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MAKING CITIES INTEROPERABLE IN TURKEY

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ABSTRACT:

The population of cities is increasing rapidly day by day, and it is predicted that this increase will continue in the following years. Accordingly, population growth creates a significant pressure in many different domains of cities such as infrastructure, traffic, energy, and environment. Smart cities come forward as a useful option to struggle with the pressure on cities caused by overwhelming population growth and to make cities liveable and sustainable. Smart city approach creates gains in the fields of sustainable development, competitiveness and environmental sustainability with its ability to transform information into economic, social and environmental benefits. However, smart city services and applications are mostly designed as independent and unrelated units so this approach causes isolated and heterogeneous data and technology islands. As the result, data flow problem occurs between vertical applications and service suppliers, and this interoperability problem causes emergence of independent silos in smart cities. Such silos hinders data integration, prevent citizens and public administrations benefit fully from smart cities, and cause vendor lock-in. In order to use the full potential of smart city approach, it's vital to secure interoperability systems and applications of smart cities. In this study, interoperability terms and their necessity for smart city ecosystem will be addressed. Afterwards, Smart City Interoperability Model's (SCIM) contributions to semantic, technical and operational interoperability will be discussed.

1. INTRODUCTION

Population of cities is increasing unprecedentedly day by day. In 1950, %30 of the world's total population was residing in cities and this number increased up to %54 in 2014 (United Nations Department of Economic and Social Affairs, 2014). Global population is expected to rise to 8.6 billion in 2030, 10.1 billion in 2050 and 12.7 billion in 2100 (United Nations Department of Economic and Social Affairs, 2019).

Smart cities come forward as a useful option to struggle with the pressure on cities caused by overwhelming population growth and make cities liveable and sustainable. Smart city approach creates gains in the fields of sustainable development, competitiveness and environmental sustainability with its ability to transform information into economic, social and environmental benefits.

In this context, ICT is the key-enabler for implementing innovative solutions, services and applications to make cities "smart" (Petrolo et al., 2015). Especially IoT (Internet of Things) technologies are being leveraged in many domains all around the world, including smart cities (A. Gyrard and M. Serrano, 2016).

However, smart city services and applications are mostly designed as independent and unrelated units (J. Hwang et al., 2019) so this approach causes isolated and heterogeneous data and technology islands. As the result, data flow problem occurs between vertical applications and service suppliers, and this interoperability problem causes emergence of independent silos in smart cities (Brutti et al., 2019). Such silos use different communication technologies, architectures and standards as well (A. Kazmi et al., 2018) and hinder data integration, prevent citizens and public administrations benefit fully from smart cities and causing vendor lock-in (A. Brutti et al., 2018).

"Interoperability" establishes a relationship between heterogeneous systems to ensure exchanging data and coordinating processes (B. Molina et al., 2014). Integrating such heterogeneous devices and system also contribute to enabling IoT technologies in smart cities (A. Gharaibeh et al., 2017).

2020-2023 Smart Cities Strategy and Action Plan of Turkey (SAP) was published in December 2019 to ensure interoperability by bringing a holistic perspective to smart city policies at the national level, to prioritize investments in line with the determined policies, and to ensure that the investments are implemented with the right projects and activities (Bayar et al., 2020).

Within the context of SAP, 26 actions are defined in total, and sixteenth action is determined as "Smart City Terminology, Smart City Data Dictionary, Interoperability Model and Reference Architectural Model will be created.", and one of the subgoals of the action is "SCIM will be prepared" (The Ministry of Environment and Urbanization of Turkey, 2019).

This paper will, in Section 2, discuss the interoperability term and the levels of interoperability. After that, in Section 3, interoperability within the scope of SAP was discussed and recommendations for smart city stakeholders that are expected to contribute to technical, semantic and operational interoperability were mentioned. Finally, Section 4 concludes the paper.

2. INTEROPERABILITY IN SMART CITIES

The concept of interoperability was used for the first time in the military field. In the study of the US Department of Defence in

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1977, it was defined as "The ability of systems, units or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together." (DOD, 1977) (Kubicek et al., 2011). One of the definitions of the term interoperability, which is especially important for information systems, is defined as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" in the Institute of Electrical and Electronics Engineers (IEEE) dictionary named "IEEE Standard Computer Dictionary" (IEEE, 1990). Another definition of this term is defined in the European Interoperability Framework as “the ability of organisations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organisations, through the business processes they support, by means of the exchange of data between their ICT systems.” (European Commission, 2017).

In line with these definitions, issues to ensure interoperability can be addressed at three different levels: technical, semantic and organizational (Novakouski and Lewis, 2012).

Technical interoperability: The data used and produced within the concept of smart cities is usually locked-in one system, domain or service provider and it is challenging to make the data shared and re-used by other applications, providers and systems (Karpenko et al., 2018).

In general terms, technical interoperability ensures data exchange. Therefore, it copes with protocol, connectivity, time management and other hardware and software related issues (Diallo et al., 2011). As data is one of the core components of smart cities (Wang et al., 2014), technical interoperability could be considered as the base of the whole interoperability ecosystem. Breaking silos between various applications is only possible by ensuring technical interoperability.

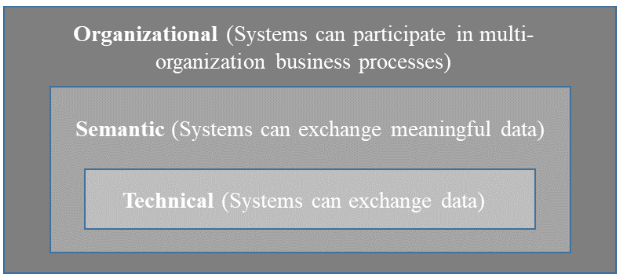

Figure 1. Interoperability Levels (Novakouski and Lewis, 2012)

Semantic Interoperability: While technical interoperability deals with technical issues during the exchange of data, semantic interoperability focuses on the “meaning” of data. Usually, stakeholders of cities tend to collect data for their applications or projects and mostly the data is not structured in a standard way to share with other smart city stakeholders that can reuse the data in similar smart city applications (Chaturvedi and Kolbe, 2019).

The aim of semantic interoperability is to use explicit semantic descriptions, thus, it will be possible to facilitate information and systems integration (Kalfoglou et al., 2005). With semantic interoperability it is possible to create a common understanding between the requested service and data (Heiler, 1995). Also, leveraging relative ontologies can support semantic interoperability (Gyrard et al., 2018).

Organizational Interoperability: Organizational Interoperability is the ability of organizations to communicate and transfer data effectively, even if they are using different information systems based on separate infrastructure (ETSI, 2008). (Hellman, 2010) addressed the barriers to organizational interoperability as low competency, lack of measurable, economic restrictions, absence of national joint efforts, project archipelago, disharmony in legislation, anaemic arenas, invisible best practice, the human factor, ubiquitous heterogeneity.

In order to establish organizational interoperability, it is necessary to address all administrative units in the ecosystem, and determine their roles and the functions under their responsibility (Yazici and Özdemirci, 2019).

3. SMART CITY INTEROPERABILITY MODEL OF TURKEY

Lately, cities carry out separate heterogeneous solutions related to different smart city domains. In order to use the full potential of the smart city approach, it’s vital to secure interoperability between these solutions (Brutti et al., 2019).

Solving interoperability issues in a particular focus area can be relatively easy by using a set of common standards. However, each of the smart city domains has developed independently from other areas for years and has created its own terminology. Therefore, there are many applications already running in every field and numerous datasets have been defined. Although it is theoretically possible to create a semantic model to cover all these areas and wait for the stakeholders in all these areas to leave the existing data structures, switch to this model will bring a huge cost in practice.

Instead of such a transition, it would be more realistic to match existing datasets with a determined model so that it can be understood by all stakeholders. For this reason, with SCIM, existing frameworks and standards have been proposed that will contribute to the work of all smart city stakeholders in terms of semantic, technical and organizational aspects, rather than introducing new standards and models.

3.1 Semantic Interoperability

As a result of systematic research on the subject of interoperability in smart cities, two semantic models that can be directly called "Smart Cities Interoperability Models" have been identified. The first one of these models is PAS 182 & ISO/IEC 30182 – Smart City Conceptual Model (BSI, 2014).

On the one hand, PAS 182, which defines an effective framework for establishing interoperability, outlines various concepts and the interrelationships between them. This comprehensive framework, defined by concepts and relationships, is general enough that it can be used to describe data from any industry regarding smart cities.

On the other hand, the smart city conceptual model provided by PAS 182 does not claim to remove all obstacles to interoperability. Decision makers should consider issues such as ensuring compliance, confidentiality, security, integrity, availability and data quality.

Component	Technology /Standard	Explanation

Smart City Conceptual Model	PAS 182	The smart city concept model (SCCM), outlined in PAS 182 by the British Standards Institute (BSI), addresses the lack of interoperability by defining an overarching framework of concepts and relationships that can be used to describe data from any industry.
Smart City Onthology	SAREF4CITY	SAREF4CITY document is a technical specification document prepared as an extension of SAREF for the Smart Cities domain.
Context Information Management	FIWARE	FIWARE-NGSI v2 is an application programming interface that aims to manage the entire lifecycle of context information, including updates, queries, registrations and subscriptions.
Data interoperability framework	ITU-T Technical Specification D3.3	Created by the ITU-T FG-DPM (Data Processing and Management Focus Group to support IoT and Smart Cities & Communities) focus group, this technical specification document outlines a framework for supporting data interoperability in IoT environments. Relevant requirements and technologies that support data interoperability are defined in this technical specification.

Table 1. Recommended Technologies and Standards for Semantic Interoperability in Smart Cities

This model is a theoretical study that has been created in general that can address almost all vertical areas of the smart city. This model will gain meaning with a mapping work that stakeholders will create to adapt to this model in order to ensure unity of meaning, instead of changing the existing models. In the case of using this model in Turkey, smart city stakeholders should do a matching study for their own datasets. Since the perspective of the model is significantly inclusive, it is thought that a match can be obtained for almost any dataset. With the model, it is possible to collect data from different organizations, facilitate reuse of the data and break the silos within smart cities.

Another semantic study is the SAREF4CITY model. The requirements of this model are built on three usage scenarios: e-Health and Smart Park, Air Quality Monitoring and Mobility, Street Lighting. For this reason, it is clear that SAREF4CITY is not a general model like PAS 182. However, since it is based on the main applications of smart cities, its practical value is quite high. In addition, it is possible to use directly rather than a mapping mechanism like PAS 182 as it contains class structures that software can directly reference. Essentially, even if these two models overlap to a certain extent, they are far from being alternatives to each other. Both are possible and necessary on a case-by-case basis.

Practical field experience shows that interoperability has many other dimensions besides conceptual models. Rather than focusing on a single model that will transcend all these dimensions, it would be more beneficial and realistic to focus on maintaining certain minimum interoperability mechanisms. It is understood and recommended that the frequently used FIWARE Context Information Management API will be an important interoperability mechanism.

Another conclusion reached from the field examples examined is that it is necessary to ensure that many heterogeneous objects work together in order to make interoperability possible in practice. One of the main alternatives to FIWARE, especially in the world of the Internet of Things, is the interfaces provided by OneM2M. These two different structures were successfully combined in a project for the cities of Busan in South Korea and Santander in Spain (J. Hwang et al., 2019).

Since smart city objects are usually chosen for different needs, searching for FIWARE compliance requirement or OneM2M compliance requirement may cause problems in procurement. If possible, it is recommended to create an architecture that will support these two different structures together.

The recommended standards and frameworks that can contribute to semantic interoperability are listed in Table 2.

3.2 Technical Interoperability

As mentioned before, technical interoperability generally copes with data exchange between independent systems and infrastructures. Smart cities should be capable of collecting, analysing and distributing data, and smart city data should remain re-usable (Brutti et al., 2019). Open standards and protocols can be utilized as a key enabler to deal with technical interoperability. If possible technical interoperability should be ensured through the use of formal technical specifications.

Another interoperability barrier demonstrated by field experience is vendor dependency. It is observed that some solutions provided by well-established companies, especially in information and communication technologies, lead to monopolization and vendor dependency over time. For this reason, it is recommended to emphasize the open technical specifications and compliance with international standards.

In this context, standards that can be used for smart city components are proposed in the SCIM. Dissemination of these standards to all components and technology infrastructure will contribute to the interoperability of smart cities. The recommended standards are listed in Table 2 for smart environment, smart transportation and smart energy components, respectively.

Component	Technology /Standard	Explanation

Environmental sensors	NTCIP 1204v03	National Transportation Communications for ITS Protocol Environmental Sensor Station (ESS) Interface Protocol is an interface protocol for environmental sensor systems. Although it was created for the USA, it is an open standard and is suitable for different country needs. If the definitions in this standard are followed, interoperability can be increased and vendor dependency can be reduced.
Traffic Data Exchange	DATEX II	DATEX II is the electronic language used in Europe for the exchange of traffic information and traffic data. It is mostly used in center-to-center communications.
SCADA/EMS /DMS	IEEE 1815	Distribution Network Protocol version 3 (DNP3) is the American version of IEC 60870-5 developed as a SCADA / EMS / DMS standard by a user group to meet the needs of North American electrical installations for transmission and distribution applications. It can be used for other industries such as water, wastewater, oil, gas and transportation.

Table 2. Recommended Standards for Specific Smart City Domains

3.3 Organizational Interoperability

SAP was prepared with a common sense of the smart city ecosystem of Turkey, including public institutions and organizations, local governments, private sector, non-governmental organizations and universities.

Within the scope of the preparation studies lasting 10 months; policy documents and relevant legislation were examined, workshops and focus group meetings were held and large-scale surveys applied to local governments. In SAP, the roles of all public institutions, local governments and universities are defined for a total of 26 actions within the concept of smart cities.

It is considered that identifying the definitions of duties and responsibilities will serve for organizational interoperability by accelerating action-based inter-institutional work and avoiding authority confusion in the future.

Moreover, smart city maturities of municipalities are being assessed and reported annually so the achievements of municipalities within the scope of their responsibilities for smart city transformation are being monitored and suggestions for the improvement of the maturity level are provided (Bayraktar et al., 2020).

4. CONCLUSIONS

The population of cities is increasing day by day, and the smart city approach stands out as a useful concept in terms of cities' ability to cope with the pressure caused by the population growth. However, the fact that smart city systems are generally created for project-based purposes causes smart city applications and the infrastructures used by these applications to be established independently and isolated from each other.

In order to provide interoperability by bringing a holistic perspective to smart city policies at the national level, to prioritize investments in line with the determined policies and to ensure that the investments are implemented with the right projects and activities, SAP has been published in December 2019 (Bayar et al., 2020). With SCIM, existing frameworks and standards have been proposed that will contribute to the work of all smart city stakeholders and has been prepared to cope with interoperability issues rather than introducing new standards and models. SCIM addresses interoperability under three main topics: semantic interoperability, technical interoperability and organizational interoperability.

Within this paper, initially, these interoperability terms and their necessity for the smart city ecosystem is discussed. Then, the contributions made to the ecosystem in terms of semantic, technical and organizational aspects with SCIM is mentioned.

Technical interoperability, as mentioned before, can be defined as data exchangeability between separate systems and it can be provided with specific standards. Hence, technical standards are recommended for smart city components within the scope of SCIM.

Since technical interoperability is about data exchange, semantic interoperability deals with the meaning of data. As for semantic interoperability, two semantic models that can be directly called "Smart Cities Interoperability Models" have been identified and recommended.

One of the two detected smart cities interoperability models is PAS 182 & ISO/IEC 30182 – Smart City Concept Model. This model is a theoretical study that can address almost all vertical areas of the smart city. Another semantic study is the SAREF4CITY model. The requirements of this model are built on three usage scenarios (e-Health and Smart Park, Air Quality Monitoring and Mobility, Street Lighting). Since this model includes application-oriented scenarios, it is understood that there is no general model like PAS 182. However, since it is based on the main applications of smart cities, its practical value is quite high. It is also possible to use SAREF4CITY directly rather than a mapping mechanism such as PAS 182, as it contains class structures that software can directly reference. Essentially, even if these two models overlap to a certain extent, they are far from being alternatives to each other.

In the context of organizational interoperability, all institutions and organizations within the smart city ecosystem at the national scale and their duties and responsibilities within the scope of SAP have been determined. Thus, conflicts of authorities are prevented and a contribution has been made to the organizational interoperability of smart cities.

This study contributes to the literature on how to deal with interoperability problems for smart cities on a national scale. As future work, interoperability issues will be addressed in the context of Reference Architectural Model of Interoperability of Turkey (RUMI).

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