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SIMULATION-BASED ANALYSIS OF THE BULLWHIP EFFECT UNDER CLASSICAL AND INFORMATION SHARING ORDERING POLICIES

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ABSTRACT

Bullwhip effect is defined as the distortion of demand information as one moves upstream in the supply chain. Ordering policies have been recognized as one of the most important operational causes of bullwhip effect. This paper investigates the impact of various classical ordering policies on ordering and inventories behaviors in a multi-echelon supply chain through a simulation study. In addition, a proposed ordering policy that relies on information sharing in a decentralized way is proposed to mitigate the bullwhip effect and overcome the problems of the classical ordering policies. A simulation model has been developed for a four-echelon supply chain, with deterministic ordering and delivery lead times, in order to analyze the supply chain performances under the different ordering policies. The simulation results show that the proposed ordering policy succeeds to mitigate the bullwhip effect and achieve an acceptable performance in terms of variance of inventory level as well.

1 INTRODUCTION

A supply chain is defined as a system of suppliers, manufacturers, distributors, retailers, and customers where raw material, financial and information flows connect participants. The lack of coordination among supply chain members and the local optimization of each member for his own benefits without considering the impact on other members cause inefficiencies in supply chains. A well-known example of such inefficiency is the bullwhip effect. A supply chain is considered to be infected with bullwhip effect when there is an amplification of demand variance along the supply chain (Lee et al. 1997). This problem of bullwhip effect has a lot of negative impacts on supply chains such as excessive inventories, low customer service level, and hence high costs of supply chain operations.

Lee et al. (1997) identified five major causes of bullwhip effect: demand signal processing, lead-time, order batching, price fluctuations and rationing and shortage gaming. Disney and Lambrecht (2007) consider demand signal processing and lead time to be of a significant importance. Under demand signal processing, demand is forecasted using a forecasting method, and hence the parameters of the inventory replenishment rules are updated in accordance to demand changes. In addition, the adopted ordering policy can be considered as a major component of demand signal processing. Therefore, ordering policies should be selected and designed carefully in order to cope with the bullwhip effect problem. In this research, we analyze the supply chain dynamics under some classical ordering policies, and we also propose a new ordering policy that could tackle the drawbacks of the classical policies and mitigate the bullwhip effect.

2 RESEARCH METHEDOLOGY

Numerous modeling approaches have been adopted to study supply chain dynamics issues and specifically the problem of bullwhip effect. These approaches can be classified into analytical approaches

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(Chen et al. 2000), control theoritic approaches (Dejonckheere et al. 2004) and simulation approaches (Barlas and Gunduz 2011). In this research, a discrete event simulation approach is adopted to analyze the supply chain performances under the different ordering policies. A simulation model has been developed for a four-echelon supply chain, with deterministic ordering and lead times, using SIMUL8 package.

In this research, we first started with analyzing the supply chain dynamics under the classical ordering policies. In particular, we consider three ordering policies; order-up-to-level (R, S), fixed order quantity (R, Q), and demand flow (R, D). The (R, S) has been widely adopted in the literature of supply chain dynamics and in practice as well. We considered two performance metrics to evaluate the supply chain performance; bullwhip effect ratio and inventory variance. After analyzing the dynamics of the supply chain under each ordering policy, the advantages and the drawbacks of each policy have been clarified and explained. Based on the findings, we have proposed a new ordering policy that attempts to utilize the benefits of the classical policies and avoid their drawbacks. The new policy relies on splitting the order of each supply chain partner into two signals; the first signal is essential to transfer the customer demand information throughout the supply chain, and the second signal is essential to adjust the inventory position of each partner. This policy has the advantage of allowing the whole partners in the supply chain to know about the actual pattern of the customer demand in a decentralized way. In addition, the amount of inventory adjustment is controlled in a way that avoids frequent reactions to demand changes.

3 SIMULATION RESULTS AND CONCLUSIONS

The simulation results show that the classical ordering policies are always having some drawbacks that can lead to instability in supply chains. The (R, S) which is the most common policy in research and practice always results in high bullwhip effect and high inventory variance but it has the capability of recovering the inventory level. This conclusion for the (R, S) policy conforms to the findings in the literature. The (R, Q) policy will simply suppress the bullwhip effect but it fails to recover the retailer's inventory position. The (R, D) can eliminate the bullwhip effect but it fails to control the inventory position of the supply chain partners as in the (R, Q) policy. The proposed ordering policy based on information sharing combines both the advantages of (R, D) and (R, S) where it keeps a stable ordering behavior and, a stable inventory level and a stable inventory variation as well.

Further analysis has been conducted on the sensitivity of the bullwhip effect and inventory variance to the important parameters of the proposed ordering policy. A further analysis will be conducted to analyze the impact of different forecasting methods on the performance of the proposed ordering policy. In addition, the proposed policy needs to be evaluated under different demand processes.

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