Too much or not enough? Planning electric vehicle charging infrastructure: modeling options and perspectives

Electric Mobility and Territories
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Marc-Olivier METAIS, Jaafar BERRADA, Oualid JOUINI, Yannick PEREZ, Emilia SUOMALAINEN
Plan

1. Background on EV and charging infrastructure

2. Charging infrastructure and linked issues

3. Location methods

4. Conclusion
Plan

1. Background on EV and charging infrastructure
   1.1. Context
   1.2. Charging infrastructure framework

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1.1. Context

ICE Vehicle

~15% of global GHG emissions\(^1\)
~40% of French GHG emissions
Acoustic pollution

Electric vehicle

No tailpipe emission
Reduced particulate emissions
Reduced noise

Two main barriers for EV adoption\(^2\)

Price

Range anxiety

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\(^2\) Nigel Berkeley, David Jarvis, and Andrew Jones. Analysing the take up of battery electric vehicles: An investigation of barriers amongst drivers in the UK.
1.2. Charging infrastructure

- Charging infrastructure
  - Power grid
  - Transportation network
  - EV user
  - Home charging

 ≠ charging speed
 ≠ costs

 How to deploy a charging infrastructure?
Plan

1. Background on EV and charging infrastructure

2. Charging infrastructure and linked issues
   2.1. Charging infrastructure and EV acceptance
   2.2. Research areas and linked issues
   2.3. Infrastructure goals

3. Location methods

4. Conclusion
2.1. Charging infrastructure and EV acceptance

Vehicle range
~1000km for ICEVs
~300km for EVs

Refueling time
~10mn for ICEVs
~30mn-20h for EVs

Refueling availability
~60 000 gas pump (France)
~30 000 charging points (France)

Need for a suitable infrastructure in order to enable the democratisation of electric vehicles[3]

[4] Delacrétaz, Lanz, and Van Dijk. The chicken or the egg: Technology adoption and network infrastructure in the market for electric vehicles.
2.2. Research areas and linked issues

3 issues:
- Location issues
- Sizing issues
- Using issues

Technical
- Charging speed
  - slow, medium, fast
- Charging capacity
  - vehicles/unit of time simultaneous charging

Economic
- Electric grid
- Infrastructure cost
- Investments
- Return on investment
- Charging cost
- Land coverage
- Charging time
- Charging availability

User
- Range anxiety
- Total EV cost of utilisation
  - time cost
  - financial cost
2.3. Infrastructure goals

Two main categories

Minimize installation costs for a given demand\(^5\)
- Installation cost
- Operation cost
- Electric power cost
- Maximize charger utilisation

Maximize the service for a given budget\(^6\)
- Minimize the waiting time
- Minimize the deviation needed
- Maximize the number of EVs
- Maximize the amount of energy provided
- Maximize the distance that can be travelled
- Maximize feasible trips

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\(^5\) Xiaohong Dong, Yunfei Mu, Hongjie Jia, Jianzhong Wu, and Xiaodan Yu. Planning of Fast EV Charging Stations on a Round Freeway
\(^6\) Csiszár et al. Urban public charging station locating method for electric vehicles based on land use approach
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   3.1. Node based approach
   3.2. Path based approach
   3.3. Tour based approach
   3.4. Main points of comparison

4. Conclusion
3.1. Node-based approach

**Covering model**
- A set of potential locations
- A set of demand points to satisfy
- Goal: minimise installation costs and distances to load points

- **SCLM**\(^7\)
  Minimize the number of facilities while covering all the demand

- **MCLM**\(^8\)
  Maximize the number of location covered for a given number of stations

- **p-median**\(^9\)
  Minimize the distance between demand and stations for a given number of stations

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\(^7\) Ying Wei Wang and Chuan Ren Wang. Locating passenger vehicle refueling stations.

\(^8\) Frade, Ribeiro, Gonçalves, and António Antunes. Optimal location of charging stations for electric vehicles in a neighborhood in Lisbon, Portugal.

\(^9\) Jia et al. A novel approach for urban electric vehicle charging facility planning considering combination of slow and fast charging.
3.2. Path-based approach

Flow-capturing model
- A set of potential locations
- Measurement of vehicle flows at locations
- Goal: minimise installation costs and capture the maximum amount of flow

FCLM\textsuperscript{[10]}
Maximize the amount of vehicles passing in front of stations

FRLM\textsuperscript{[11]}
Takes into account the limited range of vehicles

\textsuperscript{[10]} He et al. An optimal charging station location model with the consideration of electric vehicle's driving range.
\textsuperscript{[11]} Michael Kuby and Seow Lim. The flow-refueling location problem for alternative-fuel vehicles.
3.3. Tour-based approach

Event capture problem
- A set of potential locations
- Vehicle activity data recovery
- Goal: locating stations where the load opportunities are the greatest, without any additional constraints for users.

Real-data based
- Hard to collect
- More realistic

Multi-agent simulation based
- Easier access to data and results
3.4. Main points of comparison

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<thead>
<tr>
<th></th>
<th>Node-based</th>
<th>Path-based</th>
<th>Tour-based</th>
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<tbody>
<tr>
<td>Urban territory</td>
<td>+</td>
<td>- -</td>
<td>++</td>
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<td>Highways</td>
<td>-</td>
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<td>Charging need representation</td>
<td>- / +</td>
<td>+</td>
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<tr>
<td>User behaviour</td>
<td>-</td>
<td>- / +</td>
<td>++</td>
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<tr>
<td>Data requirement</td>
<td>Very low</td>
<td>Low</td>
<td>Very high</td>
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**EVs and charging infrastructure**
- EVs and charging infrastructure form a two-sided market
- The first step toward a transition from ICE to EVs have to come from the public infrastructure side

**Three main location methods in the literature**
- Node-based
- Path-based
- Tour based

**Charging infrastructure planning**
- Must be over time
- Must take into account the previous infrastructure