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ABSTRACT

Smart cities construction has been a global focus during the past ten years. It contributes to the achievement of the sustainability development goals (for economy, society, and environment) by leveraging information and communication technologies (ICTs). International organizations (such as ISO, IEC, and ITU-T) have developed standards to encapsulate precise and state-of-the-art knowledge regarding research, practice and policy. However, thousands of such standards have not been fully used due to the lack of generally agreed vocabularies or frameworks. In this article, a conceptual framework named 'ALL' is proposed. Some initial evaluations on the proposed framework have been performed. The result shows that the framework could help people observe, organize and use such standards more efficiently. Some preliminary conversations with governments prove the potential usefulness of the framework in practice.

Keywords: Conceptual framework, smart cities, international standards.

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INTRODUCTION

More than half of the world's population lives in cities (DIVISION, 2018). And it is predicted that by 2050, the world population will reach nearly 10 billion (Goals, 2017). Cities are facing unprecedented challenges. Cities need to produce wealth and innovation. Cities need to be capable of integrating people with different social and culture backgrounds. Cities also need to be green, safe, and sustainable. Authors of (Barber, 2013) argued that city government is crucial to solving many global problems, and stated "mayors rule the world".

Debates about the future of urban development have been increasingly influenced by discussions of smart cities (Hollands, 2008). In order to ensure prosperity, end poverty and protect the planet for all, cities need to be smart to pursue sustainability in economy, society and environment. The idea that Information and Communication Technologies (ICTs) are central to the operation of future cities is widely agreed (Aurigi, 2005). However, IT itself cannot automatically transform and improve cities. Rather, smart cities must start with people and human capital equation (Eger, 2000). Smart city seeks to balance economic growth with sustainability. In addition, it needs to create a shift in the balance of power between the use of IT by government, communities, business, and ordinary people who live in cities (Amin, Massey, & Thrift, 2000). Correspondingly, making a city "smart" is emerging as a strategy to mitigate the problems generated by the urban population growth and rapid urbanization. An increasing number of international examples have emerged from across the world. For instance, China has become the keenest country in the world on smart city projects development. There are 500 smart city projects which are far more than those in Europe (90 which ranked second in the world) (Deloitte, 2018). During this process, smart cities have attracted an extensive and increasing interest in both science community and industry.

Meanwhile, some international non-profit organizations have contributed to this global effort by developing a large number of standards (Trivedi, 2016). Such standards encapsulate "an agreed way of doing something, written down as a set of precise criteria so that they can be used as rules, guidelines, or definitions"(BSI, 2018a). These standards could provide state-of-the-art knowledge regarding the interface between research, practice and policy (Joss, Cook, & Dayot, 2017). Usually, these standards are developed by groups of experts which are called as Technical Committees (TC) (ISO, 2018a). TCs are made up of representatives from industry, non-governmental organizations, governments and other stakeholders who are put forward by members in the organization. Usually, each TC deals with a different subject, such as energy management, water quality or intelligent transport systems. For example, ISO/TC 268, the technical committee for Sustainable Cities and Communities, is made up of city and standardization experts from more than 50 countries around the world. It is responsible for the ISO 37100 series of standards to help cities define their sustainability objectives and put strategies in place to achieve them. Among all the standards regarding smart cities, the BSI (British Standards Institution) smart city standard was the first such specification worldwide. It has served as a template for the development of other international standards regarding smart city by the International Organization for

Standardization (ISO, 2018b). Other international organizations that have developed such standards are like IEC (IEC, 2015), ITU-T (ITU-T, 2018), and ISO/IEC JTC1 (Joint Technical Committee 1).

Despite the importance of such international standards, they have some limitations. For instance, although such standards are inevitable to ensure the interoperability of technologies and transfer best practices, present standards have not fully achieved the requirements for technology integration. Standard bodies still operate in sectorial parallel silos, developing standards which are not quite easy to understand for non-specialists, city managers for instance. In addition, the development of standards has not been fully coordinated. There are overlaps and conflicts among standards that are developed in different sectors. As a result, many valuable standards have not been used widely and efficiently in practice. It is difficult for service vendors to find the correct standard set to ensure the success of their projects (IEC, 2015). Experts advocate general frameworks and vocabularies for understanding and communicating with such standards.

In this article, we propose a framework to organize standards regarding smart cities. Based on the framework, some initial review and evaluation have been performed. The remainder of this article is organized as below. Section 2 presents some theoretical backgrounds and introduction to main international organizations. Section 3 proposes the conceptual framework named 'ALL'. Section 4 presents some initial review results based on the framework. Some related work is introduced in Section 5. And in Section 6, we conclude the article and point out some future work.

LITERATURE REVIEW

The literature related to this research is discussed in this section.

Smart City

Although the concept of smart city has been gaining attentions around the world, there is still not a clear and consistent understanding of the concept among practitioners and academia. Smart city has been defined in different ways. In a simplistic explanation, a smart city is a place where traditional networks and services are made more flexible, efficient, and sustainable with the use of information, digital and telecommunication technologies, to improve its operations for the benefit of its inhabitants (Mohanty, Choppali, & Kougianos, 2016).

(Giffinger, Fertner, Kramar, & Meijers, 2007) defined smart city as "A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens". (Harrison et al., 2010) defined smart city as a city "connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city". (Washburn et al., 2009) defined smart city as "the use of Smart Computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient". (Toppeta, 2010) defined smart city as A city "combining ICT and Web 2.0 technology with other organizational, design and planning efforts to de- materialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability". Based on the exploration of literature on smart city from various disciplinary areas, (Chourabi et al., 2012) proposed an integrative framework that can be used to examine how local governments are envisioning smart city initiatives. The following eight critical factors have been identified in the framework: management and organization, technology, governance, policy context, people and communities, economy, built infrastructure, and natural environment.

International Standards

The main focus of smart city seemed to be on the role of ICT infrastructure. However, Smart cities have lately not been limited to ICT, but and are focused on enhancing urban life regarding six dimensions: people, government, economy, mobility, environment and living (Anthopoulos, 2015).

The European Union has devoted constant efforts to working on different strategies and standards for achieving urban growth in a "smart" way for its metropolitan areas (Caragliu, Del Bo, & Nijkamp, 2011). As we look at the complexities of many different systems that make up the infrastructure of our smart cities, it is apparent that technology standards play an important role in the context of building smart cities (Trivedi, 2016). Moreover, there are no clear standard approaches to deal with different ideas and solutions of smart city.

It is believed that standards play an important role in the development and construction of the smart city. Standards are able to provide requirements for monitoring various aspects involved with developing and constructing smart cities. For instance, standards can also help address security issues with smart transportation. Standards take into account various factors such as business practices and resource management, while helping to monitor the performance of building smart cities (Mohanty et al., 2016).

Since there is no clear smart city approach yet, there have been several attempts by international organizations to standardize smart city solutions, such as for smart water, energy, transportation, buildings etc. for instance, International Standards Organization (ISO, 2014) proposed a standard for city services and quality of life, as a means to measure smart city sustainable development. These ISO models are able to capture a large number of aspects, including Economy, Education, Energy, Environment, Finance, Fire and Emergency Response, urban planning, and so on.

International Standards Organization (ISO)
ISO is an independent and non-governmental international organization. ISO makes international standards and provides a platform for developing practical tools through common understanding and cooperation with stakeholders. ISO standards are developed by groups of experts within Technical Committees (TCs). The TC of Sustainable cities and communities (ISO/TC 268), is made up of experts from more than 50 countries around the world. It is responsible for the ISO 37100 series of standards. These standards provide a framework to define what being smart means for cities and how cities can get there. For example, ISO 37101, in which the basic requirements for sustainable communities are set out, can help cities determine their sustainability objectives and put in place a strategy to achieve them. In addition, these standards also develop specific standards for various needs that are important to cities such as energy management systems, road safety, intelligent transportation, responsible water consumption, health and well-being, cyber security, connectivity and more.

International Electrotechnical Commission (IEC)
Founded in 1906, IEC is one of three global sister organizations (IEC, ISO, ITU) that develop International Standards. IEC prepares and publishes International Standards for all electrical, electronic and related technologies which are known collectively as "electrotechnology". IEC has a specific role to play in the development of smart city standards. This is because cities are giant systems with countless subsystems, while all of them depend on electric power and hardware to move people and things, collect data and exchange information. Because electricity and electronics are an integral part of nearly all city systems, the IEC doesn't propose a single suite of Smart City Standards. Instead, hundreds of IEC standards literally come into play to tailor the integration of many city and financial services such as energy generation, buildings, transportation, lighting, healthcare, and safety/security.

When appropriate, IEC cooperates with other organizations like ISO. Joint Committees are set up to combine all relevant knowledge of experts working in related areas. Therefore, international standards could fit together seamlessly and complement each other. ISO/IEC JTC 1 is such a joint committee where Information and Communication Technology (ICT) standards for business and consumer applications are developed. In addition, standards approval environments to integrate diverse and complex ICT technologies are provided by JTC1. JTC 1 recognizes the importance of Smart Cities as a trend that will shape many standards in the ICT sector. Actually, technology plays the central role of a Smart City as the concept of 'smartness' is addressed in terms of performance relevant to technologically implementable solutions. JTC1 tries to address the ICT-specific standardization requirements based on an understanding of the particular needs of Smart Cities. Such requirements include understanding and modeling Smart Cities, facilitating smart infrastructure, education, business, and services, facilitating instrumentation, analysis, decision-making, and automation, and responding to societal challenges.

International Telecommunication Union (ITU)
ITU is the United Nations specialized agency for information and communication technologies – ICTs. And similar to ISO and IEC, the Study Groups of ITU's Telecommunication Standardization Sector (ITU-T) assemble experts from around the world and develop international standards as defining elements in the global infrastructure of ICTs. In particular, ITU-T Focus Group on Smart Sustainable Cities (FG-SSC) elaborated on a series of steps to guide urban stakeholders through the gradual transitioning process to SSC. Based on this work, key desirable features for SSC and key performance indicators to monitor transitions to SSC have been elaborated. Later, the work on SSC was continued by the new ITU-T Study Group 20 on "Internet of things (IoT) and smart cities and communities (SC&C)". This study group provides a platform to influence the development of IoT standards and their application which are thought as part of urban-development master plans.

British Standards Institution (BSI)
BSI Group, also known as the BSI, is appointed by the United Kingdom Government as the National Standards Body and represents UK interests at the ISO, the IEC and the European Standards Organizations (CEN, CENELEC and ETSI). Formed in 1901, BSI was the world's first National Standards Body. BSI publishes over 2,700 standards annually, underpinned by a collaborative approach, engaging with industry experts, government bodies, trade associations, businesses of all sizes and consumers to develop standards that reflect good business practice. BSI produces technical standards on a wide range of products and services, and also supplies certification and standards-related services to businesses. Smart & sustainable city standards are also being written through BSI to reflect identified needs of diverse stakeholders, addressing urban challenges and creating common markets. Through standards, cities can provide the right conditions for open innovation and reduce barriers to systems integration. They enable collaboration and an open ecosystem for city partnerships resulting in productivity increase and service transformation in our future cities.

In particular, PD 8100 contains a smart city capability assessment/gap analysis diagnostic tool, aimed at enabling city leaders to make a quick overall assessment of the readiness of their city to take advantage of the transformational opportunities offered by smart city approaches. It helps the city define its own vision. Having derived a vision, the next step is to help a city set its strategy. PAS 181, soon to be published as an international standards (ISO 37106), gives guidance on establishing a city's unique strategy. It puts the citizen at the center, helping the city manage its digital assets, to create effective services and deliver change. With a vision and a strategy in place, PD 8101 provides guidance for holistic planning, taking into account future city potential. It recognizes that multi-party projects need a shared vision and benefits realization plan, covered within. It also recognizes that user needs and behaviors have to be incorporated in the design phase. Following planning, the following standards for implementing infrastructure have been published (BSI, 2018b).

The Standardization Administration of the People's Republic of China (SAC)

SAC is the competent authority for the unified management of the national standardization work in China. Under the impetus of the SAC, the National Standardization General Working Group on Smart City (SMCSTD) was established in 2014 (SMCSTD, 2018). The SMCSTD consists of more than one hundred member units involving technical committees, research institutions, businesses, alliances, etc. The SMCSTD is responsible for formulating the standardization strategy and advancing measures of Smart City in China. In addition, The SMCSTD formulates the framework of the standard system of Smart City in China, and formulates national standards for smart city. Until November 2018, more than 20 national standards relating to smart cities have been published by SAC (SAC, 2018).

ALL: A CONCEPTUAL FRAMEWORK FOR SMART CITY STANDARDS

The framework is named as 'ALL' according to the three perspectives it consists of:

- **A**pplication Domain: which domain or domains a standard is expected to be applied in.
- **L**ife Cycle: which development stages a standard is primarily used in;
- Smartness **L**evel: which level of smartness a standard is to address;

For each perspective, there are some options which will be introduced a little bit later. These three perspectives allow us to observe, organize, and use standards from three orthogonal angles. Application Domain and Life Cycle address "where" and "when" a standard is used, while Smartness Level addresses to what extent, or "how" smart the standard expects to regulate the smart city solutions.

To develop the framework, we reviewed and analyzed standards, white papers that have been published or underdeveloped by the three main international standard organizations regarding smart cities: ISO, IEC, and ITU-T. *Firstly*, we reviewed the standards categories to get a first eye impression on each organization. *Secondly*, we read introductory articles (overview article, white paper, or general standards) published in these organizations including corresponding technical committees or groups. We learned how these organizations divide the tasks and cooperate. *Thirdly*, we studied top level models in such articles. This time, we recorded vocabularies, dimensions, definitions, and relations, and so on, which were used in such models. By classifying, refining, combining the terminologies and their relations, we come up with the draft of our framework. We also enumerate possible options for each perspective. *Fourthly*, we reviewed standards based on this framework. For each standard, we checked: 1) whether one or several options can be used for each perspective; 2) whether the existing options were enough for the perspective. During this process, if one of the answers is no, we go back to refine the framework (perspectives and options); If both the answers are yes, we continue with the next standard. After several rounds of the process, the framework became comparatively stable as it is at present.

Application Domain

Smart city implies a very complex management system. A standard for such systems could cover everything a city must address to become smarter. Some of the standards provide cities with an overall framework for defining what "being smart" means for them and how they can get there. For example, ISO 37101, which sets out the basic requirements for sustainable development in communities, helps cities determine their sustainable development objectives and put in place a strategy to achieve them. Such standards are often supported by a number of other standards such as terminology and key indicators for measuring the performance of city services, which offer specific guidance for developing strategies and implementing them. Such standards are usually applied for all domains. But for most other standards, they are generally used in one or several specific domains, such as **Transportation** (e.g., ISO 39001), and **Healthcare** (e.g., ISO 45001). Other application domains include but not limited to: Responsible Resource Use, Environmental Management, Citizens' Health and Well-being, Governance, and Mobility.

Life Cycle

Smart city systems' development usually takes at several stages of the life cycle. We propose four stages in our framework: Plan, Construction, Operation, and Check. Usually the overall process should be iterative instead of one way and one time off. For different stages, the goals and focus differ a lot. For **Plan** stage, usually the high-level objectives should be determined and strategies to achieve them should be put in place. Thus, guides on how to determine the strategies and put strategies in place could

be provided in corresponding standards. For **Construction** stage, the system should be designed and developed. Thus, more technical details such as architecture, reference models, technical regulations, interfaces and constrains might need to be defined in corresponding standards. For **Operation** stage, best practices and practical guides for operation part can be presented in the standards. Lastly, standards containing indicators or other tools to measure the performance of city services are usually used more in **Check** stage.

Smart Level

We propose 3 levels/options in this perspective: Data level, Information level, and Application Level. This is inspired by the three levels of Management Information Systems (Guru99, 2018). The key ingredient to develop smart city solutions is data. Sensors need to be deployed throughout city infrastructures to collect raw data, and transmit them through communications networks, either wired or wireless. Data can be collected automatically or manually. Standards which regulate (most in a technical way) solutions in this part fall into the **Data** level. Further, advanced analytics can translate the large amount of raw data into meaningful and structured information that smart city applications can use. Standards in this **Information** level usually regulate how such information should be cleaned, stored, processed, conversed, combined, shared and retrieved. Some artificial intelligent (AI) technologies might be used to generate higher level information in this part. Later, information would be used for specific purposes for various users in various application domains. Thus, in **Application** level, standards focus more on how smart city applications could serve for specific purposes in a result-oriented way.

INITIA REVIEW AND USER EVALUATION

We have performed some initial reviews to evaluate this framework. For instance, nearly 30 representative standards have been introduced in the ISO smart city white paper (ISO, 2018b). For each standard, we judged the value for each option in the three perspectives and organized them in a table. Table 1 shows one part of the results. Because most of the standards are not free to download, and we could only judge according to titles and limited introductory texts, some of the value may not be ideally precise. Despite this, some useful information can be found in the table. For instance, we can easily find out which standards might be useful when we are developing smart water management systems (those with value of 'Water' and 'All' in the Application Domain perspective). Another instance is, if we are planning to start smart city projects for a new city, we may firstly need to look at those with value of 'ALL' in Application Domain, and with value 'Plan' in Life Cycle.

Table 1: A Review for ISO Standards Based on the Framework 'ALL'.

Standard ID	**Application Domain**	**Life Cycle**				**Smart Level**		
		Plan	**Construction**	**Operation**	**Check**	**Data**	**Info**	**App**
ISO 37100	All	X	X	X	X	X	X	X
ISO 37101	All	X						X
ISO 37120	All				X			X
ISO 26000	All	X						X
ISO 17742	Energy				X			X
ISO 50001	Energy	X						X
ISO 50006	Energy				X			X
ISO 39001	Urban mobility	X						X
ISO 39002	Urban mobility		X			X	X	X
ISO 24510	Water		X	X	X	X	X	X
ISO 24511	Waste Water		X	X	X			X
ISO 24512	Drinking Water		X	X	X			X
ISO 20325	Storm Water	X						X
ISO 24516	Water	X						X
ISO 24518	Water	X						X
……								

It is also possible to use the framework when we focus on one or two perspectives among all the three perspectives. Figure 1 demonstrates the case when we review Chinese National Standards regarding smart cities when Life Cycle and Application Domains are the focuses. In this figure, information in these two perspectives can be shown in a clearer and more visualized way.

For instance, GB/T33356 is about evaluation indicators for new-type smart cities, and it is primarily used in Check stage. While GB/T36333 includes top-level guides for requirement analysis, architecture design, objectives and strategies setting. Thus, it could be used in Plan, Construction, and Operation stages.

In addition, we have some initial discussions with our research partner from a local government in China. They have been trying to develop and promote some local standards to improve the interoperability among smart city solutions from different vendors. According to the representative who is responsible for integrating smart city solutions and corresponding standardization work, the framework is orthogonal, and has the potential to work as a basis for organizing and referencing existed standards, as well as developing new standards in the near future.

RELATED WORK

In (Chourabi et al., 2012), a literature review was performed, and eight critical factors of smart city initiatives were identified: natural environment, built infrastructure, economy, people and communities, management and organization, technology, governance, and policy context. This reveals various application domains that smart cities could be applied in, and different kinds of issues that smart cities could apply (e.g., technical, manageable, and governable ones). These factors can be used to examine how local governments are envisioning smart city initiatives. But this is a critical factor list, instead of a full list of factors. In addition, the review is for scientific papers regarding smart cities, not for international standards. For the latter, different scopes and focuses exist.

(Arman, Abbas, & Hurriyati, 2015) proposed the step by step process of how to identify smart city ICT related initiatives for each domain in ISO 37120. The step by step process includes: 1). Defining common smart city definition, 2). Defining smart city technology aspects, 3). Defining ISO 37120 indicator purpose, 4). Defining business architecture and system functionality, 5). Defining ICT initiatives, 6). Refining ICT initiatives. This process can lead to list of initiatives that may be applicable for city manager to move the city to next better level.

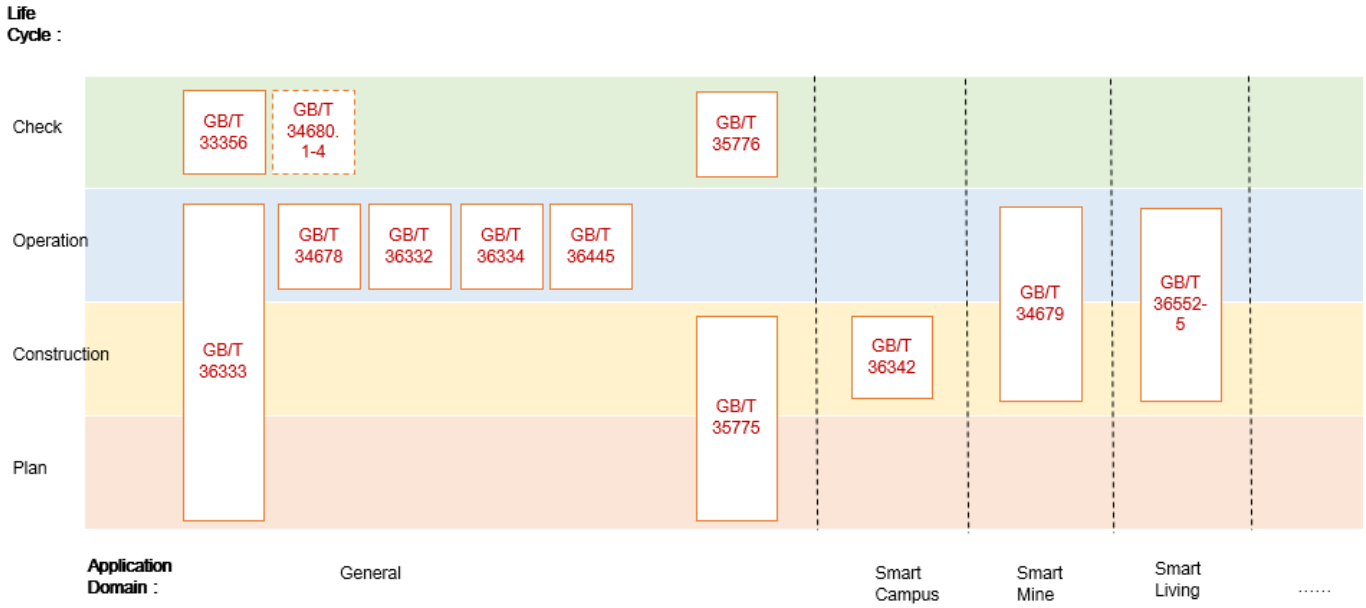

Figure 1: A Review for Chinese National Standards Based on the Framework 'All'.

In (Zdraveski, Mishev, Trajanov, & Kocarev, 2017), an architecture concept guided by the ISO 37120 standard for city services and quality of life is suggested as a unified framework for smart city dashboards. The architecture supports three tasks: acquire and manage data from heterogeneous sensors; process data originated from heterogeneous sources (e.g., sensors, OpenData, social data, blogs, and news); and implement such collection and processing on the cloud. A prototype application based on the proposed architecture concept is developed for the city of Skopje, Macedonia. This discloses one perspective that can be used to observe smart city documents or solutions. This is similar to the Smart Level perspective in our framework.

In BSI smart city white paper (BSI, 2018b), standards bodies (and most standards that have been developed in the bodies) are classified according to whether it is about strategies, processes, or techniques. For instance, ISO/TC268 Sustainable development in Communities is primarily about processes, but also somewhat strategic. While IEC Systems Evaluation Group on Smart Cities is

primary technical, but contains some content regarding processes. This approach shares some similarities with the Life Cycle perspective in our framework, but is a bit too simply and high level to organize a large number of standards.

A more complex framework/model is used in to position ISO/IEC JTC1 contributions with regard to the other international organizations. In the model, five blocks (with some sub-blocks inside) and ellipses in different colours on the blocks have been drawn representing core areas of ISO, ISO/IEC JTC1, ITU-T and the IEC. This model presents more detailed information regarding how different bodies divide the work and cooperate. In our opinion, two perspectives (Application Domain and Smartness Level) are included in this model in an implicit way. But it is not suitable to organize and provide specific information for many standards.

FUTURE WORK AND CONCLUSION

In this article, we have introduced a conceptual framework that includes three perspectives (Application domain, Life cycle, and Smartness level) to observe, communicate and use smart city standards. We reviewed some international standards which have been developed by different organizations. The result shows that the framework could help us find proper standard sets for different purposes by organizing them in a more structured way. In addition, some initial discussions have been performed with people in a governmental sector who are responsible for smart city development. They indicated that the framework is orthogonal and has the potential to be used when understanding existed standards and developing new standards.

As for future work, we do not claim that the suggested set of perspectives and corresponding options used in this article is ideally precise and exhaustive. Refinements and improvements would be made later. For instance, is there a unified set of application domains? And for Life Cycle, some people propose to use five options instead of current four options. Which proposal is better? In addition, whether such a framework could be useful in practice, in which way it could help? Larger scale review on smart city standards and more formal user evaluation have been planned in the future to solve such issues.

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