Suppliers Selection Ontology for Viable Digital Supply Chain Performance

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Abstract. Unprecedented challenges have confronted the contemporary era with serious negative effect on supply chain management performance. As known, organizations performance is dependent on their suppliers. For this reason, organizations have to improve their practices in suppliers' selection process considering resilience, sustainability and digitalization capabilities to retain competitive and ensure viable performance. In this context, this paper aims to propose an ontology-based model for suppliers' selection criteria with consideration of digitalization, sustainability and resilience capabilities. The incorporation of those paradigms while selecting appropriate suppliers enables the exploration of viable supply chain performance in regard to disruptions. The proposed method is useful to both academics and professionals because it addresses the prominent criteria taxonomy for an effective suppliers' selection in the disruption and digital era.

Keywords: Suppliers Selection, Viable Digital Supply Chain, Resilience, Sustainability. Ontology, Knowledge Management.

1 Introduction

With the spread of globalization and the evolution of industries, there is a crucial need for effective and reliable supply chain systems [1]. A more interconnected environment certainly holds both benefits and risks [2, 3]. For instance, disruptions affect the daily flow of goods or services within a system. Besides, organizations today are more exposed to increased and various disruptive events (unexpected exchange rates, supply fluctuations, dynamic markets, geopolitical tensions, volatile demand, and natural disasters) that have a direct impact on SC performance [4]. More clearly, this implies that there is an increased need for enhanced supply chain viability practice and study.

One of the supply chain management (SCM) challenges that have piqued the interest of many researchers is supplier selection [5]. In other words, the supplier is an important actor in the end-to-end value chain [6]. Because one of the most important factors to achieve an organizations' performance is the selection of relevant suppliers. Therefore, there has been an increased interest in the selection of reliable and robust suppliers [7]. In this context, to remain competitive and improve their performance, organizations need to consider and include the viable capability in suppliers' selection criteria. More clearly, the selected suppliers should have the capacity to adapt to the difficulties and function in a changing world. Besides, they should "react agilely to positive changes, be resilient to absorb negative events and re-cover after the disruptions and survive at the times of long-term" [8]. This means that organizations should take into consideration the 'digitalization', 'resilience', and, 'sustainability criteria in the supplier's selection.

Several studies focused on the suppliers' selection process methods and techniques [9–11]. However, little consideration is given to determining and selecting the right evaluation criteria. Whereas, choosing appropriate criteria determines the quality and accuracy of the developed model [12]. For this reason, it is widely recommended to exploit and develop suppliers' selection knowledge assets. Especially that spreading knowledge in supplier selection while considering resilience, sustainability, and digitalization capabilities, as well as a lack of proper knowledge about criteria describing them, create an evident necessity to have a comprehensive solution for gathering and sharing knowledge, and underlining the interrelationships between them. To overcome this research challenge, the capitalization of knowledge in an ontology for supporting supplier selection and assessment criteria is recommended. In this respect, this paper aims to provide an ontology-based model for supporting suppliers' selection for viable supply chain (VSC) performance. It analyses and organizes knowledge about suppliers' selection criteria including so-called digitalization and resilience capabilities. Moreover, it helps to share information about currently used supplier selection criteria to allow semantics-driven knowledge processing.

This article is organized as follows: in the following section, we present the related works. Section 3 illustrates the research methodology. Section 4 presents the developed ontology supporting the viable-oriented suppliers' selection. And finally, section 5 presents the managerial and practical implications.

2 Related works

Previous research explored and analyzed supplier selection in the digital supply chain using a variety of methods such as Multi-Criteria Decision-Making Methods, Mathematical Programming models, AI approaches for the development of decision support systems [9–11, 13]. However, every robust decision-making system requires a variety of context data to support the assessment process. To handle the massive amount of information in suppliers' selection process, it is valuable to use knowledge management tools [14]. Ontologies refer to a hierarchical conceptual model representing and capitalizing knowledge that provides definitions of relations and classes (concepts) that incorporate domain knowledge in an integrated manner [15, 16].

The reviewed literature also presented a range of supplier selection criteria approaches, evolving from standard data gathering methods for text analysis to more advanced semantic-matching-oriented methods based on ontologies [17]. In this context, some ontological models aimed at addressing suppliers' selection criteria have been developed. On the one side, [18, 19] suggest an ontology-based negotiating decision protocol to support the suppliers' selection. Reference [15] established a Supplier Segmentation Ontology based on knowledge derived from the literature on behavioral operations in the supply chain from 1934 to 2013. On the other side, references [12, 20] provide a conceptual context for collecting and maintaining knowledge about green supplier selection criteria, as well as formal guidance for their proper acquisition.

These ontologies have proved to expand the knowledge, but they have a restricted scope. More clearly, these ontologies have covered the green aspect or the sustainable aspect of suppliers' selection criteria. And as far as we know, there is no paper dealing with developing an ontology-based model considering the resilience and digitalization capabilities. For this reason, this paper aims to cover the three capabilities namely resilience, digitalization, and sustainability in one ontology to ensure the SC viability performance.

3 Research methodology

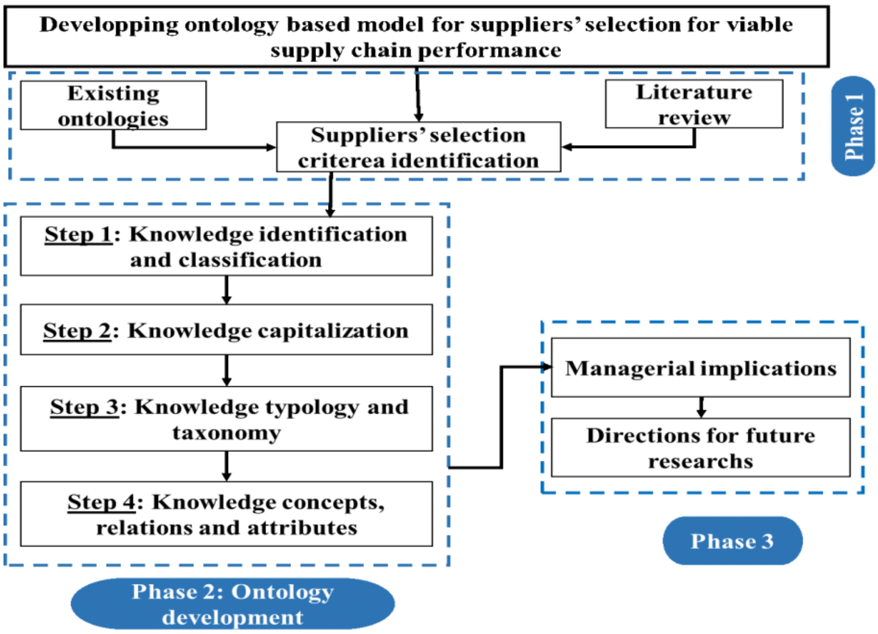

Fig. 1. Research methodology

Fig. 1 outlines the research methodology used in this study. It presents the conceptual steps used to address the study's aim. The proposed approach is divided into 3 interconnected phases. The first phase is about searching relevant documents and existing ontologies to identify and classify suppliers' selection criteria. Only relevant manuscripts have been reviewed. That is to say that the collected documents and examined ontologies are revised to produce appropriate data in the light of viable-oriented supplier selection and evaluation criteria. This phase resulted in a set of clusters with identified criteria. The second phase refers to the development of an ontology-based model to support suppliers' selection based on the previously identified set of criteria. For doing so, there are four steps to follow: (1) Knowledge identification and classification; (2) Knowledge capitalization; (3) Knowledge typology and taxonomy; and (4) Knowledge concepts, relations, and attributes. Each of these steps is described in the following section. The final phase consists of discussing managerial and practical implications and presenting future research directions.

4 Development of ontology-based model for supporting viable-oriented suppliers' selection

4.1 Knowledge identification and classification

Our ontology-based model is built on the identification and classification of knowledge via a structured approach to modeling the criteria required for supplier selection while considering three complex capabilities: "resilience", "sustainability," and "digitalization." Concepts and relations are the principal component of our model. Thus, the first step to be taken when defining the relations is to define the domain and range. For doing so, through the literature review, the unstructured data obtained from a wide variety of scientific articles have been reincorporated into semi-structured form. Besides, the collection of criteria and sub-criteria was conceptualized based on the given set of clusters and items allocated to them. More clearly, we defined five classes (Resilience Criteria, Sustainability Criteria, Digitalization Criteria, Primary Criteria, and Profile Criteria) representing the criteria ensuring the viable selection of suppliers. Besides, several sub-criteria were defined for each criterion considering also circular economy (use and recovery).

4.2 Knowledge capitalization

The analysis of literature and existing ontologies enables one to specifically define knowledge that is used and elaborated. With this analysis, we have written a series of knowledge which we have attributed to criteria. They were then verified and validated by an expert to finally can be capitalized on the taxonomy. We may build a list of knowledge that has been established as important for capitalization.

4.3 Knowledge typology and taxonomy

We generated an information classification to present a Knowledge classification for the supplier selection criteria. We also defined five Knowledge classes (Table 1).

Each class reflects a particular type of knowledge. Hence, we developed a taxonomy to organize the Knowledge. In other words, it provides a hierarchical classification of data entities based on the implied connections of the real-world entities that they represent. Besides, the grouping is based on the resemblance of the knowledge entities known as concepts. This taxonomy illustrates the layout of the necessary criteria for selecting viable suppliers (Fig. 2). More clearly, the suggested taxonomy aims to hierarchize knowledge about resilient-digital-sustainable suppliers' selection criteria that characterize viable suppliers. After identifying knowledge to capitalize, we have analyzed and studied existing ontologies that we can re-use. Among ontologies-based models for suppliers' selection, we have used [12, 21, 22]. Some of the concepts presented aided us in conceptualization, especially concerning the primary criteria, profile criteria, and sustainability criteria. The [12] ontology is veritable in selecting green suppliers. However, its concepts don't cover the resilience and digitalization capabilities. Therefore, using the presented ontologies above, we conceptualized the viable-oriented suppliers' selection criteria model and defined attributes and relationships between the concepts related to ensuring viability.

Table 1. Knowledge classification

Name of the knowledge type	**Knowledge**
ResilienceCriteria	Knowledge presenting the criteria related to ensuring resilience
SustainabilityCriteria	Knowledge related to sustainability criteria
DigitalizationCriteria	Knowledge presenting the suppliers digital abilities
ProfileCriteria	Knowledge defining the general information of suppliers
PrimaryCriteria	knowledge related to the basic criteria for suppliers selection

4.4 Knowledge concepts, relations and attributes

This step of the ontology consists of specifying concepts and relations of suppliers' selection criteria. More clearly, this phase consists of attributing a unique name for concepts, a concept ID, the inheritance ID, and a natural language definition of the concept (Table 2). Besides, it attributes potential relations name, the domain, and range (Table 3). To sum up, the proposed ontology has 399 concepts and 70 relations.

Table 2. Extract from the original concepts table

ConceptID	**ParentID**	**Natural language definition**
Economic_Risks	Risks	Risks that may affect an investment or a business
Technological_Capability	DigitalizationCriteria	Capabilities related to novel technologies
Material_Cost	Cost	Costs of materials
Risks_Identification	Risks_solutions	a step that identifies risks

Table 3. Extract from the original relations table

Relation	**Relation ID**	**Domain**	**Range**
Avoid	Avoid	Cybersecurity	Itrisks
Can Lead To	Can_Lead_To	Digitalizationcriterea	Resiliencecriterea
Ensure	Ensure	AI	Forecastingcapabilities
Has For Challenge	Has_For_Challenge	Information	Datasecurity
Has For Issue	Has_For_Issue	Profilecriteria	Resiliencecriterea
Improve	Improve	Digitalizationcriterea	Primarycriterea
Prevent	Prevent	Technologies	Risks
Secure	Secure	Blockchain	Communicationcapability

4.5 Viable-oriented Suppliers selection ontology implementation with Protégé

After extracting the concepts defining a set of criteria and sub-criteria, and, defining properties and relations between them, the core ontology model is formed. The main structure of the proposed ontology is modeled using Protégé software (see Fig.2). Protégé software is a tool allowing to visualizing, validating and building the proposed ontology in the OWL language respecting W3C recommendations [23]. Each of the presented classes contains a set of sub-classes. We have five classes namely ResilienceCriteria, SustainabilityCriteria, DigitalizationCriteria, PrimaryCriteria, and ProfileCriteria, and 394 subclasses. Each class has many sub-classes. For instance, the DigitalizationCriteria has the following sub-classes: Innovation, Process_Quality, Product_Quality, Ressources, Security, Technological_Capability, Technologies. For ResilienceCriteria class, it has 3 sub-classes namely Actions, Performance, and Risks.

In a summary, our ontology offers a structured model for storing knowledge related to relevant criteria for selecting suitable suppliers considering the viability performance. Thanks to the proposed ontology, the domain definition of viable-oriented supplier selection criteria, its attributes, and relations with other concepts may be queried, inferred, or interpreted using the formal, explicit, and rich semantics to enable efficient viable suppliers' selection.

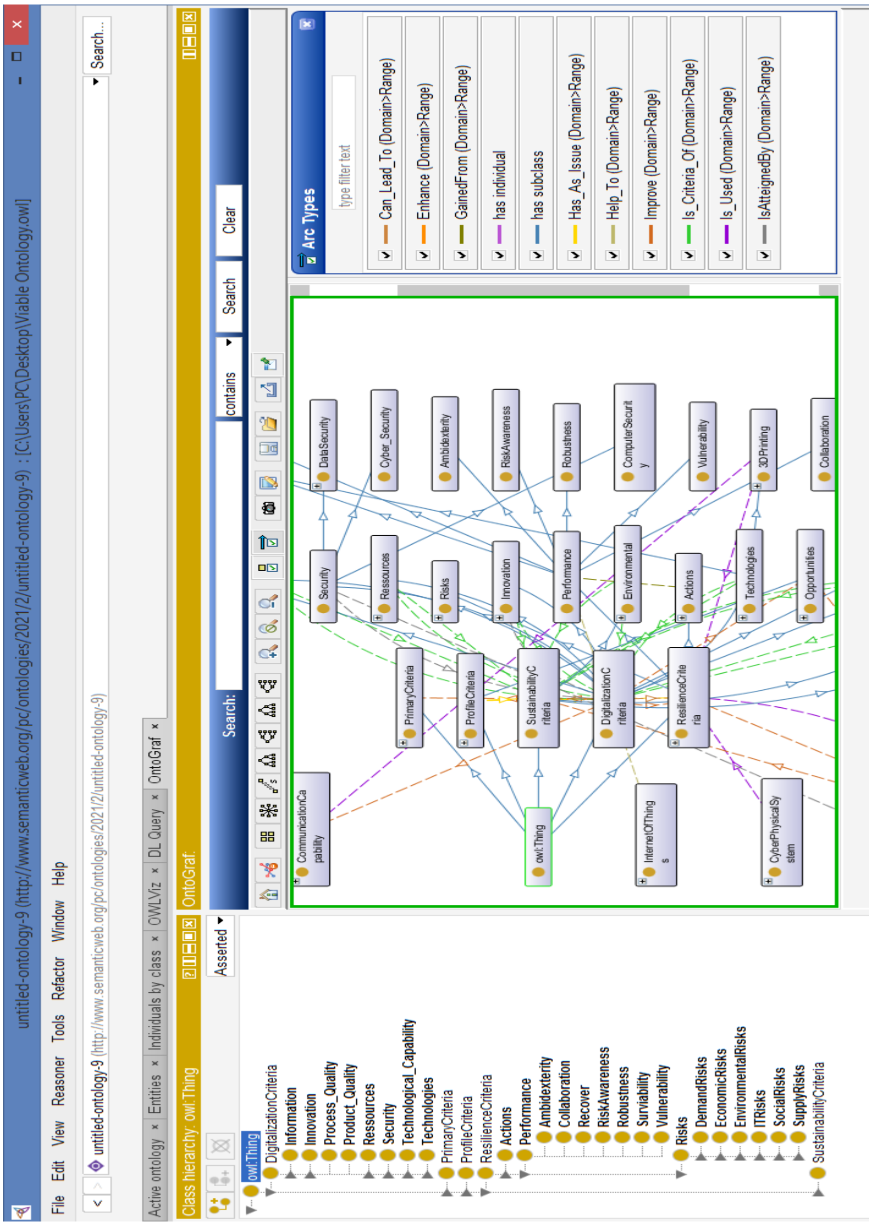

Fig. 2. Viable-oriented suppliers selection ontology implementation

5 Practical and managerial implications

The developed ontology reflects current knowledge of the viable-oriented supplier selection domain criteria. It allows many benefits. It helps to systematize knowledge of the selected set of criteria and to represent knowledge structurally. Besides, it offers the opportunity of transdisciplinary conditions to collaboration between systems. The ontology's hierarchical structure enables rigorous thinking regarding domain concepts. That is to say, that managers will have the ability to rebuild the model and replenish it with information systems data. Furthermore, it can provide a dynamic mechanism for building or integrating information and other component-based information systems. It may also contribute to the development of information systems for the evaluation of the whole domain, enabling automatization, visibility, and transparency. The proposed ontology's practical implications involve efforts to implement a large amount of knowledge covering resilience, digitalization, and sustainability dynamic capabilities that define viable-oriented supplier selection criteria. In other words, it is referencing the literature source metadata. These criteria knowledge could be used to interoperate with any knowledge base or database, or information systems. Furthermore, the proposed ontology unifies the scattered knowledge regarding viable-oriented supplier selection criteria and categorizes them into a comprehensive hierarchy.

6 Conclusion

With an increasingly global consciousness of resilience, viable-oriented cooperation in end-to end supply chains has emerged as a key feature. Because of the international changes that have arisen as a result of market globalization, technological advancements, or natural disasters [7]. Therefore, a successful viable-oriented supplier selection strategy will help reduce risks and disruptions effect while increasing organizations' competitiveness. For doing so, several sets of criteria were established to strengthen this process. While there are numerous studies on supplier selection, there is no comprehensive study considering viability issue in the suppliers' selection process.

Exchanging and transparently sharing information and knowledge represents a challenge for organizations to remain viable. To meet this challenge, this paper aims to present a new ontology-based-model for supporting suppliers' selection considering the viability performance. More clearly, the viable-oriented suppliers' selection is based on resilience, digitalization, and sustainability capabilities criteria. Thus, acquiring these criteria knowledge in an ontology is cost-effective and flexible to have access to needed information. It allows also to capitalize knowledge related to suppliers selection which can be considered as an important contribution for viable suppliers selection knowledge performance. In this article, to implement the viable-oriented suppliers' selection, the first step consisted of retrieving criteria from the literature. After that, we have identified, classified, and capitalized knowledge to draw up the taxonomy and define knowledge concepts, relations, and attributes. Then, we have implemented and visualized the proposed ontology using Protégé software.

This ontology-based-model supporting viable-oriented suppliers' selection can be pursued in further work. This ontology can promote the standardization and sharing of knowledge by qualified actor-assisted tools such as the Multi-Agent System. This paper has some limitations that provide the opportunity for potential research. In other words, there is always the potential of enhancing the veracity of data collection and enriching knowledge while implementing an ontology. Moreover, future ontologies can consider disruption phases (pre-disruption, post-disruption, and disruption) knowledge to enhance the supply chain viability. Furthermore, we can introduce fuzzy logic theory in the proposed ontology to handle the concept of the decision subjectivity.

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