Transportation Research Part E 48 (2012) 1121–1136

Contents lists available at SciVerse ScienceDirect

Transportation Research Part E

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

# Congestion, port expansion and spatial competition for US container imports

Lei Fan [b,1], William W. Wilson [a,*], Bruce Dahl [c]

[a] Department of Agribusiness and Applied Economics, NDSU Dept. 7610, Richard H. Barry Hall, 811 2nd Ave. N., Fargo, ND 58108-6050, United States
[b] Gavilon, LLC, Omaha, NE 68102, United States
[c] Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, ND 58105, United States

ARTICLE INFO

*Article history:*
Received 1 January 2010
Received in revised form 27 February 2012
Accepted 22 March 2012

*Keywords:*
Container flow
Port
Congestion
Network flow model

ABSTRACT

The purpose of this paper is to analyze spatial competition, congestion and flows of container imports into the United States. An intermodal network flow model is developed and used to analyze congestion in the logistics system for container imports. The results indicate that congestion exists at most ports and its consequences are to raise costs at these nodes, and in some cases to divert traffic to other routes. Finally, if each of the ports expanded, the value of marginal capacity would converge to nil, and expansion would reduce congestion costs and waiting times.



## 1. Introduction

One of the fastest growing segments of the world shipping industry is that of containers. The United States is one of the largest and fastest growing markets for containerized trades with growth rates in recent years in the 10–11% range per year, but there were sharp declines in 2008 and 2009 (Drewry, 2009). Transportation Research Board Executive Committee (2006) identified a set of critical issues and one of the most critical transportation issues is that of congestion. Increasingly congestion is impacting all modes and logistical functions. In fact, Shrank and Lomax (2004) indicated that "Congestion has grown everywhere in areas of all sizes. Congestion occurs during longer portions of the day and delays more travelers and goods than ever before." Allegedly, 'less than half of all container vessels arrive in port on schedule' (Bloomberg, 2011, p. 82). The growth in container trade exacerbates congestion.

In response to growth in demand, increased ship sizes and competition, there has also been near simultaneous ambitions for many ports to pursue expansion. Indeed, most ports serving the US container market are in varying stages of planning for expansions. As example, the following described these changes:

> *...to expand the port of Baltimore as ports in the eastern US push to make changes needed to serve a new generation of supersize cargo vessels... The improvements will enable Baltimore to compete for the supersize cargo vessels that are expected to start passing through the Panama Canal... The vessels are capable of carrying twice as many 40 foot containers as the cargo vessels that typically call on East and Gulf Coast ports... Other ports are considering similar expansions and hunting for the capital to get them done...* (Conkey, 2009).

* Corresponding author. Tel.: +1 701 231 7472.
*E-mail addresses:* fanlei_fl@hotmail.com (L. Fan), William.wilson@ndsu.edu (W.W. Wilson), bruce.dahl@ndsu.edu (B. Dahl).
[1] Former PhD student in Transportation and Logistics program, North Dakota State University.

1366-5545/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tre.2012.04.006

In many cases expansion is in response to expanded ship size and increased draft allowances due to the expanded Panama Canal, but also in response to congestion, and anticipated future growth in container imports. Proposed projects include dredging, construction of container terminals, and terminal reorganization to increase efficiency, including more berths, cranes, and improved rail/truck access to ports. The impact of these not only facilitates growth, but, also reduces congestion, waiting times, and system costs. In addition, congestion has important strategic impacts on inter-port and inter-route competition.

The consequence of congestion affects costs, inter-port competition, railroads, and other logistics functions. Indeed, a recent article elaborated on the forthcoming prospective inter-port competition within the United States as a result of the expanded Panama Canal (Economist, 2012). Specifically, they point to port dredging in the Eastern ports to accommodate larger ships, and anticipated diversion from west coast ports to serve the eastern and interior markets. The purpose of this paper is to analyze spatial competition, congestion and flows of container imports into the United States. An intermodal network flow model of spatial competition was developed. Queuing functions are endogenized in the model and used to estimate waiting times and congestion costs for vessels at each major container port. Important variables are endogenized including ocean shipping (ship size, route, and vessel string composition), port use, spatial flows, and the model allows traffic to be diverted if/as congestion increases. The model was used to determine network flows and to quantify congestion at each port and the extent congestion results in traffic diversion to other ports, thereby impacting inter-port competition. Finally, we used the model to evaluate impacts of prospective simultaneous expansion at major US container ports, on congestion and flows.

## 2. Congestion and port throughput

Congestion arises when users interface with others in the utilization of port resources (Talley, 2006) and has emerged to be important in many sectors of the economy and particularly in transportation. While most policy discussions regarding congestion in transportation refer to urban roads, it is similarly important for ports, railways and waterways. The topic has been extensively studied for ports and waterways, but implementation is limited. An important factor affecting RITA's Vision 2030 (US Department of Transportation Research and Innovative Technology Administration, 2008) is the increase in container traffic and increased vessels sizes. The reason for this is the apparent extreme rigidity of capacity in many cases, combined with the escalation of and randomness in demand.

There have been several accounts of these in recent media. Lloyds List (2009) described bottlenecks and congestion at West Coast ports, the difficulties of expansion, new entrants, as well as implications of the growing uncertainty in shipments. They indicated "...Ports up and down the US West Coast were totally unprepared for the massive wave of imports that engulfed them in 2004 and the following years, and congestion soon spread right along the supply chain as rail lines, freeways and warehouses found themselves equally overwhelmed by the unprecedented amount of containers being offloaded at the ports each day."[2] Talley (2009), indicated: "In the summer of 1997... the resulting backlog of containers for departure from the Ports of Los Angeles and Long Beach reached such a critical level that UP took the unprecedented step of chartering an APL ship – to transport containers from these ports, through the Panama Canal, destined for the Port of Savannah." Bonacich and Wilson (2008) indicated that congestion at Los Angeles/Long Beach threatened to delay delivery of imports to large US retailers for the 2004 Christmas season. In response, "some diverted their cargo to other West Coast ports or to all-water routes [through the Panama Canal]. From July through mid-November 2004, over a hundred ships were diverted to Oakland, Manzanillo, and other ports..."

Recent studies have analyzed varying impacts of railway capacity, port efficiency, containers and logistics. Cambridge Systematics, Inc. (2007) assessed current and long-term capacity expansion of US freight railroads and the role of congestion among corridors. Christenson Associates (2008) indicated capacity "tightness" is primarily due to congestion at terminals or other specific network locations. Port efficiency has been examined in several studies (Notteboom, 2006; Bichou, 2007; Brooks, 2007; Heaver, 2006; Talley, 2007; Rodriguez-Alvarez et al., 2011; Ramos-Real and Tovar, 2010 and De Borger and De Bruyne, 2011). Ramos-Real and Tovar (2010) examined economics of scale in container shipping and De Borger and De Bruyne (2011) examined effects of vertical integration between port activities and hinterland congestion. Notteboom (2006) evaluated the effect of delays on shipping logistics. Rodriguez-Alvarez et al. (2011) indicated that port terminal costs are impacted by demand uncertainty. O'Kelly and Bryan (1998) developed a model to reflect scale economies that are generated on interhub links. Racunica and Wynter (2005) and Rodriguez et al. (2007) used optimization models of hub-and-spoke type networks for rail freight.

Fewer studies have analyzed impacts of congestion on spatial and inter-port competition (Maguire et al., 2010; Ilmer, 2010).[3] Crainic and Kim (2007) discussed the interpretation of congestion in the context of network flow models of intermodal transportation. Asteris (2009) used discreet event simulation to analyze container flows to the UK through the English Channel.

[2] See Levinson (2006) for a chronology of the developments of the container shipping industry, and more recently, see Lloyds List (2009) for a detailed description of the implications of these factors on container shipping and logistical planning.

[3] We use the terms "inter-port" and "spatial" competition to distinguish between two specific forms of competition. Inter-port competition refers to how individual ports compete against other individual ports. Spatial competition is more comprehensive and captures impacts of all relevant logistical costs (including ocean shipping, port constraints/costs and interior shipping costs) and how these impacts the spatial distribution (routing) of containers among international and domestic routes, and ports.