Warehouse Location Choice
A Case Study in Los Angeles, CA

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Doctoral Student Transportation Research 4/12/17
Research Objectives

- Understand how and why warehouses have decentralized from central urban areas to the periphery

1. Look at warehousing location choice factors

2. Evaluate changes in location & changes location choice factors
   - Focus on large warehouses’ location change/choice
1. Warehousing Location Choice
Warehousing Location Choice

- **Warehouse?**
  - An intermediary that connects supply chain
  - Part of the logistics industry

- **Warehouse Location Choice**

<table>
<thead>
<tr>
<th>Facility Characteristics</th>
<th>Location Characteristics</th>
<th>Logistics Cost structure</th>
<th>Location Choice of Logistics Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Land prices</td>
<td>Facility costs</td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td>Market access</td>
<td>Inventory costs</td>
<td></td>
</tr>
<tr>
<td>Role in supply chain</td>
<td>Labor access</td>
<td>Transport costs</td>
<td></td>
</tr>
<tr>
<td>Logistics plan</td>
<td>Transport access</td>
<td>(unobservable)</td>
<td></td>
</tr>
</tbody>
</table>
This DC and another in Seattle WA cover the entire West Coast

Built in 2001
1.8 million ft²
Ikea Distribution Center (2001)
Ikea Distribution Center (2001)

110 miles via I-710 & I-5
2-3 hour driving from POLA
OnTrac Package Delivery (2009)

400k ft²
OnTrac Package Delivery (2009)

- Relatively expensive land prices
- Direct access to local markets
- Direct access to labor pools
- Direct access to LAX (20 miles)
2-1. Changes in Location

“...relocation and concentration of logistics facilities toward suburban areas outside city centre boundaries”

Dablanc and Rakotonarivo (2010)
Why do they decentralize?

- Economic restructuring
  - Globalized, geographically dispersed supply chains
  - Adv. in info/transport tech. – reduced transport costs
  - Adv. in logistics tech. – instant response / short dwell time
  - Access to national and global markets
  - Proximity to highways, rail and intermodal facilities

- More modernized and larger warehouses
  - To transport larger volumes of goods more frequently and reliably
  - Mega distribution center and automation

- Land price and availability
  - Low rent, large parcels, and favorable zoning
Why should we care?

- Warehousing decentralization and clustering
  - Location shifts from central areas to suburban/exurban areas
  - Concentration: counties with rich transport infrastructure

- Warehouse as a truck trip generator
  - If farther from markets, more travel miles, greater impact
  - Congestion, increased fuel consumption, air pollution, noise, vibration, infrastructure damage, environmental justice

- Warehouse as mobile sources
  - Diesel particulate matter from trucks at warehouses/DCs
<table>
<thead>
<tr>
<th>Evaluation of</th>
<th>Comparison</th>
<th>Hypothesis Test</th>
<th>Literature?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution changes</td>
<td>From t-1 to t</td>
<td>H₀: Dₜ - Dₜ₋₁ = 0</td>
<td>Multiple locations: Several</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Multidimensional aspect: No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Statistical testing: Just a few</td>
</tr>
<tr>
<td>Location choice factors</td>
<td>Cross-section</td>
<td>H₀: β of factorᵢ = 0</td>
<td>Multiple locations: Just a few</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Facility characters: Limited</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Location character: Several</td>
</tr>
<tr>
<td>Changes in location choice factors</td>
<td>From t-1 to t</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>
Data
Warehousing Location and Character.

- **CoStar**
  - Industrial real estate listings
  - Warehouses, truck terminals, distribution centers, or cold storages
  - Address, rentable building area (RBA), year of construction, N of loading docks, N of floors
  - No retrospective analysis; if demolished, left market: not available

- **What we have:**
  - 5,364 facilities (existed in 2016)
  - RBA > 30,000 ft²
  - Year of construction between 1951 and 2016
Warehouses in Los Angeles

Warehouses built between 1951 and 1980
Warehouses in Los Angeles

Warehouses built between 2001 and 2016

△ Seaports
✦ Cargo-Service Airports
★ Intermodal Facilities

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Warehouses in Los Angeles

Warehouses rentable building area between 30k and 100k ft²
Warehouses in Los Angeles

Warehouses rentable building area over 300k ft²

- Evident decentralization
- Correlation between size and built year
2-2. Changes in Location Factors
Research Approach – Discrete Choice

- Structure – Firm location choice
  - The choice of a location entails an unobservable profit $X$
  - Facility and Location characteristics jointly influence the profit
  - Choice of A over B is made if/only if $\text{Profit A} > \text{Profit B}$
  - Multinomial models

- Design of choice sets
  - Cannot evaluate every single choice
  - Independence of irrelevant alternatives (heterogeneity between choices)
  - Cluster analysis using location characteristics (Ward’s linkage)
  - Location characteristics to describe each location choice
  - From 660 census tracts (minimum 1 facility) to seven choice sets
## Design of Location Choice Sets

<table>
<thead>
<tr>
<th>Location factors</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land price</td>
<td>Population and employment densities in 2010, as proxies (Clark, 1951; McDonald, 1989)</td>
</tr>
<tr>
<td>Labor pool access</td>
<td>Sum of population (2010) with an inverse travel-time weight within 30 min driving distance</td>
</tr>
<tr>
<td>Proximity to local markets</td>
<td>Driving time to the <strong>nearest</strong> employment sub-centers (Giuliano and Small, 1991)</td>
</tr>
</tbody>
</table>
| Proximity to Transport nodes | Driving time to the **nearest** airport, seaport, intermodal terminals  
Distance to the nearest highway ramps |

*Travel time is calculated based on the SCAG Regional Transportation Plan 2012 database Using ArcGIS Network Analysts*
Location Characteristics

Labor pool access 2010

\[
L_i = \sum_{j=1}^{n} \text{POP}_j \times t_j^{-0.6769}
\]

where, \( \text{POP}_j \) = population in census tract \( j \),
\( t_j \) = travel time between census tract \( i \) and \( j \) (t < 30 minutes).

Legend

★ Intermodal Facilities
+ Cargo-Service Airports
▲ Seaports
Labor pool access
- 5th Quintile
- 4th Quintile
- 3rd Quintile
- 2nd Quintile
- 1st Quintile

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Location Characteristics

Employment Sub-centers and Trade Nodes

Legend
- Employment Clusters
- Seaports
- Cargo-Service Airports
- Intermodal Facilities

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## Characteristics of Location Choice Sets

<table>
<thead>
<tr>
<th>Loc. Sets</th>
<th>Location (N)</th>
<th>Land price</th>
<th>Labor pool access</th>
<th>Proximity to local market</th>
<th>Proximity to trade node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Downtown LA, East LA, Culver City, Inglewood, LAX (99)</td>
<td>High</td>
<td>High</td>
<td>Very close</td>
<td>Very close</td>
</tr>
<tr>
<td>2</td>
<td>Commerce, Vernon, Norwalk, Carson, Torrance, Ports (147)</td>
<td>Average</td>
<td>High</td>
<td>Far</td>
<td>Very close</td>
</tr>
<tr>
<td>3</td>
<td>Orange, Anaheim, Santa Ana, Irvine (50)</td>
<td>Average</td>
<td>Low</td>
<td>Average</td>
<td>Far but to seaports</td>
</tr>
<tr>
<td>4</td>
<td>[BASE] City of Industry, Azusa, Burbank, Chatsworth (132)</td>
<td>Average</td>
<td>Average</td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td>5</td>
<td>Ontario, Chico, Corona, Beaumont (114)</td>
<td>Low</td>
<td>Low</td>
<td>Far</td>
<td>Far</td>
</tr>
<tr>
<td>6</td>
<td>San Bernardino, Riverside (62)</td>
<td>Low</td>
<td>Low</td>
<td>Far but Riverside</td>
<td>Far but to inter-modal</td>
</tr>
<tr>
<td>7</td>
<td>The outskirts (56)</td>
<td>Very low</td>
<td>Very low</td>
<td>Very far</td>
<td>Far</td>
</tr>
</tbody>
</table>
Research Approach – Discrete Choice

- General model
  - Probability of a facility (i) to be located in 1 of 6 choice sets (j) over the base outcome (#4) is a function of facility characteristics (X)
  - Multinomial logit
    \[ \pi_{ij} = Pr(y_i = j) = F_j(X_i, \theta) \]
  - Var1: Rentable building area as a continuous variable
    - As a proxy for economies of scale
  - Var2: Built year as a categorical variable: 3 periods
    - 1) 1951-1980; 2) 1981-2000 (base); 3) 2001-2016
  - Stepwise models
    - Var1
    - Var1 + Var2

*Count data model*
Results
Share of Warehouses by Size

Downtown LA
Inglewood
LAX

Commerce
Norwalk
Torrance
Ports

Orange
Anaheim
Santa Ana
Irvine

City of Industry
Azusa
Burbank
Chatsworth

Ontario
Chino
Corona
Beaumont

San Bernardino
Riverside

The Outskirts

<table>
<thead>
<tr>
<th>Size Range</th>
<th>Downtown LA</th>
<th>Commerce</th>
<th>Orange</th>
<th>City of Industry</th>
<th>Ontario</th>
<th>San Bernardino</th>
<th>The Outskirts</th>
</tr>
</thead>
<tbody>
<tr>
<td>30k-100k</td>
<td>12%</td>
<td>33%</td>
<td>8%</td>
<td>19%</td>
<td>4%</td>
<td>4%</td>
<td>3%</td>
</tr>
<tr>
<td>100k-300k</td>
<td>9%</td>
<td>35%</td>
<td>6%</td>
<td>15%</td>
<td>6%</td>
<td>6%</td>
<td>3%</td>
</tr>
<tr>
<td>over 300k</td>
<td>4%</td>
<td>12%</td>
<td>3%</td>
<td>25%</td>
<td>15%</td>
<td>3%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Notes:
- Downtown LA: 30k-100k, 100k-300k, over 300k
- Commerce: 30k-100k, 100k-300k, over 300k
- Orange: 30k-100k, 100k-300k, over 300k
- City of Industry: 30k-100k, 100k-300k, over 300k
- Ontario: 30k-100k, 100k-300k, over 300k
- San Bernardino: 30k-100k, 100k-300k, over 300k
- The Outskirts: 30k-100k, 100k-300k, over 300k
# Multinomial Logit Results

<table>
<thead>
<tr>
<th>Multinomial</th>
<th>SIZE</th>
<th>Log(RBA)</th>
<th>Model 1 β</th>
<th>Model 2 β</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 Downtown LA-LAX</strong></td>
<td></td>
<td></td>
<td><strong>-0.304</strong></td>
<td><strong>-0.213</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>-0.213</strong></td>
<td><strong>-0.213</strong></td>
</tr>
<tr>
<td></td>
<td>YEAR</td>
<td>1951-1980</td>
<td><strong>1.098</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1981-2000</td>
<td>(base period)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2001-2016</td>
<td></td>
<td><strong>-0.326</strong></td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td></td>
<td><strong>2.872</strong></td>
<td><strong>1.282</strong></td>
</tr>
<tr>
<td><strong>2 South LA-Port</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SIZE</td>
<td>Log(RBA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.008</td>
<td></td>
<td><strong>0.087</strong></td>
</tr>
<tr>
<td></td>
<td>YEAR</td>
<td>1951-1980</td>
<td><strong>0.541</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2001-2016</td>
<td></td>
<td><strong>-0.497</strong></td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td></td>
<td><strong>0.505</strong></td>
<td><strong>-0.571</strong></td>
</tr>
<tr>
<td><strong>3 Orange-Anaheim</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SIZE</td>
<td>Log(RBA)</td>
<td><strong>-0.186</strong></td>
<td><strong>-0.115</strong></td>
</tr>
<tr>
<td></td>
<td>YEAR</td>
<td>1951-1980</td>
<td><strong>0.662</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2001-2016</td>
<td></td>
<td><strong>-0.375</strong></td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td></td>
<td><strong>1.226</strong></td>
<td><strong>0.150</strong></td>
</tr>
<tr>
<td><strong>4 City of Industry</strong></td>
<td>(base outcome)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(** if P <0.01; * if P <0.05)
## Multinomial Logit Results

<table>
<thead>
<tr>
<th>Multinomial</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta )</td>
<td>( \beta )</td>
</tr>
<tr>
<td></td>
<td>** if ( P &lt; 0.01 ); * if ( P &lt; 0.05 )</td>
<td></td>
</tr>
<tr>
<td>SIZE Log(RBA)</td>
<td>0.414 **</td>
<td>0.318 **</td>
</tr>
<tr>
<td>YEAR 1951-1980</td>
<td></td>
<td>-1.900 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.172</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-4.369 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-2.796 **</td>
</tr>
<tr>
<td>SIZE Log(RBA)</td>
<td>1.005 **</td>
<td>0.757 **</td>
</tr>
<tr>
<td>YEAR 1951-1980</td>
<td></td>
<td>-0.773 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.184 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-12.669 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-10.073 **</td>
</tr>
<tr>
<td>SIZE Log(RBA)</td>
<td>0.046</td>
<td>-0.040</td>
</tr>
<tr>
<td>YEAR 1951-1980</td>
<td></td>
<td>-0.991 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.263</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-2.175</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.987</td>
</tr>
<tr>
<td>Constant</td>
<td>-4.369 **</td>
<td>-2.796 **</td>
</tr>
<tr>
<td></td>
<td>-12.669 **</td>
<td>-10.073 **</td>
</tr>
<tr>
<td></td>
<td>-4.369 **</td>
<td>-2.796 **</td>
</tr>
<tr>
<td></td>
<td>-12.669 **</td>
<td>-10.073 **</td>
</tr>
<tr>
<td></td>
<td>-4.369 **</td>
<td>-2.796 **</td>
</tr>
<tr>
<td></td>
<td>-12.669 **</td>
<td>-10.073 **</td>
</tr>
<tr>
<td>Pseudo R2</td>
<td>0.020</td>
<td>0.089</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-9,050.6</td>
<td>-8,410.28</td>
</tr>
<tr>
<td>N</td>
<td>5,364</td>
<td>5,364</td>
</tr>
</tbody>
</table>
### Multinomial Logit Results

<table>
<thead>
<tr>
<th>Multinomial</th>
<th>β</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE</td>
<td>Log(RBA)</td>
<td>0.318</td>
</tr>
<tr>
<td>YEAR</td>
<td>1951-1980</td>
<td>-1.900</td>
</tr>
<tr>
<td></td>
<td>2001-2016</td>
<td>-0.172</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>-2.796</td>
</tr>
</tbody>
</table>

**Ontario, Chico, Corona, Beaumont**

- **Land Price**: Low
- **Labor pool access**: Low
- **Proximity to local markets**: Far
- **Proximity to trade nodes**: Far

### Marginal effect

\[ \exp(12.6) = 300k \text{ ft}^2 \]
## Multinomial Logit Results

<table>
<thead>
<tr>
<th>Multinomial</th>
<th>β</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 SB-Riverside</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIZE</td>
<td>Log(RBA)</td>
<td>0.757</td>
</tr>
<tr>
<td>YEAR</td>
<td>1951-1980</td>
<td>-0.773</td>
</tr>
<tr>
<td></td>
<td>2001-2016</td>
<td>1.184</td>
</tr>
<tr>
<td>Constant</td>
<td>-10.073</td>
<td>**</td>
</tr>
</tbody>
</table>

### San Bernardino, Riverside

<table>
<thead>
<tr>
<th>Feature</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Price</td>
<td>Low*</td>
<td>Lower than #5</td>
</tr>
<tr>
<td>Labor pool access</td>
<td>Low*</td>
<td>Higher than #5</td>
</tr>
<tr>
<td>Proximity to local markets</td>
<td>Far but Riverside</td>
<td></td>
</tr>
<tr>
<td>Proximity to trade nodes</td>
<td>Far but to intermodal</td>
<td></td>
</tr>
</tbody>
</table>

### Marginal effect

![Graph showing marginal effect](image)
Summary of Results

- **Discrete choice model: compared to locating in #4:**
  - Different location choice by size and built year
  - Larger warehouses are more likely to be in #5 and #6.
  - Newer warehouses are more likely to be in #5 and #6.
  - #5, popular since 1981-2000; whereas #6, popular since 2001

- **Changes in factors? (relative to #4)**
  - Land prices (-)
  - Labor pool access (-); Local market access (-); Transport access: (-)

- **Cost rebalances?**
  - Facility & inventory costs: (-) (land prices, scale economies)
  - Transport costs: (+)
Discussion

- Transportation costs
  - Many operational aspects to consider at the facility level (Vehicle types, shipment origin/destination, routing, time of operation)
  - Shipment consolidation through centralized facilities
  - Gains from operational efficiency might offset negative impacts (Kohn and Brodin, 2008; Dhooma and Baker, 2012)

- Expansion and concentration of large-scale warehouses
  - Major truck travel generator
  - Concentration of negative impacts
  - Environmental justice
Conclusion and Future Research

- **Conclusion**
  - Recent warehouses have prioritized lower land prices and economies of scale over labor pool, local market, and transport access
  - Cost tradeoffs between land prices and transport costs

- **Future Research**
  - Truck VMT?
  - The rise in e-commerce, instant delivery and warehouse location
Thank you!

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