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Supply Chain Management and Bull Whip Effect: A Conceptual Framework for Efficiency Improvement in Supply Chain

Tapan K Panda and Prasanta K Mohanty***

Supply Chain Management (SCM) is essential for the survival and growth of any organization. It removes the communication barrier and helps in reducing redundancies through coordinating, monitoring and controlling processes. A supply chain involves two cycles and each is performed at the interface levels of two successive stages of a supply chain process. The SCM process works as an interface of sequenced steps where one step precedes another step. There are established linkages between business operations and supply chain in terms of interactions between flow of information, materials, money and manpower. SCM as a process has its scope covering the point of origin to the point of consumption. It requires coordinated efforts and cooperation between a company's business operations in supply chains. The stocking level variability in supply chains tends to be distorted as it is moved from upstream in the supply chain. It may so happen that there is a variance of orders which can be larger than the sales and distribution cycle as one moves upstream in the SCM process. This is known as blue whip effect. We can observe such phenomenon in frequently purchased product categories and also with products with large variations in their demand and supply due to seasonality of demand and supply. This research paper introduces the concept of blue whip effect and how it impacts supply chain. Attempts are made to crystalize the blue whip effect through a framework that explains the impact of this effect. The paper also highlights how this effect can be minimized or removed from the supply chain cycles by bringing changes in business operations. The counter-strategies suggested in this article are based on both earlier research reference as well as business practices followed by large organizations. This article will help researchers and students to understand the impact of blue whip effect and apply counter-strategies for improving supply chain efficiency.

Introduction

The concept of supply chain, proposed in 1985 by Houlihan (Cooper *et al*., 1993), suggests a "process for building improved and stronger upstream and downstream business linkages". McAfee *et al.* (2002) focused on improving value for the ultimate customer (Lummus *et al.*, 1998). Related definitions of the supply chain include: "how to integrate and perform logistics and manufacturing activities" (Pagh and Cooper, 1998), or more generally, collaboration among supply chain partners. A more elaborate and applied definition is: "the connected series of activities concerned with the planning and controlling of raw materials, components, and finished products from suppliers to the final customer" (Vickery *et al.*, 1999). The purpose of Supply Chain Management (SCM) is

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described by Kaufman (1997) as to "remove communication barriers and eliminate redundancies" through coordinating, monitoring and controlling processes. As pointed out by Akkermans *et al.* (1999), the characteristics of a supply chain must include (1) multiple echelons; (2) focus on integration; and (3) goals of service and profitability, and may also involve (1) collaborative processes; and (2) value adding considerations.

The traditional view on a supply chain is the cycle view. SCM as a process has its scope covering the point of origin to the point of consumption. It requires coordinated efforts and cooperation between company's business operations in supply chains. The stocking level variability in supplying chains tends to be distorted as it is moved from upstream in the supply chain. It may so happen that there is a variance of orders which can be larger than the sales and distribution cycle as one moves upstream in SCM process. This means each cycle is decoupled from the next cycle via an inventory level so that the preceding cycle can function independent of the next cycle and optimize its own processes, and is not affected by supply chain problems of another cycle. For example, if a cycle has replenished retailer inventories by delivering from producer/manufacturer's end product inventory and another cycle that takes care of replenishing the manufacturer or producer's inventory by manufacturing or producing new end products, then there is likely an inventory-sales mismatch in the supply chain pipeline. This is known as blue whip effect. We can observe such phenomenon in frequently purchased product categories and also with products with large variation in their demand and supply due to seasonality of demand and supply.

This conceptual paper discusses the previous literature on supply chain with particular reference to 'bull whip effect'. However, in order to better understand the 'bull whip effect' with an elaborate evaluation of supply chain characteristics, this paper also introduces the concept of 'bull whip effect', its evolution in supply chain market, by illustrating beer game model, its causes and measurement methods, and scope for application in grocery business.

Conceptualization of a Food Supply Chain

Future group, one of the leading retailers in India, has to provide over 650 stores with the right products at the right time depending on the needs of the customers. Each of these 650 stores receives daily inventory from a national chain (for non-fresh products) and from one of the five regional distributors for fresh products. On an average each store carries about 15,000 different kinds of articles. In a scenario like this, a large number of manufacturers are required to replenish inventory levels at distribution centers (both national and regional levels). Each of these manufacturers has many suppliers who deliver key ingredients for the manufacturing process and the transport is arranged via a third party logistics provider. This indicates the importance of a good supply chain network that combines not only the producers but also the distributors at both national and regional level and shows the importance of SCM for the smooth operation of food and grocery retailers in a country like India.

Management of Supply Chain Networks: A Literature Review

SCM has been of interest for many years in literature (Oliver and Webber, 1982; Houlihan, 1987; and Jones and Riley, 1985 and 1987). Houlihan (1985) state that SCM is an influential ingredient in today's literature and thinking in the field of logistics. The synchronization of business operations between multiple relationships in marketing channels is often referred to as SCM (Lambert *et al.*, 1998). Alderson (1957 and 1965) recognizes the interdependence between companies' business operations in marketing channels.

Forrester (1958) also acknowledges the linkages between business operations in marketing channels, e.g., in terms of the interactions between the flows of information, materials, money, and manpower, and capital equipment. Forrester (1961) discusses the dynamics in the business environment and writes that industrial dynamics views business as an integrated system. Furthermore, Weld (1961) stresses the importance of addressing the distribution channel as a whole. SCM addresses the supply chain from the point-of-origin to the point-of-consumption. Mentzer *et al.* (2001) and Lambert (1992) argue that there is a necessity to extend SCM towards other supply chains. Furthermore, SCM requires cooperation and coordination between companies' business operations in supply chains (Xu *et al.*, 2001). Otherwise, the stocking level variability in supply chains tends to be distorted as it is moved upstream in the supply chain (Lee *et al.*, 1992; and Towill, 1996). Lee *et al.* (1997a) write that the variance of orders may be larger than that of sales and the distortion tends to increase as one moves upstream in the supply chain. This phenomenon is referred to in literature as the 'bull whip effect' (Chen *et al.*, 2000). In fact, practitioners and consultants have striven to deal with the bull whip effect, e.g., in the automotive, textile, and retail industries.

In the automotive industry, the term just-in-time has been used, while in the textile and retail industries, the terms quick response and efficient consumer response have been applied. The whole idea behind using these terms is with an aim to reduce stocking level variability in supply chains and improve profitability by substantial reduction in costs, leading to top overall improvement in the performance of supply chain.

The Beer Distribution Game at MIT

It is important to understand the bull whip effect for its application in any industry. Let us take the popular 'beer game' route to explain the impact of blue whip effect on supply chains. The beer distribution game is a management game developed at MIT Sloan School of Management in the USA (Forrester, 1961) to give managers and students insight into the consequences of managerial actions in successive stages of a supply chain. Beer game provided an exceptional way to illustrate the impact of a bull whip effect on supply chain performance and developed a new discipline of research on SCM research.

The beer game is based overdistribution and inventory management. It is a role-playing game. The participants have to minimize the inventory carrying costs by managing inventory levels in the supply chain for products. The game consists of four supply chain stages, namely, retailer, wholesaler, distributor and manufacturer. Each player has its own buffer stock to protect its business from business and seasonal fluctuations in demand for the product. All that each player has to do is to fill the orders it receives from its direct customers and then decide how much it wants to order from its suppliers. The game is designed in such a way that each player has local information but severely limited information regarding global information on inventory levels and orders. In this game, only the retailer knows the end customer demand.

There is a time line in the game. It takes two weeks to mail and order and another two weeks to ship the requested amount of beer from one player to the next. There is no possibility of cancelling the order. The stock out cost (which is associated with the possibility of losing customers) is double of the inventory carrying cost. The objective of this game is to minimize the sum of the total costs associated with players in SCM of the beer. One gets remarkable results after a few weeks of playing this game. Although consumer demand is doubled in every fifth week, one can observe huge order fluctuations and oscillations in the supply chain. While playing this game, the producer receives demand patterns with 900% amplification compared to end consumer demand fluctuations.

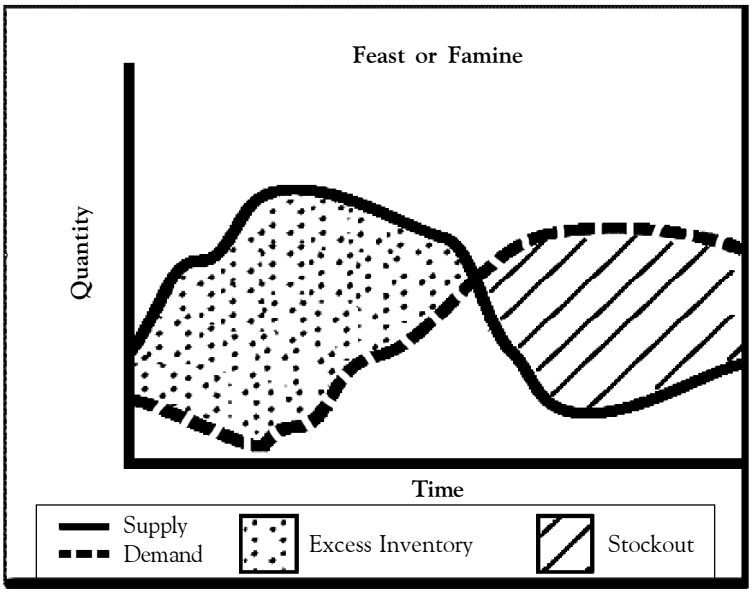
It also brings into picture huge stock outs at retailer end. When one plays this game with different set of people like students and managers with same structure and flow, similar results are obtained, which means that despite participants acting very differently as individuals while ordering the inventory, the overall behavioral trend remains the same. There is significant oscillation and amplification of order patterns and a distinct phase lag in reaction time leading to poor delivery performance and high costs. As one goes further upstream in the supply chain, there will be larger variations in demand.

This phenomenon in which orders to the supplier tend to have larger variance than orders from the buyer, and the distortion propagates upstream in an amplified form (i.e., variance amplification) is called the Forrester effect (Towill, 1997), named after the person who discovered it, or the bull whip effect (Lee *et al.*, 1997a), named so for the variations in reaction down the length of a whip after it is cracked. The effect has serious cost implications. The increased variability in the order process (1) requires each facility to increase its safety stock in order to maintain a given service level; (2) leads to increased costs due to overstocking throughout the system; and (3) can lead to an inefficient use of resources, such as labor and transportation, due to the fact that it is not clear whether resources should be planned based on the average order received by the facility or based on the maximum order (Chen *et al.*, 1999). Furthermore, material shortages can occur due to poor product forecasting.

The Evolution of Blue Whip Effect

Bull whip effect was first found at Proctor & Gamble (P&G), where logistics executives were examining the order patterns of one of their bestselling products, Pampers disposable diapers. It is found from the study that the sales at retail levels were fluctuating due to changes in demand patterns. When the same was checked by analyzing the order placed by the retailer to the distributors, they could find a variation in the actual products sold and order placed in a specific period of time. On inspection of these orders placed by the distributors to the manufacturer, it was found that the orders varied more and the orders placed by the manufacturer to their supplier had the highest variance. So they observed that while going up the supply chain, the demand variability swings were on the rise and increases at each of these levels in the supply chain. This effect was named as the bull whip effect by the P&G executives as it resembled a bull whip. The bull whip effect is also known as 'whip-lash' or the 'whip-saw effect' (Figure 1).

Figure 1: The Bull Whip Effect



Companies like HP had to rely heavily on the sales order from the resellers to make product forecasts, capacity planning, inventory planning, and production scheduling. They also found that the demand information was distorted, causing lots of problems in supply pipeline. Other companies like Eli Lilly and Bristol Meyer Squibb, distribution companies like McKesson, and retail stores like Longs Drug Stores faced similar problems of inventory duplication. It was observed that almost all computer manufacturing companies faced problems due to bull whip effect. Such a phenomenon created an urgency not only for research on this effect but also for developing suitable measures to overcome such problems.

Let us discuss the implications of a bull whip effect. Such an effect indicates that the stock level variations in supply chain tend to be higher upstream than downstream. It is caused by factors such as limited/no information sharing across the supply chain, unavailability or insufficient market data, improper method of forecasting, and any other emerging uncertainties. Fransoo and Wouters (2000) write that the bull whip effect refers to the increasing variability of demand further upstream in the supply chain, and conclude that the theory of measurement of the bullwhip effect in a practical setting has received limited attention. The research of the bullwhip effect has considered inter-organizational echelons, such as two-echelons between companies (e.g., Chen *et al.*, 2000; Fransoo and Wouters, 2000; and Yu *et al.*, 2001) or three-/multi-echelons between a sequence of companies (Metters, 1997; and Lee *et al.*, 1997a and 1997b), or intra-organizational echelons, such as companies' inbound and outbound logistics flows (Svensson, 2003) in supply chains. In addition, Svensson (2003) introduces the term 'reversed bull whip effect' (i.e., increased downstream variability), as opposed to the traditional term 'bull whip effect' (i.e., increased upstream variability).

Measuring Bull Whip Effect

The first research to extensively study the amplification of demand information in a supply chain was reported by Forrester in his seminal book *Industrial Dynamics* (Forrester, 1961). In his seminal work, Forrester reduces the root causes of demand amplification by a double whammy approach, namely, delay in transfer of demand information and then delay in transferring physical product through the supply chain by managing the lead time.

According to Lee *et al.* (1997b), the term 'bull whip effect' was first used by Proctor & Gamble when they experienced extensive demand amplifications for their diaper product 'Pampers'. Lee *et al.* (1997a and 1997b) describe the bull whip effect as the result of information distortion in a supply chain, where companies upstream do not have information on actual consumer demand. So they put their order on the basis of the incoming order from the next downstream company. This behavior or practice may lead to amplified order variability, i.e., demand coming from a downstream company has a lower variability than an upstream company in the supply chain.

Causes of the Bull Whip Effect

One can learn more about blue whip effect from the well-known 'beer game' developed at Harvard Business School. In the game, participants (students, managers, analysts, and so on) play the roles of customers, retailers, wholesalers and suppliers of a popular brand of beer. As a part of the game, the participants are not allowed to communicate with each other and they must make their decisions based only from the orders received from the next downstream players. The ordering pattern has a common recurring theme, i.e., the variability of an upstream site which will be greater than the downstream site. This will illustrate a simple and powerful bull whip effect.

This level of amplified order variation can be attributed to the channel members' irrational decision making or conservative approach to inventory management. Indeed, Sterman's experiments showed that human behavior, such as misconceptions about inventory and demand information, may cause the bull whip effect. In contrast, a study conducted by Lee *et al.* (1997a) shows that the bull whip effect is a consequence of the players' rational behavior within the supply chain's infrastructure. So companies that want to control the negative implications of blue wheel effect have to focus on the processes to modify the supply chain's physical as well as information flow infrastructure rather than the behavior of the decision maker. There are (Lee *et al*., 1997a) four major causes of the bullwhip effect. They are as follows:

- Demand Forecast Updating: It is interesting to observe how links in a supply chain base their expectations about future demand on orders they receive from their succeeding or proceeding link. If there is an increase in order, it leads to greater demand forecast which automatically gets transferred to the next link by increased order quantities. That link also observes increase in demand and updates its forecasts and distorts information for the subsequent link. The same cycle operates in reverse way when there is a decrease in demand at end customer level. A possible solution for this is to make consumer demand data directly available to all the companies in the supply chain and mostly to upstream companies in the supply chain. One can use a single source of forecasting for the entire supply chain.
- Order Batching: Though there can be a demand fluctuation either by increase in demand or depletion of inventory, companies cannot place immediate orders with its suppliers. There will be an accumulation of demand before an order is issued due to fixed order costs or distribution efficiency. Let us say a company receives its orders daily but accumulates them to place an order with the supplier on a weekly basis. So there will be a higher variability of orders placed with the supplier than the demands the company itself faces. One can make consumer's data available across the supply chain, and to add onto that, one can reduce batch size of the order and increase order frequency, which will help in reducing this effect. One can reduce batch size by using EDI so that administrative cost of ordering can be reduced and use of third party logistics service provider can make smaller loads more economical and reduce the supply chain cost substantially.
- Price Fluctuations: Many channel members wish to take benefit of price fluctuations. Companies undertake consumer and trade promotions to push sales and offload inventory. So prices fluctuate due to promotion programs which create a situation of variability in demand over a period of time. When the price of the product is low, a customer buys in bigger quantities than what he actually requires. So when prices return to normal, the customer buys less

than normal to deplete his inventory. One should take steps to stabilize prices and reduce incidents of consumer and trade promotions so that bull whip effect can be reduced.

- Rationing and Shortage Gaming: It is observed that when product demand exceeds supply, a supplier should ration its products to customers. If customer knows this or has previous purchase experience, then he will order more than what actually he requires. In a situation where there is no shortage, orders disappear. One should introduce rationing methods based on past sales rather than on orders placed. This will take away the incentives to customers to inflate order sizes.

The following section discusses methods and strategies to be followed for countering the bull whip effect. A good amount of effort has been spent in researching about the causes of bull whip effect. Some researchers have highlighted the lead times (both order and delivery) as one of the major reasons contributing to the increase in variability in the supply chain. It is observed that as lead time increases, there is an increase in variability of supply chain. While calculating safety stock level and reorder point, one can multiply estimates of the average and standard deviation of the daily customer's demands by lead time. This leads to a proposition that a greater lead time means a small change in demand variability. Such a forecast leads to significant amount of safety stock level; reorder quantity and this in turn leads to decreasing variability.

Strategies to Counter Bull Whip Effect

One can mitigate the blue whip effect by means of better management information system, greater information sharing across the distribution channel and channel alignment with an aim to improve operational efficiency. In addition, the bull whip effect can be mitigated by reduced lead times, revision of reordering procedures, limitations of price fluctuations, and the integration of planning and performance measurement (Towill, 1996 and Fransoo and Wouters, 2000). Baljko (1999) writes that the bull whip effect in the supply chain may be eliminated through measures such as shared knowledge with suppliers and customers to better gauge demand, cooperation with supply chain partners to determine what information is causing an overreaction, and usage of Internet-enabled technology and the application of the web to speedup communications and improve response time.

It is but natural that bull whip effect can be minimized if companies can reduce the level of uncertainty by sharing desired information along the whole supply chain. They should provide actual information on customer demand, helping reduce dependency on sales forecasting. They should rely more on actual demand data on forecasted information. The variances in customer demand process, either due to seasonality or nature of the product or any other known reasons, can be minimized by drastically reducing price promotion, following a pricing strategy consistent with market situation. They should try to offer prices as per the price value proposition than undertaking periodic price

promotion to boost sales and thus creating a situation that may lead to the birth of bullwhip effect in the supply chain.

Lead time can be reduced by adopting lean manufacturing and reducing costs of batching orders. It is observed that variance in order is dependent on the lead time taken for replenishment. Electronic Data Interchange (EDI) can significantly reduce order lead time that is one of the components of the total lead time between two supply chain stages. Furthermore, companies should realize that greater savings could be realized by implementing computer order system, allowing administrative costs reduction (small orders). Finally, adopting strategic partnerships, for sharing information and effective inventory management along the whole supply chain can significantly reduce the bull whip effect. One of the most important strategic partnerships is the Vendor Managed Inventory (VMI): manufacturer manages its own inventory product at the retailer outlet, deciding how much inventory to keep on hand and how much to ship to the retailer in each period (Chen et al., 2000).

Wang *et al.* (2011) affirm that the bull whip effect caused by certain predictable factors is only one kind of information distortion. The authors have defined an extended bull whip effect caused due to uncertain factors which can be predicted a priori in the SCM process. There are various reasons for this 'extended bull whip' effect and it can be actual or contrived by the practicing manager. Such extended bull whip effect is detrimental to business growth and carries the potential of destroying the business value information flow within the levels in supply chain, leading to reduction in efficiency, wastages of resources and idle manpower utilization. Even though Lee *et al.* (1997a) refer to a kind of flexibility (limited overtime) as an action to counteract the bull whip effect, there are none study the interaction between flexibility and bull whip effect reduction.

Lee *et al.* (1997a) developed a typology based on the causes of the bull whip effect and the ways to control the bull whip effect. Chen *et al.* (2000) illustrate that the bull whip effect can in part be decreased by centralizing demand information. McCullen and Towill (2001) show from supply chain modeling and dynamic simulation four material flow principles which can be used to reduce the bull whip effect, namely, control system, time compression, information transparency, and echelon elimination. Kelle and Milne (1999) conclude that the negative effect of high variability and uncertainty can be decreased by small frequent orders.

Metters (1997) indicate that the importance of the bull whip effect to a company differs greatly depending on the specific business context. Fransoo and Wouters (2000) introduce a method to document and define various ways of measuring the bull whip effect. Yu *et al.* (2001) argue that supply chain partnerships can mitigate deficiencies associated with decentralized control and reduce the bull whip effect. From the literature review, it is found that bull whip effect of order of releases and amplification of safety stock increases within the supply chain even when there is no trend of seasonal pattern observed. This has become a phenomenon in frequently purchased product categories.

Table 1 shows the different methods to handle the different causes of the bull whip effect. It also summarizes the framework for supply chain coordination initiatives.

Table 1: Framework of Supply Chain Coordination Initiatives

Causes Initiatives	Information Sharing	Channel Alignment	Operational Efficiency
Demand Forecast Update	Understanding system dynamics Use Point of Sale (POS) data Electronic Data Interchange (EDI) Internet	Vendor Managed Inventory (VMI) discount for information sharing consumer direct	Lead time reduction Echelon-based inventory control
Order Batching	EDI Internet ordering	Discount for truckload assortment. Delivery appointments consolidation logistics outsourcing	Reduction in fixed cost of ordering by EDI or electronic commerce (CAO)
Price Fluctuation		Continuous Replenishment Program (CRP) Everyday Low Cost (EDLC)	Everyday Low Price (EDLP) Actively Based Costing (ABC)
Shortage Gaming	Sharing sales, capacity and inventory data	Allocation based on past sales	

Source: Adopted from Lee et al. (1997)

Discussion and Conclusion

It is important to not only understand the bull whip effect but also to develop strategies to counter the same in any industry. An efficient management of supply chain and counter strategies for controlling bull whip phenomenon helps marketers and operation managers to develop a smooth and effective supply chain network that can improve supply efficiency and develop efficient logistics management. Many of the researchers owe both Forrester and Burbidge a great deal, since they generated the following four supply chain design principles;

- Control system principle: There is a need to select the most appropriate control system best suited to achieving user targets. Such a decision will necessitate accessing important supply chain 'states' and reducing unnecessary guesswork from the SCM system.
- Time Compression Principle: This principle suggests that every activity in the supply chain should be undertaken in the least possible time needed to achieve the task. This means removal of 'value added time' from the system. It also suggests on-time delivery of what is actually required. This principle also covers process capability.

- Information Transparency Principle: This principle suggests that all the players should access the data which is free of 'noise' and 'bias' up to the last minute. This principle suggests simultaneous removal of information delays in the system as well as 'double guessing' of other players about the desired information levels. Information on inventory levels, work in progress, flow rates and order size will be available throughout the chain, and managers can take decisions via a suitable decision support system.
- Echelon Elimination Principle: This principle suggests that there should be a minimum number of echelons appropriate to the goals of the supply chain. The objective is to have not only the optimum level of inventory (leading to situations where one can have zero inventory) but to have the minimum stocks at right place at right time.

Forrester has implied another principle which was also proven by Burbidge. This can be called the fifth principle.

- Synchronization Principle: In Forrester simulations, all events are synchronized so that orders and deliveries are visible at discrete points in time. By referring to multiple customers working on EBQ reorder principles, Burbidge has shown that such a phenomenon produced an emphatic bull whip effect. This was subsequently eliminated by continuous ordering synchronized throughout the chain.

This is very important as a source of bull whip as demonstrated in the machine-tool industry (Anderson *et al.,* 2000). This is called the sixth principle, which is inherent in the original Forrester supply chain model.

- Multiplier Principle: This principle explains a situation where orders directly multiply by a knock-on effect between the product manufacturers and their suppliers. If a product manager replaces all his machine tools on a 10-year cycle, it may decide to increase planned capacity by 10% in one year, leading to its machine tool order being doubled as a multiplier of ten to one.

There are four further principles emerging from extensions to the Forrester approach, as published by Lee *et al.* (1997a), and which have been shown by them to be significant bull whip generators.

- Demand Forecast Principle: All forecasts are estimates and their accuracies are always associated with assumptions and probabilities. Any attempt made to improve the inventory situation by building safety stocks and capability for trend detection may result in bull whip effect. All demand forecasts should cope with issues like 'product substitution' in which available stocks are sold in place of stock out items.

- Order Batching Principle: Burbidge has deplored the bane of EBQ approach. Under this principle time phased aggregation of orders also leads to bull whip effect, leading to 'lumpy' deliveries, and hence returns as 'lumpy' orders, which is a certain root cause of bull whip.
- Price Fluctuation Principle: Many a time, marketing programs are designed to deliberately empty over full pipelines. Such a decision may backlash with over ordering so as to take advantage of discounts available during the offer. When the retailer has enough stock, his next order cycle reduces to almost 'zero' in a typical boom-and-bust situation.
- Gaming Principle: There is a concept of 'hedging' seen in SCM. In an actual or perceived shortage situation, people will place orders to hedge against unpredictable supply. Both the supplier and customers are involved in this game of hedging and supply risk minimization. There is also double guessing.

Bull whip effect has a significant impact on bringing efficiency in supply chain networks. It is important to observe the blue wheel effect on frequently purchased product categories and apply the counter-strategies to control its negative effects on the supply chain to make it efficient and impactful. This literature survey and conceptual framework will help not only in developing a framework but also in designing effective research hypotheses for furthering research work on bull whip effect. ⌘

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