Jurnal Mantik, 5 (2) (2021) 790-799

Published by: Institute of Computer Science (IOCS)

Jurnal Mantik

Journal homepage: www.iocscience.org/ejournal/index.php/mantik/index

Supply Chain Ontology: Model Overview and Synthesis

Moh. Muklis Sulaeman[1], Mugi Harsono[2]

[1]Universitas Islam Lamongan, Jetis, Kec. Lamongan, Kabupaten Lamongan, Jawa Timur
[2]Universitas Sebelas Maret Surakarta

Email: [1]muklis849@gmail.com, [2]mugiharsono_fe@staff.uns.ac.id.

A R T I C L E I N F O

Article history:
Received: 01/06/2021
Revised: 07/06/2021
Accepted: 15/06/2021

Keywords:
Supply chain, Ontology, Model

A B S T R A C T

Supply chain ontology as an important medium for solving information system interoperability problems. To inform future supply chain ontology research, this paper sets out to review and analyze existing supply chain ontology models. An extensive literature review was conducted which identified six supply chain ontology models together with the three criteria that form the framework for comparison. After applying a framework has been identified which should provide insight into potential future research. The general conclusion is that we are far from using ontologies to solve information system interoperability problems. Our analysis has shown that too much emphasis is placed on the organization and structure of human knowledge of supply chains than on understanding supply chain realities. Seen from a 'philosophy of science' perspective, all the models reviewed have ontological flaws. More rigorous and theoretical analysis is needed if a more realistic and robust supply chain system is to be developed.

1. Introduction

Empirical studies suggest that supply chain integration can provide better operational and business performance. To exploit all the benefits associated with supply chain integration, businesses must change their practices from information hoarding to information sharing. More and more researchers support the idea of supply chain integration through the integration of information flows. Many business solutions are promoted by IT vendors, ranging from packaged ERP solutions, best supply chain software, e-business applications to web services. In this ecosystem of interacting business requirements and vendor offerings, interoperability of information systems is critical. Themistocleous et al. revealed that 38 percent of companies did not replace their legacy systems when they implemented ERP systems. After this they also found that 58 percent of companies did not successfully integrate their ERP system with existing legacy systems. In a similar study to compare the benefits and drawbacks of application integration, they found that all the companies included in the study still integrated their legacy systems with their ERP systems. Also, the majority of the 163 organizations surveyed (by Davenport et al.) are still in the implementation phase and moreover they have not found a single company reported as complete. Sprott attributes this "to differences in semantics and business rules between different applications that were never meant to collaborate" (p. 66). For two applications to communicate and understand each other, they must have the same syntax and semantics. ERP systems have become a standard tool for running a business. Chopra and Meindl argue that these systems generate true value only if they support decision making across the company and its supply chain, while (Themistocleous et al.) assert that ERP systems do not provide an integrated solution, ERP only further reinforces the need for integration. The study results provide evidence that ERP systems do not adequately support supply chain integration.

One reason is that these systems are not designed to address supply chain problems but to integrate enterprises. The company's inherent focus is perceived by many as a major barrier to improving the integration of information from the supply chain. Therefore, a so-called best breed supply chain system has been proposed to address the lack of information integration across the supply chain. Compared to ERP systems, these products promise to narrow and broaden their focus both upstream and downstream in the supply chain. This upstream is achieved with SCM and Supplier Relationship Management (SRM) software;

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

and downstream with Customer Relationship Management (CRM) software. Although there is evidence of synergies between the ERP system and the new system, interoperability is still an issue. Pant et al. have conducted two case studies to develop a framework that captures different information systems implementation approaches. They conclude that the challenges of integrating different systems across the supply chain are much greater than those faced by companies trying to integrate ERP systems.

2. Theoritical Review

2.1 Strategy Review

The proposed systematic literature review approach (by Tranfield et al.) was used to identify the current supply chain ontology model. This approach was adopted because it promises the accuracy, completeness and quality of the review results. It consists of three sequential stages: (1) planning the review; (2) conduct a review; and (3) reporting and dissemination. The first stage defines the purpose of the review, the keyword list and database, and inclusion and exclusion criteria, all of which provide the means for the second stage or conduct of the review. In addition to the supply chain ontology model, it was also decided to include an ontology model that addresses the problem of virtual enterprises and extended enterprises. The last two organizational structures are sometimes used as synonyms for supply chains and the theory recognizes them as similar inter-organizational arrangements. All ontology models that deal with aspects of collaborative product design or development are excluded. Only ontology models that address the flow of materials, services, and information across the supply chain are included in the review. According to Arlbjørn and Halldorsson[48] this school represents the core of the logistics discipline and therefore its basic unit of analysis. All data, information or reference models that fall within the previously stated scope are also excluded because they do not offer the same basis needed for subsequent analysis and synthesis

2.2 Supply chain ontology model

Six supply chain ontology models were selected from the literature reviewed, namely: (1) enterprise ontology, (2) TOVE ontology, (3) model by Soares et al., (4) IDEON ontology, (5) manufacturing systems engineering ontology, and (6) the model by Ye et al. Other models not selected can be read from the extensive references provided. An overview of the selected models is given below as an introduction to their evaluation presented in the fifth section.

2.3 Company ontology

An enterprise ontology (EO) was developed as part of the Enterprise Project at the University of Edinburgh to explore the value of ontology for enterprise modeling. A detailed description of EO along with the methodology used for its construction and applications using the ontology exists (in Uschold et al). The objectives of EO are threefold: (1) improving communication between people; (2) provides a basis for determining end-user applications; and (3) supports interoperability. EO consists of five parts: (1) Meta-Ontology and Time; (2) Activities, Plans, Capabilities and Resources; (3) Organization; (4) Strategy; and (5) Marketing. It should be clarified that EO does not address any aspect of the supply chain. While some of the concepts that make up EO (e.g. Activities, Machines, People, etc.) are generic to many organizations, other concepts address enterprise constructs (e.g. Non-Legal Ownership, Legal Ownership, Employment Contracts, etc.) that exist at a very high level. tall and abstract. Nevertheless, EO was included in the analysis for two reasons. First, it is a pioneering work in the field of corporate ontology;

2.4 TOVE On Ontology

The TOVE ontology was developed as part of the Toronto Virtual Enterprise Project which aims to create an enterprise infrastructure in the form of an Enterprise Model that will have the ability to infer answers to questions about tasks in an industrial environment. Tasks have been defined in great detail and include "supply chain management extending MRP to include logistics/distribution and concurrent engineering looking at engineering design coordination issues." (p.124). A single company perspective is taken and produces a set of ontologies. The ontologies developed are: resource ontology, cost ontology, organizational ontology, product ontology, activity-state-time ontology and ontology for quality management. Not all ontologies are relevant in the supply chain domain; hence only resource, organization, and activity-state-time ontologies are included in the comparison. The resource ontology aims to capture the resources in a manufacturing company while the organizational ontology captures the structural concepts of the organization such as: objectives, divisions, subdivisions, agents, roles, and resources. The activity-state-time ontology represents the foundation for the ontology and acts as a top-level ontology.

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

2.5 Model by Soares

The ontology introduced (by Soares et al.) was developed to improve human communication and define system requirements for production planning and control in a virtual enterprise environment. The ontology developed is part of a trans European project involving several academic institutions and industrial companies from the semiconductor industry sector. The concept is presented in the form of a natural language definition and then conceptualized by an object model. These are grouped under three main sections: (1) extended network/organization, (2) planning and (3) order management. The basis of this ontology is EO; more specifically Meta-Ontology.

2.6 IDEON Ontology

The IDEON ontology was introduced (in Madni et al.) The purpose of this ontology is to provide a foundation for designing, reinventing, managing and controlling collaborative and distributed enterprises. The ontology is developed using four views that aim to capture the various concepts and relationships that describe an enterprise. Each of these views is represented as a separate object-oriented model using the Unified Modeling Language notation. The four views are: (1) Enterprise Context View; (2) Company Organizational View; (3) Process View; and (4) Resource/Product View.

The purpose of the Enterprise Context View is to represent the interaction of an enterprise with its environment. This view consists of several concepts related to observing and assessing the state of an environment. The Corporate Organizational View concerns the structure of a company and deals with lower-level concepts (eg Goals, Strategies, Goals, Processes, or People) than the Enterprise Context View. The aim of Process View is to equip the ontology with the concepts needed to represent the (re)planning-execution-control cycle. Process Concepts are further classified into three concepts: Process Planning, Plans and Activities. Resource/Product View details several types of resources required for execution of a Process.

2.7 Manufacturing systems engineering ontology

The proposed manufacturing systems engineering (MSE) ontology (in Lin et al.) was developed to support the implementation of the MSE Moderator in an extended/virtual enterprise environment. MSE Moderator "is an intelligent support application designed to facilitate and improve engineering design while increasing the level of awareness, cooperation and coordination among engineering team members." (p. 5100). The MSE ontology has seven top-level classes which are further detailed and classified in a hierarchy of subclasses. Only the seven upper-level classes have been described in more detail in the references and are: (1) Projects; (2) Flow; (3) Process; (4) Company; (5) Company_Expansion; (6) Resources; and (7) Strategy. Project Class represents the Flow of physical and non-physical items during the operation of an extended/virtual enterprise. The latter are linked by a Process class representing transformations which are in turn activated by different resources modeled by the Resource class. The Enterprise class provides a structure for managing processes and resources using the different items that belong to the Strategy class. The Extended_Enterprise class represents a distinct aggregation of Enterprise objects.

2.8 The model by Ye et al.

The final supply chain ontology model to be reviewed here was developed and proposed by Ye et al. [65]. This model aims to serve as Interlingua by enabling semantic integration between heterogeneous information systems in the supply chain. The proposed ontology supply chain arrangement is a web-based or virtual enterprise and not a closed supply chain system where partners have reached agreement on the vocabulary to be used. In such an arrangement, supply chain partnerships are dynamically created and last only for a short time. The ontology was developed without a specific industry focus and consists of the following toplevel classes: Supply_Chain, SC_Structure, Party, Role, Purpose, Activity, Resource, Transfer_Object, Performance and Performance_Metric This is more specific although no information about the lower level classes is provided. It was originally conceptualized in Protégé and later coded in OWL to enable web-based supply chain integration. The ontology model by Ye et al. provides the semantic backbone for the integration framework. This framework is then used in an imaginary supply chain scenario to solve supply chain information integration problems.

3. Research Methods

This section presents the design of the comparative framework used to analyze the six selected supply chain ontology models. This framework consists of seven evaluation criteria and their respective dimensions. The criteria were developed from the literature analysis in the development of general ontology and SCM.

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

Table 1
Evaluation framework.

Criteria	Criteria dimension
Scientific conceptualization/paradigm	Objectivist and subjectivist paradigms
Granularity level	Strategic, tactical and operational
Methodological approach	Inspiration, induction, deduction, synthesis, collaboration and hybrid; evaluation

4. Research Results and Discussion

4.1 Scientific conceptualization or paradigm

This criterion aims to identify the scientific paradigm that underlies the supply chain ontology model. There are significant similarities between conceptualizations as used and introduced in ontology research (especially AI and information systems) and the notion of scientific paradigms as introduced in the history and philosophy of science literature. Smith claims that one of the reasons why information systems ontologies have failed is because they are treated as equals and it is not recognized that different conceptualizations of information systems ontologies are committed to not only unequal qualities but also mutually inconsistent. In his widely cited paper, (Gruber) defines an ontology as "an explicit specification of conceptualization" (p. 199). This definition has been so widely adopted in such a short period of time that ontology is sometimes mistakenly taken as a synonym for conceptualization. (Guarino) claims that ontology and conceptualization are different and must be kept distinctly different. In a broad sense, conceptualization always reflects a world view and this idea is often used as a synonym for a scientific paradigm that is characterized by two dimensions of ontological and epistemological. The notion of conceptualization was introduced (by Genesereth and Nilsson) which is often used to accompany and elaborate on higher-level definitions of ontology. Conceptualization is defined as “objects, concepts and other entities that are presumed to exist in some area of interest and the relationships between them.” According to Guarino the main problem with this definition is the extensional interpretation of the conceptualization in which the latter as he further claims must be understood as an intentional rather than an extensional artifact. The terms extensional and intentional are terms used in set theory.

Mizoguchi defines the difference between an extensional and an intentional set wherein the former is defined as consisting of an enumeration of all elements while the latter simply specifies necessary and sufficient conditions for the elements. The definition of an intentional set introduced here resembles the concepts of concept theory and classes from object-oriented programming. According to concept theory, a concept is intentionally defined as a collection of properties while the instances possessing those properties are extensions of them. The idea of class and categorization is central to the development of ontology. Thus, Sowa claims that “the first step in designing a database, knowledge base, or object-oriented system is to select an appropriate collection of ontological categories” (p. 670). Given that ontologies are always committed to conceptualization and since the latter must be defined as a deliberate set by specifying necessary and sufficient conditions for its elements, it is not difficult to imagine that different people would define different conditions which would result in different categorizations. . The reason for this must be found in the way people organize and structure their knowledge, i.e. epistemology, and not how the real world is structured (ontology). According to Parsons and Wand, classification structures are not inherent in the real world but constructed by us, that is, they claim that "things exist, but classes are constructed." (p.238). Furthermore, Parsons and Wand claim that the reasons why people use classification should be sought in cognitive and linguistic psychology and not in ontology.

As outlined, there is a strong relationship between ontologies, conceptualizations and scientific paradigms. Inconsistencies in ontologies can be attributed to the differences that exist between sometimes even opposing scientific paradigms. The scientific paradigm is characterized by two dimensions: ontological and epistemological; where the next two dimensions are characterized by two extreme poles. Ontological according to: realism and nominalism; and epistemologically by: positivism and interpretivism. Realism postulates that reality exists independently of the observer while nominalism postulates that reality is a subjective construction. Epistemology is concerned with knowledge of reality and what can be considered

Accredited “Rank 4”(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

valid knowledge of that reality. The positivistic epistemological stance centers on the identification of causal relationships that explain observable phenomena. The interpretivist approach holds that understanding of some domain depends on the observer's pre-understanding of that domain. Although these poles define different paradigmatic positions, Klein and Hirschheim claim that only two are significant for data modeling: the objectivist and the subjectivist paradigms. The former is defined by the realist-positivist position and the latter by the nominalist-interpretivist position.

4.2 Granularity

Any domain, including supply chain, can be queried from different levels of conceptualization or detail. The granularity criteria have been inspired by Guarino who proposes solutions to so-called interaction problems coming from the AI community. According to Schreiber et al., the interaction problem states that "control knowledge and domain knowledge are highly dependent—one cannot define domain knowledge". without knowing what the task will be, and vice versa" (p. 33). Control knowledge is also called task solving knowledge where the domain knowledge represents part of the relevant domain knowledge to use the task solving knowledge. The issue of interaction has generated much academic debate. In his paper Guarino strongly defends the thesis of independence between domain and problem solving knowledge and presents several arguments. He did not recognize the interaction problem as a problem of dependence between domain and task knowledge, what he saw as dependent on a particular task was the granularity of domain knowledge. In the AI domain, it is common to use different levels of conceptualization to reflect the different granularities of the domain. Falkenhainer and Forbus and Abu-Hanna and Jansweijer both use different granularity representations of domain knowledge to solve engineering problems that demand different levels of abstraction. in Hobbs, granularity has also been included as the first of the core theories of ontology, where granularity is defined by an "indistinguishable" relationship or the equivalent of a set of closures (p. 821). Granularity as introduced in Hobbs resembles rheology or whole-part theory, especially if we consider what Smith said about rheology: "Mereology allows ontologists to begin their investigations with complex wholes as if they were at an intermediate level of reality, and to work into up and down from this, as appropriate coarser and finer theories become available." Viewed from this perspective, interaction problems do indeed reduce to the level of conceptualization required to solve a particular task. Rudberg et al. claims that SCM can be divided into two parts: supply chain planning and supply chain execution.

They further state that the only difference between the two is in their respective time horizons, the former being more strategic and tactical, and the latter being more tactical and operational. A common view within the SCM community is that the granularity of supply chain decisions extends beyond three levels — strategic, tactical, and operational. Therefore this dimension has been adopted to characterize the level of granularity criteria.

4.3 Methodological approach

These criteria aim to detect the underlying methodological approach adopted for the development of supply chain ontologies. Gruber proposes a set of principles that should be used in ontology design to share knowledge and Uschold and Gruninger present an elaborate introduction into ontology principles, methods, and applications. Kishore et al. propose guidelines for ontology construction. They are based on two premises: (1) no ontology is ever complete; and (2) no methodology is perfect. They further argue that the best that can be done is to follow a set of guidelines.

Based on so-called three-layer guidelines, Mizoguchi also introduces an ontology development methodology and Noy and McGuinness present a simple ontology development methodology intended for use by both novice and inexperienced ontology developers. Due to the multifaceted nature of ontologies that requires capturing different views on the domain, the development of collaborative ontologies has recently gained wider interest. Holsapple and Joshi present a collaborative approach to ontology development in the knowledge management discipline using the Delphi method.

Apart from this approach which can be characterized as less formal or detailed, the literature also recognizes other approaches that are more formal and more detailed. These ontology development methodologies differ in various ways, such as: the level of formality proposed, the chosen approach, the domain for ontology development, the portion of the ontology life cycle handled by the methodology, the maturity of the methodology, and the inheritance of a methodology. However, some authors claim that ontology development is still an art rather than a science that has not yet matured enough to ensure a valid ontology construction process. This paper builds on five general approaches to Holsapple and Joshi's ontology design: (1) inspiration; (2) induction; (3) reduction; (4) synthesis; and (5) cooperation. The

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

inspirational approach aims to capture the individual's point of view about the domain while the induction approach involves the use of exploratory strategies. Deduction builds on theoretical principles related to the domain of interest while the synthesis approach aims to identify and integrate existing ontologies to characterize some aspects of the domain that are not covered by the ontology being developed. The collaborative approach recognizes the existence of multiple views on the domain and attempts to capture and/or reconcile them. The sixth approach proposed further here is a hybrid or combinatorial approach consisting of at least two or more approaches. In addition to these six approaches.

4.4 Supply chain ontology model analysis

This section reports on the analysis using the comparison framework. The analysis presented here provides insight into gaps in existing supply chain ontology research.

4.5 Enterprise Ontology (EO)—analysis

The way EO selects and defines its constructs demonstrates the use of the objectivist paradigm. It was said earlier that EO does not handle any aspect of the supply chain so no level of detail is attributed. The methodology proposed by Uschold and King[93] has been used in its development. This methodology consists of two parts: informal and formal ontology development. The informal section deals with the identification and development of relevant concepts and definitions of natural language; while the formal section converts it to the definition of Ontolingua. Ontolingua was developed for use as an interchange format and is based on first-order logic and allows for an object-oriented style of representation. The identification of relevant concepts in the informal section is based on brainstorming so it can be said that an inspirational approach is used. EO (both informal and formal) consists of five sections, of which the first section (Meta-Ontology and Time) defines the general terms Entities, Relationships and Roles which are the basic constructions for the development of terms that make up the other four sections.

Therefore, it can be said that a synthetic approach was used. Ontologies are judged on the basis of their actual use to their original purpose. It is used in four different applications with different purposes and results. Most applications (three out of four) aim to improve human communication within an organization. In applying the lens of 'philosophy of science' in this analysis, EO equates ontology with knowledge of a company which shows some ontological 'lack' that may arise from placing too much emphasis on knowledge of the company rather than ontology of the company. An example is the definition of the concept of the Meta-Ontology of Roles. This concept is one of the founding concepts and is used extensively in EO. It has been represented in Ontolingua as Role-Class and it represents the way Entities participate in Relationships which are in turn modeled as Entities. The concept of Entity is defined as "fundamental in the domain being modeled." (p. 43). The 'philosophical' question is: is a Relationship an Entity and does it exist in the corporate domain or in other domains in general? It is stated here that Relationship is a property of the Entity and therefore cannot exist independently of it.[102].

4.6 TOVE ontology—analysis

Only the TOVE ontology of resources and organizations are relevant in the supply chain domain and are analyzed here. Similar to EO, the TOVE ontology also adopts an objectivist paradigm. This is best observed in the premise of shared goals and no self-interest between agents. Also, both ontologies describe general and high-level concepts structured into taxonomies. We conclude that the level of strategic detailing is adopted without specific industry sectors being addressed. Since the activity-state-time ontology acts as a top-level ontology, it can also be said that a synthesis approach was taken when developing both ontologies. In addition to adopting the activity-state-time ontology, the methodology proposed by Grüninger and Fox is followed. This methodology states that the ontology requirements will be defined in the form of competency questions posed by the ontology developer. Since no guidelines for defining questions are provided, it can be said that their definitions are a function of the experience and prior knowledge of a developer and therefore an inspirational approach was followed. The strong legacy of AI manifests throughout the TOVE ontology, as the goal of the ontology is to infer answers to questions. This results in a strong emphasis on knowledge, rather than reality. There are instances in the organizational object taxonomy where some of the objects introduced have no ontological basis (e.g. Skill objects that cannot exist independently of their holder).

One of the greatest advantages of an organizational ontology is the formal introduction of the concept of Empowerment which models an agent's right to perform some state change act. This concept – very similar to the concept of Authority in EO – is used to link organizational structure and behavior. The application of the TOVE ontology is the TOVE Testbed which was developed as an environment for analyzing enterprise ontologies.

4.7 Model by Soares et al.—analysis

Since this ontology is built on top of EO (more specifically MetaOntology), it is concluded that an objectivist paradigm is adopted. When compared with the TOVE ontology, the ontology by Soares et al. are at the same level of granularity. This leads to the conclusion that the ontologies reviewed here are characterized at a strategic level. A threefold hybrid methodological approach was adopted. The generic technoorganizational requirements of a semiconductor virtual company were first identified by reviewing the literature related to virtual enterprises, using a deductive approach. The overall methodology used is that proposed by Uschold and King [93] and was used in the development of the EO. Since this methodology is characterized by the use of brainstorming techniques to derive ontology requirements, an inspirational approach is also used. The basis of this ontology is the EO Meta Ontology; therefore a synthetic approach was also followed. No formal evaluation is presented but since a methodology for EO development is used, it is possible that a similar evaluation approach is followed. Although the authors mention that their approach is being tested, no application of the ontology has been reported in this paper.

4.8 IDEON ontology—analysis

The IDEON ontology uses an objectivist paradigm because the idea of companies collaborating to achieve a common goal is a real world phenomenon. This ontology was developed using four perspectives to capture the various concepts and relationships that describe a company. Its related views and concepts aim to address strategic levels of supply chain detail. The IDEON ontology deals with virtual enterprises and corresponds to the scope of the inter-business network of the supply chain. The ontology was developed without a specific industry sector focus although the authors claim that the IDEON ontology is easily expandable to accommodate a wide range of application domains from healthcare to military command and control.

Only two of the many enterprise applications that the authors claim that the IDEON ontology is used to support have been briefly mentioned. The first is the planning and implementation of crisis actions and the second is the development of integrated product processes. In both cases the ontology developed is used to provide the underlying conceptual framework. No information was provided about the methodological approach used or the ontology evaluation. It is assumed that the inspirational approach is followed that the ontology is largely based on "knowledge and experience" rather than rigorous ontological analysis. This may be the reason for the many ontological deficiencies present in the model. For example, the Enterprise Context View covers the concepts of Assessment and Observation while the Resource/Product View covers the concepts of Roles. It is said that these concepts do not exist independently in reality; rather they should be modeled as properties.

4.9 Manufacturing system engineering ontology (MSE) -analysis

Only seven upper-level classes of the MSE ontology have been detailed, which represent a rather high level and generic construct, it is concluded that the objectivist paradigm and the level of strategic granularity have been adopted. Apart from referring to the manufacturing system information model as an input to the MSE ontology no further information is provided about ontology development. It is said that a synthetic approach is used. Lin and Harding offer an MSE ontology application that functions as a mediation ontology to enable information interoperability for collaboration between companies. To this end they have introduced scenarios (assume imaginary) to resolve information interoperability conflicts between different MSE software systems in a virtual manufacturing setting in the electronics industry sector. The developed MSE ontology functions as an Interlingua by enabling mapping between individual ontologies. The Resource Description Framework (RDF), RDF Schema and Web Ontology Web Language (OWL) were used to facilitate mapping. From a 'philosophy of science' view, there are two main problems with the MSE ontology. The first relates to the strong emphasis placed on solving terminological problems using the MSE ontology as a mediator to enable mapping between different software systems.

Although ontologies can greatly reduce the problems created by inconsistent and varied vocabulary, this is not the ultimate and ultimate goal. The second is the methodological approach of developing MSE ontology. TheMSE ontology is heavily based on the use of different manufacturing systems information models. The research presented in this shows the potential for erroneous requirements and the lack of rigorous analysis inherent in the information model development process. Therefore, it is not surprising that the MSE ontology model inherits some of the ontological shortcomings introduced from the source model.

4.10 The model by Ye et al. - analysis

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

Based on the view that supply chain partners have the same goals and objectives without selfish and antagonistic behavior, an objectivist paradigm is adopted. Comparing the top-level class in the model with other supply chain ontology models that have the same scope (model by Soares et al., IDEON ontology, MSE ontology), the granularity level corresponds to the strategic level. The methodology used is a combination of: inspiration, synthesis and deduction. EO is used as the main backbone for this ontology model. It is quite reasonable to conclude that the same methodological approach was followed, thus inspiration and synthesis.

The deductive approach is identified based on the use of the Supply Chain Operations Reference model. This model is used as a source to capture the supply chain performance elements of the ontology model. Ontologies provide the semantic backbone for the integration framework. This framework is then used in an imaginary supply chain scenario to solve supply chain information integration problems. From a 'philosophy of science' point of view, this supply chain ontology has two main issues. The first relates to the perception that ontology development is only to solve terminology problems. The second issue concerns the ontological deficiency of the model. These flaws include not only the intrinsic flaws in the EO that forms the backbone of the model, but also some of the newly created ones. An example for this is the Service class which is a subclass of Material_Object. This explains that every Service object is a Material Object which does have an ontological basis.

Table 2
Material Objects

Supply chain ontology model	Criteria		
	Conceptualization/scientific paradigm	Level of granularity	Methodological approach
Enterprise ontology	Objectivist paradigm	Not applicable	Hybrid: inspiration and synthesis; evaluation: there is no formal evaluation although the ontology was assessed based on its actual uses against the original purposes.
TOVE ontologies	Objectivist paradigm	Strategic	Hybrid: inspiration and synthesis; evaluation—there is no formal evaluation yet the ontology developed should comply to the competency questions posed at the beginning
Model by Soares et al.	Objectivist paradigm (since EO is the founding ontology)	Strategic	Hybrid: deduction (generic techno-organizational requirements), inspiration (since methodology by Uschold and King was followed) and synthesis (since EO was thoroughly used); evaluation—probably similar as with the evaluation of EO.
IDEON ontology	Objectivist paradigm	Strategic	Inspiration (assumed); evaluation—there is no evidence on any formal or informal evaluation.
Manufacturing system engineering ontology	Objectivist paradigm	Strategic	Synthesis built on the experiences and knowledge of published manufacturing system information models. Evaluation no formal evaluation is introduced.
Model by Ye et al.	Objectivist paradigm	Strategic	Hybrid: inspiration and synthesis since the same methodology for the development of EO was used; also deduction (limited extent) since SCOR model was used for supply chain performance; evaluation probably similar as with the evaluation of EO.

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.

5. Conclusions

Important for solving information system interoperability problems. To inform future supply chain ontology research, this paper sets out to review and analyze existing supply chain ontology models. An extensive literature review was conducted which identified six supply chain ontology models together with the three criteria that form the framework for comparison. After applying a framework has been identified which should provide insight into potential future research. The general conclusion is that we are far from using ontologies to solve information system interoperability problems. Our analysis has shown that too much emphasis is placed on the organization and structure of human knowledge of supply chains than on understanding supply chain realities. Seen from a 'philosophy of science' perspective, all the models reviewed have ontological flaws. More rigorous and theoretical analysis is needed if a more realistic and robust supply chain system is to be developed. We urge supply chain ontology researchers to consider philosophical ontologies especially new developments such as: formal ontology, rheology, and topology. More effort should be invested in achieving a closer relationship between reality and our representation of that reality. Following logic one might doubt whether supply chains as we know them exist. And some argue that the supply chain as an ontological concept or "thing" does not exist and is mistakenly considered a unit of analysis. What really exists is the flow of materials, information, and services between supply chain companies.

6. References

[1] A. Gunasekaran, EWT Ngai, Information systems in supply chain integration and management, European Journal of Operational Research 159 (2004) 269–295.
[2] A. Huang, DC Yen, DC Chou, Y. Xu, Enterprise application integration: challenges, opportunities and implementation strategies, Journal of Business and Management 9 (2003) 137–150.
[3] AZ Zeng, BK Pathak, Achieving information integration in supply chain management through B2B e-hub: concept and analysis, Industry Management & Data Systems 103 (2003) 657–665.
[4] B. Smith, in: EN Zalta (Ed.), Ontology and Information Systems, The Stanford Encyclopaedia of Philosophy, Stanford, CA, 2003.
[5] BJ Lee, K. Siau, S. Hong, Enterprise integration with ERP and EAI, Communications from ACM 46(2003) 184-205.
[6] C. Chandra, AK Kamrani, Knowledge management for consumer-focused product design, Smart Manufacturing Journal 14 (6) (2003) 557–580.
[7] C. Moller, ERP II: a conceptual framework for next-generation enterprise systems? Journal of Corporate Information Management 18 (2005) 483–497.
[8] CM Harland, Supply chain management: relationships, chains and networks, British Journal of Management 7 (s1) (1996) s63-s80.
[9] D. Chen, G. Doumeingts, European initiative to develop interoperability of enterprise applications—basic concepts, frameworks and roadmaps, Annual Review in Control 27 (2003) 153-162.
[10] DJ Bowersox, DJ Closs, TP Stank, Ten mega-trends that will revolutionize supply chain logistics, Journal of Business Logistics 21 (2000) 1–16.
[11] D. Sprott, Componentizing enterprise application packages, Communications from ACM 43 (2000) 63-69.
[12] D. Tranfield, D. Denyer, P. Smart, Towards a methodology for developing evidence-informed knowledge management through a systematic review, British Journal of Management 14(3) (2003) 207-222.
[13] ED Rosenzweig, AV Roth, JW Dean, Effects of integration strategies on competitive capabilities and business performance: an exploratory study of consumer product manufacturers, Journal of Operations Management 21(4) (2003) 437–456.
[14] FR Jacobs, E. Bendoly, Enterprise resource planning: development and direction for operations management research, European Journal of Operational Research 146 (2003) 233–240.
[15] Grubic. Tonci, Fan. Ip-Shing, *Supply chain ontology: Review, analysis and synthesis*, Computers in Industry 61 (2010) 776–786
[16] H. Aziz, J. Gao, P. Maropoulos, WM Cheung, Open standards, open source and peer-to-peer tools and methods for collaborative product development, Computers in Industry 56 (3) (2005) 260–271
[17] HA Akkermans, P. Bogerd, E. Yücesan, LN van Wassenhove, Impact of ERP on supply chain management: exploratory findings from the European Delphi study, European Journal of Operational Research 146 (2003) 284-301.
[18] JA Bateman, On the relationship between ontological constructs and natural language: a socio-semiotic view, International Journal of Human-Computer Studies 43 (5–6) (1995) 929–944.

[19] J. Cai, M. Weyrich, U. Berger, Ontological machining process data modeling for powertrain production in extended companies, Journal of Advanced Manufacturing Systems 4(1) (2005) 69-82.
[20] K. Kumar, Technologies to support Supply Chain Management, ACM Communications 44 58–61.
[21] [21] K. Kumar, J. van Hillegersberg, ERP experience and evolution, Communication from ACM 43 (2000) 23-26.
[22] K. Ramadas, RE Spekman, Chains or fetters: understanding what drives supply chain performance, Interface 30(4) (2000) 3–21.
[23] [23] K. Siau, Y. Tian, Supply chain integration: architecture and enabling technologies, Journal of Computer Information Systems 44 (2004) 67-72.
[24] M. Themistocleous, Z. Irani, RM O'Keefe, ERP and application integration: an exploratory survey, Journal of Business Process Management 7 (2001) 195-204.
[25] M. Themistocleous, Z. Irani, Benchmarking benefits and barriers to application integration, Benchmarking: An International Journal 8 (2001) 317-331.
[26] MP Papazoglou, P. Ribbers, A. Tsalgatidou, Integrated value chains and their implications from a business and technology perspective, Decision Support Systems 29 (2000) 323–342.
[27] N. Guarino, Formal ontology and information systems, in: Proceedings of FOIS'98, Trento, Italy, 6-8 June, IOS Press, Amsterdam, 1998, pp. 3-15.
[28] N. Guarino, Formal Ontology, conceptual analysis and knowledge representation, International Journal of Human-Computer Studies 43 (5–6) (1995) 625–640.
[29] PA Angeles, Dictionary of Philosophy, Harper Perennial, New York, 1981.
[30] P. Buxmann, A. von Ahsen, LM Diaz, K. Wolf, Use and evaluation of Supply Chain Management Software—results of an empirical study in the European automotive industry, Journal of Information Systems 14 (2004) 295–309.
[31] P. Kelle, A. Akbulut, Role of ERP tools in supply chain information sharing, cooperation and cost optimization, International Journal of Production Economics 93-94 (2005) 41-52.
[32] R. Cagliano, F. Caniato, G. Spina, The link between supply chain integration and manufacturing improvement programs, International Journal of Production Operations & Management 26 (2006) 282-299.
[33] R. Cagliano, F. Caniato, G. Spina, Lean, agile and traditional supply: how do they affect manufacturing performance? Journal of Purchasing & Supply Management 10 (4-5) (2004) 151-164.
[34] R. Kishore, R. Sharman, R. Ramesh, Ontology of computing and information systems: I. Foundations, Communications Information Systems Association 14 (2004) 158-183.
[35] R. Patnayakuni, A. Rai, N. Seth, Relational antecedents of information flow integration for supply chain coordination, Journal of Management Information Systems 23 (2006) 13–49.
[36] S. Chopra, P. Meindl, What will drive enterprise software shocks? Supply Chain Management Review 7 (2003) 50–57.
[37] S. Pant, R. Sethi, M. Bhandari, Understanding the electronic supply chain landscape: an implementation framework, International Journal of Information Management 23 (2003) 201–221.
[38] S. Zheng, DC Yen, JM Tarn, A new spectrum of cross-enterprise solutions: integration of supply chain management and enterprise resource planning systems, Journal of Computer Information Systems 41 (2000) 84-93.
[39] S. Zheng, DC Yen, JM Tarn, A new spectrum of cross-enterprise solutions: integration of supply chain management and enterprise resource planning systems, Journal of Computer Information Systems 41 (2000) 84-93.
[40] TC Loh, SCL Koh, M. Simpson, Investigating the value of being an extended company, International Journal of Integrated Manufacturing 19(2006) 49–58.
[41] TH Davenport, JD Brooks, Enterprise systems and supply chains, Journal of Enterprise Information Management 17 (2004) 8–19.
[42] TH Davenport, JG Harris, S. Cantrell, Enterprise systems and ongoing process change, Journal of Business Process Management 10 (2004) 16-26.
[43] TH Davenport, Putting Companies into the Enterprise System, Harvard Business Review 76 (1998) 121-131.
[44] V. Botta-Genoulaz, P.-A. Millet, B. Grabot, A survey on the recent research literature on ERP systems, Computers in Industry 56 (2005) 510-522.
[45] W. Hasselbring, Information systems integration, Communication ACM 43 (2000) 33–38

Accredited "Rank 4"(Sinta 4), DIKTI, No. 36/E/KPT/2019, December 13th 2019.