Cargo Cycles for Local and Last Mile Delivery: Lessons from New York City

Alison Conway
City College of New York
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The City College of New York

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Project Motivation and Approach
Changing Conditions for Urban Freight

- Nearly all freight moves by truck/van
- Parking is inadequate and expensive
- Demand is growing and becoming increasingly complex
- Urban streets are becoming increasingly multimodal
- New interactions/incompatibilities

- Just-in time commercial deliveries
- Omni-channel retailing
- e-Commerce
- 400 mi bike lanes since 2007
- 60+ Complete Streets projects
- 8 SelectBus corridors since 2008
- Citibike implementation
- Reduced road and parking capacities
- Narrow lanes/small turning radii
- Increased bike/ped volumes
What is a cargo cycle?

- Primarily human-powered bicycle or tricycle with cargo carrying capacity
Project Approach

- What are the potential applications of cargo cycles in NYC?
- What are the benefits, challenges, and barriers to operation?
- How do freight tricycles perform in NYC conditions?

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<tr>
<th>State of the Practice Review</th>
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<td>Literature Review</td>
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<th>NYC Case Study Analysis</th>
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<td>Data Collection</td>
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State of the Practice
<table>
<thead>
<tr>
<th>Study</th>
<th>Focus</th>
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<tbody>
<tr>
<td>Dablanc (2011)</td>
<td>Monitored the operations of La Petite Reine, a cargo cycle company performing deliveries from a consolidation platform in central Paris</td>
</tr>
<tr>
<td>Browne, Allen, and Leonardi (2011)</td>
<td>Conducted a before and after analysis of an office supply company replacing van deliveries with cargo cycle operations from a micro-consolidation center</td>
</tr>
<tr>
<td>Verlinde et al. (2014)</td>
<td>Conducted a before and after analysis of a major parcel company implementing a mobile depot utilizing cargo cycles to replace motor vehicles for last-mile delivery</td>
</tr>
<tr>
<td>Gruber, Kihm, and Lenz (2014)</td>
<td>As part of ongoing “Ich ersetze ein Auto” project, studied the market potential for replacing motorized (car and van) courier operations with cargo cycle operations</td>
</tr>
<tr>
<td>Tipagornwong &amp; Figliozzi (2013)</td>
<td>Modeled the cost competitiveness of cargo cycle vs. motor vehicle delivery operations in Portland</td>
</tr>
<tr>
<td>Koning and Conway (2015)</td>
<td>Quantified the externality savings from growing cargo cycle operations in Paris between 2001 and 2014</td>
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</tbody>
</table>
North American Survey
Commodities/Sectors Served

- Last mile parcel / courier
- B2B food deliveries
- B2C retail/restaurant deliveries
- Office supplies
- Pharmaceuticals
- Waste/recycling

Dominant sector in Europe; Large international operators

Dominant sector in North America; Small, green-oriented businesses
Benefits of Cargo Cycles

For Operators

- Lower vehicle maintenance and fuel costs
- Driver health benefits
- Demonstrated commitment to sustainability
- Infrastructure flexibility
- Parking flexibility (and reduced fines)

For Urban Areas

- Not inherently incompatible with pedestrian/bicycle-friendly infrastructure
- Reduced exposure to heavy vehicles (especially for non-motorized travelers)
- Reduced GHG and air pollutant emissions
- Reduced noise impacts
Challenges

Operational

- Requires dense market within limited radius; usually located in expensive CBD
- High cost for transloading
- Lower economies of scale vs. fully utilized larger vehicles
- High driver costs (#, worker’s compensation insurance)
- Customer perception/fear of the unknown

Regulatory

- Ambiguous vehicle classifications
Public Sector Involvement

Europe

- Funded pilot studies (EU and Local)
- Recognition schemes
- A few examples of direct operating subsidy
- Policies limiting motor vehicle access (e.g. bans, congestion charges, low emissions zones)
- Policies permitting flexible use of dedicated infrastructure

North America

- Limited research to date
- Ambiguous operating regulations
- Expensive insurance regulations (NYC)
- Limited regulation of freight access
- Limited financial investment
  - 2 cities: “capital” grants
  - 1 city: contract for recycling pickup
- Limited formal recognition of “green” best practices

Lower risk
Higher credibility
Reduced costs differential between modes
Participating Partners

City Bakery
- Local green bakery chain
- 7 locations - Midtown/ Downtown Manhattan
- 2 trikes / 5 total drivers
- Typical day: 7 AM – 7 PM
- Morning tour + on-demand deliveries

City Harvest
- Local food rescue non-profit
- 120+ potential Manhattan locations (by all vehicle types)
- 19 trucks - Long Island City
- 3 trikes - Midtown and Upper East Side / 1 driver per trike
- Typical Day: 12 PM – 12 AM
- Donation pickups < 50 lbs
Data Collection

- QSTARZ BT-Q1000XT travel recorder
  - Stored in OtterBox
  - Attached to trike undercarriage/under truck seat using high strength Velcro
  - Chosen for passive operation

- Data Collected
  - 53 unique days of data for CB Trikes
  - 40 unique days of data for CH Trikes
  - 29 unique days of data for CH Trucks

- Challenges
  - Urban canyons
  - Drift points
  - Limited battery life and storage capacity
  - Vehicles not in operation

Variables

<table>
<thead>
<tr>
<th>Local Date and Time</th>
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<tbody>
<tr>
<td>Latitude</td>
</tr>
<tr>
<td>Longitude</td>
</tr>
<tr>
<td>Spot Speed</td>
</tr>
<tr>
<td>Distance</td>
</tr>
<tr>
<td>Heading</td>
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</tbody>
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Performance Measure Estimation

Motivation and Approach
State of the Practice
Case Studies
Lessons Learned
Performance Measure 1: Corridor Moving Speed

- 60 ft road buffer
- Remove points within stop buffers and intersections
- Median is better estimator of central tendency than harmonic mean (Quiroga and Bullock, 1998)
### Operator Road Type

<table>
<thead>
<tr>
<th>Mean Speed (mi/h)</th>
<th>t Statistic</th>
<th>Maximum Difference/Mean</th>
</tr>
</thead>
<tbody>
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<td><strong>Operator Road Type</strong></td>
<td><strong>Mean Speed (mi/h)</strong></td>
<td><strong>t Statistic</strong></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td><strong>Truck Route</strong></td>
<td><strong>Non-Truck Route</strong></td>
</tr>
<tr>
<td>CB Tricycle, Avenue</td>
<td>7.7</td>
<td>7.5</td>
</tr>
<tr>
<td>CB Tricycle, Street</td>
<td>8.0</td>
<td>7.1</td>
</tr>
<tr>
<td>CH Tricycle, Avenue</td>
<td>5.2</td>
<td>3.9</td>
</tr>
<tr>
<td>CH Tricycle, Street</td>
<td>4.5</td>
<td>4.0</td>
</tr>
<tr>
<td>CH Truck, Avenue</td>
<td>12.2</td>
<td>11.0</td>
</tr>
<tr>
<td>CH Truck, Street</td>
<td>9.1</td>
<td>7.4</td>
</tr>
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### Operator Road Type

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<td><strong>Mean Speed (mi/h)</strong></td>
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<td><strong>Type</strong></td>
<td><strong>Bicycle Lane</strong></td>
<td><strong>Non-Bicycle</strong></td>
</tr>
<tr>
<td>CB Tricycle, Avenue</td>
<td>7.7</td>
<td>7.5</td>
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* Difference significant at confidence level of 95%
# Difference more than 5 percent of median observed value
Performance Measure 2a: Travel Time

- Direct evaluation of repeated trips for City Bakery
Performance Measure 2b: Stopped-Time Delay

- Direct evaluation of repeated trips for City Bakery
- Neighborhood to neighborhood trips for City Harvest

Motivation and Approach  State of the Practice  Case Studies  Lessons Learned
Performance Measure 3: Stop Durations

- City Bakery
  - Producer Locations
  - Receiver Locations
- City Harvest Trikes
  - Pickup Locations
  - Delivery Location
- City Harvest Trucks
  - Deliveries only in study area

Motivation and Approach | State of the Practice | Case Studies | Lessons Learned
Space Consumption

Moving

Estimate vehicle footprint, $f_i$, for vehicle type $i$

$\quad f_i = \text{length}_i \times \text{width}_i$

From GPS data, estimate moving speed, $s_i$, for each vehicle type

From GPS data, estimate delay time to moving time ratio, $r_i$, for each vehicle type

Estimate moving space hours consumed per mile of travel, $m_i$

$\quad m_i = f_i \times \frac{1}{s_i}$

Estimate delay space hours consumed per mile of travel, $d_i$

$\quad d_i = r_i \times m_i$

Estimate total space hours consumed per mile of travel, $t_i$

$\quad t_i = m_i + d_i$

Parked

$s_l = f_x \times D_x$

where

$s_l = \text{space consumed at location } l$

$f_x = \text{footprint of vehicle } x$

$D_l = \text{duration vehicle } x \text{ parked at location } l$
Emissions Estimation

- Model emissions of vehicle replaced using EPA’s MOVES model
NYC Externality Results: City Bakery Cycle vs. Van

<table>
<thead>
<tr>
<th></th>
<th>Cargo Cycle</th>
<th>Direct Replacement</th>
<th>Combined Tour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Road Space Consumed (ft²*hrs)</td>
<td>109</td>
<td>475</td>
<td>422</td>
</tr>
<tr>
<td>Total Parking Space Consumed (ft²*hrs)</td>
<td>164</td>
<td>599</td>
<td>541</td>
</tr>
<tr>
<td>Total Space Consumed (ft²*hrs)</td>
<td>272</td>
<td>1074</td>
<td>964</td>
</tr>
</tbody>
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### Sensitivity Analysis

- Relative space consumed by van ➔ 2.8 to 8 times cargo cycle
- Savings .7 to 2.3 × benchmark ➔ most sensitive to vehicle age

<table>
<thead>
<tr>
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<th>PM₂₅</th>
<th>CO₂</th>
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<tbody>
<tr>
<td>Rate (lbs/mi)</td>
<td>1.3*10⁻⁴</td>
<td>2.95</td>
</tr>
<tr>
<td>Estimated Annual Savings</td>
<td>(lbs)</td>
<td>(tons)</td>
</tr>
<tr>
<td>Scenario A</td>
<td>1.1</td>
<td>12.8</td>
</tr>
<tr>
<td>Scenario B</td>
<td>1.0</td>
<td>11.4</td>
</tr>
</tbody>
</table>
Lessons Learned
Performance Summary

- Speeds competitive with MV speeds in dense areas
- Speeds influenced by payload, trip distance, trip urgency
- High travel time reliability/low stopped-time delay
- Mostly short stops/some very long stops little influenced by regulations

- Emissions and space savings highly variable based on vehicle replaced, reorganization of logistics
- Emissions and space savings greatest in most severe conditions

- Trike trip distance often < motor vehicle trip distance

<table>
<thead>
<tr>
<th>Estimated 1-Mile Travel Time (min)</th>
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<tbody>
<tr>
<td>CB Trike</td>
</tr>
<tr>
<td>9.4</td>
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Observed Truck Speeds

- Less than 3.9 mph
- 3.9 to 7.3 mph
- 7.3 to 11.5 mph
- 11.5 to 18.4 mph
- Greater than 18.4 mph
Benefits of Cargo Cycles

For Operators
- Lower vehicle maintenance and fuel costs
- Driver health benefits
- Demonstrated commitment to sustainability
- Infrastructure flexibility
- Parking flexibility (and reduced fines)
- Reliable travel times in congested traffic (within limited radius)
- Shorter trip distances on constrained network

For Urban Areas
- Not inherently incompatible with pedestrian/bicycle-friendly infrastructure
- Reduced exposure to heavy vehicles (especially for non-motorized travelers)
- Reduced GHG and air pollutant emissions
- Reduced noise impacts
- Reduced road and parking space consumption
Challenges

**Operational**
- Requires dense market within limited radius; usually located in expensive CBD
- High cost for transloading
- Lower economies of scale vs. fully utilized larger vehicles
- High driver costs (#, worker’s compensation insurance)
- Customer perception/fear of the unknown
- Lower speeds in uncongested conditions/constrained by human limitations

**Regulatory**
- Ambiguous vehicle classifications
- Inhospitable infrastructure (e.g. bridge security ballards)
- (Il)legality of electric assists
Acknowledgements

- **City College of New York/UTRC**
  - Dr. Camille Kamga, Co-PI
  - Jialei Cheng, Graduate Research Assistant
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  - Quanquan Chen, Graduate Research Assistant
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  - Rianna Yuen, Undergraduate Research Assistant

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  - Joe Tario, NYSERDA
  - Bob Ancar, NYSDOT

- **Revolution Rickshaws**

- **New York City Department of Transportation**

- **City Bakery**

- **City Harvest**

- **Survey Participants**
  - Bikes at Work Inc., Ames, Iowa
  - B-Line Urban Delivery, Portland, OR
  - Metro Pedal Power, Somerville, MA
  - Pedal Express, Berkeley, CA
  - Shift Urban Cargo Delivery, Vancouver, BC
  - Stick Dog Pedicabs, Salt Lake City, UT
  - The Hammer Active Alternative Transportation, Hamilton, ON
Questions?

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Project Report

http://www.utrc2.org/sites/default/files/pubs/Final-Freight-Tricycles-NYC.pdf