SMART PARKING MANAGEMENT FOR ELECTRICAL VEHICLES: SOLAR PARKING LOTS

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ABSTRACT:

Urban population growth, which is associated with a growing prevalence of private car usage, contributes to various contemporary urban issues, including air pollution and fuel costs. The shift of the transportation industry from internal combustion engines to electric vehicles is internationally recognised as an option for addressing these problems and making progress towards more sustainable transport. Makers of electric vehicles have considered many needs of their customers, including locating suitable parking spaces and charging stations. Currently, charging locations and parking spaces can be found with the help of methods based on human intelligence. However, the development of solar parking lots using smart management system is a revolutionary step in this regard, as it provides an optimal solution to internet of things-based (IoT-Based) parking spaces and locating a charging station for electric vehicles. This paper outlines the concept of Eco-parking platforms and discusses their potential implementation in cities. The outcome of this research can inform urban planners and entrepreneurs about how to implement this project and achieve sustainable transport.

1. INTRODUCTION

Population growth and urban sprawl have become critical challenges in many countries, as they have been shown to escalate both travel distance and private car use (Giles-Corti et al., 2016). Continued car dependency is expected to result in negative environmental impacts, including threats to the survival of urban flora and fauna and increased greenhouse gas emissions (Giles-Corti et al., 2016; Lucas & Jones, 2012; Mohan et al., 1999) Overlooking such issues related to car dependency could seriously threaten public health, the environment and quality of human life.

Responding to these urban challenges, urban planners have recognised the need for a transition from internal combustion engines (ICEs) to electric vehicles (EVs) (Das et al., 2020; Harper et al., 2019; Li et al., 2019). EVs consume less energy by providing environmentally friendly modes of travel. Although EVs have the advantage of addressing car issues, maintaining and enhancing the use of EVs remains challenging because of their limited mileage range and the availability of charging stations. Currently, studies including Currently, some studies including Masmoudi et al. (2014), Mufaqih et al. (2020), and Dhaou et al. (2018) have focused on parking management using technology such as IoT, GPS, parking sensors and smart cameras, while others such as Ghotge et al. (2020), Liu et al. (2021) and Jiang and Zhen (2019) have contributed to EV charging scheduling problem. Thus, this research contributes the body of knowledge by introduction a platform combining parking management system and EV charging by developing an Eco-parking platform that provides an optimal solution for parking lots finding and the locations of charging stations for electric vehicles. Implementing Eco-parking platforms enhances EV use in smart cities toward more sustainable transport. The remainder of the paper is structured as follows: a literature review of EVs and smart cities is presented next. The Eco-parking platform and its mobile application architecture are then discussed before the research is concluded.

2. LITERATURE REVIEW

In the past few years, EVs have revolutionised the transportation industry for all kinds of vehicles, including both lightweight and heavyweight automobiles. Almost every aspect of the EV system is impactful to the extent that it has led research and development to the innovation of special kinds of batteries, charging stations and even engines. There are many reasons behind the adoption of EVs instead of ICEs. First, excessive pollution caused by ICEs gave birth to the need for an EV-type system. Another reason behind the transition to EVs is the faster depletion of fossil fuels with ICEs. Moreover, EVs have economic benefits, as they cost less to run compared to ICE vehicles.

Drawing on the reasons mentioned above for shifting to EVs and applying government regulations, many major heavyweight vehicle industries have already started shifting towards producing environmentally friendly EVs. However, establishing a more efficient system of EVs and newly developed charging stations for a successful ICE-to-EV shift will not result in a smarter system overall because smart user-friendly assistance for EV customers is also needed to find optimally located charging services. Kukkala et al. (2018) investigated autonomous vehicles by conducting a survey of several vision recognition-based advanced driver assistant systems (ADAS) and elaborated the way forward for the next generation of ADAS in autonomous vehicles. Nowadays, many researchers are investigating driver-assistance-based systems to design smarter vehicles for consumers. However, no one so far has designed an optimal system for locating a charging station that caters to vehicle constraints while considering the user's requirements. Rastogi et al. (2019) investigated multiple types of battery technologies normally used in EVs and their influence on different factors that formulate an efficient EV system—for instance, time to charge and life of battery. Nevertheless, the batteries can be standardised based on the government and international industrial laws, so the major concern is to design an assistance system instead of technology that is operated on the batteries. The global economy is rapidly heading towards smart technologies such as ambient assisted living, IoT in smart cities, etc. due to which the usage of the traditional methods that are adopted for locating a charging station has extremely reduced. Overlooking such issues related to finding parking spaces and charging stations could seriously threaten the use of EVs.

2.1 Parking management

Finding a suitable parking space in densely populated areas has become a critical challenge for EV users due to limited space and high demand for parking. An effect parking management for key urban destinations such as malls, hospitals or university is significant factor for commuters to enhance accessibility to these destinations. A project conducted by Dhaou et al. (2018) to improve parking management and to increase parking lot occupancy using IoT and sensor for car detection. Also, a project conducted by Cynthia et al. (2018) has proposed IoT based smart parking management system using an infrared (IR) sensor to find vacant slot dealing with main downsides of parking space detection systems such as low accuracy, light and weather condition. Cynthia et al. (2018) believe that smart parking management system should integrate several physical devices such as IR sensors, WIFI facility and Global Positioning System (GPS), to check the parking slot availability. Mufaqih et al. (2020) has developed smart parking management system to deal with limited parking space at commercial locations in Jakarta, Indonesia. The project uses online booking system, cashless payments, paperless ticket, and automated guided parking. The booking system gives users the ability to find available parking slot, even before they arrive and with electronic ticket, which will reduce the likelihood of missing the ticket. Cashless payment also will improve the payment process while automated guided parking navigates the clients to unoccupied parking slot without any delay. Suryady et al. (2014) gate management should be included within any smart parking management system as it reduces traffic congestion at parking lots and increases parking lot efficiency. Bluetooth technology has been introduced by Orrie et al. (2015) to enhance parking management efficiency. The study has outlined aWSN based parking management system, which includes smartphone application and wireless sensors. Car can be navigated to the vacant parking lots using smartphone application, Wi-Fi and Bluetooth connectivity. Smart parking management based on Bluetooth technology utilizes an automatic mechanical system-based valet parking service transporting cars to the vacant space and retrieves them to the user without any human intervention (Fahim et al., 2021). Bluetooth technology usually is used in a smart parking area with automated valet parking system to automate and transport cars the vacant parking space (Lewandowski et al., 2018). Masmoudi et al. (2014) believe that a vision-based vacant parking space detection method is the most system in outdoor parking area that can detect real-time parking lot occupancy rate and send available parking locations to the users. Amato et al. (2017) Add that real-time lot occupancy can be detected by smart cameras using deep Convolutional Neural Network (CNN) method comparing visual datasets with store datasets. Wan et al. (2017) highlight that many parking management system have been field to deal with the Crowdedness in parking area which cost time for drivers to find a suitable parking. To overcome this this limitation, Wan et al. (2017) suggest parking Crowdedness management system using Crowd-sensing and smartphone sensors and applications gathering Crowdedness level at parking lot.

The aforementioned studies have developed parking management methods to make finding vacant parking more efficient. However, Mufaqih et al. (2020), Lewandowski et al. (2018), Cynthia et al. (2018), Orrie et al. (2015) and Masmoudi et al. (2014) have developed their methods to suite ICE vehicles, while EVs have a limitation which is the charging process. EVs need a parking space equipped with electrical charger to deal with charging time issue for EVs that may takes up to an hour to be fully charged.

2.2 Electrical car and charging stations

The global trend developed as urban strategies which are developed for solving the challenges that are occurred due to a dense population to leverage high technology and innovation and to recover the quality of the inhabitants living in the urban areas is said to be the smart city (Desdemoustier et al., 2019; Lucas & Jones, 2012; Pour et al., 2020). It is used for diversifying several public initiatives including the knowledge that is required to design the policies for energy-saving, and from the development of improved transportation systems to endorsing creative innovation. It is also helpful in resolving the problems related to urbanisation which involves challenges in the assessment of public initiatives, energy needs, congestion in the transportation system, urban sprawl, consumption of land and environmental pollution (Cox et al., 2018; Ferreira et al., 2019).

Electromobility is known for being the term in automotive technology which is most commonly discussed. Moving to a more sustainable transport mode is expected to result from an expansion of electric vehicle use, increasing demands on constructing a network that will be sufficient for charging stations. This is the reason that combining renewable power sources with the infrastructures that are emerging nowadays is beneficial. An example of this can be the energy that is produced by the sun with accumulation possibilities and subsequently delivering it to the charging stations. In the case of an increase in the number of operators of electric vehicles, the range of cars working operating a particular area and allowing the occasional crossing of the vehicles at a medium speed which is generally about 300km must be ensured (Eisenmann et al., 2019; Moreno et al., 2018). This is because the development of a dense network that is sufficient for the charging stations is necessary. This requires the deployment of charging stations along major roads and within key regional destinations such as hospitals, universities, and malls within a maximum of 50-60 km (Moreno et al., 2018).

The phenomenon of the smart city has been developed due to some crucial challenges including gaining political support from the global institutions like OECD, European Union and the United Nations, reducing the pressures from the environment, knowledge related to the economy, establishment of innovative devices and progress in technology (Eremia et al., 2017; Winkowska et al., 2019). Creation and consolidation of innovation and knowledge are said to be the specific characters of a smart city (Badii et al., 2019; Desdemoustier et al., 2019; Menouar et al., 2017; Yan et al., 2020). Drawing on the smart cities concept, the infrastructure for EVs should be implemented and managed smartly and sustainably, giving the advantage of using EVs over ICEs across our smart cities.

Number of research overcomes with this issue by introducing EV charging scheduling system. Jiang and Zhen (2019) have the proposed a charging strategy that can effectively improve the integrating energy storage system (ESS) and photovoltaic (PV) system to reduce the electricity cost of operators. Ghotge et al. (2020) have also introduced Model Predictive Control (MPC) to reduce the peak electricity demand at an EV parking lot. The model using smart charging strategy taking the uncertainty related to future EV charging demands into account, in terms of the timing of the EV arrival as well as the magnitude of energy demand. Liu et al. (2021) believe that limited number of chargers within any station can affect charging cost and time. The bilevel programming (BP) model that proposed by Liu et al. (2021) overcome this issue providing optimal solution for EV charging scheduling. However, models introduced by Liu et al. (2021), Ghotge et al. (2020) and Jiang and Zhen (2019) have limited ability to deal with parking management problem.

To overcome with parking management and EV charging scheduling limitations, this paper presents the potential of implementing the Eco-parking platform and outline the main challenges that may affect this system's success. The outcome of this research can inform urban planners and entrepreneurs to implement this project towards sustainable transport.

3. ECO-PARKING ARCHTECTURE

The proposed Eco-parking is shown in Figure 1 outlines the key components of the project including parking spaces, data centre, mobile application and EVs. Public parking spaces available in major urban destinations, such as hospitals, universities and malls, are equipped with an electrical charging station for EVs, and these stations get electrical power from solar panels designed and installed as car parking shades. The second part of the concept is related to EVs and drivers aiming to connect EVs to the nearest Eco-parking stations to their destination. Suitable Eco-parking will be suggested by mobile applications based on the input information, including car location, remaining power in the car and parking space availability. The mobile application uses a global positioning system (GPS) to locate the car and a data centre to identify a free parking space and connect with the car to determine the remaining electrical power. The software will book the parking space for the car before it comes to ensure a smooth charging experience. If there is limited parking space, the system will send a warning notification calculating the distance for the best parking space location for the car. The classification of Eco-parking will be based upon the type of charging power, the number of available parking spaces and the size of the regional destination. This classification can determine the hierarchy of Eco-parking as either main or secondary parking.

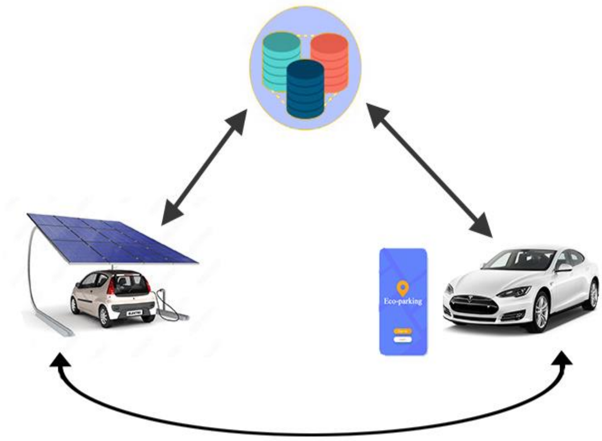

Figure 1. The architecture of Eco-parking

Application Architecture of the Proposed Eco-parking System
Eco-parking applications for end users allow them to register their cars in the system and to browse the history of past transactions to visualise all parking spaces administrated by the parking operator (Figure 2). It is also possible to search for the nearest parking space, given the current GPS location or an address of interest. The application shows the available parking space with the distance that the EV is able to reach using the remaining electrical power in the battery. The occupancy percentage of each parking space is also shown in the mobile application, determining the level of occupancy. When the parking is selected from the map, the required charging time, and the price, then the driver can book their parking space using the application before they arrive. The application can then navigate the EV to the booked parking space using GPS technology. Finally, the mobile application monitors battery consumption, driving behaviour and location of Eco-parking, suggesting several Eco-parking spaces nearby when the remaining charge in the EV is less than 30%.

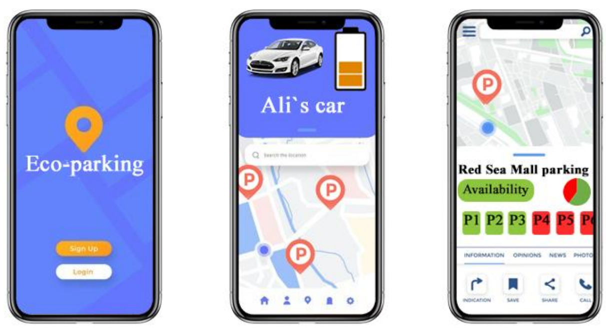

Figure 2. Application Interface of the Eco-parking System

A comparison is made between Eco-parking platforms and other solutions dealing with EV issues, such as charging location apps and solar charging stations, in Table 1. The first solution proposed to deal with PV charging issues is developing an application, such as PlugShare, to find the nearest charging stations (Eltoumi et al., 2021; Wolbertus et al., 2021). This idea has the advantage of showing the nearest charging locations, but it does not book the station for the car, making finding a free station difficult. Travelling from one station to another to find a free station may draw users away from using this application, so that they charge their car at home. The second idea related to using solar power as a main source for electrical power is making this station sustainable. This idea creates zero pollution, as it uses renewable energy, but it shares the same problem with other electrical stations: availability. Ghotge et al. (2020) have introduced Model Predictive Control (MPC) based smart charging strategy to manage scheduling system for EV using solar charging stations. The aim of this project is to reduce the peak electricity demand at an EV parking lot with photovoltaic arrays. Eco-parking overcomes this issue by using artificial intelligence to find the nearest parking space equipped with a charger based on EV location, remaining power and final destination. The platform uses AI that calculates and compares travel distance to different parking locations to recommend the shortest and the most efficient route for the driver. This calculation employed network analysis using travel cost (distance and traffic congestion), number of available parking, remaining power, GPS and number of traffic light. It then reserves the space for the car using the Eco-parking mobile application (Figure 2). The last possible solution is parking space-finding applications, such as Best Parking and Parker. This idea has the advantage of showing the available parking spaces nearby, but it has a problem with showing available charging location in real time and the ability to reserve the parking space for the car before it arrives.

	Eco-parking	Charging apps*	Solar station**	Parking management***
Time consumption (time to get to the charger)	Low	High	High	Low
Availability of parking spaces	High	Medium	Medium	Low
Pollution (as it uses stationary energy)	Zero (uses solar energy)	Medium	Zero (when solar energy is used)	Medium

* EVs' charging apps aim to fine nearest charging location such as PlugShare
** Solar parking lots provide electrical energy using solar panels as main energy sources and some station combined both power grid and solar panels see Ghotge et al. (2020).
*** Parking management apps such as Best Parking and Parker aim to managing parking lots, minimizing parking finding time and limiting ticket purchasing process.

Table 1.Comparison between Eco-parking and other cases

4. PROJECT IMPLEMENTATION

The implementation of eco-parking is mainly driven by the cooperation between public and private partnerships. Each sector has a significant role to play in delivering the project (Figure 3). The public sector has the role of developing public polices to attract investment in eco-parking by making public parking available near public facilities. In Saudi Arabia, municipalities and local sub-municipalities need to attract investment in public parking to enhance the quality of the transport systems in the city, which is the backbone for strong economic growth. The capital expenditure costs should be funded in full either by the government or through private financing (debt and equity). The government may decide to provide direct support for parking lots through subsidies, grants, equity investment or debt. These mechanisms are particularly helpful for public facilities where the projects unable to achieve financial viability or they are subject to specific risks that the private investors unwilling to manage. Government funding support can be as direct financial support to procure land, defray construction costs, provide assets, or support major maintenance. Waiving fees is another form of governmental support, which the costs and other payments must be paid by the parking lot owners to a public sector entity.

On the other hand, the private sector should move from traditional investment opportunities to invest in smart and innovative ideas that make our cities smarter. Entrepreneurs and businessmen need to discover the potential in investing in new technology and innovative ideas, which are the future of our cites. Private sector should develop and manage the platform connect EV owner with parking lots. Investors should install solar panels and charging stations at public parking are next to key urban destinations such malls, hospitals and educations institutes. Developing Eco-parking mobile application and website are also driven by private sectors taking the responsibility for parking management and financial system.

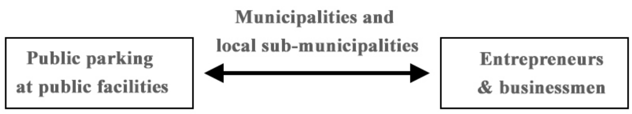

Figure 3. Eco-parking stakeholders

Policy	Stakeholder
Building public parking spaces	The owners of public facilities (mall, hospital or university)
Installing solar panels Installing charging stations Developing Eco-parking mobile application and website Eco-parking management	Entrepreneurs and businessmen
Determining the location of public parking available for investment	Municipalities and local sub-municipalities

Table 2. Policy implementation for Eco-parking

5. CONCLUSION

The main purpose of this research is to introduce an innovative solution for dealing with the two main challenges of using EVs: the limited mileage range and the availability of charging stations. The innovated part of this platform is combining parking management with EV charging scheduling to provides an optimal solution to IoT-based parking spaces and locating a charging station for electric vehicles. IoT can connect all devices are with one another through the internet. These devices can be parking sensors, mechanical gate devices, EVs, car owners and data storage units, which either connected through a wired connection or through a wireless connection. IoT can

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transfer data such as parking location, vacancy rate and remaining charging and routing to the nearest parking lots without human interaction (Abdulkader et al., 2018; Yang et al., 2012).

Implementing Eco-parking platforms enhances the use of EVs in smart cities and creates more sustainable transport. The corroboration between private and public sectors is critical to achieve this project. The government needs to provide a financial support through subsidies, grants, equity investment, waiving governmental fees or debt. While private investors should develop and manage the platform connect EV owner with parking lots using advance technology such as mobile application, parking sensors, online purchasing system, global positioning system techniques and online storage data system. This makes the function of finding appropriate parking spaces equipped with charging smarter and more sustainable, leading to a smart city.

Currently, many newly developed ideas deal with problems related to EV use, such as using charging location apps, parking management projects and solar charging stations. Studies including Masmoudi et al. (2014), Mufaqih et al. (2020), and Dhaou et al. (2018) have focused on parking management using technology such as IoT, GPS, parking sensors and smart cameras, while others such as Ghotge et al. (2020), Liu et al. (2021) and Jiang and Zhen (2019) have contributed to EV charging scheduling problem. However, these ideas have some limitations, including the time consumed, pollution and the availability of parking. Eco-parking overcomes these limitations, making this project more effective and sustainable compared to current ideas for driving the growing use of EVs. Responding to key challenges facing EV users that are related to limited mileage range and the availability of charging stations by introducing smart management for solar parking lots drive the travel behaviour transition from internal combustion engines (ICEs) to electric vehicles (EVs) leading to more sustainable cities. In future work, scholars should aim to implement this system and design a framework for the smart cab and smart bus, dealing with other aspects of our transport systems to make them smarter in future cites.

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