Effect of Forecasting on Bullwhip Effect in Supply Chain Management

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Most of the recent research in supply chain management has focussed on bullwhip effect (BWE) which is a phenomenon in which distorted information from one end of a supply chain to the other can hamper the supply chain performance. The impact of BWE is to increase manufacturing cost, inventory cost, replenishment lead time, transportation cost etc. Various factors can cause this effect, one of which is customer demand forecasting technique. In this paper, the impact of forecasting methods on the bullwhip effect has been studied. This study highlights the effect of forecasting technique, order processing cost and demand pattern on BWE. The effects of two forecasting techniques namely moving average and exponential smoothing on BWE have been compared. Simulation experiments have been carried out using full factorial design involving three factors such as order processing cost, method and demand pattern. The BWE has been evaluated using MATLAB code. The results were analyzed using ANOVA and finally the optimal parameters for minimum values of BWE have been determined.

Keywords: bullwhip effect, forecasting, supply chain management

Introduction

Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores so that merchandise is produced and distributed at the right quantities, to the right location and at the right time in order to minimize system-wide cost while satisfying service level. A supply chain is dynamic and involves the constant flow of information, material, and funds between different stages across the entire chain. It is a network of facilities that procures raw materials, transform them into intermediate goods and then final products before delivering them to customers through a distribution system (Lee and Billington, 1992). This requires an integrated approach to network management for optimization of trade-off between cost and service level, seeking new solutions to improve the firm competitiveness, and allowing companies to face with environmental changes. But lack of information across the supply chain gives rise to unrealized profit termed as

Bullwhip Effect (BWE). It is calculated as (Disney & Towill, 2003)

$$BWE = \frac{\sigma_o^2 / \mu_o}{\sigma_s^2 / \mu_s}$$

where σ^2 denotes variance and μ denotes mean. The subscripts O and S refer to orders placed to a supplier, and sales or consumption by customers, respectively.

Forrester (1958) is the first to identify bullwhip effect that occurs due to demand amplification. Lee et al. (1997) coined the term bullwhip effect and presented the analysis of BWE related to its causes, quantification, handling and mitigation. The four major causes are i) demand signal processing (forecast updating), ii) rationing game with shortage, iii) order in batches, and iv) price fluctuation.

In this paper, the main focus is to estimate and compare the bullwhip effects in a supply chain following different types of demand forecasting methods through simulation technique and to identify the significant factors using ANOVA.

Methodology

Demand Forecasting in a Supply Chain

Forecasting of future demand is essential for taking decisions related to supply chain. It involves various techniques including both quantitative and qualitative methods.

Analysis of Variance

Minitab R14 software was used for experimental analysis in the present work. The process parameters that significantly affect the performance characteristic were statistically identified using analysis of variance (ANOVA). Bullwhip effect (BWE) was minimized in the analysis.

Experimental Details

Model Analysis

A two staged real supply chain consisting of one supplier and four retailers was considered and simulated under the following assumptions (Charsooghi et al., 2008):

- The supplier can produce any required amount of the ordered products.
- Transportation costs per truck from supplier to the retailer are taken as \$225 and \$553 respectively for each retailer.
- The manufacturing lead time is equal to one period of time.
- The retailers use Economic Order Quantity (EOQ) model to make ordering decision.

- Order processing cost of \$30 per order is incurred when a retailer places an order to the supplier. So, the total order processing costs for each retailer was \$285 & \$583 respectively.
- Unit inventory holding cost per period for the retailer is \$4.

Demand Generation

The sales demand is generated through simulation using the following expression:

D_t = S+s.t+I.sin(2πt/c)+e.snormal() …(1)

where, D_t = demand in period t, S = base, s = slope, I = seasonality, c = season cycle = 7 (in this study), e = noise, snormal() = standard normal random number generator. Two demand patterns representing with and without seasonality are used in this study as shown in Table 1.

TABLE 1: CHARACTERISTICS OF DEMAND PATTERN

Demand Pattern	Base (S)	Slope (s)	Season (I)	Noise (e)
DP1	1000	0	0	100
DP2	1000	0	200	100

Retailers Ordering Decisions

First, forecast for the next period is determined using a particular forecasting method and demand is generated using MATLAB simulation. Then**,** the order quantity is determined using EOQ policy.

The forecasting methods used are:

❖ *Moving Average Method:*

The general form of this method is as follows:

$$F_{t+1} = \frac{1}{n} \sum_{i=t-n+1}^{t} X_i$$

where F_{t+1} is the forecast for the next period, t is the current time, X_i is the real demand for the period i and n is number of immediate past demand data considered. In this analysis, the value of n was taken as 50 and 300.

❖ *Exponential Smoothing*

The forecasting method is defined as the following:

$$F_{t+1} = \sum_{i=t-n}^{t-1} \alpha(1-\alpha)^i X_{t-i} + (1-\alpha)^t F_1$$

where α is the smoothing factor in the range of [0, 1] and other parameters are same as in moving average method. In this analysis, α was taken as 0.25, 0.5 and 0.75

Experimental design

A full factorial design of experiments with three factors i.e. ordering cost, forecasting method and demand pattern at four, ten and four levels are considered respectively. The four levels of ordering cost are $285 and $583. The ten levels of forecasting methods are shown in Table 2. The two levels of demand patterns are DP1 to DP2 as mentioned in Table 1. For a full factorial design of experiments, a total of 20 (i.e. 2x5x2) runs of experiments are required.

MATLAB Code

MATLAB codes were written to generate demand for different conditions, forecast using two forecasting methods and finally to calculate their respective bullwhip effect.

TABLE 2: LEVELS OF FORECASTING METHODS

Level	Forecasting Method	n	α
1	Moving Average	50	-
2		300	-
3	Exponential Smoothing	7	0.25
4		15	0.25
5		15	0.75

Results and Discussion

The significant factors are identified and analyzed using ANOVA. Table 3 shows the result of ANOVA performed on BWE. It is observed that the type of forecasting methods is the most significant factor affecting BWE followed by type of demand pattern, ordering cost. The interaction effect of forecasting method and demand pattern has also significant effect. The coefficient of determination R^2 has been found to be 97.34% which is quite satisfactory.

TABLE 3: ANOVA TABLE

Source	DF	Seq SS	Adj SS	Adj MS	F
O	1	0.0627 03	0.0627 03	0.062703	4.628211
Method	4	1.4977 19	1.4977 19	0.37443	27.63727
DP	1	0.1534 78	0.1534 78	0.153478	11.32846
O x Method	4	0.0473 00	0.0473 00	0.011825	0.872823
O x DP	1	0.0124 65	0.0124 65	0.012465	0.920062
Method x DP	4	0.0124 65	0.2108 75	0.052719	3.891257
Error	4	0.0541 92	0.0541 92	0.013548	
Total	19	2.0387 32			

Conclusions

It is observed from the above study that demand forecasting is one of the key causes for bullwhip effect. Different forecasting methods have been compared from bullwhip effect by using simulation program written in MATLAB code, and then subsequently analyzed with ANOVA for identifying the significant factors and it is obtained that type of forecasting method should be carefully selected to minimize bullwhip effect.

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