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A Cost-Based Decision Framework for Multi-Item Single-Supplier Inventory Control

Sri Suci Yuniar [a,1], *Hendro* Prassetiyo [a], *Arif* Imran [a] and *Said* Muhammad Baisa [a]

[a] Industrial Engineering Department, Faculty of Industrial Technology, Institut Teknologi Nasional, Bandung 40124, Indonesia

Abstract. Inventory control in manufacturing systems frequently involves managing multiple raw materials from a single supplier. Independent ordering policies in these settings often lead to higher inventory costs. This study presents a cost-based decision framework for determining optimal ordering policies in multi-item, single-supplier inventory systems. The framework integrates the Economic Order Quantity (EOQ) and Economic Order Interval (EOI) models to evaluate both independent and coordinated ordering strategies under deterministic demand conditions. A numerical example, based on a representative consumer goods manufacturing scenario, illustrates the application of the framework. Results demonstrate that coordinated ordering under the EOI policy achieves lower total inventory costs than independent EOQ-based ordering. Sensitivity analysis shows that variations mainly affect the cost-benefit of coordinated ordering through ordering costs and remain relatively stable despite demand fluctuations. This framework provides practical guidance for decision-makers aiming to implement cost-effective inventory ordering policies.

1 Introduction

Effective inventory management is essential for enhancing operational efficiency and cost competitiveness within manufacturing and supply chain systems. In practice, firms frequently manage multiple raw materials sourced from a single supplier, with ordering, holding, and setup costs collectively determining total inventory cost. [1] Although classical inventory models such as the Economic Order Quantity (EOQ) remain widely used as decision-making tools, recent reviews suggest that growing operational complexity necessitates more integrated inventory control approaches instead of treating each item independently.

Research on multi-item, single-supplier inventory systems has advanced considerably since the introduction of coordinated ordering concepts, commonly referred to as the Joint Replenishment Problem (JRP). Foundational studies by Goyal [2] demonstrated that joint ordering of multiple items reduces total system costs compared to separate ordering policies. The theoretical foundation of JRP by analyzing coordinated replenishment policies within a continuous-review framework. Subsequent research has focused on improving solution efficiency and expanding cost structures, including the development of efficient

[1] Corresponding author: suciyuniar@itenas.ac.id

algorithms for generalized JRP [3].More recently, advances in approximation policies and continuous-time models have been proposed to further enhance coordinated replenishment performance [4].

Despite significant theoretical and algorithmic progress, the implementation of coordinated ordering policies in industrial environments remains challenging. In many manufacturing firms, especially those producing consumer goods such as footwear, multiple essential raw materials are often ordered separately, even when sourced from the same supplier. [5]This independent ordering can result in repetitive ordering and transportation costs, increased inventory holding costs when order quantities exceed requirements, and production delays when order quantities are insufficient. [6]Coordination-oriented approaches, such as Vendor-Managed Inventory (VMI), have been proposed to address these challenges [7]. However, these approaches typically require complex information-sharing structures and high levels of coordination, which may limit their practical applicability.

A gap remains between existing theoretical models of multi-item, single-supplier inventory systems and the practical decision-making requirements of manufacturing firms. To address this gap, the present study proposes a decision framework for optimal ordering in multi-item, single-supplier inventory systems. This framework emphasizes coordinated ordering decisions across multiple items with the objective of minimizing total costs, and it focuses on both analytical solutions and decision structures that can be readily implemented in industrial settings.

2 Research Methodology

A quantitative analytical approach is employed to develop a decision-making framework for inventory control in a multi-item, single-supplier system. The production demand pattern of the manufacturing company, used as an illustrative case, is assumed to be deterministic, reflecting stable production requirements.
The inventory planning problem is formulated using the Economic Order Quantity (EOQ) and Economic Order Interval (EOI) mathematical models. These models are integrated into a decision framework to determine the optimal ordering policy. [8]

To ensure consistency with operational conditions and to simplify the analytical process, the following assumptions are adopted:

1. The lead time for each item is assumed to be constant.
2. Inventory shortages are not permitted.
3. Raw materials are assumed to arrive according to the agreed schedule, preventing production disruptions from delivery delays.

The decision-making framework developed in this study provides systematic guidance for establishing raw-material ordering policies in a multi-item, single-supplier inventory system. This framework integrates the Economic Order Quantity (EOQ) and Economic

Order Interval (EOI) models into a structured, practical process for manufacturing management.

The first stage involves identifying the inventory system by determining the number of raw material items, supplier characteristics, and production demand patterns. At this stage, all items are assumed to be sourced from a single supplier, which facilitates the implementation of a coordinated ordering policy. Model parameters, including annual demand, purchase price, ordering cost, holding cost, and lead time for each item, are collected and defined. The second stage establishes the individual ordering policy by applying the Economic Order Quantity (EOQ) model, which calculates the optimal order quantity for each item independently, without coordination among items. These results serve as a benchmark for evaluating the coordinated ordering policy. The third stage develops the coordinated ordering policy using the Economic Order Interval (EOI) model, which determines the optimal common ordering interval to allow multiple items to be ordered simultaneously within a single cycle. [9] The order quantity for each item is then determined based on this optimal interval. The fourth stage evaluates and compares ordering policies by calculating the total inventory costs generated by the EOQ and EOI models.

Total inventory cost comprises ordering, holding, and purchasing costs. The policy that minimises total inventory cost is selected. In the final stage, the optimal ordering policy is implemented, serving as the foundation for raw-material ordering decisions within the organisation. This framework offers both numerical solutions and actionable decision-making guidance, thereby facilitating more efficient management of multi-item inventory systems with a single supplier. [10]

The notation used in this study is defined as follows:

D_i = Demand for item *i* (units/year)
P_i = Unit purchase price of item *i* (IDR/Unit)
I = Holding cost rate (%/year)
h_i = Holding cost of item *i* (IDR/unit/year)
C = Ordering cost per order (IDR/order)
L_i = Lead time of item i
Q_i = Economic order quantity of item *i*
T = Ordering interval (years)
N = Number of items
C_i = Ordering cost for item *i* (IDR/order/item)
C_{gab} = Joint ordering cost
O_c = Total ordering cost (IDR/year)
O_p = Total purchasing cost (IDR/year)
O_h = Total holding cost (IDR/year)
O_T = Total inventory cost (IDR/year)

The Economic Order Quantity (EOQ) model determines the optimal order quantity that minimises total inventory costs by accounting for the inverse relationship between holding and ordering costs. Due to its simplicity and ease of application, EOQ is extensively utilised in inventory control across diverse industrial sectors [11] .

In deterministic inventory systems, the EOQ is the optimal order quantity per replenishment, assuming known, constant demand. [12] In deterministic inventory models, EOQ represents the order quantity that minimizes inventory costs. The EOQ model has been extensively applied and further developed in studies addressing multi-item inventory systems and coordinated ordering policies [2]

Tersine (1994) states that the optimal economic order quantity is determined by minimizing the total inventory cost, which is represented as follows:

$$O_T = O_p + O_c + O_h \tag{1}$$

$$O_T = \sum_{i=1}^{n} D_i P_i + f \sum_{i=1}^{n} D_i C + \frac{1}{2f} \sum_{i=1}^{n} h_i D_i \tag{2}$$

The decision variable in this study is the joint ordering frequency (f*), with the order quantity for each item (Qi) determined by the optimal ordering frequency. To minimize the total inventory cost, the total cost function is differentiated with respect to the decision variable, specifically the ordering frequency. [12]Setting the first derivative to zero yields the optimal ordering frequency as follows :

$$\frac{\partial O_T}{\partial f} = 0, \text{ therefore } f^* = \sqrt{\frac{\sum_{i=1}^{n} h_i D_i}{2C}} \tag{3}$$

The replenishment order quantity for each item is calculated by dividing the annual demand by the optimal ordering frequency:

$$Q_i = \frac{D_i}{f^*} \tag{4}$$

Substituting the value of f* into the cost function yields the minimum total inventory cost as follows:

$$O_T(f^*) = \sum_{i=1}^{n} D_i P_i + 2f^* C + \frac{\sum_{i=1}^{n} Q_i h_i}{2} \tag{5}$$

The ordering interval, denoted as T, is defined as the reciprocal of the optimal ordering frequency

$$T = \frac{1}{f^*} \tag{6}$$

The Economic Order Interval (EOI) model offers an alternative to traditional inventory control by emphasizing the determination of the optimal ordering interval rather than directly calculating the order quantity. In this framework, the primary decision variable is the ordering interval (T∗), and the optimal order quantity is derived based on the chosen interval.

The EOI approach is commonly utilized in multi-item inventory systems, as it facilitates the implementation of coordinated ordering policies that use a unified ordering interval for all items [2]
The optimal ordering interval is determined by differentiating the total cost function with respect to the ordering interval and equating the result to zero. This process yields the optimal ordering interval, as shown below [2] [12]

$$O_T(T) = \sum_{i=1}^{n} D_i P_i + \frac{C}{T} + \frac{1}{2} T \sum_{i=1}^{n} h_i D_i \quad (7)$$

The optimal ordering interval, denoted as T^*, is subsequently utilized to determine the optimal order quantity for each item within each ordering cycle. As a result, the EOI model enables the implementation of a coordinated ordering policy that is uniformly applied to all items in a multi-item, single-supplier inventory system. [12]

$$T^* = \sqrt{\frac{2C}{\sum_{i=1}^{n} h_i D_i}} \quad (8)$$

Therefore, $Q^* = D_i T^*$ (9)

3 Results and Discussion

This section presents the results of applying the proposed decision-making framework through a numerical illustration within a multi-item, single-supplier inventory system. The scenario represents a typical consumer goods manufacturing context, such as the footwear industry, with an average monthly production demand of 5,000 pairs, or 60,000 pairs annually. Several essential raw materials are procured from a single supplier and used simultaneously in the production process.

The numerical illustration demonstrates the application of the decision-making framework, which integrates the Economic Order Quantity (EOQ) and Economic Order Interval (EOI) models, to determine the optimal ordering policy and to compare individual and coordinated ordering strategies. This example does not evaluate the performance of a specific company; rather, it provides a quantitative case to illustrate inventory system behaviour.

The inventory system under analysis consists of three primary raw materials: outsole, insole (uppersole), and webbing tape, all sourced from the same supplier. The analysis uses data on annual demand for each item, ordering costs, holding costs, purchase prices, and lead time, which are consistently applied as input parameters in the inventory policy calculations.

Demand is assumed to be deterministic and stable throughout the planning period. Ordering costs are fixed per order. Holding costs are calculated by applying the annual holding cost rate to each item’s purchase price. Lead time is constant and identical for all items, which supports the implementation of a coordinated ordering policy. The details of the data used are presented as follows.

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1. Ordering Cost Data
   Ordering cost represents the cost incurred each time the company places an order for raw materials with the supplier. The ordering cost consists of a transportation cost of IDR 700,000 per order and administrative costs, including document submission, invoice printing, and other related administrative activities, amounting to IDR 10,000 per order.
   Therefore, the total ordering cost used in the inventory model calculations is IDR 710,000 per order.
2. Raw Material Lead Time
   Lead time is defined as the time required from the placement of a raw material order until the materials are received by the company. Based on the available data, the lead time for all raw material items is assumed to be identical and constant, equal to 7 days or approximately 0.25 months. This assumption supports the implementation of a coordinated ordering policy in the multi-item, single-supplier inventory system.
3. Raw Material Prices and Holding Costs
4. Holding costs are determined based on the annual holding cost rate, which is calculated as a percentage of the annual interest rate multiplied by the purchase price of each raw material. The data on raw material prices and holding costs per item used in this study are presented in Table 1.

Table 1. Raw Material Prices and Holding Costs

No.	Item	Unit Purchase Price (IDR)	Holding Cost (IDR/unit/year)
1	Uppersole (Sheet)	500,000	21,250
2	Outsole (Pair)	20,000	850
3	Webbing Tape (Roll)	600,000	25,500

The initial step involves determining the optimal ordering frequency (f^*) and the optimal order quantity (Q^*) by applying the Economic Order Quantity (EOQ) model.

$$f^* = \sqrt{\frac{(21.250 \times 2909) + (850 \times 58105) + (25.500 x 295)}{2 \times 710.000}}$$

$= 9{,}14 = 10$ orders/year

The second step involves determining the optimal order quantity per order (Q∗). Table 2 presents the optimal order quantity for each raw material item per order.

Table 2. Results of $Q*$ Calculation Using the EOQ Model

No.	Item	Q^* (Unit/Orders)
1	Uppersole (Sheet)	500,000
2	Outsole (Pair)	20,000
3	Webbing Tape (Roll)	600,000

The subsequent step involves determining the optimal ordering interval (T^*) and the corresponding optimal order quantity per order (Q^*).

1) Calculation of the Optimal Ordering Interval T^*

$$T^* = \sqrt{\frac{2\times710.000}{(21.250\times2909)+(850\times58105)+(25.500x295)}}$$

$= 0,109$ year

2) Calculation of the Optimal Order Quantity per Order (Q^*)

Table 4 presents the optimal order quantity for each raw material item per order, as determined by the EOI model.

Table 2. Results of Q^* Calculation Using the EOQ Model

No.	Item	Q^* (Unit/Orders)
1	Uppersole (Sheet)	319
2	Outsole (Pair)	6355
3	Webbing Tape (Roll)	33

By using Equation (5), the total inventory cost (Q^*) is calculated as follows.

$$O_T(f^*) = (2909\times500.000) + (850\times20.000) + (25.500x600.000) + 10\times710.000 + \frac{(291\times21.250)+5811\times850+30\times25.500)}{2}$$

$= \text{Rp. } 2.870.544.050/\text{year}$

By using Equation (7), the total inventory cost (O_T) is calculated as follows.

$$O_T(T) = (2909\times500.000) + (850\times20.000) + (25.500x600.000) + \frac{710.000}{0,109} + (\frac{(319\times21.250)+6355\times850+33\times25.500)}{2}$$

$= \text{Rp. } 2.806.624.761/\text{year}$

Based on the collected data, the company places orders once every two months. The order quantities of each item and the corresponding ordering frequency under the current inventory policy are presented in Table 3.

Table 3. Ordered Quantities and Ordering Frequency under the Current Inventory Policy

No.	Item	Q^* (Unit/Orders)
1	Uppersole (Sheet)	830
2	Outsole (Pair)	16500
3	Webbing Tape (Roll)	90

The theoretical total cost of the inventory system currently used by the company is as follows.

$$O_T = O_p + O_c + O_h \qquad (10)$$

$$O_T = \sum D_i \times P_i + f^* \times C + \sum Q_i \times h_i \quad (11)$$

O_T = Rp. 2.793.600.000 + Rp. 4.970.000 + Rp. 27.157.500
= Rp. 2.832.527.500

Sensitivity Analysis

Sensitivity analysis evaluates how variations in key parameters affect the optimal ordering policy and total inventory cost. The parameters examined are ordering cost (C), holding cost (h), and annual demand (D). Each parameter is adjusted by ±10%, ±20%, and ±30% from its baseline value, with all other parameters held constant.

aThe baseline total inventory cost used as a reference is as follows:

1. EOQ : Rp 2.870.544.050 per year
2. EOI : Rp 2.806.624.761 per year

1) Sensitivity to Ordering Cost (C)

In both the EOQ and EOI models, ordering cost is directly proportional to ordering frequency. The coordinated ordering policy (EOI) demonstrates greater sensitivity to changes in ordering cost, as this component is critical for achieving cost savings through coordination. The calculation results are presented in Table 4.

Table 4. Sensitivity Analysis of Ordering Cost

Change in C	EOQ (Rp/Year)	EOI (Rp/Year)	EOQ–EOI Difference
−30%	2.658.000.000	2.605.000.000	53.000.000
−20%	2.730.000.000	2.680.000.000	50.000.000
−10%	2.800.000.000	2.740.000.000	60.000.000
Baseline	2.870.544.050	2.806.624.761	63.919.289
+10%	2.940.000.000	2.880.000.000	60.000.000
+20%	3.010.000.000	2.950.000.000	60.000.000
+30%	3.080.000.000	3.020.000.000	60.000.000

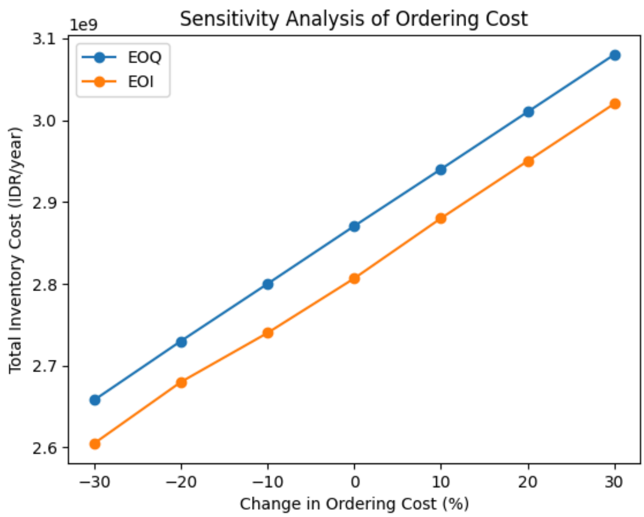

Fig. 1. Sensitivity Analysis of Ordering Cost

As shown by the calculations and in Fig 1, higher ordering costs increase the cost advantage of the EOI policy over the EOQ policy. Coordinated ordering reduces order frequency and lessens the impact of higher ordering costs.

2) Sensitivity to Holding Cost (C)

A coordinated ordering policy generally leads to higher average inventory levels compared to individual ordering. Consequently, variations in holding costs can substantially influence the cost advantage of the EOI policy. The calculation results are presented in Table 5.

Table 5. Sensitivity Analysis of Holding Cost

Change in C	EOQ (Rp/Year)	EOI (Rp/Year)	EOQ–EOI Difference
–30%	2.780.000.000	2.730.000.000	50.000.000
–20%	2.810.000.000	2.760.000.000	50.000.000
–10%	2.840.000.000	2.790.000.000	50.000.000
Baseline	2.870.544.050	2.806.624.761	63.919.289
+10%	2.900.000.000	2.850.000.000	50.000.000
+20%	2.930.000.000	2.890.000.000	40.000.000
+30%	2.960.000.000	2.940.000.000	20.000.000

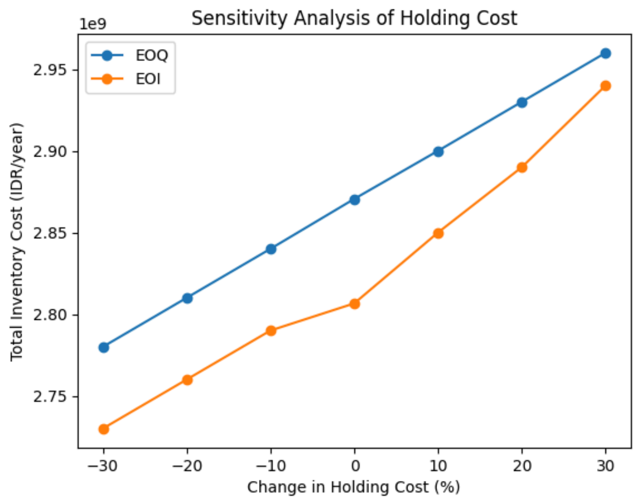

Fig. 2. Sensitivity Analysis of Holding Cost

The calculations and Fig 2 demonstrate that an increase in holding cost reduces the difference in total inventory cost between the EOQ and EOI models. This finding suggests that when holding costs are relatively high, the advantages of coordinated ordering should be reassessed, as elevated average inventory levels may diminish cost efficiency.

3) Sensitivity to Holding Cost (C)

Variations in demand influence the order quantities and total inventory costs associated with both policies. Under deterministic assumptions, these effects remain proportional for the EOQ and EOI models.The calculation results are presented in Table 6.

Table 6. Sensitivity Analysis of Demand

Change in C	EOQ (Rp/Year)	EOI (Rp/Year)	EOQ–EOI Difference
−30%	2.010.000.000	1.960.000.000	50.000.000
−20%	2.300.000.000	2.240.000.000	60.000.000
−10%	2.580.000.000	2.520.000.000	60.000.000
Baseline	2.870.544.050	2.806.624.761	63.919.289
+10%	3.160.000.000	3.100.000.000	60.000.000
+20%	3.450.000.000	3.390.000.000	60.000.000
+30%	3.740.000.000	3.680.000.000	60.000.000

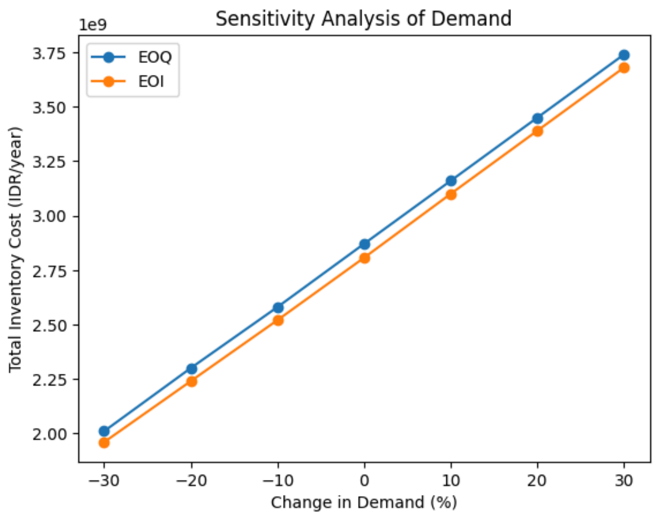

Fig. 2. Sensitivity Analysis of Demand

Variations in demand do not influence the comparative effectiveness of the ordering policies. The EOI approach consistently outperforms EOQ regarding total inventory cost, indicating robustness to demand fluctuations under deterministic conditions.

The sensitivity analysis supports the following conclusions:

1. Ordering cost has the greatest impact on the effectiveness of the coordinated ordering policy.
2. Higher holding costs may reduce the benefits of order coordination, but do not immediately remove the advantage of the EOI policy.
3. Changes in annual demand do not affect the optimal policy, so the ordering decision remains stable.

4 Conclusion

This study presents a cost-based framework for determining optimal ordering policies in a multi-item, single-supplier inventory system by integrating the Economic Order Quantity (EOQ) and Economic Order Interval (EOI) models under deterministic demand. A numerical example compares individual and coordinated ordering policies. Results show that the coordinated policy, based on the EOI model, consistently lowers total inventory costs compared to the EOQ-based individual policy. These savings result primarily from order consolidation, which reduces ordering frequency and total ordering expenses.

Sensitivity analysis shows that ordering cost has the greatest impact on the benefit of coordinated ordering. While higher holding costs may reduce the EOI policy's cost advantage, coordinated ordering remains preferable within the tested ranges. Changes in

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annual demand do not impact the optimal policy, indicating the framework's robustness to demand fluctuations in deterministic systems.

In summary, the proposed framework provides practical guidance for inventory decision-makers in manufacturing environments with multiple items from a single supplier. By identifying when coordinated ordering is more cost-effective, this study supports more efficient and informed inventory management.

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