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# Planning EV Charging Infrastructures : A Literature Review

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## Abstract

This paper summarizes the existing work on implementation models of charging stations. It aims to draw up a comparative overview of the approaches that have been used until 2020 to simulate and assess the impacts of location strategies of charging infrastructure. In particular, three categories of approaches are identified. Then, we analysed, for each approach, both technical and economic factors, in order to provide a complete analysis to stakeholders involved in EV charging infrastructure design and planning. Finally, a list of recommendation for future research works are provided in order to develop models that are closer to reality.

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*Keywords: Electric Vehicle, Charging Infrastructure, Optimization*

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## 1. Introduction

Electric Vehicles (EVs) have been gaining importance in recent years, and this trend is to be accelerated as EVs are seen as one of the solutions in order to reduce the transport sector's GHG emissions, which represents about 15% of global GHG emissions (IPCC, 2014). However, the adoption of EVs at a large scale is not possible without prior appropriate charging infrastructure (France Strategie, 2019; International Energy Agency, 2019). Due to the high cost of this infrastructure, the deployment must be made with a proper strategy, with the aim to obtain an efficient repartition of the charging stations which allows a large majority to adopt EVs, while avoiding a waste of resources with useless charging stations or grid reinforcement (Cai et al., 2014).

The paper reviews the models developed so far, with the aim to explore their findings and to assess their limitations. The reviewed models fall into three main categories having three distinguished approaches: node based, path-based and tour-based approaches. In the rest of this paper, we describe these three approaches and discuss their strengths, limits. Finally, some directions for further research works are proposed.

## 2. Simulation models description and comparison

Three main approaches for locating charging infrastructures are identified:

The most used approach is the **node-based approach**. It locates charging points in order to satisfy at each instant the overall demand of the territory. It is based on solving a maximum coverage location problem (Syvia et al., 2016). This approach is accurate when points of interest are known (for instance, residential zones where EV users need to have a charging station close to their home). Based then mainly on GIS data, node-based approach requires few data. However, it does not always leads to the best coverage with the minimal cost (Upchurch, Kuby 2010).

The **path-based approach**, is a flow-capturing model. It aims to locate stations along routes with higher flows (Wu, Sioshansi, 2017). This approach is based on vehicle paths given their origin-destination (OD). Therefore, OD locations are aggregated into larger zones that group OD-trips with nearly the same path, since data required concern the path from origin to destination and not the origin and destination points (Xi, Sioshansi, Marano, 2013). But because the charging stations are placed on paths between those two points, the charging process requires making a stop specifically for charging, which adds the charging time to the trip. As a result, this approach is more adapted for fast-charging stations, the use of which is similar to that of a conventional gas station, but not for slow-charging, which can take several hours (Sun, Gao, Li, Wang, 2018).

The **tour-based approach** is more likely to reflect the real charging needs of EV users, by taking into account the whole journeys of EVs. However, this approach requires detailed individual travel data and high computing capacity (Andrew et al, 2013). Combined with agent-based modelling of EV users, it could lead to a more accurate location of charging stations, since it enables

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to simulate the sequence of trips instead of an aggregation of each one as it is the more frequently done in the literature (Cavadas et al., 2015). With this method, an efficient charging “at destination” can be made.

### 3. Discussion and limits

In all these three approaches, the user behaviour is rarely modelled. In particular, the sensitivity to waiting time for charging, because of queuing at station, the sensitivity to fare, or the sensitivity to access distance are critical to assess the performance and economic relevance of locating a charging station. Hence, introducing a queuing model to consider users behaviour should provide more realistic results. The user’s charging choice is also dependent on the type of area (urban, or rural). In urban areas, for instance, public charging could be perceived as a back-up solution for home charging, which is always available, or a solution to make longer distances with EVs. On the other hand, when collective housings are not equipped with private parking slots, home charging is not possible, and developing an infrastructure without taking this in account can be an obstacle to the large-scale adoption of EVs in cities.

In addition, most of existing studies focus on only one type of approach, since each one has its specific application domain and is not suitable to all cases. In an urban and semi-urban environment, each zone has its most appropriate method, depending on this zone activities and characteristics which will lead to more accurate results. In order to study large territories where urban, peri-urban and/ or rural areas are in interaction, it is then required to propose a hybrid model that includes specificities of each zone.

Another limit of existing models concerns the absence of temporal effect to simulate the deployment evolution over time and to assess long-term impacts of such investment in charging infrastructure. In particular, deploying a charging infrastructure is not instantaneous in reality and can take several years. In order to support the fastest possible transition from internal combustion engine vehicles to EVs, the charging infrastructure cannot wait to be fully deployed to be really useful. Otherwise the democratization of the EVs and so the deployment could be slowed down, as soon as the EV and infrastructure markets are two-sided markets: users would not buy EVs if there is no convenient infrastructure, and operators would not install charging infrastructure if users do not have EVs (Yu, Li, Tong, 2016).

Finally, the electricity grid capacity is systematically taken as a constraint as soon as the cost of a grid reinforcement is considered to be too expensive. However, the French law about mobility stipulates that the connexion cost is covered up to 75% by the distribution system operator (DSO) (Loi n° 2019-1428). This significantly reduces the cost of such a reinforcement for the charging station operator.

### 4. Conclusion

Many works have been undertaken in order to deploy an efficient charging infrastructure, which is a necessary prerequisite to such a democratization, and three main approaches are used: node, flow and tour-based approach. However, we found that those approaches are rarely put together, and a model closer to reality, which includes EV users behavior, territories specificities, temporal effects, and grid constraints as well, should be developed in order to support EVs diffusion and help stakeholders to make strategic decisions.

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