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ONTOLOGY-BASED SUPPLY CHAIN PROCESS CONFIGURATION

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Abstract: *The complexity of the inter-organizational collaboration processes is one of the main concerns of the supply chain management. SCOR (Supply Chain Operation References) process reference model addresses those concerns by providing a process implementation roadmap, consisting of workflows, best practices, systems and performance metrics. In this paper, we use SCOR framework to develop knowledge-based solution for rapid supply chain process configuration. We describe the semantic application for supply chain process configuration, algorithms for process selection and generation of a SCOR thread diagram, describe its indented use and argue about its potential benefits.*

Keywords*: Supply Chain Management, Ontology, Semantic Technologies, Business Process Management*

1. INTRODUCTION

Supply chain is a complex, dynamic networked environment which consists of a number of different actors, assets, goals, competencies, functions and roles. The interest in creating a new discipline of supply chain management was developed in the early ‘60s with the initial motivation to investigate the increase in demand fluctuation (known as “bullwhip effect”) which occurred in deeper levels of the manufacturing supply tree [1]. With the development of processing power in the ’90s, it became possible to quantify and manage this effect.

However, despite the technology development, it appears that Supply Chain Management (SCM) paradigm is adopted unexpectedly slow. Some of the main reasons are: lack of feasible technology support; inconsistency of supply chain and individual enterprises’ business strategy; and difficulties in change management, from internal and external perspective. We relate these issues to the three pillars of supply chain management: objectives, IT systems and business functions.

Any inter-organizational collaborative form is characterized by a singular objective, expressing the common interest of involved parties to collaborate. Where supply chain has a singular objective, its actors are individually characterized by different objectives, not necessarily compatible with the overall one. This misalignment may have a negative impact on the capability of an enterprise to act upon its business strategy, when the enterprise is involved in more than one supply chain.

Advances in ICT have great impact on social, economic and technical aspects of doing business. However, rapid progress also resulted in increasing complexity and heterogeneity of systems, having a negative effect on realization of one of the fundamental requirements for ICT applications - enterprise integration capability and interoperability [2].

Besides different integration challenges imposed by inter-organizational collaboration requirements, the lack of internal, horizontal integration still remains the issue in many enterprises. Weaknesses of isolated business functions become critical when enterprise-wide information systems, such as ERP system, are implemented. This is evident from the proportion of change management uptake in ERP implementation, in overall, sometimes as high as 70% [3]. Using standard processes included in an ERP is considered as valuable implementation tool. These processes are often seen as “best practices” - collective, organized and empirically validated knowledge, enabling increase in company performance, and providing a powerful tool for change management [4].

Many researches are trying to show that the effective solution for all three classes of SCM problems is related to the use of knowledge-based technologies. Cross-functional, horizontal enterprise integration often relies on the existing body-of-knowledge, commonly represented by standards and reference models. Mainstream research of interoperability of applications focuses on federation, where mapping is done at the semantic level [4], with the use of interfaces, reference models or ontologies. Finally, the coherence between local and global objectives is enabled by ensuring the consistency of system-wide decision making, a concept of enterprise integration in the frame of enterprise modelling [5]. For the reasons above, SCM researchers today are shifting towards the exploration of semantic web technologies, where they are based on the use of so-called Ontologies.

Ontology is considered as the logic theory for explicit, full or partial description of conceptualization [6]. Its use is expected to facilitate the definition of perceptual and formal meaning of information. While the representation of common perceptions on specified domain enables efficient communication, avoiding unwanted interpretations and use of terms, the definition of formal meaning can enable reasoning of implicit facts and improve systems interoperability [7], in general. OWL (OWL 2 Web Ontology Language) is a family of knowledge representation languages, which provides the syntax for authoring and exchanging the ontologies among relevant tools and applications.

While semantic tools are candidates for technical aspect of the SCM solution, the common denominator problem of above issues is the notion of business process. In this paper, we propose ontology-based solution for the problem of supply chain process configuration. This solution is based on the Supply Chain Operation Reference (SCOR) model.

In order to gain real benefits from Supply Chain Management, information systems must span full horizontal organization of enterprises and beyond – its customers and suppliers. For dealing with the complexity of such environment, reference models played an important role. Supply Chain Operations Reference (SCOR) [8] is a standard approach for analysis, design and implementation of changes required for the improvement of five core, integrated processes in supply chains: plan, source, make, deliver and return. SCOR is implemented from the perspective of an individual enterprise and resembles all interactions and transactions of physical resources in radius of two levels downstream and upstream in its supply chain.

For the ontology-based supply chain process configuration, we use our ontological framework [9] which is based on SCOR-KOS OWL model – OWL representation of the implicit SCOR model. Its competency is validated by using following questions: 1. Which process elements constitute one SCOR process and in which order? 2. What are the input and output resources for the selected process element? 3. What are the metrics and best practices for the selected process element? 4. Which systems can facilitate the improvement of the selected process element and/or process category?

The SCOR-KOS OWL model is mapped to what we call a problem ontology – a formal representation of the domain problem which is used as a meta-model by specific semantic application. In this case, the role of problem ontology is played by SCOR-CFG OWL model, and it is exploited by the application for supply chain process configuration.

2. APPLICATION OF THE SCOR-KOS OWL MODEL FOR SUPPLY CHAIN PROCESS CONFIGURATION

In this section, we demonstrate the use of the SCOR-KOS OWL model for supply chain process configuration, namely, the inference and presentation of a SCOR thread diagram – configuration of source, make and deliver processes, on basis of asserted product topology, participants and production strategies for each component.

For this purpose, a semantic web application is developed, which relies on the application ontology – SCOR-CFG OWL model. Use of the application involves assertion of the product configuration, namely principal product topology and manufacturing strategies for each of the components and invocation of the algorithm for rendering SCOR thread diagram. Different process patterns (and roles) are applied in each of the three possible manufacturing strategies: made-to-stock, made-to-order or engineered-to-order. The approach is demonstrated on a case of production of residential evaporative cooler product, which is made to stock. Cooler is assembled from 39 components, supplied by 10 vendors, including fan, pump, nozzles, water inlets and feeds, chamber and reservoir, aluminium frame, safety mesh, louvers, casters, nuts, bolts, etc.

First, product information is acquired by using software application and corresponding meta-model for product acquisition in inter-organizational networks [10]. Then, product configuration is asserted in the SCOR-CFG OWL model. This model consists of following concepts: SC_project, SC_product, SC_production_type, SC_process (with child concepts, corresponding to different process types) and SC_participant. Relations between concepts are established by following properties:

```
hasPrincipalProduct(SC_project, SC_product)
isComponentOf(SC_product, SC_product)
employsStrategy(SC_product,
SC_production_type)
employsProcess(SC_production_type,
SC_process)
owns(SC_participant, SC_project)
preceeds(SC_process, SC_process)
produces(SC_participant, SC_product)
```

Initially, the SCOR-CFG OWL model is asserted with instances of production strategies (SC_production_type object) and processes (SC_process object). Properties employsStrategy and employsProcess are defined as subproperties of the transitive employs. These relations enable the inference of make and delivery processes involved in manufacturing of the component of specific strategy.

When product configuration is saved, new statements are asserted in the SCOR-CFG OWL model. The generation of a SCOR thread diagram is done by selecting (and rendering) participants of supply chain project, its products (components) and, finally, processes, in exact order. Participants of selected supply chain project are inferred by using a SPARQL query, represented by following DL query:

```
(produces some
(isComponentOf some
(isPrincipalProductOf value
<selected_project>)))
or
(produces some
(isPrincipalProductOf value
<selected_project>))
```

In order to enable inference of participants in the infinite number of levels of supply and demand from the main participant, `isComponentOf` property is defined as transitive.

Next, for each participant, its components of a principal product are inferred by query:

```
producedBy value <participant>
and (
isComponentOf some
(isPrincipalProductOf value
<selected_project>)
or
(isPrincipalProductOf value
<selected_project>))
```

Employed processes are inferred on basis of asserted `preceeds` relations, which determine possible transitions of SCOR process categories, within participants (Sx-My-Dy) or between them (D1-S1, D2-S2, D3-S3). The latter, cross-participant asserted transitions are valuable for the inference of source processes, on basis of principal product topology. For the selected product, employed processes are inferred by query:

```
SC_process and
(((preceededBy some
(employedBy some
(isComponentOf value <product>)))
and SC_source_process)
or
(employedBy value <product>))
```

Figure 1. shows the generated SCOR thread diagram. It is generated by application script, on basis of data collected from OWL file by SPARQL queries, represented with DL queries above.

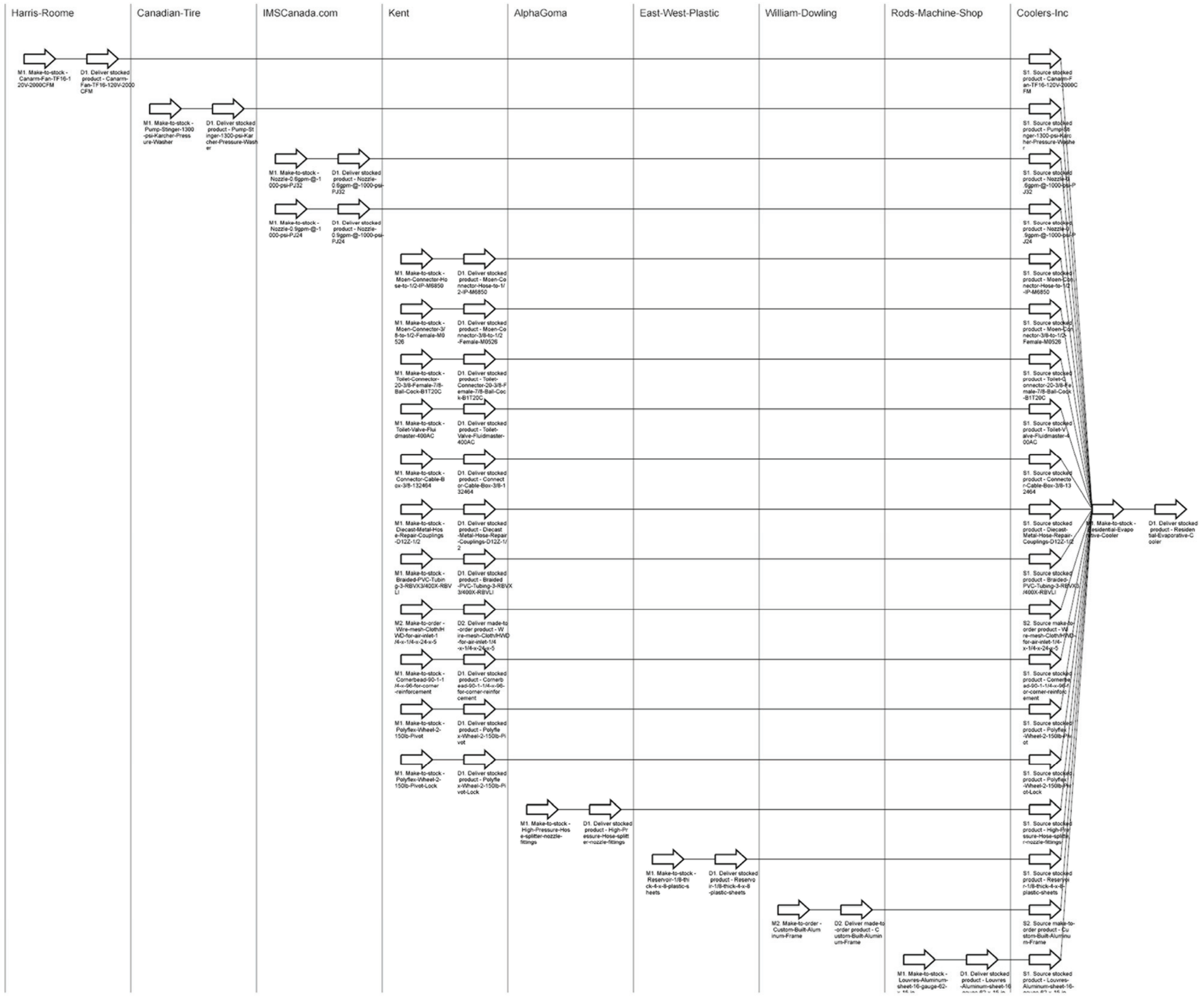

Figure 1. Generated SCOR thread diagram (partial)

The SCOR thread diagram is only a conceptual map of supply chain, built on basis of rules, asserted in SCOR-CFG OWL, prescribed by the SCOR framework. It enables the visual representation of high-level processes (process categories), roles and basic flows of information and resources between supply chain participants. Some of the features of the presented application are: development of complex thread diagrams, generation of process models and workflows and generation of implementation roadmap. These are elaborated below.

Example above shows only interactions and collaborations between 2 levels of a supply chain: principal customer and its first-tier suppliers. The number of visualized levels depends on the submitted product topology: if detailed product topology is entered, full supply chain would be represented by the resulting SCOR thread diagram, with the number of tiers corresponding to the depth of a principal product topology. Horizontal organization of individual supply chain actors can be represented in more detail, by inferring additional participants for different manufacturing strategies: warehouses (D, S), plants (M) and headquarters (P).

A SCOR thread diagram is not a process map. In fact, it is just a representation of supply chain configuration.

However, full process model can be generated by adding new rules for configuration of the SCOR PLAN activities and by exploiting alignment relations between the SCOR-KOS and SCOR-CFG OWL models.

Alignment relations between the SCOR-KOS and SCOR-CFG OWL models also provide opportunities for the generation of a detailed implementation roadmap, consisting of proposed best practices, relevant systems (or their modules, capabilities, intended use, etc.) for their execution, resource tracking (SCOR Inputs and Outputs) and environment for measuring the performance of a supply chain, by using the SCOR metrics.

3. CONCLUSIONS

The compliance to industry (community) standards is a competitive advantage of a single enterprise, especially if it depends on multiple supply chains. It is beneficial for dealing with horizontal integration, interoperability of systems and flexible governance, as critical success factors for collaborative enterprises. However, these benefits are realistic only if the compliance is managed in a manner which enables a seamless acquisition, effective use and re-use and continuous evolution of knowledge, which represent the standards themselves.

In this paper, we addressed the issues of supply chains configuration and, partially coordination. Understanding and using the SCOR reference model is a competitive advantage of a single SME, as it provides structured collaboration capability. Still, like most of the domain reference models, SCOR is a complex and dynamic set of concepts and, hence, very hard to implement and maintain, especially at bottom tiers of supply chains.

The application based on the SCOR-CFG and SCOR-KOS OWL models is expected to demonstrate the positive impact of using knowledge-based systems for SCOR implementation, in segments of supply chain configuration (by enabling generation of SCOR thread diagrams), coordination (by enabling generation of XPDL process models) and continuous improvement (by enabling generation of process implementation roadmaps). The approach relies on and builds upon widely accepted industry practice, represented in its native format. The native representation is expected to gain attention and understanding of SCM expert's community and, hence, facilitate the transition towards using more sophisticated, knowledge-based tools in the domain. Its mapping and alignment to higher-level ontologies will enable a structured support in other SCM processes, such as partners' selection, performance tracking, exceptions handling, etc. Also, it is expected to contribute to further development and/or refinement of the SCOR reference model.

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