Analysis of Bullwhip Effect Value Influenced Variaton Supply and Demand

By Agus Purnomo

Analysis of Bullwhip Effect Value Influenced Variation Supply and Demand (Simulation in Supply Chain Retail "Y" in the City of Bandung)

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ABSTRACT

Bullwhip effect or also called Whiplash Effect is a phenomenon of amplitude of demand in distribution channels triggered by forecasting demand in excess of the needs of customers. The purpose of this study was to determine the impact of supply and demand fluctuation on each element of the retail supply chain system to the bullwhip effect. The results of this study concluded that: (1) the distribution of the processing time significantly influences the value of bullwhip effect, which increased the value of most large bullwhip effect occurs at the time of the request processing cooking oil brand "B " Weibull distribution, (2) element echelon supply chain significantly influences the value of bullwhip effect, where the elements echelon Distributor-Factory (upstream side) has a value that most large bullwhip effect compared with elements of another echelon, (3) Interaction Between the processing time distribution echelon supply chain with significant element effect on value bullwhip effect, where the average value of bullwhip effect occurs amplitude by 111% for echelon element Retail "Y"-Distributors and 271% for Distributor-Factory echelon elements.

Keywords: *Supply chain, bullwhip effect, inventory, echelon element, retail.*

1. INTRODUCTION

Supply chain is a network of companies that jointly work to create and deliver a product to end users [1]. Traditional supply chain structure is divided into 6 parts: a source of raw materials, suppliers, manufacturers, retailers and consumers [2]. The same opinion also stated that the supply chain is a process involving customer satisfaction, transportation, warehousing, retailers, users and manufacturers [3]. In terms of the supply chain there are many uncertainties such as the use of materials and supplies information, it is proved that supply chain is a complicated and complex system that requires coordination of a good management [3]. In the approach echelon supply chain elements, there are two types of information flow, from upstream (manufacture) and downstream (customer / user) [4]. Simplified supply chain into four stages namely: suppliers, manufacturers, retailers and customers. There are two main objectives in the development of a simulation of the structure to examine the benefits CPFR (Collaborative Planning Forecasting and Replenishment) and the bullwhip effect which represents the product flow. By using CPFR, companies benefit from a 67% reduction in lead times, forecasting error reduction of 60%, 40% reduction in inventory levels, increasing 22% the level of service to customers and increased 47% availability of the product to be sold [5].

Problems are often encountered in the supply chain when customer demand could not met completely in stable, so the company must forecast demand well in order to cope with the increase in consumer demand. Forecasting is based on statistics, and often inaccurate. Companies often do accumulate reserves of inventory, called safety stock. Forecast consumer demand will lead to increased demand on the dealer as well and will ultimately increase the production order. This problem is usually called the bullwhip effect or Whiplash Effect is a phenomenon of the amplitude of demand in the distribution channel that triggered by forecasting demand in excess of the needs of customers [6]. The bullwhip effect is a well-known phenomenon in supply chain management. In a single-item two-echelon supply chain, it means that the variability of the orders received by the manufacturer is greater than the demand variability observed by the retailer. This phenomenon was first popularized by Jay Forrester, who did not coin the term bullwhip, but used industrial dynamic approaches to demonstrate the amplification in demand variance. At that time, Forrester referred to this phenomenon as "Demand Amplification". Forrester's work has inspired many researchers to quantify the bullwhip effect, to identify possible causes and consequences, and to suggest various countermeasures to *tame* or reduce the bullwhip effect [7].

A retailer can realize a small variation in customers' demands as a growing trend and purchase from a wholesaler more products than he needs. Increased order at wholesalers is larger than at retailers as the wholesaler cannot regularly comprehend the increased order. As the chain grows longer the order is larger. If a retailer plans the product promotion he can increase the order. If a manufacturer comprehends the increased demand as constant growth and in the same manner makes purchases, he will face the problem of inventory surplus in the end of promoting period. A variation in demands increases production expenses and expenses of the whole supply chain in an effort to deliver the ordered quantity in time. A manufacturer accomplishes demanded capacity and production but when the orders come to a former level, he remains with the surplus of capacity and inventory [8].

Retail "Y" into any problems ordering product lead time uncertainty cooking oil brand "B" to the distributors, so to keep the inventory level is always carried out orders in excess of actual needs. The number of bookings this excess would trigger a bullwhip effect in the retail supply chain. The purpose of this study was to determine the effect of probability distribution of lead time orders to the value of bullwhip effect in the retail supply chain. On the other side wanted to study whether the retail supply chain echelon elements (Factory - Distributor - Retailer - Customer) influence on the increased value of bullwhip effect and the element where the value echelon highest bullwhip effect.

2. RESEARCH METHODOLOGY AND DATA

Performance is measured in this study is value bullwhip effect, which is formulated as follows:

Bullwhip effect = VC (order) / VC (demand) (1)

VC (order) = s (order) / μ (order) (2)

VC (demand) = s (demand) / μ (demand) (3)

VC = variance coefficient, s = standard deviation, μ = average

While the steps used to conduct this research are presented in Figure 1.

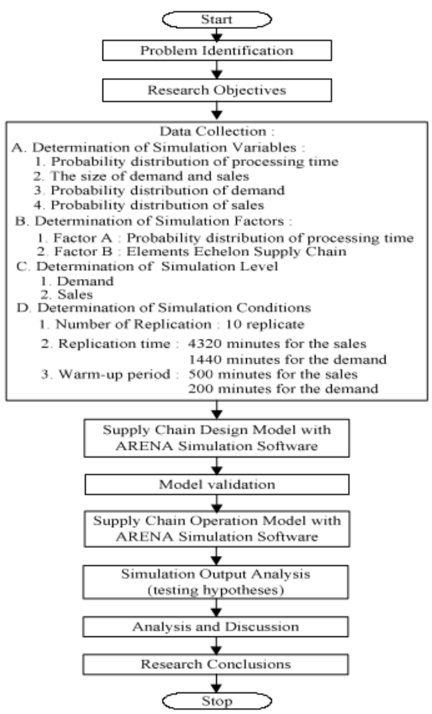

Figure 1 : Research problem-solving flow chart

Construction supply chain simulation models make do with a computer algorithm that uses ARENA version 10 (Rockwell Software Inc.) with the process of the preparation done 4 stages: (1) Simulation in the Factory, (2) Simulation of the Distributor, (3) Simulation in Retail "Y", (4) Simulation of the Customer. Once the model simulation algorithm is completed and then performed an internal validation of the verification algorithm to check the conformity made by logic models that have been designed.

Output value of bullwhip effect simulation is based on the level of demand and sales in each supply chain element. To test the hypothesis, this research uses ANOVA Two factors, namely: Factor A is the Process Time Distribution and Factor B is the element of Echelon Supply Chain. Each factor consists of several levels which determine whether the differences between each simulation output is just as random variance, or indeed those levels affect performance studied. Determination of line based on the number of treatments given.

a. Level of factor A, comprising: (1) The distribution process of the Factory, (2) The distribution process of the Distributor, (3) The distribution process of the Retailer, (4) The distribution process of the Customer.
b. Level of Factor B, comprising: (1) Total sales & Demand capacity at Factory, (2) Total capacity of sales & Demand Distributor, (3) Total capacity of sales & Retailer Demand, (4) Total capacity of Customer Demand.

Factors and levels above could be written with symbols and figures as follows:
$\alpha_a \rightarrow \alpha$: state factor A and a state level to the n in factor A
$\beta_b \rightarrow \beta$: state factor B and b states level to the n in factor B

On each factor a level consists of several repetitions output (replication) where the number of replication is adjusted for the repetition of running the program is conducted in this study.
Thus the hypothesis of this study are as follows:

H0 (1): $\alpha_1 = \alpha_2 = \alpha_3$; the influence of a factor equal to zero or distribution of the processing time was not significantly affect the value of bullwhip effect.

H1 (1): At least one α_i is not equal to zero; influence factor a is not equal to zero or distribution of the processing time significantly influence value of bullwhip effect.

H0 (2): $\beta_1 = \beta_2 = \beta_3$; the influence of factor b equal to zero or Element echelon supply chain, no significant effect on value of bullwhip effect.

H1 (2): At least one β_i is not equal to zero, the influence of factor b is not equal to zero or Element echelon supply chain significantly influence value of bullwhip effect.

H0 (3): $(\alpha\beta)_{11} = (\alpha\beta)_{12} = \ldots\ldots = (\alpha\beta)_{ab} = 0$; interaction between a factor by factor b equal to zero or interaction between the distribution of processing time with Element echelon supply chain does not significantly influence value bullwhip effect.

H1 (3): At least one $(\alpha\beta)_{ij}$ is not equal to zero; interaction between a factor by factor b equal to zero or interaction between the processing time distribution with supply chain echelon element significant effect on value bullwhip effect.

Results for the 10 data collection period in 2010, obtained the data from customer demand, retail "Y", and distributors and sales data of cooking oil brand "B" from the factory are presented in Table 1.

Table 1 : Data request (customer, retail "Y", distributors) and sales (factory) cooking oil brand "B" Year 2010

Period	Factory	Distributor	Retail "Y"	Customer	Total
1	614	421	353	249	1637
2	223	287	227	102	839
3	817	973	394	864	3048
4	421	241	137	243	1042
5	1243	1201	372	487	3303
6	302	149	970	1159	2580
7	110	149	111	141	511
8	253	523	682	987	2445
9	379	487	302	765	1933
10	192	211	119	223	745
Average	455.4	464.2	366.7	522	1808.3

The test results form the data statistical distribution of sales and demand of cooking oil brand "B" in the retail supply chain "Y" is for January - April 2010 Normal distribution, in May - August 2010 Exponential distribution, and September - December 2010 Weibull distribution. While the probability distribution of the simulated process consists of 3 distribution probability of Normal, Exponential, and Weibull are presented in table 2. For customers who referred to the process time is the time between purchases, and for retail and distributor in question is the lead time when booking process, while for the factory in question time the process is the production lead time.

Table 2 : Distribution of processing time for each echelon supply chain

Elements of suply chain	Processing time distribution					
	Sales			Demand		
	Normal	Exponential	Weibull	Normal	Exponential	Weibull
Factory	(597, 11.7)	650	(680,1)			
Distributor				(13, 1.7)	23	(21, 4)
Retail "Y"				(51, 3)	61	(47, 12)
Customer				(52, 1.3)	70	(51, 17)

3. RESULTS AND DISCUSSION

3.1. SIMULATION RESULTS

Output simulation using ARENA 10 simulation software, the obtained variance coefficient (VC) for all three types of distribution of processing time (Normal, Exponential, and Weibull) for both system sales and system demand. Furthermore, the bullwhip effect can be calculated by dividing the value of VC (order) with VC value (demand). Recapitulation of the bullwhip effect on each element of the retail supply chain echelons are presented in Table 3.

Table 3 : Recapitulation of the bullwhip effect on each element of the retail supply chain echelon

Processing Time Distribution	Repli-cation	Element echelon supply chain			Average
		Factory - Distributor	Distributor - Retail "Y"	Retail "Y" - Customers	
Normal Distribution	1	8.42	4.92	2.01	5.12
	2	8.78	3.96	2.06	4.93
	3	8.23	4.47	2.23	4.98
	4	8.72	4.82	2.05	5.20
	5	7.8	3.85	2.24	4.63
	6	8.11	4.85	2.27	5.08
	7	6.42	3.52	2.42	4.12
	8	7.65	4.12	2.3	4.69
	9	6.72	3.23	2.61	4.19
	10	8.71	3.43	2.16	4.77
Average		7.96	4.12	2.24	4.77
Exponential Distribution	1	8.73	5.36	1.84	5.31
	2	9.6	6.29	1.89	5.93
	3	11.18	6.83	1.88	6.63
	4	8.91	5.61	1.77	5.43
	5	10.15	6.01	2.05	6.07
	6	10.16	6.69	1.96	6.27
	7	10.21	7.18	2.09	6.49
	8	10.93	6.27	1.86	6.35
	9	12.36	8.03	2.35	7.58
	10	10.43	7.03	1.94	6.47
Average		10.27	6.53	1.96	6.25
Weibull Distribution	1	9.25	6.45	2.51	6.07
	2	10.36	6.67	2.59	6.54
	3	12.58	7.66	2.81	7.68
	4	10.01	6.42	2.54	6.32
	5	10.63	7.37	2.78	6.93
	6	11.02	7.39	2.83	7.08
	7	10.69	7.31	3.02	7.00
	8	11.88	7.11	2.80	7.26
	9	13.57	9.50	3.29	8.79
	10	11.41	7.68	2.70	7.27
Average		11.14	7.35	2.79	7.09

To test this hypothesis, used ANOVA on the bullwhip effect in Table 3 above, and ANOVA test results are summarized in Table 4.

Table 4 : Two-way ANOVA summary for value bullwhip effect

Source of Variation	SS	df	MS	F	F-crit
Processing Time Distribution	83.08	2	41.54	69.23	4.85
Element Echelon Supply Chain	834.79	2	417.4	695.67	4.85
Interaction	31.17	4	7.79	12.98	3.57
Within	48.31	81	0.6		
Total	997.35	89			

The calculation of ANOVA in table 4 above, then the conclusions of the research hypotheses is presented in table 5.

Table 5 : Conclusion of the hypothesis based on ANOVA

Hypothesis	F	F-crit	Conclusion
Ho(1)	69.23	4.85	Ho(1) rejected
Ho(2)	695.67	4.85	Ho(2) rejected
Ho(3)	12.98	3.57	Ho(3) rejected

3.2. DISCUSSION

The simulation results are presented in figure 1, showing an increase in the value of the bullwhip effect Customer-Retail "Y" echelon element (downstream side) to the Distributor-Factory echelon elements (upstream side) for all kinds of processing time distribution. These statistics show that increasing the upstream side of the larger buffer stock available to meet demand in the turbulent downstream side, this means more money tied up in inventory in the supply chain in Retail "Y" so as to reduce the benefits of supply chain partners.

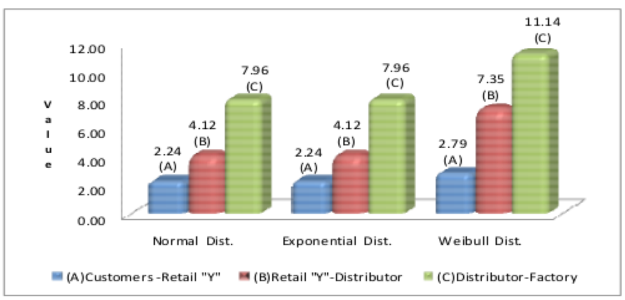

Figure 1 : The average value of bullwhip effect for each type of distribution of the processing time

ANOVA test results of hypothesis 1 conclude that the distribution of the processing time significantly influences the value of the bullwhip effect. Figure 2, shows the distribution of processing time affect the value of bullwhip effect, by increasing the value of most large bullwhip effect occurs at the time of the request processing cooking oil brand "B " Weibull distribution. The data in the field explain that the abnormal demand for cooking oil brand "B" these events occurred on religious holidays, when demand becomes larger than usual days.

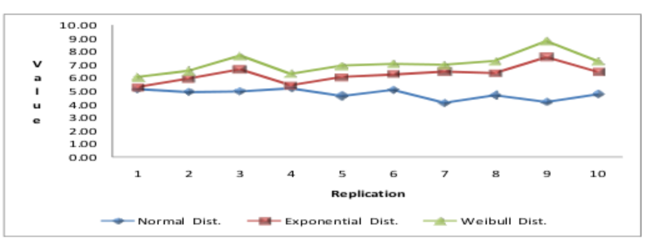

Figure 2 : The average value for each element bullwhip effect echelon supply chain from the distribution of processing time (Normal, Exponential and Weibull)

ANOVA test results for hypothesis 2 concludes that element echelon supply chain significantly influences the value of the bullwhip effect. Figure 3, shows the echelon elements affect the value of bullwhip effect, whereby the Distributor-Factory echelon elements (upstream side) has a value that most large bullwhip effect compared with elements of another echelon. This phenomenon reflects the pattern of demand for cooking oil brand "B" increases the greater the upstream side of the supply chain.

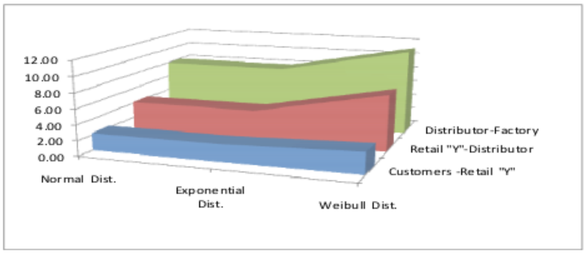

Figure 3: The average value of bullwhip effect for each echelon supply chain

ANOVA test results for hypothesis 3 concluded that the interaction between the processing time distribution with supply chain echelon element significant effect on the value bullwhip effect. Table 6, indicate that the interaction between the distribution of processing time with the elements echelon supply chain has increased the bullwhip effect is increasingly enlarged upstream supply chain (distributors echelon element-factory). The average value of bullwhip effect amplitude was 111% for echelon element Retail "Y"-Distributors and 271% for Distributor-Factory echelon elements. Results of investigation into the field to explain the increase value of bullwhip effect is due to lead time uncertainty reservations cooking oil brand "B" on each element of the supply chain, so that each element echelon tend to order in large batches to anticipate delays in delivery.

Table 6 : Percentage increase in value of bullwhip effect on the elements of Echelon Customers-Retail "Y"

Echelon elements	Normal Dist.	Exponential Dist.	Weibull Dist.	Average
Customers -Retail "Y"	0	0	0	0
Retail "Y"-Distributor	84%	84%	164%	111%
Distributor-Factory	256%	256%	300%	271%

4. CONCLUSION

Distribution of the processing time significantly influences the value of bullwhip effect, which increased the value of most large bullwhip effect, occurs at the time of the request processing cooking oil brand "B " Weibull distribution. The data in the field explain that the abnormal demand for cooking oil brand "B" these events occurred on religious holidays, when demand becomes larger than usual days.

Element echelon supply chain significantly influences the value of bullwhip effect, where the elements echelon Distributor-Factory (upstream side) has a value that most large bullwhip effect compared with elements of another echelon. This phenomenon reflects the pattern of demand for cooking oil brand "B" increases the greater the upstream side of the supply chain.

Interaction Between the processing time distribution with supply chain echelon Element significant effect on the value bullwhip effect, where the average value of bullwhip effect occurs amplitude by 111% for echelon element Retail "Y"-Distributors and 271% for Distributor-Factory echelon elements. Results of investigation into the field to explain the increase value of bullwhip effect is due to lead time uncertainty reservations cooking oil brand "B" on each element of the supply chain, so that each element echelon tend to order in large batches to anticipate delays in delivery.

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