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

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Thesis to obtain the Master of Science degree in

Energy Engineering and Management

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October 2021

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)

Resumo

A União Europeia tem em agenda a progressiva diminuição da dependência relativa a combustíveis fósseis assim como a intenção de descarbonizar o setor energético e automotivo, tendo em vista a neutralidade carbónica até ao ano 2050. Neste contexto, e com elevada relevância, faz-se incluir o transporte rodoviário. Os motores de combustão interna no setor deverão ser progressivamente preteridos em função de outros meios por diversos motivos, tais como a diminuição dos gases de efeito de estufa, ou a melhoria da qualidade do ar em contexto urbano. Esta alteração de paradigma, do ponto de vista tecnológico e de consumo, requer intervenção regulatória através de políticas públicas. Os veículos elétricos apresentam-se como uma alternativa de valor neste contexto, de modo que o presente trabalho pretende avaliar a qualidade das políticas públicas de incentivo aos veículos elétricos implementadas em contexto Europeu. O trabalho sustenta-se em ferramentas de investigação operacional, nomeadamente no método ELECTRE TRI-nC, que se faz incluir no universo dos métodos de análise multicritério (MCDA). O método permite avaliar cada um dos 27 Estados Membros da UE relativamente a um conjunto de critérios chave para esta análise. Deste modo, cada Estado Membro é alocado a categorias de avaliação mediante a qualidade das políticas públicas aplicadas neste contexto. Após a estruturação de dados e a execução do modelo, cada Estado foi avaliado relativamente às medidas de incentivo aos veículos elétricos.

Palavras-chave: Veículos Elétricos, Políticas Públicas, União Europeia, ELECTRE TRI-nC, Análise multicritério (MCDA)

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List of Abbreviations and Acronyms

AC – Area of Concern

ACEA – European Automobile Manufacturers´ Association

ACT – Annual Circulation Tax

AHP - Analytic Hierarchy Process

ARS - Access Regulation Schemes

BEV – Battery electric vehicle

Capex – Capital Expenditure

CSR – Corporate Social Responsibility

EC – European Comission

EDP – Energias de Portugal

EEA – European Environmental Agency

ESG – Environmental social Governance

EU – European Union

EV – Electric vehicle

FCEV – Fuel-cell electric vehicle

FEBIAC – Fédération Belge de l'Automobile et du cycle

FPV – Fundamental Point of view

GDP – Gross domestic Product

GHG – Greenhouse gas

HEV – Hybrid electric vehicle

ICCT – International Council of Clean Transportation

IEA – International Energy Agency

LEZ – Low emission zone

MCDA – Multiple-criteria decision analysis

Opex – Operational Expenditure

PEZ – Pollution Emergency Zone

PHEV – Plug-in hybrid electric vehicle

PIT – Personal Income tax

R&D – Research and Development

REEV – Extended-range electric vehicle

SRF – Simos Roy Figueira

SSM – Soft systems methodology

TCO – Total cost of ownership

ULEV – Ultra-low electric vehicle

VAT – Value-added tax

ZEV – Zero emission vehicle

1. Introduction

The present Chapter is divided into 4 sections. The first section provides the motivation for the current work. Section two identifies the goals and objectives of the work. Section three presents the different stages of the methodology, and the last section provides the structure of the current document.

1.1 Motivation

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

Considering that this sector relies strongly on fossil fuels, which is a limited energy source as well as a major contributing player for global warming, the European Union (EU) is deliberately shifting its agenda regarding energy policy to progressively decrease fossil fuel dependency.

Following the Paris Agreement (2015) and 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 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.

Implementing a large-scale change in a sector like transportation implies many efforts. The emerging alternative technology undergoes a maturing process. The process starts with Research and Development (R&D), followed by a slow implementation process where Infrastructure is deployed, and the final product must be financially competitive as well as attractive towards the consumer.

These stages can be fastened and positively affected by governments in the form of policy making. Through an accurate policy-making roadmap, for each of these development phases, nations can prepone carbon neutrality and promote clean mobility.

1.2 Objectives

This work´s objective is to evaluate all the 27 EU Member-States regarding their governance capabilities for EV transition, namely through policy instruments implemented by public authorities.

Despite having a common roadmap, each of the 27 EU Members 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 algorithm, the ELECTRE TRI-Nc.

1.3 Methodology

The development of the current work unfolds in six parts – see Figure 1.

Figure 1 - Sequential phasing of the dissertation

Firstly, the scope of the work is presented as well as its context and relevance. Energy in road transportation within the EU is addressed, providing insights on the EU´s current roadmaps regarding the decarbonization of the sector in the coming decades. This analysis is the prelude for EV incentives and governance frameworks. Subsequently, EVs are formally defined, and their respective trends and deployment barriers are addressed.

Thereafter, the Literature Review targets the scientific work of relevance, namely other MCDA approaches followed to evaluate EV incentives is presented. Besides, this review also provides the major governance tools currently used worldwide for EV development.

In Chapter four, the MCDA methodology is addressed, namely the tools used in the current work – the ELECTRE TRI-nC and the SRF method.

The fifth moment of this work consists of building the model. At this stage, the key concerns for the deployment of EVs are gathered, as well as the data on each State Member's governing efforts regarding EV incentives. This effort allows the definition of each criterium, and the corresponding performance scales.

The final steps of the work are the implementation of both the ELECTRE TRI-nC and SRF methods, and the analysis of the results.

1.4 Structure of the Document

The present work is divided into seven Chapters which are structured in the following way:

- Introduction outlines the current work, its scope, objectives, methods, and structure.
- Problem Definition presents the energy sector, namely in transportation and the EU roadmap of efforts to decarbonize the mobility industry. EVs are defined, their deployment barriers are presented as well as the scope of current incentive schemes.
- Literature Review presents the scientific work to date on policy intervention for EV stimulation.
- Methodological Framework introduces MCDA methodology, namely the ELECTRE TRI-nC and SRF methods.

- Model building presents the selected criteria and the final performance table. The Areas of concern (AC), the fundamental points of view and the criteria are set, and their respective performance scales are defined.
- Model Implementation provides the criteria weighting, the model elements, and the insertion of parameters in the ELECTRE TRI-Nc method. The model outputs are obtained, followed by a sensitivity analysis.
- Results provides a critical analysis of the results and the main conclusions.

2. Problem Definition

Chapter 2 starts by providing an overview of energy consumption in road transportation within the EU, presenting the current targets for transportation and mobility for the coming decades. Secondly, it introduces electric vehicles and their context in the EU. The different technological variants of EV are addressed, followed by an overview of their evolution over the past decade as well as the current deployment barriers, making evident the need for governance action towards the achievement of current targets.

2.1 Energy Consumption in the Transportation sector

Regarding transportation within the EU, road transportation is its largest consuming subsector (Eurostat, 2020). 93% of energy consumption in road transportation derives from oil and petroleum products (see Figure 2).

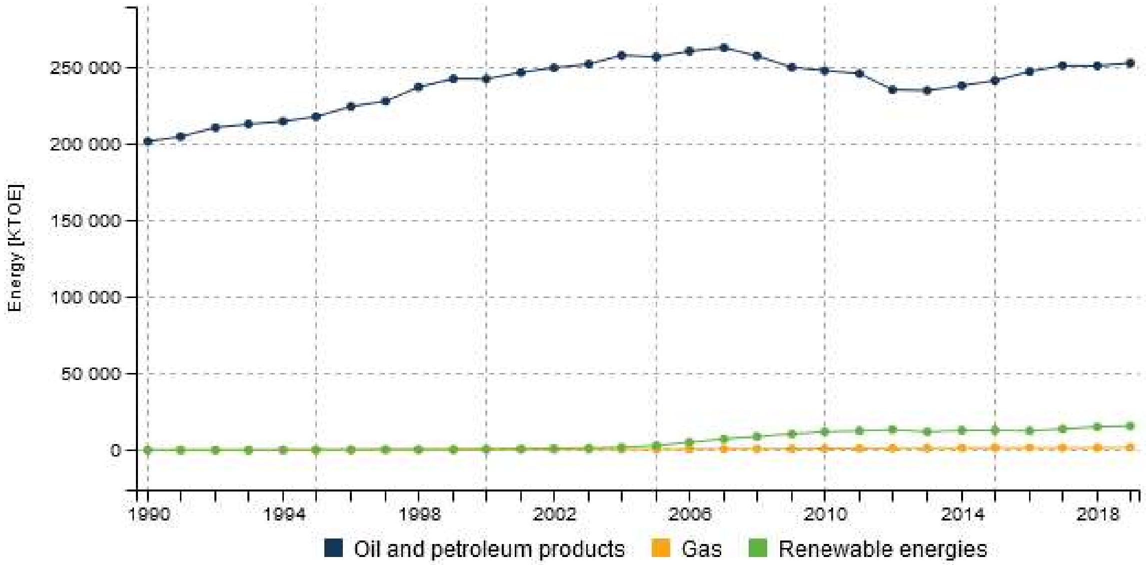


Figure 2 - Evolution of final energy consumption in Road Transportation, EU (Source: *Eurostat, 2020)*

Following the European Green Deal (EC, 2019), the European Commission reset its commitment to tackling climate and environmental changes. This commitment targets GHG emissions, aiming at zero net emissions by 2050. From the many acting vectors of this action plan, transportation, like all other sectors, must change in according to a common vision.

The EU´s climate ambition for 2030 and 2050 is set in broad terms in section 2.1.1 of the 'Green Deal', and the main driving milestones to be achieved are a decrease of 55% in GHG emissions by 2030, compared with 1990 levels, and net-zero emissions by 2050. Delivering these GHG reductions requires a review of all relevant climate-related policy instruments. These policy reforms will help ensure effective carbon pricing throughout the economy, encouraging changes in consumer and business behaviour, as well as facilitating an increase in sustainable public and private investment.

If most international partners share the same ambitions, there is no risk of carbon leakage. This phenomenon would take place in two scenarios. Either high intensity carbon production is transferred from the EU to other countries with lower ambition for emission reduction or in the case of foreign partners replacing EU products with more carbon-intensive products. Should these differences of commitment to carbon neutrality persist between the EU and foreign partners, imports within the EU will reflect more accurately their carbon content to accurately steer the EU towards a carbonless future.

2.2 Energy in Transportation - Targets in the EU

The current section outlines the EU's vision for accelerating the shift to sustainable and smart mobility as described in the 'Green Deal' (EC, 2019) and the 'Sustainable and Smart Mobility Strategy' package (EC, 2020).

Transportation accounts for a quarter of the EU's greenhouse gas emissions (EC, 2019). Therefore, achieving climate neutrality within the transportation system will require a 90% reduction in transport emission by 2050 (EC, 2019). Section 2.1.5 of the Green Deal (EC, 2019) details the driving vectors of transformation required to target such goals. They are the following:

- Increase of multimodal transportation is viewed as a priority. As of 2019, 75% of Inland freight is carried by road. Thus, the European Commission (EC), will propose a revision of the 'Combined Transport Directive' (EC, 2017) aiming for a shift onto rail and inland waterways. This shift and increase of capacity in such transportation modes should pair with smart traffic management systems whose ultimate target is to reduce congestion and pollution especially in urban areas.
- The price of transportation should reflect the impact it has both on environment and health. Fossil-fuel subsidies should end and, in the context of the revision of the 'Energy Taxation Directive', the EC will revise tax exemption for aviation and maritime fuels. Similarly, the EC will extend the European trading emissions to maritime and aviation sectors. These measures allow pricing fossil-fuels so that they embody the externalities associated with their use.
- The EU is to promote both production and deployment of sustainable alternative fuels. By 2025, 1 million public recharging and fuelling stations will be needed for the 15 million low-emission vehicles within the EU roads. The EC will support the deployment for such stations through funding mainly in less densely populated areas and long-distance routes. These measures are to be complemented with national level directives. The EC will, as well, review the 'Alternative Fuels Infrastructure Directive' to accelerate the deployment of low-emission-vehicles.
- Transport should become drastically less polluting, especially in cities. A combination of measures should address emissions, urban congestion and improved public transport. The EC will propose more stringent air pollution emissions standards for combustion-engine vehicles. The EC will also propose to revise, by June 2021, the legislation on CO_2 emission standards for cars and vans. In addition, the EC will consider extending European emissions trading to road transportation.

Following these measures, presented in the 'Green Deal' (2019), the EC further developed these concepts in the 'Sustainable and Smart Mobility Strategy' (2020), providing the concise phasing of each milestone towards sustainable, smart, and resilient mobility. 14 milestones were set. The soonest deadline is set to 2030 and the latest, to 2050 (see Table 1).

	Milestones	Impelemtation timeframe
Fossil Fuel Dependency	1.) There will be at least 30 million zero-emission cars and 80 000 zero-emission lorries in operation.	2030
	2.) Nearly all cars, vans, buses as well as new heavy-duty vehicles will be zero-emission.	2050
	3.) Zero-emission ocean-going vessels and large zero-emission aircraft will become market ready.	2030, 2035, repsectively
Sustainable transport modes	4.) Scheduled collective travel under 500 km should be carbon-neutral within the EU	2030
	5.) Traffic on high-speed rail will double by 2030 and triple by 2050.	2030, 2050, respectively
	6.) There will be at least 100 climate-neutral cities in Europe	2030
	7.) Rail freight traffic will increase by 50% by 2030 and double by 2050	2030, 2050, respectively
	8.) Transport by inland waterways and short sea shipping will increase by 25% by 2030 and by 50% by 2050	2030, 2050, respectively
Internalising the external costs of transport (through EU ETS[1])	9.) Rail and waterborne-based intermodal transport will be able to compete on equal footing with road-only transport in the EU	2030
	10.) external costs of transport within the EU will be covered by the transport users.	2050
Smart Mobility	11.) Seamless multimodal passenger transport will be facilitated by integrated electronic ticketing and freight transport will be paperless	2030
	12.) Automated mobility will be deployed on large scale	2030
Resilient mobility	13.) A multimodal Trans-European Transport Network equipped for sustainable and smart transport with high-speed connectivity will be operational by 2030 for the core network and by 2050 for the comprehensive network.	2030, 2050, respectively
	14.) The death toll[2] for all modes of transport in the EU will be close to zero.	2050

Table 1 – Milestone phasing - Adapted from *Sustainable and Smart Mobility Strategy (2020)*

[1] Emission Trading System (EU ETS).

[2] Number of directly related deaths.

2.3 Introduction to Electric Vehicles (EV)

Milestone 1 from Table 1 ("*There will be at least 30 million zero-emission cars and 80 000 zero-emission lorries in operation")* sets the pace for zero-emission vehicles deployment within the EU. This subsection aims at defining Electric vehicles and their technological variants.

EVs are vehicles whose powertrain system is electric. An EV may be powered through a collector system from off-vehicle sources (e.g., train) or through a self-contained power source such as batteries, solar panels, or a fuel-to-electricity converter (e.g., fuel cell) (Faiz et al., 1996).

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[3], 2016):

- Battery electric vehicle (BEV): a vehicle solely powered by an electric motor(s) and a plug-in battery.
- 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.
- 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.
- 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.
- 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.

Regardless of each EV variant we refer to, the indicator that provides their direct CO_2 emissions is transversal to all (g/km) (ACEA, 2020). Regarding this indicator, EV can be aggregated as well. Despite not existing universal agreement on the bordering thresholds, the definitions are as follows:

- Zero Emission Vehicle (ZEV): a vehicle which has no direct emissions (regardless of the Energy Mix of the electrical power source).
- Low Emission Vehicle (LEV): a vehicle with low direct emissions (limit value varies).
- Ultra-low emission vehicles (ULEV): a vehicle with emissions between 0 g/km and 50g/km.

The current benchmark of each definition varies from country to country, not existing a unified standard for each threshold. Regardless, the most complete approach is in Regulation EU 2019/631.

This disaggregation of EV variants becomes relevant in Chapter 5, regarding national level financial and regulatory support schemes towards these vehicles.

2.4 EV Trends and Barriers in the EU

Electric mobility has had great developments in the 2010's. This section portrays this evolution and its underlying factors, future trends and current barriers.

EVs, as seen priorly, fall into different categories and each of them has a different market share through space and time. Within the EU, the EVs deployment has been subject to rapid growth.

[3] European Environmental Agency

Gathered data from the European Alternative Fuels Observatory (EAFO, 2020) allowed the plotting of the chart of Figure 3.

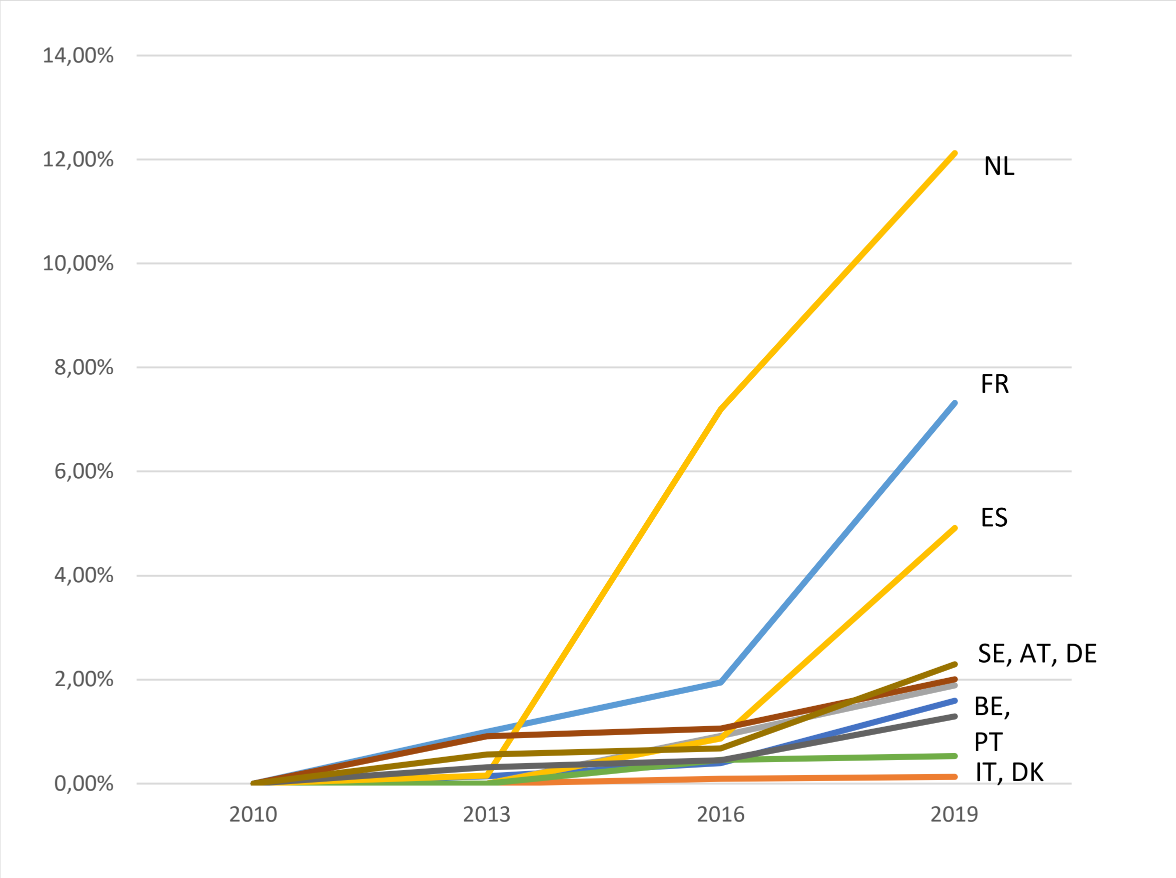


Figure 3 - Light Electric Vehicle fleet - EU

The evident heterogenous evolution derives from lack of common directives and roadmaps within the EU in the last decade. EVs evolution was dependent on national level governance, however, the overall trend shows a rapid increase over the past 5 years.

Regarding aggregated values from all the EU countries, by 2010, the overall fleet of EV was 4,593; whereas by 2015, it grew to 32,641. As of 2020, 245,342 EV were operating within the EU (EAFO, 2020).

Milestone *1* from the 'Sustainable and Smart Mobility Strategy' (see table 1) 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 and vary according to source. Table 2 provides the key barriers identified by *The Climate Group*, 2021, ordered by relevance.

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

The first barriers that EV deployment faces is the higher upfront cost of EV relative to a conventional vehicle (Lévay, Drossinos, Thiel, 2017), the availability of charging infrastructure, which inflicts range anxiety[4], and the limited consumer knowledge about the underlying technology (IEA, 2020). These barriers have been tackled with multiple tools such as purchasing subsidies, tax reductions that alleviate purchase cost, or the installation of public charging points (IEA, 2020). Nevertheless, there is common understanding that EVs' financial support schemes are a transitional, rather than permanent, tool. In the near term, a point will be reached when technology learning and economies of scale will have driven down the purchase cost of EVs and mass market adoption will be triggered (Nilsson and Nykvist, 2016).

At that point, policies will have shifted from financial only, to other types like regulatory measures, providing long term incentives towards electric mobility (IEA,2020). These include stringent CO_2 emission regulations and zero-emission circulation zones or bans on ICE vehicles.

EV deployment depends on many factors. Thus, governments have introduced a range of ambitious policies to support and structure the EV industry. These policies fall into one of four categories: (1) Legislation, (2) Targets, (3) Ambitions, and (4) Proposals.

Legislations are National level legally binding commitments such as regulations and standards. Targets, however, are government announcement targets that are part of legislation, budgetary commitments, National contributions to the Paris Climate agreement or national climate plans such as those submitted by State-Members to the EU. Ambitions are government goals or objectives as set out in policy document such as a deployment roadmap or strategy. Proposals, however, are government goals released in public documents or embedded into legislation designed to stimulate discussion as to their feasibility. This type of policy brings to the table the discussion of deadlines and phasing outs of gasoline or diesel vehicles, for instance. Proposals are presented upstream, i.e., from a Member State to the EU (IEA, 2021).

These 4 categories go from purely operational (1), to tactical (2) and (3), to strategical (4). The four level of categories are essential to ensure a long-term path towards EV deployment, or any other governance goal.

Despite being a growing market, with 40% year-on-year sales increase, EVs account for only 1% of the global car stock (IEA,2019). Thus, a breakthrough in electric mobility can only take place with the combination of multiple governance tools (Harrison and Thiel, 2016).

[4] Concern for power run out due to lack of charging stations.

2.5 Chapter Conclusions

As an integrated part of the decarbonization process inside the EU economy, EV deployment is set to be one of the key changing aspects in the transportation sector. Chapter 2 provides the elements to understand this reality. Starting with an overview of the energy sector in the EU, it is shown the central role of fossil fuels in the transportation sector, justifying the EU targets for the coming decades regarding transportation (Sustainable and Smart Mobility Strategy, 2020).

Thereafter, Chapter 2 provides a broad overview of EV technology and its market share within the EU. Several barriers to EV mass deployment are identified, highlighting the need for governance capabilities that provide a smoother and faster pace towards current targets for EV deployment.

Chapter 3 will provide an overview of the existing literature regarding these governing tools that can steer transportation towards a net-zero emission future.

3. Literature Review

The present Chapter consists of an overview of the most relevant topics of this work. On the next three sections, we provide: (1) a definition of green governance; (2) the current landscapes of implemented policies towards e-mobility; (3) the literature review of scientific work regarding policy intervention to stimulate EVs.

3.1. Green Governance Definition

Road vehicles account for about 80% of Transportation´s yearly GHG emissions (ICCT, 2020). Thus, sustainable transport solutions have been subject to high development pressure both by industry and policy makers – which leads us to the concept of Governance.

There is no consensual concept of Governance. Nevertheless, there are always several possible governing actors, with different roles (Nilsson, Hillman, & Magnusson, 2012). Firstly, the State when a state-centric society is in place. In this case, governance falls in the sphere of public actors and their institutional and political capacities to steer the legal framework, which is then followed by the private sector. If, instead, a society-centred approach is in place, a wider range of actors, i.e., private sector agents are the ones who, deliberately adapt their business in accordance with key values (Peters, 2000).

Private sector initiative occurs whenever the core business is self-regulated and adjusted to accommodate social and environmental values even if no legal requirements are implied. This mechanism is called Corporate Social Responsibility (CSR). CSR was the starting point for businesses taking ownership of their impact on society (Li, Zheng, Zhang, & Cui, 2020). Since climate change and global warming have become a large share of society´s concern, companies started developing metrics and indicators that account for climate and environmental impact of their action, commonly addressed as Environmental Social Governance (ESG). For instance, with ESG concerns included in investment decisions, financial institutions start opting for placing their equity in low-emission mobility projects rather than high-emission projects (Global Commission on the Economy and Climate, 2015).

The EU, instead, is a state-centric society (Marks, Hooghe, & Blank, 1996). The European values are strongly rooted in the collective interest, resulting in a single governing voice sustained by supranational public institutions.

Therefore, Green Governance arrangements within the EU unfold in a top-down approach, starting with International Level agreements. At the higher level, the EU defined the "Green Transport Package" in 2008, followed by the adoption of a roadmap which aims at reducing carbon emissions in transport by 60% by 2050 (CEC, 2011). More recently, higher standards were defined with the European Green Deal (2019), aiming at 90% reduction of GHG emissions in transportation and finally, as described in Chapter 2, the *Sustainable and Smart Mobility Strategy* (2020) provides the actual milestones which bind all EU State Members in commitment up until 2050.

However, public governance often collides with the private sector. The regulatory and fiscal framework face strong institutional and political barriers (Obergassel, Lah, & Rudolph, 2021). Traditional car makers have made substantial investment in internal combustion engines which creates economic and technological lock-in effects to a certain extent (Skeete,2017). This fact demonstrates how challenging governance can be. The mutual dependency between State and industry implies a two-sided commitment where the industry accepts to change and State compromises to reason the speed of the transition (Victor et al, 2019).

3.2. EV Governance – Current Landscape

Vanhaverbeke and Van Solten (2018), attempted 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 4.

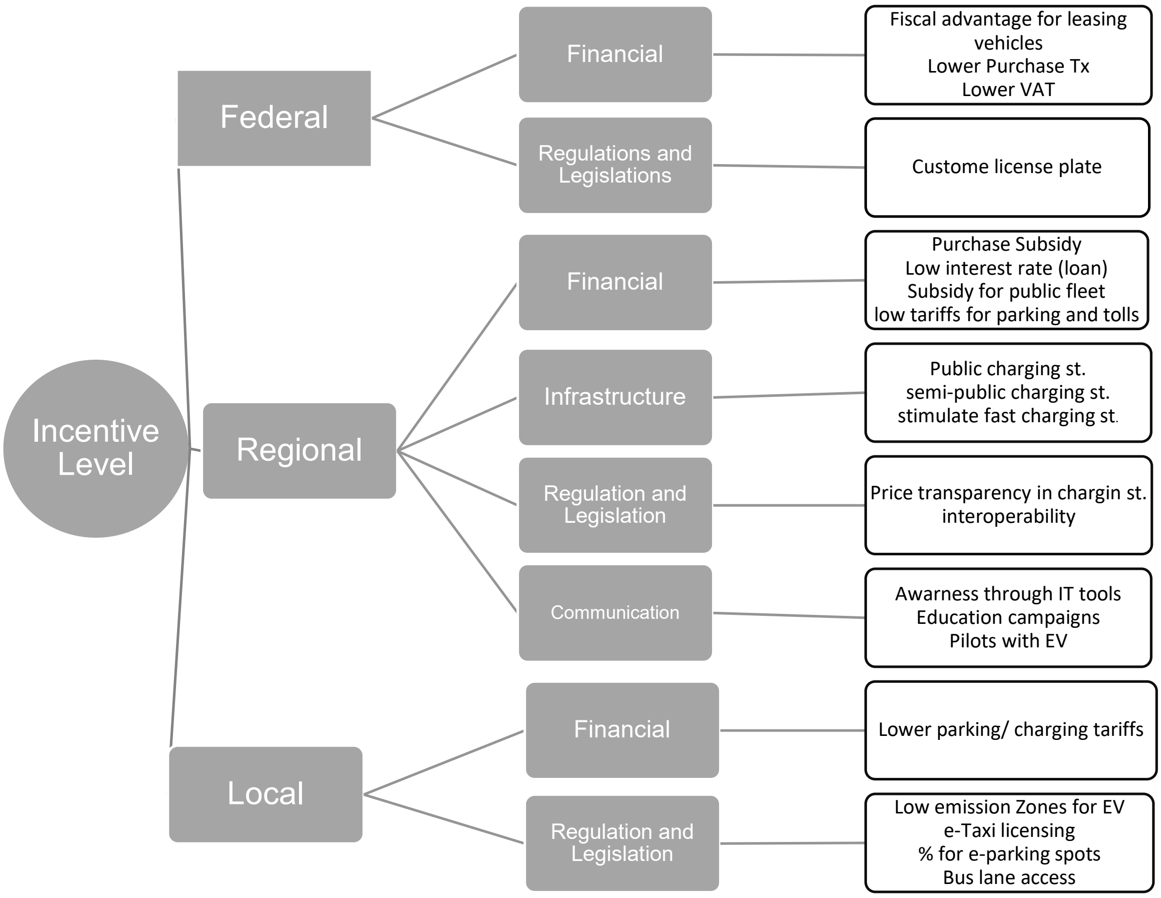


Figure 4 - Incentive levels for EV, Adapted from *Vanhaverbeke and Van Solten, 2018*

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.

Some of the incentives were evaluated by an expert panel[5] in terms of relevance, and cost-effectiveness. For the incentives in Figure 4, respondents of the survey have provided their insights on some[6] of them. The roll-out of charging infrastructure was the incentive selected the most. Different aspects were considered relevant. For fast-charging stations, parameters such as services (coffee, food, toilets, facilities), distance to the next fast-charger, and 24/7 accessibility were mentioned as relevant (15 experts). Regarding home charging infrastructure, experts point to a demand-based roll-out, i.e., stations are placed near residents. Infrastructure incentives, as well as parking incentives were evaluated as very cost-effective, i.e., a high number of new EVs in relation to the unit cost of the incentive implementation.

Pilots and demonstration projects were highly regarded as well (14 experts). Varying from size (from city level to regional level). However, these approaches were considered the least cost-effective measures in terms of impact.

Vanhaverbeke & Van Solten (2018) provide a broad overview of the current outlook of incentive tools, delivering a wide range of tools regarding EV deployment that will show very relevant in Chapter 5, through the modelling phase.

3.3. Analysis on Policy Intervention for EV stimulation

The policy intervention regarding EV transition has been attracting the attention of several authors in recent years. On a consumer-oriented approach, Lévay, Drossinos and Thiel (2017) studied the impact of direct fiscal and financial incentives on EV market penetration. Their study is based on the Total Cost of Ownership (TCO) of EV and their Internal Combustion Engine (ICE) counterpart in a cross-segment,

[5] Austria (2), Germany, Ireland, Italy, Japan (2), Portugal, China, Luxembourg, Netherlands (7), Norway, Scotland (2), Sweden, UK (2), and USA (4)

[6] Financial incentives were not considered on the survey because these incentives were already put in place in the Belgic context.

cross-country approach for a four-year period evaluation. Despite Operational Expenditure (Opex) and fuel costs being lower, the Capital Expenditure (Capex) cost of an EV is greater than its ICE counterpart. This very fact is relevant because consumers are more sensitive to Capex increase than they are to Opex decrease (Gass, Schmidt, 2012). The outcome shows that, for all segments, the EVs TCO is higher than its ICE pair if no direct incentive is provided, namely due to their Capex difference. This reflects how dependent on subsidies and incentives EV technology still is.

Despite financial Incentives playing a big role in market breakthrough of EVs, a larger penetration requires price competitiveness.

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. It is worth mentioning the fact that virtually all the inquired showed responsiveness to Pull measures only, i.e., encouraging measures towards EV, rather than responsiveness towards Push measures for ICE vehicles.

Other than Financial Incentives, there are a multitude of other incentive types, which are often conflicting. Harrison & Thiel (2016), evaluated the impact of several criteria on EV sales through a dynamic simulation of the market behaviour. The criteria considered were charging infrastructure, emission regulation, purchase subsidies, and infrastructure subsidies. The outcome shows that the absence of emission regulations stalls EV sales on the long term even if purchasing subsidies are provided. The strongest, most relevant conclusion of this work is the need for discouraging measures towards ICE vehicles such as emission regulation if a long-term effect towards EV transition is desired. If subsidies are kept for EVs and polluting emissions are not increasingly regulated, automotive manufacturers may keep high EV price, low R&D funding on EV technology while lowering their ICE vehicles price. This business model allows the automotive industry to maintain overall net earnings – perversely supported by the public subsidies on EVs.

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) aimed at defining a regulatory timeline of incentives for EV charging infrastructure. Taking into consideration the increase in electric grid demand, their work suggests that for near term penetration, home and office charging stations are the most probable scenarios for EV development – including multiple rate tariffs to accommodate daily power market fluctuations. For long term development of EV charging infrastructure, large scale public-street charging points are to be considered, requiring the implementation of Load and Frequency management systems for the grid.

Still regarding the timeliness of policy implementation, Turcksin, Bernardini, and Macharis (2011), elaborated a multi-instrumentality policy package for the Belgium Government. The aim was to rank a set of multi-instrumentality package options that could stimulate a clean fleet transition. The work was developed with a combination of two MCDA tools – Analytic Hierarchy Process AHP and PROMETHEE, an outranking method. Three policy packages (alternatives) were evaluated, i.e., a baseline scenario, a realistic scenario, and a progressive scenario.

The main result of this work is the evidence of conflict between two criteria – "Environmental Effectiveness" and "Feasibility". For the short-term implementation, the baseline alternative outranks the other two options mostly because a good performance of "Feasibility" adds up to a strong weight for this criterion. On the other hand, for the medium to long-term implementation, "Feasibility" is no longer the most relevant criterion for the decision-makers (DMs). Instead, "Environmental Effectiveness" has the strongest weight, and the progressive scenario becomes the preferred alternative.

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.

Table 3 contains a summary of these works.

Reference	Goal	Method	Criteria
Lévay, Drossinos, and Thiel (2017)	Assess the role of fiscal incentives in the TCO of EV in EU.	Comparison between TCO of EV vs ICE pairs in a cross-segment, cross-country approach.	1.) tax exemptions (VAT, Circulation tax or registration tax); 2.) subsidies;
Harrison and Thiel (2016)	To Assess the impact and mutual interaction of subsidies (infrastructure and vehicle purchase) between different EV powertrain types	Dynamic simulation of the market behaviour. Different scenarios were run in order to assess market response in medium and long-term scenarios. (2020-2050)	1.) Charging infrastructure to PiEV (PHEV+BEV); 2.) Hydrogen fuelling Infrastructure; 3.) Emission Regulation; 4.) Purchase subsidies; 5.) infrastructure subsidies
Turcksin, Bernardini and Macharis, (2011)	Defining a multi-instrument policy for Belgium's EV mobility stimulation	MCDA method, outranking method: AHP and PROMETHEE:	1.) Environmental effectiveness (spans into sub-criteria) 2.) Impact on mobility 3.) Feasibility
Gómez, Román, Momber, Abbad and Miralles (2011)	Defining a regulatory framework and business model for EV charging infrastructure.	identification of new market agents, infrastructure, and charging modes (V2G and G2V)	
Gass and Schmidt (2012)	Review of support measures for EV stimulation in Austria and EU.	TCO analysis between best-selling models (EV-ICE). Different policy incentives were considered in order to assess TCO fluctuations.	1.) Up-front subsidy 2.) CO2 tax 3.) Fuel tax for ICE 4.) Learning-effects of EV technology (battery; autonomy.)
Bjerkan, Norbech and Nordtomme (2016)	Assess the role of incentives for BEV. Characterization of different target buyers and different groups of incentives	Study based on a survey conducted with Norwegian EV Association	1) Reduction fixed cost (RFC) 2) Reduction of Use costs (RUC) 3) Priority to Infrastructure (PI).
Nilsson and Nykvist (2016)	A governance approach towards BEV breakthrough - scenarios overview	multi-level perspective (MLP) tool	

Table 3- Literature on EV incentives – summary table

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. Moreover, each country is at different speeds of development and has different governance agents regarding EV development and, therefore, there is no single route towards EV roll-out.

3.4 Chapter Conclusions

This Chapter is divided into three sections. The first section defined the concept of green governance, its strengths, limitations, and interactions with industry.

The second section provides all current governance tools implemented in a real-life context, organized through different policy levels and areas of influence. Section 3 focuses on the analysis of recent studies addressing policy intervention as a tool to stimulate electric vehicles. Key concerns for EV deployment are identified as well as their mutual interaction in time and space. The summary of some publications is given in table 3.

4. Methodological Framework

Chapter four introduces the MCDA methodology followed by an introduction to the specific Multi-Criteria Decision Analysis (MCDA) tool used in this work – the ELECTRE TRI-Nc as well as the criteria weighting method – the SRF Method.

4.1 MCDA – MultiCriteria Decision Analysis

MCDA, Multiple-criteria decision aiding is a subdiscipline of operational research that explicitly considers multiple criteria in decision-making environments. The decision-making process can be very hard both to formulate and act whenever the matter of subject is complex, involves uncertainty and regards multiple stakeholders.

Public Governance itself is an ongoing complex decision-making process and therefore, requires decision analysis tools, such as MCDA.

MCDA has been broadly implemented in all fields of governance – public and private, helping DMs and even experts take decisions because even them are subject to both cognitive and motivational biases (Tversky and Kahneman, 1991). Through MCDA, the DMs are guided through the decision process by an analyst – the facilitator. This agent conduces the process despite never interfering or taking part in the decision process.

In the words of Belton and Stewart (2002), the MCDA process goes through the following steps:

– *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.

– *Model Building:*

A defining characteristic of MCDA is the development of a model. In this framework, the ELECTRE TRI-nC algorithm is employed herein. The model helps translating the DM´s preferences, allowing to classify all given alternatives according to their performance on the selected criteria. 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 criterium – 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 to obtain an overall classification of each alternative.

4.1.1 Structuring and definition of the Criteria

The structuring process of the criteria in MCDA unfolds necessarily with the help of three key concepts: 1) Area of Concern (AC); 2) Fundamental Points of View (FPV); 3) Criteria.

The AC refers 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 (Bana e Costa et al., 1995).

The definition of a criterion is a process that follows a set of informal rules that guarantee the proper formulation of the problem (Belton and Stewart, 2002):

– *Understandability:*

The DMs must have a shared understanding of concepts to be used in an analysis.

– *Measurability:*

This implies some degree of measurement of the performance of alternatives against specific criteria. Thus, it must be possible to specify this in a consistent manner.

– *Non-Redundancy:*

When eliciting ideas during the structuring phase of the problem, the same concept may arise under different headings. If these are selected as criteria in the MCDA process, this concept could be wrongly overly regarded.

– *Judgmental Independence:*

Judgmental dependency should be avoided at all cost. If necessary, redefine the criteria. Judgmental dependency occurs whenever trade-offs between criteria are expressed by the DM. This phenomenon increases the formulation complexity.

– *Balancing Completeness versus conciseness:*

The degree to which the value tree is developed it should reflect a balance between exhaustiveness and conciseness (Keeney and Raiffa, 1976). This concept also applies regarding simplicity versus complexity of the value tree.

– *Operationality:*

Associated with the previous rule, operationality refers to the usability of the model, how easy it is to approach the DM for both questioning and contribution.

4.1.2 ELECTRE TRI-nC

The Electre-Tri-nC (Dias, Figueira and Roy, 2011) is a sorting method in which the categories of performance are set by reference actions, defined *a priori by* the DM with the analyst´s help. These categories are ordered from the worst to best category. The Electre-Tri-nC in particular, allows several combinations – a subset - of reference actions to define a single category. This feature differs from other Electre family algorithms like Electre Tri-C, by allowing the DM to characterize each category in a more flexible framework, i.e., with more than one reference action. By allowing several reference actions we avoid boundary issues between categories or even circumstances when two reference actions are incomparable and, therefore, impossible to define the boundary of each category. The implementation of the Electre Tri-nC algorithm was carried out in MCDA-ULaval[7].

Let $A=\{a_1, a_2, \ldots, a_i, \ldots\}$ be a set of potential actions, either known *a priori* or defined through the decision aiding process. These actions will be assigned to an ordered set of performance Categories – $C=\{C_1,C_2,C_3,\ldots.C_q\}$, (q≥2, for minimal sorting). Actions "*A*" are to be sorted in Categories "*C*" depending on their performance under criteria Universe "*F*". Let $F=\{g_1, g_{2\ldots}g_n\}$ be the set of criteria with n≥3. Let us

[7] MCDA-ULaval is a JAVA implementation of the Electre Tri-nC method, allowing a high-level interface for the user.

notice that for n<3 the concept of concordance is not pertinent. All criteria g_j are to be maximized and considered as a pseudo-criterion, meaning that preference increase follows criteria performance increase. For every criterion g_j, two thresholds are associated. p_j is a preference threshold and q_j an indifference threshold, such that $p_j \geq q_j \geq 0$. These thresholds are introduced in order to take into account the imperfect character of the data from the computation of performances.

Hence, saying "*a* outranks *a*'" under criterion g_j, means that "*a* is at least as good as *a*'", i.e., aS_ja', meaning that $g_j(a) \geq g_j(a')$.

However, when considering the threshold preferences, three case scenarios can arise:

– if $| g_j(a) - g_j(a') | \leq q_j$, the preference difference is small enough to state that "*a* is indifferent to *a*'" according to g_j, i.e., aI_ja.
– If instead $q_j < |g_j(a) - g_j(a')| \leq p_j$, the preference statement is considered weak, and this situation is denoted as aQ_ja'.
– In case of a strong preference of *a* over *a*' under criterion g_j, $| g_j(a) - g_j(a') | > p_j$, then aP_ja'.

The above scenarios, and underlying reasoning are further developed in section 4.1.3

The set of reference actions $B_h = \{b^r_h, r=1, \ldots, m_h\}$ characterize category C_h, for m≥1 and h=1,…, q.

Let $B \cup \{B_0, B_{q+1}\}$ denote the set of (*q*+2) subsets of reference actions. $B_0 = \{b^1_0\}$ and $B1q+1 = \{b^1_{q+1}\}$ contain two reference actions such that $gj(b^1_0)$ is the worst possible performance for *gj* and $gj(b^1_{q+1})$ is the best possible option according to g_j. As a direct consequence, for any action *a*, $gj(b^1_0) < gj(a) < g_j(b^1_{q+1})$.

The statement "*a* outranks *a*'" is based on the following concepts:

– Concordance refers to the degree to which the criteria favour the same statement (or not) i.e., whether "*a* outranks *a*'" is validated by a majority of criteria. Concordance is computed through *c(a,a')*. Each criterion has an associated weight or relevance, w_j, such that $\sum_{j=1}^{n} wj = 1$.The concordance index is defined as follows:

$$c(a,a') = \sum_{j\in C(aPa')} wj + \sum_{j\in C(aQa')} wj + \sum_{j\in(aIa')} wj + \sum_{j\in C(a'Qa)} wj\varphi j \quad (1)$$

$$\varphi = \frac{pj - [gj(a') - gj(a)]}{pj - qj} \quad (2)$$

Variable $\varphi \in [0,1]$, being close to 1 whenever the DM has a strong preference of *a* over *a*' and close to 0 if he/she is indifferent to *a*'.

– Nondiscordance occurs when none of the criteria opposes, i.e., none of the criteria vetoes the statement "*a* outranks *a*'". Each criterion´s veto threshold is such that $v_j \geq p_j$. Veto and preference are the conflicting variables that define whether discordance exists within the statement "*a* outranks *a*'" for criterion *"j"*.

This phenomenon is assessed through the discordance index d(*a,a'*):

$$d(a,a') = \begin{cases} 1 & for\ g(a) - g(a') < -v \\ \dfrac{g(a) - g(a') + p}{p - v} & for - v \le \mathrm{g(a) - g(a')} < -\mathrm{p} \\ 0 & for\ g(a) - g(a') \ge -p \end{cases} \quad (3)$$

– The credibility Index, σ, accounts for how the set of criteria *F* are either aligned or not with the statement "a outranks a'". Credibility combines both concepts – concordance and discordance within its formulation. For each criterion j it corresponds to:

$$\sigma(a,a') = c(a,a') \prod\nolimits_{j=1}^{n} Tj(a,a') \quad (4)$$

$$Tj(a,a') = \begin{cases} \dfrac{1 - dj(a,a')}{1 - c(a,a')} & for\ dj(a,a') > c(a,a') \\ 1 & \end{cases} \quad (5)$$

Thus, the credibility index can only be equal to the concordance index if for all criteria concordance is greater than discordance, otherwise, the credibility index is smaller than the concordance index.

To validate an outranking statement for the whole set F, consider λ, the lower limit for the credibility level to validate the statement such that λ ∈ [0.5; 1]. For lower values of λ, the credibility index required to validate an outranking statement is lower. On the other hand, for higher values of λ, the credibility index required to validate a statement is higher.

For the reference actions, worst and best that define each category, the validation of an outrank relation goes as follows:

For $\sigma(\{a\}, B_h) = \max_{r=1,\dots mh}\{\sigma(a, b^r_h)\}$ and $(B_h, \{a\}) = \max_{s=1,\dots mh}\{\sigma\{b^s_h, a)\}$:

– λ, Outranking: $\{a\}S^{\lambda}B_h \Leftrightarrow \sigma(\{a\}, B_h) \ge \lambda$

– λ, Preference: $\{a\}P^{\lambda}B_h \Leftrightarrow \sigma(\{a\}, B_h) \ge \lambda$ and $\sigma(B_h, \{a\}) < \lambda$

– λ, Indifference: $\{a\}I^{\lambda}B_h \Leftrightarrow \sigma(\{a\}, B_h) \ge \lambda$ and $\sigma(B_h, \{a\}) < \lambda$

– λ, Incomparability: $\{a\}R^{\lambda}B_h \Leftrightarrow \sigma(\{a\}, B_h) < \lambda$ and $\sigma(B_h, \{a\}) < \lambda$

Based on the same two joint rules as the ELECTRE Tri-C method (Almeida-Dias et al., 2010), the Electre-Tri-nC assignment procedure is composed of the ascending rule and descending rule. In order to assign a Category or Categories to action *a*, a selection function ρ is required. For *a*, a given action and B_h a subset of reference actions this function is given as:

$$\rho(\{a\}, Bh) = \min(\sigma(\{a\}, B_h), \text{ and } \sigma(B_h, \{a\})) \quad (6)$$

Let C_h be the pre-selected category for action *a* and C_{h-1}, C_{h+1} be the adjacent categories.

The descending rule goes as follows:

– Given λ, a credibility level λ ∈ [0.5, 1], and a decrease of h from (q+1) to q=t such that $\sigma(\{a\}, B_t) \ge \lambda$. C_t is then considered the pre-selected category for action *a* according to the descending rule. For any t value, select C_t as the pre-selected category. If not possible (i.e., $t = 0$ or other), select the C_{t+1} category, i.e.:

- For $t=q$, select C_q as a possible category to assign action *a;*
- For $0<t<q$, if $\rho(\{a\}, Bt) > \rho(\{a\}, Bt + 1)$, then select C_t as a possible category to assign *a*; otherwise select C_{t+1};
- For $t=0$, select C_1 as a possible category to assign *a;*

In the descending rule, a category is pre-selected taking into account that B_t is the highest subset of reference actions such that the statement "a outranks B_t" is validated with the chosen credibility level. The ascending rule, instead goes as follows:

- Given λ, a credibility level λ ∈ [0.5, 1], and an increase of h from $q = 0$ to $q = k$ such that $\sigma(B_k,\{a\}) \geq \lambda$. C_k is then considered the pre-selected category for action *a* according to the ascending rule.

For any k value, select C_k as the pre-selected category. If not possible (i.e., $t = 0$ or other), then select C_{k-1}, i.e.:

- For $k=1$, select C_1 as a possible category to assign action *a;*
- For $1<k<(q+1)$, if $\rho(\{a\}, Bk) > \rho(\{a\}, Bk - 1)$, then select C_k as a possible category to assign *a*; otherwise select $C_{k-1};$
- For $k=(q+1)$, select C_q as possible category to assign *a*

In the ascending rule, a category is pre-selected taking into account that B_k is the lowest subset of reference actions such that the statement "B_k outranks a" is validated with the chosen credibility level.

If each one of the subsets of reference action has only one characteristic reference action, then the assigning rule of the ELECTRE Tri-Nc is equal to the ELECTRE tri-C.

One of the main features of the ELECTRE Tri-nC is the capacity to consider multiple reference actions that can be considered as appropriate to be assigned to each category. Another improvement from the original ELECTRE Tri-C, is the DM can keep two characteristic reference action that define two merged categories in order to define a new category. Such feature could never take place in the original Tri-C algorithm, where the DM could only keep one of the two characteristics, or design a new one.

4.1.3 Preference Modelling and Discriminating thresholds

Another relevant feature of the ELECTRE TRI-nC method relies on its preference modelling method, which makes use of the concept of discriminating thresholds. This method, the pseudo-criterion model, in contrast with a true-criterion model, provides to decision aiding modelling the capability of dealing with imperfect knowledge (Roy, Figueira, Almeida Dias, 2014).

A *true-criterion* model is a preference model whose premises are:

- (i) the indifference between actions *a* and *a'* is established if and only if *g(a)=g(a');*
- (ii) the preference of *a* over *a'* is established without ambiguity if and only if *g(a)>g(a')* when the criterion is to be maximized and *g(a)<g(a')* when the criterion is to be minimized, respectively.

These premises are oftentimes not realistic given the subjectivity and ambiguity of data (Roy, Figueira, Almeida Dias, 2014).

The pseudo-criterion model, however, generalizes the true-criterion model, clarifying the existence of two thresholds (direct and inverse).

A pseudo-criterion *g*, with direct thresholds is a real-valued function, *g*, defined for all $a \in A$, associated with two real-valued threshold functions *p(g(a))* and *q(g(a)),* verifying the following conditions:

- (i) $p(g(a)) \geq q(g(a)) \geq 0$
- (ii) $g(a) + p(g(a))$ *and* $g(a) + q(g(a))$ are monotone non-decreasing functions of *g(a*), if g is a criterion to be maximized
- (iii) $g(a) - p(g(a))$ *and* $g(a) - q(g(a))$ are monotone and non-decreasing functions of *g(a),* if *g* is a criterion to be minimized.

Let a and a' denote two actions to be compared such that *g(a),* at least as good as *g(a').* The following holds for such pairs.

- if $| g(a) - g(a') | \leq q(g(a)$, the preference difference is small enough to state that "*a* is indifferent to *a*'" according to g, i.e., *aIa'.*
- If instead $q(g(a')) < |g(a) - g(a')| \leq p(g(a'))$, the preference statement is considered weak, and this situation is denoted as *aQa'*.
- In case of a strong preference of *a* over *a*' under criterion g, $| g(a) - g(a') | > p(g(a'))$, then *aPa'*.

A pseudo-criterion *g*, with inverse thresholds, instead, is a real-valued function, *g*, defined for all $a \in A$, associated with two real-valued threshold functions *p'(g(a))* and *q'(g(a)),* verifying the following conditions:

- (i) $p'(g(a)) \geq q'(g(a)) \geq 0$
- (ii) $g(a) - p'(g(a))$ *and* $g(a) - q'(g(a))$ are monotone non-decreasing functions of *g(a),* if g is a criterion to be maximized
- (iii) $g(a) + p'(g(a))$ and $g(a) + q'(g(a))$ are monotone and non-decreasing functions of *g(a),* if g is a criterion to be minimized.

Let a and a' denote two actions to be compared such that *g(a),* at least as good as g(a'). The following holds for such pairs.

- if $| g(a) - g(a') | \leq q'(g(a)$, the preference difference is small enough to state that "*a* is indifferent to *a*'" according to g, i.e., *aIa'.*
- If instead $q'(g(a)) < |g(a) - g(a')| \leq p'(g(a))$, the preference statement is considered weak, and this situation is denoted as *aQa'*.
- In case of a strong preference of *a* over *a*' under criterion g, $| g(a) - g(a') | > p'(g(a))$, then *aPa'*.

Figure 5 provides a graphical representation of direct and inverse thresholds for criterion maximization and minimization. If g is to be maximized:

- $aI_ga' \Leftrightarrow -q'(g(a')) \leq g(a)-g(a') \leq q(g(a'))$

If, g is to be minimized:

- $aI_ga' \Leftrightarrow -q'(g(a')) \leq g(a)-g(a') \leq q'(g(a'))$

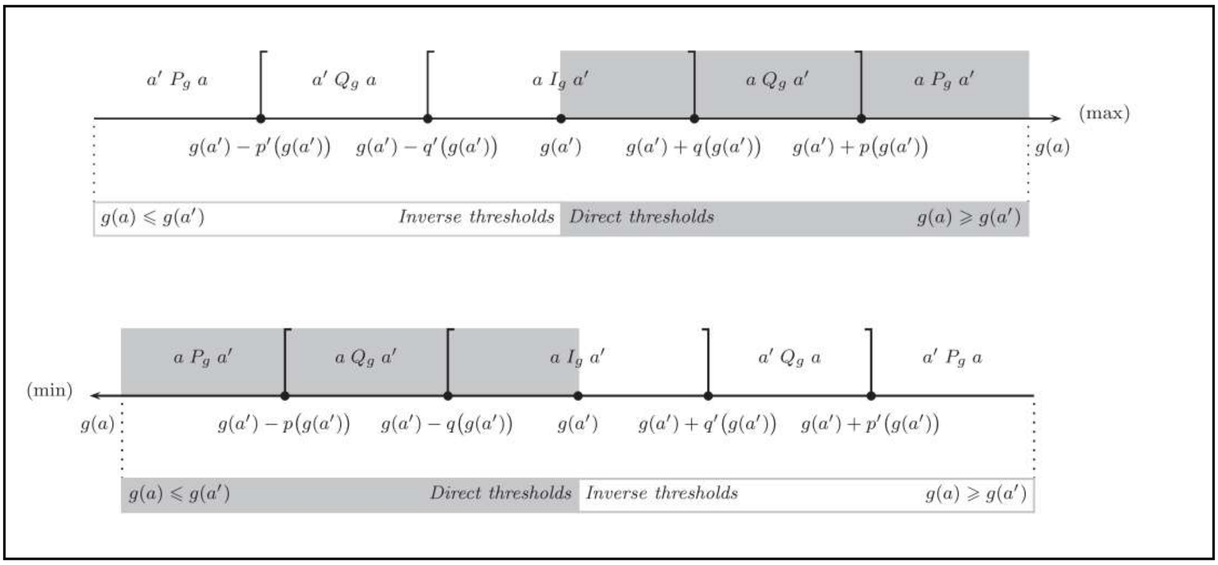


Figure 5 - Direct and Inverse thresholds; maximize (top) and minimize (bottom)

For coherency reason, two conditions must be fulfilled by the discrimination thresholds.

Condition 1, regarding direct discriminating thresholds states:

- (a) if *g* is a criterion to be maximized and *g(a)>g(a'),*

$$\frac{p(g(a)) - p(g(a'))}{g(a) - g(a')} \geq -1 \quad (7)$$

- (b) if *g* is a criterion to be minimized and *g(a)<g(a')*

$$\frac{p(g(a')) - p(g(a))}{g(a') - g(a)} \leq 1 \quad (8)$$

Equations 7 and 8 apply both to preference or indifference discriminating thresholds (replace *p* by *q*)

Condition 2, regarding inverse discriminating thresholds states:

- (a) if *g* is a criterion to be maximized and *g(a)>g(a'),*

$$\frac{p'(g(a)) - p'(g(a'))}{g(a) - g(a')} \leq 1 \quad (9)$$

- (b) if *g* is a criterion to be minimized and *g(a)<g(a')*

$$\frac{p'(g(a')) - p'(g(a))}{g(a') - g(a)} \geq -1 \quad (10)$$

Equations 9 and 10 apply both to preference, or indifference discriminating thresholds (replace *p* by *q*)

In practical situations, variable thresholds can often be modelled as affine functions (a class of variable thresholds), as follows:

- For direct thresholds:

$$p(g(a)) = \alpha p g(a) + \beta p' \quad (11)$$

$$q(g(a)) = \alpha q g(a) + \beta q' \quad (12)$$

For inverse thresholds:

$$p'(g(a)) = \alpha' p g(a) + \beta' p \quad (13)$$

$$q'\big(g(a)\big) = \alpha' q g(a) + \beta' q \quad (14)$$

For the affine functions of equations 11 to 14, if g is to be maximized and minimized, respectively, we have:

$$\alpha' p = \frac{\alpha p}{1+\alpha p} \ and \ \beta' p = \frac{\beta p}{1+\beta p}, for \ \ \alpha p > -1 \quad (15)$$

$$\alpha' p = \frac{\alpha p}{1-\alpha p} \ and \ \beta' p = \frac{\beta p}{1-\beta p}, for \ \ \alpha p > -1 \quad (16)$$

Equations 15 and 16 apply as well for indifference and veto thresholds.

4.2 The SRF Method

In the decision aiding context, determining the weights of the relevant criteria is a hard but essential task. The chosen method to assess the criteria weights is the SRF Method (Roy and Figueira, 2002).

The SRF method (Roy and Figueira, 2002), is a revised version of Simos weighting method (1990) and consists of an interactive exercise between facilitator and the DM. Each criterion is physically represented by a "playing card". A set of cards, as many as the given criteria, *n*, is given to the DM. The DM is then asked to order those n cards by relevance – from the least relevant to the most relevant. Thus, the user will rank in ascending order according to the importance ascribed to each criterium. If two or more cards have the same relevance (i.e., the same weight), they are to be placed alongside each other. Consequently, we obtain a complete pre-order on the whole of the *n* criteria. The first rank is named *Rank 1*, the second one *Rank 2* and so on.

After ranking the criteria cards by relevance, the facilitator asks the user to think about the fact that the importance of two successive Ranks (or two subsets of *ex aequo* criteria) can be more or less close. The determination of the weights must consider this smaller or bigger difference of importance in successive criteria. Therefore, a new set of cards enters the process – the white cards. Each white card represents difference of importance between successive cards (or two subsets of *ex aequo* cards). The DM is asked to introduce white cards between those criteria whose relevance gap is greater.

As such:

- Equally relevant criteria will stand alongside each other.
- Subsets with a small relevance difference will have no white card between them.
- Subsets with medium or a large relevance gap will have one or more white cards between them.

The weight difference between two consecutive cards (or subsets) will be addressed from now on as "*u*". Therefore, one white card stands for two times "*u*" and two white cards represent three times "*u*".

In the Simos' method, the least qualified card receives Position 1, the next one, Position 2, and so on. Then, the non-normalized weight of each rank is computed by dividing the sum of the positions of this rank by the total number of criteria within this rank. Subsequently, the normalized weight of each criterion is obtained by dividing the non-normalized weight by the total sum of the positions of the criteria. The main shortcoming of the Simos' method relies on not inquiring the DM about the weight difference between the most and least relevant criteria. This procedure automatically determines the ratio between the least and most relevant cards. This ratio is represented by variable "z" as follows:

$$z = \frac{(\sum_{i=0}^{q=1}(T-i))p}{(\sum_{i=0}^{p=1}(1+i))q} \quad (17)$$

For "*p*", the number of cards in the least important subset, "*q*" is the number of cards in the most important subset, and "*T*", is the total number of cards.

Therefore, the number of cards in the top/bottom subset can dramatically change the overall weighting results regardless of the DM´s knowledge.

In the SRF method, however, (Roy and Figueira, 2002), the DM is asked to define how many times the last criterion is more important than the first one in the ranking.

$$Z = \frac{w\ (most\ relevant\ criterion)}{w\ (least\ relevant\ criterion)} \quad (18)$$

The underlying difference between the two methods regarding variable *Z* stands on the fact that the SRF allow the DM to express his belief regarding the weight difference between *Rank 1* and *Rank n*. Thus, the revised algorithm goes as follows:

The non-normalized weights, *k(1), ..., k(r), …, k(ñ)* associated to each subset is determined in the following way. Let e'_r be the number of white cards between rank *r* and *r+1.*

$$\begin{cases} er = e'r + 1, \quad \forall r = 1, .. ñ - 1 \\ e = \sum_{r=1}^{ñ-1} er \\ u = \frac{z-1}{e} \end{cases} \quad (19)$$

We obtain $k(r) = 1 + u(eo + \cdots + er - 1)$, with $e_0 = 0$.

All *ex-aequo* criteria in rank "*r*" will have the same weight *k(r).*

The normalized weights k_i are computed as follows: Let g_i be a criterion of the rank *r* , and k'_i be the non-normalized expression from the previous definition, $k'i = k(r)$, then:

$$\begin{cases} K' = \sum_{i=1}^{n} k'i \\ k^*i = \frac{100}{K'} k'i \end{cases} \quad (20)$$

k^*_i is the normalized weight of criterion g_i and it is often represented in the form of k''_i, differing only by the fact that the latter is a rounded number with "*w*" figures after the decimal point (max. of 2). There is a distortion associated with the rounding process, which is necessary to obtain the final weights k_j such that $\sum_{j=1}^{n} kj = 1$, otherwise the weights sum would, virtually, never be exactly 100%.

By using the rounding technique, at last, we obtain:

$$
\begin{cases}
K'' = \sum_{i=1}^{n} k''i \leq 100 \\
\\
e = 100 - K'' \leq n * 10^{-w}, \quad for\ w = 0; 1\ or\ 2
\end{cases}
\quad (21)
$$

The rounding process can be done upwards or downwards. For d_i, the dysfunction concerning the relative error in the upwards rounding process and d_i the downwards relative error, the overall error can be minimized using an independent algorithm.

The revised Simos method, i.e., the SRF method has been successfully applied in several real-life contexts (Roy and Figueira, 2002) and has proven to be a solid weighting procedure. Not only should it be used to determine weights in the ELECTRE type methods but also in other contexts, for instance, to build an interval scale or a ratio scale.

4.3 Chapter Conclusions

Chapter four presents, at first, MCDA methodology, its development steps, and informal rules. Secondly, Chapter four introduces the ELECTRE TRI-nC and SRF method (weighting criteria method), and their formal models.

5 Model

The present Chapter addresses the main aspects of the modelling process. Section 1 identifies the key concerns for EV governance. These concerns are validated with two sources: (1) governance frameworks at the EU level and (2) academic work on EV policy intervention. Section 2 addresses the model structuring phase, identifies the final AC, Fundamental Points of View (FPV) and the selected criteria, from which the criteria tree is obtained. In the third section, the performance scales are proposed for each criterion and the final performance table is obtained.

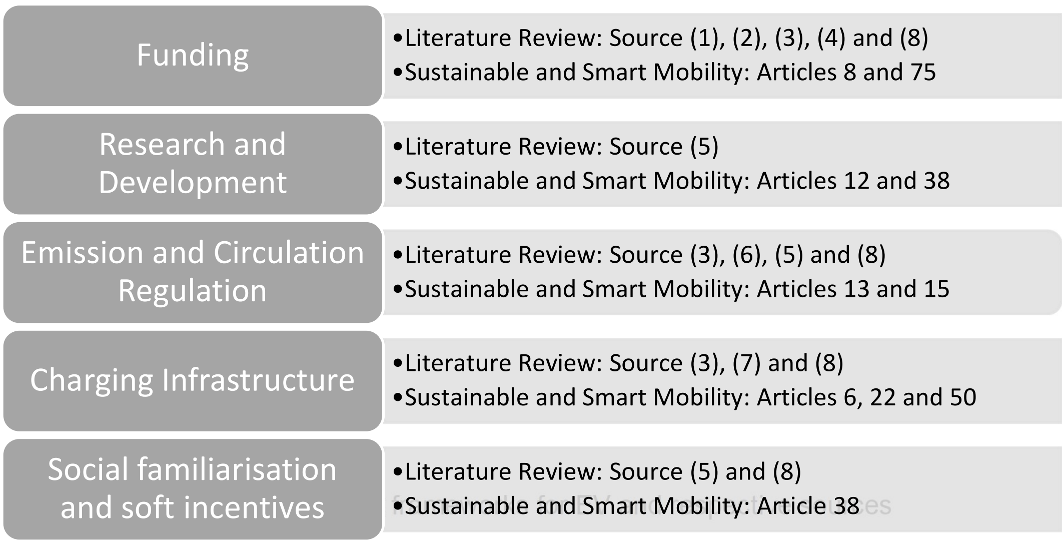
5.1 Governance Framework for EV

Comparing different Member-States regarding their governance capabilities towards EV deployment requires setting the common ground for the evaluating criteria.

The guiding sources for the construction and procurement of criteria are the literature review of the current work and the 'Sustainable and Smart Mobility Strategy'. This document sets the pace for all EU Member-States regarding EV deployment. Thus, National-level Ambitions, Targets and Legislations of EU countries must mirror the targets outlined in this document.

By combining this document with the literature review, the elected criteria will be set.

Figure 5 shows governance tools from two sources. The first tools are identified in the literature review of the current work, namely in other MCDA approaches as well as data from Table 3. The works corresponding to each literature source are numbered in Figure 5 according to the footnote[8] The second, are identified in the 'Sustainable and Smart Mobility Strategy' articles.



[8] (1): Lévay, Drossinos, Thiel, (2017)
(2): Gass, Schmidt, (2012)
(3): Harrison, Thiel, (2016)
(4): Bjerkan, Norbech, Nordtomme, (2016)
(5): Nilsson, Nykvist, (2016)
(6): Turcksin, Bernardini, Macharis, (2011)
(7): Gómez, Román, Momber, Abbad, Miralles, (2011)
(8): Vanhaverbeke and Van Solten, (2018)

Regarding the scope of financial tools, many studies highlight the need for up-front subsidies regarding EV deployment (Lévay, Drossinos, & Thiel, 2017; Gass & Schmidt; 2012; Harrison & Thiel, 2016; Vanhaverbeke & Van Solten, 2018). Ownership and purchasing tax exemptions are also considered (Lévay, Drossinos, & Thiel, 2017). Articles 8 and 75 of the 'Sustainable and Smart Mobility Strategy' target funding mechanisms as crucial through non-repayable support. This support should make electric mobility available and affordable for all, namely for remote regions and rural areas. Regarding support to companies, both Nilsson and Nykvist (2016) and Article 15 mention the relevance of financial support to corporate and urban fleets to boost the uptake of zero-emission vehicles.

R&D are addressed in Nilsson and Nykvist (2016) as potentially beneficial regarding the decrease of capital costs of EV, namely through the production process. Research is addressed not only for EV technology but for its orbiting technologies, namely for the increase of speed of charging stations and for the improvement of load management of the electric grid if demand increase rises or even in battery technology. Articles 12 and 38 of the 'Sustainable and Smart Mobility Strategy' also address R&D investment for sustainable and circular products or services related to zero emission fuels or vehicles.

Emission regulations are targeted repeatedly in 'Sustainable and Smart Mobility Strategy'. The EC will propose a revision of the CO_2 standards (Euro 7[9]) by June 2021. However, this regulatory framework is equal and transversal for all European Member-States. Thus, common standards cannot be included in this MCDA approach.

However, circulation regulations are implemented at national level and can be subject to evaluation. Article 38 states that cities are to modernize their policy toolbox including low and zero emission circulation zones. These legislations despite being applied at the city-level, they provide, in number, a clear insight of national-level targets and ambitions.

Charging infrastructure is considered a pivotal parameter of EV deployment. Harrison and Thiel (2016), Gómez, Román, Momber, Abbad, and Miralles (2011), Vanhaverbeke and Van Solten (2018), and articles 6, 22, and 50 address this need. Substantial progress is needed on effective charging infrastructure use, notably in road transportation (article 6).

Some of the incentive tools do not fit in any of the previous large concerns. Soft incentives are also mentioned in both source (5) and article 38. Better information on low-emission vehicles and low-emission zones is targeted as well as an overall social education on the technology. Such measures can be implemented with implementation tests in pilot cities.

Table 3 provides the sources that validate the choice for each concern to be developed in section 4.2. Note that other factors, which are not being included in this work, may as well influence EV deployment. Some of them are unintentional consequences of policies across other areas (externalities) that either affect positively or negatively EV deployment. These cases cannot be considered because many of them are hard to both grasp and measure across all the 27 EU State Members.

[9] European emission standard for petrol and diesel road vehicles (due in 2021)

5.2 Model Building

Model Building is the phase which requires a more convergent mode of thinking, a process of extracting the essence of the issue (Belton and Stewart, 2002). This is the phase when the key elements of the model are considered in detail – alternatives, values (criteria), stakeholders and possible uncertainties. The outcome of this stage is the value tree which captures the problems' core values.

The alternatives, which are subject to evaluation under the selected criteria will be each of the 27 EU members (as of today).

Many authors have commented on the importance of generating alternatives through the MCDA process (Keeney, 1992), and working towards improving the options resulting in a new unseen alternative or combination of alternatives which emerges through the MCDA process. This only happens when the MCDA approach aims at developing an action plan. However, our problem will not result in an action plan such as in resource allocation problems or screening processes. Our problem consists of evaluating a close set of alternatives, the EU countries, regarding their current compliance with the EU roadmap for EV transition. Alternatives cannot be added to the problem, neither can they be combined since each country is sovereign and independent. Thus, the final set of alternatives in this problem is priorly set.

The AC are the broad subjects to which the FPV fall into. There are three major AC for EV transition, i.e., Financial, Regulatory and Infrastructure concerns.

- **AC_1, Financial:**

This AC reflects all National level governance vectors regarding public financial incentives towards EV transition and is key for EV deployment, as explained in the previous Chapter.

- **AC_2, Regulatory:**

This AC regards National level Regulatory Frameworks for Vehicles circulation. Either regarding pull measures, i.e., encouraging EV mobility, or push measures, discouraging Internal Combustion vehicles, thus accounting for the current regulatory paradigm in circulation access regulations.

- **AC_3, Infrastructure:**

This AC refers to National level public charging infrastructure for EVs. Each AC is divided into one or more specific sub-concerns. These sub-concerns, the FPV, are as follows. For AC_1, it is possible to disaggregate the subject in two FPV.

- **FPV_1, Direct Tax schemes and Grants for Consumers:**

This FPV accounts for all financial public incentives regarding acquisition, ownership, or circulation of EVs. These financial incentives can either be for individuals or for companies.

- **FPV_2, R&D Funding:**

This FPV regards public funding for R&D.

AC_2, Regulatory, unfolds in one single FPV.

- **FPV_3, Regulatory:**

This FPV 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 one FPV as well.

– **FPV_4,** Infrastructure**:**

This FPV regards 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. The criteria tree for this problem follows in Table 4. Each criterion and their respective performance scales will be further developed in the next section.

Area of Concern	Fundamental Point of View	Criterion
AC1, financial	**FPV1**, Direct Tax schemes and Grants for Consumers	g1, Tax and Grants on Acquisition
		g2, Tax on Ownership
		g3, Private Use of Company Car
		g4, Other Direct Financial Incentives
	FPV2, *R&D Funding*	g10, R&D Funding
AC2, regulatory	**FPV3**, Regulatory	g5, LEZ, Low Emission Zones
		g6, Urban Road Tolls
		g7, Polution Emergency Zones
		g8, Other Regulatory Incentives
AC3, infrastructur*e*	**FPV4**, Infrastructure	g9, Charging Infrastructure

Table 4 - AC, FPV and Criteria

5.3 Criteria Scales and Performance

This section presents each of the selected criteria, their relevance, the respective performance scales, and the performance table.

5.3.1 Tax and Grants on Acquisition, g_1

The first criterion, Tax and Grants on Acquisition, aims at measuring the taxing and grants schemes for EVs in each of the 27 EU. Article 8 from *Sustainable and Smart Mobility strategy,* states:
"it is crucial that mobility is available and affordable for all, through non-repayable support schemes".
As mentioned earlier, the Capex for EVs is a relevant barrier for the mass deployment of this mode of transport. Thus, special taxing schemes for EV as well as grants have been one of many ways that EU countries adopted to facilitate the acquisition of EVs.

The comprised data for each country regarding this matter involves all type of acquisition fees (VAT, sales tax, registration tax) as well grants as of 2020. This assessment is supported by the European Automobile Manufacturers' Association (ACEA), which aggregates on a per year basis all tax data from each National association of motor vehicle manufacturers or importers.

The evaluation under this criterion is made with a four-level qualitative scale due to the nature of its content. Each country opts for a different approach, based on different indicators. Some countries opt for lump sum grants, which are the most impactful pull measures towards EV acquisition. The grant incentive changes from country to country. Some countries grant subsidies based on the vehicle CO_2 emission rate, usually for vehicles below the 50g/km threshold (ACEA, 2020). The vehicles that fall into this category are often called Ultra Low emission vehicles (ULEV), mostly composed by EVs and some PHEVs. Some other countries opt for subsidizing the purchase through VAT exemption, or a scrappage Bonus, or by inducing a Personal Income Tax (PIT) reduction. The previous methods are usually state-funded but some innovative countries adopted a, so called, "Bonus-Malus[10]" scheme that benefits EV acquisition. In this method, low CO_2 vehicle purchase is subsidized by a punitive tax imposed to high emitting vehicles. This method requires no public funding as it is self-funded.

All EU countries adopting these measures promote a significant Capital cost (Capex) decrease. These countries fall into the highest performance level for criterion g_1, which is Level "4".

Level "3" Countries, are those who promote EV acquisition by implementing a registration Tax exemption on EVs, partial EV deductibility, or other relevant price decrease mechanisms.

Level "2" countries have implemented marginally lower VAT tax based on CO_2 emissions. These measures are not targeted towards EV specifically since a low Internal combustion engine car also benefits from this approach relatively to a high CO_2 emitting vehicle.

Level "1" countries have no tax or grant approach towards acquisition of EV's.

The levels and corresponding measures follow in table 5.

[10] System which rewards one (bonus) and penalizes other (malus)

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 5 – Performance Levels g_1

5.3.2 Tax on Ownership, g2

Criterion 2, Tax on Ownership regards all ownership tax incentives within the EU framework for EVs. Annual circulation taxes (ACT) and road taxes are amongst the considered ownership taxes under evaluation.

Data on the current type of incentives also refers to 2020 and is made available by ACEA[11].

Regarding this matter, some countries opted for exemption of ACT. Either for all EVs, or for vehicles below the 50g/km threshold. Some other countries opted for ACT exemption for a 5-year period or even for road tax exemption. These countries were place in Level "4", considering that criterion 2 also uses a four-level qualitative performance scale.

Level "3" countries adopted a low ACT and Road tax schemes for EVs. These are never null but significantly reduced. Eligible vehicles fall below the 50g/km of CO_2 threshold.

Level "2" countries are those who adopted lower ownership taxes in some regions only, or marginally lower at national level.

Level "1" countries have no beneficial approach on ownership towards EVs.

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 6 – Performance Levels g_2

5.3.3 Private Use of Company Car, g_3

Article 15 from *Sustainable and Smart Mobility strategy,* states:

"Financial incentives are to boost the uptake of zero-emission vehicles in corporate and urban fleets.".

Regarding the Private Use of a company car, or a fleet, some countries adopted specific measures to promote EV incentives. Criterion three aims at measuring this specific type of incentives. On a similar approach to criteria one and two, and because the approach is very diverse from nation to nation, a qualitative performance scale was implemented for the assessment of countries.

Level "4" countries are those who promote the most benefits for company use of an EV. Some of these countries opted for measures already mentioned like ACT exemption for ULEV, or lump sum grants. Some other opted for innovative measures like increasing the deductibility of expenses of EV on corporate taxes, or even by allowing a fast amortization scheme for EV company assets, which results in lower net income.

[11] Tax Guide 2020. Available in: https://www.acea.auto/publication/acea-tax-guide-2020/

Level “3” countries are those who promote measures similar to level “4” countries but in smaller magnitude. Level “3” measures are such as registration tax exemption, or slightly higher deductible value compared to combustion engine vehicles. Other countries implemented specific measures like adopting a lower taxation rate on personal income tax (PIT) for those workers with EV, or by promoting exemption of personal income tax for the fraction of one’s salary sheet regarding the benefit of the company car use – which causes lower overall personal income tax.

Level “2” countries would be countries with marginal benefits for EV and Level “1” countries are those with no incentive for company acquisition or ownership of company EV.

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

Table 7 – Performance Levels g_3

5.3.4 Other Direct Financial Incentives, g_4

Criterion g_4 refers to all financial incentives that do not fall into the previous criteria - g_1, g_2 and g_3. Since every country adopts its own governance guidelines, some incentives cannot be placed in any of the previous criteria. This criterion is also measured with a four-level qualitative performance scale.

Some countries implemented complex instruments, like Mobility Allowances, which are conceded for those who exchanged their company car for a sum of money or for a more sustainable mode of transportation, which also results in social and fiscal privileges. Other countries conceded road tax and tolls exemption for EV. These countries are considered level “4” countries under criterion g_4.

Level “3” countries are those whose incentives have lower impact than level four countries. Such countries adopted measures like low toll charges for heavy commercial EV.

Level “2” countries adopted very low impact measures like inspection fee exemption for EV and Level “1” countries did not implement any financial incentives other than those mentioned under g_1, g_2 and g_3.

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 8 – Performance Levels g_4

5.3.5 R&D Funding, g_{10}

Criterion g_{10}, is the last criterion regarding financial subjects. R&D Funding expresses a different FPV than the previous criteria, FPV_2. R&D funding is a criterion that expresses how public governance promotes medium to long term effects on technology and industry.

If FPV_1, Direct tax Schemes and Grants for consumers, reflects a final, short term incentive towards consumers, FPV_2 targets a much more upstream approach. R&D funding fastens technology maturity and is essential in the development phase of the technology.

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):

$$R\&D\ per\ thousands\ of\ GDP = \frac{R\&D\ Budget}{GDP} x\ 10^3 \quad (22)$$

EU countries invest between zero and 1.17EUR per thousand EUR of their GDP in Research and Development, with an average of 0.27 (IEA, 2020).

5.3.6 Low Emission Zones (LEZ), g_5

Criterion g_5 falls into the second AC, AC_2, which regards the scope of Regulatory concerns at the National level.

LEZ are areas where the most polluting vehicles are regulated. Usually this means that vehicles with higher emissions cannot enter the area. In some low emission zones, the more polluting vehicles are required to pay to circulate.

Across Europe, LEZ have been implemented and regulated with different methods. Some cities allow circulation to those vehicles with a “Sticker” permit only. Other countries, like the Netherlands, implemented the so called “Milieuzones” to many municipalities, with access restrictions to diesel powered vehicles (Directorate General for the Environment, 2021).

The diverse approach towards LEZ requires a qualitative performance scale that considers three main vectors – the net number of LEZ nationwide, the country’s size, and the level of restrictions inflicted by the LEZ.

Level “4” countries are all those with over 0.2 LEZ per thousand sq. meters and high degree of circulation restrictions. These are countries like Germany, with 0.2 LEZ per thousand sq. meters with different degrees of restrictions or the Netherlands with 0.36 LEZ pert thousand sq. meters. Level “3” countries have LEZ ranging from mild to severe circulation restrictions. These are countries like Belgium, with 0.1 LEZ per thousand sq. meters or France with 0.02.

Level “2” countries have less than 3 LEZ. These LEZ are implemented in the capital city only and do not reflect a deep commitment with push measures for combustion vehicles. Level “1” countries have essentially no approach regarding LEZ.

5.3.7 Urban Road Tolls, g_6

Criterion g_6 falls into AC_2 and regards the regulatory framework for circulation restrictions.

Urban Road Tolls are a push measure instrument used to discourage combustion engine vehicles in urban areas. In most implemented areas, this mechanism is designed to fund other transportation alternatives.

Similarly to the previous criteria, this criterion was measured through a four-level qualitative performance scale and operationalized through the same rational as g_5. All gathered data was obtained from the Directorate General for the Environment [12].

5.3.8 Pollution Emergency Zones (PEZ), g_7

Some circulation restrictions within the EU are based on air quality indicators. Depending on how strict the air quality standards are, municipalities implement a set of push measures to discourage combustion engine vehicles. Measures range from an absolute ban of vehicles within those days when a pollution indicator ranks above the defined threshold to some other measures like limiting the type of vehicles allowed to circulate. Despite each country not having a national level governance on this matter and instead, this criterion considers the sum of PEZ within each country and how strict their standards are. 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. Data for g_7 was sourced from the Directorate General for the Environment[13].

5.3.9 Other Regulatory Incentives, g_8

Regulatory governance is highly diverse within the EU. Therefore, alike criterion g_4 for financial incentives, this criterion targets all regulatory measures that do not fall into any of the previous regulatory criteria – g_5, g_6 and g_7. The measures within this criterion are often called, Key Access Regulation Schemes (ARS) and they contemplate all push methods other than through payment or emission standards.

Criterion g_8 considers measures like circulation bans at certain times of the day or restricting non-EV. These measures are often enforced by cameras, physical barriers, or local authority officers. Although not being exclusively designed as an EV incentive, these measures do target the negative externalities of combustion vehicles, making them a less attractive alternative. This criterion is measured with a four-level qualitative performance scale.

5.3.10 Charging Infrastructure, g_9

Criterion g_9, charging infrastructure, fully expresses AC_3, Infrastructure. Articles 22 and 50 from *Sustainable and Smart Mobility Strategy* state:

"*Substantial progress is needed on effective charging and refuelling infrastructure to fully enable widespread uptake of zero-emission vehicles*."

This criterion is of upmost relevance since EV deployment is technologically dependent on charging infrastructure. Despite home charging solutions being able to address some charging needs, they do not accommodate the whole spectrum of citizens. Giving the consumers the responsibility of finding their own charging options would strongly stall EV transition.

[12, 13] https://urbanaccessregulations.eu/

Therefore, both public and private entities are to deploy charging stations to facilitate EV acquisition.

The assessment is based on a quantitative performance scale, measuring the amount of charging stations per 100 thousand of urban inhabitants (Eurostat, 2017[14]).

EU countries' installed capacity ranges from 0.78 charging points to 260 charging points per 100 thousand urban inhabitants. The average value in EU 27 is 40 charging stations per 100 thousand urban inhabitants.

5.3.11 Performance Table

The data used to construct the performance tables of the model were gathered from the following databases: the ACEA, for all criteria under FPV_1, the International Energy Agency (IEA) for FPV_2, the Directorate General for the Environment, for FPV_3, and Eurostat, for FPV_4.

The performance table depicted in Table 9 is the starting point for the analysis performed with the ELECTRE-Tri-nC algorithm.

As mentioned previously, the assessment made through 4 level qualitative performance scales was implemented in several criteria. In these cases, Level "4" stands for the best performance and Level "1" stands for the worst performance. On the other hand, qualitative performance scales are interval scales depending on the measured indicator.

[14] https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/energy-union-innovation/ev-charging-points_en

ACTION[15]	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10
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 9 - Global Performance Table

5.4 Chapter Conclusions

Chapter 5 aims at clarifying the main aspects of the model building phase. Section 1 identifies the different fields of action for EV governance. These are validated with two types of sources: (1) the governance frameworks at the EU level, namely the "*Sustainable and Smart Mobility Strategy",* and (2), the academic work on EV policy intervention. Section 2 is where the key concerns (AC) are identified and subdivided into FPV which are operationalized through the criteria, providing the criteria tree for the current work.

Finally, each criterion is further defined regarding its content, performance scales and data sources. Thus, the overall performance table is obtained, providing the performances of the 27 countries on all criteria. Table 9 is the starting point of the implementation of the ELECTRE-Tri-nC algorithm, which is implemented in Chapter 6.

[15]For Member States' acronyms - see Figure 9

6. Model Implementation

Chapter 6 describes the implementation of the model. Firstly, the criteria weights are defined through the SRF method. This procedure is developed twice, given that two DMs participated in the project. Then, the ELECTRE-Tri-nC is implemented and run.

6.1 Criteria Weighting

The current section aims at providing the normalized weights of the relevant criteria. These weights were obtained through the SRF method, which was explained in Chapter 4. The SRF method was implemented in a web application – Decspace[16] - see Figure 7. Decspace provides a variety of available MCDA tools designed to help facilitators elaborate the MCDA Model.

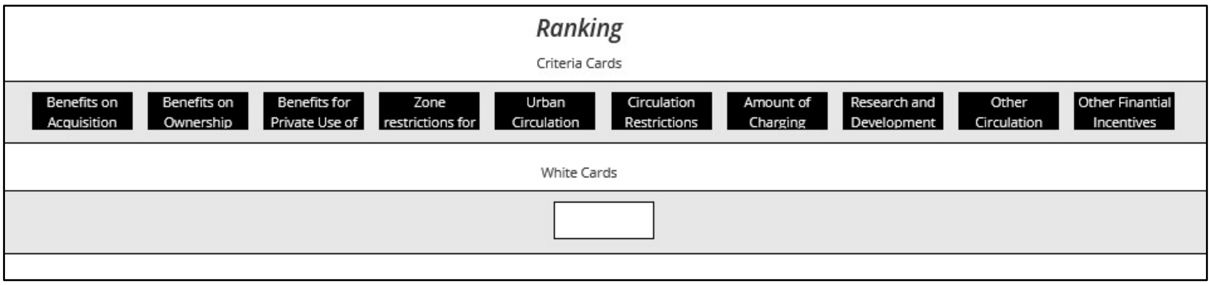


Figure 7 – Decspace Interface, Criteria cards and White cards

The weighting process lies on the subjective beliefs of each DM. Therefore, for each DM, the final category assignment of each alternative may differ. Thus, to strengthen the results of this work, two[17] real DM´s from different professional contexts, but within the EV work environment, were contacted and asked to participate in this work.

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[18], the Belgian public body representing constructors and importers of road vehicles in Belgium and EU frameworks.

Different DM´s were contacted since their views can provide different priorities regarding criteria weighting. The first DM, who works for a service provider in the energy sector, may view policy priorities differently than the second one, who works for a Belgian public sector representing automobile manufacturers and importers.

[16] http://decspace.sysresearch.org

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

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

Thus, the SRF method was performed twice in interaction with the two DMs. The process occurs as described in chapter 4. Therefore, the cards were sorted in decspace twice, and the parameter Z of Figure 8 was set twice, according to each DM:

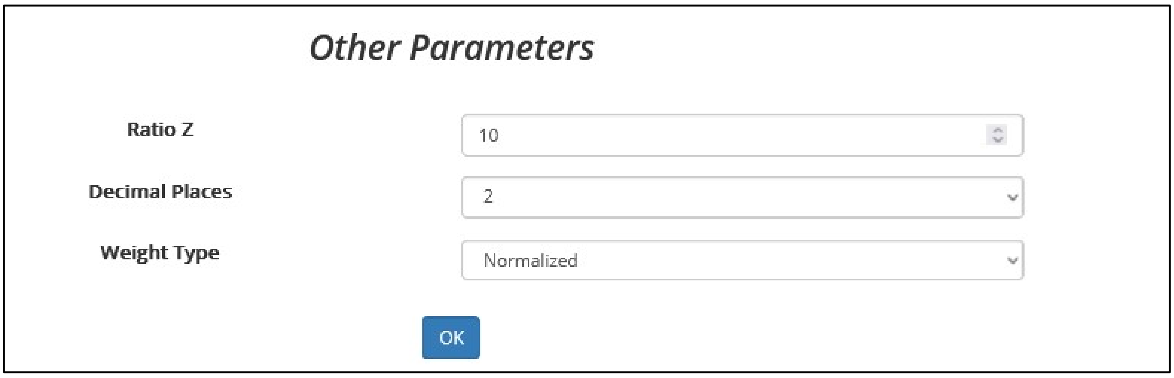


Figure 8 - Decspace interface - Parameters settings

Table 10 depicts the final weights assigned to the criteria according to the preferences of each DM, obtained through decspace.

CRITERION	DM1	DM2
1. Tax and Grants on Acquisition	12.58%	13.04%
2. Tax on Ownership	11.66%	15.80%
3. Private Use of Company Car	4.29%	14.42%
4. Other Direct Financial Incentives	7.06%	8.9%
5. LEZ, Low Emission Zones	15.33%	10.27%
6. Urban Road Tolls	14.41%	3.37%
7. Pollution Emergency Zones	13.5%	4.75%
8. Other Regulatory Incentives	8.9%	1.99%
9. Charging Infrastructure	10.74%	19.94%
10. R&D Funding	1.53%	7.52%

Table 10 - Criteria normalized weight assignment for each DM

"DM1" clearly prioritizes push measures through Regulatory incentives, which represent about 52% of the overall weight distribution. The remaining 48% are distributed between financial pull measures (37%) and Infrastructure incentives (11%).

On the other hand, "DM2", prioritizes Financial Incentives (60%), whereas the remaining weights go evenly for Regulatory Incentives (20%) and Infrastructure (20%).

Given such weight distribution, EU countries with tighter regulatory frameworks will be assigned to better categories for DM1 than DM2 in the ELECTRE TRI-nC method, whereas, for charging infrastructure and financial incentives, EU countries will be assigned to better categories for DM2 than DM1.

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

6.2 Model Elements

The successful implementation of the ELECTRE TRI-nC requires setting the reference actions, $b^r h$, that define each category.

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
- C_1 Weak

Therefore, countries with very good performance will be assigned to category C_4, those with good performance are assigned to C_3, moderate, to C_2 and weak to C_1.

Since the ELECTRE TRI-nC allows the association of several reference actions to each category, two reference actions were defined for each category, except for category C_1, Weak. Thus, we obtain seven reference actions, as follows in Table 11.

	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	259,91	1,17

Table 11 – 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. Therefore, as explained in Chapter 4, veto thresholds can be set for the ELECTRE TRI-nC. However, veto thresholds were not used to model discordance regarding outranking statements. Thus, p_j and q_j were set as follows in Table 12.

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

Table 12 – Thresholds q,p

For criterion g_9, the indifference threshold is 3. This means that for performance differences equal or lower than 3 charging points per 100 thousand urban inhabitants, alternatives are considered indifferent. For performance differences ranging from 3 to 9 charging points per 100 thousand urban inhabitants, there is a weak preference between alternatives. At last, for performance differences between two given alternatives greater than 9, there is a strong preference between alternatives.

For criterion g_{10}, the indifference threshold is 0.05. This means that performance differences between two alternatives lower or equal than 0.05 EUR per thousand EUR of GDP are considered indifferent. For performance differences ranging from 0.05 to 0.1 EUR per thousand EUR of GDP, there is a weak preference between alternatives. For performance differences greater than the preference threshold, there is a strong preference for one alternative over the other.

6.3 Insertion of Parameters

The implementation of Electre Tri-nC algorithm was carried out in MCDA-ULaval, as explained in Chapter 4. This subsection provides every step of data insertion.

Starting a new project requires the insertion of both alternatives and the criteria set. The alternative set is given by the EU countries, and the criteria set ranging from g_1 to g_{10} (see Figures 9 and 10).

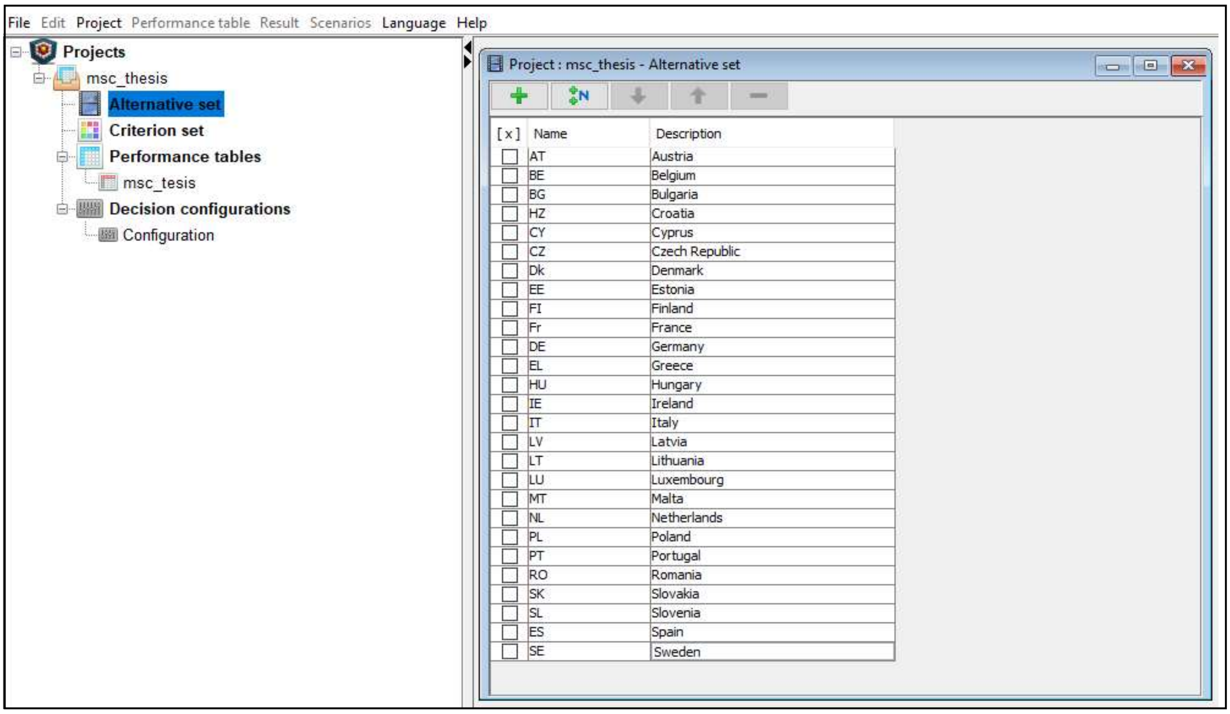


Figure 9 - Alternatives

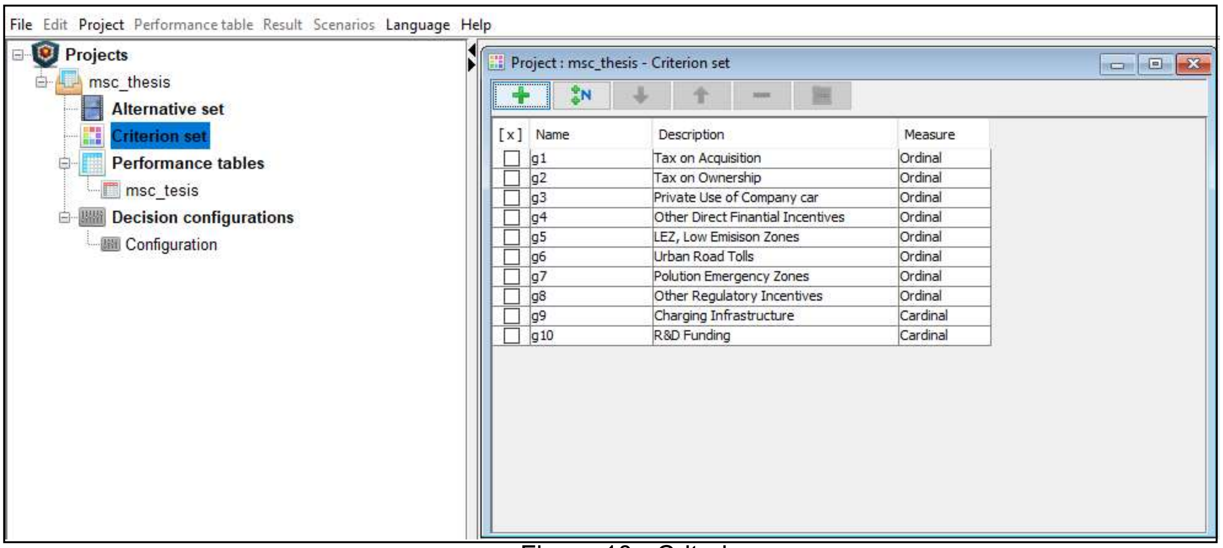


Figure 10 - Criteria

Setting each criterion requires, at this stage, defining whether the assessment is made through an ordinal or cardinal performance scales. For ordinal scales, the number of levels of performance must be defined. To define cardinal scales, the number of decimal places in each performance scale must be set.

These settings are relevant because, for cardinal scales, preference and indifference thresholds must be introduced to account for the difference of performance between values. Thus, the precision of the scale is a key to define the thresholds.

Following the definition of alternatives and criteria, the performance table is inserted. The table can be set manually or imported from CSV or XLSX files. Thus, we obtain the table as depicted in Table 13.

[Alternati...	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10
Extent	3	3	3	3	3	1	3	3	259,13	1,17
AT	L4	L4	L3	L3	L3	L1	L1	L1	130,60	0,41
BE	L4	L4	L4	L4	L3	L2	L3	L2	29,17	0,35
BG	L1	L4	L1	L1	L1	L1	L1	L1	7,10	0,00
HZ	L2	L1	L1	L1	L1	L1	L1	L1	54,25	0,00
CY	L2	L2	L1	L1	L1	L1	L1	L1	4,21	0,00
CZ	L3	L1	L1	L4	L2	L1	L1	L1	23,63	0,21
Dk	L3	L3	L3	L3	L3	L1	L1	L1	197,41	0,54
EE	L1	L1	L1	L1	L1	L1	L1	L1	65,78	1,06
FI	L2	L3	L1	L1	L2	L1	L1	L1	57,80	1,17
Fr	L3	L3	L4	L3	L3	L1	L4	L2	86,64	0,61
DE	L4	L4	L3	L4	L4	L1	L2	L3	70,43	0,30
EL	L2	L4	L2	L1	L1	L1	L1	L1	0,78	0,02
HU	L3	L4	L4	L1	L1	L1	L2	L1	15,52	0,55
IE	L4	L3	L1	L1	L1	L1	L1	L1	74,83	0,19
IT	L3	L4	L1	L1	L4	L2	L4	L4	9,44	0,31
LV	L3	L4	L4	L1	L1	L2	L1	L1	7,25	0,00
LT	L1	L1	L1	L1	L1	L1	L1	L1	12,67	0,00
LU	L4	L3	L4	L1	L1	L1	L1	L1	56,72	0,22
MT	L3	L3	L1	L1	L1	L2	L1	L1	21,07	0,00
NL	L3	L4	L3	L3	L4	L1	L1	L1	259,91	0,31
PL	L1	L1	L1	L1	L1	L1	L1	L1	5,71	0,23
PT	L4	L3	L3	L1	L1	L1	L1	L1	32,22	0,15
RO	L4	L3	L1	L1	L1	L1	L1	L1	4,41	0,00
SK	L1	L4	L4	L1	L1	L1	L1	L1	69,01	0,24
SL	L4	L2	L4	L1	L1	L1	L1	L1	57,53	0,00
ES	L2	L2	L3	L1	L2	L1	L2	L2	16,97	0,13
SE	L4	L3	L4	L3	L3	L2	L1	L1	94,25	0,41

Table 13 – Performance Table

Since this work was elaborated with two DM's, resulting in two different weighting distributions, there must be two project files, differing only in this single aspect – criteria weighting, addressed as "k" in the software interface.

[Parameter]	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10
k	13.04	15.8	14.42	8.9	10.27	3.37	4.75	1.99	19.94	7.52

Figure 11 – DM2

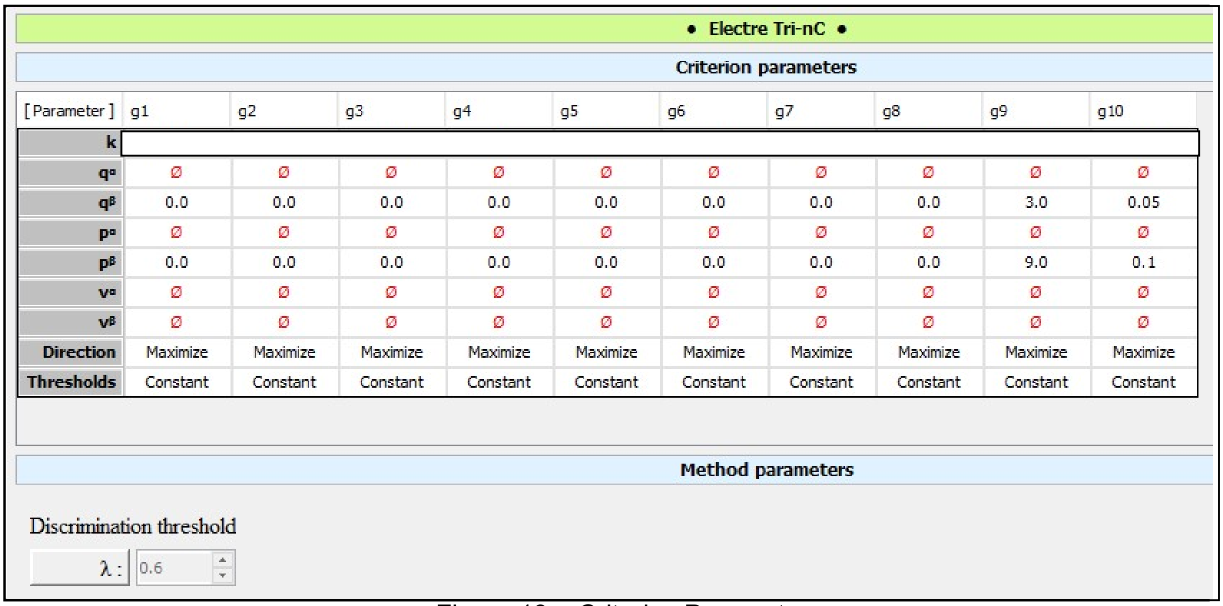
[Parameter]	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10
k	12.58	11.66	4.29	7.06	15.33	14.41	13.5	8.9	10.74	1.53

Figure 12 - DM1

The remaining parameters remain similar for the two project files.

Criteria g_1 to g_8 are assessed through qualitative performance scales in which the higher the level, the better the performance. Therefore, those are to maximize. The same applies for the cardinal scales from g_9 and g_{10}.

The lower limit for the credibility level (λ), must be set. Setting different values of λ, resulting in several model iterations will be done to perform a sensitivity analysis later in this chapter.



[Parameter]	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10
k										
q^{α}	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
q^{β}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.05
p^{α}	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
p^{β}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.1
v^{α}	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
v^{β}	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
Direction	Maximize	Maximize	Maximize	Maximize	Maximize	Maximize	Maximize	Maximize	Maximize	Maximize
Thresholds	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant	Constant

Figure 13 – Criterion Parameters

6.4 Implementation

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

Running the ELECTRE-TRI-nC in ULaval software occurs if all parameters are validated.

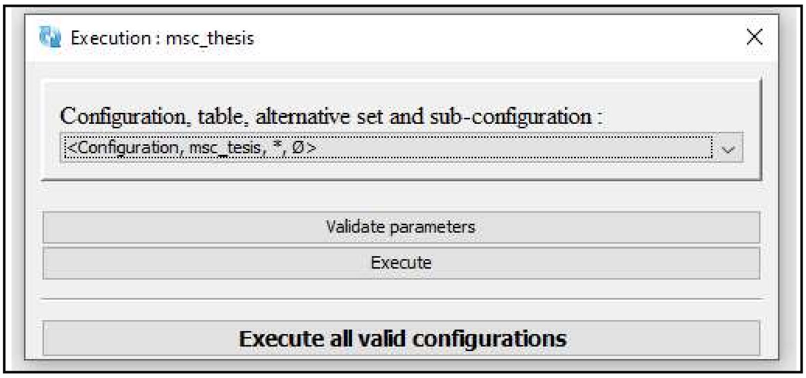


Figure 14 – Model Validation

The first iteration regarding DM1 provides the following assignments:

A large share of EU countries, 41%, fall between category C_1, Weak and C_2, Moderate. These are Bulgaria, Croatia, Cyprus, Estonia, Greece, Ireland, Lithuania, Poland, Romania, Slovakia, and Slovenia. The remaining countries are assigned to a single category. 30% of EU Countries were assigned to Category C_2, Moderate performance. These are Czech Republic, Finland, Hungary, Latvia, Luxembourg, Malta, Portugal, Spain. 22% of the EU Countries were assigned to category C_3, Good. These are Austria, Belgium, Denmark, France, the Netherlands, and Sweden. The remaining 2 countries, Germany and Italy were assigned to C_4, with a very good performance.

These assignments were based on DM1's weight distribution. As said previously, for DM1, regulatory incentives prevail as more relevant whereas financial and infrastructure concerns are less relevant.

The first iteration regarding DM2, however, provides the following results:

26% of the EU countries, fall between category C_1, Weak and C_2, Moderate. These are Bulgaria, Croatia, Cyprus, Estonia, Lithuania, Poland, and Romania. 22% of the EU countries are assigned to category C_2, Moderate. These are Czech Republic, Finland, Greece, Latvia, Malta, and Spain. 30% of the countries are assigned to category C_3, good. These are 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, with very good performance 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 14 - DM1 Assignments; DM2 Assignments

6.5 Sensitivity Analysis, λ

The current subsection provides different results for the ELECTRE TRI-nC assignments. These results were obtained by changing variable λ, which is the lower credibility level to which an outranking statement is validated.

For lower values of λ, the credibility index required to validate an outranking statement is lower and vice versa.

For the following scenarios (since $\lambda \in [0.5, 1]$), two iterations are performed. One for λ=0.5 and other for λ=1.

For DM1 and λ=0.5, the output differences were the following:

- Belgium and Sweden's assignments improve marginally, falling between categories C_3, good and C_4 very good.
- Czech Republic worsens, falling between categories C_1, Weak and C_2, Moderate.
- Germany and Italy worsen marginally, falling between assignment C_3 and C_4.
- Luxembourg, Malta, and Portugal worsen marginally, falling between C_1 and C_2.

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

Table 15 - DM1, λ=0.5; DM1, λ=0.6 (default)

For DM1 and λ=1, the output differences were the following:

- Bulgaria and Estonia improve assignments and fall between C_1 and C_3.
- Finland, Latvia, Luxembourg, Portugal, Romania, Slovakia, Slovenia, and Czech Republic improve assignments and fall between C_2 and C_3.
- Germany and Italy worsen and fall between C_3 and C_4.
- Greece, Ireland, and Hungary improve and are assigned between C_2 and C_3.
- Lithuania worsens and is assigned to C_1.

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

Table 16 - DM1, λ=1; DM1, λ=0.6 (default)

For DM2 weighting distribution, follows the same sensitivity analysis:

Given λ=0.5, the output differences are:

- France´s assignment improves and is placed between C_3, and C_4.
- Germany and the Netherland worsen their performance and is placed between C_3 and C_4.
- Greece worsens and is placed between category C_1 and C_2.
- Ireland and Slovenia worsen and are placed between category C_2 and C_3.

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_4 very good
DE	C_3 good_1	C_4 very good
EL	C_1 weak	C_2 moderate
HU	C_3 good_1	C_3 good_1
IE	C_2 moderate	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_3 good_1	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_2 moderate	C_3 good_1
ES	C_2 moderate	C_2 moderate
SE	C_4 very good	C_4 very good

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 17 - DM2, λ=0.5; DM2, λ=0.6 (default)

For DM2 weighting distribution and λ=1, follows the same sensitivity analysis:

- Austria and Belgium worsen their performance and are placed between C_3 and C_4.
- Bulgaria, Finland, Greece, Latvia, Romania and Estonia improve and are assigned between C_2 and C_3
- Croatia and Cyprus are assigned to C_2
- Czech Republic, Ireland, Luxembourg, Portugal, Slovakia, Slovenia and Hungary worsen and are assigned between C_2 and C_3
- Denmark worsens and is assigned to C_3.
- Netherlands worsens and is assigned to C_3
- Sweden worsens and is assigned to C_3 and C_4.

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

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 18 - DM2, λ=1; DM2, λ=0.6 (default)

6.6 Sensitivity Analysis, Z

Variable Z stands for the number of times that the most relevant criterion outranks the least relevant criterion. Sections 5.5 and 5.4 provide the ELECTRE TRI-nC results for *Z* value corresponding to DM1 and DM2´s inputs while undergoing the SRF weighting method. However, for sensitivity analysis, the current section intends to provide the results of the ELECTRE TRI-nC for lower Z values, i.e., for a lower standard deviation between weighting coefficients.

Thus, Table 19 provides the new weights, for Z=5.

CRITERION	DM1 Z=10	DM1 Z=5	DM2 Z=10	DM2 Z=5
1. Tax and Grants on Acquisition	12.58%	12.16%	13.04%	12.42%
2. Tax on Ownership	11.66%	11.38%	15.80%	14.65%
3. Private Use of Company Car	4.29%	5.21%	14.42%	13.53%
4. Other Direct Financial Incentives	7.06%	7.53%	8.9%	9.12%
5. LEZ, Low Emission Zones	15.33%	14.48%	10.27%	10.23%
6. Urban Road Tolls	14.41%	13.7%	3.37%	4.7%
7. Pollution Emergency Zones	13.5%	12.95%	4.75%	5.81%
8. Other Regulatory Incentives	8.9%	9.06%	1.99%	3.59%
9. Charging Infrastructure	10.74%	10.63%	19.94%	17.95%
10. R&D Funding	1.53%	2.9%	7.52%	8.00%

Table 19 - Criteria normalized weight assignment for each DM, for Z=10 (default) and Z=5

After running the ELECTRE TRI-nC with the new weighting coefficients for each criterion, i.e., for Z=5, each country was assigned to the following categories (Table 20).

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>	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

Table 20 – DM1 Z=10 (default); DM1, Z=5

Table 20 provides a comparison of results between the initial iteration on DM1 weighting coefficients (Z=10). The slight change obtained through the new weighting coefficients (Z=5) does not change any Member-State's assignment to the categories. Mind that the credibility index in both iterations remained constant, being the default value (0.6).

For DM2, the same analysis was performed. Results are depicted in table 21.

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

Statistics :

<min,max>	#	%
<1,2>	7	25,9259%
<2,2>	6	22,2222%
<3,3>	8	29,6296%
<3,4>	2	7,4074%
<4,4>	4	14,8148%

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_2 moderate	C_2 moderate
IE	C_3 good_1	C_3 good_1
IT	C_3 good_1	C_3 good_1
LV	C_3 good_1	C_3 good_1
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_3 good_1	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 21 – DM2 Z=10 (default); DM2, Z=5

The slight change in weighting coefficients resulting from the alteration of variable *Z* does not affect Member-States’ assignments for DM2, as well.

6.7 Chapter Conclusions

Chapter 6 concludes the implementation of the ELECTRE TRI-nC method, providing the final assessment of EU countries regarding policy intervention for EV deployment.

This chapter starts by revealing how impactful the criteria weighting can be in MCDA. Two very different DM´s were asked to participate in the criteria weighting process (SRF Method) and the resulting corresponding criteria weights mirror their personal views on the most and least relevant type of incentive tools.

Model parameters were defined, namely, preference and indifference thresholds, as well as the number of categories and their corresponding reference actions.

Parameters λ, and Z were subject to a sensitivity analysis, providing different iterations of the algorithm.

Overall results remain consistent throughout several iterations with mild assignment changes in some Member-States. The current chapter provides a strong perspective of which countries are assigned to C_1, C_2, C_3, and C_4. Chapter 7 will provide a qualitative analysis of these results, as well as a broad review of the current work.

7. Results and Conclusions

The ‘Green Deal’, followed by the ‘Sustainable and Smart Mobility Strategy’, define the roadmap for the decarbonization of the mobility sector in the EU. In this context, electric mobility is targeted as a sustainable alternative to internal combustion engines. However, as of 2020, only a quarter million EV circulate in the EU (EAFO,2020). To achieve 30 million EV within the next 10 years, electric mobility requires deployment incentives. The current work aims at assessing EU’s Governing efforts towards EV deployment. Thus, each Member-State was assessed regarding its national-level policies according to 10 criteria. The current Chapter presents the main steps and outcomes of this work.

The second chapter starts by providing an overview of fossil-fuel dependency in road transportation within the EU. Oil and Petroleum products account for 93% of energy consumption in this sector. Therefore, and following the ‘Green Deal’, the EU´s Climate ambitions impose a 90% decrease in GHG emissions by 2050. The pathway for this goal is defined in the ‘Sustainable and Smart Mobility Strategy’ package. This document provides 14 milestones, 5 of which regard directly or indirectly zero-emission vehicles. Following this introduction to the road transportation sector, Chapter 2 provides a broad overview of EV technology and its market share within the EU. Several barriers to EV mass deployment are identified as well as some of the multi-level policy instruments that might unlock EV mobility.

Chapter 3 addresses, firstly a definition of green governance, how it is structured at different levels, revealing a multitude of interacting agents, and calling for a necessary balance between industry and governing institutions. Thereafter, a literature review of academic work is done. At first, regarding current governance frameworks, and based on Vanhaverbeke and Van Solten (2018), a review of EV incentives currently at place is presented, which is grouped by area of influence and governance level (Federal, Regional or Local). Secondly, and based on multiple academic sources, some of which using MCDA approaches, it was possible to corroborate the work of Vanhaverbeke and Van Solten (2018) and find the main concerns regarding EV incentives.

Chapter 4 addresses MCDA methods, their relevance and why it is a proper tool for a sorting problem such as this case. 27 Member-States (alternatives) are assigned to predefined categories according to their performance under a set of criteria. Since there are a multitude of MCDA methods, chapter three introduces the methods used in this work: (1) the ELECTRE TRI-nC, and (2) the SRF weighting method.

Chapter 5 presents the first phase of the model construction, providing the overall performance table. The AC, the FPV and the criteria were set and validated through the work developed in Chapter 3 as well as the articles from ‘Sustainable and Smart Mobility Strategy’ package. Gathering data and defining the performance scales to evaluate each Member-State was challenging in some cases, namely for some qualitative performance scales.

Chapter 6 provides every step of the weighting procedure (SRF) and the model implementation (ELECTRE tri-Nc). The weighting method relied on two DMs working in the e-mobility sector. Several potential DMs were contacted but many did not respond, or some who did, didn’t quite understand the cards method through videoconference, and thus, their input was not included in this work. For DM1 and DM2, the implementation of the method was carried out in Decspace. Once determined the weighting coefficients for DM1 and DM2, the ELECTRE TRI-nC was implemented in the MCDA Ulaval software.

The iterations of the ELECTRE TRI-nC obtained from sections 6.4 to 6.6 provide relevant insight on each of the EU's Member-State performance regarding policy intervention on EV stimulation.

Since two DMs participated in this work, two criteria weighting settings were used. Additionally, parameters λ and Z were subject to sensitivity analysis. Overall, eight different model outputs were considered, and the current analysis is based on them (Tables 14 to 21).

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 parameter λ.

In all eight iterations, Germany is the only Nation clearly assigned to category C_4. All eight iterations place Germany either in 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, the Balkans and former Yugoslavia countries. These are Poland, Greece, Lithuania, Estonia, Romania, Cyprus, Bulgaria, and Croatia.

The remaining countries fluctuate around C_2, moderate.

By matching these results with section 3.2 of 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 improvement regarding a more homogenous evolution within the EU.

If compared with data from Figure 3, which regards the EV fleet evolution in some Member-States, the results of the current work do mirror, to some extent, those values. However, governance capabilities and actual EV growth may not be entirely correlated. Governance assessment does not account for private initiative and other variables that may influence actual EV growth.

Note that the current work may not cover all concerns and criteria regarding EV incentives. Finding available data to cover all EU Member-States has the consequence of reducing the span of criteria. In future work, it would be interesting to measure the actual effectiveness of these incentives, i.e., to measure overall CO_2 emission reduction in Member-State. Such measurement can only occur if the Energy Mix and EV fleet of each country are considered.

This study presents one approach for assessment of Member-States regarding their EV governance prior Green Deal. It is clear that EU countries are at different speed, and there is a lack of studies reflecting this evidence.

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