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Combining multiple trips in a port environment for empty movements minimization

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Abstract

Road transportation represents the most used transportation mode to cover short distances. However, structural lack of planning and optimization in road transportation creates negative effects both for companies and for the social community, such as environmental pollution, economic loss and road congestion. These effects are mainly due to the fact that a lack of planning can yield the necessity of a huge number of empty trips. Usually trucks that pick up or deliver a full container in a port must return back the empty container to the place where the trip started, so performing one leg of the total trip without payload. The aim of the present paper is to propose a mathematical approach for combining multiple trips in a port environment (specifically, import, export and inland trips) by considering the opportunity of carrying two 20 ft containers simultaneously on the same truck and by using the same load unit if possible. In this way, in the same route, more than two nodes can be visited with the same vehicle thus significantly reducing the number of total empty movements. Time windows constraints related to companies and terminal opening hours as well as to ship departures are considered in the problem formulation. Moreover driving hours restrictions and trips deadlines are taken into account, together with goods compatibility for matching different trips. An experimental campaign based on real data is discussed in the paper.

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Keywords: Trips combination; Optimization; MILP; import-export road trips; empty movements.

1. Introduction

One of the worst consequences of the lack of planning in road transportation is the huge number of empty truck trips, whose negative externalities affect both companies and the social community. So, empty movements must be reduced and trucks utilization has to be maximized. This can be done by a proper optimization of trips and empty containers repositioning. The trips taken into account in the present work are of three types: they may originate or end in the port (import and export trips, respectively) or they may be executed in the inland (inland trips). Full containers,

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whatever origin or destination they may have, are picked up in certain points of the network (ports, companies or inland depots) and must usually return empty to the origin of their trip for further use: this implies that one leg of the trip is performed without payload, in a not optimized way.

In the literature, some studies focusing on the problem of combining import and export trips can be found. For instance, Zhang et al. (2010) proposed a heuristic approach for determining pick up and deliver sequences for daily operations with the goal of minimizing transportation costs, while Vidovic et al. (2012) solved the problem when pick up and deliver nodes may be visited only during predefined time intervals. Lately the problem was studied by Nguyen et al. (2013), who provided a tabu search meta heuristic for time dependent and multi zone multi trip vehicle routing problem with time windows. Other meta-heuristics were proposed by Sterzik et al. (2013) where the total operating time of all trucks is minimized respecting given hard constraints, and by Ayadi et al. (2013) where the trips combination problem is solved with a local search procedure. In both these works, EU driving time regulations are not taken into account. Instead, Derigs et al. (2011) presented two heuristic approaches for solving a real world vehicle routing problem for air cargo road feeder services on which driving hours constraints are strictly considered to combine multiple trips with the same tractor. Driving hours and traffic congestion have been taken into account also by Kok et al. (2011), who proposed an integer linear problem formulation that minimizes total duty time; Goel (2010) studied the problem of scheduling working hours of team rivers in European road freight transport where a sequence of locations must be visited within given time window and solved the problem applying a depth-first-breadth-second search method which can find a feasible schedule complying with standard daily driving time limits. Caballini et al. (2014) proposed an optimization approach devoted to combine trips two by two in a cooperative environment among different carriers, but without taking into account driving regulations. The majority of works in the literature focuses on 40-foot containers while, Schnberger et al. (2013) and Funke et al. (2014) 's works consider the transportation of 20-foot and 40-foot containers, with trucks being able to transport up to two 20-foot or one 40-foot container. This extension of the basic 40-foot problem increase the complexity of the problem dramatically and it is solved by a mixed integer linear program formulation. Moving from this scenario, the aim of the present paper is to propose a mathematical approach for combining multiple trips, considering the opportunity of carrying two 20 ft containers simultaneously on the same truck with a trailer and using the same load unit if allowed. The innovation from previous work stands in the fact that, in the same route, more than two nodes can be visited, by combining up to three trips. This significantly reduces the total number of empty movements, while respecting time windows constraints as well as EU-driving hours regulation. Moreover, for what concerns the export cycle, ships' scheduled departures are also taken into account as soft time constraints. The model runs in a daily basis, in the context of tactical/operative planning and truck operators own the problem of trips combination.

The paper is organized as follows. In section 2 the problem under analysis is described; in section 3 the mathematical formulation for combining trips three by three is presented, while in section 4 the results obtained by applying the proposed model to a real case study are analyzed, discussed and compared with the cases of only two trips combination or without any combination. Finally, in section 5 some conclusions are drawn together with further research ideas.

2. Problem description

Dealing with the objective of maximizing truck utilization, this paper tries to combine three kinds of trips: import, export and inland ones. Fig. 1 provides a framework of the type of road links involved in each kind of trip. In this work, it is assumed that a single trip is performed as a "round-trip", meaning with this term a trip in which the hauler has to go back and forth between two nodes performing one leg of the trip with an empty container or without any payload: this kind of trips is often utilized because, in an environment where freight forwarders and shipping companies compete for transporting cargo in the inland, the latter, which usually own empty containers, require to bring them back to the same location where they have been picked up.

As shown in Fig. 1, in the import cycle, the truck carrier has to carry out the following activities:

- pick up a full container in the port;
- travel with the full container to the inland company where it is stripped (link port-A in Fig. 1);