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Estimating flow times for containerized imports from Asia to the United States through the Western rail network

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ABSTRACT

Queuing models are introduced for estimating container dwell times at rail intermodal terminals and transit times through rail line-haul corridors. These models are statistically calibrated on industry data. The intent of these models is to estimate changes in container flow times stemming from changes in infrastructure, staffing levels at terminals, or import volumes passing through given infrastructure. Flow times estimated for individual line segments are aggregated to provide estimates of the total transit time from West Coast rail ramps to inland destination ramps for imports moving from Asia to the Continental United States in marine as well as domestic containers.

1. Introduction

The substantial growth in waterborne, containerized imports from Asia to the Continental United States experienced until 2007 (i.e., before the onset of the subsequent economic recession) strained the capacities of West Coast ports and landside channels to inland markets. At times, "melt-downs" were experienced at certain West Coast ports and on certain Western rail lines that triggered major shifts in the port and channel volumes of such imports. In response to this trade growth, there have been major expenditures by public agencies and private carriers to expand infrastructure, continuing at the present time. In some cases, new user fees or container fees have been introduced or proposed to pay for such improvements. Rates charged by railroads have in some cases escalated dramatically.

Some of the melt-down events came as a surprise to industry managers and governmental officials. We believe this reflects a lack of practical analytical tools that can be used to predict container dwell and transit times as a function of volume, infrastructure and staffing. While there is much useful literature on simulation models and queuing formulas for operational analysis of individual transportation links and terminals, to our knowledge there is little research on practical congestion analysis of large rail networks to support strategic planning. We aim to fill that need in this article. We provide a queuing model for rail intermodal terminals, the first such model to the best of our knowledge. We develop a new queuing formula for individual rail line-haul segments and combine in a practical way the results of application of the formula to individual rail links into estimates of the total transit times in transcontinental rail container corridors. Combined with results of queuing analyses of terminals, estimates of total container flow times from arrival at origin ramp to train arrival at inland destination ramp are readily developed for multiple transcontinental corridors. To the best of our knowledge, this is the first time a practical queuing-theoretic approach has been developed for estimating transit times through large, general freight rail networks.

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Our motivation is the planning for continued growth of containerized imports from Asia to the Continental United States passing through West Coast ports and distributed across the Continental United States. The queuing models we propose are statistically calibrated on industry data for these import flows. There are many terminals and landside channels for which container flow times must be estimated. The desired accuracy of total-channel container flow times is on the order of days.

The structure of this article is as follows. We first provide an overview of the sequence of queues that imports moving in rail channels must negotiate. Next, we review the relevant literature. We then proceed to the development of our proposed queuing models and illustrate their application.

2. Supply-chain strategies and relevant queues

The majority of containerized imports from Asia to the Continental United States are retail goods or goods nearly ready for retail sale. The uninformed observer might think that all such containerized imports from Asia would move intact in marine containers from port of entry to distribution centers serving the regions of ultimate consumption, but such is not the case. In 2006, about 30% of such imports were unloaded from marine containers within the hinterland of the port of entry and re-shipped in larger domestic containers immediately or after import warehousing for some time, and this share has been steadily rising for more than a decade (Leachman, 2010).

This is significant for our purposes because domestic containers and marine (international) containers are generally handled by US railroads at separate intermodal terminals and in separate trains. Trains handling domestic containers are generally assigned higher horsepower and more priority by the railroads. Thus flow times for imports in the direct-shipment-of-marine-box import channels and in the trans-load-to-domestic-box channels, and the sensitivities of these flow times to growth and to changes in infrastructure or service levels, are different. Moreover, a shift in market shares between direct-shipment and trans-loaded supply chains results in different strains on the elements of the rail network.

Imports moving across the Rockies intact in marine containers move under what is termed inland point intermodal (IPI) service, whereby a trans-Pacific steamship line sells transportation door-to-door from Asian factory to inland USA distribution center and subcontracts with a US railroad to operate trains of double-stacked marine containers from rail intermodal terminals at West Coast port cities to distant inland rail intermodal terminals. The marine containers may be loaded into the railroad's double-stack well cars at on-dock rail terminals within the port complex, or the boxes may be drayed over streets and highways from port terminals to "off-dock" (i.e., remote) rail terminals for loading into railroad well cars.

Imports trans-loaded to domestic containers move under a new bill of lading after trans-loading, and the steamship line is not involved in the onward transportation. Such imports are drayed out of the port terminal over city streets and highways and are tendered to the railroad at an off-dock rail intermodal terminal as domestic freight after trans-loading to domestic containers.[1] Domestic containers are double-stacked in a different-sized railroad well car designed to accommodate the larger domestic containers.

The series of rail-related queues experienced by waterborne containerized imports under the alternative strategies are summarized as follows:

Port terminal queues:

- Loading containers into railroad well cars coupled into strings of well cars on parallel tracks at on-dock terminals (on-dock rail IPI movement only).
- Shuttling strings of loaded well cars from on-dock loading tracks to a nearby staging railyard, and assembling the strings of well cars into longer trains at the staging railyard (on-dock IPI movement only).

Queues experienced outside the port but still in the general vicinity of the port of entry:

- Loading domestic containers into railroad well cars at off-dock rail terminals (trans-loading supply chains) and loading marine containers into railroad well cars at off-dock terminals (for IPI movements not loaded on-dock).

Queues in line-haul movement:

- Delays to line haul movement of double-stack container trains (both marine-box stack trains and domestic-box stack trains) for meets with opposing rail traffic on single-track lines, and for following and overtaking slower rail traffic moving in the same direction.

The magnitude of delays and the sensitivity to total rail import volumes are different for the various types of queues. Considering our purposes, we develop analytical queuing models for the queues that we perceive to be very sensitive to import volume and to have flow-time impacts in aggregate that are measured in days. We approximate the delays stemming from

[1] On-dock terminals are integrated into ports. The container flow times through such terminals from vessel arrival until double-stack trains are loaded or until container drays are dispatched are the subject of a different article, Leachman and Jula (2011). Off-dock terminals are operated by railroads. The container flow time from arrival of container dray until departure of double-stack train from off-dock terminals is an important subject of this article.