Taxonomy of Smart Elements for Designing Effective Services

Completed Research Full Papers

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Abstract

Smart cities use ICT to improve citizens' quality of life. Therefore, to address the citizens' needs and meeting the smart city's quality factors, defining appropriate goals and objectives is paramount. However, a considerable count of services does not have a goal to respond to the smart cities' demands. Defining stakeholders' needs, setting consequent objectives and specifying other technical requirements happen during the design phase of the services. Therefore, there is a need to provide a view of the required smart considerations. This paper aims at introducing a taxonomy for the required elements needed to be taken into account during the design of smart services. The proposed taxonomy is evaluated using a real case study in a European smart city council. The outcome of this research contributes to defining an architecture for designing more effective services in terms of enabling responses to citizens' concerns and meeting the smart city quality requirements.

Keywords

Smart city, smart service, smart city quality factor, design phase, Enterprise Architecture.

Introduction

A smart city is an innovative city that uses Information and Communication Technology (ICT) and other means to improve citizens' quality of life and efficiency of the urban operation and services (Booch 2010; ITU-T FG-SSC 2014; Anthopoulos and Janssen 2016). To realize smartness through services, two various aspects are essential, including: citizens' needs; and smart city quality factors (Kakarontzas *et al.* 2014). A sample question in this regard is "how to facilitate citizens' daily activities with the lowest price?" (Eissel and Chu 2014). Therefore, one of the main goals for smart services should be to address citizens' concerns. Nonetheless, as Kakarontzas *et al.* (2014) stated that44% of the smart services do not have a goal and just follow innovation spirit and other goals e.g. resource savings. As such, Anthopoulos and Janssen (2016) believed that the types and purposes of smart services cannot be easily pre-defined since they are the outcome of innovation. To align design of services with smart city quality factors many principles and standards have been provided. However, by interviewing eight European mangers of service development companies, the authors realized that the managers did not have any overall views on all these standards and principles. They stated that they just followed a common sense to consider these requirements. In this situation, this study define a problem as the lack of a comprehensive collection of all these essential requirements. To address this limitation, the present paper aims at presenting a taxonomy for the requirements which have to be considered for designing effective smart services. In the presented taxonomy, these requirements are called as the elements. The relationships between the taxonomy elements lead the future users to consider all the requirements at the right time. The remainder of the paper is structured as follows: first, more details is provided to explain the motivation and the logic behind the presented taxonomy. The research approach for this study is the design science prescribed in the research approach section. The proposed taxonomy of the smart elements, is described thoroughly in the next section. As well, an extensive literature review (utilized to develop the taxonomy) is provided in

this section to support creditability of the elements and relationships. Later in the evaluation, effectiveness and usefulness of the outcome is illustrated by a real case study.

Research Motivation

The services are essential in enabling the information cities to achieve the quality goals (Feruson *et al.* 2004). Therefore, responsibility of services in the smart cities is to enhance citizens' quality of life. To achieve this goal, recognizing the citizens' concerns is essential. Then, the next step is to set appropriate objectives to address the recognized concerns and needs. Likewise, the objectives should meet smart city quality factors. Toward this, some other concerns are rising for other groups of smart city stakeholders, i.e. the authorities and service developers. The authorities' concerns are associated with ensuring the realization smartness in terms of facilitated daily activities. As such, services developers can get more market share and earn more benefits in case of producing more qualified services. In this situation, this research consider a broader range of stakeholders and their concerns toward the service design context, including the citizens, authorities, and service developers. This consideration has been concluded by reviewing many papers related to various classes of stakeholders (e.g. Savage *et al.* 1991; Freeman 1984). Regarding the abovementioned story, this research describes the term '*Smart Service*' as follows: a '*Smart Service*' is the one with the objectives corresponding to smart city goals and objectives to meet the quality factors and has a response to the smart city stakeholders' concerns. This definition for smart services emphasizes the importance of setting appropriate objectives for services while the studied literature realized that 44% of the smart initiatives lack goals and just follow the innovation spirit. To explore this challenge in the real world, the authors planned to interview some service developers to investigate their real approaches to design initiatives in practice. To develop the interview questions, this study adopted the TOGAF (The Open Group Architecture Framework 2011) architectural development method (ADM) to inspect the services developers' approaches to design their products. The ADM is a step-by-step approach to develop enterprise architectures. The first step of the ADM is to develop the architecture vision. For the purpose of the interview, we utilized the ADM vision template to question the following main elements: 1) the problem and the stakeholders; 2) the objectives; 3) the environment and the processes; 4) the principles and the constraints. By conducting the interviews, the authors realized some shortcomings in terms of an unclear problem definition, unclear stakeholders' concerns, lack of an overarching view about the requirements of the smart context (e.g. principles, standards, etc.). All these shortcomings were related to the design process of the smart initiatives. Referring to the provided definition for the smart services, this study aimed to develop a taxonomy to provide an overall view about all these requirements and considerations for developing effective smart services.

Research Approach

This paper follows the design science research approach proposed by Peffers *et al.* (2007) to present a taxonomy for designing the smart services. As the first step and to define the problem, an extensive literature review has been conducted. To provide practical evidences, eight service developer managers were interviewed. By clarifying the problem as the lack of clear goals and objectives, the stakeholders' concerns, and smart requirements, an objective was formulated to aggregate all these together in as a taxonomy. To develop the taxonomy, relying on the definition of '*Smart Services*' an extensive literature review was conducted on the elements and their relationships. For the evaluation of the taxonomy, the authors used a case study research which is acknowledged to be suitable for the design artefact (Venable *et al.* 2012). The case selected and carried out as a part of this stage is design process of smart services in a European city council (the name is omitted in order to ensure anonymity and in this research we call it as River city). Usefulness and completeness of the proposed taxonomy have been discussed as well.

Taxonomy of the Smart City Elements

Smart services are the core elements of a smart city since they support the realization of smartness in diverse aspects i.e. economy, governance, environment, mobility, and living. These services aim to enhance quality of life within a city (Anthopoulos and Janssen 2016). Kakarontzas *et al.* (2014) have specified functional requirements to improve quality properties for smart cities, as: interoperability, usability, security, availability, recoverability, maintainability, and confidentiality. Referring to the

provided definition for the '*Smart Service*', this services should meet quality factors and respond to the stakeholders' needs. Therefore, an extensive literature review has been conducted to specify the subcategories for three main elements, meaning: stakeholders, quality factors, and design process of services. Then, to specify the sub-categories for the three main elements, diverse topics in the smart city literature have been reviewed, including the stakeholders, the smart city quality factors, the services, and the smart city architectures and frameworks. The latter topic has been reviewed to realize how the existing smart city architectures comply with the smart city goals and objectives. As such, some other sub-categories (e.g. standards, principles, etc.) have been extracted from the literature review as the requirement of the smart city context. Indeed, realization of the smartness is highly dependent on considering the established principles, standards, and other requirements of the smart cities. All these requirements should be considered during the design and development of various layers (e.g. the data layer, the technology layer) of the services. A summary of the studied literature on the three main elements is shown in Table 1.

Taxonomy elements/ sub-categories		Supported By
Stakeholders and concerns		Bergman *et al.* 2011; Maxwell *et al.* 2003; Kumar *et al.* 2011; Coulter and Jenkinson 2005; Le Fauvre *et al.* 2016; Freeman,1984; Savage *et al.* 1991; Zapata *et al.* 2013; Al-Hader and Rodzi 2009; Song 2008; Fang *et al.* 2009
Quality factors		Filipponi *et al.* 2010; Hernandez-Munoz *et al.* 2011; Vega-Barbas *et al.* 2012; Wenge *et al.* 2014; Kandukuri *et al.* 2009; Fang *et al.* 2009; Sanchez *et al.* 2011
Type of services		Anttiroiko *et al.* 2014
Smart service purposes	Sustainability and Social aspects	Zygiaris 2013; Anthopoulos and Tsoukalas 2006; Anthopoulos and Fitsilis 2010
	Real Time Monitoring and Re-usable data	Filipponi *et al.* 2010; Sanchez *et al.* 2011; Hernandez-Munoz *et al.* 2011
	Interoperability	Filipponi *et al.* 2010; Hernandez-Munoz *et al.* 2011; Vega-Barbas *et al.* 2012
	Scalability and Efficiency	Anthopoulos and Fitsilis 2010; Hernandez-Munoz *et al.* 2011; Sanchez *et al.* 2011; Filipponi *et al.* 2010
	Privacy and Security	Filipponi *et al.* 2010; Hernandez-Munoz *et al.* 2011; Anthopoulos and Tsoukalas 2006
	Sensor implementation	Sanchez *et al.* 2011; Hernandez-Munoz *et al.* 2011; Vega-Barbas *et al.* 2012
Design of the services		Gregory *et al.* 2016; Soundararajan *et al.* 2012; Dingsøyr and Lassenius 2016

Table 1. Summary of the studied literature to construct the taxonomy

Plenty of the literature on different elements of the proposed taxonomy is an evidence on the relevancy of the three main categories. According to the studied literature, there is a plethora of smart cities researches which have proposed solutions to meet the quality factors. Nevertheless, the studies have realized that many of the existing smart services lack a goal consistent with the smart city quality factors and stakeholders' needs. An overall view of the presented taxonomy is shown in Figures 1 & Figure 2. In the rest of this section, the main elements and the sub-categories are introduced.

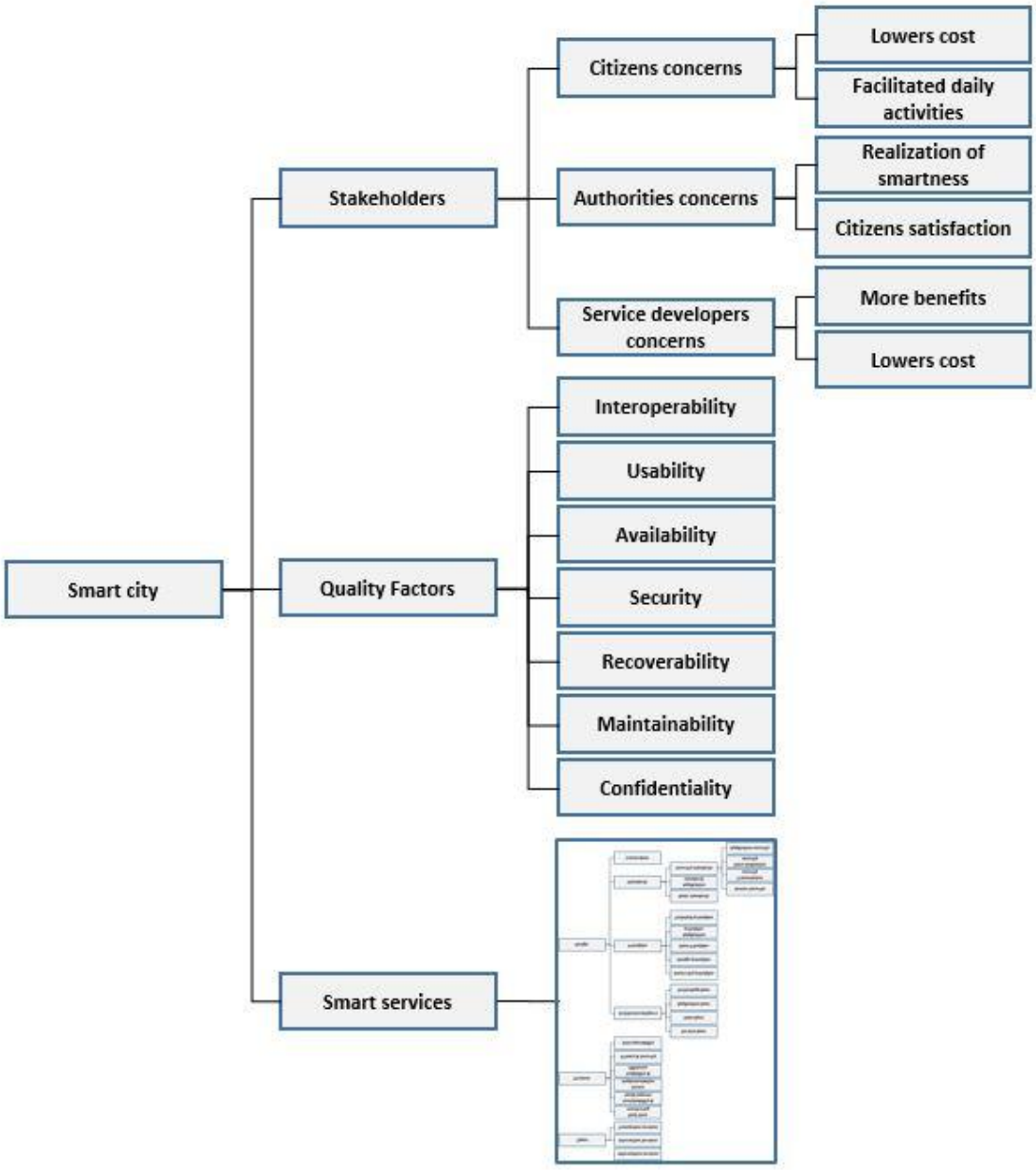

Figure 1. Taxonomy of the Smart Elements to Design Effective Services

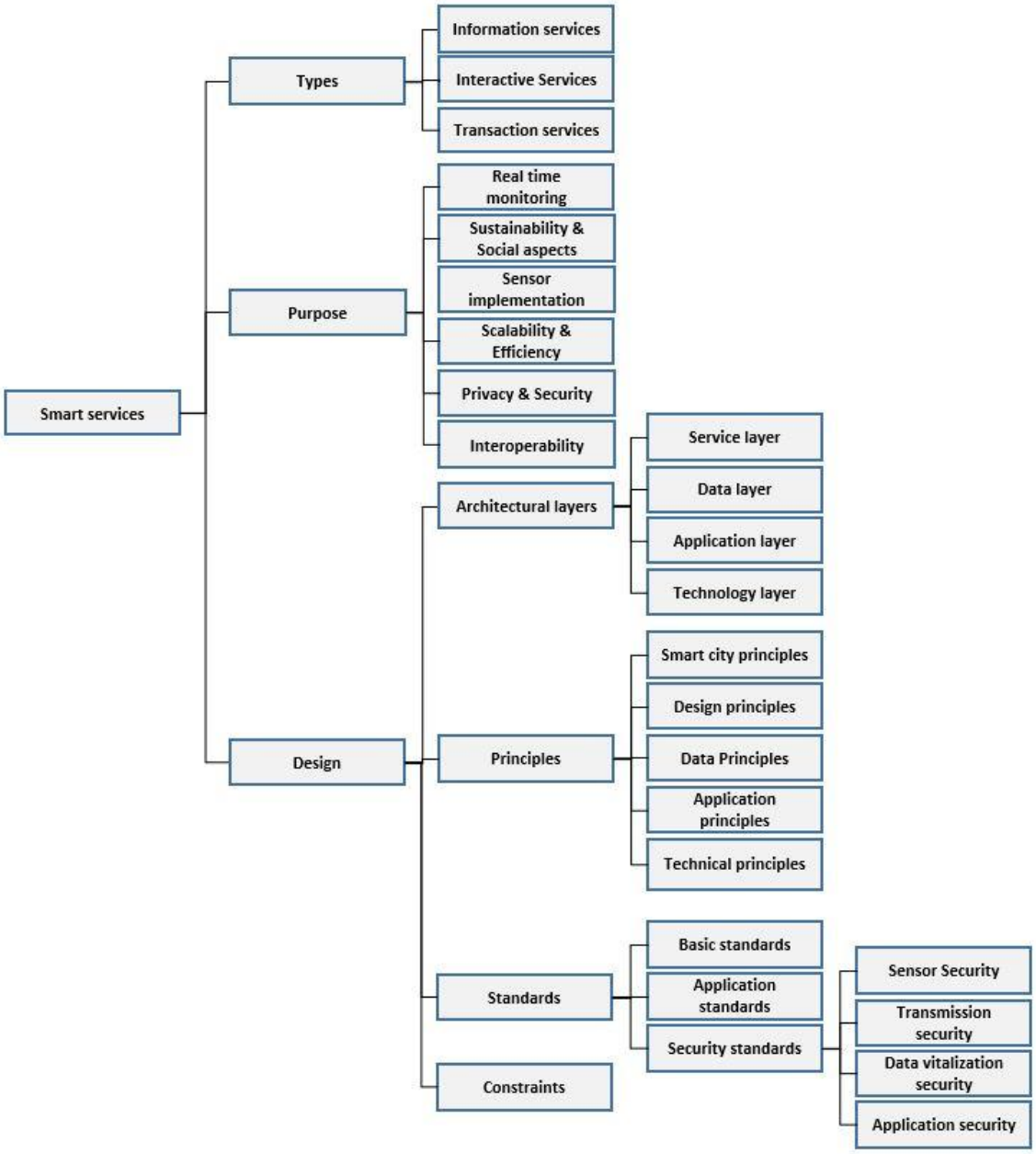

Figure 2. Taxonomy of the Smart Elements to Design Effective Services- Smart Services

Smart City Stakeholders

A smart city's core concern is to improve the citizens' quality of life. Realization of the smartness is happening through the smart services. The services are provided by service developers. Government and authorities are responsible for governing the smart cities in terms of realization of the smartness. What follows is a review of different stakeholders' classes. Freeman (1984) identified the stakeholder as "any group or individual who can affect, or is affected by, the achievement of the organization's objectives". Developing the precedent works, Savage *et al.* (1991) identified four key stakeholder types: 1) the supportive stakeholder who supports the organization's goals and actions; 2) the marginal stakeholder

who is neither highly threatening nor especially cooperative; 3) the non-supportive stakeholder; and 4) the mixed blessing stakeholder who has an equal potential to threaten and cooperate. The abovementioned classes have been defined theoretically. Similar classifications are considered in real world practices. For instance, Kumar *et al.* (2011) conducted an exploratory research on the health care system and considered stakeholders as: patients (as the users of the services), physicians, pharmacies, medical vendors, ancillary providers (as the service providers) and managers (as the governance members). Similarly, Zapata *et al.* (2013) introduced various stakeholders for the transport system as the citizens, the city councils, and the industries to provide a service. Following the pioneering definitions for the stakeholders as well as the practitioners' classifications, this research classified the smart city stakeholders into three classes including: 1) the Citizens; 2) the Authorities; and 3) the service developers. As well, referring the definition for various stakeholders, they have diverse approaches to support, have a stake or decision making. Based on an extensive literature review, the stakeholders' concerns can be summarized as: 1) Lower cost and facilitated activities for the citizens (Song *et al.* 2008; Fang *et al.* 2009; Zapata *et al.* 2013; Al-Hader and Rodzi 2009); 2) Realization of the smartness and citizens' satisfaction for the authorities; and 3) Higher profit and more market shares for the service developers.

Smart City Quality Factors

According to Kakarontzas *et al.* (2014), the most prominent quality drivers are in the order of importance: 1) Interoperability; 2) Usability; 3) Authentication and Authorization; 4) Availability; 5) Recoverability; 6) Maintainability; and 7) Confidentiality. Kakarontzas *et al.* (2014) revealed the need to provide interoperability, different access mechanisms (usability), and different authorization mechanisms (security). As well they stressed the need to recoverability regarding the reliability quality property. The services should be able to recover rather gracefully and quickly in cases of failures.

Smart Services

Based on the studied literature, three different sub-categories have been recognized for this element, including: 1) types of the services; 2) purpose of the services; and the design of the services. In the following subsection, more details are provided for these sub-categories.

Types of services

Three types of smart services have been defined, including: 1) Information services; 2) Interaction services; and 3) transaction services (Anttiroiko *et al.* 2014). The information services (e.g. SmartSantandar, community navigator, local crime GIS) facilitate the individual use or organizational actions. The interaction services (e.g. Pre-paid Oyster Card, Forum Virium) enable the consumers or organisations' interactions. The last type of the services i.e. the transaction services (e.g. M-payment, e-banking) make it possible for individuals or organizations to accomplish their daily transactions.

Purposes of the Smart Services

According to Ferguson *et al.* (2004), services enable the information cities. Moreover, such services should define their objectives to respond to the citizens' needs and should be consistent with the quality factors. Many services, architectures, and frameworks have been developed to comply with the needs for the smart cities. What follows is a classification of the six various purposes for the existing approaches.

Sustainability and Social Aspects

Anthopolous and Fitsilis (2010) conducted a research work to analyze the overall challenges for the common enterprise architecture and basic challenges throughout the other city cases. In their case, the main challenges were related to a more social aspect. As such Zygiaris (2013) discussed a smart city reference model with regard to the social aspect as well as the technical aspect. In this way, he highlighted a need to change for new innovative ideas within his seven conceptual layers.

Real Time Monitoring

Another important feature in the smart cities is real-time monitoring. The real-time monitoring is an essential requirement for maintaining city services which are constantly updated. The real-time monitoring provides relevant information that can be used to predict future scenarios and help prevent their unpleasant consequences. Some smart city architectures have implemented this feature into their research works, e.g. SOFIA (Filipponi *et al.* 2010), SmartSantander (Sanchez *et al.* 2011), and USN (Hernandez-Munoz *et al.* 2011).

Interoperability

The other significant challenge in the smart cities is interoperability of the services where an object has a connection to a specific sensor, actuator, or a device with computational capabilities. A number of significant researches e.g. by Filipponi *et al.* (2010), Hernandez-Munoz *et al.* (2011), and Vega-Barbas *et al.* (2012) disclosed challenges with interoperability. To overcome this challenge, these researchers proposed platforms or gateways.

Scalability and Efficiency

Scalability is the ability to handle a huge number of users while not influencing the behavior and quality of the services. Scalability issues are mostly related to limited storage, bandwidth, and computational capabilities. The scalability is a crucial process in improving the smart city frameworks. Many smart city frameworks have encountered challenges related to the scalability. These issues are arising from the sheer size of the information technology (IT) infrastructure, experimental facilities, services, etc. Anthopoulos and Fitsilis (2010) in their case study of Trikala, the smartSantander project, realize that there is a need to improve the scalability aspect of their research project. In terms of the SOFIA project, their unified system of the subsystems shows basic benefits as scalability over large urban areas, usability, and accessibility benefits.

Privacy and Security

The privacy and security issues are central to the acceptance and success of the future internet services for the safety of the urban environments. With the constant improvement of the services through open platforms, services with homogeneous capabilities, e.g. USN (Hernandez-Munoz *et al.* 2011), some challenges are arising from privacy and security aspects. In case of not properly managing these issues with appropriate security and privacy protocols, it can result in an imperfect situation for the companies involved in these services. Sensitive data is constantly transferred, managed, and stored from public and private sectors. That is why it is crucial to especially understand and implement certain protocols.

Sensor Implementation

Implementation of sensors is crucial to provide services in the smart cities. Many frameworks e.g. SmartSantander (Sanchez *et al.* 2011) worked on this aspect to provide constant services in an experimental and realistic nature. Sensor implementation provides an open platform to work with services to improve the growth of the internet of things (IoT) platforms. In the information management systems, the location is a crucial informative data used in the investigation of the citizen's behavior. This type of information is provided by the implemented sensors. As an example, in the USN (Hernandez-Munoz *et al.* 2011), the location discovery is an essential information.

Design Process of Smart Services

The design process of the smart services is a stage in which the service developers need to define a problem and set the objectives to address it. In this phase, defining a problem based on the smart city concerns and needs is of high importance. Moreover, setting the objectives consistent with the smart city quality factors can ensure achievement of the main goal for the smart cities to realize citizens' satisfaction. Referring to the definitions for the smart city smart service should facilitate citizens' daily activities. The citizens' needs are the first type of the requirements and are considered as the client requirements. The second type of the requirements are technical requirements which can be specified by considering the

principles and constraints and other technical requirements. Based on the TOGAF model for the relationships between the entities, the constraints specialize the requirements, while the requirements are realized by considering the principles. In the following section, the principles, standards and security are discussed as the sub-categories which have to be considered during the design of the smart services.

Architectural Layers

A service costumes the data (data layer) provided by infrastructure technologies (technology layer) and is realized through an application (application layer). Architecture is a vehicle to make sure that the design approach will yield an acceptable system (Brassard *et al.* 2007). Therefore, architectural layers are associated with the relationships between the above mentioned layers to achieve development of a service.

Principles, Standards and Constraints

Principles are general rules and guidelines that inform and support the way in which an organization sets about fulfilling its mission. Based on the TOGAF architecture vision template, there are different types of principles to be considered (TOGAF 2011). Some of these principles are data principles, applications principles, and technical principles. The TOGAF has defined these principles in line with the smart city needs. For instance, as for the data principles, there is a need to consider the open access data which is one of exact needs of the smart cities. In the design phase of the smart services, considering the related principles is indispensable. As well, Wenge *et al.* (2014) stated that a smart city comprises a huge number of information systems deployed across the city. Different systems have different stakeholders, domains, and usage contexts. In this regard, they have defined three levels of the smart city standard, including 1) The standard framework; 2) The basic standards; and 3) The application standards.

Evaluation

For the evaluation of the proposed taxonomy a case study was conducted. The unit of analysis for this case study has been a smart service in a European city we called it River city (Mamkaiitis *et al.* 2016). To collect the information related to the taxonomy, the authors conducted 10 meetings and interviews with different groups of internal and external stakeholders in the River city council. The participants of the meetings and interviews were from two groups of stakeholders including digital strategy managers and program managers. The strategy managers are responsible for planning and monitoring the city strategies. The program managers are responsible for implementing the strategies in terms of planning and running the programs. The findings from the meetings and interviews are described in the following section. For River smart city, the authorities have defined five main objectives. The objective for the purpose of this study is to develop world-class services and infrastructure. Based on the defined objectives, they have specified a goals to collect pedestrian traffic information. As such, eight main principles have been defined as: citizens needs come first; nobody is left behind; align for common vision for River city; open collaborative approach; avoid duplication; spend smarter rather than more; champion for excellence; and take the lead. Based on the defined role for the program managers, they are responsible to define services regarding the smart River city objectives. For this purpose, they defined footfall counter service. Referring to the definition for smart service, this service should respond to the concerns for all the smart city stakeholders. To evaluate effectiveness of the service the defined stakeholders for it were explored regarding the classification of stakeholders in the taxonomy. Referring to the findings from the case study, only two groups of the stakeholders and their concerns have been considered to define the new service (Footfall counter) for River city. Based on the River city principles, the citizens' needs should come first. Nonetheless they did not define any value contribution to the citizens for footfall counter service. Indeed, to define value contribution to the citizens there is a need to specify citizens' concerns in this area first. The only defined value was to the authorities (i.e. digital strategy manger and program manager) to collect pedestrian traffic information. As such, the purpose of collecting pedestrian was not clear to the authorities as well. The results of the evaluation realize that lack of an overall view on the requirements (e.g. stakeholders needs), and their relationships leads to developing ineffective services in terms of improving quality of life for citizens.

Conclusion

Smart cities are innovative cities that use ICTs and other means to improve citizens' quality of life. Improvement of quality of life in smart cities is realized through providing effective services to facilitate daily activities. However, many of the smart services fail to specify their goals consistent with the smart city's needs. Moreover, many of these services lack the ability to interoperate with the other systems. This happens while there are some existing quality factors for the smart cities. Moreover, diverse types of standards and principles have been defined to guide service developers to design more effective services in terms of responding to the current smart city needs. To overcome this challenge, this research developed a taxonomy for smart elements. The sub-categories for these elements were specified by conducting an extensive literature review on the related topic. The proposed taxonomy empowers the development stage of smart services by outline of the requirements which need to be considered to meet the smart city quality factors as well as responding to the stakeholders' needs. Finally, a real case study in the River city was conducted to confirm validity of the proposed taxonomy. The outcome of this research is being used in an ongoing research to develop a reference architecture for the design of effective smart services in cities. As our research and particular the case study indicates, the taxonomy impacts the efficiency of the service development in Cities.

Acknowledgements

This work was supported by the Science Foundation Ireland grant "13/RC/2094" and co-funded under the European Regional Development Fund through the Southern & Eastern Regional Operational Programme to Lero - the Irish Software Research Centre (www.lero.ie).

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