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A rolling horizon algorithm for auto-carrier transportation

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ABSTRACT

This paper introduces a rolling horizon algorithm to plan the delivery of vehicles to automotive dealers by a heterogeneous fleet of auto-carriers. The problem consists in scheduling the deliveries over a multiple-day planning horizon during which requests for transportation arrive dynamically. In addition, the routing of the auto-carriers must take into account constraints related to the loading of the vehicles on the carriers. The objective is to minimize the sum of traveled distances, fixed costs for auto-carrier operation, service costs, and penalties for late deliveries. The problem is solved by a heuristic that first selects the vehicles to be delivered in the next few days and then optimizes the deliveries by an iterated local search procedure. A branch-and-bound search is used to check the feasibility of the loading. To handle the dynamic nature of the problem, the complete algorithm is applied repeatedly in a rolling horizon framework. Computational results on data from a major European logistics service provider show that the heuristic is fast and yields significant improvements compared to the sequential solution of independent daily problems.

1. Introduction

In 2012 the global demand for cars, light commercial vehicles, and trucks amounted to approximatively 82 million vehicles, with an increase of about 5% with respect to 2011 (see, e.g., ANFIA (2012)). The majority of the new vehicles sold every year are first delivered by the manufacturers to third-party logistics providers (3PLs). The vehicles are then delivered by these 3PLs to the dealers who sold them, where they can be collected by the final customers. The delivery to the 3PLs is often performed via rail, as it involves a large number of vehicles, a single origin, and a single destination. Delivery to the dealers is instead performed via auto-carriers, as it typically involves a small number of vehicles and several destinations.

Auto-carriers are special trucks, usually composed by a tractor and perhaps a trailer, both equipped with loading platforms. These platforms are used to load the vehicles at the 3PL and unload them at the dealers. The vehicles are not simply loaded straight, but they can be lifted and rotated in several ways by means of special loading equipments. This is done to increase the number of vehicles that can be transported at the same time, thus improving the efficiency of the distribution process. An example of a modern auto-carrier equipped with four loading platforms, two in the tractor and two in the trailer, and carrying eleven vehicles is depicted in Fig. 1.

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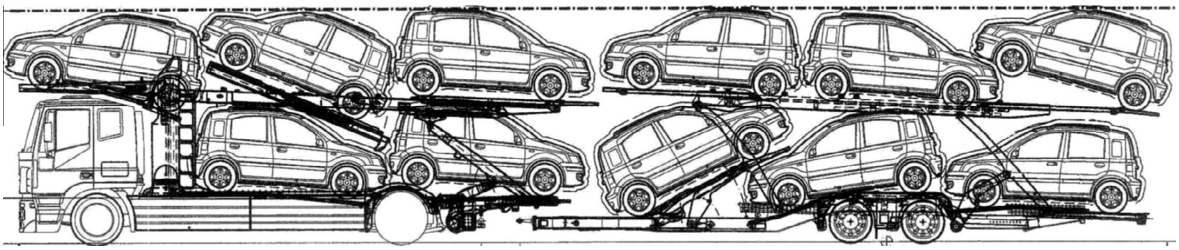

Fig. 1. An example of an auto-carrier carrying eleven vehicles. *Source:* Rolfo Spa, Italy.

Once a vehicle is sold by a dealer, the 3PL has a certain range of days, i.e., a *time window*, in which it is supposed to deliver the vehicle to the dealer. If the company fails to perform the delivery within the given time window, it incurs a penalty cost, which is determined by the contract signed between the company and the manufacturer. Some vehicles are sold customized to the customer preferences. In this case the dealer sends an order to the manufacturer, which in turn produces the vehicle and then sends it to the 3PL. As soon as the 3PL receives the vehicle, it contacts the dealer to organize the delivery. Other vehicles are instead sold turnkey, and in this case they are usually already available at the 3PL when the dealer places the order. In any case, the company has to organize the distribution plan for a few days ahead, taking care of demands that arrive dynamically on a daily basis and have to be served soon, possibly by the next day.

Companies operating auto-carriers are obviously interested in optimizing their distribution as this can clearly result in large cost savings. The problem they face is, however, very complex because it involves several constraints and objectives. Typical constraints derive from the fact that an auto-carrier has a limited traveling distance per day and, of course, the vehicles it carries should be feasibly loaded on its platforms. A *Last-In First-Out* (LIFO) policy (also known as *sequential loading* policy, see, e.g., Cordeau et al. (2010)) is usually imposed on the loading, i.e., when visiting a dealer, the vehicles it requires should be unloaded without moving vehicles destined to other dealers.

We note that the fleet that can be used for the deliveries is typically heterogenous, as it involves auto-carriers having different costs and loading capacities. Furthermore, due to the fact that long-distance routes may last more than one day, the size and composition of the available fleet varies day by day, depending on the deliveries carried out on previous days. We also note that typical objective functions include fixed costs for using the auto-carriers, traveling costs for performing the deliveries, service costs for visiting the dealers, and penalties for violations of the time windows.

Because of their importance in many markets, auto-carrier distribution problems have received a good level of attention in the past. Agbegha (1992) and Agbegha et al. (1998) focused on the subproblem of loading vehicles in the auto-carrier. They divided the auto-carrier in a fixed number of slots, and modeled it by using a loading network where each vertex corresponds to a slot. The same model was computationally evaluated on a set of random instances by Lin (2010).

Tadei et al. (2002) studied the maximization of profits over a multiple-day horizon for an Italian distribution company. They proposed a heuristic based on an integer linear programming formulation, in which the routing problem was relaxed by grouping all possible destinations into clusters. They also relaxed the loading problem as follows: (i) they computed for each auto-carrier an *equivalent auto-carrier length*, taking into account the auto-carrier loading equipments; (ii) they computed for each vehicle an *equivalent vehicle length*, taking into account the vehicle shape; (iii) they modeled the loading as a single capacity constraint, imposing the sum of the equivalent vehicle lengths to be no larger than the equivalent auto-carrier length. A similar heuristic was used by Cuadrado and Griffin (2009) to solve a distribution case in Venezuela.

Miller (2003) proposed a greedy heuristic and some simple local search procedures for a case arising in the USA market. He modeled the auto-carrier as two flat loading platforms and loaded the vehicles straight on the platforms. He studied the single-day distribution and used simple heuristics to design the routes. The USA market was also studied by Jin et al. (2010), who developed a business scheme to evaluate and compare the transportation costs via roads and via railway.

The most recent approach, as far as we know, was developed by Dell'Amico et al. (forthcoming), who proposed a heuristic algorithm for a real-world distribution case arising in the Italian market. They developed a branch-and-bound algorithm for the loading subproblem and an iterated local search (ILS) heuristic for the overall problem. Their ILS starts with a greedy heuristic solution which is iteratively perturbed and improved by the use of local search operators. The branch-and-bound is invoked to check the feasibility of the loadings considered during the ILS process.

The algorithm of Dell'Amico et al. (forthcoming) is the first one that simultaneously provides detailed solutions of both the loading and routing components of the auto-carrier transportation problem, but it can only solve a static, single-day problem. In this paper we build upon this algorithm, but extend it to the more realistic case of multiple-day distribution and dynamic demands, also including new operational constraints and additional cost components in the objective function. More precisely, we introduce a heuristic algorithm that, given partial information on the demands, plans not only the routes and loadings for the first day, but also those for the next few days. The distribution plan for the first day is then