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Supply chain management ontology from an ontology engineering perspective

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ABSTRACT

Knowledge sharing and reuse are important factors affecting the performance of supply chains. These factors can be amplified in information systems by supply chain management (SCM) ontology. The literature provides various SCM ontologies for a range of industries and tasks. Although many studies make claims of the benefits of SCM ontology, it is unclear to what degree the development of these ontologies is informed by research outcomes from the ontology engineering field. This field has produced a set of specific engineering techniques, which are supposed to help developing quality ontologies. This article reports a study that assesses the adoption of ontology engineering techniques in 16 SCM ontologies. Based on these findings, several implications for research as well as SCM ontology adoption are articulated.

Contents

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1. Introduction

The premise of supply chain management (SCM) is that the performance of a single company depends more and more on its ability to maintain effective and efficient relationships with its suppliers and customers [1,2]. Therefore, managerial tasks are moving from an organizational scale to a supply chain scale [3] and thus encompass the inter-organizational integration and coordination of dispersed supply chain activities. Empirical research suggests that knowledge sharing and reuse between supply chain participants are important determinants of supply chain performance at both the strategic and operational level [4,5]. The role of information systems to support this task is subject of much research [6–8].

Knowledge sharing and reuse between supply chain participants face many organizational obstacles such as confidentiality, trust, and norms. However, fundamental prerequisites for knowledge sharing are means for exchanging, processing, and interpreting the relevant domain knowledge by using one or more representations of this knowledge. Since such representations may be diverse and serve different objectives, formal ontology has been proposed to represent domain knowledge, enhance communication between participants, and support interoperability of systems [9]. A formal ontology formally captures knowledge through concepts, relationships and axioms, and can be regarded as the conceptual model of a knowledge base [10]. The application of ontology in SCM has led to a large number of ontologies for various SCM tasks, e.g., planning [11] as well as more generally representing arbitrary supply chains [12].

Although researchers make use of ontology specifically for SCM, this stream of research seems to be less connected with the ontology engineering (OE) field as it could be. Over the past 20 years, the OE field made significant advances with regard to its constructs, models, methods, and tools, and contributes specific techniques that assist ontology developers [13,14]. However, the extant literature does not inform us sufficiently about the concrete linkages between OE and SCM ontology. In particular, little is known to what extent the development of these ontologies is informed by the techniques available from this field. The first steps to increasing our knowledge about these ties were taken by Grubic and Fan [15], who review six supply chain ontologies: Two out of five evaluation criteria used in their review concern the methodological foundation as follows. "Scientific paradigm" studies the epistemological stance of the ontology researcher. "Methodological approach" studies the adoption of five general approaches to ontology design that were proposed in Ref. [16]. Our review complements and extends this research by (1) studying the adoption of concrete techniques from the OE literature and (2) reviewing a larger set of in total 16 SCM ontologies of which three are also found in the study by Grubic and Fan [15].

While empirical research has contributed to understanding the applicability and usefulness of OE techniques [17,18], assessing their adoption in concrete ontologies has received little attention. Therefore, the objective of this article is to review and analyze current SCM ontologies with regard to their methodological foundation, i.e., the adoption of OE techniques. This study concerns the concrete linkages between OE techniques and SCM ontology as a particular type of application ontology. The study contributes to understanding these linkages and motivates avenues of future research.

This article proceeds as follows. The theoretical background to the review is described in Section 2. The review process and the relevant SCM ontologies are presented in Section 3. The review results can be found in Section 4. The discussion of the findings and their implications for future research are part of Section 5. A summary of the research is given in Section 6.

2. Theoretical background

2.1. Formal ontology

Originally, the term ontology has its roots in philosophy. As a discipline of philosophy, ontology denotes "the science of what is, of the kinds and structures of objects, properties events, processes, and relations in every area of reality" [19]. Starting in the late 1980s and early 1990s, ontology gained increasing awareness in Computer Science and Artificial Intelligence (AI). AI requires formal representations of real world phenomena in order to reason about these phenomena. In a literal sense, AI research borrowed the term ontology from philosophy and equipped it with a computational meaning. As a result, AI coined the term "formal ontology" (or computational ontology). The key characteristics of formal ontology are part of the definition coinded by Studer et al. [20]: Ontology is "a formal, explicit specification of a shared conceptualization of a domain of interest". Conceptualization depicts an abstract representation of some (real-world) phenomenon by having determined its relevant concepts, relationships, axioms, and constraints. Further, explicit denotes the explicit (not implicit) definition of the type of concepts, relationships, axioms, and the constraints holding on their use. Formal indicates that the ontology should be readable and interpretable by machines, thus formal excludes the use of natural language. Finally, shared conceptualization requires the ontology to capture consensual knowledge that is not private to an individual person but accepted by a larger group of individuals.

SCM is a particular area of application for ontology, which results into SCM ontology. To determine the scope of our analysis, it is necessary to qualify this kind of ontology in more detail. We refer to the classification proposed by Guarino [10], which categorizes ontologies by the level of generality into four types:

- *Top-level ontology* specifies a conceptualization that is independent of a particular domain; for instance, it concerns space, time, object, and event.
- *Task ontology* defines the vocabulary related to a particular type of task such as planning, diagnosing, or purchasing. This type of ontology defines the task knowledge that is required for solving a particular type of task.
- *Domain ontology* defines the vocabulary related to a particular domain such as healthcare, automotive, or machinery.