Causes and Remedies of Bullwhip Effect in Supply Chain

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Abstract

A chain is as strong as its weakest link. The strength of a supply chain is determined by the strength of the information link across it. This paper deals in detail with the causes for the distortion of information (Bullwhip Effect) in the supply chain and the remedies for reducing this effect.

Keywords:
Bullwhip Effect, Supply Chain, Variability.

1. Introduction

A supply chain is, “a web of autonomous enterprises collectively responsible for satisfying the customer by creating an extended enterprise that conducts all phases of design, procurement, manufacturing, and distribution of products” [11]. This involves creating an extended enterprise that conducts all phases of design, procurement, manufacturing and distribution of finished goods. Customers, suppliers and manufacturers are the three primary elements of any supply chain. The main objective of a supply chain is to synchronize the requirements of the customer with the flow of material from suppliers in order to get a balance between the conflicting goals of a supply chain such as high service level, low inventory investment and low unit cost [10,p3]. The prime responsibility of a supply chain is to move the raw material from the point of procurement to the point of consumption with minimum lead-time.

Today, companies operate as individual firms even though they form a part of a supply chain. This reduces the effectiveness of the supply chain in terms of poor service level, high operating cost and increased non-value adding activities. The entire supply chain can be viewed as a single unit called the extended enterprise. Doing this reduces information distortion across the entire chain and helps in decreasing the Bullwhip Effect. The main objective of effective supply chain management is to weave each of the supply chain partners with conflicting objectives and opinions into a seamless fabric with effective information flow, physical distribution flow and cash flow for the benefit of the end customer [9,p1]. The key link in many supply chains is information. As we integrate suppliers and manufacturers with conflicting objectives and strategies, information sharing becomes the weakest link of the supply chain. As each manufacturer has different views of interpreting customer information, the variation of the information increases as we go up the supply chain. This amplification of variation as we move towards the upstream side of the supply chain is called a Bullwhip Effect or Whiplash Effect [8].

Figure 1 illustrates a simple six-stage general supply chain: consumer, retailer, wholesaler, distributor, manufacturer and a supplier. The retailer observes consumer demand and places orders to the wholesaler. The wholesaler receives product from the distributor who places orders to the manufacturer. The manufacturer places an order for raw materials, to the supplier. Thus, the demand information flows from the consumer through various supply chain links to the supplier.
Figure 1: Generic Supply Chain Model [8]

Figure 2: Bullwhip Effect in Supply Chain [Adopted from 8]
Figure 2 provides a graphical representation of orders, as a function of time, placed by different facilities (Factory, retailer, wholesaler, distributor and customer). The variation in the customer demand is less when compared with the variation caused by the intermediaries. The variation in the demand information increases as it reaches the manufacturer. Many factors and policies followed by the intermediaries influence this variation. The causes for this variation and the remedies for the factors that influence this are discussed in detail in this paper.

2. Background

In the 1980s, companies discovered new manufacturing technologies and strategies that allowed them to reduce cost and compete effectively in the market. Strategies like Just In Time (JIT), Kanban, Lean Manufacturing and Total Quality Management (TQM) became popular. By incorporating these strategies, companies reduced their manufacturing cost. Dynamic variations in customer demand forced companies to implement a new system that enabled them to increase the service level and quality with the same manufacturing cost. This was achieved by linking the customers and the suppliers by a concept called supply chain management. This linking concept had its own pros and cons due to the conflicting objectives and policies employed by the supply chain partners. The objective was to discover the possible ways to counter the information distortion due to the differences in the objectives and policies of the supply chain partners [8]. Whitman, et al. [11] compared the term supply chain with research in extended enterprises and virtual companies. It stressed the need to take a holistic view of the enterprise. Extensive research has been performed to find the reasons for the Bullwhip Effect and its remedies. Lee, et al. [5], postulated that there are four major reasons for the Bullwhip Effect. They are:

1. The inaccurate forecasts of demand called “demand signal processing”.
2. Rationing of the products by the manufacturer to retailers due to some limitations in production called the “rationing game”.
3. The ordering policy used by retailers called “order batching”.
4. Discounts and seasonal price variations.

They devised a set of simple models to illustrate how each of these factors can lead to the amplification of variance as one moves up the supply chain. They also proposed some remedies for each of these factors.

Richard Meters, [7] postulated the seasonal demand and the variation in demand due to forecasting errors as the two basic reasons for Bullwhip Effect. He viewed the impact of forward buying and order batching on the profitability of the system. The paper stated that it is relatively easy to tackle the distortion caused by seasonal demand, if the variation in the seasonal demand changes frequently.

Whitman, et al. [11] described that frequently when implementing new or maturing technologies, the impact to the entire supply chain is overlooked. They proposed a method as to how the total supply chain issues are considered in a new technology implementation. The methods given would reduce the Bullwhip Effect to a considerable extent. The paper describes modeling techniques like SADT (Structured Analysis & Design Techniques) and IDEF (Integrated DEFinition). This paper views the entire supply chain as a single unit called the extended enterprise. By considering the entire supply chain as an extended enterprise reduces information distortion across the entire chain thereby helps in decreasing the Bullwhip Effect.

Kelle, et al. [3] described the effect of the ordering policy on the demand variation in the supply chains. They considered retailer individual orders, aggregated retailer orders and the suppliers ordering / production policy to study the variation introduced by the ordering policy. They stressed that the demand correlation plays a major role in the demand variation. They stressed the need for autocorrelation to reduce the variation in demand.

Manuel, et al. [1] suggested that inventory is the economic incentive for reducing fluctuations in production levels, as well as protection against stock outs as it absorbs the demand variation. They stated that effective implementation of the inventory stabilization function will reduce the observed variability in production when compared with the variability in the market demand.

3. The Causes of Bullwhip Effect

It can be said that the Bullwhip Effect is due to the rational behavior of the decision-makers of a supply chain under a given structure. This implies that companies desiring to gain control of the Bullwhip Effect have to look at the entire supply chain structure and related processes.
There are several factors that contribute to the *Bullwhip Effect*. The factors that contribute significantly are: Demand forecast updating, Order batching, Price fluctuation and Hoarding and Rationing [9]. Each of these factors will be discussed in detail later in the following sections. Understanding the causes of the *Bullwhip Effect* aids the design and development of strategies to counter the effect.

3.1 Demand Forecast Updating:
Demand forecast updating is a result of the perception of decision makers in the chain. Decision makers create a mental model of the supply chain functioning and the demand patterns they observe. This mental picture influences their decision-making. When every downstream member places an order, the upstream member readjusts the demand forecast and then places an order to the upstream partner in the supply chain. These orders get processed and then finally reach the manufacturer as overall demand for the product. Here, the final product demand that reaches the manufacturer is an exaggerated demand and not the actual product demand. Due to this, the manufacturers’ product scheduling, capacity planning, inventory management, and part procurement multiplies leading to multiple changes in all the links. This is the major contributor to the *Bullwhip Effect*.

3.2 Order Batching:
In a supply chain, each supply chain member places orders on an upstream member using some inventory replenishment mechanism. As demand depletes inventory, a company or a supply chain entity may not order continuously, but instead will accumulate inventory replenishment requirements from its supplier. The wholesaler/retailer doesn’t place an order with the upstream member as soon as he gets information about the depleting quantity of product. He follows his own style of order placing. He might order weekly or monthly, instead of ordering frequently as required to reduce the cost per order. The reasons for such ordering policies can be due to the supplier’s capability of handling frequent orders, costs and time requirements of order processing or purchase order generation. As order cycles of disparate customers tend to randomly overlap, the result is a more erratic demand pattern than the actual demand seen by the customers - hence the *Bullwhip Effect*.

3.3 Price Fluctuation:
Distributors periodically have various schemes and promotions like rebates and coupons to increase customer demand for the product. The buying pattern of the customer during such periods does not reflect buying needs, but is a seasonal condition. This variation in buying pattern is much higher than the variation in the consumption rate. Promotions can also be an incentive for buying more than the demand requirements. These promotions result in some form of price fluctuations, which force the customer to buy more than required or to wait for a favorable price before reordering or buying. This yields temporary benefits for one player in the supply chain, but creates the *Bullwhip Effect* and increased costs upstream.

3.4 Hoarding and Rationing:
Frequently in budget driven organizations, artificial demand for a product is created as a pre-budget hoarding frenzy takes place. Here, the retailer/distributor creates an artificial scarcity for the product anticipating a price hike or a price reduction for the product. As a result, the customer tends to pay more or less than the original price of the product. In such cases, the *Bullwhip Effect* is visible in the form of excess inventory piled up in warehouses, poor customer service, high cost of correction and long-waiting time for product by the customer.

The paper still discussed the factors, which plays a major role in inducing the *Bullwhip Effect* in supply chain. Apart from price fluctuations and product rationing, forecasting and ordering policies are the significant factors that affect the smooth information flow in the supply chains. It is better to quantify before thinking of possible remedies. The following section discusses about the quantification and possible remedies of *Bullwhip Effect*.

4. Quantification
We can quantify the *Bullwhip Effect* by comparing the variation in the demand to the variation in the order quantity. The variation in the demand is a function of lead-time. The variation in the order quantity is a function of the forecasting time horizon. The ratio of the variation in the order quantity to the variation in the demand should always be as low as possible. This will reduce the contribution of lead-time and ordering frequency in turn, reducing the *Bullwhip Effect*. Instead of using variance as the tool for measuring the variation caused by demand fluctuation, ordering quantity and frequency, it is better to use the coefficient of variation as a measure to quantify
the Bullwhip Effect. As the coefficient of variation is a relative measure it gives a better measure of variation. The Bullwhip Effect can be quantified based on the forecasting time horizon and the lead-time.

Distortion has a dramatic effect on cost. Metters, [7] describes the increase in profitability due to the reduction in the Bullwhip Effect. He states the Bullwhip Effect as the distortion of the demand upstream. He proposes the seasonal demand and the variation in demand due to forecast errors as the two basic reasons for the Bullwhip Effect. The demand information gets increasingly distorted as its proceeds away from the customer. Metters considers forward buying and order batching as the two main reasons for demand distortion and views the impact of these on the profitability of the system. Retailers generally do forward buying in order to get some quantified discounts, which in turn creates a pseudo decrease or increase in demand, as the reason for the variation in the seasonal demand.

The order batching and the periodic ordering system introduce variations in the demand. Even though the demand is continuous, the cost involved in order batching and the periodic ordering introduce the variation in the demand. This problem reveals the fact that the variation in production is greater than the variation in the sales or demand. The assumptions of the model are 1) The demand is stochastic rather than deterministic. 2) Manufacturers are typically bound by their manufacturing capability and 3) Missing customer deadlines will result in a penalty. Due to the stochastic nature of the demand and typically the penalty for a shortage is normally greater than the holding cost, the inventory level increases at all levels of the supply chain, resulting in a reduced profit margin. Based on the above assumptions, Metters [7] constructed a dynamic programming model to minimize the cost, which is an indirect measurement of increase in profit. The author induced the variation caused by the forecast and the seasonal demand artificially and successfully predicted the increase in cost. There are three types of seasonal demands and three different ratios of mean to variance values for finding the cost estimates. The reduction of the time horizon in forecasting will reduce the Bullwhip Effect to a large extent. It will be easy or relatively easier to tackle the distortion caused by the seasonal demand, if the variation in the seasonal demand changes frequently. Metters concludes by stressing the need for the interchange/exchange of demand information, between the suppliers in the supply chain to reduce the Bullwhip Effect and thereby increase the profit margin.

5. Possible remedies

The central idea is that combinations of several activities are necessary to counter the Bullwhip Effect. The causes for the Bullwhip Effect and the ways to quantify them have been discussed. The following section discusses in detail the possible remedies for the Bullwhip Effect [3,5,6,8].

1. Reducing Uncertainty – Reducing uncertainty is the major step towards reducing the Bullwhip Effect. Centralizing the demand information can reduce uncertainty to a great extent. This will make the customer demand and forecasted retailer’s demand visible to all partners of the supply chain. This reduces forecasting error. But, different buying policies and forecasting methods adopted by different supply chain partners induces the Bullwhip Effect into the system. It is also true that even if all the supply chain partners use the same forecasting technique and buying policy the Bullwhip Effect cannot be eliminated completely. Data needs to be made available to all the links in the chain. This simple change in demand data transfer allows parallel forecasting and avoids the amplification that results from a multi-stage forecasting process. It also has the added benefit of eliminating the delays inherent in a multi-stage system.

2. Reducing Variability- Reducing the variability in the demand can reduce the Bullwhip Effect considerably. Frequent variation in product prices results in a pseudo increase or decrease in demand thereby introducing the variation into the system. If a product is offered for a consistent price as in EDLP (everyday low pricing), the Bullwhip Effect can be reduced to a considerable extent [8].

3. Lead Time Reduction – Lead-time can be divided into order lead-time and information lead-time. Reducing both types of lead times will reduce a significant amount of variation in the system. In forecasting, safety stock levels and reorder points are a function of lead-time; reduction in lead-time reduces the variation. Systems such as cross docking and EDI (Electronic Date Interchange) can reduce both the ordering lead-time and the information lead-time [8].

4. Strategic Partnering and Buying – Strategic partnering reduces the lead-time to a great extent. Information sharing in strategic partnering reduces variation in the system. This can be achieved by the use of a concept called
VMI (Vendor Managed Inventory). This requires the manufacturer to maintain the inventory at the point of use thus reducing the variation in the system. The strategic buying policies adopted by the buyer and the manufacturer reduce the variation caused due to quantity discounts offered by the manufacturer.

5. Advanced Information Technology – Advances in information technology has made the concept of information at your fingertips possible. E-Commerce eliminates the intermediaries such as the retailer from the system and gives the point-of-sale demand to all the supply chain partners. Elimination of the intermediaries, called disintermediation reduces the variation in the system to a large extent. This makes the demand information dynamically available to all the participants of the supply chain. This enhances the effective integration of supply chain partners having conflicting objectives and opinions. The intranet, a company internal internet, replaces the sequential information flow within the system with dynamic information flow, thereby reduces the manufacturing lead-time and in-turn the Bullwhip Effect. This also imparts flexibility to the system and increases the response speed. A good information interchange system, like the internet, coupled with a good warehouse management and transportation management system can significantly reduce the Bullwhip Effect.

6. Conclusion:
The variability in demand gets amplified as it reaches the final link of the supply chain, which results in increased cost and reduced profit margin. The flow of the information in the supply chain is the most important factor in determining the effectiveness of the supply chain. Apart from reduction in batch sizes and frequent ordering policy, the technology of making the demand and other information visible to all participants of the supply chain will reduce the Bullwhip Effect to a large extent. This can be achieved by efficient information interchange between the supply chain participants.

It can be summarized that Bullwhip Effect causes information distortion, delays in procurement, and delays in availability of the goods to the consumer. This happens mainly due to the decisions at each stage of the supply chain. This paper has discussed the major factors that lead to the Bullwhip Effect and also listed the possible remedies. It is obvious that it is not possible to completely eliminate the Bullwhip Effect, but certain care can be taken in order to ensure that it is reduced so that the end consumer is least affected. In order to help in reducing the Bullwhip Effect, information technology can be used as a powerful tool. Internet based information interchange plays a role in effective management of a supply chain, by enhancing the quality and speed of the information exchanged.

References: