IEC SRD 63233-1

Edition 1.0 2022-06

SYSTEMS REFERENCE DELIVERABLE

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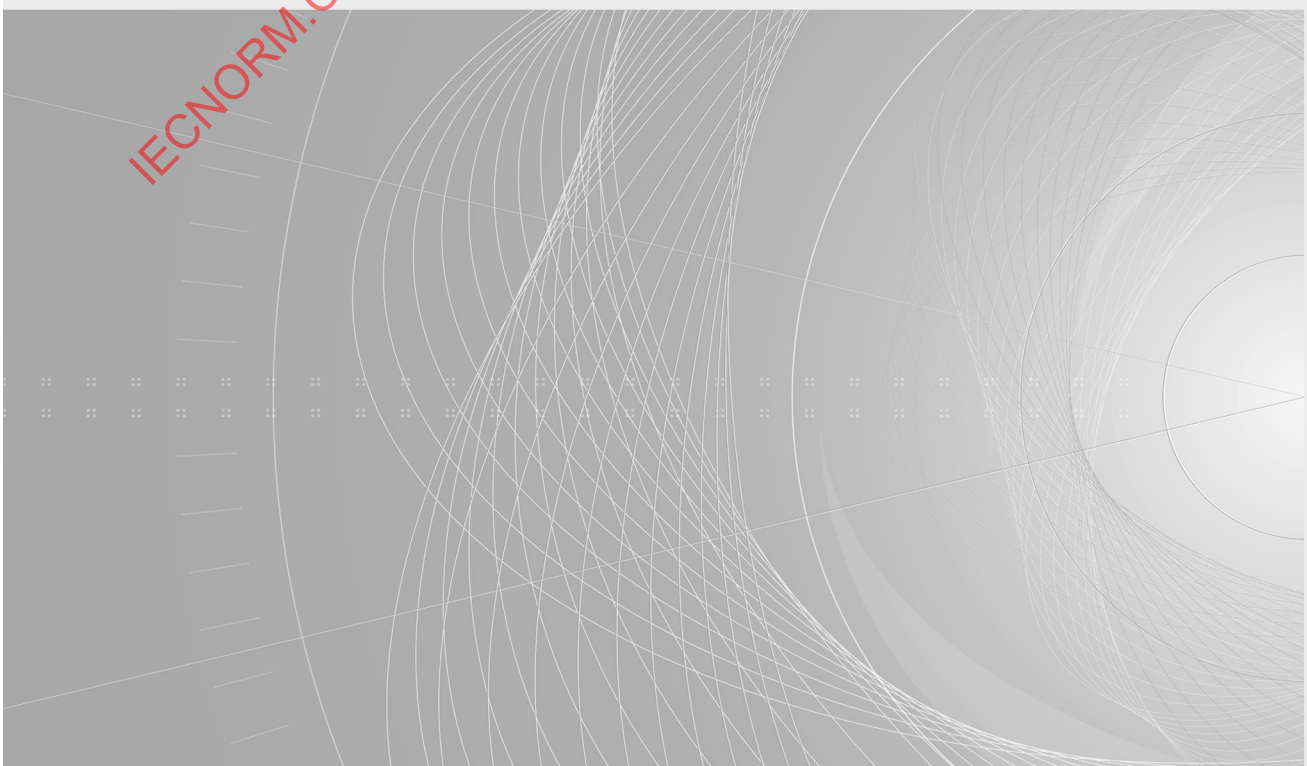
Smart city standards inventory and mapping – Part 1: Methodology



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SMART CITY STANDARDS INVENTORY AND MAPPING –

Part 1: Methodology

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The text of this Systems Reference Deliverable is based on the following documents:

Draft	Report on voting
SyCSmartCities/232/DTS	SyCSmartCities /254/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Systems Reference Deliverable is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC SRD 63233 series, published under the general title *Smart city standards inventory and mapping*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

International, and regional standards development organizations (SDOs), as well as consortia and national standardization institutions, have been vigorously promoting the development of smart city standards. But different organizations focus on standards at different levels of smart cities and the effective coordination in the standards development process needs to be strengthened. At present, there is no overall architectural understanding of standards of smart cities.

The smart city standards inventory and mapping project was initiated to provide a systematic approach to retrieve and map the standards of smart cities on smart city reference architectures, models or frameworks and provide fundamental support for the collaborative work of standard-setters and users. Standards maps are the practical base for helping SDOs and users to identify directly and instantly the standards that are needed for any aspects of smart cities (citizen services, city infrastructure, governance, etc.). Standards maps also help in identifying the standardization gap in the ecosystem.

SMART CITY STANDARDS INVENTORY AND MAPPING –

Part 1: Methodology

1 Scope

This part of IEC SRD 63233, which is a Systems Reference Deliverable, describes a systematic approach to carry out smart city standards analysis based on the IEC systems approach. It gives methods for developing smart city standards inventory and mapping.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
domain
field of special knowledge

[SOURCE: ISO 10241-1:2011, 3.3.1]

3.2
stakeholder
individual or organization having a right, share, claim or interest in a system or in its possession of characteristics that meet their needs and expectations

[SOURCE: ISO/IEC 12207:2017, 3.1.59]

3.3
use case
specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system

[SOURCE: ISO/IEC 19505-2:2012, 16.3.6]

3.4
standard
deliverable, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context

[SOURCE: IEC 60050-901:2013, 901-02-02, modified – In the definition, "document" has been replaced by "deliverable".]

3.5
standard implementer
component that enables the provision of services based on the standards

EXAMPLE A developer who needs to comply with SQL commands would be an implementer of that standard.

[SOURCE: ISO/IEC TR 20547-5:2018, 3.2.1]

3.6
standard user
person or component that interacts with a service via the standard or that accepts/consumes/decodes data represented by the standard

[SOURCE: ISO/IEC TR 20547-5:2018, 3.2.2]

4 Systematic approach to standards inventory building and mapping

Typically, establishing a standards map, for example for an IEC smart grid standards map, starts with an architectural model that can then identify points within the architecture model for where standards apply, and then perform an inventory on those points. The inventory should identify relevant SDOs, and then sub-areas within each SDO that apply to the content of the smart city architecture model, and then identify the standards to be applied to each point or area of that architecture model.

There will be a series of architecture models of different views to describe the reference architecture of smart city and SCRA (Smart Cities Reference Architecture discussed in the project development of IEC 63205), and there are also existing architecture models built by other SDOs. The systematic approach in this document is proposed for developing a mapping tool for smart cities. This tool will be designed to establish a common smart city standards pool and automatically or at least half-automatically identify relevant standards that apply to the content of a specific architecture model from this common standards repository. This will avoid repetitive labour to identify the standards applied to each architecture model from multiple different SDOs from scratch.

This document focuses on understanding and mapping the relevant standards for the various parts of the smart city ecosystem and whether they are contributing to or counteracting the objectives identified in market analysis.

Figure 1 shows the steps to perform inventory and mapping and depicts concepts about standards mapping as a context for understanding the practice of standards analysis.

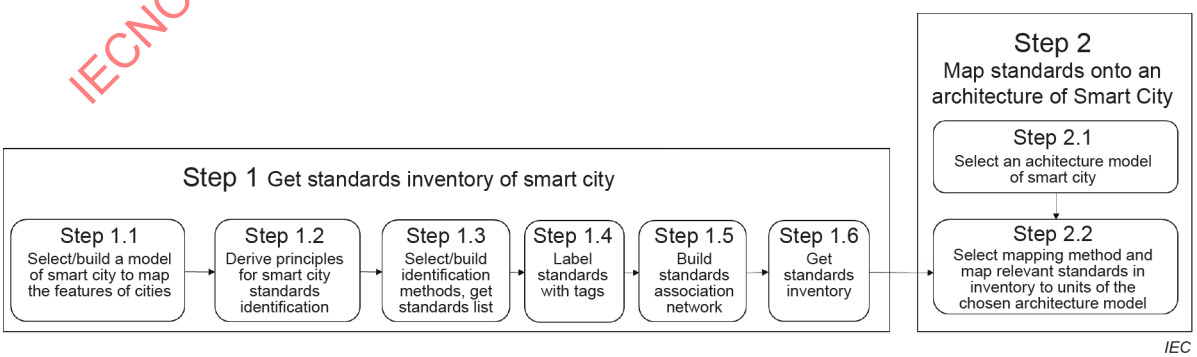

Figure 1 – Steps to perform inventory and mapping

– Step 1: Inventory of smart city standards
  - Step 1.1: select or build a model of smart city to map the features as a system by which principles for standards identification (Step 1.2) can be derived. This model can be chosen from the present models of smart cities.
  - Step 1.2: derive principles from the model in step 1.1 for identification of standards relevant to smart cities and set up criteria for smart city standards.
  - Step 1.3: select a method to identify the existing smart city standards following the principles in step 1.2 and get the list of existing smart city standards.
  - Step 1.4: label the existing standards with tags. The tags are derived from the standard's title, scope and content and used for standards mapping.
  - Step 1.5: build a standards association network described as in 6.4.1, based on the correlation between every existing two standards. It is used as a unified relationship structure of smart city standards to carry out standards mapping.
  - Step 1.6: get the standards inventory with tags for smart city standards and the standards association network.
– Step 2: Map standards onto an architecture of smart city
  - Step 2.1: for a map developer with a perspective of smart city, select an architecture model of smart city to map relevant standards onto. The architecture model can be one of IEC SCRA or others from SDOs such as developed in ISO/IEC 30145, ISO 37101 and ISO 37106.
  - Step 2.2: select a mapping method to get a standards map in which standards developers and users can find each particular standard in its corresponding section.

5 Smart city standards inventory building

5.1 Smart city standards identification

5.1.1 Guiding principles

The critical first step of city standards mapping is to identify relevant standards, noting these can number hundreds or even thousands worldwide. Identification should follow a smart city "standard" structure model described in Figure 2.

When developing the basic structure for the inventory model, common goals need to be abstracted to address the governance lifecycle of city level operational management. This then ensures consideration for the system development lifecycle across a smart city.

The model then identifies city services needed to lead and manage a smart city. Then common service delivery best practice methods can be identified and harmonized, recognizing the possibility that each operates in its own silo.

The model then lists inter- and intra-collaboration methods that can create horizontal linkages between service delivery silos. Stakeholders will take benefit from the created links. The corresponding linkages should be traced in service management (Figure 2).

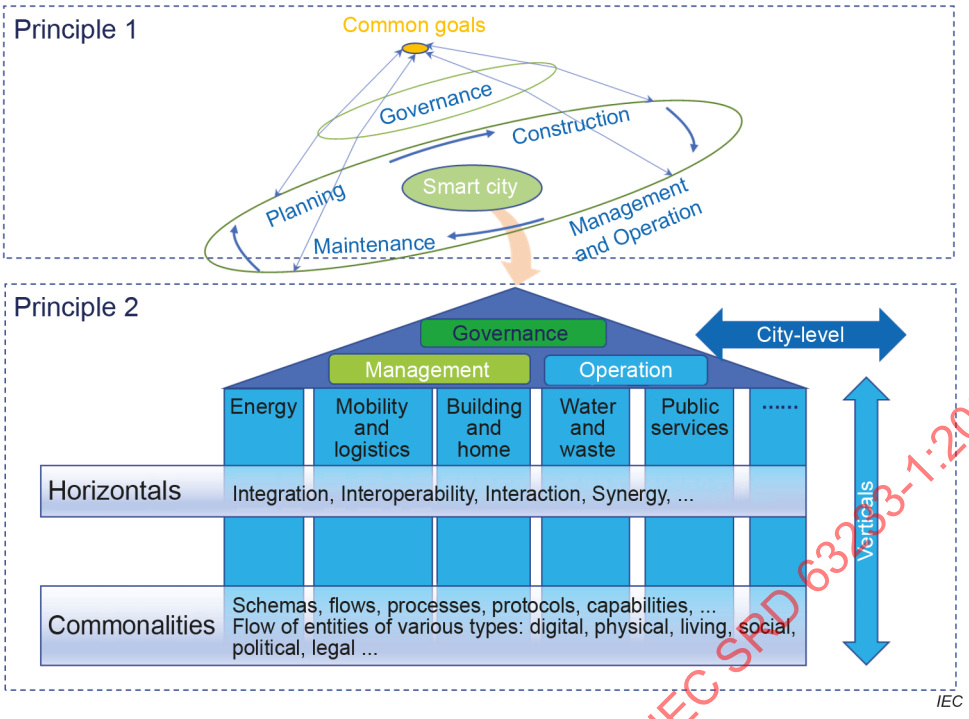

Figure 2 – A basic structure for smart city standards inventory

– Principle 1: Lifecycle of smart city evolution

  Principle 1 derives from consideration of time-dimension of a city.

  Cities are typically governed and evolve by following a lifecycle process of city design, development and operation which involves the engagement of multiple stakeholders to identify requirements and needs and deliver to expected outcomes. This level of prescriptive governance can vary but should ideally align to best practice standards and be one that is repeatable as cities evolve.

  Governance covers all the stages from planning to maintenance. A typical set of governance is a hierarchy of directives, policies, corporate standards and guidelines.

– Principle 2: City structure

  Principle 2 derives from consideration of space-dimension of a city.

  A smart city is a complicated system. It is a "system of systems", containing a variety of vertical domains that co-exist alongside and in certain cases between one another.

  Physical city structures and characteristics are expensive, disruptive and time consuming to change. Any physical constraints need to be factored into evolutionary thinking.

  City-level standards provide a city-wide perspective, whilst vertical-level standards consider specific domains such as a service the city consumes such as utilities.

  Vertical domains have points of interconnection to cooperate horizontally across cities. These interconnects are facilitated by designing communications protocols that are open between trusted service platforms to share data, processes and controls in secure ways that are either mutually beneficial or benefit the city as a whole.

  Commonalities within domains are common characteristics that are either required for compliance or are deemed to be expected best practice or a cultural norm such as approach to use and promotion of digital data and services, occupational health and safety standards, building development standards, financial audit and risk acceptance and regulatory compliance.

5.1.2 Criteria for smart city standards

A smart city is viewed as "a system of systems" in order to translate complexity into understandable, structured best practice-based standards.

a) Common smart city descriptors

   A set of reference standards and templates that describe a smart city and typical design and operation using terminology, framework, architecture, etc.

b) City-wide standards

   A set of standards on city-wide administration best practice, for example, governance, design, development, operation, management and maintenance.

   These can include city-wide goals for quality of life, service delivery, sustainability and resilience standards following a traditional lifecycle of governance, planning, management, operation and maintenance.

c) Smart city cross boundary service exchange standards

   A set of standards on system communication and control for secure and trusted data exchange and the interoperability or integration, or both, of systems for mutual benefit or the benefit of some or all parts of a city. For example, adopting open standards for data model, formats and protocols for interoperability between systems.

d) Standards supporting a system in a smart city

   A set of standards specific to one system that operates within a smart city system, for example, smart grid, smart transportation, smart water.

   These standards define requirements to support the system and ideally align to broader smart city goals.

5.1.3 Correlation analysis method

Based on the whole structure of the established basic model and the existing smart city terms and concepts widely recognized by SDOs, the semantic searching keywords for inventory can be extracted. The searching keywords can be used to form the queries to identify the smart city related standards. The existing architectures and maps proposed by some SDOs can also be used to modify the keywords system. An example is given in Annex A. The criteria to judge what standards are included in the smart city standards inventory are given in 5.1.2.

5.1.4 Use case based method

5.1.4.1 General

Use case method can be used to outline typical scenarios that a role can experience when interacting with a system to achieve a specific goal. It is good for expressing requirements at a high level with real-life relevance. Following the methodology given in IEC 62559-2, the procedure to identify reference standards is displayed as shown in Figure 3.

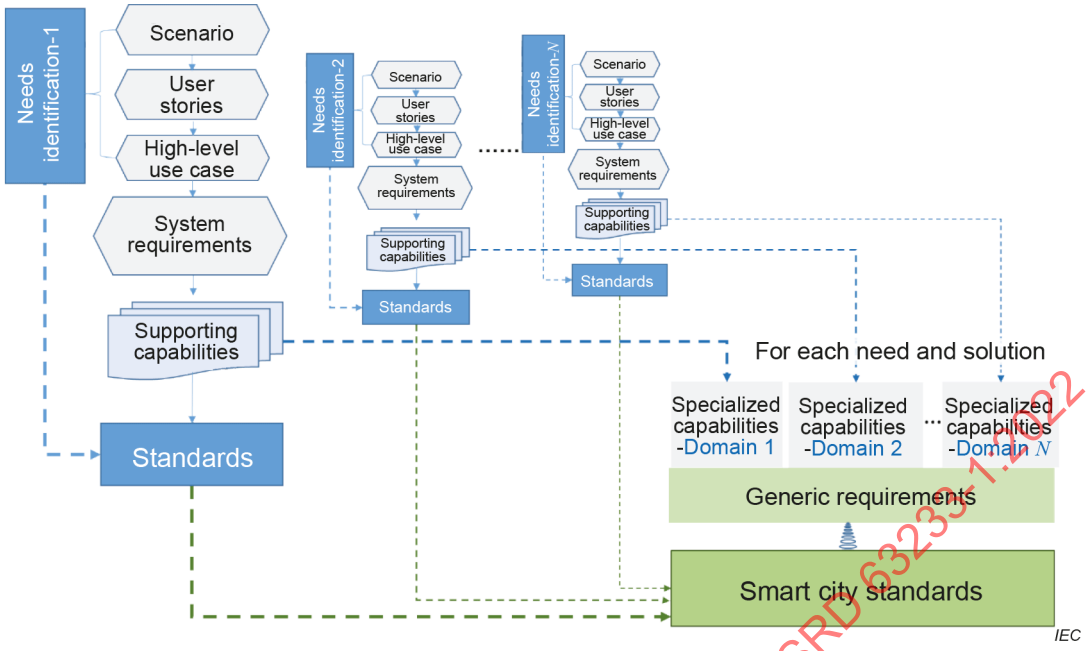

Figure 3 – Procedure to identify relevant standards using use case analysis

5.1.4.2 Identify the use case scenario

A use case scenario includes settings, actions, plots and events. Some information might be needed to characterize and outline it, like area or domain or zone, name, primary actors, and conditions.

5.1.4.3 Develop user story

Within a scenario, it is possible to create a user story to specify users' interactions with particular aspects of the system. The point of developing user stories is to create simple and short stories about a user's interaction with the system. User stories are usually created to ensure a representation of actors' goals and requirements of the system. The common template for user stories looks as follows:

As a <type of user>, I want <some goal> so that <some reason>

The "so that <some reason>" part is optional but can serve the purpose of highlighting the end user's motivation and the end goal of the interaction with the system.

5.1.4.4 Transform user story into high-level use cases

A high-level use case describes an innovative, abstract function without including the actual technical details. The goal of performing this transformation is to learn the priority needs for smart city. The needs could be summarized by actors' goals and system requirements. To be detailed, high-level use cases might comprise information like area, scope, objectives, actor list, pre-conditions, steps, post-conditions, etc.

5.1.4.5 Extract system requirements from use case summaries

Translate abstract summaries into specific functional and non-functional system requirement statements to accurately articulate the target need. For example, "The system shall …".

5.1.4.6 List supporting capabilities

List the capabilities supporting the realization of system requirements.

5.1.4.7 Identify standards relevant to the system requirements

List the reference standards used in this use case.

5.1.4.8 Select standards most relevant to supporting the smart city enablers or "system of systems" concept, or both

Smart city use cases and reference standards can vary from specific to partially linking use of a particular device to a smart city domain.

To restrict the inventory to a manageable list, standards should be chosen that support the requirements of two or more systems that require linkages to automatically interconnect, communicate and interoperate. The criteria to judge these standards are given in 5.1.2.

5.2 Structured catalogue of smart city standards

5.2.1 Basic principles of structuring the standards catalogue

The following basic principles need to be considered when categorizing the smart cities standards.

a) Stakeholders targeted

   Stakeholders in smart cities have their roles and activities, which define the scope of the relevant needs and standards.

b) City viewed as a system of systems

   A city can be viewed as an ecosystem that includes the physical structure, the living entities that it contains and the flow of interactions and information (ISO 37105:2019, 4.2). Smart city is seen as a complex system that includes social system, digital system and physical system of a city to be used together as a complementary whole when developing a smart city system to the concerns and interests of different stakeholders (IEC SRD 63235:2021, 4.2; ISO/IEC 30182:2017, 2.14). These systems operate in combination to make a city as a whole system. The requirements of standards should be considered for these systems in a city and the whole system of a city.

c) Inclusion of standards for smart elements

   Use of data and integrated technologies enabling a city smart to transform city services and improve quality of life, sustainability and resilience. The standards for these smart elements should be included.

These basic principles can guide the categorizing of standards on the city system level, and also can guide the categorizing of standards relevant to a system in a smart city, for example, public heath emergencies management.

5.2.2 Vocabulary for classification of standards

5.2.2.1 Recommended vocabulary

Several methods can be used to categorize standards. For example, ICS (International Classification for Standards) code is used to distinguish standards by different fields. Strategic, process and technical standards are classified according to different actor roles. Standards belonging to different topics are categorized based on city function such as living, education, health care and tourism.

In the standards mapping process, the standard tag is the variable to establish the relationship between standards and elements of an architecture model. The tag of a standard can be composed of several keywords, and it needs to reflect the technical field to which a standard belongs, the object of standardization and the technical features of the object. Therefore, it is recommended to mark standards using keywords with semantic meaning which depict characteristics of the standards, to more easily identify and establish linkages between standards and map in the smart city context.

5.2.2.2 Composition and format of a tag

A tag of a standard should meet the following recommendations.

– A keyword of a standard's tag should be a word or a phrase, such as security, management system. And the keyword should be from terminologies or standardized terms in the field of smart city.

– A tag of a standard should at least contain keywords that reflect the object of standardization and the technical feature specified by the standard text. And a standard tag should as far as possible include keywords that reflect the technical field of smart city to which the standard belongs.

– The number of keywords of a standard's tag is not limited. But the keywords should be independent of and complementary to each other, and their meanings should not be repetitive and intersected.

The above composition design of the tags of standards can form a natural hierarchical structure of the standards. Annex B gives an example of tags of some standards. For the subsequent process of mapping the existing standards to an architecture model, it is also very advantageous for the standards to match the architecture models of different granularity, which is beneficial to match the standards and the different levels of the architecture model.

5.2.2.3 Principles for selecting keywords of a tag

Tag keyword selection of a standard needs to comply with the following principles.

– A tag is uniquely identified.

– When standardization bodies regulate the technical features of the same standardization object, keywords that reflect the differences in its technical features are added to the standard tag to denote the revision made.

5.2.2.4 Tag keywords extraction method

a) Extracting keywords from the standard title

According to the composition rules of the standard title, a title consists of several independent elements that are as short as possible, that is, the guiding element, the main element, and the supplementary element. The three elements that make up a standard title are arranged from general to specific. Guide element (shoulder title) indicates the technical field or category to which the standard belongs, that is, the technical field to which the standardized object belongs. Subject element (main heading) represents the subject matter discussed in a particular area of expertise, for example, the object that needs to be standardized. Supplementary element (subtitle) indicates the specific technical features of the object of standardization.

The standard title with these three elements makes it easy to extract standard tag keywords. If the actual standard title information is not sufficient, the key text range can expand to the standard scope and standard body.

Take ISO 37101:2016 as an example, whose title is "Sustainable development in communities – Management system for sustainable development – Requirements with guidance for use". "Sustainable development in communities" is the guide element, which indicates the technical field in smart city. "Management system for sustainable development" is the subject element, which is the object needing to be standardized in this standard. "Requirements with guidance for use" is the supplementary element, which indicates the technical features of the standardization object. Therefore, the keywords of the tag of ISO 37101:2016 can be sustainable development, management system, requirement and guidance.

b) Keyword automatic labelling

Keyword allocation: choose suitable keywords for the tag of a standard. The terms in smart city concept system can be used as a keyword candidate set.

A smart city is a system of systems that covers all the elements of a smart city from the perspective of the whole city. Although a concept system of a smart city can focus on different relationships between different application needs and concepts, the concept system includes all elements of a smart city. Therefore, in this document, a tag for each standard and a standard label system, using the standardized concept in the concept system, is established according to the standard's two core elements: standardized object and standardized content. This standard label system can be used as an operational means for subsequent standards mapping.

Keyword extraction: if the smart city concept system is not available, choose existing keyword extraction methods, such as machine learning, to establish a keyword candidate set and extract keywords in the scope and text of the standard.

5.3 Maintenance and update of standards inventory

With more and more standards related to smart city developed, the standards inventory needs maintenance and update in time.

For flexibility, the identified smart city standards should be stored in a database, which comes to be a smart city standards repository.

a) Conditions to be maintained
   1) global information for standards inventory;
   2) backup of the data;
   3) edit permissions.

b) Situations to be updated
   1) update of the standard status, such as from "under development" to "published";
   2) addition of new standards, newly approved or newly retrieved;
   3) deletion of the withdrawn standard and the replaced standard;
   4) reconstruction of associations between standards.

c) Principles
   1) Continual improvement principle: regularly update standards data and their relationships.
   2) Consistency principle:
      i) maintain the consistency of standards data and the physical standards;
      ii) maintain the consistency of the standards data itself;
      iii) the global standards inventory information should be dynamically changed with the addition and withdrawal of standards.
   3) Standards data should be checked after updating to ensure the correctness of the update.

d) Process

Maintenance and update shall satisfy the following.

   1) Check standards inventory, tags and the association network regularly, and guarantee that they are available and reachable.
   2) Track the status and content changes of standards in the inventory and update in time.
   3) Update interval time of inventory should not be longer than 12 weeks according to the general process of standard development.
   4) Mark new standards added to the inventory following the principles and methods in 5.2.2 and the standards association network.

5) Arrange a dedicated person to maintain and update standards inventory and association network, record the date and version, and keep a good update record.

6 Smart city standards mapping

6.1 Mapping process

Mapping refers to the "corresponding" relationship between elements of two or more sets. The mapping corresponding relationship is between the requirements specification set and standards set to determine suitable standards to apply.

The appropriate architecture model for standards mapping should be selected and determined according to the user's need of a standards map. If necessary, a new architecture model needs to be established. A visual representation of standards mapping is a useful way to understand complex relationships, interconnections and linkages.

6.2 Map user and need analysis

Different groups have different purposes and needs.

a) Standardization groups need to identify overlaps with other groups and standards gaps, and find relevant material to reference.

b) Smart city administrators need to plan solutions for their cities and gain an overview of existing standards for them.

c) Technical advisors need to plan solutions for their cities and gain an overview of existing standards for them.

d) Regulators and officials (and their consultants) need to quickly gain an overview of existing standards in any given domain, independent of source, perhaps as part of a gap analysis.

e) Scientists and professionals active in any of the topic areas desire an overview of the current solutions available.

f) Citizens desire to propose options for smart city solutions.

6.3 Architecture model selection for standards mapping

Standards are mapped on an architecture model of a smart city architecture view from the perspective of specific system concerns. A concern pertains to any influence on the system of smart city in its environment, including developmental, technological, business, operational, organizational, etc. The concern of stakeholders determines the architecture model used for standards mapping.

6.4 Tags based clustering method for mapping

6.4.1 Standards association network

There are intricate relations among smart city standards, such as two standards belonging to the same sub-area of smart city, or several standards having the same standardization object that specifies different technical features of the object. A complex network is established by using these relations as characteristic variables for visualizing the relationships of smart city standards. It can be used as a unified relationship structure for implementation of standard mapping to different perspectives. Subclause 6.4.1 gives the process to establish the standards association network using relations between every two standards.

The smart city standards association network is characterized by a large number of nodes and undirected edges between nodes. Nodes represent smart city standards. The edge between nodes is the number of same keywords in the tags of these two standards; in other words, if two standards have the same keywords, the two standards are related, the edge is established.

The process steps of establishing a smart city standard relationship network are as follows.

a) Each node in the network is noted with a standard number. For the i-th standard, retrieve is carried out from $j = i + 1$ standard (i = 1, 2, …, $N - 1$, $j = i + 1$, $i + 2$, …, N, where N is the total number of standards in this network). If two standards have one or more same keywords in their tags, the number of the same keywords is noted as the edge weight and is recorded into a matrix A in which it is placed in row i, column j as $a_{i,j}$. S_n denotes the n-th standard. A is an upper triangular adjacency matrix with zero elements on the diagonal as shown in Formula (1):

$$A = \begin{array}{c} \begin{matrix} S_1 & S_2 & S_3 & \cdots & S_n \end{matrix} \\ \begin{bmatrix} 0 & a_{1,2} & a_{1,3} & \cdots & a_{1,n} \\ & 0 & a_{2,3} & \cdots & a_{2,n} \\ & & \ddots & & \vdots \\ & & & 0 & a_{n-1,n} \\ & & & & 0 \end{bmatrix} \end{array} \begin{matrix} \\ S_1 \\ S_2 \\ \\ S_{n-1} \\ S_{n-2} \end{matrix} \quad (1)$$

b) Convert the adjacency matrix into a table with four columns: source, target, weight, and type. The values of "source" and "target" are standard codes. And "source" is related to another standard "target". The range of weight is 1 to n, which indicates the number of the same keywords in the two standards' tags. n represents the maximum number of the same keywords. The value range of "type" is "undirected", which indicates that there is no direction in the relationship between the two standards. A part of the table is shown in Table 1.

Table 1 – Relationship of standards

source	target	weight	type
ETSI TR 103 376 (2016-10)	ETSI TR 103 118 (2015-08)	1	undirected
ETSI TR 103 376 (2016-10)	IEEE P2413	1	undirected
ETSI TR 103 376 (2016-10)	Y.4102/Y.2074	1	undirected
ETSI TR 103 376 (2016-10)	Y.4103/F.748.0	1	undirected
ETSI TR 103 376 (2016-10)	Y.4111/Y.2076	1	undirected

c) Convert the above table into a complex network diagram (as shown in Figure 4) using a visualization tool which can show the links between nodes. In the network, the larger the node, the greater the degree of the node, which means the standard has relations with more standards. The thicker the edge between the two nodes, the greater the weight between the two nodes, which means the greater the number of same keywords between the two standards.

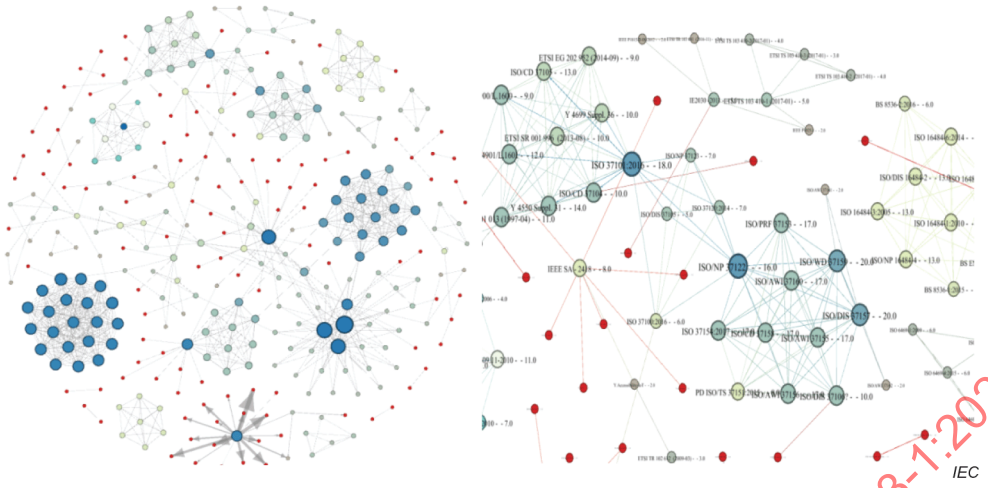

Figure 4 – A standards association network diagram

Use some community detection method to analyse the network structure, which can be used as testing or correction for the mapping onto an architecture model to verify that the relevant standards are searched for completeness and to correct the mapping.

6.4.2 Mapping relationships

Fundamentally, mapping means establishing affiliated relationships between an architecture model (including subsystems and their elements) and standards. Therefore, the mapping method, from the implementation point of view, is to match the standards using tags into the minimum unit element of the architecture model.

The standards associated network in 6.4.1 shows technology-centric relationships of these standards. A standard tag is composed of the standardization object as the core keyword and also covers the technical field and technical features to which the object belongs. Therefore, the relationship represented by the standards association network diagram is a comparison of whether two standards belong to the same field, adopt the same technology, target the same technical features, and specify the same technical index. The standards association network reflects the relationship between the content itself of two standards. The network is a form that emerges after the integration of these relationships and contains many small tree structures or clusters. This structure is naturally suitable for the partitioning of multiple units in an architecture model of a system. The process to carry out mapping is as follows.

a) Select an architecture model of smart city to map standards onto. The architecture model can be from Smart Cities Reference Architecture (being developed by the project of IEC 63205) or others such as developed in ISO/IEC 30145, ISO 37101 and ISO 37106.

b) Use the smallest unit of the architecture model as the lowest-level searching strategy to search standards by the keywords of tags in the standards association network and put the searching result into the corresponding area of the smallest unit of the reference system.

c) Take the granularity of the one level higher unit as a high-level searching strategy and search for the related standard in the standards association network to amend the result of b).

6.5 Visualization of standards map

For standards maps to be easy to view and use, they need to be visualized in some formats, such as the following:

– tree – such as smart city mindmap set up by CEN/CENELEC SSCC (Smart and sustainable cities and communities);

– block diagram – such as smart city ICT framework in ISO/IEC 30145 and smart city platform-based implementation framework (see IEC 63205 which is under development);

– network – such as standards association network in some kinds of relationship.

– other visual formats built by users.

Annex A
(informative)

Searching keywords and query combinations for smart city standards inventory

Table A.1 shows an example of searching keywords and Table A.2 shows the rationale for query combinations.

Table A.1 – Keywords for inventory

First-layer set	Second-layer set	Category	Keyword	Description
set A		city planning	planning	Describe the phase/condition where the object under study is.
			guideline	
		governance	strategy	
			digital policy	
		construction	construction	
		management	management	
		operation	operation	
		maintenance	maintenance	
set B	set B.1 city level	citizen	citizen	Describe what the object is.
			human factors	
		city	city	
			community	
	set B.2 verticals	urban mobility	transportation	
			parking	
			street light	
			vehicle	
			logistics	
		energy management	energy	
			electric	
			grid	
			power	
			gas	
			water	
			wind	
			solar	
		education-related	education	
			training	
			learning	
			campus	
		water management	water	
			meters	
		farming	farming	
		entertainment	entertainment	
			leisure	
		health care	health care	
		waste management	waste	
		environment	environment	
			nature	
		building	building	
			home	

First-layer set	Second-layer set	Category	Keyword	Description
set C	Horizontals	security	security	Describe the performance and characteristics of the object.
			cryptography	
			signature	
			privacy	
			public key	
			password	
		safety	safety	
		resilience	resilience	
		quality	quality	
		integration	integration	
		interaction	interaction	
		collaboration	collaboration	
		connectivity	connectivity	
		accessibility	accessibility	
		interoperability	interoperability	
		synergy	synergy	
		entity	entity	
			uniformity	
set D	commonalities	digital	ICT	Describe common techniques and principles shared by different verticals
			architecture	
			simulation	
			service	
			application	
			system	
			platform	
			cyber or Internet	
			modelling	
			computing	
			storage	
			data	
			code	
			software	
			access	
			interface	
			IoT	
			media	
			geographic information	
		physical	facility	
			infrastructure	
			meter	
			actuator	
			sensor	
			device	
		living	living	
			residence or inhabitancy	
			livelihood	
		social	society	
			culture	
			registries	
			census	
		political	policy	
			statement	
		legal	regulation	
			law	
		financial	finance	
			economy	

Table A.2 – Query combinations

Query combination	Rationale	Example
set B.1	This query examines standards which are on the city level. These examined smart city standards could be city, community or citizen related. Citizen-related keywords can be used to find standards that indicate the civil service and participation level.	city (set B.1) ISO/IEC 30182:2017 Smart city concept model – Guide to establishing a model for data interoperability
set B.2	This query explores smart city related standards of a specific vertical domain.	education (set B.2) IEEE Std 1484.13.1™-2012 IEEE Standard for Learning Technology – Conceptual Model for Resource Aggregation for Learning, Education, and Training
set A + set B.1	This query extracts the standards which describe the stage or condition (set A) where the object under study is. These standards are on the city level and could be city, community or citizen related (set B.1).	planning (set A) + city (set B.1) BSI/PD 8101:2014 Smart cities. Guide to the role of the planning and development process
set B.1 + set C	This query aims to find standards which describe the performance and characteristics of the object on the city level.	community (set B.1) + security (set C) IEEE Std 1888.3™-2013 IEEE Standard for Ubiquitous Green Community Control Network: Security
set B.2 + set C	This query aims to find standards which describe the interaction (set C) among different verticals (set B.2).	interoperability (set C) + energy (set B.2) + electric (set B.2) IEEE Std 2030™-2011 IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads
set B.2 + set D	This query is performed to find standards which describe the common technical and social basis (set D) shared by different verticals (set B.2).	education (set B.2) + environment (set B.2) + data (set D) ISO/IEC 19778-2:2016 Information technology – Learning, education and training - Collaborative technology – Collaborative workplace - Part 2: Collaborative environment data model