Smart City

Interoperable Data-Driven Smart City: - Enabling standard based data and service sharing platform for smart city ecosystem

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Introduction

According to the United Nations, currently, half of the world population lives in cities and it is forecasted to reach two-thirds in 2050. This growth creates a huge challenge to resources and infrastructures of urban areas. The concept of smart city is derived with the initiative to address those challenges posed by urbanization with aim of enhancing the quality of urban life with reduced cost and resource consumption. There is no absolute definition of a smart city with universally agreed definition, but it involves the uses information and communication technologies (ICTs) along with different digital technologies to address many of the long-term issues associated with city life.

It is clear that the first thing in starting smart cities initiative is to identify and classify the important stakeholders. In a more general term, smart city stakeholders can be technically categorized into four roles: citizens, service providers, application developers, and framework enablers. Without an active participation of citizens, it is difficult to analyze the needs and necessities of urban cities. Service providers like city municipalities embrace smart city services by sharing historical and operational data. Application developers can develop critical, predictive, descriptive and prescriptive applications to help citizens and service providers to make better decisions. Framework enablers coordinates data and service sharing by proposing standards and tools that can be shared across multiple applications.

In such organized smart cities, data will become a big resource that can transform the capability of a city, enabling the development of new systems and services, and supporting informed decisions. Therefore, for the sake of each stakeholder's benefit data must be open and shared so that developers can use the data for real time decision and strategists to develop longer term plans to improve the safety and quality of life for citizens.

Smart cities involve a wide range of services including public transportation, safety, energy distribution, and health care systems. However, because these services are managed by multiple independent sectors with no common business process, data models, and service interfaces, it hinders applications and users of the service to properly discover and use these services. It is only when cross-domain applications are able to communicate and discover that the full potential of a smart city can be realized. This cannot be achieved without openness and interoperability. ISO/IEC also published a report emphasizing on "Open Data" and how the value of data can be increased when combination of various data sources are used for analytics and to innovate new services.

In general, interoperability of organization across all sectors of city services can be achieved if the cities are organized on the foundation of: globally unique identification of physical and digital entities; a standardized interface to facilitate data and service sharing; a common framework for data model and structure;

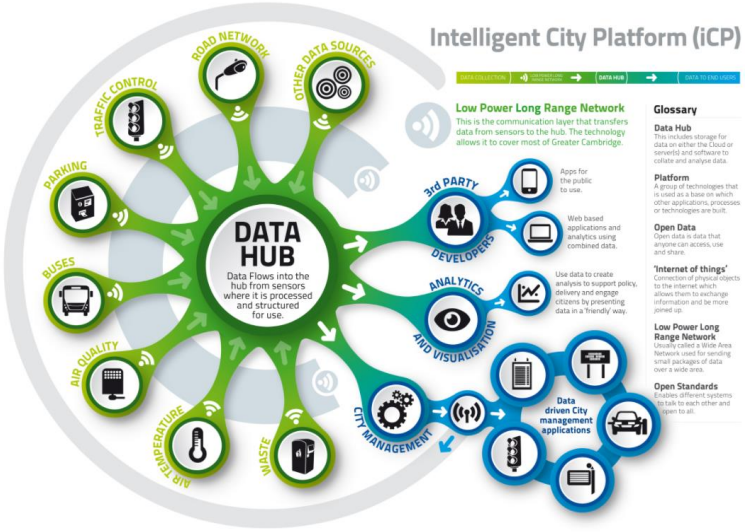
For a smart city ecosystem which contains heterogeneous things, devices, and services, identifying each of them uniquely is the first step to interoperate and manage. In this regard, the globally unique GS1 keys can be used to connect physical and digital objects with the associated information. EPCIS can be used to create smart city data hubs to enable data sharing. By standardizing and modeling smart city business processes with event and master data, a common understanding can be achieved on data format and vocabularies. Through EPCIS standard capturing and querying interface, city applications can easily interact to capture and get information from repositories. Furthermore, the competence of EPCIS for smart city comes from its independent manageability (scalability). Each resource provider (transportation, energy, etc.) can maintain their own EPCIS repositories and still be discovered and accessed. GS1 Digital Link, ONS and DS play the role in discovering services and data sources.

Smart City Trends

The concept of smart city equipped with ICT technologies is emerging as a key strategy for solving urban problems and improving cities functionalities. However smart city is not just a city that leverages ICT technologies, but is an infrastructure for the complex ecosystem made up of many stakeholders

including citizens, governments, and industries. For this reason, various smart city concepts are evolving, depending on the urban situation and the maturity of ICT technology. Two major concepts of smart city are evolving as follows:

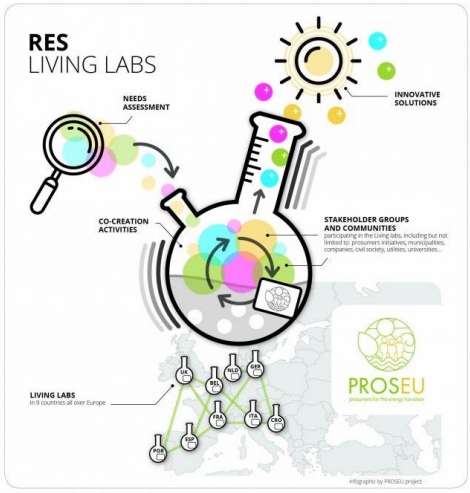
Open Data Hub for Smart City



Data – Intelligent City Platform (iCP) (Figure Credit: SmartCambridge)

The open data hub is a data infrastructure that can seamlessly collect and share public data along with open data from a variety of data sources of the city. It is an effective way to promote civic-driven innovation by encouraging openness in cities. The open data hub leverages underlying data technologies and mechanism such as, identification standard for tracking and tracing of object in the city, data model standards for the systematic labeling of data, data lakes to accommodate various types of data, data license management mechanisms for protecting copyright of data, data governance mechanisms for data quality management, data privacy and security technologies, and flexible interface standards between data and services. For example, Milton Keynes City in the United Kingdom built a data hub named MKDataHub in 2017, and presented several technologies for the data hubs such as overall architecture, service model, and data governance. It currently holds approximately 714 data sets, 28 data owners, and 11 data licenses, and has become the reference model for other smart cities.

Smart City Living Lab



Concept of Living Lab (Figure Credit: Proseu / Stephan Köhler, ICLEI Europe)

The concept of Smart City Living Lab is a paradigm that brings government, citizen, and local industry under one umbrella. The main purpose of smart city living lab is to provide a space and time that helps everyone solve urban challenges. The living labs strategy has the advantage that ICT technology can focus on consumers in the lives of citizens, rather than suppliers such as government and companies. Although the application of living laboratories has been tried in various ways, it is commonly required to prepare communication channels between participants and policies and regulations such as regulatory sandbox. Examples of living labs attempted by many countries are shown in the following table.

Country	Project Title	Description
South Korea	Seongdaegol Living Lab	Local residents are leading the use of appropriate technologies, such as solar hot air heater installation, by forming a council to solve energy problems.
United States	Dr. Tong Louie Living Lab	Development of products and environment to enhance the relationship between housing and work space
Netherland	Philips Home Lab	Residential observation apartment to see how Phillips' new products interact with people within two weeks
Norway	Tennor Home of the Future	Development of Smart IoT Home
Sweden	E2Home	In order to improve the quality of life for local residents, intelligent home solutions are provided in actual largescale apartments to provide feedback for the design of urban services.
Taiwan	Suan-Lien Living Lab	Demonstrate caring services for older people

Implementation Challenges

Fragmented data source in smart city

In the traditional city, data is fragmented. Organizations in different sectors (e.g. transportation, energy, environment, safety, and administration) manage their own data independently. This created broken city data which makes it hard to detect critical conditions based on various city services or discovering any emerging trends by analyzing multiple data sources. The fragmented business process used by each sector also incurs difficulties to understand the semantics of the data. It is not easy to search and discover data sources since proper and standardized classification is not applied.

In most scenarios the fragmentation starts on how resources are identified. In the case where there is no coordinator for allocation of IDs, those which are assigned locally are not guaranteed to be globally unique. One solution could be to use UUID without any coordinator. But it is not possible to associate semantics to such kind of ID allocation making it hard for classifications of resources and services by using the IDs.

The other major fragmentation comes on how data are models with no common agreement on the meaning of vocabularies. When each organization uses a solution of their own or selects any proprietary solution, they either put extra effort to map terms from many sectors or every sector needs to ensure common format when they bring their data in a sharable environment. The second approach is preferable for obvious reasons. Moreover, in order to reduce the number APIs and facilitate discovery of resources and services, a common interface should be designed and implemented.

Smart cities also need to have a marketplace where data is shared with legal and monetization capabilities. Public or private organizations should be able to exercise control over their data by applying for a license. On top of that, they need to be able to tag a price on the resource they are offering. In terms of data protection, privacy and security should not be compromised. Data needs to be secured and encrypted both during communication and storage. Users need to have strict permission control on the type of data they are sharing and the users they are sharing with.

In most cases the current GS1 standard can be easily applied to smart cities to solve the issue of interoperability. By analyzing existing smart city resources and services, appropriate types of GS1 ID

can be applied. For example, city resources, and services with characteristics of product and services can be identified by GTIN. GLN can be assigned to city resources with characteristics of physical locations such as buildings, bus stops, parks, and so on. GRAI can be assigned to shareable city resources such as shard bicycles, and cars. City assets which are owned by the smart city can be identified by GIAI. All other GS1 IDs such as GSRN, GDTI, and so on also can be used to identify city resources.

With a proper extension and definition of GS1 data model and vocabularies for a smart city, Master and Event data model of EPCIS can be applied in more effective and sustainable way since it allows data to be stored and shared in a distributed manner. The open EPCIS capturing and accessing API can be a good asset for smart cities also. Each silo organization can maintain their own independent EPCIS. Since GS1 Digital Link, ONS and DS play the role in discovering services and data sources, all the distributed EPCIS act as a virtually centralized system where any organization globally access irrespective of the location.

Smart city service provisioning

Nowadays various city platforms and industry groups produce growing number of city services that are associated with smart city resources. These city services are provisioned to improve citizen's quality of life and optimize city operations. Therefore, a versatile and scalable standard for service provisioning is required in building smart city. The standard should be acceptable in different sectors of the smart city and global industry groups.

Until now, most of city services are created and offered by city operators and provisioned from the city platforms to citizens unidirectionally. Thus, there has been lack of consistent city service provisioning system in which citizens and industries to create and provide city services also. Now, we are witnessing the rise of new demand of bidirectional offering of smart city services. It should allow city stakeholders to freely create and share their services utilizing open city resources. For city stakeholder's active participations and global service provisioning, leveraging global standards is required to identify city resources, register city services, and discover city services.

The smart city can leverage current GS1 standards to realize the participatory and international service provisioning. The GS1 ID can be applied to identify city resources. Since many smart city services are associated with city resources, the GS1 ID of city resources can be used as key index of the service provisioning. The Object Name Service (ONS) is a good candidate to enable city stakeholders to create, manage, and share their services globally. Also, GS1 Digital Link is providing web-based service connectivity enabling URL link promise to enhance the experiences for city stakeholders.

IoT is important in smart cities

While Internet of Things (IoT) plays an important role in enabling the connection of devices and extraction of data for services in smart cities, it still faces various challenges. As an increasing influx of companies invest in IoT solutions, fragmentation has become one of the biggest challenges in adopting IoT technologies and applications. This fragmentation is shown in many aspects, one of which is the uncertainty of interoperability across different communication networks and data streams. This lack of common identifications (IDs), industry standards, and the absence of semantics in many IDs (e.g. universally unique identifier (UUID)) can lead to significant associated adoption costs.

The necessity for IDs and standards can be seen in many examples like digital twin and IoT solutions. In digital twin, there needs to be a common way of defining a digital replica of a living or non-living physical entity. This includes Building Information Modeling (BIM) and Geographic Information System (GIS), which need common standards of IDs, data, and service in order to structurally enable digital twin for smart cities. The standards and IoT solutions like OCF, oneM2M, and FIWARE also lack interoperable IDs and any ID governance schemes.

This is where GS1 standards can provide a significant help, by bringing a set of well-defined industry standards with an extensive and highly customizable ID system. GS1 standards can support both the design and implementation of services and infrastructures inside a smart city. Sharing the same well-defined standards will resolve the interoperability issue and reduce fragmentation, which allows

potential customers in smart cities to easily procure and integrate solutions from different vendors. Furthermore, GS1 standards can define common structures for the representations of any entities in a smart city, which can greatly simplify the works necessary to enable smart cities' data and services.

Data Governance in smart city

The United Nations Department of Economic and Social Affairs (UNDESA) has defined the data governance as 1) The overall management of the availability, usability, integrity, and security of the data employed in enterprises, 2) The practice of organizing and implementing policies, procedures, and standards for the effective use of an organization's structured/unstructured data assets, 3) The execution and enforcement of authority over the management of data assets and the performance of data functions.

Data governance in smart cities is based on cooperation among city participants such as citizens, governments, and industries. It deals with integrated policies and processes for the production, utilization, sharing, data quality control, and security of urban public data. It is a smart city data synthesis system that enables sustainable urban growth and citizens' quality of life by promoting and creating new urban services.

Smart city data governance requires the social and technical consensus in various areas, the active cooperation between cities and governments, data security and privacy, data-related law and strategy creation at the government level, data ownership, and data market and pricing. In practice, we should make efforts to various research challenges such as the ID governance for smart city resources, the cooperation of urban data standardization, the sustainable data collection and quality control, and the cooperation with other smart city alliances such as UTA(Urban Technology Alliance). Also, developments of data producers and consumers, a citizen-participated data portal, smart city evaluation indicators should be considered.

Smart city data governance is essential to define the concept and scope of data in order to consistently and efficiently utilize data in various data-related industries. The plan for smart city governance should be in consideration of the situation and circumstances of each country and city. The challenges for smart city data governance are actively discussed at home and abroad, and the GS1 community should also be actively involved.

Moving Forwards

Successful implementation of a smart city requires a collaborative atmosphere between citizens, governments and industries. In addition, the principles for building open data infrastructure must be fully followed as below.

1. Identification of urban resources
Identification schemes for the major physical and logical resources in the city should be provided. These schemes not only clarify the data and service linkages between urban resources and citizens, but can also be extended to the development of intercity services.

2. Data governance
Post-development management of smart cities is more important than design and implementation. Many smart cities stopped after deployment due to improper management. To avoid this, design and development of smart cities should be prepared with data quality management protocols and communication channels for troubleshooting.

3. Data model standard
High quality data is a prerequisite for data-driven smart cities. To ensure the quality of urban data, it is necessary to design a comprehensive data model according to the city's management process (Critical Tracking Events) and provide exact context (Key Data Element) of each data.

These were areas of successful business in the GS1 community, for example, object identification in complex logistic processes, flexible data governance between various business partners, and the

EPCGlobal Standard for exchanging data. We believe that the GS1 community and its standards will play an important role in implementing data-driven smart cities.

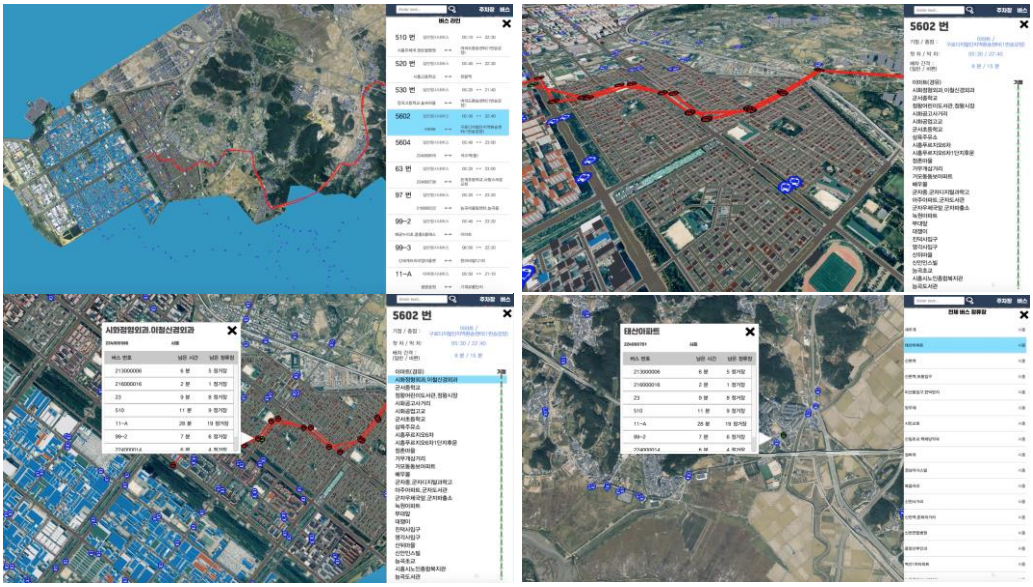
Use Case Studies

Siehung city BIS integration (Korea)

Siehung smart city project is a joint research including Auto-ID Labs, KAIST with the objective of building smart city data management and sharing platform.

The project proposed a GS1 identification system to harmonize the different local identification systems. It uses EPCIS platform to create a smart city data hub for collecting data in the area of transportation, environment, energy and welfare. Additionally, an interoperability mediation gateway has been implemented to integrate the legacy system in the newly proposed GS1 standard based smart city platform.

The data hubs are integrated with a digital twin of the city to provide a platform for new developers, expertise, and designers to simulate and foresee any potential problems. The below figure shows a demonstration of a bus information system integrated with the digital twin which accesses EPCIS.



Seokcohon Lake Park (Korea)

Songpa-gu District of Seoul and Auto-ID Labs, KAIST built citizen participation service platform which is enabling and supporting citizen participatory service registration, management, and sharing. The platform is deployed in Seokchon Lake Park area providing emergency service, facility information service, tourist information service, social media service, and so on.

To realize the citizen and 3rd party company participation service provisioning, the platform leverages GS1 standards involving GS1 identification standard, GS1 Digital Link, and GS1 Object Name Service (ONS). Auto-ID Labs, KAIST has cooperated with the Korea Ministry of the Interior and Safety to encode Korea's road name-based address system into the Global Location Number (GLN). In Seokchon Lake along the 2.5km trail, Songpa-gu has installed 120 address signs with QR code that includes encoded GLN in the GS1 Digital Link standard form. The GS1 Digital Link leads to the GS1 Object Name Service (ONS) that registers, manages and shares services associated with a given GS1 Identification Key.

Through the GS1 standard based service sharing platform of Sonpa-gu, city stakeholders register their services to ONS and citizens and tourist scan the GS1 Digital Link QR code of the address signs

installed in Seokchon Lake to access the services. Furthermore, the Korea Ministry of the Interior and Safety plans to extend GS1 standard-based citizen participation service platform to public parks.

Korea-City GCP allocation (Korea)

GS1 publishes a set of standards consisting of Identification Keys for unique identification of products and trading partners, a classification system for sharing of trade data, barcode symbologies and electronic document formats. It is the most widely used of its kind in the world. GS1 Identification Keys, one of the cornerstones of GS1 Standards, can be applied to trade items, objects and even locations and provides uniqueness for each of the entities. Its applicability not only to physical things but also to intangible ones such as service gives the keys a unique position to be adopted in almost any sector in need of an identification system.

That is why Smart City initiatives should adopt GS1 Standards. A Smart City requires a data identification system and a data classification system based on international standard to allow it to manage and share data from different urban resources around the clock, and GS1 Standards can play a pivotal role in the process. Use of GS1 Standards has another important advantage: global scalability underpinned by sharing and linking of data among international cities.

Fully aware of such significance, the Korea Advanced Institute of Science and Technology (KAIST) (also operating as Auto-ID Labs, KAIST) made a successful proposal of applying GS1 Standards to Smart City initiatives in Korea which is part of the country's strategic projects and is now working on R&D activities as part of the project. Under the project, the KAIST work with GS1 Korea to allocate GS1 Company Prefixes to entities responsible for managing urban resources including central and local government bodies, associations and industry bodies and ensure that GS1 Identification Keys and classification numbers are correctly assigned to the right urban resources in the most effective manner by issuing guidelines. In 2019-2020, GS1 Korea have provided GS1 company prefix for four Korean cities of Daejeon, Busan, Siheung, and Songpa-gu District of Seoul. In addition, KAIST demonstrate the robust applicability of GS1 Standards in Smart City initiatives by trying using it in a pilot city.

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