JIT Journal of Innovation and Technology
e-ISSN: 2721-8562; p-ISSN: 2721-8570
Vol. 2, No. 2, October 2021. Page: 40 – 45

Proposed Improvement on Supply Chain System to Minimize the Bullwhip Effect Phenomenon with Monte Carlo Simulation Approach

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Article history
Received: 20.06.2021
Revised: 19.09.2021
Accepted: 24.10.2021

DOI:10.31629/jit.v2i2.3854

Abstract
PT XYZ is one of the most company which produce welded steel pipe in Indonesia such as longitudinal and spiral pipes. In order to meet consumer's demand, this company faced with an obstacle namely the distortion of information in supply chain. Distortion of information from downstream to upstream channel causes the difference between the product demand from consumer to PT XYZ and order of raw materials from PT XYZ to the supplier which is called the bullwhip effect. The objective of this research is to calculate the value of bullwhip effect as well as designing improvements to minimize the bullwhip effect. Based on the research results, obtained the index value of bullwhip effect on longitudinal pipe products is 1.06 and the index value of bullwhip effect on spiral pipe products is 0.80. The improvement design to minimize the phenomenon of bullwhip effect is to build an integrated information system for the customer, manufacturer, and supplier. The method that is used to improve the index value of bullwhip effect is Monte Carlo simulation. Monte Carlo simulation is used to obtain the order number of raw materials in order to approach the number of consumer's demand. After applying the Monte Carlo simulation, obtained the index value of bullwhip effect on longitudinal pipe product is 1.01 and the index value of bullwhip effect on spiral pipe products is 1.00. It can be concluded that the use of Monte Carlo simulation had been optimizing the index value of bullwhip effect amounted to 4.71% for longitudinal pipe products and 25% for spiral pipe products.

Keywords: bullwhip effect, distortion of information, index value of bullwhip effect, Monte Carlo simulation, supply chain

1. Introduction

PT XYZ is a steel welding pipe company in Indonesia which produce longitudinal and spiral pipes. As one of the largest steel pipe manufacturers in Indonesia, PT XYZ is required to always meet consumer demand. In order to meet consumer demand, PT XYZ has a supply chain system to improve the performance in creating and delivering products to the end user's

DOI:10.31629/jit.v2i2.3854

hands. The parties involved in the supply chain system in PT XYZ are suppliers, manufacturers, and customers. [1].

Supply chain systems have an important role in a company, such as a managing the product flow, financial flow, and information flow. However, in its application, there are some obstacles that hamper the performance of the supply chain system. One of the obstacles that facing supply chain management in PT XYZ is distortion of information.

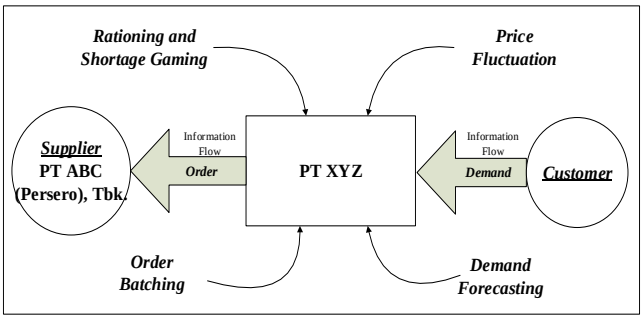

Figure 1. Example of an image with acceptable resolution

Distortion of information from downstream to upstream channel causes the difference of demand value of product with raw material order. The phenomenon of demand variability from downstream to upstream channel is called bullwhip effect. Therefore, it needs to be improved to overcome the phenomenon of bullwhip effect and eliminate inefficiency in supply chain [2].

2. Methodology

Increased fluctuation or demand variability from downstream to upstream of a supply chain is called bullwhip effect. Bullwhip effect is a condition where the demand from the customer changes, causing a demand distortion of each supply chain stage. The causes of the bullwhip effect, demand forecast updating, order batching, price fluctuation, rationing and shortage gaming [3].

Suggest that the size of the bullwhip effect in a supply chain echelon is the ratio of the order variance coefficients created and the coefficient of demand variance received by the corresponding echelon. Here's the formula of bullwhip effect index value.[4]. Bullwhip effect is mathematically written as follows [5]:

Where:

$$BE = \frac{CVo}{CVd} \quad (1)$$

$$CVo = \frac{So}{\mu o} \quad (2)$$

$$CVd = \frac{Sd}{\mu d} \quad (3)$$

Information:

BE = Bullwhip Effect
CVo = Coefficient of Order Variance
CVd = Coefficient of Variance Demand
So = Standard Deviation Order
Sd = Demand Deviation Standard
Mo = Average Order Value
Md = Demand Average Value

This research was conducted using quantitative method with descriptive research and simulation research. In this study, collected quantitative data such as data demand and order at the company. These data are then processed to obtain an index value that describes the phenomenon of the bullwhip effect. The result of bullwhip effect is descriptive then proceed by doing analytical research to find the cause of the phenomenon and to design the proposed improvement. In this study, a Monte Carlo discrete simulation was conducted to see the effect of the proposed improvement design [6]. Monte Carlo Simulation Method is a method to evaluate a deterministic model involving random numbers as one input. Monte Carlo simulation is a probabilistic simulation form in which the solution of a problem is given based on a random process [7].

3. Result and Discussion

Discussion on this research is calculation of existing bullwhip effect index, identification of bullwhip effect, design improvement proposal, Monte Carlo simulation to minimize bullwhip effect phenomenon, and calculation of bullwhip effect index value of improvement.

3.1 Index Value of Bullwhip Effect Existing Longitudinal Pipe and Spiral Pipe

Here is the index value calculation of the existing bullwhip effect on longitudinal pipe and spiral pipe products [8].

DOI:10.31629/jit.v2i2.3854

Table 1. Index Value of Bullwhip Effect Existing On Longitudinal Pipe Product

Month	*Demand (d)*	*Order (o)*
Jan-19	2937,23	1278,33
Feb-19	1926,43	458,23
Mar-19	5259,61	1787,84
Apr-19	2459,83	1865,58
May-19	2082,06	791,83
Jun-19	4441,13	698,46
Jul-19	1881,96	43,40
Aug-19	3084,01	585,77
Sep-19	1146,87	1009,35
Oct-19	3009,05	283,13
Nov-19	301,08	253,89
Dec-19	3708,07	879,45
Jan-20	1439,58	3035,81
Feb-20	4524,49	1430,11
Mar-20	3547,09	1701,92
Apr-20	3979,22	2160,96
May-20	1134,23	2432,15
Jun-20	4272,69	2233,52
Jul-20	2419,6	2526,45
Aug-20	564,72	1602,18
Sep-20	5568,51	2490,24
Oct-20	2015,48	2117,02
Nov-20	790	2544,55
Total	62492,93	34210,19
Mean	2717,08	1487,40
STDEV	1506,73	875,75
CV	0,55	0,59
BE	1,06	

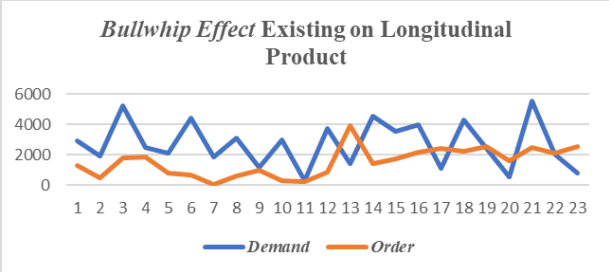

Figure 2. Bullwhip Effect Existing on Longitudinal Pipe Product

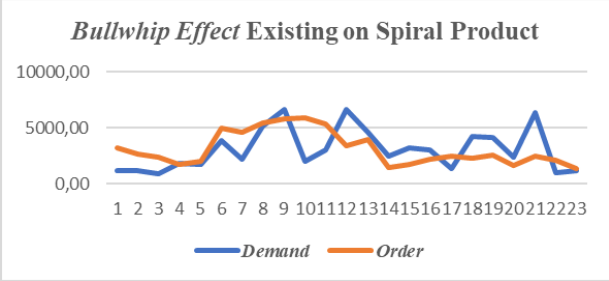

Figure 3. Bullwhip Effect Existing on Spiral Pipe Product

Table 2. Index Value of Bullwhip Effect Existing On Spiral Pipe Product

Month	*Demand (d)*	*Order (o)*
Jan-19	1158,46	3212,46
Feb-19	1118,82	2636,55
Mar-19	919,09	2379,14
Apr-19	1849,98	1677,19
May-19	1697,94	1980,29
Jun-19	3816,35	4968,61
Jul-19	2148,58	4581,84
Aug-19	5120,97	5471,12
Sep-19	6650,33	5848,10
Oct-19	1958,74	5911,91
Nov-19	2998,27	5313,80
Dec-19	6686,43	3364,64
Jan-20	4555,93	3935,81
Feb-20	2460,54	1430,11
Mar-20	3174,08	1701,92
Apr-20	2996,14	2160,96
May-20	1301,31	2432,15
Jun-20	4244,80	2233,52
Jul-20	4168,32	2526,45
Aug-20	2395,58	1602,18
Sep-20	6401,99	2490,24
Oct-20	961,31	2117,02
Nov-20	1189,42	1321,582
Total	69973,36	71297,59
Mean	3042,32	3099,90
STDEV	1859,15	1512,95
CV	0,61	0,49
BE	0,80	

Figure 2. shows the longitudinal pipe demand movement coming from the consumer and the raw material order. The graph above shows that the fluctuating demand and order movement causes the phenomenon of bullwhip effect. Figure 3. shows that there is no bullwhip effect on spiral steel pipe products, seen from the coefficient value of variance demand greater than order.

$$m_d = \frac{\Sigma Demand}{N} = \frac{2937,23 + 1926,43 + 5259,61 + \ldots + 790}{23} = \frac{62492,93}{23} = 2717,08$$

$$m_o = \frac{\Sigma Order}{N} = \frac{1278,33 + 458,23 + 1787,84 + \ldots + 2544,55}{23} = \frac{34210,19}{23} = 1487,40$$

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$$S_d = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}}$$
$$= \sqrt{\frac{48462,35 + 625138,27 + \ldots + 3713652,21}{23-1}}$$
$$= \sqrt{\frac{49945457,84}{22}}$$
$$= 1506,7$$

$$S_o = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}}$$
$$= \sqrt{\frac{43708,17 + 1059180,74 + \cdots + 1117570,89}{23-1}}$$
$$= \sqrt{\frac{16872677,44}{22}}$$
$$= 875,75$$

$$CV_d = \frac{S_d}{m_d}$$
$$= \frac{1506,73}{2717,08}$$
$$= 0,55$$

$$CV_o = \frac{S_o}{m_o}$$
$$= \frac{875,75}{1487,40}$$
$$= 0,59$$

$$BE = \frac{CV_o}{CV_d}$$
$$= \frac{0,59}{0,55}$$
$$= 1,06$$

Through calculation, obtained Table 1. index value of existing bullwhip effect on longitudinal pipe product of 1,06 and Table 2. index value of existing bullwhip effect on spiral pipe product of 0,80. It states that there is demand variability, namely the order variance coefficient and the variance demand coefficient.

3.2 Identification of the Causes of Bullwhip Effect

The identification of the cause on bullwhip effect is done by using the cause and effect diagram. It is known that bullwhip effect is caused by factor demand forecast updating, batching order, price fluctuation, and rationing and shortage game.

In the main factor of demand forecast updating, there is the root cause of bullwhip effect which is the demand without planning, bad forecasting technique, price fluctuation, and procurement of government program. The main factors of price fluctuation are market competition and unstable material prices. In the main factor of rationing and shortage game there are root that is caused bullwhip effect such as unilateral interest by each echelon and partial delivery of goods. While on the main factor of batching order, there are two root causes of the problem which are the transportation cost of raw materials and the existence of demand without planning.

The root cause of the main problem that includes the four factors is the distortion of information. Distortion of information occurs due to lack of coordination between echelon in the supply chain system which then leads to supply chain inefficiency.[9].

3.3 Improvement Design Simulation

The phenomenon of bullwhip effect can be overcome by several approaches as follows, information sharing; shortening/ changing the supply chain structure; reduction of fixed costs; creating price stability; shortening leadtime. One proposed improvement that can be applied by covering all approaches in reducing the bullwhip effect is the development of integrated information systems [10].

Monte Carlo simulation is done to get the new value orders in each period. In the Monte Carlo simulation, it is assumed that the proposed information system improvement plan has been implemented in the company[11].

The proposed improvement simulation is done to get the value of improvement order approaching the value of demand. Below is an example calculations of Monte Carlo simulations for longitudinal pipe product.

$$Total = \sum_{Demand}$$
$$= 2937,23 + 1926,43 + \ldots + 790$$
$$= 62492,93 \text{ ton}$$

$$(P) = \frac{Demand_i}{Total}$$
$$= \frac{2937,23}{62492,93}$$
$$= 0,0470$$

$$(P_{Kum}) = P_1 + P_2 + \ldots + P_i$$
$$= 0,0470 + 0,0308$$
$$= 0,0778$$

$$IB = [(P)_{kum_{n-1}} \text{ x } 10000]$$
$$= [0,0470 \text{ x } 10000]$$

DOI:10.31629/jit.v2i2.3854

= 470

IA = $[(P)_{kum_n}$ x 10000]
= [0,0778 x 10000]
= 778

(R) = *random(R)*
= 0,051468938

(t) = -2 ln (1-πR)
= -2 ln [1 – (3,14 x 0,051468938)]
= 0,352549669

NR = *Random* (t) x 1000
= 0,352549669 x 1000
= 352,54967

SO = Historical order at random number interval
= 2937,23 ton

The optimal order yield is based on existing demand which is historical data. This is done so that the value of the order generated close to the actual demand value so that the variability between demand and order is smaller.

3.4 Bullwhip Effect Index Value Longitudinal Pipe and Spiral Pipe Improvement

The following is the calculation of the bullwhip effect index value of the longitudinal pipe and spiral pipe products.

Calculation of improved index value of bullwhip effect on longitudinal pipe is 1,01. This value has decreased by 4.71% when compared with the value of the existing bullwhip effect index of 1,06. The calculation of improved index value of bullwhip effect on spiral product is 1.00. The value increased by 25% from the existing state which has an index value of 0,80 [12].

Table 4. Improved Index Value of Bullwhip Effect on Longitudinal Pipe Product

Month	Demand	Order Simulation
Jan-19	2937,23	2937,23
Feb-19	1926,43	2015,48
Mar-19	5259,61	5259,61
Apr-19	2459,83	1926,43
May-19	2082,06	3547,09
Jun-19	4441,13	4524,49
Jul-19	1881,96	1926,43
Aug-19	3084,01	2459,83
Sep-19	1146,87	1146,87
Oct-19	3009,05	3547,09
Nov-19	301,08	301,08
Dec-19	3708,07	5259,61
Jan-20	1439,58	1134,23
Feb-20	4524,49	5259,61
Mar-20	3547,09	2459,83
Apr-20	3979,22	3979,22
May-20	1134,23	2082,06
Jun-20	4272,69	3547,09
Jul-20	2419,6	2937,23
Aug-20	564,72	301,08
Sep-20	5568,51	5259,61
Oct-20	2015,48	1926,43
Nov-20	790	1146,87
Total	62492,93	64884,50
Mean	2717,08	2821,07
STDEV	1506,73	1576,05
CV	0,55	0,56
BE	1,01	

Table 5. Improved Index Value of Bullwhip Effect on Spiral Pipe Product

Month	Demand	Order Simulation
Jan-19	1158,46	919,09
Feb-19	1118,82	1158,46
Mar-19	919,09	1849,98
Apr-19	1849,98	3816,35
May-19	1697,94	919,09
Jun-19	3816,35	1849,98
Jul-19	2148,58	1158,46
Aug-19	5120,97	5120,97
Sep-19	6650,33	6686,43
Oct-19	1958,74	3816,35
Nov-19	2998,27	919,09
Dec-19	6686,43	5120,97
Jan-20	4555,931	3816,35
Feb-20	2460,541	3816,35
Mar-20	3174,078	1849,98
Apr-20	2996,135	1849,98
May-20	1301,305	1158,46
Jun-20	4244,802	5120,97
Jul-20	4168,318	5120,97
Aug-20	2395,579	1158,46
Sep-20	6401,985	6650,33
Oct-20	961,311	1158,46
Nov-20	1189,424	3816,35
Total	69973,36	68886,65
Mean	3042,32	2995,07
STDEV	1859,15	1837,80
CV	0,61	0,61
BE	1,00	

4. Conclusion

Based on the result of discussion, the index value of bullwhip effect for longitudinal pipe product is 1,06 and spiral pipe product is 0,80. This indicates that there has been an overall bullwhip effect phenomenon in PT XYZ especially for longitudinal product. The cause of the bullwhip effect is the distortion of information. Therefore, it

is designed an integrated information system to reduce the distortion of information that occurs in each echelon. Through calculation Table 4. and Table 5. using Monte Carlo Simulation, the improved index value of bullwhip effect for longitudinal pipe is 1,01 and 1,00 for spiral product.

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