Comparative Analysis and Implications of Foreign Knowledge Organization System Management Tools: Postprint

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Abstract

[Purpose/Significance] This study conducts a comparative analysis of the research status and key functionalities of representative foreign knowledge organization system (KOS) management tools within the evolving Semantic Web technology landscape, and outlines the development trends of related research. [Method/Process] Using a web-based survey methodology, ten representative foreign KOS management tools were selected and their development status was comparatively analyzed from perspectives including structure definition, project maintenance, data management, interoperability, and operating environment. Based on this analysis, recommendations are provided for the development of domestic KOS management tools. [Results/Conclusion] The findings indicate that the development of domestic KOS management tools should leverage technologies such as the Semantic Web, linked data, semantic integration, and semantic interoperability to promote functional innovation, including: flexible design and configuration of multi-type data models, support for sustainable management and maintenance mechanisms, support for distributed collaborative user management and control, knowledge-driven iterative data updates, semantic-oriented KOS reuse and evolution, and the construction of a KOS-centric knowledge organization framework.

Full Text

Comparative Analysis and Enlightenment of Foreign Knowledge Organization System Management Tools

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Abstract: [Purpose/Significance] This paper compares and analyzes the current research status and key functions of representative foreign knowledge or-

ganization system (KOS) management tools under the development of semantic web technologies, and outlines relevant research trends. [Method/Process] Through online survey methods, ten representative foreign KOS management tools were selected and compared in terms of structural definition, project maintenance, data management, interoperability, and operating environment. Based on this analysis, recommendations were provided for the development of domestic KOS management tools. [Result/Conclusion] The study found that domestic KOS management tool development should promote functional innovation by leveraging technologies such as semantic web, linked data, semantic integration, and semantic interoperability. This includes: flexible design and configuration of multi-type data models, support for sustainable management and maintenance mechanisms, support for distributed collaborative management and control, knowledge-driven iterative data updates, semantic-oriented KOS reuse and evolution, and construction of a KOS-centered knowledge organization framework.

Keywords: Knowledge Organization System (KOS) | KOS Management Tools | Knowledge Management | Vocabulary | Ontology

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Knowledge Organization Systems (KOS), also known as knowledge organization systems, constitute a general term for various norms and methods used for knowledge organization. They serve as crucial means for knowledge acquisition and utilization, encompassing not only traditional dictionaries, glossaries, classification schemes, subject headings, and thesauri, but also frameworks such as semantic networks and ontologies that support complex semantic descriptions [1-2]. In digital information management and applications, KOS acts as a bridge between user information needs and knowledge resources, helping users quickly discover required resources [3]. Initially applied primarily in library and information science fields to support services such as document annotation and indexing, query expansion, term extraction, text classification, and translation, KOS enhanced access to digital resources [4]. In information system architecture, KOS management tools (hereinafter referred to as "KOS management tools") function as middleware, serving both content management systems for metadata management, knowledge classification, and knowledge indexing modules, as well as information service systems such as classification navigation, semantic retrieval, recommendation systems, and intelligent question-answering systems (see Figure 1 [Figure 1: see original paper]). Using KOS management tools, users can quickly import, transform, integrate, and modify existing KOS, or even build and edit customized KOS from scratch, and automatically analyze text corpora to generate customized KOS data.

As early as the 1990s, library and information institutions such as OCLC launched network databases and Windows-based editing management systems to support the compilation of thesauri like DDC and LCSH [6]. With the development of KOS types and standards, the functions of KOS management

tools have continuously evolved. In addition to library and information institutions, knowledge service providers and other organizations have introduced various types of tools to support KOS management [7]. Against the backdrop of KOS becoming important components of information architecture, content management, and discovery systems in various institutions, the analysis and evaluation of related tools have become highly meaningful research topics. This paper focuses on evaluating and comparing the key functions of representative foreign KOS management tools and analyzing their current status to provide recommendations for KOS development work in domestic institutions.

2. Related Research

Existing literature on KOS management tool evaluation primarily employs two methods: First, analysis from the tool developers' perspective. For example, J. Ganzmann [8] enumerated evaluation criteria such as structural definition, data input, data output, and retrieval capabilities from the perspective of general thesaurus construction requirements and specific applications, which have been widely applied in tool selection for thesaurus construction. A. S. Chaudhry et al. [9] evaluated 12 thesaurus construction tools including DataHarmony in terms of accuracy, flexibility, format diversity, multilingual support, and maintenance capabilities. B. Pérez-León et al. [10] focused on compatibility with semantic web standards (particularly SKOS) and the ability to integrate or reuse software, comparing tools such as Thmanager from perspectives including supported vocabulary structures, data formats, editing functions, search functions, and software integration capabilities. P. Myrseth et al. [11] evaluated and scored 15 vocabulary and ontology tools including PoolParty from the perspectives of model standards, workflows, and integration. M. M. Martínez-González et al. [12] focused on information integration and semantic interoperability of thesaurus management tools in the semantic web environment, evaluating six thesaurus management tools including MultiTes from perspectives of purpose, system requirements, functions, structural definition, consistency management, and information interoperability. Bai Haiyan [6] proposed evaluation criteria for knowledge organization tool management software, including structural definition capability, consistency control capability, output and sharing exchange capability, interoperability support capability, and openness and integration capability. The most recent study is that by G. Mochón et al. [13], who developed an evaluation methodology under the development of linked open data technology, establishing five evaluation dimensions (operating environment, concept and relationship definition, creation and editing, browsing and retrieval, and interoperability) with 27 evaluation criteria for in-depth analysis of ten management tools including TemaTres.

Second, analysis based on user survey results. For example, A. Morshed et al. [14] established 16 criteria including functionality, reusability, data storage, complexity, maintainability, elasticity, reliability, robustness, learnability, usability, flexibility, and visibility, collected feedback data from 60 users, and

conducted quantitative evaluation of PoolParty, Vocbench, and TopBraid EVN tools using unsupervised machine learning algorithms. Such studies are relatively rare, and the evaluation criteria tend to be subjective.

Summary of Existing Research

Evaluation criteria for KOS management tools can be summarized into five dimensions: operating environment, structural definition, project maintenance, data management, and interoperability:

(1) **Operating Environment:** General software standards used to analyze factors such as software operating environment, unrelated to KOS editing, including data storage forms, application types, software licensing agreements, compatible browsers, operating systems, and interaction and integration capabilities with third-party systems. Relevant standards include ISO 25010, ISO 25012, and ISO 25964-1.

(2) **Structural Definition:** The data model standards followed by tools, defining the scope, attributes, and relationships of terms/concepts/classes, determining KOS capabilities, usability, information governance, storage management, publishing, retrieval, and other construction capabilities and complexity levels. Detailed guidelines can refer to ANSI/NISO Z39.19, ISO 25964-1, SKOS, OWL 1/OWL 2, and ISO/IEC 21838.

(3) **Project Maintenance:** The ability to maintain KOS, such as whether it supports multi-user collaborative operations, activity reports, and workflow management.

(4) **Data Management:** The ability to edit and manage KOS data, such as data editing (creation, deletion, modification, etc.), data browsing and retrieval, input and output, and consistency and integrity control.

(5) **Interoperability:** Refers to the compatibility, integration, and interchangeability between knowledge organization systems, such as data mapping between KOS, multilingual KOS conversion, and KOS data integration.

Analysis reveals that existing KOS management tool evaluation research has primarily focused on analyzing early thesaurus or ontology construction tools and has not yet formed a comprehensive evaluation framework. In recent years, the increasing demand for KOS construction has also driven continuous functional expansion and deepening of KOS management tools. Based on existing research, this paper develops more comprehensive evaluation criteria and compares and analyzes both the basic functions and value-added functions oriented toward semantic web development of KOS management tools.

3. KOS Management Tool Comparison Analysis

3.1 KOS Management Tool Investigation and Selection

Currently, domestic KOS management tool development is mostly based on specific tasks, with strong professionalism and domain specificity, and relatively closed usage environments, making them unsuitable for general and open KOS construction, such as the NSTL Scientific and Technological Knowledge Organization System Material Management System [15]. Foreign KOS management tool research started earlier, providing open tool services with multi-domain user application cases, and continuously evolving with the development of KOS construction needs. Therefore, this study selected representative foreign KOS management tools as research objects.

To comprehensively analyze the current development of foreign KOS management tools, we conducted extensive searches and strict screening, covering products from KMWorld's Top 100 companies in knowledge management [16], frequently mentioned products in relevant literature, tools recommended by Taxonomy BootCamp [17], etc. Ten KOS management tools were ultimately selected (see Table 1), characterized by: (1) functions primarily supporting thesaurus construction, while also including some supporting multiple types of knowledge organization systems such as thesauri and ontologies; (2) products released within the past five years that are still providing services with continuously updated versions.

Table 1 List of KOS Management Tools

Tool Name	Supported KOS Types	License Type	Version
Vocbench	Thesaurus, Ontology	Open Source	Vocbench 3
PoolParty	Thesaurus, Ontology	Commercial	PoolParty Advanced Server 7.2
Synaptica KMS	Thesaurus	Commercial	Synaptica KMS 9.0
Synaptica Graphite	Thesaurus, Ontology	Commercial	Synaptica Graphite 3.0
TopBraid EDG-VM	Thesaurus, Ontology	Commercial	TopBraid EDG 6.4

Tool Name	Supported KOS Types	License Type	Version
Mondeca ITM	Thesaurus, Ontology	Commercial	2020
SKOSShuttle	Thesaurus, Ontology	Commercial	2017
TemaTres	Thesaurus	Open Source	TemaTres 3.1
Unilexicon	Thesaurus	Open Source	2019
MultiTes	Thesaurus	Commercial	v2020.04.02u

Note: For products without version identifiers, the latest version release time is used.

3.2 KOS Management Tool Evaluation Criteria

Based on existing KOS management tool evaluation research and combined with recent functional developments, this paper establishes 18 evaluation criteria from five evaluation dimensions for comprehensive and in-depth analysis of the selected KOS management tools. Specific evaluation criteria are shown in Table 2 :

Table 2 KOS Management Tool Function Evaluation Dimensions and Criteria

Dimension	Criteria	Description
Structural Definition	Data Model Standards	Compliance with data model standards such as ANSI/NISO Z39.19, ISO 25964-1, SKOS, RDF/RDFS, OWL, etc.
	Customizable Model Extension	Whether basic models can be semantically extended, e.g., adding custom concept attributes and relationships in thesaurus models; establishing associations between "thesaurus-ontology" models to enhance semantic description capabilities using ontologies
	Multilingual Management	Ability to edit data in two or more languages within a project

Dimension	Criteria	Description
Project Maintenance	Status Management	Including project compilation status and processing status of each data item in the project
	Version Management	Recording version changes of projects and comparing content differences between versions
	History Management	Recording project history editing information such as latest update content, time, and responsible person
	User Permission Management	Ability to set different access permissions for users or user groups to projects
	Workflow Management	Managing KOS content changes, controlling processing status, and managing release cycles
Data Management	Data Editing	Beyond basic data editing functions, tools support batch editing, drag-and-drop editing, etc.
	Data Visualization	Data presentation forms including alphabetical structure, hierarchical structure, relationship network diagrams, and other visualization methods
	Data Retrieval	Including simple search, advanced search, SPARQL query, etc.
	Data Quality Control	Review and supervision of data quality to achieve content consistency and integrity control
	Data Update	Automatic mining of relevant terms from text corpora and supplementing them into KOS content

Dimension	Criteria	Description
Interoperability	Input/Output	Supporting import and export of standard format data for data sharing with other systems, including CSV, RDF/XML, N-Triple, Turtle, N3, TriX, TriG, Zthes/XML, etc.
	KOS Content Mapping	Supporting content mapping between two or more KOS
	Linked Open Data Integration	Supporting publication of KOS data as linked open data or establishing associations with data in the LOD cloud
Operating Environment	Data Storage Form	Including local data storage forms such as relational databases and RDF databases, as well as external database access
	Open Integration	Integration with various indexing and resource management systems or search engines and retrieval tools, providing open interfaces such as API or Web Services for these application systems

3.3 Comparative Evaluation and Development Status Analysis

Based on the above evaluation criteria, we conducted in-depth testing and comparative evaluation of the ten selected KOS management tools through product documentation research, customer demonstrations, tool trials, and sample data testing. According to the evaluation results, we analyzed the current development status of foreign KOS management tools.

3.3.1 Structural Definition (1) Compliance with Diverse Data Model Standards. Analysis of the data model standards supported by representative KOS management tools reveals that many tools do not strictly distinguish between "thesaurus management tools" and "ontology management tools." Instead, they increasingly support both thesaurus standards (ANSI/NISO Z39.19 or ISO 25964-1) and ontology standards (OWL and RDF), particularly the

SKOS model applicable to various controlled vocabularies [7]. This trend is natural because institutions often need to construct multiple types of knowledge organization systems. Emerging software providers have already combined thesaurus management and ontology management functions, including Vocbench, PoolParty, TopBraid EDG-VM, Mondeca ITM, and SKOSShuttle. Synaptica is an exception, offering two products: Synaptica KMS primarily for traditional thesaurus management and Synaptica Graphite primarily for ontology management. Details are shown in Table 3 .

Table 3 Comparison of KOS Management Tool Structural Definition Capabilities

KOS Management Tool	Z39.19	RDF/RDFS	ISO 25964-1	Custom Attributes/Relations	Ontology-based Thesaurus Model Extension
Vocbench					
PoolParty					
Synaptica KMS					
Synaptica Graphite					
TopBraid EDG-VM					
Mondeca ITM					
SKOSShuttle					
TemaTres					
Unilexicon					
MultiTes					

(2) Flexible and Customizable Model Extension Methods. In big data environments, as the scale of knowledge organization expands, the expression of relationships between entities becomes increasingly rich. For example, general thesauri relationships only include USE/UF, BT/NT, RT, and TT, with attributes including definitions, scope notes, history notes, and general notes, generally not exceeding 10 types. However, semantic networks in new knowledge organization systems such as UMLS contain 54 types of semantic relationships [28]. Basic thesaurus data models are insufficient to support semantic expression in new knowledge organization systems and require extension. Common methods involve adding custom data attributes or relationship attributes to thesaurus models (referencing ISO 25964-1 standards). Except for TemaTres and Unilexicon, mainstream KOS management tools support custom attribute/relation extensions for thesaurus concepts.

Furthermore, many KOS management tools support establishing associations between “thesaurus-ontology” models, using ontology models to extend seman-

tic types, attributes, and relationships of thesaurus models [29]. This approach benefits from the compatibility between SKOS and OWL. For example, PoolParty provides custom knowledge model functionality to establish associations between thesaurus content and ontologies, achieving extended description of thesaurus models at the semantic level by adding new ontology classes to the single "concept" type and inheriting all attributes and relationships of that ontology class. The process is illustrated in Figure 2 [Figure 2: see original paper]. TopBraid EDG also provides similar functionality, supporting extension and description of thesaurus models (SKOS, SKOS-XL) in ontology management by adding new subclasses (such as country, city, etc.) to the concept class (skos:concept) and adding attributes and relationships to them.

3.3.2 Project Maintenance KOS construction often requires simultaneous management of multiple projects and multi-user collaborative editing in network environments. In addition to basic project browsing and registration functions, KOS management tools continuously enhance detailed processing in multilingual management, status management, version management, history management, permission management, and workflow management.

(1) Multilingual Management Supporting International Development. With increasing information exchange needs across different cultural and language backgrounds, tools supporting multilingual information organization and retrieval have become increasingly important, making multilingualism a significant trend in knowledge organization system development. This has driven KOS management tools to provide corresponding management functions. Except for TemaTres and Unilexicon, which only allow selection of one language for data editing within a project, most KOS management tools support multilingual data editing for knowledge organization systems. For example, Vocbench and PoolParty allow users to set primary languages and other preferred languages for KOS data browsing and editing, and arrange display order. Additionally, PoolParty supports automatic translation of preferred terms based on DBpedia, with translation results optionally added to relevant preferred or non-preferred term fields.

(2) Status, History, and Version Management for Sustainable Project Maintenance. KOS status management requires hierarchical approaches, with different status management strategies for the entire KOS and individual terms within KOS. At the project level, KOS status refers to the lifecycle stage of the entire KOS content, which can be described using status information such as "under development," "under maintenance," or "deprecated." At the data level, status management primarily describes the status of individual terms within KOS (such as "active" or "deprecated"). Currently, most KOS management tools only support status management at the data level, not at the project level.

NISO recommends that vocabulary management systems should automatically record the latest update content, time, and responsible person information to

ensure that any changes can be traced and verified [30]. Except for TemaTres and Unilexicon, most KOS management tools provide history management functions, automatically recording the latest update content, time, and editor information for each data item to ensure traceability and verification of any KOS project changes. Vocbench, PoolParty, and TopBraid EDG-VM also support retrieval and filtering of history records, facilitating intuitive discovery of information changes for specific time periods or terms.

Furthermore, KOS construction is not a one-time effort and requires dynamic update mechanisms to form classification and management of multiple versions. Version control concepts are crucial in KOS maintenance, and well-designed version control strategies make content updates easier and more suitable for automated processes. Currently, Vocbench, PoolParty, Synaptica, and TopBraid EDG-VM allow authorized users to generate new versions of KOS data and establish associations between different versions. TopBraid EDG-VM also supports comparison of different KOS versions to generate data comparison reports.

(3) Permission and Workflow Management Supporting User Collaboration. KOS construction may involve large-scale collaborative work among project administrators, domain experts, and end-users, requiring different access permissions for different users to avoid risks caused by missing permission controls or improper operations. The simplest approach is to assign different roles to users or working groups and control user permissions for accessing, editing, reviewing, and managing KOS data through roles, which is adopted by most KOS management tools. Another approach is to set access permissions for each project for users based on role control, which is more rigorous. For example, in addition to basic user role management, Vocbench includes an access control list in each project containing <ProjectConsumer, AccessLevel> entity pairs, where AccessLevel can be set to R (read) or RW (read/write) values for detailed user access permission configuration.

To facilitate management of KOS content changes, control processing status, and manage release cycles, authentication workflows are often introduced to verify user operations. This mechanism is closely integrated with KOS project status management, version management, history management, and permission management. Currently, many KOS management tools have workflow management functions. For example, Vocbench has built a change tracking device at the data layer that simultaneously saves operation metadata when data changes (deletion, addition), allowing authorized users to accept or reject operations. PoolParty provides a simple approval workflow where concepts created, edited, imported, or added through recommendation systems have a default status of "draft," which automatically changes to "approved" after review. TopBraid EDG-VM controls data changes through authentication workflows: when users edit KOS project content, a copy is first generated, and all editing operations are performed on this copy. Only after the changes in the copy are approved by reviewers will they be synchronized to the original KOS data.

3.3.3 Data Management Data management is the core functional module of KOS management tools, enabling KOS data browsing, editing, retrieval, quality control, and updates. Specific management function module comparisons are shown in Table 5 .

Table 5 Comparison of KOS Management Tool Data Management Capabilities

KOS Management Tool	Batch Editing	Drag-and-Drop Editing	Auto Spell Suggestion	Hierarchical Structure	Relationship Network Diagram	SPARQL Query	Data Quality Control	Text Corpus-based Term Extraction
Vocbench								
PoolParty								
Synaptica								
KMS								
Synaptica								
Graphite								
TopBraid								
EDG-VM								
Mondeca ITM								
SKOSShuttle								
TemaTres								
Unilexicon								
MultiTes								

(1) Diverse Data Editing, Browsing, and Retrieval Forms. To improve data editing efficiency, most KOS management tools support batch editing management functions. Meanwhile, PoolParty, Synaptica, and TopBraid products support drag-and-drop editing for hierarchical structure changes. PoolParty can also provide automatic spelling suggestions based on DBpedia data during user input.

KOS data visualization provides end users with a rich, intuitive understanding of its structure and content, allowing them to review data under compilation and provide feedback for modifications. Different tools have developed various visualization forms, such as hierarchical structures, relationship networks, and visual mapping diagrams. Hierarchical structure, also known as tree structure, is the most basic data visualization form provided by KOS management tools, displaying all data according to “broader-narrower” or “parent-child” relationships in KOS data, supported by almost all tools. Relationship network diagrams display data relationships through “node-relationship links,” supported

by most tools such as SKOSShuttle and Mondeca ITM. Other forms include PoolParty's visual mapping diagram showing all relationships of concepts with different colors, Synaptica KMS's pie chart displaying data distribution, Synaptica Graphite's project structure view showing associations between different KOS models, and Unilexicon's card format supporting user adjustment and sorting of data hierarchies.

Most KOS management tools support simple and advanced search functions. Advanced search allows retrieval of labels, relationships, attributes, and other content, supporting multiple matching modes (exact match, fuzzy match, starting/ending characters, etc.) combined with data filtering functions. Vocbench and PoolParty also support SPARQL query language for experienced users to quickly customize search statements.

(2) Data Quality Control Embedded in Management Processes. KOS construction requires review and supervision of data content and quality, which often needs human participation. However, excellent KOS management tools can provide multiple data quality detection schemes to assist manual review and improve construction efficiency. Generally, KOS data quality detection is divided into structural detection and label detection: structural detection verifies data structure integrity such as missing relationships or logical circular errors; label detection focuses on completeness and consistency of knowledge object descriptions such as term repetition and information missing. KOS management tools support quality management at two levels: (1) conducting overall quality issue detection on KOS data after import or completion of a processing stage and providing detection reports; (2) real-time detection during KOS data editing with immediate error feedback to users. For example, PoolParty supports data quality management by integrating qSKOS, which can set many quality assessment standards and detect in real-time during user interaction. TopBraid EDG-VM implements real-time integrity checking through SHACL (Shapes Constraint Language) [31]. Some tools like Vocbench can also provide operation suggestions after detecting errors, allowing one-click automatic repair of label or structural errors.

(3) Data Updates Based on Machine Learning. With the development of natural language processing and machine learning technologies, intelligent updates of KOS content have become a current research hotspot and development trend. Some KOS management tools are researching how to mine relevant terms from text corpora and supplement them into KOS content. For example: (1) PoolParty supports automatic mining of relevant terms/concepts from text corpora and adding them as candidate vocabulary to thesauri. The term extraction process uses comprehensive calculations of Mutual Information Score (MIS), Content Term Score (CTS), term frequency, and other screening indicators to obtain candidate terms [32]. (2) SKOSShuttle supports information extraction based on multilingual (German, English, Spanish, French) corpora using tf-idf values to weight each term. Users can filter and sort extraction results and choose to add identified new terms to existing thesauri [33].

3.3.4 Interoperability Interoperability of knowledge organization systems is an important characteristic of current KOS management tool development, enabling the transition from independent construction of single KOS to integrated development of various KOS, and from domain-specific local construction to cross-domain integrated development. Corresponding implementation methods include input/output, KOS content mapping, and linked open data integration. Standard format data input and output is the most basic interoperability method and an important factor in measuring KOS management tool sharing and exchange capabilities. Common formats include TXT, Excel/CSV, SKOS/SKOS-XL, RDF/XML, N-Triples, Turtle, N3, TriX, TriG, and Zthes/XML. Tool support for different formats is shown in Table 6 .

Table 6 Comparison of KOS Management Tool Interoperability

KOS Management Tool	Excel/CSV	SKOS/SKOS-XL	RDF/XML	N-Triples	Turtle	JSON/JSON-LD	KOS Content Mapping	Linked Open Data Integration
Vocbench	→←	→←	→←	→←	→←	→←		
PoolParty	→←	→←	→←	→←	→←	→←		
Synaptica KMS	→←	→←	→←	→←	→←	→←		
Synaptica Graphite	→←	→←	→←	→←	→←	→←		
TopBraid EDG-VM	→←	→←	→←	→←	→←	→←		
Mondeca ITM	→←	→←	→←	→←	→←	→←		
SKOSShuttle	→←	→←	→←	→←	→←	→←		
TemaTres	→←	→←	→←	→←	→←	→←		
Unilexicon	→←	→←	→←	→←	→←	→←		
MultiTes	→←	→←	→←	→←	→←	→←		

Note: "→" represents data input, "←" represents data export.

(1) Semi-automated KOS Content Mapping. With the development of database integration applications, cross-database, cross-language, and cross-domain operational needs have emerged, making interoperability between different knowledge organization systems an important issue requiring urgent solutions. Currently, the most effective solution is mapping between KOS, i.e., establishing vocabulary correspondence relationships between two or more KOS to enable association between their indexing results. Most KOS management tools support semi-automated mapping through machine-automated identification. For example, Vocbench supports establishing mappings between different

KOS projects through label-based semi-automated searches, with relevant entities and relationships verified and then associated using standard RDFS/OWL or SKOS mapping properties, such as aligning two SKOS concepts through SKOS:exactMatch or SKOS:closeMatch.

(2) Integration with Linked Open Data. On one hand, tools support publishing thesauri as linked open data; on the other hand, they support establishing associations with datasets in the LOD cloud. For example, PoolParty, TopBraid, and Vocbench can publish KOS content on the web as linked data and establish associations with resources in linked open data (LOD) sets such as DBpedia, WordNet, LCSH, and GeoNames, thereby becoming part of the LOD cloud. Vocbench and PoolParty also support automatic matching with LOD data such as DBpedia and automatically adding discovered relevant data to KOS content.

3.3.5 Operating Environment The operating environment comparison of KOS management tools is shown in Table 7 .

Table 7 Comparison of KOS Management Tool Operating Environments

KOS Management Tool	Relational Database	RDF Database	Remote Database Access	Open Integration	Third-party API/Web Service Access	Integration with Companion Tools
Vocbench						
PoolParty						
Synaptica						
KMS						
Synaptica						
Graphite						
TopBraid						
EDG-VM						
Mondeca ITM						
SKOSShuttle						
TemaTres						
Unilexicon						
MultiTes						

(1) Support for Distributed Semantic Data Storage. With the evolution of knowledge models and the surge in data volume, KOS management tools should support large-scale, distributed semantic data storage and management. Early KOS management tools mostly used relational databases for data

storage, such as TemaTres, Unilexicon, and MultiTes. Now, RDF databases such as RDF4J, AllegroGraph, Jena TDB, Virtuoso, GraphDB, StarDog, and MarkLogic have gradually become the preferred choice for mainstream KOS management tools. For example, Vocbench and PoolParty use RDF4J as the default local semantic repository. In addition to local data storage, some KOS management tools also support remote access to other storage systems for distributed data management. For example, Vocbench and PoolParty support accessing and calling data from remote storage such as MarkLogic, StarDog, AllegroGraph, GraphDB, and Virtuoso.

(2) Seamless Integration with Other Applications. Currently, more and more KOS management tools support integration with content management systems and search software, embedding KOS data into content annotation, information retrieval, and knowledge discovery system platforms. For example, Synaptica products can be combined with various third-party applications including SharePoint, Google Search, Apache Solr, OpenText, MarkLogic, and IBM Watson, expanding application scope. PoolParty, TopBraid, and Mondeca also provide relevant supporting components for user-demand-based integration. For example, the PoolParty semantic suite includes functional components for vocabulary and ontology management, knowledge graph management, text mining/natural language processing, linked data compilation, and semantic intelligent applications, which can be freely combined and integrated according to user needs. Mondeca ITM can be integrated with content indexing management tools and extract instances to expand KOS data.

4. Implications for Domestic KOS Management Tool Construction

Research findings indicate that to support big data environments and intelligent applications, domestic KOS management tool construction not only needs to support basic KOS lifecycle management (creation, evaluation, publication, maintenance, evolution) but should also learn from advanced KOS management tool development and combine with actual KOS construction needs to focus on improving tool performance in the following aspects:

4.1 Flexible Design and Configuration of Multi-type Data Models

KOS construction must consider "how to represent knowledge reasonably and effectively," i.e., creating standardized, abstract models to describe real-world objects and support machine understanding. For thesauri, classification schemes, and glossaries, the basic elements in their models are terms or concepts; for ontologies or knowledge graphs, their knowledge models include classes, class attributes, class relationships, and related rules [34]. With the rise of knowledge graph research, how to semantically extend traditional knowledge organization systems and quickly build lightweight ontologies has become an urgent problem for KOS management tools to solve. Tools should provide different

knowledge organization schemes to support flexible data modeling, including term-based thesauri, concept-based thesauri, and ontologies describing complex semantic relationships. Specific scheme design can refer to model standards such as SKOS/SKOS-XL, ISO-THESES [35], and RDF/XML for extension.

4.2 Support for Sustainable Management and Maintenance Mechanisms

NISO points out that over time, KOS access requires adequate documentation, appropriate maintenance strategies, and active management [30]. To achieve sustainable development of knowledge organization systems, authoritative, centralized storage and management are needed for various types of KOS to support KOS discovery and reuse, including status management, permission management, history management, and version management. Among the surveyed KOS management tools, most focus on micro-level data status management and do not support macro-level project status management. Therefore, KOS management tools should provide more detailed management solutions for project development, maintenance, publication, and other statuses.

4.3 Support for Distributed Collaborative User Management and Control

Current KOS construction is characterized by large data scale and broad domain coverage, which determines that its construction process requires collaborative compilation and maintenance by multi-domain, multi-institution, and multi-level users [36]. This requires KOS management tools to: (1) support distributed collaborative work to facilitate collaborative KOS design and editing by different user groups and improve work efficiency; (2) have flexible permission and task management mechanisms to assign tasks at different levels (such as editing, reviewing, etc.) to users with different permissions and support progress management. Although most surveyed KOS management tools support collaborative compilation by users with different permissions, they do not have complete full-process task management functions from task assignment, data editing, data review to project publication. When constructing KOS management tools, complete task management functions should be provided according to actual project collaborative work needs, including customizable workflows.

4.4 Knowledge-driven Iterative Data Updates

KOS construction is iterative. In the big data era, how to save manpower and resources as much as possible and use advanced technologies such as machine learning for intelligent KOS data updates has become an important research topic [28]. Currently, PoolParty and SKOSShuttle support term extraction based on text corpora, but the algorithms are relatively simple, only judging term relevance through statistical algorithms such as term frequency and mutual information, and have not achieved relationship mining. To achieve rapid KOS construction, KOS management tools should expand performance in data

mining, supporting the loading of various algorithm models such as machine learning and deep neural networks to achieve intelligent recommendation of terms and relationships.

4.5 Semantic-oriented KOS Reuse and Evolution

The semantic web encourages data sharing and reuse. Reuse of existing terms can maximize KOS value, expand its dissemination scope, and maintain its vitality. For example, by translating, mapping, merging, and customizing existing data in KOS management tools to build new knowledge organization systems, supporting dynamic integration and decomposition according to user needs. Current KOS management tools provide content mapping and linked open data integration functions but have weak support for dynamic integration and customization of existing data. Future KOS management tools can expand data reuse methods through: (1) extracting classes or concept groups from different KOS for data integration involving synonym merging and relationship fusion; (2) uploading domain keywords and simultaneously matching them with multiple KOS data, screening matching data for integration involving term weight calculation and relationship expansion. These methods can support rapid construction of cross-domain knowledge organization systems.

4.6 Construction of a KOS-centered Knowledge Organization Framework

KOS management tool development should focus on interoperability, openness, and integration capabilities, supporting integration with content management systems, annotation, and retrieval systems to form integrated workflows that can be conveniently applied to knowledge management operations in various types of institutions. In institutional knowledge organization construction, KOS management tools should be regarded as core components supporting structured classification of various data resources, knowledge entity extraction and indexing, and understanding and analysis of retrieval statements to maximize the utility of KOS data.

From the perspective of KOS management tool users, different tools have significant functional differences. Among open-source software, Vocbench performs outstandingly in all aspects, meeting the construction needs of various types of KOS in the semantic web environment. However, its integration with third-party systems is mainly through programming calls with relatively complex operations, making it suitable for users with KOS compilation experience. TemaTres and Unilexicon have relatively simple functions, only supporting thesaurus-type KOS construction, meeting basic project and data management needs but not supporting semantic extension or semantic interoperability, making them suitable for small-scale thesaurus construction needs. Commercial software has relatively complete functions and good service guarantees. Users can select appropriate KOS management tools according to their data construction scale and application needs: (1) General thesaurus compilation users can choose Mul-

tiTes or Synaptica KMS, where Synaptica KMS has good user permission and workflow management functions, supports drag-and-drop editing and graphical display of data content, enabling rapid KOS configuration. (2) Users with multi-type KOS construction needs can choose Synaptica Graphite, Mondeca ITM, or SKOSShuttle. These tools have similar functions with distinct features: Synaptica Graphite supports drag-and-drop editing and visualization at both data and project levels; Mondeca ITM can be integrated with content indexing management tools and extract instances to expand KOS data; SKOSShuttle supports term extraction based on text corpora for intelligent KOS updates. (3) Enterprise-level users can choose PoolParty or TopBraid EDG-VM, which have numerous customer application cases, can handle complex and large-scale thesauri and ontologies, and provide supporting components for content indexing, automatic classification, graph data management, and knowledge discovery, achieving seamless integration with KOS management tools, making them suitable for enterprise-level KOS construction and management.

Conclusion

To understand the development status of KOS management tools, this paper conducted a survey and analysis of ten representative KOS management tools from five dimensions: structural definition, project maintenance, data management, interoperability, and operating environment. The analysis reveals that KOS management tools are gradually adapting to user needs and technological development, promoting functional innovation by leveraging semantic web, linked data, semantic integration, and semantic interoperability technologies. Future KOS management tool construction should focus on: flexible design and configuration of multi-type data models, support for sustainable management and maintenance mechanisms, support for distributed collaborative user management and control, knowledge-driven iterative data updates, semantic-oriented KOS reuse and evolution, and construction of a KOS-centered knowledge organization framework. Based on functional analysis, this paper provides KOS management tool selection recommendations from the user perspective.

This study has certain limitations, such as not incorporating user experience into the evaluation scope. Future work can summarize and 归纳 actual needs from end-users, project managers, and KOS data editors during knowledge service processes, learn from the advantages of existing KOS management tools, and gradually improve the construction of domestic KOS management tools.

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Author Contributions

Zhao Bingrong: Participated in investigation and analysis.
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Liu Zheng: Paper topic selection and writing guidance.

Comparative Analysis and Enlightenment of Foreign KOS Management Tools

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Abstract: [Purpose/Significance] This paper compared and analyzed the current research status and key functions of representative foreign knowledge organization system (KOS) management tools under the development of semantic web technologies, and outlined relevant research trends. [Method/Process] Through online survey methods, ten representative foreign KOS management tools were selected and compared in terms of structural definition, project maintenance, data management, interoperability, and operating environment. Based on the survey results, suggestions were proposed for the construction of KOS management tools in China. [Result/Conclusion] The study found that domestic KOS management tool construction should promote functional innovation by relying on technologies such as semantic web, linked data, semantic integration, and semantic interoperability, including: flexible design and configuration of multiple data models, support for sustainable development management and maintenance mechanisms, support for distributed collaborative management and control, knowledge-driven iterative data updates, semantic-oriented KOS reuse and evolution, and construction of a KOS-centered knowledge organization framework.

Keywords: knowledge organization system (KOS) | KOS management tool | knowledge management | taxonomy | ontology

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