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RESEARCH ARTICLE

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The sustainable development of mobility in the green transition: Renewable energy, local industrial chain, and battery recycling

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Abstract

The transportation sector has a strong negative impact on the environment and therefore requires new sustainable development measures. This paper proposes a new indicator of sustainability in transport obtained through a multi-criteria analysis based on Eurostat data and a panel of 10 academics. The results show a positive performance of Sweden in the period 2015–2019 and a small number of countries above the European average. Furthermore, a quantitative analysis based on these experts identifies the critical success factors associated with purchasing electric vehicles. The greatest importance is assigned to purchase cost, followed by battery autonomy. Our analysis proposes that electric vehicles are unable to achieve a sustainable transition unless three conditions are met: (i) use of renewable sources, (ii) local industrial development of the sector, and (iii) battery recycling. Therefore, Europe urgently needs to realize new industrial activities and avoid social unsustainability. The long-term objective of a policy plan is to promote independence from external sources of energy, materials, and other resources.

KEYWORDS

battery recycling, electric vehicles, Europe, green transition, local industrial chain, local supply chain, multi-criteria decision analysis, policy implications, renewable energy, sustainable mobility

1 | INTRODUCTION

Population growth, food production, economic development, and energy consumption are affected by emission levels (Rehman et al., 2022). Sustainability is a major challenge in which a less selfish attitude needs to be envisaged in which choices to be made that need will have a bearing on the future (D'Adamo, Gastaldi et al., 2022).

The European Commission aims to reduce net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels (Fit for 55). Achieving this target is clearly critical to being the world's first climate-neutral continent by 2050 and to realizing Europe's Green Deal. The European Parliament voted in June 2022 on a proposal to ban the sale of new gasoline and diesel cars starting in 2035. A measure that evidently pushes toward the development of electric vehicles. Transport Both developed and developing nations should urgently address the idea of sustainable transportation (Ahn and Park, 2022). Activities contribute 28.5% of total CO_2 emissions in the European Union (Abbes, 2021). Both developed and developing nations should urgently address the idea of sustainable transportation (Ahn and Park, 2022).

The literature defines sustainable mobility as achieving an overall volume of physical mobility through opportune of technologies that meet basic mobility needs and ecosystem integrity while limiting greenhouse gas emissions to a level consistent with sustainable development goals (Banister, 2008; Bardal et al., 2020). Low-mobility societies, collective transport, and electro mobility are called grand narratives capable of achieving sustainable mobility only if their simultaneous application and integration is verified (Holden et al., 2020). In addition, a number of sustainable mobility opportunities were identified during the COVID-19 crisis, such as avoidance of unnecessary

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transportation volumes, changing transportation standards and practices, and more emission-efficient transportation systems (Griffiths et al., 2021).

The relationship between sustainability and progress in technological innovation is decisive (Godil et al., 2021). In addition, the literature highlights the role of new governance models toward sustainability (Di Vaio et al., 2021) and the identification of suitable strategies (Agrawal et al., 2022). For this scope, indicators can support decision makers in transport infrastructure choices (Di Vaio et al., 2018). These aspects should then be linked to the definition of business models (Taddei et al., 2022), methodological approaches (Vacchi et al., 2021), performance of enterprises (Cucchiella et al., 2017), consumers choices (Romano et al., 2022) and cause-and-effect determinations on other strategic variables (Ullah et al., 2021). Sustainability trend analysis can be accomplished with the help of indicators that can not only synthesize information but also identify policy proposals to mitigate climate change (Benedek et al., 2021; Kubiszewski et al., 2022). There are many topics analyzed: energy efficiency (de la Cruz-Lovera et al., 2017), CO_2 emissions and material footprint (Hickel, 2020), end-of-life management of waste (Ríos and Picazo-Tadeo, 2021) and renewable energy (Le and Bao, 2020). In this context, a key role is played by the criteria/indicators that can express the output to be analyzed. Europe is typically chosen as a case study because countries' performances have very different assessments (D'Adamo et al., 2021; Szopik-Depczyńska et al., 2018) and proposed climate neutrality policies are important (Madurai Elavarasan et al., 2022). Sustainable urban mobility requires the need to develop new indicators (Morfoulaki and Papathanasiou, 2021). Indicators make it possible to describe trajectories of sustainable development, identify appropriate policies, and measure performance (Alola et al., 2021; Hirai, 2022). Achieving carbon neutrality requires long-term environmental strategies (Abbasi et al., 2021).

Within sustainable mobility, several countries have applied development plans for electric vehicles (Mallapaty, 2020; Onat et al., 2021). However, to achieve this goal, a certain amount of relevant components and raw materials are required (Baars et al., 2021), among which lithium plays a critical role within the electric vehicle industry (Sun et al., 2022). Some studies have shown that the pandemic has stimulated future demand for electric vehicles (Wen et al., 2021). In this context, innovation in eco-systems associated with the electric vehicle industry will play a key role (Arribas-Ibar et al., 2021). The overall performance of electric vehicles is highly dependent on the mix of electricity consumed during the production and use phase. Consequently, the use of green sources is likely to positively impact the environmental analysis of these vehicles (Shafique and Luo, 2022). In addition, also battery manufacturing has a substantial impact on the environment (Xia and Li, 2022). The sustainable strategy is to foster cost-effectiveness along the automotive chain (Jasiński et al., 2021). Modular electric vehicle platforms are designed to combine production efficiency and environmental regulations (Lampón, 2022).

This work has the first research objective (RO1) of assessing the current trend in Europe in terms of sustainable mobility. A multi-criteria decision analysis (MCDA) is used for this purpose, which allows dividing European countries by considering a 5-year period. A new indicator of sustainability in transport (IST) is identified by aggregating the performance of five specific indicators: (i) average CO_2 emissions per km from new passenger cars; (ii) share of energy from renewable sources in transport; (iii) share of busses and trains in inland passenger transport; (iv) percentage of total revenues from taxes and social contributions and (v) fuel combustion in transport.

The second research objective (RO2) is to define the critical success factors that can outline the future direction of sustainable mobility in Europe with specific attention given to electric vehicles. In particular, through expert evaluations we will look at both the consumer and policy-maker perspectives. Analyses aim to define factors influencing the purchase of an electric car and to identify critical factors for the green transition of electric mobility.

2 | METHODS

The use of a hybrid methodology turns out to be suitable when objectives are to be achieved that are interrelated but require different approaches. Specifically, an indicator of sustainability in the transport sector requires identifying useful criteria to represent this topic, and then by means of multi-criteria, a ranking of alternatives can be made. Next, to understand how the electric vehicle product can influence the sustainability of this sector, a 10-point value methodology is reported in order to capture the criticality of the factors analyzed.

2.1 | Multicriteria analysis

MCDA is an established method in the literature for comparing countries in order to rank them, but also for understanding how the individual components of the indicator affect the outcome (Dabkienė et al., 2022). The first step is therefore to identify suitable indicators to represent sustainability in the transport sector and the availability of these data. The use of Eurostat was used for this purpose (Kostetckaia and Hametner, 2022; Streimikis and Balezentis, 2020). Analyzing the various indicators proposed in this database the need to select only those indicators suitable for the objective is evident. Accordingly, the choice fell on the following:

- Average CO_2 emissions per km from new passenger cars (EPC).
- Share of energy from renewable sources in transport (RET).
- Share of busses and trains in inland passenger transport (BTT).
- Percentage of total revenues from taxes and social contributions (TSC).
- Fuel combustion in transport (FCT).

It can be seen that EPC and FCT have an environmental nature, BTT a social nature and TSC an economic nature. Finally, RET has a crosscutting nature. At present, 2020 data are available; however, they are missing for BTT. Consequently, the reference period considers 5 years and the last available year for all indicators (2015–2019 period). This approach is justified by literature (Colasante et al., 2022).

The new aggregate indicator proposed in this work (IST) is obtained multiplying the weights and values associated with the five indicators. The row vector is country-specific as it consists of five columns that report the values the indicators take as a function of the data proposed by Eurostat. The column vector, on the other hand, is associated with all countries and consists of five rows that report the weights that will be calculated by virtue of an AHP. Consequently, IST is dimensionless and is an associated and country-specific value. The indicator was chosen following the methodology proposed in the literature (D'Adamo et al., 2021).

$$IST_C = RW_C \times CW \tag{1}$$

$$RW_C = [vEPC_C\ vRET_C\ vBTT_C\ vTSC_C\ vFCT_C] \tag{2}$$

$$CW = [wEPC\ wRET\ wBTT\ wTSC\ wFCT]^T \tag{3}$$

2.2 | Assignment of values to criteria

Once the criteria were identified through Eurostat, the next step was immediate. In fact, it was necessary to report the associated values for the different ones and to check that no missing data were reported. This problem does not occur in this work. As for the five-year time trend, it is useful to show whether or not the ranking has changed over the years and can be useful to increase the reference sample in regression analyses. One-step before proceeding to calculate the values is to analyze the units of measurement: gCO_2/km for EPC and percentage for RET; BTT and TSC do not require changes since they are not affected by country size. Instead, FCT was reported per tonnes and therefore it had to be divided by the population number. The method used is normalization, which allows the different units of measurement and the different magnitudes associated with the values to be disregarded. Specifically, the range 0–1 is where the value 0 is associated with the weakest performance and 1 with the best performance (D'Adamo et al., 2021). All other data are assigned an intermediate value. Table 1 shows that there is always a different leading country in the five different assessments in 2019: Netherlands with 98.4 gCO_2/km (EPC); Sweden with 31.9% (RET); Hungary 28.4% (BTT); Germany 4.1% (TSC) and Romania 0.95 tons per capita (FCT). Thus, for EPC, TSC and FCT an attempt is made to reduce the value, while for RET and BTT to increase it.

2.3 | Identification of experts

Before assigning weights, it is necessary to identify experts who have subject matter expertise in order to be able to use their expertise. The method used is to analyze the Scopus database and to identify profiles of academics with at least 10 years of experience (D'Adamo & Sassanelli, 2022). The keywords searched were sustainable indicators and green transport. The different names were sent an email explaining the purpose of the project and stating that only the first 10 accessions would be analyzed. Table 2 shows some characteristics of these profiles, in which experience of a minimum of 15 years and a spatial context more related to the European context are evident.

TABLE 1 Indicators values in 2019 (RW)

	EPC	RET	BTT	TSC	FCT
EU 27	0.32	0.20	0.41	0.73	0.90
Belgium	0.33	0.13	0.49	0.73	0.86
Bulgaria	0.08	0.17	0.31	0.00	0.95
Czechia	0.12	0.17	0.88	0.75	0.91
Denmark	0.61	0.14	0.42	0.52	0.86
Germany	0.05	0.16	0.31	1.00	0.89
Estonia	0.08	0.11	0.55	0.06	0.91
Ireland	0.55	0.21	0.46	0.65	0.83
Greece	0.50	0.03	0.40	0.11	0.92
Spain	0.34	0.16	0.32	0.87	0.89
France	0.55	0.22	0.39	0.88	0.89
Croatia	0.39	0.09	0.34	0.13	0.93
Italy	0.39	0.21	0.45	0.39	0.91
Cyprus	0.18	0.00	0.48	0.44	0.84
Latvia	0.15	0.05	0.41	0.08	0.92
Lithuania	0.03	0.03	0.00	0.66	0.86
Luxembourg	0.00	0.16	0.42	0.99	0.00
Hungary	0.10	0.18	1.00	0.65	0.94
Malta	0.69	0.21	0.41	0.32	0.95
Netherlands	1.00	0.33	0.26	0.24	0.91
Austria	0.22	0.25	0.72	0.82	0.80
Poland	0.08	0.11	0.52	0.50	0.92
Portugal	0.68	0.21	0.12	0.53	0.92
Romania	0.25	0.17	0.62	0.35	1.00
Slovenia	0.27	0.17	0.21	0.18	0.81
Slovakia	0.08	0.18	0.88	0.53	0.94
Finland	0.51	0.41	0.35	0.58	0.88
Sweden	0.38	1.00	0.44	0.92	0.92

TABLE 2 List of experts

Numbers	Role	Country	Years of experience
1	Full Professor	Spain	16
2	Full Professor	China	20
3	Full Professor	Italy	18
4	Full Professor	Australia	16
5	Full Professor	Germany	17
6	Full Professor	Austria	16
7	Full Professor	USA	18
8	Full Professor	United Kingdom	16
9	Full Professor	Italy	19
10	Full Professor	France	18

There were more male respondents than female (7 vs. 3). Within the email it was reported that the survey covered two phases where in the first one the AHP would be used and in the second one the 10-point value.

It is worth noting that two of the 10 experts also helped validate the model by pointing out particularly for the second part whether certain criteria deemed suitable were absent. These two experts were chosen from the 10 following the principle of the first two accessions to the conduct of the survey.

2.4 | Assignment of weights

During April–May 2022, the 10 selected experts provided input. In general, after a cognitive email they were notified of the possibility of holding a meeting lasting up to 1 h. In the first phase of the survey, it was required to compile an AHP among the five indicators in order to assign a weight to them. AHP is a method to compare the different criteria in pairs and identify their priority (Ngo et al., 2021). Each expert filled in a five-dimensional matrix and then has to provide 10 ratings. For each analysis, the consistency ratio is checked, which can be a maximum of 0.10 (Saaty, 2008). Table 3 shows the values found by the experts, which for privacy issues do not coincide with the expert number given in Table 2. Aggregation of the weights shows that for five experts RET is the most relevant, while TSC and FCT is for three and two experts respectively.

The analysis of the distribution of countries among the experts showed that the cross-sectional aspect was considered the most relevant. RET has 0.345 and this result is also motivated by the old European strategy in which a target of 10% was set for European countries. Therefore, it is assumed that the target, and thus a policy measure in general, has prompted experts to give this indicator greater prominence. Next, we find the economic indicator that considers the impact of taxes (TSC) with a weight of 0.265. In addition, this topic has been much analyzed in the literature, as it is considered crucial to the pursuit of the green transition goal. Taxes can affect the cost of fossil fuels that deteriorate the environment. This is followed by the FCT with 0.232. There are some observations: the first three indicators weigh about 84 percent, and there is a significant difference between the two most markedly environmental indicators. This difference, evidenced by the 0.071 assigned to the EPC, probably depends on the idea that it is seen as a more specific indicator. In fact, it is proposed as related to the number of new passenger cars while the other refers to the total value of emissions. A slightly less significant result is given to the indicator of public transportation (BTT) with 0.086.

2.5 | A quantitative analysis based on the critical success factors

In the second stage of the survey, experts are asked to provide a numerical judgment on the relevance of certain factors, which can be called critical success factors. Specifically, the two questions posed to the experts were:

TABLE 3 Experts values (CW)

Expert	EPC	RET	BTT	TSC	FCT
1	0.125	0.271	0.132	0.063	0.409
2	0.064	0.419	0.119	0.092	0.305
3	0.067	0.285	0.096	0.375	0.177
4	0.087	0.430	0.071	0.207	0.205
5	0.037	0.409	0.055	0.232	0.267
6	0.042	0.216	0.062	0.530	0.15
7	0.063	0.246	0.056	0.216	0.419
8	0.093	0.424	0.124	0.276	0.084
9	0.070	0.498	0.100	0.155	0.177
10	0.065	0.254	0.049	0.506	0.126
Average	0.071	0.345	0.086	0.265	0.232

- First question (Q1): What factors influence the purchase of an electric car?
- Second question (Q2): What factors are useful for the green transition in electric mobility?

This part of the work consists of two stages. The first identifies a potential framework composed of factors that can describe the demand object (electric vehicle purchase and green transition enablers). The second aims to assign a value to these factors. The list of these criteria were obtained through technical seminars, literature reviews, and analysis of consumer questionnaires. The objective of the factors was to have no redundancies and that they could potentially be of relevance to the experts–Figure 1. The method of answering this question is the Likert Scale that provides a quantitative rating from 1 to 5. In this work, a broader parameter of values was chosen in order to allow experts to provide ratings that are more specific. The method chosen is the 10-point value method, in which the value 1 identifies a critical factor of low importance, while the value 10 identifies a critical success factor (D'Adamo & Sassanelli, 2022).

In the first question, experts identify the potential perspective of a consumer, while in the second question they assess that of a policy-maker.

3 | RESULTS

The results section is divided into two parts in order to represent the ranking of European countries in terms of sustainability index (RO1), and then the results related to critical success factors are analyzed (RO2).

3.1 | Indicator of sustainability in transport

RO1 aims to calculate values of STI for each country. The results of the new indicator are proposed for a period of 5 years (2015–2019) and are obtained as an aggregate value from the five indicators. This

FIGURE 1 List of critical factors [Colour figure can be viewed at wileyonlinelibrary.com]

Q1: Factors influencing the purchase of an electric car
Battery autonomy
Contribution to society
Respect for the environment
Purchase incentives
Operating costs
Purchase cost
Driving experience
Infrastructure (electric columns)
Noise pollution
Charging time
Savings
Administrative benefits
Noise abatement risk (due to quietness of vehicle toward people/animals)

Q2: Critical factors for the green transition in electric mobility
Regulating& controlling the price of electricity
Informing and raising consumer awareness
Green energy production
Local industrial development of the sector
Improving battery autonomy
Increasing the presence of charging stations
Increase incentives at the purchase stage
Bonuses for returning old vehicles
Reduce environmentally harmful subsidies
Improve public mobility
Reducing purchase price
Battery recycling

output uses an objective data related to the value and a subjective data related to the weight given by the experts–Table 4.

An analysis of the STI values shows a different data from other sustainability indicators of European countries (Colasante et al., 2022; D'Adamo et al., 2021). In fact, the number of countries with a value higher than the European average is very small. Sweden, France, Germany, Austria, Czechia, and Hungary are the only countries that have consistently shown a higher value throughout the five-year period. Finland and Spain also show a value that tends to be higher than the European average. There are exceptions only in specific years: Finland in 2016 and Spain in 2015 and 2017. The motivation to be found in this result is the strong positive performance of Sweden, which presents a value of 0.868 in 2019, registering a 0.336 higher than EU 27. If we apply the same delta in the lower range, we find that no country has a value of 0.195 since the ranking is closed by Latvia with 0.294. It should be pointed out that this country occupies the last position in all the years examined, while the second-to-last place is occupied by Slovenia in 2015–2017, Cyprus in 2018 and Bulgaria in 2019.

The analysis of the results can be supported by the decomposition of the aggregate indicator–Figure 2. In fact, it clearly emerges that in almost all countries the sum of the TSC and FCT indicators yields about 70% of the total value (exceptions are Malta, Netherlands, Finland, and Sweden). Similarly if we evaluate the contribution of RET we observe that it affects about 24% in Netherlands, 25% in Finland, but the most relevant value is 40% in Sweden. So we can conclude that Sweden's strong performance is related to its first position in the indicator that is the most relevant and because the performance in RET is very significant compared to the other countries: 0.345 for Sweden followed by Finland and Netherlands with 0.141 and 0.115, respectively. Further determining Sweden's strength is that in the other indicators it still occupies the top positions. Germany (0.265) leads the TSC followed by Luxembourg (0.264) and Sweden (0.243). Romania leads (0.232) the FCT, while Sweden (0.214) occupies the seventh position. The literature pays attention to the energy sustainability of Sweden (Lindfors et al., 2019; Zhong et al., 2021).

Further observation concerns the four most populous countries, from which it emerges that only Italy has a weak and declining performance as it drops from twelfth place in 2015–2016 to sixteenth in the last 3 years. Its weak performance is explained by the normalized value tending to be below 0.5 in RET, BTT and TSC indicators, and there is a worsening for EPC. In this regard, the indicator not only allowed for a snapshot for 1 year but also is useful as a benchmarking to follow the time trend. However, it should be pointed out that if other indicators are useful in describing the sustainability goal, although this would skew the time comparisons. It is evident from the data emerging from Figure 3 that the situation in 2019 is different from that in 2015. The most significant growth is for the leading country (Sweden) with 0.069, followed by Ireland with 0.039 and Spain

TABLE 4 Indicator of sustainability in transport in 2015–2019 period

	2015	2016	2017	2018	2019	Ranking 2019
EU 27	0.572	0.572	0.573	0.545	0.532	
Belgium	0.547	0.563	0.567	0.526	0.503	11
Bulgaria	0.397	0.405	0.420	0.404	0.312	26
Czechia	0.592	0.597	0.598	0.567	0.552	6
Denmark	0.498	0.499	0.510	0.459	0.465	14
Germany	0.578	0.584	0.585	0.565	0.556	5
Estonia	0.384	0.351	0.346	0.361	0.319	25
Ireland	0.478	0.472	0.510	0.499	0.517	9
Greece	0.390	0.421	0.418	0.398	0.323	24
Spain	0.518	0.580	0.570	0.549	0.543	8
France	0.659	0.651	0.649	0.607	0.590	2
Croatia	0.403	0.388	0.371	0.344	0.338	22
Italy	0.512	0.507	0.499	0.472	0.456	16
Cyprus	0.372	0.374	0.363	0.338	0.366	20
Latvia	0.293	0.286	0.280	0.282	0.294	27
Lithuania	0.480	0.459	0.450	0.404	0.385	19
Luxembourg	0.387	0.386	0.393	0.352	0.356	21
Hungary	0.616	0.616	0.603	0.569	0.545	7
Malta	0.459	0.489	0.510	0.501	0.461	15
Netherlands	0.468	0.458	0.463	0.479	0.483	13
Austria	0.645	0.623	0.599	0.581	0.566	3
Poland	0.493	0.468	0.461	0.438	0.432	18
Portugal	0.566	0.553	0.549	0.527	0.486	12
Romania	0.481	0.480	0.538	0.497	0.453	17
Slovenia	0.312	0.297	0.313	0.339	0.331	23
Slovakia	0.558	0.552	0.531	0.503	0.504	10
Finland	0.780	0.542	0.669	0.581	0.565	4
Sweden	0.800	0.852	0.861	0.862	0.868	1

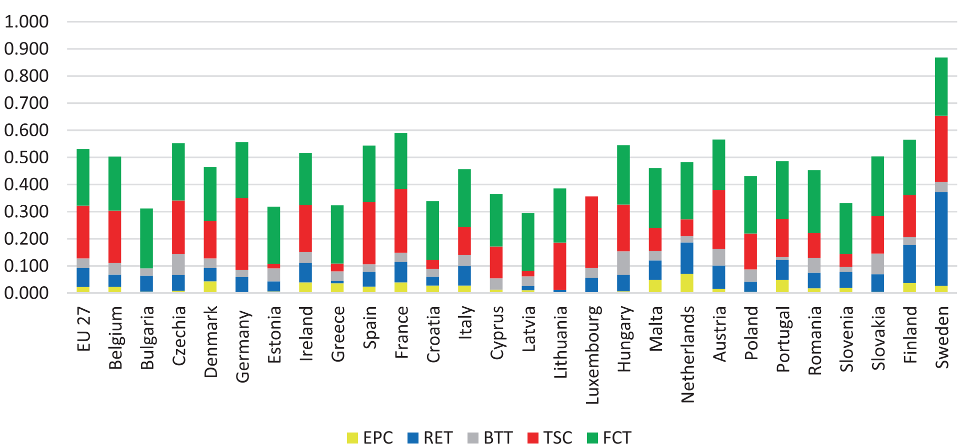


FIGURE 2 Decomposition analysis of the indicator of sustainability in transport. [Colour figure can be viewed at wileyonlinelibrary.com]

0.025. Positive sign is also recorded for Slovenia, Netherlands, Malta, and Latvia. All other countries decrease their value and in particular, the worst value is associated with Finland with −0.214 and Lithuania with −0.095. These data always read as a function of the absolute values recorded with the RET indicator. In addition, the normalization method compares the performance of all countries with respect to the leading country. Since Sweden year by year always improves, this determines that other countries may grow less than the leading country.

Finally given that a recent indicator on economic sustainability showed to have a relationship with GDP per capita (D'Adamo,

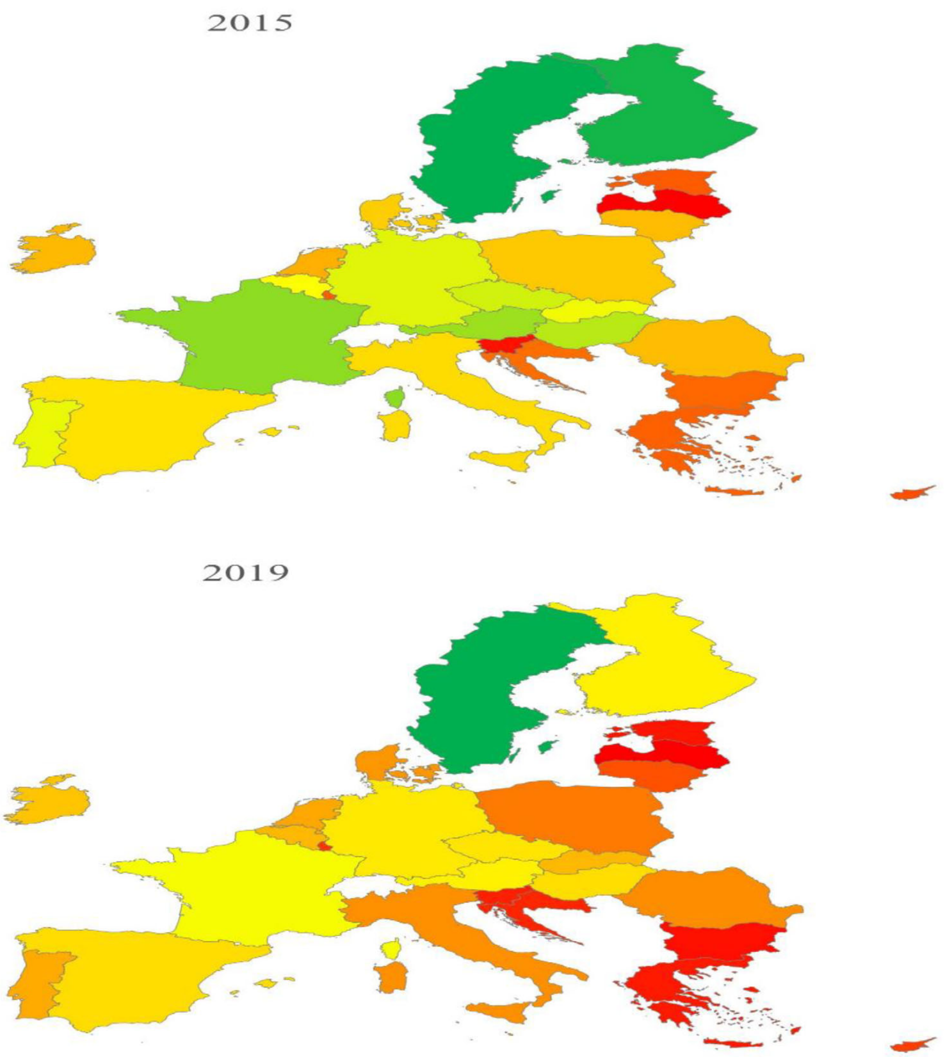


FIGURE 3 A multi-criteria comparison of STI between 2015 and 2019. [Colour figure can be viewed at wileyonlinelibrary.com]

Gastaldi et al., 2022), this work also wants to investigate how much IST is related to macro variables. Figure 4 shows that no relationship is verified with either GDP per capita or GHG emissions per capita, since R^2 obtained turns out to be very low. In the case of GDP per capita it is 0.23 and not 0.1212 because Luxembourg was excluded from the sample, which is known to have a particular trend on this parameter.

In order to assess how the indicators that make up the TSI are related to each other, a correlation matrix is proposed (Table 5). The results do not show the presence of relevant correlation. In addition, it is suggested to use correlation text and variance inflation factor when the number of parameters to be analyzed is larger.

3.2 | Analysis of critical success factors in electric mobility

RO2 is closely related to the RO1. In fact, experts provide input in order to identify critical factors. The basic idea is to identify of actions and policies that can trigger change to improve STI performance. Some factors are repeated, and this is because the factors that trigger purchase are not necessarily actual aspects that improve sustainability. Table 6 shows the purchase factors where the average value is 7.74, highlighting that most of the proposed factors are considered of interest. An insufficient value is provided in only five of the 100 evaluations (and exactly it is equal to the value of 5). Instead, the maximum value (10) is given 10 times including three to battery autonomy and purchase cost. Table 7 proposes the factors favoring green transition and in this case we find an average value of 8.84. An insufficient value is never given and the maximum value is found in 33 evaluations, including eight times for green energy production and seven times for local industrial development of the sector.

These average results on the overall data allow us to define that the proposed framework in Figure 1 was populated with relevant factors. Once all the data were collected, the average value for each factor was calculated. Each expert was assigned the same relevance. Figure 5 proposes the critical factors related to buying an electric car and Figure 6 that related to the green transition in electric mobility.

Relative to the critical purchasing factors, Figure 5 underlines that the greatest restraint is at present represented by the purchase cost

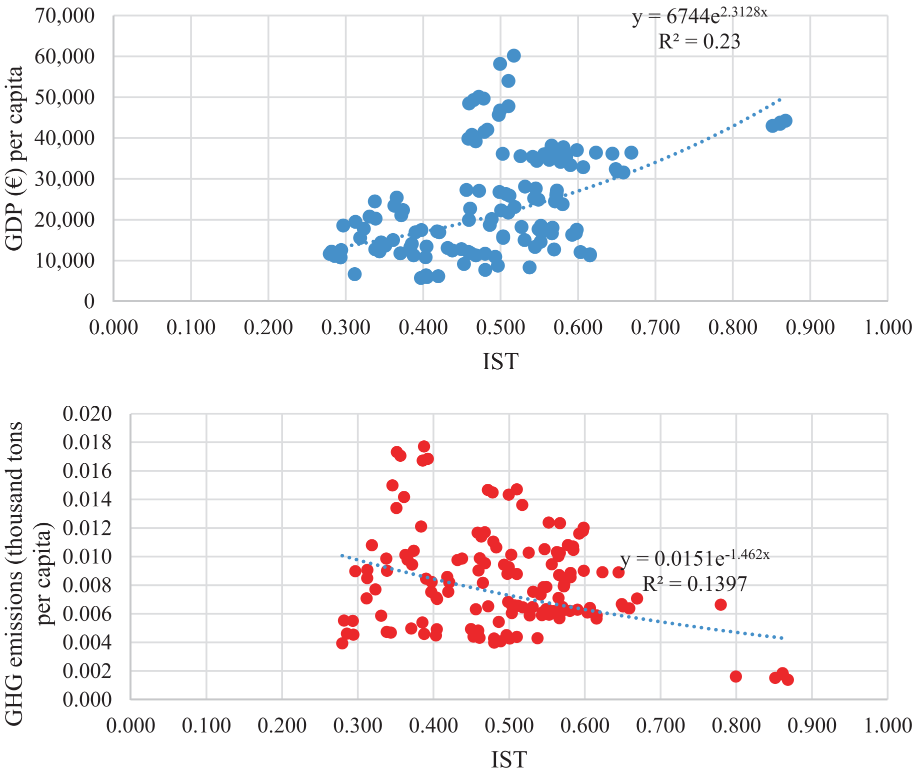


FIGURE 4 The relationship between STI and two macro-economic and environmental variables. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 5 Correlation matrix in 2019

	EPC	RET	BTT	TSC	FCT	GDP	GHG
EPC	1						
RET	−0.28	1					
BTT	0.33	0.02	1				
TSC	−0.14	−0.33	−0.14	1			
FCT	0.24	−0.06	−0.08	−0.38	1		
GDP	−0.22	0.32	−0.09	−0.57	0.73	1	
GHG	0.15	−0.31	0.16	−0.24	0.63	0.58	1

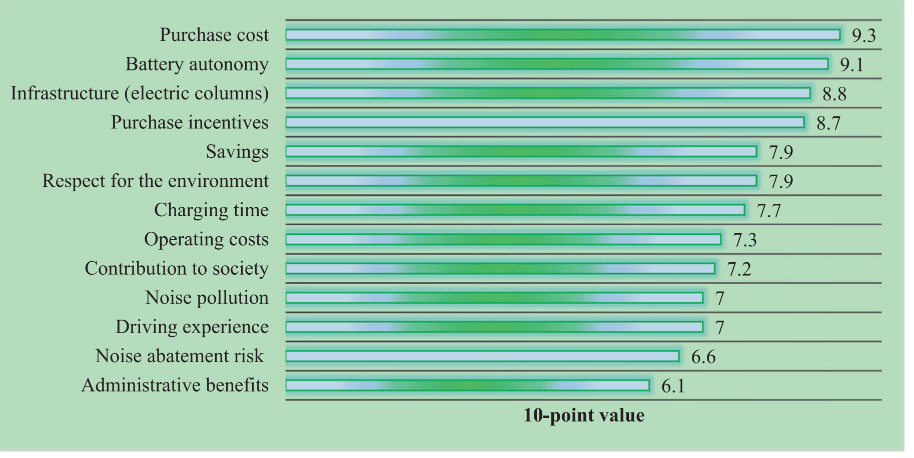
TABLE 6 Factors influencing the purchase of an electric car

No. expert	1	2	3	4	5	6	7	8	9	10
Battery autonomy	10	9	9	8	9	10	8	9	10	9
Contribution to society	7	8	8	9	7	7	7	6	6	7
Respect for the environment	9	10	8	8	8	7	7	7	8	7
Purchase incentives	9	8	9	7	9	8	9	9	9	10
Operating costs	8	8	8	8	6	7	7	8	6	7
Purchase cost	9	9	9	9	9	10	10	9	9	10
Driving experience	6	5	7	6	8	8	7	8	7	8
Infrastructure (electric columns)	10	9	8	9	9	9	8	9	8	9
Noise pollution	8	9	7	7	6	7	6	7	7	6
Charging time	10	9	8	9	7	8	7	6	6	7
Savings	8	8	9	8	7	8	7	8	7	9
Administrative benefits	8	7	6	6	5	5	6	7	5	6
Noise abatement risk	8	9	8	7	6	5	6	6	6	5

TABLE 7 Critical factors for the green transition in electric mobility

No. expert	1	2	3	4	5	6	7	8	9	10
Regulating& controlling the price of electricity	8	9	8	8	8	9	8	9	7	7
Informing and raising consumer awareness	8	8	9	8	10	8	10	9	9	10
Green energy production	10	9	10	10	9	10	10	10	10	10
Local industrial development of the sector	9	8	10	10	10	9	10	10	10	10
Improving battery autonomy	10	9	8	9	9	8	9	9	9	9
Increasing the presence of charging stations	9	10	8	9	8	8	8	9	9	8
Increase incentives at the purchase stage	9	8	8	8	8	8	7	7	6	7
Bonuses for returning old vehicles	9	8	9	8	10	9	10	9	10	9
Reduce environmentally harmful subsidies	8	8	9	8	9	8	9	10	10	9
Improve public mobility	8	8	8	8	9	7	8	7	8	8
Reducing purchase price	10	9	10	9	9	9	10	9	9	9
Battery recycling	9	9	9	10	10	10	9	10	10	9

FIGURE 5 Purchase of an electric car [Colour figure can be viewed at wileyonlinelibrary.com]



(9.30), which is still considered high and as such can induce a phenomenon of social inequality. Where in fact products and services that are sustainable and in the absence of externalities result in a higher cost, it induces them to be offered to the consumer at a higher price. This inevitably may not be affordable for some income groups. To this end, the presence of incentives to purchase such vehicles is considered stimulating (8.70); this factor would actually decrease the previous variable. However, the origin of these incentives should always be clarified: whether they come from citizen contributions or are instead financed by businesses/citizens who do not perceive climate change and continue not to change their behaviors. In addition to this economic factor, two other factors deemed important are technical: battery autonomy (9.10) and the presence of electric columns (8.80). The first wait penalizes the consumer who may because of the vehicle she/he uses forced to make more stops and thus lengthen her/his travel time on particularly long trips. This aspect evidently conflicts with a lifestyle in which one seeks to optimize time. Similarly, infrastructural endowment that could reduce the previous range problem, but certainly not cancel it, is considered important. It is also evident that some consumers could self-equip with electric columns, which by virtue of renewable facilities would lead to a reduction in costs. This economic aspect is considered to be of equal importance to the environmental aspect with a value of 7.90, which is certainly not low on a scale of 1 to 10. However, it is worth pointing out that the purchase of an electric car might not be for environmental reasons and even more so for social ones (7.20). The last criterion that falls in with a value close to a medium-high performance (8) is charging time with 7.70 linked again to optimizing one's time.

Analysis of the results in Figure 6 compared with those in Figure 5 show that the incentives to be provided at the purchase stage are not considered appropriate. In fact, the absolute value is 7.60 representing the lowest value recorded. The reason for this can be traced to the idea that electric vehicle does not equate to sustainability unless other conditions are met. Specifically, three critical factors are the basis for the sustainability of electric mobility. The most relevant is that associated with green energy production (9.80) such that the powering of these vehicles is from a clean source. Similarly, it is worth noting an emerging aspect: the urgency of local development of the sector (9.60), that is, the entrepreneurial capacity of a country not to be dependent on raw materials, on production that takes place

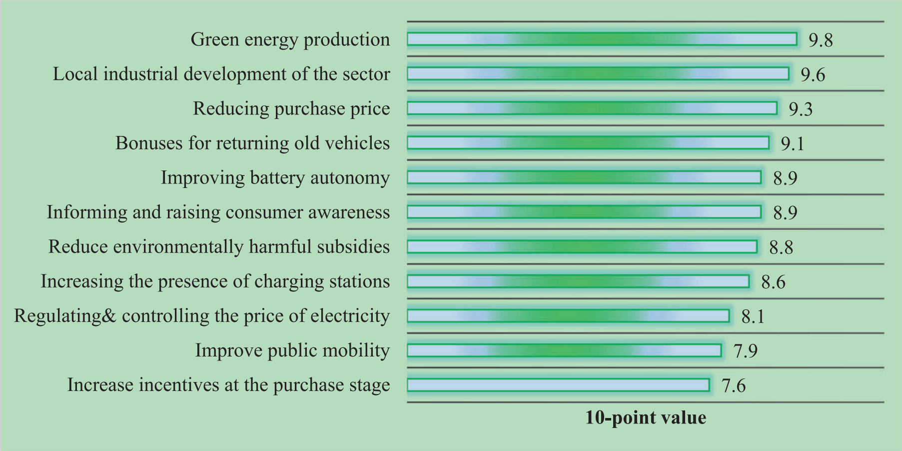


FIGURE 6 Green transition in electric mobility [Colour figure can be viewed at wileyonlinelibrary.com]

in other countries. Indeed, in such scenarios, dependence would no longer be realized on fossil fuels, but on other materials used in electric vehicles. This inevitably shifts the world's economic balance but more importantly presents geopolitical risks. Finally, the third factor considered strategic is battery recycling (9.50) since one cannot get a market off the ground without having clear technologies and resources to be able to handle all the future waste that will be generated. Sustainability has a look not at generating problems but at proposing solutions for the future.

Analyzing the other factors reveals a perception about high costs at the purchasing stage and thus the identification of tools to reduce it (9.30). A reduction in the production chain and a more integrated supply chain could act in this direction. On the other hand, the idea of providing bonuses for the retirement of obsolete vehicles finds much support (9.10). So even at this stage the circular economy model turns out to be decisive, since the environmental risk is not so much related to new models that are produced responding to more stringent regulations but to all existing vehicles that are dated in the year of registration. The bonus could be largely recovered from the recovery/recycling that would be achieved with such vehicles. In this framework, unlike the previous one, a social aspect plays an important role. Indeed, it is deemed necessary to increase the awareness of citizens (8.90), who in the new decision-making models are increasingly called upon to be involved in decision-making processes, to be made an integral part of change. Consistent with the previous data, technological developments to improve battery range (8.90) and the increase in electric columns (8.60) are relevant because by virtue of a satisfied consumer a market can expand. However, this can also occur when there are policy choices that sharply push toward the development of this market. Policy recommendations that highlight the need to reduce environmentally harmful subsidies (8.80) since they are clearly not compatible with sustainable models. Finally, they present a medium-high value but lower than the others, the systems related to price regulating and controlling (8.10) that are subject to strong fluctuations in Europe as a result of the conflict in Ukraine and yet could have less dependence in those energy-independent countries. An observation should be made on this parameter. The observed value is among the least relevant in the ranking but nevertheless has a very significant judgment considering the scale 1–10. If this aspect was not valued because of a market view in which the state tries not to intervene, the selected experts probably did not think that the Ukrainian conflict would lead to such a rise in prices. In addition, the issue of improving public mobility (7.90) is something that has already been explored in the literature. Finally, decarbonization of the transportation sector can also occur with the help of other renewable feedstocks, such as biomethane.

4 | CONCLUSIONS AND POLICY IMPLICATIONS

The proposition of indicators is a very useful tool because it allows us to aggregate different information. Data availability is a very complex element, and sometimes we can only reason about values that are not recent. An effort should be made in this direction in order to make data that are more recent available to identify the most appropriate strategies. The transport sector has a strong impact on the environment, and the role of European policies toward climate neutrality is important. This paper presents two distinct objectives.

The first provides not only managerial implications, but also methodological ones. MCDA is used to define a new IST that highlights sustainable performance achieved by Sweden, which tends to improve each year. In particular, its performance relates to the percentage of renewables in the transport sector, which is considered by experts to be the most relevant criteria. France and Austria also achieve important results. While Finland, although fourth, shows an important reduction in its performance. Generally, there is a deterioration of 20 countries in 2019 compared to 2015 data, while the most significant growth is associated with Sweden, Ireland, and Spain. A first limitation of this work is methodological. In fact, IST can be improved by using new indicators with available data. In addition, another limitation of this work is the expert panel that covers only academics.

The second objective of the work identifies several useful information about the development of electric vehicles in the European sector. It emerges from the experts' analysis that the critical success factors for consumers are first the reduction of the purchase price of these vehicles, which is still considered high compared to competing models, and a proper battery autonomy, such that time inefficiencies are not generated. In addition, it emerges that the priorities given by the same panel of experts change when considering the perspective of a consumer or those of a political decision-maker. This is the case with incentives, which would certainly be well regarded by consumers, but are considered an unsuitable policy choice. This work highlights that electric vehicles support a sustainable transition only if three conditions are met. The first concerns production of green energy to power electric vehicles, otherwise there is no difference with fossil fuels. The second regards an establishment of industries in the European territory in order not to generate dependencies and increase geopolitical risks, but also to create employment opportunities. The third concerns recycling of batteries where certain answers need to be given about their actual sustainability. Thus, circular issues (including recovery/recycling of obsolete vehicles) are closely related to sustainable mobility.

The results of this work showed that the decision-making process is composed of several factors that are all considered relevant. In such a decision-making context, choices may therefore change depending on consumers' perceptions. The future direction of the work is therefore to evaluate social aspects related to such choices, but also to surveys that can intercept the needs of businesses. Choosing pragmatic and not ideological sustainability could lead to better results as it would allow for gradual transformation. This concept does not identify that there is no need to have green or circular economy models developed, but simply that change cannot happen overnight. There is a need to create mindshare, to mature ideas, and to direct the needs of new generations toward virtuous patterns of behavior and not momentary trends. Sustainability is not a trend of the moment, but the condition so that tomorrow future generations do not start at a disadvantage. A number of policy implications may emerge in this way. The first is that when a country lacks raw materials, it can create a recycling industry, promoting the use and availability of materials it otherwise would not have. The second is a country cannot have only manufacturing sites but should be joined by innovation activities. To this end, the development of innovative and sustainable hubs involving academia and geared toward developing models of industrial symbiosis is basic. The third is aimed at a communication campaign to foster participatory models and to publicize the different changes and the needs to curb inappropriate use of resources. However, European choices should also consider what is happening in the rest of the globe, because otherwise companies will risk paying a heavy bill on competitiveness. Therefore, the fourth policy proposal comes into play, which includes instruments geared toward not creating distortions in the market caused by countries that are less attentive to sustainable practices. Therefore, it is educational to think that sustainability is achieved with everyone's contribution, it is necessary to achieve sustainable community models, but it is shortsighted to think that the goal will be achieved if all countries, and particularly those that are the biggest emitters, do not participate in the change.

For the medium term, the choice of hybrid vehicles may seem correct given the technological advancement involving the latest generation of engines and social sustainability should be taken into account by safeguarding the very significant number of people employed in the automotive sector. Training programs need to be created, industries need to be set up in the territory to replace the current ones, and through the elements of sustainability will be able to allow for market-winning models that respect eco-systems. The long-term goal of a policy strategy is to foster energy, material, and more general resource independence. It is necessary to develop industrial activities oriented toward sustainable practices and responsible consumption patterns. The development of sustainable mobility is an achievable goal if countries have renewable energy, local industrial chain, and battery recycling. The policy maker is called upon to make choices that protect local territories, as the sustainable model rewards self-sufficiency in the mobility sector as well.

AUTHOR CONTRIBUTIONS

All authors equally participated in the definition and writing of this paper.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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