Impact of Vehicle Automation on Electric Vehicle Charging Infrastructure Siting and Energy Demand

Avi Chaim Mersky and Constantine Samaras

A major cost associated with widespread deployment of electric vehicles (EVs) is deploying the necessary public recharging infrastructure. Public charging stations are expensive and can have low charging utilization rates when cars remain parked in spaces long after charging is complete. Level 4 vehicle automation enables an increase in utilization and may give more control over timing and location of charging demand than traditional vehicles allow. Mersky and Samaras investigate these potential effects by analyzing the following research question: What are the potential EV charging infrastructure efficiencies and associated energy and environmental impacts of level 4 and level 5 vehicle automation?

This paper develops an optimization model to understand how EV charger placement, utilization, and costs are affected by different levels of vehicle automation. This paper uses Seattle, WA as a case study, and uses the Puget Sound 2014 Household Travel Survey dataset. The model minimizes costs for charging station owners as well as the drivers using the charging stations. Owner costs are defined as real estate costs for parking spaces, charging equipment capital costs, and charging equipment maintenance costs. Driver costs are defined as either the costs of walking when using level 0 through level 4 automated vehicles, or the costs of additional vehicle operation when using fully autonomous level 5 vehicles, including energy and depreciation.

This paper builds off of prior mixed linear optimization work in the literature and expands upon those models to capture joint driver-owner cost minimization and the possible effects of vehicle automation on owner and driver costs. This paper is focused on building a modular optimization model, and further expands on prior work by estimating charging station owner cost in terms of a real estate component, based on assessed unimproved real estate values and the average cost to install one charging station. In this paper's model, each charging space has a limited capacity and multiple spaces can be placed in each location. This paper uses the owner cost as a component of the objective function to find the socially optimal amount and distribution of investment. This paper also uses trip distance, time, and assigned parking data to calculate the temporal changes in electricity demand caused by vehicle charging.

For the models with level 4 and level 5 automation, demand is served in terms of miles, rather than trips, to account for the ability of vehicles to queue themselves for charging without human intervention. For level 5 automation, the maximum access cost constraint is removed and cost is redefined as a function relating distance from parking to destination to the costs of energy consumption and vehicle depreciation needed to travel to and from a charging station.

The results suggest highly automated vehicle technology used in privately owned EVs could reduce the number of charging stations necessary and the cost of deployment. The optimal numbers of chargers in this case study, for level 0 to 3, level 4, and level 5 automation are 1,900, 680, and 331 chargers, respectively. This leads to each charger covering an average of 1.2, 3.5, and 7.4 trips, with 4.4 percent, 13, and 27 percent of the 13 hours from 6 a.m. to 6 p.m. spent charging vehicles. The annualized equipment and parking costs for these scenarios for levels 0 to 3, level 4, and level 5 automation are $1.75 million, $932,000, and $436,000, respectively, while the total driver and owner costs are $1.75 million, $937,000, and $540,000, respectively. Under level 0 to 3 automation, demand peaks with arrival times, between 7 a.m. and 9 a.m., with demand at just over 2,000 kWh between 8 a.m. and 9 a.m. The pattern under level 4 automation is similar, except that the 7 a.m. to 9 p.m. peak is just under 1,500 kWh, reducing about one-fourth of the peak demand. Under level 5 automation, electricity demand stays steady at just under 700 kWh until 4 p.m., when it starts decreasing. This represents about a 25 percent decrease of the peak electrical demand under level 4 automation and a decrease of about 65 percent under level 5 automation, when compared to no automation. In a transition to an electrified light-duty vehicle fleet, vehicle automation can potentially reduce the cost of deploying recharging infrastructure and the hourly peak electricity demand associated with uncontrolled vehicle recharging.