Electric Vehicles and Hierarchical Optimization Models: The Charging Facility Location Problem

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Keywords : *Electric Vehicles, Facility Location, Hierarchical Optimization, Taxonomy.*

1 Introduction

The adoption of electric vehicles is one of the main alternatives to tackle global warming; however, it is necessary to have the charging infrastructure available to meet the demand. This work is concerned with the *charging facility location problem* that aims to locate the charging facilities. Current power grid infrastructure might suffer from a lack of capacity, and the inclusion of renewable generation is an important alternative to overcome this issue. Moreover, demand response programs (DRPs) play an important role in order to leverage the flexibility EV owners have in charging [1].

2 The charging facility location problem

2.1 Charging paradigms

There are different charging modes or *charging paradigms*, describing how the connection between the vehicle and the power grid is made. There exist two possible ways to supply the energy depending on whether the vehicle should park or not. Thus, with respect to the action of driving or movement, the charging process is either *static* or *dynamic*, often called park-and-charge and charging-while-driving, respectively. Clearly, considering both paradigms is also possible, leading to *hybrid* charging.

2.2 Planning perspectives and formulation approaches

Three different planning perspectives exist in the literature regarding the planning goal along with the road choice modeling [4]: i) demand coverage, ii) flow-capturing, and iii) traffic.

Demand coverage. The goal is to represent how charging facilities are located to attract incoming vehicles. As network modeling is the approach for this kind of problem, the formulation relies on either node-based or flow-based demand. In this particular context, these two formulations reflect the focus of the decision-makers. Respectively, the difference relies on whether the demand is stable (node-based) or variable (flow-based).

Flow-capturing. This approach aims to serve the vehicles on the roads [3]. This research has a large literature considering the several characteristics of driving and charging behavior.

Traffic. An alternative approach focuses on the driving patterns, where road choices are made to travel from an origin-destination pair, and it is proposed from the perspective of the vehicle drivers.

Demand coverage and flow-capturing perspectives have a close relationship, since the latter is in essence a flow-based demand coverage approach proposed in the seminal work of Kuby and Lim [2]. Moreover, these two perspectives are often understood as the decision-makers' goal being a pure strategic approach; more precisely, the impact of the driving behavior is not taken into account. Conversely, the traffic perspective aims to deal with this pitfall by explicitly including the influence of the charging facility locations on the road choice.

2.3 Taxonomy

The charging facility location problem has multiple characteristics that must be properly considered. Although the literature is rich, there have been no attempts at consolidating the existing models. To this end, we propose a taxonomy to consolidate the models, such that the most important elements involved in the study can be easily acknowledged. Particularly, this taxonomy focuses on exposing the planning perspectives as well as the charging paradigms, along with the peculiarities of the phenomenon under study. It leverages the definitions given above such that the complexity of each problem is inherently exposed.

3 Conclusion

Advocating a taxonomy is vital for organizing the charging facility location problem related literature, harmonizing planning perspectives and electric vehicle charging paradigms. The taxonomy categorizes elements systematically for consistent consideration in future research, enhancing cohesion. It enables efficient comparisons in computational studies, advancing collective understanding. This approach seeks to establish a foundational framework, encouraging nuanced exploration of different aspects of the charging facility location problem. Notably, the proposal's flexibility allows for the inclusion of elements gaining importance in the future.

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