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Addressing Inequities in EV Infrastructure: Socio-Economic Disparities & Strategies for Equity

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ABSTRACT

Transportation accounts for the largest share of greenhouse gas emissions in the United States, with personal vehicles as primary contributors. Electric vehicles (EVs) are a critical pathway for emissions reduction. However, EV charging infrastructure deployment has been unevenly distributed and disproportionately concentrated in affluent urban areas, leaving low-income and minority communities underserved. These inequities have created "charging deserts," where limited access hinders EV adoption and worsens socio-economic disparities. This study uses an Ordinary Least Squares (OLS) regression model to examine the relationship between socio-economic, demographic, and transportation variables and EV charging infrastructure distribution across ZIP codes. Key predictors, including population size, household income, public transportation usage, and vehicle availability, were examined. Higher population size (β = 2.029e-05, $p = 0.016$) and household income above \$100,000 ($\beta = 0.0179$, $p < 0.001$) significantly increase EV infrastructure availability. Conversely, higher vehicle ownership (β = -5.574e-05, $p = 0.019$) is negatively correlated. Public transportation usage ($\beta = 0.0228$, $p = 0.004$) emerges as a significant predictor, highlighting transit-oriented areas as critical locations for infrastructure expansion. These findings emphasize systemic inequities in EV charging infrastructure distribution and underscore the need for targeted policy interventions. Addressing these disparities requires prioritizing underserved communities through financial incentives, public-private partnerships, and strategic integration of EV infrastructure into transportation and urban planning. This study contributes to the growing body of literature on sustainable transportation by providing empirical evidence to inform policies for equitable EV adoption and reduced transportation-related emissions.

Introduction

In 2018, transportation accounted for 29% of the total U.S. greenhouse gas emissions, with 58% of the transportation emissions being personal vehicles ([1]). There have been more than 7.5 million EV and hybrid vehicles sold from 2019 to May of 2024, with over 40% being electric vehicles. The growing prevalence of electric vehicles (EVs) is critical for reducing greenhouse gas emissions and achieving global sustainable transportation goals. However, the deployment of EV charging infrastructure has been characterized by significant inequities, often favoring affluent, urban areas over low-income and minority communities. This uneven distribution poses substantial barriers to widespread EV adoption, as access to reliable and convenient charging stations remains essential for supporting the growing number of EV users. Many underserved areas, particularly those with low-income and high-density populations, lack adequate charging resources, effectively creating "charging deserts" that limit the feasibility of EV ownership for residents in these communities ([4]).

In addressing these disparities, it becomes evident that EV infrastructure deployment has largely been driven by market dynamics, with stations clustered in areas deemed most profitable or logistically convenient, often near major roadways or high-income neighborhoods ([8]). However, the need for equitable deployment is crucial to ensure that all communities, regardless of socio-economic status, can participate in and benefit from the transition to clean energy. For instance, the World Resources Institute emphasizes that addressing “charging deserts” in underserved communities is essential, as the lack of convenient public chargers deters residents from adopting EVs, despite potential savings and environmental benefits ([7]). Inequitable access not only hampers EV adoption in underserved communities but also risks exacerbating existing social and economic inequalities as residents in wealthier areas gain greater access to the cost-saving and environmental benefits of EVs.

This study explores the socio-economic and demographic factors influencing EV charging infrastructure distribution at the local level. By analyzing variables such as population density, household income, and vehicle availability, this paper aims to uncover the key determinants of charging port availability in varying zip-code areas. The findings emphasize the need for targeted policies and incentives prioritizing infrastructure deployment in low-income and minority communities, where public transportation and vehicle access dynamics differ substantially from wealthier regions.

Methods

The primary datasets used for this analysis include demographic, economic, and transportation data for U.S. regions at the ZIP code level. Data on EV charger locations were sourced from the Alternative Fuels Data Center ([10]), providing detailed information on charging speeds, number of ports, and locations. Demographic and socioeconomic data, such as total population, household income, and vehicle availability, were sourced from Simply Analytics.

To more easily allow a comprehensive analysis, datasets were merged sequentially. Demographic and socioeconomic variables were merged with EV charger data using FIPS identifiers, with missing or extraneous values addressed through imputation or exclusion, depending on data availability. Selected variables included demographic indicators such as population density and projected population changes, economic variables (e.g., household income), and transportation preferences (e.g., public transportation utilization). Finally, datasets were normalized to mitigate scaling issues in the regression model.

The study utilizes Ordinary Least Squares (OLS) regression to assess the relationship between demographic, economic, and transportation factors and the presence of EV chargers. The dependent variable, represented as a combined total of Level 1, Level 2, and DC Fast chargers in each zip code, was regressed on independent variables such as population size, income levels, vehicle availability, and urban-rural status. Variables were selected based on their theoretical relevance to EV adoption and urban infrastructure patterns.

The OLS model was constructed using the statsmodels library in Python, generating coefficients, t-statistics, and p-values for each predictor variable. Variables with p-values less than 0.05 were considered statistically significant, indicating a meaningful relationship with the likelihood of EV charger presence.

The directionality and significance of each coefficient were interpreted in the context of EV infrastructure planning. Positive coefficients for high-population, high-income, and public transit usage regions suggest a priority in urban, affluent areas for charger deployment. At the same time, negative relationships with vehicle availability highlight an urban bias in infrastructure placement over suburban regions. These findings suggest the inequity of infrastructure expansion in less densely populated or lower-income areas.

Results

Summary of Results

The regression analysis offers critical insights into the determinants of EV charging port availability across ZIP codes, revealing several statistically significant relationships. These findings emphasize the relationship between socio-demographic variables, transportation patterns, and vehicle ownership characteristics in shaping the deployment of EV infrastructure. Key predictors included total population, public transportation usage, household income, and the number of vehicles per household. In contrast, other variables, such as urban versus rural population proportions and retail trade establishments, showed no significant impact.

Table 1. Regression Results

Variable	Coefficient	Std. Error	P-Value	Significance
const	3.4700	0.910	0.000	Significant
Total Population, 2023 [Estimated	2.029e-05	8.39e-06	0.016	Significant
Household Income: $100,000 or More, 2023 [Estimated]	0.0179	0.004	0.000	Significant
Vehicles Available: Occupied Housing Units, 2023[Estimated]	-5.574e-05	2.37e-05	0.019	Significant
Vehicles Available: 5 or More, 2023 [Estimated]	0.0143	0.013	0.273	Not Significant
Vehicles Available: 4, 2023 [Estimated]	-0.0183	0.010	0.059	Moderately Significant
Vehicles Available: 2, 2023 [Estimated]	-0.0077	0.005	0.091	Moderately Significant
Vehicles Available: 3, 2023 [Estimated]	-0.0043	0.006	0.497	Not Significant
Vehicles Available: 1, 2023 [Estimated]	0.0074	0.004	0.076	Moderately Significant
Vehicles Available: None, 2023 [Estimated]	-0.0105	0.006	0.085	Moderately Significant
Urban and Rural Population: Rural, 2020	-0.0047	0.010	0.627	Not Significant
Urban and Rural Population: Urban, 2020	-0.0051	0.010	0.594	Not Significant
Projected Population Change (2023-2028), 2023 [Estimated]	-8.146e-05	0.002	0.970	Not Significant
Population Density (per square mile), 2023 [Estimated]	8.832e-06	6.97e-06	0.205	Not Significant
Retail Trade: Total Establishments, 2022	0.0005	0.001	0.484	Not Significant
Transportation to Work: Public Transportation, 2023 [Estimated]	0.0228	0.008	0.004	Significant

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Legend for Significance:

- Significant: p≤0.05
- Moderately Significant: 0.05<p≤0.10
- Not Significant: p>0.1

Population and Socioeconomic Predictors

Population size emerged as a significant driver of EV charging port availability, with a positive coefficient ($\beta = 2.029e-05$, $p = 0.016$). This finding is consistent with the expectation that higher population densities generate greater demand for public charging infrastructure, as densely populated areas are likely to host more EV users. Likewise, household income displayed a robust positive association ($\beta = 0.0179$, $p < 0.001$), reinforcing the established link between wealthier areas and higher EV adoption rates. These results suggest that income-driven demand plays a significant role in attracting EV infrastructure investment.

Vehicle Ownership Characteristics

The availability of vehicles within households negatively correlates with the presence of EV charging ports ($\beta = -5.574e-05$, $p = 0.019$). This result may indicate that areas with higher car ownership levels are less reliant on public EV charging, as residents may have greater access to private home chargers. Interestingly, the percentage of households with five or more vehicles showed a positive, though not statistically significant, relationship ($\beta = 0.0143$, $p = 0.273$), suggesting a nuanced dynamic where large vehicle fleets might demand greater public charging options.

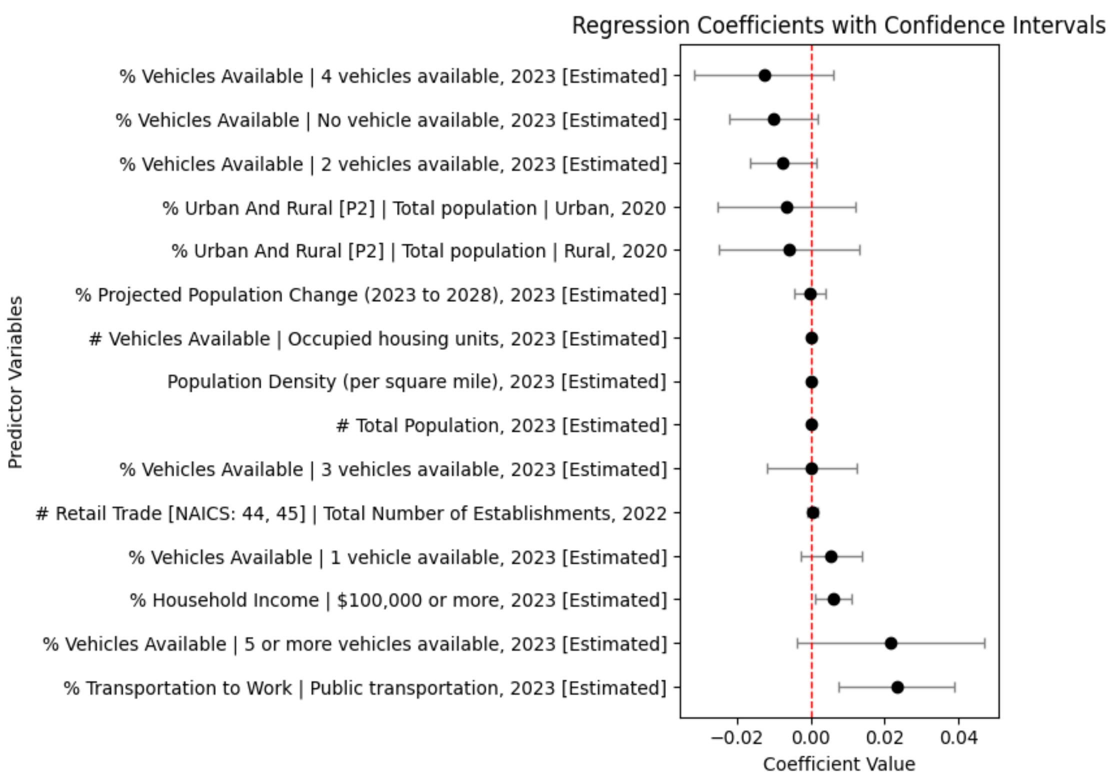

Figure 1. Positive coefficients, such as 5 vehicles in occupied housing units, public transportation usage, and

household income over $100, indicate a positive association with the number of EV charging ports. Conversely, negative coefficients, such as the number of vehicles available under 5 vehicles in occupied housing units, highlight factors negatively associated with charging infrastructure presence. Non-significant predictors, indicated by confidence intervals crossing the zero line, include urban and rural population proportions and retail trade establishments.

Transportation Patterns

Public transportation usage was a strong and significant predictor of charging port presence ($\beta = 0.0228$, $p = 0.004$). This finding highlights the role of transit-oriented neighborhoods in supporting EV adoption and infrastructure deployment. These areas often serve as hubs for commuting, creating a need for accessible public charging to accommodate diverse travel patterns.

Non-Significant Variables

Several variables did not show statistically significant relationships with the number of charging ports, including rural versus urban population proportions ($p = 0.627$ and $p = 0.594$, respectively), projected population change ($p = 0.970$), and retail trade establishments ($p = 0.484$). These results suggest that factors such as projected growth or business density might not directly influence infrastructure deployment in the same way as socio-economic and transit variables.

Implications for Policy and Planning

The results highlight key factors that policymakers should consider when planning equitable EV infrastructure deployment. Targeting high-density, low-income areas with significant transit use may optimize public charging access and drive adoption in underserved communities.

Discussion

The findings of this study provide crucial insights into the socio-economic and demographic factors shaping the distribution of EV charging infrastructure in the United States. The results emphasize the inequities in current deployment patterns, where higher-income and densely populated areas benefit disproportionately, leaving low-income and minority communities at a significant disadvantage. These disparities reinforce the idea that EV infrastructure deployment has largely been market-driven, favoring profitability over equitable access, which hinders widespread EV adoption in underserved areas.

Socio-Economic Dynamics in EV Infrastructure Deployment

The positive and significant association between household income and the number of EV charging ports strongly supports the notion that wealthier areas are prioritized for infrastructure deployment. The significant coefficient for households earning over $100,000 ($\beta = 0.0179$, $p < 0.001$) highlights how financial affluence correlates with enhanced infrastructure access. This reflects the market's response to the higher EV ownership rates and charging demand among affluent households. However, this focus on affluent areas perpetuates existing inequities, leaving low-income communities—often unable to install home chargers—reliant on limited public infrastructure.

It is vital to consider geographic and demographic factors, as strategically placed stations—guided by data on population density, proximity to major transportation routes, and income—significantly influence a location's profitability ([3]). This is because stations are especially more visible and accessible for users near major transportation routes or densely populated areas. In our scenario, these locations could be near major highways and rural neighborhoods with higher populations. Strategizing placements to attract more users of all demographics would lead to a reduction in the payback period for the initial investment([2]). By integrating these geographic and demographic factors, policymakers and EV companies can make better financial decisions regarding the site selection procedure, ensuring equity, profitability, and long-term sustainability.

The Role of Population and Vehicle Ownership

Population size significantly influences charging infrastructure deployment, as evidenced by the positive coefficient for the total population ($\beta = 2.029e-05$, $p = 0.016$). This result aligns with prior research indicating that densely populated areas are more likely to host EV infrastructure due to the higher aggregate demand. However, the insignificant effect of population density ($p = 0.205$) suggests that density alone does not drive deployment. Instead, absolute population size may be a stronger determinant, reflecting the market's prioritization of areas with larger potential user bases([5]).

The negative association between the number of vehicles per household and charging port availability ($\beta = -5.574e-05$, $p = 0.019$) is consistent with the idea that areas with high vehicle ownership rates may depend more on private charging solutions. Conversely, public transportation usage shows a significant positive relationship with charging port availability ($\beta = 0.0228$, $p = 0.004$). This finding indicates that transit-oriented neighborhoods are focal points for infrastructure deployment, likely because they serve as hubs for diverse commuter demographics, including EV users who rely on public charging during multi-modal commutes.

Policy Implications for Addressing Charging Deserts

The disparities revealed in this study emphasize the urgent need for targeted policies to address "charging deserts" in low-income and minority communities. Current deployment patterns driven by profitability fail to meet the equity requirements necessary for a just transition to clean energy. Incentive programs, such as those covering installation costs for chargers in multi-unit dwellings (MUDs) and disadvantaged areas, have shown promise in other regions and should be scaled nationally. For instance, programs in Cook County, Illinois, effectively prioritized underserved neighborhoods by mapping gaps in infrastructure and directing grants to high-need areas. Similar approaches could be adopted in other states to close infrastructure gaps and enhance accessibility. Additionally, public-private partnerships could play a pivotal role in ensuring equitable deployment. Cities like Dallas, which use data-driven strategies to prioritize high-density, low-income areas, offer a replicable model.

In a questionnaire study of 300 entrepreneurs in Thailand's EV charging station sector, it was revealed that charging stations in areas with a higher average income level or received government subsidies had a path coefficient of 0.160 ($p < 0.05$), positively impacting station selection. Government incentives motivated entrepreneurs, making otherwise less profitable areas more appealing ([9]). This statistic suggests that due to the effectiveness of government subsidies in station placement, entrepreneurs in the U.S. could be incentivized the same way, leading to an increase in EV deployment and adoption among underserved areas. Utilizing studies that explain the correlations between investments in EV infrastructure, especially government incentives, is crucial for maximizing EV charging networks' return on investment and financial sustainability([6]).

The Interaction between Equity and Sustainability

While the increasing prevalence of EVs is vital for reducing greenhouse gas emissions, the inequitable distribution of charging infrastructure risks marginalizing the very communities that would benefit most from the economic and environmental advantages of EV adoption. The significant positive relationship between public transit usage and charging port availability highlights the potential for sustainable, multi-modal mobility systems that integrate EV infrastructure with public transportation networks. As emphasized within the Thailand questionnaire study, areas with strong existing public services (transportation hubs, utilities) and room for expansion were favored, as they allowed for scalability and easier maintenance. Such locations provided long-term growth opportunities, which was appealing to entrepreneurs focused on maximizing future returns. Most importantly, areas with room for expansion had a significant path coefficient of 0.683 ([9]). By locating underserved areas that have higher populations and public transportation but lack EV infrastructure, entrepreneurs and policymakers can more effectively deploy EV transportation to make more profit and promote EV adoption within underserved communities. However, without deliberate policy interventions, these benefits will remain inaccessible to underserved communities, perpetuating socio-economic divides.

Limitations and Future Research

Several variables did not show statistically significant relationships with the number. This study's reliance on cross-sectional data limits its ability to capture the temporal dynamics of infrastructure deployment. Conducting funding analyses that incorporate time-series data across socioeconomically diverse areas could yield deeper insights into how policies and market trends influence charging infrastructure over time. Additionally, while this study focuses on socio-economic and demographic variables, future research should incorporate spatial factors such as land use, proximity to highways, and urban planning policies to offer a more comprehensive understanding of deployment patterns.

Conclusion

The results of this study emphasize the critical role of equitable infrastructure deployment in supporting widespread EV adoption and achieving sustainable transportation goals. By prioritizing underserved communities in infrastructure planning, policymakers can promote social equity, ensuring the transition to clean energy benefits all populations while accelerating progress toward sustainable transportation goals.

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