







































$$\Delta Q(t) = Q_{max}(1 - e^{-kt}) \tag{A-5}$$

The total cost of quality loss per unit time  $L(m, T)$  of raw materials for all *batches* during one production cycle can be represented by Equation (A-6).

$$L(m, T) = c_{loss} \frac{m\lambda P}{T} \int_0^{\frac{\lambda DT}{m\lambda P}} \Delta Q(t) dt \tag{A-6}$$

The total cost of the raw material inventory system at the vendor ( $TC_{rm}(m, T)$ ) is the sum of the costs of purchasing, transportation, storage, and quality degradation, presented in Equation (A-7).

$$TC_{rm}(m, T) = c_r \lambda D + A_r \frac{m}{T} + H_r \frac{\lambda D^2 T}{2m\lambda P} + c_{loss} \frac{m\lambda P}{T} \int_0^{\frac{\lambda DT}{m\lambda P}} \Delta Q(t) dt \tag{A-7}$$

The total cost of the finished product Inventory system at the vendor ( $TC_{pm}(n, T)$ ) is the sum of processing costs, installation costs, and storage costs presented in Equation (A-8).

$$TC_{pm}(n, T) = c_p D + \frac{S_p}{T} + H_p \left( \frac{DT}{2n} \left( \frac{D}{P} (2 - n) + (n - 1) \right) \right) \tag{A-8}$$

The total cost of the finished product Inventory system at the buyer ( $TC_{pr}(n, T)$ ) is the sum of the purchase costs, transportation costs, and storage costs presented in Equation (A-9).

$$TC_{pr}(n, T) = c_{sale} D + A_p \frac{n}{T} + H_p \left( \frac{DT}{2n} \right) \tag{A-9}$$

In the revenue model from buyers, based on Gusti Fauza et al. (2016), buyers set selling prices to consumers in three regions. The batch's age determines the price of each batch of product before it is shipped. Figure A-2 depicts the pricing structure based on the shelf life of each batch. The selling price before quality degradation occurs the  $\tau_{start}$  which was the maximum product price of  $p_{max}$  (region I). Furthermore, the remaining stock was sold at a discount price to attract more demands (region II). Meanwhile, products that have expired (reaching  $\tau_{sl}$ ) were set at the lowest price of  $p_{min}$  (region III). The price reduction policy is formulated using Equation (A-10).

$$p(t) = \begin{cases} p_{max} & 0 \leq t < \tau_{start} & \text{region I} \\ p_{min} + \frac{p_{max} - p_{min}}{\tau_{sl} - \tau_{start}} (\tau_{sl} - t) & \tau_{start} \leq t < \tau_{sl} & \text{region II} \\ p_{min} & t \geq \tau_{sl} & \text{region III} \end{cases} \tag{A-10}$$

The buyer accepted a *batch* that has  $E_i$  less than  $\tau_{start}$  to generate more income. The batch age ( $E_i$ ) is denoted in Equation (A-11). Each  $i$  batch received by the buyer followed the 3 cases according to when the product was last consumed or  $E_i + \tau_{\Delta}$ .

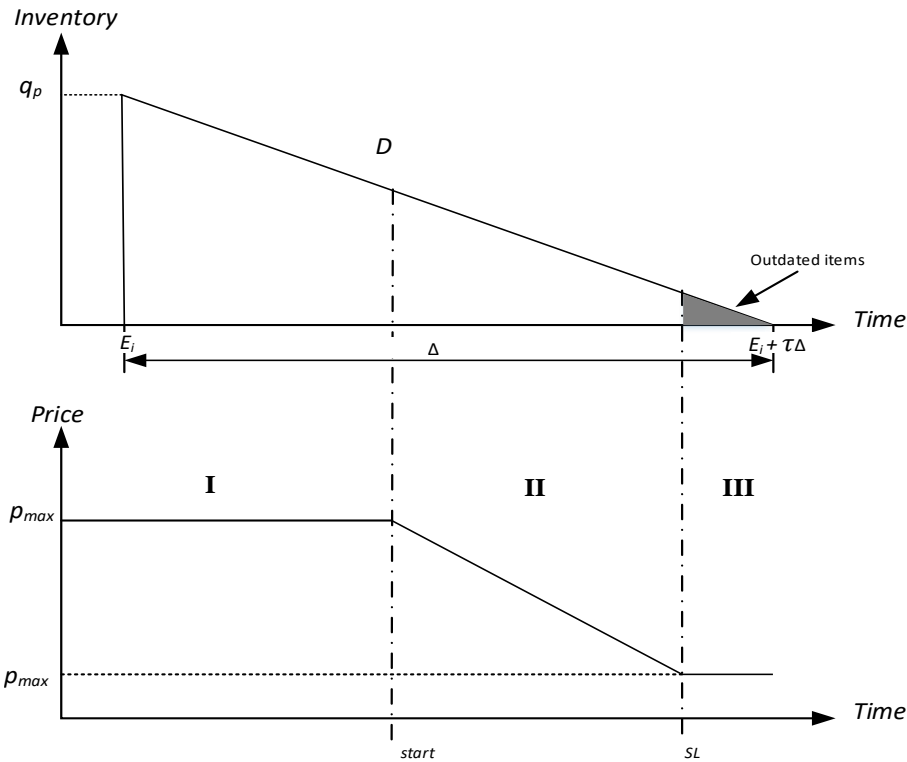


Figure A-2. Price function based on the shelf life of each batch

$$E_i = (i - 1) \frac{T}{n} - (i - 2) \frac{DT}{nP} \tag{A-11}$$

**Case 1:**  $E_i + \tau_{\Delta} < \tau_{start}$ , the annual revenue earned from this batch is determined by Equation (A-12).

$$R_i(n, T) = \frac{D}{T} P_{max} \tau_{\Delta} \tag{A-12}$$

**Case 2:**  $\tau_{start} \leq (E_i + \tau_{\Delta}) < \tau_{sl}$ , the annual revenue earned from this batch is determined by Equation (A-13).

$$R_i(n, T) = \frac{D}{T} \left[ P_{max} (\tau_{start} - E_i) + \int_{\tau_{start}}^{E_i + \tau_{\Delta}} p(t) dt \right] \tag{A-13}$$

**Case 3:**  $E_i + \tau_{\Delta} \geq \tau_{sl}$ , Equation (A-14) represents the annual revenue function of this batch.

$$R_i(n, T) = \frac{D}{T} \left[ P_{max} (\tau_{start} - E_i) + \int_{\tau_{start}}^{\tau_{sl}} p(t) dt + p_{min} (E_i + \tau_{\Delta} - \tau_{sl}) \right] \tag{A-14}$$

Total income integrated Inventory system ( $JTR(T, n)$ ) is the sum of the vendor's income with the buyer's income presented in Equation (15).

$$JTR(T, n) = c_{sale} D + \sum_{i=1}^n R_i(T, n) \tag{A-15}$$

Then the total integrated inventory profit can be calculated by subtracting the total system cost of raw materials, finished products at vendors, and finished products at buyers (Equations A-7, A-8, and A-9) to total system revenue (Equation A-15). Finally, the total profit is formulated in Equation A-16.

This study implemented three decision variables the frequency of raw material orders ( $m$ ), frequency of delivery of finished products to buyers ( $n$ ), and time during the Inventory cycle ( $T$ ). The decision variable for ordering frequency ( $m$ ) and delivery ( $n$ ) is an integer  $> 0$ . The time decision variable during the Inventory cycle ( $T$ ) is a real number with a range of 0 to 1. The mixed-integer non-linear programming model for SVSB inventory model problems is described as follows:

**Maximize :**

$$JTP(m, T, n) = JTR(T, n) - (TC_{rm}(m, T) + TC_{pm}(n, T) + TC_{pr}(n, T)) \tag{A-16}$$

Subject to :

$$P \geq D ; \tag{A-17}$$

$$E_i < \tau_{start} ; \text{ for } i = 1, 2, \dots, n \tag{A-18}$$

$$T > 0 ; \tag{A-19}$$

$$m, n > 0 \text{ (integer number)} ; \tag{A-20}$$

Equation (A-16) is the objective function of the SVSB inventory model problem to maximize profit. The constraint of Equation (A-17) ensures that the production level can meet all demands. Equation constraint (A-18) provides that all batch  $i$  ( $E_i$ ) arrive at the buyer's warehouse before the initial time of deterioration of the finished product. Equation constraints (A-19) and (A-20) guarantee that the decision variable is not zero and integer number.

**Appendix B**

**Table B-1.**  
The effect of changes in m on cost and profit

<i>m</i>	<i>n</i>	<i>T</i>	<i>k</i>	$\lambda$	<i>JTP (IDR)</i>	<i>TC<sub>rm</sub> (IDR)</i>	<i>TC<sub>pm</sub> (IDR)</i>	<i>TC<sub>pr</sub> (IDR)</i>	<i>JTR (IDR)</i>
1	4	0.76	0.50	7.2	57,047,690	78,045,069	868,974	110,658,265	246,620,000
5	4	0.76	0.50	7.2	65,141,311	69,951,448	868,974	110,658,265	246,620,000
10	4	0.76	0.50	7.2	65,966,234	69,126,526	868,974	110,658,265	246,620,000
15	4	0.76	0.50	7.2	66,027,751	69,065,008	868,974	110,658,265	246,620,000
20	4	0.76	0.50	7.2	65,895,146	69,197,613	868,974	110,658,265	246,620,000
25	4	0.76	0.50	7.2	65,684,361	69,408,398	868,974	110,658,265	246,620,000
30	4	0.76	0.50	7.2	65,434,338	69,658,421	868,974	110,658,265	246,620,000
35	4	0.76	0.50	7.2	65,161,838	69,930,921	868,974	110,658,265	246,620,000
40	4	0.76	0.50	7.2	64,875,266	70,217,493	868,974	110,658,265	246,620,000
45	4	0.76	0.50	7.2	64,579,301	70,513,458	868,974	110,658,265	246,620,000
50	4	0.76	0.50	7.2	64,276,755	70,816,004	868,974	110,658,265	246,620,000
55	4	0.76	0.50	7.2	63,969,419	71,123,341	868,974	110,658,265	246,620,000
60	4	0.76	0.50	7.2	63,658,487	71,434,272	868,974	110,658,265	246,620,000
65	4	0.76	0.50	7.2	63,344,789	71,747,970	868,974	110,658,265	246,620,000
70	4	0.76	0.50	7.2	63,028,916	72,063,844	868,974	110,658,265	246,620,000
75	4	0.76	0.50	7.2	62,711,302	72,381,458	868,974	110,658,265	246,620,000
80	4	0.76	0.50	7.2	62,392,273	72,700,486	868,974	110,658,265	246,620,000
85	4	0.76	0.50	7.2	62,072,079	73,020,680	868,974	110,658,265	246,620,000
90	4	0.76	0.50	7.2	61,750,914	73,341,845	868,974	110,658,265	246,620,000
95	4	0.76	0.50	7.2	61,428,931	73,663,829	868,974	110,658,265	246,620,000
100	4	0.76	0.50	7.2	61,106,252	73,986,508	868,974	110,658,265	246,620,000

**Table B-2.**  
The effect of changes in n on cost and profit

<i>m</i>	<i>n</i>	<i>T</i>	<i>k</i>	$\lambda$	<i>JTP (IDR)</i>	<i>TCrm (IDR)</i>	<i>TCpm (IDR)</i>	<i>TCpr (IDR)</i>	<i>JTR (IDR)</i>
12	1	0.76	0.50	7.2	65,869,299	69,063,241	1,031,238	110,656,220	246,620,000
12	5	0.76	0.50	7.2	65,987,568	69,063,241	858,16	110,711,033	246,620,000
12	10	0.76	0.50	7.2	65,706,299	69,063,241	836,52	111,013,937	246,620,000
12	15	0.76	0.50	7.2	65,393,244	69,063,241	829,31	111,334,204	246,620,000
12	20	0.76	0.50	7.2	65,072,243	69,063,241	825,70	111,658,811	246,620,000
12	25	0.76	0.50	7.2	64,748,063	69,063,241	823,54	111,985,154	246,620,000
12	30	0.76	0.50	7.2	64,422,295	69,063,241	822,10	112,312,365	246,620,000
12	35	0.76	0.50	7.2	64,095,618	69,063,241	821,07	112,640,072	246,620,000
12	40	0.76	0.50	7.2	63,768,373	69,063,241	820,30	112,968,089	246,620,000
12	45	0.76	0.50	7.2	63,440,750	69,063,241	819,69	113,296,313	246,620,000
12	50	0.76	0.50	7.2	63,112,862	69,063,241	819,21	113,624,682	246,620,000
12	55	0.76	0.50	7.2	62,784,782	69,063,241	818,82	113,953,156	246,620,000
12	60	0.76	0.50	7.2	62,456,557	69,063,241	818,49	114,281,708	246,620,000
12	65	0.76	0.50	7.2	62,128,221	69,063,241	818,22	114,610,322	246,620,000
12	70	0.76	0.50	7.2	61,799,797	69,063,241	817,98	114,938,983	246,620,000
12	75	0.76	0.50	7.2	61,471,304	69,063,241	817,77	115,267,682	246,620,000
12	80	0.76	0.50	7.2	61,142,754	69,063,241	817,59	115,596,413	246,620,000
12	85	0.76	0.50	7.2	60,814,157	69,063,241	817,43	115,925,169	246,620,000
12	90	0.76	0.50	7.2	60,485,521	69,063,241	817,29	116,253,946	246,620,000
12	95	0.76	0.50	7.2	60,156,853	69,063,241	817,16	116,582,741	246,620,000
12	100	0.76	0.50	7.2	59,828,156	69,063,241	817,05	116,911,551	246,620,000

**Table B-3.**  
The effect of change in n on cost and profit

<i>m</i>	<i>n</i>	<i>T</i>	<i>k</i>	$\lambda$	<i>JTP (IDR)</i>	<i>TCrm (IDR)</i>	<i>TCpm (IDR)</i>	<i>TCpr (IDR)</i>	<i>JTR (IDR)</i>
12	4	0.05	0.50	7.2	51,013,081	79,353,726	1,918,908	114,334,283	246,620,000
12	4	0.10	0.50	7.2	59,538,464	73,419,052	1,323,916	112,338,566	246,620,000
12	4	0.15	0.50	7.2	62,330,595	71,484,296	1,128,925	111,676,183	246,620,000
12	4	0.20	0.50	7.2	63,689,474	70,549,458	1,033,933	111,347,133	246,620,000
12	4	0.25	0.50	7.2	64,475,100	70,014,540	978,94	111,151,417	246,620,000
12	4	0.30	0.50	7.2	64,974,141	69,679,541	943,95	111,022,367	246,620,000
12	4	0.35	0.50	7.2	65,309,453	69,458,746	920,39	110,931,412	246,620,000
12	4	0.40	0.50	7.2	65,542,465	69,309,300	903,97	110,864,267	246,620,000
12	4	0.45	0.50	7.2	65,707,304	69,207,391	892,31	110,812,995	246,620,000
12	4	0.50	0.50	7.2	65,824,445	69,138,736	883,98	110,772,834	246,620,000
12	4	0.55	0.50	7.2	65,906,920	69,094,242	878,08	110,740,753	246,620,000
12	4	0.60	0.50	7.2	65,963,414	69,067,850	874,00	110,714,734	246,620,000
12	4	0.65	0.50	7.2	65,999,942	69,055,364	871,32	110,693,376	246,620,000
12	4	0.70	0.50	7.2	66,020,798	69,053,787	869,73	110,675,681	246,620,000
12	4	0.75	0.50	7.2	66,029,134	69,060,921	869,03	110,660,917	246,620,000
12	4	0.80	0.50	7.2	66,027,312	69,075,118	869,03	110,648,534	246,620,000
12	4	0.85	0.50	7.2	66,017,138	69,095,118	869,63	110,638,111	246,620,000
12	4	0.90	0.50	7.2	66,000,018	69,119,940	870,72	110,629,323	246,620,000
12	4	0.95	0.50	7.2	65,977,060	69,148,811	872,22	110,621,910	246,620,000
12	4	1.00	0.50	7.2	65,949,153	73,419,052	1,323,916	112,338,566	246,620,000

**Table B-4.**  
Effect of change in  $k$  on cost and profit

$m$	$n$	$T$	$k$	$\lambda$	$JTP$ (IDR)	$TCrm$ (IDR)	$TCpm$ (IDR)	$TCpr$ (IDR)	$JTR$ (IDR)
12	4	0.76	0.1	7.2	66,800,729	68,292,029	868,97	110,658,265	246,620,000
12	4	0.76	0.2	7.2	66,606,809	68,485,950	868,97	110,658,265	246,620,000
12	4	0.76	0.3	7.2	66,413,636	68,679,123	868,97	110,658,265	246,620,000
12	4	0.76	0.4	7.2	66,221,206	68,871,552	868,97	110,658,265	246,620,000
12	4	0.76	0.5	7.2	66,029,518	69,063,241	868,97	110,658,265	246,620,000
12	4	0.76	0.6	7.2	65,838,567	69,254,191	868,97	110,658,265	246,620,000
12	4	0.76	0.7	7.2	65,648,351	69,444,408	868,97	110,658,265	246,620,000
12	4	0.76	0.8	7.2	65,458,866	69,633,893	868,97	110,658,265	246,620,000
12	4	0.76	0.9	7.2	65,270,109	69,822,650	868,97	110,658,265	246,620,000

**Table B-5.**  
Effect of changes in  $\lambda$  on cost and profit

$m$	$n$	$T$	$k$	$\lambda$	$JTP$ (IDR)	$TCrm$ (IDR)	$TCpm$ (IDR)	$TCpr$ (IDR)	$JTR$ (IDR)
12	4	0.76	0.5	1	124,803,970	10,288,789	868,97	110,658,265	246,620,000
12	4	0.76	0.5	2	115,324,220	19,768,539	868,97	110,658,265	246,620,000
12	4	0.76	0.5	3	105,844,470	29,248,289	868,97	110,658,265	246,620,000
12	4	0.76	0.5	4	96,364,719	38,728,040	868,97	110,658,265	246,620,000
12	4	0.76	0.5	5	86,884,969	48,207,790	868,97	110,658,265	246,620,000
12	4	0.76	0.5	6	77,405,218	57,687,540	868,97	110,658,265	246,620,000
12	4	0.76	0.5	7	67,925,468	67,167,291	868,97	110,658,265	246,620,000
12	4	0.76	0.5	8	58,445,718	76,647,041	868,97	110,658,265	246,620,000
12	4	0.76	0.5	9	48,965,967	86,126,791	868,97	110,658,265	246,620,000
12	4	0.76	0.5	10	39,486,217	95,606,542	868,97	110,658,265	246,620,000
12	4	0.76	0.5	11	30,006,467	105,086,292	868,97	110,658,265	246,620,000
12	4	0.76	0.5	12	20,526,716	114,566,043	868,97	110,658,265	246,620,000
12	4	0.76	0.5	13	11,046,966	124,045,793	868,97	110,658,265	246,620,000
12	4	0.76	0.5	14	1,567,216	133,525,543	868,97	110,658,265	246,620,000