SIMULATION BASED ANALYSIS OF THE BULLWHIP EFFECT UNDER DIFFERENT INFORMATION SHARING STRATEGIES

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Abstract
In this paper we are simulating a three-stage supply chain that is based on the Stock-to-Demand inventory type. The aim of the simulation is to investigate the well-known phenomenon of the bullwhip effect, and identify the parameters that affect it. To investigate and measure this impact, a simulation model is developed using Arena 11 software package for a three-stage supply chain, consisting of a single retailer, wholesaler, and a distributor. Since the bullwhip effect is based on an interrelated network of parameters, the model will be changed to affect the change in these parameters on the variance amplification of orders. It has been observed that how lack of information, lack of transparency throughout the supply chain and a disconnect between production and real-time supply chain information result in increasing lost sales, bad customer service, high inventory levels and unrealized profits. Simulation modeling, presented in this work allows the user to analyze the performance of the three tier supply chain network and to understand the complex relationship between the parties involved. The findings from the simulation suggest that the model calculates customer service levels, total cost, waiting times, inventories and demands at every stage in a predictable manner.

Keyword: Bullwhip effect, simulation modeling, Information sharing, business performance

1. Introduction
The bullwhip effect describes the phenomena of the amplification of demand order variability’s as they moved up the supply chain. The distortion of information throughout a supply chain can lead to tremendous inefficiencies. The underlying causes for the bullwhip effect are multiple and a thorough understanding can help counteract upon it. This cannot be over emphasized, since the supply chain system is inherent to its cause; the underlying demand characteristics and replenishment lead times. The global market increasing competition, the product life cycle reduction and the more demanding customer had forced enterprises and businesses to pay more attention to supply chain management. The order information transmitted along supply chain appears scale-up effect, named bullwhip effect. It consumedly increased operation cost of supply chain and reduced its efficiency. Therefore, the study of bullwhip effect in supply chain and its restraining method is of great important. That enhancement of connection and cooperation between supply chain various nodes, and the information sharing degree, being seamless joint driven by customer demand, are the key to reduce the supply chain cost, restrain bullwhip effect and enhance supply chain management effectively. For that, we analyzed the reason of bullwhip effect development and the alleviation countermeasure, established a three-echelon supply chain simulation model base on that, implemented information sharing at upstream nodes and quantitatively analyzed the restrain effect of information sharing to bullwhip effect.

This paper is arranged as follows: After reviewing some of the most relevant literature on multi-echelon supply chains in Section 2, a detailed description of problem formulation presented, the Arena simulation model and assumptions are given in Section 3. Section 4 & 5 discusses the simulation experiment presented in this paper and provides the simulation results. Finally the conclusions of this paper and future work to be done are summarized in Section 6.

2. Literature review
The Bullwhip effect research on information sharing in the supply chain was initiated by Forrester (1961) who demonstrated that information in a supply chain, such as orders, propagates upstream with increased volatility. He illustrated the effect in case studies and pointed out that it is a result of industrial dynamics or time varying behaviors of industrial organizations. Sahay and Mohan (2002) highlighted the bullwhip effect in the ‘beer distribution game’, in an inventory management context. He attributed this phenomenon as a result of a player’s systematic irrational behavior or ‘mis-perceptions of feedback’. Chase et al. (2003) identified the bullwhip effect to demand forecasting and order lead times, based upon a model. Its effects are extended to multiple supply chains with or without centralized customer demand information and demonstrate that the bullwhip effect can be reduced but not entirely eliminated, by centralizing demand information. They studied that the use of
exponential smoothing forecast by the retailer can cause the bullwhip effect and contrasted these results with variability due to the use of a moving average forecast.

Samuel and Mohanty (2002) have said that the ‘Demand Signal Processing’ (DSP) is one of the causes for the whiplash or bullwhip phenomenon. Updating of demand forecasts from downstream level to upstream level in a supply chain based on the signals of increase or decrease in demand is referred to as Demand Signal Processing. They have studied the impact of DSP on bullwhip effect and how information sharing can minimize this effect, with the help of decentralized supply chain model and alternative information sharing model. Tang et al. (2002) have developed a program called ‘Advance Booking discount (ABD) program to manage demand uncertainty for short life cycle products. This program entices customers to pre-commit their orders at a discount price prior to the selling season. however, such orders are fulfilled during the selling season. The time between the placement and the fulfillment of these pre-committed orders provides an opportunity for the retailers to update demand forecasts by utilizing information generated from the pre-committed orders at the beginning of the selling season. Huang et al. (2007) develop models of a class of supply chain systems, including a multi-echelon supply chain system, a time-lag dynamic supply chain system, and a dual-channel supply chain with a B2B e-market, and analyze each of the bullwhip effects respectively. They address a new method for dynamic quantification and calculations of the bullwhip effect based on classical control theories and methods, and discuss the H control strategies of these systems under the worst fluctuation of demand. Finally, combined with the empirical practices of the most representative state-owned companies in China, they carry out three simulation experiments, and from the results have found that the bullwhip-effect coefficients of these three systems are all controlled and dampened with the H control method. Nienhaus and Ziegenbein (2006) describe the beer distribution game online, which is a web-based simulation of a supply chain with four tiers. Results of this simulation allow for the first time the analysis of how humans perform as a partner in a supply chain compared with simple agent-based strategies. A study by Lin and Lin (2006) examines the bullwhip effect caused by order variance from retailers. It shows that based on portfolio theory, supplier's demand variance can be reduced by adjusting the order quantities of retailers through co-ordination. The results indicate that this approach can be a useful means for alleviating the bullwhip effect.

3. Problem explanation
The main aim of this work is to compare the performance of the three tier supply chain with two types of information strategies i.e. centralized and decentralized information. The research objectives of the present work are

1. To study the existing supply chain (supply chain with decentralized information strategy) of the company ABC Ltd. and to identify the drawbacks.
2. To study the two types of information sharing strategies in supply chain management i.e. centralized and decentralized and compare the supply chain performance associated with both.
3. To find out the best information sharing strategy from the analysis which has reasonable cost and at the same time should capable enough to give the better performance.
4. Design and development of simulation models (ARENA 11.0 simulation software) of supply chain with Centralized and Decentralized information strategy in order to improve performance level.

4. Models development to bullwhip effect reduction
In the present work a multi echelon supply chain has been created in which entities are customers, retailers, distributors, output buffer, input buffer and suppliers. At the beginning the customer will place order to the retailer, the retailer will hold this demand how long the earlier customers demand have been fulfilled. Then it will check its inventory stock, if available it will provide this product to customer if not it will order from distributor. The distributor will check its demand and if not available there is a loss of customer. Further the distributor will order from the output buffer of the plant, if not available will take from input buffer. The input buffer, if not having enough stock will order it from the supplier and the process goes like this. For supplier we have assumed that there is no demand loss. So, we are taking the two flows in our supply chain (demand flow and material flow).

4.1 Model of Decentralized & Centralized Information Sharing
In the present work two conceptual supply chain models has been developed for the analysis named as Centralized and Decentralized information sharing strategy. We have compared the performance parameters of
both these information strategy models in three tier supply chain environment. It has been observed that centralized information strategy is much more efficient than decentralized. The inventory levels in the decentralized information equipped supply chain is more than in supply chain with centralized information strategy. The conceptual models has been shown in figure 1 and figure 2.

### Centralized information
- All stages have access to end customer data

**Figure 1 Supply chain model with centralized information sharing strategy**

### Decentralized information
- All stages base their forecast on the direct customer’s demand

**Figure 2 Supply chain model with decentralized information sharing strategy**

#### 4.2 Simulation Modeling of Bullwhip Effect

The Arena Simulation approach has been used to study the difference in applying both the information sharing strategies in the working of the company. It has been noticed that the Centralized information is the best strategy to be adopted by the company ABC Ltd.
4.3 Simulation Model Translation

Models have been developed by using ARENA Simulation Software to study the functioning of the company and new model has been devised to make the system performance efficient. We have built models in such a manner that what we study about the system should be same what we have developed through models. Validation confirms about the realistic characteristics of the system. We have verified the model by the analysis of the predictions. We have gone through the following strategy

1. Inspection of logic of simulation program
2. Performing of simulation test runs with which we can inspect the correctness of the program logic
3. Performing simple consistency checks

Bullwhip Effect in the supply chain is quantified by using equation 1.

\[ M = \frac{\text{Variance (O_t)}}{\text{Variance (D_t)}} \]
Where,
\[ M = \text{Measure of bullwhip effect} \]
\[ O_t = \text{Order variance} \]
\[ D_t = \text{Demand variance} \]

Verification concerns with the operational model (whether it is performing properly). It is done to ensure that: The model is programmed correctly. The model does not contain errors, oversights, or bugs. We have studied the given formula of calculating the Bullwhip Effect from Supply chain Research. To make assure that the results obtained are valid, let us take the result of the Replication \( N = 90 \) for Centralized information, for it the order variance has been calculated by using mean and standard deviations for the order and demand. Order variance = 57.81 and Demand variance = 58.59. So the value of \( M = \frac{57.81}{58.59} \) i.e. 0.9866 which is <1, so smooth working of the supply chain can be predicted and for Decentralized information for \( N = 90 \), we have order variance = 76.09645 and demand variance = 46.00284, so \( M = \frac{76.09645}{46.00284} \) i.e. 1.6541 which is >1 so Bullwhip effect is present.

5. Results And Discussions

In the present work, simulation experiments carried out for \( N = 70 \) replication and Run length has been taken as for 525600 minutes. The table 1, 2, 3, and 4 represents the results of simulation run during study. The inventory at different stages of the supply chain has been checked from the simulation results and it has been observed that the inventory at the decentralized information model is more as compared to the Centralized information sharing strategy. It is more efficient than the decentralized one. The order rate and the demand rate has also been analyzed and it has been seen that in Decentralized model, orders are more fluctuating than the demand, but in Centralized model order and demand are nearly comparable. The proposed supply chain with central information strategy has been developed for the company ABC Ltd. The proposed supply chain is practicing the Centralized information sharing strategy among all its supply chain partners. Figure 4 and 5 clearly shows the fluctuation in demands and order with centralized and decentralized information sharing strategy in supply chain management.

<p>| Table 1 Variation in Bullwhip Effect with No. of Replications (Decentralized Information) |</p>
<table>
<thead>
<tr>
<th>No of Replications N</th>
<th>Demand variance</th>
<th>Order variance</th>
<th>Bullwhip effect = M = order variance / demand variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>46.00284</td>
<td>76.09645</td>
<td>1.6541 &gt;1</td>
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<tr>
<td>70</td>
<td>44.836</td>
<td>63.7678</td>
<td>1.4222 &gt;1</td>
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<tr>
<td>50</td>
<td>43.764</td>
<td>66.34</td>
<td>1.5158 &gt;1</td>
</tr>
<tr>
<td>30</td>
<td>42.1713</td>
<td>65.85</td>
<td>1.5614 &gt;1</td>
</tr>
<tr>
<td>10</td>
<td>41.42</td>
<td>64.68</td>
<td>1.5615 &gt;1</td>
</tr>
</tbody>
</table>

<p>| Table 2 Variation in Bullwhip Effect with No. of Replications (Centralized Information) |</p>
<table>
<thead>
<tr>
<th>No of Replications N</th>
<th>Demand variance</th>
<th>Order variance</th>
<th>Bullwhip effect = M = order variance / demand variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>58.59</td>
<td>57.81</td>
<td>0.9866 &lt;1</td>
</tr>
<tr>
<td>70</td>
<td>59.0676</td>
<td>55.99</td>
<td>0.9476 &lt;1</td>
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<tr>
<td>50</td>
<td>57.87</td>
<td>57.375</td>
<td>0.991 &lt;1</td>
</tr>
<tr>
<td>30</td>
<td>57.3697</td>
<td>56.28</td>
<td>0.9810 &lt;1</td>
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<tr>
<td>10</td>
<td>55.68</td>
<td>49.175</td>
<td>0.8831 &lt;1</td>
</tr>
</tbody>
</table>

Table 3 Improvement in performance parameters
### Table 4 Number of orders at various supply chain partners

<table>
<thead>
<tr>
<th>Replications</th>
<th>Retailer</th>
<th>Distributor</th>
<th>Output buffer</th>
<th>Input buffer</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>76</td>
<td>93</td>
<td>100</td>
<td>102</td>
<td>103</td>
</tr>
<tr>
<td>30</td>
<td>76</td>
<td>91</td>
<td>100</td>
<td>101</td>
<td>104</td>
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<td>50</td>
<td>76</td>
<td>92</td>
<td>100</td>
<td>100</td>
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<td>70</td>
<td>76</td>
<td>91</td>
<td>100</td>
<td>103</td>
<td>106</td>
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<td>90</td>
<td>76</td>
<td>93</td>
<td>100</td>
<td>102</td>
<td>106</td>
</tr>
</tbody>
</table>

The proposed model will enhance the company’s performance by analyzing the cost, inventory and order levels which can reduce the wastage. It has also been observed that in Decentralized information lost sales at retailer are 20 units and it has been reduced to 18 units in centralized information. The inventory levels for the distributor have been decreased from 53 units to 51 units due to the Centralized sharing strategy. Order at output buffer goes down from 100 to 74 in case using the centralized information system. Inventory at input buffer has been shown going down from 72 to 70 which can improve the cost entities in the proposed supply chain. Order at...
Distributor comes down from 80 to 52 and for the input buffer the order level goes from 90 to 74 which is a considerable difference for any supply chain. Order level at Supplier decreases from 81 to 76 and the inventory for Retailer decreases 50 to 47, hence it has been concluded that the results obtained in Centralized models are far better than the existing Decentralized system.

6. Conclusions & Future Scope
The two different models designed in ARENA simulation software for the information sharing strategies have provided the best results related to inventory, order, demand, number in, number out and various costs like usage cost, busy cost. The variables like inventory, waiting time, amount lost and order-demand have been compared for both the strategy and it has been found that the Centralized information is the best information sharing strategy than the Decentralized one. Centralized information model can be practiced in every industry and experts can also use this for the business purposes to minimize the loss. Graphs and tables have been used to show the performance and the stability of both the information sharing strategy that leads to the bullwhip effect in the Supply chain. Since research level has no end point, same can be incorporated that the research gaps are always there. More complex chains with multiple buyers, sellers and vendors can be included in it. To make ARENA language realistic visual basic tools which are advanced tools in ARENA can also be employed for complex supply chains.

References


