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Congestion analysis of waterborne, containerized imports from Asia to the United States

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ABSTRACT

A queuing model is introduced for estimating container flow times through port terminals as a function of infrastructure, staffing, and import volume. The model is statistically calibrated on industry data. Flow-time estimates of the model are aggregated with estimates from models previously developed for rail networks to develop estimates of the total container flow times from West Coast ports to inland distribution centers. Integrated with a supply-chain optimization model, the queuing formulas are used to predict import flows by port and landside channel in scenarios of total import growth, varying all-water rates, and a higher import share for nation-wide importers.

1. Introduction

Substantial growth in waterborne, containerized imports from Asia to the Continental United States up through 2007 (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 that triggered major shifts in port and channel allocations of imports. In response to trade growth, there have been major expenditures by public agencies 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.

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 flow times as a function of volume, infrastructure and staffing. While there is much useful queuing literature for operational analysis of individual terminals, to our knowledge there is little research on practical tools for congestion analysis of large import networks. We aim to fill that need in this article.

An important analytical question faced by policymakers concerns how importers would respond to new infrastructure or increased staffing hours, and to new fees or rate increases to pay for construction of the infrastructure or the addition of working hours. Would the importers "stay and pay" or would they re-structure their supply chains to avoid increased charges, shifting import cargoes to other ports and/or other landside channels?

A practical analytical means of estimating container flow times is an important element in addressing that question, i.e., it must be determined whether or not there are sufficient reductions in flow times afforded by the proposed additions to infrastructure or staffing to offset the costs of same. A second purpose of our research is therefore to combine in a practical way the results of queuing analyses of individual transportation links and terminals into estimates of the total container flow times from port of entry to inland distribution centers.

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Our specific interest is waterborne 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 ports 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 various queues import containers must negotiate. Next, we review the relevant literature. We then proceed to the development of our proposed queuing models and illustrate their application. In particular, we discuss their integration into elasticity analysis of importers' response to infrastructure or staffing additions, and to fees to use such additions.

2. Overview of supply-chain strategies and supply-chain queues

Waterborne, containerized imports flow through a series of queues. The type and sequence of queues experienced by containers handling goods for a particular importer depend on the supply-chain strategy adopted by the importer. For the purposes of understanding the impact of congestion on import flows under alternative supply-chain strategies, it is therefore convenient to stratify imports by supply-chain strategy.

2.1. Classification of supply-chain strategies

Broadly speaking, in industrial practice there are two basic supply-chain strategies for managing flows of containerized imports from Asia to the Continental United States:

2.1.1. Push supply chains

Importers purchase transportation of marine containers from Asian factories to their regional distribution centers (RDCs). Allocation of containers to RDCs is decided before booking vessel passage. Landside movement to RDC may be via IPI (inland point intermodal service), whereby the marine box is loaded onto a double stack well car on-dock or drayed from the port terminal to an off-dock rail intermodal terminal (AKA a *ramp*), then moved in a double-stack train to a ramp in the general area of the RDC, then re-loaded onto a chassis for final dray to the RDC. Landside movement also may be via dray direct from port terminal to a local RDC or by over-the-road trucking to RDCs in regions not as distant as the regions for which IPI service is utilized. As of 2007, about 70% of total Asia – Continental USA imports were handled in Push supply chains (Leachman 2010).

2.1.2. Push–Pull supply chains

A set of 1–5 ports for handling all imports to the Continental USA is selected by the importer. In the hinterland of each selected port the importer maintains an import warehouse for storing goods that are imported far in advance of demands at its RDCs and for which it desires to delay making the decision to allocate goods to regions until regional demand forecasts become more reliable. Nearby each selected port the importer also contracts a trans-loader/de-consolidator to unload the contents of marine boxes, sort the imported goods by destination, and re-load the goods into domestic rail containers and highway trailers. Under Push–Pull, the decision is made before booking vessel passage as to how to allocate marine containers to the selected ports of entry (if there is more than one), but the decision as to how to allocate port volumes to RDCs is deferred. Just before vessel arrival, an allocation of the marine boxes is made to the trans-loader/de-consolidator in the hinterland of the port, the import warehouse in the hinterland of the port, and the local RDC. Most containers are routed via the trans-loader/de-consolidator; a smaller fraction is routed directly to the import warehouse. In the case of high-volume importers, a fraction of import containers may be routed directly to the local RDC. Drays of the marine boxes from the port terminal to these three destinations are made accordingly. For boxes routed to the trans-loader/de-consolidator, decisions are made just before the time of vessel arrival about how to allocate the contents of each marine box into domestic rail containers and highway trailers destined to various inland RDCs, the local RDC and the import warehouse. The trans-loader/de-consolidator processes the contents of the marine boxes and dispatches domestic rail containers and highway trailers accordingly. The domestic rail containers loaded by the trans-loader/de-consolidator are drayed to a nearby rail terminal, moved by train to a ramp in the general area of the destination RDC, then re-loaded onto chasses for final dray movement to the RDC. The highway trailers loaded by the trans-loader/de-consolidator are drayed to the local RDC, drayed to the import warehouse, or trucked to RDCs in regions not as distant as the regions for which domestic rail service is utilized. For boxes routed to the import warehouse, the goods in those boxes are unloaded and placed in storage. At some future times decisions will be made to allocate those goods to RDCs. For goods allocated to the local RDC, there is local dray movement. For goods allocated to distant regions, domestic rail containers are brought to the import warehouse, loaded and drayed to a nearby rail intermodal ramp. The domestic containers are moved by domestic double stack train to a rail terminal in the same area as the destination RDC, then re-loaded onto chasses for final dray movement to the RDC. For goods allocated to other regions for which rail intermodal service is not available or is not economical, the goods are loaded into highway trailers for truck movement to the RDCs in those regions. As of 2007, about 30% of Asia – Continental USA waterborne containerized imports were handled in Push–Pull supply chains (Leachman, 2010). The share of imports handled this way has been steadily rising for about a decade.