TEDARİK ZİNCİRİNDEKİ DALGALANMALARA KARŞI BİLGİ PAYLAŞIMI STRATEJİLERİ: SİSTEM DİNAMİĞİ YAKLAŞIMI[1]

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Özet: Son ürün talebindeki küçük değişiklikler, "*kamçı etkisi*" diye bilinen, tedarik zinciri boyunca artan dalgalanmalara sebep olurlar. Tedarik zinciri literatüründe, talep tahmini, sipariş birleştirme, ve tedarik gecikmesi kamçı etkisine sebep olan faktörler olarak belirlenmiştir. Bu çalışmanın amaçlarından birisi kamçı etkisininin ortaya çıkmasına sebep olan yapıyı anlamak ve talep tahmini, sipariş birleştirme, ve tedarik gecikmesinin bu etkiye ne kadar katkıda bulunduğunu analiz etmektir. Tedarik zinciri literatürü ve yönetim pratiği kamçı etkisine çözüm olarak talep ve tahmin bilgisi paylaşımını önermektedir. Bu çalışmanın diğer amacı talep ve tahmin paylaşımı stratejisinin kamçı etkisi üzerine etkilerini araştırmaktır. Birbirlerinin aynı olan aktörlerden oluşan üç basamaklı tedarik zincirinin Sistem Dinamiği modeli oluşturulmuştur. Bu model üzerinde temel stok kontrol politikaları ve "çapa atma ve ayarlama" politikası uygulanmıştır. Talep modeli, tahmin çabukluğu, tedarik gecikmesi gibi genel parametrelerin yanısıra parti büyüklüğü ve tedarik gecikmesi artırma katsayısı gibi politikaya-özgü parametrelerin değişik değerleriyle benzetim deneyleri yapılmıştır. Şu sonuçlara varılmıştır: Kamçı etkisi, tedarik zincirindeki her aktörün bir öncekinin siparişlerini kullanarak bağımsız olarak talep tahmini yapmasından kaynaklanmaktadır. Sipariş verme sürecinde bulunabilecek olası örtülü gecikmelerin gözardı edilmesi son ürün talebi sabit dahi olsa kamçı etkisine yolaçmaktadır. Daha sonraki aşamada, dinamik model, talep ve tahmin paylaşımını içerecek şekilde değiştirilmiştir. Değiştirilmiş model ile yapılan benzetim sonuçları talep ve tahmin paylaşımının denenen bütün envanter politikalarında kamçı etkisini azalttığını fakat tamamen yok edemediğini göstermiştir. Tedarik zinciri envanterlerinin "basamak stok" kavramı kullanılarak yönetilmesi kamçı etkisinin daha da azalmasını sağlamaktadır. Bu çalışma birkaç değişik yönde ilerletilebilir: Daha genel ve karmaşık tedarik ağları üzerinde benzetim tabanlı araştırma yapılabilir; alternatif tahmin yöntemleri ve her birim tarafından farklı tahmin yöntemi ve/veya sipariş politikası kullanılmasının sonuçları araştırılabilir.

Anahtar Kelimeler: *Tedarik Zinciri, Kamçı Etkisi, Envanter Dalgalanmaları, Talep Tahmini, Talep Paylaşımı, Sistem Dinamiği, Benzetim Modeli*

INFORMATION SHARING STRATEGIES TO REDUCE FLUCTUATIONS AND BULLWHIP EFFECT IN SUPPLY CHAINS

Abstract: Supply chain inventories are prone to fluctuations and instability. Known as bullwhip effect, small variations in end item demand create oscillations that amplify throughout the chain. We try to understand the underlying structure that generates bullwhip effect, and explore the effectiveness information sharing to eliminate this type of behavior, by using dynamic system simulation. Extensive parametric analysis is carried out for this purpose. Simulation results show that (i) a major root cause of bullwhip effect is independent demand forecasting performed at each stage of the supply chain and (ii) demand and forecast sharing strategies can significantly reduce but not completely eliminate the bullwhip effect. Our research continues with alternative ordering policies, supply networks and forecasting methods.

Keywords: *Supply Chain, Bullwhip Effect, Information Sharing, Coordination, Demand Forecasting, Dynamic Feedback Simulation*

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1. Introduction

Supply chain inventories are prone to fluctuations and instability. Small changes in end item demand create inventory and order oscillations that amplify as one moves up in the supply chain. (Sterman 1989; and Sterman 2000, Ch. 17, 18). This phenomenon of amplification of oscillations through the supply chain is also known as the *bullwhip effect* (Lee *et al.* 1997; Chen *et al.* 1998, Xu *et al* 2001).

Lee *et al.* (1997) identifies four main causes of bullwhip effect as: demand signal processing, order batching, rationing game and price variations. Chen *et al.* (1998) argues that the bullwhip effect is due, in part, to the need to forecast demand. Sterman (2000, Ch.17 and 18) and Forrester (1961, Ch.12) show that delays inherent within the supply chain together with demand forecasting and distortion can create amplified oscillations.Supply chain literature and management practice focus on coordination policies based on *information sharing* among supply chain members in order to reduce the bullwhip effect. Chen *et al.* (1998) argues that centralizing demand information could significantly reduce bullwhip effect. Xu *et al.* (2000) and Lee and Whang 1998 report that demand forecast and inventory information sharing is effective in reducing order fluctuations and safety stocks. Gavirneni *et al.* (1999) compares the no-information-sharing case against two different degrees of information sharing policies used by the retailer (partial and complete sharing), on a simple one retailer-one supplier chain. Gallego and Özer (2001) search optimal policies for with and without demand information sharing cases for a two stage supply chain, where retailer batches orders and faces Poisson demands. Jeong and Maday (1996) discuss the stability of a multi-echelon supply chain from a feedback control theoretic perspective. Silver *et al.* (1998) suggest demand sharing and *echelon inventory* policy implementations. Authors propose that each stage apply *echelon* (s,S) policy, in which an agent monitors its echelon inventory level (the total inventory position of the subsystem consisting of all downstream inventories, including the stage itself).

The purpose of this research is twofold: (1) to understand the underlying structures and factors that generate inventory fluctuations and bullwhip effect through the supply chain; and (2) to explore the effectiveness of some management strategies (in particular sharing demand and forecast information) in ameliorating this undesirable behavior. Dynamic feedback modeling is used as the research platform.

2. Results and Conclusions

Three typical ordering policies are considered and modeled in the context of a supply chain. Numerous simulation experiments are carried out using each of the three policies. These experiments are grouped in two: Policy-independent parameters of the supply chain and policy-specific parameters for each policy. The most general conclusion of the experiments is that bullwhip effect (amplification of orders along the supply chain) results in all cases, with all parameter values, as long as each stage utilizes local demand forecasts based on incoming orders (or end demand). So, uncoordinated local demand forecasting is discovered as the main cause of the bullwhip effect. An extension of this result is that the level of' 'responsiveness' of forecasts to the demand influences the magnitude of bullwhip effect experienced. Forecasts that are highly responsive (meaning small estimation adjustment times) to changes in the demand increase the bullwhip effect, while less responsive forecasts decrease it.

Weight of demand forecast in the ordering equation is another important factor that determines the bullwhip effect. If the weight of demand forecasts in ordering equations is high, then the magnitude of bullwhip is high, too. If forecasts are not used in ordering equation at all (zero weight coefficient or very large estimation adjustment time), then bullwhip effect does not exist. Thus, if demand pattern is known and its mean does not change (or changes very slowly), bullwhip effect may be avoided by not using demand forecasts in ordering equations or by using very slow-response forecasts. As for the other factors such as *lead time* and *batching* of orders, experiments show that these factors are not by themselves sufficient to create the bullwhip effect. But given that there already is bullwhip effect caused by local demand forecasting, these factors do increase the amplification substantially. Increased level of batching of orders and increased lead time, both cause increased bullwhip effect in these cases.

Lastly, we tested demand and forecast information sharing strategies against the bullwhip effect, as suggested by the literature. These policies significantly reduce the bullwhip effect for all ordering policies. However, if forecasting plays a role in ordering equations, demand and forecast sharing cannot completely eliminate the bullwhip; it can only reduce it. Bullwhip effect will exist in the supply chain as long as the ordering policies incorporate demand forecasts. The information sharing strategy implies managerial practices like Collaborative Planning and Vendor Managed Inventories (VMI). It also implies information systems like Electronic Data Interchange (EDI) and Point of Sale (POS) systems. (Lee and

Whang, 1998; Xu *et al.*, 2001; Sterman 2000). To avoid excessive batching, a contributor to bullwhip, Continuous Replenishment Programs (CRP) can be used. To shorten the lead time, another bullwhip amplifier, Quick Response (QR) systems can be implemented. (Aksogan and Barlas 1996).

There are two other major causes of bullwhip effect discussed in the literature: shortage (rationing) gaming and price variations. These two factors are beyond the scope of our study. For a realistic study of shortage gaming, the model should have multiple suppliers and retailers at the same stage, which we consider as a future research . (It is on the other hand possible to do a broad and rough study of shortage gaming even with single agent at each stage, provided that significant shortages occur. See for instance Sterman 2000, chapter 18, for such a rough shortage gaming modeling). As for the price variations, the model should include a price determination structure, which is again considered as further research. Finally, supply networks (rather than simple chains) will be modeled as a more realistic experimental setting.

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