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The reduction of bullwhip effect by Integrating Information Sharing, Forecasting, Economic Order Quantity (EOQ) - Vendor Management Inventory (VMI) - and Consignment (Cs) Approach

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ABSTRACT: This research aims to create a conceptual method, in order to reduce the effect of bullwhip by integrating information sharing, Forecasting, Economic Order Quantity (EOQ), Vendor Management Inventory (VMI), and Consignment (Cs) methods. The results are used to build an application that can be used for information sharing, simulation using forecasting, and Economic Order Quantity-Vendor Management Inventory-Consignment methods, which can reduce the effect of bullwhip. It can be concluded that through information sharing, the results obtained in the forecasting method is more accurate, because customer requests can be identified by suppliers and retailers. Also, the optimal product lot size and total cost was obtained by using the Economic Order Quantity-Vendor Management Inventory-Consignment model. These aforementioned integration steps were taken as an effort to reduce the effect of bullwhip.

KEYWORDS: Bullwhip Effect, Information Sharing, EOQ, VMI-Consignment, Inventory.

1 INTRODUCTION

In today's industrial world, the level of competition is getting higher, hence, companies should be able to compete in order to survive. This is because, the higher the level of competition, the more the consumers are able to benefit from the large selection of products or services available, such that they are increasingly critical about the quality of the products and services offered. Therefore, the company must be able to take strategic steps in order to compete in winning the market and achieve maximum production results to meet market demand. A strategic step that companies can take is to maintain good coordination between retailers, suppliers, and factories that form a chain called the supply chain. What often happens in the supply chain is information distortion, resulting in variations in demand, this event is called the bullwhip effect [1]

According to Jiang, Q. and Ke, G. (2019), the Bullwhip effect is a situation that occurs in the supply chain where demand from customers changes. These changes can cause various impacts, thereby resulting in the disruption of the supply chain. For instance, the amount of product demand that is always changing with fixed ordering times and the lack of accurate communication will cause various kinds of disruptions to the supply chain, such as an increase and varied demand from upstream to downstream [2]. Hence, adequate research is needed to be carried out in order to solve this problem.

The causes of the bullwhip effect include, the accumulation of orders, processing customer requests, waiting time for product orders to arrive, price changes, distrust from other parties, and the company's product inventory policy [4]. On the other hand, the ways to reduce this effect are, sharing information, reducing lead time, changing supply chain structures, creating price stability, and reducing costs [5].

Based on this description, it is necessary to integrate several methods that can be used to overcome the causes of this bullwhip effect. This will make products to be available in a timely manner and in quantity to meet customer demands.

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2 MATERIAL AND METHODS

2.1 SUPPLY CHAIN

Supply Chain is a network of several companies that work together to deliver products to customers, including suppliers, industry, shops or retail [6]. In addition, supply chain management is a series of activities meant to integrate suppliers, industry, warehouse or other storage facilities, to ensure that products arrive at the customer's hands in a timely, quantity, and precise location, in order to minimize costs and provide satisfaction [7].

2.2 BULLWHIP EFFECT

Bullwhip is an event where demand for suppliers is greater than the real demand at retail, because the data in each distribution chain is less precise [8]. The changes in customer demand causes distortion at each stages of the supply chain, thereby making demand to be inaccurate [9]. As a result, it causes inefficiencies in the supply chain [10].

2.2.1 BULLWHIP EFFECT CALCULATION

The bullwhip effect equation can be written as follows [11]:

$$\textit{Bullwhip Effect} = \frac{CV\ order}{CV\ demand} \quad (1)$$

$$\text{CV order} = \frac{S\ (order)}{\mu\ (order)}$$

$$\text{CV demand} = \frac{S\ demand}{\mu\ demand}$$

CV (order) = Variable orders to suppliers
CV (demand) = Customer demand variable
S (order) = The standard deviation of the order
μ (order) = Order request average
S (demand) = Standard deviation of customer requests
μ (demand) = Average customer demand
N = Period
$\bar{X}$ = Average value

2.2.2 BULLWHIP EFFECT CAUSES

According to Khan, M.H. and Ahmad, S., 2016 are [4]:

- Demand Signal Processing or Demand Fluctuation
- Order Batching
- Price Fluctuation
- Lead time

According to Dewi, F.R. and Garside, A.K., 2015 [5], Rationing and Shortage Gaming are also included in the causes of the bullwhip effect.

2.2.3 REDUCES BULLWHIP EFFECT

According to Dewi, F.R. and Garside, A.K., 2015 [5], the ways to reduce the Bullwhip effect include:

- ***Information sharing***

This can be done through the construction of a WEB-based information sharing system facility, to monitor existing stocks at suppliers or retail [12]. For instance, Big Data can be used, where it is necessary to provide 'speed' data properties that have the greatest potential to improve performance in the supply chain management. Likewise its operation can be used in the analysis of control techniques [13], for the information to be well coordinated, such that calculations can be made to predict future demand [14].

- ***Reducing the lead time***

The lead time can be reduced by shortening the supply chain structure, changing the means of transportation, making innovations such as cross docking, improving order handling management, rescheduling production, and better shipping. It can also be done by resetting the inventory model that is carried out, and its management can be done by a supplier known as the Vendor Management Inventory (VMI) method [15].

- ***Shortening or changing the supply chain structure***

Improvements need to be made to the supply chain structure, to know the real demand and to shorten the supply chain [16]. This is because large number of suppliers for the same product will increase the bullwhip effect. Thus, it is better to have one reliable supplier supplying the product than more, that will cause uncertainties both in product quality, timeliness, and product availability [17].

- ***Creating price stability***

To ensure price stability, various things can be done such as, price adjustments to always be in accordance with the changing circumstances [18]. Another way is to hold promotions, to reduce the effect of bullwhip during this period [19]. It should also be noted that, price control through discounting has a huge significance on the bullwhip effect [20].

- ***Reducing fixed costs for production and delivery activities***

Reduction of fixed costs can be accomplished by reducing production setup time. Also, order lots can be reduced, to minimize the fixed costs which can make improvements and new breakthroughs in the transportation and distribution system. The company gets to track several bullwhip, either intra and the ones between companies, relating to certain products, suppliers, and customers. Through this, the source of the bullwhip would be known and its effect could be reduced. Likewise, the costs could be reduced to ensure an increase in the profits [21]. Good relations and communication between various parties involved in the supply chain greatly affect the costs in the supply chain and the bullwhip effect itself [22]. Likewise, with the calculations carried out in decision making related to capacity and safety stock (in this case, you can use the Taguchi approach), where later these two things will have an impact on the total costs incurred [23]. For this reason, it is very important to link the supply chain management, transaction cost theory, and the bullwhip effect. Here, the integration of the three is expected to reduce the bullwhip effect [24].

2.3 FORECASTING

There are various forecasting methods that can be used [25], one of which is the Time Series with the following formulas,

Moving Average

Simple Moving Average

$$F_{t+1} = \frac{\sum_{i=0}^{n} D_{t-i}}{n}$$

For I = 0, 1, 2, …, n-1

Weighted Moving Average

$$Ft+1 = \sum_{i=0}^{n} W_{t-i} D_{t-i}$$

For i = 0, 1, 2, …, n - 1

Exponential Smoothing

F t+1 = α Dt + (1 - α) Ft

Trend Enhanced or Holt model

Ft+1 = Lt + Tt

Where,

Lt = α Dt + (1 – α) (Lt-1 + Tt-1)

Tt = β (Lt – Lt-1) + (1 – β) Tt-1

The determination of the forecasting method depends on historical data patterns [26].

2.4 Economic Order Quantity (EOQ) -Vendor Management Inventory (VMI) -Consignment

Furthermore, the Economic Order Quantity (EOQ), integrates the inventory management for buyers, retailers, and suppliers [27].

EOQ VMI Model

$$Q_S = \sqrt{\frac{2 \times (S_S + S_B) \times y}{h_S}} \quad (2)$$

Total buyer Inventory Cost (Retailer):

$$T_B(Q_S) = wy + \left(\frac{h_B Q_S}{2}\right) \quad (3)$$

Total supplier inventory cost:

$$T_B(Q_S) = cy + \left(\frac{(S_S+S_B)y}{Q_S}\right) + \left(\frac{h_S Q_S}{2}\right) \quad (4)$$

EOQ VMI with Consignment Model

$$Q'_S = \left(\frac{2y\,(S_S + S_B)}{(H_B + H_S)}\right)^{1/2} \quad (5)$$

Total buyer Inventory Cost (Retailer):

$$T_B\,(Q'_S) = wy \quad (6)$$

Total supplier inventory cost:

$$T_S(Q'_S) = cy + \left(\frac{(H_B + H_S)\,Q'_S}{2}\right) + \left(\frac{(S_S + S_B)\,y}{Q'_S}\right) \quad (7)$$

3 SIMULATION CASE

3.1 BULLWHIP EFFECT

Table 1. Bullwhip Effect calculation

Description	Number of Requests (unit)	Order Amount (Unit)
Total	22.100	25.400
Average	1.841,67	2.116,7
Standard Deviation	235,327	530,58
Customer / Order Variance Coefficient	0,128	0,251
Bullwhip Effect	1,962	

From this table, it can be seen that between the number of customer requests and the number ordered by retailers to suppliers, the bullwhip effect of 1,962 was experienced, which means that the demand variability has increased by 1,962 times. Therefore, corrective steps is needed to be taken to reduce this effect, which include, *information sharing, forecasting, calculation of Economic Order Quantity using traditional EOQ, EOQ VMI model and EOQ VMI with Consignment model.*

3.2 INFORMATION SHARING

One of the steps to perform information sharing is by building a WEB-based application that will provide information to both retailers and suppliers. Which include, the number of customer demands or requests, the number of retailer orders to suppliers, the number of product stock at the retailer, the number of product stock at the supplier, the number of products sent to the retailer, and whether there is a bullwhip effect or not. When there is a bullwhip effect, the supplier will not confirm the retailer's request.

The application design can be seen in the following figure:

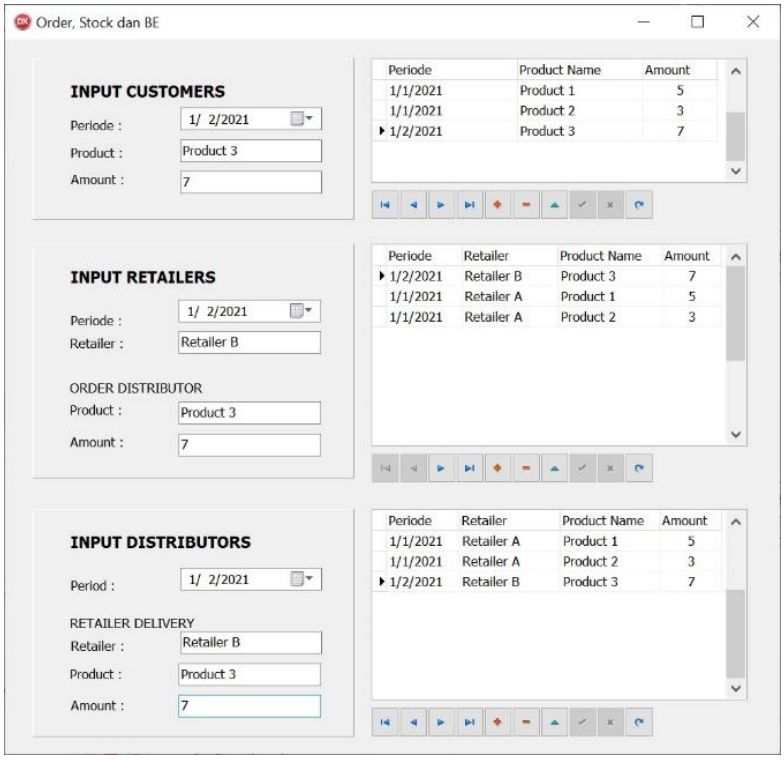

Fig. 1. Input Display for Retailers and Suppliers

In this picture, some data will be inputted by both retailers and suppliers, thus both parties can always monitor the development of data on the latest product stock and orders.

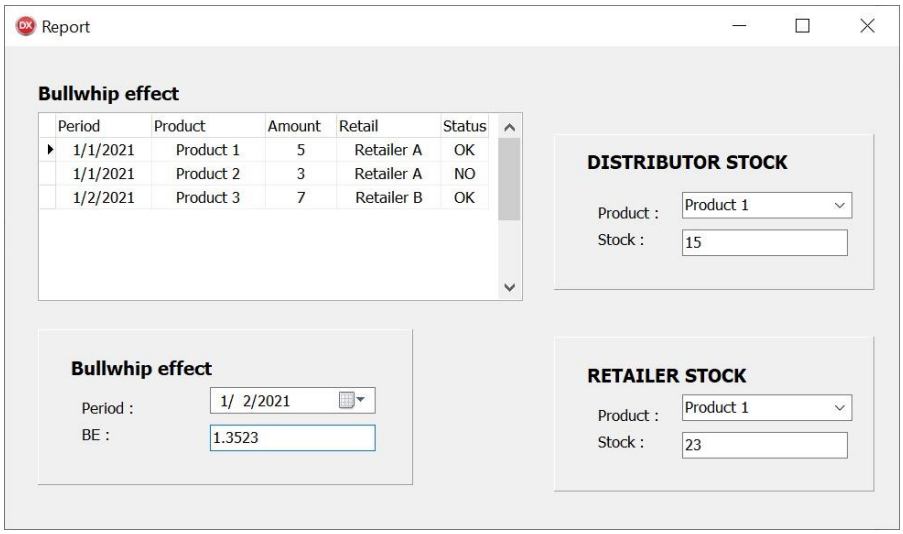

Fig. 2. Display Report for Retailers and Suppliers

Also, in the picture above, a Abstract of the products ordered by the retailers and stocks owned by both retailers and suppliers is displayed. When information sharing is carried out effectively, demand forecasting can be done more accurately. Hence, this forecasting needs to be done to enable the retailers and suppliers to predict the future demand.

3.3 FORECASTING

As previously mentioned, the forecasting results will be accurate when information sharing has been carried out effectively. Therefore, in this section, the forecasting that is needed to predict future customer demand will be simulated, to ensure that the product ordered from suppliers are closer to the actual value. Through the use of the exponential smoothing forecasting method (determined from the results of the scatter simulation data), the following shows the total forecasting, actual demand, and the data on the number of products ordered by retailers to suppliers. Where each data is entered into the traditional EOQ calculation and then compared with the results of the total cost. Hence, the importance of forecasting before retailer's place orders on suppliers can be seen.

Table 2. Traditional EOQ Calculation Results

Description	Quantity (Unit)	EOQ (Unit)	Order Frequency (Unit/Year)	Total Cost (Rp)
Order Data	25.400	2287,49	11,1	Rp. 7.646.649.000,00
Forecasting Data	21.263	2092,93	10,16	Rp. 6.403.282.000,00
Actual Data	22.100	2133,73	10,36	Rp. 6.654.858.000,00

In the table, it can be seen that the amount of EOQ and the total cost obtained from the results of calculations using order data is 8.51% and 16.26% greater, respectively, when compared to using data from forecasting results. This shows that the use of forecasting is better done, compared to placing orders with suppliers without doing forecasting calculations. Furthermore, the data can be used in the calculation process of Economic Order Quantity (EOQ) -Vendor Management Inventory (VMI) -Consignment.

3.4 ECONOMIC ORDER QUANTITY (EOQ) -VENDOR MANAGEMENT INVENTORY (VMI) -CONSIGNMENT

In this research, the simulation uses actual data because the data is a constant pattern and the results of the forecasting method cannot generate demand in one year. Meanwhile, the calculation of EOQ-VMI-Consignment requires annual demand data.

Here are some of the data used:

Order Cost Buyer: Rp. 1.200.000, - (SB)

Holding Cost Buyer: Rp.11.650, - (HB)

Unit Cost: Rp. 300.000, - / unit (w)

Set Up Cost Distributor/Supplier: 12.000.000, - (Ss)

Holding Cost Distributor/Supplier: Rp. 14.000, - (Hs)

Distribution Production Cost: Rp. 250.000, - (c)

Sales Cost: Rp. 350.000, -/unit (p)

Demand (d) = 22.100 unit/year

Table 3. Comparison of EOQ and Cost Values between Traditional EOQ methods, EOQ VMI Model and EOQ VMI Model with Consignment

Description	Traditional EOQ	EOQ VMI Model	EOQ VMI Model with Consignment
Q_B / Q_S	Q_B = 2.133 unit	Q_S = 6.456 unit	Q_S = 4.769 unit
Total Inventory Buyer Cost	Rp6.654.857.916,24	Rp6.667.606.200,00	Rp6.630.000.000,00
Total Inventory Supplier Cost	Rp5.664.225.668,23	Rp5.615.380.936,70	Rp5.647.332.481,62
Total Cost	Rp12.319.083.584,48	Rp12.282.987.136,70	Rp12.277.332.481,62

From the table above, it can be seen that by using the EOQ VMI model, the total cost is 0.29% lower than the total cost using the traditional EOQ calculation. Meanwhile, by using the EOQ VMI with the consignment model, the total cost is 0.34% lower than the total cost using the traditional EOQ calculation, and 0.05% lower when compared to using the EOQ VMI model calculation.

Therefore, it can be concluded that the lowest total cost is obtained from the calculation using the EOQ VMI with the consignment model. Basically, the requirements for using the EOQ VMI model with consignment are, the total cost of EOQ VMI ≤ traditional EOQ. Where EOQ VMI Consignment is a calculation model in which the distributor or supplier determines the number of orders and delivery schedules. While the EOQ VMI Model is a calculation that is used to determine the number of orders from distributors or suppliers.

Table 4. Comparison of Profit Rate using Traditional EOQ method, EOQ VMI Model and EOQ VMI Model with Consignment

Profit rate	Traditional EOQ	EOQ VMI Model	EOQ VMI Model with *Consignment*
buyer / retailer profits	Rp1,080,142,083.76	Rp1,067,393,800.00	Rp1,105,000,000.00
Supplier profits	Rp965,774,331.77	Rp1,014,619,063.30	Rp982,667,518.38

From this table, it can be seen that the level of buyer's profit using the EOQ VMI model is 1.18% lower than the traditional EOQ, but the supplier's profit rate is higher by 4.81%. Meanwhile, the profit level of buyers and suppliers using the EOQ VMI with Consignment model is higher by 2.25% and 1.72% respectively, when compared to the traditional EOQ. However, when compared to the EOQ VMI model, the buyer's profit rate is 3.40% higher, but the supplier's profit is 3.15% lower.

4 CONCLUSION

Through the use of good information sharing, the calculation results of the forecasting method used for predicting future demand is more accurate. Hence, it can be used in the calculation of the EOQ-VMI method with the Consignment model as a basis for determining the number of economical product lots, where the total cost of buyers and suppliers is smaller than using the traditional EOQ and the EOQ VMI Model. In conclusion, these integration steps were taken as an effort to reduce the effect of bullwhip.

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