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# Electric vehicles adoption challenges in Oman: a comprehensive assessment and future prospects for sustainable cities

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The rising popularity of Electric Vehicles (EVs), fuelled by technological advancements and supportive government policies, presents a promising solution to reduce carbon emissions from conventional cars. This study explores public perceptions of obstacles to Electric Vehicle (EV) adoption in Oman and assesses EVs' impact on city sustainability. Over 300 car consumers in Muscat participated in a survey, facilitated through Microsoft Forms, and distributed via email and social media platforms like WhatsApp, Facebook, LinkedIn, and Instagram. Data analysis utilized descriptive statistics and Structural Equation Modelling (SEM). The study finds that the main obstacles to EV adoption in Oman include a lack of public charging infrastructure, limited EV knowledge, and concerns about available EV models. Safety issues, financial constraints, and low public awareness of climate change also hinder adoption. Structural SEM results show positive correlations between cost-effectiveness, charging infrastructure availability, climate change awareness, and intention to adopt EVs. However, safety concerns negatively impact EVs purchase intention. Regarding the impact of EVs on Oman's cities, respondents generally believe in the potential for EVs to improve air quality, enhance urban living conditions, and mitigate noise and air pollution. However, the respondents were also cautious about the widespread use of EVs due to the high infrastructure investment costs and energy consumption. Therefore, this study recommends targeted interventions like awareness campaigns, better charging infrastructure, and adoption incentives. These insights are vital for policymakers and stakeholders aiming to promote sustainable EV adoption in Oman and beyond.

## KEYWORDS

electric vehicles, adoption, challenges, assessment, prospect, Oman, sustainable cities

## Introduction

Human-induced climate change, mainly from the release of greenhouse gases, presents a substantial danger to the environment, human societies, and civilization. The global temperature has escalated by 1.1°C from pre-industrial levels, and emissions of greenhouse gases persist to rise. This phenomenon has triggered widespread detrimental effects,

disproportionately impacting communities that have contributed least to the causes of climate change. Consequences encompass food and water insecurity, heightened mortality and illness due to climate-related diseases, economic harm to sectors like agriculture and tourism, and disturbances to urban infrastructure. The adverse outcomes are notably pronounced among urban residents who are economically and socially marginalized (IPCC, 2023).

The automotive industry primarily contributes to nearly all urban air pollution (Walsh and Moore, 1989). Around 24% of the world's carbon dioxide (CO<sub>2</sub>) emissions are attributed to transportation, with three-quarters originating from road transport (Ritchie, 2020). Projections indicate a potential increase in this percentage to 40% by 2030 and 60% by 2050 under a current trend (Gopal, 2023). Transport emissions have exhibited an average annual growth rate of 1.7% from 1990 to 2022, surpassing the expansion in any other end-use sector. Meeting the Net Zero Emissions (NZE) target by 2050 necessitates an annual reduction of more than 3% in CO<sub>2</sub> emissions from the transport sector by 2030. This requires the implementation of stringent regulations, fiscal incentives, and substantial investments in infrastructure to support the operation of low- and zero-emission vehicles (IAE, 2023).

With over one billion cars on roads and global revenues surpassing \$2.86 trillion in 2021, projected to reach \$9 trillion by 2030, the industry has experienced substantial growth. In 2019, transportation accounted for approximately a quarter of the EU's total CO<sub>2</sub> emissions, with 71.7% originating from road transportation. Diesel was the primary fuel for most cars on European roads in 2019 (67%), followed by petrol (25%). The European Union (EU) has set a target to achieve a 90% reduction in greenhouse gas emissions from the transport sector by 2050 (European Parliament, 2023). The International Energy Agency (IEA) proposes adopting electrification and hydrogen technologies that could decarbonize specific transportation sub-sectors within a few decades. The IEA envisions the elimination of emissions from motorcycles by 2040, rail by 2050, and small trucks by 2060. Although emissions from cars and buses are expected to persist until 2070, these measures aim to reduce the overall environmental impact (IEA, 2020).

According to Charabi et al. (2020), despite the Gulf Cooperation Council (GCC) having the world's largest oil and gas reserves and the highest per capita GDP, there are limited studies on Greenhouse Gas (GHG) emissions from transportation. Over the past decade, GCC countries have heavily invested in their transport networks, relying heavily on petrol-based car ownership and road-based freight due to rapid urbanization. Transportation accounts for over 15% of GHG emissions in the region, with aviation and shipping contributing 8% (Gopal, 2023). In Oman, transportation emissions rank third after oil/natural gas and energy industries, with road transport being the primary emitter, increasing from 66% to 92% of total transport emissions from 2000 to 2015. Carbon emissions from transportation are expected to continue rising due to high demand fueled by population growth, cheap fuel, and affordable car prices, compounded by limited public transport options (Charabi et al., 2020).

GCC nations consistently rank among the top per capita carbon dioxide emissions globally. According to World Bank data, Qatar, Kuwait, the UAE, and Bahrain hold the first four

positions, while Saudi Arabia and Oman are ranked 10th and 12th, respectively. The region's reliance on gas and oil for electricity generation significantly contributes to this high carbon footprint. For example, in Oman, 71% of energy comes from gas, 28% from oil, and 1% from coal. Saudi Arabia's energy mix consists of 60.7% natural gas, 39% oil, and a minimal 0.3% from renewables. In the UAE, natural gas accounts for 94.8%, renewables for 4%, and nuclear power for 1.2%. Recognizing the environmental impact, GCC countries actively diversify their energy portfolio with utility-scale solar, wind, waste-to-energy, and nuclear power as part of their low-carbon energy strategy (SNC-LAVALIN, 2022). Contemporary smart cities demand increased energy, mandating using renewable energy sources to meet these growing needs and uphold environmental cleanliness (Subramanian and Salvi, 2023).

The popularity of Electric Vehicles (EVs) has soared as a solution to environmental concerns, driven by technological advancements and supportive government policies. Increasingly, consumers and industries are turning to EVs to reduce carbon emissions, with global sales projected to reach 12 million units by 2025 and nearly double to 23 million units by 2030, growing at an average annual rate of about 21% (IEA, 2023; Markets Markets research, 2023). China dominates global EV sales, with over 60% market share exceeding its 2025 sales target. In Europe, electric car sales grew by over 15% in 2022, comprising more than one in five cars sold. The United States witnessed a 55% increase in electric car sales in 2022, capturing an 8% sales share (IEA, 2023). By 2030, it is projected that around 26% of new global car sales will be EVs, with an estimated addition of 58 million new self-driving cars to the global fleet that year (Ian, 2023). Oman aims for net-zero emissions by 2050, planning to transition to 79% electric vehicles (EVs) in its fleet by 2035. The Ministry of Transport, Communications, and Information Technology (MTCIT) has outlined a three-stage plan for carbon neutrality in the transport sector, targeting emission reductions of 30% by 2030, 34% by 2040, and complete elimination by 2050 (Zawya News, 2023).

Despite global efforts to adopt electric vehicles (EVs) to reduce greenhouse gas emissions, widespread obstacles persist, including concerns about charging times, limited range, high costs, insufficient infrastructure, and lack of awareness and incentives (Khandakar et al., 2020). In Oman, challenges to EV adoption include consumer preferences for larger vehicles, a small market size, extreme heat conditions, inadequate charging infrastructure, range anxiety, limited awareness, high upfront costs, and a lack of dealer incentives (Energy Environmental Economics, 2018). While global studies explore EV adoption, empirical studies on public perception and barriers in Oman are lacking. To address this gap, a survey was conducted to assess public perception of EVs adoption challenges. The paper is divided into five sections, including an introduction. Section two reviews the literature. Section three examines the research methodology. Section four presents the findings and discussion. Section five provides conclusions and recommendations for future research.

### Objectives of the study

1. To investigate public perceptions regarding barriers to adopting Electric Vehicles in Oman.

2. To explore the relationship between obstacles to adopting electric cars and the intention to purchase Electric Vehicles (EVs).
3. To examine the impact of electric vehicles on cities' sustainability.

#### Research questions

1. What are the challenges in adopting Electric Vehicles in Oman?
2. Is there a significant relationship between financial, knowledge, infrastructure, safety concerns, climate awareness barriers, and the intention to adopt electric cars?
3. What are the impacts of electric vehicles on the sustainability of cities in Oman?

## Literature review

### Concept of electric cars

Electric vehicles come in various categories, each with distinct characteristics. [Alanazi \(2023\)](#) categorizes PEVs based on their engine technology and settings, as outlined in [Figure 1](#). This study focuses on plug-in electric vehicles (PEVs), which connect to outlets or electric vehicle service equipment (EVSE) for charging. PEVs include fully battery electric vehicles (BEVs) operating solely on electricity and plug-in hybrid electric vehicles (PHEVs) using gasoline and electricity. PEVs appeal to automakers and drivers due to anticipated lower fuel and maintenance costs than internal combustion engine (ICE) vehicles, making them economically attractive. Encouraging off-peak charging for PEVs can enhance electricity network efficiency, benefiting all ratepayers. Moreover, PEVs, compared to ICE vehicles, contribute to reduced carbon dioxide emissions, improved local air quality, and decreased noise pollution ([Energy Environmental Economics, 2018](#)). Electric vehicles, specifically focusing on PEVs, offer cost-effectiveness and environmental advantages over traditional cars. Despite potentially higher upfront costs, EVs prove cost-effective in the long run due to reduced fuel expenses and less frequent maintenance needs. The simplicity of electric motors, with fewer moving parts, contributes to longer lifespans for EVs than conventional cars ([Grunditz and Thiringer, 2016](#)).

Battery Electric Vehicles (BEVs) rely solely on rechargeable batteries without a backup generator or petrol engine, making them the most ecologically beneficial electric cars due to zero exhaust emissions ([Alanazi, 2023](#); [Salmasi, 2023](#)). Hybrid Electric Vehicles (HEVs) combine electric motors and petrol engines, using electric power for low speeds and acceleration and petrol at higher speeds, with regenerative braking for battery recharging ([Salmasi, 2023](#)). Plug-in Hybrid Electric Vehicles (PHEVs) have larger batteries for internal combustion engine-powered generator recharging and external charging, offering flexibility for daily driving with or without a plug ([Daina et al., 2017](#)). Fuel cell electric vehicles (FCEVs) use hydrogen gas to generate power, producing only water vapor as waste, but they face challenges due to limited hydrogen refueling infrastructure ([Govardhan, 2017](#)). Extended Range Electric Vehicles (ER-EVs) combine features of BEVs and PHEVs, utilizing a larger battery for extended electric range and a small gasoline engine to generate electricity once

the battery is depleted ([Zhao et al., 2022](#)). The transport sector, traditionally reliant on fossil fuels, is undergoing a pivotal transition toward zero-emission vehicles like electric, hybrid, and fuel-cell vehicles. This shift involves leveraging electricity and hydrogen, often sourced from renewable energy, marking a significant step toward sustainability ([Subramanian and Salvi, 2023](#)).

### Studies on adoption of passenger electric vehicles (EVs)

Most studies used surveys to identify barriers to EVs, and one notable study by [Egbue and Long \(2012\)](#) utilized this method to rank adoption factors. Their findings concluded that respondents considered range, cost, infrastructure, and safety as primary concerns, with cost being notably more significant than environmental benefits. Another study by [Krishna \(2021\)](#) explored consumer perceptions and barriers to electric vehicle adoption using electronic word of mouth (eWOM). Unlike traditional survey techniques, this study employed thematic analysis to capture a broader range of expressions from various internet mediums, such as forums and social media, where individuals freely share their opinions on electric cars. Krishna's results revealed consumer concerns about the safety of electric vehicles due to the lack of sound and battery explosions. Additionally, consumers downplayed the significance of tailpipe emissions, suggesting that emissions merely shift from the post-usage phase to the energy production phase. Affordability was also questioned, with electric vehicles portrayed as inexpensive and environmentally friendly. However, users emphasized that these cost advantages do not account for maintenance, repairs, and the unpredictability of battery degradation.

The fear of battery degradation, accelerated by harsh weather conditions and extensive usage, was highlighted as a significant barrier. [Pelletier et al. \(2017\)](#) supported this concern, emphasizing that battery health depends on storage and operating conditions, linking weather and geography to adoption challenges. [Gerssen-Gondelach and Faaij \(2012\)](#) added that electric vehicles could only compete with internal combustion engines (ICE) in running costs if battery costs were reduced, contributing to the adoption challenges.

Infrastructure emerged as another substantial barrier. [Slowik and Lutsey \(2017\)](#) argued that public and workplace charging significantly impacts electric vehicle uptake. The scarcity of charging stations and the vehicle-to-refueling index were cited as key concerns, with users reporting long waiting times to use chargers. [Gnann et al. \(2018\)](#) highlighted the role of a lower vehicle-to-refueling index, causing higher occupation of fast chargers, which is expected to decrease with advancements in battery size and technology. However, until such developments occur, the overpopulation of chargers remains a significant challenge.

The prevailing sentiment among most consumers is a lack of trust in electric vehicle technology, driven by concerns about its readiness for daily use, susceptibility to hacking, perceived unreliability, and overall immaturity. Common doubts relate to battery performance and degradation over time, with consumers expressing skepticism about the accurate degradation calculation due to various factors. The perceived unreliability is underscored

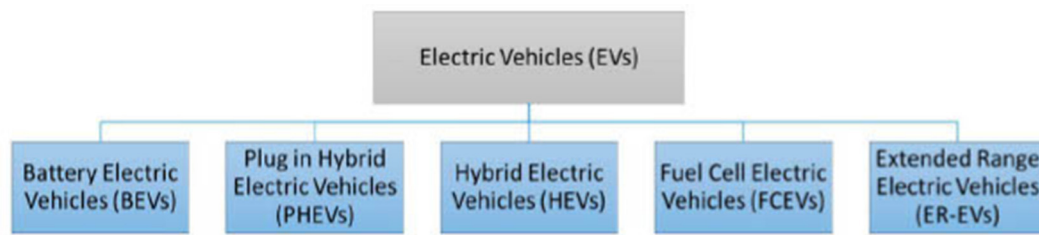


FIGURE 1

Classification of electric vehicles based on engine technology and settings. Source: Alanazi (2023, p. 7).

by users' need to meticulously plan trips, considering charging time and locations in advance. Many individuals consider the technology in its early developmental stages. They are hesitant to adopt it, expressing a reluctance to serve as early adopters or "guinea pigs" for a technology they believe requires further improvement (Krishna, 2021).

Khandakar et al. (2020) conducted a study investigating the perspectives on electric vehicle (EV) adoption in Doha, Qatar, where most vehicles currently rely on fossil fuels—the research utilized survey questions and employed two analytical methods: response-based analysis and two-sample t-test analysis. Contrary to many other countries, the study found that financial barriers are not a significant obstacle to EV adoption in Doha. However, it identified a crucial need for heightened public awareness about climate change and the potential role of sustainable transportation, such as EVs. The study suggests that increased public awareness, coupled with government incentives, could accelerate the adoption of EVs, drawing parallels with the successful adoption experiences in countries like Norway.

In a related study, Kotilainen et al. (2018) underscored the significance of price considerations, encompassing both the purchase price of EVs and charging costs. Their research highlighted the considerable price disparity between EVs and internal combustion engine vehicles despite the lower maintenance costs associated with EVs. This substantial initial investment in EVs was emphasized, providing context to the broader literature on the challenges and factors influencing the adoption of electric vehicles, particularly in the context of financial considerations.

Furthermore, Capuder et al. (2020) identified barriers to the broad acceptance of PEVs, including limitations in driving range, extended charging times, and high initial costs. Another significant impediment to the widespread adoption of EVs is the insufficient availability of charging infrastructure. Establishing this infrastructure faces the well-known "chicken-and-egg problem," wherein drivers hesitate to choose EVs without a robust charging network. However, the development of such a network is unlikely without enough EVs on the road (Ramesan et al., 2022). Addressing these challenges is pivotal for successfully integrating PEVs and EVs into mainstream transportation.

She et al. (2017) surveyed Tianjin, China, with 476 respondents to explore perceptions regarding adopting battery electric vehicles (BEVs). The study, employing the structural equation model and chi-square test, reveals a relatively low interest among consumers in BEVs, with many adopting a cautious "wait and see"

approach. Consumer uncertainty focuses on BEV performance, with safety, reliability, and range per charge identified as the top three concerns. Those prioritizing vehicle performance express significantly lower acceptance of BEVs. The primary technological obstacle to widespread BEV adoption is recognized as the high cost of batteries. Insufficient public charging infrastructure is the most significant hindrance to public service support. Analysis of respondent characteristics indicates that older individuals are more optimistic about BEVs than younger generations. Additionally, more respondents express interest in adopting BEVs as a second family car; experienced drivers are more concerned about battery and maintenance costs, and consumers emphasizing environmental concerns are more inclined to adopt BEVs.

Coffman et al. (2017) conducted a literature review to explore factors influencing electric vehicle (EV) adoption and identified notable knowledge gaps. Their findings reveal mixed evidence on the effectiveness of government incentives in encouraging EV uptake, mainly due to a limited understanding of the optimal timing and magnitude of such incentives. The literature highlights the significance of public charging infrastructure in influencing EV adoption. Although public charging infrastructure can alleviate range anxiety, especially for battery electric vehicles, there is a lack of guidance on the most effective government strategies for ensuring infrastructure.

Manjula et al. (2022) conducted a study on electric cars in India, finding that the lack of charging stations is a significant obstacle to adopting electric vehicles (EVs). Many individuals are willing to embrace EVs if there is adequate infrastructure development. The study underscores the perception that electric vehicles are environmentally friendly and emphasizes the need to develop service centers and charging stations, calling for more comprehensive infrastructure development. The high cost is identified as the most substantial barrier to EV adoption. Despite a belief among many that achieving widespread adoption of EVs in India will take more than 20 to 30 years, the majority remains optimistic about the success of the electric vehicle project, with a widespread belief that EVs will significantly contribute to improving the environment and reducing pollution.

A survey by Industry Europe (2022), involving over 2,000 UK adults, reveals that adopting electric vehicles (EVs) in the country faces more significant challenges than expected. Over half of the respondents (54%) are unlikely to own an EV during the transition, with 41% citing the expensive purchase price of EVs as a primary concern. Additional obstacles include worries about the limited



availability and accessibility of charging points and uncertainties about the performance range of EVs. The survey underscores the necessity for UK charging infrastructure to match the convenience of petrol stations, a sentiment shared by only 22% of respondents. Moreover, the charging points must meet the demands of an estimated 8–11 million electric vehicles on the roads by 2030. Despite reservations about EV drive ranges and charging point accessibility, 56% of participants expressed a likelihood of adopting a like-for-like electric model of their current vehicle at no extra cost, indicating a willingness to embrace environmentally friendly alternatives with sufficient support.

## Intention to adopt electric cars

Consumer decision-making is a nuanced process shaped by numerous factors. Scholars have introduced theoretical models like the theory of self-efficacy, the theory of reasoned action, and the Theory of Planned Behavior (TPB) to scrutinize the intricacies of purchase intentions (Irfan et al., 2021b). Our theoretical framework specifically adopts TPB. TPB suggests that an individual's behavioral intention stems from a specific behavior, which propels them to engage in it and leads to an expected outcome. This interplay of intention and action unveils the intricate dynamics of consumer decision-making (Ajzen, 1991). TPB highlights the role of fundamental convictions and evaluations in shaping attitudes toward a behavior, forming the core of our theoretical approach, which explores the nuanced connections between behavioral intention, action, and the psychological processes contributing to the formation of consumer attitudes.

The TPB is a pivotal tool for scholars investigating and predicting consumer behavior across diverse domains like green energy, e-commerce, and organizational dynamics (McBride et al., 2020). Despite its success, TPB has inherent limitations, primarily focusing on intentions through behavioral, normative, and control beliefs, inadvertently neglecting various other influential factors (Sniehotta et al., 2014).

Scholars have identified numerous factors influencing product adoption, spanning social, economic, and political dimensions. In embracing new technologies, individuals weigh considerations such as climate awareness, adherence to social values, and cost evaluations (Irfan et al., 2021a). To enhance the TPB framework, this study introduces five additional factors to gauge Electric Vehicle (EV) adoption intention, including public awareness of climate change and knowledge about EVs. This enriches the theoretical framework's comprehensiveness, as illustrated in Figure 2. Therefore, our model suggests that increased public awareness of climate change significantly influences consumers' interest in Electric Vehicles (EVs). The perceived financial benefits, including fuel and maintenance cost savings, further drive consumer motivation for EV adoption. A better understanding of EV technology positively impacts consumers' intention to purchase these vehicles. Expanding public charging infrastructure enhances convenience and accessibility, reinforcing consumer inclination toward EVs. However, heightened concerns about the safety of EV technology may negatively impact consumers' willingness to embrace EVs as a transportation solution.

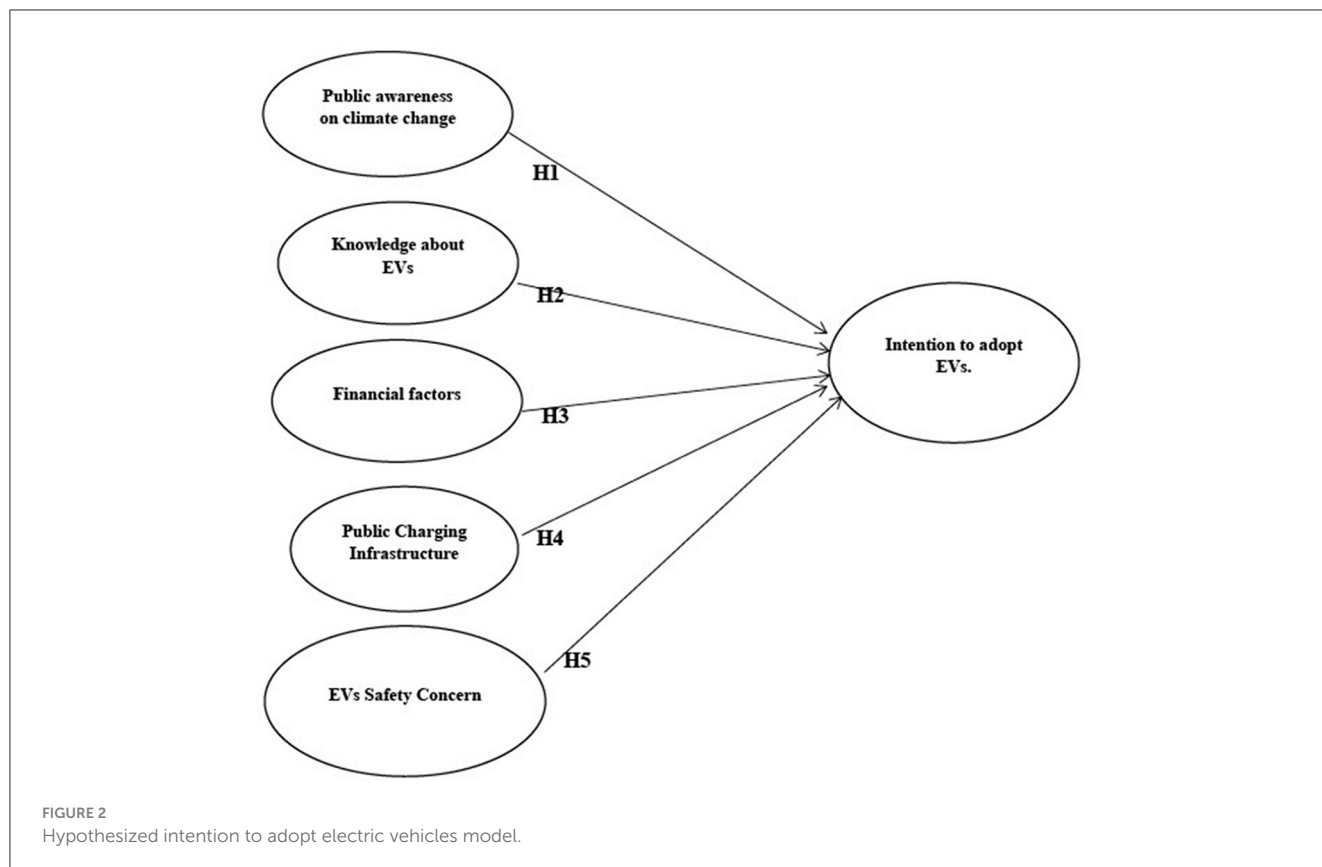
## Impact of electric vehicles on urban cities

Currently housing half of the global population, urban cities are anticipated to reach 6.3 billion residents by 2050 (Spickermann et al., 2014). This population surge raises concerns about the impact on transportation, with challenges like road congestion, inefficient public transit, and pollution becoming prominent issues (Tcholtchev et al., 2012; Anthony et al., 2020). The efficiency of urban mobility, crucial for city productivity, involves moving people and goods between various locations, including transport terminals such as ports and airports (Rodrigue, 2023). Addressing social, economic, and environmental constraints is vital for sustainable and competitive urban mobility systems, necessitating improvements in infrastructure (Spickermann et al., 2014). Electric vehicles (EVs), encompassing options like electric bicycles and cars, emerge as a potential solution for achieving sustainable mobility in smart cities (Tcholtchev et al., 2012). EV varieties like e-buses, e-bikes, e-cars, e-scooters, and e-railways play a crucial role in reducing pollution and achieving deep decarbonization in the transportation sector (Kirpes et al., 2019).

Numerous innovative city initiatives aim to reduce emissions and enhance air quality by promoting the widespread use of electric cars. With their lower maintenance and operating costs, EVs contribute to the efficiency of smart cities, and accompanying infrastructure like smart traffic control systems and charging stations facilitates EV adoption and integration (Canizes et al., 2019). The rapid advancement of EV technology, driven by environmental concerns and a desire to reduce oil dependence, has led to transformative changes in the transportation sector. EVs offer environmental benefits, including reduced noise levels, pollution, and greenhouse gas emissions, facilitating a shift away from petroleum-based economies (Anthony, 2021).

Furthermore, EVs play a crucial role in a sustainable energy future by providing an opportunity to store electricity from renewable sources through their batteries (Anthony, 2021). Modern smart cities emphasize the need for more energy generated from renewable sources while maintaining environmental cleanliness. Using electricity and hydrogen contributes to the transition to zero-emission vehicles, aligning with the goals of smart and sustainable urban development (Subramanian and Salvi, 2023).

In their investigation of renewable energy systems for sustainable urban development, Subramanian and Salvi (2023) examine various energy sources for commercial activities, weighing the pros and cons of each. The authors advocate using renewable energy to power domestic and commercial buildings in smart cities, specifically biogas/bio-synthesis gas derived from urban waste. They propose decentralized renewable energy sources, such as rooftop solar photovoltaic systems for cooling, heating, and lighting in buildings. It is suggested that the city's overall energy demands be met by centralized renewable energy systems, incorporating solar, wind, and bioenergy. While acknowledging the sustainability of energy sources like solar, wind, hydro, and biomass, the authors recognize their limitations regarding energy density and rapid production. To address this, they propose nuclear-renewable hybrid energy as a solution to bridge the gap in energy density and rapid production.



## Electric scooters play an essential role in smart and sustainable cities

Smart and sustainable cities are now encouraging electric scooters vis-à-vis conventional petrol-driven scooters. They are not only adding a modern look but also contributing to urban city life in several ways. One of the most critical aspects of an urban city is the mobility of the people, which has been a major contributor to the pollution and congestion problems. Electric scooters solve this issue by producing zero emissions from the tailpipe, reducing the greenhouse gas effect. Further, electric scooters are sleek, small, and occupy less space, thus reducing the road congestion problem. Thus, adding the micro-mobility value, electric scooters contribute effectively to urban commuting. Electric scooters add technology to smart cities through movement tracking through GPS, integrating mobility data with other social data such as safety and accidents. As the data is the lifeline of modern cities, electric scooters add informational value to the city management system. Several other aspects, such as parking, theft, convenience, and infrastructure, are effectively addressed using electric scooters in smart and sustainable cities.

Smart and sustainable city management encourages citizens to shift from traditional commuting to non-conventional. One of the sustainable modes of transportation is the use of an e-bike-sharing model. An energy-efficient e-scooter-sharing system includes establishing recharge stations, particularly near mass transit hubs such as metro and bus stations and conducting campaigns to encourage people to use the e-bike-sharing transportation model.

Essential factors that positively influence the development of an effective e-bike-sharing model include the digitalization of society, the cost of sharing, promotional programs, and the city's population size (Macioszek and Cieřła, 2022). The effective management of e-bike-sharing services should consider the role of all key stakeholders, viz., users of taxi-sharing services, employees, suppliers, investors, and financial institutions, as they influence the adoption and penetration of e-bike-sharing services in smart and sustainable cities (Macioszek et al., 2023).

## Research methodology

The overall objectives of this study are to measure the public perception of the challenges facing the adoption of electric cars and the impact of electric vehicles on urban pollution in Oman. To achieve these objectives, the study uses a survey. A survey is a research method used to gather information and data from a sample of individuals or a population (Sekaran and Bougie, 2016). Surveys provide a systematic and structured way to collect data from many respondents. This makes them suitable for gathering information on various topics, including opinions, behaviors, and characteristics (Churchill and Iacobucci, 2004). They added that surveys can be applied to various research objectives, including market research, social science studies, health assessments, customer satisfaction evaluations, and more. Moreover, a survey is often an efficient way to collect data from a large and diverse sample. They allow researchers to reach a broad

audience in a relatively short amount of time (Sekaran and Bougie, 2016).

## Population and sample

This study adopts a cross-sectional survey design as we can capture data simultaneously. The population of the study is the car consumers in Oman. Questionnaires were distributed to 300 respondents residing in Muscat Governorate using a simple random sampling technique. Two hundred and fifty-seven were collected as valid and complete; the response rate was 87%. The survey description is shown in Table 1.

## Research instrument

The questionnaire presented in Appendix 1 was adapted from Khandakar et al. (2020). Measures have been taken to ensure the confidentiality of respondents' identities. The questionnaire consists of three sections. The first section provides information about the respondents. The second section explores the challenges faced by consumers when adopting electric vehicles in Oman. The final section investigates the respondents' views on the impact of electric cars on urban pollution. Each factor item was measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The study employs both revealed and stated research methodologies to deepen the understanding on challenges face in adopting electric vehicles in Oman and the impacts of EVs on sustainable cities. The first part of the survey adopts a revealed preference approach, where actual data were collected on respondents' profiles and travel experiences. In contrast, sections two and three of the questionnaires employ a stated preference approach. Here, respondents evaluate choice scenarios and select their preferred alternative from the provided set. Typically, each respondent assesses these scenarios using a Likert-type scale. This method, as described by Elisabetta and Hensher (2015), involves hypothetical situations reflecting stated or intended behavior, allowing respondents to rank, rate, or choose among presented options. Stated Choice is commonly used due to its alignment with reality. The presented choices aim to be purposeful, rational, and efficient. However, to ensure realism and mitigate potential hypothetical bias, analysts may need to create complex survey tasks that respondents must process quickly, potentially increasing respondent burden and risking response quality (Elisabetta and Hensher, 2015).

## Procedure

Data was collected for a study using an online survey questionnaire, providing an easy and accessible way for participants to take part. The questionnaire was created with great care and detail using Microsoft Forms, to ensure that it was easy to understand for those taking part. The survey was then distributed across a range of online platforms, including email, WhatsApp,

Facebook, LinkedIn, and Instagram, to reach as many people as possible. The survey was shared not only with friends and acquaintances, but also with individuals chosen at random, creating a diverse and inclusive sample. This was done to capture a broad range of perspectives and insights. The survey was conducted between September and October 2023, allowing us to collect and analyze comprehensive data within a specific timeframe.

## Data analysis

To ensure the validity and reliability of the research instrument, Cronbach's Alpha is conducted to assess the internal consistency and test for the reliability of the questionnaire. Cronbach's alpha ranges from 0 to 1. A higher alpha value indicates greater internal consistency and a low Cronbach's alpha suggests that the items do not correlate well, indicating poor internal consistency (Hair et al., 2014). Table 2 indicates an overall, Cronbach's Alpha for 31 items measured was 0.889, indicating greater internal consistency.

The acquired data underwent analysis using the Statistical Package for Social Sciences (SPSS) version 23 and AMOS software version 16, employing a structural equation model (SEM). The determined sample size was suitable for implementing SEM to address the research objectives. As Schumacker and Lomax (2010) outlined, SEM tests theoretical models that posit relationships between constructs. SEM is a powerful and versatile statistical technique used in social sciences, economics, psychology, and other fields to analyze complex relationships among variables. SEM allows researchers to model complex, multifaceted relationships among variables. It can accommodate direct and indirect effects, making it suitable for examining intricate causal pathways (Hair et al., 2014). The SEM process entails the development of both a measurement model and a structural model. In the execution of SEM, this study initially evaluated the validity of the measurement model, followed by an assessment of the model's overall fitness. Subsequently, the hypothesized models were tested using structural modeling. Additionally, descriptive statistics played a role in the analysis.

## Results

### Socioeconomic background of the participants

The information presented in Table 3 reveals that most respondents (56%) were male, while only 44% were female. Moreover, a significant proportion of the respondents (78%) fell within the 20 to 30 age brackets, with only 8% aged above 50. The survey findings indicate that many participants held a bachelor's degree (56%). Additionally, it is worth noting that 61% of the respondents reported an income between OR. 500–O.R. 1,000, and only 10% earned above OR. 1,500. Approximately 40% of the respondents, on average, drove between 50 and 100 KM per day, while only 6% covered distances exceeding 200 KM. Regarding driving experience, 41% had 1–2 years of experience, and 27% had more than 5 years. The survey predominantly reflects the

TABLE 1 Survey description.

Parameters	Description
Period	September and October
Location	Muscat Governorate, Oman
Sample size	300
Valid responses	257
Response rate	87%

TABLE 2 Reliability statistics.

Cronbach's alpha	Cronbach's alpha based on standardized items	No of items
0.899	0.900	31

TABLE 3 Demographic profile of the respondents.

Demographic information		Frequency <i>n</i> = 257	Percentage
Gender	Male	144	56
	Female	113	44
Age	20–30	101	78
	31–40	29	11
	41–50	19	8
	Above 50	8	3
Education	Diploma	78	30
	Professionals	11	4
	Bachelor's degree	145	56
	Master's degree	16	7
	PHD	7	3
Income level	Less than O.R 500	51	20
	O.R 500–1,000	156	61
	O.R 1,000–1,500	22	9
	Above O.R 1,500	26	10
Mileage per day	Less than 50 km	83	32
	50–100 km	102	40
	100–200 km	56	22
	Above 200 km	16	6
Driving experience	Less two years	105	41
	2–5 years	83	32
	Above five years	69	27

perspectives and insights of middle-aged individuals with graduate-level education, providing valuable input for shaping future research and policies related to environmentally friendly cars.

## Barriers to adoption of electric vehicles in Oman

A comprehensive descriptive analysis was systematically conducted to investigate the multifaceted factors that could impede the widespread adoption of electric vehicles in the Sultanate of Oman. The study employed a structured survey approach, wherein participants expressed their level of agreement or disagreement with a series of carefully formulated statements. These statements were designed to understand Oman's perceived barriers to adopting electric cars. Respondents articulated their perspectives on these barriers using a five-point Likert scale, ranging from (5) denoting "strongly agree" to (1) indicating "strongly disagree." The results are shown in Table 4, which provides descriptive analysis using the mean and standard deviations associated with each identified barrier.

The detailed analysis presented in Table 4 provides a comprehensive understanding of the barriers influencing the adoption of electric vehicles (EVs) in Oman. Respondents' perceptions, as indicated by mean scores and standard deviations, reveal a consistent consensus ranging from moderate to solid agreement on identified barriers, with mean scores consistently exceeding the neutral midpoint of three on the Likert scale. The primary obstacle identified is the inadequacy of public charging infrastructure, with the highest mean score of 3.704. Participants expressed concerns about the scarcity of charging stations and insufficient public and private investments. In addition, the lack of public charging infrastructure awareness proves to be a significant deterrent to potential EV buyers.

The second-highest barrier, with an average mean score of 3.6, revolves around knowledge-related factors. Participants highlight limited awareness about EV models, functionalities, benefits, and costs. This emphasizes the need for targeted educational initiatives to enhance public understanding and drive adoption. Public awareness of climate change and its impact emerges as a significant barrier, with a mean score of 3.55. The correlation between environmental consciousness and EV adoption underscores the need for comprehensive campaigns to highlight the positive ecological contributions of EVs.

The suitability of available EV models is a notable concern, with a mean score of 3.58. Respondents' express reservations about model compatibility with regional preferences and climate, citing the preference for larger family vehicles and the impact of hot temperatures on battery performance. Safety concerns, with a mean score of 3.52, are another noteworthy barrier. Respondents' express reservations about the reliability and security of EVs, indicating a need for building trust through experiences and addressing perceived shortcomings.

Surprisingly, financial considerations are identified as the last barrier, with a mean score of 3.52. Respondents acknowledge the upfront costs of EVs but recognize potential long-term savings through lower maintenance costs. Government support, such as subsidies and tax exemptions, is crucial in mitigating this financial hurdle.

These findings are substantiated by a body of research, including studies by Egbue and Long (2012), Pelletier et al. (2017), She et al. (2017), Slowik and Lutsey (2017), Capuder et al. (2020),



TABLE 4 Scores of means and standard deviations of barriers to adoption of EVs criteria.

Criterion	Statement (barriers to adoption of electric vehicles)	Mean	Std. deviation
Climate change 1	Awareness of climate change effects on global warming.	3.70	1.133
Climate change 2	Awareness that climate change creates floods, droughts, famine, and diseases.	3.68	1.145
Climate change 3	Awareness that the auto industry is a significant polluter.	3.67	1.214
Climate change 4	Awareness that adopting electric cars can reduce air pollution and the effects of climate change.	3.15	1.275
<b>Climate Barrier</b>	<b>The total mean score of awareness on Climate criteria</b>	<b>3.55</b>	<b>1.192</b>
Knowledge on EV1	Learned about EVs from advertisements, ride and drive events, and car dealers.	3.59	1.202
Knowledge on EV2	Aware of the availability of EVs in the Oman auto market.	3.51	1.216
Knowledge on EV3	Aware that EVs have more mileage and save money compared to normal cars.	3.74	1.176
Knowledge on EV4	Learned that EVs have longer lifespans than conventional cars	3.44	1.217
Knowledge on EV5	Learned that EVs are convenient and less noisy.	3.77	1.152
Knowledge on EV6	Learned that EVs batteries can be charged anywhere.	3.51	1.170
<b>Knowledge barrier</b>	<b>Total mean score of knowledge about EVs criteria</b>	<b>3.593</b>	<b>0.997</b>
Financial barrier 1	The price of EVs is relatively high compared to standard cars.	3.51	1.293
Financial barrier 2	Government subsidies and tax exemptions can make EVs affordable.	3.50	0.969
Financial barrier 3	EVs have a high resale value compared to standard cars.	3.18	1.027
Financial barrier 4	EVs have low maintenance costs compared to standard cars.	3.14	1.155
<b>Financial Barrier</b>	<b>The total mean score of the Financial Barrier criteria</b>	<b>3.333</b>	<b>1.127</b>
Suitability 1	Most of EVs models are small.	3.12	1.262
Suitability 2	Many Omani residents prefer large-size vehicles	3.74	1.057
Suitability 3	Limited EV model choices are available in the market	3.79	1.079
Suitability 4	Constant use of A/C drains EV batteries faster and reduces travel mileage.	3.69	1.032
<b>Suitability Barrier</b>	<b>The total mean score of Suitability of EV model criteria</b>	<b>3.585</b>	<b>1.108</b>
Infrastructure 1	Limited availability of EV public charging infrastructure	3.54	1.192
Infrastructure 2	Access to workplace battery charging stations.	3.66	1.117
Infrastructure 3	Faster secure charging; cheaper high-capacity batteries	3.77	1.048
Infrastructure 4	Public and private sectors investment in public charging infrastructure.	3.71	1.048
Infrastructure 5	Public awareness on the availability of a nationwide network of public charging stations.	3.84	1.136
<b>Infrastructure</b>	<b>Total mean score of public infrastructure barrier criteria</b>	<b>3.704</b>	<b>1.108</b>
Safety Concern1	Lack of trust in EVs because the technology is new	3.32	1.271
Safety Concern 2	EVs are unsafe, unreliable, and risky.	3.30	1.225
Safety Concern 3	wait and see attitudes	3.64	1.110
Safety Concern 4	Difficult to identify fault due to lack of sound.	3.37	1.183
Safety Concern 5	Concern about EV battery's durability, reliability, and charging time duration.	3.97	1.077
<b>Safety Concern</b>	<b>The total mean score of EV safety Concern criteria</b>	<b>3.52</b>	<b>1.173</b>

Khandakar et al. (2020), Krishna (2021), and Manjula et al. (2022), among others. For instance, Krishna highlighted consumer distrust in electric vehicle (EV) technology, citing concerns about its daily usability, susceptibility to hacking, perceived unreliability, and overall immaturity. Affordability was also questioned, emphasizing that the perceived cost advantages of EVs do not fully account for maintenance, repairs, and the unpredictability of battery degradation.

Egbue and Long's (2012) study concluded that respondents identified range, cost, infrastructure, and safety as primary concerns, with cost being notably more significant than environmental benefits. Slowik and Lutsey (2017) argued that public and workplace charging significantly impact EV adoption, pointing to concerns about the scarcity of charging stations and the vehicle-to-refueling index, resulting in long waiting times for users. Khandakar et al. (2020) found that financial barriers

TABLE 5 Regression weight of measurement model.

			Estimate	S.E.	C.R.	P	Label
Intention	<—	Knowledge	0.518	0.134	3.868	***	
Intention	<—	Financial	0.577	0.190	3.037	0.002	
Intention	<—	Infrastructure	0.634	0.126	5.042	***	
Intention	<—	Safety	−0.528	0.136	−3.874	***	
intention	<—	Climate	0.982	0.192	4.643	***	

\*\*\*Regression weights for Intention in the prediction of intention variables significantly different from zero at the 0.001 level (two-tailed).

are insignificant to EV adoption. However, they underscored the need for increased public awareness about climate change and the potential role of sustainable transportation, such as EVs.

She et al. (2017) identified safety, reliability, and range per charge as top concerns, along with insufficient public charging infrastructure and apprehensions about battery and maintenance costs. These collective studies contribute to a nuanced understanding of the challenges and considerations influencing perceptions and adoption of electric vehicles.

## Analysis of intention to buy electric vehicles

In undertaking a meticulous examination of the hurdles associated with adopting electric vehicles (EVs) in Oman, our objective is to delve into the impact of these barriers on consumers' intentions to purchase EVs. With this aim in mind, we have formulated the following hypotheses to serve as guiding principles for our research into this intricate matter.

- H1: Public awareness of climate change positively correlates with intending to adopt electric cars.
- H2: Public knowledge of electric vehicles substantially influences the adoption of electric cars.
- H3: There is a significant positive relationship between financial factors and consumers' intention to use electric vehicles.
- H4: There is a significant positive relationship between the availability of public charge infrastructure and consumers' intention to use EVs.
- H5: There is a significant negative relationship between the safety concerns of EV infrastructure and consumers' intention to adopt EVs.

To investigate variable relationships in our model, we utilized various goodness-of-fit measures, including the Chi-square test, Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA), to assess the accuracy of our model in representing collected data. Figure 2 visually depicts the relationships between independent and dependent variables through Structural Equation Modeling (SEM), showing positive correlations between knowledge, finance, infrastructure, climate change, safety of electric vehicles (EVs), and the intention to purchase EVs.

The model primarily meets predefined fit criteria, indicating its suitability in explaining the intention to buy EVs. The adjusted Chi-squared index yielded a  $p$ -value of 0.00, confirming the model's good fit for the sample data. The Comparative Fit Index (CFI =

0.832) and Goodness Fit Index (GFI = 0.865) suggest a strong fit between the model and the data. The Root Mean Square Error of Approximation (RMSEA) further supports a favorable fit with a value of 0.067. The measurement model is presented in Figure 3.

According to the model, the positive relationships observed among the independent and dependent variables provide robust empirical evidence supporting that several factors encourage consumers to adopt electric vehicles (EVs). Specifically, increased knowledge about EVs, heightened awareness of climate change effects, enhanced affordability of EVs, augmented investment in public and private EV infrastructure, and improved safety features in EVs all play pivotal roles in motivating consumers to choose EVs over traditional vehicles.

The analysis results underscore the significance of affordability, revealing a strong positive correlation ( $\beta = 0.86$ ) between the cost-effectiveness of EVs and the intention to purchase. Additionally, the study demonstrates a noteworthy relationship between the availability of public charging infrastructure and the intention to adopt EVs, with a  $\beta$  coefficient of 0.56. The safety concern of EVs also emerges as a key influencer, showing a negative correlation to buy ( $\beta = -0.44$ ). Furthermore, the findings highlight the impact of climate change awareness, indicating a positive correlation ( $\beta = 0.59$ ) between understanding the environmental implications of climate change and the intention to embrace EVs.

However, it is noteworthy that the analysis reveals an insignificant relationship ( $\beta = 0.10$ ) between knowledge about EVs and the intention to purchase these vehicles. This suggests that, contrary to expectations, a higher level of knowledge alone may not significantly influence consumers to choose electric vehicles. The nuanced interplay of various factors underscores the complexity of consumer decision-making in adopting EVs. The regression weights presented in Table 5 substantiate the relationship between various factors and the intention to adopt Electric Vehicles (EVs).

## Impact of electric vehicles on urban cities

Table 6 delves into respondents' perceptions of the widespread use of electric vehicles (EVs) in urban cities in Oman, revealing a solid consensus on various aspects. Notably, 67% of participants strongly agree that embracing EVs would enhance air quality and foster healthier urban living. With only 18% expressing disagreement, the mean score of 3.61 indicates widespread agreement, albeit with a broad distribution of opinions, as suggested by the standard deviation of 1.226.

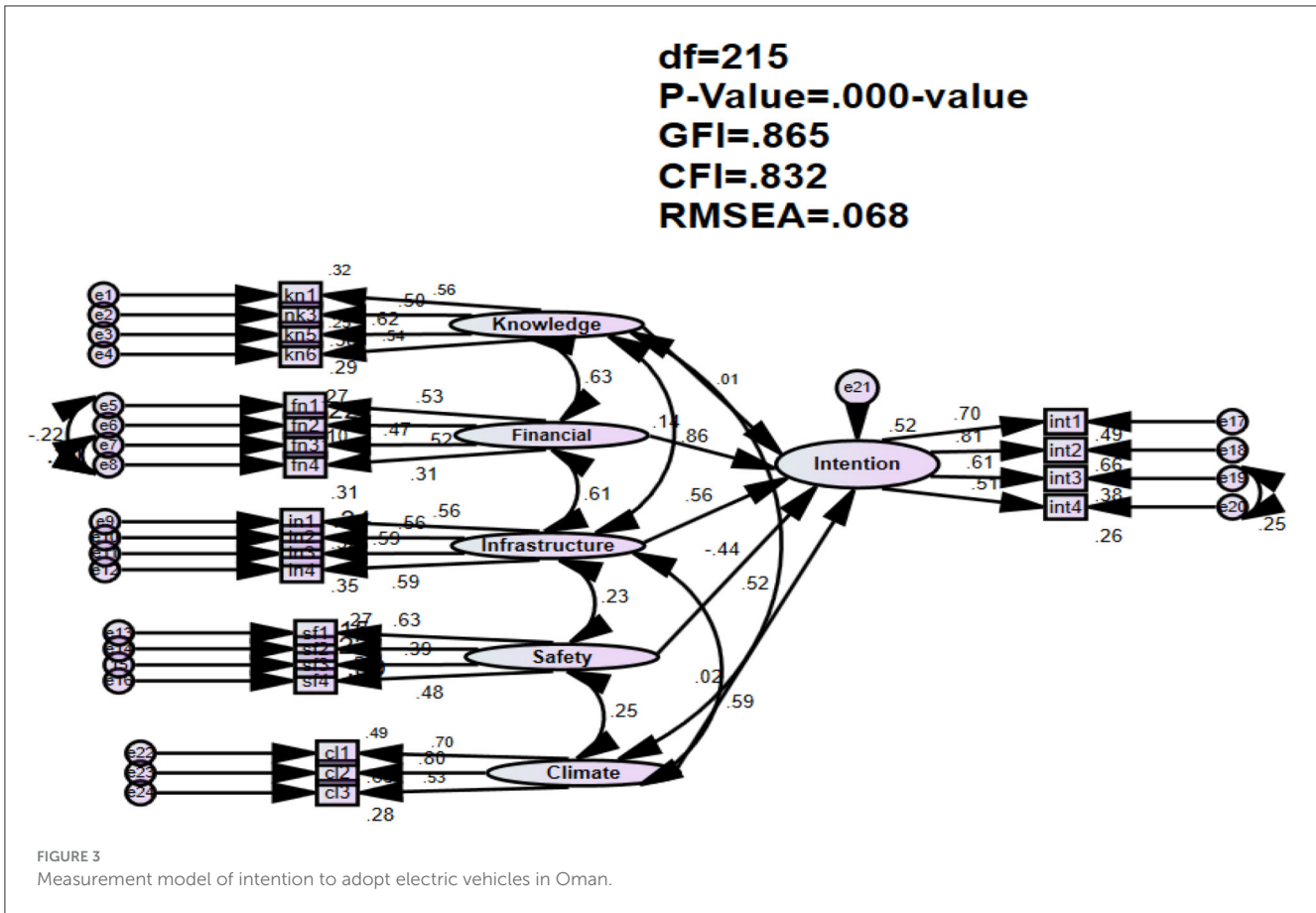


TABLE 6 Impact of electric vehicles on urban cities.

Criteria	Statements	Disagreement (percent)	Agreement (percent)	Mean	Std. deviation
Impact 1	Improve air quality and health	18	67	3.61	1.226
Impact 2	It makes cities pleasant and liveable	15	69	3.70	1.148
Impact 3	Reduce air noise pollution	16	71	3.76	1.144
Impact 4	High costs of EV infrastructure	15	65	3.66	1.114
Impact 5	Other electric modes of transport	14	70	3.73	1.055
Impact 6	EVs increase energy demand	12	66	3.71	1.033

Furthermore, 69% of respondents strongly believe widespread EV use would contribute to a more pleasant urban life. Only 15% somewhat disagree, resulting in a reinforcing mean score of 3.70. The standard deviation of 1.148 underscores the diverse perspectives on the perceived benefits of integrating EVs into urban landscapes.

Moreover, 71% of participants strongly agree that widespread EV adoption would effectively mitigate city noise and air pollution. A mere 16% somewhat disagree, with the mean score of 3.76 affirming the consensus. The standard deviation of 1.144 highlights the diversity of opinions regarding the potential environmental benefits of EVs.

Additionally, 70% of respondents strongly agree that adopting EVs would encourage using other electric modes of transport,

such as e-scooters, e-buses, and e-trains. Despite a minority of 14% somewhat disagreeing, the overall agreement is emphasized by the mean score of 3.73. The standard deviation of 1.055 suggests variability in responses, reflecting the complexity of opinions on the broader implications of widespread EV use for diverse electric transport modes.

The analysis indicates a cautious approach among respondents, particularly regarding associated costs such as high public spending on EV infrastructure and energy consumption. However, there is acknowledgment that potential benefits might outweigh costs, especially with renewable energy sources. This aligns with existing research by Tcholtchev et al. (2012) and Kirpes et al. (2019) who emphasize the role of EVs in reducing pollution and achieving decarbonization in the transportation sector. Subramanian and

Salvi (2023) further contribute to this discourse, highlighting the importance of renewable energy sources in the context of modern smart cities and sustainable urban development. The interplay between perceived benefits, costs, and environmental considerations underscores the need for a holistic and informed approach to integrating electric mobility in urban landscapes.

## Conclusions

In conclusion, this study explores the factors influencing the adoption of electric vehicles (EVs) in Oman, shedding light on both perceived barriers and the general attitudes toward the widespread use of EVs in urban settings. Analysis of barriers to EV adoption in Oman, the critical challenges identified include concerns about public charging infrastructure, limited knowledge, and the suitability of available EV models being particularly prominent. Safety concerns, financial considerations, and the necessity for increased public awareness of climate change also contribute to the complexity of the adoption landscape. Recognizing and addressing these challenges is crucial for developing effective strategies that encourage the uptake of electric vehicles in the Omani context. To determine the relationship between the barriers to adopting EVs and the intention to buy EVs, the findings reveal a strong positive correlation between the cost-effectiveness of EVs and the intention to purchase, the availability of public charging infrastructure and the intention to adopt EVs and awareness of the impact of climate change and the intention to embrace EVs. Nevertheless, there is a negative relationship between the safety concerns of EVs and the intention to buy EVs.

Regarding the impact of EVs on Oman's cities, respondents generally have positive views. Most respondents believe EVs can improve air quality, enhance urban living conditions, and reduce noise and air pollution. Additionally, there is optimism that widespread EV adoption could catalyze the uptake of other electric modes of transport. However, the cautious approach regarding associated costs, such as infrastructure investment and energy consumption, underscores the need for a balanced and sustainable implementation of electric mobility.

It is worth mentioning that one of the strengths of this study is that it aligns with existing research emphasizing the role of EVs in achieving sustainable and intelligent urban development, with a particular emphasis on renewable energy sources. The complex interplay between perceived benefits, costs, and environmental considerations underscores the necessity for a comprehensive and informed approach to integrating electric mobility. Another strength is that this research aligns with Vision 2040 of the Sultanate of Oman, emphasizing zero carbon emissions targets. This study is topical as the global emphasis is on sustainable cities and modernized transportation of goods and people. The primary limitation of this study lies in its small sample size, which restricts the generalizability of the findings. It is recommended that future research endeavors should expand the sample size to enhance the robustness and representativeness of the results. Additionally, the geographical scope of the study is confined to the Muscat region, posing another limitation. A broader perspective could be achieved through future research encompassing the entire country

of Oman, ensuring the broader applicability and generalization of the research outcomes.

Moving forward, we recommend that policymakers, industry stakeholders, and advocacy groups leverage these insights to develop targeted interventions that address the identified barriers and capitalize on the perceived benefits. Implementing robust public awareness campaigns, enhancing charging infrastructure, and incentivizing EV adoption are potential avenues for fostering a more sustainable and widespread embrace of electric vehicles in Oman. As the automotive landscape evolves globally, this study contributes valuable insights that can inform the trajectory of electric mobility in the unique context of Oman.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by Modern College of Business and Science Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

UA: Conceptualization, Investigation, Software, Supervision, Validation, Writing – original draft, Writing – review & editing, Data curation, Methodology. BF: Formal analysis, Methodology, Writing – original draft, Data curation, Supervision, Writing – review & editing. VT: Formal analysis, Project administration, Resources, Validation, Writing – review & editing, Visualization, Writing – original draft. SH: Resources, Validation, Visualization, Writing – review & editing, Funding acquisition, Writing – original draft.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frsc.2024.1360203/full#supplementary-material>

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