Journal of Manufacturing Systems 33 (2014) 567–577

Contents lists available at ScienceDirect

Journal of Manufacturing Systems

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

Cross-docking and milk run logistics in a consolidation network: A hybrid of harmony search and simulated annealing approach

Seyed Davod Hosseini, Mohsen Akbarpour Shirazi*, Behrooz Karimi

Department of Industrial Engineering, Amirkabir University of Technology, Tehran, Iran

ARTICLE INFO

Article history:
Received 11 November 2012
Received in revised form 4 March 2014
Accepted 7 May 2014
Available online 5 June 2014

Keywords:
Transportation problem
Cross-docking
Milk run logistics
Integer programming
Simulated annealing
Harmony search

ABSTRACT

In this paper, we develop a novel integer programming model for the transportation problem of a consolidation network where a set of vehicles are used to transport goods from suppliers to their corresponding customers via three transportation systems: direct shipment, shipment through cross-dock (indirect shipment) and milk run. Since the proposed problem formulation is NP-hard, we offer a hybrid of harmony search (HS) and simulated annealing (SA) based heuristics (HS-SA algorithm) in order to solve the problem. The objective of this problem is to minimize the total shipping cost in the network, so it is tried to reduce the number of required vehicles using an efficient vehicle routing strategy in the algorithm. Solving several numerical examples demonstrates that our solving approach performs much better than GAMS/CPLEX in reducing both the shipping cost in the network and computational time requirement, especially for large size problem instances.

1. Introduction

Freight transportation plays a fundamental role in every modern supply chain. It is essential to move raw materials from sources to plants, semi-finished products between factories, and final goods to customers and retail outlets. Transportation cost accounts for a significant part (often between one-third and two-thirds) of the logistics cost in several industries [1]. There are several different kinds of transportation networks: direct shipping, cross-docking, milk runs and tailored networks [2]. If a shipment consists of a full truckload (TL), it is economical to ship directly from seller to buyer. However, when orders are less than a truckload (LTL), the other three approaches can be considered [3].

The cross-docking of a product through a distribution centre is recognized as one of the basic distribution strategies [4]. Cross-docking refers to a process where the product is received in a facility, occasionally married with other products going to the same destination, then shipped at the earliest opportunity, without going into long-term storage [5]. Cross-docking produces many benefits, including: the elimination of activities associated with storage of products; faster product flow and improved customer service; reduced product handling; cuts in inventory and finally lower costs due to the elimination of the mentioned activities [6]. Cross-docking can provide greater control over delivery schedules. The use of a cross-dock is thus well suited to the Just-In-Time (JIT) manufacturing environment [7] and also to the make-to-order environment [8].

The name of milk run logistics comes from the traditional system for selling milk in the West, in which the milkman used to walk to the doors of the customers' houses with his dray in a specified route and delivered the milk in bottles to his customers and finally took back the empty bottles. This system has been used in various industries and the automobile manufacturing companies around the world have been (and are) the most important clients of this system [9]. This type of transportation system is designed for suppliers located near each other. It prevents them from accumulating their shipments to reach the truck load and also sending their shipments in the volumes of less than a truck load, which leads to an increase in the transportation cost. Indeed, making a milk run trip among these suppliers can avoid the inventory holding costs and also help goods to be transported to the customers faster. Such results coincide with the well-known manufacturing systems like JIT strategy.

The third consolidation network, the tailored network, combines both TL and LTL by allowing high-volume orders to be shipped from suppliers to customers directly, and low-volume orders to be consolidated [3]. In this paper, for the first time in the literature we focus on a tailored network where the above-mentioned three types of transportations (direct shipment, shipment through cross-dock centres and milk run logistics) can be used simultaneously in order to minimize the total transportation cost in the network. A set

* Corresponding author. Tel.: +98 21 64545370; fax: +98 21 66954569.
E-mail addresses: akbarpour@aut.ac.ir, m.a.shirazi@gmail.com (M. Akbarpour Shirazi).

http://dx.doi.org/10.1016/j.jmsy.2014.05.004
0278-6125/

of real problems that the automobile industry of Iran is facing now has created the incentive to do this research. The inbound logistics in this industry involves many part suppliers, several cross-dock centres and a few car assembly plants which are all spread through the far and near points of the country. The suppliers' manufactured parts are collected and transported to the assembly plants by a fleet of vehicles. The automobile industry has stressed the importance of production based on JIT principles in recent years, so its aim is to keep down inventory levels by transporting goods more frequently in less order volumes.

In an attempt to achieve this aim, we design a novel model that consolidates low-volume loads through cross-docking and/or milk run logistics and allows high-volume loads to be shipped directly from part suppliers to assembly plants. In fact, this model decides how the load of each supplier to each assembly plant should be routed and consolidated in the network in a way that the need for the vehicles to perform the transportations is minimized. Hence, a novel integer programming model is proposed to state the problem, but its complexity and NP-complete nature require a combination of heuristics and meta-heuristic optimization algorithms for solving, which is realized in this paper by a hybrid of harmony search algorithm (HS), simulated annealing algorithm (SA) and a heuristics.

The rest of paper is structured as follows. We review the literature in the next section. In Section 3, we define the problem and state the mathematical model. Our proposed approach is presented in details in Section 4. Next, we discuss the computational study and solve several numerical examples in Section 5. Finally, conclusions are drawn and suggestions for future research are offered in Section 6.

2. Literature review

Problems related to milk run logistics can be considered as a special case of vehicle routing problems (VRP). So far a lot of studies and research have been presented in various categories of VRP problems, their modelling and their solving, but there are only a few studies that have regarded VRP and cross-docking simultaneously.

Donaldson et al. [10] developed a cross-docking network model that determines how many trucks should be assigned to each link (origin to destination, origin to cross-dock, and cross-dock to destination) and how flow should be routed. Lee et al. [11] proposed a tabu search (TS) based algorithm to determine the number of vehicles and the best route, schedule, and arrival time of each vehicle at a cross-dock to minimize the transportation cost, considering cross-docking in the planning horizon. In the sequel, Liao et al. [12] developed a new TS algorithm and showed that it can achieve a better performance than Lee et al.'s TS. Chen et al. [13] studied a network of cross-docks taking into consideration delivery and pickup time windows, warehouse capacities and inventory-handling costs. They developed local search techniques and used them with simulated annealing and tabu search. Sadjadi et al. [9] proposed a new mathematical model for milk run problem. Their mathematical modelling is customized for a special case of an automobile industry in Iran. They used a genetic algorithm (GA) method to find a near-optimal solution. Wen et al. [14] studied a VRPCD problem (VRP with cross-docking) in which a set of homogeneous vehicles are used to transport orders from the suppliers to the corresponding customers via a cross-dock. The objective of the VRPCD is to minimize the total travel time while respecting time window constraints at the nodes and a time horizon for the whole transportation operation. A TS heuristic is embedded to solve the problem. Musa et al. [15] addressed the transportation problem of cross-docking network where the loads are transferred from suppliers to customers through cross-docking facilities, without

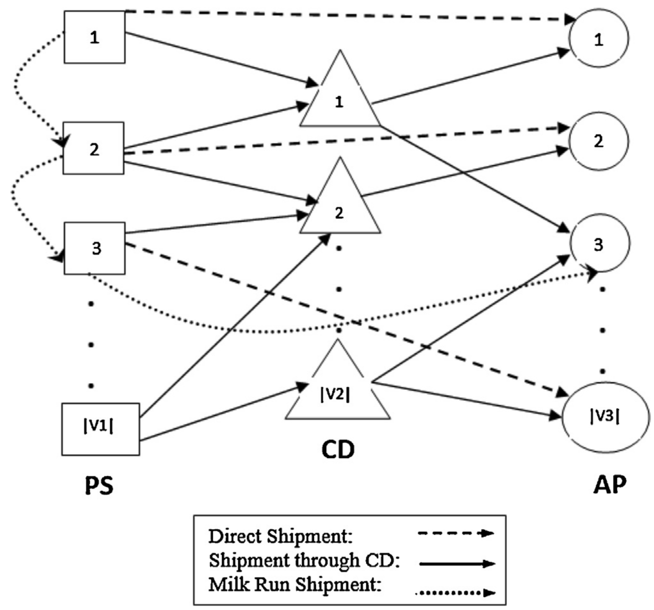

Fig. 1. Transportation problem of the consolidation network.

storing them in a distribution centre. The objective of the problem is to minimize the transportation cost in the network by loading trucks in the supplier locations and then route them either directly to the customers or indirectly to cross-docking facilities. The problem is solved using an ant colony optimization (ACO) algorithm. Our problem can be considered as a challenging extension of Musa et al.'s [15] distribution planning problem. In fact, in our model the opportunity of using milk run logistics is added to the cross-docking network studied by Musa et al. [15], although it has increased the complexity of the problem (with 5 and 12 more integer variables and constraints, respectively), and so has required us to spend much more computational time by GAMS/CPLEX and design a more complicated solution approach (a hybrid of one heuristic and two meta-heuristic algorithms). Ma et al. [16] studied a new shipment consolidation and transportation problem in cross-docking distribution networks that considers trade-offs between transportation costs, inventory and time scheduling requirements. The model is formulated as an integer programme and a heuristic solution approach is provided. Mousavi and Tavakkoli-Moghaddam [17] presented a two-stage mixed-integer programming (MIP) model for the location of cross-docking centres and vehicle routing scheduling problems with cross-docking due to potential applications in the distribution networks. Then, an algorithm based on a two-stage hybrid simulated annealing with a tabu list taken from tabu search (TS) is proposed to solve the presented model.

3. Problem definition

The network in our research comprises $|V1|$ part suppliers (PS), $|V2|$ cross-docks (CD) and $|V3|$ assembly plants (AP) (see Fig. 1). Shipping the loads from the suppliers to the assembly plants is done via three transportation systems in a way that the number of required vehicles, and as a consequence, the total transportation cost is minimized.

Our mathematical model has the following assumptions adopted from Musa et al. [15]:

(1) The loads to be sent from each supplier to each plant are known and assumed to be less than the truck capacity. Otherwise, the solution is trivial since the truck for that flow will require to go directly from the supplier to the plant.