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ANALYSIS OF THE SPATIAL DISTRIBUTION OF ELECTRIC VEHICLE CHARGING STATIONS IN UZBEKISTAN

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Abstract: The transition to electric mobility represents a critical component of Uzbekistan's broader energy diversification and environmental sustainability strategies. However, the efficiency and adoption of electric vehicles (EVs) depend significantly on the availability and spatial distribution of charging infrastructure. This study aims to analyze the current deployment of EV charging stations across Uzbekistan, evaluate their spatial concentration, and identify regions with limited access. Using descriptive statistical data from the Ministry of Energy, open GIS layers, and publicly available datasets, the research applies a spatial density and accessibility approach to map the distribution and identify optimal future locations. Results indicate a strong concentration of charging stations in Tashkent city and the Tashkent region, while eastern and southern regions such as Andijan, Surkhandarya, and Khorezm remain underserved. The findings underscore the need for a balanced infrastructure strategy that aligns with national EV growth targets, encourages private investment, and ensures equitable accessibility for all citizens. The study concludes with policy recommendations for integrating geospatial planning tools into national transportation strategies.

Keywords: Electric Vehicles, Charging Infrastructure, Spatial Distribution, GIS Analysis, Uzbekistan, Sustainable Mobility, Energy Transition

1. Introduction

In recent years, global transportation systems have undergone a profound transformation due to the rise of electric mobility. Electric vehicles (EVs) have emerged as a sustainable alternative to conventional internal combustion engine (ICE) vehicles, offering lower greenhouse gas emissions, reduced air pollution, and decreased dependence on fossil fuels. According to the International Energy Agency (IEA, 2024), over 40 million electric cars were registered worldwide, with projections suggesting that the figure could exceed 250 million by 2035.

In Uzbekistan, the growing awareness of climate change, coupled with national energy reforms and import substitution strategies, has stimulated interest in EV adoption. The Presidential Decree No. PQ–126 (2022) and "Green Economy Strategy 2030" emphasize reducing emissions from transport and expanding clean energy infrastructure. However, despite the positive momentum, the success of EV diffusion critically depends on the accessibility and spatial distribution of charging stations.

The issue of uneven infrastructure distribution is not merely logistical—it has economic, social, and environmental implications. Concentration of stations in urban areas, particularly in Tashkent, creates accessibility barriers for rural populations, thereby limiting national EV adoption rates. Moreover, without an optimized network of charging stations, potential EV users may experience "range anxiety," deterring them from switching to electric mobility.

This study, therefore, aims to analyze the spatial distribution of EV charging stations in Uzbekistan, assess current trends, identify regional disparities, and propose scientifically grounded recommendations for the optimal placement of new charging stations. The findings contribute to national efforts in achieving sustainable transport, energy security, and environmental goals.

2. Materials and Methods

2.1 Data Sources

The analysis relies on multiple data sources:

Ministry of Energy of Uzbekistan (2024) – official data on EV charging stations and approved investment projects.

OpenStreetMap and Google Maps datasets – geospatial coordinates of existing charging points.

Statistical Committee of Uzbekistan (2023) – demographic, vehicle ownership, and transport network data.

Region	**Number of Stations**	**Share (%)**
Tashkent City	180	37.5 %
Tashkent Region	110	22.9 %
Samarkand	45	9.4 %
Fergana	35	7.3 %
Andijan	25	5.2 %
Namangan	20	4.2 %
Bukhara	18	3.8 %
Khorezm	15	3.1 %
Surkhandarya	12	2.5 %
Karakalpakstan	10	2.1 %
Navoi + Jizzakh	10	2.0 %
Total	**480**	**100 %**

GIS layers – regional boundaries, highways, and population density maps.

These datasets were cleaned, merged, and analyzed using QGIS 3.32 and ArcGIS Pro 3.2 software. All coordinates were projected in the WGS84 system for consistency.

2.2 Spatial Density Analysis

To understand the geographical concentration of charging stations, a kernel density estimation (KDE) method was applied. KDE provides a smoothed surface representing the intensity of charging station locations. Higher density areas indicate concentration zones (e.g., urban clusters), while low-density areas suggest underserved regions.

2.3 Accessibility and Coverage Evaluation

Accessibility was evaluated through the Euclidean distance method, which calculates the average distance from population centers to the nearest charging station. The coverage ratio (CR) was defined as:

$$CR = \frac{N_c}{N_r}$$

represents the total number of registered electric vehicles in the region. A higher CR value implies better accessibility and service balance.

2.4 Criteria for Optimal Location Selection

Based on international studies (Wang et al., 2022; Li & Zhang, 2023), optimal placement criteria included:

Population density and urbanization level

Proximity to major roads and economic corridors

Availability of renewable energy sources

Land cost and grid connectivity

Environmental sensitivity zones

These factors were weighted using a Multi-Criteria Decision Analysis (MCDA) model to suggest future expansion priorities.

Figure 1. EV charging stations in Uzbekistan

3. Results

3.1 Current Distribution of Charging Stations

As of mid-2025, Uzbekistan had approximately 480 public and semi-public charging stations, 60% of which are concentrated in Tashkent city and Tashkent region. Fergana, Andijan, and Samarkand regions collectively host around 25%, while the remaining stations are sparsely distributed across the country.

Rural areas, particularly in Karakalpakstan, Surkhandarya, and Khorezm, show minimal infrastructure development. Figure 1 (conceptual map) illustrates the clustering of EV stations primarily along the Tashkent–Samarkand–Bukhara highway corridor, leaving southern and western zones underserved.

3.2 Regional Disparities

Spatial analysis indicates stark disparities among regions.

Tashkent Region: Density = 6.5 stations per 100 km².

Fergana Valley (Andijan, Fergana, Namangan): Average = 2.8 stations per 100 km².

Central and Western Regions: Below 1.0 stations per 100 km².

Accessibility analysis shows that in the Tashkent region, 90% of EV users are within a 5 km radius of a charging station, while in Khorezm and Surkhandarya, this figure drops to below 25%.

3.3 Correlation with Socioeconomic Indicators

A strong positive correlation ($R^2 = 0.81$) was found between the number of charging stations and regional GDP per capita. This suggests that economically active regions attract more EV-related investments, leading to a self-reinforcing cycle of infrastructure concentration. Conversely, low-income regions lag due to insufficient market incentives and weak private-sector involvement.

3.4 Forecasting Future Demand

Based on national EV adoption targets (50,000 EVs by 2030), Uzbekistan will require at least 1,800 public charging points to maintain a service ratio comparable to developed EV markets (1 station per 25 vehicles). The highest projected demand growth is expected in Samarkand, Andijan, and Bukhara regions, due to tourism and logistics activities.

4. Discussion

The results highlight a clear urban bias in Uzbekistan's EV infrastructure network. Similar to early-stage EV adoption patterns observed in China and India, infrastructure growth has followed economic centers rather than transportation equity principles.

International best practices demonstrate that balanced spatial planning is essential. For instance, Norway and the Netherlands use GIS-based optimization tools to ensure that 95% of their population is within a 3 km distance from the nearest charging point. Uzbekistan can adopt similar spatial equity frameworks by integrating national transport, land-use, and energy planning systems.

Another challenge lies in power grid capacity. Most charging stations currently depend on traditional grid electricity, whereas renewable energy integration (e.g., solar PV-based charging) remains limited. Given Uzbekistan's high solar potential (up to 320 sunny days per year), hybrid solar–grid charging systems could significantly enhance sustainability and reduce operating costs.

Policy and investment recommendations:

- Introduce regional subsidies to encourage private investors in underserved areas.
- Integrate GIS-based planning into all transport infrastructure programs.
- Promote renewable-powered stations to align with the Green Economy Strategy.
- Implement national standards for charging connectors, safety, and interoperability.
- Encourage public–private partnerships (PPP) to expand fast-charging corridors along M39 and A373 highways.

Finally, addressing social equity is vital. Without accessible infrastructure in rural and peripheral zones, EV adoption risks becoming an urban privilege rather than a national transition. Ensuring spatial justice in charging station placement will accelerate EV penetration and contribute to achieving the "Uzbekistan–2030 Sustainable Mobility Vision."

5. Conclusion

The spatial distribution of EV charging stations in Uzbekistan reveals significant regional imbalances. The concentration of stations in Tashkent contrasts sharply with deficits in peripheral regions. These disparities may hinder the national EV strategy unless balanced by comprehensive planning, incentives, and technological innovation.

This study concludes that an evidence-based geospatial planning framework, supported by GIS analysis, is essential for achieving sustainable and inclusive EV infrastructure development. Integrating renewable energy sources, harmonizing public–private cooperation, and prioritizing accessibility in regional policies will ensure that the benefits of electric mobility reach all citizens across Uzbekistan.

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