Challenges for electric vehicle fleet management and recharging

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[Webinar] Electric mobility and territories

April 8th, 2021
Introduction
Mixed fleet management
Shared Autonomous Electric Vehicles
Perspectives
Electric vehicles:
• No local pollutant emissions
• Lower noise pollution

However, the overall GHG-emissions will depend on the energy source used to produce the electricity for powering the vehicle (Casals, Martinez-Laserna, Amante Garca, & Nieto, 2016).
Motivation – Urban Electric Mobility

- **Technological advances**
  - Extended range
  - Cost-efficiency

- **However**
  - High initial cost
  - Still limited range
  - Time-consuming recharging

- **Need to utilize electric vehicles efficiently**
  - Tours considering the state of charge (SoC)
  - Stops for recharging
  - Decide on the charging amount
Mixed Fleet Management
Hybrid Heterogeneous Fleet

- **Different vehicle types with different properties**
  - acquisition costs,
  - transport capacities,
  - battery size,
  - energy consumption, ...

- **Different vehicle classes (ICEV, PHEV, BEV)**
  - each with different advantages and disadvantages
  - e.g., range and cost
Hybrid Heterogeneous Electric Vehicle Routing Problem with Time Windows and recharging stations

### 3 vehicle classes
- Internal Combustion Engine Vehicles (ICEV)
- Battery Electric Vehicles (BEV)
- Plug-in Hybrid Electric Vehicles (PHEV)

### Sub-types differing in
- transport capacity
- acquisition/utility cost
- battery capacity
- energy/fuel consumption rate

Routing a mix of conventional, plug-in hybrid, and electric vehicles
Methodology – Decision Layers

Assignment and Sequencing of customer visits

Sequencing of RS visits

- scheduling
- scheduling recharging
- scheduling recharging mode selection

ICEV

BEV
charged: 15 kWh

PHEV
charged: 12 kWh

hybrid genetic algorithm
dynamic programming/labelling
greedy extension policy
Fig. 6.1. Gap(%) of the solutions obtained with an homogeneous fleet of ICEV (left), BEV (middle), and PHEV (right), relative to the optimized solution with a mixed fleet.
Fleet Mixing Problem with ICEV, PHEV and BEV
Efficient Hybrid Genetic Algorithm
Highly competitive on other problem variants
Different fuel and energy price scenarios to observe their impact on the optimized fleet mix
The operational cost of the best mixed fleet can be 7% lower than the best homogeneous fleet with either ICEV, BEV or PHEV.
Existing approaches

- Congestion pricing (per-entry fee, time, distance)
  - E.g., in Singapore, London, Stockholm, ..

- Everybody can access alternative modes of transportation

- Traffic volumes may shift to public transport

What about logistic fleets?

- **Traffic volumes cannot shift to public transport**
  - deliveries into the city center by truck may not be avoidable
  - using EVs would be preferred by municipalities

- **Fleet managers optimize fleet operations for a given restriction scheme**
  - avoid fees when possible
  - Increased fleet utilization in the unrestricted area
  - use CVs only when cost efficient
Cities

City Center Access Restrictions:

- **Per entry:** Paid each time an ICEV enters the city center
- **Prohibited:** No ICEV allowed inside the city center (EVs can enter)
- **Per distance:** Depends on the distance traveled inside the city center
Results (Paris) – Example

(a) Unrestricted case

(b) Distance-based fee [€0.3/km]

Figure 3: Example of fee-induced detours with distance-based fee.
Fleet Composition

- Widely stable fleet composition, even with increasing fees
- The fleet composition changes at per entry fee > €10.0 and distance fee > €0.3 (break even point)
- The fleet composition equals the ‘ICEVs prohibited’ case

Customer Assignment

- When ECVs are used in the fleet composition
- They serve all customers inside,
- But also visit customers outside the city center to a large extent
Conclusions

- Fee-based restrictions can enforce the same solution as a complete ban of ICEVs from city centers.
- Event-based fee policies are more robust than volume-based policies.
- Besides reducing local emissions in city centers, access restrictions can help to reduce greenhouse gas emissions.
- The size of the city center greatly impacts the effectiveness of restriction policies.
Shared Autonomous Electric Vehicles
Shared Autonomous Electric Vehicles
Case Study

Real-world case study
Rouen Normandie metropolitan area

- about 500,000 inhabitants
- Recent transport survey (EMD 2017)
  - 5,059 Households
  - 11,107 Individuals (9,247)
  - 38,146 Trips
  - 30,342 Journey
  - 929 Activity Chains
  - 19 ones are common for 50%
  - 124 ones are common for 75%

SAEV (electric Robo-Taxi)

- 3000 standard 4-seats car
- Price: 0.4 € per kilometer
- Renault Zoe specification
- Battery capacities: 41 and 50 kWh
- Ridesharing
- No rebalancing
(a) MCLP

(b) P-Median
The performance of SAEVs is strongly correlated with the charging infrastructure

Increasing charger units (~4 vehicles per charging outlet) or deploying rapid charging increases system performance

Battery-swapping has a great impact on SAEV service effectiveness and efficiency

Recharging station locations have a significant effect on performance metrics
Perspectives
Research perspectives

- Exact approaches, heuristics, and reinforcement learning for SAEV dispatching and repositionning

- Considering the interaction of SAEV fleets and power grid
  - Techno-economic modeling and assessment of the potential for shared autonomous electric vehicles to provide power grid services
  - Resilience assessment of electric based autonomous mobility system and power distribution grid
Thank you!

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