International Journal of Operations Research and Information Systems
Volume 12 • Issue 4

The Socio-Technical Transition to Electric Vehicle Mobility in Turkey:
A Multi-Level Perspective

Şükrü İmre, Istanbul Technical University, Turkey*
https://orcid.org/0000-0003-0500-2761

Fatih Canıtez, Istanbul Technical University, Turkey

Dilay Çelebi, Istanbul Technical University, Turkey

ABSTRACT

The adoption of electric vehicles (EVs) has been examined in various settings, yet the issue has rarely been addressed for less developed settings in terms of transport institutions, policies, and practices. Turkey, with its rapidly growing emerging economy, presents such a setting for the adoption of EVs. There are various reasons for why the adoption of EVs is still considerably limited in Turkey. A multi-dimensional and multi-actor analysis of the EV landscape can help us better understand the dynamics of transition to EVs. In this paper, a multi-level perspective (MLP) framework is used to examine the current state of EV adoption in Turkey and to interpret the prospects of a possible transition to EVs. The study shows that a potential transition to EVs in Turkey presents many socio-technical challenges to overcome including current policies, institutions, market dynamics, technological infrastructure, and social limitations. The insights from this review can be used for settings where policies and institutions are not developed enough to achieve a transition to EVs.

KEYWORDS

Battery Electric Vehicles, Developing Countries, Electric Vehicle Adoption, Electric Vehicles, Multi-Level Perspective, Socio-Technical Change, Socio-Technical Transition

1. INTRODUCTION

Transport-related carbon emissions is one of the key contributing factors for the overall greenhouse gas emissions in the world. The rising demand for passenger and freight transport as well as rising urbanization have led to air and noise pollution, and health problems and aggravated the quality of life. This predicament, coupled with technological advances and rising fuel prices, have led to an exploration of the use of alternative energy sources in transportation. Electric Vehicle (EV) technologies have emerged as a promising solution in this field.

Although academic studies have shown that the potential benefits of using EVs are manifold, the widespread use of EVs in transport systems has not yet reached the desired levels, even in developed countries. A number of economic, social, political and technological factors are in play acting as barriers or enablers for the diffusion of EVs. For the wider adoption of EVs, it is important to frame these barriers and enablers within an integrated socio-technical context, which include several

DOI: 10.4018/IJORIS.294117
*Corresponding Author

key elements such as favorable policy context, economic incentives, battery technology, charging infrastructure, user awareness, maintenance and repair facilities. The maturity level of these socio-technical elements is not sufficient in many countries to ensure a widespread transition to EVs. Turkey, which can be regarded as a follower country in terms of technology adoption, is at a very early stage in EV transition. The total number of EVs in Turkey is only around 1500 (Turizm Avrupa, 2019). The lack of infrastructure, clear policy objectives, economic incentives, consumer awareness and affordable vehicles are some of the major barriers for the adoption of EVs in Turkey.

In this study, the Multi-Level Perspective (MLP) is used to understand and interpret the current dynamics as well as predict the future dynamics influencing the use of EVs in Turkey. MLP offers a multi-actor, multi-dimensional and multi-layered perspective that can address the dynamics involved in technological transformations. Therefore, the institutional and regulatory complexities in countries like Turkey can be better addressed by drawing on MLP. MLP is used for the first time in analyzing the EV transition in a developing country, which fills an important gap in EV and socio-technical transition literature. The experience of Turkey presents useful lessons for similar developing countries going through the EV adoption process.

This study contributes to the literature by exploring the factors impacting the transition to EVs in Turkey through the MLP framework and proposing policies to facilitate the transition to EVs for developing countries. In the current literature, there is a gap about the transition to EVs in developing countries including Turkey, so this study is expected to fill that gap. Canitez (2019) defined developing settings as having "fragmented institutions, ambivalent transport and land use policies, lack of public awareness regarding sustainability, incompetent authorities, vested interests and clientelist political relations". The socio-technical regime in those settings is structured around a set of rules, regulatory environment, institutional arrangements and governance practices which can differ from developed settings. Turkey is a good example of these developing countries where socio-technical factors create many barriers for the transition to EVs.

The rest of the paper is organized as follows. In the second part of the study, a short literature review is provided for the MLP and EVs. The third section describes the methodology. The fourth section gives an overview of the EV market in Turkey. The EV ecosystem in Turkey is examined through the levels of MLP, landscape, regime, and niche in the fifth sections. The sixth section provides a discussion of the three levels. The last section concludes the study.

2. BACKGROUND

2.1 Electric Vehicles

The history of electric vehicles is older than internal combustion engine vehicles (ICEVs). The first EV model was developed in 1835 in the Netherlands. The number of EVs at the beginning of the 1900s was higher than the number of ICEVs. The EVs produced at that time had a limited range, approximately one-tenth that of the ICEVs, which is seen as one of the most important reasons hindering the development of EVs (Ustabaş, 2014). The main component of the EVs is the battery, which may be in the form of lead-acid, nickel-cadmium or lithium-iodine. The lithium-iodine battery is broadly used due to its longer range compared to other battery types (Şenlik, 2015). The EVs can be grouped under three main categories: full electric vehicles, hybrid electric vehicles and fuel cell electric vehicles (Ustabaş, 2014). The scope of this study is limited to full electric vehicles and the term EVs will be used to describe those vehicles in the rest of this study.

The EV literature on Turkey is limited. Existing studies generally addressed the EV adoption problem from the perspective of decision making, mostly focusing on location selection of charging stations for electric vehicles. A number of decision-making methods such as fuzzy multi criteria decision making (Karaşan et al., 2020), special algorithm (Harighi et al., 2019) and analytic hierarchy process (AHP) and the technique for order of preference by similarity to ideal solution (TOPSIS) (Erbaş et al., 2019), and interval type-2 fuzzy sets improved by simulated annealing (Türk et. al., 2021) have been suggested for choosing the best locations of charging stations for EVs in Turkey. Varol et al. (2018) have examined the impacts of EV transition in public transport over future scenarios for modal share amongst taxis, buses and minibuses in Turkey. The results indicate that the amount of carbon emissions in inner cities significantly decrease with the adoption of EVs in public transportation. Kaya (2019) has evaluated the potential usage of EVs in Niğde, a city in Turkey, taking into account the future usage of electricity, air pollution levels and current number of conventional vehicles.

The factors impacting the diffusion of EVs have been studied in detail in the literature. Labeye et al. (2016) examine the daily use of EVs from strategic, tactic and operational levels. Calculating an estimated range for an EV along with finding locations for the charging points along the route is a strategic decision. Identifying smarter ways to charge EVs to navigate along the original established route is another example at the strategic level. The EV use at the tactical level is concerned with the low noise of EVs. The operational level addresses the driver behavior needed to handle EVs. On the other hand, many studies have identified barriers for the use (Berkeley et al., 2017, Wang and Thoben, 2017) and diffusion of EVs (Taefi et al., 2016a, Taefi et al., 2016b). Economic and financial barriers come first in those studies. The purchase price of EVs (Quak et al., 2016a) and the battery costs are underlined in many of these studies (Taefi et al., 2016a). In addition, the high maintenance and repair costs of EVs are among the reported barriers (Taefi et al., 2016a; Rizet et al., 2016). Apart from economic and financial barriers, political barriers such as lack of regulations (Wang and Thoben, 2016), particularly environmental regulations (Taefi et al., 2016a), also play an important role in the limited adoption of EVs. On the other hand, technical barriers include insufficient battery technology and limited range (Berkeley et al., 2017), limited number and variety of EV production (Quak et al., 2016b), long repair operations and limited spare parts production (Taefi et al., 2016b). Besides these factors, infrastructure issues include the incompatibility among various types of charging sockets and charging infrastructure (Taefi et al., 2016a), the lack of EVs-specific and appropriate parking facilities (Steinhilber et al., 2013).

Norway can be regarded as an outlier country accounting for 30% of the global EV sales (Berkeley et al., 2017). The main factors behind Norway's success are mainly the tax advantages and regulations making EVs far more affordable than fossil fuel vehicles. In addition to financial regulations, the market share of EVs in Norway has reached 50% as of 2019 thanks to the non-financial incentives such as the use of bus lanes by EVs, free parking and free charging (Elbil, 2019). Although Norway case is generally seen as an example of success, it has also led to many criticisms. The amount of total subsidies, up to 500 million Euros per year, has become a significant expenditure for public funding. In addition, free parking and charging services restrict local administrations' sources of income and the traffic density generated by the use of bus lanes by EVs adversely affects public transport (Figenbaum, 2018).

An optimism bias is involved in assuming the barrier-free adoption of EVs and the resulting benefits associated with this adoption. As with any technological development, in order to ensure diffusion of EVs, the socio-technical environment needs to be supportive. A multi-dimensional perspective is, therefore, crucial to look into the internal dynamics of the socio-technical system.

2.2 Multi-Level Perspective

MLP is a widely used method for examining technological transformation processes in an integrated and multidimensional way (Kemp, 1994; Geels, 2012). According to this method, technological transitions depend not only on market conditions but also on how all actors of socio-technical systems act together in technological, social, cultural and economic fields. In this context, MLP provides an analytical framework for understanding the processes of technological transitions and systemic innovations (Marx et al., 2015). MLP has been used in many sectors to investigate the transitions: land transport (Geels, 2005), shipping (Geels, 2002), aviation (Nakamura et al., 2013), clean water sector (Van der Brugge et al., 2005), highways (Geels, 2007), electricity systems (Hofman and Elzen, 2010), climate change (Anderson et al., 2015) and sustainable housing (Smith, 2007).

Van Bree et al. (2010) conducted an MLP analysis to investigate the potential for diffusion of electric and hydrogen fuel vehicles. As a result of the increase in energy costs based on fossil fuels and emission regulations, the study found that when manufacturers provide a wider range of products for alternative fuel vehicles, it gives consumers a choice which would increase their market share greatly. Berkeley et al. (2017), as a result of the MLP analysis to interpret the transition to EVs, argued that the environment created by the pressures based on environmental problems and energy sectors in Europe had a significant positive effect on the niche development of EVs in some automotive manufacturers. However, this is not the case in many countries. In fact, one of the major criticisms of MLP analysis is the lack of spatial sensitivity (Geels et al., 2012; Markard et al., 2012; Coenen et al., 2012). In response to this criticism, Kanger et al. (2019), limiting their study to a particular geographical region, investigated the development of EVs in a comparative case study in the Netherlands and the United States (US).

In general, similar studies in the literature have focused on the US or European cities, and studies outside these regions are limited. It is not applicable to transfer the results of these past studies directly to other regions, as the socio-technical structure may show quite different characteristics, especially in countries that are technological followers.

3. METHODOLOGY

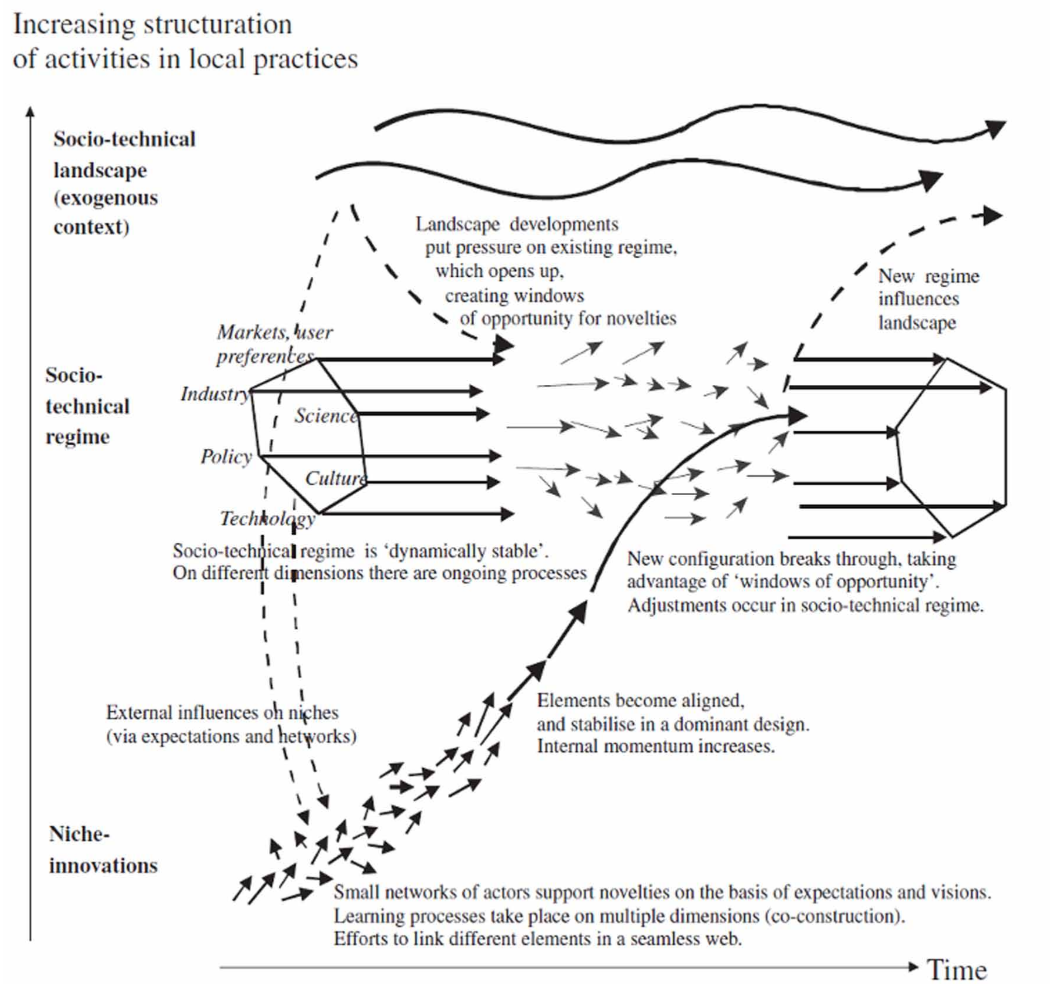
The basic tenet of the MLP is the non-linearity of transitions which are brought about through the multi-dimensional interactions among the three analytical levels: socio-technical landscape, socio-technical regime, and niche levels (Geels, 2012). The landscape refers to the wider context where long-term macro trends such as macro-economic trends, demographic changes, societal and cultural values, spatial forms influence the lower levels; namely the regime and niche levels. The developments taking place at this level are long-term and generally beyond individual actors' control. The socio-technical regime level, on the other hand, is composed of aligned elements which include technology, infrastructure, know-how, regulations and policies, user practices, cultural values and industry (Geels, 2004). The deeply-structured rules shape the socio-technical regime configuration. The extent to which those elements in this configuration is aligned to each other determines the resilience of the regime against the challenges originating from the landscape or niche levels. Lastly, niche levels are where the novelties and innovations which deviate from the regime emerge. They trigger the change processes within the socio-technical regime. The dynamics among those levels pave the way for future trajectories of transitions. Figure 1 shows the interactions of those dynamics.

This MLP framework is particularly useful for analyzing the EV adoption in the Turkish context, as it captures the complexity of the multi-dimensional and multi-actor processes involved in the transition process. According to the assumptions of MLP, a transition to EVs in Turkey can only come about if the following developments occur (Hofman and Elzen, 2010):

- Growing landscape pressures open up windows of opportunities
- The alignment among the elements in the existing regime is destabilized
- Niche innovations gain importance in the incumbent regime

In this perspective, a detailed study of existing and ongoing socio-technical position of EVs in Turkey is carried out in the following sections.

Figure 1. Multi-level perspective for transitions (Geels, 2002)



Interviews with three experts (Table 1) are conducted to understand the evolution of EV transition in Turkey, which helped us frame the information obtained through these interviews. The opinions and comments of the experts are combined with the findings of secondary data sources obtained from industry reports and academic studies.

Table 1. Organizations and Positions of the EV Experts

Organization	Position/Role	Expert Number
Public Bus Operator of Istanbul	Director of Strategy Development	Expert 1
Transport Consulting Company	Electric Vehicle Infrastructure Consultant	Expert 2
Turkish Logistics Platform	Coordinator	Expert 3

4. THE CURRENT STATE OF THE EV MARKET IN TURKEY

Studies on EVs in the world continue to increase; however, studies on EVs in Turkey have been quite limited so far. The first studies on EVs in Turkey, were undertaken by the Scientific and Technological Research Council of Turkey (STRCT). In the early days, the STRCT supported various universities and different car manufacturers in the improvement of lithium-iodine batteries (Şenlik, 2015). STRCT reports that the number of electric vehicles will increase in the next 50 years. STRCT also gives scientific and financial support to play an effective role in Turkey's EV technology in the world. Examples of these are energy management systems of EVs, development of engines and batteries, introducing new approaches to EVs' vehicle dynamics and control, and improving the engine performance of EVs by taking emission outputs into consideration (TÜBİTAK, 2019). These fields are included in the priority fields list by the STRCT. On the other hand, the first EV production and sales in Turkey took place in 2011. EVs at this time had a range of 160 km and could be charged in 8 hours (Şenlik, 2015). Various car companies have been selling EVs in Turkey since 2012 (Ustabaş, 2014). Currently, 11 different car companies in Turkey have been selling EVs with increasing vehicle diversity (Uğur, 2018). The number of EV sales in Turkey are shown in Figure 2.

One of the main reasons for the lack of EV sales in Turkey is the high the total cost of ownership. These costs include vehicle purchase, battery rental or purchase costs. On the other hand, charging stations are another factor impacting the effective usage and adoption of EVs. The number of charging stations in Turkey in 2019 is 700, as shown in Figure 2. Charging station investments in Turkey have continued thereafter (Polat, 2015; TEHAD, 2019; Turizm Avrupa, 2019).

The charging stations are generally located at car parking areas, shopping centers, recreational facilities, vehicle fleet parking points and airports (Polat, 2015). Turkey has 11 different firms installing charging stations (TEHAD, 2019). Charging station infrastructure has started to become increasingly widespread in Turkey as of 2018. The leading companies who sell and set up charging stations in Turkey are E-Şarj, Fullcharger, Greenway, Voltrun and Gersan (Polat, 2015). EŞarj builds charging stations in locations such as shopping centers and hotels. Among the locations where the charging company installs a charging station are petrol stations and recreational facilities. Voltrun designs and manufactures their own charging stations. Gersan is one of the oldest companies sharing the small EV market with EŞarj in Turkey. This company has an agreement with Tesla, which aims to operate in the EV market in Turkey. Greenway, on the other hand, has been working with Renault to establish short-term charging stations (Teslaturk, 2018).

Having approximately 23 million registered vehicles in 2018 (Turkish Statistical Institute, 2018a), the number of EVs compared to the ICEVs is quite low in Turkey. The government has issued financial incentives to promote the diffusion of EVs. Sezen and İşler (2017) pointed out that the new regulations issued in 2016 provided some tax discounts on electric vehicles and other types of vehicles in Turkey. These incentives vary by motor power and include only the reduction in private consumption taxes (PCT) as shown in Table 2.

5. THE SOCIO-TECHNICAL LEVELS

The socio-technical context of transition to EVs is examined along the three socio technical levels: landscape, regime and niche.

5.1. The Socio-Technical Landscape

Developments in the socio-technical landscape at the higher level are long-term macro-level changes that affect the socio-technical regime and open windows of opportunities. Among these changes are economic growth, increased awareness of sustainability, increased dependence on oil and government attempts to counter this excessive dependence, increased oil prices and changing user profile.

Figure 2. The cumulative number of charging stations and sales of EVs in Turkey (Polat, 2015; TEHAD, 2019; Turizm Avrupa, 2019)

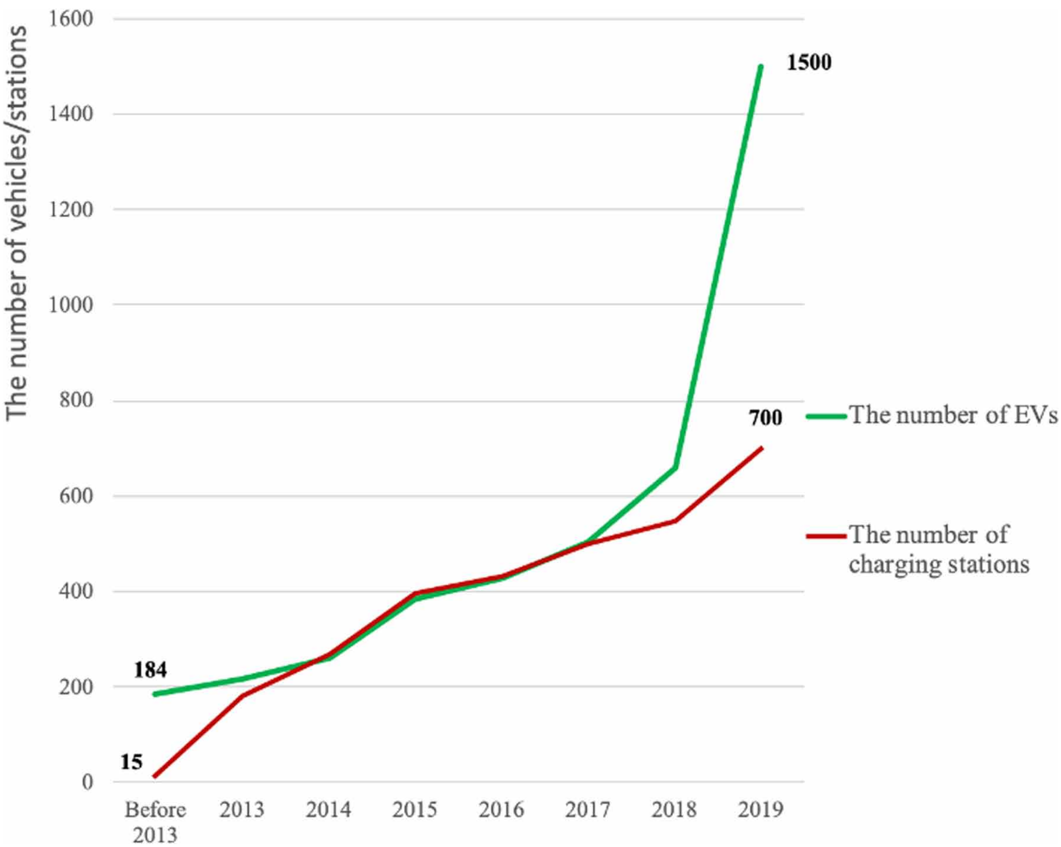


Table 2. Private Consumption Taxes Discount Rates

Motor Power	Discount Rates
0-85 kW	%3
86-120 kW	%7
121 kW and above	%15

Source: (Sezen and İşler, 2017)

In recent years, continuous GDP growth, with an average rate of 4.5%, characterized Turkey's economy (TSI, 2020). Economic development has been constantly changing trade and transport structures and accelerating the transition to service, advanced technology and value-added manufacturing sectors. This development points out that Turkey is expected to become a hub of international transport networks and increase the further adoption of the global environmental standards. Turkey's economic environment is expected to lead to changes in almost all sectors over the next few decades. Privatization, trade norms and other regulatory measures and policies related to R&D investments are expected to have a significant impact on the long-term competitiveness of the economy. Therefore, a technological and environmental context conducive to the adoption of EVs is said be emerging in the Turkish context.

Turkey's economy has been grappling with many difficulties about growing energy demand. The average energy density of the member countries of the International Energy Agency declined by 16.3% between the years 2005-2015, and energy intensity in Turkey increased by 7.1% during this time interval (International Energy Agency, 2016). The primary source of energy self-sufficiency rate in Turkey is considerably low (Bölük, 2013). Approximately 90% of energy consumption from the imported fossil fuels dominate the total primary energy supply of Turkey (Özcan, 2017). Turkey does not have major oil and natural gas reserves and the country is largely dependent on imported energy sources. In 2014, carbon dioxide (CO2) emissions from fuel combustion have increased by 141.6% since 1990 and local air pollution has been a concern in major cities (International Energy Agency, 2016).

The development of renewable energy sources and promotion of energy efficiency measures is among the priorities of energy policy of Turkey. Environmental concerns such as pollution, ozone depletion and global climate change have become important issues in the new energy policy. Reducing greenhouse gas emissions is one of the main problems aimed to be addressed by this new policy (Ustabaş, 2014). Due to energy security concerns and EU environmental policies, especially with regard to environmental standards, Turkey has started to promote renewable energy technologies and energy efficiency targets under "the Electricity Market and Supply Security Strategy and Vision 2023", set out in 2009. Within the scope of 2023 targets, a series of strategies and action plans related to energy efficiency, renewable energy and climate change have been put forward (International Energy Agency, 2016).

Oil prices for both gasoline and diesel vehicles in Turkey have increased significantly over the last three years. From 2015 to 2018, there was 36.5% increase in gasoline prices and 62.7% increase in diesel gasoline prices. On the other hand, the number of registered gasoline vehicles was 5.5%, while this ratio was 36.5% for diesel vehicles between 2015 and 2018 (Aytemiz, 2018; Turkish Statistical Institute, 2018b). With the unit charge costs of EVs decreasing in the future, an economic advantage over diesel vehicles can be achieved.

5.2. The Socio-Technical Regime

The existing socio-technical regime in Turkey is based on fossil fuels for both freight and passenger transportation. Although EVs exist as a niche technology, the adoption of EVs is relatively small compared to ICEVs that is the settled regime. Regime actors include vehicle manufacturers, maintenance facilities, car users, regulators, gas stations and non-governmental organizations such as "Turkey Driver and Automobile Federation". The use of EVs in Turkey requires changes in many aspects of this socio-technical regime.

Technology is one of the fundamental socio-technical factors impacting the adoption of EVs in Turkey. Battery technology which includes factors such as charging time, range, battery size and weight are the most important technical elements (Berkeley et al., 2017). However, the current ICEV-based technological infrastructure is opposed to the adoption of EV-based technologies. While advanced road infrastructure fully compatible with existing ICEV-based transport is compatible with EV usage, the problem is the inadequacy of the charging infrastructure. In order to overcome range concerns, urban and intercity travels should have adequate charging facilities throughout the country. Given that there are 1500 electric vehicles for 700 charging stations (Turizm Avrupa, 2019) and the total number of vehicles, approximately 23 million, it is still far from guaranteeing a transition to EVs. Furthermore, the geographical distribution of these stations is not homogeneous and the majority are concentrated in the Istanbul region (Polat, 2015). National and local authorities play an important role in financing the investment of the charging infrastructure. In addition to charging stations in public areas such as parking lots, public buildings and streets, access to charging stations in private residential areas can help promote the widespread adoption of EVs.

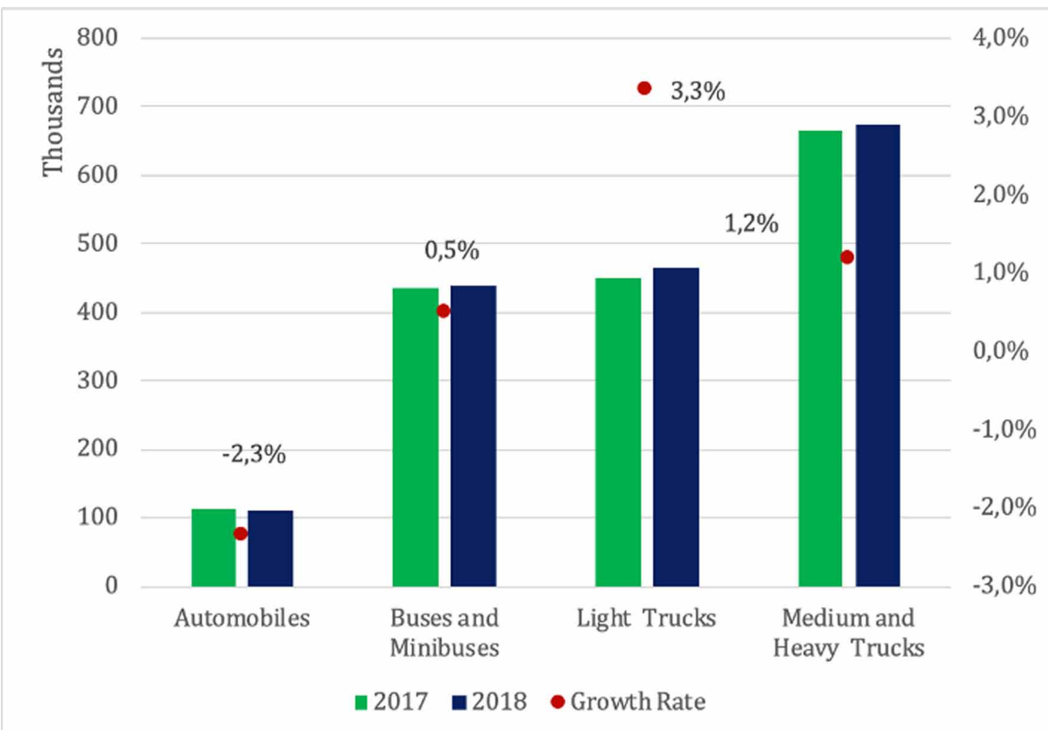
The tax system in Turkey provides some incentives to foster the diffusion of EVs. However, these incentives, which are the discount of the PCT of EVs, are not sufficient to increase the sales of EVs.

As it can be seen from Figure 3, these incentives have not led to a significant increase in EV sales compared to ICEVs. There are no government-supported incentives except for the PCT discount for EVs. Therefore, EVs cannot compete economically with gasoline and diesel vehicles. The taxes on electric vehicles in Turkey recently changed and a new draft law was approved by parliament in 2018. According to this new law, a motor vehicle tax will also apply to electric vehicles, which will be 25% of non-electric ICEVs. With the enactment of the law, it is expected to have a negative impact on the spread of both passenger and commercial EVs.

On the other hand, there are about 2 million commercial vehicles in a total of 23 million vehicles in Turkey (Turkish Statistical Institute, 2018a). As it can be seen in Figure 3, light commercial trucks have had an annual growth rate of 3.3%. This shows that incentives for commercial EVs in Turkey need to be prioritized. In addition, the government can support EV manufacturers to produce different types of commercial EVs.

50% of all vehicles in Turkey are diesel cars and light commercial vehicles are 75% of these cars. This ratio is expected to rise to 83.5% in 2021 (Corporate Vehicle Observatory, 2016). With the measures taken in Europe, diesel vehicles will be gradually removed to reduce emissions by 2030 in freight transport and 2050 in passenger transport (Taefi et al., 2016a). Many countries are eager to remove diesel vehicles from their transportation systems by introducing new political regulations and restrictions. However, Turkey still lags behind in terms of political arrangements and other economic incentives.

Figure 3. Commercial Vehicle stock, differentiated by vehicle type, in absolute numbers (Turkish Statistical Institute, 2018c)



5.3. The Niche Developments

The pioneers in the development of electric vehicle technology in Turkey are universities and research institutions. However, their projects encounter many difficulties in commercialization and there are no more than a few successful student projects. Although the interest of the private sector is low, EV investments are gradually increasing, especially in the last few years as a result of developments in environmental awareness in European markets and EV investments by foreign automotive manufacturers. Companies such as Temsa and Otosan, which produce domestic commercial and public transportation vehicles, have started to add electric motor vehicles to their product range. One of the most important recent developments in the field of EVs is the initiative to create a national automobile brand. This new electric car brand was launched in 2020. The largest manufacturing and technology companies in Turkey, Anadolu, BMC, Kıraça, Turkcell and Zorlu, came together to form a joint venture to produce these cars. With the availability of all three types of electric vehicle technology in the Turkish market, the adoption of the EVs is expected to change considerably. Moreover, many small and medium-sized manufacturing and technology companies are currently engaged in the production of small electric vehicles and the conversion of light vehicles to electric motors.

6. DISCUSSION

Understanding the interplay among the socio-technical elements across the three socio-technical levels is key to develop policy proposals. To begin with, the developments in the landscape level can be stabilizing and destabilizing and create pressures on the regime, as illustrated in Figure 4.

Turkey has a number of landscape factors encouraging a growing awareness of sustainability. According to Expert 2, the main driving force is the legal limits on emissions that contribute to improving energy efficiency in transport, thus contributing to sustainable development. In addition, increasing environmental awareness influences both purchasing decisions and consumer preferences in the market. Although it is a relatively less internalized concept with the newly comprehended environmental awareness in Turkey, increased education and income levels, rising public awareness and growing environmental campaigns, and environmental concerns have begun to shape consumer movements. This encourages green purchasing and energy saving behavior. On the other hand, economic considerations still have a stronger impact on energy and green purchasing behavior than environmental concerns (Melikoğlu, 2014). As market conditions and globalization create pressure and driving forces for Turkish companies to improve their environmental performance, the business practices in Turkey with regards to environmental concerns have also been changing. The international companies pay more attention to the sustainability performance of the companies while selecting their partners and request that the operations are carried out in a way that ensures sustainability and reduces environmental impacts. This situation leads Turkish companies to develop and implement strategies to manage the negative environmental effects and social externalities of operations. This means that besides economic concerns, environmental and social issues are also brought to the agenda of decision-makers.

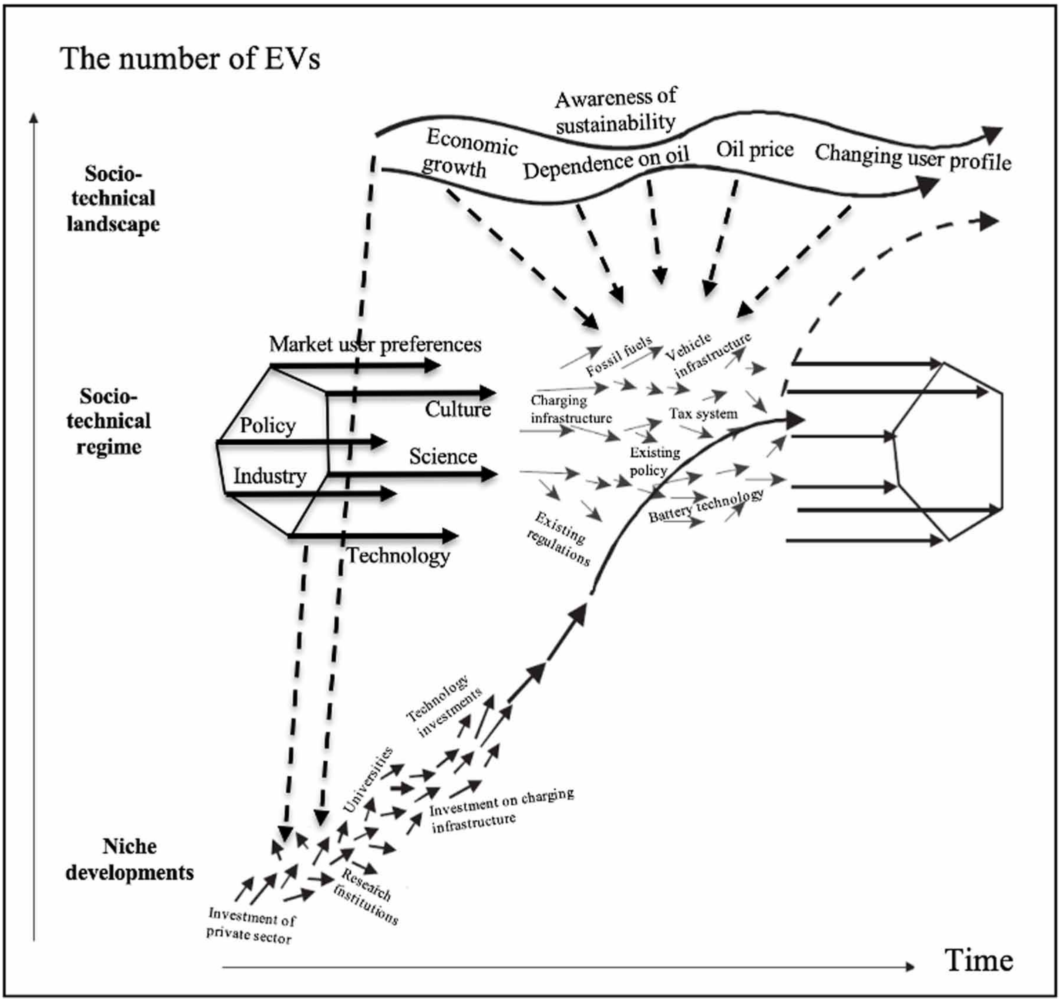
Thresholds and tipping points are key factors in system-wide changes. The dynamics facilitating the transition to EVs have to reach a threshold level to lead to regime changes. Therefore, the niche and landscape dynamics should bring about an incremental change, if not a radical change, to create tipping points for initiating system-wide transitions and new regime settings (Geels, 2012). The existing regulations and policies in Turkey that facilitate the acceptance of EVs are insufficient to ensure the wide-ranging adoption. A low-carbon mobility transition facilitating the diffusion of EVs is not within the transport policies of government and local authorities. Independent initiatives by local authorities to purchase electric buses are not sufficient for the adoption of EVs throughout the country. Expert 1 notes that the concept of sustainable urban mobility plan is not included in urban transport plans. The transition to EVs in urban areas seems to be difficult in the short and medium term, without a policy objective in local areas. The situation is not very different for national government plans. National transport targets mainly aim at building transport infrastructure instead of a low carbon transition. Turkey is already an attractive market for ICEVs-centered car manufacturers, hence without government intervention it is not likely to achieve a transition to EVs. From the consumer's point of view, the biggest barrier to the adoption of EVs is high prices (Berkeley et al., 2017). Therefore, reducing purchasing prices through tax reductions, subsidies, etc. can incentivize EV purchases. Since almost all EVs are imported rather than locally manufactured, reducing customs tax is quite key in reducing the acquisition price for EVs. According to Expert 3, the uncertainty of the secondary market and uncertainties around battery life, and concerns about the availability of spare parts and maintenance services detract consumers away from electric vehicles. Encouraging maintenance and spare parts ecosystem through financial support packages such as credits, allocating space in industrial areas, etc. can be an effective policy action by the local and national governments. Since environmental awareness in consumption habits in Turkey comes after economic considerations (Turkish Republic Ministry of Industry and Trade, 2018), it is not easy for EVs to compete with fossil fuel vehicles under current EV regulations and incentives. The government can play an important role by supporting EVs in national and local government vehicle purchases. For example, publicly owned bus operators can purchase electric buses and cars for their fleets. On the other hand, a minimum threshold for the number of EVs in the fleets of the logistics companies can be required, after a proper analysis of costs and benefits of such a policy.

Major niche developments in the EV context of Turkey mainly include initiatives of research institutes and manufacturing companies. Given Turkey's experience in automotive manufacturing and capacity of manufacturers, it can be expected to make an easy transition to EVs through the necessary technological infrastructure for the production of technical knowledge accumulated in this field. Expert 3 notes that the acquired rights of other automobile manufacturing companies will work as a regime barrier for the production and adoption of these electric automobiles. Although the investments in charging stations in Turkey are very low compared to Europe, they are increasing at an accelerated rate. 11 companies in Turkey have invested in charging stations, while 18 companies in Turkey continues its sales and marketing activities. The investments on charging stations made by small-scale companies have started to attract the attention of big companies in recent years. An example of this is Zorlu Energy's purchase of Eşarj at the beginning of 2018 and starting to invest in the EA charging infrastructure (Kara, 2018). Fuel stations may be required to allocate space for EVs and incorporate business models as well as design and layout principles for EV charging stations. This is expected to lead to an increase in the number of charging stations in Turkey. All these initiatives involving the EV infrastructure are expected to accelerate the transition to EVs. On the other hand, because other companies that invest only in charging stations do not have a license to sell electricity and can only sell the time spent at the station to users, it will be quite difficult to create a price advantage against large corporations engaged in electricity generation and distribution. Shifting to alternative energy sources for electricity production can be a long-run policy, given the difficulties of such a transformation in developing countries. This will create a monopoly that will adversely affect competition in the EV charging station market. Therefore, the competition and adoption of these niche developments with the existing IMAs depends on the strength of the socio-technical regime. However, it seems that the limited impact of these niche developments is not sufficient to create a strong pressure on the regime elements.

7. CONCLUSION

This study presented the problems and issues related with the adoption of EVs in developing settings. To better understand the dynamics of transition to EVs this paper used an MLP framework. Based on this analysis, it can be concluded that a transition from the current socio-technical regime, which is dominated by fossil-fueled vehicles in Turkey, to electric vehicles, neither the socio-technical

Figure 4. Multi-level perspective for transitions to EVs in Turkey



environment nor the niche developments are sufficient on their own to trigger a transformation. Considered from this perspective, if effective policies are not implemented to make the socio-technical environment more favorable for EVs, niche developments are not likely to result in a regime change in the short and medium term in Turkey. This requires a multi-actor engagement and collaboration across the public agencies, universities, and technology firms.

The theoretical contribution of this study is the employment of a framework involving both social and technical aspects of EV diffusion in developing country settings. What makes developing countries different and merit a distinct study is the lack of the integration across different socio-technical levels. The implementation of policies and incentives supporting the transition to EVs is harder to achieve in developing countries, because of the lack of integration across the socio-technical elements such as technological infrastructure, maintenance networks, trained labor force, and market conditions. For example, production, distribution and maintenance of electric batteries require a multi-actor collaboration across car manufacturers, spare part producers, technology firms, and universities. In addition to this theoretical contribution, this study presents many practical implications and insights for other developing countries. The data related to the tax structure and rebates for incentivizing EVs, number of EVs and charging stations as well as the overview of EV transition is quite useful from a practical point of view for a developing country looking for a case study.

When the socio-technical landscape of Turkey regarding the transition to EVs is considered, sustainability awareness is found to be a major issue. However, the current public agenda is gradually shifting towards a more favorable public opinion regarding sustainability issues. Although there are many academic studies showing the link between the use of EVs and environmental benefits, the public is not well aware of these studies. The public awareness on sustainability becoming a mainstream public opinion is expected to lead the government to take more swift and effective actions for implementing the policies incentivizing EVs. For the regime change necessary to achieve the transition to EVs, the government has a decisive role. This study indicates that the role of the government is more critical in developing countries. The lack of effective national and local government policies and tax incentives has been a major barrier for the transition to EVs. Two main niche actors are technology firms specializing in batteries and charging stations and research institutes. These firms need support from utility agencies in terms of grid capacity and favorable electricity price structure to set up charging stations across cities. Universities or research institutes, on the other hand, are critical in developing know-how and setting up collaborative partnerships with other parties. Therefore, this study underlines the critical importance of the multi-actor engagement with the government playing a key role in developing countries.

Despite the limited scope of our analysis with Turkey, insights obtained from our analysis will be useful to discuss general issues of transition to EVs in the context of other countries with similar levels of EV adoption. One of the limitations of this study is the lack of adequate sample from developing countries. Although Turkey is a good example as a developing country, other developing countries differ from Turkey with respect to their characteristics, infrastructures and problems on usage of electric vehicle. Turkey is not a homogenous country with respect to the socio-technical regime. Cities widely differ in terms of their infrastructure, market opportunities and needs. While metropolitan cities such as Istanbul, Ankara and Izmir present more opportunities in terms of EV adoption, middle and small sized cities lack critical infrastructure to facilitate the EV adoption. Therefore, this study pays more attention to those metropolitan cities. Another limitation of our study is the depth level of the analysis due to the inadequate data required to examine current situations, identify changes and predict future directions. Future studies can focus separately on each level of the framework of the current study and provide an overview of how to improve the existing dynamics by collecting primary data on consumer preferences of EVs. A new EV transition framework for developing countries can be developed as more and more case studies are carried out in these countries. Future studies can address those developing countries and cities.

REFERENCES

Anderson, K., Shackley, S., Mander, S., & Bows, A. (2005). *Decarbonising the UK: Energy for a climate conscious future*. Tyndall Centre for Climate Change Research.

Aytemiz. (n.d.). *Fuel Prices*. Retrieved from https://www.aytemiz.com.tr/faaliyet-alanlari-hizmetler/istasyonlar-hakkinda/akaryakit-ve-pompa-fiyatlari/arsiv-fiyat-listesi

Berkeley, N., Bailey, D., Jones, A., & Jarvis, D. (2017). Assessing the transition towards Battery Electric Vehicles: A Multi-Level Perspective on drivers of, and barriers to, take up. *Transportation Research Part A, Policy and Practice*, *106*, 320–332. doi:10.1016/j.tra.2017.10.004

Bölük, G. (2013). Renewable Energy: Policy Issues and Economic Implications in Turkey. *International Journal of Energy Economics and Policy*, *3*(2), 153–167.

Canitez, F. (2019). Pathways to sustainable urban mobility in developing megacities: A socio-technical transition perspective. *Technological Forecasting and Social Change*, *141*, 319–329. doi:10.1016/j.techfore.2019.01.008

Coenen, L., Benneworth, P., & Truffer, B. (2012). Toward a spatial perspective on sustainability transitions. *Research Policy*, *41*(6), 968–979. doi:10.1016/j.respol.2012.02.014

Corporate Vehicle Observatory. (2016). *Corporate Vehicle Barometer*. Author.

Elbil. (2019). *Norway reaches historical electric car market share*. Retrieved from. https://elbil.no/norway-reaches-historic-electric-car-market-share/

Erbaş, M., Kabak, M., Özceylan, E., & Çetinkaya, C. (2018). Optimal siting of electric vehicle charging stations: A GIS-based fuzzy Multi-Criteria Decision Analysis. *Energy*, *163*, 1017–1031. doi:10.1016/j.energy.2018.08.140

Figenbaum, E. (2017). Perspectives on Norway's supercharged electric vehicle policy. *Environmental Innovation and Societal Transitions*, *25*, 14–34. doi:10.1016/j.eist.2016.11.002

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8-9), 1257–1274. doi:10.1016/S0048-7333(02)00062-8

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6-7), 897–920. doi:10.1016/j.respol.2004.01.015

Geels, F. W. (2005). The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). *Technology Analysis and Strategic Management*, *17*(4), 445–476. doi:10.1080/09537320500357319

Geels, F. W. (2007). Transformations of large technical systems: A multilevel analysis of the Dutch highway system (1950-2000). *Science, Technology & Human Values*, *32*(2), 123–149. doi:10.1177/0162243906293883

Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: Introducing the multi-level perspective into transport studies. *Journal of Transport Geography*, *24*, 471–482. doi:10.1016/j.jtrangeo.2012.01.021

Geels, F. W., Kemp, R., Dudley, G., & Lyons, G. (Eds.). (2012). *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. Routledge.

Harighi, T., Padmanaban, S., Bayindir, R., Hossain, E., & Holm-Nielsen, J. B. (2019). Electric Vehicle Charge Stations Location Analysis and Determination—Ankara (Turkey) Case Study. *Energies*, *12*(18), 3472. doi:10.3390/en12183472

Hofman, P. S., & Elzen, B. (2010). Exploring system innovation in the electricity system through sociotechnical scenarios. *Technology Analysis and Strategic Management*, *22*(6), 653–670. doi:10.1080/09537325.2010.496282

International Energy Agency. (2016). *Energy Policies of IEA Countries*. Author.

Kanger, L., Geels, F. W., Sovacool, B., & Schot, J. (2019). Technological diffusion as a process of societal embedding: Lessons from historical automobile transitions for future electric mobility. *Transportation Research Part D, Transport and Environment*, *71*, 47–66. doi:10.1016/j.trd.2018.11.012

Kara, M. (n.d.). *Zorlu Enerji'den Herkese Tesla*. Retrieved from. https://www.dunya.com/sirketler/zorlu-enerjiden-herkese-tesla-haberi-394428

Karaşan, A., Kaya, İ., & Erdoğan, M. (2020). Location selection of electric vehicles charging stations by using a fuzzy MCDM method: A case study in Turkey. *Neural Computing & Applications*, *32*(9), 4553–4574. doi:10.1007/s00521-018-3752-2

Kaya, F. (2019). Niğde İlinin Elektrikli Araç Kullanim Potansiyelinin İncelenmesi. *Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi*, *8*(1), 528–537.

Kemp, R. (1994). Technology and the transition to environmental sustainability: The problem of technological regime shifts. *Futures*, *26*(10), 1023–1046. doi:10.1016/0016-3287(94)90071-X

Labeye, E. H., Hugot, M., Brusque, C., & Regan, M. A. (2016). The electric vehicle: A new driving experience involving specific skills and rules. *Transportation Research Part F: Traffic Psychology and Behaviour*, *37*, 27–40. doi:10.1016/j.trf.2015.11.008

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955–967. doi:10.1016/j.respol.2012.02.013

Marx, R., de Mello, A. M., Zilbovicius, M., & de Lara, F. F. (2015). Spatial contexts and firm strategies: Applying the multilevel perspective to sustainable urban mobility transitions in Brazil. *Journal of Cleaner Production*, *108*, 1092–1104. doi:10.1016/j.jclepro.2015.09.001

Melikoğlu, M. (2014). Demand forecast for road transportation fuels including gasoline, diesel, LPG, bioethanol and biodiesel for Turkey between 2013 and 2023. *Renewable Energy*, *64*, 164–171. doi:10.1016/j.renene.2013.11.009

Nakamura, H., Kajikawa, Y., & Suzuki, S. (2013). Multi-level perspectives with technology readiness measures for aviation innovation. *Sustainability Science*, *8*(1), 87–101. doi:10.1007/s11625-012-0187-z

Özcan, A. (2017). Eric J. Strauss Ecological modernization on Turkey's energy policy and renewable energy cooperatives suggestions for Turkey from the USA policy perspective. *Recent Developments in Social Sciences: Political Sciences and International Relations*, 27-42.

Polat, Ö. (n.d.). *Elektrikli Araç Ve Şarj İstasyonlarinin Türkiye'deki Güncel Durumu*. Retrieved from. https://www.emo.org.tr/ekler/e4bd872ffdbfb6c_ek.pdf

Quak, H., Nesterova, N., & van Rooijen, T. (2016b). Possibilities and barriers for using electric-powered vehicles in city logistics practice. *Transportation Research Procedia*, *12*, 157–169. doi:10.1016/j.trpro.2016.02.055

Quak, H., Nesterova, N., van Rooijen, T., & Dong, Y. (2016a). Zero emission city logistics: Current practices in freight electromobility and feasibility in the near future. *Transportation Research Procedia*, *14*, 1506–1515. doi:10.1016/j.trpro.2016.05.115

Rizet, C., Cruz, C., & Vromant, M. (2016). The constraints of vehicle range and congestion for the use of electric vehicles for urban freight in France. *Transportation Research Procedia*, *12*, 500–507. doi:10.1016/j.trpro.2016.02.005

Şenlik, İ. (2015). Uyuyan Devrim: Elektirikli Araçlar. *Electrical Engineering*, 64–67.

Sezen, B. & İşler, A.U. (2017). Elektrikli Araçlarin Mevcut Durumu, Tercih Edilme Ve Edilmeme Sebepleri. *Turkish Journal of Marketing*, 82-103.

Smith, A. (2007). Translating sustainabilities between green niches and socio-technical regimes. *Technology Analysis and Strategic Management*, *19*(4), 427–450. doi:10.1080/09537320701403334

Steinhilber, S., Wells, P., & Thankappan, S. (2013). Socio-technical inertia: Understanding the barriers to electric vehicles. *Energy Policy*, *60*, 531–539. doi:10.1016/j.enpol.2013.04.076

Taefi, T. T., Kreutzfeldt, J., Held, T., & Fink, A. (2016a). Supporting the adoption of electric vehicles in urban road freight transport–A multi-criteria analysis of policy measures in Germany. *Transportation Research Part A, Policy and Practice*, *91*, 61–79. doi:10.1016/j.tra.2016.06.003

Taefi, T. T., Kreutzfeldt, J., Held, T., Konings, R., Kotter, R., Lilley, S., & Borgqvist, M. (2016b). Comparative Analysis of European Examples of Freight Electric Vehicles Schemes—A Systematic Case Study Approach with Examples from Denmark, Germany, the Netherlands, Sweden and the UK. In *Dynamics in Logistics* (pp. 495–504). Springer. doi:10.1007/978-3-319-23512-7_48

TEHAD. (n.d.). *Türkiye'deki Şarj İstasyonu sayısı Elektrikli Otomobili yakaladı*. Retrieved from. http://tehad.org/2019/03/25/turkiyedeki-sarj-istasyonu-sayisi-elektrikli-otomobili-yakaladi/

Teslaturk. (2018). *2018'de Türkiye'de Beklediğim Elektrikli Otomobil Gelişmeleri*. Retrieved from. http://teslaturk.com/2018de-turkiyede-elektrikli-otomobil-gelismeleri/

TSI. (n.d.). *Turkey Annual GDP Growth Rate*. Retrieved from https://tradingeconomics.com/turkey/gdp-growth-annual

TÜBİTAK. (n.d.). *Elektri̇kli̇ Ve Hibri̇t Elektri̇kli̇ Araç Teknoloji̇leri̇ Çaği̇ri Programi Bi̇lgi̇ Notu*. Retrieved from. https://www.tubitak.gov.tr/tubitak_content_files/1003-OT01/OT01.pdf

Turizm Avrupa. (2019). *Türkiye'deki elektrikli araba üretiliyor ama şarj istasyonu yeterli mi?* Retrieved from. https://www.turizmavrupa.com/turkiyede-elektrikli-araba-uretiliyor-ama-sarj-istasyonu-sayisi-yeterli-mi/

Türk, S., Deveci, M., Özcan, E., Canıtez, F., & John, R. (2021). Interval type-2 fuzzy sets improved by Simulated Annealing for locating the electric charging stations. *Information Sciences*, *547*, 641–666. doi:10.1016/j.ins.2020.08.076

Turkish Republic Ministry of Industry and Trade. (2018). *Report of Consumer Profile and Awareness.* Author.

Turkish Statistical Institute. (2018a). *Motorlu Kara Taşıtları*. Author.

Turkish Statistical Institute. (2018b). *Main Statistics*. Author.

Turkish Statistical Institute. (2018c). *Energy Statistics*. Author.

Uğur, M. (n.d.). *Meraklılarına Duyurulur: İşte Ülkemizde Satılan Elektrikli ve Hibrit Otomobiller*. Retrieved from. https://www.webtekno.com/meraklilarina-duyurulur-iste-ulkemizde-satilan-elektrikli-ve-hibrit-otomobiller-h50773.html

Ustabaş, A. (2014). Mikro ve makro etkileri yönünden elektrikli otomobiller (Türkiye ekonomisi örneği). *Marmara University Journal of Economic and Administrative Sciences*, 269-291.

Van Bree, B., Verbong, G. P., & Kramer, G. J. (2010). A multi-level perspective on the introduction of hydrogen and battery-electric vehicles. *Technological Forecasting and Social Change*, *77*(4), 529–540. doi:10.1016/j.techfore.2009.12.005

Van der Brugge, R., Rotmans, J., & Loorbach, D. (2005). The transition in Dutch water management. *Regional Environmental Change*, *5*(4), 164–176. doi:10.1007/s10113-004-0086-7

Varol, S., Öztürk, Z., & Öztürk, O. (2018). İstanbul'da karayolu yolcu taşımacılığında elektrikli araç kullanımının incelenmesi. *El-Cezeri Journal of Science and Engineering*, *5*(2), 367–386.

Wang, M., & Thoben, K. D. (2016). The Influential Factors for Application of the Electric Commercial Vehicle in the Urban Freight Transport. In *Dynamics in Logistics* (pp. 375–378). Springer. doi:10.1007/978-3-319-23512-7_36

Wang, M., & Thoben, K. D. (2017). Sustainable Urban Freight Transport: Analysis of Factors Affecting the Employment of Electric Commercial Vehicles. In *Dynamics in Logistics* (pp. 255–265). Springer. doi:10.1007/978-3-319-45117-6_23

Şükrü İmre has PhD degree in Management Engineering Program at Istanbul Technical University. He graduated from Mathematical Department of Istanbul Commerce University in 2012 and he holds a master degree in Management Engineering of ITU in 2016. He has been studying on Electric Vehicle and Freight Transportation. In addition, Şükrü is also a Business Analytics Specialist at LC Waikiki Retail Company. He has improved algorithm and optimization model in retail problems (order picking, etc.).

Fatih Canıtez is a Research Associate of the Transport Strategy Centre (TSC) at the Centre for Transport Studies within the Department of Civil and Environmental Engineering at Imperial College London. Prior to joining TSC, Fatih worked for over seven years at IETT, Istanbul's public bus operator, in the Department of Strategy Development and assumed various roles as a business analyst, senior performance and reporting officer, and finally, manager of Business Intelligence and Project Management Department. He participated in International Bus Benchmarking Group (IBBG) as a representative of IETT and run all IBBG activities within IETT from 2013 to 2018. Fatih has a Master's degree in Industrial Engineering with a focus on Performance Measurement and Management in Public Transport Systems. He received his PhD degree in Management Engineering at Istanbul Technical University with a PhD thesis on the institutional aspects of Urban Transport Management, about which he has also published many articles in top-tier journals.

Dilay Çelebi is Associate Professor of Management at Istanbul Technical University. Her research interest include international logistics, logistics operations and modelling. Her bachelor degree is in Industrial Engineering of Middle East Technical University in 2000, and she completed her PhD studies in Management Engineering of Istanbul Technical University (ITU) in 2008. Her thesis titled "Stochastic Lot Sizing in a Centralized Distribution Network" received 2008 Doctoral Dissertation Award from Council of Supply Chain Management Professionals (CSCMP). D. Çelebi worked as a leading consultant to various international organizations, including International Transport Forum at OECD and The World Bank, as well as public authorities and government institutions in support their policy actions of transport and logistics planning.