G Model
RECYCL-3302; No. of Pages 8

ARTICLE IN PRESS

Resources, Conservation and Recycling xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

Full length article

Maximizing recyclability and reuse of tertiary packaging in production and distribution network

Sai Ho Chung[a], Hoi Lam Ma[a], Hing Kai Chan[b,*]

[a] Department of Industrial & Systems Engineering, Hong Kong Polytechnic University, Hung Hom, Hong Kong
[b] Nottingham University Business School China, University of Nottingham Ningbo China, China

ARTICLE INFO

Article history:
Received 31 March 2016
Received in revised form 26 June 2016
Accepted 28 June 2016
Available online xxx

Keywords:
Recycle and reuse
Tertiary packaging
Production and distribution
Genetic algorithm
Logistics network

ABSTRACT

Tertiary packaging is necessary for transportation in any production and distribution network because of the benefits in enhancing the logistics 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. The purpose of this research is to fulfill this research gap. Accordingly, the contribution of this paper is to propose a new optimization methodology, named modified Genetic Algorithm with Crossing Date heuristic, to maximize the collection of used tertiary packaging for reuse, meanwhile minimize the total operating cost by taking the advantages of simultaneous optimization of a multi-day planning. From the numerical experiments, it is found that the optimization ability of proposed new optimization methodology outperform the traditional genetic algorithm by a maximum of about 10%. In addition, the total operating cost is found can be reduced by using the proposed multi-day planning approach.

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 (Pearce and Turner, 1992; Rousso and Shah, 1994). Nowadays, the research focus is shifting from the legislation point of view onto the economic and financial benefits that can be obtained (Cruz et al., 2012).

In general, a packaging system consists of three main parts known as primary, secondary, and tertiary packaging (Palsson and Hellström, 2016). 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 logistics efficiency in supply chains and induce different requirements on the handling equipment, vehicles, etc. (Jahre and Hatteland, 2004). 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), 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.

In reality, DCs are usually designed with different configurations and equipped with different handling equipment to serve and handle different product types (Baker and Canessa, 2009). As a result, different products to be handled may induce different handling cost, handling lead time, and efficiency (Gaiardelli et al., 2007). Although in literature, the factor of different DCs possessing different recyclability in handling different product types has been considered (Chung et al., 2013), the optimization methodology is usually designed to maximize the return on each individual planning day alone, and lack of the consideration of the interrelationship between the demands on different planning days. However, in practice, planning horizon is usually in multiple planning days, which is in fact given sufficient data to determine a better global solution. However, the difficulty is the much higher problem complexity it induced. For this reason, a more powerful optimization methodology is required. Accordingly, the research question here is how to allocate the orders from different source points to different DCs

* Corresponding author.
E-mail address: hingkai.chan@nottingham.edu.cn (H.K. Chan).

http://dx.doi.org/10.1016/j.resconrec.2016.06.025
0921-3449/

Please cite this article in press as: Chung, S.H., et al., Maximizing recyclability and reuse of tertiary packaging in production and distribution network. Resour Conserv Recy (2016), http://dx.doi.org/10.1016/j.resconrec.2016.06.025

with the aim of minimizing the total operating cost and maximizing the reuse of tertiary packages in a long run.

In this connection, the main academic contribution of this paper is to propose a new optimization methodology, named modified Genetic Algorithm with Crossing Date heuristic, in this research area to solve this complicated problem. In addition, the proposed methodology bring some practical contributions to environment and logistic companies by maximizing the reuse of tertiary packaging during the transportation, meanwhile minimizing the total operating cost. This paper is divided into the following sections. Section 2 gives a literature review of the recent works in the field. Section 3 describes the problem to be studied. Section 4 presents the proposed optimization approach named modified genetic algorithm with crossing date approach. Section 5 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. (Ozceylan and Paksoy, 2013). Recently, Agrawal et al. (2015) gave a very detailed literature review on reverse logistics.

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. (2003) studied the recyclability and the design of the logistics network structure for electronic home appliances products (refrigerators). Jayaraman (2006) 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 (2012) 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. (2000) studied the recycling of post-used polyethylene packaging film and their possibility of being reuse. Gomes et al. (2008) 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 (2012) 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. Bing et al. (2015) carried out a feasibility study of redesigning a reverse supply chain for household waste, which distributed from Europe to China under the emission trading scheme. However, there are not many papers studying in the recycling and reuse of territory packaging.

Optimization methodologies applied in solving the production and distribution network problems in recycling and reuse can generally be classified into two main approaches, i) Linear Programming, and ii) Meta-heuristic. Regarding linear programming, earlier in 1996, BloemhofRuwaard et al. (1996) applied linear programming to test the benefits of different the recycling strategies that may be obtained in pulp and paper sector. Krikke et al. (1999) applied Mixed Integer Linear Programming approach to minimize the total operating cost for recycling and discard of products for Original Equipment Manufacturers under the producer responsibility. Shih (2001) also applied Mixed Integer Programming to optimize the infrastructure design and the reverse network flow of a recycling network. Pati et al. (2008) applied Mixed Integer Goal Programming to optimize the paper recycling network in India. Demirel and Gökcen (2008) proposed a Mixed Integer Programming to optimize the production and transportation quantities of manufactured and remanufactured products for reuse. Ozceylan and Paksoy (2013) applied Mixed Integer Programming to optimize the transportation flow, location of factories, and retailers of a recycling and reuse network with multi-products multi-periods. Recently, Demirel et al. (2016) proposed a Mixed Integer Programming to determine the reverse flow for end-of-life vehicles in Turkey.

It is obvious that many papers have applied Linear Programming to deal with their problem. However, because of the problem complexity, applications of Linear Programming in some cases may become more difficult or sometimes even impossible (Banaszewski et al., 2013). Accordingly, there are many papers proposing different heuristic/meta-heuristics/approximation approaches. For example, Chouinard et al. (2008) applied Monte Carlo sampling methods to deal with a randomness rising from the quantities of recovery items, processing, and demand. Schweiger and Sahamie (2013) proposed a hybrid Tabu search approach to design the recycling network, which consists of external procurement, and in-house recycling of paper. Kannan and Haqaan (2009) applied Particle Swarm Optimization approach and Genetic Algorithm (GA) to solve the recycling network with forward and reverse flow. Later on, Kannan et al. (2010) constructed a Mixed Integer Linear Programming modeling for a battery recycling network, however, due to the problem complexity, they proposed Genetic Algorithms to solve the model. In fact, Genetic Algorithms (GA) has been widely used in solving this kind of problem, and is recognized to be a very promising approach. Wang and Hsu (2010) also constructed an Integer Linear Programming model to model the recycling, reuse, and recovery of a green supply chain, but proposed a revised spanning-tree based GA to deal with the problem. Tuzkaya et al. (2011) proposed a GA with ANP-fuzzy TOPSIS methodology to design the recycling and reuse network for the white goods industry in Turkey. Accordingly, in this paper, the proposed optimization methodology will also be developed based on GA.

3. Model description

Set
S—set of source points
D—set of demand points
ϕ—set of DCs
I—set of Items
ϕ—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, . . ., ϕ
d—no of days, d = 1, 2, . . ., ϕ
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.
$c_{sk}^{S\phi}$—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.
$c_{kj}^{\phi D}$—travelling cost between DC k to demand point j.
Variable
σ_{isd}—quantity of collected packaging of item i to be sent back to source point s on day d.