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Title City Data Model: Part 3 Service Level Concepts

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Draft	**Date**	**Changes**
2	3 Dec 2021	• Removed reference to Observations and Loop Detectors in last paragraph of section 5.1
	4 Jan 2022	• Addressed TC204 comments • Added property to Vehicle for engine type, distinguishing combustion and electric
	29 Oct 2023	• Updated content to reflect new core model as agreed upon between TC204 and WG11

Foreword

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This document was prepared by the Joint Working Group between Technical Committee 204 and the 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.

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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 is being openly published from various organizations. A morass of data is increasingly becoming available to support city planning and operations activities. In order to be used effectively, the data must 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 traditionally have operated as silos. If during the process of becoming smarter, transportation, social services, utilities, etc. were to develop their own data models, then we would have smarter silos. To create truly smart cities data must be shared across these silos which 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. It represents who occupies a home, age, occupations, where they work, abilities, etc. Though each city service can gather and/or use different aspects of a Household, much of the data needs to be shared with each other.

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 standard.

Figure 1 identifies the three levels of the ISO/IEC 5087 series. The lowest level, defined in ISO/IEC 5087-1:2023, 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 5087-2:2024, 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 5087-3 (this document) defines 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.

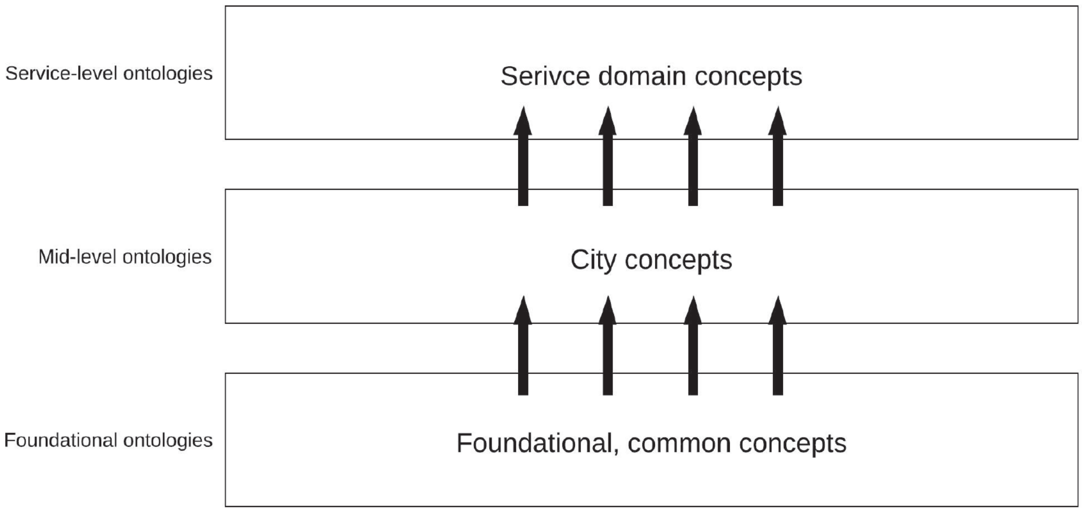

Figure 1— Stratification of city data model

Figure 2 depicts example concepts for the three levels.

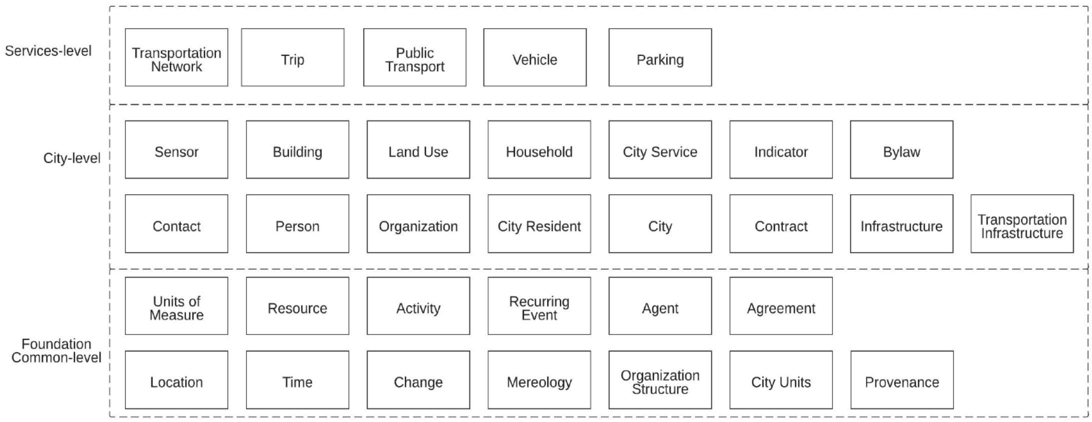

Figure 2 — Example concepts for each level

There are other existing standards that overlap conceptually with some of the terms presented in this document. The relationship between ISO/IEC 5087-3 and existing standards that address similar or related concepts is identified in **Error! Reference source not found.**.

Information technology — City data model— Part 3: Service level concepts - Transportation

1 Scope

This document defines an ontology for service-level concepts defined for transportation using terms specified in ISO/IEC 5087-1:2023 and ISO/IEC-5087-2:2024. City-level concepts defined in ISO/IEC-5087-2:2024 and service-level concepts defined in ISO/IEC 5087-3 are distinguished by city-level concepts' data being read and updated by multiple city services and stakeholders, whereas service-level concepts should be read but not necessarily written 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 documents (including any amendments) applies.

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

ISO/IEC 5087-1:2023, *Information technology — City Data Model — Part 1: Foundation Level Concepts*

ISO/IEC 5087-2:2024, *Information technology — City Data Model — Part 2: City Level Concepts*

3 Terms and Definitions

For the purposes of this document, the terms and definitions given in ISO/IEC/IEEE 24765:2017, ISO/TS 14812:2022, ISO/IEC 5087-1:2023 and 5087-2:2024 as well as the following 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
TBD

4 Symbols and Abbreviated Terms

DL	description logic
OWL	ontology web language
RDF	resource description framework
RDFS	resource description framework schema
IRI	international resource identifier

The following namespace prefixes are used in this document:

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

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

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

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

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

— 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/

— transnet: https://standards.iso.org/iso-iec/5087/-3/ed-1/en/ontology/TransportationNetwork/

— 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#

5 Conventions

The formalization of the classes in this document is specified using the following table format, which is a simplification of 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. Value restrictions are specified using the Manchester syntax. For example, Table 1 specifies that Agent is a subclass of the intersection of (Person or Organization) and org:memberOf only Organization. Value restrictions are interpreted as follows:

- "only Organization" is interpreted as the value of the property in the context of the Agent class is restricted to being subclasses or instances of the class Organization.
- "some Organization" is interpreted as the value of the property org_s:memberOf in the context of the Agent class is restricted to having at least one value that is a subclass or instance of the class Organization.
- "min 1 Organization" is interpreted as the value of the property org_s:memberOf in the context of the Agent class is restricted to having at least one value.
- "max 2 Organization" is interpreted as the value of the property org_s:memberOf in the context of the Agent class is restricted to having at most two values.
-

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 D.

6 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 5087-3 (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 5, the Agent class’s unique identifier would be:

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

Breaking the IRI down:

— “5087” identifies the series number

— “-1” 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 IRI’s unique to the application.

7 Service-Level Ontologies for Transportation

7.1 General

The service-level documents of the ISO/IEC 5087 series provide representations for concepts that are used by services that operate in the city context. These concepts may be used (consumed) by multiple different city services and stakeholders, but typically only generated by transportation services.

The patterns defined in the service-level documents of the ISO/IEC 5087 series conform to the foundational and city-level concepts defined in ISO/IEC 5087-1 and ISO/IEC 5087-2, respectively. Specific references to content defined in ISO/IEC 5087-1 and ISO/IEC 5087-2 are identified in text descriptions of pattern imports, as well as through the explicit identification of terms from ISO/IEC 5087-1 and ISO/IEC 5087-2.

7.2 Transportation Network Pattern

The Transportation Network Pattern models the core concepts involved in describing a transportation network. This includes an identification of both physical and administrative characteristics. The most general class is that of the NetworkElement, which can be further classified as one of several types of NetworkElements.

A key feature of this pattern is the formalization of the hasProperPart relationship from a NetworkElement to another NetworkElement. This allows for a representation of networks at multiple levels of detail.

7.2.1 Key Classes & Properties

The key classes and properties are formalized in Table 3 and Table 4, respectively.

7.2.2 Key classes and properties

Junction

A Junction is a TransportNode that allows a traveller to connect from one PathLink to another.

NetworkElement

A NetworkElement represents any element of a transport network. It can be a part of another NetworkElement and can be decomposed into smaller NetworkElements. Each NetworkElement is characterized with a unique identifier.

Path

A Path is a NetworkElement that represents the curvilinear length of a transport route that is identified by a specific designator. It is a generalized class that can be specialized into mode-specific terms (e.g., road, rail line). It is a type of TravelledWay, as defined in ISO 5087-2.

Each Path is defined as being a part of at least one TransportNetwork and can be decomposed into PathLinks and PathSections. Paths are identified with a unique designator.

PathLane

A PathLane is a NetworkElement that is a portion of Path intended to accommodate a single line of moving material entities (e.g., vehicles) along its length. A PathLane is a part of at least one TransportNetwork, at least one PathSegment, and is only parts of a PathSegment, PathLink, Path, PathSection, and TransportationNetworks.

PathLink

A PathLink is a NetworkElement that represents a contiguous length of a Path between two TransportNodes of operational or managerial significance. It is a type of a TravelledWayLink, as defined in ISO 5087-2. Each PathLink is a part of at least one TransportNetwork and at least one Path. A PathLink can only be a part of a Path, a PathSection, and a TransportNetwork. A PathLink can be composed of only PathSegments. A PathLink starts from one TransportNode and connects to a second TransportNode. A PathLink can be described as the allowed directions of travel (e.g., forward from the first node to the second node, reverse from the second node to the first, bi-directional, closed, etc.).

For example, a PathLink can be defined from one signalized intersection to the next or from one bus stop to the next.

PathSection

A PathSection is a NetworkElement that represents an aggregation of one or more PathLinks that jointly represent a contiguous length of a Path that shares the same management and operational strategies. A PathSection is a type of a PathSection, as defined in ISO 5087-2. Each PathSection is part of at least one TransportNetwork and at least one Path. It may only be parts of TransportNetworks and Paths. A PathSection consists of only PathLinks.

For example, a PathSection can be used to represent the portion of a Path that uses the same traffic signal coordination strategy. It can also be used to represent a bus line or subway line.

PathSegment

A PathSegment is a NetworkElement that represents a contiguous length of a PathLink characterized by the same physical characteristics. A PathSegment is a type of a TravelledWaySegment, as defined in ISO 5087-2. Each PathSegment is a part of at least one TransportNetwork and of at least one PathLink. A PathSegment can only be a component part of PathLinks, Paths, PathSections, and TransportNetworks.

For example, a PathLink can be defined to connect two TransportNodes. If the number of lanes change in the middle of the PathLink, the unique physical characteristics of each component part of the PathLink can be defined by defining separate PathSegments.

Road

A Road is a paved Path and is a type of Road, as defined in ISO 5087-2.

For example, a Road can be a paved path for vehicles or a paved path for pedestrians.

RoadLink

A RoadLink is a paved PathLink and is a type of RoadLink, as defined in ISO 5087-2. A RoadLink can be characterized by its capacity, the number of lanes defined in the link, the speed limit for the link, and the average travel time required to traverse the link.

TransportNetwork

A TransportNetwork is a NetworkElement that is a collection of other network elements that jointly represent a coherent network of paths along which entities (e.g., vehicles, pedestrians) of a specified mode can operate.

TransportNode

A TransportNode is a NetworkElement that represents a node on the transport network that can be used to designate an end to a link or to join links. Each TransportNode is a part of at least one TransportNetwork. A TransportNode is characterized by ingress and egress PathLinks.

Status

An NetworkElement may have a status that specifies the status of the node, e.g.,Open, Closed, The hasStatus property links to an instance of Status which in turn specifies the period of time for the status using both a period of time representation and separate hasStartTime and hasEndTime properties that use xsd DateTime formats. The value of the hasCode property is an instance of the Code class which can refer to a unique identifier in any existing taxonomy node/link stati.

7.2.3 Formalization

Table 3 — Key classes in the Transportation Network pattern

Class	Property	Value Restriction
NetworkElement	rdfs:subClassOf	geo:Feature
	partwhole:hasProperPart	only NetworkElement
	~~spatialloc:hasLocation~~	~~only spatialloc:Location~~
	partwhole:properPartOf	only NetworkElement
	genProp:hasIdentifier	xsd:string
	hasStatus	Only Status
TransportNode	rdfs:subClassOf	NetworkElement
	partwhole:properPartOf	some TransportNetwork
	ingress	some PathLink
	egress	some PathLink
TransportNetwork	rdfs:subClassOf	NetworkElement
Path	rdfs:subClassOf	NetworkElement
	rdfs:subClassOf	transinfras:TravelledWay
	partwhole:properPartOf	some TransportNetwork
	partwhole:hasProperPart	only (PathLink or PathSection)
	designator	xsd:string
PathSection	rdfs:subClassOf	NetworkElement
	rdfs:subClassOf	transinfras:PathSection
	partwhole:properPartOf	some TransportNetwork
	partwhole:properPartOf	some Path
	partwhole:properPartOf	only (Path or TransportNetwork)
	partwhole:hasProperPart	only PathLink
PathLink	rdfs:subClassOf	NetworkElement
	rdfs:subClassOf	transinfras:TravelledWayLink
	partwhole:properPartOf	some TransportNetwork
	partwhole:properPartOf	some Path

	partwhole:properPartOf	only (Path or PathSection or TransportNetwork)
	partwhole:hasProperPart	only PathSegment
	allowedDirections	only LinkDirection
	to	Exactly 1 TransportNode
	from	Exactly 1 TransportNode
PathSegment	rdfs:subClassOf	NetworkElement
	rdfs:subClassOf	transinfras:TravelledWaySegment
	partwhole:properPartOf	some TransportNetwork
	partwhole:properPartOf	some PathLink
	partwhole:properPartOf	only (PathLink or Path or PathSection or TransportNetwork)
PathLane	rdfs:subClassOf	NetworkElement
	partwhole:properPartOf	some TransportNetwork
	partwhole:properPartOf	some PathSegment
	partwhole:properPartOf	only (PathSegment or PathLink or Path or PathSection or TransportNetwork)
Road	rdfs:subClassOf	Path
	rdf:subClassOf	transinfras:Road
RoadLink	rdfs:subClassOf	PathLink
	rdf:subClassOf	transinfras:RoadLink
	numLanes	some xsd:nonNegativeInteger
	capacity	some xsd:nonNegativeInteger
	speedLimit	only cityunits:Speed
	travelTime	only cityunits:Duration
Junction	rdfs:subClassOf	TransportNode
Status	hasTime	exactly 1 time:DateTimeInterval
	hasStartTime	exactly 1 xsd:DateTime
	hasEndTime	exactly 1 xsd:DateTime
	hasCode	Only Code

Table 4 — Key properties in the Transportation Network pattern

Property	Characteristic	Value (if applicable)

7.3 Parking Pattern

7.4 Curb Pattern

Appendix A: Code Pattern

The Code pattern, defined in ISO/IEC 5087-2:2024 is replicated here for convenience.

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 open-ended 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.

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 some 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.

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

Annex A
(informative)

Example Use Cases

Annex B
(informative)

Relationship to existing standards

TC204 relevant standards

7.5 OpenDrive.org

http://www.opendrive.org/project.html

7.6 CityGML

7.6.1 Scope

CityGML is an XML-based standard for representing 3D city models. Target application areas identified include: "urban and landscape planning; architectural design; tourist and leisure activities; 3D cadastres; environmental simulations; mobile telecommunications; disaster management; homeland security; vehicle and pedestrian navigation; training simulators and mobile robotics." It is intended to capture the data necessary to generate 3D portrayals in appropriate tools, providing not only geometry but data regarding surface characteristics and objects of interest (e.g. buildings, water bodies).

7.6.2 Relevance

7.6.3 Data Mappings

7.7 INSPIRE

7.7.1 Scope

The INSPIRE directive is aimed at supporting the sharing of and access to spatial data throughout the EU, particularly those that may have an impact on the environment. INSPIRE aims to create an infrastructure to achieve this, part of which includes the specification of data models in UML. These specifications are defined according to 34 data themes, ranging from Addresses, to Geology, to Human Health and Safety.

7.7.2 Relevance

7.7.3 Data Mappings

7.8 37166: Smart community infrastructures—Urban data integration framework for smart city planning (SCP)

7.8.1 Scope

37166 "focuses on the integration and application of heterogeneous data from urban infrastructure systems, e.g. water, transport, energy and waste etc., so as to support smart city planning. It builds a data framework that involves possible multi-source common data through standardized data integration and sharing mechanism."

7.8.2 **Relevance**

37166 is a data framework that involves possible multi-source common data through standardized data integration and sharing mechanism. Although it refers to different categories of data, such as smart grid, transportation, and environment, it does not provide any explicit data models, hence of no relevance to 5087.

Annex C
(informative)

Location of Pattern Implementations

The patterns defined in this document are implemented as OWL files, available online at the following locations:

– Transportation Network Pattern:

Annex D

References

[1] T. R. Gruber, "A translation approach to portable ontology specifications," *Knowledge acquisition,* vol. 5, no. 2, pp. 199-220, 1993.

[2] M. Grüninger and M. S. Fox, "Methodology for the design and evaluation of ontologies," 1995.

[3] T. Berners-Lee, J. Hendler, and O. Lassila, "The semantic web," *Scientific american,* vol. 284, no. 5, pp. 28-37, 2001.

[4] S. Cox, A. Cuthbert, R. Lake, and R. Martell, "Geography markup language (GML) 2.0," *URL: http://www. opengis. net/gml/01-029/GML2. html,* 2001.