Developing Electric Vehicle Service Centers (EVSCs) as a Key to Sustainable Transportation Infrastructure

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Abstract. Green mobility presents significant issues in cities that continue to rely on fossil fuel vehicles, which contribute to greenhouse gas emissions and climate change. Air pollution from traditional transportation has a substantial impact on public health and increases reliance on fossil fuels, which are volatile in price. The advancement of electric vehicle (EV) technology, including advances in batteries, charging systems, and the use of renewable energy, has the potential to address this issue. Adequate charging infrastructure is critical to promoting EV adoption and creating a sustainable transportation ecology. Electric Vehicle Service Centers (EVSCs) play a key role in supporting electric vehicles with maintenance, charging, and battery management. This study seeks to identify variables in determining needs EVSC development, such as critical aspects: social, policy, infrastructure, and spatial. The Systematic Literature Review (SLR) method was used to examine current research trends on EVSC and its implementation in various locations. The study's findings are expected to provide recommendations for the construction of EV infrastructure that is more efficient, sustainable, and helps to accelerate the transition to environmentally friendly green cities. The findings of this study confirm that EVSCs play an important role in the electric vehicle ecosystem. The variables that need to be considered are supportive government regulations; strong economic strategies; efficient energy management; standardized technical characteristics; optimal accessibility; and understanding of user behavior. By focusing on critical aspects and using a data-driven and collaborative approach, EVSCs can help accelerate the adoption of electric vehicles and create a greener transportation future.

Keywords: EVSC, Electric vehicles, after-sales service, green transportation.

1 Introduction

Green transportation is difficult to achieve in cities where fossil fuel vehicles continue to dominate, contributing significantly to increased greenhouse gas emissions, climate change, and global warming [1]. Urban air pollution, which is primarily caused by vehicles, has a considerable negative influence on public health [2]. High reliance on fossil fuels also exposes us to oil price swings and energy insecurity, making the transition

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to clean and renewable energy sources crucial to ensuring energy security [3]. Despite these obstacles, advances in battery technology and electric motors provide increasingly affordable and efficient options [1]. As public awareness of environmental sustainability increases, the demand for eco-friendly transportation solutions continues to grow, marking the importance of electric vehicle adoption as a strategic step towards a more sustainable future.

Research on the development and administration of electric vehicles (EVs) indicates that the shift to renewable energy-based transportation is becoming increasingly essential, with a variety of techniques aimed at addressing technological and operational issues. Researchers agree that energy efficiency and EV battery management are critical to improving the sustainability of transportation systems [4, 5], as well as introducing innovations such as autonomous routing models for electric vehicles [6] and the use of solar energy as a charging power source [7]. Charging infrastructure is becoming vital in assuring the operation of electric vehicles, with some studies advocating the installation of fast charging stations on roads to boost driver convenience [4, 8].

Furthermore, research on hydrogen refueling infrastructure and fuel cell electric cars (FCEVs) highlight the necessity to establish a network of hydrogen refueling stations to support hydrogen-powered vehicles as FCEVs gain popularity [4]. Research on charging management, distribution, and pricing strategies demonstrates that proper management can lower energy costs, enhance efficiency, and promote societal adoption of electric vehicles. EVSCs are an essential component of the electric car ecosystem [8]. Establishing enough charging infrastructure can create a favorable atmosphere for the expansion of the electric vehicle sector. The importance of EVSCs can answer the main problem of EV owners, which is running out of power at diverse areas. An adequate supply of EVSCs will encourage more people to switch to electric vehicles. This will hasten the shift to more sustainable transportation.

Overall, the challenges faced by the electric vehicle industry are not only limited to the development of battery and charging technology, but also to the development of supporting infrastructure and increasing public confidence in the sustainability and efficiency of Electric vehicles [9]. EVCS is an integral part of the electric vehicle ecosystem. By establishing adequate charging infrastructure, it can create a conducive environment for the growth of the electric vehicle industry. The importance of EVCS can address EV owners' main concern of running out of power at various locations. Adequate availability of EVCS will encourage more people to switch to electric vehicles. This will accelerate the transition to more sustainable transportation. Furthermore, the development of charging infrastructure can create new jobs and boost local economic growth.

This research aims to review and analyze the development of research trends related to electric vehicles (EVs) and service stations based on open scientific publications, in order to understand the direction, scope, and scientific contributions that have been made in this field. Furthermore, considering the importance of EVSC, this research also identifies and formulates the main components that need to be considered in the planning and development of Electric Vehicle Service Center (EVSC), both from the technical, operational, infrastructure, and human resource needs aspects. Our research is expected to provide alternative recommendations for EVSC development using a systematic approach.

2 Literature Review

2.1 Sustainable and Green City

Sustainable and Green City refers to a balance of economic activity, population expansion, urban infrastructure development, and urbanization [10]. It is a response to cities' fast growth, which presents issues in terms of natural resources, air pollution, and climate change. Furthermore, the green city concept emphasizes the integration of environmental laws and practices such as renewable energy utilization, effective waste management, and sustainable mobility. These two fundamental aspects of green cities, reduced consumption and increased production, are critical in creating a more sustainable and pleasant urban environment for residents while also contributing to global efforts to combat climate change and conserve natural resources [11].

Investing in green and climate-resilient infrastructure, improving building energy efficiency, expanding access to clean energy, and supporting low-carbon transportation are all concrete examples of local climate action. To counteract the urban island effect, communities and cities can focus on sustainable waste management, local food production, and the enhancement of urban green spaces such as woods, parks, and gardens. For coastal cities, this could entail improving flood protection using levees, dikes, and seawalls, as well as planting mangrove ecosystems as buffers. These activities have the potential to significantly reduce emissions while also providing economic advantages to urban people and local economies [12].

Many cities have implemented Green City Transportation Projects to create a sustainable urban transportation network to meet people's growing travel needs, as well as to promote the development of urban social environments and economies, reduce transportation pressure, and reduce environmental pollution [13]. Green cities address a variety of complex and interdependent environmental issues, including climate change, biodiversity loss, pollution, and resource degradation. These difficulties necessitate prompt response at the urban level. It is critical to use innovative and comprehensive approaches to urban development that consider the social, environmental, and economic components [11].

2.2 Electric Vehicle Service Centre (EVSC)

The Electric Vehicle Service hub (EVSC) is an important support hub for the rapidly expanding electric vehicle ecosystem. The facility offers a variety of services, including electric vehicle maintenance and repair, battery replacement and recycling, and technical assistance to vehicle owners. Service center are electric vehicle testing, repair, fault analysis and maintenance. As the first link of the system, the after-sales service center functions to recycle scrapped power batteries. Consumers will send retired power batteries that have reached the end of their life to after-sales service. The service center has a fixed location [14].

The move to electric vehicle (EV) use is fundamentally altering the face of the automotive repair and service business. While this transformation creates new opportunities, such as lower maintenance costs and the need for specialized expertise in battery diagnostics and software, it also creates risks, such as the loss of jobs and specific parts [15]. The availability of EVSC is a crucial component of the industry, as it influences EV adoption. This is consistent with [16] research, which found that the qualities "Attitude towards Electric Vehicle Use" and "Subjective Norms" are crucial for electric car acceptance, while "Product and Service Attributes" and "Purchase Incentive Policies" have a substantial influence on adoption decisions. With EVSCs in place, consumers can gain quality assurance in electric vehicle maintenance, increase confidence in EV technology, and encourage wider adoption of green vehicles.

2.3 Electric Vehicle Service Centre (EVSC) in Jakarta

The issue of electric vehicles in Jakarta is a significant obstacle in realizing a sustainable transportation system, mainly due to the limited after-sales service infrastructure or EV service centers. Most conventional repair shops do not have sufficient technical understanding of EV technology, such as battery systems, electric motors, and charging, and lack competent tools and experts. This is exacerbated by the lack of certified human resources in the field of electric vehicles [17], as EV technician training has not been conducted massively and evenly. As a result, EV owners rely on manufacturer-authorized service centers or dealers, which are limited in number and not yet widespread throughout Jakarta, raising concerns regarding difficulty in accessing services, high costs [18], and long waiting times. In addition, the supply chain of EV parts is also unstable as it still relies on imports, leading to increased costs and delays in repairs [9]. These conditions reduce public confidence in EVs and slow down the adoption of electric vehicles in Jakarta, hence the need for a comprehensive strategy for the development of EV servicing infrastructure as an integral part of sustainable mobility policies in urban areas.

The exact number of Electric Vehicle (EV) Service Centers in Jakarta is difficult to determine as there is limited information available and not all EV service centers are openly publicized. However, here is some information that can give an idea of the availability of EV services in Jakarta:

1. Polytron EV has more than 50 service centers across Indonesia, with several of them located in Jakarta;
2. Wuling Motors has a service center in South Jakarta;
3. PLN UID Greater Jakarta has operated 84 Public Electric Vehicle Charging Stations and 41 Public Electric Vehicle Battery Swapping Stations in Jakarta;
4. Pertamina targets to operate 122 SPKLUs across Indonesia by 2024, with several of them located in Jakarta.

3 Research Methods

This study employs a qualitative approach using the Bibliometric Analysis and Systematic Literature Review (SLR) method. These two methods are considered appropriate to address two different problems. Bibliometric analysis is used to identify new trends in article and journal performance, collaboration patterns, and research elements, as well as to investigate the intellectual structure of specific topics in the current literature [19]. This method is relevant for the first research question, which seeks to map publication trends related to Electric Vehicles (EVs).

A systematic review aims to collect all relevant data that meets established eligibility criteria in order to answer particular research questions. This review employs explicit and systematic approaches to reduce bias in the identification, selection, synthesis, and summary of research. When performed correctly, this strategy yields accurate results for drawing conclusions and making judgments [20]. This method was used to answer the second research question, which was to explore the components in the development of EVSC.

This study uses scopus data sources using the following search keywords:

No	**Keywords**	**Findings**	**Analysis**
1	TITLE-ABS-KEY ("electric vehicle" AND "service centre") AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))	4	SLR
2	TITLE-ABS-KEY ("electric vehicle" AND "service station") AND PUBYEAR > 2020 AND PUBYEAR < 2025 AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (DOCTYPE , "ar"))	9	SLR
3	electric AND vehicle AND service AND station	3004	Bibliometric Analysis

Additionally, the boundaries for keyword searches are as follows:

Inclusion	• Open Access • Type Article Only • Published in 2021-2025
Exclusion	• Closed Access or Green Access, • Type Review, Book Chapter, etc • Not published between 2021-2025

The process of searching for scientific articles is documented through PRISMA:

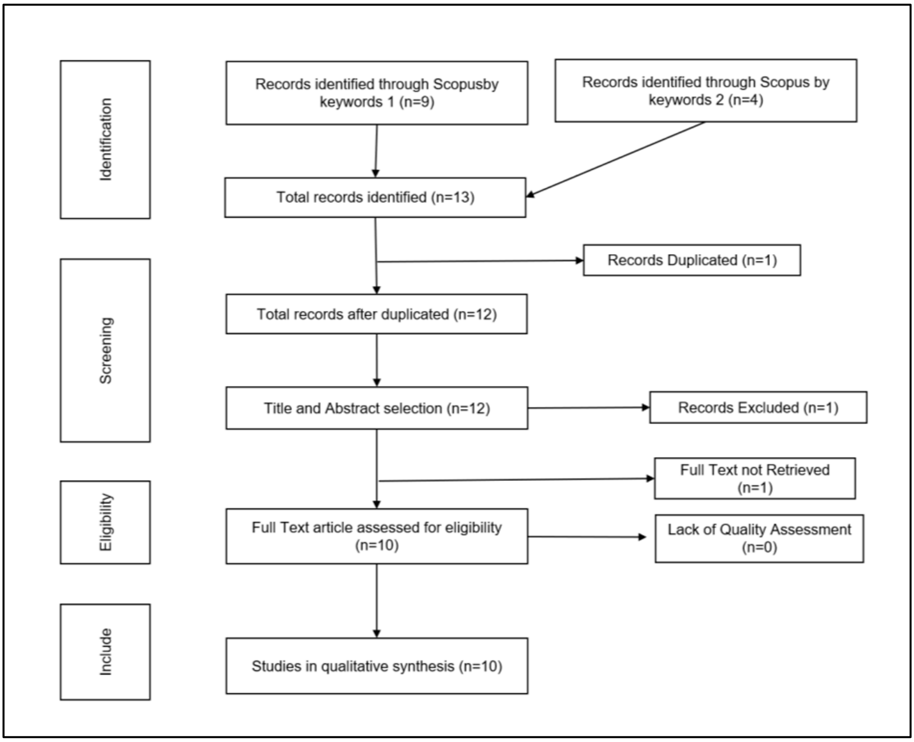

Fig. 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA)

According to the PRISMA scheme, 10 items were discovered to be synthesized. This study employs qualitative data analysis in the form of codification, which involves data gathering, data reduction, data presentation, and conclusion drafting. In the data reduction and presentation stage, the author use literature review procedures such as discovering similarities (compare) and finding differences (contrast) from 10 articles selected, then, presenting perspectives in results and findings stages, last is comparing (synthesize) and summarizing (summarize) in the discussion stages [21]. Finally, we mapping the component and its relations.

4 Results and Findings

Using Scopus data sources, 3004 research documents containing the keywords "electric AND vehicle AND service AND station" were discovered. A bibliometric analysis was performed using the vosviewer software to map keyword themes to relevant subjects.

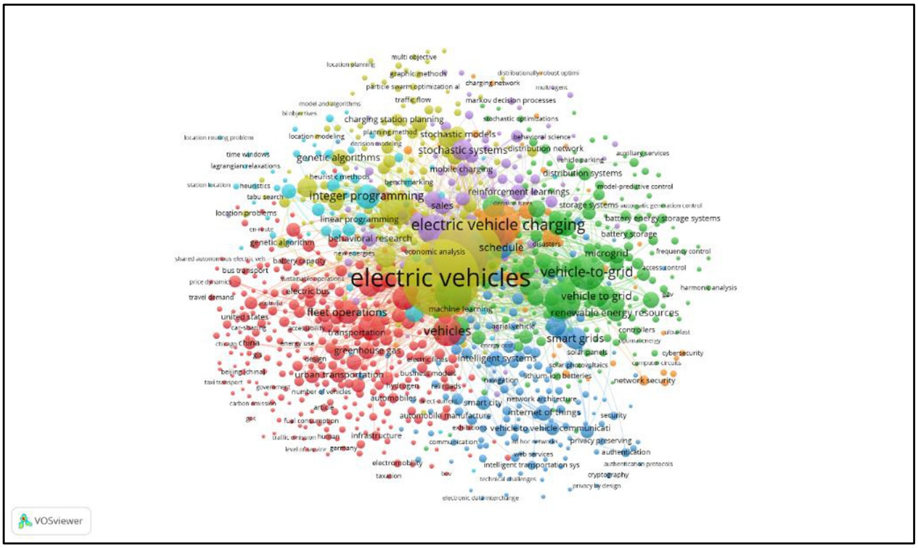

Fig. 2. Network Visualization

Based on the network visualization, 1,000 keywords were identified and grouped into eight groups, with a total of 70,605 connected networks. Each cluster has a distinct topic, represented by a different hue. The primary clusters include aspects of EV benefits in pollution reduction (Cluster 1 - red), battery management (Cluster 2 - green), technology utilization in smart grids (Cluster 3 - blue), charging infrastructure (Clusters 4 - yellow and 5 - purple), and battery linkage to travel routes (Cluster 6 - light blue). In addition, the study focused on charging speed and cost (Cluster 7 - Orange) as well as energy options including solar generation (Cluster 8 - Brown).

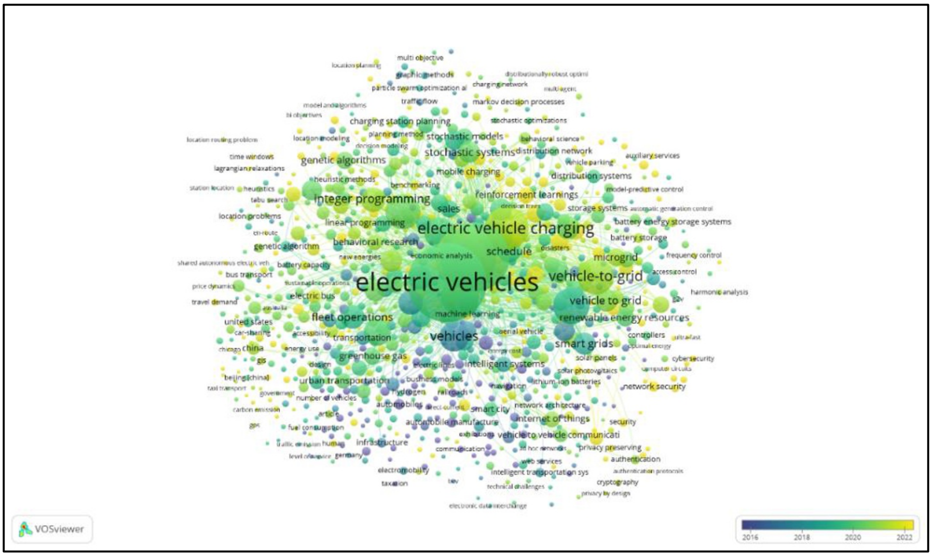

Fig. 3. Overlay Visualization

According to the overlay visualization, EV-related research has increased since 2016, with a primary focus on infrastructure and navigation. Over time, research has stressed the development of charging infrastructure [16], battery management [5. 18], and alternate charging techniques [7], particularly since 2022.

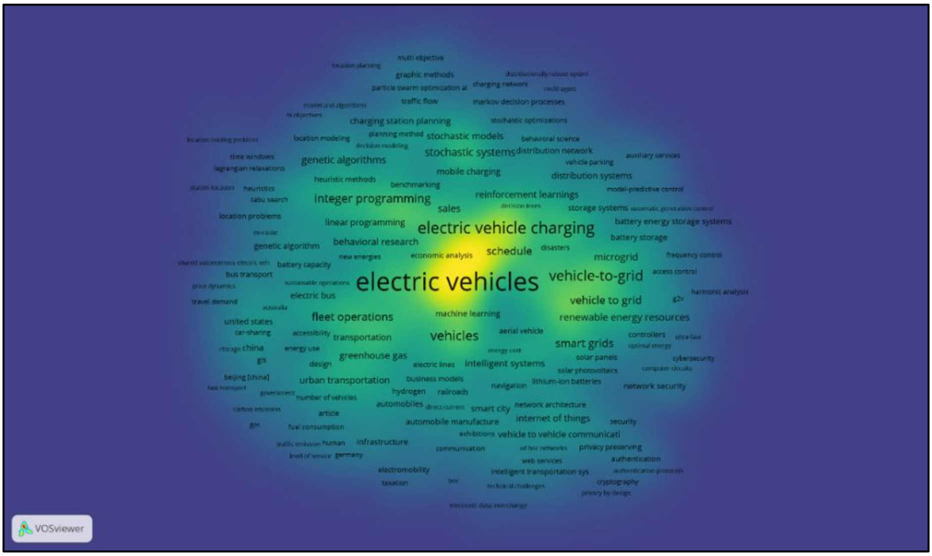

Fig. 4. Density Visualization

The density visualization study revealed that the most commonly discussed subjects were EV charging and alternative energy management solutions. However, the terms that came up did not particularly include service centers. The researcher then narrowed the terms to three relevant ones: service quality, service capacity, and service provider.

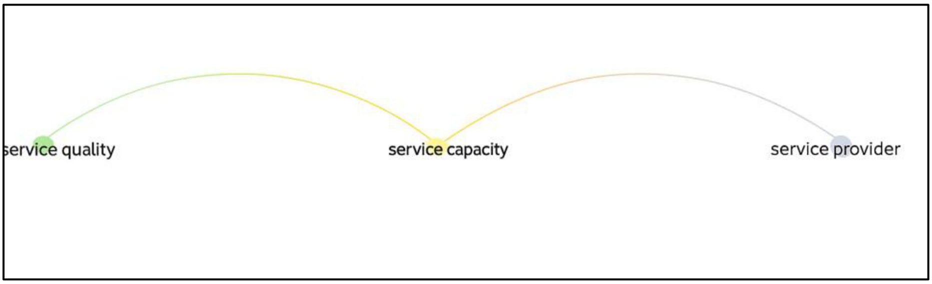

Fig. 5. Keywords Visualization

Service quality refers to charging stations that offer high-quality services for charging electric vehicles while incurring low costs for facility operators [22]. Furthermore, assessing the quality of service (QoS) evaluation difficulty for EV fast charging stations (FCSs) [14]. Meanwhile, service capacity refers to the ability of the EVSC or EVCS to provide services to EVs [23]. Furthermore, the service provider keyword refers to the presence of aggregators or charging service providers who can manage the charging of electric car fleets [24].

This bibliometric research demonstrates the complicated interplay of numerous elements that drive EVSC development. EVSC development necessitates thorough consideration of policy, economic, environmental, and technical factors. This is consistent with the study's aims, which focus on construction policies, critical factors, policies, and the supply chain. Furthermore, the challenges confronting the electric vehicle industry extend beyond the development of battery and charging technology to the development of supporting infrastructure and increasing public confidence in the sustainability and efficiency of electric vehicles [9].

The creation of an effective Electric Vehicle Service Center (EVSC) necessitates a thorough grasp of several interconnected variables. From government policies to user behavior, all factors contribute to the success of EVSCs. Based on an examination of ten selected publications, six major components of EVSC development were identified: 1) policy; 2) economy; 3) energy management; 4) technical aspects; 5) accessibility; and 6) user behavior.

Title	Authors	Policy	Economy	Energy	Technical	Spatial	Behaviors
AFARM: Anxiety-Free Autonomous Routing Model for Electric Vehicles with Dynamic Route Preferences	Ahmad Nahar Quttoum, Ayoub Alsarhan, Abidalrahman Moh'd, Mohammad Aljaidi, Ghassan Samara, Muteb Alshammari			v		v	
The photovoltaic potential for electric vehicle charging along highways: A Dutch case study	Jordi Peerlings, Angèle Reinders, Cristina Catita, Miguel Centeno Brito		v	v			
A Model for Electrifying Fire Ambulance Service Stations Considering Practical Service Data and Charging Strategies	Yih-Her Yan, Rong-Ceng Leou, and Chien-ChinKo	v			v	v	

Review of the Planning and Distribution Methodologies to Locate Hydrogen Infrastructure in the Territory	Agustín Álvarez Coomonte, Zacarías Grande Andrade, Rocio Porras Soriano and José Antonio Lozano Galant			v			
Integration of Distributed Generation and Plug-in Electric Vehicles on Power Distribution System by Using Queuing Theory	Anant Oonsivilai, Banyat Boribun, and Padej Pao-la-or				v		v
A Novel Model to Predict Electric Vehicle Rapid Charging Deployment on the UK Motorway Network	Keith Chamberlain and Salah Al Majeed	v				v	v
Analysis of Challenges for One Point Solution Study of Electric Vehicle Service Centre (EVSC) using Fuzzy– Methodology	Shabbiruddin, Dipanjan Ghose, and Sudeep Pradhan	v	v		v		v
Online Station Assignment for Electric Vehicle Battery Swapping	Pengcheng You		v	v		v	
Electromobility and Energy Transition in Cuba	Miguel Castro Fernández, Miriam Vilaragut Llanes and Jesus C. Hernandez	v	v	v	v		
Research on Optimization of Power Battery Recycling Logistics Network	Yanlin Zhao, Yuliang Wu		v			v	

Supportive Government Regulations
To operate efficiently and sustainably, Electric Vehicle Service Centers (EVSCs) require clear regulatory backing as well as a good economic strategy. A favorable policy environment is critical in stimulating investment in this area. Regulations governing energy rates, charging infrastructure development incentives, and electric vehicle safety requirements must all be carefully considered in order to build a stable and successful EV ecosystem [6, 8, 17]. Furthermore, measures that make licensing easier and provide fiscal support, such as subsidies or tax breaks, will speed up the adoption of electric vehicles and the growth of EVSCs in various regions. As done by Indonesia through Presidential Regulation No. 55 of 2019 and Ministerial Regulation of the Ministry of Home Affairs No. 6 of 2023.

Strong Economy Strategic
In terms of economics, precise cost calculations are required to assure the viability of EVSC operations. The costs of accessory acquisition, operations, and maintenance must be assessed correctly, including the potential return on investment for industry actors [9]. A clear and reasonable tariff structure for electric car charging and maintenance services is critical to balancing company success with consumer affordability. Furthermore, investment in sustainable systems is required to ensure the long-term profitability of EVSC operations [4]. With the correct regulations and economic strategies, EVSCs can help accelerate the transition to cleaner and greener transportation.

Efficient Energy Management
Efficient energy management is critical in Electric Vehicle Service Center (EVSC) operations. Good energy management entails understanding the quantity of energy used by electric vehicles as well as the total energy demand. According to [7] study, solar energy can charge more than 300 vehicles per day by combining bifacial PV noise barriers and standard mono-facial PV modules on publicly available land along highways in all three case studies, meeting 80% of the expected electric vehicle charging demand along highways in 2030. With the growing number of electric car users, power supply must be controlled properly to avoid excessive electricity load spikes [16]. Therefore, a substantial upgrade or deployment of fast charging infrastructure is required to encourage sufficient confidence in EV drivers [6].

Standardized Technical Characteristics
In terms of technical features, EVSCs must be able to provide efficient and standardized services for charging and maintaining electric vehicles. To support the long-term operation of electric vehicles, charging infrastructure and battery swapping systems must be reliable [18]. Furthermore, the quality of maintenance services, including the availability of spare parts and technician skill, must be constantly upgraded in order to best match consumer expectations [25]. However, one of the most significant problems in EVSC development is a lack of supporting industrial infrastructure [9], as well as an underutilization of technical training for personnel.

Optimal Accessibility
Strategic location is an important aspect in the success of Electric Vehicle Service Center (EVSC) operations. When determining the ideal site, consider the distance from the user's location [6], the distribution of electric vehicles in the area [26], and the service capacity that the service center can give [25]. The optimal location will improve user accessibility, reduce service time, and assure the long-term viability of EVSC operations. Furthermore, simplicity of service, such as infrastructure accessibility and the availability of supporting facilities, contributes to higher customer satisfaction and encourages more customers to migrate to electric vehicles [14].

Understanding of User Behaviors
To optimize service center operations, it is necessary to thoroughly understand user behavior when using EVSC services. Customers' arrival patterns and charging facility usage habits [27], vehicle maintenance [9, 17], and the average number of kilometers traveled by EV users [5, 8] should all be analyzed to better manage queues and provide service flexibility based on user needs. The traffic convenience factor around EVSCs is also a big concern, particularly in terms of minimizing congestion caused by queues of electric vehicles waiting to charge. Furthermore, the significant level of uncertainty in electric vehicle uptake and user habits is a problem for EVSC planning [9]. Variations in charging times [18, 27], and differences in customer needs [27] necessitate a flexible and data-driven management strategy. With the right approach, EVSCs can be an important element in driving the transition to a more sustainable and environmentally friendly transportation system.

The development of Electric Vehicle Service Centers (EVSC) is critical to the quest to achieve sustainable mobility. EVSC is more than simply a charging station for electric cars (EVs); it is also a key component in expediting the transition from fossil fuel vehicles to a more environmentally friendly transportation system. An effective EVSC will boost public trust in EVs, hastening their adoption as a future transportation solution. Adequate infrastructure, such as large charging stations and high-quality maintenance services, would boost the adoption of electric vehicles in a variety of industries.

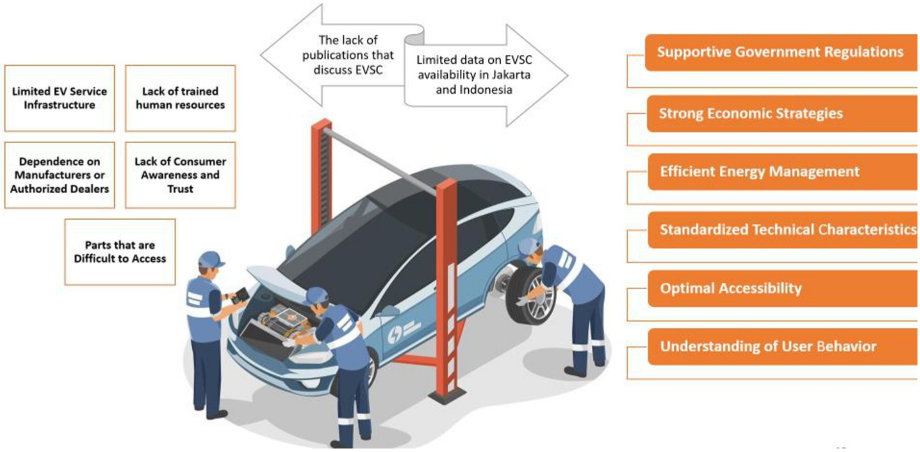

Fig. 6. Ecosystem in Developing Electric Vehicle Service Centers (EVSCs)

The authors highlights on the left, it illustrates major barriers such as limited EV service infrastructure, lack of trained human resources, reliance on manufacturers or authorized dealers, insufficient consumer awareness and trust, and the difficulty in accessing spare parts. It also points to a broader issue—the scarcity of academic publications and reliable data on the current state of EVSC availability in Jakarta and across Indonesia. On the right, the image presents essential components for building a successful EVSC ecosystem, including supportive government regulations, strong economic strategies, efficient energy management, standardized technical characteristics, optimal accessibility, and a deep understanding of user behavior. Together, these elements underscore the urgency for a comprehensive, multi-stakeholder approach to foster EVSC development and ensure sustainable electric mobility in urban settings.

Further study is required to improve service quality and assure the viability of EVSCs. More complex optimization models and algorithms can be created to improve energy distribution efficiency, increase the effectiveness of battery swapping systems, and reduce user wait times. Furthermore, advancements in charging technology, such as the development of ultra-fast or renewable energy-based charging systems, are critical in increasing the competitiveness of electric vehicles against fossil fuel vehicles. With a data-driven approach and ongoing research, EVSCs can become an essential component of a more efficient, dependable, and sustainable electric car ecosystem. By taking into account all of these factors, successful EVSC development can be realized, promoting greater use of electric vehicles and contributing to more sustainable transportation.

5 Conclusion

This study employs a qualitative approach using the Bibliometric Analysis and Systematic Literature Review (SLR) method. These two methods are considered appropriate to address two different problems. Bibliometric analysis is used to identify new trends in article and journal performance, collaboration patterns, and research elements, as well as to investigate the intellectual structure of specific topics in the current literature [19]. This method is relevant for the first research question, which seeks to map publication trends related to Electric Vehicles (EVs).

A systematic review aims to collect all relevant data that meets established eligibility criteria in order to answer particular research questions. This review employs explicit and systematic approaches to reduce bias in the identification, selection, synthesis, and summary of research. When performed correctly, this strategy yields accurate results for drawing conclusions and making judgments [20]. This method was used to answer the second research question, which was to explore the components in the development of EVSC. The adoption of electric vehicles (EVs) is a critical step in addressing climate change, air pollution, and fossil fuel dependence. Fossil fuel cars have had a substantial detrimental influence on the environment and public health, necessitating the adoption of clean and renewable energy as a vital answer to energy security and sustainability.

Electric car Service Centers (EVSCs) play a vital part in the electric car ecosystem. As the primary service facility, EVSCs offer maintenance, repair, battery replacement, and dependable charging infrastructure. The availability of competent EVSCs not only boosts public trust in EV technology, but it also promotes the adoption of electric vehicles and opens up new business prospects. Effective EVSC development must take into account a number of interconnected essential variables. The examination of ten articles revealed that these six components are critical in the construction of a successful EVSC infrastructure. Supportive government regulations, strong economic strategies, efficient energy management, standardized technical characteristics, optimal accessibility, understanding of user behavior, and ongoing research and development are critical components in developing a viable EVSC.

The effective development of EVSCs necessitates a holistic approach that includes tight collaboration among government, industry, academia, and the community. The use of data and continual research is critical for optimizing EVSC operations and improving services. Despite constraints such as a lack of supporting industrial infrastructure, a scarcity of qualified labor, and uncertainty about the adoption rate of electric vehicles, EVSC development nevertheless presents numerous prospects. In addition to providing new jobs, EVSCs have the ability to stimulate local economic growth and speed the transition to a greener, more sustainable transportation system.

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