Ref. Ares(2016)4017945 - 30/07/2016

Co-funded by
the Horizon 2020 Framework Programme
of the European Union

DELIVERABLE

D4.1 – Shared vocabularies for Smart City

Project Acronym: ESPRESSO

Grant Agreement number: 691720

Project Title: systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities

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Revision:

Project co-funded by the the Horizon 2020 Framework Programme of the European Union		
Dissemination Level		
P	Public	**X**
C	Confidential, only for members of the consortium and the Commission Services	

1. Revision history and statement of originality

1.1. Revision history

Rev	Date	Author	Organization	Description
1.0	20.05.2016	Esther Minguela	Localidata	Initial TOC (v. 0)
2.0	30.05.2016	Esther Minguela	Localidata	Revision
3.0	19.06.2016	Esther Minguela	Localidata	First Draft (v. 1)
4.0	21.07.2016	Esther Minguela	Localidata	Second Draft (v. 2)
5.0	24.07.2016	Esther Minguela	Localidata	Revision
6.0	26.07.2016	Esther Minguela	Localidata	Revision
7.0	27.07.2016	Esther Minguela	Localidata	Revision
8.0	29.07.2016	Esther Minguela	Localidata	Final Draft
9.0	29/07/2016	Irene Facchin	TRILOGIS	Quality Check

1.2. Statement of originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

2. List of References

Number	Full Reference
[1]	DWBP Data on the Web Best Practices. https://www.w3.org/TR/dwbp/#metadata
[2]	ISO/IEC AWI 30145 Information technology - Smart city ICT reference framework http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=70301

3. Table of Acronyms

Acronym	Description
CityGML	OGC City Geography Markup Language
ESPRESSO	systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities – project of which this document forms a deliverable
OGC	Open Geospatial Consortium
W3C	World Wide Web Consortium
PAS	Publically Available Specification, a specific kind of document from BSI

4. Executive Abstract

This document is the output report of **Task 4.1 Definition of shared vocabularies** for the ESPRESSO Project (systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities).

The project focuses on the development of a conceptual Smart City Information Framework based on open standards. The Smart City platform (the "Smart City enterprise application") is an important pillar of the framework, together with a number of data provision and processing services to integrate relevant data, workflows, and processes. ESPRESSO will build this framework by identifying relevant open standards, technologies and information models that are currently in use or in development in various sectors.

This document introduces the core of the Smart City vocabularies, which will enable cities and stakeholders to **share data in an interoperability way in different sectors („Sectorial Systems") of Smart Cities, not only to share information internally but externally.**

For this purpose, a set of vocabularies is used as common data structures to various Smart City sectorial services: e.g. environment, mobility, energy, healthcare, governance etc. were identified.

To achieve this goal, a broad analysis, mapping theme standards was conducted. Vocabularies were selected taken into consideration following a set of criteria: published, free, comprehensive, relevance, availability, and independence. In order to ensure the creation of a comprehensive and relevant Smart City set of references of vocabularies, them were grouped into layers based on the analysis done.

Findings from the comprehensive analysis conducted under the 4.1 task allowed a identification of 29 core indicators, under the 4 layers, which can be used by cities to address the question of smart data more in-depth.

5. Table of Content

6. Table of Figures

7. Table of Tables

N.A.

8. Introduction

The objective of this document is to analyse and propose the usage of a shared network of vocabularies and thesauri so as to ensure consistent semantics while working across a number of sectors.

8.1. Data Vocabularies

Vocabularies define the concepts and relationships (also referred to as "terms" or "attributes") used to describe and represent an area of interest. They are used to classify the terms that can be used in a particular application, characterize possible relationships, and define possible constraints on using those terms. Several near-synonyms for 'vocabulary' have been coined, for example, ontology, controlled vocabulary, thesaurus, taxonomy, code list, semantic network.

There is no strict division between the artefacts referred to by these names. "Ontology" tends however to denote the vocabularies of classes and properties that structure the descriptions of resources in (linked) datasets. In relational databases, these correspond to the names of tables and columns; in XML, they correspond to the elements defined by an XML Schema. Ontologies are the key building blocks for inference techniques on the Semantic Web. The first means offered by W3C for creating ontologies is the RDF Schema [RDF-SCHEMA] language. It is possible to define more expressive ontologies with additional axioms using languages such as those in The Web Ontology Language [OWL2-OVERVIEW].

On the other hand, "controlled vocabularies", "concept schemes", and "knowledge organization systems" enumerate and define resources that can be employed in the descriptions made with the former kind of vocabulary, i.e. vocabularies that structure the descriptions of resources in (linked) datasets. A concept from a thesaurus, say, "architecture", will for example be used in the subject field for a book description (where "subject" has been defined in an ontology for books). For defining the terms in these vocabularies, complex formalisms are most often not needed. Simpler models have thus been proposed to represent and exchange them, such as the ISO 25964 data model [ISO-25964] or W3C's Simple Knowledge Organization System [SKOS-PRIMER].

8.2. Metadata

Data will not be discoverable or reusable by anyone other than the publisher if insufficient metadata is provided. Metadata provides additional information that helps data consumers better understand the meaning of data, its structure, and to clarify other issues, such as rights and license terms, the organization that generated the data, data quality, data access methods and the update schedule of datasets.

Metadata can be used to help tasks such as dataset discovery and reuse, and can be assigned considering different levels of granularity from a single property of a resource to a whole dataset, or all datasets from a specific organization.

Metadata can be of different types. These types can be classified in different taxonomies, with different grouping criteria. For example, a specific taxonomy could define three metadata types according to descriptive, structural and administrative

features. A different taxonomy could define metadata types with a scheme according to tasks where metadata are used, for example, discovery and reuse.

9. Layers

9.1. Introduction

For the development of this document, the work done in different organizations (ISO, ITU, ETSI, W3C, etc.…) has been considered. In general, the information about ontologies/vocabularies are isolated works, generally thematic, some only based for data on the web (but usually replicable for data for the internal interoperability of the city), not specific as the concept "smart city" but applicable. But there is a on going work on ISO that start to identify the need to analice all the concepts in a global way and star to develop an structure of levels or layers of types of ontologies/vocabularies.

This document is [2] ISO/IEC JTC 1/WG 11 N 48 "Initial Working Draft of 30145 Information technology— *Smart City ICT Reference Framework— Part 2, "The Smart City Knowledge Management Framework is principally a tool for data managers within the key agencies within the city. It also address needs of service managers and strategic managers within the city, because it underpin and improve data and information sharing, collaboration and consultation. It define a generic Knowledge Managment Framework focus on smart city specific processes. and practices.*

On point "6 An upper level ontology for Smart Cities – the platform for a key programme of work, 6.1 Introduction - The problem to be solved" explains:

> *A key challenge of managing a city as an integrated whole is that the services offered to citizens, visitors and businesses etc. are delivered by a wide variety of agencies within many different city systems. Each of these organisations have their own objectives and perspectives on city life, and each of these systems work fairly autonomously from the others and have developed their own vocabularies and management processes.*
>
> *In order for the city to work effectively, its organizations and citizens need to be able to share data. This is vital to allow the interoperation of their component systems, and the sharing of data is needed to evidence the effective use of resources to bring about beneficial change.*
>
> *However, city data is often labelled using the language and terms from the sector that initially collected it. Each sector has its own models and terminologies that enable data to be discovered and understood within that sector, but form a barrier to interoperability with other sectors.*
>
> *In theory, the best approach to achieve interoperability is to force all sectors to adopt the same vocabularies, but in practice this is impossible. The alternative is to use ontology mediation approaches for data discovery and data access across these heterogeneous data models.*
>
> *This requires an upper level ontology for the city to be agreed, which can describe a set of fundamental concepts and relationships to which the specialist*

terms and vocabularies developed within individual city systems can be mapped.

Deeply in the document, it is analysed the problem to be solved, list examples of existing upper level ontologies and their use and a review of existing work, recommends to develop an upper level ontology for smart cities and finally concludes with the whole vision of pieces/blocks:

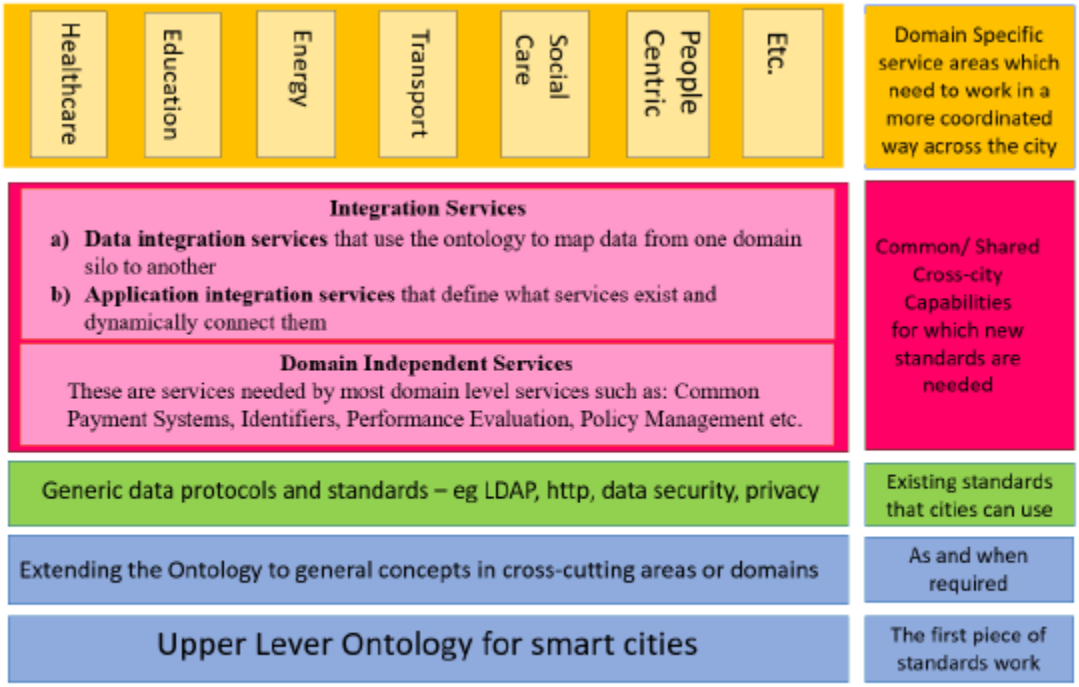

Figure 6-5 Potential program of work based on the Upper Level Ontology

Figure 1: ISO/IEC AWI 30145. Potential program of work based on the Upper Level Ontology[1].

It is understood that this approach to the problem of identifying the different layers of data types is very successful because it divides everything that can be seen as a layer of semantics city into smaller elements that are easier to analyse independently.

This has been the strategy developed to analyse and structure the vocabularies, establish different levels of vocabularies/ontologies, supporting the similar concept of upper lever ontology, domain specific services areas, common/shared cross-city capabilities, …

However for this document, this schema has been personalised respect the ISO/IEC AWI 30145:

- Layers: for this document, each "block" in ISO has been named as "layer" to facilitate and establish a common term in all the document;
- Domain sectors: only are consider the sectors of the ESPRESSO project;

[1] Source: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=70301.

- Levels that are not the upper level ontology: ISO focuses in upper level ontology but in this document are reported the rest of levels and ontologies.

9.2. Identify Layers

It has been identified five layers that correspond with different aspects and objectives

- Upper Layer ontology for Smart Cities;
- General concept in cross cutting domains;
- Specific Domain;
- Common cross-city capabilities;
- Thesauries and Code List.

This graph represents the layers and in two of them, the subdivisions on sub thematic:

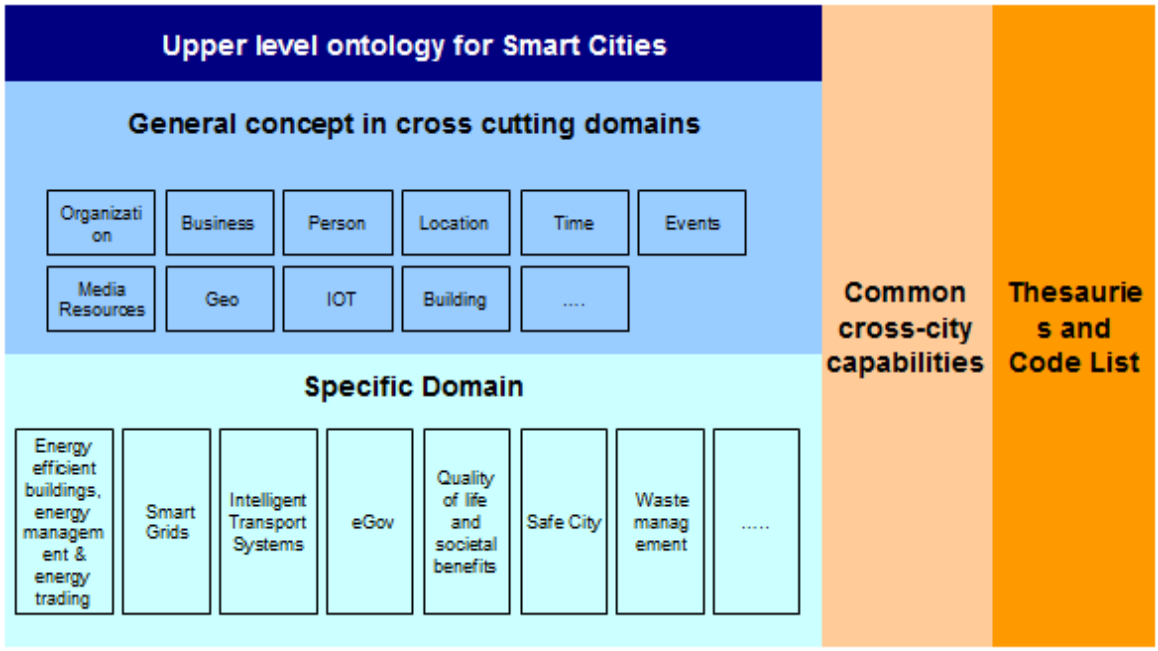

Figure 1: Layers.

This schema is in a great way similar to the developed by ISO, but the two layers considerer "cross" has been represented as vertical layers because can affect to all (or part) of the horizontal layers.

Each vocabulary has been located in one of this layers and sub thematic and is the developed in next point of this document.

10. Selection of shared vocabularies for Smart City Data

10.1. Layer Upper level ontology for Smart Cities

10.1.1. SUMO (IEEE)

http://www.adampease.org/OP/

The Standard Upper Ontology SUMO (Suggested Upper Merged Ontology) is the result of a joint effort to create a large, general-purpose, formal ontology. The IEEE Standard Upper Ontology working group promotes it, and its development began in May 2000. The participants were representatives of government, academia, and industry from several countries. The effort was officially approved as an IEEE standard project in December 2000.

10.1.2. DOLCE (WFOL)

http://www.loa.istc.cnr.it/old/DOLCE.html

DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering) is the first module of the WonderWeb Foundational Ontologies Library (WFOL). In our presentation paper (download pdf), it is described using first-order logic. The specific assumptions adopted for this module are first introduced informally, along with the basic categories, functions, and relations. We then present a rich axiomatic characterization, aimed at clarifying our assumptions and illustrate their formal consequences (theorems).

10.1.3. Schema.org. (Google, Microsoft, Yahoo and Yandex)

http://schema.org/

Schema.org is a collaborative, community activity with a mission to create, maintain, and promote schemas for structured data on the Internet, on web pages, in email messages, and beyond.

Schema.org vocabulary can be used with many different encodings, including RDFa, Microdata and JSON-LD. These vocabularies cover entities, relationships between entities and actions, and can easily be extended through a well-documented extension model. Over 10 million sites use Schema.org to markup their web pages and email messages. Many applications from Google, Microsoft, Pinterest, Yandex and others already use these vocabularies to power rich, extensible experiences.

Schema.org is sponsored by Google, Microsoft, Yahoo and Yandex.

10.1.4. DBpedia (Wikipedia)

http://dbpedia.org/ontology/

DBpedia is generated from the manually created specifications in the DBpedia Mappings Wiki. Each release of this ontology corresponds to a new release of the DBpedia data set which contains instance data extracted from the different language versions of Wikipedia.

10.1.5. Other

Este apartado muestra otros vocabularios/proyectos/… que, por diversas razones no se pueden considerar para su uso abierto e inmediato, pero son de suficiente interés como para ser tenido en cuenta ahora o en el futuro.

City Anatomy (Project City Protocol)

http://cityprotocol.org/2016/03/14/anatomy-ontology-available-for-public-review/?platform=hootsuite

NOTE: not free accessible at this moment

City Anatomy Ontology defines the main building blocks of the City Anatomy model.

City Anatomy Ontology enables the construct established in the City Anatomy to become highly adaptable, interoperable and actionable through use of a common vocabulary and machine-readable interpretation of data and content.

Km4city (Project Km4city)

http://www.disit.org/km4city/schema

NOTE: unknown actual state

Knowledge Model allows collecting all the data coming from the city, related to mobility, statistics, street graph, sensors, cultural heritage, parkings, weather, services, energy, events.

PAS 182 Concept model (British Standards Institution's)

http://www.legsb.gov.uk/smartcityconceptmodel/?Action=ShowModel&Id=10

NOTE: PAS182 is not a vocabulary but establishes a high level "Prime Concepts, Group Concepts and Relationships" that can apply as Upper Layer ontology

PAS 182 describe 27 high Layer concepts and their relationships with each other.

The more detailed and specific concepts within sector specific ontologies can then be mapped to these upper Layer concepts.

NOTE: PAS 182 has been published as a Draft International Standard (ISO/IEC 30182), comments are likely to be resolved by ISO/IEC JTC1 WG11, in conjunction with the work they're starting on ISO/IEC 30145-2 ICT Knowledge Management Framework.

10.2. Layer General concept in cross cutting areas or domains

10.2.1. Organization

The Organization (W3C)

http://www.w3.org/ns/org#

Organization Ontology describes core ontology for organizational structures, aimed at supporting linked-data publishing of organizational information across a number of domains. It is designed to allow domain-specific extensions to add classification of organizations and roles, as well as extensions to support neighbouring information such as organizational activities.

vCard (W3C)

http://www.w3.org/2006/vcard/ns#

vCard describes electronic business cards. vCards are often attached to e-mail messages, but can be exchanged in other ways, such as on the World Wide Web or instant messaging. They can contain name and address information, telephone numbers, e-mail addresses, URLs, logos, photographs, and audio clips.

10.2.2. Business

Core Business (Joinup)/(W3C)

https://joinup.ec.europa.eu/node/42441

https://www.w3.org/TR/vocab-regorg/

Core Business is a vocabulary for describing organizations that have gained legal entity status through a formal registration process, typically in a national or regional register. This document is the normative companion to the namespace document at http://www.w3.org/ns/regorg.

The RDF syntax binding of the Core Business Vocabulary has been named as Registered Organisation Vocabulary by W3C.

10.2.3. Person

Core Person (Joinup)

https://joinup.ec.europa.eu/node/42440

Core Person is a simplified, reusable and extensible data model that captures the fundamental characteristics of a person, e.g. the name, the gender, the date of birth, the location, ...

FOAF

http://xmlns.com/foaf/spec/

http://xmlns.com/foaf/0.1/

FOAF is a machine-readable ontology describing persons, their activities and their relations to other people and objects. The specification helps to describe contact information of SPOI such as email address or web page.

10.2.4. Location

Core Location (Joinup)

https://joinup.ec.europa.eu/node/42444

Core Location is a simplified, reusable and extensible data model that captures the fundamental characteristics of a location, represented as an address, a geographic name, or geometry.

LOCN (W3C)

http://www.w3.org/ns/locn#

LOCN is a simplified, reusable and extensible data model that captures the fundamental characteristics of a location, represented as an address, a geographic name, or geometry. With help of LOCN SPOI data enables to split particular components of addresses such as street, post name or postcode.

10.2.5. Time

Time Ontology. (OGC & W3C)

http://www.w3.org/2006/time#

https://www.w3.org/TR/2016/WD-owl-time-20160712/

The OWL-Time ontology is OWL-2 DL ontology [owl2-direct-semantics] of temporal concepts, for describing the temporal properties of resources in the world or described in Web pages. The ontology provides a vocabulary for expressing facts about topological relations among instants and intervals, together with information about durations, and about temporal position including date-time information.

Time ontology is currently in the process of being reviewed in the Spatial Data on the Web working group from W3C/OGC.

Timeline Ontology (Centre for Digital Music)

http://purl.org/NET/c4dm/timeline.owl#

This ontology is centered around the notion of timeline, seen here as a way to identify a temporal backbone. A timeline may support a signal, a video, a score, a work, etc. A particular instance of a timeline is the physical one, on which the 29th of October, 2007 is defined.

10.2.6. Events

Linked events (Various)

http://linkedevents.org/ontology/

http://linkedevents.org/ontology/Event

Linked events publish descriptions of historical events as Linked Data, and for mapping between other event-related vocabularies and ontologies.

The Event Ontology (Centre for Digital Music)

http://purl.org/NET/c4dm/event.owl

http://purl.org/NET/c4dm/event.owl#Event

The Event Ontology is centered around the notion of *event*, seen here as the way by which cognitive agents classify arbitrary time/space regions

This ontology has already been proven useful in a wide range of context, due to its simplicity and usability: from talks in a conference, to description of a concert, or chords being played in a Jazz piece.

DUL DOLCE+DnS Ultralite (Aldo Gangemi)

http://www.ontologydesignpatterns.org/ont/dul/DUL.owl

DOLCE+DnS Ultralite is a simplification of some parts of the DOLCE Lite-Plus library (cf. http://www.loa-cnr.it/ontologies/DLP397.owl). Main aspects in which DOLCE+DnS Ultralite departs from DOLCE Lite-Plus are the following: - The names of classes and relations have been made more intuitive - The DnS-related part is closer to the newer 'constructive DnS' ontology (http://www.loa-cnr.it/ontologies/cDnS.owl). - Temporal and spatial relations are simplified - Axiomatization makes use of simpler constructs than DOLCE Lite-Plus - The architecture of the ontology is pattern-based, which means that DOLCE+DnS Ultralite is also available in modules, called 'content ontology design patterns', which can be applied independently in the design of domain ontologies (cf. http://www.ontologydesignpatterns.org). If many modules are needes in a same ontology project, is anyway useful to use this integrated version. The final result is a lightweight, easy-to-apply foundational ontology for modeling either physical or social contexts. Several extensions of DOLCE+DnS Ultralite are being designed; see for example the extensions for information objects: http://www.loa-cnr.it/ontologies/IOLite.owl, for systems: http://www.loa-cnr.it/ontologies/SystemsLite.owl, for plans: http://www.loa-cnr.it/ontologies/PlansLite.owl, for the legal domain: http://www.loa-cnr.it/ontologies/CLO/CoreLegal.owl, for the lexical and semiotic domains: http://www.loa-cnr.it/codeps/owl/LMM_L2.owl; etc.

10.2.7. Media Resources

Media Annotations. (W3C)

http://www.w3.org/ns/ma-ont#

Media Annotations is both a core vocabulary (a set of properties describing media resources) and its mapping to a set of metadata formats currently describing media resources published on the Web.

10.2.8. Geo

Geo (W3C)

http://www.w3.org/2003/01/geo/wgs84_pos#

Geo represents latitude, longitude and altitude information in the WGS84 geodetic reference datum.

CityGML (Open Geospatial Consortium)

http://schemas.opengis.net/citygml/

http://www.opengeospatial.org/standards/citygml

CityGML is an open data model and XML-based format for the storage and exchange of virtual 3D city models. It is an application schema for the Geography Markup Language version 3.1.1 (GML3), the extendible international standard for spatial data exchange issued by the Open Geospatial Consortium (OGC) and the ISO TC211. The aim of the development of CityGML is to reach a common definition of the basic entities, attributes, and relations of a 3D city model. This is especially important with respect to the cost-effective sustainable maintenance of 3D city models, allowing the reuse of the same data in different application fields.

Geonames

http://www.geonames.org/ontology

The Geonames ontologies provides elements of description for geographical features, in particular those defined in the geonames.org data base

10.2.9. IOT

oneM2M Base (oneM2M)

http://www.onem2m.org/ontology/Base_Ontology/oneM2M_Base_Ontology.owl

http://www.onem2m.org/technical/onem2m-ontologies

The only ontology that is specified by oneM2M is the oneM2M Base Ontology, as described in TS-0012. The oneM2M Base Ontology is the minimal ontology (i.e. mandating the least number of conventions) that is required such that other ontologies can be mapped into oneM2M.

Syntactic interoperability allows for interworking with non-oneM2M devices, e.g. in Area Networks. In this case an ontology - represented as an OWL file - that contains the Area Network-specific types of communication parameters (names of operations, input/output parameters, their types and structures, etc.) is used to configure an Interworking Proxy Entity to a oneM2M solution.

SSN (OGC & W3C)

http://purl.oclc.org/NET/ssnx/ssn#

The Semantic Sensor Network Ontology (commonly known as "SSN" or sometimes "SSNO") is OWL-2 DL ontology for describing sensors and the observations they make of the physical world. SSN is published in a modular architecture that supports the judicious use of "just enough" ontology for diverse applications, including satellite imagery, large scale scientific monitoring, industrial and household infrastructure, citizen observers, and Web of Things.

The Semantic Sensor Network Ontology y is currently in the process of being reviewed in the Spatial Data on the Web working group from W3C/OGC.

Internet of Things (IoT) (Various)

http://ai-group.ds.unipi.gr/kotis/ontologies/IoT-ontology

Internet of Things (IoT) supports the automated deployment of applications in heterogeneous IoT environments. It mainly serves as a semantic registry for the registration of associations of sensing/actuating/identity/embedded with features of interest, as well as for the registration of applications that utilize the services provided by these associations.

10.2.10. Building

COINS Building Information Model (Various)

http://www.coinsweb.nl/c-bim.owl

COINS is an open BIM standard. It is complementary to standards issued by buildingSMART such as IFC, IFD Library and IDM. COINS supports the exchange of Systems Engineering information and ensures that an object tree, GIS data, 2D drawings, 3D models, IFC models and object type library can be stored in association

in a database. It also provides a BIM-container interchange format. It is used by partners in building construction projects for the purpose of exchanging building information and managing building information.

Adapt4EE Occupancy (Adapt4EE Project)

http://www.adapt4ee.eu/adapt4ee/files/archive/Occupancy_Ontology_TTL.zip

http://www.adapt4ee.eu/adapt4ee/results/ontologies.html

Adapt4EE aims at augmenting the contemporary architectural envelope by incorporating business and occupancy related information thus providing a holistic approach to the design and evaluation of the energy performance of construction products at an early stage and prior to their realization.

Occupancy patterns in the domain of constructions of commercial use appear to be more complicated, involving multiple individuals, gatherings, single or collective movement patterns and different individual behaviors.

Adapt4EE Adapt (Adapt4EE Project)

http://www.adapt4ee.eu/adapt4ee/files/archive/Adapt4EE_Ontology_TTL.zip

http://www.adapt4ee.eu/adapt4ee/results/ontologies.html

Adapt4EE aims at augmenting the contemporary architectural envelope by incorporating business and occupancy related information thus providing a holistic approach to the design and evaluation of the energy performance of construction products at an early stage and prior to their realization.

10.3. Layer Specific Domain

10.3.1. Energy efficient buildings, energy management & energy trading

Building-Layer performances, e.g. properties (e.g. energy performances) of material and processes for building constructions, standards for HVAC systems, etc. with the support of BuildingSmart, 3D City planning and usage of solar energy, optimization of energy consumption, integration of data with spatial characteristics (OGC)

SAREF. (The Smart Appliances REFerence)

http://ontology.tno.nl/saref/

(Smart appliances in the smart home /Energy-Related Data in Smart Houses)

The Smart Appliances REFerence (SAREF) ontology is a shared model of consensus that facilitates the matching of existing assets (standards/protocols/datamodels/etc.) in the smart appliances domain. The SAREF ontology provides building blocks that allow separation and recombination of different parts of the ontology depending on specific needs.

SAREF4EE (EEbus/Energy@home extension of SAREF)

https://w3id.org/saref4ee

The EEbus/Energy@home extension of SAREF.

This is the extension of SAREF for the EEBus and Energy@Home project. The documentation of SAREF4EE is available at http://ontology.tno.nl/SAREF4EE_Documentation_v0.1.pdf. SAREF4EE represents

1. The configuration information exchanged in the use case 'Remote Network Management' according to the EEBus Technical Report, Protocol Specification-Remote Network Management, version 1.0.0.2, 2015-09-19;
2. The scheduling information about power sequences exchanged in the use cases Appliance scheduling through CEM and remote start' and 'Automatic cycle rescheduling', according to the message structures described in General Message Structures, version 0.1.1, 2015-10-07;
3. The monitor and control information exchanged in the use case 'Communicate appliance status and info on manually planned cycles', according to the monitoring and control part of the Energy@Home Data Model, version 1.0; and
4. The event-based data exchanged in the use case 'Demand Response', according to General Message Structures, version 0.1.1, 2015-10-07.

Urban Energy (Semanco)

http://www.semanco-tools.eu/urban-enery-ontology

The SEMANCO Energy Model is a formal ontology comprising concepts captured from diverse sources including standards, use cases and activity descriptions and data sources related to the domains of urban planning and energy management. In particular it contains the terms and attributes that describe regions, cities, neighbourhoods and buildings; energy consumption and CO2 emission indicators, as well as climate and socio- economic factors that influence energy consumption. The ontology enables semantic tools to access the data stemming from different domains and applications.

10.3.2. Smart Grids

City-Layer energy performance assessment, e.g. definition of standardised metrics to methodology for defining carbon footprint of the city, to allow both comparison among different cities (in terms of energy performances) and to asses improvements over time of the performance of a city against standardised benchmarks.

Energy management and energy trading, e.g. exchange of energy management data, use of electric vehicles, and consumption of energy etc. (in line with Potential Action 4 of OIP) leveraging on experience of DIN, coordinating standardisation activities in the realm of electro-mobility in Germany's long term energy transition project.

CERISE CIM Profile for Smart Grids (Cerise-SG Project)

http://ns.cerise-project.nl/energy/def/cim-smartgrid

A Profile of the IEC Common Information Model (CIM) for Smart Grids, developed by the Cerise-SG project.

10.3.3. Intelligent Transport Systems

Transportation, e.g. regarding integration of different forms of transport (combined ticketing and combined use of transport models), exchange of location information about electric vehicles charging points, about parking information and integrated

parking booking systems, etc., significantly leveraging on direct experience of the city of Trento and its IEEE Smart City initiative through TRISE (involved in activities of IEEE SmartCity Trento).

GTFS (Google)

http://vocab.gtfs.org/terms#

https://developers.google.com/transit/gtfs/reference

GTFS (General Transit Feed Specification) is a translation of the General Transit Feed Specification towards URIs. Its intended use is creating an exchange platform where the Linked GTFS model can be used as a start to get the right data into the right format. For semantics of the classes and properties, see https://developers.google.com/transit/gtfs/reference

Linked GTFS (Various)

https://github.com/OpenTransport/linked-gtfs

Linked GTFS (The Linked General Transit Feed Specification) is a mapping of the GTFS in CSV reference towards RDF. It stays as close as possible to the CSV reference, including small additions to enhance usability.

10.3.4. eGov

- Leveraging on experience from SEMIC.EU and SharePSI (Public Sector Information), where partners PWC, FRAUNHOFER and OGC participate.
- Overall management of cities, based on sound experience by city involved.
- City maintenance, e.g. to support crowdsourcing by citizens
- Procurement mechanism, e.g. standardised public procurements that can encourage competition, as examples included in the database developed throughout the on-going study for DG CONNECT carried out by PwC focusing on Best practices for ICT procurement based on standards in order to promote efficiency and reduce lock-in.

Core Public Organisation (Joinup)

https://joinup.ec.europa.eu/node/148214

The Core Public Organisation Vocabulary aspires to become a common data model for describing public organisations in the European Union.

Core Public Service (Joinup)

https://joinup.ec.europa.eu/node/52597

The Core Public Service Vocabulary is a simplified, reusable and extensible data model that captures the fundamental characteristics of a service offered by public administration.

Open Contracting Data Standard (Open Contracting Partnership (OCP)

http://standard.open-contracting.org/

The Open Contracting Data Standard (OCDS) enables disclosure of data and documents at all stages of the contracting process by defining a common data model.

It was created to support organisations to increase contracting transparency, and allow deeper analysis of contracting data by a wide range of users.

PPROC Public Procurement Ontology (Various)

http://contsem.unizar.es/def/sector-publico/pproc

The PPROC ontology defines the necessary concepts to describe public procurement process and the contracts of public sector (public e-procurement). The ontology has been designed with the main purpose of publishing data about public contracts. This ontology extends the Public Contracts Ontology, an ontology developed by the Czech Open Data initiative.

10.3.5. Quality of life and societal benefits

- Quality of life in urban areas
- Assessment of social performances, e.g. to define indicators regarding social performance, efficiency of population, health and well-being of citizens
- Assessment of social citizens attitude, e.g. to define standardised ways to define citizens behaviours and attitude towards Smart City

ISO 37120 – Sustainable Development and Resilience of Communities (ISO)

http://ontology.eil.utoronto.ca/ISO37120.owl

ISO 37120 – Sustainable Development and Resilience of Communities – Indicators for City Services and Quality of Life (under TC268) http://ontology.eil.utoronto.ca/ISO37120.html This OWL file defines a class for each indicator defined in the ISO 37120 standard. Names for each indicator are provided. Text definitions are provided only for Economy, Education and Energy indicators, due to copyright restrictions imposed by ISO. This file is meant to provide a single URI for each indicator. An ontology for representing an indicator's supporting data plus meta information such as provenance, validity and trust can be found in: http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Foundation.owl. Documentation of the ontology can be found in: http://eil.utoronto.ca/smartcities/papers/GCI-Foundation-Ontology.pdf.

Global City Indicator Foundation Ontology (Various)

http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Foundation.rdf

Contains a top Layer classification of city indicators along with basic integration with Time, Measurement, Provenance, Statistics, Validity and Trust ontologies.

10.3.6. SafeCity

Crime reduction and resilience (i.e. emergency response)

VERIS (Vocabulary for Event Recording and Incident Sharing)

https://github.com/vz-risk/veris

http://veriscommunity.net/

VERIS (Vocabulary for Event Recording and Incident Sharing) is used for Event Recording and Incident Sharing

Open 311 (Various)

http://ontology.eil.utoronto.ca/open311.owl

Open 311 is a model and open standard for civic issue tracking.

10.3.7. Waste management

Solid waste management is one of the vital aspects of Smart Cities, which includes aspects such as recycling or waste segregation.

11. Selection of Shared vocabularies. Metadata

11.1. Layer Common cross-city capabilities

11.1.1. Metadata properties

DC

http://purl.org/dc/terms/

http://purl.org/dc/elements/1.1/

DC (Dublin Core) represents the basic set of metadata properties. It is standardized as ISO 15836. Dublin Core elements are in SPOI used for description of feature metadata such as data provider, original data resource, date of integration to SPOI or license.

11.1.2. Metadata management

Provenance. (W3C)

https://www.w3.org/TR/prov-o/

http://www.w3.org/ns/prov#

Provenance represents and interchanges provenance information generated in different systems and under different contexts. It can also be specialized to create new classes and properties to model provenance information for different applications and domains.

Quality Model (Various)

http://purl.org/net/QualityModel#

Quality Model describes knowledge of quality models. The ontology focuses on modelling quality characteristics and quality measures used for measuring them, and it adopts the terminology used by the ISO 25010 (SQuaRE) and by the ISO/IEC 15939 standards.

Evaluation Result (Ontology Engineering Group)

http://purl.org/net/EvaluationResult#

http://vocab.linkeddata.es/eval/index.html#

The Evaluation Result ontology is an ontology developed for capturing knowledge about results obtained in an evaluation process; it extends the Quality Model ontology (QMO).

ODRL (W3C)

https://www.w3.org/TR/odrl/

ODRL (Open Digital Rights Language) is a proposed language for the Digital Rights Management (DRM) community for the standardisation of expressing rights information over content. The ODRL is intended to provide flexible and interoperable mechanisms to support transparent and innovative use of digital resources in publishing, distributing and consuming of electronic publications, digital images, audio and movies, learning objects, computer software and other creations in digital form.

11.1.3. Metatada about statistics

Data Cube (W3C)

http://purl.org/linked-data/cube#

Data Cube allows multi-dimensional data, such as statistics, to be published in RDF. It is based on the core information model from SDMX (and thus also DDI).

SDMX-RDF (Various)

http://purl.org/linked-data/sdmx

http://purl.org/linked-data/sdmx/2009/concept#

http://purl.org/linked-data/sdmx/2009/dimension#

http://purl.org/linked-data/sdmx/2009/attribute#

http://purl.org/linked-data/sdmx/2009/measure#

http://purl.org/linked-data/sdmx/2009/metadata#

http://purl.org/linked-data/sdmx/2009/code#

http://purl.org/linked-data/sdmx/2009/subject#

SDMX extends the data cube vocabulary to support publication of statistical data in RDF, using an information model based on SDMX.

11.1.4. Datasets catalog

DCAT (W3C/Joinup)

https://www.w3.org/TR/vocab-dcat/

https://joinup.ec.europa.eu/node/63567

The DCAT Application profile for data portals in Europe (DCAT-AP) is a specification based on the Data Catalogue vocabulary (DCAT) for describing public sector datasets in Europe. Its basic use case is to enable cross-data portal search for data sets and make public sector data better searchable across borders and sectors. This can be achieved by the exchange of descriptions of datasets among data portals.

In February 2015, the ISA² programme of the European Commission has started an activity to revise the DCAT-AP, based on experience gained since its development in 2013.

ADMS (W3C/Joinup)

http://www.w3.org/TR/2013/NOTE-vocab-adms-20130801/

https://joinup.ec.europa.eu/node/42438

ADMS (Asset Description Metadata Schema) is a profile of DCAT, used to describe semantic assets (or just 'Assets'), defined as highly reusable metadata (e.g. xml schemata, generic data models) and reference data (e.g. code lists, taxonomies, dictionaries, vocabularies) that are used for eGovernment system development.

GeoDCAT-AP (Joinup)

https://joinup.ec.europa.eu/node/139283

GeoDCAT-AP is an extension of DCAT-AP for describing geospatial datasets, dataset series, and services. It provides an RDF syntax binding for the union of metadata elements defined in the core profile of ISO 19115:2003 and those defined in the framework of the INSPIRE Directive. Its basic use case is to make spatial datasets, data series, and services searchable on general data portals, thereby making geospatial information better searchable across borders and sectors. This can be achieved by the exchange of descriptions of data sets among data portals.

StatDCAT-AP (Joinup)

https://joinup.ec.europa.eu/node/147940

StatDCAT-AP aims to deliver specifications and tools that enhance interoperability between descriptions of statistical data sets within the statistical domain and between statistical data and open data portals.

12. Selection of Shared vocabularies. Thesauries and Code List

12.1. Layer Thesauries and Code List

RAMON** Classifications **(EUROSTAT)

http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM&StrGroupCode=CLASSIFIC&StrLanguageCode=EN

RAMON (Reference And Management Of Nomenclatures) is Eurostat's metadata server. Metadata are the foundations on which all statistical systems, national as well as international, are built. Thus, it is essential that statisticians have access to an extensive, reliable and regularly updated source of information on these elements. The main objective of this server is to make available the largest possible stock of past and present metadata in order to help users in the analysis of statistical data. This site will not be limited to recent documents; indeed users needing "old" metadata in order to analyse long time series will often have to consult methodological and other material which is no longer in force (for example NACE 1970, ESA 1970, etc.) and RAMON will try to provide this information.

RAMON Code List (EUROSTAT)

http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM&StrGroupCode=SCL&StrLanguageCode=EN

RAMON (Reference And Management Of Nomenclatures) is Eurostat's metadata server. Metadata are the foundations on which all statistical systems, national as well as international, are built. Thus, it is essential that statisticians have access to an extensive, reliable and regularly updated source of information on these elements. The main objective of this server is to make available the largest possible stock of past and present metadata in order to help users in the analysis of statistical data. This site will not be limited to recent documents; indeed users needing "old" metadata in order to analyse long time series will often have to consult methodological and other material which is no longer in force (for example NACE 1970, ESA 1970, etc.) and RAMON will try to provide this information.

INSPIRE Feature Concept Dictionary (EU)

http://inspire.ec.europa.eu/featureconcept

IFCD (INSPIRE Feature Concept Dictionary) acts as a common feature concept dictionary for all INSPIRE data specifications. The common feature concept dictionary contains terms and definitions required for specifying thematic spatial object types and it is main role is in particular to support the harmonisation effort and to identify conflicts between the specifications of the spatial object types in the different themes.

INSPIRE Code List (EU)

http://inspire.ec.europa.eu/codelist

The INSPIRE code list register contains the code lists and their values, as defined in the INSPIRE implementing rules on interoperability of spatial data sets and services (Commission Regulation (EU) No 1089/2010). NOTE: It does not yet include

references to external code lists and the additional code lists and extended values proposed in the Data Specification Technical Guidelines.

Eionet Data Dictionary (European Environment Agency)

http://dd.eionet.europa.eu/

The Data Dictionary is used to support the delivery of environmental data by countries to Reportnet. The contents in the data dictionary are used to generate pdfs of the technical specifications for dataflows as well as Excel templates. The Data Dictionary also introduces the possibility of simple automated validation of deliveries by countries and facilitates the development of data submission interfaces.

Data Dictionary holds definitions of datasets, tables and data elements. Each of these three levels is defined by a set of attributes, the core set of which corresponds to ISO 11179 standard for describing data elements. The whole attribute set is flexible and attributes can be added / removed from/to the system.

Metadata Registry (EU)

http://publications.europa.eu/mdr/index.html

MDR is used by the different European Institutions involved in the legal decision.

The Metadata Registry registers and maintains definition data (metadata elements, named authority lists, schemas, etc.) used by the different European Institutions involved in the legal decision making process gathered in the Interinstitutional Metadata Maintenance Committee (IMMC) and by the Publications Office of the EU in its production and dissemination process.

13. Conclusions

ISO/IEC AWI 30145, in point "6.5.3 The need of a Guidance Document on existing generic data protocols and standards", said "*There are a great many existing standards and protocols relating to the sharing of data. These have been developed by a range of standards organisations and it is therefore not easy for city data practitioners to understand how they can be* ***brought together into an overarching portfolio*** *to enable them to follow best practice. The provision of a guidance document for city leaders to guide them through the standards landscape in this area would be very helpful."*

So, in conclusion, the objective of this document is to facilitate the portfolio of actual ontologies/vocabularies at all levels of data and metadata and understand the speciality of each one to be a guide for city data managers.