A Trade-off between Overstock and Stockouts of a Perishable Raw Material with Uncertain Demands in a Cosmetics Industry

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Abstract. An inventory system is a crucial aspect of any business that deals with physical goods or products. It refers to the processes, software, and strategies put in place to track and manage the company's inventory efficiently. In a fluctuating demand situation, the importance of an inventory system becomes even more pronounced. Managing inventory effectively becomes challenging when demand is unpredictable, and having a robust inventory system can make a significant difference. A cosmetics manufacturer produces four types of body scrubs from the same type of rice groats under fluctuating product demand conditions and limited raw material shelf life, resulting in high inventory costs due to unoptimized raw material purchasing. A probabilistic inventory system was proposed based on the newsvendor model, where demands were assumed to be normal distributed. Our computation showed that the optimal rice procurement was 2,235.69 kg/month resulting a service level of 90 percent. The proposed inventory policy was able to increase the expected monthly profit from Rp 11.3 million to Rp 14.2 million, equivalent to a 25 percent increase. Results and insights for future research were discussed.

Keywords: Probabilistic inventory system, uncertain demand, Newsvendor model, expected profit.

1. Introduction

An inventory system is a set of processes and procedures for tracking and managing inventory [1]. It is important for businesses of all sizes to have an effective inventory system in place, as it can help to improve efficiency, reduce costs, and improve customer service [2]. By having the right amount of inventory, businesses can reduce their holding costs, meet customer demand more quickly and easily, reduce costs related to stockouts and backorders, and reduce the risk of obsolescence from perishable goods [3].

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In various industries, demand of products can be probabilistic, i.e., the demand does not simply predict a single demand value, but rather a range of possible demand values, along with their associated probabilities [4]. Probabilistic demand can occur due to seasonality of some products [5], trends in the market [4], economic factors like recession [6], and unpredictable events such as natural disasters [7] or policy uncertainty [8].

An inventory system for probabilistic demand should consider the uncertainty of demand, i.e., the range of possible demand values along with their associated probabilities [9]. Some inventory systems that can be used for probabilistic demand include the base stock system which maintains a fixed quantity of inventory on hand based on the expected demand and the desired service level [10], the safety stock system which maintains a buffer stock of inventory in addition to the base stock [11], the reorder point system which determines when to order new inventory based on the current inventory level and the expected demand [11], and the Just-in-time (JIT) system which minimizes inventory by ordering new inventory only when it is needed [12]. The best probabilistic inventory in a system depends on the specific situation the system.

The Newsvendor model is a mathematical model used to determine the optimal inventory level for a perishable product with uncertain demand [13]. It is named after the problem faced by newsboys who had to decide how many newspapers to buy each day in order to maximize their profits. The newsvendor model assume that the product can be sold only in one period, the demand is uncertain, the product price and the holding cost is constant, and the cost of lost sales is known. The newsvendor model is used to handle orders for perishable goods (such as fresh fruits, vegetables, sea fish, cut flowers) or other types of products that have a relatively short shelf life (such as newspapers and magazines). At the end of the sales period, the remaining product has little or no value.

2. Methodology

Rice groats, which serve as the primary ingredient for manufacturing Body Scrub in a cosmetics industry, cannot be carried over to the following period due to its limited shelf life of just one month (one month is considered as one period). Prolonged storage could result in deterioration. It is essential to effectively manage the procurement of rice as a raw material, especially given uncertain demand patterns and the short shelf life of the ingredient, to ensure efficient production and maximize benefits.

Data collection was performed through observations and interviews with relevant stakeholders. Subsequently, data calculation was performed based on the Newsvendor model, comparing expected profit between the Newsvendor model calculation and the current company inventory system, and calculating the increase percentage in the profit.

The Newsvendor model focuses on two costs, i.e., the cost of shortage (*Cs*) and the cost of overage (*Co*), as defined in Eq. (1) and (2). The cost of this product uses the full costing method which includes costs, namely fixed costs and variable costs. According to Waters [14], the basis for calculating inventory levels using the Newsvendor model is as follows:

$$Cost\ of\ shortage\ (Cs) = Selling\ price - Purchasing\ cost \quad (1)$$

$$Cost\ of\ overstock\ (Co) = Purchasing\ cost - Salvage\ value \quad (2)$$

The service level is calculated as the key to determine the optimal inventory level (*So*).

$$\text{Service Level } (SL) = \frac{Cs}{(Cs+Co)} \quad (3)$$

$$\text{Optimal Service } (So) = \mu + z_{SL}.\sigma \quad (4)$$

where:
μ = Average of the demand
z_{SL} = Probability of *SL* in the normal distribution table
σ = Standard deviation of the demand

3. Results and Discussion

The cosmetics industry had four products, i.e., BL, KB, BK and KP, which use the same raw material, i.e., rice groats. Rice groat requirement per unit of any product was 0.084 kg, while the cost of rice was Rp 9,000 per kg and the production cost was Rp 5,500 per unit. The demands of each product in a thirty-month period starting October 2020 are shown in Table 1.

Table 1. Product Demand Data

Period	Product				Total demand	Demand of rice (kg)
	BL	KB	BK	KP		
Oct-20	15,330	3,940	2,982	2,901	25,153	2,112.85
Nov-20	14,548	1,959	1,999	2,457	20,963	1,760.89
Dec-20	14,468	1,928	1,918	2,459	20,773	1,744.93
Jan-21	14,588	2,529	3,182	3,281	23,580	1,980.72
Feb-21	14,794	2,213	2,178	2,928	22,113	1,857.49
Mar-21	14,428	1,742	1,945	1,958	20,073	1,686.13
Apr-21	17,201	2,531	3,942	2,941	26,615	2,235.66
May-21	14,329	1,928	1,982	2,392	20,631	1,733.00
Jun-21	15,091	2,058	2,620	3,284	23,053	1,936.45
Jul-21	14,448	1,793	1,748	2,427	20,416	1,714.94
Aug-21	15,721	2,223	2,187	2,628	22,759	1,911.76
Sep-21	14,552	1,761	1,989	2,464	20,766	1,744.34
Oct-21	15,275	2,042	2,213	3,094	22,624	1,900.42
Nov-21	14,491	1,941	1,442	2,325	20,199	1,696.72
Dec-21	16,020	3,192	2,531	2,851	24,594	2,065.90
Jan-22	16,024	2,284	2,928	4,942	26,178	2,198.95
Feb-22	14,655	2,127	2,058	2,624	21,464	1,802.98
Mar-22	16,582	2,343	2,941	3,842	25,708	2,159.47
Apr-22	16,091	2,176	3,192	3,249	24,708	2,075.47
May-22	14,580	1,983	1,988	2,454	21,005	1,764.42
Jun-22	17,842	2,545	2,827	4,529	27,743	2,330.41
Jul-22	16,515	3,942	2,628	3,952	27,037	2,271.11
Aug-22	18,021	2,482	2,374	2,482	25,359	2,130.16
Sep-22	14,589	2,020	2,034	2,589	21,232	1,783.49
Oct-22	17,421	2,248	2,325	4,021	26,015	2,185.26
Nov-22	15,929	3,284	3,851	2,942	26,006	2,184.50
Dec-22	16,524	2,239	2,485	5,821	27,069	2,273.80
Jan-23	14,827	2,429	2,852	4,203	24,311	2,042.12
Feb-23	15,246	2,249	2,248	4,921	24,664	2,071.78
Mar-23	14,543	1,871	1,920	2,459	20,793	1,746.61

Meanwhile, the current inventory policy used in the industry during the same thirty-month period was to produce a constant amount of products as shown in Table 2. The policy was based on the desire of the industry to avoid overstock as much as possible, due to the perishability of the raw material.

The Newsvendor model originally considered the problem of ordering a commodity for a direct resale (not for production). Since the industry ordered rice groats for producing cosmetics (not directly selling the rice), we computed the proportion of rice groats in selling price, production cost, profit and salvage value (the data of these are given in Table 3).

Table 2. Current production policy

Period	Product				Total production	Use of rice (kg)
	BL	KB	BK	KP		
Oct-20 to Mar-23	14,583	2,000	2,000	2,468	21,051	1,768.28

First, we computed the proportion of rice in the production cost as follows.

$$\text{Proportion of rice} = \frac{Rice\ cost\ per\ kg\ x\ Rice\ requirement\ per\ unit}{Production\ cost\ per\ unit} \quad (5)$$

$$= \frac{Rp\ 9{,}000/kg\ x\ 0.084\ kg}{Rp\ 5{,}500} = 0.1375$$

Using the proportion, we computed the proportion of rice in selling price, production cost, profit and salvage value, as shown in the last row of Table 3.

Table 3. Product data

	Selling Price (Rp/Unit)	Production Cost (Rp/Unit)	Profit (Rp/Unit)	Salvage Value (Rp/Unit)
Per unit of product[$]	10,000	5,500	4,500	5,000
Proportion of rice[#]	1,375	756.25	618.75	687.5

$ Known data

Computed as 0.1375 of per unit of product

Then, we computed *Cs* and *Co* using Eq. (1) and (2) as follows.

$$Cs = \text{Rp } 1{,}375 - \text{Rp } 756.25 = \text{Rp } 618.75 \quad (6)$$

$$Co = \text{Rp } 756.25 - \text{Rp } 687.5 = \text{Rp } 68.75 \quad (7)$$

Using Eq. (3), the optimal service level was then calculated based on *Cs* and *Co*. Accordingly, the optimal quantity of ordering rice was calculated using Eq. (4).

$$SL = \frac{618.75}{618.75+68.75} = 0.90 \quad (8)$$

$$So = \mu + z_{0.90}.\sigma = 1{,}970.09 + 1.282 * 207.18 = 2{,}235.69\ \text{kg/month}. \quad (9)$$

The optimal service level and rice purchasing computed in Eq. (8) and (9) resulted a thirty-month period profit as shown in Table 4.

With the same computation, the current production policy of the industry which fixed the production at 21,051 units and required a rice purchase at 1,768.28 kg per month (see Table 2) brought a total profit of Rp 341,148,360 or Rp 11,371,612 monthly as shown in

Table 5. Reversing the computation in Eq. (9), the service level resulting from the current policy is calculated as follows.

$$1{,}768.28 = 1{,}970.09 + z_{SL} * 207.18 \Leftrightarrow z_{SL} = -0.9741 \Leftrightarrow SL = 0.1635 \quad (10)$$

The comparison of profit and service level between the current policy and the Newsvendor model is shown in Table 6.

Table 4. Calculation Results of the Inventory System Based on the Newsvendor Model

Period	Demand (kg)	Purchase (kg)	Production (kg)	Inventory (kg)	Overstock cost (Rp)	Stockout cost (Rp)	Profit (Rp)
Oct-20	2,112.85	2,235.69	2,112.85	122.84	100,537	0	15,462,882
Nov-20	1,760.89	2,235.69	1,760.89	474.80	388,600	0	12,582,257
Dec-20	1,744.93	2,235.69	1,744.93	490.76	401,662	0	12,451,632
Jan-21	1,980.72	2,235.69	1,980.72	254.97	208,681	0	14,381,444
Feb-21	1,857.49	2,235.69	1,857.49	378.20	309,537	0	13,372,882
Mar-21	1,686.13	2,235.69	1,686.13	549.56	449,787	0	11,970,382
Apr-21	2,235.66	2,235.69	2,235.64	0.03	25	0	16,468,007
May-21	1,733.00	2,235.69	1,733.00	502.69	411,425	0	12,354,007
Jun-21	1,936.45	2,235.69	1,936.45	299.24	244,912	0	14,019,132
Jul-21	1,714.94	2,235.69	1,714.94	520.75	426,206	0	12,206,194
Aug-21	1,911.76	2,235.69	1,911.76	323.93	265,125	0	13,817,007
Sep-21	1,744.34	2,235.69	1,744.34	491.35	402,143	0	12,446,819
Oct-21	1,900.42	2,235.69	1,900.42	335.27	274,406	0	13,724,194
Nov-21	1,696.72	2,235.69	1,696.72	538.97	441,125	0	12,057,007
Dec-21	2,065.90	2,235.69	2,065.90	169.79	138,968	0	15,078,569
Jan-22	2,198.95	2,235.69	2,198.95	36.74	30,068	0	16,167,569
Feb-22	1,802.98	2,235.69	1,802.98	432.71	354,156	0	12,926,694
Mar-22	2,159.47	2,235.69	2,159.47	76.22	62,381	0	15,844,444
Apr-22	2,075.47	2,235.69	2,075.47	160.22	131,131	0	15,156,944
May-22	1,764.42	2,235.69	1,764.42	471.27	385,712	0	12,611,132
Jun-22	2,330.41	2,235.69	2,235.64	-94.72	0	697,729	15,770,523
Jul-22	2,271.11	2,235.69	2,235.64	-35.42	0	260,892	16,207,361
Aug-22	2,130.16	2,235.69	2,130.16	105.53	86,375	0	15,604,507
Sep-22	1,783.49	2,235.69	1,783.49	452.20	370,106	0	12,767,194
Oct-22	2,185.26	2,235.69	2,185.26	50.43	41,275	0	16,055,507
Nov-22	2,184.50	2,235.69	2,184.50	51.19	41,893	0	16,049,319
Dec-22	2,273.80	2,235.69	2,235.64	-38.11	0	280,692	16,187,561
Jan-23	2,042.12	2,235.69	2,042.12	193.57	158,425	0	14,884,007
Feb-23	2,071.78	2,235.69	2,071.78	163.91	134,156	0	15,126,694
Mar-23	1,746.61	2,235.69	1,746.61	489.08	400,287	0	12,465,382
TOTAL							426,217,250
Monthly average							14,207,242

Table 5. Calculation Results of the Inventory System

Period	Demand (kg)	Purchase (kg)	Production (kg)	Inventory (kg)	Overstock cost (Rp)	Stockout cost (Rp)	Profit (Rp)
Oct-20	2,112.85	1,768.28	1,768.28	-344.57	0	2,538,113	10,487,194
Nov-20	1,760.89	1,768.28	1,760.89	7.39	6,028	0	12,964,828
Dec-20	1,744.93	1,768.28	1,744.93	23.35	19,043	0	12,834,251
Jan-21	1,980.72	1,768.28	1,768.28	-212.44	0	1,564,819	11,460,488
Feb-21	1,857.49	1,768.28	1,768.28	-89.21	0	657,112	12,368,194
Mar-21	1,686.13	1,768.28	1,686.13	82.15	66,993	0	12,353,176
Apr-21	2,235.66	1,768.28	1,768.28	-467.38	0	3,442,725	9,582,581
May-21	1,733.00	1,768.28	1,733.00	35.28	28,770	0	12,736,661
Jun-21	1,936.45	1,768.28	1,768.28	-168.17	0	1,238,738	11,786,569
Jul-21	1,714.94	1,768.28	1,714.94	53.34	43,498	0	12,588,903
Aug-21	1,911.76	1,768.28	1,768.28	-143.47	0	1,056,825	11,968,481
Sep-21	1,744.34	1,768.28	1,744.34	23.94	19,523	0	12,829,440
Oct-21	1,900.42	1,768.28	1,768.28	-132.13	0	973,294	12,052,013
Nov-21	1,696.72	1,768.28	1,696.72	71.57	58,362	0	12,439,769
Dec-21	2,065.90	1,768.28	1,768.28	-297.61	0	2,192,231	10,833,075
Jan-22	2,198.95	1,768.28	1,768.28	-430.67	0	3,172,331	9,852,975
Feb-22	1,802.98	1,768.28	1,768.28	-34.69	0	255,544	12,769,763
Mar-22	2,159.47	1,768.28	1,768.28	-391.19	0	2,881,519	10,143,788
Apr-22	2,075.47	1,768.28	1,768.28	-307.19	0	2,262,769	10,762,538
May-22	1,764.42	1,768.28	1,764.42	3.86	3,151	0	12,993,693
Jun-22	2,330.41	1,768.28	1,768.28	-562.13	0	4,140,675	8,884,631
Jul-22	2,271.11	1,768.28	1,768.28	-502.82	0	3,703,838	9,321,469
Aug-22	2,130.16	1,768.28	1,768.28	-361.87	0	2,665,575	10,359,731
Sep-22	1,783.49	1,768.28	1,768.28	-15.20	0	111,994	12,913,313
Oct-22	2,185.26	1,768.28	1,768.28	-416.98	0	3,071,475	9,953,831
Nov-22	2,184.50	1,768.28	1,768.28	-416.22	0	3,065,906	9,959,400
Dec-22	2,273.80	1,768.28	1,768.28	-505.51	0	3,723,638	9,301,669
Jan-23	2,042.12	1,768.28	1,768.28	-273.84	0	2,017,125	11,008,181
Feb-23	2,071.78	1,768.28	1,768.28	-303.49	0	2,235,544	10,789,763
Mar-23	1,746.61	1,768.28	1,746.61	21.67	17,673	0	12,847,996
TOTAL							341,148,360
Monthly average							11,371,612

Table 6. Comparison of profit and service level

METHOD	Monthly profit	Service level
Current company policy	Rp 11,371,612	16.35 %
Newsvendor Model	Rp 14,207,999	90.00 %

We found that the Newsvendor model was expected to increase the profit by Rp 2,836,387 or 24.94% from the current company policy and increase the service level from 16.35 to 90 percent. Comparing Table 4 and Table 5, it is clear that the current company policy which was intended to avoid overstock as much as possible, causing a large amount of stockout costs due to unfulfilled customer demand.

It is also important to note that the Newsvendor model optimal service level was 90 percent, meaning that 10 percent of customer demands were left unfulfilled. This occurred because the Newsvendor model optimizes overstock and stockout by looking for the least costs of these two, and it turned out that the minimum overstock and stockout costs fell at the service level 90 percent (not 100 percent). In Table 7, we showed that the service level computed by the Newsvendor model (using Eq. (8)) resulted the least sum of overstock and stockout costs. This finding is consistent with the findings in Wei, Feng [15], Xu, Wang [16] and Ovezmyradov and Kurata [17].

Table 7. Overstock and stockout costs at different service levels

Service level	Purchase (kg)	Overstock and stockout costs (Rp)
85%	2,184.73	8,436,026
90%	2,235.69	7,898,413
93%	2,275.89	7,954,651
96%	2,332.86	8,907,323
99%	2,452.20	11,837,440

4. Conclusions

The Newsvendor model was proven effective to optimize between overstock and stockout costs for raw material purchasing in the cosmetics industry studied in this research. The Newsvendor model maximized the average monthly profit by selecting an optimal rice purchasing to 2,235.69 kg/month, resulting a service level of 90 percent. The expected monthly profit increased by 25 percent from Rp 11,371,612 to Rp 14,207,242 in a thirty-month period. Using the newsvendor model can help businesses to reduce their inventory costs and improve their profits. However, the model has some limitations, e.g., its optimal service level was not usually 100 percent, meaning that it leaves some of the demands unfulfilled. Despite these limitations, the newsvendor model is a valuable tool for businesses that need to manage inventory under uncertainty.

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