FLEET RENEWAL WITH ELECTRIC VEHICLES AT LA POSTE

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Outline

I  Background and Motivation

II  Model overview

III  Analysis, Results and Insights

IV  The decision tool for La Poste

V  Implementation at La Poste
Postal sector worldwide faces significant challenges

- Declining letter mail volumes due to electronic substitution lead to stress on Postal Operator revenues and profits
- Postal Operators also continue to have broad public missions to deliver mail and parcels throughout the country
- Postal Operators, especially in Europe, face strong expectations and pressures to improve their sustainability
- Legal constraints for urban fleet operations become more stringent for polluting vehicles

Fleet operations have become a major focus for both cost improvements and sustainability initiatives

Small vans deliver 40% of mail volume nation-wide

- 45,000 vehicles, leased for 6 years
- Daily 2 Mn. km (1.3 Mn. miles), i.e. 50 times the Earth’s circumference
- Average daily mileage: 44km (28 miles)
- Total annual costs for delivery vehicles: 230 Mn. € (300 Mn. $)
- Orchestration of geography, delivery volume and ergonomics of vehicles are essential for successful operation
- 170,000 tons of CO₂ emitted by La Poste’s fleet
- Electric Vehicles (EVs) can reduce CO₂ emissions by 30%
Sustainable fleet initiative is aligned with La Poste’s sustainability agenda

The impact of low-carbon fleet operations

<table>
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<tr>
<th>Economic/Profit Impact</th>
<th>Environmental Impact</th>
<th>Social Impact</th>
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<tbody>
<tr>
<td>▪ Cost savings</td>
<td>▪ Reduced CO₂ emissions</td>
<td>▪ Local and Global Reputation</td>
</tr>
<tr>
<td>▪ New profit opportunities in Urban Logistics</td>
<td>▪ Reduced particles emissions</td>
<td>▪ Employee motivation</td>
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<tr>
<td>▪ Reduced risk and enhanced brand equity</td>
<td>▪ Noise reduction</td>
<td>▪ Increased legitimacy in discussions with regulators and the public</td>
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November 14, 2011
Paul R. Kleindorfer, Andrei Neboian, Alain Roset, Stefan Spinler
Technology options for La Poste’s fleet renewal

Most postal carriers travel short (44 km), predictable and repetitive routes making current EV technology more than sufficient for such requirements.

- **Deterministic purchase price**
- **Stochastic operational costs**
- **Low purchase price***
- **High operational costs incl. maintenance**
- **Source of local air pollution**
- **Subject to emissions regulations**

- **Stochastic purchase price**
- **Deterministic operational costs**
- **High purchase price****
- **Low operational costs incl. maintenance**
- **Local image as a “green” vehicle**
- **Benefits from governmental subsidies**

* The price of a Renault Kangoo (Diesel) is 21,000€

** The price of a Renault Kangoo Z.E. is estimated 26,000€ excl. governmental subsidy

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
What is the optimal number of EVs and ICVs to be acquired at a given period?

**Problem setting**

- Historic ICV Acquisitions

**General assumptions**

- ICVs and EVs are fully substitutable;
- Vehicle demand at $t$ is known;

**Stochastic processes**

- Battery price $B_t$: mean-reverting process;
- Fuel price $f_t$: Brownian motion with drift;

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
The objective function minimizes expected total fleet cost

\[ G^t(f^t, B^t) = \min_{n^t_e \geq 0, n^t_i \geq 0} \left\{ n^t_e(a^t_e + B^t) + n^t_i(a^t_i + \rho \cdot \mathbb{E}_{t+1 \lvert t} [s^t_{e+1} k_e f^t_{e+1} + s^t_{i+1} k_i f^t_{i+1} + G^t_{e+1}(f^{t+1}_{e+1}, B^{t+1})]) \right\} \]

Where \( s^t_e \) is the vehicle stock at time \( t \):
\[ s^{t+1}_e = \sum_{\tau = t-l+1}^t n^{\tau}_e \text{ and } s^{t+1}_i = \sum_{\tau = t-l+1}^t n^{\tau}_i \]

**Objective function**

**Decision variables**
- Number of vehicles acquired \( n^t_i \) (ICV) and \( n^t_e \) (EV);

**Model parameters**
- Total cost of leasing and maintenance per vehicle: \( a^t_e \) (EV) and \( a^t_i \) (ICV)
- Vehicle demand \( d^t \)
- Discount factor \( \rho \)
- Consumption rate per period: \( k_e \) (EV) and \( k_i \) (ICV)
- Length of a leasing contract: \( l \)

**Stochastic processes**
- Battery price \( B^t \) : mean-reverting process;
- Fuel price \( f^t \) : Brownian motion with drift;

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
We analyze four distinct replacement policies in our model

<table>
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<tr>
<th>Policy</th>
<th>Interpretation</th>
<th>Implications</th>
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<tbody>
<tr>
<td>ICV-only policy</td>
<td>No EVs in the model</td>
<td>Business-as-usual scenario</td>
</tr>
<tr>
<td>Static policy</td>
<td>All decisions are executed in the first period</td>
<td>Reduced administrative efforts and potential benefits from volume discounts through pre-commitment</td>
</tr>
<tr>
<td>Dynamic policy</td>
<td>Decisions are updated every period based on recent uncertainty realizations</td>
<td>Full flexibility through the use of “option to wait”</td>
</tr>
<tr>
<td>Perfect Information policy</td>
<td>Decisions are based on complete knowledge of future uncertainty realizations</td>
<td>Estimate for the potential benefit through further market research on future price trends</td>
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Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
We model fuel price as a Brownian motion with drift

Wholesale diesel price in France

- Rise of the fuel price is expected to be significant (IEA, 2011 and Kleindorfer et. al, 2005);
- Drift rate and the volatility for $f^t$ is based on historic data for the wholesale diesel price in France from 1999 to 2010 (Eurostat, 2010);
- Price jumps due to regulatory changes are not considered;

\[ f^t = f^{t-1} + \mu_f + \sigma_f \cdot z \]

where $z \sim N(0,1)$, $\mu_f$ is the drift rate, $\sigma_f$ is the standard deviation, and $f^{t-1}$ is the last known realization of fuel price.
Price of an EV battery pack is expected to drop by 65% until 2020

Expected Future Battery Price Development

- Cost target of 250$/kWh by the US Advanced Battery Consortium until 2020 is unlikely to be achieved;
- Expected annual production volume of 1.1 Mn. battery packs in 2020;
- Volume-dependent production costs are expected to decrease significantly especially on the cell-production level;
- Volume-independent production costs are expected to decrease modestly;

* NCA = Lithium-Nickel-Cobalt-Aluminium battery technology
We model battery price as an Ornstein-Uhlenbeck process.

Price of a 22KWh Renault Kangoo Z.E. battery*

- Battery price is modeled separately from the EV chassis
- Battery is discarded at the end of use
- 6 years is the expected battery life-time
- Learning rate estimated using above assumptions

Discrete-time formulation

\[ B^t = \mu_B(1 - \exp(-\lambda)) + B^{t-1}\exp(-\lambda) + \sigma_B\sqrt{\frac{1 - \exp(-2\lambda)}{2\lambda}} \cdot z_B, \]

where \( z_B \sim \mathcal{N}(0, 1) \), \( \sigma_B \) is the standard deviation, \( \lambda \) is the learning rate and \( \mu_B \) is the average battery price in the long run.

* 22 kWh Li-ion battery pack allowing 170 km (106 miles) range (New European Driving Cycle)
Note: Renault currently offers a battery lease for 75€/Month (limited to a 48 Months contract)
Source: www.renault.com
Wholesale electricity price in France over past 20 years has remained nearly constant

- Average national average price for an industrial consumer:
  \[ e^t = 0.0554 \text{ €/kWh} \]
- Further price reductions possible through increased EV base

Source: Eurostat (2010)
Total Cost of Ownership (TCO) is key for making optimal replacement decisions

**Optimal replacement policy**

- Acquire only one vehicle type at every period
- Vehicle type decision criterion: total cost of ownership (TCO) of a vehicle

**Expected optimal total fleet cost at \( t=0 \)**

\[
G^0(f^0, B^0) = \sum_{t=0}^{T} (\rho)^t n^t \mathbb{E}_{\xi^t|g^0} \left[ \min \{ E^t, I^t \} \right]
\]

- Number of vehicles (EV+ICV) to be acquired
- TCO for an ICV
- TCO for an EV
- Fuel and battery price at \( t=0 \)

Total Cost of Ownership (TCO) for an EV:

\[
E^t = a_e^t + B^t + k_e \sum_{\tau=1}^{l} (\rho)^{\tau} c^{t+\tau},
\]

Total Cost of Ownership (TCO) for an ICV:

\[
I^t = a_i^t + k_i \sum_{\tau=1}^{l} (\rho)^{\tau} (f^t + \tau \mu_f).
\]

Note: Operational costs incurred by vehicles acquired before \( t=0 \) are not included in the expression since these are not affected by the decision making process.
Our results entail important strategic and planning implications for La Poste

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**Expected TCO* of ICV and EV**

**Probability of EV purchase**

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- Strategic choices related to the expected time of EV introduction at La Poste
- Low relative impact of the governmental subsidy on the value of an EV to La Poste
- Expected timeframe for the EV-integration into La Poste: 2014 - 2017

* TCO = Total Cost of Ownership
Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
Over 13% of fleet costs saved through the use of EVs throughout 20 years of fleet operation

The availability of EV as an alternative to ICV provides La Post with expected cost savings of 13.2%

The dynamic policy provides only limited savings of around 0.2% compared to the static policy

The EVPI is only 0.37 Mn. € showing that the dynamic policy is very close to the lower bound

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
How does the static policy perform under model risk?

**Motivation to follow Dynamic policy**

Reduced exposure to model risk, especially of the battery price learning rate, and the option to utilize recent uncertainty realizations.

**Motivation to follow Static policy**

Contractual commitment at the beginning of the decision horizon allows to reduce administrative expenses and achieve volume discounts leading to savings of $Q^0 = 10 \text{ Mn. } \text{€}$ for La Poste.

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
How does the static policy perform under model risk?

Evaluate the Expected Downside Risk (EDR) with $N=10,000$ trials:

$$EDR_{D,S}(\lambda, \tilde{\lambda}) = \frac{1}{N} \sum_i \min \left\{ \bar{\Gamma}^{0,i}_{D,S}(\lambda, \tilde{\lambda}), 0 \right\}.$$  

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
Over a broad range of learning rates, static policy is sufficiently close to dynamic policy.

Expected value of an EV is **greater** under static policy (with fixed savings) for: 0.018 ≤ ̃\(\lambda\) ≤ 0.102

Expected Downside Risk is **insignificant** for: ̃\(\lambda\) ≥ 0.035

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
Decision tool has been translated into software to support La Poste’s fleet renewal

The model allowed La Poste to test sensitivity to disruptive scenarios

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<th>Tested scenarios</th>
<th>Scenario outcome</th>
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<td>Subcontracting the rural delivery: Reduction of the mean distance and hence strong reduction of the number of vehicles due to the change of delivery management</td>
<td>Slight impact on the expected break-even: shifting it around 3 months into the future</td>
</tr>
<tr>
<td>Cancellation of one day of delivery from 6 days a week to 5 days</td>
<td>The shift of the expected break-even 9 months into the future</td>
</tr>
<tr>
<td>Innovation in ICV: reduction of fuel consumption with slight increase in price</td>
<td>The shift of the expected break-even 12 months into the future</td>
</tr>
<tr>
<td>Transfer of the taxes on gasoline consumption to the electricity consumption by the government</td>
<td>Significant impact shifting the expected break-even 21 months into the future</td>
</tr>
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Interaction between decision model development and La Poste’s pilot EV fleet

**Design of the Model**
- Run sensitivity analysis
- Update model parameters
- Test for disruptive scenarios
- Adjust decision support software

**Pilot project with 250 EVs**
- To provide accurate figures to justify the assumptions of the model
- To support strategic purchasing and operations decisions

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1) Understanding the structure of an EV purchase contract and conducting negotiations with Renault-Nissan

2) Enthusiastic acceptance by the postmen: easy to drive, strong acceleration, no noise, easy to connect to the electricity network and the general sense of having entered into a more sustainable world

3) Significant change for the first line management because of the fundamental change in the underlying economic model of fleet operations

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
10,000 EVs to be delivered to La Poste following the recommended static policy

EVs will be delivered over the following 4 years as proposed by the decision tool

Source: Press Statements
Greenovia: new business venture to promote more sustainable commercial transport in France

The modeling environment based on this research project provides the basic elements for related activities, also leveraging the know-how of thousands of postmen’s related to large fleets.

New business venture "Greenovia" launched in April 2011 at La Poste

Business Model

- Revenues are generated by consulting services and adjustments of the current decision support tool, employing 10 professional consultants
- Assisting other fleet operators in acquiring and operating EV fleets.
- Improving the efficiency and sustainability of urban transport operations for third parties

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)
Lessons learned and conclusions

The impact of low-carbon fleet operations

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<td>13% of fleet costs can be saved, further revenues from Greenovia</td>
<td>CO$_2$ emissions can be reduced by 30%</td>
<td>Enthusiastic response from La Poste employees</td>
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- OR modeling enabled credible simulation of disruptive scenarios and confirmed the viability of the decision to invest in EVs
- Key success factor for the project was the direct involvement of the client in the research team and the on-going interaction with the client’s steering committee
- La Poste is focusing on further revenue opportunities for the mail division including Urban Logistics