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CHARGE HUB: A Comprehensive Review of Smart Electric Vehicle Charging Infrastructure, Booking Systems, and Intelligent Charging Services

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ABSTRACT - The increasing adoption of electric vehicles (EVs) has created a need for reliable charging infrastructure, convenient booking services, efficient energy management, and intelligent charging solutions. However, EV users may face problems such as limited charger availability, waiting time, uncertain charging costs, and difficulty identifying suitable charging stations. This review examines four published review papers covering EV charging station planning, smart charging, machine learning-based charging services, and charging technologies and standards. The reviewed literature indicates that effective EV charging requires coordination between charging infrastructure, digital platforms, energy management, and user requirements. Smart charging can improve energy utilization, while artificial intelligence and machine learning can support demand prediction, station recommendation, scheduling, and pricing. This paper compares the main contributions and limitations of the four reviews and identifies opportunities for integrating these functions into a unified charging management platform. The review also discusses how a system such as CHARGE HUB can connect users, charging stations, booking services, backend APIs, and databases. Finally, research challenges related to interoperability, security, real-time availability, peer-to-peer charging, and renewable energy integration are presented.

Keywords— Electric vehicles, charging infrastructure, smart charging, station booking, machine learning, IoT, energy management, CHARGE HUB.

I.INTRODUCTION

Electric vehicles are becoming an important alternative to conventional vehicles because they can reduce dependence on petroleum fuels and support cleaner transportation when supplied with low-carbon electricity. However, the usefulness of EVs depends not only on vehicle performance and battery capacity but also on the availability, accessibility, and reliability of charging infrastructure.
EV charging involves several connected activities, including locating a suitable station, checking charger availability, selecting a charging time, estimating the cost, completing the charging session, and managing energy demand. If these activities are not coordinated, users may experience unnecessary travel, waiting time, and uncertainty about charging costs. Charging infrastructure also requires careful planning to avoid underused stations, high installation costs, and excessive demand on the electricity grid.

Previous review studies have investigated different aspects of this problem. Kchaou-Boujelben [1] reviewed models and solution approaches for locating charging stations. Subashini and Vijayan [2] examined smart charging policies and technologies. Fescioglu-Unver and Yıldız Aktaş [3] reviewed machine learning applications in charging infrastructure planning, control, pricing, and routing. Acharige et al. [4] investigated charging technologies, standards, station architectures, and power converter configurations.

Although these studies provide valuable knowledge, they focus on different technical areas. This paper brings their major findings together from the perspective of a digital EV charging management system. Its objectives are to compare the four reviews, identify research gaps, and discuss an integrated framework relevant to smart charging and booking platforms such as CHARGE HUB.



II. REVIEW OF EXISTING LITERATURE

A. Charging Station Location and Infrastructure Planning

Kchaou-Boujelben [1] presented a comprehensive review of charging station location problems. The study examined the models used to determine where charging stations should be installed and the solution approaches used to address these planning problems. Infrastructure planning is important because stations must serve users effectively while considering investment costs, travel requirements, and expected charging demand.

Station location planning can help reduce the distance users travel to charge their vehicles and improve the geographical coverage of charging services. However, selecting an appropriate location is not sufficient by itself. A station may be correctly located but still provide a poor user experience if its chargers are occupied, unavailable, or unsuitable for a particular vehicle.

For digital platforms, infrastructure planning can be combined with real-time station information. A booking application can display station locations, charger types, prices, and availability, helping users choose an appropriate charging facility. Future systems can also use historical booking information to estimate demand and support better decisions about station expansion.

B. Smart Charging Policies and Energy Management

Subashini and Vijayan [2] reviewed smart charging approaches for zero-emission vehicles. Their study discussed charging policies, scheduling, and supporting technologies such as the Internet of Things (IoT), deep learning, renewable energy sources, battery storage, and vehicle-to-grid (V2G) integration.

Smart charging coordinates the charging process according to factors such as electricity demand, charging requirements, available power, and charging time. Uncontrolled charging by many vehicles at the same time can increase peak demand and place additional pressure on local distribution networks. Coordinated charging can distribute

demand over time and potentially reduce operating costs and grid stress.

IoT technologies can support communication between chargers, sensors, management platforms, and energy systems. Renewable energy sources and battery storage may further improve energy management where suitable infrastructure is available. Bidirectional charging can enable energy to flow from a vehicle back to the grid when the vehicle and charging equipment support V2G operation.

However, smart charging requires reliable communication, suitable control strategies, compatible equipment, and accurate information about energy demand. A booking platform can contribute by collecting charging schedules and estimated energy requirements, but advanced grid control requires additional hardware, measurements, and energy-management functions.

C. Machine Learning for Charging Services

Fescioglu-Unver and Yıldız Aktaş [3] reviewed machine learning applications in EV charging service operations. Their review covered infrastructure planning, charging control and scheduling, pricing, and vehicle routing. The authors discussed approaches such as forecasting, clustering, and reinforcement-based methods.

Machine learning can help predict future charging demand by examining historical charging records, station usage, time patterns, and other relevant information. Forecasting can assist operators in estimating busy periods and identifying stations that may require additional capacity. Recommendation systems can use location, charger compatibility, availability, and price to help users select suitable charging stations.

Machine learning can also support dynamic pricing and charging schedules. For example, a system may estimate demand at different times and help operators design suitable pricing policies. However, these functions depend on sufficient and representative data, appropriate model selection, and regular evaluation. Predictions may become inaccurate when user behaviour or charging demand changes.

A practical charging application can initially provide rule-based recommendations using distance, charger type, availability, and price. As reliable historical data becomes available, machine learning models may be introduced to improve demand forecasting and personalized recommendations.

D. Charging Technologies, Standards, and Station Architecture

Acharige et al. [4] reviewed EV charging technologies, international standards, charging station architectures, and power converter configurations. The review covered onboard and offboard chargers, AC and DC charging, renewable-energy-integrated stations, and bidirectional charging.

AC charging is commonly suitable for locations where vehicles remain parked for longer periods, while DC fast



charging can provide higher charging power when supported by the vehicle and station. The choice of technology depends on charging requirements, equipment costs, installation conditions, compatibility, and electrical infrastructure.

The review also highlighted the importance of charging standards and grid integration. Interoperability and electrical safety are essential for reliable charging services. Stations that incorporate renewable energy and storage may offer additional energy-management benefits, although they also introduce design and control complexity.

These technical considerations are relevant to booking applications because a digital system must represent charging stations accurately. Information such as charger type, power rating, connector compatibility, availability, and pricing can help users choose an appropriate station. Nevertheless, a software application alone cannot guarantee physical charger compatibility or safe operation; these depend on compliant equipment and proper implementation.

Table I. Comparison of the reviewed literature
Review paper

Review paper	Main focus	Relevance to charging platforms	
Kchaou-Boujelben [1]	Station location and planning models	Supports station placement and coverage decisions	
Subashini and Vijayan [2]	Smart charging policies and energy technologies	Supports scheduling and coordinated energy use	
Fescioglu-Unver and Yıldız Aktaş [3]	ML for planning, control, pricing, and routing	Supports prediction and intelligent recommendations	
Acharige et al. [4]	Charging technologies, standards, and architectures	Supports charger information, compatibility, and technical integration	

The first review mainly addresses where charging infrastructure should be deployed. The second examines how charging demand and energy resources can be managed. The third focuses on data-driven methods for improving charging services, while the fourth examines the electrical and technical foundations of charging systems.

Together, these studies show that EV charging is a multidisciplinary problem. Infrastructure planning determines where charging facilities are needed; charging technologies determine how vehicles receive energy; smart charging manages demand; and digital services help users access stations conveniently. Integrating these functions may provide a more complete service than treating each one separately.

However, the four papers have different scopes and should not be interpreted as direct experimental comparisons of the same system. Their findings are complementary rather than proof that one specific integrated platform will outperform every existing solution.

IV. RESEARCH GAPS AND CHALLENGES

Despite progress in EV charging research, several challenges remain.

1. **Integration of services:** Station planning, charger monitoring, booking, pricing, and energy management are often considered as separate problems. A common platform could connect user-facing services with operational information from charging stations.

2. **Real-time availability:** Displayed availability is useful only when station information is updated accurately. Communication delays, device failures, or incomplete updates can cause conflicts between bookings and actual charger status.

3. **Booking and scheduling:** A booking system must manage reservation times, charger capacity, cancellations, and overlapping requests. It should prevent duplicate reservations and provide clear confirmation to users.

4. Data privacy and cybersecurity: Charging platforms may process account details, booking records, and payment-related information. Secure authentication, access control, protected communication, and appropriate data handling are important for protecting users and operators.

5. Machine learning data requirements: Reliable prediction requires adequate historical data and careful model evaluation. New stations may have limited records, and models trained in one location may not perform equally well in another.

6. Peer-to-peer charging: Sharing privately owned charging facilities may increase access to charging options. However, this requires owner registration, charger verification, availability management, pricing, payment handling, and appropriate safety and regulatory arrangements.



7. Energy and grid integration: Renewable energy, battery storage, and V2G may improve flexibility, but their practical use requires compatible hardware, grid coordination, and appropriate control systems.

These gaps indicate that future EV charging platforms should consider both user convenience and the technical requirements of reliable charging infrastructure.

V. PROPOSED INTEGRATED FRAMEWORK FOR CHARGE HUB

Based on the reviewed literature, an integrated charging management framework can be organized into six connected layers.

1. **User interface:** A mobile application allows users to register, sign in, view charging stations, examine charger details, and access their bookings.

2. **Application and backend layer:** REST APIs process user requests, retrieve station information, validate bookings, and communicate between the mobile application and server.

3. **Booking and recommendation layer:** The system checks availability, validates the selected time, calculates an estimated charging cost using the configured pricing rules, and presents suitable station options. Future versions may use machine learning for demand forecasting and personalized recommendations.

4. **Database layer:** A database stores relevant information such as user accounts, station records, charger details, bookings, and pricing. Appropriate access controls and validation rules help maintain data consistency.

5. **Charger and IoT integration layer:** Where compatible devices and communication interfaces are available, charger status and charging-session information can be received from station equipment. Without such integration, the platform should not represent manually stored information as live hardware telemetry.

6. **Energy management layer:** Advanced implementations can connect charging schedules with renewable energy, energy storage, load management, and V2G systems where technically supported.

The CHARGE HUB project provides a software-oriented foundation for this approach through its Android application, REST API, and MySQL database. Its booking and station-management functions are relevant to the digital service layer. More advanced features—such as live IoT monitoring, machine learning, peer-to-peer payments, and grid-connected energy management—should be treated as extensions unless they have been implemented and tested.



Fig. 1. Proposed Integrated Framework for Smart EV Charging Management

VI. FUTURE RESEARCH DIRECTIONS

Future research should focus on developing integrated systems that combine station discovery, booking, charger status, pricing, and energy-aware scheduling. Standardized communication interfaces could improve interoperability between applications and different charging equipment.

Machine learning may be introduced to predict station demand, identify busy periods, and recommend suitable charging locations. These models should be evaluated using real or appropriately validated datasets and compared with simple baseline methods. Booking platforms should also be tested for concurrent requests, invalid time selections, booking conflicts, network failures, and database consistency.

Peer-to-peer charging presents another research direction. A future platform could allow private charger owners to list supported charging facilities, specify availability and prices, and receive booking requests. Such a system would need charger verification, secure transactions, clear cancellation policies, and compliance with applicable regulations.

Finally, energy-aware charging could be explored by combining booking schedules with electricity tariffs, renewable generation, and grid constraints. The practical feasibility of these functions should be assessed through simulations, controlled experiments, or real-world pilot deployments before making claims about cost savings or grid benefits.

VII. CONCLUSION

This paper reviewed four published studies addressing EV charging station planning, smart charging, machine learning-based charging services, and charging technologies and standards. The literature shows that convenient EV charging



requires more than the installation of physical chargers: it also requires accurate station information, effective scheduling, reliable digital services, and suitable energy management.

The studies offer complementary insights. Infrastructure planning helps determine station locations, smart charging supports coordinated energy use, machine learning can improve prediction and recommendations, and technical standards support safe and compatible charging equipment. The principal research opportunity is to connect these areas within a reliable and extensible platform.

CHARGE HUB is relevant to this direction because its Android application, REST API, and MySQL database can support station discovery and booking workflows. Future extensions could incorporate live charger monitoring, data-driven recommendations, peer-to-peer charging, and energy-management functions. These additions require separate implementation and evaluation. An integrated approach may improve charging convenience and system coordination while addressing the technical, security, and operational challenges identified in the reviewed literature.

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