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27 pawns ready for action

A multi-indicator methodology and evaluation of thesaurus management tools from a LOD perspective

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Abstract

Purpose – The purpose of this paper is to propose a methodology for assessing thesauri and other controlled vocabularies management tools that can represent content using the Simple Knowledge Organization System (SKOS) data model, and their use in a Linked Open Data (LOD) paradigm. It effectively analyses selected set of tools in order to prove the validity of the method.

Design/methodology/approach – A set of 27 criteria grouped in five evaluation indicators is proposed and applied to ten vocabulary management applications which are compliant with the SKOS data model. Previous studies of controlled vocabulary management software are gathered and analyzed, to compare the evaluation parameters used and the results obtained for each tool.

Findings – The results indicate that the tool that obtains the highest score in every indicator is Poolparty. The second and third tools are, respectively, TemaTres and Intelligent Theme Manager, but scoring lower in most of the evaluation items. The use of a broad set of criteria to evaluate vocabularies management tools gives satisfactory results. The set of five indicators and 27 criteria proposed here represents a useful evaluation system in the selection of current and future tools to manage vocabularies.

Research limitations/implications – The paper only assesses the ten most important/well know software tools applied for thesaurus and vocabulary management until October 2016. However, the evaluation criteria could be applied to new software that could appear in the future to create/manage SKOS vocabularies in compliance with LOD standards.

Originality/value – The originality of this paper relies on the proposed indicators and criteria to evaluate vocabulary management tools. Those criteria and indicators can be valuable also for future software that might appear. The indicators are also applied to the most exhaustive and qualified list of this kind of tools. The paper will help designers, information architects, metadata librarians, and other staff involved in the design of digital information systems, to choose the right tool to manage their vocabularies in a LOD/vocabulary scenario.

Keywords Linked open data, Software evaluation, Vocabularies, Semantic Web, SKOS/RDF, Thesaurus management tools

Paper type Research paper

1. Introduction

Among the existing knowledge organization systems (KOS) we can find thesauri. This kind of KOS can be defined as structured controlled vocabularies, whether generic or for a specific theme, formed of concepts represented by terms, to which meanings are given establishing equivalence among synonyms, and which are related explicitly as described in ISO 25964-1:2011 (International Organization for Standardization, 2011a).

Adapting thesauri to the web entailed a simplification in their management such as the inclusion of search in interfaces and the transformation of their terms into hyper textual links. The adoption of hypertext forms for thesaurus terms has been for some time the main, and almost only, advantage of editing such vocabularies online (Hudon, 2003). Nowadays many thesauri on the web show their content in a similar manner to printed thesauri.

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For more than 20 years, construction of web thesauri has taken place with various tools, and for around 15 years the web has been practically the only channel of presentation for these controlled vocabularies bringing these advantages:

- reduced cost: computerization of processes reduces the time needed for construction and maintenance, leading to financial savings (Arano, 2005);
- usability testing helps understand users' comprehension of their function, as participants in the creation, management, and optimization of thesauri (Arano and Codina, 2004; Arano, 2005; Greenberg, 2004);
- improved access to terminological tools for helping with information retrieval (Arano and Codina, 2004);
- the possibility to reuse terms for new projects or transfer their content to other storage forms (Arano, 2005; Pastor-Sánchez *et al.*, 2009); and
- utility in databases where each descriptor automatically links among associated registries.

Despite their advantages, thesauri on the web have limitations. One is related to the advantage of transforming terms into hypertext links. It was an important development but nowadays it is insufficient. Today many thesauri still present their content as plain text. Another limitation is the use of website or database search by thesauri. These environments offer precision and exhaustiveness that better matches user needs. García-Marco (2008) shows thesauri in the internet must overcome localism and embed themselves in networks. One approach could be using the Simple Knowledge Organization System (SKOS) data model.

SKOS is an OWL full ontology based on the Resource Description Framework (RDF). This data model allows representations of organized knowledge, such as thesauri, to be machine readable, and interchanged by software applications, thus not just published "on" the web, but being "of" the web (Méndez and Greenberg, 2012), thus increasing interoperability. SKOS is a basic standard, simpler than OWL ontologies, and more economical (Pastor-Sánchez, 2011).

The SKOS data model is a World Wide Web Consortium (W3C) recommendation for sharing and linking systematized knowledge on the web. Many KOS, including thesauri, taxonomies, and classification systems have similar structures and are useful for similar applications, facilitating interoperability.

SKOS offers a solution to the "localism" noted earlier by mapping concepts among different vocabularies. Mapping vocabularies according to the requirements for linked data will give greater possibilities to thesauri for knowledge discovery in the environments where they are implemented.

The creation of data models shared through SKOS allows vocabulary users to search and process archives in a uniform manner, but it does not solve the problems arising from the design of applications for doing so (Tuominen *et al.*, 2009).

Applications for constructing and managing controlled vocabularies that use SKOS show a lack of uniformity in their functionality, as noted by Tuominen *et al.* (2009). Various projects to migrate thesauri to SKOS use interfaces or tools created ad hoc such as:

- conversion of thesauri Integrated Public Sector Vocabulary, Medical Subject Headings, and Gemeenschappelijke Thesaurus Audiovisuale Archieven, by Van Assem *et al.* (2006);
- conversion of the Library of Congress Subject Headings in MARCXML to SKOS, by Summers *et al.* (2008);
- representation of the Thesaurus for Social Sciences (TheSoz) by Zapilko and Sure (2009);

- conversion of the Chinese Agricultural Thesaurus to SKOS by Guojian *et al.* (2012); and
- representation of the *Nomenclatura internacional normalizada de ciencia and tecnología* and of the *thesaurus de la UNESCO* by Pastor-Sánchez *et al.* (2013).

The objectives and priorities of each project, and the differences among their vocabularies, result in tools with different functionalities hardly reusable by other projects.

2. Objectives

The main objective of this study is to elaborate a set of criteria defining the most important characteristics of software for editing controlled vocabularies, especially thesauri and ontologies that manage their contents using the SKOS model. It will include aspects related to general characteristics and management of software, structure and relations between concepts, querying vocabulary content, and interoperability between vocabularies.

Other specific objectives have been determined in this work:

- analyze tools' functionalities to determine whether it is possible to establish categories of applications based on their primary goal or highlighted functions;
- compare applications' level of implementation of standards for controlled vocabularies;
- distinguish the implementation characteristics of each tool to determine its usability;
- compare the functions of each tool to determine its utility;
- asses software interoperability through import and export functions, and determine metadata support in migration operations; and
- determine the level of help offered to developers or end users.

3. State of the art: evaluation of thesaurus management software

The evaluation of software for creating and managing thesauri has generated an abundant literature in the last quarter century. From this literature, we collect parameters that we consider useful for our project.

3.1 Previous studies of evaluations of thesaurus management tools

In 1990, Jessica Milstead published an evaluation of seven thesaurus management packages: BRS/Search Thesaurus, Collection, Information Navigator, Lexico, Stride, TCS, and TMS. She maintained that the best approach to doing so is to apply the requirements for each situation, and evaluate the characteristics of each program against them in each project. Likewise, she suggested that nothing can replace testing software, and the resulting user experience. Ganzmann (1990) published a list of very detailed criteria, widely used for many years. His objective was to help users in the task of choosing tools for thesaurus creation by applying a list of detailed criteria. The author concluded that the software could sometimes be insufficient, not meeting all the requirements collected.

Some years later, Moya and Gil (2001), taking the criteria of Ganzmann, studied five thesaurus management programs: Beat Thesaurus Software 3.2, MultiTes 6.0, Stride 6.2.1, TCS-y2k, and SGAT 2.0. They asserted that independent thesaurus management systems are more appropriate when there is no requirement for interaction with the storage and retrieval systems. The authors claim that programs should be more flexible, allowing users to adapt them to the needs of each thesaurus.

Five years later, Almeida Campos *et al.* (2006) analyzed six thesaurus creation tools: TermChoir, MultiTes, Thesmain, TermTree, Synaptica, and Tematres. They conclude that

the programs evaluated are designed to perform operational tasks, but do not guide the user in the process of constructing a thesaurus. Also, that open-source tools are more limited than proprietary products.

In 2008, H. Hedden published a comparison of three single-user thesaurus creation and maintenance tools: MultiTes, TermTree 2000, and WebChoir TCS-10. Without concluding which one is better, the author affirms that user preferences and the characteristics of each project determine the best software to use on each occasion.

Few studies compare tools that manage thesauri and permit their Skosification, that is, migrating the content of the thesaurus to the SKOS format. One study by Pérez-León and Martínez-González (2010) compares four tools: ThManager, Tematres, TermTree, and Poolparty. This work pays attention to compatibility with the standards of Semantic Web and in particular SKOS, and the ability to integrate or reutilize software. The results of their analysis show that all the tools studied offer basic functionalities, but differ in the type of annotation permitted, advanced search features, and the absence of validation capability. Regarding interoperability, the authors confirm that almost all tools import and export plain text and standard formats, but not all support SKOS.

A broad study of tools for creation of ontologies and editing thesauri in SKOS is that of Myrseth *et al.* (2013). Numerous tools for construction of vocabularies and ontologies are analyzed: Adaptive Business Glossary Manager, Anzo Operational Metadata Management, IBM Infosphere Business Glossary, Business Information Modeler, Collibra Business Glossary Enterprise Vocabulary Net, Lexaurus Bank and Lexaurus Editor, Ontotext, Poolparty, Semantic Media Wiki, Semantic Xpress, SKOSed, VocBench, Onto Studio, and Web Protégé 2.0. The authors grouped their results by four sets of criteria, discarding programs which do not meet each requirement, but not drawing any conclusions.

Another study by Leroi and Holland (2010) in the context of the European project Athena, analyses ThManager, SKOSed, Annocultor, xTree, ASKOSI, Athena Ingester, and Cyclops. They conclude that no tool meets all their requirements (register a vocabulary in a repository, *skosification*, update and change management, mapping between vocabularies, and search and browse contents), and therefore recommend the complementary use of different tools and methods.

Morshed and Dutta (2012) evaluated ontology creation tools by statistical methods and the analysis of decision making. They consider it more efficient to reuse and modify an existing tool than create a new one. To determine the best tool, they compared Poolparty, VocBench, and TopBraid EVN, through a test undertaken by 60 participants based on 16 criteria, and considering the feedback provided about user experience. They conclude that the first two tools are useful for creating controlled vocabularies, of medium (VocBench) or large size (Poolparty) and for publishing them as Linked Open Data (LOD), while the third (TopBraid EVN) is more oriented to enterprise documentation.

Martínez and Alvite (2014) evaluated thesaurus managers, including Semantic Web aspects like information integration and interoperability. The authors apply an evaluation methodology to five SKOS compliant tools: MultiTes, One-2-One, Poolparty 2.7, SKOSed 1.0, Tematres 1.2, and ThManager 2.0, and conclude that there is a clear distinction between traditional thesaurus management applications and software oriented toward the technologies of the Semantic Web.

The most current analysis is a comparative evaluation of VocBench against various thesaurus and ontology editors (Web Protégé, PoolParty, Tematres, and SKOSed), which considers such aspects as import and export of data, data models supported, validation rules, semantic integration, and report generation. The paper concludes that VocBench covers the bulk of key characteristics for a SKOS vocabulary editor (Stellato *et al.*, 2015).

The general conclusion of these studies is that evaluation criteria need to be adapted for each project or situation. This avoids creating a set of restrictive criteria meaning that tools

score poorly in evaluations. Other interesting reflections included in the papers analyzed are the need of testing tools directly in order to apply criteria based on concrete requirements, the indispensability of open-source software to use existing resources, and the consideration of user feedback in evaluation.

3.2 Comparative analysis of criteria applied to thesaurus creation software

The criteria used by various authors in software evaluation are compared here. These are grouped into five thematic areas. For each we outline the gaps our study proposes to cover and the adjust criteria for thesaurus management software in the ISO standard 25964-1:2011.

3.2.1 Criteria for general software evaluation. Few studies of thesaurus tools – only four of the 11 examined – cover generic software requirements. The most complete is Ganzmann (1990), which is, notably, the oldest. This author evaluates technical data, price, user support, ergonomy, acceptance level, and data integrity. Despite the long time elapsed, these criteria provide interesting details like user access control, different types of help, and hardware compatibility.

The other three provide generic technical criteria which are either too brief, in the case of Martínez and Alvite (2014), who simply say the system requirements can impose conditions on use of the software, or confusing, as in Morshed and Dutta (2012), who offer an indicator called "complexity" to cover the usability of interface, the ease of installation and cross-platform availability. Other criteria such as those used by Myrseth *et al.* (2013) are highly abstract, seeking characteristics like confidence, solidity, capacity for support and capability of local representatives. Nevertheless, some criteria from this study prove to be very useful such as the form of the tool, details of licensing and short- and long-term costs, intellectual property rights and available forms of user help (tutorials, methodologies, and e-mail lists).

General criteria related to general software evaluation have also been taken into account. For example, the standards ISO 25010 (International Organization for Standardization, 2011b) for systems and software engineering, and 25012 (International Organization for Standardization, 2008) for software engineering, maintainability, portability to other software, interoperability and ease of learning and use are noted as important.

We have also considered other criteria used by the Software Sustainability Institute (Jackson *et al.*, 2011) to evaluate software applications. These criteria, focused in the usability, cover the difficulty of understanding the software, availability of documentation and easy use; sustainability and maintainability, with attention to licensing conditions; and software accessibility, portability, and interoperability.

The standard ISO 25964-1:2011 for thesauri and interoperability with other vocabularies lists a series of criteria applicable to all software such as the existence of good documentation, various forms of user help, friendliness of the interface, and acceptable price.

3.2.2 Creation and editing operations. The creation and editing of controlled vocabularies include operations as the generation of new terms and complementary information or relationships (notes about scope or application, definitions of use, internal codes, creation, and modification dates), as well as the possibility to modify or suppress part or all the information about terms. Some authors have positively evaluated these functions (Milstead, 1990; Hedden, 2008; Myrseth *et al.*, 2013).

The conformance of relations between terms to standards for thesauri management has traditionally been a factor of analysis, although differently named: "consistency control" (Almeida Campos *et al.*, 2006; Ganzmann, 1990; Hedden, 2008; Moya and Gil, 2001), "integrity management" (Martínez and Alvite, 2014) or "consistency of management and control" (Myrseth *et al.*, 2013). Regardless of the name, it covers criteria like coherence of the terms and their relations with established standards for thesauri (traditionally hierarchical, associative, and equivalence), rejection of duplication in a term, and automatic reciprocity

of relations. Standard ISO 25964-1:2011 recommends that thesaurus creation and editing programs include such functions.

Other elements to consider regarding editing thesauri are access control of users and collaboration in construction and change of terms. Controlling users through different levels of permission is taken into account by Almeida Campos *et al.* (2006), Myrseth *et al.* (2013), and Martínez and Alvite (2014). The second aspect is only considered in the work of Martínez and Alvite (2014).

3.2.3 Terms and concepts definition. This type of criteria is better defined by work that evaluates thesaurus editing tools, than in those that deal with software for creating ontologies or vocabularies in general.

Information about term management is evaluated by almost all authors. However, only three set of criteria are considered useful. Ganzmann (1990) notes aspects for evaluation such as presence and size limits of fields to describe providence of terms, their definition and annotations. Moya and Gil (2001) consider that the software should register information about sources of a term, its language and usage definitions.

The presence of user-defined relations, recommended by ISO 25964-1:2011, is recognized by Ganzmann (1990), Moya and Gil (2001), Almeida Campos *et al.* (2006) and Hedden (2008). But none of those studies provide information about how to evaluate the relations created by users.

Regarding terms and their relations, ISO 25964-1:2011 recommends not establishing limits to the number of terms, their length or that of notes, the number of hierarchical levels, association and equivalence relations, or languages. It also suggests that each term might have various associated code numbers, materials, and a unique identifier.

3.2.4 Consulting vocabularies: search, browsing, and retrieval. Vocabulary management programs offer various possibilities to consult the vocabularies: automatic query with simple and advanced interfaces, or faceted navigation. These ways of consulting vocabularies have been treated differently in the documentation studied, in some cases so detailed that it is infeasible to use all of the criteria, in others so generic that it is not useful for evaluating the quality of software.

Morshed and Dutta (2012), Hedden (2008), Almeida Campos *et al.* (2006), Pérez-León and Martínez-González (2010) include searching, browsing, and retrieval functionalities as evaluation criteria, but no detail of desirable elements are given.

Querying gets most attention as an evaluation criterion in various forms: flexible search (Almeida Campos *et al.*, 2006), advanced search with logical operators (Martínez and Alvite, 2014), free search using synonyms and antonyms (Myrseth *et al.*, 2013) or "explosion" of search terms, that retrieve terms and tags of a concept and the information about specific or related concepts (Martínez and Alvite, 2014; Milstead, 1990).

Navigation through indexes or interface is the least considered form of vocabularies' consultation. Only Almeida Campos *et al.* (2006), Moya and Gil (2001) and Ganzmann (1990) value various classes of index (permuted, hierarchical, systematic, or alphabetic).

ISO 25964-1:2011 recommends incorporating the following methods of consultation for vocabulary creation software:

- search, with auto completion of terms;
- an index of head terms, that offers the possibility to navigate among concepts; and
- an interface that shows the hierarchical context of a term or concept alongside its notes and relations.

3.2.5 Interoperability. In the context of hardware and software, interoperability is understood as the ability of a system to work and communicate effectively in the

interchange of data with other systems (Reitz, 2014). This definition covers perfectly the interchange of data between controlled vocabularies.

Interoperability is treated in the analyzed literature as a key concept. In four of the five sets of criteria the idea of interoperability only includes import and export of thesaurus' terms. However, Martínez and Alvite (2014) consider that interoperability includes compatibility with Semantic Web formats like SKOS, JSON, and N3 Turtle, as well as the ability to integrate the software.

The ISO standard 25964-1 on thesauri, in regards to interoperability, maintains that a standard format for data interchange should be used. The ISO standard 25964-2 (International Organization for Standardization, 2013) deals with interoperability between thesauri and other types of controlled vocabulary, listing different types of mapping relations between vocabularies and offering recommendations to map concepts between thesauri and other controlled vocabularies.

4. Methodology

The evaluation process begins with identifying the software tools. First, SKOS compliant tools were selected both free and commercial software.

To collect applications related to Semantic Web technologies and LOD especially SKOS, we used the lists we consider most up to date, complete or relevant:

- list of SKOS-related tools, in the wiki of the W3 Consortium (Semantic Web Deployment Working Group, 2014); and
- benchmarking of the Project Athena Europe wiki (Athena Project, 2010).

4.1 Tool classification

For better management of the data, tools were grouped into categories according to their principal function. Although some tools could be included in more than one category, we have associated them to only one to avoid duplications. The names of the categories have been taken from the W3C wiki, although in some cases we have modified the sense.

- Triple stores: databases designed to store and retrieve RDF data in the form of triples which can be queried with SPARQL, such as: AllegroGraph, Apache Marmotta, Linked Media Framework, and Mulgara Semantic Store.
- Converters: programs whose principal function is to change the vocabulary format, from OWL or other syntax to SKOS, or vice versa, as in the case of: Model Futures SKOS Exporter, OWLtoSKOS, SKOS Play!, SKOS2OWL, Skosify, and XL2XML.
- Editors: programs which allow the creation and modification of controlled vocabularies in SKOS format, as the following: iQvoc, Intelligent Topic Manager, Lexaurus editor, Open Metadata Registry, Poolparty, SKOSed, SKOSjs, SKOS Shuttle, Tematres, ThesaurusAPI, ThManager, TopBraid EVN, xTree, and VocBench.
- Extractors: programs that automatically extract data from documents, using data mining algorithms to produce indexes as their results. Extractors can map the content to different metadata schemas, including SKOS. Examples include: Helping Interdisciplinary Vocabulary Engineering (HIVE), Poolparty Semantic Search, Poolparty Extractor, SemanticTurkey, and SKOSSY.
- Navigators: programs that allow visualization or exploration of data in Semantic Web formats, or related to LOD, especially controlled vocabularies expressed in SKOS. This category comprises: ASKOSI, Callimachus, Finnish Ontology Library Service ONKI, Rhizomer, SKOS_WS, and SKOS Reader.

- Validators: tools used to evaluate the quality of mark-up used. This term describes testing conformance, in our case of documents and data on the web to some standards. Note that validation does not require that the object or entity validated matches some pattern. We only found two validators: qSKOS and Poolparty SKOS Quality Checker.

The evaluation criteria are only applied to the editors to test the ease of integrating them in LOD/Linked Open Vocabularies environments.

4.2 Indicators and criteria

Based on the studies cited and direct observation of tools, a set of five indicators with 27 criteria were defined to meet the objectives of our study.

4.2.1 Indicator 1: operating environment. This indicator covers aspects such as software, unrelated to editing thesauri, but of capital importance at the moment of selection. The details considered have in part been taken from lists of criteria for software in general, such as that produced by Jackson *et al.* (2011).

- Criterion 1.1: form of data storage: we distinguish three options: Databases, relational or not; unstructured document storage; and other formats, including triple stores.
- Criterion 1.2: user help: documentation that is helpful to users about the function of the program. This includes text and audiovisual material, developed by the software vendor or users, present on official web pages about the software or in other websites. The following elements are considered positively: blogs, use cases, guides, tutorials, usage methodologies, mailing lists, wikis, e-mail service, and FAQs (frequently asked questions).
- Criterion 1.3: type of application and connection method: applications are of three types: desktop tools, online tools, or both kinds. The latter is the best option, because it offers easier access for a multiuser environment, and an installed application is the least valued, because it limits simultaneous access for multiple users.
- Criterion 1.4: software license: we distinguish between commercial and non-commercial software.
- Criterion 1.5: compatible browsers: we considered the following browsers: Mozilla Firefox, Google Chrome, Internet Explorer, Opera, and Safari (for Windows). We rated higher those tools that offer all functions in the largest number of browsers.
- Criterion 1.6: software portability: assuming all the software functions on Windows, we value tools that can also function on other operating systems.
- Criterion 1.7: usability: the term refers to the friendliness and capacity for personalization of the administrator interface, considering its friendliness in regards to usefulness of menus and the complexity of creating or modifying content. Also we evaluate whether tools allow the customization of the interface.

4.2.2 Indicator 2: definition of terms, concepts, and relations. This indicator covers elements related to the form, coverage and origin of terms and concepts, and relations between them which determine when they can be used. The main sources for criteria are ISO 2788:1986 (International Organization for Standardization, 1986) and ISO 25964-1:2011:

- Criterion 2.1: limits to the number of terms or concepts, considering its presence as a negative aspect.
- Criterion 2.2: additional information for terms and concepts conforms to ISO standards: standards mention application notes, history and definitions of use. Tools should provide information separately for each of these elements.

- Criterion 2.3: possibility to create user-defined note types.
- Criterion 2.4: relations between terms and concepts conform to ISO standards. Software should enable these three types of relation: associative, hierarchical, and equivalence.
- Criterion 2.5: possibility for users to create relations between terms and concepts, as new forms of association between terms, or others created by the editors of a thesaurus for a specific purpose.
- Criterion 2.6: limited number of relations between each term and concept, considering its presence as a negative aspect.
- Criterion 2.7: possibility to assign more than one generic type to each term or concept, considering its presence as a positive aspect.
- Criterion 2.8: possibility to include equivalent terms or concepts in other languages, considering its presence as a positive aspect.
- Criterion 2.9: assignation of identifiers, codes, or categories to each term. It is considered a positive aspect, although it is not necessary that identifiers and codes are assigned automatically.

4.2.3 Indicator 3: creating, editing and managing vocabularies. This indicator covers assorted criteria related to management of terms and users:

- Criterion 3.1: consistency control: software that tests for erroneous relations and duplicate concepts within a single language is considered best practice.
- Criterion 3.2: user profile management: the software should distinguish users, through a username and password, and provide for different levels of access.
- Criterion 3.3: activity reports: software should report searching and term management activity. It is desirable that it distinguishes activity by date and user.
- Criterion 3.4: possibility to modify or suppress data: the modification or elimination of vocabulary registries should be possible by individual items, groups, or entire vocabulary.
- Criterion 3.5: possibility for multiple users to simultaneously create or modify content. Collaborative management implies a program that operates online.

4.2.4 Indicator 4: consulting vocabularies: search, browsing and visualization. This indicator groups various criteria that serve the main goal of thesauri: to enable users to consult its terms and indexes:

- Criterion 4.1: search: it can be simple or advanced. On simple search the ability to introduce search terms is considered. On advanced search the ability to combine terms using boolean operators is analyzed. In both modes, dropdown menus of applicable terms, auto completion, metadata search function, and support to SPARQL queries are considered positive values.
- Criterion 4.2: single interface with all the information about a term, especially with a graphical representation of relations.
- Criterion 4.3: visualization of content: various types of indexes: hierarchical, alphabetic, permuted, and systematic. Hyperlinked and network presentation forms would be considered positive.

4.2.5 Indicator 5: interoperability. Interoperability is understood here as the ability to import and export content in various formats:

- Criterion 5.1: export of controlled vocabularies: exporting entire vocabularies or subsets in different standard formats, preferably SKOS, according to compatibility with the vocabulary metadata.
- Criterion 5.2: import of controlled vocabularies: the capacity to import content from other tools in multiple formats. SKOS/RDF support is desirable.

5. Results

Data about software were gathered through direct use of tools as well as information provided by their developers. The tools have been analyzed by applying the five indicators and corresponding criteria previously defined.

Results come from analysis of ten of the 14 vocabulary editors identified in the methodology. The other four programs (Lexaurus Editor, Open Metadata Registry, SKOSjs, and xTree) were excluded either because there was no demonstration version available or their functionalities did not match those normally found in a vocabulary management tool.

5.1 Operating environment

Observations on operating environment show similarity among the tools evaluated, with differences due to limitations of individual tools. In general, free software tools perform better than commercial.

Commercially-licensed programs are fewer (Intelligent Topic Manager, Poolparty, SKOS Shuttle, and TopBraid EVN) than free software (iQvoc, SKOSed, Tematres, ThesaurusAPI, ThManager, and VocBench). As Table III shows, the General Public License is used by far more programs (SKOSed, Tematres, ThesaurusAPI, ThManager, and VocBench), than the Apache license (iQvoc).

Almost all tools that state the form of data storage use relational databases: JenaSQL (TopBraid EVN), Oracle (iQvoc, Intelligent Topic Manager), PostgreSQL (Intelligent Topic Manager, ThesaurusAPI, and VocBench), and MySQL (Tematres, TopBraid EVN). Only ThesaurusAPI and Poolparty use another form of storage.

Of the types of user help seen, the most common is a user manual, primarily textual. Video is used in Poolparty, VocBench, and TopBraid EVN, with Youtube links in the tools' pages. Another common form of help are wikis (Poolparty, TopBraid EVN, Tematres, SKOSed, iQvoc, and VocBench), especially in free software (Tematres, SKOSed e iQvoc). Finally, three types of help are less common: blogs (Tematres, TopBraid EVN, and VocBench), use cases (Intelligent Topic Manager, Tematres, and TopBraid EVN), and an FAQ (Poolparty). The tools that offer the widest variety in forms of help are Tematres, TopBraid EVN, and VocBench.

All of the tools are independent except SKOSed, which is a plugin for the Protégé ontology editor. Two programs (ThManager and ThesaurusAPI) are desktop applications without network capability, and the remaining seven (iQvoc, Intelligent Topic Manager, Poolparty, SKOS Shuttle, Tematres, TopBraid EVN, and VocBench) are web based.

For the seven web-based programs, browser-compatibility was tested. Four tools (iQvoc, Poolparty, Tematres, and VocBench) work with the five browsers mentioned, SKOS Shuttle and TopBraid EVN are optimized for Internet Explorer, Mozilla Firefox, and Google Chrome, while Intelligent Topic Manager, only functions correctly with the first two.

Portability between operating systems shows little difference. Excluding tools that do not declare on which system they function (iQvoc and SKOSed) and the generalized Windows compatibility, we can note compatibility for the following systems:

Linux (Intelligent Topic Manager, Poolparty, VocBench, and ThesaurusAPI), TopBraid EVN (Mac) y multiplatform (Tematres and ThManager).

User-friendliness ranges from the simplicity of Tematres to the minimal friendliness of VocBench's interface. The rest of the programs are easy enough to use, except for the process of creating and managing concepts as seen in Poolparty and ThManager. Customization of interfaces is only available in Intelligent Topic Manager, Poolparty, and TopBraid EVN (Table I).

5.2 Definition of terms, concepts, and relations

The information recommended in standards (coverage notes, usage definitions, and historical notes) are supported by Intelligent Topic Manager, iQvoc, SKOSed, Tematres, TopBraid EVN, and VocBench. The other tools do not support all these elements, or include other user-created types of notes, as Poolparty and VocBench. In addition, relations are defined according to ISO standards (hierarchical, associative, and equivalence) by Intelligent Topic Manager, iQvoc, Poolparty, Tematres, ThesaurusAPI, and ThManager. The other programs conform solely to the SKOS data model (SKOS Shuttle, SKOSed, and TopBraid EVN). Creation of user-defined note types or relations between terms is only supported by Poolparty, TopBraid EVN, and VocBench.

No program limits the number of terms or semantic relations in a thesaurus. However, as shown in Table IV there are many cases where no information is provided.

Regarding the remaining criteria, the use of a unique identifier is possible in Intelligent Topic Manager, Poolparty, Tematres, and VocBench; multiple inheritance is allowed in Intelligent Topic Manager, iQvoc, Poolparty, Tematres, TopBraid EVN, and VocBench; and equivalent terms in other languages are possible using Intelligent Topic Manager, iQvoc, Poolparty, SKOSed, Tematres, ThManager, TopBraid EVN, and VocBench (Table II).

5.3 Creating, editing, and managing vocabularies

Results on creation and management of terms are presented under the criteria of consistency control, modification and suppression of terms and complementary information. Data about user management are represented by criteria such as activity reports, profile management, and collaborative management.

Considering the management term processes, all tools allow modification or deletion of individual terms and the deletion of entire vocabularies. ThesaurusAPI and VocBench also allow deletion of blocks of information.

On version control, we find that Intelligent Topic Manager orders activity reports chronologically, while Poolparty, SKOS Shuttle, Tematres, TopBraid EVN, and VocBench also do so by content.

User profile management, with assignation of tasks and actions, is available in Intelligent Topic Manager, iQvoc, Poolparty, Tematres, TopBraid EVN, and VocBench. The profiles vary in number and denomination among tools, but the most common are administrator, editor, and user. Collaborative management is found in all the web-based programs.

Consistency control is present in eight tools (iQvoc, Intelligent Topic Manager, Poolparty, SKOSed, SKOS Shuttle, Tematres, TopBraid EVN, and VocBench), but not all perform the same check. Actions like checking the structure of vocabularies and finding duplicate terms in the same language, as recommended ISO 25964-1, are common to all these tools, but SKOS validation is only in SKOSed, Poolparty, VocBench, TopBraid EVN, SKOS Shuttle, and Intelligent Topic Manager (Table III).

5.4 Consulting vocabularies: search, browsing, and visualization

Methods for consulting vocabularies are very similar. Programs only differ in number of retrieval fields, or ways for presenting the content retrieved. All present terms as hyperlinks improving the navigability of vocabularies.

Table I.
Results for indicator 1: "operating environment"

	iQvoc	Intel. Topic Man.	PoolParty	SKOSed	Tematres	ThesaurusAPI	ThManager	TopBraid EVN	VocBench	SKOS Shuttle
Data storage										
Oracle	■	■	■							
PostgreSQL		■				■			■	
MySQL					■			■		
JenaSQL								■		
Triple store						■				
User support										
Guide/Manual	■	■	■	■	■	■	■	■	■	■
Wikis	■		■	■	■			■	■	
Blogs					■			■	■	
Use cases		■			■			■		
Videos			■					■	■	
FAQs			■		■			■	■	
Type of software										
Web based	■	■	■		■			■	■	■
Desktop only				■		■	■			
Software license										
Free (GPL, Apache, etc.)	■			■	■	■	■		■	
Comercial		■	■					■		■
Web browsers										
Explorer		■						■		■
Mozilla		■						■		■
Chrome								■		■
Safari										
Opera										
All of them	■		■		■				■	
Portability										
Windows		■	■	■		■		■		
Linux		■	■	■		■			■	
Mac				■				■		
Cross-Platform					■		■			
Usability										
Customization		■	■					■		
Interface complexity	Low	Low	Med.		Low		Med.	Low	High	

Notes: ■, the mentioned functionalities are all available. Level of Interface complexity: low/medium/high

Table II.
Results for indicator 2: "definition of terms, concepts and relations"

	iQvoc	Int. Topic Man.	Poolparty	SKOSed	Tematres	ThesaurusAPI	ThManager	TopBraid EVN	VocBench	SKOS Shuttle
Unlimited number of terms	■	■	■		■			■		
Additional information of terms (ISO)	■	■		■	■			■	■	
Notes created by users		■						■	■	■
Relationship between terms (ISO)	■	■	■		■	■	■	■	■	
Relationship between terms (SKOS)		■	■	■				■	■	■
Type of relationships created by users		■	■		■			■		
Unlimited number of relationships for each term	■	■	■	■	■			■	■	
Equivalences in other languages	■	■	■	■	■		■	■	■	■
Poly-hierarchy	■	■	■		■			■	■	■
Unique identifier for each term		■			■			■	■	

Note: ■, the mentioned functionalities are all available

Table III.
Results for Indicator 3: "creating, editing and managing vocabularies"

	iQvoc	Int. Topic Man.	Poolparty	SKOSed	Tematres	ThesaurusAPI	ThManager	TopBraid EVN	VocBench	SKOS Shuttle
Control of consistency										
Structure of vocabularies		■	■	■	■			■	■	■
Terms			■	■	■			■	■	■
Labels/links			■							■
SKOS		■	■	■				■	■	■
User profile management	■	■	■		■			■	■	■
Activity reports										
Version control		■			■			■	■	■
By date		■			■			■		
By user					■			■	■	
By content								■	■	■
Data modif. suppres.										
Single terms	■	■	■	■	■	■	■	■	■	■
Batches of terms	■	■	■	■	■		■	■		■
Vocabularies	■	■	■	■	■	■	■	■	■	■
Collaborative management	■	■	■		■	■		■	■	■

Note: ■, the mentioned functionalities are all available

Searching with auto completion of terms, boolean operators and exact matching is available in all tools. Less common are constraints on hierarchy or relations (Poolparty, Tematres, ThesaurusAPI, TopBraid EVN, and VocBench) and the use of SPARQL (Poolparty, SKOS Shuttle, Tematres, and VocBench).

Content visualization is offered in hierarchical and alphabetical indexes. Intelligent Topic Manager, SKOSed, TopBraid EVN, and VocBench only offer hierarchical indexes, while only iQvoc, Poolparty, Tematres, and ThManager present both. Intelligent Topic Manager also offers KWIC and KWOC indexes.

Other forms of visualization are: triples (Poolparty, SKOS Shuttle, and VocBench) and SKOS (Intelligent Topic Manager, Poolparty, Tematres, TopBraid EVN, and VocBench).

Finally, graphical representation as network of concept relations is integrated in Intelligent Topic Manager, Poolparty, Tematres, SKOS Shuttle, TopBraid EVN, and VocBench (Table IV).

5.5 Interoperability

The interoperability level of the ten programs was evaluated in terms of their capacity for import and export of data. It is desirable that software at least allow migration of data in plain text, CSV and SKOS formats.

Interoperability has improved in thesaurus management tools, as predicted by Pérez-León and Martínez-González (2010). Table V shows that import and export of data sets is available in almost all tools.

Poolparty, SKOS Shuttle, and Tematres stand out for the number and modernity of formats in which they can export data. The first two offer multiple formats of RDF graph serialization, while the third allows multiple file formats and syntaxes (txt, JSON, Zthes, SKOS-Core, TopicMap, BS8723, VDEX, and WXR) (Table V).

6. Conclusions

The use of a broad set of criteria to evaluate programs for managing controlled vocabularies gives satisfactory results. Our 27 criteria conform a useful evaluation system for software tools. Comparisons show big differences between evaluated tools.

The general conclusion is that Poolparty achieves a notable level for all five indicators, followed by Tematres, which is missing support for import of some formats. The separate conclusions for each indicator are as follows:

- Analysis of results concerning the operating environment highlights the significant presence of free software compared to commercial, and the preponderance of web-based systems. This demonstrates that vocabulary management software is adapted to cloud computing model, based on appropriate conditions for collaborative creation, and a good level of interoperability between metadata formats. The ability to function through a web connection, combined with browsers and operating systems, make Poolparty and Tematres the most capable tools in terms of operating environment.
- User help is generally satisfactory, especially in commercial programs, although lacking some details such as the limited use of audiovisual formats. TopBraid EVN is the tool with the best user help.
- Results for usability, covering the friendliness and interface customization, do not reach a high level in any of the products evaluated. The impossibility of personalizing interfaces and complex presentation, make many programs difficult to use. The tool with highest usability is Tematres.

Table IV.
Results for Indicator 4: "search, browsing and visualization"

	iQvoc	Int. Topic Man.	Poolparty	SKOSed	Tematres	ThesaurusAPI	ThManager	TopBraid EVN	VocBench	SKOS Shuttle
Search by…										
Boolean operators	■	■	■	■				■	■	
Initial term truncation	■		■		■			■	■	
Final term truncation	■	■	■		■		■	■	■	
Exact match	■	■	■	■	■	■	■	■	■	■
Similar terms			■							
Semantic search			■							
SPARQL query			■		■				■	■
Metadata tool search								■		
Related terms			■					■	■	
Content visualization										
All the information of a term in one interface			■							■
Hierarchical index	■	■	■	■	■		■	■	■	■
Alphabetical index	■	■	■		■		■			
Graphical index		■	■		■			■	■	■
KWIC – KWOC		■								
SKOS		■	■		■			■	■	■
Languages		■	■				■		■	■
Triples			■						■	■

Note: ■, the mentioned functionalities are all available

Table V.
Results for Indicator 5: "interoperability"

	iQvoc	Int. Topic Man.	Poolparty	SKOSed	Tematres	ThesaurusAPI	ThManager	TopBraid EVN	VocBench	SKOS Shuttle
SKOS	→←	→←	→←		→←		→←		←	
RDF/XML	←	→←	→←			→←		→←	→	→←
N-triples	→←	→←	→←			→←		→←		→←
Turtle	←		→←			→←		→←		→←
N3			→←			→				→←
NQUADS			→←							→←
JSON					→			→←		
TriX			→←							
TriG			→←							→←
Zthes					→←					
Topic Maps		→←			→←					
XLS		→←	→←						→←	
XML		→←						→		
TXT					→←					
VDEX					→←					
BS8723					→←					
WXR					→←					
SQL					→←					

Notes: →, export; ←, import

- Regarding the definition of terms and relations, Intelligent Topic Manager, Poolparty, and Tematres get the best score. On the structure of relations between concepts and complementary information, we identified a common issue: the adaptation to the SKOS structure, ignoring the classic structures outlined in ISO standards that happens in three programs (SKOSed, TopBraid EVN, and VocBench). In our opinion, both forms should coexist in an application, as they do in Poolparty.
- Other evaluation criteria such as multiple inheritance, equivalence in other languages and the length and number of terms are well handled in the tools. However, there are few which assign a unique identifier to each term or concept (Intelligent Topic Manager, Poolparty, Tematres, and VocBench).
- As for the creation, modification and deletion of terms or concepts, thesaurus and ontology management tools have good performance, especially Intelligent Topic Manager and Poolparty. However, user's management, as the level of detail of users' profiles or activity report generation, should be improved. Few programs go beyond a simple time-based log. In web-based (collaborative) thesaurus management programs, reports need at least to timestamp creation and modifications, as well as identify the user responsible for each change.
- All the tested programs seem better prepared to facilitate consulting vocabularies through internal search, than navigating indexes. These are under-used for exploration, being present in KWIC and KWOC form by Intelligent Topic Manager, which makes little sense given the versatility of Web Search.
- Beyond traditional indexes, the tested programs rarely use new forms of visualization, underutilizing techniques such as graphical representation of a network of relations, available in Intelligent Topic Manager, Tematres, and VocBench, or marking concepts according to different metadata formats as Poolparty does. The best search, browsing and visualization of vocabulary content are those of Poolparty and VocBench.
- Regarding interoperability, we consider that tested programs should support more formats for both import and export. Those tools whose import and export functionality are most complete are SKOS Shuttle, Tematres, and Poolparty.

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