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Quantification of Bullwhip effect (BWE) in supply chain management (SCM)

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ABSTRACT

A chain is as strong as its weakest link. The strength of a supply chain is determined by the strength of the information link across it. This paper deals in detail with the causes for the distortion of information (Bullwhip Effect) in the supply chain and the tools and techniques to remove and minimize this effect.

Keywords—Bullwhip Effect, Supply Chain, Variability. Introduction

I INTRODUCTION

A supply chain is, "a web of autonomous enterprises collectively responsible for satisfying the customer by creating an extended enterprise that conducts all phases of design, procurement, manufacturing, and distribution of products". This involves creating an extended enterprise that conducts all phases of design, procurement, manufacturing and distribution of finished goods. Customers, suppliers and manufacturers are the three primary elements of any supply chain. The main objective of a supply chain is to synchronize the requirements of the customer with the flow of material from suppliers in order to get a balance between the conflicting goals of a supply chain such as high service level, low inventory investment and low unit cost. The prime responsibility of a supply chain is to move the raw material from the point of procurement to the point of consumption with minimum lead-time.

Today, companies operate as individual firms even though they form a part of a supply chain. This reduces the effectiveness of the supply chain in terms of poor service level, high operating cost and increased non-value adding activities. The entire supply chain can be viewed as a single unit called the extended enterprise. Doing this reduces information distortion across the entire chain and helps in decreasing the Bullwhip Effect. The main objective of effective supply chain management is to weave each of the supply chain partners with conflicting objectives and opinions into a seamless fabric with effective information flow, physical distribution flow and cash flow for the benefit of the end customer

1.1 Bullwhip effect:

The key link in many supply chains is information. As we integrate suppliers and manufacturers with conflicting objectives and strategies, information sharing becomes the weakest link of the supply chain. As each manufacturer has different views of interpreting customer information, the variation of the information increases as we go up the supply chain. This amplification of variation as we move towards the upstream side of the supply chain is called a Bullwhip Effect or Whiplash Effect.

Figure 1 illustrates a simple six-stage general supply chain: consumer, retailer, wholesaler, distributor, manufacturer and a supplier. The retailer observes consumer demand and places orders to the wholesaler. The

wholesaler receives product from the distributor who places orders to the manufacturer. The manufacturer places an order for raw materials, to the supplier. Thus, the demand information flows from the consumer through various supply chain links to the supplier.

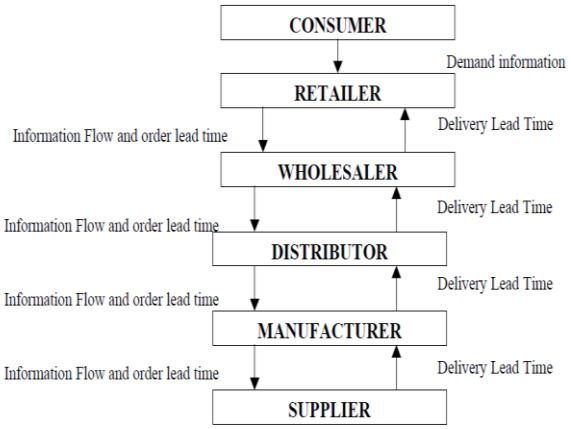

Figure 1: Generic Supply Chain Model [6]

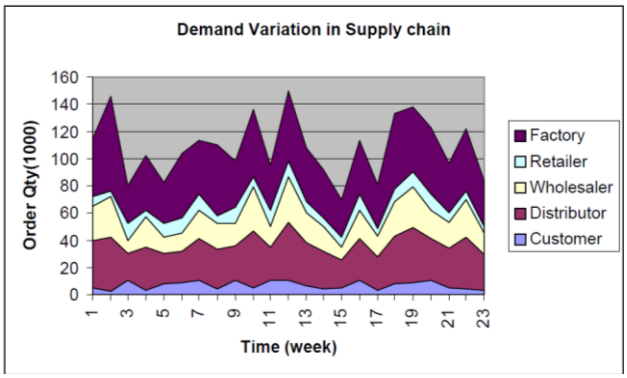

Figure 2: Bullwhip Effect in Supply Chain [Adopted from 6]

Figure 2 provides a graphical representation of orders, as a function of time, placed by different facilities (Factory, retailer, wholesaler, distributor and customer). The variation in the customer demand is less when compared with the variation caused by the intermediaries. The variation in the demand information increases as it reaches the manufacturer. Many factors and policies followed by the intermediaries influence this variation.

1.2 Background

In the 1980s, companies discovered new manufacturing technologies and strategies that allowed them to reduce cost and compete effectively in the market. Strategies like Just In Time (JIT), Kanban, Lean Manufacturing and Total Quality Management (TQM) became popular. By incorporating these strategies, companies reduced their manufacturing cost. Dynamic variations in customer demand forced companies to implement a new system that enabled them to increase the service level and quality with the same manufacturing cost. This was achieved by linking the customers and the suppliers by a concept called supply chain management. This linking concept had its own pros and cons due to the conflicting objectives and policies employed by the supply chain partners.

The objective was to discover the possible ways to counter the information distortion due to the differences in the objectives and policies of the supply chain partners [6]. Whitman, et al. compared the term supply chain with research in extended enterprises and virtual companies. It stressed the need to take a holistic view of the enterprise Extensive research has been performed to find the reasons for the Bullwhip Effect and its remedies. Lee, et al. [5], postulated that there are four major reasons for the Bullwhip Effect. They are:

1. The inaccurate forecasts of demand called "demand signal processing".
2. Rationing of the products by the manufacturer to retailers due to some limitations in production called "the rationing game".
3. The ordering policy used by retailers called "order batching".
4. Discounts and seasonal price variations.

They devised a set of simple models to illustrate how each of these factors can lead to the amplification of variance as one moves up the supply chain. They also proposed some remedies for each of these factors. Richard Meters, [7] postulated the seasonal demand and the variation in demand due to forecasting errors as the two basic reasons for Bullwhip Effect. He viewed the impact of forward buying and order batching on the profitability of the system. The paper stated that it is relatively easy to tackle the distortion caused by seasonal demand, if the variation in the seasonal demand changes frequently. Whitman, et al. described that frequently when implementing new or maturing technologies, the impact to the entire supply chain is overlooked. They proposed a method as to how the total supply chain issues are considered in a new technology implementation. The methods given would reduce the Bullwhip Effect to a considerable extent.

1.3 The Causes of Bullwhip Effect

It can be said that the Bullwhip Effect is due to the rational behavior of the decision-makers of a supply chain under a given structure. This implies that companies desiring to gain control of the Bullwhip Effect have to look at the entire supply chain structure and related processes.

There are several factors that contribute to the Bullwhip Effect. The factors that contribute significantly are: Demand forecast updating, Order batching, Price fluctuation and Hoarding and Rationing. Each of these factors will be discussed in detail later in the following sections. Understanding the causes of the Bullwhip Effect aids the design and development of strategies to counter the effect.

1.4 Objectives of the Project

The objectives of the present research work are as follows:

1. Understanding the basic structure of supply chain network and the concept of BWE.
2. Determination of BWE through demand generated using different demand patterns.

Estimating the bullwhip effect in SCM and reducing the bullwhip effect.

II LITERATURE SURVEY

2.1 Bullwhip Effect

The initial work on the bullwhip effect was carried out by Jay W. Forrester [1]. In his groundbreaking work he discovered existence of demand amplification or bullwhip effect while working on a four echelon supply chain. He predicted decision making process and time delay in each phase of Supply Chain Network (SCN) and the factory capabilities could be the main reason of the demand amplification. He also found that the advertising factor also influences the system by generating BWE. Burbidge [2] studied about production and inventory control along with demand amplification. He concluded that if demands are carried over a series of inventories using "stock control ordering" then an increase in demand variability would occur with every transfer of demand information. Sterman [3-6] in his works focused on the existence and causes of BWE using an experimental four-stage SCN role-playing simulation which simulated the beer distribution in a simple SCN. This SCN simulation game successfully portrays the idea of system dynamics. The "Beer Distribution Game", is widely used for teaching the behavior, concept and structure of SCN. He also analyzed the decision methodology of the participants of the SCN and found out that the participants are not focusing on the system delays and nonlinearities. He concluded that anchoring and adjustment heuristics are inconsequent as these heuristics lack sensibility to delay.

2.2 Causes of BWE and its Quantification

Lee et al. [12, 13] made a very important analysis which made a way for many other studies. The study was basically related to the causes, quantification and handling tools of BWE. They stated the following four major causes for BWE:

1. Demand signal processing (forecast updating)
2. Rationing game
3. Order batching
4. Price fluctuation

2.3 Effect of Forecasting Techniques and Other Factors on BWE

The authors later studied the effect of exponential smoothing forecasting technique on BWE for independently identically distributed and linear trend demand case. The study was same as the previous one. The conclusions of the study were:-

1. The size of demand variability directly influenced from the forecasting technique used to predict future demand variances and from the type of the demand pattern.
2. BWE occurs when retailer updates the order-up-to point according to the periodically computed forecast values.
3. The longer the lead time, the greater the demand variability.
4. Smoothing the demand forecast with more demand information will decrease BWE.

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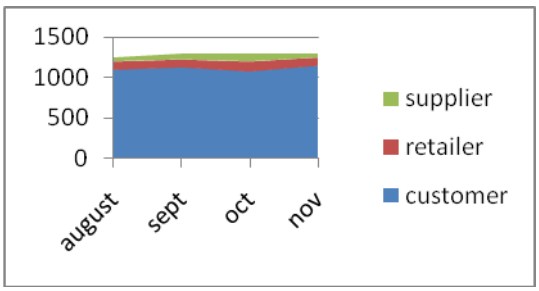
III PROBLEM STATEMENT

The problem studies briefly a two stage supply chain system from western Maharashtra , a leading supplier of industrial goods and products like ; grinding wheels , belts, bearings, industrial trolley equipments , boiler equipments , sugar industry equipments, small scale and medium scale business equipments, etc



Here is short description of the problem

Here I have considered the four retailers of the main supplier, the supplier is based in the Sangli and retailers are located at some distance from the supplier such that the ordering cost and batch quantity and demand are different from different retailers hence these costs are different from retailer to retailer.

Retailers and their locations are:

Retailer 1 is 10-12 Km away from the supplier, Retailer 2 is 23 Km away, Retailer 3 is 45 Km away and Retailer 4 is 55to 60 Km away from the supplier.

From above information we can get that the transportation cost is different for different suppliers hence batch quantity and order quantity and frequency is different for each retailer, apart from this different industrial requirements are in existence for different supplier like if a part is in demand for one retailer do not imply that there is similar demand from other suppliers the demand may be more or less than that of the retailer. Now, the supplier role is that they have to collect the data from retailers and then modify it into the orders so that they can order in the right quantity from the manufacturer or distributer and so they order about 10 to 15 % of the extra material from the manufacturer or distributer , the similar kind of situation is exists at the retailer end hence they also order the quantity to cope up with some uncertainties into the supply chain like in time delivery , demand , supply and transportation cost etc hence they order at least 5% to 10% of the items extra to that of the demand of the market .Here, as suggested earlier, one supplier and four retailers are taken into account to study the problem completely. The demands from customer, retailers and supplier for four products of grinding wheel are as given in table 3.1. Also, the demand pattern for each of the retailers for the month of August is shown in table 3.2

Table 3.1 implies the demands from customer, retailers and supplier for four products of grinding wheel.

Month/Year	Customer	Retailer	Supplier
August / 2017	1100	1200	1250
September / 2017	1130	1225	1300
October / 2017	1080	1200	1350
November / 2017	1150	1250	1300
Total	**4460**	**4825**	**5200**

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% increase	**100**	**108.18**	**116.59**

Table 3.2 shows the demand pattern for each retailer for the month of august

		R1	**R2**	**R3**	**R4**
Retailers demand	1200	390	360	300	150
Actual demand + extra order	1100+ 100	350+40	337+23	280+20	133+17
Product1	Extra cost 29*400 = □ 11,600	80+10	70+3	100+10	40+6
Product2	Extra cost 23*450 = □ 10,350	85+10	80+5	70+3	35+5
Product3	Extra cost 23*550 = □ 12,650	100+10	77+5	80+5	25+3
Product4	Extra cost 25*650 = □ 16,250	85+10	110+10	30+2	33+2
Total	Total extra cost = □ 50,850				

IV COLLECTION OF DATA

Date is collected for each product and retailer separately for every month and with date wise.

While collecting the date some assumptions are considered for simplification of complex calculations, and we can improve the complexity of the problem by adding them into the problem but now they are considered as;

1) Sunday is the weekly holiday for every retailer
2) No order is placed and received on Sunday
3) Sunday is not taken into calculations
4) Other holidays other than Sunday are taken into calculations as there is wide variation amongst each retailer.
5) Data is collected day wise but calculations are done week wise i.e. the unnecessary variation and repetitive calculations are removed.

Sample data collected is shown in the table no 4.1 below, for 1st month and retailer one for one product.

Aug 2017 R1							
Product 1	**S**	**M**	**T**	**W**	**T**	**F**	**S**
Date			1	2	3	4	5
Demand			***5***	***3***	***2***		***4***
Date	6	7	8	9	10	11	12
Demand		***1***	***9***	***3***	***6***		***6***
Date	13	14	15	16	17	18	19
Demand		*5*		*7*		*3*	
Date	20	21	22	23	24	25	26
Demand		***3***		***8***	***2***	***1***	***3***
Date	27	28	29	30	31		
Demand			***2***		***7***		

Where R1 is retailer 1 and Product 1 is respective product for which data is collected

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V CALCULATION OF BWE

According to the previous researches on the bullwhip effect measure (like Chen et al. (2000 a, b) Kim et al. (2006) and Sucky (2009)) bullwhip ratio can be calculated by equation (1):

BEM = (1)

Where Var (Q) is variance of retailer orders and Var (D) is variance of the customer demand. Therefore, to provide bullwhip effect measures we must prepare equations for two mentioned terms. If BEM is greater than 1 then Bullwhip Effect is present where as for other cases like if is equal to 1, then it is not present in Supply chain, higher the value larger the BE. Below are sample calculations of bullwhip effect in supply chain of the retailer and distributer model using the simple formulae of BEM as per the equation no 1.Table 5.1, implies the calculations of the variance of demand where as Table 5.2 implies the variance of the supply.

Table 5.1, variance calculation for demand

X	μ (mean)	(X-μ)	(X-μ)^2/N
14	80/5 = 16	-2	4/5
25		9	81/5
15		-1	1/5
17		1	1/
9		7	49/5

Demand variance is given by;

Var (D) = (4+81+1+1+49)/5

= 27.2

Similarly, for supply quantity, we can calculate the same.

Table 5.2 variance calculation for Supply

X	μ (mean)	(X-μ)	(X-μ)^2/N
10	100/5 = 20	-10	100/5
35		15	225/5
10		-10	100/5
25		5	25/5
20		0	0/5

Var (Q) = (100+225+100+25+0)/5

= 90

BEM = from equation (1)

= 90/27.2

= 3.30882

Which is greater than 1 hence, Bullwhip Effect is present in this supply chain for product 1 and retailer 1 of 1st month of study.

VI CONCLUSION

The Bullwhip effects are measured and it is observed that the products are ordered more than the required and safety stock of the retailer hence the information share is required to be more accurate, despite the fact of presence of Bullwhip effect there are many non technical causes that are coming in place to give rise to the Bullwhip effect and stocking behavior of retailers and distributors.

It is observed that the pace and accuracy of information sharing is vital amongst all and required to be more synchronous with each other and the vital elements of the supply chain network should act in cohesion with each other.

VII FUTURE SCOPE

This project has wide scope for further developing as this problem studies with the simple model of 4 products and 4 retailers with respect to the one supplier for the four number of products hence we can increase the wide application of the problem by considering the other factors that are assumed to be negligible in this problem and hence the complexity will be increased another important point to be noted here is that we may use the software like Spreadsheet, Excel for date accuracy and calculations and coding in MATLAB software will help to formulate the problem statement in mathematical terms .

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