A SURVEY ON INTEROPERABILITY SEMANTIC DATA ONTOLOGIES FOR THE CIRCULAR ECONOMY

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Abstract: Over the past few years, a transition has happened from the idea of traditional economy models to the implementation of the Circular Economy (CE) concept. The main goal of this concept is to retain resources in sustained productive cycles to preserve their utility, resulting in better resources extraction and waste management. Semantic interoperability is the capability of systems to interchange data and resources considering that contributors have a mutual understanding over the shared content. Data ontologies assure that business regulations and data are meaningful, linked, and most significantly, readable by the systems that are incorporating them. When implemented, they enhance innovativeness and truly maximize the potential of the concept. Through conducting a literature survey on the CE topic, this paper discusses its current state-of-the-art, semantic interoperability implementation and the main issues in the domain. It also discusses the potential of the development of specific data ontologies, and therefore, seeks to ensure a foundation for a more comprehensive discussion on addressing its lack of interoperability.

Key words: Semantic interoperability, circular economy, data ontologies, linked data, database design.

1. INTRODUCTION

Ontologies are used by databases, and applications that need to share the data. They incorporate usable meanings of elementary concepts in the field and the connections among them. Interoperability of the data, and CE ontologies for sharing the information about resources and materials for further reuse, are the key factors toward truly fulfilling the concept of the circular economy. In order to portray field semantics, structures, and their assets and relations in the data environment as distinguishing concept correspondent, ontologies are utilized to extend structured databases and systems that are thought to have comparable semantics. Interoperability among semantic data ontologies in the CE systems, is the capability to trade useful resources, services and data among systems. It is established on contracts among those who request services and their suppliers [1]. Semantic interoperability ensures that the demanding and supplying entities have a mutual understanding of demanded resources and data. While there have been notable standardization attempts for communication engagements, there is still deficient semantic interoperability in the domain of circular economy. In this paper, we will make a review of semantic data ontologies in the field of CE, and discuss the current state-of-the-art in the field.

2. STATE OF THE ART

2.1. Circular economy

In this section, an overview of the current state-of-the-art in the domain of CE is provided. Several publications, like [2], [3], point out the growth of this field in the period over the last few years. In [4] authors analyze different theoretical approaches, strategies and implementation cases of CE. Goal of that research has been to develop implementation tools that incorporate strategy and implementation databases. Authors in [5], help to determine the idea of circular economy from the viewpoint of the World Commission on Environment and Development (WCED), and also conduct a survey on the theory from the position of environmental sustainability. Circular economy personifies the latest effort to conceptualize

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the consolidation of economic activity and environmental prosperity in a sustainable way. In addition to the previous statement, authors in [6] trace the conceptualizations and descents of the CE, focusing on its meanings. The study discovers that while the circular economy sets prominence on the redesign of procedures and cycling of resources, which can provide a greater number of sustainable business models, it also summarizes restrictions. Regarding the current understanding of the term circular economy, and its association to many different things to different people, many researchers seek to clarify that definition. For that purpose, [7] have gathered 114 circular economy definitions, and coded them in 17 dimensions. This study points out that CE is often portrayed as a mixture of reduce, reuse and reprocess activities. It also finds additional concepts that show explicit bindings of the circular economy to sustainable development mentioned in [5].

The main ability to implement CE business models is the capability to follow information about products, parts and materials, in purpose to enhance resource optimization. Six key areas are presented in [8] as a process of integrating business models in the CE. Authors in [9] propose an ontological structure for CE, which is determined as technology for data and knowledge models to distribute resource cycling via industrial ecosystems. In [10], a framework that uses semantic web service adherence to describe technology-based on implicit data submerged in the field industrial system ontology is presented. Several authors in [11], [12], [13] take the example of China, and state that combined conceptual fundamentals of CE have encouraged China's economy to develop and adapt new economic prototypes to successfully resolve the issues connected to resources and the environment. They also aim to introduce and implement a distinctive CE indicator system. These CE indicators are practical metrics for strategy makers, and can help to accomplish CE objectives and results. In the practice of governance, an ordinary way to guide the transformation to a dissimilar condition is pursued through the setting of targets. The study [14], suggests a broaden set of new targets for the transformation to a circular economy, and all in conjunction with a fresh view on targets from scholars and policy makers. In this study, the suggested model is used to distinguish CE targets according to each strategy. It also demonstrates how fundamental CE elements such as closed cycles, material retention and waste reduction can be achieved when the targets are conveniently designed.

In the field of designing business models, [15] has concluded a survey increasingly obtaining attention in fields like strategic management, operations management, and technology management. This research proposes that corporations design their business model based on a new idea of sustainable development that decreases consumption of natural resources and preserves the environment. In [16] authors survey and conceptualize the implementation and adaptation of circular economy business models in the operations management (OM), in the areas of product design, production planning, and supply chains. The results of this research help operations managers to predict the needs for developing capacity in CE, moreover, this is one of the few articles to define the ways in which OM data can boost the transformation process towards the circular economy model, supported from the viewpoint of dynamic abilities. Various prototypes prevail to describe potential business models for the circular economy, but many of them have absents of validation in practice. In spite of the fact that a variety is normal for an emerging field like CE, establishing concurrence of terminology and models is vital for achieving discussion, which is important for the implementation of the business models [17]. Authors in [18] examine the managerial practices that companies can implement in order to design a circular economy business model and how companies can create and capture the value ofthese models. Different frameworks found in [19] propose a circular economy business models (CEBMs) that define how companies produce value while holding onto the CE concept. This study also identifies a wide span of business model design alternatives and suggest six main CEBM frameworks with the potential to sustain the closing of resource cycles. The major goal of the circular economy concept is discussed to be economic prosperity, accompanied by environmental conditions. Transitioning from the traditional economy concept to a more circular economy could bring advantages such as decreasing pressure on nature, enhancing the supply of resources, boosting competitiveness, and increasing economic growth.

2.2. Interoperability semantic data ontologies

The development from closely linked databases has been inevitable, as information technology has transited from concentrating on internal systems and databases to adopting the overall interchange and implementation of diverse systems in various fields. In [20] authors have conducted research on the use of ontologies for semantic interoperability and implementation. They state that information technology has developed into a variety of widely linked systems, and that it needs more direct interpretable semantics. In such surroundings, distinguished by substantial dispersed, distinctive, and dynamic data sources, an approach to substantial and spot-on data is becoming increasingly demanding. Authors in [21] address diverse interoperability problems and suggest solutions to these issues. Problems with interoperability have been defined as the main issue that every government policy has to address. [22] surveys how the e-governments in the United States and Europe have implemented tools such as interoperability models and business frameworks. It particularly presents how the semantic technologies and standards have been implemented into the interoperability frameworks. In [23] a survey of the issues of semantic interoperability is given, providing a semantic conceptualization of services, and examining the role of ontologies.

Authors in [24], examine several vital questions. The main question is related to the way of defining the tools and methodologies which support interoperability. Other questions regard the process of achieving optimal performance across models and frameworks. Domain ontologies and knowledge-based systems are proving to be fundamental in semantic web communities. In [25] research on the methods suggested for providing interoperability in domain ontologies has been conducted. This research also mentions some main problems that still need to be referred. Authors in [26] research the possibility of Linked Spatial Data to simplify the process of cooperation in the CE. This work suggests implementing Linked Data as a standard for linking product passports, and designs an ontology that can merge CE collaborators established on locality and their resources. In [27], a method that simplifies the procedure of constructing an Internet of Things (IoT) product passport and data interchange is suggested, empowering the following phase of CE. [28] examines the significance and suggests conceptualization of the idea of semantic interoperability. Furthermore, the authors describe that the outcome to this kind of perspective is that semantic interoperability cannot be attained without the support of ontologies. Authors in [29] examine how these models can be consolidated within interoperability. The price of implementing interoperable models is the main downside in the embracement of new technology and the evolution of the production industry. The semantic interoperability is important for the implementation of the heterogeneous nature of information coming from various origins, that could lead to a different method of explanation of its meaning, causing errors that enlarge the project price, which is time-consuming. In this context, [30] contributes to the implementation of a Semantic Interoperable Smart Manufacturing to encourage semantic interoperability across the system, considering data and methods from various domains as well as distributing them via various phases of the manufacturing procedure. Semantic applications can help CE models to perform promptly and to be reliable by enhancing their ecosystem interoperability. In [31] authors have realized that any technology for data services should address the issue of semantic interoperability, the ability of a system to interchange data and dynamic data manipulations by exploiting its domain model. Thus, the structure for data services should mainly tackle the semantic issues in supplying data service.

3. DISCUSSION

Interoperability had been a subject of discussion in terms of data interpretation and interchange for quite a while, still, it has never received prominence as it does nowadays. Basically, capability to interchange resources and data between components of systems is based on arrangements among requesters and suppliers who need to have mutual comprehension of the demanded resources and data. Semantic interoperability is primarily induced by consistent communication. In practice, attaining and implementation of interoperability, empowering the adoption of mutual models to interchange data, advancing in the implementation of the heterogeneous sources of data, and supporting the decision making is very important. Interoperability in CE is characterized as the first proposal to contribute such effective data interchange for the future circular economy models. Figure 1 illustrates the trend of research on CE regarding interoperability. The data used for this trend has been extracted from the Google Scholar database via Publish or Perish software [32]. The search query has been constructed with strings "Circular economy" filling the title field, and "Interoperability" filling the keyword field. It can be seen from the number of publications per year, that the research on interoperable CE is in expansion.

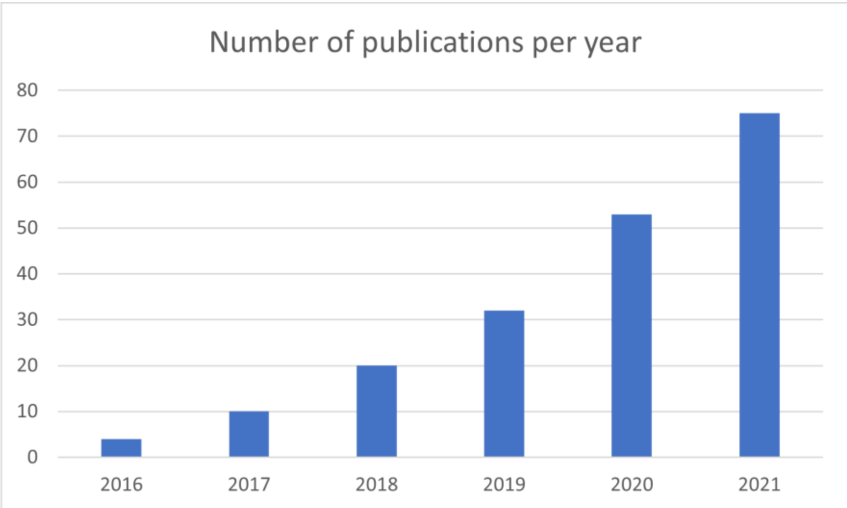

Figure 1 – Semantic interoperability model representation

Data linked to a product have to follow the whole life cycle of the product and also have to support the data flow from when the product is dismantled, its components recycled, to completely new products requesting access to servicing and regeneration histories. To prove that specific data is indeed interoperable, it is crucial that every product, object and entity have their own distinctive identity. Every one of these objects should have an elementary ID that accommodates vital data that can be accessed overtly. These ID's can be used to assist in supplying background data about all life cycles of the product. To provide singularity and interoperability via datadistribution chains, it is vital to identify products, resources and entities via open standards. Table 1 classifies the publications included in this literature review by identified categories.

Table 1 – Clasiffication of publications by categories

Publication	Conceptualization	Implementation	Business models	CE Targets	Ontology	Interoperability	Other
[1][2][3][4][5][6][7]	x						
[9][11][12][13]		x					
[14]				x			x
[8][15][16][17][18][19]			x				
[21][22][23][24][25][30][31]						x	
[10][20][24][28][33]					x		
[26][27][29]						x	x

Figure 2 illustrates a simple semantic interoperability model representation, and its incorporation with other CE components. A model is composed of products, which are practical components of the manufacturing cycle and in which a number of resource flows are utilized via particular activity and in a particular phase in order to provide the circularity of each resource. Hence, aproduct is composed of flows and tasks that are executed and assigned in a particular phase of the product life cycle. Moreover, flows are connected to various types of assets, which are utilized so that various processes may be executed.

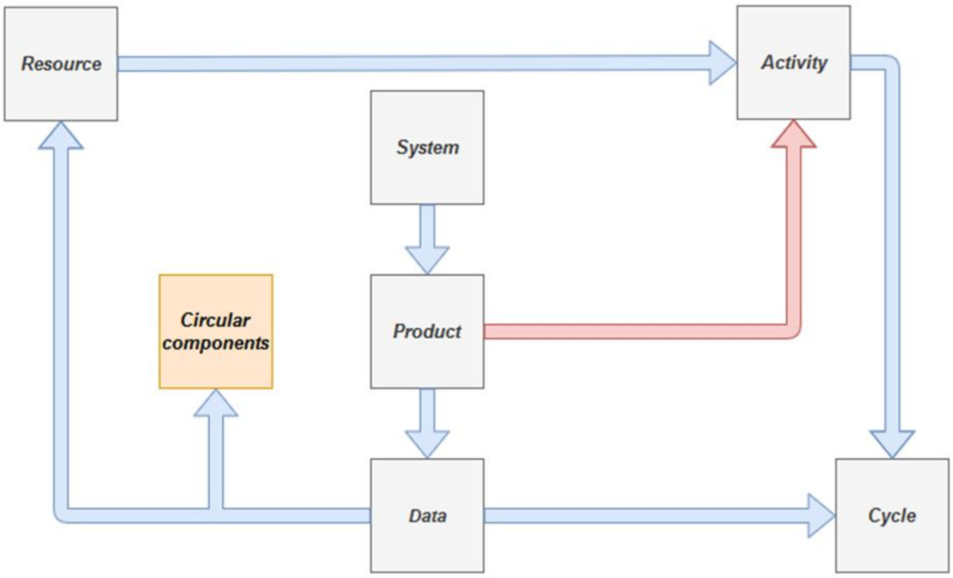

Figure 2 – Semantic interoperability model representation

An ontology enables knowledge in the domain of CE to be designed and operated. This knowledge incorporates the categorization for material consumption, energy, water, waste, and substances among models [33]. Ontology identification has the purpose to simplify the conceptualization stage of a particular data set by permitting the evolution of mutual terminological surroundings and at the same time by ensuring a simple extensible way of data modeling. In particular, ontology identification can format the definition of knowledge as a set of conceptions within a field and the relationships that are between them. To be able to give such a definition, the identification of the primary parts of the domain in terms of objects, classes, attributes and relations must be defined. Figure 3 has a purpose of demonstrating the integration of field ontologies with interoperability components. Manufacturing, resources, and other components produce extensions with particular functionality. The implementation of circular economy is achieved with the utilization of these generic components and extensions, and all by the means of making CE models interoperable by design. Interoperability components provide smooth business system connectivity.

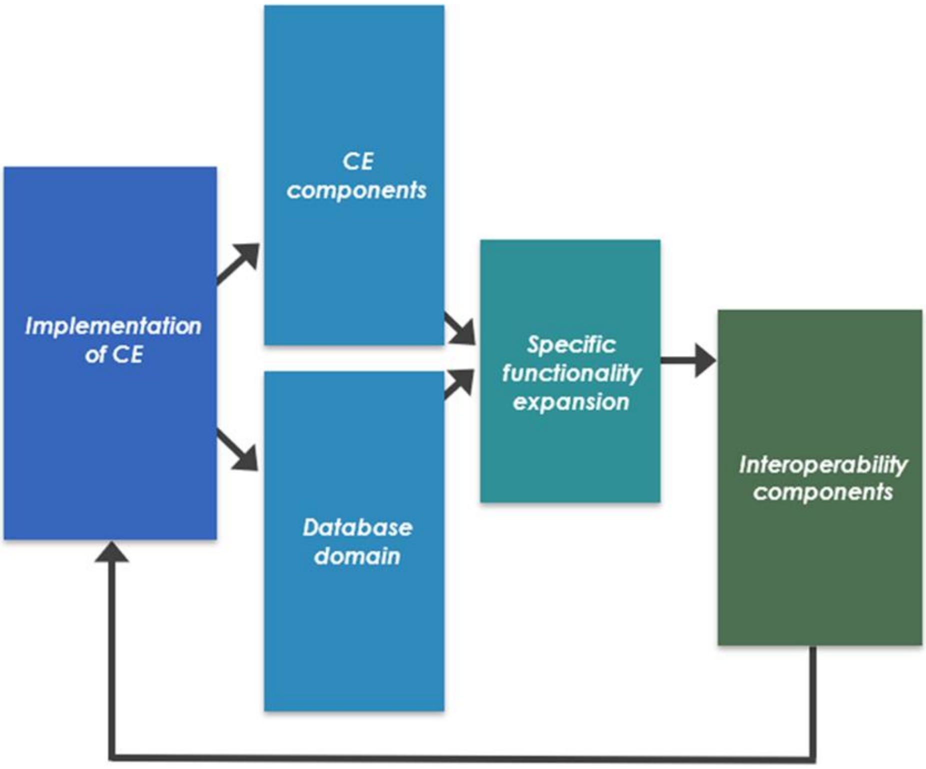

Figure 3 – Ontology integration with interoperability components

4. CONCLUSIONS

A literature survey that has been conducted, concluded that the deficiency of interoperability has been one of the major obstacles for the adoption of the CE concept and to the successful implementation of its principles. The trending standard data models are not enough, and an overarching approach is required to evolve the present-day data models to provide interoperability and performance enhancements in the circular economy. The successful implementation of the circular economy demands that the whole model that is incorporating CE, accepts its practices, the development of data models, and the dynamic cycling collaboration between its components.

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