# REUSE OF TERTIARY PACKAGING IN PRODUCTION DISTRIBUTION NETWORK

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## ABSTRACT

Tertiary packaging is necessary for transportation in production distribution network because of the benefits in enhancing the logistic efficiency. However, in the meantime, it produces a lot of packaging waste every day. In fact, some tertiary packaging after transportation may still be in good condition and can be collected back for reuse. However, this has not been widely studied in the existing literature. Accordingly, this paper proposed an optimization methodology to maximize the collection of used tertiary packaging for reuse, meanwhile minimizing the total operating cost by taking the advantages of simultaneous optimization of a multi-day planning.

**Keywords**: Reuse, Tertiary Packaging, Production Distribution, Genetic Algorithm

## 1 INTRODUCTION

Recycling of packaging waste can directly reduce the consumption of raw materials. Meanwhile it can minimize the demand on landfill and land pollutions. Earlier before the issue of the Directive 94/62/EC on Packaging and Packaging Waste (PPW) in 1994, many research studies have already working on the minimization of packaging usage and more importantly, is the maximization of recycling of packaging. By that time, the focus was mainly on taxation approach [1]. Nowadays, the research focus is shifting from the legislation point of view onto the economic and financial benefits that can be obtained [2].

In general, a packaging system consists of three main parts knowns as primary, secondary, and tertiary packaging [3]. Primary packaging is regarded as the first envelop to protect directly the product. Secondary packaging is used to protect the primary packaging. Lastly, tertiary packaging is used for bulk handling in warehousing, and transportation. Tertiary packaging will affect the logistic efficiency in supply chains and induce different requirements on the handling equipment, vehicles, etc. [4]. In a typical production and distribution network, products will usually be sent from the source points with large batch size into different transit points, known as Distribution Centers (DC),

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for further dispatching in smaller sizes to the demand points. Accordingly, products will usually be packed with different tertiary packaging, such as plastic films, polystyrene foam, carton box, net, rope, etc. in order to reduce damages and tight different products together for the ease of handling.

This paper is divided into the following sections. Section 2.0 gives a literature review of the recent works in the field. Section 3.0 describes the problem to be studied. Section 4.0 presents the proposed optimization approach by using Genetic Algorithm. Section 5.0 discusses the resulting and findings, and lastly will be concluded by a conclusion.

## 2 LITERATURE REVIEW

In general, optimization of the recycling and reuse of items in production and distribution network will usually involve the simultaneous planning of both the forward and reverse flow of the items. In which, many of them focus on designing an optimal transportation route, facility location and allocation, etc. [5].

Practical applications of production and distribution network in recycling and reuse of products can be easily found in many literatures. For example, Krikke et al. [6] studied the recyclability and the design of the logistics network structure for electronic home appliances products (refrigerators). Jayaraman [7] studied a remanufacturing model of mobile phone. They considered the recycling and remanufacturing of several core components, and proposed a Remanufacturing Aggregate Production Planning approach to minimize various costs including inventory, dissembles, and remanufacturing. Olugu and Wong [8] proposed a fuzzy rule based system to measure the green supply chain management performance of automotive industry.

Other than recycling and reuse of products or components, there are many papers specially focusing on the recycling of plastic related items. For example, Kartalis et al. [9] studied the recycling of post-used polyethylene packaging film and their possibility of being reuse. Gomes et al. [10] also studied the recycling of plastic waste initiated by the huge consumption of plastic in Brazil with an estimation of 1150 thousand tons per year. Lee and Lee [11] studied to determine the optimal delivery route for the reuse of plastic bottle for distilling water. They proposed a multi-criteria decision support system to support recycling decisions. However, there are not many papers studying in the recycling and reuse of territory packaging.

## 3 MODEL DESCRIPTION

**Set**

| | |
|---|---|
| S | set of source points |
| D | set of demand points |
| Ø | set of DCs |
| I | set of Items |
| $\varphi$ | set of Days |

**Index**

| | |
|---|---|
| *s* | no. of source points, *s* = 1, 2, …, **S** |
| *i* | no. of Item types, *i* = 1, 2, …, **I** |
| *j* | no. of demand points, *j* = 1, 2, …, **D** |
| *k* | no. of DCs, *k* = 1, 2, …, Ø |
| *d* | no of days, *d* = 1, 2, …, $\varphi$ |

**Parameter**

$q_{ijd}$ demand quantity of item *i* at demand point *j* on day *d*.

$c_k$ maximum handling capacity of DC *k*.

$p_s$ maximum production capacity of source point *s*.

$r_{ik}$ recycle rate of item type *i* at DC *k*.

$c_{sk}^{S\emptyset}$ travelling cost between source point *s* to DC *k*.

$c_{ik}^{H}$ handling cost of item type *i* at DC *k*.

$c_s^{I}$ storage unit cost of collected packaging at source point *s*.

$c_{kj}^{\emptyset D}$ travelling cost between DC *k* to demand point *j*.

**Variable**

$\sigma_{isd}$ quantity of collected packaging of item *i* to be sent back to source point *s* on day *d*.

$y_{isd}$ quantity of unused packaging for item *i* to be stored at source point *s* on day *d*.

**Decision Variable**

$x_{iskjd}$ =1, if the item type *i* is supplied by source point *s* transited through DC *k* to demand point *j* on day *d*, otherwise = 0.

The distribution network studied is shown as in Figure 1. It consists of source points (**S**), distribution centers (∅), and demand points (**D**). The demand of each item type *i* at each demand point *j* is supplied by only one source point through only one distribution center. The demand quantity ($q_{ijd}$) for different types of item *i* at each demand point *j* is different along the planning horizon *d*. For the reason of batch delivery, items will usually be further packaged by using various simply packaging, such as carton box, plastic wrap, foam box, etc. for the ease of transport and protection in practice. Each source point *s* and each DC *k* has its maximum production ($p_s$ ) and handling capacity ($c_k$ ). Moreover, the skills of labor in each DC *k* on handling different types of items are varied. Therefore, the handling cost ($c_{ik}^{H}$) and the rate of collecting the packaging back for reuse ($r_{ik}$) is varied. In this model, the collected packaging for the items will be sent back to the source point during the return of the trip. Therefore, no extra transportation will be considered. However, if the collected packaging will not be reused on the next day, storage cost ($c_s^{I}$) will be induced. In addition, demand splitting is not being considered.

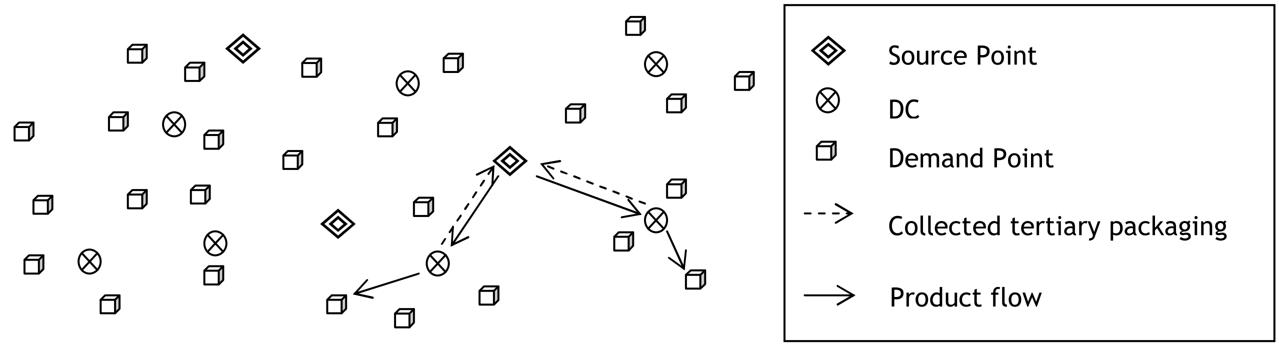


**Figure 1: Outline of the distribution network model**

The objective of the system is to minimize the total operating cost and maximize the total quantity of packaging being collected at DCs for reuse as shown in Equation (1). Among which, $Z_1$ is the total operating cost consisting of the total traveling cost from source points to DCs, total handling cost at DCs, total traveling cost from DCs to demand points, and total storage cost for collected packaging as shown in Equation (2). $Z_2$ is total quantity of packaging being collected at DCs for reuse as shown in Equation (3). $Z_1'$ and $Z_2'$ are used to normalize the total operating cost and total quantity of reused items. They can be the best known (or optimal) solution obtained by the optimization of only $Z_1$ and $Z_2$ as objective function respectively.

$$\textbf{Min } Z = \alpha(Z_1/Z_1') + (1-\alpha)(Z_2'/Z_2) \tag{1}$$

$$Z_1 = \sum_{i\in I}\sum_{s\in S}\sum_{k\in\emptyset}\sum_{j\in J}\sum_{d\in\varphi} x_{iskjd}\left(c_{sk}^{S\emptyset} + c_{ik}^{H} + c_{kj}^{\emptyset D}\right) + \sum_{i\in I}\sum_{s\in S}\sum_{d\in\varphi} y_{isd}(c_s^I) \tag{2}$$

$$Z_2 = \sum_{i\in I}\sum_{s\in S}\sum_{d\in\varphi} \sigma_{isd} \tag{3}$$

, where $y_{isd}$ = max$\{[\sum_{k\in\emptyset}\sum_{j\in J}(x_{iskjd}q_{ijd}) - \sigma_{is(d-1)} - y_{is(d-1)}],0\}$

, where $\sigma_{isd} = \sum_{k\in\emptyset}\sum_{j\in J} x_{iskjd}q_{ijd}r_{ik}$ .

***s.t.***

*Network flow constraints:*

$$\sum_{s\in S}\sum_{k\in\emptyset}\sum_{j\in J} x_{iskjd} = 1 \qquad \forall i \in I, \forall d \in \varphi \tag{4}$$

Constraints (4) ensure each demand will be supplied by exactly one source point and transit through only one single DC.

*Capacity constraints:*

$$\sum_{i\in I}\sum_{k\in\emptyset}\sum_{j\in J}(x_{iskjd}q_{ijd}) - p_s \leq 0 \qquad \forall s\in S,\ \forall d\in\varphi \qquad (5)$$

$$\sum_{i\in I}\sum_{s\in S}\sum_{j\in J}(x_{iskjd}q_{ijd}) - c_k \leq 0 \qquad \forall k\in\emptyset,\ \forall d\in\varphi \qquad (6)$$

Constraints (5) ensure the items supplied by source point *s* will not exceed the maximum production capacity of the source point. Constraints (6) ensure the items passing through the DC will not over the handling capacity of the DC.

## 4 OPTIMIZATION METHOD: GENETIC ALGORITHM

The decision in this problem is to determine the flow of the supply of items to demand points by passing through which DC. In addition, this paper aims to maximize the collection of packaging for reuse meanwhile minimizing the storage cost of the reused packaging induced due to not being used. As the demands of items at demand points along the planning days are different. Therefore, this characteristic is modeled in the encoding of the chromosome. Accordingly, a new encoding of chromosome is designed as follows.

*Encoding and Decoding of Chromosome*

The chromosome consists of $D \times J \times I$ number of genes as shown in Figure 1. Each gene consists of two values, representing i) the source point with value (1 to S), and ii) the DC ($1$ to $\emptyset$). Accordingly, the first gene with value of (4,2) in the chromosome value row represents that the Item 1 at Demand Point 1 will be supplied by Source Point 4 via DC 2. If there is no demand for a particular item at the demand point, a “-” will be given, such as Item 1 at Demand Point 2 on Day 1.

*Crossover Operation*

Two types of crossover mechanism are applied. The first type is traditional uniform crossover, in which a predefined number of chromosomes are randomly selected for crossover from the same Day *d*, which is also randomly selected. The reason of not selecting genes from different days is to avoid too random search. Figure 3 shows an example of crossover mechanism, in which two values are being selected from Parents A and B at the same position for crossover. After crossover, validation will be carried out to avoid invalid chromosome, which will be explained in later part.

**Chromosome *n***

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Day** | 1 | | | | | | | | | | | | |
| **Demand Points** | 1 | | | | 2 | | | | ... | J | | | |
| **Item** | 1 | 2 | ... | I | 1 | 2 | ... | I | ... | 1 | 2 | ... | I |
| **Chromosome value** | **4,2** | **3,1** | ... | **3,3** | **-** | **-** | ... | **2,3** | ... | **4,4** | **1,2** | ... | **-** |
| ... | ... | | | | | | | | | | | | |
| ... | ... | | | | | | | | | | | | |
| ... | ... | | | | | | | | | | | | |
| ... | ... | | | | | | | | | | | | |
| **Day** | **D** | | | | | | | | | | | | |
| **Demand Points** | 1 | | | | 2 | | | | ... | J | | | |
| **Item** | 1 | 2 | ... | I | 1 | 2 | ... | I | ... | 1 | 2 | ... | I |
| **Chromosome value** | **2,2** | **-** | ... | **3,4** | **5,2** | **2,1** | ... | **1,3** | ... | **3,5** | **4,2** | ... | **-** |

**Figure 2: A sample of chromosome encoding**

*Mutation Operation*

Two types of mutation will be applied. The first type is traditional uniform mutation operation. Similarly reason as in tradition uniform crossover, all the selected genes for mutation will be selected among the same day. Accordingly, a day will be randomly selected first. Then a predefined number of genes will be selected according to the mutation rate. The purpose is to prevent solution prematurity and increase solution diversity. In here, any selected gene will undergo mutation either in the value of source point or DC. For example as in Figure 5, the gene with value (3,3) and (2,3) being selected are undergo mutation into (4,3) and (2,2) in the value of source point and DC respectively.

## 5 NUMERICAL EXPERIMENT

This experiment aims to study the changes in terms of cost and the corresponding number of packaging(s) collected by reduction of the $\alpha$ value by using the same multi-day planning approach. The results are summarized in Table 1, in which, one can see that the total costs generally increased along with the reduction of the $\alpha$ value in small, medium, and large scale problems. This can be expected because the cost weighting is being reduced. Accordingly, on the other hand, the number of return packaging(s) collected is then increased. This can be seen in the all problem scales.

Increased Cost for each $\alpha$

$$= \frac{\text{Total cost obtained by using } \alpha \ - \text{Total cost obtained by using } \alpha{=}1}{\text{Total cost obtained by using } \alpha{=}1}$$

Increased Returns for each $\alpha$

$$= \frac{\text{Total packaging collected by using } \alpha \ - \text{Total packaging collected by using } \alpha{=}1}{\text{Total packaging collected by using } \alpha{=}1}$$

**Table 1: Summary of the results for adjusting cost and reuse weighting**

| | Small | | Medium | | Large | |
|---|---|---|---|---|---|---|
| **α** | **Increased Cost** | **Increased Returns** | **Increased Cost** | **Increased Returns** | **Increased Cost** | **Increased Returns** |
| **1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **0.9** | 0.7 | 1.1 | 1.3 | 2.2 | 1.6 | 3.1 |
| **0.8** | 0.8 | 1.3 | 2.1 | 3.1 | 2.6 | 4.7 |
| **0.7** | 0.8 | 1.3 | 2.7 | 3.6 | 3.4 | 6.3 |
| **0.6** | 1.1 | 2.3 | 3.1 | 4.9 | 4.6 | 8.2 |
| **0.5** | 1.4 | 2.5 | 3.4 | 5.2 | 5.8 | 8.6 |
| **0.4** | 1.5 | 2.8 | 3.9 | 6.1 | 6.5 | 9.7 |
| **0.3** | 1.8 | 2.9 | 4.3 | 6.8 | 7.1 | 10.5 |
| **0.2** | 2.1 | 3.0 | 4.4 | 7.0 | 7.2 | 10.6 |
| **0.1** | 2.2 | 3.1 | 4.6 | 7.1 | 7.4 | 10.8 |

## 6 CONCLUSION

Although many papers have been studied on recycling and reuse problem, recycling and reuse of tertiary packaging is not being studied thoroughly. In logistic operation, tertiary packaging helps in bulk transportation. However, this packaging will induce packaging waste and increase the demand on landfill and produce land pollution. By taking into the consideration of the variety in handling ability and recyclability of DCs, this paper proposed a multi-day planning approach to determine the product flow for every day so that the number of packaging can be collected for reuse can be maximize meanwhile the total operating cost can be minimized. The results also demonstrate that by the consideration of multi-day planning, the total operating cost can be reduced.

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