Transportation Research Part E 93 (2016) 38–56

Contents lists available at ScienceDirect

Transportation Research Part E

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

Cooperation among truck carriers in seaport containerized transportation

Claudia Caballini [a], Simona Sacone [a], Mahnam Saeednia [b,*]

[a] DIBRIS-Department of Informatics, BioEngineering, Robotics and Systems Engineering, University of Genova, Italy
[b] IVT-Institute for Transport Planning and Systems, Swiss Federal Institute of Technology, Zurich, Switzerland

ARTICLE INFO

Article history:
Received 23 November 2015
Received in revised form 21 April 2016
Accepted 12 May 2016
Available online 28 May 2016

Keywords:
Road freight transportation
Drayage operations
Horizontal cooperation
Mathematical programming

ABSTRACT

Nowadays the majority of goods passing through seaports are transported by road, resulting in a large number of empty movements and high total costs. This paper proposes an optimization model for the cooperative planning of multiple truck carrier operations in a seaport environment for maximizing the total profit derived from their cooperation. A compensation mechanism is introduced to motivate carriers to share their trips. Time windows, trip deadlines and fleet sizes are considered. The planning approach is evaluated using real data sets from the Italian port of Genoa. Numerous scenarios are tested and an extensive computational analysis is reported.

1. Introduction

The negative impacts resulting from road freight transportation are of major concern today as it contributes to congestion and environmental pollution (Castillo-Manzano et al., 2015; Demir et al., 2015). This issue is more significant in areas surrounding ports which are the origin and destination of high and increasing volumes of containers moving on a daily basis (Schulte et al., 2015). This gives rise to a significant number of short distance movements to and from the hinterland, also denoted as drayage operations, mainly realized by road (Macharis and Bontekoning, 2004). Usually, a truck that picks up or delivers a full container in a port must return the empty container to its pick up point, thus generating an empty movement, which decreases the carrier's profit and also contributes to increasing congestion on roads (Cheung et al., 2008).

From this perspective, a beneficial action both for trucking companies (from an economic point of view) and for the social community (from congestion and pollution viewpoints) is represented by an effective planning of road transport operations. Such planning aims to maximize the profit gained by the different carriers, which is equivalent to the reduction of unproductive (i.e. empty) movements. One of the approaches to achieve this goal is not only the proper organization (possibly through optimization) of trips belonging to the same carrier (i.e. the trucking company) but also the definition of cooperative schemes in which different carriers share their demands to find the most suitable combination of trips in a broader context (Van Der Horst and De Langen, 2008).

To further analyze the considered port context, the occurrence of inefficient trips in case of drayage transport is due to commercial and operational reasons, some of which are stated as follows:

- a lack of planning tools or skills on the part of road carriers (or freight forwarders themselves), especially since in many countries the majority of trucking companies are small sized and operate domestically;

* Corresponding author.
E-mail addresses: claudia.caballini@unige.it (C. Caballini), simona.sacone@unige.it (S. Sacone), mahnam.saeednia@ivt.baug.ethz.ch (M. Saeednia).

http://dx.doi.org/10.1016/j.tre.2016.05.007
1366-5545/

- an unwillingness to lease trips to other carriers due to concerns related to the possibility of losing customers;
- the requirement by shipping companies – the usual owners of containers – for empty containers to be left or collected in specific depots near the origin of trips (usually either the port for imports and an area near the inland node for exports) or in locations that do not allow the truck to travel full. This is due to the inclination of shipping companies to dominate inland transportation.

It is important, then, to design methods and realize tools for road transport operators to increase awareness and convince them of the advantages of effective trip planning. Moreover, it is crucial to define cooperative schemes which make single carriers act as a network, thus gaining competitiveness in their market. Finally, an effective planning of road trips is also beneficial as a whole, both for reducing congestion and for decreasing the social impacts resulting from a high presence of trucks on road networks.

Considering the high potential of improving trucking operations connecting seaports to their hinterlands as described above, the present paper studies one form of collaboration among multiple carriers serving their container demand to and from a seaport. The proposed collaboration scheme is a centralized one in which all the trips constituting the demand of carriers acting in the scheme are considered as a whole, and such trips are effectively organized. The goal is to optimally combine import and export trips (possibly owned by different carriers) in order to maximize the total profit obtained by carriers. The proposed scheme ensures that the profit obtained by each carrier in the cooperative scheme is larger than or equal to its initial profit (i.e. the profit without collaboration). A compensation mechanism is introduced which motivates carriers to share trips with their competitors. Various constraints such as the time windows of port terminals and companies as well as the deadlines of trips are taken into account.

The paper is organized as follows: in the following section, the most relevant previous research is referred to, along with the major gaps covered by the present study. In Section 3 the problem under consideration is described and in Section 4 the optimization model for planning the cooperation among multiple carriers is presented. Section 5 analyzes the results obtained by applying the model to a real case study; more specifically, in this section, 27 different scenarios have been compared and analyzed, and an insight into the compensation mechanism is provided. In Section 6 a computational analysis has been carried out in order to further test the efficiency of the proposed approach. Finally, some concluding remarks and highlights on future research are addressed in Section 7.

2. Previous research

Drayage operations are the short-haul transportation of containers by trucks between seaports and inland terminals (customers/shippers) (Zhang et al., 2011). High numbers of such operations pose port management issues especially related to the organization of road gates procedures. The problem has been tackled in some studies by defining and analyzing port appointment systems (Giuliano and O'Brien, 2007; Namboothiri and Erera, 2008). Moreover, port appointment systems aimed at organizing the arrival and departure flows of trucks at port gates, finally succeed in improving the port management but do not yield significant benefits to the whole circulation of trucks in the hinterland.

As regards road freight transportation, the problem of planning trips for a single carrier dates back to three decades ago (Gavish and Schweitzer, 1974; Powell, 1987). Later, other authors have addressed this issue (Imai et al., 2007; Caballini et al., 2013). This problem has been solved both for static and dynamic cases considering different objective functions, such as maximizing the total costs of deadheading or the total distribution costs. For instance, the work by Zhang et al. (2010) formulates the truck scheduling problem with multiple depots and terminals considering inbound, outbound, full and empty trips. They optimize truck operating times, considering time windows of origin and destination nodes. The same objective is pursued in Zhang et al. (2011) where the sharing of trips within a single trucking firm is studied. Sterzik and Kopfer (2013) solved a comprehensive form of this problem considering vehicle routing and scheduling and empty container repositioning using an efficient Tabu Search Heuristic. Lai et al. (2013) proposed a model for combining import and export trips related to a seaport assuming that trucks and containers are not separated during the service. This model minimizes the truck operating costs and is solved by using a variant of the Clarke-and-Wright algorithm improved by a sequence of local search phases.

More recent studies shift the attention from single carrier cases to the possibility of fostering collaboration among two or more parties (i.e. carriers or shippers). Two main research streams defined as "vertical collaboration" and "horizontal collaboration" exist when dealing with cooperative schemes in transportation. A form of collaboration which is established among stakeholders acting at different levels of the logistic chain (for instance shippers, carriers or customers) is called "vertical collaboration", whereas cooperative schemes between parties belonging to the same level of the logistic network are called "horizontal collaboration". As the objective of the paper is that of defining a horizontal collaboration framework, some approaches of this kind are outlined here. Horizontal collaborations have been studied both among shippers (Yilmaz and Savasaneril, 2012; Ergun et al., 2007a; Özener and Ergun, 2008) and among carriers (Krajewska et al., 2008; Caballini et al., 2014). In the latter, the aim is mainly that of reducing costs and competing with larger carriers, while the main goal of collaboration among shippers is to negotiate better rates with the carriers. Ergun et al. (2007a) study how carriers can collaborate to minimize asset repositioning, thereby reducing deadhead trips. They formulate the problem in terms of a lane covering problem, in which a set of constrained cycles that cover a subset of arcs in a directed graph are found. The same