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Minimizing the Bullwhip Effect for Supply Chains Single Vendor and Multi Distributor in Salt Companies

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Abstract

In a competitive market, companies anticipate demand and ensure product availability. However, demand uncertainty due to the bullwhip effect can disrupt a company's efforts to make proper plans. This research aims to reduce the value of the bullwhip effect to produce optimal inventory using the Vendor Managed Inventory (VMI) method in salt processing companies. This research uses a VMI method with a probabilistic inventory control model approach. So, the vendor determines the number of orders per period. The data type used is secondary data for each distributor and vendor from March 2023 to February 2024. The novelty of this research is the addition of product shortage cost variables, and research was carried out on distributors and vendors. The research results show that the VMI method can reduce the bullwhip effect on vendors by 71%, as well as in each distributor region, such as East Java by 71%, Central Java by 59%, West Java by 57%, Sulawesi by 67%, Sumatra by 62%, Kalimantan by 60%, NTB by 61%, and Bangka Belitung by 63%. This research helps companies effectively estimate optimal inventory for each distributor to avoid information distortion that will cause a bullwhip effect.

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1. INTRODUCTION

In the last few decades, companies have witnessed a new business paradigm in supply chains by taking a collaborative approach to decision-making (Son & Ghosh, 2020). Through a collaborative approach, companies will gain a competitive advantage (Beheshti et al., 2020). With a collaborative approach, Supply Chain Management (SCM) plays an important role (Huynh et al., 2020). Several stakeholders include suppliers, vendors or manufacturing plants, warehouses, transportation companies, distribution centers, and retailers (Putri & Pulansari, 2023). One way to make decisions with an effective solution in Supply Chain Management (SCM) is by implementing Vendor Managed Inventory (VMI) (Najafnejhad et al., 2021). Vendor Managed Inventory (VMI) is a model of supply chain collaboration between suppliers and buyers in which the supplier (vendor) is responsible for managing, supervising, and ensuring optimal product availability (Taleizadeh et al., 2020; van den Bogaert & van Jaarsveld, 2022; Wang et al., 2022).

As the population increases, the demand for salt in Indonesia also increases. Indonesia is the second country with the longest coastline of 99,093 kilometers with a pond area of 26,024 hectares (Suhendi et al., 2020). According to Sunoko et al. (2022) as part of the economy of coastal communities and with a long history, salt has an important role, especially in the Java and Madura regions. One industry on the coast of East Java processes kiosk salt into iodine consumption salt, namely XYZ Company. This company uses distributors to distribute its products to several retailers spread throughout Indonesia and abroad. Indonesia's distributors include East Java, Central Java, West Java, Sulawesi, Sumatra, Kalimantan, NTB, and Bangka Belitung. However, in the last few months, XYZ Company is still experiencing problems, namely fluctuating demand data due to distributor demand that cannot be predicted with certainty. Due to the high variability in demand in the supply chain, this is commonly known as the bullwhip effect phenomenon. In Figure 1, vendors and eight distributors experienced the highest decline in demand in February 2023, amounting to 29%. In August 2023, there will be the highest increase in demand, at 65%. This makes it difficult for companies to determine the optimal production amount for the next period.

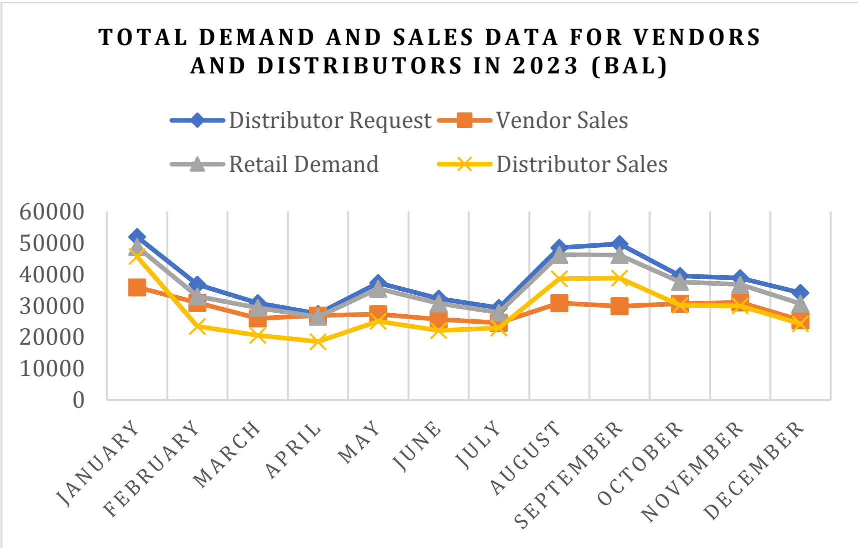

Figure 1. Amount of Demand and Sales Data for Vendors and Distributors
Source: XYZ Company (2023)

With fluctuating demand from distributors to vendors, which is relatively high in each period, the company must be able to create an efficient inventory policy. One solution that can be proposed is to apply the Vendor Managed Inventory (VMI) method. This method can be applied to manage inventory efficiently and requires involvement between vendors and buyers (Hidayat et al., 2020). Retailers or distributors (buyers) send request data from customers to vendors (suppliers) (Keshavarz-Ghorbani & Pasandideh, 2021). So, the vendor will process the inventory based on customer demand data from distributors or retailers. So, vendors can decide on policies for refilling products with distributors or retailers (de Maio & Laganà, 2020). In this case, the vendor is fully responsible for inventory strategy, implementation, and delivery to buyers (Omar et al., 2020).

In the context of reducing the bullwhip effect, Qadafi et al. (2022) and Susanto & Hutami (2021) provides the view that collaboration between suppliers and buyers by exchanging information related to demand and sales data with distributors, which will then determine the number of orders and optimize inventory by the vendor, can make a positive contribution to reducing the bullwhip effect. This concept can become a strategic basis for XYZ Company, in overcoming the bullwhip effect challenges it faces. This research aims to reduce the bullwhip effect value to produce optimal inventory using the Vendor Managed Inventory (VMI) method at XYZ Company. The variables used in previous research were demand data, sales data, ordering costs, and holding costs (Paduloh et al., 2023). The novelty of this research is the addition of product shortage cost variables, and the study was carried out on distributors and vendors at salt companies. This research uses the Vendor

Managed Inventory method to calculate the optimal order lot size. This research will help companies reduce the bullwhip effect and run supply chains more effectively and efficiently.

Literature Review

Supply Chain Management

According to Perdana (2021) Supply Chain Management (SCM) is a multi-stakeholder network for managing information, raw material, money flow , materials, and finished products. Supply chain management (SCM) integrates suppliers, producers, warehouses, transportation, distributors, retailers, and consumers (Putri & Pulansari, 2023). The main focus of supply chain management is creating customer value by optimizing the flow of products and services through an effective and efficient supply chain (Aamer et al., 2021; Yani et al., 2019), meet the correct number of customer requests, locations, and time (Wettasinghe & Luong, 2020). This is done to increase the company's competitive advantage (Oliveira-Diasn et al., 2022). The challenges in supply chain management are the complexity of the supply chain structure, demand uncertainty, lead time, and internal company issues (Purwaningtias et al., 2020). The presence of supply chain members who are geographically dispersed makes supply chain coordination difficult. Therefore, one of the strategies that helps several companies survive is supply chain management, which includes inventory management. In processing inventory management, several challenges must be faced, namely the uncertainty of demand (Wettasinghe & Luong, 2020). Uncertainty in demand can cause a bullwhip effect phenomenon with inaccurate data from downstream to upstream (Perdana, 2021). According to Nguyen et al (2022) they believe that in the supply chain, manufacturing companies can optimize operations, maximize production capacity, and reduce supply chain costs through stakeholder collaboration.

Bullwhip Effect

The bullwhip effect, commonly known as demand distortion, is a phenomenon caused by increased variability in demand from customers to suppliers (Brito et al., 2020;Liu et al., 2024). One of the causes of the bullwhip effect is errors in predicting demand. Not only that, lack of transparency in demand, grouping of orders, promotions, and lack of games are causes of the bullwhip effect (Bamakan et al., 2021; Sudarmin & Ardi, 2020). The bullwhip effect occurs if the value is >1; if =1 and <1, then the bullwhip effect does not occur (Dolgui et al., 2019). According to Punjawan & Mahendrawathi (2017) the following is the formula for calculating the bullwhip effect and parameter bullwhip effect:

Bullwhip Effect = $\frac{Demand\ Coefficient}{Sales\ Coefficient}$

Bullwhip Effect Parameters = $1 + \frac{2L}{P} + \frac{2L^2}{P}$

Where: L = lead time, p = period (month)

According to Martono (2019), the bullwhip effect occurs due to pressure from increasing production and inventory amounts in supply chain components that are increasingly distant from consumers. An illustration of this incident can be explained: if the marketing department intends to sell 100 units, then The production section is targeted at 110 units, considering the number of damaged units, safety stock, and lead time. Buyers, too, are considering the same thing by targeting 120 units. If, in the following period, the marketing department said sales decreased to 90 units, production plans and suppliers will also decrease by 100 units and 110 units, but still considering the number of damaged units, safety stock, and waiting time. So, the marketing department's request in period one can only be obtained and realized by the production department in period 2. The production department must prepare resources, costs, working hours, etc. After that, the production department sends the required quantity to the supplier. The supplier receives this information and can then fulfill it period 3. There are differences in periods between parties in the supply chain (time lag) can cause high bullwhip effect values. According to Kumila et al (2019) there is a long time lag, and the company needs to determine when something will happen, so the forecasting method (forecasting) is very necessary.

Vendor Managed Inventory

Implementing VMI, EDI, or ERP can reduce the bullwhip effect (Israel & Mahuwi, 2022). VMI is a strategy implemented by vendors to optimize supply chain processes (Omar et al., 2020). Vendors also regulate the number of products that will be sent to buyers (Phong & Yenradee, 2020), so vendors have the right to know buyer or retailer demand data (Wettasinghe & Luong, 2020). Vendors are authorized to monitor product inventory for buyers (Dasaklis & Casino, 2019). Retailers like Walmart, Kmart, Dillard Department Stores, and JCPenney have used VMI (Kumar et al., 2021). The advantage of implementing VMI is that goods are available on time and shipping costs can be reduced (Fang & Chen, 2021), can optimize inventory, and increase supply chain efficiency (Wang et al., 2022). According to de Maio and Laganà (2020), using the Vendor Managed Inventory (VMI) method can provide a competitive advantage for companies over a long planning period. This can happen because the company can achieve significant savings using optimal stock policies.

2. METHODS

This research is intended to determine the value of the bullwhip effect on vendors and each distributor for research objects carried out at XYZ Company has eight distributors in East Java, Central Java, West Java, Sulawesi, Sumatra, Kalimantan, NTB and Bangka Belitung. The method used in this research is the Vendor Managed Inventory (VMI) method. This method can be applied to manage inventory efficiently and requires involvement between vendors and buyers (Hidayat et al., 2020).

This research has two variables: the dependent variable and the independent variable. The dependent variable is a variable that is influenced or results from an independent variable's existence. The dependent variable in this research is the bullwhip effect value. Meanwhile, the independent variable is the variable that causes changes in the dependent variable and is the decision variable that will later be sought. The independent variables in this research are demand data, sales data, ordering costs, storage costs, product shortage costs, lead time, and service level XYZ Company.

This research uses secondary data by taking historical data from March 2023 – February 2024 at XYZ Company. Data obtained include demand data from retail to distributor, demand data from distributor to vendor, sales data from vendor to distributor, sales data from distributor to retail, ordering costs and storage costs incurred by distributors, lead time from vendor to distributor, and service level XYZ Company.

The vendor-managed inventory concept can use a probabilistic inventory control model in inventory management (Junior et al., 2022). According to Chandra & Sunarni (2020) and Tuffahati & Pulansari (2023) the search for solutions q* and r* can be carried out in the following stages: (1) calculate the first optimal ordering plan (q_{01}^*), (2) calculate the possibility of inventory shortage (α), (3) calculate the first reorder point (r_{01}^*), (4) Calculate the second optimal ordering plan (q_{02}^*), (5) Recalculate the possibility of inventory shortage (α) and value (r_{01}^*) with the following formula:

$$Q^* = q_{01}^* = \sqrt{\frac{2xDxA}{h}} \quad (1)$$

$$\alpha = \frac{h \ x \ q_{01}^*}{Cu \ x \ D} \quad (2)$$

$$r_{01}^* = D \text{ x } L + Z_\alpha \text{ x } \sigma\sqrt{L} \quad (3)$$

Q* = q_{02}^*

= $\sqrt{\frac{2xD[A+Cu \int_r^\infty (x-r)f(x)d_x]}{h}}$

(4)

N = $\int_r^\infty (x-r)f(x)d_x$ = σ x L [f(Z_α) - Z_α x ψ (Z_α)

(5)

The iteration will stop until the results q_{n-1}^* = q_n^* and r_{n-1}^* = r_n^* are obtained. The notation used in this research is as follows:

q* = Optimum order quantity (bal/period)
h = Holding cost (Rp/bal)
A = Ordering cost (Rp/bal)
Cu = Shortage cost (Rp)
r = Reorder point (bal)
N = Expect inventory shortages
L = Lead time (periode)
σ = Standard deviation
α = Possible shortage
f (Z_α) = Ordinal
ψ (Z_α) = Partial expectation
D = Total needs (bal/period).

3. RESULT AND DISCUSSION

Data processing in this research begins by calculating the bullwhip effect parameters with a lead time of 7 days with 12 observation data periods. After that, the bullwhip effect calculation is carried out. Suppose the VMI method can reduce the bullwhip effect as indicated by the second bullwhip effect calculation results. So, this research can continue to the inventory control calculation stage.

Vendor and Distributor Bullwhip Effect Values (Before Using the VMI Proposed Concept)

The calculation of the bullwhip effect parameters is determined using the bullwhip effect parameter formula, resulting in a bullwhip effect parameter of 1,0480. The following are the results of calculating the value of bullwhip effect 1:

Table 1. Bullwhip effect value 1

Supply Chain Levels	Parameter	Bullwhip Effect 1
Vendor (XYZ Company)	1,0480	1,3112
East Java Regional Distributor	1,0480	1,1900
Central Java Regional Distributor	1,0480	1,2150
West Java Regional Distributor	1,0480	1,1525
Sulawesi Regional Distributor	1,0480	1,3970
Sumatra Regional Distributor	1,0480	1,3028
Kalimantan Regional Distributor	1,0480	1,1469
NTB Regional Distributor	1,0480	1,1679
Bangka Belitung Region Distributor	1,0480	1,2306

Source: Data Processed (2024)

The research results show that the demand coefficient for vendors and each distributor exceeds the sales coefficient, so the resulting value exceeds 1. Table 1 shows that the bullwhip effect value for vendors and distributors exceeds the parameter value. This phenomenon indicates that demand fluctuations are more significant than sales fluctuations. This could indicate an amplification of the effects of order fluctuations along supply chain in XYZ Company.

Ordering Policy Calculation

Before calculating the ordering policy, a demand forecasting calculation is carried out to calculate the estimated number of products sold from March 2024 - February 2025. The demand forecasting method in this research can be seen from the historical data pattern of demand from March 2023 - February 2024, which has been collected. Based on historical data patterns of vendors and distributors, it can be concluded that data requests from March 2023 – February 2024 fall into seasonal and trend data patterns. So, forecasting methods that suit seasonal and trend data patterns are single exponential smoothing, double exponential smoothing, moving averages, and trend analysis.

Next, an error test was carried out on the forecasting method using MSD assisted by Minitab 16 software. The most minor forecasting accuracy result using MSD was using the Trend Analysis method. Furthermore, a forecast verification test was carried out using the Trend Analysis method, showing that none of the forecast data exceeded the upper and lower control limits. The forecasting results can be used as a parameter for the total needs (D) value, and the ordering policy can be calculated for the vendor and each distributor. The following are the results of ordering policy calculations (q) using the Vendor Managed Inventory concept with a probabilistic distributor inventory control model for the East Java region in the period March 2024 - February 2025:

Table 2. Calculation Results of Distributor Ordering Policies for the East Java Region

Period	Indicator							
	D	f (Z_α)	ψ (Z_α)	N	q	α	Z_α	r
1	3953	0,0059	0,00050	0,2	4054	0,0019	2,90	1142
2	3996	0,0059	0,00050	0,2	4076	0,0019	2,90	1152
3	4040	0,0059	0,00050	0,2	4098	0,0019	2,90	1163
4	4083	0,0059	0,00050	0,2	4120	0,0019	2,90	1173
5	4127	0,0051	0,00045	0,1	4088	0,0018	2,95	1187
6	4170	0,0051	0,00045	0,1	4109	0,0018	2,95	1197
7	4214	0,0051	0,00045	0,1	4131	0,0018	2,95	1207
8	4258	0,0051	0,00045	0,1	4152	0,0018	2,95	1217
9	4301	0,0051	0,00045	0,1	4173	0,0018	2,95	1227
10	4345	0,0051	0,00045	0,1	4194	0,0018	2,95	1237
11	4388	0,0051	0,00045	0,1	4215	0,0018	2,95	1248
12	4432	0,0051	0,00045	0,1	4236	0,0018	2,95	1258

Source: Data Processed (2024)

Table 2 above, shows that there was an increase in order demand (q) in periods 1-4 with a constant possible shortage (α) value to maintain a low level of shortage despite an increase in demand, but in period 5 there was a decrease in demand, due to the possible shortage value (α) decreased from 0,0019 to 0,0018, then the standard deviation value is normal (Z_α) can adjust the α value, which was initially 2,90 to 2,95. The value of the ordinal f (Z_α) and partial expectation ψ (Z_α) also decreased. Thus, the shortage value (N) also decreased from period 4 to 5, initially from 0,2 to 0,1. However, the reorder point value always increases in each period.

The following are the results of ordering policy calculations (q) using the Vendor Managed Inventory concept with a probabilistic distributor inventory control model for the Central Java region in the period March 2024 - February 2025:

Table 3. Calculation Results of Distributor Ordering Policies for the Central Java Region

Period	Indicator							
	D	f (Z_α)	ψ (Z_α)	N	q	α	Z_α	r
1	3379	0,0069	0,00060	0,2	3350	0,0025	2,85	990
2	3419	0,0069	0,00060	0,2	3370	0,0024	2,85	999
3	3460	0,0069	0,00060	0,2	3390	0,0024	2,85	1009
4	3501	0,0069	0,00060	0,2	3410	0,0024	2,85	1018
5	3541	0,0069	0,00060	0,2	3430	0,0024	2,85	1027
6	3582	0,0069	0,00060	0,2	3450	0,0024	2,85	1037
7	3622	0,0069	0,00060	0,2	3469	0,0024	2,85	1046
8	3663	0,0069	0,00060	0,2	3488	0,0024	2,85	1056
9	3703	0,0069	0,00060	0,2	3507	0,0023	2,85	1065
10	3744	0,0069	0,00060	0,2	3527	0,0023	2,85	1075
11	3785	0,0069	0,00060	0,2	3546	0,0023	2,85	1084
12	3825	0,0069	0,00060	0,2	3565	0,0023	2,85	1094

Source: Data Processed (2024)

Table 3 above, shows that there is an increase in ordering demand (q) in each period. The resulting possible shortage (α) value is between 0,0023-0,0025, so the closest standard average deviation (Z_α) value is 2,85. The values of ordinal f (Z_α) and partial expectation ψ (Z_α) are also constant at 0,0069 and 0,00060, respectively. This also affects the constant shortage (N) value, which is 0.2. However, the reorder point value always increases in each period.

The following are the results of ordering policy calculations (q) using the Vendor Managed Inventory concept with a probabilistic distributor inventory control model for the West Java region in the period March 2024 - February 2025:

Table 4. Calculation Results of Distributor Ordering Policies for the West Java Region

Period	Indicator							
	D	f (Z_α)	ψ (Z_α)	N	q	α	Z_α	r
1	3090	0,0079	0,00080	0,2	3155	0,0029	2,80	930
2	3133	0,0079	0,00080	0,2	3177	0,0029	2,80	940
3	3176	0,0079	0,00080	0,2	3199	0,0029	2,80	950
4	3219	0,0079	0,00080	0,2	3221	0,0029	2,80	960
5	3262	0,0079	0,00080	0,2	3242	0,0028	2,80	970
6	3305	0,0079	0,00080	0,2	3263	0,0028	2,80	980
7	3348	0,0079	0,00080	0,2	3285	0,0028	2,80	990
8	3390	0,0079	0,00080	0,2	3305	0,0028	2,80	1000
9	3433	0,0079	0,00080	0,2	3326	0,0027	2,80	1010
10	3476	0,0079	0,00080	0,2	3347	0,0027	2,80	1020
11	3519	0,0079	0,00080	0,2	3367	0,0027	2,80	1030
12	3562	0,0079	0,00080	0,2	3388	0,0027	2,80	1040

Source: Data Processed (2024)

Table 4 above, shows that there is an increase in ordering demand (q) in each period. The resulting possible shortage (α) value is between 0,0027-0,0029, so the closest standard average deviation (Z_α) value is 2,80. The values of ordinal f (Z_α) and partial expectation ψ (Z_α) are also constant at 0,0079 and 0,00080, respectively. This also affects the constant shortage (N) value, which is 0,2. However, the reorder point value always increases in each period.

The following are the results of ordering policy calculations (q) using the Vendor Managed Inventory concept with a probabilistic distributor inventory control model for the Sulawesi region in the period March 2024 - February 2025:

Table 5. Calculation Results of Distributor Ordering Policies for the Sulawesi Region

Period	Indicator							
	D	**f (Z_α)**	**ψ (Z_α)**	**N**	**q**	**α**	**Z_α**	**r**
1	6055	0,0059	0,00050	0,5	6123	0,0020	2,90	2111
2	6193	0,0059	0,00050	0,5	6192	0,0020	2,90	2143
3	6331	0,0059	0,00050	0,5	6261	0,0020	2,90	2175
4	6470	0,0059	0,00050	0,5	6329	0,0019	2,90	2207
5	6608	0,0059	0,00050	0,5	6396	0,0019	2,90	2240
6	6746	0,0059	0,00050	0,5	6463	0,0019	2,90	2272
7	6884	0,0059	0,00050	0,5	6529	0,0019	2,90	2304
8	7022	0,0059	0,00050	0,5	6594	0,0019	2,90	2336
9	7161	0,0051	0,00045	0,4	6604	0,0018	2,95	2381
10	7299	0,0051	0,00045	0,4	6668	0,0018	2,95	2413
11	7437	0,0051	0,00045	0,4	6731	0,0018	2,95	2445
12	7575	0,0051	0,00045	0,4	6793	0,0018	2,95	2477

Source: Data Processed (2024)

Table 5 above, shows that there is an increase in order demand (q) in each period with a constant possible shortage (α) value in periods 1-3 and decreasing in periods 4 and 9. So, the standard average deviation (Z_α) value can adjust the α value, initially 2,90 to 2,95 in period 9. The values of ordinal f (Z_α) and partial expectation ψ (Z_α) decreased. Thus, the shortage value (N) also reduced from period 9, initially 0,5 to 0,4. However, the reorder point value always increases in each period.

The following are the results of ordering policy calculations (q) using the Vendor Managed Inventory concept with a probabilistic distributor inventory control model for the Sumatra region in the period March 2024 - February 2025:

Table 6. Calculation Results of Distributor Ordering Policies for the Sumatra Region

Period	Indicator							
	D	**f (Z_α)**	**ψ (Z_α)**	**N**	**q**	**α**	**Z_α**	**r**
1	7137	0,0059	0,00050	0,7	7250	0,0019	2,90	2651
2	7333	0,0051	0,00045	0,6	7295	0,0018	2,95	2714
3	7528	0,0051	0,00045	0,6	7391	0,0018	2,95	2759
4	7723	0,0051	0,00045	0,6	7486	0,0018	2,95	2805
5	7918	0,0051	0,00045	0,6	7580	0,0018	2,95	2850
6	8114	0,0051	0,00045	0,6	7673	0,0017	2,95	2896
7	8309	0,0051	0,00045	0,6	7765	0,0017	2,95	2942
8	8504	0,0051	0,00045	0,6	7855	0,0017	2,95	2987
9	8700	0,0051	0,00045	0,6	7945	0,0017	2,95	3033
10	8895	0,0051	0,00045	0,6	8034	0,0017	2,95	3078
11	9090	0,0051	0,00045	0,6	8122	0,0017	2,95	3124
12	9285	0,0051	0,00045	0,6	8208	0,0016	2,95	3169

Source: Data Processed (2024)

Table 6 above, shows an increase in order demand (q) in each period, with the value of possible shortage (α) tending to be stable but decreasing in periods 2, 6, and 12. So the standard average deviation (Z_α) alue can adjust the value of α initially 2,90 becomes 2,95 in period 2, the value Zα = 2,90 has a minimum α of 0,0019. The ordinal f (Z_α) and partial expectation ψ (Z_α) decrease. Thus, the shortage value (N) decreased from period 2, initially 0,7 to 0,6. However, the reorder point value always increases in each period.

The following are the results of ordering policy calculations (q) using the Vendor Managed Inventory concept with a probabilistic distributor inventory control model for the Kalimantan region in the period March 2024 - February 2025:

Table 7. Calculation Results of Distributor Ordering Policies for the Kalimantan Region

Period	Indicator							
	D	f (Z_α)	ψ (Z_α)	N	q	α	Z_α	r
1	5959	0,0059	0,00050	0,5	6252	0,0020	2,90	2009
2	6070	0,0059	0,00050	0,5	6310	0,0020	2,90	2035
3	6184	0,0059	0,00050	0,5	6369	0,0020	2,90	2062
4	6300	0,0059	0,00050	0,5	6429	0,0020	2,90	2089
5	6418	0,0059	0,00050	0,5	6489	0,0019	2,90	2116
6	6538	0,0059	0,00050	0,5	6549	0,0019	2,90	2114
7	6660	0,0059	0,00050	0,5	6610	0,0019	2,90	2173
8	6785	0,0059	0,00050	0,5	6672	0,0019	2,90	2202
9	6912	0,0059	0,00050	0,5	6734	0,0019	2,90	2232
10	7041	0,0051	0,00045	0,4	6742	0,0018	2,95	2272
11	7173	0,0051	0,00045	0,4	6805	0,0018	2,95	2303
12	7307	0,0051	0,00045	0,4	6868	0,0018	2,95	2334

Source: Data Processed (2024)

Table 7 above, shows an increase in order demand (q) in each period, with the value of possible shortage (α) tending to be stable but decreasing in periods 5 and 10. So the value of the standard average deviation (Z_α) can adjust the value of α which was initially 2,90 becomes 2,95 in period 10; the value Zα = 2,90 has a minimum α of 0,0019. The ordinal f (Z_α) and partial expectation ψ (Z_α) decrease. Thus, the shortage value (N) decreased from period 10, initially 0,5 to 0,4. However, the reorder point value always increases in each period.

The following are the results of ordering policy calculations (q) using the Vendor Managed Inventory concept with a probabilistic distributor inventory control model for the NTB region in the period March 2024 - February 2025:

Table 8. Calculation Results of Distributor Ordering Policies for the NTB Region

Period	Indicator							
	D	f (Z_α)	ψ (Z_α)	N	q	α	Z_α	r
1	5987	0,0059	0,00050	0,6	6327	0,0020	2,90	2219
2	6149	0,0059	0,00050	0,6	6412	0,0020	2,90	2256
3	6312	0,0059	0,00050	0,6	6496	0,0020	2,90	2294
4	6475	0,0059	0,00050	0,6	6579	0,0019	2,90	2332
5	6638	0,0059	0,00050	0,6	6662	0,0019	2,90	2370
6	6800	0,0059	0,00050	0,6	6742	0,0019	2,90	2408
7	6963	0,0059	0,00050	0,6	6823	0,0019	2,90	2446
8	7126	0,0051	0,00045	0,5	6848	0,0018	2,95	2499
9	7288	0,0051	0,00045	0,5	6925	0,0018	2,95	2536
10	7451	0,0051	0,00045	0,5	7003	0,0018	2,95	2574
11	7614	0,0051	0,00045	0,5	7079	0,0018	2,95	2612
12	7777	0,0051	0,00045	0,5	7154	0,0018	2,95	2650

Source: Data Processed (2024)

Table 8 above, shows an increase in order demand (q) in each period, with the value of possible shortage (α) tending to be stable but decreasing in periods 4 and 8. So the standard average deviation (Z_α) value can adjust the value of α which was initially 2,90 becomes 2,95 in period 8; the value Zα = 2,90 has a minimum α of 0,0019. The ordinal f (Z_α) and partial expectation ψ (Z_α) decrease. Thus, the shortage value (N) decreased from period 8, initially 0,6 to 0,5. However, the reorder point value always increases in each period.

The following are the results of ordering policy calculations (q) using the Vendor Managed Inventory concept with a probabilistic distributor inventory control model for the Bangka Belitung region in the period March 2024 - February 2025:

Table 9. Calculation Results of Distributor Ordering Policies for the Bangka Belitung Region

Period	Indicator							
	D	f (Z_α)	ψ (Z_α)	N	q	α	Z_α	r
1	5178	0,0069	0,0006	0,6	5609	0,0023	2,85	1883
2	5315	0,0069	0,0006	0,6	5682	0,0022	2,85	1915
3	5452	0,0069	0,0006	0,6	5755	0,0022	2,85	1947
4	5589	0,0069	0,0006	0,6	5827	0,0022	2,85	1979
5	5726	0,0069	0,0006	0,6	5898	0,0022	2,85	2011
6	5863	0,0059	0,0005	0,5	5921	0,0021	2,90	2055
7	6000	0,0059	0,0005	0,5	5990	0,0021	2,90	2087
8	6136	0,0059	0,0005	0,5	6057	0,0021	2,90	2118
9	6271	0,0059	0,0005	0,5	6124	0,0021	2,90	2150
10	6406	0,0059	0,0005	0,5	6189	0,0021	2,90	2181
11	6539	0,0059	0,0005	0,5	6253	0,0020	2,90	2212
12	6671	0,0059	0,0005	0,5	6316	0,0020	2,90	2243

Source: Data Processed (2024)

Table 9 above, shows an increase in order demand (q) in each period, with the value of possible shortage (α) tending to be stable but decreasing in periods 2,6 and 11. So the standard average deviation (Z_α) value can adjust the initial α value to 2,85 becomes 2,90 in period 6, the value Zα = 2.90 has a minimum α of 0,0019. The ordinal f (Z_α) and partial expectation ψ (Z_α) decrease. Thus, the shortage value (N) decreased from period 6, initially 0,6 to 0,5. However, the reorder point value always increases in each period.

Comparison of Bullwhip Effect Values (After and Before Using the Proposed VMI Concept)

The following are the comparison results obtained after and before using the proposed VMI method:

Table 10. Bullwhip effect value 2

Supply Chain Levels	Bullwhip Effect 1	Bullwhip Effect 2	Up or Down
Vendor (XYZ Company)	1,3112	0,3738	-71%
East Java Regional Distributor	1,1900	0,3502	-71%
Central Java Regional Distributor	1,2150	0,5000	-59%
West Java Regional Distributor	1,1525	0,5000	-57%
Sulawesi Regional Distributor	1,3970	0,4569	-67%
Sumatra Regional Distributor	1,3028	0,4889	-62%
Kalimantan Regional Distributor	1,1469	0,4600	-60%
NTB Regional Distributor	1,1679	0,4612	-61%
Bangka Belitung Regional Distributor	1,2306	0,4594	-63%

Source: Data Processed (2024)

The vendor (XYZ Company) produces a demand coefficient value of 0,2056 and a sales coefficient of 0,1568, where the demand coefficient value is greater than the sales coefficient, so the first bullwhip effect value produced is 1,3112. The demand coefficient value for distributors in the East Java region is 0,2161, Central Java is 0,1842, West Java is 0,1504, Sulawesi is 0,2150, Sumatra is 0,2835, Kalimantan is 0,2733, NTB is 0,3116, and Bangka Belitung at 0,2850. Meanwhile, the sales coefficient value for distributors in the East Java region is 0,1816, Central Java is 0,1516, West Java is 0,1305, Sulawesi is 0,1539, Sumatra is 0,2176, Kalimantan is 0,2383, NTB is 0,2668, and Bangka Belitung at 0,2316. The results of the calculation of the first bullwhip effect value state that the demand coefficient value is greater than the sales coefficient, resulting in a bullwhip effect value that exceeds the specified parameter value. Next, the Vendor Managed Inventory (VMI) concept was implemented probabilistically. The vendor (XYZ Company) So that the second bullwhip effect value does not exceed the parameter value, likewise with the results of the demand

and sales coefficient values for the eight distributors. The demand coefficient value was found to be smaller than the sales coefficient. So, the bullwhip effect value at XYZ Company and each distributor, such as distributors in East Java, Central Java, West Java, Sulawesi, Sumatra, Kalimantan, NTB and Bangka Belitung regions, can reduce during the period March 2024 – February 2025 respectively by 71%, 71%, 59%, 57%, 67%, 62%, 60%, 61%, and 63%.

The vendor-managed inventory (VMI) concept is where the vendor is responsible for managing inventory across several distributors so that demand variability can be minimized. This will have a positive impact because companies can easily integrate production planning to send to several distributors with demand estimates close to the actual value or according to reality.

Applying the Vendor Managed Inventory (VMI) concept probabilistically will make it easy for companies to determine the planned production quantity, which will later be sent to distributors, using the optimal order quantity determined in each period by the vendor. Next, product inventory control is determined starting from the reorder point, safety stock, and maximum stock. By controlling this inventory, companies can avoid out-of-stock events.

4. CONCLUSION

The results of this research produce the optimal number of orders at each level of the supply chain at XYZ Company will reduce the bullwhip effect by implementing the Vendor Managed Inventory concept. In actual conditions (before applying the VMI concept), the value of the bullwhip effect is at XYZ Company is 1,3112. This value exceeds the specified parameters by 1,0480, which is influenced by the calculation results for the length of the lead time and the observed period. After using the proposed method (VMI), the bullwhip effect value was reduced to 0.3738. The bullwhip effect value in actual conditions at eight distribution XYZ Company, such as distributor of East Java, Central Java, West Java, Sulawesi, Sumatra, Kalimantan, NTB, and Bangka Belitung, respectively amounting to 1,1900, 1,2150, 1,1525, 1,3970, 1,3028, 1,1469, 1,1679, and 1,2306. However, after using the Vendor Managed Inventory method, the bullwhip effect value can be reduced to 0,3502, 0,5000, 0,5000, 0,4569, 0,4889, 0,4600, 0,4612, and 0,4594. After successfully decreasing the bullwhip effect, optimal inventory control calculations are carried out at each level of the supply chain. This is expected to improve supply chain efficiency by better indicating the reduction in the value of the bullwhip effect. The limitation of the research is that it only tests the bullwhip effect on distributors and calculates the optimal inventory size at each level of the supply chain without considering the enormous inventory costs. Further research can be carried out by considering inventory costs in reducing the bullwhip effect. The bullwhip effect can cause high inventory costs due to more significant fluctuations in demand from downstream to upstream.

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