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# Performance Measures in Supply Chain Management

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**ABSTRACT** *A performance measure is used to determine the efficiency and/or effectiveness of an existing system, or to compare competing alternative systems. An important element in supply chain modeling is the establishment of appropriate performance measures. Supply chains are usually complex entities that aim to deliver the materials, parts and products from the suppliers to the end users. The management of supply chain means planning, coordinating and controlling the material, information and financial flows. The decisions are made at strategic, tactical and operational levels throughout the supply chain.*

**Introduction**
An important component in supply chain design and analysis is the establishment of appropriate performance measures. Performance measures are also used to design proposed systems, by determining the values of the decision variables that yield the most desirable levels of performance. Different performance measures as important in the evaluation of supply chain effectiveness and efficiency. These may be categorized as either qualitative or quantitative. Qualitative performance measures are those measures for which there is no single direct numerical measurement, although some aspects of them may be quantified. Quantitative performance measures are those measures that may be directly described numerically. The performance measurement metrics have to be designed separately for each company and supply chain. The performance measurement system should be based on the strategy, value drivers and important goals of the companies and the whole supply chain. There is several different approaches for the supply chain performance measurement. Many approaches divide the metrics into the following SC operations: plan, source, make and deliver. In addition return or customer satisfaction is also used. Many contributors in the literature state that supply chains should be measured in different levels, typically the levels are strategic, tactical and operational. The performance metrics should be carefully selected and they should capture the essence of organizational performance. Many times it is better to use a few good performance measures rather than a large number of measures that are more difficult to handle as a one entity.

**Performance Measures Used in Supply Chain Modeling**
An important element in supply chain modeling is the establishment of appropriate performance measures. Each of the models reviewed, sought and tabulated in table-1, to optimize one or more measures of supply chain performance, given a set of physical or operational system constraints.

**Table-1: Performance Measures in Supply Chain Modeling**

| Basic | Chain supply performance major | Authors |
|---|---|---|
| Cost | Minimize cost | Camma et. al. (1997); Lee et. al. (1998) Lee and Feitenger (1995 |
| Customer responsiveness | Achieve target service level (fill rate) | Lee and Billington (1993); Lee, et. al. (1993) Towill and Del Vecchio (1994) |
| Cost and Customer Responsiveness | Minimize product demand variance or demand amplification | Newhart,et. al. (1993); Towill, et. al. (1992) Towill (1991); Wikner, et. al. (1991) |
| Cost and Activity Time | Minimize the number of activity days and total cost | Arntzen, et. al. (1995) |
| Flexibility | Maximize available system capacity | Voudouris (1996) |

**Decision Variables in Supply Chain Modeling**
In supply chain modeling, the performance measures are expressed as functions of one or more decision variables. These decision variables are then chosen in such a way as to optimize one or more performance measures. The decision variables used in the reviewed models are described below;

- **Production/Distribution Scheduling**: Scheduling the manufacturing and/or distribution.
- **Inventory Levels:** Determining the amount and location of every raw material, subassembly, and final assembly storage.
- **Number of Stages (Echelons):** Determining the number of stages (or echelons) that will comprise the supply chain. This involves either increasing or decreasing the chains level of vertical integration by combining (or eliminating) stages or separating (or adding) stages, respectively.
- **Distribution Center (DC) - Customer Assignment:** Determining which DC(s) will serve which customer(s).
- **Plant Product Assignment:** Determining which plant(s) will manufacture which product(s).
- **Buyer - Supplier Relationships:** Determining and developing critical aspects of the buyer-supplier relationship.
- **Product Differentiation Step Specification:** Determining the step within the process of product manufacturing at which the product should be differentiated.
- **Number of Product Types Held in Inventory:** Determining the number of different product types that will be held in finished goods inventory.

The approach and scope of existing research in the design and analysis of supply chains illustrates a number of issues that have not yet been addressed in the literature. This section suggests a research agenda for supply chain design and analysis in:

- The evaluation and development of supply chain performance measures.
- The development of models and procedures to relate decision variables to the performance measures.
- Consideration of issues affecting supply chain modeling.
- The classification of supply chain systems to allow for the development of rules-of-thumb or general techniques to aid in the design and analysis of manufacturing supply chains.

## PRODUCTION PLANNING AND SCHEDULING

The production planning and scheduling process is broken down into two parts: planning, based on monthly forecasts, of assembly and component parts orders and daily scheduling of packaging and sterilization based on finished goods inventory levels. During the fourth quarter of each fiscal year, the marketing and finance organizations determine an annual forecast. The annual forecast is then broken down proportionately, based on the number of weeks in the month, into monthly forecasts. As the year progresses, the central planners work with the marketing organizations to make forecast adjustments according to market trends and events. At the beginning of each month, the month's forecasts are adjusted and agreed upon by the marketing organization and the central planners.

The planning of assembly for a particular instrument begins with the monthly demand forecasts. Based on the month's forecast, the central planners determine the amount of product that needs to be transferred from bulk inventory into finished goods inventory to "meet" the expected demand. This amount, termed the finished goods "transfer requirement," is determined by subtracting the current finished goods inventory level from the demand forecast for the month plus the required safety stock. The transfer requirements, once completed for all 200-plus product codes, are passed throughout the organization for approval. This process typically takes place one to two weeks into the current month. While not actually used to schedule assembly or to alter the packaging and sterilization processes, the transfer requirements provide an estimate of the required overall production for the month. Any problems in being able to deliver to the plan can then be identified and resolved.

### Packaging

The packaging process makes use of several large packaging machines. The machines direct bulk instruments into plastic containers and then adhere a flexible sheet of material over the top of the container. The entire plastic container is then placed into a finished 16-cardboard container and shipped immediately to the sterilizer. Capacity at the packaging area has not restricted output. The supply chain optimization problem we discuss in this chapter considers production, inventory, and transportation decisions in a dynamic environment. In particular, we model a two-stage supply chain, coordinating production, inventory, and distribution decisions. This supply chain consists of F facilities and R retailers. The facilities produce and store K different commodities for which there is a demand over a planning horizon of length T. The problem is to find the production, inventory, and transportation quantities that satisfy demand at minimum cost. We formulate the problem as a multi-commodity network flow problem with fixed charge cost function. We present a heuristic procedure that can be used to solve any multi-commodity network flow problem with fixed charge cost functions. This method, called the multi-commodity, dynamic slope scaling procedure (MCDSSP) is an extension of a procedure that was proposed for the single-commodity fixed-charge network flow problem. MCDSSP approximates the fixed charge cost function by a linear cost function, and iteratively updates the coefficients of the linear approximation until no better solution is found.

The multi-commodity and multi-facility problem is solved using a LaGrange and decomposition based heuristic. The decomposition separates the problem into two sub problems that are computationally easier to solve. The decomposition is performed in such a way that it provides interesting managerial insights. The multi-facility and multi-retailer problem is solved using a primal-dual algorithm. The performance of the algorithm is tested on two groups of randomly generated problems. In the first group of problems demand shows seasonality, and in the second group demand is uniformly distributed. Results indicate that the performance of the primal-dual algorithm depends on the value of set-up costs, the value of demand, the number of facilities and the number of periods. In this chapter we also discussed a class of incapacitated, multi-facility and multi-retailer problems with linear production and inventory costs and fixed charge transportation costs. We show that this class of problems has a nice property; the linear programming relaxation of the MILP formulations gives integer solutions.

## NEXT GENERATION OF SCM

Today, virtually all industries and most companies are facing a more dynamic environment - that is, greater uncertainty of demand, shorter product life cycles, greater demand for mass customization, more significant seasonality, higher competitive intensity, fewer warehouses, more third-party service, new cost/service balance, globalization, channel integration, and so on. However, almost all existing supply chain systems are featured in one or more of the following demerits: product availability focus; reactive rather than proactive; long lead times; uncertainty throughout; lack of flexibility in systems; performance measured functionally; poorly defined management process; no real partnerships; product price lead relationship; paper, phone, fax based relationship; performance measures insufficient. In order to overcome all of these shortcomings, next generation of supply chain management systems are required to meet the needs.

### Requirements for Next Generation of SCM

The next generation of SCM should possess the following set of characteristics: integrated, customer centric, distributed; having interoperability, scalability; with open and flexible infrastructure; autonomous, capable of self-organization and reconfiguration, coordination and negotiation; with optimization and learning mechanism so evolve in and adapt to the dynamic marketplaces; synchronized and agile; involving production planning and scheduling; capable of making forecasts accurately; both active and proactive; compatible with globalized manufacturing; seamlessly integratable with e-commerce and m-commerce; and proper performance-measurements. These characteristics are interrelated.

***Integration***: The keyword that appears throughout the whole new generation of supply chain is integration, because it spells the difference between the old view of logistics as the discrete functions of transportation and distribution, and the new vision of SCM that links all the players and activities involved in converting raw materials into products and delivering those products to consumers at the right time and at the right place in the most efficient manner. Business success will be increasingly dependent on functional integration.

**Integrate with E-Commerce and M-Commerce:** While e-commerce offers some exciting opportunities to improve SCM effectiveness by lowering costs and increasing the speed of order-to-delivery, it is by no means the first stop on the path to having highly competitive e-supply chain capabilities. E-commerce is digitally connecting the entire world into one big network of supply chains. E-commerce already has, and will continue, to fundamentally change business to- business [B2B], business-to-consumer [B2C], and business-to-employee [B2E] supply chain models. Mutually, E-commerce requires intelligent supply chains that provide instant access to the right data anywhere. With the new development of mobile communication and wireless technology, it will usher in the next wave of electronic commerce - the so-called m-commerce. It allows users to access systems whenever they

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want without physically being connected to the network.

**Engage in collaborative supply chain planning, scheduling and optimization:** SCP enables companies to intelligently manage the activities of the supply chain. Collaborative SCP involves improving the coordination and information sharing for all activities, from supplier's supplier to customer's customer. In addition to coordinating activities across the entire product life cycle, SCP involves a comprehensive solution including changes made in alliance strategy, business process, performance measures and technology. The appeal of APS solutions to manufacturers is obvious: companies can optimize their supply chains to reduce costs, improve product margins, lower inventories, and increase manufacturing throughput. Exploiting Internet for collaborative SCP provides a critical link for sharing information, planning & scheduling supply chain activities.

**Integration of performance measurement:** The performance of a supply chain activity should be measured globally. The most notable measures for customer service include short order lead times and in stock availability. Such measures also may include order and invoice accuracy, access to information on order status, ability to respond to customer inquiries, and so on.

**Supply Chain Performance Measures**

Table 1 identifies the performance measures that have been used in the literature. These measures, and others, may be appropriate for supply chain design and analysis. Available research has not specifically addressed the adequacy or appropriateness of existing supply chain performance measures.

More specifically, the research questions that may be answered are:

**Are the existing performance measures appropriate for supply chains?** It is unlikely that a single performance measure will be adequate for an entire supply chain (the interested reader is referred to Beamon (1996) for an evaluation of supply chain performance measures). It is more likely that a system or function of performance measures will be necessary for the accurate and inclusive measurement of supply chain systems.

**What are the appropriate performance measures for supply chains?** That is, what types of performance measures or performance measurement systems are appropriate for supply chain performance analysis, and why?

**Supply Chain Optimization**

An important component in supply chain design is determining how an effective supply chain design is achieved, given a performance measure, or a set of performance measures. Research in supply chain modeling has only scratched the surface of how supply chain strategies (or decision variables) may affect a given performance measure, or a set of performance measures. Lee and Whang (1993) and Chen (1997) are examples of such research. Lee and Whang (1993) develop a performance measurement system that attempts to match the performance metric of individual supply chain managers with those of the entire supply chain, in an attempt to minimize the total loss associated with conflicting goals. Similarly, Chen (1997) also investigates the relationship between individual supply chain managers and the supply chain as a whole, but does so on the basis of inventory costs. In this work, Chen (1997) seeks to develop optimal inventory decision rules for managers (who have only local information) that result in the minimum long-run average holding and backorder costs for the entire system.

Table indicates that the majorities of the models use inventory level as a decision variable and cost as a performance measure. However, as also indicated in Table 2, there are a number of other decision variables (and perhaps others that have not yet been studied) that may be appropriately linked to a system of performance measures comprised of measures listed in Table 2 and perhaps others that have not yet been studied. Thus, research is needed that associates appropriate performance measurement systems to critical supply chain decision variables.

**Supply Chain Modeling Issues**

In supply chain modeling, there are a number of issues that are receiving increasing attention, as evidenced by their prevalent consideration in the work reviewed here. These issues are: (1) product postponement, (2) global versus single-nation supply chain modeling, and (3) demand distortion and variance amplification.

**Product Postponement**

Product postponement is the practice of delaying one or more operations to a later point in the supply chain, thus delaying the point of product differentiation. There are numerous potential benefits to be realized from postponement, one of the most compelling of which is the reduction in the value and amount of held inventory, resulting in lower holding costs. There are two primary considerations in developing a postponement strategy for a particular end-item: (1) determining how many steps to postpone and (2) determining which steps to postpone. Current research addressing postponement strategy includes Lee and Feitzinger (1995) and Johnson and Davis (1995).

**Global vs. Single-Nation Supply Chain Modeling**

Global Supply Chains (GSC) are supply chains that operate (i.e., contain facilities) in multiple nations. When modeling GSCs, there are additional considerations affecting SC performance that are not present in supply chains operating in a single nation. Export regulations, duty rates, and exchange rates are a few of the additional necessary considerations when modeling GSCs. Kouvelis and Gutierrez (1997), Arntzen, et. al. (1995) and Cohen and Lee (1989) address modeling issues associated with GSCs.

**Demand Distortion and Variance Amplification**

Demand distortion is the phenomenon in which .orders to the supplier has larger variance than sales to the buyer and variance amplification occurs when the distortion of the demand .propagates upstream in amplified form. These phenomena (also known collectively as the .bullwhip effect. or .whiplash effect.) are common in supply chain systems and were observed as early as Forrester (1961). The consequences of the bullwhip effect on the supply chain may be severe, the most serious of which is excess inventory costs. As a result, a number of strategies have been developed to counteract the effects of demand distortion and variance amplification. A detailed discussion of the issues and strategies associated with the bullwhip effect may be found in Lee, et. al. (1997), Towill (1996), Newhart, et. al. (1993), Towill, et. al. (1992), Towill (1991), Wikner, et. al., (1991).

**Conclusion:** Supply chain performance measurement has been studied since the concept of SCM was founded. Many researchers have stated that the SC is complicated to measure because the SCM is a huge concept and it has so many approaches and different meanings. Both management's and the employees' commitment to the measuring is highly important in order to use measurement effectively. Performance measurement of the processes and the complete supply chain are important for many reasons. Performance measurement among others provides information for management and decision makers; enable identifying the success, assists in directing management attention, revising company goals, and re-engineering business processes. The performance metrics have three basic functions: control, communication and improvement

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