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The effect of cooperation among shipping lines on transport costs and pollutant emissions

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A B S T R A C T

This study explores the effect of cooperation among shipping lines on transport costs and pollutant emissions. The quantitative benefits of the cooperation were measured via a simulation-based model that (i) optimized inland empty container reuse and (ii) considered a two-dimensional capacity (weight and size) for vehicle types and demands. Inland empty container optimization was integrated with a dynamic vehicle allocation and routing problem with time-window constraints, while the two-dimensional capacity considered minimising total transport costs in a time-varying network with road segment usage constraints by truck type. The simulation model was used to evaluate the status quo and the cooperation scenarios by analysing two weeks of import and export container movements for the port of Brisbane (Australia). The major findings from the study are: (i) the cooperation among shipping companies avoids a significant number of unnecessary truck movements and of storage days for empty containers; (ii) the cooperation translates into truck-sharing and utilisation of larger trucks, which are more environmentally friendly and cost-efficient choices when compared to smaller trucks; (iii) the introduction of a decision support system provides solutions to the freight actors regarding optimal routing and vehicle allocation, based on real-world constraints and dynamics. Remarkably, the savings in the cooperation scenario are substantial, yielding a 40% reduction of fuel consumption and pollutant emissions.

1. Introduction

International trade is a key component of sustainable development because of its contribution to the productivity of natural and human resources (Arntzen and Hemmer, 1992). However, it also entails environmental degradation because of the generated freight movements (Williams, 1993). International freight transport consists of maritime and inland transportation, where shipping lines are mainly responsible for the maritime movements, while road and rail carriers are mainly responsible for the inland movements. Nowadays, most shipping lines provide door-to-door transport services to customers in order to increase their competitiveness in the market and to control their container flows. Shipping lines may either sign long-term contracts with inland carriers and freight forwarders or own their inland transportation service. However, the imbalance of trade and economic needs in different regions implies that a significant volume of empty containers are repositioned through inland or seaborne services, with the consequent significant increase of logistics costs. Accordingly, shipping lines and shippers alike bear all associated landside handling and storage costs of empty containers and operations. Notably, empty container management consumes an equivalent amount of resources as full

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container movement, and, the separation of container operations between shipping lines entails the double handling of containers and imposes extra logistics costs.

Most of the landside container movements occur on the hinterland road network where container origins and destinations are located. Hence, container repositioning is not only costly for the shipping lines but also expensive for society, given negative externalities in terms of increased congestion, emissions, and energy consumption. As the transport sector accounted for 20. 5% of the global CO_2 emissions in 2014 (The World Bank, 2014), it is crucial that ports, in their role as key freight generators, commit to protecting and sustaining the natural environment. Moreover, it appears to be essential that ports adapt to fundamental changes in the freight transport market resulting from competition, regulations, and growing trends towards IT-based systems. In contrast to the traditional focus on individual freight companies, an upward trend exists towards collaborative and real-time control systems aimed at increasing the efficiency of the whole logistics process. As a major actor, ports can play a key role in improving the efficiency of services and increase their competitiveness by facilitating these freight cooperation initiatives.

Accordingly, this paper presents a study undertaken for the Port of Brisbane (Australia) to analyse the environmental and economic benefits of horizontal cooperation among shipping lines in inland freight transportation. Australian port container traffic accounted for 7,635,620 TEUs in 2016 (The World Bank, 2016), where 1.2 million TEUs were handled through the Port of Brisbane (Port of Brisbane Pty Ltd, 2017). Forecasts of import/export growth indicate that the total container movements (full and empty) through the Port of Brisbane are expected to increase 2.3 times by 2040 (Port of Brisbane Pty Ltd, 2013). While the road transport sector accounted for 24.7% of the CO_2 emissions in Australia in 2014 (The World Bank, 2014), trucks (articulated and rigid) contributed to about 23.3% of the annual road transport emissions (Pekol Traffic and Transport, 2015), and truck Carbon Dioxide equivalent emissions (CO_2-e)[1] were estimated to be more than 24 million kilograms per year in the Port of Brisbane precinct alone (Smit et al., 2010). Given these premises, this study focuses on inland container transportation to and from the Port of Brisbane with the aims of increasing the efficiency of land-based supply chain functions and of limiting their environmental impacts.

Inland container transportation consists of the allocation of containers and fleets between depots and customers. A typical container flow in an export chain is as follows: (i) the shipping line delivers an empty container to the exporter from an empty container park (ECP); (ii) the container is loaded by the exporter and carried to the stevedores at the port; (iii) the container is stored at either the wharf or the container terminals to be shipped. A typical container flow in an import chain is as follows: (i) the full container is unloaded by stevedores and stored at the wharf, typically between 3 and 7 days in Australian ports due to capacity constraints at the portside; (ii) the importers, who are informed about the arrival date and time of their shipments one day in advance, collect the full containers; (iii) the importers have usually a timeframe (between 7 and 10 days) to unload the container and then deliver it to the ECP; (iv) the empty containers at the ECP are either used for the export chain, returned to the port of origin, or leased to other shipping lines.

Given that only full container movements are paid by customers, container usage is directly linked to profits. Accordingly, the demand of an exporter for empty containers can be connected to the presence of nearby empty containers stored by an importer. This concept is termed "street-turn", and maximizing this connection is an important objective from the shipping lines' perspective. Specifically, coordination between shipping lines would not only reduce the number of empty container movements but also increase profits. This coordination can be provided through an online market supported by a port authority, where information about the availability of containers becomes available to all actors. This web-based information exchange allows shipping lines to match empty container demand and supply without storing the containers in an ECP. This concept is also sometimes referred to as a "virtual container yard (VCY)" or "triangulation" and has been successfully applied as either a module of a Port Community System (e.g., Virtuele Haven in the Port of Rotterdam), or a standalone market (e.g., Ports of Oakland, Los Angeles, Long Beach, and Montreal) (Maguire et al., 2010).

It should be noted that bilateral outsourcing and partnerships are a relatively new practice in maritime container trade (Fink, 2002). For example, when a shipping line encounters a shortage of empty containers in port "A", it may prefer to transport a full import container of another shipping line from port "B" instead of returning an empty container or leasing it from a container company. This decision entails additional transport and container double-handling, which translates into increased logistics costs. Rather, a partnership may be formed between the two shippers to increase efficiency and communication as well as to reduce operational costs. While such partnerships are not currently a common practice in inland container transport (Lun et al., 2010; Lee and Meng, 2015), they are expected to be a major future trend for smaller shipping lines to enable them to compete with emerging big alliances.

It should be also noted that only a few studies have analysed the potential benefits of shipper cooperation. A preliminary study investigated the feasibility of a VCY in the NY-NJ port region (Theofanis and Boile, 2007), but under the assumption that no cooperation existed between trucking companies working with different shipping lines. Only one study by Sterzik et al. (2015) examined the potential benefits of cooperation while exploring the empty container repositioning problem integrated with the vehicle routing problem of road carriers. However, the study did not consider the effects of dynamic travel times in the road network on vehicle scheduling (although the time-window constraints of customers were considered), and the study allowed for only one container type (40-foot container) and one vehicle type.

This study overcomes the limitations observed in the existing literature by considering the dynamic nature of the problem of planning for empty container repositioning, given that both demand and supply of containers are not deterministic. Time-dependent

[1] Carbon Dioxide equivalent (CO_2-e) is a quantity that describes the total amount of CO_2 that would have the same global warming potential for a given greenhouse gases (CH_4, N_2O, and CO_2), over a specified time scale (usually 1000 years).