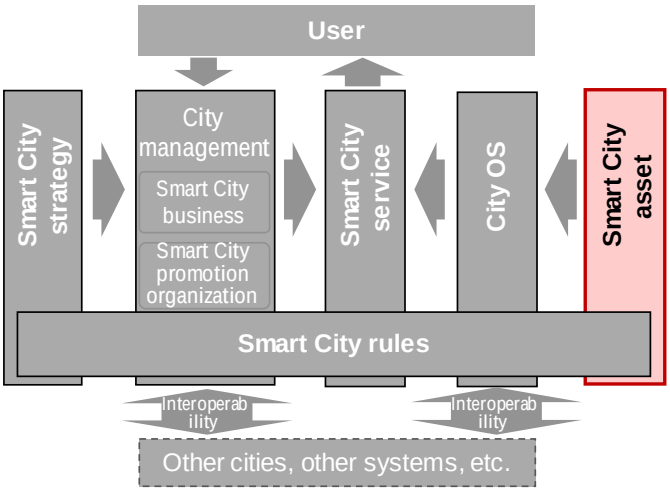
8. Smart City asset and other systems

8.1 Overview of Smart City asset



The assets as referred in Smart City are mainly properties and resources associated with the city which could be converted into data and controlled via City OS.

Smart City asset is designed to generate data required to resolve issues and consists of the devices to convert properties and resources into data, and network and transmitters to federate them to City OS. There are various types of the generated data such as environmental data like river and tidal water levels generated by sensor devices such as various IoT sensors placed across the region, operation status data of public transportation, image data from security cameras, location data acquired from automobiles and smartphones owned by the users in the region, and so on.

The required Smart City asset varies depending on the Smart City service provided to users.

Table 8.1-1 shows the component elements of Smart City asset.

Table 8.1-1 Component elements of Smart City asset

Item #	**Component element**	**Description**
1	Device	Equipment and devices which generate data, such as IoT sensors & cameras, mobile devices, and automobile computers, etc. Various standards exist regarding those equipment.
2	Short-range network	Network which delivers the data generated by devices to transmitters. There are WLAN like Wi-Fi, and WPAN like Bluetooth or ZigBee.
3	Transmitter	Network equipment which receives enormous amount of data from different types of device terminals like IoT sensors, and transfers data via wide-area network like internet.
4	Wide-area network	Network which enable servers to receive data from transmitters. There are WWAN like 4G/5G, and LPWAN like LoRA or SIGFOX.

8.2 Overview of other systems

Other systems are the systems other than City OS which get federated with when the data collected within the specific region are not sufficient to implement new Smart City service, etc. They can be categorized into data sources and data recipients. As the data source systems, there would be systems which manage various types of data such as open data related to public administrations owned by Government and municipalities, personal data like individual identification number, and data on electrical power supply and demand and the like kept by private corporations. Data transactions may happen directly or via data trading marketplace.

Table 8.2-1 shows major other systems

Table 8.2-1 Major other systems

Item #	Category	Description
1	Government-controlled system (open data)	Data on public administration events, geographical spaces, etc. owned by the Government and made available for unrestricted access, or the systems which hold them.
2	Government-controlled system (personal data)	Data on criminal incidents, information on specific diseases, etc. owned by the Government and utilized in the execution of their respective operations, and made available with a defined limitation of use and disclosure, or the systems which hold them.
3	Municipality System (open data)	Data on information on public facilities, etc. owned by the municipality and made available for unrestricted access, or the systems which hold them.
4	Municipality system (personal data)	Data on individual identification number, basic resident registry data, etc. owned by the municipality and utilized in the execution of their respective operations, and made available with a defined limitation of use and disclosure, or the systems which hold them.

Item #	Category	Description
5	Private sector system (non-personal data)	Data on platforms for private sector business domains, etc. owned by the private sectors and utilized in the execution of their respective operations, or the systems which hold them. · domain specific platforms: the systems which are managed for each domain or business operator such as traffic, electricity, etc. · Data trade marketplace: the system which enables trades by brokering between data owner and those who request to use the data.
6	Private sector system (personal data)	Data on individual identification number, basic resident registry data, etc. owned by the municipality and utilized in the execution of their respective operations, and made available with a defined limitation of use and disclosure, or the systems which hold them. · Information bank: the systems which stores data classified as personal information such as purchase logs and health conditions owned by the users, etc., and provides the data to private corporation, etc. upon approval from the opted-in individuals

As described, the data provided by Smart City assets and other systems vary greatly depending on subjects and applications, and provision methods and forms. As a result, there currently exists an issue that data models are not standardized, and it has been the reason for difficulty in data exchange. Therefore, with respect to the data provided by way of Government and municipalities, it is important to proceed with the Government-driven standardization of data models, as stated in “7.3.1.2 Oversea’s initiatives for interoperability”. Furthermore, as it is difficult to standardize data models with respect to the data provided by private sectors, it is a requirement of City OS to enable usage of such data through conversions via external data federation.

8.3 List of Useful Data

There are many different types of data generated by Smart City assets across regions or kept by other systems. To promote utilization corresponding to the regional issues to be resolved, the data extracted from various examples of Smart City around the country are presented below as reference of the data collected and brokered by City OS.

8.3.1 Theme: Dynamic & static data

Category	Measure
Weather	Government-controlled system (open data)
Disaster	Municipality system (open data)
Water level	Municipality system (open data)
Comfort level	Private system (non-personal data)
Camera image	Private system (non-personal data)
Transportation & movement	Private system (non-personal data)
Traffic congestion	Private system (non-personal data)
Flow of people	Private system (non-personal data)
Noise	Private system (non-personal data)
Availability of rental bicycles	Private system (non-personal data)
Luminance	Private system (non-personal data)

8.3.2 Theme: Geospatial data

Category	Measure
Map	Government-controlled system (open data)
Population	Government-controlled system (open data)
Fish catch volume	Government-controlled system (open data)
Crime statistics	Government-controlled system (open data)
Agricultural products yield	Government-controlled system (open data)
Tourists spending trend	Government-controlled system (open data)
Air pollution	Government-controlled system (open data)
Ocean	Government-controlled system (open data)
Disaster statistics	Government-controlled system (open data)
Education-related facility	Government-controlled system (open data)
Energy consumption	Government-controlled system (open data)
Infectious disorder	Government-controlled system (open data)
Patent	Government-controlled system (open data)
National property management	Government-controlled system (open data)
Public property	Municipality system (open data)
Road & public facilities	Municipality system (open data)
Fire-fighting operation	Municipality system (open data)
3D building information	Private system (non-personal data)
3D point group	Private system (non-personal data)
3D city	Private system (non-personal data)
3D urban geometry	Private system (non-personal data)
3D civil engineering structure	Private system (non-personal data)
Event	Private system (non-personal data)
Sales amount	Private system (non-personal data)
Supply & demand	Private system (non-personal data)
Facility/retail premises	Private system (non-personal data)

8.3.3 Theme: Personal data

Category	Measure
Defense	Government-controlled system (personal data)
Foreign diplomacy	Government-controlled system (personal data)
Administrative disposition	Government-controlled system (personal data)
National license holder	Government-controlled system (personal data)
Specified diseases	Government-controlled system (personal data)
Crime	Government-controlled system (personal data)
Labor accident	Government-controlled system (personal data)
Resident	Municipality system (personal data)
Tax affairs	Municipality system (personal data)
National health insurance	Municipality system (personal data)
Medical care & caregiving	Municipality system (personal data)
Welfare-related	Municipality system (personal data)
Delinquent childcare payment	Municipality system (personal data)
Individual identification number	Municipality system (personal data)
ID	Private system (personal data)
Opt-in attribute	Private system (personal data)
Mobile phone	Private system (personal data)
Purchase	Private system (personal data)

9. Continued curation and development of Smart City Reference Architecture

Smart City reference architecture presented in this report covers the management related subjects and the IT systems related subjects which are currently regarded to be necessary to realize Smart City. However, as the technologies implemented to realize Smart City are advancing year by year, the social acceptance of adopting such technologies also changes, and therefore Smart City reference architecture is also required to be continually maintained and advanced in steps with the times and the social backgrounds.

Furthermore, in making the continual development of Smart City reference architecture, it is necessary to consider two sets of frameworks namely a framework addressing the whole architecture such as promotion of the architecture, curation & management of the architecture, supporting international standards, human resources development, etc., and another framework addressing the adoption of the City OS specific IT related technologies evolving at ever increasing speed.

In this chapter, necessary approaches are summarized with regard to the continued curation and development of Smart City Reference Architecture (the whole architecture, and the City OS which requires professional knowledge on IT systems) assuming the situation change as time passes.

9.1 Continued curation and development of the whole architecture

In this section, some initiatives and the corresponding organizations required for the continued curation and development of Smart City reference architecture in Japan are presented by making references to the examples of the methodology (how to organize, how to promote) related to the continued curation and development of the Smart City related architectures mostly of the advanced (overseas) examples in existence.

9.1.1 Various initiatives enabling curation and development of the architecture

In reviewing the architecture studies by such organizations as NIST[66] in the USA and OASC[67] in Europe, it shows a general world-wide trend of evaluating the upper layers of organizations and rules (analog layer) of the reference architecture in addition to the systems technologies. In order to benefit from unprecedented advantages resulting from the use and application of data, it is extremely important for the creation of new innovations to amend the rules and regulations in accordance with the progress in Smart transformation, and also to ensure interoperability of policies and rules across the regions and even the nations. For that reason, it will continue to be important to assist the utilizations of Smart City Reference Architecture in collaboration with municipalities and other organizations, and to enable continually progressing approaches by feeding back the outcome of these activities into the architecture.

From the viewpoint of operational organization, in the cases of overseas SynchroniCity[68] (Europe) and X-Road[69] (Estonia), etc., the ecosystem is formed to serve as the Smart City platform. The operational issues are sorted out and addressed with improvements as a result of the standardized data which allows participation by respective stakeholders.

As for the verification of whether the developed reference architecture is truly usable, the approaches implemented to evaluate the leading reference architecture as such by the overseas standardization organizations are summarized.

With regard to the promotion of cross-sectoral data exchange, assuming the interoperability for data exchange with overseas entities in the future, a list of items currently addressable regarding the relationship with standardization is presented.

9.1.1.1 Examples of the architecture operating organizations

In order to enable continuous operation and continual curation and development of the architecture, it is important to facilitate the mechanism to continuously feed the data. The

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66 https://pages.nist.gov/smartcitiesarchitecture/

67 https://oascities.org/

68 https://synchronicity-iot.eu/

69 https://x-road.global/

overview of X-Road and SynchroniCity as the operational projects of the Smart City platform architecture in EU is described below.

(1) X-Road (Government-led type)

It is realized by multiple organizations in public-private partnership (government-led) to sustain the legal systems, other systems, and development environment.

(a) Ministry of Economic Affairs and Communications (MKM)

(b) Information System Authority (RIA)

(c) Nordic Institute for Interoperability Solutions (NIIS)

(d) X-Road Region

(2) SynchroniCity (public-private partnership type)

SynchroniCity consortium is comprised of 38 partners from government, industry, and academia with Aarhus University as a coordinator.

The OASC which leads the project is a non-profit international Smart City network with the aim of establishing open market for Smart Cities meeting the needs of cities and regions. It was established in January 2015 and more than 140 cities from more than 30 nations and regions around the world are the participating members. The implementation of the reference is mainly configured by open source software. Unlike the Smart City promotion models led by industries or nations, it is regarded as a typical European, city & citizen-centric model.

(3) Base registry

It is a project promoted by ISA^2 [70] which is a program promoted by European Commission. Its objectives are to standardize the registries and the like for address, geospace, corporation, facility, etc. kept by administrative agencies, and to make them available for open access. As it provides accurate and most up-to-date information in reference to the city, it is regarded as the indispensable environment for the sustained promotion of Smart City.

[70] https://ec.europa.eu/isa2/home_en

9.1.1.2 Evaluation of Smart City Reference Architecture

According to the definitions by United States Department of Defense, reference architecture is the firm source of information for guidance of multiple architectures, solutions, limitations, etc. in reference to a particular subject matter. Reference architecture advocates common understanding for multiple products, organizations, and fields, by providing necessary concept, viewpoint, and guidance in the system development, construction, and the like. There are several reference architectures proposed in the regions of particular subject matters, for example, Enterprise reference architecture (ISO 15704), IoT reference architecture (ISO/IEC 30141), Big data reference architecture (ISO/IEC 20547-3), etc., and international standard organizations like ISO[71], IEC[72], ITU[73], and ISO/IEC JTC1[74] are in the process of defining the common framework. However, these definitions are formulated independently from each other, and the unified reference model and architecture which encompass the entire process from strategy to process and technical guidance for the design, construction, operation, curation and management of Smart City are yet to be established.

The evaluations of the architecture itself are conducted to verify various issues such as a) whether the architecture is designed to meet the objectives (or to be able to change to adopt the new objectives), b) whether the architecture is effective and appropriate to satisfy the needs and expectations of stakeholders, c) identify the risk of mitigation, d) identify the entity or the opportunity to modify the architecture, e) clarify the needs and the areas of issues of stakeholders, and f) evaluate the level of achievement towards the architecture goals.

In order to make comparisons of various Smart City Reference Architectures such as X-Road, SynchroniCity, and the like, it is necessary to have a common description as well as evaluation indexes of the architecture. ISO/IEC/IEEE 42010[75] standards provide the main concept of the architecture description, the structure of component elements, the relationships between component elements, and principles and guidelines. The evaluation process of the reference architecture starts with verifying the compliance of the domain reference architecture descriptions with ISO/IEC/IEEE 42010 standards. If they are not

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[71] ISO/TC 268 Sustainable cities and communities

[72] IEC SyC Smart Cities

[73] ITU-T Study Group 20: Internet of things (IoT) and smart cities and communities (SC&C)

[74] ISO/IEC JTC1/WG11 Smart Cities

compliant, they need to be mapped onto ISO/IEC/IEEE 42010[75], and the framework elements of the architecture description corresponding to stakeholders, concerns, viewpoints, associated rules (restrictions), etc. are to be extracted. Then the evaluations on each of the following subject matters are conducted.

- Evaluation as reference architecture in general: Component elements will be analyzed as to whether the key elements of ISO/IEC/IEEE 42010 namely stakeholders, concerns, and viewpoint are defined in a consistent and comprehensive matter or not, and so on.
- Evaluation as domain reference architecture: Whether the associated rules (restrictions) required for a particular application domain are clearly defined, and the analysis of the relationships between the component elements based on such restrictions will be made.
- Evaluation as solution reference architecture: Analysis of whether the architecture provides functions as solutions for the resolved issues (concerns) will be made.

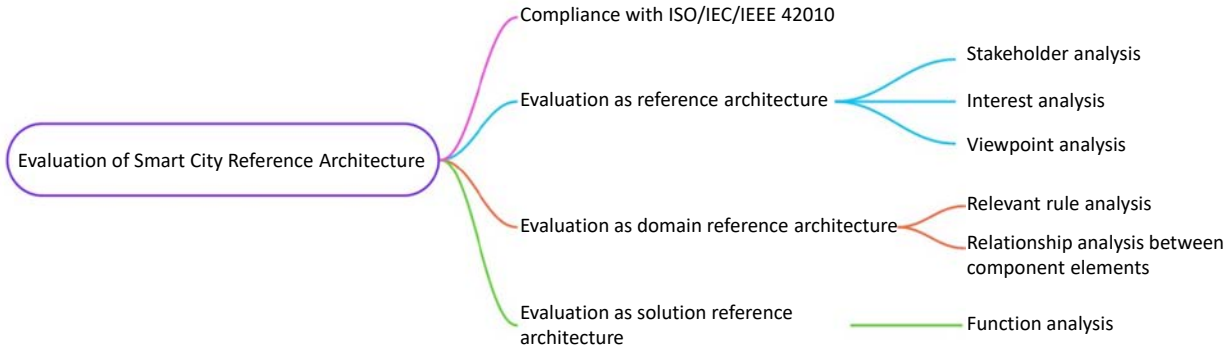


Figure 9.1-1 Evaluation tree diagram

[75] ISO/IEC/IEEE 42010:2011- Systems and software engineering — Architecture description, https://www.iso.org/standard/50508.html

(1) Organization (stakeholder) analysis

There are two objectives of organization (stakeholder) analysis, namely whether organizations (stakeholders) are listed clearly, and whether any organization (stakeholder) is missing. Organizations (stakeholders) can be categorized into individual, organization, team, and others. In the organization (stakeholder) analysis, it must evaluate whether the reference architecture clearly identifies them and whether they are always mentioned. Organizations (stakeholders) must be clearly defined, and in the organization (stakeholder) analysis, attention must also be paid towards potential organizations (stakeholders) which may be mentioned ambiguously or unclearly in the document. The organization (stakeholder) analysis must clarify how the listed organizations (stakeholders) are sorted out (for example by the viewpoint, or by other category). It is also necessary to evaluate the level of usefulness for the readers of the way the organizations (stakeholders) are sorted out.

(2) Interest analysis

As the subsequence steps of evaluation method are based on the analysis of whether interests are properly reflected or not, it is important to clarify and evaluate the interests presented in the document. The interest analysis includes whether a list of interests and the interests of a particular organization (stakeholder) is clearly described, and confirming whether there is any interest clearly missing.

(3) Viewpoint analysis

Viewpoint analysis is conducted to clarify the viewpoints, determine whether all the interests are covered, and to evaluate whether they are corresponding to each one of the interests or not. It should also include the evaluations of the methods of constructing and organizing viewpoints, for example, whether or not they fit into commonly used viewpoints from the standpoint of concept, business, practicability, or execution, or whether organizational structure is clear and comprehensive or not.

(4) Relevant rule analysis

It determines whether relevant rules are defined, and whether or not they cover the relationships aggregating the viewpoints.

Table 9.1-1 shows examples of indicators to be considered for each analysis.

Table 9.1-1 Examples of evaluation indicator

Analysis	**Example**
Stakeholder	Is there any organization (stakeholder) missing?
Interest	Are the interests listed by each organization (stakeholder) group? Are the interests described clearly and concretely enough? Is there any interest missing?
Viewpoint	Are the interests by each framework of viewpoint clear? Does the viewpoint correspond to the selected interest? Does the viewpoint reflect a particular interest, with a measurable goal?
Relevant Rules	Are the relevant rules stated clearly? Are there any relevant rules clearly missing?

In order to evaluate the architecture, it is necessary to determine quality attributes of the architecture. For each quality attribute, it is necessary to consider the potential impact to the concerns of respective stakeholders. It is most important that the quality attributes of the architecture are limited to those which are valuable to stakeholders of the architecture and in "agreement with the stakeholders". With that understanding, the indispensable and distinctive quality attributes which reflect practical interpretations of pros and cons of the architecture are described. Having sorted out the quality attributes in agreement with the stakeholders, the architecture functions and the level of achievement are used as yardsticks based on the quality attributes.

Table 9.1-2 shows a part of the examples of the quality attributes of the architecture described in ISO/IEC/IEEE 42020[76].

[76] ISO/IEC/IEEE 42020:2019- Systems and software engineering — Architecture processes, https://www.iso.org/standard/68982.html

Table 9.1-2 Examples of quality attributes of the architecture

Attribute	**Description**
Coherence	Logical consistency
Completeness	Capability to formulate in entirety
Hierarchy	Level-wise abstraction
Modularity	Separation of concerns
Subsetability	Provision of subsets of component elements required in advance
Verifiable	Feasibility of implementation as designed
Flexible	Expandability to flexibly meet the changes in conditions

In the evaluation of the interoperability of architecture, interoperability between the architectures of different domains is to be evaluated. Interoperability generally means the ability to conduct Interoperability between two different entities (software, process, system, organization, etc.). In the IOS International Standards, interoperability is defined as follows:

- Interoperability of information systems: ability of two or more systems or applications to exchange information and to mutually use the information that has been exchanged
  [Source: ISO/IEC 17788:2014, IEEE 610.12-1990]
- Interoperability of industrial automation systems: capability of two or more entities to exchange items in accordance with a set of rules and mechanisms implemented by an interface in each entity, in order to perform their respective tasks
  [Source : ISO 18435-1:2009]
- Interoperability between Smart City and regions: ability of systems to provide services to and accept services from other systems and to use the services so exchanged to enable them to operate effectively together
  [Source : ISO 37100:2016]

In this report, the definitions by ISO 37100 are recommended from the viewpoint of the interoperability of Smart City Reference Architecture. The evaluation of interoperability between architectures includes not only apparent problems but also identifying potential problems and possible resolutions thereof. By the evaluation of interoperability, it becomes possible to determine the interoperability of the architecture that can be implemented at the moment, and provide a future roadmap. The evaluation of interoperability are conducted from the following viewpoints:

- Potentiality: It evaluates the potentiality of interoperability of architecture in response to environmental changes. The objective of this analysis is to evaluate the potentiality (also called as maturity) and dynamically adopt or adjust in order to overcome the potential obstacles that could emerge as the system constructions of Smart City Reference Architecture infrastructure proceed.
- Compatibility: When two different systems are in compliance with the Smart City Reference Architecture specifications, it evaluates whether one system could replace the other and operate identically as the other. Its objective is to identify the component which causes, or potentially causes, problems by analyzing the functions of both of the federated systems.

  Performance: It evaluates Interoperability when the system is in operation. It examines the cost associated with the system implementation of the interoperable Smart City Reference Architecture infrastructure, the period between the moment information is requested and the moment the requested information is used, the quality of exchange, the quality of usage, and the quality of conformity.
- Coverage: In order to realize interoperability of higher quality, it is necessary to define the layers of interoperability for each of the interests, and analyze whether they satisfy a certain standard. It is also important to understand the relationships between the evaluation standards of different layers, and to be able to identify the impact on the entire system in case such standards are not achieved. Therefore, the entire picture is analyzed based on the applicable areas of standards of multiple interoperability layers and their interdependency.

For Smart City, ISO 37106 Standard was published in 2018 as the guidelines for the design and management of sustainability goals to be used by city administration leaders for the city-level interoperability. In ISO 37106, in order to identify the significant barriers against the interoperability required by city, and to establish the policies and initiatives to address these problems, it defines the interoperability matrix as shown in Figure 9.1-2. In this report, it recommends to draw the complete picture of the interoperability matrix by understanding the areas of barriers in collaboration with other cities, other municipalities, and the administration, and making it easy to extract the required components from Smart City Reference Architecture.

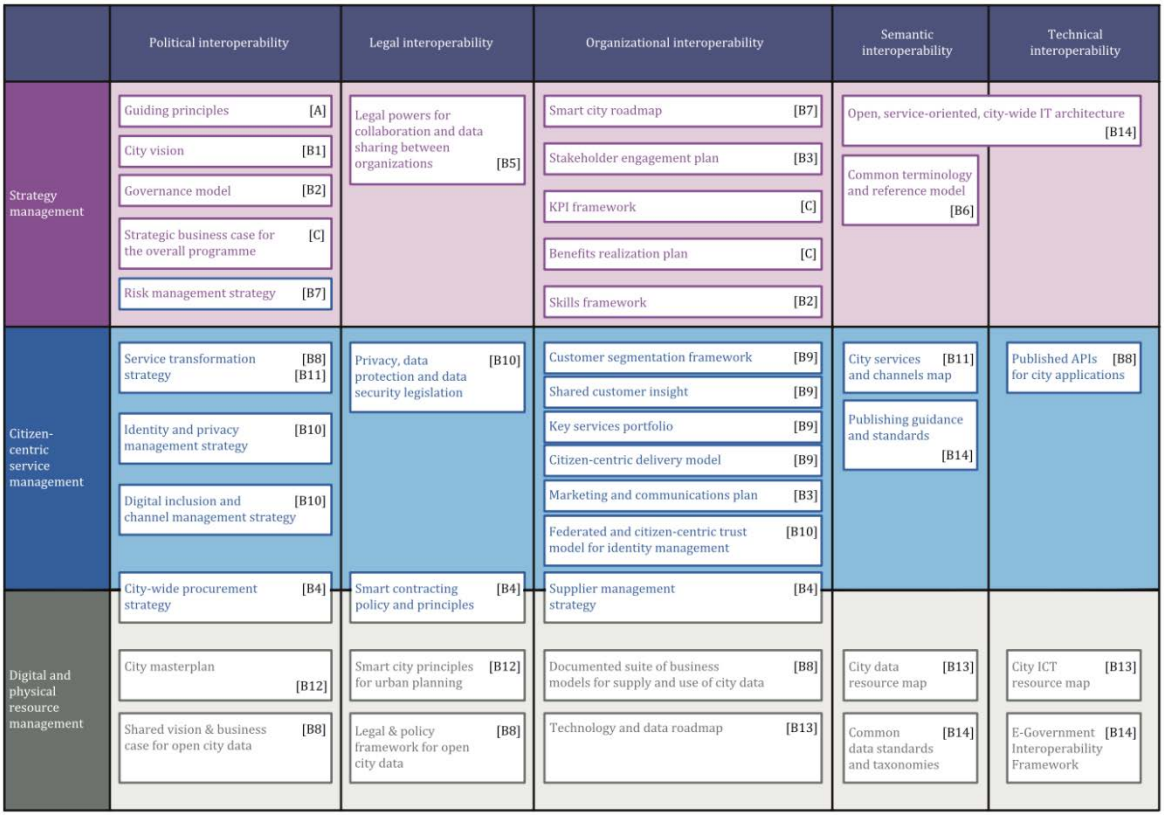


Figure 9.1-2 Matrix for the evaluation of Smart City interoperability [Source: ISO 37106:2018][77]

9.1.1.3 International standardization to enhance data exchange

In the process of constructing Smart City Architecture to enhance data exchange, obtaining international sharing of the values and consensus is a requirement for Japan to act as a member of the world-wide ecosystem. For that matter, it is important to comply with the international standards and form strategic partnership with appropriate organizations and groups amongst other things, as described below.

(1) Trends in international standardization

(a) Architecture construction process

For the construction of SoS (System of Systems) architecture represented as a complex system, there is an international standard called ISO/IEC 42010 (as described in the previous chapter). It was developed by ISO/IEC/JTC1/SC7 and prescribes the procedures (= process) of how to approach the architecture construction. The procedures first define the angles (viewpoint) of the concerns from the viewpoint of “What are the target areas?”, “Who are the stakeholders in there?”,

[77] ISO 37106:2018 Sustainable cities and communities — Guidance on establishing smart city operating models for sustainable communities, https://www.iso.org/standard/62065.html

"What are the concerns of the stakeholders?", etc., and then describe the models defined from these viewpoints (= layers). As examples of the implemented architecture based on this concept, there are IIC reference architecture IIRA (Industrial Internet Reference Architecture)[78] and IEEE P2413[79].

(b) Sets of standards related to Smart City construction and evaluation

There are sets of standards developed by ISO/TC268. From the standpoint of evaluations, ISO 37120 series provide indexes (indicators) for city evaluation. There is also ISO3710/37104 which specifies the way of city management. ISO37153 defines the matureness of the city (its infrastructure) and the methodology on how to develop evaluation schemes to evaluate and improve it. ISO37106 defines the city operation models utilizing ICT, and ISO/TS 37107 describes matureness as the evaluation characteristics of ISO37106 operation models utilizing ISO37153. ISO37105 describes the city structure. These standards are closely related to the operation and evaluation of Smart City.

(c) Sets of standards to be considered from the viewpoint of data exchange

From the viewpoint of data exchange, handling of personal information is an issue. ISO/IEC/JTC1/SC27 has identified the issue and been developing sets of standards to address it. There is ISO29100 which describes how to handle data related to personal data and PII (Personally Identifiable Information). Within ISO29100, it describes the roles of Data principal (natural persons associated with PII), Data Controller, Data processor, and the third parties, and fundamental principles of handling PII. Although it was standardized in 2011, fundamental principles of handling of personal information leading to Amendment to Act on the Protection of Personal Information (partially amended in 2018). ISO29134 provides a guideline related to handling of PIA (Privacy Impact Assessment). It is a guideline on where PII exists and how to handle it.

(2) Trends in data sharing platform development in Europe

In order to establish official rules internationally, active discussions were conducted with the members of FIWARE, IDSA and the like. Through the discussions, it was noted that the platform to realize data sharing services based on data-sovereignty (= data usage management by the data owners) promoted in Europe was the trend to watch.

For the promotion of data utilization, IDSA argues that in addition to the existence of Interoperability, Data exchange, and Sharing ecosystem, it is even more important to

[78] Reference: https://www.iiconsortium.org/IIRA.htm

[79] Reference: https://standards.ieee.org/project/2413_1.html

ensure Data ownership, Data security, and Data value to encourage data utilization. It is generally understood that “the ownership right of data does not exist but only the access right is transferred”. The understanding is common in both Japan and Europe. The argument, however, is that “data exchange will not be initiated unless the original owner of the data perceives the merit to do so”. Data Sovereignty (Data Sovereignty = Data Control) achieves exactly that. Technology-wise, it was confirmed in the reports that DRM technology is employed [80]. In other words, Data Control enables Future Usages (management of usage frequency, usage period, etc.). It complies with the spirit of GDPR of taking the data management right back to users.

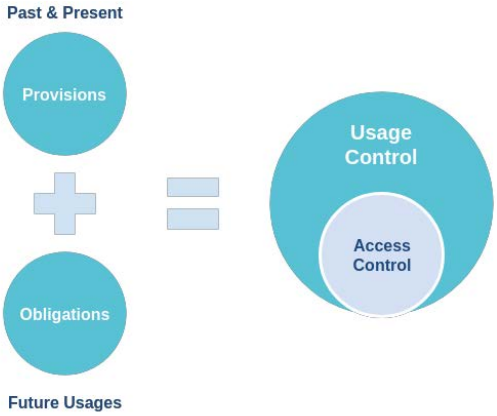


Figure 9.1-3 Usage Control realized by FIWARE

To realize these initiatives as European projects, IDSA and FIWARE are collaborating and forming partnership with TM forum. In addition, GAIA-X initiatives[8181] related to data storage were announced. It seems as a counter measure to GAFA. Figure 9.1-2 shows the relationship among the GAIA-X, IDSA, and FIWARE (and TM Forum and OASC in collaboration).

[80] https://github.com/ging/fiware-usage-control

[81] Aug.25 2019 German economy minister plans European Cloud service “Gaia-X” https://www.financial-world.org/news/news/economy/3046/german-economy-minister-plans-a-european-cloud-service-gaiax/ , then BMWi announced the plan at Oct.29 2019

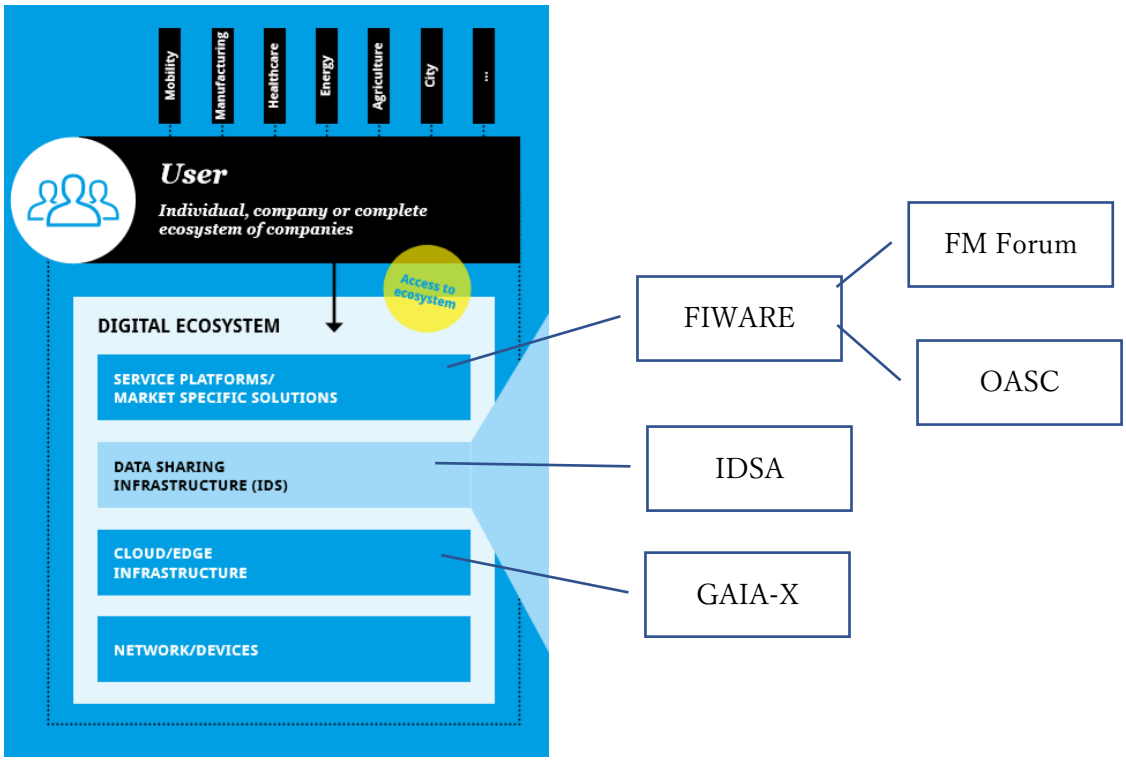


Figure 9.1-4 Relationship of four layers comprising digital ecosystem[82]

From the bottom layer, the first layer is Network/Devices, and the second layer is Cloud/Edge Infrastructure which is termed as GAIA-X (data storage management). The third layer is Data Sharing Infrastructure which addresses IDS (data usage management). The fourth layer is Service Platform/Market Specific Solutions which are addressed by FIWARE. Even though it is open to question if these four layers could be separated so distinctly, the descriptions seems feasible, and the structure is easy to understand.

(3) Initiatives towards international standardization in the future

Among the evaluation methods for cities, there are those which are recognized as international standards such as ISO/TC 268. In order to promote international standardization in the future, judging from the results of the discrepancy analysis between the international standards already recognized and the contents of the implementation in this report, the determination of the need for standardization and the contents of the proposal will be an issue.

[82] https://www.internationaldataspaces.org/wp-content/uploads/2019/11/IDSA_IDS_broschuere_online_191125_v2.pdf

In addition, it is desirable to unify opinions with relevant domestic members in the actual promotion of international standardization. In terms of international standardization of data exchange, collaboration with leading European platforms is also desirable.

9.1.2 Continued curation and development of Smart City reference architecture

Smart City Reference Architecture must be curated and developed reflecting the actual social issues of the region, and it is important to take initiatives to sustain the cycle of utilization, feed-back, curation and management of Smart City reference architecture. For that purpose, it is necessary to establish an organization which actively takes on promoting utilization, and continual and expansive development of the architecture, including such activities as thriving towards adoption as international standards with the aim of overseas expansions in the future.

As there is a limit to what an individual municipality or an individual private company can do in promoting such continual curation and development, it should be undertaken by forming a public-private partnership organization.

Subject matters to be addressed by the organization are described below.

(1) Promotion of Smart City Reference Architecture

Smart City Reference Architecture can only function when municipalities and other organizations which intend to construct Smart City actually utilize it. The organization takes initiatives in such activities as to assist utilization of the reference architecture in the form of promotion and publicity of the architecture, and sharing of the best practices in order to enable municipalities and other organizations to achieve what they strive for.

(2) Curation and management of Smart City Reference Architecture

It conducts continual curation and management of Smart City Reference Architecture based on the experiences and practices gained through Smart transformation, technology development, changes in legal system, etc.

(3) International standardization

It manages coordination with other Smart City related standards formulated by various international standardization organizations, and proposal activities aiming at international standardization in considerations of the overseas expansions of and international cooperation for the Smart City architecture.

(4) Human resources development

As the promotion of Smart City demands design skills, or imagination, and creativity, the collaborations with the academia should be promoted to develop human resources which can actively participate in realization of Smart City using the architecture by amalgamating cultural anthropology or folklore and technology.

9.2 Continued curation and development as City OS

Due to the nature of it being the logically existing IT component, it is necessary to continually develop the context defined as City OS in the Smart City reference architecture in order to accommodate the evolution of IT technology, new IT services implemented one after another, the big data generated by services, and so on.

Although the adoption of advancement in IT component is described under “7. City OS”, this section specifically describes the measures to enable continued curation and development of City OS and the organizations to realize them in the process of implementing Smart City based on City OS.

In this report, the sections of City OS which are closely related to the advancement of IT services are described in sections corresponding to the different measures to enable curation and development of the Smart City reference architecture as a whole, and the actual structure of the organization itself to maintain the architecture is not explained.

9.2.1 City OS ecosystem

In order to realize City OS ecosystem, the system must be open so that various stakeholders are able to participate in the ecosystem easily.

The core group of the ecosystem could be formed city by city but ideally it should be formed across multiple cities. It thereby attracts more participants and enables further creations of new services.

The Atomic service of SynchroniCity is one of the overseas examples already in operation. In the case of the Atomic service, the ecosystem is realized through competitions of various vendors constructing services on the open source City OS as the core based on FIWARE along with various open API known as Minimum Interoperability Mechanism (MIMs). In addition, it is effective to address the likes of data catalog utilizing such mechanisms as Data Marketplace, etc. Similarly, in the case of FIWARE, the ecosystem is realized through registration and sharing of many of the vendor services in the FIWARE catalog. It could be stated from these examples that the measures addressing the realization of City OS ecosystem are of importance in achieving Smart City.

9.2.2 Implementing continued sustainment and development of City OS

As described earlier, in order to continually curate and develop City OS, it is necessary to construct the ecosystem to encourage data utilization. There is a limit to what individual municipality, IT vendor, and others can do to achieve it, and it is expected to require measures by the public-private partnership organization including the vendors possessing professional IT knowledge.

These measures must be conducted in unity with the organizations responsible for continued sustainment and development of Smart City reference architecture.

Some of the specific measures expected to be implemented by the organization are described below.

- Setting up development environment (developers portal, validation environment)

Measures to increase service developers on City OS, and to develop new services

- Measures for data utilization on City OS, and services circulation

1） Set up API catalog

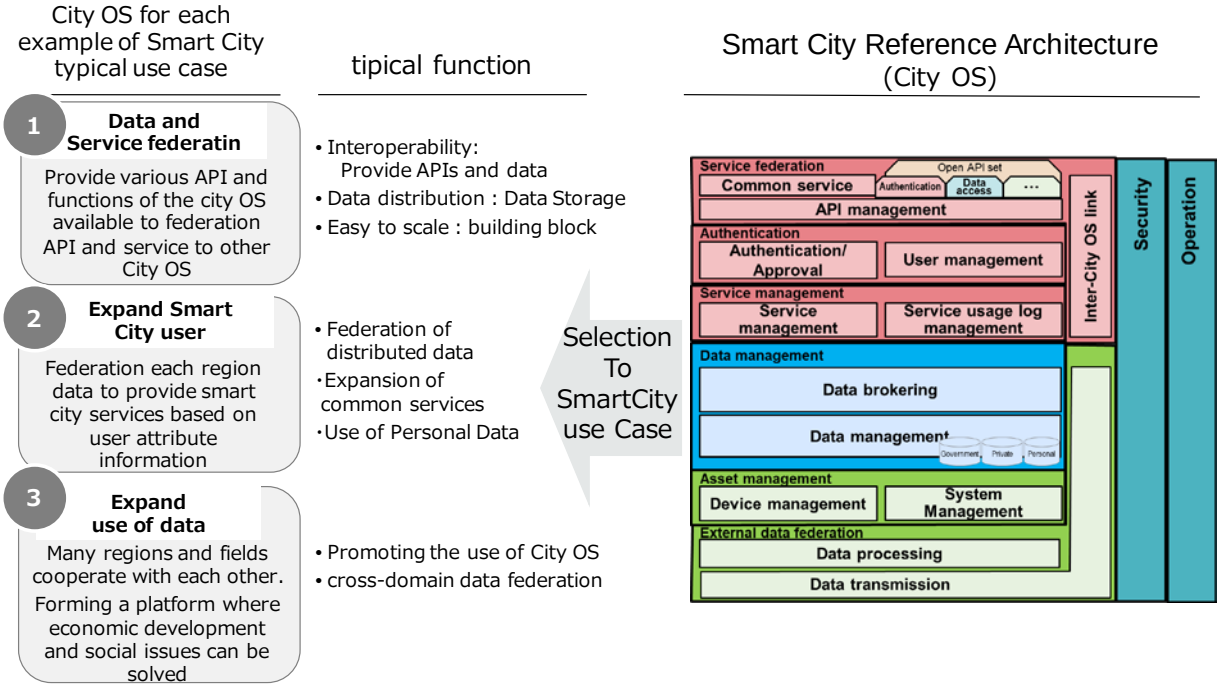
2） Set up data catalog

3） Set up service applications catalog

APPENDIX

Requirements of City OS

As shown in the following figure, it is necessary to implement City OS selecting necessary functions based on issues to be resolved and a future vision to be aimed for in a region. We also show which functions should be selected in City OS for each example of Smart City typical use case.



No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
1	Service federation	Common services	Developer portal site	For City OS users, catalog functions to enable API and data searches & publishing specifications, and console functions to enable evaluation of API, etc. must be provided.	●		

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
2	Service federation	Common services	Bidirectional communication portal site	For residents and municipalities, a function must be provided to enable aggregation, delivery, etc. of region-related services and information. It should be equipped with a function to enable bidirectional communication by connecting residents and municipalities, and residents and Smart City services, utilized for the resolution of issues and the improvement in convenience and quality.		●	
3	Service federation	Common services	Personalize	In order to present Smart City services meeting the preferences of residents, a function must be provided to prioritize the display order of articles reflecting the interest of individual residents.		●	
4	Service federation	Common services	Contents management	A function must be provided to enable creation, delivery, etc. of contents to be published on the portal sites and home pages provided by municipalities. It should be equipped with a campaign management function to enable the measurement of the effects of staged events, mail deliveries, etc.		●	
5	Service federation	Common services	Regional points management	A function must be provided to enable and manage a point program service unique to each region aiming at leading and maintaining residents'			●

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				participation in the regional issues.			
6	Service federation	Common services	Opt-in management	A function must be provided for residents to decide by themselves to designate the permitted extent of the publication of individual personal data to City OS operators and service providers.		●	
7	Service federation	Common services	Visualization/analysis dashboard	A dashboard function must be provided to enable visualization & analysis of the status of the city utilizing the data within and outside City OS for the purpose of resolving regional issues by residents and municipalities. It should be possible to measure the effects of the measures, such as the analysis based on the KGI/KPI set in the strategy.			●
8	Service federation	Open API		※No 54～	●		
9	Service federation	API management	API lifecycle management	Manage the lifecycle (register, refer, update, delete) of City OS API.	●		
10	Service federation	API management	API gateway	Execute API usage restriction, network throughput restriction, aggregation of multiple APIs, etc.	●		
11	Service federation	City OS federation	Authentication federation	Respond to the authentication request from the user based on the user authentication information on the other City OS with federation to the other City OS.	●		

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				It should be provided as a function to enable cross domain authentication federation in accordance with the functional requirement as described in "7.3.2.1 Authentication-related API".			
12	Service federation	City OS federation	Data brokering	Provide the data of other City OS to users by federating with other City OS. It should be noted that this function is equivalent to what is defined in "7.2.4.1 (1) Data brokering". Data exchange between City OSs is enabled by publishing and federating API in accordance with the functional requirements described in "7.3.2.2 Data management-related API".	●		
13	Authentication	authentication & approval	Authentication	Certify legitimacy of the user from eligibility information (user ID, password, biometric information, etc.) stored under "user management", and identify the account.	●		
14	Authentication	authentication & approval	Approval	In association with "user management", permit or restrict the usage limit of various functions of City OS and managed data based on the roles and policies associated with the account.	●		

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
15	Authentication	authentication & approval	Individual authentication	In the case of using personal data, securely confirm the identity by multi-factor authentication (a combination of biometric authentication and individual number card, etc.) * There may be cases in which individual authentication is not implemented on City OS but managed by each respective service.		●	
16	Authentication	authentication & approval	Single sign-on	Enable single sign-on by centralized management of authentication for multiple services federated to City OS. Once authenticated, it should be possible for users not having to be authenticated for each one of the Smart City services federated to City OS, hence one-stop service is realized.		●	
17	Authentication	User management	Account management	Manage authentication information (password) and attributes information (name, organization, etc.) in association with a specific ID identifying the user, and manage ID lifecycle (register, refer, change, delete).	●		
18	Authentication	User management	Role management	Manage a role that defines the group the user belongs to (user, administrator, etc.).	●		
19	Authentication	User management	Policy management	Manage the control policies which define the extent and authority to access City OS,	●		

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				separately from accounts and roles.			
20	Service management	Service management	Service lifecycle management	Manage the lifecycle (register, refer, update, delete) of Smart City services federated with City OS. A list of services managed by City OS should be published to users along with “Service federation”.	●		
21	Service management	Service management	Subscription management	Manage the status of subscription (start & end of usage, change setup for usage authorization) for the Smart City services available for use by users.		●	
22	Service management	service usage log management	Usage log management	Provide a function to store and publish user’s City OS and Smart City service usage logs upon user’s approval.		●	
23	Data management	data brokering	Data storage	Process (register, refer, update, delete) data managed by City OS by federating with “data management”.	●		
24	Data management	data brokering	Data exchange	Broker (register, refer, update, delete) data distributed across other City OSs and other systems.		●	
25	Data management	data brokering	Event processing	Execute real-time processing of the data brokered by City OS in accordance with the pre-defined policies. It hereby becomes possible to provide a mechanism to switch functions dynamically and flexibly between analysis/conversion/processing		●	

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				of the data distributed over within and outside City OS and change in access authorization reflecting the changes in social environment.			
26	Data management	Data management	Data store	In dealing with various data of different characteristics (diversity, update frequency, volumey), appropriately store and utilize data necessary for the resolution of the issues in the region. The data classification includes personal data, real-time data, etc. It should be possible to manage logs to chronologically verify such sequential data as real-time data.	●		
27	Data management	Data management	Unique ID management	Manage ID unique to each piece of data on City OS, and provide a mechanism to enable identification of a particular piece of data out of various data across regions. It is recommended to adopt regional domains, etc., as the unique ID has to be globally unique.	●		
28	Asset management	Device management	Device lifecycle registration	Manage the lifecycle (register/refer/update/delete) of device information (device ID, unique MAC address, etc.)		●	
29	Asset management	Device management	Device status management	Manage and publish device status (operation status, equipment information, etc.) for the devices registered		●	

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
30	Asset management	Device management	Device control (actuation)	Transmit commands to control devices, such as reboot and change operations of the devices connected		●	
31	Asset management	Device management	Device monitoring	Monitor operational-or-non-operational status of the devices connected, or failure incidents transmitted by the system		●	
32	Asset management	Device management	Device authentication	Permit access only from those devices registered in advance		●	
33	Asset management	System management	System lifecycle registration	Manage the lifecycle (register/refer/update/delete) of the federation information of other systems federated to City OS. Also, it should be possible to manage authentication methods and their credentials information, as other systems often require authentication.		●	
34	Asset management	System management	System status management	Manage and publish connection status (operation status, equipment information, etc.) with other systems, for other systems registered.		●	
35	External data federation	Data processing	Data conversion	Convert externally acquired data into the format that City OS can handle. Terms to be converted include vocabulary, format, subject matter, etc. and vary depending on the data to be handled.		●	
36	External data federation	Data processing	Data acceptance (queuing)	Accept data access (register, refer) to accumulate data on City OS. Federated target includes		●	

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				Smart City assets, other systems, etc.			
37	External data federation	Data processing	Data acquisition (crawling)	Regularly crawl other systems and acquire data.		●	
38	External data federation	Data processing	Data complement	Complement missing data in real-time data, etc. and improve data quality. There are various data complement methods, it should be possible to prepare complement method options in order to meet every purpose.		●	
39	External data federation	Data transmission	Protocol conversion	In order to interface with Smart City assets and other systems operated across the region, convert the standard communication protocols into the communication protocol that City OS operates with.		●	
40	External data federation	Data transmission	Cross-sectoral Data search	Search the data distributed over external City OS based on the summarized information of data (data catalog). * To be utilized for cross-sectoral data federation connectors in the future.			●
41	External data federation	data transmission	Cross-sectoral Data exchange control	Control extent of data access by checking data usage authorization based on mutual agreement rules set between City OS and other systems. * To be utilized for cross-sectoral data federation connectors in the future.			●

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
42	External data federation	Data transmission	Cross-sectoral Data exchange record	Record the data exchange logs mutually federated between City OS and other systems, in order to improve data quality through traceability. * To be utilized for federates to cross-sectoral data federation connectors in the future.			●
43	Common function	Security	Authentication	Provide a function to authorize digital access by way of verifying whether the access requester is legitimate or not, for users, Smart City services, other City OS, other systems, IoT devices, etc. which interfaces with City OS. This function is the same as what is defined in the following chapters: - "7.2.2 Authentication". Authentication for users, Smart City services, and other City OSes - "7.2.5 Asset management" Device authentication for Smart City assets	●		
44	Common function	Security	Encryption	Apply security encryption appropriate for each confidentiality level, to the communication by City OS (communication within City OS and communication with the outside world of City OS) and the data managed by City OS.	●		
45	Common function	Security	Unauthorized access prevention	Provide a function to block unpermitted communication (packets with unauthorized IP	●		

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				address and port numbers, etc.) for all the communication by City OS. It is also called a firewall function.			
46	Common function	Security	Unauthorized access detection/interception function	Provide a function to detect and intercept DoS attacks and those attacks targeting the vulnerability of application layer, etc. which cannot be dealt with the unauthorized access prevention function.		●	
47	Common function	Security	Vulnerability management	For software which makes up City OS, information relating to its vulnerability is to be collected and necessary measures such as application of patches as needed are executed. Also, vulnerability test is to be conducted for City OS on a regular basis and countermeasures in accordance with the result are executed.	●		
48	Common function	Security	Log management	Acquire logs of communication and processes carried out by City OS. The acquired logs are to be stored for a specified duration in order to preserve evidences.	●		
49	Common function	Operations	System scalability	Provide a mechanism to allow for continual and easy additions and revision of functions for future in response to the issues to be resolved in the region and the goals to aim at in the future. It should be possible to flexibly accommodate the	●		

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				reconfiguration of functions by building loosely coupled systems via the likes of building block method.			
50	Common function	Operations	Availability	Provide a mechanism for City OS to continuously operate robustly without outage in the event of a failure of City OS. It is important to minimize the impact to users by defining the service level of City OS, prompt detection and recovery of failures, implementing redundancy, etc.	●		
51	Common function	Operations	City OS planning and development management	Plan and develop extension of various functions of City OS in accordance with the service expansion due to the growth of the region, etc. Based on the plan, the implementation plan for new common services and new functions is formulated, and the process of defining the requirements, design, development, test, and transition is managed. It is desirable to adopt not only the traditional waterfall-style development but also the agile-style development process which enables rapid implementation of various functions.	●		
52	Common function	Operations	Service transition management	Formulate and manage the plan to prepare and transition Smart City services and various	●		

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				functions, in the event of going live with various functions of Smart City services and City OS.			
53	Common function	Operations	System operation management	Define management tools and processes for the operation (change management, configuration management, incident management, operation service management, capacity management, etc.) of City OS.	●		
54	Open API	authentication-related API	Authentication/ approval	Execute validation & issuing and disabling of access tokens utilizing qualification information (ID/password, biometric information, etc.) stored in ID management. Restrict specific usage capability based on the pre-registered user authorization. * Use of OAuth is recommended.	●		
55	Open API	authentication-related API	Attributes acquisition	Acquire attributes information of the authenticated user. * Use of OpenID Connect is recommended.	●		
56	Open API	authentication-related API	Personal authentication	In the case of authentication which requires high level of security such as the case using personal data, it is required to provide an authentication method which confirms the identity by multi-factor authentication with a combination of biometric authentication, individual number card, etc.		●	

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				The authentication of individuals may not be implemented on City OS but on each respective service.			
57	Open API	data access-related API	Data access	Provide APIs to manage data lifecycle (register, refer, update, delete) incooperation with data management of City OS.	●		
58	Open API	data access-related API	Publish/ Subscribe	Provide APIs to transmit a notice of change to notifying parties in real-time when the changes are made to the data stored on City OS. Also provide APIs to manage lifecycle (register, refer, update, delete) of the notices (conditions, notifying party, etc.).		●	
59	Open API	data access-related API	Data brokering	Provide APIs to manage lifecycle (register, refer, update, delete) of the location of distributed data.		●	
60	Open API	data access-related API	Personal data (sensitive personal information) delivery and acceptance	Provide this function in the case when personal data (sensitive personal information) is shared with Smart City services and other City OSs. It is required to confirm the identity prior to delivering personal data. As the method for confirmation of identity, multi-factor authentication with a combination of device authentication, biometric authentication, individual number		●	

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				card, etc. is to be used. Also provide functions to restrict the timeframe and the destination of data delivery. When the data is delivered, the usage log must be kept.			
61	Open API	Service federation	Service federation (payment transaction, etc.)	Provide functions to allow open access to APIs for services on City OS as APIs on City OS.			●
62	Open API	Service federation	Regional point management	Provide functions to execute addition/subtraction/inquiry processing, etc. of regional points associated with users.			●
63	Open API	Service federation	Opt-in management	Manage opt-in/opt-out options for the City OS users to determine which services are allowed to use the personal user information. It should be capable of managing the type of information to be provided. It should be capable of managing the opt-in/opt-out logs associated with the personal information transactions.		●	
64	Open API	Service federation	Catalog management	Execute registration/acquisition/search processing for the metadata stored in the catalog function (data catalog) of the developers portal site. * Reference: Basics for implementation of federations between data exchange platforms, published by Ministry		●	

No	L1	L2	L3	Description	Type of Usecase		
	Function Set	Functional Blocks	Individual Function		①	②	③
				of Internal Affairs and Communications.			
65	Interface	Smart City asset/other system federation	One-way communication	Enable data access via common one-way communication protocol (HTTP/HTTPS). * For data access, please refer to data access-related API.	●		
66	Interface	Smart City asset/other system federation	Bidirectional communication	Enable data access of and actuation to Smart City assets via common bidirectional communication protocol (MQTT, WebSocket, etc.)		●	
67	Interface	Smart City asset/other system federation	Network interface	Network required for federations to Smart City assets varies in characteristics (communication distance, communication speed, power consumption, etc.) depending on the issues to be resolved or specifications of the connected devices. In addition to wide-area network (WAN) like 4G/5G, etc., low-power and wide-area network (LPWAN) such as the one used for IoT/M2M communications like LPWA, etc. should also be utilized.		●	

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