EPI International Journal of Engineering
Volume 8, Number 1, February 2025, pp. 45-49
DOI: 10.25042/epi-ije.022025.06

pISSN 2615-5109
eISSN 2621-0541

Inventory Model Simulation to Reduce Bullwhip

Mujaddid[a,*], Sapta Asmal[b], Saiful Mangngenre[c]

[a]Department of Industrial Engineering, Faculty of Engineering, Hasanuddin University. Email: adit.mullen@gmail.com
[b]Department of Industrial Engineering, Faculty of Engineering, Hasanuddin University. Email: saptaasmal@unhas.ac.id
[c]Department of Industrial Engineering, Faculty of Engineering, Hasanuddin University. Email: saiful.ti@unhas.ac.id

Abstract

One of the issues that frequently arise in the supply chain is the bullwhip effect. The bullwhip effect is simply the presence of a distant intersection of supply and demand. To address this issue, inventory management must be implemented in order to provide products or services at the appropriate time and location. The goal of this study is to reduce the occurrence of the bullwhip effect, increase service level, and consider total cost and profit. The method used is the RQ policy. RQ policy is a fixed replenishment point inventory policy / fixed replenishment quantity policy referred to as an RQ policy. When the inventory level drops below the fixed replenishment point (R), the product's fixed replenishment quantity (Q) is ordered, which is simulated in anylogistix software to determine the optimal inventory policy and design. The optimal simulation results are R:15,000 and Q: 30,000 with an inventory capacity of 30,000, a bullwhip effect value of 1.62 to 1, indicating no bullwhip effect, and a service level of 0.90 to 1, indicating that all orders can be fulfilled. with the right timing and profits ranging from Rp. 74.400.000 to Rp. 101,450,000.

Keywords: Bullwhip effect; inventory; service level; model simulation; supply chain management

1. Introduction

Inventory control policies have been identified as a factor contributing to the bullwhip effect and inventory insecurity [1]. The bullwhip effect occurs when the variation in demand for suppliers is greater than the variation in sales. P&G was the first to coin the phrase "bullwhip effect" about the demand for baby diapers [2], which results in excess or shortage of stock, loss of income, lower levels of customer satisfaction, ineffective delivery, and production scheduling errors [3], [4]. Several factors that can cause the bullwhip effect include demand force updates, order batching, price fluctuations, and rotation and shortage gaming [5], while solutions to reduce the impact of the bullwhip effect include reducing uncertainty, reducing variability, reducing lead time, and working strategically [6]. The bullwhip effect is calculated using the variance of incoming goods and incoming demand, as shown in the following equation [7]:

$$BWE = \frac{\sigma_{out}^2/\mu_{out}}{\sigma_{in}^2/\mu_{in}} \tag{1}$$

where,
BWE : bullwhip effect
σ^2 : variance in demand
μ : Average value
in : inbound orders,
out : outbound orders

By implementing an optimal inventory control policy, the bullwhip effect phenomenon can be avoided [1], [8]. Inventory is a warehouse item such as finished goods or semi-finished goods that are ready for sale or the production process [7]. Inventory management issues will arise if the quantity and time of ordering are incorrectly determined. The consequence of an error in inventory management, namely, the full storage capacity, results in excessive costs and the occurrence of lost sales. In general, inventory performance is measured by service level, which is to improve service and customer demand or to provide satisfaction to incoming customers. Costs will have an impact on inventory management accuracy. Some inventory management decisions include what items will be stored, where the storage will take place, how much quantity of goods should be stored when an item should be ordered, and what size order should be placed [9].

Controlling inventory and running simulations for comparison and evaluation of inventory control in research related to the bullwhip effect. The study's findings point to optimization in terms of the bullwhip effect, total cost, inventory performance [1], [8], [10], and average service level. As a result, the purpose of this study is to provide insight into solving the bullwhip effect phenomenon using the RQ Policy inventory policy approach available on anylogistix software and building three scenarios to determine the optimal policy for coca id.

*Corresponding author. Tel.: +62-853-9526-6606
Jalan Poros Malino km. 6, Bontomarannu
Gowa, Indonesia

AnyLogistix is a software that combines analytical and dynamic modeling to allow for in-depth analysis and evaluation of supply chain efficiency while taking opportunity into account. AnyLogistix allows you to visually model the logistics process while observing the dynamically analyzed system [11].

2. Research Method

The stages in the research are described as follows:

2.1. Data collections

Product data, demand data, incoming goods data, incoming demand data, warehouse capacity, lead time, and total costs incurred in coca id SMEs engaged in cup screen printing are the data used to solve the bullwhip effect problem with inventory management. Supporting data includes general MSME data and supply chain flow.

Table 1. Data on buying and selling prices of products

Products	Unit	Buying Prices (Rp)	Selling Prices (Rp)
Cup Screen Printing	Pcs	400	800

Table 2. Demand data and supply in 2021

Months	Supply	Demand
January	40.000	46.000
February	41.000	45.000
March	42.000	42.000
April	40.000	43.000
May	38.000	48.000
June	42.000	46.000
July	40.000	42.000
August	40.000	44.000
September	41.000	47.000
October	42.000	46.000
November	40.000	48.000
December	40.000	43.000

Table 3. Average cup demand in 2021

Consumer	Units	Time	Average Demand
Ruma.id	Pcs	Month	2.000
Kopita	Pcs	Month	1.000
Digit Coffe	Pcs	Month	4.000
Kopi Teori	Pcs	Month	5.000
Sekala Cafe	Pcs	Month	2.000
At 10 coffee	Pcs	Month	1.000
Adapada	Pcs	Month	2.000
Evlogi	Pcs	Month	2.000
Goffe	Pcs	Month	1.000
Biltea	Pcs	Month	5.000
Kedai Kopi Oma	Pcs	Month	1.000
Kaganga	Pcs	Month	1.000
Tastea	Pcs	Month	9.000
Delicate	Pcs	Month	3.000
45 Coffe	Pcs	Month	1.000
148 Coffe	Pcs	Month	2.000
Exposed	Pcs	Month	3.000

Table 4. Coca Id inventory

Initial Stocks	Capacity
20.000	20.000

Table 5. Total Cost on coca id

Type	Time	Cost (Rp)
Electricity	Months	Rp 350.000
Water	Months	Rp 150.000
Employee	Months	Rp 7.500.000
Place	Months	Rp 2.000.000
Machine	Months	Rp. 500.000

Figure 1. Coca id supply chain flow

Table 6. Delivery flow and lead time

From	Destination	Lead Time
Supplier Surabaya	Workshop Makassar	7 days
Workshop Coca id Makassar	All Customer	1 day

2.2. Data processing

In existing conditions, data processing is done manually, and proposals or problem solving is done with anylogistix simulation software and optimization tools.

Three scenarios are created in the anylogistix simulation and optimization tools software for data processing to determine the value of the bullwhip effect, total cost, and profit as a proposal for optimal improvements for coca id.

3. Results and Discussion

3.1. Determine of existing condition

The following are the results of the bullwhip effect calculation based on the data in Table 2 and Eq. (1):

Calculation of the average supply cups:

$$\mu = \frac{X_1 + X_2 + X_n}{n}$$

$$\mu_{in} = \frac{486.000}{12}$$

$$\mu_{in} = 40.500$$

Calculation of the average demand cups:

$$= \frac{X_1 + X_2 + X_n}{n}$$

$$\mu_{out} = \frac{540.000}{12}$$

$$\mu_{out} = 45.000$$

Calculation of variance of supply cups:

$$\sigma^2 = \sqrt{\frac{\sum(X_i - \mu)^2}{n}}$$

$$\sigma_{in}^2 = \sqrt{\frac{\begin{matrix}(40.000-40.500)^2+(41.000-40.500)^2+\\(42.000-40.500)^2+(40.000-40.500)^2+\\(38.000-40.500)^2+(42.000-40.500)^2+\\(40.000-40.500)^2+(40.000-40.500)^2+\\(41.000-40.500)^2+(42.000-40.500)^2+\\(40.000-40.500)^2+(40.000-40.500)^2\end{matrix}}{12}}$$

$$\sigma_{in}^2 = \sqrt{\frac{\begin{matrix}250.000+250.000+2.250.000+\\250.000+6.250.000+2.250.000+\\250.000+250.000+250.000+\\2.250.000+250.000+250.000\end{matrix}}{12}}$$

$$\sigma_{in}^2 = \sqrt{\frac{15.000.000}{12}}$$

$$\sigma_{in}^2 = \sqrt{1.250.000}$$

$$\sigma_{in}^2 = 1.118$$

Calculation of variance on demnand cups:

$$\sigma^2 = \sqrt{\frac{\sum(X_i-\mu)^2}{n}}$$

$$\sigma_{out}^2 = \sqrt{\frac{\begin{matrix}(46.000-45.000)^2+(45.000-45.000)^2+\\(42.000-45.000)^2+(43.000-45.000)^2+\\(48.000-45.000)^2+(46.000-45.000)^2+\\(42.000-45.000)^2+(44.000-45.000)^2+\\(47.000-45.000)^2+(46.000-45.000)^2+\\(48.000-45.000)^2+(43.000-45.000)^2\end{matrix}}{12}}$$

$$\sigma_{out}^2 = \sqrt{\frac{\begin{matrix}1.000.000+0+9.000.000+\\4.000.000+9.000.000+1.000.000+\\9.000.000+1.000.000+4.000.000+\\1.000.000+9.000.000+4.000.000\end{matrix}}{12}}$$

$$\sigma_{out}^2 = \sqrt{\frac{52.000.000}{12}}$$

$$\sigma_{out}^2 = \sqrt{4.333.333,33}$$

$$\sigma_{out}^2 = 2.081$$

The calculation of the bullwhip effect on the existing conditions in 2021 is:

$$BWE: \frac{\sigma 2_{Out/}\mu_{Out}}{\sigma 2_{In}/\mu_{In}}$$

$$\mu_{in} = 40.500$$

$$\mu_{out} = 45.000$$

$$\sigma_{out}^2 = 2.081$$

$$\sigma_{in}^2 = 1.118$$

$$BWE = \frac{2.081./45.000}{1.118/40.500}$$

$$BWE = \frac{0,05}{0,03} = 1,67$$

In the current situation, the bullwhip effect is 1.67, indicating that there is an intersection between supply and demand for 1 year.

3.2. Calculation of the service level of the existing condition

The equation used in anylogistix simulation software to get the service level value is:

$$Service\ Level = \frac{P1}{P2}$$

where,
P1: *Products in the successful orders*
P2: *Sum of all orders placed for facility*

$$Service\ Level = \frac{486.000}{540.000}$$

$$Service\ Level = 0,9$$

In the current state, the service level value is 0.9, indicating that there are incoming requests that cannot be fulfilled or that only 90% of requests can be fulfilled for one year.

3.3. Calculation of total cost in an existing condition

Using the data in Tables 1, 2, and 5 and the following equation, calculate the total cost:

Total Cost: Inventory Spend + Other Cost

where,
Inventory Spend : Buying Price x Total of supply cup
Other Cost : Facility Cost x Time

Calculation of inventory spend:

Inventory spend: 400 x 486.000
Inventory spend: Rp. 194.400.000

Calculation of other costs:

Other costs: 10.000.000 x 12
Other costs: Rp. 120.000.000

Calculation of *Total cost* on:

*Total Cost:*194.400.000 + 120.000.000
Total cost: Rp. 314.400.000

The total cost for a year in the current condition is Rp.314.400.000.

3.4. Calculation of the profit condition existing

The RQ Policy method was used to simulate three different inventory scenarios with capacities of 20,000, 25,000, and 30,000. A fixed replenishment point inventory policy / fixed replenishment quantity policy is referred to as an RQ policy. When the inventory level drops below the fixed replenishment point (R), the product's fixed replenishment quantity (Q) is ordered. The results of the inventory scenario simulation using anylogistix software are shown below:

Table 1. Scenario 1 of inventori 20.000 and Q: 20.000

R Value	Bullwhip Effect	Servic Level	Revenue	Total Cost	Profit
r: 3,000	0,35	0,62	Rp269.600.000	Rp254.950.000	Rp14.650.000
r: 4,000	0,71	0,76	Rp331.200.000	Rp290.550.000	Rp40.650.000
r: 5,000	0,71	0,76	Rp331.200.000	Rp290.550.000	Rp40.650.000
r: 6,000	0,71	0,76	Rp331.200.000	Rp290.550.000	Rp40.650.000
r: 7,000	0,71	0,76	Rp331.200.000	Rp290.550.000	Rp40.650.000
r: 8,000	1,05	0,79	Rp345.600.000	Rp292.550.000	Rp53.050.000
r: 9,000	0,35	0,79	Rp344.000.000	Rp292.950.000	Rp51.050.000
r: 10,000	0,50	0,83	Rp363.200.000	Rp303.350.000	Rp59.850.000
r: 11,000	1,27	0,85	Rp369.600.000	Rp305.350.000	Rp64.250.000
r: 12,000	1,11	0,81	Rp353.600.000	Rp299.350.000	Rp54.250.000
r: 13,000	1,11	0,81	Rp353.600.000	Rp296.950.000	Rp56.650.000
r: 14,000	0,53	0,81	Rp353.600.000	Rp299.350.000	Rp54.250.000
r: 15,000	0,83	0,81	Rp353.600.000	Rp297.750.000	Rp55.850.000

According to the simulation results table above, the bullwhip effect value does not reach 1, indicating that there is still a crossroads between incoming goods and incoming requests, as well as the service level, which does not reach 1, indicating that they have not been able to fulfill all incoming requests.

Table 2. Scenario 2 inventori 25.000 and Q: 25.000

R Value	Bullwhip Effect	Service Level	Revenue	Total Cost	Profit
r: 3,000	0,39	0,71	Rp308.800.000	Rp280.150.000	Rp28.650.000
r: 4,000	1,68	0,73	Rp316.800.000	Rp276.150.000	Rp40.650.000
r: 5,000	0,94	0,77	Rp334.400.000	Rp285.350.000	Rp49.050.000
r: 6,000	1,18	0,78	Rp340.800.000	Rp288.550.000	Rp52.250.000
r: 7,000	0,31	0,83	Rp363.200.000	Rp306.550.000	Rp56.650.000
r: 8,000	0,73	0,82	Rp356.000.000	Rp296.950.000	Rp59.050.000
r: 9,000	3,36	0,76	Rp330.400.000	Rp286.550.000	Rp43.850.000
r: 10,000	0,98	0,85	Rp372.800.000	Rp304.150.000	Rp68.650.000
r: 11,000	1,20	0,90	Rp393.600.000	Rp315.750.000	Rp77.850.000
r: 12,000	1,00	1,00	Rp436.800.000	Rp337.750.000	Rp99.050.000
r: 13,000	0,41	0,90	Rp392.800.000	Rp315.350.000	Rp77.450.000
r: 14,000	0,94	0,95	Rp412.800.000	Rp328.950.000	Rp83.850.000
r: 15,000	1,02	0,99	Rp432.800.000	Rp336.550.000	Rp96.250.000

According to the simulation results table above, with a value of R:12,000, the bullwhip effect touches number one, indicating that there is no bullwhip effect, and the service level also touches number one, indicating that all incoming orders can be fulfilled 100% of the time. with an Rp.99,050,000 profit and a total cost of Rp.337,750,000.

Table 3. Scenario 3 inventori 30.000 and Q: 30.000

R Value	Bullwhip Effect	Service Level	Revenue	Total Cost	Profit
r: 3,000	1,30	0,81	Rp352.000.000	Rp291.750.000	Rp60.250.000
r: 4,000	2,66	0,72	Rp313.600.000	Rp275.750.000	Rp37.850.000
r: 5,000	2,66	0,72	Rp313.600.000	Rp275.750.000	Rp37.850.000
r: 6,000	1,55	0,77	Rp336.800.000	Rp284.550.000	Rp52.250.000
r: 7,000	0,82	0,84	Rp368.800.000	Rp309.350.000	Rp59.450.000
r: 8,000	1,78	0,81	Rp354.400.000	Rp298.550.000	Rp55.850.000
r: 9,000	0,74	0,96	Rp419.200.000	Rp325.750.000	Rp93.450.000
r: 10,000	0,72	0,94	Rp410.400.000	Rp328.950.000	Rp81.450.000
r: 11,000	0,70	0,94	Rp410.400.000	Rp328.950.000	Rp81.450.000
r: 12,000	0,70	0,94	Rp410.400.000	Rp328.950.000	Rp81.450.000
r: 13,000	0,53	0,83	Rp360.800.000	Rp299.350.000	Rp61.450.000
r: 14,000	1,00	1,00	Rp436.800.000	Rp340.950.000	Rp95.850.000
r: 15,000	1,00	1,00	Rp436.800.000	Rp335.350.000	Rp101.450.000

According to the simulation results table above, with a value of R: 15,000, the bullwhip effect touches number 1, indicating that there is no bullwhip effect, and the service level also touches number 1, indicating that all incoming orders can be fulfilled 100 percent, the profit is Rp. 101,450,000, and the total cost is Rp. 335.350.000.

3.5. Inventory simulation on three different inventory scenarios

Based on the simulation results, it can be seen that the inventory model simulation results are more optimal than the existing methods on Coca id, as evidenced by the bullwhip effect, profit, total cost, and profit. According to the table above, the proposed new inventory policy and design had a positive impact, increasing the value of the bullwhip effect from 1.67 to 1, indicating that there is no bullwhip effect or no intersection between demand and ordering of goods, while the total costs increased. Rp. 314,400,000 to Rp. 335,350,000, while profit increases from Rp. 74,400,000 to Rp. 101,450,000.

4. Conclusion

Based on the simulation results, it can be seen that the inventory model simulation results are more optimal than the existing methods on Coca id, as evidenced by the bullwhip effect, profit, total cost, and profit. According to the table above, the proposed new inventory policy and design had a positive impact, increasing the value of the bullwhip effect from 1.67 to 1, indicating that there is no bullwhip effect or no intersection between demand and ordering of goods, while the total costs increased. Rp. 314,400,000 to Rp. 335,350,000, while profit increases from Rp. 74,400,000 to Rp. 101,450,000.

References

[1] F. Constantino, G. Di Gravio, A. Shaban, and M. Tronci, "SPC-Based Inventory Control Policy to Improve Supply Chain Dynamics," *Int. J. Eng. Technol.*, vol. 6, pp. 418–426, 2014.

[2] A. Tanweer, Y.-Z. Li, G. Duan, and J.-Y. Song, "An Optimization Model for Mitigating Bullwhip-effect in a Two-echelon Supply Chain," in *Procedia - Social and Behavioral Sciences*, B. Mao, Z. Tian, Z. Gao, H. Huang, and X. Feng, Eds., 2014, pp. 289–297. doi: 10.1016/j.sbspro.2014.07.206.

[3] I. Kholidasari, J. R. A. Bidiawati, and M. E. Sari, "The Evaluation of Bullwhip Effect on Distribution System of a Supply Chain using Centralized Demand Information Method," in *IOP Conference Series: Materials Science and Engineering*, Padang: IOP Science, 2018, p. 012051. doi: 10.1088/1757-899X/602/1/012051.

[4] R. B. Handfield and E. L. Nichols, *Supply Chain Redesign: Transforming Supply Chains into Integrated Value Systems*. New Jersey: FT Press, 2022.

[5] H. L. Lee, V. Padmanabhan, and S. Whang, "Information Distortion in a Supply Chain: The Bullwhip Effect," *Manage. Sci.*, vol. 43, no. 4, pp. 546–558, 1997.

[6] D. Simchi-Levi, P. Kaminsky, and E. Simchi-Levi, *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*, 3rd ed. McGraw-Hill/Irwin, 2008.

[7] J. Heizer and B. Render, *Principles of Operations Management: Sustainability and Supply Chain Management*, 9th ed. Pearson, 2014.

[8] F. Constantino, G. Di Gravio, A. Shaban, and M. Tronci, "Exploring the Bullwhip Effect and Inventory Stability in a Seasonal Supply Chain," *Int. J. Eng. Bus. Manag.*, vol. 5, 2013, doi: 10.5772/56833.

[9] I. N. Pujawan and Mahendrawati, *Supply Chain Management*, 3rd ed. Yogyakarta: Penerbit ANDI, 2017.

[10] S. Kianfar, A. Saeidi, N. Nasr, and M. R. A. Jokar, "Measuring the Bullwhip Effect in Order-up-to Policies with Continuous and Periodic Review: A System Dynamics Simulation Approach,"

[11] M. Mratsenkova and K. Vaseliva, "Application of Anylogistix in Transport Chain Management," in *Proceedings of University of Ruse*, 2020, pp. 28–32.