A Heuristic Algorithm for the Inner-City Multi-Drop Container Loading Problem

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ABSTRACT

Economic globalization, increasing fuel cost, and environmental problems provide a strong stimulation for inner-city container carriers to utilize container space more efficiently in transporting goods for multiple clients during a single round trip. A wall-building heuristic algorithm based on the binary tree data structure is proposed to solve the container loading problem with multi-drop constraints. A dynamic space decomposition approach, together with a repacking and space amalgamation strategy, permits an efficient and effective loading plan to pack containers, illustrated by numerical experiments.

Keywords: City Logistics, Container Carriers, Multi-Drop Constraints, Space Amalgamation, Tree-Based Heuristic Algorithm

INTRODUCTION

As the speed of urbanization in the world increases and the values of urban land rise quickly, city logistics activities are becoming a vital factor in sustainable development of cities. Taniguchi et al. (2001) defined city logistics as “the process of totally optimizing urban logistics activities by considering the social, environmental, economic, financial, and energy impacts of urban freight movement.” The most frequent logistics activities are transportation of goods from distribution centers (DCs) to retail shops and supermarkets to ensure urban citizens’ daily consumptions. In modern cities, the distribution centers are often located in the outskirts of cities, supermarkets are built in a few downtown commercial districts, and retail outlets are scattered all over the place in cities. To many cities, it is a huge challenge to facilitate city logistics activities with limited road network capacity to satisfy population needs. Information technology is an important means to improve efficiency of city logistics activities.

In this paper, we study the activities of truck loading/unloading in city logistics to improve
utilization of truck volume and efficiency of truck loading/unloading operations. We particularly consider the problem of multiple unloading sites in a single trip. Improvement of such activities can reduce transportation costs, as achieved by vehicle routing (Murakami & Morita, 2010), and also help reduce inventory costs of retail outlets and supermarkets which are concerned in supply chain management (Mahamani et al., 2008; Mohebbi, 2010).

Truck loading problem can be seen as a particular case of container loading problem. The general container loading problem is to orthogonally pack a subset of some three-dimensional rectangular boxes into a rectangular container of fixed dimensions. Each box must be completely contained in the container and cannot overlap with other boxes. Generally, 3D container loading problems fall into the following classifications, depending on the objective function and constraints on the packed items.

**Knapsack Loading Problem**

For knapsack loading, each item has an associated profit and the problem is to choose a subset of items that can be packed into a container with fixed dimensions and maximize the total profit of all packed items. When the profit of items is set to be their volume, it is equivalent to maximize the volume utilization. This problem has been considered by Gehring et al. (1990) and Pisinger (1997).

**Strip Packing Problem**

In this problem, the container has fixed length and width, but infinite height. The objective is to pack all items into this container such that the height of container is minimized. Several algorithms for solving this problem are discussed and compared in Bischoff and Marriott (1990).

**Bin Packing Problem**

Unlike previous problems, this problem tries to pack all items into a subset of containers which results in the minimum shipping cost. This set of containers can have fixed dimension or varying dimensions. If the problem only has one type of container, the objective is always to minimize the number of used containers. Algorithms for the Bin Packing problem have been presented by Lodi et al. (2002), Martello et al. (2000), and Pan et al. (2008) among others.

Several other constraints may be imposed to the above problems. For example, the weight distribution within the container must be balanced, there may be some restrictions on the items’ bearing strength, and the container may have weight limit. The truck loading problem we consider here is also a container loading problem with some restrictions. Unlike the container loading problem in global logistics that the majority of goods for a container are of the same size and for one client, a truck container used in city logistics often needs to transport goods in different sizes and to more than one destination in one route. Hence, the inner-city truck loading problem considers not only the traditional container loading constraints, but also the loading order of goods for different destinations (like retail outlets and supermarkets), which requires that items can unload without rearranging other items at a destination. This requirement is obvious, since rearranging goods at each destination (or drop-off point) cost time and labour, and may result in goods damage.

In this paper, we present a new container loading algorithm for solving the inner-city truck loading problem. One significance of this algorithm is its simplicity and flexibility. It can be easily implemented in the real world and flexible enough to accommodate various other problems, such as vehicle routing problem, encountered in a majority of real-life applications. The algorithm is based on the tree-based wall-building algorithm proposed by Pan et al. (2009) with an enhancement of a repacking and space combination strategy. When considering Bischoff and Ratcliff’s (1995) problems as benchmark, this algorithm can generate an efficient and effective truck container loading plan for a set of goods to be distributed to different destinations in one route.

With this container loading algorithm, a loading plan for each truck can be generated
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