Integrating Collection-and-Delivery Points in the Strategic Design of Last-Mile E-Commerce Distribution Networks

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Growth in e-Commerce creates challenges for last-mile delivery

• Increasing adoption of internet and smartphones

• Global e-commerce volumes are growing rapidly

• Consumers want the convenience to pick up or return products at physical locations

• Retailers strive to minimize delivery times and reduce transportation costs

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Collection-and-delivery points (CDPs) offer a solution for both retailers and consumers

- Flexible pickup schedule for customers
- Aggregation of customer demand
  - For customer delivery
  - For returned products
- Lower delivery cost for carriers

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http://cad-ltd.co.uk/portfolio/asda-click-and-collect/
Optimal network design considers multi-echelon distribution with CDPs

- CDPs aggregate demand and enable reductions in travel time
- CDPs reduce multiple redelivery attempts due to lesser failed deliveries
- CDPs aggregate demand for return flow and multiple failed pickups for returned products
- The presence of CDPs changes the demand density in the region
Location routing problems combine location and routing optimization

- Two-tier network design with different vehicles in each tier
- Line-haul transportation from Hubs to Satellite Facilities
- Smaller vehicles to transport goods in the last mile
- Option of Dedicated CDP routes, Customer-only routes, and Blended routes
\[
\min_{\mathbf{y}, \mathbf{w}, \mathbf{x}} K(\mathbf{y}, \mathbf{w}, \mathbf{x}) = K^F(\mathbf{y}) + K^P(\mathbf{w}) + K^T(\mathbf{x}, \mathbf{w}) + K^R(\mathbf{x}, \mathbf{w})
\]

where

\[
K^F(\mathbf{y}) = \sum_{i \in I} y_i \sum_{j \in J} \sum_{k \in K} c^F_{ikj} x_{ij} \left( \gamma^F_k(\mathbf{w}) + \gamma^R_i(\mathbf{w}) \right) A_i \rho_i + \sum_{k \in K} \psi^F_{ik}(\mathbf{w}) + \sum_{k \in K} \psi^R_{ik}(\mathbf{w}),
\]

\[
K^P(\mathbf{w}) = \sum_{i \in I} c^P_i \mathbf{w}_i + \sum_{k \in K} \left( \sum_{i \in I} \psi^P_{ik}(\mathbf{w}) + \sum_{k \in K} \psi^R_{ik}(\mathbf{w}) + (\gamma^F_k(\mathbf{w})\lambda^F \mathbf{w}_i) \right) \rho_i A_i,
\]

\[
K^T(\mathbf{x}, \mathbf{w}) = \sum_{i \in I} \sum_{j \in J} x_{ij} \left( \gamma^F_i(\mathbf{w}) + \gamma^R_i(\mathbf{w}) \right) A_i \rho_i \theta^C_{ij} + \theta^P(\mathbf{w})(\sum_{k \in K} \psi^F_{ik}(\mathbf{w}) + \sum_{k \in K} \psi^R_{ik}(\mathbf{w}))
\]

\[
K^R(\mathbf{x}, \mathbf{w}) = \sum_{i \in I} \sum_{j \in J} x_{ij} f_{ij}(\mathbf{w}),
\]

\[
\psi^F_{ik}(\mathbf{w}) = \gamma^F_k(\mathbf{w}) A_k \rho_k \max\{\mathbf{F} - \eta \mathbf{F}_k, 0\}, \quad \forall i \in D, k \in I,
\]

\[
\psi^R_{ik}(\mathbf{w}) = \gamma^R_k(\mathbf{w}) A_k \rho_k \max\{\mathbf{F} - \eta \mathbf{F}_k, 0\}, \quad \forall i \in D, k \in I,
\]

\[
\gamma^F_k(\mathbf{w}) = \gamma^F_k(\mathbf{w}) - \sum_{i \in I} \psi^F_{ik}(\mathbf{w}) A_k \rho_k \left(1 + \lambda^F(1 - \beta_k)\right), \quad \forall k \in I,
\]

\[
\gamma^R_k(\mathbf{w}) = \gamma^R_k(\mathbf{w}) - \sum_{i \in I} \psi^R_{ik}(\mathbf{w}) A_k \rho_k \left(1 + \lambda^R\right), \quad \forall k \in I,
\]

\[
\gamma_k^{D,P} = \gamma_k^{D,R}, \quad \forall k \in I,
\]

\[
\theta^P(\mathbf{w}) = \sum_{k \in K} \psi^F_{ik}(\mathbf{w}) \theta^C_k, \quad \forall i \in D,
\]

subject to

\[
\sum_{j \in J} x_{ij} = 1, \quad \forall i \in I,
\]

\[
\sum_{i \in I} \left( \gamma^F(\mathbf{w}) + \gamma^R_i(\mathbf{w}) \right) A_i \rho_i + \sum_{k \in K} \psi^F_{ik}(\mathbf{w}) + \sum_{k \in K} \psi^R_{ik}(\mathbf{w}) \leq Z_{ij}, \quad \forall j \in J,
\]

\[
y_j \in \{0, 1\}, \quad \forall j \in J,
\]

\[
x_{ij} \in \{0, 1\}, \quad \forall i \in I, j \in J,
\]

\[
w_i \in \{0, 1\}, \quad \forall i \in D.
\]
Methodology applied on the network design of a leading e-commerce retailer in Brazil

- Sao Paulo metropolitan region
- ~15,000 daily customer deliveries
- Area of ~2,400 square km
- 1 distribution hub
- 5 candidate Satellite Facilities
- 85 CDP sites
Optimal network (SF) configuration is the same with and without CDPs
CDPs result in significant cost savings in last-mile distribution

<table>
<thead>
<tr>
<th>Parameters*</th>
<th>Without CDP</th>
<th></th>
<th>With CDP</th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Last-mile distribution cost</td>
<td>Total Cost</td>
<td>Last-mile distribution cost</td>
<td>Total Cost</td>
<td>Last-mile cost savings</td>
<td>Total cost savings</td>
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<td>Forward flow only</td>
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<td>1.1%</td>
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<tr>
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<td>71.0</td>
<td>94.5</td>
<td>14.0%</td>
<td>5.5%</td>
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<td></td>
</tr>
<tr>
<td>Forward flow with failed deliveries</td>
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<tr>
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<td>85.6</td>
<td>103.3</td>
<td>72.6</td>
<td>96.4</td>
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<td>6.7%</td>
</tr>
<tr>
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<td>71.6</td>
<td>95.4</td>
<td>16.4%</td>
<td>7.6%</td>
<td></td>
<td></td>
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<tr>
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<td>88.8</td>
<td>106.7</td>
<td>74.2</td>
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<td>16.4%</td>
<td>8.1%</td>
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<td>72.1</td>
<td>95.9</td>
<td>18.8%</td>
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<tr>
<td>Forward flow + Return flow. No Failed deliveries</td>
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<tr>
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<td>82.6</td>
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<tr>
<td>[100-15-0-0-20-0]</td>
<td>92.0</td>
<td>110.1</td>
<td>79.1</td>
<td>103.4</td>
<td>14.0%</td>
<td>6.1%</td>
</tr>
<tr>
<td>Forward flow + Return flow + Failed deliveries + Failed Pickups</td>
<td></td>
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*Parameters: [Forward Demand – Return Demand – % Failed Deliveries – % Failed Pickups – Demand Attracted by CDP – % Customers choosing a CDP as an alternate location for failed deliveries]*
Integrating CDPs in the strategic design of e-commerce distribution networks helps design efficient supply chains

• CDPs offer convenience to consumers and provide competitive advantage to retailers

• Last-mile is the most expensive leg of delivery

• CDPs save last-mile distribution costs by:
  - Aggregating forward and return demand and reducing transit time for carriers
  - Offering an alternative delivery location for failed deliveries and failed return pick-ups

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