Mitigating carbon footprint across Supply Chain: A Cloud ERP approach

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Abstract: *Sustainability and reduction of carbon footprint has become a matter of strategic choice for all businesses today. As business is reaching beyond geographical boundaries, it is often facing different laws and restrictions to comply with carbon emissions. Reinforcement of global climate agreements i.e. the Paris Agreement at local level often becomes compulsion for multinationals operating at local level to lower greenhouse emissions. Besides, lowering of carbon footprint is often associated with positive impacts on a firm's brand and reputation. Many developed nations have already introduced stringent emission policies like cap-and-trade system and carbon tax - which can directly penalize or incentivize a company's carbon performance. Low carbon emission initiatives - for example, switching to energy efficient assets, installing solar panels or setting up a green disposal system are often linked with high capital expenditures for business. However, operational optimizations too, may have significant contribution on carbon footprint mitigation with lesser cost. One such operational optimization can be implemented in existing supply chain as supply chains are capable of emitting up to four times of greenhouse emissions of a company's normal emissions (excluding supply chain). So managing the supply chain operation can make a huge difference on company's overall carbon performance. Poorly forecasted and planned logistics activity always results in inefficient transport of inventory and thus increases the carbon footprint of supply chain; and poor forecasting and planning is often caused by poor collaboration between supply chain partners (ex: retailer, wholesaler, distributor, manufacturer and supplier), resulting in inefficient transportation of inventory. Demand forecasting accuracy usually gets disrupted by unexpected distortion due to variation of demand caused by Bullwhip effect (BWE) in a supply chain. This Demand uncertainty or fluctuations trigger nervousness among the supply chain partners, they tend to lose confidence and further disrupt the supply chain forecasting by over ordering or under ordering. By mitigating Bullwhip effect (BWE) in supply chain, a firm can significantly improve its demand forecasting accuracy and thus minimize carbon footprints of entire supply chain to meet legal carbon compliance and to achieve significant cost reduction as well. Objective of this paper is to present a systematic approach of information sharing and collaboration among supply chain partners using cloud ERP platforms. As cloud ERP 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 and thus to mitigate carbon footprint. Aim of this paper is also to highlight an emerging research area of digital supply chain having potential for betterment of environment and society.*

Keywords: *Carbon footprint, Cap-and-Trade-system, Bullwhip effect (BWE), Cloud ERP, Digital Supply Chain.*

I. INTRODUCTION:

It is said that running a profitable business is hard, but running a profitable business with negative carbon footprint is even harder. In a cut-throat competitive market, to achieve a highly sustainable business by sticking to lowest possible emission often becomes too costly affair for incumbent firms. But climate change damages economies, devastates customers, increases resource scarcity and impacts overall cost of doing business. So for simple business reasons firms have to initiate actions to reduce carbon footprints. Besides, multinational companies are often legally bound to meet emission caps enforced by local governments. Few of such regulatory programs like cap-and-trade, strict-cap-on-emission and carbon-tax have direct impact on a firm's balance sheet. In addition, more and more customers are interested to know the carbon footprint numbers from the businesses they work with. A survey has highlighted that almost 83% consumers worldwide want businesses to implement programs to safeguard environment (Neilson, 2011).The same survey, however, revealed that only 22% of consumers are ready to pay more for environment friendly products. This underlines a serious need for organizations to control their carbon footprints while remaining cost effective.

Approximately 6% of total volume of greenhouse gases generated by humans are due to the flow of products to consumers. Research shows that supply chains can be responsible for up to four times the greenhouse gas emissions of a company's normal operations excluding supply chain (Dixon, 2016), while transportation remains as the second highest emitter of greenhouse gases worldwide. The World Economic Forum estimates in its Supply Chain Decarbonization report that logistics and transport sector has a carbon footprint of around 2,800 megatonnes. In absolute terms, road freight is the greatest part: constitutes at around 57% of the total (WEF, 2009). Also, logistics activities have a significant economic impact on countries and their societies. For example, these activities accounted for 8.3 per cent US gross domestic product (GDP) or US $1.45 trillion in 2014 and 6.8 per cent of GDP (€876 billion) across the European Union's (EU) 27 countries in 2012 (EC, 2015). Therefore, a small percentage of reduction in logistics activities may cause a major environmental impact from reduction of carbon emissions. Thus, it is evident that if business can accurately plan and optimize its logistics and transportation activities across supply chain, it will be able to achieve its carbon emission targets.

Now, let us discuss on one of the major challenges the business usually faces while planning and optimizing its logistics and transportation activity across supply chain: Demand uncertainty and fluctuation. Also, demand forecasting accuracy often gets disrupted by unexpected distortion due to variation of demand. This variation can be seasonal but, mostly caused by an inherent phenomenon of physical supply chain known as bullwhip effect or BWE. 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.

Technology can play a major role to tame bullwhip effect across supply chain enabling reliable communication and collaboration amongst supply chain partners. Logistics and transportation have interfaces with a wide array of functions within firms, and effective communication must occur between the focal firm and various stakeholders of the supply chain. During the last few decades, the use of information and communication technology (ICT) has revolutionized the way in which supply chain operates. Latest ICT technologies like: Electronic Data Interchange (EDI), Radio Frequency Identification (RFID) and real time tracking with Global Positioning System (GPS) has enabled supply chain to be more agile and resilient at the same time. Supply chain is now more adaptive to use emerging technologies like Internet-of-Things (IoT) and Machine Learning. Cloud computing is an emerging area of information and communication technology (ICT) where 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. Enterprise Resource Planning software hosted by cloud technology is termed as "Cloud ERP Software". Most cloud service platforms are constructed utilizing virtualization and burden adjusting innovation that enables applications to be conveyed over numerous servers and database resources. Thus, cloud ERPs have recently become the most cost effective dependable way to collaborate with supply chain partners. This paper is considering the rollout of cloud ERPs across supply chain as a first step to digital-supply-chain where cloud based ERP platforms can be used by all supply chain partners to collaborate and share information along supply chain with lowest possible cost.

Objective of this paper is to demonstrate capability of cloud ERP platforms as a systematic tool for information sharing and collaboration amongst supply chain partners in order to mitigate carbon footprint of entire supply chain. As cloud ERP 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 and thus to mitigate carbon footprint. Aim of this paper is also to highlight an emerging research area of digital supply chain having potential for betterment of environment and society.

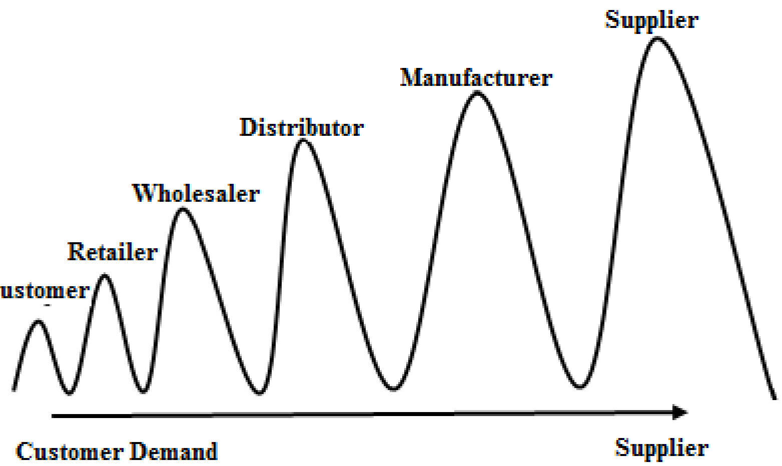


Figure-1: Demand amplification due to Bullwhip Effect

II. 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. 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. Based on the type of cloud service models, cloud ERPs can be of different types: Public cloud ERP, Private cloud ERP and Hybrid cloud ERP (Arnesen S., 2013). Zadeh et al (2018) confirmed that cloud-based ERP systems are becoming more relevant for small businesses (SMEs) in recent years, mainly due to the possibility of getting started at a low cost and small scale.

III. METHODOLOGY and IMPLEMENTATION:

Objective of this paper is to demonstrate capability of cloud ERP platforms as a systematic tool for information sharing and collaboration amongst supply chain partners in order to mitigate carbon footprint of entire supply chain. To replicate a real 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 supply chain 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. 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:

$$Var(Q) = Var(D) + \frac{2p(1-p^{lt+1})(1-p^{lt+2})}{(1+p)(1-p)^2}\sigma^2 > Var\ (D) \text{ for } p > 0$$

Where, p is known as correlation coefficient with $-1 \le p \le 1$ 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 rises 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.

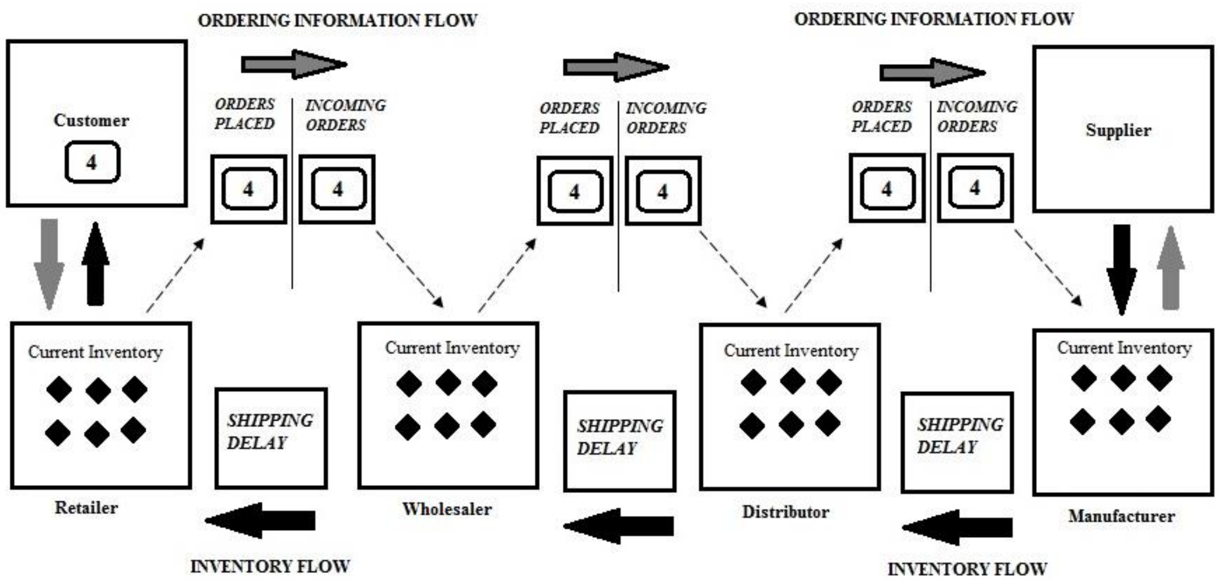
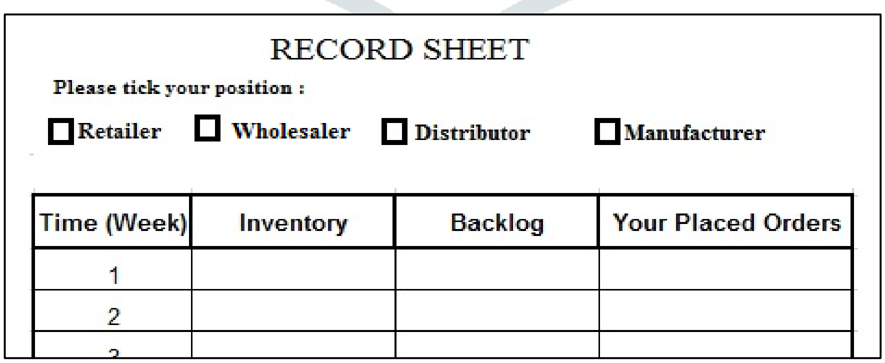


Figure-2: Beer Game set up with partners' position and ordering information flow.

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 :

☐ Retailer ☐ Wholesaler ☐ Distributor ☐ Manufacturer

Time (Week)	Inventory	Backlog	Your Placed Orders
1			
2			
3			

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

3.1.1 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 pattern 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.

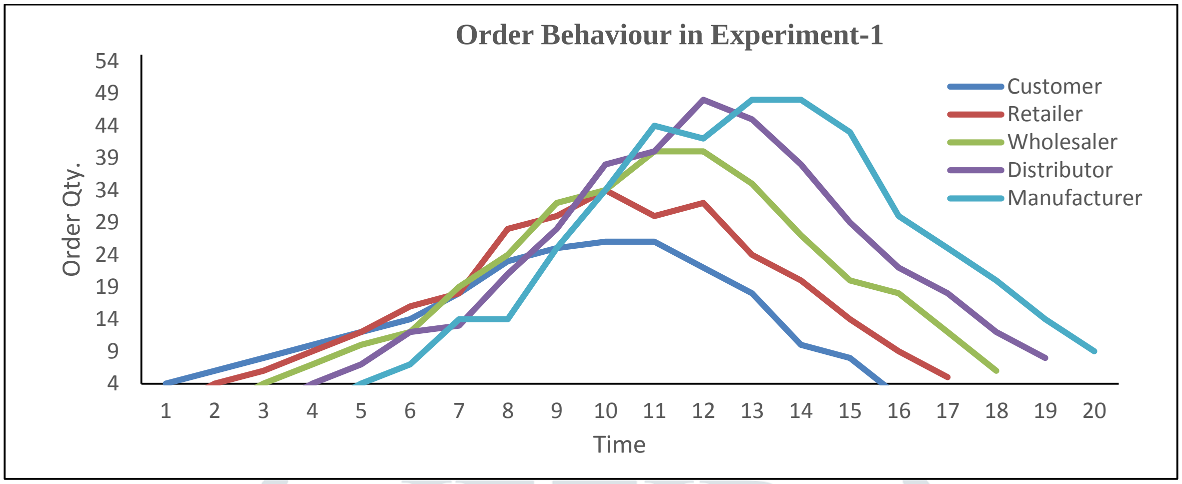


Figure-4: Order behavior chart as recorded in simulation experiment-1.

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.

3.2.1 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.

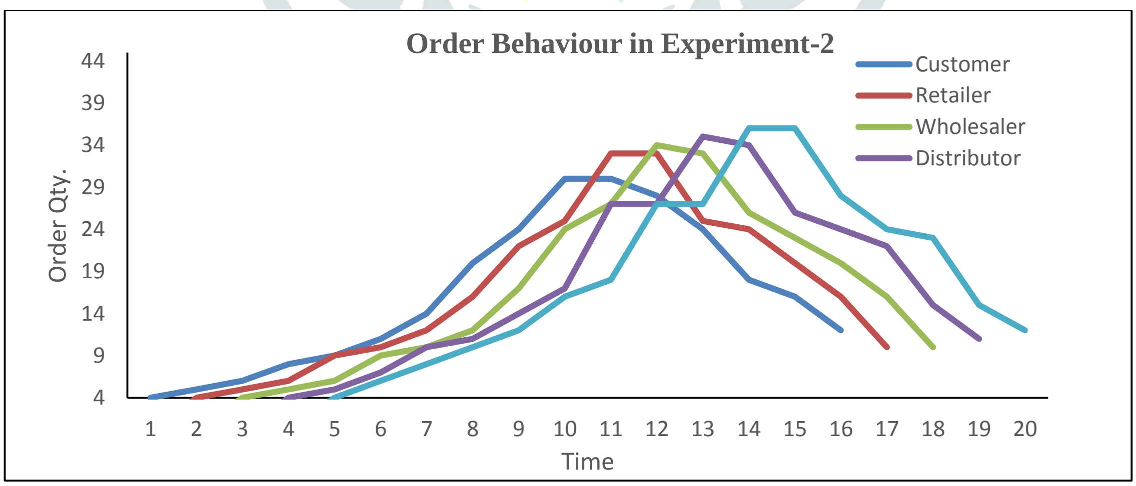


Figure-5: Order behavior chart as recorded in simulation experiment-2.

IV. ANALYSIS:

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. Thus, it becomes evident that efficient collaboration between supply chain partners can help to boost confidence of each partner in an uncertain time and this has a potential to mitigate demand amplification caused by BWE across supply chain – and cloud ERPs have the potential to become an effective tool of collaboration.

V. CONCLUSION:

This paper has attempted to present a systematic approach of information sharing and collaboration among supply chain partners (using cloud ERP platforms) to mitigate the bullwhip effect and carbon footprint of 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 ERP as a collaboration tool, and thus could mitigate carbon footprint of entire supply chain. Of late it has been noticed that incumbent ERP vendors are coming up with inbuilt Carbon Emission calculation features while planning their transportation activities across supply chain. But, simply by effective supply chain partner collaboration through low cost cloud based ERP platforms, a firm can mitigate its carbon footprint, cost of operation and simultaneously meet carbon compliance. We expect this paper has provided basic insights and opened opportunities for future research in this area. This paper may also open up new product development opportunity for cloud ERP software manufacturers and developers, who want to tap this low-cost niche market segment for small scale businesses.

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