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Inventory Control Planning for Injectable Drugs Using a Continuous Review Model with Product Expiration Considerations: A Case Study of Clinic X

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ABSTRACT

Effective pharmaceutical inventory control is essential for maintaining drug availability while minimizing losses from overstock, stockouts, and product expiration in healthcare facilities. This study examines injectable drug inventory planning at Clinic X using a Continuous Review System within a probabilistic inventory model. Historical demand data for 18 injectable drugs from January to December 2023 were analyzed through demand forecasting, calculation of optimal order quantity, reorder point, safety stock, and maximum inventory level, estimation of expired products, and comparison of total inventory cost before and after implementation of the proposed policy. The results show that the proposed model reduced total inventory cost from IDR 35,853,564 under the existing clinic policy to IDR 23,339,897, yielding savings of IDR 12,513,667, or approximately 35%. The model-based expiration estimate indicated zero expected expired units for all observed injectable drugs under the proposed ordering policy and calculation assumptions. These findings indicate that incorporating product expiration into continuous review inventory planning can support more cost-efficient and responsive drug inventory management in healthcare facilities.

Keywords
Continuous Review System; pharmaceutical inventory control; injectable drugs; product expiration; total inventory cost

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INTRODUCTION

Effective pharmaceutical inventory management is essential for ensuring continuous drug availability, maintaining healthcare service quality, and controlling operational costs. In healthcare facilities, inventory decisions are directly related to patient safety because stockouts may interrupt treatment, whereas excessive stock can increase holding costs and the risk of product expiration. Recent studies show that inventory level control and demand forecasting are important determinants of pharmaceutical supply chain performance, particularly in hospital and healthcare pharmacy settings [1], [2]. Poor inventory control may also create simultaneous problems of stockouts, overstocking, and expiry-related wastage, which reduce financial efficiency and weaken service responsiveness [3], [4].

Drug inventory management is more complex than conventional inventory control because pharmaceutical products have uncertain demand, procurement lead times, regulated storage requirements, and limited shelf life. Demand for medicines may fluctuate due to patient visits, disease patterns, treatment policies, and changes in healthcare service utilization. Under these conditions, deterministic inventory models are often insufficient because they assume relatively stable and predictable demand. Probabilistic inventory models are therefore more appropriate because they can incorporate demand uncertainty, lead-time variability, safety stock, and reorder decisions in a more realistic manner. In addition, demand forecasting is needed as an input for inventory planning so that procurement decisions can be based on expected future requirements rather than only on historical purchasing habits [1], [2], [5].

One widely used approach in probabilistic inventory control is the Continuous Review System, in which inventory levels are monitored continuously and replenishment is triggered when the stock position reaches a predetermined reorder point. This approach enables decision makers to determine key inventory parameters, including the optimal order quantity, reorder point, safety stock, and maximum stock level. Previous studies have shown that continuous review policies can reduce inventory costs by balancing ordering, holding, and shortage costs [6]. In the Indonesian industrial engineering literature, the Continuous Review method has also been reported as an effective policy for minimizing total inventory cost compared with periodic review approaches [7]. Related inventory studies in Motivection further emphasize the importance of inventory classification and safety stock calculation for improving stock control and reducing the risk of shortage or excess inventory [8].

For pharmaceutical products, however, inventory control should not only consider ordering and holding costs but also product expiration. Expired medicines generate direct financial losses because they cannot be used for patient care and may require disposal or pharmaceutical waste treatment. Inventory policies that ignore shelf-life constraints may recommend order quantities that are economically efficient in a conventional sense but impractical for perishable products. Recent studies on perishable pharmaceutical inventory show that incorporating shelf-life considerations into inventory models can reduce the value of products exceeding their usable period and improve inventory feasibility in healthcare settings [9], [10]. Similarly, research on health-supply monitoring systems highlights the importance of expiration-based stock rotation, such as the First Expired First Out principle, to prevent expired products from remaining unused in storage [11].

Clinic X faces practical challenges in managing injectable drug inventories with limited shelf life. Preliminary observations indicate the occurrence of both overstock and understock for several injectable drugs, as well as the presence of items approaching their expiration dates. These issues suggest that the current ordering policy has not fully accounted for demand variability and product shelf life. Although previous studies have examined pharmaceutical inventory optimization, demand forecasting, continuous review policies, and expiration-based inventory systems, empirical applications that combine demand forecasting, probabilistic Continuous Review parameters, expiration estimation, and Total Inventory Cost comparison in a clinic-level injectable drug context remain relatively limited.

Based on this gap, this study aims to develop an inventory control policy for injectable drugs at Clinic X using the Continuous Review System while incorporating product expiration considerations. Specifically, the study determines the optimal order quantity, reorder point, safety stock, and maximum inventory level; estimates the expected number of expired products; and compares the Total Inventory Cost between the existing clinic policy and the proposed inventory policy. The contribution of this study is practical and methodological: it provides a data-driven decision basis for injectable drug procurement in a clinic setting and

demonstrates how expiration considerations can be integrated into probabilistic inventory planning to support cost-efficient and responsive pharmaceutical inventory control.

METHOD

Research Design

This study employed a quantitative descriptive–analytical design to develop an inventory control policy for injectable drugs at Clinic X. The proposed policy was formulated using a probabilistic Continuous Review inventory model, also known as the Q model, with additional consideration of product expiration. This design was appropriate because the study aimed to estimate future drug demand, determine inventory control parameters, estimate the expected number of expired products, and compare the Total Inventory Cost (TIC) between the existing clinic policy and the proposed inventory policy. The methodological sequence consisted of data collection, demand pattern analysis, demand forecasting, inventory parameter calculation, expired product estimation, TIC comparison, and cost-efficiency evaluation, as illustrated in Figure 1.

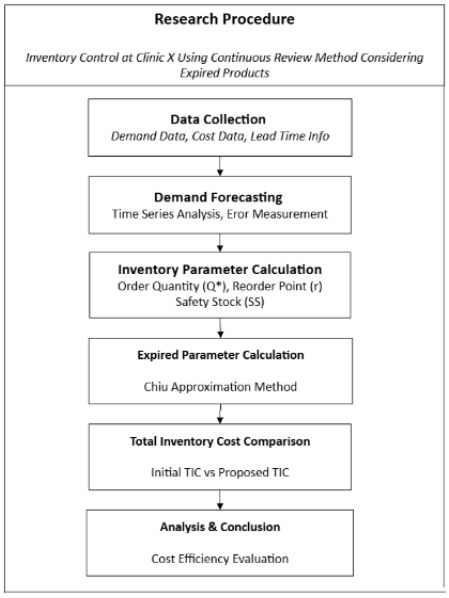

Figure 1. Research Procedure for Inventory Control Using Continuous Review Method Considering Expired Products

Research Object and Data Sources

The research object was the inventory of 18 types of injectable drugs managed by Clinic X. This study used secondary data obtained from the clinic's stock cards, purchasing reports, and pharmacy inventory management records. The data consisted of monthly historical demand for January–December 2023, ordering cost, holding or storage cost, shortage cost, expiration-related disposal cost, procurement lead time, unit price, and packaging-unit information. These data were used as input for demand forecasting, Continuous Review parameter calculation, expired product estimation, and inventory cost comparison. Because the study relied on secondary records, the analysis assumes that the clinic's stock cards, purchasing reports, and pharmacy inventory records were internally consistent. The research object was the inventory of 18 injectable drug items managed by Clinic X. This study used secondary data obtained from the clinic's stock cards, purchasing reports, and pharmacy inventory management records. The data consisted of monthly historical demand from January to December 2023, ordering cost, holding or storage cost, shortage cost, expiration-related disposal cost, procurement lead time,

unit price, and packaging-unit information. These data were used as input for demand forecasting, Continuous Review parameter calculation, expired product estimation, and Total Inventory Cost comparison. Before analysis, the available secondary data were organized according to drug item and cost component to ensure that the demand, cost, lead-time, and packaging-unit information used in the calculations were traceable to the clinic's inventory records.

Demand Pattern Analysis and Forecasting

The monthly demand data for each injectable drug were first analyzed to identify the general demand pattern, such as horizontal, trend, seasonal, or irregular fluctuation. This step was necessary because the selection of a forecasting method should correspond to the characteristics of the historical demand pattern. In pharmaceutical inventory planning, demand forecasting is important because inaccurate demand estimation may lead to stockouts, overstocking, or unnecessary holding costs [12], [13].

Several time-series forecasting methods were evaluated, namely Simple Average (SA), Moving Average (MA), Weighted Moving Average (WMA), Single Exponential Smoothing (SES), Double Exponential Smoothing (DES), Adaptive Exponential Smoothing (AES), and Linear Regression (LR). The MA and WMA methods were evaluated using the forecasting window reported in the original calculation. The forecasting procedure compared the available methods using MAD, MSE, and MAPE as error indicators, with MSE used as the primary selection criterion and MAD and MAPE used as supporting indicators. The selected forecasting output for each injectable drug item was then used to estimate annual demand and demand variability for the Continuous Review calculation. Because the complete forecasting parameter settings and error values are not displayed in the main text, the forecasting results are presented as selected forecasted demand values, while the detailed error-comparison output should be retained in the calculation file or supplementary material.

Forecasting accuracy was evaluated using Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). The best forecasting method for each drug item was selected based on the smallest forecasting error, with MSE used as the primary selection criterion and MAD and MAPE used as supporting indicators. The use of multiple error indicators is recommended because each indicator captures different aspects of forecasting accuracy, including average absolute error, squared error sensitivity, and relative percentage error [13], [14]. The selected forecasting result was then used to estimate the annual demand (D), while the historical or forecast-based demand variation was used to determine the standard deviation of demand.

Continuous Review Inventory Parameter Calculation

After the annual demand *(D)*, demand rate d, demand standard deviation, ordering cost, holding cost, and lead time were obtained, the inventory parameters were calculated using the Continuous Review model. In this model, inventory is monitored continuously, and an order is placed when the inventory position reaches the reorder point. This approach is commonly used when demand is uncertain and replenishment decisions must be made based on both expected demand and service-level protection [15], [16].

The optimal order quantity was calculated using:

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

where Q^* is the optimal order quantity, D is annual demand, A is ordering cost per order, and h is holding cost per unit per year. This equation was used to determine the economically efficient order size by balancing ordering cost and holding cost.

Safety stock was calculated to protect against uncertainty in demand during the procurement lead time:

$$SS = z\sigma_L \quad (2)$$

where *SS* is safety stock, *z* is the standard normal deviate corresponding to the target service level, and σ_L is the standard deviation of demand during lead time. The value of *z* must be determined from the service level used in the calculation. If the original data only provide monthly demand variation, the standard deviation must be converted into lead-time demand variation before being applied in the safety stock equation. Safety stock was calculated to protect against demand uncertainty during the procurement lead time. The calculation used the standard normal deviate (z), demand variability during lead time, and the procurement lead time recorded in the clinic's inventory data. Because the available manuscript data do not separately report the service level and the corresponding (z)-value, these parameters are treated as fixed calculation assumptions used in the inventory computation. The lead-time and demand-rate variables were expressed on a consistent time basis before calculating the safety stock and reorder point. Sensitivity testing for different service levels and lead-time assumptions was not conducted in this study and is therefore identified as a limitation for future research.

The reorder point was calculated as:

$$r = dL + SS \quad (3)$$

where *r* is the reorder point, *d* is the average demand per unit time, *L* is procurement lead time, and *SS* is safety stock. The term *dL* represents the expected demand during lead time, while *SS* provides additional protection against demand and lead-time uncertainty. To avoid ambiguity, *d* and *L* must be expressed in the same time basis, for example daily demand with lead time in days, or monthly demand with lead time in months.

The maximum inventory level was calculated after considering the optimal order quantity, reorder point, safety stock, and packaging-unit conversion used for each injectable drug. Because the drug items were recorded in different units, such as bottles, ampoules, vials, blisters, and boxes, all calculations should be converted into a consistent unit before reporting (Q*), (r), (SS), and (S_{max}).* The maximum stock level (S) was determined after considering the optimal order quantity, reorder point, safety stock, and the packaging-unit conversion applied in the clinic's inventory records. Because the injectable drug items were recorded in different units, such as bottles, ampoules, vials, blisters, and ordering packages, the final values of (Q*), (r), (SS), and (S) were reported according to the operational units used in the clinic's procurement and storage system. Therefore, the maximum stock level represents the upper inventory limit after accounting for the relevant ordering and storage-unit conversion for each drug item.

Estimation of Expired Products

Because injectable drugs have limited shelf life, the expected number of expired products was estimated as part of the proposed inventory policy. This study applied the Chiu approximation approach, which extends the Continuous Review model for perishable inventory systems by considering the interaction among order quantity, reorder point, product shelf life, lead time, and demand distribution [17]. The approach is relevant for pharmaceutical inventory because drug items are subject to expiration and may generate financial loss if they remain unused beyond their shelf life [18], [19].

The expected number of expired products was estimated using:

$$Q_{kd} = \int_0^{r+Q}(r+q-u)f_{m+L}(u)\,,du - \int_0^{r}(r-u)f_{m+L}(u)\,,du \quad (4)$$

where Q_{kd} is the expected number of expired products, r is the reorder point, q is the inventory level within the cycle, u is the demand variable, m is product shelf life, L is lead time, and $f_{m+L}(u)$ is the probability function of demand during the period (m+L). Demand was assumed to follow a discrete probability distribution because injectable drugs are counted in units. If a Poisson distribution was used, the author should explicitly state the assumption and justify it based on the observed demand pattern.

Total Inventory Cost Calculation

The Total Inventory Cost (TIC) was calculated to compare the cost performance of the existing clinic policy and the proposed Continuous Review policy. TIC included purchasing cost, ordering cost, holding cost, shortage cost, expiration cost, and disposal cost:

$$TIC = PC + OC + HC + SC + EC + DC \quad (5)$$

Purchasing cost was calculated as:

$$PC = P \times D \quad (6)$$

where (PC) is purchasing cost, (P) is unit price, and (D) is annual demand.

Ordering cost was calculated as:

$$OC = A \times \frac{D}{Q} \quad (7)$$

where (OC) is ordering cost, (A) is ordering cost per order, (D) is annual demand, and (Q) is order quantity.

Holding cost was calculated based on the average inventory level maintained during the inventory cycle:

$$HC = h\left(\frac{Q}{2} + SS\right) \quad (8)$$

where (HC) is holding cost, (h) is holding cost per unit per year, (Q) is order quantity, and (SS) is safety stock. Holding cost was calculated based on the average inventory level maintained under the proposed ordering policy, while shortage cost was calculated using the expected shortage component generated from the inventory model. Expiration cost was evaluated after estimating the expected number of expired products. Since the proposed policy produced an estimated expired quantity of zero for all observed injectable drug items, the expiration cost component was recorded as zero in the proposed policy. Disposal cost was included as a fixed cost component consisting of transportation and wastewater treatment-related costs for pharmaceutical waste handling. The Total Inventory Cost was then obtained by summing purchasing cost, ordering cost, holding cost, shortage cost, expiration cost, and disposal cost.

Shortage cost was calculated based on the expected shortage per cycle:

$$SC = \left(\frac{C_u D}{Q} + h\right) N \quad (9)$$

where (SC) is shortage cost, (C_u) is shortage cost per unit, (D) is annual demand, (Q) is order quantity, and (N) is the expected shortage per cycle. The author should explain how (N) was obtained because this value affects the shortage cost and total inventory cost.

Expiration cost was calculated after estimating the expected number of expired products. Since the results later show that the expected expired quantity was zero for all observed injectable drugs, the expiration cost component was treated as zero in the proposed policy. The expiration cost equation in the original calculation should be verified before final submission to ensure dimensional consistency among (Q_{kd}), unit price, and expiration-related cost parameters. Expiration-related cost should not mix unit quantities and monetary values in the same subtraction term unless the variables are first converted to comparable units.

Disposal cost was calculated as:

$$\text{DC} = \text{Transportation cost} + \text{Wastewater treatment cost} \quad (10)$$

Transportation cost refers to the cost of transporting expired drugs or pharmaceutical waste from the clinic to a destruction or treatment facility. Wastewater treatment cost refers to the cost required to process pharmaceutical waste before disposal. In this study, disposal cost was included as a fixed cost component in both the existing and proposed inventory cost calculations.

Cost-Efficiency Evaluation

After all inventory parameters and cost components were calculated, the TIC under the existing clinic policy was compared with the TIC generated by the proposed Continuous Review policy. The cost saving was calculated using:

$$\text{Cost saving} = TIC_{\text{existing}} - TIC_{\text{proposed}} \quad (11)$$

The percentage of cost reduction was calculated as:

$$\text{Cost saving percentage} = \frac{TIC_{\text{existing}} - TIC_{\text{proposed}}}{TIC_{\text{existing}}} \times 100\% \quad (12)$$

This comparison was used to evaluate whether the proposed inventory policy reduced total inventory cost compared with the existing clinic policy. The evaluation focused on cost efficiency and inventory planning feasibility rather than statistical causal inference.

RESULTS AND DISCUSSION

Demand Forecasting Results

Demand forecasting was performed using monthly demand data for 18 injectable drug items from January to December 2023. Several time-series forecasting methods were evaluated, including Simple Average, Moving Average, Weighted Moving Average, Single Exponential Smoothing, Double Exponential Smoothing, Adaptive Exponential Smoothing, and Linear Regression. The best forecasting method for each drug item was selected during the calculation process by comparing forecasting error indicators, namely MAD, MSE, and MAPE. Because the full error-comparison output is not displayed in the main results table, this section reports the forecasted monthly demand values generated from the selected best method for each injectable drug item.

Table 1 presents the forecasted monthly demand for the 18 injectable drugs based on the selected best forecasting method. Several items showed stable forecasted demand throughout the period, including Epinephrine, Mersibion, Ondansetron, Oxytocin, and Hepatitis B Vaccine. Lidocaine recorded the highest forecasted demand among all items, increasing from 116 units in January to 145 units in December. In contrast, several items showed a gradual decrease in forecasted demand, including Dextrose, Vitamin K, Buscopan Injection, Vitamin C, Omeprazole Injection, and Ceftriaxone Injection. The forecasted values in Table 1 were then used as input for estimating annual demand and calculating inventory control parameters in the Continuous Review model.

Table 1. Forecasted Monthly Demand for 18 Injectable Drug Items Based on the Selected Best Forecasting Method

No.	Injectable Drug Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Dextrose (Bottle)	6	6	6	6	5	5	5	5	5	5	4	4
2	Dexamethasone (Ampoule)	10	10	10	10	10	10	11	11	11	11	11	11
3	Epinephrine (Ampoule)	5	5	5	5	5	5	5	5	5	5	5	5
4	Ketorolac (Ampoule)	10	9	9	9	9	9	9	9	9	9	9	9
5	Kanamycin Sulfate (Vial)	11	12	12	12	12	12	13	13	13	13	13	14
6	Lidocaine (Ampoule)	116	118	121	124	126	129	132	134	137	140	142	145
7	Methergine (Ampoule)	9	9	9	9	9	8	8	8	8	8	8	8
8	Mersibion (Ampoule)	19	19	19	19	19	19	19	19	19	19	19	19
9	Ondansetron (Ampoule)	9	9	9	9	9	9	9	9	9	9	9	9
10	Oxytocin (Ampoule)	20	20	20	20	20	20	20	20	20	20	20	20
11	Pehacaine (Ampoule)	20	20	21	21	21	21	21	21	21	21	21	21
12	Vitamin K (Ampoule)	16	16	16	15	15	14	14	13	13	12	12	12
13	Hepatitis B Vaccine (Ampoule)	10	10	10	10	10	10	10	10	10	10	10	10
14	Buscopan Injection (Ampoule)	6	6	6	6	6	5	5	5	5	5	5	4
15	Vitamin C (Ampoule)	24	23	23	22	22	22	22	22	21	21	21	20
16	Ranitidine (Ampoule)	9	9	10	10	10	10	10	10	10	10	11	11
17	Omeprazole Injection (Vial)	8	8	7	7	7	6	6	6	6	5	5	5
18	Ceftriaxone Injection (Vial)	19	19	18	18	18	18	18	17	17	17	17	17

Table 1 therefore functions as the final forecasting-output table rather than as a forecasting-error comparison table. The values shown in the table were used as the demand input for subsequent Continuous Review calculations, including annual demand estimation, reorder point calculation, safety stock calculation, and Total Inventory Cost comparison.

Continuous Review Inventory Parameter Results

Table 2 presents the inventory control parameters calculated using the Continuous Review model, including the optimal order quantity (Q∗), reorder point (r), safety stock (SS), and maximum stock level (S). The parameters varied across drug items because each item had different demand levels, demand variability, lead-time requirements, and ordering or storage-unit characteristics. The smallest optimal order quantity was recorded for Buscopan Injection (Q∗=7), whereas the largest was recorded for Lidocaine (Q∗=121). The reorder point ranged from 5 units for Dextrose, Epinephrine, and Buscopan Injection to 131 units for Lidocaine. Safety stock was zero for most items, except for Lidocaine, which required one unit of safety stock. The maximum stock level was highest for Lidocaine (S=1332), reflecting its higher forecasted demand and the unit-conversion structure used in the clinic's inventory records.

Table 2. Inventory Control Parameters Calculated Using the Continuous Review Model

No.	Injectable Drug Item	(Q*) (Ordering Unit)	Reorder Point, (r)	Safety Stock, (SS)	Maximum Stock Level, (S)
1	Dextrose (Bottle)	22	5	0	27
2	Dexamethasone (Ampoule)	26	11	0	26
3	Epinephrine (Ampoule)	9	5	0	91
4	Ketorolac (Ampoule)	21	9	0	216
5	Kanamycin Sulfate (Vial)	13	13	0	237
6	Lidocaine (Ampoule)	121	131	1	1332
7	Methergine (Ampoule)	16	9	0	162
8	Mersibion (Ampoule)	32	19	0	338
9	Ondansetron (Ampoule)	23	9	0	238
10	Oxytocin (Ampoule)	26	20	0	278
11	Pehacaine (Ampoule)	32	21	0	336
12	Vitamin K (Ampoule)	20	14	0	205
13	Hepatitis B Vaccine (Ampoule)	9	10	0	98
14	Buscopan Injection (Ampoule)	7	5	0	67
15	Vitamin C (Ampoule)	23	22	0	246
16	Ranitidine (Ampoule)	24	10	0	242
17	Omeprazole Injection (Vial)	8	6	0	77
18	Ceftriaxone Injection (Vial)	19	18	0	207

Note: (Q), (r), (SS), and (S) are reported according to the ordering and storage units used in the clinic's inventory records. The values reflect the unit conversion applied between procurement packages and item-level storage units for each injectable drug.*

Estimated Expired Product Results

Table 3 presents the estimated number of expired products for each injectable drug item, expressed as Q_{kd}. The results show that all 18 injectable drug items had an estimated expired quantity of zero (Q_{kd}=0). This result indicates that, based on the calculation assumptions and

input data used in the proposed policy, no expected expired units were identified during the observed planning period.

Table 3. Estimated Number of Expired Products for Each Injectable Drug Item

No.	Injectable Drug Item	(Q_{kd})	No.	Injectable Drug Item	(Q_{kd})
1	Dextrose (Bottle)	0	10	Oxytocin (Ampoule)	0
2	Dexamethasone (Ampoule)	0	11	Pehacaine (Ampoule)	0
3	Epinephrine (Ampoule)	0	12	Vitamin K (Ampoule)	0
4	Ketorolac (Ampoule)	0	13	Hepatitis B Vaccine (Ampoule)	0
5	Kanamycin Sulfate (Vial)	0	14	Buscopan Injection (Ampoule)	0
6	Lidocaine (Ampoule)	0	15	Vitamin C (Ampoule)	0
7	Methergine (Ampoule)	0	16	Ranitidine (Ampoule)	0
8	Mersibion (Ampoule)	0	17	Omeprazole Injection (Vial)	0
9	Ondansetron (Ampoule)	0	18	Ceftriaxone Injection (Vial)	0

Inventory Cost under the Existing Policy

Table 4 presents the inventory cost components under the existing inventory policy at Clinic X. The cost components include purchasing cost (PC), ordering cost (OC), holding cost (HC), stockout cost (SC), disposal cost (DC), and total inventory cost (TIC). Under the existing policy, the total purchasing cost was IDR 20,674,550. The total ordering cost was IDR 14,472,000, while the total holding cost and stockout cost were IDR 171,343 and IDR 85,671, respectively. The total disposal cost was IDR 450,000. Overall, the total inventory cost under the existing policy was IDR 35,853,564. Among individual drug items, Hepatitis B Vaccine had the highest TIC at IDR 3,380,500, followed by Lidocaine at IDR 3,125,075 and Kanamycin Sulfate at IDR 2,804,350.

Table 4. Inventory Cost Components under the Existing Policy at Clinic X

No	Injectable Drug Item	(PC) (IDR)	(OC) (IDR)	(HC) (IDR)	(SC) (IDR)	(DC) (IDR)	(TIC) (IDR)
1	Dextrose (Bottle)	1,116,000	804,000	9,000	4,500	25,000	1,958,500
2	Dexamethasone (Ampoule)	315,000	804,000	2,750	1,375	25,000	1,148,125
3	Epinephrine (Ampoule)	660,000	804,000	5,500	2,750	25,000	1,497,250
4	Ketorolac (Ampoule)	370,600	804,000	3,060	1,530	25,000	1,204,190
5	Kanamycin Sulfate (Vial)	1,950,000	804,000	16,900	8,450	25,000	2,804,350

No	Injectable Drug Item	(PC) (IDR)	(OC) (IDR)	(HC) (IDR)	(SC) (IDR)	(DC) (IDR)	(TIC) (IDR)
6	Lidocaine (Ampoule)	2,267,800	804,000	18,850	9,425	25,000	3,125,075
7	Methergine (Ampoule)	585,800	804,000	4,640	2,320	25,000	1,421,760
8	Mersibion (Ampoule)	684,000	804,000	5,700	2,850	25,000	1,521,550
9	Ondansetron (Ampoule)	297,000	804,000	2,475	1,238	25,000	1,129,713
10	Oxytocin (Ampoule)	1,158,000	804,000	9,650	4,825	25,000	2,001,475
11	Pehacaine (Ampoule)	843,750	804,000	7,088	3,544	25,000	1,683,381
12	Vitamin K (Ampoule)	1,041,600	804,000	8,680	4,340	25,000	1,883,620
13	Hepatitis B Vaccine (Ampoule)	2,520,000	804,000	21,000	10,500	25,000	3,380,500
14	Buscopan Injection (Ampoule)	1,440,000	804,000	11,250	5,625	25,000	2,285,875
15	Vitamin C (Ampoule)	1,841,000	804,000	15,400	7,700	25,000	2,693,100
16	Ranitidine (Ampoule)	360,000	804,000	3,000	1,500	25,000	1,193,500
17	Omeprazole Injection (Vial)	1,520,000	804,000	12,000	6,000	25,000	2,367,000
18	Ceftriaxone Injection (Vial)	1,704,000	804,000	14,400	7,200	25,000	2,554,600
	Total	20,674,550	14,472,000	171,343	85,671	450,000	35,853,564

Inventory Cost under the Proposed Continuous Review Model

Table 5 presents the inventory cost components generated from the proposed Continuous Review model. The table includes purchasing cost, ordering cost, holding cost, stockout cost, expiration cost, disposal cost, and total inventory cost for each injectable drug item. Under the proposed model, the total purchasing cost remained IDR 20,674,550 because the same demand requirement was used in the calculation. The total ordering cost decreased to IDR 1,198,649, while the total holding cost increased to IDR 1,016,274. The total stockout cost decreased to IDR 425. The expiration cost column shows no cost value for all drug items, which is consistent with the estimated expired quantity of zero reported in Table 3. The disposal cost remained IDR 450,000. Overall, the proposed Continuous Review model resulted in a total inventory cost of IDR 23,339,897.

Table 5. Inventory Cost Components under the Proposed Continuous Review Model

No	Injectable Drug Item	(PC) (IDR)	(OC) (IDR)	(HC) (IDR)	(SC) (IDR)	(EC) (IDR)	(DC) (IDR)	(TIC) (IDR)
1	Dextrose (Bottle)	1,116,000	188,818	19,537	117	-	25,000	1,349,472
2	Dexamethasone (Ampoule)	315,000	32,469	32,636	5	-	25,000	405,109
3	Epinephrine (Ampoule)	660,000	46,744	47,322	-	-	25,000	779,066
4	Ketorolac (Ampoule)	370,600	35,280	35,174	-	-	25,000	466,054
5	Kanamycin Sulfate (Vial)	1,950,000	81,048	81,315	38	-	25,000	2,137,401
6	Lidocaine (Ampoule)	2,267,800	87,178	87,317	8	-	25,000	2,467,303
7	Methergine (Ampoule)	585,800	44,229	44,728	13	-	25,000	699,770
8	Mersibion (Ampoule)	684,000	47,887	47,873	-	-	25,000	804,760
9	Ondansetron (Ampoule)	297,000	31,598	31,497	-	-	25,000	385,096
10	Oxytocin (Ampoule)	1,158,000	70,218	55,285	-	-	25,000	1,308,503
11	Pehacaine (Ampoule)	843,750	53,175	53,241	-	-	25,000	975,165
12	Vitamin K (Ampoule)	1,041,600	58,932	59,245	37	-	25,000	1,184,814
13	Hepatitis B Vaccine (Ampoule)	2,520,000	91,364	92,484	-	-	25,000	2,728,848
14	Buscopan Injection (Ampoule)	1,440,000	69,161	69,048	75	-	25,000	1,603,284
15	Vitamin C (Ampoule)	1,841,000	78,665	78,520	27	-	25,000	2,023,212
16	Ranitidine (Ampoule)	360,000	34,655	34,812	6	-	25,000	454,473
17	Omeprazole Injection (Vial)	1,520,000	71,718	70,384	71	-	25,000	1,687,173
18	Ceftriaxone Injection (Vial)	1,704,000	75,508	75,857	29	-	25,000	1,880,394
	Total	20,674,550	1,198,649	1,016,274	425	-	450,000	23,339,897

Comparison between Existing and Proposed Total Inventory Cost

Table 6 compares the total inventory cost under the existing policy and the proposed Continuous Review model. The comparison includes the cost difference and percentage saving for each injectable drug item. The total inventory cost decreased from IDR 35,853,564 under the existing policy to IDR 23,339,897 under the proposed Continuous Review model. This represents a cost reduction of IDR 12,513,667, equivalent to approximately 35% of the existing total inventory cost. Cost savings were observed for all 18 injectable drug items. The highest

percentage savings were recorded for Ondansetron (66%), Dexamethasone (65%), Ranitidine (62%), and Ketorolac (61%). The lowest percentage savings were recorded for Hepatitis B Vaccine (19%), Lidocaine (21%), Kanamycin Sulfate (24%), and Vitamin C (25%).

Table 6. Comparison of Total Inventory Cost between the Existing Policy and the Proposed Continuous Review Model

No	Injectable Drug Item	Existing TIC (IDR)	Proposed TIC (IDR)	Cost Difference (IDR)	Cost Saving (%)
1	Dextrose (Bottle)	1,958,500	1,349,472	609,028	31%
2	Dexamethasone (Ampoule)	1,148,125	405,109	743,016	65%
3	Epinephrine (Ampoule)	1,497,250	779,066	718,184	48%
4	Ketorolac (Ampoule)	1,204,190	466,054	738,136	61%
5	Kanamycin Sulfate (Vial)	2,804,350	2,137,401	666,949	24%
6	Lidocaine (Ampoule)	3,125,075	2,467,303	657,772	21%
7	Methergine (Ampoule)	1,421,760	699,770	721,990	51%
8	Mersibion (Ampoule)	1,521,550	804,760	716,790	47%
9	Ondansetron (Ampoule)	1,129,713	385,096	744,617	66%
10	Oxytocin (Ampoule)	2,001,475	1,308,503	692,972	35%
11	Pehacaine (Ampoule)	1,683,381	975,165	708,216	42%
12	Vitamin K (Ampoule)	1,883,620	1,184,814	698,806	37%
13	Hepatitis B Vaccine (Ampoule)	3,380,500	2,728,848	651,652	19%
14	Buscopan Injection (Ampoule)	2,285,875	1,603,284	682,591	30%
15	Vitamin C (Ampoule)	2,693,100	2,023,212	669,888	25%
16	Ranitidine (Ampoule)	1,193,500	454,473	739,027	62%
17	Omeprazole Injection (Vial)	2,367,000	1,687,173	679,827	29%
18	Ceftriaxone Injection (Vial)	2,554,600	1,880,394	674,206	26%
	Total	35,853,564	23,339,897	12,513,667	35%

Discussion

The findings show that the proposed Continuous Review model reduced the Total Inventory Cost (TIC) from IDR 35,853,564 under the existing clinic policy to IDR 23,339,897 under the proposed policy, resulting in a cost saving of IDR 12,513,667, or approximately 35%. This result indicates that a structured inventory policy can improve procurement efficiency by determining more appropriate order quantities and reorder points for each injectable drug item. Similar evidence has been reported in drug inventory management studies showing that systematic inventory classification and ordering-policy design can improve inventory control and reduce inefficiencies in pharmaceutical stock management [20]. In addition, forecasting-based inventory planning has been shown to support more accurate procurement decisions in the pharmaceutical sector, particularly when demand uncertainty affects order quantity and replenishment timing [21].

The reduction in TIC was mainly driven by the substantial decrease in ordering cost, although the proposed policy increased holding cost. This pattern indicates that the proposed Continuous Review model did not reduce all cost components simultaneously; rather, it created a cost trade-off between ordering cost and holding cost. This trade-off is consistent with inventory management practice in healthcare facilities, where the objective is not to minimize a single cost component but to achieve a lower total cost while maintaining adequate product availability. Previous studies on healthcare inventory systems have shown that inventory performance is closely related to the ability of healthcare facilities to control stock levels, update inventory records, and apply appropriate stock monitoring mechanisms [22]. Similar findings have also been reported in health-commodity inventory management, where inaccurate stock control may lead to inefficient procurement, stock imbalance, and increased operational burden [23].

The forecasting results also have important implications for the proposed inventory policy. Several injectable drug items showed relatively stable forecasted demand, while others showed gradual increases or decreases during the observed period. Lidocaine had the highest forecasted demand and consequently generated the largest order quantity, reorder point, and maximum stock level. This finding suggests that high-demand items require different inventory treatment from low-demand and stable-demand items. Therefore, demand forecasting should be understood as a key input for inventory parameter calculation, not merely as a descriptive stage. In pharmaceutical inventory systems, inaccurate demand estimation may contribute to overstocking, stockouts, and product wastage, especially when the procurement system does not regularly update demand information [24]. More advanced inventory information systems, including vendor-managed inventory and data-driven supply chain platforms, have also been shown to improve stock visibility and support more responsive pharmaceutical supply chain management when adequate data infrastructure is available [25].

The Continuous Review calculation showed that most injectable drugs required zero safety stock, except Lidocaine, which required one unit of safety stock. This result may reflect relatively low calculated demand variability during the lead time for most drug items. However, this finding should be interpreted cautiously because safety stock is highly dependent on the service level, lead-time assumption, demand variability, and unit-conversion procedure used in the calculation. In healthcare supply chains, insufficient buffer stock may increase the risk of stockouts, while excessive buffer stock may increase holding cost and expiration risk. Drug shortages have been linked to supply chain disruption, demand fluctuation, limited supplier coordination, and weak inventory planning [26]. Supply chain reliability also plays an important role in maintaining drug availability, particularly when replenishment lead time and supplier performance are uncertain [27]. Therefore, the low safety stock values in this study

should be interpreted as model-based outputs under the available clinic data, not as general evidence that buffer stock is unnecessary.

The model-based expiration estimation indicated that all injectable drug items had zero expected expired units under the proposed policy. This finding suggests that, under the calculation assumptions used in this study, the proposed ordering policy was able to align inventory level with the estimated demand and product shelf-life condition. Nevertheless, the zero-expiration result should not be interpreted as a guarantee that expiration risk will be eliminated in actual operations. Studies on pharmaceutical procurement and inventory systems have shown that operational problems may still occur when procurement coordination, supplier response, stock rotation, or institutional monitoring is weak [28]. Medicine wastage studies also indicate that expired products can arise from oversupply, inaccurate demand planning, poor recordkeeping, and ineffective inventory control practices [29]. Therefore, the zero-expired-unit result in this study should be interpreted as an expected value generated by the model, rather than as a direct operational guarantee.

The findings are also relevant to the broader issue of medicine availability and pharmaceutical waste control in healthcare facilities. Effective inventory management requires not only correct ordering decisions but also reliable logistics records, updated stock cards, regular stock monitoring, and timely review of stock movement. Evidence from tracer-medicine studies shows that inventory performance is strongly influenced by the quality of stock records, availability of logistics tools, and consistency of inventory control practices in public health facilities [30]. In addition, empirical evidence from public hospitals shows that expired medicines can generate measurable economic losses, indicating the importance of integrating expiration control into pharmaceutical inventory planning [31]. In this context, the present study contributes by demonstrating how demand forecasting, Continuous Review parameters, expired-product estimation, and TIC comparison can be integrated into a practical inventory policy for injectable drugs at the clinic level.

From a practical perspective, the proposed inventory policy provides Clinic X with a more structured basis for determining how much to order, when to reorder, how much safety stock to maintain, and how to control maximum inventory level for each injectable drug item. This is particularly important because injectable drugs often have limited shelf life and require closer monitoring than non-perishable inventory items. The results suggest that clinic-level inventory planning can be improved by combining demand forecasting with probabilistic inventory parameters and expiration considerations. However, the proposed policy should be implemented with routine monitoring of demand changes, lead time, expiry dates, and supplier reliability. Without periodic recalculation, the inventory parameters may become less accurate when demand patterns or procurement conditions change.

Overall, the study provides a practical contribution to pharmaceutical inventory management by applying the Continuous Review model with expiration considerations in a clinic-level injectable drug context. The main contribution is not the development of a new theoretical model, but the integration of forecasting output, inventory parameter calculation, expired-product estimation, and cost comparison into a decision-support approach for drug inventory control. However, the findings should be interpreted within the scope of the available data. The study was conducted in one clinic, used one year of historical demand data, and focused only on 18 injectable drug items. Future research should apply the model to broader healthcare settings, include more pharmaceutical categories, report forecasting accuracy in greater detail, and test the sensitivity of the results to changes in service level, lead time, demand variability, and expiration-related cost assumptions.

CONCLUSION

This study developed an injectable drug inventory control policy for Clinic X using the Continuous Review model with product expiration considerations. The findings show that the proposed policy provides a more structured basis for determining order quantity, reorder point, safety stock, and maximum stock level for 18 injectable drug items. The main contribution of this study lies in integrating demand forecasting, probabilistic inventory control parameters, expired-product estimation, and Total Inventory Cost comparison into a practical decision-support approach for clinic-level pharmaceutical inventory management. The proposed policy reduced the Total Inventory Cost from IDR 35,853,564 under the existing clinic policy to IDR 23,339,897, resulting in a cost saving of IDR 12,513,667, or approximately 35%. The model-based expiration estimation indicated zero expected expired units for the observed injectable drugs under the proposed policy. However, this result should be interpreted within the assumptions and data scope of the study, rather than as a guarantee that expiration risk will be eliminated under all operational conditions. This study was conducted in a single clinic, used one year of historical demand data, and focused only on 18 injectable drug items. Future research should apply the model to broader healthcare settings, include more pharmaceutical categories, and examine the sensitivity of the results to changes in service level, lead time, demand variability, and expiration-related cost assumptions.

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