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Research Paper

A Multidimensional Comparison Assessing the Viability of Electric Vehicles in Jordan Across Key Performance Metrics

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Abstract

This study presents the first field-based, OBD-II–supported comparison of an electric vehicle (Changan Eado EV300) and a gasoline vehicle (Kia K3, 2019) under realistic Jordanian driving conditions. Using a 100 km mixed-route test and annualized projections, we evaluate energy consumption, operating cost, greenhouse-gas emissions (including battery manufacturing amortization), dynamic performance, cabin noise/comfort, and payback of purchase-price premium. Results indicate that, under predominant home charging, EV energy costs are reduced by over 60% relative to the tested gasoline vehicle, and operational CO_2 emissions fall substantially when charged from a low-carbon grid; battery manufacturing increases lifecycle emissions but does not offset operational benefits under renewable charging scenarios. EVs deliver superior low-speed torque and smoother acceleration, while ICE vehicles retain advantages in raw range and refueling time. Payback of the purchase premium is estimated at ~5.6–7.5 years (without battery replacement) and can extend beyond a decade if mid-life battery replacement is required. Findings inform policy on charging infrastructure, tariff design, and battery-lifecycle management for Jordan and similar contexts.

Keywords: Electric Vehicles; Internal Combustion Engine Vehicles; Energy consumption and efficiency; Vehicle performance analysis; Life cycle assessment

1. Introduction

The global transport sector is shifting as electric vehicles (EVs) gain traction over internal combustion engine vehicles (ICEVs), driven by rising fuel prices, environmental awareness, and battery innovations. A major driver is their potential to cut greenhouse gas (GHG) emissions. A life cycle assessment in Applied Sciences showed that EVs consistently outperform ICEVs across all sizes in both Well-to-Tank (WTT) and Tank-to-Wheel (TTW) phases, especially when powered by cleaner grids and advanced batteries [1]. Real-world studies confirm EVs' superior efficiency. Using in-vehicle sensors and machine learning, one study found EVs consume significantly less energy than ICEVs under identical traffic and route conditions, even when accounting for regional and urban variability [2]. In Ecuador's high-altitude cities, the Nissan Leaf used only 15–20 kWh/100 km versus 56–61 kWh/100 km for similar gasoline cars, though rural range and charging challenges persist [3].

Public transport also shows strong EV performance. In a Caribbean city, electric buses emitted the least CO_2 per km and served 80% of routes on a single charge, with fast charging enabling longer service. The average payback period was 4.5 years, making them cost-effective [4]. In Ghana, EVs had 30% lower total cost of ownership (TCO) over 20 years compared to ICEVs,

Nomenclature

B_C	: Battery capacity (kWh)	$\bar{F}_c$	: Annual fuel consumption (L)
B_{life}	: Battery lifespan (Year)	$\tilde{F}_c$	: Average fuel consumption (L)
C_B	: Battery cost (JOD)	GEF	: Grid Emission Factor
C_{elec}	: Electric cost (JOD)	I	: Measured sound intensity (dB)
$\bar{C}_{elec}$	: Annual electric cost (JOD)	I_0	: Reference sound intensity (dB)
C_f	: Fast charging electric price (JOD/kWh)	LD	: Sound level (dB)
C_{fuel}	: Fuel cost (JOD)	N_f	: Number of fast charging
C_{km}	: Cost per kilometer (JOD/kWh)	N_M	: Number of maintenance frequency
C_{kW}	: Fuel cost per kWh (JOD/L)	N_n	: Number of normal charging
C_L	: Fuel cost per liter (JOD)	N_Y	: Number of years (Year)
C_M	: Maintenance cost (JOD)	P_{EV}	: EV price premium (JOD)
$\bar{C}_M$	: Annual maintenance cost (JOD)	PT	: Playback time (Year)
C_n	: Normal charging electric price (JOD/kWh)	PT_{Adj}	: Adjusting Playback time (Year)
$\overline{CO}_{2,battery}$	: Annual carbon dioxide production due to battery manufacturing (kg/kWh)	R	: Range (Km)
$\overline{CO}_{2,elec}$	: Annual carbon dioxide production due electrical production (kg/kWh)	r	: Reduction factor
$\overline{CO}_{2,fuel}$	: Annual carbon dioxide production due to fuel (kg/L)	R_{Adj}	: Adjusting Range (Km)
C_T	: Trip cost (JOD)	R_{Eado}	: Range of Changan Eado (Km)
D_T	: Trip distance (km)	R_{K3}	: Range of KIA K3 (Km)
E_c	: Electric consumption (kWh)	$\bar{S}$	: Annual Saving (JOD)
$\bar{E}_c$	: Annual electrical consumption (kWh)	S_{Adj}	: Adjusting Saving (JOD)
$\tilde{E}_c$	: Average electrical consumption (L)	SEF	: Standardized Emission Factor
E_f	: Electric energy in fast charging (kWh)	TBE	: Total Battery Emission (Kg)
E_n	: Electric energy in normal charging (kWh)	T_V	: Fuel tank volume (L)
F_c	: Fuel consumption (L)		

though benefits depended on grid renewables and initial cost—indicating a need for clean energy investments and supportive fiscal policy [5].

Even in the UK, adoption is slowed by high upfront costs, range anxiety, and limited public charging. A qualitative study emphasized the role of government support and incentives [6]. Recent studies emphasize that the competitiveness of electric vehicles (EVs) is highly dependent on energy prices, taxation structures, and supportive policy instruments. For instance, thermal science and energy policy research has shown that variations in electricity generation costs and grid composition directly affect the total cost of ownership for EVs, especially in regions with limited renewable penetration [7], [8]. Complementary analyses on fuel substitution and combustion efficiency further highlight that EV adoption not only reduces per-mile operating costs but also mitigates long-term carbon emissions compared to petroleum-based fuels [9]. Additionally, broader techno-economic assessments point to the importance of life-cycle costing and battery economics in determining EV viability across markets [10], [11]. Together, these works underline that EV cost-effectiveness is a multi-factor outcome shaped by policy, technology, and energy systems.

These findings provide a strong foundation for assessing the performance, cost efficiency, and practical usability of electric versus gasoline vehicles in various driving environments. This paper builds upon this foundation by conducting a detailed technical and economic comparison under typical road and terrain in Jordan. By integrating real-world OBD-II diagnostic data, theoretical performance calculations, and economic modeling, this study aims to deliver a comprehensive evaluation that supports consumer decision-making and informs future transportation policy in the region. Although the electric EV market has experienced notable growth, several critical gaps remain that limit widespread adoption in Jordan and the broader Middle East. Previous studies have primarily focused on technological advancements and global market trends, yet there is limited research addressing region-specific challenges such as inadequate charging infrastructure, high upfront costs relative to conventional vehicles, and insufficient financial or regulatory incentives. Furthermore, consumer awareness regarding the long-term environmental and economic benefits of EVs is still low, and concerns about battery range and performance under local climate and terrain conditions remain largely unexamined. Addressing these gaps is essential for promoting large-scale EV adoption and supporting the transition to more sustainable transportation systems in Jordan and the region.

2. Method

This study adopts a comparative analytical approach to evaluate electric vehicles (EVs) and gasoline-powered vehicles (ICEVs) across multiple dimensions. While the aim is to provide a comprehensive understanding of their technical, economic, environmental, and performance-related characteristics within the specific context of Jordan in the year 2024, the methodology focuses on real-world usability and relevance to local driving patterns, fuel/electricity costs, climate, and road conditions. To achieve this, eight primary axes of comparison were identified, offering a structured framework for systematic analysis.

2.1. *Vehicle Selection Criteria*

The selected vehicles represent widely available options in the Jordanian market and belong to the same size and class (compact sedans), making them suitable for a balanced comparison. Their technical specifications, including weight, power, drivetrain configuration, and battery/fuel system capacity,were documented and used as the basis for baseline calculations. The analysis was conducted between a conventional gasoline-powered sedan (Kia K3, 2019) and a fully electric sedan (Changan Eado EV300, 2022). The Changan Eado EV300 is particularly significant in the context of Jordan, as Chinese manufacturers dominate most EV imports, and this model exemplifies the market trend toward mid-range, cost-effective electric mobility solutions. By contrast, the Kia K3 reflects the conventional segment that continues to attract consumers seeking affordability, reliability, and access to established maintenance networks. However, unlike the Eado EV300 and other Chinese-manufactured electric vehicles, the K3 does not align with the growing momentum of electrification and therefore represents the traditional alternative against which the EV sector is advancing.

2.1.1. *Kia K3 2019 (Petrol)*

Table 1 shows that the Kia K3 2019 is a compact sedan powered by a 1.6-liter inline 4-cylinder Smartstream G4FM petrol engine, producing 95.4 kW (approximately 128 horsepower) at 6300 rpm and a peak torque of 154 Nm at 4500 rpm, as the **Table 1**. It is equipped with an Intelligent Variable Transmission (IVT). The combined fuel consumption ranges between 6.7 and 7.1 liters per 100 kilometers, with a fuel tank capacity of 50 liters. The vehicle can reach a top speed of 190 km/h and accelerates from 0 to 100 km/h in approximately 10.5 seconds [12].

2.1.2. *Changan Eado EV300 2022 (EV)*

The Changan Eado EV300 2022 is a fully electric sedan powered by a 120 kW permanent magnet synchronous motor (PMSM), delivering approximately 161 horsepower and 245 Nm of torque. The vehicle utilizes a 47.8 kWh lithium iron phosphate (LFP) battery manufactured by CATL, providing an electric driving range of up to 401 kilometers based on the China Light-Duty Vehicle Test Cycle (CLTC). The average power consumption is estimated at 13 kWh per 100 kilometers. The EV300 reaches a top speed of 145 km/h and accelerates from 0 to 100 km/h in about 10.8 seconds. Charging options include fast DC charging from 30% to 80% in approximately 48 minutes and slow AC charging in around 8.5 hours [13]. The comparative specifications are presented in the **Table 1**.

The power-to-weight ratio of both vehicles is nearly identical, with the Kia K3 exhibiting a value of 12.03 kg/hp and the Changan Eado EV300 registering 12.20 kg/hp. This marginal difference (approximately 1.4%) indicates that both vehicles offer comparable performance potential relative to their mass, suggesting that acceleration capabilities are influenced more by drivetrain characteristics and torque delivery than by power-to-weight ratio alone [14]. In the present study, a single representative vehicle from each of the selected models was employed as the subject of investigation. The experimental procedures were

Table 1. Key comparative specifications [12], [13]

Parameter	Kia K3 2019	Changan Eado EV300 2022
Tare weight (kg)	1260	1615
Weight with passengers (kg)	1540	1965
Horsepower (hp)	128	161
Power (kW)	95.4	120
Torque (Nm)	154	245
Power-to-weight ratio (kg/hp)	12.03	12.20
Battery capacity (kWh)	—	47.8
Estimated operating range (km)	625	400

systematically designed and subsequently carried out on these vehicles in order to ensure consistency in testing conditions and to obtain reliable and comparable results between the two types.

2.2. *Energy Consumption and Operational Cost Evaluation*

To evaluate and compare the energy consumption and operational costs of a both vehicles under real-world driving conditions, a practical field test was conducted in Jordan. The test route covered approximately 100 kilometers and was specifically selected to simulate typical daily driving patterns encountered by Jordanian drivers. The route incorporated straight sections, elevation changes (both inclines and declines), and segments with light to moderate traffic density. Vehicle speeds reached up to 110 km/h in certain highway segments, thereby allowing the inclusion of both urban and interurban driving conditions. Therefore, the fuel and electric cost can be calculated by Eq. (1) and Eq. (2) respectively.

$$C_{fuel} = C_L \times F_c \tag{1}$$

$$C_{elec} = C_{kW} \times E_c \tag{2}$$

where, C_{fuel} is fuel cost and C_{elec} is electric cost, C_L and C_{kW} is gasoline price in JOD per litter and electric price in JOD per kWh, F_c is the fuel consumption in litter and E_c is electrical consumption in kWh.

In order to maintain consistency and minimize variables unrelated to the powertrain, specific operational conditions were standardized across both test vehicles [15]. The air conditioning system was kept active throughout the entire drive, all windows remained closed, and no auxiliary electrical or electronic systems (such as infotainment units or lighting) were engaged during the testing period.

The fuel used was regular unleaded gasoline (90 octane), with a recorded market price of 0.86 Jordanian Dinars (JOD) per liter, at the time of the test. For the electric vehicle, energy consumption was measured by recording the kilowatt-hours (kWh) consumed during charging at a public fast-charging station. The recorded charging cost was 0.198 JOD per kWh. Both the charging duration and fuel refilling time were measured with a stopwatch to assess time efficiency and operational practicality [16]. This comparative approach provides a baseline for understanding the cost differences between both vehicle types under identical operational conditions.

2.3. *Annual Operating Cost Estimation Based on Fixed Daily Usage*

To estimate the annual operating cost of an electric vehicle versus a gasoline vehicle, a fixed daily driving distance of 100 kilometers was assumed over a full calendar year (365 days). When combining normal and fast charging, the annual electric cost is calculated thought Eq. (3), the annual electric cost consists of summation of electric cost in normal and fast charging.

$$\bar{C}_{elec} = (C_n \times N_n \times E_n) + \left(C_f \times N_f \times E_f\right) \tag{3}$$

where, $\bar{C}_{elec}$ is the annual electric cost (JOD), C_n and C_f is the electric price in normal and fast charging respectively, N_n and N_f is the number of charging in normal and fast charging mode and E_n, E_f present the electric energy in normal and fast charging mode.

This approach enables the projection of energy expenses under consistent usage conditions, offering insight into long-term cost efficiency. The gasoline vehicle recorded an average fuel consumption of 5.2 liters per 100 kilometers, while the electric vehicle consumed 14 kilowatt-hours (kWh) for the same distance. The charging behavior of the electric vehicle was modeled based on a hybrid approach: charging was assumed to occur at home (normal charging) on 353 days of the year and at public stations (fast charging) 12 times annually, representing occasional travel or situations where home charging is not feasible [17]. This mixed charging model reflects realistic user behavior within the current Jordanian infrastructure context.

2.4. *Environmental Impact Assessment Framework*

To compare the environmental impact of electric and gasoline-powered vehicles, a multi-dimensional approach was applied that included emissions from operation, electricity generation, and battery manufacturing. The analysis focused on greenhouse gas emissions, particularly carbon dioxide (CO_2), due to its relevance to climate change and its significant contribution from the transportation sector. Also considered both direct operational emissions and indirect emissions associated with fuel production and electricity generation. Additionally, the environmental burden of lithium-ion battery production was evaluated and amortized across the projected service life of the battery to reflect its annualized contribution to total emissions [18], [19], [20].

2.4.1. *Operational emissions estimation*

For the gasoline vehicle, tailpipe CO_2 emissions were estimated based on the total annual fuel consumption. A standardized emission factor (SEF) of 2.31 kg CO_2 per liter of gasoline was used. Where 2.31 kg CO_2/L is the Intergovernmental Panel on Climate Change (IPCC) standard emission factor for gasoline.

The total CO_2 emissions can be estimated annually by Eq. (4).

$$\overline{CO}_{2,fuel} = \bar{F}_c \times SEF \tag{4}$$

where, the $\overline{CO}_{2,fuel}$ is the annual carbon dioxide emitted due to fuel combustion (kg/L), $\bar{F}_c$ is the annual fuel consumption (L) and SEF is standardized emission factor.

The total yearly fuel consumption was derived from the earlier energy consumption test, assuming a constant daily driving distance of 100 kilometers over 365 days [21]. For the EV, emissions were calculated based on electricity consumption and the emission intensity of Jordan's national grid using Eq. (5), Where the Grid Emission Factor (GEF) in Jordan is assumed to be 0.56 kg CO_2/kWh.

$$\overline{CO}_{2,elec} = \bar{E}_c \times GEF \tag{5}$$

where, the $\overline{CO}_{2,elec}$ present the annual carbon dioxide emitted due to electric productions (kg/kWh), $\bar{E}_c$ is the annual electrical energy used (kWh) and GEF is Grid Emission Factor.

A value of 0.56 kg CO_2 per kWh was applied to represent grid-based energy. In a separate scenario, a clean energy supply was modeled, where renewable electricity (solar or wind) contributed zero CO_2 emissions during vehicle operation [22].

2.4.2. *Battery manufacturing emissions*

The environmental impact of lithium-ion battery production was assessed using literature-derived estimates. The environmental burden of battery manufacturing is spread over its service life is explained in the Eq. (6)

$$\overline{CO}_{2,battery} = \frac{TBE}{B_{life}} \tag{6}$$

where, $\overline{CO}_{2,battery}$ present the annual carbon dioxide emitted due to battery manufacturing (kg/kWh), TBE is the Total Battery Emission (kg) and B_{life} present the estimated battery life (year).

A 60 kWh battery was assumed to generate approximately 9.2 metric tons of CO_2 during its manufacturing cycle. This figure was distributed over an 8-year lifespan, resulting in an annualized emission of 1,150 kg CO_2 per year, independent of the electricity source used for charging [23], [24].

2.4.3. *On-road emissions monitoring via OBD-II diagnostics*

To complement theoretical calculations, real-time engine and emissions data were collected using on-board diagnostics (OBD-II). The gasoline vehicle was equipped with an OBD-II scanner linked to the Torque Pro application, allowing for live monitoring of engine load, fuel flow rate, torque, revolutions per minute (RPM), and instantaneous CO_2 emissions.

Measurements were conducted under four distinct driving conditions: uphill driving, downhill driving, constant-speed cruising, and high acceleration. Each condition was selected to reflect common usage scenarios, enabling the observation of engine behavior and emission trends under varying loads. Data were recorded on a per-second basis during road tests, with special attention to changes in CO_2 output in response to variations in throttle position, vehicle speed, and road slope [25]. It should be noted that the CO_2 values captured represent ECU-calculated estimates, not direct exhaust gas measurements obtained via a dynamometer or external gas analyzer. Although accurate for comparative purposes, these figures may include a margin of error due to sensor response delays, calibration limits, and environmental influences.

2.5. *Vehicle Performance Evaluation*

The study evaluated and compared the dynamic performance of an electric vehicle and a gasoline vehicle under controlled real-road conditions, with a particular focus on acceleration characteristics and torque-power behavior [26]. Benchmark acceleration data (0–100 km/h) were collected from verified manufacturer specifications and existing literature for three electric vehicles and three gasoline vehicles of comparable weight class and drivetrain.

The practical evaluation involved live monitoring of engine behavior during various dynamic driving conditions. Measurements were taken using an OBD-II diagnostic interface connected to the vehicle's electronic control unit (ECU). This setup enabled real-time acquisition of engine speed (RPM), torque (N·m), power output (kW), engine load (%), instantaneous fuel flow rate (L/min), and calculated CO_2 emission estimates (g/km). While these values were ECU-based rather than obtained through a chassis dynamometer, they provided consistent and comparable data across test modes [26].

For the EV, motor torque and power output were recorded under equivalent dynamic conditions using the same diagnostic methodology, with attention given to RPM response, torque stability, and regenerative braking activity. Engine and motor performance curves were created by recording RPM, torque, and power at set intervals. Data were used to plot torque-RPM and power-RPM curves for both vehicles. The petrol engine's gradual torque rise and the electric motor's instant peak torque at low RPM were compared. Tests were run under controlled conditions with consistent acceleration and fixed payload. Data from idle to 120 km/h allowed a full analysis of acceleration and drivetrain efficiency [27].

2.6. *Noise and Comfort Evaluation Protocol*

To evaluate differences in noise levels and cabin comfort between gasoline-powered and electric vehicles, a qualitative and quantitative approach was used. The evaluation was structured around common sources of NVH (Noise, Vibration, and Harshness).

Both vehicles were assessed under the same driving conditions, including urban and highway environments, with consistent use of air conditioning and closed windows. Observations were made regarding cabin vibration, gearshift smoothness, braking behavior, and overall ride comfort. The perception of vibrations and the fluidity of motion were assessed by both the driver and a front-seat passenger using qualitative descriptors [28].

Cabin noise levels were measured during typical driving scenarios, including acceleration, cruising, and deceleration. A decibel meter was placed in a fixed position at the center console to ensure consistent readings. Sound levels were recorded while:

- Accelerating from 0 to 100 km/h
- Maintaining steady highway speed (80–100 km/h)
- Idling with air conditioning on

In contrast, the electric vehicle was expected to generate significantly less noise, with primary contributors being road-tire friction and aerodynamic drag at higher speeds. Sound levels were recorded in decibels (dB), with attention to both peak values during acceleration and average steady-state values [28].

2.7. *Driving Range Assessment and Adaptability to Local Conditions*

To assess the real-world usability of electric and gasoline vehicles in Jordan, their driving range and ability to adapt to local road and climate conditions were evaluated. The study focused on typical driving scenarios in Amman, a city characterized by mountainous terrain, frequent traffic congestion, and wide seasonal temperature variations. These factors were considered due to their significant impact on energy consumption and vehicle performance. For estimating expected range based on full tank present in the Eq. (7), where the Eq. (8) presents the estimating expected range based on full charging battery:

$$R_{K3} = \frac{T_V}{\bar{F}_c} \times 100\% \tag{7}$$

$$R_{Eado} = \frac{B_C}{\bar{E}_c} \times 100\% \tag{8}$$

where, R_{K3} , R_{Eado} is the range of Kia K3 and Changan Eado in (km) respectively, T_V is the tank volume of K3 in (L), B_C is the battery capacity of Eado in (kWh).

2.7.1. *Range estimation in local conditions*

For electric vehicles, the driving range reported by manufacturers based on standardized cycles such as Worldwide Harmonized Light Vehicles Test Procedure (WLTP) was compared with observed performance in urban driving conditions in Amman. Field observations and manufacturer data indicate that environmental and operational factors can lead to a 20–30% reduction in effective driving range. Influencing variables included frequent elevation changes, use of air conditioning systems during summer months, and cold temperature effects during winter, which can reduce battery efficiency and usable capacity by 10–15%. To account for real-world penalties (e.g., air conditioning, hills) we can use Eq. (9):

$$R_{Adj} = R \times (1 - r) \tag{9}$$

where, R_{Adj} present the adjusted range (km) and r is reduction factor.

For the gasoline vehicle, the declared fuel tank capacity and average consumption rate were used to calculate theoretical and practical driving range. While the reported fuel economy under normal driving conditions is approximately 6.5 liters per 100 kilometers, urban driving in Amman with heavy traffic and elevated terrain increased consumption to between 8 and 9 liters per 100 kilometers.

2.7.2. *Vehicle response to environmental and topographic factors*

For electric vehicles, the availability of instant torque was noted as an advantage for uphill driving, while regenerative braking improved energy efficiency during descents. However, frequent stops in traffic and limited public charging infrastructure were identified as operational constraints, particularly outside major urban areas. For IC vehicles, performance under load was evaluated for consistency in both high temperatures and during extended climbs. Although fuel consumption increased in hilly or congested areas, the overall performance remained stable, and the vehicles were less affected by ambient temperature changes [29].

2.8. *Annual Maintenance Cost Estimation Framework*

Structured analysis was conducted based on routine service requirements, component replacement cycles, and the likelihood of system failures. This comparison accounts for both preventive maintenance and corrective repairs, considering real-world service intervals and price ranges typical in the local and global automotive markets. Annual maintenance cost is derived from Eq. (10):

$$\bar{C}_M = C_M \times N_M \tag{10}$$

where, $\bar{C}_M$ is the annual maintenance cost (JOD) and C_M, N_M is the maintenance cost and number of maintenance frequency.

For gasoline vehicles, standard maintenance includes periodic engine oil and filter changes, air and fuel filter replacements, spark plug changes, coolant system inspections, and belt replacements. Additional costs may arise from mechanical issues involving the gearbox, ignition system, fuel delivery components, or engine-related failures. Based on international cost benchmarks and regional service data, the average annual maintenance cost for gasoline-powered vehicles is estimated to range from 355 to 850 Jordanian Dinars, depending on vehicle age, mileage, and condition.

By contrast, electric vehicles require fewer mechanical service operations due to the absence of an internal combustion engine, transmission system, and exhaust components. Routine maintenance primarily involves software diagnostics, battery health checks, air filter replacements, and periodic inspection of the electric motor's cooling system. Regenerative braking also extends brake system longevity, further reducing service needs. Despite the potential for battery degradation, charging unit failures, or electronic control system faults, the overall maintenance burden remains significantly lower. The estimated average annual maintenance cost for electric vehicles is projected to fall between 150 and 425 Jordanian Dinars, representing a 40–60% reduction compared to gasoline vehicles. All maintenance cost estimations are based on manufacturer-recommended service intervals, regional labor rates, and part prices, and are normalized over an average annual driving distance of 20,000 kilometers.

2.9. Purchase Cost Recovery Model and Long-Term Ownership Analysis

To evaluate the economic feasibility of purchasing an EV relative to a gasoline-powered vehicle, a purchase cost recovery model was developed. This model calculates the number of years required to offset the higher initial purchase price of an EV through annual savings in energy and maintenance costs.

2.9.1. Payback time calculation

Based on current market data in Jordan (as of 2024), the average price difference between comparable EV and gasoline models ranges from 5,000 to 8,000 Jordanian Dinars (JOD). Using the operational cost values calculated from earlier sections 1,631.55 JOD/year for the gasoline car and 567.13 JOD/year for the EV (assuming daily home charging and one public charge per month), the annual savings were estimated at 1,064.42 JOD. Payback time was calculated by dividing the vehicle price difference by the annual savings as presented in the Eq. (11):

$$PT = \frac{P_{EV}}{\bar{S}} \tag{11}$$

where, PT is the Payback time (year), P_{EV} is EV price premium (JOD) and $\bar{S}$ is annual operational saving (JOD).

Two scenarios were modeled:

- 6,000 $JOD\ price\ difference\ \rightarrow$ 5.78 $years\ payback$
- 8,000 $JOD\ price\ difference\ \rightarrow$ 7.71 $years\ payback$

2.9.2. Battery replacement impact

To account for long-term ownership costs, the model incorporates the likelihood of battery replacement after 8–10 years of use. With a battery replacement amortized over remaining vehicle life:

$$S_{Adj} = \bar{S} - \left(\frac{C_B}{N_Y}\right) \tag{12}$$

where, the S_{Adj} present the adjusting saving (JOD), C_B is the battery cost (JOD) and N_Y is the number of years after replacement.

After accounting for the adjusting saving, the playback time should be adjusted by Eq. (13):

$$PT_{Adj} = \frac{P_{EV}}{S_{Adj}} \tag{13}$$

where, PT_{Adj} is the adjusting playback time (year).

Based on regional service data and vehicle specifications, battery replacement costs for lithium-ion units in Jordan range from 3,500 to 6,000 JOD.

The replacement cost is amortized over the second half of the vehicle's service life (e.g., another 8 years), increasing the annual cost burden. For example, a 5,000 JOD battery replacement cost after year 8 translates to an added 625 JOD/year over the remaining 8 years. In this adjusted scenario, the effective annual savings dropped to approximately 439.42 JOD, significantly increasing the payback period:

- 6,000 $JOD\ difference\ \rightarrow$ 13.65 $years$
- 8,000 $JOD\ difference\ \rightarrow$ 18.22 $years$

3. Results and Discussion

First, the gasoline vehicle consumed 5.2 liters of 90 octane fuel, resulting in a direct fuel cost of 4.47 JOD at the time of testing, with gasoline priced at 0.86 JOD/liter. In contrast, the electric vehicle consumed 14.88 kilowatt-hours (kWh) of electricity, incurring a total charging cost of 2.95 JOD based on a public charging tariff of 0.198 JOD/kWh. This represents a 34% reduction in energy cost per 100 km in favor of the electric vehicle. The cost per km can be calculated by Eq. (14). While the gasoline vehicle refueled in approximately two minutes, the EV required 28 minutes to reach the same travel capacity, indicating a practical disadvantage in terms of time efficiency despite its economic advantage, as expressed by the cost per kilometer:

$$C_{km} = \frac{C_T}{D_T} \tag{14}$$

where, the C_{km} is the cost per 1km (JOD/km), C_T is the total trip cost (JOD) and D_T is the trip distance (km).

This confirms a 34% lower cost per kilometer for the electric vehicle in real-world Jordanian driving conditions. To quantify the difference in cost efficiency, the energy cost per kilometer was calculated. The gasoline vehicle had a cost of 0.0447 JOD/km, while the electric vehicle achieved a lower cost of 0.0295 JOD/km. This confirms a consistent operational savings of approximately 1.52 JOD per 100 km in favor of the electric vehicle under real-world usage as shown in **Table 2**.

To further evaluate the long-term financial implications of vehicle choice, an annual operating cost analysis was conducted for both gasoline and electric vehicles based on a fixed daily driving distance of 100 kilometers. For the gasoline vehicle, with a daily consumption of 5.2 liters and a unit fuel price of 0.86 JOD per liter, the total annual cost amounted to 1,631.55 JOD. In comparison, the electric vehicle consumed 14 kWh per day. The electricity cost was divided into two scenarios: Normal charging for 353 days of the year at a rate of 0.108 JOD/kWh and public fast charging 12 times per year at a rate of 0.198 JOD/kWh. The resulting annual cost for the electric vehicle was 567.13 JOD. This corresponds to an annual saving around 64.6% in favor of the electric vehicle as shown in **Figure 1**.

This considerable cost advantage demonstrates the potential of electric vehicles to significantly reduce household transportation expenses, particularly when supported by access to affordable home electricity tariffs. It is important to note that the analysis excluded other recurring expenses such as regular maintenance, insurance, and taxation, which will be addressed in a separate section. To assess that, the study evaluated the annual carbon dioxide (CO_2) emissions associated with both types of vehicles. The analysis includes emissions during operation and, in the case of electric vehicles, the indirect emissions from electricity generation as well as emissions embedded in battery manufacturing. For the gasoline vehicle, direct emissions from fuel combustion were calculated using the emission factor of 2.31 kg CO_2 per liter of gasoline, based on IPCC guidelines. Applying Eq. (4).

$$\overline{CO}_{2,fuel} = (5.2\, L/day \times 365) \times 2.31$$
$$= 1{,}898 \times 2.31$$
$$= 4{,}386\, kg\ CO_2/year$$

For the electric vehicle, CO_2 emissions with an annual consumption of 14 kWh/day, the total electricity used is:

$$14 \times 365 = 5{,}110\, kWh/year$$

Using Jordan's average grid emission factor of 0.56 kg CO_2/kWh Eq. (5):

$$\overline{CO}_{2,elec} = 5{,}110 \times 0.56 = 2{,}861.6\, kg\ CO_2/year$$

In scenarios where the electric vehicle is charged using 100% renewable energy (e.g., solar), the operational emissions reduce to 0 kg CO_2/year. Additionally, the manufacturing process of EV batteries introduces a one-time carbon cost. For a 60 kWh lithium-ion battery, the estimated emission is 9,200 kg CO_2. Spread over an 8-year service life (Eq.)6)):

$$\overline{CO}_{2,battery} = 9{,}2008 = 1{,}150\, kg\ CO_2/year$$

Thus, the total annual CO_2 emissions for each scenario are represented in the **Table 3**, The errors presented in the table can be attributed to the operating conditions of the internal combustion engine (ICE), such as catalyst efficiency and cold-start effects. In contrast, for electric vehicles, the error margin primarily arises from variations in charging station efficiency and fluctuations in the electrical load [30], [31].

These results show that electric vehicles produce 8.5% fewer CO_2 emissions than gasoline vehicles when charged from the national grid, and up to 73.7% fewer emissions when powered by clean energy. While battery production contributes a non-negligible carbon footprint, this is amortized over time and becomes relatively minor, especially when clean electricity is used. It is also worth noting that electric vehicles eliminate tailpipe pollutants such as Carbon Monoxide (CO), Nitrogen Oxides (NO_x), and Volatile Organic Compounds (VOCs), which are key contributors to urban smog and respiratory illness. **Figure 1** illustrates the variation in CO_2 emissions under different driving conditions.

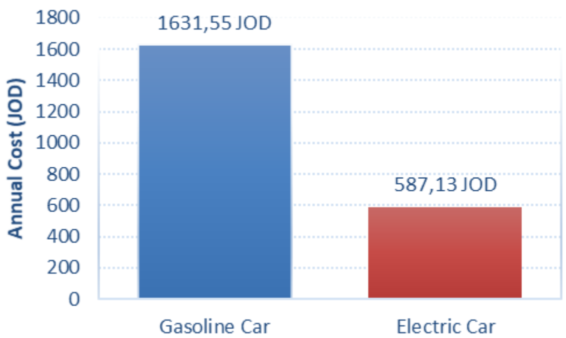

Figure 1. Annual driving cost by vehicle type based on energy source (JOD/year)

Table 2. Cost, energy, and time metrics for 100 km travel: gasoline vs. EV

Parameter	Gasoline vehicle	Electric vehicle
Fuel/Energy Consumed	5.2 liters	14.88 kWh
Cost (JOD)	4.47 JOD	2.95 JOD
Refueling/Charging Time	~2 minutes	~28 minutes
Fuel/Energy Unit Price	0.86 JOD/liter	0.198 JOD/kWh (station rate)

Table 3. Annual CO_2 emissions comparison by vehicle type

Vehicle type	Operational CO_2 (kg)	Battery CO_2 (kg)	Total CO_2 (kg/year)
Gasoline (Kia K3)	4,386	—	4,386 ± 5%
Electric (Grid charging)	2,861.6	1,150	4,011.6 ± 5%
Electric (Clean charging)	0	1,150	1,150

In **Figure 2**, section (a) shows the increase in CO_2 emissions during uphill driving, where higher engine load and fuel consumption are required to overcome gravity. (b) depicts the significant reduction in CO_2 emissions during downhill driving, where the engine load decreases, and fuel injection is often reduced. (c) demonstrates the stable CO_2 emissions during constant acceleration, where the engine maintains a steady load and fuel consumption. Finally, (d) highlights the sharp rise in CO_2 emissions during high acceleration, as the engine generates maximum torque and power, leading to increased fuel consumption and emissions. These figures collectively showcase how driving behavior and road conditions influence engine performance and CO_2 emissions.

Using On-Board Diagnostics (OBD-II) and the Torque Pro application to measure parameters such as engine RPM, torque, power (kW), engine load, and vehicle speed during actual driving conditions. It is typically evaluated using the time required to accelerate from 0 to 100 km/h. This study compares the performance of electric and gasoline vehicles through practical testing and diagnostic data, while also analyzing torque, power, and RPM behavior using OBD-II readings. In contrast, ICE vehicles require engine revolutions to build up torque, typically within the 3500–4500 RPM range. Thus, the EV accelerates approximately 75% faster under the same conditions. Sample values from Kia K3 and Changan during full acceleration are shown in **Table 4**.

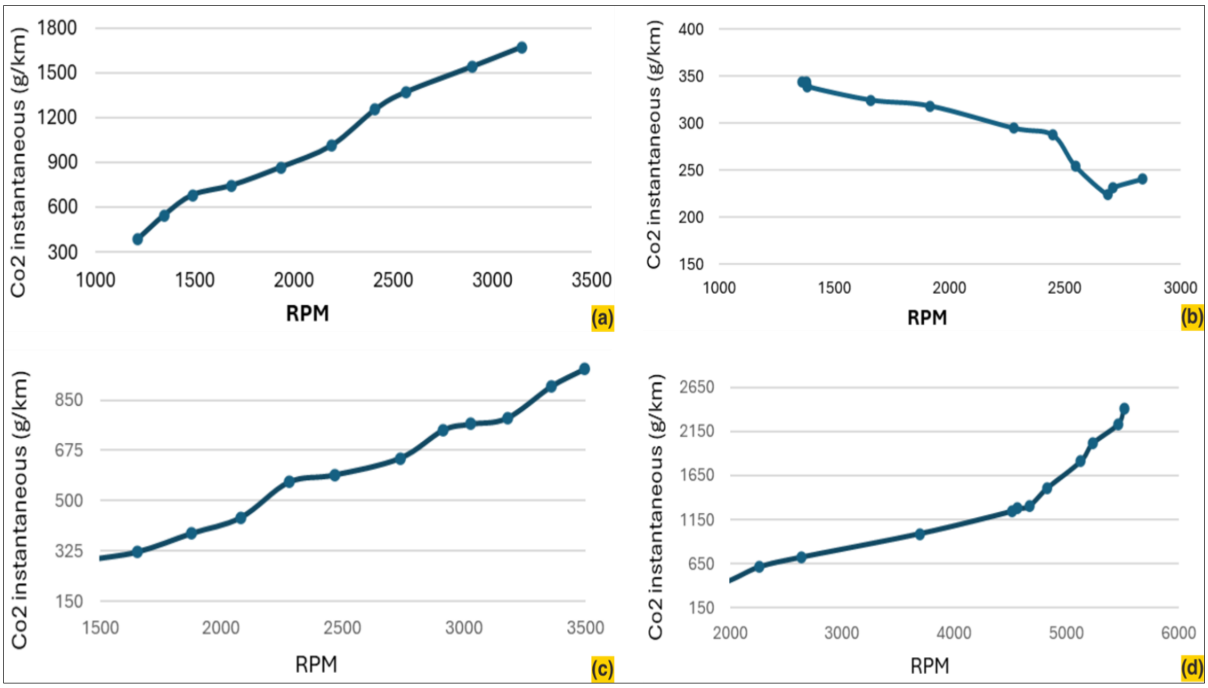

Figure 2. Instantaneous CO_2 emissions vs. RPM during various scenarios: (a) High climb; (b) Slope landing; (c) Constant acceleration; (d) High acceleration

Table 4. Comparative rotational performance metrics for ICE and EV

Type	RPM	Torque (Nm)	Power (kW)
ICE	3690	65.17	~25
	4828	103.1	~51.34
	5511	80.1	~65.88
EV	5000	95.5	~50
	5700	82.1	~49
	8600	100	~90

The results are shown in the Figure 3, illustrating the performance of both petrol and electric engines under various conditions. Section (a) depicts the petrol engine during a high climb, showing a gradual increase in RPM with rising torque and power. (b) represents the petrol engine during a descent, where RPM stabilizes, and torque and power decrease, become negative with engine braking. (c) shows constant acceleration in the petrol engine, with a steady rise in RPM and a moderate increase in power. (d) highlights high acceleration in the petrol engine, with rapid RPM increase and an exponential rise in power. (e) illustrates the electric vehicle during a high climb, showing maximum torque at the start, with decreasing torque and increasing power. (f) demonstrates the electric vehicle during descent, where torque becomes negative due to regenerative braking, and power is recovered. (g) presents constant acceleration in the electric vehicle, with smooth increases in RPM and power, while torque decreases slightly. (h) depicts high acceleration in the electric vehicle, with rapid RPM increase and decreasing torque as power continues to rise. In this study, it is important to highlight that the data obtained from the OBD-II scan tool are subject to a certain margin of error. Although OBD-II provides practical and accessible means to collect vehicle operational parameters, its readings are not always highly accurate, as they rely on sensor signals and estimation algorithms within the Engine Control Unit (ECU). Several studies have reported that discrepancies between OBD-II derived values and reference measurements typically fall within a range of 4–8%. Consequently, the values presented in Table 4 and Figure 3 of this work should be interpreted with this uncertainty in mind. This margin of error reflects the inherent limitations of OBD-II systems, which are designed primarily for diagnostic purposes rather than for precise scientific measurements [32].

Figure 4 compares the power and torque of both vehicle types, highlighting the differences in performance, with the petrol engine showing gradual changes and the electric vehicle providing instant torque with decreasing torque at higher RPMs.

Compared to gasoline vehicles, electric vehicles exhibit a significant reduction in both cabin noise levels and vibration during operation, resulting in a more refined driving experience. Quantitative measurements indicate that internal combustion engine (ICE) vehicles typically produce 70–80 dB under acceleration, whereas electric vehicles operate within the quieter range of 50–60 dB. To express sound perception more technically, the decibel scale follows a logarithmic relationship. The perceived loudness LD of a sound is related to reference intensity I0 as follows in Eq. (15):

$$LD = 10 \cdot log_{10}(\frac{I}{I_0}) \tag{19}$$

where, LD is the sound level in decibels (dB). I is the measured sound intensity and I_0 is the reference sound intensity $(10^{-12}\ W/m^2)$.

Given this logarithmic scale, a 10 dB increase is perceived as roughly twice as loud. Hence, a cabin noise difference from 60 dB (EV) to 75 dB (ICE) equates to over three times louder in perceived sound intensity, which significantly affects user comfort on long drives or in congested urban environments, as shown in Table 5.

The absence of gearshifts and the presence of regenerative braking in EVs contribute to smoother deceleration and acceleration phases, minimizing cabin jerk and improving overall ride quality. This benefit is especially pronounced in urban traffic, where constant shifting in gasoline cars can lead to driver fatigue. Subjective evaluations from field testing confirm that passengers consistently rated electric vehicles higher in terms of ride quietness, smoothness, and reduced cabin vibration. In conclusion, from both

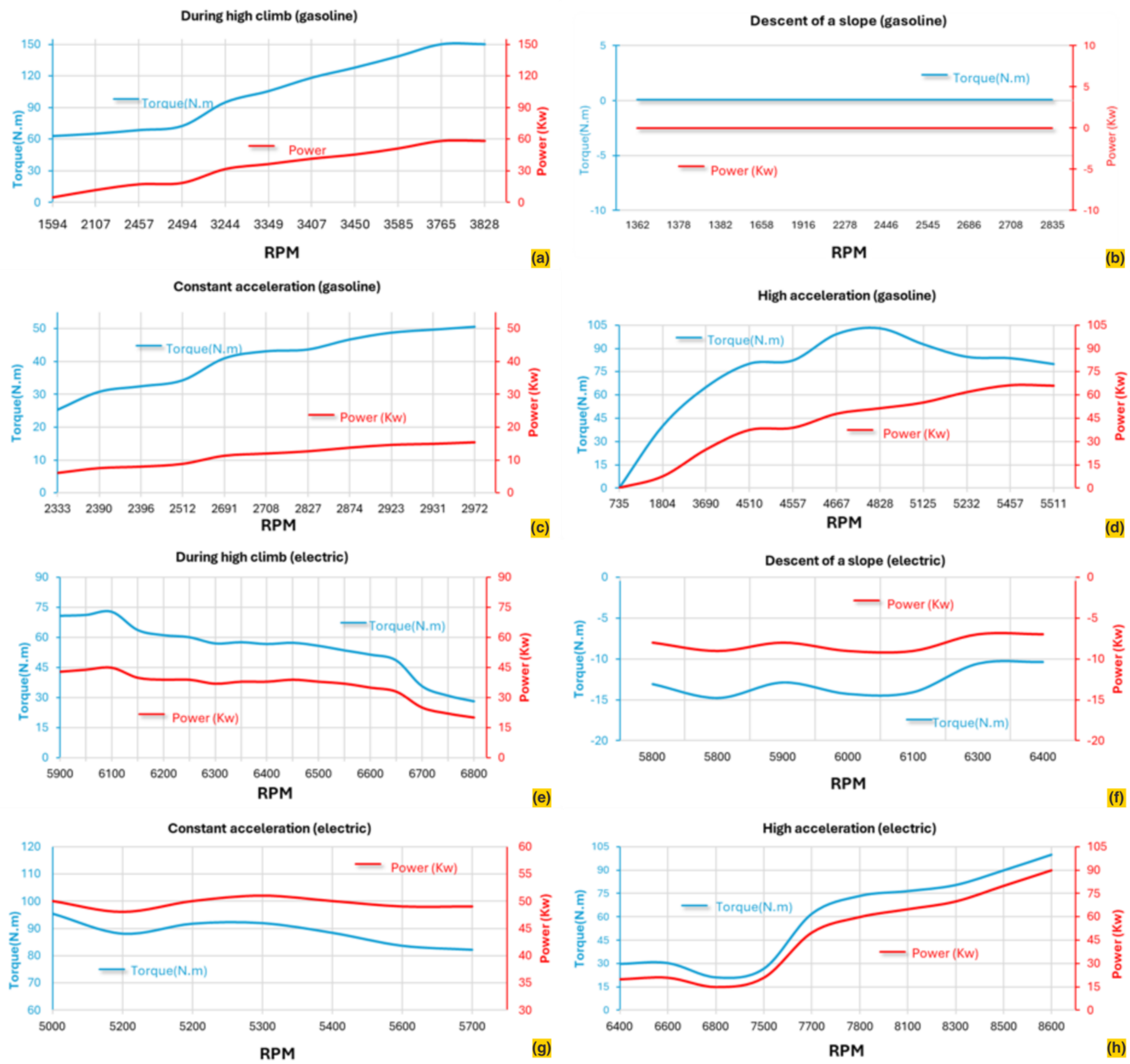

Figure 3. RPM, torque, and power profiles of petrol and EV under various driving conditions (high climb, descent, constant acceleration, and high acceleration)

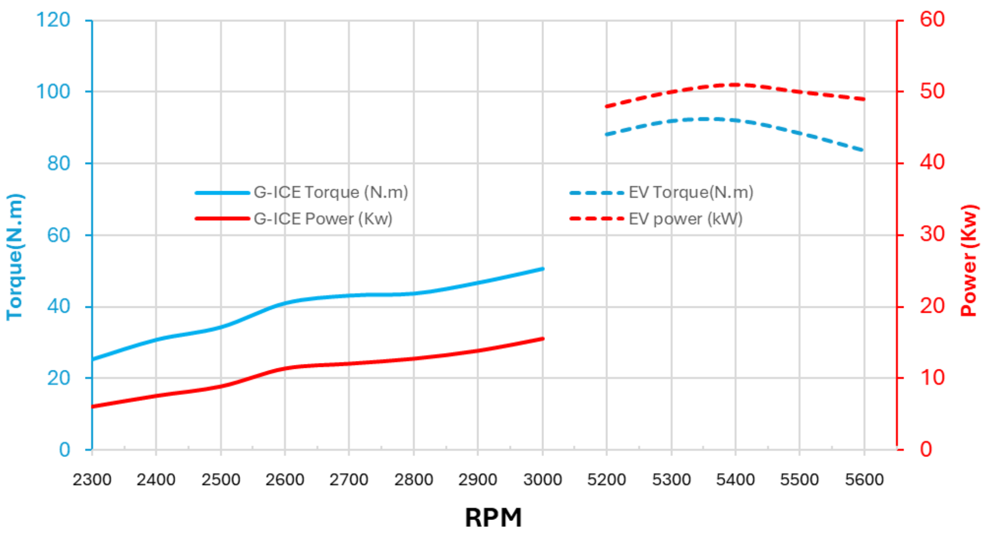

Figure 4. Comparative analysis of power and torque – petrol vs. EV

Table 5. Ride comfort and sound differences between gasoline and electric cars

Item	Gasoline Cars	Electric Vehicles
Engine sound	Relatively high	Almost non-existent
Vibrations	Note during operation	Almost non-existent
Gearshift sound	Audible	-
Exhaust sound	Variable depending on the type of car	-
Comfort level inside the cabin	Medium to Good	Very high
Average noise (dB)	70 - 80 dB	50 - 60 dB

a physiological and engineering standpoint, electric vehicles clearly offer superior acoustic and vibrational comfort, making them favorable for both short daily commutes and longer urban driving. These advantages are not only important for user satisfaction but also contribute to long-term health benefits by reducing continuous exposure to noise pollution and micro-vibrations.

The driving range of a vehicle is a critical performance parameter that reflects how effectively it can adapt to local environmental and operational conditions. In the Jordanian context, particularly within Amman's topography characterized by steep hills, frequent congestion, and fluctuating seasonal temperatures, electric and gasoline vehicles behave differently in terms of energy efficiency and practicality. Based on empirical testing, gasoline vehicles exhibit relatively stable fuel consumption across a range of environmental conditions, with consumption rising from an average of 6.5 L/100 km under standard conditions to approximately 8–9 L/100 km in Amman's hilly, high-traffic settings. With a standard fuel tank capacity of 50 liters, the estimated real-world range R_{K3} can be calculated as follows in Eq. (7):

$$R_{K3} = \frac{50}{8.5} \times 100 = 588.24\ km$$

For electric vehicles, however, the theoretical range provided by the manufacturer (e.g., 450 km for the Hyundai Kona EV under WLTP conditions) is significantly affected by factors such as gradient-induced load, ambient temperature, HVAC usage, and regenerative braking efficacy. In field observations, the actual driving range dropped by approximately 20–30%, yielding a corrected driving range R_{Adj} expressed as:

$$R_{Adj} = 450 \times (1 - 0.25) = 337.5\ km$$

This adjusted figure aligns with user feedback and energy consumption data, which ranged between 18 and 22 kWh/100 km depending on conditions. Applying this to the energy capacity of a 64 kWh battery, the estimated operational range R_{Eado} is:

$$R_{Eado} = \frac{64}{19} \times 100 = 336.84\ km$$

Key stressors include high summer temperatures, which increase cooling system load, and cold winters, where battery chemistry and HVAC systems simultaneously reduce range by an additional 10–15%. Despite this, electric vehicles demonstrated superior performance in hill climbing scenarios, leveraging instant torque delivery, regenerative braking during descent, and smoother throttle transitions in stop-and-go traffic, as represented in Table 6.

EVs typically cost more upfront than gasoline vehicles, with a price difference ranging from JOD 5,000 to 8,000 in Jordan. However, this difference can be offset by lower operating costs. Based on the field test data, annual fuel cost for a gasoline car (driving 100 km daily) is JOD 1,631.55, while for an EV it is JOD 567.13, assuming mostly home charging. Which mean around 65% is saving. The resulting annual savings is:

$$\bar{S} = 1{,}631.55 - 567.13 = 1{,}064.42\ JOD \tag{23}$$

The basic payback time for the extra cost is:

For a JOD 6,000 difference:

$$\frac{6{,}000}{1{,}064.42} = 5.63\ years \tag{24}$$

For a JOD 8,000 difference:

$$\frac{8{,}000}{1{,}064.42} = 7.51\ years \tag{25}$$

If the EV battery is replaced after 8 years at a cost of JOD 5,000, the added annual cost is:

$$\frac{5{,}000}{8} = 625\ JOD/year$$

The adjusted savings becomes 439.42 JOD per year, and then the payback would be for 6,000 = 13.65 years, and for 8,000 = 18.22 years.

Table 6. Comparative driving dynamics of gasoline and electric vehicles in Jordanian terrain

Item	Gasoline Car	Electric Vehicle
Declared driving range	600-700km	400-450 km
Actual range in Amman	555-625 km	315-360 km
Energy/fuel consumption in traffic	8-9 L/100km	18-22 kwh/100km
Altitude performance	Good (gradual torque)	Excellent (instantaneous torque)
Air conditioner effect	Increases by 0.5–1 L/100 km	Reduces range 7-10%
Cold weather impact	Not affected	Falls 10-15%

The increasing adoption of EVs in Jordan is expected to bring notable environmental, economic, and infrastructural transformations. Replacing just 20% of ICE vehicles with EVs by 2030 could cut transport-related CO_2 emissions by 10–15%, especially in congested cities like Amman. As of 2024, Jordan has 63 operational charging stations and over 230 under permitting, mainly concentrated in urban centers while there are over 730 traditional fuel stations, underscoring the need for infrastructure expansion. The government introduced time-of-use electricity tariffs in July 2024, with home charging ranging from 108 to 160 fils/kWh, and public charging reaching up to 213 fils/kWh during peak hours. Some petrol stations are already integrating EV chargers, and the trend is expected to grow. Socially, EV popularity is rising, especially among youth adopting small electric mobility solutions, fostering a culture of sustainability. Overall, EVs represent a strategic shift toward cleaner transportation in Jordan, but their success depends on coordinated infrastructure development, supportive policies, and increased public awareness (Figure 5).

4. Conclusion

This research provided a detailed comparative analysis between an EV and ICE vehicles under real-world driving conditions in Jordan, covering multidimensional axis. Through a 100 km test route replicating typical Jordanian terrain, including inclines, urban congestion, and highway speeds, empirical data were collected and analyzed using OBD-II diagnostics and real-time measurements to provide a robust evaluation of both vehicle types.

The results show that EV offer substantial advantages in operational efficiency, consuming 14.88 kWh per 100 km (costing JOD 2.95) versus 5.2 liters of gasoline (JOD 4.47). When extrapolated to annual use, the EV yields savings of over JOD 1,060 compared to the gasoline car, assuming a daily commute of 100 km and primarily home charging. From an environmental perspective, EVs emit significantly less CO_2 annually (as low as 1,150 kg when powered by clean energy) compared to 4,386 kg from gasoline cars, confirming the EV's superiority in emissions reduction and urban air quality improvement.

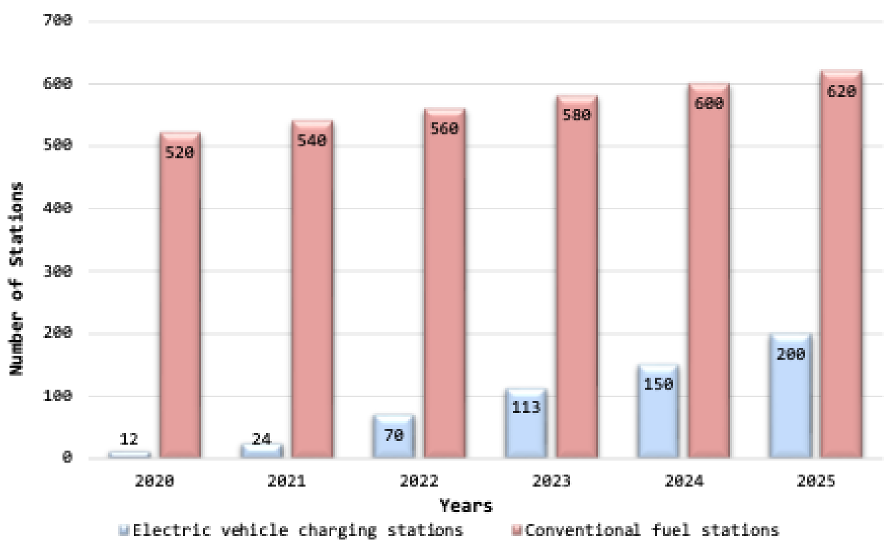

Figure 5. Expansion of station infrastructure in Jordan between 2020 and 2025

Performance-wise, EVs demonstrated faster acceleration due to their instant torque characteristics, along with smoother power delivery thanks to single-speed transmissions. OBD-II data validated that electric motors maintain higher and more consistent torque at lower RPMs compared to internal combustion engines, which require higher rev ranges to deliver peak torque. While gasoline engines exhibit a lag due to gear transitions and combustion cycles, EVs deliver nearly silent and vibration-free operation, making them superior in terms of noise levels and ride comfort. From a broader perspective, the expected widespread adoption of EVs in Jordan will bring environmental benefits, reduce fuel imports, and drive the development of local renewable energy systems. Government strategies such as the expansion of public charging stations and the implementation of time-based electricity tariffs are essential to support this transition. The analysis of fuel and electricity pricing trends from 2020–2025 also reveals that EV charging remains more stable and economical than gasoline, especially under off-peak conditions.

Battery end-of-life management and recycling are critical to reducing environmental impact and recovering valuable materials such as nickel, cobalt, and lithium. While recycling lowers emissions and resource use compared to primary mining, challenges remain due to varied chemistries, limited collection systems, and regulatory gaps. Promoting reuse, second-life applications, and harmonized recycling policies will be essential to maximize both environmental and economic benefits.

5. Recommendations

To support the transition toward electric mobility in Jordan, several key recommendations emerge from this study. First, expanding home charging infrastructure is essential, as it offers the most cost-effective and convenient option for daily users; this could be incentivized through reduced electricity tariffs and installation support. In parallel, the public charging network, especially fast chargers, should be scaled up across urban centers and highways to address range anxiety and enable long-distance travel. Additionally, comprehensive policies must be established to manage the battery lifecycle, including support for battery recycling, second-life applications, and long-term warranties to reduce future replacement costs. Government incentives such as tax exemptions or direct subsidies would further shorten the payback period for electric vehicles, making them more attractive to consumers.

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Author's Declaration

Authors' contributions and responsibilities

Conceptualization was carried out by M.B.T. and S.A.Q. Methodology and experimental design were developed by M.B.T., H.A.M., and S.R. Data collection and field testing were conducted by H.A.M., S.R., and S.A.E. Data analysis and interpretation were performed by M.B.T., H.A.M., S.R., and S.A.E. Resources and technical support were provided by S.A.Q. and S.A.A. Visualization and figure preparation were undertaken by S.A.E. and S.A.A. The original draft was prepared by M.B.T. and S.A.Q., and critical review and editing were completed by: The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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