

Code list management supported through a controlled domain vocabulary

Erik STUBKJÆR, Denmark, Hans-Christoph GRULER, Switzerland,
Scott SIMMONS, USA, and Volkan ÇAĞDAŞ, Turkey

Key words: Code lists; Semantic Web; Simple Knowledge Organization System (SKOS); Land Administration Domain Model (LADM); ISO 19152; OGC Land and Infrastructure Conceptual Model Standard (LandInfra); OGC InfraGML; Cadastre and Land Administration Thesaurus (CaLAtThe), CaLAtThe

SUMMARY

Standards like the ISO 19152:2012 Land Administration Domain Model (LADM) basically specifies classes and the relations among them. However, this methodology cannot catch the richness of variations of the domain, and therefore code lists are introduced as a supplement. In fact, the LADM mentions a number of code lists for each of the packages of the standard. The codes with name and description are not part of the standard; rather, examples are provided in an informative Annex J of the standard, while the specification of the code lists is left to ‘User communities [who] have to define and manage their own values when implementing this International [LADM] Standard’.

As the mentioned user communities all belong to the domain of Land Administration, the specification of code lists would benefit from applying a shared or harmonized terminology. The alternative would lead to communication problems and costs. Within other domains, e.g. agriculture, economy, and environment, controlled vocabularies have been developed (AGROVOC; STW–Thesaurus for Economics; GEMET), each amounting to several thousand terms. The Cadastre and Land Administration Thesaurus (CaLAtThe) was issued 2011, based on the then draft version of LADM. The present CaLAtThe version 3 of 2019 was extended to about 200 terms, reflecting also the terms of the OGC Land and Infrastructure Conceptual Model Standard (LandInfra) of 2016.

The paper explores the potential of applying CaLAtThe for code list management, motivated among others by the decision by ISO/TC 211 to revise LADM in terms of a Stage 0-project. Semantic web tools are investigated in order to provide for more explicit semantics of code list values (cf. van Oosterom et al., 2019), in line with previous proposals (Paasch et al., 2015) and (Stubkjær et al., 2018). Moreover, suggestions for international cooperation are outlined.

Code list management supported through a controlled domain vocabulary

Erik STUBKJÆR, Denmark, Hans-Christoph GRULER, Switzerland,
Scott SIMMONS, USA, and Volkan ÇAĞDAŞ, Turkey

1. INTRODUCTION

This paper focuses on management of code lists specified by the international land administration standards, namely ISO 19152:2012 Land Administration Domain Model (LADM) and OGC Land and Infrastructure Conceptual Model Standard (LandInfra) through a domain thesaurus, the Cadastre and Land Administration Thesaurus (CaLAtHe) which is available online at <http://www.cadastralvocabulary.org>.

Code lists and their recommended use are described in some detail (NISO, 2017; Scarponcini, 2017; European Commission, 2018). The name of a code list provides the base for a number of code values, each with a label (a term) and possibly a definition. As part of the design process, the publisher has to determine whether the code list is to be used in a multilingual environment. Relations between the code lists and the controlled vocabulary have to be carefully designed. The W3C recommendation: Simple Knowledge Organization System (SKOS), (W3C, 2009) provides a model for identification of vocabulary elements with URIs, labelled with strings in one or more natural languages, documented with various types of note, semantically related to each other in informal hierarchies and association networks, and aggregated into concept schemes.

CaLAtHe is encoded according to SKOS provisions but so far, code lists with their respective labels are not identified. The SKOS recommendation includes a provision for handling concept collections, which compares to the code list values (W3C, 2009, 9). The paper will discuss this option, but motivate a solution based on use of nested concept schemes (W3C, 2009, 4). As CaLAtHe provides for a semantic structuring of the terms applied by both LADM and LandInfra, an extension of the CaLAtHe vocabulary with the name of the various code lists and their corresponding labels might assist the user community to obtain more consistency within the domain.

As for the technology applied, CaLAtHe is presently based on a dedicated web server, drawing SKOS-structured content from a MySQL database by means of php code. Moreover, term relations are depicted as graphs, provided through the GraphViz visualization software. The applied technology and SKOS structure allow for implementation of multilingual recordings, and thus the present platform may support a realization of the proposed development; however, alternative options are available as well. The paper explores two such options: the Re3gistry, developed in the context of the EU INSPIRE Directive, as well as VocBench, a web application for collaborative development of multilingual thesauri, developed by the ART Research Group at the University of Rome, Tor Vergata. Both options are provided as open source software, subject to the European Union Public Licence, and both are supported by ISA, Interoperability Solutions for public Administrations, business and

citizens, a European Commission's programme. Noteworthy, AGROVOC applies the VocBench and is aligned with a number of other multilingual knowledge organization systems, including those to which CaLThe referred from the outset.

The management of CaLThe extended with the above-mentioned code list details may benefit from a more formalized management structure. The present LADM standard leaves code list issues to user communities, which includes land administration agencies and their regional associations. The concern for harmonization of domain vocabulary and of standards emerged within the research community, framed by the International Federation of Surveyors, FIG, and the international standards organisations, ISO and OGC. Surely, a more specialized unit may be needed. In fact, a joint unit for code list management was proposed in terms of a draft Memorandum of Understanding (Stubkjær et al., 2018). Alternatively, management may be framed by regional associations like the Intergovernmental Committee on Surveying and Mapping (ICSM), which is a Standing Committee of ANZLIC – the Australian and New Zealand Spatial Information Council, as well as the Permanent Committee on Cadastre in the European Union, or by large countries with federal government structure, e.g. India. Finally, code list hosting with vocabulary might follow the proposal of the OGC Code List Manifesto as implemented through OGC's overall Knowledge Management strategy (Scarponcini, 2017; Stubkjær et al., 2018). The paper will outline the management tasks of the extended CaLThe and provide an initial assessment of management opportunities. These management tasks include further contribution towards consistency within the domain through revision of LandInfra / InfraGML and CaLThe in parallel with the revision of the LADM.

2. SEMANTIC WEB TOOLS: THESAURI AND CODE LISTS

2.1 The semantic web

The Semantic Web provides for access to data, rather than to documents, allowing data to be shared and reused across application, enterprise, and community boundaries. Data access requires common schemes for representing information, in terms of the Resource Description Framework (RDF, <https://www.w3.org/RDF/>) and Simple Knowledge Organization System (SKOS, <https://www.w3.org/2004/02/skos/>).

Based on these schemes, the information to be represented may be structured with increasing detail in terms of taxonomies, thesauri, and ontologies, respectively. The following overview is based on Breitmann et al., (2007), p 17ff:

A taxonomy classifies terms hierarchically, using the father-son (generalization, is-a, or type-of) relationship. Indeed, taxonomies allow only the father-son relationship, ruling out other relationships, such as part-of, cause-effect, association, and localization.

A thesaurus contains a set of relationships among concepts, organized in a taxonomic way, together with a set of semantic relationships, such as equivalence, broader or narrower, and association, which hold among the concepts.

“An ontology is a formal, explicit specification of a shared conceptualization” (Gruber, 1993). In other terms, an ontology is a representation of the knowledge of a domain, where a set of objects and their relationships is described by a vocabulary. However, in addition to the concept hierarchy, comparable to the taxonomy, supplemented with the relationships, comparable to the thesaurus, the ontology also comprises axioms, expressed in an appropriate logical language, e.g. describing causal relationships between concepts.

The following sections provide further information on taxonomies, the structure of which fit the rendering of code lists, on thesauri (section 2.3) and on semantic platforms for these resources. Ontologies and the notion of ‘Linked Data’ (cf. Zeng & Mayr, 2018) are outside the scope of the present paper.

2.2 Code lists and taxonomies

Code Lists are list of codes to be used in documents in order to constrain input and avoid errors. When filling in forms, instead of keying in free text, a code list will constrain the accepted entry. This is an essential part of document alignment and data harmonization process for business or government messages. Code lists are published as part of standards and are essential to the interoperability of messages. Examples include the code lists of the UN EDIFACT business and government message standards, referring to ISO standards on country codes, currency codes, unit of measure, etc. (<http://tfig.unece.org/contents/code-lists.htm>).

Code lists and their recommended use are described in some detail. The taxonomic (hierarchical) structure of code lists is established as a standard includes a number of code lists, the name of which again provides the base for a number of code values, each with a label (a term) and possibly a definition. Code lists can be implemented using several technologies, in particular XML, RDF, and SKOS (NISO, 2017; European Commission, 2018).

The W3C recommendation: Simple Knowledge Organization System (SKOS), (W3C, 2009) provides a model for identification of vocabulary elements with URIs, labelled with strings in one or more natural languages, documented with various types of note, semantically related to each other in informal hierarchies and association networks, and aggregated into concept schemes. The hierarchical structure of code lists, illustrated above, does not fit into directly into the basic network structure of thesauri. However, a number of remedies are available: a) the SKOS recommendation includes a provision for handling ‘concept collections’, which compares to the hierarchical structure of code list values. However, elements of the basic SKOS ‘concept schemes’ cannot refer to elements of ‘concept collections’. b) The SKOS recommendation includes an Appendix B on SKOS eXtension for Labels (SKOS-XL), which might be applied for labelling code list values systematically; a similar approach would be use of the `skos:notation` option. This option has to be supplemented with domain-specific labelling conventions. Finally, c) the SKOS recommendation’s ‘concept scheme’ marks an aggregation of one or more SKOS concepts with their semantic relationships. However, it is allowed to establish more ‘concept schemes’ addressing the same set of SKOS concepts, and

thereby allow for both the network view and the hierarchical (code list) view of the same set. A solution is proposed in section 4 below.

2.3 Thesauri

A thesaurus (from latin; hence plural: thesauri) is collection of words, a vocabulary, arranged according to sense, while a dictionary arrange words according to alphabet. In information science, thesauri are used to specify domain models (Wikipedia). Again, the W3C SKOS is used for structuring the thesaurus. In recent years, a number of thesauri have been established, including the Agricultural Thesaurus (AGROVOC, <http://aims.fao.org/standards/agrovoc>), the General Multilingual Environmental Thesaurus (GEMET, <https://www.eionet.europa.eu/gemet/>), and the STW Thesaurus for Economics (<http://zbw.eu/stw/>). The SKOS-based thesauri are cross-referenced, e.g. through the Basel Register of Thesauri, Ontologies & Classifications (BARTOC, <https://bartoc.org/>) in order to achieve greater visibility, highlight their features, make them searchable and comparable, and foster knowledge sharing.

2.4 Semantic platforms

2.4.1 Re3gistry

A registry is an information system on which registers are maintained (ISO 19135-1), and serves as a central access point where labels, descriptions and other metadata for reference codes can be easily maintained, checked by humans or retrieved by machines (INSPIRE, 2017, p. 8). The Re3gistry, which has been developed by the European Commission's Joint Research Centre through the ARE3NA project, provides a software tool for the development of such information systems.

The Re3gistry is a reusable open source solution and a consistent central access point for managing and sharing 'reference codes', including code lists and enumerations. The mentioned 'reference codes' include the name of code lists, as well as the corresponding codes, labels and descriptions for the reference codes / code lists, which can be easily browsed by humans and retrieved by machines (cf. Re3gistry Software documentation - Version 1.3). Its last releases with their documentations are available at <https://ies-svn.jrc.ec.europa.eu/projects/registry-development/wiki>.

The Re3gistry populates the registry contents from the importing of simple text-based data files and organizes and exports the data in different formats (e.g. XML, RDF/XML, JSON, Atom, CSV). The produced files can then optionally be served online through a customizable web service (Re3gistry Software documentation - Version 1.3).

The Re3gistry software, the underlying system behind the INSPIRE registry service, is currently handling 10 registries with more than 7000 reference codes in 23 languages and served in 7 different formats. The INSPIRE compliant national registries using the Re3gistry include Slovakian registry, Registry of North Macedonia, GeoSmartCity registry, SEMIC Core Vocabularies registry, SEMIC EU Budget Vocabulary, ELISE Energy Pilot registry, Austrian (CCCA) registry, Italian (AgID) registry, France (BRGN) registry, Spanish registry,

National Land Survey of Finland, Cartographic and Geological Institute of Catalonia (ICGC) (cf. https://ec.europa.eu/isa2/solutions/re3gistry_en). Reuse experiences gained from INSPIRE Italia Registry informs in 2017 that Re3gistry has detailed documentation and strong support from the Joint Research Centre of the European Commission (JRC) which promote deployment of the software. It is also mentioned that Re3gistry allows customization of the interface to comply with national regulations and facilitates publication of the registry under coordination a number or organization. Austrian INSPIRE Registry – CCCA Data Centre experiences indicate complexities and difficulties in data import function of Re3gistry, specifically mention is made that ‘code list register, no issues for adding and maintaining the content’ (Francioli et al., 2017).

2.4.2 VocBench

VocBench is a web-based, multilingual, collaborative development platform for developing and managing SKOS thesauri, OWL ontologies and RDF datasets in general (Stellato et al., 2017; <http://aims.fao.org/interviews/vocbench>).

Two versions of VocBench are available: VocBench 2 and VocBench 3, which was developed by ART Research Group at the University of Rome Tor Vergata in the context of collaboration with the Food and Agriculture Organization (FAO) of the United Nations and the European Commission’s ISA² programme, respectively. VocBench 2 offers a web environment for maintaining thesauri, code lists and authority resources, providing advanced collaboration features such as history, validation and a publication workflow, and multi-user management with role-based access control; whereas VocBench 3 in addition offers an editing environment, with facilities for management of OWL ontologies, SKOS/SKOS-XL thesauri, OntoLex lexicons and any sort of RDF dataset. User experiences are briefly reported by the developers; no specific mentioning of code lists was found.

VocBench was born inside FAO as a collaborative framework for maintenance of the AGROVOC thesaurus. AGROVOC is a controlled vocabulary, consisting of 36,000+ concepts available in up to 33 languages, covering all areas of interest of the FAO, including food, nutrition, agriculture, fisheries, forestry, environment etc. VocBench is serving also the GEMET thesaurus of the European Environmental Agency, and the EU Vocabularies (<https://publications.europa.eu/en/web/eu-vocabularies/>), managed by Publications Office of the European Union. The controlled vocabularies among others include keywords which describe the content of documents in EU law and related documents (legislation, preparatory documents, international agreements, communications on case law, parliamentary questions, etc.).

2.4.3 OGC Definitions Server

The OGC Definitions Server is an online registry that allows for the management of resources such as terms, definitions, vocabularies and other related resources that are defined in OGC standards. The resources are recorded in registers that conform to Linked Data principles and are published through the definitions server. The definitions server provides a resolvable HTTP URI for each registered resource, thereby making it possible to uniquely identify the resource. The definitions server is intended to facilitate semantic interoperability between different systems that use OGC standards

(<https://github.com/opengeospatial/NamingAuthority>). It was announced in 2018 and is being extended to contain much of the knowledge incorporated in OGC documents as well as a single reference site for Coordinate Reference System (CRS) definitions, Discrete Global Grid Systems (DGGS), sensor models, and other specialized catalogues or ontologies (<http://www.opengeospatial.org/blog/2922>). The present implementation is based on open source products ELDA, SISSVoc, and Apache Sesame/RDF4J (https://inspire.ec.europa.eu/sites/default/files/presentations/1400_semantic_web_essentials_the_ogc_definition_server.pdf).

2.4.4 Other tools

When the scope is primarily code lists, mention is made of Unilexicon and Skosmos, respectively (European Commission, 2018, p. 13).

3. SEMANTIC TOOLS WITHIN THE LAND ADMINISTRATION DOMAIN

Related and occasionally overlapping standards seem to be an attribute of this time. Semantic tools, especially thesauri, provide a frame for identifying partly shared terminology, promoting the development of well-defined conceptual structures, applying them in software and recordings, and consequently increase interoperability. As mentioned in previous section, within a number of domains, e.g. agriculture, economy, and environment, controlled vocabularies have been developed (AGROVOC; STW–Thesaurus for Economics; GEMET), each amounting to several thousand terms.

The Cadastre and Land Administration Thesaurus (CaLAtThe) was issued 2011, based on the then draft version of LADM. The present CaLAtThe version 3 of 2019 was extended to about 200 terms, reflecting also the terms of the OGC LandInfra. A thesaurus is characterized with its top concepts, which characterize the domain covered. The five top concepts of CaLAtThe are: Land, Party, Law, Documentation, and Activity. CaLAtThe is presently based on a dedicated web server, drawing SKOS-structured content from a MySQL database by means of php code. Moreover, term relations are depicted as graphs, provided through the GraphViz visualization software.

The identification of related semantic tools is facilitated by the cross-referencing provided through the Basel Register of Thesauri, Ontologies & Classifications (BARTOC); however, no robust method for assessing closeness seems available yet. The following presents an initial assessment of semantic tools related to CaLAtThe:

AGROVOC Multilingual agricultural thesaurus provides a general framework for land administration and cadastre terms. It is maintained by FAO and a community of editors and issued as two specialized concepts schemes: AGROVOC and the Linked Land Governance Thesaurus LandVoc (<http://aims.fao.org/activity/blog/use-agrovoc-thesaurus-common-vocabulary-cgiar-core-metadata-schema-and-application>). The LandVoc meant to standardize the classification of content and resources, to improve the discoverability of and access to land-related information, from both global and grassroots sources, from all over the world. It

is emphasized that LandVoc is not meant to serve as a glossary for land governance-related issues (<https://landportal.org/voc/landvoc>).

Finto, the Finnish thesaurus and ontology service, provides a Finnish Geospatial Domain Ontology, drawing among others on the EU INSPIRE legislation, and ontologies for Public Administration including references to boundary disputes and cadastral procedures.

The World Bank Group (WBG) Thesaurus, including among others the scheme on Urban Housing and Land covering: ..., urban planning, ..., zoning, ...; urban land administration and land management including home ownership and rental tenure, tenure regularization, and street addressing in urban areas; ...

The Multilingual Land Tenure Thesaurus (2003), issued by the Land Tenure Service of FAO, is not available in SKOS format, but it covers the land administration domain in some detail, yet indicating its legacy by a missing entry on Land Administration.

The fact that two CaLAtThe-related thesauri are developed in the framework of FAO, suggest that the FAO supported VocBench setting would be more relevant for CaLAtThe than Re3gistry from a technical perspective, yet also from an international perspective. However, the focus on standards harmonization calls strongly for integrating CaLAtThe into the OGC Definition Service. Consequently, investigations are being made to allow for management of code lists through CaLAtThe, hosted at the OGC Definition Server. Mention is made that thesaurus hosting is not necessarily exclusive. As a matter of fact, CaLAtThe is presently available both at its origin: <http://www.cadastralvocabulary.org/> as well as through the BARTOC register, thereby increasing awareness – and competition.

4. DISCUSSION

As outlined above, technology and expertise are available for harmonization of standards through management of code lists, facilitated by a domain thesaurus. The following suggest an implementation of these options for the domain of cadastre and land administration, but emphasis is made that this should be considered an example of a more general means of harmonizing related standards.

The Cadastre and Land Administration Thesaurus (CaLAtThe) was developed from the ISO Land Administration Domain Model and extended to cover also the land administration part of the OGC LandInfra /InfraGML standards. It is in the process of being extended with all of the land administration-related code list names and values of the mentioned standards. Experiments, testing how code lists could best be integrated into the SKOS-based thesauri, cf. the options discussed above in section 2.2, tend to suggest an adoption of the third option, the use of one concept scheme for the domain vocabulary, and an accompanying concept scheme for the related code lists. An example file, which may be tested through the SKOS-play facility (<http://labs.sparna.fr/skos-play>) is attached.

Given web access to the domain thesaurus, CaLAtHe, now including references to the code lists of the LADM and LandInfra standards, you may imagine the following scenario or use cases:

1. A computer science engineer is engaged within a land administration agency to overhaul their information system, taking into account also new international standards within the domain. The engineer has no specific knowledge of administrative, let alone legal issues, and thus has to communicate with national specialists of these domains. The national specialists may have computer literacy at user level, perhaps higher, but have no working knowledge of modelling or use of code lists, etc.

The availability of a domain thesaurus, in case: CaLAtHe, provides the engineer with a structured representation of the universe of discourse. The dialogue with the specialists may take a point of departure in those concepts of CaLAtHe, which are familiar to the specialists. Next step would be a listing of national, administrative procedures where the found concepts are applied, followed by an identification of the documents needed in the national procedures, and the corresponding Statement class of LandInfra and the LA_AdministrativeSource of LADM. Now the various code lists come into play, and the engineer applies the standards as motivated by the need of an improved system. The likely supplement with national code list values can be integrated with the code lists of the standards organizations, thereby also supporting joint regional harmonization efforts.

2. A land administration agency (LAA) having established national LADM code lists and a neighbouring LAA cooperates on developing code lists, shared as far as possible. The availability of CaLAtHe with LADM code list names and examples provides for joint framework, where national translations of English terms may be added and their interrelationships negotiated. The thus developed partly shared code lists and the extended CaLAtHe provides an improved resource for further neighbour cooperation.

4.1 Organizational considerations

The present LADM standard leaves code list issues to user communities, which includes land administration agencies and their regional associations, and also (affiliations of) global software vendors and local software companies. The concern for harmonization of domain vocabulary and of standards emerged within the research community, framed by the International Federation of Surveyors, FIG, and the international standards organisations, ISO and OGC. Surely, more specialized units may be needed to drive development and identify local potential for cooperation in this rather technical domain.

A joint international unit for code list management was proposed in terms of a draft Memorandum of Understanding (Stubkjær et al., 2018). Alternatively, management may be framed by regional associations like the Intergovernmental Committee on Surveying and Mapping (ICSM), which is a Standing Committee of ANZLIC – the Australian and New Zealand Spatial Information Council, as well as the Permanent Committee on Cadastre in the European Union (PCC). As for the latter, the strong position of Finland with respect to ontology development, cf. section above, might suggest that Finland take an initiative in this

respect. The fact that the National Land Survey of Finland is in charge of organizing the upcoming Conference and Plenary Meeting of the PCC, to take place 20.11.2019 – 21.11.2019 only supports this idea. For Latin America, the *Comité Permanente sobre el Catastro en Iberoamérica* (<http://www.catastrolatino.org/>) similarly might stimulate cooperation in this issue. Finally, large countries with federal governmental structure, like the USA, China, Russia, and India, could pave the way for others in demonstrating the benefits of a joint unit for code list management.

5. CONCLUSION

Related and occasionally overlapping standards seem to be an attribute of this time. Semantic tools, especially thesauri, provide a frame for identifying partly shared terminology, harmonizing conceptualizations, and consequently increase interoperability. Standards like the ISO 19152:2012 Land Administration Domain Model (LADM) basically specifies classes and the relations among them. However, this methodology cannot catch the richness of variations of the domain, and therefore code lists are introduced as a supplement. The paper explored the potential of including code lists from related standards, in case the LADM and the OGC Land and Infrastructure Conceptual Model Standard (LandInfra) in a domain thesaurus, the Cadastre and Land Administration Thesaurus (CaLAtHe). Available through a semantic platform, the thesaurus would facilitate shared code list management.

The W3C recommendation: Simple Knowledge Organization System (SKOS) provides a model for recording of thesauri. The SKOS data model provides more options for code list rendering. An extensive *Guidelines for the Use of Code Lists* (European Commission, 2018) does not discuss these, yet three options are presented in the paper and evaluated. The tentative conclusion is to apply two *Concept schemes*: one concept scheme for the domain vocabulary and an accompanying concept scheme for the related code lists. The proposal is tested against the W3C RDF Validation Service and validated successfully. Also, graphical rendering of both domain vocabulary and code lists and combined are demonstrated. An example file, which may be tested through a public *SKOS-play* facility, has been developed.

A semantic platform provides for web access to the thesaurus with code lists. Three platforms have been investigated. Maintaining that availability on platforms need not be exclusive, the investigation suggests that from a technical perspective, yet also from an international perspective, the Food and Agriculture Organization (FAO) supported VocBench platform would be relevant for CaLAtHe. However, the focus on standards harmonization calls strongly for integrating CaLAtHe into the OGC Definition Service. Consequently, investigations are being made to allow for management of code lists through CaLAtHe, hosted at the OGC Definition Server.

Expertise on thesauri and code lists is globally yet scarce and international standardization efforts have to be aligned with local engagement to ripe the benefits of joint efforts for code list management. The paper proposes a focus on organizations at the regional level to drive development and identify local potential for cooperation in this rather technical domain. Specifically, is mentioned the Intergovernmental Committee on Surveying and Mapping

(ICSM), the Permanent Committee on Cadastre in the European Union (PCC), and the *Comité Permanente sobre el Catastro en Iberoamérica*, as well as large countries with federal governmental structure, like the USA, China, Russia, and India.

REFERENCES

- Breitman, K., Casanova, M.A. & Truszkowski, W. (2007). *Semantic Web: Concepts, Technologies and Applications*. Springer Science & Business Media.
- European Commission (2018). Guidelines for the Use of Code Lists. <https://joinup.ec.europa.eu/sites/default/files/document/2018-05/Guidelines%20for%20the%20Use%20of%20Code%20Lists%20v1.00.pdf>.
- Francioli, D., Epure, E., Hernandez Quiros, L., Lutz, M. (2017). Re3gistry version 2 - Manage and share reference codes in a simple way. INSPIRE Conference, Strasbourg 6 September 2017.
- Gruber, T.R. (1993). A translation approach to portable ontology specifications. *Knowledge acquisition*, 5(2), 199-220.
- INSPIRE (2017). Best Practices for registers and registries & Technical Guidelines for the INSPIRE register federation. INSPIRE Maintenance and Implementation Group, 2017-05-31, Version 1.0.
- ISO 19135:2005 Geographic Information – Procedures for Item Registration. International Organization for Standardization (ISO), Geneva, Switzerland, 2005.
- ISO 19152:2012 Geographic information – Land Administration Domain Model (LADM). International Organization for Standardization (ISO), Switzerland, 2012.
- NISO (2017). Issues in Vocabulary Management. National Information Standards Organization, Technical Report TR-06-2017. <https://www.niso.org/press-releases/2017/09/niso-releases-issues-vocabulary-management-technical-report>.
- OGC Land and Infrastructure Conceptual Model Standard (LandInfra), <http://docs.openeospatial.org/is/15-111r1/15-111r1.html>.
- OGC InfraGML 1.0 - Part 7 – LandInfra Land Division - Encoding Standard, <https://docs.openeospatial.org/is/16-107r2/16-107r2.html>.
- Paasch, J.M., van Oosterom, P., Lemmen, C., & Paulsson, J. (2015). Further modelling of LADM's rights, restrictions and responsibilities (RRRs). *Land Use Policy*, 49, 680-689.
- Scarponcini, P. (2017). Code List Manifesto. - OGC document 17-050r1 https://portal.openeospatial.org/files/?artifact_id=75291&version=1.
- Stellato, A., Turbati, A., Fiorelli, M., Lorenzetti, T., Costetchi, E., Laaboudi, C., Van Gemert, W. & Keizer, J. (2017). Towards VocBench 3: Pushing Collaborative Development of Thesauri and Ontologies Further Beyond. In 17th European Networked Knowledge Organization Systems Workshop, NKOS 2017 (Vol. 1937, pp. 39-52). CEUR-WS.
- Stubkjær, E., Paasch, J., Cagdas, V., van Oosterom, P., Simmons, S., Paulsson, J. and Lemmen, C. (2018). International code list management - The Case of Land Administration. 7th Land Administration Domain Model Workshop, Zagreb, Croatia, 11-13 April 2018.
- van Oosterom, P., Kara, A., Kalogianni, R., Shnaidman, A., Indrajit, A. & Alattas, A. (2019). Joint ISO/TC211 and OGC Revision of the LADM: Valuation Information,

Spatial Planning Information, SDG Land Indicators, Refined Survey Model, Links to BIM, Support of LA Processes, Technical Encodings, and Much More on Their Way! FIG Working Week 2019, Hanoi, Vietnam, April 22–26, 2019.

- W3C (2009). SKOS Simple Knowledge Organization System Reference. W3C Recommendation 18 August 2009, <https://www.w3.org/TR/skos-reference/>.
- Zeng, M.L. & Mayr, P. (2018). Knowledge Organization Systems (KOS) in the Semantic Web: A multi-dimensional review. International Journal on Digital Libraries 2018.

BIOGRAPHICAL NOTES

Erik Stubkjær is emeritus professor, having served as professor of cadastre and land law at Department of Development and Planning, Aalborg University 1977 – 2008. He was engaged in standardization activities, contributing to OGC standards LandInfra and InfraGML (2016/17). He graduated as land surveyor in 1964 and obtained his Ph.D in 1969. During 1979-1988, he was member of the Tribunal of the Danish Association of Chartered Surveyors.

Hans-Christoph Gruler is the representative of Leica Geosystems in the Open Geospatial Consortium and Building Smart International. Within OGC he is the chair of the Land and Infrastructure Standard Working Group, inside bSI member of the Product Room Steering Committee. He is also part of the Integrated Digital Built Environment (IDBE) joint working group from both standard organizations that has the objective of achieving better interoperability between the geospatial and built environment domains through coordination of development of the standards. He holds a Master of Science degree in Geodesy and Geoinformatics from the University of Stuttgart.

Scott Simmons is Chief Operations Officer of the Standards Program of the Open Geospatial Consortium. In this role, he coordinates member-driven standards development activities and ensures that all OGC standards progress through the organization's consensus process to approval and publication. His OGC-related research has focused on data lifecycle management, integration, and dissemination. He has also served as an Adjunct Professor at the College of Wooster, on the Advisory Board of the GIS Cluster at the Rocky Mountain Innosphere, and as a subject matter expert for seminars at universities and conferences around the World. He holds a Bachelor of Science degree in Geology from the University of Texas and a Master of Science degree in Geology from Southern Methodist University.

Volkan Çağdaş is associate professor in cadastre and land administration at Yildiz Technical University (YTU), Department of Geomatic Engineering, Istanbul / Turkey. In 2010, he became an assistant professor in YTU, and in 2014 he was awarded the associate professorship. He has been teaching cadastre, immovable property law, land re-adjustment, immovable property valuation, and land information management systems at undergraduate and graduate levels. His research interest covers both the technical and the institutional aspects of cadastre and land administration.

CONTACTS

Erik Stubkjær
Aalborg University, Department of Planning
Rendsburggade 14, niveau 3
DK-9000 Aalborg, DENMARK
Phone: +45 23319553
E-mail: est@land.aau.dk
Website: <http://people.plan.aau.dk/~est/>

Hans-Christoph Gruler
Leica Geosystems AG,
9435 Heerbrugg, SWITZERLAND
Email: hans-christoph.gruler@leica-geosystems.com
Website: <http://www.leica-geosystems.com>

Scott Simmons
Executive Director, OGC Standards Program
Colorado, USA
E-mail: ssimmons@opengeospatial.org
Website: <http://www.opengeospatial.org/ogc/organization/staff/ssimmons>

Volkan Çağdaş
Yıldız Technical University, Department of Geomatic Engineering
34210 Esenler, Istanbul, TURKEY
Phone: + 90 212 383 5313
Fax: + 90 212 383 5274
E-mail: volkan@yildiz.edu.tr
Website: <http://yildiz.edu.tr/~volkan/>

