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MEASURING BULLWHIP EFFECT IN A MULTISTAGE COMPLEX SUPPLY CHAIN

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ABSTRACT

Bullwhip effect refers to the amplifications in orders in a supply chain. Industries with reliable demand forecasts waste millions of dollars every year because they are not able to match production to demand. In this research authors conducted the study on a complex supply chain to examine different aspects of bull whip effect with the real data. However, this research is mainly aimed to study the supply chain in an industry which is running in Bangladesh. The supply chain used here is a multistage supply chain consists of three retailers, one distributor, one warehouse and a factory. This research mainly deals with the causes of the supply chain and investigates whether there is any existence of the bullwhip effect in the supply chain or not. After this study it can be easily determined which member is contributing to the presence of bullwhip effect and where to take an effort to mitigate the problems of bullwhip effect.

Keywords: Complex Supply Chain, Ordering Quantity, Simulation, Amplification Ratio.

1. INTRODUCTION

A supply chain is an integrated process which includes all activities associated with the flow and transformation of goods from raw material stage through to the end user [1]. It involves the integration of information which flows up and down the supply chain. Businesses today are not separate entities; they are all working together in one supply chain, which can improve the quality of goods and services across the supply chain. The primary objective of a supply chain is to satisfy customer while generating profit. The supply chain activities begin with a customer order and end when a satisfied customer has paid for the purchase.

The bullwhip phenomenon refers to the amplification in orders in supply chain. It is referred as an incident of demand variability amplification as moving upwards the stages of a supply chain (i.e. moving away from customer demand) [2]. Demand variability causes serious problems for supply chain partners such as excessive inventory, inaccurate demand forecasts, extra production capacity, increased storage space and additional investment cost. Moreover bullwhip effect reduces the profitability of a supply chain by making it more expensive to provide a given level of product availability.

Bull whip effect is not an event for any particular cause. There are many reasons which create bullwhip effect in a supply chain. Forecasting parameters and lead time have direct impact on bullwhip effect. When a product demand exceeds supply, a manufacturer often rations its product to customers or if the price of products changes dramatically, customers will purchase the product when it is the cheapest. So there are always a number of reasons for which bullwhip effect occurs.

In this research the bullwhip effect is studied in a complex supply chain. The following section reviews relevant different studies on this field. Then we gradually studied the case to find the orders for different members and then after that the amplification ratio is calculated to show the existence of the bullwhip effect.

2. LITERATURE REVIEW

Recently there has been a surge of interest and research on the phenomenon popularly called the bullwhip effect. Numerous researches have paid their attention to analyze bullwhip whip effect. Some of the searchers tried to providing empirical evidence supporting the existence of the bullwhip effect. Some tried to analytically demonstrate the existence of bullwhip effect. Some of the researchers tried to find out the causes to minimize it.

The phenomenon named bullwhip effect has its origin in system dynamics theory developed by Forrester [3] where, in many cases, the variance in perceived demand for a manufacturer was several orders of magnitude larger than consumer demand. In addition, Forrester identified that this amplification effect occurred at each stage in the supply chain. One of the major factors which caused the bullwhip was that the information feedback loop between companies was too complex for managers to resolve intuitively. Forrester proposed that the only way to resolve these complex

supply interactions was to treat the supply chain as a complete system. Managers could then model the complete system to determine the appropriate action to be taken.

In an inventory management experimental context, Sterman [4] reports the evidence of bullwhip effect in the "Beer Distribution Game". The experiment involves a supply chain with four players who make independent inventory decisions without consultation with other chain members, relying only on orders from the neighboring players as the sole source of communications. The experiment shows that the variances of orders amplify as one moves up the supply chain, confirming the bullwhip effect.

Later, Lee et al. [5, 6] shows that a number of major companies also faced problems due to the bullwhip effect. Procter and Gamble were one of them. Logistics executives at Procter & Gamble (P&G) examined the order patterns for one of their best-selling products, Pampers. Its' sales at retail stores were fluctuating, but the variability was certainly not excessive. However, as they examined the distributors' orders, the executive were surprised by the degree of variability. When they looked at P&G's orders of material to their suppliers, such as 3M, they discovered that the swings were even greater. At first glance, the variability did not make sense. While the consumers, in this case, the babies, consumed diapers at a steady rate, the demand order variability in the supply chain were amplified as they moved up the supply chain. P&G then called this phenomenon the "bullwhip" effect.

There have been many researches to quantify the bullwhip on a supply chain. In measuring bullwhip, here are a number of different approaches that can be adopted. At a simple level, a proxy for the level of bullwhip is to consider the maximum order placed during a simulation run and was used by Riddalls and Bennett [7]. While this provides a qualitative idea as to the behavior of bullwhip, it is not necessarily suitable for finding an analytic solution. Another approach is to divide the coefficient of variation for orders placed by the coefficient of variation for orders received [8]. In calculating the variability of orders Cachon [9] have also adopted this coefficient of variation approach.

3. CAUSES OF BULLWHIP EFFECT

Bullwhip effect is often created for mainly behavioral and operational causes.

3.1 Behavioral Causes

The behavioral causes are rather straightforward. Supply chain managers may not always be completely rational. Managers over-react (or under-react) to demand changes. Often people are over optimistic and confuse forecasts with targets. Decision makers sometime over-react to customer complaints and anecdotes of negative customer reactions. Moreover, there are cognitive limitations as supply chain networks are often very complicated, operating in a highly uncertain environment with limited access to data.

3.2 Operational Causes

Lee et al. [5, 6] identify five major operational causes of bullwhip. These factors interact with each other in different combinations in different supply chains but the net effect is that they generate the wild demand swings that make it so hard to run an efficient supply chain. These factors must be understood and addressed in order to coordinate the actions of any supply chain. They are,

- *Demand signal processing*

Demand signal processing as the practice of decision makers adjusting the parameters of the inventory replenishment rule. Target stock levels, safety stocks, and demand forecasts are updated in face of new information or deviations from targets.

- *Lead time*

A second major cause of the bullwhip problem is the lead-time. The lead-time is a key parameter for calculating safety stock, reorder points, and order-up-to levels. The increase in variability is magnified with increasing lead-time [5, 6].

- *Order batching*

Order batching occurs because companies place orders periodically for amounts of product that will minimize their order processing and transportation costs. Because of order batching, these orders vary from the level of actual demand and this variance is magnified as it moves up the supply chain.

- *Price fluctuations*

The third major cause of bullwhip as highlighted by Lee et al. [5, 6] has to do with price fluctuations. Retailers often offer price discounts, quantity discounts, coupons or in-store promotions. This results in forward buying where retailers (as well as consumers) buy in advance and in quantities that do not reflect their immediate needs.

- *Product rationing and shortage gaming*

A further cause of bullwhip is connected with rationing and shortage gaming. Inflated orders placed by supply chain members during shortage periods tend to magnify the bullwhip effect. Such orders are common when retailers and distributors suspect that a product will be in short supply. Exaggerated customers orders make it hard for manufacturers to forecast the real demand level.

The following figure shows different causes of bullwhip effect.

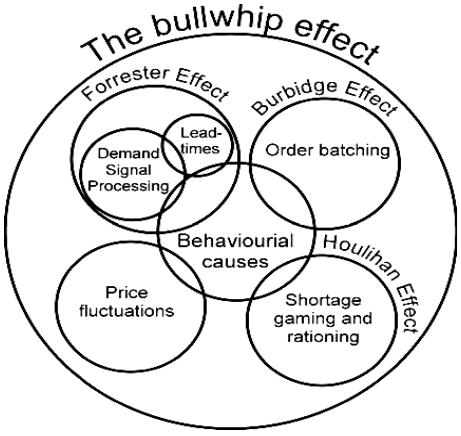

Fig 1. The causes of Bullwhip Effect [10]

4. METHODOLOGY

Theoretically the Bullwhip effect does not occur if all orders exactly meet the demand of each period, otherwise results in greater safety stock which can lead to either inefficient production or excessive inventory as the producer needs to fulfill the demand of its predecessor in the supply chain. This also leads to a low utilization of the distribution channel. Despite of having safety stocks there is still the hazard of stock-outs which results in poor customer service. Furthermore, the bullwhip effect leads to a row of financial costs. It will increase the inventory cost, backorder cost, distribution cost etc.

In this research the study was conducted on a complex supply chain to examine different aspects of bull whip effect as well as measuring it with the real data. The supply chain used here is a multistage supply chain consists of three retailers, one distributor, one warehouse and a factory. The factory is one of the leading manufacturers of Bangladesh which manufactures many products and has many distributors and retailers and one warehouse. In order to make the study more applicable only one product of that particular manufacture is considered. Though this particular product is distributed through many distribution centers to thousands of retailers of all over the country, again to study appropriately we have considered only one distributor and three retailers for this research. To collect more reliable data, three branches of a renowned superstore of Bangladesh are chosen as three retailers for the study. The supply chain network becomes like the following:

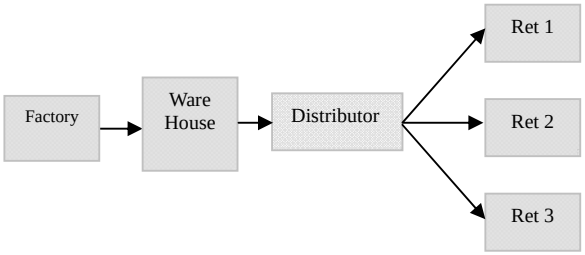

Fig 2. Supply Chain Network of the assigned product

4.1 Data Collection

The customer demand for a particular time period which is 52 weeks of year 2008 is collected. A range of data for the demand are collected which are then generated randomly for the research purpose [11].

4.2 Inventory Policies

To find the ordering quantities for the existing data, information about the inventory policies are essential. Here all the members of the supply chain have their own inventory policy except the customers. Table 1 shows the inventory policy all the members.

To find out the ordering quantities for the members of the supply chain, a fixed amount of beginning inventory for each member of the supply chain is assumed. Ordering cycle time and lead time is set according to the real scenario. Replenishment point is different for different members. Each of the retailers keeps stock equal to one weeks' minimum demand. Distributor keeps 2 week demand of the retailers as a stock. Warehouse also keeps double of the average demand of the distributor and the factory keeps the stock what ever the ware house keeps.

Table 1: Inventory Policy for each member of the supply chain.

Elements	Ret 1	Ret 2	Ret 3	Distri-butor	Ware house	Fact.
Beginning Inventory(units)	20	20	20	75	90	100
Lead time (week)	1	1	1	1	1	1
Ordering cycle (week)	1	1	1	1	1	1
Replenishment point (cases)	10	10	10	60	100	100

4.3 Determining Orders for Each Member

Based on the collected customer demand and the inventory policy, ordering quantities are calculated for each of the member of the supply chain by a simulation on the basis of the following equations [12],

Order for each member =
Max (0, Indicated order) (1)

Indicated order =
Demand from the immediate downstream +
Adjusted Inventory Stock + Shortage quantity (2)

Adjusted Inventory Stock =
Replenishment Point - Inventory level (3)

The following figure 3 shows the different ordering patterns for each of the members of the supply chain along with the actual sales. These ordering quantities are obtained from the simulation.

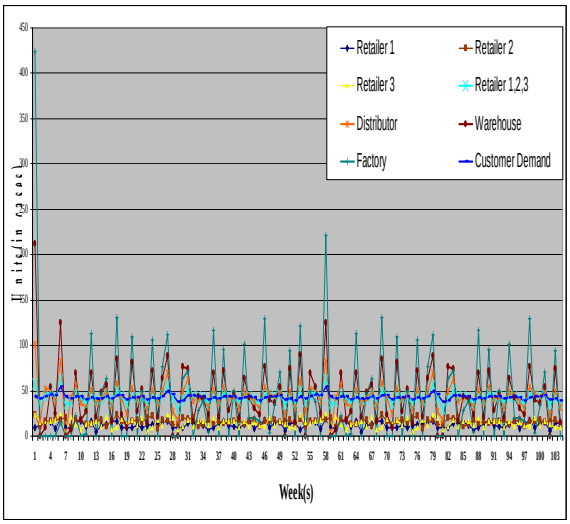

Fig 3. Existing ordering pattern and actual sale for each supply chain member.

5. MEASURING BULLWHIP EFFECT

After the computation of the ordering pattern of each of the members for the whole year the next step is to find out the existence of bullwhip effect in the supply chain. The approach taken here to search for the bullwhip effect is measuring the amount of instability an industry contributes to the supply chain: An industry faces unstable demand from its customers, and then imposes its own instability on its suppliers. The bullwhip effect is exhibited by an industry when the variance of its order is greater than the variance of its demand, i.e., if its amplification ratio is greater than one [8].

$$\textit{Amplification ratio} = V(q)/\,V(Q) \qquad (4)$$

The variance of customer demand for year 2008 is 7.303 and retailers order's variance is 33.68639. So, the ratio is 4.61, which is greater that 1. Here the variance of retailers is calculated by adding the demands of all three retailers. Since this ratio is greater than 1, which clearly indicated the presence of bullwhip effect in supply chain.

Now like retailers, the variances for the other members are also calculated. The variances for distributor order, warehouse order and factory orders' are 232.803, 1360.785 and 4712.802.

With the help these variances the amplification ratio for each of the member is achieved by the above equation 4. The following table 2 shows the amplification ratio of each members of the supply chain for year 2008.

Table 2: Amplification Measures for Supply chain members for 2008 (yearly)

Supply Chain Member	Amplification Ratio
Retailer Vs Customer	4.61
Distributor Vs Retailer	6.91
Warehouse Vs Distributor	5.85
Factory Vs Warehouse	3.46

6. RESULTS

After calculating the variances, it is clearly shown that the variances of orders increased from retailer to factory gradually.

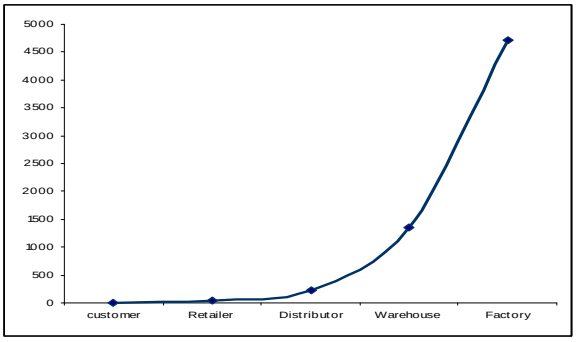

Fig 4. Variances of orders of different supply chain members

The differences between the variances of order from the downstream supply chain member to upstream supply chain member are huge, which clearly shows afterwards that the amplification ratio is always greater than 1. Figure 4 shows the gradual increment of variances of orders from downstream to upstream of supply chain member.

Another observation from table 2 shows that bullwhip effect is present is in every member of the supply chain as the amplification ratio is always greater than 1. This implies that all the members are asking more to its suppliers than the demands. This clearly makes the presence of bullwhip effect in the supply chain for that particular product.

7. PROBLEMS ASSOCIATED WITH BULLWHIP EFFECT

As unnecessary demand variability complicates the supply chain planning and execution processes, the same happened in that particular manufacturing organization and the retailer stores too. The following undesirable effects increase in their severity as bull whip effect negatively impacts operating performances of each member of the supply chain,

i. Schedule variability increases.
ii. Capacity for each member of the supply chain (retailer 1, retailer 2, retailer 3, distributor, warehouse, and factory) is sometime under loaded, sometime overloaded.
iii. Final and the most severe problem of is that the overall costs of supply chain increases

8. CONCLUSION

Effective supply chain has already played a very important and significant role in the business area of all over the world. It has always been a very popular topic for the industries and researchers of the developed countries to conduct more and more researches to make their supply chain more efficient, but for a developing country like Bangladesh it is a newly emerging concern of the industries. This conducted study in a manufacturing organization of Bangladesh illustrates that there is the existence of a bullwhip effect which can cause many problems in the supply chain. Our study proves the presence of bullwhip effect in all the member of the supply chain. Now to mitigate its effect, the attention should not be provided to only one member but to all over the supply chain.

9. NOMENCLATURE

Symbol	Meaning
q	Order
Q	Demand
V	Variance

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