Digital and Smart Services - The Application of Enterprise Architecture

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Abstract. The digitalization of public administration presents significant challenge for many municipalities. At the same time, many larger cities have well progressed towards applying Information and Communication Technologies (ICT) to develop modern urban spaces, commonly referred to as Smart Cities. Smart Cities are complex systems whereby ICT plays an essential role to address the needs of many stakeholders. Obviously public services are key for the development. However many municipalities and cities face challenges to transform and digitalize these services. Although single projects are often successful, the coordination and coherence of services, the consideration of many stakeholders together with strategic alignment is complex. The concept of Enterprise Architectures is seen in many organizations suitable to manage the complexity of heterogeneous systems and technologies. Therefore in this paper we extend our earlier work, and present key concepts for Enterprise Architecture Management in Smart Cities that can assist cities and municipalities to digitalize and transform public services. We particular focus on the alignment and connection related to the service layer in the Architectural Framework, and present key concepts related to this layer.

Keywords: Digitalization · Public services · Enterprise architecture Smart city · Service layer

1 Introduction

With the expected continuation of urbanization it has been estimated that the urban populations will increase by 84% to 6.3 billion by 2050 globally [1]. Commonly referred to as 'Smart City', major bases of recent urban planning include the implementation of information systems by adopting novel Information and Communication Technologies (ICT). Aiming to improve overall the quality of life, Smart Cities are described as innovative cities that are underpinned by advanced information technologies (IT). As a result, Smart Cities require the constant development of dynamic, advanced and novel services [2]. The importance of ICT has been emphasized in many publications, relating IT, processes and services and the associated business and information architectures. With a focus on various stakeholders [3], services are central in cities and municipalities. At the same time, the use of new and often disruptive ICT

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(i.e. data analytics, Blockchain, Internet of Things, Sensors, and Machine Learning, Artificial Intelligence etc.) in the public sector is growing and is expected to increase efficiency and effectiveness of the sector. Yet, the application and adoption of these new technologies is challenging and best practices, implementation paths and associated risks are largely unknown. Implementations and projects depend often on experience from other sectors. As a result, deploying these innovative technologies in the public sector requires a coherent and structured approach for the digitalization and transformation of public services.

On tool for assisting the digital transformation in the public sector might be Enterprise Architecture (EA). Numerous researchers describe concepts and frameworks for EA, and emphasize its benefits. EA frameworks, concept and modelling approaches aim to support efficiency gains while ensuring business innovation and strategic alignment. Indeed alignment of various views and aspects is one of the key drivers for EA approaches. Organizations may use EA frameworks to manage system complexity and align business and ICT resources within an enterprise.

Thus, we argue that EA may be suitable and beneficial to support the digital transformation in the public sector. Indeed, EA assists to consider, organize and describe the various elements, stakeholders' views, goals, considerations, factors and components and IT applications as well as constraints by facilitating the transformation and digitalization of public services. The benefits of applying EA approaches are – among others– increase in organizational stability and support of managing complexity. This helps to manage constant change in complex (organizational) systems, better strategic agility, and improved alignment with business, strategy and IT. EA is suitable to manage the complexity of large enterprises where multiple stakeholders and heterogeneous systems and technologies coexist and interact. In the sense of a blueprint of the enterprise, EA impacts opportunities, capabilities, qualities and services of a City.

In this paper, we build on our previous work on applying EA to Smart Environments, in which we have broaden the traditional EA view of multi-layered frameworks by incorporating the elements of context and services [3–6]. In our opinion, the wider view is essential to capture the various stakeholders' views as well as providing a description for services in Smart Cities. Guided by a design oriented research approach [7] and collaboration with Cities in Ireland, in this paper we identify key concepts and discuss the framework application. In this paper, a focus is given to the service layer and its relation to the information layer. This helps to structure a layered design, allowing the consideration of various views and strategic aspects in transforming and digitalizing public services.

The remainder of the paper is organized as follows: Section introduces the background in relation to EA and Smart Cities. Section 3 presents our main contribution, key concepts related to the Service Layer within our EA reference framework for Smart Cities. Section 4 discusses an application of the framework and Sect. 5 concludes the paper and proposes future directions for this work.

2 Enterprise Architecture in Smart City

Many definitions and constructs associated with Smart Cities exist. Due to the emphasis on ICT we follow the International Telecommunications Union definition of a Smart City as: “An innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects” [8]. Following this definition Smart Cities are characterized with a high level of innovation. Smart cities are underpinned by ICT solutions that help to increase efficiencies and improve service delivery in urban areas and thus overall to improve the quality of life of citizens. Smart Cities are also characterized by a high degree of complexity using many individual systems, involving many stakeholders and aiming to fulfil multiple aims and goals.

Smart Cities can be viewed as entities in form of enterprises, with organizational aspects, governance and innovation capabilities. Therefore, Smart Cities can be seen as enterprises with multi-layered and multidimensional issues [9]. How to integrate, plan, manage and maintain these various systems and aspects is yet an open challenge. At the same time, cities are rapidly moving to the adoption of ICT and thus transformation, digitalization and planning aspects are critical. The fundamental idea behind this scheme is that ICT is needed to build smart social and public systems, which help to achieve the goals within cities and help to improve urban life in a sustainable manner. However, many case studies show that Smart Cities and the digitalization of public services are difficult to realize.

EA assists in providing an integrated environment supporting continuous alignment of strategy, business and IT [10, 11]. Architectures may be defined as “the fundamental organization of a system embodied in its components, their relation-ships to each other, and to the environment, and the principles guiding its design and evolution” [12]. EA is viewed as an engineering approach to determine the required enterprise capabilities and subsequently designing organization structures, processes, services, information, and technologies to provide those capabilities [13]. Elements, views and layers of EA are specified in many publications. However, a common agreement concerning architecture layers, artefact types and dependencies has not been established yet, and there is ongoing discussion what constitute the essence of enterprise architecture [19]. [19] for example propose a hierarchical, multilevel system comprising aggregation hierarchies, architecture layers and views and interfacing requirements with other architecture models. The suggested approaches using a multi-layered architecture include for example [9, 14–17].

EA may help to address the complexity of Smart Cities [18]. Therefore, to manage complexity, many frameworks use the concept of views and layers to describe elements of architectural content. Core layers of EA models represent business architectures, application and information architectures, and technology architecture. General examples range from simple, three-layered frameworks to multi-layered EA frameworks [19, 20]. Each view illustrates a distinct perspective meaningful to specific stakeholder groups. Layering decomposes a system into distinct but interrelated components, key concerns and inter-related layers. Static relationships as well as behavioral aspects are considered in order to describe an architecture. For example, a technology layer supports an application layer which in turn provides application services to the business layer. The data flow and information exchange can be viewed as behavioral aspect of the system. With the concept of layers and views, EA assists to understand and manage the complexity of enterprises. However the complexity of Smart Cities with diverse interests and objectives from a range of stakeholders are hamper the use of EA concepts in this domain, although at the same time EA approaches are particular beneficial in such complex environments.

One example, the European project 'ESPRESSO', highlights the application of EA to Smart Cities. However, the use of EA concepts as overall approach to manage IT within Smart Cities and the wider public sector are still rare. The ESPRESSO project applies the Open Group Architecture Framework (TOGAF) as a foundation to describe a reference architecture for Smart Cities. Using a systems approach, the project focuses on the development of a conceptual Smart City Information Framework based on open standards. It consists of a Smart City platform and a set of data management services [14].

3 Key Concepts Related to the Service Layer

In our (earlier) work we have adopted the TOGAF architecture development method together with its modelling language Archimate [3–6]. This related work presents an initial version of a reference framework for designing and transforming smart services. The framework consists of four main layers, including: (1) contextual layer, (2) service layer, (3) information layer, and (4) technology layer. An example for layers 2–4 in Archimate is presented in Fig. 1. The approach helps to address the complexities associated with service systems in the public sector. It can be used to highlight open challenges of developing enterprise architecture in Smart Cities and to guide future work.

3.1 Extracting Architectural Concepts

The TOGAF content metamodel structures architectural information in an ordered way to meet stakeholder needs. Due to its definition of architectural concepts to support consistency, completeness, traceability, and relationship of components and layers [23], this study uses the TOGAF content metamodel as foundation. The metamodel is represented in the core content which contains the fundamental elements and the extension content which represents elements that enrich the core metamodel [22]. Table 1 presents the entities and the relationships extracted from [23], to connect the business architecture and the information systems architecture (data and application architectures) within the core and extension content. The definition of these entities is used by TOGAF as the basis for designing the content metamodel [23].

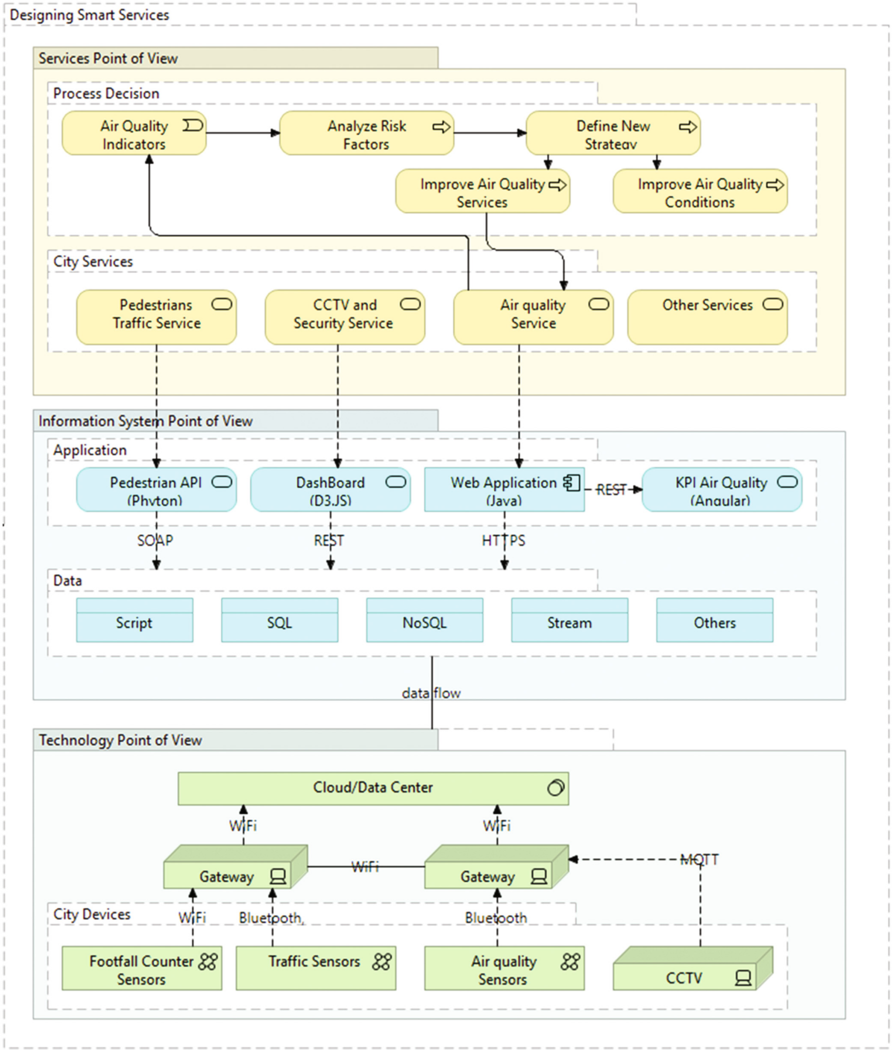

Fig. 1. Layered architecture

Table 1. Metamodel relationships, extracted from [23]

Source entity	Target entity	Name
Actor	Data entity	Supplies/Consumes
Business service	Data entity	Provides/Consumes
Business service	Information system service	Is realized through

These entities constitute a set of justifications regarding the architecture and they can be used as starting points for maintaining traceability links [22]. This paper analyses this list of concepts in Smart City contexts as a foundation for designing an effective Smart City reference architecture. We have identified the following four key concepts most relevant to the service layer:

- **Stakeholder.** A stakeholder typically relates to related group or organization unit that have similar interest in a particular matter [16]. Comerio et al. [24] define a procedural path for the life-cycle of the planning, design, production, sale, use, management and monitoring of services. They view this from the point of view of three main actors: the planner (e.g. Public administrator), the service provider (e.g. public administrator or private broker), and the consumer of the service (e.g. citizens, communities, retailers, etc.).
  Example. A citizen who changes the address may be interested in requesting several services, such as facilities for the use of public transport in the new municipality; the transfer of the telephone number into the new building; updating insurance policy contracts [24].
- **Smart Service.** Many researchers have stated, that one of the goal of utilizing ICT is to improve existing city services by digitizing these and thus making them more efficient, more user-friendly and, in general, more citizen-centric [25]. Therefore, Smart Services support the city, usually by using ICT to facilitate and optimize intelligent decision making. Smart Services can be described as Services that are used by and provide direct value to various stakeholders in a city by the use of ICT. The consideration of various stakeholders' concerns is important.
  Example. The noise-monitoring service of a city measures the amount of noise at any given hour in various places of interest. The service meets the concerns of the authorities and citizens regarding the safety of the city at night and the reliability of public establishment owners [26].
- **Information Service.** In order to include 'smartness' into a city, and to maintain interoperability among different systems [27], integration of various information services across different city domains (e.g. education, environment, energy, health, tourism, transportation, etc.) is required. [28] examine three types of information services: computational, adaptive, networking and collaborative processing capabilities. These types are mainly oriented on information exchange. In contrast, in [5] we have described various types of EA Services based on a lifecycle approach.
  Example. A smart parking service is provided to visitors of the mall. This service aims to help visitors find parking space near to their desired entrance. The smart service is supported by an information service which offers following example operations: Read Plate Number, Get User Profile, Allocate Parking Spot (based on disability and nearest entrance), Update Registry, Inform User (on his smartphone) [29].
- **Data Entity.** Data in various formats exists and are valuable in Smart Cities, and as such require particular attention. Therefore, data entities need to be governed, managed and maintained. Organizational concepts with clear responsibilities and processes as well as data ownerships and access rights are important. The

identification of data entities facilitates the inter-change and operation of data, providing the application developers with the opportunity to design services efficiently [30].

Example. A footfall-counter sensor is installed in the city center. A service provider provides a data entity of the service with attributes such as zone name, sensor name, sensor type, site name, location name, registration date, the number of entries and exits. An Application Programming Interface (API) is developed based on these parameters and offered to the citizens. The city council defines the data entities regarding the location or end-point of the service in the network, to find and consume the service when necessary. An analysis of the collected data is used for making decisions about the performance of pedestrian mobility, the assessment of tourism strategies and the future planning of city environments.

4 Discussion

In the following, we present a conceptual example of a layered enterprise architecture as the first indication of the utility of the proposed architectural concepts and reference framework.

Conceptual Example

Figure 2 depicts a model representation of the architectural concepts and relationships among the service layer and information layer using Archimate. One of the most important layers is the Service Design and Architectural vision, in which several stakeholder views across various domains converge. This is analogous to a political layer, wherein various interests and constraints are balanced to define a suitable value proposition for the enterprise. The business oriented layer of EA concerns business processes and services and relates to organizational structures (including roles and responsibilities). This layer is closely related with value drivers that should be aligned to the business strategy and business models [31]. Following the classification presented in [32], in Table 2 we outline some examples services related to the business layer for the domains transport and health.

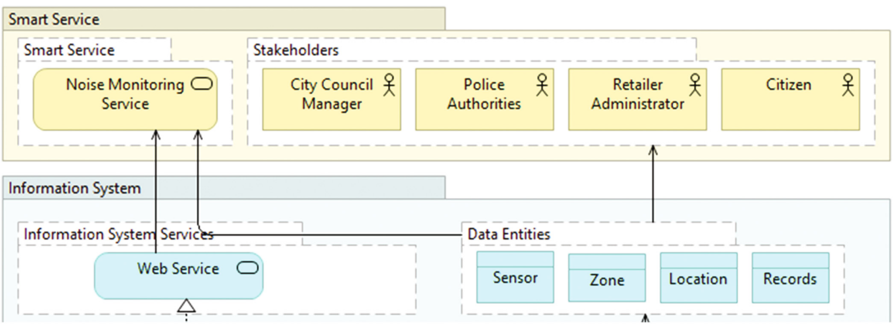

Fig. 2. Key concepts on service and information layer

Table 2. Examples in Traffic and Health, extracted from [5]

	Domain traffic	Domain health
Information services	Traffic flow; Environment Information; *Noise Monitoring Service*	Hospital Indicators
Interactive and Planning services	Pedestrian Flow for Infrastructure Planning	Capacity Planning for Emergency Services
Transaction services	Motor Tax and road charges	Prescription and Referrals

The selected *'noise monitoring service'* represents an example smart service which addresses concerns regarding the safety of the city. This service uses a web service to provide data about the amount of noise produced in various places of interest. The data is used by different stakeholders such as city council managers, police authorities, retailer administrators and citizens. The noise information service are represented by data entities such sensor, zone, location, and records. All the data collected by external services may be integrated via some API (i.e. such as REST). The relationships between smart service layer and information layer provide a way to connect the different architectural components resulting in coherent and integrated architecture to guide the design of Smart City services.

Overall Positioning of Contribution and Related Work

Smart Cities result in increased complexity resulting from connecting various, often heterogeneous systems to deliver advanced services. Many researches have proposed ways to address the complexity issues. In the follow, some selected existing architectures and frameworks are discussed in order to contrast those with our work.

Some research focus on *development methodologies*, such as in [34] presented. [34] propose a development methodology of a sample digital city, which can act as a general implementation model. The methodology includes multiple considerations and the investigation of parameters that influence a digital environment. [27] elaborated critical success factors in smart cities including, administration requirements, security (sensor security, transmission security, data vitalization security and application security), and standards. In [33] a Smart City infrastructure architecture development framework is proposed.

Many authors propose a range of *architectures and frameworks*, often open and modular following a service oriented concepts. These architectures facilitate interoperability and sharing of data as well as its management. [36] developed an integrative framework to explain the relationships and influences between 8 critical factors of Smart City initiatives. [9] present a common enterprise architecture for a digital city. [39] describe a framework which described foundation and principles for IT in Smart Cities. [35] propose a high level architecture for Smart Cities based on a hierarchical model of data storage. [37] propose an open service architecture that allows a flexible interaction, collaboration, integration, and participation, whereas [33] describes a modular structure for architectures. [15] describe a conceptual architecture for Smart City sensors interconnection with the organization, and interconnection between organizations. [27] propose a Smart City architecture from the perspective of data that underpins functionality of Smart Cities. [38] present an Event Driven Architecture that allows the management and cooperation of heterogeneous sensors for monitoring public spaces as a solution architecture.

Table 3. Overview of selected smart city architecture frameworks (Own source)

	Service	Info	IT
Open service architecture [37]	–	✓	–
Multi-tier architecture of digital city [9]	✓	✓	✓
Smart city Unites [33]	–	–	✓
A high level Smart City architecture [38]	✓	–	–
Hierarchical Model of interconnection [39]	–	–	✓
Smart City initiative framework [36]	–	–	–
Conceptual Architectural framework [15]	–	–	✓
Smart city architecture [27]	–	–	–
Service oriented architecture [35]	–	✓	✓

In Table 3 we present an overview of selected architectures and frameworks, highlighting the important architectural layers. Each of the examined architectures has their own perspective to address complexity issues. Relative few approaches address the interrelation between layers and in particular the relation to strategy and stakeholder views. Although some of the architectures have considered stakeholders as one of the architectural components, none of the selected frameworks examine or detail relationships between layers. In particular the incorporation of stakeholders concerns into the service layer is lacking.

5 Conclusion and Further Research

Smart Cities are complex systems that typically operate in a dynamic and uncertain environment. EA is suitable to manage the complexity of Smart Cities [14, 18]. A relative small number of existing EA developed for Smart Cities describe different components and layers. However, they mostly are derived from experience in the corporate and profit oriented sector, with limited consideration of specifics of the public sector. They often fall short in investigating specific architectural concepts and their relationships between different layers. Furthermore continuous strategic alignment in the public sector is challenging. This results in Smart City systems that often fail or do not provide desired level of services and innovativeness.

In order to address this problem, this paper provides a list of key concepts as references to assist the design and digitalization of Smart Services. The paper builds on a reference framework together with a first example for utilizing this framework within the context of Smart Cities. Our work allowed us to understand the wider challenges in developing EA in Smart Cities. Smart Cities should ensure that goals and objectives trace to services. Cities have many broad initiatives in different domains such as mobility, environment, sustainability, etc., and thus we believe the presented architecture reference framework can assist cities in this challenge.

Considering the challenges faced with the digitalization of public services, as part of the future work we need to identify other concepts, elements and relationships that should be considered between smart service layer and other architectural layers. We aim to continue with the evaluation of the proposed approach for its improvement and refinement. Future research will investigate the templates for Smart Service description as well as a deeper understanding of inter-layer relations. This will allow the design of coherent and integrated architectures in Smart Cities. It can help Smart City initiatives to design and offer desired services, and assist the digitalization and transformation of public services.

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