FLEET RENEWAL WITH ELECTRIC VEHICLES AT LA POSTE

Daniel H. Wagner Prize Finalist Presentation

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Outline

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

Source: Crew, Michael A. and Paul R. Kleindorfer (eds.), *Reinventing the Postal Sector in an Electronic Age*, Edward Elgar, Cheltenham, UK: 2011.

Small vans deliver 40% of mail volume nation-wide

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- 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 CO_2 emitted by La Poste's fleet
- Electric Vehicles (EVs) can reduce CO_2 emissions by 30%

Sustainable fleet initiative is aligned with La Poste’s sustainability agenda

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The impact of low-carbon fleet operations

Economic/Profit Impact	Environmental Impact	Social Impact
▪ Cost savings ▪ New profit opportunities in Urban Logistics ▪ Reduced risk and enhanced brand equity	▪ Reduced CO_2 emissions ▪ Reduced particles emissions ▪ Noise reduction ▪ Reduced level of ozone precursors	▪ Local and Global Reputation ▪ Employee motivation ▪ Increased legitimacy in dicussions with regulators and the public

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 purchase price
Stochastic operational costs	Deterministic operational costs
Low purchase price *	High purchase price **
High operational costs incl. maintenance	Low operational costs incl. maintenance
Source of local air pollution	Local image as a "green" vehicle
Subject to emissions regulations	Benefits from governmental subsidies

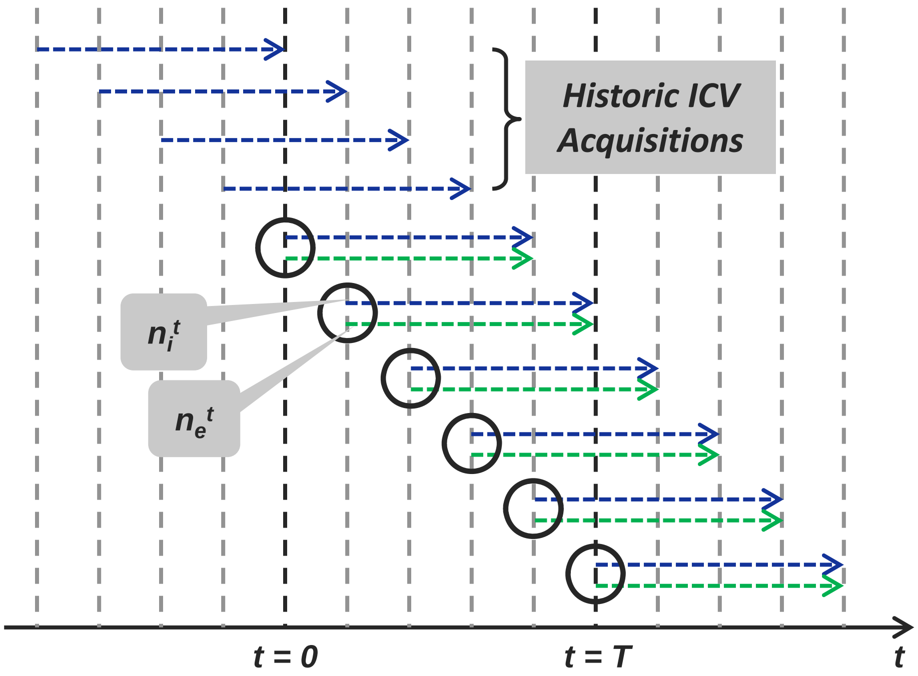
* The price of a Renault Kangoo (Diesel) is 21,000€

** 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

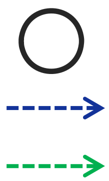


General assumptions

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

Stochastic processes

- Battery price $\mathbf{B^t}$: mean-reverting process;
- Fuel price $\mathbf{f^t}$: Brownian motion with drift;



Source: Kleindorfer et al (2012), Interfaces (Forthcoming)

The objective function minimizes expected total fleet cost

Objective function

$$G^t(f^t, B^t) = \min_{\substack{n_e^t \geq 0 \\ n_i^t \geq 0}} \Big\{ \overbrace{n_e^t(a_e^t + B^t) + n_i^t a_i^t}^{\text{Acquisition costs at } t} + \overbrace{\rho \cdot \mathop{\mathbb{E}}_{\xi^{t+1}|\xi^t} \left[s_e^{t+1} k_e e^{t+1} + s_i^{t+1} k_i f^{t+1} + G^{t+1}(f^{t+1}, B^{t+1}) \right]}^{\text{Expected future acquisition and operation costs}} \Big\}$$

Where s_e^t is the vehicle stock at time t :

$$s_e^{t+1} = \sum_{\tau=t-l+1}^{t} n_e^{\tau} \text{ and } s_i^{t+1} = \sum_{\tau=t-l+1}^{t} n_i^{\tau}$$

Decision variables

- Number of vehicles acquired $\boldsymbol{n_i^t}$ (ICV) and $\boldsymbol{n_e^t}$ (EV);

Model parameters

- Total cost of leasing and maintenance per vehicle: $\boldsymbol{a_e^t}$ (EV) and $\boldsymbol{a_i^t}$ (ICV)
- Vehicle demand $\boldsymbol{d^t}$
- Discount factor $\boldsymbol{\rho}$
- Consumption rate per period: $\boldsymbol{k_e}$ (EV) and $\boldsymbol{k_i}$ (ICV)
- Length of a leasing contract*: **l***

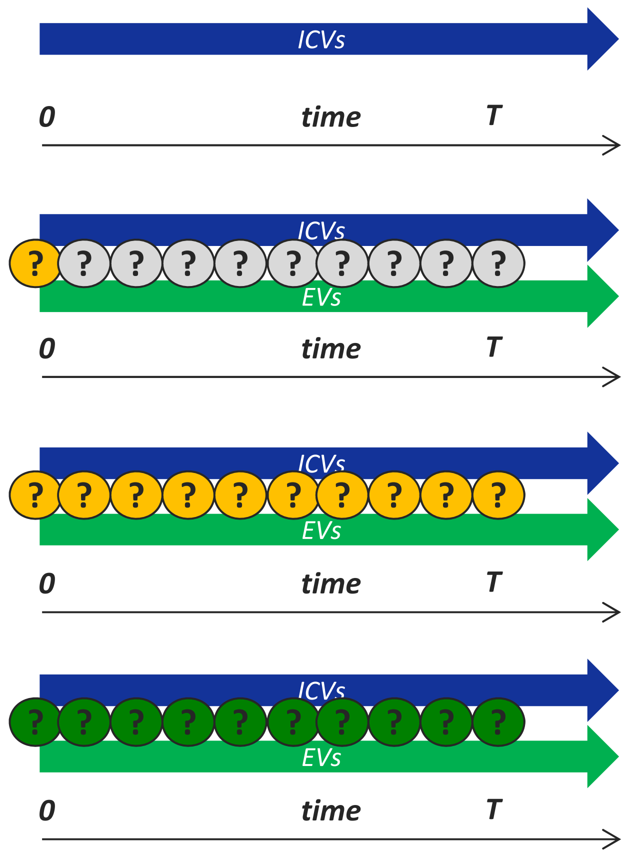
Stochastic processes

- Battery price $\boldsymbol{B^t}$ *:* mean-reverting process*;*
- Fuel price $\boldsymbol{f^t}$ *:* Brownian motion with drift;

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)

We analyze four distinct replacement policies in our model

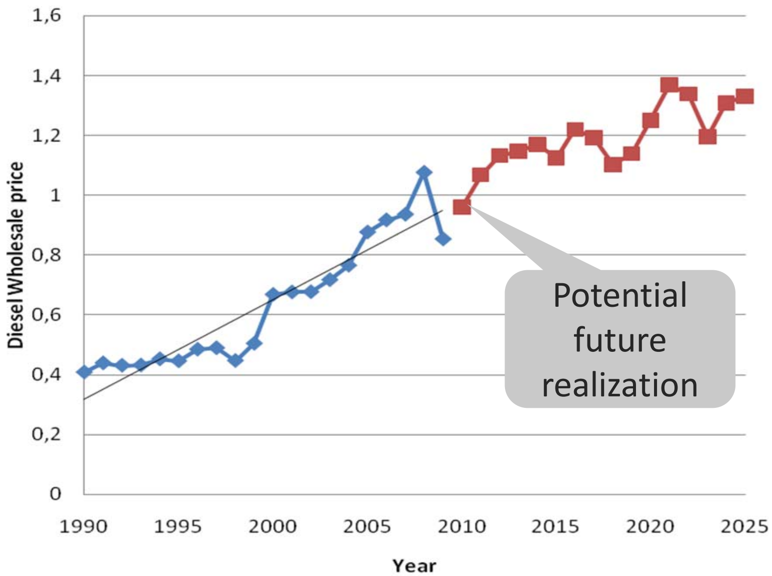
Policy	Interpretation	Implications
ICV-only policy	No EVs in the model	Business-as-usual scenario
Static policy	All decisions are executed in the **first period**	Reduced administrative efforts and potential benefits from volume discounts through pre-commitment
Dynamic policy	Decisions are updated **every period** based on recent uncertainty realizations	Full flexibility through the use of “option to wait”
Perfect Information policy	Decisions are based on **complete knowledge** of future uncertainty realizations	Estimate for the potential benefit through further market research on future price trends



Source: Kleindorfer et al (2012), Interfaces (Forthcoming)

We model fuel price as a Brownian motion with drift

Wholesale diesel price in France



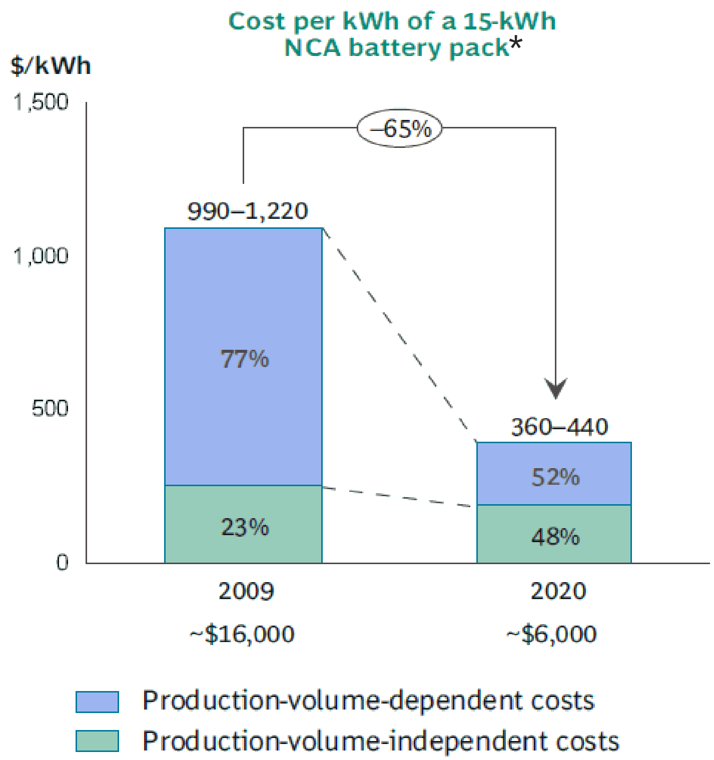
- Rise of the fuel price is expected to be significant (IEA, 2011 and Kleindorfer et. al, 2005);
- Drift rate and the volatility for f^t is based on historic data for the wholesale diesel price in France from 1999 to 2010 (Eurostat, 2010);
- Price jumps due to regulatory changes are not considered;

Discrete-time formulation

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

where $z \sim N(0,1)$, μ_f is the drift rate, σ_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

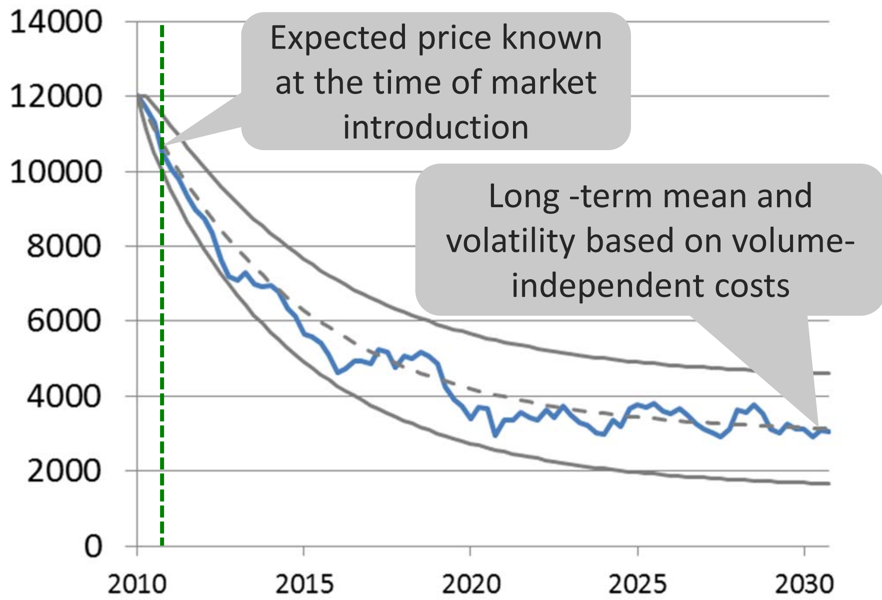
- Cost target of 250$/kWh by the US Advanced Battery Consortium until 2020 is unlikely to be achieved;
- Expected annual production volume of 1.1 Mn. battery packs in 2020;
- Volume-dependent production costs are expected to decrease significantly especially on the cell-production level;
- Volume-independent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

* NCA = Lithium-Nickel-Cobalt-Aluminium battery technology

Source: The Boston Consulting Group, 2009: “Batteries for Electric Cars: Challenges, Opportunities and the Outlook to 2020”

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

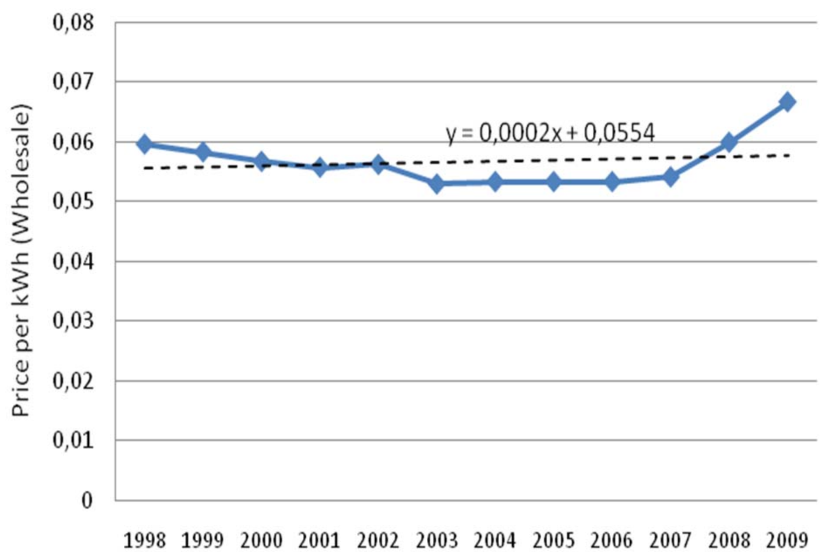
$$B^t = \mu_B(1 - exp(-\lambda)) + B^{t-1}exp(-\lambda) + \sigma_B\sqrt{\frac{1 - exp(-2\lambda)}{2\lambda}} \cdot z_B, \tag{2}$$

where $z_B \sim \mathcal{N}(0,1)$, σ_B is the standard deviation, λ is the learning rate and μ_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

Wholesale electricity price in France



- 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*

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

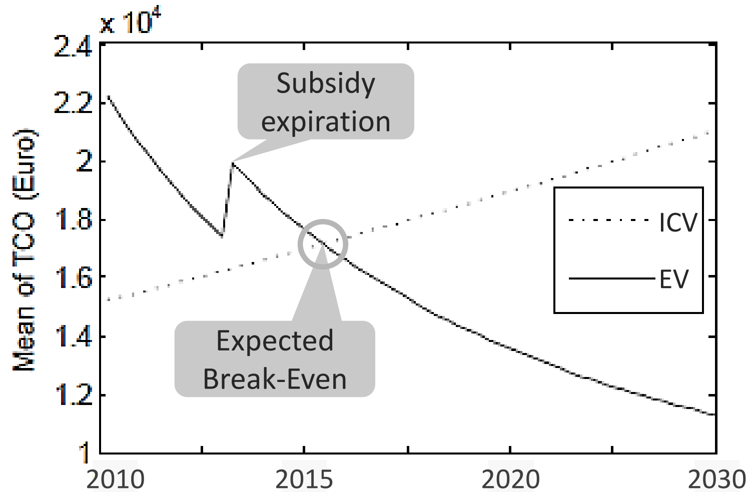
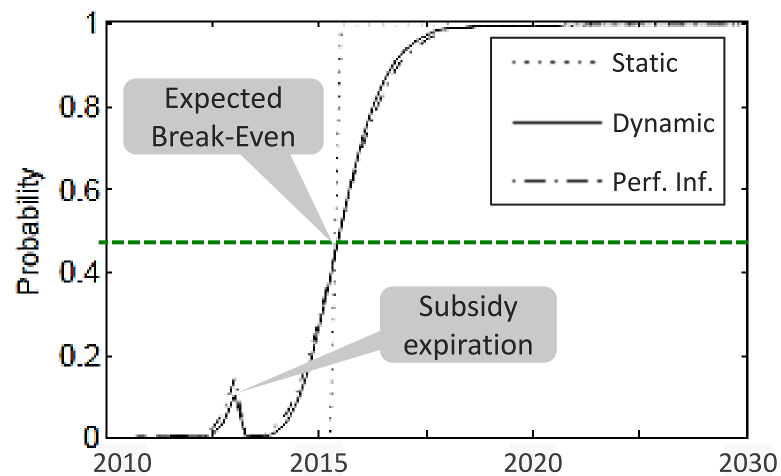
- n^t: Number of vehicles (EV+ICV) to be acquired
- I^t: TCO for an ICV
- E^t: TCO for an EV
- f^0, B^0: Fuel and battery price at ***t=0***

Total Cost of Ownership (TCO) for an EV: $E^t = a_e^t + B^t + k_e \sum_{\tau=1}^{l} (\rho)^\tau e^{t+\tau},$

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

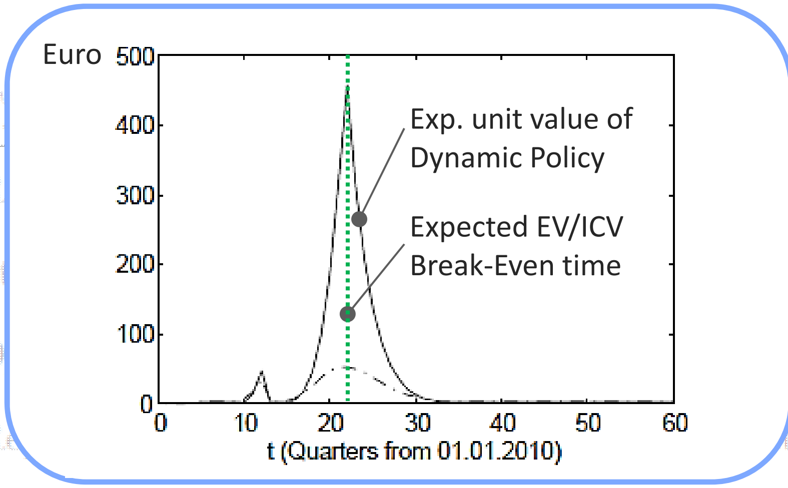
Our results entail important strategic and planning implications for La Poste

Expected TCO* of ICV and EV	Probability of EV purchase
	

- 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

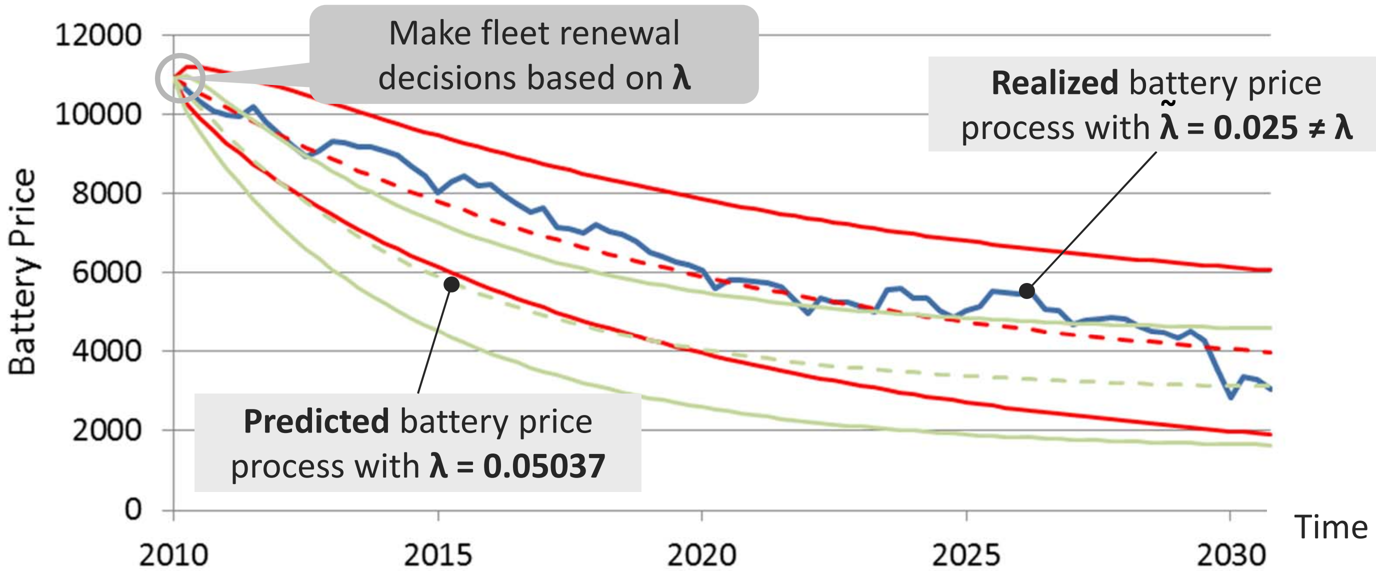


T...	Total cost (Mn. €)
R...	665.03
S...	578.71
D...	577.45
Re... ...t in... ...ation	577.08
Expected total value of EV under dynamic policy	87.58
Expected total value of the dynamic policy	1.26

- 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)

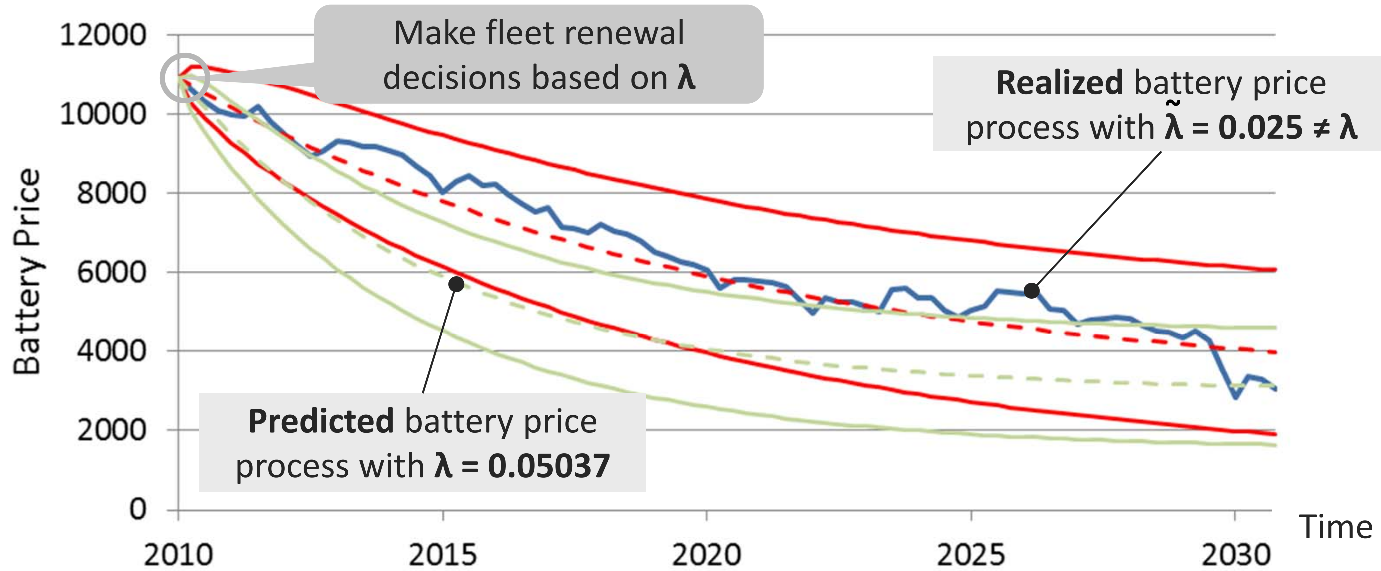
How does the static policy perform under model risk?



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 Mn. €*** for La Poste

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)

How does the static policy perform under model risk?



Modeling Risk with Monte-Carlo simulation

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

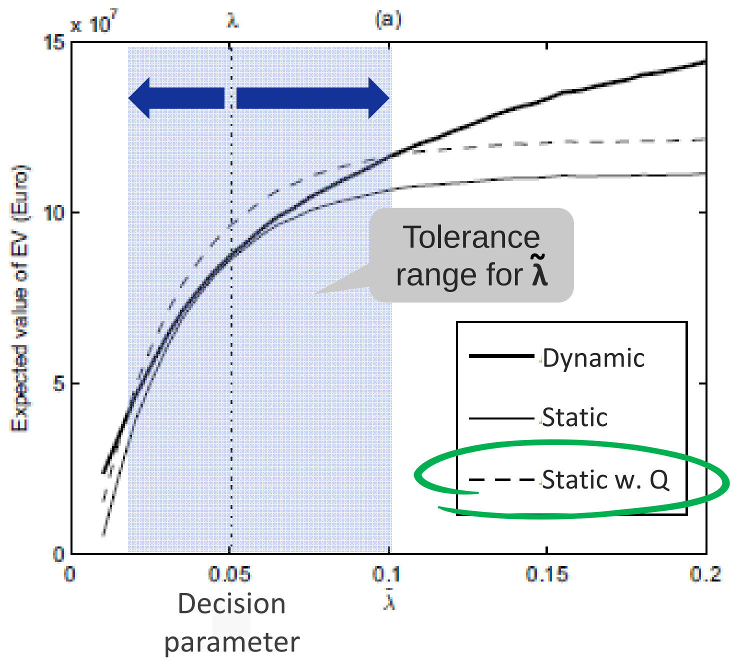
$$EDR_{D,S}(\lambda,\tilde{\lambda}) = \frac{1}{N}\sum_i \min\left\{\bar{\Gamma}^{0,i}_{D,S}(\lambda,\tilde{\lambda}),0\right\}.$$

Simulated realization of the EV value at t=0

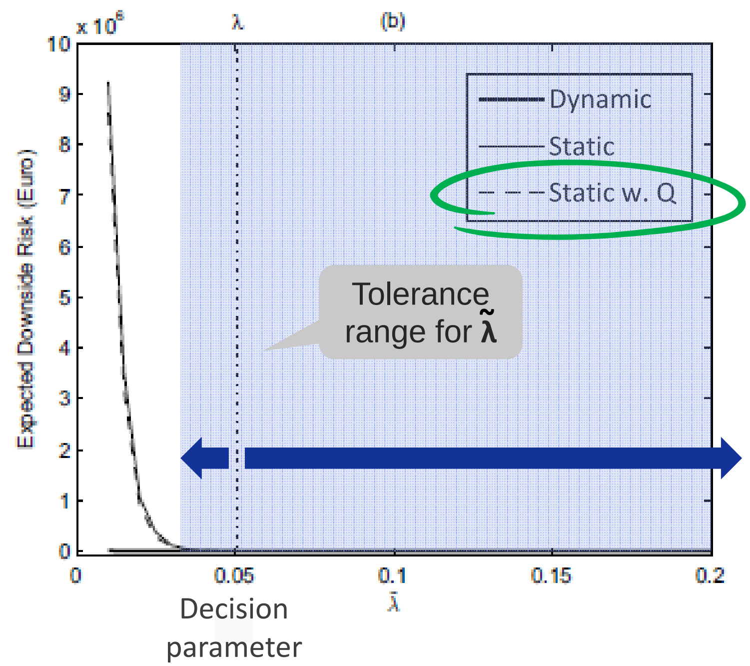
Source: Kleindorfer et al (2012), Interfaces (Forthcoming)

Over a broad range of learning rates, static policy is sufficiently close to dynamic policy

Expected EV Value



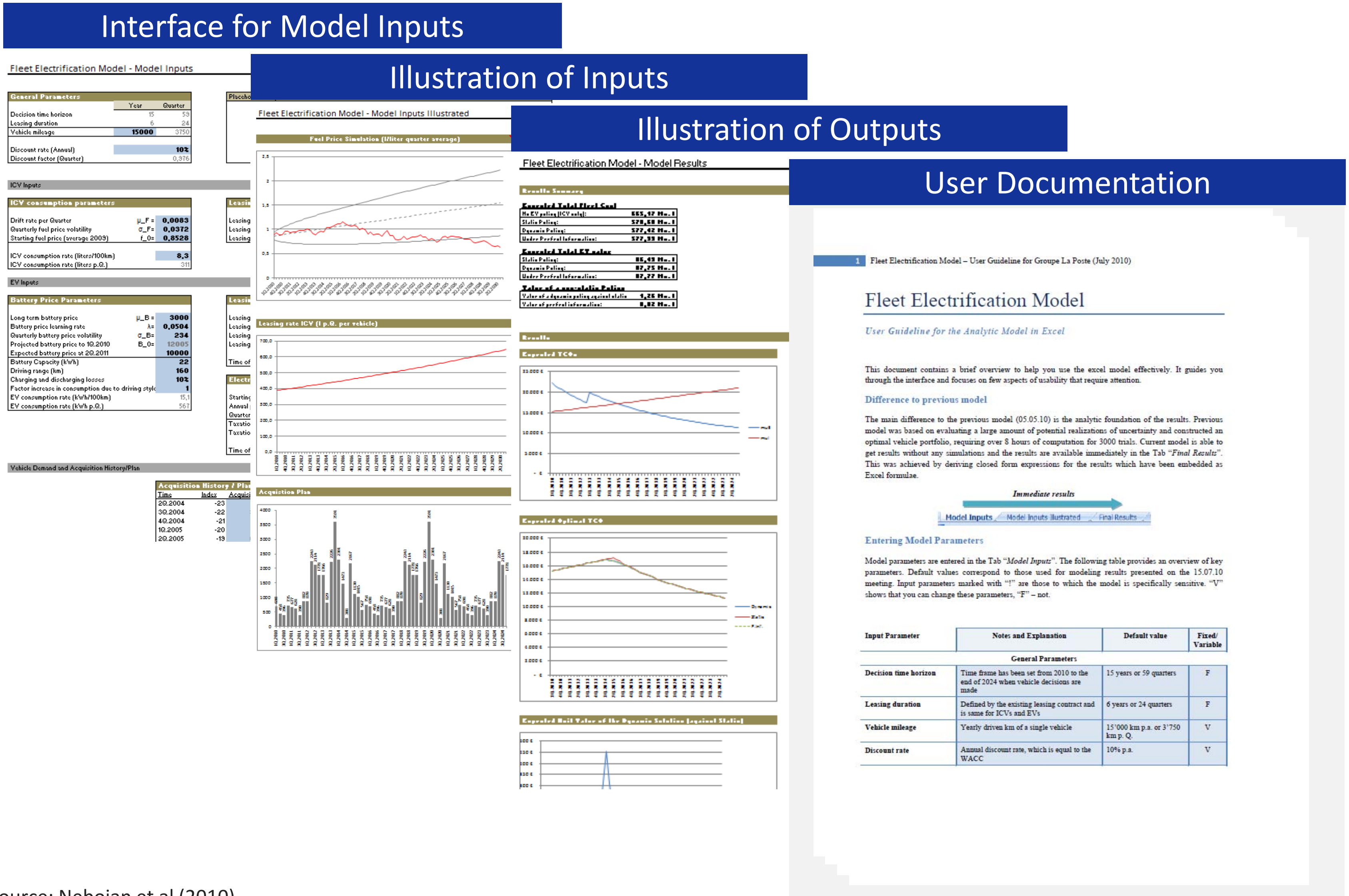
Expected Downside Risk (EDR)



- Expected value of an EV is **greater** under static policy (with fixed savings) for: **$0.018 \leq \tilde{\lambda} \leq 0.102$**
- Expected Downside Risk is **insignificant** for: **$\tilde{\lambda} \geq 0.035$**

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)

Decision tool has been translated into software to support La Poste's fleet renewal



Source: Neboian et al (2010)

The model allowed La Poste to test sensitivity to disruptive scenarios

Tested scenarios	Scenario outcome
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	Slight impact on the expected break-even: shifting it around **3 months** into the future
Cancellation of one day of delivery from 6 days a week to 5 days	The shift of the expected break-even **9 months** into the future
Innovation in ICV: reduction of fuel consumption with slight increase in price	The shift of the expected break-even **12 months** into the future
Transfer of the taxes on gasoline consumption to the electricity consumption by the government	Significant impact shifting the expected break-even **21 months** into the future

Source: Kleindorfer et al (2012), Interfaces (Forthcoming)

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

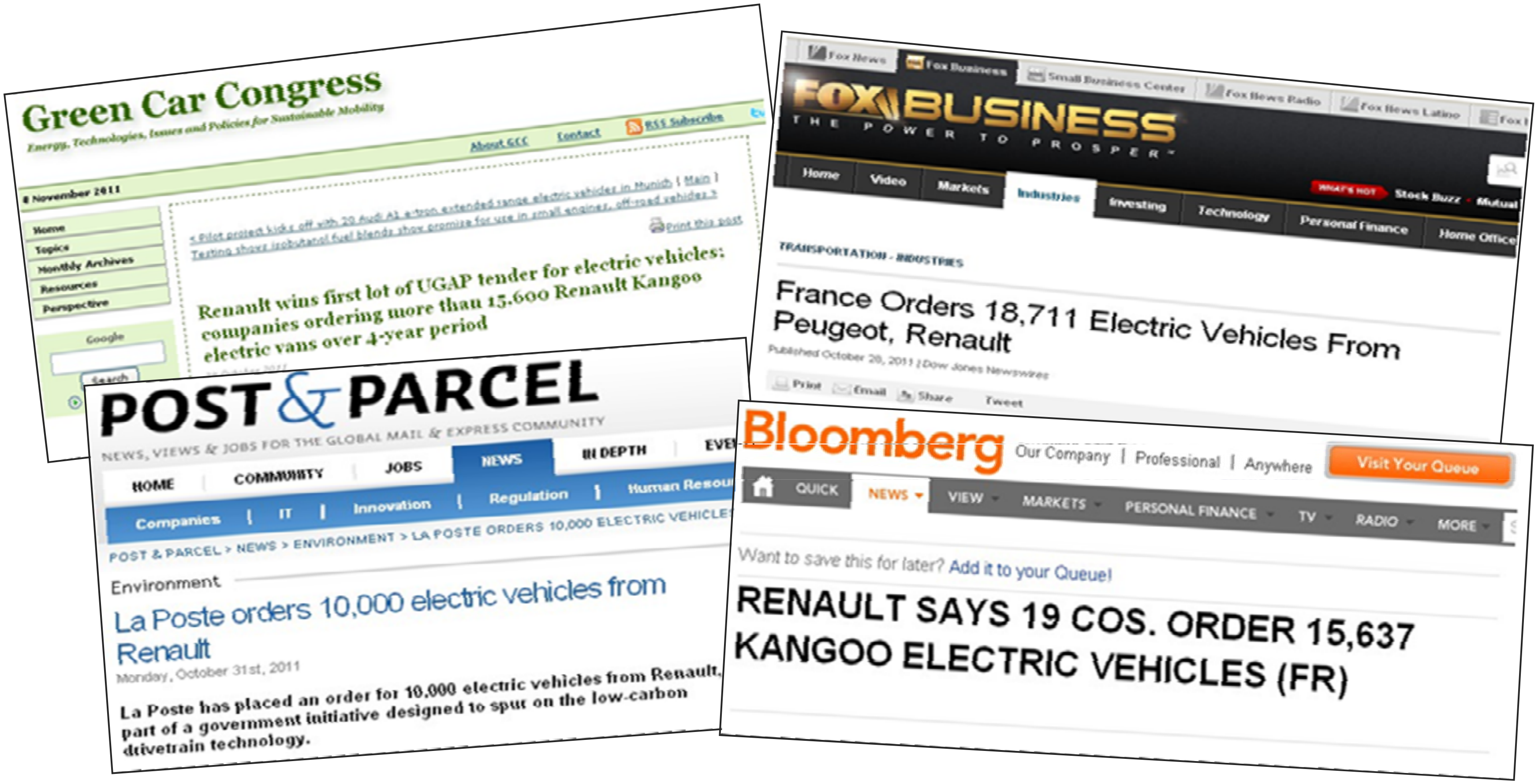
1) Understanding the structure of an EV purchase contract and conducting negotiations with Renault-Nissan

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

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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

Greenovia

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

Economic/Profit Impact	Environmental Impact	Social Impact
13% of fleet costs can be saved, further revenues from Greenovia	CO_2 emissions can be reduced by 30%	Enthusiastic response from La Poste employees

- 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