Simulation for analyzing effect of Silver Meal lot sizing rules in bullwhip effect

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Abstract. Bullwhip effect is a variability of demand distorting phenomenon in supply chain. The difference in variability of demand is caused by varied methods in interpreting the data. One of the causes is the lot sizing rules which are used by the suppliers. This research analyzes the effect of lot sizing rules on bullwhip effect on determine the order quantity with Silver Meal method. The supply chain model consists of two suppliers who are retailer and wholesaler. The bullwhip effect can be seen on the variability of wholesaler's demand. This paper will also show the impact of higher variability and the impact of holding cost. The result showed that Silver Meal method will produced higher variability on demand wholesalers. Using Silver meal on higher variability demand will decrease the bullwhip effect by only 1%. By reducing the holding cost it will be increasing the bullwhip effect however the total cost will be lower

Keywords: Simulation, Bullwhip effect, Lot Sizing, Silver meal, Dynamic, Supply chain

1 Introduction

Bullwhip effect is distorted information that occur in the supply chain. The information is distorted are quantity order and quantity demand from a downs tream to an upstream channel in the supply chain. The longer of the supply chain may cause the bullwhip effect will be even greater. The bullwhip effect can be seen in the difference information supplied in the form data of ordering or demand. Data received by the retailer will be different from the data received by wholesaler as well as distributors and factory. The order quantity is determined by considering the amount to be ordered and the inventory cost. The quantity to be ordered by the company is also consider the quantity of demand and the quantity for the inventory. The different methods used in determining the order quantity will produce different results for each supplier. One of the most used methods is Silver Meal. This research is done by developing research of Pujawan [1] who's researching the effect of lot sizing rules on one level supplier and it is not known the impact of the bullwhip effect occurs at two levels, retailer and wholesaler. Potter and Disney [2] derived closed form expression when demand is deterministic and the found that careful selection of batch size can impact bullwhip effect. Pujawan and Silver [3] developed heuristic procedures to select appropriate augmented quantity for single item, discrete time, lot sizing situation. Wang and Disney [4] stated that ordering policies is one of element that build bullwhip effect. In this paper we introduce simulations for analyzing the effect of lot sizing for bullwhip effects. Simulation has been used for analyzing bullwhip effect such as an application in hard goods retailer [5]. Silver meal lot sizing method is used since it one of lot sizing metho that is sed widely theoretically dan practically. One theoretically analysis of silver meal is conducted by Govindan [6]. In this paper, effect of Silver Meal methods effect to bullwhip effect is analyzed by using three retailers and one wholesaler. This situation is different than Pujawan [1] that only consider one retailer and one wholesaler. A situation where there are more than one retailer is more applicable than only use one retailer.

2 Problem Description

The bullwhip effect is one of the problems that usually happen in supply chain which caused by ordering in one supplier to other supplier. We want to know the impact of the bullwhip effect occurs in a supply chain caused by the lot sizing rules at two level of suppliers.

It is also not yet known the impacts on each supplier if use a set of different methods, inventory cost, and order variability. The purpose of this research is to know the impact of the bullwhip effect caused by the method of determining the quantity order by Silver Meal method in each supplier.

Lee (1997) [7] stated that bullwhip effect is a phenomenon where the order variability received by the supplier will tend to greater from the seller to the buyer. There are four causes that will create the bullwhip effect.

The supply chain consists of some suppliers that will have a different way of forecasting. The different way is caused by different perception in each supplier. The unstable forecasting can cause the bullwhip effect. The bullwhip effect can be also caused by the using of forecasting methods. Various forecasting methods will produce different demand depending on the demand of each supplier. The number of demand that result from forecasting is usually not the real amount of demand but have had more quantity.

Order batching system is a way the company in making ordering. This order batching shows the ordering frequency. The ordering policy in a company can be done by every day, every week, or every month. A company will do ordering by consider the ordering cost and transportation cost. Most company do not have a certain ordering policy so if a variability of demand is low so the company will do ordering with large amount.

Most of transactions made by distributor and factory are wholesaler and doing the ordering repeatedly. The price in each suppliers is also unstable and fluctuate. The factory is usually giving the promotions to distributor like discounts, quantity discounts, and coupons. This promotion causes the price to be changeable. This price change is causing the distribution tend to buy in bulk during the promotions period. These promotions will also cause the ordering repeatedly based on the high or low the price. The quantity of demand will unstable and unlike the actual demand.

The costumer needs is known by the distributor is utilized by the distributor to make an order. Sometimes the distributor are doing "gaming" to attract the customer needs. The distributor is usually changing the amount of demand. One of the suppliers whose doing the gaming on demand will cause the factory will not know the actual demand. So that will happen shortage or overstocking in the market. The thing can do by distributor is divide the number of items proportionally to each suppliers.

Material requirement planning is a systematic technique that is used to determine the quantity and time in the process material control of the component materials for dependent demand. One of the basic steps in conducting the material requirement by using the lotting system. Lotting system is the process of determining the optimal quantity order for an item based on the net requirement.

Ordering cost is the costs associated with the effort to get the raw materials. Ordering cost covers the cost of writing, cost of raw material, cost of invoice, transportation, dan security. The more often the order is made so the ordering cost will be higher. Holding cost is the cost to invested in inventory in the company. For the examples are the cost of building, maintenance, electricity, security salary, the equipment assurance.

Silver Meal is a a method with an approach by finding a minimum average cost in each period for a period to be planned. This method will produce a number of lot that can minimize the total costs per period. Demand from successive periods will be accumulated into a lot size. Pujawan [1] examine the value of expected quantity that is the expected value of the quantity order at each period. The expected quantity (E(Q)) for Silver Meal can be expressed as follows:

$$E(Q) = (M - p)\mu \qquad (1)$$

E(Q) : Expected quantity
M : Ordering period
p : The probability of shortage
μ : Mean of demand

The quantity order is also affected by uncertainty demand. So in determine the quantity order also have to consider the variance of the order quantity. According Pujawan [1], the variance of the order quantity for Silver Meal can be obtained as follows:

$$Var(Q) = s^2 + p(1-p)\mu^2 - \frac{2s\mu}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}\left(\frac{\xi^2}{s}\right)\right)$$

Var(Q) : The variance of order quantity
s : standard deviation of demand
p : probability of shortage

μ

:

mean of demand (2)
ξ : safety stock

The expected quantity and the variance of order quantity will be used to determine the quantity order. So that the quantity order can be obtained by this equation:

$$Qt = E(Q) + Z \times \sqrt{Var(Q)} - I_{t-1} \quad if \quad D_t - I_{t-1} > 0 \tag{3}$$

$$Otherwise;\ Qt = 0$$

Qt : Quantity order
E(Q) : Expected Quantity
Z : Service level
Var(Q) : The variance of order quantity
I_{t-1} : Inventory level at the end of period t

3 Model dan result

3.1 Model Solution

The model settlement is done with 2 level of suppliers, retailer and wholesalers. There are 3 retailers and 1 wholesaler. All of retailers will have different mean and variance of demand. Then all the retailers will determine their quantity order depend on their demand in each period. All the quantity order by retailers in each period will be summed and become data of demand to wholesaler. The mean and variance of three retailers successive sequence is 100-10; 200-20, and 500-50.

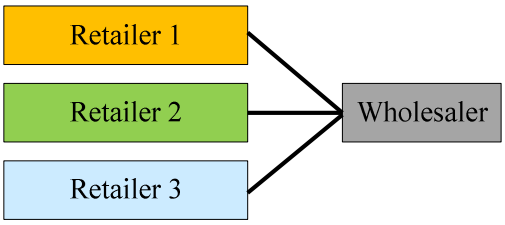

Figure 1. Flow of supply chain

The settlement of the model is by counting the quantity order in each period and calculate the cost per unit in each supplier. The calculation is performed for 156 weeks and we assumption the ordering cost is $400 and the holding cost is $1 per unit.

Step of completing

Step of completion is done as follows:

- Generating the demand of 3 retailers by using Random Number Generate based on mean and variance of demand in each retailers.
- Determine the quantity order in every period for each retailers. To determine the quantity order by using Silver Meal is depend on the number of ordering period (M) for each suppliers. The number of ordering period in each supplier will be different depend on the optimal cost which is the lower cost per period. The number of quantity order can be determined by using equation (3).
- Calculating the number of inventory in each period by using equation as follows:

$$It - Number\ of\ quantity\ order_{(t)} - Number\ of\ demand_{(t)} + I_{(t-1)} \quad (4)$$

- Calculating the ordering cost and holding cost. There will be charged an ordering cost if there is an order in that period. So the total of ordering cost for 156 weeks was obtained from the number of ordering is multiplied by the ordering cost. And there will be charged a holding cost if there is an unused inventory item in that period. Where is the total of holding cost was obtained from the number of inventory is multiplied by the holding cost per unit.
- Calculate the demand of wholesaler which is obtained by summing the quantity order of 3 retailers in each period.
- Calculating the mean and standard deviation of demand for wholesaler that will used to determine the quantity order. To determine the quantity order at wholesaler will using the same method as retailers.
- Calculate the ordering cost, holding cost, and the total cost per unit for wholesaler with the same method as retailers.

The first step to completing the model by using silver meal method by determining the number of ordering period (M). Where is to determine the number of ordering period (M) is based on comparison of cost per period for each additional period covered. To determine the number of M is done by calculating the cost per unit of the number of ordering period for M = 2,3,4,5 and so on until an increase in the cost per unit. The number of service level that is used is 1,65 so the number of safety stock is obtained by 1.65s. The result of determining the number of M with Silver Meal can be seen as follows:

Table 1. Result of the determination the number of M by Silver Meal

H = 1	retailer 1	retaile r 2	retaile r 3	wholesale r
M = 2	2,773	1,775	1,185	1,457
M = 3	2,642	1,970	1,574	1,955
M = 4	2,852	2,258	1,996	2,347

The results of determine the number of M by Silver Meal above show the average cost per unit for each supplier with each number of M. The calculation is done with M are 2, 3, dan 4. The results show that for every additional period, so that the cost per unit will be higher with M = 3 except for retailer 1. Then for the retailer 1, we additional the period with number of M is 4. The cost per unit for retailer 1 with M = 4 will be higher so the calculation is stopped. The results above show that retailer 1 is better to make an order with Silver Meal method with number of ordering period (M) is 3. While for retailer 2, retailer 3, and wholesaler are better to make an order with number of ordering period M = 2. That is because of the lower cost. This calculation was run with 10 replications to get the average of cost per unit.

Table 2. Average of cost per unit ($/unit)

H = 1	retai ler 1	retai ler 2	retai ler 3	wholes aler	tot al biaya
Silver meal	2,65 1	1,79 3	1,17 9	1,441	7,0 65

Table 3. Mean and standard deviation of demand retailer and wholesaler

	Retailer 1	Retailer 2	Retailer 3	Wholesaler
Mean	100	200	500	805,1
Standard Deviation	10	20	50	598,77

The results of the calculation of cost per unit from retailer 1 to retailer 3 shows the change in cost per unit becomes lower. The cost per unit at the wholesaler will be higher than retailer 3 because of the higher variance of demand wholesaler then the quantity order in each period is unstable and often a shortage or overstocking.

Verification is a step to verify the model which has been made. The verification was conducted to test whether the models are in compliance or not. Verification is done by increasing and decreasing the standard deviation of demand. Small standard deviation given by 5% of the mean of demand while large standard deviation given by 30% of the mean of demand.

Table 4. The number of changes standardd deviation (unit).

	Mean	StDev Small	StDev	StDev Large
Retailer 1	100	5	10	30
Retailer 2	200	10	20	60
Retailer 3	500	25	50	150

The model have been verified if the changes of standard deviation corresponding with the changes of the cost per unit.

Table 5. Verification (unit)

	retailer 1	retailer 2	retailer 3
Small Stdev	2,614	1,788	1,176
Averger Stdev	2,651	1,793	1,179
Large Stdev	2,793	1,952	1,318

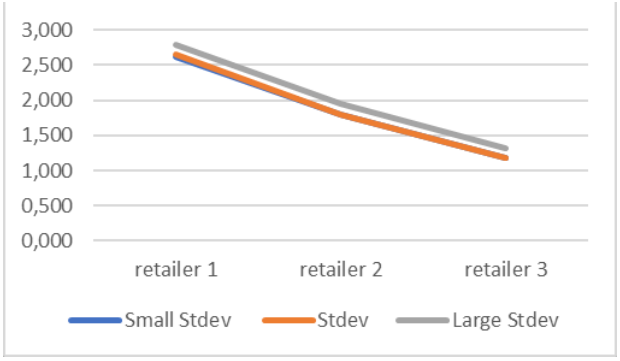

Figure 2. Verification

The verification results of Silver Meal show that the cost changes occur that affected by changes of standard deviation. The average overall cost per unit would be smaller if the standard deviation diminished as well if the standard deviation was raised, then the average cost per unit will be greater. Figure 2 also shows a decrease in the line that showing a decline in the cost for each standard deviation. The result of this varication indicates that he model that has been made in compliance.

The ordering cost and the holding cost to be one of the factor to be considered in making an order. The cost is surely will affect the frequency and quantity of ordering. The different comparison between the ordering cost and holding cost will affect the different bullwhip effect. In previous calculations is using $400 for ordering cost and $1 for holding cost. This simulation is done by changing the holding cost from $1/unit to $0,1/unit. And it affect the number of ordering period that used. The calculation result for determine the number of ordering period with the holding cost $0,1/unit can be seen as follows:

Table 6. Result of determination the number of M with H = $0,1/unit

	retailer 1	retailer 2	retailer 3	wholesaler
M = 2	2,100	1,089	0,485	0,596
M = 3	1,484	0,809	0,399	0,341
M = 4	1,466	0,799	0,386	0,359
M = 5	1,048	0,636	0,396	0,383
M = 6	0,949	0,625	0,412	0,464
M = 7	0,897	0,621	0,452	0,415
M = 8	0,875	0,626	0,484	0,454
M = 9	0,874	0,650	0,521	0,531
M = 10	0,870	0,690	0,569	0,486
M = 11	0,899	0,706	0,606	0,618

Table 7. Comparisonofthecostperunit($/unit)

H = $1				
retailer 1	retailer 2	retailer 3	wholesaler	total biaya
2,651	1,793	1,179	1,441	7,065
H = $0,1				
retailer 1	retailer 2	retailer 3	wholesaler	total biaya
0,886	0,618	0,384	0,655	2,543

The average of cost per unit will be lower if the holding cost be diminished to $0,1/unit. That is because the holding costs are cheaper so that each supplier is better to performing inventory rather that ordering. This is because the number of ordering period is larger so that will be saving the ordering cost. This can be evidenced from the frequency of ordering made for 156 weeks as follows:

Table 8. Frequency of ordering (times)

	retailer 1	retailer 2	retailer 3	wholesaler
H = 1	79,0	80,8	79,8	78,0
H = 0,1	23,0	23,3	23,3	23,3

These results suggest that if the holding cost diminished so the frequency of ordering made will also be reduced which saves about 50 times ordering. This will save the ordering cost because the holding cost is cheaper.

Sensitivity analysis is an analysis performed to determine the result of a change in a parameter to change the value of the other. Sensitivity analysis performed in this research is the change the cost of storage. This analysis to know the impact of changes the holding cost. The holding cost that performed are $0,1, $0,2, $0,5, $0,7, $0,8, and $1. This analysis is done to see whether changes in holding costs will have a significant impact on the cost per unit at each supplier.

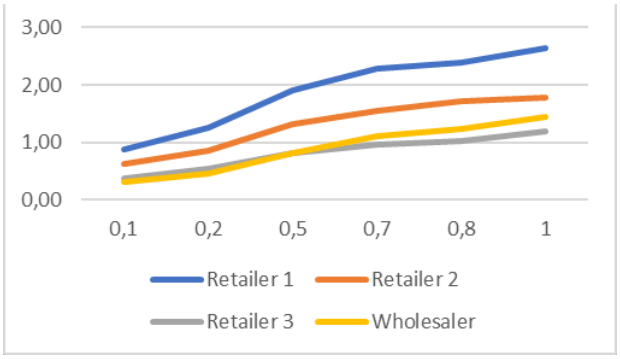

Figure 3. Sensitivity analysis of holding cost ($/unit)

Figure 3 shows that the higher holding cost will produce cost per unit higher and any increase of $0,1 will be affect the cost significantly. This result also shows that with Silver Meal method then the cost will change more constant. These results also indicate that the changes of holding cost at wholesaler is smaller than retailer. This is because of the higher of standard deviation at wholesaler.

The analysis of bullwhip effect that will be seen that the effect caused by the method of determining the quantity order with method Silver Meal. The supplier that will receive the impact of bullwhip effect is the wholesaler because the wholesaler will receive the ordering from 3 retailers with a different quantity in each period. So that the wholesaler will not receive the actual demand. The bullwhip effect can be seen from changes of standard deviation of demand at wholesaler.

Figure 4. The bullwhip effect of silver meal (unit)

The figure above shows the changes of demand standard deviation from retailer to wholesaler and the standard deviation of ordering at wholesaler. Where the standard deviation of ordering at wholesaler will be used as the standard deviation of demand at factory. The results above show a huge gap from retailer to wholesaler and to factory. The changes variation of demand from retailers that increasingly large until factory is called Bullwhip Effect.

This bullwhip effect is caused by use Silver meal method where the ordering is done in a lot size (M) so the ordering not performed at each period. These is causing the demand at wholesaler is unstable on each period. Another thing that affects the bullwhip effect on wholesaler is the ordering of retailers are independent. There will be different impact of bullwhip effect if the wholesaler could know the real demand that needed by retailers and the wholesaler will combine the demands which are called Aggregate planning. By aggregate planning, the wholesaler can adjust the requirement of the 3 retailers. This is also will affect the changes of mean and standard deviation of demand at wholesaler.

Table 9. The changes of mean and standard deviation of demand wholesaler (unit)

Mean of demand wholesaler	Mean Aggregate	Non Aggregate
Silver meal	276,7	805,1
Standard deviation of demand wholesaler	Mean Aggregate	Non Aggregate
Silver meal	556,81	598,77

The table shows the result of changes in the mean and standard deviation of demand wholesaler by aggregating and non-aggregating the demand. The mean and standard deviation of aggregate demand is smaller than non-aggregate demand. This is because the wholesaler combines the ordering of three retailers so that mean of demand at wholesaler will be smaller. And for the standard deviation of demand, with aggregating the demand so that the standard deviation of demand will be smaller.

Table 10. The cost per unit of wholesaler ($/unit)

	Mean Agregat	Non Agregat
Silver Meal	1,461	1,441

This is also will impact the cost per unit at wholesaler. which that the cost per unit at wholesaler with aggregate demand and non-aggregate will not different significantly. So, by aggregating the demand, the mean of demand will smaller by 4 times of the non aggregate while the standard deviation will smaller by 10% of the non aggregate and the cost at wholesaler will not different significantly.

The next simulation is to perform an calculation analysis if the variation of demand at each retailer be enlarged. The calculation of this simulation conducted to see the effect and changes that occur because of changes in variation of demand. The changes variation of demand is made by changing the standard deviation of demand at 3 retailers becomes larger, while the standard deviation at wholesaler will depend on quantity order of the three retailers.

Table 11. Changes standard deviation of retailers (unit)

	Mean	Stdev	Large Stdev
Retailer 1	100	10	50
Retailer 2	200	20	100
Retailer 3	500	50	250

The changes standard deviation of demand based on 50% of mean of demand at each retailer. Change in the standard deviation of retailer will certainly have an impact on the standard deviation of demand received at wholesaler. With other word, the bullwhip effect that received by wholesaler. The impact of bullwhip effect received by wholesaler can be seen on the standard deviation at wholesaler.

Table 12. Standard deviation of wholesaler (unit)

H = 1	Stdev	Large Stdev
Silver meal	598,8	605,8
H = 0,1	Stdev	Large Stdev
Silver meal	1071,5	1093,9

The result above shows the changes of standard deviation of demand at wholesaler that caused by enlarged the variation at retailers. With Silver Meal method, the standard deviation of demand at wholesaler will be even greater with an enlarged variation. However the impact of bullwhip effect is only increased ±1% of the beginning variation. This is certainly affecting the changes of cost per unit at each suppliers.

Table 13. Changes of cost per unit at each suppliers ($/unit)

	H = 1		H = 0,1	
	Stdev	Large Stdev	Stdev	Large Stdev
Retailer 1	2,819	2,882	0,911	0,915
Retailer 2	1,783	1,968	0,619	0,634
Retailer 3	1,181	1,367	0,445	0,456
Wholesaler	1,458	1,300	0,443	0,438

These results indicate that with increasing the variation of demand at retailers don't have a significant difference on a smaller ordering cost. While for the holding cost $1 then average changes of cost will only affect 10% of beginning cost. But the cost at wholesaler decreased by enlarge the variation at retailers. It allows because the demand at wholesaler depend on three retailers.

4 Conclusion

Bullwhip effect is a phenomenon where there is a difference between the variation of demand at each suppliers within a supply chain. One of the factors that cause this difference is the method to determine the quantity order that are used by each supplier. This research analysis is conducted by develop with two levels in supply chain. The results showed that Silver Meal method will cause the bullwhip effect is greater than the retailer to wholesaler and to the factory. Where the standard deviation of demand received at wholesaler will be higher so that the ordering is done by wholesaler to the factory will also higher. And with aggregating the demand of three retailers, the wholesaler will receive smaller mean and standard deviation but the cost per unit will be same.

The impact of the bullwhip effect will also be influenced by the proportion of costs used. Where the greater gap between holding cost and inventory cost will affect the bullwhip effect produced by Silver Meal method will also increase. But the impact of the bullwhip effect generated by Silver Meal on a large variation will not increase much and only increase by 1% of beginning variation

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