SELECTING OPTIMAL LOCATIONS OF PUBLIC CHARGING STATIONS FOR ELECTRIC VEHICLES USING THE BIG DATA OF DRIVING BEHAVIORS: A CASE STUDY OF SEOUL, KOREA

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Overview

As environmental concerns on global warming have increased, reducing greenhouse gas (GHG) emissions has been recognized as one of the major duties for sustainable development around the world. Especially, in the transportation sector, which contributes to a significant portion of GHG emissions, electric vehicles (EVs) are receiving much spotlight as an effective alternative to conventional internal combustion engine vehicles (ICEVs). In this trend, many countries are implementing various policies for EV penetration in their countries. Until now, however, EV has a shorter operation distance than ICEVs when fully charged due to its limitation in battery capacity. Also, many kinds of literature show that consumers' EV preference is greatly affected by charging station accessibility. It implies that stable charging infrastructures are necessary for successful EV diffusion. Meanwhile, in big cities such as Seoul of Korea, where population density is much higher than other cities, public EV charging stations should be properly located because it is difficult to install private EV chargers in the household. Furthermore, charging demand for EV drivers can be different depending on their driving behavioural factors, such as the purpose of driving and driving routes.

The purpose of this study is to estimate EV charging demand considering drivers' behaviors and to select optimal locations of public charging stations to maximize demand coverage using optimization models. A case study in Seoul, Korea is presented and the optimal locations derived by our model and locations of currently installed charging stations in Seoul are compared from the viewpoint of demand coverage and economic perspective.

Methods

In this paper, the potential EV charging demand is generated based on the big data of driver's origin-destination (OD) in Seoul, which was extracted from the 2018 report of Korean Ministry of Land, Infrastructure, and Transport. The data represents the amount of vehicle movement for each purpose from a particular origin to a particular destination during the day. The OD points are used as the indicators of demand points. EV charging demand amount for each demand point is estimated through the function of driver's driving range and EV penetration rate.

There are two types of EV charger; fast charger, which takes 30 ~ 40 minutes to be fully charged, and slow charger, which takes 5~6 hours to be fully charged. The demand for each charger will be different by driver's behaviour. We assume that if driver uses EV for commuting, he will use slow charger, since car will be parked nearby his workplace or home for a relatively long time. For any other purpose, we assume that he will use fast charger. We can estimate the potential EV charging demand for each type of charger in each point through the procedure.

Based on the potential demand of EV charging in each demand point, set covering model and p-median model is used to find the optimal locations of public charging stations. The potential charging station candidates are selected from public car parks. Each charging station can contain several slow chargers, and fast chargers.

The analytic procedure is mainly referred to He et al. (2016). We find the minimum number of optimal locations to fully cover demands from set covering model, combined with cost minimization model.

Results

The potential EV charging demand for each demand point is estimated. The ratio of slow charging demand and fast charging demand was quite differed region by region. Especially, the demand for slow charging is significantly high in residential areas work areas, whereas fast charging is needed a lot in commercial areas.

The optimal number and locations of EV charging stations are selected from the candidates through optimization models. In order to assess the optimality of locations, number of covered demand points, amount of covered demand, and average distance between charging stations and demand points are calculated. The set covering model and cost minimization model is combined to figure out the optimal installation of slow and fast chargers.

Conclusions

In the study, a case study of selecting optimal public EV charging stations in Seoul, Korea is presented. By using OD data, the potential EV demand is generated realistically. The optimal locations of public charging stations and the number of each type of charger in Seoul are revealed. Sensitivity analysis and comparison analysis is conducted to verify the validity of the optimal locations which are suggested by our model. Since governmental policies to establish stable charging infrastructures should consider to locate charging stations satisfying EV user's demand, the research on optimal locations will need to be carried out continuously. In a further study, more realistic EV charging demand considering time preference can be measured. Also, more various optimization models can be applied to solve the optimal location problem.

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