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Bullwhip Effect in Different Network Configuration

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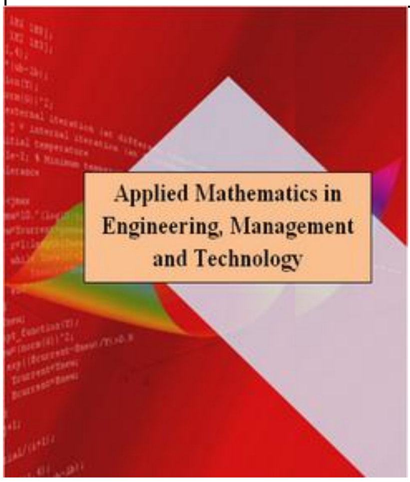


Abstract

The Stock fluctuations usually known as Bullwhip Effect is a very challenging issue in supply chain management. The Bullwhip effect can be considered as amplification in the fluctuation of order, from the retailer to the partners placed upstream of the supply network. In this paper, we describe the network type impact on the accumulation of the individual uncertainty in demand estimation. False demand estimation may cause the factory's production rate greatly exceeds the retailer's sales rate. This will increase stock level in supply network partners, and this effect is amplified in network upstream. The impact of network type on Bullwhip effect is briefly discussed, by illustrative example.

1. Introduction

21st century is the century of further globalization and deregulation of markets. Firms now can easily access to the resources, customers and developed local markets from in any country. Also the customers have more choices in this market. Competition in customer acquisition and increasing the market share, companies are concerned with improving customer service through an efficient supply chains management. The rapid evolution of Supply Chain Management (SCM) a provides an evidence that companies no longer compete but entire value chains (Holweg and Helo 2014). As the concept of SCM evolved the term "network" came into use (Mills, Schmitz, and Frizelle 2004). Supplier–buyer relationships which historically was independent adversarial are becoming cooperative partnerships to improve customer service and cost cutting. The point is cooperative partnerships should be established in the new era. To survive in such an environment, there is an extreme need to develop long-term, co-operative and trusting relationships between buyer and suppliers (Mills, Schmitz, and Frizelle 2004) or in another word, collaborative network for a supply chain partners in which they connect and interact efficiently and effectively. A good investigation for necessity of collaboration can be found in (Barratt 2004).
In Drucker's (1998) new management theories, this concept of business relationships goes over organize entire business processes throughout a value chain of multiple companies (Mehdi Safaei and Thoben 2014). In this new paradigm, there is a need for the integration of business processes of a firm relating to a supply chain (Mills, Schmitz, and Frizelle 2004). Applying the concept of "network" and collaborative operations in SCM for integrating the business processes has been caused to extend the SCM concept into more strategic areas. Dell and Hewlett Packard are examples of those firms which successfully operate collaborative supply networks via information technologies that each partner concentrates on only a few key strategic activities. This inter-organizational collaboration in SC is a form of organizations which the firms can decide about their responsibility in managing each part of supply chain (Mehdi Safaei and Thoben 2014). The concentration in on expertise and collaborating among them leads to a highly competitive performance of the supply chain, increasing product standardization, rapid communication and globalization(Mills, Schmitz, and Frizelle 2004).
Some of the first studies of supply networks took place in the automotive industry (Womack, Jones, and Roos 2007). This four-level framework provided by Harland (1996) shows the roadmap of academic research in this area over time from level 1 in the 1960s to level 4, in the early 1990s (Mehdi Safaei and Thoben 2014) (Mills, Schmitz, and Frizelle 2004).

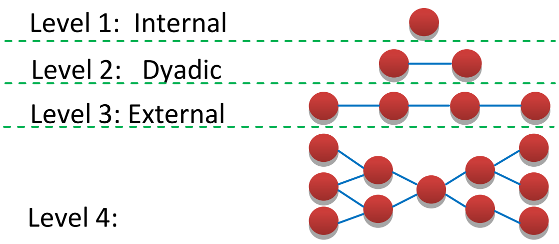


Figure 1: Harland framework for SCM (Mills, Schmitz, and Frizelle 2004)

Based on this framework, value creation within the manufacturing industry is realized in supply networks. So it can be inferred that the management of quality, cost and time is not the issue of one single organization any more but of the collaboration(Mehdi Safaei and Thoben 2014).

Since the market changes time to time, market opportunities are becoming short term and and customer expectations are dynamic, a SC which is eager to capture the market needs to be more dynamic to gain more market share (M.a Safaei, Seifert, and Thoben 2010).

The point is that short term opportunities means dynamic demand. A fixed design of SC can't handle the variability of the demand and leads to inventory oscillation. Inventory oscillations lead to instabilities in supply chains causing boom & bust cycles and overshoot and collapse (M.a Safaei, Seifert, and Thoben 2010). Shortcomings of current production and material flow planning, logistics schematization and control systems or in general, supply chain strategies processes to confront with dynamic circumstances, made the initial idea of reconfiguring the conventional material handling and planning systems. Exploiting the concept in practice as a new logistic and material handling system requires some conformities with continuous improvement methods and with existing material flow and handling strategies.

The objective of dynamic supply chain design is to reaction to the market and capture individual fluctuating demands in a reliable way. It means that planning can't be done based on historical data and a new approach to estimate demand and inventory control is needed to ensure reliable deliveries of supply chains (Mehdi Safaei 2014). In a competitive market, customer's demand should be provided just in time, with desired quality and in a reasonable price.

The problem of inventory oscillations, also known as the Bullwhip or Forrester effect, is unavoidable in a dynamic demand environment (Delhoum 2008). Backlogs, delay in demand delivery, demurrages, warehousing costs and product total prices increase as a result of stock fluctuations and Bullwhip effect (M.a Safaei, Seifert, and Thoben 2010). Other than demand fluctuation, Material handling and flow policies, inventory control and the way that enterprises interact with their supply chain partners have a large impact on stock fluctuations. Designing and organizing appropriate material flow and inventory control strategies in a network in order to reduction of instability in supply chain and put bridle on inventory oscillations can be assessed from the position of network configurator who has to identify and establish adequate relations in the network.

The common basic network which describes the SC network structures types are star, bus, ring, and tree. More complex networks can be built as hybrids of two or more of the basic types called "generalized networks" (Thoben and Jagdev 2010). This research tries to provide the better understanding of the network type impact on uncertainty and Forrester effect.

3. Literature Review

Bullwhip Effect is widely investigated in the modern day SCN management research (Dominguez, Cannella, and Framinan 2015). The configuration of the SCN in most papers is assumed to be serially-linked (Dominguez, Cannella, and Framinan 2015) (Wei, Wang, and Qi 2012) (Li and Liu 2013) (Trapero, Kourentzes, and Fildes 2012). Dominguez et al focused on how two common modelling assumptions in the Bullwhip Effect (BWE) literature (i.e., assuming the return of the excess of goods and assuming a serial network) may distort the results obtained. They considered a robust design of experiments where the return condition (return vs. no return) and the configuration of the Supply Chain Network (SCN) (serial vs. divergent) are systematically analysed. They found an important interaction between the impact of returns on the BWE strongly and the SCN configuration.

Gebennini et al considered two star configuration and analysed the reconfiguration of distribution networks in which order picking activities have a significant impact on the system performance (Gebennini et al. 2013). In of the configurations, it is generally prevented from under- standing the final customer demand, causing information distortions and amplifications of demand variability, i.e. the so-called ‘‘bullwhip effect’’.

Hassanzadeh et al analysed the causes of bullwhip effect in centralized and decentralized supply chain using response surface method (Hassanzadeh, Jafarian, and Amiri 2014). They simulated a three stage supply chains consisting of a single retailer, single wholesaler and single manufacturer under both centralized and decentralized chains. They analysed the causes of bullwhip effect from two dimensions of order and inventory variance using the response surface methodology. Their research results showed that in both supply chains, rationing factor is considered as the least important cause of bullwhip effect. While the wholesaler’s order batching and the chain’s order batching are considered as the main causes for the bullwhip effect in the decentralized and centralized chains, respectively.

Safaei et al proposed a computational method in analysing of delivery time uncertainty for highly complex supply networks (Mehdi Safaei, Mehrsai, and Thoben 2014). They considered an uncertain complex supply network with various configurations.

Zheng-ying analysed bullwhip effect and synthetic compensation in multi-echelon tree-type supply chain (Zheng-ying and Ren-bin 2009). They provided a series of quantitative index of bullwhip effect by which impacts of multi-echelon tree-type topology structure, competition, information transformation, lead time, distribution, prediction on bullwhip were studied. They simulated the whole compensation process under stochastic demand, competition, promotion and flying goods in tree-type supply chain.

Croson et al analysed behavioural Causes of the Bullwhip Effect and the Observed Value of Inventory Information (Croson and Donohue 2006). They studied bullwhip phenomenon from behavioural perspective in the context of a simple, serial, supply chain subject to information lags and stochastic demand.

Agrawal et al studied on impact of information sharing and lead time on bullwhip effect and on-hand inventory (Agrawal, Sengupta, and Shanker 2009). They considered a two echelon (warehouse–retailer) serial supply chain to study the impact of information sharing (IS) and lead time on bullwhip effect and on-hand inventory.

Alwan et al surveyed stochastic characterization of upstream demand processes in a supply chain (ALWAN, LIU, and YAO 2003). They studied bullwhip effect in an order-up-to supply-chain system when minimum Mean Square Error (MSE) optimal forecasting is employed as opposed to some commonly used simplistic forecasting schemes. They showed that that depending on the correlative structure of the demand process it is possible to reduce, or even eliminate (i.e., "de-whip"), the bullwhip effect in such a system by using an MSE-optimal forecasting scheme.

4. Types of Network

The supply network concept is somehow more complex than the supply chain concept (Newlands and Hooper 2009). Supply networks are complex networks including lateral links, reverse loops, and two-way exchanges, and a broad, strategic view of resource acquisition, development, management, and transformation (Fleury and Tereza Fleury 2007) (Harland et al. 2001). However, there are other type of supply networks.

A supply network described by nodes representing the companies and the links/edges (relationships) between these nodes. Network type is defined as the structure of linking between the nodes (M.a Safaei, Seifert, and Thoben 2010). Figure 2 depicts the most possible basic types of a network. Generalized networks can be described as a combination of these basic types.

Linear network shows the interaction of the partners’ in a chain. Maximum in and out degree for any inode (firm) in the network is one. However In this network, multiple tiers exist but every firm has only one supplier. The processed juice industry and natural resource industries are good examples this networks (Pathak, Dilts, and Biswas 2007). In the star networks, all suppliers of the supply network interact with a single firm (manufacturer). Its maximum depth is one, and includes single tier. eBay is a star supply network (Pathak, Dilts, and Biswas 2007).

In the ring-type, firms share resources and play multiple roles. Two kinds of rings are illustrated in figure 2; in the left side ring, each node has a direct relationship with its neighbour nodes but in the other, each node can make a direct relationship to others. Defence supply industries are good example of ring networks in which a firm can simultaneously compete, cooperate, be supplied by and be a supplier to another firm(Pathak, Dilts, and Biswas 2007).

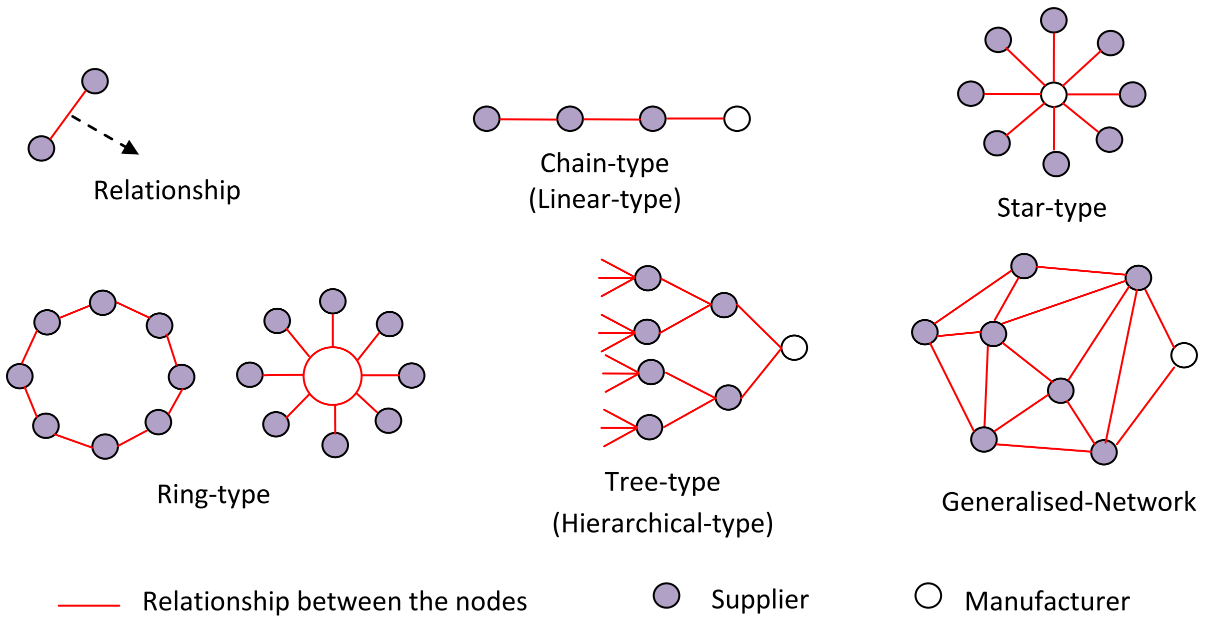


Figure 2: Basic network types (Mehdi Safaei, Mehrsai, and Thoben 2014) (Thoben and Jagdev 2010) (BOCCALETTI et al. 2006)

The Hierarchical topology or tree-type, is a ‘‘normal’’ structure for a supply network, similar tp star topology except that it doesn’t use a central node. It is a kind of directed acyclic graphs (DAG). The tree topology results from the connection of several stars to a network. It is used for dividing complex systems into subsystems. The information and goods flow is generally from left to right (Mehdi Safaei and Thoben 2014).

5. Problem Definition

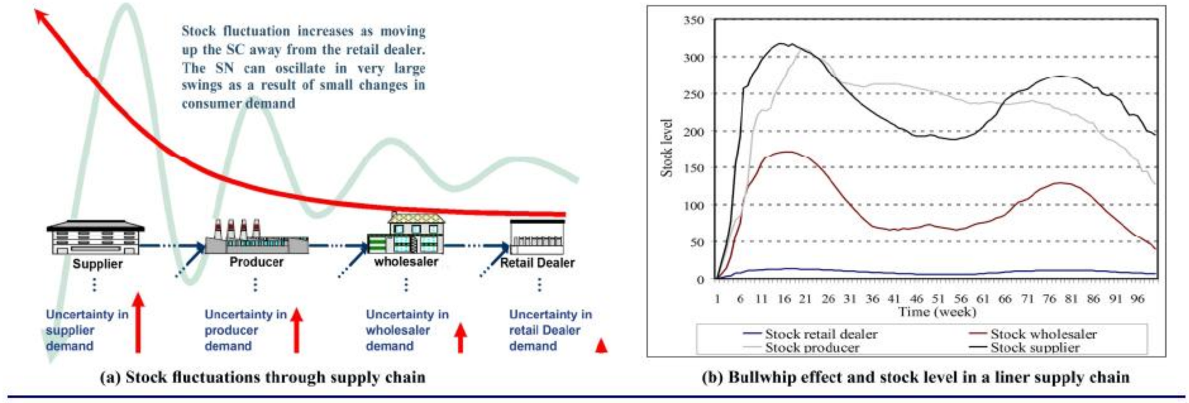
The Bullwhip effect describes the variability of orders to the supplier and retailers. It can be considered as amplification in the fluctuation of order, from the retailer to the manufacturer (Bhattacharya and Bandyopadhyay 2011). So the variance of demand gains magnitude as the demand signal propagates from the retailer to the supplier in a typical four node supply chain made up of a retailer, wholesaler, producer and supplier.

Definition Bullwhip effect points to the three implications: (i) oscillation and fluctuations of demand and inventories; (ii) amplification as when the factory's production rate greatly exceeds the retailer's sales rate, and (iii) phase lag (Delhoum 2008). This phenomenon is characterized as demand distortion in a supply chain(Lee, So, and Tang 2000). Small changes in consumer demand may lead to large variations in others placed upstream. Eventually, the network can oscillate in very large swings, since each entity in supply chain seeks to solve the problem from its own perspective (Muller 2011). This leads to the problem of efficient inventory control and material flows in a supply chains. Figure 3 (a) illustrates Stock fluctuations through supply chain and (b) shows the Bullwhip effect and stock level in each period in a liner supply chain.

Malfunction in any supply network partner such as overreaction to backlogs, neglecting to order in an attempt to reduce inventory and delay times for information and material flow can contribute to the bullwhip effect (Engell 2008).

Considering the description given, stock fluctuation depends on overall inventory control and material flow strategies in supply chain, types of network relations between suppliers and buyers and individual material flow and inventory control policies of the members in a supply chain.

Some research approaches try to solve this problem by optimizing internal elements of systems such as internal material handling, production optimization and etc. while others look for the causes in relationships and interdependencies among different organizations and propose strategies for planning and control overall instigated supply networks.



(a) Stock fluctuations through supply chain (b) Bullwhip effect and stock level in a liner supply chain

Figure 3: Stock fluctuations through supply chain

In this paper, inventory control and material flow policies are both considered when demands and lead times are stochastic. Time horizon is assumed to be *t* periods and backorder is allowed. We develop a multi-objective model for a multi-echelon single item inventory system. Objective functions are minimizing shortages and stock level besides minimizing costs overall the supply chain. We can also put bridle on stock fluctuation by proper restrictions.

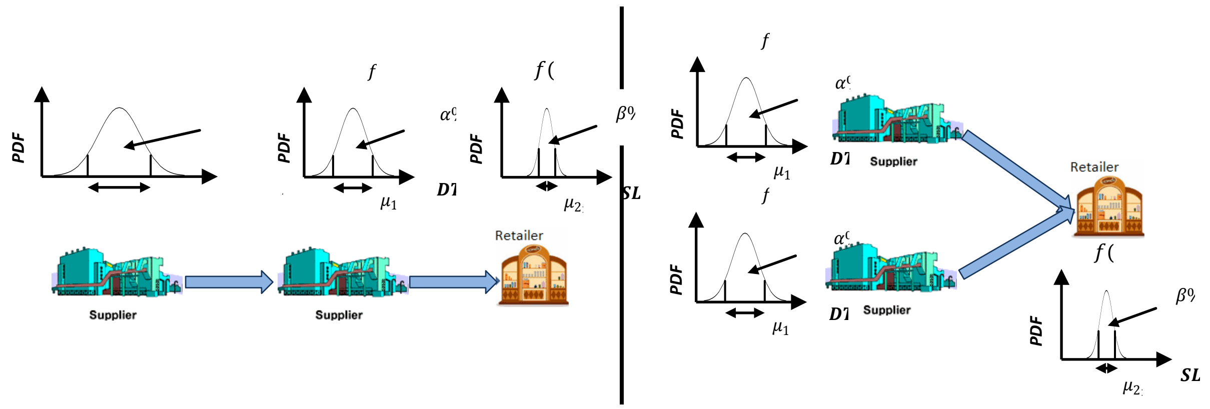
The model is under the assumption of (*s*, *Q*) policy. A *Q* size order is placed when the reorder level (*s*) is reached. In this model the inventory level for each supply chain partner at time *t* is: $S(t) = s_0 + n_t Q - \int_0^t D(t)$, where s_0 is inventory level at the beginning of time period, n_{t0} is number of deliveries until time *t* in this period, *Q* is the order quantity and *D*(*t*) is the demand rate.

The problem is analyzing how the members' individual strategies and network overall strategies influence the stock fluctuation in a supply chain in different network types. The knowledge about the interdependencies between these strategies and the stock fluctuation is important to identify those parts of the network which has the highest potential for improving the total stock fluctuation in order to develop a proper approach to achieve stability and proper material handling system in a supply chain.

5. The Impact of Network Type on Bullwhip Effect

In this section, we discuss the accumulation of an individual stock level in a network with three nodes (with one retailer and two suppliers). Figure 4 a. shows liner configuration of a three node supply network. As it is illustrated, demand uncertainty in retailer amplifies the uncertainty at supplier 1 as a result of Bullwhip Effect. Similarly this uncertainty increases going upstream of network i.e. in supplier 2. So the stock level in supplier 1 is much greater than retailer and the stock level in supplier 2 is much greater than stock level in supplier 1.

Figure 4 b. shows star tape configuration of a three node supply network. As the result of Bullwhip Effect, demand uncertainty in retailer amplifies the uncertainty at supplier 1 & 2.



a. Liner type configuration of a three node supply network

b. Star type configuration of a three node supply network

Figure 4: The impact of network type on Stock fluctuations

Although the stock level in supplier 1 & 2 is much greater than retailer, it is obvious that the overall stock level in the network is less than accumulative stock level in liner type. So we can conclude that: the configuration of supply network is directly effects on final accumulation of uncertainty in the network and as a result on Bullwhip Effect.

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