

# Mitigating the Bullwhip Effect in Supply Chain: A Cloud computing approach

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## ARTICLE DETAILS

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## ABSTRACT

The Bullwhip effect (BWE) in a supply chain creates unexpected distortion due to variation of demand and often cripples demand forecasting accuracy. In absence of accurate demand forecasting, stakeholders in a supply chain (ex: retailer, wholesaler, manufacturer and supplier) face inventory disruptions like overstocking, under stocking & stock out situation resulting in higher cost, lower quality and lower customer satisfaction. Adoption of generic solutions like Vendor Managed Inventory (VMI) or Standardization of Order Lot-sizing often becomes unfeasible for smaller suppliers due to associated high cost of capital. Objective of this paper is to present a systematic approach of information sharing and collaboration among supply chain partners using cloud computing platforms. As cloud computing services are 'on-demand', billed on 'pay-as-you-use' model and offers seamless mobility, all supply chain partners can use it to collaborate with each other with least possible cost to mitigate the impact of Bullwhip effect along entire supply chain.

## 1. Introduction

In simple terms, supply chain represents a network between an organization and its partners (ex: retailer, wholesaler, distributor, manufacturer and supplier) to produce and deliver a product or service to the end customer. Supply chain plays a crucial role for any business organization to gain customer satisfaction, confidence and retention. Thus in a crowded marketplace, an efficient supply chain always helps to create and sustain competitive advantage. A tightly controlled supply chain acts as the backbone of business and any minor disturbance in it may create a magnified effect on various business functions. Supply chain is also exposed to various risks –amongst them most prominent is demand uncertainty. Demand uncertainty or fluctuations create nervousness among the supply chain partners, they tend to lose confidence and disrupt the supply chain balance by under stocking or overstocking.

A bullwhip effect (BWE, shown in Fig.-1) refers to a phenomenon where unexpected fluctuations, variations and distortions in demand information are observed within a supply chain as a result of shift in end customer demand. This distortion propagates upwards (from customer to manufacturer to supplier) in an amplified manner and cripples demand forecasting accuracy of entire supply chain - resulting in inventory disruptions, poor quality, higher cost and low customer satisfaction. The bullwhip effect was named after the whip used for bulls – when a bullwhip is cracked, a small wrist movement makes a successively larger wave moving along the length of the whip.

Behavioral causes are often attributed to create bullwhip effect. Minor variance in demand can create panic among the supply chain partners. In absence of a formal communication channel they tend to lose confidence and multiply the variance by ordering manifold of actual demand. Thus, sharing information using a common platform across entire supply chain can play a vital role to mitigate bullwhip effect. Imagine if upstream supply chain partners have access to view the actual

demand and inventory levels of downstream partners, the numbers will never be amplified so significantly. Also, if retailers can have the visibility and transparency of their manufacturers' inventory level, then they will not include safety stock and buffer in their ordering quantities. All these can be achieved by collaboration (sharing information using a common platform) amongst the partners across entire supply chain.

Cloud computing is an emerging service provided by network of remote servers hosted on the internet to store, manage and process data, instead of local server or personal computer. Cloud computing services are cheaper, maintenance-free and flexible for end customer as they are 'on-demand' in nature and charged on 'pay-as-you-use' model. Small businesses (for example, retailers in a supply chain), who have a very low Capex capability can purchase cloud services at low cost. Cloud based ERP platforms can be used by all supply chain partners to collaborate and share information along supply chain.

Goal of this paper is to present a systematic approach of information sharing and collaboration among supply chain partners using cloud computing platforms to mitigate the bullwhip effect in supply chain.

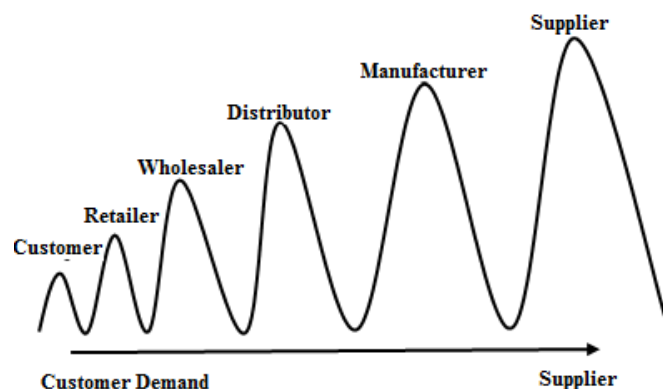


Fig.-1: Bullwhip Effect – Demand amplification curve

## 2. Literature Review

Bullwhip effect (BWE) is a well-known phenomenon in distribution & supply chain management and numerous scholars and researchers have noted it in the past. The concept was first discussed in J.W. Forrester's Industrial Dynamics (1961) as 'Forrester effect'. Forrester was pioneer to introduce the demand variance amplification effect using his industrial dynamics approach. Later, simulation of this phenomenon was prototyped with the famous 'Beer Distribution Game'. Sterman (1989) published data from the game attributing the amplification to a tendency in which players overlook the inventory-on-order, as cause of amplification. Since 1990s, a large chunk of literature on bullwhip effect and its various interpretations, causes and remedies have emerged and continued to grow. Towill and Naim (1993) further expanded Forrester's work - explored various remedies for mitigating demand amplification including just-in-time (JIT), vendor managed inventory (VMI) etc. Lee, Padmanabhan, and Whang (1997) proposed four causes of bullwhip effect: demand signal processing, price variation, batch ordering and shortage gaming. Geary, Disney, and Towill (2006) described ten principles to reduce the phenomenon. Miragliotta (2006) classified bullwhip research in three focus areas - empirical assessment, causes and remedies with a new taxonomy model. Similar work done by Giard and Sali (2013) who subdivided bullwhip papers in thirteen dimensions.

Contrary to BWE, cloud computing is an emerging concept in information & communication technology (ICT) where network of remote computers hosted on the internet are used to store, manage and process data. Though popularization of cloud computing is attributed to Amazon for releasing its first

cloud product in 2006, the term was coined as early as in 1996 by Compaq in their internal document. However, many believe that the first use of 'cloud computing' in its modern context happened in August 2006, when the then Google CEO Eric Schmidt introduced the term in a conference. Since inception, cloud computing was perceived as SaaS (Software-as-a-Service) platform and Educause (2009) predicted that the users of cloud computing will get increased reliability and cost decline due to economies-of-scale. Sultan (2009) identified three prominent areas of cloud services: IaaS (Infrastructure-as-a-Service), SaaS (Software-as-a-Service) and PaaS (Platform-as-a-Service). Cloud based ERP platforms started to grow since 2009 and many research literatures attempted to compare benefits of cloud vs. on premise ERP systems. Scavo et al (2012) chalked a comparative analysis between these two forms of ERPs and it was evidently clear that small businesses are benefited more from cloud based ERP platforms.

## 3. Material, Methods and Implementation

Objective of this paper is to demonstrate a systematic approach of information sharing and collaboration (through cloud computing platforms) among supply chain partners to mitigate the bullwhip effect in supply chain. To imitate a typical supply chain (consisting of retailer, wholesaler, distributor, manufacturer and supplier) experiencing bullwhip effect, we have taken help of Beer Distribution Game (1960) set up in an experimental way. Five volunteers acting as SC entities passed demand information upstream with a piece of paper with numbers written on it and inventory chips to immediate downstream player to fulfill demand and replenish stock (shown in Fig-2).

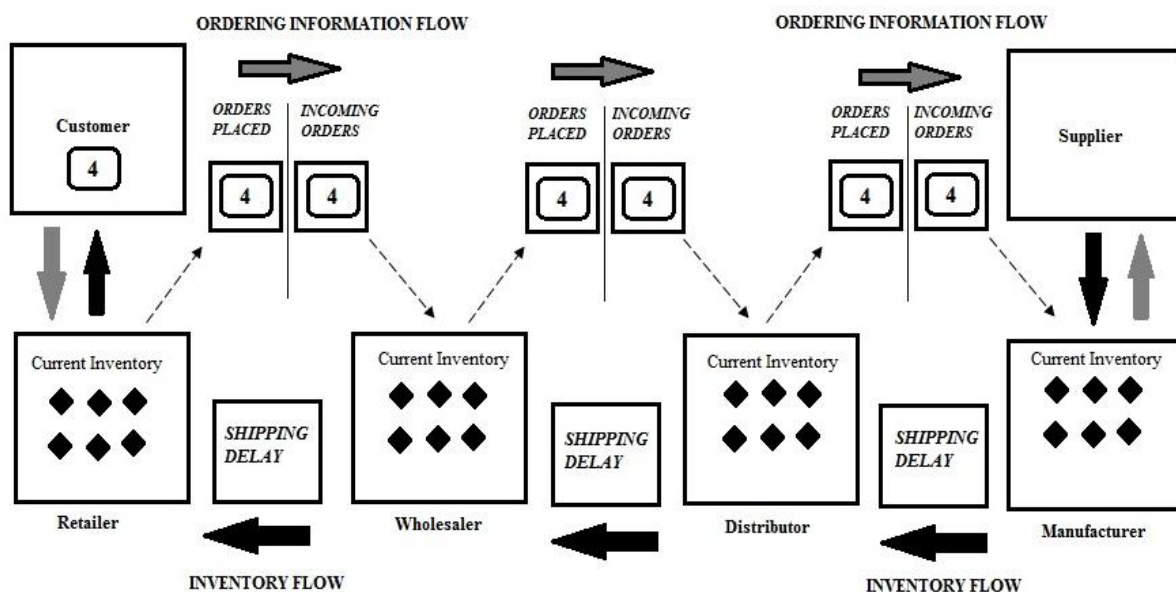


Fig.-2: Beer Game set up with partners' position and ordering information flow.

This way customer demand and product moved through the supply chain without any verbal communication between the partners. There was one shipping delay box in between two partners and objective of each partner was to meet the customer demand without excess inventory or shortage. Obviously, customer demands were pre-determined but not revealed to anyone except the retailer and revealed at regular

intervals as the game progresses. Thus, each partner had to decide on ordering quantities based on locally available information.

Each partner had to keep in mind a few factors while deciding on ordering quantities. Those include: existing demand, expected demand, current inventory, incoming

inventory-in-transit and desired inventory. Each partner tried to reduce the gap between desired and current inventory keeping in mind inventory-in-transits. Therefore, following basic rule was adhered to while ordering:

Orders to be Placed (at time T) = Backlog (of T-1) + Current Orders (at time T).

If a partner was having enough inventory, he had to ship all the orders to ship and record new inventory.

If a partner was not having enough inventory, he had to ship whatever inventory he had and record the remaining unfilled orders to fill as new backlog. A record sheet was used to record each of the individual partner's Inventory, Backlog and Order Placed quantities. After a few rounds of play, the ordering patterns of SC partners started to exhibit demand amplification (BWE) as per the equation suggested by Chen et al. (2000):

$$BWE = \frac{Var(Q)}{Var(D)}$$

Where,  $Var(Q)$  is variance of retailer orders and  $Var(D)$  is variance of customer demand.

For serially correlated demand in a given period,  $Var(Q)$  can be expressed as:

$$Var(Q) = Var(D) + \frac{2p(1 - p^{lt+1})(1 - p^{lt+2})}{(1 + p)(1 - p)^2} \sigma^2 > Var(D)$$

for  $p > 0$

Where,  $p$  is known as correlation coefficient with  $-1 \leq p \leq 1$  and  $lt$  is lead time.

If lead time ( $lt$ ) is zero, then,  $Var(Q) = Var(D) + 2p\sigma^2$

Approach was to conduct two experiments, record and graphically represent ordered quantities for each to investigate any mitigation in BWE. In first beer game experiment, partners are restricted to any communication except order information pass. In second beer game

experiment, partners are allowed to communicate with a cloud based group chat application to update inventory, backlog and order figures after each movement.

**3.1 Experiment-I Setup:**

For first experimental game setup, five volunteers acting as individual SC partners (retailer, wholesaler, distributor, manufacturer and supplier) were asked to pass ordering information upstream and inventory downstream at regular intervals. Customer demands were pre-written as random numbers on stacked pieces of paper and revealed only to the retailer at regular intervals. Every SC partner was provided some initial stock before the game was started. They were instructed to pass on the ordered quantity (received from previous partner) to shipping delay box and place new orders to next partner as per requirement. This way ordering information passed on opposite direction to physical stock movement in supply chain. No communication except passing of ordering information (with a token piece of paper) was allowed in between the partners and they had to make their individual ordering decisions based on current order-in-hand plus backlogs. There were penalty provisions for excess inventory and inventory shortages, so ordering decisions must consider incoming stock-in-transit and orders-to-be-delivered quantities. Penalty provisions were incorporated to mimic real life supply chain where excess inventory raises inventory carriage costs and shortages lead to business opportunity loss & customer churn. Also, penalty provisions keep SC partners in pressure during the entire game and they try to be more accurate while placing orders.

A record sheet (shown in Fig-3) with a pencil was provided to each of the SC partners to record their Inventory, Backlog and Order Placed quantities. SC partner with adequate inventory, had to ship all the orders to ship and record updated inventory in the record sheet. In case a SC partner not having enough inventory, he had to ship available inventory and record the remaining unfilled order quantities as new backlog in the record sheet.

RECORD SHEET			
Please tick your position :			
<input type="checkbox"/> Retailer	<input type="checkbox"/> Wholesaler	<input type="checkbox"/> Distributor	<input type="checkbox"/> Manufacturer
Time (Week)	Inventory	Backlog	Your Placed Orders
1			
2			
3			

Fig-3: Sample record sheet used in Beer Game experiments conducted

**3.2 Experiment-II Setup:**

Second experimental game setup was kept exactly same as the first one except a smartphone was provided to each volunteer to collaborate with a cloud based mobile group chat application. Each volunteer acting as a SC partner needs to update inventory, backlog and order placed figures in record sheet as well as via smartphone after each movement. This set

up enables each partner to view inventories and order figures across entire supply chain.

**4. Results**

**4.1 Experiment-I Results:**

Game play results were recorded in record sheets and charts were drawn to represent each SC partners' order

quantities (shown in Fig-4). Initially the ordering patterns of each partner across supply chain were similar in nature and as the game progressed, more volatile orders were placed by the customer. In absence of any collaboration platform, an individual partner had no inventory or backlog visibility of other partner. As a result of it, they took their individual ordering decisions just by magnifying incoming order quantities. This

way the order behavior graph started exhibiting demand amplification and BWE gripped across supply chain. For example: in response to customer demand of 26 Qty., retailer ordered 30; wholesaler ordered 40; distributor ordered 45 and manufacturer ordered 48 i.e. BWE amplification ratio at peak was 1.85.

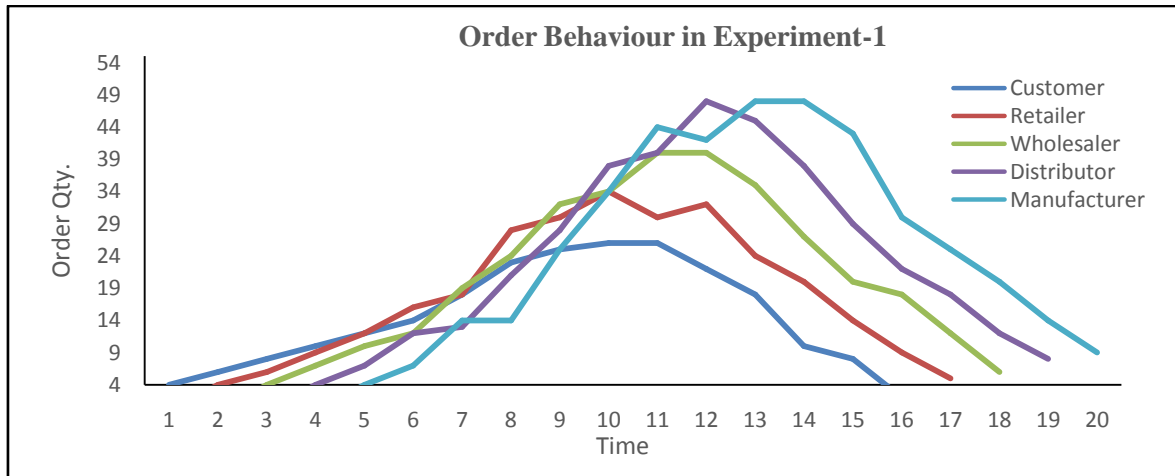


Fig-4: Order behavior chart as recorded in simulation experiment-1.

**4.2 Experiment-II Results:**

Second game play results were recorded in record sheets and charts were drawn to represent each SC partners' order quantities (shown in Fig-5). Demand amplification and BWE across supply chain was displayed in this case too but, in a

moderate form. For example: in response to customer demand of 30 Qty., retailer ordered 33; wholesaler ordered 34; distributor ordered 35 and manufacturer ordered 36 i.e. BWE amplification ratio at peak was 1.2.

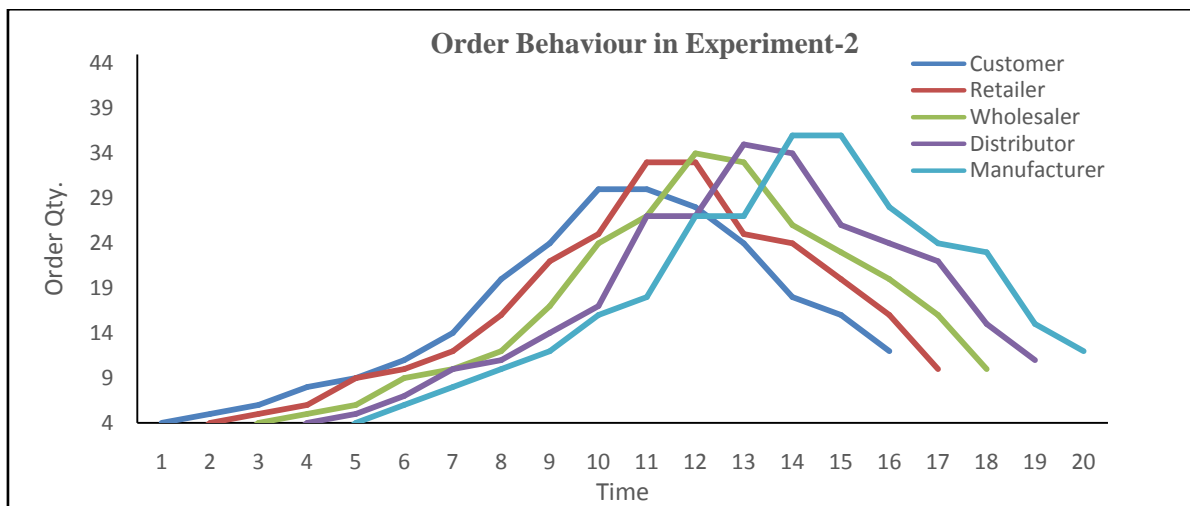


Fig-5: Order behavior chart as recorded in simulation experiment-2.

**5. Analysis and Discussion**

Analysis of the results of simulation experiments (SE-I & II) clearly showed mitigation of demand amplification across supply chain in second experiment – due to systematic information sharing and collaboration amongst SC partners (through cloud based group chat application). BWE amplification ratio was drastically reduced from 1.85 to 1.2 at peak. Each partner in supply chain was having a clear visibility of inventory and order status of other partners. This had helped to build trust and confidence across supply chain which in turn helped to mitigate amplifications at the time of demand fluctuations. For example, in second game-play retailer was

having clear visibility and transparency of wholesaler's inventory level, so he had kept safety stock and buffers in his ordering quantities to a minimum level. This behavior had rippled downstream supply chain causing further reduction in BWE. As each partner in supply chain knew the inventory status of immediate next partner, he was confident that his order will be respected and fulfilled in due course of time, so they tried to avoid over-ordering up to a certain extent.

**6. Conclusion**

This paper has attempted to present a systematic approach of information sharing and collaboration among

supply chain partners (using cloud computing platforms) to mitigate the bullwhip effect in supply chain. This demonstration of mitigation (of BWE) was based on a Beer Game simulation experiment setup and a cloud based group chat application was used as a basic collaboration platform. More accuracy and complex business objectives can be achieved by using full-fledged cloud ERP platforms (like: SAP Ariba, Salesforce, C4C etc.) for mitigating BWE in supply chain. On the basis of experimental results we can conclude that real time demand

information and inventory visibility problem (and BWE) in a typical supply chain can be addressed with cloud computing. As real-time demand information can be shared and collaborated at lowest possible cost through cloud, even small businesses can afford to achieve a sustainable competitive advantage by improving supply chain performance using cloud as a collaboration tool. We expect this paper has provided basic insights and opened doors for future researches in this area.

## References

- [1] Forrester, J.W. *Industrial Dynamics- Systems Dynamics Series*, Productivity Press, MIT Press, 1961.
- [2] Towill, D.R. and Naim, M. "Supply chain: partnership sourcing smoothens supply chain dynamics", *Purchasing & Supply Management*, 1993.
- [3] Sterman, J.D. "Modeling managerial behavior: misperceptions of feedback in a dynamic decision making experiment", *Management Science*, 1989.
- [4] Lee, H.L., Padmanabhan, V. and Whang "Information distortion in a supply chain: the bullwhip effect", *Management Science*, 1997.
- [5] Geary, S., Disney, S. M., & Towill, D. R. (2006). On bullwhip in the supply chain - historical review, present practice and expected likely impact. *International Journal of Production Economics*.
- [6] Miragliotta, G. (2006). Layers and mechanisms: a new taxonomy for the bullwhip effect. *International Journal of Production Economics*.
- [7] Giard, V., & Sali, M. (2013). The bullwhip effect in supply chains: a study of contingent and incomplete literature. *International Journal of Production Research*.
- [8] Antonio Regalado (2011). "Who Coined 'Cloud Computing'?". *TechnologyReview.MIT.www.technologyreview.com*.
- [9] Educause (2009). 7 things you should know about cloud computing. Educause, August. URL: <http://www.educause.edu>.
- [10] Sultan, N. (2009). Cloud computing for education: A new dawn. *International Journal of Information Management*, in press.
- [11] Scavo, F., Newton, B. & Longwell, M. 2012. Choosing between cloud and hosted ERP, and why it matters. *Computer Economics Report*. Vol. 34 No. 8
- [12] Chen, F. Drezner, Z. Ryan, J.K. Smith-Levi, D. (2000a). Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times and information. *Management Science*, 46, 1.