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Forward and reverse logistics network and route planning under the environment of low-carbon emissions: A case study of Shanghai fresh food E-commerce enterprises

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ABSTRACT

In view of the rapid development of low-carbon economy, the increasing distribution demand and returned demand which caused by the short shelf life and spoilage of fresh food, network and route planning model of a two-stage forward/reverse logistics is firstly proposed for fresh food e-commerce enterprises under the environment of low-carbon emissions (The objective in the first stage is to minimize the overall cost of the system, and the minimum overall cost of the circulation-type distribution vehicles routing is considered in the second stage). And the validity of the model is verified by adopting genetic algorithm (GA) and particle swarm optimization (PSO) algorithm with the study of the fresh food e-commerce enterprises of Shanghai. Furthermore, a good reference can be provided to build the forward and reverse logistics network and optimal route planning model of fresh food e-commerce enterprises and reduce the carbon emissions during its operation process.

1. Introduction

With the great concern of climate changes, many countries have taken actions to reduce carbon emissions by issuing more stringent legislations or setting emissions targets (Gracceva & Zeniewski, 2014). The Chinese Government launches a voluntary action and has pledged to cut the intensity of greenhouse gas emissions per unit of GDP by 40–45% over the period 2005–2020 (Cui et al., 2014; Liu et al., 2014; Yu & Qu, 2013). Naturally, these global policies and international climate agreement will require industries to reduce carbon emissions for fighting global warming (Tang et al., 2015). The carbon dioxide emissions which come from the transportation sector occupies approximately one quarter of overall carbon dioxide emissions (Nanaki & Koroneos, 2016; Van der Hoeven, 2012), and city logistics distribution industries have developed rapidly in recent years (Cattaruzza et al., 2015), thereby various initiatives emphasize the importance of taking CO_2 emissions account for e-commerce enterprises in the transportation.

The integration of the forward and reverse logistics network can avoid the sub-optimality and achieve optimum planning (Keyvanshokooh et al., 2013; Lee & Dong, 2008), which plays a critical role in carbon emissions (Cholette & Venkat, 2009). A well-designed logistics network is the optimal pursuit of eco-efficiency, which can balance economic and environmental efficiency (Fang, 2010; Wang, Lu, & Zhang, 2013). Ramezani, Bashiri, and Tavakkoli-Moghaddam (2013) proposed a stochastic multi-objective model to maximize the profit for forward/reverse logistic network design in which the objectives of the logistic network are customer responsiveness and quality. Alumur et al. (2012) considered a comprehensive MIP model for multi-period reverse logistics network design and investigated the reaction of an OEM to the trends in the return streams and secondary markets by determining the extent of its involvement in reverse logistics. Cattaruzza et al. (2015) developed a vehicle routing optimization model for urban goods distribution and analyzed those challenges raised by vehicle routing. Roghanian and Pazhoheshfar (2014) considered a multi-product, multi-stage reverse logistics network problem with minimum fixed opening cost and total shipping cost, and a mixed integer linear programming model is established. It could be found that there are limited attentions considering the design of forward and reverse logistics network and optimal route planning simultaneously for e-commerce enterprises.

There has been an increasing interest within the field of environmental issues (Jabbour et al., 2015). Shaw et al. (2016) formulated a sustainable supply chain network design model considering carbon emissions and carbon trading issues in which the

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network design problem is solved using a Benders-based solution methodology. Yang, Guo, and Ma (2016) presented a city logistics distribution network planning model considering the constraint of low-carbon resources and they analyzed how to control carbon emissions. A carbon footprint-based reverse logistics network design model is proposed by Kannan et al. (2012) with the goal of minimizing the total cost and the emissions. All the aforementioned research considered the situation separately either relating to the design of forward and reverse returned logistics network or involving the environment of carbon emissions.

Since 2013, fresh agricultural products have become the fourth largest category of online selling products in China (China Electronic Commerce Research Center, 2014; Li, 2014), and the fresh good may be easily spoilt during delivery (Lin, Yeh, & Huang, 2013), which leads to a large amount of returned products. As a consequence, the establishment of efficient logistics network is essential for fresh food e-commerce (Dablanc, 2007). A vehicle routing problem is addressed for perishable food by Hsu, Hung, and Li (2007) with time-windows (VRPTW). Osvald and Stirn (2008) developed an algorithm for the distribution of fresh vegetable with time windows and time-dependent travel-times (VRPTWTD). Govindan et al. (2014) proposed a two-echelon location–routing problem by formulating a multi-objective optimization model in a perishable food supply chain network (SCN). These previous researches did not take the fresh food into consideration, and none of them took into account the design of forward and reverse returned logistics network for fresh food e-commerce.

Based on the analysis above, this paper firstly proposes a forward/reverse logistics network and closed-loop route planning model for fresh food e-commerce enterprises under the environment of low-carbon, which includes construction cost, operation cost, information-processing cost, transportation cost and carbon tax. In the first stage, minimizing the total system costs is objective function. In the second stage, minimizing the transportation costs of the distribution vehicles closed route is objective function. The optimal solution of this system is determined by the interaction of the operations in these two stages. And a calculating case study of optimal operation in Pudong new area, a district in Shanghai, China of fresh food E-commerce enterprises is used to verify the feasibility of the model by adopting genetic algorithm (GA) and particle swarm optimization algorithm (PSO).

The main contributions differentiating our efforts from published papers on the subject are as follows. First, due to the perishable feature of fresh food, the model could provide an effective mode for the distribution and returned products recovery of fresh food e-commerce enterprises with the goal of reducing costs and the negative effect caused by carbon emissions. Second, the regional forward and reverse logistics network and route planning model for fresh food e-commerce enterprises under the environment of low-carbon emissions is firstly proposed, and the model is more appropriate for the actual operation of enterprises. The features of the cited papers and gap in the literature are shown in Table 1. And the framework of the paper is shown in Fig. 1.

2. Fresh food e-commerce forward and reverse logistics network design and path planning model

2.1. Model structure analysis

Fresh food e-commerce forward and reverse logistics network structure is shown in Fig. 2, which consists of seven parts

Functions of each part in the network are described as follows:

- Customers: consumers who buy or return fresh products.
- E-commerce enterprises: enterprises that receive customers' orders or returned information, and send messages to the distribution/recovery centers.
- Pick-up points: TPL distribution terminals, customers' picking up points and returned products collected points.
- Distribution/recovery centers: in order to reduce total system cost, an integrated distribution and recycling center is used in the model, which can be used to receive orders information from e-commerce enterprises and distribution products in forward logistics and can also be used to receive returned products' information from e-commerce enterprises and classify returned products, and here whether the returned products are transported to the food processing plants or the landfills is arranged.
- Food processing plants: it is responsible for processing returned products into canned or semi-finished products and so on.
- Landfills: it is responsible to receive and landfill the returned products from recovery centers.
- Carbon emissions: The emissions which occur during transportation.

2.2. Mathematical model

(1) Assumptions

To model the forward and reverse logistics system, the following assumptions are introduced:

- Locations of candidate pick-up points, locations of candidate distribution/recovery centers, and locations of customers, food processing plants, and landfills are all known.
- Each customers' picking up point can design its capacity selected from among three types, i.e., small, medium, and large size. These three types have different but fixed capacities (Song, Ko, & Hwang, 2015).
- Calculate the distance between nodes by Euclidean distance.
- Excellent linearity among the transportation cost of returned products shipped from recovery centers to food processing plants or landfills and transportation volume and distance is achieved.

Table 1
Comparing our paper with the cited articles.

	Forward logistics	Reverse logistics	Logistics network	Route planning	Low carbon	Fresh food e-commerce
Ramezani et al. (2013)	√	√	√			
Alumur et al. (2012)		√	√			
Cattaruzza et al. (2015)	√			√		
Roghanian and Pazhoheshfar (2014)		√	√			
Shaw et al. (2016)	√		√		√	
Yang et al. (2016)	√		√		√	
Kannan et al. (2012)		√	√		√	
Hsu et al. (2007)	√			√		
Osvald and Stirn (2008)	√			√		
Govindan et al. (2014)	√		√	√		
Our paper	√	√	√	√	√	√