

Electric Vehicles

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E-mobility sustainability assessment is becoming more comprehensive with research integrating social aspects without focusing only on technical, economic, and/or environmental perspectives. The transportation sector is indeed one of the leading and most challenging greenhouse-gas polluters, and e-mobility is seen as one of the potential solutions; however, a social perspective must be further investigated to improve the perception of and acceptance of electric vehicles.

Keywords: electric vehicles ; social sustainability ; social perspective ; research trends

1. Introduction

In 1987, the World Commission on Environment and Development presented the report “*Our Common Future*”. They attempted to explain how important sustainability is to protect the environment for future generations and integrate social and economic progress. They also argued that governments should incorporate environmental considerations into decision-making ^[1]. The importance of sustainability was then expanded and was implemented in laws, meaning countries started adopting sustainability-oriented laws ^[2], and at the same time, consumers became more and more aware of sustainability, mostly from the economic and environmental perspective ^[3]. This has also impacted the transportation sector, presenting considerable environmental, social, and economic challenges ^[4]. However, transport is vital from the economic perspective employing about 11 million people and generates almost 5% of the EU’s GDP ^[5]. However, transportation accounted for about 24% of all greenhouse gas emissions in the EU. It consequently plays a significant role in air pollution resulting in climate change due to greenhouse gases (GHG) emissions ^[6].

Furthermore, road transport, in particular, accounted for about 18% of all EU emissions in 2012 ^[7]. A European Green Deal is one of the most impactful EU priorities that aims to transform the EU into modern, resource-efficient, climate-neutral, and sustainable. Decoupling growth from material use and emissions is especially challenging for sustainable mobility—a part of which is also e-mobility.

Replacing the internal combustion vehicles with new technologies such as electric vehicles (EV) could be a step towards more sustainable transport and reduced environmental impacts ^[8]. When just considering the use phase, reducing polluting emissions during driving of EVs is automatically achieved by all EVs ^[8] as they allow zero-emission driving. However, a negative impact is also perceived for using EVs since electricity for charging can be produced from environmentally disputable sources, e.g., fossil fuels ^[9]. Again, EVs impact the environment and human health in the production phase and end of life cycle, particularly particulate matter formation ^[10]. Furthermore, EVs’ manufacturing presents a greater environmental burden with respect to gasoline cars, especially for the large use of metals, chemicals, and energy required by specific components of the electric powertrain such as the high-voltage battery ^[11]. Not only do EVs impact on the environment, but also on the social dimension. Onat et al. ^[12] argue that social impacts of alternative vehicle technologies should be further investigated to develop effective, sustainable mobility strategies. Furthermore, it is crucial to integrate the social perspective when studying electric vehicles’ impacts, as the social perspective is interlinked with the environmental one ^[13]. Additionally, focusing only on the environmental perspective, substantial positive or negative social impacts regarding the electric vehicle impact can be overlooked; positive, for instance, presenting reduction of noise pollution, which can be positive or negative ^[14], while negative, for example, presenting the potential for exploitation of child labor ^[15]. Some of the impacts of EVs might even have social implications as byproducts (social impacts, social costs, etc.), which can influence EV acceptance and perception as well as social welfare. Some authors also expose user experience as one of the social factors as it is far from being related only to technical aspects. Moreover, 17 sustainable development goals (SDGs) defined by the United Nations (UN) to be achieved by 2030 represent a framework on which research and industry—also car manufacturers, as well as e-mobility in general—should focus in the future ^[16].

Inspired by the importance of social impacts of EVs, this paper presents a systematic overview of research papers related to EVs' social aspect in a five-year period of 2015-2019. With respect to reviewed papers, it was found out that linking EVs with their impact, user perception and acceptance was already researched. However, lacking examinations of their relation to UN SDGs was identified as well as dividing them into different categories.

2. Priority Research Focus on EV Studies—Lessons Learned from a Systematic Literature Review

Papers published on the thematic of EVs' social impact have recently been frequently studied. The WoS research comprehended twenty-eight scientific papers published and related on topics “electric vehicle” and “social impacts” thematic and the graph that presents the publishing frequency per year can be seen in Figure 1. It can be seen that there has been an increase in the last two years of papers published regarding the social impact of EVs, meaning that this topic gains scientific as well as political importance. In 2018 and 2019, eight papers were published on the social impact of EVs thematic, respectively, while there were five papers published in 2017, four in 2016, and only three in 2015. This can also be supported by the fact that EVs are gaining more and more of the market share, especially in China [20], and this leads to EVs being studied more and more frequently. This is also due to methods, such as social life-cycle assessment (SLCA) gaining importance and being commonly used in the last three years [21] and due to social dimension and social sustainability being studied frequently regarding the supply chains [22].

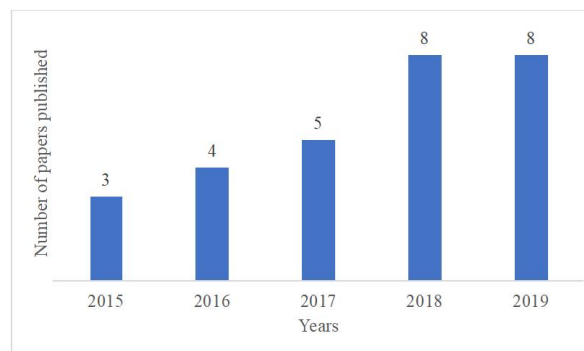


Figure 1. Published papers related to the social aspect of electric vehicles (EVs) (annual publications).

As described in the methods section, we have grouped the papers into categories based on their contribution to the field of EVs' social impact. Figure 2 thus presents the grouping of papers, based on the categories, which are: “Acceptance”, “Perception”, “Welfare”, “Social cost”, “Impact” (using methods such as SLCA), “User experience” and “Readiness”. The papers studied evaluated or studied mentioned categories regarding the EVs.

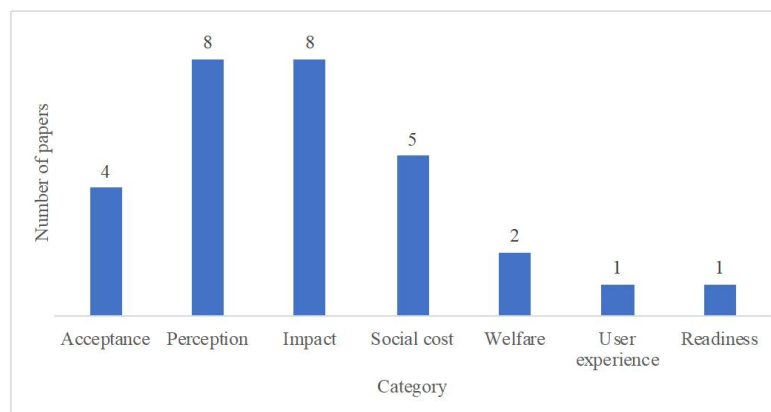


Figure 2. Papers divided in specific categories related to social aspects of EVs.

The authors studied the social aspect of “Acceptance”, as of 28 papers, 4 coincided into the “Acceptance” category. Onat et al. [23] studied EVs' social acceptability, the environmental and economic impacts in the United States. Yousefi-Sahzabi et al. [24] also assessed the social acceptance of EVs in Turkey and concluded that the EVs are highly accepted and supported. Furthermore, the authors frequently focused on studying the “Perception” of EVs. For example, Brase [25] studied consumers' perception and decision-making about electric vehicles in the U.S., while Sovacool et al. [26] studied the perception that kids have of electric vehicles and sustainable transport in Denmark and the Netherlands. They [26] found out that children overwhelmingly seem to agree on the future direction of car-based transport, but cars must be safer, more energy-efficient, and alternatively fueled.

Investigating which topics are gaining or losing importance is highly important for defining future research priorities. Accordingly, the results in Figure 2 show the current research focus of studied papers divided into categories through the last five years per year, presenting which category has been given the central priority in a particular year.

Observing Figure 3, it can be seen that the year 2015 delivered papers that focused on perception, impact, and social cost of EVs. The number of impact papers has risen to two papers in 2016, while one paper related to social costs and one on the perception category was conducted in 2016. The year 2017 presented a reduction of impact studies, as none of the papers in the impact category have been published. Two papers related to category acceptance and one related to perception, welfare, and readiness respectively had been published in 2017. Furthermore, 2018 included three papers in the perception category, one in the acceptance category, two in the social cost category, and one in each impact and welfare category. The number of papers related to social impacts has once again increased in 2019, as three papers on the social impact of EVs were published in 2019, and two perception related papers were also delivered. A user experience related paper was also published in 2019, showing that user as a research focus might be more critical as a research focus in the future.

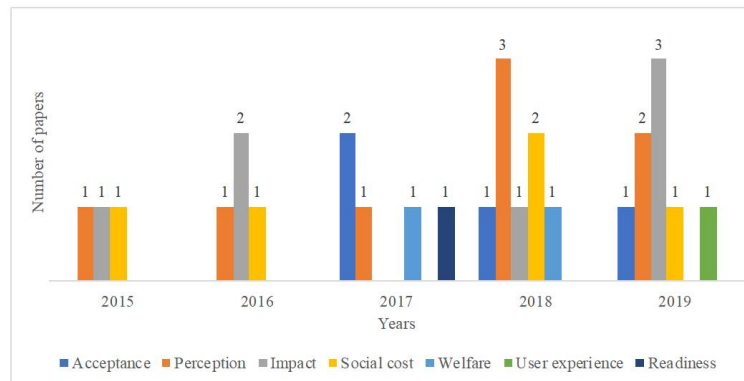


Figure 3. The research focus of papers related to social aspects of EVs included in Web of Science (WoS) in the last five years.

However, the authors allow the possibility that different social dimensions were studied and covered in published papers that were excluded from this study (e.g., papers published in journals not listed in WoS, conference papers, etc).

The authors most frequently focused on studying EVs' social impact with a method such as SLCA (or simplified SLCA). Social impact assessment of EV was identified in 8 out of 28 papers. For instance, Onat et al. ^[27] used seven sustainability indicators to indicate the social, environmental, and economic impact of different vehicles, including EV and perceived EV, to be the best alternative in the long-term for reducing human health impacts and air pollution from transportation. Onat et al. ^[28] also evaluated the social impact of EVs, although employing a life-cycle sustainability assessment, which includes the SLCA. They also presented a framework for assessing the sustainability of EV. They perceived that the optimal vehicle distribution in the U.S., considering the socio-economic indicators, would comprise internal combustion vehicles in the majority. Albergaria de Mello Bandeira et al. ^[29] also assessed EVs' sustainability in the last mile delivery and perceived several positive social impacts of EVs.

EVs social costs were investigated in 5 out of 28 papers. Newbery and Strbac ^[30] evaluated the EVs regarding what is needed for battery electric vehicles to become socially cost-competitive, while Luo et al. ^[31] analyzed charging stations for EVs to minimize social costs, which are in both cases bigger than conventional vehicles.

Only two papers covered category welfare (one user experience and one readiness), meaning these categories were less addressed, but user experience might become more critical in the future.

The distribution of the published papers among journals has shown that most of the papers related to social aspects of EVs were published in the journal Transportation Research Part D (Transport and Environment), followed by Applied Energy and Transportation Research Part A (Policy and Practice) (Table 1).

Table 1. List of journals covering the social aspect of electric vehicles (EVs).

Transportation Research Part D (Transport and Environment),	6
Applied energy	3

Transportation Research Part A (Policy and Practice)	3
Technological Forecasting & Social Change	2
Energy	2
Journal of Cleaner Production	2
Renewable and Sustainable Energy Reviews	2
Other journals	8

Papers included in the detailed analysis are presented in Table 2. Additionally, the geographical area of the conducted study for each paper is also shown. Moreover, the studied paper was related to 17 United Nations Sustainable Development Goals (SDGs) ^[16].

Table 2. Research focus, category, geographical area, and relation to the sustainable development goals (SDGs) (alphabetically).

Paper	Paper Focus	Social Aspect Category	Geographical Area	Relation to SDGs
Albergaria de Mello Bandeira et al. (2019) ^[29]	Proposing a method to assess alternative strategies for the last-mile of parcel deliveries in terms of social, environmental, and economic impacts	Impact	Brazil (Rio de Janeiro)	Climate action, Sustainable cities and communities, Decent work and economic growth, Good health and well-being
Andwari et al. (2017) ^[32]	Evaluating the technological readiness of the different elements of BEV technology	Readiness	-	Climate action, Sustainable cities and communities, Decent work, and economic growth
Brase (2018) ^[25]	Psychology of consumer perceptions and decisions about EVs	Perception	U.S.A	Climate action, Sustainable cities and communities, Decent work, and economic growth
Cherchi (2017) ^[33]	Measure the effect of both informational and normative conformity in the preference for EV	Perception	-	Sustainable cities and communities
Daramy-Williams et al. (2019) ^[34]	Reviewing the user experience, driving EVs	User experience	UK	It cannot be defined

Fang et al. (2018) ^[35]	Estimating marginal emission rates of electricity and the marginal price of electricity provided for charging EVs at different times of the day	Social cost	U.S.A.	Climate action, Sustainable cities, and communities, Decent work and economic growth
Giordano et al. (2018) ^[36]	Comparing diesel and battery electric delivery vans from an environmental and economic perspective	Impact	EU, U.S.A.	Climate action, Sustainable cities, and communities, Decent work and economic growth, Good health and well-being
Günther et al. (2015) ^[37]	The study analyzes where jobs could be created or cut down and the other two dimensions of sustainability	Impact	Germany, China, EU	Climate action, Sustainable cities, and communities, Decent work and economic growth
Hardman et al. (2016) ^[38]	The distinction between high-end adopters and low-end adopters	Perception	-	Climate action, Sustainable cities, and communities, Decent work and economic growth
Helveston et al. (2015) ^[39]	Consumer preferences for conventional, hybrid electric, plug-in hybrid electric (PHEV), and battery electric (BEV) vehicle technologies	Perception	China, U.S.A.	Climate action, Sustainable cities and communities, Decent work and economic growth
Herrenkind et al. (2019) ^[40]	Conducting qualitative research to identify relevantly factors influencing individual acceptance of autonomously driven electric buses	Acceptance	Germany	Sustainable cities and communities, Industry, innovation, and infrastructure
Kershaw et al. (2018) ^[41]	Assessing the contemporary 'consumption' of the motor-car in the context of increased uptake of EVs as part of a transition to a low carbon automobility	Perception	UK	Climate action, Sustainable cities and communities, Decent work and economic growth
King et al. (2019) ^[42]	Investigating the effects of stereotype threat on EV drivers	Perception	UK	Sustainable cities and communities

Kontou et al. (2015) ^[43]	Optimal electric driving range of (PHEVs) that minimizes the daily cost borne by the society when using this technology	Social cost	U.S.A.	Climate action, Sustainable cities, and communities, Decent work and economic growth, Industry, innovation and infrastructure
Luo et al. (2018) ^[31]	Proposing an optimization model for minimizing the annualized social cost of the whole EV charging system	Social cost	China	Sustainable cities and communities, Decent work and economic growth, Industry, innovation, and infrastructure
Luo et al. (2019) ^[44]	Proposing a comprehensive optimization model concerning the joint planning of distributed generators and EVs charging stations	Social cost	China	Climate action, Sustainable cities and communities, Decent work and economic growth, Industry, innovation and infrastructure
Newbery & Strbac (2016) ^[30]	What would make EVs to become socially cost competitive	Social cost	UK	Sustainable cities and communities, Decent work and economic growth
Onat et al. (2016a) ^[27]	Uncertainty-embedded dynamic life cycle sustainability assessment framework	Impact	U.S.A.	Climate action, Sustainable cities and communities, Decent work and economic growth, Good health and well-being
Onat et al. (2016b) ^[28]	To advance the existing sustainability assessment framework for alternative passenger cars	Impact	U.S.A.	Climate action, Sustainable cities and communities, Decent work and economic growth, Good health and well-being
Onat et al. (2017) ^[23]	Suitability of battery electric vehicles in the United States and the social acceptability of the technology	Acceptance	U.S.A.	Climate action, Sustainable cities and communities, Decent work and economic growth, Affordable and clean energy
Onat et al. (2019) ^[12]	Presenting a novel comprehensive life cycle sustainability assessment for four different support utility EV technologies	Impact	Qatar	Climate action, Sustainable cities and communities, Decent work and economic growth, Good health and well-being, Clean water and sanitation

Pautasso et al. (2019) ^[45]	Proposing a model for evaluating environmental, social, and economic impacts exerted by the diffusion of EVs	Impact	Italy	Climate action, Sustainable cities, and communities, Decent work and economic growth, Good health and well-being
Shao et al. (2017) ^[46]	Social welfare of monopoly and duopoly of EVs and gasoline cars	Welfare	-	Climate action, Sustainable cities and communities
Sovacool et al. (2018) ^[47]	Assessing of the demographics of electric mobility and stated preferences for EV	Perception	Nordic region	Climate action, Sustainable cities and communities, Decent work and economic growth
Sovacool et al. (2019) ^[26]	Assessing how schoolchildren between 9 and 13 years of age think about electric mobility	Perception	Denmark, Netherlands	Sustainable cities and communities
Wang et al. (2019) ^[48]	Explore the potential factors that affect consumers' acceptance of EVs in Shanghai	Acceptance	Shanghai	Climate action, Sustainable cities, and communities
Yousefi-Sahzabi et al. (2017) ^[24]	Social acceptance of low-carbon energy technologies in Turkey and the current status of the energy sector from a social perspective related to EVs	Acceptance	Turkey	Climate action, Sustainable cities, and communities, Decent work and economic growth, Affordable and clean energy
Zheng et al. (2018) ^[49]	Investigating the impact of EV manufacturing- and society-related factors on balance among manufacturer profits, environmental impact, and social welfare.	Welfare	China	Climate action, Sustainable cities, and communities, Decent work and economic growth

Table 2 presents that most of the studied papers are national studies related to one country or even region only (20 papers). Only four included more than one country and could be identified as international studies. The remaining four papers did not specify their geographical orientation.

Table 2 and Figure 4 display that most papers contribute or are related to one or more UN SDGs. Most identified SDG was the relation with “sustainable cities and communities” (96.43% of papers are related to this goal), “climate action” (75% of papers are related to this goal), and “decent work and economic growth” (75% of papers are related to this goal). It is seen in Figure 4 that “sustainable cities and communities” was one of the priorities through all studied years but rocketed in 2019 to be much more represented than other SDGs.

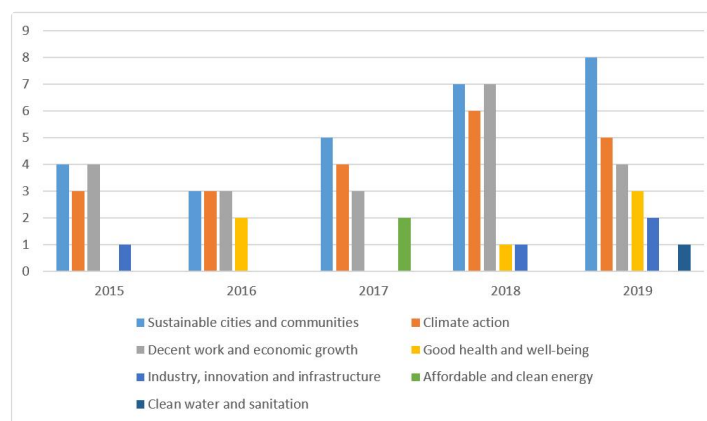


Figure 4. Relation and focus of studied papers towards UN sustainable development goals.

Papers are less related to SDGs such as “affordable and clean energy” (only 3.57% of papers related), “good health and well-being” (17.86% of papers related), “clean water and sanitation” (only 3.57% of papers related). “industry, innovation and infrastructure” (14.29% of papers related) seem to have moderate importance, and research focus in some cases can be associated with this goal as well, mainly due to investigating charging infrastructure associated with EVs.

Almost all papers are related to more than one SDG. The study of Albergaria de Mello Bandeira et al. [29] was related to goals “climate action”, “sustainable cities and communities”, “decent work and economic growth,” and “good health and well-being”. As the authors focused on proposing a method to assess alternative strategies for the last-mile of parcel deliveries, they also focused on the impact on worker’s health, and the paper is therefore related to “good health and well-being”. The goal is to ensure healthy lives, and this can be done by first evaluating and then reducing the impact of different factors on worker’s health. Relation with “climate action” can also be identified since it assesses the environmental impacts of EV use and it takes urgent action to combat climate change and its impacts. Albergaria de Mello Bandeira et al. [29] study further relates to “decent work and economic growth”, which aims to promote sustained, inclusive, and sustainable economic growth. As they assess different delivery strategies from an economic perspective, they support sustainable economic development. The paper also relates to “sustainable cities and communities”, the goal of which is to make cities and human settlements inclusive, safe, resilient, and sustainable. They assess postal deliveries in Rio de Janeiro from all three sustainability perspectives to make cities safe and sustainable.

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