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Adaptive memory artificial bee colony algorithm for green vehicle routing with cross-docking

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ABSTRACT

Cross-docking distribution is becoming increasingly prevalent in supply chain management (SCM) due to the replacement of storage and order-picking with efficient product consolidation. Several successful cross-docking applications have been put into practice by companies such as Wal-Mart, FedEx, and Home Depot. Cross-docking consists of interrelated operations which require proper synchronization. Only a few early attempts have addressed the vehicle routing problem in this context. Moreover, the social consciousness of sustainable development has brought up the issue of green SCM which is not only environment-friendly but also beneficial to business values. This paper first addresses a previously studied problem and then proposes a new problem version for planning the least cost green vehicle routing in which the deployed vehicles transport the final products from suppliers to customers through a cross-dock subject to a CO_2 intensity constraint. We develop an adaptive memory artificial bee colony (AMABC) algorithm to tackle both problems. Compared to a Tabu search proposed in the literature, the AMABC algorithm can reach higher fuel efficiency by managing the loading along the route and yield less cost and CO_2 intensities. Statistical tests of simulation and geographic data show that the AMABC method is robust against the problem size and convergence of the objective value is guaranteed with high confidence.

1. Introduction

Many logistics strategies exist in practice for supply chain management (SCM). Among others, cross-docking distribution has become prevalent since no or very little holding inventory is incurred in transshipping [1]. Cross-docking distribution considers the pickup and delivery of goods from backhaul suppliers to linehaul customers in the supply chain. A fleet of inbound vehicles leaving from the cross-dock takes routes to visit backhaul suppliers and pickup the ordered goods, then returns to the cross-dock to unload the goods. These goods are sorted inside the cross-dock according to the orders and are directly reloaded into the outbound vehicles which then deliver the requested goods to the destination customers. Compared to traditional distribution center logistics strategies, cross-docking has the following advantages.

- Labor saving (no need to perform an order picking function inside the cross-dock);
- Cost reduction (no or very little inventory holding cost);
- Time saving (shorter delivery lead time to requested orders);
- Better resource utilization (no or very little storage space and facility in the cross-dock).

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The distribution strategy performed by cross-docking entails several operational research topics for facilitating efficient logistics. Some of these topics include: (1) The vehicle routing of the fleet should be optimized to minimize the transportation cost; (2) optimal dock-door assignment for inbound and outbound vehicles to reduce the handling cost of goods sorting; (3) optimal scheduling (sequencing) of inbound and outbound vehicles in front of the dock doors in order to shorten the makespan of the cross-docking; and (4) optimal location selection and layout design of cross-docks. These cross-docking research topics cast new operation scenarios on some classic combinatorial problems, such as the vehicle routing [2,3], task allocation [4], flow-shop scheduling [5], and *p*-median [6] problems. Resembling the existing methods for these noted complex combinatorial problems, the major cross-docking solutions fall into three kinds of approaches: mathematical programing, heuristics, and metaheuristics. Due to the ability to provide a good tradeoff between solution quality and consumed computations, metaheuristics is more preferred in the literature than the other two approaches.

According to a most recent cross-docking survey [7], few studies related have investigated the vehicle routing problem as compared to other topics in the cross-docking context. All of these early studies adopted the Tabu search as their major solution method and the obtained results were not compared to those obtained by using other metaheuristic methods. A lot of space still exists for investigating the strengths and weaknesses between applications using the Tabu search and those using other metaheuristics. The addition of new practical elements to the previously studied problem and the adaption of the algorithms to the new version of the problem are also worth further consideration.

Moreover, the implementation of green logistics has interested many researchers and practitioners [8]. Green logistics involves using or producing environmentally-friendly materials in all processes of a supply chain. One of the main issues is the reduction of the carbon dioxide (CO_2) emissions. The Paris protocol released in 2015 at the United Nations Climate Change Conference got 196 countries involved emissions reduction. It is anticipated that the restriction on carbon emissions will be more rigorous in the future. This inspires us to take into account the impact of CO_2 emissions in cross-dock logistics due to the use of fossil fuels for vehicle routing.

This paper first addresses the previously studied cross-docking vehicle routing problem and then proposes a new metaheuristic algorithm as an alternative solution method. Our method is an adaptive memory artificial bee colony (AMABC) algorithm which hybrids the adaptive memory programing [9] and the artificial bee colony [10] in a single framework to synergize the respective advantages of the combined methods. We then introduce new elements including cost definition and carbon emissions that could be added to the problem and explain how the proposed algorithm could be adapted to consider them. The experimental results with the dataset of the previously studied problem and the real geographic dataset of the new problem show our algorithm achieves remarkable improvement when compared to existing approaches.

The remaining of this paper is organized as follows. Section 2 presents a literature review of the related problems and approaches. Section 3 describes the addressed problems and the proposed algorithm. Section 4 presents experimental results and performance evaluation. Finally, concluding remarks are given in Section 5.

2. Literature review

2.1. Pickup and delivery

The general pickup and delivery problem (GPDP) considers logistics strategies for suppliers and customers with a fleet of vehicles [11,12]. It contains three types of logistics, as illustrated in Fig. 1. The first-type strategy renders logistics where all goods delivered should be loaded at one or more depots and all goods picked up have to be transported to one or more depots. The depot(s) provides goods storage and order-picking to improve vehicle-loading. The second-type of strategy refers to a situation where the goods are transported from customers to customers. No depots are needed in this practice; however, the utilization of vehicle capacity is low. In the third-type strategy, empty vehicles firstly pickup goods from backhaul suppliers and transport them to one or more cross-docks where the goods are sorted and consolidated according to the orders and then reloaded into outbound vehicles for transshipping to linehaul customers. No or little goods storage is provided in the cross-dock, so almost no inventory-holding cost is incurred. Moreover, cross-docking performs goods sorting and consolidation, aiming to make full usage of vehicle capacity.

The features of GPDP can be better realized by comparing the various characteristics possessed by existing works for tackling the three types of problems. The related literature is thus referred to in the following dimensions: problem

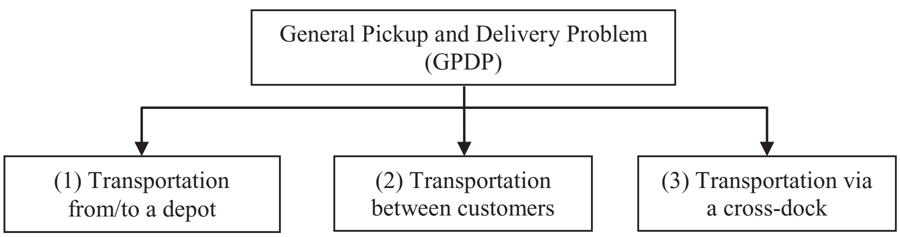

Fig. 1. Three types of logistics strategies for the general pickup and delivery problem.