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

Alison Conway
City College of New York

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

Alison Conway, Assistant Professor of Civil Engineering
The City College of New York

Friday Seminar Series, Portland State University, December 4, 2015
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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<th>NYC Case Study Analysis</th>
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<td>Data Collection</td>
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Motivation and Approach | State of the Practice | Case Studies | Lessons Learned
State of the Practice
# Literature Review

<table>
<thead>
<tr>
<th>Study</th>
<th>Focus</th>
</tr>
</thead>
<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>
</tr>
</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
NYC Case Studies
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
- Local Date and Time
- Latitude
- Longitude
- Spot Speed
- Distance
- Heading
Performance Measure Estimation

Motivation and Approach

State of the Practice

Lessons Learned

Case Studies
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)
## Dedicated Infrastructure

### Operator Road Type

<table>
<thead>
<tr>
<th>Operator Road Type</th>
<th>Mean Speed (mi/h)</th>
<th>t Statistic</th>
<th>Maximum Difference/Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Truck Route</td>
<td>Non-Truck Route</td>
<td>Difference</td>
</tr>
<tr>
<td>CB Tricycle, Avenue</td>
<td>7.7</td>
<td>7.5</td>
<td>0.2</td>
</tr>
<tr>
<td>CB Tricycle, Street</td>
<td>8.0</td>
<td>7.1</td>
<td>0.9</td>
</tr>
<tr>
<td>CH Tricycle, Avenue</td>
<td>5.2</td>
<td>3.9</td>
<td>1.2</td>
</tr>
<tr>
<td>CH Tricycle, Street</td>
<td>4.5</td>
<td>4.0</td>
<td>0.5</td>
</tr>
<tr>
<td>CH Truck, Avenue</td>
<td>12.2</td>
<td>11.0</td>
<td>1.1</td>
</tr>
<tr>
<td>CH Truck, Street</td>
<td>9.1</td>
<td>7.4</td>
<td>1.7</td>
</tr>
</tbody>
</table>

### Operator Road Type

<table>
<thead>
<tr>
<th>Operator Road Type</th>
<th>Mean Speed (mi/h)</th>
<th>t Statistic</th>
<th>Maximum Difference/Mean</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Bicycle Lane</td>
<td>Non- Bicycle Lane</td>
<td>Difference</td>
</tr>
<tr>
<td>CB Tricycle, Avenue</td>
<td>7.7</td>
<td>7.5</td>
<td>0.2</td>
</tr>
<tr>
<td>CB Tricycle, Street</td>
<td>7.0</td>
<td>7.7</td>
<td>-0.7</td>
</tr>
<tr>
<td>CH Tricycle, Avenue</td>
<td>5.1</td>
<td>4.2</td>
<td>0.9</td>
</tr>
<tr>
<td>CH Tricycle, Street</td>
<td>4.1</td>
<td>4.0</td>
<td>0.1</td>
</tr>
<tr>
<td>CH Truck, Avenue</td>
<td>10.2</td>
<td>12.0</td>
<td>-1.8</td>
</tr>
<tr>
<td>CH Truck, Street</td>
<td>7.5</td>
<td>8.2</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

* Difference significant at confidence level of 95%
# Difference more than 5 percent of median observed value

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Motivation and Approach

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Case Studies

Lessons Learned
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

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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
Space Consumption

Moving

- Estimate vehicle footprint, $f_i$, for vehicle type $i$
  
  $f_i = \text{length}_i \times \text{width}_i$

- 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

  $d_i = r_i \times m_i$

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

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

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

  $t_i = m_i + d_i$

Parked

\[ s_l = f_x \times D_x \]

where

- $s_l = \text{space consumed at location } l$
- $f_x = \text{footprint of vehicle } x$
- $D_x = \text{duration vehicle } x \text{ parked at location } l$
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</td>
<td>109</td>
<td>475</td>
<td>422</td>
</tr>
<tr>
<td>(ft²*hrs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Parking Space Consumed</td>
<td>164</td>
<td>599</td>
<td>541</td>
</tr>
<tr>
<td>(ft²*hrs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Space Consumed</td>
<td>272</td>
<td>1074</td>
<td>964</td>
</tr>
<tr>
<td>(ft²*hrs)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>PM$_{2.5}$</th>
<th>CO$_2$</th>
</tr>
</thead>
<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>

Sensitivity Analysis

- Relative space consumed by van → 2.8 to 8 times cargo cycle
- Savings .7 to 2.3 x benchmark → most sensitive to vehicle age
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>Observed Truck Speeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 3.9 mph</td>
</tr>
<tr>
<td>3.9 to 7.3 mph</td>
</tr>
<tr>
<td>7.3 to 11.5 mph</td>
</tr>
<tr>
<td>11.5 to 18.4 mph</td>
</tr>
<tr>
<td>Greater than 18.4 mph</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated 1-Mile Travel Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB Trike</td>
</tr>
<tr>
<td>9.4</td>
</tr>
</tbody>
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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
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  - Dan Wan, Graduate Research Assistant
  - Quanquan Chen, Graduate Research Assistant
  - Emmanuelle Lezais, Visiting Student Intern
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  - 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?

aconway@ccny.cuny.edu

Project Report

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