Study and analysis of electric vehicles adoption: a middle eastern country as a case study

Muzhir Shaban Al-Ani¹, Thabit Sultan Mohammed², Karim M. Aljebory²
¹Department of Information Technology, University of Human Development, Sulaymaniyah, Iraq
²Department of Computer Technical Engineering, Al-Qalam University College, Kirkuk, Iraq

ABSTRACT

Adaption of hybrid electric vehicles (HEVs) and electric vehicles (EVs) is an important choice that has many positive environmental and economic impacts, where, it helps in reducing exhaust emission, participation in dropping down the amount of noise pollution, and improving the air quality. With these encouraging impacts as well as the reduction in the price of fuel consumption, electric vehicles become at the top of car industry. A study on electric vehicles and their impact on improving the quality of environment is the main motive of this research. Selected theories and factors related to the electric vehicles’ adoption are investigated and analysed. The main factor that led to the spread of electric vehicles is the reliance on electric energy, so it is considered as zero emissions. But there is another effect, which is that these vehicles need continuous electric charging daily, which in turn needs to generate electricity, which leads to environmental pollution indirectly.

Keywords: Adoption, Clean environment, Electric vehicles, Friendly environment vehicles, Hybrid electric vehicles

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1. INTRODUCTION

Recently, electric vehicles (EVs), which are driven by electric power, have been widely used [1]. Many applications have been designed to use the original delegation-based vehicle engine and use an electric motor, as a replacement [2]. This is the easiest technique to switch from petroleum to electricity [3]. In addition, the vehicle's components, and the engine is provided with the required power by several special batteries that store electricity [4]. It has the advantage of preserving the environment from pollution compared to traditional vehicles with internal combustion engines [5]. Electric vehicles starting with its actual development in 2009, were produced with short-range and heavy batteries, that are of high price [6], [7]. Innovation, therefore have focused on increasing the distance per the charging cycle as well as reducing the charging time [8], [9]. Several governments have begun to strongly encourage the adoption of this type of vehicles despite few complications related to them. Among such related problems are the need to ensure high enough supply voltage, as well as the fear of explosion of the vehicle when it collides due to heavy battery weight [10], [11].

By considering reports, that are recording a dramatic increase in the global market for electric vehicles [12], [13], one might likely to wonder if electric vehicles are a better choice than traditional vehicles. In fact, technologies that supporting EVs and batteries continue to evolve. Obstacles and impediments, such as high cost, limited range and performance efficiency, long charging time and scarcity of charging stations, are gradually fading [14], [15]. Furthermore, as EVs are having no emissions, they can be the dominant in the roads with the environment been better, and the air is kept cleanerv [16], [17]. Rewards to this practice will be obtained through living in a clean environment and breathing fresh air, which contribute to overall human health and a low incidence
of disease worldwide. This will eventually mean less pressure on public health systems, and hospitals [18], [19]. Moreover, reducing emissions will preserve the ozone layer, reduce our carbon footprint, and help reducing the global warming [20], [21]. With all these positive impacts, electric vehicles are the future means of transport in cities and countries around the world that save money and make a big difference to the environment [22], [23].

In addition to the real demand of large volume of the market, the European anti-pollution regulations are contributing to the factors encouraging the adoption of electric vehicles [24], [25]. Electric vehicles have recently reached a level of autonomy and self-sufficiency, performance and price, that make them a perfectly effective and valid option for an increasing number of drivers. The requirements that have to be kept in consideration is that a connection point has to be made available in the garage, and to ensure that journeys are not exceeding 300 km between refills, especially if there are strong slopes in the path [26], [27]. The advanced technology that is adopted in manufacturing hybrid and electric vehicles is contributing to worldwide goal of reducing the carbon emissions levels [28], [29]. Studies and statistics are reporting that the adoption of plug-in electric vehicles in cities in Los Angeles, for example, caused significantly lower carbon emission [30], [31]. It’s worth mentioning, that applying new strategies to electric vehicles, such as intelligent control could be an important issue for electricity to be renewable generated [32], [33].

With all the given supporting factors, that are favouring the adoption of electric cars, resulting in clearly widespread use of these vehicles. Driven by the fact they do not need to use fuel, and being free of emissions, electric vehicles are a double-edged sword, where they require large electric charging energy leading to indirect environmental pollution. Literature is witnessing continuous studies and works related to electric vehicles and the factors affecting the tendency towards producing and adapting them.

Sierczula [34], it was clarified that governments and private companies are responsible for the majority of purchases of electric vehicles worldwide. Fourteen companies that adopted electric vehicles, were considered in the study to determine the factors that have behind purchasing decisions. Additionally, the study concentrated on primary and secondary factors affecting the adaption of electrical cars, where, new technology was found to be the main factor affecting the adoption of electric vehicles.

Bockarjova and Steg [35], the results obtained from a large number of dutch drivers, are analysed. The theory of motivation for protection is found to be an applicable theory to completely model the adoption of electric vehicle using different indicators. It’s further shown that all theoretical contexts are excellent predictors of various indicators. Adoption of electric vehicle are more interested when they perceived that the negative consequences of conventional vehicles were more severe and that electric vehicles would be expected to mitigate them. They found that environmental risks are greater when we predict indicators close to adoption; while security risks are more important for predicting distance adoption indicators.

Wu et al. [36] showed that the usage of electric vehicles with respect to the indicators at that time was insignificant. One of the reasons for the modest adoption figures is that the massive acceptance of electric vehicles depends largely on the perception of electric vehicles by consumers. This work provides an overview of the factors and barriers to adopt plug-in electric vehicles, as well as they applied theoretical perspectives to understand consumer intentions and adoption behaviour with respect to electric vehicles. In addition, they identify gaps and limitations were also identified to highlighting the guide lines of the future works.

The extent to which plug-in electric vehicles (PEV) are more friendly environment, for most polluting species, than conventional cars in Texas, after taking into account energy emissions and the impacts of battery supply processes, is studied in [37]. The results indicated that PEVs in the current network can reduce GHG, NOx, FM10 and CO emissions in urban areas, but generate high level of SO2 emissions than existing light vehicles. As emission rates for conventional vehicles improve, it seems that electric grids must do the same improving of emission technologies.

An index to classify and identify the preparation of major cities in USA to adopt the electric vehicles, is presented in [38]. Preparation refers to sorting the cities in their order of supporting the adoption of electric vehicles, as evidenced by the presence of different types of policies, development of infrastructure, investments in PEV technology. They compared and sorted the cities of the states participating in the zero-emission vehicle program with the others, in order to understand the participation in this program has a significant impact on PEV preparation.

The sales of electric vehicles at different levels in Norway, is analysed in [39]. Authors of that work have further analysed the sales of EVs with the corresponding local demographics to determine the factors that led to a greater adoption of electric vehicles. It was contributed that access to vehicle charging infrastructure, was adjacent to the main cities, and that had the greatest power of sales growth. In addition, it was contributed that short-range vehicles were offered slightly more revenue than long-range vehicles.

Some effects in the adoption of the hybrid electric vehicle (HEV), were examined in [40]. This contrasted with most of the existing analyses, which focus on the analysis of factors related to socioeconomic and demographic. This article estimated the strength of neighbourhood effects in the adoption of HEV via application of special model, namely that the decision to adopt HEV of each consumer may be influenced by the decisions to
adopt HEV. They found that the adoption of HEV has significant effects. In addition, they applied time series analysis and showed that the historical adoption of HEV has a significant impact effect on future adoption.

The relationship between the presence of government incentives and the market share of electric vehicles, as well as other important socio-economic factors, is presented in [41]. This research relies on a cross-sectional analysis/time series, and the developed model is an aggregate binomial logic model, which provides an estimate division among conventional and electric vehicles from different US states between 2003 and 2011. The results showed that the price of electricity was negatively associated with the use of electric vehicles, while urban roads and incentives of government were positively correlated with the market share of state electric vehicles.

An analysis study covering non-adopters, potential adopters and early adopters of electric vehicles, is performed in [42]. The results of that study indicated that psychological and sociodemographic factors played an important role in predicting the adoption of EV. In addition, early users tend to live in areas with financial incentives for electric vehicles. They identified four potential adopter’s groups of electric vehicles based on their assessment of the motivations for buying and not buying electric vehicles. Potential segments of adopters are differed in their sociodemographic and psychological characteristics, in addition to their political incentives. They discussed their findings to design effective marketing policies and marketing systems.

Vickers [43] mentioned that governmental incentives may be granted for people adopting electric vehicles. The concepts of these incentives include services that were applied to cover maintenance of electric vehicles. The operation of micro-networks, the exchange of energy, and the exchange of vehicles are among the service contexts. The research study analysed the types of services in each context by evaluating the most modern service provision approaches. The results offered an overview of the possibilities of harnessing the full economic potential of electric vehicles. For the adoption of electric vehicles to be increased, business models and technologies should be supported.

A questionnaire covering 482 participants to collect data about electric vehicles customers in Beijing, was conducted in [44]. The obtained results indicated that social acceptability of electric vehicles in the long term was affected with hazard-related attributes. The attributes of the resources have negative effects on their long-term acceptability and purchase intent. They found that the importance of attributes moderates the effect of hazard attributes and resources on adoption indicators. In addition, risk perception has positive effects on consumer adoption indicators, and government dependence and responsibility to protect the environment also influences the intention of consumer behaviour.

Zhai et al. [45] performed an online survey with respondents from a region identified as a potential leading market for electric vehicles, but has not yet reached a significant part of the electric vehicle market. The online survey tested the effect of two behaviour-based strategies on electric vehicle preferences: standards-based intervention and outstanding intervention. In order to identify the effect of treatment, they controlled the identity of the environment, the heterogeneity of key economic preferences and size. The obtained results indicated highlighting future cost savings greatly increases the probability of choosing electric vehicles.

A study on the best and optimal design of the location and charging capacity of electric vehicles is presented in [46]. Two mathematical models to obtain an optimal design that takes into account the balance between the choice of road and the waiting time for loading, was presented. The objective is to minimize the common costs of building facilities, travel and waiting times for drivers of electric vehicles. The upper-level model divided the facilities and their capacity, while the lower-level model characterized the balance behaviour of the driver's routes and the options of the loading facilities. They conducted a comprehensive experiment on three networks to evaluate the performance of the algorithms, the strength of the solutions, and to understand the possible expansion of the solution approach.

New ways of operating the network to improve the integration of electric vehicles by avoiding additional network reinforcements, was presented in [47]. Authors of this published work proposed a new fast-charging station topology for electric vehicles based on a multi-terminal DC link arrangement via applied the same power electronic devices. Terminals are connected to different feeder so that the electric vehicle's load can be shared between the secondary substations upstream. The experimental results were validated in a reduced system that mimics the main characteristics of a real BT distribution system. The proposed solution can be considered as a catalyst for electronic mobility due to minimizing the impact of billing and maximizing the use of current assets.

After this section, section 2 is presenting a comparative analysis, where a table is constructed with a number of factors adopted in the surveyed works and studies, such as; the theories used, and the adoption context. A case study is presented in section 3, where the Jordanian electric vehicle market is studied and analysed to project the scope of adoption of electric vehicles in a middle eastern country. The conclusions of the paper are shown in section 4.

2. METHOD

Considering the literature work and studies presented in previous sections, Table 1 is made to summarize this literature into a number of factors, namely; Authors and year of publication, adoption context, theories used, 

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participants/organization, environment/actors, technology, and pollution reduction. In this table, the adoption of new technology for hybrid and electric vehicles that are considered zero-emissions vehicles, are shown. Some theories and factors are selected related to adaption of electric vehicles. In addition to this, there other factors that are mentioned in literature such as; barriers against consumer adoption, the distribution of charging station management system, and roles and policies. This set of factors are not considered in Table 1. Moreover, many recent research papers are emphasizing the analysing of factors affecting the adoption of hybrid and electric vehicles, while other works are focusing on both pros and cons of using HEVs and EVs and their effects on the consumers.

<table>
<thead>
<tr>
<th>Author(s)/year of publication</th>
<th>Adoption context</th>
<th>Theories used</th>
<th>Participants/organization</th>
<th>Environment/actors</th>
<th>Technology</th>
<th>Pollution reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sierzchula (2014) [34]</td>
<td>Significant factors for organizations that extended their EV fleets collective and individual concerns predict different pointers of adoption</td>
<td>test group is designed to represent population fourteen companies that adopted electric vehicles</td>
<td>Consumers</td>
<td>qualitative case study</td>
<td>Zero Emission</td>
<td></td>
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<tr>
<td>Bockarjova and Steg (2014) [35]</td>
<td>Adoption of EV depend on perception of electric vehicles by consumers barriers against consumer adopting plug-in EVs,</td>
<td>Protection inspiration theory predict pro-environmental behavior</td>
<td>Dutch drivers</td>
<td>Consumers</td>
<td>Descriptive statistics of variables (dependent and independent)</td>
<td>Zero Emission</td>
</tr>
<tr>
<td>Wu et al. (2015) [36]</td>
<td>Adoption of EV are more friendly environment, to make PEV adoption easier and more affordable effects of many of the incentives on per capita EV sales the decisions to adopt HEV</td>
<td>Life-Cycle Analysis Comparison statistical test of difference in means</td>
<td>Texas-USA</td>
<td>Industry</td>
<td>Electric vehicle emissions model investments in plug-in electric vehicles (PEV) technology</td>
<td>Zero Emission</td>
</tr>
<tr>
<td>Nichols et al. (2015) [37]</td>
<td>Mersky et al. (2016) [38]</td>
<td>Liu et al. (2017) [40]</td>
<td>Government incentives can be used to improve adoption factors focus on the analysis of factors related to socioeconomic and demographic effects on the consumers.</td>
<td>Industry</td>
<td>Consumers</td>
<td>Regression methods applied time series analysis</td>
</tr>
<tr>
<td>Priessner et al. (2018) [42]</td>
<td>Chen et al. (2020) [46]</td>
<td>Kuki et al. (2011) [47]</td>
<td>The targeted participants are potential car consumers shift in electric vehicle adoption location and charging capacity of EV charging station management system</td>
<td>Conducted an online survey A five-point Likert scale balance between the choice of road and the waiting time new fast-charging station topology</td>
<td>Ministry of transport-Italy Consumers Comprehensive experiment on three networks Laboratory testing platform</td>
<td>Industry</td>
</tr>
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</table>

Table 1. Selected theories and factors related to the adoption of electric vehicles
3. RESULTS AND DISCUSSION

Among the biggest environmental issues reported nowadays on earth, are the emissions of greenhouse gases as well as the global climate change. Many countries are dealing with these issues by implementing policies for making a transition to zero-emission vehicles, such as electric vehicles. Moreover, automobile industries have responded to global movements by changing the orientation of car production from internal combustion engine-based to other environmentally friendly vehicles. Jordan is considered as one of the pioneers in adopting electric vehicles in the Middle East, therefore it is considered as a suitable case study. Related data are obtained from the Jordan free zones investors authority market covering six years from 2014 to 2019, where a year before dealing with hybrid vehicles was surveyed to the year in which the Coronavirus appeared.

In the following Figures 1-6, trade statistics of different vehicles are illustrated for the adopted six years (i.e. 2014-2019). In the figures, numbers of vehicles per months of the corresponding year, are shown. Sales in the local market of conventional vehicles (CV), HEV, and electric vehicles (EV), are shown together with number of exported vehicles. Figure 1, is showing the statistic of vehicles entered and exported of Jordanian market in 2014. This statistic shows that all the sales are focusing more on CV, and there is no mention of HEV and EV vehicles in this year because there is no adoption yet of these new cars.

In Figure 2, a summary of vehicle sales during 2015, is presented. The Figure is showing the first appearance of hybrid vehicles in the Jordanian market. In December of that year, it is noted that the sales of hybrid electric vehicles have become approximately half the sales of conventional vehicles.

![Figure 1. Trade statistics of different vehicles in the Jordanian market 2014](image1.png)

In Figure 3 however, statistics of vehicle sales during 2016, is illustrated. A slight increase in the sales of hybrid vehicles in the Jordanian market can be noticed. Compared with December of the preceding year, the sales of hybrid electric vehicles have become close to sales of conventional vehicles for the same month of this considered year (i.e December 2016).

![Figure 2. Trade statistics of different vehicles in the Jordanian market 2015](image2.png)
Figure 4 is presenting statistics for the sales of vehicle during 2017. Significant increase of hybrid vehicles in the Jordanian market, can be noticed. The increase in sales of hybrid vehicles is evident starting from June, and sales gradually increase until it has reached five times the sales of traditional vehicles in December 2017. In addition, the total number of sales of HEVs vehicles is more than that of the CVs.

Evolution of vehicle sales during the year 2018, is illustrated in Figure 5. A noticeable incident shown in this figure, is that the sales of hybrid vehicles have a sharp decline, reaching approximately to zero in the months of February and March. The reason for the significant decay in the sales of hybrid vehicles is due to the fees and taxes added to the trade of these vehicles. On the other hand, abolition of fees and taxes on the import of electric vehicles is behind the significant increase in the sales of these cars.
Figure 6, demonstrates the sales of vehicles during the year 2019. In which the sale of EVs has approximately reached to zero in May and June. The reason for the significant decline in these two months is justified by the slight increase in the fees and taxes. The year 2019 is the year of the car sales setback (and in the rest of the business), as a result of the spread of the Coronavirus pandemic, and this has continued until 2020.

In addition to the presented statistics, and their analysis, the electric vehicle market in Jordan continue in expansion, where reports of the Jordan free zone investor commission (JFZIC) have stated a trade of 18,641 gasoline vehicles, 10,055 diesel vehicles, 18,039 hybrid vehicles and 5,083 electric vehicles, during the year 2021. The year 2022, on the other hand, noticed a trade of about 56,000 vehicles, with almost 180 per cent increase related to electric cars. The worldwide increase in carbon emission, and the rising levels of air pollution, as well as the global move of adopting renewable energy sources, is another factor contributing to the development of the market. This market has projected a growth at compound annual growth rate (CAGR) of 34.0% during 2019-25. The Jordanian government is also working to strengthen the electric vehicle charging infrastructure in co-operation with the private companies.

![Figure 6. Trade statistics of different vehicles in the Jordanian market 2019](image)


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