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Integrated production and transportation scheduling for multi-objective green supply chain network design

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Abstract

A green supply chain has been attracting attention as a new approach to minimize a product or service ecological footprint. Our previous researches proposed a basic green supply chain network model consisting of two model components, clients and suppliers. The model provided a numerical method to determine suitable prices and delivery times of ordered products through the modification processes of both production schedules by using genetic algorithms and transportation schedules by heuristic rules and the negotiation processes between suppliers and clients by using an auction based method. The objective of this paper is to propose an integrated scheduling method of production and transportation problems in order to further reduce carbon dioxide emissions without decreasing profits of suppliers. The proposed method makes an efficient transportation schedule that ensures a low vacancy rate and a high loading ratio of transportation vehicles by repeating the modification processes of production and transportation schedules alternately. Experiments were carried by using a developed supply chain simulation system. As the results of the experiments, new method was able to decrease carbon dioxide emissions without decreasing profits.

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Keywords: Green supply chain; Carbon dioxide emissions; Prodution schedule; Transportation schedule; Genetic algorithm

1. Introduction

Sustainability issues, such as greenhouse gas emissions, hazardous industrial waste, and environmental pollution, have become serious problems facing the international community. Greenhouse gas emissions have been especially blamed for raising the Earth's temperature [1]. A green supply chain is expected as a new approach for reducing waste, minimizing pollution, saving energy, conserving natural resources, and reducing carbon emissions. Logistics and transportation activities attract the most interest among companies which claim to have established a green supply chain. Most of the companies have made changes to their transport and logistics operations, and half have made cuts in transportation. About 80 percent of the companies claim to factor environmental concerns into their strategic decisions, but fewer have implemented green supply chains [2]. Gungor and Gupta [3] pointed out that the effort must be made for environmentally conscious manufacturing systems to be profitable in order to continue developing and planning of these systems.

Our previous researches proposed a basic green supply chain network model for considering not only environmental but also economic aspects in order to obtain a large amount of profit and to reduce the amount of carbon dioxide emitted during the transportation process [4]. The model consists of two model components; those are clients and suppliers. The model provided a numerical method to determine suitable prices and delivery times of products through the modification processes of both production schedules by using genetic algorithms and transportation schedules by heuristic rules and the negotiation processes between suppliers and clients by using an auction based method in order to obtain profit considering carbon dioxide emissions reductions in the transportation processes.

This paper presents an integrated scheduling method of production and transportation problems in order to further reduce carbon dioxide emissions without decreasing profits of suppliers. This method makes an efficient transportation schedule that ensures a low vacancy rate and a high loading rate of transportation vehicles by repeating the modification

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processes of production and transportation schedules alternately. A prototype of supply chain simulation system is developed for production and transportation scheduling problems. Experiments are carried out on a two-layered supply chain model in order to verify the effectiveness of the proposed method from the viewpoint of both the profits of suppliers and the amount of carbon dioxide emitted from transportation process.

The reminder of this paper is organized as follows. Section 2 presents a background. Section 3 explains the previous basic supply chain model. Section 4 formulates the scheduling method proposed in this research. Section 5 assesses the effectiveness of the proposed method by using a developed supply chain simulation system and demonstrates results of experiments. Finally, Section 6 concludes this study.

2. Background

Environmental issues are gaining popularity among society, governments and industry due to negative environmental developments [3]. Bloemhof-Ruwaard et al. [5] introduced some OR models and techniques to deal with the environmental issues. Cholette and Venkat [6] calculate the energy and carbon emissions associated with the transportation links and warehousing activities in food and beverage supply chains, particularly in the wine industry. A carbon labeling system of products has been emphasized to help consumers' environmental decisions in the supply chain. The implication is that an effective mechanism to encourage green cooperation along the supply chains still needs to be developed [7]. Many businesses that sell environmentally friendly, green or sustainable, low carbon emission products tend to cost more [8]. This cost is usually passed onto the consumers in the form of higher prices. Sundarakani et al. [9] proposes that companies that do not measure and manage carbon emissions along their supply chains and in collaboration with their supply chain partners will place themselves at a disadvantage. As only papers dealing with supply chain management are taken into account, it is logical that economic issues are addressed. The green and sustainable supply chain management is the management of material, information and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of sustainable development, i.e., economic, environmental and social, which are derived from customer and stakeholder requirements [10]. Therefore, a method for green supply chain management should be superior from the viewpoint of both the economical aspect and environmental aspect.

3. Basic supply chain model

3.1. Two-layered supply chain model

In this paper, a two-layered dynamic supply chain model is considered as a basic supply chain model, as shown in Fig.1. The model consists of two stages or levels including two kinds of components respectively; they are a client and a supplier. The clients require products and send orders for them to all the suppliers. The suppliers generate offers and send them to the client. The offers include information about bid prices and possible delivery times for the products, which have been determined by the modification processes of the production and transportation schedules and by the negotiation processes between the clients and the suppliers.

Figure 2 shows a combination between a production schedule and a transportation schedule. The following conditions are assumed in the transportation model.

- A product is transported form a supplier to a client by a transportation vehicle. The transportation vehicle does not travel to two or more clients in one delivery.
- Each transportation vehicle leaves a supplier at a constant time interval and transports products in a given time.
- The capacity for loading products is limited on a transportation vehicle. The quantity of products loaded on a vehicle is less than or equal to the limit of the capacity.

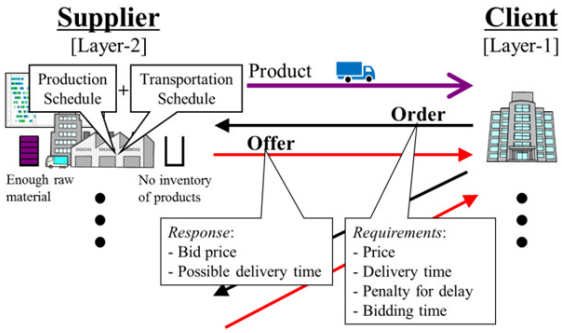

Fig. 1. Two-layered dynamic supply chain model.

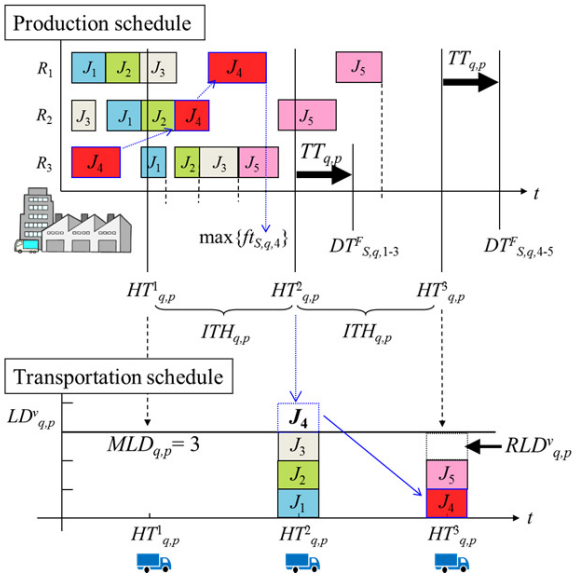

Fig. 2. Combination between production and transportation schedules.