17th European Symposium on Computer Aided Process Engineering – ESCAPE17
V. Plesu and P.S. Agachi (Editors)

Industrial Supply Chains: Performance Measures, Metrics and Benchmarks

Alicia C. Böhm,[a] Horacio P. Leone,[a] Gabriela P. Henning[b]

[a]*Instituto de Desarrollo y Diseño (Universidad Tecnológica Nacional – Consejo Nacional de Investigaciones Científicas y Técnicas), Avellaneda 3657, Santa Fe S3002GJC, Argentina. {abohm, hleone}@ceride.gov.ar*
[b]*Instituto de Desarrollo Tecnológico para la Industria Química (Universidad Nacional del Litoral–Consejo Nacional de Investigaciones Científicas y Técnicas), Güemes 3450, Santa Fe S3000GLN, Argentina. ghenning@intec.unl.edu.ar*

Abstract

Industrial organizations are moving toward more integrated supply chains (SCs) to remain competitive. To be effectively designed and managed, these SCs need to be measured and evaluated in a consistent way. The formal definition of different metrics, benchmarks and performance related concepts will facilitate the measurement process and enable the effective communication among the SC stakeholders. For this reason, it is important to acquire a common and unified understanding of the SC associated performance, process and structure concepts. With this intention an extension of *SCOntology* [1] is proposed.

Keywords Supply Chain, Performance Indicators, Metrics, Ontology

1. Introduction

In contemporary global environments companies are moving towards more integrated SCs to remain competitive. Within this context, it is essential to integrate activities into critical supply chain processes and to establish performance measurement systems to provide data on whether the SC is performing appropriately.
In order to facilitate the effective communication among SC stakeholders, it is

first necessary to acquire a unified understanding of the SC processes, structure, and measurement concepts. To tackle this need, *SCOntology*, was proposed [1]. It is a framework which formalizes and extends the SCOR model [2]. This reference model is nowadays widely adopted by enterprises since it provides the foundations to achieve a shared conceptualization of the SC. Nevertheless, this ontology needs to be extended to include concepts related to SC performance measurement, its processes and structure. In order to achieve this objective, an ontology that conceptualizes Performance Measures, Metrics and Benchmarks for Industrial Supply Chains is proposed in Section 2 and is illustrated by means of various examples. In Section 3, conclusions are presented.

2. Ontology

Measuring the supply chain is difficult because of diverse reasons, like the existence of multiple participants having distinct objectives and employing diverse performance terminology. By establishing standard concepts, the stakeholders' communication as well as the evaluation and monitoring of the whole chain, or a part of it, could be much easier. To incorporate performance related concepts for the measurement of the SC as a whole, and at different levels of detail, the conceptualization of an ontology, which extends *SCOntology*, is presented in this section.

2.1. Conceptualization

As a given enterprise can participate in various SCs, and each of them should be managed according to its own strategy, it is important to have information about the various metrics that could be used to evaluate their efficiency at different levels. Thus, to reflect the fact that an *Organizational Unit* (*OU*) can be part of more than one SC, the *Organizational Perspective* concept is included in the ontology (See Fig. 1). This class models the different views that an *OU* presents with respect to the various SCs in which it is involved. On the other hand, it is assumed that an *OU* could be either a process unit or a customer one. So, the *OU* concept is specialized into *Customer Unit (CU)*, representing SC final clients, and *Process Unit,* modeling every *OU* that is not a SC final customer. Since the SC is viewed under the perspective of a specific organization, having its own standpoint of what a final customer is, an *OU* cannot be a customer and a process unit simultaneously. *Supply Chain* (another concept included into the ontology) could be composed of a *SC Market,* target of the SC, and of one or more *Product Types*. The *Product Type* class represents information of individual products or groups of them having common features. The *SC Market* is a SC's final client, or a group of them, and so, it is composed of *CUs*.
The various metrics that can be identified in a SC performance evaluation process are related with a variety of processes and decision centers, at different abstraction levels, and regarding various flow types and decision time horizons.

In order to allow the evaluation of the SC in these different aspects, the concept of *Entity* is incorporated into the ontology. An *Entity* could be an *Organizational Unit*, a *Process,* a *Supply Chain* or a *SC Object*, having performance attributes that could be measured. In addition, an *Entity* can be decomposed into subentities, so as to permit its decomposition at different abstraction levels.

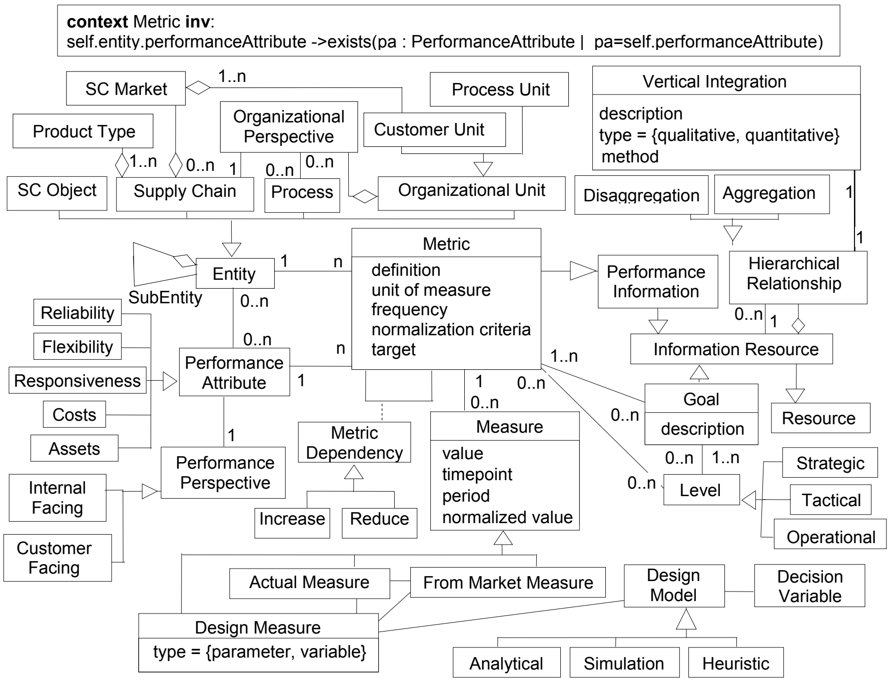

Figure 1. SC ontology concepts focused on performance measures, metrics and benchmarks

Each *Metric* is defined as a method to evaluate an *Entity's* particular *Performance Attribute (PA)*, as it is presented in the SCOR model. Therefore, a given metric could only be used to measure a specific *PA* of a particular *Entity*. It should be noted that a given *PA* of an entity can be measured through one or more metrics, each one having its own values. Likewise, each *Metric* could only be associated with an *Entity* and a *PA*, which, in turn, are linked to each other (see OCL expression at the top of Fig. 1). The value that results from the measurement done using a metric, and also its normalized value, are represented by the *Measure* class. The time point and the period attributes identify when the measurements were performed and which was the evaluated period.

Since one of the main purposes of SC management is to gain advantage over competitors, it is desirable to assess the company's performance by benchmarking. To allow the aforementioned comparison, the *Measure* class is specialized in *Actual Measure* (values measured in a specific *SC*) and *From*

Market Measure (values obtained from benchmarking activities). However, the performance measures can also be established in a SC design process, by determining the values of the *Decision Variables* that might represent the most desirable level of performance. Therefore, the *Measure* class is also specialized in the *Design Measure* concept, which models the values that are obtained as dependent variables or that are defined as parameters in a design process.

On the other hand, the specialization of the *Performance Attribute* class that was proposed permits decoupling the *Performance Perspective (PP)* from the *PA* and, in this way, allows clarifying their meanings. As a result, the *PA* class is specialized, in principle, in the *Reliability*, *Flexibility*, *Responsiveness*, *Costs* and *Assets* concepts, and the *PP* one in *Internal* and *Customer Facing*.

In addition, due to various reasons (data availability and error minimization, etc.), information used at higher decision levels, is more aggregated than the one employed at lower levels. However, these information pieces, having different granularities, are generally related. This notion is reflected by the *Hierarchical Relationship* and the *Vertical Integration* concepts, representing, on the one hand, that the information could participate in diverse aggregation or disaggregation relationships, and on other hand, that each hierarchical relationship must be associated with a *Vertical Integration* association, whose attributes are the description, its type (qualitative or quantitative) and its calculation method. Since metrics influence the decisions to be made at strategic, tactical, and operational levels, they should be classified into these levels of management, in such a way that they can be successfully handled by the proper management level and thus, better decisions could be made.

It is also important to consider that a balanced approach between financial and non financial metrics is needed to adequately measure the SC performance from both, the network design and management perspectives. This issue could be achieved by considering the different *PPs* and *PAs*. Similarly, for effective SC management, it is also essential to define SC goals in accordance with the proposed strategy and to control these goals by means of appropriate metrics. For this reason, it would be advantageous, to identify those metrics that will be used to control the diverse goals. In consequence, the *Goal* concept is incorporated in the ontology, as a specialization of *Information Resource*. Thus, each *Goal* should be controlled with at least one *Metric* and should be associated with the proper decision horizon *Levels*. Another important information for SC managers is the dependency relationships between the various performance metrics, since it provides insight whether an improvement on a specific metric could affect, by reducing or increasing, the performance of another entity's attribute (measured by a different metric). This issue is conceptualized in the *Metric Dependency* association class, which is further specialized in the *Increase* and *Reduce* classes. For example, a manufacturer whose product availability is poor and order cycle times are long, may force wholesalers to carry more inventory as safety stock in order to offer an acceptable service level to the retailers (Fig. 2).

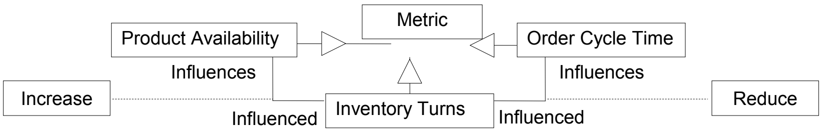

Figure 2. "Product Availability's" and "Order Cycle Time's" Impact on "Inventory Turns" metric

2.2. Supply Chain Metrics

Hausman et al. [3] proposed various metrics to evaluate global SCs and recognized three key dimensions: Service, Assets and Speed, that could be mapped to different specializations of the *PA* concept in *SCOntology*. As an example, he identified the amount of inventory all along the SC as one of the major asset measures, which is calculated by adding the monetary value of all the inventories (work in progress, in transit, etc.) in all the *OUs* of the SC. The model of this measure, referred as *SC Inventory*, is presented in Fig. 3 along with its relations with other concepts, like its aggregation from the *OU Inventory* metric, which evaluates the monetary value of stocks in each *OU*.

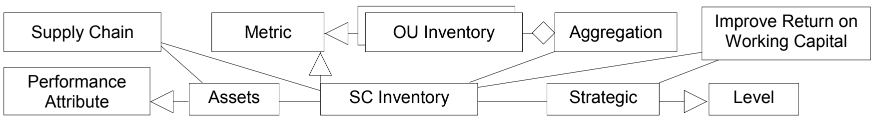

Figure 3. "SC Inventory" metric model

Other authors, like Lambert and Pohlen [4], propose metrics that are merely based on the financial or economic performance of the whole SC. They provide a framework to develop SC metrics, where the SC Performance is determined by the increase in Market capitalization of each firm in the SC and operational measures are tied to the firm's EVA (Economic Value Added) and to profitability reports for customers and suppliers. Therefore, they propose the following metric to evaluate the SC performance:

$$SC\ MarketCapitalization = \sum_i \Delta OU\ MarketCapitalization_i \text{ ;where i is a firm in the SC}$$

Fig. 4 describes the aggregation that represents the "SC Market Capitalization" metric as well as other performance evaluation concepts. Note that a Market Value *PA* is incorporated, since the previously defined attributes could not reflect this SC aspect. Thus, an open world assumption is made in the specification of the ontology. On the contrary, Kleijnen and Smits [5] state that each company, as an independent economic and legal entity, should have its own performance measurement system, neglecting global SC metrics. A metric used to evaluate the Plan SC process of OUs could be "Fill Rate". This metric, which applies to items which are planned to be manufactured under a made-to-stock policy, represents the percentage of orders that can be completed by resorting to the available stock at the time the order is placed. Its aggregation from other metrics called “Completed Order”, which expresses if an order is completed from stock when demand occurs, is shown in Fig. 5.

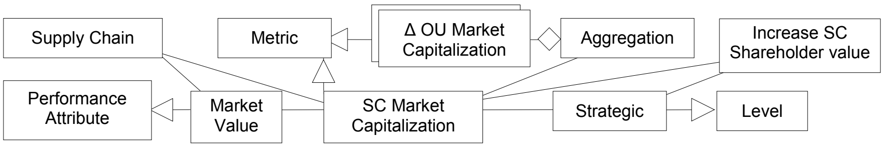

Figure 4. “SC Market Capitalization” metric model

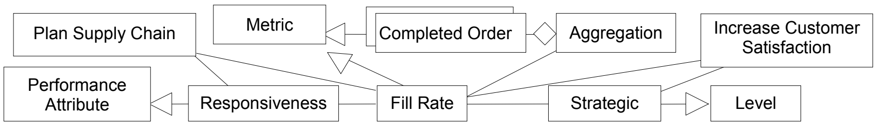

Figure 5**.** “Fill rate” metric model

3. Conclusions

SCOntology allows formally describing a SC at various abstraction levels, by sharing a precise meaning of the information exchanged during the communication among the SC stakeholders. This contribution extends a previous version of *SCOntology* with concepts that are related to the performance evaluation of the SC, including the measurement of *PAs* of different types of entities (*OUs*, processes, etc.) that are relevant in the SC.
Provided that a SC cannot be evaluated by means of a single metric, this proposal offers mechanisms to formally describe metrics´ composition and decomposition from other metrics as well as other types of relationships among them. In addition, this work introduces classifications of metrics and performance attributes that are valuable in the complex process of evaluating a SC both, from the network design and management perspectives.

Acknowledgements. This work has been supported by CONICET, UTN, UNL and ANPCyT (PICT 12628).

References

1. S. Gonnet, M. Vegetti, H. Leone and G. Henning. “SCOntology: A Formal Approach Towards a Unified and Integrated View of the Supply Chain” in Adaptive Technologies and Business Integration: Social, Managerial and Organizational Dimension. M. Cunha, B. Cortés and G. Putnik (eds). Idea Group Publishing, 2006.
2. SCOR: www.supply-chain.org/page.ww?section=SCOR+Model&name=SCOR+Model
3. W. Hausman. C. Billington, T. Harrison, H. Lee and J. Neale (eds), “Supply chain performance metrics” in The Practice of Supply Chain Management. Kluwer, Boston, 2003.
4. D. Lambert and T. Pohlen, International Journal of Logistics Management, 12 (1) (2001), 1.
5. J. Kleijnen, M. Smits, Journal of the Operational Research Society, 54 (5) (2003), 507.