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Estimation of an Origin-Destination Table for U.S. Imports of Waterborne Containerized Freight

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Sandia National Laboratories

Introduction

- In 2014 U.S. imported nearly *20* million twenty-foot equivalent units(TEUs), worth about *$1.7* trillion.

- Nine U.S. ports handle *83%* of all TEUs imported.

- Small number of infrastructure elements,
  Large amounts of freight transportation,
  The volume continues to rise.

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Goal

- Estimation of an origin-destination table of US imports of containerized freight (measured in TEUs) using available data
- Estimation of the domestic mode share (rail and truck)

Related Research

- Estimating an origin–destination table for US imports of waterborne containerized freight (Levine, Nozick, and Jones. 2009)
  - Done for 2004
  - Extend that model to deal with changes in the underlying datasets and incorporate uncertainty

- Port and modal allocation of waterborne containerized imports from Asia to the United States(Leachman and Robert C. 2008)
  - Identify the best supply chain strategy for retailers from Asia
  - Use per capita personal income statistics to determine O-D table

Related Research

- The worldwide maritime network of container shipping: spatial structure and regional dynamics.(Ducruet, César, and Theo Notteboom. 2012)
  - Focus on the role of different ports in maritime shipping
  - Gravity model to predict flows between ports
- A disaggregate analysis of factors influencing port selection.(Malchow, Matthew, and Adib Kanafani. 2001)
  - A discrete choice model for shipper to select ports
  - Location plays an critical role in the selection

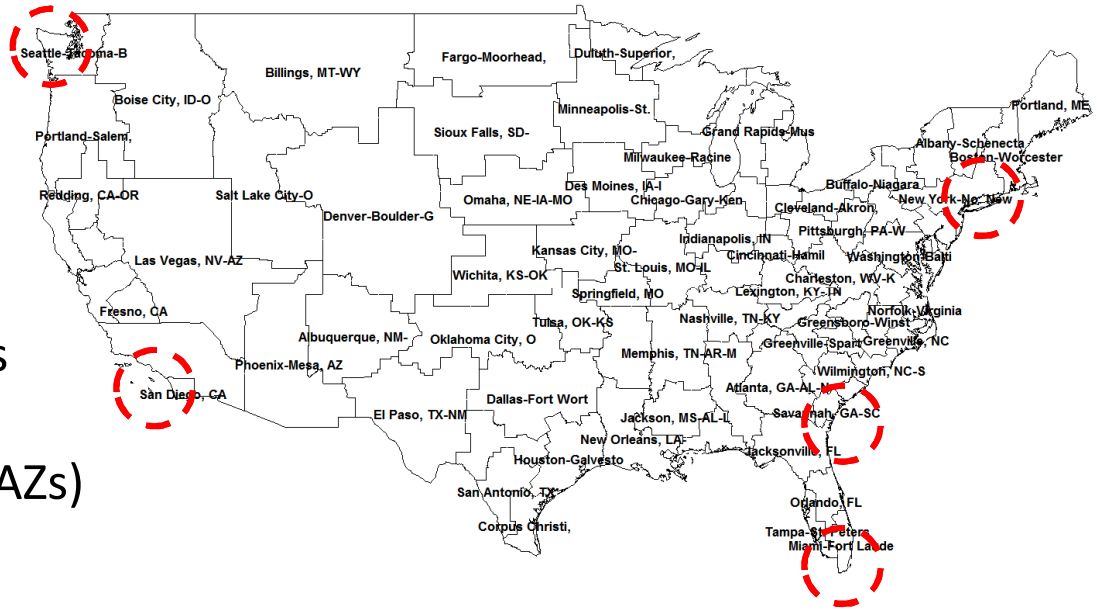
Outline

- Section 1: Dataset
- Section 2: Model Description
- Section 3: Insights From the Estimation

Section 1:
Dataset

Geography and Port Facilities

- 67 foreign countries, 94% of the total TEUs imported(Origins).
- 32 U.S. ports.
- 2 traffic mode(rail and truck).
- 177 Bureau of Economic Analysis (BEA) are grouped into 84 Transportation Analysis Zones (TAZs) for the analysis.(Destinations)



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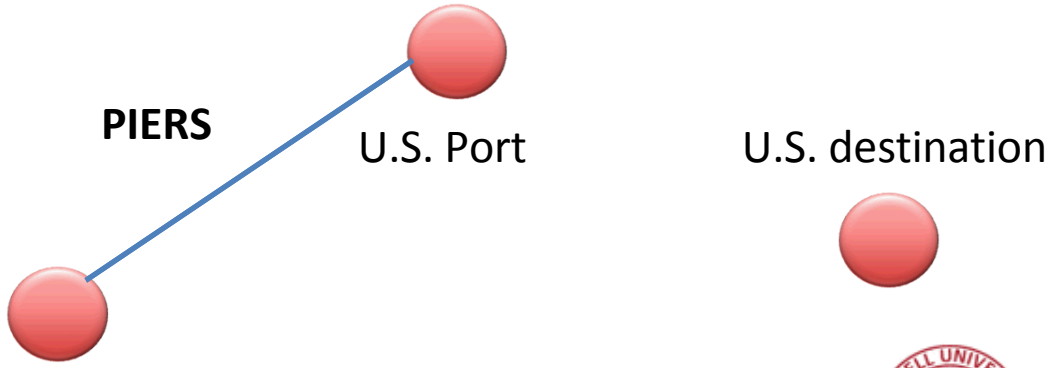
Maritime data from the Journal of Commerce's Port Import Export Reporting Service (PIERS)

- The worlds largest database of U.S. waterborne trade in the world

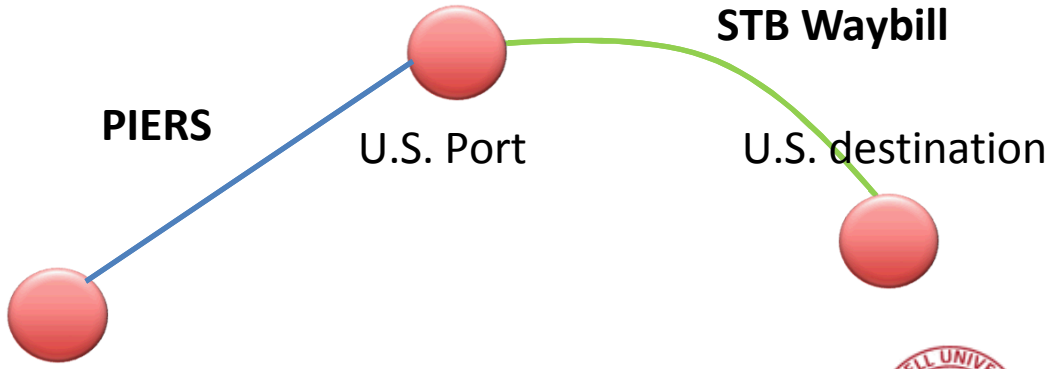
- PIERS gathers raw data from import Bills of Lading for all waterborne cargo vessels that enter and exit ports in the United States, sourced by U.S. Customs and Border Protection.



The Surface Transportation Board (STB)

- Rail waybills generated in the U.S. by carriers that handled at least 4,500 cars annually

- Reports the origin and destination for each waybill. Unfortunately, there is no reliable indicator of whether a particular waybill record was the result of an import or export

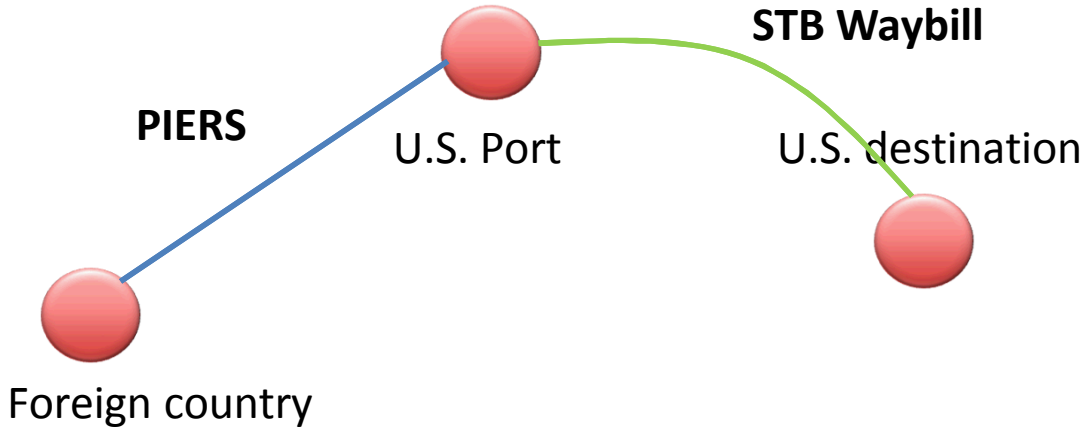


Section 2:
Model Description

Section 2 Constraints

I. Match TEUs originating in each foreign country that are shipped to the U.S. ports.

II. Match rail waybill volumes.



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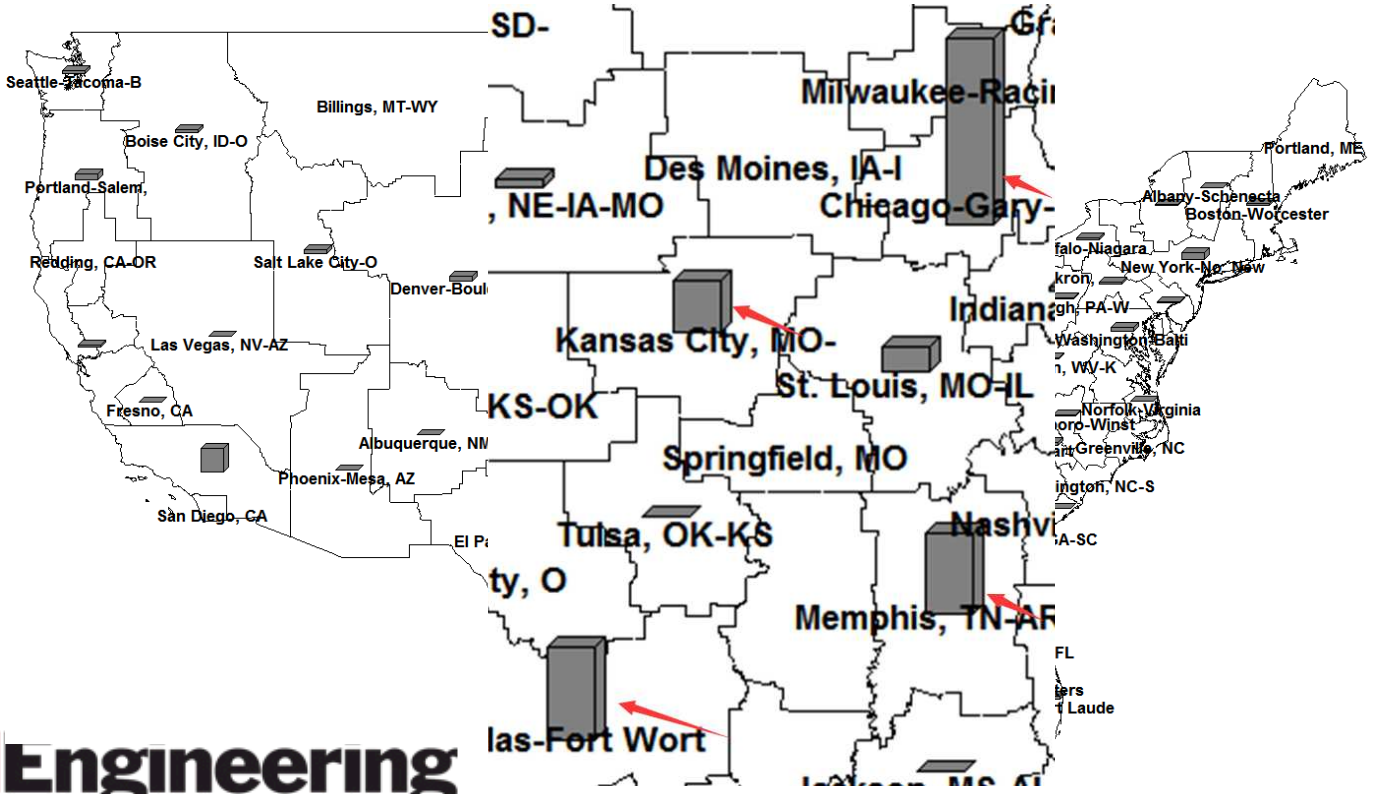
Section 2 Constraints

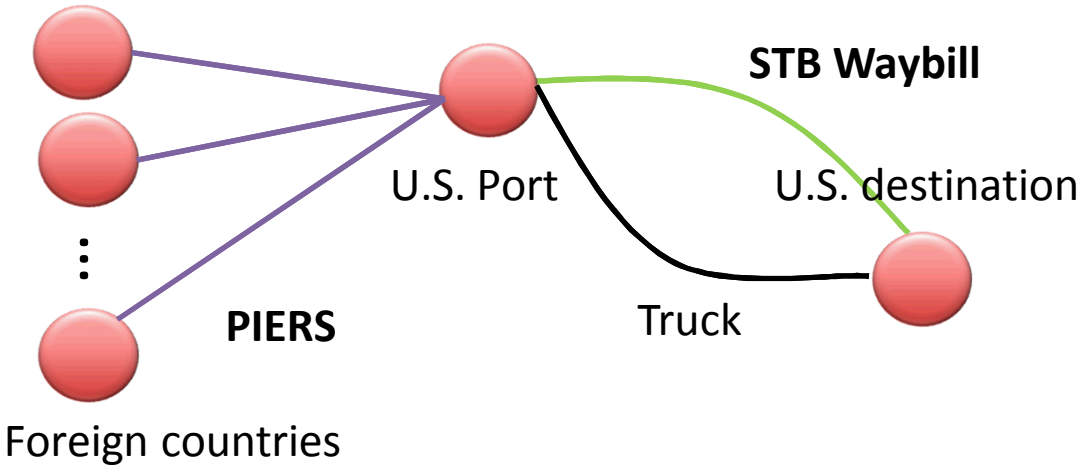
- Rail waybill has larger numbers of TEUs terminating in Dallas-Fort Worth, Memphis, Chicago and Kansas City
- Result of interchanges between rail carriers
- Model allows some of this traffic to continue to other destinations in the same direction of travel



Section 2 Constraints

III. Match the import values at the ports

IV. Match the mode split for specific ports



Section 2 Objective Function

V. Look for an origin –destination table that is consistent with a gravity model

For each O-D pair=
country specific factor($\widehat{K}_o$) × gross domestic product of TAZ (G_d) × distance and λ is the distance parameter ($d_{od}^{-\lambda}$)
$\pm$error

Objective function(Minimize):

Deviations of the estimates based on PIERS dataset + deviations in the 2012 STB Waybill + deviations in the mode share for specific ports + deviations from the gravity model + term to encourage the model to choose solutions that imply more direct routes

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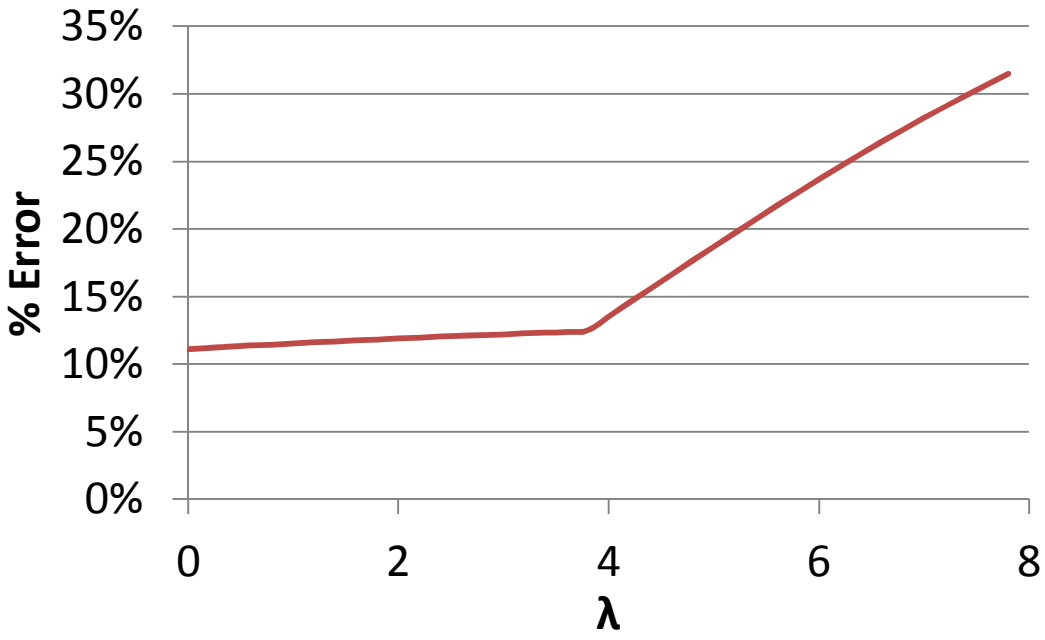
Section 3:
Insight From the Estimation

Section 3 Results Analysis

Optimization model for different values of λ from 0 to 8 increment of 0.2.



Model Errors as a Function of λ

$\lambda = 0$: 11.11%
$\lambda = 3.8$: 12.50%

- Different λ will lead to different O-D tables.
- The exact value of λ is unknown but could be described by a uniform distribution from 0 to 3.8.

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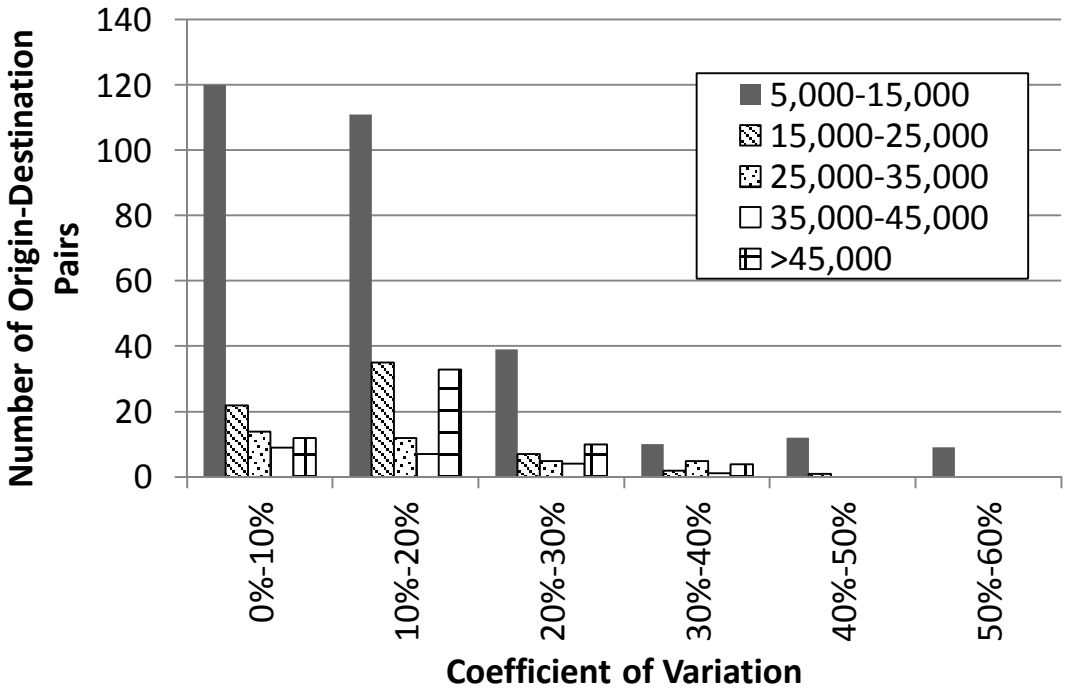
Section 3 Results Analysis

λ is unknown but could be described by a uniform distribution from 0 to 3.8.



- 75% of the origin-destination pairs (with volumes greater than 5,000) have coefficients of variations that are less than 20%.
- These origin-destination pairs constitute almost 80% of the total volume

Relative alternation for OD pairs with TEUs over 5000/year.

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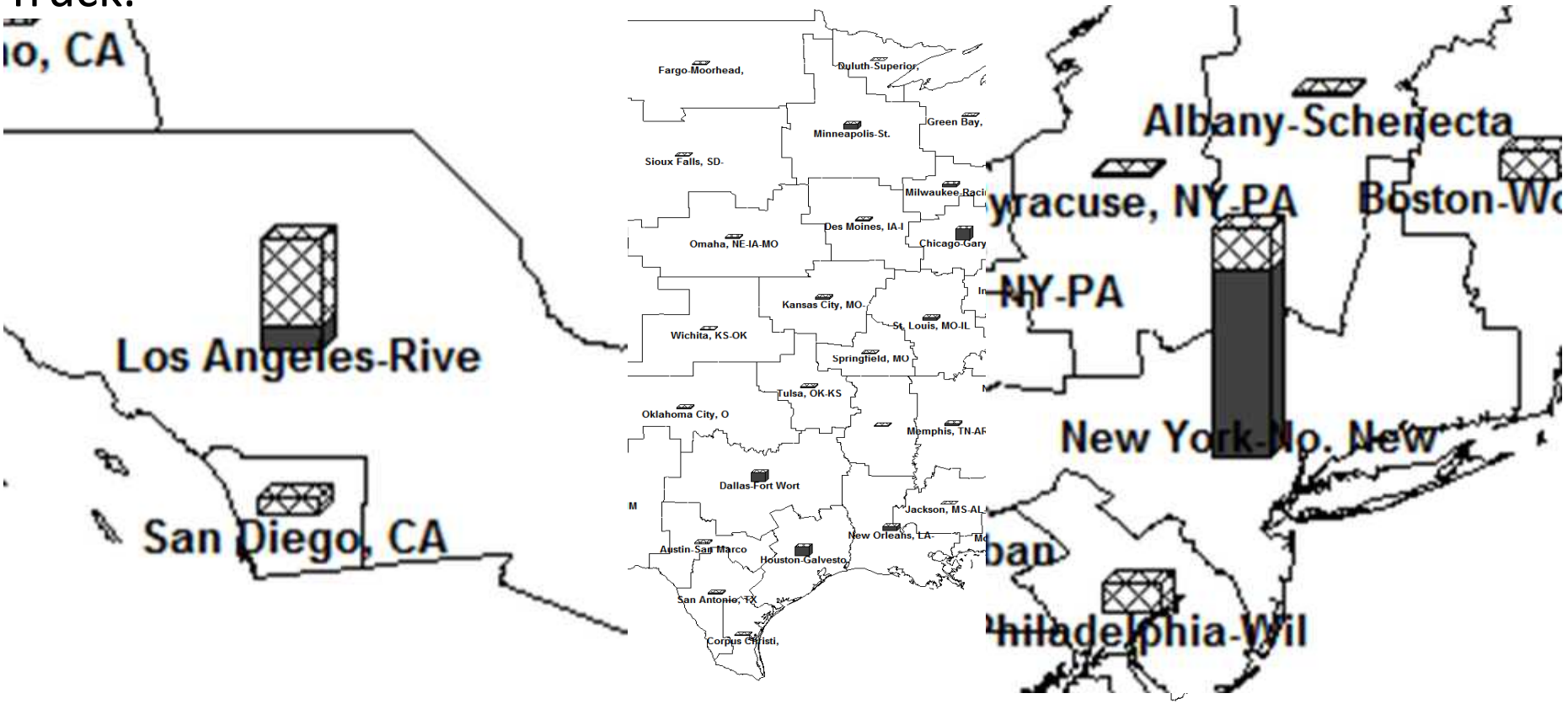
Section 3 Results Analysis

Estimated Numbers of TEUs Imported from China to TAZs by Rail and Truck.



Levine et al. uses a value of 1.2 for λ.
It is still an appropriate choice.

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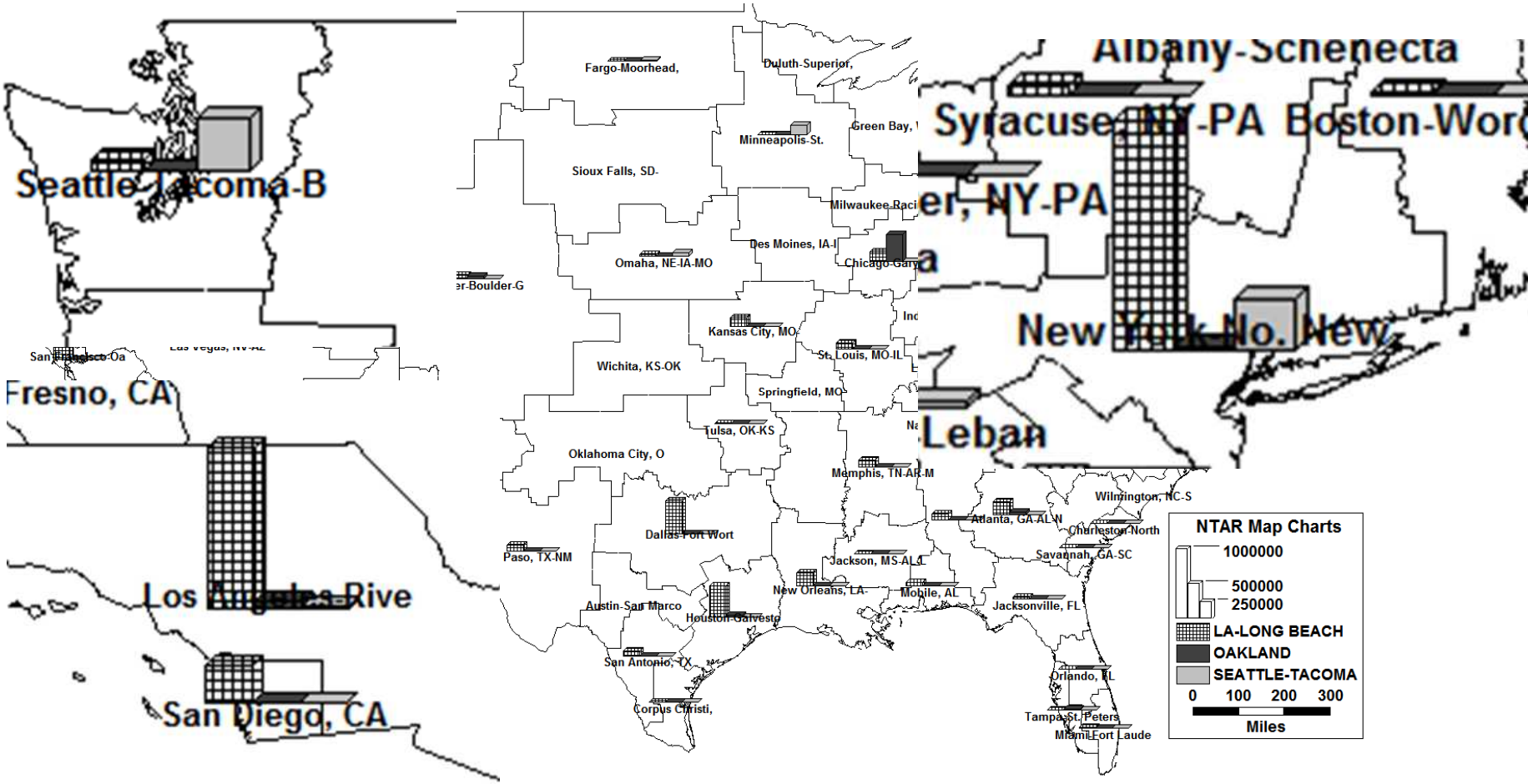
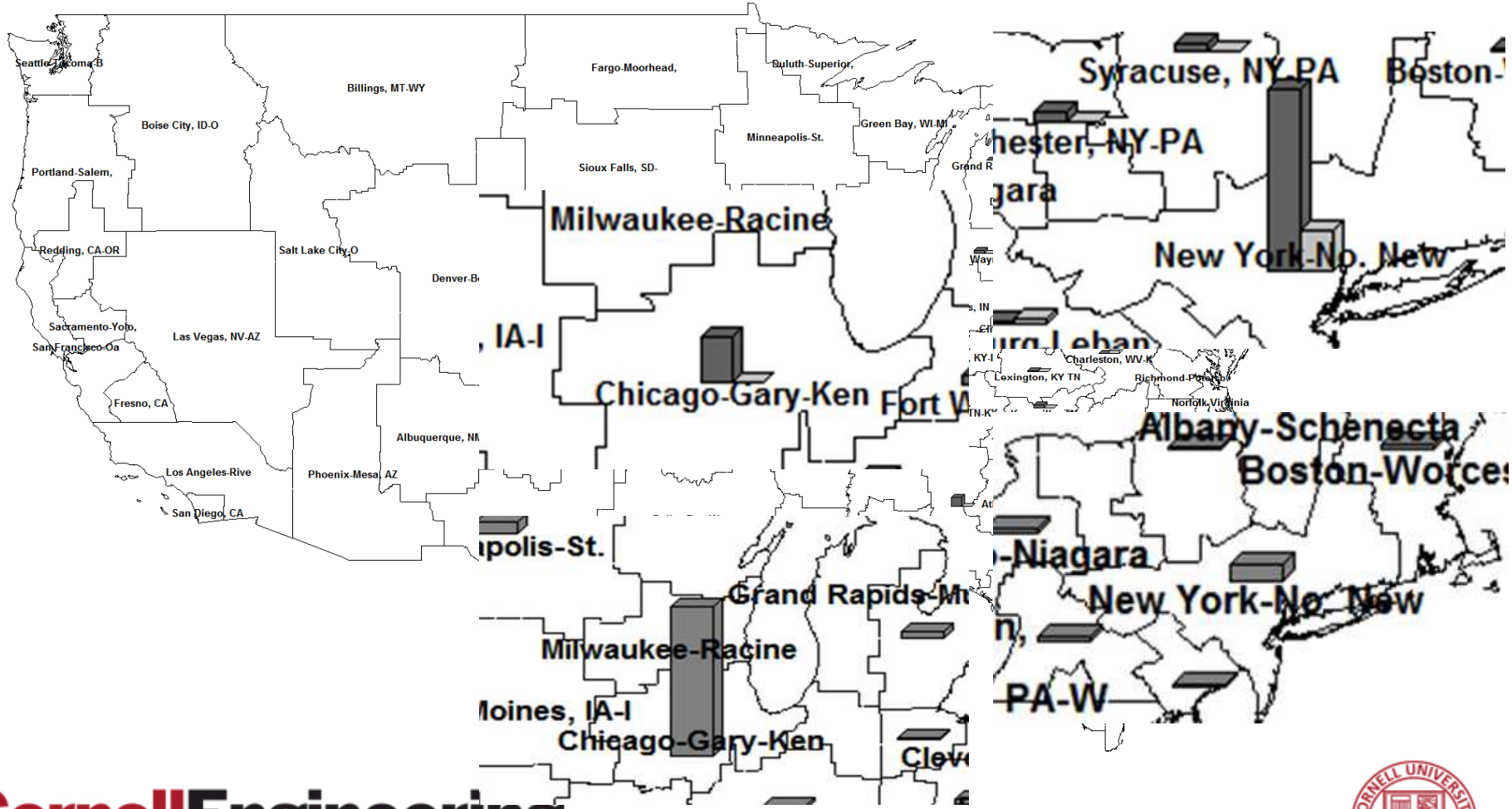
Section 3 Results Analysis

Flows of Containers from Key West Coast Ports to TAZs.



Section 3 Results Analysis

Estimated Rail Flows from West Coast Ports through Chicago, Memphis, Dallas and Kansas City.



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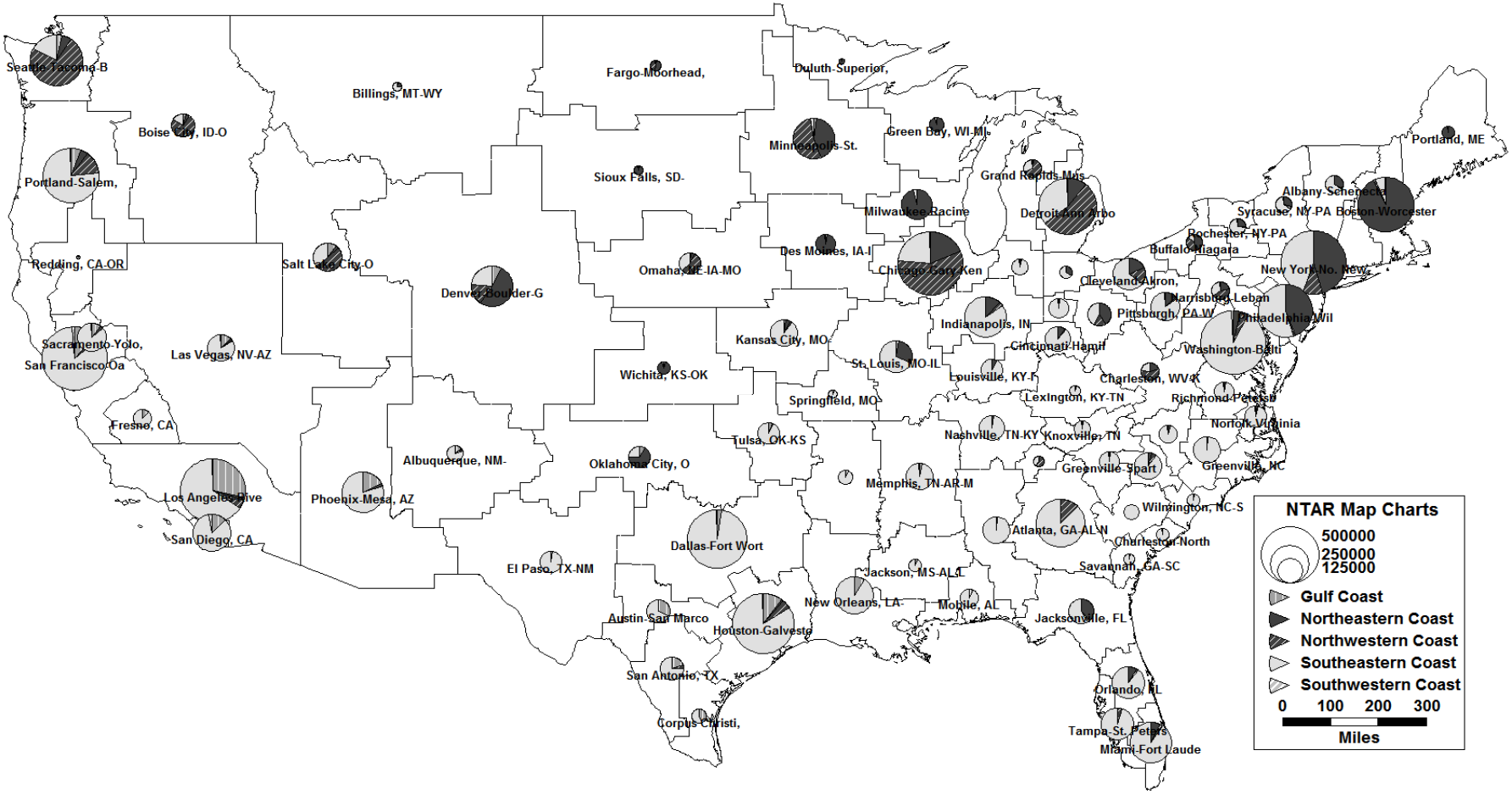
Section 3 Results Analysis

Estimated Service Areas for Port Regions.



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Thank you!

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