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An inventory model for a perishable and recoverable product

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Abstract. Some perishable products are recoverable. This type of products is further constraint by its nature which quality and acceptability degrade with time. Insufficient inventory problem leads to inventory management problem which increased inventory cost. An inventory model is developed in order to optimize inventory cost. By investigating recent development and performance in inventory of perishable product, this model introduces the concept of recoverable behavior of perishable product. The model is developed in three stages which started with conceptual model, followed by mathematical model and represented in software-based model. The final result determined whether to wait for next stock replenishment or to assign other resources to fulfill demand.

1. Introduction

Research on inventory of perishable products usually deals with time and quality level. The longer the product is being stored, the lower the quality it will be. The common policies used in perishable products are First In First Out (FIFO) and Last In First Out (LIFO) ([1], [2], [3], [4]). Perishable product has the probability that it may be spoiled before it reaches the market if no suitable inventory control method is applied. However, some perishable product may be recovered to become a lower graded product or a secondary product that can be resold. As the quality of the product is time dependent, it is important for the manufacturer to optimize the storage time of the product as to minimize the inventory cost.

Leandro [5] and Sarbjit [6] classified perishable product according to how they decay. According to [7], an assumption in the traditional inventory model is that the item conserved their physical characteristic while being kept in store. The assumption might be true for some products but not for all. The perishable products on the other hand are subjected to continuous loss of their physical ability, functionality, quality and quantity throughout their lifetime. This is due to decay, damage, spoilage and other penalties. Therefore, the inventory of perishable products gives a challenging yet interesting task to be studied by the researchers.

This research focus more on to scheduling the recovery of degrading product before it is totally spoilt and when and where to get more inventories when there is insufficient inventory to fulfill demand. Minimizing the inventory cost for this type of product is a daunting effort as it involved minimizing contradicting factors due to the nature of the product that degrades with time.

In order to minimize the inventory cost, decision need to be made with the cost worthiness of waiting for the new supply in the next period against getting supply instantly from other distribution center but at a higher cost. Each time an alternative involves time lag (waiting), product degradation and the ability for recovery have to be considered.

This paper is organizing as follow. Section 2 explains on perishable products. Section 3 discusses the conceptual model while Section 4 discusses the mathematical model. Section 5 discusses the



numerical example. Result and discussion are explained in Section 6. The last section explains the conclusion of the model.

2. Perishable product

Perishable product is generally known as product that experiences damage or decay. Piramuthu [4] defined perishable product as product that has short shelf life. Managing the inventory of perishable product is different from non-perishable product as it requires special need in terms of maintaining the best condition.

Leandro [5] and Sarbjit [6] classified perishable product according to how they decay. There are two types of perishable products.

The first type of perishable product are products that has constant value over time until it reaches a specified due date. After the due date, the value of the product drops down almost instantaneously to zero. This type of product is usually used within a specific period before it becomes useless. It can be product that consumers consumed seasonally. Some examples are like calendars, year books, maps and electronic gadget. When the new generations are produced and marketed, the old products become obsolete. Most of the time, even though the product may still be in a good condition, they are simply no longer useful. Products with expiry date are in the same category as well. This product can be consumed within a specific period, but when it reaches expiry date, it is totally spoiled and cannot be consumed anymore.

The second type of perishable product is product that decays over time. Generally, the value of this product is determined by its quality level. As the products decay over time, each of them might have different decay rate and lifetime before they are completely spoiled and unfit for consumption. Some examples are vegetables, flowers and fruits. Sometime, when the products are approaching the lowest acceptable quality level, they will be sold at a discounted price. Customers however are usually less attracted to low quality products unless they are cheaper. Some products can be reprocessed and sold as secondary product before they pass certain quality level. This research will focus on this type of perishable product.

3. Conceptual model

Conceptual model is the basic idea of the research. It is represented in a flow diagram with the details of the model. This model assisted in the development of the mathematical model. Figure 1 shows the conceptual model of the research.

It starts when demand from retailers is received (Level 1). Then, the model is check if the inventory is adequate to fulfill the demand (Level 2). The inventory level is calculated with consideration to the nature of the product that degrades with time.

Level 3 is triggered when the inventory is inadequate to fulfill the demand. If the inventory is sufficient to supply the demand, the product will directly be distributed to the retailer. The consideration in level 3 is the main contribution of the model. There are two options in the decision when the inventory is not enough to supply the demand in order to minimize the inventory cost.

First option requires waiting for the next inventory replenishment for the next period while second options is by assigning external resources to fulfill the demand. Both options consider different parameter that affects in the decision making.

In the first option, waiting for the next inventory replenishment will consider the cost of spoilage of the currently available inventory due to the degradation of the inventory as it waits. In the second option, where external resources are needed to fulfill demand immediately, spoilage due to time dependent degradation of currently available inventory does not occur. However, extra cost is incurred due to external source of inventory.

Finally, the decision is made to either to wait for next inventory replenishment or to assign external resource which minimizes inventory cost. The model will also calculate the total inventory cost of the decision. The detail explanation of the model will be discussed in the next section.

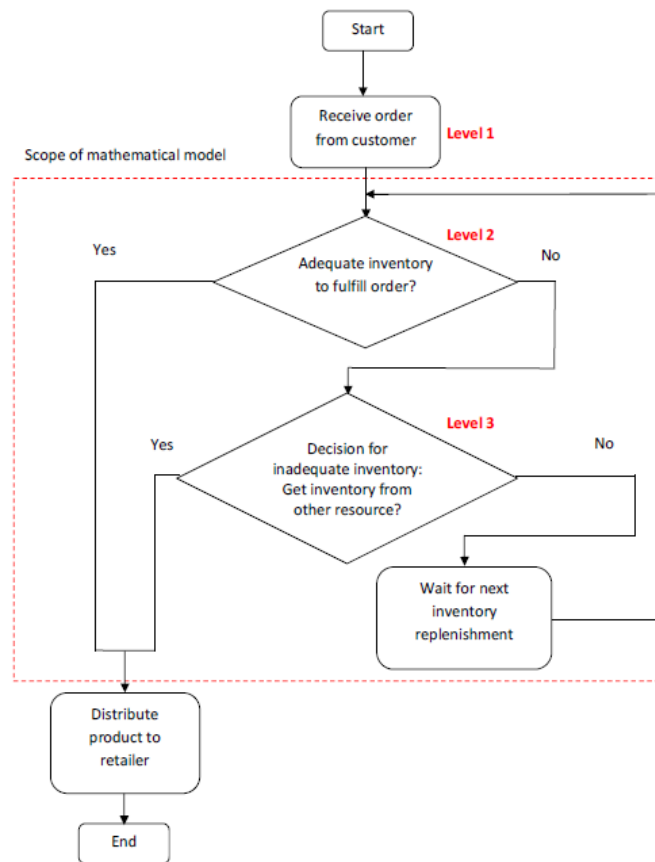


Figure 1. Conceptual model.

4. Mathematical model

This section gives an overview of the proposed mathematical model. Only one type of perishable product with single distribution center and multi retailers is considered. This model considers FIFO policy where the first items enter the inventory is issued first.

The mathematical model of the research is presented as below.

A. Definition of Indices and Notations

- b index for product batch ($b = 1, \dots, B$)
- r index for retailer ($r = 1, \dots, R$)
- g index for products age ($g = 1, \dots, G$)
- t index for periods ($t = 1, \dots, T$)
- G maximum age before product is not allowed to stay in the inventory as it is now reached the level where it must be reprocessed for recovery

- HC Total holding cost
- RV Total income from reprocessed product
- SC Total spoilage cost
- TAWC Total cost to assign external resource to fulfill demand
- TIIC Inventory cost due to inadequate inventory
- TWC Total waiting cost

This research aims to minimize inventory cost for a perishable and recoverable product by determining the best option between to wait for the next stock replenishment in the next period or to assign other distribution center instantly to fulfill the demand when inventory is insufficient.

There are a few assumption made in order to develop the next phase of the model. This assumption is made to simplify the model without changing its functionality. The model is developed base on basic and realistic assumptions [8].

B. Assumption

The following assumptions are applied to the model:

- The time unit may be selected based on the replenishment cycle of the inventory and the degradation of the product.
- The new batch of product entering the inventory is assumed to have zero spoilage.
- The demand of retailer is met by the warehouse assigned to it unless the warehouse is not able to satisfy the demand.
- The product is transported to retailer from warehouse.
- Distribution of product from retailer to retailer is not allowed.
- Model will cover the inventory before its expiry date. Beyond this date the product is considered unrecoverable

C. Model Development

The objective function of the mathematical model is presented as follows:

$$\text{Minimize Inventory Cost} = \min \{ \text{Total waiting cost, Total cost to assign external resource} \} \quad (1)$$

Total holding cost is written as

$$HC = CHc (I'_t) \quad (2)$$

Total spoilage cost is written as

$$SC = CSp (sp_{t+1}) + CSp (spr_{t+1}) + CRp (spr_{t+1}) \quad (3)$$

Total revenue of secondary product is written as

$$RV = Clr (spr_{t+1}) \quad (4)$$

Total cost to assign external resource is written as

$$TAWC = CEp (-N_t) \quad (5)$$

The quantity of inventory in good condition is calculated by subtracting the quantity of spoiled product of each batch from the total quantity of inventory as shown below

$$I'_t = I_t - sp_t - spr_t \quad (6)$$

The quantity of non-recoverable spoilage is the total of non-recoverable inventory of each batch at current period as shown below

$$sp_t = \sum_{b=1}^B \sum_{g=1}^{G-1} sp_{b,g,t} \quad (7)$$

The quantity of recoverable inventory is the total of recoverable inventory of each batch as shown below

$$spr_t = \sum_{b=1}^B spr_{b,g,t} \quad (8)$$

Figure 2 shows the mathematical formulae arranged in sequence based on the conceptual model.

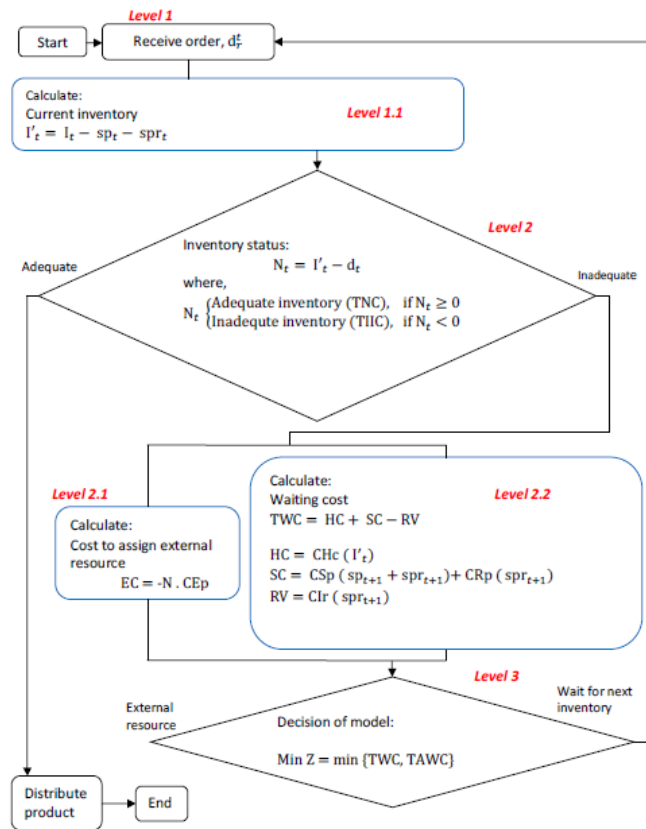


Figure 2. Mathematical formulae.

5. Numerical example

The example of calculation consists of the inventory of six periods. In this example, the insufficient inventory occurred at fifth period. Table 1 show the summary of inventory of period five.

Table 1. Summary of inventory at period five.

Batch, b	Inventory of batch, $I_{b,g,t}$		Non recoverable inventory, $sp_{b,g,t}$		Recoverable inventory, $spr_{b,g,t}$	
b=2	$I_{2,3,5}$	0	$sp_{2,3,5}$	-	$spr_{2,3,5}$	-
b=3	$I_{3,2,5}$	312.88	$sp_{3,2,5}$	18.773	$spr_{3,2,5}$	0
b=4	$I_{4,1,5}$	600	$sp_{4,1,5}$	24	$spr_{4,1,5}$	0
b=5	$I_{5,0,5}$	600	$sp_{5,0,5}$	0	$spr_{5,0,5}$	0
Total	I_5	1512.88	sp_5	42.773	spr_5	0

The inventory of period six is predicted to estimate the cost of waiting for the next inventory replenishment to fulfill the demand. Table 2 shows the summary of estimated spoilage of period six.

Table 2. Estimated spoilage at period six.

		Period											
		1		2		3		4		5		6	
$I_{1,0,1}$	1200	$I_{1,1,2}$	800	$I_{1,2,3}$	544	$spr_{1,3,4}$	305.92						
$sp_{1,0,1}$	0	$sp_{1,1,2}$	56	$sp_{1,2,3}$	38.08								
		$I_{2,0,2}$	600	$I_{2,1,3}$	600	$I_{2,2,4}$	564	$spr_{2,3,5}$	0				
		$sp_{2,0,2}$	0	$sp_{2,1,3}$	36	$sp_{2,2,4}$	45.12						
				$I_{3,0,3}$	600	$I_{3,1,4}$	600	$I_{3,2,5}$	312.88	$spr_{3,3,6}$	294.107		
				$sp_{3,0,3}$	0	$sp_{3,1,4}$	6	$sp_{3,2,5}$	18.773				
						$I_{4,0,4}$	600	$I_{4,1,5}$	600	$I_{4,2,6}$	576		
						$sp_{4,0,4}$	0	$sp_{4,1,5}$	24	$sp_{4,2,6}$	24		
								$I_{5,0,5}$	600	$I_{5,1,6}$	600		
								$sp_{5,0,5}$	0	$sp_{5,1,6}$	24		

By implementing the formulae, the problems, the results of both options (cost to wait for the next inventory replenishment and cost to assign external resource) are shown in Table 3.

Table 3. Results of options.

Option	Cost (RM)
Cost of assigning external resource	194622
Cost to wait for next replenishment	123092

By using the equation of the objective function (1), the result show that assigning external resource to fulfill demand has the minimum cost value compared to waiting for the next inventory replenishment where,

$$\begin{aligned}
 Z &= \min (\text{TWC}, \text{TAWC}) \\
 Z &= \min (194622, 123092) \\
 &= 123092 \text{ TAWC (cost assign external resource)}
 \end{aligned}$$

Sensitivity analysis has been done and showed that the ability of the model to achieve result is validated and the result obtained is reliable.

6. Result and discussion

From the results obtained, it proved that the model is able to make decision and produce result. The mathematical model developed is feasible to be implemented in the real case of inventory management. Even though the data used for calculation is an example and assumptions were made based on limited information provided by the company, the model is able to calculate and obtain a clear result. The sensitivity analysis in Figure 3.1, Figure 3.2 and Figure 3.3 proved that the results obtained from the model are reasonable and the model is able to make optimum decision in order to minimize inventory cost.

Moreover, the model developed is generic as the values of parameter and variables are not restricted to the specified value. The number of warehouses considered in the model is single but the quantity of retailers in the distribution network is not limited to any number. The model can be used as the decision tool in the inventory problem of the company in order to minimize the inventory cost for recoverable product with time dependent degradation.

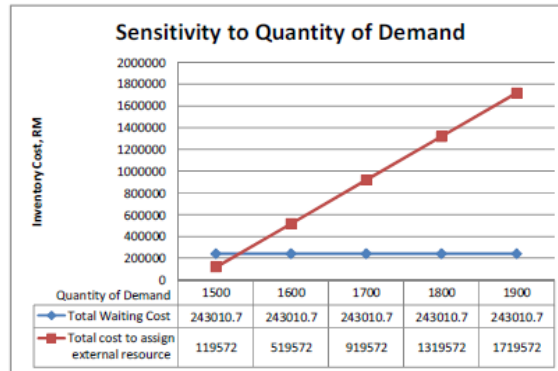


Figure 3.1. Sensitivity to quantity of demand.

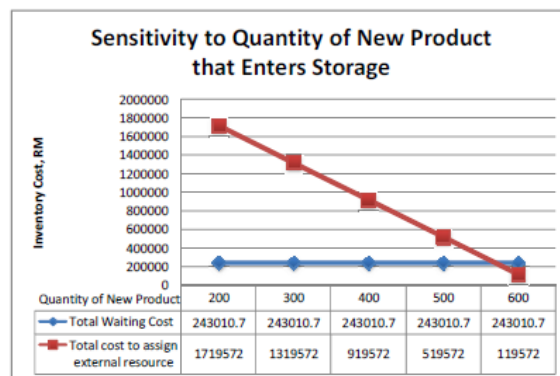


Figure 3.2. Sensitivity to new inventory.

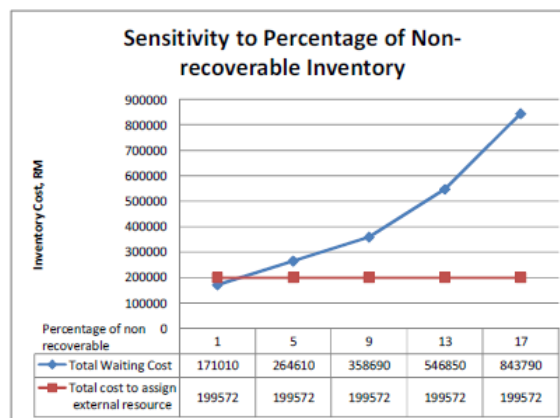


Figure 3.3. Sensitivity to non-recoverable inventory.

This model is developed and can be implemented by companies who consider the similar case. It is also suitable for company who deals with perishable and recoverable product. As the perishable behavior is dependent with time, this model considers the time management while keeping the inventory in the storage. Furthermore, this model takes into account the sustainability of product resource as it optimizes the waste of the products by planning to recover them before they are totally spoiled and rejected.

7. Conclusions

This study proposed a decision making model for inventory management of perishable and recoverable product that minimizes inventory cost. The proposed model is able to calculate inventory cost and make economic decision when there is inadequate inventory to satisfy the demand and minimizes inventory

cost. This study contributes to a better inventory management of perishable and recoverable inventory. Significantly, a better inventory management is advantages not only to the company but to customer as well as the demand can be fulfilled continuously.

Moreover, this study supports effort to minimize wastage due to spoilage and contribute to the sustainability of food resource or other resource with similar characteristics. This will also support efficient production planning where the company may supply demand without shortage due to spoilage.

8. References

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9. Acknowledgements

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