Cities as Enterprises: A comparison of Smart City Frameworks based on Enterprise Architecture requirements

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Abstract. There is a significant challenge in the smart cities implementation because it is not straightforward to align the smart city strategy with the impact on the life of quality. Stakeholders' concerns are multiple and diverse, and there are a high interdependency and heterogeneity of technologies and solutions. To tackle this challenge, cities can be understood as enterprises. Enterprise Architecture (EA) approach can be applied to support its development and transformation. This approach specifies core requirements on business, information, and technology domains, which are essential to model architecture components and to establish relations between these domains. Existing smart cities frameworks describe different components and domains. However, the main domain requirements and the relations between them are still missing. This paper identifies essential requirements of enterprise architecture in smart cities. These requirements will be used to review and compare current smart city frameworks.

Keywords: Enterprise Architecture, Requirement, Smart City Framework

1 Introduction

A smart city is an ultra-modern urban area that addresses the needs of businesses, institutions, and citizens [1]. The smart city implementation assumes applying the city strategy into an effective improvement of life quality for the citizens. This is a complex task because it involves different sectors, multiple stakeholders, high interdependency, cross-sectoral cooperation, inter-departmental coordination, and novel, dynamic, and interactive services [2]. Smart city should be composed by a well-constructed business plan [3], and a design of information and technology infrastructure to provide a platform for services integration. Industry and academy have proposed several frameworks to describe smart cities architectures in response to this complexity.

These smart city frameworks all specify different layers of the architecture but it is often difficult to see a clear connection between these layers and the alignment with the smart city strategy. Some of these frameworks focus on city goals, objectives and indicators whereas others emphasize on solution architectures and technical details.

Enterprise architecture (EA) is the process of translating business vision and strategy into an effective enterprise change by creating, communicating and improving the key requirements, principles and models that describe the enterprise's future state and enable its evolution [4]. The benefits of applying EA are visible in increased stability of an enterprise in an environment of constant change, better strategic agility, and improved alignment with business strategy. If a smart city is modelled as an urban enterprise [5], enterprise architecture approach can support its development and transformation based on the city strategic plan.

The Open Group Framework Architecture (TOGAF) specifies a detailed method for developing EA. This framework is based on interrelated areas of specialization called architecture domains: business architecture, information system architecture and technology architecture [6]. TOGAF specifies that the output of the previous domain is the input for the next one and it highlights that the relevance of each solution should be a result of the design and development of these architecture domains [6]. These domains have core requirements which are defined as entities in the TOGAF content metamodel. The content metamodel defines these architectural concepts to support consistency, completeness, traceability and relationship of components and layers in the enterprise architecture [7].

Implementing a smart city initiative does not only mean to reach technological success. It requires to articulate smart projects to specific initiative, such as: to deliver high quality e-services and to achieve outcomes desirable for the citizens [8]. This paper proposes to view a city as an urban enterprise to achieve alignment between strategy and smart city services solutions and to support its development and transformation. In this regard, we aim to identify essential requirements of enterprise architecture in smart cities. These requirements will be used to review and compare current smart city frameworks.

This paper is structured as follows: section 2 presents our research approach followed by the review of the content metamodel. Next, we inspect smart city frameworks to select the ones which proposed a more completed definition. Thereafter, selected types of architectures will be compared regarding core requirements. Finally, we discuss on the completeness of smart city frameworks in relation to EA core requirements.

2 Research Approach

In this paper, core requirements of The Open Group Architecture Framework (TOGAF), are used to examine selected smart city frameworks. The content metamodel of TOGAF is reviewed to extract core architectural requirements for the business, information and technology domains. Next, the smart city frameworks are se-

lected. This selection is based on the major detail of description, number and type of layers. Then, the core requirements for each EA domain are mapped to the smart city frameworks. Finally, a discussion of the findings is defined in section 6.

3 Enterprise Architecture Core Requirements

Enterprise architecture serves as a valuable instrument to guide the enterprise through the transformation from a current to a future state [9]. The scope of the enterprise architecture includes the people, processes, information and technology of the enterprise, and their relationships to one another [4]. The Open Group Architecture Framework document specifies a detailed method and a set of supporting tools for developing Enterprise Architecture and authors have chosen TOGAF as an example of the standard that combines business and technical threads [7].

TOGAF defines three architecture domains: business architecture, information systems architecture and technology architecture [6]. Business architecture describes the strategy plan of the services offered and structure, functions, resources and process involved. Information system architecture supports the information of business architecture and the concerns of the stakeholders. It includes the development of data and application architectures. Data architecture describes how data is collected, stored, arranged, integrated, used and governed in different data systems. Application architecture describes the set of applications, the interaction between them and the relation with the core business process. Technology architecture describes the hardware, software and network infrastructure required to support the implementation of data and applications.

These architecture domains have core requirements which are defined as entities in the TOGAF content metamodel. The TOGAF content metamodel introduces the relevant concepts of the architecture represented in entities and key relationships that support architectural traceability [7]. These entities incorporate most of the enterprise architecture components and the content metamodel shows the relations between them. Enterprise Architecture claims to align and integrate strategy, people, business and technology and for that reason, these relations are fundamental in an EA framework.

This paper focuses on these entities viewed as core requirements in the architecture domains as defined in Table 1. The core requirements in the right column are described as follows:

- Smart city initiatives are based on a set of goals. For this reason, goals are selected as a core requirement.
- Business processes are the operational activities that provide, produce and deliver its business services. It is important to analyse the existence of the business process within the smart city context.
- Application portfolio and interface cataloge represent an encapsulation of application functionality aligned to implementation structure and the interfaces between smart city services respectively.

- Data entities define which data are being used by the business functions, processes, and smart services in the city. They can further model citizens, employees, innovators and visitors.
- The Technology standards document the agreed standards for technology across the smart cities, such as ubiquitous computing, big data, cloud computing, service-oriented architecture, IoT and the smart city technologies related.

Table 1. Enterprise architecture core requirements present within the Core Content Metamodel [6].

Enterprise architecture domain		**Core Requirements (Entities TOGAF content metamodel)**
Business architecture	Definition of business including strategy, structure and process.	Goal
		Business process
		Organization unit
		Business services
Information system architecture	Data architecture, representation of all data systems.	Data entity
	Application architecture, set of applications and their interfaces.	Application portfolio
		Interface catalog
Technology architecture	The software and hardware infrastructure required to support the deployment of system components.	Technology standards

4 Selecting Smart City Frameworks

A smart city framework enables cities to constitute a standard and a guide for an implementation and management of smart city services [10]. This literature review includes research that describe frameworks for smart cities in a conceptual and architectural fashion. The criteria for selection encompasses the presence of at least three specific layers or domains, the detail of layers' description, and the existence of some business components in the frameworks. In the next section, five frameworks for smart cities are reviewed.

4.1 Review of Smart City Frameworks

This section provides a high-level comparison and analysis of five smart city frameworks. The review is based on the concept-centric approach for literature reviews [11]. Table 2 compiles and synthesizes how each research work meets core requirements from an EA point of view.

Cisco provides a conceptual Smart City Framework [12] that enables stakeholders to thrust and test smart city initiatives. The framework has four layers which consider the city´s objectives in social, environmental and economic terms; city indicators to measure and benchmark cities using predefined methodologies; city components related to city´s physical locations; and city content to encompass how smart city solutions are implemented. The Cisco smart city framework emphasizes the relationship among five key stakeholders: policy, regulators, developers, owners and operators. This framework presents a high-level overview of city objectives and their connection with city indicators. The city content layer deals with the development and implementation of smart city solutions. This layer is connected to city components and objectives. However, this framework does not address layers and connections between data, application, and technology.

The Framework for Smart City Applications Based on Participatory Sensing [13] is constructed upon XMPP (Extensible Messaging and Presence Protocol) for mobile participatory sensing based on smart city applications. This framework proposes layers for mobility prediction: the streaming framework, persistence components and custom analytics. This framework enables service innovation, and the emerging popularity of crowd-sensing for data collection. Three roles are defined such as producers, service providers, and consumers which interact among them using an event based publish-subscribe mechanism. This framework also provides a value chain which presents details of the data collection and the interaction between the roles. However, this framework does not address completely the business layer with the specification of smart city goals, processes and business services.

A Conceptual Enterprise Architecture Framework for Smart Cities [14] is proposed based on relevant quality properties of smart cities. This framework examines the current state in business aspects in relation to the IT support for smart city projects. It provides a justification through quality attributes using the layered approach rather than concentrating on specific types of services that may differ from city to city. This framework for smart cities includes a business logical layer with diverse public or private services. The application layer uses the messaging pattern to gather data from different applications and interfaces. The proposed framework makes suggestions for the business aspects, however, it focuses only on the application layer of the smart city.

A framework for the realization of smart cities through the Internet of Things (IoT) [15] is presented as an urban information system, from the sensor level and networking support structure. This framework proposes an IoT infrastructure from three different domains: network-centric IoT for communication, cloud-centric IoT for management, and data-centric IoT for computation. This information framework involves networking modules and their connection with the communication stack (i.e. application, transport, network, MAC and physical layer). The data is interpreted, managed, processed and collected by the application layer. The integration is supported by data management and cloud-based integration. Even though this research presents a framework to model cost based on supply and demand, there are no additional details about components of the business layer such as goals, processes, organization units or business services.

A Community Architecture Framework for Smart Cities [16] is presented to tackle the complexity that represents the management of multiple stakeholders, their interrelationships and the conflict of interest resolution. Goals of each stakeholder, planner, public and developer are considered. This framework is used to develop a tool to support developers, planners, and communities to participate in the planning of their cities by proposing innovative ideas for their areas of interest. The research work is based on the Zachman framework [17]. The community architecture framework consists of data, function, network, organization, schedule and strategy components. The connection between these components is represented through different artifacts and models. However, the details of these artifacts or models are not present.

Table 2. Smart City Frameworks and EA Core Requirements

Core Requirements	**Business architecture**				**Data architecture**	**Application architecture**		**Technology architecture**
References	Goal	Business process	Organization unit	Business services	Data entity	Application portfolio	Interface catalog	Technology standards
Cisco Smart city framework: a systematic process for enabling smart + connected communities. [12]	X		X					
Framework for smart city applications based on participatory sensing. [13]			X		X	X		X
A conceptual enterprise architecture framework for smart cities: A survey based approach. [14]						X	X	
An Information Framework for Creating a Smart City Through Internet of Things. [15]					X	X	X	X
A Community Architecture Framework for Smart Cities. Citizen's Right to Digit City. [16]	X		X			X		X

Table 2. Indicates that few frameworks are just concentrated on the business layer (goals, objectives and city indicators). The majority are focused on data, application and technology layers (i.e. solution architecture and technical details). Next section presents a discussion of the findings which are related to the completeness of the smart city frameworks and the existence of a clear connection between different layers.

5 Discussion

The review allows to identify that various conceptual frameworks deal with smart city goals. However, they do not provide a deeper insight on data, application, and technology aspects. Some architectural frameworks comprise of stakeholders (i.e. organizational unit), data, application, and technical requirements. But, the relationship between different domains of the evaluated frameworks is still absent.

The evaluated frameworks are focused on smart city services and they do not consider the existence of business services. The last evaluated framework mentions community processes but there is not a major detail about these architectural components. The rest of the evaluated frameworks, do not take the business process into account. It is important to analyze in future works the relevance of business process within smart cities because of the relation with smart services.

Smart cities require linking smart projects with specific initiatives, such as: to deliver high-quality e-services, to achieve outcomes seen as desirable by the citizens and to increase trust in public institutions [8]. The lack of business plans in many cases, as well as the existence of a multitude of potential business goals, imply that these projects can be considered at the time as an umbrella under which many different applications coexist and can grow in many different directions in the future [14]. However, some evaluated frameworks do not involve a strategic plan based on goals.

This paper proposes to view a city as an urban enterprise to achieve alignment between strategy and smart city services. The smart city implementation requires applying the city strategy into an effective improvement of life quality for the citizens. The impact of this approach is indicated in Table 3.

Table 3. Research Proposal and Impact in Life Quality

Research Proposal	Impact
Achieving alignment between smart city strategy and services.	Delivering high-quality services connected to real needs of citizens.
	Offering better and more convenient services for citizens.
	Understanding service requirements to deliver desirable outcomes.
Connecting smart city solutions and initiatives (i.e. education, health, transportation, environment initiatives, etc.)	Supporting development and transformation of sustainable cities.
	Delivering benefits to citizens to improve their life quality.

6 Conclusions and further Research

Many cities are experiencing exponential growth as people move from rural areas looking for better jobs and services. Consequently, cities' services and infrastructures are being stretched to their limits in terms of scalability, environment, and security as they adapt to support this population growth [1]. There is a significant challenge in the implementation of Smart City Transformation. Understanding cities as enterprises, we can apply Enterprise Architecture [18]. This approach can support the development and transformation of Smart Cities based on the strategic plan of the city and the needs of the citizens. Enterprise Architecture can help to establish the current and the desired state of the city.

Existing smart cities frameworks describe different components and domains. This paper identifies essential requirements of enterprise architecture in smart cities. These requirements are used to review and compare current smart city frameworks. The obtained results indicate that few smart city frameworks are concentrated in the business layer and the majority are focused on data, application, and technology architecture; and there is no a clear connection between these domains. These frameworks have their own advantages in terms of addressing smart cities challenges, however, this comparison does not include technical issues or technical details to indicate possible success or failure of these frameworks.

As further steps for this research, it is important to define the connection between layers in an Urban IT Reference Architecture and to define use cases in real scenarios to validate this approach. Moreover, smart city frameworks can be explored based on different EA domains and the TOGAF metamodel.

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