realized through the implementation of Open Smart City Platforms able to organize real-time data coming from heterogeneous sources (e.g. sensors, tags, smart meters, etc.) and to optimize decision-making at operational and strategic levels. In this highly dynamic context, which still appears to lack in shared consolidated references, the clear definition of cognitive tools and interpretive categories - useful for reading the evolution of UFM services - appears necessary, also in order to allow city administrations, investors and city managers to understand the contribution of UFM smart services in ensuring the city efficiency and smartness, so that policies and strategies can be properly calibrated. In light of this, the contribution proposes reading keys for understanding the features and the role of the UFM smart services in the context of a smart city, useful to support administrations and stakeholders in managing UFM smart services in a smart ICT-based perspective. In particular, the paper proposes: (i) a definition of UFM domains; (ii) a mapping of the UFM services offered by a sample of 21 Smart Cities on a European scale and related trends in implementation approaches; (iii) an analysis of existing enabling technologies and information platforms; (iv) the definition of trends in the approach to city governance. Lastly, with respect to these tools, the city of Milan has been described and analyzed, highlighting strengths and weaknesses, opening up perspectives for future improvements and innovations that take into consideration new organizational models, deriving from the adoption of digital technologies.

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