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Supply chain knowledge management: A linked data-based approach using SKOS

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Abstract
Nowadays, knowledge is a powerful tool in order to obtain benefits within organizations. This is especially true when semantic web technologies are being adapted for the requirements of enterprises. In this regard, the Simple Knowledge Organization System (SKOS) is an area of work developing specifications and standards to support the use of knowledge organization systems. Over recent years, SKOS has become one of the sweet spots in the linked data (LD) ecosystems. In this paper, we propose a linked data-based approach using SKOS, in order to manage the knowledge from supply chains. Additionally, this paper covers how SKOS can be enriched by ontologies and LD to further improve semantic information management. This is due to the fact that the supply chain literature focuses on assets, data, and information elements of exchange between supply chain partners, despite improved integration and collaboration requiring the development of more complex features of know-how and knowledge.

Keywords: knowledge; linked data; management; semantic; SKOS; supply chain.

Administración del conocimiento en cadenas de suministro: Un enfoque basado en Linked Data usando SKOS

Resumen
Hoy en día, el conocimiento es una poderosa herramienta para obtener beneficios en cualquier organización. Especialmente cuando las tecnologías de la Web semántica son adaptadas a los requerimientos de las empresas. En este sentido, el sistema simple de organización de conocimiento (SKOS) es un área de trabajo que ha desarrollado especificaciones y estándares para trabajar con sistemas de organización de conocimiento. Tomando esto en cuenta, en los últimos años SKOS se ha convertido en uno de los puntos clave en el ecosistema de Linked Data (LD). En este artículo, proponemos un enfoque basado en LD usando SKOS, con la finalidad de administrar el conocimiento en las cadenas de suministro. Adicionalmente este artículo cubre como SKOS puede ser enriquecido por ontologías y LD para mejorar la semántica en la administración del conocimiento. Esto se debe a que la literatura de cadenas de suministro se enfoca en los recursos, los datos y la información que se intercambian entre los socios de la cadena de suministro, a pesar del hecho que para mejorar la integración y colaboración entre socios requiere del desarrollo de características complejas de "saber-hacer" y conocimiento.

Palabras clave: administración; cadena de suministro; conocimiento; Linked Data; semántica; SKOS.

1 Introduction

Nowadays, the efficient use of knowledge has been critical to the organization's survival as well as its success in competitive global markets. It has a strong potential to problem solve, make organizational performance enhancements, undertake decision-making, and innovate. There is a growing recognition that supply chain management (SCM) offers significant opportunities for organizations to create strategic advantages Wen and Gu [1]. In this regard, knowledge management (KM) is the process of capturing, developing, sharing, and effectively using organizational knowledge [2]. The term SCM was coined in 1982 by Laseter and Oliver [3]. According to Mentzer, DeWitt, Keebler, Min, Nix, Smith and Zacharia [4], supply chain management (SCM) is "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole". Due to the relevance of KM in organizations, several pieces of research and industry efforts have been focused on the topic in order to improve supply chain knowledge management (SCKM). In the literature, there are seminal research works with different approaches to KM, for instance, Capó-Vicedo, Mula and Capó [5] propose a social network-based model to improve knowledge management in multi-level supply chains formed by small and medium-sized enterprises (SMEs);Shih, Hsu, Zhu and Balasubramanian [6] propose a knowledge management architecture to facilitate knowledge management within a collaborative supply chain; and Raisinghani and Meade [7] explore the linkage between organization performance criteria and the dimensions of agility, e-supply-chain drivers, and knowledge management, among other approaches. Lopez and Eldridge [8] presented a working prototype to promote creation and control in a knowledge supply chain with the objective of diffusing the best practices among supply chain practitioners. In this sense, the adoption of best practices in conjunction with information technologies represents an advantage for organizations.

In addition to the relevance of knowledge management in organizations, collaboration between supply-chain partners is one of the most promising areas of study for academics and practitioners. This is because there are several benefits that can be achieved by companies and supply chains such as, intelligent inventory management, new product development, collaborative product design management, to mention but a few.

According to Andreas Blumauer, since 2014 the Simple Knowledge Organization System (SKOS) has become one of the 'sweet spots' in the linked data ecosystems. This is due to SKOS playing a key role in order to improve semantic information management, especially in terms of its following capabilities, taxonomy and thesaurus management, text mining and entity extraction, and finally knowledge engineering and ontology management. SKOS is an area of work in which there are developing specifications and standards to support the use of knowledge organization systems (KOS), such as thesauri, classification schemes, subject heading systems, and taxonomies within the framework of the Semantic Web.

However, even though many studies have reported theoretical and practical foundations for knowledge management, there has been very little research reported using semantic technologies and SKOS.

In this regard, Linked Data based IT-architectures cover all of SKOS's capabilities, and provide the means for agile data, information, and knowledge management. SKOS can increase the value of organizations data and better use of existing data can be fostered by semantic searches, agile data integration and content personalization. Taking this into consideration, a linked data-based approach in combination with SKOS is feasible for organizing knowledge management in organizations, specifically for supply chain management, due to its ability to coordinate and synchronize interdependent processes, and to integrate information systems and to cope with distributed learning [9].

The aim of this paper is to introduce a linked data based approach-using SKOS in order to improve and facilitate knowledge management between supply chain partners. The importance of using a new approach relies on the benefits of linked data and SKOS. These benefits are: 1) obtaining open data sources of knowledge (linked open data), 2) automatizing data organization and procurement for non-expert organizations, 3) improving organizations' process, 4) improving operational and organizational performance, and 5) improving the decision-making process, to mention but a few. This paper is structured as follows: in section 2, the related works are discussed, in section 3 the linked data-based approach using SKOS for supply chain knowledge management is presented, in section 4 a brief case study is conducted, section 5 discusses future work possibilities in order to talk about this research limitations and implications, and, finally, section 4 concludes with this research's findings.

2 Related works

Recent advances in the field of knowledge management and semantic technologies have increased the significance of knowledge management in organizations using information technologies. Through electronic networks, organizations can achieve integration by tightly coupling processes at the interfaces between each stage of the value chain. According to Williams Jr [10], electronic linkages in the value chains have been fundamentally changing the nature of inter-organizational relationships. Organizations are redesigning their internal structure and their external relationships, creating networks of knowledge to facilitate the communication of data, information, and knowledge, while improving coordination, decision making, and planning. Taking into account these organizational changes, the use of flexible and scalable information technologies is preferred in order to take advantage of the know-how from the supply chains. In this section, each of the most significant papers related to this work will be presented, starting with the exploitation of knowledge sharing across the supply chain.

Wu [11] addressed the problem of coordination among multi-agent systems. The issue of coordination problems in supply chains was presented, and how to design multi-agent systems to improve information and knowledge sharing was highlighted. Becker and Zirpoli [12] carried out research on the theme of knowledge transfer in outsourcing activities. In particular, the focus was on designing an outsourcing strategy to improve knowledge integration. Holtbrügge and Berg [13] carried out a study of the knowledge transfer process in German multinational corporations (MNCs). These three works focused on knowledge sharing and how exploit it. This is due to the fact that one of the most suitable ways to improve processes in organizations is through knowledge exploitation. In this regard, Sivakumar and Roy [14] proposed the concept of knowledge redundancy as a critical factor for supply chain value creation. Knowledge redundancy deals with there being a sufficient knowledge overlap to provide the opportunity to have good communication and, thus, effective operation activities. At the moment that an organization exploits the knowledge, some benefits can be obtained; for instance, Raisinghani and Meade [7] investigated the links between the supply chain, the firm's agility, and knowledge management. Their focus was on the strategic decision making perspective. In this perspective, knowledge comes from every relationship in the supply chain. Hult, Ketchen and Arrfelt [15] stated that knowledge acquisition activities, knowledge distribution activities and shared meaning were related with faster cycle time. For instance, Piramuthu [16] developed a knowledge-based framework for a dynamic re-configuration of supply chains over time.

In García-Cáceres, Perdomo, Ortiz, Beltrán and López's research [17], the authors analyzed the supply and value chains of the Colombian cocoa agribusiness, in order to detect the agents, phases, stages, and factors influencing the planting and harvesting of the product. They also analyzed =the chocolate and confection production process, as well as the final consumption. Within the supply chain stage identification and effects context, Avelar-Sosa, García-Alcaraz, Cedillo-Campos and Adarme-Jaimes's [18] work analyzes the effects of regional infrastructure and the services in supply chain performance in manufacturing companies found in Ciudad Juarez, Chihuahua, Mexico. The results indicate that if regional infrastructure has a good level then there will be a positive impact on logistics services, and as a consequence, on costs. In addition to these works, Espinal and Montoya's research [19] identifies the state of the art and the current use of Information and Communications Technologies (ICT) in the supply chain as well as its application level in Colombian industry. The research does this through analysis of existing studies and, at the end of the review, the authors observed that most of these technologies contribute to cost reduction and improvement of the information flow among the actors in the supply chain.

Other approaches were also seen in the literature, for example, Lau, Ho, Zhao and Chung [20] analyzed a process mining system for supporting knowledge discovery in daily logistics operations. Niemi, Huiskonen and Kärkkäinen [21] pointed out the process of knowledge accumulation. They presented it as an ongoing procedure in which the implementation of organizational processes and inventory techniques takes place gradually. Niemi, Huiskonen, and Karkkainen's aim [22] was to evaluate the adoption of complex supply chain management practices. In order to do this, Niemi et al. used the knowledge maturity model and strategies to accelerate knowledge creation as theoretical frameworks. The purpose of their approach was to intend to provide meaningful knowledge management. Halley, Nollet, Beaulieu, Roy, and Bigras [23] suggested that the management of the relationships present in the supply chain could be useful to share and acquire knowledge, instead of building external business relationships.

Apart from the previous research, Douligeris and Tilipakis [24] carried out a study on the new opportunities provided by the semantic web. They focused their attention on the introduction of web technologies on supply chain management. In particular, the use of ontologies in improving knowledge management applications was described. Taking this into consideration, Huang and Lin [25] addressed the problem of managing knowledge heterogeneity in the context of interoperability among multi-entities in a supply chain. They proposed a solution for sharing knowledge using the semantic web. Their solution was based on a semi-structured knowledge model to describe knowledge, not only in an explicit and sharable way, but knowledge that also had a meaningful format, an agent-based annotation process to determine issues related with the heterogeneity of knowledge documents, and an articulation mechanism to improve the efficiency of interoperability between two heterogeneous ontologies.

The aforementioned research works emphasized the importance of integrating information and knowledge flows within the manufacturing supply chain, and highlighted the importance of handling distributed knowledge. For instance, Craighead, Hult, and Ketchen Jr [26] used an economics perspective to measure the impact of a knowledge development capacity on supply chain performance. They measured the effects of an innovation-cost strategy on the supply chain. They found that knowledge development capacity and intellectual capital efforts are a good complement to other supply chain strategies. However, these works lack the availability of data sources due to the requirements of managing and organizing data in organizations. Additionally, this task it's very complex for small and medium size organizations. Moreover, some of the techniques used for knowledge management were conceived to manage the data, and not to infer knowledge from raw data. Finally, some organizations do not have the right tools to manage knowledge. This is due to the nature of the data; in some domains the same words have different meanings. In this regard, we propose a linked data-based approach for supply chain knowledge management using SKOS.

3. Linked data-based approach for supply chain knowledge management using SKOS

Interest in supply chain management has steadily increased since the 1980s when firms saw the benefits of collaborative relationships within and beyond their own organization. Firms are finding that they can no longer compete effectively while isolated from their suppliers or other entities in the supply chain [27]. The term supply chain management has a variety of different meanings, some related to management processes, others to the structural organization of businesses. Supply chain management itself integrates the management of supply and demand. According to the Council of Supply Chain Management Professionals (2014), it encompasses “the planning and management of all activities involved in sourcing and procurement, conversion and logistics.” Supply chain management also covers coordination and collaboration with channel partners, such as customers, suppliers, distributors, and service providers.

According to Thomas and Griffin [28] historically, there are three fundamental stages of the supply chain, procurement, production, and distribution. These have been managed independently and buffered by large inventories. Increasing competitive pressures and market globalization

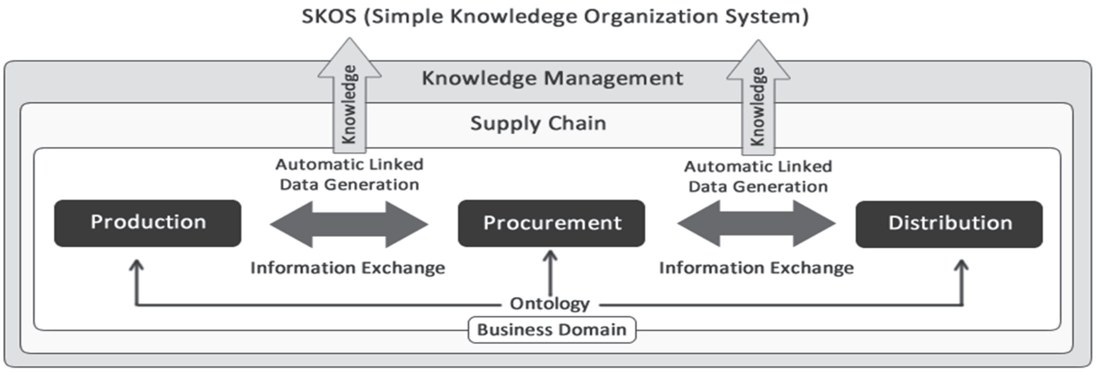

Figure 1. Conceptual schema.
Source: Authors

are forcing firms to develop supply chains that can quickly respond to customer needs. To remain competitive, these firms must reduce operating costs while continuously improving customer service. Taking this into consideration, with recent advances in communications and information technology, especially in semantic Web technologies, organizations have had an opportunity to reduce operating costs by coordinating the planning of these stages. In order to manifest the general idea about this proposal, in Fig. 1 a conceptual schema was depicted.

As can be seen from the conceptual schema, this proposal focuses its efforts on the automatic knowledge generation and management through linked data using SKOS and ontologies. These efforts were focused on technical information flows across the supply chain. This is due to the strong positive relationship that was found between the knowledge management process and the operational and organizational performance. In general terms, as a result of the information exchange across the supply chain among production, procurement, and distribution, Linked Data was produced in an automated way. This was due to domain specific knowledge (business domain) that was inferred from the ontology, and finally passed out to SKOS in order to provide both meaningful information and benefits for organizations. Due to the ontologies' relevance on this scenario, in the next subsection a brief table of highlights is included in order to explain the ontology used for this proposal in the context of a particular business domain.

3.1. Ontology

Originally, the term ontology has its roots in philosophy. An ontology denotes ‘‘the science of what is, of the kinds and structures of objects, properties events, processes, and relations in every area of reality" [29]. Ontologies can be a component of knowledge-based systems, but also provide a "common language" for communication between domain analysts, developers, and users. In our proposal, SKOS can be improved with the use of ontologies. In this sense, a brief comparative analysis was performed on the results of the initial search query for "supply chain" AND "ontology" using online databases which were used for a keyword-based search. We also used the following alternative terms to reflect the actual use of various terms for the key concepts: "supply network", "supply chain management", "knowledge model", "semantic model", and "ontology model". These terms were based on the parameters proposed by Scheuermann and Leukel [30] in their literature review. The literature provides various SCM ontologies for a range of industries and tasks. Table 1 lists the suitable ontologies reported in the literature for this work.

A more detailed discussion about the ontologies presented in Table 1 was found in Scheuermann and Leukel's research [30], which is a review about ontologies for supply chain management. Taking into consideration the results discovered in the literature, IDEONTM and SCOntology are suitable for the purposes of this work. In this sense, these approaches have been used in the design of the software architecture used as a basis for Linked Data generation and knowledge management using SKOS.

IDEONTM is an extensible ontology for designing, integrating, and managing collaborative distributed enterprises, and SCOntology is a formal approach that gives a unified and integrated view of the supply chain. We found that IDEONTM and SCOntology are suitable for the purposes of this work due to the support it gives for processes, activities, resources, deliveries, and return schemas provided for each one.

3.2. SKOS

Using SKOS, concepts can be identified using URIs (strings of characters used to identify the name of a resource). These are labeled with lexical strings in one or more natural languages (for instance, a business domain language), they are assigned notations (lexical codes), documented with various types of note, linked to other concepts and organized into informal hierarchies and association networks, aggregated into concept schemes, grouped into labeled and/or ordered collections, and mapped to concepts in other schemes. All these features allow the integration and management of knowledge in a particular domain, for instance in supply chain management. In Fig. 2 the main elements of the SKOS data model was depicted.

Table 1.
Ontologies for Supply Chain Management

Author(s)	Language	Knowledge Representation Paradigm	Ontology Evaluation	Name	Key Concepts
de Sousa [31]	Thesaurus, UML class diagram	Algebra of sets	Not reported	Not reported	Organizational unit, plan, resource, order, product, activity.
Madni, Lin and, Madni [32]	UML class diagram	Algebra of sets	Application	IDEON™	Enterprise, process, resource, objective, plan, activity.
Pawlaszczyk, Dietrich, Timm, Otto and, Kirn [33]	Frames	F-Logic	Not reported	Not reported	Activity, plan, product, organization, time, event, transfer-object, flow, performance.
Fayez, Rabelo and, Mollaghasemi [34]	OWL	DL	Not reported	Not reported	Functional units, processes, materials, objects, information, information resources.
Matheus, Baclawski, Kokar and, Letkowski [35]	OWL, SWRL	DL	Application	Not reported	Airbases, aircraft, parts, facilities, remote supply depots, event object attribute.
Chandra, and Tumanyan [36]	Algebra, XML Schema	Algebra of sets	Scenario	Not reported	Agent, input, output, environment, objectives, functions, processes, products.
Gonnet, Vegetti, Leone, and Henning [37]	OWL (UML)	DL	Scenario	SCOntology	Organizational unit, process, resource, plans, source, make, deliver, and return.
Grubic, Veza, and Bilic [38]	Frames	F-Logic	Case studies & Scenario	Not reported	Asset, coordination, location, metric, process/activity, buyer, flow, person, supplier, system.
Sakka, Millet, and Botta-Genoulaz [39]	OWL	DL	Scenario	Not reported	Top level, configuration level, and process category level.
Anand, Yang, Van Duin, and Tavasszy [40]	OWL	DL	Informed argument & Case studies	GenCLOn	Stakeholders, objectives, KPI, resources, measures, activity, R&D.
Scheuermann and Hoxha [41]	OWL	DL	Experiment Scenario	Not reported	Logistics actor, Logistics role, logistics service, logistics object, logistics KPI, logistics resource, logistics location.

Source: Authors

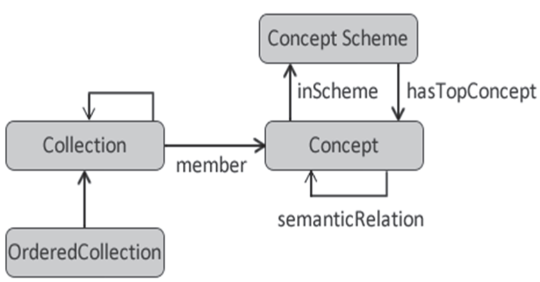

Figure 2. Main elements of the SKOS data model
Source: Authors

The SKOS data model enables the features [42] listed above by defining the elements depicted in Fig. 2. These features are:

- Identifying
- Labeling
- Documenting
- Linking and mapping concepts (even in other schemas)
- Aggregating concepts into concept schemes or collections

Taking into consideration SKOS' features, for the purposes of this research, SKOS has been used to express, in an interoperable way, different types of Knowledge Organization Systems (specifically for a supply chain model)—sets of terms or concepts, whether listed with definitions (glossaries), in hierarchical structures (basic classifications or taxonomies), or characterized by more complex semantic relations (thesauri, subject heading lists, or other advanced structures). In the next section an overview of the proposed architecture was described.

3.3. Architecture

The knowledge management focuses on the supply side; in contrast, knowledge creation is located on the demand side. Johnson and Whang [43] proposed the term e-collaboration for systems that facilitate the Internet-based coordination of decisions for all members of the supply chain. Taking this into consideration, our approach is focused on the demand side, through an Internet-based coordination of knowledge. The use of the proposed technologies was intended to generate raw knowledge in an automated way.

Our architecture has a layered design in order to organize its components. This layered design allows scalability and easy maintenance because its tasks and responsibilities are distributed.

The general architecture is shown in Fig. 3. Each component has a function explained as follows:

Data layer: This layer stores supply chain management data; additionally, it contains all the configuration tables allowing the operation of the modules and services offered by our proposal. This layer comprises two key components, the business data and the ontology; these components are the core of the knowledge of the entire software architecture.

Data Management layer: This layer communicates with the Data layer in order to obtain business data and provide their representation through the ontology mapper in order to converting it to RDF.

Linked Data Generator: All data retrieved from Data layer through the Data Management layer is parsed in RFD in order to publish a local dataset of Linked Data.

Integration Layer [API]: This allows the creation of new educational applications through a series of public interfaces, which provide easy access to a set of services provided by the architecture. Service compositions are presented and defined in this layer. Specifically, the Data Manager component is responsible for providing interaction through raw data and the user interface.

Presentation Layer: In this layer, the architecture determines the best way to display the business data by using XHTML when HTML5 is not supported. The Presentation Layer does not know what events are taking place inside inferior layers and how the services are provided; it only uses them to show the end-user interface. It is worthwhile to mention that, for the purposes of this work, a graphic user interface was not used. However, the software architecture has been designed in order to support a Web-based user interface.

In additionally to the layer descriptions, there are a few main components that also need to be described:

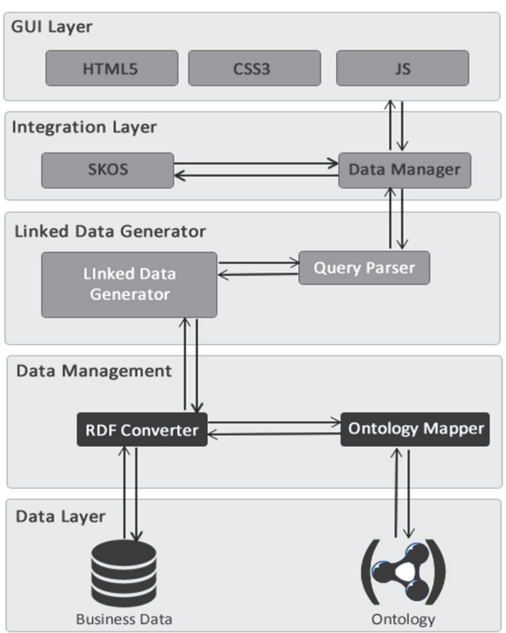

Figure 3. Architecture
Source: Authors

Business Data: As part of the Data Layer, in this repository (actually a database of structured or non-structured data), this component is responsible for the storage of the raw data from information exchanges across the supply chain.

Ontology: This component is responsible for managing the data representation and structure of the supply chain knowledge. In this component the IDEONTM and SCOntolgy has been used.

RDFConverter: In order to generate a Linked Data dataset, this component converted raw data mapped through the Ontology Mapper component to RDF (Resource Description Framework).

Linked Data Generator: This component is responsible for Linked Data Generation. In this component a local dataset of Linked Data is managed through the Query Parser component. At the end of the process, a set of structured RDF data is created and managed by a Linked Data engine.

Query Parser: This was used in order to translate a user-defined query into a natural language (a business domain specific language). This component translates the original query into SPARQL in order to retrieve the desired data, in this case the supply chain knowledge.

SKOS: In thesauri and other structured Knowledge Organizations Systems, concepts can be classified into semantically meaningful bundles. For example, arrays are used to group specializations of a concept that share a common feature: the concept "cars" might be primarily grouped by a feature "cars by engine" (''V8'', 'V6'', among others), and a second group of "cars by function" ("transport", "family", "sport", among others). Taking this as starting point, the SKOS component is responsible for the classification and management of the vocabulary used by the Data Manager component to retrieve processed and managed knowledge from the presentation layer.

Data Management: This component is responsible for managing the petitions performed by the GUI Layer, specifically the user request for data and knowledge.

It is worthwhile mentioning that Carrer-Neto, Hernández-Alcaraz; Valencia-García, and García-Sánchez; [44] and Ruiz-Martínez, Valencia-García, Martínez-Béjar, and Hoffmann's work [45] present the use of a top level ontology based framework to populate biomedical ontologies from texts and a social knowledge-based recommender system represent. These can be used to improve our software architecture in future work with the use of their techniques to extract knowledge from texts as a data source, and recommend knowledge resources through social network interactions among supply chain customers.

3.4. Data acquisition

This knowledge is related to the following aspects, which should be improved in supply chain management:

- **Demand:** Demand management is an essential element in supply chain management. It focuses companies and their partners on meeting the needs of customers, rather than the production process.
- **Integration:** Integrating supply chain processes helps each member to reduce their inventory costs.
- **Collaboration:** Collaboration in the supply chain

strengthens relationships between members by improving teamwork and helping all members increase their business.

- **Communication:** Effective communication helps the entire supply chain improve the efficiency and productivity of its operations by enabling all members to share the same demand and operational information.

For this research, the information required was obtained from broker web pages, ERPs, CRMs, and intranet applications, to mention but a few. In Fig. 4 a conceptual schema for data acquisition was depicted.

4. Case study: Detecting processing issues in a milk supply chain

The purpose of this case study was to put our knowledge management approach into practice. This case study should encourage supply chain practitioners and managers to use the experience and learning of this application to be able to develop and refine the application of knowledge management by using semantic web technologies.

Let us suppose that a supply chain in the field of milk production in the United States requires information (knowledge) about the delay that occurs between the procurement stage and distribution stage. This will be caused, in some scenarios, as a result of the product expiring because of the transit time, which represents losses and extra fees for the organization. The eight stages in the milk supply chain are:

a) Production of feed for cows: The dairy supply chain begins with growing crops such as corn, alfalfa hay, and soybeans to feed dairy cows.
b) Milk production: Dairy cows are housed, fed, and milked on dairy farms across the country.

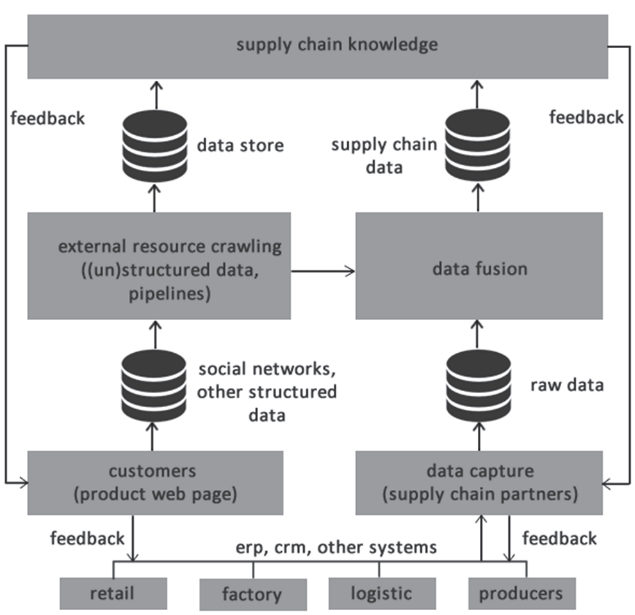

Figure 4. Conceptual schema for data acquisition and feedback
Source: Authors

c) Milk transportation: Milk is transported from the farm to the processing company in insulated tanker trucks. The average truck carries 5800 gallons of milk and travels approximately 500 miles on a round trip.
d) Processing: There are more than 1,000 U.S. processing plants that turn milk into cheese, yogurt, ice cream, powdered milk, and other products.
e) Packaging: This is typically done by the dairy processor. Both paperboard and plastic containers are designed to keep dairy products fresh, clean and wholesome.
f) Distribution: Distribution companies deliver dairy products from the processor to retailers, schools, and other outlets in refrigerated trucks.
g) Retail: Milk and dairy products are available at 178,000 retail outlets of all shapes and sizes.
h) Consumer: Milk and milk products deliver nine essential nutrients to consumers.

These stages should be grouped into the three main categories previously mentioned in the conceptual schema contained in section 3. The groups are: 1) production (production of feed for cows and milk production), 2) procurement (processing and packaging), and 3) distribution (distribution and retail).

In order to understand the full supply chain cycle, Fig. 5 shows the value chain of milk production.

Following the previously mentioned scenario, knowledge acquisition through the SKOS approach retrieved the following information:

- Production of feed for cows either increases or decreases the milk production.
- Production of feed for cows affects the quality of the produced milk.
- Due to the lack of communication between the processing and packaging phases, the milk spends a lot of time in the packaging process. The packaging unit does not accurately know way which milk product is to be released first. This is due to of the variation in milk quality. Some derivate products cannot be produced within the same processing time.

Figure 5. Milk supply chain
Source: Authors

In general terms, the lack of communication affects the operation of all stages in the milk supply chain. The degree of implication is directly proportional to the time needed to take countermeasures to change the production process in early stages. In order to take advantage of the knowledge produced in the supply chain, a more detailed analysis about production implications in the retail stage (sales, profits, among others) is required. In this sense, analysts can use data mining and big data tools. In future work, an analytic module must be added to our architecture in order to complete the cycle of knowledge management and data exploitation.

6. Conclusions and future directions

The primary contribution of this paper to the literature is to show how supply chain knowledge management can be improved with semantic web technologies. Fast evolving Web-based and semantic technologies provide, not only platforms for the development of powerful applications, but also opportunities to alleviate linguistic barriers to supply chain data across partners. In this study, a linked data-based approach using SKOS for supply chain knowledge management was presented. The findings showed how SKOS can be enriched using ontologies. Additionally, with automatic generation of linked data from supply chains, small and medium organizations without expertise, infrastructure, or resources to organize information can benefit from knowledge management. In this regard, knowledge sharing and reuse are important factors that affect the performance of supply chains. Due to this, a novel approach that combines the generation of Linked Data and ontology enriched SKOS was presented in this work, which can improve supply chain knowledge management.

Thinking about possible future directions, this research potentially has two key limitations or opportunities. First, the proposal contained in this case study addressed one particular business domain. In this regard, we need to prove this approach can be effectively used in other domains, which has to do with the Linked Data generation mechanism and their ontology-based knowledge management and acquisition. Second, there is a need to know and control the full scenario of the supply chain management. What will happen if one of the three stages (production, procurement, and distribution) it is out of scope, and the information exchange is not accessible for analysis and interaction? These two key limitations represent an opportunity to improve this proposal. Consequently, we plan to elaborate on this research in order to fulfill this gap.

Acknowledgments

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