THE SPATIAL DYNAMICS OF AMAZON LOCKERS

INU F 2019 – LOCAL/LAST MILE PICKUP AND DELIVERY

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Outline

1 Introduction
2 Literature
3 Research Framework
4 Data Collection
5 Data Analysis Methods
6 Results and Findings
7 Conclusions
1 INTRODUCTION

• Background
• Research Questions
Background

- Increasing Truck Activities – Online shopping
- Social impacts: safety, congestion, parking
- Environmental impacts: pollutant, emissions
- Strategy: Pick-up Points (PP) + Automated Parcel (AP) Networks
  - Replace truck trips with walking/biking
  - Reduce negative social and environmental impacts?
  - Low costs? + higher efficiency?
(1) What is the spatial distribution of Amazon Lockers in Los Angeles?
   - Clustering?
   - Autocorrelation?

(2) Why are those lockers located there?
   - Variables that affect the distribution
     o Demographics
     o Built Environment

(3) How do people pick up their orders?
   - Travel behaviors
2 LITERATURE

- Summary
- Research Gaps
Literature Review – Location Matters

• The Environmental Benefits of PP Networks
• The Variables that Affect the Design of PP Networks
• Developing Sustainable Networked Delivery System

<table>
<thead>
<tr>
<th>Authors</th>
<th>Place</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weltevreden (2008)</td>
<td>Netherlands</td>
<td>Both shoppers and pick-up points benefit from vicinity.</td>
</tr>
<tr>
<td>Morganti, Dablanc, &amp; Fortin (2014)</td>
<td>France</td>
<td>Population density and internet penetration</td>
</tr>
<tr>
<td>Iwan, Kijewska, &amp; Lemke (2016)</td>
<td>Szczecin</td>
<td>Proper location of the machines used for deliveries → efficiency</td>
</tr>
<tr>
<td>Deutsch &amp; Golany (2017)</td>
<td>Canada</td>
<td>Optimize the locker network based on location, size and demographics.</td>
</tr>
<tr>
<td>Lachapelle, Burke, Brotherton, &amp;</td>
<td>Australia</td>
<td>Proximity to highways, to public transport, population density, a balance of jobs and population, and higher rates of households Internet access</td>
</tr>
<tr>
<td>Leung (2018)</td>
<td></td>
<td></td>
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</table>
Research Gaps

• Few studies describe the spatial distribution patterns of pick-up point locations
• No studies have investigated the spatial distribution of Amazon Lockers in US cities
• LA – a mix of walkable and non-walkable places ≠ European cities

• Try to fill this gap by
  – Describing the spatial pattern using spatial analysis tools
  – Analyzing the socio-economic and built environment variables
  – Estimating the potential GHG emission reduction
  – Starting from LA and expand the studies to other major cities in the US.
3 Research Framework

• *Describe*
• *Explain*
• *Estimate*
**Description**

Clustering

Kernel Density, K-function

**Spatial Autocorrelation**

Moran’s I Index

**Dependent Variables**

**Spatial Regression**

**Demographic**

- Population
- Age
- Education
- Race
- Internet
- Income

**Independent Variables**

**Built Environment**

- Walkability/ Bikeability
- Transit
- Parking

**Explanation**

**Travel Behavior**

**Estimation**

**Truck Routing**

**GHG Emission Reduction**
4 Data Collection

• Amazon Locker
• Built Environment
• Demographics
Amazon Locker Locations

- Google Map API - “Text Search”
  - Circle search
  - Radius limit
- Python
- Hexagon fishnet
  - $r=2\text{miles}$
  - $N=502$
- 273 Lockers in total.
Built Environment Data

- API + Python
- The same fishnet grid as Amazon Locker search
- Walkability/Bikeability
  - Walkscore.com API
- Parking Density
  - Google Map API – Nearby Search
    - “type” parameter = “parking”
- Transit density
  - LA Metro Bus and Rail GIS Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Data</th>
<th>How to use it in research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walkability</td>
<td>Walk/Bike score at the centroid of each census tract</td>
<td>Walkscore at the centroid of each census tract</td>
</tr>
<tr>
<td>Bikeability</td>
<td>Bike score at the centroid of each census tract</td>
<td>Bike score at the centroid of each census tract</td>
</tr>
<tr>
<td>Transit</td>
<td>The number of transit stops</td>
<td>The number of transit stops / Tract Area</td>
</tr>
<tr>
<td>Parking</td>
<td>The number of parking lots</td>
<td>The number of parking lots / Tract Area</td>
</tr>
</tbody>
</table>
Demographics Data

- Source: US Census Bureau, 2017, ACS 5 year estimates
- Variables (unit of analysis – census tract)

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<tr>
<th>Variable</th>
<th>Data (unit of analysis – census tract)</th>
<th>How to use it in research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>The number of people</td>
<td>The number of people / Tract Area</td>
</tr>
<tr>
<td>Age 15-39</td>
<td>The number of persons aged 15-39</td>
<td>The number of persons aged 15-39 / Tract Area</td>
</tr>
<tr>
<td>Education</td>
<td>The number of people with bachelor’s degree or higher</td>
<td>The number of people with bachelor’s degree or higher / Tract Area</td>
</tr>
<tr>
<td>White</td>
<td>The number of white people</td>
<td>The number of white people / Tract Area</td>
</tr>
<tr>
<td>Internet</td>
<td>The number of household with internet use</td>
<td>The number of household with internet subscriptions / Tract Area</td>
</tr>
<tr>
<td>Income</td>
<td>The median household income ($)</td>
<td>The median household income ($)</td>
</tr>
</tbody>
</table>
5 Methods

- Clustering
- Autocorrelation
- Regression
Spatial Analysis Tools

- **Spatial Point Pattern Analysis** → Original Locker Location Data (Point Data)
  - Kernel density – when the points are distributed independently
  - Ripley’s K-function – when the points are distributed dependently

- **Spatial Autocorrelation** → Locker Service Availability in Each Census Tract (Polygon Data)
  - Availability – the # of 1-mile locker buffers intersecting each census tract
  - Moran’s I statistics – check tracts are affecting each other

- **Spatial Regression**
  - Ordinary Least Squares (OLS) Regression – Global
  - Geographically Weighted Regression (GWR) – Local
6 Findings

- Clustering √
- Spatial autocorrelation √
- Spatial Regression  ?
- Spillover effects  !
Clustering

- Kernel Density Test $\rightarrow$ Three-tier-clustering
  - Tier 1 ($d=0.9$): 1, 2
  - Tier 2 ($d=0.6$): 3, 4
  - Tier 3 ($d=0.3$): 5-12

- K-Function Test
  - Significant Clustered at 99% conf. level
Spatial Autocorrelation

Step 1 Point data → Polygon data (Spatial Join)

Step 2 Moran I’s statistics – Significant + Positive

Count = # of 1-mile locker buffers intersecting each census tract → Dependent variables Y

Count > 0: 1718 tracts
Count = 0: 624 tracts

Given the z-score of 122.8430, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.
Spatial Regression – OLS

- Narrow the geographic boundary to Urbanized Area
  - 13 census tracts removed (Non-urbanized)
  - 1718 tracts with lockers
  - 611 tracts with no lockers
- Unit of analysis: census tracts
- Correlation test and Variable Filtering before OLS
  - The correlation coefficients with Y > 3.0;
  - The correlation coefficients with other selected independent variables \((X_n) \leq 0.7\);
- Selected Independent Variables (2 sets):
  - Walk, parking, transit, income, education, internet
  - Walk, parking, transit, income, education, population
## Spatial Regression – OLS

<table>
<thead>
<tr>
<th></th>
<th>Model (1)</th>
<th>Model (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>0.293***</td>
<td>0.292***</td>
</tr>
<tr>
<td>Parking</td>
<td>0.120***</td>
<td>0.115***</td>
</tr>
<tr>
<td>Transit</td>
<td>0.110***</td>
<td>0.112***</td>
</tr>
<tr>
<td>Income</td>
<td>0.042</td>
<td>0.070**</td>
</tr>
<tr>
<td>Education</td>
<td>0.545***</td>
<td>0.256***</td>
</tr>
<tr>
<td>Internet</td>
<td>-0.426***</td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td></td>
<td>-0.163***</td>
</tr>
<tr>
<td>N</td>
<td>2329</td>
<td>2329</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.2493</td>
<td>0.2376</td>
</tr>
</tbody>
</table>

**Standardized beta coefficients**

* p<0.05, ** p<0.01, *** p<0.001
Negative Effects?

Population Density

Internet Use Household Density
### Spatial Regression – GWR

<table>
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<th>Model (1)</th>
<th>Model (2)</th>
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</thead>
<tbody>
<tr>
<td>Adjusted R-squared</td>
<td>0.4123</td>
<td>0.4010</td>
</tr>
<tr>
<td>AIC * (Aikake Information Criterion) * Model performance for GWR</td>
<td>8085.22</td>
<td>8133.50</td>
</tr>
</tbody>
</table>

- GWR better than OLS (Adj. R²)
- Very little difference between Model 1 and Model 2
- Places in red are better explained by the GWR model.
Spatial Regression – GWR – Predicted Results

Model (1)

Model (2)
Other variables – Spillover Effects

- Small business: bring foot traffic that may transfer to sales (711)
  - Little overlapping products
  - Few stipends
- Business cooperation with Amazon
  - WF, Chase, Sprint
- Double foot traffic to Amazon.
7 Conclusions

- Conclusions
- Limitations and future studies
Conclusions

- Kernel Density tool identified a “three-tier-clustering” pattern based on the level of density.
- Global Moran’s I Index detected a significant positive spatial autocorrelation at 99% confidence level.
- GWR model can explain 41% of the variation in dependent variables, while OLS model can only explain 24% of the variation in dependent variables.
  - Three demographic variables – population/internet use, income, education - **
  - Three built environment variables – walkability, transit, parking - ***
- Beyond the spatial model, potential spillover effects and business cooperation are also important factors that affect the distribution of lockers.
Limitations and Future Studies

- Model specification – still over half of the variations cannot be explained
  - Internet Use Household Density
    - Smart phone use may be a better indicator than internet use
    - Household density also includes the influence of population density
  - How to quantify business cooperation and spillover effects and include them into the regression model.
- Estimating GHG savings needs real travel behavior data from customers and couriers.
  - Survey to be implemented
References


Thanks for Your Listening!
Comments are Welcome!