Designing Charging Infrastructure for Electric Vehicles from an Urban Perspective

A Conceptual Analysis

Volume 6, No. 3

June 2025

Michael Leyer University of Marburg

Wieland Müller University of Rostock

Kenan Degirmenci Queensland University of Technology

Alistair Barros Queensland University of Technology

Layout & Design: Oliver Behn

The research behind the paper

White Paper Series of the Chair ABWL:
Digitalisation and Process Management

Volume 6

Abstract

The transition to electric vehicles (EVs) represents a crucial step toward a sustainable energy future. The success of this transformation heavily depends on the development of a robust and efficient charging infrastructure—especially within urban environments. This white paper presents a conceptual analysis of EV charging infrastructures, drawing on the Energy Informatics Framework and Actor-Network Theory. It explores the complex interactions among key stakeholders—ranging from energy providers and consumers to municipal administrations—and highlights the technological and infrastructural components underlying these networks. The analysis underscores the central role of collaboration, data integration, and technological innovation in creating a sustainable and user-oriented EV charging ecosystem. From this, targeted recommendations are derived to support cities in the effective and future-ready planning and implementation of charging infrastructure.

Concept of Urban EV Charging Infrastructure

At the core of a successful EV charging infrastructure lies the recognition that cities function as complex socio-technical systems, where diverse actors interact with different interests and needs. While EVs have the potential to significantly reduce urban environmental impacts, they require a thoughtfully designed charging network that meets both technical and social demands. Developing citywide charging infrastructure involves more than just installing charging stations. It requires integration into existing energy systems, consideration of user behavior and preferences, and alignment with urban planning and mobility strategies. Cities must balance rapid implementation with long-term sustainability. The Energy Informatics Framework offers a structured approach by analyzing information flows between energy providers, infrastructure operators, and users. Complemented by Actor-Network Theory, both technical and social factors are considered. This combined perspective enables a holistic understan-

ding of charging infrastructure complexity and supports the development of forward-looking solutions.

Approach to User-Centered Design

The first step in developing urban EV charging infrastructure is the identification of central interactions between relevant actor groups. These include, in particular, user groups, energy providers, infrastructure operators, and municipal administrations. The analysis of these interaction patterns creates a systemic understanding of how requirements arise, are passed on, and are implemented. These relationships form the basis for user-oriented planning.

Building on this, the second step involves differentiating the perspectives of the various stakeholders. In addition to current and potential EV users (such as commuters, sharing users, or commercial fleets), less visible groups such as property owners, businesses, or homeowners' associations must also be included. These actor perspectives can be captured through mobility analyses, surveys, and traffic data. A comprehensive needs analysis must also take into account socio-economic differences and usage barriers.

The third step should be the analysis of the technical infrastructure and sensor networks. This includes the existing physical and digital charging infrastructure—including the spatial distribution of charging points, grid capacities, access systems, and digital control units. Technological solutions must be evaluated regarding their scalability, grid integration, and user-friendliness. The results form an important basis for the design of robust and future-oriented charging points.

The fourth step consists of integrating physical systems and digital objects into a coherent overall concept. A comprehensive evaluation is carried out, taking into account economic, ecological, and social criteria. In addition to the classical cost-benefit analysis, questions of environmental impact, synergies with urban energy systems, and citizen acceptance come into focus. Data protection, ease of use, interoperability, and transparent communication are considered central success factors.

In addition, the analysis reveals five key principles on which sustainable and future-oriented charging infrastructure should be based:

1. System Integration: Charging infrastructures should not be planned in isolation but as part of the entire mobility and energy system.

2. Data-Based Approach: Site selection, capacity planning, and charge management must be based on comprehensive, networked data analyses.

3. User-Centricity: Charging speed, accessibility, ease of use, and pricing systems should be aligned with real usage profiles.

4. Flexibility: Infrastructures must be designed in a modular and scalable way in order to be able to respond to technological developments.

5. Cooperativeness: Various stakeholders—from municipal utilities to property owners to mobility providers—must be involved in planning, construction, and operation.

These principles form the normative framework within which concrete measures, strategies, and priorities can be defined.

Conclusions and Recommendations for Action

Our analysis shows that the development of urban charging infrastructures for electric vehicles requires an integrated, strategically considered, and cross-actor approach. In particular, city administrations play a key role in coordination, planning, and implementation. The following five recommendations offer a practical starting point for municipal actors:

1. Regular analysis of user behavior and needs: Cities should systematically capture how different user groups use the charging infrastructure (e.g., everyday trips, commuting routes, commercial use). These data are essential for targeted and equitable infrastructure planning.

2. Develop a data-based and flexible overall strategy: A long-term, technology-open charging infrastructure master plan helps avoid isolated solutions and be prepared for future developments (e.g., V2G, new business models).

3. Strengthen cooperation with private actors: Municipalities should specifically address owners of parking spaces, residential complexes, or commercial properties and involve them in infrastructure expansion through incentives and partnerships.

4. Ensure standardization and user-friendliness: Uniform technical standards as well as simple access and billing systems increase willingness to use and lower barriers—even for less tech-savvy groups.

5. Use data integration for control and optimization: Real-time data from charging infrastructure and apps should be merged city-wide in order to effectively manage grid load, energy flow, and future expansion needs.

These recommendations form the basis for sustainable, user-centered, and efficiently operated charging infrastructure. Further recommendations for action and the complete framework can be found in the original paper:

https://www.sciencedirect.com/science/article/pii/S0301421525000230

CONTACT

Prof. Dr. Michael Leyer
Chair of ABWL:
Digitalisation and Process management

School of Business and Economics Marburg

Adjunct Professor, School of Management,
Queensland University of Technology,
Brisbane, Australien

Email michael.leyer@wiwi.uni-marburg.de