Knowledge Organization and the UN 2030 Agenda through the lens of Interoperability

Jorge Revez – Universidade de Lisboa, Faculdade de Letras, Centro de Estudos Clássicos, Portugal
Carlos Guardado da Silva – Universidade de Lisboa, Faculdade de Letras, Centro de Estudos Clássicos, Portugal
Luís Corujo – Universidade de Lisboa, Faculdade de Letras, Centro de Estudos Clássicos, Portugal

Abstract:

This paper seeks to understand the relationship between the technological and semantic interoperability (metadata) of information systems with sustainability, a global proposal of the United Nations 2030 Agenda for the development of our societies. Through a systematic literature review and an analysis of the results, it intends to understand the contribution of knowledge organization and interoperability to the enhancement of sustainable development. Two research questions were addressed: What is the role of interoperable systems in environmental, social, and economic development? How can knowledge organization and interoperability contribute to sustainable development? The results show that interoperability is seen as fundamental to sustainable development, especially when building integrated and standardized information systems. The role of interoperable systems in environmental, social, and economic development is relevant, as knowledge organization and interoperability contribute, indirectly but decisively, to sustainable development. They enable the exchange of information, encourage the construction of global communities of practice and overcome local limitations and deficits. It is concluded that knowledge organization plays a cross-cutting role in projects, which aim to implement the Sustainable Development Goals.

1.0 Introduction

This paper seeks to assess the relationship between interoperability and sustainability. Focusing on Sustainable Development, it intends to assess the existing literature on the contribution of interoperability as a sustainability factor. Sustainable Development, which develops from an eminently environmental perspective, and which emerges in the 1960s (Scott and Rajabifard 2017), is a concept coined in 1987 by the World Commission on Environment and Development. That year, in the *Bruntland Report*, the United Nations (UN) defined Sustainable Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987), aiming at quality of life and respecting the limits of the capacity of ecosystems. With social and political evolution, the concept broadened and consolidated, reaching a definition close to its current semantic content in 1994, when the International Council for Local Environmental Initiatives (ICLEI) defined Sustainable Development as the development that provides basic economic, social, and environmental services to all members of a community, without compromising the viability of the social, natural, and manufactured systems on which they depend. The concept would assert itself, above all, from the beginning of the 21st century with the 2nd Earth Summit (2001), in Johannesburg (South Africa), under the title *World Summit for Sustainable Development*, integrating the economic, social, and environmental pillars, as well as with the *Prepcom*, preparatory conferences for the Johannesburg Summit (Silva 2003). In 2015, a comprehensive set of goals was consolidated into the 17 Sustainable Development Goals (SDGs), which form the UN 2030 Agenda. This encompasses universal problems, such as hunger or poverty, and aims to develop essential aspects, such as health, education, gender equality, access to clean water and sanitation, renewable energy, decent work, innovation, reduction of inequalities, sustainable cities, sustainable production, and consumption. It also seeks to combat climate change, protect oceans and terrestrial ecosystems, and achieve peace and justice, in a global effort of partnerships for development (United Nations 2015).

Despite the terminological and epistemological debates (Hjørland 2012), different authors distinguish between Organization of Information and Knowledge Organization (KO) (Brascher and Café 2008). The first formulation concerns the organization and representation of informational objects (Svenonius 2000; Joudrey and Taylor 2018), while the second applies to units of thought, to concepts, giving rise to knowledge organization systems, that is, conceptual structures of knowledge representation, which end up being essential for the representation of information itself. As we will see further on, reality ends up calling for both perspectives, in close articulation, as the Organization of Information is inseparable from KO, and vice-versa: "KO is about describing, representing, filing and organizing documents and document representations as well as subjects and concepts both by humans and by computer programs" (Hjørland 2020).

Among the various subareas that give body to KO, metadata creation and management is one of the most relevant fields. These 'data about data' or 'information about information' may have diverse origins, natures, and structures, they may be created or automatically generated, they may be descriptive, administrative, technical, for preservation, or use (Baca 2008; Riley 2017).

A fundamental aspect of metadata is its ability to be interoperable. Interoperability means the ability of two or more systems or components to exchange and use information (ISO 25964, 2013). Interoperability has different layers: semantic (data context); structural (data architecture), syntactic (languages and formats); and systemic (networks, applications, etc.) (Zeng 2019). Bearing in mind that sustainable development will only be achievable through the effort and contribution of all mankind and that this will necessarily imply the convergence of multiple management and information exchange systems, the starting question of this research is: is interoperability, by its nature, a sustainability factor? Can interoperability contribute decisively to sustainable development?

Another way, alternative or complementary to interoperability, would be the merger or convergence between information technology systems, but as has been observed in the case of libraries, archives, and museums, such solutions do not present any immediate advantage, because what matters is the overall mission, not only the tools used. What is essential is to make information a connecting element between all human beings: “We should not be constrained by the existing institutions and practices but must focus on how to provide systems and services that serve the users. This is not primarily a technical issue but is intimately connected to an understanding of the value and relevance of what is mediated” (Rasmussen and Hjørland 2021).

In the literature, there is a remarkable amount of recent work that points to the relationship between interoperability and Sustainable Development. Themes such as smart cities (Jeong et al. 2020), energy efficiency (Martínez et al. 2021), cultural heritage (Turillazzi et al. 2021), biodiversity (Buttigieg et al. 2019; Magagna et al. 2021), agriculture (Adam-Blondon et al. 2016; Alreshidi 2019), among others, show the diversity of research in the search for the construction of information systems that break up information silos (Pennington and Cagnazzo 2019), in pursuit of effective sharing and re-use of open and research data (Charalabidis et al. 2018), concerning FAIR principles (*Findable*, *Accessible*, *Interoperable*, *Reusable*) (Grandcolas 2019). These principles were proposed in 2016 and have since been recommended by several organizations (Wilkinson et al. 2016).

For this research, two questions were established: Q1: What is the role of interoperable systems in environmental, social, and economic development? Q2: How can knowledge organization and interoperability contribute to sustainable development?

In the following section, the methodological details of the systematic literature review will be presented. In the Results section, an analysis of the selected sample will be carried out. The Discussion confronts the results with the previous literature, and the Conclusion answers the two research questions.

2.0 The method

To answer the two research questions, a systematic search was conducted in the SCOPUS database, chosen for its relevance and comprehensiveness. The search was replicated in the Information Science databases LISA (ProQuest) and LISTA (EBSCO), to obtain specialized literature and cover some sources that are not available in generic databases. According to PRISMA (*Preferred Reporting Items for Systematic reviews and Meta-Analyses*) methodology (Page et al. 2021), a systematic review “uses explicit, systematic methods to collate and synthesize findings of studies that address a clearly formulated question” (2021, 3).

Given the semantic ambiguity of the expressions 'interoperability' and 'sustainability', it was decided to create a search expression as precise as possible, considering the research questions, articulating the concepts of metadata, interoperability, and sustainable development. The search was limited to studies after 2010, to reduce the universe of retrieved records and to retrieve the most recent works. No other elements limiting the search, such as the language or the type of document, were introduced. However, the search was only performed with terms in the English language. The retrieval path and its different options are summarized in Table 1. Searches were performed on September 24th, 2021.

The choice of Information Science databases does not restrict the scope of this analysis to historical constructs or information services, such as libraries and archives, because it assumes the transversal dimension of KO in all human activities. In the Results, it is presented a relationship of the analyzed literature with the SDGs, which show the transversality of interoperability.

Table 1 – Sources, Search Expressions and Results (24-sept-2021)

Source	Search Expression	Results

SCOPUS	Titles, Abstracts and Keywords (2010-): metadata AND “sustainable development” AND interop*	25
LISA	All Fields (2010-): metadata AND “sustainable development” AND interop*	35
LISTA	All Fields (2010-):	0
	metadata AND “sustainable development” AND interop*	
	Total	**60**

The results were gathered in an *MS Excel* sheet so that they could be worked out. Three duplicates were removed before the screening process, according to the PRISMA model (Page et al. 2021). The exclusion criterion applied relates to the non-recognition of a relationship between the study and the various dimensions of Sustainable Development, as proposed by the 2030 Agenda. This criterion was applied during abstracts' reading by the Authors, resulting in 39 documents excluded. No inclusion criteria were systematically applied, meaning that all the documents which revealed a relationship with Sustainable Development were considered. All the 18 documents' full-text was successfully retrieved, and after the full-text reading none was excluded according to the exclusion criterion, confirming the final sample of eligible records (n=18). The methods used for the analysis and synthesis of the included studies were cross-analysis and categorization of each study with the assignment of one or more SDGs. Therefore, results are structured following this categorization.

3.0 Interoperability and Sustainability

In this section, the relationship of the literature with the SDGs is highlighted. This relationship shows the transversality of interoperability and its importance for the development of projects, which aim at the Sustainable Development of human communities.

Studies that comprehensively address the SDGs were retrieved, showing that interoperability can serve different purposes. Additionally, specific research was detected around 5 of the 17 SDGs: SDG 2 - End hunger; SDG 6 - Water and Sanitation; SDG 13 - Combat climate change; SDG 14 - Oceans, seas, and marine resources; SDG 15 - Terrestrial ecosystems and biodiversity.

In the context of the 2030 Agenda, the problem of hunger is directly related to the issue of agriculture. Regarding sustainable agriculture, a team from the University of Nottingham has proposed a model to enhance the interoperability of open data, also using open source software and open standards. Focusing on geospatial data, the scheme will enable not only the interaction of agricultural data but also its hosting and future availability (Santos et al. 2016). Also, in the same theme (SDG 2), researchers in Nigeria have developed a system that allows farmers to receive real-time information on the needs of growing vegetables. The interoperability of geo-referenced data on different relevant aspects (climate and soils, for example) connects with farmers' mobile devices, enabling the application of Big Data analysis to sustainable agriculture (Nwankwo and Ukhurebor 2021).

The management of drinking water is one of the fundamental components of Sustainable Development (SDG 6). A Brazilian researcher sought to design an interoperability mechanism between different hydrological research datasets, using the Open-Streetmap platform and exploring Linked Open Data technology. Any data ecosystem is dependent on the contribution of the various actors involved; however, it is also possible to develop linkage mechanisms between publicly available data. Open data is a key element for Sustainable Development. This study also used different W3C (World Wide Web Consortium) standards, demonstrating that interoperability requires the construction or use of pre-existing models and languages that allow the combination of data (Leyh 2018).

Beyond drinking water and agriculture, urgent measures are needed to combat climate change and its impacts. SDG 13 aims precisely to rally communities to this battle. In the selected sample, a Swiss research team proposed a scheme to monitor climate change from observations of our planet, called LiMES (Live Monitoring of Earth Surface). This model aims to leverage different open data sources, such as repositories, to automate the process of monitoring environmental changes. It is a clear example of the usefulness of developing interoperable services, linking primary data (mainly satellite images) from hundreds of observation points. According to the authors, this prototype is one of the first attempts to provide a global-scale tool to monitor climate change both spatially and temporally (Giuliani et al. 2017).

The problem of conservation and sustainable use of the oceans, seas, and marine resources (SDG 14) is one of the most addressed themes in the studies analyzed. Some of these investigations are motivated by the UN Decade of Ocean Science for Sustainable Development 2021-2030, a program launched by the UN in 2021 to support solutions for the Sustainable Development of the oceans (United Nations

2021). Referring to the experience of the Ocean Best Practices System (UNESCO), an international team of scientists argued that the development of these solutions, supported by the work of science, is only possible by building a global community of practice. This community needs a common language so that its results can be used and reused continuously and with minimal entropy. The capacity to elaborate a common language depends on the interoperability mechanisms implemented, and only the success of this language will allow the passage from a local scale of scientific knowledge production to a global scale (Pearlman et al. 2021). In the same line of research and with some authors from the same team, another study presents the need for appropriate methods of documenting scientific practices so that this knowledge can be more easily recovered and shared: “structured templates, clear and complete metadata, version control, as well as mechanisms to support convergence and interdisciplinary exchange are foremost among the community’s needs” (Hörstmann et al. 2021, 2). Again, harmonization is the key component to create a community of practice because the exchange of information is the key element of scientific research that welcomes and benefits from digital technologies. A link is established here between Open Science, especially on the issue of transparency and reproducibility, interoperability, and Sustainable Development.

Given the date limits set for this review, there were some selected works published before the 2015 UN Resolution announcing the 2030 Agenda. Earlier work on oceans, also in the SDG 14 theme, showed that the issue of sustainability was a long-standing concern of scientific research. A French team addressed the issue of the exploitation of marine resources, pointing out that, in addition to the problem of sharing information resources, the issue of their retrieval and discovery summons interoperability as the solution to optimize these processes. In the case of information resources generated locally but also captured globally, the authors present an information system called Ecoscope, which aims to harmonize metadata standards (syntactic interoperability), ontologies (semantic interoperability), and geographic information, using the Dublin Core Metadata Initiative as a unifying scheme of the different schemes found in informational objects; in the case of ontologies, they indicate the development, still to be completed, of an ontology that allows a semantic interoperability (Barde et al. 2011).

Interoperability is fundamental to optimize the work of large consortia, which bring together massive amounts of data, geographically dispersed and of different natures. The case of JCOMM (WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology) is presented by a large international team. It aims to build a system that coordinates the different ocean observations, data management, and forecasting services. Being an international consortium at a global scale, the system aims, among other things, to provide open data, in free access, and available in a fast way, based on FAIR principles. Interoperability will enable ocean research to become a global practice, overcoming the local deficits already recognized and inadequate for a set of phenomena that have no borders (Pinardi et al. 2019).

In the case of the European Union, another major consortium presents similar needs for interoperability. Data collected by oceanographic research remain scattered and fragmented, despite the guidelines provided by the 2007 European INSPIRE Directive (Infrastructure for Spatial Information in the European Community) (European Commission 2021). Italian researchers have shown the importance of interoperability in building a network of data portals called the European Marine Observation and Data Network (EMODnet), specifically the chemistry data portal. Interoperability aims to improve the availability of high-quality marine environmental data and build a knowledge base that can drive Sustainable Development (Vinci et al. 2017).

SDG 15, along with SDG 14, represents an area that is widely addressed in the studies analyzed. This goal aims to protect, restore, and promote the sustainable use of terrestrial ecosystems, sustainable forest management, combat desertification, halt and reverse land degradation and halt biodiversity loss. The interoperability of biodiversity data motivated an international team to develop the Biological Collections Ontology and related ontologies to increase semantic interoperability. The study shows the need for the development of semantically enriched languages to link data from different sources, including museum collections, which are a fundamental basis for the biodiversity archive (Walls et al. 2014). Two researchers from Ecuador also addressed the issue of semantic interoperability, presenting SmartLand, an initiative created in 2014, and its data system SmartLand-LD, to map and integrate data on Sustainable Development indicators in territories with high biodiversity, aiming their smart management. These initiatives aim to respond to the 2030 Agenda's call for better data management to support national and international projects that implement the SDGs. To create an ecosystem for semantic interoperability, the authors indicated four levels of interoperability, which form the system architecture: legal (the most comprehensive), organizational (strategic), semantic (exchange of meanings), and technological (exchange of data and content) (Piedra and Suárez 2018).

The study of biodiversity implies the relationship between local data, often dispersed and collected on a case-by-case basis, and global, aggregated, and normalized data, which allow the construction of products for the analysis of the situation of natural species. Around the concept of Essential Biodiversity Variables, a minimum set of taxonomic-spatial-temporal variables used to study changes in biodiversity, a wide range of researchers pointed out the need to promote a data management infrastructure that can support the development of products based on the data obtained, according to those variables. This development depends on FAIR data and metadata, including interoperability of formats and units of measurement. Existing standards related to species abundance and distribution are reviewed and analyzed, although the authors acknowledge that an information model that allows semantic interoperability and integration of data from such diverse sources does not yet exist (Kissling et al. 2018).

To accelerate the interoperability process and develop products based on the collected data, according to the Essential Biodiversity Variables, the Bari Manifesto (Kissling et al. 2018) proposed 10 principles of interoperability that all organizations should follow:
(1) data management plan; (2) common data structure; (3) metadata with commonly accepted standards; (4) data quality control; (5) accessibility through interfaces; (6) documentation and publication of data-based product creation flows; (7) provenance information of primary data; (8) ontologies and description vocabularies; (9) preservation in repositories with persistent identifiers; (10) open access and FAIR principles (Hardisty et al. 2019). This roadmap enables the link between primary data and product development, showing the mediating nature of interoperability, essential for a global and transnational understanding of changes in biodiversity.

The field of sustainable forest management is another important aspect of SDG 15. A literature review conducted by an international team showed that several studies on the role of digital technologies in the sustainability of supply chains have been con ducted. The authors underline that, in addition to syntactic and semantic interoperability, the development of effective collaboration structures is needed, although interoperability is the basis for the optimization of processes (Scholz et al. 2018).

Some studies have addressed, in a cross-cutting manner, the SDGs, and it is not possible to associate them with only one of the goals. One such example is the development of The Environment Ontology (ENVO), with an expansion of its initial scope to cover habitats, environmental processes, anthropogenic environments, and relevant entities for the 2030 Agenda. The changes implemented sought to articulate with another ontology, Sustainable Development Goal Interface Ontology (SDGIO), developed since 2015 by the UN Environment Programme (U. N. Environment 2020). The semantic representation of environmental issues, through the Web Ontology Language (OWL), makes ENVO a key tool for the interoperability of the systems that manage research data (Buttigieg et al. 2016).

In the case of scientific natural history collections, the presentation of a pan-European project for 2019-2023, SYNTHESYS+ (SYNTHESIS 2021), on digital access to specimens, which continues a consortium of museums, botanical gardens, universities, and companies started in 2004, shows the importance of KO for the management of massive amounts of resources. To reverse the fragmented access to the richness contained in collections, a centralized research infrastructure with global access is proposed. Special focus is given to the problem of interoperability, to overcome previously identified shortcomings, and a work package of the project is dedicated to it. This project lays the foundations for the Distributed System of Scientific Collections (DiSSCO), an infrastructure that will bring together collections from 115 European museums from 21 countries (Smith et al. 2019).

The field of geospatial information is transversal to several SDGs. Many of the problems that have an impact on Sustainable Development need the geographic information to obtain solutions, so it is essential to integrate and connect it at a global scale. One of the studies analyzed presented a strategic framework to implement this aspiration (Scott and Rajabifard 2017). However, the authors recognize that, especially in developing countries, primary data of national origin lack quality and interoperability, so this issue becomes crucial for the success of a global strategy: “data, as the basis for evidence-based decision-making and accountability, will be crucial to the success of the 2030 Agenda. The key word here is “data”. The future success of the global development agendas will be dependent on data, and not whether it is statistical, geospatial, environmental, economic, health, demographic, education, or other data – just data!” (Scott and Rajabifard 2017, 73).

Also, in the same field of geographic information, an Australian team pointed out the inability of this type of data, such as georeferencing metadata, to meet all FAIR requirements and, as a result, not yet have the possibility to support the implementation of the SDGs: “the FAIR precise positioning data ensures timely and accurate access good health and well-being (SDG 3), efficient management of clean water and sanitation (SDG 6) and well-functioning smart and sustainable cities (SDG 11). Moreover, FAIR precise positioning data help in a responsible consumption and production (SDG 12) and assure life below water and on land (SDG 13 and 14)” (Iványová et al. 2019, 38).

4.0 Discussion

The highlighted examples clearly show the relevance of interoperability for sustainability. With great emphasis on SDG 14 and 15, concerning aquatic and terrestrial ecosystems, the results show the fundamental contribution of interoperability for Sustainable Development, especially in the construction of integrated and standardized information systems.

FAIR principles are referred to in several studies, showing the importance of open data, with emphasis on the I for interoperability (Wilkinson et al. 2016). Convergence with these principles seems to be a one-way path, as it is the solution for full integration of the raw material that will enable knowledge production on a global scale. The sharing and reuse of data allow the reproducibility of research, but also the implementation of other processes involving informational objects, such as Linked Open Data technologies (Charalabidis et al. 2018). The aim is to overcome the local dimension of data and its closure in information silos (Pennington and Cagnazzo 2019). In other words, the motto "act locally, think globally" is also possible and desirable at the information level.

The studies also show the Big Data landscape in which scientific research is currently operating. This panorama will itself have to be sustainable, but above all, it must allow the globalizing approach that Sustainable Development requires. There is no sustainability without interconnection, collaboration, and collective effort. These premises also apply to metadata (Riley 2017), as it is these that will make a global response to challenges as important as climate change.

Standardization and the use of internationally recognized tools and languages play a central role in the whole process. The creation of global communities of practice, in close collaboration, requires a common language, an essential element of the intellectual foundations of the Organization of Information (Svenonius 2000). This collective work will mitigate local deficits and support developing countries in producing interoperable information and increasing the reproducibility of locally produced knowledge.

The studies analyzed present a close relationship between the Organization of Information and KO. If they are conceptually distinct (Brascher and Café 2008), are intertwined by their common goal of managing and making information and knowledge accessible (Hjørland 2020). At this point, the field of ontologies stands out. Studies show an enormous effort in the semantic interoperability, especially about biodiversity, aimed at creating enriched languages to optimize the management and exchange of information, but also the interaction with museum collections, which are after all one of the most important archives of science.

In summary, the analysis shows that interoperability plays a central role, a place of mediation or agreement (Zeng 2019), between primary or raw data, including the metadata of informational objects, and the different products designed to obtain knowledge and support sustainable development. In this regard, different studies testify to the importance of geographic information as the foundation for various approaches to the SDGs.

5.0 Conclusion

This research allows us to assess and demonstrate the transversality of KO. Not being limited to the domain of historical constructs such as libraries, archives, or museums, KO is a central, if not intrinsic, element of scientific research. To support decision-making and to underpin public policies, aiming to implement the 2030 Agenda, the development of optimized KO mechanisms will be essential for an effort that is intended to be global.

The role of interoperable systems in environmental, social, and economic development is relevant, as KO and interoperability contribute indirectly but decisively to Sustainable Development. They enable the exchange of information, encourage the construction of global communities of practice and overcome the limitations and deficits of local action. We conclude that KO plays a transversal role in projects aimed at implementing the Sustainable Development Goals.

The limitations of this study are mainly related to data collection, as the use of other search expressions could have formed different samples. However, the review indicates aspects that appear to be structural and that could also arise in the analysis of other studies.

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