

# The Relationship between Electric Vehicles and Smart Cities: A Literature Review

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**Abstract.** This literature review explores the interconnectedness of electric vehicles (EVs) and smart cities, focusing on sustainability and technological integration. The study examines infrastructure requirements, sustainable mobility applications, and the digital aspects of smart cities and EVs. It discusses the role of technologies like the Internet of Things (IoT) in facilitating EV integration, the implications of policy and economics on EV adoption, and the importance of urban planning and societal perspectives. The paper also highlights existing research gaps and the need for further exploration into the synergistic relationship between EVs and smart cities.

**Keywords:** Electric Vehicles; Smart Cities; Sustainability; Technological Integration; Infrastructure; Internet of Things (IoT); Urban Planning; Policy Implications; Economic Implications; Societal Perspectives.

## 1. Introduction

The modern world has brought about great concerns over sustainability and how to ensure that issues related to climate can be mitigated. Electric Vehicles (EVs) and Smart cities are progressing rapidly. While the focus on digital aspects of these technologies is significant, there is also a focus on ensuring that maximum sustainability can be achieved. As we strive towards creating urban environments that are increasingly efficient, climate-friendly, and tech-driven, understanding the relevance and application of EVs within the blueprint of Smart Cities has gained paramount limelight. The purpose of this literature review is to develop the connection between smart cities and EVs since these two are interlinked and have to be integrated within the future environment. Some of the areas that shall be the center of focus include infrastructure requirements, sustainable mobility, applications, and other aspects of digital technology. Furthermore, since humans are at the center of attention, the idea is to explore how the impacts of EVs and Smart cities would be eventually visible for humans and societies, especially considering the behavior of users. The more these technologies progress, the tighter the link that shall be eventually developed and that is where the significance of the study lies. An enhanced understanding of the various elements associated with progress would help researchers in the future uncover the intricacies of the topic.

## 2. Sustainability, Smart Cities, and Electric Vehicles

Sustainable areas of interest concerning these technologies is the way sustainable mobility shall be ensured. Considering both technologies separately at first, one can understand the eventual aims associated with these. Smart Cities are developed to ensure efficient operations within a city paired with improved living and overall optimization. This optimization reduces the overall carbon footprint and allows for a more breathable community. The case is similar with EVs where fossil fuel burning is minimized and reliance on alternate power generation is maximized. Combining the two, the study by Razmjoo and others (2021) highlights the imperativeness of EVs within smart cities. The goal of EVs is also to ensure much improved urban living paired with environmental safety. Smart cities, with their fundamental precepts of using technology and data to enhance livability, can play an instrumental role in facilitating this transition. Building on the topic of the integration of EVs in smart cities, Aymen and Mahmoudi (2019) elaborate on how the integration of the two concepts can be

achieved. While the inclusion of EVs is one thing, smart cities also rely on optimization and maximum efficiency, as highlighted before; in such cases, the inclusion of charging systems, smart grids, and the linking of renewable energy sources is pivotal when designing smart cities. The idea is to have a city that provides energy-feedback capabilities. The synergy that exists between these two technologies can thus pave the way for improved outcomes, especially concerning sustainability. The aim should be to have a seamless connection between the two within a more elaborate setup.

### **3. EV Provision in Smart Cities**

The designs associated with smart cities help to promote optimization and efficiency within its infrastructure, thereby requiring an upgrade to support EVs. The data gathered from different sensors allows overall improvement in the ways transportation and other services work. The study by Yi and others (2022) elaborates on how smart cities can adopt upgrades to their overall setup to successfully integrate EVs within them. The interlinked network of charging points, whether at residences, public centers, highways, or workspaces, forms the core of EV-specific infrastructure (Yi et al., 2022). Smart cities can facilitate this through digital connectivity, Internet of Things (IoT) tools, and data manipulation capabilities. As the primary source of hindrance could be charging stations, communication, control, and management of charging points hold immense significance in these circumstances. The study by Zhukovskiy and others (2019) elaborates on this connection and the way synergy is integrated within the setup. With the use of setups such as Vehicle-to-Grid (V2G), smart cities can provide two-dimensional support for EVs and smart grids. This ensures that the element of optimization remains and there is less overall power consumption. Thus, the development of a well-connected, accessible, and intelligent charging network for EVs is pivotal for their broader adoption.

### **4. Secondary Technology Integration**

It is important to note that while EVs are the central point of discussion in smart cities, their isolated integration is not possible to optimize the overall setup. There is a need to have a setup that combines different pieces of technology to form the entire network. IoT is one such technology that acts as the facilitator of real-time data sharing. The use of IoT has been highlighted by Raj and Appadurai (2022), specifically focusing on the context of EVs and their existence in smart cities. IoT devices are capable of providing features such as monitoring and management of EV charging as per the study. The outcome is that overall range anxiety among users is minimized drastically. However, it is not only about charging but other aspects as well such as detection, navigation, and others that tend to surface. Thus, an entire network of features is formulated. Similarly, as highlighted by Lotfi and others (2022), these devices can leverage data collected from numerous sensors, optimize traffic flows, minimize congestion, and improve overall energy efficiency in a city teeming with EVs. At the same time, one cannot be complacent about the storage, sharing, and communication of huge quantities of data. For this purpose, it is best to utilize cloud platforms in order to enhance overall support. This allows the development of a wireless setup in an already technology-oriented environment. The outcome is a seamless interconnection of devices that ubiquitously work together. Therefore, the connection between EVs and Smart Cities is enhanced through technological advancement designed to ensure efficient operation and user convenience.

### **5. Policy and Economic Implications**

While installation and maintenance of the entire EV and smart city setup is one thing, having the essential resources to manage it is another. This is where economics and policies come into play. Studies conducted by many experts focus on proper government-related policies and fiscal management as a way to ensure EV integration. The study by Brückmann and Bernauer (2020) elaborates that these measures might encompass subsidies on EV purchases, reduced taxes, or preferential access to city centers. Furthermore, researchers like Anthony Jnr (2021) have focused on the aspect of implementation, for example, questioning how implementing such policies can be

streamlined within a Smart City framework. This is because it is like an environment where digital solutions like blockchain can be used for the transparent and effective execution of incentive schemes. The economic perspective also underscores the significant changes to energy markets with wider EV adoption, resulting in reduced dependence on the conventional oil industry, and opening avenues for green job creation and a renewed energy market focused more on electricity. Hence, the synergy between EVs and Smart Cities is not only marked by technological symbiosis but also interlinked on policy and economic playing fields.

## **6. Design Strategies of Smart Cities**

The design of a smart city is vital as it is the basis of an efficient infrastructure to maximize the capabilities of the connected devices. With an increased adoption of EVs within smart cities, the role of redesign would become pivotal, and planning considerations would have to be changed. As per Danese and others (2022), the need for parking areas, charging stations, and designated lanes would require a redesign. Similarly, the smart grid setup would need an upgrade to maximize its charging capabilities through a sustainable power source. Therefore, as highlighted by Lotfi and others (2022), accommodating growth in EV adoption should be factored into the planning stages. Since the focus would be on renewable energy, energy generation capabilities and storage would also need to increase. Thus, the relationship between EVs and Smart Cities is also manifested through urban planning and design adaptations. Such strategic planning transforms cities into more sustainable, adaptable, and innovative ecosystems that can accommodate future growth and technological advancements.

## **7. Social Perspective**

The role of user behavior and societal perceptions regarding this change is pivotal. Currently, people have mixed opinions about the role of EVs, especially with regard to their safety. According to Shahzad and others (2021), user acceptance of the proposed technology is one factor that should be considered in integrating it into the current setup. The overall outcome may not be favorable or profitable enough for authorities if it does not receive support from most citizens. Other factors that also need to be considered to ensure acceptance include the vehicle's driving range, charging infrastructure accessibility, cost of ownership, and environmental benefits which play an essential role in determining the rate of EV adoption. Smart Cities can help alleviate some of these concerns through real-time data dissemination on charging point locations and traffic status and providing digital platforms for easy accessibility to information. Secondly, as highlighted in a study by Apata and others (2023), the deployment of secure devices to the physical network infrastructure will also improve security measures like cryptography. One should mention here that such factors as noted above trickle down even towards issues of public transportation and car-sharing services. The study by Radakovic and others (2022) concentrates on these dimensions of transportation depending upon shared ride services and public transportation. By setting up these programs, shared EVs can be booked via mobile apps. Such can also be considered to be effective as people's confidence in EVs is boosted and it also demonstrates whether EVs are capable of providing people with mass transit service. In addition, the endeavor towards a smart city objective is renewable and sustainable as resources are maximally utilized. Therefore, shaping user behavior will also have an effect on determining how EVs interact with Smart Cities whereby such is influenced both by technical solutions as well as strategic city planning.

A comparative analysis of various case studies affords useful insights into understanding the intricacies of incorporating EVs into the Smart City paradigm. Several cities worldwide have made great strides here and every city does so in a unique context such as the geographic, demographic, or economic circumstances they are embedded in. As highlighted by Suravi (2021), an example of Amsterdam can be taken. The area has a charging point network, filled with provisions such as a dynamic pricing model for convenience. People can thus use these facilities in an effective and efficient manner. Additionally, Shenzhen in China has focused on a public transport model. As a city

that can be considered a model for a smart city, it provides a means of understanding the integration of EVs, paired with an understanding of challenges and opportunities that may exist. Therefore, these different examples crystallize the versatility of Smart City strategies and the role of EVs as a sustainable mobility solution in various global contexts.

## 8. Existing Gaps

The relative unfamiliarity of the experts to the future potential of EVs and smart cities tends to leave gaps in research. The issue of focusing on individual EV usage and not overall public usage is a major problem. This is a prime opportunity to develop a thriving public transportation infrastructure. The outcomes are clear that there can be an even lower carbon footprint overall. Additionally, as highlighted by Vilathgamuwa and others (2022), research on the impact of integrating EVs and renewable energy sources within smart cities remains limited. Meanwhile, as the large-scale deployment of EVs in smart cities has not been tested, there is a concern about the overall load that the systems may be able to manage. Since many devices like IoT have limited overall storage and processing, large-scale data is something that needs to be addressed. IoTs have limited potential in terms of storage and processing currently. As highlighted by Sodiq and others (2019), since IoT devices also have limited protection capabilities in terms of encryption, security concerns are significant. Hacking of such systems can lead to major road incidents that can lead to major loss of life. The study by John (2020) has elaborated on the potential reasons that can further aggravate the matter. EVs and Automatic Vehicles (AVs) can be linked directly. EV technology has paved the way for the formation of AVs that can auto-drive and navigate easily. However, as per the study by Blanco (2019), the confidence rate in EVs is close to 50 percent while the percentage is in the 30s for AVs. Such low rates of confidence have been associated with charge wait times, security, and other such problems. Thus, unless these changes are introduced within the larger context of these technologies, their deployment might not be so smooth within the dynamics of the smart city. The future direction of research in this domain can thus focus on these niche areas to ensure a smoother integration of EVs within the smart city framework. This pressing needs to bridge the gaps in current understanding and approach further underlines the intricate and evolving relationship between EVs and Smart Cities.

## 9. Conclusion

In conclusion, the link between EVs and smart cities does exist and there is a need to better research this avenue to explore the potential outcomes in the future. Smart cities and EVs both rely on sustainability and efficiency improvement with greater emphasis on renewable energy. However, the inclusion of EVs within the smart city setup cannot be executed unless there are major changes to the infrastructure and planning so that EVs and other supporting technologies can be easily integrated. The two paradigms feed into each other, merging into a comprehensive push toward an environmentally friendly, technologically advanced, efficient, and sustainable urban future. While there are increasing concerns over climate change, the combination of the two technologies can pave the way for a compelling solution that can bring down the damage being done. However, it must be noted that there do exist challenges within such integration that have to be resolved. Issues like security, setup change, and other economic issues can be thrown into the mix. Therefore, a proactive approach becomes pivotal to overcoming the stresses that are associated with the change, especially with the help of the relevant authorities.

## References

- [1] Anthony Jnr, B. (2021). Integrating electric vehicles to achieve sustainable energy as a service business model in smart cities. *Frontiers in Sustainable Cities*, 3, 685716.
- [2] Apata, O., Bokoro, P. N., & Sharma, G. (2023). The risks and challenges of electric vehicle integration into smart cities. *Energies*, 16(14), 5274.
- [3] Aymen, F., & Mahmoudi, C. (2019). A novel energy optimization approach for electrical vehicles in a smart city. *Energies*, 12(5), 929.

- [4] Blanco, S. (2019). Consumer Confidence In Self-Driving And Electric Vehicles Needs Some Work. *Forbes*. <https://www.forbes.com/sites/sebastianblanco/2019/07/30/study-consumers-not-exactly-confident-about-autonomous-electric-vehicles/>
- [5] Brückmann, G., & Bernauer, T. (2020). What drives public support for policies to enhance electric vehicle adoption? *Environmental Research Letters*, 15(9), 094002.
- [6] Danese, A., Torsæter, B. N., Sumper, A., & Garau, M. (2022). Planning of high-power charging stations for electric vehicles: A review. *Applied Sciences*, 12(7), 3214.
- [7] Fantin Irudaya Raj, E., & Appadurai, M. (2022). Internet of things-based smart transportation system for smart cities. In *Intelligent Systems for Social Good: Theory and Practice* (pp. 39–50). Springer.
- [8] Lotfi, M., Almeida, T., Javadi, M. S., Osório, G. J., Monteiro, C., & Catalão, J. P. (2022). Coordinating energy management systems in smart cities with electric vehicles. *Applied Energy*, 307, 118241.
- [9] Radakovic, D., Singh, A., Varde, A. S., & Lal, P. (2022). Enriching Smart Cities by Optimizing Electric Vehicle Ride-Sharing through Game Theory. 2022 IEEE 34th International Conference on Tools with Artificial Intelligence (ICTAI), 755–759.
- [10] Razmjoo, A., Nezhad, M. M., Kaigutha, L. G., Marzband, M., Mirjalili, S., Pazhoohesh, M., Memon, S., Ehyaei, M. A., & Piras, G. (2021). Investigating smart city development based on green buildings, electrical vehicles and feasible indicators. *Sustainability*, 13(14), 7808.
- [11] Shahzad, F., Javed, A. R., Zikria, Y. B., Rehman, S., & Jalil, Z. (2021). Future smart cities: Requirements, emerging technologies, applications, challenges, and future aspects. *TechRxiv*.
- [12] Sodiq, A., Baloch, A. A., Khan, S. A., Sezer, N., Mahmoud, S., Jama, M., & Abdelaal, A. (2019). Towards modern sustainable cities: Review of sustainability principles and trends. *Journal of Cleaner Production*, 227, 972–1001.
- [13] Suravi, R. H. (2021). *EV Friendly Cities: A Comparison of Policy and Infrastructure in Sixteen Global Cities*. University of Washington.
- [14] Vilathgamuwa, M., Mishra, Y., Yigitcanlar, T., Bhaskar, A., & Wilson, C. (2022). Mobile-Energy-as-a-Service (MEaaS): Sustainable Electromobility via integrated Energy–Transport–urban infrastructure. *Sustainability*, 14(5), 2796.
- [15] Yi, Z., Liu, X. C., & Wei, R. (2022). Electric vehicle demand estimation and charging station allocation using urban informatics. *Transportation Research Part D: Transport and Environment*, 106, 103264.
- [16] Zhukovskiy, Y. L., Suslikov, P. K., Russkih, N. I., & Korolev, N. A. (2019). The use of vehicle-to-grid technology for the integration of electric vehicles in the power system of the city. *Journal of Physics: Conference Series*, 1333(6), 062032.