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MATHEMATICAL PRODUCT RECOVERY MODEL FOR PERISHABLE GOODS

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Abstract

This paper presents a perishable product recovery model that aim to maximize the total recovery value of the return product. The perishable product under consideration has a property of quality degradation over time and can be reprocessed. The proposed model are expected to decide which, when and how does the return product being retrieve from the retailer.

Keywords: Product return; Perishable goods recovery

Abstrak

Kertas kerja ini membentangkan mengenai model yang terlibat dengat prosess pemulanagn produk yang mereput dari peruncit. Model matematik ini bertujuan untuk memaksimumkan nilai yang boleh didapati melalui kutipan produk yang dipulangkan. Produk yang terlibat dalam model ini mempunyai ciri-ciri degradasi kualiti dari masa kesemasa dan produk ini juga boleh diproses semula. Model ini membuat keputusan bilakah masa yang paling optimum untuk mengambil produk yang ingin dipulangkan dari peruncit.

Kata kunci: Pemulangan produk, pemulihan produk

1.0 INTRODUCTION

Product recovery management involves the efficient management of returned, used and discarded product [1]. Product recovery aims to minimize the amount of waste sent to landfills by recovering the materials and parts from old or outdated products through cannibalization, reuse, recycling, and remanufacturing [2, 3]. The importance of product recovery activity has increased as there are high returns due to shorter product lifecycles [4]. A number of researchers have addressed the issue of product recovery through case study such as sand recycling [5, 6], copier machine [2, 6], electronics goods [7], computer [8], bottles, containers and pallets [9], and hazardous waste [10]. Companies involved in manufacturing products have been incorporating reverse logistics in their supply chain planning as a method of fulfilling environmental regulations and sustainability expectations, as well as gaining business advantage from the recovered products [11, 12]. However, there is only a small number of researchers studied recovery return products of perishable goods. Naturally perishable goods deteriorate with time and will be useless by the end of their lifetime. Some of the perishable goods can be recovered by recycling or reuse before it became totally unrecoverable.

Perishable goods supply chain networks are different than other supply chain because the quality of the product will degrade with time [4, 13]. In this paper, a mathematical model that aims to maximize the total product recovery value of perishable goods will be discussed. This model can be used to estimate the functionality remains in the return product in order to decide whether it is worth or not to retrieve the product.

2.0 LITERATURE REVIEW

In the last decades, many attempts have been made to develop and optimize product recovery network models. Thierry *et al.* [2] defined the five product recovery systems: remanufacturing, repairing, refurbishing, cannibalization and recycling. Their study included a comprehensive discussion of the product design approach for recovery, the importance of reducing disposal waste, the preparation of customers for green products and environmental legislation issues for recovery systems.

Majority of existing product recovery models have so far focus on recovering products which are non-perishable such as recycling sand [5, 6], copier machine [2, 6], electronics goods [7], computer [8], bottles, containers and pallets [9], tire[14], steel [15], glass [16], battery 16], cartridges [17], paper [18] and hazardous waste [10].

Unlike previous study, this study would like to focus on the recovery of perishable product. Most foodstuff, photographic film and pharmaceutical products have their expiration date, as they have a fixed known lifetime. Any items, which remain unsold by their expiration date, are considered outdated, and must be removed from inventory to be discarded with disposal cost or sold at discounted price. In this regard, a number of research papers appeared which deal with the inventory model for the perishable goods. However, few research concern about the recovery or reprocess of perishable goods.

Product deterioration is an important issue in product recall of perishable item [19]. Piramuthu *et al.* [13] developed a tracking and tracing system for contaminated product recall in perishable food supply networks with different actors in the supply chain (supplier, manufacturer and retailer). However, in their case the items usually are not reprocessed or recovered because there is no economic value in these items once they are identified to be contaminated. Hasani *et al.* [4] showed a case that recovery of the perishable product are not time dependent so the returned product can be reused at any time.

In this research perishable goods are product or goods which deteriorate with time can still be partially recovered depending on the level of deterioration. Grain based product such as rice exhibit this behaviour whereby partially degraded product maybe reprocessed into secondary product such as rice noodle and broken rice. Therefore, this research aims to reprocess the returned products before it totally deteriorates and simultaneously maximize the total recovery value of the product.

3.0 PROBLEM DESCRIPTION

With the proposed model, manufacturers responsible for perishable return product are able to decide when to retrieve the return products while maximizing the recovery value. The decisions to be made include: which, when and how does the return product being retrieve from the retailer with the objective to maximize the recovery value. The product loses its recovery value with time as the deterioration rate increase. Therefore, the decision has to be made regarding the return of this product for recovery process.

There are two types of transportation modes for returned products in this case. The first one is using the opportunity of forward distribution channel, as they can collect the returned products on the way back to the manufacturer which saves transportation cost. However forward transportation is not always available for the return product and waiting for the next available forward transportation will cause to deteriorate further with time. Another alternative is to have specially assigned transportation to retrieve the returned products but at added cost. Thus, this research aims to develop a mathematical model that could maximize the recovery value of perishable return product with minimum cost.

4.0 CONCEPTUAL FRAMEWORK

This conceptual framework is proposed to develop the model to solve the problem in retrieving return products from retailer. Figure 1 shows the flow chart of the proposed conceptual framework for the mathematical model.

Acceptance of request for return product from retailers will trigger the return product decision model. Non-recoverable product will not be considered for further analysis to prevent unnecessary transportation. Only products which are able to be recovered will be considered. The manufacturer needs to collect details regarding the return products for analysis.

Generally, if there is no request for return product from retailers than the model will not be used. This proposed model aim to handle if there is request to return the product from retailers occurred. A request to return product from retailers will trigger the return product decision model. Usually, this process takes place through communication process between manufacturer and retailer using telecommunications device.

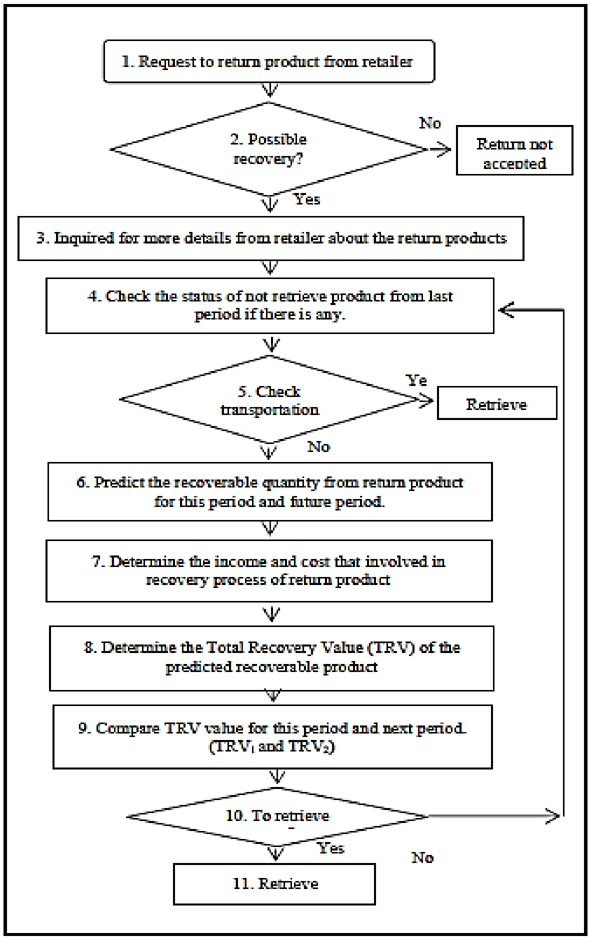

Figure 1. Conceptual Decision Framework of the mathematical model

Then, the manufacturer need to make decision whether to accept the request of return product or not. The decision depends on the functionality remains with the product. The model will proceed to next step if the products are recoverable. Non-recoverable product will not be considered for further analysis to prevent unnecessary transportation.

The mathematical model goal is to decide when to retrieve the product with optimum value. The mathematical model consists of determining the recoverable quantity of return product, the income and cost involved, and finally the total recovery value (TRV). All the parameters mention must be determine for current period and future period. As for the final decision will be obtain by comparing the TRV for current period with TRV for future period, for example comparing TRV for this month and TRV for next month. The decision to retrieve the product will be made at the period with the highest value of TRV. If the TRV for current period higher, then the product will be retrieve at current period and the reverse transportation will be utilized. However, if TRV for future period is higher, then the product need to wait and will be retrieve by next period with forward transportation.

5.0 MATHEMATICAL FORMULATION

This section describes the development of the mathematical model that represents the problem. The model formulation is based on the decision framework. The assumptions, the notations, and definitions used in this mathematical model will be described.

5.1 Assumption of the Model

The following assumptions are considered for the model.

- The return products have gone through the forward supply chain and are with the retailer.
- Single product and multi period are considered for this model.
- The costs for forward transportation are ignored. The costs of forward transportation are absorbed by forward distribution network.
- The fixed costs of production and transportation are known.

5.2 Notations

List of indices and parameters used in the model are:

Indices

n	index for retailer, n= 1,2,…..,N
t	index for time periods, t= -T,….,T

Parameters of the model

Q	Quality
FC	Forward channel transportation
RC	Reverse channel transportation
$\sum RV_t$	Total recovery value at month t, t = 1, 2
IRP_t	Income from recoverable return product at month t, t = 1, 2
ΣCRP_t	Recovery production cost at month t, t = 1, 2
SP	Sale price recovery product
KE_{nt}	Quantity of product that request to be returned from n retailers at period t
$KSPD_{nt}$	Quantity of product to be returned from n retailers because of packaging defects at period t.
KSE_{nt}	Quantity of product to be returned from n retailers because exceeds or almost expiry date at period t.
KSI_{nt}	Quantity of product to be returned from n retailers because of insect contamination at period t.
$KRPD_t$	Estimated quantity of recoverable product which encounter packaging defect at period t.

KRE_t	Estimated quantity of recoverable product that exceeds or almost expired at period t.
KRI_t	Estimated quantity of recoverable product that encounter with insect contamination at period t.
RRE_t	Recovery rate of product exceeds or almost expiry date at period t.
RRI_t	Recovery rate of product infected with insect contamination at period t.
RRPD	$_t$Recovery rate of product encounter packaging defect at period t.
FC_p	Fixed cost involve such as setup cost, maintenance cost, labour cost
VC_p	Variable cost
TPC_p	Recovery production cost
TC	Transportation cost
KT	Quantity of transportation
FTC	Fixed transportation cost for each vehicle such as labour and vehicle rent
VTC	Variable transportation cost per kilometre for each vehicle
D	Distance travel
TRV_t	Total recovery value at period t, t = 1, 2

5.3 Model Formulation

The formulation of the mathematical model is according to related problem regarding retrieving perishable return product.

Decision variable:

$$Q = \begin{cases} 1, & \text{if the return product can be recycled} \\ 0, & \text{if the return product cannot be recycled} \end{cases} \quad (5.1)$$

TC=

$$\begin{cases} 1, & \text{if forward transportation is not available,added cost for retrieval} \\ 0, & \text{if forward transportation is available,no added cost} \end{cases} \quad (5.2)$$

$$\text{ReT} = \begin{cases} 1, & \text{Retrieve now if TRVt} > TRV(\text{t+1}) \\ 0, & \text{Waitif TRV(t+1)} > TRV\text{t} \end{cases} \quad (5.3)$$

If the ReT=1 then the product will be retrieve at current period and the reverse transportation will be utilized. However, if the decision is ReT= 0 then the product need to wait and will be retrieve by next period with forward transportation.

Objective function:

Maximize [Total Recovery Value = Total Income - Total Cost]

$$\sum_{t=1}^{T} \text{TRV} = \sum_{t=1}^{T} \text{IRP} - \sum_{t=1}^{T} \text{C} \quad (5.4)$$

Constraints:

$$\sum K_{Ent} < C_{RP} \quad (5.5)$$

Total quantity of return product from retailer, $\sum K_{Ent}$ must not exceed the storage capacity, CRP for return product.

$$0 < RR \quad (5.6)$$

Recovery rate, RR must not more or equal than 1. If RR=0 this means that 100% material of the product has deteriorated and is unrecovered.

$$\sum K_{Ent} \geq 0 \quad (5.7)$$

$$K_{RPt} \geq 0 \quad (5.8)$$

Constraint: Non negativity

5.4 Example Application Of The Proposed Mathematical Model

The following is a simple example of the proposed mathematical model for understanding the model:

For example a request for a recall are made for 1000kg of rice at time, t=0. Assumed the product will start to deteriorate when it requested to be recalled and the forward transportations are not available.

Assuming:
Q= 1 (return product can be recycle)
TC= 1 (forward transportation not available)
Deterioration type = deterioration due to insect contamination only

In this example, the products deteriorate with time at the rate of 20% in the first period, 50% in the second period and 75% in the third period. Table 1 shows the result for quantity of recoverable product for each period and the income that could be earned from the predicted recoverable product.

Table 1 Recoverable product quantity for each period

	$t_{0\,(now)}$	t_1	t_2	t_3
Quantity of requested to be returned (kg),	1000			
Recoverable product (kg) at t_1 (20% DR)		800		
Recoverable product (kg) at t_2 (50% DR)			400	
Recoverable product (kg) at t_3 (75% DR)				100
Sale price for recovered product (Rm/kg)	10	10	10	10
Income (Rm)	1000 0	800 0	400 0	100 0

The value from Table 1 is used to calculate the total recovery value as shown in Table 2.

Table 2 Total recovery value (TRV) for each period

	Income (Rm) [a]	Transportation Cost (Rm) [b]	Production Cost (Rm) [c]	Total recovery value (Rm) = [a]- (b + c)
t_0	10,000	800	3,000	6200
t_1	8,000	-	2,400	5600
t_2	4,000	-	1,200	2800
t_3	1,000	-	300	700

Highest TRV value is $TRV_0 = 6200$

Therefore, ReT = $\begin{cases} 1, & \text{Retrieve now if } TRVt > TRV(t+1) \\ 0, & \text{Waitif } TRV(t+1) > TRVt \end{cases}$

ReT = 1

The Total Recovery Value, TRV for each period is calculated and the results are as shown in Table 2. The value TRV_0 of current period are larger than other period ($TRV_0 > TRV_1$, TRV_2 and TRV_3), Therefore the decision for retrieving the product will be made at current period. Although there is additional cost on transportation but worth it as the income at that moment are the highest and could overcome the additional cost.

6.0 CONCLUSION

Perishable return products which face deterioration process with time raise the issue on how to retrieve the product while the product can still be recovered or reprocessed with minimum cost. In this paper, we proposed a mathematical model for retrieving the perishable product recovery problems. The paper also contributes to the return product literature by improving our understanding of how manufacturer needs to react to the request for perishable return product. This mathematical model promotes better management of resources and how to systematically retrieve the perishable return product for recovery.

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