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Integrated Inventory Planning Using Periodic Review and Discrete Event Simulation for Perishable Products in Retail

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Abstract: Perishable products pose inventory management challenges in retail due to their limited shelf life and susceptibility to waste; inventory decisions must balance product availability against excessive stock and lost sales. This study develops an integrated inventory planning framework combining sales forecasting, periodic review inventory policies, and Discrete Event Simulation (DES) to evaluate inventory performance in retail operations. A quantitative simulation-based quasi-experimental design was employed using secondary data from ten retail stores in Indonesia. The dataset comprised daily sales from 1 October to 31 December 2025, shelf life, lead time, minimum order quantity, opening stock, and existing company inventory policies. The DES model simulated daily inventory movements, including replenishment, deliveries, sales, waste, and lost sales, enabling inventory performance evaluation at the product, department, and store levels. Across ten stores, the aggregated waste ratio was 5%, while the lost sales ratio was 4%. At the product level, Leafy A1 recorded waste and lost sales ratios of 2% each, whereas Salad Q14 recorded 13% and 11%, respectively. These variations across products highlight opportunities for improvement in inventory planning. Integrating periodic review policies with daily DES provides a practical framework for evaluating replenishment decisions and identifying inventory performance issues across multiple products and stores. Further research should investigate alternative review periods, dynamic safety stock, improved forecasting accuracy, and product-age tracking to further improve inventory performance and reduce waste.

Keywords: Discrete-event simulation, inventory control, periodic review, perishable products, retail, waste

INTRODUCTION

According to the Ministry of Finance of the Republic of Indonesia, the government is strengthening the retail industry as a key driver of the national economy. The development of the retail sector is expected to contribute to the government's target of achieving 8% economic growth by 2028 (Kementerian Keuangan Republik Indonesia, 2025). The Indonesian retail market is projected to reach a market size of USD 56.78 billion in 2025 with a compound

annual growth rate (CAGR) of 5.6%. This growth is expected to continue at the same CAGR through 2032 (DataMarketView, 2026). In the retail industry, product assortment is a key strategy to enhance customer attraction and retention (Hübner & Kuhn, 2024). Supermarkets offer larger assortments than convenience stores, including perishable products. Perishable products have a limited shelf life and high susceptibility to quality deterioration (Badakhshan et al., 2024). Perishable products that experience quality deterioration will become waste.

Perishable products contribute approximately 40% of total revenue in the food supply chain but also generate the highest value of waste (Hasiloglu-Ciftciler & Kaya, 2025). Based on the company's data, perishable products contribute 79% of the company's total waste. These products are divided into three departments, consisting of Vegetable and Fruit, Fish, and Meat. Vegetable and Fruit contribute 61% of total perishable sales but generate 79% of total perishable waste with waste rate of 9–12%. This indicates that the Vegetable and Fruit Department is the most critical to manage because of its short shelf life and high risk of waste. Besides waste, product availability is another consequence of inventory decisions in perishable retail operations. Insufficient inventory may reduce service level and lead to lost sales, making these indicators essential for evaluating inventory performance alongside waste.

Vegetable and Fruit products in retail are not produced by retailers but by suppliers. Therefore, ordering decisions are an essential part of inventory planning to maintain product availability and prevent excessive inventory that may lead to waste. Among the various inventory policies, periodic review is widely adopted in retail operations because it aligns with the trading terms between retailers and suppliers. Hendrix et al. (2023) used periodic review inventory policies based on the company's policies. Similarly, some studies applied review periods determined by operational practice rather than deriving them through optimization models (Clarkson, n.d.; van Donselaar & Broekmeulen, 2025; Kusomrosananan & Phumchusri, 2024). Therefore, this study uses the existing periodic review based on the company's policies.

Discrete Event Simulation (DES) is a simulation method used to model how system changes over time through a sequence of discrete events. DES provides a suitable approach for representing inventory systems. DES has been applied in inventory management to evaluate inventory and logistics decisions under uncertainty (Staff & Mustafee, 2023). In perishable inventory management, DES is relevant because inventory flows, replenishment, sales uncertainty, product age, and waste can be represented within the simulation model (Maidana-Aquino et al., 2026). Previous retail applications have also presented the use of DES for determining inventory policies (Pathom, 2023). In this study, DES represents the daily inventory for each product and each store.

Previous studies have integrated forecasting and periodic review inventory policies (Cano-Olivos, 2021). Hasiloglu-Ciftciler and Kaya developed a dynamic model that integrates ordering and pricing to balance profit and waste, and simulation has also been applied to such systems (Hasiloglu-Ciftciler & Kaya, 2025). Solari et al. developed a DES model to evaluate daily inventory and reordering policies but focused on a single product (Solari et al., 2025). Research integrating sales forecasting with periodic review inventory policy and evaluating its implementation through DES using operational data from hundreds of perishable products across multiple stores remains limited.

This study aims to develop a simulation-based inventory planning framework to support the implementation of the existing sales forecasting, periodic review inventory policy, and DES for perishable products in retail operations. Sales forecasts are used to estimate product demand, while safety stock, opening stock, minimum order quantity, lead time, and review period are incorporated into the ordering process. DES is used to generate daily inventory movements and evaluate inventory performance, including not only waste but also service level and lost sales. This study contributes to both academic knowledge and practical retail operations. From an academic perspective, this study offers valuable insight into the integration

of inventory planning for perishable products and its evaluation through DES within one framework. From a practical perspective, it provides actionable recommendations to accelerate decision-making processes in the retail industry.

METHODS

3.1 Research Design

This study employed a quantitative simulation-based quasi-experimental design. Quantitative research uses numerical data and objective analysis, while quasi-experimental design is appropriate when a controlled experiment cannot be conducted directly in an actual condition (Sugiyono, 2025).

3.2 Research Data and Data Collection

All data used in this study were secondary data from internal company documents. The data were collected through a document study approach. The dataset included daily sales from 1 October to 31 December 2025 across 10 retail stores, shelf life, lead time, Minimum Order Quantity (MOQ), periodic review policy, opening stock, and waste. The ten retail stores were coded as S-A, S-B, S-C, S-D, S-E, S-F, S-G, S-H, S-I, and S-J.

3.3 Data Analysis Method

3.3.1.Periodic Review

This study applied the Periodic Review policy previously implemented by the company. Under this policy, inventory was reviewed at fixed intervals. Table 1 shows the periodic review classification. All periodic review intervals are shorter than the shelf life. The review period also served as the ordering interval. The review interval was determined based on each product's shelf life. For example, products with a shelf life of 1 or 2 days were reviewed and reordered daily. Products with a shelf life of 3–5 days were reviewed and reordered every 2 days.

Table 1. Periodic Review Classification

Shelf Life (days)	Periodic Review (days)
1	1
2	1
3	2
4	2
5	2
6	3
7	3
8	3
9	3
10	7
14	7
21	7
30	14
60	30
90	30
180	30
360	30
365	30

3.3.2.Sales Forecasting Data

This study used sales forecast data previously calculated by the company. The forecasting results were aggregated as demand over the ordering interval and used as input for safety stock calculations.

3.3.3.Standard Deviation

The standard deviation of demand was calculated to measure demand variability during the observation period. The standard deviation was computed using the following equation (1).

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{t=1}^{n}\left(D_t - \widehat{D_t}\right)^2} \quad (1)$$

where:

σ :standard deviation of demand
D_t : actual sales at period t
$\widehat{D_t}$: forecast sales at period t
n : number of observations

3.3.4.Safety Stock

Safety stock is used to ensure product availability when supplier service levels are unreliable. It is calculated based on demand during the review period (R) and lead time (L). The company used a service level of 90%. Based on the Z table, the z-score for a service level of 90% is 1.28.

$$SS = z \cdot \sigma\sqrt{R + L} \quad (2)$$

where:

SS : Safety Stock
z : service level factor
R : review period
L : lead time

3.3.5.Order-up-to-level

The order-up-to level (S) represents the target inventory level in the periodic review policy. At each review period, the replenishment quantity is determined to restore the inventory position to the target level (Solari et al., 2025).

$$S = \mu_{R+L} + SS \quad (3)$$

Where:

S : Order-up-to-level
μ_{R+L} : sales forecasting during review period and lead time

3.3.6.Order Quantity

Order quantity was determined by comparing the order-up-to level with the opening stock. When the opening stock had reached or exceeded the target level, no replenishment was placed. If the required replenishment was below the minimum order quantity (MOQ), the order was adjusted to meet the company's ordering policy.

$$Q_t = 0, \ if \ \ S - I_t \leq 0 \quad (4)$$
$$Q_t = MOQ, if \ 0 < S - I_t < MOQ$$
$$Q_t = S - I_t, if \ S - I_t \geq MOQ$$

Where:

Q_t : order quantity at period t
I_t : opening stock at period t
MOQ : Minimum Order Quantity

3.3.7.Service level

$$SL = \frac{Deliver\ quantity}{Order\ quantity} \times 100\%$$

3.3.8.Waste

In the daily movement, the waste quantity was calculated as 20% of the closing stock aging on the last day of shelf life. The waste value was calculated as the waste quantity multiplied by the average price. Then, %Waste was calculated as the waste value divided by the actual sales value.

$$Waste = \text{Waste quantity} \times \text{average selling price} \quad (5)$$

$$\%Waste = \frac{Waste}{Sales} \times 100\% \quad (6)$$

Where

$\%Waste$: waste percentage
Waste : total waste value
Sales : total actual sales value

3.3.9.Loss Sales

In the daily movement, the lost sales quantity was calculated every day. The lost sales value was calculated as the lost sales quantity multiplied by the average selling price. Then, %Loss Sales was calculated as the lost sales value divided by the actual sales value.

$$Loss\ sales\ quantity = max(0, actual\ sales - opening\ stock) \quad (7)$$

$$Loss\ sales = \text{loss sales quantity} \times \text{average selling price} \quad (8)$$

$$\%Loss\ Sales = \frac{Loss\ Sales}{Sales} \times 100\% \quad (9)$$

Where

%Waste : lost sales percentage
Loss Sales : total lost sales value
Sales : total actual sales value

3.3.10. DES Inventory Movement Simulation

The inventory movement simulation was conducted on a daily basis using sales forecasting results as the input. On each day, the model checked whether it was a periodic review day. If the review condition was met, the safety stock and order-up-to level were calculated to determine the order quantity; otherwise, no new order was generated. The delivery quantity was then determined based on the ordering process and applied to calculate the daily service level. Next, the opening stock was calculated by considering the inventory carried over from the previous day and the incoming stock. Actual sales were then recorded, followed by daily waste and lost sales calculations. Finally, the closing stock was calculated after accounting for the daily inventory movements. This process was repeated for each day throughout the simulation period until the final day was reached, after which the inventory performance was evaluated based on the simulation results.

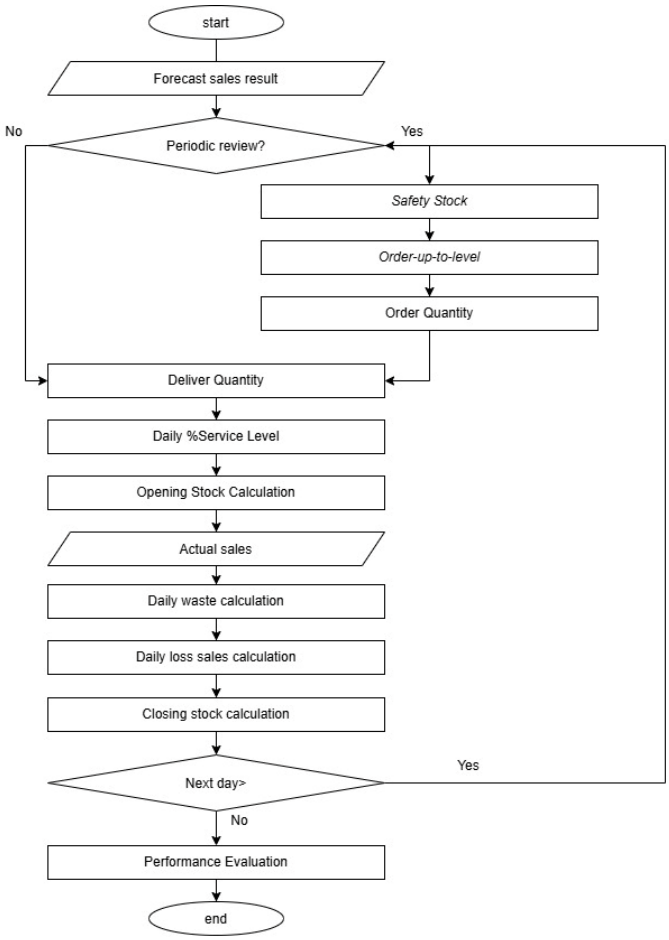


Figure 1. Inventory Movement Flow Using DES

RESULTS AND DISCUSSION

This study used a large-scale dataset from ten stores and multiple products. To present the simulation results more comprehensively and clearly, four representative sample items were selected for the discussion. The selected items represent different product characteristics, such as lead time, review period, shelf life, MOQ, and Unit of Measurement (UOM). Table 2 shows the selected items and their attributes. In the Vegetable Department, the selected items are Salad Q14 and Leafy A1. Salad Q14 has a lead time of 1 day, a review period of 2 days, a shelf life of 3 days, and an MOQ of 1 piece. Leafy A1 has a lead time of 1 day, a daily review period, a shelf life of 2 days, and an MOQ of 1 piece. Leafy A1 represents a highly perishable product that requires more frequent replenishment. In the Fruit Department, the selected items are Stonefruit D and Banana N. Both of them have a lead time of 2 days and a review period of 3 days. Stonefruit D has a shelf life of 7 days with an MOQ of 10 hg. Banana N has a shelf life of 6 days with a large MOQ of 130 hg. The differences represent the various operational conditions used for the implementation of the proposed inventory planning model.

Table 2. Attributes of Four Sample Products

Dept	Item Name	Lead Time	Review Period	Shelf Life	MOQ	Unit of Measurement	Average Price
Vegetable	Salad Q14	1	2	3	1	Pcs	12,541
Vegetable	Leafy A1	1	1	2	1	Pcs	7,313
Fruit	Stonefruit D	2	3	7	10	Hg	5,957
Fruit	Banana N	2	3	6	130	Hg	2,528

4.1. Safety Stock Calculation

Safety stock was calculated by item and by store. Table 3 shows the forecast results and actual sales of Store S-A, one of the ten stores. Standard deviation was calculated from the forecast errors from 1 October to 31 December 2025 using equation (1). Standard deviation of Salad Q14 was 13 pcs. The safety stock was $1.28 \cdot 13 \cdot \sqrt{2+1} = 28.8$ pcs and rounded to 29 pcs. Standard deviation of Leafy A1 was 3 pcs. The safety stock was $1.28 \cdot 3 \cdot \sqrt{1+1} = 5.4$ pcs and rounded to 5 pcs. Standard deviation of Stonefruit D was 76 hg. The safety stock was $1.28 \cdot 76 \cdot \sqrt{3+2} = 217.5$ hg and rounded to 218 hg. Standard deviation of Banana N was 274 hg. The safety stock was $1.28 \cdot 274 \cdot \sqrt{3+2} = 784.2$ hg and rounded to 784 hg.

Table 3. Forecast Sales and Actual Sales of Four Sample Products in Store S-A

	Salad Q14			Leafy A1			Stonefruit D			Banana N		
Date	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error
1-Oct	7	8	1	11	13	2	180	201	21	1916	2187	271
2-Oct	13	13	0	23	24	1	217	218	1	1834	1882	48
3-Oct	9	9	0	18	17	-1	243	227	-16	1920	1743	-177
4-Oct	0	0	0	49	44	-5	630	647	17	2681	2872	191
5-Oct	21	22	1	44	42	-2	866	886	20	3116	3326	210
6-Oct	12	10	-2	22	22	0	534	529	-5	2183	2455	272
7-Oct	6	6	0	27	26	-1	527	471	-56	2123	2017	-106
8-Oct	11	10	-1	15	14	-1	317	284	-33	2455	2139	-316
9-Oct	6	6	0	18	17	-1	225	199	-26	1911	1630	-281
10-Oct	6	5	-1	21	19	-2	347	270	-77	2370	2109	-261
11-Oct	14	12	-2	12	11	-1	874	797	-77	3514	3200	-314
12-Oct	11	12	1	31	29	-2	831	782	-49	4055	3770	-285
13-Oct	7	6	-1	22	22	0	445	408	-37	2569	2349	-220
14-Oct	5	5	0	23	21	-2	334	328	-6	2349	2222	-127
15-Oct	4	4	0	22	23	1	720	713	-7	1878	2001	123
16-Oct	8	8	0	28	25	-3	561	564	3	2284	2254	-30
17-Oct	11	10	-1	21	19	-2	481	397	-84	2383	1895	-488
18-Oct	12	11	-1	32	30	-2	731	642	-89	4158	3750	-408
19-Oct	8	8	0	33	33	0	1021	963	-58	4255	3898	-357
20-Oct	7	7	0	31	31	0	668	639	-29	2371	2139	-232
21-Oct	9	8	-1	11	10	-1	346	336	-10	2087	1845	-242
22-Oct	11	10	-1	22	20	-2	213	186	-27	2298	1870	-428
23-Oct	10	8	-2	12	10	-2	259	232	-27	2144	2001	-143
24-Oct	9	8	-1	22	18	-4	239	224	-15	1857	1702	-155
25-Oct	10	9	-1	30	27	-3	265	278	13	3048	2958	-90
26-Oct	13	11	-2	41	35	-6	781	696	-85	3145	3132	-13
27-Oct	9	8	-1	28	25	-3	259	248	-11	2262	1923	-339
28-Oct	6	6	0	16	14	-2	465	449	-16	2515	2368	-147
29-Oct	5	4	-1	15	14	-1	400	361	-39	2145	2134	-11
30-Oct	11	9	-2	18	15	-3	111	107	-4	1908	1809	-99
31-Oct	7	6	-1	30	26	-4	276	240	-36	2116	2025	-91
1-Nov	11	10	-1	35	33	-2	406	432	26	3411	3206	-205
2-Nov	1	1	0	45	44	-1	556	554	-2	3867	4238	371
3-Nov	6	6	0	23	24	1	268	275	7	2748	3046	298

	Salad Q14			Leafy A1			Stonefruit D			Banana N		
Date	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error
4-Nov	10	11	1	29	30	1	380	412	32	2889	2801	-88
5-Nov	9	9	0	19	19	0	286	287	1	2181	2165	-16
6-Nov	10	10	0	16	17	1	227	226	-1	2370	2167	-203
7-Nov	11	13	2	12	13	1	267	278	11	1447	1511	64
8-Nov	13	13	0	10	10	0	342	358	16	3613	3747	134
9-Nov	9	9	0	12	13	1	586	648	62	3559	3972	413
10-Nov	8	8	0	27	30	3	217	227	10	1400	1571	171
11-Nov	11	12	1	21	22	1	234	223	-11	1445	1461	16
12-Nov	5	5	0	14	14	0	143	153	10	1988	1978	-10
13-Nov	10	10	0	11	12	1	152	141	-11	1870	1866	-4
14-Nov	11	13	2	14	15	1	265	228	-37	1994	1813	-181
15-Nov	16	15	-1	18	18	0	641	594	-47	3573	3352	-221
16-Nov	11	11	0	32	33	1	438	459	21	4219	4509	290
17-Nov	14	13	-1	35	34	-1	283	301	18	2450	2701	251
18-Nov	13	12	-1	22	21	-1	169	153	-16	2245	2016	-229
19-Nov	8	8	0	21	25	4	39	37	-2	1911	1998	87
20-Nov	12	12	0	20	22	2	249	220	-29	2141	2025	-116
21-Nov	10	10	0	12	12	0	711	669	-42	2577	2073	-504
22-Nov	20	20	0	37	36	-1	424	355	-69	3596	3226	-370
23-Nov	14	14	0	11	11	0	572	540	-32	3619	3266	-353
24-Nov	19	18	-1	32	30	-2	344	334	-10	1683	1570	-113
25-Nov	8	9	1	22	22	0	284	279	-5	1991	1857	-134
26-Nov	11	11	0	18	20	2	266	268	2	1345	1342	-3
27-Nov	9	9	0	4	4	0	549	506	-43	1669	1493	-176
28-Nov	10	11	1	12	16	4	424	496	72	1900	2029	129
29-Nov	16	18	2	21	23	2	696	714	18	3274	3336	62
30-Nov	19	19	0	42	45	3	673	680	7	3151	3162	11
1-Dec	16	18	2	25	28	3	420	438	18	2626	2571	-55
2-Dec	10	12	2	19	25	6	369	391	22	2527	2780	253
3-Dec	18	19	1	8	9	1	207	218	11	1997	2081	84
4-Dec	3	3	0	10	10	0	331	275	-56	1992	1590	-402
5-Dec	8	8	0	27	27	0	449	418	-31	2288	2082	-206
6-Dec	21	20	-1	37	35	-2	737	654	-83	2957	2654	-303
7-Dec	8	8	0	25	24	-1	774	744	-30	3643	3438	-205
8-Dec	15	15	0	30	26	-4	383	375	-8	2539	1982	-557
9-Dec	10	9	-1	25	23	-2	481	432	-49	2787	2508	-279
10-Dec	7	7	0	18	18	0	515	475	-40	2174	1856	-318
11-Dec	16	14	-2	23	19	-4	243	196	-47	2309	1800	-509
12-Dec	13	13	0	25	23	-2	563	482	-81	1835	1626	-209
13-Dec	16	15	-1	25	23	-2	965	839	-126	2547	2659	112
14-Dec	13	11	-2	46	40	-6	986	787	-199	2929	2495	-434
15-Dec	10	9	-1	23	19	-4	537	479	-58	2057	1897	-160
16-Dec	8	7	-1	20	18	-2	736	646	-90	2525	2098	-427
17-Dec	11	12	1	28	26	-2	589	519	-70	2190	1944	-246
18-Dec	8	7	-1	20	19	-1	508	451	-57	2152	2046	-106

	Salad Q14			Leafy A1			Stonefruit D			Banana N		
Date	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error	Forecast Sales	Actual Sales	Error
19-Dec	11	10	-1	11	10	-1	443	401	-42	2033	1787	-246
20-Dec	30	25	-5	33	29	-4	650	479	-171	2805	2140	-665
21-Dec	11	10	-1	32	30	-2	795	610	-185	3560	2592	-968
22-Dec	14	12	-2	30	26	-4	688	615	-73	2214	1932	-282
23-Dec	8	8	0	12	12	0	416	414	-2	1440	1459	19
24-Dec	11	12	1	5	5	0	393	437	44	1708	1862	154
25-Dec	15	17	2	15	19	4	777	898	121	1995	2285	290
26-Dec	4	5	1	23	27	4	617	687	70	1413	1680	267
27-Dec	23	18	-5	31	25	-6	817	595	-222	1859	1576	-283
28-Dec	19	14	-5	22	16	-6	1281	899	-382	2400	1840	-560
29-Dec	26	30	4	21	25	4	953	1012	59	1861	1744	-117
30-Dec	78	139	61	14	25	11	601	847	246	1519	2262	743
31-Dec	206	315	109	11	17	6	633	855	222	1083	1641	558

4.2. Integrated Periodic Review Policy and DES Inventory Movement

The implementation of the integrated periodic review policy through Discrete Event Simulation (DES) was conducted using a daily simulation. The daily simulation was generated by item and by store. This simulation began with the determination of the ordering interval, which was based on the periodic review in Table 1. Tables 4 and 5 show the daily inventory movements of the four sample products in Store S-A. Table 4 shows the order quantity, delivery quantity, %SL, opening stock, closing stock aging, closing stock, and closing stock prediction, while Table 5 shows the actual sales, waste, and lost sales. Table 5 shows %Waste and %Loss Sales. Waste Qty Prediction was calculated as 20% of the opening stock minus the forecast sales, while Waste Qty was calculated as 20% of the opening stock minus the actual sales.

Salad Q14 had a 2-day review period, so orders were placed every two days. The lead time was one day, so orders were placed one day before arrival. No orders were placed on 1 October because that date was not within the review period. An order was placed on 2 October for delivery on 3 October. The order quantity was 38 pcs. This value was calculated from a safety stock of 29 pcs, plus the forecast sales for 3 and 4 October, which totaled 9 pcs, minus the predicted closing stock of 0 pcs, and was rounded to the 1-pc MOQ. The predicted closing stock on 4 October was obtained from the predicted closing stock on 3 October minus the forecast sales and the predicted waste on 4 October. The forecast sales for 3 and 4 October were considered because the next delivery was scheduled to arrive on 5 October. On 5 October, 39 pcs arrived, resulting in a %SL of 98%

Leafy A1 had a 1-day review period, meaning that orders were placed every day. The lead time was one day, so orders were placed one day before arrival. On 1 October, an order of 19 pcs was placed for delivery on 2 October. This value was calculated from a safety stock of 5 pcs plus the forecast sales for 2 October, which were 23 pcs, minus the predicted closing stock on 1 October, which was 9 pcs, and was rounded to the 1-pc MOQ.

Stonefruit D had a 3-day review period, so orders were placed every three days. The lead time was two days, so orders were placed two days before arrival. No orders were placed on 1 and 2 October because those dates were not within the review period. An order was placed on 3 October for delivery on 5 October. The order quantity was 2,150 hg. This value was calculated from a safety stock of 218 hg plus the forecast sales for 5–7 October, which was 866, 534, and 527 hg, respectively. The order-up-to level was 2,145 hg, which was then reduced by the predicted closing stock on 4 October. The predicted closing stock on 4 October was obtained from the predicted closing stock on 3 October minus the forecast sales on 4 October,

resulting in 0 hg. Consequently, 2,145 hg was rounded to the company's 10-hg MOQ, resulting in a final order quantity of 2,150 hg.

Banana N had a 3-day review period, so orders were placed every three days. The lead time was two days, so orders were placed two days before arrival. No orders were placed on 1 and 2 October because those dates were not within the review period. An order was placed on 3 October for delivery on 5 October. The order quantity was 8,060 hg. This value was calculated from a safety stock of 784 hg plus the forecast sales for 5–7 October, which was 3,116, 2,183, and 2,123 hg. The order-up-to level was 8,206 hg, which was then reduced by the predicted closing stock on 4 October. The predicted closing stock on 4 October was obtained from the predicted closing stock on 3 October minus the forecast sales and the predicted waste on 4 October. Consequently, the required quantity was rounded up to the company's 130-hg MOQ, resulting in a final order quantity of 8,060 hg.

This study used a Discrete Event Simulation (DES) approach to model inventory movements. Tables 4 and 5 present the daily inventory movements of the four selected products from 1 to 7 October 2025. The tables include Actual Sales Qty (actual sales quantity), Order Qty (order quantity), Deliver Qty (delivery quantity), %SL (service level), Opening Stock, Closing Stock, Closing Stock Prediction, Sales (sales value), Waste Qty (waste quantity), Waste (waste value), %Waste, Loss Sales Qty (lost sales quantity), Loss Sales (lost sales value), and %Loss Sales.

For Stonefruit D, the opening stock on 2 October was 678 hg, calculated from the closing stock on 1 October (483 hg) plus the delivery quantity on 2 October (195 hg). The closing stock on 2 October was 460 hg, calculated by subtracting actual sales of 218 hg and waste of 0 hg from the opening stock of 678 hg.

Closing Stock Prediction is used to calculate the order quantity and is obtained by subtracting forecast sales from opening stock. Since Stonefruit D has a shelf life of seven days, waste is calculated on the seventh day as 20% of the remaining stock after actual sales are deducted from the opening stock. On 7 October, the closing stock aging was 178 hg, obtained from the opening stock of 649 hg minus the actual sales of 471 hg, so the waste quantity was 36 hg, calculated as 20% of the closing stock aging. The waste quantity of 36 hg was multiplied by the product price, resulting in a waste value of IDR 232,320. The waste value was then divided by the actual sales value of IDR 2,805,709, resulting in a %Waste of 8%.

Lost sales are calculated daily when actual sales exceed the available stock. On 4 October 2025, actual sales reached 647 hg, while the opening stock was only 233 hg. Therefore, the lost sales quantity was 408 hg. The lost sales value was calculated by multiplying 408 hg by the product price, resulting in IDR 2,430,423. Dividing this value by the actual sales value of IDR 3,854,127 resulted in a %Loss Sales of 64%.

Table 4. Inventory Movement Part 1

Item Name	Date	Order Qty	Deliver Qty	SL	Opening Stock	Closing Stock Aging	Closing Stock	Closing Stock Prediction
Salad Q14	1-Oct	0	6	86%	20	12	12	13
Salad Q14	2-Oct	38	0	95%	12	0	0	0
Salad Q14	3-Oct	0	36	95%	36	27	22	27
Salad Q14	4-Oct	40	0	95%	22	22	22	22
Salad Q14	5-Oct	0	39	98%	61	39	39	40
Salad Q14	6-Oct	24	0	95%	39	29	23	27
Salad Q14	7-Oct	0	19	83%	42	36	36	36
Leafy A1	1-Oct	19	10	91%	20	7	7	9
Leafy A1	2-Oct	22	17	90%	24	0	0	1
Leafy A1	3-Oct	53	19	90%	19	2	2	1

Item Name	Date	Order Qty	Deliver Qty	SL	Opening Stock	Closing Stock Aging	Closing Stock	Closing Stock Prediction
Leafy A1	4-Oct	48	48	92%	50	6	5	1
Leafy A1	5-Oct	26	40	84%	45	3	3	1
Leafy A1	6-Oct	30	21	81%	24	2	2	2
Leafy A1	7-Oct	17	28	94%	30	4	4	3
Stonefruit D	1-Oct	0	164	91%	684	483	483	504
Stonefruit D	2-Oct	0	195	90%	678	460	460	461
Stonefruit D	3-Oct	2150	0	95%	460	233	233	217
Stonefruit D	4-Oct	0	0	95%	233	0	0	0
Stonefruit D	5-Oct	0	2064	96%	2064	1178	1178	1198
Stonefruit D	6-Oct	1020	0	95%	1178	649	649	644
Stonefruit D	7-Oct	0	0	95%	649	178	142	122
Banana N	1-Oct	0	1820	95%	7335	5148	5148	5419
Banana N	2-Oct	0	1522	83%	6670	4788	4788	4836
Banana N	3-Oct	8060	0	95%	4788	3045	3045	2868
Banana N	4-Oct	0	0	95%	3045	173	173	364
Banana N	5-Oct	0	7254	90%	7427	4101	4101	4311
Banana N	6-Oct	7540	0	95%	4101	1646	1317	1918
Banana N	7-Oct	0	0	95%	1317	0	0	0

Table 5. Inventory Movement Part 2

Item Name	Date	Actual Sales Qty	Sales	Waste Qty	Waste	%Waste	Loss Sales Qty	Loss Sales	%Loss Sales
Salad Q14	1-Oct	8	100,325	0	-	0%	0	-	0%
Salad Q14	2-Oct	13	163,027	0	-	0%	0	-	8%
Salad Q14	3-Oct	9	112,865	5	62,703	56%	0	-	0%
Salad Q14	4-Oct	0	-	0	-	0%	0	-	0%
Salad Q14	5-Oct	22	275,893	0	-	0%	0	-	0%
Salad Q14	6-Oct	10	125,406	6	75,243	60%	0	-	0%
Salad Q14	7-Oct	6	75,243	0	-	0%	0	-	0%
Leafy A1	1-Oct	13	95,069	0	-	0%	0	-	0%
Leafy A1	2-Oct	24	175,512	0	-	0%	0	-	0%
Leafy A1	3-Oct	17	124,321	0	-	0%	0	-	0%
Leafy A1	4-Oct	44	321,773	1	7,313	2%	0	-	0%
Leafy A1	5-Oct	42	307,147	0	-	0%	1	7,313	0%
Leafy A1	6-Oct	22	160,886	0	-	0%	1	7,313	0%
Leafy A1	7-Oct	26	190,139	0	-	0%	0	-	0%
Stonefruit D	1-Oct	201	1,197,341	0	-	0%	0	-	0%
Stonefruit D	2-Oct	218	1,298,609	0	-	0%	0	-	0%
Stonefruit D	3-Oct	227	1,352,221	0	-	0%	0	-	0%
Stonefruit D	4-Oct	647	3,854,127	0	-	0%	408	2,430,423	64%
Stonefruit D	5-Oct	886	5,277,831	0	-	0%	0	-	0%
Stonefruit D	6-Oct	529	3,151,211	0	-	0%	0	-	0%
Stonefruit D	7-Oct	471	2,805,709	36	232,320	8%	0	-	0%

Item Name	Date	Actual Sales Qty	Sales	Waste Qty	Waste	%Waste	Loss Sales Qty	Loss Sales	%Loss Sales
Banana N	1-Oct	2187	5,527,686	0	-	0%	0	-	0%
Banana N	2-Oct	1882	4,756,793	0	-	0%	0	-	0%
Banana N	3-Oct	1743	4,405,467	0	-	0%	0	-	0%
Banana N	4-Oct	2872	7,259,037	0	-	0%	0	-	0%
Banana N	5-Oct	3326	8,406,532	0	-	0%	0	-	0%
Banana N	6-Oct	2455	6,205,062	329	988,260	13%	0	-	0%
Banana N	7-Oct	2017	5,098,008	0	-	0%	235	593,967	35%

4.3. Performance Evaluation

By implementing Discrete Event Simulation (DES) on a daily basis, inventory performance can be evaluated continuously at both the item and store levels. The daily simulation enables the calculation of waste and lost sales for each item and each store, providing a more detailed assessment of inventory performance than a single-period replenishment calculation.

Data for each product can be summarized by order frequency, order quantity, delivery quantity, %SL, sales quantity, waste quantity, lost sales quantity, sales value, waste value, lost sales value, %Waste, and %Loss Sales during the research period. Tables 6 and 7 present the summary of the four selected products from 1 October to 31 December 2025 in Store S-A.

During the 92-day observation period, Salad Q14 had an order frequency of 46. The total order quantity was 1,614 pcs, while the delivery quantity was 1,446 pcs. Then, %SL was calculated by dividing the delivery quantity by the order quantity and reached 90%. %Waste was 13%, calculated by dividing IDR 2.4 million by IDR 17.8 million. Similarly, %Loss Sales was 11%, calculated by dividing IDR 1.9 million by IDR 17.8 million. The relatively high waste percentage of Salad Q14 was caused by the high safety stock level. The high safety stock resulted from an anomaly in the forecasting results on 31 December. Therefore, future research is expected to implement dynamic safety stock or improve forecasting accuracy during seasonal periods.

Leafy A1 had an order frequency of 92, which means that orders were placed every day. The total order quantity was 2,277 pcs, while the delivery quantity was 2,028 pcs. Then, %SL was calculated by dividing the delivery quantity by the order quantity and reached 89%. %Waste was 2%, calculated by dividing IDR 0.3 million by IDR 14.9 million. Similarly, %Loss Sales was 2%, calculated by dividing IDR 0.3 million by IDR 14.9 million. This product had a %SL of 89%, slightly below the company target of 90%. This performance can be used by the company to push suppliers to increase their service level.

Stonefruit D had an order frequency of 30. The total order quantity was 46,230 hg, while the delivery quantity was 41,812 hg. Then, %SL was calculated by dividing the delivery quantity by the order quantity and reached 90%. %Waste was 3%, calculated by dividing IDR 8.5 million by IDR 251.0 million. Similarly, %Loss Sales was 3%, calculated by dividing IDR 7.4 million by IDR 251.0 million. The %Waste and %Loss Sales of Stonefruit D were below the company target of 5%.

Banana N had an order frequency of 30. The total order quantity was 227,760 hg, while the delivery quantity was 211,769 hg. Then, %SL was calculated by dividing the delivery quantity by the order quantity and reached 93%. %Waste was 4%, calculated by dividing IDR 24.2 million by IDR 540.9 million. Similarly, %Loss Sales was 3%, calculated by dividing IDR 16.2 million by IDR 540.9 million. The %Waste and %Loss Sales of Banana N were below the company target of 5%.

Table 6. Summary Performance of Four Selected Items in Store S-A Part 16

Dept	Item Name	Order Frequency	Order Quantity	Deliver Quantity	%SL
Vegetable	Salad Q14	46	1,614	1,446	90%
	Leafy A1	92	2,277	2,028	89%
Fruit	Stonefruit D	30	46,230	41,812	90%
	Banana N	30	227,760	211,769	93%

Table 7. Summary Performance of Four Selected Items in Store S-A Part 27

Dept	Item Name	Quantity			IDR (million)			Ratio	
		Sales	Waste	Loss Sales	Sales	Waste	Loss Sales	%Waste	%Loss Sales
Vegetable	Salad Q14	1421	191	152	17.8	2.4	1.9	13%	11%
	Leafy A1	2042	41	45	14.9	0.3	0.3	2%	2%
Fruit	Stonefruit D	42137	1429	1234	251.0	8.5	7.4	3%	3%
	Banana N	214009	9575	6414	540.9	24.2	16.2	4%	3%

Order frequency was strongly influenced by the periodic review policy. The company's existing periodic review interval was established to remain below the product shelf life, thereby helping maintain product availability. In addition, its implementation was practical because it aligned with the company's trading terms with suppliers. Therefore, future research may explore alternative review period scenarios to further evaluate inventory performance while maintaining product availability. The findings could support retailers in discussing replenishment schedules and trading terms with suppliers.

Table 8 presents the summary of sales, waste, and lost sales for each store after implementing the daily DES. The simulation enabled inventory performance to be summarized at both the store and department levels, including sales value, waste value, lost sales value, %Waste, and %Loss Sales throughout the observation period. The Vegetable Department generated a %Waste of 5% and a %Loss Sales of 4%, while the Fruit Department generated a %Waste of 4% and a %Loss Sales of 4%. This summary provided a clearer evaluation of inventory performance across stores than a single replenishment calculation, allowing waste and lost sales to be identified for each store during the research period.

In this study, waste was evaluated using the company's existing operational assumption, where waste was incorporated as a predefined operational parameter within the daily DES inventory movement simulation. This approach enabled the simulation to reflect the current retail operating practice without requiring inventory age tracking. Future research is recommended to integrate waste evaluation with batch aging and the First-In First-Out (FIFO) method to represent product rotation more realistically and improve the accuracy of waste estimation.

Table 8. Summary Performance in Department and Store Level

Department	Store	IDR (million)			Ratio	
		Sales	Waste	Loss Sales	%Waste	%Loss Sales
Vegetable	S-A	12,764	581	531	5%	4%
	S-B	5,964	307	246	5%	4%
	S-C	10,176	470	454	5%	4%
	S-D	6,357	365	251	6%	4%
	S-E	5,202	317	172	6%	3%
	S-F	5,943	308	257	5%	4%
	S-G	5,111	293	158	6%	3%

		IDR (million)			Ratio	
Department	**Store**	**Sales**	**Waste**	**Loss Sales**	**%Waste**	**%Loss Sales**
	S-H	4,158	250	133	6%	3%
	S-I	3,863	250	148	6%	4%
	S-J	2,729	203	86	7%	3%
Vegetable Total		**62,267**	**3,346**	**2,437**	**5%**	**4%**
Fruit	S-A	6,383	210	283	3%	4%
	S-B	2,645	88	124	3%	5%
	S-C	4,273	146	198	3%	5%
	S-D	3,035	101	130	3%	4%
	S-E	2,017	71	87	4%	4%
	S-F	2,952	114	127	4%	4%
	S-G	2,119	71	97	3%	5%
	S-H	1,497	57	69	4%	5%
	S-I	1,269	50	54	4%	4%
	S-J	908	42	38	5%	4%
Fruit Total		**27,098**	**950**	**1,208**	**4%**	**4%**
Grand Total		**89,365**	**4,296**	**3,645**	**5%**	**4%**

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

This study successfully integrated the company's existing sales forecasting and periodic review policy into a daily DES model for perishable products in retail operations. The simulation embedded replenishment decisions into daily inventory movements by continuously updating deliveries, opening stock, sales, closing stock, waste, and lost sales throughout the simulation period. The proposed approach enabled inventory performance to be evaluated at both the item and store levels by providing operational indicators, consisting of order quantity, delivery quantity, order frequency, total sales, service level, waste, and lost sales. These results demonstrate that daily DES provides a more comprehensive evaluation of inventory performance than a single replenishment calculation.

Future research is recommended to optimize the review period to evaluate whether the existing periodic review policy can achieve better inventory performance, to develop a dynamic safety stock approach, and to improve forecasting accuracy, especially during seasonal periods, in order to reduce waste. Finally, waste evaluation could be integrated with batch aging and the First-In First-Out (FIFO) method to represent product rotation more realistically.

Limitations

This study has several limitations. First, the research was conducted using data from ten retail stores in Indonesia over a three-month observation period, limiting the generalizability of the findings to other retail settings or industries. Second, the simulation relied on the company's existing sales forecasts and periodic review policies, without comparing alternative review intervals or optimized inventory policies. Third, waste estimation followed the company's existing operational assumptions and did not incorporate detailed product-age tracking or the First-In First-Out (FIFO) method. Therefore, the findings should be interpreted within the scope of the data and assumptions applied in this study.

Recommendations

Future research should evaluate alternative periodic review intervals and dynamic safety stock policies to improve inventory performance. Longer observation periods and

improved sales forecasting methods, particularly during seasonal fluctuations, are also recommended. Furthermore, incorporating product-age tracking and the FIFO method into the DES model may provide more realistic waste estimates. Comparative studies across additional retail stores and product categories could also strengthen the applicability of the proposed framework.

Author Contributions

All authors contributed to this study, including research conceptualization, development of the theoretical framework, data collection, data analysis, interpretation of results, manuscript preparation, critical revision, and final approval of the manuscript for publication. All authors have read and approved the final version of the manuscript.

AI Disclosure Statement

During the preparation of this manuscript, the authors used DeepL solely for translation purposes. The authors reviewed and verified the translated content and take full responsibility for the content and publication of this manuscript.

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