Simulating Demand Uncertainty and Inventory Control Variability of Multi-Echelon Distribution Supply Chain

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ABSTRACT

Development of simulation models allows performance analysis of multi-echelon inventory networks, and this part of supply chain is not well-established research area. Moreover, by encapsulating all major characteristics of multi-echelon system, the simulation modeling does not allow only its study, but also it provides the means to achieve the desired system performance. This paper deals with a multi-echelon distribution inventory system made of suppliers, distributors and retailers. The retailer faces stochastic demands placed by customers and replenishing from its distributor, which in turn procures from its supplier at the upstream of the chain. The main purpose of this simulation model is to analyze the multi-echelon distribution system behavior according some key performance metrics such as cost and backorder, as well as customer service level at each echelon.

Keywords: Backorder, Inventory Control Policies, Multi-Echelon Inventory System, Quality Service, Simulation Modeling, Stochastic Demand

1. INTRODUCTION

A Multi-Echelon Distribution Supply Chain (MEDSC) is a complex system, which may extend to the international level. It consists of several inventory locations that are connected to each other’s. The performance analysis of this type of chain is a major interest of decision makers. Indeed, the concept of MEDSC was born in the 60s when the socio-economic business has evolved. Since then, it became a wide field of study.

Numerous concepts have revealed in the literature review that there are several features and configurations of multi-echelon distribution system, which complicate its management. Also, among the most important reasons for this complexity, one can mention (Villeminot, 2004; Hajji, 2007):

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• The dynamic nature of interactions between all elements of the chain.
• The existence of a random nature of events in each network node.
• The size of system which is often large (dimension related to the structure).

Therefore, it is necessary to properly configure the multi-echelon system to get the maximum benefits in relation with the objectives set by the company. Thus the simulation modeling is proposed as a suitable tool for this task and to evaluate the impacts in a particular context. However, in the literature review, several studies have focused on MEDSC modeling; most of them used analytical models rather than simulation models. Nevertheless, analytical model can solve small instances, and approximately solve larger instances via scenario reduction techniques, but it cannot handle arbitrary nonlinear constraints or other nonstandard features. Simulation is an alternative approach that has recently been applied to such problems, using policies that require only a few decision variables to be determined (Niranjan, 2008).

Supply chain simulation modeling approach deals with complex systems and combines two powerful techniques that are computer modeling and simulation. The choice of this approach is that the analytical models are not able to describe the chain with all its complexity, and also the advantage of simulation in characterizing the stochastic behavior of logistics networks before their implantation (Lee, 2002). These models can replicate the behavior of the supply chain in order to make forecasts and performance evaluation. They have the ability to capture the uncertainties and the dynamic behavior of complex systems. Indeed, the simulation modeling has been considered as one of the best methods to analyze supply chains and assess its performance.

Recently, numerous models have been proposed to treat the MEDSC. Some previous works, illustrate the diversity and the complexity of these categories of chain. Brady studied a multi-echelon series network, considering the supply and the demand as stochastic, simulation modeling was developed with ARENA and the aim was to assess the impact of the choice of flow management policy of each retailer’s service level (Brady, 1999). Beek et al., simulated the dynamics of multi-echelon multiproduct, using inventory control policy with periodic review and deterministic lead times (Beek, 2000). Ng et al., have simulated the running of supply chains composed of N echelons, with stochastic lead times and they have compared the types of inventory control policies (Ng, 2003). Rossetti et al., have analyzed and simulated a system composed of N echelons and N products, and taking into account the variability of demand (Rossetti, 2008). The model allows changing the inventory control policy according to the forecasts of anterior demands. Niranjan simulated a multi-echelon system by combining a convergent structure and series structure (three-, four-, five-and m-echelon), where the model assumes that demand and capacity are stochastic, and lead time between echelons is deterministic (Niranjan, 2009). Wan and Zhao presented a simulation model for a multi-echelon made of five actors (manufacturer, distribution center and three retailers), under the assumption that the demand and the lead time are stochastic (Wan, 2009).

The purpose of this model is to analyze the relationship between the fill rate and the average stock of the entire supply chain. Considering the same structure of network adopted by Wan and Zhao, Yu et al., developed a simulation model, with a continuous inventory control policy (r, Q), to optimize costs of the inventory taking into account the target service level (Yu, 2009). Patil has adopted an integrated approach based on a simulation model, to reduce the cost and to improve sales of a network of two levels (distribution center, three retailers), with the introduction of emergency transshipment between retailers (Patil, 2011).

Our contribution lies in the development of a simulation model that will bring solutions to a dynamic and stochastic behavior of MEDSC. Indeed, this model can be adapted to different configurations of a multi-echelon system and...
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