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Information technology — City data model —

Part 2:
City level concepts

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Contents

Page

Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

A list of all parts in the ISO/IEC 5087 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

The intended audience for this document includes municipal information systems departments, municipal software designers and developers, and organizations that design and develop software for municipalities.

Cities today face a challenge of how to integrate data from multiple, unrelated sources where the semantics of the data are imprecise, ambiguous and overlapping. This is especially true in a world where more and more data of interest are being openly published by various organizations. A morass of data is increasingly becoming available to support city planning and operations activities. In order to be used effectively, it is necessary for the data to be unambiguously understood so that it can be correctly combined, avoiding data silos. Early successes in data "mash-ups" relied upon an independence assumption, where unrelated data sources were linked based solely on geospatial location, or a unique identifier for a person or organization. More sophisticated analytics projects that require the combination of datasets with overlapping semantics entail a significantly greater effort to transform data into something useable. It has become increasingly clear that integrating separate datasets for this sort of analysis requires an attention to the semantics of the underlying attributes and their values.

A common data model enables city software applications to share information, plan, coordinate and execute city tasks, and support decision making within and across city services, by providing a precise, unambiguous representation of information and knowledge commonly shared across city services. This requires a clear understanding of the terms used in defining the data, as well as how they relate to one another. This requirement goes beyond syntactic integration (e.g. common data types and protocols), it requires semantic integration: a consistent, shared understanding of the meaning of information.

To motivate the need for a standard city data model, consider the evolution of cities. Cities deliver physical and social services that have traditionally operated as silos. If, during the process of becoming smarter, transportation, social services, utilities, etc. were to develop their own data models, the result would be smarter silos. To create truly smart cities, data need to be shared across these silos. This can only be accomplished through the use of a common data model. For example, "Household" is a category of data that is commonly used by city services. Members of Households are the source of transportation, housing, education and recreation demand. This category represents who occupies a home, their age, their occupations, where they work, their abilities, etc. Though each city service can potentially gather and/or use different aspects of a Household, much of the data needs to be shared.

Supporting this interoperability among city datasets is particularly challenging due to the diversity of the domain and the heterogeneity of its data sources. The purpose of this document is to support the precise and unambiguous specification of city data using the technology of ontologies[1],[2] as implemented in the Semantic Web.[3] By doing so it will:

— enable the computer representation of precise definitions, thereby reducing the ambiguity of interpretation;

— remove the independence assumption, thereby allowing the world of Big Data, open-source software, mobile apps, etc., to be applied for more sophisticated analysis;

— achieve semantic interoperability, namely the ability to access, understand, merge and use data available from datasets spread across the Semantic Web;

— enable the publishing of city data using Semantic Web and ontology standards; and

— enable the automated detection of city data inconsistency, and the root causes of variations.

With a clear semantics for the terminology, it is possible to perform consistency analysis, and thereby validate the correct use of the document.

Figure 1 identifies the three levels of the ISO/IEC 5087 series. The lowest level, defined in ISO/IEC 5087-1, provides the classes, properties and logical computational definitions for representing the concepts that are foundational to representing any data. The middle level, defined in ISO/IEC 5087-2 (this document), provides the classes, properties and logical, computational definitions for representing urban-specific concepts common to all city services but not specific to any service. The top level provides the classes, properties and logical, computational definitions for representing service specific concepts that are used by other services across the city. For example, ISO/IEC TS 5087-3:—[1)] is intended to define the transportation concepts. In the future, additional parts will be added to the ISO/IEC 5087 series covering services such as education, water, sanitation, energy, etc.

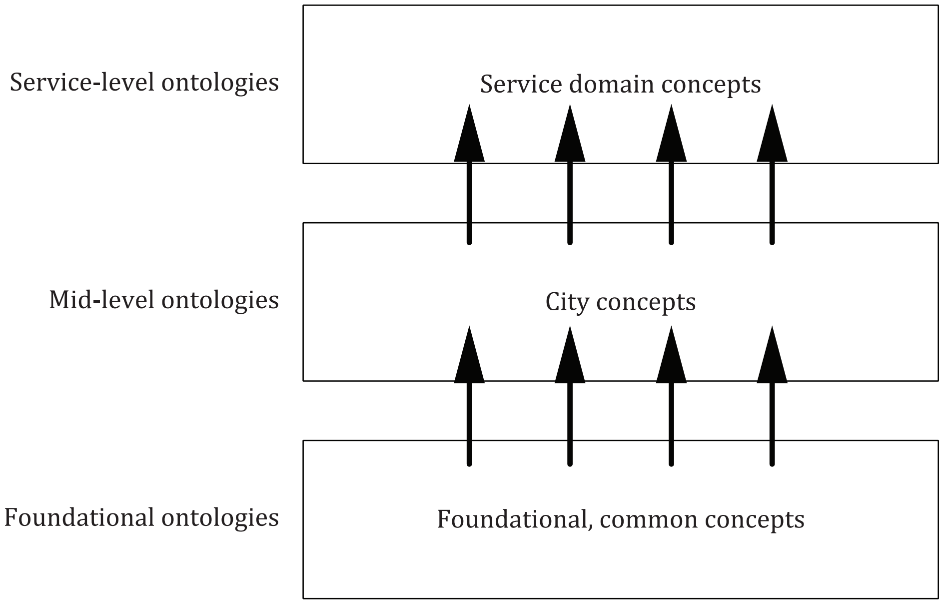

Figure 1 — Stratification of city data model

Figure 2 depicts example concepts for the three levels.

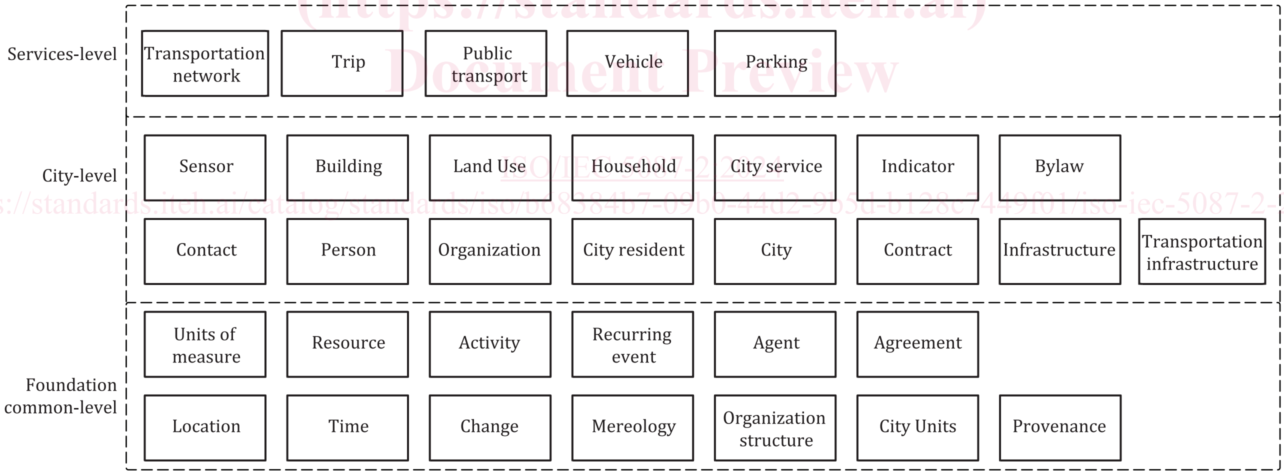

Figure 2 — Example concepts for each level

There are other existing standards that overlap conceptually with some of the terms presented in this document. The relationship between this document and existing standards that address similar or related concepts is identified in Annex A.

1) Under preparation. Stage at the time of publication: ISO/IEC AWI TS 5087-3:2024.

Information technology — City data model —

Part 2:
City level concepts

1 Scope

This document defines an ontology for city-level concepts defined using terms specified in ISO/IEC 5087-1. City-level concepts are used to represent data that is shared across multiple services and stakeholders in the city. City-level concepts are distinguished by their data being read and updated by multiple city services and stakeholders.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

SEMANTIC SENSOR NETWORK ONTOLOGY, W3C Recommendation 19 October 2017, https://www.w3.org/TR/vocab-ssn/

ISO/IEC 5087-1, *Information technology — City data model — Part 1: Foundation level concepts*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
cardinality
number of elements in a set

[SOURCE: ISO/TS 21526:2019, 3.11]

3.2
description logic
DL
family of formal knowledge representation languages that are more expressive than propositional logic but less expressive than first-order logic

[SOURCE: ISO/IEC 21972:2020, 3.2]

3.3
manchester syntax
compact, human readable syntax for expressing Description Logic descriptions

[SOURCE: https://www.w3.org/TR/owl2-manchester-syntax/ (Copyright © 2012. World Wide Web Consortium. https://www.w3.org/Consortium/Legal/2023/doc-license).]

3.4
measure
value of the measurement (via the numerical_value property) which is linked to both Quantity and Unit_of_measure

[SOURCE: ISO/IEC 21972:2020, 3.4]

3.5
namespace
collection of names, identified by a URI reference, that are used in XML documents as element names and attribute names

Note 1 to entry: Names may also be identified by an IRI reference.

[SOURCE: ISO/IEC 21972:2020, 3.5, modified — Note 1 to entry has been added.]

3.6
ontology
formal representation of phenomena of a universe of discourse with an underlying vocabulary including definitions and axioms that make the intended meaning explicit and describe phenomena and their interrelationships

[SOURCE: ISO 19101-1:2014, 4.1.26]

3.7
ontology web language
ontology language for the Semantic Web with formally defined meaning

Note 1 to entry: OWL 2 ontologies provide classes, properties, individuals and data values and are stored as Semantic Web documents.

[SOURCE: ISO/IEC 21972:2020, 3.7, modified — The preferred term "OWL 2 Web Ontology Language" has been replaced by the preferred term "ontology web language".]

3.8
quantity
property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

Note 1 to entry: Quantities can appear as base quantities or derived quantities.

EXAMPLE 1 Length, mass, electric current (ISQ base quantities).

EXAMPLE 2 Plane angle, force, power (derived quantities).

[SOURCE: ISO/IEC Guide 99:2007, 1.1, modified — NOTEs 1 to 6 have been removed; new Note 1 to entry and two EXAMPLEs have been added.]

3.9
Semantic Web
W3C's vision of the Web of linked data

Note 1 to entry: Semantic Web technologies enable people to create data stores on the Web, build vocabularies, and write rules for handling data.

[SOURCE: https://www.w3.org/standards/semanticweb/ (Copyright © 2015. World Wide Web Consortium. https://www.w3.org/Consortium/Legal/2023/doc-license).]

3.10
unit_of_measure
definite magnitude of a quantity, defined and adopted by convention and/or by law

[SOURCE: ISO/IEC 21972:2020, 3.9]

4 Abbreviated terms and namespace prefixes

AAFC	Agriculture and Agri-Foods Canada
CGRM	Canadian Government Reference Mode
CLUMP	Canada Land Use Monitoring Program
DL	description logic
IPCC	International Panel on Climate Change
IRI	international resource identifier
LBCS	Land Based Classification Standards
OWL	ontology web language
RDF	resource description framework
RDFS	resource description framework schema
UML	Unified Modelling Language

The following namespace prefixes are used in this document:

— activity: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/Activity/

— agent: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/Agent/

— agreement: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/Agreement/

— building: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Building/

— bylaw: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Bylaw/

— city: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/City/

— cityresident: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/CityResident/

— cityunits: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/CityUnits/

— code: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Code/

— contact: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Contact/

— contract: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Contract/

— genprop: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/GenericProperties/

— geo: http://www.opengis.net/ont/geosparql#

— i72: http://ontology.eil.utoronto.ca/ISO21972/iso21972/

— infras: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Infrastructure/

— landuse: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Landuse/

— org: http://www.w3c.org/ns/org#

— org_s: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/OrganizationStructure/

— org_city: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Organization/

— owl: https://www.w3.org/2002/07/owl#

— partwhole: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/Mereology/

— person: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Person/

— rdf: https://www.w3.org/1999/02/22-rdf-syntax-ns#

— rdfs: https://www.w3.org/2000/01/rdf-schema#

— recurringevent: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/RecurringEvent/

— resource: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/Resource/

— loc: https://standards.iso.org/iso-iec/5087/-1/ed-1/en/ontology/SpatialLoc/

— service: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/CityService/

— transinfras: https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/TransportationInfrastructure/

— time: https://www.w3.org/2006/time#

— xsd: https://www.w3.org/2001/XMLSchema#

The formalization of the classes in this document is specified using the following table format, which is a simplification of description logic (DL) where the first column identifies the class name, the second column its properties and the third column each property's range restriction It shall be read as: The <Class> is a subClassOf the conjunction of the associated <property>s with their <value>s. Range restrictions are specified using the Manchester syntax. For example, Table 1 specifies that Agent is an rdfs:subClassOf the intersection of (Person or Organization) and org:memberOf only Organization.

Table 1 — Example formalization of the Agent class

Class	Property	Value Restriction
Agent	rdfs:subClassOf	Person or org_s:Organization
	org_s:memberOf	only Organization
	individual	{joe, frank}

CamelCase is used for specifying classes, properties and instances. For example, "legalName" instead of "legal_name". The first letter of a class name is capitalized. The first letter of a property and instance name are not capitalized. An instance of a class shall satisfy the class's definition. The instance's properties and values shall satisfy the value restrictions of the class it is an instance of.

The formalization of the properties in this document is done similarly, using the following table format that allows for the identification of properties and their sub-properties, inverse properties, or other characteristics. It is to be read as: The <property> is <characteristic> of <value>, or simply the <property> is <characteristic> if no value is applicable. For example, in Table 2 hasPrivilege is a sub-property of the agentInvolvedIn property. Characteristics are specified using the Manchester syntax.

Table 2 — Example property formalization

Property	Characteristic	Value (if applicable)
hasPrivilege	rdfs:subPropertyOf	agentInvolvedIn
	Irreflexive	

In the case of DL definitions of classes where the simplified table representation is insufficient, the DL specification will be supplied as an addition to the content in the table.

The patterns defined in this document have also been implemented in OWL and made available online. The location of these encodings is identified in Annex C.

5 Unique identifiers

All classes, properties and instances of classes have a unique identifier that conforms to Linked Data/ Semantic Web standards. The unique identifier is an IRI. When using ISO/IEC 5087-2 (this document) in an application, a class is identified by the IRI for the pattern of which it is a member, followed by the class name. In the Agent example in Clause 4, the Agent class's unique identifier would be:

https://standards.iso.org/iso-iec/5087/-2/ed-1/en/ontology/Agent/Agent

Breaking the IRI down:

— "5087" identifies the series number

— "-2" identifies the part number

— "ed-1" indicates that the class is defined in edition 1 of the document

— "en" indicates that the class is defined in a pattern implemented in English

— The first "Agent" identifies the Agent Pattern

— The second "Agent" identifies the Agent class within the Agent Pattern

The IRI can be shortened using the prefix's defined in Clause 4:

agent:Agent

where agent: is the prefix for the Agent Pattern.

Properties are identified in the same manner. The IRI's of individuals created by an application of ISO/IEC 5087-2 would have IRIs unique to the application.

6 City-level ontologies

6.1 General

Much as the foundational concepts defined in ISO/IEC 5087-1 are common across arbitrary domains, concepts also exist that are generic across all cities. These concepts define the domain upon which city services operate. They are common for all cities but not specific to any one service. The city data model defines sixteen city-level ontologies, or patterns, to capture these concepts. These are described in the following subclauses. The content of these ontologies defines terms needed to capture these concepts at a generic level. They are not intended to be exhaustive, nor to capture the variety of classification systems and taxonomies that are potentially of interest for different user groups. The common terms defined here provide the foundational, common language that may be extended by different users as required.

The patterns presented here shall conform to the foundational concepts defined in ISO/IEC 5087-1. Specific references to foundational content defined in ISO/IEC 5087-1 are identified in text descriptions of pattern imports, as well as through the explicit identification of terms from ISO/IEC 5087-1.

The cardinality restrictions specified in the pattern formalizations are weakened intentionally in many cases to support the pragmatic implementation of the ISO/IEC 5087 series. For example, while common sense dictates that all persons should have at exactly one legal name, in practice there are many possible applications of city data where persons may be represented with no name at all. Users of this document are encouraged to extend and strengthen these restrictions where possible or warranted by the application.

6.2 Code pattern

6.2.1 General

The Code pattern provides a structure to address the challenge of value enumeration with a general approach. In city data there are many classes of things that are intended to be instantiated using a set list of values (e.g. classification systems). However, these values can change based on application or context. In such cases it is not desirable for a standard to prescribe a restricted set of possible values which will potentially not satisfy the needs of all applications. On the other hand, leaving the values completely openended provides no utility for interoperability. The Code Pattern provides an intermediate solution for this challenge by introducing a generic set of classes and properties that can be used to extend such classes to define various classification systems in an integrated way.

Instead of enumerating value sets for classes in this document, values can be defined with an associated Code that specifies additional metadata about the value and its origins. This allows these classes to be extended with various value-systems as required by a particular application, while providing the necessary information to support interpretation and integration as needed.

6.2.2 Key classes and properties

The key classes and properties are formalized in Table 3 and Table 4, respectively. A code is introduced to capture the possible value of an object, according to a predefined system of values. It has the following key properties:

— **definedBy**: identifies the Organization that defined the code.

— **specification**: specifies a URI where the definition of the code can be found.

— **hasIdentifier**: identifies a unique identifier for the code.

— **genprop:hasName**: specifies a name or title for the code.

— **genprop:hasDescription**: specifies a description of the code.

6.2.3 Formalization

Table 3 — Key classes in the Code pattern

Class	Property	Value restriction
Code	definedBy	max 1 org_s:Organization
	specification	only xsd:string
	genprop:hasIdentifier	max 1 xsd:string
	genprop:hasName	only xsd:string
	genprop:hasDescription	only xsd:string

Table 4 — Key properties in the Code pattern

Property	Characteristic	Value (if applicable)
hasCode	rdfs:range	Code

6.3 Infrastructure pattern

6.3.1 General

The Infrastructure pattern defines the concepts needed to capture various types of city infrastructure, such as buildings and roads. The Infrastructure pattern reuses the Spatial Location pattern (from ISO/IEC 5087-1) in order to capture the location of these Infrastructure Elements.

It is extended by the Building pattern, and the Transportation Infrastructure pattern. It can be extended with other types of infrastructure as required.

6.3.2 Key classes and properties

The key classes are formalized in Table 5. An Infrastructure Element is a generic representation of a city structure of interest. All Infrastructure Elements may have a defined, where locations are spatial geometries as defined in ISO/IEC 5087-1. The Mereology pattern (from ISO/IEC 5087-1) is also reused in order to support