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Review Paper

# Supply Chain Modeling Using Simulation Techniques

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**Abstract**:

In today's global market, managing the entire supply chain becomes a key factor for the successful business. World-class organizations now realize that non-integrated manufacturing processes, on-integrated distribution processes and poor relationships with suppliers and customers are inadequate for their success. They realize the impact of an organization's plan on the other areas of the supply chain. The impact of an organization's plan on the whole supply chain is unpredictable before its execution. Simulation permits the evaluation of operating performance prior to the execution of a plan. In the practical application of this concept, the development of the simulation model for the supply chain management has become a necessity. This paper discusses the issues of supply chain management and the requirements for supply chain simulation modeling.

In a today's highly competitive market manufacturers face the challenge of reducing manufacturing cycle time, delivery lead-time and inventory reduction. However, every organization (company) has its own objectives and its own way of decision-making processes. Due to the conflictions among the objectives of each organization and non-integrated decision making processes, there has been a need for a new mechanism, which help to resolve those conflictions and to integrate processes. In the early 1990s, the phrase "supply chain management" came into use. Supply chain management is a process of integrating/utilizing suppliers, manufacturers, warehouses, and retailers, so that goods are produced and delivered at the right quantities, and at the right time, while minimizing costs as well as satisfying customer requirements.

Figure 1 shows the structure of a typical supply chain. It consists of a number of organization – beginning with suppliers, who provide raw materials to manufacturers, which manufacture products and keep those manufactured goods in the warehouses. Then they send them to whole sales or distribution centers who ship the goods to retailers. The customers then buy products from retailers. Different industries have slightly different structures of the supply chain networks. The structure of this paper is as follows. Firstly we compare industry solutions in this area, secondly, we review functions and benefits of supply chain management, thirdly we address the necessity of discrete event simulation for the supply chain modeling and finally we suggest procedures and data requirements for the real world simulation of supply chain management.

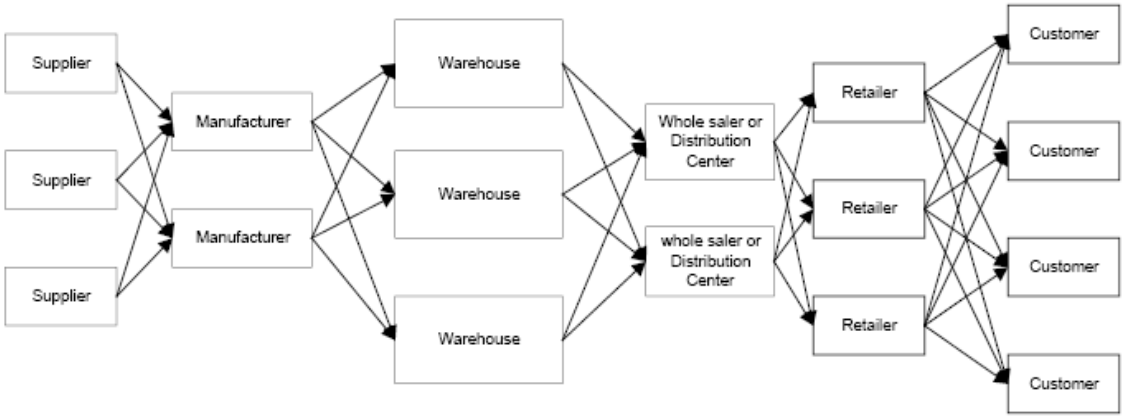


**Figure 1: A typical supply chain**

**Enterprise Resource Planning (ERP) Vs. Supply Chain Management**

In the early 1990's, MRP-II was further extended to cover areas like Engineering, Finance, Human Resources, and Project Management etc. Hence, the term ERP was coined. ERP can be defined, as a software solution that addresses enterprise needs to meet the organizational goals (including manufacturing goals) of an enterprise tightly integrating all functions of an enterprise. An ERP system can include software for manufacturing, order entry, accounts receivable and payable, general ledger, purchasing, warehousing, transportation and human resources. While ERP systems provide a great deal of planning capability, the various material, capacity, and demand constraints are all considered separately in relative isolation of each other (sequentially rather than concurrently).

A large number of software packages have emerged in the mid 90's that are called supply chain management (SCM) systems or advanced planning and scheduling (APS). The SCM system apply advanced technologies to achieve improved plans that take into account most of the factors and constraints that limit the ability to deliver on time. The leading edge SCM system are able to consider all the relevant constraints in the procurement, manufacturing, distribution, transportation and warehousing operations simultaneously, and to perform real-time simulations of adjustments in the constraints.ERP systems have a harder time adding these kinds of capabilities because they are mainly concerned with transaction processing, and also have much more tasks to do than just supplier chain optimization. Getting answers from a SCM system may take minutes or seconds whereas getting answers from ERP systems may take hours. Moreover, the answers from SCM achieve significantly superior results for the company's business drivers. Those are the main reasons why leading ERP vendors such as Oracle (www.oracle.com), SAP (www.sap.com) and JD Edwards (www.jdedwards.com) developed new advanced planning modules and other components of SCM.

**Functionalities and Benefits of the Supply Chain Management**

The following table shows general areas of supply chain management.

**Table 1: Functionalities/Areas of supply chain management**

| Areas of supply chain | Description |
|---|---|
| Demand planning | Demand planning aims to reduce forecast error and to suggest buffers considering demand variability. In order to improve accuracy of forecasting, collaborative forecasting is essential. |
| Master planning | Provide multi-site planning. Master planning based on the material, capacity, transportation and other constraints, simultaneously. |
| Procurement | Constraints such as vendor capacities, costs and lead times can be modeled as part of supply chain resulting in superior plans. |
| Transportation | Consider dynamic transportation requirement and generate optimizing transportation plan. |
| Manufacturing | Plan considering material, capacity and other constraints which impact on manufacturing. |

Expected benefits of supply chain management can be described as follows:

- Throughput improvements: Better coordination of material and capacity prevents loss of utilization waiting for parts.
- Cycle time reduction: By considering constraints as well as its alternatives in the supply chain, it helps to reduce cycle time
- Inventory cost reductions: Demand and supply visibility lowers the requirement of inventory levels against uncertainty. Ability to know when to buy materials based on the customer demand, logistics, capacity and other materials needed to build together.
- Optimized transportation: By optimizing logistics and vehicles loads.
- Increase order fill rate: Real-time visibility across the supply chain (alternate routings, alternate capacity) enables to increase order fill rate.
- Analysis of the supply chain can help to predict propagation of disturbance to downstream.
- Increase customer responsiveness: Understanding the capability to deliver based on availability of materials, capacity and logistics.

**Why Simulation needed in Supply Chain Management?**

Due to the Bullwhip effect, a poor plan can easily propagate to the whole supply chain areas [1]. The impact of a poor plan on the overall business is huge. It causes cycles of excessive inventory and severe backlogs, poor product forecasts, unbalanced capacities, poor customer service, uncertain production plans, and high backlog costs, or sometimes even lost sales. Although the ERP and SCM solutions provide lots of benefits to industries, it is too costly to use those solutions for academic research. Discrete event simulation permits the evaluation of operating performance prior to the implementation of a system: It enables companies to perform powerful what-if analyses leading them to better planning decisions; it permits the comparison of various operational alternatives without interrupting the real system; it permits time compression so that timely policy decisions can be made. Most of simulation tools are designed as interactive tools to be used by a human planner not as real time decision-making tools, which are directly linked to control system to dispatch tasks. Simulation tools aid human planner to make a right decision by providing information. However, human planner should be able to interpret and modify the plan in order to achieve better supply chain performances.

Benefits of supply chain simulation are as follows:

- It helps to understand the overall supply chain processes and characteristics by graphics/animation.
- Able to capture system dynamics: using probability distribution, user can model unexpected events in certain areas and understand the impact of these events on the supply chain.
- It could dramatically minimize the risk of changes in planning process: By what-if simulation, user can test various alternatives before changing plan.

**Data requirements for Supply Chain Modeling**

In supply chain, decisions taken are usually classified as strategic, tactical, or operational. Strategic decisions are related to the company's strategy and are long term (2-5 years) with involvement of the most partners in the supply chain. Tactical decisions are mid term (a month to 1 year). Operational decisions are short term, which are related to the day-to-day activities. Tactical and operational decisions are taken in individual area of the supply chain (e.g. plant and warehouse). They deal with issues in demand, procurement, production warehouse and distribution. Gunasekaran et al.[2] developed a framework on metrics for the performance evaluation of a supply chain. They also distinguished the metrics as financial and non financial so that suitable costing method can be applied. Selection of performance measures is dependent on the organizational goal.

Example performance measures can be found from [2].

The following procedures may be suggested for the simulation study of supply chain management:

- Understanding supply chain processes (understanding the business process and industry characteristics) and planning processes
- Design scenario (Most of the time it is not reasonable to model every details of the supply chain. It is a good idea to focus on the problem areas)
- Data collection (Refer to table 2)
- Performance measures
- Define target (what is near optimal) for each performance measure
- Define termination condition
- Evaluation of supply chain policies/strategies

Figure 2 and Table 2 show a simple supply chain model and example data requirements for the supply chain modeling, respectively. Some of the questions the users might have are as follows:

- Which supplier policy is achieving best delivery performance under given demand pattern?
- Which supplier policy is most robust under demand fluctuation?
- Which is the most cost saving inventory policy under given demand pattern?
- How profit can be impacted by adding xx % more capacity?
- What is the trade-off between delivery performance and inventory cost when building more inventories?
- What is the impact of information accuracy on the manufacturing performance (e.g. cycle time, order fill rate)

Many researchers are investigating the possibility of creating a simulation-based real time scheduling system that will be able to monitor the system status and make decisions in real-time. To have the capability, it is desirable to have (1) capability to interface with legacy databases to obtain information (2) hardware and software processing capability to run simulation within very short time- at least, pseudo in real time (3) capability to interface with the control system to assign tasks and receive feedback on system status and performance.

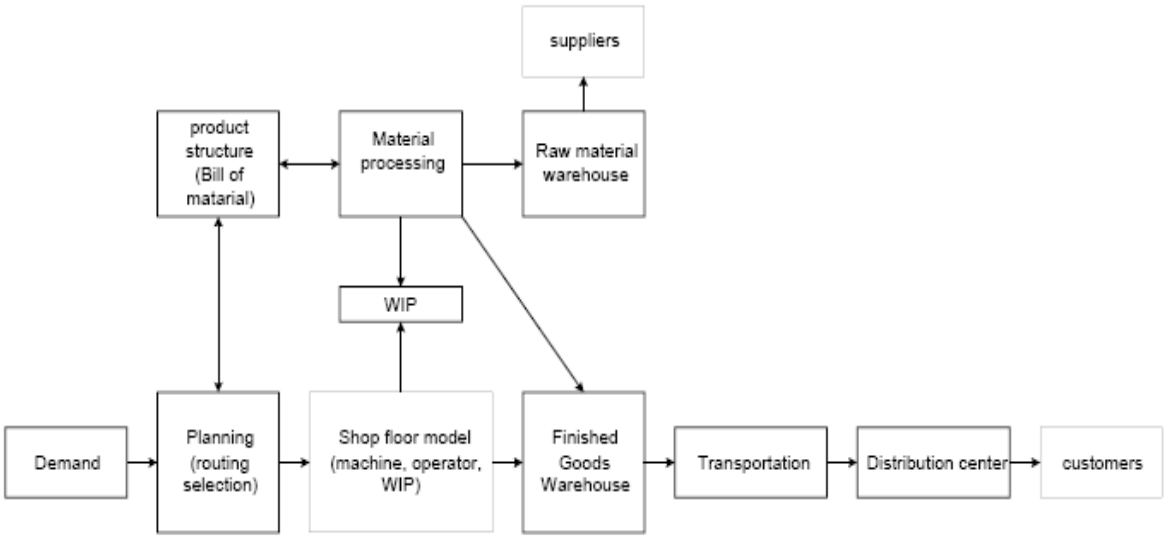


**Figure 2: Diagram of an example supply chain simulation model.**

Table 2: Example data requirements for supply chain model

| Area | Data required |
|---|---|
| Manufacturing Process and time information | Manufacturing process data (process time, queue time, setup time, number of machine in each process, alternate route)<br>Calendar data (shift information, holiday information, preventive maintenance information)<br>Machine data (Number of machine, mean time to failure, mean time to repair, alternate resources data, preventive maintenance time)<br>Bill of material structure |
| Inventory control policies information | Safety stock level, reorder point<br>Inventory level of finished products, raw material and intermediate parts<br>Any stock location in shop floor |
| Procurement and logistics information | Supplier lead-time<br>Supply lot size<br>Supplier capacity<br>Procurement horizon<br>Procurement time |
| Demand information | Due date<br>Priority<br>Start and end data<br>Demand pattern |
| Policies/Strategies information | Order control policies, dispatch policies |

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**Conclusion**

The objective of supply chain management is to meet customer demand for guaranteed delivery of high quality and low cost with minimal lead time. To achieve this objective, companies need to have better visibility into the entire supply chain of their own plans as well as those of their suppliers and customers. Companies today should be agile enough to adjust and rebuild plans in real time, to take care of unexpected events in the supply chain. These needs have propelled the application of discrete event simulation for analyzing entire supply chain process. In this paper, we reviewed the benefits, functionalities and data requirement of the supply chain, which needed to prepare for the modeling of supply chain simulation.

Efficient supply chain management can be achieved through careful consideration of capacity and material information. Companies today want to reduce inefficiencies in their business processes and to redesign their business processes in order to achieve world-class business performances. Some of inefficiencies can be found from the company, some of them are caused by their suppliers and some of them are caused cause by both. Simulation can help companies become more aware of their supply chain dynamics and efficiency. When developing simulation models of a supply chain, first of all a good understanding of the overall supply chain is most important. Good understanding of the business characteristics (e.g. performance measures, make-to-stock or make-to-order) is also essential since every industry has different business characteristics and supply chain management processes. It is better to focus on the problem area based on the specific scenario. Setting proper performance measures is another important task.

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At present HOD Management (IT & Projects - Brainware Group), and visiting faculty - Globsyn NC, Army Institute of Mgmt, ICFAI Business School, IISWBM etc. MTPL- Core Member, Delivery Head- Soft Wizards, and provides Software Consultancy services in the areas of Business Intelligence, Analytics & other areas also.