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Application of particle swarm intelligence algorithms in supply chain network architecture optimization

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ABSTRACT

In today's globalization, the success of an industry is dependent on cost effective supply chain management under various markets, logistics and production uncertainties. Uncertainties in the supply chain usually decrease profit, i.e. increase total supply chain cost. Demand uncertainty and constraints posed by the every echelon are important factors to be considered in the supply chain design operations. Optimization is no longer a luxury but has become the order of the day. This paper specifically deals with the modeling and optimization of a three echelon supply chain network using the particle swarm optimization/intelligence algorithms.

1. Introduction

In 21st century, particularly with the globalization of the world economy and revolutionary developments of information technology, the critical challenge to manufacturing enterprises is to become flexible, responsive and quickly adapt to environment changes under a dynamic and uncertain business environment. Moreover, these changes generally reflect on their supply chain. The ability to manage the complete supply chain network (SCN) and to optimize decisions is increasingly being recognized as a crucial competitive factor in order to make good decisions within a SCN. The supply chain is made up of all the activities required to deliver products to the customer, from designing product to receiving orders, procuring materials, marketing, manufacturing, logistics, customer service, receiving payment and so on. Anyone, anything, anywhere that influences a product's time-to-market, price, quality, information exchange or delivery, among other activities, is part of the supply chain. The old way of delivering product was to develop relatively inaccurate projections of demand, then manufacture the product and fill up warehouses with finished goods. The old ways are fading fast as management across all industries has come to accept that collaboration with customers and suppliers in the planning and replenishment process can and must be made to work very effectively. As customers and suppliers band together in mutually beneficial partnerships, the need of integrated supply chain management processes and systems are more evident and becomes a very high business priority. For many companies, it has become clear that a supply chain that flows information and material best can be a significant differentiator, the competitive winner. All the way to the boardroom, improving supply chain management is getting lots of attention because forward-thinking management knows it is the best strategy to increase and maintain market share, reduce costs, minimize inventories and of course, improve profits. In many industries, market share will be won and lost based on supply chain performance. With the stakes so high, there is a frenzy of activity along the supply chain front. Executive managers are assessing how their companies do business, especially in supply chain activities. They often find dysfunctional sets of policies, processes, systems and measurements. And these exist at all points in the supply chain, including business partners. The former vague image of a company of silos is very apparent and, most importantly, a new clarity of needs and goals emerges for supply chain management. There is a need to transform from dysfunctional and unsynchronized decision making – which results in disintegrated and very costly supply activities – to a supply chain that performs in such a way that it is one of the company's competitive advantages.

Effectively integrating the information and material flows within the demand and supply process is what supply chain management is all about. In most companies, however, two major and very interdependent issues must be simultaneously addressed. The first deals with delivering products with customer-acceptable quality, with very short lead times, at a customer-acceptable cost – while keeping inventories throughout the supply chain at a minimum. The second issue, which tends to be less understood and accepted, is the need for high-quality, relevant and timely information that is provided when it needs to be known. For any customers and manufacturers, business processes and support systems will not measure up to the task

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of quickly providing planning and execution information from the marketplace to production and onto vendors so that the customer's objectives are consistently met. The fact is, most information supplied is excessive, often late and frequently inaccurate. Regardless of industry and customer base, more effective supply chain management will be a prerequisite to future success. In fact, effective supply chain management must become an integral part of competitive and survival strategy.

2. Background

A large amount of literature on supply management places great emphasis on integration of different components of the chain. Finding the right strategy that is optimal across the entire supply chain is a huge challenge (Quinn, 2000; Simchi-Levi, Kaminsky, & Simchi-Levi, 2001). An emerging principle for the management of supply chains is that a supply chain perspective provides the opportunity for significant savings in inventories from the better coordination and proper scheduling purchasing, production and distribution of goods across the supply chain network. As described by Hicks (1999) supply chains can be defined as "…real world systems that transform raw materials and resources into end products that are consumed by customers. Supply chains encompass a series of steps that add value through time, place, and material transformation. Each manufacturer or distributor has some subset of the supply chain that it must manage and run profitably and efficiently to survive and grow". From the above definition it is comprehensible that there are many independent entities in a supply chain each of which try to maximize their own inherent objective functions (or interests) in business transactions. One of the earliest works in supply chain configuration design area was initiated by Geoffrion and Graves (1974). They described the mixed integer programming model for determining locations of distribution facility and a solution technique based on Bender's decomposition. As recent researchers Truong and Azadivar (2003) rightly mention, supply chain problems are complex and difficult to solve. The reasons could be the number of entities in the supply chain (length), the lead times at each node (Cakravastia, Toha, & Nakamura, 2002), inventory management (Giannoccaro & Pontrandolfo, 2002), logistics (Lummus, Krumwiede, & Vokurka, 2001), to mention a few. Most of the research in this area is based on the classic work of Clark and Scarf (1960), Clark and Scarf (1960, 1962). More recent discussion of two echelon models may be found in Diks, De Kok, and Lagodimos (1996). Williams (1981) presented seven heuristic algorithms for scheduling production and distribution operations in an assembly supply chain network and also he developed a dynamic programming algorithm for simultaneous determining the production and distribution batch sizes at each node within a supply chain network. Ishii, Takahashi, and Muramatsu (1988) developed deterministic model for determining the base stock levels and lead times associated with the lowest cost solutions for an integrated supply chain on a finite horizon. Cohen and Lee (1989), present a deterministic mixed integer, nonlinear mathematical programming model, based on economic order quantity techniques. Cohen and Moon (1990) extend Cohen and Lee (1989) work by developing a constrained optimization model, called PILOT, to investigate the effects of various parameters on supply chain cost and consider the additional problem of determining which manufacturing facilities and distribution centers should be open. Lee and Billington (1993) developed a supply chain model operating under a periodic review

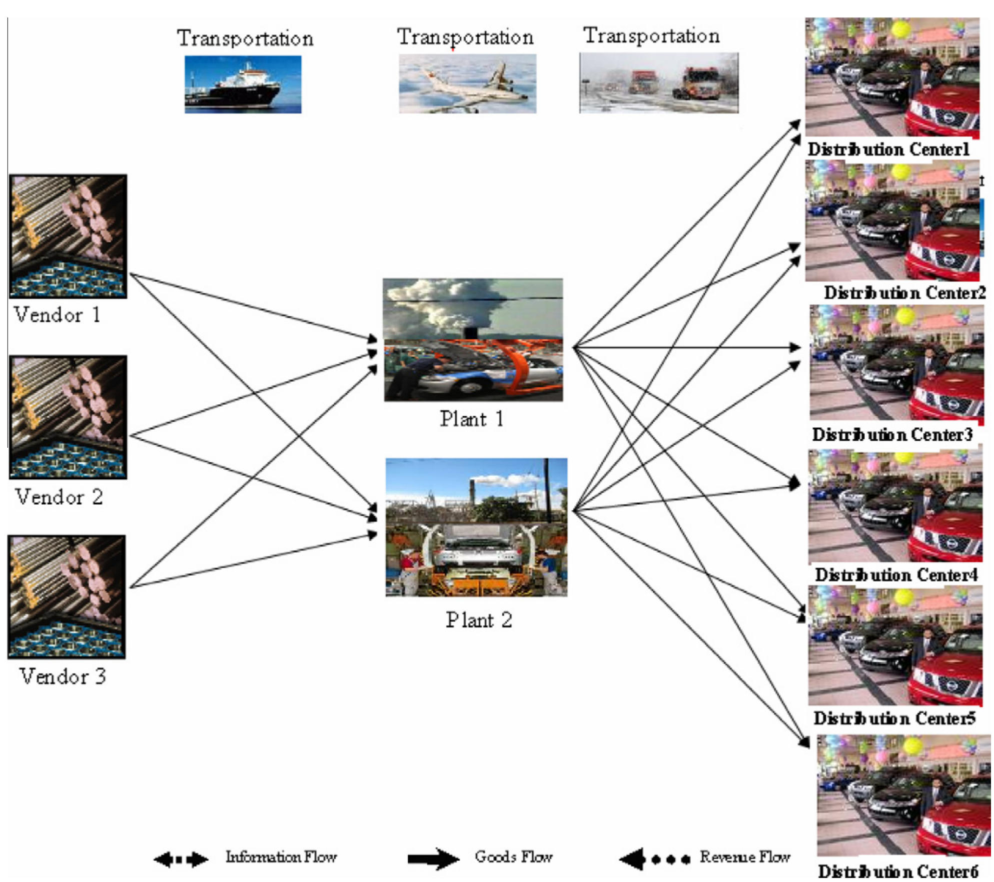

Fig. 1. Three echelon supply chain network architecture.