Utilization of Dedicated Electric Vehicle Plug-In Charging Stations in a College Campus Environment

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ABSTRACT
As electric mobility is expanding at a rapid pace, the standardized availability of gas stations compared to a scarcity of charging stations continues to be the greatest challenge for electric vehicles. With cities, university campuses and businesses promoting electric vehicle infrastructure and incentives, it is necessary to develop key performance metrics and visualizations that can track the utilization of the charging infrastructure. This study performs a manual data collection at dedicated plug-in charging stations across Purdue University to assess their utilization. Approximately 2,800 observations were conducted over 50 days across seven level 2 plug-in charging stations. Results showed that for large portion of the observations, vehicles were parked at the spots (40%) but not plugged in. Vehicles plugged in to charging stations accounted for 34% of observations. Charging station spots were vacant for 25% of observations indicating that current infrastructure meets the demand. There were 74 unique vehicles that used the spots, of which 27% were plugged in more than 10 times. Illegally parked vehicles accounted for less than 1% with only 4 repeat offenders who used these spots more than once. As electric deployment continues to increase, performance metrics will be an integral tool for agencies and decision makers to help with the maintenance and expansion of electric vehicle infrastructure.

Keywords: electric vehicles, plug-in, charging station, utilization

BACKGROUND

The electric vehicle (EV) market is currently expanding at a rapid pace. In 2018, approximately 5.1 million electric vehicles were sold worldwide, an increase of roughly 2 million from the previous year (*1*). The total EV sales in the United States increased in 2018 by an estimated 81% compared to 2017 (*2*). However, one of the biggest challenges that EV's continue to face is the availability of a convenient and ubiquitous network of public charging stations that can improve "range anxiety" among users. Cities, governments and private companies are continuously working to deploy charging infrastructure to promote this environmentally friendly mode.

Numerous studies have outlined the importance of public charging infrastructure, linking its availability to the penetration of EVs in the market (*3–5*). Researchers from the Idaho National Lab analyzed three years of data from roughly 8300 EV's to find that majority of the charging was done at home and work (*6*). The study also discovered that public charging stations are most useful when installed at locations where cars are parked for longer periods such as shopping malls, commuter parking lots and airports. It is projected that nearly 40 million charging stations will be installed and available worldwide by 2030 (*7*). With the rapid expansion of the infrastructure and technological advancements, it will be critical for charging station operators and agencies to understand the utilization of the charging stations so they can make the appropriate charging infrastructure investments. Although vast number of studies have tried to estimate and predict the utilization characteristics using simulation (*8–10*) and gasoline vehicle data (*11*), there are limited number of studies that use real-world data to assess the utilization.

STUDY MOTIVATION AND SCOPE

Reports have shown that by 2040, electric vehicles may outsell gasoline-powered cars (*1*). Performance measures that provide parking operators with information to guide their management and investment in EV parking structure are needed. This study performs a manual data collection at dedicated electric vehicle charging stations across Purdue University to assess their utilization. As electric vehicle deployment continues to increase, these performance metrics will be an integral tool for agencies and decision makers to help with the maintenance and expansion of electric vehicle infrastructure.

EV INFRASTRUCTURE AT PURDUE UNIVERSITY

The electric vehicle charging stations were setup at Purdue University as part of a grant obtained from General Electric (GE) in 2010. These stations are equipped with GE WattStation, a level 2 public charging station with a solid Society of Automotive Engineers (SAE) J1772 connector. The charging stations are free to use for Purdue personnel after purchasing a $50/year EV permit along with a Purdue University "A" parking permit that costs $250/year. Guests and visitors may also purchase the EV permit for $2/day.

DATA COLLECTION

There are seven geographic locations on the Purdue campus that support electric vehicle parking and charging (Figure 1). Each location has one charging station between two electric vehicle parking spots that require special parking permits. Parking is enforced between 7AM and 5PM on all weekdays. One location, the Northwestern garage, has two additional spots with a charging station. These two locations in Northwestern are referred to as "Northwestern A" and "Northwestern B" in this study.

Data was collected manually by visiting every parking spot and recording its status – vacant, plugged in, not plugged in or illegally parked (Figure 2). Brief description of the status at the time of observation is provided below:

(i) Vacant: if the spot was unoccupied
(ii) Plugged in: if an electric vehicle was using the charging station
(iii) Not plugged in: if an electric vehicle was parked at the spot, but did not use the charging station
(iv) Illegally parked: if a non-electric vehicle was parked at the spot

Observations were taken twice a day – once in the morning and once in the afternoon, between 8AM and 5PM on weekdays. The vehicle make, model and license plate was also recorded to identify the number of unique users and illegally parked vehicles. Data was collected for a total of 50 days (100 observations at each spot) between Nov 2018 and April 2019 across the seven locations. The parking spots at Armory (callout v in Figure 1) were temporarily closed due to construction after Dec 2018 and data from this location was hence discarded from the analysis to remove any potential bias.

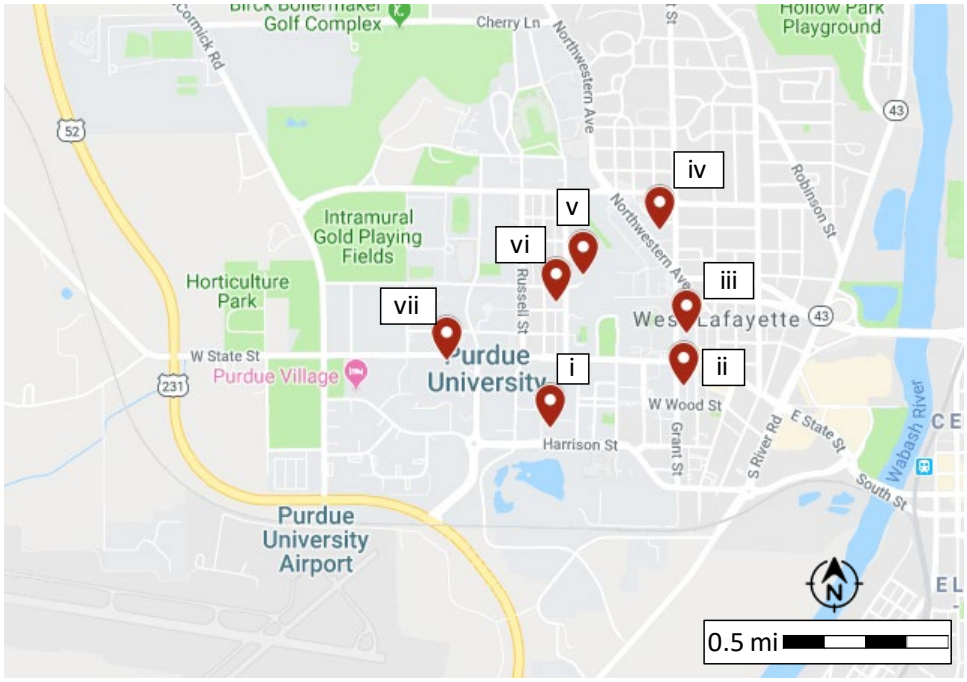
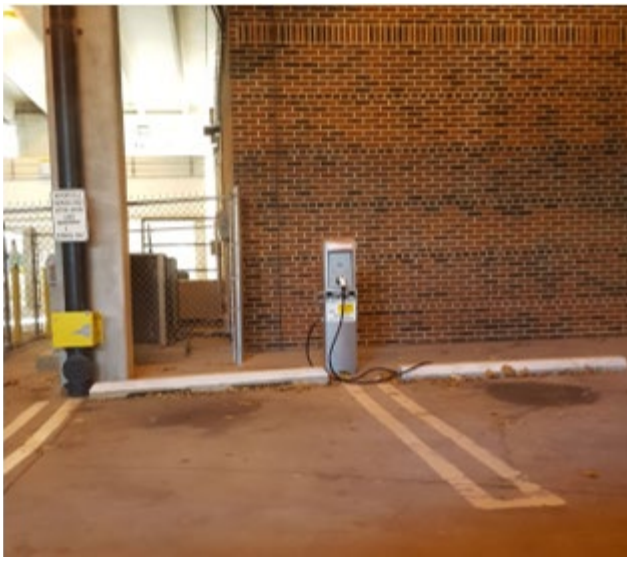
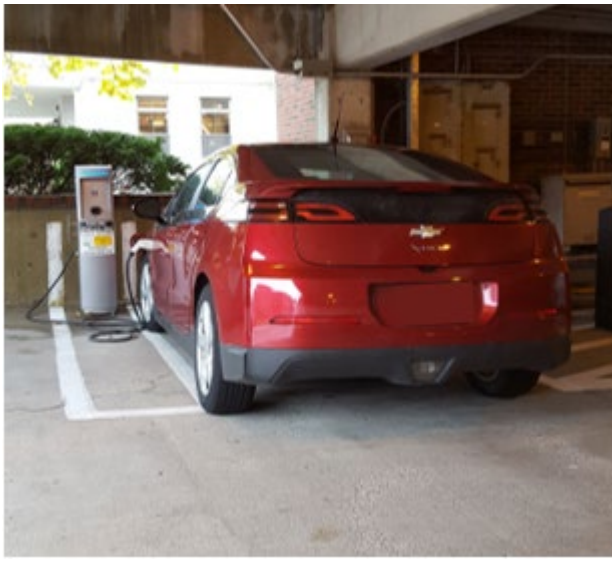


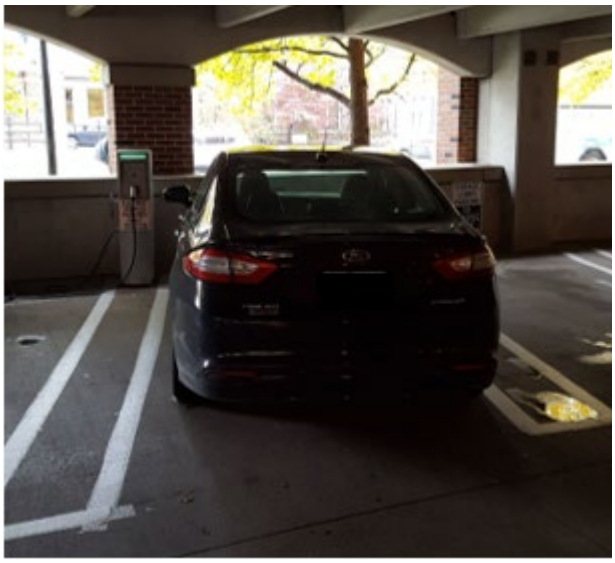
Figure 1 Overview map of level 2 public charging stations at Purdue University, IN
(i - Harrison, ii - Wood, iii - Grant, iv - Northwestern, v - Armory, vi - University, vii - Birck)



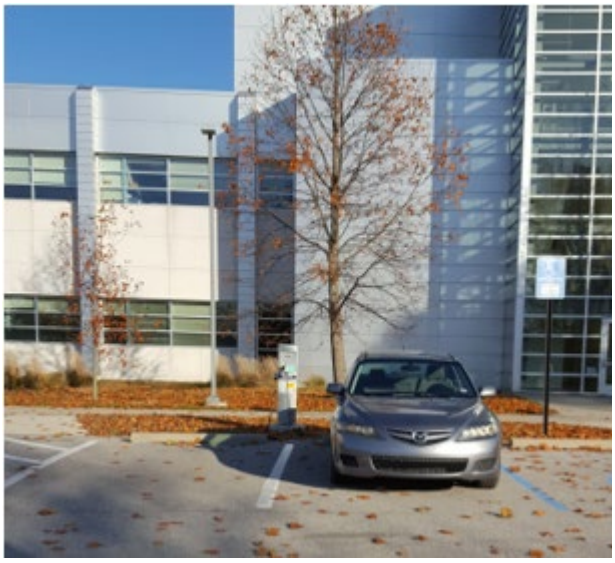
(a) Vacant



(b) Plugged in



(c) Not plugged in



(d) Illegally parked

Figure 2 Data collection

ANALYSIS

Observations

Figure 3 shows the overall distribution of the parking spot status from the total 2800 observations collected across the 14 spots at the six geographic locations included in the analysis. For a large portion of the observations, electric vehicles were found to be just parked at the spot (40%) rather than plugged in (34%). The spots remained vacant for nearly one-fourth of the observations and illegally parked vehicles only constituted for less than 1%. Results show that the electric vehicle parking and charging infrastructure across campus is sufficient to meet the current demand.

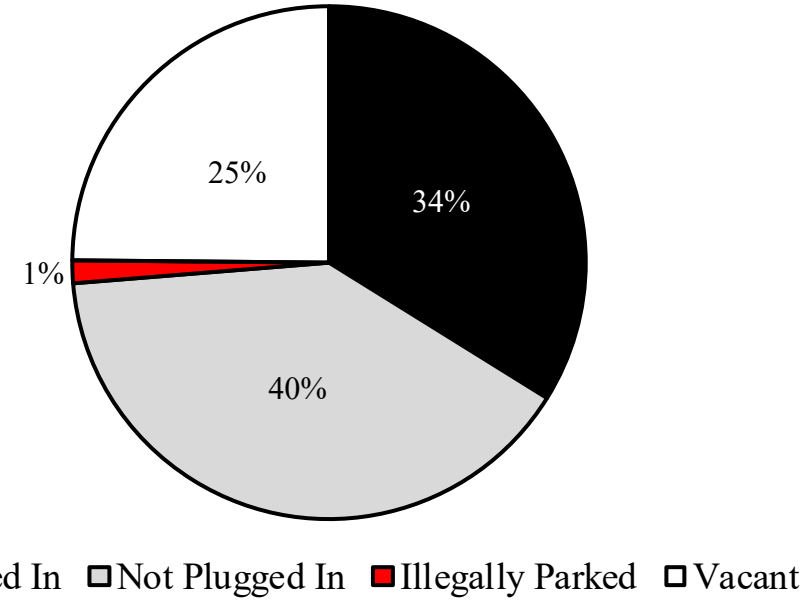


Figure 3 Pie chart of observations

Usage across locations

Figure 4 illustrates the usage across the seven charging stations. Overall, four out of seven stations were occupied (plugged in and not plugged in) for 80% of the observations (callout i). Four locations also had vehicles plugged in for more than 40% of the observations (callout ii). The spots at Grant and Northwestern B were the most utilized with nearly 85% occupancy (40% plugged in), probably due to their prime location on the campus. Birck was the most under-utilized with the spots remaining vacant for more than half of the observations. These spots are located in the Discovery Park area on the west side of campus that are mostly used by research staff and faculty. Construction activities near this area could also have contributed to the low usage.

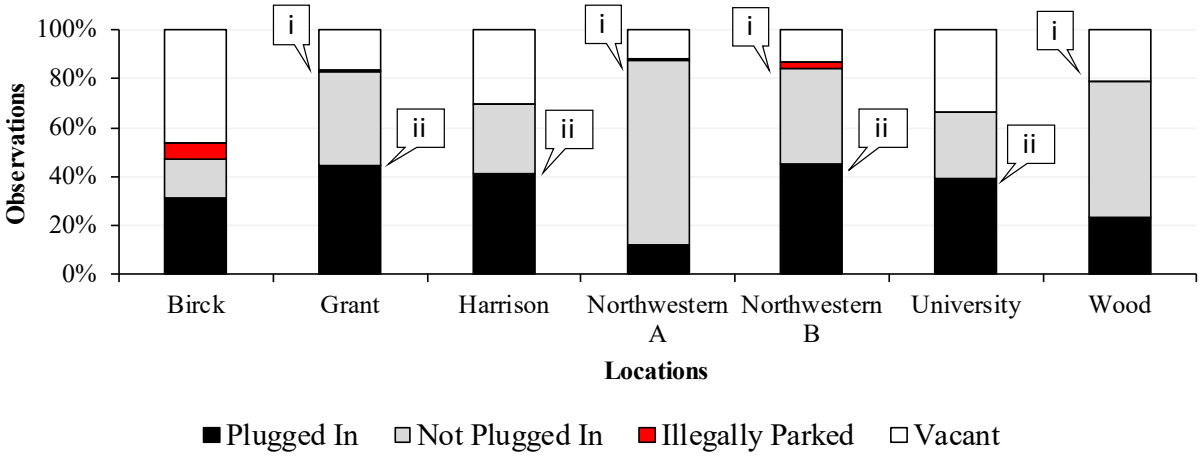
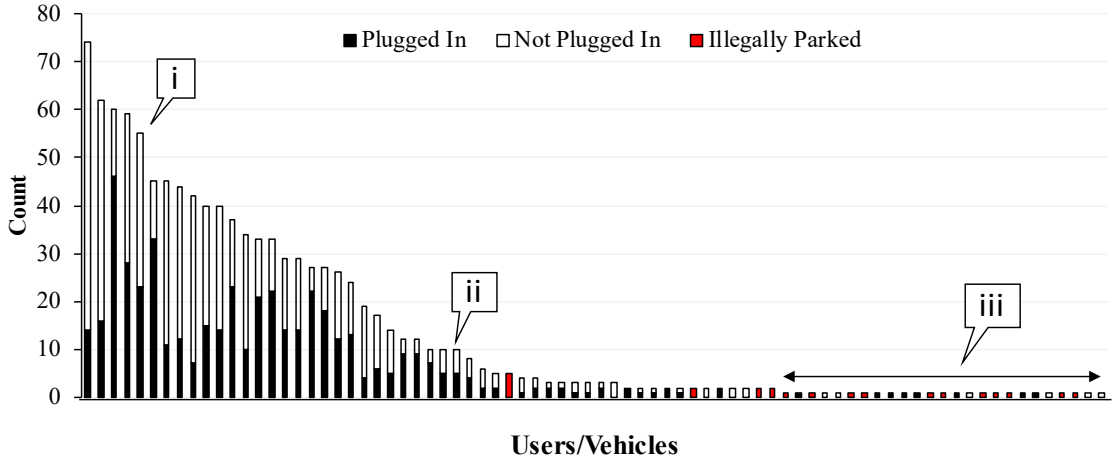


Figure 4 Usage by locations

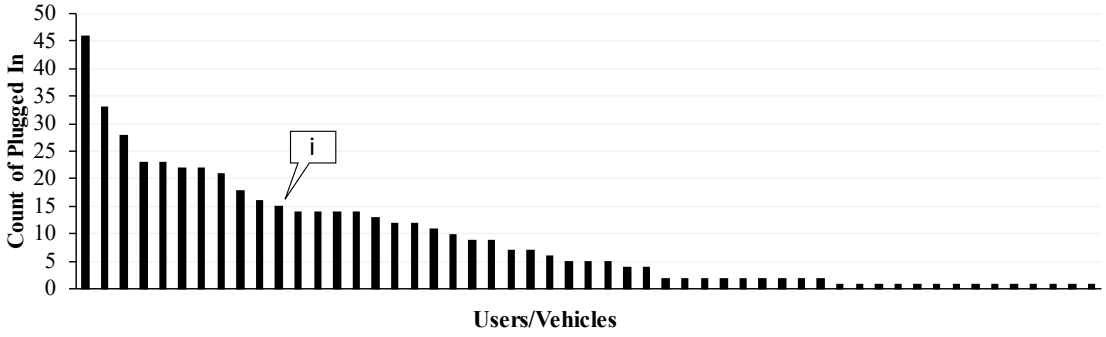
Usage across vehicles/users

Figure 5a shows a pareto sorted plot that illustrates the usage across individual vehicles/users. Of the total 74 unique vehicles that used the spots, 5 vehicles (nearly 6%) were spotted for more than 50 times (callout i). Approximately 39% were regular users that occupied the spots more than 10 times (callout ii). Approximately 33% of the vehicles were only spotted once (callout iii), which could include guests purchasing one day passes.

Figure 5b shows a pareto sort for the plugged in vehicles. In total, there were 53 unique vehicles that used the charging stations. On average, each of these 53 vehicles used the stations for 8 times. Only 20 vehicles (nearly 27% of all vehicles) were spotted plugged in more than 10 times (callout i). Three vehicles used the stations more than 25 times.



(a) All vehicles

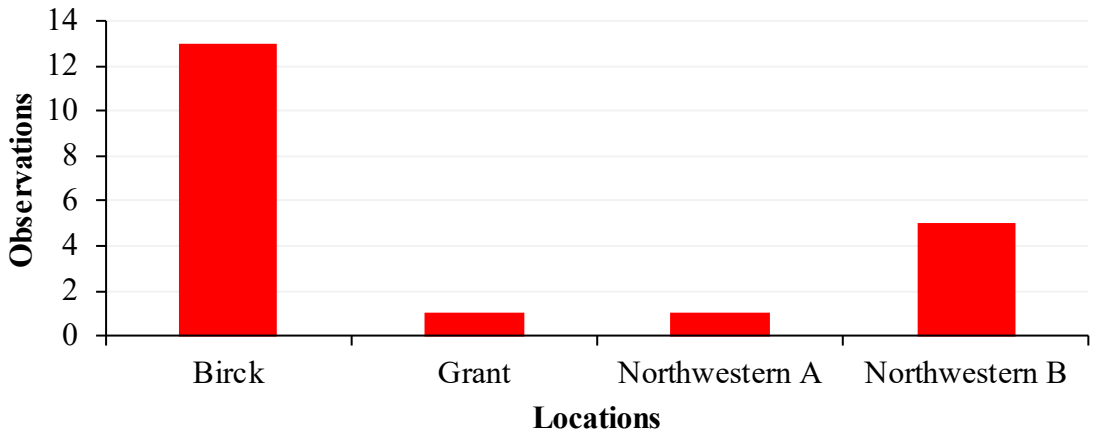


(b) Pareto sort of plugged in vehicles

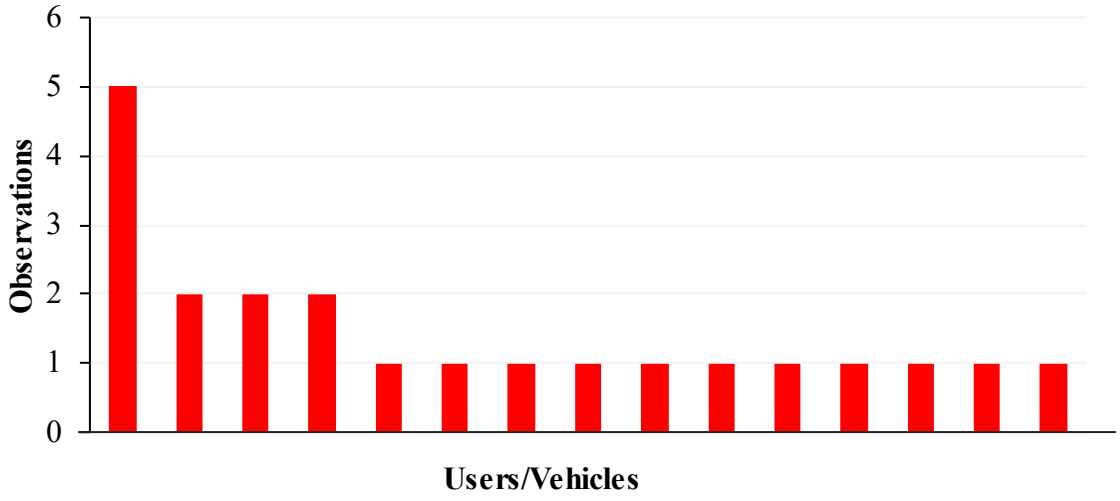
Figure 5 Usage pattern by vehicles/users

Illegally parked vehicles

Figure 6 depicts some information on the non-electric vehicles that parked illegally at the electric vehicle parking spots. Birck, Grant and Northwestern were found to have vehicles parked illegally. Birck topped the chart, with illegally parked vehicles found at this location more than 12 times (Figure 6a). Overall, 13 unique vehicles parked illegally with four of them being repeat offenders (Figure 6b). Although these vehicles constitute less than 1% of the total observations, it will be important to enforce strict parking rules so that charging stations are available for electric vehicles as the need increases in the future.



(a) Locations



(b) Users

Figure 6 Illegally parked vehicles

SUMMARY

This study provides a simple assessment of the electric vehicle infrastructure on a university campus. Data was collected across seven locations on the Purdue University campus that support electric vehicle charging stations and parking. Around 2800 observations were carried out over 50 days and some of the interesting findings are:

- For a large portion of the observations, vehicles were just parked at the spots (40%) but not plugged in. Vehicles plugged in to charging station accounted for 34% of observations. Charging station spots were vacant for 25% of observations.
- Around half of the locations were occupied nearly 80% of time. The spots at Grant and Northwestern were the most utilized whereas Birck recorded the lowest usage.
- 74 unique vehicles used the spots, of which 27% were plugged in more than 10 times. On average, a vehicle would use the charging station 8 times over the course of the 50 days which would result in an average utilization of 0.16 times/day.
- Illegally parked vehicles accounted for less than 1% with only 4 repeat offenders who used these spots more than once.

With nearly 25% of the spots remaining vacant during observations, results show that the current infrastructure is adequate to meet the electric vehicle needs on campus.

The penetration of electric vehicles in the automobile market is projected to increase significantly and the literature on use of public charging stations is sparse. This paper presented some simple performance metrics that parking providers can use to assess the utilization of dedicated charging stations. Longer term, instead of manually collecting this data, it would be desirable for charging stations to automatically tabulate information regarding occupancy of the space and charger utilization so performance measure data can be collected in a more systematic and scalable manner.

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AUTHOR CONTRIBUTIONS
The authors confirm contribution to the paper as follows: study conception and design: Darcy Bullock; data collection: Deborah Horton; analysis and interpretation of results: Jijo Mathew, Deborah Horton, Darcy Bullock; draft manuscript preparation: Jijo Mathew, Deborah Horton, Darcy Bullock. All authors reviewed the results and approved the final version of the manuscript.

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