A multicriteria classification approach for assessing policy interventions to stimulate transition of electric vehicle technology in the European Union

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Abstract

The European Union is setting foot to progressively decrease fossil fuel dependency as well as decarbonizing the entire energy and automotive system, aiming at carbon neutrality by 2050. As such, road transportation plays a great role in this process. Internal combustion engines (ICE) are to be slowly decommissioned as other powertrain systems rise for multiple reasons - from greenhouse gas emissions (GHG) emissions to urban air quality, the sector urges change. To change both the technological and consumer landscapes', governments must take action through policy-making intervention. Electric vehicles (EV´s) provide a significant opportunity to address this issue and as such, the current work aims at assessing national level policy intervention within the European Union (EU) regarding EV transition. The study relies on an Operational Research tool - the ELECTRE TRI-nC algorithm, a Multiple Criteria Decision Aiding (MCDA) method. This method allows to evaluate each of the 27 EU Members regarding a diverse range of performance criteria. Nations are then placed into Categories from best to worst regarding their Policies. After gathering data, and running the model, each country was assessed regarding their national governance in terms of promotion of electric vehicle technology.

Keywords: Electric Vehicles, Governance, European Union, ELECTRE TRI-nC, Multiple Criteria Decision Aiding (MCDA)

1. Introduction

Transportation is accountable, worldwide for 66% of fossil fuel consumption and 25% of worldwide Greenhouse gas (GHG) emissions (IEA, 2018).

Following the European Green Deal (EC, 2019), the EU became committed to carbon neutrality by 2050. Since then, public funding and policy making in the EU have been articulated in order to promote the development of other energy solutions across all sectors. Regarding road transportation, new powertrain systems are to be implemented, namely, Electric Vehicles (EVs).

EVs are a scalable solution for road mobility, alternatively to Internal Combustion Engine (ICE) vehicles. Therefore, the European Commission is seeking to promote the roll-out of alternatives to ICE vehicles.

The objective of this thesis is to evaluate the 27 EU Member-States regarding their current governance capacity regarding EV transition.

Despite having a common roadmap, each of the 27 EU Member-States implements his own policies independently, at national level. Therefore, countries were sorted into Categories, according to their performance on a selected range of performing criteria. This process was carried out with an MCDA model, the ELECTRE TRI-Nc.

2. Problem Definition

2.1 Energy in Transportation - Targets in the EU

The EU´s overall climate ambitions were firstly set in broad terms in section 2.1.1 of the 'Green Deal' (EC, 2019). The goals to be achieved were a decrease of 55% in GHG emissions by 2030, compared with 1990 levels, and net-zero emissions by 2050. Regarding the transportation sector, specifically, the EC elaborates the 'Sustainable and Smart Mobility Strategy' package (EC, 2020). This package provides an action plan in the form of 14 phased milestones towards sustainable, smart, and resilient mobility, 5 of which are directly related to EV deployment: (1) There will be at least 30 million zero-emission cars and 80 000 zero-emission lorries in operation by 2030; (2) Nearly all cars, vans will be zero-emission by 2050; (4) Scheduled collective travel under 500 km should be carbon-neutral within the EU (6) There will be at least 100 climate-neutral cities in Europe; (10) External costs of transport within the EU will be covered by users.

2.2 Electric Vehicles (EV)

To date, several variants of road EVs have had scalable developments and their definition is relevant because their technological aspects differ. They are as follows (EEA[1], 2016): (1) Battery electric vehicle (BEV), a vehicle solely powered by an electric motor(s) and a plug-in battery; (2) Fuel-cell electric vehicle (FCEV), a vehicle that runs on electricity using hydrogen from an on-board tank that is combined with atmospheric oxygen and emits only water and heat; (3) Hybrid Electric vehicle (HEV), a vehicle that relies on a conventional combustion engine as its main source of energy but uses an electric motor and battery as a complementary power source; (4) Plug-in hybrid vehicle (PHEV): a vehicle that is powered by a combination of an electric motor and a plug-in battery, on the one hand, and an internal combustion engine (ICE), on the other, allowing these to work either together or separately; (5) Range-extended electric vehicle (REEV), a vehicle powered by an electric motor and a plug-in battery. The auxiliary combustion engine is used only to supplement battery charging.

Regarding direct CO_2 emissions (g/km) and despite not existing universal agreement on the bordering thresholds, the definitions are (ACEA, 2020): (1) Zero Emission Vehicle (ZEV), a vehicle which has no direct emissions; (2) Low Emission Vehicle (LEV), a vehicle with low direct emissions (limit value varies); (3) Ultra-low emission vehicles (ULEV): a vehicle with emissions between 0 g/km and 50g/km.

As of 2020, 245,342 EV were operating within the EU (EAFO, 2020).

Milestone *1* from the 'Sustainable and Smart Mobility Strategy' aims at 30 million zero-emission light vehicles in the EU by 2030. This means that the amount of EV in European roads must be 120 times greater within the coming 10 years. The current barriers ahead of EV deployment are several (Table 1).

Barrier	Concern
Market	Lack of Charging Infrastructure Lack of Appropriate EV offer
Financial	Capital Cost of EV
Technological	Charging Time
Regulatory	Uncertain policy landscape

Table 1 - Barriers to EV deployment, Adapted from *The Climate Group (2021)*

[1] European Environmental Agency

3 Literature Review

3.1 EV Governance – Current Landscape

Vanhaverbeke and Van Solten (2018), attempt to identify the major types of incentive tools towards EV transition currently at place. An extensive review on e-mobility incentives at different policy levels (i.e., federal, regional, or local) was conducted. These incentives were grouped by area of influence and are listed in Figure 1.

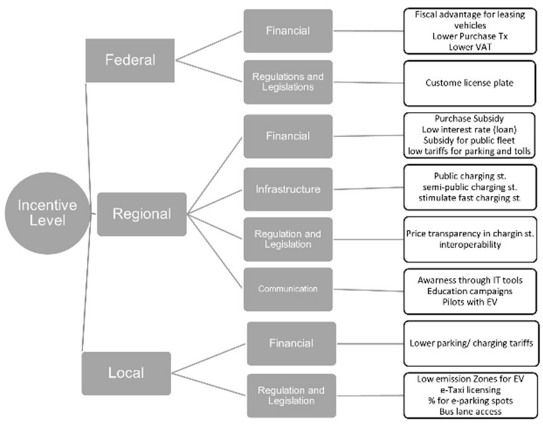

Figure 1 - Incentive levels for EV, Adapted from Vanhaverbeke and Van Solten, 2018

At federal level, incentives range from Financial to Regulatory (Vanhaverbeke & Van Solten, 2018). The financial incentives put in place were: (1) Fiscal advantage for leasing vehicles; (2) Lower Purchasing tax for EV; (3) Lower Value added tax (VAT) in the acquisition process. At regulatory level: (1) permit for a custom license plate. At Regional level, the degree of freedom is greater and the areas of influence increase. There are Financial incentives, Infrastructure, Regulatory or Communicational. The financial incentives put in place were: (1) Purchasing subsidies; (2) Low interest rate in credit; (3) subsidy for public fleet acquisitions; (4) low tariffs for parking and road tolls. Regarding infrastructure, the incentives were: (1) instalment of public charging stations; (2) semi-public charging station; (3) stimulation of fast charging options. At Regulatory level, the incentive tools in place were: (1) price transparency in charging fees; (2) interoperability. At communicational level: (1) awareness regarding EV technology through IT platforms; (2) Educational campaigns; and (3) Pilot programs with EV. At local level, authorities apply both financial and regulatory tools. At financial level: (1) Lower parking and charging tariffs are put in place. At Regulatory level, many are the tools in hand of local authorities: (1) Low emission zones implementation; (2) e-taxi licensing; (3) regulating the distribution of e-parking spots on public facilities; (4) implementing bus lane permits for EV.

3.2 Analysis on Policy Intervention for EV stimulation

Policy intervention regarding EV transition has been attracting the attention of several authors in recent years. Many authors highlight the critical role of financial incentive mechanisms regarding EV roll-out. Despite Operational Expenditure (Opex) and fuel costs being lower, the Capital Expenditure (Capex) cost of an EV is greater than its ICE counterpart (Lévay, Drossinos and Thiel (2017)). This very fact is relevant since consumers are more sensitive to Capex increase than they are to Opex decrease (Gass, Schmidt, 2012).

The previous viewpoint is corroborated by Bjerkan, Norbech and Nordtomme (2016). Their work, based on a Survey with 11 000 EVs owners from Norway, assesses which were the decisive criteria for EV acquisition. The most impactful criterion in the decision-making process was the Up-front price subsidy provided in Norway. Other criteria such as VAT exemption, low licensing fees, or even road tolling exemption were shown relevant

Other than Financial Incentives, other incentive tools are identified. According to Harrison & Thiel (2016), the absence of emission regulations stalls EV sales on the long term even if purchasing subsidies are provided. Thus, the need for discouraging measures towards ICE vehicles such as emission regulation if a long-term effect towards EV transition is desired

Not only the Nature of the Incentives is relevant but also their timeliness and duration can be decisive regarding EV transition. On this matter, Gómez, Román, Momber, Abbad and Miralles (2011) advocate that EV roll-out depends, for near-term, on home and office charging infrastructure, with multi-rate tariffs, whereas for long-term development, large scale public charging points are to be developed, which require an accurate load and frequency interaction with the grid.

Still regarding the timeliness of policy implementation, Turcksin, Bernardini, and Macharis (2011), elaborated two MCDA models to assess different policy packages– Analytic Hierarchy Process AHP and PROMETHEE. The the main result of this work is the evidence of conflict between two criteria – "Environmental Effectiveness" and "Feasibility".

Other studies suggest that EV penetration depends not only on the regulatory or financial framework but also on softer matters. Nilsson and Nykvist (2016) advocate that for near term penetration, investment towards public familiarisation is relevant to educate on EV technology. By breaking stigmas like "range anxiety", or by testing e-mobility in specific pilot cities, the governing states can tackle the existing adverse inertia towards EV transition.

The academic work regarding EV incentive tools is underdeveloped. Despite a clear identification of the main concerns regarding EV development, there is no common ground for measuring the key indicators regarding EV governance.

4. MCDA – MultiCriteria Decision Analysis

In the words of Belton and Stewart (2002), the MCDA process goes through the following steps: (1) *Problem Structuring*: On a first contact with the problem, this is the moment where the objective(s) are identified, the relevant criteria are selected, and the possible courses of action and decision are foreseen. There are multiple Problem Structuring methods which involve techniques like Cognitive Mapping, Soft Systems Methodology (SSM) or developing Value trees; (2) *Model Building:* A defining characteristic of MCDA is the development of a model. In this framework, the ELECTRE TRI-nC algorithm is employed herein. To successfully implement an MCDA model, the following steps must be paved: (1) Defining the set of relevant criteria; (2) Defining the performance scales of each criterion – either qualitative or quantitative; (3) Scoring the alternatives and weighting the given criteria according to the DM´s preference; (4) Performing sensitivity analysis and testing the model in order to obtain an overall classification of each alternative.

The ELECTRE-Tri-nC, (Dias, Figueira and Roy, 2011) is an outranking method designed to sort a set of actions $A=\{a_1, a_2, \ldots, a_i, \ldots\}$ to an ordered set of categories – $C=\{C_1,C_2,C_3,\ldots.C_q\}$ depending on their performance under criteria $F=\{g_1, g_{2\ldots}g_n\}$. The set of categories is such that C_1 is the worst and C_q is the best category. This method allocates each action *a* to certain C_q categories depending on how closely related *a* is to each of the default reference actions of each category: $B_h = \{b^r_h, r=1,\ldots,m_h\}$, for C_h.

Hence, saying "*a* outranks *a*'" under criterion g_j, means that "*a* is at least as good as *a*'", i.e., aS_ja'. This statement is based on the following concepts: (1) concordance, which refers to how strongly the criteria favour the statement aS_ja'; (2) nondiscordance, instead, refers to how strongly the none of the criteria oppose to aS_ja'; and (3) credibility index, σ, accounts for how the set of criteria are either aligned or not with the statement aS_ja'. In order to validate an outranking statement for the whole set F, λ, the lower limit for the credibility level must stand within the range [0.5; 1]. The ELECTRE Tri-nC assignment procedure is composed of two joint rules: (1) The descending rule states: for a given λ ∈ [0.5, 1], decrease h from (q+1) to q=t such that $\sigma(\{a\}, Bt) \geq \lambda$; The ascending rule, instead, states: given λ, a credibility level λ ∈ [0.5, 1], increase h from q = 0 to q = k such that $\sigma(Bk,\{a\}) \geq \lambda$.

The underlying preference modelling method featured in the ELECTRE Tri-nC is the pseudo-criterion model, which makes use of the concept of discriminating thresholds (Roy, Figueira, Almeida Dias, 2014). This model generalizes the overly simplified *true-criterion* model, clarifying the existence of two thresholds (direct and inverse)

Implementing the ELECTRE Tri-nC also requires setting the criteria weights. The chosen method to assess the criteria weights is the SRF Method (Roy and Figueira, 2002)., which is a revised version of Simos' weighting method (1990).

5 Model

5.1 Governance Framework for EV

By combining content from the literature review of the current work and the 'Sustainable and Smart Mobility Strategy', the elected criteria are set.

Regarding the scope of financial tools, several sources highlight the need for: (1) up-front subsidies (Lévay, Drossinos, & Thiel, 2017; Gass & Schmidt; 2012; Harrison & Thiel, 2016; Vanhaverbeke & Van Solten, 2018, and articles 8 and 75 of the 'Sustainable and Smart Mobility Strategy'); (2) Ownership and purchasing tax exemptions (Lévay, Drossinos, & Thiel, 2017); (3) financial support to corporate and urban fleets (Nilsson and Nykvist 2016, and Article 15; and R&D (Nilsson and Nykvist, 2016 asand Articles 12 and 38 of the 'Sustainable and Smart Mobility Strategy'.

Regarding circulation regulation, Article 38 states that cities are to modernize their policy toolbox including low and zero emission circulation zones.

For Charging infrastructure Harrison and Thiel (2016), Gómez, Román, Momber, Abbad, and Miralles (2011), Vanhaverbeke and Van Solten (2018), and articles 6, 22, and 50 address the need for substantial progress in this field.

5.2 Model Building

Model Building is the phase of MCDA process that identifies alternatives, values and stakeholders. The outcome of this stage is the value tree which captures the problems' core values. The alternatives, which are subject to evaluation are the 27 EU Member-States.

The Areas of Concern (AC) refer to the field or broad subject to which the FPV refers to. Each FPV details a specific sub-concern within the larger common AC. The Criteria are the operational implementation of the FPV. Each criterion reflects a FPV.

There are three major AC for EV transition, i.e., Financial, Regulatory and Infrastructure concerns: **AC_1, Financial,** reflects all National level governance vectors regarding public financial incentives towards; **AC_2, Regulatory,** regards National level Regulatory Frameworks for Vehicles circulation; **AC_3, Infrastructure,** which refers to National level public charging infrastructure for EVs.

Each AC is divided into one or more specific sub-concerns, the FPV. For AC_1, we can identify: **FPV_1, Direct Tax schemes and Grants for Consumers,** which accounts for all financial public incentives regarding acquisition, ownership, or circulation of EVs, either for individuals or for companies; **FPV_2, R&D Funding,** regards public funding for R&D.

AC_2, Regulatory, unfolds **FPV_3, Regulatory,** which reflects fully the AC_2, with pull and push mechanisms that promote EV Transition. This FPV accounts for measures like the limitation of road access to internal combustion engines in certain areas, or the implementation of road tolls in urban regions.

The last AC, AC_3, Infrastructure, unfolds in **FPV_4 Infrastructure**, accounting for National level public charging infrastructure for EVs.

These AC and FPV are operationalized by criteria. There can be one or more criterion for each FPV.

g1: Tax and Grants on Acquisition, aims at measuring the taxing and grants schemes for EVs. The evaluation under this criterion is made with a four-level qualitative scale. Levels 4 and 1 represent the best and worst performances for g_1, respectively.

Level	Measures
4	Lump sum subsidies up to 7.5k€; VAT exemption; other
3	Registration Tx exemption; partial VAT deductibility; other
2	Tax benefits based solely on CO_2 emission standards
1	None

Table 2 – Performance Levels g_1

g2: Tax on Ownership regards all ownership tax incentives within the EU framework for EVs. The performance scale of criterion g_2 is a four-level qualitative scale. Levels 4 and 1 represent the best and worst performances for g_2, respectively.

Level	Measures
4	ACT exemption; road taxation exemption
3	Low ACT and road tax for vehicles below 50g/km emissions
2	Marginally lower, or implemented solely at regional/city level
1	None

Table 3– Performance Levels g_2

g3: Private Use of Company Car regards incentives for the Private Use of a company car, or a fleet. Levels 4 and 1 represent the best and worst performances for g_3, respectively.

Level	Measures
4	Lump sum grants up to 7.5k€, ACT exemption, higher deductibility in corporate tax; fast amortization.
3	Registration tax exemption; marginally higher deductibility in corporate taxes; PIT benefits for employee
2	Diverse Marginal benefits
1	None

Table 4 – Performance Levels g_3

g4: Other Direct Financial Incentives refers to all financial incentives that do not fall into the previous criteria - g_1, g_2 and g_3. Levels 4 and 1 represent the best and worst performances for g_4, respectively.

Level	Measures
4	Mobility allowances for vehicle replacement (ICE-EV); road toll exemption for all EV;
3	Road toll exemption for some EV categories
2	Inspection fee exemptions
1	None

Table 5 – Performance Levels g_4

g10: R&D Funding expresses a different FPV than the previous criteria, FPV_2. To assess the EU countries under this criterion, a quantitative performance scale was implemented.

The index that allows a fair comparison of different EU countries is as follows (IEA, 2020):

$$R\&D\ per\ thousands\ of\ GDP = \frac{R\&D\ Budget}{GDP} x\ 10^3 \quad (1)$$

g5: Low Emission Zones falls into AC_2,. LEZ are areas where the most polluting vehicles are regulated. The performance scale of criterion g_5 is a four-level qualitative scale that accounts for: (1) LEZ per thousand sq. meters; and (2) degree of circulation restrictions.

g6: Urban Road Tolls falls into AC_2. Urban Road Tolls are a push measure instrument used to discourage combustion engine vehicles in urban areas**.** This criterion was measured through a four-level qualitative performance scale and operationalized through the same rational as g_5

g7: Pollution Emergency Zones

are restrictions within the EU based on air quality indicators. Under a 4-level qualitative performance scale, each EU country was assessed concerning both the number of PEZ per thousand sq. meters and their standards' strictness similarly to g_5.

g8: Other Regulatory Incentives

Regulatory governance is diverse within the EU. Therefore, alike criterion g_4, this criterion targets all measures that do not fall into any of the previous regulatory criteria – g_5, g_6 and g_7, measured with a four-level qualitative performance scale.

g9: Charging Infrastructure fully expresses AC_3, Infrastructure. The assessment is based on a quantitative performance scale, measuring the amount of charging stations per 100 thousand of urban inhabitants (Eurostat, 2017).

The overall performance table is therefore obtained for all criteria (Table 6).

g	1	2	3	4	5	6	7	8	9	10
AT	4	4	3	3	3	1	1	1	130.6	0.41
BE	4	4	4	4	3	2	3	2	29.17	0.35
BG	1	4	1	1	1	1	1	1	7.1	0
HZ	2	1	1	1	1	1	1	1	54.25	0
CY	2	2	1	1	1	1	1	1	4.21	0
CZ	3	1	1	4	2	1	1	1	23.63	0.21
Dk	3	3	3	3	3	1	1	1	197.41	0.54
EE	1	1	1	1	1	1	1	1	65.78	1.06
FI	2	3	1	1	2	1	1	1	57.8	1.17
Fr	3	3	4	3	3	1	4	2	86.64	0.61
DE	4	4	3	4	4	1	2	3	70.43	0.3
EL	2	4	2	1	1	1	1	1	0.78	0.02
HU	3	4	4	1	1	1	2	1	15.52	0.55
IE	4	3	1	1	1	1	1	1	74.83	0.19
IT	3	4	1	1	4	2	4	4	9.44	0.31
LV	3	4	4	1	1	2	1	1	7.25	0
LT	1	1	1	1	1	1	1	1	12.67	0
LU	4	3	4	1	1	1	1	1	56.72	0.22
MT	3	3	1	1	1	2	1	1	21.07	0
NL	3	4	3	3	4	1	1	1	259.91	0.31
PL	1	1	1	1	1	1	1	1	5.71	0.23
PT	4	3	3	1	1	1	1	1	32.22	0.15
RO	4	3	1	1	1	1	1	1	4.41	0
SK	1	4	4	1	1	1	1	1	69.01	0.24
SL	4	2	4	1	1	1	1	1	57.53	0
ES	2	2	3	1	2	1	2	2	16.97	0.13
SE	4	3	4	3	3	2	1	1	94.25	0.41

Table 6 – Global Performance Table

6. Model Implementation

6.1 Criteria Weighting

The criteria weights were obtained through the SRF method. The SRF method was implemented in a web application – Decspace[2]

2 http://decspace.sysresearch.org

Two[3] real DM´s from different professional contexts, but within the EV work environment, were contacted and asked to participate in this process. The first DM is a Graduate Aerospace engineer working in an electric mobility business unit within an energy producer, distributer, and service provider (Energias de Portugal, EDP). The second DM is a chemistry graduate and spokesperson for FEBIAC[4], the Belgian public body representing constructors and importers of road vehicles in Belgium and EU frameworks.

CRITERION	DM1	DM2
g1	12.58%	13.04%
g2	11.66%	15.80%
g3	4.29%	14.42%
g4	7.06%	8.9%
g5	15.33%	10.27%
g6	14.41%	3.37%
g7	13.5%	4.75%
g8	8.9%	1.99%
g9	10.74%	19.94%
g10	1.53%	7.52%

Table 7 Criteria weights

"DM1" clearly prioritizes push measures through Regulatory incentives, which represent about 52% of the overall weight distribution. On the other hand, "DM2", prioritizes Financial Incentives (60%),

After gathering the weights, it is then possible to start implementing ELECTRE TRI-nC.

6.2 Model Elements

For the current work, four categories of performance were defined to describe EU countries regarding their policy interventions on electric vehicle technology stimulus: C_4 Very Good; C_3 Good; C_2 Moderate and C_1 Weak. Since the ELECTRE TRI-nC allows the association of several reference actions to each category (its main feature), those are the following (Table 8):

	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10
$b^1 1$	1	1	1	1	1	1	1	1	0	0
$b^2 2$	2	1	1	1	2	1	1	1	7	0,08
$b^1 2$	2	2	2	1	2	1	2	2	25	0,15
$b^2 3$	3	2	2	2	3	2	3	2	55	0,2
$b^1 3$	3	3	3	3	3	2	3	3	80	0,3
$b^2 4$	4	3	3	3	4	2	4	3	120	0,45
$b^1 4$	4	4	4	4	4	2	4	4	259	1,17

Table 8 – Reference Actions

Reference action b^1_4 and b^2_4 define category C_4. Actions b^1_3 and b^2_3 define category C_3 whereas b^1_2 and b^2_2 define C_2. Finally, category C_1, Weak, is defined by reference action b^1_1.

Preference and Indifference thresholds, p_j and q_j, must be set for those criteria whose performance scales are quantitative (Table 9).

	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10
q									3.00	0.05
p									9.00	0.10

Table 9 – Thresholds q,p

For criterion g_9, the indifference threshold is 3. Meaning that: for performance differences equal or lower than 3 charging points per 100 thousand urban inhabitants, actions are considered indifferent; for performance differences ranging from 3 to 9, there is a weak preference between actions; for performance differences greater than 9, there is a strong preference between alternatives. Criterion g_{10}, follows the same rational.

6.3 Implementation

The first iterations of the model are performed for DM1 and DM2 considering λ=0.6.

For DM1, a large share of EU countries, 41%, fall between category C_1, Weak and C_2: Bulgaria, Croatia, Cyprus, Estonia, Greece, Ireland, Lithuania, Poland, Romania, Slovakia, and Slovenia. The remaining are assigned to a single category. 30% of EU Countries were assigned to Category C_2: Czech Republic,

3 Many potential DM's were contacted but only two of them were considered in the work

[4] Febiac, Fédération Belge et Luxembourgeoise de l'automobile et du cycle

Finland, Hungary, Latvia, Luxembourg, Malta, Portugal, Spain. 22% of the EU Countries were assigned to category C_3, Good: Austria, Belgium, Denmark, France, the Netherlands, and Sweden. Germany and Italy were assigned to C_4 For DM2, however: 26% of the EU countries, fall between category C_1 and C2: Bulgaria, Croatia, Cyprus, Estonia, Lithuania, Poland, and Romania. 22% of the EU countries are assigned to category C_2: Czech Republic, Finland, Greece, Latvia, Malta, and Spain. 30% of the countries are assigned to category C_3: France, Hungary, Ireland, Italy, Luxembourg, Portugal, Slovakia, and Slovenia. Falling between categories C_3 and C_4 stands Denmark only. Assigned to category C_4 stands Austria, Belgium, Germany, the Netherlands and Sweden.

Statistics :

<min,max>	#	%
<1,2>	11	40,7407%
<2,2>	8	29,6296%
<3,3>	6	22,2222%
<4,4>	2	7,4074%

ACTION	Minimum	Maximum
AT	C_3 good_1	C_3 good_1
BE	C_3 good_1	C_3 good_1
BG	C_1 weak	C_2 moderate
HZ	C_1 weak	C_2 moderate
CY	C_1 weak	C_2 moderate
CZ	C_2 moderate	C_2 moderate
Dk	C_3 good_1	C_3 good_1
EE	C_1 weak	C_2 moderate
FI	C_2 moderate	C_2 moderate
Fr	C_3 good_1	C_3 good_1
DE	C_4 very good	C_4 very good
EL	C_1 weak	C_2 moderate
HU	C_2 moderate	C_2 moderate
IE	C_1 weak	C_2 moderate
IT	C_4 very good	C_4 very good
LV	C_2 moderate	C_2 moderate
LT	C_1 weak	C_2 moderate
LU	C_2 moderate	C_2 moderate
MT	C_2 moderate	C_2 moderate
NL	C_3 good_1	C_3 good_1
PL	C_1 weak	C_2 moderate
PT	C_2 moderate	C_2 moderate
RO	C_1 weak	C_2 moderate
SK	C_1 weak	C_2 moderate
SL	C_1 weak	C_2 moderate
ES	C_2 moderate	C_2 moderate
SE	C_3 good_1	C_3 good_1

Statistics :

<min,max>	#	%
<1,2>	7	25,9259%
<2,2>	6	22,2222%
<3,3>	8	29,6296%
<3,4>	1	3,7037%
<4,4>	5	18,5185%

ACTION	Minimum	Maximum
AT	C_4 very good	C_4 very good
BE	C_4 very good	C_4 very good
BG	C_1 weak	C_2 moderate
HZ	C_1 weak	C_2 moderate
CY	C_1 weak	C_2 moderate
CZ	C_2 moderate	C_2 moderate
Dk	C_3 good_1	C_4 very good
EE	C_1 weak	C_2 moderate
FI	C_2 moderate	C_2 moderate
Fr	C_3 good_1	C_3 good_1
DE	C_4 very good	C_4 very good
EL	C_2 moderate	C_2 moderate
HU	C_3 good_1	C_3 good_1
IE	C_3 good_1	C_3 good_1
IT	C_3 good_1	C_3 good_1
LV	C_2 moderate	C_2 moderate
LT	C_1 weak	C_2 moderate
LU	C_3 good_1	C_3 good_1
MT	C_2 moderate	C_2 moderate
NL	C_4 very good	C_4 very good
PL	C_1 weak	C_2 moderate
PT	C_3 good_1	C_3 good_1
RO	C_1 weak	C_2 moderate
SK	C_3 good_1	C_3 good_1
SL	C_3 good_1	C_3 good_1
ES	C_2 moderate	C_2 moderate
SE	C_4 very good	C_4 very good

Table 10 - DM1 Assignments; DM2 Assignments

6.4 Sensitivity Analysis, λ and Z

1.) The model was subject to sensitivity analysis by varying the default value λ=0.6 to its limiting thresholds, λ=0.5 and λ=1. Member-States' assignments varied slightly from from category C_n to C_{n+1} or $C_{n-1.}$

2.) The sensitivity analysis provided from varying variable Z, provides slightly different weighting coefficients for all g_i. After running the ELECTRE TRI-nC with the new weighting coefficients for each criterion, i.e., for Z=5, instead of original values, Z=10, each country was assigned exactly to the same categories range as the first iterations, both for DM1 and DM2.

7 Results and Conclusions

The results are generally consistent. Each iteration assigns each of the 27 EU countries to one of four categories. C_1, Weak, C_2 Moderate, C_3 good, and C_4, very good. The Nations that are best and worst classified remain constant regardless of both the DM and variation of parameters λ and Z.

In all eight iterations, Germany is the only Nation clearly assigned to category C_4 or between C_3 and C_4.

The Netherlands, Italy, Sweden, Belgium, Austria, and Denmark are consistently assigned to categories C_3, Good and C_4, very good in all six iterations, whereas France was mostly assigned to category C_3, good.

On the other side of the spectrum, oftentimes assigned to C_1, Weak or between C_1 and C_2, Moderate, stand Nations from Eastern and South-Eastern Europe: Poland, Greece, Lithuania, Estonia, Romania, Cyprus, Bulgaria, and Croatia. The remaining countries fluctuate around C_2, moderate.

By matching these results with the literature review, three main factors stand out for the current results. Financial Incentives still play a big effect in EV deployment since the TCO of an EV is significantly higher than its ICE counterpart (Lévay, Drossinos and Thiel, 2017). Criteria g_1 to g_4 reflect this aspect. Those countries with greater concern on this topic were generally better classified than the rest.

Charging Infrastructure also plays a critical role, either making or breaking the deployment of EV (Gómez, Román, Momber, Abbad and Miralles, 2011). The worst classified Member-States, those oftentimes assigned to C_1, Weak, have very little charging points per 100k urban inhabitants (Table 7).

In a general way, the current work allows a clear view on how EU State Members are at different speed in terms of Governance regarding EV deployment. This fact is, in part, justified by the lack of common governance grounds at the EU level prior to 2020. Since the *Sustainable and Smart Mobility Strategy* (2020) was published, very clear milestones were set, and the coming years may show a more homogenous evolution within the EU.

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