

Optimization of Inventory Management for Two Demand Seasons with Consideration of Temporary Price Reduction

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ABSTRACT

In the globalization era, the competition among retailers is continually increasing and at the same time consumers are more selective in purchasing the products. Therefore, in this situation retailers should be able to provide a better service, prices, and easy access. Sometimes suppliers give a temporary price reduction for short period for the products and this situation tempts the retailer to order more. In this situation the retailer often does not realize that it could increase the inventory cost that potentially harm the retailer. This study will develop a mathematical model that can be used to calculate the optimal quantity of special order size in response to temporary price reduction offered by suppliers. Decision to order is depend on the difference between the total cost of not doing the special order and doing the special order. If the difference of total cost is positive which means the total cost of the special order are smaller, then the special order will be performed and PT X will get a cost saving and avoid the stock-out due to the relatively large order. The application of this mathematical model is then used to PT X which produces raincoats which is a product of two seasons. It can be seen that the difference in total cost for all the products ordered to suppliers is positive. This indicates that the special order should be performed for each product when there is a temporary price reduction offered. Inventory management at PT X has previously been improved by using P (R, T) model, so its application, the optimal quantity size of regular order is also based on the P (R, T) model.

KEYWORDS: Inventory Management, Temporary Price Reduction, Special Order

INTRODUCTION

PT X is a company that produces raincoats and PT X will produce raincoat when there is demand for the product (make to order). There are three types of raincoats, namely jackets (JC), poncho (P), and raincoat (RC). The plastic sheet is the main raw material in the production supplied by two suppliers, ID and IN. There are 41 plastic sheet types used in the high demand season but in the low demand season, there are several types of plastic that are not needed, there are only 30 plastic sheet types. This study transforms the data of raincoat demand to the plastic sheet demand then the problem is the plastic sheet inventory problem. These plastic sheets are not easily damaged so there is no special maintenance done by PT X. There are 20 types of products of these three types of raincoats. Raincoats are the seasonal products. The demand will be high only in certain months, which is usually in the rainy season, i. e, from August to January, while in the other month, from February to July, the demand tends to be low. The data of seasonal product demand can be seen in Figure 1. At the time of the high product demand season, inventory will quickly run out and re-ordering process will be performed rapidly. In contrarily, during the low product demand season, products will longer be sold so that the ordering interval will be greater. The ordering quantity for the high product demand season and the lower product demand season will also be different. This causes the graph in product inventories differ between seasons of high product demand and lower product demand season, as shown in Figure 2. Sometimes suppliers provide a temporary price reduction on a particular product and for short period. With this temporary price reduction, the price of plastic sheet material will become cheaper than the regular price. Thus, PT X is likely to gain more profit than usual due to ordering more the material. However, if the purchased product must be stored for a long time before it is sold, the holding cost will be greater and the total cost payable by PT X may not be less than the total cost of ordering the product at a regular price.

Research on the temporary price reduction offered by suppliers was first performed by Naddor, E. [1]. He assumed that a period of price reduction is precisely started at the time of the ordering period. Furthermore, Tersine & Price [2] did the same work but with a different method. The optimum inventory policy is made by establishing a model of EOQ that can be used as the optimal number of order on special sale held by suppliers to coincide with the re-ordering period. Next development is done by Barker & Vilcassim [3] who developed an inventory model to respond an offer of price reductions given by supplier who are within the range of sale period offered by retailers. Ardalan, A. [4] further develop an optimal ordering policy resulting from the research

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conducted by Tersine and Price. This development is performed by looking at various possible scenarios relationship between periods of price reductions offered by suppliers in a re-ordering period. The same is then done by Tersine & Schwarzkopf [5] which reduces the assumptions used by previous research regarding the long period of temporary price reductions from suppliers and allow any ordering number performed by a retailer during the period of temporary price reductions.

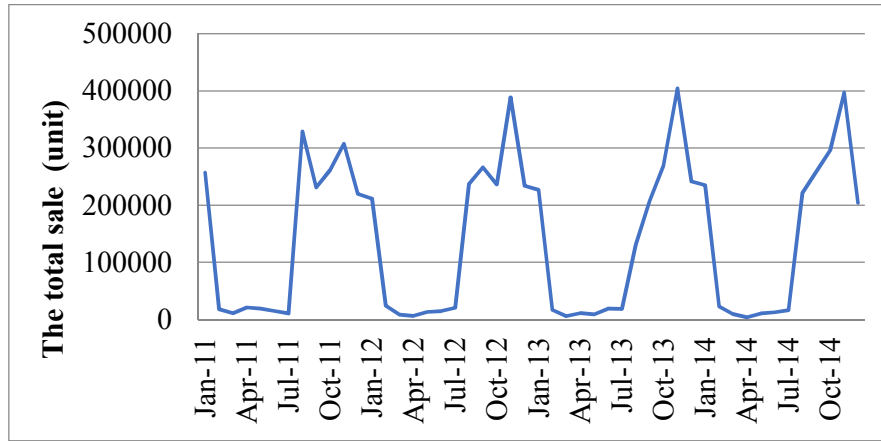


Figure 1. Raincoat Demand at Year 2011-2014

Furthermore, Ardalan, A [6] has redevelop the optimal ordering strategy using three scenarios that depend on the retailer's decision to offer price reductions at the time of offer price reductions takes place or after the bidding ended, or continue to sell the product at a normal price. Arcelus and Srinivasan [7] established the model that is more common with additional restrictions of the maximum quantity of product purchased at special sale prices. Furthermore, Martin [8] makes improvements in the results of research conducted by Tersine (1994) by obtaining a better inventory model for conditions of price reduction. Goyal [9] analyzed the inventory model for conditions of price reduction that has been obtained by Martin (1994) by calculating the average inventory on a regular policy and draw the conclusions that the research conducted by Tersine (1994) does not have any weaknesses as stated by Martin (1994). Aul-Hyde [10] established a model of inventory for temporarily price reduction by allowing the backlog. Abad [11] also developed a model of inventory on the price reduction condition by considering that the demand for products are affected by the price and freight costs. Furthermore, Arcelus, et.al. [12] developed an inventory model conducted by Lev & Weiss (1990). They established a reorder point model that is more optimal by considering the unknown duration of the price reduction. Yang, et.al [13] examined the impact of temporary price reduction to the retailer replenishment policy with a longer lead time and affect on the order quantity. In addition to the research conducted in developing a general supplier inventory model for temporary price reductions, various studies were also developed to solve the inventory problems for price reductions in the condition of perishable product or item deteriorating. Wee & Yu [14] analyzed the impact of decline in value of the product on the EOQ model that consider the price reduction. Likewise done by Shah, et.al [15], Dye, et.al [16], Ouyang, et.al [17], and Jaggi & Khanna [18]. Research inventory model for seasonal products generally assume that the costs incurred by the retailer is constant. Some research on seasonal product inventory mode are done by Gupta, et.al. [19], Chen, KK, & Chang, CT [20], Panda, S., et.al [21], Rahman [22], Rodriguez, MA, & Vecchietti, A. [23], Park, et. al [24], He, Y & Huang, H [25].

From the results of many references regarding to the inventory management for temporary price reductions and inventory management for seasonal products, there have been no studies that have discussed the seasonal product inventory model when supplier offers temporary price reduction to the retailer. Therefore, this research will focus on solving the problems of seasonal product inventory when suppliers offer temporary price reduction to the retailer

MATERIALS AND METHODS

The $P(R, T)$ model is used in the study, thus the company has a constant ordering interval as shown in figure 2. The time T_1 is the interval for high demand season and the time T_2 is the interval for low demand season, respectively. The season length for high product demand season and low product demand season may be different. X_1 to X_2 is the time length for lower product demand season and S_1 to S_2 is the time length for high product demand season. The quantity of the product ordered is as much as the maximum inventory quantity for the season (E_1 if the season is high product demand season and E_0 if the season is low product demand) less the inventory on

hand at the time of ordering. Because the supplier requires time (lead time) for production and delivery process, so when the products ordered arrive, inventories have been reduced due to the demand during the lead time (q_b to the high demand season and q_a for the of low demand season).

With the temporary price reduction is equal to d , the price will drop to $(P-d)$ and it is expected that the total cost also decreases. In this case retailer should know the next replenishment time. If the next replenishment time is in the range of price reduction period, the special order will be made on the replenishment time. However, if the next replenishment time is after the price reduction period, then the special order must be made when the time approaches the end of price reduction period that is at the end of the price reduction period minus the lead time.

Furthermore, retailers should also able to determine the special order size if the price of the product is reduced to $(P-d)$ and retailers must estimate how long the inventory will be depleted by giving attention to history of data demand, which are also influenced by both the length of the remaining period of the season and the demand for the next season. The ordering will only be performed if the value of the order quantity is greater than 0 and the different between the total cost of performing and not performing the special order is positive.

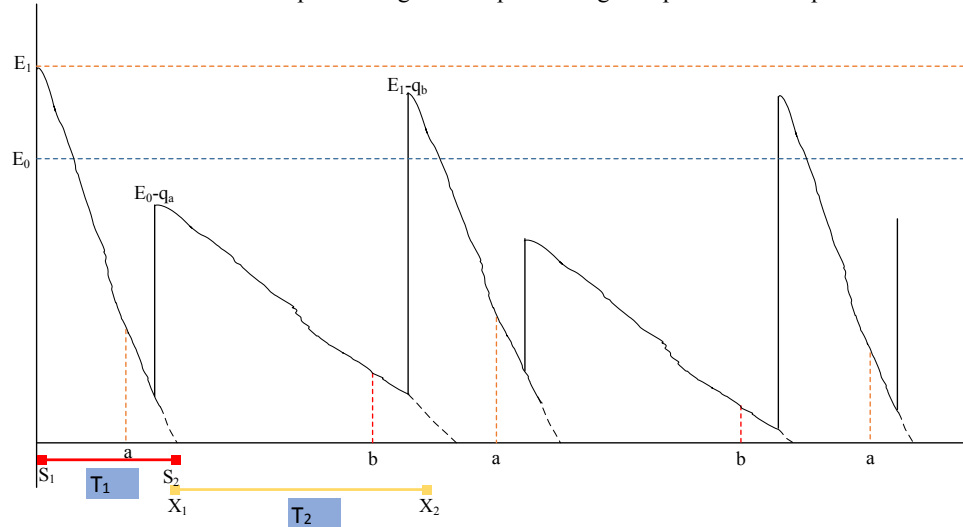


Figure 2. The high product demand and lower product demand season

The model derivation assumes that the temporary price reduction exists in the high product demand. The following table shows the plastic sheet types for high demand season with their data distribution, mean in high demand season (λ_h), mean in the low demand season (λ_l), the purchasing price (P), and the holding cost (h).

Table 1, Normal Distribution Test Results for Products in High Demand Season

Code	P-value	Distribution	λ_h	λ_l	Standar Deviation	Purchasing Price (IDR)	Holding Cost (IDR)
IN-42	0.15	Normal	4431.83	0.00	2582.38	3465	180
IN-344	0.15	Normal	2873.39	127.28	685.67	4240	220
IN-773	0.15	Normal	2873.39	127.28	685.67	4240	220
IN-784	0.15	Normal	4386.50	0.00	2928.09	3540	184
IN-0A0	0.15	Normal	51152.83	2258.44	12209.57	4070	212
IN-C03	0.15	Normal	15466.17	946.44	8458.56	7185	374
IN-C09	0.147	Normal	18185.78	0.00	7411.93	3530	184
IN-C11	0.15	Normal	102.89	0.00	48.12	3460	180
IN-C22	0.15	Normal	102.89	0.00	48.12	3460	180
IN-C3A	0.15	Normal	15079.50	0.00	7084.18	3460	180
IN-C70	0.15	Normal	102.89	0.00	48.12	3460	180
IN-C79	0.147	Normal	18185.78	0.00	7411.93	3460	180

When retailers get information about the temporary price reduction for one of the products, retailer should take this opportunity to maximize the benefits that can be gained from the sale of products by ordering more products. However, the incorrect order size can cause retailers experienced losses due to the bigger holding cost. In this study, this order size is called as the special ordering size, \hat{Q} .

The Periods of temporary price reduction is generally only temporary and short. This leads to the possibility that the replenishment time either is outside or inside the period of the temporary price reduction. The following is the derivation of total cost when the replenishment time is outside the temporary price reduction period.

To avoid the excess of inventory cost due to the product in the warehouse, retailers can order the products at the time close to the end of temporary price reduction period. It is assumed that q equal to the inventory level when the products ordered by special order arrive at the warehouse. It is illustrated by figure 3. The regular order (using P (R,T) model) is indicated by the yellowline, while for special orderis shown by the red line. Point M represents as the time when the season is change. Point N is the time where the product ordred by the special order is finish. Point K is the time when the joint order is performed. To reach point K, the customized ordering, Q_x , is performed for the product that experiencing the temporary price reduction.

The total cost if there is no special ordering is;

$$\begin{aligned}
 TC_r &= \left(\frac{\theta - Q_p}{Q_h} + \frac{(\hat{Q} - \theta + Q_x)}{Q_l} + 1 \right) C + p(\hat{Q} + Q_x) + \frac{pfq^2}{2\lambda_h} + \frac{hq^2}{2\lambda_h} \\
 &+ \frac{pfQ_h(\theta - Q_p)}{2\lambda_h} + \frac{hQ_h(\theta - Q_p)}{2\lambda_h} + \frac{pfQ_p^2}{2\lambda_h} + \frac{hQ_p^2}{2\lambda_h} \\
 &+ \frac{pfQ_l(\hat{Q} - \theta + Q_x)}{2\lambda_l} + \frac{hQ_l(\hat{Q} - \theta + Q_x)}{2\lambda_l} \\
 &= \left(\frac{\theta - Q_p}{Q_h} + \frac{(\hat{Q} - \theta + Q_x)}{Q_l} + 1 \right) C + p(\hat{Q} + Q_x) \\
 &+ \frac{(pf + h)(q^2 + Q_h(\theta - Q_p) + Q_p^2)}{2\lambda_h} + \frac{(pf + h)Q_l(\hat{Q} - \theta + Q_x)}{2\lambda_l} \quad (1)
 \end{aligned}$$

The total cost if the special ordering is performed:

$$\begin{aligned}
 TC_s &= 2C + (p - d)\hat{Q} + pQ_x + \frac{pfq^2}{2\lambda_h} + \frac{h \cdot q^2}{2\lambda_h} + \frac{(p - d)f\hat{Q}q}{\lambda_h} + \frac{h\hat{Q}q}{\lambda_h} \\
 &+ \frac{(p - d)f\theta^2}{2\lambda_h} + \frac{h\theta^2}{2\lambda_h} + \frac{(p - d)f\theta(\hat{Q} - \theta)}{\lambda_h} + \frac{h\theta(\hat{Q} - \theta)}{\lambda_h} \\
 &+ \frac{(p - d)f(\hat{Q} - \theta)^2}{2\lambda_l} + \frac{h(\hat{Q} - \theta)^2}{2\lambda_l} + \frac{pfQ_x^2}{2\lambda_l} + \frac{hQ_x^2}{2\lambda_l} \\
 &= 2C + (p - d)\hat{Q} + pQ_x + \frac{(pf + h)q^2}{2\lambda_h} + ((p - d)f + h) \\
 &+ \left(\frac{(2\hat{Q}q + \theta^2 + 2\theta(\hat{Q} - \theta))}{2\lambda_h} + \frac{(\hat{Q} - \theta)^2}{2\lambda_l} \right) + \frac{(pf + h)Q_x^2}{2\lambda_l} \quad (2)
 \end{aligned}$$

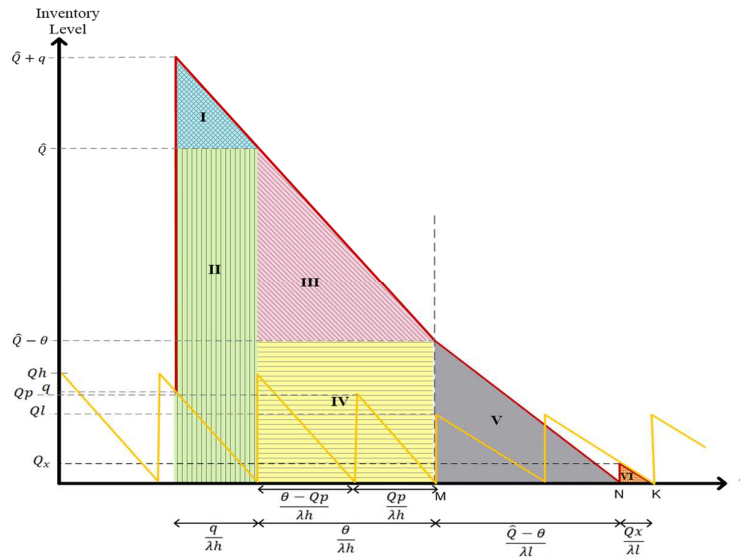


Figure 3.The Special and Regular Ordering for Two Seasons When There is a Temporary Reduced Price

Where;

C : The ordering cost per order

P : The product price per unit

- f : The holding cost fraction
 h : The holding cost
 d : The reduced pricevalue
 λ_h : The product demand rate when the temporary reduction price is occurred
 λ_l : The product demand for the next season
 q : The inventory position when the special order is performed
 \hat{Q} : The special order size for the products experiencing the reduced price
 θ : The number of product needed to fulfil the demand until the last season
 Q_p : The size customized product ordered when approaching the change of seasons
 Q_x : Adjusted product order size to meet product demand after product ordered through special order is finish
 Q_h : The optimal order size in the season when the temporary price reduction occurs (the high demandseason)
 Q_l : Optimal order size for next season (the low demandseason)

The total saving g is found by calculating the difference between TC_r and TC_s .

$$\begin{aligned}
 g &= TC_r - TC_s \\
 &= \left(\left(\frac{\theta - Q_p}{Q_h} + \frac{(\hat{Q} - \theta + Q_x)}{Q_l} + 1 \right) C + p(\hat{Q} + Q_x) + \frac{(pf + h)(q^2 + Q_h(\theta - Q_p) + Q_p^2)}{2\lambda_h} \right. \\
 &\quad \left. + \frac{(pf + h) Q_l(\hat{Q} - \theta + Q_x)}{2\lambda_l} \right) \\
 &\quad - \left(2C + (p - d)\hat{Q} + pQ_x + \frac{(pf + h)q^2}{2\lambda_h} \right. \\
 &\quad \left. + ((p - d)f + h) \left(\frac{(2\hat{Q}q + \theta^2 + 2\theta(\hat{Q} - \theta))}{2\lambda_h} + \frac{(\hat{Q} - \theta)^2}{2\lambda_l} \right) + \frac{(pf + h)Q_x^2}{2\lambda_l} \right) \\
 &= \left(\frac{\theta - Q_p}{Q_h} + \frac{(\hat{Q} - \theta + Q_x)}{Q_l} - 1 \right) C + d\hat{Q} + (pf + h) \left(\frac{Q_h(\theta - Q_p) + Q_p^2}{2\lambda_h} + \frac{Q_l(\hat{Q} - \theta + Q_x) - Q_x^2}{2\lambda_l} \right) \\
 &\quad - ((p - d)f + h) \left(\frac{2\hat{Q}q + 2\theta\hat{Q} - \theta^2}{2\lambda_h} + \frac{\hat{Q}^2 - 2\theta\hat{Q} + \theta^2}{2\lambda_l} \right) \quad (3)
 \end{aligned}$$

The optimal special order \hat{Q} can be found by taking the first derivative of g with respect to \hat{Q} and set them to zero;

$$\begin{aligned}
 \frac{dg}{d\hat{Q}} &= 0 \\
 \frac{C}{Q_l} + d + \frac{(pf + h)Q_l}{2\lambda_l} - ((p - d)f + h) \left(\frac{q + \theta}{\lambda_h} + \frac{\hat{Q} - \theta}{\lambda_l} \right) &= 0 \\
 \frac{\hat{Q}}{\lambda_l} ((p - d)f + h) &= \frac{C}{Q_l} + d + \frac{(pf + h)Q_l}{2\lambda_l} - ((p - d)f + h) \left(\frac{q + \theta}{\lambda_h} - \frac{\theta}{\lambda_l} \right) \\
 \hat{Q} &= \frac{\lambda_l}{(p - d)f + h} \left(\frac{C}{Q_l} + d \right) + \frac{(pf + h)Q_l}{2((p - d)f + h)} - \lambda_l \left(\frac{q + \theta}{\lambda_h} \right) + \theta \quad (4)
 \end{aligned}$$

If the difference between the total cost is positive, then the special order should be performed with a special order size given by equation 4, so that the retailer can gain the maximum profit.

From equation 4 it can be concluded that the average demand in the next season (λ_l) become the important factor of the order size. When λ_l equal to 0, this leads that Q_l will also be equal to 0, so that the order size \hat{Q} will be equal to the product needed to meet demand until the end of the season, θ .

RESULTS AND DISCUSSION

The application of the model uses some assumptions as follow;

1. The replenishment time is outside the temporary price reduction period.
2. The value of q is half of the optimal order size based on EOQ.
3. The price reduction (d) offered by IN supplier is 20%.
4. This price reduction occurs when the remaining time until the end of the high demand season is 5 months.
5. The special order size that exceeding 2 seasons are not taken into account due to the products that are stored for too long can result in large of inventory cost.

6. There is no either the capacity and capital problem considered in the study.

The Calculation is performed using equation 4 and the results for each product are shown in the column \hat{Q} of table 1.

Furthermore, the calculation is performed to determine when the total inventory ($t\hat{Q} + q$) finish. If it turns out that the inventory finish over the next season period (6 months), then \hat{Q} will be adjusted so it will finish in the maximum next season period.

Table 2. Special Order Size \hat{Q} for Products that Experience the Temporary Price Reduction

Code	(P-d)	Q_h	Q_r	Q	Θ	Q_p	\hat{Q}
IN-42	Rp2.772	3369	0	961	22133	1002	22747
IN-344	Rp3.392	2989	673	700	14348	358	14842
IN-773	Rp3.392	2989	673	700	14348	358	14842
IN-784	Rp2.832	3334	0	946	21907	1106	22507
IN-0A0	Rp3.256	12277	2349	3011	255681	2757	259048
IN-C03	Rp5.748	4331	1098	1246	77297	45	78694
IN-C09	Rp2.824	7275	0	1928	90876	2211	90323
IN-C11	Rp2.768	618	0	147	511	218	714
IN-C22	Rp2.768	618	0	147	511	218	714
IN-C3A	Rp2.768	6032	0	1773	75349	883	75157
IN-C70	Rp2.768	618	0	147	511	218	714
IN-C79	Rp2.768	7275	0	1947	90875	1313	90352

Adjustments for \hat{Q} are also made when there is no demand for the next season ($\hat{Q}_{adjusted}$), so that the products ordered through a special order must finish in one season and the inventory costs due to products stored in the next season can be avoided. Next, Q_x is calculated. This value is adjusted product order size to meet product demand after product ordered through special order is finish and it also sets the next replenishment and adds an additional cost to the total cost. The calculation of the total cost for both of no special order and special order will use the equation 1 and 2, respectively. It can be seen from Table 3 that the difference in total cost, g , for all products ordered to suppliers IN is positive. This indicates that the special order should be performed for each product when there is a 20% temporary price reduction offered.

Table 3. The Total Cost Difference for no Special Order and Special Order

Code	$t\hat{Q}+q$		$\hat{Q}_{adjusted}$	Q_x	$TC_n(\text{IDR})$	$TC_s(\text{IDR})$	$g(\text{IDR})$
	High	Low					
IN-42	5	0	22133	0	78,455,192.18	69,412,956.91	9,042,235.27
IN-344	5	3.88	14842	270	66,255,053.87	59,281,301.93	6,973,751.95
IN-773	5	3.88	14842	270	66,255,053.87	59,281,301.93	6,973,751.95
IN-784	5	0	21907	0	79,320,566.77	70,190,384.89	9,130,181.88
IN-0A0	5	1.49	259048	2655	1,073,315,729.40	968,810,746.25	104,504,983.15
IN-C03	5	1.48	78694	1095	579,328,769.09	522,630,233.90	56,698,535.19
IN-C09	4.97	0	90323	553	324,349,967.03	290,131,474.11	34,218,492.92
IN-C11	5	0	511	0	2,053,567.16	1,691,499.40	362,067.76
IN-C22	5	0	511	0	2,053,567.16	1,691,499.40	362,067.76
IN-C3A	4.99	0	75157	192	263,952,168.60	235,825,923.27	28,126,245.33
IN-C70	5	0	511	0	2,053,567.16	1,691,499.40	362,067.76

Conclusion

This study is focus on the seasonal product (in this case is raincoat). Sometimes suppliers give a temporary price reduction for short period for a product and this situation tempts the retailer to order more. In this situation the *retailer* often does not realize that it could increase the inventory cost (in this case is the holding cost) that potentially harm the retailer. In this situation, inventory management could use the equation 4 to create cost saving g and to avoid the stock-out. The application of this equation 4 is then used to PT X which produces raincoats which is a product of two seasons. It can be seen that the value g for all the products ordered to suppliers is positive. This indicates that the special order should be performed for each product when there is a temporary price reduction offered. This model is used for the products that are usually ordered individually. The study shows that there will be a saving if a special order if performed.

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