

## **IT-SUPPORTED MODELING, ANALYSIS AND DESIGN OF SUPPLY CHAINS**

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**Abstract:** A common language is a prerequisite for analyzing and optimizing supply chains. Based on experiences with three case studies, this paper identifies the aspects of a supply chain that have to be mapped to take informed decisions on its operations. Current, integrated modeling approaches for supply chains, like the SCOR and the GSCM model, will be analyzed and an advanced approach will be defined. The resulting approach takes advantage of IT-support.

**Key words:** Supply Chain Management, Modeling, SCOR, GSCM

### **1. INTRODUCTION**

Before supply chains can be optimized, they need to be understood. A hurdle, most companies come across in mapping supply chains, is the lack of a common language, since logistics managers of a couple of companies are involved. Common modeling techniques, like flow charts, fall short when it comes to transcorporate issues, because they only cover a limited number of the aspects a supply chain has. Therefore modeling a supply chain takes an integrated modeling approach that combines different modeling techniques on multiple levels of detail. Those currently are limited in number. Most known are the SCOR (“Supply Chain Operations Reference”) and the GSC (“Global Supply Chain”) model.

In chapter 2 the relevant aspects of a supply chain that have to be mapped for taking well-founded decisions will be identified. Chapter 3 will give an insight into integrated modeling approaches for supply chains, for what purposes they can be used and where they fall short. While chapter 4 deals with amend-

ments to those models, chapter 5 shows, how the resulting advanced approach to supply chain modeling can be supported by information technology.

## 2. ASPECTS OF A SUPPLY CHAIN

The supply network a company is involved in is of a very complex nature, because companies have up to 10'000 suppliers of direct material. That is why for analyzing it, restricting attention to supply chains is necessary. A supply chain is the product-specific part of a supply network that is defined by the product's bill of material and by the suppliers that contribute to the product. In Figure 1 gray boxes mark the supply chain of product 14. It differs from the pure bill of material, since suppliers are assigned to its components. In cases of single or multiple sourcing (as opposed to sole sourcing, see [3], p. 47) this leads to multiple occurrences of a product. Product 07, which can be supplied by site A or B, is an example for such a situation.

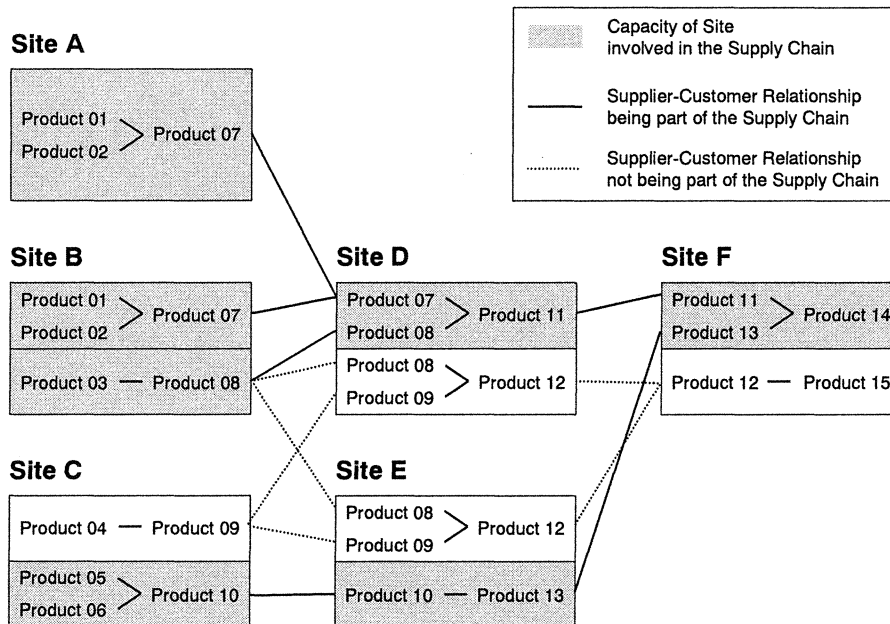


Figure 1. The supply chain – a product-specific part of a company's supply network

The question “What do supply chain operations look like?” is equivalent to “Who does what with which things in which order and according to which rules in the supply chain?” In modeling, four views allow answering this

question: The organization, function, object and process view (see Figure 2). Most modeling techniques map two of these views, e.g. a flow chart has process as primary and function as secondary view, while in state diagrams object is the primary and process is the secondary view (see [2] and [6] for more information).

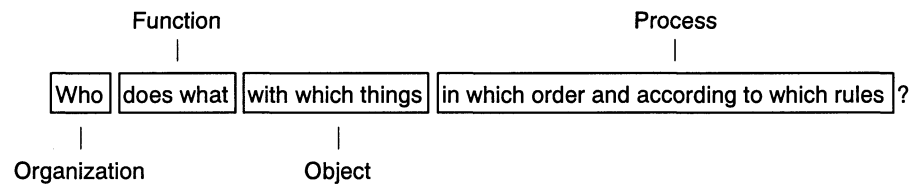


Figure 2. Aspects of supply chains - four modeling views

In the following we will look at which aspects of supply chains should be modeled in the four views and how this should be done to enable logistics managers to take well-founded decisions on their supply chain operations. Process and function view are strongly connected to each other, because order of functions and rules cannot be mapped without mapping functions themselves. Therefore, they are grouped in one sub-chapter.

The aspects are derived from experiences with modeling three supply chains, which are different in respect of production concept within the international research project ProdChain (IMS 99006, IST 2000-61205).

## 2.1 Aspects of a Supply Chain in the Organization View

Organizations are of interest in supply chains from two points of view:

- Companies own information, sites, capacity and products.
- Companies, their subsidiaries and the subsidiaries' departments are responsible for certain functions within a process. This implies, that organizations being responsible for functions – like functions themselves – have to be mapped on different levels of detail.

## 2.2 Aspects of a Supply Chain in the Object View

Organizations in a supply chain deal with objects: They buy products, produce and store them in their production and warehouse sites and sell them to customers (see Table 1). Size and weight of the product limit the means of transportation. The transportation costs can be calculated as a function of these product attributes, the mean of transportation and the distance between two sites given by their locations. Because the price of a product varies from supplier to supplier, its value should not be included in the model as an

attribute of the product but rather as an attribute of the relationship “Supplier of product to a site”, which is listed in Table 2.

*Table 1. Aspects of a supply chain - objects*

Object	Attributes
Product	Size, Weight
Site: Production	Location, Capacity/Contracted Capacity
Site: Warehouse	Location, Capacity

Distinguishing between production and warehouse sites is necessary in order to map the stocking level of products within the supply chain. This is reflected in the relationship “Stock” in Table 2. Similar to transportation costs, storage costs for products on stock can be calculated as a function – here mainly of product size and value.

Three types of flows take place in a supply chain: Material, money and information. While material and financial flow are directly related to a product and can be described in a structured way, information is as manifold that there probably is no structured approach to describe its flow. Though financial flow is mainly relevant on the company level, it should be mapped on the more detailed level of sites keeping the relation of material to money flow. Aggregation to the company level is possible by the relationship “Ownership of site”.

*Table 2. Aspects of a supply chain – relationships between objects*

Relationship	between objects	Attributes
Bill of material	Product - Product	Number of components used for assembled product
Supplier of product to a site	Company - (Product - Site)	Price of product, delivery reliability
Stock	Product – Site	Number of products, storage costs
Material flow	Product - (Site - Site)	Time, mean of transportation, transportation costs
Financial flow	Product - (Site - Site)	Time, duties/tariffs to deduct
Information flow	Site – Site	Time, type of information, frequency
Ownership of site	Site – Company	
Ownership of product	Product - Company	

### **2.3 Aspects of a Supply Chain in the Process/Function View**

The basic functions of a company are planning (balancing aggregated demand and supply to develop a course of action that best meets the requirements), sourcing (procuring goods and services), production

(transformation of products to a finished state), product delivery (provide finished goods or services) and managing product returns. Each of these processes has interfaces to other partners in the supply chain – be it suppliers or customers. For understanding the supply chain, the processes within these five high-level groups (Plan, Source, Make, Deliver, Return) need to be mapped to identify the rules according to which the supply chain works. The SCOR model (see [4] and chapter 3) provides a good basis to cover aspects of supply chains in the process and function view.

### **3. CURRENT APPROACHES FOR MODELING SUPPLY CHAINS**

As mentioned earlier, only integrated modeling approaches are able to cover the aspects of a supply chain. Such modeling approaches combine pure modeling techniques on different levels of detail and allow users to navigate between models as well as between levels of detail. Objectives of modeling usually are to analyze and improve a system. Integrated modeling approaches offer different ways to reach improvement (see Figure 3):

- Some modeling approaches stop with visualizing the current state. ICON SCC, for example, provides users with a full view of stock levels throughout the supply chain. But taking decisions based on this information is in the hand of users.
- Other approaches provide users with reference models. Firstly, those can be used to configure the current state from a “common” state of a system. Secondly they are benchmarks and can give hints to what a good system should look like.
- Simulation models give numeric feedback on the current and possible future states of a system under different scenarios. Users decide, which possible future state is the one to choose.
- Finally, optimization models calculate the best future state of a system by an algorithm (see [5], part two).

For humans modeling, analyzing and designing a supply chain only visualization and simulation models are in scope. In contrast to optimization models, those are little demanding in terms of modeling effort needed and rich in visual feedback. From reference modeling approaches, only process reference models cover a number of the aspects of supply chains mentioned.

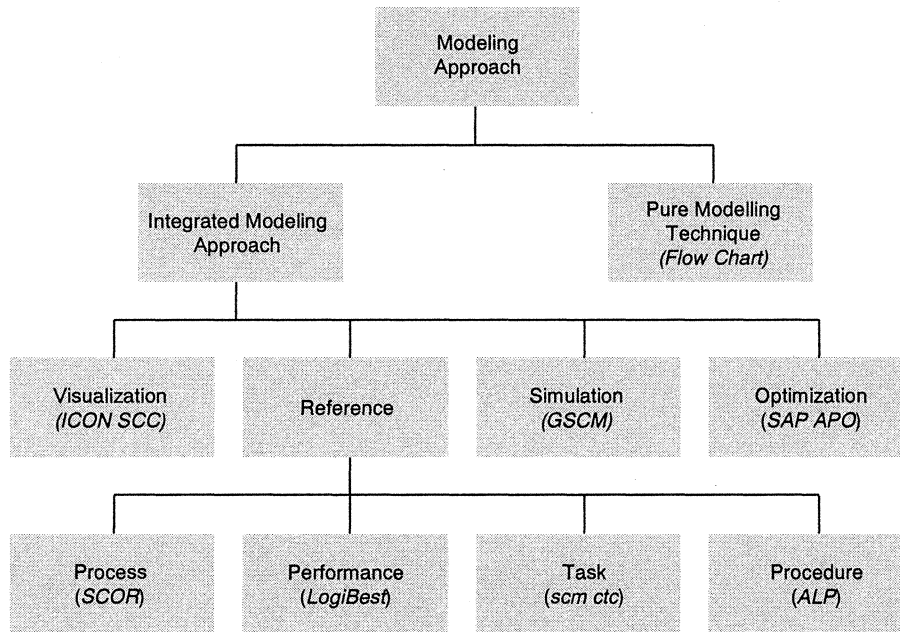


Figure 3. Hierarchy of modeling approaches for supply chains

The SCOR model has its focus on the process and function view. In its current version 5.0 the model (see [4]) describes 26 core processes down to a detailed level of elementary functions. Organization view, performance indicators and best practices are arranged around this main view. Its drawback is, that it is not capable to map product-related and financial information. GSCM, on the other hand, mainly covers the object view, having weaknesses in mapping organizational issues and the rules according to which a supply chain operates. For more information on GSCM, please refer to [1].

#### 4. AN ADVANCED APPROACH TO SUPPLY CHAIN MODELING

Table 3 shows five charts that in combination answer the question “Who” (O) “does what” (F2, F3) “with which things” (B, G) “in which order and according to which rules?” (F2, F3). To reduce complexity, aspects covered by the chart are partly optional (marked in gray in Table 3), so that the end user can filter information.

Table 3. Combination of five modeling techniques covering the aspects of a supply chain

Chart	Organization View	Object View	Process/Function View
Organizational Chart (O)	– Company	– Site: Production	
	– Subsidiary	– Site: Warehouse	
	– Department	– Product: Stock Level	
		– Flows	
		– Costs	
Bill of Material (B)	– Company	– Site: Production	
		– Site: Warehouse	
		– Product: Bill of Material	
		– Stock Level	
		– Flows	
Geographic Overview (G)	– Company	– Site: Production	Processes from the five SCOR level 1 categories (Plan, Source, Make, Deliver, Return)
	– Subsidiary	– Site: Warehouse	
		– Product: Bill of Material with suppliers (see Figure 1)	
		– Product: Stock Level	
		– Flows	
Flow Chart, Level 2 (F2)	– Company	– Flows	Processes from the 26 SCOR level 2 categories
	– Subsidiary		
	– Department		
Flow Chart, Level 3 (F3)	– Company	– Flows	Processes from SCOR level 3
	– Subsidiary		
	– Department		

This approach integrates the strong process and function view of the SCOR model and enriches it with product-related and financial information like financial flow, stock levels, storage and transportation costs.

The charts are connected to each other in two ways. On the one hand, they may include the same aspect (e.g. organizational chart and flow chart, which both have “company” as entity) allowing navigation on the same level of detail while keeping focus on the shared aspect. On the other hand, a chart may allow drilling down to a more detailed view of the same chart (e.g. from geographic overview to flow chart, level 2).

## **5. HOW INFORMATION TECHNOLOGY CAN SUPPORT SUPPLY CHAIN MODELING**

Enriching the SCOR model with product-related and financial information has an obvious drawback: While the structural data necessary for mapping a supply chain according to the SCOR model can be collected from logistics managers of the companies involved in about 9 hours, product-related data and financial information is of high volume and only available from a company's ERP system. Thus support of software with a link to an ERP system is crucial for applying the approach presented in chapter 4.

Most of the structural data gained from logistics managers in workshops can be obtained from an ERP system as well: Starting from the bill of material, suppliers of components can be identified. The result is the bill of material view (B). Geocoding suppliers then yields the geographic overview (G). Of course, an ERP system only can provide information on a company, its suppliers and its customers. Thus, mapping supply chains on more than these three levels means coordinating multiple ERP systems.

## **6. CONCLUSION**

It has been presented what the aspects of a supply chain are, that logistics managers want to have mapped for taking informed decisions. These currently are covered by integrated modeling approaches only to a limited extend. The advanced approach to supply chain modeling enriches the SCOR model with product-related and financial information, for which it needs to link to an ERP system.

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