Direct Impacts of Off-Hour Deliveries on Freight Emissions

José Holguín-Veras,
William H. Hart Professor
Director of the VREF Center of Excellence for Sustainable Urban Freight Systems
jhv@rpi.edu
Colaborators

- Trilce Encarnación, M.S.
- Carlos A. González-Calderón, Ph.D.
- James Winebrake, Ph.D.
- Sofia Kyle
- Nilson Herazo-Padilla, M.S.
- Lokesh Kalahasthi, M. Tech.
- Wilson Adarme, Ph.D.
- Víctor Cantillo, Ph.D.
- Hugo Yoshizaki, Ph.D.
- Rodrigo Garrido, Ph.D.
Off-Hour Delivery Programs

GOAL: Shift to deliveries made during off-hours (7PM to 6AM)
Direct Environmental Impacts
Outline of Research Approach

1. Engage receivers in areas of interest
2. Engage receivers’ suppliers, install GPS devices
3. Collect GPS data for duration of study period
4. Clean GPS data
5. Estimate emissions and analyze results
Case Studies

OHD PILOTS

Bogota, Colombia

NYC, USA

Sao Paulo, Brazil
New York City
Two Major Phases

**First phase: Focus on Staffed OHD**
- Conducted behavior research to identify incentives
- Analyzed the strategic interactions among agents
- Conducted a pilot test with 35 companies

Key → finding unassisted OHD is feasible!

**Second phase: Focus on Unassisted OHD**
- 33% of establishments have a Trusted Vendor, they could do OHD without problem
- The program was expanded to more than 400 companies
- Use technology to:
  - Reduce noise during OHD
  - Facilitate Unassisted OHD
Current Status...

- Key participants (+400 companies):
  - Sysco: 31 OHD routes/week (18% of their routes, 171) delivering to 140 unassisted off-hour delivery customers
  - Wakefern: 5 OHD routes/day (25% of their total)
  - Duane Reade: Approximately 120 of their 160 Manhattan stores receive OHD on a regular basis
  - Dunkin Donuts: 72 stores out of 121 in Manhattan
  - Beverage Works (Red Bull) has approximately 130 routes in the NY Metro, 22% are OHD
  - Waldorf Astoria
Bogotá OHD Pilot

Why were the zones (UPZ) chosen

1. Commercial and industrial concentration
2. Public space invasion
3. Congested roads
4. Unrestricted vehicle circulation as well as loading/unloading activities
5. Variety of the type of establishments and supply chains

**Partial OHD: 6PM – 10PM**

*Cargo vehicle attraction rate/day in commercial establishments.*

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**2.100 establishments**
- 54% commerce
- 17% services
- 11% industry
- 18% Others

**6.236 establishments**
- 43% commerce
- 23% services
Sao Paulo
São Paulo Off-hour Deliveries (OHD) Project

- Pilot test area – 11km²
  - Inside truck ban cordon
  - Mixed land use
  - Some large traffic generators

- Receivers
  - All volunteer group
  - 11 companies, 45 stores
  - 60+ delivery route shadowing's

- First large collaboration project between the traffic authority and private sector regarding freight transportation: SETCESP carrier syndicate and IDV (institute for development of retail).
# Emission Reductions per Route

<table>
<thead>
<tr>
<th>City\Pollutant</th>
<th>ROG</th>
<th>TOG</th>
<th>CO</th>
<th>CO2</th>
<th>NOX</th>
<th>PM10</th>
<th>PM25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogotá</td>
<td>13.49%</td>
<td>13.49%</td>
<td>13.50%</td>
<td>13.12%</td>
<td>12.70%</td>
<td>13.41%</td>
<td>13.41%</td>
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<tr>
<td>New York City</td>
<td>67.17%</td>
<td>67.17%</td>
<td>67.00%</td>
<td>55.14%</td>
<td>59.47%</td>
<td>65.53%</td>
<td>65.53%</td>
</tr>
<tr>
<td>Sao Paulo</td>
<td>49.98%</td>
<td>49.98%</td>
<td>51.43%</td>
<td>42.52%</td>
<td>44.64%</td>
<td>45.90%</td>
<td>45.90%</td>
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</tbody>
</table>

Partial OHD (6PM to 10PM)

Full OHD (7PM to 6AM)
<table>
<thead>
<tr>
<th>City\Pollutant</th>
<th>ROG (g/km)</th>
<th>TOG (g/km)</th>
<th>CO (g/km)</th>
<th>CO2 (g/km)</th>
<th>NOX (g/km)</th>
<th>PM10 (g/km)</th>
<th>PM25 (g/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogotá</td>
<td>0.146</td>
<td>0.166</td>
<td>2.090</td>
<td>748.923</td>
<td>0.294</td>
<td>0.050</td>
<td>0.048</td>
</tr>
<tr>
<td>New York City</td>
<td>0.166</td>
<td>0.189</td>
<td>2.416</td>
<td>853.705</td>
<td>0.346</td>
<td>0.057</td>
<td>0.054</td>
</tr>
<tr>
<td>Sao Paulo</td>
<td>0.156</td>
<td>0.178</td>
<td>1.746</td>
<td>555.542</td>
<td>0.232</td>
<td>0.043</td>
<td>0.041</td>
</tr>
<tr>
<td>Grand average</td>
<td>0.156</td>
<td>0.178</td>
<td>2.084</td>
<td>719.390</td>
<td>0.291</td>
<td>0.050</td>
<td>0.048</td>
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<tr>
<td>Standard deviation</td>
<td>0.010</td>
<td>0.011</td>
<td>0.335</td>
<td>151.260</td>
<td>0.057</td>
<td>0.007</td>
<td>0.007</td>
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<tr>
<td>Number of cases</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
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<tr>
<td>CI Upper Limit</td>
<td>0.165</td>
<td>0.187</td>
<td>2.378</td>
<td>851.975</td>
<td>0.341</td>
<td>0.056</td>
<td>0.054</td>
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<tr>
<td>CI Lower Limit</td>
<td>0.148</td>
<td>0.168</td>
<td>1.790</td>
<td>586.805</td>
<td>0.241</td>
<td>0.044</td>
<td>0.042</td>
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</tbody>
</table>
CO$_2$ Emissions for NYC

- RHD routes
- OHD routes

- Hudson river crossings
- Distance (km)

- CO$_2$ (g)

- OHD1
- OHD2
- OHD3
- OHD4
- RHD1
- RHD2
Speed distributions

Cumulative Distribution Function of Instantaneous Speeds

a) New York City (Full-OHD, 7PM to 6AM)

b) Bogota (Colombia) (Partial OHD, 6PM to 10PM)
Global Estimates
FTG for FIS, and STA for all sectors

Deliveries to Commercial Establishments:
FTG (trips/day) = 0.065*Population (USA)
FTG (trips/day) = 0.055*Population (Medellin)

Internet Deliveries to Households:
FTG (deliveries/day) = 0.054*Population (2009) (USA)
FTG (deliveries/day) = 0.094*Population (2014) (USA)
FTG (deliveries/day) = 0.20*Population (2015) (S. Korea)
Assumptions

- FTG is generated at a rate of:
  - Developing countries: 0.03 deliveries/person-day
  - Developing countries: 0.06 deliveries/person-day
- Each delivery generates one additional km of travel
- 30% of these deliveries are made with midsize trucks like those studied in this research;
- 10% of the deliveries are switched to OHD;
- Average reductions in emissions are equal to the differences between RHD and OHD average emissions
- A year = 260 days of average travel conditions
Top Ten Countries
Global Impacts

The graph shows the reductions in CO₂ (10⁶ tons) per year for different metropolitan areas considered. The areas are categorized into various regions:

- Australia-NZ
- East Europe
- North Europe
- West Europe
- South Europe
- East Africa
- South Africa
- Middle Africa
- West Africa
- North Africa
- Cent. Am. & Carib.
- South America
- North America
- West Asia
- South-East Asia
- South Asia
- East Asia

The graph indicates the total reductions for Top 10, Top 25, Top 50, Top 100, and All metropolitan areas.
Closing Remarks

- OHD brings about tremendous emission reductions
  - Partial OHD (6PM to 10PM) $\rightarrow$ 13% reductions
  - Full OHD (7PM to 6AM) $\rightarrow$ 45% to 67% reductions

- Significant global emission reductions
  - Top 10 cities $\rightarrow$ 70 million tons of CO$_2$
  - All cities larger than 2 million $\rightarrow$ 300 million tons/year of CO$_2$
  - Larger contributors:
    - Asia 55%
    - North/South Americas 25%
Questions?