Light Electric Freight Vehicles for Last-Mile Delivery

* A case study at PostNL *

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### Agenda

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1 - Introduction
Postal market developments require cost savings and network capacity adjustments

Mail market
- Declining mail market (-10%)
- Liberalization & E-substitution
- Universal Service Obligation

Parcel market
- Growing parcel market (+15%)
- Capacity expansion
- Competition intensifies

Network optimization
Synergy opportunities?
1 - Introduction
Rise of LEFV but limited research regarding impact on distribution cost and network design

What is a Light Electric Freight Vehicle (LEFV)?

- Wide variety of types and payloads
- No universal definition, general consensus:
  - Limited speed 25 km/h
  - Electrical motor assistance (typically cycling)
  - Limited payload 0.5 m³ – 3 m³

Why LEFV specifically for Postal Operators (PO)?

- Alternative for mail delivery by bicycle
  - Higher speed
  - Less physical strain
- Possible solution for parcel delivery in cities
- LEFV could enable combined delivery of mail and parcels
  - Bicycles: payload too limited for parcels
  - Vans: high operating cost for low value mail items

Benefit and limitations of LEFV

- Easy to park
- Manoeuvrable
- Zero emission
- Limited driver training
- Low purchasing cost
- Limited range
- Limited speed
- Small payload
- Safety
2 - Problem Formulation

Hypothesis: LEFV reduce distribution cost and enable synergy between the parcel and mail network

Research Question

*Will the introduction of LEFV in the mail and parcel delivery network lead to reduced distribution costs?*

Key Topics

- Impact of LEFV on the distribution cost
- Integration of the mail and parcel network
- Impact of LEFV on network design
- Geographical characteristics suited for combined delivery
2 - Problem Formulation

Two echelon location routing problem (2E-LRP)

Mixed multi-tier distribution system

Problem Formulation

1. **Feeder Tier**
   - Depots to satellites
   - Multi-depot vehicle routing problem (MDVRP)

2. **Delivery Tier**
   - Two delivery options:
     - Originating from depot (direct delivery)
     - Originating from satellite (indirect delivery)
   - Continuous Approximation (CA)

3. **Key Assumptions**
   - Heterogenous vehicle fleet (bike, scooter, LEFV, car, van)
   - Capacited locations and vehicles
   - One-directed
## 3 - Methodology

**Mixed Integer Linear Programming Model (MILP model)**

### Decision Variables

**Binary variables** showing:

- i. Route sequence for truck delivery from depot to satellite
- ii. Allocation of satellites to active depots
- iii. Open a depot

**Feeder Tier**

**Binary variables** showing:

- i. Depot or satellite allocation
- ii. Vehicle choice
- iii. Network type

**Delivery Tier**

### Objective Function

\[
\text{minimize total cost} = \text{facility cost} + \text{handling cost} + \text{transport cost} + \text{delivery cost}
\]

### Key Constraints

- Satellites and customers served
- Subtour Elimination
- Throughput constraints

- Vehicle Capacity
- Flow Constraints
- Physical storage capacity
3 - Methodology
Selected geographic zone and scenarios

Case: Geographic Zone

- Variety of densities
- Points of delivery: 7,876
- Daily mail volume: 6,591
- Daily parcel volume: 809

Tested Scenarios

0. **Base Cases**: Standalone mail & standalone parcel network

1. **Scenario A**: Standalone mail network with LEFV

2. **Scenario B**: Standalone parcel network with LEFV

3. **Scenario C**: Combined delivery network (current fleet)

4. **Scenario D**: Combined delivery network with LEFV
4 - Results

Scenario A: Standalone mail network with LEFV

**Distribution Cost**

<table>
<thead>
<tr>
<th></th>
<th>Mail Base Case</th>
<th>Mail with LEFV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100,00%</td>
<td>96,96%</td>
</tr>
</tbody>
</table>

**Vehicle fleet composition**

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Mail Base Case</th>
<th>Mail with LEFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bikes</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Scooter</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Car</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Van</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LEFV</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

**Active Locations**

<table>
<thead>
<tr>
<th></th>
<th>Mail Base Case</th>
<th>Mail with LEFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depots</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Satellites</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
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**Main Observations**

1. Reduction of distribution cost by 3%
2. Longer maximum service time, higher payload and a higher intra-stop speed result in substitution of bicycles to LEFV
3. Faster linehaul speed of LEFV leads to reduction of depots
4 - Results
Scenario B: Standalone parcel network with LEFV

**Main Observations**

1. Reduction of distribution cost reduce by 2.7%
2. Substitution of vans to LEFV in high density areas.
3. Indirect delivery (via satellites) to overcome the long linehaul distance with LEFV.
4. A payload between 2 m³ and 3 m³ is advised.

**Vehicle fleet composition**

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Parcel Base Case</th>
<th>Parcel with LEFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bikes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Scooter</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Car</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Van</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>LEFV</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

**Distribution Cost**

- Parcel Base Case: 100.00%
- Parcel with LEFV: 97.29%

**Active Locations**

- Parcel Base Case: 1 Depot, 0 Satellites, 1 Satellite
- Parcel with LEFV: 3 Depots, 1 Satellite

**Effect of Payload**

- Distribution cost saving vs Payload in cubic meters

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4 - Results

Scenario C+D: Combined Delivery and the impact of LEFV

**Main Observations**

1. With the current vehicle fleet network integration is severely limited (only a combination via van in rural area)

2. The introduction of LEFV leads to an additional cost reduction. *Total cost reduction is 4.9%*

3. Combined delivery with *LEFV is advised in high density areas.*

4. The changes in the vehicle composition and location structure are similar to the parcel scenario.
5 - Conclusion & Future Research

LEFV are a viable addition to the vehicle fleet for mail and parcel delivery

**Conclusions**

- Adding LEFV to the vehicle fleet results in lower distribution cost and can facilitate network integration for POs
- LEFV require hubs in close proximity to the delivery area
- High drop density areas are more suited for LEFV.

**Future Research**

- Apply the model to a larger scale dataset
- Create a model with stochastic demand (e.g., volume variations and dimensions)
- Develop a VRP including time-windows for parcel delivery via LEFV
- Develop a process design for combined delivery by POs
- Develop the optimal LEFV for delivery (payload, maneuverability)