Multi-Contextual Smart City Model for Service Interconnections

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Abstract. The key issue of smart city development usually lies in the understanding of the complexity of the services' structure. Thus, smart city models are developed to improve current outlooks on Smart City Services' structure by using service-dominant logic and service science. However, the contextual changes are usually not fully considered in the existing smart city models. It is in turn difficult to catch the changes among the layers in the smart city model. Therefore, in this paper, we propose a complex and innovative structure of smart city services. The main contribution of the proposed approach is to consolidate the interconnection of services that is affected by the changing context. It will also lead to a better understanding of the complexity in a smart city. The presented conceptual model has a direct influence on the practical development of a smart city. Since every country and city approaches the services' structure differently, the smart city model is derived with the lack of a common understanding of various smart cities. In the case of accepting our model as a common solution, the sharing of knowledge and information among cities and countries would be easier and more valuable. The paper also shows how the current knowledge in service-dominant logic and service science helps to develop a new practical approach to understanding the smart city structure.

1 Introduction

With the exponential increase in the world population and the rapid urbanization of cities, it was deemed appropriate to provide for a paradigm shift in the field of city conception [1]: many nations are evaluating the adoption of smart cities in their inhabited centres, which - thanks to the support of big data analysis tools - will be able to achieve high levels of sustainability and improve the citizens' quality of life [2].

According to the digital agenda for Europe, smart cities mean smarter urban transport networks, improved water supply and waste disposal facilities, together with more efficient ways to light and heat buildings, a more interactive and responsive city administration, safer

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public spaces and meeting the needs of an aging population [3, 4]. The concept of smart city suggests a city that values the inventiveness and creativity of its citizens; in fact, such a system involves multiple groups of stakeholders and has multiple objectives [5]. It includes creative and innovative solutions based on the exploitation of technologies in various aspects of urban life, integrating its economic, social, environmental and governmental dimensions and it is considered as a holistic process of redesigning urban areas, aimed at achieving sustainable urban growth, efficient service systems and increase the quality of life of citizens and the competitiveness of the city, since it includes all the actors of the city: institutions, businesses and citizens [6].

Despite being a widely discussed concept, there is still a gap in the development of smart city models [7]; in fact, for smart cities to be successful, it's necessary to develop a conceptual and cultural model, as a mutation of citizen behaviour is expected in a new urban space that uses information and communication technologies to collect and analyse useful data to the definition of intelligent, efficient and sustainable solutions to improve the quality of their life [8]. This highlights the transition from a traditional city system, based on the dominant logic of goods, to a smart city system that embraces the dominant service paradigm, which recognizes the role of resources and knowledge management in managerial research, thanks to which users evaluate the service based on the value that it can bring to them, which are central to this paradigm. For this reason, it's important to understand the acceptance and propensity of citizens to effectively use the services provided by smart cities, since without smart citizens there would be no smart city and there would be a need to include and involve users; not surprisingly, the ubiquity regarding the form of participation in smart cities legitimizes a closer look at the conception and implementation of the smart city [9].

In the implementation of smart cities, however, there is a further problem: the complexity of the structure of services. Therefore, this paper aims to develop a conceptual model that focuses on the systematic nature and interconnection of services and contexts involved. The paper begins with a literal background in which the different models of Smart Cities are discussed, then focuses on those proposed by Layered and Stanicek, identifying their components and the different levels of user perception depending on the context: smart features, smart services, supporting services, infrastructure services. This represents the foundations for the construction of a new conceptual model of the Smart City, as well as its value chain. In fact, in the second part of the paper a structure of the smart services in the context of ICT is developed that includes the consequences of the value chain in the Smart City, in which it can be seen that value is always created by services at all levels (infrastructure, support services, intelligent services and intelligent functions) and, for this model, two types of services are foreseen: service category and service package. Finally, the possibility of being able to help - even in a smart city system - the value chain is discussed.

2 State-of-the-art Research on Smart City Models

A smart city model is a combination of numerous complex solutions and multi-sector social groups with different characteristics, cultures, perceptions, perspectives, and languages. One of the significant challenges is to use one model language and to have a common understanding. If you ask ten professionals from Environment, Urban planning and Energy, "What is infrastructure?" you may get ten different answers, depending on their context, knowledge and perspective. Therefore, it is crucial to spread the correct understanding evenly, especially in a smart city. Usually the service catalogue can be used to narrow the gap between the user and the service provider and improve understanding. It will enhance knowledge between a user and a service provider and improve performance among all sectors in the smart city, stakeholders in each sector, and members of the service team.

A smart city has a comprehensive view of services and service systems. A clear structure of smart city services and their systems will improve the efficiency and effectiveness of all phases of a smart city. Also, it will improve the functioning of the smart city, systematically manage those services, improve the understanding of smart city services by stakeholders at all stages of the smart services, and improve communication and cooperation among them. The service structure highlights the role of these systems, the dependencies and interactions between them. It allows creating new systems and services that allow for the most efficient operation of smart cities and systems. Understanding the interconnections between these services and systems is critical for a smart city. It can lead to the highest efficiency and effectiveness by systematically managing these services and their systems and creating a clear structure.

A smart city is constructed by many complex services, and not everyone knows how these service systems are interconnected and interact with each other. Smart cities, governments, and consumers consider smart city services as separate systems that do not understand how these services are designed and delivered, and lack information about them. If we understand the interconnections and interdependence of these services, we may create different opportunities, from optimizing smart city operations to increasing efficiency and productivity. Understanding these interconnections of smart city services allows you to work more proactively and avoid different kinds of risks. For example, upgrading or shutting down a smart city system may affect all the systems and services associated with it, and knowing these links can help you connect and take action to prevent any risks in advance and keep the city running smoothly.

Managing smart city services is not just about managing customer-facing services. For example, municipalities and governments usually consider the visible customer-facing services as all the services of a smart city, and focus only on improving these services. However, the main services that enable these customer-facing services are background services. By managing the balance of management of these two types of services, it is possible to create more opportunities for smart city services to operate at full capacity. The type of smart city background service consists of a wide range of services, and understanding and managing these services requires a wide range of knowledge and skills. If city observers, industry experts, and city officials drew the structure of these services, they may all draw it differently, depending on their knowledge, education, and perspective, and they may all be right. Since it is not possible to combine those different perspectives and knowledge, we need a contextual view of those services. The new model of Smart City Service allows you to create structures depending on the context and help you see and manage the diversity of your services.

This paper is based on a previous literature review and evaluation of existing smart city models from [10]. These reviewed models were first sorted into two groups based on their characteristics, either conceptual or structural, and then evaluated with regard to four key features – service structure, interoperability, multicontextuality and adaptability. We will revisit two models with most relevant key features‘ fulfilment from each group, starting with the conceptual models.

Authors of [11] are proposing a model (Figure 1) that is to assist the smart city practitioners with facilitation of stakeholder relations and digital technologies, evaluating risks, funding needs and also on assisting with designing a long term Smart City strategy and vision. This model shows four primary dimensions - strategy, technology, governance and stakeholders. Each of these dimensions has its sub-elements and together they form meaningful interrelations. Moreover, they provide a comprehensive and systematic approach to smart city design, development and implementation. This model is not fulfilling any of the defined key features [10].

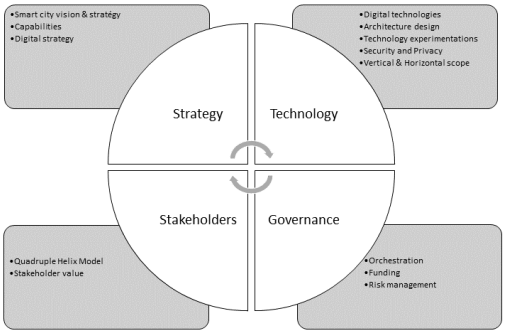

Figure 1. A conceptual model for the smart city design [11]

[12] introduces three identified issues of the smart city environment - the importance of governance/stakeholders' involvement, the necessity of showing a comprehensive vision of smart city projects, the required understanding of the smart city as a tool that can help with tackling the urban challenges. Authors then propose a model (Figure 2) based on the analysis of these issues - they are shown as interrelated parts. This model is partially fulfilling the key feature of interoperability between smart city elements and services [10].

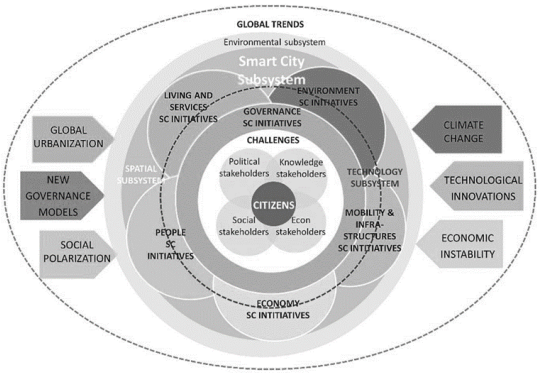

Figure 2. Smart city implementation and discourses: An integrated conceptual mode [12]

The model in Figure 3, the first model from the structural group, is based on the Internet of Things. The authors describe key supporting technologies of smart cities and build upon them the main framework of their smart city model. It is structured, showing a hierarchy

of four layers - distributed sensor layer, ubiquitous network layer, service-oriented middleware layer, and intelligent application layer [13]. This model fulfills the service structure key feature and partially also the interoperability of services [10].

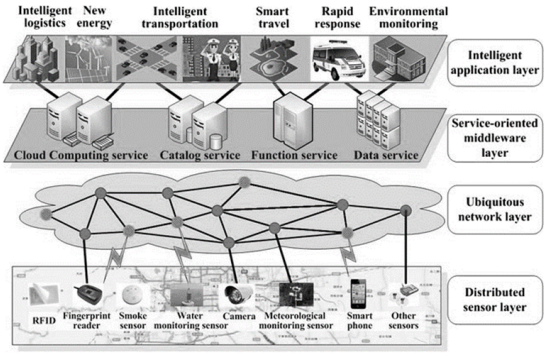

Figure 3. A framework of the smart city based on the Internet of Things [13]

The last model (Figure 4) is a structural Smart City model that focuses on the services in Smart city environment, their interconnectedness and structure. It proposes a view which in addition to connecting the services identifies common layers that they rely on as well. This helps with understanding the influence services have on their underlying infrastructure and IT services. [14] also emphasizes the role of citizens as stakeholders, and their involvement in the value creation process. The Layered model fulfills the key feature of service structure while simultaneously partially fulfilling the interoperability of services [10].

Results of the evaluation [10] show that none of the models is fulfilling all of the defined categories, and therefore, there is a need for such model. Moreover, the results suggest ways in which the reviewed models can be improved and work collaboratively, indicating how to design Smart City models in the future. Building on the results of [10], this paper will focus on one of the evaluated models with the most fulfilled evaluated key features, the Layer model [14]. We will apply the principles of Service Science and propose an innovative structure of Smart City Services by introducing a new conceptual model of Smart City.

3 Conceptual Model of Smart City

The development of the smart city model that can be adapted in most situations is a very challenging work. To suggest a model that will be suitable for most of the tasks and understandable for most of the stakeholders, the layered model [14], introduced in the previous section, can be used. However, we need to specify its usage context. First, we need to establish a specific aim of the model for IT infrastructure, where a smart city is dependent heavily on IT infrastructure. However, infrastructure may have further meanings. For example, if we interview a transportation expert, he or she would understand the infrastructure is somehow different such as the motor ways, areas for pedestrians, traffic lights, and all technologies that keep the transportation system running. For energy experts, the infrastructure may be

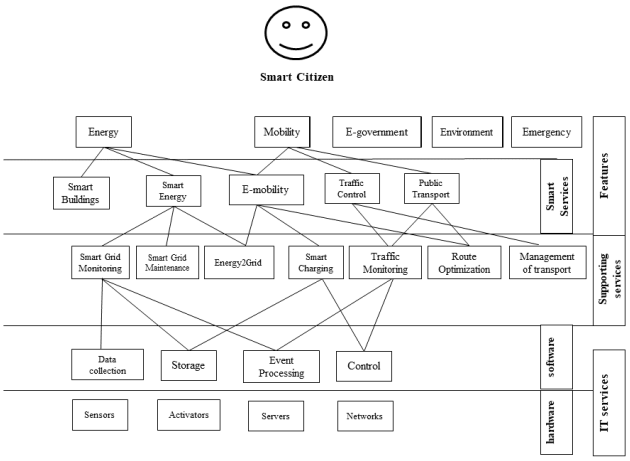

Figure 4. The structure of smart city layers [14]

represented by different devices that are related to the management of energy. This view has been analyzed in the 4 diamonds model, introduced by [15, 16], where a model is described as perception of selected Item by depending on the context. Therefore, we need to simplify the view - we are using four different layers in general:

- Smart features - that define the perception of Smart City for the end users such as citizens, companies, tourists, and other stakeholders.
- Smart services - that define the specific content of the feature, depending on particular circumstances in the municipality. Some municipalities will focus on carbon neutrality, some on other aspects of resilience, some on energy consumption, etc.
- Supporting services - services, provided by the municipality and/or private entities to support the provision of smart services. They are not primarily seen by the users, but without them, the provision of smart services would not be possible like pollution monitoring, payment systems, etc.
- Infrastructure services - they represent the basic services, enabling the exchange of data and information among other services. Their main feature is that they are not designed to be used by one or more particular services, but they are designed for common usage – IT infrastructure is designed for usage by different IT devices, transport infrastructure can be used by different kinds of transport services, etc.

This structure, more generally used, can be a good base for the new conceptual model of Smart City. We can observe it as a triangle mode shown in Figure 5. To develop the analysis, we use the ideas and approach of ITIL adaptation, elaborated in two master theses [17] [18]. We can consider the perception of the services by the end user of the service and also how this specific structure will be used by the experts from different domains such as transportation, energy, and mobility. The role of supporting and infrastructure services is irrelevant to the customer of the services. They are interested in the value, represented by smart features and smart services, and not in the complete value chain. It is usually the case that the customer is not an expert and is solving their own problems. Based on this, we can categorize smart feature and smart service as customer facing services.

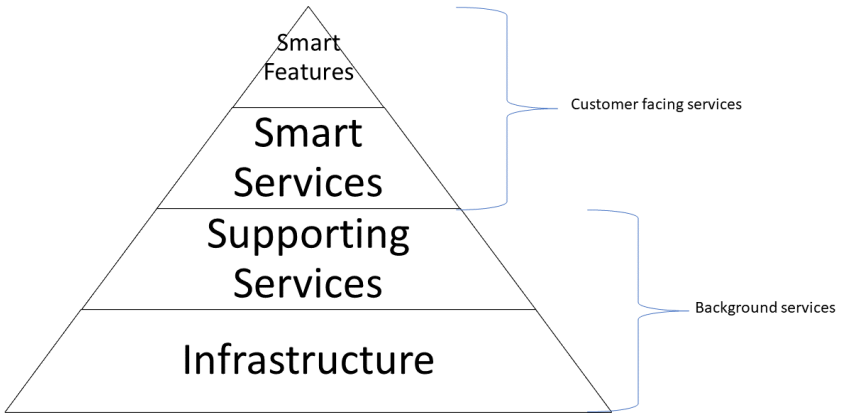

Figure 5. Structure of the Smart services. Source: author´s elaboration

The perspective of the two other layers, which are supporting services and infrastructure services, is different. First, they are not seen by the customer, they are in the background of the service value chain. It is termed as background services. Second, their perception and structure are strongly related to the view of an expert who is observing or defining them. It means that the same structure of smart features and smart services can be linked to more structures of supporting and infrastructure services, depending on the domain of the expert. Therefore, we can propose a new version of the layered model by reflecting the findings above. To create an advanced view, we need to define the general layer by using the position of an observer. It is a context in which one sees the structure of all the services. This reduces the previous layered model as just one possible version of our advanced model, focused on ICT context as shown in Figure 6.

The same structure can be presented quite differently from the perspective of Mobility context. It is because of the understanding of supporting the same structure of services, features, as well as the infrastructure. It depends on the perception of the particular expert. The proposed model works for both contexts. It can be used in every other context as well with one common feature to mention - the structure of Customer facing services is always the same, but the structure of Background services is changing based on the specific context. The main purpose of the model is to understand all the consequences of the value chain in the smart city. The value is created by the services from all levels in terms of infrastructure, supporting services, smart services, and smart features. To enable analyzing the service and its provision, one needs to take into consideration all connected services. Also, due to the inspiration from ITIL, we use the methodology adapted by [17]. There are two different groups of services that are defined.

- Service category, which is a group of services that belong to the same layer. A service category can categorize services from many different perspectives based on the context and they can be interconnected. For example, in terms of IT context, services on the Infrastructure layer can be categorized into servers, networks, database management systems, software, and hardware [17].

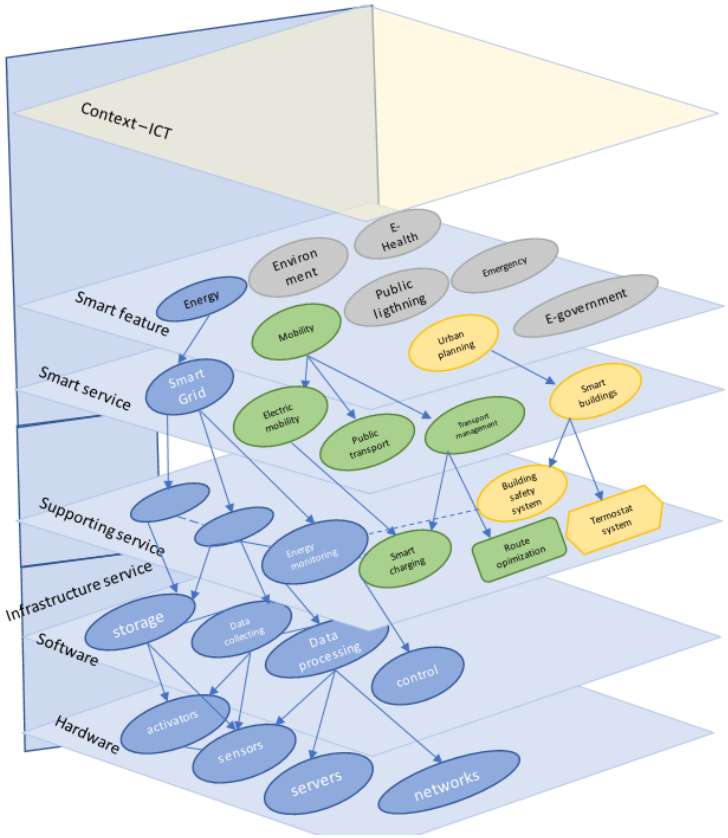

Figure 6. Structure of the smart services in the context of ICT

- Service package, which can be created by grouping services on several layers vertically. The service package contains more than one service and is distinguished by the above three types of services, and it is possible for more than one service from one type to belong to one package. The service package may also include another package of services, which will be introduced to the customer and delivered as a single service [17].

To have the possibility to group services into categories and packages also gives the researchers a unique possibility for better understanding the structure of service provision - where one package or category could serve more services in multiple ways - see Figure 7.

The content of background services in the value chain depends on the specific context that can be the view of the observer, expert, etc.. However, if we use a more holistic approach, we can see one **multi-contextual value chain**. It means that the value chain in one context can affect positively or negatively the value chain in another context. The effect of this interconnection, the possibilities of using it, and the influence on the value will be investigated. This model seems to be a universal modeling tool for the Smart City environment. There is no situation that could not be covered by this model, furthermore, it is easily adaptable for new (not yet known) situations and services. All previous relations and consequences can remain unchanged, the new situation can add new contexts, new services, and features.

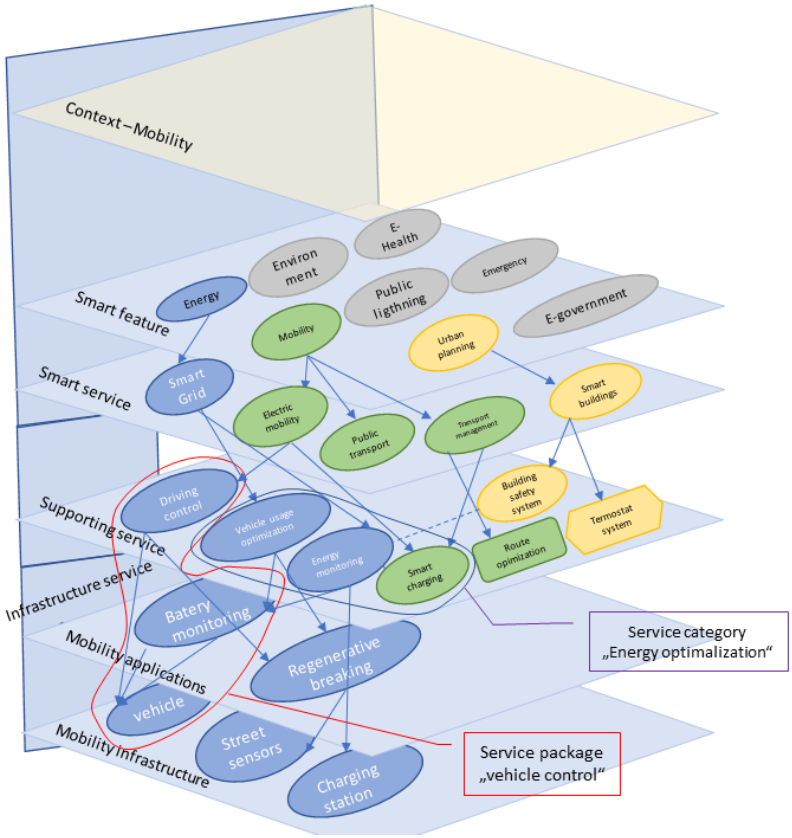

Figure 7. Service package and Service category examples

4 Discussion

Given the interconnectivity of the smart city models, a city is smart when investments in human/social capital and information technology infrastructure fuel long-term growth and improve the quality of life through participatory government. Because of the use of ICT to improve life and work inside a city in significant and fundamental ways, technology is vital in becoming a smart city. A smart city offers interoperable, internet-based government services that allow for ubiquitous connection to revolutionize essential government activities, both internally among departments and staff and externally to individuals and businesses. Affinity for lifelong learning, social and ethnic diversity, flexibility, inventiveness, cosmopolitanism or open-mindedness, and participation in public life are all elements of the intelligent people notion. Urban agglomeration problems can be tackled by innovation, human capital, collaboration among essential stakeholders, and innovative scientific concepts and "smart solutions." As a result, the term "smart city" refers to ingenious solutions devised by inventive people. Smart governance entails numerous stakeholders (particularly people) in decision-making and public and social services. Introducing residents to an intelligent city effort and making the decision and implementation process transparent, IT-mediated government, also known as e-governance, is critical to enabling smart cities. The central spirit of governance is a citizen-centric, citizen-driven approach.

5 Conclusion

In this paper, we have proposed a new conceptual model of a smart city that can be used to analyze the multi-contextual environment of smart services. It reflects the structure of the services, where some of the services are not seen by the end user such as citizens, tourists, business entities, or others. It also works with the fact that the value of the service can be affected by the change made in another context, for example, the value in the mobility context is affected by the efficiency of energy production in the Smart Grid.

We consider that this model can help analyzing not only the current smart services, but also the situation of the creation of new and innovative services, In this model, the service creation can be automatically part of the ecosystem, where the model is then guiding the designer to use a holistic approach to explore the consequences and not to focus on isolated solutions. In the proposed model, the approach where all services can be decomposed into four easy-to-understand layers, appears to be promising in practice. Importantly, all the relationships with the other services can be investigated by using the same methodology.

As future work, the practical usage of the model and the potential of its help new smart city services will be investigated in further research. It needs to be discussed not only in the service science but also with the service design practitioners and with detailed feedback.

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