Computers & Industrial Engineering 97 (2016) 137–145

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

The vehicle loading problem with a heterogeneous transport fleet

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ARTICLE INFO

Article history:
Received 17 August 2015
Received in revised form 28 April 2016
Accepted 30 April 2016
Available online 2 May 2016

Keywords:
Vehicle loading problem
Finished vehicle logistics
Heterogeneous multi-type fleet
Improved branch and bound algorithm
Greedy search

ABSTRACT

As an emerging variant of the vehicle loading problem, the heterogeneous multi-type fleet vehicle loading problem in finished vehicle logistics (HVLP–FVL) is modeled and solved. The HVLP–FVL maximizes the total profit of a vehicle fleet where different models of finished vehicles result in different profits and routing costs are considered based on distance traveled. Addressing the vehicle structures, simplified geometric models of both the finished vehicle and transport vehicle are defined. The optimization considers which finished vehicle orders to transport and then makes the loading assignment to the transport vehicles. To improve the computational performance of the traditional branch and bound algorithm, an enhancement using greedy search based on oscillation analysis is proposed. A real case study is used to evaluate the effectiveness of the improved algorithm and a series of experiments are conducted over a set of finished vehicle loading problems. The results demonstrate the proposed approach has superior performance and satisfies users in practice. Contributions of the paper are the modeling and solving of a real complex problem in vehicle manufacturing logistics and a simple branch-and-bound speed up that could be used in other problem classes.

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1. Introduction

In recent years the auto industry was witnessed greater development of finished vehicle logistics. It is now becoming standard practice to use third party logistics providers for transportation, storage, and services. Finished vehicle logistics is a bridge between auto manufacturing enterprises and auto dealers, and provides efficient service for both. Finished vehicle logistics is broadly defined as a series of associated processes from assembly plants to final destinations. Problems and trends arising in the finished vehicle logistics supply chain motivate researchers and practitioners to study these processes with the aim to improve them. Among them, the loading process is a distribution logistic operation that is of vital importance. It is not only the beginning of a series of finished vehicle logistics operations, but also the quality of the loading solution is a crucial economical factor. To take a simple example, two finished vehicles with a length of 4 m, a width of 1.5 m and a height of 1.4 m cannot be loaded in a transport vehicle space with a length of 6 m, a width of 2 m and a height of 2 m although the volume of both finished vehicles makes up just 70% of the vehicle loading volume. Issues such as this motivate the vehicle loading problem in finished vehicle logistics (VLP–FVL). In practice, the VLP–FVL is done by a manager's experience or through simple heuristics. However, with increasing industry competition, the logistics enterprise's objective is to maximize the possible profit with a reasonable computation time. With the number of factors involved it is difficult to achieve this by personal experience or simple heuristics. If the transport fleet is heterogeneous, it makes the problem more challenging. By providing an effective and practical solution approach to this complex problem this paper contributes to the automotive logistics field. And by improving the branch and bound algorithm with a greedy search based on oscillation analysis this paper contributes in general to the optimization literature.

The paper is organized as follows. The next section describes the problem. Section 3 cites the related literature. Section 4 builds geometric models for both the finished vehicle and the transport vehicle. Section 5 introduces a solution method for the HVLP–FVL. Section 6 presents a branch and bound approach using greedy search. Real test instances, search process comparisons, and performance analyses are discussed in Section 7. Finally, conclusions are drawn in Section 8.

2. Problem overview

In Fig. 1, the problem considers a set of ordered items (finished vehicles) characterized by length, width, height, weight and profit and a transport vehicle fleet types characterized by length, width,

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http://dx.doi.org/10.1016/j.cie.2016.04.021
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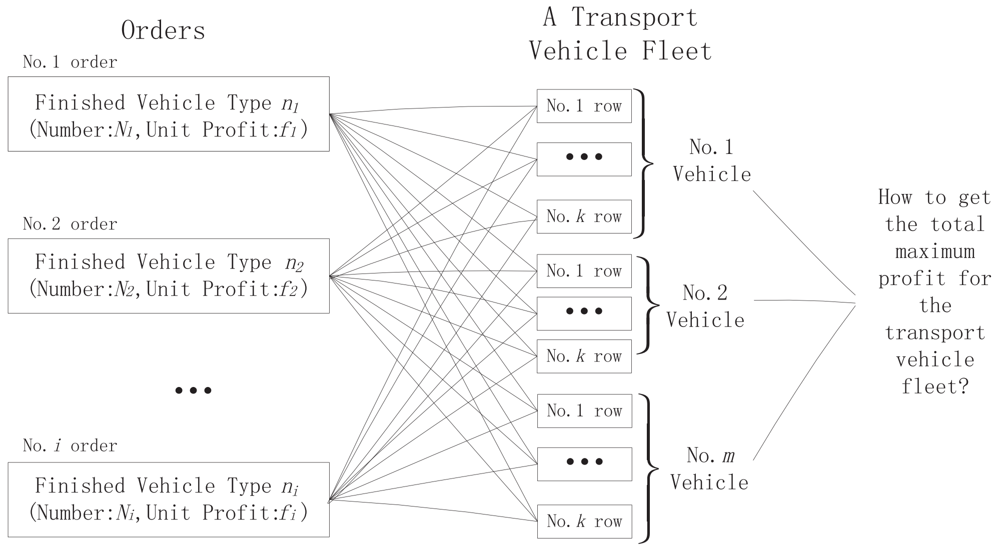

Fig. 1. The description of the HVLP–FVL.

height, floors and allowable loading weight of each vehicle type. The objective is to select the finished vehicles to load and the transport vehicles into which to load them to maximize the total profit of a fleet of transport vehicles. We term this problem the *Heterogeneous Multi-type Fleet Vehicle Loading Problem in Finished Vehicle Logistics* (HVLP–FVL). Although the HVLP–FVL is found widely in real automotive supply chains, it is very seldom studied in the literature. A typical example is given in the following description:

(1) The automotive factories produce various types of finished vehicles, such as sedan, pickup truck and SUV. A logistics company has its own vehicle fleet consisting of different kinds of transport vehicles, for example, 4-axis truck, 5-axis truck and 6-axis truck. In practice, the loading space of each transport vehicle is divided into multiple floors, and each floor may be divided into row loading space with specified length, width and height. There are also some private trucks contracted by the logistics company, and they can be hired if its own vehicle fleet cannot satisfy all orders.
(2) The logistics company receives orders from the automotive factories (considered suppliers) to transport different kinds of finished vehicles to dealers (considered customers). The set of finished vehicles is initially located at a main depot.
(3) The dealers are located in different cities, and might be far away from each other. Therefore, it is not economical to deliver finished vehicles along a single route. The logistics company defines one center city for each cluster of dealers based on their locations. A branch depot is located the center city. Then, routing is planned from the main depot (located in the supplier's city) to the branch depots (located in the cluster center cities). There is a transport vehicle fleet assigned to each route, however, the vehicle fleet is not fixed.
(4) Drivers will return to the main depot after they finish delivery. Having necessary rest, they report to the scheduling department of the logistics company, so the schedulers know how many transport vehicles are available and their types. These available vehicles form the vehicle fleet that day.
(5) Different vehicle loading solutions result in different profit depending on the type and number of finished vehicles selected because profit varies according to type of finished vehicles. The problem aims at determining a heterogeneous vehicle fleet loading solution maximizing profit.

According to the description above, there are some assumptions and constraints, as follows:

(1) Split delivery for orders is allowed. That is, an order can be serviced by more than one transport vehicle.
(2) Any type of finished vehicle can be loaded in any kind of transport vehicle. For the same reason, any type of transport vehicle can transport any kind of finished vehicle.
(3) The delivery from manufacturers to the main depot is not considered. Similarly, the delivery from the branch depot to each dealer is not considered. Loading and unloading costs are not considered.
(4) Routing cost includes highway toll, labor cost, and power cost; these are assumed to relate linearly to distance.
(5) The total weight of all finished vehicles loaded in a transport vehicle must not exceed an upper limit of the load weight capacity.
(6) Volume constraint: Each finished vehicle has a positive volume with length, width and height. Since the transport vehicles have a complex loading structure with floors and rows (see Section 4.2), the items loaded in any vehicle must meet the loading volume limit of the relevant row on the relevant floor.
(7) If the transport fleet consists of identical vehicles it is denoted homogeneous, while it is heterogeneous if different types of transport vehicles are present, as herein.

3. Literature review

If the transport vehicle loading space were one-dimensional, then the HVLP–FVL is reduced to the classic Knapsack Problem (KP). From an optimization objective view, the HVLP–FVL is analogous to the KP because both maximize profits. From an operation process view, the HVLP–FVL is like a bin packing problem (BPP) since both pack into a number of containers. In principle, the HVLP–FVL derives from the vehicle loading problem (VLP).

3.1. Knapsack problem

In the classic KP (Martello & Toth, 1990a; Kellerer, Pferschy, & Pisinger, 2004), each item has an associated value, and the objec-

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