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Determination of charging infrastructure location for electric vehicles

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Abstract

The deployment of charging infrastructure is the prerequisite for the spread of electric vehicles. A well-established charging network increases vehicle miles using electricity, relieves range anxiety and reduces inconvenience concerning charging process. The research question was, where to install the charging stations to facilitate the long-distance travels and to meet the urban (local) demands considering both the existing stations and the installations are to be realized by legal regulations. We have elaborated weighted multi-criteria methods for both the national roads and the counties or districts. Several demographic, economic, environmental and transportation-related attributes, as well as the available services (points of interests) that influence the potential for charging station use, have been identified and their effects have been revealed in system approach. On the national roads point-oriented assessment, whereas in urban environment territorial unit-oriented assessments have been applied. On the national roads, the existing rest-places as prospective charging stations have been investigated. The strategic points (nearby border stations and capital city) as mandatory charging stations have been also designated. The methods have been applied to Hungary (on the level of national roads) and to Újbuda (11^{th} district of Budapest, on urban level).

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Keywords: electric vehicle; charging infrastructure; long-distance travel, local demand, multicriteria method

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1. Introduction

In recent years, many European countries made efforts to raise the rate of battery electric vehicle (BEV) use. Financial subsidies can efficiently contribute to this aim, but it is of utmost importance to provide public electric charging network too. The main problem is that the refueling process of a charging vehicle extremely differs from a conventional vehicle. The charging time of a BEV is several times more than the refueling time of a conventional one and the drivers would not give up the comfort of a fast-refueling process. Furthermore, in the absence of mass market, the return of a charging station installation is not guaranteed. Hence, the key to success is to seamlessly suit the charging process to the current travel behavior and adjust the location of charging station to the charging demand. In this paper, the following questions were addressed:

- What are the main charging demand types?
- What are the main variables that influence the charging demand?
- How can the sites of charging stations be derived from the charging demand?

Therefore, we determine the charging demand types and the main variables, such as travel behavior and electric vehicle (EV) characteristics, and how they influence the charging demand or the quality of time spent with charging. We develop two charging station location methods based on the variables and make a proposal for chargers at locations. The first users and beneficiaries of the methods should be the governments because we cannot expect the charging infrastructure developments to take place on a market basis in the early stage. The structure of the paper is the following: after a brief literature review in Section 2, we present the charging deployment method for long journeys and urban areas in Section 3. The application of the methods is provided in Section 4. Finally, the conclusion has been drawn.

2. Literature review

Since a well-established charging station network is a key element of the spread of EVs, several studies focus on charging infrastructure development. There are two main viewpoints in charging infrastructure planning: energy network and travelers. From the traveler viewpoint, studies derive the charging station locations from travel behavior. We further categorized these studies into two groups: inter-city and intra-city charging infrastructure development. The general approaches of these groups are also different. Inter-city charging infrastructure developments usually use a flow-based approach (Hodgson, 1990), while intra-city developments use a node-based approach (Hakimi, 1964); however, there are exceptions as well. The reason for the difference is that the range of BEVs is enough for short trips in the metropolitan area, but not enough for a long trip. Thus, charging demand in the urban area occurs at the origin or at the destination of the trip, while inter-city charging demand arises during the trip. Node-based approaches assume point demands, which are specific for intra-city charging demands, while flow-based models assume that the demands are given as origin–destination (O–D) flows and the aim is to serve as many O-D flows as possible. Hence, flow-based models are better suited to tackle charging station optimization at the state scale (Upchurch and Kuby, 2010).

The base of papers dealing with inter-city charging demands is a flow-based or also known as flow capturing location model (FCLM); however, the application of the models and the set of variables may differ. Sathaye and Kelley (2013) determine the locations of charging stations mainly considering the characteristics of traffic flows. In addition, the demographics were also taken into account. Tan and Lin (2014) provide a stochastic FCLM that takes into account the stochastic user demands along the routes as well as the installation cost and the service quality of a charging station. However, the sole use of stochastic model provides a lower service coverage rate than the deterministic model, because of the statistical fluctuation. Lin and Hua (2015) provide a particle swarm optimization model based on FCLM for establishing an optimal selection of charging station location. The optimization is performed according to the installation cost, the service area of a charging station and volume of traffic flow. Kuby and Lim (2005) adjust FCLM to alternative-fuel vehicles to determine the optimal location of refueling facilities. The FCLM was extended with a refueling-logic, where a flow is captured only if the vehicle never runs out of fuel. The location of fuel stations depends on the vehicle range, the arc length, and the node spacing of the transportation network. Later they extend the flow refueling location model by adding candidate sites along the arcs (Kuby and Lim, 2007) and propose efficient heuristic algorithms for siting fuel stations (Lim and Kuby, 2010). Davidov and Pantoš (2017) also determine the candidate sites and driving routes, then use a discrete set modeling approach to reduce the complexity of location modeling.