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Minimizing cost of empty container repositioning in port hinterlands, while taking repair operations into account

T. Hjortnaes [a], B. Wiegmans [a,*], R.R. Negenborn [a], R.A. Zuidwijk [b], R. Klijnhout [c]

[a] Delft University of Technology, Delft, The Netherlands
[b] Erasmus University Rotterdam, Rotterdam, The Netherlands
[c] Maersk Line BV, Rotterdam, The Netherlands

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ABSTRACT

Shipping companies are striving to optimize their empty container repositioning strategies which also contribute to reduced congestion and environmental improvements. In this paper we propose a multi-commodity model that makes an explicit distinction between flows of non-damaged containers, on the one hand, and flows of damaged containers, on the other. The model is tailored for the repositioning of these containers in the representative setting of a network of off-dock empty depots, ocean terminals, and inland terminals. In our case study, cost savings of up to 17% are found, depending on the composition of the network, container type, and particular evacuation and repositioning strategy. In particular, directly transporting containers from inland terminals to other inland terminals (direct repositioning) results in cost savings of up to 15% for dry containers and up to 17% for reefer containers. Furthermore, the total costs might be optimized by actually preventing the container failure from occurring possibly leading to considerable additional cost reductions. Finally, exporting damaged containers might seem to be the optimal solution from a regional cost perspective, but, this does not necessarily lead to total cost optimization from the global perspective.

1. Introduction

Shipping companies mainly focus on providing transport between major ports in a global network. Chang et al., (2015) analyzed the minimum transportation cost for the repositioning of empty containers for an entire shipping network. However, also a trend of incorporating the port hinterland into a carrier's supply chain can also be observed (Gadhia et al., 2011). In general, the carriers' customers are not located directly near the terminal, and it is therefore necessary for shipping companies to transport containers between the ocean terminals and provide empty containers at the customer's front door in the hinterland. This is complicated due to the existence of large trade imbalances between the continents (e.g. from Asia to Europe). These imbalances contribute to policy requests to reduce these additional empty transport flows causing congestion and environmental problems on a local and regional level. In an ever-growing volatile container transport market, cost reductions and efficiency improvements are required. For container carriers it is therefore crucial to (re)position empty containers optimally (i.e. at the lowest possible cost). Indirectly this also contributes to reduced congestion and environmental pollution.

1.1. Empty container repositioning in a regional network

Empty container repositioning is performed at various network levels, viz. global, regional, and local scales. The local level covers the repositioning of empty containers between inland terminals or depots and surrounding customers. The regional level focuses on hinterland transport between inland terminals, off-dock empty depots, and ocean terminals. In a research, Mittal et al., (2013) determined optimal inland-empty container depot locations under stochastic demand for the New York/New Jersey port region. The global level focuses on balancing international trade flows between ocean terminals. Inland terminals hereby serve as nodes which connect the regional and local-scale network, while ocean terminals serve as gateways to interconnect the global scale with the regional-scale network. Trade imbalances can be observed leading to regions being either surplus (i.e. import dominated) or deficit (i.e. export dominated) regions, resulting in empty container transport. At a regional level, this results in repositioning flows between the deficit and surplus areas on a regional scale. At a global scale, this results in what are called ‘evacuation flows’ between continents (e.g. from Europe to Asia). In general, approximately 20% of the exports are empties, but a wide range from 0 to 90% can be observed. Overall this means that empty flows can be considerable.

There are various types of empty-container flows between: ocean terminals at a port (1), off-dock empty depots at the port (2), inland terminals in the port hinterland regional network (3), and customers (4).

* Corresponding author.
E-mail address: b.wiegmans@tudelft.nl (B. Wiegmans).

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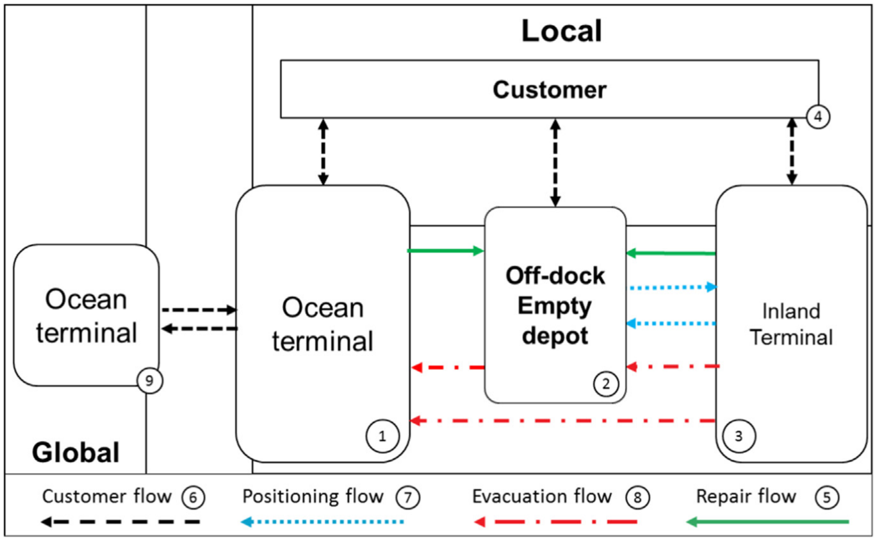

Fig. 1. An overview of the regional network surrounding the ocean terminal in relation to the transport super-network. (based on Rodrigue et al., 2013).

Off-dock empty depots serve as container storage locations, from where containers are picked up, and to where they are returned to serve export demand. As illustrated in Fig. 1 below, flow interactions exist between these different locations: repair flows for transporting damaged empty containers to workshops located at depots (5), customer flows (6) to meet local demand, repositioning flows (7) to meet regional demand and evacuation flows (8) towards a global network to serve overseas deficit areas (9).

Meeting customers' demand globally through the repositioning of empty containers follows a hierarchical order from local via regional to global scale, until the costs exceed the price of producing new containers (Theofanis & Boile, 2009). At each location what is called a 'safety stock' in the form of a Target Stock Level (TSL) is maintained to meet demand. The TSL is based on historic data and the carrier's expert knowledge. Hardly any information regarding the actual distribution and availability of empty containers throughout the network is available.

1.2. Non-damaged versus damaged empty containers

Containers are a commodity that is not handled gently. They are built to last, however during the transport process, containers can get damaged, which is often inflicted by careless handling on a terminal or during transport, failure of cooling equipment, regular maintenance, etc. This can have a significant influence on the available supply of empty containers. Currently, as soon as a container is damaged, it is taken out of service until it has been repaired. A repair activity is a direct reduction of the available supply of empty containers for meeting

Table 1
Existing literature on relevant empty container repositioning models and their relationship to our proposed model.

	Model type						Solution methods						
Authors	Linear	Explicit	Continuous	Deterministic	Dynamic	Multi-commodity	Substitution	Street turn	Leasing	Depot direct	Foldable containers	Container repair	Contributions
(Crainic et al., 1993)	X	X	X	X	X	X	X		X				Cost function design
(Choong et al., 2002)	X	X	X	X	X				X				Cost function design
(Olivo et al., 2005)	X	X	X	X	X				X				Aggregated macro-nodes
(Jula et al., 2006)	X	X	X	X	X	X		X		X			Depot direct solution
(Moon et al., 2013)	X	X	X	X	X						X		Cost function design
(Wang & Wang, 2007)	X	X	X	X	X	X							Inventory equality constraint
(Furió et al., 2013)	X	X	X	X	X	X		X					Cost function design and street-turn solution
(Olivo et al., 2013)	X	X	X	X	X		X		X				Influence of future requirements (TSL)
This article	X	X	X	X	X	X		X		X		X	