ABSTRACT

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EVALUATION OF CHARGING STATION LOCATIONS: INFRASTRUCTURE FOR FULLY ELECTRIC SEMI-TRUCKS IN THE U.S.A.

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Purpose

The world is ever-changing with technological advancement. National economies and private organizations are shifting their infrastructure to adapt to innovation and technology. We are seeing a significant shift in our transportation ecosystem as well. Vehicle manufacturers are launching fully electric semi-trucks (EST) or Heavy Goods vehicles (HGV)s on the road for freight transportation. Electric trucks will have a long-term effect on many industries and the national economy in the United States. Compared to conventional automobiles, the limited range of electric vehicles is a major obstacle. To adapt electric vehicles (EVs) to our national transportation system, a proper charging infrastructure is needed and must be supported by the energy grid. Though we have been adapting the passenger EVs, the EST needs more extensive charging infrastructure capabilities to charge the large batteries of these trucks to complete the journey. The most important aspect is the geographical locations of these mega-charging stations along U.S. highways. The purpose of this research is to determine the capability of the existing charging network's ability to support ESTs in the United States, and where, if any, are the shortfalls that are limiting that ability.

Research Approach

To analyze the optimal locations of these charging infrastructures, we use the framework from Csiszár et al. (2020), an origin-destination (O-D) data model. O-D is classified as the original location of the freight to the end destination. We also use the flow-refueling location model (FRLM) from He et al. (2019). This framework showcases the optimal locations in each route in order to complete the O-D pairs. Data from the U.S. Department of Energy for charging station locations is used. U.S. Department of Transportation's Freight Analysis Framework data from 2019 provides O-Ds of freight tonnage between those locations.

Additionally, we use the U.S. Department of Transportation's Bureau of Transportation Statistics in order to procure a dataset of existing truck stops and analyze their feasibility of converting into a charging station. All datasets are secondary and produced by the U.S. government's official organizations. Our study provides an analysis and evaluates the existing charging stations and truck stops in the required geographical locations to serve the major O-D freight transportation routes. We employ the mixed-integer linear program (MILP) model for the feasibility of all O-D routes.

Findings and Originality

Our investigation reveals the dearth of mega charging stations. Current DC rapid charging stations are generally available but have certain challenges such as charging time and vehicle access. Research suggests that enhancing existing truck stops with mega charging stations is a valid option. Our research addresses the gap in the literature and contributes to the O-D and FRLM theories. Previous literature emphasized optimal placement of charging stations without regard to existing infrastructure. This research examined the coverage of the existing infrastructure and highlights where additional charging stations are needed.

The top 1000 O-D pairs in our analysis represented 415,748.3 million ton-miles. Using an EPA estimate of 161.8 grams of CO_2 per ton-mile, this amount of cargo represented 67.3 million metric tons of CO_2 by traditional diesel trucks. By using the existing DC Fast Charger network, 36.8 million metric tons of CO_2 (54.7%) could be removed by converting those shipments to ESTs. Due to the small number of mega chargers available, only 2% of the ton-miles could be converted to ESTs, resulting in the reduction of 1.3 million metric tons of CO_2. By enhancing existing truck stops with mega chargers, 54% of those ton-miles could be moved to ESTs representing a reduction of 36.2 million metric tons of CO_2. This is the current best-case scenario if 100% of shipments on an O-D route where ESTs could operate were shifted from diesel tractor units.

Research Impact

This study identified the current state of the US charging station infrastructure directly related to the feasibility of moving freight from traditional diesel-powered tractor units to electric semi-trucks. We have shown that the current network shows some level of feasibility but that the need for mega-charging stations is underdeveloped. There are signals that with a proper charging network and continued technology improvements in ESTs, the widespread adoption of ESTs is possible. Future research will focus on network capacity on the top O-D routes to better identify weaknesses in the charging infrastructure.

Practical Impact

In late 2021, the U.S. President, the U.S. Department of Transportation (USDOT), and the U.S. The Department of Energy (USDOE) announced an investment of $5 billion over five years for electric vehicle (EV) charging infrastructure nationwide (Bipartisan Infrastructure Law, 2022). The cash will be utilized to deploy EV charging stations nationwide, with an emphasis on underserved and rural populations. The objective is to speed the transition to electric vehicles and minimize transportation-related carbon emissions. The funding will be allocated to underserved communities and specific locations where access to electric vehicle charging infrastructure is frequently limited. Our study will demonstrate the specific routes and locations where charging stations should be located and which states should receive the funding accordingly. This research will directly assist policymakers with current and future subsidies for the infrastructure of charging stations in the U.S.

References

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