Bullwhip Effect Reduction Using Vendor Managed Inventory (VMI) Method in Supply Chain of Manufacturing Company

D Ernawati*, E Pudji, N Rahmawati, M Alfin

Department of Industrial Engineering, Faculty of Engineering
University of Pembangunan Nasional Veteran Jawa Timur, Surabaya, Indonesia
*Corresponding author: diraernawati@gmail.com

Abstract. Prediction of the amount of production can be done by forecasting demand and using appropriate methods. The supply chain studied at ABC company consists of manufacturing (vendors) and sales offices. Initially forecasting is done at each level of the supply chain with different forecasting methods. Therefore, uniform forecasting methods are needed for each supply chain actor. Based on testing the forecasting method conducted, the Winter’s Method. The model is used to link forecasting and implementation using the Vendor Managed Inventory (VMI) approach. Inventory planning in the supply chain cannot be done individually and must be thought of as a coordinated system. Inventory control is done by using the optimal lot calculation, namely Economic Order Quantity (EOQ). Based on demand forecasting and optimal lot determination, it can be calculated the value of the Bullwhip effect that occurs after the use of VMI in the supply chain has changed from 1.359 to 0.514 at the Manufacturing level.

Keywords: Layout, Group Technology, Cellular Manufacturing System, Rank Order Clustering

1. Introduction

Very tight competition between manufacturing industries and consumer demand that continues to increase every year, making industry players must carry out industry activities optimally. To provide cheap, high-quality, and fast products by carrying out internal improvements in a manufacturing company is not enough. These three aspects require all parties role ranging from suppliers who process raw materials from nature into components, companies that convert components and raw materials into finished products, transportation companies that send raw materials from suppliers to companies, and distribution networks that deliver finished products to consumers. Awareness of the importance of the relationship of all parties is a Supply Chain Management (SCM) concept. [1][2]

In recent years at ABC Company there was a significant difference between demand data and sales data received by the company and the nine sales offices owned by the company. Especially for rice flour products with 500gr packaging. This happens because of the distortion of information and the lack of synchronization between the company’s supply chain actors so that a phenomenon called the bullwhip effect has occurred in the company. The existence of uncertainty requires companies to produce more products as inventory to avoid shortages. Based on the problems that occur in the company, the approach that can be used to solve this bullwhip effect problem is with information sharing. With the CPFR collaboration model (Collaborative, Planning, Forecasting, and Replenishment) is a good solution to synchronize information for all supply chain parties, one of the CPFR concepts that implements collaboration or coordination between producers and retailers is Vendor Managed Inventory (VMI) [3][4]. The Vendor Managed Inventory (VMI) method is a system where the needs of distributors and
retailers are monitored and controlled by the company or vendor [5]. The vendor will be responsible for delivering the product in the right amount and time so that there is no stock out which can have an impact on the customer service level at the distributor and retail level [6].

2. Literature Review

2.1 Supply Chain Management

Supply chain is a network of companies that are jointly working to create and deliver a product to the end user. These companies usually include suppliers, manufacturing plants, distributors, retailers, and supporting companies such as logistics service companies. The supply chain function is to provide products and services that are fast, in a timely manner, and at desirable conditions while still providing optimal contributions to the company. If the supply chain is the physical network, that is, companies involved in supplying raw materials, producing goods, or sending them to final consumers. Whereas supply chain management is a method, tool, or approach to its management. Supply chain management is one strategy that can be used to overcome the problem of supply of goods [7]. One of the key factors to optimize the work of the supply chain is to create a flow of information that moves easily and flexibly and accurately between the network or the chain of the supply chain and the movement of goods effectively and efficiently which will produce maximum satisfaction for customers [8]. The challenges that must be faced in the supply chain are as follows (1) The complexity of the supply chain structure, (2) Uncertainty, (3) Uncertainty of request, (4) Uncertainty from suppliers, (5) Internal uncertainty [9].

2.2 Information Distortion and Bullwhip Effect

Distortion of information on the supply chain is one source of constraints in creating an efficient supply chain. Often, information about consumer demand for a product is relatively stable over time, but demand from stores to suppliers and suppliers to factories is much more volatile compared to the demand patterns of these consumers [10]. Bullwhip effect is an increase in variability from the lower level to the upper level and in a supply chain network. In this situation the company does not have accurate demand information. Bullwhip effect, this term was coined by Procter & Gamble management who saw the amplification of information distortion as information in the supply chain. The existence of this bullwhip effect can make it difficult for companies to understand the demands of market needs, which can cause companies to produce more to meet market demand [11] [12]. Several studies have investigated the bullwhip effect on inventory uncertainty.

2.3 The Main Causes of Bullwhip Effect

There are four main causes of the bullwhip effect, including the following (1) Demand forecasting updating, the update of demand forecast influences the accuracy of forecasting because the company is aware of the latest information related to customer demand and the actual market situation [13], (2) Order batching, retailers who sell products on a small scale will order products in large enough quantities within a specified period. This causes the distributor to get more volatile demand compared to the demand faced by retail [14], (3) Price fluctuations, the existence of discounts to distributors that affect fluctuations in demand from distributors [15] (4) Rationing and Shortage Gaming, in situations where demand is higher than inventory, sellers often do what is called rationing, which only fulfills one hundred percent of customer orders, but only a percentage of the total volume ordered. Knowing that requests have not been fully fulfilled, many customers have sought to increase the size of their orders in the hope of getting sufficient quantities.

2.4 How to Reduce Bullwhip Effect

Some approaches that can be taken to reduce the bullwhip effect are:

(1) Information Sharing, the CPFR collaboration model (Collaborative, Planning, Forecasting, Replenishment) is a good solution for synchronizing information on all parties. One of the CPFR concepts that establishes collaboration or close coordination between producers and retailers is VMI (Vendor Managed Inventory) [16]. (2) Shortening or changing the supply chain structure, with a leaner and shorter supply chain structure, companies can immediately find out the actual patterns of consumer demand. (3) Measurement of Fixed Costs, large batch size is one source of the bullwhip effect. Therefore
the reduction in the bullwhip effect can be done by striving to reduce fixed costs so that both production and shipping can be done with small batch sizes. (4) Creating price stability, discounted discounts by retail distributors must be reduced or directed towards continuous price reductions. Or if promotional activities are held, all parties in the supply chain must know the situation [17].

2.5 Measurement of The Bullwhip Effect

The bullwhip effect measurement equation can be formulated as follows:

Calculation of coefficient of variance:

\[
\mu (\text{Demand}) = \frac{\text{Total Demand}}{\text{Period}} \quad \text{(1)}
\]

\[
\mu (\text{Order}) = \frac{\text{Total Order}}{\text{Period}} \quad \text{(2)}
\]

\[
\sigma = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}} \quad \text{(3)}
\]

\[
C_v(\text{Order}) = \frac{\sigma (\text{order})}{\mu (\text{order})} \quad \text{(4)}
\]

\[
C_v(\text{Demand}) = \frac{\sigma (\text{demand})}{\mu (\text{demand})} \quad \text{(5)}
\]

Where:

- \( \mu (\text{Demand}) \): Average demand
- \( \mu (\text{Order}) \): Average order
- \( \sigma (\text{Demand}) \): Deviation standard of demand
- \( \sigma (\text{Order}) \): Deviation standard of order
- \( C_v(\text{Demand}) \): Demand variance coefficient
- \( C_v(\text{Order}) \): Order variance coefficient

Calculation of the bullwhip effect with the following formula:

\[
\text{Bullwhip effect} = \frac{C_v(\text{Order})}{C_v(\text{Demand})} \quad \text{(6)}
\]

Calculation of the bullwhip effect using the correlation parameter to get a significant source of constraints on the reduction in bullwhip effect that occurs. Measurement of increasing variability by calculating the variability faced by manufacturers and comparing it to the variability that occurs in retailers. By using the formula:

\[
\frac{\text{Var (Order)}}{\text{Var (Demand)}} \geq 1 + \frac{2L}{P} + \frac{2L^2}{P} \quad \text{(7)}
\]

Where:

- \( L \) is leadtime, \( P \) is period

If the calculated variability value meets the terms of the equation above, it can be concluded that the company has a bullwhip effect

2.6 Vendor Managed Inventory (VMI)

Vendor Managed Inventory (VMI) is a cooperative strategy between users and sellers with availability, lowest costs, and optimizing products for both parties. The Vendor Managed Inventory Strategy is an effective method to solve the amplification requirements phenomenon caused by different modes of inventory operation with companies in the supply chain system, and increase the level of supply chain synchronization [18]. The application of VMI has been successful in helping to reduce costs and improve customer service levels [19]. Basically, there are two main aspects of VMI, namely information sharing and control transfer [20]. The following is a mathematical model of supply chain using Vendor Managed Inventory:
3. Methodology

The method used in this research is the Vendor Managed Inventory method, by calculating forecasting using methods that fit the pattern of demand data at the manufacturing and sales office levels. The method used is the Winter’s Method because data patterns tend to be seasonal and trendy. Then to calculate the optimal ordering policy, the EOQ (Economic Order Quantity) method is used.

The data that will be used in this research are data on the number of requests and the number of orders starting from the level of manufacturing vendors to nine sales offices owned by the company, namely the Banjarmasin, Samarinda, Makassar, Kendiri, Jember, Jogja, Surabaya, Semarang, and Bali sales offices. This data is data of rice flour products with 500gr packaging with units.

Table 1. The Data of Demand and Order of Manufacturing Vendors in October 2018-September 2019

| Month    | Demand (Unit) | Order (Unit) |
|----------|---------------|--------------|
| October  | 264,540       | 294,479      |
| November | 221,439       | 228,812      |
| December | 238,960       | 252,461      |
| January  | 221,461       | 238,052      |
| February | 232,580       | 248,050      |
| March    | 272,998       | 307,238      |
| April    | 240,120       | 259,260      |
| May      | 244,941       | 257,029      |
| June     | 237,620       | 253,978      |
| July     | 244,654       | 259,176      |
| August   | 243,041       | 257,151      |
| September| 275,874       | 309,502      |

4. Result and Discussion

The steps to calculate the bullwhip effect at the manufacturing level are as follows:

1. Calculation of the average demand and ordering of 500gr rice flour products.

\[
\mu_{\text{Demand}} = \frac{(257.952 + 220.242 + 240.119 + \ldots + 245.801 + 243.899 + 276.590)}{12} = 245.606,3
\]

\[
\mu_{\text{Order}} = \frac{(258.901 + 236.456 + 247.094 + \ldots + 250.130 + 249.210 + 265.207)}{12} = 249.930,4
\]

2. Calculation of standard deviation of 500gr rice flour products

\[
\sigma = \sqrt{\frac{\sum_{i=1}^{n}(X_i-\mu)^2}{n-1}}
\]
The authors gratefully acknowledge the constructive and helpful comments of anonymous referees on the earlier version of the manuscript and thanks to the manager of Faculty of Engineering University of Pembangunan Nasional Veteran Jawa Timur Indonesia for supporting.

5. References

References

[1] Dai, Jianhua et al., (2017). “Mitigation of Bullwhip effect in Supply chain Inventory Management Model”, Procedia Engineering 1229-1234.
[2] Dai, Hongyan et al., (2015). “Bullwhip effect and supply chain costs with low- and high-quality information on inventory shrinkage”, Journal Of Operational Research.
[3] Mateen, Arqum dan Chatterjee, AK., (2014). “Vendor Managed Inventory for Single-Vendor Multi-Retailer Supply Chains”, Journal Decision Support System.
[4] Pramudyo, CS dan Luong, HT., (2017). “One vendor-one retailer in vendor managed inventory problem with stochastic demand”, Journal Industrial and System Engineering Vol.27. No.1.
[5] Xun Wang, Stephen M. Disney, (2016), “The Bullwhip Effect : Progress, Trends and Directions”, European Journal of Operational Research, Vol. 250. pp 691-701
[6] Spring C. Hsu, (2016), “Modelling the Bullwhip Effect under the Implementation of Supply Chain Management Software”, *International Journal of Management and Applied Research*, Vol. 3 No. 3

[7] E. Fradinata, S Suthummanon, W. Suntiamorntut, (2019), “Compare the Forecasting Method of Artificial Neural Network and Support Vector Regression Model to Measure the Bullwhip Effect in Supply Chain”, *Journal of Mechanical Engineering and Sciences*, Vol. 13 pp. 4816-4834

[8] Divesh Ojha, Funda Sahin, (2019), “Is there a performance trade off in managing order fulfilment and the bullwhip effect in supply chains? The role of information sharing and information type”, *International Journal of Production Economics*, Vol. 208 pp. 529-543

[9] Yungao Ma, Nengmin Wang, Zhengwen He, (2015), “Analysis of the Bullwhip Effect in two parallel Supply Chains with Interacting Price-Sensitive demands”, *European Journal of Operational Research*, Vol. 243 pp. 815-825

[10] Jianhua Dai, Shengbo Peng, Shibiao Li, (2017), “Mitigation of Bullwhip Effect in Supply Chain Inventory Management Model”, *Procedia Engineering*, Vol. 174, pp 1229-1234

[11] I Kholidasari, A Bidiawati JR, and M E Sari, (2019), “The Evaluation of Bullwhip Effect on Distribution System of a Supply Chain Using Centralized Demand Information Method”, *IOP Conf. Series : Materials Science and Engineering*, 602, 012051

[12] Su-Yol Lee, Robert D. Klassen, Andrea Furlan, (2014), “The Green Bullwhip Effect : Transferring Environmental Requirements along a supply chain”, *International Journal Production Economics*, 156, 39-51

[13] Antonio Carlos Braz, Adriana Marotti, (2018), “The Bullwhip Effect in Closed-loop Supply Chains : A Systematic Literature Review”, *Cleaner Production*, DOI. 10.1016/j.jclepro.2018.08.042

[14] Anna Vokhmyanina, Marina Zhuravskaya, (2018), “The Issue of Bullwhip Effect Evaluating in Supply Chain Management”, *Scientific Journal of Logistics*, 14 (2), 163-170

[15] K. Ramesh Redd, Dr. C. Nadhamuni Reddy, Dr. B. Chandramohana Reddy, (2016), “Evaluating The Bullwhipp Effect of Supply Chain Under Uncertainty Environment by Using Simulation Techniques”, *International Journal of Science, Engineering, and Technology Research*, Vol. 5, Issue 7

[16] Junhai Ma, Liqing Zhu, Ye Yuan, (2017), “Study of the Bullwhip Effect in a Multistage Supply Chain with Callback Structure considering Two Retailers”, *Hindawi*, DOI. 10.1155/2018/3650148

[17] Shoaib Yousaf, Matloub Hussain, (2017), “Analyzing The Relationship Between Batch Sizing and Bullwhip Effect in Two-Tier Supply Chain : A Case Study of Selected Pakistani Rice Firms”, Advances in Economics, Business and Management Research, Vol. 37

[18] Davor Dujak, Dario Sebalj, Adam Kolinski, (2019), “Towards Exploring Bullwhip Effects in Natural Gas Supply Chain”, *Scientific Journal of Logistics*, 15 (4), 557 – 569

[19] Julius Kuria Njuguna and Dr. Noor Ismael, (2017), “Effects of Bullwhip on Supply Chain Performance in Manufacturing Sector in Kenya, A Case of Cooper K Brands Limited”, *International Journal of Supply Chain Management*, Vol. 2, Issue 2, No.5, pp.76-91

[20] Nia Novitasari and Dida dialh Damayanti, (2018), “Bullwhip Effect in Supply Chain for perishable Product (A Systematic Literature review”, *Journal of Advanced Management Science*, Vol. 6, No. 2