

## Information Logistics for Supply Chain Management within Process Industry Environments

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### Abstract

This contribution proposes the design of an ontology that provides the foundations for the specification of information logistics processes in extended supply chains associated to process industries. The proposed ontology includes concepts and relationships that are necessary to formally describe, measure and evaluate a supply chain (SC), thus simplifying the visualization and analysis of networks. A SC ontology is a first step towards achieving a standard description of SC design and management processes.

**Keywords:** Supply Chain Management, Ontologies, SCOR Model

### 1. Introduction

Nowadays, process industries are usually involved in “extended” supply chains (ESCs), therefore they are forced to leave aside the traditional supply chain (SC) company-centric view (Shah, 2004). There is a real need to track and trace product-related information in extended multi-company SCs, either for management or optimization purposes or just for the observance of products liability requirements. The ESC context emphasizes the importance of information logistics (IL) as a key issue for integration. IL processes make accessible to the business management, **task-specific and relevant information** coming from production, management and business processes as well as from external sources (e.g. suppliers’ and customers’ data). The role of IL processes is to interlink business process management cycles and to mainly support the monitoring and communication activities in a SC. Thus, the supply chain management (SCM) poses not only the problem of the efficient administration of material inventories and flows but also the challenge of the efficient storage and flow of the associated information.

The Supply Chain Council (Stewart, 1997) presented a general framework for the SCM, named SCOR (“Supply Chain Operations Reference Model”). It is based on the consideration that all supply chain tasks and activities can be assigned to five fundamental processes - *plan, source, make, deliver and return* – and thus simplifies the visualization and analysis of networks. Therefore, SCOR is a good starting point for the communication among SC stakeholders. However, it has some limitations and it is necessary to extend it in order to obtain a system of consistent concepts that could be used by all the actors and components of an ESC in a process industry environment.

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In order to tackle the consistency problem, this contribution proposes the use of the ontology technology, which is discussed in the next section. The proposed ontology, called *SCOntology*, provides the foundations for the specification of information logistics processes in ESCs associated to process industries. It is introduced in Section 3, where the concepts and relationships that are necessary to describe, measure and evaluate a SC are discussed.

## 2. Towards a Supply Chain Ontology

Even though many ontology definitions exist, the classical one was proposed by Gruber (1993): “an ontology is a *formal, explicit* specification of a *shared conceptualization*”. A *conceptualization* refers to an abstract model of some phenomenon in the world, which identifies the relevant concepts of that phenomenon. *Explicit* means that the type of concepts used and the constraints on their use are explicitly defined. *Formal* refers to the fact that the ontology should be machine-understandable. *Shared* reflects the notion that an ontology captures consensual knowledge; so, it is not restricted to some individual, but accepted by a group. Therefore, the construction of an ontology for SCM would provide a framework for sharing a precise meaning of information exchanged during the communication among the many stakeholders involved in the SC.

Although many methodologies have been proposed to build ontologies, each having different principles, design criteria and development stages, the approach of Grüniger and Fox (1995) has been selected for the development of the *SCOntology*. According to this approach a set of natural language questions, called *competency questions*, must be defined to determine the ontology scope. These questions and their answers are employed in the following step of the methodology, called *conceptualization*, which consists in extracting the ontology main concepts and their properties as well as relationships and axioms.

IL processes have as premises to access the right information, with the right content and quality, at the right time and at the required place. But which is the right information, the right content and quality for it, as well as the right time and place to access it? In order to define the scope of *SCOntology*, the previous generic competency questions are reformulated as follows: i) which is the required information for each supply chain process?; ii) which is the structure and content of each piece of information?; iii) which is the place to access it?; iv) which are the processes that provide it?; v) which are the processes that consume it?; vi) when is each information piece supplied?; vii) when is it consumed?, etc. Having posed and answered these questions, the conceptualization stage will help to organize and structure the acquired knowledge using a representation language that must be independent of both the implementation language and environment. In this contribution, the well-known UML language will be employed for conceptualizing the *SCOntology*.

## 3. Defining the Conceptual Model

The relevant concepts of *SCOntology* that arise when posing and answering competency questions are directly linked to the information associated to the ESC and the processes using it. They can be summarized as follows: (i) Information resources,

defining the information and its structure; (ii) SC Processes, acting as information suppliers and clients; (iii) Locations, where processes are performed and the required information is needed, (iv) Relationships among processes and information resources, such as provider, consumer; (v) Relationships among processes, which allow tracing the information flow associated with particular workflows.

A good starting point to represent a framework able to answer competency questions is to consider an enterprise model. Though there are several models available, Coordinates (Mannarino, 2001) has been chosen because it allows representing the process and product views in an integrated fashion. The main concepts are shown in Fig. 1. According to this model, a *Process* is employed to represent a set of activities in terms of a set of resources that participate in different ways in order to achieve the process' goals. As only certain aspects or characteristics of a *Resource* may be of interest to a given process, a particular perspective of the *Resource* (*ResourcePerspective*) is actually viewed by such *Process*. This fact is modelled by means of the *Use Mode* relationship that reflects the role that the *Process* plays in relation to the *Resource Perspective*. The following roles have been considered in this contribution: *creates/eliminates* (non-renewable resources), *produces/consumes* (renewable resources), *modifies, uses, and employs* (exclusive usage). The incorporation of these role types extends the SCOR original approach, which only considers *input* and *output* roles.

As can be inferred from the previous paragraphs, processes relate among themselves indirectly by means of the resources they operate on. However, two processes can be directly linked through explicit temporal relationships. Furthermore, a *Process* can be described at different abstraction levels, according to the complexity of the activity that is being modelled. Hence, a process can be decomposed into *subprocesses*. Other concepts that take part in the model are: (i) the *Organisational Unit* one and (ii) the specialization of the *Resource* concept into *Material* and *Information Resources*.

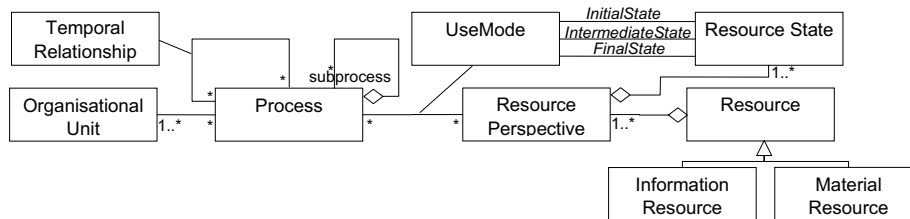


Figure 1. Supply Chain Conceptual Model Elements

This basic conceptual model is extended with the concepts introduced in the SCOR framework, which includes three levels of process detail. At *Level One* (see Fig. 2), SCM is defined in terms of the following integrated core processes: *Plan, Source, Make, Deliver, and Return*, spanning from the suppliers' supplier to the customers' customer, and all aligned with each company's operational strategy, work, material, and information flows (Bolstorff and Rosenbaum, 2003). These processes, with the exception of *Plan*, are considered as Execution type of processes (*Execute*); thus, they are the ones that represent raw materials acquisition (*Source*), transformation (*Make*) and product distribution to customers (*Deliver*). *Return* processes are associated with receiving any returned products, having two perspectives built into them: *Delivery Return-* returns from customers, and *Source Return-* returns to suppliers. It can be seen

that *Plan* processes cover all activities for the preparation of future material flows; thus they perform the *Planning* of the SC and the *Execution* processes. In addition, SCOR includes a series of *Enable* elements for each of these processes. An *Enable* process is a one that prepares, maintains or manages information or relationships on which planning and execution processes rely.

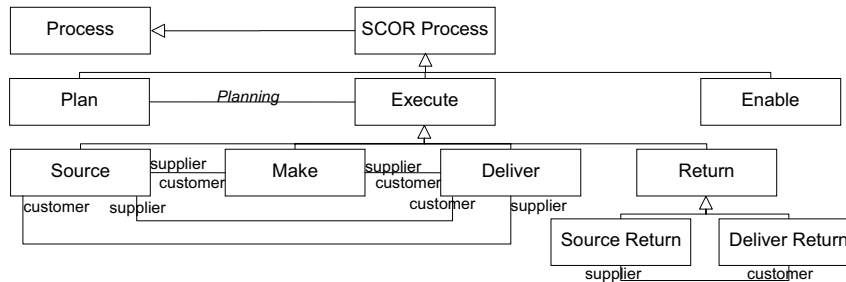


Figure 2. Supply Chain: Level I Model

The five basic elements are further divided into process categories at the next level, called *Level Two* or *configuration level*. It defines the configuration of planning and execution processes using standard categories, like *make-to-stock*, *make-to-order*, and *engineer-to-order*, employed by companies to fulfil customer orders. The configuration is defined by the specification of which processes are used to move materials from location (organizational unit) to location. Thus, at *Level Two*, the five *Level One* process categories (*Plan*, *Source*, *Make*, *Deliver*, and *Return*) are decomposed into thirteen supply chain *execute* process types and five *plan* process types (*P1: Plan the whole supply chain; P2: Plan Source; P3: Plan Make; P4: Plan Deliver; P5: Plan Return*). Furthermore, at this second level, *Enable* is also extended into five processes (*EP: Enable Plan; ES: Enable Source; EM: Enable Make; ED: Enable Deliver; ER: Enable Return*), one for each basic process. This decomposition is shown in Fig. 3, including the aggregation association over the *SCOR process* class, which specialises the process-subprocess link introduced in Fig. 1.

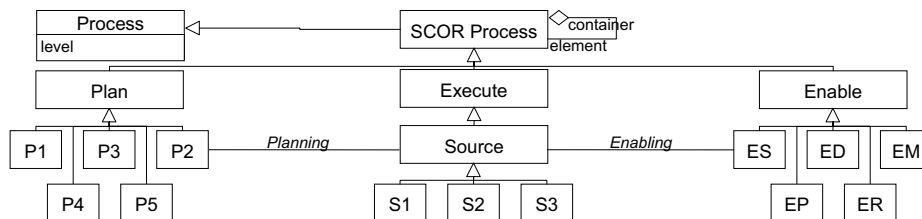


Figure 3. Supply Chain: A Partial View of the Level II Model

Fig. 3 shows the specialisation of *Plan* and *Source* processes. The *Source Level Two* process types (*S1 – Source stocked product, S2 – Source make-to-order product, S3 – Source engineer-to-order product*) attempt to characterize how a company purchases raw materials and finished goods. A level two *Source* process is guided by the planning made by a *P2* process, therefore such *P2* process has to be performed before the execution of the corresponding *Source* process. This temporal relationship is refined by the *Planning* link. The specialization of the *Make*, *Deliver* and *Return* processes was done in a similar fashion, though it is not shown due to lack of space.

Fig. 4 illustrates a partial view of the P1 and P2 processes and their relationships with the associated information resources. In particular, P2 is the process of comparing *total material requirements* (a *Supply Chain Plan Information Resource*) with the *constrained forecast* (another *Information Resource*) created by the P1 process and generating a material requirements resource plan (*Sourcing Plans Information Resource*) to satisfy landed cost and inventory goals by commodity type. This translates into a material release schedule that lets the buyer know the amount of product that must be purchased based on current orders, inventory and further requirements.

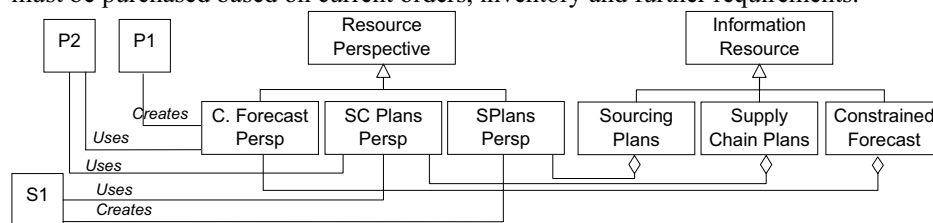


Figure 4. A Partial View of Relevant Information to Perform some Level II Activities

Level Three defines the business processes used to transact sales, purchase and work orders, return authorizations, replenishment orders, and forecasts. Fig. 5 shows a new class, *Process Element*, that represents those processes. A set of *Process Elements* defines a *level two* SCOR process. In the figure, it is possible to see the definition of the S1, and S3 particular ones. At this level, the SCOR model defines work and information flows. Thus, the workflow is specified by temporal relationships. As can be seen in Fig. 5, this link type is represented by *customer-supplier* relationships that define the roles of the associated *Processes*; and the information flow is specified by the set of data that are inputs and outputs of the *Process Elements*. As it was mentioned before, this is included in the proposed ontology by the *Use Mode* relationship, that allows specifying the semantic of a process in relation to a related information resource.

The proposed *SCOntology* was implemented by adopting the OWL ontology language (<http://www.w3.org/TR/owl-features/>) and the Protégé 2000 ontology editor (<http://protege.stanford.edu/>). In order to test *SCOntology*, a refinery industry supply chain process (Julka et al., 2002) has been modeled. Figure 6 shows a partial view of the three SCOR representation levels for the crude procurement process treated in this work.

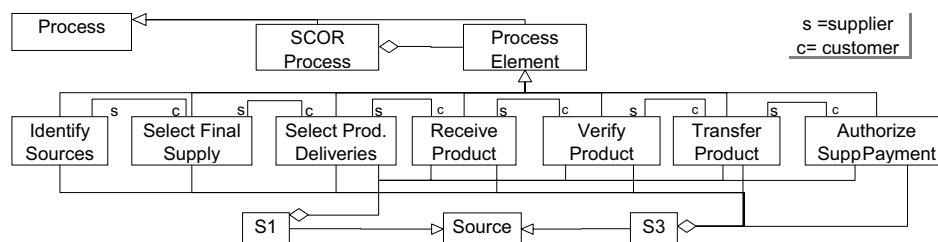


Figure 5. Supply Chain: A Partial View of the Level III Model

#### 4. Conclusions and future work

The SCOR model is a business process reference model that provides a standard description of SC planning and operational activities. Thus, these tasks could be

unambiguously described and communicated among supply-chain partners, providing the basis for SC improvement. However, in its current version, the SCOR model provides partial and very abstract answers to the competency questions that could be formulated in real situations. One of its main drawbacks is the weak representation that information and data have, as well as the lousy modelling of their usage by means of the actual SC processes. Moreover, the sources of most information flows are *Enable* type of processes; but the SCOR model does not explicitly specify which are those processes and which information is employed in such data creation. The *SCOntology* presented in this contribution formalizes and extends the SCOR model in order to overcome some of these limitations. Future work will involve specifying the information flows participating at levels III and IV and testing the model with other case studies.

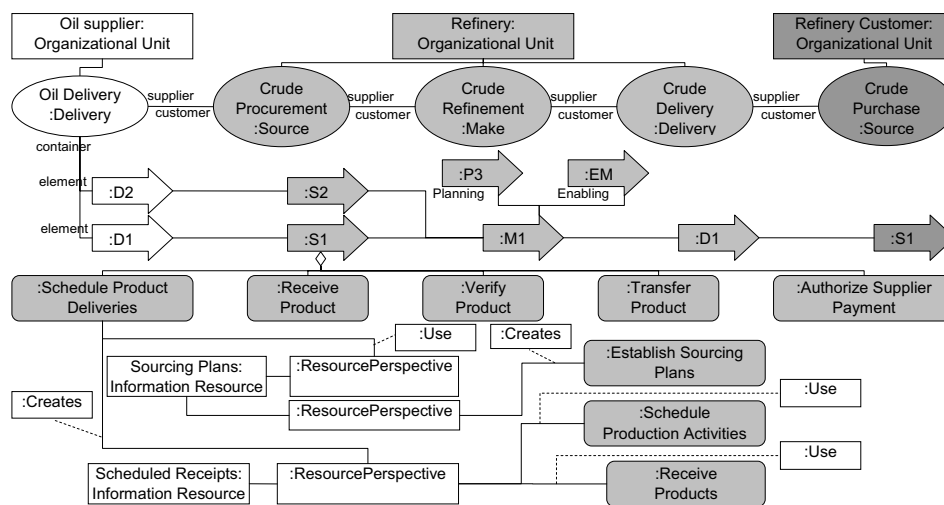


Figure 6. Case Study: A partial view of a Refinery Supply Chain model.

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