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Optimizing Inventory Control Using Min-Max Method for Sustainable Manufacturing Process

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Abstract. Inventory plays an important role in a company's production process, especially in the sustainable manufacturing industry. The inventory of raw materials such as rayon, polyester, and cotton is an essential element that needs to be controlled to maintain a smooth production process. This research aims to plan and control raw materials through the min-max method, with a focus on evaluating inventory control to identify and overcome existing problems in the raw material warehouse at a yarn and textile manufacturing company. The results show that each type of raw material has a different reorder level, which guides the company in avoiding the risk of shortage or excess stock. By applying the right reorder level, the company can improve its production efficiency and inventory management. This research contributes to the practice of inventory control in the sustainable manufacturing industry, which supports operational stability and minimizes resource wastage. The implications of the findings could expand the application of min-max method-based inventory control in other industries to support operational sustainability.

Keywords: *Inventory Control Systems, Inventory Optimization, Production Sustainability, Raw Material Management, Supply Chain Management*

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1. Introduction

Inventory is one of the policies a company uses to manage an effective control system [1]. One approach to managing control is a safety stock-based policy that is needed if actual demand exceeds initial estimates [2] [3]. Inventory can also be defined as goods that are stored for use or sale at a future time or time. Inventory can be in the form of raw materials, auxiliary materials, work-in-progress, finished goods, and spare parts [4]. Inventory plays an essential role in storing goods at a minimum cost [5] [6]. Inventory control not only affects the company but also plays a key role in stabilizing and coordinating consumer demand [7].

On the other hand, if the company tries to reduce inventory, it will face difficulties [8]. If there is excess inventory, the risk of loss and damage to goods will be greater [9]. Therefore, efficient inventory management in raw material inventory is essential to avoid unnecessary costs and prevent production delays [10].

Companies use inventory control strategies to determine the minimum and maximum stock of goods [11]. Applying the min-max policy, which is usually for products whose historical demand shows a particular trend, makes it possible to know the order reference number during the reorder period and will guarantee that the amount of inventory in the warehouse is not excessive [12]. The min-max method is a raw material control method based on the assumption that raw material inventory is at two threshold levels, namely maximum and minimum. The minimum level is the point at which reorders should be placed, and the maximum level is the maximum amount of inventory to be kept [13].

The requirement in minimum order is that the order quantity must meet or exceed a specific limit. On the other hand, the constraint in the maximum order is that the order quantity does not exceed a predetermined amount [14]. In this context, the min-max method provides better flexibility than other methods, such as Economic Order Quantity (EOQ), as it not only minimizes procurement costs but is also able to maintain stock balance under fluctuating demand conditions, as is often the case in the textile industry. Although EOQ is ideal for stable demand conditions, min-max is more relevant in ensuring the availability of raw materials without the risk of shortage or excess stock [15]. Therefore, in inventory management, decisions can be made on the time and amount of raw materials to be replenished [16]. This step can reduce overall operating costs and minimize potential waste of resources [17] [18]. Raw material inventory is significant for the company because the productivity level of the company's production process is said to be good if the raw material supply process can be appropriately guaranteed. However, if the raw material is delayed in a production process, it will affect other processes, which will cause losses for the company.

Inventory management not only focuses on the number of stock items but also involves the minimum and maximum cost of inventory and the level of service provided. Cost includes setup, shipping, and storage costs, as well as costs due to stock shortages [19]. From the service aspect, it is considered an attractive, practical approach [20]. The minimum and maximum inventory levels required by a company vary depending on the production volume, plant type, and process [21]. If the ending inventory reaches zero, this can lead to various problems, including affecting the initial production plan so that the quality of the solution decreases over time [22]. In logistics systems, the min-max approach is essential in decision-making, which is usually driven by the desire to maximize profits while reducing failures in the production system [23]. Therefore, effective inventory planning in inventory management is required to determine effective operating policies in the supply center [24] [25].

Research by Dai et al. [2] has studied inventory replenishment planning in distribution systems; this research extends the application of the method in the context of raw material inventory control in a textile company warehouse. PT PQR is a subsidiary company of the XYZ Group that manufactures yarn or textiles. Its primary raw material is cotton, which is made up of various types of cotton, including rayon, polyester, and cotton. These materials must be available in raw materials or warehouses within the company so that smooth production is maintained. Therefore, raw material planning and control must be carried out to maintain and control the stock in the warehouse while the production process is running.

2. Method

The use of the min-max method in this study is relevant to some previous findings. Hernandoko et al. [4] demonstrated the successful application of this method to determine inventory control limits, albeit without considering external factors such as supplier delays or market instability. Asana et al. [11] mentioned the importance of adding external parameters, such as holidays or national events. This underscores the limitations of conventional approaches that rely on historical data without considering market variability. Dai et al. [21] and Angelina et al. [1] add that safety stock policies and min-max analysis can reduce costs and improve efficiency but still require consideration of demand fluctuations and supply chain disruptions.

This research has several stages, starting with recognizing problems in the warehouse, collecting and processing data, analyzing and interpreting the results, and making decisions and conclusions. The data collected is the number of incoming goods from each type of material, namely rayon, polyester, and cotton, during the period January to October 2023. The data can be seen in Table 1.

Table 1. Material Purchasing Data

No	Month	Purchase (bale)		
		Rayon	Polyester	Cotton
1	January	4100	550	790
2	February	5200	760	810
3	March	3670	680	830
4	April	5870	730	940
5	May	5970	480	740
6	June	4500	580	960
7	July	6150	630	680
8	August	4560	700	750
9	September	5480	750	690
10	October	4350	420	620
	Total	49.850	6.280	7.810

Furthermore, monthly usage data for each material is collected and analyzed. This information is needed to identify consumption patterns, determine the material with the highest usage rate, and anticipate future material requirements. Thus, companies can carry out more efficient inventory planning and avoid the risk of shortages or excess stock. Material usage data can be seen in Table 2.

Table 2. Material Usage Data

No	Month	Purchase (bale)		
		Rayon	Polyester	Cotton
1	January	3850	350	350
2	February	4780	650	650
3	March	3265	525	525
4	April	5365	628	628
5	May	5345	410	410
6	June	4325	475	475
7	July	5850	560	560
8	August	4230	615	615
9	September	5165	635	635
10	October	2960	350	350
	Total	45.135	5.198	7.280

Based on purchase and usage data, the next step is to process data containing inventory control analysis by processing the data that has been obtained. This safety stock calculation is carried out to be an input in the calculation of minimum and maximum inventory. The calculations in the min-max method are as follows:

2.1 Safety stock

Safety stock = (Maximum usage – T) x C
Description:
T = Average item usage per period
C = Lead Time

2.2 Minimum inventory

Minimum inventory = (T x C) x R
Description:
T = Average item usage per period
C = Lead Time
R = Safety stock

2.3 Maximum Inventory

Maximum Inventory = 2 (T x C)
Description:
T = Average item usage per period
C = Lead Time

2.4 Reorder Rate

Q = Max – Min
Description:
Q = Reorder rate
Max = Maximum inventory
Min = Minimum inventory

3. Results and Discussion

The company's current cotton raw material stock system has no standardization, so ordering materials is only based on production estimates for the next few months, which is done when the stock in the warehouse runs low. This condition often hampers the production process because the raw materials in the warehouse are not always sufficient. This research analyzes the application of the min-max method to determine the minimum amount of yarn raw materials (rayon, polyester, and cotton) to keep production running smoothly. The effectiveness of this method can be improved by considering supplier lead time and order frequency. Research by Dai et al. [21] shows that a distribution system with Primary Distribution Centers (PDCs) reduces replenishment costs through product consolidation and safety stock policies, improves customer fulfillment rates, and reduces deviations compared to traditional approaches, supporting the superiority of the min-max method in stock management [2].

The following is the application of the min-max method in the calculation of yarn raw materials consisting of rayon, polyester, and cotton.

3.1 Rayon Material

Table 3 presents data on the purchase and use of rayon materials. This data includes the amount of material purchased and used each month, which is then further analyzed to understand the consumption patterns and stock requirements of rayon materials.

Table 3. Rayon Material

No	Month	Rayon	
		Purchase (Bale)	**Usage (Bale)**
1	January	4100	3850
2	February	5200	4780
3	March	3670	3265
4	April	5870	5365
5	May	5970	5345
6	June	4500	4325
7	July	6150	5850
8	August	4560	4230
9	September	5480	5165
10	October	4350	2960
	Total	49.850	45.135
	Average	4.985	4.513

Calculation of analysis with the min-max method. The following is the calculation of the min-max method on rayon material based on this data.

Known:

Lead Time: 2 days (ordering)
Starting stock for 2023 = 650 bales

a. Ending stock in 2023

(Total purchase - Total usage) + initial stock
= (49.850 - 45.135) + 650 = 5365 bales

b. Safety stock
(Maximum usage – T) x C
= (5850 – 4513) x 2 days = 2674 bales

c. Minimum inventory
Minimum inventory = (T x C) + R
= (4513 x 2 days) + 2674 = 11.700 bales

d. Maximum inventory
Maximum inventory = 2 (T x C)
= 2 (4513 x 2 days) = 18.052 bales

e. Reorder rate
Q = Max – Min
Q = 18.052 - 11.700 = 6352 bales

3.2 Polyester Material

Table 4 presents data on the purchase and usage of polyester materials. This data includes the amount of material purchased and used each month, with a total purchase of 6,280 bales and a total usage of 5,198 bales throughout the period. This data provides an initial overview for analyzing consumption patterns and stock requirements of polyester materials.

Table 4. Polyester Material

No	**Month**	**Polyester**	
		Purchase (Bale)	**Usage (Bale)**
1	January	550	350
2	February	760	650
3	March	680	525
4	April	730	628
5	May	480	410
6	June	580	475
7	July	630	560
8	August	700	615
9	September	750	635
10	October	420	350
	Total	6.280	5198
	Average	628	519,8

Calculation of analysis with the min-max method. The following is the calculation of the min-max method on polyester material based on these data.

Known:
Lead Time: 2 days (ordering)
Starting stock for 2023 = 120 bales

a. Ending stock in 2023
(Total purchase - Total usage) + initial stock
= (6280 - 5198) + 120 = 1202 bales

b. Safety stock
(Maximum usage – T) x C
= (650 – 519,8) x 2 days = 261 bales

c. Minimum inventory
Minimum inventory = (T x C) + R
= (519,8 x 2 days) + 261 = 1300 bales

d. Maximum inventory
   Maximum inventory = 2 (T x C)
   = 2 (519,8 x 2 days) = 2079 bales
e. Reorder rate
   Q = Max – Min
   Q = 2079 - 1300 = 779 bales

3.3 Cotton material

Table 5 presents data on the purchase and use of cotton materials. This data includes the amount of material purchased and used each month, with a total purchase of 781 bales and a total usage of 728 bales throughout the period. This data provides an initial overview for analyzing consumption patterns and stock requirements of cotton materials.

Table 5. Cotton Material

No	Month	Cotton	
		Purchase (Bale)	Usage (Bale)
1	January	790	710
2	February	810	750
3	March	830	780
4	April	940	885
5	May	740	715
6	June	960	910
7	July	680	630
8	August	750	685
9	September	690	640
10	October	620	575
	Total	7810	7280
	Average	781	728

Calculation of analysis with the min-max method. The following is the calculation of the min-max method on polyester material based on these data.

Known:

Lead Time: 1 month (30 days) (ordering)
Starting stock for 2023 = 225 bales

a. Ending stock in 2023
   (Total purchase - Total usage) + initial stock
   = (7810 - 7280) + 225 = 755 bales
b. Safety stock
   (Maximum usage – T) x C
   = (910 – 728) x 30 days = 5460 bales
c. Minimum inventory
   Minimum inventory = (T x C) + R
   = (728 x 30 days) + 5460 = 27300 bales
d. Maximum inventory
   Maximum inventory = 2 (T x C)
   = 2 (728 x 30 days) = 43680 bales
e. Reorder rate
   Q = Max – Min
   Q = 43680 – 27300 = 16380 bales

4. Conclusion

The processing and analysis carried out show that the application of the min-max inventory control method can assist companies in managing the optimal availability of raw materials during the production process. By knowing the reorder level for each material, the company can organize the reorder schedule more efficiently to avoid shortages or excess inventory, which is very important for the smooth production process, especially in raw materials such as rayon, polyester, and cotton, which have different demand levels.

However, to improve the effectiveness of this method in a real-world context, companies need to take into account external factors that affect demand fluctuations, such as market instability and supplier delays. In addition, challenges such as supply variability and unpredictable demand fluctuations may hinder the success of the min-max method. Therefore, it is recommended that more complex inventory planning methods, such as prediction or simulation-based methods, be implemented to optimize inventory control in the face of uncertainty. Further research needs to be done to explore how these external factors can be incorporated into the inventory control model to improve reliability and responsiveness in supply chain management.

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