

A Review on the Investigation of the Causes of Bullwhip Effect in Supply Chain Management

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ABSTRACT

In this study the review on the investigation of the causes of Bullwhip effect (BWE) associated with supply chain management is presented. It refers to a trend of large and larger swing in inventory in response to changes in customer demand swings in demand due to changes in customer demand throughout the whole process from supplier to customer. Supply chain management consists from raw material suppliers to customers. There are several stages in this chain. In this paper presents a details classified study of the overall research studied on the effect of both the operational and behavioral factors on bullwhip effect. Step taken by the various industries in order to tackle the bullwhip effect is also discussed in this paper. Finally the various scopes for further researches and instructions of the present and newer companies are also provided in this paper.

Key Words: Bullwhip effect, Collaboration, Operational causes, Behavioral causes.

1. Introduction

“Bullwhip effect” is one of the major obstacle in supply chain management. Due to incoordination the manufacturer can't forecast the actual demand of the customer. Actual demand is fluctuated among the stages. This demand fluctuation and the demand information distortion phenomenon is called “Bullwhip effect” [1]. The retailer is not interested to know the reason for the sudden demand of the products or services. They think that the demand has increased more than the previous time so the retailer demands more products to the distributor. By this way it reaches to the suppliers in an extensive demanded form which is many times than the actual demand of the customer [2]. The demand is oscillated within the stages of the supply chain. This oscillation of demand amplifies the demand along the supply chain. There are many studies to identify the causes of the Bullwhip effect. However the most “real world” supply chains are not easy to access [3]. The supply chain process is consists of several stages. So it is difficult to identify the actual reason for BWE.

BWE is a forecast driven problem. Bullwhip effect is a dynamic phenomenon and is the reason of the tendency of the variability of the order rates. Bullwhip creates unstable production schedules are the cause of a range of unnecessary costs in supply chains. Companies have to invest in extra capacity to meet the high variable demand. This capacity is then under-utilized when demand drops [4]. In the previous period many studies had described different modelling and causes of Bullwhip effect [1-52]. The Bullwhip effect can be described by different modelling. Analytical, agent-based and simulation modeling have been discussed in [8-16]. One the major problem in supply chain management is Bullwhip effect that associated numerous reasons for it related to information distortion, demand fluctuation, price variations and other reasons.

These reasons have been discussed in different way [1-52]. The lead time variability, local optimization within functions or stages, demand forecasting error, large lead time for information shearing, lack of supply chain coordination and other causes have been interpreted by investigation [38-52]. Therefore, in this paper presents a details classified study of the overall research studied on the effect of both the operational and behavioral factors on bullwhip effect. Step taken by the various industries in order to tackle the bullwhip effect is also discussed in this paper. Finally identified the various scopes of the further research for the future researchers and instructions of the present and newer companies are also provided in this paper. The bullwhip effect can be explained with a quadratic equation [52] by the amplification of the order rate from customer to manufacturer.

Bullwhip effect

Bullwhip effect is a problem which is related with the supply chain management. Supply chain management is related from the customer to raw material suppliers. The bullwhip effect is an observed phenomenon and forecast driven. The Bullwhip effect is mainly the fluctuation of the demand of product. When the information of demand order is distorted from stage to stage in the supply chain management, the demand order is fluctuated along the supply chain. Bullwhip effect is a trend of large and larger swing in inventory in response to changes in customer demand. The concept of Bullwhip effect was first appeared in *Industrial Dynamics* (1961) by “Jay Forrester”.

1. Supply Chain Modelling

1.1 Analytical Modelling

The characteristics of the BWE can be derived by different mathematical theories such as probability,

calculus, or linear algebra [2]. These theories derived the Bullwhip effect from the different angles. Since there are numerous causes of Bullwhip effect, stochastic variables and capacity constraints, it is difficult to derive the appropriate model of it. From [7] Kahn showed that a serially correlated demand results in the Bullwhip Effect. Lee et al. (1997a) used the same demand assumption in which orders, D_t , depend on the orders in the previous time interval, D_{t-1} , as:

$$D_t = \rho D_{t-1} + d + u_t \quad (1)$$

There are two constants d and ρ where $d > 0$ and $-1 < \rho < 1$, and u_t is normally distributed with zero mean and variance, σ^2 . (Negative demands are unlikely when $\sigma \ll d$).

1.2 Agent-Based Modelling

The agent-based concepts has emerged in literature relevant to computer applications since 1990s [8]. Agent exhibits adaptability, mobility and rationality. It also exhibits autonomy, social ability and responsibility [9]. In order to advance in the artificial intelligence (AI) field it has to investigate the possible solutions of supply chain management problems in the form of multi agent systems [2]. Each agent is autonomous and achieving its system goal by coordination by independent computer program [10]. For the collaborative, autonomous and intelligence system the multi agent technology has many beneficial features in the distributed environment. Recent research literature acknowledges intelligent agents as the most appropriate technology for trading and auctioning in electronic markets [11]. Agents are able to track demand, eliminate the Bullwhip effect, discover the optimal policies (where they are known), and find good policies under complex scenarios where analytical solutions are not available [2].

1.3 Simulation modelling

In the supply chain management the analytical methods are impractical because the analytical problems are related to mathematical models relate to realistic cases. Usually too complex problems are solved by analytical methods. These complex methods are not possible to solve by physical experimentations because it is high cost related. For the large scale situations a modeling and simulation approach is the only practical recourse for exploring the performance. The simulation model where to be used depends on the problems of the supply chain [12]. Almost every aspect of manufacturing systems simulation has been successful in mimicking. Enterprises has discovered an environment through supply chain management that increased customer satisfactions. Due to stochastic properties in the supply chain there have been encountered difficulties in the large number of uncertain variables [13]. For the theory development the simulation has become a significant methodology and strengthening the organizations [14-18]. As the primary method several influential efforts have used [19, 20]. For the research the simulation

model software is important. The simulation model makes the supply chain simple.

2. VARIOUS CAUSES OF THE BULLWHIP EFFECT

Bullwhip effect is a problem for the supply chain management. There are many causes of BWE. Many papers have been published on the causes of BWE. From the research of previous literatures there all the cases of BWE have been gathers. Price fluctuations [2], demand forecasting error [21-24], order batching [21-25], Rationing and shortage gaming [22], Machine Breakdown [23], Number of echelons [21,26], Lead time of information and material as the primary reason for the bullwhip effect [28-32], Lead Time Variability [27-39], Workloads [40], Local optimization within functions or stages of a supply chain [41], Information-processing obstacles [42], Lack of information shearing [43], Demand information uncertainty [43,44], Demand information dynamic [43,44], Secondary reasons for the bullwhip effect: Planning and behavioral [45], Inventory policy [46,47], Exaggerated order quantity in case of delivery bottlenecks [48,49], variability of machine reliability and output [50,51], Replenishment policy [52] are the main causes of BWE.

3. Supply Chain Structure and Processes

There are the following causes of BWE under supply chain structure and processes.

3.1 Demand forecast updating

Demand forecasting is related with pricing decisions of the customers it may be used in making pricing decisions, in assessing future capacity requirements, or in making decisions on whether to enter a new market [21-24]. Since demand forecasting is related with pricing, product demand fluctuates with the fluctuation of the price. Shortage or surplus may arises due to lacking of updating of demand forecasting.

3.2 Order batching

Aggregating products through a short size order can be called "lumpy" order. Grabara and Patyk [21] and McBurney P et al. [25] also explained the "lumpy" order size. Order picking deals with the retrieval of articles from their storage locations in order to satisfy customer requests. The transformation and consolidation of customer orders into picking orders (batches) is pivotal for the performance of order picking systems. Typically, customer orders have to be completed by certain due dates in order to avoid delays in production or in the shipment to customers. Batching of orders minimizes unit ordering and production costs. However, it causes the distortion of demand information. From Alony and Aneiro [22] the supply chain upstream members receive periodical spikes in customer demand.

3.3 Rationing and shortage gaming

From [22] Rationing schemes that allocate production in proportion to orders places by retailers leads to a magnification of information distortion. This can occur when a high demand product is in short supply. HP, for example, has faces many situations in which a new product has demand for that far exceed supply. In such situation manufacturers come up with a variety of mechanisms to ration the scarce supply of product among various distributors of product. Buyers' strategic ordering behavior as a possible cause of the bullwhip effect. They explain that in an environment where there is supply shortage, buyers tend to over-order to secure resources for themselves, and suppliers tend to correct this over ordering by rationing back to smaller quantities.

3.4 Price fluctuations

Chopra et al. [2] discussed that Trade promotions and others short term discounts offered by a manufacturers results in forward buying, by which a whole seller or retailer purchases large lots during the discount period to cover the demand for future periods. Forward buying results in large orders during the promotion period to cover demand during the promotions periods followed by very small orders. The promotions thus results in a variability in manufacturer shipments that is significantly higher than the variability in retailer sales.

4. Supply Variability

4.1 Machine Breakdown

In the supply chain management the whole process from supplier to customer is related with one another. Due to the breakage of any stage causes the whole process distortion. Breakdown is the loss of functional ability efficiently. When machine breakdown occurs at the top level of supply chain management then the product supply will be hampered in the downstream stages. The supplier will not be able to fulfill the demand of its following stages. There will create the shortage of the product. When the retailer will be unable to fulfill the customer demand arises bullwhip effect.

4.2 Capacity Limit

The capacity of a manufacturer means its production ability during a specific time period. The manufacturer supply goods or services to all its downstream stages. When it takes to produce more time the product or production delay increased, the downstream stages remains in the lack of product. From Chopra [2] and Talor [23]. Since the manufacturer takes more time to supply the products or services it causes erratic ordering by the downstream members and create a bullwhip effect. The distributor can't fulfill the retailer's demand, the retailer can't fulfill customer's demand. The demand

becomes more erratic from stage to stage. However the capacity limit has a significant effect in the supply chain system and causes the Bullwhip effect.

4.3 Number of echelons

Grabara and Patyk [21] suggested that there should be minimum number of echelons appropriate to the goals of the supply chain. According to Alony I [26] more echelons need more time to process. In the supply chain system there are five or six echelons in some cases again two or three echelons in some cases. Where there are more echelons it takes more time to reach goods or services to the customers. Besides there creates a lack of information shearing due to having numerous echelons, there may be created misunderstanding and miss collaboration among them and that may not result in actual demand of customers.

4.4 Lead Time Variability

Lead time is the time between the placement of an order and delivery of a new product. Otherwise lead time is the latency between the initiation and execution of a process. When lead time is short the customer gets their goods or services soon. So there is not such impact of Bullwhip effect. Jörg Nienhaus [27] represented that the longer time of information or material have the strong effect on the Bullwhip effect. But when there is long lead time there is great impact of bullwhip effect. The BWE due to lead time variability has been discussed [27-39]. This long waiting exacerbates the customers, i.e. increases the effect of Bullwhip effect.

4.5 Workloads

Workload is the extra pressure of works that one or a group has to do within a certain time period. If the manufacturer has to perform numerous task within a short time then the firm cannot gain 100% accuracy. Akkermans and Vos [40] found that the more workloads the more Bullwhip effect. Besides the higher workload is the reason of rework and that product requires more time to repair. Workload is a cause of Bullwhip effect. Due to workload sometimes it is not possible to obtain the better efficiency. Workload is the cause of rework that means higher workloads. Sometimes in the supply chain management the Bullwhip effect is measured through by the measurement of backlogs instead of the measurement of finished work.

4.6 Lack of supply chain coordination

A lack of coordination occurs either because different stages of the supply chain have objectives that conflict or because information moving between stages is delayed and distorted. Different stages of the supply chain may have conflicting objectives if each stage has a different owner. As a result each stage tries to maximize its own profits, resulting in action that diminish total supply chain profits [2] and [22]. There is

missing the coordination among these stages. For that reason the owner of a stage is not interested to know another's stage owner. There creates a lack of information shearing that is the reason of the fluctuation of demand. Finally creates Bullwhip effect.

4.7 Local optimization within functions or stages of a supply chain

Incentives that focus only on the local impact of an action result in decisions that do not maximize total supply chain profits [41]. One stage namely transportation manager wishes to lower transportation system that ultimately requires more time for transportation that increases the profits of the transportation manager but not the total supply chain management. This creates the variability of the available product and cause Bullwhip effect. Other causes of BWE are discussed in Table 1.

Table 1 Other causes of BWE

Causes of BWE	Causes discussed by
Sales force incentives	Chopra, Meindl et al. [2], Moyaux T et al. [41]
Information-processing obstacles	Sohn SY, Lim M [42]
Forecasting based on orders not on customer demand	Sohn SY, Lim M [42]
Lack of information shearing	Sohn SY, Lim M [42]
Demand information uncertainty	David H. Taylor [43], Sohn SY et al [44]
Nonlinear delayed information	David H. Taylor [43], Sohn SY, Lim M [44]
Staggered timing of the node because of information game	David H. Taylor [43], Sohn SY, Lim M [44]
Planning and behavioral causes	Nienhaus J et al. [45]
Inventory policy	Chandra C, Grabis J [46], Aharon B-T et al. [47]
Exaggerated order quantity in case of delivery bottlenecks	Lee, L. H et al. [48-49]
Variability of machine reliability and output	Huang Lizhen Liu Yongping [50], Taylor DH [51].

5. Scope for the further research

Since BWE has a great influence on the supply chain system, further researches are required to eradicate BWE. There are some issues for further researches:

- It may be investigated the ways that minimizes the complexity of the supply chain.
- Finding out the ways that improve the collaboration among the stages of the supply chain.
- It may be surveyed that how many manufacturers are concern about all the causes of BWE.
- It may be researched that what will happen if one or more intermediate stages are eliminated of the supply chain.
- Investigation the gaps of the previous researches.

6. Instructions for the supply chain system

From the above discussion, many causes of BWE and the scope of further research were pointed out. Now this paper is providing some instructions for the present business firms and companies. First, the each stage of supply chain will be aware of the information sharing and there should have technology based way of information shearing. Second, avoid the as usual demand forecasting method and select a way that can investigate the actual customer demand. Third, the coordination must be improved among the different stages of the supply chain system to avoid disruption of information shearing. Forth, there will have a restriction against local optimization within functions or stages.

Conclusion:

The supply chain is a complex chain system that starts from the raw material suppliers to customers. Any type of disruption causes the BWE makes the supply chain complex. The all causes of BWE have been categorized into some categories (1) causes due to supply chain processes and structure (2) Causes due to material and information lead time (3) Causes due to supply variability (4) causes due to other causes. Although the modelling and causes of Bullwhip effect have been discussed extensively, there are also some limitations in the total system. Vast awareness and concentration is needed to overcome this problem. But for the most company in supply chain there are some limitations for this reason it becomes difficult to overcome this problem. From the literature review supply chain modelling and causes like long lead time, order batching, rational and shortage gaming etc. are discussed in this paper. Strong management policy and more concentration should take extensively to minimize the BWE. Often it becomes difficult to investigate the actual causes of Bullwhip effect. This review paper will help to find out the causes of BWE and provides the appropriate actions to tackle the BWE. Finally, this paper represents the scope of further research in the area

of BWE. Additionally, this paper provides a brief instruction against BWE to the manufacturer.

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